VOL. XI. 1897. *PART I.*

TRANSACTIONS

OF THE

Canadian Society of Civil Engineers

JANUARY TO JUNE, 1897.

CONTENTS

Portrait, Thos. C. Keefer, C.M.G., President, 1897 .... Frontispiece.

No. of Paper.		PAGE
	Report of Committee on Abstracts	55
	Abstracts.—1. Water Power, its Generation and Transmission	57
	2. Water Power of Cahoos Falls	58
	3. The Transverse Strength of Beams	59
	4. The Underpinning of Heavy Buildings	60
	5. Methods and Results of Stadia Surveying	61
	6. The Liverpool Water Works	63
	7. Relative Tests of Cast Iron and Strength of Cast Iron	65
	8. The New Water Scoop of the Pennsylvania Railway	67
	9. Water Power and Compressed Air Transmission Plant for the North Star Mining Co	67
	10. Foundations of Tall Buildings	69
	11. Solar Work in Surveying	71
	12. Through Barren Lands	73
	The Transmission of Power by Compressed Air, Gas, and Steam. By PROF. J. T. NICOLSON, Mem.Can.Soc.C.E. and Prof. R. J. DURLEY, Assoc. Mem.Can.Soc.C.E	75
119.	Fraser Valley Reclamation. By H. E. PALMER, B.A.Sc., Assoc.Mem.Can.Soc.C.E.	143
	Abstracts.—13. Comparative Tests of Steam Boilers with Different Kinds of Coal	151
	14. Paint as a Protection for Iron	152
	15. Inclined Plane Railways	154
120.	The Albion Mines Railway. By D. A. STEWART, B.A.Sc., Mem.Can.Soc.C.E.	157
121.	The Separate System of Sewerage in Ontario. By WILLIS CHIPMAN, B.A.Sc., Mem.Can.Soc.C.E	162
	Discussion on Paper 121. By Messrs. VANBUSKIRK, A. G. ARDAGH, WILLIS CHIPMAN, H. J. BOWMAN and T. HARRY JONES	185

ILLUSTRATIONS.

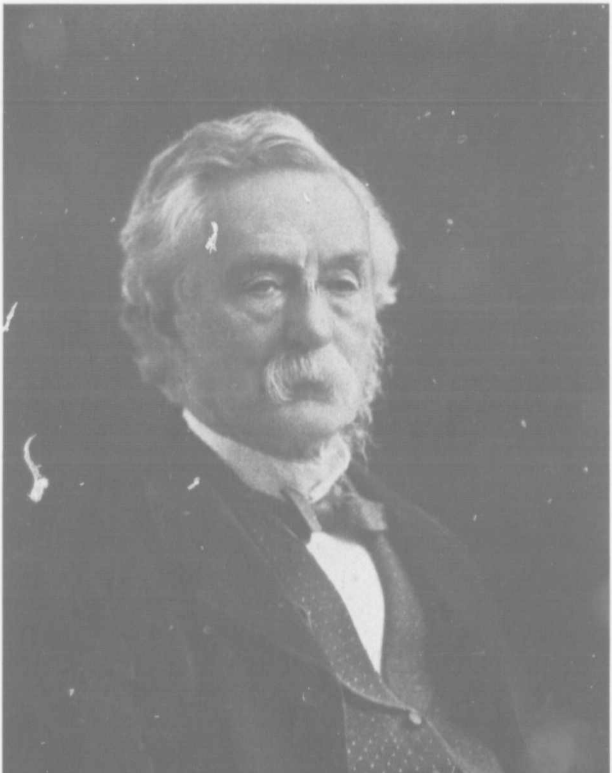
Plate showing Flood Box and Gate, Fraser Valley Reclamation ......Facing page 143
Plate showing Locomotive of Albion Mines Railway ...... do. do. 159
Plate showing Flush Tanks used in the Separate System of Sewerage in Ontario ...... do. do. 163

PROCEEDINGS.

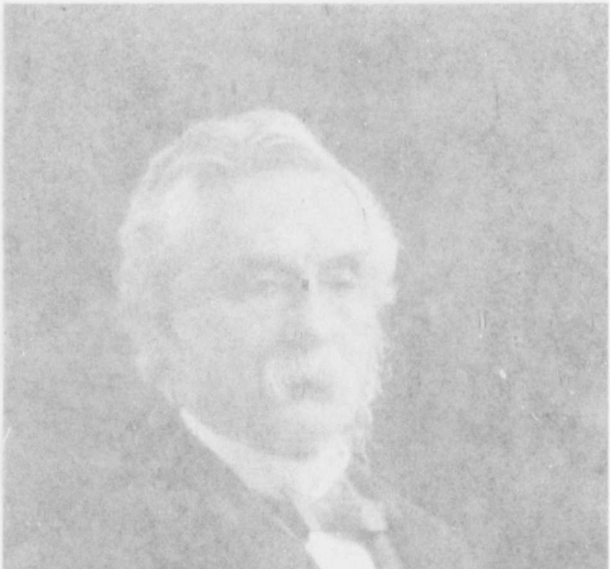
Annual General Meeting 3
Report of Council for 1896 10
Report of Library Committee 16
President's Address, H. WALLIS 23
Election of Members 3, 73, 156, 163
Memoirs of deceased Members:
Alan MacDougall 191
H. L. L. Langevin 191
H. F. Perley 192

Montreal:

Printed for the Society by JOHN LOVELL & SON, 1897.



TRANSACTIONS



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OF

The Canadian Society of Civil Engineers.

VOL. XI., PART I.

JANUARY TO JUNE,
1897.

Montreal:
PRINTED FOR THE SOCIETY
BY JOHN LOVELL & SON.
1897.

The Society will not hold itself responsible for any statements or opinions which may be advanced in the following pages.

"The papers shall be the property of the Society, and no publication of any papers or discussion shall be made except by the Society or under its express permission."— By-Law No. 47.

CONTENTS.

No. of Paper. PAGE

Portrait, Thos. C. Keefer, C.M.G .... Frontispiece.

Report of Committee on Abstracts 56

Abstracts.—1. Water Power, its Generation and Transmission .. 57

2. Water Power of Caratunk Falls 58

3. The Transverse Strength of Beams 59

4. The Underpinning of Heavy Buildings 60

5. Methods and Results of Stadia Surveying 61

6. The Liverpool Water Works 63

7. Relative Tests of Cast Iron and Strength of Cast Iron 65

8. The New Water Scoop of the Pennsylvania Railway 67

9. Water Power and Compressed Air Transmission Plant for the North Star Mining Co 67

10. Foundations of Tall Buildings 69

11. Solar Work in Surveying 71

12. Through Barren Lands 71

The Transmission of Power by Compressed Air, Gas, and Steam, by Prof. J. T. Nicolson, Mem.Can.Soc.C.E., and Prof. R. J. Durley, Assoc.Mem.Can.Soc.C.E 75

119. Fraser Valley Reclamation, by R. E. Palmer, B.A.Sc., Assoc. Mem. Can.Soc.C.E 143

Abstracts.—13. Comparative Tests of Steam Boilers with Different Kinds of Coal 151

14. Paint as a Protection for Iron 152

15. Inclined-Plane Railways 154

120. The Albion Mines Railway, by D. A. Stewart, B.A.Sc., Mem.Can. Soc.C.E 157

121. The Separate System of Sewerage in Ontario, by Willis Chipman, B.A.Sc., Mem.Can.Soc.C.E 163

Discussion on Paper 121, by Messrs. Vanbuskirk, A. G. Ardagh, Willis Chipman, H. J. Bowman, and T. Harry Jones 185

ILLUSTRATIONS.

Plate showing Flood Box and Gate, Fraser Valley Reclamation .... Facing page 143

Plate showing Locomotive of Albion Mines Railway ...... do do 159

Plate showing Flush Tanks used in the Separate System of Sewerage in Ontario .... do do 163

PROCEEDINGS.

Annual General Meeting 9

Report of Council for 1896 10

Report of Library Committee 15

President's Address. H. Wallis 35

Election of Members 73, 156, 163

Memoirs of Deceased Members:

Alan MacDougall 191

H. L. L. Langevin 191

H. F. Perley 192

INSTRUCTIONS FOR PREPARING PAPERS, ETC.

In writing papers, or discussions on papers, the use of the first person should be avoided. They should be legibly written on foolscap paper, on one side only, leaving a margin on the left side.

Illustrations, when necessary, should be drawn on tracing paper to as small a scale as is consistent with distinctness. They should not be more than 10 inches in height, but *in no case* should any one figure exceed this height. Black ink only should be used, and all lines, lettering, etc., must be clear and distinct.

When necessary to illustrate a paper for reading, diagrams must be furnished. These must be bold, distinct, and clearly visible in detail for a distance of thirty feet.

Papers which have been read before other Societies, or have been published, cannot be read at meetings of the Society.

All communications must be forwarded to the Secretary of the Society, from whom any further information may be obtained.

The attention of members is called to By-laws 46 and 47.

	1895.	1896.	1897.
TERSON.	Thomas Monro.	Herbert Wallis.	Thomas C. Keefer.
GALL.	W. T. Jennings.	Henry T. Bovey.	{ Henry T. Bovey.
EORGE.	M. Murphy.	Chas. Macdonald.	{ G. H. Duggan.
	H. Wallis.	W. G. Thompson.	W. T. Jennings.
			W. G. Thompson.
	P. S. Archibald.	W. D. Barclay.	St. Geo. Boswell.
BALD.	J. D. Barnett.	J. D. Barnett.	M. J. Butler.
ETT.	H. T. Bovey.	St. Geo. Boswell.	G. C. Cuningham.
.	G. C. Cuningham.	M. J. Butler.	C. E. W. Dodwell.
.	C. E. W. Dodwell.	W. R. Butler.	H. Irwin.
GHAM.	J. Galbraith.	H. J. Cambie.	E. H. Keating.
	H. D. Lumsden.	G. C. Cuningham.	G. A. Keefer.
AN.	D. MacPherson.	W. B. Dawson.	D. H. Keeley.
TH.	H. N. Ruttan.	G. H. Duggan.	D. MacPherson.
EN.	J. M. Shanly.	H. Irwin.	A. MacDougall.
NS.	H. B. Smith.	E. H. Keating.	C. H. Rust.
LEOD.	W. J. Sproule.	A. Macdougall.	E. Marceau.
	R. Surtees.	W. G. Matheson.	M. Murphy.
AN.	W. G. Thompson.	D. A. Stewart.	H. Peters.
E.	L. A. Vallee.	W. J. Sproule.	H. N. Ruttan.
			W. J. Sproule.
R.	T. C. Keefer.	T. C. Keefer.	*Col.* Sir C. S. Gzowski
WSKI.	Sir C. S. Gzowski.	Sir C. S. Gzowski.	John Kennedy.
EDY.	John Kennedy.	John Kennedy.	E. P. Hannaford.
AFORD.	E. P. Hannaford.	E. P. Hannaford.	P. Alex. Peterson.
	P. A. Peterson.	P. Alex. Peterson.	Thos. Monro.
		Thos. Monro.	Herbert Wallis.
D.	C. H. McLeod.	C. H. McLeod.	C. H. McLeod.
KWELL.	K. W. Blackwell.	K. W. Blackwell.	K. W. Blackwell.
.	Wm. McNab.	Wm. McNab.	W. McNab.

CANADIAN SOCIETY OF CIVIL ENGINEERS.

LIST OF OFFICERS FOR THE YEARS 1887 TO 1897.

	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
President....	T. C. Keefer.	S. Keefer.	C. S. Gzowski.	C. S. Gzowski.	Sir C. S. Gzowski.	John Kennedy.	E. P. Hannaford.	P. Alex. Peterson.	Thomas Monro.	Herbert Wallis.	Thomas C. Keefer.
Vice-Presidents....	C. S. Gzowski. J. Kennedy. W. Shanly.	C. S. Gzowski. E. P. Hannaford. H. F. Perley.	E. P. Hannaford. H. F. Perley. P. A. Peterson.	E. P. Hannaford. J. Kennedy. H. F. Perley.	E. P. Hannaford. J. Kennedy. F. J. Lynch.	W. T. Jennings. Thos. Monro. P. A. Peterson.	W. T. Jennings. Thos. Monro. P. A. Peterson.	A. Macdougall. P. W. St. George. H. Wallis.	W. T. Jennings. M. Murphy. H. Wallis.	Henry T. Bovey. Chas. Macdonald. W. G. Thompson.	Henry T. Bovey. G. H. Duggan. W. T. Jennings. W. G. Thompson.
Members of Council..	F. N. Gisborne. E. P. Hannaford. W. T. Jennings. S. Keefer. L. Lesage. H. D. Lumsden. A. Macdougall. H. F. Perley. H. Peters. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Schreiber. H. Wallis.	H. Abbott. F. R. F. Brown. F. N. Gisborne. J. Hobson. W. T. Jennings. J. Kennedy. L. Lesage. A. Macdougall. H. A. F. Macleod. M. Murphy. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Schreiber.	G. F. Baillairge. J. D. Barnett. K. W. Blackwell. St. G. J. Boswell. F. R. F. Brown. G. C. Cuningham. E. Gilpin. F. N. Gisborne. W. T. Jennings. G. A. Keefer. J. Kennedy. M. Murphy. B. D. McConnell. E. Wragge. J. A. Vanier.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. W. T. Jennings. G. A. Keefer. H. G. C. Ketchum. T. Monro. G. H. Massy. P. A. Peterson. H. N. Ruttan. P. W. St. George. J. W. Trutch. E. Wragge.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. H. Donkin. F. N. Gisborne. E. A. Hoare. J. Hobson. W. T. Jennings. T. Monro. P. A. Peterson. H. N. Ruttan. P. W. St. George. Sir J. W. Trutch.	J. D. Barnett. K. W. Blackwell. H. T. Bovey. H. J. Cambie. C. E. W. Dodwell. F. C. Gamble. F. N. Gisborne. E. A. Hoare. Jos. Hobson. C. H. Keefer. H. G. C. Ketchum. H. D. Lumsden. A. Macdougall. H. N. Ruttan. P. W. St. George.	J. D. Barnett. St. Geo. Boswell. H. T. Bovey. F. R. F. Brown. G. C. Cuningham. C. K. Domville. C. H. Keefer. H. D. Lumsden. A. Macdougall. E. Mohun. G. A. Mountain. H. S. Poole. Frank R. Redpath. Thomas Ridout. P. W. St. George.	H. Abbott. P. S. Archibald. J. D. Barnett. H. T. Bovey. O. Chanute. G. C. Cuningham. H. Donkin. G. H. Duggan. J. Galbraith. G. H. Garden. Wm. Haskins. H. A. F. MacLeod. H. Peters. H. N. Ruttan. L. A. Vallee.	P. S. Archibald. J. D. Barnett. H. T. Bovey. G. C. Cuningham. C. E. W. Dodwell. J. Galbraith. H. D. Lumsden. D. MacPherson. H. N. Ruttan. J. M. Shanly. H. B. Smith. W. J. Sproule. R. Surtees. W. G. Thompson. L. A. Vallee.	W. D. Barclay. J. D. Barnett. St. Geo. Boswell. M. J. Butler. W. R. Butler. H. J. Cambie. G. C. Cuningham. W. B. Dawson. G. H. Duggan. H. Irwin. E. H. Keating. A. Macdougall. W. G. Matheson. D. A. Stewart. W. J. Sproule.	St. Geo. Boswell. M. J. Butler. G. C. Cuningham. C. E. W. Dodwell. H. Irwin. E. H. Keating. G. A. Keefer. D. H. Keeley. D. MacPherson. A. MacDougall. C. H. Rust. E. Marceau. M. Murphy. H. Peters. H. N. Ruttan. W. J. Sproule.
Past Presidents and Hon. Councillors....	....	T. C. Keefer.	T. C. Keefer. S. Keefer.	T. C. Keefer.	T. C. Keefer.	T. C. Keefer. Sir C. S. Gzowski	T. C. Keefer. Sir C. S. Gzowski. John Kennedy.	T. C. Keefer. Sir C. S. Gzowski. John Kennedy. E. P. Hannaford.	T. C. Keefer. Sir C. S. Gzowski. John Kennedy. E. P. Hannaford. P. A. Peterson.	T. C. Keefer. Sir C. S. Gzowski. John Kennedy. E. P. Hannaford. P. Alex. Peterson. Thos. Monro.	*Col.* Sir C. S. Gzowski John Kennedy. E. P. Hannaford. P. Alex. Peterson. Thos. Monro. Herbert Wallis.
Secretary..	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey. C. H. McLeod.	C. H. McLeod.	C. H. McLeod.	C. H. McLeod.	C. H. McLeod.	C. H. McLeod.	C. H. McLeod.
Treasurer..		H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	K. W. Blackwell.	K. W. Blackwell.	K. W. Blackwell.	K. W. Blackwell.
Librarian....	....	F. Chadwick.	F. Chadwick.	F. Chadwick.	F. Chadwick. Wm. McNab.	Wm. McNab	Wm. McNab.	Wm. McNab.	Wm. McNab.	Wm. McNab.	W. McNab.

REPORT OF PROCEEDINGS.

ANNUAL GENERAL MEETING.

Convened at 10 a.m., Tuesday, 12th January, 1897.

HERBERT WALLIS, President, in the Chair.

The Secretary read the notice convening the meeting.

The minutes of the Annual General Meeting held on the 14th and 15th of January, 1896, and those of the Special General Meeting held in Toronto on the 17th, 18th and 19th June, 1896, were read and approved.

The President read a telegram from Lord Derby expressing good wishes for the welfare of the Society and for the success of the Meeting. The following reply to Lord Derby's telegram was authorized: "Society Civil Engineers now in Session sends many thanks for good wishes, and notes with pleasure your Lordship's continued interest in its welfare."

The President also read a letter from Sir Casimir Gzowski, expressing his regret at being unable to attend the meeting, and conveying good wishes for its success.

The following gentlemen were appointed scrutineers of the ballot for the election of Officers and Members of the Council:

Messrs. A. Rhodes, J. A. Duff and A. Crumpton.

The following gentlemen were appointed scrutineers of the ballot for the election of the Nominating Committee:

Messrs. E. Berryman, W. Chase Thompson and W. F. Angus.

The following gentlemen were appointed scrutineers of the ballot on amendments to By-laws:

Messrs. C. B. Smith, H. W. Umney and L. B. Copeland.

The President announced that the Members' dinner would be held that evening in the Windsor Hotel at 7 p.m., and asked those wishing to be present to communicate with the Secretary immediately after the meeting.

The President also announced that the Board of Directors of the Art Gallery, as had already been intimated, had invited the Members to visit the Gallery during the week of their meeting. He had also to inform them that sleighs would be provided presently to take all who wished to go out to Lachine to inspect the works of the Lachine

Rapids Hydraulic and Land Company, where by the kindness of the contractors a luncheon would be served to Members and their friends. He asked all who wished to take this trip to inform the Secretary at once.

The meeting was then adjourned to Wednesday, 13th January, at 10 a.m.

ADJOURNED ANNUAL MEETING.

HERBERT WALLIS, President, in the Chair.

The Meeting was called to order at 10 a.m., on Wednesday, January 13th, 1897. The Secretary read the following Report:

REPORT OF COUNCIL.

ANNUAL MEETING, JANUARY 12TH, 1897.

The Council begs to present the following report on the work of the Society during the past year.

ROLL OF THE SOCIETY.

The elections comprised *eight* members, *eleven* associate members, *three* associates and *eight* students. *Five* associate members have been transferred to the class of members, and *six* students to the class of associate members.

Resignations have been received from *three* members, *one* associate member, *four* associates and *five* students, while *five* members, *four* associate members, *one* associate and *seventeen* students have been removed from the roll for non-payment of dues.

The deaths have been :—

Members.—Job Abbott, William Haskins, Henry George Clopper Ketchum.

Associate Members.—Leander Meyer Bowman, Napoleon Julien Giroux.

At the present date the membership stands as follows :—

	Non Res.	Res.	Total.
Honorary Members	6	2	8
Members	218	53	271
Associate Members	115	30	145
Associates	27	15	42
Students	194	31	125
			591

At the same date last year the membership was as follows:—

	Non Res.	Res.	Total.
Honorary Members	6	2	8
Members........	217	52	269
Associate Members......	111	29	140
Associates..........................	26	18	44
Students.........	90	55	145
			606

There has therefore been a slight increase in the number of members and associate members, but a considerable decrease in the number of students. This latter, however, is entirely due to removal from the membership roll on account of non-payment of dues.

At the time of the last Annual General Meeting there were three new applications, and at the present time there are eight applications for admission into the Society.

ANNUAL MEETING.

The Tenth Annual Meeting was called to order at 10 o'clock a.m., Tuesday, January 14th, 1896, Mr. Thomas Monro, President, in the Chair. The scrutineers for the ballots were appointed by the President. The Chairman of the Committee on Professional Status presented the report of the Committee, embodying a draft of amendment to the Dominion Act of Incorporation, and an Act of Incorporation for the Provincial Legislatures. A discussion on the proposed incorporation of the Society then took place, and was continued throughout the forenoon. At the conclusion of the discussion the meeting adjourned to Wednesday at 10 a.m.

On Tuesday evening a Members' Dinner, presided over by the retiring President, was held in the Queen's Hotel. The dinner was largely attended.

The meeting re-assembled on Wednesday, January 15th, at 10 a.m., to hear the Report of the Council and transact the general business of the Society.

On Wednesday evening at 8 p.m. a lecture by Prof. C. A. Carus-Wilson was delivered to the members and their friends in the Physics Building, McGill University, on "Electric Power Waves."

ORDINARY MEETINGS.

Fifteen ordinary meetings have been held during the year, at which the following papers were read:—On "The Penn Yan (N.Y.) Waterworks," by Angus Smith, Stud.Can.Soc.C.E.; on "The Effects of Engineering works on Water Currents," by Cyrus Carroll, M.Can.Soc. C.E.; on "The Dry Dock at Kingston, Ontario," by Henry F. Perley, M.Can.Soc.C.E.; on "The Sewerage of Victoria, B.C.," by E. Mohun, M.Can.Soc.C.E.; on "The Storage of Water in Earthen Reservoirs," by Prof. Samuel Fortier, M.Can.Soc.C.E.; an illustrated lecture on "The Designing and Building of Bridges," by Mr. J. A. L. Waddell, Ma.E., Bridge Engineer of Kansas City, Mo.; on "Experiments on the Strength of Concrete, made at McGill University," by Messrs. Theo. Denis, G. G. Hare and Carl Reinhardt, Students Can. Soc.C.E.

Owing to the difficulty in obtaining papers for discussion and to the falling off in attendance at the ordinary meetings, a circular letter has recently been issued to resident members, reminding them of the obligations they assumed upon joining the Society, and requesting them to contribute to the usefulness of the Society by a renewal of their interest in its ordinary meetings.

SPECIAL GENERAL MEETING.

A Special General Meeting of the Society was held in Toronto on the 17th, 18th and 19th of June last, and was attended by about fifty members of the Society. An important discussion on the incorporation of the Society took place. Two papers were also read and discussed; a paper on "Pneumatic Power Applied to Workshops," by John Davis Barnett, M.Can.Soc.C.E.; and a paper on "The Discharge of the St. Lawrence River," by Prof. C. H. McLeod, M.Can.Soc.C.E. Both papers were followed by interesting discussions. There were excursions of interest to places in and about Toronto during the first two days of the meeting, and on the third day the members and their friends visited Niagara and several of the works of engineering interest there.

The marked success of this, the first summer meeting of the Society, seems to warrant a repetition of the experiment.

ROOMS.

Owing to the considerable expenditure which is likely this year to be incurred in other directions, the Council has not considered it advisable to make any new departure in the matter of rooms, but has obtained a renewal of the lease of the present quarters for one year. The difficulty in obtaining storage accommodation has been temporarily solved by an arrangement to place the surplus pamphlets and transactions in boxes, and store them until such time as full accommodation can be obtained.

PROFESSIONAL STATUS.

In accordance with instructions issued at the last Annual Meeting, the Council appointed a General Committee to further consider the question of the incorporation of the Society, and also named committees in the several provinces of the Dominion. The Council also appointed a sub-committee, which on two occasions visited Ottawa in order to ascertain if the time were favourable for the introduction of the proposed amendment to the Dominion Act. It has, however, been considered inadvisable to introduce the bill during the past year.

In the Province of Manitoba the Provincial Committee acted so energetically that an act of incorporation, resembling very closely that proposed by Mr. Creelman, was assented to on March 19th, and became law on July 1st, 1896.

It was unfortunately found, owing to the absence of some members of the Central Committee and to the illness of others, that it was impracticable for this committee to perform the work for which it was appointed. The Council, therefore, in order to carry out the wishes of the Annual Meeting, appointed a special sub-committee of its members to take charge of matters relating to the incorporation of the Society. The committee has been actively engaged in the work, especially in connection with the Act for the Province of Quebec since its appointment in November.

The Committee in the Province of Nova Scotia, under date November 2nd last, reported that the Act in that Province would be introduced as a public act at the next ensuing session of Parliament. The Nova Scotia Legislature is summoned to meet on the 27th inst.

In the Province of Quebec an Act is now before the Legislature as a public measure. Unfortunately, it was introduced somewhat late in the session, but it is still hoped that time will admit of its passage before the legislature is prorogued.

No action has yet been taken in any of the other provinces.

In connection with the passage of the Manitoba Act, it became necessary to hold a meeting of Council in Winnipeg, and in order to economise in travelling expenses, Messrs. St. Geo. Boswell, W. B. Dawson and J. D. Barnett, members of the Council, very generously volunteered their resignations, in order to admit of members resident in Winnipeg or its neighbourhood being elected to replace them, thus making it possible to obtain the necessary quorum there. Messrs. H. N. Ruttan, H. F. Forrest and G. H. Webster were appointed to fill the vacancies in the Council, and at the Winnipeg meeting there were present Messrs. H. Irwin, H. N. Ruttan, D. A. Stewart, H. F. Forrest and G. H. Webster. Mr. Stewart acted as Chairman and Mr. Irwin as Secretary of the meeting. The special thanks of the Council and of the Society are due to the gentlemen who so kindly resigned their positions in order to facilitate the work of the Council and of the Society.

The Society having been invited to send a representative to Glasgow in June last to attend the ceremonies in connection with the Jubilee of Lord Kelvin, Hon. M.Can.Soc.C.E., an address was prepared by the Council and presented to Lord Kelvin on behalf of the Society, by Mr. James Ross, M.Can.Soc.C.E., who, being in England at the time, kindly placed his services at the disposal of the Council for the purpose.

On the recommendation expressed at the Special General Meeting held in Toronto, the Council has decided in future to issue from time to time, to voting members, in advance of the regular ballot, a list of candidates seeking admission to the Society in order to verify the qualifications under which membership is sought, and to save time which is now lost in correspondence. It is hoped that members will assist the Council to make this practice effective.

The Council records with thanks to the donor, the permanent endowment of the Gzowski medal by Sir Casimir Gzowski, with three shares of the Canada Permanent Loan & Savings Company.

The Council also expresses its appreciation of the bequest of the late Mr. H. G. C. Ketchum, M.Can Soc.C.E., of $500 towards the funds of the Society.

FINANCES.

The income for the year was $3,791,77, and the expenditure $3,564. 17, leaving a balance of $227.60, and a total balance to carry forward in the general fund of $7,445.37. The balance to the credit of the building fund is now $3,859.27, making the total balance to credit of the Society $11,304.64.

REPORT OF THE LIBRARY COMMITTEE.

Donations to the Library of books, pamphlets or money have been received from E. H. Keating, M.Can.Soc.C.E., Alex. C. McCallum, A.M.Can.Soc.C.E., H. Irwin, M.Can.Soc.C.E., Chas. Baillairgé, M.Can. Soc.C.E.; P.W. St. George, M.Can.Soc.C.E.; J. W. Heckman, A. M. Can. Soc. C.E., and W. McNab, M.Can.Soc.C.E.

Exchanges of Transactions have been arranged for during the year with the Western Society of Engineers, Chicago, and the Engineers Society of Western New York.

The following journals, in addition to those reported in previous years, are also received in exchange for our Transactions:—Railway Review, Chicago; Railway Age, Chicago; Chicago Journal of Commerce.

In accordance with the resolution of Council, reported at the last Annual Meeting, exchanges, for advance proofs of papers read before the Society, have been effected with the following journals, which are now regularly received :—

American Architect and Building News, *Boston.*
Electrical Age, *New York.*
Electrical Engineer, *London.*
Electrical News, *Toronto.*
Electrical Review, *New York.*
Electrical Review, *London.*
Engineering, *London.*
Engineering Magazine, *New York.*
Industries and Iron, *London.*
Locomotive Engineering, *New York.*
Mechanical World, *Manchester, Eng.*
Mining Journal, *London.*
Mining and Scientific Press, *San Francisco, Cal.*
The Sanitarian, *Brooklyn, N.Y.*
The Sanitary Plumber, *New York.*
Western Electrician, *Chicago.*
La Revue Technique, *Paris, France.*

Three of these, viz: Engineering, the Engineering Magazine and the Mining Journal were previously subscribed for. The following is a complete list of the publications regularly received and to be found in our Reading Room :—

American Society of Civil Engineers, Transactions, *New York.*
American Society of Mechanical Engineers, Transactions, *New York.*

American Institute of Electrical Engineers, Transactions, *New York.*
American Institute of Mining Engineers, Transactions, *Philadelphia.*
American Society of Irrigation Engineers, Transactions, *Denver.*
American Architect and Building News, *Boston.*
American Engineer and R.R. Journal, *New York.*
Austrian Engineers and Architects Society, Transactions, *Vienna.*
Association of Industrial Engineers, Transactions, *Barcelona.*
Association of Engineering Societies, Transactions, *New York.*
Association of Engineers of Virginia, Transactions, *Roanoke, Va.*
Boston Public Library Bulletin, *Boston.*
Bureau of Mines, Reports, *Toronto.*
Canadian Institute, Transactions, *Toronto.*
Cornell University, Bulletin, *Ithaca, N.Y.*
Cleveland Institute of Engineers, Transactions, *Middlesborough.*
Cassier Magazine, *New York.*
Engineers' Club of Philadelphia, Proceedings, *Philadelphia.*
Engineering Association of New South-Wales, Transactions, *Sydney.*
Engineering Association of the South, Transactions, *Nashville, Tenn.*
Engineers Association of Western Pennsylvania, Transactions, *Alleghany, Pa.*
Engineering News, *New York.*
Engineering and Mining Journal, *New York.*
Engineering, *London.*
Engineer, *London.*
Engineering Magazine, *New York.*
Electrical Age, *New York.*
Electrical Engineer, *London.*
Electrical News, *Toronto.*
Electrical Review, *New York.*
Electrical Review, *London.*
Electrical Engineering, *Chicago.*
Electrical Literature, *Chicago.*
Engineer's Gazette, *Newcastle-on-Tyne.*
Franklin Institute, Journal of, *Philadelphia.*
Geological Survey of Canada, Reports of, *Ottawa.*
Hanover Architects and Engineers Society, Transactions, *Hanover.*
Hungarian Society of Civil Engineers, Transactions, *Buda-Pesth.*
Institution of Civil Engineers, Transactions, *London.*
Institution of Mechanical Engineers, Transactions, *London.*
Institution of Electrical Engineers, Transactions, *London.*

Industries and Iron, *London.*

Iron and Steel Institute, Transactions, *London.*

Ironmonger, *London.*

Indian Engineering, *Calcutta.*

Institution of Civil Engineers of Ireland, Transactions, *Dublin.*

Institution of Engineers and Shipbuilders in Scotland, Transactions, *Glasgow.*

Junior Engineering Society, Transactions, *London.*

Journal of the U.S. Artillery, *Fort Monroe, Va.*

Liverpool Engineering Society, Transactions, *Liverpool.*

Locomotive Engineering, *New York.*

Midland Institute of Civil, Mechanical and Mining Engineers, Transactions, *Barnsley.*

Marselles Scientific and Industrial Society, Transactions, *Marseilles.*

Manchester Association of Engineers, Transactions, *Manchester.*

Mechanical World, *Manchester.*

Mining Journal, *London.*

Mining Institute of Scotland, Transactions, *Hamilton.*

Mining Society of Nova Scotia, Transactions, *Halifax.*

Mining and Scientific Press, *San Francisco.*

Minnesota University (Year Book), *Minneapolis.*

North of France Industrial Society, Transactions, *Lille.*

Nova Scotian Institute of Science, Transactions, *Halifax.*

North East Coast Institution of Engineers and Shipbuilders, Transactions, *Newcastle.*

National Car and Locomotive Builder, *New York.*

New York State Library, Bulletin of.

Patent Office Library, Reports of, *London.*

Philosophical Society of Glasgow, Transactions, *Glasgow.*

Physical Review, *New York.*

La Revue Technique, *Paris.*

Royal Society of Canada, Transactions, *Ottawa.*

Report of Chief of Engineers U. S. Army, *Washington.*

Royal Engineers Institute, Transactions, *Chatham.*

Royal Artillery Institution, Transactions, *Woolwich.*

Royal Institute of British Architects, Transactions, *London.*

Royal United Service Institution, Transactions, *London.*

Royal Dublin Society, Transactions, *Dublin.*

Royal Society of Edinburgh, Transactions, *Edinburgh.*

Royal Scottish Society of Arts, Transactions, *Edinburgh.*

Royal Institute of Engineers, Transactions, *The Hague.*
Royal Irish Academy, Transactions, *Dublin.*
Railroad Gazette, *New York.*
Sanitarian, *Brooklyn, N. Y.*
School of Mines, Quarterly, *New York.*
Sanitary Plumber, *New York.*
Society of Engineers, Transactions, *London.*
Society of Arts, Transactions, *London.*
South Wales Institute of Engineers, Transactions, *Merthyr Tydvil.*
Society of Civil Engineers, Transactions, *Paris.*
School of Practical Science, *Toronto.*
Technical Society of the Pacific Coast, Transactions, *San Francisco.*
Technology Quarterly, *Boston.*
U.S. Naval Institute, Transactions, *Annapolis.*
U.S. Geological Survey, Reports, *Washington, D.C.*
Western Railway Club, Transactions, *Chicago.*
Western Society of Engineers, Transactions, *Chicago.*
Western Electrician, *Chicago.*
Wisconsin University, Bulletin of, *Madison, Wis.*

It is still a source of regret to the Committee that, owing to the lack of space in our present quarters for the systematic storage of unbound journals, they cannot, except with difficulty, be referred to after they have been removed from the reading table.

GRANVILLE C. CUNINGHAM, *Chairman.*
W. McNAB, *Librarian.*

CANADIAN SOCIETY OF CIVIL ENGINEERS.

ABSTRACT OF RECEIPTS AND EXPENDITURES FOR THE YEAR ENDING DECEMBER 31st, 1896.

Balance from 31st Dec., 1895			$7,217 77
GENERAL RECEIPTS.			
Subscriptions :			
Arrears	$ 714 00		
Current	2,218 00		
Advance	582 00		
Extra on Cheques	1 55		
		$3,515 55	
Transactions sold		43 95	
Donation to Library		6 00	
Interest to Dec. 31st, 1896		226 27	
			$3,791 77
BUILDING FUND.			
Balance from Dec. 31st, 1895		$3,729 42	
Interest to Dec. 31st, 1896		129 85	
			$3,859 27
			$14,868 81

GENERAL EXPENDITURES.		
Transactions published and printed	$1,161 95	
Advance proofs, etc	44 75	
Printing and stationery	206 80	
List of Members, charters and by-laws	83 70	
Postage	167 92	
Messengers	22 45	
Cabs	7 50	
Secretary's salary	300 00	
Asst. do do	480 00	
Janitor's wages	120 00	
Janitor for washing towels	6 00	
Office funiture	15 60	
Rent of rooms for one year	550 00	
Telephone service	30 00	
Bank commission on cheques	8 40	
Water rate	25 22	
Electric lighting	36 15	
Bookbinding	34 90	
Books and magazines	33 35	
Telegrams	10 92	
Address to Lord Kelvin	26 03	
Expenses *re* Close Corporation	160 58	
Insurance for three years	14 40	
Express Charges	68	
Prof. Carus Wilson's Lecture (being cost of arrangements of apparatus, etc.	16 87	
		$3,564 17
BALANCES.		
General Fund Treasurer	$7,445 37	
Building Fund Treasurer	3,859 27	
		$11,304 64
		$14,868 81

K. W. BLACKWELL,
Treasurer.

Examined with books and vouchers, and found correct,

E. P. HANNAFORD,
W. J. SPROULE, } *Auditors.*

It was moved by Mr. Walter Shanly, seconded by Mr. P. A. Peterson, and resolved : "That the report be adopted."

Mr. Wallis.

Mr. Wallis said that he had a statement to make with regard to the question of Close Corporation. He reminded the members that at the last Annual Meeting provincial committees were appointed to report to a central committee of which Mr. MacDougall was chairman. Unfortunately Mr. MacDougall was obliged to leave Canada for the benefit of his health, and the result was that the General Committee never reported. This being the case it devolved upon the Council either to proceed with the matter or to abandon it. After several meetings it was decided to proceed, and notice was given in the Quebec Gazette of the proposed legislation on behalf of the Society. It was found, however, that this notice was too late. Mr. Wallis had then visited Quebec, and the Government was induced to accept the Act as a public measure. The bill passed its first reading, but, owing to the late stage of the Session at which it was introduced, it did not reach its second reading before the prorogation of the House. This much progress has, however, been made ; the bill is in good shape, and, after one or two amendments which we shall have to concede, it can be passed. He regretted being unable to report that the bill had passed the Legislature. The special Committee to which this matter had been referred had held many meetings and had spent much time and energy in the work devolving on it. It is proposed to present a similar bill to the Nova Scotia Legislature, and to endeavour to pass it there. With regard to the other Legislatures, he thought they should proceed in due course in the same way. The Secretary then read the bill as drafted for the Quebec Legislature as follows :

BILL.

An Act concerning Civil Engineers.

Whereas by an Act of the Parliament of Canada, 50-51 Victoria, chapter 124, "The Canadian Society of Civil Engineers" was incorporated, and it is deemed advisable to establish the qualifications necessary to permit persons to act or practise as civil engineers in the Province of Quebec ;

Therefore, Her Majesty, by and with the advice and consent of the Legislature of Quebec, enacts as follows :

1. The following expressions in this Act have the meanings hereby assigned to them unless there is something in the text repugnant to such construction :

1. The expression "the Society," means the Canadian Society of Civil Engineers ;

2. The expression "the Council," means the Council of the said Society ;

3. The expression "corporate member," means a Member or Associate Member of the said Society ;

4. The expression "civil engineer," means any one who acts or practises as an engineer in advising on, in making surveys for, or in laying out, designing or supervising the construction of railways, bridges, roads, canals, harbours, river improvements, light-houses, and hydraulic, municipal, electrical, mechanical, mining or other engineering works ; but it is not deemed to apply to a mere skilled artisan or workman.

2. On and after the first day of January, 1898, no person shall be entitled, within the Province of Quebec, to use the title of civil engineer, or any abbreviation thereof, or any name, title or description implying that he is a corporate member of the said Society, nor to act or practise as civil engineer within the meaning of the first section of this Act:

(*a*) Unless such person is a corporate member of the Society ; or,

(*b*) Unless he is entitled, by some statute of the Dominion of Canada, or of the late Province of Canada, or of the Province of Quebec, to use the title of civil engineer ; or,

(*c*) Unless he is practising as a civil engineer in this Province, and within one year from the passing of this Act becomes a corporate member of the Society.

3. The following persons shall be admitted as corporate members of the Society :

1. All persons, being practising civil engineers within the Province, at the time of the coming into force of this Act, who, within one year therefrom, apply for admission to and pay the subscription fees required under the by-laws of the said Society ;

2. All persons who, having been admitted to study under the provisions of this Act, shall have passed the prescribed examinations and shall have been licensed as civil engineers by the said Society.

4. The Council shall name a board of examiners, of not less than six persons, any three of whom shall be a committee to examine candidates for admission to the study, or for admission to the practice of civil engineering.

The said board shall meet at least twice each year, at the cities of Quebec and Montreal alternately, on the first Tuesday in May and November.

5. A candidate for admission to study shall:

(*a*) Give one month's notice to the secretary of the Society of his intention to present himself for examination, and at the same time shall pay such secretary the sum of twenty dollars as a fee, one half of which shall be remitted in the event of failure to pass the prescribed examination;

(*b*) Produce a certificate of good character;

(*c*) Pass an examination in the following subjects, namely: general geography, that of Canada in particular; history of Canada; arithmetic; elements of geometry; use of logarithms; algebra, up to and including quadratic equations; trigonometry, up to and including the solution of plain triangles.

If successful, the candidate shall be entitled to a certificate that he has passed such examination.

If the candidate holds a degree of Bachelor of Arts, Bachelor of Sciences, or Bachelor of Letters, conferred upon him by any Canadian or British University, he shall, on making satisfactory proof that he is the person named in such degree, be entitled, on payment of the abovementioned fee, to receive a certificate permitting him to study.

6. A candidate for admission to practice shall:

(*a*) Give one month's notice of his intention to present himself for examination, and at the same time pay the said secretary the sum of forty dollars, as a fee;

(*b*) Produce a certificate of good character;

(*c*) Establish that he is at least twenty-one years of age;

(*d*) Establish that, since his admission to study, he has been engaged in the pursuit of engineering in the office or in the service of a member of the Society for a period of at least five years, or, for a period of two years, if he has a degree from any college or university in Canada granting degrees or diplomas in applied science after a course of not less than three years.

(*e*) Pass an examination before the board of examiners of the Society on the theory and practice of engineering, and specially in one of the following branches at his option, namely: railway, municipal, hydraulic, mechanical, mining or electrical engineering.

7. Any student who has passed the examination prescribed by this Act is entitled to receive a diploma and becomes a corporate member of the Society.

8. No by-laws passed, or that may be passed, by the Society, shall have force or effect in this Province until approved by the Lieutenant-Governor in Council.

9. No person practising the profession of civil engineer, and not entitled to do so under this Act, shall recover before any court of justice any sum of money for the professional services rendered in such practice.

10. Whosoever, not being entitled to do so under this Act, practises as a civil engineer within the Province for a remuneration or in the hope of being remunerated, rewarded or paid for his services, directly or indirectly, or who falsely pretends that he is a civil engineer or a corporate member of the Society, shall be liable to a fine of not less than twenty-five dollars, nor more than fifty dollars for each offence; and, in default of payment, to imprisonment not exceeding thirty days.

11. Prosecutions under this Act are subject to the provisions of part LVIII of the Criminal Code, 1892.

12. Nothing in this Act shall be deemed to encroach upon the rights and privileges conferred upon provincial land surveyors by any Act of the Legislature of this Province.

13. This Act shall come into force on the day of its sanction.

Mr. Shanly thought it would be a very difficult thing to get the penalty clause put through. Mr. Shanly.

Mr. Wallis said there had been no opposition put forward to that. Mr. Wallis.

Mr. Peterson said that it was understood that every one must pass an examination. Supposing a foreign engineer wished to enter the Society, would he also have to pass this examination? Mr. Peterson.

Mr. Wallis said the examiners may take such action as they think fit. If Sir Charles Russell or anybody else wanted to practice law in Canada, he would be obliged to pass an examination. Mr. Wallis.

Mr. Peterson said he thought it should have been left to the Council to determine this. Mr Peterson.

Mr. Wallis said the members must not lose sight of what this really meant. It is a public bill. It was not intended that the Council should have the right to act on its own responsibility. Mr. Wallis.

Mr. Peterson. Mr. Peterson said he did not think that the Government would object to leaving this in the hands of the Council.

Mr. Shanly. Mr. Shanly thought that this bill should have been distributed amongst the members.

Mr. Wallis. Mr. Wallis said there was not time to send a copy of the bill out to members.

Mr. Sproule. Mr. Sproule said the point regarding the entrance of foreign engineers looked very awkward to those who had not been familiar with the discussion that had taken place. But it was very fully discussed with the lawyer who had charge of our bill, and as a matter of law it seems it would be impossible for us to admit any man without an examination or without at least the form of an examination. Such was the practice in law and medicine. It is necessary for them to pass an examination, and, as the Council had the power of examination in its own hands, it must be clear to every one that it could use its own discretion in the matter of admitting foreign engineers. If one man were permitted to come in without an examination any man could come up and demand to be admitted in the same way. It was understood that in the case of an eminent engineer that the examiners would practically make the examination a dead letter.

Mr. Peterson. Mr. Peterson said he thought that, if we had an Act of Parliament that allowed us to admit foreign engineers without examination, there would be no difficulty about it. If the Council were given the right to use its own discretion in this respect he thought it would be much better.

Mr. Boswell. Mr. Boswell said the Government would never allow us any option of that kind.

Mr. Wallis. Mr. Wallis said that such a thing would not be acceptable to the Government. Our lawyer had frequent interviews with the law office at Quebec, and practically this bill was drafted under the supervision of clerks of the House of Commons in Quebec.

Mr. Hannaford Mr. Hannaford enquired of the President if the land surveyors had objected to any specified clauses in the bill, or were their objections of a general nature ?

Mr. Boswell. Mr. Boswell said the land surveyors as far as was known objected to the words "bridges" and "roads." They said they made their living to a great extent by laying out bridges and roads, but they would be satisfied if the colonization roads and bridges were eliminated from the bill.

Mr. Hannaford Mr. Hannaford said the bill should be made as acceptable as possible to the land surveyors without injuring the interests of the civil engineers. He thought that they should endeavour to induce the surveyors to join them in the passage of the Act.

Mr. Wallis said they would have all the rights of civil engineers while the engineers would not enjoy any of their rights. Mr. Wallis.

Mr. Hannaford said he would feel inclined to get the bill passed and waive certain objections. Mr. Hannaford

Prof. McLeod said if there were a money limit placed upon the roads and bridges it might meet the views of the land surveyors. Prof. McLeod.

Mr. Shanley said the Manitoba Act had a money limit, but there was absolutely no penalty. Mr. Shanley.

Mr. Wallis said the Manitoba Act would have to be amended. Mr. Wallis.

Mr. Peterson said he did not think the Society should make any objection to allowing the land surveyors to lay out these roads. Engineers have never been employed on the Colonization roads, and he thought the Society might very well waive that point. Mr. Peterson.

Mr. Sproule said he thought it would be a good thing to meet the land surveyors to a certain extent. He was of opinion that it would only be a few years before the land surveyors and the engineers were one body, and there would not then be any trouble in that respect. Mr. Sproule.

Mr. Irwin said that in accordance with the wishes of the Council he had called upon the Secretary of the land surveyors and learned from him that there was no opposition at all at the time, and so far as he was concerned he did not think they would as a body oppose it. He thought there were only one or two land surveyors in Quebec, and one especially who was not engaged in practice, who were disposed to work in opposition to the present bill. He did not think there would be any great objection to putting in a clause excluding colonization roads from the engineering works which must not be undertaken by any one not an engineer. He did not think, however, that any of the land surveyors were capable of building an expensive bridge, or that they knew anything about it. He thought some money limit might be placed upon such matters. Mr. Irwin.

He thought the Society ought to consider the question of the incorporation in the different provinces in a light perhaps in which they had not as yet looked at it. It was this:—that members who would become qualified to act in the Province of Quebec, under the close corporation if the act comes into force, would not have any right to practice in the Province of Ontario, and he thought that there should be a clause inserted in each bill saying that members admitted to practice as engineers in one province might be admitted to practise in another province provided that province reciprocates. Otherwise it would almost seem as if members who would be authorized to practice in Quebec would be debarred from practising in the other provinces. One of the senior members had remarked that it would be well if all the members knew something about this bill, but unfortunately there had been no time to have it issued to members. He thought it would be a good idea if the Society was to pass judgment upon the bill as it stood.

Mr. Baillairgé

Mr. Baillairgé said most of their land surveyors are of the "Canadian persuasion," and he believed that in the French translation there are some words that are disagreeably suggestive to the surveyor of the engineer doing some of his work, and in reality it is not the proper translation; the city engineer is not a translation, nor is city inspector. He thought the word "arpentages" should be eliminated and replaced by the words "mesurage et relevé n'ayant trait."

Mr. Irwin.

Mr. Irwin said he might say that the title of the surveyor has hitherto been "arpenteur, provincial."

Mr. Wallis.

Mr. Wallis said the Council would like to have an expression from the meeting as to what their future procedure was to be in regard to seeking incorporation. In fact, he said, it would be remembered that the Council was perhaps not exactly authorized to have this bill passed. The last annual meeting instructed the committees to find out if the different provincial legislatures would pass these bills. There was of course only one way to find this out, and that was by applying to the legislatures. It would be necessary for some one to move an endorsement of the action of the Council and to give the Council some instruction as to what should be done in the future. It was idle for any one to suppose that this work was going on without any expense. It was for the Society to say what the future procedure in the matter was to be.

Mr. Sproule.

Mr. Sproule said legislation of some kind had been talked of for several years. He had the honour of moving that an expression of opinion be obtained from the Society. It was very well for gentlemen who may have been comfortably in bed or sitting by their firesides while committees were hard at work here discussing all the clauses of the bill to say that nothing had been accomplished. The bill had now assumed a definite shape—the form in which it must go before the Quebec Legislature. It had been returned several times, as containing matter to which the legislators would object. Much time and energy had been expended upon it, and he did not think that the non-resident members who were present should be imbued with the idea that nothing had been done.

Mr. St. George said he was very glad to be able to express his opinion in favour of what the members of the Society had done towards obtaining legislation. He believed that this Society of Engineers was instituted for the benefit of the profession and engineering work in Canada. Now that the older members of the Society had obtained their professional status, he thought it was their duty to back these young men who are just starting out in the world, and he believed that these were their reasons for attempting to accomplish the passage of this bill. He thought that the members of the Council and of the Committee had worked wonderfully well in advancing the bill to its present state. He thought the Council was deserving of the warmest thanks from every member of the Society and of every engineer in Canada for their work in connection with the bill, and that, if any member thought he should for any reason oppose it, he had better step out of the Society and fight it from the outside. Mr. St. George.

Mr. Wallis said that it was very true that if they were not united in themselves it would be impossible for the Government to pass any measure in their favour. However, in so far as the body of engineers was concerned, he had no doubt that they were united. It might go abroad owing to some action or other that they were not united when in reality they were thoroughly so. Mr. Wallis.

Mr. Peterson understood that the bill was so worded that any person desirous of joining the Society must be admitted. Mr. Peterson.

The President replied that any one could gain admission who could pass the required examination. The President.

Mr. Irwin, having attended all the meetings in connection with this bill, was familiar with all the various questions involved. He said the President was no doubt somewhat embarrassed in giving explanations as to his own action and with regard to the vast amount of trouble and attention which he had expended upon the bill. The opposition which had been alluded to had not assumed a vigourous shape. No person would wish to pay the entrance fee and yearly fees unless he could gain some professional advantage, and a person occupied in another calling (*e.g.*, plumbing) would have no object in seeking admission to the Society. The matter had been exaggerated. A clause in the Provincial Surveyors Act, if interpreted strictly according to the letter of the law, would absolutely prevent all engineers from working with a chain, transit or other instrument, but that the land Mr. Irwin.

surveyors know that the Act in that respect has to be interpreted to mean that which it was intended to mean. They know that their work consists in the determining of areas and lines and the laying out of the same. All Acts must be interpreted in a commonsense way.

Mr. Peterson. Mr. Peterson asked if it would not be well to have the Act so clearly expressed that it would not require any special interpretation.

The President. The President said that the bill was now before the meeting, and any alteration which might be thought necessary along the lines referred to could be dealt with. He was quite certain that the Council would undertake to make this bill as clear as possible; if any word in the English language could convey their meaning that word would certainly be employed. It was generally conceded that the shorter the bill was the better. The Council would have this bill before it again, and would have an opportunity of making any amendment necessary. He did not himself believe that any member of the Society had acted in any way except in so far as he considered to be to the best interests of the Society. He had sufficient confidence in the members of the Society to know that it was not the intention of any individual member to work against the best interests of the Society or of the Profession as a whole.

Mr. Kennedy. Mr. Kennedy said that a general committee and provincial sub-committee had been appointed to carry out the work in connection with the desired legislation, but that the Council had been compelled to take upon itself the duties of the committees in order to carry out the wishes of the Society, and he thought that the action of the Council should be endorsed and, if it were thought proper, they should be instructed to proceed. The objections which had been made, he thought, were made by those who had not read the bill. He thought that if they were to read the bill they would find their objections were removed.

Mr. Goad. Mr. Goad wished to know what funds were available for the purpose of legislation. He did not know whether the Council should be given a limit in the matter of expense.

Mr. Hertzberg. Mr. Hertzberg said, while he was in sympathy with this movement, he thought as the last speaker had intimated that it would be businesslike to find out to what expense they should go to ascertain what it would cost the Society to pass this bill and how the money was to be provided. He also spoke about pushing the bill through in Ontario.

Mr. Jennings. Mr. Jennings said he had consulted with the different engineers in Toronto and also with the solicitors, and they considered that it would be inadvisable to proceed with the bill in Ontario at the coming session. He asked if it would not be well to consult with the Mining Institute of Quebec. They would add strength to the Society if united to it. If the committee conferred with the land surveyors he thought they should also consider the mining engineers. He believed them to be men of considerable importance, and men whom they should have with them. The expense should not be considered at the moment. If it were worth doing at all it were worth doing well. The Ontario Legislature would meet in a month or less. In conformity with the law he thought they were too late to take action during the coming session, and, further, as it would be the last session of the present parliament which would be opposed to doing anything other than carrying out the necessary affairs of the province.

It was moved by Mr. John Kennedy, seconded by Mr. W. J. Sproule, and carried :—

"That the action of the Council in endeavouring to secure close corporation powers in the province of Quebec be endorsed."

It was moved by Mr. John Kennedy, seconded by Mr. Walter Shanly :—

"That the Council be and is hereby authorized and required to take measures for the incorporation of this Society in the various provinces of the Dominion as nearly as practicable in terms of the bill already presented before the Legislature of Quebec, and, further, that the necessary expenses of the same be authorized."

It was moved in amendment by Mr. P. W. St. George, seconded by Mr. St. George Boswell :—

"That the Council be given power to present the bill as read at this meeting to the various local legislatures as soon as possible, and that it be authorized to confer with such persons or organizations as it may think fit for the purpose, if necessary, of amending the bill in such a way as to insure its passage, and that the Council be authorized to pay the necessary expenses incurred."

The main motion was lost on division, and the amendment was declared carried.

The Secretary read the following report of the Committee on Standard Measures :

REPORT OF COMMITTEE ON STANDARD MEASURES.

The following extracts and summaries having reference to measures of length are made from "the Weights and Measures Act" of the Dominion of Canada, chapter 104, Revised Statutes of Canada.

Section 3 provided that—" The bronze bar and platinum weights "more particularly described in the first part of the first schedule to " this Act, and deposited at the Department of Inland Revenue, in the "custody of the Minister of Inland Revenue, shall continue to be the " Dominion standards of weights and measures." Section 4 provides for " two copies of the standards of measures and weights, which shall "be deemed to be Parliamentry copies of the said standards." Section 9 defines the standard yard, with reference to the bronze bar in section 3. Section 10 defines the length of other units of lineal measure with reference to the standard yard. Section 21 enacts that—" Every " contract, bargain, sale, or dealing made or had in Canada in respect "of any work, goods, wares, or merchandise, or other thing which has "been or is to be done, sold, delivered, carried or agreed for by weight " or measure, shall be deemed to be made and had according to one of "the Dominion weights or measures ascertained by this Act, or some " multiple or part thereof, and, if not so made or had, shall be void, " except when made according to the metric system."

Section 29 enacts that " Every trader, manufacturer, carrier, public " weigher, gauger, measurer, surveyor or other person who uses for " any purpose of buying, selling or charging for the carriage of any " goods, wares or merchandise or thing, or of measuring any land, "goods, materials or other thing, for the purpose of charging for or " ascertaining the amount or price to be paid, or the charge to be made " therefor, any weight or measure, or weighing machine which has "not been duly inspected and stamped according to this Act, is guilty " of an offence against this Act, and shall, on conviction thereof, incur "a penalty not exceeding fifty dollars and not less than five dollars for "each such offence; and every such unstamped weight, weighing " machine or measure so used, found in his possession, shall, on being " discovered by the inspector or his assistant, be forfeited and forthwith " seized and broken by him, without suit or authority other than this " Act."

Section 36 requires "all comparisons, verifications, etc., with reference to standards to be conducted under the supervision of the Commissioner of Inland Revenue."

Section 43 empowers local inspectors to stamp and verify measures submitted to them.

The Dominion Standard for determining the length of the Standard Yard is described in the first Schedule, Part 1, and the Parliamentary copies are described under Part 11 of the said schedule.

The Revised Statutes of Ontario, chapter 152, section 27, enacts that "Every land surveyor, duly admitted and practising, shall procure, "and shall cause to be examined, corrected and stamped or otherwise "certified by the Commissioner of Crown Lands or some one deputed "by him for that purpose, or by the Secretary aforesaid, a standard "measure of length, under the penalty of the forfeiture of his license "or certificate, and shall, previously to proceeding in any survey, "verify by such standard the length of his chains and other instru- "ments for measuring."

The Revised Statutes of the Province of Quebec, Articles 4129 to 4134, enact as follows:—"Every land surveyor shall compare the "standard measure of length which he is bound to keep, with the "standard of English measure of length and the standard of French "measure of length, compared with and corrected by the standards "for such measures established in this province and supplied by the "Commissioner of Crown Lands.

"The standard of French measure of length as well as a pattern of "the English measure of length, which shall continue to serve as the "standard of measures for the purposes of this section, shall be deposit- "ed in the hands of the Secretary of the Board of Management of "Land Surveyors.

"The Secretary of the Board of Management of Land Surveyors "has the same power as the Commissioner of Crown Lands to examine, "test and stamp the standard measures of length submitted to him. "For each standard measure examined by him the Secretary has a "right to a fee of fifty cents.

"Every Land Surveyor duly admitted to the profession and practis- "ing in this province shall, under penalty of forfeiting his license or "certificate, procure and cause to be examined, corrected and stamped "or otherwise certified by the Commissioner of Crown Lands or some "one by him duly authorized, or by the Secretary of the Board of "Management of Land Surveyors, a standard measure of length.

"Every such Surveyor shall, previously to the proceeding on any "survey, verify by such standard the length of his chains and other "measuring instruments."

Your Committee desires to put out first that the citations made from the Dominion Act show clearly that it is illegal to make such measurements as are required in the major part of engineering practice with a measure not having the stamp of the Department of Inland Revenue, and second, that it is to be observed that there is a broad principle in constitutional law which requires, that in cases where there is concurrent jurisdiction between two courts, states or authorities, when the superior power acts, the inferior one looses its authority. The Dominion Act therefore overrides the Provincial Acts, and makes it penal not only for Engineers and others employing measures without the Dominion stamp but also for Surveyors provided only with Provincial Standards, and making measurements by reference thereto.

Your Committee is of the opinion that in order to obviate the difficulties now existing in obtaining standardized measures suitable for engineering work and to provide for the proper standardizing of measures, that certified standards of considerable length should be established at several points. It would point out that McGill College has an accurate fifty foot comparator well adapted for the standardizing of tapes and chains. There is also in the School of Practical Science, Toronto, a one hundred foot mural standard. The Department of Weights and Measures has already recognized one hundred foot standard of the character required, erected for the purposes of the Dominion Land Surveyors in Ottawa.

The Committee recommends, 1st, that such standards as are above named be, after due comparison with one of the Parliamentary standards, authorized and accepted by the Department of Weights and Measures as local standards, and that the Officer in charge of each standard in the several institutions in which they are placed be declared for the purpose of measuring and certifying steel tapes and bands, an Officer of the Department of Weights and Measures, and, 2nd, that Civil Engineers and Land Surveyors be required to provide themselves with steel tapes not less than fifty feet in length for the purpose of comparison with their working measures, such tapes to be standardized on one of the recognized comparators.

That the penalty clause at present existing in the Act should be abolished in respect to making it illegal to make measurements by any but stamped tapes, and requiring only that engineers and surveyors shall from time to time compare their working measures with the certified standards.

(Signed), M. J. Butler,
W. J. Sproule,
C. H. McLeod.

Mr. Hannaford

Mr. Hannaford said that he would move that the report be received and it be printed in the usual manner in the Society's proceedings.

Prof. McLeod said that there should be some communication with the Department of Weights and Measures with the object of having an amendment to the Act passed. The Committee had seen Mr. Miles, who had expressed himself as being entirely in favor of an amendment to the Act along the proposed lines. Prof. McLeod.

Mr. Sproule said that it was not the intention of the Committee to allow the report to lie there after it was received. Mr. Miles, the Assistant Commissioner, had admitted that it was ridiculous that such a condition should exist. Mr. Sproule agreed with the Commissioner, and that the only thing necessary was to have an amendment that should state the conditions. If this were not carried out the object for which the Committee was appointed would not be attained. He thought that somebody should be authorized to confer with the Department and have it amended. Mr. Sproule.

Mr. Boswell thought that it was a question that only affected land surveyors. He thought it should be left to the Council to deal with if necessary. Mr. Boswell.

Mr. Jennings thought that every member of the Society should have a copy of this report in order that they might study it thoroughly.

It was moved by Mr. Hannaford and seconded by Mr. Jennings and carried :—

"That the report be received and be referred to the Council for action."

The following report on the award of the Gzowski Medal Committee was read :—

MONTREAL, January 13th, 1897.

I beg to report that the Gzowski Medal Committee has awarded the Gzowski Medal for the year 1896 to Mr. E. A. Mohun, M. Can. Soc. C.E., for his paper on "The Sewerage of Victoria, B.C."

HENRY T. BOVEY,
Chairman of the Committee.

Mr. Rust drew attention to the fact that the Ontario Government permitted the Secretary of the Provincial Board of Health, who was a medical man, to pass judgment upon plans submitted to engineers on behalf of municipalities in the Province. He spoke about this because he was not himself engaged in private practice, but engineers who were felt this very keenly, and he had been requested to bring this matter before the Society. It did not seem fair to the engineers and to the Province, and he thought that representation should be made to the Ministers of the Ontario Government regarding the practice. Mr. Rust.

It was suggested that a committee of three, consisting of Messrs. Jennings, Rust and Galbraith, be appointed to consider the best method of proceedure and to report their decision.

The question of having an increase in the amount of real estate which the Society, by its Dominion Act, can hold, was mentioned, and it was decided that a clause covering future requirements should be inserted in the next bill.

The report of the Scrutineers on the election of the Nominating Committee was then read; and

The President announced the Nominating Committee for the ensuing year to be as follows:—

Province of Quebec.—G. H. Duggan, H. Irwin.

Province of Ontario.—A. Macdougall, J. Galbraith, W. T. Jennings.

Maritime Provinces.—P. S. Archibald.

North-West Provinces.—D. A. Stewart.

Outside of Canada.—J. M. Shanly.

The President then read the report of the Scrutineers on the election of Officers and Members of Council for the ensuing year. And declared the following to have been duly elected:—

PRESIDENT.

THOMAS C. KEEFER.

VICE-PRESIDENTS.

HENRY T. BOVEY, W. T. JENNINGS,
W. G. THOMPSON.

TREASURER.

KENNET W. BLACKWELL.

SECRETARY.

C. H. MCLEOD.

LIBRARIAN.

WILLIAM MCNAB.

COUNCIL.

ST. GEO. BOSWELL,	M. J. BUTLER,
GEORGE HERRICK DUGGAN,	H. IRWIN,
GRANVILLE C. CUNINGHAM,	E. H. KEATING,
CHARLES E. W. DODWELL,	W. J. SPROULE,
G. A. KEEFER,	M. MURPHY,
D. H. KEELEY,	H. PETERS,
D. MACPHERSON,	H. N. RUTTAN,

A. MACDOUGALL.

It was moved by Mr. Kennedy, seconded by Mr. Garden, that the thanks of the Society be accorded to the Scrutineers for their arduous duties, and that the ballot papers be destroyed.

Mr. Wallis then gave up the chair to Mr. Keefer, who, in accepting office, said he thanked the Society most sincerely for the honour done him. He would endeavour to do his duty as far as possible, considering his non-residence in the city, and he only trusted that he would succeed as well as his immediate predecessor. He could not possibly equal the ability and the energy which Mr. Wallis had devoted to the business of the Society during the past year. In looking over the ten years since the Society had been organized he thought he could congratulate the Society on its success and also on the prospects for the future. He saw no reason why they should not progress even better than in the ten years of their existence. Their profession differed, as had been pointed out by the late President of the British Institution of Civil Engineers, from other professions in that it makes the food which supports it; in other words, one public work produces another, and he thought we had an illustration of that in what we saw going on around us. He saw for the Mining Engineer, the Railway Engineer, the Hydraulic Engineer a better prospect of employment in these branches than there had ever been, and he certainly trusted that his impressions and hopes would be realized.

Mr. Herbert Wallis, the retiring President, read the following address :— Mr. Wallis.

PRESIDENT'S ADDRESS.

MR. PRESIDENT AND GENTLEMEN,—

Ten years ago the Canadian Society of Civil Engineers entered upon its existence. It was then that the germs which had been for a long time dormant emerged from their condition of embryo, and took material shape, fostered and guided under the parental care of Mr. Thomas C. Keefer, its first President.

If the success of the original conception was at any time problematical, the first six months in the congenial atmosphere of a new life removed the doubt, for during that time the infant Society gave such promise of vitality and endurance, as to claim recognition in the brotherhood of those other societies incorporated by the Dominion Legislature, from which body it received on June 23rd, 1887, a charter, constituting it "a body politic and corporate under the name of the Canadian Society of Civil Engineers."

And following upon this comes the recognition of Civil Engineering as a profession, and the admission of its members by the Legislature of the Province of Manitoba, the first of the provinces to act in this direction, to the enjoyment of privileges of close corporationship, such as are accorded the learned professions of Law and Medicine, a fitting tribute to the importance of Engineering and Mechanical Science and to the work of the Society during the first decade in its history.

And it seems to me appropriate, that you should have elected as President for the ensuing year the gentleman who, as it were, became the father of the Society, when he accepted office at its birth, and when he agreed to occupy the presidential chair during the first period of a possibly struggling infancy. Succeeding generations of engineers will think of Mr. Keefer as a Canadian Telford, and his first address will stand as a reference book in the historical annals of Engineering Science in this country.

It may be truly said, I think, that we are entering upon a year that marks an epoch, perhaps the most important that has yet been chronicled.

And now, gentlemen, it is a duty which I owe to you, as well as it is a privilege and a pleasure to myself, that I should observe the time-honoured custom of addressing you upon some subject of interest to the Society ere the close of this meeting, and on my retirement from the office of President, to which office a year ago you conferred upon me the great honour of election.

Presidential addresses have, in the past, not infrequently assumed the character of historical retrospect, and once in a decade at least it seems right they should do so, with the object of reviewing past progress, of registering steps in the march of improvement, of chronicling possibly well known but imperfectly collated facts, and of indelibly marking what otherwise might become mere "footprints on the sands of time."

The last address of this nature was read before the Society in 1889, and it is perhaps with a sense of relief, based upon the knowledge of my own shortcomings, and the belief that others are better able to undertake such a review, that I feel permitted to abstain from inflicting upon you that which under the circumstances might prove uninteresting and wearisome.

There are many subjects commonplace in themselves, whose very commonplaceness makes them interesting. Coal, for example, entering as it does so largely into our domestic economy, is a subject upon which few people are not willing, in some way, to express an opinion, and about this season of the year, when the mercury in our thermometers is ranging in the neighbourhood of zero, it becomes a matter of deep interest to most of us, whether that supply which was so carefully cellared during the summer is going to outlive our necessities, before inexorable laws require that it shall be again replenished.

It has occurred to me, that you might not be unwilling, in lieu of a general retrospect, to hear something about fuel in its various forms, of which coal is one, and especially in its relation to locomotive steam practice in Canada, where, owing to the extremes of atmospheric temperature and to climatic disturbance, the conditions under which it is used are perhaps dissimilar to those existing in most other countries.

Assuming, then, that this should be the case, I shall have to ask you to go with me while I retrace my steps, in reviewing the practice and past operations of the Grand Trunk Railway, that great Canadian artery, with which, as is known to many of you, I have been identified for a quarter of a century, and from which I have collected such data as I propose to bring before you to-day.

I do not claim that my conclusions have been reached as the invariable result of exhaustive experiment, or that my figures are beyond criticism. They are suggested rather as a contribution to practical literature upon a subject which has occupied in the past, and which will unavoidably continue to occupy, the minds of those engaged in solving the great problems arising from the frequent calls for cheaper and more rapid transportation, in connection with which this question of fuel through the energy derivable therefrom stands out as the prominent feature.

The fact that the coal bill alone in the accounts of our great Railways absorbs some 14 per cent. of the total expenditure is sufficient to constitute it, as it literally is, a burning question.

Years ago, when fire-boxes were made of copper and tubes of brass, when their repairs caused no anxiety in the minds of those engaged in their daily work of operating railways, and when their renewals did not constitute an important feature in the general expenditure, the forests of Canada supplied the staple fuel for locomotive consumption.

It is true that trains had to be stopped every forty miles or so, to have the tender loaded with a fresh supply, an operation which occupied ten or fifteen minutes; but these were halcyon days, when time was not so valuable, because competition was not so keen as it is to-day, and no inconvenience apparently resulted from the not infrequent arrival of passenger trains long after their schedule time.

It was only when the possibility of sharing in the distribution of the great produce of the West suggested an assimilation of the gauge of the Grand Trunk with that of the American lines, that it was seen how totally inadequate was cord wood to meet the requirements of a first class railway service.

Even then the substitution of coal had to be very gradually effected, on account of the expense attending the conversion of the locomotives. A wood-burning engine was *hors de combat* after a very short tussle with coal, and the renewals of fire-boxes and tubes were of such a costly nature, as to suggest oftener than not the substitution of an entirely new engine and the relegation of the old one to the "scrap" heap.

It is not therefore to be wondered at that cord wood outlived for many years the introduction and even the extensive use of coal, particularly upon branch lines, from the neighbourhood of which it could for many subsequent years be obtained cheaply, and also in other districts where competition was the least active, to the extent necessary to wear out those locomotives, which, while being still equal to service, were not worth the expense of conversion.

Fuel wood was purchased by the measure, in cords of 128 cubic feet, and was delivered under various contracts upon the railway "right of way" at the nearest points to the sources of supply. The piles were measured and removed by specially appointed and equipped trains to the wood sheds upon the line of railway, where the process of drying was supposed to be undergone.

For a variety of reasons, however, this process was rarely completed, and, as may be imagined, the fuel differed very widely in its calorific value. The system of acceptance by measurement took no account of the density of fibre or of the amount of moisture it contained, and although hard and seasoned wood commanded a higher price than the soft or greener article, there was no practical means of establishing an accurate or reasonably accurate standard of value as a check upon extravagance on the part of users.

For general statistical purposes, 3,712 lbs. was held to be the average weight of one cord of mixed and seasoned wood, and probably the figure was sufficiently reliable. In the year 1878 careful tests were made to determine the values relatively of the hard and soft woods which were delivered on the line of the Grand Trunk Railway in Eastern Canada. The former comprised chiefly hard maple and birch, and the latter covered those non-deciduous trees of which pine, spruce and hemlock are representative. The weight per cord of seasoned wood was about 4,000 lbs. for hard and 2,700 lbs. for soft. The result of the tests showed that one cord of the hard wood was fully equal in calorific value to one and a half cords of soft.

So far back as the year 1868, the Grand Trunk Company, with the object of checking the advancing price of cord wood, introduced peat as a competitor. This peat was cut from the bogs at Lapigeonnière and at St. Hubert, in this province, and after being partially cured and otherwise prepared was hauled as in the case of wood to the way station delivery sheds.

The difficulties in its use, anticipated at the outset, were such as applied to cord wood. The crude peat was not uniform in quality, it was liable to imperfect manufacture and to absorb an undue amount of moisture. It was, moreover, very unpopular, owing to the pain its use inflicted upon the eyes of the firemen, and its death knell was rung about the year 1875.

The last year's record, based upon issues of about 80,000 cords of mixed wood at 3,712 lbs. per cord, and of 8,000 tons of peat at 2,000 lbs. per ton, showed a consumption per engine mile of 95 lbs. of the former and 118¼ lbs. of the latter, the actual cost of peat per car mile being about 50 per cent. more than that of wood.

These figures were, however, the result of the daily working of the railway, and the conditions were not perhaps in all respects the same.

In 1876, I made very careful experiments to determine the relative values of the two fuels, upon representations having been made that a superior quality of compressed peat was in the market, which would eclipse anything that had been previously introduced, both as to its calorific value and its price.

The cost of the wood was $3.33 per cord of 4,031 lbs. delivered upon the tender, and that of the peat $1.71½ per ton of 2,240 lbs. similarly delivered, and the evaporative efficiency proved to be 3.09 lbs. and 2.33 lbs. respectively of water per lb. of fuel, while the quantity used per ton of train hauled one mile, excluding the engine and tender, was .263 lb. in the case of wood, and .362 lb. in that of peat, or an excess as against the latter of over 37 per cent.

It was during the autumn of 1873, when, after the gauge of the railway had been changed from Montreal westward, to conform to that of American lines, that the Grand Trunk Company contracted largely for bituminous coal.

During that year upwards of 150 engines, constructed for the purpose, replaced others of the wood-burning type, which were subsequently rebuilt or otherwise disposed of, and the number of coal-burning engines was largely augmented the following year, on the completion of the change which made the Grand Trunk a 4′ 8½″ or standard gauge railway throughout its entire length.

As a result, the influx of American traffic from the Western States to the seaboard, coupled with the increased capacity and fitness of the new engines, so greatly increased the mileage and added to the weight of the trains, that the superiority of coal and the insufficiency of cord wood as a steam generator could not be ignored, and the absolute retirement of the latter became merely a question of time.

During experiments made in 1876, a locomotive hauling a freight train of 340 tons consumed .263 lb. of hard dry maple, weighing something over 4,000 lbs. per cord, per unit of work (one ton one mile), as against .105 lb. of good Welsh steam coal, and the efficiency of the boiler under similar conditions was 3.09 lbs. and 7.94 lbs. of water evaporated per lb. of fuel respectively.

Similar experiments made at the same time with stationary boilers of locomotive type produced similar results, so that it may be broadly stated that one pound of good steam coal effectually burned will in practice yield an equal result with two and one-half pounds of hard dry maple, or that a ton of coal is equal to a cord and a quarter of seasoned hard wood by measure.

The best of soft woods did not yield by measure more than one half the duty of coal, one ton or 2,000 lbs. by weight producing equal results with two cords.

Meantime the gradual clearing of the country contiguous to the railways was making cord wood difficult to obtain, while competition and improved facilities in transportation were cheapening the price of coal. While therefore the issue of coal during the year 1871 amounted in all but to 200 tons, it had risen in 1875 to 140,000 tons, and in 1895 the quantity used exceeded 700,000 tons, and from the year 1884 cord wood ceased to be used except for lighting fires or to a limited extent for stationary purposes.

In the early history of the use of coal upon the Grand Trunk Railway, the supply was, for the most part, obtained by water delivery, either at Montreal from Cape Breton and Nova Scotia, with occasional cargoes from Great Britain, or at Toronto, Belleville or Brockville, by way of the lakes from the coal fields of Ohio and Pennsylvania.

Thus a large stock had to be provided during the season of navigation to meet winter requirements, which, by exposure to the atmosphere (for the quantity was too large to admit of it being piled under cover), lost much of its calorific value by decomposition and the gradual volatilization of the hydrocarbons. This loss was accentuated, in coals which contained sulphur, in a more than ordinary degree, to the extent that active combustion not infrequently followed upon or resulted from the heat generated on account of its presence.

The loss by breakage in loading and unloading the vessels, as well as the loss of interest on invested capital, furnished additional reasons for inducing the opening of all rail routes, and for making recent contracts on the basis of continuous daily delivery.

Coal from some seams, owing to a soft and friable nature, is specially liable to damage in the process of mining and subsequent handling, and quantities varying from 75 to 25 per cent., according to the nature of the coal, pass through the screens, in the form of dust and slack, which, if used in the fire-boxes, would escape through the tubes in a condition wholly or partially unconsumed, thus helping to swell the volume of smoke, which imperfect combustion the result of forced fires too often produces.

It has often become a question as to whether it is not desirable to forego the expense of screening, and to be satisfied with what is known as the "run of mines" supply.

The result of experiments made in 1887 with coal from three widely separated mines indicated a higher evaporative efficiency in favour of screened coal by as much as 7½ per cent. In these trials one car load from each mine was used as delivered under a "run of mine" contract, as against other cars from which the coal was handpicked.

The comparative freedom from smoke and dust seems to point to the desirability of screened coal for passenger train service, and in countries like Canada, whose importations are large, and where the import duty is alike for screened and unscreened coal, it is a question if the balance of advantage is not in favour of the former.

Pennsylvania anthracite, or what is usually known as hard coal, has not found favour in Canada as a locomotive coal, owing to its relatively higher first cost.

For passenger train service, it cannot be excelled, on account of its freedom from smoke and dirt, but it requires from 12 to 15 per cent. more by weight to equal the duty obtained from bituminous coal, and the greater wear and tear consequent upon its use shortens fire-box life from one to two fifths.

A very careful record made under the supervision of Mr. T. N. Ely, chief of motive power of the Pennsylvania Railroad Company, showed that during one month, the amount by weight of anthracite coal required to work the local trains leaving Broad street station, Philadelphia, exceeded by 11 per cent. that of bituminous coal required to perform the same work.

On the Reading Railroad, where the use of the Wooten boilers permits of a very large fire grate area, the evaporative efficiency of soft coal was superior by 15 per cent.

Patent fuel, a combination of coal dust and tar manufactured under pressure into "briquettes," while giving good evaporative results, has not, owing to the cost of production, been equal to successful competition with coal.

Petroleum by-products have been tried, and are successfully used in Russia. In Canada, the uncertainty as to cost, owing to limited area and extent of production, and the unavoidable risk which would attend operations on a scale of sufficient magnitude, constitute objections which are not likely to be overcome, so long as coal can be obtained at or about present prices.

On the Great Eastern Railway of England satisfactory results are reported from the residual product of the illuminating gas used in passenger coaches. On that railway the oil and coal are used together, and the ultimate cost of operating is about the same as for coal alone; but a use is thus found for a refuse commodity which otherwise would be difficult to dispose of.

To accomplish a given amount of work, petroleum occupies about one-half the space of coal, and this fact is no doubt a point towards a favourable consideration of its merit.

I will now call your attention to some of the influences which affect the consumption of fuel in locomotives.

Apart from the loss sustained through interruptions and obstructions by snow, there is a well defined condition of inverse ratio due to heat radiation from the boiler and cylinders on the one hand, and to the temperature of the feed water on the other, existing as between atmospheric temperature and fuel consumption.

Some interesting information as to relative summer and winter operations extending over a number of years will be found in the following figures:—

YEAR.	January.				February.				July.		August.	
	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.	Snow fall, Montreal, inches.	Snow plow miles run per mile of railway.	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.	Snow fall, Montreal, inches.	Snow plow miles per mile of railway.	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.	Coal used per car per mile, lbs.	Temperature of atmosphere, Montreal.
1882..	4.02	13	28	.69	3.74	19	23	.99	2.83	68	2.86	68
1883..	4.46	6	20	4.71	5.80	12	17	10.78	3.00	67	3 08	66
1884..	5.23	6	44	6.68	4.56	18	29	1.97	2.95	68	2.95	70
1885..	4.15	13	22	1.03	4.95	4	44	5.87	2.96	71	2.91	64
1886..	4.02	11	17	.82	4.06	11	10	2.38	2.92	70	2.96	68
1887..	4.63	5	50	10.17	4.50	12	34	6.98	2.99	75	3.12	66
1888..	4.76	2	34	5.63	4.41	13	30	2.15	3.15	70	3.32	65
1889..	4.14	9	41	.60	4.87	9	32	7.48	3.21	69	3.26	65

These figures are based upon the total car mileage of the Grand Trunk Railway. It is quite true that a possible variation in the rate of train speed or in the weight of the cars or their contents would interfere with a too close comparison as between one year and another. They are nevertheless quite reliable as illustrating my remarks. The figures show that over a series of eight consecutive years, the average weight of coal required to carry the freight traffic of the Grand Trunk Railway was 50 per cent. more per car per mile during the months of January and February than during those of July and August.

They also show that while January has been the colder month during the time referred to, the rate of coal consumption has been relatively higher in February owing no doubt to greater interference by snow during that month. If exception should be taken to the use of Montreal thermometric records, I will say that the traffic of the Grand Trunk Railway is chiefly derived from the West, and that the prevailing winds from that quarter seem to regulate the atmospheric temperature in something like an equal ratio throughout the section of country to which the statistics apply.

This will be seen from the records in degrees Far., also given, for the months of January and February, 1888 and 1889, at the five terminal points:

YEAR.	Detroit.		Buffalo.		Toronto.		Montreal.		Portland.	
	Jan.	Feb.	Jan.	Feb.	Jan.	Feb.	Jan.	Feb.	Jan.	Feb.
1888........	15	21	17	21	15	22	2	13	11	19
1889........	27	16	29	18	28	18	19	9	27	17

The following figures give the coal consumption per car per mile for each month during 1895 :—

1895.	Temperature of air, Far.	Cars per train.		Speed of trains in miles per hour.		Coal consumed in lbs. per car per mile.	
		Pass'r.	Freight.	Pass'r.	Freight.	Pass'r.	Freight.
Jan.....	14.9	4.7	17.5	21.1	11.9	13.19	4.95
Feb.....	14.2	4.5	17.4	19.3	10.5	13.85	5.08
March. .	22.1	4.6	18.6	21.5	12.2	12.25	4.41
April. ..	41.2	4.8	19.1	22.0	12.8	11.18	3.84
May....	58.3	4.8	19.3	22.2	12.9	10.51	3.53
June. ..	69.5	4.9	18.7	21.9	12.9	10.31	3.40
July. ..	67.2	5.2	18.2	21.7	12.8	10.20	3.47
August.	65.8	5.3	18.0	21.6	12.7	10.14	3.53
Sept....	60.3	5.4	18.8	21.8	12.8	10.16	3.57
October.	41.2	4.9	19.0	22.7	12.5	11.07	3.91
Nov.. ..	34.3	4.8	19.5	22.9	12.2	11.62	4.13
Dec.....	22.5	4.9	19.0	22.5	11.8	12.22	4.37

I have included the results of the passenger as well as of the freight train service, though the latter furnish the better guide, owing to the fact that freight trains are, as a rule, worked more closely to the capacity of the engines. The average rate of speed is also recorded, and the number of cars of which the trains were made up, so that these influences upon the rate of fuel consumption may be duly appreciated.

Unfortunately the weight of the trains is not obtainable, though it is likely the variation as between one month and another for a year would not be important.

The advantages accruing to railway companies, whose lines are removed from the rigour of our Northern latitudes, is made by these figures sufficiently apparent.

The influence of gradients and curvature may here be illustrated by reference to trials made some years ago on the main line of the Grand Trunk Railway between Sarnia, a town situated on the river St. Clair, and Portland, Maine, the distance being 798 miles. This mileage was divided into nine locomotive divisions, of which the shortest was 58 and the longest 125 miles in length.

A locomotive having cylinders 17 inches diameter and 24 inches long, with four coupled driving wheels of 62 inches diameter over the tires, made the run over the entire distance, completing the work of one division each day, with a freight train of a weight corresponding to its capacity. The fuel was of the same quality, and was accurately weighed, and the trials took place at a time of year and time of day when the variation of atmospheric conditions was inconsiderable.

The intention was to compare the cost of working upon the various divisions, and no effort was spared to ensure accuracy in the result.

The following table gives the particulars :—

DIVISION WEST TO EAST.	Miles apart.	Difference in altitude of terminals, feet.	Lift between terminals, feet.		Cars per train.		Tons per train.		Coal in lbs. per mile.				
									Per Train.		Per Ton.		
			East.	West.	East.	West.	East.	West.	East.	West.	East.	West.	Average.
Sarnia & Stratford...	80	57	615	...	21	35	494	346	57.75	34.39	.1169	.0993	.1081
Stratford & Toronto ..	88	937	...	994	21	32	494	346	36.20	59.16	.0733	.1708	.1221
Toronto & Belleville..	113	59	305	275	19	35	448	315	48.07	42.57	.1076	.1352	.1214
Belleville & Brockville	95	5	100	110	21	35	489	345	44.20	43.52	.0904	.1262	.1083
Brockville & Montreal	125	230	...	300	27	45	617	345	45.24	46.76	.0751	.1050	.0900
Montreal & Richmond.	76½	345	565	225	23	35	541	344	56.62	36.86	.1106	.1160	.1133
Richm'd & Island Pond	71	796	989	...	19	35	446	344	63.77	28.25	.1431	.0822	.1126
Island Pond & Gorham	58	389	...	389	24	35	563	344	41.56	50.22	.0738	.1461	.1099
Gorham & Portland...	91½	787	...	787	24	35	563	344	34.70	49.45	.0616	.1526	.1071

The cars were loaded going eastward and empty westward, in consonance with the general direction of traffic. It will be noticed that the consumption of fuel per ton per mile is fairly proportional to the lift in feet. In cases where this rule does not obtain, excessive curvature, the assistance of a pilot engine, or a longer run between stations, reducing the percentage of coal used in firing up, may be said to account for the difference.

The variation in the rate of consumption is from 1 to 2.3 in connection with eastbound, and 1 to 1·85 with westbound trains.

In August, 1882, arrangements were made under which the Grand Trunk and Great Western Railways were cemented into one system under Grand Trunk management.

Each Company owned a line from the West to the Niagara frontier, and also to Toronto.

Owing to representations made by myself, it was decided to make use of the Great Western line, which with its lower gradients runs nearer to the level of the lakes, for eastbound "through" freight traffic, and to convey the westbound business, consisting largely of empty or return cars, by way of the main line of the Grand Trunk, which rises, in the neighbourhood of Stratford, to an elevation of 1000 feet.

Thus the partial effect of a double line of railway was secured, and the easiest gradients were made use of for the heaviest trains.

The new, or what has been since called "circular" system went into operation September, 1883, and the first three months gave the following results :—

	October 1st to December 31st.			
	Western Division.		Central Division.	
	1883.	1882.	1883.	1882.
Coal tons....................	18,365	20,669	33,878	32,484
Train miles..................	505,821	550,170	794,608	827,037
Car "	10,432,390	10,315,884	19,466,668	19,747,683
Cars per train..............	20.6	18.7	24.5	23.9
Coal, lbs., per train mile....	72.61	75.14	85.27	78.56
" " " car "	3.52	4.01	3.48	3.29

The two divisions, viz., the Western and Central, met at Toronto, and the figures show how the former working under the "circular" system compared with itself when under the old system, and with the Central division upon which the system remained the same.

It will be seen that while the coal requirements per car per mile increased on the Central division, due to various causes applicable to both, by six per cent., they decreased on the Western division by twelve per cent., thus effecting a saving of over 2,500 tons, and a very much larger saving, if it is, as it reasonably may be, assumed that the then prevailing conditions would have warranted the rate of increase which obtained upon the Central division.

It is an interesting fact that while the empty engine mileage westward advanced by 37 per cent. on the Central, the advance was 18 per cent. on the Western division, showing the advantage of a better balancing of traffic under the "circular" system.

The desirability of low grade railways is of course understood, but a greater regard for the cost of operation, especially in the matter of fuel, would often prevent the construction of lines of railway which are destined from their inception to be unprofitable ventures.

It may be safely asserted that the great increase which has taken place within comparatively recent years in the haulage power of locomotives has reduced the rate of coal consumption per unit of work (one ton one mile).

The train mile, that most unreliable standard of work measurement, has in the past unquestionably been the means of encouraging the use of small engines, and thus of interfering with economical operation.

It may, however, be doubted whether improved service in the form of more roomy coaches, frequent trains and more rapid transport induced by keener competition has not more than absorbed the savings which might otherwise have been effected.

The old 40 feet coach has expanded into the 55 feet car of to-day, with its wash and smoking rooms and other conveniences not thought of 25 years ago, so that its weight has been added to, without material or proportionate increase of carrying capacity.

The calls upon the locomotive boiler for steam to warm the cars, to apply the brakes, to ring the bell and to signal the train could only be effectually responded to by a more frequent resort to the coal bin, and these calls must of necessity be intensified with an increase in the rate of train speed.

To reduce the drain upon the boiler, the compound engine has without doubt been effective, and the use of steam pressure as high as 200 lbs. per square inch, a natural outcome of the compound principle for single expansion engines, has been productive of economy. Additional attempts have been made, with more or less success, to utilise exhaust steam to raise the temperature of the feed water; more attention has been paid to the boiler clothing and to the graduation of the valve "cut off," and slower and more perfect combustion has resulted from the abandonment of double exhaust nozzles and from the use of the extended smoke-box and improved arrangement of the netting and diaphragm plates forming that necessary evil, the spark arrester.

Material benefit has been derived from the duplication of main lines in crowded thoroughfares, from the correction of grades, and from the greater stability and more perfect alignment of the permanent way.

More care has also been exercised in design, and specially in regard to the better relative proportions as between tractive force and adhesion, the engines of years ago being very deficient in weight for the capacity of their cylinders.

An interesting comparison may be made as between the years 1875 and 1895, if applied to the Central division of the Grand Trunk Railway for the last six months of each year.

During both periods the fuel consisted of soft coal, but during 1875 the locomotives were practically all of one type, having cylinders 17″ x 24″ and working with from 135 to 140 lbs. boiler pressure. In

1895 the passenger engines had 18″ x 24″ cylinders, the steam pressure was from 160 to 180 lbs. per square inch, and the freight engines working at the same steam pressure had 18″ x 26″ cylinders. The Central division covered 333 miles of railway between Montreal and Toronto, and the train mileage over it exceeded two millions during the six months.

The figures are here given :—

SIX MONTHS ENDED	Passenger trains.			Freight and mixed trains.				
	Cars per train.	Lbs. of coal per		Cars per train.	Lbs. of coal per			Tonnage per train excluding engine and tender.
		Car mile.	Train mile.		Ton mile.	Car mile.	Train mile.	
Dec. 31st, 1875.	7.4	6.39	47.57	21.9	.18	2.83	61.87	340
do 1895	5.9	10.57	62.13	25.1	.16	3.37	84.62	517

Turning to the working time tables for this division, I find the schedule rate of speed in the earlier period to have averaged 24 miles per hour for passenger trains, while the average during the latter period was 30 miles per hour, being an advance of 25 per cent. The passenger trains though composed of fewer cars did not, though this cannot be actually demonstrated, show a material decrease of weight. As a matter of fact, the larger engines were needed to meet the requirements of faster service, and to secure the comforts and safe-guards, which during the intervening period railway companies were called upon to provide.

As regards freight trains, the average weight has been estimated, on the basis of 10 tons in 1875 and 12 tons in 1895 per empty car, which together with the actual weight of the contents, and exclusive of the engine and tender, make up the train tonnage, which, it will be noted, has increased in the latter period by 50 per cent., a circumstance to which must be attributed the improvement recorded in the rate of fuel consumption per ton per mile.

Freight trains were not scheduled in the time tables during the years under consideration, and the average rate of speed cannot therefore be drawn from that source; but dating from the year 1886, very accurate records of averages were kept, and these show that the rate of speed in 1895 exceeded that of 1886 by eleven per cent.

It is a fact, however, that the calls upon freight engines for what may be called extra work have not been so numerous or exacting as upon those engaged in working passenger trains, and it is also true that the former have benefited to a greater extent by the reduction in delays or train detentions, consequent upon the establishment upon this Central division of a practically double track railway.

"The greater the tonnage per train the greater the gain" ought to be a good maxim to adopt in dealing with freight traffic, especially with the traffic of those railways which are called in the United States and Canada the "Trunk lines," and of which the Grand Trunk is an example.

Such a maxim suggests easy gradients and curves, allied with a road-bed and structures of sufficient stability for rolling stock of the maximum carrying capacity, and the observance of such a maxim would yield a profitable return out of all proportion to the necessary increase in dead weight of train, while a reduction would follow in the rate of those operating expenses of which the cost of rolling stock maintenance partially and wages almost wholly may be considered as proportional to the number of trains rather than to the tonnage per train.

The consideration of my subject from this standpoint suggests a reference to the compound principle as applied to locomotive engines.

In the autumn of 1895 the Grand Trunk Company completed, in their work-shops at Montreal, the construction of two locomotives, of which the first, being No. 567, had a pair of cylinders 18 inches diameter, with a piston stroke of 26 inches, its weight in working order being 100,212 lbs. and which was worked single expansion at a boiler pressure of 190 lbs. per square inch; and the other No. 326 being of the compound type, having a high pressure cylinder of 19 inches and a low pressure of 29 inches diameter, with a piston stroke also of 26 inches, and carrying a steam pressure of 190 lbs. per square inch. This engine weighed 118,412 lbs. Both engines had three pairs of coupled driving wheels of 62 inches diameter outside the tires, and virtually were of the same design.

These engines were placed on that section of the Central division which extends from Montreal to Brockville, 126 miles in length, and for a number of trips the results were accurately kept in order to determine the relative fuel consumption.

A distinction has been made in the table of figures which is submitted, as between the west and east bound trips, because the trains composing the former consisted of mixed empty and loaded cars, whereas the east-bound cars were all loaded, also because the gradients are in favour of east-bound trains.

The coal used on the trips from Brockville was from the Punxsutawny mines, Pennsylvania, and at Montreal it was supplied by the Dominion Coal Company from their Gowrie mine, Cape Breton.

Great care was taken to prevent loss of water or steam at the safety valves, from the injectors, or by priming, so as to ensure as far as was possible accurate comparative results.

The trials were made during the months of September and October.

	Single Expansion.			Compound.	
	394	567		326	
	East.	East.	West.	East.	West.
Train miles........	2,000	630	504	756	630
Car "	54,000	33,516	21,042	38,556	26,149
Ton "	1,186,289	875,649	418,792	1,007,914	556,787
Cars per train.....	27	52.2	41.75	51	41.5
Tons " " ex engine and tender..	593	1374.7	830.9	1333.2	883.8
Weight of loaded car, tons........	22	25.8	19.9	26.1	21.5
Coal used, lbs......	107,555	71,035	57,280	53,220	48,085
Coal used per train mile, lbs........	53.78	112.8	113.6	70.4	76.3
Coal used per car mile, lbs........	2.00	2.12	2.72	1.38	1.84
Coal used per ton mile, lbs.........	.091	.081	.137	.052	.086
Coal used per sq. foot of grate per train mile.	3.36	6.18	6.22	3.88	4.19
Water evaporated. lbs........	792,253	394,842	301,292	353,976	309,556
Water evaporated per train mile,lbs.	396	627	598	468	491
Water evaporated per ton mile, lbs.	.668	.451	.719	.351	.556
Water evaporated per lb. of coal,lbs.	7.37	5.56	5.26	6.65	6.44
Water evaporated per lb. of coal from and at 212°......	8.81	6.78	6.31	7.98	7.73
Temperature of air Far.............	69.2	53.6	53.4	66.5	72.6
Temperature of feed water............	62.73	48.6	48.8	69.1	68.6
Boiler pressure, lbs. per sq. inch......	122.6	174	171	175	177

	Single Expansion.			Compound.	
	394	567		326	
	East.	East.	West.	East.	West.
Rate of speed, miles per hour........	19.6	19.2	19.4	21.	21.3
Engine in steam per 100 miles, hours, minutes	10.5	8.0	7.4	7.3	7.3
Stoppages per 100 miles...........	12.9	7.9	8.5	7.6	7.8
Ashes and clinker.	12,580	3600	3275	3520	3235
Per cent. of coal....	11.7	5.07	5.72	6.61	6.72
Fire grate surface, sq. feet..........	16	18.25	18.25	18.25	18.25
Heating surface, sq. feet......	1099.6	1122	1122	1122	1122
Weight of engine in working order, lbs.	70,000	100,212	100,212	118,412	118,412

For additional comparison I have added another column containing particulars of a trial made in the autumn of 1882 with No. 394, one of the old type of freight engines having cylinders 17″ x 24″, and two pairs of coupled driving wheels also 62 inches diameter over the tires. The initial boiler pressure in this engine was 140 lbs. per square inch, and the train mileage was wholly in the easterly direction, viz., from Brockville to Montreal.

Comparing the results of the single expansion types, it will be seen that the larger engine consumed less fuel per ton of train per mile by 11 per cent., notwithstanding the inferior evaporative efficiency of its boiler, due to the disproportionate area of fire grate (unavoidable in this type of engine), and in spite of the loss of power due to the extreme length of train.

Extending the comparison to the compound engine in the same direction of travel, it will be seen that with a somewhat similar train length and tonnage, the gain, expressed as in the previous case, per unit of work over the larger of the two single expansion engines was 35¾ per cent., and over the smaller, of 42¾ per cent., and in respect of westbound trains, the comparison as between the single and compound engines of the same capacity closely approximates to these figures, the difference in favour of the latter being 37¼ per cent.

A very interesting and instructive feature in these figures is that which shows that a locomotive boiler is not, as ordinarily arranged, capable of economically supplying sufficient steam under the extreme conditions which obtain on this continent, or perhaps I should say in this country and in the United States.

Train tonnage has increased without, as a rule, a corresponding increase of boiler capacity, and fire grate area and heating surface are generally altogether inadequate to economically fulfill the conditions now imposed upon them.

Especially is this the case with the fire grate area, as will be seen by reference to the figures of coal consumption per square foot, per train mile, and those of water evaporated from and at 212° per lb. of coal consumed.

It will be seen that the firing of engine 567 was forced to an extent that reduced the evaporative efficiency of its boiler, and although, owing to its heavier train, the engine was able to show a lower rate of fuel consumption than No. 394, the rate was greatly in excess of No. 326, which, on account of the second expansion in the larger cylinder, required less fuel, and was thus able with the same grate area to shew a higher comparative efficiency.

In running engines 567 and 326 without trains over the same division, it was found that the boiler of the former evaporated from and at 212 deg., 10.09, and of the latter 9.24 lbs. of water per ton of coal.

The following figures show the effect of train tonnage upon the consumption of coal per ton per mile, and the effect of the quantity of coal burned per square foot of fire grate, per hour and per mile upon the evaporate efficiency of the boiler.

In these figures, the engines and tenders are included in the total train tonnage.

Engine No.	Direction of train.	Size of cylinders, inches.	Tonnage of train.	Coal (lbs.) consumed per Ton mile.	Coal (lbs.) consumed per Sq. foot of grate area per Hour.	Coal (lbs.) consumed per Sq. foot of grate area per Train mile.	Lbs. water evaporated per lb. coal from and at 212°.	Remarks.
567	East.	18 x 26	90	.231	27.7	1.14	10.09	Engine only.
326	"	19 / 29 x 26	100	.240	36.8	1.31	9.24	do.
394	"	17 x 24	666	.081	65.8	3.36	8.81	
326	"	19 / 29 x 26	1433	.049	81.5	3.88	7.98	
326	West.	19 / 29 x 26	984	.077	89.3	4.19	7.73	
567	East.	18 x 26	1465	.076	118.6	6.18	6.78	
567	West.	18 x 26	920	.125	120.7	6.22	6.31	

In boilers of more recent construction for burning soft coal, the much desired increase of grate area has been obtained by raising the level above that of the frames, thus securing greater width and allowing of an extension over the rear drawing axle. Such an arrangement adds materially to the weight of the engine, but the grate area can be doubled.

It is fairly well established, that a well designed locomotive on the compound principle will effect a saving in steam, under equal conditions, of 20 per cent., and thus it would seem that further economy in coal consumption lies for the present in that, rather than in the direction of abnormal increase in the weight of engines, which now sufficiently tax the endurance of existing roadbed and structures.

And in closing, gentlemen, it remains for me to thank you, and I take this opportunity of thanking you again for the honour conferred upon me in my election to the presidential chair, and for your confidence during my year of office.

That the year 1896 has not been without its peculiar anxieties and responsibilities, you will all probably understand, but the ready and cordial co-operation of the Council has made these comparatively light.

To these gentlemen and to the office-bearers I tender my best thanks. I need scarcely say that though my responsibilities will be lighter, my interest in the Society's welfare will not abate, and I venture to hope and to believe that this new year upon which we have entered will be a happy and prosperous one for the Society as a body, as I wish it may be for each of you individually.

Mr. Jennings. Mr. Jennings said it had fallen to him to ask the Society to join with him in a vote of thanks to the retiring President, Mr. Wallis. He was sure that all appreciated very highly his care and attention to the business of the Society. They all wish to thank him for the admirable paper which he has just read on "The Consumption of Fuel in Canadian Locomotive Steam Practice." The address was highly interesting, and would be of great value when embodied in the Society's Transactions.

The motion was seconded by Mr. G. H. Duggan and was carried unanimously.

Mr. Wallis. Mr. Wallis said he was much obliged for the vote of thanks. He was sure it had given him much pleasure in doing what he could to advance the interests of the Society. If he had carried out its wishes he could ask nothing further.

It was moved by Mr. St. Geo. Boswell, seconded by Mr. A. Rhodes, and carried :—

"That the best thanks of the Society are due and are hereby tendered to Mr. Blackwell for his duties as Treasurer during the past year."

It was moved by Mr. C. H. Rust, seconded by Mr. C. H. Keefer, and carried :—

"That a cordial vote of thanks be tendered to Prof. McLeod for his valuable and untiring efforts as Secretary during the past year."

It was moved by Mr. D. MacPherson, seconded by Mr. E. H. Drury, and resolved :—

"That the hearty thanks of the Society are due and are hereby tendered to the Librarian, Mr. McNab, for his zealous and very effective services during the past year."

It was moved by Mr. J. M. McCarthy, seconded by Mr. W. G. Warner, and carried :—

"That a vote of thanks be tendered to the Lachine Rapids Hydraulic and Land Co., and to Messrs. Davis & Sons, contractors, for the hospitality and kindness shown by them to the Members of the Society, and that the Secretary be instructed to convey to them the thanks of the Society."

It was moved by Mr. C. H. Keefer, seconded by Mr. W. T. Jennings, and resolved :—

"That the thanks of the Society be tendered to the Canadian Pacific Railway, the Grand Trunk Railway System and to the Intercolonial Railway, for their courtesy in granting the Members attending the meeting a special reduction in fare."

It was moved by Mr. Wallis, seconded by Prof. McLeod and resolved :—

"That the thanks of the Society be tendered to the President and Council of the Art Association of Montreal, for the privileges of attending the Gallery during the week of the Annual Meeting."

It was moved by Professor H. T. Bovey, seconded by Mr. Herbert Wallis, and carried :—

"That it is in the interests of the Society that the Council when issuing any amendment or amendments to the By-Laws should express its approval or disapproval of the same."

It was moved by Mr. John Kennedy, seconded by Mr. H. Irwin, and carried :—

"That in order to comply with the Manitoba Act the meeting make the election of Officers for the parent Society hold good for the Manitoba Society, the three groups be decided by greatest number of votes, the five who have the greatest number to act for three years."

The meeting was then adjourned.

Thursday, 28th January.

PROF. H. T. BOVEY, Vice-President, in the chair.

The following report of the Committee on Abstracts was read by Prof. J. T. Nicolson, Chairman of the Committee:—

"Your Committee on Abstracts appointed at the last ordinary meeting beg to report as follows:—To the original Committee consisting of J. T. Nicolson, Chairman, C. B. Smith, J. G. Kerry, G. H. Duggan, D. MacPherson, J. A. Douglas, Mr. Vautelet was added. Owing to the temporary retirement of Mr. Duggan the Committee suggests the addition of Mr. Irwin.

Two meetings have been held: at the first the available Literature for abstracting was distributed amongst the Members of the Committee; at the second the method of abstracting and of presentation were determined on. It was considered that any opinion or criticism by the abstractor, however valuable or desirable, ought to be carefully distinguished from the context of the abstract, *e.g.*, by enclosure within square brackets. It was also decided that discussion on papers extracted should also be extracted where valuable.

The Committee advise that should valuable discussions arise at the meetings out of the Abstracts presented, the publications of such discussions in our Transactions should take the form of topical discussions without special reference being made to the Abstract in connection with which such discussion is commenced.

It is the hope of the Committee that the presentation of these Abstracts at the meetings will, by affording information on at least one or two subjects of interests to every member present, attract larger meetings of the Society, thereby encouraging the preparation of original contributions besides largely extending the value of the Society's Transactions, especially to non-resident members."

(Signed), J. T. NICOLSON,
Chairman.

ABSTRACTS.

WATER-POWER—ITS GENERATION AND TRANSMISSION.

By Samuel Webber, Charlestown, N.H.

(Trans. Am. Soc. Mech. Eng., Vol. XVII., p. 41.)

The author arrives at the conclusion that it is practically possible to store and secure for power about one-third of the total annual rainfall. This rainfall he reckons at 42 inches as a fair average for the larger part of the United States east of Kansas and Nebraska, amounting therefore to about 3 cubic feet per second per square mile of catchment area. One-third of this or 1 cubic foot per second per square mile of drainage surface is therefore the supply which can usually, by the aid of storage, be relied upon.

A sketch of the evolution of the modern turbine is then given, the credit of inventing the inward and downward combined flow turbine, which is the exemplar of all modern American turbines, being given to A. M. Swain, a mechanic who had been employed at the Lowell machine shops in the construction of the Boyden and Francis wheels. The result of this change from the Founeyvon type is to produce turbines of equal power in one-half the space and at one fifth the cost.

The first cost of turbine installations is discussed and itemised for several plants, and is shown to vary from $50 to $100 per horse power. The cost of water-power per horse power per annum is estimated in three instances, at $8.64, $10.00 and $11.05; and is stated to be generally covered by the figure $15.00 per annum per horse power.

In the discussion the credit for putting in the first pair of turbines coupled together on a horizontal axis is given to Emile Geyelin of Philadelphia.

J. T. N.

D

WATER POWER OF CARATUNK FALLS, KENNEBEC RIVER, MAINE.

By Samuel McElroy, New York City.

(Am. Soc. Mech. Eng., Vol. XVII., 1896, p. 58.)

The river basin is of about 5,917 square miles area, of which 3,800 square miles are forest, and 450 square miles are lakes and ponds, 311 in number. (Moosehead Lake alone has an area of 120 square miles.) Mean summer temperature 61° F. to 67° F., winter do. 19° F. With a large snow fall the thaw of the lower layers maintains the winter stream flow ; and in spring the dangerous freshets of milder climates are delayed until the ice is, as a rule, brittle.

The Caratunk falls have large natural pondage above and below the falls, whose cascade has a natural fall of 28 ft.

Annual rainfall 44.5 inches (1839 to 1888), maximum 54".6 (1887), minimum 33".7 (1860).

There was no time to make a continuous gauge of the river ; but from experience on this and other rivers a safe present plant outlay for 5,000 horse power was determined upon.

The lowest permissible flow is discussed for various rivers, special reference being made to the lessons to be learnt from the Lowell and Lawrence water powers. The rainfall for 50 years of the Kennebec basin is analysed, and the conclusion is arrived at that the fall is good now for 5,000 horse power, as above, and has a great prospective value as the timber supply diminishes, and allows the Moosehead Lake, now impounded for logging purposes, to become available for maintaining an equable flow in the summer.

The cost of dam, flume, head gates, wheel pit, etc., was in this case $15 per horse power for the 3,500 H. P. actually provided on the west side ; cost of wheels for 3,000 H. P. about $9, or $24 in all. The fixed charges on this the author reckons at $5.24 per H. P. per annum.

For comparison the cost of a 3,000 horse power steam plant in this pulp-mill (where no exhaust steam is used for other purposes) is calculated, and found to be $52.17 per H. P. per annum. (Coal $6.00 per ton.)

Reference is made to the commercial value of a water power ; that at Lowell with a 4,085 square mile basin being valued at $2,787,200 ; and at Lawrence with an area of 4,553 square miles at $2,866,720.

Hundreds of feet of floating light wood frames are used in Maine in the races above the mills to promote ice formation, and prevent the production of anchor ice. At Caratunk the reach above the dam freezes for two miles up stream, with blue ice 24 inches thick, which effectually prevents the anchor ice from getting to the falls.

Mr. W. S. Aldrich discusses curves of combined turbine and dynamo efficiency for various loads.

J. T. N.

THE TRANSVERSE STRENGTH OF BEAMS AS A DIRECT FUNCTION OF THE TENSILE AND COMPRESSIVE STRESSES OF THE MATERIAL.

By M. Lewinson.

(Proc. Am. Soc. C.E., Vol. XXII., 1896.)

The writer first states the law usually supposed to hold true :—that the neutral axis is the centre of gravity of the section, and that the maximum fibre stress, in unsymmetrical sections, is at those extreme fibres more distant from the neutral axis, disregarding the relative strength of the material in tension and compression ; or that in a beam of symmetrical section the failure will take place on the side of the weaker fibres.

The writer criticises the law, claims that it is not upheld by experiments, and propounds another law, which he claims accords with facts.

The fundamental principle which the writer lays down is, that under transverse breaking the upper and lower fibres are strained to their maximum resistances in direct tension and compression, *i.e.*, the neutral axis shifts closer to that side capable of bearing the greater strain, and that the opposite strains are not in proportion to their distances from the neutral axis, but are in the limit proportional to the tensile and compressive breaking strength of the material (example) denoting the maximum compressive stress C,

and " " tensile " T.

Then the turning couple is

$$(\tfrac{2}{3}\,h) \times (\tfrac{1}{2}\,C\,a.\,x.) = (\tfrac{2}{3}\,h) \times (\tfrac{1}{2}\,T\,a\,(h-x)\,)$$

and $\therefore$ solving $x = \dfrac{T}{C+T}\,h$

for rectangular beams

(*e.g.*) Cast iron $C = 100000$ $T = 20000$

$$\therefore x = \tfrac{20}{100} h = \tfrac{1}{5} h$$

Yellow pine $C = 14000$ $T = 7000$

$$\therefore x = \tfrac{2}{3} h, \text{ etc.}$$

again substituting in bending moment equation,

$$W = \tfrac{1}{3} C. a. x. h. = \tfrac{1}{3} \frac{C\ T}{C+T} a h^2$$

from which the transverse strength of a beam can be deduced before testing by substituting values of T and C known from previous experiments or general averages of the given class of material.

The writer then takes up the more complicated questions of the same law as applied to beams of triangular and Tee shapes, of cast iron, where T and C are widely divergent, and proves, by 18 experiments in groups of 3 each, that his formulæ are close to facts.

The writer claims in conclusion that this theory will give a clearer conception of the stresses acting in a beam under strain, and will aid in selecting more suitable cross sections and material.

[Experiment on strength of C. I. grate bar of Tee section at McGill Laboratories confirms this law. By old theory, tensile strain was 33,000 lbs. per sq. in., and compressive 20,800 lbs. per sq. in. at failure, while by this theory, tensile strain = 22,030 lbs. per sq. inch, and compressive strain = 102,050 lbs. per sq. inch.]

C. B. S.

THE UNDERPINNING OF HEAVY BUILDINGS.

By Jules Brenchaud.

(Proc. Am. Soc. C.E, Vol. XXII., Dec., 1896.)

The writer refers to the great difficulties experienced in preventing injury, by settlement of heavy buildings, when it is necessary to excavate and build on the immediate adjacent building site.

The specific case treated is of a building which was to be carried 30 feet (2 stories) below the street level, over ½ of which had to be made water-tight as it was below water level. The total depth of foundation being 45 to 50 feet below the sidewalk, these foundations consisted of close fitting rectangular pneumatic caissons all around the exterior of the new building site and cylindrical intermediate ones for columns.

As every square foot of the property had to be built upon, the problem was to pin the adjacent buildings up during caisson sinking and construction periods. This was accomplished by placing vertical cylindrical iron columns in slits in the walls, extending from the foundation upwards. These were founded at the bottom on rock or very hard hard-pan, and at their tops the bearings were spread out by transverse horizontal slits in the walls, in which were placed nests of I beams on top of the columns.

The cylindrical columns were 10" to 30" in diar., the smaller ones being forced down by a 60 ton hydraulic jack, in sections 5 feet long at a time, to proper bearing; some also were partially sunk by water jet. The larger ones under the heavier building were sunk by compressed air, as the water jet or jack would neither force them through a layer of hard pan to the rock.

The larger columns were first made of cast iron, but after one becoming injured by forcing past a boulder, the rest were made of rivetted steel sections.

These columns were filled, after sinking, with Portland cement concrete.

The writer then details several similar cases where the application has been successful, and concludes by stating that while this method is not (evidently) of universal application, it will be found the best means of transferring the load of an adjacent building to a lower foundation with a minimum of obstruction to the building site about to be used, also that as these underpinnings are left in place, there is no danger of that slight subsidence which takes place when other kinds of temporary underpinning are removed.

[This method is evidently expensive, and only applicable when the bearing soil is poor, *e.g.*, quicksand, and the necessity imperative. When necessary, it would appear to be a very admirable one.]

C. B. S.

METHODS AND RESULTS OF STADIA SURVEYING.

F. B. Maltby.

(*Journal Assn. of Eng. Societies*, Sept., 1896.)

For good results from stadia surveying, both good workmanship and good equipment are necessary. The writer recommends for use a transit-theodolite having the same graduation on vertical and horizontal circles (preferably reading to 20"), with a telescope magnifying to not less than 30 diameters. Field of the telescope to be flat and as large as possible. Vernier of the vertical circle to be swung from the horizontal axis of the instrument, and to be provided with a good level, to keep its zero in position independent of the plate levels. Such instruments are not at present in common use. Rods to be of well seasoned white pine 5 inches wide, 12 feet long, and $\frac{5}{8}$ inch thick, shod with strap iron at each end, straps having hole in them to place over station nail. Rod to be well pointed, graduated symmetrically, and preferably after the pattern used by the Mississippi River Commission. The length of the rod divisions may be determined by trial so as to correspond with the wire interval of the instrument, or may be laid off to some standard of length. The last is perhaps preferable, as the average stadia constant can be determined with great accuracy by running over long lines under all conditions of weather and exposure, the exact length of such lines being previously determined by triangulation. Value of the stadia constant varies in practice according to description of work to be done; usually it is from 100 to 125. With such constant the graduations on the rod should be metres or yards and tenths rather than feet, $3\frac{1}{2}$ to 4 inches being the minimum graduation spot desirable in ordinary practice.

Party should consist of topographer, recorder, and as many rodmen and axemen as circumstances call for. Topographer can average 500 points observed in a day, and it is true economy to work the topographer and recorder up to their full capacity by supplying them with all the rodmen and axemen that they can keep busy. Topographical surveying is to define general features rather than precise points as land monuments, and care should be taken that the area covered should be taken in equal detail in all parts. To secure this, the writer advises the use of a small plotting board about 15″ x 20″, upon which a continuous plotting of the stations can be carried on to small scale as they are occupied, and the fact that all the area has been fully covered can be graphically demonstrated. The sheets are made to overlap in the usual manner, and are of great assistance in the final plotting. For reducing the observations, the Colby slide rule is recommended, and three reductions per minute are instanced as easily possible with this apparatus.

The line of occupied stations is plotted by lat. and dep., or by distances and bearings from a printed circle on the paper. The latter is quicker but not so accurate as the former. For plotting the intermediate and side readings the Colby protractor is particularly recommended. About $3\frac{1}{2}$ points plotted per minute is given as average work for two men.

Statements of the final errors of many stadia run lines are given, and the writer's opinion is given that a discrepancy of not more than 1 in 1,500 can be obtained in average work, and that this is considerably more accurate than ordinary chaining. Levels when the instrument is equipped with a level on the vernier arm of the vertical circle can be carried for all distances with 0.50 feet.

The cost of surveys made by stadia varies very greatly, and a few examples are given :—

City of Baltimore topographical work (including buildings, streets, alleys), etc., $1.50 per acre, 200 ft. to 1 in. City of St. Louis topography 73 cents per acre, 200 ft. to 1 in. Mississippi River Commission, 1,000 ft. to 1 in., including 5 ft. contours, buildings, roads, fences, etc., 1891, $36.00 per sq. mile. Missouri River Com., 1895, $31.00 per sq. mile. Newer instances from 20 to 50 cents per acre. In the discussion it is stated that the inaccuracies of stadia work are less than those due to plotting and expansion of paper under varying conditions ; that attempts at minute accuracy only add to the difficulties and expense of the work, and that the best use is made of the method when the work is carried on without regard to the optic conditions of the atmosphere, and reduced by a constant obtained by stadia measurements of triangulation lines.

J. G. K.

THE LIVERPOOL WATERWORKS.

G. F. Deacon, M. Inst.C.E.

(Proceedings of the Inst. C. E., Vol. CXXVI.)

The Liverpool new water supply is taken from the Vyrnwy River in Wales, and the aqueduct connecting Liverpool with the reservoir is about 76 miles long. It includes 4 tunnels, 6 railway crossings, 13 river crossings and 6 canal crossings, the latter including the Manchester ship canal. These crossings are in most cases subways, though in some cases the aqueduct was carried overhead.

Lake Vyrnwy is said to be the largest artificial reservoir in Europe, its area being 1,121 acres, and its capacity 12,131 millions of gallons below sill of dam and above outlet to the aqueduct. The author states that the dam for impounding this lake is the first high masonry dam used in Great Britain, its extreme height from overflow to base of foundation being 144 feet. A carriage and footway 19 feet wide is carried along the crest of dam on masonry arches. The author states a novel feature of this dam is the employment of relief drains from the foundations emptying into a tunnel in the heart of the dam. The idea of these drains was to prevent the development of pressure due to invisible springs, which it was thought, when the reservoir was full, might accumulate to such an extent under the foundations as to be of importance as one of the forces to be considered having a tendency to overturn the dam.

To quote the author's words: "Along the base of each of the more important beds of rock, not within 15 feet of the faces of the dam, a drain was formed by the masonry between 6 in. and 9 in. square, and from these drains funnels were carried up, in different vertical transverse planes of the dam, to above backwater level." There are 27 of these funnels in a length of 66 feet of the deepest part of the dam, which empty into a longitudinal tunnel 4′ 3″ × 2′ 6,″ from which a cross tunnel to face of dam serves as an outlet and for access to main tunnel.

The tunnel under the River Mersey was one of the most difficult parts of the work, and the author states was the first tunnel ever constructed by means of a shield, under a tidal or other river, through entirely loose material. This tunnel had a cast iron lining of 9 feet interior diam., and it was driven through loose water bearing strata 51 feet below high water. Inside the tunnel was laid the aqueduct, consisting of two 32 in. diam. pipes, of rivetted steel plates. The author says the site for this tunnel was favorable for laying the pipes in the muddy bed of the river, but that parliamentary exigencies forced upon the corporation the construction of the tunnel for which the site was the worst possible.

These waterworks were begun in July, 1881, and finished July, 1892. The total cost has been about £2,300,000 for a supply of 14,000,000 gallons per diem, but the author claims it can be increased to about 40,000,000 gallons per diem for additional cost of £1,600,000.

D. M.

Thursday, 11th February.

PROF. H. T. BOVEY, Vice-President, in the Chair.

RELATIVE TESTS OF CAST IRON and STRENGTH OF CAST IRON.

By W. J. KEEP, DETROIT, MICH.

(Trans. Am. Soc. Mech. Eng., Vols. XVI., p. 542, and XVII., p. 674.)

These papers contain the results of tests made for the Committee on Method of Testing of the Am. Soc. Mech. Eng.

The object of the experiments is to find a method of testing which shall reveal the physical properties of the cast iron.

Cast iron being an aggregation of compounds combined both chemically and mechanically is so much altered by any change in the proportion of these compounds, or by any change attending its production in the blast furnace, during remelting or solidification, that it becomes a material of different qualities.

Cast iron is a comprehensive term, separated often into 20 grades by differences in the appearance of its exterior surface or of its fracture ; but the proportion of silicon it contains is the determining element in its constitution, provided other elements do not exist in it in excess.

Increasing the proportion of silicon changes white iron into gray, causes combined carbon to become graphitic, makes hard iron soft. removes brittleness, thus increasing the strength of small castings by preventing brittleness, and decreasing the strength of large castings by increasing the size of the grain.

Carbon in melted iron is probably always combined (or dissolved), as more can be retained by the iron when fluid than when cold. On cooling, any surplus carbon separates out into graphite, and makes a gray casting. When in the graphitic form, carbon divides the grains of the metal, softening it, also removing brittleness, and by the mechanical separation of the grain causing weakness.

Now silicon lessens the ability of iron to hold carbon in the combined state when cold; hence the action of silicon as stated above. This action is not direct, but through the change produced on the carbon. The greater the quantity of combined carbon present (in the fluid state), the greater will be the influence of the silicon.

Silicon is thus the controlling element, the only one the founder need take account of, except to see that the iron contains sufficient carbon for the silicon to act upon. When the silicon effects the change of combined carbon into graphite, the casting occupies a greater volume than if the carbon remained combined. This is one cause of a decrease of shrinkage. Within limits the more silicon, the more graphite and the less shrinkage. As silicon grows less, shrinkage increases. Silicon of itself would increase shrinkage and harden cast iron; but by its influence on carbon—that is, by driving it out of the combined state—it softens the casting and decreases shrinkage.

Shrinkage is also much affected by the size of the casting. Large castings cool more slowly than small ones; and as the more slowly cooling takes place, the larger the crystals will be and the more loosely they fit into each other; so a large casting shrinks less in its outside dimensions than a small one from the same metal.

The effect of the size of the test bars when used for transverse tests is largely entered into. The shrinkage of a half inch square test bar is stated to be a mechanical analysis for silicon. A one inch square test bar gives records of strength more nearly alike for cast iron of different composition than a test bar of any other section.

A two by one inch bar is more clumsy to handle, and requires a larger testing machine. Larger bars are seldom used.

A chart is presented on which are contoured curves of different proportions of silicon, which co-ordinate the same shrinkages for different sizes of test bars; or from which the shrinkages which will ensue with different percentages of silicon when used on the same sized test bar can be inferred.

Another chart is given compiled from the very numerous tests in the paper, which gives the strength of castings of different sizes containing different percentages of silicon.

Tensile tests in the hands of Carpenter & Houghton were found to give as regular results as transverse tests, but no more so.

In the discussion Gus. Henning discusses the correct shape of the stress-strain curve for tension in cast iron.

The appendix contains thirty pages of tables of results of tests.

J. T. N.

THE NEW WATER SCOOP OF THE PENNSYLVANIA RY.

(*The Railroad Gazette*, January 8th, 1897.)

Railways have for a long time made use of water scoops, let down into troughs set between the rails, to refill engine tenders without stopping trains. Such devices, it is claimed, have never been entirely satisfactory, because water could not be taken in this way without running slowly. If the speed were too great it became impossible to lift the scoop from the water, and in consequence it was smashed against the end of the trough. The Pennsylvania Railway has since the middle of 1894 adopted as standard a device, in which it is claimed the power required to lift the dipper from the water is entirely independent of the speed of train.

This result, to speak generally, is arrived at by balancing the lower curved portion of dipper near its centre on trunnions about which it turns within limits. The upper end of this dipper is connected with the uptake pipe by a joint supported on another pivot.

The force of impact of water on the lower half of dipper tends to hold it down, while the similar force acting on the upper half tends to lift it. It is stated that these forces practically balance each other, and that trains have, with this device, taken water at a speed of 70 miles per hour, filling a 3,000 gallon tender in 9 seconds.

The advantages claimed are easy manipulation, no lost time, less water wasted by being splashed out of trough, and more water taken per 100 feet of trough, which can therefore be shorter and cost less for construction and maintenance.

The article is illustrated.

D. M.

A WATERPOWER AND COMPRESSED AIR TRANSMISSION PLANT, FOR THE NORTH STAR MINING CO., GRASS VALLEY, CAL.

By Arthur De Wint Foote.

(Trans. Am. Soc. C. E., Vol. XXII., 1896.)

The writer states that the price of water used was 1 cent per 1,000 gallons taken from old placer mining canals, the water being conveyed to the lowest convenient point by a 20″ rivetted steel pipe, the total distance being nearly 4 miles, with a head of 735 ft., or a static pressure of 335 lbs. per square inch.

The consideration of transmission from Pelton wheels to pumps was between electricity and compressed air, and was decided in favour of the latter, on account of less first cost of plant, greater economy of power and less liability of accident, but chiefly because almost absolute security against stoppage could be obtained by having a set of boilers on hand, as the air motors could be driven by steam by changing a few valves.

To obtain a rim velocity of Pelton wheel $\frac{1}{2}$ of spouting velocity, and not to work compressors more than 60 or 70 revolutions per minute, would require a wheel 30 ft. diameter. The Pelton Water Wheel Company did not care to attempt such a large wheel. A compromise was effected by building a wheel 18 ft. 6 inches diameter, with a guaranteed efficiency, at full load, of 85 per cent., and an average efficiency from $\frac{1}{2}$ load to full load of 75 per cent., and to so govern the wheel as to not give more than 120 revolutions per minute, or to not raise the air pressure above 105 lbs. in any case. The ordinary pressure was 90 lbs., and the air being used in hoisting engine pumps, drills, blacksmith's forge, etc.

The Pelton wheel has 4 sets of nozzles for $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and full loads, and for intermediate loads hoods are used. Efficiencies of over 90 per cent. were obtained in tests at each $\frac{1}{4}$ load, these efficiencies becoming slightly less at intermediate stages, where the hoods were brought into use to throttle the supply. A novel feature of the air compressors is the inter-cooler. The air compressors work in duplicate, the air leaving the 1st compressor at a temperature of 200° F. passes through a nest of 49 soft copper pipes 1″ diameter, 18 ft. long. The water from the Pelton wheel dashes against these pipes, and reduces the temperature of the air to 60° F. before it enters the 2nd compressor.

The air is led to the mines by $5\frac{3}{4}$″ screwed pipe, and is there reheated to from 350° F. to 400° F. before being used; $\frac{1}{2}$ cord of pine wood per day is needed to heat 700 c. ft. of air per minute.

The exhausted air from air motors is used for heating and for drying clothes.

The air conducted to the pumps in the mines arises at 275° F. and exhausts at 60° F., giving cool, fresh air to the man.

The following efficiencies were obtained by tests made by Mr. Rix :—

Efficiency of wheels.. 93 p. c.

Efficiency of compression and transmission of air, including
reheating... $78\frac{1}{2}$ p. c.

Efficiency reckoned from water delivered to air motors, including cost of reheating.. 73 p. c.

Efficiency from water delivered to work done by air engines .... $61\frac{1}{2}$ p. c.

Electricity was not needed for lighting or tramways, or otherwise the comparison would not have been so favorable to compressed air.

C. B. S.

FOUNDATIONS OF TALL BUILDINGS.

RANDELL HUNT.

(*Journal Assoc. Eng. Societies*, July, 1896.)

In this paper the author discusses the various methods of founding modern tall buildings, and the principles involved in designing such substructures. The danger of placing a uniform foundation under a modern columnar building whose weight is concentrated at certain points is noted, and the failure of the Cooper Institute of New York is quoted as an example. The Chicagoan practice of separate foundations, proportioned to the weight borne by each column, arose from the failures from the above mentioned cause. The author states that this practice is not perfectly satisfactory, because it is well known that weak soils will not carry as great a load per unit of area on large areas as they bear on small areas. The use of steel beam and concrete piers is stated to have arisen partially from the fact, that to spread the bearings of a column by masonry footings necessitates a foundation of considerable depth, because the step of a masonry footing is necessarily small. Chicago is built on a twelve ft. layer of firm soil underlaid with soft clay, and deep foundations would have destroyed the bearing power of this layer, and therefore both economy and good practice called for the use of shallow rapidly widening piers.

Recent experiments seem to show that when a pressure is borne by a limited area of soil, the lines of pressure in the soil diverge from the vertical at an angle equal to one-half the angle of repose of the material. Careful investigation of all doubtful foundation sites is advised, and it is stated that although such investigations are not capable of being carried out to great accuracy, a thorough knowledge of the thicknesses and character of the layers of soil under a building will furnish data sufficient to secure it from disaster. The author questions the justifications of loading soils up to their full bearing power while employing factors of safety with all other building materials, and states that architecture is a science and art largely based upon historical precedent, but that the foundation of a modern high building is a question of engineering construction, and excepting that precedent furnishes information with regard to the strength of materials, it is a dangerous guide to follow blindly. The question of vibration effects, especially from earthquakes, is discussed fully, and experience in Japan is stated to have proved that substructures are rarely damaged by such shocks, and that the safety of a building depends upon its vibrating in unison, and upon all parts receiving an equal impulse from the foundation. The strain induced in tall buildings by transmitting an impulse to the great roof and upper stories is enormous, and the precedent of construction in earthquake-affected countries is to make the mass of the superstructure as light as possible. It is known that the earth impulses vary greatly in a small area, and independent pier foundations are therefore unsuited for places liable to earthquakes, because they will transmit unequal impulses to the building. In such cases the author recommends a concrete and steel beam foundation of sufficient weight to minimise the vibrations and of sufficient strength to equalise the column pressures over the bearing area below. The "Call" building in San Francisco is instanced as an example.

In the discussion it is stated that Chicago practice is to expect a heavy building to settle at least two inches, and the architects endeavour chiefly to make this settlement uniform. If some columns do not settle as rapidly as others, loading with pig iron is resorted to, and on buildings with heavy towers the area on which the tower will rest is sometimes loaded to its ultimate pressure at the beginning of construction, and the pig iron removed gradually as the work progresses, in the hope that the settlement and compression of the soil will have been accomplished before the building is far advanced. The practice has not been uniformly successful. Piles are not viewed with favour because the Chicago subsoil does not settle around the pile, and hold it as is generally the case, and the variation of the level of subsoil water subjects them to the most dangerous condition for wood structures.

J. G. K.

SOLAR WORK IN SURVEYING.

J. D. VARNEY.

(*Journal Association of Engineering Societies*, Nov., 1896.)

This paper mentions that land surveys by distances and courses have been in practice since the earliest recorded civilisation, that it is desirable that all courses should be referred to the true meridian, and describes one of the latest devices for determining the meridian from the position of the sun without computation. It consists of the usual transit-theodolite, with one attachment and one modification. The modification is that the telescope is carried in a tube which is connected to the horizontal axis in the same manner that the telescope usually is, and is free to revolve in this tube about its own axis. The attachment is a mirror revolving on an axis attached to a small ring which fits on the object end of the telescope. Slow motion is provided for. The mirror is set with the aid of the horizontal circle and a special target, so that it reflects the line of collimation at an angle equal to the angle between the earth's axis and a line from the earth to the sun (*i.e.*, ninety degrees—sun's declination). The telescope is set at an angle of depression equal to the latitude of the place. The instrument is revolved about its vertical axis, and the telescope about its own axis, until the image of the sun appears in the cross hairs, and then the instrument is pointing in the meridian. The writer claims that with due regard to refraction and hour angle a meridian of sufficient accuracy for all ordinary work can be obtained.

THROUGH THE BARREN LANDS.

J. W. TYRRELL.

(Proceedings of Association of Ontario Land Surveyors, 1896.)

This paper describes an exploratory survey through the northern part of the North-West, and the explorer gives the following as an ideal instrumental outfit for such work :—Large sextant with folding mercurial horizon, pocket solar compass with extesionn leg tripod, two prismatic compasses, one boat's compass, two pocket compasses, two boat logs, one pedometer, two clinometers, one dipping needle, one pocket chronometer, three American watches, one aneroid barometer, a set of thermometers, a pair of field-glasses, and aluminium binocular telescope and a 4″ x 5″ hand camera.

The methods of surveying are described thus :— On lakes distances were measured by log, and when landings were made courses were taken with the prismatic compass or occasionally with the boat's compass without landing. As frequently as possible the solar compass was set up, the magnetic declination determined and bearings taken. A continuous check was in this manner kept upon the magnetic courses. Latitude observations were taken every day when the sun at noon or the stars at night were visible, and from time to time at initial points or the route longitude observations were made. On portages, distances were determined by pacing, and on rivers by taking the time occupied in covering them. The river travel was nearly north, and a distance check was therefore furnished by the latitude observations, and it was found possible to estimate the day's travel very closely in the manual above described.

J. G. K.

Thursday, 25th February.

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

Professor Nicolson delivered his third lecture on Transmission of Power by Compressed Air. The lecture was illustrated by lantern projections.

Thursday, 11th March.

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

The following candidates having been balloted for were declared duly elected:

MEMBERS.

W. Z. EARLE. D. WILLIAMS.

ASSOCIATE MEMBERS.

L. J. MARIEN. CHAS. J. PIGOT.
J. W. LE B. ROSS.

Transferred from the class of Associate Member to that of Member:

T. HARRY JONES.

Transferred from the class of Student to that of Associate Member:

H. R. LORDLEY.

STUDENTS.

R. C. F. ALEXANDER. G. R. MACLEOD.
J. T. FARMER. G. L. MATTICE.
A. M. RUSSEL.

Prof. Durley delivered a lecture on "Thermal Storage and Distribution of Power by Steam."

Thursday, 25th March.

E. MARCEAU, Member of Council, in the Chair.

Professor Nicolson delivered a lecture on "The Transmission of Power by Gas.'

LECTURES

ON THE

Transmission and Distribution of Power

BY COMPRESSED AIR, BY FUEL GAS,
BY STEAM (including Thermal Storage),
AND BY WIRE ROPES.

—— BY ——

JOHN T. NICOLSON, B.Sc., M.Can.Soc.C.E.

—— AND ——

R. J. DURLEY, B.Sc., A.M.Can.Soc.C.E.

Professors of Mechanical Engineering at McGill College.

PREFACE.

These lectures were delivered in Montreal, under the auspices of the Faculty of Applied Science of McGill University, and of the Canadian Society of Civil Engineers, during the months of February, March and April, 1897.

Lectures I to IV and VII were by Professor Nicolson, lectures V, VI, and VIII were by Professor Durley.

The lectures (which were originally destined for the senior engineering students of McGill College) are intended to give a succinct statement of the technical principles underlying the subjects in question, and to make a numerical comparison of some of the methods along commercial lines. They do not treat their subject matter so exhaustively as do the well-known Howard Lectures of the Society of Arts, delivered in 1893, by Professor Unwin; but yet they will be found to be, in some respects, supplementary to these.

August, 1897.

INTRODUCTORY.

At the present time it is with considerable difficulty that any system of transmission of power can compete successfully with that of carrying it by rail in the form of coal. Although the revenue derived by the railways of the United States amounts in the aggregate to fifty millions of dollars annually for the transportation of coal, that commodity is nevertheless supplied for the use of consumers of power at a price which is almost always less than that of energy in any other form. It appears, therefore, that, so long as coal remains as abundant and therefore as cheap as it now is, all other natural sources of power must occupy only a secondary place. Our cataracts, our rapids, and our tides must wait for their more extended utilization until the enormous stores of mechanical energy accumulated in the coal fields of the world have been more or less exhausted.

There are, no doubt, numerous instances in which such competition with coal has had a successful issue; but the broad general statement may be accepted as true that, in comparison with the utilization of power from coal by means of steam boilers and steam engines throughout the world, all other forms of energy transformation are of secondary magnitude.

This result is not *à priori* to be expected; it occurs to everyone to ask how coal-power can be cheaper than, *e.g.* a conveniently situated water-power, since the water costs nothing and the coal must be paid for at $4.00 per ton! The reply is, that the interest on the capital expended on the plant necessary to intercept the power from the falling water and to transmit it to the required locality is usually greater than the annual cost due to capital expended on boilers and engines and the price of coal used. The cost per annum for interest and depreciation of one horse-power delivered by a turbine; for the dam, head and tail-races, penstocks, gates and wheel-pit varies from $2.00 to $15.00, according to the nature of the site of the waterfall impounded. On the other hand, the sum of $20.00 per annum will amply cover the cost of one horse-power delivered by a large steam engine. The difference between these figures, varying between $18.00 and $5.00 per H.P. per annum, is what remains available to cover the expense of transforming the power at the water supply into a form suitable for transmission; for its subsequent conveyance; and for its retransformation into mechanical work at the point where it is to be employed. The interest on the capital outlay and running expenses of any such transmission system usually exceeds the above available balance, and the steam engine is found to be the cheaper.

Such being the case, the utility of a course of lectures on the transmission of power might be open to question, were it not for the fact that, when an engineering or other problem is of comparatively infrequent occurrence, its solution is unlikely to be so much a matter of common knowledge. The lecturer has in fact during the last few years been asked by many different power users to furnish data regarding some of the more common methods of distribution, and this it was which led him to suggest to the Faculty of Applied Science the desirability of taking the matter up in a public way as well as for the benefit of McGill College engineering students.

Besides this: even granting the great preponderance of the use of coal as the source of our energy at the present day, very large and important issues may be raised in regard to whether our modes of employing the fuel at our disposal are as economical as they ought to be, keeping in view (1) the ultimate and inevitable exhaustion of the supply in the earth's crust, and (2) the present condition of manufacturing industry as regards the mutual relations of capital and labour.

Take one example only. It was carefully emphasized above that it is only in the case of large engines, say of over 500 H.P., that power can be obtained at the very reasonable figure of $20.00 per H.P. per year of 3000 hours. As the size of the engine diminishes the cost of the power increases very rapidly indeed; so that, with engines of 200, 50, 10 and 1 H.P., it rises from $20.00 to $35.00, $50.00, $100.00 and $200.00 respectively per H.P. per annum. If now it be considered that in large cities a great proportion of the steam power plants are of comparatively small size, it will be obvious that the average cost of a horse-power to a consumer in a large town is much greater than the above $20.00, which it might cost if generated in large units. As a matter of fact, from data collected by the lecturer, the mean rented value of one horse-power in the city of Montreal varies between $60.00 to $120.00 per annum. So that it becomes a proper object of inquiry to ascertain whether, by generating the mechanical work by means of very large steam engines in central stations, or in stations in the outskirts of great cities, such power could not be transmitted and distributed to customers so much more economically as to leave a large margin to all concerned over the present sporadic method of generation.

The lecturer made this inquiry the subject of a paper read before the Canadian Society of Civil Engineers in February, 1893. Taking compressed air as the particular medium of distribution, it was shown in that paper that 500 consumers in this city of an average of four horse-power each could effect a saving of at least 50 per cent. on their present power bills, by uniting themselves to form a Common Power Supply Company, this Company paying at the same time 10 per cent. interest on its invested capital!

The commercial possibilities due to this predicted result are waiting for their trial; at any rate in this country. In Europe the scheme has been put into execution with more success; as, for instance, in Paris, where 18,000 horse-power is installed, about half of which has been in operation for six or seven years with gratifying results to its promoters.

In this connection a very large and momentous question may be opened up as to the possible effect upon the present unsatisfacty relations of capital and labour which would result from the encouragement of small industries by the more economical distribution of power and its consequent cheapening to those using it in small quantities. Any one interested in this matter will find it briefly discussed in articles written by the lecturer for the Canadian Record of Science for April and October, 1893.

The object of the present course is not, however, to recapitulate these old results, but to deal with concrete problems of not infrequent occurrence of a different nature. So far as concerns the lectures to be given by the present speaker, long distance transmission will more definitely be kept in mind; and it is the intention to show that compressed air, and fuel gas more or less compressed, will in the future become the most formidable competitors of electricity as the media to be employed by engineers whenever power has to be obtained from a natural source, transformed and transmitted for utilization to considerable distances from that source.

LECTURE I.

COMPRESSED AIR.

We shall now take up what is specially the subject of our first four lectures, the transmission of power by the pneumatic system.

In such a system the chief parts are: the natural source of power; the prime mover; the air-compressor; the mains; the preheaters; and the motors. The detailed discussions of these several portions in order will be of a technical character, and will wherever possible give practical results worked out numerically from first principles.

I. The Source of Power.—We have already spoken of the paramount importance, at present, of coal as the source of our mechanical energy. The United States, however, is an example of a country where the natural conditions are such that water power enters somewhat more largely than usual into connection with steam power, and a similar condition of affairs obtains in Canada. We shall consider in what follows, as concrete examples, the transmission of power from a waterfall as the source of power to a motor station at some distance therefrom, and shall work out the various losses to be expected in such a compressed air transmission, with the object of determining the commercial as well as technical feasibility of such undertakings, and of comparing this method with others in this respect.

II. Prime Movers.—These are, as a general rule, turbines, whose price and efficiencies under all conditions of working are well known. They will not here be further referred to, but the figures required regarding them in the tabulation of costs will be entered without discussion.

The direct compression of air by falling water without the intermediary of any moving machinery has quite recently been successfully accomplished by Mr. C. H. Taylor, of Montreal, in a plant of 160 horse-power at Magog, Que. This form of prime mover has probably a great future before it, and will come up for closer consideration in a future lecture. (v. Lecture IV.)

III. The Air Compressor.—If the air be compressed quite slowly, so that the work done upon it by the compressing piston, which is changed into heat (or vibration energy in the particles), has time to pass away into the walls, the compression will take place at the temperature of the entering air (*i. e.*, isothermally), and a notable reduction in the work required to raise the pressure by the desired amount will be effected over what would be spent if the heat were allowed to accumulate in the air. If, on the other hand, when the compressing is done so quickly that the temperature of the air rises in the cylinder, the compressed air is used in motors close by, no great harm is done; as the extra work put in is returned again in the motors. But, if the heated air has to travel through a long main before being used, its temperature has time to fall to that of the earth, and all the extra work necessarily accompanying high temperature compression is thrown away. For transmission purposes, therefore, the most economical way of compressing the air is the isothermal method; and this has long been acted upon in practice by the use of cooling jackets round the cylinder and even in the pistons, as the slow compression process above mentioned would be impracticable, owing to the great first cost of the large-sized machines which would be necessary. For the purposes of a large first-class compressing station, however, this jacket cooling is far from being the best possible system, and is only to be recommended for mining plants where the injection of a spray of cold water into the cylinder itself is impossible, owing to its impurity or to undesirability of any additional mechanism. Even with the best forms of spray injection now in use, only a relatively small proportion of the heating can be prevented. Instead of remaining at the temperature of entry, say 60°F., the air, when being compressed to 100 lbs. absolute, heats up to about 300°F., as against 455°F., which would be the terminal temperature if no heat had been taken away at all.

A much better method of dealing with the difficulty is to compress in two or more stages. This is accomplished by permitting the air, after its pressure has risen a certain amount, to flow into an intermediate receiver of sufficient capacity to allow of the lowering of the temperature of the air down to that of the atmosphere before it is inhaled into the next cylinder. Professor Riedler has applied this plan to the new installation of 10,000 horse-power in Paris with very great success; but, as to the inventor of the method, no certain information is obtainable, although the Newark Iron Works, Conn., constructed compressors on this principle as early as 1881; and Mr. Northcott of London (England) made a compound compressor with intercooler in 1878.

EXPANSION AND COMPRESSION OF AIR.—We may now begin the detailed investigation of these various modes of working; and exemplify the same by diagrams from actual compressors, and, to commence with, we must establish the ordinary formulæ which express the work done by, or upon air, when it expands, or is compressed, under the various conditions adopted in practice.

We commence by recalling the experimental relations determined by Boyle & Charles with respect to the more permanent gases, expressed in the formula:

$$P V = c T \ldots\ldots\ldots\ldots\ldots\ldots (1):$$

where P is the pressure in pounds per square foot; V is the volume in cubic feet to the lb.; T is the absolute temperature Fahrenheit (461 added to the ordinary temperature Fahrenheit), and c is a numerical constant, which for air has the value 53.18. For example, $P V$ has the value 27,700 ft.-lbs. for air at 60° F., and at atmospheric pressure.

When air expands or is compressed, the expression which states the relation between successive values of the pressure and volume during the expansion (or compression) is of the form:

$$P V^n = constant \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The value of n depends on the quantity of heat supplied during expansion (or removed during compression). If no heat be supplied during expansion, the energy necessary to do the work must come out of the internal or vibrational energy of the air; and as the temperature only remains constant so long as the quantity of internal energy contained by the mass of gas remains the same, in this case the temperature must fall. If, on the other hand, heat is continuously added during the process of expansion at the same rate as energy is removed externally, then the temperature will not fall, and the product $P V$ in expression (1) will remain constant, or the pressure will vary inversely as the volume. In other words, the index of expansion (above called n) will be equal to unity. In the case last mentioned, of no heat being supplied, the value of n is 1.4, and we may have every intermediate value between 1 and 1.4, according to the pains we take to warm the fluid while it expands. We may even have n less than unity if more heat be added than is removed in the form of external work, whilst n may also have a value greater than 1.4 if the air be cooled while it is expanding.

When a gas expands with the addition of heat at such a rate that its temperature just remains the same, it is said to expand *isothermally*;

but, if no heat be either added or substracted during expansion, it is said to expand *adiabatically.* The modes of expansion which most commonly occur in motors are intermediate between these two.

Whatever value n may have, except unity, the work expended during expansion (or required for compression) is expressed by :—

$$W = \frac{P' V' - P^\circ V^\circ}{n - 1} = \frac{c\,(T' - T^\circ)}{n - 1} \text{ per lb. of air.........(3)}$$

Here P' and V' are the pressure and volume of the compressed air, and P°, V° are those of the air at atmospheric conditions. The ratio of the temperatures of the air compressed and uncompressed is given by :

$$\frac{T'}{T^\circ} = \left[\frac{V^\circ}{V'}\right]^{n-1} = \left[\frac{P'}{P^\circ}\right]^{\frac{n-1}{n}} \text{ ....(4)}$$

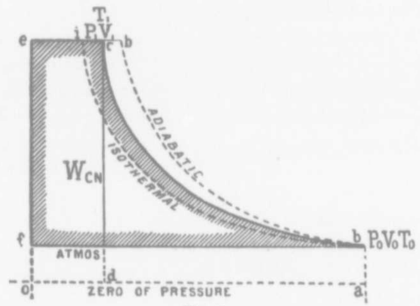


Fig. 1.

In Fig. 1 the area which the expressions in (3) represent is $a\ b\ c\ d$, where the curve of compression is shown as running intermediately between the adiabatic and the isothermal curves. A further amount of work of amount $P'\ V'$, is obviously done in delivering the air into the reservoir against the pressure therein, and this is shown in the figure as $d\ c\ e\ o$. On the return stroke the atmosphere does work on the piston (since we have been reckoning from the absolute zero of pressure) of amount $P^\circ\ V^\circ$; shown in the figure as $o\ f\ b\ a$.

The net work done by the piston is therefore :

$$W = P'\ V' + \frac{P'\ V' - P^\circ V^\circ}{n - 1} - P^\circ V^\circ, \text{ which may be written :}$$

$$W = \frac{n}{n - 1}\,(P'\ V' - P^\circ V^\circ) \text{.................. (5)}$$

This may also be written in the form :

$$W = \frac{n}{n-1} c\ (T' - T^{\circ}) \quad \text{.....................} \quad (6)$$

It will be convenient to insert in this the value, from expression (4), of the ratio of T' / T° in terms of the pressure, viz. : $(P'/P^{\circ})^{\frac{n-1}{n}}$; in this way we obtain as the general expression for the work done in compressing and delivering 1 lb. of air :

$$W = cT^{\circ} \frac{n}{n-1} \left[\left(\frac{P'}{P^{\circ}} \right)^{\frac{n-1}{n}} - 1 \right] \quad \text{..................} \quad (7)$$

In order to shorten our work, we may write Q' for P' / P° ; and for the fractional exponent $\frac{n-1}{n}$, which is very awkward to print, we shall write $1/m$: so that (7) will now become :

$$W = cT^{\circ} m\ (Q'^{\,1/m} - 1) \quad \text{.......................} \quad (7)$$

In the particular case when heat is neither gained nor lost during compression (adiabatic compression), n is denoted by the Greek letter γ (which has been retained for expressing the ratio of the specific heat of gases at constant pressure to that at constant volume) ; which, for air, has the value 1.4. Then $m = 3.5$ in (7).

As was mentioned above, expression (3) does not apply when the expansion is isothermal ; on the contrary, the quantity of work done during expansion (or compression) must be found by another process, and is expressed by :

$$W = P^{\circ} V^{\circ} \log_e \frac{P'}{P^{\circ}} = cT^{\circ} \log_e Q' \quad \text{...................} \quad (8)$$

It is noticeable that nothing need be said in the case of isothermal working with regard to the work of delivery. In fact, this work of displacement is exactly equal to that done by the atmosphere on the return stroke ; so that expression (8) gives also the number of foot-pounds of work required to compress *and deliver* one lb. of air isothermally at temperature T°, starting at pressure P°, against a reservoir pressure P'.

Two Stage Compression.

If compression takes place in two stages, being completed in a second cylinder after having been cooled down to atmospheric temperature in an intermediate receiver of large capacity, expression (7) requires simply to be altered to suit. It becomes, if each compression is adiabatic, and Q' and Q are the final delivery and intermediate receiver pressures, respectively:

$$W = cT^{\circ}m \left[\quad ^{1/m} - 1 + \left(\frac{Q'}{Q}\right)^{1/m} - 1 \right]$$

It can easily be shown that the best value to give to the receiver pressure is that which makes $Q = \sqrt{Q'}$. Inserting this in last written expression, we obtain:

$$W = cT^{\circ} \times 2m \left[Q'^{\,1/2m} - 1 \right] \ldots\ldots\ldots\ldots (9);$$

where m has the value 3.5, if the compressions be adiabatic; and 6, if they be carried out in a first-class modern compressor with spray-injection.

Three Stage Compression.

In quite a similar way for a three stage compressor, we have:

$$W = cT^{\circ} \times 3m \left[Q'^{\,1/3m} - 1 \right] \ldots\ldots\ldots\ldots\ldots\ldots (10),$$

giving the work required to compress one lb. of air in three successive cylinders, and finally deliver it against a pressure of Q' atmospheres absolute; m having the values 3.5 or 6, according as the compressions take place adiabatically or with the injection of a spray of water in each cylinder.

If Q and R be the pressures in atmospheres absolute, in the first and second intermediate receivers respectively, the best values of these pressures are given by the formulæ:

$Q = Q'^{\,1/3}$, and $R = Q'^{\,2/3}$. and these are the only values for which formula number (10) is true.

Numerical Example.

We may now, as practical example of the above formulæ, show how to determine the proportions of an air-compressor large enough to absorb 1000 H. P. delivered by the jack-shaft of a turbine, which makes, say, 80 revolutions per minute. Let it be required to expend this horse-power in compressing atmospheric air at a temperature of 60° F. (initially) to a pressure of 10 atmospheres absolute, or about 132 lbs., gauge pressure, in two stages, with intermediate cooling in a large reservoir, and with the injection of a spray of water into both cylinders of the compressor.

To begin with, about 10 per cent. of the power of the turbine will be spent in overcoming the mechanical friction of the working parts of the compressor, so that we shall only have about 900 H. P. available for actual compressing. The work spent on compression is, therefore, $900 \times 33{,}000/80 = 371{,}200$ ft. lbs. per revolution of the compressor shaft; or 185,600 ft. lbs. per stroke if the compressor be double-acting. We must now find how much work is necessary to compress a lb. of air in the manner proposed. The formula to be used is No. (9), putting $m = 6$, thus:

$$W = cT^{\circ} \times 12 \left(Q^{1/12} - 1\right) = 53.521 \times 521 \times 12 \left(10^{1/12} - 1\right)$$
$$= 27{,}700 \times 12 \times .212 = 70{,}500 \text{ ft. lbs.}$$

The above 185,600 ft. lbs. will therefore compress 185600/70500 = 2.63 lbs. of air per half revolution of the compressor. To find the volume which this air will occupy at any pressure and temperature we use formula No. (1): obtaining, $V = cT/P$: (now we know that when the temperature is 32°F. and the pressure is 14.7 absolute, P° is 2116, V° is 12.4, and T° is 493, from which the value of c is known. The above expression may therefore be written:

$$V = \frac{P^{\circ} V^{\circ}}{T^{\circ}} \frac{T}{P} = \frac{V^{\circ} T P^{\circ}}{T^{\circ} P} = \frac{V^{\circ} T}{T^{\circ} Q} = \frac{12.4 T}{493 \; Q} = \frac{T}{40Q} \text{ very nearly,}$$

so that, if we decide to find the volume which 2.63 lbs. of air will occupy at 132 lbs. gauge pressure and 60°F., we have to divide the absolute pressure corresponding to 132 gauge by 14.7, which gives Q, and to add 461 to 60 in order to get T; then the volume required is: $2.63V = 2.63 \times 521 \div 40 \times 10 = 3.43$ cub. ft. per half rev. of the compressor, or about 549 cub. ft. per minute, at 132 lbs. and 60°F. What we at present require, however, is the size of each of the compressor cylinders; for this purpose we need the volume of 2.63 lbs. at 14.7 lbs. abs. and 60°F., as this is the volume of the low pressure cylinder. Here $Q = 1$, $T = 521$, so that $2.63\ V = 2.63 \times 521/40 = 34.3$ cub. ft. Taking the stroke at 5 ft., the cylinder diameter comes out about 35.5 inches. In the same way, to find the H.P. cylinder dia., the volume of the 2.63 lbs. must be found at a pressure $Q = 10^{1/2} = 3.17$; this is found to be 10.85 cub. ft., which, with a stroke of 5 feet, gives a cylinder of about 20 inches.

A compound compressor with cylinders 20″ and 35.5″ dia. and 60″ stroke, will thus absorb the given 1000 horse-power of the turbine; and will compress $34.3 \times 160 \times 60 = 329{,}000$ cub. ft. of air at atmospheric pressure and 60°F. in the manner indicated to a gauge pressure of 132 lbs. per hour. This is at the rate of 329 cu. ft. per horse-power hour (*i.e.*, per turbine horse-power hour).

In this calculation no allowance has been made for losses which may occur in the compressor, due to valve-resistance, valve-slip or clearance; in a good machine this ought not to amount to more than about 4%.

Were it possible to make an isothermal compressor, we should have to use formula No. (8), from which would be obtained for the work required to compress one lb. of air in such a compressor:

$W = cT^{\circ} \log_e Q' = 27{,}700 \log_e 10 = 27700 \times 2.3026 = 63{,}300$ ft. lbs. per lb. of air, *vice* the 70,500 last worked out. The ratio of the work of an isothermal to that of an actual compressor with no diagram loss may be taken as a measure of the efficiency of the process of compression; and, in this case, it amounts to 63300/70500 = 0.90. Thus, a perfect or isothermal compressor would yield 320/.90 = 366 cu. ft. (measured at atmospheric pressure), compressed to 132 lbs. gauge pressure per H.P. hour supplied.

On the other hand, a compressor with perfect valves, and no clearance or other losses of that kind, but working on the worst possible method of compression, viz., adiabatic, and in one stage would require per lb. of air a work:

$W = cT^{\circ} m \left(Q'^{\,1/m} - 1\right) = 27700 \times 3.5 \left(10^{1/3.5} - 1\right) = 27700 \times 3.5 \times 0.931 = 122{,}600$ ft. lbs. The efficiency of such a compressor would be but: 63300/122600 = 0.515. The number of cubic feet of air at atm. press. it would compress to 10 atms. abs. is = 366 × 0.515 = 189. This example shows in a very concrete manner the usefulness of a cooling process during compression. Many of the compressors put on the market by firms of repute in Canada, the United States and Great Britain, are but little better and many of them a greater deal worse than the last calculated compressor. This is due to the fact that the mining engineers, for whom these machines have chiefly hitherto been made, have been content with almost any compressor that would merely go round and deliver air under pressure. In the sale catalogues, the unwary purchaser is invited to view with satisfaction the fact that the area of the compressor indicator-card is 96 per cent. of that of the steam-card of the cylinder driving it, whilst, as a matter of fact, this gives no information whatever as to the qualities of the machine as a compressor, but only as to the friction loss between steam and air cylinders. The true comparison should be, on the other hand, between the actual air-card and an isothermal card for the same weight of air as the machine actually delivers, having its line of discharge pressure at the height corresponding to the pressure of the reservoir.

As an example of a good compressor card, such as the lecturer has not seen equalled in this country, one is here reproduced (see Fig. 2),

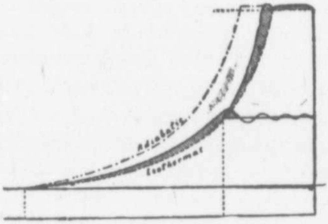


Fig. 2.

taken from a machine made in Germany, at Augsburg, by the firm of Riedinger & Co. It is a two stage spray-injected air compressor, of the exact type for which the first example above calculated was shown to have an efficiency of 90 per cent. That obtained from the actual diagrams was 84 per cent., the difference being due to valve-losses, for which no allowances, as above stated, were there made.

In order to facilitate the calculation of the values of such expressions as Nos. (7), (9) and (10), which are of very frequent occurrence in this subject, the lecturer has worked out a number of the most usual cases, and has graphed the results in the accompanying Plate (Fig. 3).

The values of $Q'^{1/m}$, which are somewhat troublesome to obtain, can be taken from the figure for any reservoir pressure up to about 500 lbs. per square inch by the gauge, and for several different methods of compression.

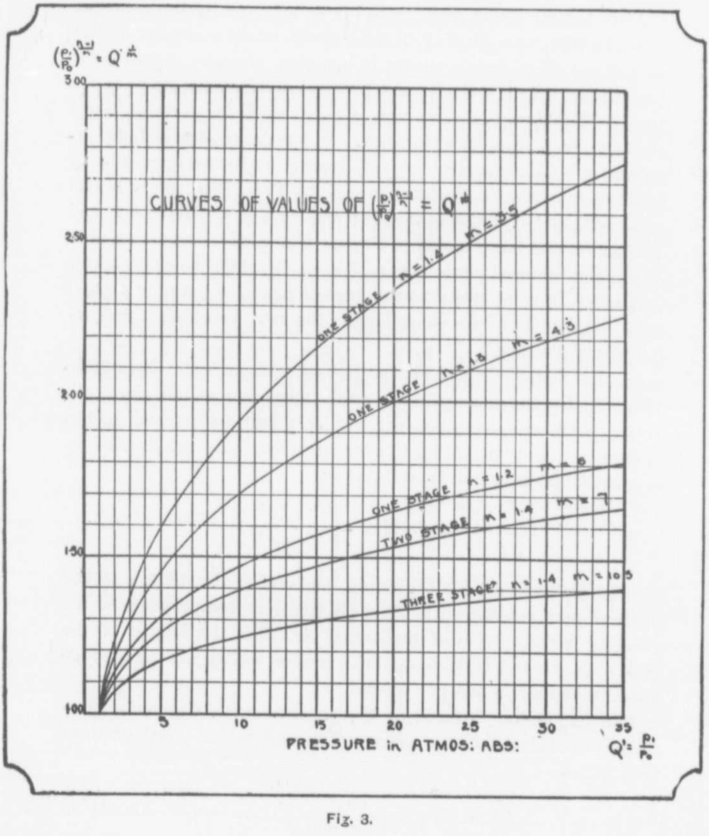

$\left(\frac{p_1}{p_0}\right)^{\frac{n-1}{n}} = Q'^{\frac{1}{m}}$
3.00
2.50
2.00
1.50
1.00
CURVES OF VALUES OF $\left(\frac{p_1}{p_0}\right)^{\frac{n-1}{n}} = Q'^{\frac{1}{m}}$
ONE STAGE n = 1.4 m = 3.5
ONE STAGE n = 1.3 m = 4.3
ONE STAGE n = 1.2 m = 6
TWO STAGE n = 1.4 m = 7
THREE STAGE n = 1.4 m = 10.5
5
10
15
20
25
30
35
PRESSURE in ATMOS: ABS:
$Q' = \frac{p_1}{p_0}$

Fig. 3.

LECTURE II.

After the air under pressure has been delivered by the compressors into reservoirs fitted with baffle-plates, or some similar device for getting rid of the moisture it contains, we may suppose it to be supplied into a main for the purpose of transmission to a distance. The question which now presents itself for solution is one of very great theoretical interest. It has been attacked mathematically by Unwin, Grashof, and Bresse; and experimentally by Stockalper at the St. Gothard tunnel, by Prof. Devillez, in a coal mine with pipes of different sizes; and by Profs. Gutermuth and Riedler on the large mains of Paris. The problem is: In a pipe of a given material, diameter and length, in which compressed air is flowing, in what way does the drop of pressure per mile depend upon the density of the air and upon the rate at which it is flowing along the pipe?

In the *Zeitschrift des Vereins Deutscher Ingenieure*, May 28th, 1892, H. Lorenz has made a careful comparison of all the available experiments, on pipes varying from two to fourteen inches in diameter, and lengths up to over ten miles. He has devised an epirical formula, which is as follows:

$$\frac{p' - p''}{p} = 0.00112\ \frac{T^{\circ}}{T} \cdot \frac{Lu^2}{D^{1.3}}\ ; \text{ where } p' \text{ and } p''$$

are the pressures at the beginning and end of the main, p is the average pressure therein; T° is the absolute temperature of the freezing point, T that of the actual air; L is the length of the pipe in miles, and D its diameter in inches, whilst u is the average speed of the air in feet per second.

The expression deduced by Unwin (and with slight modifications that of Grashof and Bresse) from theoretical considerations is as follows:

$$\frac{p''}{p'} = \left(1 - \frac{Lu_1^2}{74{,}300{,}000\ d}\right) \qquad (11)$$

where d is now the diameter in feet and u_1 is the initial velocity. The analysis leading to this result may be referred to, either in the Encyclopædia Britannica, ninth edition, Art. Hydromechanics,

p. 491; or the Howard Lectures for 1893 by Prof. Unwin (pub. Longmans), p. 216. (This analysis was reproduced in the lectures, but is too long to be reprinted here.)

Lorenz' expression is intended to represent quite closely the results obtained by all the experimenters whose results he collected; it suffers, however, from the obvious defect that the mean velocity enters into the formula, and as this depends on the pressures at both ends of the main, one only of which is known, and may differ widely from the assumed velocity at either end (except for very moderate speeds), it can only be used for cases, the conditions of which are known very approximately beforehand, and will probably be useful for checking the losses in installations which have been preliminarily designed by the use of formula (11).

Professor Unwin has calculated (Howard Lectures, p. 216) the pressures in a twelve inch pipe at every mile for two cases, of initial speeds of 25 ft. per sec. and 50 ft. per sec. The lecturer has, with his permission, reproduced these results here, and has tabulated with them figures obtained by using Lorenz' formula, employing for the speeds those obtained by averaging Unwin's speeds; in Case I those at 0 and 10 miles, in Case II those successively at 0 and 1, 0 and 2, etc., were employed.

Distances in miles from commencement of main..........	0	1	2	3	4	5	6	7	8	9	10
Case I. Speed of air, ft. sec......	25	25.6	26.2	26.9	27.6	28.4	29.2	29.9	31.2	32.3	33.6
Press. lbs. sq. in. abs. Unwin...	115	112.3	109.8	107.0	104.3	109.4	98.5	96.1	92.3	89.1	85.7
Do do Lorenz..	115	111.5	107.6	104.0	100.6	97.3	94.2	91.1	88.2	85.1	82.6
Case II. Speed................	50	55.1	62.3	73.2	93.1	149.4					
Pressure, Unwin	115	104.3	92.3	78.6	61.8	38.5	0				
Do Lorenz..............	115	102.0	87.5	69.0	43.9	negative.					

The results are seen to be very satisfactorily confirmatory of each other.

The problem presented for solution in practice, however, is often different from that which we have just exemplified. In the cases just worked out, the initial pressure and velocity of the air, and the size of the pipe-line, or the quantity of air supplied to the main by the compressors per unit of time, form the data, and we are required to find the pressure at the motor end. On the other hand, we may be given the pressure desired at the motor-end, and the quantity of air to be delivered there per second (say), it being required to find the pressure at the compressor end when the size of the main is given.

Formula (11) must then be modified to suit. It will then read:

$$\frac{p'}{p''} = 1/\sqrt{\left[1 - \frac{L u_2^2}{74,300,000\, d}\right]} \qquad (12)$$

where u_2 is now the speed of the air at the motor instead of at the compressor end of the main. If we are given the quantity of air the motors are to use per second in cubic feet measured at pressure p'' lbs. per sq. in., then if q be this quantity, we must have: $0.7854\, d^2\, u_2 = q$, or $u_2 = q / 0.7854\, d^2$ ....(13)

Substituting this in the last expression we obtain:

$$\frac{p'}{p''} = 1/\sqrt{\left[1 - \frac{L q^2}{45,800,000\, d^5}\right]} \qquad (14)$$

Again, the expected indicated horse-power of the motor may be given, together with the nature of the expansion process under which the air will be used, and the pressure it is desired to employ at the motor end. Then if G lbs. be the weight of air supplied to the motors per second at temperature T'' (abs.) and pressure Q'' (atm. abs.), and if Wm ft. lbs. be the work per lb. of air which would be done by a motor working on the given system of expansion, without valve or other cylinder losses, then:

$$G\,Wm = 550\ IHP \qquad (15)$$

where IHP is the expected horse-power calculated from a theoretical card without valve or other loss. Now Q'', V'' and T'' being the pressure, volume and temperature of the air (units as before) and d the diameter of the pipe in feet, we have at once $V'' = T'' / 40\, Q''$ and $GV'' = 0.7854\, d^2\, u_2$; hence:

$$G = \pi\, d^2 \times 40\, Q''\, u_2 \,/\, 4\, T'' \qquad (16)$$

Eliminating G from (15) and (16), we get:

$$u = 9120 \frac{IHP}{Wm\ Q''\ d^2} \quad \text{.......................} (17)$$

This being substituted in (12) we have:

$$\frac{p'}{p''} = \frac{Q'}{Q''} = 1 / \sqrt{\left[1 - \frac{5910\ (IHP)^2\ l}{Wm^2\ Q''^2\ d^5}\right]} \quad \text{......} (18)$$

From this expression we know the ratio of the absolute pressures at the beginning and end of the main, in terms of the diameter and length of that main, and of the pressure at which the air is to be supplied to motors of a given horse-power, if we know the work that each pound of air may be expected to do in these motors under given conditions of expansion (*Wm*).

Before going further into the question of the losses in the main, we shall therefore look at the conditions of expansion in the motor as affecting the value of *Wm*, the amount of work to be got out of each lb. of air supplied and expanded.

A few words, however, may first be said about the question of the leakage which may be expected to take place from a compressed air main.

Loss by Leakage from Mains.—From the experiments of Gutermuth and Riedler on the mains of Paris, which are 10 miles long and 1 ft. in diameter, it appears that a loss of 2500 cu. ft. of air, measured at atmospheric pressure, took place per mile of main per hour when the pressure was 6 atmospheres by the gauge.

If we may assume that the joints are of similar construction in all sizes of pipes, and that there are an equal number of them in the same length of main whatever be the diameter, then the leakage will be proportional to the pressure-difference inside and outside of the pipe and to the length of jointed surface, *i.e.*, to the circumference of the pipe. We shall then have the approximate formula:

$$Z = \frac{2500\ p\ d}{90} = 28\ p\ d \quad \text{..........................} (19)$$

where Z is the number of cubic feet of air leaking from one mile of main of diameter d feet, the pressure in which is p lbs. per sq. inch above the atmosphere.

This quantity is lost by leakage *at all times*, irrespective of whether air is flowing in the pipes or not; so that it may form a large percentage of the air supply at times of minimum flow.

If the above law, that the leakage increases as the *diameter* of the pipe, be true, then since the quantity of air transmitted increases as the *area* of the pipe, *the percentage lost by leakage will diminish as the diameter of the main increases.*

In a one foot pipe, leak may be expected to take place at a rate equivalent to a loss of about one horse-power per mile of main for every one atmosphere of pressure by which the pressure in the pipe is in excess of the atmosphere.

We may now pass on to the

MOTORS.—The air having arrived at the delivery end of the main, with a pressure p'' and a volume per lb. V'' cu. ft., will return very varying quantities of work according to the way it is allowed to expand, that is, according to the style of motor in which it is used.

The most usual and the most interesting cases will here be illustrated by the following six examples:

Case I. The air may expand adiabatically in one stage.

Case II. It may expand in one stage with spray injection.

Case III. It may expand adiabatically in two stages, being warmed up to atmospheric temperature in an intermediate receiver. No heat must be credited to the motor for this intermediate warming, as all heat lost in the mains went to the atmosphere and is therefore fairly returnable here.

Case IV. The air may expand in two stages, with spray injection in each cylinder, and with intermediate warming from the atmosphere.

Case V. It may be preheated by passing through a stove before being allowed to expand in two stages adiabatically; preheating also taking place in the intermediate receiver.

Case VI. Lastly, the air may be doubly preheated as in Case V; but may also have a spray injection in each cylinder, which will materially help in maintaining the pressure during expansion.

A perfect motor would obviously be one which, receiving air at the temperature of surrounding bodies, would maintain it at that temperature during expansion. This would, as in the similar case of the compressor, necessitate an extremely slow expansion so as to give time for the heat to flow in from the atmosphere, and would of course be impossible in practice. This isothermal motor can only be used as a standard of comparison for actual motors when an amount of heat equal to the external work done by the motor during expansion has been made available by its previous loss to the atmosphere during transmission or compression. Clearly a perfect system of compressor, main, and motor, would be one having isothermal compression, no loss of pressure or increase of volume during transmission, and isothermal expansion, so that the motor card would have the exact area of the compressor card. In that case the heat rejected to the atmosphere by the compressor would be exactly equal to that absorbed by the motor. On the other hand, a system of adiabatic compressors and motors may also lay claim to perfection in so far as that the work done in the motor cylinder would be exactly equal to that in the compressor cylinders, if the mains could be prevented from losing any heat by carefully clothing them with non-conducting material.

This case does in fact happen more or less closely, when the main is very short. It is obviously, however, not the ideal system; as, besides the difficulty and expense of clothing the pipes, it would be necessary to make the main considerably larger on account of the greater volume occupied by the air at the higher temperature due to adiabatic compression.

Perfect Motor.—The work to be obtained from a perfect motor, in which the air must expand isothermally from the pressure of the main p'' to that of the atmosphere p° is:

$$Wmi = cT^{\circ} \log_e p'' / p^{\circ} = cT^{\circ} \log_e Q' \qquad \text{(8)};$$

the same formula as already given for a perfect compressor.

The work to be expected from a motor with any other system of expansion will be less than this; first, on account of the drop of pressure during expansion, due to the rate of heat supply being insufficient; and secondly, because of losses by wire-drawing through the valves, etc., which make the area of the card less than that of the ideal diagram corresponding to the given process of working.

The ratio of the area of this ideal diagram to the isothermal diagram of the same weight of air will be called *the efficiency of the process of expansion*, and will be denoted by the symbol Ee. The ratio of the actual card from the motor to that of the ideal diagram will, on the other hand, be called *diagram-factor* of the motor, and will be denoted by the symbol f''.

We shall now find the value of Ee, the efficiency of the expansion, for the six examples described above.

Case I. The work done up to the point of cut-off is $P''V''$. That done during expansion is $\frac{P''V'' - P^{\circ}V^{\circ}}{\gamma - 1}$, whilst that done by the atmosphere during exhaust is $P^{\circ}V''$; each of these quantities being in ft. lbs. per lb. of air. The work done on the whole is therefore:

$$Wma = \frac{\gamma}{\gamma-1}(P''V'' - P^{\circ}V^{\circ}) = c\frac{\gamma}{\gamma-1}\ (T'' - T^{\circ}) \ldots\ldots(20)$$

Also $T^{\circ} = T''\,(P^{\circ}\,/\,P'')^{\frac{\gamma-1}{\gamma}}$; so that in terms of P'', P° and T'' the work done in the motor, on the assumption of this ideal diagram with no valve or other losses, is:

$$Wma = cT''\ \frac{\gamma}{\gamma-1}\left[1-\left(\frac{P^{\circ}}{P''}\right)^{\frac{\gamma-1}{\gamma}}\right] \ldots\ldots\ldots\ldots(21)$$

denoting, as before, the fractional exponent by $1/m$, and the ratio of the initial to the final pressure by Q'', (21) may be written:

$$Wma = cT''\ \left[1-\left(\frac{1''}{Q''}\right)^{1/m}\right] \ldots\ldots\ldots\ \ldots\ldots\ldots\ldots(21)$$

The efficiency of the process of expansion is in this case:

$$Ee = \frac{Wma}{Wmi} = \frac{1 - (1/Q'')^{1/m}}{\log_e Q''}\,m \ldots\ldots\ldots\ldots\ldots\ldots\ (22)$$

E.G. If Q'' were 6.5 ($p'' = 96$ lbs. abs.), then:

$$Ee = \frac{3.5\,[1 - (1/6.5)^{1/3.5}]}{1.8718} = 0.77.$$

If the area of the actual motor card is three per cent. less than this ideal one on account of valve loss, then we should have $f'' = .97$ and $f'' \times Ee = 0.97 \times 0.77 = 0.746$, giving the efficiency of the actual motor relatively to a perfect one.

Case II. The only change in this case from the last is that γ becomes n, and if this latter be taken equal to 1.2 as in the case of the compressor m becomes 6. With $Q'' = .6.5$; we shall therefore have:

$$Ee = \frac{6\,[1-(1/6.5)^{1/6}]}{1.8718} = 0.86$$

and $f'' \times Ee = 0.97 \times 0.86 = 0.83$.

Case III. The formula for this case, that of a compound motor, is easily found after the same manner as for a compressor, and is :

$$W2ma = cT' \times 2m\left[1 - (1/Q'')^{1/2m}\right] \quad \ldots\ldots\ \ldots\ldots\ldots \quad (23)$$

where for this case m has the value 3.5. Thus for $Q'' = 6.5$ we get :

$$Ee = \frac{7\left[1 - (/6.5)^{1/7}\right]}{1.8718} = 0.878$$

$$\text{and } f'' \times Ee = 0.97 \times 0.878 = 0.85.$$

Case IV. Here the only change necessary is to put $m = 6$; which gives :

$$Ee = \frac{12\left[1 - (1/6.5)^{1/12}\right]}{1.8718} = 0.926$$

$$\text{and } f'' \times Ee = 0.97 \times 0.926 = 0.896.$$

Case V. If according to the stipulation of this case the entering air be heated from the temperature of the mains T'' to some higher temperature denoted by T, the pressure being kept constant during the process, then the volume of a pound will be :

$$V = V'' \frac{T}{T''};$$

and the only change required in expression No. (23) will be the substitution of T for T''; as in this case a two-fold expansion and heating up to T was agreed upon. Then we shall have :

$$Ee = W2pma = cT \times 2m\left[1 - (1/Q'')^{1/2m}\right] \ldots\ldots\ldots \quad (24)$$

The efficiency of this process of working will be :

$$Ee = \frac{W2pma}{Wmi} = \frac{cT \times 2m\left[1 - (1/Q'')^{1/2m}\right]}{cT'' \log_e Q''}.$$

For $Q'' = 6.5$, we have :

$$Ee = \frac{T}{T''} \quad \frac{2 \times 3.5\left[1 - (1/6.5)^{1/7}\right]}{1.8718} = 0.878 \times \frac{T}{T''}$$

so that the efficiency increases in proportion to the rise of temperature. If for example the air be heated from 60° F. to 400°F. (a temperature often attained in practice), we obtain :

$$Ee = \frac{861}{521} \times 0.878 = 1.48;$$

that is to say that the work done in this preheated motor is forty-eight per cent. greater than we can get from a perfect or isothermal motor. The quantity of fuel which must be expended in order to obtain this result is found in actual practice to be of a quite insignificant amount. Theoretically, it should only be (expressed in thermal units) 0.237 $(T - T'')$ per pound of air. It is found to be about 30 per cent. more than this, owing to radiation and chimney losses from the stoves.

Lastly, Case VI. Here the value of Ee is merely that of Case IV. multiplied by T/T''; and if this ratio be taken the same as for the last example, it is :

$$Ee = 1.65 \times 0.926 = 1.53.$$

Each of the efficiencies last obtained are subject to a deduction of three per cent. on account of valve loss ; but we see what a very large amount of additional work can be obtained by adding a small charge of heat just at the working point. This is the only form of energy transmission in which it is thus possible to inject, so to speak, a subsequent charge of energy sufficient to wipe out all the various losses due to transmission and imperfections of every other kind.

LECTURE III.

It will be useful and convenient to recapitulate and collect here the most important quantities and efficiencies dealt with in a transmission of power by compressed air. We have hitherto always used the quantities of work done by or upon one pound of air in the motor or compressor. For example, *Wmi*, the work which would be done by one lb. of air if used in a perfect isothermal motor; *W2pma* that done by a lb. in a doubly preheated motor, in which the air is expanded in two stages, both adiabatic and so on. For similar series of operations in the compressors the symbols would be *Wci* and *W2ca*; in the latter case the cooling corresponding to the preheating in the motor being tacitly assumed. Now, however, it will be preferable to compare the quantities at the various stages of the transmission by speaking of the horse-power developed at any such stage. This is, of course, easily obtained from the work per lb. by multiplying by the number of lbs. used per minute and dividing by 33,000.

Beginning from the motor end we have the following :

(1) Brake horse power of motor denoted by .... *BHP*
(2) Indicated horse power of motor from actual diagram... *IHP*

(3) Indicated horse power of motor from ideal diagram under given conditions of expansion........................ *ihp*

(4) Indicated horse power of motor (using same weight of air as actual motor) but preheated..................... *ihpp*

(5) Indicated horse power of motor (using same weight of air as actual motor) with isothermal expansion...... HP''

(6) Indicated horse power required by compressor (using same weight of air as motor but at other end of main) with isothermal compression.................... HP'

(7) Indicated horse power of compressor (using same weight of air as motor) from ideal diagram under given conditions of compression...................... *chp*

(8) Indicated horse power of compressor from actual diagram.. *CHP*

(9) Net horse power (brake horse power) delivered by turbine.. *THP*

(10) Gross horse power due to water flowing through turbine... *GHP*

The ratios of those quantities which are found to be most useful in practice are :

(*a*) Mechanical efficiency of motor........................ $\dfrac{BHP}{IHP} = Em''$

(*b*) Diagram-factor of motor............................... $\dfrac{IHP}{ihp} = f''$

(*c*) Efficiency of given process of expansion :—

$$\frac{Wma}{Wmi} \text{ or } \frac{Wpma}{Wmi} = \frac{ihp}{HP''} \text{ or } \frac{ihpp}{HP''} = Ee$$

(*d*) Ratio of areas of isothermal diagrams with and without preheating................................ $\dfrac{Wpmi}{Wmi} = r$

(*e*) Efficiency of pipe-line .... $\dfrac{HP''}{HP'} = Ep$

(*f*) Efficiency of given process of compression :—

$$\frac{Wci}{Wca} \text{ or } \frac{Wci}{W2cn} = \frac{HP'}{chp} = Ec$$

(*g*) Diagram factor of compressor........................ $\dfrac{chp}{CHP} = f'$

(*h*) Mechanical efficiency of compressor......... .... $\frac{CHP}{THP} = Em'$

(*i*) Efficiency of turbine.................................. $\frac{THP}{GHP} = Et$

(*j*) The total efficiency of the system of transmission $\frac{BHP}{THP} = E$

The last mentioned efficiency (being the ratio of the net horse power of the motor to that given by the turbine) is obviously the product of all the others or $E = Em'' \times f'' \times Ee \times Ep \times Ec \times f' \times Em'$. The problem of determining the efficiency of the transmission thus resolves itself into that of finding the values of the factors of which it is composed; and we therefore propose here to calculate and tabulate values of these efficiencies for a few cases which are likely to occur.

(*a*) *Em''* The mechanical efficiency of the motor will vary from 0.85 to 0.90, and will in our calculations be taken at 0.87.

(*b*) *f''* The ratio of the area of the actual motor diagram to the calculated or ideal area corresponding to the work *Wma* or *W2ma*, etc., will be assumed to be 0.95, a value usually obtained in good motors.

(*c*) *Ee*. This efficiency has already been calculated for half a dozen different methods of working, and was seen to vary from 0.77 to 1.50 when the pressure was 6.5 atmosphere absolute.

It will be remembered that the expression for *Ee* is

$$Ee = \frac{T}{T''} \; \frac{m\left[1 - (1/Q'')^{1/m}\right]}{\log_e Q''}$$

To facilitate the calculation of the innumerable different cases which may arise, the following diagram of values of $\left(\frac{1}{Q''}\right)^{\frac{1}{m}}$ has been prepared for values of Q'' from 5 to 35 atmosphere absolute and for the ordinary values of m that is $\frac{n}{n-1}$ (v. Fig. 4.)

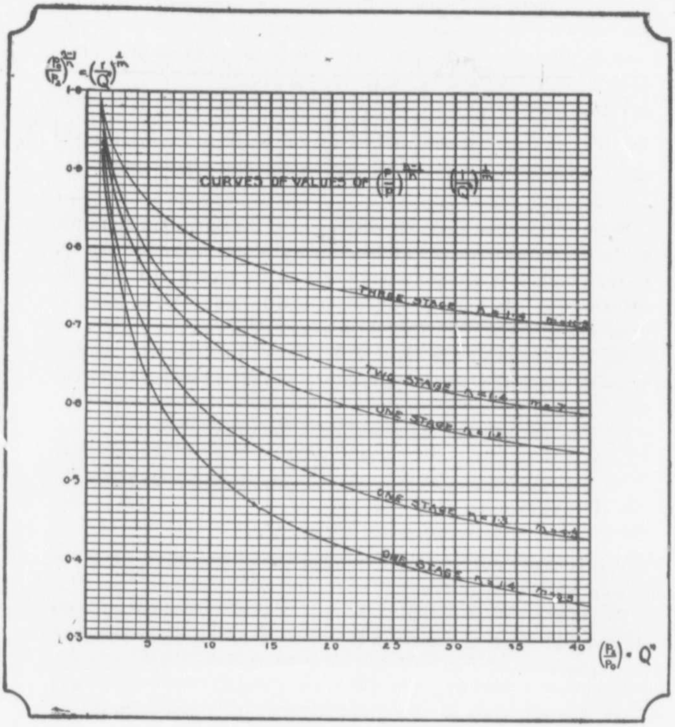


Fig. 4.

As an example of the use of this diagram it will be interesting to find the effect upon the value of *Ee* of variation of the pressure of supply Q''. Take a two stage adiabatic non-preheated motor (Case III ante). Here $n = 1.4$ $m = \frac{2n}{n-1} = \frac{2.8}{\cdot 4} = 7$, and $T = T''$;

and we have to find the value of $m \left[1 - (\frac{1}{Q''})^{1/m}\right]$ for $Q'' = 5, 10,$ 15, etc.

TABLE OF VALUES OF EFFICIENCY OF EXPANSION.

Q''	5	10	15	20	25	30	35	40
$m\left[1-(1/Q'')^{1/m}\right]$	1.44	1.96	2.25	2.44	2.58	2.69	2.79	2.86
$\log_e Q''$	1.609	2.303	2.708	2.996	3.219	3.401	3.555	3.689
Ee	.898	.852	.830	.815	.803	.793	.785	.776

From this we see that the efficiencies of the expansion diminish as the pressure increases; at first rapidly, afterwards more slowly. So that while it is advantageous so far as the size of the main is concerned to use high pressures, a loss in the motor is thereby incurred.

(*d*) This is simply the ratio T/T'', that of the absolute temperature to which the air is preheated, to that at which it arrives from the main.

(*e*) The efficiency of the pipe line is the ratio

$$\frac{Wmi \text{ at pressure } Q''}{Wmi \text{ at pressure } Q'} = \frac{cT''}{cT'}\frac{\log_e Q''}{\log_e Q'} \text{ which, if } T' = T'',$$
$$\text{is} = \log_e Q''/\log_e Q'.$$

This is easily got from tables of Naperian logarithms, if Q' be known when Q'' is given.

Formulæ (14) and (18) give the ratio of these quantities in terms either of the speed of the air in the pipe or of the horse power to be transmitted.

(*f*) The efficiency of the given process of compression is $\frac{Wci}{Wc}$ where Wc is a general expression for the work required on an ideal diagram for the given method. This is equal to :—

$$\frac{\log_e Q'}{m\left[Q'^{1/m}-1\right]}$$

and the diagram mentioned in Lecture I may be used to facilitate its calculation.

As an example we may show the effect of variation of pressure on the efficiency of a two stage adiabatic compression for the same range as was worked out for (*c*).

TABLE OF VALUES OF EFFICIENCY OF COMPRESSION.

(Two stage adiabatic compression.)

Q'	5	10	15	20	25	30	35	40
$7\left[Q'^{1/7} - 1\right]$	1.792	72.73	3.32	3.75	4.10	4.37	4.64	
$\log_e Q'$	1.609	2.303	2.708	2.996	3.219	3.401	3.550	
Ec	.896	.844	.815	.799	.785	.780	.766	
(Two stage spray-cooled compression.)								
Ec	.906	.893	.883	.874	.866	.859	.855	

From which we see that the effect upon the efficiency of compression of a variation of pressure is similar to what it is upon the efficiency of expansion.

(*g*) The diagram factor of the compressor will be taken 0.95.

(*h*) The mechanical efficiency of the compressor will be taken the same as that of the motor, 0.87.

(*i*) The efficiency of the turbine need not be entered into here, except that it ought to be emphasized that, as a general rule, the turbine shaft *can be directly coupled to an air compressor ;* whereas it must usually be geared up to a dynamo, unless the fall is very great. This is a serious drawback to the electric method. It involves a loss of at least eight per cent. of the power of the turbine more than need take place in the case of the direct-coupled compressor. A good plan in the event of turbines being employed with vertical shafts is to group the compressor cylinders at angles of 120° to each other (in plan) round the shaft, the connecting-rods all working on the same crank-pin.

EXAMPLE OF TRANSMISSION.—We may now take a numerical example of a complete transmission, and tabulate our results. Let it be required to find the best size of pipe-line to transmit 5000 brake horse power to distances of 5, 10, 15 and 20 miles ; the pressure of the air at the motors being ($Q'' = 10$) 132 lbs. per sq. in. by the gauge. In estimating the total cost of the installation, we shall take the prices as follows:—The pipes will cost for supply, distributing, trenching, laying jointing, and filling \$ (1340*D*—6500) per mile ; if strong enough to stand a test-pressure of 700 lbs. per square inch. Here *D* is the diameter of bore in inches.

The compressors will cost, with reservoirs and spray-cooling apparatus complete, $15 per net turbine-horse-power, at 10 atmospheres pressure ; and $5 more per *THP* for every additional 20 atmospheres in excess of the first 10. They will thus cost $15 + 0.25\ (Q' - 10) = 12.5 + 25Q'$ per *THP*.

The air-motors will cost $12.50 per actually indicated horse-power, and $15 per *IHP* when fitted with preheaters.

The turbines and wheel-pits will cost about $15.00 per *THP* ; and there is a constant quantity (*i.e.*, one independent of the turbine horse power) to be added for land, dam, races, gates, waste-weir, and power house, amounting on the average to $25.00 per turbine horse power. These last figures are hardly necessary to us, as this expenditure would be equally incurred whatever the method of transformation and transmission might be.

The tables which follow, giving the numerical results of this and other transmissions, are almost self-explanatory. It may, however, be pointed out that column 5 is the product of the figures in the first four columns. *E* is, as above defined, the total efficiency ; and is obtained by multiplying together columns 5, 6, 10 and 11. Col. 13 gives the horse power required at the turbine, and is got by dividing 5000 by *E*. The last column gives the total first cost of the installation, including of course the price of the motors which is constant and is taken at $75,000. There is seen to be a size of pipe in each case giving the minimum cost.

In order to decide quickly on the best sizes of pipe to be worked out so as to arrive at this minimum, it is best to find first the impossible size, *i.e.*, the value of *d* which just makes the denominator of the fraction in expression (18) equal to nothing, afterwards trying the next few larger even sizes.

5000 *BHP* TRANSMISSION $Q'' = 10$.(132 lbs. gauge).

Friction and Valve-losses.					*Ee*	*D* ins.	*Q''/Q'*	*Q'*	*Ep*	*Ec*	*E*	*THP*	Cost of.		
Em''	*f''*	*f'*	*Em'*	Together.									Compser $		Total $
CASE I.—Distance 5 miles.															
.87	.95	.95	.87	.90	.852	15.6	Impos	sible	–	–	–	–	–	–	Motors $75,000
						16	.36	27.8	.693	.869	.358	13950	272000	74700	421700
						17	.60	16.6	.820	.890	.434	11500	192000	81500	328500
						18	.72	13.9	.876	.896	.468	10650	170000	88000	333000
CASE II.—10 miles.															
.87	.95	.95	.87	.70	.852	17.9	Impos	sible	–	–	–	–	–	–	Motors $75,000
						18.5	.40	25.0	.716	.874	.372	13400	250000	183000	508000
						19.5	.59	16.9	.815	.889	.431	11600	194000	196000	465000
						20.5	.70	14.2	.870	.895	.464	10780	172000	210000	457000
						21.0	.74	13.4	.890	.897	.476	10500	166000	216000	457000
CASE III.—15 miles.															
.87	.95	.95	.87	.70	.852	19.4	Impos	sible	–	–	–	–	–	–	Motors $75,000
						20	.38	26.5	.704	.871	.365	13700	260000	304200	639000
						21	.58	17.2	.810	.888	.429	11650	196000	324000	595000
						22	.67	14.8	.855	.894	.456	10950	177500	345000	547500
						23	.76	13.2	.894	.897	.478	10450	164500	364000	603500
CASE IV.—20 miles.															
.87	.95	.95	.87	.70	.852	20.5	Impos	sible	–	–	–	–	–	–	Motors $75,000
						21	.32	30.8	.672	.865	.346	14450	292000	432000	799000
						22	.54	18.6	.787	.886	.416	12000	205000	460000	740000
						23	.66	15.2	.846	.893	.451	11100	181000	486000	742000

G

LECTURE IV.

The compression of air by the direct action of falling water has recently been brought to a successful issue by Mr. C. H. Taylor, of this city (Montreal). There is no moving machinery, and practically no expense for maintenance or attendance.

The water is conveyed to the compressor by means of an open flume; or, as shown in the diagram, through a pipe supplying a tank or stand pipe round the headpiece of the compressor, where it can attain the same level as the water in the dam or source of supply.

Around the headpiece are placed a large number of small horizontal air-pipes, drawing their supply of air through large vertical pipes, which extend above the surface of the water and open to the atmosphere.

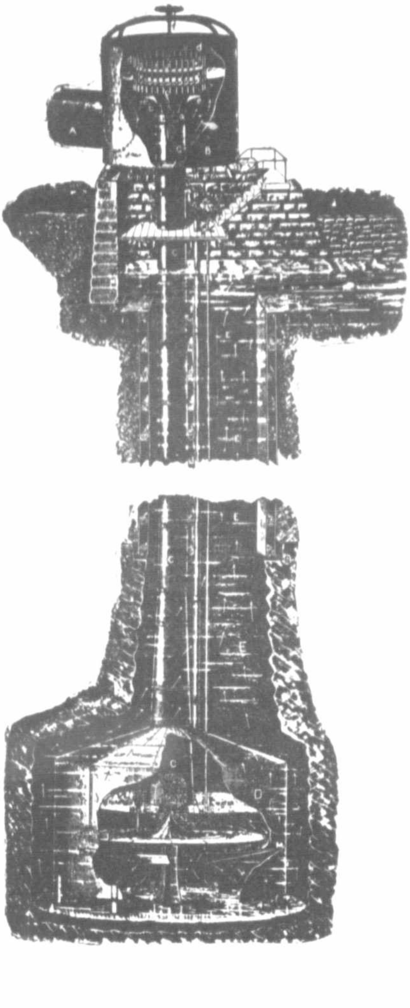
As the water enters the down flow pipe and passes the ends of these small air pipes, it draws in the air constantly in the form of small uniform globules, which, becoming entangled in the descending water, are carried down to the air-chamber at the bottom of the pipe, compressing the air by the pressure of the water surrounding these globules, according to their depth below tail-race water level until they reach the point of separation. The pressure on the air is then maintained so long as any air remains in the air-chamber.

The receiver or air-chamber at the bottom of the compressor is sufficiently large to allow the air to rise to the surface of the water therein; from thence it is taken through the air pipe for transmission.

Should the volume of air taken down be greater than that being used, it accumulates in the air-chamber until it forces the water below the lower end of the receiver, and the surplus air passes up with the return water, thereby forming an automatic safety valve.

The material used in the construction of the down-flow pipe need only be of sufficient strength to carry the pressure due to the working head of the water, as, once it reaches the tail-race level, the internal pressure is counteracted from that point down by the external pressure of the return water, so that any compression of air may be obtained without increasing the strength of the down-flow pipe. The material for the down-flow pipe may be of iron or wood hooped with iron, and the shaft may be constructed of a cheap grade of timber, and as the timber is preserved by being constantly in the water there is practically no limit to its durability.

By reference to the diagram it will be noticed that the head piece is telescoped into the down-flow pipe and raised by means of a hand



wheel on top to permit of its being regulated, so as to furnish water, from one-third up to its full capacity; or the head piece can be raised above the water level and the flow of water stopped.

By means of side screws or bolts the area of the inlet to the down pipe may be increased or diminished so as to regulate the speed of the water past the end of the air pipes, and can then be fixed permanently at the most efficient working point. At the bottom of the down-flow pipe is an upright cone which turns the course of the water towards the circumference of the air-chamber, thus facilitating the escape of the air from the water; while round the circumference, to turn the course of the water back towards the centre, as indicated by arrows, is a deflecting apron, under which any air then in the water is caught and conveyed through a small pipe to the main body of air in the air-chamber.

The annexed drawing shows a complete compressor, its details being as follows :—

A. Penstock, or water supply pipe.

B. Receiving tank for water.

C. Compressing pipe.

D. Air-chamber and separating tank.

E. Shaft, or well, for return water. (The required pressure is proportional to the depth of the water in this shaft.)

F. Tail-race for discharge water.

G. Timbering to support earth.

H. Blow-off pipe.

I. Compressed air main.

J. Head piece, consisting of:—

a. Telescoping pipe, with

b. Bell-mouth casting opening upwards.

c. Cylindrical and conoidal casting.

d. Vertical air supply pipes. (Each pipe has at its lower end a number of smaller air inlet pipes branching from it towards the centre of the compressing pipe.)

e. Adjusting screws for varying the area of water inlet.

f. Hand-wheel and screw for raising the whole head piece.

K. Disperser.

L. Apron.

M. Pipes to allow of the escape of air from beneath apron and disperser.

N. Legs by which the separating tank is raised above the bottom of the shaft to allow of egress of water.

P. Automatic regulating valve.

The water is conveyed to the tank *B* through the penstock *A*, where it rises to nearly the level as the source of supply. In order to start the compressor the head piece *J* must be lowered by means of the hand-wheel *f*, so that the water may be admitted between the two castings *b* and *c*. The supply of water to the compressor, and consequently the quantity of compressed air obtained, is governed by the depth to which the head piece is lowered into the water. The water enters the compressing pipe between the two castings *b* and *c*, passing among and in the same direction as the small air inlet pipes. A partial vacuum is created by the water at the ends of these small pipes, and hence atmospheric pressure drives the air into the water in innumerable small bubbles, which are carried by the water down the compressing pipe *C*. During their downward course with the water the bubbles are compressed, the final pressure being proportional to the column of return water sustained in the shaft *E* and tail-race *F*.

When they reached the disperser K, their direction of motion is changed, along with that of the water, from the vertical to the horizontal. The disperser directs the mixed water and air towards the circumference of the separating tank D. Its direction is again changed towards the centre by the apron L. From thence the water flows outward, and, free of air, passes under the lower edge of the separating tank. During this process of travel in the separating tank, which is slow compared with the motion in the compressing pipe C, the air by its buoyancy has been rising through the water and pipes M, M, from under the apron and disperser, to the top of the air chamber D, where it displaces the water. The air in the chamber is kept under a nearly uniform pressure by the weight of the return water in the shaft and tail-race.

The air is conveyed through the main I up the shaft to the automatic regulating valve, and from thence to the engines, etc.

In 1894 the author subjected this system to a prolonged series of trials, made with models varying in size from 1 to 3 inches dia. of down pipe, and obtained therefrom efficiencies of from 50 to 55 p. c. He at that time indicated that the system might be made a success techically on a large scale.

When the first plant was put in (of 150 I.H.P.) at Magog, P.Q., Prof. McLeod, of this Society, was requested to make tests of the installation. This he did, and the results of his work are reproduced by his permission in the accompanying table.

RESULTS OF TRIALS OF THE TAYLOR HYDRAULIC AIR COMPRESSOR AT MAGOG, P.Q., ON AUGUST 7TH AND 13TH, 1896.

No. of Trial.	Quantity of water discharged in cubic feet per minute.	Available head in feet.	Available horse-power.	Quantity of air delivered in cub. ft. per minute at atmospheric pressure.	Pressure of air in compressor.	Actual horse-power of compressor.	Efficiency of compressor.	Temperatures.		
								External air.	Water.	Compressed air.
1	6,122	21.4	247.7	1,377	52	132.5	53.5	79	75.2	75.2
2	5,504	21.9	228.0	1,363	52	131.0	57.5	83	75.5	75.5
3	4,005	22.3	168.9	1,095	52	105.3	62.4	80	75.6	75.6
4	7,662	21.1	305.9	1,616	52	155.4	50.8	75	80.0	80.0
5	6,312	21.7	260.0	1,506	52	144.8	55.7	77	80.0	80.0
6	7,494	21.2	299.8	1,560	52	150.2	50.1	75	80.0	80.0

LECTURES V AND VI.

THE DISTRIBUTION OF POWER BY STEAM.

Examples of Power Distribution by means of Steam to small distances are found in almost every factory. In these lectures, however, the author deals briefly with cases in which the area of supply is greater and the amount of steam used more considerable than is usual in single factories. As instances of such installations may be taken the systems of steam supply from central stations employed at the cities of New York, and Syracuse, N. Y. In such cases the maximum distance of transmission for economy under ordinary conditions appears to be about one mile. The chief source of loss is condensation, and efficiency diminishes rapidly as distance increases, especially since the loss is a constant one whatever the amount of steam passing. Taking losses as actually found in New York the efficiency at full load for 1 mile of main is about 0·78, but at ¼ load it becomes only 0·47, *i. e.*, to deliver 500 H.P. through 1 mile of main capable of carrying 2,000 H.P., we must supply sufficient steam for 1,050 H.P., the loss on that length being about 550 H.P., this allowance including both leakage and condensation losses.

Among the advantages of central station steam supply may be mentioned the facts that steam is of course generated more cheaply in large stations than by small individual consumers, while the trouble and cost of handling coal and ashes are proportionately diminished.

The exhaust steam from a large power supply is available for heating purposes, and the most successful installations have been those in which the exhaust has been thus used.

The leading particulars of the power supply installations mentioned above are as follows :--

NEW YORK STEAM COMPANY (STATION B.)

The boilers are of the Babcock & Wilcox Type of 250 H.P. each, suited for 80 lbs. working pressure. The total capacity is 13,000 H.P., to be increased if required to 16,000 H.P.

The mains vary from 16″ to 11″ diameter and about 5½ miles are laid. The pipes are of welded wrought-iron about ¼″ thick, and have cast-iron flanges jointed with corrugated copper rings.

Special expansion joints or variators with copper membranes are fitted every 50 feet to allow for the effect of alteration of temperature. The bends and crossings are securely anchored to masonry.

The pipes are laid on brick supports in trenches lined with brick-work, and are then lagged by packing slagwool round the pipe. The trenches are roofed with planks and tarred paper, and then filled in. As far as possible the pipes are drained towards boiler-house.

Traps are provided wherever water can accumulate, and discharge it into return mains. Steam is sold by meter, the meters giving diagrams of which the ordinates are proportional to the rate of flow, and from which the amount of steam is calculated. About 2,800 lbs. per mile of pipe per hour are lost by leakage, and about 1,400 lbs. per mile per hour by condensation. The leakage loss is large on account of the inaccessibility of the joints on the pipe line in many places.

It was originally intended to return all condensed water to the boilers by a separate condensed water return main, but the use of this pipe had to be discontinued as corrosion was excessive. From this and other instances it appears that iron is specially liable to corrosion from the action of hot water at a temperature of about 212° F.

From figures given by Dr. Emery, for the year 1891, it would appear that for the whole year the average steam supplied did not exceed about 0·26 of the capacity of the station. About 75 per cent. of the steam was used for power purposes, the remainder being employed for heating only, and the waste steam was discharged into the atmosphere, while the condensed water escaped to the sewers. The station was set to work in 1881.

AMERICAN DISTRICT STEAM COMPANY AT SYRACUSE, N.Y.

The Babcock & Wilcox boilers are of 200 H.P. each, and work at a pressure of 70 lbs. per square inch during the day, and at a reduced pressure at night. The steam is employed for both power and heating.

The mains are 12″ diameter and about 2½ miles are laid, the furthest point being 1 mile from station. The pipes are wrought-iron and have screwed flanges. Variators are fitted every 50 feet, as in New York.

The pipes are lagged with 1″ asbestos yarn, outside which is a wood casing tarred and laid in a brick trench. All stop valves and variators are accessible, while the main forms a complete steam ring. The water evaporated is in summer about 75,000 gallons per 24 hours; in winter about 140,000 gallons per 24 hours.

The annexed tables give the results of working in the two instances selected. The "capacity factor" is the ratio of the actual amount of steam supplied during the whole year to the capacity of the plant, as distinguished from the "load factor," which is the ratio of the mean supply during any given period to the maximum supply during that period. It is evident that the financial success of the installation depends on the capacity factor rather than on the load factor, and this point will be again referred to.

PARTICULARS OF STEAM STATIONS.

New York Steam Co.—Station B.

Capacity of station in 1891	13,000 H. P.
Average H. P. sold through year	2,100 "
Loss from leakage and radiation	1,200 "
Coal burnt per day (average)	200 tons.
Steam speed in main	4,800 ft. per min.
"Capacity factor"	0.16
Total cost of works	$1,600,000.00
Price of 1 H. P. for 3,090 hours (average)	50.00
" " 1,000 lbs. steam for heating	.55

American District Steam Co.—Station at Syracuse, N.Y.

Capacity of station in 1893	2,500 H. P.
Average H. P. sold through year	1,000 "
Loss from leakage and radiation	350 "
Coal burnt per day (average)	65 tons.
Steam speed in main	9,000 ft. per min.
"Capacity factor"	0.4
Total cost of works	$240,000.00
Price of 1 H. P. for 3,090 hours (average)	not given.
" " heat per sq. ft. of heating surface per year	$0.50

It will be noted that the conditions necessary for a successful steam distribution are briefly the following :—

(*a*) Demand for power and heat within a somewhat limited area.

(*b*) Suitable position for station near rail and river or canal, and within the area of supply or close to it.

(*c*) Main a complete ring ; joints, etc., accessible, carefully lagged, and leakage minimised.

(*d*) Exhaust steam sold for heating purposes where possible.

(*e*) Condensed water returned to boilers by return main.

(*f*) Waste of fuel avoided as far as possible by uniform load.

The first four conditions do not call for special remark. With regard to the return main it seems probable that corrosion could be avoided by the use of a brass pipe, and the cost of such a main would be justified by the saving effected in coal consumption due to the higher temperature of the feed water.

The sixth condition requires further consideration. It is obvious that in a central power or heating station the boilers must be capable of supplying steam at a rate much in excess of the average. The figures already given, for instance, show that in Syracuse the mean amount of steam supplied is only 0.4 of that which the boilers are capable of furnishing. Evidently if it were possible to render the demand for steam more uniform, the first cost of the plant might be considerably reduced, while the total output would not be diminished.

The uniformity or otherwise of the load depends in any given case largely on local conditions. It is, however, possible to diminish the first cost and working expenses of a boiler installation working with a variable load by employing one of the systems of Thermal Storage suggested by Mr. Druitt Halpin. Mr. Halpin's object was, by storing heat, to enable boilers to maintain a more or less uniform rate of evaporation, while supplying a variable demand for steam.

There are two methods of doing this :—

(*a*) *Feed Storage.* Closed feed tanks, working under boiler pressure, and large enough to take all the feed the boilers will require during the time of heavy load, contain water which is warmed by the circulation of surplus steam during periods of light load. For example, a tank of 8 ft. dia. × 30 ft. will contain an available supply of 75,000 lbs. of water. Supposing the heavy load lasted for 12 hours, each tank would contain sufficient hot feed water to supply say 200 H. P. for that time. During heavy load the boilers would have simply to evaporate the water from their own temperature, no feed being then supplied except from the tanks. It will be observed that this system does not make the rate of evaporation quite uniform, but lightens the work of the boilers when under heavy load, and increases it during light load.

(*b*) *Steam Storage.*—Feed tanks are provided which are closed, and together with the boilers are worked at a pressure 100 to 150 lbs. per square inch above the steam pressure in the pipe main. The system forms practically one large boiler, such that, during heavy load, steam can be generated at the expense of the heat stored in the water without increasing the rate at which heat is supplied by the furnaces.

The water level during this time will fall, and so will the pressure and temperature in the boiler. All steam is taken from the tanks through a reducing valve, and the rate of firing is uniform. Each pound of hot water at this high pressure can furnish one-sixteenth to one-twentieth of a pound of steam, hence one tank of the above dimensions will supply about 4,600 lbs. of steam or $12\frac{1}{2}$ H. P. for 12 hours.

Before attempting to determine the size of main and approximate cost of a steam distribution for a given case, it will be well to form an idea of the variation of load to be expected. A station supplying steam from a central station for use by small consumers of power for such purposes as driving small workshops, lifts, and the machinery scattered throughout the busy portion of a large city, would experience a large and fairly uniform demand during the hours from say six a.m. until five or six p.m., after which the demand would be much smaller and more fluctuating in character. A diagram for such a station capable of supplying 2,000 H. P. would then have a load diagram for an ordinary working-day something like that shown on Figure 6. Some-

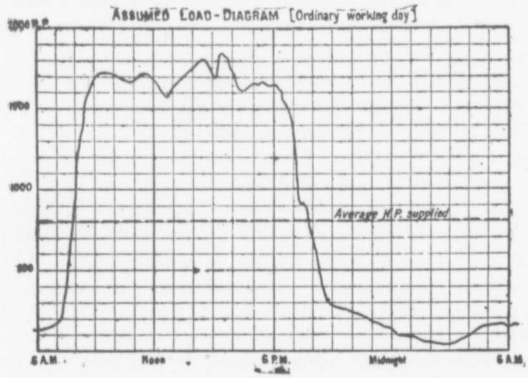


Fig. 6.

what similar diagrams are actually obtained, for instance, from the London Hydraulic Power Company's station. On holidays and Sundays the diagram is a smaller one. From experience it may be estimated that for a station of the capacity and kind mentioned above, the mean H. P. supplied during the 24 hours would be, for an ordinary working-day, 800 H. P., and taking the average over a whole year, about 520 H. P. These figures must be borne in mind in dealing with the cost and working expenses of the imaginary power station for which calculations will now be made.

SIZE OF STEAM MAIN.

The diameter of a long steam pipe delivering a given weight of steam with a given difference of pressure between the two ends may be determined with sufficient accuracy for practical purposes by a modification of the formula used in the case of a long main for compressed air; expressions for the latter were worked out by Grashof in 1875 and Unwin in 1876.

Let P_1 and P_2 be the absolute pressures in lbs. per square foot,
V_1 V_2 the volumes of one pound of steam in cubic feet,
H_1 H_2 the kinetic energies of one pound of steam, at the beginning and end of the main respectively.

Also let W = weight of steam delivered in pounds per second,
L = length of main in feet,
ζ = coefficient of friction of steam in the pipe,
and d = diameter of pipe in feet.

Consider the way in which the total energy of one pound of the steam changes its form in passing along a small length δL of the pipe, and suppose the pressure P of the steam changes by a small amount δP, its kinetic energy H by a small amount δH, while at the same time an amount of work δR is wasted in friction against the inner surface of the pipe. We assume that the pipe is laid horizontally so that difference of level need not be taken into account. If the volume of the pound of steam be V to commence with, it may be shown that in passing along the length δL the internal energy of the pound changes by an amount $V \delta P$ and, further, that this change of internal energy is accounted for by the corresponding change in kinetic energy and by the work done in friction. This is expressed in mathematical form by the equation

$$V \delta P + \delta H + \delta R = 0 \quad \text{.........................(1)}$$

We shall assume that in passing along the pipe, the pressure and volume of the steam are connected by the relation $P\ V^n =$ constant, hence

$$V = V_1 \left(\frac{P_1}{P}\right)^{\frac{1}{n}} \text{.................................(2)}$$

Again, the work done against friction is given by the well-known expression

$$\delta R = \frac{4\ \zeta\ H}{d} \delta\ \ L \text{.................................(3)}$$

$\frac{d}{4}$ being the hydraulic mean depth for a pipe of circular section.

The speed of steam in the pipe is evidently $\frac{W\,V}{A}$ where A is the area of cross section, hence the kinetic energy of one pound is $\frac{W^2\ V^2}{2g\ A^2}$ or

$$H = \frac{W^2}{2g\ A^2}\ \ V_1{}^2 \left(\frac{P_1}{P}\right)^{\frac{2}{n}} \text{....................(4)}$$

On substituting from (2) and (3) in equation (1) we get

$$V_1 \left(\frac{P_1}{P}\right)^{\frac{1}{n}} \delta P + \delta H + \frac{4\ \zeta\ H}{d}\ \ \delta\ L = O$$

or, dividing by H and substituting its value from (4)

$$\frac{2g\ A^2}{W^2 V_1} \left(\frac{P}{P_1}\right)^{\frac{1}{n}} \delta P + \frac{1}{H}\ \delta H + \frac{4\ \zeta}{d}\ \ \delta\ L = O \text{............(5)}$$

Equation (5) expresses the changes that take place while one pound of steam passes along a small length δL of the main; to apply this result to the whole pipe of length L we must proceed to the limit, integrate, and we obtain

$$\frac{2g\ A^2}{W^2 V_1} \cdot \frac{n}{n+1} \left\{ \left(\frac{P_2{}^{n+1}}{P_1}\right)^{\frac{1}{n}} - P_1 \right\} + \log_e \frac{H_2}{H_1} + \frac{4\zeta}{d}\ L = O$$

Now from equation (4) it may be shown that

$$\frac{H_2}{H_1} = \left(\frac{P_1}{P_2}\right)^{\frac{2}{n}}$$

hence

$$\frac{2g\ A^2}{W^2 V_1} \cdot \frac{n}{n+1} \left\{ \left(\frac{P_2{}^{n+1}}{P_1}\right)^{\frac{1}{n}} - P_1 \right\} + \frac{2}{n}\ \log_e \frac{P_1}{P_2} + \frac{4\ \zeta}{d}\ L = O \text{....(6)}$$

In order to work with this equation we must know the values of n and ζ, and it may be noted that for any range of pressure likely to be met with in practice $\log_e \frac{P_1}{P_2}$ is a very small quantity compared with either of the other two terms in the equation, and may therefore be neglected in further calculations.

We shall take $n = 1$ and $\zeta = .003$ (as for air), data as to the actual values of these quantities not being available. Putting $.7854\ d^2$ for A we now get as a working formula

$$\frac{19 \cdot 85\ d^4}{W^2 P_1 V_1} \left(P_2^2 - P_1^2\right) + \cdot 012 \frac{L}{d} = O \text{ .... } (7)$$

This expression takes no account of heat lost by radiation, or of condensation, but as the amount of steam passing is only known approximately, and in steam stations the main only has to deliver its maximum amount occasionally, a greater degree of exactness in obtaining the diameter of the pipe would in most cases be unnecessary in practice.

CALCULATIONS FOR A STEAM STATION.

We may take as a definite example for calculation the case of a station supplying steam for 2,000 H.P. in the City of Montreal, the boiler pressure being 90 lbs. per square inch by gauge, and the loss of pressure in the main not exceeding 10 lbs. per square inch per half mile of pipe. Under these circumstances. :—

P_1 = 105 lbs. per sq. inch abs. = 15,120 lbs. per sq. foot absolute.
P_2 = 95 " " " " " = 13,680 " " " " "
L = half a mile or 2,640 feet.
$P_1 V_1$ = 63,150 ft. lbs. per pound.

On substituting these numbers in (7) we get

$$W = 20\ d^{\frac{5}{2}}$$

giving the relation between the diameter of pipe and weight of steam passing under the above conditions, which are nearly those originally intended at New York.

The rule obtained in a different fashion by Dr. Emery and used at New York corresponded to

$$W = 14\ d^{\frac{5}{2}}$$

and gave a size of pipe which appears unnecessarily large. This is borne out by experience in later installations.

Loss from condensation.—The following table gives *approximately* the No. of B.T.U. lost per sq. foot of pipe per hour, with various kinds and thicknesses of pipe covering. The figures given are derived from the comparison of a number of published experiments.

B. T. U. LOST PER SQ. FT. OF SURFACE PER HOUR—(Approximate)

Dia. Pipe.	½″ thick.			1″ thick.			2″ thick.			4″ thick.		
	Felt.	Slag Wool.	Asbesto	Felt.	Slag Wool.	Asbestos	Felt.	Slag Wool.	Asbestos	Felt.	Slag Wool	Asbestos
6″	119	202	298	70	119	175	42	71	105	26	44	65
8″	105	179	263	61	104	153	36	61	90	22	37	55
12″	96	163	240	59	100	148	31	53	77	19	32	47

Temperature of steam 320° F. Temperature of air 60° F.

In the present case, suppose the pipe is 12″ dia. and lagged with the equivalent of 2″ of slag wool, we may assume a loss of 60 B.T.U. per hour, which for 1 mile of pipe gives

Heat lost = 995,000 B.T.U. per hour,

corresponding to the condensation of nearly 1,200 lbs. of steam per hour.

Loss from leakage.—This depends on design and workmanship, and in New York was about 2,800 lbs. per mile of pipe per hour. We shall take it at 1,000 lbs. per mile of pipe per hour giving a total loss of 2,200 lbs. per mile per hour, or about 73 H.P.

Further data for calculations.

H. P. delivered..2,000.
Boiler pressure .... 90 lbs. per sq. in. by gauge.
Least pressure in main..................80 lbs. per sq. in. by gauge.
Area of supply.............. ....1 mile × ¾ mile.
Length of main................................ ....5 miles.
Number of consumers................ .. ..150.
Loss from condensation and leakage............... ....400 H.P.
Power used for station purposes .... 50 H.P.
Capacity of boilers....... .... 2,450 H.P.

The steam pipe is to form a complete ring through the principal streets, and an exhaust main is to be provided for supplying steam for heating purposes at low pressure, while condensed water is to be returned to the boilers by a brass main. The size of steam main is found as follows :—

Allowing 30 lbs. of steam per H.P. per hour, the main must carry

$$2{,}400 \times \frac{30}{3{,}600} = 20 \text{ lbs. per second.}$$

Its diameter is, therefore, given by

$$20 = 20\, d^{\frac{5}{2}}$$

from which $d = 1$ foot.

The steam speed at beginning of main will be

$$\frac{4.18 \times 20 \times 60}{0.7854}$$

$$= 6{,}400 \text{ ft. per minute.}$$

(The volume of 1 lb. steam at 105 lbs. per square inch absolute is 4.18 cu. ft.)

For the pipe line will be required about

				Weight
2 miles of	12″	wrought pipe ¼″ thick	}	335 tons.
3 "	6″	" " " "		
3 "	1″ to 3″	" " " "		
2 "	4″	brass pipe ⅛″ thick		64,000 lbs.
2 "	7″	cast iron pipe.		

ESTIMATED COST OF PIPE LINE COMPLETE.

Quantity.	Description.	Rate.	Total.
335 tons.	Wrought iron pipe various sizes.	$70	$23,450
64,000 lbs.	4″ brass pipe...................	20 cts.	12,800
11,000 ft.	7″ cast iron pipe................	60 cts.	6,600
50 tons.	Cast iron flanges and fittings....	$90	4,500
12½ tons.	Bolts and nuts for jointing......	160	2,000
	Jointing materials..............	....	500
250	Variators and crossings.........	30	7,500
1,000	Stop valves various sizes......	3.50	3,500
100	Steam traps	25	2,500
150	Meters.........................	20	3,000
15,000 ft.	Trenching complete, including distributing and laying pipes, lagging, brickwork, and making good......	$4	60,000
	Incidental expenses, say..	....	10,000
	Total....................	....	$136,350

Boiler House, etc.—Land suitable for the purpose, not on a main street, could probably be obtained in Montreal for 50 to 75 cents per square foot, and about 3,500 square feet would be required.

Boilers of the Babcock & Wilcox type would cost about $20 per H. P. and say $5 per H. P. additional for setting.

COST OF POWER STATION COMPLETE.

Quantity.	Description.	Rate.	Total.
2,450 H. P.	10 Babcock boilers.............	$20	$49,000
	Setting "	5	12,250
10	Feed pumps complete...........	500	5,000
	Coal hoisting gear.............		500
	Feed tanks and connections.....		1,700
3,500 *ft.*	Land for station...............	0.75	2,625
2,450 H. P.	Buildings and chimney........	6	14,700
	Legal expenses and incidental...	....	2,000
	Total.....................	....	$87,775

The total capital expended would be

Pipe line complete	$136,350
Power station complete....................................	87,775
Salaries and superintendence during construction.............	8,000
Incidental expenses, say....................................	5,000
Total..	$237,125

Say $238,000.

The annual charges will include both fixed expenses and station expenses, the largest item being coal.

We may expect that the average H.P. sent out for every hour in the year will be at least 0.26 of 2000, or 520, corresponding to a total sale of 4,550,000 H.P. hours per annum, while (400 × 365 × 24 =) 3,550,000 H. P. hours are lost by leakage and radiation and say (50 × 365 × 24 =) 438,000 are used for station purposes.

Then total No. of H.P. hours = 8,538,000 per annum.
H. P. hours sold = 4,550,000 " "
Lbs. of coal burnt (at 4 lbs.
per H. P. hour) = 34,152,000 " "
(or say 17,000 tons of 2,000 lbs.
Coal used for banked fires = say 100 tons.

Depreciation may be reckoned on $225,000, the approximate cost of station and pipe-line.

ANNUAL CHARGES.

	Rate.	Amount.
Fixed expenses—		
Interest on $238,000	5%	$11,900
Depreciation on $225,000	5%	11,150
Taxes and insurance	2%	4,500
Salaries and office expenses	....	8,000
Station expenses—		
Repairs on $225,000	5%	11,150
Water and gas	....	500
17,100 tons coal, including cartage and handling ashes	$3.50	59,850
Wages	0.40	6,840
Stores and sundries	....	2,500
Total	....	$116,390

To render the station financially successful it would be necessary to sell the power at $21 per 1,000 H. P. hours, and a portion of the exhaust steam for heating purposes at 30cts. per 1,000 lbs. We should then have the following

ANNUAL RECEIPTS.

Steam sold for power:—	
4,550,000 H. P. hours at $21 per 1,000	$95,550
Exhaust sold for heating, 70,000,000 lbs. at 30 cents per 1,000	21,000
Total	$116,550

We may now inquire what would be the effect of providing such an installation with a system of Thermal Storage. The adoption of "steam storage" would involve tanks able to supply about 900 H. P. for 12 hours, the boilers meanwhile steadily supplying steam for 800 H.P. It will be found that, although the boiler power is so much reduced, no less than 64 tanks, each 8 ft. dia. x 30 ft. long, would be required, and the space occupied and cost incurred would be so great as to render this arrangement unadvisable. In the case of "feed storage," however, it appears that an advantage would be obtained. Remembering that the mean H. P. during a working-day is about 800 and the maximum load lasts about 10 hours, it is plain that tanks must be provided for feed for 10 hours at about 1,700 H.P., and as each tank 30 ft. x 8 ft. stores feed enough for 2,400 H. P. hours, we should require say 7 tanks of that size. If suited for 90 lbs. working pressure, these will weigh about 8 tons each, and cost, with lagging, etc., complete in place about $2,400 each, or say $16,800 for the set.

The effect of the feed storage is to increase the capital expenditure, but to save coal. Prof. Forbes gives the saving in an electric light station due to a more even rate of evaporation in the boilers as 40 per cent. In this case we will assume 20 per cent., so that the coal consumed per annum will be 13,680 tons instead of 17,100.

When working from tanks at 331° F. each lb. of steam at 90 lbs. requires 881 B.T.U. for its production. When working from feed at 100°, 1112 B.T.U. are required. Hence the boilers need only be of $\frac{881}{1112}$ or 0·8 their original power, *i. e.*, of $0{\cdot}8 \times 2{,}500 = 2{,}000$ H.P.

We then have :—

Cost of Power Station (with Feed Storage.)

Quantity.	Description.	Rate.	Total.
2,000 H.P.	8 Babcock boilers............	$20	$40,000
	Setting	5	10,000
7	Feed storage tanks...........	2,400	16,800
	Other expenditure, as before..	....	26,825
	Total..................	....	$93,625

The total cost of plant is then $229,975.

The total capital expenditure is :—

Cost of plant..	$229,975
Salaries, etc..	8,000
Incidental expenses..	5,000
Total	$242,975

Say $243,000.

Annual Charges (with Feed Storage).

	Rate.	Amount.
Fixed expenses—		
Interest on $243,000..........................	5%	$12,150
Depreciation on $230,000......................	5%	11,500
Taxes and insurance	2%	4,600
Salaries and office expenses	....	8,000
Station expenses—		
Repairs on $230,000	5	11,500
Water and gas.................................	....	500
13,680 tons of coal...........................	$3.50	47,800
Wages........	0.40	5,470
Stores and sundries...........................	....	2,500
Total.....................................	....	$104,020

Allowing the same receipts for heating as in the previous case, the price of steam sold for power purposes can be reduced to $18.25 per 1,000 H.P. hours. The receipts would then be:

Steam sold for power :—	
4,550,000 H.P. hours at $18.25 per 1,000, say	$83,040
Exhaust steam sold for heating, 70,000,000 lbs. at 30 cents per 1,000	21,000
Total..........	$104.040

For purposes of comparison the results obtained are tabulated below, together with those for a compressed air power station under similar circumstances. In the latter case, of course, no part of the receipts are obtained from heating, and the figures given have been calculated from particulars given in Lectures I–IV.

Estimated Results from an Installation delivering 2,000 H.P. in Montreal.

	Steam.	Steam with Feed Storage	Compressed Air.
Cost of station	$ 89,325	$ 93.625	$ 166,970
" pipe line	136,350	136,350	66,500
Total capital expenditure........	239,000	243.000	247,000
Annual expenses	116,440	104,020	75,700
H.P. hours delivered per year...	4,550,000	4,550,000	4,550.000
Coal burnt per year (tons)	17,100	13,680	6,140
Price of 1,000 H.P. hours........	$ 21.00	$ 18.25	$ 16.64
" 1 H.P. per year (3,090 hrs.)	62.10	56.39	51.40
" heating steam per 1,000 lbs.	30 cts.	30 cts.	....

The prices given above would of course be paid on the basis of the power actually consumed by the user. From inquiry it is found that rented power in small factories and workshops in Montreal is supplied at from $60 to $120 per H. P. per year of 3090 hours, and this rent has to be paid whether the whole of the available rented power is utilised or not, so that the power actually used by the renter costs him considerably more than the nominal prices.

From the examination of the examples of power transmission worked out above it is of course impossible to make a general statement as to the advisability, or otherwise, of selecting any particular system. The engineer must be guided, in deciding such a matter, by careful study of the local conditions of a proposed plant. The probability of a large demand for steam for heating purposes might cause him to choose a steam installation, and with satisfactory results; while for a large area of supply, or if the boiler station cannot be placed near the district to be served, it is likely that the adoption of a compressed air or an electrical transmission would be more successful, both from a financial and from a technical point of view. In any case the institution of a central station supplying power at from $50 to $65 per H. P. per year, as actually consumed, would evidently lead to considerable economy where it replaced the present system, either of renting power, or of developing it by small, isolated, and wasteful boilers and engines.

For further information on the subject of steam distribution the following may be consulted :—

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Proc. Am. Soc. C. E., 1885 and 1891.
Proc. Am. Soc. M. E., vol. viii.
Unwin, Howard Lectures, 1893.
Zeitschrift d. V. Deutscher Ingenieure, 15 July, 1893.

LECTURE VII.

TRANSMISSION AND DISTRIBUTION OF POWER BY GAS.

The distribution of gas for power purposes has, to all appearance, hitherto attracted but little attention, while its distribution for lighting purposes has been practised for 30 years. At the same time the use of lighting gas in gas engines is very extended, and we have really been building up a power distribution system of a new kind, without noticing it specifically under that name. There are probably not less than a quarter of a million gas engines in the world of an average horse power of 4 to 5 ; so that the gas engine is no inconsiderable rival of the steam engine. This competition is due to the intrinsic thermodynamic excellence and handiness of these engines rather than to their superior mechanical construction.

In 1861 Lenoir used 124 cub. ft. of gas per horse power hour. Not many years ago 40 was about the figure. Now we may reckon on even small (2 horse power) gas engines consuming not more than 28 ; whilst larger machines working with good lighting gas consume but 23 cub. ft. per horse power hour. This means with gas, whose heating power is 500,000 ft. lbs. per cubic foot, the conversion of over 25 per cent. of the energy of the fuel into mechanical work ; so that on the score of economy of fuel a gas engine can surpass the best steam engine, which can only return 15 per cent. of its fuel energy as work.

It may be objected that gas is an original and not a transformed source of mechanical energy, and that therefore it cannot fairly be compared with media which are in such advantageous and adaptable forms as water, compressed air or electricity. In a similar way it has recently been proposed in the United States to convey powdered coal along great pipe lines by mixing it with 60 per cent. of water, and using ordinary pumping engines to force it along. This is in order to escape the $50,000,000 annual tariff which the American railways impose upon the transportation of coal. It would probably pay better to gasify it and transmit it in that form; especially as a coal dust engine has yet to be perfected, for the true criterion as to whether we are discussing a real power medium or not seems to be its capability of being connected directly to a prime mover.

In this respect fuel gas loses nothing in comparison with the above mentioned energy media by reason of its necessitating a chemical combination for the release of its contained energy. In fact the energy it possesses is in a form highly suitable for transmission, as it is not associated with a necessarily high mechanical pressure or electric tension.

In comparing the system of transmission and distribution of power by gas with other methods, the mains as usual ought first to be considered.

The magnitude of some of the systems of gas mains at present in use for lighting is such as to compel our attention. A town of half a million inhabitants uses on the average one million cubic feet of gas per hour; which, reckoned for power purposes at 25 cub. ft. per horse power hour, would be capable of continually supplying gas engines of a total horse power of 40,000! The systems of mains in such cities vary from 100 to 600 miles in total length; and we have here, in fact, a much more extended system of distribution than has been practised along any other line, or even along all other lines put together; including hydraulic, electric, pneumatic, and telodynamic transmissions.

It is interesting to compare the first cost of an electric lighting with that of a gas lighting plant. The capital expenditure on gas mains (with house connections) has been found to be about $4.00 per light. And as an average of a large number of towns in Europe it was found that there were 15 lights every 100 feet of main.

The capital cost for a three wire electric light installation is about $13.00 per light. For alternate current lighting the cost is about $8.00.

So that the first cost for mains is ½ to ⅓ for gas of what it is for electricity.

If the gas used for one light be 4 cubic feet per hour, then 6 gas lights use energy at the rate of one horse power; whilst 10 incandescent lights are usually taken as the equivalent of one horse power.

The capital invested per horse power hour is therefore :

$4 × 6 = $24 for gas.

$8 × 10 = $80 for electricity (alternate current).

$13 × 10 = $130 for electricity (direct current).

The capital expended in distributing plant is thus from 4 to 6 times as great in the case of electric as for gas distribution.

Some false notions have got abroad about the losses by leakage from gas mains. It has been maintained, for example, that there is really a large loss due to *diffusion* ; that is, diffusion of air into the pipe and of gas out into the air. According to Herr Oechelhäusen, a German authority on gas, the total loss in a gas pipe system is made up of 5 factors; of which : (1) leakage is of course the principal. From statistics of the German Continental Gas Co., it was found that the total loss in a number of cities in Germany, whose mains have for the most part been laid for 30 years, varied from 2½ per cent. to 7 per cent. Of these losses only 2 or 3 per cent. can be set down to leakage of the pipe mains themselves, as pipes without branches proved to be almost perfectly tight. Several connecting mains, up to 3 miles long, between gas holders in neighbouring towns, which were under considerably higher pressures than those used in the ordinary distribution pipes of towns, showed a hardly perceptible loss of gas even after years of service.

(2) Besides leakage, a source of loss exists in the water vapour, naphthaline, etc., contained in the gas, which is partially condensed in the pipes.

(3) The gas meters in the houses are on an average at a somewhat lower temperature than those in the gas works ; so that the volume of gas paid for is on the whole less than what leaves the works owing to this temperature difference.

(4) Street lamps are not usually paid for by meter, but the quantity used is determined by calculation. These lamps usually burn more gas than they are supposed to do.

(5) Breakages in pipes forms a fifth source of loss.

Diffusion through the C. I. mains to any sensible extent has not been proved to take place ; and in view of the other sources of loss which seem competent to account for the whole, it is unnecessary to assume its existence.

In connection with the leakage loss it ought to be pointed out that as in the case of compressed air, water, and steam, the larger the pipe diameter, *i.e.*, the greater the amount of power transmitted, the smaller will be the percentage loss due to this cause. For the quantity of gas passing increases as the area, whilst the leakage increases only as the circumference of the pipe increases. (It may here be remarked that the first cost per horse power varies in the same way.)

The total loss for a well kept system of distribution mains ought not to exceed 6 to 7 per cent., whilst that for single transmission mains for long distances will certainly not exceed 1 per cent.

Two instances of actual gas transmission may be referred to :—

(1) That at Berlin, where two mains 33″ diameter and 3 miles long connect the gas works at Schmargendorf with the gas holders in the city (Wormserstrasse). These two mains together supply 638,000 cubic feet per hour, equivalent to 25,000 horse power, and only require 20 horse power to be expended on the exhausting fans which raise the pressure for distribution to 10″ of water!

Here we have a power transmission of 25,000 horse power through 3 miles at an expenditure of only 1-1250ths of the whole; or the efficiency of the transmission is :—

$$\frac{24{,}980}{25{,}000} = .9993 \text{ ; } i.e., \text{loss} = 0.07 \text{ per cent. !}$$

These mains cost only $8 per horse power, or about $5.75 per foot.

(2) The Beckton-London mains, two in number, each of 4 feet diameter, and nearly 8 miles long, convey 3 million cubic feet of gas per hour, equivalent to 120,000 horse power. The drop of pressure is only 23.″6 — 5.″9 = 17.″7 water, = 0.64 lbs. per square inch; the speed being about 30 feet per second. The horse power of the fans is only 120; so that there is a loss of power due to transmission of but $\frac{1}{1000}$; efficiency = .9990.

According to the experiments by E. C. Riley, coal gas loses only 0.37 per cent. of its calorific value at 20 lbs. above atmosphere; so that a diminution in the size of mains by increasing the pressure of the gas during transmission is quite feasible, and would, of course, mean a large saving in the cost of piping.

As an instance of ***high pressure*** transmission, that of natural gas at Pittsburg, U.S., is very remarkable. According to the Iron Age (Vol. 56, p. 1321) the Philadelphia Natural Gas Co. of Pittsburg have at the present time (1897) completed the largest and longest gas line in the world, bringing their total of main and branches up to over 1000 miles of pipe. The line in question is 101 miles long, and penetrates the gas fields of West Virginia. The first section from Pittsburg, 14 miles long, is 36″ diameter, and is laid 4 feet deep; the second section is 23″ diameter and 5 miles long; and the remainder is 82 miles long, and from 6″ to 12″ in diameter. Over 48 miles are now in use from the Green County Wells.

This natural gas was first met with, as stated by Mr. Andrew Carnegie, in boring for oil; and was at first used to raise steam for oil pumping engines. At Murraysville, 18 miles from Pittsburg, an enormous outburst of gas occurred from a depth of 1320 feet. The drills were thrown high in the air, and the derrick broken to pieces and scattered around; the roar of the escaping gas was heard at Munroville, 5 miles distant. After four two-inch pipes had been coupled on, the gas was ignited, and the whole district for miles around was lighted up. For five years this valuable fuel was allowed to waste; then a company engaged to take it 9 miles to Messrs. Carnegie's works. They were to be paid for the gas the value of its equivalent in coal until the capital cost of the pipe line was repaid. After that the gas was to be supplied at half the cost of the equivalent amount of coal. Notwithstanding the fact that coal in Pittsburg costs but 50 cents to $1 per ton, the cost of the pipes was recouped in 18 months, and the gas has since been supplied at half the cost of its equivalent in coal.

The largest well discharged 30 million cubic feet of gas in one day, which at the lowest value of 600,000 T.U. per 1000 cubic feet would be capable of working plant of about 400,000 horse power. Taking $20 per annum as the cost of one horse power running continuously, we have here a waste during five years of no less than $40,000,000!

In five years about five cubic miles of gas has been used, so that unless in these oil districts there are cavities in the earth filled with gas compressed even to a point of which very little idea can be formed, it is very clear that exhaustion must occur in a comparatively short period. It may be that the seat of generation of this gas is at such a depth that the process of distillation is going on from either liquid petroleum or solid carboniferous deposits in contact with igneous rocks. The gas is given off at a pressure of 200 lbs., and there seems to be little or no diminution in the pressure from the day they began. The pressure at Carnegie's Works, after passing through 9 miles of pipe, is 75 lbs. per square inch; and the natural gas is sometimes piped on to small engines which are worked by direct pressure without troubling about igniting it!

It is seldom that Nature deals so beneficently as she has done in the Pennsylvania iron-producing districts, where they not only have coal in all the known varieties of that valuable mineral, liquid fuel in apparently inexhaustible quantities, but also vast quantities of a rich combustible gas.

The effect of such high pressures as 200 lbs. per square inch on the properties of ordinary coal or producer gas is unknown; but with such moderate and feasible pressures as 10 or 20 lbs. above the atmosphere a very large horse power may be transmitted at a cost for mains *far less than on any other known system.*

Unwin's formula No. 12 already given for compressed air, when adapted for lighting gas gives for the ratio of the initial to the terminal pressure

$$\frac{p'}{p''} = \frac{1}{\sqrt{\left[1 - \frac{L}{89730\,d}\right]}} \qquad \text{(1)}$$

for an initial velocity of 45 feet per second. (Howard lectures, Unwin, p. 262.)

A table is here reproduced (somewhat amplified) from Prof. Unwin's Howard lecture on this subject, which gives the initial pressures in mains of various sizes and lengths when the terminal pressure is that of the atmosphere, and the initial velocity is in each case 45 feet per second (formula (1)).

TABLE OF POWER TRANSMISSION BY COAL GAS THROUGH 1, 5 AND 10 MILES.

Distance	Dia. of main inches.	Init. speed ft. per sec.	Init. press. absolute lbs.p.sq.in.	Fall of press. between ends inch.water.	Quantity of gas c. ft. per hour.	H.P. transmitted.
1 mile.	6	45	15 65	26.2	33,900	1,280
	12	45	15.16	12.7	131,000	4,940
	24	45	14.94	6.6	519,000	19,600
	36	45	14 86	4.4	1,157,000	438,000
5 miles.	6	45	22.90	309	49,600	1,970
	12	45	17.50	105	151,300	5,720
	24	45	15.95	34 5	552,000	20,800
	36	45	15.50	22	1,208,000	45,600
10 miles.	6	45	......	......	......	......
	12	45	22.9	309	198,000	7,370
	24	45	17.5	105	604,000	22,750
	36	45	46.4	47	1,280,000	48,300

These calculations show amongst other things that the Beckton-London mains are much larger than is necessary; that, in fact, instead of two four-foot mains, two two-foot ones would have been quite sufficient. With an insignificant running expense for power, an enormous saving in the cost of the pipe line might have been effected.

We thus see that existing gas main systems show an efficiency in their possibilities of power transmission which has been exhibited by no other method. Power distribution by lighting gas has, however, one special and peculiar advantage over all other systems, which consists in the special adaptation of gas works with their holders for storage of power in the cheapest way and on the largest possible scale.

In London, *e.g.*, the total gas holder capacity is about 140,000,000 cubic feet, a storage sufficient to develop about 500,000 horse power for 10 hours!

Cities of half a million inhabitants, *e.g.*, Liverpool, Manchester, or Glasgow, have a storage capacity of about 10 million cubic feet, equivalent to 40,000 horse power for 10 hours.

The cheapness of this storage relatively to other systems is evident from the following considerations.

An electric light and power station with accumulators, sufficient for 250 horse power during 4 hours or of 1,000 horse power hours capacity, costs about $35,000, or about $35 per horse power hour in first cost.

Gasometer volume for 1000 horse power hours would amount to about 25 × 1000 cubic feet, and would cost in small gas holders about $7,000, or about $7.00 capital per horse power hour stored; whilst in the case of the new London gas holders, the capital expenditure drops to about 50 cents per horse power hour stored.

We infer that the electrical storage of power on the largest scale at present practised is from 5 to 70 times as expensive in first cost (depending on the size of gas holders used) as storage by means of gas holders.

Loss by leakage from these gas holders absolutely does not take place; and if they are roofed and covered in, there will be, even in the severe Canadian winters, a very small loss by condensation. On the other hand, the loss due to electrical accumulators is at least 20 per cent. In spite, however, of this high first cost, relatively to gas holders and serious loss in use, storage batteries have proved themselves of great advantage in direct current working for power or light stations. This is due to the fact often alluded to in the course of these lectures, that a central station which cannot store power cheaply, and to a large amount, is foredoomed to commercial failure on account of the great capital expenditure it is necessary to make on reserve engine and boiler power. In conclusion the following advantages of this system of power distribution would seem to have been established.

(1) Coal gas is very specially adapted for the distribution and transmission of power from central stations, and has already taken a large part in this, as is evident from the fact that the number of gas engines in use is very great.

(2) Gas mains now easily supply cities, their suburbs and even neighbouring towns to any extent with a fuel which is well adapted for use as power. The internal combustion motor here used is so economical and handy as compared with the combustion of fuel in steam boilers and its use in steam engines, that a successful future is already assured for it. The size of gas engines is steadily increasing; 500 and 600 horse power engines are now on the market, a size quite sufficient for all the demands of power distribution.

(3) The capital expenditure for storage and distribution and the cost of transmission are extraordinarily small, as also are the losses in gas holders and mains.

The simplicity and every day occurrence of the system has almost rendered it devoid of interest, and has prevented attention from being specially devoted to its investigations and comparison with others which are more pretentious.

LECTURE VIII.

TRANSMISSION OF POWER BY WIRE ROPE.

The system of Wire Rope or "Telodynamic" Transmission was first introduced by Hirn in 1850, and has been largely adopted, especially on the Continent of Europe. The wire ropes are employed as belts, and are usually of steel wire having a hemp core in each strand and in the centre of the rope. It is customary to dress the ropes with boiled oil, so as to diminish the internal wear consequent on the movements of the individual wires on one another as the rope is bent. The size of rope in general use is from $\frac{3}{8}''$ to $1''$ in diameter, consisting of six strands made of wire from 25 to 14 gauge. The maximum power transmitted by a single rope is about 300 H.P., and the life of the rope may be taken at from 200 to 300 days.

The pulleys have wide grooves lined at the bottom with leather, wood, or gutta percha, on which the rope rests. Their diameter is from

6 to 18 ft., or say 200 to 250 times the diameter of the rope. Many wire ropeways have been made having spans up to 2,000 ft., but such lengths of span are impossible for a power transmission, since a wire rope belt not only carries the tension on the tight side (which is about 2 to 3 times that due to the power transmitted), but has also a bending stress on the individual wires due to their passing round the pulleys. The usual span is from 300 to 500 ft., the maximum at present being 630 ft. With very long spans, except in special cases, the sag of the rope becomes so great as to be inconvenient.

The speed of the rope is fixed by the strength of the pulley rim, which is generally of cast iron and runs at a linear velocity of 50 to 100 feet per second.

The arrangement of spans should be such as to reduce the losses from journal friction, etc., and to reduce the height of the piers without employing excessive tension on the rope. Two systems are in use.

(*a*) Each span has a separate rope.

(*b*) There is one continuous rope along whole length of transmission. Guards are fitted under the rope where breakage would be dangerous to passers-by. Splices must be long and properly made, and after about three years the pulley lining requires renewal.

As examples of Wire Rope Transmissions we may take :—

(*a*) *Schaffhausen.* This installation was established in 1864, and distributes 760 H.P., developed by three axial flow turbines working with a fall of 13 to 16 ft. 150 H.P. is transmitted along a shaft from the turbine house, the remainder is taken by two wire ropes each 1″ diameter, the tensions being equalised by means of differential bevel gear on the shaft. The first shaft makes 80 revs. per minute, and has two rope pulleys, each 14′ 9″ dia. The change stations have bevel gear where the direction of the transmission is altered.

$20 to $30 per H.P. per year of 365 days is charged for power, $16,500 being received in 1887, when the number of consumers was 23.

The installation with all branches cost $150,000 complete, the length of main transmission being 2,000 ft.

(*b*) *Gokak* (Southern India), constructed in 1887. The three turbines develop 750 H.P. collectively, and drive a cotton mill distant 750 ft. horizontally and 270 ft. vertically, by means of three ropes each 1″ dia. The speed of rope is 93 ft. per second. The fall at turbines is about 180 ft., the revolutions 155 per minute, and the rope pulleys are 11′ 6″ diameter.

Wire Rope Transmissions seem suitable where the consumers are few and the distance does not exceed say 6,000 ft. There is no loss of efficiency due to difference in level of the terminal stations.

SPAN AND DEFLECTION OF ROPE.

In calculations for wire rope transmissions it is usually sufficiently accurate to treat the rope as hanging in the form of a parabola, hence if T be the tension at the lowest point, and w the weight of unit length of the rope, we have from Fig. 7,

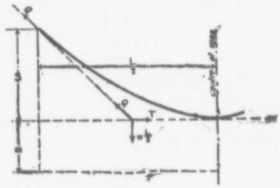


Fig. 7

$$\frac{w}{2}\frac{L}{T} = \frac{4\,s}{L}$$

$$\therefore \quad T = \frac{w\,L^2}{8\,s}$$

(This assumes that the load is uniform per foot of span).

A flexible uniform rope does not actually take the form of a parabola but of a catenary, and in a catenary of parameter m, the tension at any point at a height s above the lowest point is

$$Q = w\,(s + m),$$

hence also $T = w\,m$ and $Q = w\,s + T$.

Substituting for T from the equation above, we get

$$Q = w\left(s + \frac{L^2}{8\,s}\right)$$

This gives the maximum tension on the rope. Note that for a given span this equation gives two values of s, except when $Q = \frac{w\,L}{\sqrt{2}}$

$$\text{then } s = \frac{Q}{2\,w}$$

It is easily seen that this value of Q gives the least tension possible for a given span, but in practice it corresponds to such a large deflection as in most cases to be inconvenient.

If the two ends of the span are not on the same level the values of s and $\frac{L}{2}$ will of course be different for the parts of the rope on each side of the lowest point, whereas T is the same for both.

Let $\frac{L_1}{2}$ $\frac{L_2}{2}$ be the horizontal distances from the lowest point to the ends of the span. Then in this case it may be shown that

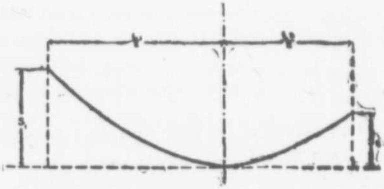


Fig. 8

$$\frac{L_1}{2} = \frac{L_1 + L_2}{2} \times \frac{\sqrt{s_1}}{\sqrt{s_1} + \sqrt{s_2}} = \text{span} \times \frac{\sqrt{s_1}}{\sqrt{s_1} + \sqrt{s_2}}$$

and similarly

$$\frac{L_2}{2} = \text{span} \times \frac{\sqrt{s_2}}{\sqrt{s_1} + \sqrt{s_2}}$$

In a rope transmission the tension on the slack side of the rope is usually made about half that on the tight side; the correctness of this will be seen from the following calculation:—

Let T_2 and T_1 be the tensions on the tight and slack sides respectively, and let f be the coefficient of friction between the rope and pulley, then it may be shown that

$$\log_e \left(\frac{T_2}{T_1}\right) = f\theta$$

or

$$\frac{T_2}{T_1} = e^{f\theta}$$

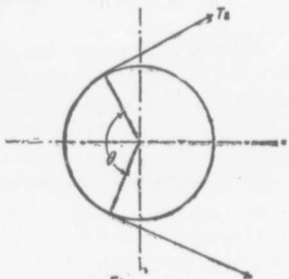


Fig. 9

where θ is the angle of the pulley embraced by the belt or rope.

For ordinary wire rope transmission we may take

$$f = 0.24 \text{ nearly, and } \theta = \pi \text{ usually,}$$

$$\therefore f\theta = 0.755 = \log_e 2.12 \text{ nearly,}$$

$$\text{Hence } \frac{T_2}{T_1} = 2 \text{ approximately.}$$

In order to show the method of determining the leading particulars of a wire rope transmission we may take the following data:

Span 500 ft.

Rope $\frac{3}{4}''$ dia., composed of 36 wires each $0.072''$ dia. (15 *L. S. G.*)

Weight of rope 0.815 lbs. per foot run.

Pulleys 15 ft. diameter.

Speed of rope 100 ft. per second.

Ends of span are on the same level.

Least possible tension.—This would be for the given span,

$$\frac{0.815 \times 500}{1.414} = 288 \text{ lbs.}$$

and the corresponding deflection would be

$$\frac{288}{1.63} = 177 \text{ ft.},$$

which is too great and would necessitate very high towers for the end pulleys. Actually then the tension on slack side of rope must be much more than 288 lbs.

Stress on wire due to bending.—This may be shown to be

$$f_b = E \frac{\delta}{D}$$

where $E = 30 \times 10^6$ lbs. per sq. inch.

δ = dia. of wire,

D = dia. of pulley.

Stress due to centrifugal force.—This may be shown to be

$$f_c = 0.13\ v^2$$

where v = vel. of rope in ft. per second. In the given case we have :—

$$f_b = \frac{30{,}000{,}000 \times .072}{180} = 12{,}000 \text{ lbs. per sq. inch.}$$

$$f_c = 0.13 \times 10{,}000 = 1{,}300 \text{ lbs. per sq. inch.}$$

The total stress on steel wire of good quality should not exceed 25,600 lbs. per sq. inch when used in a wire rope transmission.

This leaves 25,600 – 12,000 – 1,300 or 12,300 lbs. per square inch as the stress in wire on tight side due to the weight and deflection of rope.

The tension on rope at pulley on tight side will then be

$$12{,}300 \times 36 \times .00407 = 1{,}800 \text{ lbs.},$$

and that on slack side may be say 900 lbs. The H. P. transmitted is then

$$\frac{(1{,}800 - 900)\ 100 \times 60}{33{,}000} = 163.6$$

The deflection on tight side of rope will be given by

$$Q = w\left(s + \frac{L^2}{8\,s}\right),$$

from which

$$s = \frac{Q}{2w} \pm \sqrt{\left\{\frac{Q^2}{4w^2} - \frac{L^2}{8}\right\}}$$

$= 1104.4 \pm 1090.7$

$= 2195.1$ or 13.7 feet.

For the deflection on slack side

$s = 552.2 \pm 523.1$

$= 1075.3$ or 29.1 feet.

Evidently the smaller number is to be taken in each case.

On level ground the piers would thus have to be at least 21 ft. to centre of pulley in order that bottom point of tight side of rope might clear the ground.

LOSSES IN WIRE ROPE TRANSMISSION.

(1) The stiffness of the rope causes a loss of energy which is expended in bending the rope.

Fig. 10 shows the effect of stiffness on a rope while running on a pulley, and transmitting no power, *i.e.*, if the pulley is supposed to revolve freely.

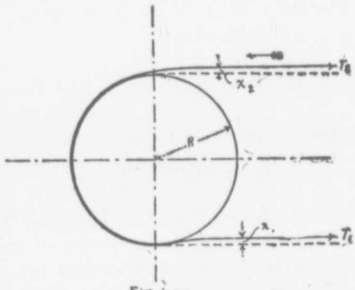


Fig. 10.

Under these circumstances, if the rope were perfectly flexible, the tensions T_1 and T_2 would of course be equal. If the rope is stiff, it will be bent outwards on the running-on side and inwards on the side on which it leaves the pulley, hence T_1 must be greater than T_2.

The quantity $T_1 - T_2$ is the measure of the stiffness of the rope, and will be denoted by the symbol S. In a wire rope belt transmitting power T_1 is greater than T_2 apart from any effect of stiffness, and the above result must be modified accordingly. When such a rope is running it is probable that the distance x_1 on the tight side is very small compared with that x_2 on the slack side, and then it may be shown that approximately

$$S = \frac{T_2 x_2}{R}$$

The work lost is $2\pi R(T_1 - T_2)$ foot-lbs. per revolution, and the H.P. lost at n revolutions per minute

$$= \frac{\pi D S n}{33000}$$

According to Eytelwein's formula

$$S = k \frac{d^2}{D} T$$

where k is a constant $= 0{\cdot}1$ to $0{\cdot}15$ for wire rope.

d = diameter of rope in inches.

D = diameter of pulley in feet.

T = tension on slack side of rope in lbs.

The value given for k has been obtained from the results of experiments on a transmission at Oberursel, but further information is much wanted on this point.

(2) Friction of journals. Let Δ be the journal dia. in inches and W the total load, f the coefficient of friction. The work lost per revolution is $\frac{f W \pi \Delta}{12}$ foot-lbs. and the H.P. lost is therefore

$$= \frac{f W \pi \Delta n}{12 \times 33000}$$

(3) Total H.P. lost in a wire rope transmission. The loss from air friction may be neglected. Let there be N spans, and $2N$ pulleys, with $N+1$ shafts, the total length of transmission being L feet. Assume a speed of rope of 6,000 feet per minute,

i.e., let $\pi D n = 6000$.

For ropes up to 1″ dia. we may put $D = 20d$, hence

$$nd = \frac{6000}{20 \times 3.14} = 95{\cdot}5$$

Usually the tension on slack side of rope is about 2500 d^2 lbs. Thus H.P. lost from stiffness of rope at one pulley

$$= \frac{\pi D n k d^2 T}{33000 D} = \frac{0{\cdot}1 \times 3{\cdot}14 \times 95.5 \times 2500}{33000} d^3$$

$$= 2{\cdot}3\, d^3 \text{ nearly,}$$

and the whole loss from stiffness on the transmission of N spans

$$= 4{\cdot}6\, d^3 N$$

In calculating the H.P. lost in journal friction, f may be taken as 0·09. W is the weight of all pulleys and shafts and the weight of rope, and its approximate value is

$$W = 220\ D\ (N+1) + (1{\cdot}34\ d^2 \times 2\ L)$$
$$= 4400\ d\ (N+1) + 2{\cdot}68\ d^2\ L \text{ lbs.}$$

The journal dia. Δ averages about $\frac{D}{3}$ inches,

$$\text{Thus H.P. lost} = W \times \frac{{\cdot}09 \times 3{\cdot}14 \times 95{\cdot}5 \times 20}{12 \times 33000 \times 3}$$
$$= {\cdot}00045\ W$$
$$= 2d\ (N+1) + {\cdot}0012\ d^2\ L \text{ nearly}$$

and the total H.P. lost in transmission approximately

$$= 2d\ (N+1) + {\cdot}0012\ d^2\ L + 4{\cdot}6\ d^3\ N.$$

We are now able to find the efficiency of a transmission in any given case, supposing the proportions are those assumed above, and that the speed of rope = 100 feet per second.

Take the case of a $\frac{3}{4}''$ rope at 500 ft. span and 100 feet per second. Suppose 200 H.P. are transmitted.
(An approximate rule based on actual results is :– $H.P. = 400\ d^2 - 20$)

We have

H.P. lost $= 2d\ (N+1) + {\cdot}0012\ d^2\ L + 4{\cdot}6\ d^3\ N$, from which the table below has been calculated :

EFFICIENCY OF $\frac{3}{4}''$ WIRE ROPE TRANSMISSION TAKING 200 H.P.

L.	N.	H.P. lost.	H.P. delivered.	Efficiency.
100 ft.	1	4·0	196	0·980
200	1	5·0	195	0·975
500	1	5·2	194·8	0·974
1,000	2	8·5	191·5	0·96
2,000	4	16·5	183·5	0·92
4,000	8	31·5	168·5	0·84
6,000	12	46·4	153·6	0·77
8,000	16	61·2	138·8	0·69
10,000	20	76·4	123·6	0·62
15,000	30	114	86	0·43
20,000	40	150	50	0·25
25,000	50	189	11	0·05

N = No. of spans. L = length of transmission.

The efficiencies given would of course be higher if the rope carried more than 200 H.P., which is possible in many cases. The above are to be taken as average results only.

At Oberursel, tests were made on a transmission taking 117 H.P. on a $\frac{5}{8}''$ rope at 73 ft. per sec., with 400 ft. spans.

The efficiency of 1 span was 0·962, and the efficiency of 7 spans or nearly 3,000 ft. was 0·885. It will be noticed that these numbers are somewhat higher than are given by the above formula, but are in fair agreement with the table when allowance is made for the difference in diameter of rope, length of span, and power transmitted.

It may be interesting to inquire what would be the efficiency of a shaft transmitting power to such distances as those given in the table above.

We have seen that if W be the load on a bearing of diameter Δ, and co-efficient of friction f, then the H.P. wasted will be

$$\frac{f\, W\, \pi\, \Delta\, n}{12 \times 33000}$$

where n is the number of revolutions per minute. Evidently in a shaft W will be its weight.

At 120 revolutions a 4″ shaft will transmit 200 H.P. with a maximum stress of about 9,000 lbs. per square inch, and its weight is 42 lbs. per foot run.

Thus if L be the length in feet, $42 \times L = W$ and

$$H.P.\ \text{lost} = L \times \frac{\cdot 09 \times 42 \times 3\cdot 14 \times 4 \times 120}{33000 \times 12}$$

$$= 0\cdot 144\, L.$$

From this we find for the efficiency of a 4″ shaft: –

L.	H.P. delivered.	H.P. lost.	Efficiency.
100 feet.	198·6	1·4	0·993
200	197·2	2·8	0·986
500	193	7·0	0·965
1,000	186	14	0·93
2,000	172	28	0·86
4,000	144	56	0·72
6,000	116	84	0·58
8,000	88	112	0·44
10,000	60	140	0·3

It should be noted that up to say 350 feet the efficiency of the shaft is higher than that of the wire rope, but it diminishes rapidly, so that, at a length of about 14,200 feet, the whole of the 200 H. P. would be absorbed in overcoming the frictional resistance to the shaft's motion. A rope transmission of this length would still have an efficiency of nearly 0.4. The efficiency of a wire-rope transmission under the "most favorable interpretation of the experiments" is given by Unwin as 0·6 for 15,000 feet, a result which is higher than that given by our calculations, but based on tests made on a smaller rope and transmitting proportionally more power than has been allowed in the present case.

It would appear then that the efficiency of a wire rope transmission is such as to make its use advantageous for distances greater than 350 feet, up to say 5,000 or 6,000 feet. In practice the most usual distances are from 2,000 to 3,000 feet. The comparative results of the use of shafting and wire rope are shown in Fig. 11.

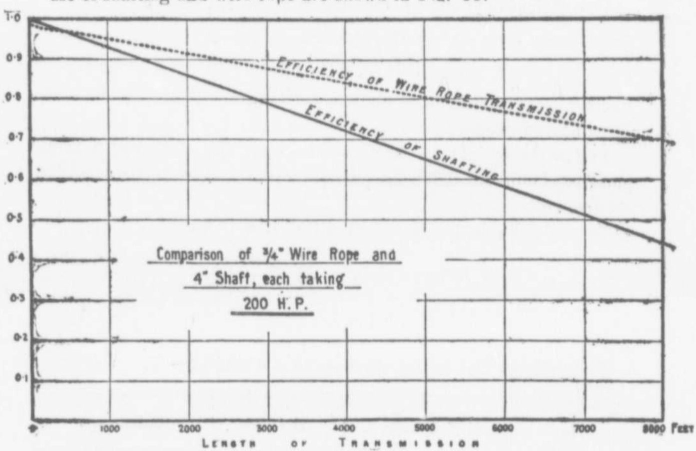


Fig. 11.

The cost of wire rope transmissions is given by Unwin as about $1,650 per mile, exclusive of terminal stations, for which a further amount of $5 per H.P. must be estimated. These figures seem to be rather low, the price per mile of double rope being about $1400 for the rope alone, if of ¾″ diameter. In the author's opinion, for distances from 1,000 up to 10,000 ft., using a rope ¾″ diameter and spans of 500 feet, not less than from $5,000 to $8,000 should be allowed per mile of transmission complete, the cost per mile being of course higher for the shorter distance than for the longer one.

A list of formulæ likely to be of use in calculations connected with this subject is appended.

Approximate formulæ of use in calculations for wire rope transmissions.

(*a*) *Deflection* (ends of span at same level)

$$s = \frac{Q}{2w} \pm \sqrt{\left\{ \frac{Q^2}{4w^2} - \frac{L^2}{8} \right\}}$$

(*b*) *Stress due to bending* $f_b = E \dfrac{\delta}{D}$

(*c*) *Stress due to centrifugal force* $f_c = 0.13v^2$

(*d*) *Stiffness of rope* $S = 0.1 \dfrac{d^2}{D} T_2$

(*e*) *H. P. lost from stiffness* $= \dfrac{0.1\, \pi\, n\, d^2\, T}{33,000} \times 2N$

(*f*) *Load on bearings and H. P. lost from journal friction.*

$$W = 220\, D\, (N + 1) + 2{\cdot}68\, d^2\, L \; (D \text{ in feet})$$

$$H\, P = \frac{f.\; W.\; \pi.\; \Delta.\; n}{12 \times 33,000}$$

(*g*) *Total H.P. lost.* Assuming $\Delta = \dfrac{D}{3}$, also $D = 20\, d$ and $nd = 95.5$, which are usual proportions, then if $T = 2,500\, d^2$

$$H.\,P.\,(lost) = 2d\,(N + 1) + .0012\, d^2\, L + 4.6\, d^3\, N.$$

(*h*) *H. P. transmitted* is given approximately by

$$H.\,P.\,(carried) = 400\, d^2 - 20$$

(*i*) *Dia. of rope and number of wires* (ν)

$$d = \delta \left(\frac{\nu}{13} + 7 \right) \text{ approximately}$$

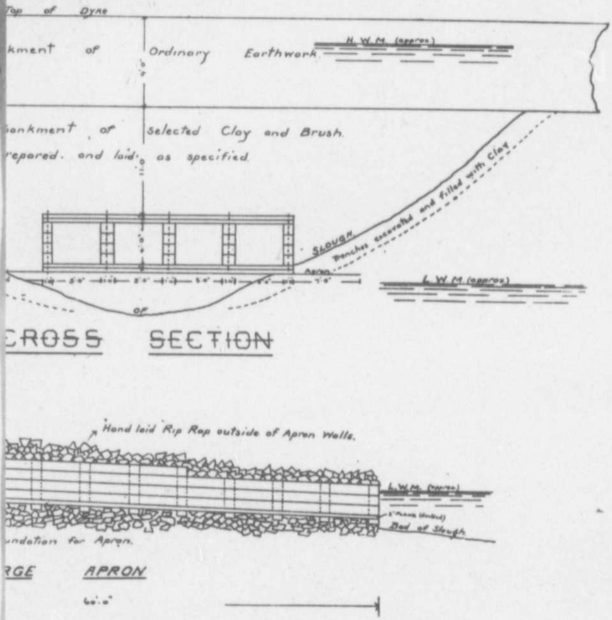
(*j*) *Weight of rope per foot*

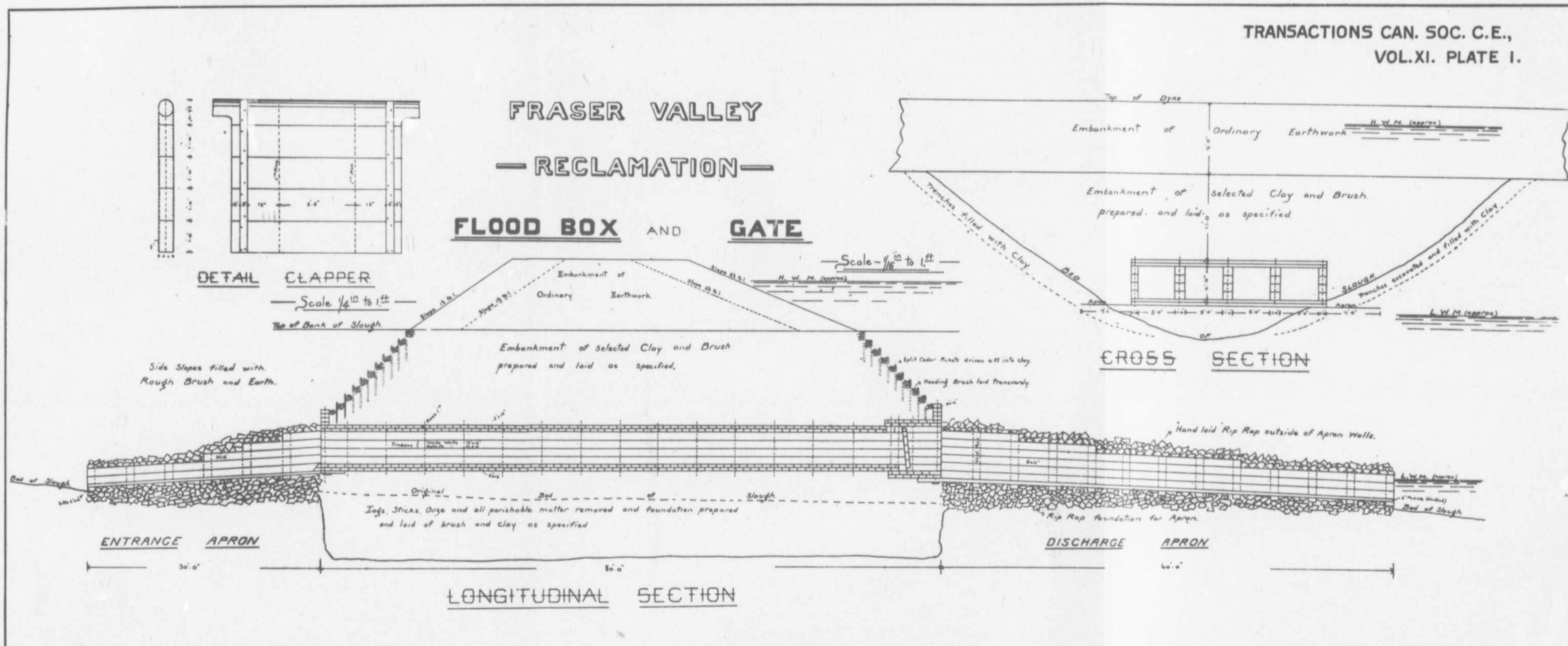
$$w = 1.341\, d^2 \text{ lbs.}$$

For further information on Wire Rope Transmissions, the following authorities may be consulted :—

Min. Proc. Inst. C. E. vols. xxxix, xli, xlv, lxix.
Min. Proc. Inst. M.E. (English), 1880.
Schweitzerische Polytechnische Zeitung, 1867. (Schaffhausen)
Engineering, 8th June, 1888. (Gokak).
Unwin, Howard Lectures, 1893.
" Machine Design, Part I., pp. 410-434.

TRANSACTIONS CAN. SOC. C.E.,
VOL. XI. PLATE I.




TRANSACTIONS CAN. SOC. C.E.,
VOL. XI. PLATE I.
FRASER VALLEY
— RECLAMATION —
FLOOD BOX AND GATE
Scale — 1/16 in to 1 ft
DETAIL CLAPPER
Scale 1/4 in to 1 ft
Top of Bank of Slough
Embankment of Ordinary Earthwork
H. W. M. (approx.)
Embankment of Selected Clay and Brush prepared and laid as specified.
Side Slopes filled with Rough Brush and Earth.
Split Cedar Pickets driven into clay
Heading Brush laid Transversely
Hand laid Rip Rap outside of Apron Walls.
Bed of Slough
Original Bed of Slough
Logs, Sticks, Ooze and all perishable matter removed and foundation prepared and laid of brush and clay as specified
Rip Rap foundation for Apron.
L. W. M. (approx.)
Bed of Slough
ENTRANCE APRON
DISCHARGE APRON
30' 0"
80' 0"
40' 0"
LONGITUDINAL SECTION
Top of Dyke
Embankment of Ordinary Earthwork
H. W. M. (approx.)
Embankment of Selected Clay and Brush prepared and laid as specified.
Trenches filled with Clay
BED OF SLOUGH
Trenches excavated and filled with Clay
L. W. M. (approx.)
CROSS SECTION

Thursday, 8th April.

G. H. DUGGAN, Member of Council, in the Chair.

Paper No. 119.

FRASER VALLEY RECLAMATION.

CONSTRUCTION OF TWO SLUICE BOXES AND FLOOD GATES.

By R. E. PALMER, B.A.Sc., Assoc. M. Can. Soc. C.E.

The freshets or floods of the Fraser River, British Columbia, occur as a rule between the latter end of May and the middle of July, caused principally by the melting of the snow upon the mountains.

In the reclamation of portions of the delta lands of this valley from these freshets, the most difficult part of the schemes at present adopted is the satisfactory design and building of the sluice boxes and flood gates.

Up to the present time, that portion of the delta reclaimed lies in patches, each portion being protected by itself, and not connected with any other portion. Generally these patches or valleys front on the main river, and are surrounded on all sides, with the exception of the frontage, by high lands, which discharge all their drainage upon the flats. This water finds its way over these flats through sloughs and creeks which discharge into the main river, during the low or ordinary stage of the water, namely, from August to the end of April.

The system of reclamation adopted up to the present day has been that of the construction of dykes or embankments, of different dimensions, along the banks of the river, from high lands to high lands, and of the building in the creeks or sloughs, over which the dykes would pass, of flood gates, and sluice boxes as they are called, which are so constructed as to close during the high water, preventing the river water from backing up the sloughs and flooding the prairies. They are constructed also to open, so soon as the water in the river begins to fall lower than that in the sloughs, and drain the prairies, the sloughs during the period when the gates are closed acting as reservoirs, to hold the ordinary drainage from the surrounding hills.

In ordinary cases the sloughs have not enough capacity to hold the drainage during the time when the gates are closed, and pumping has to be resorted to for about a month in the year.

One of the most difficult operations connected with these schemes is the proper designing and construction of these boxes. It is a very difficult matter to keep them tight, and the material in and surrounding these sloughs is such that when once the slightest leakage occurs, under pressure, it is a very short time before the whole box finds its way into the river or up the slough.

Again, the many and varied kind of sloughs and creeks, the different classes of material through which they pass, varying from gravel and sand, to silt and clay, the fact that some discharge into the river where there is a regular rise and fall due to the tide, while others discharge at points where the tide does not reach—(the gates of the former having of necessity to close and open during each tide, while in the latter they need only close during the freshet)—all tend to require very careful examination and much experience before deciding upon the proper design for the gates.

In fact, almost every locality requires a gate of a design unique in itself, with some special features differing probably very materially from that required in a locality not half a mile distant. The boxes required for the sloughs located on the river above the effect of the tides are subjected to a very severe test and strain during high water. They are often subjected to a pressure of water due to a head of from 18 to 20 feet and lasting from a month to six weeks. On the other hand, those located on that part of the river affected by tidal waters are relieved twice every day during ebb tide.

The writer gives a description of two of these boxes built by him, one in March, April and May, and the other in August and September, 1896, all being under the same contract. They are built in two sloughs discharging into the Fraser, through what is known as the Matsqui Prairie. They were designed in 1893 by Mr. Fred. J. L. Tytler, C.E., at present supervising engineer for reclaiming lands for the Provincial Government of British Columbia, and were built with several changes under contract by the writer. The plans (Plate I) are those upon which they were actually built. It may also be mentioned that in each of these sloughs prior to the construction of the ones described there had been built three different and distinct boxes, each of which had succumbed to the effects of the freshets, and had been torn apart or scoured out, and carried by the flood for long distances over the prairies.

One of the present boxes, the only one built at the time, was subjected to a very heavy freshet in July last, the water in the river reaching to a point only 2 feet 11 inches below that reached during the disastrous flood of 1894 ; but although the work was barely completed when the flood came, and had in consequence scarcely reached its true bearing, still there was no sign of leakage, or scour, or damage in any one particular. The lumber used in the boxes was all of rough sound cedar, with the exception of the clappers or doors, which were of dressed Douglas fir. The boxes are identical in design, each being 80 feet long by 26 feet wide by 5 feet 8 inches outside measurement, having four openings each 4 feet by 5 feet. They have also each an entrance apron 30 feet x 40 feet, and a discharge apron 60 feet x 40 feet ; each contains about 90,000 feet B.M. The plans (Plate I) give a general idea of the timber-work. All spikes were specified to be galvanized.

The most important part of the work is the method of setting the box, and the proper placing of the brush and clay and pickets, and this will be now described.

At this point of the Fraser River there is an ordinary rise and fall of tide, due to the backing up of the river, of about 4½ feet, while during the freshet no difference of rise and fall is perceptible. Both boxes being identical in design, it is only necessary to describe the manner of placing one—the most difficult—and located in what is known as No. 3 slough.

This slough as shown on the plan is about 80 feet wide at the top, and from 25 to 30 feet deep, with water at the time of construction about 10 to 16 feet deep. It drains a large portion of the prairie, besides receiving a large creek from the surrounding hills, and as the weather was very wet at the time, it was necessary for it or the off-take ditch to carry away a large amount of water. The banks of the slough sloped at about ¾ to 1 and were interwoven with roots, and gave signs of sliding from adjacent springs and seepage of water.

The method devised and afterwards adopted for placing the box was to build a temporary dam a short distance above the site of the box, another a short distance below the site, excavate an off-take ditch, and having pumped out the portion of the slough between the dams, to commence operations. The off-take ditch was excavated through fairly good clay, being about 12 feet wide at the bottom, with side slopes of about 1 to 1, and varying in depth from 4 to 14 feet.

In constructing the upper dam a crib of logs was first built across, notched down and securely drift-bolted together, the logs on the upper side having a batter of about 6 inches to the foot. Along the upper side were driven sheet piles, consisting of 3 and 4 inches plank which penetrated from 4 to 8 feet into the bottom, but on account of the presence of many sunken logs and stumps, it was impossible to get all the plank down to a proper bearing; but they were intended merely to hold the brush and earth, afterwards conveyed in, from being swept down by the current so soon as it was deposited.

At first it was considered practicable to commence this sheet piling at one side, and continue along, finishing at the other, but it was found that the banks were of such a treacherous nature, that the increased current due to the narrowing of the channel would scour away the banks more quickly than the sheet piles could be driven, and thus destroy the location of the box. It was then decided to commence at both ends, make them thoroughly secure, and work toward the center. This was done, the sheet piling from each side being closely followed by labourers dumping earth to form an embankment on the upper side of the crib, keeping plenty of brush on the outside, to prevent the earth being scoured away by the current. After having proceeded thus toward the center, and when the current became too strong, due to the narrow opening, to hold the earth from being washed away, the gap in the sheet piling was closed, and the backing deposited as soon as possible. But the material in the bottom of the slough was of such a treacherous nature, that no sooner had the water on the upper side begun to rise on the piling than it broke through underneath, the water following the piles down, where it encountered a coarse red sand, which was soon scoured out, and in a very short time an open channel was made underneath the piling.

Sacks were immediately obtained and filled with earth (about 1,200 of them), and these dumped into the channel or hole with loose hay and earth, finally held the current until a large earth embankment was built across. No more trouble was afterwards encountered, although it was subjected at one time to a pressure due to a 27 foot head. The lower dam was built in much the same way, but with less difficulty, there being only a 4 feet tide to contend against.

The specifications required all ooze, logs, sticks or perishable matter to be removed from the bottom of the slough, between the two dams, to a maximum depth of 6 feet below the bottom of the box, in order to secure a proper foundation on which to lay the brush and clay. Should the material below that be soft and mushy, then wild hay was to be tramped in below that again, until a firm bed was obtained. But it was to be left to the judgment of the engineer as to how deep up to the six feet the excavation was to be made.

After having pumped out the location—a centrifugal pump with a 4 inch discharge having been used with a maximum lift of about 15 feet—the bottom of the slough was carefully examined and the material tested. The first 2 feet or thereabouts consisted of ooze, slime, brush, logs, stumps and every imaginable kind of worthless matter. Beneath this for from 4 to 6 feet was a bed of silt, of a bluish colour, containing minute particles of mica, and very gritty to the touch, but the particles of sand being fine. This when left in its natural bed, and not disturbed, is impervious to water, but once it is moved and displaced, and exposed to the action of water under pressure, it becomes a veritable quick-sand. Beneath this was a bed of fairly coarse red sand.

After having made this examination, the cause of the former boxes having been scoured out was apparent to the writer. They had been constructed in the form of coffer-dams built by driving rows of sheet piles braced to ordinary piles, and filling the intervening space with earth or clay. These piles had penetrated this bluish silt, and were driven into the red sand. When the water acquired the necessary head on the outside, after the closing of the gates, it followed down the piles through the silt, into the sand and up again on the other side. The intervening earth was soon washed out, and with it the bottom of the piles, until a channel was formed underneath, and very little time elapsed before the whole structure was scoured out.

After having been enlightened as to the nature of the bottom, it was decided to lay the foundation upon this bed of bluish silt, without disturbing it more than necessary. This was done after all the decayed material—logs, ooze, etc.—had been removed from the bottom, and all roots, slides and loose material cleaned off the sides of the banks, and proper slopes of about 1½ to 1 excavated from them. The foundation under the box proper was built up of clay and brush, that under each apron of rip-rap.

Clay.—The specifications for the clay read as follows:—"To be of first class quality, and when kneaded stiff into a pyramid of an inch or so in height, and immersed in water, will remain intact for 24 hours without crumbling."

Brush.—"To be of green bushy fir or cedar trees, of young growth, not more than 15 feet in length, when the stem is cut close to the head, which it shall be, or limbs similar in character."

The separate limbs were afterwards practically excluded, and brush allowed much longer than specified, which served the purpose better.

The first intention of the writer was to obtain the clay from a bed about a mile up the slough, above the site of the box; but after the temporary dams had been built, a great quantity of rain fell, and as the off-take never was intended to carry off all the drainage, the water backed up, so that the clay could not be reached. Another bed of blue clay of excellent quality was then located on the river bank, about two miles below the mouth of the slough, and was conveyed by steamer and scows at a heavy expense.

FOUNDATION.—This was laid as follows:—A bed of this clay was deposited on the bottom of the slough about 2 feet in thickness, and 80 feet in length, that is under the site for the box proper. This was laid in layers a few inches in thickness, carefully spread and levelled, and well tramped and pounded down. On top of this was laid a row of brush with butts to the end. These small trees were laid close together longitudinally, from one side of the slough to the other, and at one end of the foundation. The branches standing up were "nicked" in order to let them lie close. After the first row was laid, another was placed on top partially covering the first layer, similar to shingling a roof, butts all lying out in the same way as number one row. Then another row was laid in a similar manner, until the layer of clay below (80 feet in length) was covered for about two-thirds the distance from one end, or between 50 or 60 feet. After this had been completed a layer of clay was laid on top from 1½ to 2 feet in thickness, covering the whole foundation. This was thoroughly compacted, and tramped down with horses and then levelled up. Upon the top of this clay was laid another layer of brush similar to the lower layer, but this time commencing at the opposite end of the foundation butts out, and extending for about two-thirds of the way towards the first end, and thus overlapping a portion of the first layer of brush, but care being taken that there was a good layer of clay between, so that the brush in no instance would be continuous through the entire length of the foundation. Upon the top of this was laid another layer of clay similar to the previous layer and so on, until the proper height was obtained to lay the box.

The accompanying plate is intended to show a longitudinal section through the foundation.

When the foundation reached the required height, it was carefully levelled off and made ready for the box. The lower planks of the box floor (5 x 12 x 26 feet) were then laid close together, each one being levelled up and pounded down with a heavy pounder, until it lay on an even bed throughout, in contact with the clay. Upon the top of this floor was built the box as shown on the plan.

From the box to each bank of the slough was laid clay and brush in a similar manner to that in the foundation, care being taken that in no case should the brush extend in a continuous layer right through the embankment, or that it should touch the sides of the box. The clay was laid in thin layers and thoroughly tamped and pounded down, especially close to the box, and also carefully knitted into the banks on each side by key walls. A brush and clay embankment laid in this manner was carried up on each side and on the top of the box, until the top of the banks of the slough were reached, with the exception that, after the top of the box level was reached, the slopes on each end were carried up by driving split cedar pickets about 3 inches in diameter and 6 inches apart, 4 feet into the embankment,—each row being 1 foot higher than the preceding one, and 1 foot nearer the center of the box, thus making a slope of 1 to 1 at the ends. Behind, or inside each row of pickets, was laid "heading brush" or brush laid transversely with the box to keep the clay in place. From the top of the bank of the slough, a dyke of ordinary earth-work was built to the height of the river dyke, about two feet above maximum high water.

The aprons were built as shown on the plan, the walls flaring out from the ends of the box to the end of the apron, and rip-rap being hand laid outside of the walls upon the floor, to load it down. From the rip-rap walls to the banks, the slopes were built of rough brush and ordinary earth, laid in a similar manner to the clay and brush.

GATES OR CLAPPERS.

The gates or clappers used on the box, a detail of one of which is shown on the plan, are of the "top hung" pattern. A difference of opinion seems to exist among the engineers of this district as to advantages derived from that style over the "side hung" gate. The trouble experienced with the gates on this box was as follows: when the freshet first begins to come, the river only rises a few inches in 24 hours, and, according to the state of the weather, may in its steady rise never exceed 6 to 12 inches in one day. Consequently, the gates not being hung perpendicularly—but when closed have a batter of about 1 inch in 12—the water keeps running in underneath the clapper, filling the slough inside as quickly, or nearly so, as the river rises outside, and the clapper to all intents and purposes floats on the stream, there being practically no pressure against it, at least not enough to close it.

Weights were attached to the bottom of the clapper which assisted materially in closing them. In the case where the water rises rapidly outside, as in tidal waters, no trouble is encountered, for once it begins to rise, a head very rapidly forms, and the gates will close with a sound as of the discharge of a cannon. Another disadvantage of the "top hung" gate is this: when the slough is discharging, the water inside as a rule is very slightly higher than the falling water outside. Also there are always more or less branches of fallen trees, sticks, pieces of logs, etc., being carried out through the boxes. These must necessarily pass underneath the slightly opened clappers, and in many cases are caught between the floor of the box and the bottom of the gate. Then when the tide changes, and the water turns to flow back into the slough, the debris prevents the particular gate from closing. Well designed grillages both above and below the gates ward off much of the debris, but notwithstanding this it is impossible to keep some branches, fence rails, etc., from passing through.

In the "side-hung" gates, less trouble is encountered from this. Here the gates are hung in pairs, closing at the center of the openings; the debris can then float upon the top of the water, and not being dragged along the bottom of the box, has only the two edges of the gates to encounter, and the gates being evenly balanced, will open enough to allow the debris to pass through. This difficulty of course is only encountered when the head on either side is small, and the gates in consequence are very slightly opened. In "side hung" gates there is a slight disadvantage in that it is very difficult to prevent the gates from sagging through length of time, which prevents them from closing tightly. They must be well designed with very heavy and strong hinges.

In many of these boxes on the Fraser, the gates are hung on the outside of the box, and have the advantage that they are more easily reached should anything prevent their closing during high water.

These gates cost practically $10,000 each.

Thursday, 22nd April.

P. A. PETERSON, Past President, in the Chair.

ABSTRACTS.

COMPARATIVE TESTS OF STEAM BOILERS WITH DIFFERENT KINDS OF COAL.

By CHAS. E. EMERY, New York.

(Transactions American Society Mechanical Engineers, Vol. XVII. (1896, p. 237).

This is a paper prepared to suggest discussion by the members of the Society of the standard method of conducting boiler trials proposed by the committee of 1886.

The author states (§ 5) that the evaporative efficiencies of anthracite and semi-bituminous coals containing less than 20 per cent. of volatile combustible (as, *e.g.*, most coals of Eastern United States) are independent of chemical composition. As proportion of volatile matter increases beyond the above limit, the percentage of the total calorific value which is practically utilised is reduced.

The calorific and practical value probably varies much with the "mechanical structure" of the coal (§ 7).

In § 8, he refers to method of loss due to volatilisation, as to whether this takes place by the escape of unburnt elementary or compound unburnt gases, and gives a table of Isherword & Johnson's analyses of 13 different kinds of American and English coal, and a description of modes of making boiler trials of same, §§ 9 to 14.

In § 15 gives results of 15 different kinds of coal obtained on tests at the Navy Yard in 1862; but no analyses were made. Discussion of same, §§ 16 and 17.

References to Johnson's experiments, 1843-44 (§§ 18 to 22), on 41 samples of authracite and semi-bituminous coal from Maryland, Pennsylvania, Virginia and other places, states that his report is a compendium of useful information on the general subject.

§ 23 refers to Kent's review of Scheurer-Kestner and Meunier's tests of European coals.

§§ 25 to 35 contain a discussion of the above results as exhibited in a series of platted curves on a base of percentages of fixed to total carbon.

§ 36 refers to calorimetric tests made by Professor R. C. Carpenter of 28 varieties of anthracite and bituminous coal. The anthracites show on the average lower calorific value than the bituminous; but there is no relation traceable between this and the percentage of fixed carbon.

In § 36 it is suggested that the results of proximate analysis be stated in terms of "fixed combustible" and "volatile combustible" vice "fixed carbon," etc.

In § 39 alludes to Baron's tests (by Bryan Donkin's calorimeter) of coals without chemical analysis; concludes that a boiler test is much better, as not liable to errors from improper sampling and the delicacy of the calorimetric method.

In § 45 gives curves of evaporation as affected by rate of combustion. A formula representing the curves approximately is:

$$E = \frac{27}{c + 2} + 1$$

where E is the number of lbs. of water evaporated from and at 212° F; c is the lbs. of combustible burned per square foot of heating surface per hour. With c varying from 0 to 5, E varies from 14.5 to 4.9 lbs. per lb. combustible.

J. T. N.

PAINT AS A PROTECTION FOR IRON.

By E. A. Custer and F. P. Smith.

(Proceedings of the Engineers' Club of Philadelphia.)

The prime requisites of a protective coating are that it shall be a good base for subsequent ornamentation, and that it shall prevent rust.

A dry atmosphere of oxygen or carbonic acid gas or both mixed will not rust *bright* iron; even a slight amount of moisture added will not rust bright iron, but if the iron is already rusty, the rust present has the power of absorbing oxygen and condensing moisture.

Prof. Brown is quoted as giving the following explanation of rusting:— "that the carbonic acid dissolved in water which is necessary to rusting "is not *used up* in the process, but is given off when the ferrous bi-car-

"bonate is oxidised into ferric hydrate, and is ready to act on a new "surface of metallic iron, etc. Thus, as long as water and oxygen are "supplied, the process goes on, and the porous rust already formed "tends to aid the process by collecting moisture from the air."

The qualities of a paint necessary to prevent rust are (1) that it shall adhere firmly to the iron surface; (2) that it shall itself not corrode the iron; (3) that it shall form a surface hard enough to resist frictional influences, and yet elastic enough to conform to expansion of the metal; (4) that it shall be impervious to and unaffected *by moisture or other atmospheric influences.* Red lead and linseed oil satisfy the first three requirements but not the last; the reason given is that the red lead is an *active* pigment, *i.e.*, that it acts on the acid of the oil to form a metallic soap, and liberates the other constituent of the linseed oil, glycerine. Now, this glycerine is not a stable product, but is soluble in water and volatilized by heat. Thus it leaves the pores of the metallic soap, and the result is that the paint becomes porous.

Red lead combines somewhat with glycerine also, and volatilisation is somewhat prevented, and the hardening of this paint is of a double nature, setting somewhat like a cement, besides drying out. Red lead only contains 10 per cent. of oxygen. Oxide of iron contains 30 per cent. of oxygen. Therefore, the former cannot be considered a dangerous conveyer of oxygen, and it cannot be admitted that it aids rusting in itself, at all. Dr. Dudley's experiments determined that linseed oil was not water resistant, and that the addition of red lead, while improving matters, did not make the mixture impervious. Attempts were made to add an impervious material to the red lead and linseed oil, but were all unsuccessful, as the good effects of the red lead on the oil were nullified.

Experiments with oxide of iron as an outer coating demonstrated that it had power to destroy organic matter, and rendered the inner coating of linseed oil inelastic and brittle before it destroyed it completely. It was determined that oxide of iron was a direct and also indirect promoter of rust.

Red lead and linseed oil being somewhat porous, however, will not prevent any surface of iron that has begun to rust from continuing to do so, as it is somewhat porous, but it will not actively cause rusting itself, in the same way that oxide of iron will do.

The writers then commenced experimenting on materials to form a second impervious coat to put on top of the first coat of red lead and linseed oil, and their conclusions were that the vehicle must again be linseed oil, and the filler or pigment a completely inert one, but the second coating must be able to resist acids and frictional resistance as well as being impervious. The nature of this second coating the writers did not state, but after warning engineers against using paints that were cheap because they covered a large area per gallon, or in which the pigment was rosin oil, or some other inefficient substitute, they pointed out the necessity of thorough removal of rust and mill scale by use of wire brushes or scraping before paint was applied, and stated that a paint must often adhere to hot iron surfaces in which the temperature changed 300° or 400° F. in an hour, and also where sulphuric acid fumes were prevalent. Specimens were exhibited covered with the two coatings recommended which had had long service under severe trials, and shewed the paint adhering as firmly as ever and the iron bright beneath.

In the discussion, Mr. Trautwine referred to the similar necessity of two coats of asphalt when put on concrete surfaces : 1st, a priming coat of 70 per cent. gasoline, 30 per cent. liquid asphalt is used, which carries the asphalt into the pores of the concrete ; after this coating is dry, the melted asphalt is laid on with brooms, and adheres tenaciously, whereas without the priming coat the asphalt would peel off easily.

Mr. Schumann spoke of African Sandarac Gum dissolved in alcohol as a waterproof paint, and also resisted acids ; but others present stated that vegetable gums will not stand the weather.

Mr. Schumann also gave an account of his method of cleaning iron before painting. This was done by means of a sand blast, driven by compressed air under 12 lbs. pressure per sq. in. The cost was about equal to one coat of paint, and the method of application was by a flexible hose and nozzles. This work must be done at a distance from machinery so as to prevent injury to it by sand grit.

C. B. S.

INCLINED PLANE RAILWAYS.

S. Diescher.

(Proceedings Engineers Society, Western Pennyslvania, November, 1896.

This paper discusses some problems in connection with the handling of passenger and freight traffic up heavy grades. Nine per cent. is stated to be the limiting grade for direct operation without auxiliary appliances ; and this for short lengths only. In the early part of the century endless cables with grip attachment were devised for hoisting canal boats over the Alleghany Mountains on the Portage Road, and this system has been considerably used. The steepest known grade operated by endless cable and grip is twenty-two per cent., and it is very short. Inclined planes are more economical than cable lines, because in the former the weights of the ascending and descending cars balance one another. Steep grades on electric and cable lines have been operated by the "balance system," which on a single track line employs a dummy car to take the place of the second car of the inclined plane railway. The safety rope is proved by experience to be the best safety attachment to an inclined plane railway. The power mechanism is discussed, and an engine operating through gearing upon a large single wound drum is preferred, and two instructive accidents in connection with the mechanism are described. One on a road operating in a plane of seventy-two per cent. Wire ropes of English make are mostly used on the inclines, and a wire of crucible steel, ultimate strength 160,000 lbs. per square inch, and elongation four per cent. in twelve inches, is recommended. The history of a set of ropes two inches in diameter of Nos. 9, 10 and 12 wire is given and of the tests made on them. A full sized test showed a strength of 222,000 lbs. before using. One rope ran three years, another four and a half years, and the third is still running after five and a half years. The tests after replacing showed little deterioration in the strength of the first rope, although it was condemned because 46 wire fractures were counted in twelve inches. It ran 20,000 miles. 50,000 miles is stated as the life of a very good rope, and a rope should be condemned when 40 per cent. of the wires are fractured in the length of a strand pitch.

In the discussion it is stated that wire tests are preferable to full sized tests of rope, because failure generally arises from fracture from brittleness. The wire breaks straight across, and the ends remain in contact after fracture, indicating that the breaking arises solely from brittleness. Sheaves of 1 foot dia. for every quarter inch diameter of rope are given as a minimum.

J. G. K.

Thursday, 6th May.

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

The following candidates having been duly balloted for were elected:

Members.

L. H. Buck.

Associate Members.

A. H. N. Bruce. Richard J. Durley.

Geo. E. Pesley.

Associate.

F. X. Berlinguet.

Students.

J. A. Burnett, A. B. Newcombe.

Transferred from the class of Associate Member to that of Member:

F. G. Jonah, J. M. McCarthy,

L. R. Ord.

Transferred from the class of Student to that of Associate Member:

E. C. Amos, L. B. Copeland.

A letter was read from the Secretary of the Amer. Soc. C.E. inviting the Members to be present at the Annual Convention to be held at Quebec, June 30th, July 1st and 2nd.

Paper No. 120.

THE ALBION MINES RAILWAY.

By D. A. STEWART, M.Can.Soc.C.E.

It seems desirable that such information about the earlier railways in Canada as can now be obtained should be preserved in the papers of this Society, and it is in the hope of drawing out any such information that may be available that the following brief notes are presented.

THE ALBION MINES RAILWAY.

1. Patterson's History of Nova Scotia says: "The road was laid out and operations commenced in the year 1836. The surveys and plans were made by Peter Crerar, Esq.; when they were sent to Britain, it was proposed to send out an engineer to superintend the construction of it. When his plans were submitted to a competent engineer they were found to need no better superintendent than the man who prepared them, and so the supervision of the work was entrusted to one who had never seen a railroad, and he accomplished it satisfactorily. It was the first road to be opened in British America, and three locomotives ran upon it in 1839. Two of these are still in use (1877), and though very slow, are enormously powerful. Their builder was Timothy Hackworth, who competed with Stephenson at the first trial of locomotive engines in England. This railroad was six miles long and so nearly straight that the least radius of any of its curves was 1,300 feet. Its width was 18 feet. The quantity of excavation was 400,000 cubic yards. At the terminus was a wharf 1,500 feet long by 24 feet broad, commanding a fall of 17 feet above high water level at the shoots. The rails were of malleable iron, and the estimated cost $160,000."

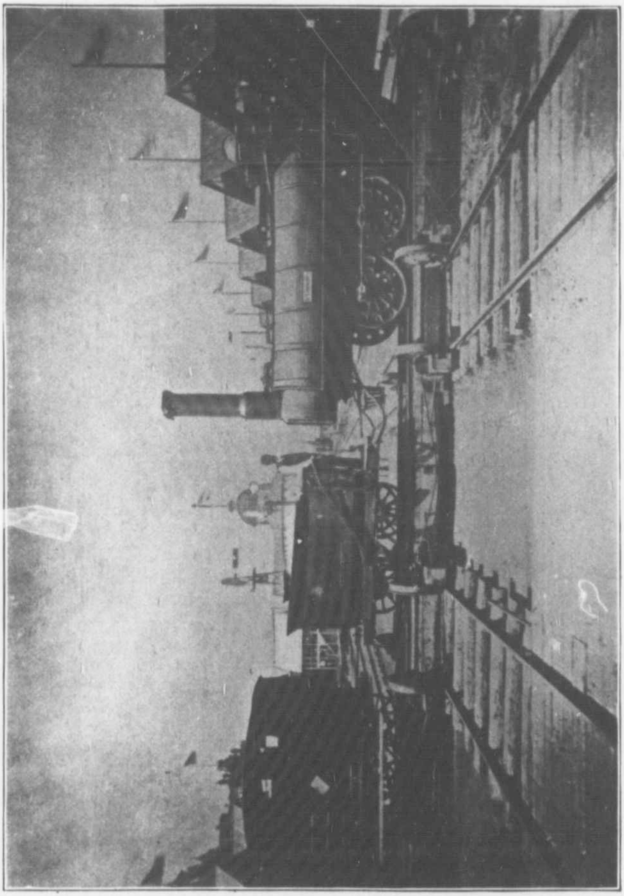
2. The following is from the *Mechanic and Farmer*, a weekly newspaper published at Pictou, N.S., under date May 1st, 1839:—

"THE ALBION MINES AND THE COAL TRADE.

"About ¼ of a mile below the bridge at New Glasgow and about 2½ miles down the railroad stand the shipping wharves, shoots, etc. Here the old railroad terminates, here the coal brought down from the mines in wagons of one chaldron each (one horse bringing four or five) are loaded into lighters or vessels not exceeding eight feet draft of water....... As you proceed down the river the attention is attracted by the excavations, embankments, bridges, etc., of the new *locomotive railroad.* About three miles down from the shipyard is South Pictou, where may be seen the largest bridge and range of wharves in Nova Scotia. The wharves, which are situated on the banks of the channel, are 600 feet in length, and present many conveniences for loading vessels engaged in the coal trade, amongst them a steam engine of 18 horse power called a 'transfer engine.' It was erected last autumn, and adds materially to the previous facilities in shipping. The coal is placed in boxes containing two chaldrons each, the engine raises the box with its contents, and places it over the vessel's hatchway, when a trap door in its bottom is opened and the whole speedily transferred to the ship's hold ; sixty chaldrons can thus be transferred with safety and ease in an hour's time. Here the new railroad is to terminate, being about six miles in length, and connected with the wharves by a bridge 1,600 feet in length, built on piles and raised about 20 feet above high water mark. It is in a very forward state, and will probably be completed in three months. This part of the establishment is under the superintendence of our worthy townsman, Robert McKay, Esq. During the last summer from 25 to 35 sail of American vessels might frequently be seen here at one time. Over 300 sail of vessels of various descriptions were loaded here last year.... There are three locomotive engines on their way from England, and when these arrive the steam engines to be in operation during the course of the summer will be twelve in number."

3. The following information was given by Mr. George Davidson now of Port Morien, C.B. :—

"I landed in Pictou the 18th of May, 1839, with three locomotives, the first in this country. We got the engines together, and began to ship coal below New Glasgow on September 17th, the same year. We could load schooners there that drew 9 feet of water ; larger vessels were loaded at Pictou ; the coal was towed down in lighters. There was a transfer engine to lift the coal from the lighters to the ship's hold, and there were 5,300 lbs. in each box of the lighter. There were two steam tugs to tow the lighters up and down...... The railway from the Albion mines to the loading ground at South Pictou was completed in the latter part of 1839. The locomotives were of 20 horse power, and carried 50 lbs. steam, and hauled 90 tons of coal each trip."



4. Mr. Hudson says: "The rails were fishbelly wrought iron rails 40 lbs. to the yard. The quality of the iron was excellent. There has been none like it about here since. The Londonderry Iron Company got a great part of them, and the New Glasgow Iron, Coal & Railway Company (now the Nova Scotia Steel Company) has bought up and turned into steel all they could get."

The accompanying photograph shows one of these old locomotives as it appeared at the Chicago Exhibition.

The following information was kindly furnished by Mr. C. W. Archibald of the Intercolonial Railway:

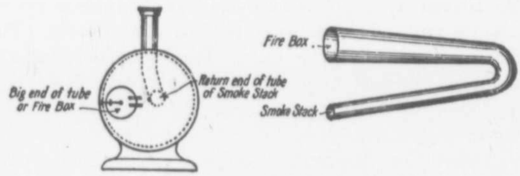
"I now give you what information I can from memory. In 1883, when I took this engine to the Railway Exposition at Chicago, I had its history, and that of the railway on which it ran, well in mind, but I have now forgotten many points about it.

"'The Samson' was built in the machine shops of Timothy Hackworth, Sheldon, Durham, England, in 1834, two others of the same class and style being manufactured at the same time, and for the same Company. (The Company referred to was that operating the 'Albion Mines.' I have forgotten the official designation of the Company, but Sir George Elliott, who resided in England, was President of the Board of Managers.)

"The engines came to Nova Scotia in the spring of 1836, and the 'Samson,' the first erected, was turned out of the Stellarton Shop, September 21st or 26th, of the same year.

"George Davidson 'The Old Driver,' whom I had running the locomotive at the Exposition, worked on its construction for Hackworth, and was sent out with the engines to put them together. After erecting the engines he continued to drive the 'Samson' for nearly forty-seven years, and is yet living, I believe, with relatives at some of the Collieries in Cape Breton. At the Exposition the 'Old Driver' was the lion of the Brotherhood of Locomotive Engineers, whose guest he became, and was used splendidly. He was conceded to be the oldest driver in America, and great wonder was expressed that he had been associated with the *same locomotive* during all these years.

"The 'Samson' was a mogul, having three pairs of drivers coupled, but without any bogie truck. The cylinders were situated immediately over the rear driving wheels, the piston rods working vertically. The boiler was a return tubular one, the fire-box being one end of the tube, while the smoke stack was the other.

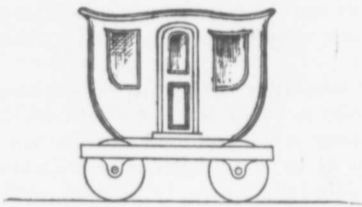


"The wheels were cast in two sections which were secured to each other by a series of oak plugs. It was said by the driver that their object was to overcome anticipated trouble in this cold climate from contraction of metal.

"The fire-box as related was beneath the smoke stack at the forward end of the boiler, and in consequence the tender preceded the locomotive, while the driving gear was at the rear of the boiler. The driver sat on an iron arm chair at the boiler end, but was totally without shelter, no cab or protection from the weather being provided.

"The tender ran on four rigid wheels, similar to but smaller than those in use on hopper coal cars to-day, and the only brake on the locomotive was applied to the tender wheels (one pair) by an iron lever on which the fireman surged, and secured beneath teeth on a bar of iron on the side of the tender.

"The passenger car was equally a curiosity, it was built after the style of a 'Concord' stage coach body, with two pairs of rigid wheels. The brake was similar to that on the tender, and connection to the locomotive was made by a two feet of chain. The doors were in the sides similar to a cab, and the car held six people, three on each seat facing each other. The sketch is in very bad proportion, but will give the idea. The wheels were only about 20″ in diameter.



"The car was very nicely upholstered in very light gray broadcloth, and in its time had carried many notable people, from the fact that before the construction of Government railways in Nova Scotia, the ships of the North Atlantic Squadron were frequently in Pictou Harbor, and the admirals, officers, etc., were frequently the guests of the Managers of the coal mines. In order to reach the mines, this now celebrated engine and car was sent for them. In this way such notables as the Prince of Wales, Lord Dundonald, Lord Dufferin, with admirals and officers too numerous to mention, have enjoyed its comforts.

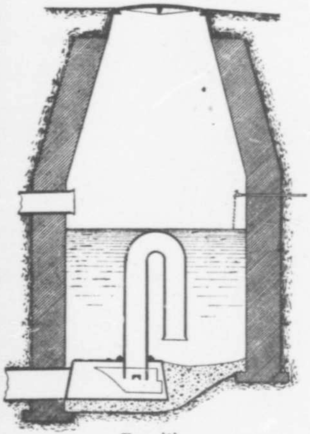
"The track was also quite interesting in many ways. It is said the engineer who built the railway (Mr. Crerar of Pictou) had never seen a railway, nevertheless the work was thoroughly done, and I believe the masonry in many of the structures is in first class shape to-day. It was supposed at that time that the traction of a locomotive would overcome little or no grade, and the railway from end to end was practically level. The road was finished, ballasted and all, before a locomotive was allowed on it. The ballast, rails and ties were hauled by oxen and carts, I am told. The rail was what is known as the 'Fish-belly' rail, and was laid in small chairs, which in turn were secured to stone blocks and tie rods provided occasionally to maintain the gauge, which, strange to say, was what is now our standard, viz., 4' 8½".

"I have forgotten what the distance was from centre to centre of chairs; but if my memory serves me, it was about three and a half feet. The rails of course were multiples of this spacing, but were generally very short rails.

"I have overlooked many details which are interesting. The other two engines similar mentioned before, the 'John Buddle' and 'Hercules,' had a shorter existence, partly from the fact that they were in collision, and partly that they changed drivers frequently and did not receive the care given the 'Samson' by Davidson.

"In 1883 the boiler of one of these was used for pumping purposes in the mine, and the other engine had lately found its way to the scrap pile."

WINNIPEG, April 24, 1897.



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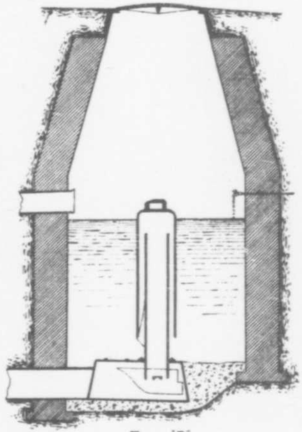

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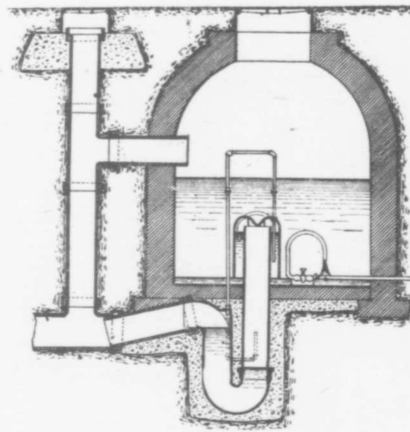

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Thursday, 20th May.

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

The following candidates having been balloted for, were declared elected:

MEMBERS.

JOSEPH DE GUISE, GEO. J. DESBARATS, R. A. ROSS.

ASSOCIATE MEMBERS.

HUGH JARDINE, JOHN MACCUNN, J. H. MOORE, WM. E. MCMULLEN.

STUDENTS.

W. W. COLPITTS, E. G. MATHESON, GEO. A. MCCARTHY, WALTER W. BENNY.

Transferred from class of Associate Member to that of Member:

ABBOTT TRUE, JOHN WOODMAN.

Paper No. 121.

THE SEPARATE SYSTEM OF SEWERAGE IN ONTARIO.

By WILLIS CHIPMAN, M.CAN.SOC.C.E.

The following paper has been prepared to briefly describe the several separate systems of sewerage that have been constructed in the Province of Ontario to this date, and to specially point out such modifications in the system as originally designed for a sub-tropical climate that appear necessary in a Northern climate.

The defects that have manifested themselves in each of the works to be described will also be mentioned.

In November, 1879, Geo. E. Waring, M.Inst.C.E., of Newport, R.I., read a paper before the American Public Health Association at Nashville, Tenn., that introduced the Separate System of Sewerage to the United States and Canada, from which circumstance that system has been generally known to the American public as the "Waring System" from that date.

The Separate System had been in operation in England for many years before that time; the first city to introduce it being Alnwick in the County of Northumberland, but, in England, it had been the general custom, as it is still, to permit a limited amount of storm water to enter the sewers, and this irregular flushing is depended upon to keep them free from deposits. Col. Waring recommended two important improvements, viz. : the complete exclusion of storm water, and the adoption of an automatic flush tank at the head of every lateral sewer. The ventilation of the sewer system was to be effected through the house sewers and the soil pipes which were to be carried above the buildings, and were not to be provided with main traps. The sub-soil water was to be lowered by laying porous agricultural tiles in the same trenches as the sewers, thus keeping cellars and basements dry.

In 1878 the city of Memphis was visited by an epidemic of yellow fever, caused doubtless by its unsanitary condition and lack of sewerage, the deaths from this disease for that year being over 5,000 in a population of about 30,000 ; in 1873 there had been 2,000 deaths from the same disease. Owing to bad management of the city's finances and a collapse of the "boom" following the Civil War, the city was practically bankrupt. A committee from Memphis saw in the suggestions of Col. Waring a possibility of constructing a sanitary system of sewers at a small cost as compared with the cost of a combined system which had been designed for the city by competent engineers a few years previous to this.

The National Board of Health took up the question, with the result that there were constructed in Memphis in 1880 about eighteen miles of sewers according to Col. Waring's scheme, at a cost of $137,000.

Owing to the necessity of extreme economy, manholes were omitted in many places where it was found necessary to build them afterwards, and the proportion of small 6 inch mains appears to have been too great.

It must be remembered that this was the first sewerage system constructed in the country, in accordance with Col. Waring's method, and that the work was rushed. It is not surprising, therefore, that the results were not perfect, but the defects that manifested themselves were all of minor importance. They were sufficient, however, to raise a storm of adverse criticism that the writer considers was quite unwarranted.

After the completion of the Memphis system many other similar works were projected and constructed in the United States. The most northerly towns to have adopted the system before 1886 were Keene, in Southern New Hampshire, and Schenectady, N.Y.

BROCKVILLE.

In 1885, the writer, then acting as Town Engineer for Brockville, Ontario, visited many cities and towns in the Eastern States, to obtain information respecting sewerage; among the places visited was Schenectady, N.Y. Under the guidance of Prof. Staley, then Consulting Engineer, the sewerage system there was thoroughly examined in detail, with the result that the writer was convinced that the Separate System was admirably adapted for many Canadian towns and cities that could not afford a complete combined system, the only one then known to the Canadian people in general.

In 1886 Col. Waring was engaged to report upon the proposed Brockville system, and in 1887 construction began.

Brockville had a population at that time of 8,500. It is situated on the north shore of the St. Lawrence, the ground rising gradually from the shore, the highest point in the inhabited portion of the town being 100 feet above the river, which is 246 feet above mean sea level. On the outskirts of the town is a small millstream flowing in a westerly direction. Further down its course it turns towards the south and south-east, and finally discharges into the St. Lawrence. The whole of the town area drains naturally to this brook or to the river direct.

In 1882 the town entered into an agreement with a private company for a water supply for all purposes. The Water Company, with the consent of the Council, located the pump house in the easterly part of the town, and below the outlet of the small stream above mentioned, the intake pipe being about 200 feet from the shore line and only 40 feet beyond the wharves at this point.

Although the citizens did not object to the location of the water works intake at the time, objections were taken to discharging any sewage into the river above it.

A long intercepting main sewer was therefore constructed to collect the sewage from the valley of the small stream above mentioned, and from the river front. This sewer was provided with a submerged discharging pipe 924 feet long, the outlet of which was located about 1,000 feet below the water works intake in a strong permanent current and in 45 feet of water. The western part of the town is very rocky and irregular, the rock comprising the quartzites, schists and gneisses of the Lower Laurentian. The eastern part is underlaid with thin bedded irregular limestone and sandstone of the Upper Potsdam formation. The subsoil in the highest central parts is sandy loam with boulders, requiring but little shoring in trenching where rock is not encountered. Quicksand was struck on these streets only. Stiff clay was also struck in many streets. It is evident from this description that nearly every variety of soil and of rock was met with in the excavations.

The Brockville works were designed and constructed by the writer, who had become familiar with the details of the system by acting as assistant engineer in the construction of similar works in New York State designed by Col. Waring, Prof. Staley, Geo. S. Pierson and W. B. Landreth.

In reporting upon the Brockville system Col. Waring recommended as follows :

1. The exclusive separate system.
2. Automatic flush tanks.
3. Some six inch street sewers.
4. A depth of sewer on business street of seven feet only.
5. The omission of manholes on smaller line of sewers, and inclined inspection pipes substituted.
6. The laying of ordinary drain tiles in sewer trenches at the sides of the sewer pipes to reduce the level of the subsoil water.
7. The ventilation of the system through the house drains by omitting main traps.
8. No house drains to be more than four inches in diameter.
9. No sewer to be less than six inches in diameter.

These recommendations were practically the same as those adopted in Memphis in 1880.

The Town, upon the advice of its engineer, adopted the exclusive separate system, the automatic flush tanks, the porous drain tiles, and the four inch house sewer without traps, but rejected the inclined inspection holes and the six inch main sewers. As to the mains, they were laid deeper than seven feet below the surface, except in a few places where a greater depth was impossible.

The Brockville system was commenced in 1887 and practically completed in 1891, when eight miles of sewers had been constructed at a cost of $95,000, about $15,000 of which represented rock excavations. In 1892, 1893 and 1894 about one mile of sewers was added.

Cellar drainage in cities and towns is an important matter in northern climates, and a matter that has not been given sufficient attention by engineers. For a month or more the temperature may not rise above the freezing point, the snow is shovelled from the sidewalks outwards towards the roadway, forming banks occasionally five feet, and frequently three feet high; the snow is also removed from back yards, private walks, etc. With a sudden rise in temperature, frequently accompanied by rain, this snow melts, and the water naturally fills the depressions thus made, runs beneath walks, under verandahs, porches, etc., and thus finds an entrance into cellars and basements, through windows, doorways, cracks in walls, or, as frequently happens, it runs down the outside of the walls, and enters beneath them. Occasionally cellars are filled by the water entering through a newly made water service trench, or through an old box drain which has become wholly or partially blocked.

On side hill towns the water from the upper buildings and lots will flow towards the lower, and may thus cause cellar flooding in some places.

It is evident, from the above considerations, that the nature of the soil or of the subsoil, which may be frozen solid or covered with ice, has little or no effect upon cellar flooding in the winter season, and it is then that the greatest damage is done, and the greatest dangers, in a sanitary point of view, are to be apprehended. A flooded basement or cellar in winter may cause damage to goods or supplies, and dampness in the building for the remainder of the season, a condition conducive to many zymotic diseases.

The porous drain tiles in Brockville were laid as recommended by Col. Waring and other sanitary engineers, the grade being the same as that of the sanitary sewer. These porous tiles were laid alongside of every sewer, and given outlets wherever practicable.

The Brockville system has now been in operation about eight years, and the results there as enumerated below may be of interest to the profession.

1. The sanitary sewers have been maintained in a good sanitary condition.

2. The automatic flush tanks keep the sewers free from deposits, and wash out the dead ends thoroughly at least once a day.

3. The flush tanks require constant inspection to maintain continuous action—one-fifth of them being found not working properly on each fortnightly inspection. Generally the rapid filling and emptying of the tank a few times will insure its working for a week or more. About ten per cent. of the tanks require more serious attention and possibly resetting once every year.

4. No stoppage has occurred in the sanitary sewers. (The main sewers were cleared out by pill once a year for two years after completion.)

5. The four inch house sewer connections have caused no trouble except in the case of two hotels and one or two other places, where they became blocked by the carelessness of the tenants. A long 6 in. sewer from the General Hospital, laid at a flat grade, became blocked with banana peelings in the summer of 1894.

6. The subsoil water has been reduced in level in nearly all parts of the town, as is evident from the more rapid drying up of the streets in April and May, and after heavy rains; but it is probable that the credit for the improvement is due in part to the sewer excavation, and not altogether to the porous tiles.

7. Generally, cellars and basements are kept dry indirectly by the porous tiles, which have the effect of lowering the subsoil water.

In three or four cases basements became flooded after connecting with the porous tiles along the street sewer, and it was necessary to connect directly with the sanitary sewer through traps. The flooding was caused in these cases by the sudden entrance of surface water which the drain tiles failed to remove immediately. In some cases the tiles between the building and the street sewer became blocked by corks and other matters floating from the cellar, while in others they removed the water within the day following the flooding.

8. The ventilation of the system through the house sewers is perfectly satisfactory, and no complaints have been made against this method.

Although Brockville was the first place in the Province to adopt the Separate System, the result there has been very satisfactory indeed.

It might be stated, however, that in Brockville, stringent rules and regulations governing plumbing and the laying of house sewers were adopted before a connection was made with the mains.

If old plumbing work was found defective in design and badly constructed, or in an unsanitary condition, the owner was not allowed to connect with the sewer system until such changes were made as the Engineer directed. The house sewers were all laid under the supervision of the Engineer or his Inspectors, and all reported stoppages or defects were at once investigated by the Engineer and remedied as soon as possible.

The Engineer keeps a complete record with plans and sketches of all the house sewers and the plumbing (old and new). These records were the first of the kind to be introduced into Canada, and are probably the best to be found in the Dominion to-day.

The maintenance of the Brockville system has been under the direct personal control of the Town Engineer since its completion, and the inspectors who have been employed from year to year to superintend the laying of house sewers, to test plumbing, to inspect the system, etc., were continuously engaged on the works during construction, and are consequently very competent men.

Before the construction of the Sewerage System, the town had provided many box drains for the removal of storm water and for draining cellars; some of these drains caused flooding of cellars in excessive storms.

These old box drains built of rough stones without cement had been used for carrying sewage, the owner in many cases first connecting his cellar, then his sink, then his bath, and lastly his water closet, until an offensive and dangerous nuisance had been created on many streets.

The old drains were retained for storm water, after being cleaned out, and the sewage directed from them to the sewers proper. New storm sewers were constructed on a few streets where the storm water had not previously been provided for.

The defects that have manifested themselves in the Brockville system are of minor importance. If the system were to be built now after the experience gained in other places, the average depth of the Sanitary System would be slightly increased; larger porous drain tiles would be used and heavier sewer pipes with deeper sockets. Some improvements would also be made in the designs of manholes and flush tanks.

On the main sewer a few pipes of standard thickness were found broken a year after they were laid. This occurred in a rock trench refilled with frozen earth.

The present Town Engineer, B. J. Saunders, Esq., Assoc. M. Can.Soc.C.E., reports that the Sewerage System is giving general satisfaction, and he considers that the town acted wisely in adopting it. He also suggests that, if the sewer outfall pipe and the lower part of the intercepting sewer had been made larger, the storm water that now flows into the river near the water works could have been diverted into the Sanitary System. This is now done at the street running at right angles to the river from the water works.

There is no current in the river at the inlet to the water works intake, or for several hundred feet above or below it, except surface currents caused by winds, this slack water area being produced by a projecting railway pier 500 yards above it.

The storm water may in the future find its way to the water works intake, in which case the intake can be extended. This will be found a more economical solution of the difficulty than to have anticipated it by constructing a larger and much more expensive intercepting sewer and outfall pipe.

CORNWALL.

In 1888 the writer was engaged by the Town of Cornwall to report upon a system of sewers. This town has a population of about 7,000. It is situated on the St. Lawrence, below the Long Sault Rapids, but is cut off from the river front by the canal in which the water surface is above a considerable portion of the town. Previous to 1888 the Dominion Government constructed a sewer along the north bank of the canal, to intercept water percolating through the bank, and, as the canal cut off the natural drainage of the town from the river, the Government permitted the use of this drain as a main sewer, the discharge pipe reaching the river by means of a syphon culvert under the canal.

For economical reasons, the Separate System was adopted in the town, except on the main business street, where the sewer is designed to carry off rainfall at the rate of one inch per hour, from half a block on each side of the main street.

In Cornwall the soil is either a tough, tenacious, blue clay or a fine sand, becoming a quicksand when wet. The town authorities decided to omit the porous drain tiles, but adopted the automatic flush tanks.

The writer was engaged to superintend the construction of the main sewers only, and has no personal knowledge of the working of the system, but is informed by the town officials that it is giving good satisfaction.

BARRIE.

In 1889 the writer was engaged to report upon a system of sewers for the town of Barrie; and his suggestions were adopted. Construction commenced in 1890 under the writer's supervision, and the work was completed in 1892. The population of the town is about 6,000.

Barrie is situated on the northwest angle of Kempenfeldt Bay, an arm of Lake Simcoe, about 12 miles in length, and varying in width from three miles at its junction with the main lake to one mile at

Barrie. Lake Simcoe has an elevation of 718 feet above main sea level.

The water supply of Barrie is taken from artesian wells, this being the source recommended by the writer; but the private company which constructed the water works evidently had no faith in the source recommended, as they laid an intake from the pump house to the Bay, months before sinking the wells. This intake has never been used, and remains as a monument of the stubborn resistance the company made to the town's contention that artesian water must be supplied. If the company had succeeded in its resistance, the disposal of the sewage of Barrie would have been a serious matter, as it certainly could not then with safety be deposited in the land-locked Bay on the banks of which the town is situated.

The soil is generally a gravelly sand, in some few places saturated with water. On three streets fine quicksand was found.

There is no rock in Barrie and very little clay.

The winters of Barrie are similar to those of Brockville and Cornwall, but the snow fall is probably a little more, owing to its greater elevation above the sea and its proximity to the great lakes. Cellar drainage was badly needed in a few streets, but generally speaking it was not required as urgently as in Brockville, owing to the more porous character of the soil.

A few storm water drains of wood had been constructed in Barrie before 1890, and the writer constructed one combined sewer.

The Separate System was recommended here for financial and for sanitary reasons. Given a certain sum of money, a larger number of people could be served by the Separate System than by the combined system, and the surface grades were such that the rainfall caused no inconvenience, the street gutters being sufficient to remove what is not absorbed by the porous soil. The cost of constructing combined sewers would have exceeded the financial ability of the town to pay.

Except upon one street the Separate System was recommended and adopted, but the works are designed to carry a limited amount of storm water (the roof water) from the business street only.

The combined sewer above referred to discharges its dry weather flow into a smaller intercepting sewer, but the flood flow passes directly to the Bay.

The sewage is disposed of by discharging it, through two submerged cast iron pipes, into the Bay at such distance from shore and at such a depth that it is not noticed, at least no objection has ever been made to the method of disposal adopted.

The Barrie sewer system comprises about three miles of sewers.

Porous agricultural drain tiles were laid here as in Brockville, with the result that the subsoil water has been so lowered as to permit cellars in places where they were impossible before. In one place where the subsoil water was within 3 feet of the surface, the construction of the sewer drained wells within 100 feet in ten days, and wells within 250 feet in two months. On the main street the porous tile became blocked at a depth of nearly 20 feet while the writer was in charge of construction, causing the usual complaints against the system. Investigation, however, showed that the stoppage was caused by an hotel having been connected with it instead of with the sewer proper. This is the only stoppage reported to the writer, with the exception of one pipe which was blocked by quicksand.

Since 1891, when the writer's term of employment ceased, the sewer system has been under the supervision of the Chief of Police who, in 1892, was also Sanitary Inspector, Plumbing Inspector and Assessor. This officer was not employed on the sewer works when under construction, and was not a plumber or a drain layer by trade. His official duties were such that the sewer system could only receive attention when there was something wrong or when there was nothing else to do.

The reported defects will now be discussed.

In the latter part of 1891 the owners of properties along the main street petitioned the Town Council to put in all house sewers on this street from the street sewer to within the walls of the buildings as a local improvement, such works to be done by tender under the writer's supervision and according to his plans and specification.

This work was done hurriedly by a contractor who took the work at too low a price ; but notwithstanding this, only two connections were reported as being misconstructed up to January 1st, 1895. The writer is of opinion that an investigation by a competent inspector might have proved that these house sewers had been improperly used.

Citizens are prone to saddle the misdeeds of themselves and their households upon a town or city corporation, for which reason stoppages of house sewers cannot be too carefully investigated.

The town adopted a stringent by-law regulating plumbing and the laying of house sewers ; but the by-law is not enforced as in Brockville and Brantford, where the work is under the supervision of the City Engineers.

In 1891, an inverted syphon 40 feet long was built to carry the sewage beneath a stream near one of the outlets. This syphon was of cast iron pipe 6 inches in diameter with a fall of 6 inches in its length, and was laid about 3 feet below grade. This pipe became blocked several times in 1892 by the accumulation of solids and by the sudden detachment of large masses of sewage fungus in the manhole at the head of the syphon.

After clearing it several times it was abandoned, and a straight iron pipe laid to grade substituted therefor. This is the only structural defect that has manifested itself, notwithstanding the very little attention the system has received by unqualified officials.

Much doubt was expressed as to the proper working of the long submerged outfall pipes, but they are reported to be working perfectly, although one, 495 feet in length, is only 6 inches in diameter.

The Separate System in Barrie is giving general satisfaction, the sewers and drain tiles requiring little attention.

BRANTFORD.

In 1890, the writer was engaged to report upon a system of sewers for the city of Brantford; before its adoption his report was submitted to Geo. A. Pierson, Esq., M.Am.Soc.C.E., who approved of it entirely, except as to the location of the main sewer between the city limits and the outlet.

In September, 1890, work was commenced and completed in 1892, the total length of sewers constructed being 12½ miles.

Brantford is an inland city of 16,000 population, situated on the Grand River, a stream with a dry weather flow of less than 300 cubic feet per second.

The greater portion of the city is located in the River Valley, two comparatively small areas being below flood water level.

These low areas are protected from floods by a system of dykes completed in 1894.

The problem at Brantford was the proper disposal of the sewage. The river channel in summer weather is very irregular in cross section, the flow being over beds and bars of gravel, which are shifted by freshets. In the summer months nearly all of the flow of the river passes down an hydraulic power canal, leaving the river bed proper nearly dry. Along the bank below the business part of the city are many residences, the owners of which would have objected to the discharge of sewage in any quantity into the river above them. The Provincial Health Act also prohibits the pollution of any river or stream with sewage.

It was, therefore, decided to discharge the sewage into the river at a point about two miles from the business centre of the city, or about 5 miles following the course of the river. The grade and route adopted are such that all the sewage of the city, except from the two low areas above mentioned, can be distributed by gravity upon suitable land.

When the low-lying areas are sewered it will be necessary to raise the sewage therefrom by pumps, and discharge it into the main sewer, which was designed of sufficient size to accommodate these additional areas.

The water supply of Brantford is taken from filter galleries in the valley of the river above the city, consequently the question of polluting the water supply did not enter into the problem of disposing of the sewage, and below Brantford no town or village takes a water supply from the river.

Brantford adopted the strictly Separate System, no storm water, not even roof water, being permitted to enter the sewers. The soil here is altogether different from that of Brockville, there being no rock and very little clay. The sandy soil was frequently quite loose, requiring close shoring from the top to the bottom of the trenches. Some few clay ridges were cut through, in which cases subterranean reservoirs of water were generally drained or given new outlets. Quicksand was met with in several places, the work on one street being the most difficult the writer ever had to perform. On this street the conditions were as follows :—depth of the sewer about 12 feet, diameter of pipe 13 inches, depth to subsoil water 5 feet, soil sandy gravel, subsoil fine sand with a gravel stratum about two feet below grade, a small spring stream parallel to street and about 100 yards distant, with its water level about three feet higher than the sewer, and a railway track along the street. A steam pump was necessary to keep the water down sufficiently to lay the pipes, and during construction the sewer was displaced by settlement or by the rising of the bottom of the trench. One manhole sunk after construction and another one rose above grade. Since the completion of this sewer, the pipe has been relaid at five different points in two blocks. Four of these breaks occurred where the sheeting has been omitted in the trenches, but the cost of making the repairs exceeded but little the cost of the sheeting omitted. This was the greatest of the unforeseen difficulties the engineers and contractors encountered. It was well known that on this street water would be encountered at a short distance from the surface, but it was assumed that as the excavation advanced, the level of the subsoil water would lower sufficiently to permit of the work being proceeded with by the use of diaphragm pumps.

For a short distance, four of these were in continuous use, after which a No. 5 Maslin pulsometer pump was added. There was no evidence of the level of the subsoil water lowering during the months of September and October, 1891 (when under construction).

In another portion of the city, where it was reported that large quantities of water would be met with, it was found that the subsoil water began lowering when the sewer construction was 400 yards distant, and continued to lower as the work proceeded. When the sewers were laid on the streets where it was prophesied that the water would be struck, the trenches were found no worse than others, the subsoil water having fallen to the bottom of the trenches. At another point in cutting through a bank of clay, an unusually large flow was struck in a street located on a plateau overlooking the bottom land along the river and within 150 yards of it. The grade of the sewer was 20 feet above the river bottom lands. On the main sewer also enormous quantities of water were met with in a loose gravel.

Almost one-half of the trench excavation in Brantford was in loose sand at or near grade, varying in fineness from fine brick mortar sand to fine gravel; about one-fourth was in saturated gravel or sand, and the remaining fourth in clay, quicksand, silt, indurated sand and other materials.

Automatic flush tanks were placed at the ends of all sewers, each discharging about 200 gallons. One discharging 1000 gallons was placed at the Institution for the Blind.

Based upon his experience with the Brockville system, the writer recommended that Brantford adopt the same method of ventilating the system; similar rules and regulations respecting laying house sewers and plumbing with the recorded sketches of the work as completed and accepted; the periodic inspection of all parts of the sewer system; all of which recommendations were adopted by the city, and have been faithfully carried out since then by the City Engineer and his inspectors.

No provision whatever was made for the storm water in the Brantford system, owing to the surface grades, the location of natural watercourses, and the very porous character of the soil. There are few cities in which the storm water causes so little inconvenience. The streets are as yet unpaved, the storm water being removed by tile and box drains provided for this purpose.

The wooden structures will probably be rebuilt as brick sewers when they fail.

On the main sewer (which was not of brickwork) heavy sewer pipes were used with thickness one-tenth the diameter, but with sockets only 2 inches deep. In the city the pipes were all heavier than standard, being one tenth thickness, and all having deep sockets of Scotch patterns. The joints were made with Portland cement mortar, varying in strength from one of sand to one of cement, to two of sand and one of cement. The Portland cement was carefully and continually tested, none being accepted that would not give a tensile strain of 125 pounds to the square inch after 24 hours' immersion in water. Notwith. standing the deep sockets, the good quality of mortar used and the exceptional care exercised in making the joints, large quantites of water entered the sewer system on some streets in the city and along one section of the main sewer. The total flow of the subsoil water in the main sewer from the complete sewer system varies from 150 c.f. to 200 c.f. per minute, according to the saturation of the ground, and at least half of this enters in two miles of the system.

At present the porous tiles in general discharge into the manholes along the sanitary sewers.

For many years this flow of clean water through the sewers will be a great advantage, as, without it, the main sewers would be sewers of deposit. The quantity of sewage now entering produced by a population of about 5,000 will not sufficiently fill a main sewer designed for 30,000 people, to make it self-cleansing.

At least one-half of this subsoil flow can be diverted from the sewer at overflows constructed at different points. The great flow of subsoil water in the Brantford sewers was a source of great anxiety to the writer and to the contractor during construction. If the works were to be constructed again with the present knowledge, some changes in design would be adopted.

In general, selected porous agricultural drain tiles were laid alongside the sewers at about the same grade, frequently two lines were laid one on each side, and when quicksand was encountered in different places, glazed pipes with cemented joints were substituted for the porous tiles.

With the exception of the street where the greatest flow of subsoil water was met with, and where a 6-inch glazed pipe was laid instead of a porous tile, all the porous tiles have given good satisfaction. In two or three places they became blocked during the years 1893 and

1894. In one place the stoppage was caused by a house having been connected with the porous tile instead of the sanitary sewer. The sewage of course blocked the tile, and entered the basement of the house. In the second case the porous tiles were found crushed, thus causing a block. In the third case the writer is not acquainted with the facts.

The six inch glazed subsoil pipe above mentioned has never been cleared for two blocks since the contractor handed the work over to the city. The writer believes that even this could be done, but it is not now necessary.

The necessity of cellar drainage in Brantford is much less than in Brockville, as the snow fall is comparatively light, the soil is very porous, there are few "side hills," the residences have more open ground about them, the storm water drains, street gutters, and water channels can be easily kept open all winter, the buildings as a rule are newer, and have cellars of less depth, and the surface of the ground is less irregular.

Since the sewer system has been completed the necessity for cellar and basement drainage in Brantford has practically disappeared, and no connections are made with cellars or basements.

In May, 1893, two sewers in Brantford were reported obstructed. The writer immediately made an inspection of the works, and examined them. There appeared to be the same flow through the sewers as formerly, but the sewage more than filled the pipes. In one 12-inch sewer with a normal flow of $7\frac{1}{2}$ inches the sewage stood 24 inches deep in the manholes, and in another 12-inch sewer the depth was 28 inches while the normal flow was 6 inches. By flushing with a fire hose and a "pill" these sewers were easily cleared, but in two months they were in as bad condition as ever, and another flushing with accompanying cathartic followed.

These stoppages occurred in sewers where the subsoil flow was the greatest, and where the greatest amount of water entered the sewers. Unfortunately no analyses have been made of this water, but it is evident to the sense of taste and from discolourations that it contains considerable iron. The temperature of the subsoil water does not rise above 55 degrees in the summer months, nor fall below 44 degrees in mid-winter.

An examination showed the pipes lined with a fungoid growth, greenish black in colour, slimy in feeling, slippery and almost impossible to hold in the hand, attached at one end to the surface of the pipes and the other floating down stream. This substance arrested light floating matters in the sewage and checked the flow by decreasing the size of the pipe and by increasing the friction until a temporary block occurred at some point. On one occasion, on the arrival of the labourers to clear a reported obstruction, the section was found perfectly clear, it having broken away before they reached the spot. When the sewage rose above the top of the sewer pipes, the manholes became catch basins, retaining all floating matters until a cake was formed firm enough to support a brick, ventilation then became impossible, and the manhole and sewer very foul.

A microscopic examination of the fungus proved it to be Beggiatoa Alba, a common growth in sewage-laden streams.

Mr. Stearns, of the Massachusetts' State Board of Health, stated to the writer that Crenothrix had been found in large quantities in the under-drains of sewage farms in that State, but that he knew of no case where either Beggiatoa or Crenothrix had caused a stoppage in sewers or drain tiles.

In Brantford it is necessary to remove the fungous growth in two or three sewers about once in three months to maintain the flow within the pipe sewers.

To provide for the sewage from the Provincial Institution of the Blind at Brantford, a nine inch sewer 2,029 feet long was laid from the buildings to the city sewers in the fall of 1892. This sewer had very steep grades, varying from one per cent. to four per cent. On the grounds of the institution the sewer was laid at a depth of about 5 or 6 feet in dry fine yellow sand. On each side of the line ornamental shrubs and small trees had been set out, the greater part of them during the three years preceding the construction of the sewer.

In December, 1894, this sewer became blocked, the sewage overflowing at a manhole, but at so low an elevation that no damage was done or inconvenience suffered thereby.

Upon examination it was found that the pipe sewer below the manhole was completely filled with a growth of roots, chiefly from soft maple trees (acer rubrum), distant from 20 to 25 feet from the sewer. The largest roots were ½ inch in diameter. The pipes were found perfectly jointed, but the cement had disintegrated or softened. Of the 240 feet between this manhole and the next one below, a length of 187 feet was relaid and rejointed. The next section below was examined, but found clear, although the joints were surrounded by roots which had failed to find an entrance. In the succeeding section below, 104 feet were relaid and rejointed, the roots filling the pipe being elm and maple.

In Brockville the writer drew from a porous tile laid at a depth of 9 feet from the surface a long bundle of roots completely filling it, one continuous section being 16 feet in length and 4 inches in diameter, but he never found in his experience such a remarkable growth as that reported from Brantford.

The Brantford system under the official management of City Engineer T. Harry Jones, Esq., M.Can.Soc.C.E., is giving universal satisfaction.

BERLIN.

In 1892 and 1893, the town of Berlin constructed a system of sewers, under the supervision of H. J. Bowman, Esq., M. Can.Soc. C.E., Town Engineer. Berlin is a manufacturing town of 8,000 people, drained by a very small brook flowing in the Grand River. The water supply of the town is taken from another branch of the same brook. To have discharged the sewage of the town directly into this small stream would have intensified the intolerable local nuisance which was then caused by the factories discharging refuse into it.

The writer was called upon to design a sewage farm, which work was commenced in 1893.

The climate of Berlin is a mean between that of Brantford and that of Barrie. The soil is clay and sand with no rock and some quicksand.

Automatic flush tanks have been adopted to a limited extent.

Porous agricultural drain tiles were not used, but glazed pipes with cemented joints were laid alongside the sewers for cellar drainage.

The town adopted a stringent by-law regulating the laying of house sewers and the construction of plumbing, the filing of records, etc., which by-law is almost identical with the by-laws previously passed by Brockville, Barrie and Brantford.

As the Berlin system has been from the first to the present time under the supervision of the Town Engineer it has been a success, but the sewage farm has not been satisfactorily managed.

In the first place, the soil is not suitable for the treatment of sewage, being in general a gravelly clay, overlaid with a few inches of mould loam and sand, which was removed from a great portion of the farm in the grading, and deposited in the depressions.

In the second place, the surfaces of filtrating areas were not brought to the grades as designed by the writer, the surface slopes being left double that shown on the plans, to save expense. As a result the sewage flowed so rapidly across the areas that ruts were formed which could not be filled when the ground became frozen.

During the summers of 1893 and 1894 the sewage was distributed upon the different areas, in such a way that no nuisance was created at the farm; but at night the sewage was allowed to flow directly into the stream.

In the summer of 1894 the surface inclination of the original areas was reduced, and additional tract was laid out into flat filtrating beds.

About 12 acres have now been prepared for the reception of sewage, all being well under-drained. The trenches in which the porous agricultural tiles were laid were filled with gravel.

One man only is engaged to attend to distributing the sewage on the various areas, his residence being in the town, about two miles from the farm. In summer, labourers are engaged as required to cultivate and harvest the crops.

On February 8th, 1895, the writer visited the farm with the Town Engineer. The thermometer had registered from 5° to 25° Fahrenheit below zero for four consecutive days previously, and the ground was covered with more than a foot of snow, blown into drifts five feet high. The sewage had then been allowed to flow for about two weeks continually on one bed, forming ice a foot or two thick, under which the sewage was flowing for a short distance from the point at which it entered the plot. Several other beds appeared to be covered with ice from one foot to two feet in thickness, the greater part of which was frozen to the ground below. The affluent could not be examined owing to the depth of snow and ice, but the edges of the stream were discoloured with the dyes in the sewage. This discolouration was produced by the night discharges of sewage directly into the brook.

With smaller beds properly graded, it is the opinion of the writer that sewage can be disposed of on land even in this climate, but to do so successfully requires competent management.

The writer had heard it stated that the sewage farm at Berlin had proven a failure, but these reports were made by unqualified observers. The best reply to these statements is the fact that the town of Waterloo, only two miles from Berlin, is adopting a similar system for the disposal of its sewage.

TORONTO JUNCTION.

In December, 1891, the town of Toronto Junction, a suburb of Toronto, entered into an agreement with the city by which the town was permitted to discharge its sewage into the sewers of the city, all storm water to be excluded. The Separate System had been recommended by the writer previous to this date, and Emil Kuichling, Esq., M.Am. Soc. C.E., also reported confirming the above recommendation. In 1892 the writer was engaged to design the system and to superintend constructions.

The town has a population of about 5,000, some large factories and one business street. It is situated upon a plateau rising in the northerly part of the town and at a distance of 2½ miles from the shore, to an elevation of 175 feet above the lake. At the southerly limits of the town, one mile from the lake, the elevation of this plateau is 135 feet, the average surface inclination being about one in two hundred. Into this plateau two deep ravines enter from the south, cutting off any sewer connection between the southwest part of the town and the city sewers of Toronto. When in the near future this fashionable residential quarter requires sewers, it will be necessary to resort to pumping, or to carry the sewage direct to the lake. As the water supply for the town is now taken direct from the lake near the point where the sewage must be discharged, it will become necessary te secure some other source of water supply, should the latter method be adopted.

The soil in Toronto Junction is generally sand, sharp coarse sand, fine sand, fine blowing sand, white sand, yellow sand, and all other varieties, with a little gravelly clay mixed with the sand in a very few places.

The climate is similar to that of Brantford, the winters not being so severe as in Barrie or in Brockville. In one section of the town the subsoil water stood at a short distance from the surface of the ground, keeping cellars damp and in some places flooded during a great part of the year. Trouble was anticipated in constructing sewers in this section, but as the work proceeded the groundwater lowered, and, although generally some water was struck above grade, the quantity was so small that pumps were seldom required, and the difficult points were few. This was a surprise to everyone, but it must be said that, where unfathomable quicksand was reported, a stiff and comparatively dry subsoil was found overlaid with a black, mucky, spongy surface soil that retained the water.

On very few streets was pumping or bailing necessary to keep down the subsoil water, and on many streets not a drop of it was met with, even at depths of 16 feet. The trenches required shoring, but not to half the extent they required in Brantford.

An automatic flush tank was placed at the head of each lateral sewer, and agricultural porous tiles were laid alongside the sewers for subsoil drainage. On several streets where live quicksand was found, glazed pipes with cemented joints were substituted for the porous tiles, and on flat grades two lines of tiles were laid.

The works were constructed during the years 1892 and 1893 under the direct supervision of foremen and inspectors appointed by the town. With the exception of two sewers all the work was done by day labour, at a cost well within the estimates.

In Toronto Junction the excavation was less difficult than in Brockville, Cornwall, Barrie or Brantford; there were very few stones, no rock, and practically no clay. The quicksand was not surcharged with water. In fact there was very little water to be found.

In addition to the above advantages the work was done by day labour under engineers who had had experience on other works, and the inspectors were competent men.

Every part of the work was done in a substantial and workmanlike manner, and, when completed, the Engineer confidently reported that the Separate System of sewers in Toronto Junction was better in every respect than the works constructed by him in preceding years.

Under the writer's supervision were constructed about seven miles of sanitary sewers and four miles of storm sewers, the latter discharging into the ravines leading to Lake Ontario.

In prosecuting all Municipal Public works, the "opposition" has frequent opportunities of criticising the Engineer and his methods, the acts of the Board of Works, and perhaps the necessity of the works under progress.

In 1891 and 1892 the opposition in the Toronto Junction Council was active, but generally reasonable in its attacks. About this time the effects of the collapse of the real estate boom were severely felt in the town. At the end of 1892 hundreds of houses were vacant (some of which were so cheaply built that they were falling to ruin); rents were low; mortgages were being foreclosed; land sold for taxes, and, with the completion of the sewer system, labourers who had been temporary residents were emigrating.

Retrenchment was the cry, and at the January elections of 1893 the opposition swept into power. The expenditure on the sewer system was pointed out as one of the causes of the town's unsatisfactory financial standing, and at every opportunity the Separate System was ridiculed.

The new Council initiated its policy of retrenchment by reducing the salary of the Town Engineer by one-half, and by placing the sewers directly under the Inspector of Plumbing. The old Council had placed the Town Engineer, a very competent man, in charge of the sewer system.

This Inspector of Plumbing was also inspector of the laying of house sewers, and sanitary inspector. He had not been engaged on the works during construction, and knew nothing about flush tanks, or other parts of the system. If he had been acting under the instructions of a competent engineer, he might have succeeded ; but during the summer of 1894 he reported more stoppages from drain tiles blocking with sand than the combined stoppages in Brockville, Barrie and Brantford from the time of completion of each system to this date.

It was also reported that the porous tiles were found standing vertically on end. An investigation of the system made by the writer, the Town Engineer and the City Engineer of Brantford in October last proved that the maintenance of the system was not in competent hands ; that the reported defects were greatly exaggerated ; that the tiles had in many instances been filled with sand, and even misplaced by flushing them with fire streams, and that the avowed hostility to the system by the Council had much to do with the reported failure of the porous tiles.

In one place, the porous tile was found completely filled with sand, although, when laid, the trench was perfectly dry for several blocks each way from the point where it was examined. The soil here was a perfectly dry sand, standing in wet weather with comparatively little shoring ; water would disappear immediately in this ground, and there could be no doubt but that it was filled by unnecessary flushing or owing to some other abuse of the system.

Only one case of a cellar becoming flooded has been reported during the year, and this was doubtless caused by the carelessness of the owner, as the stoppage of the tile occurred between the building and the sewer.

Toronto Junction also adopted a stringent plumbing by-law, rules and regulations governing the laying of house sewers similar to the Brantford and Brockville by-laws and regulations, but owing to its proximity to the city of Toronto, where tile pipes are allowed in basements, traps and " breathers " prescribed for house sewers and " medium " weight of soil pipes permitted, the opposition to these radical by-laws was very strong, and the writer believes that, under the present management, the by-laws are not being strictly carried out. Records of the work done are, however, kept, and in general the sewer system is ventilated through the house sewers.

It is admitted by all that the sanitary sewers, the storm sewers and all accessories, were economically constructed, that they are working satisfactorily, and are all in a perfect sanitary condition, the only objection to the system being that made against the drain tiles, which were supposed by many to drain cellars directly. Too much was expected of these tiles, and their usefulness has been impaired, and in some places they have been misplaced and filled with earth by too frequent and too heavy flushings, which were, in many cases, quite unnecessary.

CONCLUSION.

From his experience with the system in operation the writer concludes :—

1. That in Ontario the Separate System has given entire satisfaction when intelligently looked after and properly maintained.

2. That cellar drainage is a much more important matter here than in warmer climates, requiring modifications in the Separate System as recommended by Col. Warihg and others.

3. That in the colder parts of the province and in hilly towns, where storm water floods basements and cellars, direct connections with the sewer became necessary. In these places glazed pipes should be substituted for porous tiles, and they should be provided with water seal traps and mechanical valves.

4. That, where practicable, the street sewers should be laid at least three feet lower than cellars or basements, to permit the direct connecting of drains if this be found necessary at any time in the future.

5. That the only practical system of thorough ventilation of sewers in this climate is by means of the soil pipes, unprovided with main traps, "breathers" and other devices. The by-law regulating the laying of house sewers can only be efficiently enforced where the work is under the supervision of the City Engineer.

6. That automatic flush tanks perform their work when periodically examined by competent inspectors.

7. That, as the sewers in this system are much smaller than in the combined system, the cost is much less, consequently a larger area can be sewered and a greater population served with the same amount of money.

DISCUSSION.

The writer has read with much pleasure Mr. Chipman's paper on the "Separate System of Sewerage in Ontario," and decidedly agrees with him that any system will prove unsatisfactory unless properly looked after by officials who thoroughly understand it in all its details. Mr. Van-

There can be no doubt that many sewers are practically ruined through making house drain connections in a crude and improper manner. The average citizen thinks that a large size is all that is really necessary for a house drain, and that such trimmings as tight joints, perfect grades and alignment, etc., are as unnecessary as an engineer to inspect it.

The writer does not approve of putting in small drain tiles at the sides of sanitary sewers, as in most cases where subsoil drainage is necessary, small so-called porous tiles are of little use when put in at the depths necessary for sanitary sewers, and, further, they cannot be easily reached when stopped up. Subsoil drains, when put in the same trenches as sewers, should be of large size, and should be laid in such a manner that they can be easily inspected and cleaned from man-holes. It is generally found best to place such subsoil drains below the sewer in order to prevent unequal settlement of earth and resulting distortion of line of sewer. A six inch hub and socket tile subsoil drain was put in under one of the main sanitary sewers of Woodstock, Ont., in 1896, by Major W. M. Davis, M.Can.Soc.C.E., resulting in the thorough drainage of a considerable area of cedar swamp land, consisting almost entirely of quicksand. This is in perfect working order at the present time, and the writer is of opinion that it would have been extremely difficult to put in the sanitary sewer pipe and man-holes without such heaving and distortion as Mr. Chipman mentions in the case of one of the sewers of Brantford unless the under drain had been laid first.

The writer considers the Separate System of Sewerage the better for most of the smaller cities and towns of Ontario on account of the smaller cost, and of the necessity in most cases of purifying the effluents before discharging them into streams and lakes.

All methods of sewage purification are expensive, and the cost of purification varies directly with the quantity to be treated; obviously, therefore, the cost will be less in places where storm water is kept out of the sewer system and the volume of flow kept uniform.

The writer is of opinion that the Berlin "sewage farm" has not proved a success since the area is too small for broad irrigation, and the soil entirely unsuited for filtration. The Rivers' Pollution Commission defines filtration as "the concentration of sewage at short "intervals on an area of specially chosen porous ground, as small as "will absorb and cleanse it; not excluding vegetation, but making the "produce of secondary importance. The intermittency of application "is a *sine qua non* wherever complete success is aimed at." Sand or fine gravel soils are the only ones at all suitable for filtration, since the sewage must be mingled with air in the pores of the filter in order to permit the bacteria of nitrification to live and do their work.

Again, the depth of soil above the under drains at Berlin is insufficient for proper purification. The State Board of Health of Massachusetts, the recognized authority on filtration, lays down the rule that at least five feet depth of filtering material is necessary for complete purification of sewage.

It would appear that the Berlin "Sewage Farm" must be classed as an area of land prepared for partial purification, and that the term "filter beds" is misleading.

Filter beds when properly constructed of suitable materials are capable of thoroughly purifying sewage and at less cost than by any other means, and the writer is of opinion that it is highly important for engineers to use proper terms when speaking or writing of sewage purification. More especially as the subject is new and the public is easily led astray.

Mr. Willis Chipman.

It is gratifying to the writer of the paper to find so little criticism of an adverse character offered.

The size of the subsoil pipes should depend entirely on the amount of subsoil water to be carried. Whether porous tiles be used or glazed pipes for this purpose depends upon the conditions. The writer has experienced little difficulty in removing stoppages in the porous tiles laid alongside the sewers, where exceptionally large quantities of ground water are met with; ordinary glazed pipes should certainly be substituted for the unglazed, but in general the porous tiles have proven satisfactory, and have so lowered the subsoil water as to give dry cellars and basements where they were unknown before the construction of the sewer system.

To lay a subsoil drain below a sewer may effectually drain the surrounding soil, but how this position of the drain will prevent settlement or distortion of the sewer built above it is not clear to the writer. There was no "heaving or distortion" of the sewer referred to in Brantford, with no under drain and with the side drain blocked. This sewer is an exceptional one, and the writer doubts if there be another sewer in Ontario that carries so great a volume of subsoil water relative to its length.

The selection of the area of land for the purification of the sewage at Berlin was not made by the writer, but mainly upon the advice of a member of the medical profession. The writer was not engaged until the main sewer had been constructed from the town to the farm. In the paper no attempt was made to disguise the unsatisfactory management of the disposal of the sewage. The land was originally unsuitable ; the sewage has been poured on it irregularly and without proper care ; the sewage contained gas works refuse, which should have been excluded, and during the winter months and at night the greater part of the sewage was allowed to flow directly into the creek. Could satisfactory results be expected from such conditions?

As the irrigated areas become over-burdened with sewage, it will become necessary to convert them into filter beds or to increase the area irrigated.

The depth of the filtering material was limited by the elevations of the main sewer and of the creek into which the sub-soil drains discharge. The writer agrees with Mr. Vanbuskirk that it is important for engineers to use proper terms in discussing sewage purification, particularly "sewage" and "sewerage," "filter beds" and "sewage farms." As first laid out, the land at Berlin was a sewage farm, filter beds being subsequently added.

There is, therefore, no confusion of terms in the paper.

To judge by the facts that the system receives no proper supervision and very infrequent inspections, and that no complaints are received, the separate system must be pronounced a success in Barrie. Mr. A. G. Ardagh.

Very heavy rains are of frequent occurrence here, and several extraordinary downpours have occurred in the last few years. These frequent, heavy rains would require large and expensive sewers if an effort were made to carry them off in that way, but as it is they find their way to the lake without damage by natural courses and a few sections of box drains. Besides this, however, the extraordinary rains herein referred to, which bid fair to become chronic, could not be coped with by any sewer which the people could be persuaded to build.

As to the flush tanks, I think that all probably require some looking after, but some designs much more than others. They are a proper part of the system, but I believe many a sewer here has been looking after itself until the people confidently believed it was being flushed and no stoppages reported.

Private parties have laid six inch connections in certain cases. For self-cleansing purpose, four inch are best, but it is true that stoppages do occur from grease, etc., in them, when it is probable such would have been avoided, as a firm of drain-layers here particularly lay stress on this point.

The subsoil drains are found in cases to be stopped.

A recent inspection of two lateral sewers gave results as follows:—

1. A 4 inch agricultural tile laid in 1895 beside a 9 inch sewer was found quite clean at every manhole, and water several inches deep flowing quickly through it.

2. A 4 inch glazed sewer pipe laid in 1896 beside an 8 inch sewer with joints, supposed to be gasketed but not cemented, was found quite plugged with sand—the grade was very gentle.

I think that with the sewer a proper depth below the basements, that they will drain without a drain, but, as we have always laid the subsoil pipe, I cannot speak authoritatively.

Mr. H. J. Bowman. The paper by Mr. Chipman is an important contribution to our engineering literature, preserving the history of the introduction of the Separate Sewerage System into Ontario. The Town Council of Berlin, Ont., encouraged by the example of Brockville and Brantford, adopted the separate system, and, at the general expense of the town, built a main outfall sewer and prepared a tract of land for disposal of sewage. This main sewer, about two miles in length, is of vitrified salt-glazed sewer pipe, but has no subsoil drain, and, in consequence, about 75,000 gallons per day of spring water finds its way into the sewer, and is discharged on the land that would have been avoided with a subsoil drain. The lateral sewers are built as local improvements, and generally consist of 9 inch pipes for the sewage proper and a subsoil drain of 6 inch glazed pipes laid at one side and one foot lower than the larger pipes. By this means practically all the subsoil water is diverted and does not enter the main sewer leading to the sewage farm.

The sewage farm is now being satisfactorily managed, the area first prepared having been converted into flat beds, with numerous drains laid about three feet below the surface, and the trenches filled with gravel. No attempt was made this year (1897) to grow crops of vegetables, etc., as formerly done, and the beds were thus always available for the application of sewage. Upon visiting the farm a few days ago with the Secretary of the Provincial Board of Health, the latter expressed himself as well pleased with the appearance of the effluent and of the brook below the farm. He also advised making arrangements with the Gas Co. to stop the discharge of tar water into the sewers. The town of Berlin has a large number of manufacturing establishments, and the waste water from some of these renders the sewage very foul. Three tanneries discharge into the sewers, one of them having a capacity of 150 hides per day, and next year another large tannery will probably be connected. Dye-water from a button factory and from a felt factory and laundry-water from a shirt factory all add to the difficulty of the problem, and these factories are the largest of the kind in the country. In spite of these difficulties, the sewage of Berlin is being disposed of so that no nuisance is caused by discharging the effluent into the brook, in proof of which it may be stated that a fishing club has stocked a pond a little over a mile below the farm. Were there no factories in the town but simply house sewage to be treated, it would be a simple matter to dispose of it by application to the land.

Mr. T. Harry Jones.

The writer was engaged by Mr. Chipman as Resident Engineer on the construction of the Brantford Sewerage System, and has since as City Engineer had charge of the maintenance of the system.

The writer is of the opinion that for the smaller cities and towns in Ontario that many advantages are to be derived by the use of the Separate System.

On account of the smaller sewers admissible, not only is the cost of construction and maintenance less, but it is possible to have the sewers flushed out daily by the use of a comparatively small quantity of water, which from a sanitary point of view is a great advantage. The amount of water used in Brantford daily for that purpose is about 10,000 gallons. By the exclusion of the storm water from the sewers, the cost of the after treatment of the sewage when this is necessary is also greatly lessened. The construction of the sewerage system in Brantford has so lowered the level of the subsoil water that, generally speaking, the necessity for cellar drainage no longer exists. This result the writer believes is attributable principally to the laying of the sanitary sewers rather than the drain tiles. While no trouble so far has been experienced from the few cellar drainage connections made, the writer is of the opinion that in sandy soil, where cellar drainage is necessary, a glazed tile not less than 6 inches in diameter should be laid. The additional cost would be more than counterbalanced by the lessened liability to stoppage and the greater facility with which it could be cleaned.

In many of the longer blocks in Brantford lamp-holes were built on the sewers in the centres of the blocks.

The writer has found that, by the use of long elm strips bolted together, a stoppage in the sewer can be accurately located without the use of a lamp-hole. The distances between man-holes in the writer's opinion should not as a rule exceed 300 feet.

The house sewers used in Brantford have been 4 inches in diameter, except for hotels or public buildings, when 6 inch sewers have been substituted. The annual cost to the city during the past five years for removing stoppages in house sewers has not exceeded $25.00.

The street portions of the house sewers are constructed by the city and the lot portions laid under city supervision.

The experience of Brantford in the use of automatic flush tanks has been the same as that of Brockville. With proper care they have given good satisfaction, and in but few cases has it been found necessary to flush any of the 9 inch sewers by other means.

Owing to the fungoid growth described by Mr. Chipman, it is found necessary to flush two of the 12 inch sewers three or four times during the year. Instead of using the ordinary copper or wooden spherical "pill" in flushing, a plunger has been substituted which gives more satisfactory results. It consists of two rubber discs of the same diameter as the sewer to be flushed, backed by wooden discs, strung about 8 inches apart on an iron rod.

The writer endorses all Mr. Chipman has written as to the difficulties met with in constructing some of the sewers in Brantford, owing to the enormous quantities of subsoil water and as to the universal satisfaction which the Brantford Sewerage System has given.

OBITUARY.

MR. ALAN MACDOUGALL, who died at Exmouth, Devon, England, on the 23rd of April, 1897, was the third son of the late Col. MacDougall of Edinburgh, Scotland, where he was born and where he received his early education. From 1859 to 1863 he was articled pupil to Chas. Jopp, Consulting Engineer of North British Railway Co., under whom he had charge of the Galashiels & Peebles Branch, and in 1865 he became Resident Engineer in the Monkshall, Ormiston, and Dalkeith Branches of the North British Railway.

Coming to Canada in 1868 he became employed on preliminary Surveys as Chief Assistant on Construction on the Toronto, Grey & Bruce Railway, under Edmund Wragge, M. Inst. C. E. He afterwards had charge of the construction of the North Grey Branch of the Northern Railway of Canada. In 1873 he was on Mr. Kingsford's Staff, Department of Public Works, Ottawa, in charge of Harbor and River Improvements on the upper lakes and Lower St. Lawrence, and when this staff was disbanded in 1877, he returned to Britain as Chief Draughtsman under the late Sir James Bell, in charge of the head office of the British North Railway Co. In 1882 he came again to Canada and was appointed Divisional Engineer on the South Western Branch of the Canadian Pacific Railway. In the following year he entered into practice as Consulting Sanitary Engineer with headquarters at Toronto.

Mr. MacDougall was a member of the Institute of Civil Engineers, a Fellow of the Royal Society of Edinburgh, and a Fellow of the Royal Scottish Society of Arts. He took an active part in the formation of the Canadian Society of Civil Engineers, of which he was a Charter Member, and much of its early success is due to his work. The Transactions have frequently recorded his services to the Society and to the Profession to which he was so deeply attached. He served on the Council in the years 1887, 1888, 1892, 1893, 1896 and 1897.

HECTOR LOUIS LAFORCE LANGEVIN was the only son of Sir Hector Langevin of Quebec, in which city he was born in 1861. He passed through the Seminary of Quebec, and then applied himself to the

Study of Engineering, and especially to the Construction of Hydraulic Works and Piers in deep waters. He was connected with the construction of the Docks at the mouth of the St. Charles River and also those at Point Levis built for the Harbor Commissioners of Quebec. He designed three telescopic fire ladders or escapes for Quebec, Montreal and Ottawa. These ladders are quickly worked and have proved to be of great service in life saving.

Mr. Langevin died on the 19th of May, 1897. He was elected Associate Member of the Canadian Society of Civil Engineers on 27th of June, 1888.

Henry F. Perley, who died at Bisley Camp, England, July 15th, 1897, was born at St. John, N.B., in 1831, and entered the public service of New Brunswick in 1848, being employed up to the summer of 1852 in the exploratory surveys for a proposed system of railways. In the latter year he was engaged by Messrs. Petto, Betts & Brassey on surveys in New Brunswick and Nova Scotia, and remained with the same firm during 1854-5 and '56, being employed on the construction of the Grand Trunk Railway. In 1856 he again entered the service of New Brunswick as Resident Engineer on the European and North American Railway between St. John and Shediac, which position he occupied till the line was completed in 1860. From 1861 to 1863 Mr. Perley was engaged in private practice.

In May, 1863, he entered the service of the Government of Nova Scotia, continuing as Provincial Engineer till August, 1865, when he resigned to accept the position of agent for Messrs. Kelk, Waring Bros. and Lucas, contractors for the construction of the Metropolitan Extension (underground) Railway, London, England.

On the completion of this engagement in 1870, Mr. Perley returned to New Brunswick, taking charge of the works in connection with the improvement of the freighting facilities of the Government railways in that province and the construction of the deep water terminus and extension line thereto at St. John. In May, 1872, he was appointed Engineer in charge of the harbors, etc., in the Maritime Provinces for the Department of Public Works, holding that position until the close of 1879, when he was appointed Chief Engineer of Public Works.

The troubles of 1891 led to Mr. Perley's retirement, but in 1893 he was again employed by the Department of Public Works as an Engineer, and was so employed up to the time of his death.

In 1861, he volunteered during the Trent affair, and assisted in raising the New Brunswick Engineers, with which corps he was connected until 1881, when he was appointed Engineer Officer at headquarters, and attached to the staff with the rank of Major.

Mr. Perley has written several valuable papers which have appeared in the Transactions of the Society, and in 1895 was awarded the Gzowski Gold Medal for his paper on "The Resistance of Piles."

He was elected member of the Canadian Society of Civil Engineers, January 20th, 1887, and served on the Council in that year. He was Vice-President of the Society during the years 1887 and 1889.