Paper VII.—ENGINEERING AND ENGINEERS.

By Lt.-Col. B. H. MARTINDALE, C. B., *Deputy-Controller, Associate Institution Civil Engineers, and Member Institution Mechanical Engineers.*

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"Engineering is the art of directing the great sources of power in nature, for the use and convenience of man." So said Thomas Telford, the eminent Civil Engineer, just 51 years ago, when, as first President of the Institution of Civil Engineers, he delivered his inaugural address. So, with even greater justice and honest exultation, may the Engineer of the present day exclaim, looking back at the mighty strides which science has made in the last half-century, and on the amazing results which surround us.

So numerous, so vast are those results, that we are fairly staggered with the magnitude of the subject as we begin to recall them. They meet us at every turn of daily life, and fill us with ever-fresh surprise at the powers which the Divine Creator has hid in nature, and at the ability with which He has endowed man to develop those powers.

In peace and in war, in our quiet homes and in the rushing travel of the day, on land and at sea, we meet the Engineer, and enjoy daily a thousand advantages and comforts from his skill and labor. The lighthouse which welcomes us as we approach the land; the breakwater which secures the anchorage; the quays and wharves at which the ship, itself of iron curiously wrought together, unloads; the engines within it, so mighty as to be capable of urging the mass, weighing thousands of tons, against the storm and over the ocean to the appointed post, and yet so delicately made that a bearing scarcely heats, and that the touch of a finger can govern the whole; the motive-power of water so combined with heat as to create steam—a power so terrific, that uncontrolled it can shatter into fragments the vast fabric which it is made to move, and yet so exquisitely controlled as in its use to prevent the very evils that would neutralize its power, and, as in the locomotive, to fan the flame that, fanned, creates fresh steam ; the railroad, which, diminishing distance in proportion as time is saved, bears along that ever-increasing freight, and those ever-increasing myriads which no other known means of communication could have borne, carries the weary man of business and the toil-stained mechanic daily from the smoky stifling town to the clear invigorating country, or the eager traveller from the ship to his expectant home, to which his approach has already, swiftly as by lightning, been made known by the "winged word" which electricity speeds over the earth and under the sea,—one and all of these reflect the Engineer; while that home itself, lighted with gas, supplied with water, and warmed, ventilated, and drained, presents ever-present proofs of what we owe to science, and speaks of labor and discoveries not less real, if less striking, than the steamer, the railroad, and the telegraph, and certainly not contributing less to our daily comfort and increasing health and power of life.

Or if we turn to war: those fortresses which enable the defenders of a country to resist the attack of a superior force; those torpedoes and submarine mines which defend its shores and rivers; those huge guns, 35 tons in weight, carrying a missile of 700 lbs. in weight a distance of six English miles; the improved missiles themselves; those great plates of iron so craftily bolted together as almost to defy even such missiles; those cunning and yet simple rifles, breech-loading, deadly at 1000 yards in skilful hands; those adaptations of light, of signals, and of electricity, for instant communication to troops scattered over long distances; those most ingenious means of ascertaining the velocity with which the projectile leaves the gun from which it is fired, and of ascertaining the disruptive force of the powder when fired upon the gun itself; those carriages in which the very recoil of the gun is made of use to cover the gun out of sight of an enemy,—these and many other such-like things, among which may be mentioned the balloon, pressed into the service, present to us the Civil, the Mechanical, and the Military Engineer, combining with the Artilleryman in labors honorable to themselves and useful in the highest degree to their country.

Or, returning to the wants of peace: in the canals and locks which evade the rushing rapids, and turn the flank even of Niagara; in the improvement generally of internal navigation; in the drainage of low lands; in the construction and maintenance of embankments to resist the encroachments of the sea; in the formation of roads, carried with gentle gradients over the scientifically-sought lowest summits; in the erection of bridges over wide and rapid rivers—as, for example, the world-famed Victoria Bridge at Montreal; in the infinitely varied machinery, which appears almost endowed with life and reason, so wonderfully does it perform the ponderous as well as the delicate tasks entrusted to it in the factory, in the mill, in the arsenal, in water, and on land,—we recognize, once again, the skill and toil of the Mechanical and Civil Engineer.

Among the labors of the Engineer, none, perhaps, possess more interest to this country, and especially at the present time, than those connected with

CANALS.

It appears not improbable that the earliest canals were constructed in Egypt, and had for their object the better irrigation of the Delta of the Nile. Herodotus, whose narratives, however, must generally be taken "*cum grano*," speaks of the formation of a lake called Mœris, 450 miles in circumference, which was completed about 1385 years B. C. This was connected with the Nile by three canals, and its objects were to prevent the Nile continually overflowing the country, and to maintain a supply of water for irrigation.

Many canals are said to have been subsequently formed in Egypt by Sesostris; and about 610 years B. C., Necos is said to have commenced a canal to unite the Mediterranean and Red seas. This was continued by several monarchs, but apparently never completed, and was finally abandoned, until the Caliph Omar, about the year A. D. 644, or some 1254 years after its commencement, re-opened it, and cut another canal, which was used for upwards of 120 years, until the commerce of Alexandria was destroyed.

In Greece, many attempts to cut a canal across the Isthmus of Corinth, a distance of about five miles, failed. The traffic, and even the smaller craft, were, therefore, carried across it—somewhat as our passengers and goods are conveyed overland between Carillon and Grenville, *en route* to Ottawa.

Spain is indebted to the Moors for her canals, and for her system of irrigation generally. In China, the canals were said to have been of great antiquity; but they are probably not older than 900 years ago, a hundred years later than the first irrigation of Valentia.

In Italy, canals were of very early date. That through the Pontine marshes was cut about 162 years B. C.; and the Etruscans had made many before this, in connection with the river Po. The Romans attached very considerable importance to such works, and, both at home and abroad, frequently executed extensive works to improve the inland water-communication. But these works fell into decay with the decline of the Empire, and it was not until the 12th century that the construction of canals recommenced in Italy and Holland.

Between the 12th and 15th centuries many improvements in connection with canals were made in the navigation of the rivers Brenta, Mincio, Arno, Reno, Ticino, and Adda. But it was not until the year 1481 that two brothers, said to have been Dionisio and Pietro Domenico, of Viterbo, introduced, in a canal running from Padua to Stra, the lock-chamber enclosed by a double pair of gates, instead of the arrangement called the "conch," which had been in use in Italy since the 12th century. The fame of the invention of the lock spread throughout Europe, and the whole system of inland navigation benefitted by it.

Among the first navigable canals commenced in France, after the Roman era, was that from the Saone to the Loire. This was begun about the middle of the 16th century; but progress was suspended from time to time, and it was not finally completed till about the close of the 18th century. The canal is about 71 English miles long; the length of each lock is 100 feet, and breadth 16 feet; breadth of the canal at the top, 48 feet; at bottom, 30 feet; with an average depth of 5 feet 3 inches. There are 30 locks from Dijon to the summit-level, giving a rise of about 240 feet; from whence to the Saone there is a descent of 400 feet, accomplished by fifty locks.

The canal of Languedoc connects the Garonne, below Toulouse, with the Mediterranean, at Cette. It was commenced about the year 1666, and completed in 15 years. It is 64 feet broad at top, 34 feet at bottom, and 6 feet 4 inches deep. The vessels which navigate it carry about one hundred tons.

Another remarkable canal is that connecting the Somme with the Scheldt, which was commenced in 1766 and completed in 1810. Its length is 32½ miles, including two tunnels—one of 1200 yards, and the other of 3¼ miles long. It rises in its course 33½ feet, and falls 124 feet.

There are now in France nearly 3,200 miles of canals, a vast extent, especially when we consider that such works were commenced in that country nearly 400 years after they revived in Italy, and when we reflect upon the interruptions to which they were subjected during all their earlier history.

Before quitting the subject of canals, in connection with French engineering, we must for one moment refer to the Suez canal. This canal, nearly 100 English miles in length, runs from Port Said to Suez. The mean level of the Red sea is only 6 inches higher than that of the Mediterranean, and the tides in both seas are feeble; consequently, there are no locks. It is intended to attain a depth of 26 feet of water throughout. Its cost will probably be £20,000,000 sterling. Its execution is mainly due to the rare courage and perseverance of Mr. Ferdinand de Lesseps, who, by cutting across the sand uniting Asia and Africa, has opened a water-communication which may revolutionize the mode of conducting the traffic between the east and west, and which may never be closed while civilization exists.

Late as France was in the field, England was even later; for the first canal of any importance in England was that from Worsley to Manchester, constructed by James Brindley for the Duke of Bridgewater, who, in 1758 only, got an Act of Parliament for it in order to open out his coal-fields in South Lancashire. The construction of canals then became the rage, and prevailed during 40 years, and less ardently for nearly 30 years longer. As a result, there are about 120 canals in the United Kingdom, having an aggregate length of 3,000 miles. And as the superficial area of France to the United Kingdom is as 12 to 7, the latter possesses, in proportion to the size of her territory, very much more canal-accommodation than France.

Among the canals in Britain, the Bridgewater canal, already referred to, is justly celebrated for the excellence of its works, constructed, as they were, in the infant days of canal-making, by which, except for a distance of 600 yards, at Runcorn, where the Mersey is entered by 10 locks, which are together 82 feet 6 inches, the navigation for 73 miles is on one level.

The Caledonian canal, connecting the Scotch lochs, and affording, with 21 miles of canal, a navigable line upwards of 100 miles in length, between the seas on the eastern and western coast, will never be forgotten by any who have had the happiness of beholding the surpassing beauty of the surrounding scenery.

The depth of water in the canal is 20 feet. The canal is 122 feet broad at top, and 50 feet broad at bottom ; and there are 23 locks, 40 feet wide each, and 172 feet long. The work occupied from the year 1803 to 1829, and the total cost was nearly £1,000,000 sterling.

On the Ellesmere and Chester canal is a celebrated aqueduct, by which the canal is carried at a level of 127 feet over the river Dee. The bottom and sides of the canal are here made of cast-iron plates, within which the water flows. The water-way is 11.10, of which the towing-path covers 4.8. The total cost of the aqueduct was about £47,000, sterling.

The Grand Junction canal, which connects the iron and coal fields of the Midland Counties with London, falling into the Thames at Brentford, is 90 miles long, 42 feet wide at the water-surface, 28 at bottom, and 4 feet 6 inches deep ; lock-chambers, 80 feet long; breadth, 14 feet 6 inches. Steam-power is required to raise the water for the supply of the canal from one reservoir to another. The canal, in its course, first rises 37 feet, then falls 60, and then 112 feet ; rises again 192 feet, and falls again, first 127, and then 268 feet. Its total cost was about £2,000,000 sterling.

In the Huddersfield canal, there is a rise of no less than 436 feet, made by 42 locks, and a subsequent descent of 334 feet, divided by 33 locks. The Leeds and Liverpool canal is 127 miles long, with a rise to summit-level of 411 feet, and a fall of 433 feet. The locks will receive boats 70 feet long and 14 feet beam, and the least depth of water is 4 feet 6 inches.

The Shropshire canal presented a very curious feature in its inclined planes. It passed through a rugged country with a great scarcity of water. On the banks of the Severn on an inclined plane 1050 feet long, with 207 feet of perpendicular height, was a strong double railway, up which the boats, with their loads of five tons each, were drawn. They then passed along a level canal, descended by another inclined plane, and so on. These works were completed in 1792.

The canal tunnelled through the chalk between the Thames and Medway is in all 7 miles long, of which 2½ miles form the tunnel. It occasioned considerable anxiety and inconvenience by affecting the wells in the neighbourhood ; but it saves the passage round the Nore and up the Medway, and nearly fifty miles in navigation.

A curious tunnel was one constructed by Brindley, only 9 feet wide and 12 feet high. It was nearly 3000 yards long, and boats could only be propelled through it by men called "leggers," who, lying on their backs, pushed against the sides and top of the roof with their feet. A boat occupied two hours in passing through. It has been replaced by more convenient works.

On the Great-Western canal were made lifts 46 feet high, up and down which boats weighing about eight tons ascended and descended in cradles, in about three minutes, with an expenditure of about two tons of water only.

Holland.

Holland, the level of a great portion of which is beneath the sea, is a country covered with embankments and canals. The very rivers are maintained within their course by artificial banks. Where the canals do not unite, vessels are transported from one to the other by mechanical contrivances. As a modern work may be mentioned a new ship-canal, to be finished in five or six years, now in course of construction, to connect Amsterdam with the ocean. The distance by the present canal is fifty-two miles; that by the new canal will be 15½ miles only, navigable for larger vessels than can now come up. This canal will be 197 feet wide at top, and 88 feet at bottom; minimum depth, 23 feet; locks, 59 feet wide. It will connect with a magnificent new harbour, which is being formed on the coast, by three locks or entrances. At the other extremity, below the city and wharves of Amsterdam, will be a vast dyke to shut out the Zuyder Zee, with three locks and sluices. The surface-water of this canal has to be kept twenty inches under low-water-mark; and the locks at each end are required for locking down. Besides the locks and sluices, three centrifugal pumps have been provided, which, together, will lift 440,000 gallons of water per minute. The shallow lakes through which the canal runs have to be re-drained to admit of this.

The United States.

It would be useless for me to enter here into any description of the canals existing in the United States. They are probably better known to most present, practically, than they are by me, even theoretically. It may be sufficient to say that in this, as in other Engineering works, the people of the United States have shewn themselves worthy descendants of the mother-country. No labor has been spared to render inland-water-communication complete. One of the peculiar features has been the admirable use made of timber in the construction of viaducts. Another is the vast length of the conjoined canal and river lines. Thus, the Ohio canal, between Portsmouth and Cleveland, is 307 miles in lentgh; the canal between Albany and Buffalo, on Lake Erie, with its numerous branches, and that between Albany and Oswego, on Lake Ontario, are respectively 363 miles and 209 miles in length; and the canal from the Hudson river into Lake Champlain is sixty-five miles in length. In the Morris canal, the rise and fall of 1674 feet in about 102 miles was mainly overcome by inclined planes, with a lock at each end and at the top of each plane, the boats being drawn up and lowered down the planes by machinery. The length of the canals in the United States much exceeds that in Britain; and there can be no doubt, from the energy and vitality which its people display, that wherever a canal is required in the States, there it will be made.

Canada.

In Canada itself, the Welland canal, 28 miles in length, connects Lakes Erie and Ontario. It has a fall of 260 feet, and can pass through vessels of 400 tons. From Lake Ontario to Lake St. Louis, seven short canals of the total length of 47 miles, overcome the fall of 220 feet in the river St. Lawrence. Through these, vessels of 650 tons can pass. The United States canal, of about one mile in length, at the Sault St. Marie, connects Lakes Huron, Superior, and Michigan. Vessels of 2000 tons can pass through this canal.

By these canals, and those already referred to as connecting Lake Erie and Lake Ontario with Albany, navigation exists between the tidewaters of the Hudson, the Upper Lakes, and the St. Lawrence sea-navigation.

The further improvement of canal-communication would appear to be of the highest importance to the development of Canada; and it is satisfactory to know that the subject is attracting more and more attention.

The Canal Commissioners, in their recent report, dated 24th February, 1871, recommend the construction of a new canal in Canadian territory at the Sault St. Marie; the enlargement of the Welland canal and of the St. Lawrence canals; the construction of a second set of locks at the lower entrance of the Lachine canal, with 17 feet of water on the sills; and the improvement of the channels of the St. Lawrence, so as to give 14 feet of water throughout above Montreal, and 22 feet draught, at low water, between Montreal and Quebec: the canals to have an uniform width of 100 feet, with locks having 270 feet of chamber between the gates, 45 feet in width, and 12 feet of clear draught on the sills; the bottom of the canal to be at least one foot below the sills of the locks. By these means, it is considered that vessels ranging between 1000 and 1500 tons could trade between Chicago and Montreal, a distance of 1261 miles.

In addition to the above, the Commissioners recommend, as works of first-class importance, the improvement of the existing line from Allanburgh to Port Dalhousie; the Ottawa canal improvements, from Ottawa city to Lachine; the enlargement of the Chambly canal, and the construction of the Bay-Verte canal.

The locks for the Ottawa and Chambly canals are recommended to be 200 feet by 45 feet, with 9 feet draught over the sills; the locks for the Bay-Verte canal, 270 feet in length of chamber, 40 feet in width between the gates, and 15 feet draught of water on the sills.

The Commissioners further recommend, as works of the second-class, but prospectively of the utmost importance, the construction of the Upper-Ottawa canal, and the deepening of the rapids of the St. Lawrence to a minimum depth of eight feet at the lowest water.

The Rideau Canal should be maintained as one of the public works of Canada; but the construction of the Caughnawaga canal, and of the Erie and Ontario ship-canal, the Commissioners consider should be left entirely to private enterprise. The projected Georgian Bay canal, which is equal in length to that of the Suez canal, and is encompassed with natural obstacles infinitely greater, is regarded as commercially worthless, if not as physically impossible.

The cost of the improvements recommended is estimated at $19,170,000. But this expenditure is considered as insignificant when compared with the immense benefits that would arise from the carrying-trade of the great West passing through Montreal and Quebec. The Government, as I gather from the columns of the daily press, have decided to proceed with a portion of the improvements recommended for the Welland canal, for the Ottawa canal at Grenville, and for the St. Lawrence; but have deferred action regarding the remaining recommendations, on various grounds. Cordially must we all unite in hoping that in these most important works, Engineering and Engineers may assist its people to the utmost possible extent in developing the resources of this noble country, before which such prospects of a great, useful, and happy future are being so continuously unfolded.

RAILROADS.

The question of *railroads* is not of less importance to the Dominion of Canada than that of canals.

Prior to the 17th century, wooden railroads were in use at the Newcastle coal-fields. Originally, the waggons worked along single lines of longitudinal timbers; but as the frequent repair interfered with the traffic, an upper rail of wood was pegged to the timbers, and renewed as it wore away.

The first iron rails were probably those of cast-iron used at the Norfolk colliery, near Sheffield, about 1776; but cast-iron wheels had been introduced about ten years before at the Colebrooke-Dale iron works. At this time the flange was on the rail, instead of on the wheel, as at present.

Various improvements succeeded; and in 1820 a patent was obtained, embodying the principles upon which rails are now made for railroads, viz., by passing them, when red-hot, through rollers grooved in the required form.

In 1802, the first patent was taken out by Richard Trevithick for a locomotive-carriage, on the high-pressure principle, to work on a road or railroad. In 1811, Mr. Blenkinsop took out a patent for the first double-cylindered engine. This weighed five tons, and drew 94 tons on a level, at 3½ miles an hour; one wheel being toothed, and working in a rack on the side of the railway. Various improvements followed; and in October, 1829, took place the famous trial in which Mr. Stephenson's and Mr. Booth's locomotive, the *Rocket*, won the prize.

The *Rocket* and tender weighed only 7½ tons, and drew 44 tons, gross, at the rate of 14 miles per hour. From this may be said to date the present locomotives.

Between 1811 and 1822, increasing attention had been drawn to the subject of railroads. In that year the Stockton and Darlington Railway was proposed; but, from the opposition met with, the act was not obtained until the following year. This was the first railway opened in England. In 1824, the bill for the railway between Liverpool and Manchester was lost, in committee, from a similar cause, and withdrawn. It was not again introduced until 1826, when it triumphed over all opposition, and the line was at once proceeded with. From that time the construction of railways proceeded with increasing rapidity in England, until it became almost a mania, which reached its climax about 1845, and vast fortunes were made and lost in railway speculations. Since that time, however, many lines have been made, but with more consideration as to their necessity and probable commercial results.

From England the construction of railways spread over Europe, and extended to the United States. But it is a fact, and remarkable as shewing how slow the very ablest men sometimes may be in grasping the value of the results of science, that, soon after Louis Philippe came to the throne of France, Monsieur Thiers, now President of the present government in France, was sent to England to examine into the advantages of the railway system, and reported against its adoption in France; and that thus the introduction of railways in France was postponed for eight or ten years. Such an error of judgment may, however, be the more readily excused when it is remembered that so late as the year 1835, Dr. Lardner, a man unquestionably of the highest ability, declared that it was a mechanical impossibility for steamers successfully to cross the Atlantic.

As a sort of contrast, and as among the most interesting works of the period, we may turn to those known as the Mont Cenis Tunnel and the Mont Cenis Railway. The estimated length of the tunnel, which does *not* pass under Mont Cenis, is $7\frac{3}{8}$ miles (English), and the cost not less than £4,000,000. It is intended to connect the railways of France and Italy. The rails of the Mont Cenis railway, which is altogether independent of the tunnel, follow the surface of the road over Mont Cenis. The necessary adhesion is obtained, and also perfect safety to the train, by the pressure of horizontal wheels on a central rail. The new engines will take up loads of 50 tons. Between St. Michel and Susa, the line is 50 miles in length. It cost, with engines and rolling-stock, about £8,000 a mile, and affords an admirable solution of the difficulty of surmounting mountain ranges at a moderate cost. The working expenses are, however, heavy.

There are now in England between 14,000 and 15,000 miles of railway; in France, between 10,000 and 11,000 miles; and in the United States, upwards of 43,000 miles. The latter lines, however, though made to carry the traffic which passes over them, cannot compare for finish with the lines at home.

Railroads in Canada.

In the Dominion of Canada there are already upwards of 3,000 miles of railway; and the new lines in process of construction, including the Intercolonial line, will increase this length by nearly one-half. The means by which the Canadian Pacific Railway, spanning the continent and connecting the two great oceans, is to be accomplished, are now under the consideration of the Dominion Parliament. Before this can be completed, many other lines will, no doubt, have also been made. We may hope that there may never be found wanting, to the Dominion, statesmen to advocate and carry out such railways as may be of vital aid in its development, nor Engineering and Engineers to execute, at the least expense, and with the best work, the railways which the State or private enterprise may undertake.

Before quitting this subject, may I be allowed to express my dissent from the extreme strictures which I have heard passed upon the manner in which the railways in Canada are managed. I am not saying that some improvements in details might not be effected. But I do say (and I have some right to give an opinion on such matters, having had charge of the construction and working of railways in New South Wales, in addition to that of the telegraph, roads, and other public works of that colony,)—I do say, that when the extreme difficulties arising from the climate are considered, and the inconveniences unavoidable with long single lines of railway, the working of the lines, the comparative rarity of accidents, and the almost entire absence of loss of life, merit approbation, rather than such censure. I say, further, that in a comparatively new and sparsely settled country, twenty miles an hour, actual distance made, is a sufficient rate for practical purposes. Still, there are improvements which might easily, I should conceive, be made. For instance, the *unnecessary* delays between Montreal and Quebec might cease; and I was glad to see that the Board of Trade* of Quebec had been urging on the Managing-Director of the Grand Trunk Railway the necessity of better

* NOTE.—The establishment of the Dominion Board of Trade must be considered as a measure calculated in the highest degree to benefit the Dominion of Canada.

arrangements in connection with Quebec. There can surely be no real difficulty in arranging that we may take our tickets and check our baggage on this side of the St. Lawrence, instead of on the other ; and we may even hope that in time we may be ferried over so as to catch the train, and not some hours before it starts. Indeed, so evident does it appear that much of this could with ease be done, that I am disposed to think that the fault rests more with ourselves for letting such matters sleep, than with those whom in all my relations with them I have invariably found so courteous and willing to attend to any suggestions for the public convenience, as the officials of the Grand Trunk Railway.

ELECTRIC TELEGRAPH.

I must absolutely refuse to be seduced into saying anything whatever about the Electric Telegraph, a subject which so naturally recurs to the mind in connection with improved communications. It affords, in itself, matter more than sufficient for one evening. I will only say that we appear to be still in the infancy of our knowledge of electricity, and that we may anticipate, from the development of its powers, perhaps even greater wonders than the amazing and invaluable results already obtained.

ROADS.

The wonderful inland water navigation of Canada, and the early introduction of railways, render *Roads* a subject of less importance than in other countries. Still they must have a large influence on the future of Canada.

As an instance of their value, it may be remembered that the Highlands continued in a state of semi-barbarism until the construction throughout their length and breadth, by the government, of roads ; and the law still holds good that there is no surer means of increasing the prosperity of a country than by improving its means of communication.

I shall not occupy your time with any description of those superb roads constructed by the Romans, not only in Italy, but wherever their conquests extended, and which have won the admiration of all succeeding ages. Of these, the great roads alone extended over 53,000 Roman miles. They were constructed with vast labour and expense, and maintained with the utmost care. But with the decline of the Empire, they fell into decay, and the succeeding period of barbarism was as fatal to the *preservation even* of internal communications, as it was to science and art generally.

Some efforts towards improvement were, indeed, made in the seventh century, under King Dagobert, and these probably involved the partial restoration of some of the Roman roads.

In the same era we find existing the abominable system of "*corvée*" or forced labor on the roads, which cropped up from time to time, until it finally disappeared in the revolution of 1790.

Charlemagne, towards the close of the 8th century, revived "the ancient laws and customs" under which each district was bound to construct bridges and roads; and this was more or less enforced to the middle of the 9th century. But the bridges were mere causeways or approaches to ferries over rivers, and the roads for the next three centuries were little better than winding horse-paths. But the crowds of pilgrims flocking yearly to the shrines of favorite saints, and the crusades imparting new activity to travel, and slowly-growing civilization, forced, in the twelfth century, attention to the state of the roads. Then, to build a bridge was a work of charity, and large properties were dedicated for ever for their construction and maintenance. And about this date arose the celebrated monastic order of Bridge-builders, known by the name of "Brothers of the Bridge," or Pontifex (Bridge-builder). Their reputed founder was the whilom shepherd, St. Benezet, who built the bridge of Avignon over the Rhine, between 1177 and 1187, A.D. They were a mendicant order, solely however to raise funds for bridges, and continued for several hundred years, and constructed bridges in most parts of Europe. The last of them was the Monk Romain, who was also probably the first of the engineers in the far-famed *Corps des Ponts et Chaussées* of France, when instituted in the early part of the last century.

Efforts were made in France in the reign of Louis XI. and subsequently, by the establishment of post-horses and relays of horses, and by the appointment of the Treasurers of France, afterwards known as the Receivers-General, to improve the great highways; but even these were never suited for rapid travelling, except by horsemen, and they had fallen into a miserable condition at the death of Louis XIV. But under the celebrated *Corps des Ponts et Chaussées*, improvements on systematic and scientific principles were commenced and continued, and admirable roads by degrees provided. These under Napoleon the First were divided into three classes—the royal, the departmental, and the rural roads—the 1st kept in repair by the State, and the 2nd and the 3rd by the provinces and by the districts through which they passed. France has, or at any rate had until now, about 100,000 miles of good carriageable roads.

The best roads in Great Britain, for centuries, were the remains of those left by the Romans. In the 13th and 14th centuries we find efforts made to improve the communications by the removal of trees on either side, and by the levying of tolls to repair roads reported impassable. Turnpike roads were established and acts were passed for repairing and widening some of the public roads on the return of Charles II.; and between the years 1700 and 1770, no less than 530 acts of Parliament relating to turnpike roads were passed. For all this, however, a century ago the roads of Great Britain were in a sufficiently miserable condition. But between this period and the present, there have been constructed or improved

160,000 miles of good carriageable roads in the United Kingdom, of which many are probably as perfect specimens of road-making as can exist,—affording daily proofs, to the thousands who traverse them, of the practical value of Engineering and Engineers.

LIGHTHOUSES, BREAKWATERS, HARBOURS, DOCKS, QUAYS, WHARVES, AND RIVERS.

To a great maritime power like the Dominion of Canada, fourth, if not indeed since the misfortunes of France third among the maritime powers of the world, lighthouses, breakwaters, harbours, docks, quays, and wharves, and the improvement of rivers by embankments, cuts, or dredging, must ever be subjects of primary interest. It is obvious, however, that we can to-night take but the merest glance at them.

One of the most celebrated ancient lighthouses on record was that built on the Isle of Pharos by Sostratus, of Cnidos, to render the harbour of Alexandria approachable at all times. This Pharos was built of stone, and was 450 feet high; and, it is said, could be seen at a distance of 100 miles. The light consisted of fires lighted in a species of lantern at the top.

The Romans constructed pharos or lighthouses, as at Ostia, Terracina, Puteoli, Antium, &c., the lighting of which was also managed by fires at the top. Some of these were superbly built of stone, and contained accommodation for those entrusted with the care of the ports. A specimen of the Roman Pharos, but of a ruder description, may be seen in England, in Dover Castle.

A very remarkable lighthouse in France was constructed at Cordouan, two leagues from Bordeaux, between 1584 and 1610, by Louis de Foix, on an island, dry at low water, but completely covered at high water. The height of the building from the rock was 162 feet. Reflected light was used in this tower for the first time about the year 1780.

The shores of the narrow seas which surround Great Britain abound in lighthouses: among the most famous are the Eddystone and the Bell.

The first Eddystone lighthouse near Plymouth, was built between 1696 and 1699, and was destroyed in 1703 by a violent storm, in which the engineer and workmen employed in its maintenance, as well as the keeper, perished. It was rebuilt between 1706 and 1709, but destroyed by fire in 1755. It was recommenced under the celebrated Smeaton, in 1756, and again completed in a little more than three years, and, happily, remains now as perfect as when built.

The Bell-rock lighthouse, which protects the trade of the friths of Forth and Tay, and of the North sea and German ocean in the vicinity of the Bell-rock, was commenced under the equally celebrated Robert Stephenson, in 1807. Its principle is the same as that of the Eddystone lighthouse.

At Lowestoft is a lighthouse nearly 200 years old, situated on the cliff overlooking the German ocean. In this the light was formerly given by a coal-fire within a glazed chamber, and was said to be visible for a great distance at sea.

About twelve or thirteen years ago, a lighthouse was constructed on Roman Rock, at Simon's Bay, Cape of Good Hope. The structure was a circular tower, 15 feet diameter, 48 feet high, of cast-iron plates, with a central shaft 16 feet diameter for the revolving machinery. Great difficulties existed, as only once in three years was it so calm that no sea broke over the rocks at *low* water. From various reasons, the iron plates failed; and it was found necessary to surround the first 24 feet in height of the tower with granite, backed with concrete. This was completed by the end of 1866, and the tower now serves to warn the mariner against the "Cape of storms."

Moles and Breakwaters.

The use of moles and breakwaters to break the force of the waves and afford additional security to anchorage, dates from the earliest ages, and has been continued by every seafaring nation. It is impossible to do more here than just to refer to them. Among the most celebrated at home, and worthy of special mention for the lesson which it teaches of the value of consulting nature in such works, is the *Plymouth Breakwater.*

This work is 5100 feet long at the top, and 5310 long at low-water-line. The depth of water in which it is situated varies from 36 to 60 feet at low-water spring-tides. The tides rise from 12 to 18 feet. The lighthouse is on the west end. The work was commenced in 1812, and is mainly composed of vast masses of lime-stone thrown into the sea, *which has been allowed to form the outer slope.* In 1841, when the work was considered as completed, nearly 3,400,000 tons of stone had been used in it, and the cost had amounted to nearly 1½ millions sterling. A fort has recently been constructed in rear of the centre of the breakwater, which, with the works on either shore, defend the entrance into Plymouth.

Harbours, Docks, Quays, and Wharves.

My space absolutely forbids that I should enter into any detail regarding harbours, docks, quays, and wharves. They have necessarily occupied the attention of maritime nations in every era; and now, not only the ever-growing traffic of the world, but also the vastly-increased tonnage of the ships that bear that traffic call for fresh efforts. Nothing in engineering involves heavier expense or requires more sound judgment and sterling ability than works of this nature; and the manner in which the wants of the age are met reflects the highest credit upon Engineering and Engineers.

Bermuda Dock.

As an interesting and novel effort in providing a dock, may be mentioned the building, and transport across the ocean, of the Bermuda dock. A dock capable of receiving large vessels of war had long been an absolute necessity at Bermuda. It was found impracticable to construct it of stone. A hulk was, therefore, constructed at home, with hollow sides and bottom, each fully 20 feet wide. The interior of the hulk is shaped to the form of a large vessel, and gives a dock 330 feet long, 84 feet wide, and 53 feet deep. The hulk is of wrought-iron, about half an inch thick, and weighs about 8,200 tons, besides 400 tons in the caissons. It will take in any vessel now afloat, except the *Great Eastern*, which is too wide. Our largest ironclads, having a displacement of 10,200 tons, can be lifted by it so as to have their keel out of water. The dock, using her caissons, will lift and lay completely dry a vessel weighing 8,000 tons; and the dock, being in the form of a ship, can be heeled over so as to be thoroughly cleaned from fouling. The dock occupied two years and nine months in building, and was thirty-six days in being towed to Bermuda. Her draught of water, light, is 11 feet 2 inches, and 50 feet when submerged for docking a large ironclad. We are indebted to Lt.-Colonel Clarke, of the Royal Engineers, C. B., Director of Works to the Admiralty, for this dock.

Harbours and Docks in Germany and Malta.

In northern Germany, great attention has been, and is still, being paid to the construction and improvement of dock-harbours and dock-yards, both for naval and commercial purposes. Among these may be mentioned the Royal dock-yards at Wilhelmshaven on the Jade, and at Kiel. But the widest and deepest dock in the world is the new Royal naval dock at Malta, which was opened on the 16th of February last, and named the "Somerset Dock." It is 34 feet deep, 80 feet wide at entrance, 104 feet wide between the copings, and 430 feet long. It cost, including the heavy works necessary in making an entrance to it, about £150,000 sterling.

Improvement of Rivers.

The improvement of rivers by embankments, cuttings, dredging, &c., requires the nicest judgment in the Engineer. The force of an apparently trivial flow of water is so irresistible when that flow is stopped, and the action of water on a large scale so often varies from the expectations entertained, that the best Engineering is required to deal with such forces.

Holland.

Holland is pre-eminently the land of embankments, not only as regards its rivers, but also the dykes raised to resist the encroachments of the sea. These are, in many places, 30 feet above the level of the ocean. And as an instance of how the simplest may often be found the most effective means, it may be mentioned that bundles of reeds twisted together, laid horizontally, and secured to the dykes, with piles driven in above the reeds, are found among the best methods of retaining the dykes towards the sea.

It has been by these means, and by drainage, that Holland, much of which is below the sea, now embraces some of the richest land in the world, and bears its testimony to the happy results of Engineering and Engineers.

Embankment of the Thames.

The embankments in England, along the river Thames, date back certainly from the period of the Romans. As a magnificent specimen of modern work may be mentioned the embankment from Westminster bridge towards London bridge, along the northern bank of the same river.

DRAINAGE OF LOW LANDS.

The drainage of low lands presents, not only on account of the rich soil which is usually thus acquired, but of the improved health gained for the entire vicinity, another field for Engineering and Engineers, the value of which will increasingly be felt in Canada.

WATER FOR IRRIGATION AND GENERAL USES.

In connection with drainage, our thoughts naturally turn to the supply of water for irrigation, and for the general uses of man. We trace the progress of this branch of Engineering in the simple contrivance of the pole and bucket, still to be seen in daily use in many parts of the world; in the adoption of the principle into most countries, and its extension by the use of animal power; in the land " watered by the foot;" in the narrow channels along which the fertilizing water was led as it is led to the present day; in those canals of which we have already spoken; in those vast reservoirs in India which count their embankments by thousands of miles, and their works of art by the hundred thousands; on which vast territories depend at times for their very existence, and which Australia, if she intends to grow in prosperity as she should do, must in some measure imitate. We have it in another form at Jerusalem, and find it's witness in the ruins lately explored there; in the ancient Alexandria; in those superb Roman aqueducts and other works, the very remains of which are magnificent; in such works as those which supply busy Glasgow, by gravitation, with the purest of water from the distant shores of lovely Loch Katrine, or as supply, on this continent, the young giant city Chicago; or—and we are glad to note the exception to the general gloom and decay which have settled on modern Spain—as evidenced in those works which have recently supplied Madrid with good water at a cost of upwards of 2¼ millions sterling. And we trace its more delicate touches in the artificial lakes and refreshing fountains which give fresh charms to our cities, parks, and gardens; and in that additional comfort in our homes, the value of which we, perhaps, only realize when extreme cold or other causes deprive us of it.

DRAINAGE AND SEWERAGE OF TOWNS.

The drainage and sewerage of towns present another field of Engineering, and one of daily-growing importance as population increases, and as the absolute necessity is seenof avoiding the pollution of streams and rivers. Certainly, there are at least many situations in which some "dry-earth" system must receive an amount of attention greater than has as yet been bestowed upon it. The cloacæ of Rome and the main sewerage of London may be mentioned as remarkable ancient and modern instances of this branch of Engineering.

MACHINERY.

We must pass by the entire branch, wonderful indeed as it is, of machinery; from the mighty marine engine; the locomotive, with its surprising strength and speed; the whole system of pumps and pumping engines; the hydraulic press; the ponderous Nasmyth hammer; the mighty planes for iron; the steam-rollers for road-making; the exquisite machines that supply more accurately and with infinitely greater rapidity than man, their maker, could do the most delicate articles for peace, and the finest portions of the stores required for war, in the production of which this continent has rivalled Europe. On one point only, and that because it is of practical and growing importance in every-day life, will I for a moment detain you. I refer to the necessity of the utmost care in the construction and maintenance of steam boilers, and of their periodical inspection.

A very interesting paper on this subject, by Mr. Martin, of Stourbridge, was read at the Nottingham meeting of the Institution of Mechanical Engineers, in 1870. During the four years from June, 1866, to June, 1870, there were no less than 565 explosions, or about five in every two days. Of these, 219 occurred in England and 346 abroad. By the 219 which occurred in England, 315 persons were killed and 450 persons injured. Out of these 219 explosions—

95 were due to faults of construction or repair;
62 " " to faults to be detected only by periodical examination;
54 " " to faults which should be prevented by careful attendants; and
8 only to extraneous or uncertain causes.

Thus, with the exception of eight out of 219 cases, the causes of explosion would have been detected by periodical examination. It must be remembered also that all boilers, however good in original construction, are liable in course of time to get out of order and explode, and that this liability is vastly increased if the boilers are originally so constructed or set, as is still often the case, as to render examination next to impossible. Further, that even with boilers whose original construction promises safety, that safety is ensured so long only as everything is maintained in good condition; and that an originally excellent boiler may be so weakened by repairs as to ensure explosion. This matter comes closely home to us all; for, out of the above-named explosions, between six and seven per cent. occurred in domestic or heating-apparatus boilers, and several in the portable crane boilers so commonly used on wharves.

It may be well, further, to mention that—1st, boilers which bear the hydraulic test may still be dangerous; 2nd the condition of a boiler can be satisfactorily ascertained *only* by periodical examinations; and 3rd, the cost of periodical examination is so little as to be far outweighed by the greater security obtained.

MILITARY ENGINEERING.

A very few remarks must be given to the large subject of Military Engineering. The improvements in arms has led to alterations in works of defence, the new system superseding those previously adopted, as completely as these set aside the works of previous ages. Among the objects now principally sought are so to trace the works as to prevent enfilade while securing a heavy fire on a besieger; the cover from hostile fire of such masonry as must of necessity be used; sufficient casemated protection; and the retention of good ditches and powerful flanks protecting the ditches to the latest possible period of a siege. In the arms themselves, we see the results of the earnest application of science to Military Engineering in the production of guns whose powers are marvellous, and of the breech-loading rifles, and ammunition, and mitrailleuse, of the day. Of the guns, the latest offspring is that named the "Woolwich Infant," 35 tons in weight, with a bore 11½ inches in diameter, and a projectile of 700 lbs. weight, capable of a charge of 160 lbs. of powder, and of a range of 6 miles. Ten similar "infants" have been ordered to be manufactured, that, with others, will probably be lodged, trained, and made of use as necessary, on board the large monitors now building, each vessel carrying four in two turrets. Of the rifles, the Henry-Martini, the last approved, is considered to surpass even that most beautiful weapon, the Snider-Enfield. The ponderous weight of the guns has, in turn, evolved the most ingenious mechanical appliances for working them and for supplying their ammunition. The excessive recoil produced by the heavy charges has been neutralized by similar means, and even taken advantage of by Captain Moncrieff, R.A., to lower the gun under cover. The enormous pressure on the guns, produced by the same heavy charges, has led to the invention of Captain Noble, R.A., for testing the pressure of the charge when fired upon every part of the gun, and to the substitution of gunpowder of greatly increased size and of slower combustion—the later arising, I am informed by one of my brother-officers in the Artillery here, mainly from increased compression. The importance of the slower combustion may be seen from the fact that projectiles fired with one description of powder may produce no more effect than those fired with another description of powder upon the object aimed at, while the disruptive effect of the powder upon the gun from which it is fired may be one-third greater; or, in other words, one powder can do an enemy no more harm than the other, while it will do its own gun one-third more harm. The tremendous effect of such missiles and powder upon works of defence has evolved a combination of iron-plates so ingeniously held together and so placed upon the works as to defy even that effect; while the power of vessels armed with such guns as the "Woolwich Infant," and themselves armour-plated, has led to fresh means of defence in torpedoes and submarine mines exploded by electricity. And it is a fact, full of significance, that Lord Napier of Magdala is an Engineer—Napier, who, in Abyssinia, shewed with what a lavish hand and with what effect England, idly called degenerate, can pour out her men and treasure when the lives and liberty of Englishmen are concerned; and that Moltke, the now world-famed strategist of Germany, is also an Engineer.

My time and I am sure your patience are exhausted; and yet, as you will have perceived, many subjects have been barely sketched, and very many have been altogether omitted. In considering those subjects which *have* been touched upon, I have very freely availed myself of the papers of the Institution of the Civil Engineers (including the charming address of Mr. Vignolles, its very able President in 1869-70); of the papers of the Institution of Mechanical Engineers; of Cresy's

Encyclopædia of Civil Engineering; of the Year-Book of Canada for 1870; and of the columns of the Daily Press. My thanks are also due to S. J. Dawson, Esq., C. E., of the Department of Public Works at Ottawa, for a number of reports and pamphlets on the public works of the Dominion of Canada.

Before I sit down, I would just bring under your attention the encouraging fact—encouraging especially to a young country before which such a vast future is unfolding itself as is the case with the Dominion of Canada,—the encouraging fact of the comparatively very recent period within which the most useful inventions of modern times have arisen, and of the speed with which these inventions have been improved upon. It is barely a century since the construction of canals and roads was commenced in earnest in Great Britain, or since the first little steamers appeared in France and Scotland; and it is much less than a century since the first efficient steamer was made. It is about three-quarters of a century only since Murdock first lighted his house and offices at Red Ruth in Cornwall with gas; it is 63 years only since a very *small* portion, and much later since any *large* portion, of London was lighted with gas. The birth of railways and of the electric telegraph is cöeval with that of those present here to-night of middle age. What, then, may our descendants not hope to see? And is it too much to say that in its progress towards prosperity, power, and increasing influence for good, the interests of this great Dominion of Canada are inseparable from those of Engineering and Engineers?