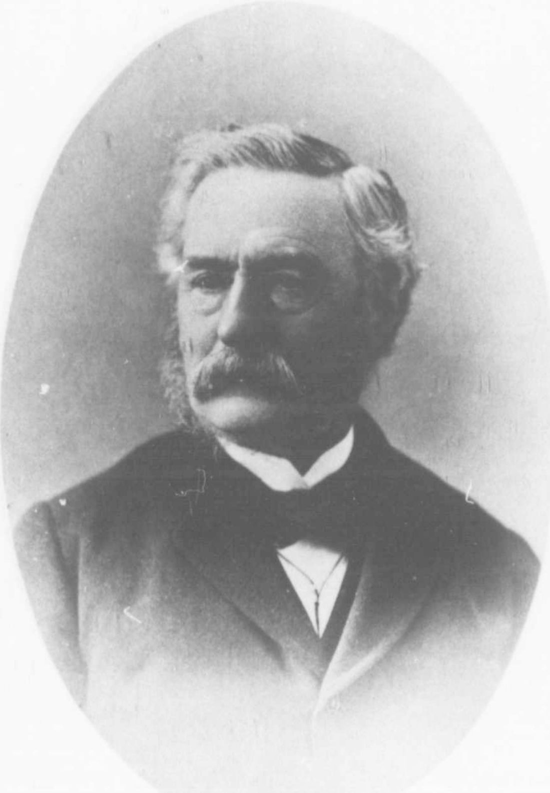

Very truly yours
Thos. C. Keefer.

FIRST PRESIDENT CAN. SOC. C. E.

1887.

WM. NOTMAN & SON, MONTREAL.

Issued April, 1889.

TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL. II.

JANUARY TO DECEMBER

1888.

Montreal:
PRINTED FOR THE SOCIETY,
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ERRATA.

VOL. I.

Part II.

Page	43	*line*	21	*for*	"full" *read* "fuel."
"		"	97	"	8 *after* "50 per cent." *insert* "of its bulk or 33$\frac{1}{3}$ per ct."

VOL. II.

Page	1	*line*	5	*for*	"Monday" *read* "Thursday."
"	28	"	23	"	"beds" " "bells."
"	85	"	11	"	"*Lignovia*" " "*Lignoria.*"
"	102	"	20	*after*	"Structure" *insert* "is"
"	192b	"	19	*for*	"have been laid" *read* "have not been laid."
"	192b	"	33	"	"have now only about one inch," *read* "have worn only about one half inch."
"	194	"	19	"	"coves" *read* "cores."
"	"	"	25	"	"coves" " "cores."
"	263	"	31	"	"1839" " "1849."

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Canadian Society of Civil Engineers,

SESSION 1888.

TRANSACTIONS.

ANNUAL GENERAL MEETING.

Monday, 12th January.

THOMAS C. KEEFER, C.M.G., President, in the Chair.

The notice convening the meeting having been read,

Messrs. W. E. Gower, J. H. Peck and W. Kennedy, jun., were requested to act as scrutineers for the election of the President, Vice-Presidents, Treasurer, Secretary and other members of the Council for the year 1888, and

Messrs. C. E. Dodwell, D. Macpherson, and F. F. Miller, were requested to act as scrutineers of the ballot for the proposed Amendments to the By-laws.

Resolved.—That the scrutineers of the Ballot for the election of officers be instructed to make a return of all the names receiving votes, together with the number of votes cast in each case, and that such return be published with the minutes of the annual meeting.

The Ballot having been declared open, the Secretary read the annual report of the Council upon the proceedings of the Society during the year 1887.

Resolved.—That the report of the Council be received, approved, and printed in the Transactions.

Resolved.—That a subscription book be opened and donations be solicited for the formation of a fund to secure permanent accommodation for the Society's work in the City of Montreal, and that a Committee be appointed (at first by the Council) to take charge of the movement; the funds to be deposited by the Treasurer from time to time as a special building fund, and no expenditure to be incurred unless by the consent of the Society

Resolved.—That the Secretary be requested to transmit the thanks of the Society, To the Governors of McGill University for accommodation generously provided in the College buildings.

To the Harbour Commissioners for the use of their building.

To the management of the Grand Trunk, Canadian Pacific, and Intercolonial Railways for travelling facilities.

Resolved.—That the cordial thanks of the Society be tendered to Professor Bovey for his services to the Society during the year 1887.

Professor Bovey replied thanking the Society for its expression of approval.

The scrutineers next announced the following as the result of the Ballot for Amendments to By-Laws.—

1. After By-Law 6, introduce :—" At the annual general meeting a committee shall be appointed, composed of *five* corporate members (neither officers nor candidates for office), whose duty it shall be to select the names of such members as in its opinion are best qualified to fill the offices of President, Vice-Presidents, Treasurer, Secretary, Librarian, and Members of Council for the ensuing year, and who shall signify to the Committee their willingness to accept their several nominations. Such names shall be forwarded to the Council, not later than the first day of the following November, and thereupon a copy of the list of the names shall be sent to each member of the Society for his guidance in voting. The Chairman of the Committee shall be resident at the headquarters of the Society." *Carried by* 90.8 *per cent. of the votes.*

2. In By-Law 13, after " and Library of the Society," insert, " shall edit the Transactions.—*Carried by* 95.3 *per cent. of the votes.*

3. In By-Law 15, " Two years will be allowed to any graduate," substitute " The term of ten years will be reduced to eight years in the case of any candidate who has graduated...."—*Carried by* 89 *per cent. of the votes.*

4. In By-Law 16, omit " Two years will be allowed to any graduate who has passed with honours in his Engineering Course."—*Carried by* 89.5 *per cent of the votes.*

5. At end of By-Law 16, insert, " Provincial land surveyors shall be eligible as associate members." *Lost by* 63.4 *per cent of the votes.*

6. At end of By-Law 18, insert, " He shall not remain in the class of students for more than *nine* years."—*Carried by* 93.2 *per cent. of the votes.*

7. In By-Law 19, for "due notice," substitute " one month's notice." —*Carried by* 97 *per cent. of the votes.*

8. In By-Law 21, for " Ten negative votes shall exclude a candidate," substitute, " If seven per cent. of the votes cast for any candi-

date be negative, such candidate shall be excluded, provided always that the number of negative votes cast be not less than three."—*Withdrawn.*

9. By-Law 24 to run:—

"Each resident member shall pay $10, and each non-resident member $8 per annum."—*Carried by* 85.2 *per cent. of the votes.*

"Each resident associate member shall pay $8, and each non-resident associate member $6 per annum."—*Carried by* 88.8 *per cent. of the votes.*

"Each associate shall pay $10 per annum."—*Carried by* 94.7 *per cent. of the votes.*

"Each student shall pay $2 per annum."—*Carried by* 94.7 *per cent. of the votes.*

N.B.—*This amended By-Law will come into operation on the* 1st *January*, 1889.

10. At end of By-Law 38, insert the following:—"(*d*) Students' meetings shall be held at eight o'clock in the evening, at such dates as shall be determined by the Council, and of which due notice shall be given."—*Carried by* 98.1 *per cent. of the votes.*

11. By-Law 41, to run:—"These By-Laws may be added to or amended by a vote taken at the annual meeting, provided that notice of the proposed change shall have been given at least two months previously. The voting shall be by sealed letter ballot, to be returned on or before the date of the said meeting, and not less than two-thirds of the votes cast shall be required to effect any change."—*Carried by* 97.2 *per cent. of the votes.*

Resolved.—That Messrs. F. R. Redpath, Montreal; T. C. Keefer, Ottawa; T. Monroe, St. Catharines; H. J. Cambie, Vancouver, and H. G. Ketchum, Sackville, N.B., be the committee to nominate the officers and council for the year 1889.

Resolved.—That the council be requested to appoint a committee to revise the By-Laws.

The scrutineers then reported that the following had been duly elected as,

President, Samuel Keefer, Brockville.

Vice-Presidents, C. S. Gzowski, Toronto; E. P. Hannaford, Montreal; H. F. Perley, Ottawa.

Treasurer, H. Wallis, Montreal.

Secretary, H. T. Bovey, Montreal.

Members of Council, H. Abbott, Port Moody, B.C.; F. R. F. Brown, Montreal; F. N. Gisborne, Ottawa; J. Hobson, Hamilton; W. T. Jennings, London; J. Kennedy, Montreal; L. Lesage, Montreal; A.Macdougall, Toronto; H. A. F. MacLeod, Ottawa; M. Murphy, Halifax, N.S.; P. A. Peterson, Montreal; H. S. Poole, Stellarton, N.S.; H. N. Ruttan, Winnipeg; P. W. St. George, Montreal; C. Schreiber, Ottawa.

Scattering votes were cast for the following:—J. E. Belcher, C. H. McLeod, H. D. Lumsden, St. G. Boswell, R. Steckel, E. H. Parent, G. H. Massy, D. MacPherson, R. A. Davy, H. Peters, W. T. Sproule, T. Ridout, W. Shanly, T. C. Keefer, J. Galbraith, J. W. Schaub, G. H. Henshaw, W. P. Anderson, C. Sproatt, E. Wragge, H. Donkin, P. S. Archibald, J Abbott.

The Ex-President having left the chair it was taken by the President, S. Keefer, Esq.

Resolved.—That the cordial thanks of the Society be given to T. C. Keefer, Esq., C.M.G., for his unremitting attention to the duties of the office of President and for his constant endeavors to advance the interests of the Society,

Mr. T. C. Keefer returned thanks, expressing his appreciation of the Society's vote.

Resolved.—That the thanks of the Society be presented to the scrutineers for the satisfactory manner in which they had discharged their duties, and that the ballot papers be destroyed.

ANNUAL REPORT.

In presenting the first Annual Report of the Canadian Society of Civil Engineers, the Council cannot but express great satisfaction at the almost unlooked for success which has marked its progress. The necessity for the formation of some such Society had long been felt, and this while accounting in great measure for the past success is also the best augury for the future. Up to the present time no definite status has been given to the profession of Civil Engineering in this country. It may now be confidently anticipated that the membership roll of this Society will constitute a professional criterion which has been hitherto lacking.

ROLL OF THE SOCIETY.

At the first general meeting held to inaugurate the Society, on the 24th February, 1887, it was announced that in answer to the circular issued by a Committee composed of delegates from Ottawa, Toronto and Montreal, no less than 288 members of the profession had signified their desire to join such an institution. This response was considered so encouraging as to warrant the immediate application to the Dominion Government for a charter incorporating the Society. The Bill was introduced by Walter Shanly, Esq., M. Can. Soc. C.E., M.P., and the charter was granted on the 23rd June, 1887. The Government recognizing the national utility of such an organization also refunded the usual fee of incorporation.

Since the date of the inaugural meeting 57 have been added to the class of members, 26 to the class of associate members, 15 to the class of associates, and 37 to the class of students, making a total of 225 members, 65 associate members, 27 associates, and 106 students, or a grand total of 423.

During the past year the Society has lost three of its members by death,—Mr. H. W. Keefer, Mr. T. Guerin, and Mr. T. W. Harrington. Their memoirs are published in the Transactions.

PUBLICATIONS.

The Transactions, which promise to become a historical record of Canadian Engineering, must necessarily be an all important branch of the Society's work, and on their intrinsic merit must largely depend its claim to the support of its members. On the other hand it would be equally true to say that this merit must depend upon the co-operation of all the members, who should, as far as possible, take part in the fortnightly meetings or, at least, contribute to the discussions in writing. Such contributions would greatly enhance the value of the papers and prevent all risk of the discussions assuming a one-sided or local character.* This desirable object would doubtless be further promoted by the establishment of Branches as provided for in the by-Laws, and the Council strongly recommends the immediate formation of as many as possible at suitable centres.

The volume of Transactions for the year 1887 contains the following papers, which were read and discussed at 13 ordinary meetings of the Society:—

On "Frazil Ice," by Mr. G. H. Henshaw; on the "Canadian Pacific Railway Grain Elevators," by Mr. S. Howard; on the "Foundations of the St. Lawrence Bridge," by Mr. G. H. Massy; on the "Superstructure of the St. Lawrence Bridge," by Mr. J. W. Schaub; on the "Warming, Ventilating and Lighting of Railway Cars," by Mr. J. D. Barnett; on the "Construction of a Guard Lock," by Mr. L. N. Rhéaume; on "Snow Slides in the Selkirk Mountains," by Mr. G. C. Cunningham; on "Petroleum as a Fuel," by Mr. L. M. Clement; on the "Works on the River Missouri, at St. Joseph," by Mr. H. Killaly; and on the "Quebec Harbour Improvements," by Mr. St. G. Boswell.

Other papers read and discussed at the meetings were on "Water Purification," by Professor Leeds, of Cambridge, Mass., and on the "Necessity of a School of Arts for the Dominion," by Mr. C. Baillargé.

One students' meeting has been held at which papers were read on the Prince Edward Island Subway by Mr. F. G. Jonah; and on Crank Shafts by Mr. A. E. Childs. The Council hopes to see considerable development in this department, by the establishment of regular students' meetings, thus awakening the interest of the younger members of the profession, on whom must ultimately depend the status and strength of the Society.

LIBRARY.

In the month of September a circular was issued, requesting the members of all grades to aid in the formation of a Society Library. The response has certainly been most generous, as will be observed from the list of donations and exchanges which will shortly be printed and published with the Transactions. It may be stated in brief that already Exchanges have been secured with 29 engineering and kindred

* In order to make this possible, *advance* proofs of the papers to be read are always issued, and may be obtained on application to the Secretary.

societies, and donations of books and pamphlets received to the number of upward of 400. Special reference should be made to the exceedingly valuable gifts of a complete set of its publications from the American Society of Civil Engineers, of 12 volumes of Proceedings from the Institution of Civil Engineers (Eng.), of 9 volumes of Professional Papers from the Royal Engineers (Eng.), and of a number of important works from the Geological Survey of Canada, and from various Government Departments in the United States.

No little praise is due to the many members whose practical aid has so successfully initiated this movement, and it is hoped that all the members will unite in their efforts to make the library—what it should be—a thoroughly useful adjunct to the work of the Society. At present the books, journals and other publications are being arranged, and catalogued in the Secretary's office, at McGill College, where they may be consulted by members of the Society.

ACCOMMODATION.

Through the courtesy of the Governors of McGill University, the Society has been granted the gratuitous use of rooms in the College buildings. The growth of the Society, and the rapid increase of the library may soon render it necessary that the Society should consider the advisability of providing itself with more permanent accommodation.

FINANCES.

The income for the year ended on the 31st December, 1887, amounted to $2280.77, and the general expenditure reached $1319.85, leaving a balance of $960.92, to be carried forward. Deducting from this sum the amount of fees paid in advance, viz., $394, and a sum of $250, the approximate cost of Part II, Vol. I of the Transactions for the year 1887, there is left a balance of $316.92 to the credit of the Society.

ABSTRACT OF RECEIPTS AND EXPENDITURE FOR THE FISCAL YEAR 1887.

RECEIPTS.

To Subscriptions :—		
Current	$1865 00	
Advance	394 00	
		2259 00
" 40 Pamphlets on River Missouri Improvements		4 00
" Charter of Incorporation : Repayment of Fee		200 00
" Interest on the Deposit Account in the Merchants Bank	13 36	
Do do do	4 41	
		17 77
		2480 77

EXPENDITURE.

By Publications :—		
Transactions	$407 00	
Charter, By-Laws, List of Members	165 72	
		572 72
" Postage	196 44	
" Stationery and Printing	254 55	
		450 99
" Fees for Charter of Incorporation		200 00
" Clerks, Messengers, Telegrams, Charges for Parcels, Cheques		250 82
" Books, (Minute, Scrap, Registers, Directory)		24 95
" Repayment of Excess Subscriptions.		6 00
" Rent of Telephone (six months)		14 37
		1519 85
" Balance : Cash in hands of Secretary Treasurer, 31st Dec.		$960 92
		$2480 77

Examined with the Books and Vouchers, and found correct.

Signed, H. WALLIS, P. W. ST. GEORGE. } *Auditors.*

HENRY T. BOVEY,
Secretary Treasurer.

PRESIDENT'S ADDRESS.

In retiring from the office to which I have been elected as their first President by the members of the Canadian Society of Civil Engineers, I desire, first of all to express my sincere gratitude for this exhibition of their confidence, and to assure them that I fully appreciate the honor they have conferred upon me as one which I consider to be the highest to which any member of our profession can aspire.

The duty of a President of such a Society as our own, according to the practice of older societies, has been most frequently, though not constantly, to give a review of engineering progress during the year of his tenure of office. This is always a task of sufficient magnitude, even when treated in the most superficial manner.

A summary of the past year's engineering progress presupposes acquaintance with the previous condition of things; and, doubtless, to most of our members the progress as well as previous condition is familiar through the numerous excellent journals devoted to the profession. When I began my profession there were no journals of engineering, except one in London, devoted also to architecture. The Institution in London did not commence publication of their transactions until 1836. I know that to many of you the progress and condition of those branches you have followed is much better understood than I could hope to make it.

The Annual Address of the President of the Institution of Civil Engineers, delivered in November last, deals exhaustively with the progress of Civil Engineering during the Victorian era. As the worthy President, Mr. Bruce, entered the shops of Robert Stephenson, at Newcastle, shortly before Her Majesty ascended the throne—his was a Jubilee address, with personal knowledge of the wonderful advance made in all branches of his profession:—and as this is the fiftieth year of my own practice,—begun upon the Erie Canal in 1838,—I am able the more to appreciate as well as confirm much of what he has so well said.

If I depart from the usual custom, it is because this is the initial address before a new society, and the proper occasion for some account of the rise and progress of Canadian Engineering, as also of the origin of this Society. This chair will annually fall to representative men of the different branches of our profession, and thus we may put upon record for the benefit of our own members the rise and progress as well as the existing condition of the half dozen great branches which constitute a Society of Civil Engineers.

The Association of Civil Engineers for mutual improvement is the outcome of the present century, the English Institution having been established in 1818, and incorporated in 1828, and the American Society in 1852. There was a Society of Engineers founded by Smeaton, in 1771, but it was rather a social club than a scientific association. The English Institution has increased during the Queen's reign from 238 members of all classes to 5400, and in revenue from £713 to over £21,000. The American Society, owing to wide expanse of territory and the formation of numerous local societies and clubs, does not show corresponding growth, although it numbers over 1,000 members, and is representative of all branches in the profession and of all sections of this continent. Its proceedings were published at irregular intervals until November 1873, since which date they have been issued monthly.

I am unable to say when the first agitation for the formation of a Canadian Society of Civil Engineers began. I know it was a subject of discussion among Engineers, and I believe also of newspaper communications by Engineers, long before any concerted action was attempted. The Canadian Institute, incorporated in 1851, was formed "more particularly for promoting surveying, engineering and architecture."

I think the agitation dates from the formation of the Land Surveyors into a close corporation. Formerly, the surveys in connection with the right of way upon canals and railways were made by the Engineers engaged upon the work, as well as the topographical surveys connected therewith. Engineers out of employment were prohibited from practising as land surveyors, without first undergoing an apprenticeship, as well as passing an examination. On the other hand, Land Surveyors, whether competent or not, could practice as Civil Engineers. It was natural, therefore, that a feeling should grow up, that not only was a standard of qualification required, but that the profession should be put upon the same footing as Land Surveying, and be restricted to those who were qualified by law; but whenever this was proposed, the general sentiment was found to be against it. This is probably due to the knowledge that the great Institution, organized at the Kendall Coffee house, in Fleet street, on the 2nd January, 1818, by William Maudslay, Joshua Field, Henry Robinson Palmer, James Jones, Charles Collinge and James Ashwell, of which Telford was the first President, and which is the mother of us all, had proved a magnificent success without protection; as well as to the reflection that the founders of the profession in Great Britain and the United States were born Engineers, and sought only a free field and asked no favors.

In May, 1880, Mr. E. W. Plunkett, now a member of this Society, obtained a list of Canadian Engineers, and issued a circular signed X. Y., setting forth the necessity and advantages of organization. He described the advantages as concerted action, the record, comparison, and discussion of professional work, the adoption and operation of a professional code. "At present," the circular said, "the engineering profession in Canada has no entity or representative body, and consequently it does not enjoy the essentials of healthy professional life—a standard of qualification, an active progress in working membership, a professional code, an opportunity for encouraging and cultivating engineering talent, and generally the preservation and promotion of the interests of the profession." Mr. Plunkett did not propose a close corporation, but thought the Charter should resemble, as nearly as practicable, that of the English Institution which has been so eminently successful, but with any modifications which the special circumstances of Canada obviously require. This circular was anonymous in order that the ideas thrown out in it might be considered on their merits apart from personal considerations.

As Mr. Plunkett's circular was sent to all the known engineers, it is most likely that a Bill which was introduced into the Ontario Legislature, in February, 1881, was suggested by it. This Bill was entitled, "An Act respecting Civil Engineers," although it did not shew much respect to the opinions of many of them. The Bill was not founded upon a petition signed by any body, but the preamble states that it is expedient, with a view to the proper and efficient qualification of Civil Engineers in the Province of Ontario, that the same should be regulated by Statute. It divided Engineering into departments or branches, and Engineers into grades or classes, and constituted fourteen engineers by name as Civil Engineers in grade A, within the meaning of the Act. All the rest were left out in the cold, until a Council of ten, appointed by the Crown, had examined and admitted them. The Commissioner of Public Works for Ontario was to be ex-officio chairman of this Board of ten examiners, and, as the quorum for the examination of candidates was only three, this gentleman, not necessarily an engineer or even land surveyor, but most probably a lawyer, doctor, merchant or farmer, could have decided the fate of the candidate. For any other business of the Board the quorum was to be six.

Students, before being indentured, were to pass a preliminary examination, and no one was to receive a commission as Civil Engineer until he had passed a satisfactory examination before the triumvirate quorum in the subjects enumerated in a schedule printed in the Act, which schedule would have served as a very full index for an Encyclopedia of Civil Engineering.

Members of the Institution of Civil Engineers were by this Bill made eligible for final examination by the votes of at least three lawfully constituted Canadian Engineers.

The Board was empowered to charge annual fees for membership —to divide Engineering into branches, and to grant a diploma entitling candidates to practice in those branches only upon which they had gone up for examination. Also to classify Engineers into grades A, B. C, D. An A1 man, who could take the whole twenty-eight engineering subjects described in the Index, was to rank as Chief Engineer. B was to pass in more than one branch to be Chief Engineer only in the branches for which he had passed and been commissioned. C was a one branch man, and his diploma made him a simple Engineer in that only. D held a second class diploma and was ranked as Assistant Engineer.

The Board could fix the fees to which Engineers were entitled in the absence of agreement, suspend or dismiss from practice any Engineer for cause, but the Court of Appeals of Ontario could quash their decision. They could also examine candidates for admission under oath "as to his practice and with regard to his instruments." All Engineers (except the original 14 Parliamentary ones) on passing their final examination were to give a bond of $5,000 to Her Majesty, supported by two securities, and take an oath of office.

All those who had not mastered the A, B, C, as well as D, of their profession as above defined, and come into the fold before 1st June, 1881, were prohibited from practising as Civil Engineers under a penalty of $100 for each offence, one half to go to the informer.

As there is a substantial difference between imposing a fine and collecting one, I do not think the business of an informer would have proved a lucrative one under this Act, especially since the Bill mercifully did not provide for imprisonment in case of the non-payment of the fine.

The final clauses of the Bill exhibited some practical features. It provided that the examiners while on duty should receive five dollars per diem, including time going and returning, together with living and travelling expenses, to be paid out of the Consolidated fund of the Province. Fines and fees might provide for the contingencies, but for the main items of the estimate the Provincial Treasury was the only reliable source of supply.

The Bill did not reach a Committee, it was repudiated by the majority of the fourteen Engineers named in it, who had not petitioned for it, and were ignorant of its inception. If this had not been done the Government would have expunged the clause aimed at the Provincial Treasury, and this would probably have proved fatal.

I have given the details of this Bill in order that it may be contrasted with the simple provisions of our Charter, which while giving us a better legal status enables us to pass regulations and by-laws for the direction and management of all the affairs of this Society.

Apparently this difference of opinion, as exemplified by Mr. Plunkett's circular of 1880 and the Ontario Bill of 1881, checked further effort for the time being.

In January, 1886, Mr. Alan Macdougall, now a member of this Society, issued a circular over his own signature which led to the formation of this Society, about a year later on. In this circular he refers to the previous one of Mr. Plunkett, which he says was well responded to, but he proposed a close corporation, and this no doubt prevented some Engineers from responding to his proposal, although he invited correspondents to communicate their own views ;—but he followed up his circular in an eminently practical way. In February, 1886, he issued a second circular and called a meeting in Toronto, and afterwards he applied to Mr. Kennedy, one of our Vice-Presidents, to preside at a meeting of Montreal Engineers for the purpose of considering the question. This meeting was held on the 4th March last, and resulted in a draft for a constitution. A similar meeting was called by Mr. Macdougall in Ottawa, for 30th March, at which the Montreal draft was considered and afterwards amended by the Ottawa local committee. Delegates were appointed by the local committees of the three cities, empowered to submit a constitution and elect a Provisional Committee, who met in Montreal on 9th December, 1886. A circular signed by Mr. Macdougall, as Provisional Secretary, was sent out to members of the profession, on 21st Dec., 1886, enclosing a copy of the constitution, and notifying them that the Committee would meet in Montreal on the 11th January, 1887, for the election of members, and for the further purpose of sending out a ballot paper for the Officers and Council. Recipients were requested to sign a printed slip attached to the circular if they desired to become members of the Society. In this way the Provisional Committee would know at their meeting in January who were willing to join, and thus be able to elect such as members. On the 20th of January last another circular was issued by the Provisional Committee, announcing that 188 gentlemen from all parts of the Dominion had responded favorably to their first circular, and requesting members to forward their fees to meet printing expenses and cost of Charter.

Every Society must have a beginning, and there could be no self-constituted body to demand credentials from other members of the profession, their equals, at least, if not their superiors. Before a constitution could be adopted or further progress made there must be members to vote upon it, and these members could be chosen only from those who had signified their willingness to join the Society. The circular invited those Engineers who had joined to examine the printed list of members elected by the Provisional Committee, and solicit any of their professional brethren whose names did not appear therein to become members. Thus an additional number sent in their names in time to receive the ballot papers for the Officers and Council. In this way 288 members of all classes were elected by the Provisional Committee up to 24th February, 1881, since when all elections have been made by ballot. Of this total number of 288, 168 were members, 39 associate members, 12 associates, and 69 students. Since the 24th February last, the addition to our number of members who have been elected by ballot is about 50 per cent., as follows: Members 57, associate members 26, associates 15, students 37. The Society now numbers, before the close of the first year of its existence, 423 members, classed as follows: members 225, associate members 65, associates 27, students 106.

The ballot papers were sent out for Officers and Council and a General Meeting was called for 24th February, at which the result of the ballot was announced, the constitution adopted, and application for Charter made to the Dominion Parliament, which obtained the Royal sanction on 23rd June following, and then our Society began its legal existence. All our preliminary proceedings up to this time were annulled by the Charter, which does not set up anything previously done as law, and it became necessary that a new election and adoption of constitution should be had, which was done by submitting the tickets for officers, and the constitution adopted at the annual meeting, to a second vote of the members.

Our Charter was carried through Parliament by Mr. Walter Shanly, M.P., a Vice-President of this Society, and we owe it to his representation that the fees were refunded.

I propose to refer in very general terms to the engineering progress of Canada under the following heads: RAILWAY, HYDRAULIC, CIVIC, MECHANICAL, MINING and ELECTRICAL. Many things which ought to be noticed are not, not only for want of space but also from want of knowledge, and I trust this deficiency will call forth better information from members of this Society more qualified than I am to write upon many of the points raised. In this way valuable papers can be contributed for publication in our transactions.

RAILWAY ENGINEERING.

Railway Engineering, although the most recent, with the single exception of Electric, is, whether we consider its widespread influence on the human race, or the amount of capital employed by it, first in importance, especially as it embraces more or less of every branch of the profession. In 1831, the year after the opening of the first passenger railway of the world, that between Liverpool and Manchester, steps were taken in Montreal for connecting the waters of the St. Lawrence with those of Lake Champlain by railway. The Charter was obtained in February, 1832, and the line was opened for traffic, first with horses in 1836, and the following year with locomotives. Of all those named in the Charter, Mr. T. S. Brown of this city is I believe now the only survivor. It was a strap-rail road until 1847, up to which time it was the sole representative of the system using locomotives in Canada. There was a railway chartered in 1835 and opened in 1839 between Queenston and Chippewa, designed to restore the ancient portage route around the Falls of Niagara, which had been rendered obsolete by the construction of the Welland Canal. The grade near Queenston was beyond the capacity of the locomotive of that day, and it was worked with horses, but the terminus at Queenston being 100 feet above the level of the river, it soon fell into disuse, was afterwards extended both ways to Niagara and Buffalo, and is now a portion of the Michigan Central system.

New Brunswick commenced the line between St. Andrews and Woodstock in 1844, took 11 years to open the first 25 miles and 18 years to get through the distance of 90 miles. The St. Lawrence and Atlantic was chartered in 1845 and opened to St. Hyacinthe in 1847, and in 1853 the first locomotive railway in Ontario was opened between Toronto and Lake Simcoe. The main line of the Great Western was opened immediately afterwards in '53 and '54.

These Ontario roads were compelled to adopt the gauge of the St. Lawrence and Atlantic as a condition of their receiving Government aid, which from 1849 to 1852 was applicable to all lines 75 miles in length and was a subsidy of one half the cost. The road from Prescott to Ottawa, then called Bytown, opened in 1854 was too short for Government money, and therefore retained its American gauge.

The St. Lawrence and Atlantic was a Montreal Company which had been undertaken to connect with the Atlantic and St. Lawrence, an American Company starting from Portland in Maine. Fearing that Boston would become the real terminus of a road from the St. Lawrence, Portland had adopted an exceptional gauge, to compel transhipment there, and had bound the Canadian Company to this gauge.

The Grand Trunk Railway was chartered in 1852 and absorbed the line from Montreal to Portland, in consequence of which the gauge of 5 ft. 6 in. became the Provincial gauge, and Canada thus cut herself off from interchange of cars with New York, New England, and the Western American States. No doubt there was an honest belief that a wide gauge would give a superior railway for competition with American lines, but the strongest inducement held out to Eastern Canada was to prevent the diversion of Western trade across the Niagara River. The fact that New York and New England were the only termini of our Canadian system in winter, and that American traffic was essential to the existence of the Grank Trunk, soon made this break of gauge intolerable, and after various devices of changing the trucks of freight cars, and adjustable gauge axles, the Canadian gauge was abandoned first by the Great Western and then by the Grand Trunk, and gradually by their branch lines.

In the United States a similar fate has overtaken all the exceptional gauges. Less than two years ago over 11,000 miles of railway in the Southern States were reduced from 5 ft. to the standard of 4 ft. $8\frac{1}{2}$ in. within five days.

The Canadian Pacific Railway is our last and greatest effort, and is not only the most important road in Canada, but, in some respects, in the world. No other road under one administration connects the Atlantic with the Pacific on the shortest lines between Europe and Asia. No line of equal magnitude has been built so recently and therefore possesses such a modern equipment; and, owing to the munificent subsidies of the Canadian people, no similar line is so lightly burdened with interest-bearing securities;—and no line has a greater area tributary to it. Its most unpromising mileage may yet develop a valuable mineral traffic; but though hundreds of miles may remain a comparative desert in common with other Pacific routes to the South of us, its prairie region will soon tax all the resources of a single line for their through traffic. Way traffic at all points (however valuable) is not essential to the success of every railway. The Panama Railway was built for through traffic. The Suez Canal, more costly than the same length of railway, is without way traffic, but has the through traffic of continents.

The Government and municipal expenditure upon railways has reached the large sum of one hundred and fifty-seven millions of dollars up to the 30th June, 1886, of which sum one hundred and twenty-five millions were contributed by the Dominion Government in the first 19 years of its existence. With the exception of about $15\frac{1}{2}$ millions loaned, the whole of this 125 millions was a free gift to the railways. The Provincial Governments have granted 17½ millions as bonuses to the railways, and the municipalities of the Provinces of Ontario, Quebec, New Brunswick, Nova Scotia and Manitoba have given nearly ten millions more, of which Ontario's contribution alone is about 8½ millions.

As the total amount paid up on account of Canadian railways to 30th June, 1886, exceeds 650 millions of dollars, nearly 500 millions have been contributed by share and bond holders. We have given as a people three times as much to the railways as to the canals, but this liberality has not been fruitless since it has drawn three times the amount of our subscription from other sources.

The free gift of the Canadian people to railways completed and in progress up to 30th June, 1886, amounts to very nearly one hundred and forty millions of dollars, or over three times as much as they have expended upon the canals. This shows us the relative popularity of the two classes of expenditure, and explains why the enlarged Lachine Canal has as yet proved to be only an enlarged mill race.

The total number of miles of railway under traffic in Canada at present is 11,221, and the miles on which track is laid 12,400. Our mileage is only exceeded by that of the five great powers of Europe, the United States, and British India. For mileage in proportion to population we rank among the first if not the first in the world.

Some of the questions exercising the Railway authorities at present are:—

1st. The safer heating and lighting of passenger trains, for which purpose steam from the locomotive, and stored electricity, have already been applied with success.

2nd. The increasing load of rolling stock and freight cars calling for heavier rails and stronger bridges, as well as more efficient brake power. The air brake is being rapidly substituted for hand power on freight trains.

3rd. The necessity for uniformity in construction of cars, whose range is now wider than that of the Buffalo which the railway has extinguished. The adoption of a uniform continental gauge, with cars moving between the Atlantic and the Pacific and between Canada and Texas, makes uniformity in height and mode of coupling above the rail imperative. The absence of a standard automatic train coupler is the chief cause of the almost daily loss of life or limb in car-coupling.

The Pennsylvania Railroad is substituting stone arches for iron bridges where practicable, and the same question is attracting attention in England. The centralizing system by which bridge plans have been decided at the head office from profiles of the crossings has no doubt been responsible for many cases in Canada where iron girders and abutments have cost as much as an arch. The girder is always a Bridge with all its contingencies; while the arch, where it can be depended upon, practically abolishes the crossing, and substitutes a causeway for a Bridge.

HYDRAULIC ENGINEERING.

This "most ancient and honorable" branch of our profession embraces not only the works on which our navigation interests depend, but those which affect the health and comfort of our great centres of population. It dates its origin back to the earliest records of history, and until the advent of steam and the Railway era was the widest field in our profession.

CANALS.

About the year 1780 the improvement of the navigation of the St. Lawrence was commenced by the construction of short canals and small locks at the most difficult points between Lake St. Louis and Lake St. Francis, and above the latter—in the Long Sault Rapids. These were chiefly constructed by Royal Engineers, though some were the result of private enterprise. Merchandise at that time was carted to Lachine, from whence the batteaux and Durham boats took their departure in brigades of five or more boats, in order that their united crews might aid each other at the Rapids. At the Cascades three fourths of the cargo was discharged and carted to the head of the Cedars, the boat with the remaining fourth being locked past the Cascades, dragged up the Split Rock and the Cedars, and reloaded—passing the Coteau by a lock into Lake St. Francis. Above Cornwall there were two locks in the Long Sault, one of which was private property, and between Mille Roches and the head of the Long Sault, and between the Cascades and the Cedars, lighterage was necessary, three-fourths of the cargo being discharged and hauled overland. From Prescott the boats sailed up to Kingston, or, after 1818, were towed by steamers. The time of the voyage from Lachine to Kingston was 12 days, and the actual cost of transport about fifteen dollars per ton.

In 1821 the first Lachine Canal was commenced, and completed in 1825, at a cost of $440,000, by the Provincial Government. The lock chambers of substantial masonry were 108 feet long by 20 feet wide. This was our first completed canal. The Welland Canal was undertaken by a private company in 1824, and the first vessels were passed through in 1829. The locks were of wood with a chamber 100 feet by 22 feet.

They endured the traffic and climate until 1845, by which time they were fully worn out. The whole cost of the canal with 40 locks and 350 feet lockage, with some exceptionally heavy work, was a little over a million dollars.

As designed by the private company, the Welland Canal connected the Welland River, a branch of the Niagara flowing in above the celebrated Falls, with Lake Ontario. The Welland River is slack water and about ten feet lower than Lake Erie, the Niagara River having about that fall between Buffalo and Chippewa, the point of junction with the Welland. A clay cut, 70 feet in depth, was necessary to convey the waters of the Welland through the summit ridge. In November, 1828, this cutting was nearly completed, when slips occurred of such formidable character, that the attempt to bottom it out so as to feed from the Welland River was abandoned.

The Grand River, one of the largest Canadian affluents of Lake Erie, was dammed at a point 27 miles from this deep cut where the slides took place, a feeder canal of this length brought down and carried by an aqueduct over the Welland River, and four additional locks for connection with this river were constructed between November, 1828, and November, 1829, and the canal was opened for traffic within five years of its commencement. The aqueduct and locks being constructed of wood alone permitted the accomplishment of so much work in one season. We have on our railways now frequent experience of the value of timber, when the utmost expedition is required.

The capacity of the Grand River as a feeder diminished with the settlement of its watershed, while the demand for water for the canal increased with the growth of its traffic: Lake Erie therefore was decided upon as the feeder, to effect which it was necessary to lower the head level which embraces the greater half of the entire length of the canal.

Companies were chartered in 1818 for the construction of the Lachine and Chambly canals, but being unable to proceed the Provincial Government took up both enterprises.

The Chambly Canal was not commenced until 1831, work was suspended in 1835, and completed in 1843, after the union of the Provinces in 1841.

The Rideau Canal was undertaken by the Imperial Government as a military work in 1826, and completed in 1834. Previous to this, the Imperial Government offered Upper Canada £70,000 stg. as a bonus for its construction; but the Legislature declined, on the ground that a much less expenditure would render the St. Lawrence route more convenient for all purposes of trade. It is 126 miles in length of navigation,—of which only sixteen and a half are canal—has 47 locks and 457 feet lockage.

The lock chambers are 134 feet by 33 feet wide. Its location at the Ottawa terminus has been criticized because (without additional lockage) the navigation might have been extended about forty miles higher up the Ottawa River, had this canal entered it at the foot of Lac des Chênes, six miles above Ottawa. It was commenced upon an estimate of $845,000, for locks 100 by 22 feet chambers, but the cost was about $4,000,000. It has 24 dams, one of which is sixty feet in height:—11 of these are of cut stone.

The Imperial Government had commenced their military route to Lake Ontario via the Ottawa River, as early as 1819, by the construction of locks to pass the Long Sault Rapids, between Carillon and Grenville. The Grenville locks were completed on the scale of the old Lachine Canal, the remainder upon that of the Rideau. The route between Lachine and Carillon was via Vaudreuil, where the rapids were navigable at all stages, while by the shorter route of Ste. Anne's they were only so at high water. A lock was built at Vaudreuil in 1832 by a forwarding company. Navigation was maintained upon this route until 1843, when the lock at St. Anne's, which was commenced in 1837, was completed. This lock has a chamber 200 feet long by 45 feet in width. The first enlargement of the Lachine Canal, completed in 1848, was upon the same dimensions as the lock at St. Anne's, but the scale of navigation between Montreal and Ottawa was limited by the size of the diminutive Grenville lock, until the recent enlargement of the latter by the Dominion, by which also a new and larger lock has been built at St. Anne.

The Cornwall Canal was commenced by Upper Canada, in 1834, but was not completed until after the Union in 1842. The locks were 200 feet long and 55 feet wide. This width was reduced 10 feet for the Beauharnois Canal, which was not undertaken until 1842, and completed in 1845. The short canals above Cornwall were completed in 1847, and the first enlargement of the Lachine Canal in 1848, in which year through navigation between Montreal and Lake Erie for the first time became practicable, with locks on the St. Lawrence 200 by 45 feet, and on the Welland, 150 by 26½ feet.

The enlargement now in progress has only been completed as regards the Lachine and the Welland canals. It differs from preceding ones in that it has been for a uniform scale between tide water and Lake Erie. The lock chambers have been lengthened to 270 feet, but the width of 45 feet has been maintained. Large lake vessels can reach Kingston from Lake Superior, and could no doubt come to Prescott; but until the enlargement between Lachine and Prescott is completed, no improvement in transportation between these points over what was practicable 30 years ago can be had. Whether the larger lake craft will descend to Montreal, or transfer their cargoes at or above Prescott, is the problem to be solved by experience. This transfer is now made by vessels in the grain trade, which could descend to Montreal, but do not. Longer locks and deeper water may enable Canadian coal to compete with American upon Lake Ontario, especially if the colliers can obtain return cargoes. For the grain trade the barges become floating warehouses, and can carry more in proportion to the steam power required, their crews and the cost of their tonnage than the lake craft, and can better afford the loss from delay and the want of back freight.

Our canal enlargements proceed so leisurely that it is possible we may revise their scale before completion, as we have done more than once at intervals of only 25 years. The present enlargement has been in progress about fourteen years, and very little has been done to the St. Lawrence Canals above Lachine. The explanation no doubt is to be found in the large demand for railway construction in which everybody is interested. The canals have fewer friends.

If, as Engineers, our foresight were as good as our backsight, we would plan locks to suit the vessel of the future, instead of having to build vessels to suit the locks. It should be mentioned, however, that the dimensions of our locks were established by a commission representing the trade, of which commission the late Sir Hugh Allan was chairman.

We are about to commence the Sault Ste. Marie canal, which, since Lake Superior has become an important entrepot of Canadian commerce, is necessary to complete the Canadian system. It will, no doubt, be upon a much larger scale than any other Canadian canal, and, if so, will, I think, soon raise the question of a further enlargement of the Welland Canal, so that vessels which can now reach Buffalo may extend their voyage to Prescott, within a little over 100 miles from the ocean steamer.

There was a narrow canal and lock at Sault Ste. Marie at the beginning of this century, the work of the Northwest Fur Company. The lock was 38 feet long, $8\frac{3}{4}$ feet wide, with 9 feet lift, the lower gate let down by windlass, the upper one having two folding gates with a sluice. The canal was nearly half a mile long, with a tow path for oxen.

The first survey for a Canadian canal at this point was made in 1853.

Besides the canals connected with the St. Lawrence and Lake Champlain routes, and the interior military route by the Rideau Canal, detached efforts have been made upon the Upper Ottawa at the Chats and the Culbute, and upon the Trent. In both cases the expenditure was commenced in the middle, and the ends are yet to be worked out.

Fifty years ago locks were commenced on the Trent, between rapids, as part of a system to connect the Bay of Quinté with Lake Huron, upon a route 235 miles long with 832 feet lockage. The Welland Canal accomplishes the same result with 27 miles canal and 330 lockage, but upon a route 220 miles longer to reach Lake Superior. The greater speed obtainable in the open lake and the saving of about 500 feet lockage will always make the Welland the shorter route in point of time, as well as the cheaper in cost, because its route affords double the draft of water possible by the inland system.

Thirty years ago, after the expenditure of nearly half a million, work was abandoned on the Chats Canal, which, if completed, would have only connected two short and shallow lakes without outlets to any further navigation at either end. Higher up at the Culbute, a similar connection of detached and inaccessible reaches has recently been completed at a cost of $380,000, but since it was commenced in 1874, the boats for which it was intended have been driven off the river by the railways constructed upon both sides of the Ottawa.

The total canal expenditure upon the St. Lawrence, Ottawa, Rideau, Richelieu and Trent navigation, the St. Peter Canal, in Cape Breton, and Baie Verte Canal surveys is about fifty millions of dollars, of which over four millions were contributed by the Imperial Government. The Provincial expenditure, previous to Confederation, which included the first enlargement of the Welland and Lachine canals was sixteen millions of dollars. The expenditure by the Dominion Government in the last 20 years is about thirty millions, which includes the second enlargement of the Welland and Lachine.

Our whole public expenditure upon engineering works,—exclusive of public buildings which have cost over $15,000,000, Dominion steamers $753,893 and Telegraph lines $581,127—exceeds $200,000,000.

The accidents due to drawbridges for railways over canals shew the necessity for a double opening and a double channel, so that trains in either direction, which will persist in running into an open draw, may lie there till they are fished out without suspending navigation.

A new machine for excavating rock under water is being put in operation in the Suez Canal. The work is done by long chisel-shaped cutters, weighing about four tons each, falling about 20 feet, and smashing the rock into dredgeable matter. The principle has been tested successfully upon some of the hardest rock in Scotland. The quantity to be removed is some 3,000,000 tons, and it is expected the cost in 30 feet water will not exceed one dollar per cubic yard. One man controls the whole machinery for which the indicated power is over 1,000 horses. This system was employed years ago at the DesMoines River improvement.

The Quadrant valve for the sluices of lock-gates was introduced on the first enlargement of the Lachine Canal, by David Wilkinson, a Newburyport mechanic and a most ingenious inventor. He was born a British subject before the Revolution, and died at Caledonia Springs about 1855. He was the contractor for the lock-gates on the St. Lawrence Canals, and also for the Suspension Bridge at Ottawa. He was the original inventor of the most important improvement in tools for mechanical engineering, the modern slide-rest for lathes. It was patented in Philadelphia in 1796, when Congress held its sessions there. It was never, I believe, patented in England, but was first introduced there by Maudslay and Field, two of the Engineers who founded the English institution. Wilkinson's patent expired before he derived any benefit from it, but many years after the United States Government granted him a considerable sum for the benefits derived from it in the national arsenals.

Previous to the adoption of the slide rest, the tool was either held by hand, or upon a plate, moving along a groove as in common drawers, worked irregularly, and required constant attendance. In substituting the knife edge rest with three bearing points, and loading it with a weight, steadiness of action was secured and attention dispensed with. Contrasting the faithful action of gravity with the inattention of apprentices, Wilkinson said to me: "Gravity never forgets to pull; if you set him at work at night you will find him hanging on there in the morning." He said he was led to this invention by observing his grandmother putting a chip under her four-legged table and chair while her three-legged pot stood firm anywhere. He called it the Trinity of Mechanics, and said that although brought up a Quaker he had been sceptical until he saw that three, and no more nor less than three, points of support were necessary to ensure stability.

Wilkinson also invented the crooked arm for cast iron wheels, previous to which the more rapid cooling of the straight arms separated them from the greater mass in the rim of the wheel.

Jacob Perkins, of steam gun celebrity, was a townsman of Wilkinson, a frequent visitor at his shop, and an excellent mechanic. He carried Wilkinson's inventions to England long before the United States offered any important field for them.

The lathe has now reached a length of 75 feet and a weight of 100 tons, operating upon "subjects" 60 tons in weight, and reeling off turnings 1½ inches deep by ¼ inch thick, at the rate of one ton per hour with four tools; one with eight tools removes 20 tons of steel in ten hours. Planing machines of 90 tons weight operate over surfaces 20 feet by 15 feet upon subjects 60 to 70 tons in weight. It is to these great machine tools that mechanical engineering owes its greatest triumphs of to-day.

RIVER IMPROVEMENTS.

Our most important river improvement, whether we consider the amount of work performed and money expended, or the results to our commerce, is the deepening of the ship channel between Montreal and Quebec, whereby we have established a seaport nearer to Chicago, St. Paul and Winnipeg than any other upon this continent.

A submerged canal having an aggregate total length of about 32 miles, with a bottom width of 300 feet, is being excavated at a total cost of over four millions of dollars, and will be completed during the present year. This excavation if unwatered would show in Lake St. Peter one continuous cutting 18 miles in length—9 miles of which has a depth of 17 feet. One mile and a half of this artificial channel, 50 miles above Quebec, is dredged out through solid slate rock where the depth at high tide is 40 feet.

The cost of this work, in 1886, was as follows:—

In Lake St. Peter soft clay in 30 feet water, 3 cents per cubic yard.

At Cap à la Roche solid slate rock in 25 to 40 feet water, 30 cents per cubic yard.

At detached shoals, boulders and hard pan, 30 feet water, 10 cents to 75 cents per cubic yard.

The total amount excavated was 1,524,000 cubic yards at average cost for the whole of $11\frac{6}{10}$ cents, exclusive only of interest and depreciation of plant. The channel depth has been increased from 11 to $27\frac{1}{2}$ feet; and the effect has been to bring ocean steamers with ten times the tonnage of the old Montreal traders to a fresh water seaport, 250 miles above salt water and nearly 100 miles above tide. This result is I believe due to the fact that Montreal is upon an air line between Liverpool and Lake Erie. If the course of the Hudson river had been east and west instead of north and south, some point west of New York would probably now be the terminus for the ocean steamers.

Another class of river improvements, for navigation in one direction only, is that undertaken to facilitate the descent of timber, and in this respect we have done perhaps more than any other country.

The expenditure to 30 June, 1886, on river improvements, not including the deepening of the channel between Montreal and Quebec, by the Montreal Harbor Commissioners, is $1,370,335 ; upon slides and booms, $1,775,071.

The first slide for the transfer of a crib of timber without change from head to foot of a rapid was constructed at Hull, on the Ottawa, in 1829, by Philemon Wright, the pioneer of that quarter, in the early part of this century.

There are two descriptions of slide, the single stick, and the crib slide. In the former the timber is put through piece by piece, but in the latter the crib descends with the two men who have guided it into the slide, and also the cook house and provisions on board.

Before any improvements were made, timber was floated loose through the rapid rivers and chutes, (where it was much damaged by the rocks,) and caught in booms at the lakes or slack water reaches, rafted up and conveyed through these until another rapid, not navigable by the cribs of which the raft was composed, was reached—broken up, put through and re-rafted; this was repeated as often as necessary. On the smaller tributaries the narrow single stick slides were built to pass the rapids, but upon the main river crib navigation was practicable, except upon the greater falls and chutes. Short slides, wide enough to pass a crib (about 26 feet,) are built at these, of greater or less length and gradient the slope conforming closely to that of the water fall. Above the crib slides there is a pier dam with an opening for the crib to pass through, which is provided with stop logs used only for high water—or when it is needed to shut the water off. A difference of level of several feet may be maintained at the stop logs over which the crib can pass safely, so long as the depth of water floats them clear of the logs. Similar logs at the head of the slide take a further portion of the fall in high water, the slide floor being set for the low water navigation. When the fall is great it is necessary to curve the lower end of the slide, so as to throw the crib off horizontally. This is effected by hinged aprons which float to a level, but not higher, with the rise at high water below the slide. When the rise is great, two of these aprons are used one above the other. In low water they fall down and form part of the floor of the slide. The pine timbers in these cribs have no fastenings. Two long round timber floats are placed about 25 feet apart and parallel with each other, and the space between filled with a single course of the timber. Four traverses are laid across the tops of the timber and fastened to the floats; upon these traverses four heavy loading timbers are hauled, the weight of which sink the crib, the lower timbers of which are kept in place by pressure against the traverses, arising from this sinking.

In descending a slide, the men put their handspikes between the timbers of the crib and pry in opposite directions to produce side friction, otherwise the dragging of the larger sticks which only touch the bottom of the slide would allow those drawing less water to move faster and dismember the crib. The cribs pass out of the high slides with great velocity, and if their direction were not changed by the aprons would dive into the dead water at the foot, the loading timbers would go forward and the under ones backward, and the crib be wrecked, crushing or drowning the crew.

The first application in Canada of the Bear Trap sluice was made in 1845, at Ottawa, to a timber slide. This ingenious contrivance was invented in 1818, by Josiah White, President of the Lehigh Coal and Navigation Company. This, like the timber, was a descending navigation only. Coal was taken in "arks," a kind of scow which was broken up and sold as lumber when discharged of its cargo at tide water. A similar system obtained on the St. Lawrence in the last century, when grain was brought down both on rafts and in "arks."

Even with the aid of wing dams, the Lehigh in low water could not float the arks over all the shoals. It became necessary to dam up the water, collect the arks at the head of the shoal and flush the fleet over it by opening the dam.

The requirements of timber navigation are different; the slides require a uniform flow over the breast or entrance, as too much water will wreck the cribs and too little strand them. Moreover different quantities are needed for heavy and light timber, and if these follow each other in rapid succession, frequent changes would be necessary with stop logs of different thickness.

The Bear Trap sluice consists of two leaves or shutters, similar to lock gates laid horizontally, which recline against each other, so as to present a triangular vertical section, and contain beneath them a space capable of being filled with water from the superior level, and emptied thereof at will; the contained angle at the vertex when the gates are up being rather more than 100°, in order that the leaves may slide easily the one over the other, which they evidently would not do if the vertical angle of the uplifted gate were either a right or an acute angle. This gate is raised and depressed by hydrostatic pressure applied and removed upon the principal of the Hydrostatic Bellows. A child can manipulate the inlet and outlet valves and set the gate to pass any required depth of water, which it will thereafter maintain automatically, rising and falling with the fluctuations of the superior level. Locks were subsequently constructed on the Lehigh with these hydraulic gates. As these gates will not work in dead water a head sufficient to overcome the weight and friction of the gates must have been available, but there was a plan for using large air vessels in connection with the upper gates. The plans for this Bear Trap sluice were prepared in 1845 by Mr. Samuel Keefer, then chief engineer of Public Works, from a description published in the *Civil Engineer* and *Architect's Journal.* These gates were successfully used for years on the Ottawa slide, but were not continued when worn out, the reason for which I am unable to give.

Some beautiful models of the Bear Trap sluice, the gates being made wholly of iron, were exhibited by the French Engineers at the Paris Exhibition of 1878. They would, I think, be valuable wherever a given supply was to be taken off from a fluctuating level, as in cases where compensation water has to be supplied, or in connection with storage reservoirs, such as those upon the head waters of the Mississippi River. In this climate it would be necessary to have them under cover and protected from frost, if to be used during the winter.

Strong eddies across the outlets of the slides have, under favorable circumstances, been killed by directing a current of water from above into them—making water fight water.

Upon the Ottawa the lumbermen build all crib work open, secured by long iron spikes, and where timber is bolted to the rock, the fox wedge with lead is not used, but soft pine pins, about half the diameter of the drilled hole, are dropped in, and the iron treenail is driven. The compression of the pine holds it more securely than the fox wedge bolt.

Booms temporary and permanent of all descriptions and sizes and for the strongest currents are employed. Ordinary saw logs are strung together and stretched across to form an ice bridge, where the strength of the current would otherwise maintain open water in winter. In the heaviest currents cribs 20 feet wide are used as booms, as in these, wide booms only will prevent the logs being drawn under. The permanent booms, when exposed to a strong current in high water, are not emptied entirely, but a sufficient number of old logs are left in to widen the boom for service when the new logs come in with the spring rush of water.

Reservoirs have been constructed upon the Upper Mississippi to store 85,000,000,000 cubic feet of water. In 1885, they were drawn upon for 70 days, increasing the channel depth at St. Paul 18 inches. In 1886, they were drawn upon for 170 days with same result, although they were not intended to be drawn upon in any one year for more than 90 days. The great mills at Minneapolis during July and August, depended wholly upon steam. Since the construction of these reservoirs, one half their power in these months has been supplied by the river.

HARBORS AND LIGHTHOUSES.

For harbors and breakwaters we have expended over ten millions of dollars, and for lighthouses, in the Provinces of Ontario and Quebec, three millions. The cost of lighthouses in the other provinces has not been ascertained. We have no costly sea-works to rival those in European harbors, excepting the graving docks recently completed near Quebec, and at Esquimault on the Pacific coast. In accordance with the practice of this continent, wood is the material used in the form of crib work in all our harbors, sea and inland, with the exception of the unfinished work at Quebec, where masonry is employed. Nature has made our harbors and left us little more to do than to construct the wharves; when breakwaters are required these are constructed in crib-work. Nor have we any lighthouses in exposed positions like the Eddystone, Skerryvore and Bell Rock. There are 670 lights, embracing 124 seacoast or main headland lights, 138 secondary coast lights, 393 river and harbor lights, and 15 light ships. Most of the main lights are either large size dioptric lenses (36), or revolving catoptric lights, and most of the inferior lights are upon the catoptric principle. The buildings include 41 stone or brick towers, one iron tower, one wooden one upon iron screw piles, and 477 wooden towers. The remainder are chiefly mast lights. Two of the lights in the more exposed positions stand upon circular stone piers built in iron caissons.

There are 46 steam fog alarms, most of them with duplicate machinery, 10 fog guns, 7 bells operated by machinery, a large number of automatic bell and whistling buoys, and 7 gas buoys, 2 of which carry beds. The annual cost of maintenance is $323,000.

In lighthouse construction a noticeable recent work is the Rothersand in the North Sea at the entrance to the River Weser. An oval iron caisson 36 x 46 feet diameters was towed to the site and sunk 50 feet into the sea-bed, or 70 feet below low water. The superstructure is continued upward in iron, and drawn in to a diameter of 5-10 metres.

Portland cement concrete, to which with the aid of caissons modern hydraulic engineering owes its greatest strides, has not only revolutionized the method of preparing foundations by abolishing the cofferdam, but has made it possible to cope with the great forces of the ocean wave. Monoliths of concrete, 350 tons in weight, have been used by Mr. Stoney, at Dublin, and sacks containing one hundred tons have been deposited in plastic form to adjust themselves to an uneven bottom where they become as hard as stone. The most remarkable application of the caisson is at Toulon, where the whole foundation for a dock, 472 feet long by 134 feet wide, and 62 feet deep, was covered by a single iron caisson, and excavated by the pneumatic process.

CIVIC ENGINEERING.

This is a wide field of increasing importance embracing hydraulic, mechanical, electrical, gas, railway and road engineering, that is water supply and sewerage, electric lighting and the electric railway, the elevated and the cable railway and pavements, any one of which is the subject for a separate and extended essay. I can, therefore, only refer to a few questions in connection with each.

Water supply and drainage or sewerage, on account of their influence on the health, protection and comfort of the citizens, are first in importance. Every epidemic is immediately ascribed to the water supply or the sewers, although typhoid and diphtheria are often more prevalent in country districts, where no fault can be found with the water or the drainage. It is an annual plague in the Rocky Mountains as well as in the Panama or Roman marshes. This outcry has given rise to a new name in our profession, the Sanitary Engineer. The jurisdiction of the City Engineer does not extend into the houses. With the best arrangements, eternal vigilance is the price of exemption, and as we cannot tell how everything is working if not always in sight, and when sealed up by ice and snow, I believe the only safety is in providing for the worst. Wherever this gas can get in, make a way for it to get out,—ventilate the exposed rooms as well as the sewers.

Undoubtedly there is much room for improvement in the drainage of our towns—both as to streets and houses—but the best systems for both assures us no guarantee against the ravages of an epidemic. The health commissioners have ascribed the recent epidemic at Ottawa, to the water, not because they discovered anything wrong in it—but because they could find no other solution of the question. We cannot even suggest a remedy until we know the cause. Experts are not agreed upon that—the drainage, the water supply, the heat, the drouth, and deficient supply of electricity in the atmosphere, have, one or more, in turn been held responsible. As all, with the same exposure, are not victims, the individual constitution must be an element in the question. If the exciting cause can be located upon the terra firma, engineers may be able to deal with it,—but if it is in the air we must remember that it can get there from the four quarters of the compass as well as from under our feet, from above as well as from below, and this will go on in spite of all our efforts until the last Vial is poured out into the air.

Periodical outcries against the water are accompanied by demands for filtration at the works. Filtration has two sides,—you "hive" all the impurities in a limited space, and compel all the water to run the guantlet through them. Frequent cleansing of the filter beds would be necessary, and how is this to be accomplished with the thermometer 20° below zero ? We cannot cover acres and heat the enclosure to handle ten millions of gallons daily. Of this ten millions, two per cent. or less may be used for drinking and culinary purposes. Filtration, therefore, like ventilation should be done in the houses by those who demand it, and they must see that, by daily cleansing, they get the water in as good condition as it comes to them.

The Insurance Companies are reminding us that fire protection should be a leading consideration in every system of water supply. In gravitation supplies like Quebec with sufficient elevation, and in pumping supplies where water power is used, as in Ottawa, this result is obtained without additional cost. But where steam power is required, as in Toronto, the best fire protection—that from direct pressure from hydrants—is secured only by increased consumption of coal. The people there complain of their coal bill, but if it were less their insurance bill would be greater. They compare their consumption of coal with cities which do not lift the water half the height to which it is lifted in Toronto.

Our principal cities, Halifax, St. John, Quebec, Montreal, Ottawa, Toronto, Hamilton and London, have very efficient systems of water-supply, in respect to quality and pressure. As compared with the older systems in New York, Philadelphia and Boston, our pressure is greater and our use of Steamers for fire is less. We pay more for pumping and less for fire insurance. With the exception of Winnipeg, Vancouver and Belleville, all our cities own their water-works. Quebec, Halifax, St. John, St. Catharines, Victoria and Vancouver have gravitation supplies. Montreal and London have water power supplemented by steam, with distributing reservoirs. Ottawa has water power exclusively ; continuous pumping without stand pipe or Reservoir since 1874, and without any failure in the supply. Both pumping power and mains are duplicated, because, with a single pump and main, in the absence of a Reservoir, a break down of either suspends the delivery instanter, and in toto.

Brantford, Guelph and Stratford pump by steam, Peterborough, Port Hope and Lindsay by water power; the two latter for fire purposes only. Brampton has a gravitation supply. In Stratford and Port Hope the water power is used at nights for the Electric Light. This is also done in Victoria, where, with a gravitation system, the high levels are supplied during the day by steam from the Electric Light boilers. This economical arrangement is only applicable—for constant supply, where there is a reservoir and sufficient pumping capacity to keep it filled by working only during daylight.

Vancouver's gravitation supply is only commenced. The water is brought from a mountain canôn—nearly ten miles distant—through steel pipes 22 and 16 in. diameter, and carried across an arm of the sea in 60 feet water by a cast iron flexible jointed pipe. The fountain head in 430 feet above tide, the highest parts of the city being about 250 feet lower than the source of supply.

There are a number of other Canadian towns and villages which have water works. I trust we will receive a full account of them, as well as of those mentioned, through local members of this Society.

An economical and ingenious method of supplying a limited number of houses, above the distributing reservoir head has been in successful operation in Burlington, Vermont, for the last six years. An hydraulic motor is inserted in the pumping main near the Reservoir, the water surface of which is 289 feet above Lake Champlain, the source of supply. Two ten-inch rising mains connect the pumps and reservoir, passing through the city. The distributing pipes are fed from these mains, receiving from the pumps, when in motion, and from reservoir when pumps are standing, the pressure on the motor being greater on the pump side when the latter is working, and upon the reservoir side at other times. When the reservoir is full the head is between 12 and 13 feet, and the pressure a little over 5 lbs. This motor raises the water 60 feet, and delivers it through a mile of pipe into a tank having an overflow pipe into the main, so that no water is wasted. The speed of the pump worked by this motor varies from 5 or 6 strokes per minute in the night, to 22 strokes per minute in the day time. The cost of this application was under $2000.

Mild steel is competing successfully with cast iron for mains, rivetted for the larger sizes and lap welded for 12 inch and under. The strength and security is greater, and the cost on the whole less, because of the lighter weights, longer pipes, fewer joints, and lesser cost of transportation Cast iron, however, maintains its supremacy for all purposes of distribution on account of the facility and economy with which connections can be made with it. Its greater durability on account of its greater thickness also checks the extension of the use of steel.

I can only direct attention to the great works going on for the further supply of New York, Liverpool, Kansas City, San Francisco, etc., and to the rapid extension of water supply to the smaller towns and villages on this continent. This last is the result of the organization of large water companies, having like the bridge companies able engineers. A contract is made securing an efficient fire service for a stipulated annuity from the corporation. This secures the whole or the greater part of the interest on the outlay and the companies trust to other consumers to make up any deficiency. Many towns prefer to pay an annual subsidy to undertaking the works, in some cases because they are unwilling to entrust their representatives with their construction. Belleville has agreed to pay an American company $3\frac{1}{2}$ per cent. on an estimated cost of $200,000, for the construction of water works.

I am not aware of the formation of any company in Canada for this purpose. If our unsupplied towns have not wisdom enough to construct and own the works which should pay them as well as it pays a company, capitalists and engineers may do a good thing for themselves and the country by shewing them how it can and ought to be done.

SEWERAGE.

The foremost question in connection with sewerage is whether the combined or separate system should be adopted for new towns or for new extensions in older ones having the combined system. For house drainage, sewers require a deeper excavation than is necessary to get rid of surface water, and are therefore very costly when large enough for both purposes. The combined system is necessarily weaker in form and therefore more exposed to damage from excessive rain fall. Much depends upon climate and surface inclination of the streets, as well as the relation between the street grades and basement openings in the buildings. Before towns are sewered all the water is carried off upon the surface, but with level streets and particularly in Northern towns when the snow is melting fast there is a necessity for rapidly relieving the streets by underground drainage, in order to prevent flooding of basements. In the sewers of the combined system, the gas is diluted by contact with a larger body of air and water, and these sewers are flushed by the rain fall, but at irregular intervals which are too long in the dry season of summer and the cold one of winter. In the separate system, the pipe sewers are flushed automatically, and at frequent intervals at all seasons; but for this purpose water must be provided although comparatively little is required.

The separate system being much cheaper than the combined will doubtless be adopted where the question of cost is decisive, and surface water can be disposed of as before.

Our new city of Vancouver has adopted the separate system for which all the conditions are favorable, a mild climate, excessive rain fall for six months, and good grades for rapid removal of surface rain fall.

The needs of this city were so urgent that they could not wait for metalled roadways, or for sewer pipes from Glasgow by the long voyage around Cape Horn. They therefore have covered their roadways with plank, and made their sewer pipes of the same material, with rubber joints, for which when necessary earthenware pipes will be substituted, all man holes, etc., being monoliths in Portland cement.

The proper disposal of sewage is the great question in other countries, especially where the discharge causes river pollution or endangers the source of the water supply. Chicago is extending her tunnels four miles into the Lake, instead of the two miles which were considered sufficient to escape the pollution of the Lake shore, by her "cloaca maxima" the Chicago River.

Toronto is agitated over intercepting sewers, pumping, and sewage farming. The utilization of sewage to diminish the cost of its diversion from the natural outlets is limited by local conditions. Clarification and irrigation both involve pumping, and the latter is only practicable where large areas of low level and cheap land are to be obtained.

No system can surpass the discharge into large flowing rivers, or large bodies of water, and where these are the sources of the water supply, the best and cheapest course is to remove the intake of the latter to a safe distance.

The removal from the streets of garbage and rubbish, which may be washed into sewers, and the cremation of all combustible trash, is attracting deserved attention in towns where this new departure is needed. This cremation is as old as Jerusalem, where the fires in the Valley of Hinnom were never quenched.

PAVEMENTS.

The gradual approach to the old Roman method of roadway is the result of increasing wealth and intelligence in our large cities. I give the precedence to wealth as intelligence is useless without it. It is money and men with us, while with the ancients men were plentiful and a little money went a long way. In fact the men had to do the work whether the money was forthcoming or not. The knights of those days were not Knights of Labor. Our practice has been to veneer the graded surface with a shallow coating of stone or wood, as well,—or otherwise (and sometimes otherwise) as the money would warrant; but, chiefly for want of a proper foundation (which is the expensive part) there was no durability. A temporary system is in fact the only one applicable to growing towns. The constant breaking up of streets for gas, water, drainage, tramways, etc., is the great drawback to a permanent system. The wooden block pavements were no sooner completed than they were chopped through for these purposes and the statu quo could not be restored in the necessarily hasty refilling of the trench. There is apparently no limit to this;—larger gas and water pipes may be required, and telegraph, telephone, and electric light wires must yet go under ground, and it must go on until we can afford permanent sub-ways as in Paris, and then all connections can be made without breaking through our pavements. All street work for all purposes should be under one city control. Where two or more parties have the right to open the streets, there is no remedy for injury done but the unsatisfactory one of litigation.

TRAMWAYS.

Electricity as a means of propulsion for city railways is making great strides in the United States to the south and west of us, where it dispenses with horses and therefore stables, but in our climate it is only available about seven months in the year. It is more efficient and in some cases more economical than horse power, but whether it will prove so for our car season only will depend on the traffic. The horse stock and stables must be retained, and the former must either go to other work or be sent to grass.

The cable system for the same reason is shut out from Eastern Canada, but both it and the Electric are available when they can be afforded on our Pacific Coast. An elevated railway is the only one upon which continuous car traffic can be maintained on our streets throughout the year. This city is forced by the mountain to extend chiefly along the river, and I think that an elevated road between Cote St. Paul and Hochelaga will become a practicable enterprise in the near future.

MECHANICAL ENGINEERING.

The enormous strides which have been made in Mechanical Engineering are strikingly illustrated by a statement recently published that 4-5ths of the engines now working in the world, of which over 100,000 are locomotives, have been constructed in the last 25 years—that their aggregate horse power is 46 millions, and their working power equivalent to the labor of one thousand millions of men, or more than double the working population of the globe. This recent construction of so much machinery is not alone the result of recent expansion or of the necessity for reconstruction, but of substitution. The machinery has not been worn out, but thrown out. A machine becomes valueless in these days of competition as soon as another one is invented which can produce the same thing at less cost.

Canada manufactures her steam engines, both stationary and locomotive, and is the only colony which produces the latter. The steam-pumping engines at Hamilton, London, and other towns are Canadian manufacture, as well as the water power pumping machinery at Ottawa. The pair of compound engines erected for the Hamilton

Water Works were the first of that class on this continent. They were started by the Prince of Wales in 1860. Compound engines are now to be found in our inland steamers, mills and factories. In machinery of all descriptions required for the country, Canada made an exhibit at Philadelphia in 1876 which surprised both English and American experts, and received the highest encomiums from the British expert John Anderson, L.L.D., who said it was neither English or American but had a distinctive character of its own, shewing originality, individuality and adaptation to the work to be done. I am indebted to Mr. Barnett of the Grand Trunk Railway for the following interesting particulars. "The equipment for locomotive work in Canada includes the making of the heavy forgings. Boilers and furnaces are exclusively of steel, and the hydraulic equipment, principally under the Tweddle patents, is not exceeded in variety and effectiveness elsewhere on this continent. Within the last 10 years injectors have displaced pumps completely for boiler feed, economizing fuel, and reducing delays and failures to trains, owing to the greater exemption of injectors as compared with pumps to injury from frost. These injectors are now made in Canada.

Steel castings are growing in favor, replacing awkward iron ones and expensive forgings, but no success has as yet attended the use of steel for resisting sliding friction, and the use of steel for axles is not increasing.

The use of cast iron slide valves distinguishes the practice of this continent from that of Europe generally, and equilibrium or relieved pressure slide valves are every day practice.

Steel tyres and lap welded tubes are not yet manufactured in Canada.

The horse power of Canadian locomotives has been increased 26 to 30 per cent. within the last ten years, and their centre of gravity above rail level has been raised, and in the same period the use of wood for locomotive fuel has been practically abandoned. Locomotive turntables have increased from 45 to 55 feet in diameter, and are now constructed wholly of iron. Passenger coaches have been increased in length from 40 feet to 65 feet, and freight cars from 10 tons, the capacity of 15 years ago, to 20 tons. Our neighbors are now building them for 30 tons carrying capacity. The use of steel-tyred wrought iron wheels of large diameter in place of cast iron ones is one of the most recent changes in the direction of safety.

Uniformity in construction, with interchangeable parts, is aimed at, and the couplings of passenger coaches are the same from Vancouver to Halifax. The same uniformity extends to the automatic brake gear and its couplings.

Exposed frost proof tanks, 24 to 36 thousand gallons capacity, have taken the place of stove-heated house tanks. The heat of this mass of water is sufficient in ordinary weather to prevent dangerous formation of ice. An additional precaution is the passing of the water in the rising main through an annulus surrounding the exhaust pipe from steam pump cylinder. The ascending column of water acts as a condenser, and absorbs a degree or two of heat, so that no trouble is experienced even with India rubber water valves, at a temperature 20° below zero.

In shops there is an increased use of milling tools, and of the portable twist drill, by which much handwork is displaced.

Increasing cost of fuel has stimulated the manufacture of engines with independent slide valves for steam supply and exhaust, such as the "Brown Engine."

Mr. Brown, Mechanical Superintendent of the Canadian Pacific Railway, has kindly contributed the following notes:

"Progress in locomotive designing and building made by the Canadian Pacific Railway Company, in connection with increasing the haulage capacity of the locomotive by adding to the weight and raising the boiler pressure without increasing the size of the Cylinders.

For instance, in 1883 the standard 17 in. x 24 in. cylinder locomotive built by the company weighed 83,000 pounds in working order, the boiler pressure being 150 pounds to the square inch. To-day the same class of engine with similar size of wheels and cylinders and duplicating patterns in all important parts, weighs 88,000 pounds in working order; this additional weight being all on the driving wheels, and the boiler pressure being 160 pounds to the square inch, enables the improved locomotive of '87 to haul on a 1 per cent. grade three average loaded cars or two fully loaded cars more than locomotives of '83, with same size cylinders. On the level the increased haulage power may be put at double the above.

This class of engine is also used for light passenger service, 69 inch wheels being substituted for 62 inch. The Westinghouse Air Brake with brakes on driving wheels being added, making a total weight in working order of 90,500 pounds, the boiler pressure is here raised to 170 pounds to the square inch.

In designing other types of locomotives these principles are adhered to, with a view on the one hand to increasing the efficiency and economy in fuel consumption, and maintenance; and on the other hand of avoiding the great fault of having an over cylindered engine, bringing with it its attendant evils in the shape of high fuel consumption combined with heavy cost of maintenance and repairs.

The first locomotive constructed in Canada was built by Kinmond Brothers in 1852 for the Grand Trunk Railway, and about 650 engines have since been constructed in Canada.

The locomotive built by Stephenson in 1832 for the Laprairie and St. Johns road had cylinders 10″×14″ :—the recent ones built by the Can. Pac. Ry. have cylinders 19″×22″.

One result of the Basic process for direct conversion of iron into steel, is to give a commercial value to the slag for agricultural purposes. This slag, which is known as the " Thomas " slag, contains 10 to 25 per cent. of phosphoric acid, averaging about 16 per cent. It is ground into a fine meal, and sold at a cost of about one-third that of superphosphate in Germany, where 400,000 tons are now used annually for this purpose, and is said to contain as great a quantity of phosphoric acid as the superphosphates. This by-product of steel manufacture has an interest for us as exporters of apatite.

MINING ENGINEERING.

Canada contains such a vast mineral area in proportion to her population that with the exception of coal upon her sea coasts, no extensive mining has yet been accomplished. Her productions, however, embrace all the precious and commercial metals and minerals, excepting precious stones and tin. Gold, silver, copper, lead, iron, slate, apatite, graphite, gypsum, asbestos, antimony, arsenic, mica, petroleum, salt, and barytes have been worked. Zinc, nickel, petroleum, antimony and bismuth are known to exist. Besides other minerals used for chemical manufactures, manures, pigments, refractory materials in soapstone, fire clay, kaolin, sandstone, grinding and polishing materials, whetstones, infusorial earth, and polishing powders, as well as materials for construction, including marble, granite, slate, flagstone, hydraulic lime, etc., and many applicable to fine arts and jewellery, from lithographic stone to jaspers and agates.

The total coal and lignite bearing area, surveyed and partially surveyed, is nearly 100,000 square miles. Anthracite has been found on Queen Charlotte Island, where is the only known deposit on the Pacific coast. It is being worked also in the National Park near Banff. The Wellington coal on Vancouver Island is considered the best on that coast, and is selling at $10 per ton in San Francisco; the cost at the mine dock is, however, $4 per ton. Coal is extensively worked at Lethbridge in Alberta, N. W. T., on the main seam of the Bow River deposit, which deposit is estimated to contain 330,000,000 tons.

The amount of coal raised in Nova Scotia in 1886 was 1,682,924 tons, on Vancouver Island, 326,636 tons. In Nova Scotia a vertical depth of 1350 feet has been reached in the Vale coal mine, and about half of that depth at Nanaimo on Vancouver Island.

Coal mining began in Nova Scotia as early as 1827. Since 1880 the annual production has exceeded one and a half million of tons and is now increasing yearly.

Coal was discovered on Vancouver Island in 1835, and mining was commenced by the Hudson Bay Co. in 1850. The first steamboat which ran on the North Pacific Coast was placed there in 1836 by the Hudson Bay Co., and is still in commission. The first locomotive also on that coast was imported for the Nanaimo Colliery.

Our total production of coal in 1886 was 2,091,976 tons, of which about 500,000 tons were exported chiefly by British Columbia. In that year we imported about 2,000,000 tons, nearly half of which was anthracite.

The gold production of British Columbia since 1858 amounts to $50,000,000, and of Nova Scotia in the same period $7,706,000.

The Crown Copper Mine at Capleton, Sherbrooke Co., Quebec, has reached a depth of 1520 feet on an inclined shaft, and the Albert mine at same place 810 feet. This is a sulphuret with about 4 per cent. copper, and has, after failing to pay as a copper mine, been successfully worked for sulphuric acid, the yield of copper paying all expenses, and thus giving the whole value of the acid for profit.

The Silver Islet mine in Lake Superior, which yielded millions before it was abandoned, reached a depth of 1160 feet, and the Shuniah 760 feet. Very valuable silver mines are now being worked west of Port Arthur, one of which, the Beaver mine, is reported to have millions in sight.

Our total mineral production for 1886 including structural materials is valued at $10,529,361, of which coal made up five millions, and gold one and one-third millions:—petroleum, copper, phosphate, pig iron, silver, and asbestos rank next in value in the order named.

Some of the important discoveries in connection with mining engineering have been the result of accident. In boring for water petroleum was discovered, and in boring for the latter natural gas in the U. S., and rock salt in Canada, have been found. Petroleum had flowed out of Oil creek in Western Ontario as long ago as Indian tradition extends. It was gathered from the surface of the water by Indians, and was sold under the name of Seneca oil as a specific for rheumatism. This oil exuding from the ground had filled a low depression away from Oil creek, several acres in extent and several feet in depth. It had dried out, and become an ill-smelling, viscous, dark brown mass known as the "gum bed." Samples were sent to the Paris Exhibition in 1855, and found to yield paraffine wax. When the distillation of oil from bituminous shales commenced, preparation was made to utilize the gum bed. A steam boiler and retorts were sent up, and a pit was sunk in the stiff clay to collect surface water for the boilers. Instead of water petroleum flowed into the excavation, was barrelled and shipped. Just then news came of the discovery of rock oil at Titusville, Pa., by a man who was boring for water, and thus the Canadian oil wells were started at Enniskillen about 1861. The retorts were never used.

The late Sir Charles Siemens maintained that gas will be the fuel of the future, and that this was the only solution of the smoke question for London. Since his death the use of natural gas has solved it for Pittsburg. Taking the cost of producing gas for all England, it was shown a few years ago that the value of the by-products exceeded the cost of coal and labor, and that if all the works were pooled, *more Americano*, the whole charge for gas was available for dividends. Where natural gas does not come to the relief of our towns, the question for our engineers will be how far gas fuel can be laid on economically from central stations, which will much depend upon a market for the by products. Electric lighting will doubtless turn the attention of the gas companies to this problem.

A French engineer, Mr. Chalon, has published in *Le Génie Civil*, the results of some experiments in blasting without tamping. He plugged the hole with a handful of wet clay, and the effect with black powder was extraordinary. The mean of five experiments was 13 cubic yards of rock removed per pound of powder used, whereas in the same quarry under the ordinary system only 7½ cubic yards per pound of powder was removed. He says that with hard tamping, the powder has not time to burn completely, as much as 20 per cent. of the charge being blown out. In his experiments the air chamber between the clay and powder permitted the latter to become thoroughly ignited, and the developed gas to expand. He proved that the force of projection of the tamping was diminished—by inserting a wooden plug in the clay and measuring the shorter distance to which it was thrown.

ELECTRICAL ENGINEERING.

The practical application of electricity in Canada for lighting and locomotion is very recent, dating since 1882, and in fact its whole development as a commercial question is confined to the last ten years. The Avenu de l'Opéra, in Paris, was lighted in 1878 on the Jablokoff system, each light requiring 2½ horse-power. It was regarded as a luxury then, and the lights were extinguished at midnight. The same result is now produced with one horse-power. Montreal was the first harbor in the world lighted by electricity, whereby she secures the utmost despatch in the discharge and loading of her ocean visitors.

Ottawa is exclusively lighted with electricity by the arc light, which has replaced gas at the same cost, the fine water power of that city driving the dynamos. It has also the incandescent system for interior lighting. This system has also been introduced in our new towns of Vancouver and Calgary in advance of the gas.

It is estimated that the capital invested in electric lighting in Canada reaches $2,000,000 already, that there are about 3,000 arc lights, and about 15,000 Edison incandescent lights in use here.

A street railway has been successfully worked by electricity upon the over head system, between Windsor and Walkerville, in Ontario, for several years. It was one of the earliest applications of the system upon this continent. There is also an exhibition one in Toronto.

The line between St. Catharines and Thorold is worked by electricity.

The Phonograph is the latest wonder of Electric application. It was invented 10 years ago by Edison, but remained a curiosity until last year, the inventor meanwhile having been occupied with the incandescent light. Hardened wax cylinders have been substituted for the original tin foil covered ones. These cylinders are provided with a mailing case, so that not only the spoken words, but the expression and inflection of the voice can be transmitted to distant points. It will replace the stenographer, can make no mistakes, will be an unimpeachable witness and cannot be confused by cross-examination. Besides its use in Court, it will report speeches, songs, lessons, and orders, and read to the sick in hospitals, etc. Four cylinders, each 4 inches in diameter and 8 inches long, will record the whole of Nicholas Nickleby.

EARLY ENGINEERS.

I am unable to give much information about the early engineers of Canada. Royal Engineers controlled the Rideau Canal, but had civil engineers as assistants, all of whom I believe came from Britain. Nichol H. Baird, who was the chief, and John McTaggart, are two of the names associated with that work. When the Lachine Canal was undertaken, Thos. Burnett was brought out from Britain as Chief Engineer. Francis Hall, a pupil of Telford, was the Engineer of the Shubenacadie Canal, which was commenced in 1825. As this work was suspended, and remained so, he removed to St. Catharines, and was consulted with respect to the Welland Canal, and also that at Burlington Beach near Hamilton.

Samuel Clowes, a British engineer, was employed by the commissioners of Internal Navigation in 1824, to report upon the Rideau Navigation before the Imperial Government assumed that work, and also upon the St. Lawrence Canals, in 1826.

The completion of the great Caledonian Canal in Scotland, by Telford in 1820, set free a number of British hydraulic engineers some of whom came to Canada; and the opening of the Erie Canal, in 1824, supplied a number of American engineers educated upon that work for both the Welland and St. Lawrence Canals.

Hiram Tibbetts made a preliminary survey for the Welland Canal in 1823; but the Chief Engineer during construction was Alfred Barrett, who was afterwards engaged on the first enlargement of the Lachine Canal, and died in Montreal. Barrett's location of the Welland was revised by Geddes and Roberts, two American engineers of large experience. Samuel Clowes and his son were employed on this location. George and Samuel Keefer were engaged in the construction of the Welland; the latter, only eighteen years old, on the completion of the work, went from the Canal to Upper Canada College, and subsequently, both—he first, and his elder brother afterward, were engaged upon the Cornwall Canal. In 1838 George Keefer was removed to the Chambly Canal. He retired after the opening of the Grand Trunk Railway upon which he was engaged at Gananoque, in 1856, and died two years ago, at the age of 86,—62 years from the time he commenced upon the Welland Canal. He was therefore probably the oldest Canadian engineer,—by which I mean one who has acquired his professional experience in Canada. Samuel Keefer left the Cornwall Canal in 1840, and in 1841 became Chief Engineer of the Board of Works, which was created at the union of Upper and Lower Canada in 1841. The chairman of this Board was the late Hon. H. H. Killaly, a British engineer, who had been some years in this country, and had been associated with N H. Baird, in reporting upon the Trent Navigation, and upon the Welland Canal Enlargement in 1838.

The engineers employed upon the location of the Cornwall Canal in 1833 were all Americans, except Samuel Keefer. John B. Mills, one of Moncure Robinson's pupils, was Chief Engineer, and he brought with him Wm. J. McAlpine and James Worrall. The location was revised by Geddes; and also by Benjamin Wright, who was retained as Consulting Engineer. McAlpine and Worrall left on completion of the surveys; and for construction, Mr. Rodrigue of Philadelphia, and Samuel Keefer, were the Division Engineers. Mills, the Chief Engineer, resigned after two years, and was succeeded by Col. Phillpotts, of the Royal Engineers. Rodrigue also resigned and was succeeded by George Keefer. Both McAlpine and Robinson are celebrated American engineers, still living, —the first in New York, and the second in Philadelphia. Moncure

Robinson is related to the family of the late Sir John Beverley Robinson of Toronto.

Peter Fleming, a British engineer, reported upon the Chambly Canal in 1829, and Mr. Hopkins was the engineer in charge during construction in 1835. Fleming was a good mathematician, and published a work upon the quadrature of the circle, in which he succeeded —as well as could be expected.

James Cull, a British engineer, reported upon the Toronto harbor in 1833, and was also engaged upon macadamized roads in the neighborhood of Toronto and Kingston.

Alex. Stevenson, a British engineer, reported upon the Beauharnois Canal in 1834.

I have mentioned only those engineers who were engaged upon our public works previous to the Union and the establishment of the Board of Works in 1841, as well as previous to the railway era. I may have omitted several names which ought to be mentioned. I think in those days there were few City Engineers, and that all the public works were Government ones. Since 1841 the Annual Reports laid before Parliament, and, later, the railway reports, record the names of the engineers.

PROJECTED WORKS.

Of future engineering works I can say but little. Our railway system penetrates all parts of the Dominion, and will extend itself wherever and as soon as required. The only remaining national railway not yet accomplished is the one projected to reach Hudson's Bay. I do not believe this will become an exporting route in competition with the St. Lawrence, nor that 500 or 600 miles of railway without local traffic or through connection, can be sustained by a few months ocean navigation in Arctic waters. The crop of the North West cannot be exported before navigation closes, and the railway will have little traffic to keep open its line during winter, because grain will rarely be sent to cool off for six months or more in elevators on Hudson's Bay. Our eastern trunk lines, with the advantage of a local traffic through our richest territory, cannot hybernate at Montreal and Quebec, but have been obliged to push on to the open sea.

I believe, however, that as a nation we should tap Hudson Bay at the bottom, in James Bay, where it approaches within a few hundred miles of our railway system in the Ottawa Valley. I believe the valuable fisheries, furs and other Arctic exports from an enormous coast line would gravitate southward to such a railway, and that its terminus would be the depot for a fishing fleet, which could compete with the whalers of the United States.

In bridges Canada has the finest samples of the various types, and the only tubular ones on this continent. While there is undoubtedly a surplus of iron in the Victoria Bridge, I do not think there is an unnecessary amount of masonry in the piers. Its location and exposure to ice shoves require more massive piers than bridges where only running ice has to be encountered. Moreover, the liberal dimensions in the direction of the stream are sufficient for a second line of rails.

But we have a bridge project, which when carried out will in length of span be second only to the Forth which is 1661 feet. This is the proposed cantilever at Quebec. The car traffic of the Canada Atlantic has warranted that road in deciding to supersede a costly ferry system by a bridge, and let us hope that a similar case may soon be made out for Quebec.

The Railway Bridge over the St. Lawrence at Lachine recently completed by the Canada Pacific Railway is an example of rapid construction of the best masonry in a difficult situation, which has not I believe been equalled anywhere before—the work being done between the leaving and the taking of the ice in the same year.

The tunnel or subway to give railway connection with Prince Edward Island is another of the great Engineering works proposed. It is difficult at present to say whether the physical or the financial obstacles are the greatest, but when the money is forthcoming I have no doubt a way will be found to reach the Island.

The last great project I have to notice is the proposed ship railway between the Bay of Fundy and the St. Lawrence, located in the neighborhood of the route surveyed for the Baie Verte canal. I will not anticipate the paper to be presented to this Society by one of our members, who is the projector of the scheme, by an attempt to describe it in detail, but will only say: No route could be more favorable in an engineering sense for the inauguration of this new system. A practically straight and level line less than 20 miles in length, is available. I have the utmost faith in the practicability of the enterprise. There is no novelty in raising, or moving vessels on wheels. France is now transferring torpedo boats between the Atlantic and the Mediterranean by rail. Ships have been hauled out on wheels, and been put back in the same water; the ship railway only proposes to carry them farther and put them in another water.

In conclusion, when we reflect that steamboat navigation began less than 80, and railway construction less than 60 years ago, the telegraph 40, and the Atlantic cable less than 30 years ago, and that the telephone, electric lights, and motors are yet in their infancy, and then look at their position and work of to-day, we have reason to be proud of a profession to which the world owes so much; and, having regard to the great interests committed to us, we have need to take counsel together for we cannot say of each other, no more than the foot to the hand, I have no need of thee!

Motive power until the days of Watt was limited to the use of wind and water. The invention of the steam engine gave to Engineers a new and constant power, unlimited in its application and extent, and has revolutionized navigation. But it was the much later application of steam to locomotion which gave birth to the Railway system, and is revolutionizing the world. The Mining Engineer gives us the coal, the Mechanical Engineer the stationary, locomotive, and marine engine, as well as the metal steamship, the Railway Engineer supplies the road for the locomotive, and the Hydraulic Engineer the harbor and docks for the commerce which they create.

The extension of commerce due to steam transportation by land and water has vastly increased the population of the older cities and created new ones of fabulous growth, and the Municipal Engineer, in giving drainage, water-supply and fire protection—whereby the terrible destruction of life and property due to plague and fire so common in the middle ages has been arrested—provides for the health, comfort, and safety of the citizens.

In addition to these five branches of Engineering there is another and most important one, a great power in Nature,—electricity, until recently with little commercial value, and valuable chiefly for electro-plating or as a health officer in dispelling a sultry or vitiated atmosphere, but inestimable in value if admitted to be the agent through which the clouds "drop down their fatness" on the earth. Invisible like steam, and like it known chiefly by its effects, its range is universal,—in the heavens above, and in the earth beneath, and apparently in all things living, in all animal and vegetable life. It transports with equal velocity the weakest tones of the human voice, and the irresistible force of the thunderbolt. It traverses the ocean as well as the continent. It lights the harbor, it moves the car, it pumps the mine, it welds the metals, it vitalizes the human frame. We cannot forecast its future, or limit its possibilities of production. Economically, it may yet become the cheapest source of power with the exception of wind, water, gravity, or the sun, and by chemical energy may become as constant and universal in its application as the sun itself, to which in common with the other natural powers we may ascribe its origin, even though that be the limit of our knowledge concerning it.

Thus are we the complement one of the other, and thus has grown up in the present century a great army of Civil Engineers with different branches of service, but all working together for the same end—"the directing the great powers in nature for the use and convenience of man."

6th January, 1888.

E. P. HANNAFORD, Vice-President, in the Chair.

The following having been balloted for were declared duly elected as

MEMBERS.

RICHMOND HERSEY CUSHING.
JAMES ALEXANDER DICKEY.
ALLAN JOHN LAWSON.
JOSEPH LENNON UNSWORTH.
HENRI ETIENNE VAUTELET.
EWARD ASHLEY WILMOT.
JAMES ALLISON PATERSON.

ASSOCIATE MEMBERS.

SAMUEL FORTIER, B.A.Sc.
CHARLES MONTSERRAT ODELL.
JAMES HUGH MACKENZIE.

STUDENTS.

PERCY HOWE MIDDLETON.
WILLIAM SIMEON DENISON.
HUGH YELVERTON RUSSEL.

Paper No. 12.

THE TELEPHONE.

By F. N. GISBORNE, M. Can. Soc. C. E., F.R.S.C., &c., &c.

Many and bitter have been the writings and discussions as to the *Original Inventor* of the Telephone.

The earliest *record*, vide copy of the "Jahresbericht," of 1861, in the British Museum, proves that Philip Reis, of Berlin, had then experimented with the avowed object of *transmitting speech* by electricity, and that musical sounds had been conveyed by his apparatus. Moreover, his original instruments now reproduce speech, when the electrodes are moistened with a drop of water, or oil.

Fifteen years later, 1876, Professor Elisha Gray, while endeavoring *to transmit speech*, invented his *harmonic telegraph;* and Graham Bell, who was in search of a *harmonic telegraph* (vide his original United States Patent of 1876), discovered the simple and beautiful method of *transmitting speech*, which has since bestowed upon him fame and fortune.

Two years later, 1878, Professor Hughes gratuitously gave to science and the world, his microphone; and based upon such discovery, viz., the varying resistance of carbon electrodes under more or less pressure, Thomas A. Edison invented and improved telephonic transmitters; and now the combined inventions of Bell, Edison, Gower, Blake and others constitute the commercial value of those Bell Telephone Company's acquired patents which have been upheld by the law courts of the United States and Europe with such liberality of scope as greatly to astonish the scientists of the world.

Innumerable attempts have consequently been made to transmit speech *without infringing* upon original patents, and to such efforts are we, in great measure, indebted for the researches of and results obtained by electricians of note; for although admirably effective under favorable environment, the telephone is still susceptible of material improvement, and already we have mathematically correct formulæ and laws as guides for experimenters in the practical transmission of sound waves by electrical impulses.

The diverse theories advanced by prominent electricians, at a late meeting of the Society of Telegraph Engineers and Electricians, London, is the speaker's apology for preparing the present paper for discussion, he may at once state, that the following requirements are *essentia* and to the *satisfactory* transmission of speech:—

1st. That articulation shall be clear and natural in tone.

2nd. That the apparatus shall be free from inductive or extraneous sounds.

3rd. That increased electrical energy shall be provided for long-distance transmission of speech and loudness of sound.

4th. That a material reduction in the number of wires or circuits, at present required for a Telephonic Exchange, is the basis for economic maintenance.

At the meeting already referred to, Professor Sylvanus Thompson stated:–That all diaphragms and springs have distinctive tones, and thus those of low fundamental pitch impart a *boomy* sound in reproduced speech, while higher keyed ones, yield a metallic or *tinny* sound.

That the transmission of electric impulses from sound waves are not dependent upon the varying resistances of the electrodes under pressure, but are occasioned by the millions of minute electrical discharges between the molecules which fly to and fro, between the adjustable electrodes, from higher to lower potential, as they approach or recede under the varying forces of sound waves; and that the effectiveness of transmitters was improved, as their electrodes rise in temperature, either by applied heat or from the passing of the electric currents.

This statement was in part endorsed by Mr. Stroh (formerly assistant to Sir Chas. Wheatstone), who remarked, that he did not believe in the effectiveness of *applied* heat; but that when the current first passes through the electrodes, their minute points offer so much resistance, that heat is produced and they burn off, so that the surface contacts become larger and the instruments convey speech; but when too large, silence ensues;—that when properly adjusted, a rapid bombardment of moveable atoms between the electrodes occur, very quickly from the positive and more slowly from the negative poles. And he instanced the following curious experiment, under microscopic observation, that when a drop of oil was placed between two platina pointed electrodes and a current passed through them, a great disturbance took place between the particles of oil, which rotated between the points with wonderful rapidity, one point becoming hotter than the other, as in the electric arc light, although reversing the polarity did not *invariably* reverse their heat.

Professor Sylvanus Thompson stated that the snap sounds heard in telephones, which are generally attributed to make and break contacts, are really due to sparks between the electrodes, and that when such sparks are suppressed the noises cease and that they can be almost entirely eliminated (even when very strong currents are used) by introducing double differentially wound electro magnet into the circuit.

In this connection Mr. Stroh observed that when new carbons are used, at their first contact, they click and then vibrate, with such rapidity as sometimes to produce musical sounds, which cease as the spring or weight pressure is increased, and until vibrations are again started by sound waves. Again, if a watch were placed upon a microphone, all kinds and qualities of sound could be obtained by manipulating the points, thus clearly proving that it is not the tick of the *watch* which is heard, but the microphones *own sounds*, started by the tick of the watch; and that from such fact it would appear that the mechanical movements due to sound waves have the effect of governing and controlling the frequency, amplitude, and form of the vibrations which the microphone sets up through every disturbance of its equilibrium.

Professor Thompson further stated that by using a differentially wound induction coil in the transmitter, not only is articulation greatly improved, but the vibratory induction disturbances, from approximate running machinery, are innocuous even to a sensitive Blake transmitter, and that two small induction coils, having their primary wires united in parallel and their secondaries in series, gave a much more satisfactory result than is obtainable from the ordinary coil in present use.

That granulated hardened coke, as used in the Hunning's transmitter, presents more numerous points of contact than two solid electrodes, and hence the greater vibratory effect produced in a distant receiver; but that comparative tests between metallic alloys, demonstrate, that a platina point, resting upon an electrode of copper, treated either with a mixture of selenium and sulphur, or with tellurium, reproduces speech with a clearness of articulation far superior to anything obtainable from hard carbon, although such alloy requires a greater initial pressure, at the electrodes, than is required by carbon.

For many practical reasons, the speaker considers this latter statement of Professor Thompson's an important one.

Professor Thompson then exhibited a transmitter, designed with the object of dispensing with the patented diaphragm. At the small end of a speaking tube, a ball or valve of metal rested upon three metallic points and the sound waves suspended, or in part relieved, the weight of the ball; but Professor Hughes observed, that if the tube were plugged below the valve and the air allowed to escape through side holes, the instrument remained equally effective, thus proving that the tube itself became a diaphragm of different form, and that under any circumstances, for well known mechanical reasons, the practical limitation of three points of support would render the instrument less powerful than many others in use.

The experimental transmitter just described will serve in great measure to explain the broad claim allowed at law in favour of the *diaphragm*, as patented by Professor Bell.

It appears, however, that a simple grid of small carbon bars, suspended upon a platina wire, within a non-vibrating leaden frame, and acted upon direct by sound waves, proves to be an effective transmitter, and by such device a diaphragm may be totally dispensed with.

Professor Hughes stated that if a series of small bars or pencils of carbon were attached to the inside rim of a bowl, or box, filled with water in order to eliminate the hollow tones of such receptacle, such a transmitter would operate with increased power, because every portion of the water would then be in a state of tremor from the sound waves.

This remarkable power of water for conveying sounds has already been utilized for discovering leaks in water pipes; even the leakage of a few drops may be localized by the application of a delicately constructed telephonic receiver; and there can be little doubt that under favourable circumstances distinct signals can be telephonically conveyed through several miles of water.

Magneto-electric transmitters have, since the introduction of the microphone, been superseded by local circuit battery power transmitters; but from the results of practical experiments made with the "Gisborne

& Keeley" patented telephone, now owned by the Bell Telephone Co. of Canada, it seems desirable, if possible, to dispense with the always uncertain and varying action of introduced galvanic battery power.

Professor Thompson suggested a transmitter based upon the principle of a dynamo-electric machine; but the advantages of such mode of increasing the power of the currents would be more than counterbalanced by the increased inertia consequent upon the to and fro movement of the armature.

In concluding his observations at the meeting referred to, Professor Thompson stated that in his opinion the progress of long distance transmission of speech would depend upon increasing the power of the transmitter, and reducing the sensitiveness of receivers to induced sounds from extraneous disturbances.

To such general conclusion Mr. W. H. Preece (electrician to the London Post Office and telegraphs) took exception, and stated that clearness of articulation and long distance telephony depended entirely upon the line wires being freed from electro-static and electro-magnetic induction, and that when the environment was favorable, the most ordinary form of instruments would convey speech as well over long as over short circuits. That the law, which determines the transmission of currents through a wire, to produce speech, is precisely the same, in every respect, as the law which determines the flow of currents through submarine cables, and that it is absolutely impossible, to obtain any greater number of signals, along a given conductor, by any alteration or improvement in the instruments.

That the ratio values of conductors were as follows: iron 1,000, copper in cables 1,200, copper exposed 1,500. That the difference between iron and copper was due to the self induction of the iron; and between copper in cables and copper exposed, the difference was entirely due to the insulation of the former; the leakage from suspended wire enabling it to discharge its static charge, and still more quickly from a suspended copper than from an iron wire.

That experiments showed, that when the speed of the currents was .004 to .003 of a second, the transmission of speech was bad; when .003 to .002, it was fair; when .002 to .001, it was good; and if under .001, perfect.

That the average number of sonorous vibrations in the human voice, was about 1,500 per second. Experiments made upon the Irish cables and lines proved the relative values of the different circuits, and that even with a powerful "Berliner" transmitter, the rate of speaking was neither increased nor varied from the result obtained when ordinary transmitters of much less power were used.

That Professor Fleeming Jenkin had verified the law of static induction and consequent retardation of signals, through the French Atlantic cable of 2500 miles in length, when he found it possible to obtain $2\frac{1}{2}$ reversals of current, per second; and that both theory and practice demonstrated that speech was limited in such class of cable to a distance not exceeding 96 to 100 miles of its length.

That telephonic disturbances are principally due to secondary currents induced by primary currents in neighboring lines, and that short circuits are more disturbed by such influences than are long circuits, such disturbances being due, not merely to the strength or potential of neighboring currents, but to the rate at which the said currents rise and fall.

That although the effects of induction might in some measure be neutralized by strengthening the transmitter and weakening the receiver, it would be almost impossible to convey intelligible speech, when very strong currents (such for instance as were used in a Wheatstone transmitting telegraph) were traversing neighboring lines, the induction effects from said currents being 100,000 times stronger than telephonic currents.

Professor Hughes was of opinion that greater attention should be given to the transmitter induction coils, and that the battery cells and primary wire of the coils should be in proportion to the internal resistance of the transmitter; and he agreed with Professor Thompson, that more powerful transmitters and less sensitive receivers indicated the path of progress in telephony.

Mr. Bidwell held, that the constituent elements of a transmitter should be an arrangement in multiple-arc of heavy carbon pencils, with light points of contact, that the resistance of such a microphone should be proportionately as small as the rest of the circuit, and that the current should be as strong as the number of contacts and amount of pressure would warrant.

With due regard to the foregoing views and experiments of eminent electricians, the speaker ventures to express the opinion:—

That clearness of articulation and natural tones are best obtainable from magneto-electric transmitters, which are free from the disturbing and varying action of local galvanic cells.

That loudness, and progress in long-distance telephony, will depend in great measure upon increased power in the transmitter and decreased sensitiveness in the receiver.

That whereas it is impracticable to control the environments of telephone wires, attention must be given to the elimination of induced disturbing currents, by utilizing twisted all-metallic circuits, or some equivalent device.

That economy in line construction can be effected by utilizing one such twisted all-metallic circuit, of low resistance, for several exchange connections.

In conclusion the author begs to state that this paper has been compiled with the sole object of inviting discussion upon one of the most important inventions of the nineteenth century, by the members and associates of the Canadian Society of Civil Engineers.

DISCUSSION.

Mr. Keeley explained that his presence was due to the fact that Mr. Gisborne was unable to travel through illness. He further stated that Mr. Gisborne had considered it advisable that he should bring some apparatus, in order to make clear any points that might be brought into question, such apparatus was now on the table, and Mr. Keeley thus continued :—

Mr. Keeley

It occurred to Mr. Gisborne, that as this paper would be the first one on the subject of Telephony brought before the Society, it should be made as comprehensive as possible; and for that reason he has in it set forth his own ideas and the views of the several prominent electricians who participated in the discussion at a meeting of the Society of Telegraph Engineers and Electricians, when the whole subject was thoroughly considered. Having read the full report of that discussion, and noticed what an amount of acrimony was exhibited by some of the participants, it might be stated, that Mr. Gisborne has given in his paper, all of the valuable information elicited, just as one would serve up honey, without a hint of the stings that had been associated with it.

Without entering into a discussion of the question as to the origin of the telephone, but simply dealing with the subject as we now find it, the speaker would direct attention to one particularly important point that to his mind is conspicuous amongst the many other discussable points with which Mr. Gisborne's paper fairly bristles.

Papers treating broad subjects of this character in a general way are necessarily provocative of much discussion; and unless it be for purposes of criticism, little good is derivable from an attempt on the part of any single individual to discuss such a paper, clause by clause or point after point, where numbers of points are discernable. Attention will therefore be directed to one important point.

It is pretty generally admitted that the British electricians, whose names figure so prominently in Mr. Gisborne's paper, are authorities upon the subject of telephony. If they be so, the importance of the point which the speaker desires to consider is beyond doubt.

It is this:—The *Question* as to the possibility of improvement in telephony.

Now, one would hardly believe this possible with advanced scientists, in view of the fact that it was only a little while ago the telephone was introduced, and almost daily the journals remind us that the thing is yet in its infancy. Nevertheless, there appears to be good ground for the doubt that has arisen; and an attempt will be made to shew wherein it lies.

Every question has necessarily two sides. In this instance we have as representatives of the contrary views, Prof. Sylvanus Thompson on the one hand, and Mr. W. H. Preece on the other.

Both of these gentlemen have actually experimented; they speak authoritatively from the results of their experiments; and they are agreed that the real impediment to uniformly successful operation consists in circuit induction.

They are not agreed, however, as to what is requisite for the elimination of this difficulty.

Each claims the other's conception to be erroneous and impracticable.

Hence, if each is an authority and if both are wrong in their conceptions, as the speaker has reason to believe they are, the future of the telephone is still problematical.

To be more explicit Prof. S. Thompson considers the apparatus at present in use to be at fault; it is far too sensitive. He conceives the requirement to be a receiver insufficiently sensitive to be affected by currents induced from extraneous sources; and a transmitter sufficiently powerful to produce currents to modify any extraneously induced, and consequently sufficiently strong to be effectual in the receiver.

Mr. Preece, on the other hand, considers the apparatus at present in use as faultless. He conceives the difficulty rests with the circuit, and that uniform results can only be secured by its isolation, or, as he would express it, by getting rid of its mischievous environment.

Each of these gentlemen combats the other's view, and with good reason.

It is quite certain there would be a limit, a low one, to the power of Prof. Thompson's transmitter; whereas, the strength of currents induced from adjacent wires (electric-light circuits, for instance) is practically unlimited.

It is also evident that the isolation of any one of a number of adjacent wires is physically impossible without the interposition of an invulnerable screen between it and the others throughout its length; and as the material for such a screen has yet to be discovered, Mr. Preece's idea is less hopeful than Prof. Thompson's.

It therefore follows that as these gentlemen are recognized authorities, that as both are decided as to the impediment existing, and that as they are mutually skeptical as to each other's conception of what is needful to remove it, the development of the telephone is at a standstill, and it is actually questionable with them whether any further improvement is possible.

Now, assuming that it will be considered this point is well taken, it may be stated, for the comfort of those who have the future of the telephone at heart, that there is no good cause for alarm. It can be borne in mind that the mere fact of a standard time-piece, coming to a full stop, does not necessarily throw the entire time service of a community out of gear.

Further, it may be said that perhaps there is another way out of the difficulty that has not occurred to the minds of our British collaborators other than that advocated by Mr. Gisborne, who proposes the use of twisted all-metallic circuits, an expedient that would certainly bridge the difficulty, and whose only disadvantage consists in the cost. The way the speaker would suggest is one that will involve neither the abandonment of the apparatus at present in use nor the reconstruction of the circuit; it has reference solely to the disposition of the apparatus *in* the circuit.

In order to convey a clear understanding of this idea, will you recall the explanations given in the text books with reference to the origin of the quadruples in telegraphy. It will be remembered the duplex was in existence, the duplex enables us to operate a wire from both ends simultaneously—that is a system of double transmission, but the transmission is in opposite directions; the problem was to devise a system whereby we should have double transmission in the same direction. At that time, as at present, the open-circuit system of Morse telegraphy was in existence in England, and the closed-circuit system in America. The former is operated by reversals of the transmitting battery, and the latter is operated by the introduction and withdrawal of the battery. The idea occurred to two electricians (experimentalists they were, too), Messrs. Edison & Prescott, that these systems might be combined. That idea was the solution of the problem.

Now, it was in a somewhat analogous manner the speaker viewed this telephone difficulty. The apparatus is worked in the one way all the world over; but if there are not two continents to look to, we have two departments in the system itself, the Primary and Secondary circuits; the former is operated by the variation of resistance, and the latter is operated by induction. Suppose we combine these two, and arrange the whole so that the induction currents will be neutralized, while the direct current will control the instrument. It seems probable that it can be done. Some time ago the speaker conceived that the receiver and battery might be so disposed in the circuit, that, while currents induced in the circuit from extraneous sources would traverse the receiver in opposite directions, thus producing no effect in it, the latter, having the battery current conducted through it in *one* direction, would be responsive to the fluctuations in the current strength occasioned by variations of resistance in the circuit. But, exactly how this result is to be secured, cannot be said. The speaker has made a large number of experiments, the results of which, if not satisfactory as regards the solution of the problem, are yet interesting, in that they throw more light upon the subject, and afford a better understanding of the actions obtaining in the premises.

It would hardly be in order to go into a further explanation of this idea now; but the experiments in connection with it are nearly completed, and if the matter is considered of sufficient interest, the details may be communicated to the Society at one of its future meetings.

Very little of any thing can be added to the very clear explanations and remarks, as given by Mr. Keeley. A few remarks, respecting the delicate character of the Blake transmitter, may now be made. Mr. Thornberry.

It is interesting to know just how delicate an instrument the Blake transmitter is; and when it is stated that it is possible to use but 10 or 15 per cent. of the current supplied by one cell, such as you see on the table, you can comprehend its delicacy. By the expression "use but 10 or 15 per cent. of the current," it is meant that the variation of the contact caused by the voice waves causes a variation of only 10 to 15 per cent. of the current supplied to the instruments.

A word might be added in reference to the instrument designated, the Draubaugh. This instrument has been very much improved in the States. The Bell Telephone Co. has adopted it on its lines between New York and Philadelphia, and between New York, Boston and Albany. When the first experiments were made by the American Bell Telephone Co. with this transmitter, the speaker was connected with that company, and has frequently whispered between New York and Boston. The line between Boston and New York is about 300 miles long, and cost in the neighborhood of $30,000.

Conversation is now carried on between Boston and Philadelphia, 350 miles, and the line also goes to Albany.

Perhaps a few remarks in reference to the underground question may not be out of place. An expression very frequently heard is to the effect that "the telephone wires are a nuisance and should go under ground." The remarks Mr. Keeley read in his paper when he said, telephony is impossible on sub-marine cables, except within 95 to 100 miles, illustrated the difficulty to be contended with in an underground cable; and that is the effect of the charge the cable has a capacity for. The charge referred to of is the capacity of the metal of the conductor, and the metal surrounding the cable in connection with the earth to take on a charge of electricity, which charge opposes the currents sent out by the speaker and so retards his conversation. This is what makes underground work so unsatisfactory. Then the expense is so great that necessarily the rate must be raised. Few would wish for this, especially as the present rate is thought to be too great, while the service is also as good as it can be made.

A misapprehension is prevalent respecting the way in which a Blake transmitter should be spoken, to and should be corrected. No advantage is gained by talking in a loud tone of voice; that only does an injury, and "breaks up the conversation" so that it is misunderstood. A full even voice, three or four inches away from the instrument, is the best.

In reply to the remarks of Professor Bovey, a humming noise heard in the telephone at night, which is often so loud as to drown at a time all conversation, the speaker stated it to be due to induction caused by the Electric Light. The Electric Light Co. runs its wires regardless of ours.

Mr. McFarlane. Mr. L. B. McFarlane said: There seems to be a statement made in Mr. Gisborne's paper, to the effect that Prof. Thompson had found platinum and copper treated with selenium the best microphonic contact for Transmitters. It will be asked, by those not familiar with the telephone business, why this contact is not used in practice. For their information it might be explained that platinum and copper so treated will answer for a short time only. The Telephone companies are constantly experimenting in this direction, and have found nothing to equal what they now use.

Mr. Keeley. In reply to the question that has been asked, with reference to a form of telephone in which the south pole of the magnet is bent round and fixed to the outer edge of the diaphragm, it may be said that the object of that arrangement is to strengthen the magnetic field by bringing the north and south poles as nearly as possible together. The object can hardly be said to be attained, however, as the mass of iron in the diaphragm is too little to conduct the lines of force. A great many instruments have been constructed in which that feature is found. The Crown telephone has a system of eight magnets, each with its south pole in contact with the outer edge of the diaphragm, and all of the north poles directed towards its centre. In the Gisborne-Keeley instrument (Fig. 8), there are four magnets on each side of the diaphragm similarly disposed. The speaker has handled a good many instruments with and without this feature. In some forms the magnet is arranged in that way for convenience, or for neatness in design; beyond that it has no advantage.

Mr. Hannaford next requested Mr. Keeley to describe the apparatus. Mr. Hannaford.

Two or three years ago an impression somehow got abroad that the Superintendent of Government Telegraphs (Mr. Gisborne) wanted to get hold of a telephone that would beat everything of the kind in existence. The result was that a great many inventions were sent or brought to him by the inventors or their representatives, and each claimed that his was *the best in the world.* All inventors do that. In the midst of all this there was a certainty, and that was the necessity for a standard for comparison. Mr. Gisborne examined all the instruments that were sent to him. It was the speaker's privilege to assist him in his examination and tests. The instruments of the Bell Telephone Company were taken as the standard—the same that you are all familiar with, and which you make use of every day. Here Mr. Keeley.

FIG. 1

FIG 2

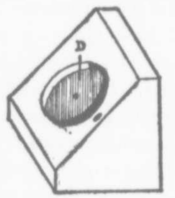


FIG 3

they are—the Blake transmitter (Fig. 1) and the Bell receiver (Fig. 2). These were our standards. Few of the instruments tried were as good, none were better. There was one form of transmitter, somewhat different from the Blake, and possessing some good features that held our attention. It is this one (Fig. 3), made by the Consolidated Telephone Company of London, England. It is a first rate instrument. You observe there is a number of carbon pencils and blocks

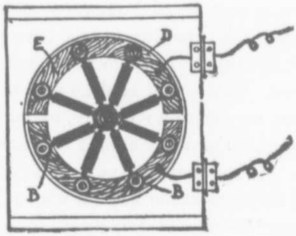


FIG 4

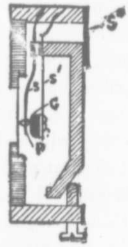


FIG 5

here (Fig. 4, plan of microphone of instrument shewn in Fig. 3), arranged radially like the spokes of a wheel; the hub fixed to the centre of a mica diaphragm (*d*). Half of the number of blocks (*b*) are fixed to a semi-circle of metal, E, on one side, and the other half similarly fixed on the other side of the annular space (*a*) back of the diaphragm. This device seems to have originated with Dr. Herz, of Vienna, and was independently invented by Mr. Crossley, in Scotland. It is a form of instrument used very extensively in England and France. (They have a mouth-piece on it there; this open-faced diaphragm is an improvement, suggested to the makers of the instrument by Mr. Gisborne.) It seems that the Bell Telephone Company's patents cover this instrument, and it may be interesting to shew how it compares with the Blake transmitter, in order that you may conceive why it is not made use of in this country. In this Blake transmitter (Fig. 1) the microphone (Fig. 5, plan of microphone of instrument shown in Fig. 1) consists in a carbon button (*c*) and a platinum point (*p*); that is what is called a single contact. You see these parts are hung in a very pretty piece of mechanism; a wonderfully nice system of springs, whose appearance alone clearly proclaims the scientific construction of the instrument. By means of these springs (s, s', s",) the adjustment of this transmitter is practically unlimited; it can be made extremely sensitive, and the reverse. In practice, as you are all aware, it is so adjusted that it is possible to communicate through it in ordinary convertional tones. Now, look at this English instrument. The microphone consists in these pencils and blocks of carbon (Fig. 4); this is called multiple contact. You perceive there is nothing adjustable about this; it is put together, once and for all; so that what is true of almost everything else made in England is true of this transmitter,—it is substantial and reliable. Comparing the two, therefore, one would hardly expect to find this one so sensitive as the Blake—and it is not so. Consequently, when we approach a Blake transmitter, we are disposed to say, in a tone as low as possible: "Do you hear me now?" Whereas were we using this multiple contact microphone we would in a louder tone enquire: "*Are you there—!—!?*" However, this latter instrument has one great advantage: it is possible to talk loudly into it with perfect success, the louder the better; and sometimes it is a great satisfaction to a man to talk loud. This cannot be done with the Blake as ordinarily adjusted; it must be spoken to quietly, naturally, and without effort at precise utterance. For this reason it is preeminently fitted for the field it occupies. If you want to put up a telephone out in the country far beyond the reach of the experts who adjust the Blake instruments for exchange work, and far away from people acquainted with apparatus of this kind, then send the English style of instrument. Mr. Gisborne sent a pair of them out to the North-West, during the trouble there in 1885; they were put up and operated by parties who had never handled such apparatus before. On the other hand, if you wanted connections in town or in any place where if required the apparatus could be adjusted, it would be better to put in the Blake.

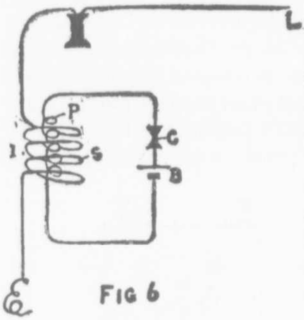


FIG 6

The peculiarity of the Blake transmitter is that you cannot operate it successfully with more than a single cell of battery. In these transmitters you know the arrangement consists of an induction coil (I.Fig 6), the primary wire (*p*) of which is in circuit with a battery (B) and microphone contact points (*c*). In the Blake instrument the microphone is a single contact between the platinum point (*p*, Fig. 5) and the carbon button (*c*). Now there is a theory that bodies apparently in contact are not actually so unless they are incorporated and solidified; there is a film of air between them. In this Blake microphone, therefore, a film of air—a minute space—is interposed between the carbon button and the platinum point, and if we put in circuit with it a battery of sufficient intensity, the current will pass in a series of spark discharges across this space and produce a clicking and roaring noise in the telephone (in circuit (Fig. 6) with the secondary wire (*s*), of the induction coil, I.). Two cells of battery will afford a current of sufficient intensity for this discharge. If the roaring is overcome by increasing the normal pressure between the carbon and platinum point, the microphone will be rendered less sensitive and it will be necessary to talk loud in using it. On the other hand, a single cell of battery does not afford a sufficiently intense current to produce these discharges; hence, the finest adjustment and the best results can be secured with a single cell in connection with this transmitter. The telephone companies on this continent have used this instrument in preference to all others, although it is evidently a much more costly transmitter than this English machine, which is probably the best and cheapest multiple contact transmitter in existence. Perhaps the most valuable feature of this latter form of microphone—the multiple contact arrangement—is that several cells of battery may be put in circuit with it. As there are so many contacts presented for the passage of the current, the force of the battery is not directed to any one point, but is divided up amongst them all, and there is consequently none of that discharge or sparking effect that we get in the Blake; and since there is no variation in the adjustment of the parts, it follows that an increased battery power will increase the effectiveness of the transmitter.

There is another form of instrument—the Drawbaugh long-distance transmitter. In this, the microphone is composed of a chamber containing granulated carbon, and a metal plate; the latter forming at once the cover of the carbon chamber and the diaphragm of the instrument. It was designed to be operated in a peculiar way. (Fig. 7) shews the

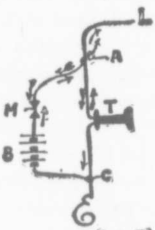


FIG 7

FIG 8

arrangement of the circuit. The receiver (T) is in the main circuit (E. L.), and the transmitter (*m*) and battery (B) are shunted around it. When the local circuit (a.m.B.C.) is closed, the current from the battery (B) divides at the junction (*a*) of main and local circuit, one part goes to the line (L) and distant receiver; and the other part flows round through the telephone (T), in the direction of the plain arrows. The passage of the current through the telephone coil induces a pulsation in the opposite direction; this induced current, represented by the feathered arrows, also divides at the junction (*a*); the part that flows to line (L) is in the same direction as the battery current, and augments the effect of the latter in the distant receiver. This system requires a large battery in consequence of the greater part of the direct and induced currents being absorbed in the local circuit. The transmitter is not sensitive; and the entire arrangement presents no advantages over the other apparatus that we have here.

Consider now the receivers. This instrument is the Gisborne-Keeley telephone (Fig. 8), mentioned in Mr. Gisborne's paper, and as it was allowed a little while ago that inventors claimed that their own inventions were the best in the world, there is no reason why this instrument should be considered exceptional in that respect. Mr. Gisborne has referred in his paper to experiments made with this instrument as a magneto transmitter. It is a good *transmitter;* but not so reliable and uniform in its operation as is requisite in a transmitter; its adjustment does not hold good. It is however a splendid and very excellent *receiver*. An illustration on the black-board will shew wherein its excellence lies. You know that the ordinary telephone receiver (Fig. 2) contains in the handle a permanent bar magnet, which is in contact with the soft iron core of the coil that influences the diaphragm; and that the object of that magnet is to polarize the soft iron core. Well, omitting the permanent magnets in the illustration the polarized cores only will be shewn. There are two of them (A. B.,

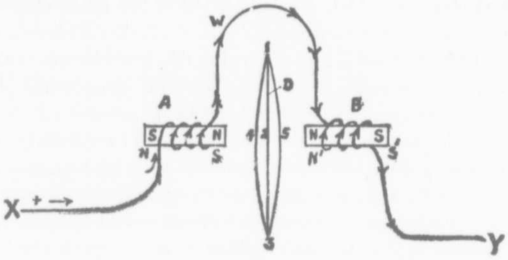


FIG 9

Fig. 9); one on each side of the iron diaphragm (D); and the north poles (N) are presented to the diaphragm. Now put a coil of wire (*w*) on each of these cores; you perceive the direction in which it is wound, from right to left, starting from the outside (*s*) end of left hand core (*a*); and from right to left, starting from the inside (N) end of the right hand core (B). As currents of electricity induce magnetism, it stands to reason that if a current be put through from this end (*x*) to the other (*y*) in circuit—its course round the cores being in the same direction, and the polarity of the cores being reversed—the magnetism of one core will be partially neutralized and lessened, and that of the other augmented; and the diaphragm (D) will be attracted to the stronger side. For instance, viewing the diaphragm (D) from the left hand side (*x*), if a positive (+) current is sent through from this end (*x*), the magnetic effect of the current, represented by n. s., n′ s′., will partially neutralize the magnetism S N in the left hand core (A), and proportionately augment the magnetism N S in the right hand core (B). The diaphragm (D) will consequently leave the plane (1, 2, 3,) and assume the concave (1, 5, 3,); and if a negative (—) current is sent through from the same end, the conditions are reversed and the diaphragm assumes the convex (1, 4, 3.). Therefore, each succeeding pulsation will vibrate the diaphragm between the lines 4 and 5 and, the amplitude of that vibration is referable solely to the strength of the currents transmitted. In the ordinary instrument (Fig. 2), there is only the vibration obtaining between the plane and concave; there is no convex effect; besides that, the diaphragm is at a disadvantage, being under a constant strain due to the presence of the magnet on only one side; whereas in this new instrument the magnets are on both sides exerting an equal influence, and in consequence leaving the diaphragm free from strain and perfectly free to vibrate in response to variations in the strength of the magnetism on either side.

A good idea of the relative powers of these two instruments may be obtained by fingering the microphone with which they are here in circuit. You will perceive a much louder sound in this new instrument than in the other, as, in addition to its more powerful construction, the permanent magnets are so arranged as to afford the greatest possible room for the sounds to issue from the diaphragm. You will find, however, that to perceive these effects it is necessary to bring both instruments close to the ear; and then there naturally arises a question as to wherein the advantage lies with this new instrument which is so much more cumbersome than the other. This brings the speaker back to the transmitters. It was explained just now that the amplitude of the vibration of the diaphragm depended upon the strength of the transmitted currents. It will be noticed there is but a single cell of battery here. With three or four cells in connection with this English transmitter a very loud effect can be produced in this new instrument; and when the transmitter is spoken at with a loud voice, the words are reproduced in this receiver more loudly than in any other instrument that the speaker knows of. That is why he says it is the best; although possibly many persons might object to having three or four cells of battery when for all ordinary purposes he can get equally good results from a sensitive Blake transmitter with one cell of battery and the ordinary Bell receiver held to his ear. This little instrument (Fig. 2) with which you are all so familiar is a scientific triumph in its way. If Prof. Bell and his associates had spent twenty years in considering the design for its construction, they could hardly have produced a neater or more perfect thing than this which made its appearance at the very beginning of their operations. When this instrument was first introduced, you will remember it was used as a transmitter as well as receiver. You can converse well if you yell into it; some people like that sort of thing. It was only the other day, it was reported in one of the electrical papers that the government of one of the European countries—Germany—had just decided to adopt a microphone transmitter; an improvement without which they had so far managed to get along. An explanation might be given of the operation of a magnetic transmitter—for that is what the ordinary receiver becomes when spoken into.

You know that if a strong magnet is brought into the vicinity of a coil of wire and then withdrawn, it induces a pulsation of current in the wire at each approach and withdrawal; and that if the magnet were put into the coil, and its power increased and diminished it would induce these currents. You also know that if a piece of soft iron is brought near a permanent magnet, it will have magnetism imparted to it. Now what is the case in the present instance? The telephone handle contains a powerful magnet (S.N., Fig. 10) which imparts its magnetism to the iron core (*s.n.*) of the coil (*c*). The outer end (*n*) of the core thus becomes the end of the powerful magnet, and imparts its magnetism to the diaphragm (D). Now, if the diaphragm be vibrated, it is evident that when it approaches the end (*n*) of the core the magnetism increases, and when it recedes the magnetism diminishes, not only in the diaphragm, but also in the core (*s.n.*), and these latter fluctuations will induce currents in the coil, which if arranged in circuit will transmit them to a similar instrument at a distance where the fluctuations and vibrations will be reproduced.

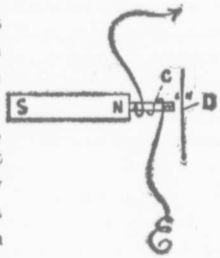


FIG 10

The apparatus has now been pretty fairly explained, and probably you will be disposed to agree that the instruments are all right; Mr. Preece says they are. The noises that interfere with our operations are, as every one admits, caused by currents traversing neighboring wires; the currents induced from the adjacent wires operate in the receivers just in the same way as the currents produced by the transmitter itself; hence, the development of these noisy effects is due to no fault in the apparatus. Besides this it appears the trouble encountered in long distance transmission is also due for most part to the proximity of other wires. Mr. Preece experimented upon a long line that was far away from any electric light or telegraph wire, and got excellent results; the poorest form of instrument he had worked as satisfactorily as the best. That experiment speaks for itself, and in the speaker's opinion establishes a fact that ought to be sufficient to shew that Mr. Preece has substantial grounds for his argument.

With reference to the question as to why the dry battery is not made use of in connection with telephone work, Mr. Keeley said that its high internal resistance, if nothing else, renders it unsuitable for the purpose. That Prof. Hughes and a good many others consider it very desirable that the resistance of the battery and microphone should be as nearly as possible equal to that of the primary wire of the induction coil. The resistance of the primary wire cannot be increased without rendering the coil less effective. It is less than a single unit. The microphone is greatly in excess of that, and it is therefore necessary to keep the battery resistance as low as possible. It is principally to secure a low internal resistance that the single cells of Le Clanche used with the telephone apparatus are so large. The internal resistance is increased as the size of the plates and volume of fluid is decreased.

In reply to Mr. McFarlane's remarks, concerning the use of electrodes composed of selenium and copper, it may be that he is right as to the failure of the combination to act for any considerable period; the speaker had no knowledge of the composition in question and was not aware that it had ever been used excepting in an experimental way. It will be noticed that in Mr. Gisborne's paper reference is made only to the result of experiments made by Prof. Thompson. Besides, Mr. Gisborne remarks that the combination requires a greater initial pressure than required in the carbon microphones. From this it may be inferred that it is not so sensitive as the latter, and in that case it would need to be spoken to loudly.

The member who enquired as to whether the coldness of these nights had any effect on telephones must have misunderstood his informant as to the kind of telephone referred to. The buzzing sound heard in the electric telephone is due to induction from the electric light wires. It is probable reference was had to an acoustic telephone; it is not unlikely that effects would be produced on it on a cold night that would not be produced on any other night, for the reason that the wire, already tightly strung and under tension, would be contracted by the frost, and be thereby subject to such a high tension that the least thing would vibrate it. As electric currents produce heat, it is not at all impossible that currents induced from neighboring electric light wires would obtain in this tightly strung wire, and each pulsation would in a minute degree vary the temperature of the wire; a constant repetition of this effect would very soon create a vibration in the wire, that would produce in the acoustic telephone precisely the same sounds we get in the electric telephone from the same primary source.

With reference to Mr. Thornberry's remarks relative to the operation of the metallic circuit between Boston and New York, it might perhaps be explained how it is that the instruments on such a circuit are not affected in any way by induction from neighboring wires. Suppose

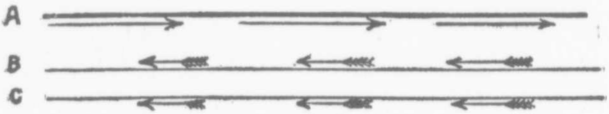


FIG 11

this line (A, Fig. 11) is a telegraph wire, with an intermittent current traversing it in the direction of the plain arrow, and this other line (B), below, is a telephone wire, it is known that currents flowing in one direction induce currents in the opposite direction; so there is an induced current in this telephone wire, in the direction of the feathered arrow. Suppose this third line (C) is another telephone wire; in it an induced current from the telegraph wire is also set up in the direction of the feathered arrow. Suppose now these two telephone wires are connected into one round circuit through the telephones (T and T,' Fig. 12), at either end of the line. Is it not quite evident that the current induced in the wires will be opposed in the instruments, and will mutually neutralize each other? Now, that is just what does occur; hence the telegraph current doos not affect the telephone at all. But a current sent out from the transmitter at one end will circulate round in one direction (plain arrows) in the circuit, and the receiver at the other end will respond to it.

FIG 12

If it were not for the expense and inconvenience of the thing, the metallic circuit, and Mr. Gisborne's twisted metallic circuit in particular, might be considered as the solution of all telephone difficulties. Electricians are however looking for other means for getting rid of the trouble. The speaker has already stated what his own idea is in this connection; and as so much attention is now being given to the matter in all quarters, no doubt there will be some further interesting developments before long.

9th February, 1888.

Mr. P. A. PETERSON, Member of Council, in the Chair.

The following candidates were declared to have been balloted for and duly elected as

MEMBERS.

RANDOLPH CLARKE.
HENRY JOHN CAMBIE.
WILLIAM DALE HARRIS.
HUGH NEVILLE BROCK HOLLINSHEAD.
JOHN YEEDON LLOYD.
EDWARD MOHUN.
HENRY BADELEY SMITH.
GEORGE ALEXANDER STEWART
PETER SUMMERFIELD.

ASSOCIATE MEMBERS.

JOHN MCINTYRE.
JAMES WARREN.
CHARLES EDWARD STUART BOOTH.

ASSOCIATES.

JOSEPH ERNEST BELANGER.
ANDREW THOMAS DRUMMOND.
JOHN STEWART MCLENNAN.
HUGH RUSSEL.

STUDENTS.

WILLIAM FOSTER FRASER.
THOS. ED. EDGECUMBE PEARSE.
THOMAS SIMPSON RUSSELL.
NORMAN JAMES MCMILLAN.
RODERICK MCCOLL.
WILLIAM CHASE THOMPSON.
JOHN KING MCDONALD.
HENRY GRATTAN TYRREL.
JOSEPH AMEDÉE LAFERRIERE.
GEORGE SINCLAIR SMITH.
ANDREW YOUNG.

The following was transferred from the Class of Associate Members to that of Members

L. J. R. STECKEL.

The following was transferred from the Class of Associates to that of Associate Members

WILFRED THEODORE SKAIFE.

Paper No. 13.

THE SIX-FOOT WOODEN CONDUIT FOR THE TORONTO WATER WORKS.

By T. J. McMinn, M.Can.Soc.C.E.

The original scheme for a water supply for the City of Toronto (carried out by the late Water Works Commission) was briefly, as follows: The water was to be brought through about 6,000 ft. of four-foot wooden pipe and about 4,500 ft. of three-foot cast-iron pipe, from a "basin" excavated on "the Island," near the shore of Lake Ontario, to the engine house, situated on the north side of the harbor, and from this point it was pumped to the city and to a reservoir on the high land some three miles distant.

At certain seasons of the year, as in the spring, when the ice is breaking up, and also during long-continued storms, the waters of the lake, for a great distance out from the shore, are discolored with clay and other matter in suspension, and one of the objects of the construction of the before mentioned "basin" was to secure clear water at all times, and especially when the lake was disturbed. It was intended to act as a filtering basin, was about 3,000 ft. long, 80 ft. wide, and of an average depth of 13 ft. 6 in. below mean water or "zero" level. The average distance from the water of the lake to that of the basin was about 155 feet.

After a long continued trial of this basin, it was found that the quantity filtered was not sufficient, nor was the quality of the water as good as desired, and in 1877 two channels, some 500 feet apart, were cut from the basin into the lake.

One of these channels was filled with flat stones and boulders and then gravel, and in the other a four-foot wooden pipe was laid from the inside of the basin, through the embankment and beach for a distance of 245 ft. lakeward, terminating in a submerged crib. From this crib another length of pipe was carried 50 feet farther into the lake, and this was perforated over its entire surface with 2-inch holes. The space around the crib and the perforated portion of pipe was filled in with stone and gravel in the same manner as in the other cut. The embankment and beach were afterwards restored to their original shape.

These channels worked very well for a time, but became choked up with sand during the following year, and in 1879 surveys were made, soundings taken, and plans and specifications prepared for a conduit to be laid into the lake. The basin was abandoned and also the "channels," and it was decided to connect the new conduit to the southern termination of the four-foot pipe (in the basin), and carry it out a sufficient distance into the lake.

For the determination of the best location for the conduit, a series of soundings was carefully taken, so as to give a contour plan of the bottom of the lake, outwards from shore to a depth of from 30 to 70 feet, and embracing an area of over 160 acres. These soundings were at first taken at equal distances apart, but afterwards lines of continuous soundings were taken and the position of the sounding line fixed or "cut in" by theodolite at equal intervals of time, as the boat was being slowly and steadily rowed out "on line." The nature of the bottom was also ascertained at a number of places, and was found to be all sand and gravel.

The 30 feet contour line was distant from shore about 800 feet at the west (off Lighthouse Point), and about 2,700 feet at the east end of the area embraced. From the shore outward to this line the slope of the bottom was gradual, but from 30 feet to 70 feet depth (and greater) the descent was rapid; in fact, the 30 feet contour line seemed to be the edge or brow of a hill having a slope of about three to one.

In fixing upon the depth from which the water should be drawn, it was important that the inlet should not be so near the surface as to be exposed to the dip of the waves during storms, or be blocked by floating ice, nor yet near enough to the bottom to permit the entrance of the heavier matter subject to be stirred up by the agitation of the water, or to become closed up with sand. It was at first decided to place the crib in 30 feet of water, but this was afterwards changed to 26 feet. The point selected was nearly in a direct line with that of the four-foot conduit, and was about 2,000 feet from the shore. To the westward the water was either too shallow or too deep, and the change from one to the other very sudden, while to the eastward the distance was too great.

The "lake crib," as originally designed, was hexagonal in shape, each face being 30 feet in length. The walls had a batter of 1 in 10 up to a height of ten feet above zero level, and at this elevation the deck was placed. Above the deck a bulwark of timbers surrounded the crib. There were two solid walls of 12 in.× 12 in. timber enclosing spaces between to be filled with stone, and a centre "well" or inlet chamber. The inlets, two in number, were rectangular flumes 7½ feet by 6½ feet, and placed about 14 feet below zero level. All the compartments were to have been filled with stone, and a large quantity was to have been placed outside as high up as the inlets. As the location of the crib was close to the course taken by vessels and steamers entering or leaving the port, it was intended that a lighthouse and lightkeeper's dwelling should be erected thereon.

It was afterwards decided to place an entirely submerged crib here instead of the above, as being less expensive in construction, requiring no large sum for maintenance, and answering the purposes just as well as the large crib, and accordingly the present one was designed. It is built of white pine, is 40 feet square, 11 feet high, and the inner walls are divided into eight compartments for stone and a centre well in which the conduit terminates. The outer and inner walls are of 12 in. by 12 in. timbers, and laid with 3 inch spaces between each course. A bottom course of six 12 in. × 12 in. mudsills was laid, and upon this a close flooring of 6 inches thickness was put down. The timbers are all 40 feet long, no splicing being allowed. The water enters the centre well from the top at a distance of 11 feet above the bottom and about 15 feet below the surface of the lake. The well is 9 feet 9 inches square, is protected at the top by an oak grating, and the sides and bottom are lined with $1\frac{1}{4}$ inch tongued and grooved sheeting, carefully caulked, while the outer sides next to the stone filling are closely boarded with 2 inch plank, all fastened with $\frac{3}{8}$ in. × 6 in. wrought iron spikes. The grating is made of strips of oak 2 inches thick and 4 inches deep, laid on edge, with 3 inch spaces between each, blocked at the ends, and all fastened together with iron rods and spiked to the crib. A piece of 6 foot pipe, about 19 feet long and fitted with flanged castings at each end, is built into the north side of the crib, projecting 3 feet beyond its outer face. The courses are secured to one another by rock elm treenails at the angles and where the timbers intersect, and 36 bolts of $1\frac{1}{4}$ inch diameter are carried up from the bottom to the top of the crib. The total weight of the structure loaded with stone is about 400 tons.

The conduit is 6 feet internal diameter, and is built of white oak staves 6 inches in width and 5 inches in thickness, banded together with 3 inch by $\frac{3}{4}$ inch wrought iron hoops placed at 2 feet centres. The outside circumference is made to conform to a radius of 3 feet 5 inches, and the edges of the staves are bevelled to suit radii of the same circle. The staves were kept of as great a length as possible, and would average in the whole conduit from 14 to 15 feet. In building the pipes the staves were so arranged that all would break joint, and each joint come beneath a hoop. The butt ends were tongued together with sheet iron plates $\frac{1}{8}$ inch thick, the full width of the centre of the stave, and let 3 inches into the ends of the staves. The hoops are made in one piece and strongly welded. Large castings provided with flanges and slotted holes in same were securely bolted to the ends of each length of pipe. All the castings, hoops, bolts, plates and other iron work were coated with tar before being placed in the work.

The pipes are weighted down by cribs filled with stone, which are built around the centre of each 100 ft. length. (The first three lengths of pipe are each 200 ft. long, and upon them no cribs were required, as they are laid through part of the Island and beach.) These "pipe cribs," as they are called, are 22 ft. square and 8 feet high. They are floored with 3 inch plank, and contain each about nine toise of stone. They are built of 12 in. × 12 in. pine, framed so as to leave 3 ins. spaces between each course, and fastened with treenails. The courses are bound together with twelve 1¼ inch bolts carried through from the bottom to the top of each crib.

The four-foot wooden conduit, previously laid, terminated at the "Inlet Crib," in the basin. This crib was entirely removed, and a new one, called the "Shore Crib," placed on the same site. It is 22 ft. square, about 18 ft. high, and built of 12 in. × 12 in. pine. It is floored throughout with 6 inch timber laid upon the bottom course of mudsills. Each course of timber is spiked to those below it with inch rag spikes 30 inches long, placed 5 feet apart, and driven at an angle of about ten degrees to the perpendicular. Eight 1¼ inch bolts or rods were carried up from the bottom of the crib to the top of the ninth course above the flooring. There is a well in the centre of the crib, 7 ft. 9 in. by 10 ft. 9 in., and it is made water-tight by means of two walls and a flooring of sheeting, spiked to the timbers, all the seams being carefully caulked with oakum and pitch. Pieces of pipe (4 ft. diameter on the north and 6 ft. diameter on the south side) are built into the crib, projecting 3 ft. beyond the outer faces, and being provided with the necessary flanged castings. The compartments surrounding the centre well are filled with sand and gravel from the excavation. The crib is decked over with 2 inch plank. A small house is built over the well, and is intended to contain tackle for raising and lowering gates or bulkheads or screens, if at any time these are required. It was originally intended to place a wrought iron tank or lining in the well, but this has not been done. The crib was sunken to a depth of 13 ft. 6 in. below zero level.

The excavation of the trench for the pipe was done by a single spoon-dredge. The contractors first cut as rapidly as possible from the lake, through the beach, and the south bank of the basin; then after doing some excavation around the old "Inlet Crib," they turned and began working southward. In the meantime, a tool house and some scows had been built, pine timber, oak and ironwork had been contracted for, and the construction of the pipes and cribs had been started, so that by the time the dredge had prepared some 800 or 900 feet of trench, the "Shore Crib" had been placed in position, and three 200 ft. lengths of pipe had been laid. The fourth section (200 ft. long) was then sunk in position, but the contractors experiencing some difficulty in making the joint determined to replace it by a shorter length, hoping to save time thereby. The pipe was raised and floated to the side of the cut, but there was some delay in getting the other length out, and the weather became so rough that work had to be stopped. During the storm which followed, the pipe was carried down the shore a short distance, where it was stranded and very much distorted in shape. It was afterwards cut in two by the contractors, who hoped to save it, but another storm stranded the sections in different places, and only portions of them were saved.

At the first, the pipes were built on each bank of the north arm of the basin, but afterwards they were built whithin the harbor at the Engine House wharf and the Credit Valley Ry. dock, and from thence taken to their places by tug, suspended between scows.

The work accomplished during the year 1881 was, the removal of the old "Inlet Crib," the placing of the "Shore Crib," the laying of 600 ft. of pipe, the construction of some 600 ft. ready for laying, and also the building of the "Lake Crib."

Much of the dredging which had been done was, of course, washed in during the time which elapsed between the cessation of work in 1881 and its resumption in 1882. The cut from the lake to the basin was entirely filled up, thus imprisoning four 100 ft. lengths of pipe, with cribs on each, which had been built in the basin in 1881, and three of which had been launched there. These were taken apart in 1882 and rebuilt at the wharf. The cost of taking apart these pipes and cribs, carrying the oak, timber, hoops and other material to the beach (some 300 ft. distant), and loading the same on scows, was approximately \$260$\frac{00}{100}$. The oak staves from these pipes were carefully inspected, and all pieces injured in removal were culled.

In 1882 the contractors commenced dredging at the south end and worked shoreward. The average time worked per day was 9 hrs. 16 min. The dredge worked on 71 days, including four Sundays. According to the measurement of the dump scows 23,230 cubic yards were taken out. The dredge was laid up for repairs and was idle on account of storms, or from other causes, 33 days during the season. The position of the dipper arm was taken daily, and the proper depth of cutting signalled to the engineer in charge.

In dredging it was found that the sand ran in so rapidly from the sides of the trench that it was necessary to excavate from 18 inches to two feet below the gradient, to allow for this filling in. The depth of the bottom of the conduit is 11 feet below zero level at the "Shore Crib," and 23½ ft. below at the "Lake Crib."

The "Lake Crib," which was built at the wharf in 1881, and left there all winter, was placed in position on the 14th of June. One length of pipe was attached to the crib and sunk at the same time.

The pipes were laid from the "Lake Crib" inward until eleven had been put in position; the remainder were laid outward from the last pipe laid the previous year. When the mouth of this pipe was reached, it was found that the bulkhead placed on it had been washed away, and the pipe was nearly filled with sand. Divers were at once set to work to clean out the sand, and this occupied about nine days. It was then examined by our own diver, who reported it clear as far back as his hose would reach (about 120 ft.). Six lengths were then laid from this point southward, and the closing section 10 ft. 6 inches long was placed in position. This point was chosen to put in the connecting piece on account of its being beyond the deeper excavation, in which it was very difficult to keep the trench open to the proper depth, every "blow" washing in the sand.

During a severe storm in June, 1882, one of the sections of pipe was wrecked. It had been placed in position six days before, but there were only a few bolts in the joint and very little stone in the crib. The bolts were broken off, the crib parted, and then rose and was washed away. The pipe was afterwards raised, and together with the portions of the crib towed to the wharf and taken apart.

On the 5th, 7th and 8th of October, a thorough personal examination in a diving dress of all the cribs and such parts of the joints as were exposed, i. e., not covered with sand, was made by the resident engineer.

When everything was favorable a pipe could be towed to place, sunk and the joint made, in from ten to twelve hours; but, owing to stormy weather and other causes, the average was about twice that time. To tow a pipe to place, and afterwards the scows with stone to complete the crib filling, necessitated between three and four trips for the tug from the wharf to the work (a distance of some four miles). Two divers, who relieved one another, were employed in making the joints, and our own diver to expedite the work very often assisted them. The packing used in making the joints was of pine. The filling over each pipe was proceeded with as soon as our diver had reported that the joints were properly made.

The average number of men per day engaged in building the pipes and cribs, sinking the same in position, making the joints and ballasting the cribs with stone, was twelve, but there were at times twice that number employed. There were also about ten men on the dredge, and two or three on the tug. The average cost for labor alone in building one length of pipe (100 ft.), including the crib, was $64.24. The average cost of building 600 ft. of pipe in 200 ft. lengths without cribs (in 1881) was $37.93 per 100 ft.

A large quantity of the oak was culled, on account of the rough planing of the sides of the staves, but these were afterwards put through the planer, and reduced from 6 inches thickness to $5\frac{1}{2}$ inches. They were then built into the pipe if found good.

At the time the specifications were prepared, it was thought probable that 200 ft. lengths of pipe might prove somewhat too heavy and cumbersome to be readily handled, and that more speedy and efficient work would be ensured by constructing the pipe in shorter lengths, especially in the open water, and consequently provision was made to cover a reduction in the length of the sections, should such be deemed expedient. The first lengths laid were found unwieldy in launching and placing in position, and liable to be strained and opened at the joints; but the 100 ft. lengths were handled quite readily, and when being placed in position were easily shifted a little one way or the other in order to make the joint.

The distance from the centre of the "Lake Crib" to the centre of the "Shore Crib" is $2357\frac{1}{2}$ ft. The total length of 6 ft. pipe, including the pieces built into the above cribs, is 2341 ft.

The total cost of the work was $41,683.36

Made up as follows:—

Conduit 2311 ft. in position, at $11.56............	$26,715.16
Shore Crib complete in place........................	1,500.00
Lake Crib complete in place..........................	2,600.00
Pipe Cribs complete in place, 17 at $450........	7,650.00
Removing old Inlet Crib..........	1,000.00
Extra flange castings................................	1,555.20
Extra pipe and flange bolts and washers..........	90.00
Extra stone..	864.00
Other extras..........................	60.00
	$42,034.36
Deduction for filling (not completed by contractors), 2700 cubic yards at 13c.	351.00
Total..............	$41,683.36

The above prices for pipe and cribs include the cost of dredging and refilling over the pipe to the original surface.

The average weight of the oak was about $58\frac{1}{3}$ lbs. per cubic ft.; average weight of wrought iron hoops on pipe, 162 lbs. each, and of flange castings 2163 lbs. each. The calculated weight of one 200 ft. length (without cribs) is about 60 tons, and deducting the weight of the water displaced, is about $5\frac{1}{2}$ tons. The 100 ft. lengths with pipe cribs attached, and without any stone filling, floated nicely, the top of the pipe being only two or three inches above the surface of the water.

It has been mentioned before that the "Lake Crib" is placed near the course taken by lake craft in making Toronto Harbor, and it was necessary on this account to mark its position so that mariners might avoid it; accordingly one of the largest size of "Brown's Nautical Automatic Bell Buoys" is moored nearly over the crib, while to the eastward and westward, at a distance of some 250 yards, two large can buoys are placed.

From the Drawings accompanying this Paper, Plates I and II have been prepared.

DISCUSSION.

Mr. Peterson.

Mr. Peterson remarked that having been Chief Engineer of the Toronto Waterworks he might naturally be expected to say something with reference to the interesting paper which had just been read, and at the same time to explain why such a work came to be carried out.

The pipe in question is, except as regards its size, a duplicate of the pipe laid from the Gibraltar point to the filtering basin, which was four feet in diameter, constructed and laid in a precisely similar manner, except that the original pipe was made with alternate staves of oak and pine partly on the score of economy and partly because it made the pipe, with the iron upon it, of about equal specific gravity with water, which enabled it to be very easily handled and at the same time very readily sunk to the required position. This pipe, as you will understand, became necessary because the city council had come to the conclusion that the filtering basin was a failure and could not be used to supply the city with water.

When the speaker took charge of the water works in 1872, he found that Messrs. T. C. Keefer (Past President) and the late E. S. Chesbrough, Past President American Society of Civil Engineers, had approved of the plan of taking the water supply from a filtering basin to be excavated in the Island in front of the City.

The Water commissioners elected early in 1872 had visited Hamilton and had seen a filtering basin in a very similar position, working in a most satisfactory manner, which had been in operation since 1858, and had supplied the city with pure, clear water, and this no matter how muddy the condition of the Lake might be. The Hamilton basin had been constructed by Mr. Keefer, and had been extensively copied in many waterworks in the United States, one city having expended more than half a million dollars with the hope, not the certainty, of obtaining water by a somewhat similar method. Borings for the Toronto Basin had been made by an experienced man, brought from the United States before the speaker took charge of the works, and his report was considered to be in every way satisfactory as to the quality of the material through which the water would have to pass. The only question in the speaker's mind, as to the success of the basin, was as to the quantity of water which the basin would filter, and after the dredge had commenced excavation, he decided to more than double its size, as he was convinced that instead of three million gallons per day the city would require five millions by the time the works were completed.

There were many prophecies by persons calling themselves engineers and others as to the certain failure of the basin. One saying that the sand would not allow the water to pass through it, another that the embankment could not be maintained and would be washed away by the first storm, another that the iron in the sand would contaminate the water and render it unfit for use. However, none of these prophecies were fulfilled, and when the basin was completed it filtered not only three million gallons but six millions, quite easily in 24 hours. The basin did not wash away during the time it was under the Speaker's charge,—and had it been properly cared for could have been maintained for all—time, neither did the iron in the sand contaminate the water, but owing to a stratum of vegetable matter about 13 feet below the surface, which the borings failed to discover, the water filtering under the head necessary to pass six million gallons per day was very much affected by some rust colored impurities contained in this narrow stratum of black sand filled with vegetable matter, having the appearance of roots of coarse grasses which had grown in the bottom of a marsh.

To get rid of this coloring matter experiments were made for a short time by pumping the basin down to the lowest possible level, then allowing the water to filter under as great a head as possible, in order to see if this coloring matter would not be forced out of the sand. It was necessary, however, to use the pumps at the engine house in order to keep up the water supply, and hence this test could not be made with the pumping engines for a sufficient length of time to find out whether this process would be effectual or not. The Speaker's advice was that a wrecking pump should be placed on the edge of the filtering basin to simply pump the water from the basin into the lake, keeping it down so low that the head of water would force out the impurities, and he has no doubt that this could have been done. He also recommended that a dredge should be put into the basin in order to dredge out the lower portion of the slope of the side wall which contained the contaminating matter, and to replace this with coarse sand from the upper portion of the slope. The speaker has no doubt that either of these methods would have proved effectual, and that taken together they would have entirely remedied the evil. The misfortune was that after the works were handed over to the council, no one who had been connected with the construction of the works was ever called upon to give an opinion as to the best means to be adopted to overcome the difficulty. It would have been natural to suppose that the Consulting Engineers and the Chief Engineer would have been consulted and their opinions asked as to what should be done, or at least that some engineer of well established reputation as an hydraulic engineer would have been requested to report on the works and suggest a remedy. Certainly the Consulting Engineer and the Chief Engineer had the interest of the works at heart and could have made the works on the original line of design successful; but this course would not have suited the parties who had predicted failure and who had the power to make good their prophecies.

Looking at all the disadvantages under which the works were initiated, they have been a success; they were commenced with a grant of $500,000, to supply a population of 60,000 inhabitants, and the works from the Island to the reservoir were designed on this basis; then $600,000.00 more was obtained and then again $900,000.00, making a total of $2,000,000.00. Had this amount been granted at first, or had there been an idea that this amount could have been obtained, the works from the city to the Island would certainly have been designed upon a larger scale. Up to the present time the city has had a good, pure supply of water, and notwithstanding all that has been said and written to the contrary the works were well and substantially built. The city has now a population of over 120,000, and yet the water supply is dependent upon a system laid down 16 years ago for less than half this population. That the system has served its purpose so long, under so many disadvantages and much neglect, shews that if there were any defects in it they must have been of very little moment to have given such satisfactory results.

Mr. Keefer.

When the filtering basin was undertaken, the late John Worthington, Chairman of the Water Commissioners, put the question to me: "What if it does not filter?" I replied, "You have decided to take the water from the Lake at this point as the best in the vicinity of Toronto; if it does not filter, all you have to do is to extend a supply pipe into the lake, and use the filter basin as a settling basin." Had the basin been extended to about double its length, it would have yielded the then supply, without "milking the cow till the blood came." The Island was then unoccupied, and the road was clear for an extension by dredging as far as the Eastern Gap. Periodical extension would have been necessary with the growth of consumption.

The basin was proposed on the plan of the successful one at Hamilton upon the belief that there would be days possibly weeks when the water would be too much disturbed by storms, to be fit for consumption. It would be interesting to know to what extent this has proved to be the case, under the present arrangement. If the inlet crib can be maintained at a point where the water is always clear, no filtration is necessary. If that point is not yet reached, or cannot be reached, or cannot be reached without greater cost and risk than that of an adequate filtering basin, then the abandonment of the filtering basin has been a mistake.

The connection of the supply pipes across the basin, and the abandonment of the basin itself are no doubt the result of popular prejudice and fear of contamination from adjacent marsh water. If the basin were large enough and adjacent marshes filled in, even without open connection with the Lake, pumping would, by washing out, have soon exhausted all taint from the surrounding soil. But with open connection with the Lake, there need be no draft upon the marshes, and if with the present location of the inlet crib, the water is now disturbed by storms, it would have been better to have maintained the shorter supply pipe and the inlet at the Basin using the latter as a settling one.

Mr. Macdougall. Mr. Alan Macdougall remarked through the Secretary:

That the system adopted in laying the large tube was efficient and economical. The density of the oak plank would have a tendency to sink the tube, the position of the weighting or anchoring crib in the centre of each length, enabled the contractors to float the tube horizontally and to weight it as required. He learned from the author, that the balance was so well adjusted the divers were easily able to pry the tube into position with crowbars. The anchors thrown out at the ends of the scows attached gave the divers control, and enabled them to draw the ends up quite close. The tube has worked well, there has been no trouble from it, and the freedom from "frazee" is worthy of remark, as the intake cribs at Buffalo and Cleveland are both much hampered by it, that at Cleveland particularly so.

When the 4 ft. conduit across the bay was delivering its full quantity, about $14\frac{1}{2}$ million galls. per day, the theoretical lowering of head in the inshore crib on the island should be $2\frac{1}{2}$ inches, this is correct, according to measurements made last summer. The question of increasing the water supply to the city received much attention last summer; from investigations made by himself, the superintendent of the water works and others, it was calculated that this 6 ft. tube was capable of supplying enough water for another 4 ft. tube or conduit pipe across the bay.

The execution of such work as this could only be carried out in calm water and this he learned was the case. The author is to be complimented on the very practical and useful nature of the information he has imparted.

23rd February, 1888.

E. P. HANNAFORD, Vice-President, in the chair.

Paper No. 14.

CONCRETE AS A SUBSTITUTE FOR MASONRY IN BRIDGE WORK.

By M. Murphy, M. Can.Soc.C. E.

For the last five years the author has been using concrete as a substitute for masonry, with a fair degree of success. With a few introductory observations, his paper will be confined to remarks on the theory and practice of Portland cement concrete as a building material, and to its employment in the construction of highway bridges, and other works coming within the scope of his own supervision in the Province of Nova Scotia.

In Nova Scotia, as well as in other new countries, the improvised wooden bridges of the early settlers supplied their wants for crossing rivers and streams, and, as at each successive stage of progress their numbers necessarily increased, the desirability of more permanent construction became more and more important. The frequent replacement of these timber structures taxed the Provincial resources to such an extent, that it became urgent that means should be adopted whereby the annual drain on the revenue for their renewal and maintenance might be lessened.

In 1883, an Act authorizing a Provincial Loan of $500,000 was passed for rebuilding the old wooden bridges where advisable, with materials such as stone and iron. Encouraged by the successful operation and results of this measure, the Government provided two further grants of $250,000 each, in the years 1885 and 1887, respectively, making one million of dollars available towards rebuilding those bridges in a more substantial form. Even with the additional votes of the two years last named, two-thirds of the highway bridges of the whole Province could not be erected in the permanent manner contemplated. Nor was it desirable that they should all be erected with iron superstructure, because there were many instances where wooden structures or cheap pile bridges could subserve more economically and accommodate equally well the public requirements. In positions favorable for solid foundations; in places where rapid currents are spanned; in situations prone to ice-jams, necessitating longer spans; and in saline water where, the *teredo navalis* or the *lignoria lignorum* are active, all other things being equal, iron bridges on stone concrete and iron supports were preferred, whilst in locations of an alluvial nature, in peaty or marshy deposits, or in quicksands, or where fresh water streams keep aloof or exclude those destructive agents, and where artificial foundations would be necessary, but too expensive, wooden structures or cheap pile bridges or other bridges of wood suited to the situation were adopted.

In carrying out the public works in any country, it is desirable, as far as possible, to use the material of the district, and though Nova Scotia can furnish both freestone and granite of excellent quality, it cannot furnish either of them, in the majority of instances, within the means at the disposal of the engineer. If stone suitable for masonry could be had so that the work could be performed for eight or nine dollars per cubic yard, that material was invariably used; if it could not, concrete was substituted.

In the construction of these highway or public road bridges, concrete has borne an important part. It was at first—in 1883—employed sparingly and with hesitation, but of late it has been used largely and with much confidence. Its use, for the support of the superstructure of iron bridges, was prompted by necessity, because of the scarcity of materials suited for ashlar masonry, the cost of transportation, the want of skilled workmen, and the rapidity with which it could be erected with ordinary labor.

This leads to the more immediate object of this paper, which is to introduce to the notice of the Society what has been done in Nova Scotia towards the substitution of concrete for masonry, and the results so far observable.

The introduction of concrete was at first treated as an expensive innovation. It was not to be expected that it would receive favorable public consideration, and it did not. It was alleged that in the climate of Nova Scotia it was an impracticable intrusion and would not suit its intended purpose, and although it could not be said to be an experiment, because it had been used so largely in other countries, still it was commented upon with disfavor. Nevertheless, concrete piers have been erected in the most exposed positions, in the midst of strong currents, without any external coating of wood or stone, where they are exposed to ice-floes, to blows from timber-drives, and in some instances, to undermining by scour, with comparatively favorable results. Exposure to sudden alternations of temperature has so far produced no visible damaging effect. Violent blows strike more impotently than upon masonry, and it is not so liable to fragmentary slips or segregations because of its monolithic character.

In forty-four iron bridges, with spans varying from 50 to 160 feet, supported upon concrete piers thus exposed, three only of the piers shew marks of abrasion, but not to such an extent as to need repair. Two of these defects are traceable to faulty workmanship and poor material. The third one, however, exhibits unmistakable symptoms of disintegration, and requires special notice. It will be referred to further on.

The abutments and piers were erected within a skeleton frame work, closely boarded against the face as the work proceeded upwards. They were built of Portland cement rubble concrete faced with Portland cement fine concrete. The facing of fine concrete was generally six inches in thickness, but varied to a width of nine inches in rapid currents or where liable to more severity than is due to ordinary exposure. The Portland cement rubble concrete was composed of one part of gravel or small stones not exceeding one inch in diameter, five parts of large stones, weighing 20 lbs. and upwards, two parts of sand, and one part of Portland cement. In mixing the concrete, the gravel, sand, and cement were turned over three times whilst dry. Water was then added and the material again turned over at least three times and well agglomerated before being placed in the work. The gravel, sand, and Portland cement for the fine concrete were first mixed to form a matrix or body of concrete, and the large stones of the rubble concrete were placed therein by hand. These stones were placed end upwards, two inches apart, and the spaces between them grouted up solid with the matrix to form a compact mass, and any holes or cavities in the work were run full and flush with Portland cement compo, consisting of two parts of sand and one of cement. The fine concrete facing was kept at least six inches higher than the rubble concrete, and united with it so as to form one homogeneous mass. In every instance the top of the pier or abutment was finished with fine concrete for a depth of one foot six inches, and the shoes of the iron truss posts were laid thereon without the usual bridge seats of stone.

The width of piers at top finish, varied from three feet to four feet six inches, according to the superincumbent weight they had to bear. In piers of twenty feet in height, the hardening, or "set," was sufficiently rapid to allow six laborers working on each pier to proceed to completion without intermission, the progress being from two to three cubic yards per man per day.

The concrete work for the last three years has been executed by the Government's own engineers and workmen, without the intervention of contractors, a system which, however inapplicable in some countries, has been found to answer well in Nova Scotia. Upon the proper composition and incorporation of the ingredients which enter into the concrete, and which are mixed up and set with the rubble stone in the work, will depend the requisite adhesion and stability, and although reliable contractors were always available, still it was considered more advisable to carry out the work by men working by the day and trained under proper supervision, until they became sufficiently skilful, and as interested as the engineer in the success of the undertaking.

A bridge of 160 feet span, 15 feet roadway, loaded with 80 lbs. per square foot, gives a total weight of 304,000 lbs. Taking one fourth of this weight distributed over an area of three feet square by the bed plates, and the cohesion of the cement itself, we should have a weight supported equal to about 51 pounds to the square inch, or quite within the margin of safety even for comparatively freshly set concrete. Since an abutment, to fail only by reason of a direct pressure from the weight of the bridge, could only do so by the crushing of the particles of cement together, and since this crushing could not take place without first rupturing the face of abutment at its point of least resistance, we may take this point as a measure of our bearing capacity, that is, take the distance from centre of pressure to nearest face of abutment as one half of our available width, and this width squared as our bearing area. For a bridge of this size the width thus found would not be less than four feet, and the distributed weight would be 33 lbs. per square inch on the walls, which are battered 1 in 6 or 1 in 8.

The use of concrete for over ground work in Nova Scotia commenced with the filling in of the voids in crib-work abutments constructed of closed faced timber work. It was next employed *en masse* for abutments and bridge piers that stood divested of all outer shield or covering; also for retaining walls exposed in like manner, and later for the building of arched bridges. Examples of abutments and piers of concrete work can now be seen in every county in the Province. The retaining wall is built with alternating arched panels and buttresses. It stands in front of the Provincial Building in the city of Halifax. An arched concrete bridge of two small spans of fourteen feet each, is built from the shingle sand of the sea beach at Cow Bay, near Halifax, and there is an oblique arch of 30 feet span at Acadia Mines, Londonderry. The author is aware that these are small examples to refer to, still it should be considered that the aim of the paper is merely to bring to the notice of the Society how exposed surfaces of concrete have so far withstood the climate, and to what extent concrete may be relied upon as a substitute for masonry.

The concrete work forming the arches was built in courses radiating the same as dressed stone in courses for arch work, so as to prevent any horizontal tendency to set flakey as the work went on. Each course was moulded on the lagging of centres, by securing theron a board in the true radial line between soffit and extrados, and the concrete was placed therein in its final position to form the course. When sufficiently set the board was removed and placed again for the next succeeding course. A setting template, the same as masons make use of when laying voussoirs, or arch stones on centres, readily gave the inclination of the board. The foreman in charge was cautioned not to permit any course to be partially filled up and allowed to set before the whole was completed. In this way each course was expected to have the same consistence throughout. The concrete used in the arches was of the same admixture as described in this paper as "fine concrete." The writer, however, considers that rubble concrete can be made use of for arched work as advantageously and far more cheaply, if the rough stone concrete and grout are conformably and proportionately equalized and adjusted.

The symptom of failure in the piers of one bridge already referred to, occurs in a tidal stream at Petite Rivière, in Lunenburg County. Two piers of concrete support an iron bridge of 100 feet span. At low tide there is not more than one foot of water. Ordinary neap tides rise five feet, springs generally about six and one half feet. The outer shell or matrix of fine concrete, where exposed to the tidal fluctuations, exhibits fissility, and will crumble at a slight blow. Above high tide it is solid and impervious. Two fragments cut from pier above and below tide are exhibited for examination. The bridge was erected in the summer of 1885, about eighteen months ago. Although erected by a careful foreman and with the usual component parts of material for submerged work, viz., two of gravel, one of sand, and one of cement, it never attained the same degree of coherence as other work of the same character, and it has now become so friable as to point to the necessity of renewal at no very distant day. The concrete work in fresh water streams, as well as in salt and brackish water, had already given such evidence of permanency that one was loath to acknowledge a failure, or with M. Vicat, ascribe the result to the presence of magnesia in the sea water, which acts injuriously on the lime. In this instance the failure cannot be attributed to carelessness in the selection and admixture of the concrete ingredients employed in building, because the disintegration and brittleness extend upwards only as far as the tides reach. Above that level it is compact and firm. There is no sulphur or sulphate of lime in the neighborhood. The gravel and sand are from the slates and quartzites of the Lower Silurian or Cambrian formation, the auriferous rocks of Nova Scotia.

Now, Portland cement, being a mixture of chalk and clay, which is supposed to be burned to the extent of driving off the carbonic acid, thus becoming an hydraulic lime, nevertheless, through imperfect calcination, may not form a cement which would resist the action of salt water, although it might succeed well enough in fresh water. Again, if there was any sulphate of lime in the clay it would not at once enter into combination with the lime, and would be likely to cause the disintegration experienced at Petite Rivière.

If the material from which the Portland cement is made was underburnt or imperfectly decarbonated, and contained an excess of free or disengaged lime, which, not being united with the silica and alumina, would absorb moisture largely, "and would fall to pieces in water, in this case, says Mr. G. F. White, the silicate of lime and alumina had not been formed, and the result would be an incomplete cement characterized by a light yellow color, moderate specific gravity, immediate setting, and imperfect induration."

Three briquettes of the cement employed at Petite Rivière bridge, after seven days' setting, gave a tensile test of 329½, 358, and 396 lbs. respectively to the square inch. The color and gravity were not noted at the time. The cement was quite fresh

Portland cement is not always uniform; its manufacture requires much care; it is not free from risk, though its employment both in fresh and sea water, above and below water, is generally satisfactory. There have been no visible signs of expansion and increase of bulk, or unusual contraction, which is presumably owing to careful manipulation and having been used in small quantities.

The author has employed the Medina cement, made by Messrs. Francis, of London, in pointing and repairing the sea walls retaining the embankment at Bray Head, on the Dublin, Wicklow and Wexford Railway, and the sea walls of the Dublin and Kingstown Railway, when resident engineer on those lines of railway, with a greater degree of success than when Portland cement was employed. The rapid setting of the natural cement proved more advantageous, up to the level of high water, than the too slowly setting Portland or artificial cement, during the operation of tide work. It was considered better to employ both, the natural cement for pointing and lipping up to ordinary high water, and the artificial cement from that point upwards, and the result seemed to justify the practice. When the exposed surface of the base of the piers of Petite Rivière bridge becomes more abraded, or when renewal is necessary, it is contemplated to submit the Medina to a similar test beside the Portland.

There is at present an iron bridge under construction to replace the

Victoria Bridge, Bear River, consisting of a swing span 160 feet in length, two fixed spans of 125 feet each, and one of 100 feet. The swing span is to revolve on a circular pier 24 feet in diameter, entirely constructed of concrete. Each pier for the fixed spans consists of two wrought iron cylinders five feet each in diameter filled with concrete, coupled together by laced channel beams and lateral bracing, and sheathed between main tubes to prevent lifting or displacement by ice floes. It is, however, the circular or concrete pier that comes more properly within the bounds of these remarks, and to this alone shall reference be made here. There is 18 feet of water at ordinary low tide in the navigable channel; spring tides rise 26 feet. The *Lignovia* are here so active that the bearing power of piles, or of timber submerged below the level of low water, is, where exposed, affected if not destroyed within six years. The supports of the old wooden structure had to be renewed twice within a period of twelve years. The new bridge is being placed immediately above the old one, and if founded on piles similarly unprotected would be no less reliable. The river bed here is characteristic for instability and increasing change caused by the rapid currents of the Bay of Fundy tides on gravel beds and loose deposits, pointing to piles as most desirable. For these reasons, as well as one no less obvious, viz., limited means, it was decided to adopt piles driven at centers three feet apart over the whole base of pier, and protect them with a circular envelope of concrete three feet in thickness. The hexagonal circuit of close piling shewn by figure No. 2, is driven merely as a mould to retain the outer wall of concrete whilst it is being erected. The piles are to be cut at the level of low water spring tides, the intervening spaces between them filled up with small stones, and the usual platform of 12" × 12" timber framed thereon, thus completing the base of the circular pier up to the level of low water. The concrete superstructure from that point upwards to finish is a frustrum of a cone having a solid vertical central pillar 4' × 4' to support the pivot, and four walls, 2'–6" each in width, radiating therefrom to outer circular wall or periphery, which is 2'–6" wide at top and increases downwards with a batter of 1 in 8. The four voids thus left in the body of the prism have vertical sides to within four feet of the top, where they corbel to an apex and are covered with two feet of fine concrete. The swing span which is to turn on the centres, and is made to revolve on live rollers, will be lifted on its centre pivot by the usual screw device or central press, thus relieving the rollers of part of their weight. There will be during the operation of turning 118,596 lbs. superimposed on the four feet square wall or pillar of concrete, or 51½ lbs. to the square inch. Figure No. 2 gives the form and details of this pier. With respect to the three feet wall surrounding the piles under water, it will be filled up with concrete lowered in paper bags, each containing a cubic foot of fine concrete. This mode of placing concrete under water between piles, or within iron tubes where the intervening spaces are small, has been practiced in Nova Scotia very successfully. The iron tubes of the Avon bridge, at Windsor, have been filled up to the level of low water in this manner. The bags cost $1.35 per hundred or 36 cents per cubic yard additional for their use. They are made of rough brown paper well stiffened with glucose, which is immediately destroyed by immersion, the residue helping to assist the induration and strength of the concrete, whilst there is very little if any of the cement lost by submergence. Rubble concrete can also with care be placed under water in alternating courses of fine concrete and stone, by lowering the stone so that they would not rest against or upon each other and lowering a course of fine concrete in bags thereon.

An objection may perhaps be raised to the circular pier of Victoria bridge being built of concrete, on the ground that the piers of the Petite Rivière bridge have already exhibited symptoms of failure owing to the action of sea water. It must, however, be admitted that this failure is but one contrasted with many that have proved successful, and, moreover, that within the limits of those phenomenal fluctuations characteristic of the Bay of Fundy, concrete has, so far as it has yet been employed, given satisfaction. On the other hand, the author is not aware of any one instance where an ashlar masonry structure, erected within the same tidal influence, is not more or less a failure. The railway bridge that carries the Windsor and Annapolis Railway over the Avon River at Windsor is an instance. The bridge is supported by eight piers and two abutments of freestone ashlar masonry, and consists of nine spans of lattice truss, six of which are 160 ft. each, the other three, or shore spans, being smaller. There is very little water—not more than from two to three feet—in the stream at low water. Neap tides rise about 24 feet, ordinary springs four or five feet higher. The piers of this bridge have been a source of annoyance and expense to the Railway Company. The water penetrates the body of the masonry at high tide, and not being able to escape as fast as the tide recedes, or to escape altogether, a severe frost operating upon it adds at every successive reflux its expansive influence to the already tottering face stones. The result is, that notwithstanding repeated repairs, the piers will have to be altogether taken down and reconstructed. In view of such a tendency to displacement as shewn in this instance, as well as in another similar instance no less prominent, experience would lead one to select the concrete as the most suitable to be adopted in this particular locality. Owing to its homogeneous character it will be more impermeable to water, less susceptible to displacement by frost, and, in this case, more coherent and endurable as a support.

But it may be asked, what is the justification for the employment of concrete at all above ground in lieu of stone? Why, the fact that walls and bridges are produced which perform the service expected of them at a much less expense than masonry, that by the utilization of materials otherwise inoperative, such as the shingle of the beaches and streams, and the boulders encumbering the surface, permanent bridges can be readily built with the assistance of ordinary labor; that by the employment of concrete, limited means will yield more desirable results, that evidence exists that such adoption would secure, at low cost, works of great efficiency, is sufficient to justify the use of concrete as well as the introduction of the subject here. Local conditions largely modify local architecture and requirements. Down here by the sea, the Trenton limestone of Montreal cannot be had in adjacent quarries, neither will the necessity of its adoption warrant its introduction. Materials at home must suffice to supply the needs at home. If stone cannot be had, or if it is of too refractory a nature to be made available, brick must take its place, and for the same reason concrete may in many situations be introduced as a substitute for stone as well as brick.

Although the history of rubble concrete dates as far back as the history of architecture, the introduction of Portland cement to the admixture of concrete may be said to be the history of our own times. In England, George Semple in 1774, Dr. Higgins in 1775 to 1779, Smeaton in 1756, and Parker in 1796, by their respective investigations, reduced the practice of concreting gravel with lime to a system. Semple having studied the works of Alberte, who explained the system used by the ancient Romans in building walls in coffer-dams or cases of small materials grouted, proposed to follow the same plan in foundations of bridges. Dr. Higgins' book on mortars gives the effect of earth and metallic oxides on bones and chalk limes, and on concreting gravel with lime for surfaces of roads, etc. Smeaton's work on the Eddystone Lighthouse taught the properties of English limestones and compared them with pozzuolana and tarras, and Parker took out a patent for making cements obtained from certain stones or argillaceous productions or nodules of clay. This stone was termed Sheppystone, from being found near that island. The stones were burnt in kilns and afterwards ground to powder. It was called Roman cement, and was used in preference to Aberthaw, Halling, or Dorking hydraulic limes or cements. This Roman cement was used almost universally until eclipsed by the Portland cement of Messrs. Bazley, White & Co. In France and in Holland the application of béton seems to have been contemporaneous with its use in England, and has been much more extensively practised in the erection of monolithic structures during the present century. The report of the Jury of the Paris International Exhibition of 1855 awarded M. Vicat, a distinguished French Engineer, a "Medal of Honor," and observed that he had devoted himself entirely to the study of the theory of the action of limes with silicious materials, and had successfully demonstrated that France possessed all the elements of the pozzuolanas, and by the simple admixture of calcined or raw clays with lime, artificial cements could be obtained for hydraulic purposes. He discovered nearly three hundred quarries in France whence hydraulic cements could be obtained.

The manufacture of Portland cement, first called artificial cement, is attributed to experiments commenced in 1826 by Major-General Sir Charles Pasley, and continued through a series of years.* It is composed of two simple ingredients, clay and chalk. It is principally manufactured on the Thames and Medway. In white chalk districts the clay forms 25 per cent. to 30 per cent. of the whole bulk, and in grey chalk districts 16 to 23 per cent. Much care is required in the selection of the clay, so that it will be free from sand. These proportions still vary with the character of the lime, and are the result of experience gained in its daily manufacture and use, extending over a period of fifty years.

Messrs. White, of London, were the first to make and introduce this artificial compound as a cement. They, however, dropped the word artificial, and placed it on the market under the name of Portland cement, whether from its resemblance when set to Portland stone, or because the word artificial might be injurious to its introduction, is not generally known.

Up to 1856, the use of Portland cement in Great Britain was comparatively limited, Roman and Medina cements being more extensively adopted, whilst in France and other parts of Europe, Portland cement manufactured in England was steadily gaining favor, having been used extensively for large harbor and dock works. The extensive adoption of this material by the Metropolitan Board of Works, in 1858, in the construction of sewers, drew the attention of Engineers to its value and importance. In December, 1865, Mr. John Grant, M. Inst. C. E., in one of the most able and useful papers that has been written on Portland cement, entitled "Experiments on strength of cement, chiefly in

* Vide observations on limes, calcareous cements, mortars, etc., by C. W. Pasley, London, 1838.

reference to the Portland cement used in the Southern Main Drainage Works" * (London), gave the results of 15,000 experiments made by him from 1858 to 1876, whilst Divisional Engineer in charge of that district of the great system of drainage for the metropolis. Since that time almost every engineering text book quotes from Mr. Grant's paper on the strength and properties of Portland cement.

The recapitulation of some of the results and experiments shewn by tables is as follows:—

1. Portland cement has been proved to be suitable for hydraulic works.
2. The longer it is in setting the more the strength increases.
3. Neat cement is stronger than an admixture with sand.
4. Cement mixed with one, two, three, and four parts of sand may be said to be at the end of one year, approximately $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ respectively of the strength of neat cement.
5. The cleaner and sharper the sand the greater the strength.
6. The less water is used in working it up the better.
7. Salt water is as good for mixing Portland cement as fresh water.

It is now twenty years since Mr. Grant's paper was published, and the results then announced are for the most part in accord with the experience of to-day. The information thus realized has not only assisted in establishing Portland cement as being the best for employment where great tenacity and permanency are indispensable requirements, and where hydraulic properties are desirable, but it has also contributed to raise the standard of its manufacture. The seven results quoted above are picked out from twenty-two obtained from many thousands of tests, and those selected are numbered arbitrarily for reference here. They are, however, the results of extended experiments with cements furnished to meet the requirements of a high standard, where four millions of bushels were wanted, and where manufacturers vied with each other in the home market in the production of the best material on account of the large sales anticipated. These results serve as desirable examples. The question is how to arrive at or maintain that degree of excellence by judicious selection. If the cement is required in sufficiently large quantity to warrant shipment direct from the producer, the problem of selection becomes easy. But when, in this country, the engineer or contractor wants Portland cement in comparatively small quantities, and too frequently wants it immediately, where the best tests of time and futurity are not available, being too remote for immediate selection, the solution becomes more difficult. In

* Vide Minutes of Prodeedings Inst. C. E., vol. 25.

this case, in the humble opinion of the writer, it would be safer to select from a well known brand of a respectable manufacturer, than from any conditional test he is aware of.

There are at least two indispensable tests which cement must bear thoroughly before it can be pronounced good. One is adhesive strength at various ages neat and mixed, the other resistance to water.

The following are the usual tests applied, and they are in some instances unreliable:—

(*a*) For fineness—by sifting and residue. The importance of having cement finely ground is generally acknowledged as a concomitant to a test for weight. Imperfect calcination or an excess of lime, or an incomplete light cement would, however, be more easily pulverized and would give a finer test from less grinding.

(*b*) For strength—by breaking or by a certain resistance to tensile strain. The test from briquettes after having been set seven days will be in favor of quick induration, which is in itself objectionable; extend the time to four weeks, the test will be found more reliable. If the cement is coarsely ground, considered comparatively, the tests will be equally good, yet coarsely ground cement is objectionable. Again, a small excess of lime will not affect the maximum strain in the machine, still the excess of lime may be injurious.

(*c*) For weight. Weight, specific gravity, and color are important elements. Until the same mode of ascertaining the weight is more generally adopted, or a more universal means is established so as not to be affected by the question as to whether the cement was more or less compact in the measure, the present means of testing will be unreliable for comparison.*

(*d*) Immersion in water. By making two parts of cement paste, one to be put in water, the other to be set in the open air. If there is an undue quantity of clay, the cake put in water will assume a buff color. If there is too much chalk, or if it is overburnt to the point of danger, cracks will be visible round the edge of the cake in the air. There must, however, be quite an excess of one or the other before these tests will be noticeable.

It has been frequently alleged by manufacturers and others that Portland cement can be made to pass all these tests and yet may have an excess of lime or sulphate of lime, and afterwards prove to be dangerous. However, enough is now known of the qualities of Portland cement, as well as its manufacture and behavior under different conditions, to direct the engineer in its application under the varying cir

* Vide remarks of Mr. F. J. Bramwell, p. 136, 137, vol. 25 Trans. Inst. C. E.

cumstances that may arise in the course of his practice. But it occurs to the author, as it has no doubt to several others, that in case of emergency a more practical and reliable test than any now available is necessary, to enable the purchaser to arrive at least at a more approximate value of Portland cement, and here chemical tests suggest themselves. Mr. Henry Reid gives a chemical analysis for a good average Portland cement, capable of passing the following six tests, viz.,—weight 112 lbs. per imperial bushel, strength 300 lbs. tensile per sq. inch, texture 2500 atoms or a sieve (50 gauge) to a square inch, hydraulicity, after six days' immersion perfect without crack or fracture, color by an air sample grayish blue or steel grey. Such a quality of cement would produce with a moderate divergence of range the following analysis of the main ingredients:—

Lime	60.05
Magnesia	1.17
Alumina	10.84
Silica	24.31
Alkalies	1.54

Adopting the above or the best standard, the skilful chemist might determine practical tests for excesses or injurious ingredients, which are generally beyond the province of the otherwise actively employed engineer. For emergency, some more practical test than any at present available is required.

Passing over results 1 and 2, and taking 3 and 4 as factors determining measure of admixture, and adopting the theory of all good concrete, which is to coat every particle of stone and gravel with a film of the cement, the deduction from the theory would be that the more intimate the union, the more perfect would be the concrete resulting from the combination, and since in a perfect Portland cemen the admixture of lime and clay (3) with neat cement is stronger than an admixture with sand, it follows that the more cement is employed, the stronger and better the concrete.

Next taking result (4), cement mixed with an equal quantity of sand is $\frac{3}{4}$ of the strength of neat cement, with 2 parts $\frac{1}{2}$ the strength, with 3 parts of sand $\frac{1}{3}$ of the strength, and with 4 parts of sand $\frac{1}{4}$, but with 5 parts of sand it is about $\frac{1}{6}$ of the strength of neat cement. It would appear that the proportions are maintained up to the intermixture with four parts of sand, but there is perceptible loss with a greater or fifth measure, and this fourth intermixture is practically a proper limit. Fine concrete for external employment in this climate should not be more than three or four parts of gravel to one of cement. With this proportion a coat of solid lime will be deposited round each grain of sand and gravel. When freshly mixed, each particle will be embedded in a saturated solution. If three to one, and fine sharp sand is used, the absorption of the water will cause a contraction, in mortar, of between $\frac{1}{3}$ and $\frac{1}{4}$ of its bulk, which will increase its solidity and draw all the particles together. When the mortar or fine concrete is rich in perfectly formed cement this theory stands the test of practice, its impermeability to water after the hardening or "set" has taken place being a prominent feature. Setting is the work of hours or days, induration is the action of months and years, making the mass still stronger (2) and preventing injury from the expansive influence of freezing. Stones sufficiently solid and impervious themselves to be safe from congelation by frost may be safely introduced into the body of the mass in the manner shewn by Figure No. 3, without very materially affecting its stability, whilst at the same time they largely contribute to fill up and form the desirable bulk and reduce the expenditure within practical and economical limits.

It is almost a universal opinion that Portland cement is frequently spoilt in its manipulation with other ingredients by an excess of water in the mixture (5). This theory is proven practically by almost every one moulding cement paste into briquettes. Where concrete is turned over and mixed in troughs by hand, the disastrous habit of avoiding exertion in mixing by repeated doses of water, is too prevalent among the workmen. If the pasty material is too adhesive to fill up all voids round the stones, a dose of well tempered compo may be resorted to. This latter increment is against the true theory of concrete, and should be sparingly and carefully introduced.

Salt water is as good for mixing Portland cement as fresh water (7). This theory holds good in practice for concrete placed in salt water. Owing to the frequent and abnormal changes of temperature in the climate of Nova Scotia in the months of February and March, efflor escence is more noticeable on exposed surfaces where salt water has been used in mixing. In the opinion of the author fresh water sand and fresh water are preferable, and their use would likely be attended with better results in this country.

So much has been said and written respecting slags and their value in hydraulic mortar, that the author has recently paid some attention to their supposed hydraulic properties, and the result leaves little doubt on his mind that they are not reliable as an hydraulic agent. The following analysis of the slag from the furnaces of the Steel Company of Canada, at Londonderry, was supplied by John Sutcliffe, Esq., Manager.

	4	5	23	35	37	39
Silica	38.066	37.21	32.35	37.81	35.47	33.96
Alumina	15.289	11.05	10.74	8.62	10.30	9.79
Ferrous Oxide	0.310	0.80	1.06	1.95	0.99	
Manganous Oxide	0.381	1.04	0.44	3.55	2.78	1.00
Lime	36.148	42.92	47.60	42.99	43.71	49.60
Magnesia	7.012	4.24	4.01	3.43	2.43	4.56
Calcic Sulphide	2.451	2.239	3.15	2.09	4.14	
Potash			0.13			
Soda			0.08			
	99.657	99.499	99.56	100.44	99.82	98.91

4—Grey slag.

5—Grey slag. Hot and fluid.

23—Grey stony slag, white face.

35—Grey cinder.

37—Grey cinder, white face, hot, fluid.

39—White, very dry cinder.

The results obtained from tensile tests in a Fairbank's Testing Machine were no better than a Portland cement intermixture with sand would be. They were as follows,—

			lb	lb	lb
Pure cement	set 28 days		448	386	505
1 slag to 1 cement	" 28 "		182	257	288
2 " 1 "	" 28 "		212	245	245
3 " 1 "	" 27 "		77	96	126
4 " 1 "	" 27 "		106	113	121
5 " 1 "	" 26 "		38	54	
6 " 1 "	" 23 "		23	27	

The barrel of slag supplied, from which the briquettes were made, shewed the silica in a vitrified condition; also fused silicate of lime already formed with the alumina burnt to a white dry cinder. These tests will be continued on greyer and heavier slag; it is hoped in time to supplement this paper with better results.

N.B. Since this paper was submitted to the Canadian Society of Civil Engineers, the small concrete arch bridge referred to as being built at Acadia Mines, Londonderry, was carried away by the breaking of a milldam higher up stream, and a descent of logs which lodged against it, The accident to this bridge, one of the 44 referred to as being constructed. could not in any way be attributable to defects in concrete as a building material. Although the bridge had been quite recently constructed, it stood the pressure of the flood until the water covered the parapets, and would not have been destroyed then but for the breaking of the dam higher up stream.

DISCUSSION.

Mr. E. Gilpin, jr With respect to the action of the tide water on the Petite Riviere Bridge piers, Mr. Gilpin would remark that, taking for granted the normal goodness of the cement and the care of the overseer, the cause of the frittering of the pier must be sought either in the water itself or the materials incorporated with the cement. Mr. Murphy says that this material was derived from the Cambro Silurian strata of the district.

It may be remarked that frequently the quartzites of this horizon are made up of grains of silica with silicious cement impacted as dense as flint, and the metamorphic states are equally solid. Under these circumstances the adhesion of the cement, most effectual when in contact with an aggregate of moderate porosity, may have been defective. The alternations of dryness and moisture, of heat and frost, would promptly effect a disintegrating effect.

The retaining wall erected on the property of the Provincial Government has so far stood very well. There is a decided magnesian efflorescence which has been attributed to the sand being taken from an old sea beach. Whatever proportion of the efflorescence may be due to the presence originally of salts of magnesia in the sand, Mr. Gilpin thinks that the effect may be more properly attributed to magnesia salts present in the cement, and enquiry may show that the best cement apart from its essential ingredients may safely hold iron only as an accessory.

With respect to Mr. Murphy's tests of furnace slag from the Londonderry iron works, I presume the poorer the slag for his purposes the better the furnace master has studied his charges. The analyses of the Londonderry slags are about the average of similar furnaces in England, and differ widely from Mr. Murphy's typical cement. According to Bodeman the most fusible slag contains silica 56, lime 30, alumina 14 per cent. The cement maker aims at stability; the furnace master wants the most readily combining and the most fluid compound he can contrive for his slag—and in this would apparently lie the practical want of success attending the utilization of furnace slags for cement.

Mr. Uniacke. The paper by Mr. Murphy on concrete as a substitute for masonry in bridge work must be interesting to all engineers, and especially so to those who have occasion to build substructure works in localities where suitable stone cannot be obtained for masonry in the neighborhood, and when the available means is not forthcoming to provide for the usual expensive transportation.

The speaker is familiar with most of the instances in the Province of Nova Scotia where concrete has been employed, and can concur with the writer of the paper that as a whole its use has been attended with gratifying results. As its efficiency as a building material has become more clearly shown, so has its adoption met with more popular favor in this Province.

One of the early uses of concrete under the Nova Scotia Bridge Act was in building the abutments of Valley bridge near the Intercolonial Railway in Colchester Co. Here the bed of the river is composed of gravel and sand, and owing at times to sudden rising of the river during freshets, any ordinary foundations would be liable to scour. If masonry had been employed, it would have been necessary to sink the foundations to a solid substratum, cofferdams would have been required, and the cost of the substructure would have exceeded the proportionate amount of appropriation for the county set apart for that bridge.

The abutments of the U form, and supporting a 140 foot span of irons were founded in this manner, the gravel was excavated to a depth of 5, feet and large enough to leave a margin of 2 feet all around, this pit was completely filled with ordinary bags, each bag being partially filled with concrete, and laid breaking joint header and stretcher up to level of low water; upon this foundation the abutments were erected, by means of a temporary frame work, and covering, as described in the paper for naked concrete.

During a heavy freshet a scour took place and undermined one corner of an abutment; this was refilled, and although nearly four years have passed, during which time some of our highest freshets have arisen, no further trouble has occurred. The concrete is of good quality and one of the best examples we have. It may be safely said that under the same circumstances masonry would have failed where the concrete from its monolithic structure stood firm.

It may have seemed a risk to set concrete abutments upon this kind of a foundation, but by the method employed, and the circumstances which followed, this course seems to have been fully warranted.

The case spoken of at Bear River Bridge is one in which concrete would seem to apply very well, and the proposed manner of erection, and especially that of the pivot pier, seems to be quite practicable. It would, however, be interesting to learn after the bridge has been completed, with what success this method has been employed, or what alterations or modifications, new conditions or unforeseen difficulties, may have necessitated.

The failure referred to of the piers of at Petite Rivière, would seem to call for special investigation as to its cause, for although some disturbing influence, not quite apparent, must have caused disintegration, yet this same difficulty is liable to occur in any other structure built under similar conditions, but, as the writer of the paper states, "this is but one failure contrasted with many that have proved successful." The dry dock now being built of concrete at Halifax will be under similar conditions respecting tides, and its progress and composition will be watched with interest.

The railway bridge cited at Windsor is not a solitary instance of the failure of masonry within the influence of the Bay of Fundy tides, but as it is the largest structure we have, it appears to have called for special mention. The Intercolonial Ry. bridge across the Shubenacadie river is a similar case, being built of ashlar masonry, and has required repairs and extensive renewals to its piers.

Mr.Macdougall Mr. Allan Macdougall remarked through the Secretary :—

That in his opinion the danger of using concrete *en masse* would be the tendency to rush the work and not allow sufficient time for the settlement and consolidation of the concrete. Work was now pushed on in many cases too rapidly, and carried on during portions of the year and under temperatures which in the more conservative practice of our seniors was forbidden. He deprecated the system now so much in vogue of building in winter when temperatures were low; heating the sand and water did not avail much when put on an ice cold stone, or in a thin brick ring. Evidences of this come under one's notice constantly.

Relative to the setting of cement, his experience in this country is that a fast setting cement finds most favor. In the sewer work in Toronto this is the case, and he has noticed it in reference to other engineers' work. The hydraulic limes from Thorold and Napanee were used in Toronto for some time, but they have lately been discarded, except for concrete over the tops of arches. This concrete has been used in running sand, and found to have set perfectly hard, the evidence being obtained when private drain and sewer connections were made.

Napanee appears to be more even bodied than the other native cements, and strengthens rapidly with age. Samples taken from Dover Court Road during construction of the sewer stood as under:

Age in days........................	6	12	26	100	150
Strength in lbs. per sq inch...	10	40	45		
" "	10	35	50	80	
" "					130

A new cement from Queenston (Niagara) sent for test gave:

Age in days....	3	6	9	50
Strength in lbs.	12	20	22	55

This has not been used in Toronto.

The above tables are offered to shew that the native cements do harden and are effective in certain situations. The writer does not advocate their use, where a large quantity is to be used *en masse*, in wet foundations or under water.

The system of throwing a cement arch described by Mr. Murphy is such as to ensure its stability and homogeneity. An interesting and novel use of a concrete arch is described in Trans. Inst. Engrs. and Shipbuilders of Scotland, 31st session. During the construction of Glasgow City and District Railway, quicksand was found in the tunnels, the sand was brought to a certain level, then an arch of 27 feet span was thrown; the substrata were carefully drained and removed, and the tunnel walls and arch built without disturbing the concrete arch or cracking the adjoining houses.

Iron cylinders, if filled with cement, should be employed only for caissons; the columns of the first Tay bridge were filled with concrete, they cracked and had to be hooped with iron. Several other examples of pillars cracking when filled with cement have come under his notice.

Mr. Murphy is to be congratulated upon the use he has made of concrete in the highway bridges he has built in Nova Scotia, and the information he has given respecting the behaviour of Portland cement concrete will supplement that contained in Mr. Boswell's paper on the Quebec Harbour Improvements. **Mr. Perley.**

Mr. Murphy describes how in constructing arches "to prevent any horizontal tendency to set flakey as the work went on," he built them "in courses radiating the same as dressed stone in courses for arch work."

In 1868, Mr. Perley, then in charge of the construction of the Metropolitan District (underground) Railway, in London, built a bridge entirely of concrete, 75 feet span, and 7½ feet rise, and a copy of the working plan is submitted herewith, Plate 7.

A portion of the railway in Earls Court was in open cutting, and a connection had to be made between the properties on either side. It was suggested to Sir John Fowler, the Engineer in Chief, that an arch bridge of concrete should be built, and his approval was obtained.

The first operation was experimental (as it was not known at that time that an arch of concrete of the dimensions proposed had ever been built or attempted), and consisted in the building of blocks of concrete on either side, 14 feet wide, 4 feet thick, and $10\frac{3}{4}$ feet high, as springers for the arch, the cutting being through gravel. After the centering, a width of 12 feet of the arch was erected, the laggings being made smooth and tight, and the side boarded up to retain the concrete and ensure the proper thickness being put in; it was found that the springers had set sufficiently to warrant the arch being proceeded with, before which an ample quantity of gravel and cement had been brought to the site and placed in readiness on either side.

The concrete consisted of 6 parts gravel, 1 part of cement, and 1 part of sand, was mixed by hand and wheeled directly into place, care being taken that it should be distributed evenly so as to prevent unequal pressure on the centering, and the work was continued without cessation for 16 hours when a strip of arch, 12 feet in width, $3\frac{1}{2}$ feet deep at the centre, and 8 feet at the springing, has been put in place.

This strip was carefully watched, and in due time the wedges under the centres were slacked a little, and the arch tested with a level for settlement. When it was believed that complete setting had taken place, the centres were struck and the strip of arch was covered with earth to a depth of 18 inches at the crown, on which a railway track was laid. For testing, ordinary lorries carrying a load of 55 (gross) tons were passed slowly to and fro, and at last were permitted to remain on the arch for 48 hours.

The results obtained from this strip of arch were so satisfactory, that the competition of the bridge to a clear width of 40 feet was proceeded with, as per plan, the string courses, parapets and copings, being made entirely of concrete, the external finish being made with cement composittion, and when completed the bridge had theappearance of being built of cut-stone.

This bridge stood for a couple of years, when, owing to a widening of the railway, it had to be removed, and during removal it was found to be *solid* throughout, in fact homegeneous and the expense of removal has been greater than that of its construction.

The foregoing is stated to show that there is not any necessity for building concrete arches in "radiating courses," and that all that is required is to have an ample supply of materials on hand, and that the work, once commenced, shall not cease until it has been finished.

Mr. Armstrong. In discussing Mr. Murphy's very interesting paper, the speaker cannot claim a very extensive experience in concrete work, but used it for part of the foundations of Dorchester Penitentiary which were of somewhat greater depth than usual. In this work the clay was dug out of the trench and replaced first by a layer of cement concrete, dumped in by the tubfull, and then a layer of rough rock of as large a size as could be handled,—levelling up with concrete and some smaller stone,—and so on, adding concrete and rock up to the ordinary level for the foundation walls.

The concrete was made rich in cement and rather thin, so as to work into the spaces between the rock.

For the rest, his experience has been rather experimental and in connection with the manufacture of special forms of building blocks, for which he holds patents, and of which the following is a short description (for those who may be sufficiently interested a full description is presented):—

Concrete being generally the material from which they are made, the object obtained is the greatest economy in quantity and material used, and the most convenient form to handle, transport and erect.

There are two sorts or descriptions of blocks; the one reversely curved or zigzag in horizontal section, so made that they can be laid up, breaking joint, and while they each make a large wall surface, using a small quantity of material, their form gives breadth of base to the wall.

In fact, it is building a corrugated wall on a large scale with rigid blocks that are properly bonded.

These curved blocks, together with part blocks of corresponding shapes, form buttressed as well as straight walls, and walls that can be turned at any angle.

They are specially adapted for building continuous hollow walls.

The second description of blocks are merely slabs variously formed, and built in with the others so that they practically form flanges or webs through and across the corrugations of the wall, and answer as base courses, string-courses and cornices, while they add strength to the wall and provide bracing surfaces for beams, etc., and a special bond when the wall is backed with concrete or rock work.

Door and window casings are made with somewhat similar slabs or with cut stone.

In engineering, these blocks would be chiefly used as a casing or facing to concrete works made of rougher or inferior material, as in retaining walls, dock walls, piers or abutments.

Under water they can be very easily handled whenever a diver can work, and they would take the place of a wooden caisson as well as give a permanent facing, thoroughly backed up and tied into the work, and made under circumstances and of materials to resist all tendencies to decay.

The speaker would like to see a very full discussion of the different materials for concrete best adapted for various uses, and the best modes of mixing, depositing and also of treating the concrete while in process of setting.

With different ends in view he has experimented with different materials as clinkers, gas-coke, broken stone and shingle, mixed with Portland cement mortar, or with also a portion of lime or lime water (viz., water in which quicklime has been emersed).

The kind of concrete which he considers most favorable for general purposes is one made of good Portland cement with clean hard sand (*not too fine*) and shingle of several grades from a size larger than can be called sand to that of about an inch in diameter, excluding everything approaching an inert powder or muck; and then practically adding, as described in Mr. Murphy's paper, large pieces of solid *hard* rock.

He is in favour of the use of shingle rather than broken stone, when both are procurable with equal ease. He claims that the cement clings more strongly to the smooth surface than to the shattered surface of broken rock, that when the materials are properly graded and mixed they will more readily compact, and that the spaces between the pieces of hard material are smaller.

It is a waste of binding as well as of expensive material to have large spaces to be filled with mortar of sand and cement.

The mixture of lime water or kalsomine, as it is sometimes called, improves the concrete, while the lime with which it is made can still be used for plastering.

All cement work should be kept at least damp from the time it begins to set till the crystalization is complete.

Gas-coke makes a light concrete rather slow in hardening thoroughly, but apparently good for some purposes.

Referring to Mr. Murphy's paper, he would suggest the use of facing blocks of concrete of the kind described, or something similar, that could be made and hardened under the most advantageous circumstances, either on the ground or to be transported there, and such that they could be perfectly bound into the body of the work.

He does not quite understand the paragraph when Mr. Murphy says:—

"Since in a perfect Portland cement the admixture of lime and clay with neat cement is stronger than an admixture with sand, it follows that the more cement is employed the stronger and better the concrete." It looks like a slip of the pen, and he does not think the words convey the idea intended, perhaps in more than one way.

1st. The admixture of ordinary lime and clay with cement would not make a very good mortar. 2nd. It would seem to be open to question, whether the neat cement mortar is always stronger than the larger stoney material of the concrete, and Mr. Armstrong is inclined to think, the finer the perfect film of cementing material between two adjacent pieces the better and more economic the concrete. There then would be a limit to the proportion of cement in the concrete.

Though the dividing line may be fine, he would draw it somewhere between mortar and concrete.

Mr. Murphy's paper on the use of concrete as a substitute for masonry is an important contribution. That the value of this process has been so slow of recognition is remarkable, since, as he points out, it is by no means of recent discovery. It was long since shown that monolithic massiveness, rarely to be obtained in quarried stone, was of the first importance in resisting the impact of waves. Over thirty years ago this was demonstrated by the success attending the construction by the French of the celebrated Niole at Algiers, which for centuries had defied the efforts of its previous masters to keep in repair at the cost of millions of money and many lives, and yet we read in the address of the last President of the Institution of Civil Engineers that it is still considered as an experiment, though one the success of which is practically assured. **Mr. Henshaw.**

That cement concrete, or what has long been known under its French name of Béton, can be made fully equal to the best natural stone, has long been the opinion of the speaker. His experience supports all that has been said by Mr. Murphy in its favor, especially as regards the use of Portland cement. In all cases where time can be given, slow setting cement like Portland is the best, because its hardness increases with time, and because slowness of setting gives time for the important process of manipulation upon which its character greatly depends. What is called "heating the set," after the process has begun, means irreparable damage to the part affected, unless by complete removal. These facts are probably the cause of the caution hitherto observed in adopting this mode of construction, for until contractors, who make this process a specialty, become numerous such work can only be satisfactorily done under the eye of the trained engineer with constant supervision.

The speaker must, however, as on a previous occasion, protest against the use of large stones in concrete, and insist on homogeneity as an essential feature for the best results. Leaving out work done under water, which cannot be so treated, he considers that the concrete should always be laid in layers not over a foot thick and thoroughly punned, so that the moisture of the mortar, which should be the minimum, will appear on the surface, thus showing that all interstices are filled. This cannot be done effectually when large stones are introduced. Mr. Boswell in his paper on the Quebec Docks explains that in that work the stones were laid regularly so as to form a sort of rubble masonry, but in the speaker's opinion, the result would be neither concrete, properly speaking, nor good rubble. The joints would be formed of thin layers of concrete, in which the stones would bridge instead of fill cavities in the beds.

Mr. Murphy's plan of setting them vertically is almost as objectionable, for though he gains in being better able to force out cavities he loses in bond. The bond between the large stones and concrete is not so great as in the concrete itself, and fractures by compression or concussion will be guided by the surfaces of these intruded nodules. The speaker does not deny that the actual strength of the work done may be quite sufficient for the purposes intended, but that an equal strength without these stones could be obtained, he fully believes, at no greater cost.

Cheapness appears to be the only reason given for using these stones; but it appears doubtful whether the cost of getting and setting these stones would be materially less than the amount of concrete they represent. In some cases a cellular structure or posts set up in the mass would save more. At any rate the increased strength of the structure surely worth more than a trifling advantage in cheapness.

Mr. Dodwell. It has been said that the man who causes two blades of grass to grow where formerly but one had place is a benefactor of mankind; and if this be true, then is that man equally a benefactor, who at a cost of one dollar can erect a structure equal in stability and permanence to that which formerly required an expenditure of two dollars. The author of the paper now under discussion, while he can hardly be said to have succeeded in reducing the cost of permanent structures to the extent of 50 per cent., is undoubtedly deserving of congratulation for the bold and fearless way in which he has made use of his material. Concrete as a substitute for masonry in the piers and abutments of bridges is, in this country at least, a decided innovation, and one to which Mr. Dodwell is inclined to attach considerably more importance than it has hitherto received. Here in America, English engineers are apt to be regarded as conservative in their practice, but in some points Canadian and American engineers are quite as much so. The use of concrete is a case in point; for while in Great Britain this material is used to an enormous extent for every imaginable purpose, in this country its use has hitherto been restricted almost exclusively to foundations.

If every member of this Society were to be asked the question,—"Why is not concrete more extensively used in this county as a substitute for masonry?" Nine replies in ten would probably give two reasons. Firstly, because of its inability to withstand the effects of intense frost, and secondly on account of its excessive cost. The tenth man would perhaps with greater candor reply : "Because I never tried "it and do not know anything about it. I have no precedent to go upon, "and would be afraid to make the experiment." Now, with regard to the effect of the Canadian climate on concrete in exposed places above ground, we have, so far as Mr. Dodwell is aware, no instance of failure either from the intense cold of winter followed by the thaw and freeze and freeze and thaw of early spring, or from the excessive dry heat of midsummer. On the contrary there are evidences before us that properly made Portland cement concrete is entirely unaffected by either extreme of temperature. Mr. St. G. Boswell, M. Can. Soc. C.E., in his paper on the Quebec Harbour Works, recently read before the Society, says as follows: "In the year 1879, blocks of concrete, each "6 inches square, composed of different proportions of cement, sand and "pebbles, were made for experimental purposes in connection with the "tests of Portland cement to be used on the Quebec Harbour Works. "These blocks have remained out in the open air since then, and are "now, after eight years' exposure to all kinds of weather, in as good "condition as when made, the frost not having injured them in the "slightest degree. Concrete walls constructed in connection with the "Harbour Works, and left exposed to the weather for five years, re"ceived no injury." Now, although these instances cannot perhaps be regarded as positive proof that concrete would remain wholly unaffected by climatic influences for any indefinite period of years, they are certainly sufficient to refute the very prevalent idea that when unprotected by a facing of masonry it would undergo rapid disintegration.

The climate of Nova Scotia, although not characterized by quite such a wide range of temperature as that of the upper provinces, is more severe in its effects on masonry and concrete, owing to the more rapid and frequent changes in meteorological conditions. If, therefore, walls and piers of concrete can there successfully defy the elements, there can be no question but that the material would do so at least as well in any other part of Canada. The author says he has been building piers and abutments of concrete for the past five years, and that out of a total number of forty-four bridges built in this manner he has not a single instance of failure from the effects of climate. The only failure of importance that he records—that of the piers of the Petite Rivière bridge in Lunenberg Co.—is to be attributed to the effect of the salt water on the cement, and not in any degree either to temperature or climate. That salt water has a prejudicial effect on concrete, or at least on concrete made with certain cements, there seems reason to fear. It is a great pity that Mr. Murphy did not preserve samples of the cement with a record of its brand that he used in these piers, for then he would probably have been able to throw some light on the question as to what peculiar properties in cement are to be attributed its liability to disintegration after prolonged immersion in sea water. That such liability exists under certain conditions is evidenced by the damage recently found to have been caused to the concrete entrance walls to the graving dock at the Aberdeen Harbour Works. These works were completed and opened in July, 1885. They were constructed to a large extent of concrete, some of the exposed faces being protected by granite masonry, and others merely by a thin coating or skin of a richer composition of concrete. Early last year the wall forming the entrance to the dry dock was found to be crumbling and softening under the action of the salt water to such an extent as to render necessary immediate and costly repairs. In July and August last, a thorough examination of the whole dock, and of the methods and materials employed in its construction was made by Mr. P. J. Messent, M.Inst.C.E., of the Tyne Harbour Works. Mr. Dodwell is indebted to Mr. Kennedy, M. Can. Soc. C.E., for bringing to his notice two most instructive articles on this subject in recent numbers of "Engineering." (Nos. 1129 and 1152.)

An important feature of the investigation consisted of an exhaustive series of chemical analyses of samples of the concrete, both from the disintegrated portions of the wall and also from the uninjured parts.

Without going further into the details of the investigation, it will suffice to say that it showed first that the concrete had been made of too porous a composition, and that the outer skin or facing of richer concrete was too thin to provide against fracture and abrasion, it being merely a rendering of a composition of one of sand and one of cement only one inch in thickness. The net result of the whole examination is pretty well summed up in the following sentence: "I am of opinion" (Mr. Messent says) "that the cause of the damage to the dock is the "injurious effect of sea water, which entered through the holes in the "plaster at four points, percolated the concrete of the intermediate "portion of the wing-walls and of the mass behind the altars of the "dock walls, and in so percolating extracted lime from, and deposited "magnesia in, the cement portion of the concrete, causing it to dete-"riorate and expand, and that the injurious percolation was facilitated "by the inappropriate relative proportion of the cement, sand and "stones, or the insufficient quantity of cement in the original composi-"tion of the deteriorated concrete."

The lessons to be drawn from these works and Mr. Messent's able report upon them are too obvious to require enlarging upon here. Portland cement concrete has in many instances successfully resisted the action of salt water for many years, and nothing in the Aberdeen experiments or experience has proved anything to the contrary.

Now as regards the second objection to the substitution of concrete for masonry, namely, its alleged excessive cost, Mr. Dodwell is convinced that a fair trial under fairly favorable conditions, and with experienced and intelligent supervision, would immediately establish its economic value in a score of applications, in which, in this part of the country, it has never been tried. On the Canadian Pacific Railway, so far as Mr. Dodwell is aware, concrete has only been used in foundations, and in these instances the price paid for it has included and covered so much risk and so many other expenses connected with foundation work—such as caissons or coffer-dams, pumping, the use of divers, etc.,—that a largely fictitious idea of its actual cost has become prevalent. In the Lachine bridge the concrete was paid for at the same price as the masonry, which price included all expenses and all risks in connection with sinking foundations under extraordinarily difficult conditions. Similarly, at the Ste. Anne and Vaudreuil bridges, concrete and masonry were at the same price, all incidental expenses being included. Mr. Murphy has most unfortunately omitted from his otherwise valuable paper all information regarding the cost of his concrete piers, and in looking for evidence of its economic value, for the purposes to which he has put it, we can only fall back on the very legitimate assumption that he would not have used it so freely had he not been perfectly satisfied that he was getting the worth of the public money. There is one sentence in the paper however, that bears on the question of cost, and from this we can fairly infer that he got his concrete built for *less* than eight or nine dollars per cubic yard. How much less must remain an unknown quantity pending more detailed information from Mr. Murphy. When suitable clean and coarse gravel cannot be had, and stone has to be specially broken by hammer, concrete would cost probably seven to eight dollars per yard, which price should of course include moulds. Where good gravel can be obtained near the site of the work, and in cases where the moulds, centres and laggings, etc., are not of an unusually complicated and expensive character, good Portland cement concrete should be built for five to six dollars per yard, and in some instances for even less. This latter figure is considerably less than the cost of any but the roughest kind of masonry. It is about the average price paid for rough, dry rubble, a class of masonry entirely inadequate for many of the purposes to which concrete is eminently adapted, and quite unsuited for such structures as Mr. Murphy has been building all over Nova Scotia.

Mr. Dodwell happened to be in Halifax for a few days in March of last year, and while there he had a conversation with Mr. Murphy on the subject of his paper. He was quite enthusiastic about his bridges, and confident that in their construction of concrete instead of masonry he had effected a saving to the Province of many thousands of dollars. Mr. Dodwell saw the concrete retaining wall on the north side of the Provincial building, and so far as one could judge by appearance it was equal to the very best masonry. The surface was like a finely dressed, close-grained, dark-colored freestone, without cracks, joints or anything to mar the smooth monolithic character of the wall.

Mr. Murphy Every engineer must be guided by the particular materials or mode of construction, by the locality, the facility for obtaining suitable materials and the purposes which the work was intended to serve. When stone of a suitable nature for building can be had we still prefer it; but where it cannot be acquired within reasonable limits and at moderate rates we may be justified in copying nature in rock-making and substituting manufactured monoliths in its stead. Concretes differ in quality according to the care bestowed in the selection of the materials used and the methods by which they are compounded, and, as has been ruly remarked, until it becomes a specialty, such work can only be satisfactorily done under the eye of the trained engineer. The subject has been dealt with in a fair and comprehensive manner. There are however, a few observations that require notice, to which reference will be made.

Mr. Macdougall's experience in this country—that a fast setting cement finds most favor, that in the sewer work in Toronto such is the case, and that he has noticed it in reference to other engineers' works—is a new theory. It is not the opinion of Mr. Henshaw, who very forcibly expresses opposite views, nor is it the opinion of many Canadian Engineers with whom the author, through a term of twenty years' practice in this country, has come into contact. It is against the expressed views of English engineers and cement manufacturers who have brought Portland cement into prominence, such as Messrs. G. F. White, C. L. Francis, Carleton Baynes, and Sir J. W. Bazalgette. It is an important point in the selection of cement, and should not be lightly passed over on account of the teaching which it would be likely to engender The quicker setting Medina, Roman and other natural cements have been superseded by the slow setting Portland or artificial cement, and the quality of Portland cement may be fairly ascertained by its slow setting. The heavy cement is obtained by hard burning, and there can be no doubt that heavy cements set very slowly. Mr. Reid's treatise on concrete is the text book of to-day, it is careful and concise. Mr. Reid says:—"It is advisable to remember that according to the density of Portland cement, is its property of setting reduced or increased. A cement weighing 100 lbs. per bushel may be regarded as quick setting, and its plasticity will have disappeared in about half an hour. Cement of about 120 lbs. per bushel has its set prolonged, and probably six or eight hours will elapse before the indurating process begins," see p.p. 77-78, and again at p.p. 59-60 he says:—"Quick setting cement cannot be expected to reach the prescribed strength in twenty-eight days, nor, with some qualities of inferior cement, would such a breaking ever be realized. The primary object of the excellent system of testing is to encourage the manufacture of high class heavy cements, to the exclusion of inferior quick setting qualities." The results of tests given from samples of, natural cements from Dover's Court and Niagara are below any ordinary standard. These tests, however, leave some important points unsettled as, for instance, the age at which the cement ceases to increase in strength.

The remarks that iron cylinders filled with cement should be employed only for caissons, and that the columns of the first Tay bridge that were filled with concrete cracked, and had to be hooped with iron, are no less misleading if not further explained. The columns referred to were, according to the Minutes of the evidence from proceedings of investigation of Board of Trade, of cast iron, 18 inches in diameter. The castings were proven to be scabby and inferior. The concrete or cement was placed within them merely to prevent corrosion There were three broken pillars of this class reported by Mr. Noble, Inspector to Sir Thomas Bouch. They were hooped with iron and remained so when the structure toppled over. No one ever alleged that they had anything to do with the disaster. Mr. Noble thought they were cracked by vibration from the train brakes having been applied above them. Sir Thomas Bouch said it was from contraction of the iron on the cement, and quoted Mr. Brunlee's bridge across the Solway, as a similar example, which he should not have done, as the columns of the Solway bridge were entirely dissimilar. The latter was built upon cast iron hollow piles driven by a pile hammer. The piles were only twelve inches in diameter, the shell being $\frac{7}{8}$ inch thick. Major Marindin reported to the Board of Trade that some of these piles cracked from the freezing of the water within them, others by ice floes impinging against them. Sir Thomas Bouch also said that he knew of bridges built on columns by the late Mr. Brunel and others, that had also cracked, but inquiry reveals that he was mistaken or misinformed. There are examples of bridges in Europe at least thirty years old, supported by cylinders filled with concrete giving desirable results, and the practice is seemingly growing into general favor with time. Athlone bridge by Hemans, Ouse bridge by Harrison, Czernowitz by Heavyside, Copenhagen bridge by Burmeister, Hull and Charing Cross bridges by Hawkshaw, Peterborough by Fowler: these are quoted as modern examples, and are selected out of many to shew the extent of range in climate and in practice. There is no report of failure in any of them, so far as can be traced by the author. There is a bridge of the same class in Nova Scotia, on the Sydney and Louisbourg Railway over the Mira River, which was erected about sixteen years ago. There are no cracks visible in the columns, although the river is frozen around them for an average of four months in the year.

Mr. Henshaw's remarks are theoretically correct, and generally of practical application. His protests, however, against the use of large stones being placed within the concrete body, and his persistence that because homogeneity is an essential feature to obtain the best results, that they should not be employed, will not prevent their application as an inexpensive and desirable component. The assumption that the bond between the large stones and the concrete is not so great as in the concrete itself is not a convincing one. Although tests by compression on small concrete columns give varying results, according to the kind of stone and other materials used, it is not difficult to observe that the planes of cleavage are in the concrete itself, and that the results, contrasted with similar tests on similar kinds of stone broken to the size of macadam, are not at all so much in favor of the smaller intermixture as would warrant the exclusion of large stones. Examples of this kind, but in another form, are experienced, when a rubble masonry wall, which has been built in cement mortar, is being removed. The force employed to displace the stones, no matter how applied, will not loosen them between the surface of the stone and the mortar. Quite a film of mortar will invariably remain attached to the stone. If the stone is of less strength than the mortar, as in "free stone," fractures will first take place in the stone itself; if tougher or less yielding it will take place in the mortar, but will seldom yield or shew fracture between the stone and the mortar. Mr. Armstrong notices this fact, as will everyone that will experiment as he has done. He favors the use of large pieces of solid hard rock, and claims that the cement clings more strongly to the smooth surface than to the shattered surface of broken rock. The desirability of the employment of large stone in an economical sense will be determined by the supply available. In Nova Scotia they too frequently encumber the ground; Nova Scotia is rich in rocks, it keeps a supply at Windsor Junction. When Mr. Henshaw says that it appears doubtful whether the cost of these stones would be materially less than the amount of concrete they represent, he undervalues the resources of Nova Scotia. Their adoption lessens the price of concrete more than forty per cent. Ten four-hundred pound barrels of Portland cement will, on an average, build from eight to nine cubic yards of concrete, and all the intervening intermixture of concrete will be rich in cement. Take the homogeneous plan of Mr. Henshaw, he cannot build half the bulk with the same relative degree of richness. If you adopt his plan and build nine cubic yards with the same quantity of cement, you would have a structure that would be likely to tumble to pieces under the same load that Mr. Armstrong's plan would bear with safety, so that cheapness is not alone the only reason for using these stones.

Mr. Perley's method of constructing concrete arches, by having an ample supply of materials on hand, and continuing the work to completion without intermission, would, no doubt, be attended with desirable results. If the rate of progress was insufficient to ensure such completion, the method adopted in Nova Scotia of building in courses radiating the same as dressed stone in courses, might be equally well made use of. In either case the weight on centres should be relieved by first continuing a strip of arch across the crown midway between spandril walls. These details will, however, suggest themselves to the skilful builder as the work proceeds.

Mr. Armstrong's experiments are interesting. That all concrete work should be kept damp from the time it begins to set until crystalization is completed is quite obvious. When moulding concrete flags for a sidewalk, such a course was suggested to the author by a practical builder. The mixture was kept damp by sprinkling from a watering pot through a finely perforated nozzle. A decided improvement in the strength and tenacity of the slabs was quite apparent. It should be remarked that the work was being done in sultry weather. The intermixture referred to, such as clinkers, gas cake, broken stones and shingle with Portland cement mortar, is precisely the same as first experimented upon by M. Coignet in France. At the commencement he employed a crude mixture of coal cinder with lime, and subsequently he substituted sand for the former ingredient and mixed with powdered lime, moistening both together instead of wetting the lime, as he had first done. The beton Coignet which bears his name is a mixture of a large proportion of sand with a small proportion of lime, to which is added a percentage of cement. The mass is reduced in a grinding mill to a stiff paste, and is introduced into moulds and subjected to the action of repeated and heavy blows from a hammer. By this means it is thoroughly agglomerated, and the mould being almost immediately removed, the beton shaped to the desired figure almost immediately becomes set and acquires the hardness of stone.

The paragraph that Mr. Armstrong refers to should read: "Since in a perfect Portland cement, with the proper admixture of lime and clay, neat cement is stronger than an admixture of cement with sand, it follows the more cement is employed the stronger and better the concrete." The admixture of lime and clay refers to the true proportion for calcination in the manufacture of the cement, whilst the latter part of the sentence refers to the strength after the induration is completed.

The employment of concrete *en masse* within bottomless caissons for the St. Lawrence bridge foundations,* and its subsequent use by Mr. Dodwell, in like manner, in the foundations of the Canadian Pacific Railway bridges over the Ottawa river at Ste. Anne and Vaudreuil, may be quoted as among its numerous and novel adaptations of comparatively recent origin. The foundation is first dredged. The bottomless caisson is floated and sunk in position, concrete is next placed within it for one-third of the depth of water and allowed to remain until set, when the water may be pumped out and the masonry commenced on the solid artificial substratum below. What operation can be more simple, practical and inexpensive? It is the science of our daily experience. To the young engineer it is a simple and practical process; to the older and more experienced, he may well say, "how is it? I have been pumping and paddling in foundations for years and have not seen it." If we cannot all contribute to the experiments by which these ascertained facts, these results, are reached, we may follow their reasoning and accept them on the authority by which they are established. Mr. Dodwell's tenth man, although having no precedent of his own to go upon, may accept the results on the authority of the universal voice. Concrete in various other forms of application is fast superseding masonry. The difficulties surrounding the use and control of skilled labor urges its adoption. That there are varied and extensive uses in store for it is generally recognized.

For the past two years the failure of the concrete sea walls of Aberdeen graving dock has been of world-wide notoriety. Extracts from reports of Mr. Smith, Professor Brazier and Mr. Messent, descriptive of the manner in which the cement was used, the specification to which it was supplied, and the argument on which the theory was based, viz., that magnesia precipitated from the sea water enters into and becomes a compound part of the cement thus destroying it, have been too widely circulated. The result of a large number of experiments, comparing the

* Vide Mr. Massy's paper (No. 3), Vol. 1, Trans, Can. Soc. C.E.

behaviour of cement when gauged in sea water and when gauged in fresh water, shows that sea water has no deleterious chemical action on a sound and properly used Portland cement, and that the failure at Aberdeen must be attributed to some other cause, either to an inherently bad cement having been used, or to an injudicious use of it in a plastic form. The concrete at Aberdeen was used in what is called a "plastic" form, *i.e.*, it was allowed to partially set and was then broken up and placed in position. Mr. Dodwell quotes an extract from Mr. Messent's report, attributing the failure to the injurious effects of sea water and the insufficient quantity of cement in the original composition of the concrete. In a paper read before the Society of Engineers at Westminster Town Hall, on the effect of sea water on Portland cement, by Mr. Henry Faija, M. Inst. C.E., on the 5th ultimo, the paper referred to certain conrete work at Aberdeen graving dock, and to several published reports, ascribing the failure to the chemical action of the sea water on the cement. After pointing out that Portland cement has been used in marine works for forty years, and that until now any failures that may have occurred have never been traced or ascribed to the chemical action of the sea on the cement, the author gave a general description of the work carried out at Aberdeen. The specification and the analysis of the cement used at Aberdeen were considered, and it was pointed out that although such a specification was not antagonistic to the production of a good cement, there was nothing in it which ensured a good and sound cement being delivered. The author was of opinion that, given that a cement is well ground and is proved sound, it will in nearly all cases be strong enough for any purpose for which it is likely to be used. That lurking dangers from faulty construction and from faulty cement also contribute to disastrous results such as Mr. Dodwell points out, is quite certain, and that such failures are too often attributed to the Portland cement alone is no less convincing.

With respect to the cost of rubble concrete, such as has been employed in Nova Scotia, it can be erected in abutments and piers in the manner described in the paper for from five and a half to six dollars per cubic yard *en bloc*. It can be let by contract for somewhat less.

From the drawings accompanying this Paper Plate III has been prepared.

8th March, 1888.

H. WALLIS, Member of Council, in the Chair.

RAILWAY ACCIDENTS AND A RAILWAY COMMISSION.

By A. T. Drummond, A.Can.Soc.C.E.

Railways are now such important factors in the convenience and prosperity of every community, that whatever improvements will tend to diminish the danger of loss of life upon them must be of public interest. Whether every railway accident is preventable is open to question, for after all the improvements with which human device has aided railway construction and equipment, and after all the care and foresight which able men have exercised on the best constructed roads, accidents, unaccountable, will happen to both passengers and employees. And yet, seldom a month passes, but some other appalling catastrophe, proved to be due to oversight or negligence on the part of the employees, or to defects in the roadway or the rolling stock, convinces us of the absolute necessity on every railway of stringent management, careful inspection, and proper material and workmanship. During the past year, accidents both in the United States and Canada, leading to heavy loss of life, have once more forcibly drawn public attention to the subject, and in the United States, railway commissions have been recommending and legislatures have been enacting, more stringent laws with a view to, if possible, prevent such terrible fatalities in the future.

The vast extension of the railway system in the United States has led there to greater inquiry into the condition of railways, to more systematic oversight, and, at least in the older States, to more legislation regarding railway construction and railway management than exist in Canada. Permanent railway commissions have been appointed in twenty-one of the States, including each of the Northern States, excepting Indiana and Vermont. Some of these commissions are the result of relatively recent legislation, but others have been in operation for many years. The effect of these appointments has been that closer attention is now paid to the wants of the public in the service of the trains, in the establishment of rates, and in the safety of the roadway, bridges and rolling stock; minute details are furnished of the equipment and the operating of each railway system; and every serious accident occurring within the borders of several of these States is closely investigated to ascertain its cause with a view to prevention in the future.

In Canada, however, with a contentment that is remarkable, we stand still. The experience gained by our neighbors is unheeded by us. The knowledge, that the same causes which have led to disasters on the railways in the United States exist equally in Canada, is overlooked. Catastrophes occur again and again, but fail to awaken us to such a sense of responsibility as would demand, under legislative enactment, that every precaution within reason, which science and skill can afford, shall be taken by the railways to protect the lives of their passengers and their employees. It is open to question whether in every case legislation, which would lay down hard and fast rules for the railways to observe, would be the best course; but it is obvious that the time has come when this whole subject must be discussed with a view to some action upon it. A railway is now rather to be regarded as a great factor in the public convenience and in the national prosperity, than as a means through which private individuals may be enriched. It ought therefore to be largely subservient to the public interests—certainly in the respect that the safety of its own employees and of travellers by it should be first thought of. And yet, it is to the interest of every railway company to avoid disasters. Every person familiar with railway management is aware that it is to the manager himself that disasters on his road must strike home with the most startling import, and that no one should be more earnestly desirous of avoiding them. Apart from the injury and loss of life they often occasion, and the heavy consequent claims for injury which arise, they also mean immense damage to the rolling stock and to the track, loss of revenue this rolling stock would earn, and loss of prestige, for the public is generally ready to lay the blame of disasters on the condition of the road or its equipment, or on the lack of improvements which the management ought to have adopted. It is only fair to the management of many roads—and they probably include our leading Canadian roads—to say that they are only waiting to adopt the most effective improvements so soon as these have undergone a fair test to establish their qualities. Let them not, however, wait for impossible ideals. With other railways it is a matter of expense, and much as the manager would like to adopt every improvement, he has to follow the instructions of his superiors with whom economical construction, equipment and operating are considerations of importance. There are, again, still other roads to which it would appear necessary to apply some sharp goad to compel them to adopt progressive ideas, and which seem to rest in the hope that a kindly Providence will in their case continue to avert disasters.

The records of accidents on railways, whilst they, on the one hand, show how safe travelling is now, compared with fifty years ago, are not pleasant chapters to read, and must convince every one that much requires yet to be done to render travelling as safe as it can be made. It may be said that not a few of these accidents arise from the culpable carelessness of the parties injured, but this makes it all the more necessary that laws should be made to, if possible, protect men even against their own carelessness.

The statistics of railway accidents in Canada, after making all allowances which may be claimed, appear not to be as favorable to our railways as they might be. Under any view which may be taken, they convince us that much can yet be done for the safety of the railway employees as well as of travellers. The two years selected for illustrating, as far as the official returns will admit, the passenger traffic and accidents in Canada and some of the leading states of the Union, are given, not merely because the statistics are the most recently published, but because they may be taken as representing results under the favorable circumstances of the newest regulations and the most recent appliances adopted by the railways to secure safety. The selection is not unfair to Canada, as the returns of these two years here compare very favorably with the average of the last ten years, though the poverty of the passenger traffic suggests either some error or a remarkable domesticity among the Canadian people. The particular States selected have been chosen at random, with this qualification, that in each of these states there has been a railway commission at work for some years. In all such railway statistics, however, the grave defect which detracts from their value for the purposes of comparison, is the lack, in the different States, of a uniform system of collecting these statistics.

Year.	State or Country.	Passengers carried. (*with reserve.*)	Killed or injured.	
			Passengers.	Employees and others.
1885	Massachusetts ...	69,603,700*	74†	443†
1886	do ...	75,842,581*	107†	476†
1885	Connecticut......	17,430,921*	12†	222†
1886	do	19,011,381*	42†	297†
1885	New York.......	73,555,179*	112	1435
1886	do	81,463,709*	125†	1516†
1885	Ohio..............	32,895,641*	78	1061
1886	do	31,781,707*	49†	911†
1885	Illinois	20,593,478†	145†	1318†
1886	do	22,727,934	64†	1254†
1884	Michigan	24,782,322*	36†	459†
1885	do	22,970,564*	36†	403†
1885	Canada	9,672,599	84	757
1886	do	9,861,024	79	636

* Includes the total returns of the entire lines of the through railways.

† Includes only returns properly referable to the particular state.

Whilst the railway accidents in Canada seem to be numerous, it would be hardly fair to form even general comparisons from the above statistics. It is, in fact, most difficult to arrive at any fair comparison between the results of railway travelling in Canada and those in the United States. The general returns covering the whole United States are not all official, and are not all collected under the same system and with the same attention to correctness and detail which in several of the Northern States characterise the official returns. On the other hand, these official returns are at times equally unserviceable to the statistician, because the great through lines appear sometimes to return to each State the total passengers or total accidents, instead of confining the numbers to those referable to the particular State to which the returns are made. Comparisons are thus without any exact value. Again, in Canada, the passenger mileage is not given in official reports. In the State official reports, it is not unusual to find the safety of railway travelling judged in a general way by the proportion which the passenger accidents bear to the whole number of passengers carried. For reasons already given, this sometimes might lead to an exaggeration. The passenger mileage, on the other hand, has been thought by many to afford a more correct basis, because it admits more particularly of suburban travel being considered. Suburban travel, however, arises from enlarging cities and a more dense population surrounding them, and has associated with it increased elements of danger in more frequent and more crowded trains on the same tracks and at the hours when the ordinary passenger traffic is greatest, more crowded platforms, more level crossings and greater proportionate traffic across them, more employees and more trespassers on the tracks. If in the carrying of suburban passengers safely, employees or others are killed or injured, another element of importance has to be considered by those who would guage safety simply by the passenger mileage. To illustrate this, the Michigan Central Railway operates 1514 miles of road, of which only 49 are in Illinois. Now, while the total accidents on the whole line for 1885 and 1886 averaged 149, those for Illinois alone averaged 27.

The statistics of the Canadian railways do not give the number of employees, and it is impossible to institute any comparison between the number killed or injured and the whole number employed. Apart from this, however, the returns of accidents to employees do not appear favorable on the Canadian railways, nor, further, do the similar returns from the railways in the above States of the Union. It may be urged that many of the accidents on the Canadian roads arise from trespassers walking on the track, etc., but on some American railways a larger proportion of accidents is due to this cause. And the life of an employee is as valuable as that of a passenger.

The analysis of the causes of accidents in Canada is not so full as it might be in the government returns, but fo· the two years 1885-6, the following results appear:

	1885.		1886.	
Falling from engines or cars,	125	(8 being passengers)	75	(8 being passengers)
Jumping on or off trains,	64	(24 do)	65	(16 do
Making up trains,	20		10	
Putting head or arms out of windows,	3		1	
Coupling cars,	285		222	
Collisions or derailment,	97		89	
Trespassers on track,	153		135	
Striking overhead bridges,	10		8	
Explosions,	2		0	
Other causes,	82		110	(98 being employees)
	841		715	

In the case of a large number of accidents on their lines, railway companies are in no wise responsible. Many arise simply from the existence of the railway and the carelessness of the injured. Whilst however it may be impossible to prevent every accident, a humanity common to us all impels us to agree with the Massachusetts commissioners in their more than once expressed conviction that a preventable accident is a crime, and forces us to feel that every known precaution and every admittedly successful remedy with which railway men are familiar should be imperatively adopted in the endeavour to lessen this loss of life and this injury to passengers and employees.

The subject naturally leads to a consideration of certain safeguards, which the experience of railway commissions and of some of the leading American railways has suggested as necessary on every properly equipped road, and which have equally commended themselves to some Canadian engineers and railway officials as improvements still imperatively needing introduction on some Canadian railways. To the unprofessional public they will all appear as of the first importance. In some of the Northern States, certain of these safeguards have, in either an absolute or qualified way, been made the subjects of legislative enactment, and there seems no reason why, in Canada, some of them, regarding whose importance there is no division of opinion, might not equally be given the force of parliamentary sanction. But why will not railways view improvements from a business point? A derailment on a bridge unprotected by guards, or the burning of a train furnished with stoves, may occasion such injury and loss of life, that the claims made and the damage done to the line and equipment would ten times over pay for the improvements, which would have averted the disaster, as well as for many such improvements over the whole line.

BRIDGES AND EMBANKMENTS.

GUARD RAILS.—On all embankments exceeding a certain height, and on all bridges and viaducts, there should be on the outer side of each rail of the main line, guard rails or guard timbers, faced with angle iron, and securely bolted to the ties underneath, and these guard rails or guard timbers should be continued for a short distance on each side of the bridge, viaduct, or embankment. The object of the guard rails is to prevent the cars from entirely leaving the track at these dangerous points.

Between the main line rails on all bridges and embankments, and the approaches thereto, there should be guard rails, forming a somewhat curved V, so securely placed as to guide the wheels, when off the track, back to the main line.

Every bridge should have a floor system strong enough to support a derailed locomotive or car in motion.

Under the Connecticut laws of 1878, the commissioners were empowered to order guard rails to be placed on the bridges and trestles.

In 1881, the Massachusetts commissioners accompanied a circular on the subject, with two sheets of illustrations of various improved forms of track construction in actual use on bridges in that State and elsewhere. Among these, the Sabula bridge on the Chicago, Milwaukee and St. Paul Railway, affords the best illustration of an earnest endeavour to secure safety by an efficient flooring. Not only are there guards faced with angle iron on both sides of each steel rail, with a flooring of $\frac{3}{8}$" plate iron between, upon which derailed wheels can run, but outside of all on each side of the bridge and near the trusses are, securely bolted down, 10" square longitudinal stringers as a further protection. On the approaches to the bridges, the commissioners suggest not only the curved V rail between the main line rails, but, instead of guard timbers, outside guard rails which gradually flare out beyond the ends of the bridge to a width of 12 feet.

The Dedham disaster revealed the fact that the bridge there had no suitable guard rails, that the floor system was not sufficient, and that the bridge had not even been tested.

On very high embankments, these guard rails are of almost as great necessity as on bridges and their approaches, so considerable would be the fall in the event of complete derailment of a train.

Guard rails are often neglected on our Canadian roads, and when they are present, are not usually faced with angle iron. Probably on no Canadian lines are plate iron floorings found between the rails, and yet, in the event of derailment, it is not difficult to see the great importance of such floorings placed over closely laid ties, in conjunction with the V shaped guards between the main rails. The Latimer bridge guard, which really comprises steel rail guards placed in this V shape, with a gradually rising floor piece on either side of each rail of the main line, is directly known to have saved terrible loss of life and property in February, 1885, on the New York, Pennsylvania and Ohio Railway, at the Lyon Brook iron viaduct, which is 165 feet high and 800 feet long. Here an express train, running at thirty miles per hour, was brought back to and kept on the track, notwithstanding a broken tire and derailed truck of the engine. The Ohio commissioners report most favorably on the Latimer guard.

Bridge inspection.—There should be frequent, periodical, careful inspections of all bridges, whether of iron or wood, by competent officials, and unless pronounced safe, no trains should be allowed to cross at a high speed.

There is an absolute necessity that all bridges constructed years ago, when railways had lighter engines and cars, and each car carried a smaller load than now, should be reconstructed, with a view to increasing the strength to the new requirements. Particularly is this the case with those short roads, which the exigencies of competition and consolidation have transformed into parts of great through lines between great commercial centres, and which have in consequence become burdened with heavy traffic. It is, in such cases, equally a necessity that the track should be renewed with heavier steel rails. The engines and the loads carried on each freight car are now often double what they formerly were.

The New York commissioners have gone further than others in the inspection of bridges and trestles. They correctly assume that bridge foremen—however otherwise competent—have not the technical education which enables them to properly inspect bridges. They have, therefore, insisted not only on inspection by themselves or their representatives, but on drawings being furnished of all truss railroad bridges in the

State, showing their construction and dimensions and the floor system adopted. These drawings are required to be accompanied by a strain sheet showing the strain on each member produced by the maximum moving load allowed on the bridge. These strain sheets are carefully gone over by the commissioners. It has been observed by them that rolling loads from cars alone sometimes reach 3600 lbs. per running foot.

After the terrible Dedham disaster, last winter, it was ascertained that the bridge had year after year been examined by the same man, who was a mere machinist.

OVERHEAD BRIDGES.—Every bridge forming part of the line of the railway, every bridge crossing the track, and the roof of every tunnel and snowshed, should be so constructed that at least seven feet should intervene between the roof of the highest freight car and the lowest point of the bridge over head or the roof of the tunnel or snowshed. This precaution is in the interest of brakemen on freight trains, many of whom when on duty have been killed by their heads striking against the bridge timbers above them. The Dominion Railway Act, provides for this height above the car, but accompanies the provision by a saving clause, which practically prevents it from operating, except on the newer roads. If all freight cars were provided with power brakes, controlled by the engine driver, there would be less necessity for brakemen being on the roofs of cars and less necessity therefore for this provision.

The Ohio commissioners appear to aim at having the lowest point of the roof at least 18 feet above the track. The Connecticut commissioners were given power to require every railway to erect and maintain suitable warning signals, at every bridge less than 18 feet above the track, whilst the New York Act of 1884, made the placing of these warning signals directly imperative on every railway. Warning signals are however unsatisfactory, because liable to go out of order. Suspended cords not only rot and fall off, but in the event of a gale blowing in the same direction with the moving train, might never be noticed by the brakeman. The correct principle is to have the lowest point of the roof sufficiently high above the cars to admit of a man moving freely on the top of the cars.

FREIGHT CARS.

POWER BRAKES ON FREIGHT CARS.—Freight cars should be furnished with automatic power brakes. This would be a great boon to the trainmen, besides being more effective and economical than the present system. The brakeman on freight trains has a very hazardous occupation, more particularly during the winter season, when with the train in motion and the cars swaying from side to side, he has frequently, in the course of his duty, to run from car to car along their often slippery roofs. The numerous deaths and injuries annually arising from brakemen falling from the cars, could be largely avoided by the use of power brakes, whilst economy would result from the employment of fewer men. Power brakes are in use in the United States, on the Pacific roads, the Denver and Rio Grande, the Pittsburg, Cincinnati and St. Louis, the Chicago, Burlington and Quincy, and the Atchison, Topeka and Santa Fe railways. The difficulty may be urged as in the case of couplers, that on through lines they cannot be brought into use unless adopted by all connecting lines as well, but surely railway men, if united in opinion as to the value of power brakes, can overcome this difficulty when economy of service is the result, unless they are waiting for impossible ideals in these brakes.

Railings.—The New York commissioners suggest that a low railing should be placed on the roof along the centre, lengthwise of the freight car, so that in the event of slipping, the brakeman could seize it, and probably save his life. As an additional safeguard, the central boards covering the apex of the car roof, should be extended somewhat beyond the ends of the car, so that with the similar extension on the next car, a bridge would be formed, and the brakeman spared the risk of a dangerous leap when running from car to car.

Couplers.—Automatic couplers which will not need to be guided by the hand into position, which will not require the brakeman to go between the cars and which will readily adjust themselves to other couplers, especially the old link coupler, should be adopted on all freight cars. The fact that in Canada nearly one-third of the whole casualties to passengers, employees and others on railways, arise from the coupling of cars, proves how pressingly some remedy is required. In Massachusetts, it has been an increasing cause from year to year, until, in 1886, the causalities arising from it, were four times the number of ten years before. In Michigan, during the same year, the proportion of causalities ascribable to it, was between one-third and one-fourth of the whole. In other States the proportion was equally large.

In dealing with the question, the difficulty at once arises that unless all roads adopt either the same or an adjustable coupler which will suit any other coupler, the liability to the constant recurrence of casualties will continue. The railway commissioners of several States have given great attention to the subject, and, after careful trials, several automatic couplers embodying the above stated requirements have been selected by, among others, the commissioners of Michigan and Massachusetts. The selection includes the Janney, Hilliard, Cowell, United States, Ames, Aikman, Perry and Marks couplers, and was made in view of the law passed by the legislatures of these States, requiring under a penalty the adoption of automatic couplers after a given date, on all new freight cars or cars under repair. Connecticut and New York State have passed similar laws, and the commissioners of the latter state have given the matter much thought. Whilst through the legislatures of leading States, taking up the matter in this way, other legislatures will undoubtedly soon follow, still some of the Railroad Commissioners are convinced that being also an interstate matter, Congress should take it up as well.

If the good points of several of the vast number of patented couplers could be combined in one, a perfect coupler might be had, but this could only be accomplished by purchasing the different patents. In the meantime, should these great casualties be allowed to continue because railways in their search for an ideal, practically impossible to obtain, ignore or cannot agree on the merits of several praiseworthy, well-tested couplers? Why should not railway managers confer and come to some conclusion on this pressing matter? Is not this also a fair subject for the Dominion Legislature to consider and act upon?

The Master Car Builders' Association in the United States has more recently selected the Janney and those which couple with it, and it is to be hoped that where this association has influence good may result.

PASSENGER CARS.

Tools.—Each passenger car should be provided with, at least, axes, securely placed at either end of the car within glass casings. When cars are over-turned, it is generally most difficult to find appliances with which to get the imprisoned passengers quickly out. The glass casings prevent theft of the tools.

The New York State law of 1884 requires not only an axe to be provided, but also a crow bar, sledge hammer and hand saw—the whole under a heavy penalty.

Testing of wheels.—The wheels of the locomotive and cars of every passenger train should be tested every, say, sixty miles by a competent employee. This precaution is not so universal as it should be.

Air brakes.—Every car intended to be attached to a passenger train should be provided with air brakes under which the motion of the train would be entirely under the control of the engine driver. The use of air brakes on passenger cars is almost universal, but the old fashion hand brake is still seen on old rolling stock in use on accommodation trains and upon branch roads. The Canadian Act is so indefinite that if the power brakes were only on the wheels of the locomotive or of the tender, the law would be complied with.

The New York State law of 1884 excepts from its provision on this point any passenger car attached to a freight train where the speed does not exceed twenty miles per hour. When freight cars are furnished with air brakes, this exception in favour of accommodation trains will be unnecessary.

ELECTRIC LIGHT.—Every car intended to be attached to a passenger train should be lighted by electricity or some other efficient source of light other than oil or other inflammable substance. It has been contended that oil which would stand 300° test is absolutely safe for the lighting of cars, but the proofs are by no means conclusive. It has been thought that a sudden shock which a derailment or a collision would give to the car would at once extinguish the lights, and remove the source of danger. The evidence is, however, rather to the contrary. Besides, the swaying of a Pullman car, in the event of derailment, would bring inflammable material like curtains and bedding into contact with the lighted lamps, and if they should take fire, such fire would find increased fuel, should the oil from any of the lamps have become scattered over the car furnishings. Gas is not only open to the same objection but to the even greater objection that there is danger of explosion should the reservoir of compressed gas be burst open by the shock of a collision or otherwise. The only absolutely safe means of lighting, at present known, appears to be the electric light, and considerations of expense can alone prevent its general adoption. It does not add to the heat of the car, is under immediate easy control, has the advantage of cleanliness and freedom from unpleasant odors and gives a steady agreeable reading light. The Julian system has been introduced into Canada. Whilst, however, the daily cost per car—claimed to be $1.83 per 24 lights for each ten hours,—will soon now be known beyond the range of mere experiment, the features which seem to still militate somewhat against its general use on all cars of passenger trains are the considerable first cost of the plant, the weight added to the car by the cells, and the necessary renewal of these cells every two or three years. And yet in railway economy, safety should be a vastly more important consideration than expense.

STEAM HEATING.—All cars intended to be attached to a passenger train should be provided with appliances for heating by steam generated in the locomotive, or by an efficient source of heat other than coal or wood in stoves or heaters erected in or about such cars, or other fuel which would be liable, in case of accident, to communicate fire to the car. The pressing need for the abolition of the stove on passenger trains hardly requires to be discussed in view of the terrible fatalities from fire during the past two years. The New York and Massachusetts Commissioners have both in special reports condemned the use of the ordinary stove and the New York legislature has now passed an act in the same vein. The question remains—what efficient substitute can be applied whatever the climate may be? The Baker heater in use on the Pullman cars can, it is contended, be encased with an iron jacket which it would be practically impossible to burst open unless the whole car collapsed, but this is not actually established. It cannot be too often pointed out that it is not the ordinary, if the term may be used, but extraordinary accidents where the complete collapse of the cars is probable, that have to be the most guarded against, for there the loss of life is greatest. The very weight of a heavy heater is in itself an element of danger when the car is overturned at an embankment or bridge. The popular verdict, without doubt, is in favour of steam supplied as under the Martin system through a reducing valve from the dome of the locomotive. Various experienced railway managers and superintendents have, after actual trial, pronounced decidedly in its favor. The result of enquiries made by the Massachusetts and New York Railroad Commissioners, appears to prove that the actual loss of power to the locomotive, ascertained from careful experiment, was insignificant, that the cost was little, if at all, more expensive than present methods, and that the heat could be stored for a considerable time after the steam was cut off.

If has been questioned if the system will work on railways with heavy gradients, but, even if the locomotive did there require all the steam, the cars once heated should remain comfortable for a considerable time without fresh steam—half an hour, the Martin system people claim-which would far more than suffice to overcome any ordinary grade. The objection that, on through trains, Pullman cars will be side tracked at points in the course of the journey, is overcome by the fact that these are usually important points where the station buildings are already or can be with economy heated by steam which can be readily supplied to the side tracked cars. It has also been urged that the colder climate of Canada will interfere with the practical working of the system here, but it would be better if those who take this view would speak from an actual experience before detracting from the merits of a system which appears to produce an uniform pleasant heat under easy control, and which seems to possess the merits without the attendant risks of the best car stove. Recent experiences in the severe weather of this winter have been decidedly in favour of steam heating.

Heating by steam is in successful use on the Cleveland, Columbus, Cincinnati and Indianapolis, Chicago and North Western, Chicago, Milwaukee and St. Paul, Dunkirk, Alleghany Valley and Pittsburg, Lake Shore, Boston and Albany, New York Central, Long Island, Staten Island Rapid Transit, New York Elevated and other railways, and its use has been inaugurated, experimentally, on the Intercolonial Railway.

PULLMAN UPPER BERTHS.—The upper berths of every sleeping car should be provided with such proper appliances other than wire attachments to the lower berths, as will, in the event of accident to the car, render it impossible for such berths to close whilst in use by passengers.

PASSENGER ACCOMMODATION.—Every railway should be compelled to furnish seating accommodation for all passengers. Especially on excursion and suburban trains is this necessary. The company should have no right to sell tickets to more parties than can be accommodated. There would then be no excuse for passengers crowding the platforms and blocking up the central aisles of the cars; and as at St. Thomas, on the London and Pt. Stanley Railway, intensifying the loss of life in the event of accident.

LOCOMOTIVES.

LOCOMOTIVE BOILERS.—Locomotive boilers should be subjected to test before going into service, and annually thereafter. The Truro and Stellarton explosions on the Intercolonial Railway are sufficient warnings of the necessity of this. The Massachusetts law of 1882 and the Commissioners' regulations under it, require not only boiler tests but special examinations, at least every three months, of the stay bolts, and an annual report of the results of these tests to the Commissioners.

SAFETY VALVES.—Locomotives should be provided with safety valves to prevent the escape of steam and scalding water in case of accident. The importance of this is shown by the Massachusetts Commissioners' statement in their 1887 report, that 162 persons in six railroad accidents occurring in the United States within a year and a half, had been killed or seriously injured by scalding.

TRACKS.

BLOCKING FROGS.—It should be made compulsory on railways to adjust, fill or block the frogs, switches or guard rails in connection with switches so as to prevent the feet of employees or others from being caught in them. Michigan and Massachusetts have laws providing for this.

Level crossings.—With regard to level crossings already existing in the populous parts of towns and cities, a suggestive course is to make it the duty of the municipal councils to select such streets crossing the railway as it is desirable to have kept open at such crossings, and thereupon the railway company should erect gates at such selected crossings, and close up on either side of the track all other crossings. The expenses of erecting and maintaining the gates and of the gate-keeper should be borne in equal shares by the municipality and the railway company. Every town is bound to protect the lives of its citizens, and it is not right that the railway company, which is such a factor in the progress of the place, should bear the whole expense of this protection so far as rendered necessary by the entry of the railway, more especially when the crossings are often new streets opened since the construction of the railway. If the municipality has to bear one-half of the annual charge as well as of the first cost, there will be no desire to keep open unnecessary crossings and there will be a twofold interest in exercising care at the crossing kept open at the joint expense. At present the law gives a discretionary power to the Railroad Committee to direct changes in crossings and to apportion the cost, but practically, action has been seldom taken upon it. Canada has 7,241 level crossings.

In Connecticut the statute of 1883 provides that when a town desires a gate, flagman or electric signal at a crossing, this may be ordered, but the town may be directed to pay one-half the cost.

Those who urge the substitution of high level crossings or subways, little know the cost. It has been estimated by the Commissioners of Massachusetts, that such a substitution in every case of grade crossings in that State alone, would entail an expense nearly equal to the whole cost of the railways of that State. In Connecticut it is provided that new crossings must be either highways or subways, and if required by a town or municipality, shall be built at the joint expense of the railway and it. Alterations in existing level crossings in the same State, where ordered, are also to be at the joint expense, but only one crossing per year was to be charged on any one railroad. These Connecticut laws are well worthy of consideration in Canada.

Where railways cross on the same level, the New York and Massachusetts laws require all trains to stop, unless an inter-locking switch and signal apparatus is in operation there.

WALKING ON TRACK.—It should be made an offence punishable with a penalty to be found walking on a railway track, unless the offender is simply crossing the track, or is an employee then on duty. The need of stringent laws in this respect is seen in the fact that 299 persons were through this killed, and 171 injured, in all 470, in New York State, in 1886, 110 of these being employees and the others trespassers.

EMPLOYEES.

INTEMPERANCE. OVERWORK.—There are, affecting employees, two very important subjects which have each a direct bearing on the liability to accidents—intemperance and overwork. The one is within the control of the employee; the other within that of the railway corporation. The New York State law whilst providing for six months imprisonment, or $100 fine if an employee on duty is found intoxicated, also provides that any act or neglect of his when in that state, which shall occasion death or injury, shall be punishable by imprisonment for a term not exceeding five years. The railway companies themselves can do much to prevent intemperance by prohibiting the sale or use of liquors on their premises.

Rest to employees is also a preventative of danger. How often is the mis-sent message or the mis-placed switch due to an operator or a switchman whose hours of service had been unduly prolonged! Sunday trains should also be discouraged as much as possible. The railway employee needs the rest of the seventh day as much as the merchant or the highest peer of the realm.

BOARD OF RAILWAY COMMISSIONERS.

The organization of railway commissions in the United States is the outgrowth of public opinion. Railways from being merely private enterprises have become necessary elements in the national prosperity. The unexampled advance made in their construction; the need of some state supervision in order to ensure as far as possible the safety of both passengers and employees, and the numerous local questions always arising between the public and the railway, as well as between the different railways themselves, all created a necessity for a board representing the state which would have certain powers of control itself and would see that the State laws affecting railways were properly carried out. Railway companies as a rule have not desired the appointment of commissions. The managers from their stand point as representing private shareholders, naturally prefer, in the institution of improvements, to consider the means at their disposal; in the settlement of questions with the public to suit their own convenience; and in the case of accidents and loss of life, to privately investigate the causes themselves.

The bare fact that the loss of life and the injuries, both to passengers and to employees on railways, is very considerable in Canada, is of itself a sufficient reason for a Railway Commission. The public has a right to enquire why causalities should occur, and equally a right to know whether needed remedies cannot be applied. At present there is a Railway Committee of the Privy Council clothed, under the Railway Act, with certain powers. The members of this committee are required to be members of the Dominion Government, but however able each in his own department is, he cannot lay claim to any special knowledge of the working of a railway. When references are made to the committee, the investigation and adjudications are made at Ottawa, dependence being placed on the reports of others and on the arguments of counsel. There is no personal inspection of the scene of the inquiry. Beyond the fact that the committee may appoint a commissioner in each case—and this is rarely, perhaps, done—there is no special provision for examining into the causes of accidents on the railways with a view to prevention in future, and no machinery which could be utilized in the personal inspection or testing of new appliances which might aid in lessening these causalities. New railways, before being operated, are required to be inspected, but the inspection is made by some engineer who exercises his own judgment and discretion, there being no well defined rules laid down for his and the railway company's guidance, and no standard up to which every road must be strictly brought before it is opened for traffic. There is no inspection and test of bridges and trestles to ascertain the maximum moving load which can, with safety, be allowed upon them, and no inquiry into the nature and heaviness of the traffic which must pass over them. There are no stated inspections of each road to see if the law is complied with and to give such directions or make such suggestions in regard to the general condition and equipment as would promote the safety and convenience of the public. And the want of these inspections favors cheaply built and inefficiently maintained railways. The machinery of the committee is besides cumbersome and tends to delay inquiries and decisions, through the ministers, whose other duties necessarily require their first attention, being not always accessible. As a matter of fact, the Railway Committee, as a board of reference and control, is not often taken advantage of by the public. Were its scope extended in the direction of the enlarged functions of the Railroad Commissions of the United States, the very composition of the committee would prevent many proper complaints from being brought before it and would thus cause much injustice.

A difficulty—of less importance than it seems—in the way of the appointment of a railway commission whose field of operations would extend over the whole Dominion, is that certain railways have been incorporated by and are subject to the laws of the Provinces within which they wholly lie. Th efusion of many of the smaller railways with the larger systems, and the extension of others, is however yearly lessening that difficulty. The last published government report indicates that in 1886 there were 11,523 miles of road being operated within the Dominion, and an analysis of this shows that whilst 1,240 miles might be regarded as subject to provincial control, there were 10,283 miles of railway, comprising through and local lines and their leased or purchased branches, which can be regarded as, or made, subject to Dominion control, and therefore could be brought within the jurisdiction of a Dominion Railway Commission. The proportion at the present time is probably even more in favour of railways under Dominion control.

It will be argued that the vast extent of the Dominion will preclude the satisfactory working of a commission. In time it might, when the number of miles operated here should approach the enormous mileage of the United States, but when it is known that the mileage in Canada is actually less than the miles of track built in New York State, there need not be a fear that the business for the commission for many years to come will be greater than it can overtake.

Is, however, a railway commission a necessity in Canada? As far back as 1851, when railways were in their merest infancy in the country, Parliament decided that it was, but, as commissioners, appointed ministers of the Crown. The functions of the commission were however limited, and the actual work it accomplished probably even more so. And thus it has been ever since. The Board of Railroad Commissioners afterwards developed into the Railway Committee of the Privy Council, but, whilst after the federation of the provinces, there was a more extended field of operations, and the commission had somewhat wider functions, it does not appear to have commended itself to the general public as—and was perhaps never expected to be—a committee of reference and control. The railway system of the country in recent years has largely developed, and its bearing on the social and material welfare of the people, has increased in an even greater ratio, and yet in its duty to the people, the government has not maintained that actual control over the railways, which governments in the United States have found necessary, nor has Parliament afforded to the public those ready facilities for redress which communities and individuals served by powerful railway corporations should always have. If the railway corporation has been given enormous privileges and powers by the State, communities and individuals have also rights to which the State should give even greater heed.

The results from the operation of railway commissions in the United States have been most favourable. In some States they have undertaken their work with an energy, a fairness and a thoroughness that have made them powerful agents for good. Apart from the laws which have been enacted on their recommendation, and from the improvements whose introduction has been suggested or enforced by them, the earnest efforts in some of the older States to lessen the causes of accidents, form a marked testimony in their favour. There could be no stronger tribute to the value of a well organized commission than the report of the enquiries made in 1886 by the United States Senate committee on Interstate Commerce.

The suggestive duties which a railway commission in Canada should have are:—

To consider every application for a railway charter and report to Parliament on the necessity for the same and on the *bona fides* of the applicants and their ability to construct the railway.

To promote the health and comfort of passengers, as in ventilation and other sanitary essentials in cars and station buildings.

To secure safety for passengers and employees by regular inspection, by examining into the causes of accidents, and by investigating and, if necessary, directing the adoption of improvements, which would tend to ensure safety.

To prevent excessive or unreasonably discriminating rates, and to see that railways afford reasonable facilities to the public for traffic, as in station buildings, and in the location of such buildings and of the tracks.

To regulate questions between the municipalities and the railways, as in matters of taxation and level crossings.

To determine differences between different railways, as in railway crossings, interchange of freight and, possibly, competition in rates.

To obtain accurate and full statistics of the construction, equipment and results of operating, of each railway.

The first of these considerations is probably unusual, but the great number of railway charters granted by Parliament, which never reach beyond the embryonic existence of the statute book, and still other railways, which have been actually built into a country already well served by existing lines, make it necessary that some tribunal, uninfluenced by party politics or by mere local considerations, should be, at least a preliminary, if not a final, referee in the projection of new railways.

The duties of the commissioners should be advisory rather than directory, and its members should depend rather upon the justice of their decisions and upon the influence of public opinion, than upon any powers which the legislature might give them to enforce their decisions.

DISCUSSION.

If he understood the drift of the Author's remarks, it was to the effect–that the risk to travellers on American Railways was less than in Canada–that this condition of matters had been brought about by the appointment of Boards of Railroad Commissioners in the former country–and that, therefore, the Railway Committee of the Privy Council in Canada should be superseded by a Board of Commissioners similarly constituted. Mr. Wallis.

He desired to speak of the gentlemen forming the various Boards of Commissioners in the United States with respect. They presented to the public valuable statistics which otherwise would be known only to the Railway Companies, and that they made use of their authority, and of the information at their disposal in a wise and useful manner, was obvious from an examination of their various reports. This was especially noticeable in the report of the Commissioners of Massachusetts for the past year, which for detail, excellence of arrangement and illustration was perhaps unequalled. He did not think, however, that the public requirements could be more satisfactorily met, or that anything more was necessary in Canada than the Railway Committee of the Privy Council. The information was obtained in each case from the same source, and could be added to or enlarged at discretion.

The author of the paper believed that the statistics of accidents during recent years, proved that the risk to railway travellers and employees was greater in Canada than in the leading States of the Union. The meeting was asked to accept as proof of this apparently unfavorable condition of affairs, a statement based on the number of passengers carried, without reference to the length or extent of their journey. The area of Canada was 400 times that of Massachusetts, and its population per square mile less than a two hundredth part. Under such conditions, the conclusion was natural, that the average Canadian journey covered a long distance, at any rate much longer than in the smaller State with its dense population. An examination of the Massachusetts Commissioners report shew that about 15 miles was the State average per trip per passenger. In Canada, the statistics for comparison were not furnished in the Blue Book, nor were they, as far as he was aware, then recorded by Railway Companies. It would, however, be consoling to those whose lot required them to travel in the Dominion, to know that the average of distance in Canada was nearly five times that of the State of Massachusetts, and that the travellers in that State reduced their risk, not by comparative Canadian insecurity, but, obviously, because their journeys were shorter. The Speaker based his statistics for the Dominion on the working of the Grand Trunk Railway, which for the year 1881 (the last year in which they were compiled) gave an average distance per passenger of 70 miles. The opening of the Canadian Pacific Railway would certainly tend to increase this distance per passenger, so that he did not hesitate to deal with the Grand Trunk figure as considerably below the average of the whole Dominion.

He could not attach any value to a comparison of the records of so short a period as two years, when the figures shewed that they differed so widely from each other as to make it appear by the method of reasoning adopted by the author, that it was three times more dangerous to travel in the state of Connecticut in 1886 than in 1885. He would read a quotation from the 17th Annual Report of the Massachusetts Commissioners :—" It cannot, however, be claimed that our Railways are " thus proved to be safer than those situated elsewhere. Another year " may show a preponderance against them by a single train accident, and " it is only by taking the record of a number of years that fair compari- " sons can be made." Also, in reference to the returns of killed and injured, which were lumped together without any reference to the proportion of each, the Massachusetts Commissioners, recognizing the unreliability of a comparison under this head had remarked : " There is " no uniform rule as to the degree of injury which should require a " report, and of course the reports do not afford a correct basis for com- "parison of such accidents on different roads." In his advocacy of a Railway Commission, the author had taken ground, which authorities on the subject like the Massachusetts Railroad Commissioners, recognized as untenable, and he would not be surprised, therefore, if such arguments failed to impress those who held opposite views.

There was nothing in the figures submitted to shew that Railway casualties in Canada were as stated more frequent than elsewhere. An analysis of the number of passengers killed for the two years referred to, shewed an average per annum of 7 for Canada and 17 for the State of Massachusetts, and during the year 1887, the number of killed in Massachusetts reached 37, or more than double the average of the two previous ones. These figures could not be called unfavorable to Canada with its passenger mileage of probably but one third less than that of the State of Massachusetts.

The same remarks applied to the number of employées killed, which, for the same period, was 139 for Canada and 91 for Massachusetts, compared with a tonnage mileage in favor of Canada of probably 3 to 1.

The author's method of reasoning seemed a poor argument in favour of his contention, as could be seen from the figures copied from the Commissioners' report, before referred to, for the past 6 years :—

Year.	Passengers carried (000 omitted).	Passengers killed and injured.	One in (000 omitted).
1882.........	55,868	27	2,069
1883........	61,531	61	1,008
1884.........	66,517	76	875
1885.........	69,604	74	940
1886.........	75,842	107	709
1887	82,923	198	419

It was true that the train mileage per mile of Railway was much greater in Massachusetts, but the danger from such cause was more than compensated by the use of a large proportion of a second main line, of which Massachusetts had some 40 per cent., and which, with the "block" system, was far safer than any condition of working on a single main line as in Canada.

It was somewhat surprising, in view of the number of deaths and injuries from collisions and derailments, that this fact should not have been referred to and dwelt upon as a necessity for the use of double lines of railway and the "block" system of working them; also for the interlocking system of switches and signals, to which reference appears to have been made. Possibly the author had at this stage reached the information that Canadian Railway investments returned per annum but 1½ per cent., as against 5 per cent. in Massachusetts. The shareholders, therefore, could hardly be included among the enriched private individuals mentioned in the early part of the paper.

Managers were not likely to find fault with a system of inspection which would secure the construction of first-class railways, but there would be some difficulty in persuading investors to continue to embark their capital in undertakings which, with the enforcement of a rigid system of inspection, would offer them practically no return. The construction of cheap railways might seem to the author unwise, but it was necessary. If the pioneer railways in the country had been constructed under the rigid rules applicable to densely populated districts, there would have been less mileage, and the progress of the country must have been retarded. The Trunk lines of Canada were however well equipped and of solid construction, and notwithstanding a lighter traffic, were not behind those of the United States in construction, equipment or management.

There was not one of the appliances mentioned by the Author in general use in the United States which was not as general in Canada.

In train signals Canadian railways could claim to be in advance of the majority of those of the United States. If by progression was meant the adoption, of the numerous untried, devices patented by irresponsible inventors, who came in the guise of public philanthropists to cure all the ills that railways were supposed to be afflicted with, Canada was non-progressive. Railway managers were conservative and required the best of reasons for making changes. Real progress had however been made. Power brakes and tight couplings on passenger trains had been in general use for years, their non-application to freight trains was incidental to the necessity for an interchangeable, and therefore uniform, system, and was not in the nature of delay specially attributable to Canada. The call for electric lighting and steam warming of passenger cars had met with an immediate response. The leading railways at once undertook experimental trials of the various systems. It had not required special legislation to suggest the doubling of some of the main arteries when in the public interest it had been found advisable to do so.

As for a proposed inspection of locomotive boilers, the fact that only two injuries had occurred in Canada during the year referred to, was sufficient indication that Railway officers were alive to the importance of that subject, and that their system was sufficiently thorough. Could the same results have been achieved in regard to domestic arrangements? and would not an inspection of kitchen ranges and house furnaces, and the appointment of certified attendants have been more to the point?

A Board of Railway commissioners might furnish more statistics but would they give more safety in travel? The author thought so; but while he had for reference the elaborate statistics produced by ideal Boards, an analysis of them rather favored an opposite opinion. The fact, admitted by the author, that it was to the interest of Railway Companies to avoid disasters, was in itself a sufficient public safeguard.

Mr. M. Butler. Railway commissions in the various States of the Union have not been thought favourably of by railway managers. It may be taken for granted, that in too many cases, political power has been a more cogent reason for an appointment as a commissioner, than railway knowledge. In the majority of the states it will be found that the commission is composed of one or two lawyers and a merchant. Such being the state of affairs, it is not to be supposed that men, who have given their time and best energies to the study of the special questions relating to railway management, should view with favor the meddling of men they deem incompetent give advice in their special line. Is there even one State commission composed of Civil Engineers and railway managers? How then can it be expected under this condition of affairs that the system will improve? It is a case of the blind undertaking to lead those who can see.

It is true that in many states, men of great ability and intelligences have been appointed commissioners, and in a number of cases they have called to their aid the assistance of skilled Civil Engineers, as in Massachusetts, New York, Ohio, and doubtless in other States.

Some good has certainly accrued to the public from their existence. The radical defect in the establishment of a railway commission, in the various states of which the writer has knowledge, lies in the fact that has been apparently overlooked, that the vested interest of the railway is a sacred one, that it is the only source of income to a very great many people, and hence, that if a commission has the power to regulate the receipts of a railway, it should also have the power to prevent the altogether unnecessary paralleling of existing lines. In the various States of the Union, it only costs a very small sum of money to secure a Charter. This seems quite wrong, for if the law is to sayhow much a railway may earn, it should at least protect it in those earnings.

The paper deals so fully with the various causes of accidents that it is unnecessary to discuss it at much length.

Bridges.

There should be a systematic inspection of every bridge— not a mere inspection of a submitted strain sheet—which may or may not agree with the structure it is supposed to represent. This means a great deal of work, and it also means that the Inspector should be free from all control, that his position should be like that of our Supreme Court judges—one of great independence; he should be well paid and hold his appointment for life, unless it could be shown that he was incompetent; his removal to be similar to that applied in the case of the highest judges. On the Atchison, Topeka and Santa Fè Railway we have power brakes on all freight trains, the result being that very fast time is made with greater safety. The Westinghouse Automatic brake is used exclusively. On such a road as the Colorado Midland, where a four per cent grade and 16 curves are in use, it would be impossible to operate it without power brakes. The Denver and Rio Grande Railway also uses the Westinghouse Automatic brake; as these roads including the Burlington route, probably interchange as many cars as any other on this continent, the argument that because *all* railways do not adopt them *none* should, does not apply with much force.

Couplers.

The recent action of the Western Mechanics Association, in recommending the Janney type of coupler, will no doubt soon bring about the adoption of a better mode than the old barbarous pin and link.

Steam heating.

The speaker would draw the attention of the members to a report of the William's system of low pressure steam heating direct from the engine, contained in the Railway *Gazette* of 24th February, 1888.

Walking on the Track.

There is already a law on this point in the Statutes of Canada, but hitherto it has not been enforced.

Bridge Guard Rails.

The Latimer Child's device is so well known and so thoroughly efficient, that, such railways as are too penurious to adopt it, should be compelled to do so by law. A great many other devices are in use, but none of them can show such a record. Mr. Butler knows of only one bridge in Canada protected by this guard.

Mr. MacPherson.

Mr. D. MacPherson remarked that Mr. Wallis' able and exhaustive statement of the facts under discussion left very little, if anything, necessary to prove that Canadian Railways were not behind the times as regards safety and convenience for the public.

The author of the paper before us draws rather an alarming picture of the conditions and risks incident to railway travel in the world generally, and in Canada in particular, but seems to have brought forward no very definite practical remedies. On behalf of the railways, he may be permitted to say, speaking as a Resident Engineer of a leading Canadian Railway, that there is very often great risk attendant upon the adoption of so-called improvements in guard rails, switches, &c., &c., until they have been shewn to be real improvements. The best safety appliances, which no amount of patent combinations will supersede, are competent and reliable employées.

The safest road to travel upon is the one which has the most experienced management combined with the most skilful, careful and reliable subordinates of all grades. Such a management *will not accept* the ideas of every "crank" who has or wishes to get a patent on an entirely unpractical device, but *will adopt* improvements which can be practically shewn to be such.

Again, we have a mass of figures given in this paper which are intended to shew the number of passengers killed in proportion to the total number of passengers carried, in certain parts of the United States, and also the same figures for Canada during corresponding years. Now it appears to the speaker that these figures prove nothing at all. It is perfectly absurd to say that the risk of travel is in direct or anything like direct proportion to the number of passengers carried. If the author will carry his researches further and say, in addition, the average number of miles travelled by each passenger, he may then deduce something like a ratio of the risks of travel.

At present, from the facts given by older and more experienced men here to-night, railway men in Canada have every right to assume, and the public every right to rest assured, that travelling in this country is no more risky and perhaps very much less so, than is the case across the border.

Mr. Drummond's paper on Railway Accidents brings forward a very important subject. It is undoubtedly the case that many preventable accidents occur, and though travelling by rail is safer than any other mode of locomotion, still there is room for improvement where such accidents take place. By preventable accidents are meant those which, by the exercise of proper care, and the employment of the accumulated experience bearing on the subject, in the construction, maintenance and working of railways, would not have occurred. Accidents which are caused by defective track, defective bridges or trestles, inefficient fences, low bridges, buildings too close, &c., &c., are in by far the greater number of instances preventable accidents. And yet many railway corporations prefer to run the risk of accident, and pay the damages when they arise, rather than be at expense of removing the apparent cause. There are railways that could easily be named (running through long settled country) where there are no fences to speak of, and where the management prefers to pay for cattle killed, or passengers injured, rather than fence the track, and laughs at legislative enactments that no one ever undertakes to enforce. There are railways, where the low overhead bridge counts more than one or two victims, and yet continues to exist; and there are numerous examples to be found, of weak, rotten and unguarded trestles, patiently waiting the time when they will spring into notoriety, as the cause of a "frightful accident." * Such things demand the attention of those who aim at making railway travelling more secure. Mr. Cunningham.

To the civil engineer the part of the subject that lies most within his province, is that which deals with the construction and maintenance of the roadbed, track, bridges, trestles and buildings, rather than that which deals with locomotives and cars, or the running or management of trains, and it is to this that the present correspondence is confined.

In order to have a track in perfect condition there is no one thing that is more essential than thorough drainage. A perfect roadbed is one on which no water stands and no moisture collects in the ballast. Drainage is essential in every country, so as immediately to carry off heavy rainfalls, and prevent "washouts," or settlement from soakage; but it is doubly necessary in such a climate as the Canadian, where we are sub-

* At the very time of writing comes the news of the terrible accident at Blackchear, near Savannah, caused by the train first being thrown from the track by a broken rail, and then striking and knocking down a trestle.

ject to sudden thaws, followed by severe frosts, when, if the water has not been drained off, the track is "heaved" by ice forming, and thrown badly out of surface. The consequences of this "heaving" are that the train may be derailed, particularly if the heave is on the inner side of a curve, or a rail may be broken by an undue strain being thrown on a particular spot, where the rail is acting as a girder, holding up the ties instead of being supported by them. In order temporarily to remedy these defects, the section men have recourse to "shimming up" the track by packing blocks of wood of the necessary thickness between the rail and the ties. But the frost comes and the evil is done all at once, whereas it takes the section men days to get over the section and take out the worst spots; and in the meantime the traffic rattles along over the track, "always on time," while the cars oscillate and swing with that sickening motion so familiar to passengers. When the spring thaw comes, the evil is just reversed; the frozen humps thaw out and settle down, leaving the high spots where the track has been "shimmed."

Few people, who have not paid special attention to the subject, have any idea how much particular kinds of soil heave with the frost. The writer has seen a point in Prince Edward Island, where it was necessary to "shim up" the rail 11 inches, in order to take out inequalities caused by the frost. The Island soil is unusually troublesome in this respect, and this was on a part of the Island Railway where there was, practically speaking, no ballast.

To radically cure such defect, perfect drainage and plenty of clear, dry ballast are necessary. Without these there never can be a track safe for fast running. A strong rail, with rigid connections, is of great value in giving a uniformly smooth surface, and has much effect in reducing the heaving by frost. In an instance that came under the writer's personal observation, a weak iron rail was taken up and the track relaid with a strong steel rail. The immediate effect of this was to reduce the heaving by the frost in a most surprising degree. A little observation shewed the reason. Under the locomotive, the iron rail yielded to a considerable extent, causing a "pumping" action of each tie; this sucked up moisture, which was frozen, and the track heaved; but with the stiffer steel rail, the "pumping" action was much reduced, there was less moisture drawn up, and consequently less heaving. For similar reasons, a rigid connection of the rails should be sought for, and the angle plate joint is a great improvement over the fish plate. With a weak connection in spongey ballast, it will always be noticed that the track heaves at the joints.

Constant attention should be given to maintain the proper elevation of the rail on curves. The elevation should be set to suit the speed of the fastest trains. But even on old established and well appointed road the straining and jerking of the cars, as they round sharp curves at a high speed, often shew that even this most elementary precaution is not attended to.

It hardly needs pointing out that the ties should be immediately renewed whenever they shew rot or cutting from the flange of the rail, and yet the fact that they are not always so renewed may be sufficient reason for directing attention to it here.

In the writer's opinion, the steps that should be taken to maintain a track in safe condition, should follow the lines above indicated, rather than those tending to supply guards in the event of a train leaving the track. Mr. Drummond's proposal to lay down guard timbers on high embankments is open to grave objection. The timbers, to be of any service, would have to be at least 8 or 9 inches square, and in order that the snow-plough (a most indispensable agent in Canada) running in winter should clear these, they should be at least 6 feet clear of the centre of the track. This would necessitate a much wider bank and longer ties than at present in vogue; and this again would render more difficult that perfect tamping and packing of the ballast on which the life of a track depends. Laying double rails inside the main rails on embankments is also objectionable, as allowing the track to become clogged with hard packed snow and ice. It is of great importance in winter that the track should be as clear as possible of fixtures between the rails, so that the "flanging car" may be run freely over it.

Heavy guard timbers, with wide floor timbers placed close together, should be on all trestles, as Mr. Drummond suggests; also the inner rails, brought to a V at either end of the trestle. The writer has known of a serious accident having been prevented by this precaution.

In many instances where wooden trestles are erected, it would be more consonant with good engineering that stone arch culverts should be built and the hollow filled in with earth. Of course this is objected to on the score of expense, and for cheap lines, intending to do business at moderate rates of speed, the objection may be allowed; but on a first class road, that proposes to run trains on a schedule time of 55 miles per hour or so, such objection should be overruled.

The writer is well aware that the recommendations in regard to maintenance of track, set forth above, embody nothing that is new to the engineering profession. Yet it often seems that sufficient importance is not attached to the carrying out of such rules by railroad managers, and those who directly control the expenditure on railways. The money expended on absurdly gorgeous parlour, dining, or sleeping cars would usually be of much more benefit to the property and the public, if laid out in ballast, ties, and sectionmen's wages. But the first mentioned expenditure is always the more pleasing to the management on account of the display it makes on the road; while the second is unseen by the travelling public, though it may always be distinctly felt.

That the line should be properly and securely fenced, that bridges should be strong enough, that they should not be too low, that buildings should not be too close to the track, all these go without saying. And yet an examination of some roads would disclose the fact that even in these matters there is much room for improvement, and need for pressure being brought to bear, to enforce agreement with sound precepts.

This suggests the propriety of some form of railway commission for the purpose of overseeing in the interests of the public the various matters connected with the construction, maintenance and working of railways. It certainly seems strange that in this country, where railways have been built largely by Government and Municipal aid—by money supplied by the general public—there should be no public functionary or officer whose duty it should be to see that the line is maintained and worked with a proper regard to safety, and that the various legislative enactments are complied with. In England such work is performed by Inspectors appointed by the Board of Trade, and the "Railway Inspector's Office" forms part of that department of Government. It is also the duty of these Inspectors to hold enquiries into the cause of accidents when they occur, and their reports are of great weight in fixing the blame upon or exonerating the Railway Company. In this country, officers appointed by the Dominion Government would labour under the disadvantage, that the Government itself is also a Railroad Corporation, and one not guiltless of the sins of omission and commission above alluded to. Some form of periodical inspection of Railways, together with an organized system of official enquiry into the causes of railway accidents, by competent and unbiassed men, would be of much service to the Canadian public, and would have a marked influence in reducing those defects in construction and management which produce accidents. As a means towards obtaining this, the appointment of a Railway Commission to enquire into the subject would, in the writer's opinion, be a move in the right direction.

Mr. Barnett. Mr. Barnett remarked that if the author's statements and reasoning are to be accepted the logical conclusion is that the State should purchase at great expense, improve and then work all railways.

If, however, a commission must be appointed to control private property, its province and its power to compel a Railway Company to spend money, should at first be restricted to new construction until such time as its decisions have been successfully tried, and the commissioners themselves have gained experience.

The paper covers wide ground, and he could only touch upon a few of the points mentioned by the author.

One is the safety of mineral oil of 300° flash test. There have been numerous tests of this oil. Flaming cotton waste and hot cinders dropped into it have been extinguished, and hot cinders put on to a board saturated with it, only charred a small surface slightly larger than the cinder. There is no record of any American railway casualty in which lamps burning this quality of oil caused any injury to passengers.

Steam heating is still in the experimental stage on all the railways mentioned by the author, except the suburban service in New York and its neighborhood, where the Gould storage system is used. These coaches, every 2 or 3 hours, are connected with a stationary high pressure boiler, steam from which warms up brine in a 5″ or 6″ tube running the length of the car. This acts as a storage reservoir, and is fairly effective; but there is no case of storage system and *low* pressure steam in through pipe from locomotive being worked satisfactorily together. Where the storage system is used, the passengers are not present when high pressure (high temperature) steam is passed through pipes and couplings.

No Railway officer would, last fall (with the limited experience then possessed), have been justified in recommending the expenditure and changes necessary to equip all the passenger stock of a through Railway with any patented system of steam heating, their known defects and possible failures being too serious. The particular patent recommended has but one point to distinguish it, viz., the coupling between car pipe and car pipe, the use of reduced pressure steam being common to most of the sy tems.

One fine morning this winter, the speaker examined a waiting branch train equipped by the patentee, and water was passing from every point. Judging by the volume of this water, more steam was being used to keep a short, unused train comfortable, than inventors generally claim is required to do the whole work with train in motion when temperature is low. A through fast train passed through this same depot, using another style of coupling, and so much water had leaked out that it was a matter of surprise that the automatic brake gear was workable.

A Railway committee is at present endeavoring to secure a flexible pipe coupling that shall not only do its work effectively, but also permit the free interchange of coaches.

In the matter of automatic car couplers, he said he knew of no single thing that had done so much to check progress in their general adoption, than the action of the various bodies of Railway Commissioners.

They had in various States, enforced the use of different types that were far from coupling automatically with each other, and the result was that the men had to go between the cars to make the coupling when two odd kinds of automatic couplers came together, with risk to life and limb, increased beyond what followed the often careless coupling with the link pin and old-fashioned bullhead drawbar. Railway men have now taken heart again in this matter, and the Master Car Builders (not the Master Mechanics) Association is actively engaged in settling the lines of a hook coupling, which shall be automatic and yet have a wide limit of application.

The author has large faith in Government boiler inspection; but the example he quotes scarcely justifies this faith, as the only boiler casualties in Canada mentioned in the two years taken for comparison, are boilers under the control and inspection of the Government.

It is not proven that the railings at the sides of the roof plank walk, even if all cars were so equipped, would be any additional protection for brakemen. Certainly while in course of change, the risk would be increased, and the same could be said of the oft-repeated recommendation for an increase in the width of walk. Inequality of present equipment may have its risks, but it is not wise to increase their number. This matter of railings and increased width of walk is very fully investigated and discussed by the Ontario Legislature's special committee on Railway accidents. See its report in 1880.

In the matter of additional means to prevent the upper berths of sleeping cars, is it on record that the wires attached to such berths ever failed to keep the berth in position?

The author properly recommends the testing of passenger train wheels every 60 miles (a daily practice for all cases of trains in Canada); but does not say anything about increasing the safety of the wheel itself. One railway, where travel is alleged to be so dangerous (the Grand Trunk Railway of Canada), uses for its passenger truck an expensive, but practically indestructible wrought iron wheel, fitted with steel tyre and circular clips, so that in any case of failure, neither the tyre nor any short segment of it can be lost.

Hence, in this matter, our practice is in fact far beyond that of our neighbors, with whom we are compared, and (it is believed) far beyond the action of any American Board of Commissioners.

Statistics such as those referred to in the paper and by other speakers are so capable of distortion, either intentionally or unintentionally, that deductions therefrom should be drawn only with the greatest care; and when the mileage run and the number of travellers and employees are considered, the wonder is that the casualty list is not larger, and the speaker for one, gladly gives railway men the credit due to them. At the same time, there is no reason why every possible means should not be taken to reduce the risks of travelling and railway working to a minimum. He would therefore approve of Mr. Drummond's suggestion of "regular inspections," made in connection with or by order of a Railway commission.

It is noticeable that our railway friends have the idea that any commission connected with the government would be a farce, and the members fools. But there is no necessity that it should be so. A commission of practical utility exists in the old country, and there are very good indications of the benefits of commissions in the United States. It is not natural to expect that railway men should favour a commission any more than they are likely to suggest a reduction of their salaries; but we are human and fallible, and no matter how high-minded, conscientious or solicitous of the public safety, a manager may be, we are all the better for being looked after. The government inspection of steamshipping is indisputably wise, and there can be no one present who is prepared to deny that a great number of lives have been saved by the Board of Trade regulations. Why should railroads be differently treated from steamships? What is practical and beneficial in the one case, would be so in the other. It may be freely admitted that to a manager, it is a nuisance to be liable to have to put your ship in dry dock when she is worth ten dollars an hour, to have your boiler strained, your steam pressure reduced, hose pipes and life belts condemned, &c., &c.; but the effect is to promote increased carefulness, better construction, and the use of a higher class of property, while the compensation is in the increased confidence and patronage of the travelling community. Those individuals or companies, which receive pay from the public in exchange for travelling accommodation, ought to offer the best assurance of safety possible. In the case of railways or subsidized steamship lines, the public through the government of the day, grants valuable rights and privileges, which give them (the public) the right to see that the maximum of safety is insured. Mr. T. Brown.

A Railway commission competently formed and adequately empowered appears to be desirable, and the speaker does not hesitate to say that no manager of any transportation company fit for the position would fear the commission or its inspectors.

The method of applying the brakes on freight trains is at present attracting attention, with the endeavour to devise a system which will make it unnecessary for the brakesmen to pass along the roof of the cars to apply the brakes. If this practice could be abolished, it would have an important bearing on the prevention of accidents; not only directly, but also in rendering the construction of overhead crossings practicable in a much larger proportion of instances. In this country, the Mr. Dawson.

legal headway required in the case of overhead crossings is twenty-one feet clear from the top of the rail, which is enacted for the safety of the brakemen when on the roof of the cars. In France, where this is rendered unnecessary by applying the brakes in another way, the legal headway is only 15 feet 9 inches, which has the further advantage of reducing the cost of overhead crossings in a marked degree. In a level district, undergrade crossings or sub-ways are impracticable, as it would often be impossible to drain them or to prevent them filling with snow; and for overhead crossings this difference in headway would reduce the cost to about one-half. In travelling in a flat country like Yorkshire, it is impressive to a Canadian engineer to see every road carried overhead across the track. Without going into the question of how the brakes might best be applied, it is important to note the indirect bearing of the change on the prevention of accidents arising from the prevalence of level crossings.

Mr. Henshaw. The prevention of Railway accidents has engaged the attention of the public for many years. At first sight, since nearly all these accidents are preventable, it seems a simple matter to make them so, but on investigation we find this by no means to be the case. Take for instance innumerable patents for railway couplings, all of them good but for some fatal objection. What man of a mechanical turn has not invented, or at least designed, a coupling? The speaker has designed two. Early in life he invested $100 in a perfectly infallible one, which, however, was never heard of. The inventor told him that each railway manager promised to adopt it if he could get all the rest to do the same, a very safe offer as it proved. In fact, the first essential preliminary to an universal coupler is a continental law, fixing one exact height from the level of the rail to the centre of the draw bar.

Leaving this, the most fruitful source of accidents, for the present we find that other sources of accident are equally difficult of practical solution.

The New York commissioners, as Mr. Drummond informs us, recommend a low railing on the top of the cars along the centre, and an extension of the running board beyond the ends of the cars, and a similar plan is understood to be recommended to the Canadian Government. Now, according to the speaker's experience, it seems very doubtful that these recommendations have originated with the parties most concerned They seem suggested for the benefit of old or timid men, who are precisely those not employed. Brakemen are always young and active men, and accidents from slipping off the top of the car are almost unknown. The running boards are flat, while the top of the car is round. Therefore, as the first impulse of a man when slipping is to squat down and grasp the edge of the running board, there is no need of a railing which is otherwise a nuisance to his freedom in balance, and in handling the signal cord. Falling between the cars is a more frequent accident, and sometimes occurs in passing from car to car, but more often by a jerk received when braking. It is to be noticed that these accidents are more frequent with the older hands than with beginners.

To project the ends of the running boards beyond the ends of the cars seems to the speaker not only useless, but dangerous in the extreme. The cars of a freight train are rarely of uniform height. In leaping or stepping, the foot always lands on the edge to prevent its slipping forward. The accident occurs from a side jar, and the man has a better chance to save himself on the edge of the car than half way between. As perfect a remedy as is possible for this as well as that from the jerk of the brake, would be to put the ladders always (as is mostly the case now) on the left side of each car gable, and to connect them with an iron rod running the whole length of the gable, level with the roof and below the level of the running board. This would give something to the falling man to hold on to, and make his way thereby to the ladder.

About one-third of the total loss of life, or injury by railway accidents, is due to the coupling of cars, and almost all of these on freight trains. Taking all things into consideration, there does not appear much probability that the old link coupling will be superseded, nor on the whole does the speaker believe that a much better contrivance will be found for simplicity and effectiveness. Accidents here are caused by lifting the link with the hand, by which the hands or fingers are crushed. Freight trains cannot be backed with the steadiness of passenger trains, and hence a sudden dash of the cars catches the hand before it has time to withdraw. For the same reason, the man is often struck, and his foot slipping, he is thrown down and injured, or killed before he can escape.

An old brakeman told the speaker that he had coupled cars daily for twenty years and never had an accident, though he had had dangerous bumps while between cars. He said he never lifted the link with his hand but always with the pin, and the instant the link entered the jaw he put the pin in its place. Now if a long iron stirrup or step, reaching down to within a few inches of the ground, was fastened to the end of the car near the draw-bar, with an iron handle placed at a convenient height above, to be grasped by the left hand while the foot rested in the stirrup, the coupler could easily and safely use the right hand with the pin in it to lift the link and afterwards insert the pin; while being on the car itself he would not be in danger of injury from a sudden jolt.

Mr. Drummond does not refer to a recent invention for preventing car trucks from turning at a dangerous angle in cases of derailment. The plan, though new, has been severely and successfully tested by an accident to a Canada Atlantic passenger train, which, in consequence of a bush fire that consumed the track sleepers, was derailed and almost entirely consumed without a single car having been damaged by telescoping or collision ; and thus not a single passenger was injured. This is a very remarkable case, and well worthy of careful consideration. One more point is to be noticed : namely, the tools that the law requires to be carried in Passenger cars. These are generally placed in receptacles that can be opened ; and now-a-days, for that reason, the places are to be commonly seen but not the tools. The best mode is to place them in a cage, formed of light wooden slats, which must be broken before they can be got at.

Mr. Macklin. In selecting "Railway Accidents and a Railway Commission" as a subject for a Paper. Mr. Drummond has opened a somewhat comprehensive question to friendly criticism, that can only be lightly touched upon within the limits prescribed for the discussion of a scientific paper.

It has first to be shewn, that the proper and most effective means of exercising control over Railways, whether in regard to accidents, or generally in respect to all matters in which the public interest in Railway is concerned, can be best secured by creating a so called Railway Commission.

Experience of the working of Railway Commissions, whether in England, the United States or Canada, has not proved its adoption to be the one and only successful way of dealing with the question.

The subject, in this country, has long exercised some of our legislators in the Provincial as well as the Dominion Parliaments ; but we often find that the most active supporters of State interference with Railways, and of positive measures of Railway legislation, come from among those who know least about the difficulties surrounding the subject. These gentlemen, if they could, would prescribe the management and policy of the Railways of the country, regardless of the fact that though public highways, they are also private property.

It was probably to guard against, and put a stop to unpractical legislation, and to satisfy hobby riders on Railway reform, that the Dominion Government deemed a full enquiry by Royal Commission the most business-like way of getting the facts concerning so important a matter. Hence it is, that to the Report of the late Royal Commission we must look for the only opinion of real value, so far as Canada is concerned, that has yet been given on the subject of a Railway Commission.

It is true its investigations were confined chiefly to enquiries respecting tariffs, discriminating rates, and so forth; but the object for which the Commission was established, was to discover if the necessity existed for creating a permanent Commission that should be empowered to deal with all matters of Public Policy relating to Railways.

The report is unfavorable to the founding of such a tribunal. Its recommendations lie chiefly in the direction of giving more extended powers to the existing Railway Committee of the Privy Council, a conclusion which, it may be safely stated, will be generally accepted as wise and practical, as being the proper means of regulating our commerce, of protecting and conserving public interests in all matters concerning Railways, and of solving a problem, fraught with many concealed difficulties, without friction to the companies and with least injury to the important private interests entrusted to the management of Railways.

Mr. Drummond refers to the fact that Permanent Railway Commissions have been established in twenty-one States of the Union. We may congratulate ourselves that we are not similarly afflicted.

In the first Report of the Interstate Commerce Commission, it estimates that no less than twelve hundred Railways, operated by five hundred corporations, are subject to the Provisions of the Act.

Is it not, therefore, a striking commentary, that whereas twenty-one Permanent State Railway Commissions, out of a possible thirty-eight, have been created to control a portion only of the enormous Railway System of the Union, the Federal Government, under the Interstate Commerce Act, is satisfied to place in the hands of four men, the entire responsibility of dealing with the most perplexing problems relating to the Regulation of the vast business of the whole of the 138,000 miles of Railways in the United States?

Judging from this, therefore, it seems that we can, at present, at all events, without unduly burdening our Ministers, place in their hands the duty of dictating the public policy that shall control our 11,000 miles of railway.

We should not look altogether for guidance, or place too much reliance on the experience of State Commissions. They are often affected by State Politics. According to the judgment of the Supreme Court of the United States, the Legislatures of the several States have complete control in all respects, of the Railways within the limits of the State. As a consequence of this power, legislation is introduced to meet every supposed grievance, and laws are enacted that do a manifest injury to railway property, and an injustice to those who have invested their means in them. As instance the fact, that there are now before the State Legislature of Iowa, a State possessing a Railway Commission, no less than seventy-five Bills introduced since January, each providing some sort of regulation of railways. The statement is made in regard to it, that if the proposed legislation becomes law, as it probably will, politics being at the bottom of it, the value of the railway property of the State will be decreased at least one-half, or $175,000,000.

Such a condition of affairs might have its parallel in Canada, if our Provincial Legislatures controlled each in their own way the large Railway interests of the country.

What, among the list of suggested duties of a Railway Commission laid down by the author of the paper under discussion, could not be equally well treated in the public interest by our Railway Committee?

With the Consolidated Railway Statutes before it, to guide its deliberations, and proper departmental officers to advise it, there is no reason why the public interests should suffer. The history of this tribunal in the past has been eminently satisfactory to the public and to the Railway Companies.

With Mr. Drummond's statistics it is not my purpose to deal. They are very unfavorable to Canada, and would reflect seriously on the management of our Railways and on our laws, were it not for Mr. Drummond's subsequent remark that they are "*without any exact value.*"

We shall all be pleased to feel that it is so, that we need place no reliance on them. But what are we to think of the publication of such disquieting statements? Why, if fallacious, make use of them at all?

Statistics, to be of value as an instrument of reference, must be expressed in figures of undeniable accuracy; and the most conscientious enquirer will fall into difficulties in preparing comparative statistics, if, in order to support his argument he resorts to figures that can only be comparable when based on equal conditions.

Turning briefly to consider Mr. Drummond's recommendations for the greater safety of the travelling public:—

GUARD RAILS ON BRIDGES AND EMBANKMENTS.

There is a wide difference of opinion as to the value of Guard Rails on Bridges. Personal experience leads one to doubt their efficacy, and to conclude that the advantages claimed for them are of questionable utility in time of emergency, as in the event of sudden derailment of a train at high speed, except, perhaps, under certain circumstances.

The exceptions are where bridges are approached by curves or built on curves of greater curvature than, say, 4°. In such cases a check-rail should be placed next to and inside the lower rail, to counteract the centrifugal tendency of trains at high speed, to leave the track on a tangent.

The speaker knows of no practical system that can be shown to be a real safeguard in the event of derailment, not even the complicated and expensive Latimer Guard referred to by Mr. Drummond. Our guards are necessarily set too low, to clear the Snow Plough, to have much effect in turning the direction of a derailed train. Why bridges should be selected for special protection, has always appeared to him to be an anomaly. As a general thing the track on bridges, being unaffected by frost or weather, is usually in better alignment and surface than other parts of the line. It is also suggested that *guards* be placed on embankments. What embankments? What is the least height of embankment to be so provided? Where are we to draw the line? The result of a "run off" on a five feet bank is as likely to be as disastrous to those concerned as if it had happened on a ten feet bank; so that, to be consistent, we must place the "guards" on five feet banks as well, and why not then *ad infinitum.*

All Engineers will agree with Mr. Drummond that the decks of bridges should be laid close, by which is meant that the ties should be spaced not more than 4 inches apart, and be strong enough to carry a derailed locomotive. Moreover, all bridges should be designed to meet, with a wide margin of safety in their favor, any strains that may be legitimately put upon them, whether due to frequent traffic, heavy rolling stock, or high speed.

All these important points, however, will be wisely considered and looked to on any important line, where responsible and efficient officers are employed, with special duties to perform, and reputations to uphold.

Other safeguards and suggestions for the safety of public travel and railway employés, referred to by Mr. Drummond, are steps more or less in the right direction.

Railway officials are fully alive to the question of safety, and realize only too forcibly, by the most telling evidence, the immense responsibility placed upon them by the public; and they will be found ready to adopt, without the goading influence of Railway Commissioners, any safeguard of unquestioned value that will commend itself to their practical judgment and experience, as being likely to prevent loss of life and property.

The speaker would pronounce against the establishment of a Railway Commission, or any tribunal other than the Railway Committee of the Privy Council, because in that body with its Book of Statutes, compiled by Parliament as experience dictates and the country needs, with means of extending its powers indefinitely in any direction that Public Policy may require, with a properly constituted staff of Departmental officers as an advisory Board, and its actions for good or evil, subject to the full criticism of the Parliament of the country, the wants of the public in the direction of Railway regulation will be amply provided for.

Mr. Harkom

An examination of the statistics set forth in this paper shew the truth of the saying—that figures may be made to prove anything—if it is sought to shew that travelling in Canada is more hazardous than in the United States.

The remarks referring to the table compiled from U. S. statistics, rob it however, of any value it might otherwise have had, for they shew it to be impossible to calculate any percentage of casualties for purposes of comparison with Canadian statistics. The speaker has not had the opportunity of examining them very closely, and has left them to those gentlemen who are more competent than himself to deal with them. He will confine his remarks to the more or less practical suggestions offered as likely to render railway accidents less frequent, and which it would be the part of the duty of a Railway commission to see put into practice.

They being under separate headings, he will discuss them in the order in which they occur in this paper.

GUARD RAILS.—The proposal to put guard rails on all embankments exceeding a certain height naturally suggests the question, "What height?"

As on all Railways within the region affected by snow-fall, it is desirable to build the road-bed at least three feet above the level of the surrounding country, and there being also a ditch beside the track, we may reasonably expect to see a bank five feet high, down which a very respectable tumble would result to any train leaving the rails.

This being the case we might as well put guard rails all along the road bed, and to carry the suggestion out, might make a trough, put the rails in the shape of runners on the cars with wheels in bottom of trough, when we might reasonably expect never to get off the track. One thing is particularly noticeable in this connection, and that is, that it is assumed that the running gear is always in good order after the derailment, the latter being, so far as this paper is concerned, a mysterious dispensation of Providence, and something not considered. The fact is, however, that in only too many cases we hear of broken wheels, caused by the tremendously heavy strains to which they are subjected in this North American climate, as being the cause of derailment, and no guard rail will keep a broken wheel in its place after it has once struck the top of the guard rail.

The proposal to put heavy additional guard rails near the trusses of bridges is a peculiar one, as the consideration of the position of the body of car when the wheels reach that point will shew.

The question whether the floor system is able to carry a derailed train is of no importance, as when a train gets into that position, a few more precautions such as those recommended, do not amount to much, for if the speed of train is reasonably great the cars will pile up. It is also altogether overlooked what the result of a derailment in a cutting would be, where cars pile up far worse than on a bank on which there is room for them to spread. It is apparently inferred in this paper that guard rails and a stronger floor system would have modified if not prevented the Dedham disaster, whereas, if the cause, as generally given, was the true one, they could have had no effect on it whatever.

Bridge Inspection.—In this connection the inference is made that Canadian roads get an insufficient amount of inspection, which the speaker challenges as an unsupported charge. Such inspection is not only considered necessary, but carefully carried out on any road that carries passengers or freight, with a view to profit, the result of a failure being only too likely to affect the earnings to a very considerable extent. The remarks concerning the New York Commissioners are a little confusing, as the distinction between design, construction and maintenance is lost sight of, and, on behalf of a most intelligent and trustworthy class of men, the bridge foremen, it may be declared that the New York Commissioners did not desire to throw discredit upon them if on any one.

The Dedham bridge is again here brought in under a different aspect, and another slur, on what may be called the very backbone of mechanical production, viz., "machinery," is given.

It is by no means shewn by this paper, or by anything the speaker has heard on this subject, that any theoretical examination would have detected what was actually a mechanical failure, and we may reasonably dismiss the subject in this connection, by saying that this particular machinist did not do his duty thoroughly.

Overhead Bridges.—It is not at all to be considered as a direct consequence of the adoption of power brakes on freight cars, that it will be unnecessary for the brakemen to be on top of the cars, as, especially on long grades, they have to go over them to relieve brakes in order to prevent overheating by continual application, it being unsafe on many grades for the brakes to be released on all the cars at the same time.

The correct principle would seem to be to regulate the height of the cars as well as that of the bridges.

In Canada, however, we are on this point a long way in advance of the U. S. in our railway legislation, our head limit being more.

Freight Car Power-brakes.—So much has been said on this point, that it calls for little notice in these remarks beyond the statement, made as the result of experience as a Railway official actively connected with the working of a large district, that the cases of men falling from cars are largely over-estimated.

RAILINGS.—Such protection, as is suggested here, and as was brought up in the Ontario Legislature some years ago, is simply impracticable and really more likely to cause than to prevent the evil (so largely exaggerated) complained of. The best safeguards for a man in the position of a brakeman on freight cars are a clear head, quick sight and a firm foot, and any one not possessing these has no business there.

COUPLERS.—The amazing statement that nearly one-third of the casualties to "*passengers*, employees, *and others*," arise from coupling cars, leads one to suppose that the author of this paper must have been misled by the statistics he has consulted.

The very fact of the use of automatic couplers on passenger cars for so many years, and the fact that the speaker never remembers hearing of injury or death resulting to *passengers* and *others* from this cause, helps to cast a doubt upon the reliability of statistics quoted elsewhere.

The statement as to increase in Massachusetts, also seems to call for more light before a conclusion can be arrived at, and it may be stated that in the case of a man coupling cars, and apart from falling or stumbling, etc., there is no necessity for him to get crushed between draw-bars, as no man need put his fingers to do what a piece of stick will do equally well, and with less cost for sticking plaster in case of squeezing.

The enumeration of a number of well advertised freight car couplers, out of the large number which are to be found in the Patent Office, at Washington, is by no means a proof that they do their work satisfactorily; and the fact that the Master Car Builders are even now trying to reconcile the different principles or designs, shews them to be unsuitable for the purpose intended, and they are really only attempts to do by other means what is so ably done by the Miller Hook and Buffer in use on passenger cars.

PASSENGER CAR TOOLS.—A very good thing and very practically set forth in the paper.

TESTING OF WHEELS.—This is imperative, and is actually done more carefully and oftener in Canada than on American roads generally.

ELECTRIC LIGHT.—Whenever practically perfected, this will without doubt come into use without legislative action; meanwhile, the using of the mineral sperm oil of 300° fire test is the best thing that can be done, and cases where damage is said to have followed its use have never been properly verified.

STEAM HEATING.—This matter is still in its infancy, and until the experiments have been properly made, the Baker heater is really the very best thing in use. The speaker has himself seen them very completely inverted by derailment of car and no escape of fire or damage result therefrom.

This system can also be combined with a supply of steam from the locomotive, and that will be the most satisfactory and practical solution of the demand made by the public since the deplorable loss of life by overturned stoves in passenger cars has been so frequently brought before it.

A satisfactory combination such as this, is the one to be desired in view of the difficulty noticed in this paper, of cars being side-tracked at local stations.

PULLMAN BERTHS.—The inference made concerning the appliances used to secure berths from being closed while in use, is not a just one, as no specified cases are known where the fastenings referred to failed; but under any circumstances, the hanging of a coat or other garment, on the hooks above, will effectually prevent the berth being closed and locked, no matter how it may be placed.

PASSENGER ACCOMMODATION.—So long as passengers are allowed to pay fare on the cars, so long will there be no remedy against sudden overcrowding.

LOCOMOTIVES.—Under this head the author makes an imputation of neglect, which a practical acquaintance with the construction and maintenance of loco-boilers would have saved him from.

SAFETY VALVES.—He makes a suggestion which bears on the face of it strong recommendations, but if such a safety valve as he describes were adopted, the incrustation, which is so well understood to form about all such openings as are referred to, would in a few days render it inoperative. The reduction of the number of openings in a boiler is the best cure or prevention of the danger indicated.

It is a little unfortunate that the author was not a little more clear in the description, as at first sight it is very like a recommendation to hermetically seal boilers, which safety valves, as generally used, are carefully arranged not to do.

Another case of difficulty in understanding statistics as set forth, occurs under this head, where it is stated that within a year and a half one hundred and sixty-two persons were killed or seriously injured, by scalding, in six accidents.

Now this makes an average of twenty-seven, and the speaker has no hesitation in saying that there must be a mistake somewhere, as it is to scalding by locomotives that this extraordinarily large number is said to have been due.

TRACKS.—The suggestion as to blocking frogs is good, but again this is not unknown in Canada.

It is perhaps an oversight that among all the suggestions for inspection made in this paper, no mention is made of the inspection of tracks, which, however, is always carried out, and much confidence is felt in consequence of the knowledge that such regularly and daily takes place.

The reference to level crossings of railways affords another instance of imputation of neglect, whereas the Dominion Railway Act is more particular in its requirements than those referred to, a full stop being always required.

EMPLOYEES.—The question of intemperance is not alone within control of the employee, but is actively and energetically dealt with by Railway managers and officials, as experience would shew the author if he were acquainted with any employee who developed such habits.

The question of rest is not the one it is represented to be, the trouble railway officials have, being rather to get men to take enough of rest than the urging them to work too long.

As to Sunday trains, let the public discourage them and they will not exist.

COMMISSIONERS.—The arguments advanced in favor of the appointment of such a body are not sound, and, moreover, a body clothed with the powers suggested would be simply unable to do the work indicated.

The qualifications which suggest themselves as required by its members are :—

1. Political economist. 2. Financial expert. 3. Commercial expert. 4. Architect. 5. Civil Engineer. 6. Mechanical Engineer. 7. Statistician. 8. Experienced R.R. manager.

When these can be secured in such a body, then it may be desirable to change the present system; meanwhile, the power of the railway committee is quite sufficient to meet any case, especially as all are so easily made amenable to the ordinary law for failure of any kind.

Mr. Peterson. That Mr. Drummond has made an unfair comparison between the accidents occurring in the United States, as compared with those in Canada, has been clearly proved by Mr. Wallis, and it remains yet to be shewn that the appointment of Commissioners has had the effect of rendering travel in the United States safer than in Canada.

One of the most serious accidents that has occurred for many years, took place last summer near Boston, in a State which the author quotes as being a model Railway State, and as having one of the best systems of Railway Commissions. He says that the appointment of Commissions has resulted in the safety of the roadway and rolling stock. The accident referred to was one caused by a defective bridge; the design of which was bad and the inspection of which must have been also defective, or such imperfect construction would have been noted and repaired. In Canada we have never had a single accident arising from a cause so evidently preventable by the exercise of a reasonable amount of oversight. The author affirms that while the United States are making such improvements in everything conducive to the safety of roadways, bridges and rolling stock, Canada with a contentment that is remarkable, is standing still, and the experience gained by our neighbors is unheeded by us. He has not, however, shewn in what way we are standing still, nor what experience gained by our neighbors we are not profiting by. The speaker has travelled within the last few years, over portions of most of the Trunk lines in the Eastern and Middle States, and has carefully examined the roadway and equipment of these lines. He fails to see in what respect the Trunk lines of Canada are behind those of the United States. Our road-beds are generally as well built and as well ballasted as those in the United States, and as regards the Canadian Pacific Railway, he could only say that the bridges are certainly as safe, in every respect, as those in the United States, and in many respects safer.

As to Overhead Bridges, Tunnels, &c., the Canadian Government requires that there shall be a clear headway of seven feet over the top of the highest car, which height is assumed by the Canadian Pacific Railway to be 14′ 6″. It must be apparent to any one travelling in the United States that less headway is provided there than in Canada.

The author lays down certain requirements which all Railways should be forced to provide or to carry out, relating to Guard Rails, Bridge Inspection, Overhead Bridges, Power Brakes on Freight Cars, Railing, Couplers, Tools, Testing of Wheels, Air Brakes, Electric Light, Steam Heating, Upper Berths, Tests of Locomotive Boilers, Safety Valves, Blocking Frogs, Level Crossings, &c., &c.

As to Guard Rails on all embankments exceeding a certain height, the author does not fix this height, and it would be difficult to do so, seeing that serious accidents have taken place just as often by running off low as off high embankments, and if Guard Rails are put on embankments it would be necessary to place them along the whole line, which even the author himself would hardly advise.

On the Canadian Pacifiic Railway double guard rails are put on all bridges, and every bridge is made strong enough to carry a locomotive when off the track, as safely as when on the track.

The author has only to examine the floors on the Canadian Pacific Bridges near Montreal, in order to see that at least some Canadian roads are as fully alive to rendering their bridges safe, as any Railway in the United States under the most vigilant Commissioners.

As to Bridge Inspection, the Canadian Pacific Railway has a body of Inspectors, who inspect each bridge every month, and are constantly going back and forward making careful examinations of them. They have special forms for bridge reports, upon which they state the condition of the bridge and give a full and detailed account of the necessary repairs. These reports are sent to the Head Office, where they are entered in a book provided for this purpose, an inspection of which shews the Engineer at a glance the condition of every bridge.

Power Brakes on freight cars will only be possible when all the Railways both in Canada and the United States agree upon a uniform height of cars and a uniform system of brakes, and when this is done automatic couplers will probably be adopted, if all the Railway Companies can agree as to which of the many shall be adopted. It is a fact not generally known that very few men are killed in coupling cars, the majority of accidents taking place when the cars are being uncoupled.

In the matter of tools on passenger cars, the Canadian Pacific Railway not only provides tools in each car, but provides a box of tools at the back and front of every train, and in this respect exceeds the requirements of the New York State law to which the author refers.

The question of testing wheels was a very much more important one in old days, and it is even more so in the United States than it is in Canada, where the trunk lines have not a single cast-iron wheel under any passenger car or locomotive.

In the matter of Electric Light, the Canadian Pacific Railway is quite prepared to adopt it, when any system has been devised that will be satisfactory. He knew of one road in the United States which had adopted the Electric Light, but which, a great portion of the time, has oil lamps burning along with the Electric Light. The oil used on the Canadian Pacific Railway cannot be set on fire even by throwing burning waste into it, so that there is no question of a fire arising from burning oil.

As regards heating, the Canadian Pacific Ry. has hot water heaters in every car, so arranged that in case of an accident, the water in the coils would almost invariably put out the fire. It must not be thought that there is no danger in connection with steam heating, for, to be efficient, a pipe with live steam must be carried either in or through the car, and in case of an accident and the breakage of one of these pipes, the car would in all probability be filled with live steam. It would seem preferable to run the chance of being burnt rather than the certain death that would result from live steam being allowed to escape into a closed passenger car.

Attempts have been made to heat the cars with steam at low pressure, and the front cars are by this means fairly heated, but in a case of a long train the rear cars cannot be made comfortable in this northern climate.

The upper berths of the Canadian Pacific Railway sleeping cars are not only provided with wire attachments to prevent them from closing in case of accident, but, unlike most American sleepers, they do not close by being pushed into position; they will only close when the handle is turned.

The frogs used on the Canadian Pacific Railway are all blocked, as are Switches, Guard Rails, etc. Where Railways cross on the same level in Canada, the law requires all trains to stop, and he knew of no case in which this law is not most strictly carried out.

In short, it may be said that in no one point are the Trunk lines of Canada behind those of the United States in matters pertaining to the safety of passengers, and it will be difficult to prove that Commissions would render railway travelling safer or more comfortable than it is at present.

It appears questionable if the present laws affecting railways, and referring to their inspection, would be improved by a Commission whose duty would be to report directly to the Government. Mr. Hannaford

This power is now vested in the Railway Committee of the Privy Council, which sends Government Engineers to examine and report on all questions that may arise, requiring their assistance to explain the position to the Committee.

The speaker has had experience in the working of several of the State Railroad Commissions.

In *Maine*, examinations are made twice each year. These are superficial, and a Report is published, giving the new material used, and general work done.

In *New Hampshire*, examinations of the railway are made only at intervals (and then superficially), it is rarely that the Commission meets, except on the demand of some locality for increased facilities.

In *Vermont*, the inspection is at intervals only, and then superficial.

In *New York State*, the Commissioners do not inspect in detail.

In *Michigan*, the Commissioners attend more to laws regulating railways than to the physical condition of the roads or to the details of structures.

He considered that some of the suggestions made by Mr. Drummond would not be practicable.

Guard rails on embankments and between the Main Line rails would be highly dangerous, tending to derail a train if anything jammed between the rails.

He has always objected to guard-rails on the inside of Main Line rails on bridges for the same reason.

Guard-rails on embankments, on the outside of Main Line rails, would be attended with great inconvenience, and in winter would require removal for purposes of clearing snow, and for shimming.

The Engineer of a railway will always use extreme care in having everything safe, according to his views and experience.

He is of the opinion that in Canada the power vested with the Railway Committee of the Privy Council is much more effective than any State Commission. It is but recently that in the City of Buffalo, N. Y., the State Commissioners failed to meet the public want, and that a bill is now being sought for in Albany to meet the difficulty respecting level crossings, and to appoint a Commission for such purpose. It would seem that the Reports of the State Commissioners, whilst containing much information, lack uniformity, and that practical examination which their position implies, whilst the system in Canada, being vested in the Federal Government, is uniform, and the power of the Railway Committee can be (and has been) increased from time to time as the growing demands of the country require.

Much of what Mr. Drummond states about appliances—patents or otherwise—which he considers applicable to our railways, would be useless and cumbersome. Railways have to apply remedies with great care, and after mature consideration.

Mr. MacDougall The essayist makes statements against the railway management of the Dominion, which are in some respects startling. The proportion of passengers injured and killed is beyond the limits of any figures Mr. Macdougall had ever seen. He had occasion some years ago to look into this subject, in a paper he read before the Royal Scottish Society of Arts, and the proportion then was immensely in favor of Canada. In our country we have no suburban traffic to speak of; in the busy centres of Britain the suburban passenger traffic bears a large ratio to the whole passenger traffic. Suburban and express main line traffic pass over the same rails, with greater immunity from danger and freedom from accident than the traffic of the streets.

This is due to the rigid regulations they have in force in Britain relative to interlocking of signals, and facing points interlocking with signals, as well as to the absence of fire in the trains. Any one who has had experience with the "foot pan" will absolve that innocent article from being a cause of heat far less of fire.

The telegraph system of working trains, in use on the continent, could be easily adapted to a system of interlocked signals. As he is not now connected with railway work, he cannot write with authority on the subject of signals; he would like to remark, however, that he considers the present system of signalling crude in the extreme. The first principle of a danger signal is a man facing a train with his arm at right angles to the *right side* of his body. This is laid down as the foundation of signalling by the British Board of Trade. In this country the arm is nearly always on the *left side*, and many examples can be produced where it is placed sometimes on the right sometimes on the left. If a semaphore is a warning, or a guide to an engine driver, he ought to have some uniformity of practice to guide him. The night danger signal is always red, the day danger signal should be likewise uniform.

The question of guard rails which is now so much agitated is, a curious revival of a disused custom. About 25 years ago, they were uniformly adopted on bridges and viaducts on the great Scotch Trunk lines; after a few years they fell into disuse, as they were looked upon as a source of danger to the wheel. Since the Tay bridge accident, they have come into use again, and are placed on the new bridge, but not near the rail.

The numerous cases of wheels leaving the rail, and at the points (or switches) in particular, which have been reported this winter, call for some amendment to the present system. The Engineering journals are full of advertisements of switch and signal locking apparatus, but the employment of it does not seem to find favor. It is to be hoped some member, whose work lies particularly in track maintenance will now, or in a future paper, give the Society information on these important points. A train should have no difficulty in running through a properly set and guarded "facing point." Hundreds of trains do this daily in Britain.

Many of the other points referring to accidents could be dealt with, if there were an organization similar to the English Railway department of the Board of Trade, with officials having the power to compel railway Companies to carry out their orders.

On one point he disagreed with the essayist, that of making city and municipal corporations bear the greater share of the cost of forming and watching level crossings, and of constructing bridges in cities. He says: "A railway is now rather to be regarded as a greater factor in the "public convenience and in the national prosperity, than as a means "through which private individuals may be enriched." Such being the case, when a railway helps to build up a city, it in turn builds up the railway. If a railway crosses a street which has been established before the advent of the railway, and in consequence of increased traffic both on railway and street, the public safety is endangered; or if a Company has a bridge which has long failed to meet the demands of street traffic passing over it, it is the province of the railway to increase the accommodation of the bridge, and in the case of a level crossing to provide a suitable safe means of traverse. This rule is enforced in Britain, where railways are worked as purely commercial enterprises for the profit of the shareholders. The Companies are compelled to put up bridges over level crossings, and provide other safeguards for the public at their own cost. He regretted the example recently set by the city of Toronto in undertaking a costly work, which should really be carried out by the companies themselves.

Mr. Drummond That such an interest has been taken by the members is very satisfactory. It was hardly to be expected that those who were connected officially with our numerous railways would be in entire sympathy with the objects of the paper, which was written largely in the interests of humanity and rather from the point of view which the public would take.

The main point of the paper has been in part lost sight of by some who have discussed it. Control over railways is needed in the interests of the public, and has to a certain extent been provided for by Parliament. The channel through which this control was intended to be exercised has not proved efficient from causes which are apparent. What is being done to remedy this? The general fact, which must appeal to every one's feelings of humanity, is apparent, that both in the United States and Canada large loss of life and injury to persons, annually arise in connection with railways from causes some of which certainly can be remedied. Provision exists on the Statute books for investigation into this. What under these Statutes is being done in Canada to consider efficient remedies and secure their adoption?

The statistics have been given in the paper to call attention in general terms to the number of accidents, and to the lack of uniformity in and the defective nature of the statistics in the United States, and not to afford a means of comparison between the accidents in the United States and Canada. The smallness of the passenger returns from Canada strongly suggests some way of making up the returns in the railway offices here, different from elsewhere. It seems unaccountable that States, with a population so very much less than that of Canada, should have as large, and in some cases an immensely larger passenger traffic, and the result is still surprising, even after allowing for the domesticity of the French-Canadians.

Mr. Wallis and Mr. Macklin appear to have overlooked the fact that no comparisons are drawn from the statistics given. Mr. Wallis is correct in so far as he says that the passenger mileage should be taken into account in ascertaining the proportion of accidents to number of passengers carried, but at the same time it is indisputable, that even the passenger mileage is an unfair criterion, more particularly as actual facts indicate that suburban travel leads to a very largely increased proportion of injuries and deaths to employees. Though the passenger mileage in Canada is not given in the official returns, Mr. Wallis must not take that of the Grand Trunk as a criterion for the whole country. The mileage of a large number of the leading railways of the United States shows that in some cases the number of miles travelled is very high (as for instance the Baltimore and Ohio, 88, and the Chicago and Grand Trunk, 85 per passenger during 1886), and yet the actual average number of miles travelled by all passengers in the different States, whose returns have been consulted, varies only from 14 in Massachusetts to 38 in Michigan. The addition of the returns of the Canadian Pacific was supposed by some speakers to increase the miles travelled in Canada to 100 or even 200 miles per passenger, but the speakers gave this as mere conjecture, and quite lost sight of the fact that the bulk of the travel on the Canadian Pacific is in Ontario and Quebec, and that one train each way suffices for all the passengers offered across the continent. It must be remembered that there are fifty roads in Canada, nearly all of them comparatively short lines, and it is the average of the travel on the whole that must be taken.

The statement has been made that the American roads do not make a return of all accidents, leaving the conclusion to be inferred that Canadian roads are more honest in their reports than those of the United States. This is a mere assertion. The American official returns are under oath in most, if not probably all, States, and wherever the details of accidents are given, they include a record of the smashed finger as well as of the dead and permanently disabled.

Though no particular railways have been referred to in the paper, it will readily occur to every one that many useful improvements have already been or are being introduced on leading Canadian lines of railways, and that an earnest effort is being made by them to produce a high standard of efficiency. There are, however, many other lines where this high standard is wanting, and there is no railway official who cannot find on his own road some room for improvement, which will conduce to greater safety of either employees or passengers, though he may be in doubt as to the best form of that improvement. One result of accidents on bridges within the last year, and the enquiries of the railway commissioners into their causes, is that certain new England railway companies, which have had the highest reputation for efficiency, and which never spared expense in attaining that efficiency, have found that notwithstanding all their efforts in the past, some of their bridges, hitherto considered strong, were defective in strength, and required to be thoroughly overhauled.

It has been said that a new country requires cheap railways. It none the less needs safe railways. New roads should be built to a fixed minimum standard in character of road bed, strength of bridges and capacity of rolling stock, commensurate with the maximum load and speed to be allowed. Among many railway promoters Government inspection is regarded as very superficial. It has happened on provincial roads that a trip over the line by a member of the local government, in company with some of the railway directors, has not only secured the payment of the government subsidy, but has enabled the railway company without further inspection to open its line for traffic.

The subject of steam heating, referred to by various speakers, is now gradually going beyond the range of mere experiment. It was the general principle and not any particular system which was advocated in the paper. After careful trial, the Boston and Albany and Connecticut Valley, among other roads, have recently decided to equip, the one its whole the other its through, service on this particular principle, and to abolish stoves.

Electric lighting has now been introduced on the Great Northern Railway of England, four whole trains being equipped each with ninety-two lights--two in every compartment--and with forty four accumulators. The initial cost, however, is £400 stg. per train, and the weight added two or three tons.

The chief aim of the paper is the advocacy of a railway commission. If the Railway Committee effectively exercised even the powers which it possesses, it would be a source of much good; but its members have other duties which properly have prior importance, and do not give and cannot possibly give that extended time and attention which is absolutely required in investigating the various matters which the Railway Act has placed under their jurisdiction. The public—aware of this—seldom take advantage of this tribunal. It is no disparagement of the acknowledged abilities of the members of the Committee to say this. The recent suggestions on this point of the Royal Commission would be an improvement; but it is still a question whether members of the Government, which itself owns and operates railways, can form an impartial tribunal. A commission responsible directly to Parliament would seem more advisable.

There seems to be an impression that a railway commission exercises an unjust interference with private rights, but the fact is forgotten that these private rights in the case of a railway are all obtained from the public through its Legislatures. Besides, as Mr. Brown has stated, corporations and individuals, and he might have added even governments, are none the worse of some supervision. No railway company can claim to be absolutely perfect in the arrangements connected with its business, and infallible in the opinion of its management; and in the nature of things the private interests of the corporation will occasionally seriously clash with those of the public. Apart from this, however, a properly constituted impartial railway commission is a tribunal of which the railways themselves would take frequent advantage, as in the matter of railways crossing each other, roadway crossings, right of way, municipal taxation, interchange of traffic, parallel railways, and in many other respects.

Mr. Macklin's criticisms are briefly answered by the fact that the Royal Commissioners' Report of January last expressly admits that both the public and the railways have been benefited by the existence of railway commissions in the United States and Great Britain, and recommends the extension of the powers of the Railway Committee, not as a permanent remedial measure but as in the Royal Commissioners' own opinion the best plan, until further experience has been gained of the working of the commissions elsewhere. Further, whilst these Royal Commissioners' enquiry was intended to be chiefly if not almost exclusively into discriminating rates, the report expressly recognizes by its recommendations that investigation into the causes of accidents on railways should be an important function of the Railway Committee. The Interstate Commerce Act, to which also Mr. Macklin refers, is intended to deal it might be said entirely with discriminating rates, does not touch the subject of accidents, and can only affect railways running from one State to another or to a foreign country. The Act, therefore, whilst dealing with one subject which the Railway Commissions in the separate States had not been able to satisfactorily meet, left these State Commissioners' powers practically where they were before.

22nd March, 1888.

E. P. HANNAFORD, Vice-President, in the Chair.

The following candidates were balloted for and duly elected as

MEMBERS.

Horace Clements Alexander.
Richard Clayton Boxall.
Charles Henry Dancer.
Edwin Forse.
John Galt.
Charles Edward Goad.
William McCarthy.
James Rudston Perry.
James H. Taylor.
John Fraser Torrance.
Thomas Hoggan Mather.

ASSOCIATE MEMBERS.

Archibald William Campbell.
George Herrick Duggan.
Alexander King Kirkpatrick.
Alfred Thomas.

ASSOCIATES.

Charles Cyprien DuBerger.
William Henry Davis.
John Ferguson, M.P.
William Hobbs.
Hubert R. Ives.
James Isbester
Kenneth Sutherland.

STUDENTS.

Sidney Calvert.
Charles R. F. Coutlée.
John Sterling Covert.
William Kendrick Hatt.
William C. P. Heathcote.
Benjamin A. L. Huntsman.
John George Gale Kerry.
Harold Archibald Morrow.
William Russel.
Henry Black Stuart.
Douglas Bury Wilson.

The discussion upon the paper on Railway Accidents and a Railway Commission by Mr. A. T. Drummond, occupied the whole evening.

5th April, 1888.

P. A. PETERSON, Member of Council, in the Chair.

The discussion upon the paper on Railway Accidents and a Railway Commission by Mr. A. T. Drummond, occupied the whole evening.

19th April, 1888.

P. A. PETERSON, Member of Council, in the Chair.

The following candidates were balloted for and duly elected as

MEMBERS.

RICHARD PLUNKETT COOKE. GEORGE HOWARD ELLERS.

ASSOCIATE MEMBERS.

HERBERT JOSEPH BOWMAN. WILLIAM ROBERT PILSWORTH
ROBERT B. KENRICK. ALFRED PAVERLEY WALKER.

ASSOCIATES.

WILLIAM ELLIS BROWNE. JOHN MCKENZIE.

STUDENTS.

WILLIAM DUVAL BAILLARGÉ. ERNEST ALBERT STONE.
JAMES ANTHONY GALLAGHER. JAMES J. TAYLOR.
DAVID ANDREW ROSS. WILLIAM H. H. WALKER.
JOHN EDWARD SCHWITZER. THOMAS HENRY WINGHAM.

16.

THE C. P. R. BRIDGES OVER THE OTTAWA RIVER AT STE. ANNE AND VAUDREUIL.

By C. E. W. DODWELL, M.CAN. SOC. C.E.

The Ontario and Quebec Railway, built some four years ago between Smith's Falls and Toronto, and forming the most important part of the Eastern system of the Canadian Pacific Railway, was extended in the years 1886 and 1887 easterly from Smith's Falls direct, thereby cutting out Ottawa, and reducing the distance between Toronto and Montreal by nearly fifty miles. The line from Smith's Falls to Vaudreuil, about 100 miles, is as nearly as possible an air line. At the latter point it comes into parallelism with the Grand Trunk Railway, running close alongside it from thence to Lachine Bank, where it slightly diverges to the north to make connection with the Atlantic and North-west Railway running from Mile End to the new bridge across the St. Lawrence at Lachine.

At Ste. Anne the line crosses a branch of the Ottawa river flowing between the Island of Montreal at Ile Perrot, by a bridge parallel to, and 61 feet distant, centre to centre, from the Grand Trunk Ry.

bridge. The bridge consists of two abutments and thirteen piers of masonry, and fourteen girder spans of steel.

Beginning at the east end, and measuring from centre to centre of piers, the first three spans are 104 ft. 9 ins. each. These are lattice "through" girders, the object being to give as much head-room as possible over the canal locks. The fourth span is 324 ft., and the girder a pin-connected through truss of the most modern American design. The corresponding span on the G. T. Ry. bridge, is only 220 ft. Owing, however, to the obliquity of the current in the river at this point and the consequent danger to descending rafts, the Department of Railways and Canals required, that in the new bridge there should be no pier in the stream opposite to No. 4 of the G. T. Ry. bridge; consequently pier No. 4 of the new bridge corresponds with No. 5 of the G. T. Ry., and there is one span of the former to two of the latter. The 5th span is 101 ft. 4 ins., and the 6th 100 ft. 9 ins., both being lattice "deck" girders. The remaining eight spans are 66 ft. 1½ ins. each, and are plate "deck" girders.

The East abutment is built directly on the solid rock, which was found at a depth of 2 or 3 feet below the surface of the ground.

The rock here is the Potsdam sandstone overlaid in the immediate vicinity by the Trenton limestone. It is of the latter stone that the whole of the masonry is built.

At pier No. 1, which comes between the public road and the new lock, the excavation was carried down about eight feet below the surface, at which depth solid rock was found sloping to the S. W., at an angle of about 15°. Convenient fissures in the rock enabled a trench to be formed a couple of feet deep and about the same in width, along the axis of the pier, in order to provide against the possibility of the pier sliding on the rock. Concrete was then deposited in this trench, and brought up level to the height of the highest point of the rock, the masonry being started on the base thus formed.

Pier No. 2 came between the old and new locks, and the excavation for the foundation encountered the puddle trench and its crib-work backing, that was formed to exclude the water from the works of the new lock constructed in 1882. This puddle trench, as well as a quantity of cribwork, had to be removed in order to reach a solid foundation. The last foot or two of the excavation being under water was finished by the aid of a diver, and at about 15 ft. below the surface of the ground, the solid rock was struck, lying with but a slight fall to the S. W. After the surface of the rock had been thoroughly cleaned off by a diver, it was covered by a bed of concrete about 5 ft. thick and about a foot larger each way than the bottom course of the masonry.

The first stone of the bridge was laid in this pier on the 3rd of August.

Pier No. 3 was the most troublesome and expensive of the whole thirteen. It came between the old canal lock and the river, and the South wall of the former, and the cribwork bank of the latter, contributed to render its construction both tedious and costly.

The excavation was carried down to water-level in the ordinary manner without much trouble. To continue the excavation below this level it became necessary to remove some forty feet in length of the cribwork in the river front; permission to do this having been obtained from the Department of Railways and Canals. A dredge was then brought up and fixed in position in the river abreast of the pier site, the excavation being by means of it carried down very nearly to the solid rock. Owing, however, to the proximity of the wall of the lock, the dredge had to work with extreme care, in order to avoid disturbing its foundations. As soon as the dredge had done as much of the excavation as could be safely and conveniently done by it, three divers were sent down to complete the cleaning of the bottom; and a bottomless rectangular caisson 34 ft. long and 13 ft. wide was framed in position of whole timbers 12 inches square. The object of this caisson was to prevent the sides of the excavation from filling in and covering the site of the pier, as well as to form a mould for the bed of concrete. By means of accurate soundings, the caisson was framed as nearly as possible to conform on the upper side to the irregularities of the rock and the projections of the lock wall. On the lower, or river side, there was a space beneath the lowest timber of some three or four feet As soon as the caisson was finally and accurately fixed in position, this space, as well as the small cavities that still remained under the timbers on the upper side, was enclosed by driving 3 inch planks around the outside of the caisson and spiking it firmly to the timbers. Inside the caisson as now fixed and enclosed, three divers continued and completed the final cleaning of the bottom, about ten days being occupied by this work. When this was satisfactorily accomplished, a bed of concrete, varying from 5 to 9 ft. in thickness, was deposited within the caisson by means of a square box of $\frac{3}{8}$ inch boiler-plate holding a cubic yard, the bottom of which was hinged in two flaps and adapted for tripping, the scow carrying the derrick that raised and lowered it, and on the deck of which the concrete was mixed, being in the old lock immediately abreast of the pier. The top of the concrete was levelled up and finished to a height of about 6 inches above low water, and eleven days later the masonry was begun.

Pier No. 4 is the first river pier, the site being bare rock and the water about four feet deep at lowest level. The caisson for this pier was framed to half its height at a convenient spot on the river bank below the bridge, and then towed up-stream by a tug, and lowered into position. On reaching the site of the pier, it was rigidly held in place by anchors at bow and stern, and the remaining height of timber was added. A bed of concrete, about 2½ feet in depth, was then deposited in it, and as soon as this had set sufficiently the water was pumped out and the masonry commenced. This pier, as well as No. 5, is built on a skew of 10°. 30′, i. e., the axis of the pier makes an angle of 79°. 30′ with the centre line of the bridge.

The 5th and 6th piers were built in a precisely similar manner; the water was of about the same depth, and the bottom also bare rock. At piers 7 and 8, the water being less than 2 ft. deep, caissons were not necessary, the water being excluded from the foundations by means of plain rectangular cofferdams of square timber built round the site. These were surrounded by a low wall or bank of puddle and then pumped out. All the excavation necessary, consisted of the removal of about a foot of loose and shattered surface rock. At pier 7, no concrete was necessary, the masonry being laid directly on the rock. At No. 8, the rock after being stripped of the loose surface was covered or levelled up with a bed of about a foot in thickness.

Piers 9, 10 and 11 are situated on a low rocky island, the surface of which is from one to two ft. above low water level; none of them required either caisson or cofferdam. No. 9 has no concrete under the masonry, while at 10 and 11, after stripping the loose rock from the surface, the bottom was merely levelled up with it.

Piers 12 and 13 coming in a foot or two of water, required cofferdams and a thin bed of concrete to level up with. At the West abutment, the rock, which was covered with some three or four feet of soil and loose material, was found to dip to the North at about the same angle as it did to the South at the East abutment. It was benched to receive the masonry, and no concrete was used.

A small bridge across a creek between Ste. Anne and Vaudreuil, consists of two spans of lattice deck girders 100 ft. 9 ins. each; the masonry comprising two abutments and one pier. These were built on solid rock, and present no features of special interest. The pier required a cofferdam, and the rock under it was levelled up with about a foot of concrete, none being used in the abutments.

At Vaudreuil the line crosses another branch of the Ottawa, flowing between Ile Perrot and the main land. The bridge here is parallel to, and distant 67 feet, centre to centre, from the Grand Trunk Ry. bridge. It consists of two abutments and sixteen piers of masonry with seventeen spans of steel "deck" girders. Beginning at the East End and measuring from centre to centre of piers, the first eight spans are 100 ft. 9 ins. each, lattice girders, the next seven spans are 71 ft. $2\frac{1}{2}$ ins. each, plate girders, the remaining two are 65 ft. each, also plate girders. The East abutment stands just above low water mark. Its foundation was carried down to a hard bottom of stoney clay at about 5 ft. below the surface. The first seven piers, and the sixteenth, were built in water varying from 8 to 20 ft. in depth. The first operation in their construction, after having closely covered the site of each pier with accurate soundings, was the removal of the gravel, mud and boulders overlying the rock, which was accomplished by an ordinary floating steam dredge anchored over each foundation in succession. Bottomless caissons built of 12 inch square timber, and pointed at bow and stern, were then towed into place, their exact positions being determined by means of two transits, one on the centre line of the bridge on shore, and the other on the G. T. Ry. bridge in the line of the axis of the pier produced. They were then firmly held in place by suitable and sufficient anchors, and weighted until they rested on the bottom. Very accurate and careful soundings having been taken over the exact sites of the piers subsequent to the operation of dredging, the bottom (i.e., the bottom edges) of the caissons were framed to fit the irregularities of the rock. As soon as they were in position, the bottom, within their area, was thoroughly cleaned by divers of all gravel and small boulders left by the dredge, any crevices between the bottom timbers and the rock being tightly packed with pea-straw. A depth of concrete equal to about one-third of the depth of water was then deposited with them by means of the iron box, and the surface of this bed levelled up by the divers. When the concrete had set the caissons were pumped out by a 6 inch centrifugal pump, driven by a floating engine of about 15 H. P., and the masonry commenced.

In one or two instances when the water was nearly all pumped out the bed of concrete was burst upwards by the pressure from below. When this happened, the caisson of course filled immediately, and it became necessary to send down divers to repair the leak, additional concrete also being put in for the purpose. Piers 8 to 15 inclusive, being in shallow water, required no caissons. The foundations were surrounded by cofferdams built of large flatted timbers, sheeted outside with 3 inch plank and with well rammed puddle walls all round. After the spaces enclosed by these water-tight dams were baled out, the excavations were carried down to the necessary depth with pick and and shovel, and the masonry built directly on the hard bottom without the use of concrete. The West abutment, like the East one, was built just above low water mark. A solid foundation of hard-pan was reached at a depth below the surface of about 8 ft. The whole of the masonry was finished about the 1st June, 1887.

The concrete used in these bridges was composed of Portland cement, sand and limestone broken to pass through a 2 inch ring. It was mixed in the proportions of 1 volume of cement, 1 of sand, and from 4 to 5 of broken stone, which made an exceedingly rich concrete. In fact, generally the beds upon which the masonry was built were almost as hard as the stone itself. A less expensive composition in the foundations would have easily and safely carried all the weight they were called upon to bear; but one of the objects in making the concrete so rich was that it might be capable of withstanding the strain of the upward pressure of water, due to the difference in level between the outside and inside of the caisson. This was occasionally considerable, in some cases being as much as 800 lbs. per sq. ft., and consequently any economy effected by stinting the cement, would probably have been sunk by the additional expense of repairing leaks, and by the loss of time in extra pumping.

The concrete was mixed on a decked scow anchored alongside the caisson. In the centre of the scow was a pile of broken stone, and at each end a number of barrels of cement and a pile of sand, leaving a clear space on each side of the pile of broken stone. A barrel of cement being broken open, the contents were spread out in a layer five or six inches thick; an equal quantity of sand was then added, and the whole intimately mixed in the dry state with shovels and hoes. A sufficient quantity of water was than poured into the centre of the mass, which was immediately worked into a moderately thin mortar. The broken stone was then thrown in from the heap, the quantity being so regulated that each fragment of stone was completely covered with and imbedded in the mortar. The whole heap, after it was thoroughly incorporated, by being turned over two or three times with shovels, was then thrown into the box which it just filled. While at one end of the scow the concrete was being mixed, at the other end it was being thrown into the box and deposited in the caisson; two gangs were thus kept constantly going and no time lost. The contractors for the whole substructure of these bridges, were Messrs. Wm. Davis & Sons of Ottawa.

The temporary staging for the erection of the superstructure of these bridges was of the ordinary character of trestle-work, consisting for the most part of four post bents at spans of about 14 ft.; with the exception that for the fourth span (324 ft.) of the Ste. Anne bridge, it was all erected in the winter, and calls for no special description.

Owing to unforeseen delay in the shipment of the 324 ft. span from Glasgow, where it was made, the false work for it could not be erected during the time of low water in the winter. When at length the iron did arrive, further delay was caused by having to wait till all the ice had broken up and gone down the stream. In consequence, the false work for this span, commenced May 5th, 1887, had to be erected when the river was at its highest and the current at its swiftest; the depth of water at the deepest point of the channel being 37 ft., and the current from 7 to 8 miles per hour at a considerable skew. Preparatory to framing the bents, accurate soundings were taken at the position of each post by means of lengths of gas-pipe steadied by lines to bow and stern of a scow, which was held in place by wire cables to the cribs described further on.

The bents were 13 ft. apart; those under panel points, i.e., every alternate bent, had five posts each; the intermediates three each. They were framed on a large scow lying alongside the upper canal pier. Before sending any of them down to their place, two small but heavy cribs, about twelve feet square in plan and six or eight feet high, were framed, loaded with stone, and sunk in the stream some four or five hundred feet above the bridge. In addition to these anchor cribs, two tugs were employed during the greater part of the time that this span of false work was in course of erection. As each bent was framed, the scow carrying it was lowered down stream into position, escorted by a tug, and steadied by wire cables to the anchor cribs. On reaching the site the lines to the cribs were made fast and the scow firmly held. The bent was then raised with suitable tackle by two small engines, one on top of each of piers 3 and 4, wire cables having first been made fast to the feet of the posts and carried up to the anchor cribs. As the posts in the channel bents were from 35 to 70 ft. long, the current from 7 to 8 miles per hour and the water 60 ft. deep, as has been said, it will readily be seen that the difficulties to be overcome in the construction of this temporary staging were of no ordinary character. In one or two instances the posts, upon feeling the force of the current, began to swing, the bracing gave way, and the whole bent had to be dropped into the stream to save the scow from being broken to pieces by the lashing backwards and forwards of the posts as the motion increased. A tug was then despatched to pick up the posts and tow them up the canal to be re-framed.

Immediately upon each bent reaching a vertical position, it was promptly steadied from the water line to the tops of the posts, a height of about 30 ft., by braces and waling pieces of 6 ins. × 10 ins. stuff bolted and spiked to the last preceding bent. Owing to the utter impossibility of ascertaining to a few inches the exact depth of water in which each post would stand, the braces and caps were all double, and attached to the bent by bolts passing through them, but not through the posts, thus leaving the latter free to move up and down to a small extent to suit the inequalities in the bottom. In addition to the wire cables attached to the feet of the posts, and as a further precaution against slipping, they were furnished with a heavy pointed spike bolt driven into the timber.

The last bent was successfully placed in position on the 27th of June, the "traveller" was completed on the 29th, and the erection of the span commenced on the 30th.

Superstructure. The following table gives the more important particulars of the superstructure of the three bridges :

Number of Spans.	Length Centre to Centre of Piers.	Neat length of Girders.	Width Centre to Centre of Girders.	Weight of each Span. lbs.	Price per lb. erected.	Remarks.
	Ft. In.	Ft. In.	Ft. In.		Cts.	
1	324.0	323.3*	20.0	931,749	4.80	Pin connected "Through" Truss.
3	104.9	104.4		176,870	4.15	Riveted Lattice " Girders.
1	101.5½		10.0	108,478	4.15	" " "Deck" "
11	100.9		10.0	108.478	4.15	" " " "
7	71.2½		10.0	64,337	3.77	" Plate " "
8	66.1½		10.0	55,541	3.77	" " " "
2	65.0		10.0	55,300	3.77	" " " "

*Centre to centre of end pins.

Plates 5 to 8 give general elevations of the bridges, and detail drawings of the piers, abutments &c. Extracts from the specification are given in an appendix.

The whole of the spans are of steel, built under the direct supervision of the Company's inspector.

The contractors for the work were the Union Bridge Co. of New York. The sub-contractors who actually built the spans were as follows: —For the 324 ft. span, Arrol Bros., Glasgow (except for the eye-bars, which were made at the Union Bridge Company's own works in Buffalo). For the 104 ft. 9 ins. spans, The Horsely Co., Tipton, Staffordshire, England. For the 101 ft. 5½ ins. and the 100 ft. 9 ins. spans, The Cleveland Bridge Co., Darlington, England. For the 71 ft. 2½ inches 6 ft. 1½ ins. and the 65 ft. spans, Arrol Bros., Glasgow.

The cost of the bridges described is given by the following statement:—

STE. ANNE BRIDGE.

ITEM.	QUANTITIES.	RATE.	AMOUNT.	AMOUNT.
Earth excavation. Cub. yds.	1,830.4	$0.31	$567 42	
Loose rock........ " " .	112.6	0.90	101 34	
Earth and loose rock excavation under water. C. yds.	573.3	2.00	1,146 60	
Concrete. Cub. yds..........	474.00	15.00	7,110 00	
First class masonry. Cub.yds.	5,290.94	15.00	79,364 10	
Rough rip-rap. " .	147	1.50	220 50	
				$88,509 96
Sundry Extras.—Removing buildings from site of E. abutment, cutting checks for girder bed-plates in pier copings, handling timber, etc., etc.........................				1,110 97
Iron and Steel in Superstructure.—				
747,566 lbs. @		0.04^{15}	31,023.99	
444,328 " @		0.03^{77}	16,751.17	
931,749 " @		0.04^{80}	44,723.95	
				92,499 11
Timber in Floor.—				
181,852 ft. B. M. @ per M.		15^{00}	2,727 78	
11,560 " " "		18^{00}	208 08	
Extra work on floor, labour, etc.			150 68	
				3,086 54
Total cost of St. Anne's Bridge.........................				$185,206 58

"STOCKERS" CREEK BRIDGE.

Earth excavation. Cub. yds.	259.2	$0.31	$ 80 35	
Loose rock do " .	31.4	0.90	28 26	
Earth and loose rock excavation under water. C. yds.	37.3	2.00	74 60	
First class masonry. " .	939.77	15.00	14,096 55	
Concrete " .	4.70	15.00	70 50	
				$14,350 26
Sundry Extras.—Cutting checks for bed-plates, handling timber, etc.				361 39
Iron and Steel in Superstructure.—				
216,956 lbs. @ 0.04^{15}				9,003 67

Timber in Floor, etc.—

31,526 ft. B. M. @ per M.	15^{00}	472 89	
Handling timber		34 19	
			507 08
Total cost of "Stockers" Creek Bridge.............			$24,222 40

VAUDREUIL BRIDGE.

Earth excavation.	Cub. yds.	388.1	$0.31	$120 31	
Loose rock do	" .	5.5	0.90	4 95	
Earth and loose rock excavation under water.	C. yds.	1,566.1	2.00	3,132 20	
Solid rock excavation under water.	Cub. yds.	71.6	3.00	214 80	
First class masonry.	" .	3,385.68	15.00	50,785 20	
Concrete	" .	978.12	15.00	14,671 80	
Rough rip-rap	" .	4,728.	1.50	7,092 00	
					$76,021 26

Sundry Extras.—Handling timber, cutting checks for bed-plates, etc.. 870 69

Iron and Steel in Superstructure.—

867,824 lbs. @ 0.04^{15}		36,014 70	
560,264 " @ 0.03^{77}		21,121 95	
			57,136 65

Timber in Floors.—

213,422 ft. B. M. @ per M. 15^{00} 3,201 33

Total cost of Vaudreuil Bridge........................ $137,229 93

SUMMARY.

Ste. Anne Bridge..............................	$185,206 58
"Stockers" Creek Bridge....................	24,222 40
Vaudreuil Bridge..............................	137.229 93
Total cost of three bridges.......................	$346,658 91

During the progress of this work, there occurred two fatal accidents. On Friday, Jan. 21st, 1887, Mr. Harold W. Keefer, M.Can.Soc.C.E., Assistant Engineer, while in the discharge of his duties, fell from the top of the girders of Vaudreuil Bridge, a height of about twenty-one feet. He struck on his head and shoulders, the blow causing concussion of the brain, from which he died at half past six the following morning. Mr. Keefer was 29 years of age, a son of Mr. T. C. Keefer, C.M.G., Past-President Can. Soc. C.E., and an engineer of marked ability and great promise. The author is glad of this opportunity of recording the highest appreciation of his excellent qualities. As an engineer he was well up in his work, active, energetic and thoroughly devoted to duty. Of sterling worth as a man, he, in every respect, commanded the highest regard and esteem of all who knew him. Generous, open-hearted and the soul of honour, he was, in a word, his father's son.

On the 30th April, during the erection of the false work for the long span at Ste. Anne, a scow with five men on it, while being towed up stream by a tug, capsized in the channel just above the bridge line. Four of the men were rescued by boats from the shore, but the fifth, a young man by the name of Rodgers, from Glasgow, an employee of the Union Bridge Co., sank before help reached him. His body was recovered about a week later.

The chief engineer of the above work was Mr. P. A. Peterson, M. Can. Soc. C.E.; the resident engineer being Mr. C. E.W. Dodwell, M. Can. Soc. C.E.

From the drawings accompanying this paper, Plates 5 to 8 have been prepared.

DISCUSSION.

Mr. D. MacPherson.

The author has given a very detailed and graphic discription of the work, from its inception to the final completion of the falsework, for the superstructure of two large bridges, which were by no means easy of construction, though there seems to have been not more than the ordinary engineering difficulties encountered in bridging any deep rapid stream. The details of cost are valuable, but perhaps not so valuable as would at first sight appear, being doubtless the railway contract prices. It is to be hoped, for the sake of the contractors, that these are not the actual figures of the cost of the works to them.

The author will doubtless supplement his valuable paper by giving at least the *total* actual cost to contractors of the finished substructure, with as much detail as possible.

Mr. Peterson.

The author has missed one of the principal points in connection with the construction of these Bridges, viz., the rapidity with which the masonry was built. The contract was awarded to Messrs. Davis & Sons on the 17th May, 1886. The location of the channel piers of the St. Anne's Bridge was not fixed by the Government untill the 1st of July, 1886. The masonry was commenced at the St. Anne's Bridge on the 11th August, and at Vaudreuil on the 13th August. The masonry was all finished by the 24th December of the same year. The total quantity of masonry and concrete in the two bridges was 10,129 cub. yds., which is at the rate of nearly 2,500 cub. yds. a month.

The erection of the channel span of the superstructure of the St. Anne's bridge was the most difficult piece of work, owing to the depth of water in the channel which is 40 feet, and to the velocity of the current, at the time the false works were put in, which was about 10 miles an hour. In addition, it should be mentioned that the cross section, upon which the bents of the false works had to be placed, varied from 12 to 40 ft. in depth, rendering it extremely difficult to place them in position on the steep sloping surface of the rock. The experience gained here goes to shew, however, that bridges can be erected by means of false works in very difficult places, and that cantilevers are not so indispensable for such places as they have lately been considered by many prominent Engineers.

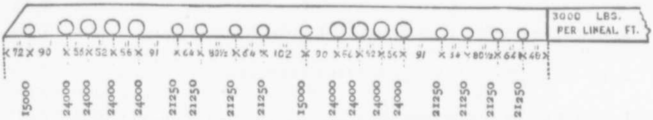
APPENDIX.

ONTARIO AND QUEBEC RAILWAY.

Extracts from General specification for the construction of the Bridges on the Ontario and Quebec Railway between Montreal and Smith's Falls.

5. Through spans, less than 100 feet in the clear, must have a clear width between the trusses of 16 feet. The 324 feet span must be 20 feet centre to centre of trusses. Deck spans less than 100 feet must be 10 feet centre to centre of trusses.

Spans of 80 feet and under may be either plate or lattice girders. Those over 80 feet and under 100 feet in the clear are to be lattice girders, and spans over 100 feet in the clear may be pin connected.



10. All spans must be proportioned to carry, in addition to the dead load, two consolidation engines coupled as shewn in the above diagram, followed by a train load of 3,000 lbs. per lineal foot, and the maximum strains due to all positions of the live load must be taken in proportioning all the parts of the structure. Floor to be laid with 8″ x 8″ pine ties, spaced 12 inches centre to centre with two guard-rails on each side of track, one 6″ x 8″ and the other 10″ x 10″.

11. Variations in temperature to the extent of 180 degrees Fah. must be provided for.

12. All parts of the structure shall be so proportioned that maximum loads shall in no case produce a greater tensile strain upon the net section than the following:—

		Pounds per sq. inch.
On bottom chords and diagonals	iron	10,000
" " "	steel	12,000
On counter rods, long verticals, and end lower chords	iron	8,000
" " " " "	steel	10,000
On lateral bracing (with 10,000 lbs. initial strain)	iron	15,000
" " " " "	steel	18,000
On bottom flange of riveted floor beams	iron	8,000
" " " "	steel	10,000
On bottom flange of longitudinal plate girders (over 20 ft.)	iron	8,000
" " " " " "	steel	10,000
On bottom flange of longitudinal plate girders (under 20 ft.)	iron	7,000
" " " " "	steel	9,000
On suspension loops or other members liable to sudden loading	iron	6,000
" " " " " "	steel	7,000
On solid rolled beams	iron	8,000
" "	steel	10,000

13. Compression members shall be so proportioned that the maximum load shall, in no case, cause a greater strain than that determined by the following formula:—

$P = 8,000 \div \left(1 + \frac{L}{40,000\ R^2}\right)$ for square end compression members.

$P = 8,000 \div \left(1 + \frac{L}{30,000\ R^2}\right)$ for compression members with one pin end and one square end.

$P = 8,000 \div \left(1 + \frac{L^2}{20,000\ R^2}\right)$ for compression members with pin ends.

P = Allowed compression per square inch of cross section.
L = Length of compression member in inches.
R = The least Radius of gyration of the section in inches.

For steel substitute 10,000 for 8,000 in formula.

No compression member shall have a length exceeding 45 times its least width.

14. In rolled beams and girders compression shall be limited as follows:

		Pounds per sq. inch.
In rolled beams used as floor beams or stringers	iron	8,000
" " " "	steel	10,000
In riveted plate girders used as floor beams, gross section	iron	7,000
" " " " "	steel	9,000
In riveted longitudinal plate girders (over 20 ft.) gross section.	iron	7,000
" " " " "	steel	9,000
In riveted longitudinal plate girders (under 20 ft.) gross section	iron	6,000
" " " " "	steel	8,000
In riveted lattice girders gross section	iron	7,000
" " "	steel	9,000

15. Members subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain. Both of the strains shall be assumed to be increased by an amount equal to 8-10 of the least of the two strains for determining the sectional areas, by the above allowed strains.

16. To provide for wind strains the top lateral bracing in deck spans and the bottom lateral bracing in through spans shall be proportioned to resist a lateral force, equal to 30 lbs. per square foot on the surface of the train averaging 12 square feet per lineal foot, and also on the vertical surface of one truss; the 360 lbs. pressure from the train surface to be treated as a moving load, and the pressure on the bridge surface as a fixed load. The bottom laterals in deck spans and the top laterals in through spans shall be proportioned to resist a lateral force equal to 50 lbs. per square foot upon the vertical surface of both trusses.

17. The strain in the chords from the assumed wind force arising from wind displacement (capsizing) and direct wind (transverse) strain will only be taken into account when they exceed one-quarter of the maximum fixed strain for dead and live loads. The sections shall then be increased until the total strain per square inch will not exceed by more than one quarter the maximum fixed for dead and live loads only.

18. The rivets and bolts connecting the parts of any member must be so spaced that the shearing strain per square inch shall not exceed 7,500 pounds or ¾ of the allowed tension per square inch upon that member; nor the pressure upon the bearing surface per square inch of the projected semi-intrados (diameter x thickness of piece) of the rivet or bolt hole exceed 12,000 pounds, or one and a half times the allowed tension per square inch upon that member. In the case of field-riveting the above limits of shearing strain and pressure shall be reduced one-third part. Rivets must not be used in direct tension.

19. Pins shall be so proportioned that the shearing strain shall not exceed 7,500 pounds per square inch for iron, and 9,000 per square inch for steel; nor the crushing strain upon the projected area of the semi-intrados of any member connected to the pin be greater per square inch than 12,000 pounds for iron and 14,000 pounds for steel; nor the bending strain exceed 15,000 pounds per square inch for iron and 20,000 per square inch for steel when the centres of bearings of the strained members are taken as the points of application of the strains.

20. In case any member be subject to a bending strain from its own weight, or from local loadings, such as distributed floors on deck bridges, in addition to the strain produced by its position as a member of the structure, it must be proportioned to resist the combined strains.

21. Plate girders shall be proportioned upon the supposition that the bending or chord strains are resisted entirely by the upper and lower flanges and that the shearing or web strains are resisted entirely by the web plate; no part of the web plate shall be estimated as flange area.

22. The iron in the web plate shall not be subjected to a shearing strain, greater than 4,000 pounds per square inch; and no web plate shall be less than three-eighths of an inch in thickness.

23. The web of plate girders must be stiffened at intervals of about the depth of the girders, whenever the shearing strain per square inch exceeds the strain allowed by the following formula:

$$\text{Allowed strain} = \frac{12{,}000}{1 + \frac{H^2}{3{,}000}}$$

When H = ratio of depth of web to its thickness.

24. No iron or steel plate shall be used less than $\frac{3}{8}$ inch thick, except for lining or filling vacant spaces.

The compression flanges of beams and girders must be stayed against transverse crippling when their length is more than 30 times their width.

The unsupported width of any plate subjected to compression must not exceed thirty times its thickness.

25. The flange plates of all girders must be limited in width, so as not to extend beyond the outer lines of rivets connecting them with the angles more than five inches or more than eight times the thickness of the first plate. When two or more plates are used on the flanges, they shall decrease in thickness outward from the angles.

26. In members subject to tensile strains, full allowance shall be made for reduction of section by rivet holes, screw threads, etc.

27. All spans shall be given a camber by making the panel lengths of the top chord longer than those of the bottom chord in the proportion of $\frac{1}{8}$ of an inch to every ten feet.

28. The inner guard rails shall be let down over the ties, till the top of the 3″ × 3″ angle iron, with which the upper inner angle is covered, shall be level with the top of rail. The angle iron must be straightened, and the holes for the $\frac{5}{8}$″ screws, with which it is to be fastened to the timber, must be slotted at the ends, so as to provide for a temperature varying between 40° Fah. below zero, and 140°. Fah. above zero. Holes to be in each leg of the angle, three feet apart in centre, and eighteen inches apart at each end. The guard rails must be bolted to every fourth tie with a $\frac{3}{4}$-inch bolt, so that heads of bolts on the inner guard will not be above the top of the angle iron.

29. All eye bars, rods, bolts and pins shall be made of a tough, ductile, fibrous iron, uniform in quality, and which shall be capable of withstanding the following tests, when applied to full sized sections of the material tested.

30. Round bars up to 1½ inches in diameter must bend double, or until inner sides are in contact when cold, without showing signs of fracture.

Square bars must bend cold through 180 degrees around a cylinder having a diameter equal to two-thirds the length of side, without showing signs of fracture.

Flats must bend cold through 180 degrees around a cylinder having a diameter equal to the length of the shortest side, without sign of fracture.

The ultimate strength of the bar iron used shall not be less per square inch than $52,000-\left(\frac{7,000 \text{ x area}}{\text{periphery}}\right)$ pounds; area and periphery being expressed inches.

The elastic limit shall not be less than 26,000 lbs. per square inch, and the elongation of the bar before rupture shall not be less than 20 per cent. in 12 diameters.

The reduction of area of breaking point shall not be less than 25 per cent. of the original section.

31. All plate and shape iron used in tension members, or in members exposed to both compressive and tensile strains, shall fulfill all the foregoing conditions when tested in specimens of one inch area and fifteen inches length of smallest section, except that the breaking strain per square inch shall not be less than 49,000 lbs. for angles, 48,000 lbs. for beams and channel iron, and 47,000 lbs. for plate iron.

These classes of tension iron must bend cold, without fracture, as follows:

For Shape Iron, - 140 degrees	and the ductility must be	For Shape Iron, -	16 p. c.
For Plate Iron, - 100 "		For Plate Iron, -	14 "

32. Wrought iron for compression members must be tough, fibrous, uniform in quality, and with an elastic limit of not less than 25,000 lbs. per square inch.

Specimens of one square inch area shall bend through 90 degrees around a cylinder 1½ inch in diameter, without signs of fracture.

All cast iron used shall be good, tough, grey iron, of such quality that a bar five feet long, one inch square, and four feet six inches between knife edge supports, will sustain a weight of 475 lbs. on knife edge at middle of beam before breaking.

33. All steel used in tension shall have a minimum tenacity of 60,000 lbs. per square inch, a ductility of 18 per cent. in 12 diameters, and test pieces 15 inches long and 1 inch in sectional area, cut either or both cross-wise or length-wise, of plate steel, and length-wise of bar or shape; after being heated to a low cherry red and cooled in water of 82 degrees of Fahr., must stand bending double in a press or under the hammer to a curve of which the radius is one-and-a-half the length of the shortest side of the test piece. These test pieces may be cut in a planing machine and may have the sharp edges removed. Two samples shall be cut from each plate—one of which shall be tested for tenacity and ductility, and the other for temper and bending, as above described.

Steel failing on both sets of tests shall be rejected.

Steel up to the standard in tenacity and ductility, but deficient in bending and temper test, shall be annealed after punching.

Steel up to the standard in all but ductility may be annealed and retested.

Steel that is up to the standard in all the tests need not be annealed.

34. All steel used in compression shall be of good quality of mild steel having a minimum tenacity of 65,000 lbs. or over, per square inch, an elastic limit of not

less than 40,000 lbs., a ductility of 12 per cent. in 12 diameters, and not less than 15 per cent. reduction of area at breaking point.

Specimens one square inch in area of section shall bend cold through 140 degrees around a cylinder, the diameter of which is four times the length of the shortest side of the test-piece.

No steel shall be struck with a hammer or worked while at a black heat.

All steel, whether with drilled rivet-holes, or holes punched and reamed, shall be matched with the other parts of same member, and before being riveted up, all holes shall be matched and brought to a fit by reaming alone and without the use of drift-pins.

The matching of the holes shall be sufficiently close to permit the parts to be riveted up without producing an initial strain on the steel. Splice riveting in steel will be governed by the specifications for top chords and columns.

35. All tension iron shall be rolled from piles composed of piling pieces, each the full length of the pile. The use of old rails will not be allowed in the piles or this grade of iron.

All rolled iron or steel shall be thoroughly welded during the rolling, and must be straight—of full section at all points—and free from injurious or unsightly seams, blisters, buckles, slivers, cinder spots and imperfect or crooked edges.

All material as it comes from the mill must be first-class in every way; rolled pieces cut too close to the crop ends will not be accepted.

36. All specimens for testing, cut out from large pieces, whether of iron or steel, shall have a uniform least section of one square inch for a length of not less than 15 inches.

All bar and rod iron shall be tested in full sized sections whenever practicable.

No test specimen shall be hammered or forged after being cut from the original piece.

Complete facilities for inspection of material and workmanship must be given by the Contractor. Facilities and specimens for testing, and also the necessary labor, shall be furnished by him without charge when called for by the Engineer or Inspector. But when any full sized manufactured iron or steel members are tested to destruction, and proved to be up to the standard required, such material shall be paid for at cost, less scrap value to the Contractor.

Should such members fail to reach the standard they will not be paid for, and the Inspector may reject all similar members made of the same material.

The testing machine used by the Contractor shall be compared with the U. S. Government machine at the Watertown Arsenal or the Kircaldy machine in England; and if the results vary, the difference shall be equated, and added to or subtracted from the results obtained from the machine used by the Contractor.

37. All workmanship must be strictly first-class, and not what is commonly termed "merchantable work." Finished pieces shall be true to size, section and line, straight and out of wind at all points, and all machine, hydraulic, rivet or smith work done upon them shall be of the best character.

All measurements in laying out work shall be made with iron standards of the same temperature as the iron measured.

38. All eye bars shall be either upset on the solid bar, upset with pilling piece, or rolled without welding. No patching at the forge fire will be allowed on bar or head. All heads shall be clean, full-sized forgings formed centrally on the bar in true line and "out of wind."

Bars of the same class and belonging to the same panel shall be drilled at the same temperature.

Pin holes in eye-bars shall be bored to exact size and distances, and to a true perpendicular to the line of strain. The pin hole shall be in the middle of the head and in the centre line of the bar. No error in length of bar or diameter of pin hole exceeding $\frac{1}{64}$ of an inch will be allowed.

The section of metal opposite the centre of the pin hole across the eye shall be proportioned according to the following table, the diameter of the bar being the unit :

PIN.	BAR.	EYE SECTION.	
		Upset Heads or Weldless Bar.	Heads Rolled on Bars.
0.67	1.0	1.50	1.33
0,	1.0	1.50	1.33
1.	1.0	1.50	1.50
1.	1.0	1.60	1.50
1	1.0	1.70	1.60
1.	1.0	1.85	1.67
1.	1.0	2.00	1.67
2.00	1.0	2.20	1.75

For hammered eyes, the shape to be used shall be determined by the Engineer after the contract is awarded. No shape, which on testing shows five per cent. of breakages in the eye or neck, will be accepted.

Pins must be turned true to size and straight, no error of more than $\frac{1}{50}$ of an inch in diameter being allowed.

Pins connecting chords, posts and tie bars shall be fitted for pilot nuts, and shall not be more than $\frac{1}{40}$ of an inch less than the pin holes of the eye bars.

Pins connecting laterals with other members shall be turned down to a diameter of not more than $\frac{1}{60}$ of an inch less than the pin holes.

Pin holes in wing nuts, channel nuts or other arrangements for lateral connections shall be drilled or else punched and reamed to a size not exceeding $\frac{1}{16}$ of an inch larger than the pin.

Rods, round or square, used for ties or counters, shall be fabricated with the same precision and care as prescribed for eye bars. They may have loop-welded eyes with reamed intrados, the proportions of the loop to be approved by the Engineer. Screw ends shall be upset so as to give 10 per cent. more sectional area at the bottom of the screw thread than in the body of the bar. Sleeve nuts, clevises, or other members used for adjustment must have the pin holes, if any, drilled, and must be of sufficient strength to break the bar to which they are attached.

Rods, used for lateral or vertical bracing, may have pin holes $\frac{1}{16}$ of an inch larger than the pin, but otherwise are to be made with the same care as counter rods.

All eye bars and counter rods are to be tested to 18,000 lbs. per square inch, and bars showing structural defects, permanent set, or too great extension under strains, shall be rejected.

39. These shall be made of such iron or steel as is prescribed for members exposed to compression strain, except when otherwise specified. The splices shall be composed of edge-rolled plates in all cases. Abutting joints shall be milled off to exact lengths and square to the line of the chord. All pin holes shall be bored to an exact

size, true to the line of strain, and correct as to position. No errors exceeding $\frac{1}{50}$ of an inch in length of part or in diameter or position of pin hole will be allowed. The pin holes may be bored $\frac{1}{32}$ of an inch larger than the pin, this is the utmost limit. Rivet holes in the splices shall be punched $\frac{1}{8}$ of an inch less than required, and then reamed to fit. After the splice plates are riveted on in the shop, each line of chords or columns shall be assembled—the joints matched, their abutting joints brought to a tight fit by turnbuckles, and all rivet holes in the ends of chords and splices in which the rivets are to be field-driven shall be reamed to an exact match and fit. Match marks shall then be made on each piece.

Parts composing posts or tie struts must be in one length, without splices between end bearings, unless specially permitted by the Engineer.

When necessary, pin holes in posts, chords or tie struts shall be reinforced by additional material, which must contain rivets enough to transmit the strain to the original member. The open sides of posts, chords, struts and tie struts shall be connected by lattice or trellis bars, the angles of which shall not exceed 63° 25' for single bars, or 45° for double bars with riveted intersection.

The unsupported length of any lattice bar shall not exceed 45 times its thickness. All members of which the parts are connected by lattice or bracing bars shall have connection plates at each end, the row of rivets in which shall be equal to the width of the member in length and not more than four rivet diameters in pitch.

In all compression members the connecting rivets within two diameters of the ends shall be pitched not to exceed four times the diameter of the rivet.

The several pieces forming any built member shall fit closely together, and the member shall be free from bends, twists and open joints.

40. All joints shall be square and truly dressed. Rivet holes shall be accurately spaced, and the rivets must be of the best quality of iron for the purpose, and when driven must completely fill the holes.

All rivets with crooked heads, or heads not formed centrally on the shank, or rivets which are loose, either in the hole or under the shoulder, shall be cut out and replaced with good rivets.

Rivet holes shall not be spaced less than $2\frac{1}{2}$ diameters between centres, nor more than 15 times the thickness of thinnest outside plate,—9 inches being the maximum pitch allowed in plate riveting.

No rivet hole shall be less than $1\frac{3}{4}$ diameters from the end of a plate, or $1\frac{1}{4}$ diameters from the side of a plate, nor *ever* less than $1\frac{1}{4}$ inches from centre of hole to edge of plate, except in cases where the plate or side of angle is less than $2\frac{1}{2}$ inches.

The diameter of hole shall not exceed the diameter of the rivet more than $\frac{1}{16}$ of an inch.

Where two or more thicknesses of plate are riveted together, the outer row of rivets shall, if practicable, not exceed three rivet diameters from the side edge of plate.

Where plates more than 12 in. wide are used in the compression flanges of girders or floor beams, an extra line of rivets, with a pitch of not over 9 inches, shall be driven along each to draw the plates together.

All joint rivet holes shall be so accurately spaced that rivets of the proper size can be passed through all the holes in the joint, after the parts are placed in position, without the use of drift pins.

All slice plates in which the holes are mismatched, either in the plates themselves or with the adjoining chord or flange, shall be matched and the holes reamed to fit before leaving the shop.

No inaccurate or otherwise defective work will be accepted under any circumstances in connection joints of riveted work.

The riveted field connections of floor beams, stringers, posts and struts, must be accurately matched before leaving the shops, and all unmatched holes reamed to fit.

All rivets in splice or tension joints must be symetrically arranged, so that each half of a tension member or plate will have the same uncut area on each side of its centre line. Whenever practicable, rivets must be machine driven.

41. All bed plates must be of such dimensions, that the greatest pressure upon the masonry shall not exceed 200 pounds to the square inch. All spans shall have at one end nests of turned friction rollers, formed of wrought iron or steel, running between planed surfaces. The rollers shall not be less than 2 inches diameter, and shall be so proportioned that the pressure per lineal inch of iron roller shall not exceed the product of the square root of the diameter of the roller in inches multiplied by 500 pounds ($500\sqrt{d}$). For steel rollers the pressure per lineal inch of roller shall not exceed the product of the square root of the diameter of the roller in inches multiplied by 600 pounds ($600\sqrt{d}$). All the bed plates and bearings under fixed and roller ends must be fox-bolted to the masonry.

42. All iron work before leaving the shop shall be thoroughly cleansed from all loose scale and rust, and be given one good coating of red lead paint, mixed and applied as directed by the Engineer.

In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing plates, and any parts which are not accessible for painting after erection, shall have two coats of paint; the paint shall be a good quality of iron ore paint, subject to approval of the Engineer.

After the structure is erected, the iron work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil, of such color as may be directed.

All turned and faced surfaces shall be coated with white lead and tallow before being shipped from the shop.

43. The contractor shall furnish all staging and false work, shall erect and adjust all the iron work, and put in place all floor timbers, guards, &c., complete, ready for the rails.

The contractor shall so conduct all his operations as not to interfere with the work of other contractors, or close any thoroughfare by land or water.

The contractor shall assume all risks of accidents to men or material prior to the acceptance of the finished structure by the Railway Company.

The contractor must also remove all false work, piling and other obstructions, or unsightly material produced by his operations.

P. ALEX. PETERSON,
Chief Engineer.

3rd May, 1888.

E. P. HANNAFORD, Vice-President, in the Chair.

CEDAR BLOCK CARRIAGE WAYS.

By Alan Macdougall,
M. Can. Soc. C.E., F.R.S.E.

The discussion of the merits and demerits, advantages and disadvantages of cedar and wooden block roadways has been carried on for a number of years, eliciting many diversities of opinions from engineers, physicians, medical health officers, and boards of health. Much valuable information has been gained from what has been written and said, but it is not intended in the present instance to go over any of these arguments or to deal with the sanitary or biological side of the question as affecting public health. The method of constructing cedar block carriage ways in Toronto will be described, the experience of wear and tear upon them given, and such inferences drawn therefrom as this experience will permit.

In the province of Ontario, where numbers of the cities and country towns are improving their carriageways, wood block roadways become a necessity as a matter of economy, where macadamized streets are not approved of. If it can be shown that they are not, when carefully constructed, more detrimental to health than the macadamized roads, a good word will be offered for a carriageway within the reach of urban municipalities.

Cedar from its general abundance of distribution and low price has been the timber most generally adopted on this continent for improved roadways. The blocks are used as cut from the tree, the sizes ranging from 4 to 10 ins. in diameter. This is a complete divergence from the British practice, where the blocks are uniform in size and rectangular in shape. They are not treated with any preservative. In the larger cities of the United States this material does not now find favor for carriage ways any more than macadam, which seems to have gone out of fashion, and against which a great deal is now being said and written. The writer regrets that macadam has been reported against so largely of late, as in his opinion a macadam road is capable of rendering good service if properly looked after.

When the City Council contemplated the introduction of cedar block carriage ways some years ago, the late M. Redmond Brough, then city engineer, reported against them in an exhaustive and valuable report.

After the adoption of the "Local Improvement" system, an impetus was given to street improvement, with the result that cedar block paving was unanimously adopted.

These roadways were laid down first in 1881, and since that date, under the "Local Improvement" plan, their construction has been continued, so that there is now a large mileage. The average width of the roadway is 24 feet, but where street railway tracks are laid the width is 40 to 42 feet. The specified crown is 8 ins. for 24 feet, and 9 ins. for the wider streets.

The durability and prospective "life" of these roadways was examined into by a special committee of the City Council. Sample blocks were taken out of 20 of the oldest streets in various parts of the city, and with 2 or 3 exceptions, all were found to be in good, sound condition. Since that time the author has given much attention to the subject, excellent opportunities being afforded for examination during the laying of private drain connections, gas and water services. Hardly one bad block has been taken out, no rotten ones have been found, and the condition has been generally sound. Where the bark was left on, decay has set in, the sapwood has given way and a part of the heart shows signs of decay. With some exceptions, to be noticed hereafter, the bottoms of the blocks are all sound, and have not been affected by the sand.

The wear has been satisfactory so far, though the streets do not get fair play, they are so constantly opened up for drain, water and gas connections. It is very galling, after a street has been well and carefully paved, to find the surface disturbed within a few weeks of completion. The workmen who open up the street have not the same interest in the work as the original constructors; they are not paviors, and consequently a number of blocks are left out every time a street is opened, the surface is not restored to its former condition, it is left too high, or else finished in such a manner that it sinks with the first rain storm. In spite of these drawbacks, a good, smooth surface is presented on all streets free from street car traffic.

The blocks wear evenly, and what is the surprising part of the roadway, the smallest sized blocks seem to wear better than the largest. The wear takes the form of bruising or brushing, the sap wood gives way, yields at the edges, and causes the blocks to wear round on the top. The small blocks do not show this so much, in spite of many of them having a large proportion of sap wood. The streets maintain a good surface all the year round, and frost does not affect them, except where street railway tracks are laid. On all streets where tracks are laid, there seems to be more traffic than on parallel streets. The main car routes are on the principal thoroughfares,—Yonge, King and Queen streets, the wear on these is greatly in excess of that on any of the other streets. It can readily be understood that between the tracks the wear must be very heavy, the blocks wearing into ruts where the car horses run. On the average suburban or residential street, the wear is about $\frac{1}{5}$ of an inch per annum, on the streets named above from $\frac{1}{4}$ to $\frac{1}{3}$ inch per annum for the carriageway, and $\frac{1}{2}$ inch per annum between the car tracks. Alongside the rails the blocks experience unusually heavy wear, in many places deep ruts are cut, and the blocks are very much worn.

The principal trouble with these carriageways arises in winter when the blocks between the tracks, in the "3ft way," rise, as do those close to the outer rail. The only remedy for this is to take out all the raised blocks, and fill in with gravel or ashes. Very cold weather, or a sudden frost after mild weather, cause the blocks to rise rapidly, and it requires constant attention to keep the street clear for the street cars, as well as to prevent accidents to sleighs and vehicles using the street.

The only theory the writer can advance is that the vibration caused by the horses' hoofs, imparts a slight springing action to the end of the tie, which is always at work under the block, raising it slightly; during the heat of the day the surface thaws and moisture enters between and under the blocks, whilst the other blocks expanding, press those nearest the rails against them, and a constant "prying" or leverage is going an all the time. Then at night frost gets into the wet joints, and in freezing the water raises the blocks. An arch of blocks extending from one set of rails to the other from 2 to 3 inches above the sand is of common occurrence. None of the intersections of King, Yonge or Queen, laid with stone late in the autumn, have shewn any disturbance.

Under the "Local Improvement" by-law, the life of the carriageway is estimated at 10 years. Few of the streets have yet reached $\frac{1}{2}$ of the term, and how the blocks will hold out after they have been laid for $\frac{2}{3}$ or more of their time, it is difficult to say. Exemption is granted from repairs by the by-law, and no provision is made in the assessment for any fund for executing repairs.

The mode of construction calls for no special remarks. After the street has been graded, it is covered with 8 inches of clean, sharp sand, great stress being laid on the quality of sand. In former years the sand used for building purposes was employed. As a rule it is a fine, soft, white sand, but in certain parts of the city it is of a yellow color. On those streets where the yellow sand has been used, the blocks have been injuriously affected, they have rotted rapidly, the rot extending half way up the block. The city is fortunately placed for abundant supplies of the best quality of sand and gravel for paving purposes, as on the east and north-east are the extensive Norway gravel pits, in the centre of the city, on Bloor street, close to Bathurst, there are valuable gravel pits, while on the west at Carlton, an abundant supply is obtainable. For the information and benefit of members of the Society, who may have block-paving to construct, the author would advise the exercise of great care in selecting coarse, sharp, clean sand or fine gravel, and the exclusion of all loam.

After the sand has been spread, it is well watered and rolled with a heavy iron roller. The city specifications call for 8 inches of sand when the road bed is ready for the blocks, and it is found that 9 inches of sand, ready for the blocks, will pound down about one inch. In places where the subsoil is fine sand, the blocks can readily be pounded down over an inch; in some experiments made last season, the blocks were pounded down two inches on the sand subgrades.

In laying the blocks, it is important to follow up closely with the sand which is spread over them and swept in. Traffic should always be suspended on the blocks until they have been consolidated with the sand, as almost any vehicle however light will displace the blocks, and turning means ruination to the surface. After the blocks have been filled in with sand, all which have been disturbed are lifted with a pick, and as the sand exercises a strong binding influence, it is difficult at times to raise the blocks. The pounding is effected by means of a heavy wooden maul weighing about 60 lbs., with a 12 inch face. The final coat, or top dressing of sand, should be very carefully selected and well laid on and brushed in. The best material obtainable near this city is a small, hard pebbly, sand or gravel about the size of peas.

Curbs are of wood, usually cedar, 14 inches deep, 4 inches thick, fastened to cedar posts 3 ft. 6 ins. long, 6 feet apart.

In breaking up the old roadways, which are chiefly macadam, horses are used at the plough, and last year (1886) a portion of Church street was ploughed by steam. The plough was attached to the drum of an ordinary hoisting engine, by a steel wire rope. It worked well and was cheaper than the use of horse power, when ploughing on the street required more than two teams.

This year (1887) a departure has been made in those streets having street railway tracks, by introducing stone between the rails. On Queen street East, between the Greenwood avenue and the Woodbine, cobblestone pitching was placed for 18 inches on each side of the outer rail, and between the tracks, the length is about 4000 feet. College avenue, from Bathurst to Ossington, was cobble-paved over the whole distance covered by the street railway, viz., 16 ft. 8 ins. This street is to be paved in this manner as far as Dufferin St.

Dundas street has been paved somewhat differently. In addition to the cobble stone, a row of sets is placed on each side of the outer rail and one on the inside of the inner. The object is to catch the heavy wear alongside the rails, but the street has not been paved long enough to ascertain its working. Church street, from Front to Bloor, is paved with stone sets, in the ordinary way. At the outer edge the set is placed parallel to the rail. A portion of this street, from King to Gerrard (about ½ the full length), was finished in 1886. The sets are from the Medina sandstone and Niagara limestone formations. They are hard in quality, and well shaped. The sizes run from 8 to 10 ins. long, 3½ to 4½ ins. wide, 7 ins. deep. It is noticeable that the cedar is commencing to wear into ruts in some places alongside the stone sets.

With a view to improving the construction of the carriageways, a select committee of the City Council visited a number of the leading cities in the United States this year (1887). They presented a long and exhaustive report on their labors, with a number of recommendations, the result will be an improvement in several points of detail in our methods of construction. At present, there is no water channel, the curbs are of wood, street crossings are of cedar block, which is raised sufficiently high to shed the water, and at the curb cast iron crossing plates are used to form a water channel at the crossing. It has been recommended that curbs in future be of stone, that stone water channels be laid down, street crossings be laid with stone, and crossing plates be abandoned. Mr. Sproatt, M. Can. Soc. C.E., the city engineer, contemplates making the junction of the cedar and stone alongside of street railway tracks in irregular courses, fitting the cedar blocks into the stone sets and toothing the stone in an irregular manner. This will probably answer well and protect the wood from being cut into.

Next year a considerable portion of the railway tracks will be relaid with stone sets, the wood having worn out so much, that it requires to be replaced.

There is only one street laid on a prepared foundation, York street, which has been laid for several years. From examinations made of the concrete during the laying of drains and other connections, the concrete appears to be in good condition. The frost has not affected it seriously, the upper surface, too, is apparently in good order. The mass seems to be homogeneous.

In the construction of sewers, the inspector is paid by the contractor at a rate mentioned and included in the contract, and the work is consequently pushed on with as little delay as possible. On roadways, the cost of inspection is charged directly against the improvement, the result is that there is not the same need for expedition in completing the contract, so long as it is finished within the specified dates. Many contracts are finished well within the specified date, whilst others drag on their full time. In the three most rapidly completed contracts this year, 7200 sq. yds. were finished in 44 days on Adelaide street, 1000 sq. yds. in 12 days on Argyle, and 3400 sq. yds. in 28 days on Manning avenue; this includes the whole time, for grading, blocking and cleaning up.

An average day's work for a good cedar block pavior, when he has an abundant supply of blocks, is 250 sq. yds.; if pushed, as much as 300 sq. yds. can be laid. For cobble-stone paving between tracks, 40 sq. yds. is a good daily average, and for stone sets 25 sq. yds. per day.

The advantages in favor of this carriage way, as laid in this city, are a cheap and efficient roadway, in all streets not exposed to heavy traffic, and one on which an even surface is maintained. As a roadway, it is not difficult to sweep and keep clean, it does not collect as much dust as macadam, and has the advantage of being the most noiseless of the permanent roadways.

The disadvantages are, that the material is too soft for roadways exposed to heavy traffic, that it is not adapted to streets on which street railway tracks are laid, that it is easily affected by frost, and becomes very troublesome in severe winter weather from the action of frost raising the blocks.

For sanitary reasons, the consensus of opinion is against the use of this class of carriageway, but there are not in this city any outbreaks of epidemic or of any special sickness which can be directly attributed to the influence of cedar block roadways.

Weighing the facts for and against the use of cedar block paving in the light of experience gained in Toronto, the author is of opinion that in the Province of Ontario, at present, street improvement will be retarded unless this paving is employed. Stone is too high priced for the smaller municipalities, and even for the larger to use very extensively, the bituminous pavements are expensive, and the report of the select committee of the City Council is not favorable to them. It is probable that by employing a harder and more durable material than cedar, such as tamarac, a roadway will be produced, which will answer the requirements of forming a cheap and fairly permanent roadway.

The "Local Improvement" by-law of this city, which was passed in December, 1884, is different in many particulars from that in force in the large cities in the United States. It has been prepared with a special view to the protection of the ratepayer, to prevent any improvement being hurried through, to his detriment; in this it has been successful, as the shortest time in which an improvement can be commenced after the petition has been presented to the Council is twelve weeks.

When a petition asking for the widening or extension of a street, a sewer or block paving, stone flag, wooden, granolithic or other sidewalk has been presented to the Council, and referred to the Committee on Works, it is examined by the city clerk. To be "sufficiently" signed, must bear the signatures of two-thirds of the owners, representing at least one-half the value of the lands to be benefited (exclusive of the value of improvements). When found to be correct, it is registered by him in a book specially kept for that purpose, and then sent on to the Works Committee. If "insufficiently" signed the same course is adopted, the petition bearing the words "insufficiently signed." The petition then comes before the city engineer, and in the case of a sewer, the medical health officer, and the commissioner of Health, who examine into the matter and report to the committee; it is usual for the city engineer only, to report, unless there are some special reasons for the Medical Health officer being consulted. In the case of sewers, the report says whether the sewer is to be constructed for sanitary or drainage purposes. Under a "sufficiently" signed petition the procedure is on "petition," under an "insufficiently" signed petition the work proceeds on "sanitary" grounds; for any of the other improvements as will be explained further on, the procedure is called the "initiative."

In reporting to the Committee the engineer states, (*a*), what property is to be immediately benefited by the improvement; (*b*), the probable lifetime of the improvement; (*c*), the estimated cost with the amounts to be assessed against the property; and (*d*), the proportion in which the assessment is to be made on the various properties.

In the event of the Committee recommending the report for the adoption of the Council, and if it has been adopted by them, the city clerk sends a copy of the petition to the assessment commissioner along with a certified copy of the report of the Engineer as adopted in Council. The city clerk then advertises, in two city papers for two weeks, the intention of the Council to undertake the proposed work, giving details of nature, cost and proposed rates of assessments. If no petitions representing one-half in value of the lands signed by one-half of the owners, be presented against the petition within one month from last date of publication of notice, the work is sent to the Court of Revision. If the petition be "insufficiently" signed, the work is commenced on what is called the "initiative." In the event of the petition being opposed by the full number of owners named above, no new notice for the improvement can be given by the Council for two years.

If everything goes well to this point, the city clerk sends certified copies of the Works Committee's report as adopted in Council, along with the certified copy of the engineer's report to the assessment commissioner, who gives a ten days notice of the meeting of the Court of Revision for the hearing of appeals. Any property owner can appeal from the ruling of this Court to the county judge.

The decision of the Court of Revision (with the ruling of the county judge when appealed to) is sent by the city clerk to the Works Committee. If everything has passed so far, tenders are called for, and as soon as they are accepted, the Council is asked to order the Treasurer to make an "interim appropriation" for the carrying on of the Works.

The contracts are then prepared in the usual manner, first signed by the contractor and his sureties, then presented to the Works Committee for approval, then sent to the city clerk for the signatures of the mayor, treasurer and city clerk, and finally to the solicitor, who issues a warrant that the contract has been properly executed. Until the certificate of the city solicitor has been obtained the Engineer cannot order the work to be commenced.

Under the city contracts, 85 per cent. in value of the work done is paid for on progress estimates, 90 per cent. on completion of the work, 95 per cent. six months after completion, and the balance at the expiration of one year. Exception is made in the case of patent roadways and pavements, the contractors with their sureties having to give a further bond to maintain their works for five years after completion.

If the above procedure savours somewhat of red tape, it can easily be seen that it has all been framed for the protection of the ratepayer.

DISCUSSION.

The subject so carefully treated by Mr. Macdougall is one of very great importance to growing cities, and is a branch of municipal engineering, which, more than any other, has received the attention of councils and the general public. Numerous civil deputations have traversed the country for the purpose of examining pavements, in order that they might be able to report the best for adoption in their several localities; but, notwithstanding the immense amount of labor which has been expended, the subject is as open to discussion and difference of opinion as it was ten years ago. Mr. H. N. Ruttan.

The difficulty of deciding upon what is the best pavement, is largely increased by the fact, that while a pavement under certain conditions may be satisfactory, under different conditions of climate or use, it may be worthless.

In Winnipeg, tamarac blocks have been largely used for pavements.

The Main Street pavement, which was commenced in 1884, consists of 7 in. round Tamarac blocks, laid upon a foundation of 2 in. pine plank, and filled in with coarse sand. The plank foundation is supported by 2-ins. x 8-ins. pine stringers, laid across the street, 4 feet apart. The stringers and planking are laid upon 4 ins. of sand and gravel. The blocks at the present time shew little wear and no decay of any consequence. The pavement is, however, worn into ruts in places, not by wear of the top of the blocks, but by settlement of the planking. On pavements subsequently laid, the depth of the blocks has been reduced to 6 ins., and the foundations prepared as follows:—

The surface of the roadway is carefully graded to the form of the pavement and consolidated by rolling.

Three inches of sand and gravel is then laid on the prepared foundation, and consolidated by rolling.

Upon the sand is laid a course of one inch boards, the boards are laid across the street 2 inches apart, and they are brought to a firm bearing upon the sand; another course of one inch boards is then laid diagonally upon the first course. The tamarac blocks are laid upon the second course, and the interstices between them filled with sand and gravel.

No trouble has, so far, been experienced from the blocks rising or wearing into ruts, except in one instance. The market square pavement was laid late in the fall, and very dry blocks were used. The following spring, when the blocks became saturated with water, they swelled to such an extent, that on the street crossings (which are raised 2 ins. above the remainder of the pavement) the blocks were pushed out of place and piled up to a height of 2 feet. No damage, however, was done to the foundation, the blocks, which could be conveniently replaced, were laid, and no trouble has sinec occurred.

The pavement, as described, cost from $1.05 to $1.20 per sq. yard, and, so far, it has cost practically nothing for maintenance.

Most City Engineers will sympathise with Mr. Macdougall in the annoyance which he has experienced from the destruction of pavements, by the incompetent and careless workmen of pipe and drain layers.

Mr. Ruttan thinks that all work of the class referred to, should be done by the trained employees of the municipality, and the cost charged to persons interested.

After making an examination of the pavements in most of the large cities in the United States, Mr. Ruttan is of the opinion, that wooden block pavements should be treated as temporary works only, and as most suitable for suburban and new business streets, where sewer, gas and water mains have been laid. A pavement consisting of a concrete base, covered by wooden blocks, would be found both economical and efficient; when the blocks become unserviceable, they may be completely renewed at a small cost.

From a sanitary point of view, such a pavement would be much superior to that with a porous foundation, and it would have the further advantage, that any desired wearing surface could be substituted for the wooden blocks, without entailing additional expenditure for the foundation.

In comparing tamarac with cedar as a wearing surface, in reference to the disadvantages of the latter, as stated by Mr. Macdougall, it has been found that in Winnipeg, that tamarac in the street railway tracks has worn fairly well. On a mile and a half of poorly constructed pavement on Main St. North, which has been in operation for about six years, the blocks in the horse track have now only about one inch, and in none of the paved street railway tracks ($4\frac{1}{2}$ miles) has trouble occurred by frost raising the blocks.

Mr. E. Mohun. Mr. Macdougall's paper cannot fail to be of interest to those engineers who more especially devote their attention to civic improvements; and the general results of the author's observations would appear to show :—

1st. That the cedar block pavement, constructed as described, forms a cheap and efficient covering for streets subjected to a moderate amount of traffic.

2nd. That for heavy traffic, either a different mode of construction, or a different material is required.

3rd. That on lines of street car routes, the cedar blocks in the vicinity of the rails are liable to be lifted by frost.

It seems that cross sections of small trees, from which the bark is not always, and the sapwood is never removed, are used. Under these circumstances, it cannot be a matter of surprise if some of the blocks shew symptoms of decay; although the general results, in this respect, appear to be highly satisfactory.

The form taken by the blocks when worn by traffic seems, however, to be to a certain, perhaps limited, extent objectionable,

1st. Because, instead of an even it presented an irregular surface, somewhat similar to that of a cobble-stone pavement.

2nd. Because, owing to the irregularities of the surface, the rain-water would be offered facilities for penetrating the roadway, instead of rapidly passing over the surface of the gutters.

The speaker may have, unintentionally, exaggerated these irregularities of surface, in which case the objections of course fall to the ground.

It is difficult to assign a reason for frost only affecting those streets through which street cars run; it appears, however, that ruts are worn in the pavement between and on the outer side of the rails; is it not possible that, prior to the frost, the rainfall collects in and is retained in these ruts and by the rails, until the foundation is saturated, and becomes susceptible to the action of the frost?

If such is the case, it will be obvious that drainage is the only remedy against the displacement of the blocks.

It would be interesting to know whether any other mode of construction with the same material, in positions where it would be subjected to great wear, has been tried, for instance with rectangular or hexagonal blocks laid nearly close and keyed together.

With regard to the unsatisfactory state in which streets are almost invariably left after pipe laying, we do not under any other circumstances attempt to erect a superstructure upon a foundation consisting partly of solid and partly of new made earth. The remedy would appear to be either in the construction of subways, or in placing a rigid flooring on solid bearings across the new made earth. In most cases the contractor is bound to leave the surface in as good a state as he found it, but does not do so.

Although the author states that cedar block pavements for streets of light traffic are good and economical for young towns which cannot afford better, this argument is not to be accepted by Engineers, and therefore should not be taken into consideration, as they must professionally recommend to the people who employ them, a pavement which will stand Mr. St. George.

a period of years, which recoups itself for the outlay of capital, in a certain time, by the least expenditure in maintenance, and which is also salubrious and noiseless in business centres. He would take examples from the City in which the author has obtained his information. In the streets on which street railway tracks are laid, such as Yonge, King and Queen streets, the blocks between the rails and between the tracks are worn out into a trough as much as 4 inches to 6 inches below the rail levels, and where they are not worn, the blocks have been heaved out; more recently even this is seen in College Street, which has only been laid two years, and therefore, as the author says, cedar blocks on a sand foundation cannot stand the traffic where street railways exist. This is undoubtedly due to the water running along the rails and entering between the rails and the blocks through the open joints to the foundation, when the sand becomes movable, and the frost entering heaves the blocks in combination with the vibration of the traffic, on the rails.

Referring now to the Streets of light traffic, you will notice that the blocks are worn in holes or basins, the blocks themselves being of such unequal diameter, that the cedar blocks in the larger size of 4 inches to 6 inches in diameter; the fibres of the wood from the heart or centre becomes more open and softer which wears quicker than the smaller blocks, the outside of the larger blocks becoming worn, leaves the heart, being the hardest part of the wood, projecting, making a knot or knob in the centre.

The principle of the foundation and jointing is wrong. The joints being pervious to the water, allow the rain and moisture to descend to the sand, which then becomes movable and unstable. The blocks themselves are placed with the fibres of the wood downwards, and soak up the water from the moist foundation by capillary attraction so that they are always moist throughout.

Cedar block pavements are only useful in one way, that is for land speculators to lay out their property, in order the more readily to sell their lots, but when traffic is established on the street they become an expensive roadway to maintain, and, in the speaker's opinion, should not be recommended by any Engineer as an economical and durable pavement. From a sanitary point of view it does not seem that such a pavement would be recommended, as the moisture retained by the blocks under the influence of a hot sun must cause a miasma to ascend, while its humid state causes it to retain particles of street detritus which are injurious to health.

Quoting from the Board of Public Works, Detroit :—

"In their last annual report, the Board called attention to the questionable policy of extending the mileage of wood pavements in the city, but no action has been taken by your honorable body in relation thereto, and in consequence of its cheapness the people are not inclined to ask for any other and more durable pavement, so long as wood pavements have the sanction and countenance of the city authorities.

The policy of buying the lowest priced article for use in perpetuity, is no more commendable in the case of paving streets than in the affairs of domestic and business life, and the Board look with alarm on this extension of wood pavement, believing that they can see in the near future, if the custom is persisted in, an extraordinary amount of taxation to keep our streets even in a passable condition.

From eight to ten years is conceded to be the life of a cedar block pavement, and within the period named it is found that extensive repairs must be made.

The majority of lot owners are generally averse to being assessed for repaving, and the city is unable with the limited appropriations made for the purpose to make the necessary repairs; we have, as the result, streets dangerous to traffic, filled with rotten and rotting timber, saturated with filth, and engendering malarious disease.

We have now about seventy-five miles of wood pavement, much of which has been in use for years, and all of which must, in the usual course of things, be replaced in the near future, calling for taxation by special assessments to the amount of about one million dollars, in addition to the regular annual taxes; every decade in the future will bring its equivalent of taxation for the same purpose, and we will be still as far from a durable and permanent roadway as ever, and this with the contingency of enlarged boundaries and an ever increasing mileage.

We feel that we cannot too strongly recommend a change of policy by the City in this matter, a change tending to the building of roadways that shall be permanent and healthful in character, even at an increased first cost for construction.

The Board would recommend Medina Stone, laid in the best manner on business streets, as being the most durable and satisfactory in all respects of which they have knowledge, and especially for streets given to heavy traffic. Streets paved in this manner are much more easily kept clean than wood pavements, which is an additional argument in their favour.

It is obvious that the substitution of stone pavement for wood will, in any event, be a work of time, and must be done by degrees. The only way for its final accomplishment will be by discontinuing the practice of laying new pavements with wood, and in every case substituting stone in repaving worn out streets in the central part of the City."

Quoting again from the Board of Public Works, Chicago, as follows :—

"The year was one of great activity in the street Department, as will be seen by reference to the work done. The fact that the former administration, in its anxiety to make elaborate exhibits, had left the City a debt of over a quarter of a million dollars for paving street intersections, was an early embarrassment, for, in providing for this, the Council was limited in its appropriations. But the best possible use was made of the money at the Department's command. Contracts were let at favourable prices, the result of insisting upon wide competition; and the character of the improvements, will more than favourably compare with those of former years. The tendency is toward the greater use of the more permanent material. This should be encouraged, so that in a few years all the great thoroughfares of the City will be paved with granite, or some other substance more durable than the old-time wooden block. Special reference to the use of more permanent material is prompted by the belief that it is destined to be much cheaper than it has been.

17 May, 1888.

JOHN KENNEDY, Member of Council, in the Chair.

The following Candidates were balloted for and duly elected as

Members.

Anton L. Hertzberg.
James Black Hegan.
John Thomas Morkill.
Matthew Neilson.

Associates Members.

Louis Gauthier.
Charles McGreevy.
James William McKenzie.
Charles le Baron Miles.
William C. E. Phillips.
Abbot True
Willis Whited.

Associates.

W. E. P. Cassels.
Charles George Griffin.
Alfred Henry Mason.
Britton Bath Osler.
Bruce Price.
Hugh Ryan.
Thomas G. Shaughnessy.
W. C. Van Horne.
James White.

Students.

Cyrus Hitter Archibald.
Douglas Cator.

ELECTRIC LIGHTING.

By H. Y. Thornberry.

The object of this paper will be to give a brief résumé of Electric Lighting, of its discovery and development until the present time.

Very little was known of Electricity in 1790; yet from that year dates the discovery by Galvani of the electro-chemical action of two metals in the presence of moisture.

It was not until six years later that Volta devised the Voltaic Pile the first source of a constant current of electricity.

It may be remarked as a queer coincidence that illuminating gas was discovered, and the possibility of making gas from coal demonstrated at a date almost coincident with the discovery of the galvanic current. It was not, however, until 1810, a Gas Company was formed for general lighting in London. It was in that year Sir Humphrey Davy discovered the Voltaic Arc.

So rapid, however, was the introduction of gas as an illuminant that 20 years had made it general, while the Electric Light had as yet only been born.

It must not, however, be supposed that the want of progress in Electric Lighting was due to inactivity on the part of those from whom the world was to have the discoveries that were to make it a success.

Among the inventions of eminent men that led the way to electric lighting may be mentioned those of Arago, who discovered the magnetizing effect of the galvanic current, and gave us the beautiful experiment termed the Arago Disk.

Faraday, in 1831, began his masterly researches, and gave the world his discovery of magneto-induction. In Faraday's discovery, Electric Lighting takes its rise, and from his time date the inventions that have made it a possibility.

Following Faraday, Pixi and Saxton produced the magneto-electric machine.

The Pixi machine is composed of a strong horseshoe permanent magnet, before the ends of which two spools of covered wire wound on U shaped iron coves are made to revolve. In forming the U shaped magnet, one end of each spool core is connected with an iron bar, the other end remaining free, and they thus form what is termed an electro-magnet. At each half revolution or on every passage of the free ends of the spools, before the ends of the horseshoe magnet, currents are induced in the spools by reason of the magnetism imparted to the iron coves by the large permanent magnet, the currents alternating in direction at every passage, the strength of the current depending on the speed of the spools.

The explanation of the action referred to is as follows: between the free ends of any permanent magnet are continuously maintained lines of force, so termed, made visible by the familiar experiment of placing iron filings on a glass plate over the poles of the magnet, and gently shaking the filings into position, when they assume the form of the passing lines of force or magnetism. When a single closed wire coil is passed from the weakest to the strongest part of a field of magnetic force, a current is generated in the wire. If we multiply the convolutions of the single coil 50 or 100 times, we can by one rotation of the drum on which the wire has been wound cut the lines of force 50 or 100 times, and remembering that the strength of the current is proportional to the speed and length of the wire (the strength of the magnet remaining the same), we thereby increase the pressure of the current as many times as there are turns of wire on the drum.

The lines of magnetism may be represented, though imperfectly, by the lines or rays of heat being radiated from a heated body. If we imagine a copper drum to be rotated in front of the heated body, and on the opposite side of the copper drum place a mass of metal kept at a low temperature, the copper drum on being rotated takes up a portion of the heat given off by the heated mass, and imparts that heat to the cold mass. The simile is this: a given amount of energy as heat is converted by the drum on each half-revolution; in the dynamo-machine a given amount of energy in the form of magnetism is converted on each half-revolution, the amount of energy converted depending upon the difference in potential energy represented in either case.

The simile is almost exact, for, in either case, the conditions remaining the same, the energy converted is proportional to the speed and to the work done.

Some ten years later than Pixi's invention, a compound Pixi machine was constructed, and gave Faraday great pleasure. He saw in it the growing infant he had before given the world.

It was not until twenty years after Faraday's discovery that the first successful machine was produced, capable of sustaining the electric arc light.

Pacionotti is recorded as the first designer of a continuous current machine. Pacionotti conceived the method of revolving a continuous ring of iron before the poles of a strong magnet. The ring he divided into sections, with projecting teeth and wound on each section a coil of wire. On revolving the ring the polarity of each successive section or portion of the ring is changed, as it passes before the poles of the magnet, and currents are induced in each coil, as it comes into the position of greatest magnetism. Instead of the alternating current of the Pixi machine we obtain in the Pacionotti dynamo a continuous current by means of a commutator or ring, divided into as many segments as there are sections in the revolving ring, each segment being connected to the corresponding spool of wire. The current is commuted and carried away by means of strips of copper resting on the commutator.

The action of this machine and of all continuous current dynamos may be likened to the familiar chain pump. The chain pump you will remember is operated by the revolution of an endless chain running over a wheel, and passing through a tube just large enough to admit the disk formed links, placed at intervals in the chain's length.

On revolving the chain, the disk links act as buckets bringing to the top of the tube a given amount of water on each revolution. The energy absorbed is proportional to the speed at which the chain travels and to the amount of water raised. In the Pacionotti dynamo and, in fact, in all dynamos, each spool of wire acts as does the disk links on the chain, throwing into the electric circuit a given amount of electricity at every revolution.

The analogy is not quite true, but will serve as an illustration of the primary action occurring in the dynamo. The difference lies in the fact that the potential of the water raised remains constant, but the potential of the electric current produced increases as I have before stated directly as the speed.

In place of the permanent magnet used by Pixi, Pacionotti used the current generated by his machine to charge its own field magnets, the method now universally used in all continuous current machines. Pacionotti was followed soon after by Gramme who reinvented his ring, and by Siemens.

The action of the Gramme ring is in all respects the same as that of the Pacionotti ring. The Gramme ring differs only from the Pacionotti ring in the absence of teeth or projections on its periphery. The winding of the armature is greatly facilitated by the absence of the projections. The Gramme construction, because of its many advantages, has been adopted by several designers of dynamos. The Siemens armature, termed the drum armature, is used very largely by dynamo builders, because of the ease with which it can be wound. The Gramme and Siemens type of armature are more largely used than are any other designs.

The Brush armature follows the design of Pacionotti. One fourth of this armature is constantly out of connection and does no work.

Electric Lighting, to-day, is a business of such magnitude, we may well be astonished at the rapidity of its growth. The principal cause of the sudden growth of a system practically in its infancy in 1878 may be ascribed to two causes: the Paris Exhibition and the Jablochkoff Electric Candle exhibited there. Machines we had, a practical electric lamp we had not. The Jablochkoff candle, so astonishingly simple, seemed destined to fill the vacancy, and caused a great revival of interest in Electric Lighting. The Jablochkoff candle, however, was not to fill the void. It remained for others to devise a lamp more suited for general use than was the Jablochkoff candle. The Jablochkoff candle is suited to the alternating current only, and never came into extended use because of its unsteady light.

On our side of the water new life was given to Electric Lighting by the invention of Brush, of Cleveland. His invention made it possible to sustain many lamps on one wire, which electricians at that time said could not be achieved.

In Arc lamps, before the time of Brush, a rack and pinion with a clockwork movement was the most reliable method in use for maintaining the carbon rods at a given distance from one another. In such a system, it was impossible to keep more than one lamp burning on one circuit from one machine.

Brush devised a very simple method termed a shunt, which forms a part of every lamp, making each lamp independent of each other lamp. Good lamps are now so perfect in action, it is impossible to see the movement of the carbon rods as it occurs.

Following Brush came many inventors, notably Weston, Maxime, Thomson and Houston, with all of whom you are doubtless familiar.

In incandescent lighting, experimental attempts date to Page and Star in 1842. Sawyer and Man, in 1878, were undoubtedly the original inventors of the first successful incandescent lamp. The researches of Edison gave great stimulus to that branch of Electric Lighting.

The incandescent lamp is composed of a carbonized filament of Bamboo, chemically treated paper, or other suitable substance reduced to the requisite thinness. The filament when ready for use is mounted in a suitable glass globe,in which a vacuum equal to the one-millionth atmosphere is produced, and the globe hermetically sealed by a glass blower. The lamp is then mounted as you see them in use.

The incandescent form of lamp has been made of various candle power, from 1 to 150 candles, and recently of 600 to 800 candles. Lamps of such high candle power have not heretofore been made. The economy of such a lamp remains to be established.

We have to-day another method of electric lighting, termed the alternating system. The method employed is to produce by an improved machine an alternating current of very high pressure, and to reduce or convert it to a low pressure suitable for house-lighting. The conversion is for two purposes, *first*, economy. because by running the machine at a high pressure, a much smaller wire is necessary, and the current can be carried a great distance at a comparatively small cost for wires, a large item in installing an Electric Light plant ; and *secondly*, safety, because a low pressure current is comparatively harmless.

In explanation of electric pressure, the speaker would repeat a very apt illustration of the action of a dynamo machine in forcing a current into a wire or series of wires.

It is this; the action is analogous to that of a force pump keeping up a pressure upon a line of hose pipe. Every point where leakage of the electric current occurs may be likened to a pin hole in the hose. Water leaking at innumerable pin holes reduces the pressure in the pipe, until perhaps the farthest end of the line of pipe receives no pressure at all. The higher the pump pressure at the source the greater the leakage at a given pin hole. So in handling the electric current we must provide against such leakages by making our conductors as perfect as possible, and see that in no place does the wire come into contact with the limbs of a tree, or anything which might convey a portion of the current pressure to the ground. We must, as engineers do, allow for a given loss of pressure due to the friction of the current traversing the conductor, and to reduce this loss of pressure or heat we make our conductor as large as economy in outlay will permit.

The converter used in the alternating system is a well constructed induction coil. The construction in a simple form is as follows: a bundle of iron wires are wound on one end, with a spool of very fine wire, called the primary, on the reverse end with a spool of comparatively coarse wire, termed the secondary. To the primary wires are connected the wires from the Dynamo machine, and to the secondary, the wires leading to the lamps to be lighted.

The action in the coil is as follows: on every reversal of the charging-current, 200 and upward times per second, a reverse current is induced in the secondary wire by reason of the discharge and reversal of magnetism in the bundle of iron wires. The reversals of the current are so nearly continuous, that no perceptible variation is discernible in the lamps.

The alternating current method of generating power has been applied to the electric arc light and to electric motors, making it a complete system, and leaving nothing further to be desired. A prediction was made at the last convention of Electric Light men, that the alternating system will eventually displace all other systems, by reason of the safety with which the current can be handled by the consumer. This is admitted by reason of the conversion from a high to a low pressure at the entrance to house or workshop.

Having given you a brief outline of some of the attempts in Electric Lighting, the conditions under which it is necessary to construct a successful Electric Lighting system, will now be stated.

The first consideration in any system is the source of power.

If steam power is to be used, high-class engines are necessary to obtain regularity of speed. Slight variations in speed affect the brilliancy of the electric lamp very materially.

A second consideration in adopting steam, is to divide the power so that a break-down shall not cause a dead stop of all the machinery. To accomplish this, considerable judgment should be used to so proportion the power, that the greatest economy shall be obtainable with all the varying lead. The favourite method has been, and is still to a large extent, to use high speed automatic engines of moderate power.

Large stations are, however, in many places replacing the high speed engines with slow speed and condensing engines, thus obtaining greater economy. Independent condenser pumps have been adopted to a limited extent.

The experienced Electrical Engineer recognizes the fact that electric light is power, pure and simple, and he therefore aims at the most economical method of producing power, per se.

When water power is used, economy of power is not taken so much into consideration. The observations made as to a division of the source of power are as applicable, however, in the case of water-power as in the case of steam-power.

Having determined the kind of power to be used, the next consideration is the cost of the wiring or conductor for carrying the current. This will be determined by the cost of power and by the location of the station in relation to the districts to be lighted.

Having located the station and determined what power (or coal) will cost, we then determine the amount of power that can be economically lost in transmitting the current or in heating the wires. The balance is found when the cost of power lost is equalled by the interest on the money invested in construction and in the copper conductors.

Having determined this to equal, say, 10 p.c. of the energy developed by the dynamos, the calculation as to cost of wiring is easy.

The consideration of loss in power is one that presents itself the moment a station is proposed. The limit of distance as between the direct and the alternating system is in the neighborhood of 1,000 ft. from the station. If a greater distance is found to be necessary for locating the station the alternating system would most likely be selected.

These considerations apply to incandescent lighting alone. The limit of 1000 feet does not apply to what is termed the multiple series system.

In this system the pressure is constant, but four or five times as high as in the direct system.

The disadvantages are, that when one lamp of a series of five is wanted, the current for five is consumed, causing something of a loss in power over the direct system.

If the system selected is to be an arc light system, the loss of power is not so serious a consideration. The arc light system and the alternating system are somewhat upon the same footing in that respect, in that both systems are run at high pressure. Everything remaining equal, the higher the pressure the smaller the wire required for a given current. The current into the pressure is a measure of the capacity for work.

One of the practical difficulties to be met is that of insulation; that is, to prevent a loss of current by leakage caused by moisture or contact of the wires with the limbs of trees, or other obstruction capable of absorbing moisture. When it is impossible to clear shade trees, a specially covered water-proof wire is used. Carelessness or negligence in this respect has caused the burning of many fine shade trees and in some instances of buildings.

In the early days of Electric Lighting cheapness in construction was the ruling feature. Electrical companies are to-day awakening to the fact that cheapness does not pay. Cheap construction means heavy maintenance, charges and a consequent reduction of profit. Cheap insulation means heavy leakage of the current and consequent loss of power, with danger to life and property, and is almost altogether an absent feature of an Electric Light system as constructed to-day. The tendency is toward the more expensive methods in every branch of the work, enlisting more public confidence in the utility of Electric Lighting in general.

The cost of maintenance is naturally of prime importance, and to the end that this item shall be as low as possible, the most improved system of furnaces for the consumption of cheap fuel should be put in place. Leakages of every kind should be reduced to a minimum, economy in the lamp itself is of the greatest importance. Economy in this direction means economy at the coal pile. The decision as to the type of lamp that shall be used, will depend on the life and economy of that particular lamp, and on its capacity to maintain its candle power. Some incandescent lamps, retain more of the occluded gases than other makes, and consequently blacken in much less time.

The system to be adopted for any particular kind of lighting will depend upon the conditions under which it is to be operated. If the lighting is to be in a thickly settled portion of the city and near the station, the direct system would undoubtedly be selected. In direct lighting the three wire system has been adopted very largely, and results in a great economy in copper for conductors, increasing the construction account somewhat, however.

The alternating system has a very decided advantage over the direct three wire system, requiring much less copper in construction.

If the lighting extends through a thickly settled district and a great distance from the station, the alternating system would unquestionably be selected.

If for street lighting alone, where large lights are to be placed at intervals only, the arc light system would be most desirable for this work; however the alternating system has of late come into prominence because of its flexibility. Small lights at shorter intervals give a more satisfactory distribution of light than does any system of large lamps, unless the large lights are multiplied so as to cover the territory sufficiently to prevent shadows. Of late the electrical accumulator has come into prominence as a method of storing electrical energy. While this system has become a valuable adjunct to systems already in place,—referring to isolated plants alone—it has not as yet proved economical enough to recommend itself for commercial lighting. It is safe to say, however, that the further development of this system of storage of power will undoubtedly be a valuable assistance to the electrical engineer.

Some figures as to the number of electric lights of various kinds in use in the United States may be interesting. The last estimate places the incandescent lamps at 1,750,000, an increase of 29 per cent. in the last year, and the arc lamps at 175,000, an increase of 29 per cent. also in the last year. This number of lamps are contained in 1000 central stations, and 3000 plants of various kinds, representing approximately $125,000,000 invested in a business that has been developed since 1878.

In concluding, allow me to express a sentiment which you will echo, that is, that evolution is a natural law, and applies no less to electrical inventions than in other branches of science. Every inventor has had his device or method improved by some one following him. Evolution is the guiding factor. The newly invented machine is never the perfected one. It was ever so and ever shall continue to be.

The present outlook for the future development of Electric Lighting and kindred Electrical appliances is very bright.

Astonishing strides have been made in the ten years since the Electric Light and Telephone have been given to the world, and who can say what developments in electrical research, as great and even greater, await us in the future.

DISCUSSION.

Mr. Lawson.

Mr. Lawson remarked that he had listened with attention and interest to Mr. Thornberry's paper, and particularly admired the diagrams which he had shown, notably of such apparatus as the Brush lamps and Thomson-Houston, Weston, and Edison dynamos, and has congratulated him on the his lucid and generally fair descriptions of the different systems.

In showing the Thomson-Houston arc machine, Mr. Thornberry had shown a machine which is wonderful for its regulation, but inferior in actual commercial economy to the Brush and Crompton arc-light machines, and especially inferior in that respect to the Weston, Edison, Edison-Hopkinson and Crompton incandescent machines, in many of which the commercial efficiency is as high as 92 per cent. In fact, the electrical efficiency of the 1000 light machine now constructed by the Edison Company is as high as 97 per cent., and its commercial efficiency will be about 94 per cent., whereas the commercial efficiency of arc lighting machines generally is about 76 to 80 per cent. The Thomson-Houston arc lamp he considered inferior to some others, although the system taken as a whole is among the best of the arc light systems.

Now with regard to distribution on the 3-wire system, and by transformers as mentioned by Mr. Thornberry, he would say that it is natural that having started with a wrong hypothesis he should arrive at erroneous conclusions.

The 3-wire system is capable of distributing lights at a distance of three quarters of a mile, with a higher efficiency than the converter system, even allowing 15 per cent. loss in the feeders, instead of distribution by this system being confined to a thousand feet, as specified by Mr. Thornberry. This makes quite a difference. Mr. Lawson has himself carried out distribution by it at a distance of two miles and a half.

He would say also that when he mentioned a loss of 15 per cent. on feeders, this loss appears much larger than the average loss really is. 15 per cent. is the maximum loss with a full load; and this load varies considerably in most stations from five to seven or eight o'clock in the winter, say three hours, and from seven to eight o'clock in the summer, when it is a maximum. This gives a daily average of only two hours of greatest loss in the wires, leaving the other 22 hours with a much lighter load and a minimum loss. Under such circumstances 3 per cent. probably would be the maximum average loss.

From 3-wire stations power can be supplied by motors and storage batteries charged, whereas the alternating system has the disadvantage of being unable to do either the one or the other.

It is possible that eventually motors may be run from an alternating current systsm, but at present it is impracticable, and such a system will never be able to supply a storage battery, nor will such a system be able to compete in reliability nor approach in efficiency, the direct system, even should the power be obtainable only at a distance from the district to be supplied with light. In such case, we would use direct current transformers.

One word with respect to the safety, which Mr. Thornberry claims for the alternating system.

Some present may have taken the shock from an ordinary magneto bell, such as is used in the Bell Telephone, which gives an alternating current. The pressure, however, is small, and the current inappreciable. Imagine, then, the effect of getting a shock from an alternating current of one or two thousand volts. It would be instant death.

Another source of danger is, that the current from the primary coil frequently passes through the secondary coil and thence through the houses in which the lamps are used, destroying the lamps and endangering life. He has himself observed the effects of the current passing from the primary to the secondary wires in this way. This is not theory but actual experience.

Now as to efficiency. The transformer system, which has its highest efficiency with a full load, gives possibly in the transformers, 90 per cent. and assuming the efficiency of each machine to be 90 per cent., which is really making a allowance to which it is not entitled to, we get 81 per cent. of efficiency only.

With a small load, the efficiency of a converter seldom exceeds 75 per cent., and thus, assuming the efficiency of the machine to remain as high as a full load, which it does not do, the efficiency of converter and machine combined, in such case would be only about 67 per cent.

This does not take account of the lower economy of the leads from the converter to the lamps, caused by the use of low resistance lamps. This additional defect will probably give from 3 per cent. to 5 per cent. loss in the mains. This again with the loss in the primary wire of 3 per cent. to 5 per cent. more, makes a very bad showing for the alternate system, its maximum efficiency being when there is a full load, say, for two hours per day. Its greatest loss is, therefore, during the greater part of the time of its use, instead of during the shorter space, as with the 3-wire system.

He also took issue with Mr. Thornberry in regard to his statements concerning the invention of the incandescent lamps. As well might he claim for DeMoleyns of Cheltenham, who invented an incandescent lamp in 1841 having a platinum irridium conductor; for Petrie, who invented an incandescent lamp in 1849; for Starr of Cincinatti, who used as the light giving body, a carbon rod; for Greener and Staite in 1846, whose semi-incandescent lamp was also patented; for Lodyguine, who obtained through S. W. Konn a patent in 1872, using a graphite conductor in a species of lantern, hermetically closed and filled with nitrogen, or other gas which does not support combustion; for Lodyguine's patented lamp in 1873 in which he used a solid stem of carbon surrounded by an inert gas; for Kosloff, who obtained a patent in 1875 for a similar lamp, with sticks of carbon surrounded by nitrogen gas; for Chauvin, Goizet and Aubrey, who obtained a patent in the same year for an incandescent lamp, using platinum wires or carbon rods in a lamp hermetically closed by an india-rubber plug; for Lane Fox, who obtained a patent for an incandescent lamp in 1878, having a platinum irridium conductor, as to claim for Sawyer and Mann the invention. Their first lamps consisted of carbon rods fed over pulleys in an incandescent lamp structure, or short carbon rods heated to incandescence by a current, in the path of which they found it necessary to insert dissipators of heat. In other words, these Sawyer and Mann lamps were as far from being practical incandescent lamps as were any of the lamps of earlier experimenters, and the very current which should have produced the light and been economically used, was wasted by them.

Edison's patent of 1879 produces the first approach to a practical incandescent lamp, covering the principles of all practical and present commercial incandescent lamps, and he, and he alone, can be claimed as the only inventor of the commercial lamp of to-day.

Swan's first patents for incandescent lamps, in which cotton threads treated by sulphuric acid were used, the same as at present, are dated January 20th, 1880, and Maxim had a patent issued in July, 1880, for an incandescent lamp with a carbon in a receiver containing hydrocarbon vapour, which it was supposed could be precipitated to the thinnest and consequently hottest part of the filament, thus forming the carbon when the lamp was actually in use. From these facts, Mr. Lawson challenged Mr. Thornberry to prove the claims of his clients, Sawyer and Mann.

One more word about distribution. We shall no doubt have a high resistance lamp in the near future which will take 150 volts and over, and will be as much more efficient as our 3 1-10 Watts per candle are to the only 4½ Watt ones. Even now for storage battery purposes we make a lamp having an efficiency of $2\frac{1}{2}$ Watts per candle, although we do not recommend such extreme economy of current which is obtained at a slight loss of life of the filament.

With such high resistance lamps and the additional economy which they will enable us to obtain in the cost of our conductors, Mr. Lawson believes that the distribution of the future will, as the greater part is now done, be wholly carried out upon the 3-wire or other low pressure system, to the entire abandonment of the alternating system, and therefore with absolute safety both to life and property.

Mr. Kimball remarked that he had been extremely interested in Mr. Thornberry's paper this evening, and desired to make a few remarks on certain points. Mr. Kimball

First, in regard to the Jablochkoff Candle, he had on one occasion visited a mill which was lighted with this kind of lamp and remembers the pleasing effect of an illumination which seemed a cross between that of the arc and the incandescent lamps. But like many things it has its objections, the most serious of which is that if the current is cut off and stopped but for an instant, the lamp will not relight without assistance, on account of the separation of the carbons.

A very singular effect is shewn in the picture illustrating the magnetic lines of force between two pole pieces and an armature revolving inside, where the lines are seen going horizontally, from one pole piece to the other, outside the armature and at an angle on the inside, owing, as described by Mr. Thornberry, to the magnetic lag in the iron. From another point of view, this is due to the magnetising effect of the current in the armature, which acts at right angles to the magnetising force of the pole pieces, and distortion is the result. This distortion also causes the non-sparking point, where the brushes should be placed, to alter from time to time, making it necessary in the Edison machine for instance, not only to change the resistance box governing the strength of the magnets, but also to change the yoke carrying the brushes by hand, as this non-sparking point changes.

He had hoped to hear a description of an improved machine called a compound wound machine, which overcomes these difficulties, and is manufactured by the Thomson-Houston Company, and the Royal Electric Company of this city. A completely automatic dynamo is made by using this principle of compounding, which may be briefly described as taking the main leading conductor which feeds the lamps, and winding it a few times around the magnets of the machine, depending upon this chiefly to magnetize the field magnets. Thus, as the lamps are turned off or on, the current is increased or decreased around the magnets, varying the strength of the pole pieces as the current changes in the armature; and consequently keeps the non-sparking point at the same place and makes it unnecessary to use a resistance box, or to require an attendant to watch the machine in case lamps are turned off or on.

With regard to the representation thrown on the screen of an arc lamp, it might be interesting to state that the Thomson-Houston arc lamps referred to by Mr. Lawson, have an automatic device that cuts in the lamp, should a heavy wind or other mechanical influence put the lamp out for an instant, enabling it to start up again and burn as brightly as ever.

Speaking of the multiple series system. One of the most beautiful installations Mr. Kimball has seen of this way of lighting, was in the Narragansett hotel, Providence, R.I., where a fine building was wired up in such a manner that the lamps were in groups of seven. Of course when one lamp gave out seven were extinguished at the same time, which is the necessary evil attached to the system, unless, as in the Weston, a complicated switching device is introduced for every lamp, together with either another lamp in readiness to light, or a bundle of wire which will consume an equivalent amount of energy and dissipate it in heat. There are other disadvantages about this system, not the least of which, is the necessity to provide sufficient insulation in buildings and chandeliers, etc., when we remember that it is customary to use currents of from five hundred to six hundred volts, which, if not dangerous, would prove decidedly uncomfortable if sent through a person.

Mr. Lawson's remarks were interesting as showing his side of the story. It is treading on rather delicate ground when we come to discuss apparatus connected with each other's business, and yet from no one could we expect to get more or better information than from those who are actually engaged either in the use or manufacture of the machines etc. under discussion.

The speaker hardly agrees with Mr. Lawson's statement that it is possible to run the three wire system a distance of anything like a mile, or even a half mile from the central station, without bringing the cost of conductors to such an enormous figure as to render it out of the question for a company expecting to pay any dividends.

On the other hand the alternating system can be installed for a distance of one, or two miles, or more if necessary, without requiring an amount of copper in conductors which would be fatal to the success of the enterprise.

A system of continuous current generators can be nothing but a delusion and a snare, requiring as it does at present, the interposition of a large number of commutators, entirely foreign to the idea of induction coils, and thus bringing into prominence the most delicate and expensive part of a dynamo, the point where the currents are turned in one direction, the commutator.

As for using a system of dynamos to drive motors, at the place where lamps are wanted, in turn to drive dynamos, and to feed the lamps, and considering that small motors have as a rule only about 80 per cent. efficiency, or less, thus losing 20 per cent. in the motor in addition to at least 10 per cent. more in each dynamo and 10 per cent. in the conductors, or 58 per cent. in all, this method is out of the question.

Another point in favor of the alternating system is that by using a low voltage lamp like the 50 volt lamp, a much better and longer lived lamp can be made, giving ten 16 candle power lamps per horse power, while the best that has ever been claimed heretofore, for the low tension system are 8 lamps per horse power. This increases the revenue of the company using the alternating system, at least 20 per cent. over the three wire system, other things being equal, and using the present lamps.

As for any improvement in incandescent lamps which Mr. Lawson prophesies, it will prove equally beneficial to the lamps of both systems.

Again, reference may be made to the absence of danger from the alternating system when it is properly installed. The high tension currents of electricity are kept outside the house and reduced out of doors to a mild and harmless current, before entering the building. As an additional precaution, a ground can be attached to the secondary or house circuit, as it has no electrical connection with the high pressure wires, which would make it simply impossible for a person to obtain a shock in case of a leak from primary to secondary, even if he were so disposed.

Mr. Lawson. In regard to Mr. Kimball's claim for the efficiency of a certain compound-wound machine, such claim can only be made by a person unfamiliar with ordinary dynamo construction, as, although such machines on account of being practically useless for central station work, are not generally made by the Edison Company, yet for several years past they have been supplied to customers demanding them; so that compound winding is not peculiar to that machine nor original with the inventor of that machine, Brush having been the first to employ this means of regulation.

In reply to Mr. Kimball's statement respecting the limit of the three-wire system, it is sufficient to state, that such Edison stations as Harrisburg and Sunbury, where the current is supplied over a radius of a mile, are dividend paying institutions.

Mr. Kimball evidently forgets that the resistance of a wire is a vital factor in the alternating system as it is in any other system. From his criticism of continuous current generators it must be inferred, that he is unfamiliar with that system of distribution, as separate dynamos to drive motors are not wanted; dynamo and motor being combined, and the current for the excitation of the field magnets from the high tension dynamo is ample to produce a sufficiently strong field in the dynamo motor, both for the primary and secondary circuits of the armature. Such a machine would have an efficiency of nearly 90 p. ct., instead of 80 p. ct.; nor is it intended in such a system to use small motors to drive separate dynamos. The total efficiency assuming other items to be as stated by Mr. Kimball, viz.; dynamo 90 p.c., converter 90 p.c., wiring 90 p.c. would give 73 p.c. instead of 50 p.c. Mr. Kimball's estimates for efficiencies of such a system are low.

In regard to efficiency of lamps, those now made and supplied by Edison give 192 candles per mechanical horse-power, or twelve 16 candle power lamps. This is equal to about 15 lamps of 16 candles each per electrical horse-power.

The statement as to the efficiency of such lamps is not a prophecy but a statement of actual fact.

Respecting the safety of the alternating system, Mr. Kimball is careful to say "when the same is properly installed." Mr. Lawson has seen many such installations, but as all are absolutely dangerous it must be assumed that *none* have been properly installed. Also, he has yet to find out where an alternating current station yields a dividend on the investment. The chief merit of the alternating system used in America is that it has enabled $5,000,000 of watered stock to be sold.

To quote the remarks of Mr. W. R. Kimball uttered last August at a meeting of the National Electric Light Association held in Boston:

"The question of the insulation of high potential wires is one which appeals to every part of the electric light station, whether he be lineman or manager. In the one case it is his own life and limb that are involved; and in the other case it is property.* And yet there is danger in carrying high potential wires into cellars and basements."

"The question of the insulation between the primary and the secondary of the inductive coil is governed by a variety of causes. Where converters are placed out of doors moisture will get in. No matter how careful the wires may be placed, the current will be affected. This bold expedient of grounding the inside wire has been brought to the attention of this Convention and the public, by some of

* He might add "and life of others."

the electrical papers. It seems to me that it opens a field for discussion. The question naturally arises in the minds of insurance men, whether running electrical wires down to the ground is not an unheard of thing."

And, in conclusion, Messrs. Siemens & Halske, the most eminent of European manufacturers of such apparatus, state that:—

"So far legislation has not concerned itself with the dangers of this [the alternating] system, but sooner or later will be compelled to do so."

In reply to Mr. Kennedy's question regarding the danger, it might be said that death is due mainly to carelessness. Mr. Thornberry.

Probably the chairman has particularly in mind the deaths which lately occurred at Halifax. It seems that the Halifax company is running two machines on one circuit, thereby saving two return wires to the station. By running the machines in series a very high pressure (about 4,000 volts) is put upon the wires. In cleaning a lamp it appears that the men who were killed, carelessly took hold of the opposite or return wire, while holding the lamp, and consequently formed a nearer path for the return of the outgoing current, the strength of it being enough to cause instant death.

There is no special danger from fire if the circuits are frequently tested for leakage and are kept sound. If a leak occurs on the circuit at a given point, and if on the opposite side of the outgoing loop another occurs, in a building say, where the wires entering are being poorly insulated, enough current may escape through moisture clinging to the point on the outside walls, or through other causes sufficient to generate heat enough to start a small fire, which may finally develop into a larger one, when the fire department must be called out.

If proper care is taken in an installation no such accident as this will occur.

This paper was accompanied by numerous practical illustrations.

no. 19.

May 31st, 1888.

S. KEEFER, President, in the Chair.

MASONRY ARCHES FOR RAILWAY PURPOSES.

By W. Bell Dawson, M.A., Ma.E., M. Can. Soc. C.E.

In dealing with the arch, the writer feels that it will be necessary to proceed carefully; as many Engineers have the impression that for any possible view of the subject some authority may be cited, and that all of them are still more or less at variance with the practical results obtained in construction. The writer of the present paper has no desire to propound any new theory of the arch, or to advocate any one in particular; but will rather make it his aim to compare the theories which have obtained the greatest currency with the object of ascertaining the conditions of construction and loading to which they are applicable, and also to indicate directions in which further investigation is still required to meet the case of railway arches carrying heavy rolling loads.

As it often happens, the discussion on this subject is largely due to misunderstandings which have arisen, owing to the different points of view taken by different authors, and the differing conditions which they have in their minds and do not sufficiently explain. The physical and mechanical properties which the materials are assumed to possess, the method of design and construction, and the purpose of the arch as regards the duty it has to fulfil, are seldom given with the clearness that such fundamental considerations should have. In most cases it is only by reading and re-reading, examining the conditions as expressed mathematically, and noting carefully some obscure hint occurring in the course of the investigation, or even by reference to the examples cited, that the assumed conditions can be inferred. The investigation in different countries has also been carried on without sufficient reference to what has been ascertained elsewhere.

The older theories of the arch need not be reviewed here. The modern study of the subject dates from the introduction of railways, and originated with Méry and Moseley, who were the first to investigate the properties of the curve of pressure. (1) The various theories on the subject have now resolved themselves into two leading ones, which under more or less modified forms have obtained by far the greatest currency. The first of these may be briefly stated as follows: the curve of pressure must remain within the middle third of the arch ring, in order that the stability of the structure be assured. The second is based upon the principle of least resistance, and maintains that the thrust developed at the key, will not exceed the least amount capable of maintaining equilibrium. The first of these has great currency amongst English authors, and being endorsed by Rankine, is often referred to as an axiom. On the Continent, the second is largely adopted as an improvement on older theories, and prominent among its exponents are Dupuit and Scheffler. Since Graphical Statics has developed so widely from the foundations laid by Culmann and Lévy, (2) it has been almost universally adopted as the best method for the investigation of the stability of the arch. It must be noted, however, that so far as the arch is concerned, it is only a method, and does not afford a solution apart from more general principles. We have also the help of a large amount of observation and experiment, but these must be distinguished from each other. In observing structures during and after their erection, all the conditions are present, but the difficulties of observation admonish corresponding care in the inferences drawn. In making experiments with models, these difficulties can be largely removed, but the material employed being usually different, the difference in physical properties must be allowed for.

A complete theory of the arch must apply to the finished structure fulfilling the purposes of its construction; but before proceeding to examine the theories referred to, we may first mention the conditions which accord with the ordinary principles of statics and for which no special theory is required; and we must also examine carefully the physical and mechanical properties of the material with which we have to deal, as explained in works on the subject. The design, method of construction, and purpose of the arch with respect to the loading it has to carry, furnish further conditions which must be taken up in connection with the theories themselves.

There are only two ways in which a perfect arch can be constructed, and these are the converse of each other; either the curve of the arch must be designed to correspond with the loading, or the loading must be placed to correspond with the curve adopted. This can always be done when only dead weight or a stationary load are in question. For example, in the case of uniform loading, the catenary and the parabola are familiar as the forms required, according as the load is uniformly distributed along the curve itself or along a horizontal line; and a circular arch may also become equilibrated by a suitable distribution of the loading upon it. If these methods were adopted, the curve of pressure would coincide with the centre of the arch ring throughout, and the direction of the pressure would be perpendicular to the joints. There would be entire harmony between principle and practice, and the only condition of stability would be the absolute pressure admissible in accordance with the material used. When it is the loading that is prescribed, the form required for the arch is usually difficult of construction, owing to the continual change in the radius of curvature; but notwithstanding this, close approximations to the true forms have been adopted with economy on aqueducts and canals. Their advantages disappear however when a change in the position of the loading has to be allowed for; and for railway purposes semi-circular, elliptic and segmental arches are substituted. Although this is the case, a valuable improvement in the stability of the arch may be obtained by a suitable distribution of the dead weight. To simplify construction the ellipse is often replaced by circular arcs, and there are very elegant methods of describing these by means of a series of centres, (3) to which the name of "basket-handle arches" has been given.

When both the form of the arch and the loading are defined, the arch is subjected to conditions diverging from those required for perfect equilibrium. This is unfortunately the case we are called upon to consider in practice, and for which a theory has to be found. The curve of pressure no longer cuts the joints of the arch ring at the centre, and a weak point develops at the haunch known as the joint of rupture where the curve passes nearest to the intrados.

In considering a series of voussoirs in such an arch, we must first determine how the pressure on the surface of a joint will be distributed when the resultant of the external forces is known. We will suppose, the resultant known in position and magnitude, and for simplicity we will take it perpendicular to the surface of the joint. We further take the surfaces at the joint to be in perfect contact, but without cohesion, so that only compression can be resisted and not tension. With regard to stone and brick we have also some evidence that we are dealing with a material that is elastic and therefore also compressible. As boys we learn that a marble will bounce on a paving stone; the amount that a brick chimney will oscillate in the wind cannot be attributed to the mortar alone; and we have further the corroborative evidence that stone expands with heat. (4) Co-efficients of elasticity have been determined for glass and also for slate; but not for the materials ordinarily used in construction and when under direct compression, so far as the writer is aware. It is the existence of elasticity and not its amount however, that affects the question; and it is doubtful whether any solids exist which are either absolutely incompressible or infinitely hard. Without going further into those physical properties of stone and brick for which the experimental data are so meagre, it is enough that we have the right to infer that they are elastic, and to apply to masonry the same Theory of Elasticity as to other materials. In accordance with this theory, the particles which are in a plane when the body has its natural shape will remain in a plane when the body becomes deformed under compression, the new plane being either parallel or inclined to its original position. Apart from this theory we have no means of determining the distribution of pressure at a joint; and although some thing might be inferred from the final conditions obtaining on the failure of the arch, we could have no knowledge of the internal strains at any other time. We find accordingly that all authors describe the pressure at the joints as being distributed in a lineal ratio to be determined by the position of the resultant; and in doing so, whether they give the explanation or not, they are assuming either that stone and brick are elastic or that they act as if they were; and not only so, but that they conform to the accepted Theory of Elasticity. (5)

With regard to the nature of the contact at the joint, the most accurate workmanship could not be depended on to make it perfect without the intervention of mortar. Nearly all authors agree in considering this the only function of the mortar, (6) and even in the case of cement the adhesion is not counted upon, but is left to form part of the margin of safety. Some few make an exception of brickwork built in cement, and consider both tension and compression as occurring at the joints. This amounts to transferring brickwork from the conditions of masonry to those of a metallic arch, and limiting masonry to stonework only; but there are few who make such a distinction between stone and brick. The only remaining action considered at the joint is friction, which renders an inclination of the resultant compatible with stability when within the limits of the angle of friction.

It follows then directly from the theory of elasticity that when the resultant passes through the centre of the joint, the pressure is uniformly distributed over its surface; and also that as it moves from the centre the pressure becomes unequal, till on reaching a point at one-third from the edge the pressure becomes zero at the other edge, as shown in Fig. 1. This is necessarily the limiting position of the resultant for which the whole joint can be in compression; and the theory that the curve of pressure must be within the middle third of the arch ring is therefore equivalent to maintaining that every joint in the arch must be in compression over its entire surface. This corresponds with a much higher degree of stability than many arches actually have; and we may therefore

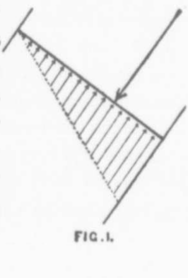


FIG. 1.

follow the effects produced at the joint as the resultant passes out of the middle third and approaches the intrados. The joint will no longer be entirely in compression, but the pressure will extend over a width equal to three times the distance of the resultant from the inner edge, and the pressure at that edge will be double the mean pressure on that area. As to the remainder of the joint it carries nothing, not being capable of bearing tension. (Fig. 2.) Strictly speaking, the outer edge will open, but only by an amount that is entirely inappreciable. It is capable of calculation, being proportional to the compression of the stone at the inner edge; but the compressibility of stone is so infinitesimal that practically it cannot be measured; and the "opening" of the joint under such circumstances is therefore entirely theoretical. This position of the resultant is then still compatible with stability. As the resultant continues to approach the edge, the same action continues in an increasing ratio, until the pressure at the inner edge reaches the ultimate strength of the material, when crushing will take place, rotation through a small angle will ensue, and the joint will open visibly at the opposite edge. This is the true limiting position of the resultant in actual cases; and for hard and sound material it may be very near the intrados. That the resultant may be very near the edge of the joint, without causing the failure of the arch, is also held as proved by authors who base their conclusions on experiment. Prof. Cain shows by experiments with wooden models that at the joint of rupture the curve of pressure passed on an average at only one-eighteenth of the width of the joint from the edge without rupture ensuing. He also calculates that in the bridge of Neuilly the thrust at the crown might pass within less than two inches from the edge without crushing the material. (7) We must therefore conclude that in the case of actual masonry, the curve of pressure may approach extremely near either to the intrados or the extrados without rupture occurring in the arch. This shows the great difficulty of deducing a theory from existing structures, as so little can be inferred from the bare fact that a structure remains standing.

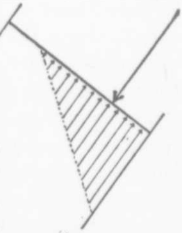


FIG. 2

Let us now take the accompanying outline to represent a portion of the arch-ring in a full arch, either semi-circular or elliptic. We will take it in the usual way to represent by its area the weight of a unit of width in the direction of the axis; and the loading may also be shown as an area representing its average amount per unit of width. We will also consider the loading as placed symmetrically on each side of the key, and a half arch will therefore be sufficient for the figure. For

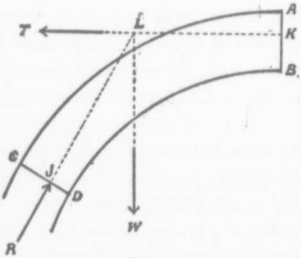


FIG. 3

the forms of loading we have ordinarily to consider it may be broadly stated that the curve of pressure will resemble a parabola. It is easier to determine its general form than to determine its position in the arch-ring; but if such a curve is placed within an arch ring of either circular or elliptic form, it will approach the intrados at two opposite points at the haunches, and at those points it will be parallel to the tangent at the intrados. This determines the positions of the joints of rupture, one of which is shown at *CD;* and if we also take a vertical joint *AB* at the key, these are the only ones which the curve of pressure will necessarily cut at right angles. The moments of the forces must therefore be taken with reference to the portion *ABDC;* as to divide the arch ring at any other point would introduce a radial force representing friction.

We have then three forces to maintain equilibrium. The thrust *T* is horizontal on account of the symmetry. The line *LW* is either a vertical through the centre of gravity of the area representing the arch ring itself between the joint of rupture and the key; or it is the resultant of the weight of the arch ring, and the pressures upon its extrados between the same points. When these pressures are all vertical, *LW* will also be vertical and may be termed the *Gravity line.* When the joint of rupture is known in position, it becomes known in position, direction and amount; and the resistance *R* also becomes known in direction. Thus of the three forces two are known in direction only; but to maintain equilibrium they must intersect in a point at *L*, and this may be termed the *Condition of intersection.* The position of the joint of rupture must correspond with this condition.

It is evident that if the position of the points *K* and *J* can be determined, the curve of pressure also becomes determinate,* and consequently the value of the thrust *T*. These are the *Determining points* in the curve, but unfortunately we have no means of deciding their position *a priori*. The reason for this is only too apparent. We

*As the curve of pressure is symmetrical for symmetrical loading, and the points *K* and *J* imply direction as well as position, they are mathematically equivalent in the complete arch to six determining points on the curve. It would therefore have to be of a very high order to take two different positions between *K* and *J*.

have an external moment produced by the load; but no equivalent moment of resistance is developed in an arch ring as it would be in a metal rib. Hence until the points of application K and J can be determined, the equation between the moments of T and W remains indeterminate, and we cannot therefore proceed either to an analytical or a graphical solution. This abundantly accounts for the great variety of opinions amongst authors. All the theories of the arch can be classified in accordance with the positions they attribute to these points. In mathematical works it is often very difficult to discover the reasons for the choice made; and in works treating the subject graphically, while there is ample explanation of the method of drawing the curve of pressure, there is usually a lack of clearness as to the principles upon which the position of these determining points depends. Although an author may give good reasons for their position in one case, he may be too hasty in making a general application of the result to all cases. It is for this reason that some theories have fallen into discredit, although they undoubtedly have some good features in them, and may be quite applicable under certain conditions.

The direct determination of the position of these points has been attempted at about the same time by Scheffler and Dupuit, based upon the principle of least resistance, but applied in very different ways. This principle is due to Moseley (8) and may be briefly stated thus: the thrust developed at the key will not be greater than the amount which is just sufficient to maintain equilibrium. As it is evident that the least amount of thrust will correspond with the co-incidence of K with A, and J with D, Moseley takes the curve of pressure as tangent to the extrados and intrados at the key and joint of rupture respectively. Scheffler (9) generalizes the same view, and takes a curve of pressure tangent to the extrados and intrados of the arch ring for all cases of loading, whether symmetrical or not. Such a curve corresponds obviously to the case of a structure in which both the arch ring and abutments are everywhere on the point of giving way. If the abutments are about to yield, and the joints CD and AB are about to open, we have the required conditions, and failure will take place in the way so often represented in text-books. Although it can be shown that the curve will only take this position in extreme cases, it may nevertheless be useful as a means of investigation. This theory is also in favor with experimentalists, (10) as it accords with the final conditions which can be observed at the moment of failure. An arch might be designed in accordance with it, by giving it minimum dimensions throughout, and afterwards adding material to cover the possibly greater values of the thrust and other pressures that might occur.

Dupuit (11) applies the same principle but proceeds more carefully. He brings it into relation with the ordinary process employed in the building of arches, and the effects that can be observed when the centres are struck. By following the steps he takes, we will be best able to judge of the principle, and to determine the range of its applicability to the arch.

The following summary of his reasoning is taken from Claudel: (12) While the arch remains on its centres the pressure in the arch ring is zero throughout; and as the centres are eased, the pressures found in the finished arch are developed. These pressures therefore must pass through all the intermediate values from zero upward; and in accordance with the principle of least resistance, he infers that when once the least amounts necessary for stability are reached, there is no further reason why the pressures should continue to increase. In the movement which occurs when the centres are struck, there is something fixed and certain which depends only upon the curve of the arch, and also an amount of uncertainty depending upon the nature of the materials and the methods of construction, so that the uncertainty finally remaining is reduced to such narrow limits as to have no further interest from a practical point of view. While the arch remains on its centres the curve of equilibrium is entirely beneath the arch, and is determined by the intersections of the verticals through the successive centres of gravity, with the production of the joint lines. (Fig. 4.) This may be called the curve of static equilibrium, and corresponds with an absence of pressure in the arch ring. This curve serves merely to indicate the point in the arch around which rotation would tend to take place. As a small thrust develops at the key, this curve rises toward the arch and indicates more distinctly the position of the point of rotation D. When the thrust increases sufficiently to make the curve of pressure pass through the point D, it is evident that it is sufficient to maintain equilibrium. There is therefore no reason why the curve should pass this point and take up a position in the interior of the arch, as such a position would correspond with a greater amount of thrust at the key. The point D being determined we know in what direction the arch will move if the half arch is for a moment left unsupported. The path which each point in the arch tends to take is evidently the arc of a circle around D as a centre. Thus the points A and B will tend to describe the small arcs AA' and BB' corresponding to the same angle at the centre D. The resistance of the other half of the arch however, prevents actual motion; but it follows that the points A and B support unequal pressures, as the amount of compression at these points is evidently proportional to the horizontal distances through which they would move respectively, if they were free to do so. The effect produced by the other half of the arch is to maintain the joint AB in a vertical position; and it follows that the horizontal compression at each point is proportional to the decrease in length of the horizontal projections of the radii drawn from D to A and B respectively. It is easily shown that this proportion is the same as the ratio of $h+t$ to h. If we take (Fig. 5.) two lines AP and BQ in this ratio, it follows from the accepted theory of elasticity that the resultant of the whole pressure on AB will pass through the centre of gravity of the trapezium $APQB$. The point K is therefore not at the centre of AB, but always a little above it. For the limiting cases, if $h=o$ as in the *plate-bande* or straight arch, $BK=\frac{2}{3}t$; and if $h=$infinity, $BK=\frac{1}{2}t$. This reasoning assumes that the point D is rigidly fixed, or in other words that the abutments are immovable and incompressible; and here we meet with the uncertainty mentioned at the outset. If the point D were to yield laterally, the point K would rise in proportion; and would approach as near to A as the strength of the material allowed.

The figure employed in the demonstration is for a segmental arch; but for a full arch it can be shown by similar considerations that the curve of pressure must be tangent to the intrados where it meets it, and that the point of contact determines the position of the joint of rupture. In the actual arch the curve must be sufficiently within the intrados at the joint of rupture to prevent crushing. He further shows that the positions which the joint of rupture can take are always between one half and two-thirds of the rise, in the case both of the semi-circle and ellipse. The exact position depends on the ratio of the thickness of the arch ring to the rise of the arch, as this affects the distance of the centre of gravity from the key; but for the ordinary proportions found in practice, the joint will be very nearly at half the rise.

Dupuit's conclusion is then that with unyielding abutments the position of the curve of pressure will be determined as follows:—

The point K will be at the centre of $A\,B$ for a semi-circular or elliptical arch, and at the upper third of $A\,B$ for a plate-bande. For intermediate forms it will lie proportionately between these limits.

For semi-circular and elliptical arches the curve of pressure will be tangent to the intrados at the joint of rupture, and the joint of rupture is to be determined by this condition. For segmental arches of less amplitude than the arc between the joints of rupture in the full arch, the curve of pressure will pass through the point D at the springing.

In examining this theory it is evident that the determination of the point K would not be appreciably affected if the point J were to move out along the joint of rupture; but on the other hand it does depend entirely on the supposition that the abutments are unyielding. If the abutments give laterally under the effect of the thrust, the joints of rupture will open and also the joint at the key. The curve of pressure will then necessarily pass through A and D; but the value of the thrust will be considerably less than for a curve passing through K and D. We see then that any yielding of the abutments gives an immediate reduction in the value of the trust; and therefore the abutments require greater strength to resist yielding than to stand after a slight motion has taken place. This accounts for the regained stability of structures in which a slight movement has occurred. We have also in this a distinguishing difference between the theories of Dupuit and Scheffler. As examples of cases in which the condition of unyielding abutments becomes perfectly realized, we may mention a segmental arch springing from the solid rock, or a series of arches all equal and equally loaded; but it will be practically fulfilled in any case in which the abutments themselves and their foundations are sufficiently resisting.

It cannot be too carefully noted, however, that Dupuit's reasoning is based upon the consideration of the arch ring itself while standing alone. For that case then we must consider his conclusions as established. But in supposing that the curve of pressure will remain tangent to the intrados when the arch ring carries the weight of the spandrel walls, backing and filling, Dupuit is certainly going beyond the limits of what he has actually proved; although he renders most valuable assistance to the consideration of the subject by indicating the true starting point and the first steps to be taken before more complicated conditions can be examined with advantage. His method for the completed arch is to find by trial a new position for the joint of rupture which will fulfil the condition of intersection; the tangent at the joint and the thrust at the key having to intersect on the gravity line. This new position will be lower than for the arch ring itself, as the gravity line will be further from the key.

It is not usual, however, to complete the whole structure before removing the centres, as any settlement of the arch ring would render very uncertain the actual distribution of the pressure upon it. To suppose the arch built in this way in order to apply the principle of least resistance to the finished structure, is to introduce a large and unnecessary amount of uncertainty. Now when the gravity line moves further from the key it is evident from the condition of intersection, either that the joint of rupture will take a lower position, or that the point J will move out from the intrados to maintain L J at right angles to C D. To decide between these alternatives we must first examine the question as to how the pressure from the spandrel is transmitted to the back of the arch ring, as it is possible that when the arch ring carries its weight the line $L\ W$ may no longer be vertical. As a limiting direction, the pressure may be everywhere at right angles to the extrados; but this condition can only be realized by taking exceptional precautions with the object of obtaining the "hydrostatic arch," and we cannot therefore suppose it to be the usual case. Again, the pressure may act along inclined lines similar to those given by the pressure of earth. This will be the case for deeply buried culverts and for sewers; but these we cannot now consider, as their stability depends on conditions too far removed from those we have before us. Some Engineers maintain that the pressure of masonry will also act similarly along inclined lines of fracture. It is possible that this may be the case to some extent, especially towards the haunches; but for the central portion of the arch, it is sufficient to adopt the ordinary supposition that each voussoir carries the portion of the load vertically above it. As regards the haunches it is an almost invariable rule to carry up the backing to the level of the joint of rupture as found for the arch ring, before the centres are struck. When this is done the question is much simplified, as the whole of the masonry below that joint can then be taken as forming in reality a part of the abutment. We will assume then that it is only the remainder of the spandrel which is added after the centering is removed; and this has the sanction of the best constructors. When the arch is built in this way, we are not at liberty to suppose that the joint of rupture will take up a lower position than it had in the arch ring, and we are left to the alternative that on the addition of the spandrels the point J moves out from the intrados. We see at the same time the advantage derived from adopting this method of construction.

This also seems the more probable when we compare the form of the spandrel with a form of loading which will make the curve of pressure coincide with the centre line of the arch ring throughout. This form can readily be found by reversing the ordinary graphical process. The centre line of the arch ring is assumed to be the curve of pressure, successive tangents to it are drawn, and a force diagram constructed in which the successive parts represent the weights that have to be applied along the curve. (See Greene's "Arches," Art. 140.) By plotting these parts from the intrados as ordinates, the weight of the arch ring is taken into account, and the area indicated by the ordinates is the loading required. Its form is given in Fig. 6; and on comparing this form as far as the joint of rupture with the usual form of the area representing the weight of the spandrel, the similarity is sufficient to enable us to infer that the addition of the spandrel improves the position of the curve of pressure. This accords with experiment, and with observations on completed structures. It would justify also the practice of increasing the thickness of the arch ring toward the springing; for while this would add nothing to the strength of the arch ring standing alone, it becomes of real service when the structure is completed. There is therefore every reason in favor of the conclusion that when on the addition of the spandrel the gravity line takes up a position further from the key, the joint of rupture will not change its position, but the point J will move out from the intrados. This change, however, will not affect the considerations which led to the determination of the position of K.

For the structure completed as above described, and with unyielding abutments, the following general method of finding the determining points is suggested as harmonizing with the best discussion of the subject as given by different authors :—

The point K will remain at the same position as in the arch ring.

For a semi-circular or elliptical arch the joint of rupture will remain at the same position as in the arch ring, and the point J will be found by drawing from L where T' and W intersect, the line LJ at right angles to CD. Similarly for a segmental arch, the point J will be determined by drawing LJ parallel to its former position in the arch ring.

To make the position of the points K and J dependent upon the position of the gravity line as this method does, is much more reasonable than to give them the same arbitrary position for all cases. It also affords a means of ascertaining the most advantageous distribution of weight in the spandrel. As a rule the point J will be only a short distance out from the intrados; but in extreme cases, if there is a large amount of loading over the haunches, the gravity line may be so far from the key as to bring the point J to the centre of CD and eventually even to the extrados. We have been assuming, however, that the loading acts vertically; but in such a case the assumption may reach a limit beyond which it is no longer true. When the loading is so highly concentrated over the haunches it is more than probable that the direction of the pressure becomes inclined to the back of the arch ring. This is difficult to estimate in amount, but in semi-circular or elliptical arches it will be quite sufficiently allowed for, by supposing that when J reaches the centre of CD, the line LJ then becomes tangent to the centre line of the arch ring. In a segmental arch in like manner, the pressure of the spandrel will prevent J from passing the centre of CD. It would, however, be preferable to increase the thickness of the arch ring towards the springing, or to re-distribute the weight in the spandrel, rather than to count upon any inclination in the pressure above the joint of rupture to improve the position of the curve of pressure. Such positions of J are not likely to occur for any ordinary form of spandrel.

Let us now compare this method with the theory that the curve of pressure must remain within the middle third of the arch ring. This theory is endorsed by Rankine, and the weight of his authority has tended more than it should to deter further investigation. His statement is that the stability of an arch is secure if the curve of pressure can be drawn within the middle third; and he goes so far as to say that although arches have stood and still stand in which the curve lies beyond the middle third, the stability of such arches is either now precarious or must have been precarious while the mortar was fresh. (13) We must first endeavor to ascertain the nature of the arch and the conditions of which Rankine is treating. It is to be inferred from the cases he takes up and the examples he gives, that he is considering arches for which the amount of the moving load can be neglected in comparison with the weight of the structure itself. Prof. Wm. Allan in his "Theory of Arches," which he describes as being an amplification and explanation of Rankine's chapters on the subject, takes for granted that this is Rankine's point of view: "In all stone or brick arches the changes in the curve of pressure due to passing loads are usually slight, because the weight of such passing loads is generally small compared with the weight of the arch itself and its backing." (14) This statement affords the key to Rankine's explanation of the subject. If this had been distinctly pointed out in his works, a large amount of discussion and misunderstanding might have been avoided. The same explanation of the range of application of the theory of the middle third is given in the article on "Bridges" in the last edition of the *Encyclopædia Britannica:* "The masonry arch differs from the superstructure of other bridges in the following respect: it depends for its stability on the presence of a permanent load specially arranged, and so considerable in amount that the changes produced in the direction and magnitude of the stresses by the passing load are insignificant." (15)

The theory of the middle third corresponds then to the case of the finished structure without appreciable moving load. To find in accordance with the method suggested above the limits within which the gravity line must keep in order that the curve should remain within the middle third of the arch ring, is merely a matter of geometrical construction; and we have thus a ready means of comparison by which to verify the results. Take for example the case of a semi-circular arch of radius r, in which the arch ring has a uniform thickness t, and the joint of rupture is at 30°. The possible limiting positions of K and J for a curve remaining in the middle third will be, the upper third at the key and the lower third at the joint of rupture, or the lower third at the key and the upper third at the joint of rupture. The distance g of the gravity line from the key corresponding to these limits will be: $g = r \tan 30°$ and $g = (r + t) \tan 30°$ Or numerically, for semi-circular arches of 10 ft. and 100 ft. diameter, in which the thickness t is determined by Rankine's formula, the limits will be :—

10 ft. arch, 0.577 r and 0.664 r. 100 ft. arch, 0.577 r and 0.605 r. As it happens, the gravity line for spandrels as generally built has very nearly this position in full arches and a corresponding one in segmental arches; and this accounts for the currency of the theory as applied to the conditions supposed.

This theory also implies, as we have seen, that every joint in the arch must be entirely in compression. This corresponds with a much higher degree of stability than is necessary under quiescent loads; but the advocates of the theory take it practically as a margin of safety. They consider that if the curve is within the middle third in the structure bearing its own weight, it will be sufficiently stable under any moving loads it may be called upon to carry. (16) As the theory is fairly in accord with the form which the spandrel usually has, it may be sufficiently near the truth as regards road bridges; but it is taking quite too much for granted in the case of arches carrying heavy engine loads. It could only be brought into reasonable agreement with such cases by lowering the springing and increasing the depth and weight of the spandrel, till the moving load became relatively small enough to neglect; but such a construction would be inconsistent with economy. To have the curve of pressure within the middle third of the arch ring is very desirable and should be aimed at; but it cannot be laid down as a principle that it must be so. It is in reality only a special case coming under a more general method; and it would therefore be more correct to work in the converse direction, and to find the depth of the spandrel and the amount of backing required to make the curve take the desired form, as nearly as the case will allow.

We may now proceed to consider the arch carrying a live load symmetrically placed. This load we may reduce in the usual way, to an area representing an equivalent amount of masonry.

The load on Railway arches is now often as great or greater than the weight of the structure itself, which shows again how unsafe it is to apply methods which depend upon its amount being neglected. If the load is uniformly distributed, the centre of gravity of the whole area representing arch ring spandrel and load between the joint of rupture and the key, will almost always be further from the key than the centre of gravity of the arch ring itself; and this being the case, the reasoning given before will be entirely applicable. The joint of rupture will still have the same position as in the arch ring, and the general method as given for the full arch and the segmental arch will remain the same.

The gravity line with a distributed load will be nearer the key than in the unloaded arch, and the point J will also be nearer the intrados. With an excessive distributed load, or with a load increasing towards the key (while still symmetrical as regards the two sides of the arch), the point J may reach the intrados. This is an unfavorable position, but it does not necessarily compromise the stability of the arch. It is desirable if possible to prevent its occurrence, either by thickening the arch ring, modifying the form of the arch, or re-arranging the weight in the spandrels in order to keep the gravity line further from the key. If for any positions of the line load which the arch has to carry the gravity line is brought still nearer the key, the line $L\ J$ will continue tangent to the intrados and the joint of rupture will rise. In such extreme cases it is possible that the point K may also rise at the key, even with unyielding abutments.

It appears both from experiments with models, and by comparison with the form of the funicular polygon, that the curve of pressure will rise immediately under any highly concentrated load; and with a moving load such concentration is necessarily greatest at the crown. It would therefore seem probable that the thickness of the arch ring at the crown depends' more directly upon the heaviest concentrated load passing over the arch than on any other consideration. Vibration on the contrary has more effect towards the haunches. We are still dependent, however, upon empyrical formulae for the thickness at the crown. Early authors suggested an equation of a linear form; but this has now been replaced by the forms

$$t = C\sqrt{s} \quad \text{or} \quad t = C\sqrt{r}$$

t being the thickness required, s the span of the arch, and r the radius at the crown, all in feet; and C a constant. (17) The values most generally adopted for C are those given by Rankine and Dupuit, which are as follows :—

Rankine. $t = \sqrt{0{\cdot}12\ r}$ for a single arch.

$t = \sqrt{0{\cdot}17\ r}$ for an arch of a series.

Dupuit. (Co-efficients reduced for feet)

$t = 0.36\ \sqrt{s}$ for a full arch.

$t = 0.27\ \sqrt{s}$ for a segmental arch.

Rankine's introduction of the radius of curvature at the crown instead of the span, is based upon a comparison between the arch and an elastic rib; but he deduces the co-efficients from actual examples. With regard to the greater value in the case of arches in series, he considers that yielding is more likely to take place when a loaded arch stands between two unloaded ones, than if it stood between abutments. Dupuit's formulae are based directly on very numerous examples, a large proportion being Railway bridges. He refers only to actual construction as justifying the lower co-efficient he gives for segmental arches. (18)

The starting point for all such formulae is the semi-circular arch of diameter d; and for it a comparison between the formulae can readily be made. We have for a single arch :—

Rankine. $t = 0{\cdot}24\sqrt{d}$; Dupuit. $t = 0{\cdot}36\sqrt{d}$

The greater value given by Dupuit's formula is probably due to the greater proportion of Railway arches on which it is based, and perhaps also to the lower average strength of the stone used in France. If we consider the span to remain the same, and the arch to change from a semi-circle to a straight arch by passing through the intermediate segmental forms, we find that Dupuit would give the arch ring a diminished thickness. Rankine's formula, on the contrary, would make it continually increase, and on arriving at the straight arch the thickness would be infinite, or in other words a straight arch would be theoretically impossible. This may result from the supposition that the joint lines are always radial; and his formula might still be applied to the straight arch by taking the point from which the joints radiate as the supposed centre. An intermediate formula has been proposed by Trautwine in the last edition of his Pocket-book:—

$$t = 0.25\sqrt{r + \tfrac{1}{2}s} + 0.20 \text{ (for feet)}$$

For a semi-circular arch this is practically the same as Rankine's with the difference of the constant added. It does not increase the thickness so rapidly as his, but gives also an infinite thickness to the straight arch.

There is still need of agreement respecting the rational basis for such formulae, as they differ in principle. They could only be satisfactorily compared by dividing the examples on which they are based into classes, in accordance with their purpose and the conditions of their construction.

To determine the stability of the abutments it is only necessary to continue to the foundations the curves of pressure corresponding to the various cases considered. As we have already had occasion to notice, the abutments require greater strength to resist yielding, than to stand after a slight motion has taken place; because the position of the point K as determined for unyielding abutments, corresponds to a greater thrust and greater pressures throughout the structure than if it rose to A through the opening of joints in the arch ring. With symmetrical loads the greatest resistance will be required when the arch is completely loaded; and although the effect of partial loading may possibly be greater, this is almost invariably left to the margin of safety. If the curve of pressure strikes outside of the middle third of the base, there is a portion of the abutment whose weight should not be taken into account. (Fig. 7.) The effective width of each course is then only three times the distance from the curve to the back of the abutment; and the curve of pressure should be drawn again, omitting the weight of the remainder. This precaution is especially necessary in the case of segmental arches. When all the cases of loading are considered, the abutment will be undoubtedly stable when the resulting curve is sufficiently within the base to prevent excessive pressure, provided the foundations are thoroughly sound. It will be quite unnecessary to double the thrust from the arch as recommended by some authors, unless indeed this is done to allow for positions of the load which are not considered.

When arches are built in a series, somewhat different conditions arise. When the weight only of the structure is to be taken into account, the pressure on the piers is vertical and the resistance to crushing is the only consideration. For arches carrying a moving load, a pier is the most unfavorably situated when it is between a loaded and an unloaded arch. The reactions at the joints of rupture in the two arches respectively, when compounded with the weight of the pier, give the final resultant, which in a pier should always meet the base within the middle third. Before failure can take place however, the thrust of the loaded arch will develop a much greater reaction at the joint of rupture of the unloaded arch than the amount due to its weight only. If the loading increases to the limiting amount, the loaded arch will fail in the ordinary way, but the joints in the unloaded arch will open in the reverse direction, corresponding to a curve of pressure passing through B and C, and therefore also to a largely increased thrust. Such a thrust should not be counted upon except in the case of small arches used as counterforts, or transverse arches in the interior of an abutment; but it will at least be allowable to consider the pressure at the joint of rupture of the unloaded arch to become equally distributed under the influence of the thrust from the adjoining arch, and so to place J at the centre of $C\ D$ in the unloaded arch.

The various theories have now been compared in the endeavor to point out the conditions under which they are applicable, and to ascertain the position of the determining points in the curve of pressure which best accords with them in the various cases considered. It will be unnecessary to proceed further into detail, as the method of drawing the curve, when these points are known, is fully given in works on Graphical Statics. In applying the graphical method, a distinction has in some cases to be made between the "curve of pressure" and the "line of resistance," according to the division of the arch ring into vertical laminae or actual voussoirs. The method of passing from one to the other is given by Prof. Clarke. (19) The distinction between these curves was originally pointed out by Moseley, and is well illustrated by Dubois. (20)

We have not considered the case of unsymmetrical loading, as so few authors touch upon it at all, and those who do differ so widely in opinion. When an arch is loaded symmetrically, it has been maintained that the thrust at the key will remain the same, if the load is removed from one half, leaving the load on the other side only. This seems plausible at first sight, as this thrust is undoubtedly sufficient to support the loaded side of the arch; but on continuing the curve on the unloaded side it will often pass entirely out at the extrados in existing structures which could not possibly stand if this were the case. On the other hand, a mean between the values of the thrust for the loaded and unloaded arch, is not sufficient to support the loaded side. From a general theorem given by Collignon (21), it would appear that with unsymmetrical loading friction is developed at the key, or in other words, the direction of the thrust is inclined towards the less loaded side. This accords also with the direction of the tangent at the centre of an unequally loaded catenary. In the case of an arch with an engine load on one side only, an inclination of 5° to 10° in the line of thrust will usually prove sufficient to keep the curve within the arch ring; and this is a very moderate amount compared with the limiting angle of friction. The curve corresponding to such an inclined thrust is found to rise under the load, as would be expected. The joint of rupture tends to fall on the loaded side and to rise on the unloaded side; and if the arch is so constructed that the joint of rupture cannot take a lower position, the value of the thrust for any assumed inclination can be found after a few trials by equating the moments on the loaded side only. So far as the writer has been able to determine, the effects of such partial loading may be actually greater than with a complete load, especially as regards the abutments. Although we may infer the general opinion to be, that the results would not differ largely from those already obtained for complete loading, the effects produced, should not be left to the margin of safety in the structure; and this part of the subject therefore requires further investigation.

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(1.) *Curve of Pressure.* Its properties were first discussed by Méry in 1827, though his work remained in manuscript till 1840. In the meantime Moseley's article appeared in 1833. (See No. 8.)

(2.) Culmann. "Die graphische Statik," Zurich, 1866.

Lévy. "La Statique graphique," Paris, 1874.

(3.) *Basket-handle arch or false ellipse.* A summary of various methods proposed for drawing these is given by Morandière, "Traité de la Construction des Ponts et Viaducs," chap. 3, pages 168 to 181 ; Paris, 1874. For the methods proposed by Michal and Perronet, see also Claudel, "Aide-mémoire des Ingénieurs," Art. 854. 9th Edition ; Paris, 1877.

(4.) *Expansion of stone by heat.* Mentioned by Stoney as occurring in masonry arches; "Theory of Strains in Girders," &c., Ch. 19, Art. 414. Observed in an experimental arch of 148 feet span designed by Romany for the Pont du Louvre, Paris; "Annales des Ponts et Chaussées," 1866, 2e semestre, page 10. Also cited in Morandière's "Traité," page 217.

(5.) *Theory of Elasticity applied to Masonry.* Well explained by Collignon. "Résistance des Matériaux," Arts. 30 to 66, and Art. 228.

(6.) *The function of mortar.* See Moseley, "Engineering and Architecture," 2nd Edition, page 482. London, 1855.

(7.) *Limiting positions of the Curve of Pressure.* See pages 85 and 28 in "A practical Theory of Voussoir Arches," by Prof. Wm. Cain; Van Nostrand's Science Series, No. 12, 1874.

Principle of Least Resistance.

(8.) Originally published by Moseley in the "Philosophical Magazine" for October, 1833. See also his "Engineering and Architecture," Art. 332. The priority claimed for Coulomb cannot be established.

(9.) "Theorie der Gewölbe und Futternzauern," Scheffler, 1857. Translated into French by Victor Fournié, "Théorie des Voûtes," Paris, 1864.

(10.) Scheffler's theory compared with experiment, "Voussoir Arches," by Prof. Wm. Cain; Van Nostrand's Science Series No. 42, 1879.

(11.) Dupuit's Theory. Published originally in the "Annales des Ponts et Chaussées," 1858. In a separate form as "Traité de l'équilibre des Voûtes;" Text and Plates. Paris, 1870.

(12.) Summary of Dupuit's work given in Claudel, "Aide-mémoire des Ingénieurs," sections 870 to 934. 9th Edition.

Theory of the Middle Third.

(13.) Rankine, "Civil Engineering;" Arts. 123 to 141, and 276 to 298.

(14.) Rankine's chapters on the Arch amplified and explained by Prof, Wm. Allan, "Theory of Arches," Van Nostrand's Science Series No. 11, 1874.

(15.) "Encyclopædia Britannica," ninth Edition, 1876. Article "Bridges," by Prof. Fleeming Jenkin.

(16.) See foot note to Art. 178 in "Graphical Statics," by Prof. Dubois New York, 1883.

Thickness of the arch ring at the key.

(17.) The equation of the form $t=C\sqrt{r}$ was first proposed by J. T. Hurst, "Building News," Feb. 27, 1857; though the corresponding form was adopted independently on the Continent.

(18.) For the bridges on which these formulæ are based, see Rankine's "Civil Engineering," Art. 290; and Dupuit's "Traité," Chapter 7 and Plate 5.

(19.) *Graphical methods.* Change from vertical laminæ to real joints, given by Prof. Clarke, "Graphic Statics," Art. 52. London, 1876.

(20.) Difference between curve of pressure and line of resistance. Illustrated by Dubois under the names "pressure line" and "support line" in his "Graphical Statics," Art. 176 and Fig. 102.

(21.) *Unsymmetrical loading.* See Collignon's general theorem, "Résistance des Matériaux," Art. 225.

Examples of Arches.

Morandière, "Traité de la Construction des Ponts et Viaducs." Masonry Bridges, pages 1 to 508; and plates 34 to 136, being 12″ x 18″ engravings. Paris, 1876.

From the Drawings accompanying this paper, Plate IX has been prepared.

DISCUSSION.

Prof. Collignon. MR. E. COLLIGNON, Professor of Applied Mechanics at the *Ecole, des Ponts et Chaussées*, Paris, in reply to a request to take part in the discussion, says that he looks somewhat skeptically on the theory of arches. The leading improvement which could be made in it, would be to introduce as an element in the problem, the elasticity of the stones and the compressibility of the mortar; two points on which our present knowledge is extremely imperfect. We accordingly fall back upon principles which are more or less arbitrary, as for example the principle of least resistance; and this, in reality, is only a way of covering our ignorance as to the real conditions of the problem.

It is the fundamental character of the masonry arch, to be so massive and heavy, that the effect of the moving load may be almost inappreciable. It is doubtless for this reason that the arch is the most durable form of construction. The attempt to design an arch so light, that the moving load must be taken into account, results in a marked variation in the local pressures in the structure. It passes then into the class of modern structures which may be light and elegant, but which require continual repair in order that they may last out their time.

Prof. Greene. As Mr. Dawson opens his interesting paper with a statement that he makes it "his aim to compare the theories which have obtained the greatest currency," the writer cannot perhaps fairly criticize him for giving little or nothing in regard to the treatment of the masonry arch as an elastic rib; for it is very probable that the method, given in detail in Greene's *Graphics, Part III., Arches* may not come under the above designation. It will be clear, however, to any reader of that book, that the stone arch is there viewed from a totally different stand-point from those taken by the authors Mr. Dawson has referred to.

It would naturally follow that the writer would dissent from those ways of looking at the problem and from some of the assumptions and empirical rules. It is not necessary to discuss the several points in detail, as he would refer, for his method of analysis and results, to the work above cited; but, taking advantage of the opportunity so kindly offered to discuss this paper, the writer would submit the following views.

There is no good reason for separating arches of stone or similar materials from those of metal, and for using a different method of analysis. All structures are subject to the conditions of statical equilibrium, and suffer elastic deformations under the stresses produced by their weight and applied loads. A masonry arch must resist the bending moments and thrusts caused by such weight and loads, and the magnitude, direction and position of the resulting internal forces are governed by the figure of the arch and the distribution of such weight, in conformity with the laws of statics and of elastic change of form, just as in the case of an iron or steel rib of the same proportions, fixed at its ends in direction. But the magnitude at any point of the bending moment under which it is possible for the arch to maintain its shape, is *practically* limited by the requirement, that the intensity of thrust at any joint shall be sufficient to neutralize the maximum intensity of tension which would be found there from the bending moment alone; and this requirement amounts to saying, that the curve of equilibrium shall nowhere leave the middle third of the arch-ring, unless it is considered of little consequence that joints should open slightly under the greatest moments, when somewhat greater deviation of the equilibrium curve from the centre line can be permitted in the design.

By, therefore, determining the equilibrium curve for a linear arch of the desired span and rise, under a weight assumed, as nearly as may be (and afterwards corrected if necessary), equal to and distributed like that of the proposed arch, and by finding also the deviations of that curve or the new curve, for travelling loads in the *worst* positions, the required depth of voussoirs can be found for all points of the arch. No empirical rule is required for depth of keystone, and, indeed, if such depth is determined by an arbitrary rule, little remains to be done in designing the voussoirs themselves.

The height to which the solid backing is carried, has an influence on the necessary depth of voussoirs, and experience and investigation have shown approximately the height to which economy in the thickness of ring and amount of backing would lead. That point in the ring where the curve of equilibrium approaches most nearly the edge, be it inside or outside, is properly the point of rupture, and that point may be anywhere in general, depending on the loading,—sometimes at the crown, and not necessarily at the haunches,—and as soon as movement begins there will be three joints of rupture, if not more.

Mr. Dawson says, "We have an external moment produced by the load; but no equivalent moment of resistance is developed in an arch ring, as it would be in a metal rib." But if, from the moment produced at any point of the arch by the external forces and the vertical component of the abutment reaction, is subtracted the moment about the same point of the horizontal thrust at the abutment, the result is the bending moment on the arch at that point, and the moment of resistance to balance it must be afforded, if equilibrium is to be maintained. It is the introduction of thrust which distinguishes the arch from beams and trusses, and modifies as above, the bending moments to which it is subjected. As the horizontal thrust is at first unknown, and is to be found by the application of the proper conditions, the values of the bending moments cannot be found at the outset, as for a truss; but such a view of the matter assists in a clear understanding of arch action. The preceding statement is not incompatible with the distribution of stress at a joint illustrated by Figs. 1 and 2; for that results from the combination of a moment of resistance equal to the above bending moment, with the thrust at the joint; and the stone arch differs in action from the metal rib only, in the existence of joints which can offer little or no resistance to tension, and which therefore limit the minimum depth of voussoirs through the possible moments of resistance which they can supply in combination with the thrust.

If the position ascribed to Moseley and Scheffler, as the writer understands it, were sound, no arch could give way by rising at the crown and sinking at the haunches, as has sometimes been the case with arches lightly loaded at the crown and heavily loaded towards the springings; for the arch always tends to move from the equilibrium curve. Again, symmetrical loading will not always exist with rolling loads, and the thrust at the crown will not continue horizontal.

The truth of the proposition, that the equilibrium curve which gives the minimum horizontal thrust is the most probable curve of pressures, is doubted. The principle of least resistance, as laid down by Prof. Rankine, after Mr. Moseley, in his *Applied Mechanics*, p. 215, is:— "If the forces which balance each other in or upon a given body or structure be distinguished into two systems, called respectively *active* and *passive*, which stand to each other in the relation of cause and effect, then will the passive forces be the least which are capable of balancing the active forces, consistently with the physical condition of the body or structure. For the passive forces being caused by the application of the active forces to the body, will not increase after the active forces have been balanced by them, and will therefore not increase beyond the least amount capable of balancing the active forces."

From this statement the writer is not disposed to dissent, but he objects to the assumption that the load and the vertical components of the abutment reactions are the active forces, and that the horizontal component alone of the same abutement reactions, is the passive force and therefore the least possible.

That an arch should stand, it is necessary that, at every point, the three conditions of static equilibrium should be fulfilled, and that it should have a definite span. The attempt to spread gives rise to the inclined thrusts at the abutments, and, in a masonry arch, like a rib with fixed ends, or beam built in at both ends, these thrusts must have such directions and points of application, that the aggregate of the bending moments, arising from the position of the resulting equilibrium curve, shall cause no *horizontal* or *vertical displacement* at either springing point with reference to the other, and no *rotation* or change of direction of the tangents at those ends. By the application of these three conditions the equilibrium curve for any given arch can be determined, and hence the proper proportions for such an arch can be derived. The method is equally true for horizontal or inclined applied forces, and has been successfully tested in that way also. It is believed that the designs which have resulted from the use of this method, and the causes of failure which it has explained, furnish ground for confidence in its accuracy.

As enough of heresy has been advanced in this communication, the writer will close by expressing his belief that,—were it not for the fact that the live load to which stone arches have been subjected, bears so small a ratio to the weight of the arch itself and the spandrel filling, that this live load produces but little movement of the curve of pressure,—many such structures, where an excessive amount of material would not have been used, have given evidence that the methods by which they have been designed were very inaccurate.

Mr. B. Baker remarked that he had found little to comment upon in Mr. Dawson's paper, as the different views held on the subject of arches have been so fairly and ably set forth by the author. During the past 25 years he has had a great deal to do with arched bridges of all spans up to 150 feet, and his practical experience has necessarily led him to form certain conclusions. Amongst these is one, long since expressed in print, that the theory of the "middle third," has no practical application whatever, and that Rankine's views as to the precarious stability of arches, in which the curve of pressure did not fall within the middle third, were based solely upon the strange misconception, that a hair-line crack in a masonry joint is equivalent to "precarious stability." As a matter of fact, owing to the settlement of foundations and abutments, the compression of mortar joints, and the small amount of elasticity in masonry, slight cracks are the rule and not the exception, and the "middle third" theory cannot therefore be regarded by the practical engineer as more than a possibly interesting exercise for students. A few years ago he had to uphold Telford's fine masonry arch of 150 feet span across the Severn, built some 60 years ago. Telford reported that on striking the centres the arch came down 2 inches, and some time afterwards it came down suddenly a further 8 inches. When the writer Mr. B. Baker.

inspected the bridge the total settlement was about 15 inches, owing to further yielding of the abutment, and the soffit of the arch at the centre had a slight reverse curvature. The joints of the arch stones were open in places as much as an inch, and one could walk through the cracks in the spandrils. The 4,000 tons thrust was carried through the edges of the arch stones. Similarly, on the Metropolitan Railway, he had several cases where, owing to distortion of the brick arches, the joints were open nearly an inch. He has also studied the stability of certain masonry arches, partially blown down by the Prussians in the late war, and found many instructive lessons.

Shortly it comes to this:—Owing to the small amount of elasticity in masonry, a slight settlement in foundation or abutments, will cause open joints, and as the engineer cannot guarantee there will not be a slight settlement he must design his arch to be strong enough to do its work under those conditions. Practical experience, rather than mathematical investigation, is here required, and hence we find that in 99 cases out of 100, masonry arches are designed according to some empirical rule and not as a result of calculation. Where calculation is employed, it must be accompanied by sound judgment based upon experience. The writer does not think experience will justify the author's statement, that, as regards the physical properties of stone and brick, "it is enough that we have the right to infer that they are elastic and to apply to masonry the same theory of elasticity as to other materials." He necessarily also disagrees with the writers referred to by him, who act upon that theory. He has no objection to a student calculating the stresses on a masonry arch of as an elastic solid, provided he does not attach any value to the result. Of course, he would assume a constant value for the modulus of elasticity for the bricks, stones, concrete and mortar, so the problem would be easy. Let him take the actual facts, however, and the problem will not look so inviting. For example, if he refers to Eads's experiments for the modulus of limestone arch stones, he will find it range from 5,000,000 to 13,000,000. Then as regards the mortar made of one part of America cement to two of sand, he has a choice of anything from 220,000 to 6,500,000. Finally, if he is dealing with concrete, he may consult the writer's experiments and select any value he likes between 900,000 and 2,600,000. When it is remembered all these values may be jumbled together in one arch, it will be seen that the fact of masonry being elastic does not assist in the least degree in the determination of the stresses or the voussoirs.

In practice what generally happens is this:—The mortar joints get strained in places beyond the elastic limit, and the pressure transmitted, is practically distributed uniformly on the arch stones, for a certain distance on each side of the curve of pressure. As regards moving loads, if the curve of pressure falls within such limits, that an ideal arch, following the curve of pressure, and of the thickness corresponding to the required working stress upon the masonry, is included within the actual arch, then according to Mr. Baker's experience and practice the arch is safe. For example, say that the working stress on a brick arch is to be 8 tons per square foot and that the resultant thrust from the load is 16 tons per lineal foot of the width of the arch, then the thickness of the arch should be such that there would be a minimum distance of 1 foot between the curve of pressure and the extrados and intrados of the arch. All the arches carrying buildings over the Metropolitan railway were so proportioned by him, and the loading was in many cases very unequally distributed.

Mr. Irwin.

Before proceeding to say anything in particular as to the paper just read, the speaker would wish to state that he agrees in the main with the opinions expressed by Mr. Dawson, and that he wishes to express his appreciation of what he considers to be an honest, painstaking and able endeavor to compare the various theories regarding arches, and to sum up the results of his investigations in giving what seems to be the best manner of treating the subject.

The speaker also thinks that Mr. Greene is mistaken as to Mr. Dawson's application of the elasticity of stone to his method of treating the subject of arches, as Mr. Greene seems to think that Mr. Dawson would treat a stone arch as an elastic rib, whereas he only stated that stone must be elastic in order to transmit pressure uniformly.

With reference to elasticity of stone as referred to in the paper before us, the speaker does not see that it is even *necessary* for stone to be elastic to transmit pressure ;—supposing it were uniformly compressible to a small extent, it would still transmit a pressure uniformly, just as if it were elastic, only when the pressure were removed it would not recover its original shape. The speaker believes that an inelastic but slightly compressible material, providing it were strong enough, would make a very good *theoretical* arch for a dead load which is the case under consideration; it would not, however, be suitable for a moving load.

The speaker does not in any way wish to deny that stone is elastic, but simply to say that he does not see that it is *absolutely necessary* to the theory that it should be so.

With regard to Mr. Dawson's remarks as to a brick chimney rocking in the wind, the speaker thinks that this is due rather to the yielding of the mortar than of the bricks, as Stoney gives the tensile strength of good 2 to 1 cement in brickwork of good absorbent bricks, as 54 lbs. per square inch, while the compressive strength of similar brick-work is about 500 lbs. per square inch; a chimney in the wind would therefore rather give way on the windward side and turn towards the leeward side.

While referring to the subject of mortar, the speaker would like to hear the opinions of some of the other members as to the best kind of cement to use in building arches. His own opinion is that a slow setting cement is the best, as if the cement be well set before the centres are struck, any settlement would have a tendency to break it up, whereas a very slow setting cement would probably not harden until after the settlement had taken place, and the arch would then be in a much better position to withstand a moving load.

There is also another practical point with regard to which the speaker would like to have some further information—namely, the best size to make the voussoirs.

Theoretically the smaller they are, the more nearly the curve of pressure will agree with the curve of resistance. Practically the more voussoirs the greater the expense in dressing their joints.

There is also a practical limit in reducing their size.

Mr. Dawson states, that it is possible to load an arch of the form of a catenary or parabola, so that the curve of pressure will correspond with the centre of the arch ring throughout. This statement does not seem to correspond with the theory of least resistance given further on in his paper, and also seems to "beg the question," as to the points of application of the thrust. In any case the speaker does not believe that it is *practically* possible.

With regard to the transmission of pressure through a stone, the speaker does not think that, when it is not applied uniformly, it is transmitted in such a manner that, if the transmitted pressures were plotted, their bounding line would be straight, but that it would be curved, a part of the excess of pressure towards one side of the face of application being transmitted obliquely towards the other side of the opposite face

The author, also states that at the joints of rupture, the line of pressure will be parallel to the tangent to the intrados—in arches very heavily loaded at the haunches this may not always be the case.

Again the author says that "the *moments of forces must be taken* with reference to the portion" between the crown and the joint of rupture, as otherwise radial forces representing friction, would be introduced—as regards *taking moments*, it is quite possible to take moments round any other joint than the joint of rupture, without including the friction, as the friction at a joint, would have no moment round any point on that joint.

The necessity for considering the whole of the portion in question, only arises when we want to consider the *three* forces acting on said portion, so as to form with them a triangle of forces in equilibrium.

Respecting the position of the joint of rupture, as referred to in the paper, it would be necessary, in practice, to take it at a joint between two voussoirs.

In corroboration of the theory as to the joint of rupture, the speaker was told by the Professor of Engineering in Dublin, during his lectures, that he found, when taking down arches, that they always broke off more easily at a point corresponding to the joint of rupture than at any other place, the mortar or cement having no tenacity at the said joint.

In regard to Dupuit's theory of the arch, as summarized by Claudel, the Author states that "while the arch remained on its centres, the pressure in the arch ring is zero throughout." The speaker thinks that this is not quite correct. It is true that while the centres are up, there is no thrust due to the mutual pressure of each half of the arch against the other, but the arch has to bear all the pressure due to the weight of the stone, up to an angle of 30° say, and from 32° up to about 60° or 70°, quite a considerable part of the weight of the stone is transmitted to the abutments.

As to the assumption that, when the centres are struck, the curve of pressure passes from below upwards into the arch ring, the speaker does not think that this theory will hold good in the case of an arch overloaded at the haunches, and which has a tendency to fail through the sinking of the haunches and the rising of the crown, in which case the curve of pressure must pass very close to the points B and C of Figure 3, and would not be necessarily a tangent to the extrados at the point C.

In the paper it is stated that when the thrust increases sufficiently to make the curve of pressure pass through the point D, it is evident that it is sufficient to maintain equilibrium; now the speaker thinks that it is *possible* that the curve of pressure, as shewn above, may never pass through the point D, and in any case to say that when it does, it is sufficient to maintain equilibrium, is like begging the question, as the arch under consideration may possibly not be in equilibrium at all.

In giving a general method of finding the determining points after adding the spandrels, the author says that "the point K will remain in the same position in the arch ring, perhaps it would help to make the matter clearer to add—as before completing the spandrels; for though the horizontal thrust must increase as the load is increased, yet K need move, for though the centre of gravity moves from the crown, it does so not more slowly than the load increases, so that the moments may remain equal without moving K.

As regards unequal loading, the theory that the horizontal thrust at the crown remains the same, can immediately be upset, by taking moment for each half of the arch round the abutments, the moments on each side would give a different horizontal thrust at the key.

The thrust at the crown in the case of unequal loading is not, however, horizontal. The point where it is horizontal might be found tentatively as follows:

Let W be a weight placed on one side of an arch, and suppose C to be the point where the thrust is horizontal, P to be equal to the weight of the part of the arch to the left of C, and the weight W, Q to be the weight of the portion of the arch to the right of C, x = the horizontal distance of A from the vertical through the centre of gravity of P, and Y = the distance of B from the vertical through the centre of gravity of Q, A and B being the centres of resistance at the abutment; then C will be a point such that $P \times X = Q \times Y$, as it is evident that each must $= T \times h$ when C is the point where the thrust is horizontal. C would only be found tentatively. A small error as to the position of the point C might also occur through the uncertainty as to the position of the points A and B; A should be taken a little nearer to the right side of its abutment than B; moving both A and B a little towards the intrados or extrados would not affect the position of C materially. Having found C as closely as possible, the curve of pressure and horizontal thrust might then be found for the unloaded side, as in the case of symmetrical loading, and the horizontal thrust being known, the curve of pressure might be drawn on the loaded side.

With reference to the value often given in books for the horizontal thrust at the crown, namely $R \times P$ where R = the radius at the crown and P = the unit pressure, the speaker thinks it might not be out of place to state, for the benefit of any who may be only commencing their studies, that the above expression does not hold good for ordinary road or railway arches, but is only true in the case where the pressure is uniform throughout and normal to the curve of the arch.

In conclusion, the speaker thinks that the method arrived at by Mr. Dawson for finding the position of the curve of pressure in an arch is as good as can be found; and that since friction may come into play in an arch, that in the case of arches built with good cement, some tensile strength may be counted on, and that a live load will not be transmitted vertically, the method referred to would be the least favorable to an arch, and would help to increase the factor of safety.

The few criticisms that the speaker has made are rather with a view of putting some points more clearly, as the points criticised do not affect the general conclusions.

Mr. Vautelet. Mr. Vautelet has read with much interest the excellent paper written by Mr. W. B. Dawson, and has very few remarks to make, as he fully agrees with him in nearly all the opinions he has given. He would like, however, to add to the list of references, the works of Mr. Durand-Claye, especially his study of arches where the resistance of the mortar is to be taken into account, the method of General Peaucellier, and the application of Durand-Claye's method to an unsymmetrical arch by Mr. Cesare Ceradini.

He only disagrees with Mr. Dawson when he says that Scheffler's and Dupuit's methods are based upon the same principle of least resistance, and it is sufficient to translate what Dupuit has written on the subject, to see how much his method differs from Scheffler's.

Comparing the two maxims "Natura horret vacuum" and "Natura horret inutile" he says:

"The one is not any truer than the other; nature has none of those passions it is supposed to have; it is subject to inflexible and invariable laws, of which, all that happens, is a necessary consequence. One cannot but acknowledge how easy it is for us to be misled, in that path where, instead of reason, we take imagination for our guide. The one says, nature resists with the least thrust, which gives the greatest pressure on the joints; the other says, nature resists with the least pressure per sq. inch. Why could we not say, too, that nature, having its choice between all the curves of pressure, chooses the one that is nearest to the straight line, because of its abhorrence for by-roads."

Dupuit starts from the simple observation of what takes place when the centres are removed, and from that point the exposé of his method as given by Mr. Dawson is perfectly clear and exact.

It has been a question of much controversy to know at what time the centres must be removed. The question has little importance in small arches whether they are semi-circular or segmental; but for large elliptical and basket-handle arches it is very different.

We can imagine an elliptical arch which will be secure when sustaining its own weight, but which will fail by rising at the key, when the spandrel is built on both sides, from the joints of rupture. If the centres are to be removed, it would be good practice to have worked beforehand the curve of pressure for such special cases of loading. As for the theory of the middle third, there are so many arches which have stood for years without complying with that condition, that it is clearly shewn it is not wanted. If it were always complied with, there would be compression in all parts; and we know that a motion will always take place in an arch, if there is no cohesion due to the mortar; and as demonstrated by Dupuit, the curve must remain very near the intrados when equilibrium is reached. Such a motion may not be noticeable because of the elasticity of the cement; or if ordinary mortar be used with bricks, because of the small size of the voussoirs, the opening of the extrados being divided over a great number of joints.

In France two methods are in general use for drawing the curve of pressure, the thrust being supposed horizontal at the key, in both of them.

The first one is based on the supposition that there is no tension at the key nor at the skewback; there are then four limiting curves joining the extremities of the middle third. Usually one curve only is drawn from the upper part of the middle third at the key to the middle of the skewback.

The other is the method of Dupuit, taking the curve not as tangent to the intrados at the joint of rupture, but at $\frac{1}{4}$ of the joint in small arches, at $\frac{1}{5}$ in large ones, from the intrados.

As very little is known about the exact theory of arches, we must of course rely greatly on the experience of others, always remembering that the construction is an important factor in the stability of an arch. Durand-Claye's method, although long in its application, allows us to go very far in the investigation of the stability of an arch, and should always be resorted to for large spans of unusual forms. The study of small wooden models may give some interesting results, but cannot be relied upon, as on account of the smallness of the thrust the material is practically incompressible, and the elasticity and adhesion of the cement cannot be taken into account.

The narrative of the different methods given by Mr. Dawson, and the excellent way in which he shows the strong and feeble points of each of them, will prove of much value to every engineer; nobody was better qualified than he to make a comparison between the methods followed in England and France, since he is both an English and French engineer, a graduate of McGill College and of l'Ecole des Ponts et Chaussées.

APPENDIX.

TABLE shewing the weights, specific gravities, deflections, breaking and crushing loads of some of the British Columbia Woods. The pieces tested for transverse strength were one inch square, with a span of one foot, supported at both ends and loaded at the centre. The pieces tested for crushing were rectangular and twice as long as they were thick. All the pieces were fair average specimens of timber, partly seasoned, but free from knots and flaws. The results obtained from exceptionally good or bad specimens are not included in this table.

DESCRIPTION OF TIMBER.			Weight of a cubic foot in lbs.	Specific gravity.	MEAN DEFLECTION IN INCHES.										High't breaking Load. lbs.	Low't breaking Load. lbs.	Mean breaking Load. lbs.	Mean Crushing Load in lbs. per sq. inch.	
					200 lbs.	250 lbs.	300 lbs.	350 lbs.	400 lbs.	450 lbs.	500 lbs.	550 lbs.	600 lbs.	650 lbs.				End-wise.	Side-wise.
Alder.	(Alnus rubra.)	Bongard.	32.16	.5158	.092	....	.117	....	.158	.2	.25	....	....	....	600	530	567	6500	1500
Arbutus.	(Arbutus Menziesii.)	Pursh.	53.29	.8547	....	....	....	....	....	....	....	....	....	....	......	......	......	5900	1600
Birch.	(Betula papyrifera.)	Marsh.	37.57	.6025	.05	.087	.1	.117	.142	....	.2	.225	.25	....	660	630	650	7000	1750
Cedar.	(Thuja gigantea.)	Nutt.	24.95	.4001	.01	.133	.158	.2	.25	....	....	....	....	....	460	450	453	5500	1500
Crab Apple.	(Pirus rivularis.)	Dougl.	50.21	.8052	....	....	....	....	....	....	....	....	....	....	......	......	......	.....	......
Cypress, Yellow.	(Chamæcyparis Nutkaensis.)	Spach.	31.21	.5005	.05	....	.082	.117	....	.15	.2	....	.25	.31	700	680	693	5900	1400
Fir, Red.	(Pseudotsuga Douglasii.)	Carrière	34.00	.5453	....	.075	.09	.114	.119	....	.181	.21	.25	....	650	600	638	7000	1750
Hemlock.	(Tsuga Mertensiana.)	Carrière	31.41	.5037	.09	.1	.14	.18	....	....	....	....	....	....	420	380	400	5000	1000
Maple.	(Acer macrophyllum.)	Pursh.	37.41	.5999	.063	....	.113	.15	.2	....	.27	....	....	....	610	550	580	7000	1500
Oak.	(Quercus Garryana.)	Dougl.	51.73	.8296	.06	.16	.229	.312	.344	.354	.458	....	....	....	550	550	550	6500	2500
Pine, White.	(Pinus monticola.)	Dougl.	27.79	4457	.1	.125	.15	.2	.25	....	....	....	....	....	500	450	473	5500	1000
Spruce.	(Picea Sitchensis.)	Carrière	25.[illegible]8	.415	.1	...	.15	.2	.3	....	....	....	....	....	440	420	427	5000	1000
White Thorn.	(Cratœgus Douglasii.)	Lindl.	51.04	.8185	....	....	....	....	....	....	....	....	....	....	......	......	......	5300	1600
Yew.	(Taxus brevifolia.)	Nutt.	49.05	.7865	....	....	....	....	....	....	....	....	....	....	......	......	......	5900	2400

VICTORIA, B.C., 15th March, 1886.

EDWARD MOHUN, C.E.

OBITUARY.

ROBERT BOAG was born in the village of Coalville, Derbyshire, March, 1838, and commenced a long and successful career in 1856 on the Midland Railway of England, in the locomotive department of which company he was employed for 17 years, at the bench and as a locomotive engineman and fireman.

In 1873 he was offered a situation on the Grand Trunk Railway by Mr. Wallis, the Supt. of the mechanical Dept. of that railway, who knew him in England and saw in him a man of ability and promise. On arriving in Canada he continued his old occupation as engineman till he was familiar with the system of working, when he was appointed locomotive foreman which position he held at various stations till February, 1881, when he became mechanical inspector on the Chicago and Grand Trunk Railway, a line of 335 miles from Fort Gratiot to Chicago affiliated to the Grand Trunk Railway. He returned to Canada in February, 1883, to accept the position of assistant mechanical supt. of the latter Railway in which capacity he had charge of the repairs of 125 locomotives and the working of 500 miles of road.

At the fusion of the Grand Trunk and Great Western Railways he took much interest in the carrying out of the arrangement by which the parallel lines of the two companies were made to serve the purpose of a double track for East and West bound through traffic.

He was also engaged in perfecting a system under which the vacuum in the section pipes of water station steam pumps was greatly improved by the introduction of the exhaust steam, with the additional advantage of raising the temperature of the tank water to a point which overcame a difficulty previously existing due to the accumulation in winter of ice at the sluice valves.

A trip to England in 1887 did not improve his failing heatth and he died in Stratford, Ontario, of Bright's disease, January 20th, 1888, at the age of 50 years.

He became a member of this Society February 24, 1887.

Canadian Society of Civil Engineers.

SESSION 1888.

TRANSACTIONS.

Thursday, 11th October.

SAMUEL KEEFER, President, in the Chair.

The following having been balloted for were declared duly elected as

MEMBERS.

JOHN HARVEY ARMSTRONG.
BENJAMIN BAKER.
HENRY EDWARD CRANMER CARRY.
HENRY FRY, JR.
PETLEY LLOYD AUGUSTUS PRICE.
JAMES ROSS.
ALEXANDER SIEMENS.
JOHN SUTCLIFFE.
THOMAS HENRY TRACY.
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Paper No. 20.

THE SEWERAGE SYSTEM OF VANCOUVER, B. C.

BY E. MOHUN, M.CAN.SOC.C.E.

Vancouver, the Western Terminus of the Canadian Pacific Railway, is situated upon a peninsula, along the northern shore of which extends the magnificent harbour of Burrard Inlet, while its southern beach is washed by the shallow waters of False Creek.

The population at the present date, February, 1888, is about 6,000, and is rapidly increasing, every incoming train and steamer bringing some addition to the number of its residents.

On the 13th June, 1886, occurred the disastrous fire, which destroyed the whole city with the exception of two houses; yet, six months afterwards, such was the indomitable pluck of the inhabitants, not only was the city rebuilt, but companies were formed for the introduction of the electric light, gas, water, and street tramways; and the question of sewerage was being discussed.

In addressing an assemblage of engineers, it is needless, at the present day, to insist upon the necessity of efficient sewerage, and upon the criminal negligence of civic authorities who neglect the means which science places at their disposal for preserving the health of, and decreasing the mortality among their fellow citizens. The only points as to which there can be a diversity of opinion are, the system to be adopted and the details of construction.

In May, 1887, the author received instructions to prepare plans and specifications for sewering the most densely populated district.

In deciding upon a system of sewerage, it was considered advisable that such a plan should be adopted as would be capable of extension with the growth of the city, so that the work first performed, would, in the end, become a portion of an efficient and economical system for the whole city.

It will be readily believed, that after the disaster before referred to, the City Council was in no position to expend money in costly or experimental works; and, to use the homely phrase, we had to cut our coat according to our cloth. The construction of an economical system was greatly furthered by the peculiar circumstances of the case; the city was favourably situated for sewering, and there were no vested interests to be consulted.

Since the utilization of the sewage could not be undertaken, its deposit in the sea was the only available mode of disposal.

In weighing the comparative merits of the "combined" and "separate" systems, it was considered, that under the conditions which obtain in Vancouver, the latter should be adopted for many reasons.

From October to March the mean monthly rainfall, as observed in the neighbouring city of New Westminster, is 7.27 inches, and from April to September, 2.48 inches.

The climate is mild; the frost rarely penetrates the ground more than a few inches in depth; the snow-fall is light, and the snow seldom lies for more than a day or two.

The city is built on two small eminences, rising gently on all sides from the salt water, to a height of about 150 feet, and its site offers every facility for the rapid and economical removal of surface water.

Further—the cost of the "separate" system was within the means of the Corporation, while had local conditions rendered the adoption of the "combined" system advisable, the available funds would have been inadequate for the purpose.

The city was subdivided into the Eastern, the North Central, the South Central, and the Western Sewerage Districts.

The Western District, having collected the sewage in intercepting sewers, will have its outlet in English Bay. A few blocks in this District have been sewered, and these, for present convenience, are temporarily connected with the North Central District sewers.

The North Central District, in which, up to the present, most of the work has been done, discharges into Burrard Inlet.

With reference to the South Central District, as it would be unadvisable to discharge sewage into the shallow land-locked waters of False Creek, it is proposed that an intercepting sewer should be constructed along Prior street, and thence along the shore to Dupont street, where the sewage would be discharged into a reservoir, from which it would be raised, by a hydraulic engine, supplied from the water main, into the Columbia Avenue main sewer, and conveyed thence into the Harbour. The pumping might be done at night, when there would be but a small demand upon the capacity of either the water mains or the sewers.

The Eastern District would discharge directly into the Harbour.

The following recommendations were approved by the City Council:—

1st. That the sewers should be constructed for the conveyance of sewage alone, the surface waters being carried to their natural outlets over the surface.

2nd. That the city should not undertake the sewerage of basements; thus practically putting a stop to the unsanitary custom of placing water closets and kitchens beneath the surface of the ground, while permitting the minimum depth of excavation to be placed at 5 feet instead of 11 or 12. ft.

3rd. That the outlet works and manholes should be of a permanent character; while the sewers should be constructed of timber, to be replaced in the future, when desirable, with vitrified pipe.

It may be remarked here that vitrified pipe is not manufactured in British Columbia; on English, Scotch, and Californian pipe there is a duty of 35 per cent., while the freight on pipe from Eastern Canada is not less than $20 a ton.

Twenty-five thousand dollars were voted by the people in order to commence the work. Tenders were called for in June, and the contract was let in July, 1887.

The dimensions of the sewers, and their falls, were determined from the following data :—

1st. That the sewer, running half full, should have a capacity of five gallons an hour for each inhabitant of the area sewered.

2nd. That the estimated population should be based upon the assumption, that every twenty-five feet frontage of the area sewered, was occupied by a house with five inhabitants.

Wherever practicable, the sewers have been laid in the alleys, in the rear of the buildings, and, in consequence, the danger, arising from carrying sewers beneath dwellings, is generally averted, while the cost to the individual householder is materially decreased. Further, better grades for private sewers are obtained, while the expense and inconvenience resulting from tearing up and remaking the streets, either for original construction, repairs, or connections, are reduced to a minimum.

Such are the general principles upon which the Sewerage System of Vancouver is based.

The author will now endeavour to describe, in as few words as possible, some of the details of construction.

OUTLET WORKS.

The Outlet Works for the North Central District, consist of a concrete chamber, the bottom being faced with hammer-dressed granite, into which three mains independently discharge at points near, but above high water mark; from the bottom of the chamber, the sewage is carried in a 12-inch cast iron pipe $\frac{5}{8}$-in. thick, 369 feet long, to a point in the Harbour 50 feet beyond extreme low water mark, where it is discharged beneath the surface. The chamber is also furnished with a 12-inch cast iron overflow pipe, 100 feet long, and both pipes are encased in concrete for a distance of 100 feet from the chamber; beyond that point the pipe is covered with rock. These pipes have a fall of 1 in 40.

MANHOLES.

Manholes are built of 5 to 1 concrete with timber covers, and are placed at all junctions, and at all changes of direction, horizontal or vertical. The curves in the manholes at junctions have not a less radius than 5 times the diameter of the sewer, and have increased falls to compensate for the loss of velocity due to the increased friction. Inverts exposed to heavy and rapid flows are lined with hammer-dressed granite. On steep gradients, ramp breaks are provided.

Each manhole is furnished with a flushing groove, and can be used for a flushing chamber, provision being made for a connection with the water main.

Gratings, flap doors, and ladders are provided for the purposes of ventilation and inspection.

Galvanized iron dirt-trays are placed beneath the gratings.

The inlet ends of sewers are provided with vulcanite flap valves.

VENTILATION.

In addition to the means of ventilation afforded by the manholes and private sewers, ventilators, which also act as lamp holes, have been placed at average distances of from 225 to 250 feet.

SEWERS.

The sewers are built of picked planed timber, three inches thick for 12 and 9-inch sewers, and two inches thick for 6-inch sewers; the pipes are from twenty to twenty-five feet in length. The sewers are rectangular and are laid with one diagonal vertical. The planks are spiked together with 6 and 5-inch cut steel spikes, a strip of tarred felt being placed in each joint.

The pipes are butt jointed, each joint being covered with a timber sleeve, lined with tarred felt, securely spiked to the pipes.

The junctions of ventilating shafts with the sewers are encased in blocks of 6 to 1 concrete.

In made or unsound ground 2-in. by 12-in. planks are first driven down, until a solid foundation is obtained; they are then centred and levelled, and notches sawn in them to fit the pipe.

The following sewers have been laid under the first Contract:—

1,800	lineal	feet	12″	square,	equivalent	to 14″	circular
6,000	"	"	9″	"	"	" 10″	"
8,400	"	"	6″	"	"	" 7″	"

The sewers are laid in absolutely straight lines, vertical and horizontal, from manhole to manhole.

They are invariably carried beyond the last house to be drained, and are provided at their heads with a ventilating shaft and automatic flushing tank. Doulton's patent syphons are used.

GRADES.

The grades are generally good, and in only one instance has a main a less fall than 1 in 400. In the branches the grades are rarely less than 1 in 150.

HOUSE JUNCTIONS.

The City provides cast-iron junctions for connecting private with public sewers.

These are cast in one piece, and consist of a plate, through which a curved socket pipe passes, screwed on to the upper plank of timber sewer.

By the adoption of this plan, there is a great gain in economy, since the cast-iron junction can be fitted at any time and point, without injury to the sewer: whereas, in laying vitrified pipe, junctions must be provided as the work proceeds, not only at the points at which they are immediately required, but also at those at which connections may possibly be needed in the future.

COST.

The cost of labour in Vancouver, compared with Eastern rates, is high; thus, foremen get from $75.00 to $100.00 a month. Masons get from $4.00 to $5.00; carpenters $3.00 to $4.00; and labourers $2.00 a day.

The work has been done at the following rates, principally by Contract:—

Excavation per cubic yard	$0.60
Trenching and refilling average depth 7 feet (with a considerable amount of rock), per lineal foot	0.35
Earth filling per cubic yard	0.40
Rock " " "	1.50
Granite for facing inverts per superficial foot	0.50
Concrete (3 to 1) per cubic yard	15.00
" (5 to 1) " " "	11.65
" (6 to 1) " " "	10.00
Sewers in place 12 inch square, per lineal foot	0.38
" " 9 " " " " "	0.31
" " 6 " " " " "	0.17
Cast-iron outlet pipes in place; per ton	55.34
Galvanized iron dirt trays, each	1.50
Ventilators in place, average cost each	24.75
Flushing tank, approximate cost each	85.00
Cast-iron junctions for house sewers, 4 inch diam, each	1.75
" " " " " " 6 " " "	2.20

The following observed results of the flow in the timber sewers may be of interest. A sewer, 9 inches square, with a fall of 1 in 400, was almost choked with earth washed into it from a cave in an uncompleted manhole. Wishing to flush the sewer, the surface water was admitted to the pipes and manholes to the extent of 9,000 gallons; on removing the flush gate, the whole quantity was discharged in 13 minutes, carrying with it from 15 to 20 cubic feet of earth.

The mean velocity was 5.4 feet a second.

The length of pipe was nearly half a mile, with three changes of direction.

The amount of solid matter was in excess of the proportionate amount of solid sewage.

Other experiments have been made at various times, which more or less bear out the general results of the above.

HOUSE SEWERAGE.

While the Council has recognized the construction of public sewers, as coming more especially within its province, it has also been fully aware that defective House Sewerage would render the best designed and constructed public system of no avail, and by an amendment of the Health By-Law, it retains the control of all the sanitary appliances used by private individuals in connection with the public sewers, within the city limits.

The author had advocated the entire suppression of all privy vaults and cesspools, and the substitution therefore, at the discretion of the owners, of earth or water closets.

The Council, however, did not see its way at the time to so radical a sanitary reform, and sought to reduce the evil to a minimum by the following regulations:—

1st. Every privy, vault, or cesspool, if connected with a public sewer, shall be connected by a 4-inch vitrified or cast iron pipe, such pipe to leave the privy vault or cesspool at a height of not less than two feet above its floor, the upper end of such pipe to be provided with a grating of $\frac{1}{4}$-inch iron, with openings of not more than one inch in width securely fastened into the wall; each seat to be provided with a pan and drop pipe, reaching three inches lower than the level of the outlet-pipe and a ventilator reaching above the roof. All privy vaults shall be of brick, set in cement, or other impermeable material, and the floor thereof shall not be placed more than four feet below the surface of the ground.

2nd. Any person desirous of connecting a water-closet with the public sewer, shall give 48 hours' notice in writing to the Inspector, who shall examine the premises, and on finding the water-closet, soil-pipe, ventilators, and traps efficient, and provision made for an ample and automatic supply of water, shall authorize such connection to be made by a licensed pipe layer, under the supervision of the Inspector.

3rd. Every water-closet shall be provided with a waste preventor cistern, a ventilating and a soil pipe, the pipes to be 4 inches in diameter, open on top, and carried up above the roof; the foot of the soil pipe to be provided with a fresh air inlet, and the pan with a trap and ventilating pipe.

4th. Every person desirous of connecting sinks, baths, lavatories, wash-houses, etc., with a public sewer, shall give 48 hours' notice, in writing, to the Inspector, who shall examine the premises, and finding all discharge pipes properly trapped and connected with a grease trap, shall authorize such connection to be made by a licensed pipe layer, under the supervision of the Inspector.

5th. No person other than a licensed pipe layer, acting under the supervision of the Inspector, shall be permitted to make any connection with a public sewer.

6th. No extension of any work previously accepted, or alterations to, or new connections with, such work shall be made, except under the authority and supervision of the Inspector.

7th. The work of laying private sewer pipes shall not be commenced or continued, unless the permit is on the ground in the hands of the pipe layer.

8th. All openings for private sewers must be so made as to cause as little inconvenience as possible to the public; on completion, the surface must be left in as good order as it was before the opening was made, and all materials, loose earth, and rubbish must be removed within 24 hours; all such openings are to be fenced by day and lighted at night in such a manner as may be approved of by the Inspector.

9th. No house sewer shall have a less fall than 1 in 40, unless special permission is granted by the Inspector.

10th. The ends of all pipes, not to be immediately connected with the house service, are to be securely closed against the intrusion of earth, rubbish, etc.

11th. The interior of every sewer pipe to be left perfectly clean and smooth after it is laid, and all iron pipes to be coated inside and out with black varnish.

12th. No sewer in actual use shall be disturbed, except under the special direction of the Inspector.

13th. All water and gas pipes shall be protected from injury or settling to the satisfaction of the Inspector.

14th. No exhaust from steam engines, or blow off from steam boilers, shall be connected with either private or public sewers, without special permission from the Inspector.

15th. On all changes of direction, horizontal or vertical, curves of a radius not less than five times the diameter of the pipe shall be used.

16th. All house sewers shall be 4 inches, and all waste pipes 2 inches in diameter, except when otherwise authorized by the Inspector.

17th. All private sewers or soil pipes shall be of cast-iron or vitrified pipe, with lead joints for the former and cement joints for the latter.

To recapitulate: the two objects aimed at have been: 1st, Efficiency, and 2nd, Economy.

With a view to their attainment, the endeavour has been made to secure absolutely tight, straight, and truly graded sewers, and also to keep sewage in unceasing motion in all parts of the sewers. It is stated that fresh sewage affords food for fish, while after the process of decomposition has set in, it becomes poisonous; it is therefore sought to discharge it into the harbour before decomposition takes place, and before any dangerous gases are generated.

By the system of automatic flushing, we hope to keep the sewers free from deposit, while the frequent and sudden rushes of water will, it is anticipated, dispel any gas which may be generated, through the numerous outlets provided for it.

By the arrangement shewn on the plan "Typical House Sewerage," it is believed that the traps can neither be forced nor syphoned. With reference to the "interceptor," it should be understood, that no particular form of trap is intended to be represented, but merely the illustration of a principle, by which an exit is provided for the gas generated in the sewer, and a fresh air inlet for the ventilation of the soil pipe.

From some little experience of the timber in British Columbia, the author is inclined to believe that these sewers will probably last for ten years, perhaps much more; once laid they are always wet,—a condition unfavourable to rapid decay.

CONCRETE.

Owing mainly to a pressure of business, accurate measurements, unnecessary for the purposes of the contract, of the raw material requisite for a definite quantity of concrete in place, have not been made; but it is believed that the undermentioned results are not far from correct.

As, owing to local conditions, broken stone could not be procured, unless specially broken for the purpose, a process too costly to be incurred, it was resolved to use shingle; this, with clean, sharp sand, was procured at and brought in scows from a point about eight miles outside of Burrard Inlet, both being, naturally, perfectly free from loam and other impurities.

By weight, the shingle showed voids of about 33 per cent., and on this basis the Contractor was informed as to the approximate amounts required for the different portions of the work. The results agreed fairly well with the estimated quantities.

In all cases the concrete was spread in thin layers, and thoroughly well punned.

Taking the aggregate of the materials in the 5 to 1 concrete,—the proportion principally used,—it was found that to make one cubic yard of concrete, approximately the following quantities were required, viz.,

Cement	6.48	cubic feet.
Sand	16.20	"
Shingle	16.20	"
	38.88	

but while there is every reason to believe that these figures are closely approximate, they cannot be guaranteed from actual measurement.

It should be added that the whole of the cement used was the best English Portland, White's or Beavan's.

As far as principles are concerned, there is very little new in the Vancouver System; the only novelties in it are:—

1st. The substitution of concrete for brickwork—and it may be submitted for the consideration of Engineers, whether concrete might not be more frequently and advantageously employed in construction than it now is.

2nd. The mode in which the pipes have been constructed and laid—and the author would call attention to a natural, though at first sight a curious, result, namely, that with equal falls, the sewage, which will half fill a pipe, will have the same velocity in any other larger pipe, irrespective of its size.

3rd. The substitution of vulcanite for the (costly in this Province) usual cast-iron flaps with hinges, double or single.

Since the original article was written, house connections have been made, and up to the beginning of September the sewers had been working satisfactorily for several months. No stoppages have occurred in the sewers, and only one complaint has been made as to an offensive smell from one of the ventilators. This is believed to be due to insufficient flushing, and will probably be cured when, the water being brought in and connected with the flushing tanks, a daily flush is provided. Until then, the tanks are supplied by water cart, two or three times a week.

DISCUSSION.

Mr. P. W. St. George remarked that the author in his paper called attention to the fact, that there was little that was new in the construction of the sewerage system, except the use of vulcanite instead of iron for valves. As to the system of wooden boxes, the use of which at the present day has become nearly obsolete, he imagined that they were only employed by the author on account of his inability to get either a brick sewer or a tile pipe. The most expensive part of the work, however, viz., the excavation, had been carried out, and the difference in the cost of a wooden box and a tile pipe would have been but a small proportion of the total outlay. The substitution of a tile or a brick pipe for the wooden box will now necessitate a re-excavation, entailing as great an outlay as at the first. Wood should not be regarded by young engineers as a desirable material for sewers. Square sewers, especially in separate systems, require a large quantity of water for flushing purposes, involving a constant supervision of the flushing tanks. The cost of maintaining these flushing tanks, and the necessity for the appointment of superintendents to see that the flushing is properly carried out, would be a serious disadvantage in any system of sewerage. In adopting a system, the form of sewer, requiring a minimum amount of water to keep it clear, should be adopted. This object cannot be attained with a square section. To facilitate flushing and to diminish the amount of water required, the sewer should be made of as small a radius as possible. In the combined system it is usual to depend upon rain-water for flushing. In placing sewers, calculations as to the amount of water available for flushing should not be based upon the amount used by the inhabitants, but upon the amount of rainfall in a given area. Mr. Mohun had adopted the form of sewer which required the largest quantity of water for flushing, and had not availed himself of the natural rainfall. His system was therefore entirely dependent upon artificial tanks, which had to be continually replenished. It had not been long enough in operation to judge fairly of the result; and with a 12 in. box, and in a much more densely populated place than Vancouver, it would be three or four years before any serious obstruction would be observed. There was practically nothing to choke the sewers except the human excreta. He considered the square section faulty, and he would warn young engineers against its adoption. It should, however, be borne in mind that the system adopted was a cheap and temporary method of giving drainage to a city which cannot at present afford a better. Mr. St. George.

Prof. Bovey.

Mr. Mohun has distinctly given us to understand that the construction of timber sewers was only undertaken as an expedient, because of the lack of funds, and that they would be replaced as soon as possible by vitrified pipe. He has also explicitly stated the pressing reasons which led to a choice of the separate system. Respecting other features of the system, the speaker is of the opinion that except when the sewers are running full, they would not be completely saturated, and there would be a tendency to decay, notwithstanding the moisture retained by the surrounding earth. No provision seems to have been made for the removal of subsoil water, a precaution of the greatest moment, and one which is absolutely necessary for the well-being of the people.

Mr. Mohun is certainly in error in saying that when the sewer is running half full, the velocity of flow, for equal falls, is the same for sewers of different sizes. This can only be true when the mean hydraulic depth, $\left(=\frac{\text{area of water-way}}{\text{wetted perimeter}}\right)$ is constant. In the present case the mean hydraulic depth, for a depth of water h, (less than half the depth of the sewer), is $\sqrt{\frac{h \sin a}{2}}$, 2 a being the lowest angle. In other words, so long as the sewer is not running more than half full, the velocity of flow will vary as the square root of the depth of the fluid, a being constant. When the sewer is more than half full, the expression for the mean hydraulic depth is a little more complicated.

Mr. Peterson.

Mr. Peterson remarked that Mr. St. George, in speaking against the square section, seemed to have overlooked the fact that Mr. Mohun had laid the sewers with the diagonals vertical, so that a very small amount of water will suffice to flush them. The objectionable point in connection with the present flushing arrangement is, that the water is to be supplied to the flush tanks by means of carts. Such a method may very probably result in some of the tanks being missed or in the work being entirely neglected, in which case the sewers will become foul. This difficulty will be overcome when the city obtains a regular supply of water, by gravitation, which, the speaker is informed, will be effected in the course of a few months. The water can then be so connected with the tanks that flushing can take place as often as may be required. A small amount of water suddenly thrown in a mass from a flush tank will suffice to keep the wooden pipes clean and absolutely free from sediment. With the combined system, very little flushing would be done by the rainfall during the season when it is most required, as the summer in Vancouver is very dry. In his opinion, the system adopted will prove satisfactory, and while there was not much that was novel in it, he thought that Mr. Mohun had taken the best course considering the limited means at his disposal.

Mr. St. George stated that in his opinion the humidity of the earth would keep the sewers damp. Means should certainly have been provided for drainage of cellars, and he also thought that the boxes would have been much stronger if placed with vertical sides. As to the difference between the combined and separate systems, the latter system was advocated 12 or 15 years ago by Mr. Shedd of Providence. That city was sewered almost entirely with tile pipes on the separate system. To-day nearly all these pipes have been taken up, and the combined system substituted. With a large population there was not sufficient water, unless the rainfall was also utilized, to flush any system of sewers except by the adoption of very costly methods. This has been the experience at Providence, which is now considered one of the best sewered cities in America. Mr. St. George.

Mr. Peterson said, that in Providence, where they had spent millions upon the water works, they were obliged to pump the water, whereas in Vancouver they would soon obtain a large supply for flushing purposes, by gravitation, and, therefore, at little or no expense. Providence is a manufacturing city with a very dense population, and in his opinion should be provided with the combined rather than the separate system of sewers. He was far from advocating the separate system for every place. Mr. Peterson.

No one can say that any system is best for all situations. That system should be adopted which is best suited to the local conditions and requirements of the place to be drained.

There are many towns and small cities in this country that, owing to the expense of a proper combined system, have existed for a long time without any system of drainage at all. If, however, the separate system, with its small expense, had been adopted, the drainage would have been efficient and the death rate very much lower. There can be no doubt that every city should be thoroughly drained so as to take away the surface water, and to drain below the foundations of all the cellars. When this is not done by natural means, it should certainly be done by artificial, and it then becomes a question whether or not there should be two systems, one for house drainage, and another for surface and for subsoil water; but as he had already remarked, the system to be adopted could only be determined after a careful study of the question in all its bearings.

In the case of Vancouver, it is certainly better to have a separate system for house drainage, leaving the surface and subsoil water to take care of itself, than to have no system at all, thus allowing the house drainage to run into pestiferous cess-pools to poison the air in the surrounding dwellings, as is still done in many parts of Montreal.

Mr. St. George. Mr. St. George thought that if Mr. Mohun had given some data as to the area of land to be drained, and the amount of rainfall, they would be better able to judge whether he had adopted the best system. The rainfall without the area was not of much value.

Mr. Metcalfe. Mr. Metcalfe, said it seemed to him, that in order to consider the question properly, some information as to the water supply should have been afforded, and some idea of the hydraulic power available for pumping should have been given.

It is generally necessary at some point to pump the sewage, and it often becomes the most important feature in the scheme. Taking into consideration the different facts, as stated by the author, he thought that Mr. Mohun had adopted the best and cheapest method, especially as there would be a good head for pumping.

Mr. St. George. Mr. St. George further desired to say that if the area Mr. Mohun had to drain were known, it would be possible to judge whether the box he had built would be able to drain the rainfall also. A 14-ins. box would drain a large area of land with a heavy rain-fall. In this connection be thought that if Mr. Mohun had combined the two, he would have had ample means for a thorough cleansing during the rainy season.

Mr. Metcalfe. It seems that Mr. St. George does not think that the surface drainage has been properly dealt with. The speaker, however, considers that with the falls given and the apparently small area of Vancouver, there was hardly any question of disposal. The city of Melbourne, with a population nearly twice as large as Montreal had, up to 1884, all its rainfall removed by surface drainage.

Mr. Gower. Mr. Gower thought that under the circumstances, Mr. Mohun had no alternative but to use wooden pipes. It would have taken months to get tile pipes to Vancouver by sea. If he remembered rightly, the Water-Works in Victoria had, through an accident at sea, to wait 12 months after the contract had been given, before their pipes arrived. Besides, in a railway journey of over 3,000 miles, the chances are that there would be a breakage of tile pipes to the extent of perhaps 50 or 75 per cent., while the rate of freight would be about 85 shillings or $25 per ton. He thought a mistake had been made in not adopting the combined system, as the expense would not have been much more. With regard to the 14-in. pipe, hydraulic tables shewed that a 12-ins. circular pipe would carry off the sewage of a town of 50,000 inhabitants, as well as a rainfall of 25 miles of streets.

Mr. Waring.

Mr. G. E. Waring had been very much interested by Mr. Mohun's description of the sewerage of Vancouver. Mr. Mohun certainly has the true engineering instinct for the application of means to ends; or, rather, for finding a way to reach his end when ordinary means are not available.

So far as he knew Mr. Mohun's use of rectangular wooden sewers set with one diagonal vertical is entirely original, and he has no doubt that it will prove successful in accomplishing the end now in view—, *i.e.*, the satisfactory sewerage of the town during its earlier stages, when the usual material is not available because of its cost. Indeed, it is not improbable that these wooden conduits may last so well in view of their almost complete saturation, as to make it seem advisable, when they finally do fail, to replace them with the same material.

The speaker would not hesitate, if the occasion should arise in his own practice, to follow Mr. Mohun's lead in this matter.

Mr. R. Hering

Not knowing the local conditions, it is very difficult to say much about the value of Mr. Mohun's recommendations in general or detail. Still, some ideas may be safely expressed.

The fundamental recommendations approved by the City Council seem to be wise.

The topography, the rainfall conditions, and the item of cost for so small a community as 6,000 inhabitants, strongly point to the superiority of the separate system of sewerage, and to the wisdom of not having water-closets and kitchens in cellars or basements, and thereby securing shallow sewers over the whole city.

The laying of sewers in the back alleys instead of in the streets is likewise a very good custom, for the reasons given by the author of the paper discussed.

As to the wisdom of using wood, with the expectation of replacing the sewers later with vitrified pipe, the speaker can express no opinion. Here, in the East, this would not be done, even if it were necessary to pay double the price for the pipe, as the excavation and laying are the largest items in the expense.

Mr. Mohun's provision to place manholes at all changes of direction, horizontal and vertical, and their details, are, we here consider, the best plans and methods.

If wooden sewers are the best, then the rectangular section with one diagonal vertical is the proper way to lay them. The cast iron junctions, for the house sewers, are a very good contrivance.

That the Council has recognized the propriety of controlling also the house sewerage is a very fortunate circumstance, and one which is often difficult to secure in the older cities.

Without knowing the local circumstances, it is impossible to say much about the details of plumbing. It is difficult to understand why, when a sewer is built to the house, a privy vault, placed not more than four (4) feet below the ground, should, in any case, be preferred, as specified in the 1st section, unless it exists already, and is kept simply for economical reasons. To build a new one, as described, water-tight, would cost more than a plain hopper closet. The method of ventilation and flushing is good, as are, also, the details mentioned in sections 2 to 17. The latter section provides that private sewers shall be of cast iron *or* vitrified pipe. It is not safe to have vitrified pipes inside the buildings, because the cement joints are not always air-tight, and it seems that a further provision should cover this point.

In the arrangement shown on the plan of typical house sewerage, it appears that the alley sewer is ventilated through an opening in the yard, in the same box with the fresh air inlet in the house drain. If this is so, it would appear that the escaping sewer air might be objectionable at such a point. It would be preferable that the sewer air should escape into the alley, and it is not a matter of importance to secure any ventilation for the short branch pipe, because if there should be an undue pressure of air at any time, which rarely occurs, it would escape through the trap and fresh air inlet.

The speaker fully agrees with Mr. Mohun that concrete sewers, of Portland cement, have great advantages; not the least of which is the smooth and even surface which can be given them.

It is difficult to understand the conclusion reached, that, with equal falls, the sewage, which will half fill a pipe, will have the same velocity in any other larger pipe, irrespective of its size. In the flow formula, $v = c\sqrt{RS}$. If v. c. and S are constant, R must also be constant; therefore the same velocity will occur, only as long as R., *i.e.*, the mean radius, remains the same.

The *shape* of the sectional area, however, can vary; R being constant, the same velocity will be obtained in every case. If this is the intended meaning, Mr. Mohun's conclusion is correct.

Mr. Fleming. Mr. R. P. Fleming said he had considered the paper carefully, and thought that the system of ventilation and flushing of the sewers was very satisfactory. It would, perhaps, have been better to have spent a little more money, and made a combined system of sewerage, as the lack of any surface water drainage was an objectionable point. There are always some level lying streets, where rubbish will collect and decay in stagnant pools of water, and this is a condition dangerous to the public health. With regard to the wooden pipes, he thought there was always a tendency to retain a temporary system after it had become inefficient. The top of the wooden boxes would probably decay rapidly, as they would not often be flushed. The trapping of the house branches he approved of, but disapproved of the ventilation of the sewer into the courts close beside the drain trap, as the escaping sewer air from its proximity to the fresh air inlet would certainly be drawn into the latter and the purpose of the trap frustrated. The ventilation of the sewers was so thorough that any additional ventilation was unnecessary, and the additional ventilation proposed was dangerous. This he considered one of the most important points of the system.

The section of the sewers he said, was the best possible with wooden sewers, and he approved of the manholes and flap valves, the latter improving the efficiency of the ventilation by making each section of sewer between manholes ventilate independently. On steep grade sewers, there is a tendency for the sewer air to rush to the highest point and escape there, passing by intermediate ventilating manholes.

The construction of the sewers in the back lanes he thought was a good plan, having many advantages pointed out by the author. The gradients fixed for house drains he also approved of, and the system of house drainage and plumber work generally. He, however, disapproved of coating the cast-iron soil pipes with black varnish, as it hid defects in the piping. The best solution for this purpose is that patented by the late Dr. Angus Smith, which is transparent and unacted upon by sewage. He believed it was the only satisfactory solution yet in the market. He referred also to the author's remark on the flow of sewage through a pipe which it half filled, wherein he said the writer was evidently in error.

In this system perhaps the greatest defect is that it does not provide Mr. Hopkins. for the drainage of basements. In many places a cellar, undrained, stores up the surrounding surface water, and there is no reason why this should not be the case in Vancouver, particularly as there is no systematic surface drainage, while there will in all probability be many basements. Most of the sewers, however, will be self cleansing on account of their good gradient.

Mr. St. George said the discussion being for the benefit of the mem- Mr. St. George. bers, especially the young members, if Mr. Mohun had given some idea of the area he had to drain, they could have judged better whether he had used the right system or not. Some of those who had taken part in the discussion seemed to have jumped to the conclusion that Mr. Mohun was perfectly right in adopting the separate system, without any basis upon which to form their opinions as to the best system of drainage.

They should be careful not to form any opinion until they had some information as to depth of rainfall and drainage area.

Mr. Hopkins. Mr. Hopkins said that possibly a drain laid carefully under a house did not do any harm, especially if the house were occupied by the owner, and were properly looked after; but while engaged in examining houses with the smoke-testing machine, he had observed the course of the smoke showing the track of the drain-pipe under the house most distinctly, and sewage gas would come up in the same manner. This would happen in many of the poorer parts of the city, and he therefore thought that the locating of sewers at the back of the houses made it very much safer for the majority of the people. With reference to the trap, the author had said he simply wished to represent a trap, not any particular kind, and, therefore, he did not think Mr. Mohun intended to have the one ventilated into the other, as would seem probable from the sketch. He thought a mistake had been made in allowing cess-pools to be built; they were not only expensive but dangerous. With the wooden pipes, of course, there was more friction, but the fall was very great, and it was therefore unnecessary to have a very finely shaped sewer.

Prof. McLeod. Professor McLeod said he had with him the average rainfall covering a period of 15 years for New Westminster. He failed to find any great period of drought as had been mentioned by some. The figures were as follows:—

Jan. 7·57 in., Feb. 6·88 in., March 6·68 in., April 3·18 in., May 2·41 in., June 2·42 in., July 1·67 in., Aug. 2·03 in., Sept. 3·20 in., Oct. 5·61 in., Nov. 7·90 in., Dec. 8·98 in.

The rainfall, even in the dry period, cannot be considered as exceedingly small, and in the autumn, winter and spring it is extremely great. He quoted the figures merely as a commentary upon the remark that there were extended periods of drought.

Mr. Peterson The rainfall record, as quoted, was a *mean* for a period of 15 years, but there might still have been droughts during that time, lasting a month or even more.

Mr. W. Whited Mr. Whited asked if it would not be an improvement to insert a fillet of wood so as to make the bottom of sewer flat for one or two inches in width. It would afford less chance, he thought, for solids to lodge in the sewer, and the expense would be very small. It would also diminish the coefficient of friction.

Prof. McLeod. Professor McLeod said that it occasionally happened that for a month in that district there was little or no rainfall, but there was no such thing as a "succession" of months with no rainfall.

Mr. Dodwell. Mr. Dodwell said it was rather late to add anything to the very full discussion, which he thought, however, had been rather on the severe side. The means at the disposal of the people of Vancouver for sewage works were very small, and he thought Mr. Mohun had made about as good use of them as was possible. The system was not of a permanent character.

Mr. Fleming remarked, with regard to the triangular wood proposed to be placed in the bottom of the sewer, that it might be an improvement as it would reduce the chance of obstruction in the sewer, especially if the wood had a very smooth surface. **Mr. Fleming**

Mr. Gower said that the fillet idea did not seem to him a very good one, because unless it was glued to the bottom, the nails and cross joints would catch lint and solids, and would cause much more obstruction than is experienced with the present form of construction. **Mr. Gower.**

Mr. Rust thought that the experience gained in the case of the sewers of Toronto would indicate that a mistake had been made in not constructing the sewers of sufficient depth to drain the basements. Doubtless, the growth of Vancouver within the next few years will be large, and it will increase in proportion, necessitating the construction of a number of wholesale and manufacturing establishments, and the inability to drain the lower floors of such buildings will give rise to serious complications, as generally, boilers, furnaces, washrooms, sinks, etc., are necessarily confined to the basements. **Mr. Rust.**

In Toronto, unless sewers are built at a sufficient depth to drain the basements, it frequently happens that an application to the Court results in the property owners being exempted from paying any portion of the cost of the work.

In his opinion, a mistake was also made in not taking the sewers to a sufficient depth, to lower the subsoil water below the buildings, which is considered a most important desideratum by sanitary engineers. The extra cost would probably not exceed 30 cents per lineal foot of sewer.

The question of carrying sewers in the alleys in rear of the building, is one that demands a careful consideration, and opens up to a certain extent the question of combined or separate sewers. Looking at the growth of Vancouver, Mr. Rust would imagine that some means will be required to provide, by means of street gullies, for the removal of surface water, especially from the principal streets. The question of carrying sewers beneath buildings is merely one of sentiment. With perfectly constructed house drains the danger is only imaginary, and when the alley-ways are private property, the question becomes still more complicated. It also gives the property owners every facility and encouragement for draining that abomination of abominations, the filthy privy pit, which further deposits a large quantity of solid excreta in the sewer without the compensating power of water, which is obtained when properly constructed closets are built in the house. The question of better grades has to be considered only when the buildings are constructed on shallow lots.

There is some doubt as to the durability of plank. The upper portion being, comparatively speaking, dry, will no doubt decay quicker than the lower which is covered with water at all times. The expense of a sewerage system is not confined to the first cost; there is an annual one for repairs which in sewers constructed of plank rapidly increases.

It is therefore a question whether the Council has not made a mistake in not asking the people for, say, $5,000.00 more, and substituting pipe in place of plank.

In reference to the substitution of concrete, he entirely agrees with the writer that the substitution of concrete for brickwork can in a large number of cases be made with advantage.

Mr. Ruttan. Mr. Ruttan desired to refer briefly to two points in Mr. Mohun's description of the Vancouver sewers:—

1st. The use of wood instead of vitrified pipe; and

2nd. The construction of the sewers at a minimum depth of five feet.

It is generally understood that, when a temporary purpose is to be served, or when it is a question between the adoption of inexpensive work or none, as in the case of wooden pavements and bridges, engineers are justified in recommending such temporary works. In the case of sewers, however, the difference in cost between permanent and perishable material, should be very great to justify the adoption of the latter, particularly in a growing city like Vancouver, the streets of which will, no doubt, soon be paved.

He thinks that the author has under-estimated the expense and annoyance which will be occasioned by renewing the sewers with more permanent material in the near future.

The cost of vitrified pipe, less freight, would have been something less than the cost of the wooden sewers.

The freight, in the quantities of pipe used, would, at $20 per ton, have been $4,500, a small amount to have influenced the decision in favor of a temporary system of sewers.

In regard to statement, that the Council has not undertaken the sewerage of basements, and that the minimum depth of sewers has been fixed at five feet, instead of the 11 or 12 ft., Mr. Ruttan is not aware of any other place where people would either do without basements and cellars, or undertake their own drainage, independently of a system of public sewers for which they were taxed.

One of the greatest sanitary advantages to be derived from the system of sewers is the removal of subsoil water, sewers only five ft. in depth, can perform this necessarily only to a limited extent.

For the reasons stated, he does not think that any adequate advantage has been obtained from the saving in cost effected by using perishable material, and placing the sewers at such a short distance below the surface of the ground.

Mr. Mohun.

Mr. Mohun begs to express his sincere appreciation of the honor done him, and is much gratified with the interest which has been evinced on a subject which he deems of such vital importance to the inhabitants of any city.

The principal objections which have been made are as to the wisdom of adopting the separate system, and the choice of the material of which the sewers have been built.

The separate system was adopted for the reasons given in the paper, not entirely as has been suggested on the ground of economy, though that consideration had much weight.

There is not in Vancouver any necessity for carrying surface water in the sewers; there is probably no part of the city more than half a mile from, and with easy grades to, the salt water. A system of surface drainage independent of the sewers is now being carried out and will cost but little. The rainfall is never of a tropical character, necessitating underground drainage to prevent the inundation of streets and basements.

The city of Providence has been referred to as an instance of the failure of the separate system; but a system should not be condemned on that account, rather thecauses of failure should be sought, and it might perhaps be found that local conditions from the first pointed to the combined system as the better. The first city, it is believed, sewered on the separate system was Alnwick, Eng., population 7,000, in 1839, and this system still gives satisfaction. In our President's address last January, the separate system in Vancouver was referred to as one "for which all the conditions are favorable." There are merits in both systems, and only a consideration of the local conditions can justify a decision on the point. Reasons, which seem to many adequate, have been given for the adoption of the separate system in Vancouver, nor does the writer think that its opponents have advanced arguments to prove their fallacy.

With regard to material, the extra cost of vitrified pipe has been under-estimated by both Messrs. Rust and Ruttan.

Quotations were obtained for English, Scotch, Canadian and American pipe, and timber was found to be so much cheaper, that its adoption was unanimously voted by the Council, doubtless the fact that such a course would cause the expenditure of a considerable sum among our own people had some influence on the City Fathers.

Mr. Mohun fears he is regarded by some as an advocate for timber in preference to vitrified pipe; this is not the case, as the following extract from his report to the City Council will show:—

"The choice of material appears to be limited to vitrified pipe and timber. The former, though more expensive, is in every way far preferable to the latter. The only advantages timber possesses over the former, arise from its comparative cheapness, and the greater ease with which it can be laid in a straight line to a true gradient."

From some experience of timber in British Columbia it is not anticipated that the pipes will soon decay. Nine years ago the writer constructed a somewhat similar chain of the same material at his house in the country, which is still quite sound; and he was informed that some wooden pipes taken up in Victoria, after being in the ground over twenty years, showed no signs of decay; this, however, he cannot vouch for from personal observation.

The writer thinks with Mr. St. George that Prof. Bovey is mistaken in assuming that the crown of the pipes will not be perpetually wet, believing that the water in the made earth over them will keep them saturated.

Mr. St. George has misunderstood, as pointed out by Mr. Peterson, the mode in which the pipes are laid, which is in accord with the principle of the egg-shaped sewer. As regards strength, they are in any position stronger than the vitrified pipe.

It may not be out of place to describe the precautions which were taken to insure good workmanship in the pipes. Each plank was examined to see that it was perfectly straight, smoothly planed, of true dimensions, and free from soft knots, shakes, or other imperfections, and any which did not come up to this standard were rejected. The pipe was then made and tested to see that it was truly rectangular; that the ends which had been cut in a mitre box were square; and that no spikes or splinters projected into the pipe; a failure in the first or last of these qualifications involved the rejection of the pipe; if the ends were not square they had to be sawn again until cut truly.

In laying, the upper half of the sleeve was not put on until a close butt joint had been made, and if the two ends did not fit closely, one was raised and recut, after which the sleeve was completed and the joint accepted.

The small quantity of water required for flushing the pipes of the separate system, the use of the automatic tanks which require no supervision beyond that of an occasional visit, and the abundant supply of water, combined to render this method of cleaning preferable to that which is dependent on rainfall at irregular intervals, which generally also involves a considerable extra expenditure in the dry season.

It is proposed to try the effect of a daily flush at first, and, if necessary, shorten the interval as may be required. The present supply by cart is a temporary expedient in order to obtain the use of the sewers at once. By arrangement with the Water Works Co. the twelve flush tanks now built will each be supplied once daily for $292 per annum, and as often as may be necessary at the same rate.

The water pipes are being laid in the town, and in a few weeks Vancouver will have one of the best water supplies on the continent. This is, however, a subject which it is to be hoped will be dealt with by another member of the Society.

The question of basement sewerage was one that received very careful consideration, and it was decided that the special conditions of the case would not warrant the additional expenditure. There are not probably more than twenty basements in a city of, to-day, 9,000 inhabitants, each of these basements can be and it is believed has been drained by its owner with from 60 to 150 feet of pipe, and it is not reasonable that the whole of the rate-payers should have their sewer rates doubled for the benefit of the few. Indeed it would have been cheaper for the Council to have paid for the extra pipe required. Again, some members of the Council felt strongly that there was a risk of the foreshore being contaminated through the discharge of the sewage into the harbour; though not sharing this feeling, the author suggested that it would be easy to raise the sewage in such a case into the proposed intercepting sewer discharging into English Bay; in this event it would be very undesirable to increase the amount to be raised by pumping. Again, the practice of placing w. c.'s and sinks in basements is most unwholesome, and should be discouraged in any city by the authorities. The additional cost was, however, the chief objection; and while the author is completely in accord with those who recognize the importance of thorough drainage, he still thinks the decision arrived at was wise, more especially when it is understood that to have so lowered the sewers would have brought their outlets below H. W. M., and, without pumping, the discharge would have been stopped for some hours each day. He regrets that by his failure to correct a figure in the proof he may have misled Mr. Rust as to the cost of trenching and refilling; the contract schedule price was 55 not 35 cents a lineal foot for a depth of 7 feet, for 12 feet deep $1.00, and for 14 feet deep $1.20. Hence while with a minimum depth of 5 feet we had an average depth of 7 costing $8,960.00;

a minimum depth of 12 feet with an average of 14 would have cost $19,640.00 and this for trenching and refilling alone, without taking into consideration the extra cost on manholes and flushing tanks.

While acquiescing with Mr. Rust, that "with perfectly constructed house drains the danger is merely imaginary," the author believes that the danger is in practice very real, since in spite of all care absolute perfection is rarely attained, and prevention, being better than cure, would place the sewers where the risk was least.

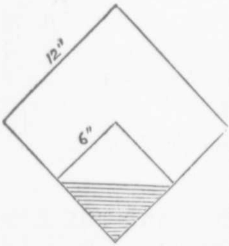
The exact area sewered cannot now be given by the author, as he has no map with him. It is, however, about 100 acres, and it must not be forgotten that the system has been designed so as to permit of extension, when expedient, over a much larger area without alteration in the work already completed.

With reference to the iron pipes for house drainage, the writer quite agrees with Mr. Fleming as to the desirability of testing before use. Under the By Law, the Inspector has large power, and need only accept such materials and workmanship as are satisfactory. The coating of American black varnish appeared to answer well with some of the cast iron outlet pipes which were exposed to the weather from October to March.

Some engineers think an interceptor between the house and the sewer unnecessary, while others recommend it. In the case in question it is intended as an additional safeguard (should the ventilation of the sewer prove defective), by which an exit is provided for any gas which may find its way into the house drain; it also provides a fresh air inlet for the soil pipe. If too close to the house the foul air outlet might be connected with a ventilating pipe.

The author does not understand Mr. Fleming's remark, if correctly reported "that the two pipes were exactly together. They came up into one chamber, the grating under the house certainly had a draft, and the air escaped exactly at that point." If the two pipes referred to are the soil and ventilating pipes, they are supposed to be each provided with their own fresh air inlets and foul air outlets. The ventilating pipe is not connected with the soil pipe at the foot of the furnace.

Since the Council declined to sanction the entire suppression of privy vaults, the regulation referred to by Mr. Hering was adopted to meet cases in which cesspools had been or were about to be constructed in accordance with the By-Law. A reference to the paper will show that Mr. Rust is incorrect in assuming that any solid matter can be introduced into the sewer from these vaults.



In the case of the velocity, Mr. Mohun regrets that he failed to make his meaning plain, but must still maintain that his statement, as referring to the sewers under consideration, is correct, and capable of proof as follows: $v = c \sqrt{s. R}$. If c, s, and R are constant, then v is constant. The value of c depends on the values of n, s, and R. Take the case of a 6" pipe running half or less than half full, and assume that its contents are transferred to a 12" pipe (both pipes having the same fall), then the material and the fall of both pipes being the same in each case, n and s are constant, and as not only a, but p, is constant (owing to the angles of the inverts being the same) $\frac{a}{p} = R$, also a constant; hence c, s and R being constants, v is the same in the large pipe as in the small one. It is of course obvious that no such result follows with circular pipes.

From the Drawings accompanying this Paper, Plate X has been prepared.

25th October, 1888.

JOHN KENNEDY, Member of Council, in the chair.

Paper No. 21.

INCEPTION OF ELECTRICAL SCIENCE AND THE EVOLUTION OF TELEGRAPHY.

BY F. N. GISBORNE, M.CAN.SOC.C.E.,
F.R.S.C., &c., &c.

Six hundred years B.C., Thales of Milete noted the electrical phenomena developed by friction upon Amber; two hundred years later Plato theorized upon Electricity; and A.D. 1522, Martinigo (a Venetian), the engineer in defence of Rhodes, applied one end of a drum head at the end of his counter mine, to discover the vicinity and direction of the enemy's underground galleries, and thus, by utilizing the molecular disturbance of the earth in sound waves, conceived the basis of telephony. It was not, however, until A.D. 1690, that Von Guerick made the first machine for generating frictional electricity, nor until A.D. 1726, that Wood recorded the fact that frictional electricity would pass through a considerable length of wire, and could therefore be utilized for the transmission of signals. To Wood of England is therefore due the honor of first suggesting the feasibility of electric telegraphy.

A.D. 1745. Murschenbrok, Germany, invented the Leyden jar, by which means frictional electricity could be stored for experimental purposes. A.D. 1747, Dr. Watson, England, erected the first telegraph line between Shooters Hill and London; and A.D. 1753, C.M. (believed to be the initials of Charles Mathews) published the manner in which he had indicated the letters of the alphabet through a system of 26 wires, by frictional electricity. During the latter half of the eighteenth century inventors of all nations endeavored, by means of two or more wires and *frictional* electricity, to transmit intelligence between distant places; but it was not until A.D. 1800, when Volta proclaimed his own and Galvani's prior experiments in the production of *chemical* electricity, that electric telegraphy, as now developed, became practicable.

A.D. 1819. Oersted (Denmark) discovered that a freely suspended magnetized needle would move to the right or left, in accordance with the polarity of a current of electricity through an adjacent wire.

A.D. 1820. Arago (France) discovered that when a bar of soft iron was wound with a copper or insulated iron wire, it became a magnet whenever a current of electricity traversed the wire, and was immediately demagnetized (or nearly so) when the wires were disconnected from the source of the current.

A.D. 1832. Faraday (England) discovered that when a coil of insulated wire was placed adjacent to, but not connected with, another coil of wire, through which an intermittent current of electricity was passed, induced currents of increased intensity and alternating polarity were developed in the unattached coil. Also that the movement of a permanent bar magnet within a coil of wire, or the movement of an electro-magnet near the poles of a permanent magnet, would develop currents of electricity.

To the foregoing rudimental *discoveries* of Galvani and Volta, Oersted, Arago and Faraday, is the world indebted for the numerous subsequent *inventions* which have developed electric telegraphy, plating, illumination, transmisssion of power, and other valuable results attained during the 19th century.

The purport of the present paper is, however, necessarily limited to the *Evolution of Telegraphy*, in its several branches of *Material, Construction* and *Apparatus*, for the transmission of intelligence between distant places, and to the "*Survival of the Fittest.*"

First in order under the heading of *Material* are the *Poles;* underground wires being commented upon in conjunction with submarine cables.

Throughout Canada and the Northern United States, the red and white cedar (Thuya Occidentalis) poles are the most durable of all woods. Standard poles, say 25 feet in length, 6 inches diameter at top, and averaging 10 inches diameter at butt, if cut during the winter months before the sap rises, or in summer and *dried* with the sap in, will continue serviceable for 25 years, and if placed near the sea coast 5 years longer. Hacmatac, *i. e.*, Juniper or Larch (Larix Americana) will last 14 years; black spruce (Abies Nigra) 10 years, and poplar (populus tremuloides) barely 3 years.

In tropical climates, where white ants and other fibre-devouring insects are prevalent, even chemically prepared wood is rapidly destroyed, and iron posts or tubes have been substituted with economical advantage. Upon the treeless prairies of the North West Territory where fires rage, and where travellers and teamsters are apt to utilize telegraph poles for fuel, the "Gisborne" tubular iron poles have been erected, with economy in cost of maintenance. It may here be stated that the "G" iron tube is of wrought iron, galvanized, 18 to 20 feet in length, $1\frac{1}{4}$ in. diameter inside at top, $2\frac{1}{2}$ at bottom, and weighs complete 80 to 85 lbs., the special merit of such poles being their bed and grip plates, which render them immediately and permanently stable, although planted but three feet deep in the ground, *versus* the five feet necessary for wooden poles.

The next item for consideration is the *Wire.* Galvanized iron and copper are the metals in general use. In order to convey a clear understanding of the experimental and practical results obtained during the last decade or two, it is essential that the values of the definite units for electrical measurements, as adopted at the International Congress of Electricians, A. D. 1881, should first be explained.

Electricity by whatever means generated is the result of the expenditure of energy; and, as the measurement of energy involves space, matter, and time, the three fundamental units adopted were the centimetre for length, the gramme for mass, and the second for time; technically known as the "C.G.S." system; and upon these fundamental units all practical electrical units are based, viz.:—

1st. *The Volt* represents the unit of *electro-motive-force* or *potential.* It is about 8 per cent. less than the E.M.F. of a standard Daniell cell, and is analogous to the *head* or *pressure* of water in a cistern.

2nd. *The Ohm* represents the unit of electrical *resistance.* It is about equal to that met with in a length of 232 feet of No. 18 guage pure copper wire (=100 standard at 60 ° Fah.), and is analogous to the *frictional* resistance to water as it passes through a pipe.

3rd. *The Ampère* represents the unit of *current.* It is equal to a Volt of E.M.F. passing through an ohm of resistance, and is analogous to the *flow* of water through a pipe.

4th. *The Coulomb* represents the unit of *quantity.* It is the quantity given by an Ampère of current in a second, and is analogous to the *volume* of water passing through a pipe.

5th. *The Farad* represents the unit of *capacity.* A condenser has a capacity of one Farad, when a difference of E.M.F. of one Volt between its two sets of plates charges each of them with one Coulomb, and is analogous to the capacity of a cistern.

6th. *The Watt* represents the unit of *power.* It is equal to the power developed by an Ampère of current, in a circuit whose ends differ in E.M.F. by a Volt, and is analogous to the *power* of water, estimated at 10 ergs or $\frac{1}{746}$ part of one horse power.

Each one of the foregoing established units represents approximately 10 C.G.S. units, viz., 10^{8}, 10^{9}, 10^{1}, 10^{1} 10^{6} and 10^{7} respectively.

Reverting to the item of *Wire,* a careful selection of ores and admixture of metals has resulted in greatly increased tensile strength with diminshed resistance the standard for the No. 6 galvanized iron wire adopted by the Canadian Government being 570 lbs. weight per statute mile, 1700 lbs. breaking strain, 18 twists within 6 inches of length, without break or split of fibre, and 8 ohms maximum resistance per mile. Phosphor bronze, silicate and hard drawn copper wires have the advantage of less electrical resistance, but the cost is much greater, tensile strength less, and resistance increases after use. Steel wire coated with pure copper combines strength with minimum resistance, but from the unequal expansion and contraction of the two metals under varying temperatures and other causes, its conductivity rapidly deteriorates. As an experiment the Baltimore and Ohio Telegraph Co. erected several hundred miles of 200 lbs.-to-the-mile hard drawn copper wire, at a primary cost of $44 per mile, the resistance being $4\frac{44}{100}$ ohms, and tensile strength 572 lbs., but within 3 or 4 years such wire elongated 1.28 per cent., and the strength was reduced to 530 lbs. The subject of copper wire will be further commented upon under the item of underground and submarine conductors.

Insulation: The difficulties attending all attempts to convey intelligence by electricity during the 18th century were greatly increased by the high intensity of frictional currents, but the Galvani-Volta discovery of chemically produced electricity of low intensity rendered insulation, either by an external coating of the wire or by its suspension from non conducting substances, both inexpensive and practical. Wood, vegetable gums, glass or porcelain have all been utilized in various forms and patterns for aerial wires, the latter material being preferable.

The "Gisborne" white porcelain insulator, as adopted by the Canadian Government and by the Canadian Pacific R. R. Co., has been designed for strength, facility for clearing, freedom from insects, and maximum insulation during wet and foggy weather. The nominal *standard* for the resistance or non-conductivity of any insulator when dry is 100,000 megohms,—a megohm being 1,000,000 ohms, and for pole suspended wire, during dry weather one megohm; but in wet weather the insulation drops to $\frac{1}{4}$th of a megohm, and during storms and fogs it becomes so low as to require that messages shall be repeated over short sections of line, and hence the importance of the "G" standard insulator, which costs but 7 cents, *versus* glass at 5 cents each.

The resistance of insulating substances used in submarine and underground circuits diminishes with elevation of temperature, and they vary materially; for instance, at 24° centegrade, a cubic centimetre of gutta percha has a resistance of 84×10^{12} ohms, vulcanized rubber $15,000 \times 10^{12}$ ohms, while at 46° centegrade ebonite tests $28,000 \times 10^{12}$ ohms, and Paraffin wax $34,000 \times 10^{12}$ ohms.

Perfection of resistance is however only one of the qualifications required for the insulation of underground and submerged conductors; freedom from absorption of moisture, cracks, etc., being vital elements. Gutta percha and all vegetable gums part with their essential oils, and become brittle when exposed for some time to the atmosphere; and, unless protected by an infusion of sulphur, India rubber liquifies when in direct contact with copper, which metal should for this reason be coated with tin.

To the invention of submarine telegraph cables we are indebted for much practical knowledge, both in conductive and non-conductive materials, for instance, placing the standard of pure chemically precipitated copper at 100 units.

Lake Superior ingots grade............................	98.8 units.
Australian "Burra-Burra".....	88.7 "
British "best selected "................................	81.3 "
Russian...	59.3 "
Spanish only............	14.2 "

or little better than iron.

And whereas the copper conductor in the first Atlantic cable proved to be 40 units standard only, the following cable tested 89, and the last one laid 98 units. Purity of metal lessens resistance, and upon long lines a reduction of one ohm per mile signifies fewer battery cells and less perfect insulation required for the transmission of signals.

Perfect insulation is, however, essential for underground and submarine wires and cables, as exemplified by the great number of dead (*i.e.*, useless from imperfections) lines throughout the world.

The disadvantages attending long distance underground wires are, first cost, reduced rate of speed in signals, and difficulty and expense of repairs, which are materially increased where a multiplicity of wires are required. A sample of underground cable manufactured in Germany, and placed experimentally in a trench, through alkali grounds, in the North West Territory of Canada, became defective after two years; but even though imperishable in material, the cost, difficulty and delay attendant upon repairing damage (from frost heaving the soil, or by animals or lightning,) when the ground is frozen and covered with snow, would greatly counterbalance any other advantages over ærial wires; but in towns, where a multiplicity of poles and wires are a source of danger, annoyance and disfigurement, there can be no question as to the practicability, immediate necessity and ultimate advantage to shareholders, of all electric wires, gas and water pipes, being placed in traversable underground conduits, or in troughs in the sidewalks, and that the corporations should charge companies a sufficient rental to cover interest upon cost of construction and maintenance expenditure.

With perfection of material and manufacture, experience in laying, and improved transmitting apparatus, *submarine* cables are now safe and profitable investments, the localization of breaks or faults and the making of repairs being subject to scientific skill.

To the *uninitiated*, the localization of a fault or break in a mid Atlantic cable is incomprehensible, but the following brief explanation of the main feature or original basis of the method may be interesting, although but one of the many items of scientific and professional attainments necessary for detecting the exact locality of either a break or fault.

Suppose the copper conductor of a cable has a resistance of 10 ohms to 1 *mile*, and a bobbin containing 1 *foot* of fine drawn platina wire, which is a bad conductor, to have a resistance of 10 ohms.

The above resistances being equal, if a battery current is passed through both conductors separately and simultaneously, it will divide or split evenly as to quantity, and when connected with a differential galvanometer, the needle will remain steady at zero.

Now, supposing the cable to be broken 10 miles seaward, its conductor to that point will have 100 ohms resistance, and it will require 10 bobbins of platina wire to balance the needle of the galvanometer at zero. By adding up the number of the bobbins you thus note the distance to the break.

The foregoing explanation may be misleading in its simplicity, unless it be added that the true internal resistance of the cable core depends upon its contact with rock, mud, or water only, and that much more delicate tests are required to localize a fault, based upon dialectric resistance, inductive capacity, percentage of electrical discharge, etcetra.

Galvanic cells or batteries, the source of current, must next be considered, the standard for comparative efficiency being the Daniell cell =1.104 E.M.F. and 0.33 ohm internal resistance:—

the E.M.F. of a	Grove cell being	1.93	Resistance	0.15
"	Bichromate	2.00	"	0.25
"	Le Clanche	1.47	"	1.50
"	Gravity	1.05	"	2.00

The efficiency of all batteries in great measure depends upon their E.M.F., constancy, and low internal resistance. Hitherto the high resistance in *dry* cells has militated against their utility; but a new form known as the "Gassner," with an E.M.F. of 1.44, has an internal resistance of 0.32 only, and is admirably adapted for open circuit requirements.

Dynamic and magneto currents are also applicable, and under some conditions economically utilized for the transmission of signals.

From Woods' first conception of an electro-telegraph, A.D. 1726, more than a century elapsed before Cooke and Wheatstone, (England,) A. D. 1837, adapted Oersted's discovery of A.D. 1819, to the *first practical* and *commercially successful* system of what may be termed *visual* electric telegraphy; and some months later Morse and Vail, United States, adapted Arago's discovery of A.D. 1820, to the first system of *recording* electric telegraphy, Vail being the inventor of the dot and dash alphabet.

A.D. 1838. Steinhill, Germany, adapted Oersted's discovery to the first recorded system of sound or *aural* telegraphy, and first utilized the earth in lieu of a second wire or all metallic circuit. It is by no means certain, that there is any electric current flowing through a wire, or that a wave of electricity like the waves of sound traverses it. It is simply a customary expression to indicate a difference in and around a wire to the conditions in which said wire was when no electricity was present in it.

A.D. 1839. Wheatstone invented the step by step alphabetical indicating telegraph; and A.D. 1848, House, England, invented the alphabetical type printing telegraph, which was subsequently improved upon by Hughes, England.

A.D. 1846. Bain, England, invented the chemical dot and dash recording telegraph, which, combined with Wheatstone's automatic transmitter, hereinafter explained, is the most rapid method of conveying intelligence in present operation.

Finally, A.D. 1876, Bell, United States, invented the telephone, and by accomplishing the electrical transmission of speech, thus attained possibly the highest degree of perfection in intercommunication of intelligence.

And now as to the "*Survival of the Fittest,*" regarding which the writer ventures to express his opinion, with a view to inviting discussion for the benefit of the members and students of the Canadian Society of Civil Engineers, viz.:—

That timber poles, preferably of Cedar, duly provided with lightning conductors at every 5th or 10th pole, are best adapted for telegraph lines throughout Canada, excepting through prairie lands, subject to fires, where iron posts are desirable.

That No. 6 galvanized iron wire, per specification herein before cited, is preferable to copper or composite wires, for aerial lines of considerable length and in exposed localities.

That porcelain insulators are the most economical and efficient, under similar conditions.

That gravity batteries are the most reliable for closed circuits, and Gassner's dry cells for open circuits.

That in towns and populous districts all electric wires, gas and water pipes should be placed in traversable underground conduits, or the wires in sidewalk troughs.

That the Morse and Vail system, with sounding apparatus operated by dot and dash signals, is the most effective in the hands of skilled operators, for general purposes.

That the Wheatstone automatic transmitter, by a paper tape or strip previously perforated with dot and dash or all dot lettering, drawn rapidly between contact makers, and reproduced mechanically upon plain, or chemically upon prepared, receiving paper, at the possible rate of 1000, and *practical* rate of 400 or 500 words per minute, is the best combination for the rapid transmission of intelligence.

That the most successful and profitable telegraph companies of the future will abandon the present system of a multiplicity of wires for the transmission of intelligence; and at business centres, and important stations, will employ female labor for perforating, and comparing with the original manuscript, despatches to be forwarded by automatic transmitters; an additional wire or two being operated by Morse sounders for the correction, when needed, of automatically transmitted messages, and also for the requirements of intermediate local business, such additional wire or wires being available for duplex, quadruplex, or multiplex instruments.

DISCUSSION.

Mr. Lawson. The only objection to Mr. Gisborne's paper is, that the subject being one on which experience only can provide material for discussion, the author has gone into it so fully as to preclude criticism.

The placing of telegraph wires underground is an important one. Those of the Telegraph Department of the General Post Office, London, are now nearly *all* underground in that city, and the service has benefited by this to a great extent; breakages and consequent delays in transmission were frequent on the aerial lines, but now are a minimum. Gutta percha insulated wires "drawn in" to iron pipe conduits are the rule; and these conduits are laid as Mr. Gisborne suggests under the curb stones in the streets.

In submarine cables, gutta percha is supposed to be the best all round insulator and is the one most used. An objection to it is that in shallow and warm waters the teredo which does not touch India Rubber cores, attacks it, and destroys the insulation of the line; but this has been provided against by Clifford and by Siemens, who have put a muntz-metal sheathing over the core before closing, and all cables recently laid in shallow waters in the Mediterranean, Red Sea and Indian Archipelago are thus protected.

It would be interesting to know if Mr. Gisborne has found any trouble caused by the teredo on the Pacific Coast Canadian cables, as the speaker has observed its ravages on wood piles in the wharves at Vancouver and Victoria; and having in view the proposed Pacific cable (Vide Mr. Gisborne's Appendix No. 1), it is a subject of peculiar interest.

As to conductivity, Mathiessen's standard for copper is too low, and for proof, it may be stated that some lengths of Atlantic cable supplied by Siemens Bros., and laid by the "Faraday," tested about 100·25 the conductivity of pure copper according to Mathiessen's standard.

One thing which might interest members of the Society would be a table of depths of water in which cables have been "hooked," as it would give some idea of the perfection to which submarine telegraph laying has attained. For example it may be mentioned that in the repairs of the Brazilian cable,—Lisbon-Madeira section—by the "Seine," the depth was $2\frac{3}{4}$ miles, of the Atlantic cables, by the "Great Eastern" and "Scotia", 2 to $2\frac{1}{2}$ miles, and of the West India and Panama cables by the "Dacin" 3 miles.

As a sample of fine testing an experiment by F. A. Hamilton, Electrician of the Anglo-American Telegraph Co., may be mentioned. By his tests of a fault—not a total break,—Captain Trott placed the "Minia" in position, and grappled for and hooked the cable at less than half a mile from the fault, which was distant from the Nova Scotia shore about 800 miles.

It is of importance that the transactions of our Society should contain a full discussion or further papers on "Phoneplex" working, "Long Distance Telephony," and other kindred subjects.

An omission from the list of batteries is De la Rue's chloride of silver battery now much used for cable testing.

For electric lighting no difficulty really prevents the placing of *all* wires underground except first cost.

Many stations in large cities have the conductors for incandescent lights underground, and in Europe, notably in Rome and Milan, no trouble has been experienced with cables made by Siemens Bros. & Siemens & Halske, which carry alternating currents of 2,000 volts. It is simply a question of proper insulation and chiefly a question of paying for it.

Mr. Gisborne's paper is so complete and comprehensive a disquisition upon the telegraphic industry of the present day, and covers the ground in so practical a manner, that we are forced to accept his conclusions without question. Mr. Kimball.

The rise and progress of the science of Electricity—for it surely has risen to the dignity of a science,—may be compared to a tiny stream which originated in the discovery of the properties of Amber and the Leyden jar, and which as it trickled along was increased and strengthened by the revelation of that mysterious connection between magnetism and electricity, discovered and applied by Oersted, Arago, Faraday and others, until the little stream has grown to such dimensions, that men have embarked upon its surface and risked their fortunes in such enterprises as the Telephone and Telegraph and the Electric Light, and the volume of this on-flowing river is constantly increasing, and its banks widening, and already we can see it opening into an ocean that is boundless.

The undergrounding of conductors for the purposes of electrical distribution has probably taken up as much of the attention of electricians as any one problem connected with their vocation.

The recent exhaustive report of Mr. S. S. Wheeler, of the New York Board of Electric Control, while stating that considerable progress has been effected in the burying of telephone and telegraph wires, the placing underground of electric light wires has been carried out successfully in but a few places, so far as the arc lighting systems are concerned.

The Edison system of underground conductors is one of the most complete, but the history of many of the stations using this underground system, will be found to be a chapter of accidents, as great care must be taken in the construction and maintenance of these tubes, to avoid trouble.

Although electrical apparatus which is simply perfect in action, has been invented and constructed, the first cost and expense of maintenance are still as great as can be borne by the user, and any increase in the expense of maintenance or first cost must revert back upon the consumer.

Any practical system of underground conductors, to take in the electric light wires, must at present be expensive.

There are some companies, however, which would go to the necessary expense could they be assured that such a system would be reliable, but experience has shown that it is a doubtful undertaking, and that where some have succeeded more have failed from an economical point of view, and that the best insulator is that fluid which surrounds the globe, and which, acording to Dr. Otto A. Moses, of New York, we have only to "open our mouths and breathe in."

Mr.Thornberry, Mr. Thornberry said, that if it would be interesting to the Society, he would explain the underground system in use in New York. He had been there recently, and also in Boston, and had carefully studied the subject. In Boston their original system is still adhered to, and is thought the best. In New York, a pitch and asphaltum concrete conduit pressed into form, is used, as many ducts being made as are required for the lines. They are laid in sections of 4 or 5 ft. in length, and are cemented together with tar. They are found to be successful but not so favorable for the purpose as an iron pipe.

Manholes are inserted every 300 to 400 feet,—the interval depending on street intersections—for use in drawing in or repairing cables.

The least expensive material of all would be creosoted wood conduits laid with as many ducts as are required, in lengths of from 10 to 15 feet, the length being governed by the lumber and the weight of the ducts. The creosoted wood is largely adopted by the companies which could not go to the expense of laying iron tubes and by companies doing their own work. Creosoted wood has been found to last 15 to 20 years. It would probably last longer, but we cannot say from experience, as we do not know the quality of the wood nor how the creosoting has been done. The creosoted wood ducts present greater advantages for drawing in cables than any other after they are laid, and perhaps for this reason they are more in favor. First cost is the primary object. He also stated, in relation to a non-conducting metal, that Major Williams of Boston had been directing his attention, for three or four years back, to the manufacture of a wire which shall have a covering of non-conducting metal. He had combined manganese with steel, with some remarkable results. The iron being compounded with manganese is almost wholly diamagnetic; it can not be magnetized. Should his experiments turn out successfully it would be a great advance in electrical science.

With regard to batteries, he had tested the Gassner and LaClanché, and was not in favor of the former for heavy work as it would not last. The fluid battery gave better results. He had put all the batteries under a test by running them constantly through 20 ohms resistance. The Gassner battery was a failure, and the Law battery he found much worse. The LaClanché battery depends upon the material put into it. If first class material is used in its manufacture, a first class battery is the result. Referring to the writing telegraph, he remarked that when he happened to be in Rochester about two years ago, the telephone people had formed a combination, and many schemes were introduced to effect communication outside the telephone,—among others the writing telegraph. He tried to write with the machine, but could not recognize his own hand writing. He had difficulty in forming some of the letters. The writing was done with a style on a piece of moving paper. A moving tape makes it very awkward to form letters with loops in them. The man exhibiting the arrangement was quite expert and wrote very nicely. A great many people purchased the machines, but they have never been used to any great extent.

Mr. St. George having been asked, in connection with Mr. F. N. Gisborne's paper on Telegraphy, to describe the underground system now in use in the United States, submitted the following account of a visit to the cities of Boston, New York, Brooklyn, Philadelphia, Chicago and Detroit, where the underground systems have been adopted. Mr. St. George

The successful work of underground conductors for Telephone and Telegraph service appears to be decided; the electric light underground system is still somewhat in doubt, although so far, it is working in Philadelphia successfully. The experience gained in the practical working of underground systems in the cities visited points to the probable development of no serious difficulties, at least within the limits of an ordinary Telephone line.

The conduits or subways, of whatever kind or construction, merely protect the enclosed cables or conductors from injury.

The character and mode of construction of the subways or conduits should be determined by the local conditions in which they may be placed.

The principal systems of electrical subways may be classified: First, as to their material composition, and second, as to their mechanical construction and the manner in which the wires are laid in them.

The material composition of subways is :—

1st. Insulating material, such as wood, glass, asphalt, concrete, etc.

2nd. Conducting material, as iron.

The different subway systems are :—

1st. Tunnel system.

2nd. Drawing-in system.

3rd. Solid system.

In the *tunnel system* sufficient space is provided underground, irrespective of the cost of construction, to allow of the passage of men to and fro, to place wires therein.

In cities like Paris, where large sewers exist in most of the streets, such a plan is practicable, but is not to be considered in such cities as Toronto and Montreal.

The *drawing-in system*, or that in which manholes are provided in the streets and are connected by tubes or pipes, through which the wires or cables can be drawn, are next to the tunnel system in convenience.

In Boston, at first, wrought iron pipes, 2¾ inches in diameter, were laid in concrete, and then creosoted wooden boxes with from 12 to 6 ducts in them. Also in New York, Brooklyn, Philadelphia, Chicago and Detroit, iron and wooden pipes were used, and also the wooden box conduits,—the latter system being the most general.

The *solid system* is that in which the wires are permanently embedded in insulating material and are incapable of being reached, except by tearing up the streets and the insulation. It is, or was, in use to a certain extent in Chicago and Washington, and about half a mile of it was laid in Montreal three years ago.

This system has not been extensively adopted, and the mere statement of its character appears to indicate inherent defects, and a lack of flexibility as compared with the drawing-in system.

The report of the Board of Commissioners of Electrical subways for the city of New York states that:—" Leaving out of consideration all " tunnel systems as too expensive, we must also discard any system " which calls for the simple laying of insulated cables in the earth.

" They would not stand the chemical action of the gases and acids; " the streets would be continually torn up for new connections and re-

"pairs. We are thus confined to the question of electrical subways or "conduits in which the wires or cables, insulated or otherwise, must be "placed, and which, once laid down, shall meet all the requirements of "the present and near future. Of conduits, it may be safely predicted "that, so far as the experience of this (New York) and other cities is a "test, some form or other of a drawing-in system is most convenient. "The life of the best cable is by no means satisfactorily decided, and of "any particular cable, to predict how long it would last would be purely "speculation. Of wires not contained in cables, it may be said they are "more uncertain in their length of life and usefulness. At all events, "for purposes of distribution, it is desirable that the wires should "be easily approached at frequent intervals, and the commission cannot "countenance any plan that looks to the disturbance of pavements more "than is absolutely necessary. It may be, that through lines of wires would "be better protected if laid in permanent beds of insulating material; but "a drawing-in conduit system allows space to be provided for new wires "without the frequent tearing up of pavements. The commission can, "therefore, give their approval to a drawing-in system with frequent "manholes, as the general form of subways best adapted to meet the "requirements of the electrical service of the present."

The question is narrowed down to the consideration of the material and form of the drawing-in system.

Conduits of the drawing-in system have been constructed and are in use in various cities, formed of a variety of materials, including asphalt, cement, glass, iron and cement, tiling and wood. Regarding cement, glass or tile conduits, the laborer's pick has been one of the great objections to these, and they are now nowhere seriously considered; consequently, asphalt, iron and wood, as materials, remain to be considered.

The New York commissioners' report above referred to, has adopted asphalt for certain reasons. The report says:

"While it appears that any kind of conduit which will protect the "insulated wires will answer; and on the other hand, that no conduit "has yet been found which works perfectly, or is an ideal one; "it may be said with confidence, that the weight of evidence before "the commission is towards the use of an insulating material for conduits; and of insulating materials, asphalt or bituminous concrete has "certain advantages over all others, viz.:

"1st. It is cheap.

"2nd. It is durable.

"3rd. It is capable of standing harsh treatment.

"4th. It can be easily and closely jointed.

"5th. It can be made absolutely free from moisture, and free from "contraction and expansion.

"6th. It is a bad conductor of heat as well as electricity."

In reply to the above points, we may say that in Montreal:

1st. All such conduits would have to be imported and would obviously cost more than wood.

2nd. Its durability is unquestioned, but being of a composite character, we are of the opinion that it is open to the pick axe objection, which therefore raises a question of harsh treatment.

3rd. The joinings of wooden or iron conduits can be made tightly.

4th. It could be hardly kept free from the deposition of moisture in this extreme climate, any more than wood or iron; its freedom from expansion and contraction is no doubt perfect as compared to iron.

5th. Wood is also a bad conductor of heat and also of electricity. With reference to the employment of iron as a material, it may be stated that in the cities of New York, Philadelphia, Chicago and Detroit, iron pipes are principally used.

In Brooklyn, wood alone is used. In Boston, in 1882, iron was used at first, and afterwards wooden boxes. Mr. Joseph P. Davis, vice-president of the Metropolitan Telephone Co. and Telegraph Co., says: "As "regards an iron conduit, I had three years experience with one in "Boston. The longest line was about 1500 feet, and the moment "the wires were put in use, the subscribers complained and pro-"tested that they could not hear. This was caused by retardation. "They could not get their voices through. A greater conductivity in "the wires could not remedy this. You could use a much longer line "in a conduit that is an insulator than in one that is a conductor. No "amount of insulating material around the wire could make it work as "well in an iron as in an insulated conduit."

The question of retardation is a very serious one, and the use of the iron is undoubtedly a great disadvantage. The durability of iron pipes, of such a thickness as could be conveniently used for conduits, would not compare favourably with creosoted wooden conduits, unless thoroughly coated with asphalt, varnish or some similar substance, and in no instance should they be laid without being enclosed in a creosoted wooden box filled with asphalt or cement. Necessarily iron must cost more than wood.

Wood is therefore cheaper than iron and equally durable and better as an electrical non-conductor.

Mr. Starr. Mr. Starr said that it gave him much pleasure to be present and listen to Mr. Gisborne's most interesting paper. It was not generally known that the world was under great obligations to Mr. Gisborne. He had been personally acquainted with him for a number of years and knew something of his history. To Mr. Gisborne he knew we were indebted for the Atlantic cable. What gave Mr. Gisborne his original idea was the success of the first cable laid between England and France—but he had publicly advocated an Atlantic cable before, the news from England was landed in despatches at Cape Race, and by a line (constructed by himself) transferred via Cape Ray, by cable, to Cape Breton and thence to New York. Other people had received the credit of the institution of the Atlantic cable, but he believed that it was really due to Mr. Gisborne. (See Appendix No. 3.) He was pleased to hear that there was some hope of an independent cable for Canada before long. He himself had been residing on the other side of the Atlantic for two or three years, and a few weeks ago read an article in the *London Standard*, telegraphed from New York, purporting to be the result of a meeting of the Dominion Cabinet. It reported that Mr. Thompson, Sir H. Langevin, and others were intent upon war with the United States, but that Sir John MacDonald pronounced the matter all moonshine. Now, when the press people sent such arrant nonsense as that across the water, it was quite time that we had an independent cable and an independent press association of our own.

It might be interesting to the members of the Society to know that there were many new inventions coming out on the other side, connected with electrical and metallurgical matters. It came under his notice a few months ago that a new composite metal had been discovered in France. It was a combination of nickel and iron, and possessed some extraordinary merits. It was said that wire made with a certain proportion of nickel was one of the best conductors for electricity known, better even than copper, and that a different proportion of nickel made the iron a perfect non-conductor and perfectly inoxidizable. Some of the wire had recently been sent to Mr. Preece, the Engineer of the Post Office and Telegraph in England, for a practical test, and before long the public would know the result. If it proved to be all that was claimed for it, it would answer the purpose which Mr. Gisborne thought so desirable,—of having one metal that was a perfect non-conductor to cover one that was a good conductor.

Mr. Gisborne stated in reply to Mr. Thornberry, that for **Mr. Gisborne.** a large Telegraph company, where they were working the whole time, and practically upon a closed circuit, the gravity cell would of course be preferable; but for home use, telephones, electric bells, etc., where the current was taken off for a few minutes, and then had time to recuperate before again being used, he thought the open circuit cell was better. There was a vast difference between the uses of an open circuit and a closed circuit battery. The question was whether the Gassner dry cell was the best form for open circuits, where the Leclanche cell was now in use, and from very careful experiments made at his office, he was prepared to adopt the dry cell improvement.

In the course of his paper, Mr. Gisborne also made the following supplementary and explanatory remarks:

He was not sure that a pole, cut with the sap in and dried before it was put up, was not better than a pole cut in the winter.

When in Prince Edward Island, about four years ago, he noticed the stumps of some juniper and black spruce poles which he had planted along the coast, near Souri, thirty-six years ago, but there were no remains of those erected further inland.

From experience in the North West, where there is no cedar, the poplar poles had to be renewed every two or three years, so that it was decided to experiment with some iron ones. The expense of transportation was greater than the original cost of the poles themselves, but he had put up 100 miles of iron poles across the Prairie between Battleford and Fort Pitt, where they had withstood heavy gales of wind and blizzards, and of course had not been burnt down and utilized by teamsters for fuel. Between Moose Jaw and Wood Mountain, where 90 miles of cedar poles obtained from Rat Portage had been erected, he had this year to put in 30 new ones to replace those stolen by teamsters, and 25 or 30 to replace others destroyed by lightning.

The iron poles were not affected by lightning. It would therefore be understood that although the first cost of iron poles were double those of wood, they would probably last some 25 years, besides being free from the dangers referred to; he believed therefore that it would be economical to adopt iron throughout the North West, and had recommended the government to give them a fair trial for two or three years, in order to ascertain what would be the effect of the alkali ground upon the galvanized iron, and if it did not act upon them injuriously, then undoubtedly the iron poles would be used in future.

Respecting the iron poles now upon trial, Mr. Gisborne stated that, they were wrought iron galvanized tubes, tapering from $1\frac{3}{4}$ inches at top to $2\frac{3}{4}$ inches at bottom, 16 feet in length and weighing 42 lbs. only; and that by adding 3 feet to their length and a little more weight of metal, he would be able to use fewer poles and have an improved line. The light weight of the poles erected proved, however, that if they would stand the test of sleet and gale, an 85 pound pole would assuredly be a perfect success.

If a heavy man were sent up a wooden pole when first planted, say, 5 feet in the ground, the pull, when stringing the wire, would move it several inches from the perpendicular, and it would have to be retamped, and again the following year, before it was firmly settled; whereas the iron pole, although planted but 3 feet in the ground was at once perfectly fixed, so that it would break off at the surface rather than move, and under strain would bend like a fishing rod, but come up straight again when the wire was finally adjusted. The patented peculiarity and merit of the Gisborne iron pole was in the underground fastening device. The bed plate was made of galvanized boiler plate 8 inches square and $\frac{1}{4}$ inch thick, with its four corners turned up and its centre punched up for a tongue, with a $\frac{1}{4}$ inch hole through it.

The iron tube rested upon this bed plate with the tongue on the inside of it, and a piece of No. 6 wire, passed through both tube and tongue, held it loosely in place. It did not signify, therefore, whether this bed plate was put into a perfectly flat-bottomed hole, which would be necessary if the tube was firmly fixed to its bed plate by a collar and screws, for otherwise if the pole was not perpendicular, the collar would be carried away, or the pole bent, upon endeavouring to plumb it; whereas, after the earth was put upon the bed plate described, the pole could be righted at pleasure and without injury to it; the ends were turned up, so that under pressure, the bed plate would not cut sideways into the ground.

Two feet of earth was then tamped over the bed plate. The grip plate, also of $\frac{1}{4}$ iron and 8 ins. square, with turned up corners, had a $2\frac{1}{2}$ inch hole in its centre, and was slipped corners down over the top of the pole, another foot deep of earth placed upon the top of the grip plate completed the setting,and the pole was then a permanent fixture. It was also a cheap plan of erecting poles, because to dig the last two feet of a hole costs much more, proportionately, than to dig the first three feet of a five foot hole. In this there was an economy to balance in part the first cost of iron poles. Where there was a sharp angle, a flat ring, pierced with four side holes for wire stays, was slipped over the top of the pole, and its tapering causes it to lodge 3 feet from the top. No. 6 wires were then attached to the ring and to small square iron plates sunk into the ground, and thus a light pole would withstand a very considerable side strain.

Explanatory of the more essential electrical units mentioned in the paper read, he had introduced their comparative analogies to water, so that engineers who were not thoroughly posted in electrical matters would understand their relative value.

There were several other units which electricians had, from time to time, endeavoured to introduce, but if the six he had mentioned were borne in mind, they would be sufficient to understand the subject. They would also notice that the units were all taken from men prominent in electrical engineering science, the "Watt" for instance being chosen to express power.

Just before leaving Ottawa, he had received the following valuable statement from Mr. Carson, M. Can. Soc. C.E., engineer of the Whitecross Manufg. Co., of England,—from whose works the government wire was purchased—to the effect that by a careful selection of ores, etc., they had during the last 20 years, decreased the electrical resistance and increased the tensile strength of iron wire to a remarkable extent.

WARRINGTON, September 29th, 1888.

F. N. GISBORNE, ESQ., Ottawa.

MY DEAR SIR,

But that I have been absent in Spain, the information as to wire which I undertook to supply you with for your paper, would long ago have reached you. I now make such notes as will perhaps afford you a ground for your observations.

The necessities of the telegraphist have been the direct cause of the great improvement in the manufacture of wire which has taken place within the last twenty years. At first commercial wire was used; experience was required to teach the telegraphist the importance of long continuous pieces and low resistances. So, during the twenty years the single piece of 20 lbs., equal to say 80-90 yards of the standard size of 400 lbs. to a mile, has become 112-150 lbs. equal to 500-600 yards, or 3 to a mile.

As every joint is not only a source of weakness, but of loss, and also a possible point of contact during gales, and of collection during snow storms, the importance of this advance cannot be overrated.

This improvement in length has been accompanied by an equal improvement in the character of the material employed, and hence in the conductivity of the line. The theoretical value of wire as a conductor was not even approximated to in the first lines, such a value being obtained as the result of experiments upon material obtained by electrolysis. With the ruder methods of manufacture then practised this was a perfectly illusive standard, but the electricians did not allow the manufacturer to sleep; steady pressure was kept up to improve quality, and the result has been that the Engineer can to-day lay down conditions which were considered impossible of fulfilment even a few years ago.

The resistance of an iron wire being in the direct ratio of the proportion of metallic iron contained therein, the difficulty which manufacturers have met with is to reduce the foreign matter as low as is consistent with sound material. It may be said to be like human nature in this respect, that without infirmities, iron is of no use as a practical material. It may be theoretically pure, but unfortunately it will not hold together for any useful purpose. From this arise the difficulties of the manufacturer; impurities, *i. e.*, carbon, silicon (as little of this as may be), manganese, and sulphur, with some phosphorus, must form the constituents, but only so much as will be sufficient to make a malleable material. To balance these ingredients is the business of a successful maker nowadays, and he is successful or otherwise, according to the percentage of conductivity he can provide for the service of the Engineer.

Then much will depend upon the purpose for which the wire is demanded; in England where heavy gales with continuous snow storms are not common, the Engineer can dispense with the condition of great tensile strength, in favour of better conductivity. Thus the British Postal requirement is only some 30 tons per square inch of strain, but what with long circuits and quadruplex instruments, the highest noted conductivity.

The India government, on the contrary, have to build in ice and snow, in all climates, and with sudden variations of temperature, and they are willing to forego somewhat of conductivity in favour of a stronger wire, equal perhaps to 45 tons strain per square inch of section. And these are the conditions which obtain in Canada, where the latter specification has been very widely adopted.

The running sizes, with tests required of the specifications, are subjoined, and it will be seen at once where the differences come in.

Recently, owing to the extreme price of copper, the British authorities have been on the look-out for a material possessing a higher conductivity with greater mechanical strength, and though it cannot be said that this has been generally reached, yet from one firm an approximation has been attained to a more perfect result. A considerable quantity, some hundreds of tons of the standard size of No. 8 (.171 in. diameter, 400 lbs. to a mile), has been erected, having a breaking strain equal to the India Government requirements, with a resistance electrically of only $11\frac{1}{4}$ ohms per mile as a maximum; much of this material showing as little as $10\frac{3}{4}$ ohms resistance per mile This is represented in the specification as being from 4,300 to 4,500 constant (constant being (W. × R.) where W represents weight per. mile in lbs., and R resistance in ohms per mile).

But this is by no means the best that is to be looked for, as the manufacturers of this material assure me that they have now a material on the stocks which shall not exceed a constant of 4,000, with equal mechanical tests to those of the India Government, such as we ourselves insist upon for Canadian work.

But it must be noted that all the care of the manufacturer is thrown away, if the tests which the Engineer lays down, in regard to quality, are not carefully carried out when the material is presented for inspection. When it is stated that a difference of $\frac{1}{2}$ an ohm per mile in the resistance makes a difference in value of something like £2 a ton in the cost of the material, it will be seen at once that if the systematic testing of the material, electrically as well as mechanically, is not conscientiously done before the reception of the wire, the Engineer may not only be paying more for his material than it could be purchased for from the honest maker, but he may be paying the utmost price for what the honest maker would refuse altogether to supply for telegraphic purposes, with conditions of conductivity attached.

In this way the conscientious maker is discouraged, and honesty is no longer the best policy.

If the Engineer wants a cheap line, irrespective of electrical results, let him ask for ordinary fence wire in long lengths; but if his line will warrant him in paying for a lower resistance material, let him above all things, by careful testing, see that he gets what the maker professes to sell him.

This is not difficult when it is remembered that in the works of the three or four leading telegraph wire makers, all the necessary appliances are provided with a competent staff who are at the disposal of the inspecting officer during the inspection.

The percentage for inspection varies according to circumstances, but if all goes well 10 per cent. is usually the lowest proportion. But here the value of a competent man is shewn; a slight falling off in the days work is at once counteracted by an increased percentage of tests, so that a variation is at once traced to an accidental circumstance, or to something more serious, to which the Engineer's attention may be called.

It will be evident that it is of no use to spend money on a line to avoid leakages, to ensure quick and continuous working, and to resist all conditions of weather, unless the Vital Factor, the conductor, is also as good as can be made. And, further, it is of no use to accept the lowest bid of inexperienced makers, when the necessary check of consistent testing is not carried out completely. One constantly hears of Engineers being appealed to against the inspectors result, that the difference is "only half an ohm, what is half an ohm in resistance?" But when it is remembered that this ½ ohm is worth £2 a ton, and that the determination of the skilled manufacturer, when he tendered at a higher price, was to give the specified resistance, not more, and as much less, as possible, and further that if this half ohm had been stated as the specified resistance, the skilled manufacturer in all probability would have supplied at a lower price; it will be evident of what importance proper inspection is, in the erection of a line which shall give the very results which the Engineer designed it should give.

It may be added that the material of which the British Postal wire is obtained has the following percentages of metallic iron:

	4,300 to 4,500	constant	99.85
	4,800	"	99.65
and for the India Government wire,	5,400	"	99.50

The accuracy of manipulation which the manufacture of really high class material requires is well shewn in these figures, where not only so near an approach to pure iron is obtained, but also where so small a variation in the percentage of metallic iron causes so great a falling off in conductivity.

I hope you will be able to draw from these remarks so much as will be important in giving your hearers the latest news as to what can be got out of iron wire.

(Signed) Wm. Carson, M. Can. Soc. C. E.

The Canadian Pacific Ry. Co., he believed, had purchased some No. 6 wire from Germany, presumably of the same quality as the Government's wire, but he found that the resistance of such wire was an ohm or more greater than that of the Whitecross wire, thus making a difference in actual value of (as explained by Mr. Carson) £2 or more pounds sterling per ton. It was only of late years that electricians realized that it was essential that wire should be of low resistance, less perfect insulation and less battery power being required with superior conductivity. Electric current, have a natural tendency to escape, and more especially where the insulation is defective.

The ordinary test for wire, the tenacity of which is also a very important *factor* in line maintenance, is readily made by taking a piece of iron wire and drawing an ink mark along the top of it, then by holding it fast between two vices, 6 inches apart, and twisting it around, the ink will show every twist in symmetrical lines which can be counted. The Government test requires that every coil of wire should show at each end, 18 twists within the 6 inch length, without break or division of fibre, and any faulty coil was rejected.

In repairing telegraph lines, you may have to travel some 50 miles to find the break. During that time business is delayed, and horses and men have to be employed at considerable cost, while the stoppage of messages often results in a permanent loss of business to the line, because people would not trust to the telegraph unless it was perfectly reliable. The mere additional cost of £2 or £3 per ton for wire was not therefore to be considered in view of other advantages gained.

With regard to phosphor bronze and silicate metals, he had obtained the best wire made of such material directly from the manufactory in France, and of the same gauge as the iron wire, and strung it across from Gabriola to Valdes Islands in British Columbia, a stretch of about 1000 ft., and each wire from different poles. At the end of the first season the ordinary iron wire was standing, while the composite copper wire had broken.

A great deal had been said in favor of hard drawn copper wire, and of the steel wire coated with copper put up between New York and Chicago; but for the reasons mentioned in his paper, he thus far preferred iron for long distance lines in North America. For small resistance pure copper was advocated by Mr. Preece in England; but our climate is different from that of England. There they were not subject to such heavy falls of sleet and snow and gales of wind, as we were in Canada, and their distances being so much shorter, with railway facilities for repairs, the wires were easily and quickly maintained. The primary cost of even the smaller gauge hard drawn copper wire was at least 4 times greater than that of iron, and irrespective of first cost, copper had to be tightened up every spring, and it would have to undergo the same process every year at the end of three years. It would elongate to the detriment of both its strength and conductivity. This was practical experience against using hard drawn copper wire in our northern climate. He had had a large experience with the different kinds of pole insulators, and when he erected the first line in Prince Edward Island in 1852, experimented with gutta-perch insulators; but they now knew that after a very short time gutta-percha would part with its essential oil (unless placed under water), and the insulators would become like so much old putty, would crack, and were not of the slightest value. He then tried iron insulators. These insulator cups were globular, so as to prevent moisture from internal condensation. The wire was insulated with porcelain, precisely the same as the iron saucepans of the present day. Then the iron pin was coated with porcelain, and fastened within the cup with porcelain ; but they had only been in use one winter when the difference in temperatures, acting precisely the same as he had shown in the case of the steel coated with copper wire, caused the porcelain to crack, almost imperceptibly to the naked eye, but quite sufficiently for the moisture to get to the iron and thus allow the electric current to escape. Other materials had also been tried, but from the experiments he had made he concluded that solid porcelain cups set upon oak pins were the best insulators in this climate. Referring to the white porcelain insulators on the Canadian Pacific Ry. lines, they had probably noticed a number of glass insulators, which had previously been utilized, but across the continent they had one wire suspended from the G insulators, and, if they inquired from their manager, they would be informed that this insulation could be worked through in wet weather over long distances, whereas they had difficulty in working much shorter circuits provided with the glass ones. This again was practical experience. The Canadian Pacific had purchased over 250,000 of them at a primary cost of 7 cents each; this porcelain insulator was open to the light, and did not tempt spiders and other insects to make their nests in it, as was the case with insulators of darker material and more sheltered form.

Referring to the large insulator upon the table, he said it was very much upon the same principle as the smaller ones in general use, but it took a large pin, and before the pole was put up this pin was strapped to the pole by wire. The pole having been raised, the man with the wire on his shoulder mounted it, and readily tilted it over into the slot where it was secure until it was drawn tight from below, when he could put the tie wire through the hole which ran parallel with the slot, without risk or exertion.

In the cables that he had laid in the gulf for the government and in British Columbia, he had abandoned gutta-percha in favor of what was called ozokerited rubber insulation. The copper conducting wires were first tinned, then covered with a sticky compound known as Chatterton's, and served with a tape or strip of pure rubber, then served with a tape of partly vulcanized rubber, and again with a rubber tape differently treated with sulphur. It was again the 4th time served with a tape saturated with a rubber compound, and finally immersed in a hot solution of ozokerite,—a natural mineral wax mined in Hungary—by which all the rubber servings are amalgamated into a compact mass, when the insulation is found to be much higher, than the best gutta-percha cores now manufactured.

If gutta percha was not kept wet or cool, it would become plastic like putty, and the result would be that in a bent cable the wire would press through the gutta percha, and come in contact with the fibrous matter serving, placed between the gutta percha and the outside armour wires; and if it was exposed to the heat of the sun, the result would be the same.

In certain cases, the government cables in outlying places are sometimes accidentally exposed to the sun for some days or weeks, and yet the ozokerite rubber insulation remained unaffected.

The great cable manufacturing companies of England were associated either with the original gutta percha company, or had costly manufactories of their own, and they would naturally recommend gutta percha, and impress upon the shareholders of new cables the danger of adopting a new insulating substance, when gutta percha had been proved successful. The Henley and the Hooper companies were the two exceptions.

From his experience, the rubber cable was the best; he hoped we would soon have an opportunity of proving it, as he was satisfied that they were on the eve of having a special cable belonging to Canada, and worked for Canadian interests, when the rubber cable manufacturers would have an opportunity to tender for its construction.

Referring to copper, his friend and associate, the late T. B. Baker, R.N. C.B., chief engineer Chatham Dock Yard, and inspector of machinery for the Admiralty, was, with other engineers and scientists, puzzled by finding that the copper sheathing on vessels did not remain serviceable as long as in former years. Many eminent chemists were called upon to analyse the copper mass, but could not discover what was wrong. Mr. Baker, however, visited the works at Swansea, where the copper was being smelted from the ore, and he noticed the men skimming off the dross from the top of the copper and putting it with some of the surface metal into a separate cauldron. He asked the manufacturers why this was done, and was told that the copper thus skimmed made the best copper tubes; they were, in fact, taking off the cream of the metal, and when it was returned to the copper the sheathing lasted as long as formerly was the case. For this and other good services, Mr. Baker received a special pension.

If two metals were smelted together each of a given resistance, say, copper at 100 and lead at 8, instead of the alloy being of proportionate resistance, say 54 ohms or units, it would probably shew less than half that measurement. It was a curious fact that if you amalgamated any two metals, the resistance of the alloy would almost invariably be greater than that of the pure metals. He had been experimenting with a view to obtaining an unoxidizable alloy of such inferior conductivity, that it might answer as an insulator to cover a copper or other wire of greater conductivity. Such an invention would be of great value, and he would recommend those interested in electrical matters to well consider this subject, because he was sure that in time it would be accomplished. To be able to coat a metal with a metal, so that it would be practically useful for underground purposes, was one of the coming events of the age.

He did not recommend underground wires in all cases. It would be impossible in the Northwest to maintain underground cables. The power of the frost heaving the ground was well known, and if it took hold of a cable, it would be sure to injure it. Then, whenever you come to a brook or river crossing, you had to take it out and carry it across stream and again into the ground. Owing to the cost and difficulty connected with repairs, it would not pay. It might be profitably accomplished if you had a business through a populous country like England, where a great number of wires were required, and you could afford to run the risk of 6 out of 20 being dead, but it would not answer in the Northwest, where one wire is more than sufficient for the whole business of the country, and it would be absurd to lay a wire under long stretches of prairie, where a fault would probably stop the whole business of the country until the return of Spring enabled you to dig it up for repairs.

He exhibited two models of an underground conduit. He was sorry Mr. St. George, the city engineer, was not present, as he had made a report a short time ago upon the different forms of conduits, with their advantages and disadvantages. He had showed Mr. St. George the conduit now before them, which he approved of, on account of its cheapness and effectiveness. It was the same section which was now on the table. The conduit was made of red cedar, and to give them an idea of the great durability of cedar, he might say that a year or two ago a very large tree of Douglass pine was blown down on Vancouver Island, the rings, though not always a safe criterion as to the age of a tree, numbering six or seven hundred, and this tree in going over brought up, firmly grasped by its central roots, a very large log of cedar in a *perfectly sound condition.* The G conduit was supposed to be made of sound cedar boards; the first outside pieces being 1 inch thick and 12 inches, broad; the next 2″, $1\frac{1}{2}$″, $1\frac{1}{4}$″ and 1″ of reduced breadths and with $\frac{1}{2}$ in. boards between them. They were all then treenailed together, the result being that you have a trough with four grooves or recesses of different depths say for two Telephone Cos., a Telegraph Co., and an Electric Light Co., etc., so that each groove could be got into without disturbing the wires in the adjacent grooves. A connection with any house for any purpose could thus be made without interfering with another company's wires. They could have as many grooves as they liked, and, being placed at the edge of the sidewalk, the distance between the conduit and the house would be only 7 or 8 feet, so that the expense would be very small if a piece of connecting cable, containing more wires than were required, was laid into the building, thus obviating the necessity of taking up the sidewalk for future requirements. India rubber and good copper would stand exposure to heat or cold. Messrs. Henley & Co. were now making him some samples of wire for conduit purposes. These wires would be numbered upon their outside covering, and any one could thus be selected without cutting other wires for electrical testing and identification. This sample form of conduits was cheap, costing about 50c a foot. He was not advocating his own invention, but simply gave it as an idea which may or may not be adopted.

It was thought at one time that the life of an Atlantic cable was 10 years. They had been in use 20. Our gulf cables had been down 9 years, and when raised for repairs last summer, no wear at all had been discovered, and they would probably last 10 or 15 years longer with repairs after damaged by ice or anchorage.

The Groves cell was the most powerful battery known to them,—then the Bichromate, but the former gave off unhealthy nitrous fumes and required daily attention, and the latter speedily lost its electro motive force, when in closed circuit. He would now show an improvement in that most useful of all batteries, the ordinary gravity cell used in telegraph offices. Instead of a clamp which held the crow foot form of zinc on the edge of the glass and often broke it, or a tripod resting on the glass, from which the zinc was suspended, this new form (stamped with his name) rests upon two knife edges of zinc, and as every contact with the glass allowed the escape of more or less electric current, and caused more or less creepage of the mineral salts in solution, the improvement was obvious, and had been adopted on the Government and Canadian Pacific Ry. lines.

The Gassner cell, which he also exhibited, had no water in it and no glass to break, the outside case being zinc, and although they had been in use two years, there was very little wearing of the zinc. One wire was fastened to the zinc case and the other to a hollow cylinder of carbon, within the case,which was filled in only between the outer surface of the carbon and the case with a mixture of moist Plaster of Paris, manganese and salammoniac, which is the existing element of the mixture; finally a little wax was run upon the top of the plaster to prevent creepage.

The Electric motive force was greater and the internal resistance less than that of the ordinary LeClanche cell, and after being placed upon short circuit for 3 days, the remaining electro-motive force of the dry cell was greater than that of the wet cell, and he had substituted Gassner for LeClanche cells on the Government lines.

The Sampson battery now exhibited had given good results. The formation of this battery was an outer glass cell, within there was a rod of zinc and a larger central rod of carbon, and just enough of water was introduced minus salammoniac to wet the mineral wool packing. According to the paper he had read the electro-motive force and internal resistance were just about the same as the LeClanche, but he intended to test the cell as to its relative value with the dry battery, and would report result at some future meeting of the Society.

The W. U. Telegraph Co. in New York, had adopted dynamic currents in some of their lines, and with satisfactory economic results. They might answer on Western Union and possibly on the Great North Western main lines, but for lines conveying a moderate amount of business it would be found an expensive substitute for chemical batteries.

Morse was credited with being the inventor of the Morse alphabet, but such was not the case. In a late number of the *Century* there was an interesting article on the subject, where Vail was clearly proved to be the inventor of the dot and dash alphabet which was the principal merit of the Morse system.

It was not generally known that Steinhill used the needle as a sounder, listening to the ticking of the needle. He found this fact in an old German work. In 1847, and for several years afterwards, operators upon the Morse system were not permitted to take messages by sound, but were ordered to transcribe them from recorded marks on paper, but it was found in practice that fewer errors occurred when sound superseded visual signs in telegraphy.

Steinhill also first used the earth to complete an electric circuit, not that a return circuit by the earth was an established fact or that the current was known to flow through a wire, he was inclined to believe that electricity was diffused through a conductor as rays of light were.

Instead of using the earth to complete circuits, if our telephone companies were compelled to take their currents back through a twisted metallic circuit, we should not have all the annoyance we now have from induced currents and sounds in our telephone lines.

The Wheatstone perforator was simply a long strip of paper passing through a stamping machine, by which the dot and dash or all dot characters were punctured through the paper. The paper being a non-conductor. It was then passed between metal rollers over which ran a metal style, and the style dropped into the holes, made contact with the metal roller through which the current passed, and thus automatically reproduced the dots and dashes at the other end of the line, and no matter how rapidly the paper was drawn between the rollers, the style would impress upon the paper at the other end an exact counterpart of the original puncturing.

Thus one hundred words could be transmitted in the course of a few seconds, and as the punctured strips could be used over and over again through a series of rollers connected by different wires to different cities, you will understand how long speeches in parliament and press news generally is so rapidly transmitted to all parts of the world.

Mr. Gisborne concluded his remarks by saying that he had already trespassed too long upon their time and patience, and would, therefore, defer all further reference to cable enterprises (Vide Appendices Nos. 1 3 and 4) and to the different modes of telegraphy until he had again the pleasing gratification of meeting the members, probably about the 30th November, when he would be enabled by colored diagrams and in non-technical terms to explain even to the uninitiated the working of various forms of instruments in general use.

APPENDIX NO. 1

The Proposed Pacific Ocean Cable.—We have received the accompanying amended statement of the suggested routes for the Pacific cable, the proposals for which are now under the consideration of the Imperial, Colonial and United States Governments :—

Landing places.	Distances, nautical miles.	Length of cable.	Estimated cost at $700 per mile, laid.	Average soundings (in fathoms).	Nature of ocean bed.
Route projected by F. N. GISBORNE, *C.E., and Electrician.*					
Vancouver Island, British Columbia, to Unimak, Aleutian Islands....	1,350	1,485	$1,039,500	2,000 to 2,800	Ooze, mud and sand.
Unimak to Attou, Aleutian Islands....	800	880	616,000	Not sounded. Probably 100 to 200	" " "
Attou to Yezzo, Japan....	1,300	1,430	1,001,000	2,700 to 3,000	" " "
Totals....	3,450	3,795	$2,656,500		
Route projected by S. FLEMING, *C.E.*					
Vancouver Island, B.C., to Honolulu, Sandwich Islands...	2,300	2,530	$1,771,000	2,000 to 3,100	Ooze, mud and clay.
Honolulu to Fanning Island....	1,040	1,145	801,500	1,300 to 3,000	" " "
Fanning Island to Vanua Lavu, Fiji Islands....	1,674	1,841	1,288,700	2,000 to 3,300	" " "
Vanua Lavu to Brisbane, Australia....	1,486	1,634	1,143,800	930 to 2,600	" " "
Totals....	6,500	7,150	$5,005,000		
Route projected by C. W. FIELD, *Merchant.*					
San Francisco, Cal., to Honolulu, Sandwich Islands....	2,070	2,277	$1,593,500	2,000 to 3,120	Ooze, mud and clay.
Honolulu to Morell Island....	1,500	1,650	1,155,000	1,500 to 3,100	" lava and clay.
Morell Island to Nipon, Japan....	1,800	1,980	1,386,000	2,700 to 3,000	" mud and clay.
Totals....	5,370	5,907	$4,134,500		

N.B.—Actual rate of working speeds attained through existing cables :—

French Atlantic: Brest to St. Pierre, 2,584 miles (nautical), 15 words per minute.

Anglo-American Cables: 1,896 and 1,857 miles (nautical), 17 words per minute, and 25 maximum, experimentally.

The estimated speed of a cable of 1,500 nautical miles being 33 words per minute with a maximum of the highest rate attainable by an operator.

APPENDIX NO. 2.

THE ORIGINATOR OF TRANS-ATLANTIC CABLES.

In an article upon Submarine Cables, of March 30, 1883, we invited Mr. FREDERICK NEWTON GISBORNE to submit any additional evidence at his command in support of our declaration, that to himself belonged the sole credit of having originated trans-Atlantic submarine telegraphy. That gentleman has responded by forwarding to us the annexed copies of certain letters in his possession, and we may add that the public records and leading articles which appeared in the newspapers of the day, 1850-51, coincide exactly with them. The communications in question were addressed to Mr. GISBORNE respectively by the late Hon. JOSEPH HOWE, then Colonial Secretary for Nova Scotia, afterwards Secretary of State for Canada and Lieutenant-Governor of Nova Scotia; and by Mr. JOHN W. BRETT—the latter being the submerger of the first European submarine cable between Dover and Calais in 1851, while Mr. GISBORNE himself submerged the first American submarine cable between Prince Edward Island and New Brunswick, in 1852. Such evidence appears to be complete and unassailable, not a link in the chain being wanting. We therefore now leave all question as to the originality of conception and the practical initiation of the most important enterprise of its day to the impartial judgment of the world at large:—

From the HON JOSEPH HOWE, *Colonial Secretary of Nova Scotia, in* 1848, *and afterwards Secretary of State for Canada, and Lieutenant-Governor of Nova Scotia, to* FREDERICK NEWTON GISBORNE, F.R.S.C., *Engineer and Electrician, and at present* (1888) *Government Superintendent of the Telegraph and Signal Service, Dominion of Canada.*

MY DEAR GISBORNE,—

Without desiring in the slightest degree to undervalue the services rendered to civilization, by the body of eminent men who have just been rewarded for laying the Atlantic cable, I own to some feeling of disappointment in not seeing any mention made of your name, as I have reason to believe you were the first pioneer of the enterprise, as well as the original promoter of electric telegraphy in the Maritime Provinces.

In the winter of 1848 you came to Halifax and interested the Government, of which I was a member, in the subject of telegraphic communication. A bill was introduced, and £4,000 was expended by the Government for construction of lines to connect Halifax with New Brunswick, Canada, and the United States. When that line was completed, you were employed to manage it, under a Commission, of which I was the Chairman, the Hon. George Young and William Murdoch, Esq., being the other members. This line was subsequently purchased from the Government by a Company, which has since extended branch lines to every shire, town and seaport in the Province. In 1850 you discussed with me, and subsequently laid before the Commissioners, a plan for connecting Newfoundland with the Continent of America, and obtained leave of absence to enable you to go to that Island and secure support to the project. My brother commissioners are both dead. On your return you asked leave of absence to go to New York to promote an extension of the line to England,' and spoke confidently of being able to extend it across the Atlantic and connect Europe with America. Up to this time I never heard the idea suggested, and though reading the English and American papers, never saw any allusion to the practicability of such an enterprise. As no capital could be got in Halifax, you naturally sought in London and New York for co-operation and assistance. I do not, of course, know what took place abroad, but of this I have no doubt, that until you went to New York nobody had suggested or taken any step towards promoting an Atlantic telegraph. As the original pioneer and projector of this great work, it appears to me, that you ought to place yourself in your true position, and that, if not included among those who are to be honored and rewarded, you should at least endeavor to obtain from your countrymen, and from the world at large, who are to be benefited, the recognition which you deserve as the *originator* and *practical prime mover* of the great enterprise now so happily brought, by a combination of public-spirited and able men, to a fortunate consummation. It ought not to be forgotten that the very line across Newfoundland now used by the Anglo-American Co. was originally, at great pecuniary sacrifice and risk of health, explored by you, and constructed by yourself as Chief Engineer of the New York, Newfoundland, and London Telegraph Company.

Believe me,

Very sincerely yours,

(Signed), JOSEPH HOWE.

London, 25 Savile Row, Feb. 12, 1867.

Extracts from MR. JOHN W. BRETT'S *published letters to* MR. GISBORNE.

LONDON, July 12, 1852.—"Major Carmichael Smith, a friend of your Hon. Mr. Howe, has just called and given me your plan."

LONDON, May 26,1853.—"Are you now prepared to co-operate in opening up telegraphic communication between Newfoundland and Ireland ?"

LONDON, July 8, 1853.—"On my return from Paris I found your satisfactory letter of 4th June. Let me recommend you to secure in our joint names an exclusive privilege for establishing a submarine telegraph between Newfoundland and Ireland for 50 years."

LONDON, April 21, 1854.—I should be glad, therefore, of a line from you, stating clearly whether, as agreed, this is to be carried out between us as Brett & Gisborne's Atlantic Telegraph here, and *vice versa* in America."

From the above it is manifest that Mr. CYRUS W. FIELD and his associates could not have become interested in Mr. GISBORNE'S enterprise before the spring of 1854. This sustains us in our recent view that the pretention of Mr. C. W. FIELD to be the originator of this great project is simply preposterous.—*Shareholder, Montreal.*

APPENDIX NO. 3.

THE WORLD'S

SUBMARINE CABLES IN OPERATION, DEC. 31st, 1887.

OWNED BY GOVERNMENT ADMINISTRATIONS.

NATIONALITY.	Number of Cables.	Nautical Miles.
Austria	31	99
Brazil	19	19
Canada	21	218
Cochin China	3	810
Denmark	36	123
Dutch Indies	1	31
France	46	3,197
Germany	35	461
Great Britain	104	876
Greece	45	457
Holland	20	59
India	72	1,873
Italy	22	613
Japan	11	55
New Caledonia	1	1
New Zealand	3	196
Norway	236	228
Russia in Asia	1	70
Russia in Europe	5	201
South Australia	5	49
Sweden	9	61
Spain	3	127
Turkey	8	330
Total	737	10,154

OWNED BY CORPORATIONS.	Number of Cables	Nautical Miles.
African Direct	7	2,739
Anglo American	15	10,437
Black Sea	1	351
Brazilian	6	7,326
Central and South American	9	3,178
Commercial	6	6,937
Francaize Paris à New York	4	3,409
Cuba	3	940
Direct Spanish	2	699
Direct United States	2	2,983
Eastern Extension	21	12,035
Eastern and South African	5	4,554
Eastern	64	21,627
Great Northern	20	6,108
Hamburg, Helgolander	2	40
India Rubber Gutta Percha and T. Works	2	122
Indo-European	2	14
Mexican	2	709
River Plate	1	32
Spanish National	5	1,172
Submarine	10	803
Vereinigte-Deutsche	2	1,119
West African	11	2,825
West Coast America	7	1,698
Western & Brazilian	9	3,801
West Indian and Panama	20	4,119
Western Union	4	5,537
Grand Total Governments and Corporations.	979	115,468

N.B.—The longest cable worked in one circuit is, between France and St Pierre and Miquelon, 2,648 knots.

(See The Electrician's Directory.)

Grand Total Governments and Corporations.	979	115,468

N.B.—The longest cable worked in one circuit is, between France and St Pierre and Miquelon, 2,648 knots.

(See The Electrician's Directory.)

Appendix No. 4.

THE WORLD'S CABLE FLEET, 1888.

The following Table gives the Names and other Information concerning Vessels engaged in Cable-laying throughout the World, together with the Companies owning them. (See the Electrician's Directory)

COMPANY, &c.	Steamer.	Gross Ton.	H.P Nominal.	Captain.	Usual Station.
Anglo-American	Minia	1,986	250	S. Trott	Halifax, N.S.
Canadian Government	Newfield	785	90	R. A. Guilford	Halifax, N.S.
Commercial Cable	Mackay-Bennett	1,717 $\frac{89}{100}$	300	P. Le Fanu	London.
Compagnie Française du Télégraphe de Paris à N. York.	Pouyer-Quertier	1,385	160	Stuart Fossard	Havre.
Chinese (Formosa) Government	Fee Chew	1,034	150	W. R. Lugar	Formosa.
Eastern	Amber	978	160	....	Mediterranean.
Eastern	Electra	1,000	200	R. Greey	Lisbon.
Eastern	John Pender	1,213	98	Perkins	London.
Eastern	Mirror	1,500	—	G. Pattison	London.
Eastern	Chiltern	1,304	200	....	Suez.
Eastern and South African	Great Northern	1,352	130	Hales Dutton, R.N.	Zanzibar.
Eastern Extension	Recorder	1,201	250	C. O. Madge	Singapore.
Eastern Extension	Sherard Osborn	1,429	200	W. Fawcus	Singapore.
French Government	Ampère	304, 753	707	....	Brest.
French Government	Charente	747, 824	120	....	La Seyne.
General Post Office, London	H.M.S. Monarch	2,170*	1,040†	R. Draper	Woolwich.
Great Northern	H. C. Oersted	749	120	G. Oersted	Copenhagen.
Great Northern	Store Nordiske	832	120	Einar Suenson	Woosung (Shanghai)
Henley's	Roddam	2,365	200	....	London.
India Rubber, Gutta Percha, and Telegraph Works	Buccaneer	770	220	....	Silvertown.
India Rubber, Gutta Percha, and Telegraph Works	Dacia	1,856	170	....	Silvertown.
India Rubber, Gutta Percha, and Telegraph Works	International	1,380	110	....	Silvertown.
India Rubber, Gutta Percha, and Telegraph Works	Silvertown	4,935	400	....	Silvertown.
Indian Government	H.M.S. Patrick Stewart	1,150	130	W. A. Tindall	Kurachi.
Italian Government	Citti di Milano	1,247	180	Palermo (R.I.N.)	Spezia.
Siemens Bros. and Co	Faraday	4,916	500	P. Le Fanu	London.
Submarine	Lady Carmichael	369	165	Batchelor	Dover.
Telegraph Construction and Maintenance	Britannia	1,524	200	J. Seymour	London.
Telegraph Construction and Maintenance	Calabria	3,321	220	....	London.
Telegraph Construction and Maintenance	Kangaroo	1,773	160	J. Kennedy	London.
Telegraph Construction and Maintenance	Medina	328	45	....	London.
Telegraph Construction and Maintenance	Scotia	4,667	550	W. R. Cato	London.
Telegraph Construction and Maintenance	Seine	3,579	500	H. Manning	London.
Western and Brazilian	Norseman	1,372	200	W. H. Lacy	Pernambuco.
Western and Brazilian	Viking	436	60	W. F. Wardroper	Monte Video.
West Coast of America	Retriever	624	95	W. B. Minhinnick	Callao.
West India and Panama	Duchess of Marlborou'h	402	80	J. W. Dickinson	West Indies.
West India and Panama	Grappler	868	100	J. Farrier	West Indies.

*These figures indicate the tons displacement. † Effective horse-power.

8th November, 1888.

JOHN KENNEDY, Member of Council, in the Chair.

Paper No. 22.

CONSTRUCTION OF TORONTO SEWERS.

By C. H. Rust, M. Can. Soc. C.E.

The system in use at Toronto is that known as the combined, that is, storm water and subsoil or ground water, in addition to house sewage, are all provided for in one and the same sewer. There are 136.65 miles of sewers of various kinds in the city, the total cost having been $1,838,291.84. During the past nine years 83 miles have been constructed. In 1887, 16.14 miles were built at a cost of $188,895.45, and of these, 12,633 yds. were of brick, 6,064 yds. of 18 in. pipe, 8,488 yds. of 15 ins. and 1,236 yds. of 12 in. pipe.

It may be mentioned that the City Engineer has the power to recommend the construction of a sewer on sanitary grounds and for drainage purposes, assessing the cost on the property benefited by the contemplated work, in such annual amount as shall meet the interest on such debentures as may be issued, the time over which payment shall extend being fixed at twenty years. In the case of sewers of an area of 4 sq. ft. or more, the city pays one-third of the cost of the sewer and the culverts necessary for taking the surface water off the roads. Any sewer of a less area is paid for by a tax on the property fronting on the street, except in the case of culverts, which are in all cases paid for by the city.

American or Scotch pipe is used in Toronto for sewers up to a diameter of eighteen inches, and beyond this, brick sewers are used. Of the latter the greater number are egg-shaped, though a few main sewers are circular in form. The average depth to invert of sewers below the surface of the street is about 13 ft. The value of the work will depend greatly on the accuracy with which a record is kept of the exact location of every part of the system constructed.

In setting out the work, the author's practice, in the case of a sewer being constructed on a street already laid out, has been to give the Inspector the centre line at intersecting streets. On large sewers, where the sewer followed the valley, as in the Garrison and University creeks, stakes were driven at 100 ft. stations on tangents, and at every 25 ft. on curves, all stakes being set with the transit.

It is usual to run into cross streets with a curve of 30 ft. to 40 ft.

radius, depending on the width of the street. As soon as the contractor is ready to make the connection with the main sewer, the levels are given, which cannot be done accurately until the exact grade of the intercepting sewer is ascertained. On the curves of pipe sewers, the practice has been to give the pipe a rise of one-eighth of an inch to the foot from the street line to the termination of the sewer grade. Stakes are driven at intervals of 300 ft. on the opposite side to the one on which the excavation is thrown, and at a distance from the side of the sewer trench of about 2 ft., so as to avoid any danger from disturbance. A distance of 300 feet is about the limit of sight for boning rods, although in some few cases they are 400 ft. apart. It might be stated that all sewers are laid in Toronto by means of boning rods. These boning rods are made out of a piece of inch stuff about 2 ins. wide, with a cross piece nailed to the top about 18 ins. long. In the case of brick sewers, two pieces are fastened on the rod, one for the bottom of the trench and one for the invert. Bridges, or sights, as they are called, are simply two upright stakes driven into the ground on each side of the excavation, with a cross-piece nailed to them corresponding to the length of the boning rod. In a large number of cities, especially in the States, stakes are driven at frequent intervals along the bank, and the depth taken by means of a graduated rod. The author fails to see the advantage of this, nor does he think that as true a grade can be obtained, while it entails a large amount of extra work on the part of the Engineer in charge.

From these stakes the depth is given to the Inspector, who then erects his bridges so as to correspond with the length of his boning rod. As an example, the depth at stn. O is 12 ft., and the boning rod being 15 ft. long, the cross piece on the bridge will be 3 ft. above the top of the stake. The construction of sewers is carefully watched, by an Inspector, who is continually on the work, and who must be a bricklayer, his wages being $3.25 per day of nine hours. The Inspector makes weekly reports of the quantity of work done, the number of hours of labor, and the amount of material used. The Inspector is also compelled to give security to the amount of $1000. In sewers of a length of 1200 feet or under, the author generally sets out all the work at once, but in the case of a longer sewer, or one with a very flat grade or one of considerable importance, the Engineer only gives the Inspector two sights at a time, and in all cases checks levels once or twice during the progress of the work. The General Inspector, who visits the works every day, measures the sights or bridges and the boning rods, while the Inspector on the work has orders to measure the sights every morning previous to commencing work. Accidentally, of course, a boning rod has been known to become shorter during the night, or a bridge to become lifted nearer the sky, and this generally happens in very bad wet ground or in hard pan. The Engineer on his visit to the work should also measure the sights. Cases may be instanced where the Inspector and Contractor have erected the sights and carried the work a foot deeper than the plan called for.

In constructing pipe sewers, the average width of cut for a 12 or 15 inch pipe is 2 ft. to 3 ft., and for an 18 inch, 2 ft. 6 ins. to 3 ft. 6 ins., depending on the nature of the soil. In very bad running sand, it is advisable to open the cutting to a sufficient width to allow of ample room for timbering. It might be remarked that during the past ten years some 90 miles of sewers have been constructed in the city, a large number in very bad running sand, and not one life has been lost owing to the caving in of the banks. In constructing sewers in quicksand, it is necessary to use the greatest precaution to keep the sand from filling the pipe, as, if the sand enters the pipe, it is almost impossible to move it, and this precaution is especially necessary in streets upon which there are no hydrants for flushing purposes.

Nothing smaller than a 12 ins. pipe is used on any street. Some Hamilton pipes were used a short time ago, but they have not given entire satisfaction. Pipes manufactured at St. Johns (Que.) were introduced here last year. They appeared to be good hard burnt pipes with a deep flange, but with scarcely so good a finish as the Scotch or American. A few were used; but the presence of some pieces of lime were noticed, after which their use was discontinued. The author has since ascertained that this lime was due to a purely local cause, and some small pipes, from the same manufactory, which have been recently used for junctions, appear to be of a good quality and better finish than those previously tried.

Egg-shaped brick sewers are used, the sizes varying from 2 ft. × 3 ft. to 2 ft. 8 ins. × 4 ft, and are constructed with two rings of brick. For larger sizes circular sewers are used, the number of rings being from two to three, according to the nature of the soil and depth of excavation.

Some time ago the Committee on Works ordered small brick sewers to be substituted for pipe, and they were built egg-shaped 1 ft. 8 ins. × 2 ft. 6 ins., one brick thick, the arch being covered with concrete, but the cost exceeded by 30 per cent the cost of a pipe sewer of sufficient size to meet the required drainage. The nature of the soil in Toronto has been fairly favourable for the obtaining of a good foundation. Where an artificial one is found necessary, concrete is generally used, composed of one part of Portland cement to three of sand, and three of broken stone and gravel. At the outlet of sewers running into the lake, where the invert is below water level, a timber foundation has been found to give good satisfaction.

In some cases where concrete has been used as a covering for the top of the brick arch in single brick sewers, one part of Napanee or Thorold cement mixed with five parts of sand and gravel has been substituted for the Portland cement concrete with satisfactory results.

In constructing brick sewers in very bad ground, cradles are used, made of strips one inch thick, nailed to ribs; the ribs being on the underside of the strips so as not to interfere with the key of the work.

There is nothing connected with the building of brick sewers of more importance than having a first-class cement properly mixed. Too much should not be mixed at a time, and the mixture should not be allowed to stand. There is always a tendency, on the part of the laborers employed in mixing the cement, to make it too wet, and to make up a rather larger quantity than can be promptly used.

It is important that the bricks should be thoroughly wetted by immersion before being laid. Every brick laid should have full mortar joints on bottom, sides, and ends, with $\frac{1}{4}$-inch joints, and in upper course of invert $\frac{1}{8}$ inch. In the invert and arch, the practice in Toronto is to lay three or four courses dry, and to fill the interstices with grout, composed of equal parts of cement and sand. The mortar used is composed of one part of Portland cement to three parts of clean sharp sand. The bricks used are first-class, hard burnt, either grey or red; white bricks are not allowed in the work. It is a question, where the sewers consist of two or three rings, whether a second class brick could not be used in the outer or middle ring, the difference in price being sometimes as much as $2 per 1000. The contract price paid by the city for 1887 was $8.25 per 1000 delivered, the price at time of writing (March, 1888) is $9.50. This contract was for some work that was being done by day labour. Bricks made to the proper radius are used in the invert and arch of all sewers less than 2′ 0″ × 3′ 0′. When the centres are removed the interior face of the brickwork is carefully cleaned of all projecting substances and neatly pointed up.

In constructing pipe sewers, care must be taken to secure an equal bearing for the pipe over the whole surface upon which it is to lie, by sinking joint holes for the flanges of exactly the depth and width necessary to receive them; the pipes are then laid down, and the joints fitted for the full length of the sockets, and well braided or twisted gaskets are driven tightly into the sockets so as to pack the joints, which are then made perfectly water-tight with neat Portland cement. Great care must be taken that no cement is allowed to remain inside the pipe.

The American pipe in lengths of two feet seems to be preferred to the Scotch with a length of three feet, as a better bearing is obtained. More failures have been noticed here from Scotch pipe than American, the latter being more easily handled, which is an advantage especially in a deep drain heavily timbered. One advantage possessed by the Scotch pipe is its greater depth of flange and also its being constructed of a great thickness. The junctions used in all sewers are Y's built at distances of 25 feet apart. We are now constructing private drains from sewer to street line at the same time the main sewer is being built; this considerably increases the cost of the sewer. It will not be out of place at this point to say a few words as to the keeping of an accurate record of the exact location of the private drain connections; the practice here is for the Inspector to keep an accurate measurement of the position of the junction, and plot it on his working plan, which is returned to the office on the completion of the work; if possible, the position on the street line is also marked, but this is only temporary. At Hamilton, the practice has been to erect a wire carried from the junction to the level of the ground. It would be of interest to hear from engineers as to the practice for permanently and temporarily marking the position of the junction in other cities.

In building pipe sewers, the greatest care must be taken to have the sides well filled and thoroughly pounded. A great number of failures in pipe drains have been caused by not sufficiently ramming the backfilling against the haunches; also by the use of improper material and the withdrawal of sheeting after backfilling. The fracture generally takes place on the top of the pipe. We had occasion a short time ago to take up an 18 inch drain (replacing it with a large brick sewer), laid with Scotch pipe in a newly annexed territory, when it was found that about 75 per cent. of the pipes were cracked, a large majority on bottom, top and two sides. The sides had never been properly filled, leaving, as the Inspector said in his report, "room enough for a cat to run up alongside of each pipe." Probably if this sewer had not been disturbed, the pipes would still have stuck together. In pipe sewers of a depth greater than fourteen feet, the speaker recommends that a covering of concrete be used and well packed into the haunches. Another fruitful cause of discussion is the rejection of pipes with broken flanges. Of course when the broken piece is only small, that part of the pipe can be placed on the top and covered with cement. Blisters, fire cracks, etc., are other causes of contention. Mr. Chester B. Davis, civil engineer of Chicago, in his specifications for sewers, gives the following: "Lumps or broken blisters on the outside of the pipe will not "cause the pipe to be rejected, unless it cannot be laid properly with "the blister at the top, and except where the depth of the blister is one "quarter of the normal thickness of the pipe, the length over four "inches, and the width more than one-tenth the circumference of the "pipe. When the pipe must be laid so that the blisters come at the "bottom, they must not exceed one half of the limiting size and depth "for those allowed for the top of the pipe.

"No pipe having a piece broken from the hub which is more than "one inch wide will be used, unless such pipe can be properly laid with "the broken part on the top, and in this event the width of the break "must not exceed one-twelfth the circumference of the pipe.

"Any pipe or special, having more than two longitudinal fire cracks, "or having two at either end, or having more than one transverse fire "crack, or having one crack caused by any other than the process of "burning, shall be rejected.

"No longitudinal fire-crack over one and a half inches long, extending "entirely through the pipe or specials, or over four inches long extend-"ing half way through, or over seven inches long extending one-quarter "way through, nor any transverse crack longer than one-tenth of the "circumference, will be considered admissible, and pipe or specials with "cracks exceeding these limits, or being more than one-eighth of an inch "wide, will be rejected. In case of uncertainty concerning cracks, not "covered by the above specifications, the decision of the Engineer in "charge must be obtained."

One objection to the American pipe is its insufficient thickness. No pipe should be of less thickness than one-twelfth the diameter, which, for an 18 in. pipe, would give one inch and a half, while the general run is barely 1¼ in. Our contract for the supply of pipe for 1888 for repairs, etc., was awarded to a firm which supplies Scotch pipe at the following rate per lineal foot, delivered where required, 6″ at 15½c, 9″ at 28c., 12″ at 40c, 15″ at 55c, 18″ at 70c.

In timbering sewers the general practice in Toronto is first to put in two frames of inch boards 6 feet long, followed by a frame of 2 inch plank, carried down to the depth required, the waling pieces consisting of 2 ins. plank 10 ins. wide and 14 ft. long, struts 4 ins. × 4 ins., except in wide cuttings when 6 ins. × 4 ins. are substituted. Care must be used in drawing out the planking, especially in pipe drains constructed in running sand to prevent the sides from running in and damaging the pipe. A sketch is attached shewing the usual manner of timbering.

Drawings of the culverts and manholes used are also shewn. A large number of culverts are trapped with "Palmer's Patent Stench Trap." This trap has been used here for about eight years, and has given very good satisfaction, the cost, viz., $6.50, is rather much, considering the amount of work in it.

Several circular brick culverts with an iron basin and an automatic trap, have been used but their use was discontinued owing to sticks, road detritus, etc., preventing the trap from working.

A few of "Darke's patent stench traps" have also been used, which give good satisfaction and take a large quantity of water; the objection to their more liberal use is the cost.

During the past year a few culverts have been constructed without any traps, on streets where the houses are built some distance back from the street line, and it is a question whether all traps on wide streets used for residences could not be discontinued. It is noticeable that during the winter the air from the sewer was forcing its way up through a great many culverts supposed to be trapped, and melting the snow.

The manholes are all rectangular in shape, are covered with a cast iron grating with openings for ventilation, and are fitted inside with wrought iron steps or foot irons weighing about 6 lbs. each. These shafts are also used for ventilating purposes, and are constructed along the line of sewer at distances apart of 300 ft., care also being taken to place one at every change of grade. These are the only means of ventilation employed and seem to answer every purpose. There has been considerable discussion by the Provincial Board of Health on the advisability of overhead ventilation, by means of pipes extending from the sewer up the sides of buildings, but it does not appear that it would give as good satisfaction as the manhole shafts.

The construction of flushing shafts, and lampholes have been abandoned in favor of manholes. The cost of the latter is about $45 as against $20—but they afford better ventilation and means of getting into the sewer when necessary.

At the present time, all sewer contracts are let by the lump sum, any additions or deductions being made at the schedule rate attached to the specification; this lump sum also covers the cost of inspection.

The sewer plans are all prepared on mounted profile paper plate, ruled with red lines, and plotted to a horizontal scale of 40 feet to the inch and a vertical scale of 10 ft. to the inch. The City datum is 40 ft. below the zero level of the Lake.

The construction of sewers is carried on both summer and winter. During the past winter, no less than 14 or 15 sewers have been built both of pipe and brick, and hardly more than two weeks have been lost through severe weather. On a bright still day, even with the thermometer at zero, work is carried on for about 6 hours. The temperature at the bottom of a deep trench is always considerably higher than that at the surface. The water and sand are of course heated, the mortar is used as soon as made, and the work is well protected. Several sewers, constructed during the past three or four winters, have been examined, and only in one instance has the work appeared inferior to that built during the mild weather. This was in a brick sewer with only a depth of 9 feet, in which the work had been stopped for three weeks during intense cold, and not being sufficiently protected the frost got into the banks and damaged the sidewalls which spread. Experience has shewn that this work could not be so well done with Canadian as with Portland cement. It does not seem that the contractor can carry on the work more economically during the winter; laborers do not command quite as much money as in summer, but bricklayers are paid the same, and while the extra expense of excavating and moving frozen earth, and the trouble of heating the sand and water, more than counterbalances the difference in wages.

The following formula for finding the number of bricks in circular and egg-shaped sewers by Mr. Meadows, M. Can. Soc. C.E., is very convenient, and gives very close results :—

Rule for circular sewers. Multiply the internal diameter of sewer, in inches, by 1.1424, which will give No. of bricks in first ring, then add 10.28 for each additional ring.

Rule for egg-shaped sewer :—Multiply the internal transverse diameter (in ins.) of sewer by 1.4418 and add 10.28 as in rule for circular sewers.

The foregoing calculations are for bricks $8\frac{1}{2}'' \times 2\frac{1}{2}'' \times 4,''$ and $\frac{1}{4}''$ joints.

In designing our large intercepting sewers the amount of rainfall reaching the sewer has been assumed as three inches in 24 hours less 50 per cent. allowed for evaporation. From Report of Observations at the Magnetic Observatory, Toronto, from the year 1840 to 1871, the heaviest rainfall in one day was 3.45 ins. which occurred in September, 1843, the mean heaviest fall for that time being 2.071 ins. This was also the year in which the greatest amount of rain fell, being 43.55, the mean for the past 30 years being 29.41.

The following formula mentioned in Mr. Rudolph Herring's admirable "Report on Sewerage of European Cities," is frequently used by the speaker.

Cubic ft. per second reaching the sewer

$$= \left\{\begin{array}{l}\text{a coef.}\\ \text{according}\\ \text{to judgment}\end{array}\right\} \times \left\{\begin{array}{l}\text{av. cub. ft. of rainfall}\\ \text{per second per acre}\\ \text{during heaviest fall.}\end{array}\right\} \times \sqrt[4]{\frac{\text{av. slope of ground in feet per 1000 ft.}}{\text{No. of acres drained.}}}$$

His coefficient for paved streets is .75, for ordinary cases .625, and for suburbs with gardens, lawns, and macadamized streets .31.

The following are the actual costs of constructing several sewers in Toronto during 1886 and 1887.

Spadina road Bloor street northerly. The contractor having refused to proceed with this sewer, the city decided to construct it by day labor.

The contract comprised the construction of 378 lineal yds. of 2′. 0′ × 3′, 0″, 9″ work.

4 manholes, 8 culverts, 74 private drain connections, average depth of cutting 14′, 0″. The ground was hard pan nearly the whole length.

	129,400 bricks at $8.25 per 1000	$1067 55
	287 bbls. of Portland cement at $3	861 00
	77 loads of sand (1½ yds.) at $1.50	115 50
	74 private drain connections at 35c	25 90
	64′ of 9″ pipe for culverts at 25c	16 00
	69 earthenware stoppers at 10c	6 90
	6 curves for culverts 9″ at 95c	5 70
	2 lengths of 18″ pipe for street connection.	2 68
	Blacksmith's bill	79 30
	8 culvert stones	2 40
Iron work	8 culvert grates at $4.75	38 00
	8 " traps at $6.50	52 00
	4 manhole tops at $9	36 00
	25 " steps at 25c	8 75
Cartage, $4.50; coal oil, $1.50; oatmeal, $3.76		9 76
Paid 25c., powder and fuse, 25c.; car fare, $1.10		1 60
Foreman's wages, 65 days at $3.25		211 25
Bricklayers, 1062 hours at 40c		424 80
Bricklayers' laborers, 258 hours at 15c., 775½ hours at 16c., 481 hours at 17c		244 55
Laborers' wages excavating and filling in		2037 11
	Total cost	$5246 75

The cost of brickwork laid complete was $21.70 per 1000 bricks, and the average quantity of bricks laid per day of nine hours was for each bricklayer 1220.

The excavating and filling in cost 85c. a cubic yd.; the excavating for each culvert cost $4.00.

In the case of Dovercourt Road sewer, College to Bloor street, built in the autumn of 1887, the contractor refused to proceed with the construction of the sewer, and the city carried out the work.

The contract called for 945 lineal yds. of 1′. 8″ × 2′. 6″ egg-shaped sewer 4½″ work, with a covering of concrete 3″ thick composed of 1 part of Napanee cement to 6 parts of gravel on the arch, 10 manholes, 20 culverts, 210 private drain connections, average depth of excavation 13′, 0″.

132,800 bricks at $8.25	$1095	60
8,700 " (radiators) at $9	78	30
90 loads of gravel (1½ cubic ft.) at $1.60	148	50
85 " of sand (1½ cubic ft.) at $1.50	127	50
350 bbls. Portland cement at $3	1050	00
160 bbls. Napanee " at $1.25	200	00
3 pieces of 15″ connection for street connection	3	00
159 " 9″ connection at 42c	66	78
104 ft. of 9″ pipe for culverts at 25c	26	00
24′ 6″ connection at 23c	5	52
50′ 9″ slants at 48c	24	00
216 stoppers at 10c	21	60
12-9″ curves for culverts at 95c	11	40
60 ft. of 9″ pipes for culverts at 42c	25	20
1 elbow	1	70
Cartage	2	80
Blacksmith's bill	37	56
Iron work	342	10
2 centres	3	00
Bricklayers' wages, 1792 hours at 40c	716	80
" laborers	305	64
Foreman 76 days at $3.25	247	00
Laborers' wages, mixing concrete	88	50
" " excavating and filling in	2400	70
Hauling away surplus earth	216	38
Coal oil, pails, cartage, etc	25	03
Total	$7271	61

The cost of the brickwork laid complete was $23.70 per 1000. Bricklayers laid on an average 720 bricks per day of nine hours, their wages being 40c an hour. Excavation and filling-in cost 57c. a cubic yd.

Culverts cost for excavation, $2.56 each, the laborers' wages ranged from 14c. to 17c. per hour. The material excavated consisted of sand at commencement, then for a short distance hard pan, the balance being good hard clay.

Each lineal foot of sewer took 1.20 cubic ft. of concrete for covering on arch, and by actual measurement, 129 cubic yds. of concrete contained 164 bbls. of Napanee cement and 1080 bbls. of gravel. The concrete cost about $3.40 per cubic yd. in place.

No allowance has been made for lumber and tools as both are returned to the yard on the completion of the work. The difference in the number of bricks laid per day in this sewer and in that along Spadina road is accounted for by the fact that the latter is 9″ work and Dovercourt road only 4½.

Langley avenue sewer was built in December, 1885, and consisted of 338⅓ yds. of 15″ pipe, 4 manholes, 8 culverts, 60 private drain connections, the average depth being 9′. 6″, and the width of cutting 2′. 6″.

Laborers, 239 days at $1.25	$298 75
Bricklayers, 12 days at $3	36 00
Bricks, 13,000 at $7.50	97 50
Cement 14 bbls. at $2.75	38 50
Sand 5 loads at $1	5 00
Pipe 1015 ft. at 52c	527 80
Foreman's wages, 28 days at $2 } Inspector's " " $3 }	133 00
Gasket, ironwork	117 00
Total	$1255 53

The total cost per cubic yd. for excavating, pipe laying and filling in, was 28c., the ground being bad running sand. The contractor's price for this work was $1199.

Salisbury street sewer was built in Oct., 1886.

The average depth was 11′, 0″, the material of excavation being good dry sand and gravel.

Labor 675 hours at 15c	$101 25
495 y. 12″ pipe at 32c	158 40
5600 bricks at $8	44 80
28 junctions	28 00
Ironwork	50 00
11 days Inspector at $3	33 00
" Foreman at $2	22 00
Bricklayer	16 80
10 bbls. cement at $3	30 00
Gasket	3 00
Total cost	$487 25

The contract price was $651 and called for 165 lineal yds. of 12" pipe, 3 manholes, 2 culverts, 28 private drain connections.

Excavation and filling in, including laying pipe, cost 38c. a cubic yd.

The following Table gives the approximate cost per lineal yard for sewers, including manholes, culverts, connections, inspection, etc., laid complete for the year 1888.

Description of Sewer.	Average depth.	Cost per lineal yard.	Cost per lineal yd. including the construction of private drains up to the street line 25 ft. apart.	
		$ c.	$ c.	
2', 0" x 3'. 0" in. 9" work.	14', 0"	14.70	19.70	
1', 8" x 2'. 6"	14. 0	9.50	....	4½-inch with a covering of 3" of concrete on arch.
1'. 8" x 2'. 6"	12. 0	9.10	....	
18" pipe	12. 0	7.30	8.40	
18" "	14. 0	7.68	10.80	
15" "	9. 0	6.20	8.40	
15" "	13. 6	6.80	9.10	
15" "	8. 0	6.10	8.70	
12" "	12. 9	6.00	9.30	
12" "	11. 0	5.50	7.00	
12" "	14. 0	6.40	9.70	
12" "	10. 0	5.50	7.50	

These figures are all over rather than under, and give a profit of 10 per cent. to the contractor.

About six years ago a Riéhlé cement testing machine was purchased by the Department, and a large number of tests are constantly being made more especially with Napanee and Thorold cements, but the results so far have not been satisfactory, and, owing to their unreliability, the use of both cements has been almost entirely discontinued and only Portland cement employed.

The great fault of the Thorold cement is its tendency to blow, which shews a too large proportion of free lime; this was not so pronounced in the Napanee, but its tensile strength was a long way below the standard required. It seems a great pity that the manufacturers of Canadian cements cannot be induced to take greater precautions to turn out a reliable brand of cement. Engineers in their specifications should fix a standard of strength and insist upon having it carried out, and should also make frequent tests. Even when a proper testing machine is not accessible, it is a simple matter to make up a few pats and place them in water to detect the presence of free lime. It is certain that if this were done we should soon see a better article turned out from the works, and thus amount of money would be kept in the country, as Toronto alone uses some six or seven thousand barrels of Portland cement annually.

The manner of making the tests was as follows :

The cement was firmly pressed into the moulds with the trowel, struck off level and then laid on glass.

Clean water was used at a temperature of between 60 and 70 degrees Fah., and the room in which the briquettes were kept was also at the same temperature.

The amount of water used to gauge the cement was not taken, but enough water was added to make a plaster mortar somewhat stiffer than is commonly used on the work.

Brass moulds were used. The briquettes had a breaking section of one square inch. The sand used was the same class as that employed on the different works, as it was thought desirable to use this rather than any standard sand.

The weight of the cement was obtained by using a hopper and shoot, as recommended by Mr. Faija in his book on "Portland cement for users." The shoot made of zinc or tin, being fixed to the stand at an angle of 55 degrees, and the measure placed under so as to have 5 inches between the top of the measure and the shoot.

The sieves used for sifting were those recommended by the Committee of the American Society of C.E., on a uniform system of testing.

A very large number of briquettes of Thorold and several of Napanee fell to pieces when placed in water. This is the great trouble with this class of cement, and if we could only depend on its hardening in water it could be more frequently used. A large number of tests were made with Thorold or Napanee mixed with Portland cement, the results were very fair.

In the case of sewer construction the work is subjected to the greatest strain at once; the sewer trench being filled in and rammed very often within a few hours of the completion of the masonry, which of course renders it absolutely necessary that only a first class cement should be used.

In comparing the result of the tests made by the department with the average minimum and maximum strength of some good cements, given by the Committee of the American Society of C.E., it will be seen that the tests made in Toronto fall considerably below the average.

	American Soc. C.E.
	lbs.
Portland neat after 1 year in water	450 to 800
" " " 1 month "	350 " 700
" " " 6 days "	250 " 550
American natural cement neat after 1 year water	300 " 400
" " " " 6 days "	60 " 100
Canadian " " " 1 year "	170 " 210
" " " " " 6 days "	10 " 70

Tensile strength of a number of samples of cements of various brands tested during the years 1885-6-7.

Brand.	Weight per bushel.	Residue p. c. after sifting through sieves, hours. 50	74	100	Placed in water hours after gauging.	Time in water.	Proportion.	Tensile strength per sq. in. of section, having remained in water the whole time.	Remarks.
Napanee....	73	6	12	....	24 hrs.	1 year.	neat	180	Av. of 6 briquettes.
	73	6	12	....	"	30 dy's	"	76	" 12 "
	73	6	12	....	"	6 "	"	39	" 30 "
	73	6	12	....	"	1 year	2 to 1	150	
	73	6	12	....	"	30 dy's	"	25	
Thorold (Bottles)...... ...	77	18	23	....	"	1 year	neat	210	Av. of 3 briquettes.
	77	18	23	....	"	30 d'ys	"	85	" 8 "
	77	18	23	....	"	6 "	"	42	" 40 "
	77	18	23	....	"	1 year	2 to 1	150	" 3 "
	77	18	23	This cement was forwarded to the office by agts. to be tested; none of these brands were used in the works.	"	30 d'ys	"	50	" 10 "
Thorold, (Norris & Carruthers)	78	12	18		"	30 "	neat	50	" 2 "
	78	12	18		"	6 "	"	24	" 6 "
Hull (P.Q.)	...	...	...		"	30 "	"	70	" 6 "
	...	...	...		"	6 "	"	33	" 6 "
Hochelaga, (P.Q.).....	62	9	20		"	30 "	"	50	" 4 "
	62	9	20		"	6 "	"	10	" 4 "
	62	9	20		"	30 "	2 to 1	23	" 6 "
Cumberland, Am. Natural cement	72	3	15		"	30 "	neat	110	" 3 "
	72	3	15		"	6 "	"	78	" 8 "
	7[illegible]	3	15		"	30 "	3 to 1	50	....
	72	3	15		"	30 "	"	25	....
Ontario, (Georget'n)	64	7	14		"	....	......	....	Several samples of this cement were forwarded to the Dept. to be tested, but after being in the water some hours fell to pieces.
	64	7	14		"	....	......	....	
Portland, K. B. and S...	105	12	25	30	"	1 year	neat	475	
	105	12	25	30	"	30 d'ys	"	320	Av. of 3 briquettes.
	105	12	25	30	"	6 "	"	220	" 16 "
					"	60 "	3 to 1	105	" 6 " (coarse sand.)
					"	60 "	"	63	" 8 briquettes equal parts of coarse and fine sand.
	105	12	25	30	"	6 "	"	45	Av. of 3 briquettes. (coarse sand.)
	105	12	25	30	"	6 "	"	40	" fine sand

Brand.	Weight per bushel.	Residue p. c. after sifting through sieves, hours.			Placed in water hours after gauging.	Time in water.	Proportion.	Tensile strength per sq. in. of section, having remained in water the whole time.	Remarks.
		50	74	100					
Portland, Wallsend....	108	1	12	25	24 hrs.	30 d'ys	neat	340	Av. of 8 briquettes.
	108	1	12	25	"	6 "	"	220	" 12 "
	108	1	12	25	"	30 "	3to1	95	" 3 "
	108	1	12	25	"	6 "	"	30	" 3 "
	108	1	12	25	"	10 "	"	45	6 briquettes, all placed out in frost during January.
	108	1	12	25	"	9 "	"	35	
Portland, German....	108	1	12	25	"	1 year	neat	550	
	108	1	12	25	"	30 d'ys	"	400	
	108	1	12	25	"	6 "	"	275	
	108	1	12	25	...	20 "	"	300	Outside in frost during February.
	108	1	12	25	...	20 "	"	300	In air in testing room.
Portland for Stuart's Granolithic Paving Co.........	106	6	15	29	24 hrs.	1 year	"	485	Av. of 2 briquettes.
	106	6	15	29	"	30 d'ys	"	450	" 2 "
	106	6	15	29	"	6 "	"	250	" 2 "
Portland for Eureka Paving Co	108	3	14	23	"	6 "	"	245	" 2 "
Portland, Johnston ...	108	10	18	28	"	30 "	"	365	" 9 "
	112	7	21	31	"	6 mos	"	400	....
	112	7	21	31	"	30 d'ys	"	350	Av. of 6 briquettes.
	112	7	21	31	"	6 "	"	180	" 6 "
	112	7	21	31	"	30 "	3to1	137	" 8 coarse sand.
	112	7	21	31	"	30 "	"	50	" 8 fine sand.
	112	7	21	31	"	30 "	"	55	" 8 loamy sand.
Francis Bros.	104	6	20	29	"	30 "	neat	350	" 9 briquettes.
	104	6	20	29	"	30 "	"	250	" 9 "

DISCUSSION.

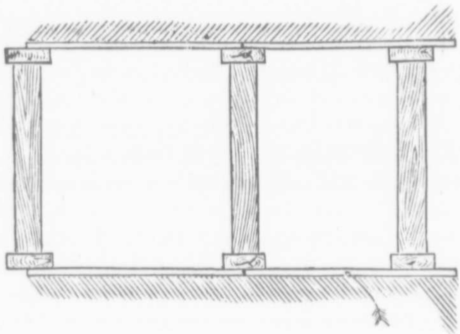
Mr. Evans.

Mr. Rust in this interesting paper recommends that the grade stakes be placed 2 feet from the sides of the intended excavation, as there is always a greater or less settlement on either side of the trench ; the stakes, if placed so close to the side, would be very liable to become disturbed owing to this settlement. Would it not therefore be advisable to place them never less than 3 feet from the side, and where the space will permit, 4 feet therefrom?

The use of boning rods is to be preferred to all other methods of carrying the levels along the sewer. A good method of erecting bridges for this purpose is to sink a barrel on either side of the trench, about half way into the ground, to place a post in the centre of each barrel, and then to fill the barrel with well punned earth ; this method has the advantage of keeping the posts rigid and firm, without digging such deep post holes; upon the posts the sight bar or straight edge is then fixed by the level at the required elevation.

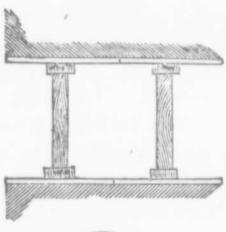
Mr. Evans' experience has been that it is a mistake to make the trenches too narrow, and after several not very satisfactory trials, he came to the conclusion that it did not pay in any case to make the trench less than 3 feet wide, the increased width allowing more freedom for the men to work, and more than compensating for the extra excavation and refilling. Mr. Rust apparently confirms this conclusion; for in the Langley avenue sewer, built in December, 1885, the excavation (including laying 15 in. pipes and filling in) in bad running sand only cost 28 cents per cubic yard, the trench being 2 ft. 6 ins. wide, whereas in the Salisbury St. sewer, built in October, 1886, where the trench is presumed to have been only 2 feet wide, the excavation (including laying pipes and filling in) costs 38 cents a cubic yard, and this notwithstanding the fact that the men had a lighter pipe to handle, and that the excavation was in good dry sand and gravel.

Mr. Rust undoubtedly deserves great credit for the construction of 90 miles of sewer without loss of life. Were statistics obtainable, they would probably prove this to be the exception and not the rule, although there is no reason, if proper care be taken and due diligence used, why it should not be general; the fact, however, of such a large amount of work being done without one fatal accident speaks highly of the method of timbering the trenches. An economic system of timbering trenches, although not permissible on quicksand, is that known as poling, (see sketch); this method was used by Mr. Evans without



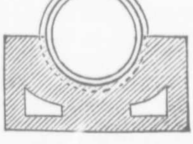
a single failure in the excavation of a trench about $\frac{3}{4}$ of a mile long, 8 feet wide, and from 30 to 84 feet deep, made for the purpose of obtaining a water-tight stratum upon which to commence a concrete wall below ground, and a puddle wall above ground for a waterworks dam. This system of timbering must not be confused with the more common but totally unreliable method shown below.

Mr. Rust has adopted the system of timber foundations in bad



ground. In the case, however, of pipe sewers, has Mr. Rust ever made use of earthenware invert blocks?

These blocks make a good foundation upon which to lay the pipes, and also permit of the drainage of the water during the construction of the sewer.



The use of a second class brick in the second or outer ring of sewer should be strongly opposed. Where two classes of brick are allowed upon the ground, the bricklayers and their laborers have an extraordinary knack of using these second quality bricks as often as possible, in preference to the better and more expensive one, and even the best inspector will find it impossible to entirely prevent it; it would be better therefore to recommend not only that first quality brick alone be used, but to insist (in accordance with the usual terms of the specification) that condemned bricks be at once removed from the works.

In reply to Mr. Rust's query as to the various methods of obtaining a record of the position of junctions, it may be stated that on the Urmston & Flixton Sewerage in England, it was the practice to take careful measurements of their position, and where practicable to take also the measurements from any two points upon a house or building, the same being afterwards plotted upon the plan.

Overlooking the refilling of trenches is generally much neglected by the inspector. The free application of water from a street hydrant every now and again, has however a most wondrous effect upon this portion of the work.

The objection made by Mr. Rust to the use of Scotch pipes on account of insufficient thickness, is probably owing to a want of understanding when placing the order. In the north of England (Manchester and district), pipes of the very best quality can be obtained of any desirable size or thickness, pipes of not less than one-tenth the diameter for 18 in. and 24 in. pipes, and 1-12 diameter for 12 in. pipes, not only being kept in stock, but being frequently called for in sewerage specifications.

The figures relating to the cost of sewers are extremely interesting, and on account of the very detailed manner of showing the cost are beyond doubt valuable. One thing however that is wanted to make these thoroughly complete is the quantity of cement used in making the joints of the different sizes of pipe. Even this information from the figures given could be pretty accurately determined, had Mr. Rust stated whether pipes in lengths of 2 or 3 feet had been used.

Mr. Rust does not state in his paper at what depth tunnelling is permitted; this is a question upon which Mr. Evans would be glad to receive his opinion.

Mr. Evans agrees entirely with Mr. Rust in his strictures upon Canadian cement manufacturers ; so long, however, as engineers will permit the use of this totally unreliable cement, the manufacturers can hardly be expected to spend more money and take greater care in its manufacture.

Mr. Trotter. In the advance proof, Mr. Rust says: "Pipes manufactured at St. Johns (Que.) were introduced here (at Toronto) last year. They appeared good, hard burnt pipes, with a deep flange, but with hardly such a good finish as the Scotch or American. Some few were used, but the presence of a few pieces of lime were noticed when the pipes were condemned and have not been used since."

Since the above was printed, Mr. Trotter has explained to Mr. Rust that the lime complained of was due to an accidental cause, having been traced to chips of limestone that fled under the mason's hammer on to the clay heap, when the limestone blocks were being prepared to make the foundation of a new kiln, which was being erected at that time. Mr. Rust has accepted this explanation as satisfactory, and has acknowledged it in his paper just read.

At the request of several members of the Society, the following short description of the manufacture of drain pipes, as applied in the factory at St. Johns, is given :

The bulk of the clay used is imported from the State of New Jersey, and the kinds employed are known as fat clay and sandy clay. The fat clay is plastic, and the sandy clay highly refractory—plasticity is accompanied by shrinkage in drying and burning, and sandy clay is used to reduce excessive shrinkage and to add strength to the clay; shrinkage is also controlled by the admixture of ground saggers, or refuse burnt pipes, and is used in proportion of $\frac{1}{8}$ to $\frac{1}{4}$ of the total bulk.

The following analysis of clays was made by the late H. Sugden Evans, chief analyst of the Dominion.

FAT CLAY (red).	
Silica	64
Alumina	28
Protoxide of iron	5.31
Lime	1.42
Water	1.27

FAT CLAY (black).	
Silica	72
Alumina	24
Oxide of iron	2.54
Alkalies	1.78

SANDY CLAY.	
Silica	66.00
Alumina	32.00
Alkalies	2.00
Lime	trace
Iron	"

BLUE CLAY (native).	
Silica	47
Alumina	48
Oxide Iron	1.05
Lime	2.5
Water	1.

The relative proportion of silica and alumina, as indicating the fire resisting properties of fire clay, are of little moment, as both these constituents are eminently refractory elements.

In preparing the clay for the press, the most important point is to thoroughly grind and mix it, and to break up the natural lamination of the clay. To do this, it is first ground in a wet pan, running 35 revolutions to the minute, and with sharp chilled rollers, 5″ face each, weighing 50 cwt. Here the clay is ground and mixed for about three minutes (100 revs.), then the clay is emptied upon an endless belt, which carries it to a spiral pug mill, where the clay is again worked by the knives revolving different ways, and from which it is delivered in a solid stream 8" diameter, and is then a homogenous mass with the different kinds of clay and "grog" thoroughly mixed. From the pug mill, the clay is conveyed up an elevator to the pipe press, where it is fed into the clay cylinder, and pipes ofthe desired size are pressed out by direct steam power furnished by a steam cylinder, 36 diameter by 5' high, worked by steam, 100 lbs. to the square inch pressure. The pressure exerted in forming the socket of a pipe is 45 tons.

The sockets of the pipes are first formed, and when properly pressed the socket head of the machine is released from the clamps, and the body of the pipe follows,—the whole (socket and body) being made in one piece. Most of the Scotch pipes are hand socketed, that is, the barre of the pipe only is made in the press, and the socket is put on by hand afterwards. The disadvantage of this system is that the joint where the socket is made is the weakest part of the pipe and is liable to open.

After the pipes leave the press, they are stood upright on the spigot end in the drying room until the socket is hard enough to bear the weight of the pipe, and until a certain amount of shrinkage has taken place. They are then burned over and cut to uniform length, and when quite dry, are placed in the kilns for burning.

The process of burning takes four days. The first 36 hours, the fires are kept low, and what is known as "water smoking" takes place—that is, all moisture is gradually evaporated out of the clay, and passes off in a vaporous smoke: the fires are then gradually raised until about 18 hours from the finish, when the greatest heat is attained and is maintained until the process of salting takes place. The heat of the kiln is then "dazzling white" heat, about 2730° Fahrenheit.

About 12 to 15 hours after "closing the fires" and reaching the maximum of heat, and when the burner is satisfied from observation that the heat has worked down, the salt is applied to the sides of the kiln. Common salt is applied to each fire-hole (of which there are 10 to a kiln, 21" diameter) about a small shovelful to each fire hole, and the fires are again made up, and the intense heat maintained for about an hour, when the process is repeated, and after the lapse of another hour, the third salting is put on, and this is generally sufficient, although, in case of a bad draft and lack of heat, it has occasionally to be repeated five or six times.

After the last salting, the fires are allowed to die out gradually, and the process of cooling takes three days. There are six kilns, and one is drawn and filled each day. The action of the salt (chloride of sodium) in making the glaze is as follows:—clay contains silica, alumina, lime and iron, and when the chloride of sodium, volatilized at a high temperature, comes in contact with these substances, the chlorine of the salt attacks the iron forming chloride of iron, and the sodium combines with the silica, forming silicate of soda, which, in its turn, combines with a quantity of silicate of alumina (which is clay), and makes a compound silicate of a glassy character, which is the "salt glaze," which, when fused, absorbs the oxide of iron, and makes the color of the glaze more or less yellow, red or brown, according to the degree of heat and the relative proportion of oxide of iron contained in the clay. Too much stress is laid upon the color of the glaze, and the majority of pipe manufacturers have to arrange the mixture of the clay to meet the popular demand for a dark brown pipe. Some clays that would make a perfect pipe have to be mixed with others containing a larger proportion of oxide of iron, simply to gratify the demand for color, and often to the detriment of the article produced.

Undue stress is also laid upon the ring of vitrified pipes. Some clays that burn with a solid, strong body have no ring, but, in every respect, they are equal to those clays that ring sharp as a bell. For instance, sandy clays and clays like the "Dinas," although possessed of the highest refractory properties, ring with a hollow cracked sound, whilst a fat clay of inferior quality and out of which all the body is burnt, that is, where the body has assumed a glassy, brittle character, will ring like a bell; but of the two, the sandy clay will make the best pipe, and probably be 50 per cent. stronger.

The pipes made at St. Johns are of a dark plum color, a color due to a strong semi-fat clay, the analysis of which has been given, and which contains 5·31 of protoxide of iron. These pipes fulfil all the requirements as to strength, and show a great deal in excess of any demands. The specification of the city of Montreal requires 12″ pipes to stand a crushing weight of 2,000 lbs. to the square inch.

The result of a practical test made by Mr. St. George, city surveyor, on March 7th, 1888, proves them to stand an average of 5,696 lbs. to the square inch, being 3,696 lbs. in excess of specification.

Strength and resistance to acids and absorption are the prime requisites of a good sewer pipe; and to ensure these qualities, a pipe must be hard burnt, dense in body, and thoroughly vitrified.

Tests made with acids on St. Johns' pipes, by Mr. St. George, showed that acids had no effect on them.

A competitive test made with Scotch pipes, and St. Johns' in 1885, showed that Scotch pipes absorbed 1 in 18, while St. Johns' pipes absorbed

1 in 46, being $2\frac{1}{2}$ in favor of St. Johns'. This is due to a denser body and more perfect vitrification.

Mr. Rust says, "it seems a great pity that a good, reliable pipe cannot be manufactured in Canada." In answer to that, it might be said that, a good, reliable pipe is being manufactured in Canada, and only merits a better acquaintance and a fair, impartial trial. Canadians are too apt to think that nothing good can be made in Canada. She is a young manufacturing country; but, as she advances in years, it will be to her advantage as a nation, to support her own institutions first, and those of foreigners, when she cannot get what she wants at home.

The following table gives the results of a series of tests, with St. Johns' and "Gartcraig" pipes, made by MM. St. George and Fleming.

TESTING VITRIFIED CLAY PIPES, MARCH 7, 1888.

Maker.	Size of pipe.	No. of test.	Thickness.	Weight of pipe in lbs.	Breaking weight in lbs. to sq. in.	Average.
Standard Drain Pipe Co.	12 in.	2	1 in.	131	5764	5696
" "	12 in.	3	1 in.	130	5628	
" "	9 in.	4	$\frac{7}{8}$ in.	88	4812	4854
" "	9 in.	5	$\frac{7}{8}$ in.	88	4676	
" "	9 in.	6	$\frac{7}{8}$ in.	88	5804	

ABSORPTION OF PIPES.

No. of test.	Weight dry.	Weight wet.
1	$11\frac{1}{2}$ oz.	$11\frac{3}{4}$ oz.
2	$7\frac{1}{4}$ "	$7\frac{1}{2}$ "
3	$15\frac{1}{4}$ "	$15\frac{1}{2}$ "
4	$5\frac{1}{4}$ "	$5\frac{1}{2}$ "
5	$8\frac{1}{4}$ "	$8\frac{1}{2}$ "
6	$16\frac{1}{4}$ "	$16\frac{1}{2}$ "
	$63\frac{3}{4}$ oz.	$65\frac{1}{4}$ oz.
	Difference	$1\frac{1}{2}$ oz.
		Equals 1 in $42\frac{1}{2}$.

TEST OF VITRIFIED CLAY PIPES, MAY 3, 1888.

Size of pipe.	Thickness.	Gartcraig.	St. Johns.
6 in.	$\frac{3}{4}$ in.	3307	3163
6 in.	$\frac{3}{4}$ in.	3403	3499

SMOKE TEST.

Eight lengths of each Pipe and three Junctions.

St. Johns.	Gartcraig.
Leaked at one small hole.	Leaked at sockets and junctions of three junctions, and leaked in three lengths of pipe.

Mr. Rust's paper on the Toronto Sewers contains much interesting information as to the practice there, and many valuable hints as to general construction. **Mr. E. Mohun,**

Although the speaker is an advocate for the "separate" system where the local conditions are favorable, it is quite probable that circumstances in Toronto render the "combined" system preferable. At all events the latter has been adopted, and the question need not be discussed.

There are, however, one or two points to which attention may be drawn.

The practice of laying pipe sewers on curves is not one which, in the speaker's opinion, should be generally adopted. If sewers are laid in absolutely straight lines, from manhole to manhole, the change of direction being made in the manhole, the risk of stoppage is reduced to a minimum; the line of sewer can be located with the greatest care for any purpose, and, if obstructed, the position of the obstruction may be determined with considerable accuracy; further, if deposition takes place in the sewer, it can, by the proper use of the lamp and manholes, be removed before it becomes serious.

With regard to flushing the large sewers of the combined system, it is to be presumed that, as usual, they are flushed at very irregular intervals by the rainfall, or by the collection in and discharge from the manholes, of the sewage itself; it should be quite practicable so to arrange matters, that such collection and discharge should be automatic, at regular intervals. From such information as the speaker has been able to gather of the effects of irregular flushing by rainfalls in cities where the fall during the summer months is inconsiderable, the results are not invariably satisfactory.

The sewerage of London is, without doubt, the most gigantic example of the combined system in the world, and yet there, in several instances, it has been found advisable to separate the sewage from the drainage waters. This has been done by carrying the sewage in iron pipes laid in the large sewers.

The curved junction, such as is made by Doulton, London, Eng., is, in the speaker's opinion, preferable to the commonly used Y, since both streams are at the point of union, running in exactly the same direction.

In setting out the work in Vancouver, the line was roughly given by rods; sight rails were erected 25 feet apart; the line was then ranged with theodolite and marked on each rail with a shingle nail. From these nails plumb bobs were suspended, giving the true centre of the sewer, and the depth of invert below rail was marked on each rail in feet and hundredths. The pipes were 20 feet long, and no error in level of more than $\frac{1}{100}$ in a length was permitted. This method proved most satisfactory.

In draining a tract of 7,000 acres, a few years ago, the speaker found that about four-tenths of the rainfall reached the outlet. From this it would appear that Mr. Rust's allowance of 50 per cent. is not too large an amount of rainfall to be provided for in a paved city, and it would be interesting to know whether with this allowance the sewers have ever been surcharged.

With reference to quicksand, Sir Robert Rawlinson says: "Cast iron pipes may be used for main sewers with economy and advantage, as when the trench contains quicksand, or when the strata are full of water: also in narrow streets when deep trenches have to be excavated. A cast iron sewer may be $\frac{2}{3}$ the diameter of an earthenware pipe or a brick sewer, as the cast iron pipe may work full or even under pressure."

Nearly thirty years ago, the speaker remembers that his Chief was much troubled when draining an estate in Sussex with stoppages caused by Hastings sand, and overcame the difficulty by surrounding the pipes in the trench with a layer of surface soil; through this, the sand, which would find its way by the smallest crevice in the joints of the pipes, did not penetrate.

Mr. Macdougall. Mr. Alan Macdougall remarked through the secretary that a field of investigation was open to pipe makers and engineers as to strength. There are in this city pipe sewers of Canadian, American and British manufacture, all of which collapse under similar circumstances, leading to the opinion that the pipes are not thick enough.

In the western portion of the city the subsoil is very wet, in many streets so full of running sand that even in the depth of last winter the pipes were laid with difficulty; these sewers are being opened almost daily to make "private" or house-drain connections. In nearly every street the sewer has been reported broken, and the pipes have had to be renewed at the point of connection. In other streets in this district, in light clay and loam, the pipes are crushed. In the central portion of the city, in good clay digging, pipes are reported crushed. The eighteen inch pipe suffers more than the fifteen, while the twelve inch holds its own well.

In a wet sand the pipe becomes buried and must necessarily be bedded. Some inspectors think the pipes are disturbed when the shoring of the trenches is removed. The pipe is wrenched, and when the earth is filled in, the strain comes on unequally. Cases have been found of careless filling in, on one street a 12 inch board was found end on to the pipe, and choking the sewer. In another instance, a nice sand digging, with a moderately wet bottom,—trench 9 to 10 feet deep,—work done by the city 2 years ago under an inspector who now holds a prominent situation, —30 feet of pipe had to be taken out and replaced before a sufficiently sound pipe could be found with which to connect.

For general neatness of finish the Ohio pipe is perhaps the favorite; Hamilton pipe is also well burned and glazed, St. Johns, Que., not such a showy pipe, and Scotch the least taking to the eye. In the smaller sizes 9 and 6 inches, the Scotch is rather thin, the Ohio being thicker is preferred. In the 15 and 18 inch pipe, the 2 ft. pipe is preferred to the 3 ft. pipes, the layers can handle the 2 ft. better at the bottom of the trench, it is not so heavy as the 3 feet length.

There is a strong preference in this city among all drain layers for 2 ft. lengths, even for house drains, which the writer has never been able to argue against. The men will not be convinced of the advantage of greater length and fewer joints.

Pipe makers can with profit turn their attention to the following points: a longer flange or hub—the short hub of the American & Western Canadian pipe being in the writer's opinion, a great drawback. The width or increased diameter at the socket or hub does not receive proper attention from the maker. There is not enough space to make a proper cement joint. This has led to a certain make of Canadian pipe being discarded in this city, as the joints do not withstand the water pressure when tested in house drains.

On the question of imported British pipe, the writer is sceptical; notwithstanding the assurances of the representative of a large Scotch house, he is not convinced that inferior pipe does not find its way into this market. He is led to this conclusion from the number of failures in pipe both before being laid and when laid, and he believes that the very best American pipe cannot find its way into this market.

American engineers to whom he has spoken on this point do not seem to have a similar experience in finding broken pipes in sewers.

A word on the form of fracture; the pipe is always broken along the top for its full length, and on both haunches at the semi-diameter or springing line, and very often along the bottom as well. The form of fracture, as seen when a few lengths are laid bare, gives the impression that the weight has been applied at the top, pressing it down, and causing fracture at the haunch.

Trench filling cannot be too carefully performed, not only should selected earth free from stones be used about the pipe and well tamped in, but the pipe should be well covered for at least one-third of the depth of the trench before any back filling is thrown down.

Mr. Fleming. Mr. Fleming, referring to the Scotch pipe, which was said to be of insufficient thickness, remarked that the pipes could be obtained of any thickness specified, and the reason for not getting the thick pipe was the increased freight. The thickness for a 12-in pipe should be one inch. He had tested some pipes on the preceding day, and had found them fully up to the requirements. It had become customary to import these pipes on account of the freight. There was one brand, the Craig, Kilmarnock, which would fill every requirement as regarded strength, thickness and finish, but they were rarely imported, owing to the fact that they are 10 per cent. dearer than ordinary pipe.

As to the removal of timber, a plan often adopted in the old country in difficult soils, is to specify that the timber should be left in, and consequently no strain would be brought upon the pipes by the removal of the timber.

In the use of boning rods, there was a saving of time and also greater accuracy than with the use of a spirit level, and the inspectors could check the levels themselves, which they could not otherwise do. Referring to careful jointing, he said that it was a good plan to use the "mirror test," which consisted in looking through the drains by means of a mirror placed at one end and a bull's eye lantern at the other. A considerable number of lengths of pipe could be examined at one and the same time by this method.

There is an objection to the use of two ft. lengths in house drains, as it is here of importance to diminish the number of joints as much as possible.

He also thought that there should be a record of the plans shewing the exact position of all proposed sewers, branches and sections, which should be made beforehand and kept and fyled away, so that it might be inspected at any subsequent time.

Ventilation through manhole shafts in England had been found to be very satisfactory. Shafts up the buildings had often been spoken of, but this method was somewhat impracticable, besides being liable to danger, while the proprietors would not hear of any such thing. Leaving the gully traps open, however, was a plan which he thought might be of service in Montreal, where manholes could not be kept open in the winter time. The climate in Toronto must be very different from that of Montreal, if it is found possible to keep the ventilation going on during the whole of the winter.

Mr. Torrance said there was one thing in the paper which inter- **Mr. Torrance.** ested him, and that was the keeping an accurate account of the connections with all buildings, and he was reminded of an experience he had a short time ago. His firm had leased new premises for their business, and he went to the City Hall for information in regard to connections with the city sewers. After some delay the gentleman in the office condescended to inform him that they did not keep such records, nor would he be likely to find them in the Health Department or in the Water Department. The only way to obtain the information would be to look up the builder. Now the building was a rather old one—50 years old, in fact—and to look up the builder would have been a little difficult, so that he had to give it up as a bad job.

In regard to the ventilation of sewers in this city, he thought one of the most successful efforts in that direction was the use of an inverted roof on private dwellings with the connection direct to the sewer through the sink, and he knew of buildings in which they had been tried, and in which they had proved successful in keeping the snow off the roof, and in allowing the gas to escape freely, thus diminishing the danger from sewer gas. It was surprising that the system was not more generally adopted.

Prof. Bovey remarked that inverted roofs had not always proved suc- **Prof. Bovey.** cessful. Their effectiveness depended very much upon their local surroundings, and unless the soil pipe was protected from the cold northern blasts, the moisture, which is always present at the upper end of the pipe, would freeze, gradually accumulate, and eventually completely close the pipe's mouth.

In the latter part of his paper, Mr. Rust had given many valuable details and results of experiments upon Canadian cements. These results shewed most emphatically that Canadian cements are a most inferior material of construction. This arose from the fact, not that there was a lack of good material for its manufacture—for that can be obtained of a quality equal to the best and in any required amount—but that the manufacturers neither knew anything about the best mode of producing a good cement, nor did they care to do anything but place upon the market a substance that would sell. Engineers should severely leave such cements in the manufacturers' yards, and should refuse to use a material which cannot but fail, and lead to the destruction of important engineering works. It is therefore a matter of surprise to the speaker that a mixture of Canadian cement with Portland should have been allowed on the Toronto sewerage works, as the sole effect must be to make a good material bad.

The following results of actual experience in excavating sewer trenches may be of some interest:—

As the depth increases to 6 ft., the first set of timbering is introduced about 2 ft. from the surface, the stage planks being placed upon the shores, and successive stages are introduced at intervals not exceeding 6 ft.

Call C the cost per. cub. yd. of digging the top soil, filling it into barrows and wheeling it a distance not exceeding 60 ft. It must be remembered that the cost in trench work is greater than the cost of stripping wide areas in consequence of the necessity for a more frequent change of barrow roads.

The cost per. cub. yd., of casting earth on to stages whose extreme height does not exceed 6 ft. $= \frac{7}{8}$ C.

The cost per cub. yd. of excavating each successive foot in depth in a trench will be found to be very approximately that given by the subjoined table:—

1st. foot,	getting and wheeling	60 ft	= C,
2nd "	"	cast 12 ft.	= C.
3rd "	"	9 "	= C.
4th "	"	6 "	= C.

5th " " cast to top = C, and thence to heap $= \frac{C}{2}$, or $\frac{3}{2}$ C in all.

6th foot, getting and cast to top $= \frac{5}{4}$ C, and thence to heap $= \frac{5}{8}$ C, or $\frac{15}{8}$ C.

7th foot, getting and cast to 1st stage, $= \frac{3}{4}$ C, thence to top $= \frac{5}{8}$ C, thence to heap $= \frac{5}{8}$ C, or 2 C in all.

8th foot. getting and cast to first stage, $= \frac{7}{8}$ C, thence to top $= \frac{5}{8}$ C, thence to heap $= \frac{5}{8}$ C, or $\frac{17}{8}$ C in all.

9th foot, getting and cast to 2nd stage $= \frac{3}{4}$ C, thence to 1st stage $= \frac{3}{4}$ C, and thence to top and heap $= \frac{5}{4}$ C, or $\frac{11}{4}$ C in all.

10th foot, getting and cast to 2nd stage $= \frac{3}{4}$ C, thence to 1st stage $= \frac{3}{4}$ C, and thence to top and heap $= \frac{5}{4}$ C, or $\frac{11}{4}$ C in all.

11th foot, getting and cast to 2nd stage $= \frac{7}{8}$ C, thence to 1st stage $= \frac{3}{4}$ C, and thence to top and heap $= \frac{5}{4}$ C, or $\frac{23}{8}$ C in all.

12th foot, getting and cast to 2nd stage = C, thence to 1st stage $= \frac{3}{4}$ C, and thence to top and heap $= \frac{5}{4}$ C, or 3 C in all.

13th foot, getting and cast to 2nd stage $= \frac{9}{8}$ C, thence to 1st stage $= \frac{3}{4}$ C, and thence to top and heap $= \frac{5}{4}$ C, or $\frac{25}{8}$ C in all.

14th foot, getting and cast to 2nd stage $= \frac{5}{4}$ C, thence to 1st stage $= \frac{3}{4}$ C, aud thence to top and heap $= \frac{5}{4}$ C, or $\frac{13}{4}$ C in all.

The cost of timbering trenches may be estimated at $\frac{C}{2}$ per cub. yd. for labor, wear and timber, and it is also optional to make a charge of $\frac{C}{4}$ for superintendence. When the trench is being filled in, *one* man can fill in as much as *one* man can ram. With a trench, say, 10 ft. deep and 3-ft wide, the spoil heap will be 9 or 10 ft. wide and must be cast twice. Thus *two* fillers will be required to one rammer, and the cost of filling per cub. yd. will be about $\frac{5}{4}$ C.

Mr. MacPherson said that Mr. Rust in his paper said, "we had occasion a short time ago to take up an 18-ins drain (replacing it with a large brick sewer,) laid with Scotch pipe in a newly annexed territory and about 75 per cent. of the pipes were cracked, a large majority on bottom, top and two sides." If this were so he would like to know in what manner the remainder broke. **Mr.D.MacPherson.**

He would like to obtain some satisfactory information as to what were the larger sizes in the brick sewers and what were their grades. As to the blisters he thought they had been liberally dealt with, and that pipes with any internal blisters should be avoided, except on steep grades.

Mr. Metcalfe referred to the difference in the prices of the work carried out by the City Engineer and by contractors, as in the cases mentioned, where the contractor refused to go on with the work, and it was completed at a lower rate by the engineer. **Mr. Metcalfe.**

In most cases he thought it would be found that the engineer could carry out arterial sewerage work, except in the case of very large main-sewers, at less expense and far more satisfactorily than by letting it out to contractors.

Mr. Fleming referred to the necessity of leaving timber in trenches where the ground was very bad, and it was often impossible to say where this would be necessary till after the trench had been opened, thus making a very uncertain quantity to be dealt with in tendering and afterwards leading to much dispute in final settlements.

With reference to junctions for house drainage his experience had always taught him to leave sufficient, and to spare no pains in keeping accurate records of their location, as very serious harm arose from cutting into pipe sewers.

There was one other point in the otherwise valuable paper that had just been read, which called for very marked criticism, and that was the building of sewers on curves, which was wrong both in theory and practice, and had become obsolete many years ago; *first*, because the flow was seriously impeded; *secondly*, silting up was sure to result, and *thirdly*, it was very difficult indeed to inspect such sewers. The acknowledged practice now is to place manholes at all changes of direction, and to keep all sewers in straight lines.

Mr. Torrance. Mr. Torrance said that last summer he inspected one of our large cement quarries, and if one of the members of the society was going to read a paper on the manufacture of Canadian cements, he thought it would be a good thing if something was said about the *want* of manufacture, because to leave the important work of quarries and kilns of cement to the management, or rather *mis*management, of uneducated men, and then to expect to turn out a material equal to Portland cement, was altogether contrary to common sense.

Mr. Fleming. Mr. Fleming said it was not well to leave too much room for jointing. In some pipes of English manufacture the joints were perfectly tight, so that the joint was almost a mechanical joint, nothing being required but a little pitch poured in at a small hole in the faucet.

Mr. Kennedy. Mr. Kennedy said that the pipes for the Toronto sewers seemed to have been taken just as they were found in the market. A manufacturer makes what he can sell, and if cities take everything he makes, he will certainly make what is cheapest rather than what is best. There was something wrong when pipes broke in whole sections. The pipes must have been selected without reference to the work they had to do, or they had work put upon them which no pipe ought to have had. Either the pipes or the laying had been bad.

The same laxity prevailed in regard to cement. Our Canadian manufacturers have just taken a rock with some little hydraulic properties and ground it up. It could be sold cheaper than the imported cements, and they were hardly to be blamed for making it when there was a demand for it. But this state of affairs seemed to be drawing to a close, because it was now better understood what cement ought to be, and what cements could be obtained, so that the poorer article was being driven out of the market. Of course the manufacturer was interested in selling the cheaper article, but with proper inspection it would be driven out, and we would then unquestionably have the good home-made cement, because we have all the necessary material in Canada, and it is only a question of persistent demand.

Mr. Brittain. In his paper, Mr. Rust has principally confined himself to methods of construction employed in carrying on the works, and the following remarks, therefore, will chiefly refer to differences in practice under similar circumstances.

Although the mileage is not given by the author, tile pipe sewers would appear to be largely used in Toronto, but their use in this city has been found very unsatisfactory. They were usually laid with a forty feet radius into outfall sewer, with a fall of not less than 1 inch in 150 on the curve, and 1 inch in 300 on the straight line and with lampholes every 200 feet. In this city a large number of privy pits were connected with the public sewers, and from these pits came pieces of wood and other solid matter that lodged at the junction with the sewer and caused stoppages; this was of so frequent an occurrence that in many cases it was found cheaper to replace the tile pipes with 3 ft. × 2 ft. brick sewers than constantly have to remove obstructions. The making of additional connections was found difficult, as the leaving of junctions at regular intervals did not meet with the requirements of property owners; but a more serious objection to tile pipe sewers in a large district sewered under the combined system was their lack of storage capacity, or inability to provide for a sudden and large influx of storm water.

This defect appears to have been experienced in other cities where tile pipe sewers are largely used. According to a report for 1877 from the City Engineer of Providence, U.S., it appears that although the sewers of that city were designed to carry off so much of an inch of a rain-fall per hour as should reach the sewers within that hour, there were frequent over-flows from the sewers into cellars; the evil was so great that the City Engineer, proposed to throttle the inlets from the street gullies to the sewers.

The main sewers for the natural drainage districts of Montreal are designed to carry off so much of half an inch of rain-fall per hour as shall reach the sewers within that hour; this is usually considered a small provision, and would not be sufficient were pipe sewers much used, owing to their lack of storage capacity. The Ward of Hochelaga is principally sewered with tile pipes laid on the right-line system, with lampholes and conical manhole at change of grade and alignment; but the conditions there are exceptional, and the system is not capable of further extension. Our lateral sewers are almost without exception now built 3 ft. × 2 ft. in diameter with tile inverts of 3 ft. radius.

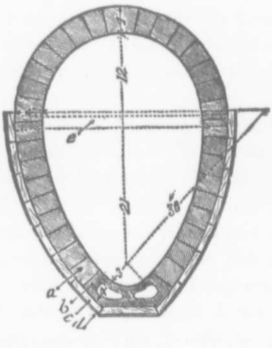
The author mentions that brick sewers in Toronto are generally constructed of two rings of brick; probably owing to difference in quality of brick, one ring has been found sufficient in Montreal when the sewer does not exceed 3 ft. × 2 ft. in diameter, and a vitrified tile invert is generally used. The use of tile invert blocks largely obviates the necessity for cradling in hard ground. When cradles are employed, light iron ribs are always used, as considerable difficulty was experienced in solidly bedding cradles with the projecting timber ribs mentioned by the author.

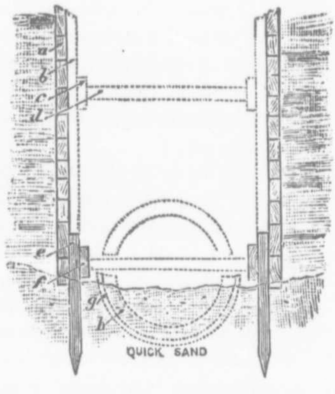
The thickness of the ribs and sheeting of the cradles varies according to the sides of the sewer. For a 3 ft. × 2 ft. sewer $1\frac{1}{4}$ in. × $\frac{1}{4}$ in. flat iron ribs, 4 feet apart, are generally used with sheeting of 1 in. pine battens, pure cement mortar being used in the side walls, and lime mortar in crown.

All mortar is used thin, and the bricks run up brick to brick, the bevelled form of the brick being more relied upon than the mortar to preserve the arch form.

The employment of Drain Inspectors to give intermediate levels between the grade stakes given by the engineer, as described by the author, has not been found to answer in this city, because in case of error in grade, contractors claimed to be relieved of responsibility, having followed levels given by the city official, and such levels could not be recorded.

The accompanying diagrams illustrate the cradles and timbering successfully adopted by the speaker, in Montreal.





a brickwork
b tile invert
c board sheeting
d iron rib
e temporary brace

a horizontal sheeting
b vertical stay
c block
d strut

e sheet pile
f waling piece
g cradle
h brickwork

The speaker has found it more satisfactory to give elevation and alignment points on sight-rails (bridges) at change of grade and alignment only, and to hold the contractor responsible for keeping the grade and alignment between those points. The system of timbering trenches in Toronto as described by the author differs from that employed in

Montreal, where, in bad ground, horizontal sheeting is usually employed for the reason that it does not require driving more than 10 inches (the width of the plank), and can be withdrawn again in 10 inch courses as the filling comes up. The driving of sheeting was found to cause the formation of cavities behind it. In re-constructing old defective sewers varying in size from tile pipe to six feet in diameter, their failure was generally due to spreading at the haunches, and appeared to be caused by improper timbering of the trench, the old waling pieces showing that the sheeting had sunk after being placed in position.

The system of ventilation, through perforated manhole cover only, described by the author as satisfactory in Toronto, is hardly found sufficient in Montreal, as the perforations filled with snow in Winter, and to a considerable extent with dirt in Summer. The street gullies were formerly left untrapped, but iron gullies having a moveable trap are now used. These gullies are untrapped in Winter. In the opinion of the speaker the sewers can, in a climate like Montreal, only be ventilated through the house drains, which should be continued untrapped up though the roof, the domestic fittings only being trapped. The air in the main sewer is less offensive then that in the laterals, and the air in the laterals is less offensive then that in the house drains, so that the latter would not be contaminated by the air from the former. The rapid extension of the sewerage system of Toronto shown by the author, can be accounted for by the large proportion of the cost for sewerage that is borne by the city, and the time for payment allowed to property owners who may have been specially assessed.

Local opinion varies considerably in determining how far sewerage should be considered a local improvement and a local charge, and in the opinion of the speaker Municipal engineers would be greatly aided by a record of how the cost of sewerage is borne and paid in different cities. It may be said that it is not an engineering question, but it is one on which the successful carrying out of a scheme depends, because those who will have to pay for the work will make their opinions felt and get designs modified accordingly.

With regard to taking up old sewers, a great deal has been said about the contamination of the soil from old sewers in the reports of Boards of Health. He had seen many miles taken up in Montreal and could not recollect ever finding the soil contaminated to a depth of more than two or three inches. Through Craig Street, where the principal part of the sewage passed, excavations had been made to the depth of forty-two feet, and there was no sign of contamination, so that he thought the alarm raised in this connection uncalled for.

He had confined his remarks principally to Montreal, because Mr. Rust's paper dealt with the details of construction, and did not go into the sewerage system of Toronto.

Prof. Bovey. Professor Bovey said there was one point upon which he would like further explanation. Mr. Brittain had said that, in his opinion, the proper method was to ventilate the sewers through the house soil pipes. He did not think any sanitary authority would now advocate such a system, and in other cities it was not allowed.

He saw no reason why traps should not be introduced between the main sewer and the house. It was said to be impossible to place traps on the out-side of houses in Montreal, but experience had proved this opinion to be entirely without foundation. During the past three years a large number had been introduced and had never been known to freeze. In fact the heat of the sewers and of the connecting pipes was quite sufficient to prevent freezing. He would strongly object to having the sewer gas from the city passing through his house drains, as he did not believe that any water closet had yet been invented which had proved to be a safeguard against the admission of sewer gas into the house. In the summer, the traps dried out, in the winter the tops of the soil pipes, and especially in the case of those which are untrapped on the outside, are continually frozen up solid, so that sewer air in the one case finds a free passage into the house, and in the other case must of necessity force such passage. Many such instances had occurred and were daily occurring in Montreal in houses without outside traps.

Mr. Brittain. Mr. Brittain said that in regard to the objection to carrying the ventilation of the sewer through the house drains, because the latter would thereby become contaminated, he had mentioned that the air in the larger sewers was much less offenisve than that in the lateral, and he would like to know what other means of ventilation they could have.

Prof. Bovey. Professor Bovey replied that, admitting Mr. Brittain's statement of the less offensive character of the air in the main sewer, there was one, in his opinion, insuperable objection, viz., the possibility of disease germs, which are being developed in all such sewers, being brought into the house by the system advocated by Mr. Brittain.

To prevent such an evil, outside trapping is of the utmost necessity, and it is of primary importance that the city should without delay take further steps for the proper flushing and ventilation of the sewers.

Mr. Walbank. Mr. Walbank regretted that he had not an opportunity of seeing an advance proof of the paper on construction of Toronto sewers, as it was a question in which he felt a deep interest. He fully coincided with

Mr. Brittain's remarks regarding the use of brick sewers in preference to tile pipes, in cases where the sewers were called upon to carry storm water as well as house excreta. He could not agree with Prof. Bovey's remarks regarding the insertion of traps in the private sewers leading to the main sewers. He held that nothing could possibly be better than to have a properly soldered iron pipe from the sewer in the stree carried straight above the roof, there to take the rain water of the building to the sewer. His idea would be to properly trap all the fixtures of the house, such as basins, sinks and water closets, and connect them to the said pipe, but to take proper precautions to see that all such traps were properly back ventilated to prevent syphonage. The speaker claimed that in all cases that came under his notice he treated them in this way, and he had yet to hear of any one of them failing in the object sought after. He thought that the traps Prof. Bovey spoke of as, having been placed on the line of sewer outside of the house, would sooner or later give trouble. He could not see any necessity of said trapping of private sewers. He was aware that at certain times, as for instance when warm water expanded the air in the sewer, or when storm water compressed it, it was bound to get out somewhere, and for his part he would much prefer that it should become diluted with the atmosphere above the roof of the house, than enter the front door and penetrate the whole house. He claimed that if the system he proposed became universal, the objections against the principle would very soon be reduced to a minimum. The theory that the pipe would become frozen was absurd, as the heat of the sewer would keep it free from frost. He was glad to see Mr. Brittain agreed with his theory.

Mr. Brittain said that of all the houses he knew of in Montreal that had been connected directly with the sewers, there was not a single complaint of being contaminated. The Medical college on Ontario street was ventilated straight through from the sewers, and there had been no trouble from the sewer gas there. The soil pipe had frequently been pierced, and the draft had always been found to be inwards. Mr. Stephens had all his warehouses connected in that manner, and in not a single one had the sewer air made its appearance, but where they had the air inlets, ice had formed in the house drains owing to the cold air being admitted into them. **Mr. Brittain.**

Professor Bovey said his experience was exactly the contrary, as far as freezing went. The introduction of the trap had lessened the chance of freezing by causing an influx of dry air. In fact, houses, which **Prof. Bovey.**

were found to freeze before the introduction of the inlet pipe, now kept open the whole winter.

Mr. Kennedy. Mr. Kennedy remarked that the ventilation question was an important one just now. There was a By-law before the City Council at the present time on the subject, which proposed to prohibit the use of traps, which were however recommended by the Sanitary Association and the Board of Health. He asked the question, why should sewers be ventilated at all? He referred to ventilation in the true sense of the term. Of course he understood that sewers should have abundant relief openings, so that when there was a flow of water the air would be discharged. Why should a sewer be ventilated in the way a house was ventilated by the use of pipes? or an effort made to draw air into the sewers to get all the gas possible out? Why should not the gas be kept there, and relief openings used to let out what must be displaced by storm water? As to sewers with pipes and untrapped drains, he said that last winter the weather a good deal of the time was below zero, and he knew of several instances where ventilating pipes had frozen. This had been the case in his own house. A new ventilating pipe was put in, the end of which during one night was frozen, and all in the house were nearly choked. The traps were being forced and the house filled with sewer gas.

He had seen a good many miles of sewers, and thought Mr. Brittain was correct in saying that the main sewers were less offensive than the laterals. The surface sewers from the houses seemed to be the worst, and yet they knew it must be a different kind of gas altogether. An ordinary house sewer was probably very offensive, and yet perhaps not unhealthy (unless there was actual disease in the house), in the sense of gases that had become putrid from fermentation or whatever goes on in sewers. Certain gases might not smell badly and yet be deadly, while on the other hand some that smelled very badly were not deadly. A distinction had to be made as to the degrees of impurity. People living in the lower parts of the city, St. Dominique St., should not have the drainage coming from the Hospital.

Mr. Fleming. Mr. Fleming thought that the only correct system, where house drains are connected with public sewers, was to have the latter thoroughly ventilated, independently of the house drains, which should then be protected from the public sewers by a suitable intercepting trap with fresh air inlet.

It is perfectly true that in most cases where the sewers are properly constructed and flushed, the air in them is less offensive to the sense of smell than that of the laterals or private house drains; but it does not follow that it is less noxious. In one point at least, and that the most important, the air of the public sewers is more to be dreaded than that of private drains,—that is in its constant liability to contamination by disease germs. This is the great danger to be guarded against, and is perhaps one of the most fruitful causes of the spread of epidemic diseases in towns. It would not be difficult to prove that, from 80 to 90 °/₀ of the drains and soil piping in houses in Montreal are in a leaky condition, and it cannot, therefore, be the proper thing to ventilate the public sewers through them. The only way to obviate this is to ventilate the public sewers in some other proper manner, and to insert a suitable trap on the main drain of private houses between the house and the sewer. These are no real objections to such a trap. Any that have been raised have not been founded on fact. The trap has been objected to as an obstruction No doubt the old form of trap being badly designed, was a very serious obstruction, but it has now been superseded by numerous admirable and also simply constructed traps, which practically cause no obstruction to the free flow of the sewage. It is further maintained by many that the insertion of a trap on the main drain, by stopping the current of sewer air through the house pipes, causes the tops of the soil-pipes to become frozen. This statement has not been borne out by experience. On the contrary, during the very severe cold weather experienced in this city last winter, it was found in several notable instances that where traps had been inserted, the tops of the soil-pipes remained open long after many pipes connected directly with the sewers were completely frozen over. In one instance where a soil-pipe connected directly with the sewer had been in the habit of freezing during severe weather, no freezing took place after the insertion of the trap. These facts are accounted for by the trap on the main drain, excluding the large amount of moisture which accompanies the air from the sewers, and by the fresh air inlet admitting cold dry air into the house drains, both circumstances helping to reduce the chances of freezing at the top of the soil-pipes.

Mr. Fleming was further of opinion that, except in cases where the soil-pipe is in close proximity to the sewer with which it connects, the heat of the sewer air, by the time it reaches the top of the pipe, is not appreciable, in comparison with the heat generated in the house drains themselves.

The trap, moreover, is of more service than in merely excluding the sewer air from the house drains. It has other important advantages. Its insertion enables one to send a constant current of pure fresh air through the house drains, so that any leakage of gas from them is practically without danger. It further provides a point at which the flow of the sewage through the main drain can be inspected at any moment; and this is a point which no properly designed system of drainage should be without.

With reference to the fresh-air inlet freezing the water in the pipes, Mr. Fleming has never met an instance of this happening. He knew of one case where there is little or no hot water sent down the drains, and yet no freezing has occurred.

Mr. Keating. Although Mr. Rust states that his paper was prepared chiefly for the benefit of the younger members of the profession, it presents points of interest to the general rate-payer and to engineers who have had some practice in Sewer construction.

The method described of assessing the cost of the works on the property owners benefited would appear to involve a large amount of unnecessary labour upon the Engineering staff, and to be unjust to land owners on streets where large sewers are necessary. It would be interesting to know if complaints on the latter score have not arisen in Toronto. A somewhat similar system was tried in Halifax some years ago, but caused so much trouble and dissatisfaction that it was abandoned and a uniform frontage rate of $1.25 per lineal foot was adopted in preference.

In Halifax the cost of sewerage works is greatly enhanced, owing to the solid rock formation which, as a rule, is encountered. This rock is not, however, uniform. In places it extends up to or near the surface, while at other points it is found at various depths, making it extremely difficult to form any correct estimate of the cost of works before opening the ground. Under the old system of assessment, at points where little or no rock was met, the abutting owners claimed that they were not liable for the same rate as their more unfortunate neighbours, and hence disputes and litigation followed which resulted in the adoption of the uniform frontage tax.

Unless the cellars or the gas or water pipes in Toronto are very deep, it would appear to be unnecessary to place the sewers at so great an average depth as 13 feet. It is, however, a good fault if the parties interested are willing to pay the additional expense, not only on the sewer itself, but on their private drain connections, and is better than having the sewer too shallow. There would however appear to be a medium.

Mr. Rust's system of putting in curves at the street intersections is open to objections. It is desirable that all sewers should be easily accessible and readily examined. With this end in view, the writer's practice is to construct sewers almost invariably in straight lines, preferring a sharp angle to a curve where it can possibly be avoided, except on sewers of very large dimensions. At all angles and at points where one sewer joins another, a ventilating shaft and man-hole of ample dimensions are built, with a step in the bottom from four inches to a foot, or more, according to the quantity of water discharged, *i.e.*, the water from above and from the lateral sewers has a drop or fall into the man-hole. Man-holes are also provided at all changes of grade, and at about 250 feet apart, a step in like manner being formed in these also where sufficient descent is attainable without much extra cost. This fall in the sewage combined with the break caused by the man-hole is also serviceable in assisting ventilation. It will be seen by constructing sewers thus carefully in perfectly straight lines from man-hole to man-hole, that it is a simple matter to examine them at any time, by simply sighting from one man-hole to the other, and as a precaution such an examination should be made yearly. Different engineers no doubt adopt different methods in setting out and carrying on work. The method preferred by the writer is to cause line and level pegs to be driven a few feet to one side of the trench and from 50 to 100 feet apart. Boning rods are used by the foreman of laborers, but not by the bricklayers, who are furnished with a straight edge from 12 to 15 feet in length, carefully planed to the required grade. By this straight edge they first check the grade from one station to another. If there is the slightest discrepancy, attention is at once called to it, and if not they proceed to lay the invert. It is seldom that differences of over ½ an inch have been detected where ordinary care has been exercised. By this method the superintending engineer's labour and anxiety are reduced to a minimum. The writer's experience with earthenware pipes was so unsatisfactory, some years ago, and the difficulty so great of persuading the city authorities to purchase and use none but the very best, that he has since abandoned their use almost entirely for public sewers. It is an unusual thing in the city of Halifax to find a pipe sewer of over 12 inches in diameter in a perfect state. On examination they are found to be so badly cracked, that it is a wonder how or why they hold together at all. Sometimes they do not hold together. Good, sound and well burnt vitrified pipes, of course, ought not under ordinary circumstances to be rejected, but considerable care is needed when laying them in rock excavations, or in fact almost anywhere. They are very apt to be seriously injured in several ways, and especially by large stones thrown into the trench before there is sufficient covering over the top. A case occurred in Halifax, in clay soil, some years ago, where a long length of 15 inch earthenware pipes collapsed entirely, a few months after being laid. The work was done late in the Autumn or early in the Winter, and before the trench could be filled in the ground became frozen. The frozen earth and clay were injudiciously thrown back and placed around and over the pipes. In the Spring the sewer had ceased to exist, and another had to be laid.

Within the past two years moulded invert blocks made of Portland cement concrete have been used in all brick sewers, in the city of Halifax, with very great advantage and satisfactory results. The smallest brick sewer adopted, up to within a couple of years, was 18 in. × 12 in., but latterly the minimum size has been increased to 21 in. × 14 in. as it was found to be no more expensive than the other, owing to the fact that the masons could work to more advantage, while the cost of laying bricks per 1000 was less than in the smaller sewer. Wedge-shaped bricks are used, of a uniform make, wherever they will work in, so as to avoid cutting, or large gaping joints at the back, small sewers taking, of course, more in proportion than large ones.

During the past season some of the sewers have been built entirely of concrete blocks, which are found to be more economical than brick work. In sewers where double brick work is required, the saving is very considerable, and the work so far, has been highly satisfactory, and presents a very neat appearance.

These blocks are cast in wooden moulds, and are made in sizes not larger than can be conveniently handled by two men. The concrete is composed of one part Portland cement, two parts ordinary sand, two parts very coarse sand or small gravel, and four parts road metal. The work is performed by the paupers at the Halifax Poor House, and the Commissioners of Charity are paid for this labour at the rate of 7 cents per cubic foot of concrete produced, the city furnishing all materials. The blocks ought to be kept three months before being used, but in time of need they have been placed in the sewers when only three weeks old. Although masons have been employed in building these blocks into the sewers, there is no reason why intelligent laborers under proper supervision could not perform the work equally well. In fact, laborers were at first employed by the writer in laying the concrete inverts, but owing to the opposition of the Bricklayers' Society, and their refusal to allow a society man to work on the same job, the practice was discontinued.

It may be asked, if concrete can be used to advantage in sewer construction, why not make and deposit it in place at once, and save the cost incurred by producing it in blocks. There is no reason why this may not be done. There is, however, likely to be a difficulty in arching small sewers in this way, owing to the length of time the centres would have to be left in and the short distances that it would be practicable to arch over at one time. In large sewers, capable of admitting a man easily, a number of centres could of course be employed next to each other, and be removed from the inside when the concrete had sufficiently set, which would obviate leaving a long length of trench open at one time.

Owing to the difficulty of obtaining proper and thorough inspection, and the frauds which many contractors are known to resort to when the least opportunity occurs, not only in the execution of the works, but in trumping up claims of every imaginable kind, the writer prefers carrying on sewerage works as a rule by days' labor under efficient foremen. In his experience this method has produced the most satisfactory results, and he cannot, at present, recall an instance when the cost of a single sewer so constructed has not been very considerably below the lowest tender. In the last sewer constructed by him, in this way, a few weeks ago, the work was carried out for about half the amount of the lowest tender.

In answer to Mr. Evans as to the advisability of placing the grade stakes four feet from the edge of the cutting, it may be stated that in ground at all liable to slip, it is to be recommended. Mr. Rust.

The author can corroborate Mr. Evans' remarks as to opening trenches of sufficient width. Unfortunately in several cases, the con tractor, from mistaken ideas of economy, has narrowed the trench with the result of causing serious loss and delay.

The use of invert blocks has not yet been introduced into Toronto although at the present time it is in contemplation to have some for small brick sewers. It does not appear to be advisable to use too much water in the trench. It would seem that the failure of some of our pipes has been caused by a too liberal use of the hydrants.

Water used in moderate quantities does much to consolidate the earth. One of the author's reasons for prefering Scotch pipe is that they are of a greater thickness than the American, the majority being 1-12 of the diameter; and it is now proposed to specify that the American pipe must be of the same thickness. The quantity of cement used for jointing pipes varies of course with the diameter and class of pipe used. The following is about the average:

Scotch pipe.					American pipe.			
12,"	1 bbl.	will lay about		600 ft.	12,"	1 bbl.	will lay	760 ft.
15"	"	"	"	450 "	15"	"	"	600 "
18"	"	"	"	375 "	18"	"	"	500 "

Gasket is used in all cases.

The author cannot account for so many broken pipes. The Scotch pipe seemed to have failed more frequently than the American, the 18 in. being those most generally found broken. The Committee on Works has recently decided to build all sewers of over 12 in. diameter of brick, 14 in. × 21 in., for 15 in., and a slightly larger size for 18 in. pipes. As the cost is from 10 to 15 per cent. more than pipe, and as from a sanitary point of view brick sewers are not to be commended, the author is satisfied that if this extra 15 per cent. were spent in furnishing concrete, pipe sewers could be laid with entire success.

Mr. Macdougall is perfectly correct in his remarks as to the preference of our sewer men for a two ft. over a three ft. length. It is further probable that we did not always get the very best class of pipe either Scotch or American. The class of pipe laid during the past 12 years has been of a better description than that previously used.

Mr. Trotter's interesting account of the manufacture of the pipe as carried on at his factory is of great importance, and it is satisfactory to know that a good reliable pipe is being manufactured in Canada.

It is sincerely to be hoped that our cement manufacturers will make an effort to turn out a first class article. The opinion of the members as to the uncertain quality of our Canadian cement is practically unanimous. There is certainly a wide field here for an energetic man with a good knowledge of the various ingredients necessary to make a first class brand of cement. It is sincerely to be hoped that this discussion will be the means of shewing our cement makers the necessity of turning out a good and reliable material. In reply to Mr. Mohun, as to the practice of laying pipe sewers with a curve, the author would state that, in his opinion, when building sewers of over 12 in. diameter, the curve is to be preferred. Generally speaking, his practice has been to locate a manhole at both ends of the curve, and also to give the curve a slightly increased fall. It seems to him that the volume of water that frequently comes through a 15 in. or 18 in. pipe, enters the connecting sewer far better than when only a short curve is made in the manhole. It might be stated that with nearly 140 miles of sewers in charge, we have never had a stoppage in a curve that could not be overcome by flushing. Any sewer that is reported to be in a bad condition is immediately flushed. There are a few brick sewers, constructed some years ago, that require constant attention. A pipe sewer of half the area would keep itself clean.

The allowance of 50 percent. of a rainfall being evaporated seems about correct for ordinary streets; but in the centre of the city, on well paved streets, it is almost certain that after a sudden storm, as much as 75 per cent. will sometimes reach the sewer. Mr. Rudolph Hering in his investigations of the sewerage of New York city found that it reached 90 per cent. in some instances. Timber is rarely left in the trenches except in the case of a water or gas main running close to the open excavation, or in a narrow lane with tall buildings on each side; of course leaving the timber in increases the cost considerably. The failure of pipes is sometimes caused by the sudden drawing of timber. It used to be the practice in Toronto to drive 2 in. runners down to the bottom of the trench, and when in bad ground, the sudden withdrawal of these sometimes caused trouble. The practice now, except in very bad ground, is to put in three or four frames of 1-in. boards 4 ft. long.

When the timber is ordered to be left in by the engineer, the contractor is paid for it at the rate of $10 per 1000 ft., B.M.

The ventilation through manholes, seems to answer very well, even in winter, the warm air forcing its way up and melting the snow on top of the iron grating.

Prof. Bovey's table on the cost of excavating is very valuable. We used one of Carson's excavating machines here last summer, on a sewer of about an average depth of 20 ft., the soil being a good clay, fairly easy to handle. The cost was found to be fully 20 cts. per cubic yard less. The machine will pay well in good ground and where the depth of excavating exceeds 12 ft. It is also valuable in narrow streets or where the traffic is not to be interrupted. It is good for winter work as the earth is immediately dumped back on the completed portion of the sewer.

In reply to Mr. MacPherson, in reference to broken pipe, the speaker meant that the majority of pipes were broken into four pieces, the balance into two pieces.

The author hardly understood Mr. Metcalfe's reference to sewers not built with curves. In the so called separate system, in small sewers the junction is made in manholes. But in pipe sewers of 15 or 18 in.

diameter or in brick sewers, the curve is far from "obsolete" and the flow is certainly not impeded especially with curves of a radius of 30 to 40 ft.

In reply to Mr. Evans as to tunnelling, the author's experience has been limited. We do not fix upon any arbitrary depth. In some narrow streets or in winter, we sometimes drive headings at a distance apart of 15 to 20 ft., and we have carried on work in open cuttings at a depth of 30 ft. A paper on the construction of sewers in tunnels would, no doubt, be interesting.

In reply to Mr. Keating, as to assessing the cost of sewers, it might be stated that so far there has been no objection on the part of the ratepayers to pay for their portion of the work.

It may not be out of place to give a more detailed account of the manner of making the assessment.

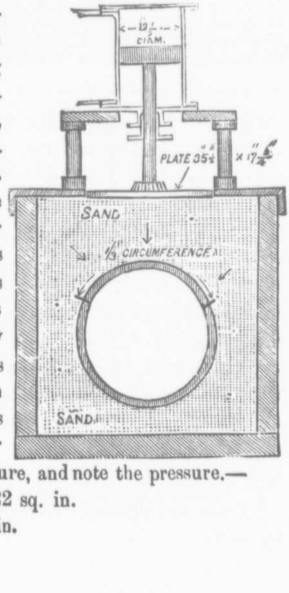
The ratepayers may petition for the work, or the Engineer may take the initiative and recommend the sewer on sanitary grounds, giving at the same time an approximate cost. The assessment commissioner then sends notices to each ratepayer on the street, giving the date of calling the Court of Revision, with the frontage of the party assessed, also an approximate cost of the work. The Court of Revision meets and hears the complaints if any. Its duty is to hear all complaints of wrong measurements; but sometimes on a vigorous complaint from some property owner, it will refer the whole matter back to the Committee on Works for reconsideration; this, in the case of sewers, is very rarely done. If the Court of Revision confirms the assessment against the opposition of a ratepayer, he has the privilege of carrying the case to the County judge; this is frequently done, especially in the case of a property owner who claims that the sewer is not deep enough to drain his property. The judge's verdict is in all cases final. After the Court of Revision has confirmed the assessment, the contract is let and the work proceeded with. On the completion of the work the total cost of the work is made up and a By-law drafted, apportioning to each ratepayer his share of the costs per foot frontage.

The ratepayers have again an opportunity of appealing. After the Court of Revision has finally passed the work, the By-law is read a third time and passed. The city of Toronto has certain special powers relating to the construction of sewers, giving the City Engineer authority to construct, regardless of opposition, sewers which he considers necessary on sanitary grounds and for drainage purposes.

It may be wondered why one sitting of the court would not do all that was necessary; this used to be the case, when the approximate estimate was inserted in the By-law. There was often a surplus after the sewer was constructed. This was applied to other purposes, and gave rise to the "Sewer Surplus Scandal;" the law was then altered, and it works very satisfactorily.

In the case of the large intercepting sewers that have been built, the city as a whole has borne the cost. The average depth of the lateral sewers is between 11 and 12 feet, the main sewers on streets running north and south averaging 15 feet. This depth is rendered necessary to enable the cross streets which are very flat to be drained.

As previously stated, the author cannot agree with Mr. Keating's objections to curves, especially in the case of sewers of over 12 in. diameter. Curves have always been used here, and have answered very well. It would seem that one cause of the failures of pipes in Halifax is owing to the rock formation. It would seem that with proper care in selecting pipes, and by using due precaution in laying, a good and permanent sewer can be constructed, with the advantage of economy, and, from a sanitary point of view, preferable to a small brick sewer of the same area.



Sewer Pipe Testing.—The machine in use for this purpose may be described as being of the direct acting hydraulic type. The pressure is obtained from the city Water-works, which will range up to 80 lbs. per sq. inch. This is supplemented by a force-pump, which will give a pressure on the piston in the hydraulic cylinder up to 300 lbs. per square inch. Pipes to be tested are treated as nearly as possible under the same condition as when laid for sewer purposes; they are buried in a bed of sand which is rammed tightly in a strong wooden casing, so that only one open end is exposed. By this means the operator is able to see the first indication of fracture, and note the pressure.—

Area of upper surface of piston = 122 sq. in.

Area of pressure plate = 630 sq. in.

Note, the surface of pipe acted upon by pressure taken as $\frac{1}{3}$ pressure circumference × length of pressure plate actually pressing on pipe.

Longitudinal section = sectional area of pipe through one side = length of pipe under pressure × thickness.

During the past month some tests have been made of the various kinds of pipes used. The following table gives the result :—

No. of Test.	Maker	Laying Length	Weight	Thickness	Diameter	Breaking pressure on gauge	Total pressure on surface of pipe	Pressure per sq. inch of surface	Pressure per sq. inch on longitudinal section
			lbs.	ins.	ins.	lbs.	lbs.	lbs.	lbs.
6	American. Buffalo.	2′.0.″		$1\frac{1}{8}$	15	72	8,784	19.2	289.2
7	Canadian. Hamilton.	2′.0.″	110	$1\frac{1}{8}$	15	82	10,004	21.9	329.4
8	American. Akron.	2′.0.″	148	$1\frac{1}{8}$	18	75	9,150	16.9	301.2
9	Do. Do.	2′.0.″	152	$1\frac{1}{8}$	18	65	7,930	14.5	261.1
10	Canadian. Hamilton.	2′.0.″	152	$1\frac{5}{16}$	15	230	28,060	60.8	791.9
11	Do. Do.	2′.0.″	92	1	12	125	15,250	41.5	564.8
12	English.	2′.6.″	167	$1\frac{1}{4}$	15	160	19,520	34.7	472.9
13	Scotch. Cartcraig	3′.0.″	150	$1\frac{1}{4}$	12	200	24,400	48.8	542.2
14	English.	2′.6.″	100	1	12	80	9,760	21.0	295.7
15	Scotch. Cartcraig.	3′.0.″	110	$\frac{15}{16}$	12	225	27,450	56.6	813.3
16	Do. Do.	3′.0.″	184	$1\frac{1}{4}$	15	200	24,400	38.8	542.2
17	English.	2′.6.″	230	$1\frac{3}{8}$	18	100	12,200	18.3	266.6
18	Scotch. Glenboig.	3′.0.″	230	$1\frac{5}{16}$	15	200	24,400	39.6	516.0
19									

With a good system of inspection, certainly no stones or frozen earth ought to be thrown on top of the pipe. Mr. Keating does not state the brand of pipe that collapsed so badly.

It would be interesting if some member could furnish detailed costs of concrete sewers as compared with the cost of those constructed in brick.

The class of work now being done on the sewers by the contractors is of good quality; the inspection is very rigid, and the inspectors (who are all members of "The Union") are held strictly to account. If a sufficient number of good foremen can be obtained, there is no doubt that in the majority of cases the city can construct sewers cheaper than by contract work, especially where a "little combine" exists as is sometimes the case.

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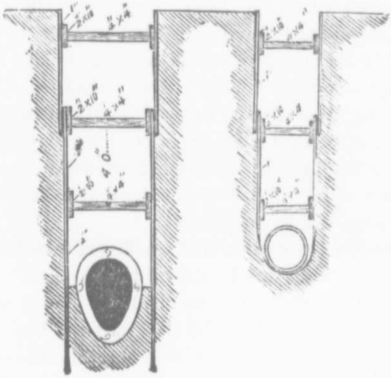
* From the drawings accompanying the paper Plate 11 has been prepared.

NOTE 1.—The subjoined sketches shew the system of timbering employed in trenches for brick sewers and tile pipes, in Toronto.



Thursday, 22nd November.

E. P. HANNAFORD, Vice-President, in the Chair.

Paper No. 23.

COAL MINING IN NOVA SCOTIA.

By E. Gilpin, Jr., A.M., F.G.S., F.R.S.C., etc.

Deputy Commissioner and Inspector of Mines.

The earliest discoverers do not mention coal in their accounts of Cape Breton, although its outcrops in the sea cliffs are visible for miles. The first printed account is found in Denny's work, published in 1672. In 1711 considerable amounts of coal were taken away by the French and English, being broken out by crowbars, and loaded into boats. The building of the great fortress of Louisberg in 1720 led to the first regular coal mining in the Island of Cape Breton. The great numbers of artificers, soldiers, etc., engaged in its construction were supplied with fuel from the ten feet seam on the north side of Cow Bay, now known as the Block House seam. These old workings were carried on above water level, and can still be entered.

During the English occupation of Cape Breton from 1745 to 1749, the beds of coal at Burnt Head and Little Bras D'Or were drawn upon for fuel, and block houses were built to protect the workmen against the Indians and Pirates. In 1752 the pit at Burnt Head took fire, and the fort and other buildings were burned. The traces of the fire are still visible for nearly a mile along the outcrop of the seam. From this date until 1784, when Cape Breton was erected into a province, little was done in the way of coal mining. No satisfactory leases were issued, and the records show little beyond the supplies of fuel dug by the soldiers for the garrison at Halifax, and the steps taken to prevent theft of the coal by Americans, etc.

In 1820, when the island became part of the Province of Nova Scotia, more decided steps were taken, and considerable amounts of coal were mined from the Sydney main seam. Finally, in 1827, all the mines of the Province passed into the hands of the General Mining Association of London. It may be remarked here that in the Pictou and Cumberland districts the coal seams attracted less attention, as they were not so accessible as in Cape Breton; but previous to 1827 numerous attempts were made to open mines in Pictou County. The causes of the ill success of all these ventures hitherto made were the excessive royalties charged, the shortness of the leases, two to five years, and the want of a regular market.

From 1785 to 1827 the annual coal sales in Cape Breton varied between 2,000 and 11,000 tons. The selling price per ton being about $2.50. The royalties charged were from 60 to 90 cents per ton.

The transfer of the crown mineral franchises of the Province was a curious one, and marks almost the last of the excessive prerogatives exercised by the English crown in colonial matters. The Duke of York having become greatly embarrassed financially, his brother King George the Fourth, by an act of the Royal prerogative, granted him for 60 years all the mines and minerals of the Province, subject to certain rents and royalties, for the purposes of the provincial civil list. This princely gift, recalling the generosity of eastern potentates, was transferred by the Duke of York to the great firm of London jewellers, Messrs. Rundell & Bridge, who had organized the General Mining Association of London, for the purpose of acquiring and working mines in various parts of the world.

This company expected at first that the copper ores of Nova Scotia would prove a source of revenue to them, but after a careful mineral survey they decided to turn their attention to the coal deposits. They vigorously opened mines at Sydney, Bridgeport and Lingan in Cape Breton, in Pictou County at a point now known as Stellarton and at the Joggins in Cumberland County, and worked them with varying success up to the year 1858, which saw the opening of a new page in this history.

The monopoly was at first viewed with great approval in the Province, and the immense expenditures necessarily involved in starting these mines, and their equipment of foundries, machine shops, tramways, etc., were favorably received by a scattered population, entirely engaged in farming, fishing, and lumbering. In a few years, however, as population and enterprise increased, the restrictions of so great a monopoly began to cause irritation, which found expression in many an angry speech in the Provincial Legislature. Finally in 1858 the General Mining Association agreed with the Province that they would retain for a term of 18 years certain large tracts of coal lands, with powers of extension under lease, and surrender for ever all other coal seams and other minerals. The consideration for this was the reduction of the royalty on large coal to $4\frac{8}{10}$ d, and the abolition of the fixed rent of £3,000 per annum. The General Mining Association under this agreement retained possession of 46 square miles of coal lands. These areas were selected by Mr. R. Brown, then their general manager, with excellent judgment. His work on the coal fields of Cape Breton gives the Coal mining history in full detail.

By the judicious and well timed compromises made by the four parties interested,—the crown, the representatives of the Duke of York, the Province of Nova Scotia, and the Association, a happy settlement of this great monopoly was arrived at. The incubus of a single corporation, owning by an unassailable title the varied minerals of a Province, in great measure settled by those who left the rebel colonies to live under the English flag, was happily removed in time to prevent the development of feelings inimical to the powers that thoughtlessly perverted the guerdon of nature to those who had, by the greatest possible test, demonstrated their loyalty.

The energy and wealth of this Company was of great benefit to the Province, and its conduct and that of its chief officers has ever been honorable, and calculated to set an example of honesty and reliability. The Association has now disposed of all the coal lands owned by it in Nova Scotia proper, and retains its selections in Cape Breton, operating chiefly in the historical Sydney main seam, which has been drawn upon by the miner for over one hundred years.

The natural result of the unlocking of so vast an amount of possibilities of mineral wealth beyond the dreams of avarice followed this settlement. The development of the gold, gypsum and other minerals immediately followed the period during which the simple farmer doubted if clay were a mineral or not. The Government upon the completion of the agreement threw open the coal districts, and leases were readily obtained. A large number of collieries were opened and much speculation indulged in. The 24 per cent. ad valorem duty on coal going into the United States having been removed in 1853, it was anticipated that an unbounded market was assured. The total sales in 1858 were 226,725 tons, of which 186,743 were sent to the States. From this date up to 1867, when a duty of $1.25 was imposed, the exports to the United States had increased to 404,252 tons out of a total sale of 471,185 tons.

In 1872 the duty was lowered to 75 cts., when the United States took 154,092 tons out of 785,914 tons sold. Last year the State took 73,892 tons (of which about 50,000 tons were smalls) out of a total of 1,519,684 tons sold. These figures show the steady growth of the home markets, and the fact that there is at present little room for Nova Scotia coal in the New England markets. The mutual removal of the duties on soft coal would, in the opinion of many of the provincial coal mine managers, result in the almost total loss of the Upper St. Lawrence trade, without any prospect of replacing it by a trade with the Eastern seaboard of the United States, which would have to start with a basis of at least 750,000 tons.*

The following Tables show the coal sales to the United States for number of years, and the annual sales to all quarters by decades:—

* The ton of coal in this paper is 2,240 lbs.

COAL.

NOVA SCOTIA EXPORTED TO THE UNITED STATES.

Years.	Tons.	Duty.	Years.	Tons.	Duty.
1850	118,173	24½d.	1869	257,485	$1 25
1851	116,274	"	1870	168,180	"
1852	87,542	"	1871	165,431	"
1853	120,764	"	1872	154,092	75
1854	139,125	Free	1873	264,760	"
1855	103,222	"	1874	138,335	"
1856	126,152	"	1875	89,746	"
1857	123,335	"	1876	71,634	"
1858	186,743	"	1877	118,216	"
1859	122,720	"	1878	88,495	"
1860	149,289	"	1879	51,641	"
1861	204,457	"	1880	123,423	"
1862	192,612	"	1881	113,728	"
1863	282,775	"	1882	99,302	"
1864	347,594	"	1883	102,755	"
1865	465,194	"	1884	64,515	"
1866	404,252	"	1885	34,483	"
1867	338,492	$1 25	1886	66,003	"
1868	228,132	"	1887	73,892	"

Nova Scotia coal sales from 1785 to 1887.

Year.	Sales.	Year.	Sales.
1785 to 1790	14,349	1841 to 1850	1,533,798
1791 to 1800	51,048	1851 to 1860	2,399,829
1801 to 1810	70,452	1861 to 1870	4,927,339
1811 to 1820	91,527	1871 to 1880	7,377,428
1821 to 1830	140,820	1881 to 1887	8,992,226
1831 to 1840	839,981		

The following figures will show the markets in which Nova Scotia coal is being sold at present:—

COAL.—SALES.—1887.

Markets.	Year 1887.
Nova Scotia :	
Land Sales	266,005
Sea borne	203,459
N. S.—Total	469,464
N. Brunswick	186,511
Newfoundland	82,053
P. E. Island	50,615
Quebec	650,858
West Indies	6,140
United States	73,892
Other countries	151
Total	1,519,684

The limits of this paper would be too extended were the geological and chemical particulars of the Nova Scotia coal beds to be given here, and the author trusts that at some future time the Society may see fit to allow a description of them to find a place in the Transactions.

The coal of Nova Scotia is bituminous and frequently coking, the differences in quality between the various districts being referable perhaps to local conditions of pressure, etc. Stratigraphically the Cape Breton seams hitherto worked are flat lying, those of Pictou and Cumberland are pitching, the average of the former being, say, 1 in 10, of the latter 1 in 3. The thickness of the seams worked in Cape Breton varies between 4 ft. 9. in. and 9 feet, of the Pictou seams 4 to 15 feet, and of the Cumberland seams 3 ft. 6 in. to 11 feet. The conditions of floor and roof vary in each mine but do not present any striking peculiarities. In the thicker seams when the roof is bad, it is sometimes practicable to leave on a few inches of coal to assist in supporting it. In some cases this coal is recovered when the pillars are drawn.

The earliest operations in the pitching seams of the Pictou district were conducted by sinking pits to gain successive lifts. The Pictou main seam, having a thickness of 38 feet, has so far been mined on two systems, of which the following account, taken from a paper read by the author a number of years ago before the North of England Mining Institute will serve as a description. The first system has now been abandoned, but it is interesting, as by it the coal was taken to the full height.

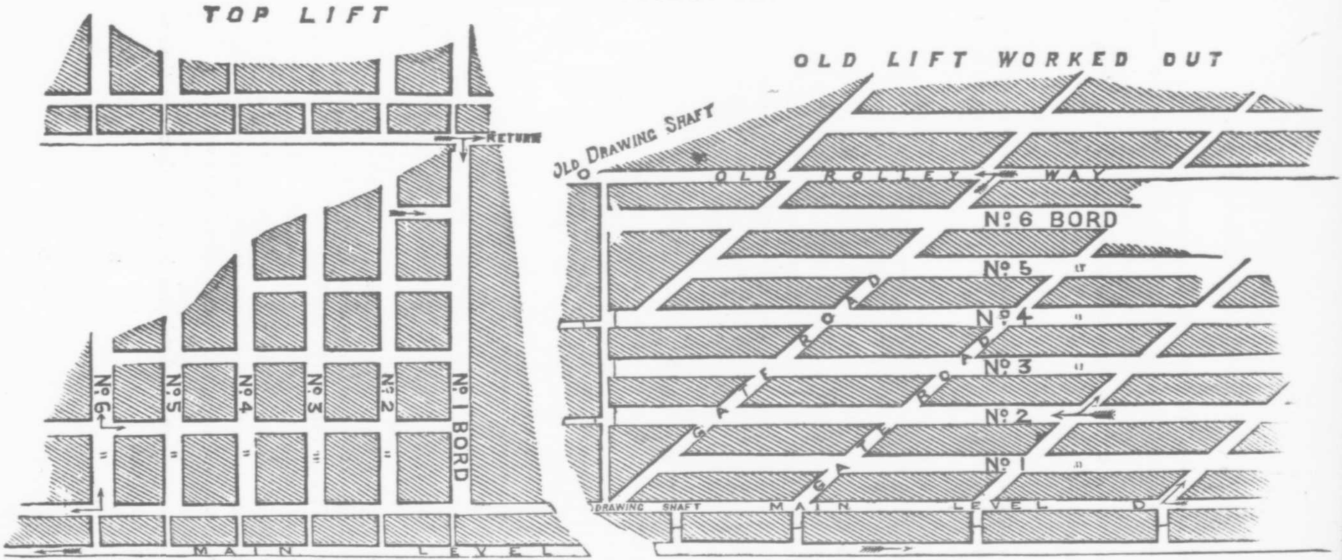
Levels were turned right and left from the pit, and when the shaft pillar was won, incline or gate roads were driven uphill, one half on the angle of the seam, every 50 yards. Six "bords" or working places, 18 feet wide, were turned away as the gate road went up, parallel to the levels, and at distances far enough apart to secure pillars 8 to 10 yards thick. Eighteen inches of coal were left on as a roof. These "bords" were driven 12 to 15 feet high, and continued until intersected by the next "gate" road. Rails were laid up the gate roads, and into the bords, and over them the tubs, holding 12 bushels, were drawn by horses, into the working faces, filled, and taken down to the level. The force of the loaded tub descending the inclined gate road was lessened by fastening to the rear of the tub a loose chain passing round a stout post, fixed at the head of the gate road, and dragging on the ground.

When it was determined to work the lower division of the seam, the same gate roads were driven level until the bottom of the coal bed was reached, and then continued as before. The second lift of 15 to 20 feet in height was taken out in bunches of regular open cast work in the former bords already worked in the top of the seam. Beams of 6 inch timber placed horizontally at the level of the pavement of the former bords secured the sides of the pillars, and if the roof proved bad, props were set on them. This plan of working was attended with much danger to the miner. His eye could not reach the roof of these murky chambers, and his candle's gleam was reflected only by the white fungus which covered the timber. The shape of the pillars at right angles to the dip, narrow, and having long jibs, was not calculated for strength. The dip of the seam rendered the course of the bords imperative, and the ribs were weakened by the cleat of the coal running obliquely across them. These pillars were never robbed, and have now nearly all crushed. As considerable amounts of gas were given off, ventilation was attended with difficulty, and serious fires happened, some of which were put out only by filling the workings with water.

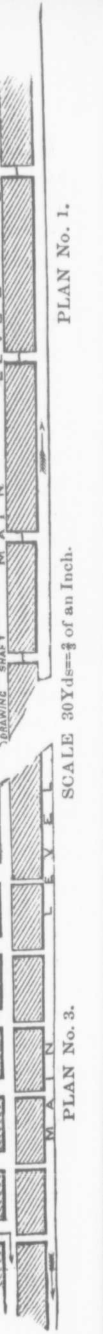
The accompanying sketch plan No. 1 will show how these workings were laid out.

MAIN SEAM WORKINGS

PICTOU CO.



PLAN No. 3. SCALE 30Yds.=$\frac{2}{3}$ of an Inch. PLAN No. 1.



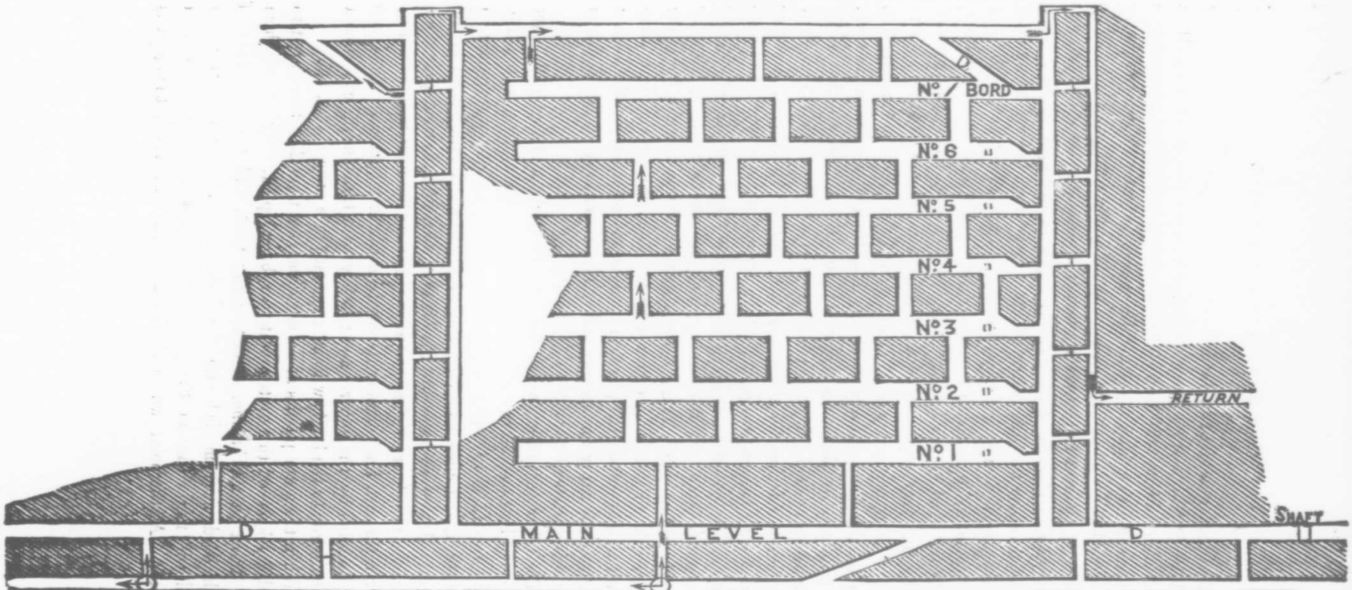
The plan now most in favor is to drive a "balance" 10 feet wide and 10 feet high from the level straight to the rise of the seam for a distance of about 450 feet. One or more parallel airways are driven at the same time, and of smaller dimensions, in order that the necessary air may be carried uphill and down again as the work progresses. Two tracks of about 2 feet gauge are laid in the balance to within 20 feet of its face. Upon one of these tracks is placed an empty tub to be filled with ballast, on the other a truck having its floor made level through one pair of wheels being greater in diameter than the other. A section of rail corresponding in gauge to that used in the pit is laid on the platform.

At the head of the balance is placed a drum, having a powerful brake, and two ropes leading to the ballast tub and platform. The former being at the top of the balance, and the platform standing in a gap in the level railway or in a siding from it, a continuous track is obtained by the rails referred to on the platform. An empty tub being pushed on the platform it is evident that the road becomes self-acting, for the tub, at the top of the balance, on being loaded with ballast, will by its weight draw up the empty tub and platform. The platform can be arrested by means of the brake opposite the mouth of any of the bords which are driven similarly to those already referred to. There being a section of track in the bord, the empty tub is landed and replaced by one filled with coal. This additional weight causes the platform to descend and draw up the ballast box which is ready for another tub. The accompanying sketch shows how this system of work can be laid out.

The pillar above the level is left 50 feet thick, and the bords start from the balance and run level for about 150 yards to the next balance. They are 15 to 18 feet wide, and 12 to 15 feet high, with pillars 35 feet thick, and cross cuts for air every 60 feet. The top bord is frequently driven through into the next balance, and the rest squared up, leaving a thin barrier of coal; but to gain time the next balance can be driven through the pillars of the bords of the first balance. The boxes are handled by the miners, and two boys can transfer the coal from a dozen bords to the level, without any assistance from horses, etc.

When the seam pitches at an angle heavier than 25° there are two modifications of this system that can be adopted. By one of them the track in the balance is done away with, and the coal tubs of each bord are emptied into the balance itself. In this case the coal will run either in the pavement or in a shoot made of iron sheets. At the point where the balance meets the level, the shoot is

METHOD OF WORKING PITCINHG SEAMS.—NOVA SCOTIA.



SCALE 30 Yds.=⅜ of an Inch.

PLAN No. 2.

carried at a lessened angle, so that it will project into the level at a height sufficient to allow the pit tubs to pass under its mouth. They are filled by lifting a door at the mouth of the shoot opened by the driver with the assistance of a lever. In the other modification the bords are driven direct to the rise from the level and a shoot laid in each one. The coal is loaded from the shoots on the level in the manner just described. This system has not been generally approved of from the difficulty of airing so many uphill places, and the cost of getting timber to the faces, etc. On the other hand, the cost of material is less, there being no rails or tubs required in the bords, and the pillars are formed parallel to the dip of the seam.

In the Pictou and Cumberland districts, of late years, the seams, whenever local conditions permitted, have been opened by slopes. The slopes are usually driven in pairs with one or more back slopes for ventilation. A crop pillar of two or three hundred feet being left, the first levels are turned away at a distance of six or seven hundred feet from the crop, and operations carried on as from a shaft. The slopes are driven wide enough to admit of a double track of the gauge of the pit tubs, usually from 1 ft. 6 ins. to 2 ft. 6 ins., and provided with the usual switches. The signalling is done by wire signal cord striking a gong or giving a blow by means of a hammer on an iron plate. This method answers with a well stretched wire neatly hung and smartly handled, but electric signals would prove more satisfactory. The writer understands that the experience of H. S. Poole, Esq., agent, with electric signalling at the Acadia Colliery, is so far satisfactory. Telephonic communication, between the pit workings and the bank head has been tried, but at present is in operation only at the Vale Colliery. There is an arrangement made at some mines, whereby the ascending train of loaded tubs by striking a lever a few yards before the bankhead is reached rings a bell in the engine room, and cautions the engine tender. To prevent the empty tubs from running down the slope should they escape the banksman's hands, a weighted lever is placed at the head of the slope, between the rails of the track for the empty tubs. When at rest, the unweighted end rises above the rails so as to engage with any descending tubs, while it offers no obstacle to the passage of ascending tubs, which are heavier than the weighted end.

In the flatter lying seams of Cape Breton, the methods of winning and working the coal do not differ materially from those common in England. Usually the levels are driven in pairs from the shaft bottom.

Gate or horse roads are turned away from them, and the bords opened out of the horse roads at such angles as may best suit the requirement of the mine. As the bords advance the gate road is frequently turned up the first bord until it reaches a point near the working faces, when it resumes its normal course, so as to shorten haulage.

At the Gowrie Colliery bords are driven eleven yards wide and the pillars left seven yards thick. When the bord is first started a road is laid on each side, and the dirt, etc., stowed in the centre. Afterwards a cut is made through the stowage, and the double road maintained only at the face. By this system under a moderate cover, the maximum of coal is got at the first operation, and the drawing of the pillars when the rooms have gone their distance, should give a good pillar coal with little danger of creep.

Pillarage.—The shape and size of pillars varies with the depth of the seam, and the nature of the roof. The earliest workings along the crops of the seams left small square pillars, which have frequently crushed and caused trouble by the admission of surface waters.

At Springhill between the 1,300 and 1,900 feet levels, the main "level pillar" is 100 feet thick, then succeed 12 feet bords, with 35 feet pillars, with the middle pillar of the balance 50 feet thick. There are seven bords on each balance, and the block of coal between the 1,300 and the 1,900 feet level is 550 feet wide. The loss of coal in working the bords and heads is about 18 per cent., and when taking out the pillars the loss is 15 to 20 per cent. in the high coal (9–14 feet), and in the low coal (4 feet thick) about 5 per cent. At the Albion Colliery, when working nine to fifteen feet of the upper part of the main seam at a depth of 900 feet, the bord pillars were left 35 feet wide and from 75 to 100 feet long, the level pillars being a little thicker.

In Cape Breton, at the Sydney (main seam) workings, in the earlier mining, the bords were 6 or 7 yards wide, and the pillars 10 by 14.5 yards. In the Queen Pit workings, 360 feet deep, the bords were 5½ yards wide. In the present workings, 600 to 800 feet deep, the size of the bords has not been altered, but the pillars have been made a little larger.

These examples will serve to show the practice generally adopted. In a few collieries the extraction of pillars is systematically carried on, and usually closely follows the completion of a panel of bord and pillar workings. No regular rule has been laid down for the initiation and conduct of the operation. In some mines, as soon as the workings of any lift are finished, the pillars are drawn back; in others the pillars of each balance or shoot are drawn to suit the trade. The experience so far gained is in favor of the former practice. Frequently, the extraction is so arranged, that the upper pillars are worked in advance of the lower ones, under a belief that by this means the roof is most readily let down and settled. In other cases the line of the full dip is taken as the range of the working faces.

The top and bottom pillars, forming the high and low sides of the levels of the various lifts, are allowed to remain untouched, in order to provide for drainage, etc., or the bottom pillar, immediately above the main level, is left to be taken out in the extraction of pillars in the next lift, whenever there is other provision made for air, etc. The pillars are either attacked from the lower end next the goaf, and carried back the full width, or a head is driven into the pillar and widened out sideways, first toward the goaf and then backward. The aim is to allow the roof to fall as quickly and completely as possible, to prevent weight from being thrown down-hill on the levels or any lower workings, and the timbering is proportioned so as to afford protection only for the removal of the succeeding pillar. But it will be understood that in steep seams, with questionable roof, having a thickness of 10 to 15 feet, no hard and fast rule can be carried out.

In the flat lying seams of Cape Breton, little pillar work has been done except at the Caledonia colliery, where the pillars lying under a pressure of 100 to 200 feet, and of good dimensions, have been successfully drawn.

In many cases, however, the pillarage has been viewed rather from the standpoint of a support to the roof than as a future supply of coal. The great question is that of water, and no doubt in many of the Cape Breton collieries worked at shallow depths, the increased pump costs would, at the present price of coal, outweigh any gain from the cheapness with which it can be mined in comparison with bord coal. At present the most advanced mining practice in the province, is in favor of moderate sized pillars, to be drawn at the earliest possible moment. Even adopting this principle, except in the case of a few mines, the conditions of trade are unfavorable to extended and systematic pillar workings at considerable depths, for the shipments are interrupted during the depth of winter. When pillars are not taken out, the percentage of coal removed may vary between 25 and 35 per cent., when they are drawn, as high as 90 per cent. of the seam has been gained.

In Cape Breton the coal lying, as already mentioned, at easy angles is attacked through shafts, except at the Victoria and Reserve collieries. At the Victoria mine, at Low Point, the seam lies at a heavy angle.

Here two slopes spread out on the half pitch of the seam, and have, intermediate between them, one driven on the full pitch of the seam. This is used for ventilation and pumping, and will ultimately serve for the tail ropes of a system of haulage, which will pick up the tubs in the level and haul them direct to bank. The empty tubs running down the slopes by their own weight, will be taken along the levels by the tail ropes. This arrangement will do away with the level horses. The balance system has been adopted here.

At the Reserve mine, the seam was opened by a slope, but the mining wisdom of this procedure is doubtful, the seam lying at so low an angle that the empty tubs are landed with difficulty at the bottom of the slope. In order to provide more pit room, at a point in the slope, about ten chains from its mouth, a steeper slope, having an inclination of one in three and a half, has been driven to intersect the Emery seam lying 95 feet below the one at present worked.

The following Table shows the depth of the main shafts of the principal collieries:—

Sydney,	681 feet.	Round diameter 13 ft.
International,	87 "	14·5 by 16·5 ft.
Glace Bay,	224 "	10·5 by 11 ft.
Caledonia,	205 "	11 by 11 ft.
Gowrie,	260 "	11·5 feet diameter.

At the Sydney mines of the General Mining Association is found the largest shaft plant working in the Province. The main pump and back shafts were sunk under unusual difficulties from heavy feeders of water. The shafts are situated at the Northern point of Sydney Harbor, a few yards from the sea shore, and were intended to command the coal in an area of four square miles extending under the sea. At a depth of 200 feet heavy feeders of salt water reaching 1800 gallons per minute were met, and after severe exertions they were stopped by cast iron tubbing.

The following memorandum of tubbing used in the new shafts will be of interest:—

	Depth tubbed,	Segments,	Weight lbs.
Winding shaft,	275 ft. 6 in.	1269·	658,724
Pumping "	284 ft. "	1168·	569,639
Staple "	283 ft. 3 in.	736	323,975
			1,552,338

Underground, two large engines stand near the shaft bottom, and draw the coal along a rise engine plane with dip slants. The rope on he main level is an endless one. The train of full tubs starting from the anding near the face of the plane run by gravity to the pit bottom, and he train of empties, is drawn out by the tail rope. By means of spare ropes lying in the dip slants, this system can be extended in any direction, and has been found to work satisfactorily for a number of years. Under this arrangement, horses are used only to collect and distribute the tubs from the landings and working falls, and their employment for the long level haulage, which is over a mile on one side of the pit, is avoided.

At the International mine the coal to the rise of the shaft (80 feet deep) having become exhausted, a slope was driven from a point a few yards to one side of the shaft, on the full dip of the seam, for a distance of about 2,500 feet, and at an inclination of $5\frac{1}{2}°$. The engine stands at bank and is signalled from the foot of the slope. The track is of the ordinary character, and a double rope being used, the employment of an automatic switch allows the train of empty tubs to pass the full ones, irrespective of the landing they are being drawn from.

At the Caledonia mine a portable engine and boiler have been placed underground at the head of the slope driven to the full dip. The smoke is led into the return. The system of raising steam underground is open to objections. Precautions are taken to remove the soot, and to lessen its liability to combustion, but any fire underground is a standing menace to a mine. The writer is pleased to learn that preparations are being made to generate the steam for the underground haulage at the surface, as such an arrangement must add to the safety of the pit.

At the Gowrie mine the haulage from the dip slant is conducted on a system resembling that referred to as adopted at the International.

The tables of machinery will give full particulars as to size of engines above and below ground, their loads, steam supply, etc.

VENTILATION.

The furnace was employed for ventilating the Nova Scotia mines, until a change was made in 1871 by the introduction of a Guibal Fan at the Albion mines. This fan was ten feet wide, and thirty feet in diameter, and yielded 75,000 cubic feet per minute at 47 revolutions, being driven by a direct acting engine having a 24 in. stroke and 24 in. cylinder. The length of air ways was about 15,000 feet. Afterwards fans were introduced at the Sydney, Intercolonial, Low Point, and

Springhill collieries. At the latter the seams being inclined and close together, it was found practicable to use "blow-down" fans placed directly over the downcast and driven by a belt, so as to air the mine in sections having comparatively short airways. The volumes of air in cubic feet passed per minute by these fans vary from 15,000 to 89,000. The highest record being that of the Intercolonial colliery, which during the year 1887 maintained an average monthly circulation of about 85,000 cubic feet.

In Cape Breton at the Reserve, International, Caledonia, and Gowrie mines, furnaces are still used, but the rapid extension of the workings of these collieries during the past few years renders a more efficient ventilating power imperative. At one mine only, the Gowrie, is there any opportunity given for the furnace to do proper duty. Here it is placed near the bottom of the drawing shaft, being connected with it by an ascending drift, which enters the shaft above the door heads.

Its dimensions are, length of bars 7 feet, height of bars above floor 2 ft. 6 ins., width of bars 7 ft. 8 ins., length of heated column, 307 feet, height of crown of arch above bars, 5 feet.

The total length of air course is about 170,000 feet, least sectional area, 56 ft., average sectional area, 64 feet. There are two air courses, 8,000 and 9,000 feet long. This furnace passes on an average 44,000 cubic feet of air per minute, with a consumption of about $1\frac{1}{2}$ tons of coal during the twenty-four hours. The capacity of the furnace could be increased to about 50,000 feet if required.

At the other mines, wooden chimnies fifty to eighty feet high have been placed on the shallow crop pits, which were first used for ventilating, but as the efficiency of the furnace increases in a ratio much smaller than the increase in length of the upcast, these additions give little assistance. The furnaces are of the usual pattern, being of brick, with arched roof, and having the grate about 2 feet from the floor, about 6 feet wide, and 9 feet long. The volumes of air passed vary from 20,000 to 43,000 per minute, the consumption of coal varying from one to two and a quarter tons a day.

The furnace under favoring conditions of large grate area, roomy air ways, and a long heated column, forms an efficient ventilator, but the last named condition in our mines is but partially presented at the Gowrie Colliery. At present, they are operated under conditions which should lead to the prompt replacement of the furnace system by mechanical ventilators. The cost of the latter, if one of the smaller and semi-portable patterns be adopted, is but littte larger, and it yields a much greater efficiency on the basis of coal consumption. Its work can be constantly supervised, its maximum capacity readily reached, and in case of accident, if it be properly placed, it is readily available for renewing the ventilation of the patterns adopted here. The Guibal has most satisfactorily stood the test of steady and long continued work, and its strength and durability recommend it for mines having extended and irregular airways. The Capel fan, which is highly spoken of, has not yet been introduced here.

The seams of the Cumberland and Cape Breton districts are very free from gas, it having been met in appreciable amounts only in the Springhill, Sydney, and Caledonia collieries. Still, reasonable care in systematically carrying the air through the workings is needed to prevent dangerous accumulations. Paradoxical as it may seem, mines giving off a small but steady amount of fire damp require constant watchfulness on the manager's part, as the employees do not bear in mind that their enemy, although easily routed, seldom omits to avail himself of any forgetfulness. Open lights and powder are used in all these mines.

In the Pictou district the seams are decidedly fiery, and much care is given to ventilation. They are as far as possible divided into separate districts for ventilating purposes, and in all safety lamps are more or less used, and the use of gunpowder either guarded by appointing men to fire the shots, or in special cases prohibited.

TABLE SHOWING PRINCIPAL MECHANICAL VENTILATORS.

ENGINE AND FAN.

Colliery.	Name of Fan.	No. of cylinders.	Drain of cylinders, inches.	Length of stroke, inches.	Width of Fan, feet.	Diam. of Fan, ft.	Av. cubic feet per m.	Revol. per minute engine.	Pr. of Steam, lbs.
Pictou Co.									
Intercolonial.....	Guibal	1	16	20	7	20	85,000	52	70
Acadia.............	Guibal	1	20	24	8	24	54,000		105
Vale	Guibal	1	24	24	10	30	42,000	55	90
Do	Blowdown	1	12	24	6	16	20,000	......	85 Belt, 2 to 1
Albion	Guibal	1	24	24	10	30	80,000	39	45
Nova Scotia......	Sturtevant	1	8	12	5.5	2.75	15,000	......	70
Cumberland Co.									
Springhill.........	Blowdown	1	12	36	7.5	18	41,000	35	55 Belt, 2 to 1
Do	Do	1	12	36	6	14	42,000	35	60 "
Do	Do	1	14	30	8	20	41,000	35	70 "
Cape Breton.									
Sydney.............	Guibal	1	24	24	10	30	67,000	40	35
Victoria.........	Champion.	1	8	17	4 turn fans	59	40,000	65	35 geared 3½ to 1

PUMPING.

The seams of the various districts may be considered as not carrying large amounts of water. In the Springhill district three seams, lying close together, are worked with a steady extraction of pillars, under a roof carrying several beds of porous sandstone, and a heavy surface cover, and these conditions cause a heavy pump charge.

In the Pictou district the overlying measures are shaley and compact and pass little water, and at a depth exceeding 700 feet the workings are dry and dusty. In Cape Breton nearly all the mines are above the dry zone, but they are not very wet. In the Sydney mine workings there is little water, the submarine workings being remarkably dry. At this colliery a large amount of water from the old workings has to be handled. The pump is a direct acting Cornish one, the dimensions being given in the table of Cape Breton pumps, working through two lifts, the low set 335 feet, the staple set 350 feet, total lift of water to delivery drift from pump being 668 feet. The same was noticed in the "Lingan" submarine workings. Under the Mines Regulation Act submarine seams having a cover of less than 500 feet must be worked in panels, and approaches cannot be driven under a cover less than 100 feet thick.

At several of the Cape Breton mines the pit waters are decidedly acid, and necessitate phosphor bronze and other patent linings, etc., for the working parts of the pumps.

At the Gowrie mines, Mr. Chas. Archibald has had much trouble in contending against corrosive effects of the pit water. The pumping shaft is 200 feet deep, and is divided into two bucket lifts. It was found necessary to use babbit metal lining for the working barrels, and iron and brass and gun metal shells, falls, etc. As the water grew more acid from running over the small coal and stone in the bords, as the workings extended, it was found that pump rods, pumps, nuts, etc., were very quickly eroded. Finally wood pumps were used, and the straps, clamps, flanges, etc., protected by layers of tarred flannel. Similar precautions were taken with the rods, and finally the bucket doors and clack pieces were made of wood instead of iron. Mr. Archibald gave an interesting account of this matter in the Transactions of the North of England Mining Institute. The writer published some years ago a paper on the Nova Scotia pit waters, from which he gives the following analysis as serving to show the composition of some of these acid waters.

Block House mine; Cow Bay Analyst, Geo. Suv. Canada, 1872-73.

Suspended matter.	
Sulphate of iron	·1510
Insolution.	
Iron (as per salt)	·2426
Iron (as proto salt)	·1168
Manganese	·0078
Aluminum	·0420
Calcium	·1498
Magnesium	·0618
Potassium	·0134
Sodium	·1884
Silica	.0116
Sulphuric Acid	1·4808
Chloric Acid	·4100
Phosphoric Acid	traces
Organic matter	·2844
Total in 1,000 parts	3·0094

Water, yellowish brown color, acid reaction, and styptic taste.

*Gardener Colly, Bridgeport.

Iron Sulphate	2·750
Potassium sulphate	·185
Calcium Carbonate	·736
Magnesium Carbonate	·025
Sodium Chloride	·096
Alumina	trace
Silica	·225
Total in 1,000 parts	4·881

Water, clear with blueish shade, after standing, deposited reddish sediment, acid reaction and highly styptic taste.

The appended table will show that direct acting pumps are at present the most fashionable, especially those of the Cameron and Knowles pattern.

* Analyst, E. Gilpin, Jr.

DETAILS OF PUMPING APPLIANCES.

CAPE BRETON.

COLLIERIES.	Number of Pumps.	Name and Style of Pump.	Steam Cylinder diam. inch.	Water Plunger diam. inch.	Length of Stroke.	Strokes per Minute.	Length of water-pipe.	Length of steam pipe.	Steam pressure at Bank.	Steam pressure at pump.	Vertical Lift.	Gallons water per day.	Tons of Coal raised during 1886.
Sydney Mines (Queen)......	1	Made to order.	30	8	48 in.	17	360 ft.	430 ft.	27 lbs.	....	360 ft.	172,620	139,646
do (Princess Pit)....	2	do	62	20	84 "	4½	720 "	....	40 "	....	720 "	139,863	
Victoria....................	1	Elliot.	18	7	44 "	14	590 "	890 "	40 "	37 lbs.	305 "	142,380	50,156
International	1	Knowles.	24	8	24 "	30	2100 "	2250 "	45 "	33 "	195 "	....	118,129
do	......	do	12	5	12 "	60	3547 "	1592 "	45 "	20 "	185 "	64,000	
Reserve......................	2	do	12	7	24 "	60	....	2080 "	50 "	35 "	....	115,984	81,783
do	......	do	14	9	18 "	50	3037 "	1486 "	50 "	35 "	283 "	12,450	
Caledonia (two setts)	2	Lifting.	......	8	48 "	12	128 "	....	30 "	....	123 "	86,400	72,810
do do	......	do	......	8	48 "	12	60 "	....	30 "	....	60 "		
Little Glace Bay	3	Cameron.	8	8	30 "	40	310 "	340 "	....	....	260 "	205,834	33,382
do	......	Lifting.	6	6	48 "	10	255 "	....	....	....	255 "		
do	......	do	6	6	48 "	10	255 "	....	....	....	255 "		
Gowrie	3	Knowles special.	20	10	48 "	20	254 "	244 "	43 "	35 "	215 "	328,265	95,307
do Lifting	......	Built to order.	......	10	36 "	36	110 "	....	....	....	110 "		
do do	......	do	......	10	36 "	36	110 "	....	....	....	110 "		

1886. DETAILS OF PUMPING APPLIANCES, PICTOU AND CUMBERLAND.

COMPANY.	Appliances.	Length of Stroke.	Diameter Steam Cylinder.	Diameter Water Cylinder.	Number strokes per minute.	Steam pressure at Boiler.	Distance of pump from boiler in ft.	Steam pressure at pump.	Vertical height of Discharge.	Pressure of head per sq. in. lbs.	Length Steam pipe.	Length Water Pipe.	Diameter Water Pipes.	Diameter Steam Pipes.	Average gal on discharge per day approximately		Tons of water raised, year 1886. (Estimated)	Tons of coal raised during year 1886.	REMARKS.
INTERCOLONIAL COAL COMPANY. Westville. Connected.	Top. Cameron Pump. No. 8.	36 in.	18 in.	8 in.	20 to 40	lbs.	480	lbs. 79½	350	lbs. 208	800	....	....	5 in.			104,500	108,498	Pipes cover'd with composition made by Mechanical Engineer.
	Mid. No. 3.5.	12 "	10 "	4 "	40 to 60	80	1380	77½	300	130	900	900	3×2½	2×2½	60,000		......	....	
	Bot. No. 3.4.	12 "	7 "	3½ "	40 to 60		1780	75	113	49	400	400	2 in.	2 in.			......	....	
ACADIA COAL CO. Westville.	Duplex Compound Pump.	24 "	H. P. 12 " L. P. 22 "	5½ "	45	105lbs	2600	95	996	433	2600	2400	6 in.	4 in.	108,000 per day of 24 hrs.		167,000	93,891	Pipes cover'd composition clay & straw.
JOGGINS.	Burling and Johnston's Pump.	40 "	20 "	8½ "	15	60 "	1500	38	205	89	1500	600	8 in.	4 in.	84,000		153,300	22,243	Pipes not covered.
VALE COLLIERY. 6 ft. Steam.	Cameron Pump.	24 "	15 "	5 "	50	80 "	1240	70	365	159	1240	1040	....	....	144,000		262,800	128,539	Pipes cover'd to pit head. Balance of pipes in mine exposed.
	Blake Pump.	12 "	8 "	5 "	60	......	510	....	130	57	510	310	....	....	8,640		......		
VALE COLLIERY. McBean Seam. Connected.	Bot. Knowles.	30 "	30 "	8 "	25	70 "	1400	60	650	282	1400	1200	....	6 in.	234,000	Disc'rgs to mid. pump.	......		
	Mid. Cameron	30 "	20 "	6 "	50	......	500	....	238	103	500	500	....	4 in.	252,000	Disch'rgs at surface.	459,500		

DETAILS OF PUMPING APPLIANCES, PICTOU AND CUMBERLAND.

SPRING HILL MINES.	West Slope. Connected.	Top Allison Pump.		6 ft.	30 in.	14½ in.	15	75 "	750*	68	340	148	750	75	12 in.	9 "	1080,000	Disch'rgs at surface.	1976,000	416,739	750 feet of pipes covered.
		Bottom. Allison Pump.		......	......	.....	......	......	1430	55	310	134	680	680	12 "	6 "	1080,000	Disch'rgs to top pump.	....		
		Special Blake.		3 ft.	28 "	11½ in.	32	60 "	512	40	430	187	890	850	8 "	4 "	742,080	....	1354,296		Covered from boil'r to pit mouth with infusorial earth.
		Blake, not used.		......	......	... ..	......	......	......	....	....	....	....	....	....	....	....	....	....		
	Cameron Pump.	Special, No. 7.	Connected.	30 in.	22 "	9 in.	40	60 "	......	40	....	....	....	....	....	....	460,200	....	840,960		
		No. 5.		24 "	15 "	7 "	50	85 "	1500	60	278	*121	1500	1400	4 "	3 "	216,000	....	394,200		
		No. 3.		18 "	10 "	4 "	65	85 "	1800	50	32	14	300	300	2 "	2 "	86,400	Disch'rgs top to pump.	....		
ALBION COLLIERY		Foord Pit.		Two	Iron	T'nks	8 ft.	6 in. x	6 ft.	x3ft	40ta	nks	per	ho'r	22 h	per	dy.873,840	....	1599,758	....	....

From these Tables it appears that in the year 1885, 1,352,205 tons of coal were raised, and that during the same period 3,646,889 tons of water were pumped—or nearly three to one. This estimate of the relative amounts of coal and water extracted has seldom been made over so large a district, and is interesting for reference beside the enormous tonnage of water to ore in many metal mines. It should however be remembered in considering these results that much of the water is from old workings, and forms a permanent duty. At the Sydney mines the present workings make little water, and the pumps have to handle the seepage of the acreage resulting from a century of mining and pillar working. At the Albion Colliery the pump duty represents in a similar manner the water of the underlying seam, as well as of the old workings in the thick coal which broke the roof for many feet. Here the main shaft of the workings furthest from the dip has been selected for pumping. The work is performed by substituting for the two cages, two tanks each 8 ft. 6 ins. by 3 ft. 3 ins. by 5 ft., which automatically open on entering the water, and by engaging with a lever at the top of the shaft discharge without any attention. The tanks are raised and lowered by the winding engine at an average rate of 600 trips per day of 20 hours, which is equivalent to about 520,000 gals.

The pump at the Acadia Colliery is one of the best in use in our coal mines. The lift is one of the heaviest single lifts in America, and the following note will be of interest.

The mine is opened by a slope 2400 feet long, vertical depth 1000 feet. The pump is a Knowles of the duplex compound condensing type, with high and low pressure steam cylinders, 12 and 22 inches in diameter, 24 inch stroke with four 5½ inch plungers working against a head of 435 lbs. per square inch. The column is six inches in diameter, of wrought iron, the air chamber is 30 by 15 inches, the steam pipe, 2600 feet long and four inches in diameter, takes the steam from Babcock boilers on the surface, at a pressure of 105 pounds. The pipe is protected with an infusorial earth jacket, the material being taken from a local deposit. After four years' service this pump has given no trouble, and no joints have leaked. There is no suction on the pump, the lower valves being below the level of the water. The pump usually makes 10 double strokes a minute, but could run 25 strokes, equal to 100 feet piston speed a minute. A small hydraulic ram will raise the water from the lower level to the pump.

PARTICULARS OF WINDING ENGINES NOVA SCOTIA COAL MINES.

Colliery.	Nos. of cylinders.	Dia. of cylinders, inches.	Length of stroke, in.	No. of Drum brls.	Dia. of Drum barrels, feet.	Weight of load, cwt.	Diam. of rope, inches.	Length of haul in ft.	Pressure of steam, lbs.	
Pictou Co.										
Intercolonial Colliery, Slope	2	16	36	2	8	126	1	1,800	70	Geared, 2 to 1; dip 15°
Intercolonial Colliery, Underground	2	16	28 / 24	2	8 / 8.66	126	1	1,200	70	do 3 to 1; do
Acadia Colliery (Slope)	2	16	42	1	9	*100	1⅜	3,100	85	Geared, 3½ to 1; dip 27°
Vale Colliery, McBean Slope	2	32	60	1	14	120	1⅜	2.400	55	Direct, dip 35°
Vale Colliery, Six-feet do	2	16	36	2	10	†80	1	1,800	60	Geared, 3 to 1; dip 23°
Albion Colliery (McGregor Pit)	1	24	72	2	—	‡80	4 ×	1,800	45	Flat ropes, direct acting
Cumberland Co.										
Springhill Colliery, West Slope	2	20	36	1	9	100	1¼	1,300	55	Geared, 3 to 1; dip 25°
Springhill Colliery, North Slope	2	15	30	1	9	120	1¼	800	60	Do
Springhill Colliery, East Slope	2	16	36	1	9	60	1⅛	800	70	Do
Joggins Colliery (Slope)	2	18	36	1	9	60	1	1,350	75	
Cape Breton Co.										
Sydney Colliery (Pit)	2	36	60	1	18	132	1¾	660	40	Direct acting.
" " (Underground)	2	16	36	2	4	792	⅞	5,400	40	Gross lead, geared 2¾ to 1
do	2	16	24	2	4	252	⅞	5,800	40	Gross load, geared 1¾ to 1
Victoria (Slope)	2	22	54	2	6	152	1	1,959	50	Direct, dip 15°.
International Col'y Pit	2	16	40	1	7	39	1⅛	100	40	Geared, 2 to 1.
International Col'y Underground	1	12	20	2	3 × 3½	224	¾	2,100	40	Stands at Bank, dip. Geared, 3 to 1.
Caledonia (Pit)	2	11	24	2	6	49	3½ × ⅝	205	50	Geared, 4 to 1.
Glace Bay (Pit)	2	12	36	1	6½	58	1¼	245	47	Geared, 2½ to 1.
Gowrie, (Pit)	2	20	42	1	8	49	1 3-16	235	60	Direct.
Gowrie, (Underground)	2	10	12	1	4¾	192	⅞	1,000	45	Geared, 5 to 1; dip 8°.
Reserve, French	2	20	54	2	4	256	⅞	2,754	50	Do 2 to 1; dip 5° 20'.
Reserve, Slope						256				Twin engine at Main slope.

* Wt. of coal, tubs, ropes, etc. 200 cwt; add. 5 p.c. for friction; total, 210 cwt. † Coal only. ‡ Gross weight, § Nett Load.

Expansion in the steam pipes is guarded against by U pieces. The pump stands in a house lined with brick, and having a cement floor.

The appended Table shows the winding engines at the principal collieries, above and below ground. They are generally direct acting for shaft work and geared three to one for drawing through slopes. As fuel forms a small item in the expenses of raising coal, low pressures and simple engines are in use. The economy is more apparent than real, and compound engines with the lessened wear and tear of boilers would prove more satisfactory. The speed in the shafts is low owing to their comparative shallowness. In the slopes the speed is practically limited by the rate at which the empty tubs can run safely down the incline.

At many of the deeper slopes, the men are raised in long tubs, holding from one to two dozen, with extra couplings, and a trip bar, or "durkey" at the end of the last tub.

At the Intercolonial colliery, the coals are drawn up the slopes, dipping at an angle of 15°, 1,800 feet long, the gross weight being 11,400 lbs. in the space of 1 minute and 50 seconds, and the empty tubs are lowered by brake in one minute.

The tubs hold from one half to one and a quarter tons of coal. The wheels are made with fast or loose axles, and vary in diameter from 10 to 12 inches. The gauge of the tracks is from 2 ft. to 2 ft. 8-in.

The following table will show the tubs used at the principal mines:

A TABLE

OF THE DIMENSIONS OF PIT TUBS IN USE AT THE PRINCIPAL COLLIERIES.

NAME.	Track Gauge.	Dia. of Wheels.	Wheel base.	Height above track.	Width.	Length.	Height.	Capacity.
	in.	in.	in.	in.	in.	in.	in.	C.ft.
Joggins	30	12	20	37	37	48	23	23 6
Acadia	28	11	22	31	42	60	24	35.
Albion Mines	26	12	18	42	33	44	28	23.5
Intercolonial	32½	14	20	42½	26	50	28	21.
Caledonia	24	11	22	38	33	94	24	35.5
Glace Bay	30	10	16	36	33	60	24	27.5
Gowrie	24	12	18	38	34	80	24	19.6
International	32	14	18	45	30	49	29	24.6
Reserve	26	11	20	43	32	44	30	24.4
Sydney	24	11	16	40	34	37	27	19.6
Vale 8 ft seam	29	10		45	33	54	26	26.8
" 6 ft. seam	29	12		42	33	54	25	25 7

Boilers.—In Cape Breton the boilers used for supplying steam to the pumps and winding engines are generally plain egg ended and cylindrical. Their dimensions vary in length from 20 to 37 feet, in diameter from 3 to 5½ feet. The working pressure varies from 30 to 50 lbs.

In Pictou and Cumberland there is a greater variety seen. At the Acadia Colliery four Babcock boilers, running at a pressure of 105 pounds, supply the fan and underground engine and pump.

At the Vale Colliery, Lancashire and tubular boilers are used. At the West Slope, Springhill Collieries, two Galloway boilers, 7 by 30 feet, form part of the battery. At several mines the plain egg ended boilers are used with pressures varying from 30 to 55 lbs. The consumption of coal, part round and part slack, used for stationary and locomotive engines, during the year 1887, was about 139,777 tons.

Transportation.—The various collieries are provided with railways varying in length from one half to thirty-seven miles for shipment of coal. The longest line in operation is that of the Cumberland Railway and Coal Company, who carry coal four miles to the Intercolonial Railway and thirty-three to Parrsboro on the Bay of Fundy. The latter line is operated at present principally for general passenger and freight business, but it is expected that when their shipping facilities are completed, much of their coal will find an outlet to St. John, New Brunswick, and the United States, via Parrsboro. The same company are now building toward the Gulf of St. Lawrence to obtain an outlet at Pugwash, so that they can secure water transportation to Quebec and Montreal during the summer months. A branch line ten miles long from Macan, on the Intercolonial Railway to the Joggins shore, runs along part of the outcrop of the northern edge of the Cumberland coal field. It has been opened this year, and promises to develop several valuable coal seams.

The Pictou Collieries are connected with shipping piers in Pictou Harbor, and with the Intercolonial Railway by short branches which they operate with their own engines and cars, using the Government rolling stock when shipping over the Intercolonial road. In Cape Breton the Sydney mines ship at North Sydney while the Victoria, International, Reserve and Bridgeport Collieries ship at piers on the south side of the Harbor. At Glace Bay, a brook, emptying into the Atlantic, has been dredged into a spacious dock, capable of holding half a dozen large steamers and twice as many square rigged vessels. This dock was originally made through the enterprise of the Glace Bay

Coal Company, but the Caledonia Coal Company have recently utilized it for shipping coal. At Cow Bay the Gowrie mine coal is shipped at a pier protected by the Government breakwater. The railway now being built through the Island of Cape Breton will, it is expected, be extended, so as to connect all the principal mines with Sydney Harbor, and ultimately to reach Louisburg Harbor, so that during the summer, the busiest season, two outlets will be available, while the lessened winter trade can be accommodated at Louisburg. At present the cost of maintaining roads from one to eleven miles in length, with the rolling stock equal to a shipment of 2,000 tons a day, for summer shipments, only forms a heavy charge.

The various colliery roads and their equipments call for no special notice. The locomotives are of English and American types, the cars carry from four to six tons, and empty below. At the Sydney Mines effective service is rendered by a locomotive built in the Company's shops, the frame, axles and tyres only being imported.

The locomotives vary in power and weight up to a Baldwin 50 ton freight engine. The roads are largely laid with steel rails, and are kept in very fair order. The only road calling for any special notice is that of the Sydney and Louisburg Coal Company. This road runs from Sydney to the Reserve mine, a distance of 8 miles, and 10 miles further to the colliery at Schooner Pond, formerly operated by the company, and extends to Louisburg Harbor, making in all 32 miles. At present the line is working only from Sydney to the Reserve Colliery, the rest having been closed during the late depression in the coal trade. It is expected, should the trade continue to improve as it has for the past few years, that operations will be resumed on the Schooner Pond branch, and the shipping piers at Louisburg be again utilized.

The road is well built and ballasted. Its gauge is 3 feet, with maximum grades of 1 in 100 against, and 1 in 75 with, the traffic. The nature of the country has permitted a nearly straight line with a minimum of curvature. In addition to two ordinary tank locomotives, it is equipped with three Fairlie double truck locomotives, 25 tons loaded weight, with 11 inch cylinders, 19 inch stroke, and 3 feet 3 inch wheels, about forty trucks, holding 4 tons each, make a train.

These locomotives have done very good work, but it is a question if this pattern of engine on a narrow gauge road, will prove as effective in winter as one of American pattern on the standard gauge, as they are not so handy in snow, and have very little clearance.

The wharves for coal shipments are all of wood, usually constructed with blocks and lines of piling. The cheapest form is that of a long pier with shoots on each side. In some cases a fall is given to a central track for the loaded cars to run towards the end of the pier, and a reverse grade for them to pass back to the shoots and return empty. In other wharves the loaded and empty cars are moved by horses. Where a level pier top is adopted, a system of ropes with hydraulic capstans would be found quicker and cheaper than horse-power.

The pier of the Sydney and Louisburg Railway, as described in the report of the Geological Survey, may be taken as a type of the most approved wharf. This structure, at the terminus of the railway in the town of Sydney, is a handsome and substantial structure, 620 feet in length, and 40 feet wide, with 36 feet of water at the end at high tide (the rise and fall being about 4 feet.). The top of the pier standing 24 feet above high tide level is furnished with 4 tracks, and seven loading shoots, and four traversing tables. The wharf is built upon very long and stout piles of Baltic timber, creosoted, and suitably braced by caps, ties, and trusses. The superstructure is of native timber of good quality, and strongly framed. The cost of the wharf is given at about $20,000.00.

The creosoting has proved an effectual preservation against the ravages of the teredo, and the piles, except a few imperfectly impregnated, are in good condition at the end of fifteen years. The author is not aware of other applications of chemically prepared timber for this purpose in Nova Scotian wharves. Reference has been made to the very acid water pumped from the Gowrie colliery. This water runs into the sea alongside their shipping pier, and, it is said, exercises a decided effect in preventing damage from the naval borers, etc.

The systems of cutting the coal vary slightly. In the Pictou and Cumberland districts, the bords, except in the very steep seams, are necessarily driven level, regardless of the cleat of the coal. In the flat Cape Breton seams the bords can be frequently turned so as to reap any benefit from the aid afforded by the vertical natural divisions of the seams. In the thicker seams the work embraces taking down the "fall" or division of the seam next the roof, in a layer 3 to 4 feet thick, and then lifting the rest of the coal in two benches of 2 to 4 feet in thickness. The precise thickness of each division is regulated by any partings or "dirt bands."

The coal is "holed or undercut" below the fall to a depth of 3 to 4 feet, and the low side wall continued about the same distance into the solid coal, so that a shot in the upper fast corner will bring all the coal down. The benches are kept a few feet behind, so as to allow a footing for work at the fall, and are blown up in one or more lifts as the face advances. In Cape Breton the holing is in the coal on the floor, the coal being nicked on one side or in the middle. In the Gowrie seam, the coal in the bords, thirty feet wide, after being holed, and allowed to stand, is brought down without powder.

Each working place has two miners, who sometimes employ a loader. The coal in some of the Cape Breton pits is riddled underground through meshes of $\frac{1}{2}$ to 1 inch, and screened at Bank over bars $\frac{1}{3}$ to $\frac{3}{4}$ inch apart. At the International mine the slack coal is raised by an elevator, the Culm, separated by screening, and the nut added to the round coal. At this colliery, Riggs' patent screen and tipper are found to prevent much breakage of coal.

The prices paid for cutting coal vary slightly in each district. In Pictou the prices paid in pillar working are from 37 to 40 cts. Bords 40 to 50 cts., narrow work 55 to 70 cts. per yard. The width of the bords varying from 9 to 15 feet. Shiftmen are paid $1.30 to $1.50 a day.

Loaders $1.20 to $1.30 a day. Boys employed on balances 80 cts. to $1.00. Driver and trapper boys 50 cts. to $1.00 a day.

In Cape Breton the price per ton in bords varies from 35 to 47 cents, the highest being at the Victoria mine. Pillar coal varies from 35 to 40 cents. The cross cuts are paid at the rate of 35 to 59 cents. Levels and winning places 50 to 69 cents, the wages paid to deputy overmen vary from $1.25 to $1.60. Shiftmen are paid 80 cts. to $1.25. Laborers wages are from 85c. to $1.00. Drivers underground 60 to 85 cts. Trappers and couplers receive 32 to 40 cts. The miners in all the districts generally live in houses provided by the companies, which are rented at from $1.10 to $4.00 a month.

In the Springhill district the prices are nearly those of the Pictou mines, so that the figures given fairly represent those of the Province.

The coal seams of the Province, as may be inferred from the historical sketch, belong to the Government. The principle upon which they are leased may be briefly discribed as follows : A license to search for twelve months is granted over an area not exceeding five square miles in extent. During this period the holder of the license can select a block of one square mile out of the five square mile area. This is called a License to work, and can be held for three years. If during this period effective mining operations are begun, the Licensee is entitled to a lease for eighty years in four equal periods. A few of the leases pay a royalty of 9.7-cents on every ton of 2,240 lbs. of round coal only, *i. e.*, coal that has passed over a screen, the bars of which are not more than ¾ inch apart while others pay 7.5 cents in every ton of coal round, slack, or run of mine. In both cases coal used for workmen and engines is free. There are at present 190 square miles under lease for coal mining, of which not more than a quarter is actually being worked.

All leases, transfers, etc., are registered in the Mines Department, which facilitates enquiry into title of mining properties held all over the Province. There is also a Mines Regulation Act, based on the English act, and the companies comply readily with its provisions.

The accompanying Tables, pages 379-381, will show the production and sales of each colliery during the year 1887. The amounts used for engine purposes include pumps, winding and other engines, locomotives, etc., and are not in every case directly representative of the power required for raising coal and pumping water.

The writer desires to express his indebtedness to the Deputy Inspectors, Mr. P. Neville, of Bridgeport, C.B., to Mr. Wm. Madden, Jr., of Westville, Pictou county, and to the managers of several collieries, for tabular and other information. Among the sources of information on the coal deposits of the Province may be mentioned Dawson's "Acadian Geology," "Coal Mining in Cape Breton" by Mr. R. Brown; "Mines and Mineral Lands of Nova Scotia" by E. Gilpin; Reports of the Department of Mines 1862–1887; Papers by the writer and others in the Transactions of the North of England Mining Institute and of the Nova Scotia Natural History Society; and the Royal Society of Canada, etc.

In conclusion, the writer trusts that the sketch given by him of Coal Mining in Nova Scotia may serve in a general way to show the systems followed, and to indicate the capabilities of the different mines to meet any expansion of trade. The tabular information has been carefully revised, and it is trusted that the sins of omission have not been important. Within the scope of a brief paper it has been found best, as far as possible, to speak in general terms, as any detailed reference to each colliery would have necessitated much repetition, and occupied much space.

Statement of the Classes and Number of Men employed, etc., at each Colliery during the year ended December 31st, 1887.

COLLIERIES.	Underground.				Above Ground.				Construction.				Total.		Average number of tons per Cutter.	Average tons per day per Cutter.	Average quantity raised per day.	Horses.		Pits Worked.
	Skilled Labor.	Laborers.	Boys.	Days' Labor.	Skilled Labor.	Laborers.	Boys.	Days' Labor.	Skilled Labor.	Laborers.	Boys.	Days' Labor.	Persons.	Days' Labor.				Above.	Below.	Days.
Cumberland Co.																				
Chignecto	20	9	5	8224	2	9	3	4289	....	....	....	....	48	12513	824	2.9	58	1	1	283
Joggins	32	7	8	8643	4	21	6	7103	4	....	....	283	82	16029	520	2.5	81	4	2	204
Springhill	506	237	142	248033	80	130	19	62651	9	10	..	5227	1133	315911	881	3.2	1622	17	60	275
Pictou Co.																				
Acadia	263	210	81	120382	66	133	20	62250	3	....	....	132	776	182764	876	5.2	1389	16	16	166
East River	5	1	....	1395	1	....	....	330	1	....	....	250	8	1975	229	1.1	5.6	....	....	201
Intercolonial	129	62	69	74496	32	56	9	30733	1	1	....	258	359	105487	1186	4.2	543	7	18	281
Barton	2	1	....	187	....	....	..	....	....	....	....	....	3	187	162	1.3	2.7	1	....	117
Cape Breton Co.																				
Block House	9	3	....	1646	8	...	...	1613	....	....	....	....	20	3259	852	5.2	47	2	3	163
Bridgeport	19	....	2	6090	2	3	1	1671	....	....	....	....	27	7761	1013	5.6	107	2	3	179
Caledonia	115	10	32	30137	17	31	12	14579	4	....	....	1157	221	45873	590	3.2	940	7	20	183
Francklyn	7	....	2	2315	....	....	1	274	....	....	....	....	10	2589	774	3.2	22	....	1	241
Glace Bay	101	9	15	21910	23	24	4	12737	....	....	....	....	176	34647	787	4.2	425	4	16	187
Gowrie	131	14	46	38674	21	52	19	22782	....	....	....	....	283	61456	980	5.6	738	9	40	174
International	109	29	33	13951	32	33	12	5931	....	....	....	....	248	19882	1003	(?) 9.4	1032(?)	6	25	106
Ontario	20	2	3	3827	3	2	1	1558	....	....	....	....	31	5385	388	2.6	52	4	2	147
Reserve	97	15	30	27395	17	18	5	9653	2	....	2	1361	186	38409	915	4 7	425	6	17	209
Sydny	230	40	108	91624	57	85	35	50533	7	....	1	2382	563	144589	712	3.0	708	11	42	241
Victoria	87	31	10	34880	7	38	7	16083	....	....	....	....	180	50963	701	2.3	240	4	5	296
Inverness Co.																				
Mabou	3	....	....	15	....	...	..	....	....	....	....	....	3	15	....	....	....	....	....	....
Totel.	1885	680	586	733824	372	635	154	304820	31	11	3	11050	4367	1049694	....	....	....	101	271	3653

The statement of men employed and labor performed may be taken as correct except in the averages. The averages of coal per man per day are not reliable, as the softness of the coal varies, and pillar work yields coal more readily than the bords, and in many cases coal is cut and loosened on idle days, and hoisted on days that the pit is working.

$40 00 | $3407 00 | $11578 00 | $18950 00 | $5008 00 | $5658 00 | $3007 00 | $716 00 | $33 00 | $329 00 | $48726 00

COAL PRODUCE OF NOVA SCOTIA DURING THE YEAR ENDED DECEMBER 31ST, 1887.

COLLIERIES.	Produce.	Sales.				Colliery Consumption.	
		Round.	Slack.	Run of Mine.	Total.	Engines.	Workmen.
Cumberland Co.:							
Chignecto	16,480	7,237	3,131	2,160	12,528	3,708	215
Joggins	16,649	10,415	2,971	....	13,386	3,122	1,013
Lawson	120	90	10	....	100	....	....
Patrick	....	....	....	....	....	....	....
Spring Hill	466,223	38,307	75,766	325,061	439,134	21,363	5,718
Pictou Co.:							
Acadia	230,611	129,663	64,532	....	194,195	34,558	4,154
Barton	325	150	11	....	161	....	....
East River	1,145	1,200	515	....	1,715	206	174
Intercolonial	152,825	109,052	33,911	....	142,963	5,565	2,877
Cape Breton Co.:							
Blockhouse	7,676	7,522	....	....	7,522	....	154
Bridgeport	19,265	16,688	1,326	....	18,014	115	110
Caledonia	108,144	72,293	29,797	....	102,090	1,494	1,259
Francklyn	5,422	4,219	1,203	....	5,422	....	....
Glace Bay	79,516	66,778	8,864	....	75,642	3,109	4,094
Gowrie	128,477	96,413	[illegible]	....	119,754	2,968	1,601
International	169,404	58,712	[illegible]	25,370	102,485	2,009	2,994
Ontario	7,768	7,426		....	7,447	276	125
Reserve	88,849	66,142	10,063	....	76,205	5,957	3,573
Sydney	170,782	129,950	15,260	....	145,210	15,618	7,772
Victoria	61,057	48,555	5,800	1,296	55,651	2,773	2,103
Inverness Co.:							
Mabou	100	60	....	....	60	....	....
Total	1,670,838	870,872	294,925	353,887	1,519,684	102,841	37,936

COLLIERY CONSTRUCTION ACCOUNT, 1887.

COLLIERIES.	Shafts.	Slopes.	Adits.	Machinery.	Colliery Build'gs	Dwell'gs	Surface Works.	Railw'ys	Wharv's	Prospecting.	Totals.
CUMBERLAND CO.											
Chignecto	....	....	....	....	....	....	....	....	....	....	....
Joggins	....	....	$ 200 00	....	$750 00	....	....	....	....	....	$ 950 00
Springhill	....	$981 00	....	$7600 00	2900 00	$5259 00	$2360 00	$716 00	....	....	19815 00
PICTOU CO.											
Acadia	....	338 00	....	721 00	187 00	....	285 00	....	....	....	1531 00
Intercolonial	....	....	....	8367 00	584 00	....	....	....	....	$329 00	9280 00
Barton	....	....	....	....	....	....	....	....	....	....	....
East River	$40 00	300 00	....	200 00	150 00	....	240 00	....	....	....	930 00
CAPE BRETON CO.											
Bridgeport	....	....	....	....	....	....	....	....	....	....	....
Blockhouse	....	....	....	....	....	....	....	....	....	....	....
Caledonia	....	....	1830 00	....	....	....	....	....	....	....	1830 00
Francklyn	....	....	....	....	....	....	....	....	....	....	....
Glace Bay	....	....	....	....	....	....	....	....	....	....	....
Gowrie	....	....	1156 00	....	300 00	....	....	....	....	....	1456 00
International	....	....	....	....	....	....	....	....	....	....	....
Ontario	....	....	85 00	....	....	....	80 00	....	$33 00	....	198 00
Reserve	....	753 00	829 00	....	137 00	70 00	....	....	....	....	1789 00
Sydney	....	....	....	2062 00	....	338 00	....	....	....	....	2400 00
Victoria	....	1035 00	7478 00	....	....	....	....	....	....	....	8513 00
INVERNESS CO.											
Mabou	....	....	....	....	....	....	34 00	....	....	....	34 00
	$40 00	$3407 00	$11578 00	$18950 00	$5008 00	$5658 00	$3007 00	$716 00	$33 00	$329 00	$48726 00

COAL PRODUCE OF NOVA SCOTIA DURING THE YEAR ENDED DECEMBER 31ST, 1887.

DISCUSSION.

Sir W. Dawson. Sir Wm. Dawson in the course of his remarks referred to the good works which had been done by Mr. Gilpin in connection with coal mining in Nova Scotia, and said that he was indebted to him for much information and assistance in connection with the Geology of the Province of Nova Scotia.

Mr. Gilpin's history of the coal mining of the Province was very interesting and in the main correct. The name Pictou is said to have originated with the old Micmacs, because of the gaseous emanations which were continually taking place on the outcrops of the coal seams, and the mines of that county had been opened by private enterprise, a long time before they were acquired by the General Mining Association. He referred in this connection to some of the early pioneers of coal mining in Pictou.

The coal wealth of Nova Scotia was undoubtedly great, and it would be long before anything like exhaustion took place. On the contrary the mining was only beginning to be developed, and he had no doubt that the time would come when Nova Scotia and Cape Breton, would become the England of the Dominion and great centres of population. Mining and minerals, unless a great change took place, would undoubtedly form the basis of the wealth of the Dominion; and determine the position of the great cities of the future.

He was not prepared to speak of the professional aspects of the question, but he thought they could gather from Mr. Gilpin's paper a good deal of information in regard to the work that had been done, and the fact that a good deal of mining skill had been brought to bear upon the mines. The difficulties that had occurred in mining some of the pits, especially in regard to the inflammable gases, had caused considerable trouble and many serious accidents, notwithstanding the precautions that had been taken and the means provided for the ventilation of the mines. It was a matter of regret that so much good coal had been lost by these accidents, and it was to be hoped that the mining companies would guard against them so that the loss of life and of money might be reduced.

Mr. Bartlett. Mr. J. H. Bartlett considered this paper a very valuable one, not only because it gave a history of the development of the mines and so many details of the various collieries, but because it brought so clearly before the Society the value to the Dominion of the Coal Fields of Nova Scotia.

There were one or two points he desired to call attention to. The first was the marked increase in the annual consumption of coal since Confederation, which had risen from $\frac{3}{4}$ of a million tons in 1867 to $3\frac{1}{2}$ million tons in 1886, the production of coal in Canada having risen from 623 thousand tons to 2,100,000 tons in the same period. The substitution of coal for wood on most of the railways no doubt accounted in a measure for this large increase—but the increase in railway mileage from 2,218 miles in 1867 to over 13,000 miles in 1886, the addition of $1\frac{1}{2}$ million people to the population, and our constantly increasing manufacturing interests must not be forgotten.

Having given some special attention to this subject of the coal trade, and published some statistics, he presented tables showing the details of the trade since Confederation as well as other particulars of the collieries.

He desired to make a few remarks about the waste of coal in the pits, the loss of time at the collieries, and on the subjects of handling and freighting.

It will be noticed that the markets for Nova Scotia coal have, owing to alterations in the United States Customs Tariff, been repeatedly changed and, that since the duty was fixed at 75 cents per ton, very little coal has been sent there, the local home market and the interprovincial trade having to be relied upon instead. This trade is growing, but even with the duty of 60 cents per ton against imported coal, there is a very small margin in the Montreal market between the prices of American Bituminous Coal and that from Nova Scotia.

The methods of conducting the business have been entirely changed within the last few years. The old plan was to give a price per ton at the shipping wharf in Nova Scotia; competition now necessitates a price being given delivered, so that a coal mining company has now not only to mine and ship coal but has to charter vessels, or engage freight and look after all the details of delivery and be responsible for the condition of the coal when delivered here.

The customary methods of selling coal by what is known as "run of mine," which, as the name implies, is the coal of all sizes as it comes from the pit, or the opposite method of screening and separating "the round" from "the slack," need only be mentioned except to say that as it costs as much per ton to carry any size to market, and as a much better price is obtained for "round" coal, it is obviously an important matter to prevent breakage as much as possible.

In many of the Cape Breton mines the coal used to be and may still be riddled in the pit and only the screened coal hoisted, the slack coal being left as not being of sufficient value to pay for the labor and government royalty.

The season of navigation limiting the time of water shipment from Pictou and Cape Breton, it naturally follows that in order to get a good output, the mines have to be equipped to do what should be a year's business in six months' time, and during the winter there is nothing to do for a considerable period, except to keep the pits pumped and in good order. If by any means this waste of coal and time could be obviated it would be of great benefit to the trade and the solution would appear to be found in the manufacture of coke and of iron.

It has been found in the United States that coke can, to a large extent, take the place of anthracite coal, and a large and important business is done in crushing coke into sizes to correspond with the size of anthracite coal so that it can be used in the same stoves, grates or furnaces. It is used domestically for cooking in base burning stoves and in open grates. Large quantities are used in hotels for broiling purposes, as it makes a very clear and hot fire, and manufacturers of all kinds use it in preference to anthracite.

The questions of handling and freighting are naturally considered together, and owing to the short season of navigation, and the long distance, about 800 miles by water to Sidney or Pictou, dispatch and facilities for both loading and unloading are of the utmost importance, a few hours extra delay per trip often losing a round trip in the season. The number of round trips varies, of course, with the speed of the steam collier, but about 12 to 13 round trips is an ordinary season's work, depending upon the dates of the opening and closing of navigation. Most of the vessels are hired by time charter for the season, and cost from 100 to 150 dollars per day, exclusive of the fuel they burn and the pay of the crew. The vessels carry from 1,600 to 2,000 tons of coal to Montreal and return to Nova Scotia with water ballast, there being no return cargo.

The usual time of unloading is from 25 to 30 hours, and means that a vessel is usually in port 1 day and 2 nights, or 2 days and 1 night loading and trimming taking about from 1 to 3 days.

Modern appliances, except bottom dumping coal waggons, are not used at any of the colliery shipping points. The waggons or cars are run out on to the pier the bottom dropped, and the coal falls into the vessel.

As many of the collieries are isolated, they could not afford any improved appliances, but in many instances there can seem to be no good reason why every individual coal mine should own a separate and distinct railway to the loading ground and a separate and distinct shipping pier. The situation at Pictou is shown on the map on the wall. Had the same amount of money been spent instead in rolling stock and improved appliances for loading, much money would have been saved. The Port of Montreal with a fine water power running to waste in the very harbour, seems to be equally innocent of modern progress in the way of facilities to expedite unloading and to save breakage. The colliers use their own steam winches, and when the coal is raised in buckets from the hold it is dumped over the side of the vessel into carts. The lighter the vessel the higher the drop,or when dumped on to a stock pile in the dock it is even more roughly handled in the height of the drop.

An interesting account of modern coal shipping machinery is to be found in a paper read by Mr. McConnochie before the Institution of Mechanical Engineers, England, (Vol III, 1884).

Ninety hydraulic cranes are employed in the coal trade at the Royal Albert Docks, London, seventeen at the Bute Docks, and one hundred and twenty-two at the Tilbury Docks, of which fifteen are portable.

A method, and one much in use in the United States, which handles coal very quickly and cheaply is Hunt's Automatic Machinery. Several examples of this plant, owned by private individuals, are to be seen in Montreal on the Canal.

Mr. T. B. Brown remarked that Mr. Bartlett had seen most of the ground within his range. He would say, however, that he was much interested in the accounts given of the several appliances. But the trouble was that while they would like to have anything that would facilitate the handling of coal, reduce the breakage and enable the collieries to place it in the market at a lower price, the difficulties of season, navigation, wharves and barges stood very much in the way and made it impossible for them to advance as they would like, however much they might desire to do so. Those who were interested in the business would welcome anything that would improve matters, but no one knew better than they did the danger of going too fast. Some time ago a company was started that brought into use, or tried to bring into use, what they considered the most suitable appliances for the purpose, but owing to various difficulties that could not be overcome, connected with the season trade, the flooding of the wharves, etc., the appliances fell into disuse, much to the regret of those who would have liked to continue their use. Mr. Brown.

While in years to come they might have a better process of handling coal, he thought that the facilities in the St. Lawrence, and particularly at Montreal, had improved very much, when the difficulties of the situation were borne in mind. The speed with which the coal was discharged had greatly increased, although the somewhat simple method of discharging by means of the ships own winches was still resorted to.

A good many propositions of new methods were made, but he found that they generally emanated from those who knew the least about the practical working of the coal.

The coal that came from Cape Breton was very friable, and those who saw it leave the collieries in large round handsome pieces, averaging the size of one's head, would be surprised to see it arrive here as small as it might be seen at any time on the wharves. The Pictou and other coals were much harder and arrived here in better condition, although of course all the advantages were not supposed to be with that coal.

It might not be appropriate at an engineer's meeting to say so, but he would remark that there had not been that superabundance of profit in the business to encourage or enable those engaged in it to launch out into the improvements that such a trade demanded.

He would be delighted if any means could be introduced whereby the conditions of this valuable trade could be improved. It was of great commercial interest to the community at large, but, as he had said, they had many difficulties to contend with, and he did not know any business whatever to which the adage of making haste slowly, could be better applied.

Mr. Kennedy. Mr. Kennedy asked if Mr. Brown could give any items of cost of transportation, etc., to work upon, so that they might see what margin of improvement could be made.

Mr. Brown. Mr. T. B. Brown said that his commercial memory was very faulty, and though he might at some future time be glad to volunteer Mr. Kennedy the information asked for, he did not think that it would be exactly the thing for him to go into a general anatomy of the trade just then.

Mr Bartlett. Mr. Bartlett said it seemed to him that if they could attain a saving of a bag and a half on each cargo it would make considerable difference in the cost of transportation. The methods that he had given a description of were being used in Duluth, and the speed at which vessels were unloaded was remarkable. A two thousand ton vessel could be unloaded in 12 hours. The features of the trade there were very much the same as in this country, the work being all done by seasons, but there they understood and appreciated the value of the saving of time.

Sir W. Dawson suggested that it would be more advantageous to discuss the introduction of manufactories and the possibility of smelting ores at the places where the coal occurs rather than the manner of handling the coal and reducing the breakage. Sir W. Dawson.

Mr. St. George remarked that there were some rich men in Nova Scotia, but there seemed to be little enterprise. Mr. Brown had spoken of Cape Breton coal being friable and broken up on its arrival here. He thought this was due in some measure to the way in which it was handled. He had seen coal dumped from a height of 40 or 50 feet into the hold of a vessel. Mr. St. George.

Mr. Kennedy could corroborate what Mr. Brown had said in regard to the friability of the coal. It was not altogether a question of handling. The coal would arrive here in large lumps, but about a week or two after landing on the wharf, the lumps would fall to pieces of their own accord. This he presumed was occasioned by the action of the weather. It seemed to him that it would scarcely pay to handle this coal carefully because it would fall to pieces anyway. Mr. Kennedy.

Mr. St. George thought that if the coal had not been cracked or broken before it arrived the weather would not effect it so easily. At the mines he had seen trolleys running along with three or four blocks on a trolley, but after it had been let down into the hold, the coal could be counted in a hundred pieces. It might keep better if it were placed in sheds. Mr. St. George.

Mr. E. Hannaford, chairman, asked Sir Wm. Dawson if he could suggest the cause of the disintegration of the coal. Mr. Hannaford.

Sir Wm. Dawson replied that the coal was traversed by joints running transversely (sometimes filled with thin films of pyrite or sulphide of iron) which admitted air and water causing the coal to decompose and fall to pieces. This was particularly the case with the Cape Breton coal. If exposed to the weather for any length of time it was apt to become very friable, the least disturbance causing it to fall to pieces. The Pictou coal was not so bad in this respect. Sir W. Dawson.

He referred to the fact that a good deal of coke was now being made at Londonderry, and was of opinion that a large amount of slack coal, now being shipped would make good coke. It was the purest of coal yet of no marketable value except as fuel for blacksmiths' fires, but would make excellent coke.

Mr. K. Blackwell said that he had occasion to look into the system of undercutting the coal in the mines by the use of a pneumatic coal cutting engine. He went down to Ohio and investigated the matter Mr. Blackwell.

thoroughly and found that this machine had been the means of saving all through the State from 25 to 30 cents a ton. He had purchased a plant for the Galt mines at Lethbridge in the N. W., which was now working and giving every satisfaction with a saving of about 25 cents a ton.

The Spring Hill were the only mines in Nova Scotia having a decent output and where perhaps it would pay them to get the best modern machinery, but if all the mines at Pictou were under one management the output might be sufficient to demand modern appliances also.

Mr. Bartlett. Mr. Bartlett said, that the total output of the Pictou district was under half a million tons and not so much as that of the Spring Hill collieries.

Mr. McLennan. Mr. Gilpin has so happily summarised the salient facts of a very extended subject that only one or two remarks need be added with special reference to the practice in the Cape Breton coal field.

In discussing his description of plant, it must be remembered that Cape Breton collieries have a daily output of from 50 to 100 per cent. greater than that for which the shaft, hauling and hoisting apparatus was originally designed.

This increase has been made rather by extension or forcing of existing appliances than by modifications which every expert would suggest. Consequently we have many appliances obviously uneconomic, but with an ultimate justification in a state of trade for several years so depressed, that no surplus has been available for reconstruction on the most approved methods. Therefore, for example, the different capacities of pit tubs does not indicate different views of the most economical size, all the tubs are the maximum the shaft in each case will admit. Again we do not consider hauling and pumping from long distances to the dip or furnace ventilation from shallow upcasts good practice, but the alternative is usually a new winning, which an engineer would recommend, to be met by the *non possumus* of his directors.

Again the isolation of Cape Breton has developed a system of home production really foreign to the business of mining, and a good deal of mechanical work is made which at collieries nearer trade centres is bought. At the Sydney mines of the General Mining Association, the shops are extensive, and this year they built or finished building a locomotive. Probably when we have rail connection with the continent this will gradually disappear.

The readers of Mr. Gilpin's paper will scarcely realize the destructiveness of the water in some of the pits from his or any description of its effects. The illustration usually given to visitors is that a steel shovel placed underneath a drip from the roof over night, will be eaten through by the morning. At the International mine the corrosive bronzes of pumpmakers were tested by hanging them in the discharge, and were all eaten although this test is less severe than service as a working part.

Mr. Charles Carmichael, mechanical engineer of the Gowrie mines, after many experiments compounded a Babbitt metal, on which pit water has no effect. The principal pump at Gowrie mines, is a Knowles plunger pump, with four large valves instead of nests of small ones, and with the plunger covered with their own composition. So strong was the opposition oft he mechanical staff at the Knowles works that a special mandate from the president was necessary to have the pump built as ordered. It has worked perfectly, and when through the kindness of Mr. Archibald, manager of Gowrie, the International ordered a pump on the same lines, the Knowles people began to feel that their anticipations of failure were not to be realized. They have, the writer thinks, now adopted Mr. Carmichael's formula. It is as follows:

Tin,	25 parts
Lead,	65½ "
Copper,	5 "
Antimony,	4½ "
	100

It is, of course, soft, but even with a certain amount of grit in the water, a covering of tar and tallow keeps a smooth surface on it. Hard brass valves, with rubber facing give a fair service.

Some of the new aluminum bronzes might stand well, but the writer does not know of their having been tried. Wooden suction and discharge pipes are much more satisfactory and cheaper than iron. Those made by the Wykoff process are capable of withstanding as heavy pressures as our service requires.

The fact that these corrosive waters are found chiefly in the roof and underlying strata, in immediate contact with the coal rather than in it, saves us from being thrown out of the market. As a matter of fact prepared coal from Cape Breton is remarkably low in ash and comparatively free from sulphur. It has the reputation of being hard on bars, owing mainly to a fact so hard of comprehension by ordinary stokers, that a coal high in volatile carbon compounds must be treated differently from coal the carbon in which is mostly fixed. Proper firing is every day giving us perfectly satisfactory results. So too with spontaneous ignition. Even in the summer of 1887, when coal from the old country, the United States and Nova Scotia, was on fire at different places on the St. Lawrence, the writer knows of only one coal from Cape Breton which, *piled by itself*, ignited. That was from a mine where the coal was not screened at bank, a practice which is to be abandoned next season.

The above remarks apply only to large coal. They may not be apposite, but the matter is important and one on which but little apparently is known. Was there any atmospheric condition in 1887, which made the ignition of coal heaps so common? Why should coals from different mines ignite more easily than if piled alone? These are questions in which both the consumer and burner are interested.

The screening of coal has much to do with its economic value. Several Nova Scotian collieries have apparatus working different from the ordinary fixed bear screens, but the subject may perhaps be worth treating in a special paper.

Mr. Leonard. On reading Mr. Gilpin's paper on Coal Mining in Nova Scotia one can only admire the completeness of the paper and the conciseness with which he has treated the prominent features of the industry.

While the subject is under discussion the following description of a balance for lowering the coal down to the railroad level, which, although hardly beyond the experimental stage, is doing very good work here, may be of interest and may be found very serviceable under similar circumstances elsewhere. The Spring Hill coal is of a tender nature and crushes easily. In the deep workings it is costly to keep a place wide enough for a double track timbered up to prevent crushing. In these lower workings several balances have been driven just wide enough for the cage.

About midway up the balance, the track is laid on longitudinal sills instead of on cross ties. Between these cage tracks, is laid the narrow gauge back balance track.

The back balance is made of two long cast iron square bars with channels on the under sides fitting over the square axles.

This forms the balance weight, and it runs under the cage at the "meetings" where the cage tracks are laid on the longitudinal sills. The drum at the head of the balance is fitted with a separate rope for the balance and for the cage as usual, one winding on as the other winds off.

This method secures the advantage of the separate ropes with the short single drum necessary in this case to prevent the fouling of the ropes.

The important point to be decided, as to the method of how coal is to be worked in a seam, is the percentage that can be removed with safety and economy. Mr. Archibald.

For some years the Gowrie seam, four feet six inches to five feet in thickness, was worked by pillar and stall, the stalls being six yards, and pillars seven yards. Above the natural water level the pillars were removed. In 1872 the rooms were widened to eleven yards, resulting most favorably to the owners and miners. The bords or stalls are started from the main level, at a width of six yards, and widened gradually to eleven yards: a turn is then put in and a road is extended upon each side, close to the pillar. In order to economize rails, as the room advances, only one road is left permanent, and the crossing is moved from time to time. Two great advantages were gained by widening the rooms; a much larger percentage of coal was obtained by the first working, and the cost reduced, less rails bring required, but the greatest reduction of expense was found in removing pillars. By the old system a road was laid in the middle of the bord, and all the roof coal and dirt were stowed on each side, which cost a large sum to remove, when the pillars were required. By the new system, the roof coal and dirt, are stowed in the centre, thus leaving the pillars free from all debris. If the roof were bad, and the cover heavy, wide rooms could not be worked with safety and economy, but here this method is feasible, and the pillars can be removed. In the writer's opinion it is more satisfactory, and less expensive than longwall.

Underground haulage is one of the most important features that can engage the attention of a manager. Where a large quantity of coal has to be raised in ten hours from one shaft, the supply to the bottom, must be well arranged to keep the hoisting engine constantly employed. Good and well kept roads, and perfect running tubs assist the transportation of coal immensely. Hadfield's fixed steel wheel seems to be a great improvement upon the cast iron wheel formerly used. At the Gowrie Mines they are used entirely. The tubs carry from twenty-five hundred to three thousand pounds of coal, and the wheels only weigh thirty pounds each: the wheels are turned on the axle, and run perfectly. In point of wear, it may be stated that we have wheels running that have been in constant use for five years, and have never had one break, whereas the old cast iron wheel, weighing sixty pounds, rarely lasted three years, while accidents from broken wheels were frequent. In connection with the Hadfield wheel, there is a patent keep which does not cover the bearing, but allows the axle to be satisfactorily greased. This patent keep enables an automatic tub grease to be used, which is a great saving of grease and labor, and has the advantage of being more reliable than boys. The automatic tub grease was patented in the United States and Canada, and has been in use at the Gowrie Mines for the past three years, giving every satisfaction. Excepting at Sidney Mines, the coal is hauled on the levels by horses. Self-acting inclines are used in several of the mines, where practicable, and this is one of the cheapest methods of reducing the number of horses required to haul the empty tubs up to the faces of the bords.

Mr. Poole. In this paper Mr. Gilpin touches on the history, trade statistics, and methods of working the Nova Scotia coals, each of which divisions might be independently and variously treated in more or less detail according to the bent of the individual writer.

Geologically the different fields have been reported on in the most comprehensive form by the officers of the Survey, who of course utilized the material supplied by the several observers who had preceded them in each locality. The official reports relating thereto begin with that of 1866-9.

The early history found in Mr. R. Brown an exponent in his "History of the Island of Cape Breton," and in his "Coal Fields and Coal Trade of Cape Breton"—works which necessitated much research and are now freely quoted. One historical note may be added: prior to the granting of the general lease to the Duke of York, coal was freely stolen from the unleased outcrops exposed on the Cape Breton cliffs, and preventive officers were appointed; of one, it was related to the writer by an old revenue officer, that zealous in his duty he effectually prevented further depredations by setting fire to the exposed coal.

The lease to the Duke of York that Mr. Gilpin speaks of being "a princely gift" did not prove so to his assigns, for many a year; as it seems that the first dividend paid by the General Mining Association was not until 1845. They had, however, in addition to the royalties, to pay certain sums to the Duke's creditors for the transfer of the lease.

The royalties reserved by the Duke's lease would not in the present day be considered merely nominal. A concession certainly was named for the first five years, but afterwards the rates were 5%. on gold, silver, &c. (the present rate is 2%); 4 pence per ton on iron ore (the present rate is 5 cents per ton), and for every ton of coal one shilling (the present rate is 9.7 cents); and as there were reserved leases and grants of land without reservation of mineral, the monopoly was not a close one, and it was not felt except in coal—the reserved leases having subsequently been bought up by the General Mining Association until the modification of the lease in 1857.

Mr. Gilpin speaks of the development of the gold, gypsum and other minerals immediately following the period during which the simple farmer doubted if clay were a mineral or not.

The practical discovery of gold was not made until 1860, three years later; gypsum had been quarried and exported in large quantities for many years, regardless of any rights the monopoly legally may have had for 80 or 90 years' says Professor How, in his most valuable "Mineralogy of Nova Scotia," 1868; and he gives a table of the shipments of gypsum running back to 1833, in which year no less than 52,460 tons were quarried. He also speaks of the bricks made and the limestone quarried prior to 1857, and describes at length the operations at the Londonderry Iron Mines, then as now independent of the great Monopoly.

Mr. Brown in his book, page 76, speaks of the General Mining Association *purchasing* the leases held by parties at Pictou, but that Mr. G. Smith, who on payment of £1100 cash held a lease for 20 years from Nov. 3rd, 1819, did not so regard his share of the transaction in question, is evident from his petition to the Government for redress in 1831. He wrote as follows:

"The strongest ground I think I have for compensation to rest my claim on is that it was not the intention of Government, at the time I obtained my lease, to license any other person in the district of Pictou, while I continued to comply with the terms of my lease, and the attempt of his Royal Highness' sub-lessees to interfere with me would not be justified on any principle. I had the opinion of the late Attorney General on this subject, who stated to me that under my lease I might follow the seam to the Bay of Fundy, provided I could satisfy the proprietors of the soil for surface damage; but to hold as against the Government and enter into a competition with the lessees of the Duke, whose lease was for 60 years, while, during the first five years they were only to pay 20% per annum, and I having to meet their capital and gratuitous lease, with annual rent of £370 and 3d. per chaldron of 36 bushels over 1400 chaldrons, you will at once see that whatever might be my legal right I could not persist with safety to myself and therefore I sold my material and utensils for some £400.0.0 to the agents of the General Mining Association."

He elsewhere in explanation of this writes: "In consequence of the construction which by the Colonial Government was given to my lease, I was compelled to pay £110 annual rent for a mine on the East side of the East River, which, owing to the quality of the coal, I never was able to work."

Mr. Gilpin speaks of careful revision of the accompanying tabular statements, which previously had been published in his and the Inspector's Reports to the commissioner of mines. The writer is inclined to hold that too great care cannot be taken in the preparation of tables from which any deductions are to be drawn, and therefore the writer would venture, in spite of a possible charge of being captiously critical, to point out errors that have crept in or have not been corrected since the figures first appeared in the Departmental Reports.

First, he would correct one of his own making when the Table of Sales was compiled. It was due to want of data, since partially obtained.

The sales of coal should be increased from the figures given for the decades

1811—20 to not less than 104,650 tons.
1821—30 " " 169,282 tons.

The Table of Pit Tubs has not been revised since 1872, except in the additional cases, the Vale, where the 'contents' figure up to 26½ not to 14 cubic feet as given in the table, while changes have been made in at least three of the cases cited. The wide mine gauge of 4 feet has been done away with, and one of 26 inches substituted, for one reason, because at greater depths the increased pressure necessitated narrower places than the wide gauge required; and as it is now, at greater depths bords driven in 9 feet wide become so reduced in size by the pressure when the pillars are being drawn, that there is nothing to spare between the tubs on the narrower tracks and the timbers of the bord.

In the table of Winding engines, the gross load, coal, cages and ropes, and in the case of inclines the additional friction of rollers and pulleys, does not seem to be uniformly given, nor is the vertical height of the lifts stated, so that the work done by the several engines does not clearly appear, nor why ropes of such various sizes should be used. In some cases it would seem the table is in error, and in three at least the sizes of the ropes are too large.

Under the head of Pumping the estimates of the total output of water can be at the best but approximate only, and would be better in round numbers; in some cases due allowances do not seem to have been made for idle days, and the figures would appear rather over than under the actual make of water.

Explanatory notes seem necessary in connection with some of the tables:—By that of Exports to the United States it might be inferred that all the late shipments of coal to that country paid a duty of 75 cents per ton, when in fact about half of those of late years, being entered as "Culm", paid but 40 cents duty.

Mr. Gilpin rightly questions the reliability of the averages, for without full explanations or knowledge of the varied conditions, no deductions as to average earnings of men, or labor cost of production, could be made from the Returns given quarterly to the Government. For example, one concern may shew the cost of transportation in labor chiefly on the colliery railway, while another has no such charge, cash being paid to an independent organization for carriage of coal to the port of shipment. Again if we take the number of hands employed, and the total days' labor they perform during the year, it would appear that at some mines the men and boys below ground average but 175 or 190 days, and that consequently their gross earnings must be small indeed, while at another mine, with an average of 270 days, the circumstances of the workmen must be vastly superior, and yet the former may not be so badly off, as a large proportion may be transient, employed during summer only, and retiring to their farms during the dull season.

The construction account given is from data supplied in consequence of requirements in the Leases, and is supposed to include charges to capital account only. If rightly given, a comparison of several years would show periods of expansion and depression.

The sketch Mr. Gilpin has given of the older method of working by gate-roads driven at half pitch recalls a still older system, when skips were used before the introduction of tubs, *i.e.*, mine cars, say, prior to 1852. Then, on the railway bord at the foot of each gate-road, where Mr. Gilpin shews a head down to the parallel mine bord below, there was a "horse hole", a place where the horse could turn when he dragged the skip on to the platform at that point. The skip was a sled with runners, and a strong iron bale over which broad iron rings were thrown as the coal was skilfully built up within them; hoisted to the surface it was run on a trolley to the screen or brow of the coal heap, and toppled over, the rings of course rolling down to be subsequently collected and carried back to the pit mouth.

Mr. Gilpin brings before us so many subjects of colliery interest, and the practice is so varied, that one is at a loss what to select and what to avoid. Success in mining the soft coals, especially in inclined seams, largely depends on the judicious use of mechanical appliances, and the cost of production has a wider range under what might appear very similar conditions than would be supposed.

The difference in the life of ropes for the amount of work done at the several mines is almost incredible, and consequently the cost of many thousands of feet of rope is of no small moment. The variation is at least four to one. Various sizes, makes and qualities may be seen; the "lock coil" looking like a continuous bar of iron, and presenting a continuous surface, with consequently less abrasion for itself and the pulleys and rollers that bear it; Lang's patent with the lay of the strands and the wires in the same direction, and ropes of the ordinary lay of fine and course wires of all qualities from plough steel down to iron. Ropes of one half the weight, but of improved quality, have in some cases been substituted with advantage. Then again the treatment ropes receive is various, some drag on the ground or are exposed to the corrosive action of mine waters, others are lubricated with an oil that searches in between the wires; more ropes are destroyed by internal corrosion than by external abrasion, some are well rollered, and others pass over pulleys lined with wood.

The gauge of mine tracks and sizes of tubs or cars calls for a division of opinion; one contends he has effected economy by enlarging, another by reducing the size.

The efficiency of the blow down fans of local design is open to question. Mr. Gilpin refers to and contends that the measure of success they enjoy is due rather to an absence of friction in the air-ways than to their construction.

Signalling is not alone confined to the method spoken of, there is an improved means by two taut reciprocating wires conveying uniform motion to pointers on dials thousands of feet away; and electric signalling is in use in at least one mine, and so arranged within reach of men riding on the incline that contact can be made at any point; but in that position it is exposed to damage or rather annihilation, when a run-away of the rake of mine cars clears the slope of wires, timbers and rollers. Speaking of run-aways brings up the "durkey" question and appliances for catching the tubs when rope or coupling breaks. The ordinary durkey, a pointed bar trailing behind the rake, is useless on slopes of 20 degrees or more that are too high for the bar to thrust the hind tub to the roof. In ordinary course of working the durkey is seldom used, more reliance being placed on careful inspection of ropes and couplings, but a frequent thorough examination of all draw bars and links is not possible, and a more efficient safeguard than the ordinary durkey is desirable. The writer devised, and has in use on some riding tubs, a contrivance which relies on the reversed motion pressing knife edges into the sills to which the inclined rails are spiked, and so bringing the car with its load of men to rest without the sudden jerk that the use of the rigid durkey entails.

These are small matters which have been referred to, Mr. Gilpin having introduced the broad outlines of the practice at the Coal Mines, comments on modification or details alone are left. Yet details are not to be despised if improvements—elsewhere designed—are to be successfully adopted, and certainly the practice of the colliery engineer gives many opportunities to effect economies by attention to little things. He also can with advantage bear in mind the lesson taught the cotton spinner when told to "chalk your bobbins".

Mr. Gisborne.

Mr. Gisborne desired to express his regret that he was unable to be present at the reading of Dr. Gilpin's interesting, historical and practical paper upon the Coal Fields of Nova Scotia.

He had been the engineer and manager of four collieries in Cape Breton, during the years 1869 to 1875, and had opened the "Reserve," "Lorway," "Emery," and Schooner Pond mines from the surface, besides being the contractor for the construction of the Sydney and Louisburg Railroad and piers, and the shipper of all the coal raised by the Company to Canadian, United States and other foreign markets.

His experience with narrow gauge railways and Fairlie engines (originally adopted by the English Company which he represented, as a matter of (false) economy and contrary to his advice) was conclusively in favor of the standard 4 feet $8\frac{1}{2}$ inches gauge and ordinary engine, for as a matter of fact, two out of his three Fairlie engines were almost invariably "in hospital."

Then again narrow gauge coal trucks cannot be efficiently and economically unloaded from their bottoms; but had to be discharged from their sides, which was a slow process until he invented a balanced tip-shoot-platform, by which the entire truck was tilted sideways, and then returned to its horizontal position automatically. An inspection of this invention, which enabled one man to discharge 60 to 80 tons of coal per hour into a vessel's hold, would be interesting to narrow gauge railway proprietors.

There was a considerable difference also in the economic value of the bituminous coals of Nova Scotia as would be noted in the following analysis, some being better adapted for household fuel, other seams for steam raising purposes and others for gas.

	Thus Old Sydney gave:	Pictou coal gave:	And Spring Hill, Cumberland:
Volatile matter,	28	27	22
Carbon,	67	60	66
Ash,	5	13	12
	100	100	100
	Yielding 6,500 feet of gas to the ton.	Yielding 7,000 feet of gas to the ton.	Yielding 6,900 feet of gas to the ton.

Whereas the Reserve Cape Breton gave the following analysis of cargoes sent to the Manhattan Gas Company of New York and a later sample to the Royal School of Mines in London:

	Bank crop coal at New York:	Deeper mined coal at London:	And Schooner Pond:	
Volatile matter,	34·5	37·26	Volatile matter,	38·10
Carbon,	59·5	58·39	Fixed Carbon,	58·45
Ash,	6·0	4·35	Ash,	3·45
	100·	100·		100·
	Yielding 9,500 minim. to 9,950 max. feet of gas to the ton.		Yielding about 9,500 feet of gas.	

All of the foregoing gases averaged 13 candle power.

Another matter of vital interest was the cost of freighting Canadian coal, by steam or sailing vessels and the loss from demurrage when unloading, either from lack of facilities at the receiving ports, or the suicidal labor combinations to which colliery proprietors were helplessly subjected.

He had employed two English steamers, the "Dodd," carrying 1,300 tons and the "Dione" 850 tons at the chartered rate £1 stg. per *registered* ton per month, and notwithstanding that these vessels were invariably loaded within 48 hours the result of the season's work showed a heavy loss, solely and entirely from the two causes above referred to.

He might add that frequent strikes among the coal cutters greatly augmented the risk of loss to colliery proprietors, but that from his own experience he was decidedly in favor of a friendly interest in the well-being of the men and conciliatory though firm dealing with incipient discontent.

Colonial coal fields, at the time to which the writer refers, were eagerly fought for and unstintedly provided with powerful machinery and transport facilities. Within a brief period, however, the British coal fields were proved to have two or three centuries of mineral supply in reserve, and the bright outlook for Nova Scotia mines was relegated to the future—Cape Breton coal became a drug on the market, even at less than $1.40 per ton at the mines, and his company collapsed after an expenditure of over $2,000,000, having made no profit out of which they could pay interest upon their bonded debt. The property passed out of the hands of the shareholders, and thus he had abandoned mining ventures and returned to his "first love" Electrical Science.

Mr. Gilpin. In closing the discussion begged to express his thanks for the kind references to his paper. He regretted that the space and time at his disposal did not permit of his giving more details on some of the interesting points connected with the practice of coal mining in Nova Scotia. The tabular statements had received numerous corrections since they had been submitted to the Society, and he hoped that when published they would be fairly accurate.

He, like Mr. Poole, approves of the exhaust fans as conducing to more permanent efficiency, and as capable of bearing greater burdens than the ordinary pattern of forcing fans. The friability of the Cape Breton coal has been employed as an argument against its use for all ordinary purposes. The fact, however, remains that under intelligent handling more heat can b egot from small than from large coal, which is in the line of the experiments that show that the ultimate greatest efficiency of a pound of coal is to be sought from its component parts on the eve of their greatest dissociation.

If it were possible to ship the coal as run of mine, screen it at point of delivery, and make coke and briquettes out of the slack coal, there would be a larger percentage of round coal for the conservative householder.

The percentage of ash in the Cape Breton coals is lower than in the Nova Scotia coals, but although the total theoretical evaporative power may be highest in a low ash coal, there are, as a rule, certain practical objections to this. There seems to be an advantage in a considerable percentage of ash in coals burned under a very strong draft, and the explanation may be that the slightly retarded combustion is the most perfect.

In this connection, Johnstone, in his little work on the Coals of British America, gives the result of an official test by the American Government of Sydney and Albion coal as follows:

Sydney coal-ash, 6 p.c.; lbs.of steam from 212°, 7·90.

Pictou coal-ash, 13·38 p.c.; lbs.of steam from 212°, 8·41.

In a paper read some years ago, before the North of England

Mining Institute, on Canadian coals, the author gave a fairly complete set of analyses of the ashes of Cape Breton coals. These analyses show that, broadly speaking, the composition of the Cape Breton coal ashes, as distinguished from those of the mainland is of a ferruginous character, while that of the latter is silicious. It would seem that the fusible clinker of the former with too thick a fire, is the principal reason why complaints are heard of the destructive action of Cape Breton coal on fire bars. This can readily be avoided by proper firing.

There is no question that the interests of the coal owner demanded the introduction of mechanical cutters and haulers. The first cost was very heavy for air compressors and pipes, and the use of electricity seemed to afford the happy medium of cost versus portability. The ingenuity and skill displayed by the management of the Gowrie mine in dealing with acid pit water was deserving of the greatest praise, and he would suggest that Mr. Archibald and his staff should devise some plan of revenge upon the acid water by utilising it in some commercial process, which in return would call for their coal for steam and power raising.

6th December, 1888.

E. P. HANNAFORD, Vice-President, in the chair.

The following candidates were balloted for and duly elected as

MEMBER.

HENRY STUART THORNBERRY.

ASSOCIATE MEMBER.

PERCY C. GIROUARD.

ASSOCIATES.

THOMAS MCCABE, JOHN STARR.

STUDENTS.

ROBERT BICKERDIKE, ALBERT HOWARD HAWKINS, CHARLES HERBERT ELLACOTT, GEORGE EDWARD MCCREA.

The discussion upon the paper on Coal Mining in Nova Scotia, by E. Gilpin, Jr., occupied the whole evening.

20th December, 1888.

JOHN KENNEDY, Member of Council, in the chair.

Paper No. 24,

A MINE PUMP WORKING UNDER A HEAVY PRESSURE.

By H. S. Poole, M. Can. Soc. C.E.

In the Pictou coal field, it is generally the practice to win the seams by slopes started from the outcrop or a shallow pit, and extend the workings by inclines to the deep.

From time to time, as sinking progresses, levels are driven along the line of strike at distances of 400 or more feet apart, and section by section, or by " lifts," as these strips, so cut off, are called, the coal is worked away.

Water follows down as operations extend to the dip, and although little or none is found in the seams, when first cut, at depths exceeding 800 feet, it is seldom possible to catch sufficient at the higher levels to make it worth while to retain independent pumps at such points; the consequence is that before many years, pressures of some moment have to be considered and met.

At the Acadia slope, Westville, the mine was first drained by a range of plunger pumps worked by rods from a surface engine. As the slope lengthened, additions were made to the rods until a length of 2,000 ft. was obtained, when it was apparent that the appliance had reached the limit of its capacity, and a remodelling or substitute was necessary. The slope, it may be mentioned, has an inclination of from 24° to 28°.

A duplex compound condensing engine of Knowles' make was selected, and placed at the 2,400 feet level to pump through one continuous column of 2,400 feet of pipe, direct to the surface, a vertical height of 977 feet, against a consequent pressure of some 435 pounds on the square inch. The cylinders are pairs of 22″ and 12″, and the four plungers have diameters of $5\frac{1}{2}''$, the stroke of all being 24″.

Steam is supplied by Babcock and Wilcox boilers at the slope mouth working at 105 lbs. pressure, and conveyed through 2,600 feet of covered 4″ pipes: the loss of pressure, due to condensation, is about 10lbs.

per square inch. Lying on an incline, the steam pipes have a tendency to draw down hill, when exposed to variations of temperature, and ordinary expansion joints failed to give relief, but by substituting bends and circles in the course of the pipe at every 400 or 500 feet, practically the difficulty was overcome, and leaky joints are less frequently met with.

The delivery column lies in a perfectly straight line, except at one point where it makes an offset of six feet, and then continues a parallel course; it has no expansion joints, is of heavy wrought pipe, with ends upset and screwed into large and thick metal flanges with Allison's vanishing thread. By these means, a pipe of equal thickness throughout is secured, and the parts which of ordinarily coupled pipes are the weakest become the strongest. The flanges are plain faced, but one of each pair has a recess of 1-16″ deep, to hold in position a rubber ring $\frac{1}{8}$-in. thick by $1\frac{1}{2}$-in. wide. This joint has kept perfectly tight, and would seem to be preferable to joints of fancy form, with high bosses and deep recesses. Flange joints were selected because of the facility they afford for substituting a new length should repairs be required, and for the same reason the lengths were uniformly made 18 feet.

On two occasions, the efficiency of the column has been well tested, the water heated by the condensed steam, to a temperature of about 120 Fah., caused the pipe to buckle across the 7 feet wide slope in which it is placed, yet when jacked back into position all leaks were stopped by merely screwing up the flange bolts.

Fortunately, the water of the mine is not corrosive, and a simple coating of asphalt appears to protect the pipe internally. External corrosion is prevented by keeping the column out of the wet dirt of the mine, which is generally found injurious to ropes and rails exposed to its action.

Makers of duplex pumps generally contend that as such pumps have four plungers, the stream thrown is so steady that an air chamber is unnecessary. In this case, when the pump was started, the pressure gauge recorded a variation of 160 lbs., and it was therefore thought better to put a small air chamber on the column. One was made 4 feet long out of a piece of 15 inch wrought pipe, which, when charged with air, had the desired effect, and reduced the shock to the system to less than 20 lbs. per square inch.

The method adopted for charging the chamber with air against a pressure of 30 atmospheres is as follows:—Two small pipes lead from the air chamber (A) to a 9 feet length of 6 inch pipe used as a charging chamber (B), placed below the level of the pump: the connecting pipe (C) that leaves the neck of the air chamber is fitted with a globe valve; the second pipe (D) leaves A at a higher point, and is fitted with a check valve at its connection with the highest point of B; close by is fitted another check valve (E) opening into B; at the further end of B is a globe valve (F). The action is as follows: B being full of air at the atmospheric pressure, F is closed, C is opened, and B fills with water under the full pressure of the column compressing the air in B, then the weight of the water in C forces the compressed air up through D into A, from whence it is prevented from returning by the check valve on D, when F is again opened, B refills with air through E.

In practice, three such charges of air in a shift of ten hours maintain the chamber two-thirds full of air. Any attempt to keep the chamber nearly full is met by an increased absorption of air by the moving column of water apparently without a corresponding gain.

To reduce the tendency of the water to find the lowest workings, a thick pillar has been left across the area, in the hope that the greater part of the water may continue to be diverted to the pump and such of the seepage as escapes may be within the capacity of an hydraulic pump placed below, and obtaining its power from the main delivery column. A small hydraulic pump is now successfully doing this, delivering some five gallons per minute in addition to the power water into the sump of the steam pump. This small pump is placed at a vertical depth of 1300 feet.

Thursday, December 20th, 1888.

J. KENNEDY, Member of Council, in the Chair.

Paper No. 25.

THE SPRING HILL COLLIERIES.

By R. W. LEONARD, A.M. Can. Soc. C.E.

In presenting a paper in any way relating to coal mining, the writer feels considerable delicacy, knowing that there are many older members of this society who have made a life-long study of this particular branch of engineering, and who could contribute very valuable papers on mining. However, in response to the honour of being requested to contribute a paper on the above subject, the writer will endeavour to give a description of one of the greatest private industries of Canada, and to present a general idea of the method of working these mines, which may be of interest to those members of the society who, in the various ups and downs of their professional careers, have never had the experience of "digging dusky diamonds."

The Spring Hill Coal Field (the property of the Cumberland Railway and Coal Company) is situated near the centre of Cumberland Co., N.S., four and a half miles south of the Intercolonial Railway, and on the western slope of a detached hill (about 600 ft. above tide water), forming a northern outpost to a range of high hills, extending from Parrsboro' on Minas Basin, in a northeasterly direction to Spring Hill (about 25 miles). The village (about 6,000 inhabitants) is built on the top and west side of the hill, and the coal seams now being worked crop out lower down on the west side.

Coal was first discovered in this, at that time, densely wooded home of the moose, about forty years ago, and was owned in common with all mines and minerals in Nova Scotia, by the General Mining Association, until the year 1857. The Spring Hill Mining Co. owned and worked them until 1884, when the Cumberland Railway and Coal Co. bought out the mines and the Spring Hill and Parrsboro' Railway.

Although coal was known to exist here forty years ago, it was useless, except for supplying the very small local demand, until the opening of the Intercolonial Railway in 1873. The same year (August, 1873) the rails were laid on a branch railway, four and a half miles long, from the mines to Spring Hill Junction on the Intercolonial Ry., and two years later (1875), a railway, twenty-seven miles long, was completed from Parrsboro', on Minas Basin, to Spring Hill.

These railways now afford shipping facilities for the coal. In order to supply the large demand for Spring Hill coal in the southern parts of Nova Scotia, New Brunswick, and in the United States, the Company built a large shipping wharf at Parrsboro' last year, over which 1,200 tons per day can be loaded into vessels. The wharf is a trestle built on pile foundation, to such a grade, that the cars run by gravity, and turn on an automatic turntable to the return track. These piles were driven under the somewhat peculiar conditions of a tide, rising from 18 to 24 feet, although the bed of the river is dry at low water, being about half tide above low water mark in Minas Basin.

The Company is now building a railroad from Spring Hill, a distance of 14 miles, to connect with the Oxford and New Glasgow Ry. (under construction, by the Dominion Government), at the village of Oxford. This railway, which will be opened early next summer, will give shipping facilities to Montreal and the West, from Pugwash Harbour, on the Northumberland strait.

Mr. Scott Barlow made an examination of these coal fields, for the Dominion Government, during the years 1873-4, and, by means of numerous borings and test pits, made a very accurate report on the seams of coal existing beneath the heavy glacial drift which covers the outcrops. In some places coal was found only about 10 feet from the surface. The only hole bored with the diamond drill in the immediate vicinity of the mines was driven by order of Mr. John Livesey, the Managing Director of the Londonderry Iron Mines, who used the English diamond drill for that purpose. Several hundred feet were bored, but no coal was intersected. Fig. 1 is a general plan showing the outcrop and dip of the seams and the positions of the various slopes.

Mr. Wm. Hall, the present manager of the mines, started to sink the west slope, on the 10th of June, 1873, and the same autumn, started to sink the east slope.

These two slopes were reported by Mr. Barlow to be in the same seam, and were generally believed to be so until the Fall of 1876, when the levels in the workings overlapped. The following year, the seams were connected by a tunnel, 200 feet long, through the intervening strata. The fault between the two slopes, as shown in Fig. 1, and the deep covering over the outcrops were the causes of this error.

The sinking of the north slope was begun in 1882, on a seam overlying the east slope seam, 600 feet, measured horizontally, and the south slope in 1884, near the site of the old Barlow pit, started in 1873 or 1874. Fig. 2 shows the arrangement of the strata between the east and north slope seams, as found in the tunnel connecting these seams across the metals.

Mr. Barlow told of the great fault or change in the dip of the strata, near the south slope (shown in Fig. 1), and reported that the seam, on which the south slope was afterwards sunk, was the same as that of the north slope, but that this fault between was a great downthrow extending through the measures.

When Mr. R. G. Leckie became managing director of the Cumberland Ry. and Coal Co., and studied the coal field, he predicted that this partial downthrow and great change of dip in the southern portion of the coal field would prove to be but one of the faults occasioned by the crumpling together of the strata at that point, incident to a change in the direction of the dip from north of east to south. This theory was subsequently proved to be correct, as the more recent discoveries of coal in the southern part of the areas all dipping almost south have proved.

Notwithstanding Mr. Barlow's report, the south slope seam was generally believed to be the same as the west slope seam, until an underground survey, made by the writer early last year, shewed Mr. Barlow to be correct. The workings were connected a few months later, at the 800 feet level of the north slope seam, at which depth the fault disappears and the seam is continuous, this level conforming with the 2100 feet level of the south slope.

Fig. 3 is a vertical section on the line of dip at the north slope, and shows the relative positions of the coal seams. Fig. 3A is a vertical section on the line of dip at the south slope, showing the relative positions of the seams in that locality.

As shown in Fig. 3, the bulk of the coal now being worked lies or dips at an angle of about 30 degrees. It is all drawn to the surface through slopes sunk down the coal seam on the pitch or direction of the dip. These slopes are 10 feet wide, and contain a double track of 2 feet 2 inches gauge coming together near the bottom, and again branching out, so as to draw coal from the main level on either side of the pit.

A double cylinder winding engine on the surface draws up one loaded train of cars (" rake of boxes ") on one track, while another empty train descends on the other. Each car or "box" contains about 1,650 lbs. of coal, and a train or "rake" consists frequently of six boxes.

These boxes are landed on the bank head, where they are run along by hand to the screens, over which they are dumped immediately into railway cars, which are held on a grade of about one per cent., while being loaded.

For the benefit of those not familiar with coal mining, we will suppose the reader to get into one of the empty boxes being lowered down the west slope at the rate of about 400 feet per minute to the 1300 feet level. Arrived at the foot of the slope a horse is hitched to the rake, when he is driven as fast as he can trot or run along the dark level to the first crossing siding, where a full rake is passed on its way out to the bottom, then away again, at full speed, for (it may be) a mile to where the empties are required at the foot of a balance.

A balance is a place about 12 feet wide, cut up through, and following the seam, say, 400 feet. To one side of the balance, places called "bords" are driven parallel to the main level, and generally about 40 or 50 feet apart. In each of these bords a track is laid. A double track is laid in the balance, on one of which runs a "cage," or level platform carrying the box, while on the other travels a counterweight, which is so proportioned, as to carry up the empty box to any desired bord, and to lower the loaded one by means of a wire rope over a friction drum at the head of the balance.

This method of working coal in an inclined seam was introduced first into this country at the Albion mines, Pictou county, in 1863, by Mr. Wm. Hall, who is, the writer understands, the inventor of the system.

These balances are generally about 400 feet apart along the level, and as above indicated, the block of coal between two balances, for about 400 feet above the main level, is divided up into smaller blocks (called pillars). These pillars are afterwards worked out by commencing at the inner ends of the upper bords first. This pillar-drawing is perhaps the most dangerous part of coal mining, as the miner is always cutting away the support to the roof, which continually settles and falls behind him as he works further into the pillar. Large blocks of coal may also be worked out by the "long wall system," commencing at the bottom on a long face and working this face upwards.

The relative economy of the two systems depends upon the nature and height of the coal and the soundness of the roof.

Fig. 4 is a tracing of the actual plan of part of the workings (always reduced to horizontal measurement), showing the method of working out the coal.

Besides the main slope in each seam, there is a travelling slope for the use of the men, a pump slope for the steam pipe and water main, and an airway which carries the air driven down by a large fan at the surface.

The main pumps used in these collieries are the Allison, the Blake, and the Cameron pumps. Of these, the Allison pump gives the greatest satisfaction, on account of the smaller valve surface exposed to the corroding action of the water, which contains a large percentage of free sulphuric acid (sometimes 12 grains per gallon). There are two Allison pumps on the line of the west slope, of the following dimensions: stroke, 6 ft.; steam cylinder diameter, 30 inches; water cylinder diameter, 14¼ inches, strokes per minute, 15. These discharge over 1,000,000 gals. per day each, against a head of 310 and 340 feet respectively.

In carrying steam to these pumps, there is not as much loss as might be expected through condensation. In passing through 750 feet of 9 inch pipes, and 680 feet of 6 inch pipes, the pressure of 70 lbs. at boilers is reduced to 55 lbs. at the pump.

At the east slope, there is a Blake pump at the 800 feet level, a Cameron at the 1,300, and a Blake at the 1,800 feet level. The steam pipes are 9 inches diameter to the 1,300 feet level, and 6 inches from the 1,300 to the 1,800 feet level. All the seams being connected, the water from all the workings is carried to the sump at the 1,300 ft. level of the west slope seam. The pump at 1,300 feet level of the east slope and that at the 800 feet level are for a reserve, the lower one drawing from a long lodgment in which the water is collected when it is not desirable to let it all go to the West slope sump. The steam pipes are covered with infusorial earth underground and with plaster of Paris for outside pipes. The best, cheapest and most durable covering for outside pipes is found to be straw rope, covered well with clay and old sail canvass. This covering is dangerous underground, because of its liability to catch fire from a miner's lamp.

The workings are ventilated by means of three large fans forcing the air down the airways at the three principal slopes.

The fans in use at this colliery are like large paddle wheels revolving in a spiral casing, and throw on an average about 40,000 cubic feet of air per minute each, when working about 80 revolutions per minute. The largest fan (at the east slope) is 8 ft. long and 20 feet diameter, the blades being iron plates 8 ft. by 6 ft. 4 inches. The fan is connected to the engine by a belt, thus allowing a slow motion and causing comparatively light wear on the engine, which is an important consideration in machinery which has to run for long periods of time without stopping.

Spring Hill collieries are remarkably free from gas or fire-damp and naked lights are used in all parts of the workings. They are also free from that other dangerous cause of explosions,—coal dust.

Although there is not an undue amount of water to be dealt with, all the working places are damp, and consequently there is no fine coal dust floating about in the atmosphere. It has recently been discovered that this fine coal dust is the cause of more disastrous and extensive explosions than gas in moderate quantities. It is doubly dangerous where it exists, not only on account of the difficulty of discovering its presence, as it is harmless until disturbed and fired (and this frequently happens in older parts of the workings where the miner expects no danger), but also because very few miners are aware of its dangerous effects. In these respects it differs very much from fire-damp, the danger of which every miner understands from experience, and the presence of which is readily detected by the safety lamp in the hands of the fire boss in his regular rounds.

It is necessary to keep a large portion of the mine opened up by continually sinking the slopes and extending the levels, ready to put out coal from new areas, as the daily output (frequently 2,000 tons) is equivalent to a block 3 feet wide, 3 feet deep, and about one mile long.

The north slope is now drawing coal from the 800 ft. level, the west slope from the 1,300 ft. level of the three seams, and the east slope has lately been extended to draw from the 1,800 ft. level of the two underlying seams. A tunnel has lately been completed on the 1,300 ft. level to connect with the three seams, and the north slope is being extended by driving up from this lower level to meet it above the 800 feet level; such work requires particularly careful surveying.

In order to further extend this slope, a 6 inch hole has been drilled down from the surface 600 ft. to open into this lower level. Through this hole, it is proposed to convey power to a hoisting engine, and to a pump at a lower depth for use in the work of further sinking the slope.

It is not yet decided whether this power will be conveyed by a fast running endless rope, by compressed air, or by electricity. It is probable that compressed air will be used, as the Company has an extensive plan on hand. The writer has no doubt that electricity is the simplest, cheapest and most suitable power for such work.

There are now in operation four slopes besides the south slope, from which workings the coal is drawn to the north slope.

The separate machinery and surface men, the railway sidings, shunting of cars, etc., form a large item in the cost of coal mining.

In order to reduce these costs, it is proposed to sink a vertical shaft (where shewn in Fig. 1) through all the seams, and to hoist all the coal through this shaft. This method would centralize all the machinery and surface work, and consolidate the workings very materially.

Note.—Since writing the above the ground over the north slope workings has suddenly settled, drawing into the mine a large quantity of surface water (the result of the late excessive rainfall). This water has caused considerable temporary inconvenience and irregularity in the work.

From the Drawings accompaying this paper Plate XII has been prepared.

DISCUSSION.

Mr. Poole.

If it were possible to get from Mr. Leonard's paper information on a few more points, it would make the paper, it seems to me, of still greater value.

The fault between the north and south slopes is of special interest, and I wish the plan showed:—where the levels connecting the workings of the two slopes are continuous—dotted lines representing the levels running up to the fault; the direction and underlay of the fault (or faults composing the dislocation); the probable contact of the crops of the underlying seams in the South slope district with the fault; and the extent in feet of the dislocation; the approximate scales on which the plan and section are made.

Perhaps Mr. Leonard could kindly supply this information before the paper is read, and thus correct if necessary the conclusion derived from the data supplied:—viz.: that the dislocation which terminates at the 800 feet level of the North slope workings increases so rapidly on its eastward course that at the mouth of the South slope it amounts to some 400 feet.

With reference to the credit given for the introduction of the successful back-balance system of working, as it is somewhat at variance with the statement in the Geological Survey Report, 1869, p. 93, a confirmation of one or other statement would be desirable.

The Report reads:—"During the past two years the new back-balance or self-acting counter-balance system has been introduced at these mines (the Albion of Pictou County), and is now in successful operation at the cage pit workings. This was first used in Lancashire, England, and was introduced into the Province by Mr. Hudson, of the General Mining Association."

The forcing fan described has radial blades deeper than is usual, 6 ft. 4 ins. out of the 10 ft. radius, or over half, while the more common practice is to have them one-third or thereabouts. It would be interesting to know the water gauges and volumes of air obtained at different speeds with this fan of unusual proportions.

Mr. Gilpin.

Mr. Leonard's paper gives a good general idea of the Collieries as at present worked; and their early development by St. John, (New Brunswick) Capitalists was a bold and well carried out enterprise, which laid a good foundation for the present greatly enlarged operations.

The present pumping appliances have proved satisfactory, and shew a considerable amount of ingenuity in overcoming difficulties. In mines where the water is at all corrosive the aim of the management should be to expose as little corrodible surface as possible in the pumps. Following out this view it is a question if in many cases the use of low speed, with columns of large diameter and working through rams or bucket lifts is not the most advisable.—Similarly in shafts of moderate depths with a water burden not excessive, tanks may in many cases be found superior to direct acting or plunger pumps.—The length of haulage in slopes is found to be against the use of tanks. A good example of water bailing is given in the writer's paper on Coal Mining in Nova Scotia, where it is mentioned that at the Albion Colliery tanks have been used with success for steady water mixing to a depth of 900 feet.

The writer does not quite agree with Mr. Leonard's remarks that coal dust has been the cause of more disastrous and extensive explosions than gas in moderate quantities. So far as his experience goes, coal dust alone has not caused any explosions in these mines. In several cases where it has been pointed out as the sole and determining cause of explosion careful enquiry has elicited the information that at or near the point of ignition there has been an opportunity or chance of more or less gas being present. A small quantity of gas on explosion would have its effects greatly augmented by the presence of coal dust, and a coal dust laden atmosphere if accompanied by a small percentage of gas, is undoubtedly a very dangerous mixture to expose to any agency capable of heating even a limited portion of it.

In this connection it is interesting to note that in Collieries where there is a steady exudation of gas, which, if not attended to, would accumulate in dangerous amounts in a few hours, a strong and steady air current will remove it so rapidly that the most delicate tests will fail to show more than a trace in the returns. The steady passage of large volumes of air of from 50,000 to 100,000 cubic feet per minute, by minimising the percentage of fire damp, forms the best safeguard. The formation therefore of large return air trays, subdivision and shortening of the currents across the working faces, and ample air propelling power are among the chief studies of a Mining Engineer.

Mr. Leonard. The dotted line on Plate XII[A], shews where the levels connecting the north and south slope workings are continuous.

The direction of the fault is also shewn on the plan wherever it has been met in the workings. It extends nearly east and west, and appears to consist of a series of rocks and folds, and a tearing of the strata, extending westward from the surface, gradually becoming less and finally disappearing about the 800 feet level of the north slope or 2100 feet level measuring down the south slope.

The fault shown on plan between the east and west slopes, and extending through the two underlying seams, runs in the same direction and (though much smaller than the one at the south slope) also runs out to the deep, disappearing entirely at the 1,300 feet levels. It is rather peculiar that this fault does not exist in the overlying north slope seam, but that this seam is parted about this point by a band of stone which increases rapidly to the north east to about 130 feet measured horizontally.

The approximate point at which the fault cuts the outcrops of the underlying east and west slope seams is also shown by the dotted lines. The explorations have not yet been made to show the positions of the outcrops of the other underlying seams in this locality.

The dislocation, measured horizontally at the surface is about 1400 feet—Dip to south 12°, and to north 25° approximately.

The dislocation at the south slope increases from nothing at the 800 feet level to 1400 feet at the surface, measured horizontally.

From the Drawings accompanying this Paper Plate XIIA has been prepared.

29th November, 1888.

P. A. PETERSON, Member of Council, in the Chair.

Students' Paper No. 1.

THE WATER-SUPPLY OF THE CITY OF CHARLOTTE-TOWN, P.E.I.

By S. R. Lea, Stud. Can. Soc. C.E.

Charlottetown is a city of about 12,000 inhabitants, situated near the junction of the North River with the Hillsborough (see Plate XIII). It is built on gently rising ground, the highest point being near the outskirts of the city at a point marked S on the plan, which has an elevation of 50 feet. The geological formation in the vicinity of the city and underlying it is that of the new red sandstone; and in this particular locality, many of the sandstones are porous, and some of them considerably jointed,—the strata containing numerous cracks and chasms through which the surface water can find its way with very little resistance. Hence the water supply, which was at first obtained wholly from wells dug within the city limits, was never pure, and became less so as the population increased. Some of the wells referred to were shallow, some of considerable depth, but the water from all was more or less contaminated by surface drainage.

In 1848, the population of Charlottetown was 4,700; in 1871 it had increased to about 8,800. About that time, the growing demands of the inhabitants for purer water led certain persons to undertake the better supply by bringing it in carts constructed for the purpose, from "Spring Park,"—a well of comparatively pure water near the city. (See Plate XIII). On this source the city has depended till the present time, at an annual cost of over $12,000.

On account of this difficulty of obtaining pure, or even impure, water in any quantity, the question of a more efficient water supply was taken into consideration by several of the citizens. Accordingly in 1875 the City Council employed an engineer, Mr. Gilbert Murdoch, of St. John, N.B., to "Make a survey, and report in writing the best and most economical system, and probable cost, of furnishing Charlottetown with a copious supply of water, sufficient to meet the demand for domestic and manufacturing purposes and for extinguishing fires." In selecting the source, the following points were taken into consideration:—That it should be able to furnish water, pleasant to sight, taste, &c., free from organic impurities, and capable of furnishing an immediate daily supply of about 800,000 gallons, and a prospective one of twice that quantity, and that the pressure should be sufficient to dispense with the employment of fire engines.

Artesian wells were first tried. Borings were made—the deepest of which was 500 feet; and although several large veins of water were struck, it was in every case prevented from rising to the surface by rents and fissures in the rock. On this account the borings were discontinued.

In a northeasterly direction from the city, and at a distance of about 5 miles from it, there is an elevated ridge of land, on the northern slopes of which Winter river has its sources, and flows thence into the gulf of St. Lawrence, by way of Bedford Basin. It was proposed to build dams for storing water at either of two points on this river, viz., near the Matheson mill site, or at a point on the Cobb farm, about a mile and a half higher up, the position of which may be seen by referring to the plan. The elevation of Cobb's is 74 feet above high water level, or about 20 feet above the highest point in the city; that of Matheson's is about 70 feet above city datum. The area of the water-shed above Cobb's is 3,100 acres, and above Matheson's about 5,000 acres. By erecting a dam 16 feet high and 264 feet long at Cobb's, a reservoir could be obtained with a capacity of about 27,000,000 gallons. The gaugings made there during the months of August and September, when the water was lowest, varied from 1,607,000 to 2,068,000 gallons per 24 hours. No gaugings were made at Matheson's mill, as the volume of water flowing there was deemed, beyond doubt, ample for the wants of a city three or four times the size of Charlottetown. The water of this river possessed all the required essentials.

The ridge of high land between the heads of the river and the city rises to a height of 186 feet above high water, or about 100 feet higher than the suggested Cobb reservoir; so that to make its water available for city use, pumping or tunnelling would have to be adopted. If the pumping method were chosen, a reservoir would have to be built on the summit of the ridge, from which the water could be sent directly to the city by gravitation with a high pressure, viz., from 100 to 136 feet above the highest city level. The "lift" or difference of level between the pumps and the summit of the hill would be about 100 or 120 feet

The length of the rising main would be about 7,000 feet, and of the leading main, from the reservoir to the city, about 21,000 feet.

By the tunnelling method, the water would be delivered at from 30 to 36 feet above the highest city level, and *there would be about* 24,000,000 *gallons of stored water available in seasons of extra drought.* The length of tunnel required would be about 2½ miles, part or all of which would have to be lined with brick. The greater cost of the tunnel compared with the pumping system, as well as its inferiority as regards pressure, prevented it from being seriously considered.

Two other sources of supply were examined, viz.: Gates' Brook and Curtis' Brook (See Plate XIII). By building a dam at Gates' 34 feet high the surface of the stored water would be raised to a height of 12 feet above the highest city grade. To obtain a high pressure, a reservoir would have to be built on Mt. Edward or College hill (see Plate XIII); or the "Holly" system of getting pressure direct from the pumps would have to be employed. In case of necessity, arrangements could be made to add to this supply, that of Curtis' Brook also.

Curtis' Brook as a source of supply was examined, and its flow of water was found to be more equable, and less directly affected by the rainfall, than that of the other streams examined. By building a dam 35 feet high, the surface of the water would be raised to 35 feet above the highest city level; and about 7 miles of cast iron pipe would be required to bring the water to the city. Estimates were made of the cost of the several schemes proposed, and are set down in the following table:—

Winter River....	Tunnelling..................	$256,385
	Pumping.	132,678
Gates' Brook	Gravitation	123,583
	Pumping	138,000
Curtis' Brook......	Gravitation	166,388

Reports on all the above systems were prepared, but nothing was done until the year 1886, when, after repeated appeals from physicians and others who looked on the subject from a hygienic point of view, and when the city had suffered from the effects of two or three destructive fires, a city council was elected pledged to obtain an efficient water supply.

In June, 1887, a commission was appointed by the council to proceed at once with the carrying out of the scheme for the construction of Water Works. From the evidence furnished by a number of private wells, many prominent citizens were of the opinion that a subterranean supply of pure water sufficient for all purposes could be procured near the city. Therefore the services of an engineer who had had experience in tube or driven gang wells were secured. The engineer was Mr. M. M. Tidd, of Boston, Mass. Mr. Tidd arrived in Charlottetown on the 5th of August, 1887, and having examined the different streams and watersheds within 8 miles of the city, north of the Hillsborough, recommended the commissioners to sink test wells a few yards from the "Three Mile Brook," near the upper Malpeque Road (See Plan). Several wells were bored, each of which overflowed freely at the surface. One of the fire engines was tried on one of the tubes for several hours, without exhausting it. A large shallow well was dug, and two other engines and pumps were employed. Several tests were made at the driest season of the year, by which it was proved that a discharge from the well of about 1,000,000 gallons per 24 hours left the force and volume of the spring below unabated.

The drainage area which furnishes the water of the Three Mile Brook is about 900 acres. It has been found upon examination, that beneath this valley, at a depth below the surface of from 18 to 20 feet, there occurs a stratum of solid rock.

Fig. 16 represents part of a section through the valley. A is the layer of rock, B is a layer of loose gravelly clay about 2 feet thick, C is the part between it and the surface which consists of clay, stones, etc., much firmer than B, but yet porous enough to allow the rainfall to make its way through it readily enough. When it reaches the stratum of rock it is deflected toward the lowest part of the valley, along which the brook flows. Hence there is a continual flow of water through these upper strata towards the stream, along the course of which it breaks out in the form of springs. It was within a few yards of this stream that the test wells were dug.

A careful examination of the drainage area, the test wells, and the results of the experiments, was made by the engineer. It was considered that a sufficient supply of water for the city for years to come could be collected from this source.

If necessary, a large amount of water could be stored in the valley by a dam 8 feet high at the lower Malpeque Road (see Plan), which would back the water nearly up to the proposed pumping station. This water could easily be taken into the pump well by a pipe from the upper end of the pond. The water of Gates Pond could easily be taken to this pond by gravity. And thus the supply from both these ponds could be obtained as well as that of the well. The estimated cost of the dam, gate pipes, etc., to effect this was $7,500; but as the supply from the well is considered sufficient for some years to come, these works will not be constructed till actually necessary.

Mr. Tidd, who had, during his first visit, been engaged to proceed with the preparation of specifications and plans of such parts of the work as would be common to all sources of supply, was now authorized to complete them; on the basis of placing the pumping station near the big well, the reservoir on Mount Edward, the force main straight from the pumping station to the reservoir, and the delivery main thence by the Mount Edward and St. Peter's roads to the city.

The specifications were prepared as follows:

1. For coated cast iron water pipes, and special casting.
2. For laying cast iron water pipes and their appurtenances.
3. For water stop gates and hydrants.
4. For pumping machinery, boiler, etc.
5. For furnishing materials and constructing a reservoir.
6. For furnishing materials and constructing a pumping station.

The following are the tenders accepted:—

1. For coated cast iron pipes, etc.	$ 61,355.15
2. Laying pipe, etc.	23,708.74
3. Water stop gates, etc.	7,167.00
4. Pumping machinery	10,070.00
5. Reservoir	14,278.73
6. Pumping station	16,615.50
Total	$133,195.12

In addition to the above sum, to be included in contracts, the engineer estimates that $6,400 will be required for engineering and special castings about the reservoir and pumping station. The commissioners estimate that $5,000 will be required for land, damages and water rights. This will make the whole cost of the work stand as follows:—

Contracts as above	$133,195
Engineering, castings	6,400
Land damages	5,000
Preliminary work	3,000
Total	$147,595

Work was begun last spring as early as possible, and is going on at the present time. It is expected that all parts of the work will be completed about the last of November of this year. What follows is a description of the work as it will be when completed, beginning with the supply well and pumping station.

The excavations for the supply-well were begun at a point near the Upper Malpeque Road, on the north side of the stream, and at a distance of 8 or 10 yards from it. (Fig. 1 and Fig. 2 on Plate XIII). As the work proceeded sheet piles were driven all around the four sides of the excavation, to prevent the earth caving in. These were held in position by a frame work of the form shown in Fig. 7, where the sheet piling (in section) is represented by A. These piles, which had been cut of sufficient length for the purpose, were driven down farther and farther, as the excavation was deepened. Two pumps were employed to keep the well free from water. At a depth of 19 or 20 feet the rock was reached. Here the work of excavating stopped, after a level foundation had been prepared for the masonry, which was to form part of the wall of the complete well. The inside diameter of this well (finished) is 25 feet. It is circular in form. The lower courses of the wall consist of rough blocks of Nova Scotia grey sandstone, laid loose in order to permit the free passage of the water into the well. This is carried up to a distance of nineteen feet, and is backed with broken stone (Fig. 1). From that point upward the wall is built of well burnt bricks laid in Portland cement, 3 of sand to 1 of cement. The well is provided with an overflow.

On the opposite side of the stream and about the same distance from it, the pumping station is built. This consists of a one storey brick building 35 feet x 40 feet, which contains the pumping engines and pump well; and a building of similar construction, the dimensions of which are 28 ft. x 34 ft., to serve as a boiler room. The excavations for the pump well were conducted in the same manner as those for the supply well. When the rock was reached a level surface was prepared and covered with 2 feet of concrete. By referring to Fig. 2 the position of the pumps and pump well with its four chambers, and the position of the screens, will be seen. The foundations for the pumps are carried up from the solid rock, for fear of shallow foundations being undermined by the action of the water flowing towards the big well, so that the area covered by the concrete includes the base of the foundations of the pumps, as well as that of the pump well. The concrete foundation extends 20 inches beyond the walls of the pump well and pump foundation. The walls of the pump well are built of brick laid in cement. The foundations of the pumps, above the concrete, consist of stone masonry laid in cement. The water is brought from the supply well by a 14 in. cast iron pipe, laid in the position shown in Fig. 2.

Only one pumping engine is to be procured at present. The second one will be put in when it is considered necessary. The engine is being built by the Geo. Blake Manufacturing Co. of Boston. It is of the compound Duplex pattern with inside plunger, 14 in. high pressure cylinder, 28 in. low pressure cylinder, with a 14 in. pump cylinder, and 18 in. stroke. The specifications require it to be capable of delivering 2,000,000 gallons of water in 24 hours, against a vertical head of 200 feet through 4,722 lineal feet of 14 in. pipe, with a pressure of steam on the boiler of 60 pounds per sq. inch. The engine is to be fitted with all the latest improvements with regard to its parts. The suction and discharge openings are to be joined by Y connections, each surmounted by an air chamber. As accessories to the engine, there are to be an independent air pump and a jet condenser, of sufficient capacity to maintain a vacuum of 28 inches of mercury column, while the main pump is in operation. There will also be a feed water heater with cast iron shell, containing a 75 ft. coil of $1\frac{1}{4}$ inch copper pipe; also one straight-way 14 in. check valve placed upon the force main, with a clear water-way through it equal to a 14 in. pipe, also a 4 in. Ashton relief valve attached to the force main in such position, that in case of excessive pressure the water will flow over into the pump well or into the suction pipe. To supply steam for the engine there will be a horizontal tubular boiler made of C. H. No. 1 wrought iron, $\frac{3}{8}$ in. thick, with a tensile strength of 50,000 lbs. per square inch of section at least, tested to 150 lbs. cold water pressure. The shell is to be 16 ft. 2 in. long and 72 inches in diameter with 112.3 inch tubes, 4 inch main steam connections. The boiler will be set in brick with an iron front covering the masonry.

From the pumping station a straight line of 14 in. cast iron pipe, 4,722 feet long, is laid, to the reservoir (Plate XIII). From the reservoir the water is carried by a 14 in. pipe to the city, by way of Mt. Edward and St. Peter's roads; and here, it would perhaps be as well to give a short description of the pipe itself and the manner of laying it, which will have a general application to all the pipe laid as well as to the part connecting the pumping station with the reservoir.

The contractors for the pipe, etc., are Messrs. Laidlaw & Sons, Glasgow, Scotland.

The following is an extract from the specifications for "coated cast iron water pipes, etc.:"

Estimated quantities.

106	tons of	14 in.	pipe Class	B.
301	"	14 in.	"	C.
265	"	14 in.	"	D.
183	"	10 in.	"	D.
190	"	8 in.	"	D.
75	"	6 in.	"	C.
585	"	6 in.	"	D.

40 tons special castings.

"The pipes to be made with hub and spigot joints, 12 feet in length, exclusive of socket. Iron to be of first-class quality with a tensile strength of at least 16,000 lbs. per sq. inch......cast in dry sand moulds in a vertical position, with hub end down, curved pipes in loam; to be free from defects of every nature......surface of pipes, after being entirely free from rust, to be coated inside and out with coal pitch varnish, according to Dr. Angus Smith's process......"

The following are the engineer's estimates of the length of the different kinds of pipe to be laid:—

15,767	lineal feet	of	14 in.	pipe.
6,767	"	"	10 in.	"
9,645	"	"	8 in.	"
49,045	"	"	6 in.	"

There are to be 87 hydrants and 170 gate boxes.

The pipe is laid at such a depth that the top of the pipe is $5\frac{1}{2}$ feet below the surface. Where it is considered necessary, a concrete foundation is put in to support the pipes and other work.

At the time when laid, the spigots of the pipe are so adjusted in the sockets, as to give uniform space all round. The specified depth for the lead to be run is 2 inches for all sizes of pipe; also the joints of the sleeves are to be run with lead to a depth not less than the joints of the pipe upon which they are placed. The gasket packing to be of clean sound hemp yarn twisted, applied in one piece and tightly driven so as to leave the required depth of lead. In refilling the trenches care is taken to give the pipe a solid bearing throughout its entire length by packing the earth under and around the pipe and other castings with proper rammers, etc.

The reservoir which is almost completed at the present time is built on Mount Edward (Plate XIII), at a short distance to the east of Mount Edward Road. It is circular in form, the dimensions being, 135 feet in diameter on the finished bottom, 186 feet on top to the inside line of embankment, and 17 feet deep. The general width of the embankment on the top is 15 feet, and the slopes are $1\frac{1}{2}$ to 1, as shown in Figs. 3 and 5. Its appurtenances include a gatehouse with screen well, settling pipes, gates, valves, special castings, etc. It is built partly by excavation, partly by embanking, in such a manner that the portion excavated approximates to the contents of the embankment.

The ground to be covered by the reservoir was first cleared of trees, roots, stumps, stones, etc., and soil, the last of which is stored in spoil banks, close at hand, for subsequent use on the surface of the embankment. All soil from the excavations is stored in spoil banks for use in forming the embankments. All parts of the embankment start from a well prepared base, fitted for incorporation with the filling, and the earth of which it is formed, before being used, was freed from roots, muck, stones of more than 3 inches in diameter, etc.; the small stones are not allowed to exceed 1 per cent. of the material. The embankments are carried up in layers, level longitudinally but slightly concave in cross section, and about 6 inches in thickness. Each layer is carefully rolled with a heavy grooved roller, and watered more or less as required. No lumps are allowed to go in, and the earth is well and solidly rammed with heavy rammers, at such points as could not be reached with the rollers. When the embankment had been carried up in the way to a vertical height of 8 feet (See Section of embankment Figure 4), the bottom of the reservoir was levelled and smoothed, and covered with a layer of clean sand 4 inches thick. Over this is placed a layer of clay puddle, 2 feet thick, which is carried up the slopes to a vertical height of 8 feet, and then horizontally to a distance one foot and six inches past the centre of the embankment (Fig. 4.).

The puddle is composed of a good, pure, adhesive clay, which is obtained near the pumping station; mixed with clean gravel in proportions determined by the engineer. The materials were well mixed while dry, and then a sufficient quantity of water added, and the whole worked up until each layer was sufficiently tough and impervious to water. The puddle is applied in horizontal layers not exceeding 6 inches in thickness, each layer being allowed to set firm and stiff, but not dry, before another layer is applied. Upon the puddle a core wall two feet thick is built, at a distance of 6 inches from the edge of the puddle (see Fig. 4). This wall is built of rubble masonry laid in mortar, composed of 1 part Portland cement to 2 parts of clean sharp sand, and is plastered upon the inside face one inch thick with the same mortar. The wall is 6 feet high, and with the puddle makes the reservoir water-tight.

When the wall was completed, the work of adding to the embankment went on as before. When it had been carried up to the required height—17 feet vertical—the inner slope was dressed true to line, and a layer of broken stone, averaging about 9 inches in thickness, was applied. The stone used was first freed from fine material by screening, and, after being laid in place, was well compacted by ramming.

The inner slope is paved with good sound stone, whose dimensions average 3 in. x 3 in. x 1 in., and are never less than 12 in. in thickness. These stones are laid dry, and as close together as is practicable, each stone having a firm bearing on the broken stone backing, and every precaution being taken to make it secure in place. The lower course at the footing of the slope is constructed of stone, of the full depth of the surface paving and the broken stone backing, and is laid in such a manner that its top surface is parallel to the slope of the embankment. This lower course is laid in cement and has a footing of concrete. (See Fig. 4).

The gate house 15 ft. x 11 ft. is constructed of hard burnt brick, as is the screen well. The walls of the screen well are 16 inches thick, resting upon a foundation of concrete 18 inches thick, and one foot larger on each side than the walls of the well. The brick masonry of which the walls are composed is laid in the best hydraulic cement, and the walls are plastered on the inside and outside with as heavy a coat of mortar as possible. There is also a stratum of cement mortar connecting with the concrete floor of the screen well, and passing upwards between two vertical courses of brick to the belt course, at the grade of the top of the embankment. One course of brick was built in advance of the other, and the mortar plastered upon its face. The other was then built up leaving a space of 1 inch, which was filled with mortar. These two courses of brick are not bonded together. There are two screens, 16 meshes to an inch, and there is a wing wall on each side of the well, into which the screen guides are built. When the walls reach the grade of the top of the underpinning, there is a belt course of sandstone laid upon them. The walls of the gate-house are built upon this belt course.

Where concrete is used in the above work, it is made of sound stone broken, so as to pass through a screen of two inch mesh, and none so small as to pass through one of one inch mesh. The material, after being cleaned from dirt and dust, is properly wetted and thoroughly mixed with mortar, in boxes, in such proportions that the volume of the mortar is always slightly in excess of the volume of the voids in the broken stone. The mortar used in the concrete is such as above described for stone masonry, except that the proportions are one part of cement and three parts loose sand.

The following is the engineer's table of quantities, materials, etc., in the reservoir :—

1.	7,346	cubic yards	earth excavation.
2.	3,104	"	rock "
3.	2,458	"	of puddle.
4.	649	"	of concrete.
5.	401	"	of broken stone.
6.	1,702	square yards	slope paving.
7.	330	cubic yards	rubble masonry.
8.	1·9	"	sandstone "
9.	61·7	"	brick "
10.	745	"	of soil on top and slopes.
11.	175	"	of sand on bottom.

The elevation of the water, when the reservoir is filled, is 150 feet above tide level.

With regard to the water furnished by the above system, the following is the result of an analysis by Professor T. M. Drown, of the Mass. Institute of Technology. There are two samples: No. 1 being from Gates' Brook, and No. 2 from the big well (The water was lifted on the 16th and analysed on the 26th) :—

		No. 1.	No, 2.
Residue of evaporation.	Total	8·82	8·54
Loss on Ignition,	"	2·38	2·31
Fixed,	"	6·44	6·23
Ammonia, Free,	"	·0139	·0014
Albuminoid,	"	·0122	·0025
Chlorine,	"	·67	·67
Nitrogen as nitrites and nitrates,		·091	·018
Nitrates		Present	Trace.
Hardness equivalent to carbonate of lime		6·70	6·70

The greatest exception that can be taken to the water is its hardness; but this is common to all water in the province, owing to the red sandstone formation of the Island. But even in respect to hardness the water shows well. By Dr. Clarke's notation, one degree of hardness represents as much of the hardening salts as would take up and precipitate as much soap as a grain of carbonate of lime would do, in a gallon of water. There are 6·70 grains, equivalent to carbonate of lime in a gallon of the big well water. Water whose permanent hardness does not rise above six degrees of Clarke's scale, is taken conventionally as a soft water. But a part of the hardness in the big well water is due to carbonates, and is not permanent since it escapes by boiling in the form of carbonic acid gas. According to Clarke's scale, therefore, the water is a soft water, and is almost wholly free from nitrates, ammonia, and other unwholesome ingredients.

The engineer in charge of these works is Mr. F. Coffin, C.E., of Boston, and Mr. J. P. Ball, B.A. Sc., is his assistant.

From the drawings accompanying this paper plate XIII has been prepared.

APPENDIX

DRAINAGE AND IRRIGATION DITCHES.

By E. Mohun, M. Can.Soc. C.E.

The following Tables have been computed from Kutter's Formula, and give the velocity in feet a second, and the logarithms of discharge of ninety different sized ditches with varying falls.

The value of n has been taken at 0.03 as for ditches in fair average order.

The upper line gives the velocity in feet a second by inspection; and the lower the logarithms of discharge.

The discharge is found thus; to the log. obtained from the Table

add the	constant	log.	3.556303	for cubic feet	an hour
"	"	"	4.936514	" "	a day
"	"	"	4.350937	imp. galls.	an hour
"	"	"	5.731148	"	a day
"	"	"	1.532408	Miner's inches (Canadian)	

the results will be the logarithms of the numbers required. For instance, to obtain the number of Miner's Inches discharged by a ditch 5 feet wide, 4 feet deep, sides 1 to 1, and with a fall of 6 feet a mile; the logarithm of discharge obtained from the Table is 1.998388

The constant log. for Miner's Inches is 1.532408

No. of Ins. = 3395 = 3.530796

Of course the operation may be reversed and the size of the ditch obtained for a given discharge.

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TABLES OF VELOCITY OF FLOW & DISCHARGE IN DRAINAGE & IRRIGATION DITCHES.

Fall in Ft a mile	Depth of water	Slopes: ½ to 1. Width of bottom of Ditch. 2′	3′	4′	5′	6′	7′
3	1′	0.6947 0.239763	0.7694 0.430225	0.8188 0.566377	0.8539 0.671760	0.8802 0.757514	0.9006 0.829581
	2′	1.0015 0.778813	1.1221 0.953120	1.2117 1.083393	1.28 1.186380	1.3345 1.271450	1.3793 1.343777
	3′	1.2102 1.104059	1.3546 1.262148	1.4681 1.384228	1.5596 1.483051	1.6349 1.565671	1.699 1.636739
	4′	1.5321 1.389406	1.6886 1.528556	1.8134 1.638713	1.9165 1.729668	2.0029 1.806818	2.0764 1.873608
	5′	1.6093 1.558829	1.7733 1.687827	1.908 1.792468	2.0237 1.880162	2.1232 1.955388	2.2104 2.021093
4	1′	0.807 0.304803	0.893 0.494925	0.9503 0.631088	0.991 0.736419	1.0213 0.822085	1.046 0.894216
	2′	1.1616 0.843204	1.3006 1.017248	1.404 1.147326	1.4824 1.250246	1.5456 1.335212	1.597 1.407416
	3′	1.4023 1.168020	1.5686 1.325845	1.6995 1.447796	1.8051 1.546538	1.8916 1.629023	1.9653 1.699974
	4′	1.8144 1.452856	1.9532 1.591779	2.0976 1.701942	2.2164 1.792804	2.3157 1.869830	2.4007 1.936639
	5′	1.8629 1.622381	2.05 1.751069	2.2064 1.855561	2.3392 1.943100	2.4543 2.018320	2.554 2.083908
5	1′	0.905 0.354607	1.002 0.544905	1.0657 0.680842	1.111 0.786072	1.1452 0.871788	1.1714 0.943782
	2′	1.3014 0.892575	1.4576 1.066736	1.5732 1.196776	1.6611 1.299588	1.7317 1.384612	1.7887 1.456658
	3′	1.5713 1.217478	1.7573 1.385184	1.903 1.496916	2.0206 1.595524	2.1179 1.678085	2.2001 1.748977
	4′	1.9857 1.502030	2.1863 1.640731	2.3474 1.750801	2.4799 1.841589	2.5911 1.918630	2.6852 1.985280
	5′	2.0856 1.671405	2.2942 1.799968	2.469 1.904399	2.618 1.991999	2.7453 2.066984	2.8568 2.132575
6	1′	0.994 0.395328	1.0993 0.585390	1.1699 0.721345	1.2197 0.826605	1.257 1.912233	1.2858 0.984233
	2′	1.4286 0.933052	1.5998 1.107140	1.7253 1.236866	1.8222 1.339775	1.8991 1.424678	1.9616 1 496731
	3′	1.7236 1.257634	1.927 1.415203	2.0868 1.536961	2.2158 1.635557	2.3218 1.718013	2.4120 1.788905
	4′	2.1574 1.542051	2.3969 1.680677	2.5732 1.790691	2.7181 1.881431	2.8395 1.958395	2.9426 2.025042
	5′	2.2874 1.711530	2.5151 1.839885	2.7062 1.944237	2.8685 2.031689	3.0083 2.106714	3.1303 2.172275
7	1′	1.0754 0.429519	1.1898 0.619551	1.2655 0.755473	1.3193 0.870715	1.3601 0.946484	1.3921 1.018733
	2′	1.5448 0.977013	1.7298 1.141088	1.8655 1.270789	1.9700 1.373655	2.0526 1.458425	2.1206 1.530578
	3′	1.8634 1.291498	2.0832 2.449059	2.2556 1.570742	2.3948 1.669310	2.5101 1.751874	2.6063 1.822571
	4′	2.3535 1.575833	2.5902 1.714371	2.7809 1.824397	2.9371 1.915078	3.0681 1.992024	3.1795 2.058659
	5′	2.4710 1.745064	2.7180 1.873580	2.9240 1.977859	3.0995 2.065317	3.2504 2.140320	3.3819 2.205853

Fall in Ft a mile	Depth of water	Slopes: 1 to 1. Width of bottom of Ditch. 2′	3′	4′	5′	6′	7′
3	1′	0.7249 0.337370	0.7862 0.497577	0.8286 0.617327	0.8598 0.712536	0.8836 0.791376	0.9025 0.858526
	2′	1.0995 0.944304	1.1914 1.076055	1.2612 1.179963	1.3168 1.265664	1.3603 1.337751	1.4 1.401393
	3′	1.4063 1.324255	1.5081 1.433705	1.5915 1.524015	1.661 1.600593	1.72 1.666890	1.7706 1.725238
	4′	1.6774 1 604852	1.7836 1.698453	1.8955 1.782871	1.9517 1.846717	2.0188 1.907159	2.0781 1.961126
	5′	1.9261 1.828736	2.0338 1.910363	2.1286 1.981307	2.2096 2.043285	2.2825 2.098767	2.3474 2.148735
4	1′	0.8416 0.402221	0.9125 0.562305	0.9607 0.681570	0.9980 0.777283	1.0252 0.855891	1.047 0.923012
	2′	1.2746 1.008450	1.3805 1.140045	1.4611 1.243851	1.5252 1.329458	1.5753 1.401492	1.6218 1.465285
	3′	1.6283 1.387823	1.7457 1.497247	1.8418 1.587460	1.922 1.663954	1.9899 1.730192	2.0482 1.788487
	4′	1.9418 1.668428	2.063 1.761669	2.167 1.841009	2.2567 1.909774	2.3339 1.970139	2.4022 2.024067
	5′	2.2271 1.891813	2.3511 1.973335	2.4573 2.043666	2.5535 2.106099	2.6371 2.161494	2.7118 2.211412
5	1′	0.9441 0.452146	1.0234 0.612126	1.0784 0.731755	1.1187 1.826846	1.1495 0.905599	1.1738 0.972702
	2′	1.4283 1.057918	1.5468 1.189422	1.6368 1.293173	1.7084 1.378720	1.7644 1.450714	1.8156 1.514284
	3′	1.8236 1.437010	1.9547 1.546358	2.062 1.636512	2.1515 1.712952	2.2273 1.779144	2.2924 1.837407
	4′	2.1726 1.517199	2.3091 1.810597	2.425 1.889860	2.5251 1.958579	2.6113 2.018322	2.6874 2.072778
	5′	2.4921 1.940627	2.6303 2.022070	2.752 2.092857	2.856 2.154733	2.9502 2.210212	3.0327 2.259987
6	1′	1.0366 0.492727	1.1235 0.652650	1.1837 0.772228	1.2279 0.867317	1.2617 0.946049	1.2883 1.013122
	2′	1.5672 1.098211	1.6968 1.229641	1.7954 1.333348	1.8739 1.418874	1.9353 1.490859	1.9911 1.554371
	3′	1.9999 1.477100	2.1434 1.586385	2.2609 1.676498	2.3588 1.752907	2.4417 1.819061	2.5129 1.877302
	4′	2.3819 1.757140	2.5313 1.850497	2.658 1.929707	2.7675 1.998388	2.8618 2.058701	2.9452 2.112563
	5′	2.7315 1.980475	2.8827 2.061862	3.0158 2.132611	3.1296 2.194466	3.2319 2.249819	3.3229 2.299663
7	1′	1.1215 0.526904	1.2155 0.686797	1.2807 0.806407	1.3282 0.901415	1.3656 0.980408	1.3935 1.047204
	2′	1.6947 1.132181	1.8346 1.263553	1.9411 1.367237	2.0258 1.452731	2.0921 1.524693	2.1524 1.588206
	3′	2.162 1.510940	2.3169 1.620182	2.4437 1.710263	2.5493 1.786631	2.6389 1.852784	2.7158 1.911019
	4′	2.5742 1.790871	2.7354 1.884174	2.8724 1.963388	2.9905 2.032044	3.0922 2.092327	3.182 2.146158
	5′	2.9526 2.014122	3.0619 2.088058	3.2584 2.166220	3.3812 2.228044	3.4914 2.283365	3.5896 2.333197

Fall in Ft a mile	Depth of water	Slopes: 1½ to 1. Width of bottom of Ditch. 2′	3′	4′	5′	6′	7′
3	1′	0.7277 0.406023	0.7814 0.546092	0.8203 0.654317	0.8496 0.742118	0.8727 0.815931	0.8913 0.879427
	2′	1.1346 1.054861	1.2074 1.161030	1.2659 1.248533	1.3141 1.322739	1.3544 1.387019	1.3887 1.443623
	3′	1.4743 1.458631	1.5529 1.543328	1.6195 1.615914	1.6745 1.678735	1.7264 1.735453	1.77 1.785798
	4′	1.7784 1.755186	1.8582 1.825498	1.9288 1.887354	1.9898 1.942262	2.0447 1.991867	2.0938 2.036937
	5′	2.0584 1.990214	2.1388 2.050331	2.2085 2.103772	2.2724 2.152358	2.3301 2.196685	2.3827 2.237401
4	1′	0.8446 0.470724	0.907 0.610819	0.9519 0.718966	0.9858 0.806713	1.0126 0.880481	1.034 0.943947
	2′	1.315 1.118941	1.399 1.224994	1.4665 1.312412	1.522 1.386547	1.5686 1.450775	1.6081 1.507335
	3′	1.7064 1.522228	1.7982 1.607016	1.8741 1.679331	1.9377 1.742130	1.9972 1.798741	2.0475 1.849047
	4′	2.0561 1.818203	2.1489 1.888512	2.2303 1.950433	2.3004 2.005263	2.3636 2.054824	2.4203 2.099868
	5′	2.3794 2.053160	2.4707 2.112976	2.5522 2.166586	2.6258 2.215149	2.692 2.259375	2.7524 2.300053
5	1′	0.9478 0.520800	1.0171 0.660563	1.0676 0.768757	1.1055 0.856460	1.1354 0.930205	1.1594 0.993636
	2′	1.4733 1.168382	1.5674 1.274370	1.6428 1.361719	1.705 1.435826	1.7569 1.500015	1.801 1.556547
	3′	1.9113 1.571353	2.0122 1.655858	2.098 1.728341	2.1692 1.791135	2.2356 1.847697	2.2916 1.897966
	4′	2.3024 1.867325	2.4049 1.937406	2.4957 1.999247	2.5739 2.054044	2.6444 2.103565	2.7076 2.148588
	5′	2.6619 2.101886	2.7637 2.161647	2.8548 2.215243	2.9372 2.263816	3.0107 2.307966	3.0779 2.348596
6	1′	1.0406 0.561369	1.1168 0.701198	1.1719 1.809246	1.2134 0.896920	1.2462 0.970657	1.2725 1.034077
	2′	1.6167 1.208633	1.7194 1.314564	1.8021 1.401897	1.87 1.475958	1.9269 1.540133	1.9752 1.596646
	3′	2.096 1.611422	2.204 1.695400	2.3003 1.768320	2.3781 1.831072	2.4508 1.887616	2.5121 1.937861
	4′	2.5231 1.907223	2.6361 1.977270	2.7355 2.039095	2.8211 2.093867	2.8982 2.143362	2.9679 2.188454
	5′	2.917 2.141637	3.0286 2.201404	3.1281 2.254951	3.2177 2.303419	3.2986 2.347637	3.3724 2.388282
7	1′	1.1258 0.595549	1.2082 0.735337	1.2677 0.843374	1.3126 0.931041	1.348 1.004748	1.3764 1.068167
	2′	1.7482 1.242587	1.8591 1.348483	1.9442 1.435789	2.0217 1.509835	2.0831 1.573990	2.1352 1.630477
	3′	2.2657 1.645228	2.385 1.729672	2.4862 1.802071	2.5703 1.864822	2.6487 1.921341	2.7149 1.971578
	4′	2.7275 1.940921	2.8487 2.010946	2.9559 2.072744	3.0481 2.127487	3.1313 2.176972	3.2059 2.221953
	5′	3.152 2.175277	3.2645 2.233977	3.3796 2.288530	3.4762 2.336987	3.5636 2.381192	3.6426 2.421749

DR

	18 Feet
	0.5067
5	1.30681
	0.8095
7	1.85269
	1.0390
5	2.17496
	1.2296

TABLES OF VELOCITY OF FLOW & DISCHARGE IN DRAINAGE & IRRIGATION DITCHES.

Fall in Ft. a mile.	Depth of Water in Feet.	Slopes: ½ to 1. Width of bottom of Ditch. 10 Feet.	12 Feet.	14 Feet.	16 Feet.	18 Feet.	20 Feet.
	2′	0.4634 1.008573	0.4769 1.093378	0.4890 1.167290	0.4992 1.229758	0.5067 1.284571	0.5130 1.333397
	4′	0.7063 1.530227	0.7377 1.616057	0.7632 1.688832	0.7863 1.752918	0.8024 1.807493	0.8178 1.857120
0.33̇	6′	0.8794 1.836286	0.9230 1.919438	0.9596 1.990701	0.9908 2.052910	1.0176 2.108053	1.0414 2.157476
	8′	1.0189 2.057340	1.0712 2.137090	1.1162 2.206106	1.1553 2.266820	1.1881 2.320383	1.2200 2.369636
	10′	1.1390 2.232618	1.1977 2.308800	1.2490 2.375307	1.2942 2.434210	1.3343 2.486982	1.3702 2.534738
	2′	0.6739 1.171037	0.6946 1.256696	0.7106 1.328765	0.7235 1.390886	0.7339 1.445440	0.7427 1.494035
	4′	1.0083 1.684847	1.0511 1.769827	1.0858 1.841939	1.1147 1.904481	1.1390 1.959607	1.1598 2.008851
0.66̇	6′	1.2430 1.986551	1.3004 2.068723	1.3508 2.139181	1.3927 2.200750	1.4287 2.255313	1.4601 2.304270
	8′	1.4302 2.204603	1.4999 2.283260	1.5599 2.351466	1.6119 2.411462	1.6557 2.464484	1.6976 2.513128
	10′	1.5902 2.377549	1.6682 2.452687	1.7360 2.518306	1.7957 2.576461	1.8486 2.628575	1.8960 2.675776
	2′	0.8351 1.264174	0.8603 1.349601	0.8797 1.421469	0.8953 1.483452	0.9080 1.537889	0.9186 1.586377
	4′	1.2402 1.774717	1.2914 1.859240	1.3332 1.931078	1.3678 1.993362	1.3971 2.048305	1.4220 2.097396
1.0	6′	1.5219 2.074482	1.5923 2.156262	1.6511 2.226385	1.7012 2.287666	1.7444 2.342028	1.7820 2.390791
	8′	1.7461 2.291280	1.8297 2.369583	1.9012 2.437390	1.9631 2.497068	2.0154 2.549866	2.0653 2.598277
	10′	1.9364 2.463089	2.0301 2.537974	2.1110 2.603232	2.1796 2.660589	2.2451 2.712960	2.3013 2.759912
	2′	1.0318 1.356024	1.0624 1.441274	1.0862 1.513015	1.1051 1.574868	1.1206 1.629224	1.1335 1.677658
	4′	1.5231 1.863973	1.5853 1.948294	1.6358 2.019922	1.6777 2.082052	1.7130 2.136845	1.7432 2.185821
1.5	6′	1.8656 2.162924	1.9484 2.243918	2.0193 2.313801	2.0796 2.374893	2.1316 2.429082	2.1768 2.477697
	8′	2.1336 2.378340	2.2340 2.456289	2.3222 2.524256	2.3944 2.583324	2.4571 2.635943	2.5170 2.684184
	10′	2.3634 2.549627	2.4748 2.623998	2.5718 2.688989	2.6571 2.746621	2.7325 2.798289	2.8011 2.845269
	2′	1.1970 1.420506	1.2322 1.505642	1.2601 1.577518	1.2813 1.639118	1.2990 1.693407	1.3139 1.741867
	4′	1.7613 1.927080	1.8327 2.011272	1.8906 2.082776	1.9386 2.144811	1.9795 2.199639	2.0135 2.248441
2′.0	6′	2.1516 2.224854	2.2485 2.306138	2.3297 2.375907	2.3987 2.436886	2.4581 2.490971	2.5098 2.539519
	8′	2.4604 2.440231	2.5753 2.518030	2.6735 2.585442	2.7585 2.644789	2.8302 2.697337	2.8984 2.745461
	10′	2.7231 2.611160	2.8505 2.685363	2.9612 2.750215	3.0584 2.807714	3.1446 2.859289	3.2254 2.906530
	2′	1.3423 1.470280	1.3816 1.555348	1.4121 1.626974	1.4363 1.688737	1.4563 1.743020	1.4728 1.791385
	4′	1.9713 1.975989	2.0508 2.060101	2.1154 2.131552	2.1686 2.193518	2.2137 2.248200	2.2522 2.297088
2′.5	6′	2.4056 2.273316	2.5135 2.354518	2.6038 2.424200	2.6804 2.485105	2.7464 2.539130	2.8039 2.587637
	8′	2.7490 2.488392	2.8766 2.566086	2.9857 2.633404	3.0802 2.692695	3.1600 2.745200	3.2356 2.793258
	10′	3.0408 2.659073	3.1823 2.733188	3.3053 2.797963	3.4132 2.855375	3.5088 2.906880	3.5941 2.953532

Fall in Feet a mile.	Depth of Water in Feet.	Slopes: 1 to 1. Width of bottom of Ditch. 10 Feet.	12 Feet.	14 Feet.	16 Feet.	18 Feet.	20 Feet.
	2′	0.4669 1.049391	0.4803 1.128673	0.4909 1.196177	0.4996 1.254905	0.5067 1.306813	0.5127 1.353333
	4′	0.7273 1.609924	0.7535 1.683251	0.7753 1.746799	0.7937 1.802747	0.8095 1.852691	0.8232 1.897785
0.33̇	6′	0.9267 1.949233	0.9611 2.016204	0.9907 2.075126	1.0164 2.127645	1.0390 2.174965	1.0590 2.218004
	8′	1.0966 2.198398	1.1362 2.259584	1.1711 2.314100	1.2020 2.363204	1.2296 2.407819	1.2544 2.448673
	10′	1.2487 2.397506	1.2918 2.453625	1.3303 2.504159	1.3649 2.550076	1.3962 2.592094	1.4246 2.630808
	2′	0.6784 1.211722	0.6972 1.290510	0.7120 1.357621	0.7240 1.416026	0.7339 1.467690	0.7422 1.513986
	4′	1.0370 1.763979	1.0726 1.836611	1.1022 1.899575	1.1272 1.955087	1.1485 2.004614	1.1671 2.049377
0.66̇	6′	1.3067 2.098437	1.3528 2.164661	1.3925 2.222963	1.4269 2.274954	1.4570 2.321832	1.4836 2.364454
	8′	1.5338 2.344124	1.5865 2.404569	1.6328 2.458456	1.6738 2.507015	1.7104 2.551149	1.7431 2.591563
	10′	1.7357 2.540502	1.7926 2.595904	1.8433 2.645803	1.8889 2.691174	1.9300 2.732705	1.9674 2.771011
	2′	0.8406 1.304815	0.8634 1.383369	0.8814 1.450311	0.8959 1.508581	0.9079 1.560127	0.9181 1.606333
	4′	1.2744 1.853504	1.3172 1.925843	1.3528 1.988583	1.3829 2.043883	1.4086 2.093262	1.4309 2.137874
1.0	6′	1.5983 2.185941	1.6540 2.251956	1.7011 2.309900	1.7421 2.361658	1.7782 2.408337	1.8101 2.450826
	8′	1.8700 2.430198	1.9329 2.490338	1.9842 2.543088	2.0369 2.592279	2.0804 2.636209	2.1194 2.676467
	10′	2.1106 2.625427	2.1783 2.680544	2.2386 2.730193	2.2929 2.775358	2.3417 2.816685	2.3861 2.854815
	2′	1.0385 1.396623	1.0662 1 475014	1.0881 1.541835	1.1059 1.600003	1.1205 1.651461	1.1328 1.967598
	4′	1.5648 1.942646	1.6166 2.014785	1.6596 2.077342	1.6959 2.132491	1.7269 2.181739	1.7539 2.226268
1.5	6′	1.9557 2.273572	2.0222 2.339256	2.0793 2.397104	2.1289 2.448729	2.1723 2.495279	2.2105 2.537621
	8′	2.2825 2.516774	2.3581 2.576692	2.4244 2.630114	3.4829 2.678268	2.5352 2.722074	2.5819 2.762195
	10′	2.5715 2.711209	2.6526 2.766093	2.7249 2.815561	2.7898 2.860549	2.8482 2.901735	2.9015 2.939740
	2′	1.2047 1.461075	1.2366 1.539378	1.2617 1.606121	1.2821 1.664236	1.2990 1.715664	1.3131 1.761765
	4′	1.8092 2.005672	1.8685 2.077670	1.9178 2.140130	1.9594 2.195211	1.9949 2.244400	2.0258 2.288861
2.0	6′	2.2569 2.335779	2.3332 2.401367	2.3984 2.459095	2.4551 2.510640	2.5046 2.557095	2.5484 2.599384
	8′	2.6306 2.578419	2.7171 2.638218	2.7927 2.691533	2.8597 2.739618	2.9193 2.783343	2.9727 2.823403
	10′	2.9606 2.772408	3.0532 2.827183	3.1358 2.876554	3.2099 2.921462	3.2766 2.962587	3.3372 3.000498
	2′	1.3509 1.510845	1.3866 1.589093	1.4146 1.655784	1.4373 1.713857	1.4561 1.765256	1.4719 1.811321
	4′	2.0246 2.054520	2.0907 2.126468	2.1455 2.188863	2.1918 2.243891	2.2313 2.293043	2.2658 2.337486
2.5	6′	2.5216 2.383942	2.6074 2.449638	2.6806 2.507314	2.7430 2.558797	2.7916 2.605209	2.8402 2.647476
	8′	2.9381 2.626434	3.0341 2.686154	3.1183 2.739432	3.1926 2.787447	3.2581 2.831124	3.3180 2.871130
	10′	3.3047 2.820157	3.4076 2.874868	3.4991 2.924168	3.5814 2.969029	3.6555 3.010099	3.7227 3.047978

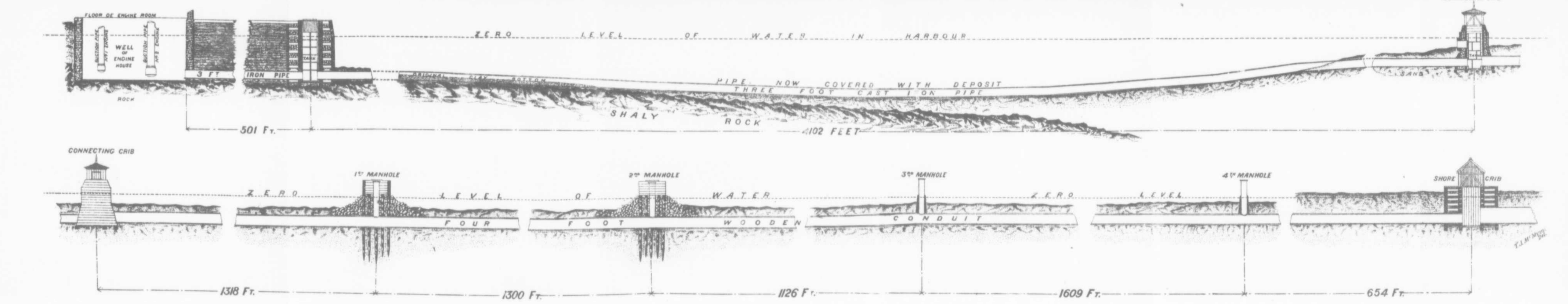
Fall in Feet a mile	Depth of Water in Feet.	Slopes: 1½ to 1. Width of bottom of Ditch. 10 Feet.	12 Feet.	14 Feet.	16 Feet.	18 Feet.	20 Feet.
	2′	0.4612 1.078832	0.4742 1.153054	0.4846 1.216897	0.4933 1.272856	0.5005 1.322631	0.5066 1.367435
	4′	0.7258 1.666998	0.7490 1.731826	0.7688 1.788906	0.7858 1.839817	0.8007 1.885716	0.8137 1.927492
0.33̇	6′	0.9359 2.028117	0.9648 2.084828	0.9903 2.135662	1.0129 2.181666	1.0330 2.223618	1.0511 2.262195
	8′	1.1191 2.294398	1.1514 2.344536	1.1804 2.390100	1.2065 2.431781	1.2302 2.470201	1.2503 2.505261
	10′	1.2858 2.507124	1.3201 2.551962	1.3511 2.593100	1.3796 2.631129	1.4058 2.666443	1.4282 2.698863
	2′	0.6705 1.241388	0.6886 1.315106	0.7032 1.378564	0.7152 1.434210	0.7252 1.483727	0.7337 1.528306
	4′	1.0344 1.820881	1.0665 1.885304	1.0934 1.941872	1.1165 1.992347	1.1371 2.038072	1.1542 2.079319
0.66̇	6′	1.3189 2.177119	1.3578 2.233220	1.3920 2.283512	1.4222 2.329042	1.4491 2.370601	1.4732 2.408810
	8′	1.5639 2.439712	1.6067 2.489234	1.6452 2.534283	1.6799 2.575519	1.7112 2.613521	1.7379 2.648278
	10′	1.7847 2.649509	1.8298 2.693765	1.8708 2.734425	1.9083 2.772008	1.9427 2.806916	1.9723 2.839049
	2′	0.8310 1.334554	0.8530 1.408071	0.8707 1.471360	0.8853 1.526890	0.8974 1.576209	0.9074 1.620759
	4	1.2719 1.910632	1.3109 1.974586	1.3440 2.030930	1.3701 2.081224	1.3942 2.126610	1.4155 2.167928
1.0	6′	1.6129 2.264525	1.6596 2.320382	1.7004 2.370436	1.7365 2.415764	1.7696 2.457378	1.7975 2.495219
	8	1.9058 2.525584	1.9570 2.574885	2.0028 2.619707	2.0440 2.660737	2.0815 2.698586	2.1134 2.733217
	10	2.1688 1.734161	2.2277 2.779227	2.2714 2.818693	2.3159 2.856085	2.3568 2.890838	2.3921 2.922855
	2′	1.0275 1.426757	1.0536 1.499789	1.0752 1.562959	1.0929 1.618362	1.1077 1.667680	1.1203 1.712092
	4′	1.5618 1.999804	1.6078 2.063557	1.6469 2.119751	1.6801 2.169808	1.7086 2.215159	1.7351 2.256369
1.5	6′	1.9734 2.352115	2.0295 2.407753	2.0786 2.457648	2.1221 2.502864	2.1607 2.544114	2.1955 2.582074
	8′	2.3255 2.612036	2.3870 2.661150	2.4420 2.705815	2.4916 2.746718	2.5364 2.784424	2.5749 2.818996
	10′	2.6414 2.819772	2.7057 2.863649	2.7641 2.903946	2.8175 2.941219	2.8663 2.975835	2.9088 3.007780
	2′	1.1911 1.490939	1.2220 1.564197	1.2469 1.627297	1.2672 1.682646	1.2843 1.731921	1.2982 1.776296
	4′	1.8057 2.062824	1.8584 2.121469	1.9032 2.182581	1.9417 2.232667	1.9751 2.277857	2.0041 2.319020
2.0	6′	2.2772 2.414300	2.3413 2.469823	2.3975 2.519639	2.4472 2.564766	2.4914 2.605966	2.5312 2.643867
	8′	2.6797 2.673604	2.7501 2.722632	2.8131 2.767224	2.8695 2.808049	2.9207 2.845699	2.9647 2.880219
	10′	3.0404 2.880878	3.1103 2.924169	3.1805 2.964891	3.2414 3.002099	3.2971 3.036652	3.3456 3.068539
	2′	1.3359 1.540740	1.3703 1.613926	1.3979 1.676971	1.4207 1.732300	1.4397 1.781526	1.4559 1.825886
	4′	2.0207 2.111691	2.0794 2.170279	2.1293 2.231322	2.1721 2.281353	2.2093 2.326528	2.2419 2.367650
2.5	6′	2.5452 2.462629	2.6166 2.518101	2.6792 2.567882	2.7343 2.612943	2.7834 2.654096	2.8275 2.691947
	8′	2.9938 2.721596	3.0709 2.770560	3.1406 2.815081	3.2034 2.855857	3.2604 2.893480	3.3092 2.927966
	10′	3.3954 2.928826	3.4749 2.972301	3.5187 3.012472	3.6163 3.049624	3.6782 3.084144	3.7331 3.116020

INDEX.

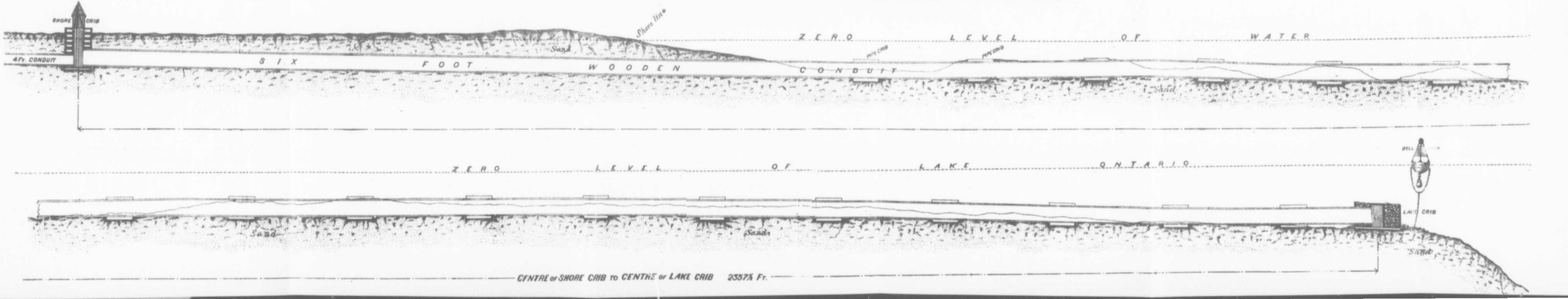
1888.—January to December.


HB.
EVEL
Sand
RIO

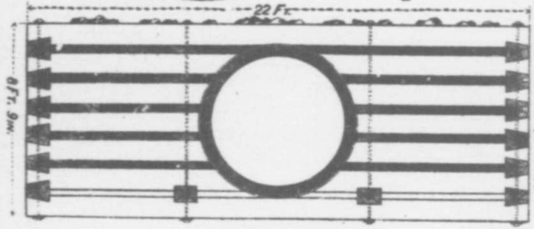
SECTION SHEWING THE ENGINE HOUSE WELL AND THE CONDUIT LINE WITH STRUCTURES AS FAR AS THE SHORE CRIB.

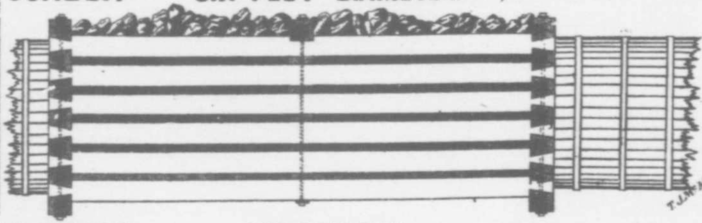


SECTION SHEWING THE CONDUIT EXTENSION FROM THE SHORE CRIB SOUTHWARD INTO THE LAKE.



CONDUIT SIX FEET DIAMETER.





END ELEVATION.

PIPE CRIBS.

SIDE ELEVATION.

T. J. McMinn Del.

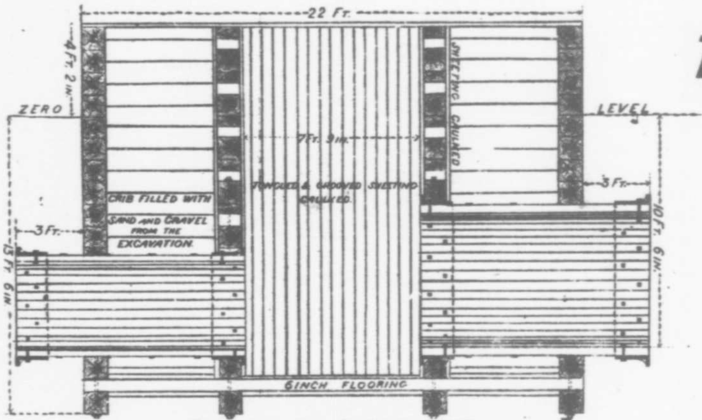
THE BURLAND LITHOGRAPHIC CO. MONTREAL.

TORONTO WATER WORKS.

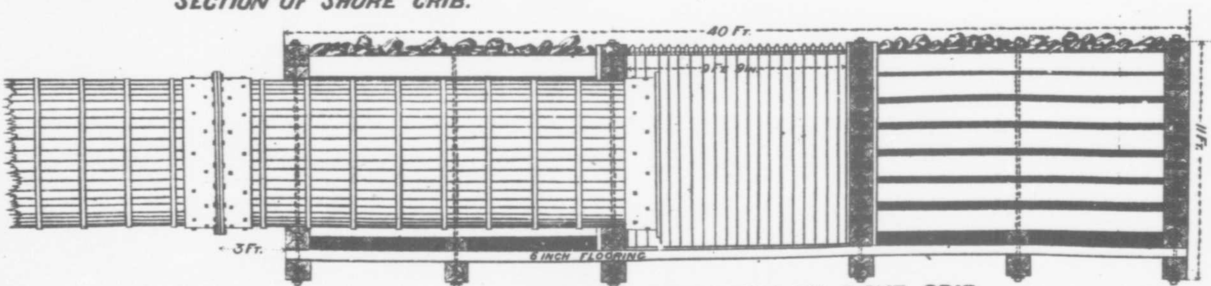
LAKE EXTENSION

DETAILS OF

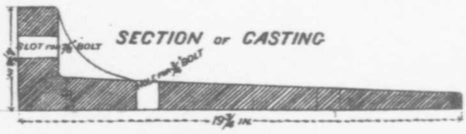
CRIBS AND CONDUIT.

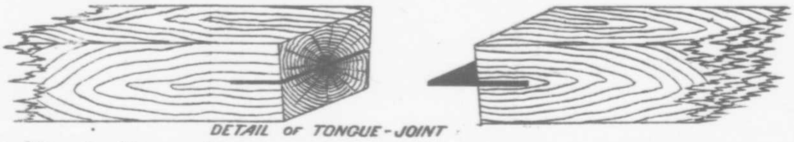


SECTION OF SHORE CRIB.

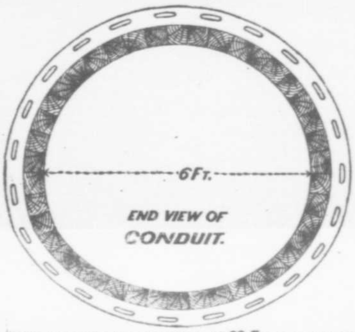


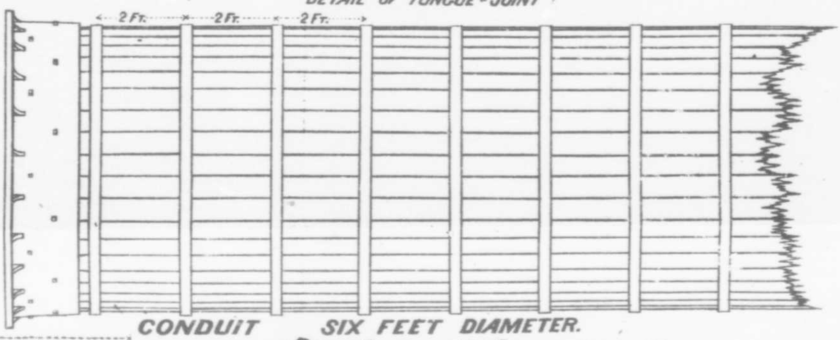
SECTIONAL ELEVATION OF LAKE CRIB.





DETAIL OF TONGUE-JOINT





CONDUIT SIX FEET DIAMETER.

END ELEVATION.

SIDE ELEVATION.

PIPE CRIBS.

THE BURLAND LITHOGRAPHIC CO. MONTREAL.

OLIT

Sco

19.

Concrete Monolithic Structures.

Nova Scotia.

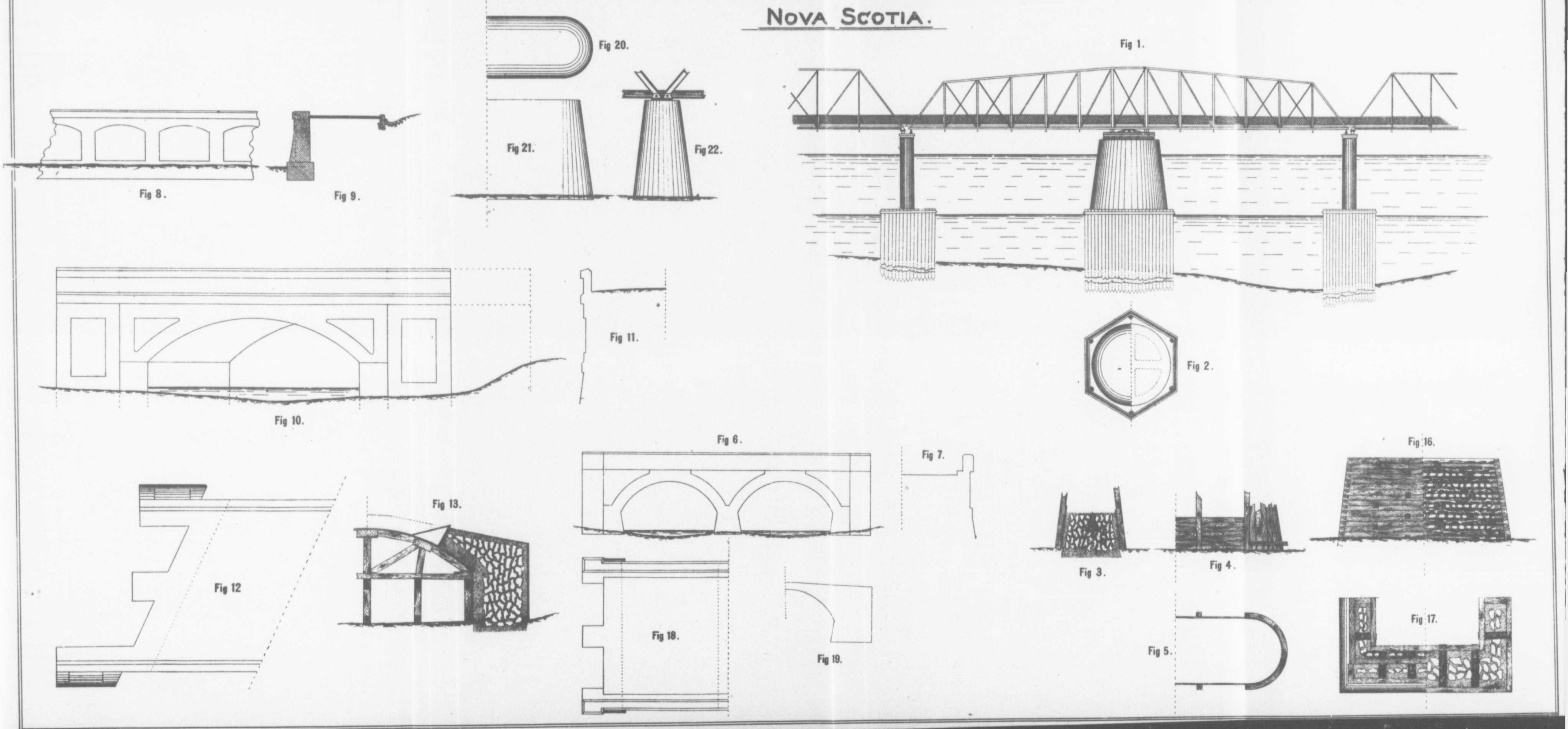
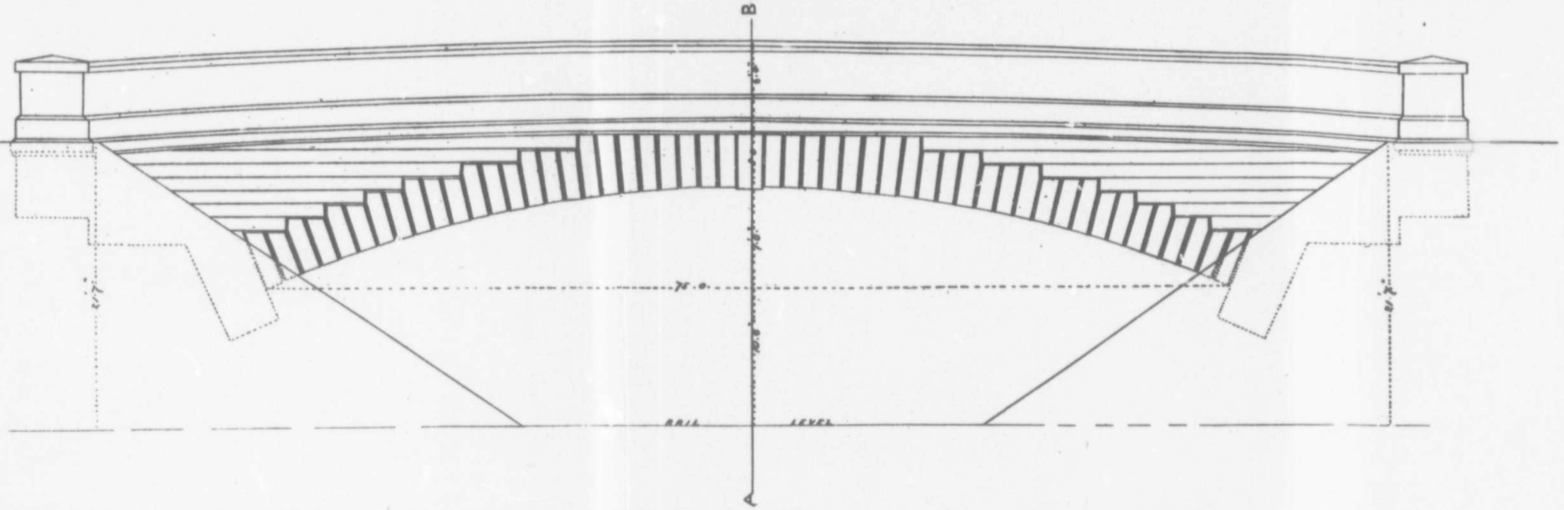
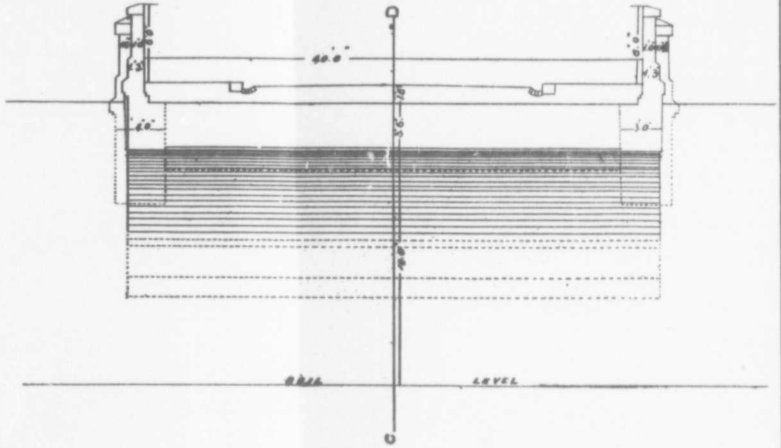


PLATE 4

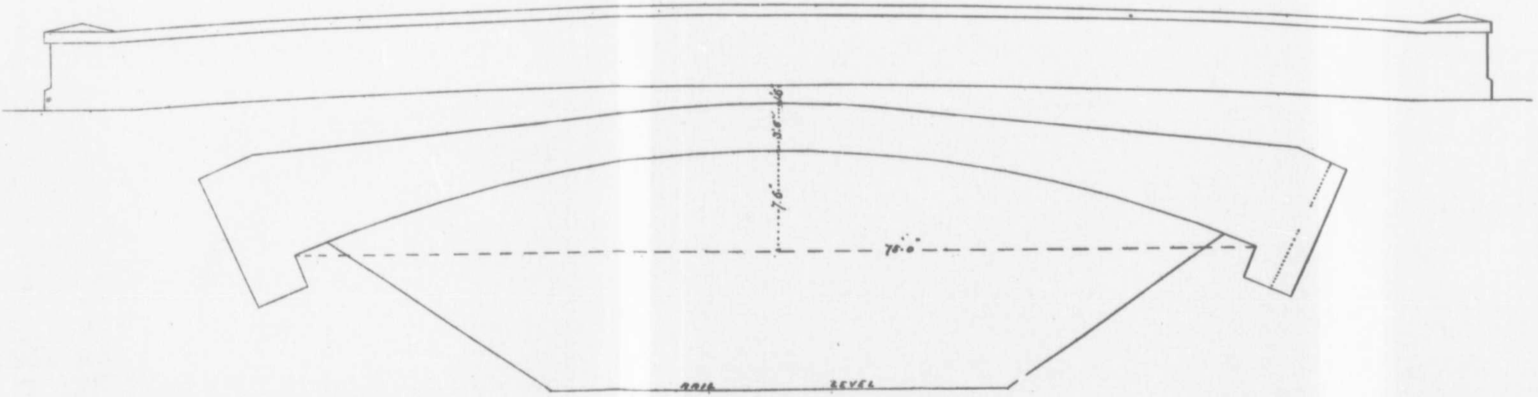
ELEVATION

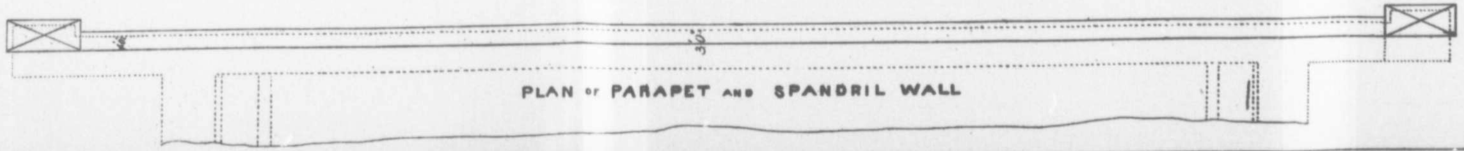


SECTION A.B.



SECTION C.D.





PLAN OF PARAPET AND SPANDRIL WALL

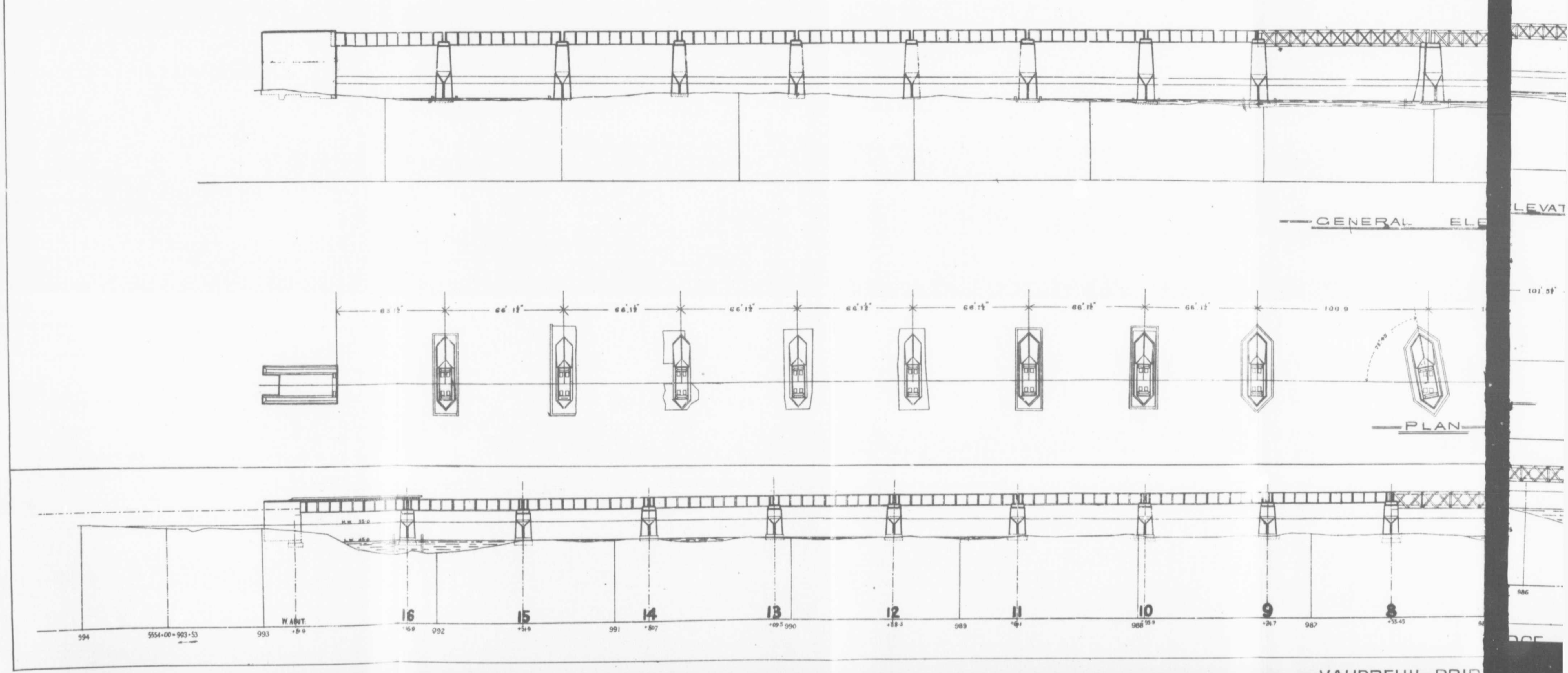
METROPOLITAN DISTRICT RAILWAY

CONCRETE ACCOMMODATION BRIDGE

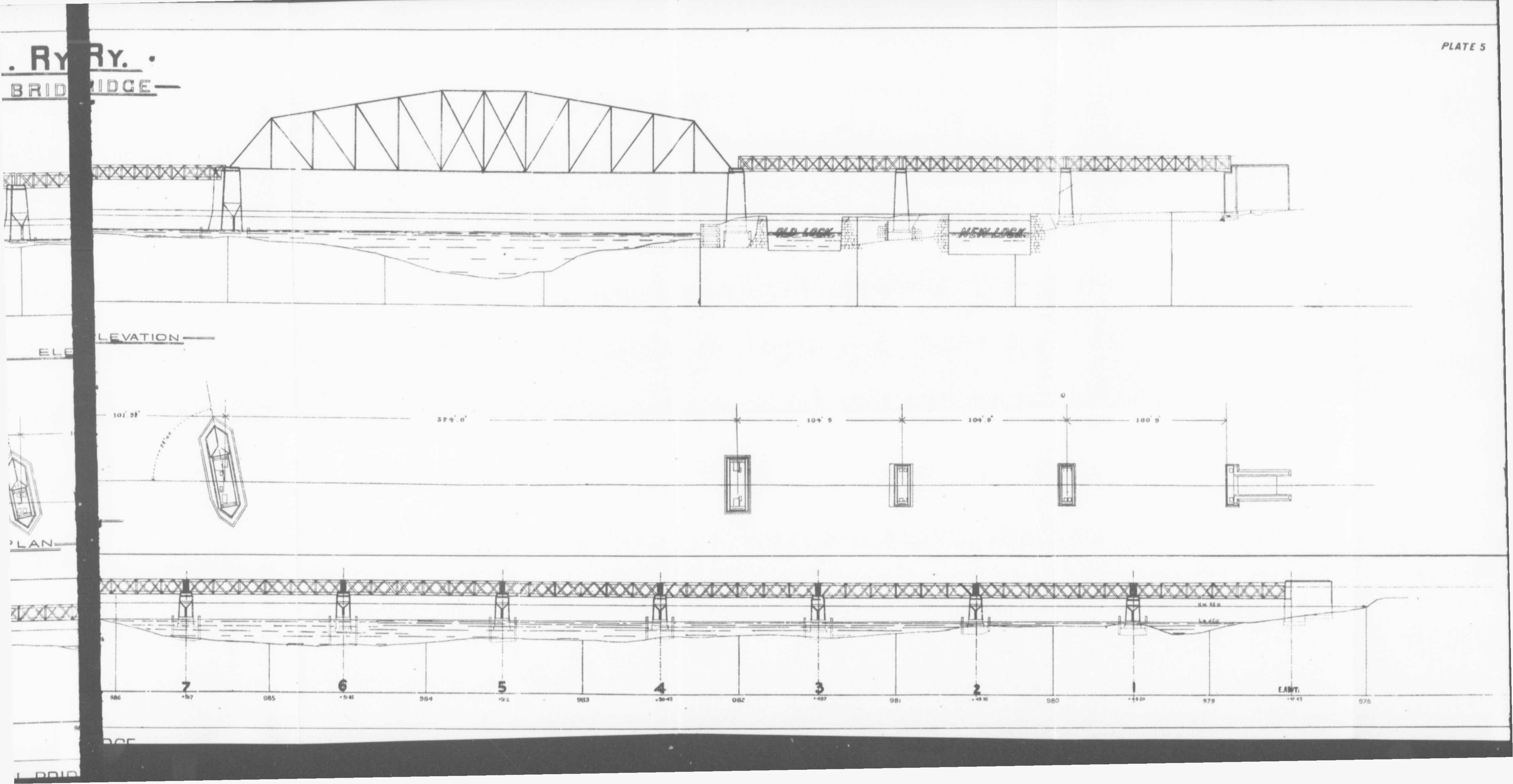
OVER RAILWAY Nº 3.

O. & Q. Ry Ry.

STE ANNE BRID RIDGE



VAUDREUIL BRID


. RY RY.
BRID RIDGE
OLD LOCK
NEW LOCK
ELEVATION
ELE
101' 5½"
324' 0"
104' 9
104' 9"
100' 9
PLAN
7
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E. ABUT.
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980
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978

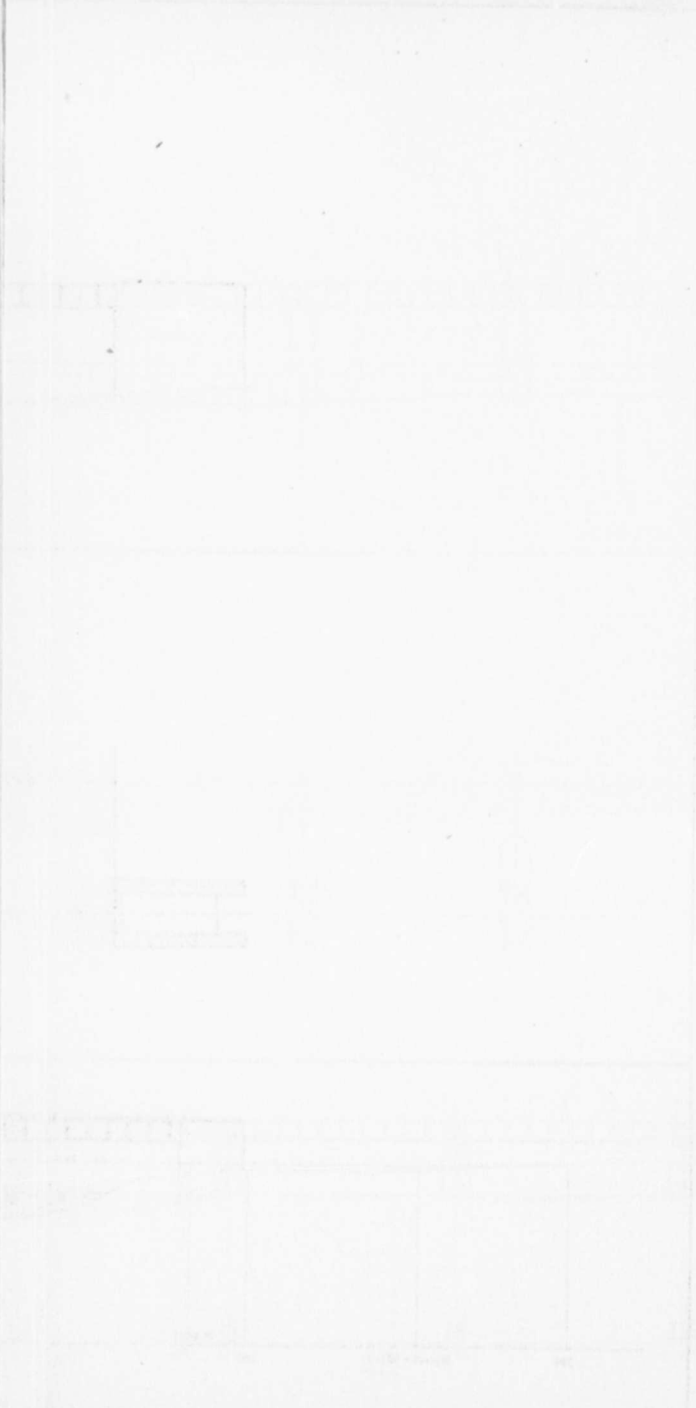
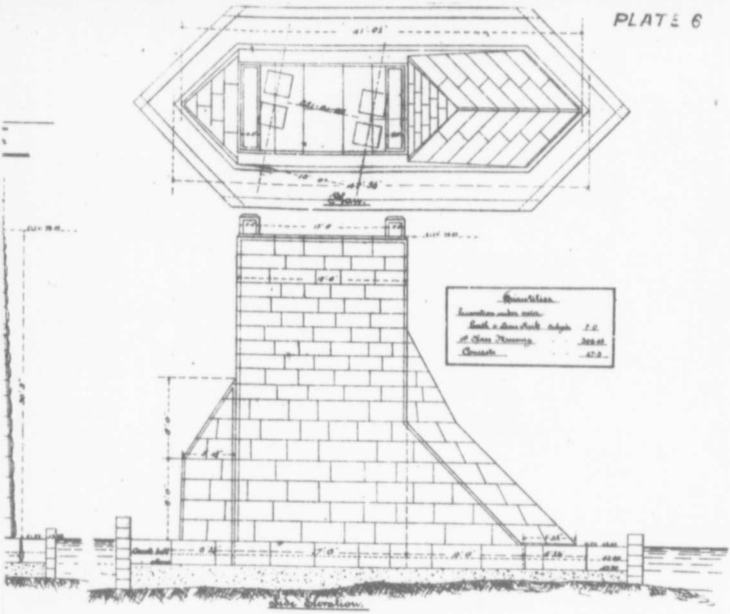


PLATE 6

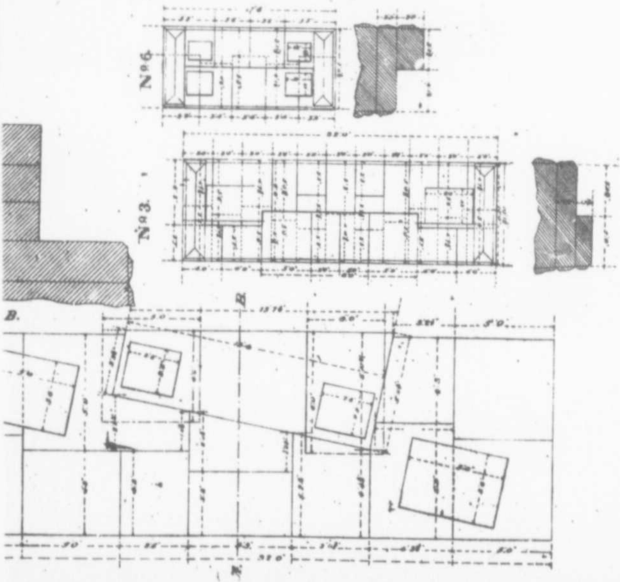


O. & Q. R.

STE. ANNE BRIDGE.

DETAIL PLAN OF BRIDGE SEAT COURSES, PIERS 3.4.6.

SCALE ft.



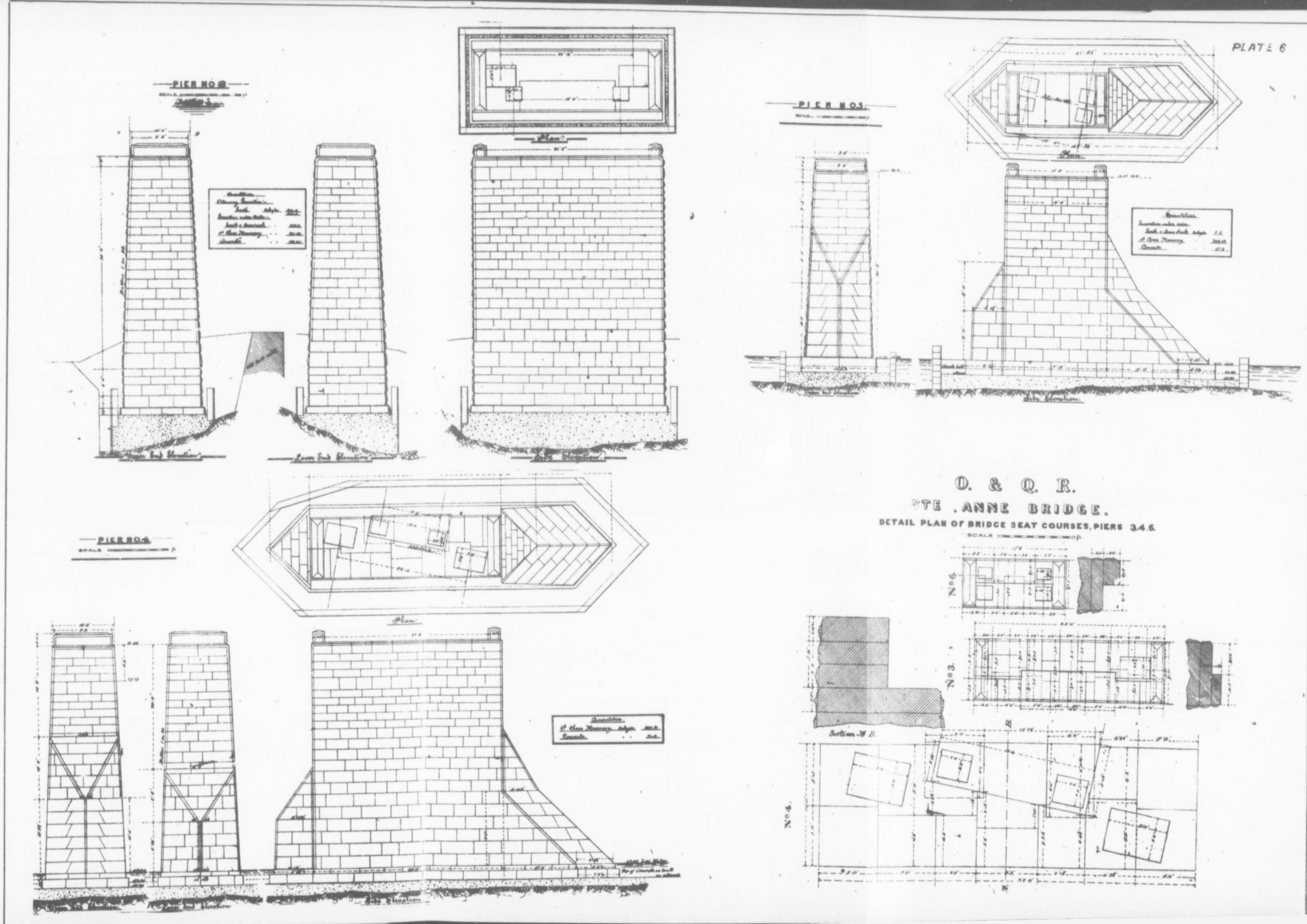
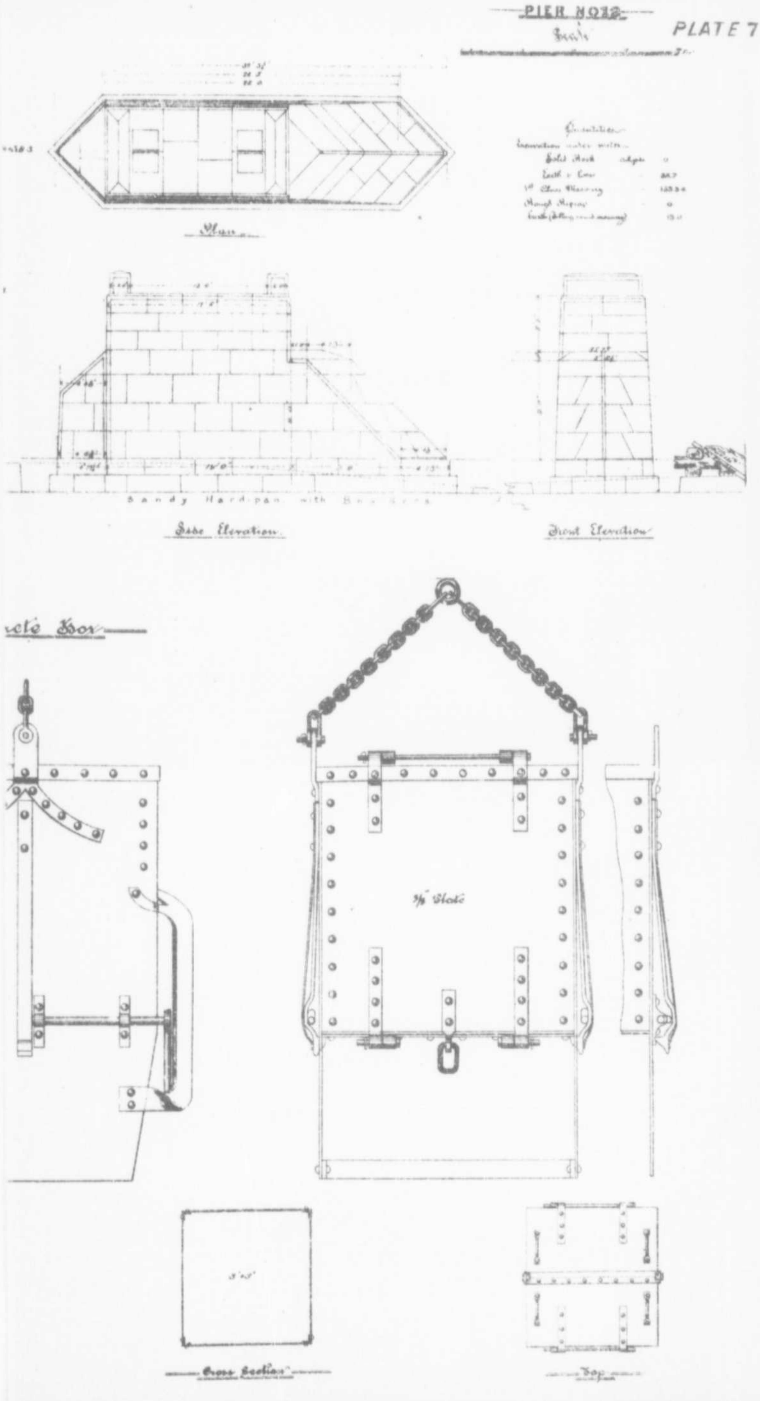


PLATE 6
PIER NO 5.
PIER NO 4.
Plan
Side Elevation
Upper End Elevation
Lower End Elevation
O. & Q. R.
STE. ANNE BRIDGE.
DETAIL PLAN OF BRIDGE SEAT COURSES, PIERS 3.4.6.
No 6.
No 3.
No 4.
Section A B.

PLATE 7



PIER NO 12
Scale
Plan
Sandy Hard-pan with Boulders
Side Elevation
Front Elevation
3/8" Plate
Cross Section
Top

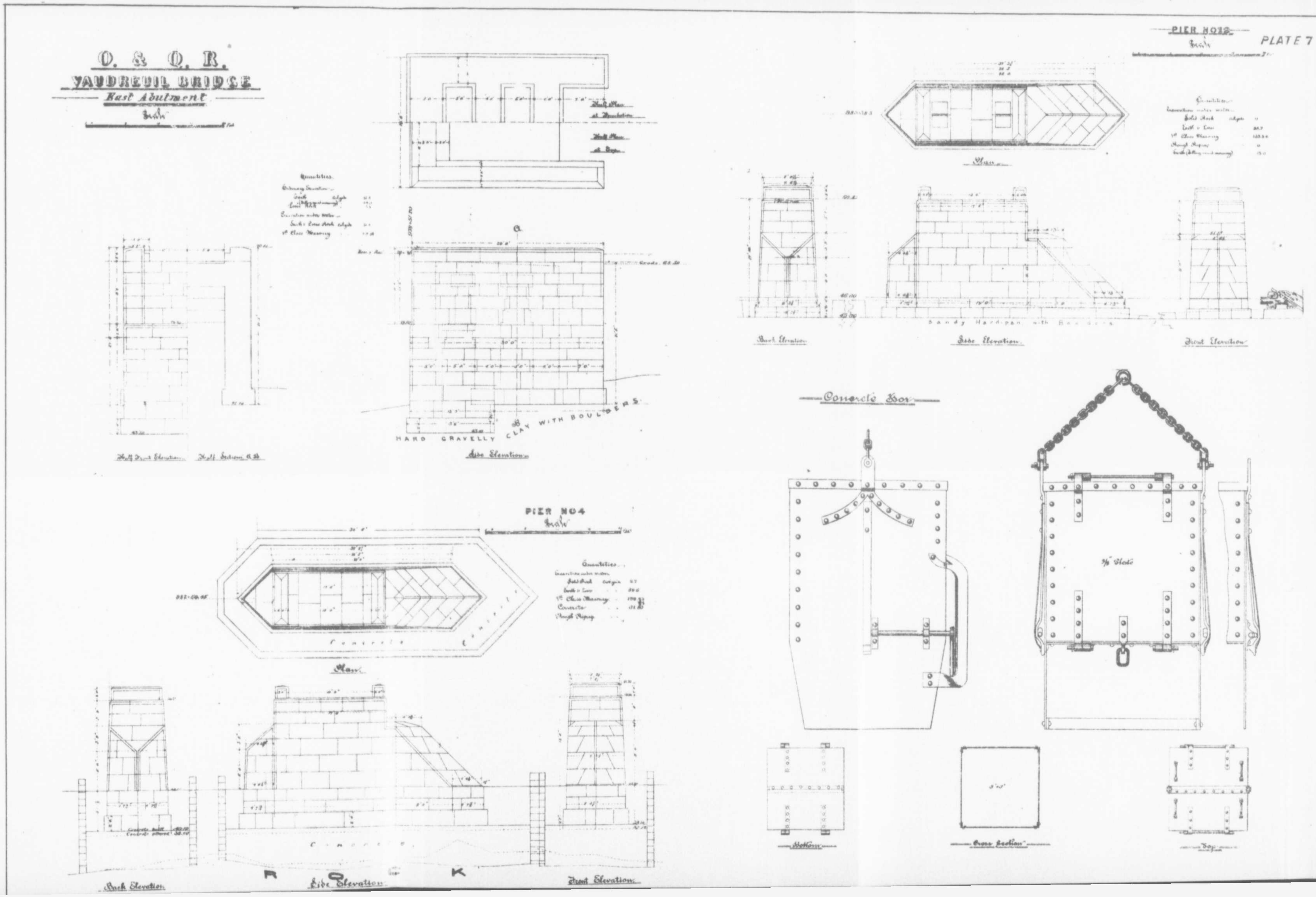
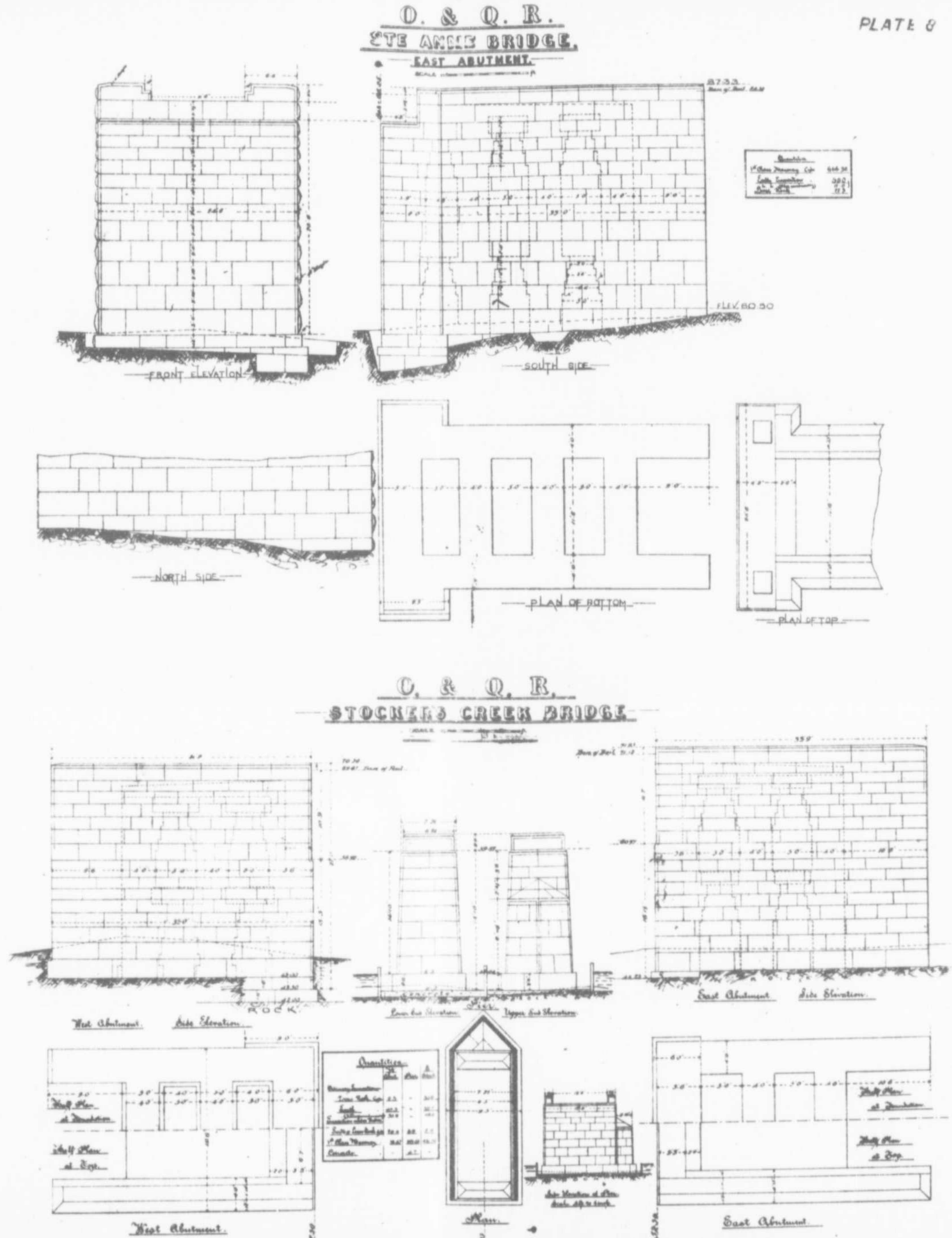


PLATE 7
O. & Q. R.
VAUDREUIL BRIDGE
East Abutment
Scale
Half Plan at Foundation
Half Plan at Top
Quantities
Half Front Elevation
Half Section A.B.
Side Elevation
HARD GRAVELLY CLAY WITH BOULDERS
PIER No. 3
Scale
Plan
Quantities
Back Elevation
Side Elevation
Front Elevation
Sandy Hard-pan with Boulders
Concrete Box
3/8" Plate
Bottom
Cross Section
Top
PIER No. 4
Scale
Quantities
Concrete
Plan
Back Elevation
Side Elevation
Front Elevation
ROCK

PLATE 8


O. & Q. R.
STE ANNE BRIDGE.
EAST ABUTMENT.
FRONT ELEVATION
SOUTH SIDE
NORTH SIDE
PLAN OF BOTTOM
PLAN OF TOP
O. & Q. R.
STOCKELS CREEK BRIDGE
ROCK
West Abutment
Side Elevation
East Abutment
Side Elevation
Quantities
West Abutment
Plan
East Abutment

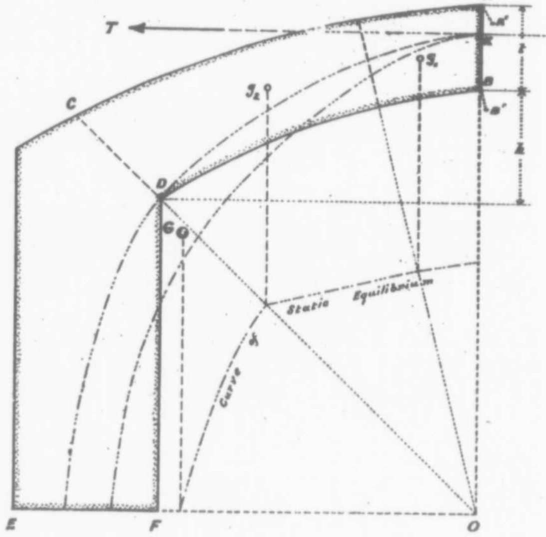


FIG. 4.
(From Dupuit's "Traité" Fig. 26.)

FIG. 5.

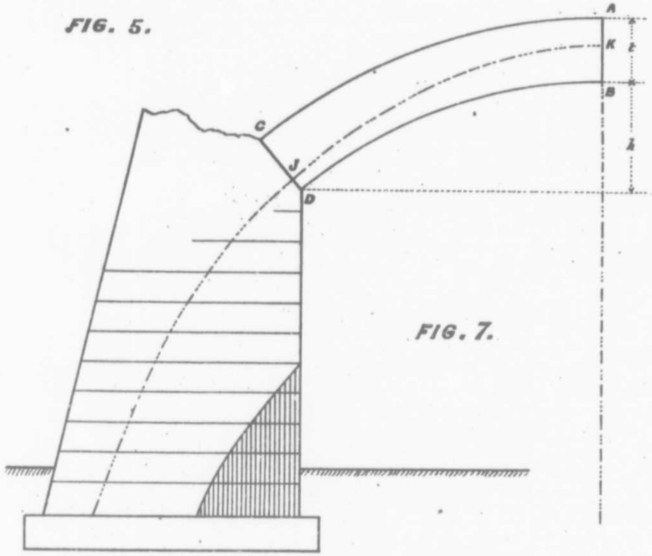


FIG. 7.

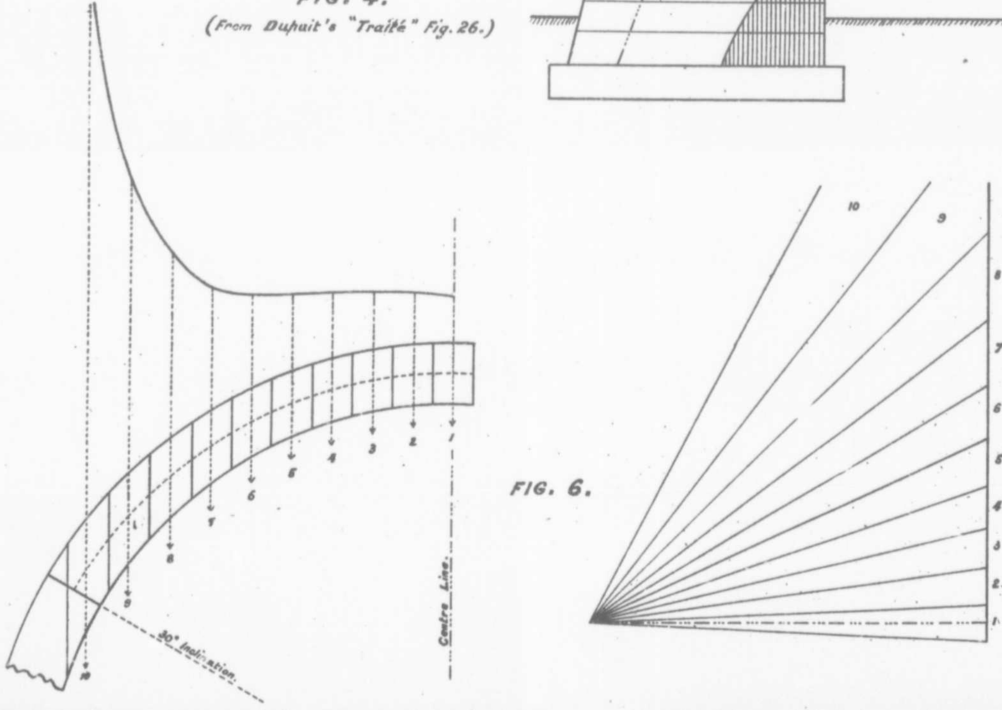
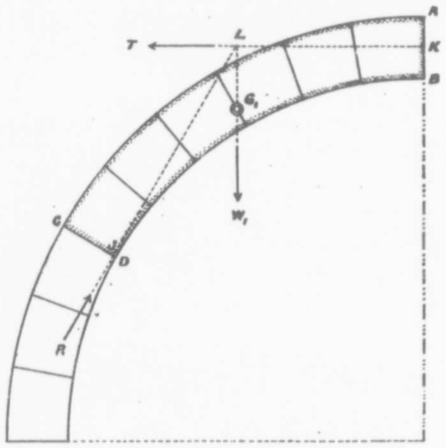
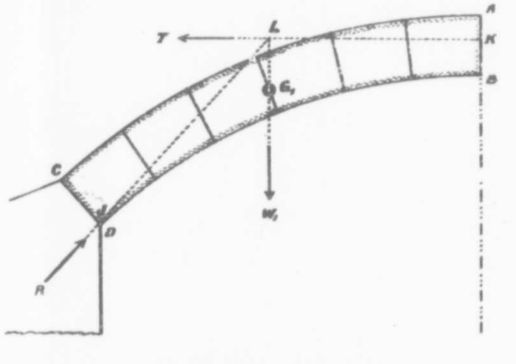


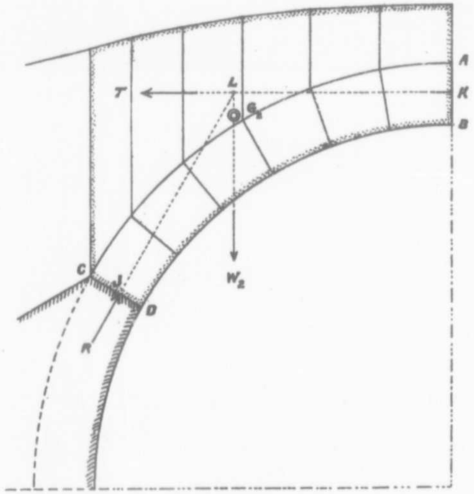
FIG. 6.



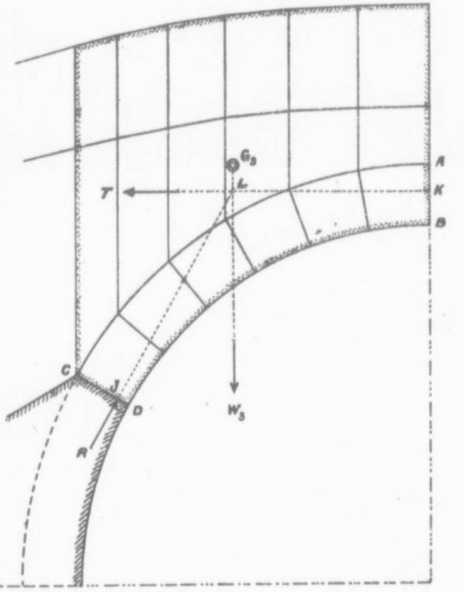
DETERMINATION OF THE JOINT OF RUPTURE IN THE ARCH RING.



CORRESPONDING FIGURE FOR THE ARCH RING OF A SEGMENTAL ARCH.



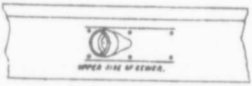
ARCH CARRYING DEAD WEIGHT ONLY.



ARCH CARRYING WEIGHT AND LOAD.

W.E.D.

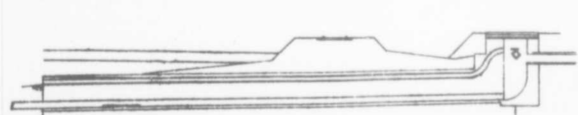
CAST IRON JUNCTIONS FOR HOUSE SEWERS.

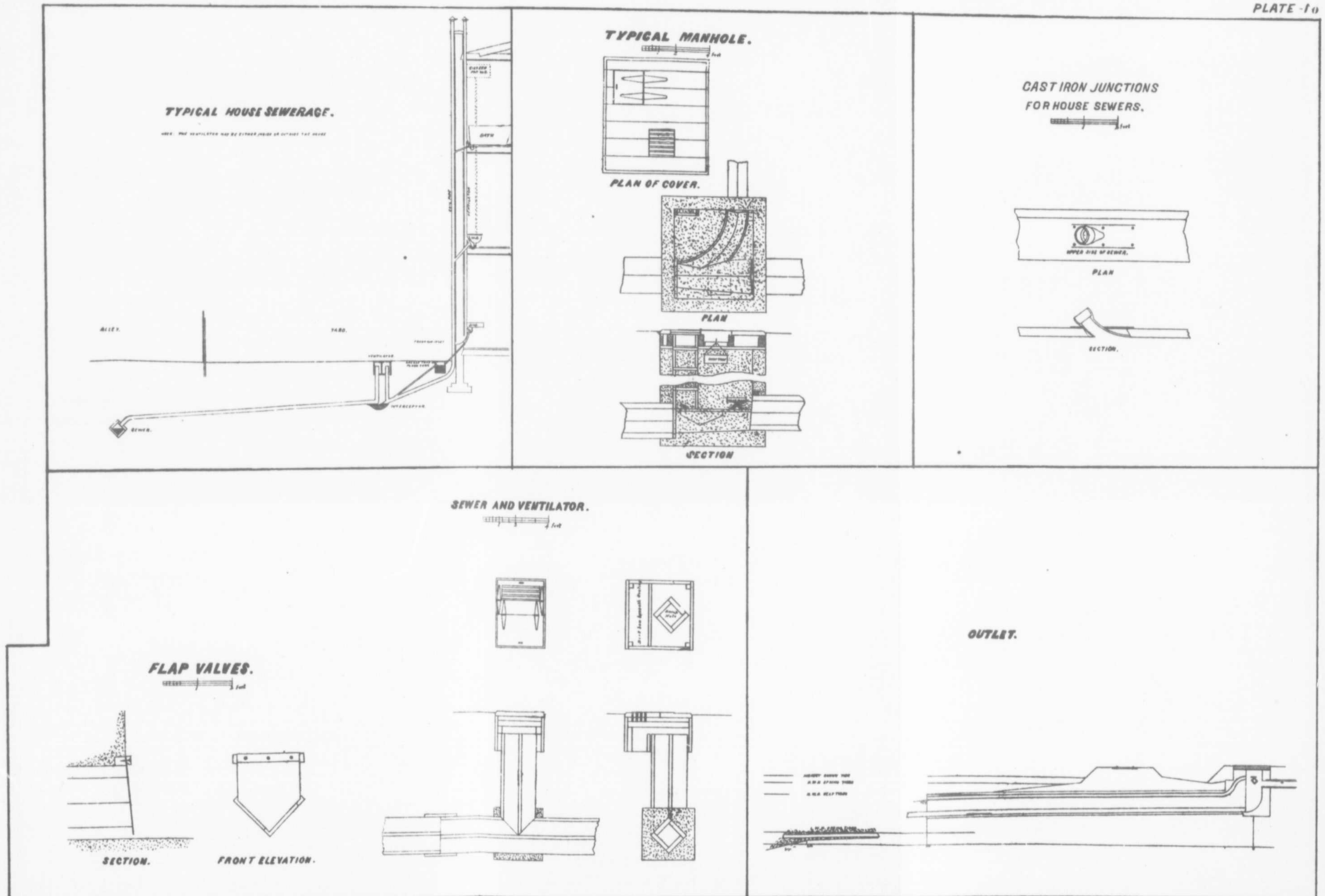


PLAN

SECTION.

OUTLET.

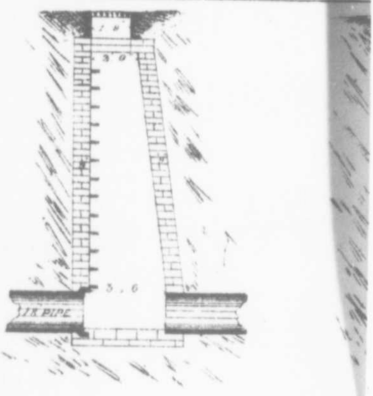



TYPICAL HOUSE SEWERAGE.
ALLEY.
YARD.
SEWER.
TYPICAL MANHOLE.
PLAN OF COVER.
PLAN
SECTION
CAST IRON JUNCTIONS
FOR HOUSE SEWERS.
PLAN
SECTION.
SEWER AND VENTILATOR.
FLAP VALVES.
SECTION.
FRONT ELEVATION.
OUTLET.

T

MA

MANHOLE FOR PIPE



MANHOLE FOR BRICK

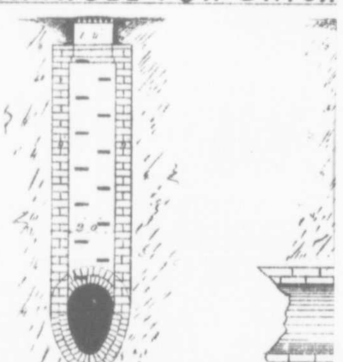
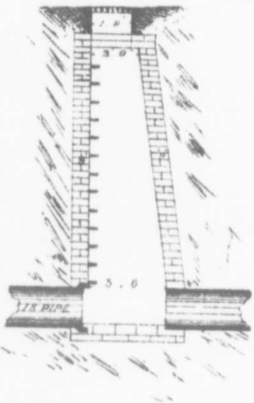
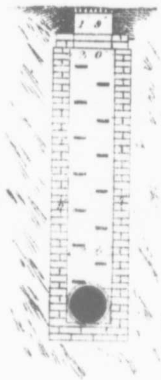


PLATE. II.

TYPE FOR MANHOLE

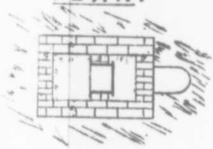
MANHOLE FOR PIPE SEWERS.



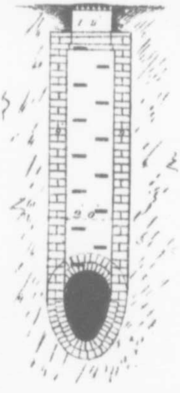


CULVERT.

PLAN.



MANHOLE FOR BRICK SEWER.



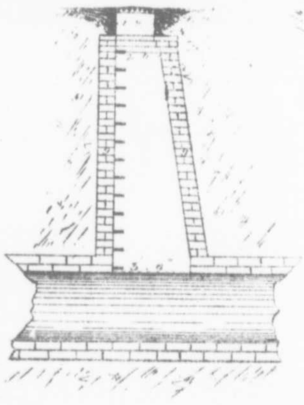
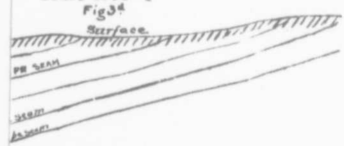


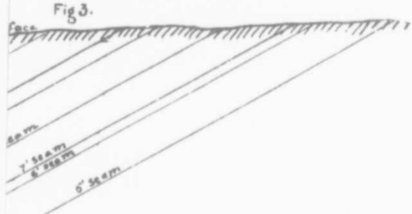
PLATE XII.

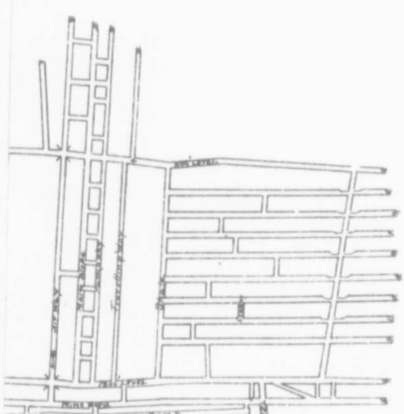
…CAL SECTION OF COAL SEAMS
…E OF DIP AT SOUTH SLOPE.
Scale 1000'=1"
Fig 3ª



…other seams underlying.

… SECTION OF COAL SEAMS
… OF DIP AT NORTH SLOPE
Scale 800'=1"
Fig 3.



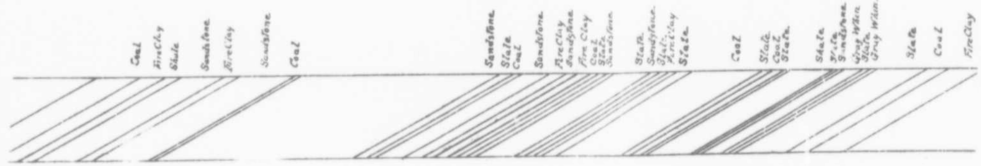


PLAN OF
… OF WEST SLOPE WORKINGS
Scale 330'=1"

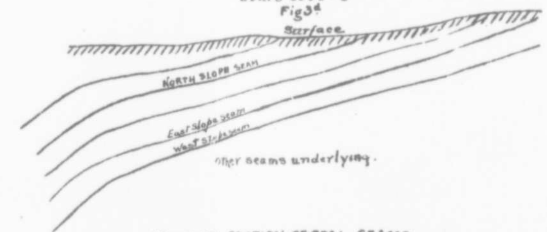
PLATE XII.

SPRINGHILL · COLLIERIES

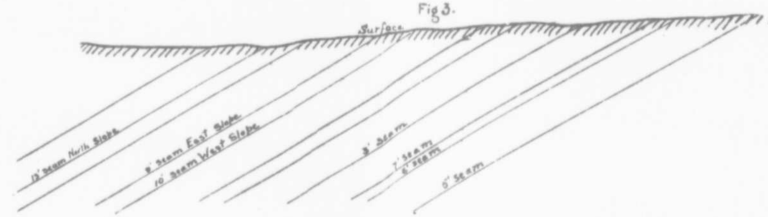
Vertical Section on line of Dip Shewing Arrangement of Strata between East Slope Seam & North Slope Seam.
Scale 120' = 1"



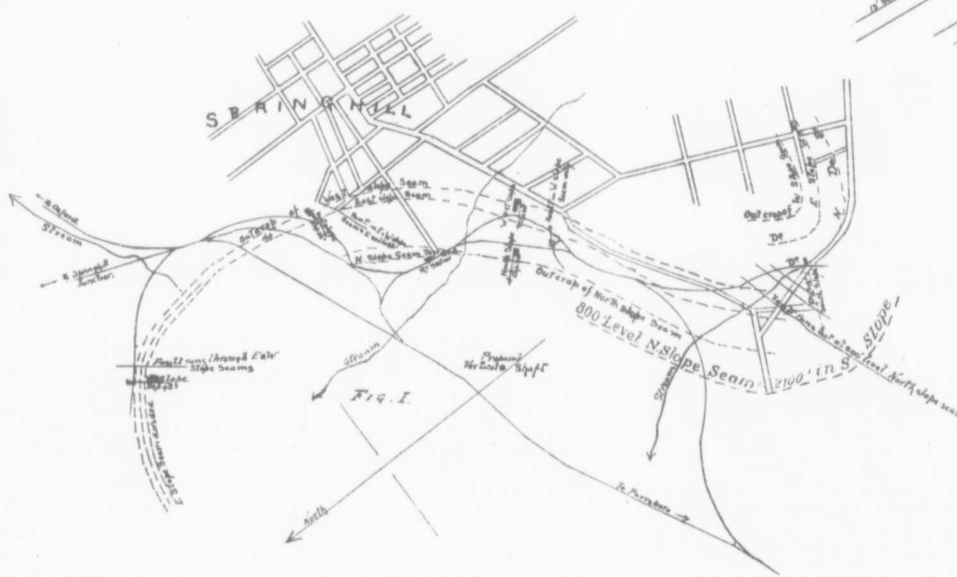
VERTICAL SECTION OF COAL SEAMS ON LINE OF DIP AT SOUTH SLOPE
Scale 1000' = 1"
Fig 3a

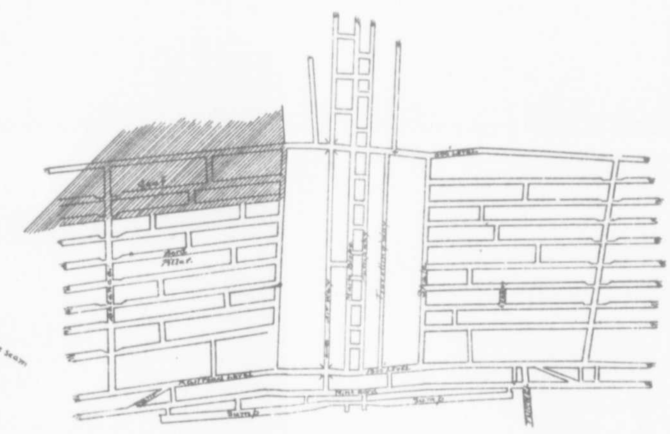


VERTICAL SECTION OF COAL SEAMS ON LINE OF DIP AT NORTH SLOPE
Scale 800' = 1"
Fig 3.



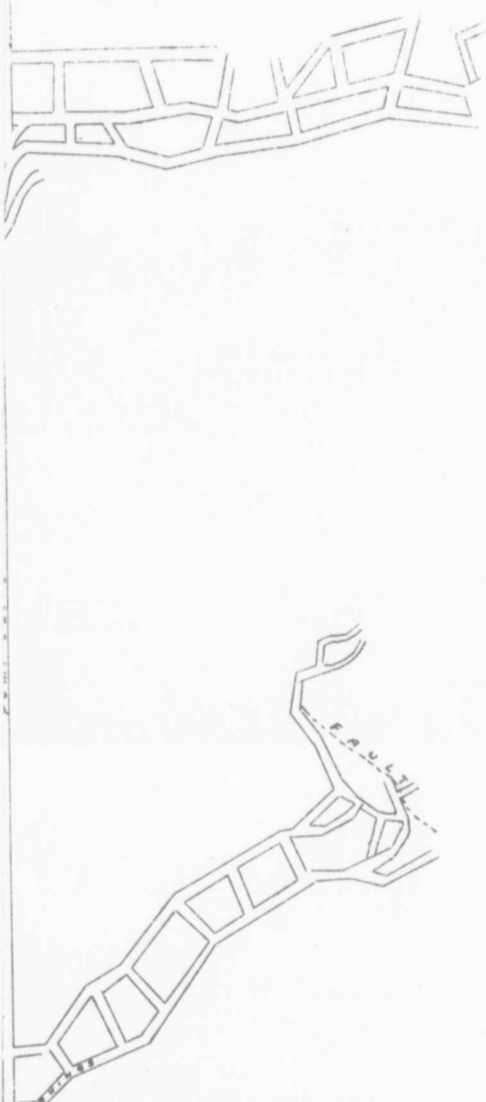
PLAN
Shewing Out Crops of Coal Seams & Position of Slopes
Scale 1830' = 1"

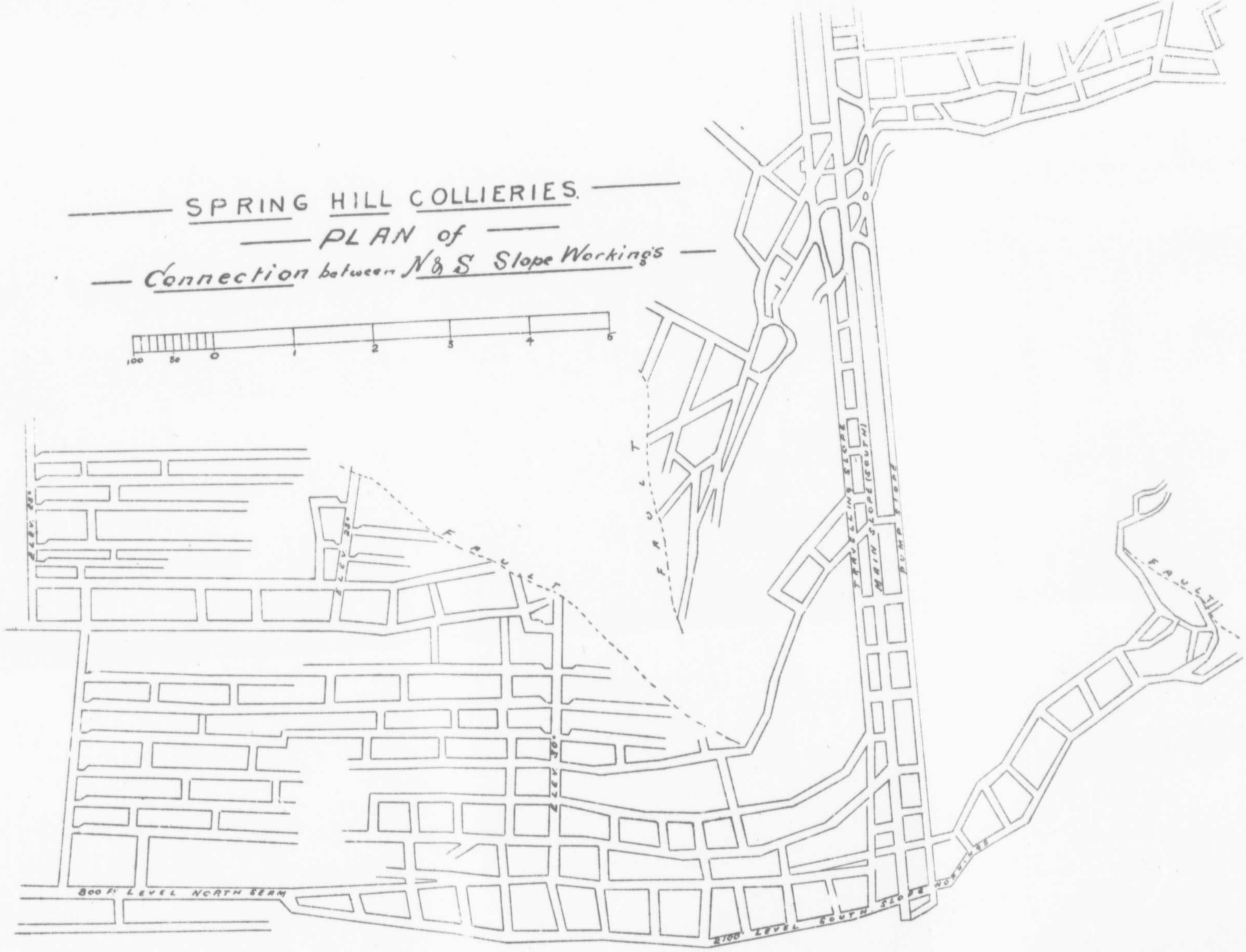




PLAN OF
PART OF WEST SLOPE WORKINGS
Scale 330' = 1"

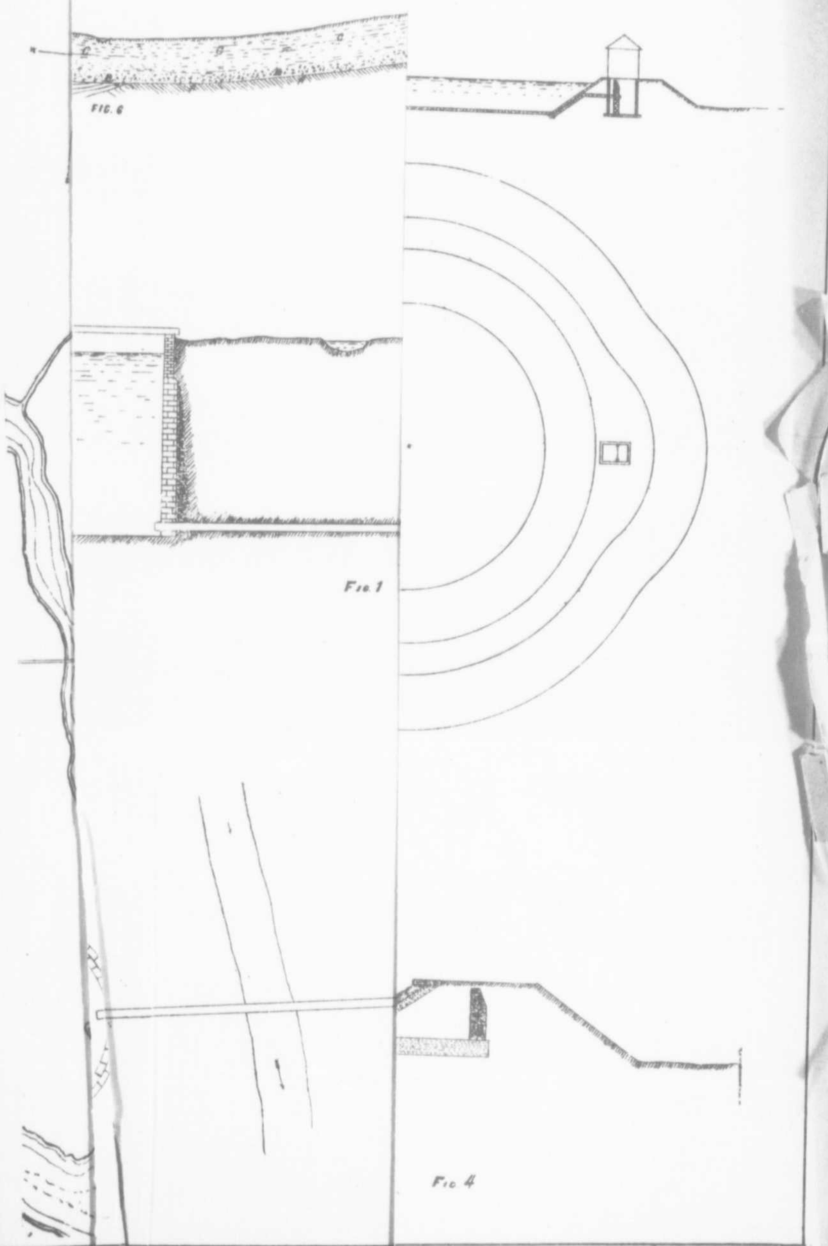
PLATE XIIA.




SPRING HILL COLLIERIES.
PLAN of
Connection between N & S Slope Workings
100 50 0 1 2 3 4 5
FAULT
FAULT
FAULT
TRAVELLING SLOPE
MAIN SLOPE (SOUTH)
PUMP SLOPE
800 Ft LEVEL NORTH SEAM
2100' LEVEL SOUTH SLOPE WORKINGS

WORKS AT CHARLOT

PLATE XIII.



WATERWORKS AT CHARLOTTETOWN, P. E. I.

PLATE XIII.

FIG. 6

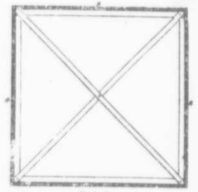
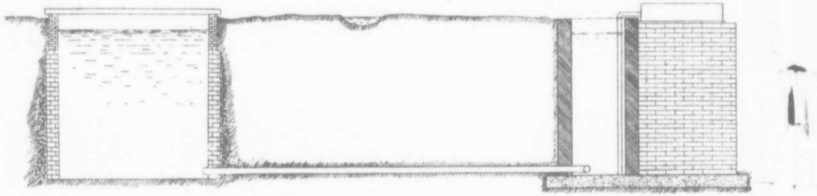


FIG. 7



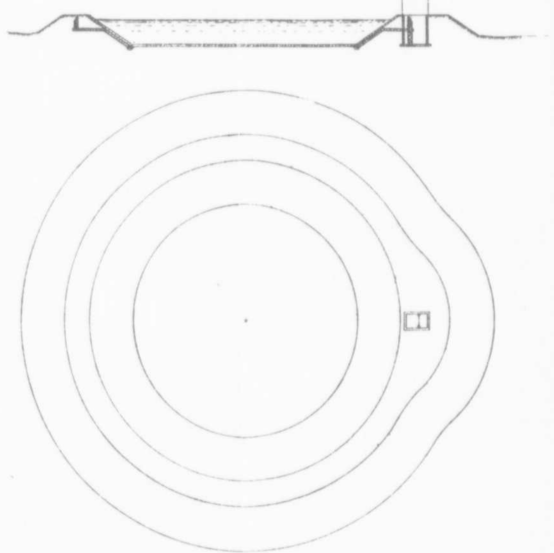


FIG. 5

FIG. 1

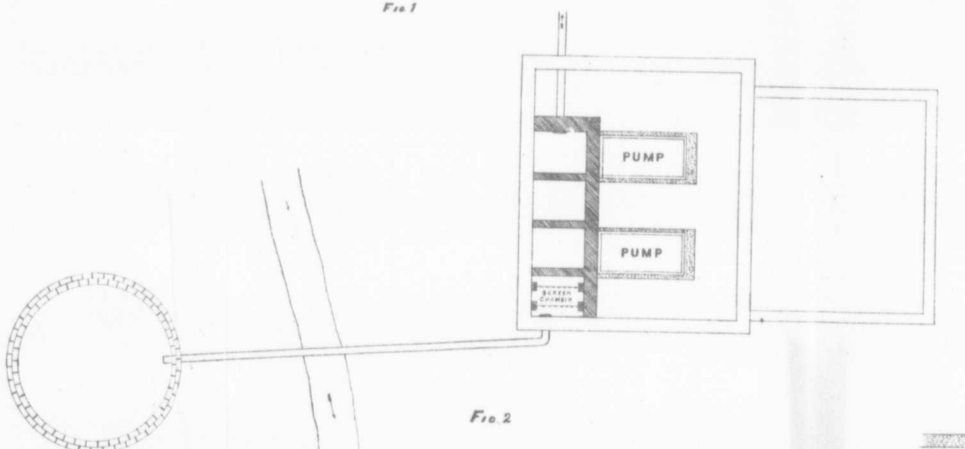


FIG. 2

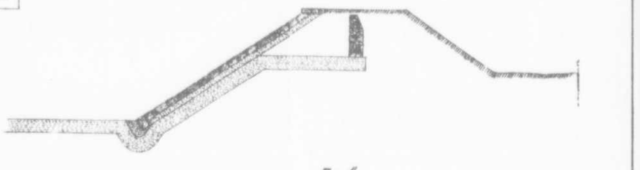


FIG. 4