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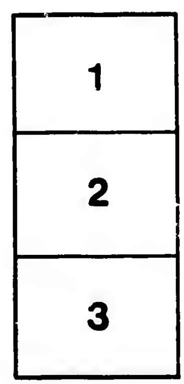
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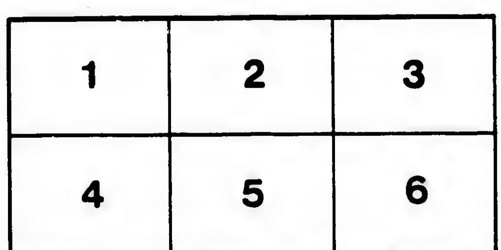
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ADDRESS,

BY

T. C. KEEFER, C.M.G.,

M.Can.Soc.C.E.

BY THE PERMISSION OF THE COUNCIL.

EXCERPT MINUTES OF THE TRANSACTIONS OF THE SOCIETY

Vol. II. Part. I. Session 1888.

Montreal:

PRINTED BY JOHN LOVELL & SON.

Canadian Society of Civil Engineers.

SESSION 1888.—Part I.

TRANSACTIONS.

12th January, 1888.

SAMUEL KEEFER, President, in the Chair.

Mr. T.C. Keefer, C.M.G., the retiring President, addressed the meeting in the following terms:—

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

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

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

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

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

The Association of Civil Engineers for mutual improvement is the outcome of the present century, the English Institution having been established in 1818, and incorporated in 1828, and the American Society in 1852. There was a Society of Engineers founded by Smeaton in 1771, but it was rather a social club than a scientific association. The English Institution has increased during the Queen's reign from 238 members of all classes to 5,400, and in revenue from £713 to over £21,000.

The American Society, owing to wide expanse of territory and the formation of numerous local societies and clubs, does not show corresponding growth, although it numbers over 1,000 members, and is representative of all branches in the profession and of all sections of this continent. Its proceedings were published at irregular intervals until November, 1873, since which date they have been issued monthly.

I do not know when the agitation for the formation of a Canadian Society of Civil Engineers first began. It was a subject of discussion among Engineers, and I believe also of newspaper communications by Engineers, long before any concerted action was attempted. The Canadian Institute, incorporated in 1851, was formed "more particularly for promoting surveying, engineering and architecture."

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

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

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

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

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

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

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

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

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

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

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

I have given the details of this Bill in order that it may be contrasted with the simple provisions of our Charter, which while giving us a better legal status enables us to pass regulations and by laws for the direction and management of all the affairs of this Society. Apparently this difference of opinion, as exemplified by Mr. Plunkett's circular of 1880 and the Ontario Bill of 1881, checked further effort for the time being.

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

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

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

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

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

RAILWAY ENGINEERING.

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

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

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

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

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

In the United States a similar fate has overtaken all the exceptional gauges. Less than two years ago over 11,000 miles of railway in the Southern States were reduced from 5 ft. to the standard of 4 ft. 8½ in. within five days.

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

The Government and municipal expenditure upon railways has reached the large sum of one hundred and fifty-seven millions of dollars up to the 30th June, 1886, of which sum one hundred and twenty-five millions were contributed by the Dominion Government in the first 19 years of its existence. With the exception of about 15½ millions loaned, the whole of the 125 millions was a free gift to the railways. The Provincial Governments have granted 17½ millions as bonuses to the railways, and the municipalities of the Provinces of Ontario, Quebec, New Brunswick, Nova Scotia and Manitoba have given nearly ten millions more, of which Ontario's contribution alone is about 8½ millions.

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

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

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

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

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

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

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

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

HYDRAULIC ENGINEERING.

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

CANALS.

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

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

They endured the traffic and climate until 1845, by which time they were fully worn out. The whole cost of the canal with 40 locks and 35 et lockage, with some exceptionally heavy work, was a little over a million dollars.

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

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

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

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

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

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

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

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

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

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

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

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

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

There was a narrow canal and lock at Sault Ste. Marie at the beginning of this century, the work of the Northwest Fur Company. The lock was 38 feet long, 8¾ feet wide, with 9 feet lift, the lower gate let down by windlass, the upper one having two folding gates with a sluice. The canal was nearly half a mile long, with a tow path for oxen.

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

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

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

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

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

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

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

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

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

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

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

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

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

RIVER IMPROVEMENTS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

HARBORS AND LIGHTHOUSES.

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

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

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

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

CIVIC ENGINEERING.

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

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

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

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

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

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

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

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

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

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

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

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

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

SEWERAGE.

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

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

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

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

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

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

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

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

PAVEMENTS.

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

TRAMWAYS.

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

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

MECHANICAL ENGINEERING.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MINING ENGINEERING.

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

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

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

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

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

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

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

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

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

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

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

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

A French engineer, Mr. Chalon, has published in *Le Génie Civil*, the

The deepest well which has been bored is one near Pittsburgh, Pa., where a depth of 4,618 feet has been reached; there is another of 4,300 feet, two of 3,500 feet, and one over 3,000 feet in the U.S.

In Europe there are six wells over 3,000 feet in depth, the deepest one is 4,515 feet at Schludeback; the diameter for the first 189 feet is 11 inches, for the next 416 feet 9 inches, at 4,000 feet the bore is 2 inches.

shorter distance to which it was thrown.

ELECTRICAL ENGINEERING.

The practical application of electricity in Canada for lighting and locomotion is very recent, dating since 1882, and in fact its whole development as a commercial question is confined to the last ten years. The Avenu de l'Opéra, in Paris, was lighted in 1878 on the Jablokoff system, each light requiring 2½ horse-power. It was regarded as a luxury then, and the lights were extinguished at midnight. The same depth of 1350 feet has been reached in the Vale coal mine, and about half of that depth at Nanaimo on Vancouver Island.

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

ELECTRICAL ENGINEERING.

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

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

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

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

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

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

EARLY ENGINEERS.

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

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

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

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

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

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

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

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

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

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

PROJECTED WORKS.

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

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

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

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

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

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

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

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

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

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

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

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

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