MAN & SON, PHOTO.

TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL. VI., PART I.

JANUARY TO JUNE,

1892.

Montreal:

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Plate I.

MAN &

INSTRUCTIONS FOR PREPARING PAPERS, ETC.

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

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

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

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

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

The attention of Members is called to By-laws 39 and 40.

CANADIAN SOCIETY OF CIVIL ENGINEERS.

LIST OF OFFICERS FOR THE YEARS 1888 TO 1892.

	1888.	1889.	1890.	1891.	1892.	1892.
President	S. Keefer.	C. S. Gzowski.	C. S. Gzowski.	Sir C. S. Gzowski.	John Kennedy.	John Kennedy.
Vice-Presidents	C. S. Gzowski. E. P. Hannaford. H. F. Perley.	E. P. Hannaford. H. F. Perley. P. A. Peterson.	E. P. Hannaford. J. Kennedy. H. F. Perley.	E. P. Hannaford. J. Kennedy. F. J. Lynch.	W. T. Jennings. Thos. Monro. P. A. Peterson.	W. T. Jennings. Thos. Monro. P. A. Peterson.
Members of Council	H. Abbott. F. R. F. Brown. F. N. Gisborne. J. Hobson. W. T. Jennings. J. Kennedy. L. Lesage. A. Macdougall. H. A F. Macleod. M. Murphy. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Schreiber.	G. F. Baillairge. J. D. Barnett. K. W. Blackwell. St. G. J. Boswell. F. R. F. Brown. G. C. Cuningham. E. Gilpin. F. N. Gisborne. W. T. Jennings. G. A. Keefer. J. Kennedy. M. Murphy. B. D. McConnell. E. Wragge. J. A. Vanier.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. W. T. Jennings. G. A. Keefer. H. G. C. Ketchum. T. Monro. G. H. Massey. P. A. Peterson. H. N. Ruttan. P. W. St. George. J. W. Trutch. E. Wragge.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell, C. E. W. Dodwell. H. Donkin. F. N. Gisborne E. A. Hoare. J. Hobson. W. T. Jennings. T. Monro. P. A. Peterson. H. N. Ruttan. P. W. St. George. Sir J. W. Trutch.	J. D. Barnett. K.W. Blackwell. H. T. Bovey. H. J. Cambie. C.E.W. Dodwell. F. C. Gamble. F. N. Gisborne E. A. Hoare. Jos. Hobson. C. H. Keefer. H.G. C. Ketchum. H. D. Lumsden. A. Macdougall. H. N. Ruttan. P.W. St. Georg	J. D. Barnett. K. W. Blackwell. H. T. Bovey. H. J Cambie. C. E. W. Dodwell. F. C. Gamble. F. N. Gisborne. E. A. Hoare. Jos. Hobson. C. H. Keefer. H. G. C. Ketchgm. H. D. Lumsden. A. Macdougall. H. N. Ruttan. P.W. St. George.
Past Presidents and Hon. Councillors.	T. C. Keefer.	T. C. Keefer. S. Keefer.	T. C. Keefer.	T. C. Keefer.	T. C. Keefer. Sir C. S. Gzowsk.	T. C. Keefer. Sir C. S. Gzowski.
Secretary.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey. C. H. McLeod.	C. H. McLeod.	C. H. McLeod.
Treasurer	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.
Librarian	F. Chadwick.	F. Chadwick.	F. Chadwick.	F. Chadwick. Wm. McNab.	Wm. McNab.	Wm. McNab.

Thursday, 28th January.

JOHN KENNEDY, President, in the chair.

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

MEMBER.

Ulric Valiquet.

ASSOCIATE MEMBERS.

S. Hanlan Baker, Aquilla Ormsby Graydon.

ASSOCIATE.

Robert Weddell.

STUDENTS.

Frank Albro Creighton, Leonard Lee Street.

The following have been transferred from the class of Students to that of Associate Members:—

Wellington Thomas Ashbridge, Robert McDowall.

Paper No. 59.

AN OLD REVETMENT WALL.

By W. J. Sproule, Ma. E., M. Can. Soc. C.E.

The old Revetment Wall along the city front in Montreal Harbor is a very instructive example for Civil Engineers—more instructive than modern examples of massive masonry which show no signs of failure and in which there may be much surplus strength, and hence much unnecessary capital buried. It is an example of a wall so nearly equal to the requirements that part of it remains in good condition, while part has failed. The accompanying cross sections show that the wall is much lighter than the practice of the present day warrants for similar situations, as is seen by comparing its cross section with that of the Canadian Pacific Railway revetment wall recently built, and yet after fifty years' duty a considerable part of the wall is but little disturbed and with a similar rate of degeneration would not be in bad condition fifty years hence, while part has failed so badly that it became unsafe, and timber props were resorted to several years ago. Part of the wall was built in 1831 and part in 1840-41. The failure during recent years has been very gradual and the displacement probably nearly equal from year to year. Parts of both the older and newer portions of the wall have failed. Their cross sections differ but little. This seems to indicate that the wall of 1831 had not shown signs of failure in 1841, otherwise the newer wall would likely have been built heavier. The wall is an ordinary retaining wall to support a city street. In the rear the ground rises rapidly in part, and in part is level for a considerable distance back. The wall is about one mile long, and on the harbor side is bare for a height of about ten feet from the wharf level to the coping.

In the beginning of winter, but always after a considerable interval of severe frost, in which the thermometer usually goes below zero, the river rises until the wall is partly immersed, the average height reached by the river at the "taking" of the ice being, for the last forty years, a level within five feet of the coping of the wall, varying, however, much from this level, often being lower and frequently nearly up to the coping. After the ice becomes stationary on the river the water falls gradually and usually recedes from the foot of the wall, but at times remains for a long period in winter one to three feet up on the face of the wall, fluctuating one to two feet with variations in the temperature of the air. Part of the wall in this way is often exposed to temperatures 15° to 20° below zero after being immersed in water for days or weeks. But this does not seem to be the determining cause of failure, for the best and worst parts of the wall have been equally exposed to these conditions. The masonry on the inclined surface of the ramps, however, at about one to three feet above wharf level is much displaced. The wall is built of limestone from quarries in the vicinity of Montreal. A few stones are cracked and somewhat weathered, but sufficient disintegration has not taken place in the stones themselves to perceptibly affect the general stability of the structure. The face is Bush Hammered Ashlar backed with rubble masonry. The face courses vary from ten inches to thirteen inches in thickness, but are in general eleven or twelve inches thick, and the stones in certain parts average three feet in length; in other parts, three feet five inches. The bed joints average 0·22 inches in thickness. The coping stones average five feet two inches in length, twelve inches in thickness and two feet six inches in width. The wall has failed by sliding on the joints especially at eight to ten feet down from the coping or one to two above the wharf, and by revolving on the joints, but as no systematic observations are available, it is uncertain whether these two motions have taken place simultaneously, or that the revolving began after the sliding movement had seriously affected the equilibrium of the wall. The sliding movement amounts to five inches in a single course in certain places, and a very slight displacement on joints seems to have taken place even in the best portions of the wall, but are here so slight as to make it uncertain whether the irregularities observable are due to imperfections in the setting or to subsequent movement. The mortar seems to have lost all its bonding strength and as picked from the joints appears as a granulated mixture of earthy materials and lime. No openings or "weepers" appear on the face of the wall to drain water from behind. Where excavations have been made near the best parts of the wall the foundation is a coarse sand, apparently the old river beach, and this porous material no doubt has served a useful purpose in draining the wall, but the examinations have not yet been extensive enough to warrant the conclusion that the superior condition of the wall here is wholly due to this cause. Fortunately the wall has served its purpose. and must be taken down and entirely obliterated in carrying out the general harbour improvement project lately adopted, and this would be necessary even if the wall were in the best condition. When this is done, something more may be learned of weak points of the wall and of the causes that preserved or destroyed it.

DISCUSSION.

Mr. Irwin said it is not at all surprising that the Harbor Revetment Wall failed as much as it did. It has no weep holes in its face. The two upper sections shown on Plate I. have no frost batter, and the counterforts in those sections have not been carried up sufficiently high. It would appear from what Mr. Sproule says with regard to the filling behind parts of the wall that have not been pushed out of place, that had weep holes been left in the face of the wall, and had the back been filled in with small stone or gravel, so as to let the water behind drain out, and the counterforts been carried up to the top, and a frost batter provided with a smooth current face, the wall would probably not have failed at all. **Mr. Irwin.**

The slipping of the courses over each other, which the speaker observed in another wall which did not fail altogether, seems to disprove the statement often seen in text books to the effect that if the wall is strong enough to stand there is no fear of the stones sliding on each other.

The retaining wall of the Canadian Pacific Railway, mentioned by Mr. Sproule, and which looks much thicker than the Harbor Wall, was built to carry, not only the filling behind it, but also a double line of railway along which heavy trains and engines pass at considerable speed, in some places round pretty sharp curves; the wall, therefore, had to be built strong enough to prevent the possibility of any movement at all, as any failure would result in a serious accident. With regard to the sections of the Harbor Wall which did not fail, possibly the layer of concrete under the sidewalk, and just behind the wall, may have saved it, partly by keeping water from getting in close behind the wall, and partly by keeping frost out.

The wall on Lagauchetiere street, mentioned by the President, has been repaired twice within the last twelve or fourteen years.

With regard to the wall on the north side of Seigneurs street, the speaker thinks that the roots of the trees behind and above the wall alone keep the earth from pushing the wall down.

CORRESPONDENCE.

Mr. G. E Robertson.

Mr. Robertson said the section of the 1831 wall seems to be weak at the wharf level, but from the sections, it seems to have stood better than the wall of 1840. The absence of weepers was probably to prevent the water rising behind the wall when the face was flooded, and then freezing. Was the filling behind these walls of water tight material? The slipping at so many joints may have been caused by the flooding and freezing in open joints, the slipping taking place as the layer of ice melted. It seems to the writer that if the failure was merely caused by the thrust it would not show at so many joints. In a wall exposed as this was to flooding in cold weather the pointing should be attended to every year. The writer does not like the Canadian Pacific Wall; unless founded on rock, he thinks the centre of gravity should fall back of the middle of the base, so that when the thrust is applied there will not be such an excess of pressure at the toe.

Mr. R. A. Davy.

Mr. Davy said the failure may be attributed in a great measure to the back of the wall near the top having a slope and the adjacent surface being used as a highway, the constant traffic over which compacts the soil, which, in this case, would act like a wedge against the battered back. The incline of the concrete seems to indicate a considerable depression, caused by the traffic on the road, and would indicate the advisability of using a heavier cross section of wall when near a road and of making the back of the wall perpendicular for eight feet at least below the surface of the road.

Mr. W. J. Sproule

Mr. Sproule said in answer to Mr. Robertson's question: So far as examined, no provision seems to have been made for drainage behind the wall. The filling varies from sand and ordinary refuse street filling to sticky clay.

Friday, 5th February.

JOHN KENNEDY, President, in the Chair.

Paper No. 60.

NEWARK'S NEW WATERWORKS.

By JAS. TIGHE, Stud. Can. Soc. C. E.

In the north-eastern part of the State of New Jersey, about thirty miles from the city of Newark, and forty-five miles from the city of New York, are three storage reservoirs in course of construction, which, when finished, are intended to give a supply of water to Newark city of 50,000,000 (U. S.) gallons daily.

These reservoirs, together with the steel conduit of 4 feet diameter, which is being laid to convey the water from the lowest reservoir to Newark, make up what will be eventually known as the Newark Waterworks.

The city of Newark, with a population of almost 200,000 inhabitants, is situated on the river Passaic, which discharges the drainage of an area of 981 square miles into Newark Bay, Atlantic Ocean. The river is navigable as far as the city of Passaic, a distance of fifteen miles inland. From this river is drawn Newark's present water supply, which is raised 167 feet by pumps into Bellville reservoir, from a place about two miles outside the city limits. For some years this water was excellent, and Newark's inhabitants could boast of having an inexhaustible supply of some of the best and purest water in the State, little thinking that the time was fast approaching when it would become so polluted as to be unhealthy, and unfit for household purposes.

Like all other rivers of any size in the eastern part of the United States, the Passaic came in for its share of those industries which have developed so greatly during the last twenty or thirty years. The small mills which were at first erected on the Passaic, later on developed into manufactories, thus giving rise to towns and cities, and, as a consequence, the purity of the river water suffered deterioration.

About thirteen or fourteen years ago the citizens of Newark began to notice more or less the impurity of the water. Since then it has become worse, until finally it has reached such a state that the Passaic river, the water of which was once, to use the words of the late Professor Cooke, then Geologist of New Jersey, "pure, cool and sparkling," is now nothing better than a cesspool or main drain to carry away the sewage and surface water of Paterson city, Passaic city, and other towns as well.

The great question of finding a new source of water supply has been discussed by the different governments of Newark for many years. In 1880 a committee was appointed to make investigations, in order to ascertain, if possible, where this source might be found. For some reason none of the several conclusions arrived at by this committee were carried out, notwithstanding the well known want of 198,000 suffering people. It was not until 1888 that a few private persons, prompted by a feeling of philanthropy or actuated by a love of gain, formed the company whose scheme was accepted by Newark's "City Fathers." This scheme, although of great magnitude, is in itself a simple one, but differs in its development from all other schemes of this character in the eastern part of North America.

In looking over the accompanying sketch (Plate II), taken from a map of New Jersey, and tracing the Passaic towards its source, we meet with the four main tributaries which make up this river, known as the Rockaway, Ramapo, Wanaque and Pequannock. The Pequannock, with its smaller tributaries, has been chosen as the source of Newark's new water supply. This stream is over thirty miles in length, and has an average flow of 80,000,000 gallons per day. It rises at the foot of the highest summit in New Jersey, and courses the valleys of the mountainous districts which lie on each side.

If we follow the course of the stream for twenty miles from its source, we observe lofty mountains behind, and on each side, while straight ahead, are wavy summits clothed with a forest growth of tall and slender trees. At our feet the soil is poor and shallow, consisting of a gneissic detritus of little benefit to the agriculturist. The slopes are richly covered with brushwood. Ponds and small lakes are hidden here and there in the recesses of the valleys. The population is sparse throughout, an isolated homestead only being visible at intervals.

The drainage area of the Pequannock is about 90 square miles, and has a descent of 300 feet in the first 20 miles, or an average of 15 feet per mile. About 10 miles below its source the first reservoir is located, at an elevation of 800 feet above the level of the sea. This reservoir, known as the "Oakridge Reservoir," has a drainage of 27 square miles of area, and has a capacity of 2,500,000,000 gallons, extended over a surface of 420 acres. The reservoir is formed by the natural elevation of the hillsides, together with an earthen dam of vast proportions built across the river at right angles. About three miles across country from this point, and divided by a mountain ridge, is the second reservoir, which has a capacity of 3,500,000,000 gallons, extended over a surface area of 430 acres, and at an elevation of 155 feet higher than the first. This is known as "Clinton Reservoir." It is located upon one of the Pequannock's tributaries, a small stream which has a drainage area of about 15 square miles, and is the outflow of three small ponds. Here, again, the natural elevation of the hill-slopes encompasses the reservoir on all sides, except that at right angles to the flow of the stream, where another large dam is constructed on similar principles to that at Oakridge.

On the Pequannock river, 8 miles down from the Oakridge reservoir and about 7 miles from the Clinton reservoir, is located the Intake, or, as it is sometimes called, the Macopin Reservoir, from the fact that it receives the outflow of Macopin Lake, a sheet of water two miles distant and nearly four square miles in size. The Intake, owing to the rapid depression of the ground in this vicinity, is small compared with the other reservoirs, its capacity being only 35,000,000 gallons, extended over a surface area of 15 acres. It also differs from the other reservoirs in so far as the construction of its dam is concerned, which, instead of being of earth, is of solid masonry. The steel conduit of 48 inches in diameter is laid from here to the Bellville reservoir, a distance of $21\frac{1}{8}$ miles. There is no pipe laid from either Clinton or Oakridge reservoir. The water from each place will follow to the Intake the natural course that it followed previous to the construction of the reservoirs.

The work of construction is done by the company (known as the East Jersey Water Co.) that proposed the present scheme. The terms of contract between itself and the government of

Newark are, that for the moderate sum of six millions of dollars, the new supply of water of 50 million gallons per day shall be furnished the city of Newark from the first day of May, 1892. But that, in consideration of Newark not having to pay two millions of the cost for eleven years, the surplus water above 27½ millions of gallons per day can be used by the company to furnish a supply to any other towns requiring it; that, at the end of this period, Newark shall have the full delivery of the 50 millions of gallons daily as well as sole ownership of everything connected therewith.

The scheme was developed by the company's engineer and superintendent, Clemens Herschel, M. Am. Soc. C. E., and late of Holyoke, Massachusetts.

The designs and details of construction are of great importance, points being found in both which show the skill and originality of the great specialist in hydraulics.

Construction.

Before proceeding to this part of the work it might be well to say something about the data upon which the whole scheme is based, even though, in so doing, some of what has already been stated should be repeated. Newark, with a population of 198,000 inhabitants, wants a new supply of pure water, the quantity of which must not only be sufficient to supply the demands that would be made upon it at the present time, but, according to contract, a quantity which will give water enough to the city for years to come, allowing for increase of population and commercial enterprise. Thirty miles from Newark, on the Pequannock river and its tributaries amongst the mountains of New Jersey, where the average yearly rainfall is 42 inches, the source of this supply is found.

The quantity of water required at Newark, at present, is about 15,000,000 gallons per day. The quantity of water discharged by the Pequannock in certain seasons of severe drought would scarcely furnish this amount, while in other seasons it would furnish a large surplus over and above it. To regulate the extremes of seasons the water must be collected in one or more basins from which an equal daily supply can be furnished the whole year round. In the present scheme, this is done by the three storage reservoirs already alluded to, which though only impounding the head waters of the Pequannock river, will furnish a constant supply of 52,000,000 gallons daily.

The dam, which forms one side of Oakridge reservoir, is situated in a narrow portion of the river valley between a rocky bluff at one extremity and a hard gravel slope at the other. Its length is 650 feet, while its height is 56 feet above the river bed. The top is 18 feet wide and at an elevation of 842½ feet above mean sea datum level. Its sides are sloped 2 to 1 and have riprap facings of cobble stone 2½ feet thick. Thirty feet down from the top the dam is offsetted, making two berms of 10 and 14 feet wide; the larger offset being on the up stream side. The core of the dam is made of concrete started on the solid rockledge which was in some places 30 feet below the surface of the ground. This core at the bottom is 9 feet wide. It is battered on both sides to within 4 feet of the top of the dam. Here the core ends; its width being 5 feet. (See Plate III.) The longitudinal section (see Plate III.) shows the height the concrete core was raised per month. The dotted lines show the height the earth was raised per month in the year 1891.

The outlet of the reservoir is a trench 900 feet in length, excavated through the rocky bluff, apart entirely from the dam. It has a width of from 12 to 20 feet, and a depth ranging from 30 to 50 feet. In this outlet, about 300 feet from its opening, and where the excavation is in depth a maximum, the gatehouse is located. This structure consists of two chambers built of stone, laid in Portland cement and made water-tight with the rock ledge against which it rests on two sides. In each chamber, and on a level with the bottom of the reservoir, two 42-inch pipes are laid, with two gates in each pipe to control the outflow of the reservoir. About 50 feet from here, and running almost at right angles to the outlet, the place for the overflow is located. This "spillway" is 370 feet long and 6½ feet lower than the crest of the dam. The overflow discharges into the outlet at a point behind the gate-house, a channel being cut through the rock ledge for its conveyance. The outlet of the reservoir was completed before the construction of the gate-house was commenced, so as to change the course of the river before the foundation of the structure was laid.

The excavation was made by the use of dynamite. Steel drills were kept working night and day, and although hundreds of men were employed at the work, not the slightest accident occurred to any of them.

The dam is constructed of a gravelly earth found in the hill-slope of the western side, from whence it was carted and spread in layers from 6 to 8 inches high. Each layer was well watered by hose carts and temporary service pipes placed here and there on the structure, and the layers were well hardened into each other by rollers weighing from one to two tons. Objections are often raised against the use of rollers for this purpose on account of the plane surfaces made by them being a drawback to good work. Such cannot be made here, as the rollers were corrugated, hence making broken instead of plane surfaces.

The gravel deposited was always commenced on that portion of the dam nearest the bank from which it was taken, thus bringing the whole traffic of the horses and laden carts several times on the new layer as it advanced.

The concrete for the core of the dam consisted of three parts of sand, one of cement, and four of broken stone. "Improved Ports-Union Cement," which is a mixture of Portland and natural cement, was used. According to the specifications briquets of this cement, one hour after being taken out of the water where they were submerged for twenty-four hours after being made, must bear a tensile strain of not less than 60 lbs. on the square inch. That the whole of the cement should be so finely ground as to pass through a sieve containing thirty meshes to the linear inch, and that the residue on a sieve containing sixty meshes to the linear inch must not be greater than 10 per cent. of the quantity placed thereon.

Tests were made from samples taken from each car load as it arrived. The tensile strength of 150,000 bags or 50,000 barrels already tested was 226 lbs. per square inch for maximum, 68 lbs. per square inch for minimum, and 127.87 lbs. per square inch, the average of the whole.

After the sand, stone and cement in their proper proportions were thoroughly mixed on a movable platform laid alongside the core of the dam, the concrete was shovelled into a wooden casement, made of plank sheeting two feet high, put up to retain it. When the concrete set or became hard enough to sustain itself by its own cohesion, the wooden casement or mould was removed to a higher level in preparation for the next layer to be deposited. As the concrete was thrown into the mould it was tamped by heavy mallets used for the purpose. The core was always kept in advance of the earthwork; the latter being puddled for two feet wide at the seams.

The Clinton dam was constructed on the same principles as that at Oakridge. It is not straight in plan like the latter, but curved for about half its length where its height is greatest. The curved part which is a compound curve convex up stream, was at first intended to be a parabola and would be so constructed were it not for the great care and trouble it would take to keep it in that shape until the structure should be finished. The present shape is, however. almost parabolic, its deviation therefrom being very slight indeed. The lengths of the curve and tangents measure 794 and 804 feet respectively, and the whole length of the dam 1,598 feet, or $2\frac{1}{2}$ times the length of the dam at Oakridge.

Both extremities of Clinton dam rest on rock ledge. The outlet of the reservoir is made near the western extremity. It is an excavation in the rock ledge 320 feet long, arched on the sides and overhead with rubble stone found in the district. Needless to say the arch is made strong enough to sustain the pressures of the superstructure above it. In this outlet, and at the middle or core of the dam, tbe gate-house, which is similar in every respect to the gate-house at Oakridge, is located. For 300 feet from the other extremity of the dam towards its centre, provision is made for the overflow of the reservoir. Throughout this distance the sides of the dam have slopes of 4 to 1. The crest is a coping of rubble stone 5 feet wide, laid in cement, and 7 feet lower than the top of the remainder of the dam. At each extremity of this 300 feet two wing walls were constructed to protect the earth embankments behind them from being washed away by the overflow. The greatest height of the dam is $55\frac{1}{2}$ feet, and the elevation of the top 997 feet above sea level.

Intake Dam.

Before describing the intake dam reference should again be made to the reservoir of which the dam forms one side. The intake is small compared with the other reservoirs. In its vicinity the fall of the river is very rapid, thus making a site for a storage reservoir of a large capacity impossible. However the best site for a reservoir was selected, not altogether with a view to its storage capacity, but to a shortening of the conduit, which was in this case an important consideration. Hence the reservoir was located as far down the river as possible, a sufficient head being still available to give the desired quantity of water at Newark.

The intake has an independent drainage area of its own of 30 square miles, but this is of little account owing to the small capacity of the reservoir. However at certain seasons of the year when this drainage will give a sufficient daily supply, the gates at the other reservoirs will be shut until water from them is again required.

The dam is constructed across the river and is of solid masonary. It may for convenience be divided into two portions, one called the dam proper and the other the waste weir or overfall.

The dam proper (see Plate IV.) is straight in plan while the overfall is curved, convex up stream, and runs at an angle of about 60° with the same. The dam and overfall meet near the southern bank of the river where they form an angle of 126°. The foundation of the overfall rests on rock ledge which was here the surface of the ground. A hard gravel pan is the foundation of the dam proper. For greater security a trench 4 feet wide and 5 feet deep was made in the hard pan under the foundation course and filled with concrete. The length of the overfall is 250 feet. The length of the dam proper is 156 feet and its top is at an elevation of 592 feet above sea level, or 7 feet above the crest of the overfall.

As is seen in the section (Plate IV) the overfall is built in two divisions, a cement seam of two inches thick running longitudinally between them to prevent the percolation of water through the masonry. This seam extends throughout the whole structure.

At the southern extremity of the overfall is the double gate-house from which the 48-inch pipe starts to Bellville reservoir. The house contains four chambers, two of which are for screens, and the other two contain a 48-inch pipe each. The second pipe is to serve if anything occurs to the other or service pipe.

The stone used in the construction of the dam, overfall and gate-house, was taken from a granite rock in the hillside close by, except the coping of the overfall, which is pure granite, quarried in Moonsoon, Massachusetts. This coping consists of huge stones cut to order, each stone crossing the whole top of the overfall. In laying they were dowelled together. At every ten feet the dowels were connected with other iron pins anchored four feet down in the masonry. The structure was so designed that the centre of pressure is at a distance less than one-quarter the base from the centre of the same.

The facing of the overflow, on the down-stream side, is all ashlar work, each stone being on an average 2 by 2 feet. The up-stream side of the whole structure was rough-casted with cement mortar.

Below is a summary of the three reservoirs giving capacity, drainage, area, &c. :—

Reservoir.	Height above the Level of the Sea, in feet.	Drainage Area in Miles.	Size of Reservoir in Acres.	Capacity in Gallons.
Oakridge..............	836·5	27	420	2,500,000,0(0
Clinton	990·0	15	430	3,500,000,000
Macopin or Intake.....	535·0	30	15	30,000,000
Totals..........	....	72	865	6,030,000,000

The Pipe Line.

The most important or at least the most interesting part of the Newark new waterworks, is the steel pipe of 48 inches diameter which is to convey the water from the intake to the Bellville reservoir near Newark. This part of the work is of interest not only on account of the size of the pipe and the material from which it is made, but it is the pioneer steel pipe of any length used for hydraulic purposes in the eastern part of America. On the western coast in California steel and wrought iron pipes have for years been successfully used as conduits. The largest pipe, however, in use is only 44 inches in diameter.

The stretch of $21\frac{1}{8}$ miles of country between the intake and Bellville reservoir is broken and mountainous, and offers no advantages for the laying of a pipe of so large a size. Under these circumstances Mr. Herschel considered it advisable that the most reliable metal should be used, and to strengthen his opinion he subsequently went to California where he made a careful examination of some of the larger steel and wrought iron pipes in that part of the country. From the experience he acquired there, and from calculations made on the different metals used in water pipes, he decided that steel would serve best in this case where the pipe line was so hilly, and where the pressure on the pipes in some places would be 200 lbs. on the square inch.

The contract for the construction of the pipe was let to McKee and Milson, of Bethelem, Pennsylvania. Owing to the amount of pipe to be made, the contractors thought it advisable to fit up a new plant in Paterson for this special work so as to be as near as possible to the place where the pipe was required.

In August, 1890, the first sections of pipe were turned out and laid, and the work of placing the pipes has continued almost night and day ever since.

The steel used is purchased from Carnagie & Co., Pittsburg, Pa. It is shipped from there in sheets $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{5}{16}$ inches thick. The standard superficial dimensions of each being 7 feet long by 12′ 10″ wide. However, 20 per cent of the whole number of sheets is allowed to be slightly below the above standard. In their shipment great care is taken to secure them from rust. Closed cars are used for the purpose, and the same precautions are taken as if the cars contained burnished steel.

Although the thickness of the pipe should vary according to the different "heads" upon it throughout its length, it was found more economical in this case to use only three thicknesses of $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{5}{16}$ inches, which accounts for the difference in the thickness of the sheets mentioned above.

The pipe, when laid, is calculated to deliver a supply of 50 millions of gallons per day at the Bellville reservoir near Newark. To overcome frictional resistance, etc., this requires a fall of 11 feet per mile. All through the upper portion of the country the pipe where practical was kept as near to this gradient as possible. At Pompton "notch," a distance of 28,300 feet from the intake reservoir, hydraulic grade is touched for the last time; the lay of the country prohibiting it any further. After leaving here the pipe falls 330 feet in a horizontal distance of 2,700 feet to the plains below, known as Pompton plains, where it traverses three miles of what is practically a flat country without any change of grade whatever. A little further on from Pompton plains, Pompton river is crossed on an iron bridge specially constructed for the purpose. About 200 feet beyond this river the pipe commences to climb "Aunt Sally's Hill." On reaching the summit of this hill, which is at an elevation of 376 feet, the pipe descends again towards the Passaic river which it crosses on another bridge similar in construction to that over Pompton river.

The conduit is hung by iron rods attached to the upper chords of the bridge. The conduit for this length is encased in a wooden casement. Further on the Orange mountains are encountered, over which the pipe passes at a point called the "Great Notch," where the elevation is 325 feet feet above sea level. Here as in "Pompton Notch" the line, in order to avoid steep grades, follows the winding of the pass.

The company once thought of making a supply reservoir at this place, for which a site was chosen and surveys made. This reservoir would supply Newark should any serious break occur in the conduit anywhere between here and the Intake.

Below this, or for the last three or four miles, the pipe-line is practically straight and passes through farming country to Bellville, where the water is discharged into the reservoir now in use by the pumping plant which has supplied Newark with water from the Passaic river. From Bellville reservoir the new supply of water will be conveyed by a 36-inch pipe, which will follow the line of streets through the suburbs of Newark to the low-service distributing reservoir at Orange, a distance of 24,600 feet.

Process of Pipe-Making and Laying.

The sheets of steel are rolled and rivetted together in lengths of 27 feet. The pipes are then dipped in a bath of asphalt at a high temperature. On removal from the bath they are allowed to drain and cool, and they are then covered with a coating of asphalt 1-16 inch thick, which protects them from the corroding action of the earth. The method of making the pipe is similar to ordinary boiler work, the completed sections being in all respects similar to locomotive boiler shells with their heads left out. The pipes are double rivetted longitudinally, and the sections when in place are jointed telescope fashion and held by a single row of rivets.

The lengths or sections of pipe are loaded on flat cars, each car carrying four sections, each section weighing from 2 to 3 tons. The cars deliver their freight at the most convenient stations along the railroad from whence it is hauled to the pipe line on specially designed trucks.

When the trench is ready the sections of pipe are lowered by two derricks. In all instances two of the 27 feet lengths being first riveted together on the bank, except where the gradients and angles of the pipe make this impracticable. In order to rivet the joints in the trench the latter is widened and deepened, making what are termed bell holes to give sufficient room for the riveting and caulking. Any place where the asphalt coat became worn off a paint known as the "P. and B.," which is also a preparation of asphalt, is used to replace it. It is put on cold with a brush as in ordinary painting; two or more coats being given.

Sections of the pipe are now and then tested before they leave the shop. They are to sustain an hydraulic pressure of one and one half times the maximum pressure on that part of the conduit where they are to be used. In places where the conduit is of necessity above ground, as in crossing streams, it is covered with a wooden casing. Over brooks less than 12 feet wide the conduit forms its own bridge so to speak, although in almost all cases it passes under the smaller streams.

Pipe laying was begun at the first crossing of the Pequannock river, a point 6,300 feet from the intake reservoir, on the 22nd of September, 1890. McKee and Milson, the contractors, laid in that season 8,300 feet of the conduit while the company itself did the ditching. The work was discontinued in the beginning of winter as the coming frost would make ditching too expensive.

In the following spring the contract was sublet to Messrs. McKiernan and Bergin, of Paterson. This firm having laid about half a mile made such slow progress that the company considered it better to make a new contract as the pipe had to be all laid in the season of 1891, if the terms made with the city of Newark were to be fulfilled. Hence the contract was awarded anew to the present firm, Gillispie Brothers, who were better equipped for such business, having been engaged for years in laying large natural gas mains throughout the State of Pennsylvania. They contracted to lay 15,000 feet per month beginning in May last, which they have more than accomplished as now (September, 1891) there are only 2½ miles of the 48 inch conduit and the 24,600 feet of the 36-inch conduit to lay, both of which will in all probability be completed about the end of November next.

Fixtures.

These are "manholes," "inlets," "blow-offs" and "gates." Manholes are placed, on an average, 1,184 feet apart, and are similar to the ordinary boiler type. Air inlets are placed at the summit of the conduit, and are regulated by automatic valves, thus allowing the air to escape and closing as soon as the water reaches the valve. These inlets are fitted with stop-gates varying in size according to the amount of pipe from which air collects. Blow-offs are placed in the hollows and are used for draining the pipe. In places where it is impossible to do this; for instance, where the surface of the ground does not permit of taking the discharge pipe below the level of the conduit, the idea is to pump it out when necessary, hence the discharge pipe is brought to the surface of the ground close to the conduit. In most cases the blow-offs discharge into streams. Blow-offs are also placed at each 48-inch gate.

The 48-inch gates are made by the Eddy Valve Co. of Waterford, New York, and are ponderous affairs, weighing, all complete, from 12 to 14 tons each, and are the largest valves ever made in this country. They are furnished with by passes 16″ by 10″. These by-passes are augmented by the interlocking blow-offs referred to above, which are connected to the gearing of the 48″ gate by an interlocking gear devised by Mr. Herschel and used for the first time in a work of this kind. The 48″ gates are placed at average distances of 11,678 feet apart, thus dividing the conduit into 10 sections. The blow-off gates below the Pompton river are calculated to discharge the normal flow of the conduit so as to prevent the static pressure coming on the pipe when the gates are closed.

Above this the capacities of the blow-offs are only partial;

the conduit being at a greater elevation so that the static pressure does not seriously affect it.

NOTE.—Owing to the loss of the drawings, the illustrations of Mr. Tighe's paper had to be omitted from this volume. They will appear in the second part.

Friday, 12th February.

PROF. C. H. McLEOD, Secretary, in the Chair.

In consequence of the small attendance of members, it was unanimously resolved to postpone the reading and discussion of papers to the next meeting.

Friday, 26th February.

JOHN KENNEDY, President, in the Chair.

The discussion of the Society's affairs occupied the evening.

Tuesday, 8th March.

W. McWood, M. Can. Soc. C. E., in the Chair.

Paper No. 61.

THE PASSENGER CAR.

By G. S. Smith, Stud. Can. Soc. C. E.

When Stephenson's "Rocket" started in the now famous locomotive competition of 1829, the cars for passenger accommodation were obtained by placing the stage coaches of the time on suitable flanged wheels. These cars were considered sufficient, and on all the roads that were opened within the next few years this same style of carriage was adopted. Some time afterwards when the Stephensons thought it advisable to improve the carriages, they found that it would be an expensive and uncertain undertaking, to do away with the old carriages and build others better adapted for passenger traffic. The masonry platforms, bridges, cuttings and tunnels, all being too small or too close to the rails would have to be rebuilt. On this account it was decided that it would be utterly impossible to make such a great change in the passenger car, and this is the reason that to-day we find such small cars on the British railways. In these cars the greatest allowable width, for the 4′ 8½″ gauge, from outside to outside of eaves, is only 8′ 10″, so that the few Pullman cars running on these roads had to be built to that width, and 13″ lower than ours on account of the small tunnels and bridges. Being thus bound down to such a narrow car, it is difficult to adopt our plan of construction with the central aisle and double seats on each side. If, however, it were decided to adopt our style of a central aisle, it would be necessary to reduce the length of the seats on one side, from that suitable for two persons to that for one. For short distances and till the close confinement becomes tedious, nothing can be more comfortable and luxurious in pleasant weather than the first class English cars; but the absence of all toilet conveniences is a great drawback on long journeys. On most of these trains there is still no way of communication between the passenger, conductor, and engine driver, or from one car to another, while the train is in motion. Some, however, use a bell rope passing along the top of the floor, and others one running along on the outside just below the eaves, which can be easily reached by opening the window. There has been great rivalry between the brake companies for the British trade, and it seems that the vacuum brake has found greatest favour, though quite a number of the cars are equipped with the Westinghouse Air Brake. The heating of these cars is done in a very primitive manner by means of hot water foot-cans. At certain points along the line there are large tanks for heating the water used in these cans, and when a train is nearly due sufficient cans are got ready for it. When it arrives a porter rushes along opening all the doors and the cold cans are replaced by hot ones, but during this exchange each compartment gets filled with cold air, so that it is doubtful whether the passengers have benefited by the exchange. It seems strange that a method of heating by means of steam, hot water, or hot-air pipes, has not been introduced so that the temperature of each compartment could be kept at any required point throughout the journey.

Let us now turn to the American passenger car, which owing to better acquaintance we shall be able to discuss more minutely. The cars built for the first railroads in America were not, as in England, taken from the stage road, but were designed and built for the comfort of the passengers. As new cars were made improvements were added until we have arrived at the present car. The car of twenty years ago was a very poor affair as compared with the present one, for among other improvements in the ordinary passenger car, leaving out of account altogether the parlor and Pullman cars, may be mentioned the better method of ventilating by means of the monitor roof and double windows, improved heating arrangements, more comfortable seats, and a finer finish throughout, to which we might add the Westinghouse Air Brake and the Millar platform and drawbar.

Let us examine more closely into the construction of our modern first class car, beginning at the trucks. Trucks may be generally divided into two classes, four wheeled trucks and six wheeled trucks, though there is another class which is known as trucks with outside bearings, but they are not very numerous.

Both classes are built on the same general plan, the brakes only being placed on four wheels, on each end of the truck, in both cases. A few months ago it was proposed to do away with the flange on the middle wheel of the six wheeled truck, in the hope that it would enable it to turn sharp curves more easily, but sufficient experiment does not seem to have been made. The use of the lateral motion swing bolster is nearly universal, though it has greatly improved in many ways. The axles do not vary very much, usually weighing about three hundred and ninety pounds. As the failure of axles cause a great number of the railway accidents that happen, railway men are very particular in giving specifications and tests for new ones. The following is a very good example :—"The axles are to be finished exactly the "size indicated in the tracings. The iron is to be of a clean, "close, fibrous quality. It is also to be straight and concentric "at all points, free from flaws, blisters, cinders, or any other de-"fects, with a smooth and neat finish, and the maker's name with "date of manufacture plainly stamped on each axle between the "wheels. The finished axle is to be able to stand four blows "with a four thousand six hundred pounds hammer from a "height of 26 inches; all on the same side and direction, with-"out showing any flaw or sign of distress, so that it may be "straightened again and used. They must be of such a quality "as to be bent with twelve blows to an angle of from 70° to 75°, "and the metal should be such that a bolt one half inch square "in section could be taken out of the axle, which would stand a "tensile stress of twenty-nine tons per square inch, with a con-"traction of from 20 to 25 per cent, and an elongation of from 12 "to 15 per cent."

Of wheels there is an endless variety used for passenger cars, and of sizes running from thirty-six to forty-two inches in diameter. It is, however, generally admitted among master car builders that the 42-inch wheels are not so lasting and easy running as the smaller sizes. In making these passenger car wheels, cast iron seems to be out of the question altogether, unless it is as a centre for some more durable metal. Steel tyred wheels with rolled wrought iron centres seem to be in great favour just now, and have a high reputation among master mechanics, but they are too expensive and some cheaper kind must be found. Steel tyred wheels with cast iron centres make good strong ones; but they have not been much used. The trouble is to get a wheel with a hard and solid tyre and a softer centre, so that it can be easily bored. A few months ago large works were set up in Boston to make wheels wholly out of Bessemer steel, but after making several attempts it was found that the centre was so hard that it could not be bored for the axle. The reason the tyre has to be so hard is on account of its having to carry such a weight, for in an ordinary passenger car carrying sixty people and weighing, with its load, about sixty thousand pounds, there is an average load on each wheel of seven thousand five hundred pounds. At each instant during the revolution of the wheel this load has to be carried by a mere line of contact between it and the rail, and in case the metal in either is not hard enough to support the load it will flow. This may often be plainly seen, especially in some of the large yards where heavy shunting engines are constantly moving over the rails. The life of one of these 42″ wheels is placed at about 500,000 miles, but for different causes they have often to be renewed before that time has expired. The wheels are pressed on the axles with an hydraulic pressure of about thirty tons. The truck springs, known as laminated springs, form one of the most important parts of the car, for on them depends the ease with which it rides, and it is very necessary that they should be properly designed for the weight they are to carry. The formula, as given by Clark, for finding the safe load in long tons for one of these springs, is $\frac{B \times T^2 \times N,}{11.3 \times L}$ where B is the breadth of the spring, T the thickness of each leaf in sixteenths of an inch, N the number of leaves in the spring, and L the length of the spring between the bolt centres in inches. This kind of spring gives a much more steady motion to the car when running, than any other kind. For heavier cars the number of the leaves is increased, but the thickness of the plates T in the above equation, is generally three-eighths of an inch. Of late years it has become common practice to use what are known as iron clad sides in the trucks, that is, the truck side sills have iron plates on each side $7'' \times \frac{3}{8}''$ in section, and they are all formed into one solid piece by bolting them together with a number of round headed bolts. This iron clad side greatly strengthens the frame of the truck and makes it less liable to get out of square.

In the frame we now find the iron body bolster composed of two plates ten or twelve inches wide, and three-quarters of an inch thick, which is a great improvement over the old trussed $5\frac{1}{2}'' \times 16''$ oak bolster. The frame, as well as being stiffened by cross rods, distance pieces between the longitudinals, and two transomes beneath, has two needle beams of oak, sometimes trussed like transomes, between the transomes and the bolsters. The outside longitudinals of pitch pine are $8\frac{1}{2}'' \times 5''$, and the four intermediates are $7\frac{3}{4}'' \times 4''$, so that a $\frac{3}{4}''$ pine flooring laid crossways of the car brings it level with the top of the side timbers. On this pine underflooring is laid the pitch pine flooring, lengthways of the car, in strips three inches wide and $\frac{7}{8}''$ thick. Great attention is now given to the deafening floor, so that the noise from the trucks will not be heard in the car through the floor. For this purpose a deafening floor of pine sheathing is placed $2\frac{1}{4}''$ above the underside of the longitudinals. Sheathing paper is laid on this and then the space is filled up to level with the floor with mineral or slag wool, and then another layer of paper is laid on that before the under floor is laid. This mineral wool, besides deadening all sound, is as incombustible as asbestos, so that in the event of a smash up and the wreck catching fire, the mineral wool would be very apt to smother it, especially as there is so much in each car. The truss rods, running the entire length of the car, 50, 55 or 60 feet as the case may be, are usually four in number of $1\frac{1}{4}''$ round iron, enlarged to $1\frac{3}{8}''$ at the centres for the turnbuckles, and at the ends for hexagonal nuts, so that the rods may be of the same strength throughout. The joint bolts through the ends of the longitudinals and the end sills, are now being considered a source of weakness to the car instead of strengthening it. Of what use can they be, when alongside of them pass the large $1\frac{1}{4}''$ truss rods for the same purpose, which being so much stronger take all the strain off the joint bolts. These then, having no strain on them work loose with the running of the car, and, as may be seen on many old cars, these shaking nuts have torn away part of the end of the longitudinal, thus weakening instead of strengthening the frame.

In the body of the car there are two stanchions of oak between each window, which are tenoned into the sill and plate, and fastened together by dove-tailed pieces of oak. Below the window sill a piece of ash belting runs all around the car, being halved into the stanchions. Beneath this the car may be stiffened by oak braces running diagonally from the bolster in the main frame, to the centre and ends of the car against the belting, or the space from the belting down to the side sill may be filled in solid with $1\frac{1}{8}''$ whitewood, which is fitted in and halved for the stanchions, after the car has been given a small amount of camber by tightening the truss rods. This last is evidently the better plan, for in the other there are so many joints that the car may have a camber in the wrong direction before they are all brought up tight, and also it gives a better backing to which the sheathing may be nailed and glued. The body is further strengthened by the usual stanchion rods, running from plate to sill, and by a truss strap $2\frac{1}{2}'' \times \frac{1}{2}''$ in. section, which rises from the lower corner of the main frame to the bearing on the top of the bolster immediately below the window sill, and runs along underneath it to a similar bearing above the bolster at the other end, and then down to the main frame, each end being drawn out round and threaded for $1\frac{1}{8}''$ nuts.

In the roof there are seven iron frames called iron carlings, $2'' \times \frac{1}{2}''$ in section, with their ends resting on the plates and bent so as to have the same shape as the roof has in section. These help to preserve it in its proper shape as well as stiffening it. The rafters $1\frac{5}{8}''$ thick, in the lower roof, are placed about $18''$ apart, and any extra ones that may be required for the finish of the car inside are put in. The carlings for the upper, clere story, or monitor roof are arranged in the same way and are the same thickness as the rafters. On these the roofing is laid of pine strips $3''$ wide and $\frac{3}{4}''$ thick, which are sprung to the shape of the roof. This is generally covered with one or two coats of good paint to fill the pores, and before it is dry stout canvas is drawn tightly over it and tacked down all around the edges, care being taken that all the air is excluded and then the outside receives a coat. Sometimes, however, after being painted, the roof is all sheathed with tin instead of canvas, the joints all being soldered together, and then the tin is well painted. This is a much more expensive method and may be not as good as the other. The curved ends of the monitor, the hoods, should be struck with short radius, a four-foot one making a very good sweep.

The "Millar" platform with the "Millar" coupler and buffer are the most common type and are generally of the one standard construction. Sometimes the coupler is made of cast steel, but it is generally considered best when made of wrought iron with cast iron distance blocks between. The only part of the platform liable to much change is the steps. One of the best pattern of these is the ordinary straight sided wooden one with two wrought iron straps bent to the shape of the steps, with two small bolts in each step and riser, and hung from the step stringer of the platform. The ends of the lower step are hung as usual by the rods, and on each side of the steps there is a piece of thin sheet iron tacked to them and extending up to the main frame. The "Millar" drawbar is so made that it can be connected with the freight car coupler by a link and pin. A test for these, which have to be very carefully made, is the following: The iron has to be clean, close, of a fibrous quality, free from flaws, cracks, cinders, blisters and all other defects. It has to stand a tension of from 45,000 pounds to 50,000 pounds, must have a contraction of 25 per cent and an elongation of from 15 to 25 per cent.

In this country the "Westinghouse Air Brake" is altogether used with the attachments for hand brakes, so that the brakes may be applied in either way. In passenger cars the pressure generally carried in the pipes is from 70 pounds to 80 pounds, but the levers should be so adjusted that a pressure of 50 pounds per square inch on the piston would bring a force on the brakes equal to the weight carried.

In our cold climate it has been found necessary to have double windows, so that where the sashes are double, as a great number are, there would be four sashes to each window. The glass used in all of these sashes is 26 oz. The blinds now used are known as "Flexible" blinds, being composed of a number of thin slats, the length of the width of the window, strung on four small steel rods with distance pieces between them to let the light through. They run in slides as the old fashioned ones, except that the guides are curved to the shape of the roof so that when the blind is raised it curves up inside along the lower roof. The monitor windows are generally hung on the patent ratchet hinge which enables them to be left open in any position for ventilation. The glass in them has some pattern sandblasted on it with the monogram of the road in the centre. Outside these windows there are fixed screens made of fine brass wire netting to prevent dust going into the car.

The style of finish of cars like everything else, changes according to the fashion. A few years ago the cars were all finished on the outside in whitewood and heavily painted, but now, except where otherwise ordered, the car is finished in the natural color of the wood and only varnish is used on the outside. At present the wood finish on the outside of the car is all either cherry or mahogany and no paint whatever is put on it, simply gold leaf lining. Inside, the roof or headlining still continues to be painted, but not so heavily as a few years ago, when the cotton headlinings were simply covered. Sometimes there is just a fine wreath stenciled along the sides, and perhaps the centre panels have some fine gold lining on them, but when we have such rich headlinings in quartered oak, bird's-eye maple, curly ash, or curly mahogany, there is very little painting required. These headlinings are about $\frac{1}{4}''$ thick, and composed of three layers of wood, the centre layer running lengthways of the car and the other two crossways. To give them the curved shape to fit the roof, they are after being put together with glue, placed in large presses of the necessary form where they are left to harden. The rest of the inside finish is generally mahogany, and with a narrow carpet laid in the aisle of a color to match both the painting and upholstering it looks very neat. These cars are fitted with saloons, lavatory and heater rooms (if required.) There are several methods of heating employed, which may be classed under the three heads of hot water, steam, and hot air, the stove having at last died a natural death. In hot water heating the hot water may be obtained either from a "Baker" heater in one corner of the car and circulated under the seats in the car by means of pipes, or the cold water may be heated by steam from the engine and then circulated. In steam heating the steam is carried in pipes from the engine and circulated through the cars, thus saving the room required for the heater. In hot air heating two "Spear" heaters are required, one on either side of the car, and a hot air pipe carries the hot air along the car, distributing it by means of radiators at the seats. In heating cars by carrying steam from the engine, there is the great difficulty of getting suitable couplings between the cars, and unless they are perfectly tight, the platform gets covered with ice in winter, making the entrance to the car dangerous. Another, but uncommon style of heating, is by passing steam at regular intervals from the locomotive through earthenware pipes in the cars, and as these retain the heat for a long time the temperature of the car is not liable to reach such extremes as it does with other heaters. If there is too great a surface of heating pipes in a car the circulation is bad, and it has been found from experiments that the most satisfactory results are obtained with about one hundred and forty superficial feet.

In ventilating the cars there used to be shutters for that purpose placed in the monitor roof between the windows, but of late they have been discarded and all the ventilating is done through the windows and sometimes through an air passage running from the under side of the hood to the end of the monitor which can be opened to any distance.

The lighting of the cars is generally done by four or five large centre lamps in the main part of the car and a small double one in each end. Sometimes these have electrical attachments as well, or the incandescent lamps may be arranged along the bottom of the monitor with the storage battery underneath the car.

The car seats have also been improved of late, and now instead of the low back and stationary seat, we have a high back and a seat which moves forward a couple of inches when the back is turned over. As examples of these seats we may take the "Forney" or the "Hale & Kilburn," both of which are very comfortable and largely used.

Before leaving this subject we might notice what ratio the load bears to the weight of the car, or what ratio exists between the carrying capacity and the tare. A car such as we have been considering would carry about sixty people, and giving these an average weight of one hundred and fifty pounds, this would give a carrying capacity of nine thousand pounds. The tare of the same car would be about fifty thousand pounds, so that the ratio would be as nine to fifty, or the carrying capacity would be about one-sixth of the tare, which is a ridiculously small ratio. A remedy for this, and one which gave promise of great results a few years ago when it was patented, was the building of steel cars, but although works were put up in Chicago and some built, they have practically come to nothing so far. Some practical method of raising this ratio must soon be found and not till then may we hope to have economical rolling stock on the railways.

Friday, 11th March.

JOHN KENNEDY, President, in the Chair.

The following candidates having been balloted for, were declared duly elected as

MEMBER.

AUGUSTUS BURGES BARRY.

ASSOCIATE MEMBERS.

JAMES HENRY CHEWETT,
JAMES EWING,
FREDERICK CROSSLEY,
FREDERICK BOWLES FRIPP,
EDMUND ANTOINE HEBERT.

STUDENTS.

ELSWORTH BOLTON,
JOHN ANDREW BURNS,
REGINALD M. COURTNEY,
ARTHUR RAMSAY HOLDEN,
ALFRED A. LOEB,
CHAS. HY. BLACKWOOD LONGWORTH,
A. STEWART MCBEAN,
ALPHONSE ROBERT,
HENRY CHARLES STIFF.

Paper No. 62.

THE USE OF SAFE EXPLOSIVES IN COAL MINES.

By Edwin Gilpin, Jr., M. Can. Soc. C. E.

The following notes on explosives adapted for use in coal mines have been collected in connection with researches made in the Province of Nova Scotia for the purpose of determining how far, from the point of view of safety, modern explosives could replace gunpowder.

The subject ranges over a wide field as Cundel's Dictionary of Explosives contains some 200 pages. The enquiry, however, of the Commission was limited to the question of an explosive safe enough to use in coal mines.

Gunpowder, after an undisputed reign of centuries, was attacked by chemists with a view of lessening its cost, or increasing its power. The substitution of Sodium Nitrate for saltpetre, gave a cheaper explosive at the cost of increased hygroscopicity, etc. Potassium chlorate was also substituted for saltpetre, producing a powder increased in strength indeed, but in many cases too ready to explode by friction or percussion. These admixtures of potassium chlorate have many names, among which may be mentioned white powder, Teutonite, Pyrolithe and Lydite. The resulting explosives are not yet commercially used here, and it is probable that by the time chemists have learned to divest potassium chlorate of its ultra sensitive properties, a better use will be found for it as an explosive than as a component of gunpowder.

The discovery of nitro-glycerine in 1847, by Sobrero, marked the commencement of a new era in modern explosives, and since that date the chemists of every country have devoted much attention to the important problems connected with complex readily decomposed organic substances.

Nitro-glycerine, with whose properties the engineering profession is well acquainted, was at first used alone in the liquid form, and then mixed with gunpowder. The dangers attending its use neutralised its benefits; and it was not until innumerable experiments were made that it again found its way into public favor, absorbed in porous silica (kieselguhr), under the name of dynamite.

Some years ago Mr. Alfred Nobel observed that the lower orders of nitro cotton were gelatinisable in nitro-glycerine. The practical application of his researches has produced the useful group of explosives known by the name of blasting gelatine and gelatine dynamite. Of these, blasting gelatine is one of the most powerful explosives known, as it contains about 93 per cent. of nitro-glycerine against 75 per cent. of dynamite, and 7 per cent. of nitro cotton which, unlike the inert silica of dynamite, is itself combustible in some degree. Gelatine dynamite consists of a thin blasting gelatine mixed with other substances such as nitrate of potash and wood meal. By these admixtures the strength of the explosive can be readily graded for the work to be performed. These compounds possess with dynamite the disadvantages of freezing at a comparatively high temperature. But while dynamite becomes much more inert when frozen, blasting gelatine is more sensitive to percussion, and gelatine dynamite holds an intermediate position in this respect. Unfrozen dynamite, however, is not as inert under any conditions as the unfrozen gelatinous compounds. These preparations do not part with their nitro-glycerine under water and can thus be safely stored in hot climates, and, owing to their greater strength and safety, they are preferred by many engineers. Passing over in this connection the innumerable compounds of nitro-glycerine grouped under two heads,

1st. Dynamite with a inert base, used merely as an absorbent, such, for example, as No. 1 Dynamite,

2nd. Dynamite with an active base more or less explosive, of which Dynamite No. 2, lithofracteur, and blasting gelatine may be selected as examples, we come to the gun cotton compounds.

Braconnot, in 1832, pointed out that highly concentrated nitric acid, converted woody fibre, etc., into highly combustible bodies. The best example of these is military gun cotton, so called on account of its being for many reasons the high explosive best adapted for the military and marine engineer. If the formula of cellulose be represented by C_{24}, H_{40}, O_{20}, the various nitrates formed by the action of nitric acid upon it may be expressed by replacement of hydrogen by $NO_{\cdot 2}$, consequently we have military gun cotton corresponding very nearly to decanitric cellulose, $C_{\cdot 24}$, $H_{\cdot 30}$, $NO_{\cdot 2, 10}$, $O_{\cdot 20}$. Similarly "mining gun cotton" is nononitric cellulose, and so on. Collodion cotton is a variety which has obtained a greater importance, as Eisseler remarks, than gun cotton itself, owing to its many uses, for instance in photography, in surgery, in the manufacture of celluloid goods, and in the thickening of nitro-glycerine to form explosive gelatine. It is a dinitro celleluse, according to Bechamp. It is produced from cellulose by the action of nitric acid weaker than that used for forming the military gun cotton. As gun cotton has not found as much favor with the mining engineer as with the military authorities, it is not necessary to discuss its qualities here, although, as will appear later, this nitration of certain carbonaceous organic compounds forms the basis of another set of explosives at present attracting much attention from coal mining engineers.

In 1871 a German chemist named Sprengel announced a new principle for compounding explosives, the mixture of an oxidising with a combustible substance, and their decomposition by a detonator. These two ingredients are not explosive when kept separate. Reference has already been made to the formation of various nitrates of cellulose, and in the class of explosives now under our notice this nitration is also adopted in many instances. By the action of nitric acid on benzole, a derivative of coal tar, nitro-benzole is formed, a substance used in the manufacture of aniline. By the further action of nitric acid di-nitro-benzole is formed. Similar compounds are produced from napthaline, etc. It may be noted here that nitro-benzoles are true nitro substitution compounds. Nitro-glycerine and gun cotton are nitric ethers, although formerly also considered nitro substitution compounds.

Among these compounds may be mentioned Favier's explosive containing 91·5 parts of ammonium nitrate and 8·5 parts of mono-nitro-napthaline. Roburite, bellite, and securite, are similar in composition, being mixtures of di or tri-nitro-benzole with nitrate of ammonia. Rack-a-rock consists of compressed cartridges of chlorate of potash impregnated shortly before use, with dead oils or other liquid hydrocarbons. Picric acid, the basis of melinite, forms, when prepared in a certain manner, a very powerful explosive, but I believe that it has not yet been brought into common use.

Having surveyed in the most cursory manner the innumerable varieties of explosives concocted by chemists, it remains to point out the difficulties which restrict the mining engineer in his choice of explosives for blasting coal, and for the occasional removal of stone interfering with the symmetry or regularity of his underground operations. Under ordinary circumstances, when inflammable gas is absent from the workings of a coal mine, gunpowder is as convenient and effective as any known explosive, for both stone and coal work, the sandstones and other rocks met in coal mining being only in exceptional cases strong enough to require dynamite, or other form of high explosive.

The repeated disasters that have occurred in gaseous and dusty mines, and have been traced to the use of gunpowder, have rendered imperative the employment of an explosive incapable, under ordinary conditions, of igniting dust or gas, and necessarily similar to gunpowder in its effects upon the coal. There are coals so soft that the pressure of the superincumbent strata is enough to dislodge them when the miner plies his pick or wedge. Other coals again must be blasted, and the force must be, comparatively speaking, applied gradually, so as not to break the coal into small pieces. Dynamite or gun cotton, for instance, are entirely too strong and too local in their effects, as they shatter the coal to provide an escape for the gases liberated by their detonation, and do not tear it off in large pieces as gunpowder does. Many attempts have been made to use hydraulic wedges, or locking wedges forced in by blows of a hammer, but the result has not been satisfactory. These methods consumed much time, an important item in coal getting; or the wedges bedded themselves without meeting resistance enough to detach the coal. Ingenious experiments were made to loosen the coal by means of cartridges of lime, which, when inserted in the hole and tamped, were wetted by water under hydraulic pressure, or by the action of acids liberating gas in the stemmed shot holes, etc. All these attempts have been found slow, costly, and often uncertain. Engineers then turned their attention to the use of substances which could quench the flame of the explosive so as to prevent its igniting gas. A paper read by Mr. Cockson last spring, before the Manchester Geological Society, gives a concise summary of the best known of these proposed tampings. Among these may be mentioned the following: The Settle cartridges are paper bags 1 foot 8 inches long, and 1¼ or 1½ inches in diameter. The explosive, for instance dynamite, is placed in the midst of the cartridges filled with water, and in order to ensure its being surrounded by water a wood plug is slipped into the bottom of the bag, and a tamping of clay placed above the water before closing the mouth of the bag. The McNab process consisted in tamping with cylinders filled with water. Mr. Galloway proposed to form the first part of the stemming with moss saturated with water. Sir Francis Abel also proposed to use as tamping above the charge liquified carbonic acid in iron cylinders. The Heath and Frost process is applicable to the Settle cartridge, but for the water is substituted a gelatinous substance made from soap and water. The Securite Explosives Company propose enveloping the cartridge in a flannel bag, chemically prepared, and dipped in water before the hole is charged. In the French process it is proposed to surround the charge, Tonite, with sawdust chemically prepared with substances claimed to be flame extinguishing.

The objections to all these plans are,the increased size and cost of the bore hole,the lessened density and compactness of the tamping, the risk of any want of care or attention on the part of the workmen allowing a shot to flame or blow out (not an unreasonable one, as shown by the Apdale explosion), and the increased cost.

The trials of the French Commission with these tampings were not satisfactory, and the necessity of pursuing this enquiry is much diminished, as experience has shown that the high explosives can be replaced by others now being perfected which can be stemmed and fired in the ordinary way with comparatively little danger of producing a temperature capable of igniting gas.

The English Commission on accidents in mines recommended in 1886, as safeguards against ignitions of gas and dust through blasting by gunpowder, or other high explosives, used in the ordinary way,

1st. The removal of dust from the working places, and main roads.

2nd. The damping by water, or by chemicals, of the dust so as to render it non inflammable.

3rd. The search for some means of rendering blown out shots impossible.

4th. The substitution of mechanical coal getters for explosives.

5th. The adoption of such measures as may render the flame of shots innocuous.

6th. The use of explosives as far as possible flameless.

The objections to some of these recommendations have already been dwelt upon. The complete removal or effectual damping of coal dust appears to be impossible. No care has yet prevented blown out or flaming shots, and no mechanical appliance has yet been found practicable in coal mines, from the point of speed and economy in mining coal. The question has now narrowed itself down to the adoption of a safe explosive. Gas and dust can be ignited in three ways by a shot.

1st. The flame, although invisible to the observer, may light a blower of gas underneath the coal loosened by explosion.

2nd. A crack in the coal may permit part of the flame of the explosion to pass into the air and ignite gas.

3rd. The stemming may be blown out and the flame of the explosion projected into the air, like a charge from a cannon. Manifestly, therefore, the safe explosive must be one incapable of producing a flame to ignite gas.

The Prussian Fire Damp Commission, instituted in 1880, published a number of interesting experiments and conclusions, which are in some respects not consistent, and even contradictory. The summary of the experiments on the detonation of explosives in gas and dust is given as follows by Mr. Hugo Lohman :—"After the experiments just described, the author is of opinion that the use of the actually known explosives, in the presence of gas, and especially when dry coal dust is present, is much more dangerous than is generally supposed, and that the prohibition of gunpowder, and analogous explosive substances would have but an insignificant influence on the number of explosions of fire damp or coal dust."

The results of the experiments made by the Commission as regards explosives appear to be of a negative character, their capabilities of igniting fire damp were tested, but experiments with explosives modified as suggested by observed facts were not carried out.

The English Fire Damp Commission was instituted in 1877, and terminated its labors in 1886. As regards explosives their efforts were little more successful than those of the Prussian Commission, and were largely confined to the consideration of the best method of preventing the heat of high explosives from communicating itself to gas. The sum up, the English Commission spoke favorably of gelatine dynamite (as better resisting the solvent power of water) for use in water cartridges. The use of this method of blasting, when all precautions were carefully attended to, was considered efficacious against mixtures of gas and air not in themselves explosive but rendered so by means of coal dust, but as not sufficing in the presence of explosive mixtures of air and fire damp. The Commission deprecated the employment for stemming of solid substances producing under the influence of heat any water or uninflammable gas, such as carbonate of soda, or of lime, as it was considered that the suddeness of the detonation would not permit of the disengagement of enough gas or water to damp the flame of a high explosive. They also pronounced clearly against shot firing by fuse, and recommended electrical firing.

The French Commission was appointed in 1877, and in 1888 the Explosive Substance Commission reported. This report is the most valuable contribution yet made to the important subject of safe explosives. The basis of the enquiry of the French Commission, was the postulatum that an explosive when detonated in the presence of inflammable mixtures must have at the moment of detonation a temperature less than the igniting point of fire damp.

By a process of elimination, blasting powder, dynamite, ammonia dynamite, military and mining gun cotton, blasting gelatine, gelatine dynamite, and a number of other explosives were ruled out as they were found to readily ignite gaseous mixtures. Experiments with Pyroxiline powder, a mixture of octonitric cellulose with nitrate of barium and of potassium showed, that it was possible to find an explosive which, fired without an envelope, did not ignite gaseous mixtures. In following out this line of investigation trials were made of mixtures of dynamite with soda crystals, ammonia alum, salammoniac, coal dust, and nitrate of ammonia, and of gun cotton with sal-ammoniac and nitrate of ammonia. The admixtures of sal-ammoniac were found to decompose too slowly to produce any cooling effect and the result was practically the explosion of the dynamite or gun cotton alone. The other substances except the nitrate of ammonia were found to be only very partially decomposed by the detonation. The admixture of nitrate of ammonia was found to act differently. The substance is explosive and gives off heat, much less, however, than that of dynamite, consequently the diminished per centage of dynamite required, ensures the lessened temperature of the detonated compound. Similarly it was found that lowly nitrated gun cotton formed a safe compound when mixed with nitrate of ammonia. These experiments showed that it was possible, by mixing certain substances with explosives whose detonation ignites fire damp, to lower its temperature so that the resulting gasses would not ignite as a rule the gaseous mixtures they may be fired amongst.

By practical experiments it was found that the temperature of ignition of fire damp, as shown by the heat produced by the explosives igniting it, was about 3,992 degrees Fah. Mallard and La Chatelier estimated the temperature of ignition of fire damp at 1,202 dgrees F. These observers, however, laid great stress upon the considerable retardation of ignition. This fact allows the explanation of the apparent paradox that with a gaseous mixture inflammable at 4,202 degrees Fah. gases may be produced, without causing the explosion of the mixture, whose temperature is above 3,632 degrees F. But as these gasses have been formed by the detonation of an explosive they are suddenly given off and at a very high temperature, they expand and cool with extreme rapidity (in some thousandths of a second) before having had time to ignite the mixture of air and fire damp they come in contact with. Safety would doubtless be secured were it possible to employ a simple substance, which, detonated confined or unconfined, would yield a sufficiently low temperature and incombustible products. Nitrate of ammonia fulfils these conditions as its temperature of detonation is far below that at which fire damp can be ignited, but its complete detonation is not effected with facility.

Recourse must therefore be had to mixtures, at the simplest dual, to be made as intimate and complete as possible. If, for instance, one of the compounds is combustible itself, or when detonated alone is capable of attaining a temperature higher than 3,992 degrees F. or of giving off combustible gaseous products, it may happen that owing to imperfect uniformity a particle of that substance lying externally in the cartridge may ignite fire damp when it is exploded unconfined. These irregularities and the fact that the detonation of an unconfined explosive produces chemical changes and decompositions differing from those accompanying detonation in closed vessels, or shot holes, explain many anomalies in the numerous experiments which have been made of testing the inflammable qualities of explosives by detonating them unconfined in the presence of fire damp. The dangers of such ignitions increase with the greater proportion in the explosive of the substance capable of producing such ignition, the want of care in mixture, and the increase in exposed surface, or what comes to about the same thing, the greater the weight of the cartridge.

Experiments also appear to show that aqueous vapor when present during warm and stormy weather, tends to diminish the retardation of ignition of fire damp already alluded to. It may be found on further enquiry that the greatest development, with explosive tendencies, of blown out shots in coal mines may be connected with this point, and possibly with certain electrical conditions of the atmosphere indicated but not yet investigated.

In the study of safety explosives two classes of dual mixtures are to be noted. Either the two mixed substances are both explosive and supporters of combustion, or else one being explosive and a supporter of combustion, the other explosive or non explosive is capable of being burned by the excess of oxygen yielded by the decomposition of the first.

Mixture of two combustion supporting substances. The principle explosives now known decomposing with excess of oxygen are nitro-glycerine and nitrate of ammonia. From the experiments of the Commission it appears that the mixture of 20 per cent. of dynamite with 80 of nitrate of ammonia, and even of 30 dynamite with 70 of nitrate may be considered as possessing high guarantees of safety. This compound is also abundantly powerful for many mining purposes, as the mixture containing 20 per cent. of dynamite is only 25 per cent. less powerful than No. 1 dynamite, and can be detonated readily by plugged caps containing 8·72 grains of fulminate.

Mixtures in which one of the substances is a supporter of combustion and the other a combustible may be noticed. The only combustion supporting explosive which can be employed is nitrate of ammonia, but there is an abundant choice of combustible explosives such as cellulose more or less nitrated, dinitro-benzol, napthaline, etc. Octonitric gun cotton was selected by the Commission as most suitable for admixture with nitrate of ammonia. An explosive containing at the highest 20 per cent. of cotton and 80 of nitrate was recommended. It is, however, to be noted that these compounds detonate badly when the weight of fulminate in the detonator is less than 23 grains.

Mixtures of dinitro-benzol and nitrate of ammonia are made by melting the dinitro-benzol and incorporating it in very finely powdered nitrate of ammonia. The grains of nitrate are thus enclosed by the dinitro-benzol and protected from damp to some extent. A recent patent proposes to protect nitrate of ammonia, intended for explosive purposes, from damp by means of a coating of vaseline, but the writer is not aware of any practical tests having yet been made. Complete combustion is effected with a mixture containing 12·5 per cent. of dinitro-benzol, and detonated by a cap containing about 15 grains of fulminate. Bellite appears to contain about 15 per cent. of dinitro-benzol. The roburite as originally manufactured contained nitrate of ammonia and dinitro-benzol only. Experiments led to the incorporation of chlorine with the dinitro-benzol, forming chloro-dinitro-benzol, with the formula as given in Cundall's Dictionary, $C._6\ H._3\ Cl\ (H.\ NO._2)_2$ The presence of chlorine is believed to exercise a cooling effect on the heat evolved upon detonation.

Attention should be drawn here to the readiness with which chlorine unites with salts of ammonia to form nitrogen-chloride ($N.\ Cl._3$), an exceedingly unstable and explosive compound discovered by Dulong in 1812. The formula for the manufacture of roburite granted by the British Government requires the thorough purification of the chloro-dinitro-benzol, similar to that required in the manufacture of nitro-glycerine. Very great care has to be exercised to procure and maintain purity and uniformity in the compounds used in explosives, in order that they may not become in any way decomposed when stored.]

The proportion of this gas, owing to its irritating fumes, is limited to four per cent. of the dinitro-benzol contained in the explosive. Mixtures containing 10 per cent. of dinitro-benzol are considered very safe and explode readily with a 23 grain detonator, yielding an explosive power nearly three-fourths of that of dynamite. A mixture of nitrate of ammonia and napthaline, lately introduced under the name of amonite, possesses considerable power, and appears to be quite safe. There are innumerable similar compounds, a few of which appear likely to be of economic value.

The Commission advise the following conditions as essential for safe explosives :—

That they should develop a temperature as low as possible, and in all cases less than 3,992 degrees F., not yield combustible gasses after complete detonation; possess sufficient explosive force not to require the use of great weight of explosive; possess readiness of detonation in shot holes; to reduce the number of miss shots; be able to resist damp and atmospheric changes; and be produced at reasonable prices.

These researches of the French Commission united in a remarkable and most praiseworthy degree the benefits of practical tests and scientific deductions. So minutely and carefully have these trials been carried out that the formulae for calculating the temperature of detonation of any modern dual explosive can be relied upon as expressing its safety with as much exactness as could be deduced from numerous and costly practical tests. Upon the report of the Commission the French Government passed from the stage of recommendation to that of enactment as regards the use of explosives in dusty as well as in gaseous mines. Upon the classification of a mine as gaseous or dusty the following explosives may be used :—

1st. A mixture comprising 20 per cent of No. 1 dynamite and 80 per cent of nitrate of ammonia.

2nd. A mixture of blasting gelatine (91·7 per cent. of nitroglycerine and 8·3 per cent. of nononitric cotton) with 88 per cent of nitrate of ammonia.

3rd. A mixture of 9·5 per cent. of octonitric cotton with 90·5 per cent. of nitrate of ammonia.

These are the maximum strengths of the above explosives as used for coal getting, somewhat stronger mixtures being allowed for stone work in coal mines. A mixture of 10 per cent. of dinitro-benzol with 90 per cent. of nitrate of ammonia is allowed for stone work.

In addition to the substitution of these explosives for gunpowder, dynamite, etc., the general rule is laid down that for stone blasting, the temperature of detonation should not exceed 1,900 degrees C., and for coal getting 1,500 degrees C., as calculated by a formula laid down by the chemists of the Commission.

This regulation will permit the use of any new explosives that may be found satisfactory in other respects. Regulations are also laid down prohibiting the use of any explosives if gas be present in the working place, requiring at least 20 inches of stemming of some plastic material, etc., etc.

In England at present a good deal of Roburite is used, this is the chloro-dinitro-benzol and nitrate of ammonia explosive referred to, and with fairly satisfactory results. The only limitation being that it must be fired by electricity, and not be stemmed with coal dust.

Friday, 25th March.

JOHN KENNEDY, President, in the Chair.

Paper No. 63.

MULTIPHASAL ALTERNATING CURRENTS.

By ARTHUR EDWARD CHILDS, B.Sc.

STUD. CAN. SOC. C. E.

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The analytical treatment of multiphasal alternating currents has not yet been so fully developed as that of the simple alternating current. Experimental work has, however, been much more fruitful of results. This paper is an attempt to bring under notice, as briefly as possible, the present state of experimental knowledge on this latest of all subjects of interest to electrical engineers.

Alternating electric current distribution has gained a considerable footing and would certainly increase to a greater extent than continuous current distribution if we possessed a fuller knowledge of how to utilize it in connection with electro-chemical and electro-dynamic operations. Further, could we store the electric energy of alternating currents, and transform into mechanical energy, a greater impulse would be given this branch. For such work the continuous current has taken the lead. In spite of this lack of knowledge alternating current systems have been largely adopted because of simplicity, cheapness of construction of alternators, the easy attainment of high potentials, the simple transformation of currents by apparatus containing no moving parts, and the high efficiency obtainable. Although we cannot deny the many good qualities of the continuous current, experience has shown that the alternating current is alone suited for the distribution of power on a large scale over long distances. Until, recently no practical alternating motor has been put forward, and it is to this subject that the attention of engineers and scientists has been directed.

All their efforts produced no results until 1888, the year of the birth of the distribution of power by alternating currents. The discovery of Ferraris and the experiments of Tesla were published in that year. Many others also worked on the use of alternating currents differing in phase, without any practical result being reached. Tesla's motor, which attracted so much attention when it came out, has not fulfilled anticipations, as no commercial application of it has yet been made. Tesla's arrangement with two quite independent currents, differing 90° in phase, possessed little advantage. Its faults were avoided by others, and less than two years ago motors with a larger number of alternating currents were worked out by Bradley, Hasselwander, Wenström and Von Dolivo-Dobrowolsky. Brown of the *Oerlikon Machinenfabrik*, also worked out an alternating current motor, which has lately been employed with success at Frankfort. Prior to 1886 no progress in this branch was made because of the low efficiency and insecurity of dynamos of that date, but from 1886 to 1888 the English school of electrical engineers made such improvements in dynamos as to render possible the transmission of power on a large scale. During this time, the *Oerlikon Machinenfabrik* did good service in this direction, but continuous currents, on account of the delicacy of the commutator and the difficulty of transformation, being little suited for distribution and transmission of power over long distances, the hopes of engineers have hitherto remained unfulfilled. The construction of a continuous current machine to supply energy at 10,000 to 20,000 volts to single motors or to lamps, is practically an impossibility and will certainly remain so. Engineers, therefore, watch with interest the progress which alternating current work is making toward this point.

The employment of two or more alternating currents differing in phase in a motor has the effect of making the resultant magnetic field rotate relatively to the machine, as will shortly be seen, instead of remaining stationary as in the case of the continuous current dynamo. The resultant of two or more alternating currents, upon which this rotating magnetic field depends, has been called a *rotary current*. In order to show how this rotation comes about let us turn to an analogy which has been used in this connection, viz; that of elliptical and circular polarization of light. An atom of ether simultaneously performs two simple sinusoidal oscillations of equal period, the directions of which are perpendicular to each other. For each phase the radius vector of the resulting movement is the diagonal of a parallelogram, the components of which are the two distances from the centre which the atom would have reached, at that phase, if it performed only one or the other of the two simple oscillations. If the phase difference of the two simple oscillations be made $\frac{0}{8}$, $\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$, $\frac{4}{8}$, of a period, and the amplitudes equal, then in this case, we obtain the curves of Fig. 1.

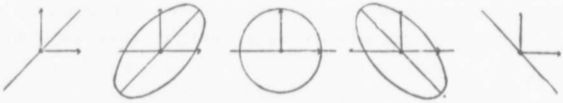


Fig. 1.

If, on the other hand, the phase difference between the component oscillations be fixed, at say $\frac{2}{8}$ of a period or 90°, and the amplitudes successively varied, we obtain for half a period the curves of Fig. 2.

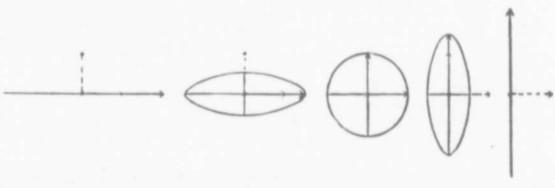


Fig. 2.

Clerk-Maxwell proved mathematically and Dr. Hertz experimentally, that optical and electromagnetic phenomena were identical. Doubtless the similarity of elliptical and circular polarization and electromagnetic phenomena led Professor Ferraris to prosecute his experiments on the phenomena of electromagnetic rotation produced by rotary currents. If we substitute the two superimposed oscillations of the atom by the variations of two superimposed magnetic fields, we obtain a resulting field the direction and intensity of which is defined by the direction and length of the radius vector of the corresponding curves of optical oscillation. In employing such a rotary field to drive electromotors, its intensity and angular velocity ought to be as nearly as possible constant. This corresponds to perfectly circular polarization in the optical analogy. To attain this has been the special aim of those working at this subject. The theoretical conditions deserve particular attention. It is only when the amplitudes of the two component oscillations are equal and have a phase difference of 90°, that the oscillation curve becomes a true circle as shown in Fig. 1. We cannot, however, apply this case to electromagnetic rotation because circular polarization is only obtained when the directions of the two components enclose a fixed angle of 90°, whereas in a rotary current motor using more than two alternating currents, this angle requires to be other than 90°. To obtain perfectly circular polarization the amplitudes of the two components must be made equal, and the angle which their directions contain must be the supplement of the angle of phase difference. In Fig. 1 we have the case of equal amplitudes and varying angle of phase difference. Fig. 3 is obtained from it by making the angle contained by the components equal to the supplement of the phase difference.

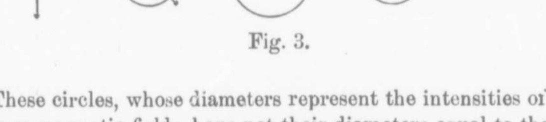


Fig. 3.

These circles, whose diameters represent the intensities of the rotary magnetic fields, have not their diameters equal to the amplitudes, as in Fig. 1, but equal respectively to the product of the amplitudes into the sines of the angles contained by the components. This electro-optical method gives a representation of rotary magnetic fields easily followed. The case where more than two component oscillations are combined gives rise to a number of modifications which need not be followed up.

There are several methods of obtaining rotating magnetic fields. Consider a continuous magnetisable ring wound with a series of coils in such a way that separate electrical connection exists between the coils of each section. Such a ring is shown in Fig. 4.

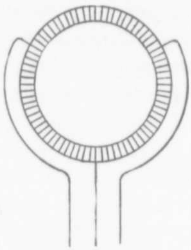


Fig. 4.

By using three wires from the generator it is possible to employ currents of equal periodicity, lagging behind one another by one-third of a period. By taking advantage of the employment of three currents retarded in this way, the algebraical sum of the currents at any instant can be made zero, and one of the three wires can always serve as a return to the currents traversing the other two. We may have four sections with three or four leads as shown in Figs. 5 and 6.

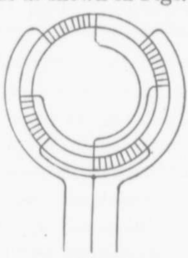


Fig. 5.

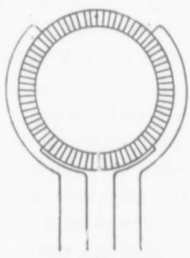


Fig. 6.

Still further we may have a large number of sections as shown in Fig. 7.

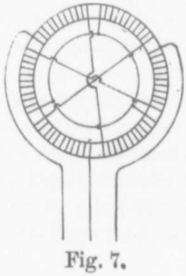


Fig. 7.

Using the sine curve to represent the alternating current, with ordinates as amplitudes and abscissae as periodic time, we can in any particular case represent the action of the current graphically. In the case of three currents we have Fig. 8.

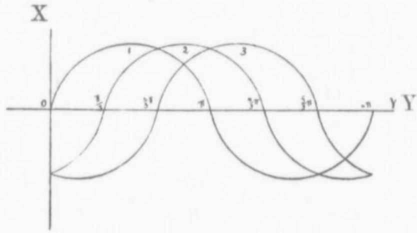


Fig. 8.

While current 1 is increasing from 0 to a positive maximum, current 2 is increasing from a negative maximum to 0. While current 1 is decreasing from a positive maximum to 0, current 2 is increasing to a positive maximum, and current 3 is passing from a negative maximum to a positive maximum, and so on. Here the difference of phase between any two currents is $\frac{\pi}{3}$.

There are several methods of obtaining, from a single alternating current, two alternating currents differing in phase, producing a rotating magnetic field. The single current is split up into two branches, into one of which is inserted a small resistance and great inductance, into the other a large resistance and small inductance. The phase difference in this case may approach 90°, but will always be smaller. Let us assume it to be 45°, for instance, then the resulting curve will be the ellipse of Fig. 1, supposing, of course, that the ampère windings in both coils have been made equal. This method gives great fluctuation in intensity of magnetism of the rotating field, a thing to be avoided. Another method, upon which the writer has spent considerable time in endeavouring to develope, is to split the single current into two and introduce into one branch a condenser. This has the effect of giving an advance difference of phase of 90°. The difficulty with this method, which has not as yet been overcome, lies in the fact that a condenser of sufficient capacity and insulation has not been brought forward. Mr. Tesla, in his later motors, makes use of the first of these methods, but the conditions for constancy of velocity and intensity of the rotating field are very imperfectly fulfilled. In his latest design of rotary current motor a four pole machine is chosen. Eight radial electromagnets are placed at equal distances on the inside of an iron ring, and are wound in such a way that every second bobbin has a low resistance and high inductance and *vice versá*. Each set of bobbins is connected in a series and both sets in parallel. As we cannot even freely choose the values of inductance and resistance, a phase difference of 45° between the two currents will hardly be attained. In this case the resulting field would be illustrated by the stretched ellipse in Fig. 2. A similar result is obtained in all motors in which only one current is used to obtain a rotary field whether the first, second, or any other method be employed.

In 1891, Messrs. Siemens and Halske made a series of experiments on motors of the types given in Figs. 4, 6 and 7. Interesting results were obtained for the three-coil motor showing that, whatever the position of the rotating magnetic field, the magnetic axis was generally curved, and the lines of force contracted at one pole and spread out at the other, that is, the intensities of the two poles were never the same. The four-coil motor gave a considerably better result. The magnetic axis was always straight, and both poles had equal intensities. The six-coil showed a still more equal resulting field. The intensities of the rotary field was obtained by hanging a coil in the centre of the ring, in such a way that its magnetic axis was perpendicular to the measured direction of the resulting magnetic axis of the ring. The coil was then excited by a constant continuous current, and was kept in its position by a spring. The torque of the spring served as a measure of the intensity. The horiozontal component of the magnetism of the earth was neglected because the ring surrounding the measuring coil effectually served as a magnetic screen. In this way they found that the mean intensities in the three, four, and six-coil motors were as 117 : 127 : 136. The fluctuations of intensity were not appreciable in the six-coil motor. In the four-coil motor those fluctuations did not quite reach 13 per cent. of their minimum value. In the three-coil motor the measurements of the intensities were not very valuable because the resulting axis was generally bent. The fluctuations of the angular velocity of the resulting axis were much larger than the fluctuations of the intensity in all three motors. In the three-coil motor it was found that the two poles always moved with different velocities. Since the velocity of the poles themselves chiefly influence the armature, it follows that this type is certainly not very advantageous. In the four-coil motor the variations of velocity are very much smaller, and are still smaller in the six-coil type. These experiments are of great value in that they throw a good light on the fluctuations of the rotary current field.

The result of a rotating magnetic field in the interior of a ring acts almost as if a constant magnetic field were mechanically revolved in it. On this principle extremely simple motors, without either sliding contacts or brushes, can be built, and the usefulness of large motors, having these advantages, has been one of the strongest reasons for experimental work in this branch. It has been stated that the conditions for constancy of velocity and intensity of the rotating field are very imperfectly fulfilled in the Tesla motor. In fact the excitation of the motor varies as much as 40 per cent of its minimum value, so that the magnetic field is not merely rotating, but also pulsating to a very considerable extent. The action of the motor is accordingly far from being simple. The type of alternating current motor designed by Professor Elihu Thomson affords us an example where the two properties of the rotating field may be considered separately. This motor consists of a magnetic field due to an alternating current, and an armature of which the windings form closed circuits. Like all synchronous alternating current motors, it must be brought up carefully to the proper number of revolutions per minute before the alternating current takes up the work. If the work be thrown on too soon, or if the motor be overloaded, the effect is to stop the machine. As the pulsations of the field only serve to turn the armature when it is going at a particular speed, and as the currents induced in the closed circuit armature do not correspond properly in time and direction to those of the field, it is very difficult to start such an armature in its alternating field. When a two-phase motor, with closed circuit armature, such as Tesla's, is not running synchronously the torque is only equal to the difference between the effect of its rotating field and the checking due to the pulsations of the magnetism. The motor, therefore, does not run well under load. At full speed it has a tendency to synchronism up to a certain load, beyond which its speed and torque rapidly diminish. The usefulness of such a motor is limited, and it can only be regarded as an improvement on the perfectly synchronous motor of Thomson, by reason of its power to start under a heavy load.

To produce a good motor we must diminish the amplitude of the pulsations of the alternating magnetism of the field. An ideal field would be without magnetic pulsations. This ideal is approached by increasing the number of currents, of which the phases are made to follow one another. In the case of three currents, Fig. 8, it will be seen that the algebraic sum is sufficiently constant, the tops of the curves representing approximately the values of the fluctuations. A simple calculation shows that the pulsation of this field is only 15 per cent instead of 40 per cent as in Tesla's motor. Since the number of alternations is relatively small, the saturation of the iron can be carried up to a high degree without impairing the efficiency, so that for a variation of 15 per cent in the ampère turns, the total quantity of magnetism remains practically constant. With four alternating currents differing in phase the value of the pulsations would be still further reduced. But here we are met by the fact that the increased number of conducting wires constitutes an obstacle to the practical application of their transmission. Even in the case of three currents we would require at least four wires, which would still be too costly. Von Dolivo-Dobrowolsky has worked out an arrangement by which three currents can be conveyed by three conductors. He supplies three currents differing by 120° instead of 60° in phase, and reverses the connections of the bobbin which supplies one current. To each of the circuits in the motor correspond at least two oppositely wound coils producing opposite poles, so that he is able to add the currents obtained by reversing their signs. This results in a figure quite analogous to Fig. 8, which represents the currents differing in phase by 120° instead of 60°. He has two methods of joining the sections on his ring, one similar to Fig. 4, which he calls a *closed* connection, and the other similar to Fig. 9, which he terms an *open* connection.

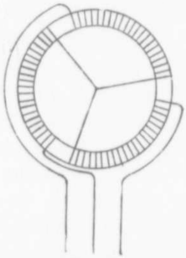


Fig. 9.

These connections render possible the conveyance of the three currents through three conductors, in that the current flowing in one conductor finds its way back by the other two. A similar system can also be employed in the case of more than three currents. Von Dolivo-Dobrowolsky states that in the course of careful experiments carried out by him with the *Allgemeine Elecktricitäts Gesellschaft*, and while working out the details of his system, there appeared many cogent reasons for abondoning this simple arrangement. Amongst these were the small output and consequent low efficiency, the heavy cost of dynamos and motors, and the difficulty of regulating, controling, and measuring the currents in the three connected circuits.

In March of 1888, Professor Ferraris first made public the principle of rotary current motors, the development of which now seems likely to cause a revolution both in long distance transmission work and in the distribution of electric energy for small motors. The following is the principle established by Ferraris:—*When two alternating currents of the same period, lagging one behind the other by a quarter period, are passed through two circuits arranged at right angles, the result is a constant rotary magnetic field revolving at a constant speed, making one complete revolution per period. If now a closed magnetic circuit is placed in this rotary field it will be the seat of induced currents, and these induced currents will tend to turn the induced circuit in the same direction as the rotary field.* In fact it will be seen that the rotary current motor works in virtue of Foucault currents which are induced in the rotating closed magnetic circuit. These Foucault currents would be zero if the circuit were stationary with regard to the field, that is to say, if the circuit revolved at the same speed as the field; and it is the effort of the circuit to fulfil this condition of relative immobility that makes it turn within the field, and in the same direction. In short, the circuit runs after the field. Although of relatively recent invention, rotary field motor systems are already very numerous and varied in design and arrangement of circuits. They are distinguished amongst themselves chiefly by the mode of producing the rotary field, and by the generator which supplies current to the motor.

The transmission of power over long distances has been the special end aimed at in all developments relating to rotary current work. High efficiency is to be gained in the use of the alternating current due to its easy transformation and adaptability for long distance transmission. The problem has yet to be completely solved, but those working at it have lately received a great impulse from the success obtained in the Lauffen-Frankfort transmission, to be described later on. The methods described above are applicable principally to the case of distribution of comparatively small motors. For the purpose of long distance transmission on a considerable scale, it is preferable to have recourse to special generators, no longer producing ordinary alternating currents, but several currents lagging a fraction of a phase one behind the other, that is to say, a multiphasal alternating current. We may employ two currents and four wires, or two currents and three wires (using one as a common return), or three currents and three wires. Systems using either of the first two combinations have been developed by Ferraris, Tesla, Shallenberger, Huntin and Leblanc. Developments in the last combination are due to Von Dolivo-Dobrowolsky, Brown, Haselwander, Bradley and Wenström.

To use a three-phase current with a system of transformers it is only necessary to have three leads if the primaries are arranged as in Fig. 10

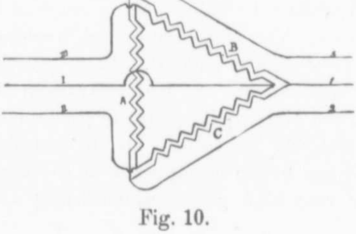


Fig. 10.

The primary A of the transformer is traversed by currents over the leads III and II, from the first section of the coils on the armature. Similarly, primary B is fed with currents from the second section, and C from the third section. Lead I goes to the common junction of the primaries B and C. Lead III is thus the common wire for current impulses from the end of the first section of coils and beginning of the second section; lead I for impulses from end of second and beginning of third sections; and lead II for impulses from end of third and beginning of first sections. The same order prevails for the secondaries of the transformer. In this arrangement no current impulses act against each other in any part of the circuit. As the current in A increases, the magnetisation also increases; after the maximum has been reached both decrease in A, but increase in B, and so on. Briefly, the magnetism travels from A over B to C, thus completing the cycle.

Here, then, we have a transformer which depends upon the rotation, by means of the rotary current, of a magnetic field inside a closed iron ring without poles, whilst the compound current supplied from the machine excites in the secondary coils similar current impulses following behind one another. The transformation corresponds to the action that takes place in a rotary current dynamo, except that in the transformer the field rotates about fixed coils, whilst in the dynamo the armature is mechanically rotated in a fixed field. In this transformer we have three connected currents differing by 120° in phase, producing a rotary field, and this has led to the idea that the same loss will occur that takes place in the case of the currents in a motor. This actually does occur to the extent of about 15 per cent loss in pressure, because the ratio of transformation is not the ratio of the number of turns on the primary to those on the secondary, but it is only necessary to increase the number of turns in the secondary by 15 per cent in order to fully utilize the primary currents. The efficiency of the transformer is consequently only very slightly affected. As a general rule, the loss in the transformation and the cost of transformers are not of great importance, since it is generally preferable to build machines for a relatively low voltage, and to transform the energy to a high voltage before supplying it to the conducting wires. In the case of very high pressures, exceeding 1,000 volts, it is much cheaper and safer to build a dynamo with a terminal voltage of from 50 to 100, and transform up to the required line potential. It is, in fact, so much cheaper that a transformer pays for itself, and the low pressure machine works so much more economically that the three or four per cent loss in the transformer is balanced.

When at the second transformation at the receiving station the currents are to be used for running large motors or lamps it will be well to resolve the combined currents, for reasons similar to those which apply to dynamos.

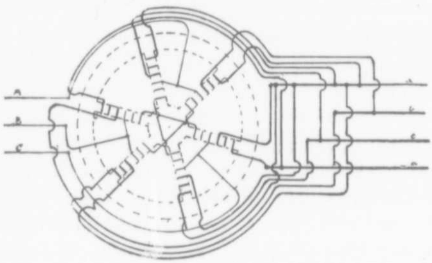


Fig. 11.

Fig. 11 shows one of many methods of doing this. A, B, C represent the long distance leads carrying high pressures and small currents. The letters a, b, c, d refer to the low pressure leads running directly to motors, etc. The transformer ring is shown dotted. The behavior of the currents of the secondary winding is a reproduction of that of those in the separate primary circuits, so that the regulation of current and tension is comparatively simple. By connecting the secondary currents we also secure the advantage that the long and expensive conductors need only be three instead of four in number.

It can readily be proved that *the weight of the conductor required for equal energy, is not greater for the three wires of the rotary current system than for the two wires of the ordinary system.* In determining the section of the conductor for a combined rotary current, such as is used in transmitting power over a long distance, it is necessary to obtain a clear idea as to the amount of energy conveyed. The determination is made in the same way as in the case of an ordinary alternating current, with the assumption that there is no self-induction, i.e., no difference of phase between current and electromotive force. Should self-induction exist, the same modifications that occur with an alternating current also present themselves with a rotary current. The three conductors should be considered as equally loaded, since only the full normal load need be considered in determining the section of the conductor. As the last of these three conditions never, or very seldom, holds good, the determination of the sectional area of the conductor would not be sufficiently correct for practical work, though of course the general proposition holds true. In a central station the rotary currents would usually be uncombined and independent, so that the control of the loads could be very easily effected by the electrician in charge. In taking measurements of the total consumption at the receiving station, the combined current being there resolved into its components, care should be taken, when self-induction exists in the circuits, to obtain readings from separate ammeters and voltmeters, and not from wattmeters. In the latter case the watts obtained would be too small. All lamps should be placed on some two particular mains, and account taken of them by simple recording apparatus. Large motors should be placed on separate circuits and their consumption measured by suitable wattmeters. For small motors supplied with the combined rotary current one measurement is sufficient without any correction for the difference of load in the separate circuits.

Reference has been made to experiments carried out by Messrs. Siemens and Halske on certain motors. In the same year the *Allgemeine Electricitäts Gesellschaft* published the results of tests on a two horse-power motor built for low pressures, such as is used in the mains of a town, transformation being avoided. The arrangement of the motor was practically an inversion of the Tesla motor, the magnet rotating inside the closed circuit armature. The motor required 70 volts and 35 complete periods per second. The tests were carried much higher than the normal allowable load in order to determine the behavior of the machine under excessive load and abnormal conditions. The weight of the motor was about 360 lbs., and, from several trials, it appeared that a load of 2 horse-power, after a long run only heated it slightly. This was fixed as the normal load, which, it is claimed, was by no means relatively low. The motor was entirely devoid of synchronism, the number of revolutions when running at no load being below that calculated from the number of alternations. Between no load and the maximum, the number of revolutions fell about 6 per cent, an amount which for a 2 horse-power motor is similar to that which occurs in any direct current motor of equal power. The speed fell off more quickly, however, as the load increased, although at 100 per cent overload the speed was still fairly high, showing that the property that alternating motors have of coming to rest when overloaded is quite done away with. From the curve of efficiency obtained it was seen that the utilizable work rose nearly in proportion with the electrical energy consumed, up to three horse-power, from which point the proportion fell off. The losses in the motor due to ohmic resistance, hysteresis, Foucault currents and friction were all separately determined and plotted as functions of the total watts consumed. The most important of these losses, viz, that in the copper, increased pretty rapidly, thus tending to make the curve of efficiency fall off with increased load. All the other losses were found to be approximately constant. It was found that at half-load the efficiency reached 75 per cent, at normal load, 2 horse-power, over 80, reaching its maximum 81.4 at about 2.3 horse-power. From the flatness of the curve obtained it was shown that the economical regulation of the motor was very good, and that momentary overloading, which is unavoidable in practice, has very little effect on its efficiency. A comparison with direct current motors shows clearly that rotary current motors of the same size are a distinct advance in point of capacity and efficiency and, further, as rotary current motors can start from any position with considerable force, no friction or other coupling is necessary.

Certain rotary current systems have been very fully worked out and are, at the present time, giving satisfactory evidence of their great usefulness. The *Allgemeine Electricatäts Gesellchaft* has developed a system in which the dynamos supply several perfectly independent currents, usually six, although any number may be adopted. A large number of currents enables the dynamos to be used to the best advantage, in that the whole circumference of the armature can be covered with active turns which, as is well known, cannot be effected with ordinary alternators. An increase in the output in relation to size is also rendered possible from the fact that a multiple phase machine gives out energy continuously, while ordinary alternators only pulsate. The energy flowing in the conductors is also constant, since the arithmetical sum of the separate currents is practically constant, as in the case of the continuous current. The distinct unconnected currents supplied by the machine are carried separately through switches, regulators and measuring instruments, and then combined by suitable transformers into three connected currents, differing by 120° in phase. These are conveyed wherever they are required, and finally again split up in order to be utilized. In their system they generally use a type of motor employing a transformer, fed by three wires carrying the three combined high pressure rotary currents, which supplies from its secondary double the number of currents of low voltage, the phases of which follow closely after one another.

The *Oerlikon Machinenfabrik* have always devoted a good deal of attention to electrical power transmission. Their engineer, Mr. C. E. L. Brown, who has given special study for a long time to the multiphase system, has created a type of machine which utilizes in an excellent manner the characteristic qualities of the system. In his 300 horse-power multiphasal alternator the armature circuits are arranged to give three alternating currents lagging 120° behind one another, so that they may be combined so as to supply a three wire system. He avoids rubbing contacts by making the armature stationary and the field magnets revolve. The armature conductors are bars of copper, insulated inside asbestos tubes, and buried in holes punched out of the iron close to the internal periphery. Eddy currents, which would attain enormous values in the copper conductors, if they were arranged in the ordinary way, are by this device avoided. Experiments made with buried conductors do not show that any power is lost by these heating currents. This method of arranging the armature conductors is mechanically strong, and, as it enables asbestos to be used as an insulator, results in an armature which is absolutely incombustible. The reduction in the air space, and the consequent improvement of the magnetic circuit reduces the exciting current. Corresponding to the number of poles of the field magnet each of the three circuits of the armature has an equal number of copper bars, connected in series by transverse pieces. There are, therefore three times as many bars on the armature as there are magenetic poles. The three circuits are joined up to each other in a manner similar to the three circuits of the Thompson-Houston arc machine. The exciting circuit is coiled around a sort of cast-iron pulley. Two steel rings, each armed with horns forming pole-pieces, are bolted on to the pulley, one on either face. The spacing between the horns on each steel rim allows the horns of the opposite one to intersect, thus giving an alternating series of poles. This machine can work equally well as a synchronizing motor, and can be made to start without difficulty. It is claimed for this design that the total weight of copper on the field-magnet is very much less than is required for other machines of the same size. To excite the machine on open circuit only one-twentieth per cent. of the output is required. At full load, owing to the reaction of the armature, this amount is slightly increased. At full speed and with normal volts, the friction losses amount to about 1·6 per cent. of the maximum output. The loss due to heating, (C^2R), by the currents is a little less than this. When all losses are taken into account it is claimed that the machine has a commercial efficiency of 96 per cent.

The dynamo used in the Lauffen-Frankport transmission, to be described further on, was of this type and was constructed by Mr. Brown's company. They have been so successful that very shortly similar generators with vertical spindles, for coupling direct to turbines, and motors with horizontal spindles, are to be employed to drive the whole of the machinery at the *Oerlikon Machinenfabrik* from a waterfall 15 miles distant.

A system which is not properly a rotary current system, but a transition from the ordinary alternating current to the rotary current has been developed by the Schuckert Company of Nuremberg. The generator used for the development of a two-phase alternating current is the same as a continuous current machine, with a difference in the connections of the armature coils, and the addition of four collector rings. The armature is a flat Gramme ring, the connections of the coils with the commutator bars being made in the usual way. The machine thus resembles a self-exciting alternating current machine, with the difference that two alternating currents are obtained with a phase difference of 90°. In this way its efficiency as an alternating current generator is greatly increased. If a continuous current machine were to be used as an alternator, by omitting the ordinary commutator and substituting two collector rings, the efficiency would be about 30 per cent. less in the latter than in the former. With this double arrangement the machine delivers at once, alternating currents for one or two circuits and a continuous current for a third. The motor is a machine similar to the generator. The armature, when fed with the two phase current, will begin to rotate by means of the cyclic shifting of the magnetic polarity around the ring, and the corresponding action of the iron of the field magnets magnetised by induction. It is not necessary to have synchronism, although the machine attempts to attain it. If the field were excited by an alternating current it would necessitate it being constructed of laminated iron, and there would be loss due to hysteresis. The field of the generator is excited by a continuous current, either from a separate source or from its own commutator. This self-excitation is usually begun when the motor has attained synchronism. The method adopted is to bring the machine up to synchronism, at which moment the brushes are placed on the commutator, and the motor becomes self-exciting. The peculiar construction adopted gives great flexibility to the system, and the machine may be used as a continuous current dynamo, a self-exciting alternator furnishing currents of one or two phases, a continuous current motor, an alternating current motor, or as a transformer of continuous into alternating currents or vice versâ. As no results as to the efficiency of generation, transmission, or transformation have yet been published it is impossible to say whether this system will attain any considerable commercial importance or not.

The summer of 1891 saw great advances in the transmission of electric power by means of multiphasal alternating currents. The transmission of power from the waterfall at Lauffen-on-the Neckar to Frankport-on-the-Main, by means of these currents is one of the greatest achievements yet obtained in this direction. The dynamo-machine at Lauffen generated a three-phase alternating current, each component of which had a pressure of 50 volts and 1,400 amperes. The potential difference was then raised from 50 to 18,000 volts by means of transformers placed in oil to secure sufficient insulation. (Towards the end of the experiments the pressure was raised to 30,000 volts). From the transformers the currents passed along three No. 8 S.W.G. bare copper wires to Frankfort 112 miles distant. The line consisted of wooden poles 26 feet high, placed about 195 feet apart. The porcelain insulators used with the line were constructed with the lower edge turned up inside so as to form an oil bath. This bath was filled with resin oil so that no leakage could take place except across its surface. At Frankfort the high-tension currents were again transformed to 100 volts with corresponding current. Half the power transmitted, i.e., about 100 horse-power, was employed to light an illuminated sign. The remaining half was used to run a motor working a centrifugal pump. This pump raised water for an artificial waterfall 32 feet high. Thus a complete cycle was made from the waterfall at Lauffen to that at Frankfort. The generator and part of the oil transformers were built by the *Oerlikon Machinenfabrik*, while the motor working the pump, and the remaining transformers were built by the *Allgemeine Electricitäts Gesellschaft*. The special committee appointed to test this insulation has not yet sent in their report, so that no very certain figures can be obtained regarding the working of this line. Mr. Huber, director of the former company has, however, put forward a few figures relating to it. Only one insulator broke down under 30,000 volts. Two slight disturbances took place caused by the breaking of a wire and by a defective insulator, both due to faulty manufacture. The cost of installation was $300 per effective horse-power, of which $210 were for the line construction. According to Mr. Huber, the efficiency of transmission was 77 per cent. He further states that rain and fog had no effect whatever upon the insulation of the line. If these figures are substantiated by the official report of the commission, then the Lauffen-Frankfort experiment will place electric transmission of power on a very much firmer basis.

Since the economic transmission of power by electricity has been generally established, the question of the distribution of energy to great distances assumes more and more prominence, especially the distribution from remote waterfalls. In such cases it is, of course, especially necessary to work with higher tensions than have been customary heretofore. The direct current does not permit the employment of these high tensions, while the alternating current, owing to the fact that it is easily transformed, affords a very suitable medium for this purpose. It must be possible in such systems to drive motors of any desired size, a demand which at present the simple alternating current is less able to meet than the direct current, whereas the multiphasal alternating current is fully adapted to satisfy it.

The chief aim of the present paper has been to draw attention to the rotary current as a new means of transmitting power, and to give a general idea of the systems employed and experimental results arrived at.

The foregoing rapid enumeration of the methods employed, or now being investigated, for the convenient transformation of the energy of alternating currents for mechanical purposes shows that we may consider the problem as practically solved. Alternating currents will soon assume a commercial importance superior to that of continuous currents, and a new evolution of electric systems will be observed pending that which will be ultimately arrived at by the employment of multiphasal alternating currents.

DISCUSSION.

Mr. Keeley. Mr. D. H. Keeley said:—It is hardly possible that any one can have carefully followed Mr. Childs' paper through from beginning to end without becoming impressed with the author's thorough and firm grasp of his interesting and important subject, and it is perhaps to be regretted that he should have gone out of his way to adopt a decidedly mythical title for a thorougly practical discourse.

In this very interesting paper—for which I am sure every member of the Society will feel indebted to Mr. Childs—we are led on by stages from the consideration of the supposed nature of the multiphase alternate current, to an examination of the methods of its production and to a contemplation of the possibilities of its application. However, it won't do to take anything for granted in the conclusion arrived at. Is there anything to justify the assumption that a further development of continuous current methods is impracticable? It will have been noticed that Mr. Childs expresses himself very decidedly on that point in prefacing his introduction of multiphase current apparatus.

Now let us just pause for a moment and see what a multiphasal alternate current really is.

Looking at the matter from a practical standpoint, or at least trying to so regard it, there appears to be nothing to warrant serious consideration of the geometrical figures that are intended to illustrate its characteristics as being coincident with something foreign to the subject.

If, *in a single conductor*, the state of things represented in Fig. 8 (reference being had to the paper) could obtain, there would then be every good reason for going into the theoretical aspect of the matter presented to us. But as a matter of fact we have in Fig. 8 only a sketch of what obtains at a given moment *in three separate and distinct conductors*, through which pulsations of unit length are being transmitted. The one marked with the number 3 was sent on its course, a third of its length ahead of No. 2; which followed *on another wire*, a third of its length ahead of No. 1, and No. 1 in its turn comes along *on a third wire*. The length of one of those pulsations is conveniently described by a circle, so that in this case we find the difference of phase as it is called, is ($\frac{360°}{3}$ =) 120°.

Now that's all there is to it apparently, and if that really is all there is to it, the term multiphasal or multiphased *current* is a wrong and misleading one. The current in each of the three wires is a *single current* made up of alternate + and — pulsations. It is the wires that are multiplied, not the currents, and the descriptive phrase employed in this instance cannot properly be "multiphase current" or "triphase current," but should be "triple circuit alternate current;" or to cover the whole—the generator, the conductors and the receiver—let us use the comprehensive term employed in the United States and call it a "*triphase system.*"

Now taking the subject of Mr. Childs' paper as a whole, and viewing it from an engineering standpoint and away from electrical considerations that are always more or less suggestive of novelty and provocative of enthusiasm, doesn't it look rather odd that the tendency at the present time is to multiply the number of circuits in order to make the alternate current effective, when with the continuous current systems a single circuit would do the work, and when it was for the very reason that the alternate current appeared to afford a means for the transmission of large currents at a greatly reduced cost for conductors, that the continuous current systems were forced to make way for it? When this question comes to be duly considered it will have the effect of redirecting the earnest attention of the electrical world to the better utilization of the continuous current. To some of us there must appear to be abundant evidence that the transmission of power by continuous current methods is not so hopeless as to warrant Mr. Childs in his assertion that "the construction of a continuous current machine to supply energy at 10,000 to 20,000 volts * * * * is practically an impossibility and will certainly remain so." The only trouble is that the attention of inventors and experimentalists has for a short time been allowed to drift away from that particular problem. We ought to remember that Brush and Thomson found out how to generate, in different ways, the continuous currents of 3,000 volts that are given out in their arc light circuits right along at the present time. The great point they made was in simplifying the commutator. Now we all know that the trouble encountered in the generation of currents of high voltage is the tendency of the current to jump from one segment or bar of the commutator to another; and if we space them sufficiently to obviate this, the brush leaves one bar before it reaches another and interrupts the circuit, and at the moment the interruption occurs the current follows the brush and forms a destructive arc between the brush and the commutator bar which it has just left. Now we can obviate this arc formation by overlapping two consecutive bars with the brush; but that involves a momentary short circuit, and if the section of the armature thus short circuited is of any considerable proportion there will be a burn out. There then is the difficulty, and the solution of it will probably be an adaptation of the "low resistance coil with high inductance" in such a manner that at the moment of short circuiting at the commutator, the E. M. F. generated in the closed section will be off set by a counter E. M. P. from the coil. There doesn't appear to be anything chimerical about that? At any rate it looks sufficiently feasible to justify a belief in the premises that a 20,000 volt continuous-current generator is not altogether a hopeless conception.

However, before it becomes an accomplished fact, a half-way combination may be hit upon. It might be conceived that the greatest *desideratum* of all is *an alternate-current with electromagnetic properties.* We could easily get this with a generator of a multiphase-current, properly so called, that is a current that would be made up of several positive and several negative pulsations (for example + + + — — —) alternately. It is after all only a matter of commutation, and very soon after the tide of ingenuity that is now overwhelming the transformation of alternate currents shall have returned to direct current channels, we will have *this* ideal generator brought to view. And when we see it we will know that a spirit of prophesy inspired Mr. Childs when he coined the phrase descriptive of a thing to be that was not.

Mr. F. A. Bowman said :—The speaker agrees with the author that the alternating current will be used where very high potentials are required for long distance transmission. The most obvious advantage of the alternating over the direct current being the facility with which it can be transformed to a higher or lower potential according as the necessity of economy in wire or safety in handling is predominant. The system of "step up" and "step down" transformers permitting the use of a comparatively low pressure at the dynamo, a high one in the line and again a low one where the power is to be utilized. A limiting factor in the employment of high tension direct current dynamos is the commutator. Anyone who has had practical experience with direct current machines of high voltage knows how rapidly the difficulty of keeping the commutator in order increases as the potential rises. A limit to to the number of segments is soon reached and also to the difference of potential allowable between any two segments. Once the latter limit is passed the troubles with a commutator become endless and interfere materially with the continuous running of the dynamo. If the speaker understands Mr. Childs rightly the radius vector of any of the curves in Fig. 1 will give a graphic representation of the varying strength of the magnetic fields due to plane difference producing that curve. The speaker would like to ask the author what value of the current is used in calculating the size of wires for multiphasal work. Mr. Bowman.

Mr. Childs, in reply, said :—The author has to thank those who have discussed his paper, for the appreciative manner in which they have received it. The discussion of such a subject is full of interest from the position which the transmission by multiphasal currents has already taken, and from the vigor with which its application is being pushed by those who have set themselves the task of making it the foremost and best for long distance transmission. Mr. Childs.

The remarks by Mr. Keeley show that he has carefully read the paper, but the author is not prepared to endorse all his ideas; on the contrary he is opposed to many of them. The object of introducing geometrical figures was to present the subject in such a way as to give a method of leading up to it. Electric currents can only be thought of by means of an analogy. The figures chosen were those relating to *Optics*, a subject which the theory of alternatiug currents has annexed bodily to itself, and it is now by the study of this subject that we are enabled to obtain clear ideas of the laws of alternating currents. Mr. Keeley takes exception to the expression " multiphasal currents," and proposes to call the system a "triphasal" one. Now, as we may and often do have more than three sets of currents the term is not one suitable to cover a general view of the subject. If we consider any single conductor, we see that the return is formed by two other conductors in parallel, and in this way any single conductor acts not only for itself but for the other two sets also, so that *we really do have a multiphasal, or in the case of three wires, a triphasal current*, on any individual conductor. He speaks hopefully of the solution of the problem of constructing a direct current machine of very high voltage on the principle of a low resistance coil with high inductance. A little consideration will show the difficulties involved in this method of preventing sparking. The coils on the armature in this case must be so constructed as to fill the required conditions. The general formula for the self induction of any coil may be written

$$L = \frac{n^2 \ a^2}{\varphi \ (s)}$$

Where n is the number of turns, d the diameter of the coil, and φ (s) some function of the square dimensions of the conductor. From this we see that in order to have a large self-induction, n and d must be large and φ small. This would involve constructing a dynamo having an armature of great diameter with many turns of wire whose sectional area must be small. But with small square dimensions we have large increase of resistance, the very thing we are trying to avoid. Here then comes in a difficulty which seems insurmountable. This being the case the author can only reiterate that the construction of a continuous current machine to supply energy at 10,000 to 20,000 volts to single motors or lamps, seems practically an impossibility.

In answer to Mr. Bowman, the author would point out that not only does the radius vector of the curves in Fig. 1 give the strength of the magnetic field at the moment each curve is drawn for, but it also gives the direction of the resulting field.

In the calculation of the size of wire to be used with a multiphasal current we proceed in this way. The amount of work to be transmitted is given in watts. The working potential is decided arbitrarily. Then the current which, multiplied by this pressure and by a factor dependent on the number of currents, the phase differences, and the capacity of the line gives the work in watts, is the current used in determining the size of wire. The correcting factor is always slightly less than one and requires to be determined separately for each case. If we work from Ohms law we will always obtain a value of the current larger than the actual current required to transmit the given amount of work, so that in using this value we obtain a size of wire on the safe side.

In a letter which the author has received from Professor W. C. Unwin, dated London, April 10th, 1892, he says:—"What struck me about the Lauffen machine when I saw it in pieces was its great mechanical merit. It was so free from the wire and shellac and patch work so common in dynamos." From a mechanical, as well as from an electrical point of view then, the multiphasal system is to be regarded with favor.

The following the author has received from Dr. Coleman Sellers:—

3301 Baring St., Station B.,
PHILADELPHIA, March 19th, 1892.

DEAR MR. CHILDS,—

Yours of March 16th arrived in due time, but the paper which you spoke of, the advance proof of your contribution on multiphasal alternating currents only came to-day; waiting for the receipt of this, I have delayed acknowledging your letter. * * * * * It comes to me very opportunely, as it is a subject that I have had brought to my attention through the offer made by the Oerlikon people to introduce this system at Niagara. * * * * * I enclose with this letter a memorandum on this subject submitted by me to the Engineers' Club of Philadelphia, the wording of which should be marked as a quotation as it is mainly taken verbatim from a letter received from Switzerland. * * * * *

I am yours truly,

(Signed) COLEMAN SELLERS.

ELECTRICAL TRANSMISSION FROM LAUFFEN TO FRANKFORT.

By Coleman Sellers, Active Member of the Engineers Club.

The following information relating to the transmission of power from Lauffen to Frankfort, a distance of 175 kilometers, is recently obtained from letters from Switzerland.

The writer states that on the 14th of September "he arrived at Lauffen at 11.30 a.m., where he was present at the starting of the 300 horse-power turbine supplying the power to a three-phase dynomo furnished by the Oerlikon Company. The tension of the current furnished by this machine in 65 volts only. These currents are sent into a transformer placed near the machine. The transformer carries the tension from 65 to 25,000 volts. The three-wired line from Lauffen to Frankfort has a diameter of four millimeters per wire."

"The wires are supported by porcelain insulators with oil grooves, fixed on ordinary wooden telegraph posts. The distance between these posts is about 50 meters, or 164 feet. On arrival at the Frankfort Exhibition, the high-tension current is transformed again into an alternating current at 65 volts, which current supplied, on the evening of the 14th of September, on the one hand, 1,000 incandescent 16-candle lamps, and, on the other hand, a three-phase receiving dynamo of 100 horse-power furnished by the Allgemeine Electricitäts-Gesellschaft of Berlin, which is working in conjunction with the Oerlikon Society for the Lauffen experiment. The insulation works well, but nothing as yet can be said about the exact efficiency."

"Up to the present time the power developed at Frankfort has not exceeded 120 horse power, not because the efficiency is so low, but because the company fears accidents. It is intimated that there were some little difficulties at first, that made it prudent to wait until the month of October, toward the end of the Exhibition, to make tests at full power. Up to now the tension has not exceeded 15,000 volts instead of 25,000, and the quantity of electricity has not exceeded 1,500 ampères instead of 4,000 on the primary current. The 100 horse-power dynamo furnished at present only 40 horse-power to a centrifugal pump."

"It is a noteworthy fact that the ordinary ampère-meters and volt-meters give false indications—a phenomenon as yet unexplained, but resulting probably from a difference of phase between the maximum of tension and the maximum of quantity. The result is the surprising phenomenon that the number of watts, or the product of the ampères multiplied by the volts, is greater at Frankfort than it is at Lauffen. This result, which would indicate an efficiency of more than 100 per cent, is, of course, only apparent. A special watt-meter must be constructed in order to measure exactly the currents at the start and at the arrival."

"It is understood that a special commission, under the presidence of Prof. Weber, professor of the Polytechnikum of Zurich, will proceed to a complete series of experiments to ascertain exactly the efficiency of the installation running at full power. There is general satisfaction felt at the choice of Prof. Weber for this position."

"The interesting part, to this country, is that what has been accomplished at Frankfort is very favorable to the lesser effort contemplated of sending power from Niagara to Buffalo, the distance being only about 32 kilometers, or 20 miles, as compared to 175 kilometers, or 109 miles."

I should have mentioned that there are enthusiastic advocates of the alternating current in Europe, who are not entirely committed as to the advantages of this three-phase dynamo as proposed by the Oerlikon Company, believing that as good results in efficiency will be obtained with the Mordey alternator, which has been demonstrated to me by actual experiment to be as efficient for a motor as a dynamo, with the great merit of simplicity and durability, the rotating motion being given to the field magnets, making the more delicate armature stationary and not liable to be disarranged.

The students of this subject of the transmission of power will do well to examine the paper recently read by Prof. Unwin on "The Transmission and Distribution of Power," the calculations being based upon experiments on air-motors, by Prof. Reidler and Prof. Gutemuth, and it shows a very favorable outlook for the transmission of power to the distance of at least twenty miles as being practicable, as it seems that air compressed by 10,000 horse-power to $132\frac{3}{10}$ pounds per square inch, can be transmitted to a distance of twenty miles in a 30-inch main with a loss of pressure of only 12 per cent. The power delivered at a distance of 20 miles by using compressed air can be counted upon as yielding 40 to 50 per cent, if the air is used cold, and 59 to 73 per cent if the air is re-heated.

In regard to the re-heating of air, experiments have been tried in this country by Mr. Saunders, of New York, of applying the combustion within the air mains, with the result that leaves little to be desired, inasmuch as the whole product of combustion is added to the quantity of compressed air, and the heated combustion is used in increasing the efficiency of the transmission.

Friday, 8th April.

JOHN KENNEDY, President, in the Chair.

The following candidates, having been balloted for, were declared elected as:

MEMBER.

CHARLES ORRIN FOSS.

ASSOCIATE MEMBERS.

JOHN WILLIAM ASTLEY, LEANDER MEYER BOWMAN, FREDERICK PERCY SHEARWOOD.

STUDENTS.

LOUIS GREENBERG. JAMES ALEXANDER MCPHAIL.

The following were transferred from the class of Associate Members to that of Members.

FRANCIS WILLIAM WHITNEY DOANE. CHARLES ANTHONY STOESS.

The following was transferred from the class of Students to that of Associate Members:—

GEORGE HERBERT DAWSON.

The discussion on Mr. Sproule's paper on "An Old Revetment Wall," and on Mr. Childs' paper on "Multiphasal Alternating Currents," occupied the evening.

Friday, 22nd April,

P. A. Peterson, Vice-President, in the Chair.

Paper No. 64.

THE PROFESSIONAL STATUS.

A PLEA FOR A CLOSE CORPORATION.

By Alan Macdougall, M. Can. Soc. C. E.

When Telford founded the Institution of Civil Eugineers the future of engineering was being developed in a manner no one at that date could foresee. It has been a happy event in the life of the profession that there was in that day a band of men who were so deeply interested in scientific advancement. Engineering was to enter upon its greatest discoveries, and to those who were members of the profession in that day were to come honors and rewards much more enduring than those earned by them during their honorable and useful careers. To the engineer was soon to be assigned one of the foremost places in science. Among the brilliant names which have distinguished every decade of this century in the world of science, the engineer has been found holding his own place. We are naturally disposed to turn to our " home " land as we think over the great achievements of science, the romance of its long historic existence clings to our imagination, and engaged as we are here, in the very stern battle of the realities of life we forget what has been done on the American Continent. When the world grows a little older, and men have grown richer and can afford to take leisure to study the history of advancement in this century, Canadian and American Engineers will not fail to have places awarded to them as conspicuous as those held by their professional brethren in Britain.

As soon as Stephenson had won his great battle of the Steam Engine, a new life opened to the engineer, which has supplied him for over 60 years with fresh fields of conquest, and new materials and forces of nature to develop and turn to useful purposes. Each step in this forward movement was accompanied by a necessary change in the practise of the profession. The old time system of long apprenticeships, chiefly of a practical character, yielded to shorter terms, and theory gradually came forward, the why and the wherefore had to be found out, the composition of new materials had to be experimented upon and lessons learnt therefrom.

The Institution of Civil Engineers, it is gratifying to remember, kept itself well abreast with the times, and has always opened its doors to the youngest members of the profession. A desire sprang up for better education about 20 years ago, in which the Institution took a prominent part; from the date of its very extensive and valuable research into the question, technical engineering education improved in great strides. Yet in spite of all the improvement, there was a great deal of keeping to the old habits; the system of apprenticeships in offices and workshops is the generally recognized path by which the profession is to be entered; the nearly universal idea is, an engineer should be a practical man, higher education does not receive its due merits.

Since the publication, in 1870, by the Institution, of the report on "Engineering Education," a marked improvement has taken place in the *morale* of the profession, mental qualifications are more highly valued, a place has been found for a theoretical engineer; men in the rush of daily life unable to keep up the reading of younger days gladly turn to their more theoretical *confrère* from whom they obtain the data on which they base their great achievements, which form many of the marvels of science.

The report, or manual as it might be called, of the Institution on engineering education, did not offer practical suggestions, it was a statement of professional practice in a great many countries, from which one gathered that in France alone, at that day, was there any approach to a close profession; the position of the engineer being somewhat akin to the Provincial Land Surveyor, in so far that he had to obtain government authority to practise. Following on this report, increased activity in engineering education has followed, schools and colleges were founded; existing corporations which had on their foundation chairs of engineering took pains to resuscitate them; in others, they were founded either by the faculty or private benefaction.

In the decade following this publication by the Institution, one noticed the growth of a feeling that something more was required, than the college training or degree of Civil Engineer to be obtained from College or University; the movement never took any more active form than a good deal of newspaper correspondence, which nevertheless has had its effect.

In 1878 the present writer presented an original communication to the Institution of Civil Engineers entitled "The Degree of Civil Engineer,"* in which he advanced the arguments he now lays before the CANADIAN SOCIETY OF CIVIL ENGINEERS. The principles he then advocated, he adheres to more strongly, as they have been strengthened by the experience of the period which has passed. The dearly cherished hope of seeing the profession in the Dominion, as well as elsewhere, placed in the most honourable position among learned bodies, societies and professions, has been partly realized by the formation of our Society, the success of which is the best evidence of its being required; a further step is required, however; the profession is like a man standing on the brink of a river, afraid to take a header into the stream in which his companions are sporting.

British opinion has come up to a certain point, and beyond that it has always been afraid to move. There are certain good conservative rules which govern practice in Great George Street; one of which is apprenticeships. The profession has been built upon this system; it is easy to understand that any infringement or proposition for a radical departure would have to be long considered, and fought for step by step. This change is taking place gradually, and almost year by year, in every engineering society, the professional status comes up for consideration; men are generally very closely agreed on the necessities, many know in their own hearts what is required and how it can be accomplished, but they are all afraid to mention such a radical subject, or as it were to plunge into the stream towards which they are looking on whose banks they are standing.

ACTION BY THE INSTITUTION.

During the period 1878-82, the position of the profession created a good deal of interest, an extensive correspondence was carried on in the professional papers in Britain, architects as well as engineers seemed to long for some distinctive recognition. The term of apprenticeship in an office with the addition of architect or civil engineer to the end of the name did not satisfy

* Proc. Inst. C. E., Vol. LV, p. 200.

the desires of the younger men, they hungered after something more practical; frequent expressions can be found in the professional papers of that date suggesting and even calling for examinations of candidates, and the issue of a degree or diploma to carry some professional weight with it. Though the movement was confined to the younger men, it was fairly representative, and cannot have been in vain: an indication of this may be taken by the action of the Institution which began to awaken about this time. In the annual report of the Institution for 1881, the admission of Students is referred to.

"It has been suggested that only those candidates should be "accepted who have received a suitable preliminary education; "to be shown either by their having passed certain prescribed "examinations at recognized Collegiate institutions to be "approved from time to time; or else by presenting themselves "for examination by examiners to be appointed by the Council, "and passing such examinations satisfactorily. Pending a "decision on this point, candidates are now required to furnish "satisfactory evidence that they are by education qualified to "enjoy the privileges they seek."*

A graceful token of continued interest in the welfare of Telford's work, was shewn in 1882, when the widow of Mr. Henry Robinson Palmer, Telford's Chief Assistant and a Vice-President of the Institution, bequeathed a sum of money to found a scholarship at Cambridge tenable by the son of a civil engineer, the holder to be nominated by the Council of the Institution.†

From this year (1881) a noticeable change appears in the policy of the Institution, each annual report deals with the question of entrance qualifications of candidates, (which includes Students) enforces the necessities of the candidates being well, known by the proposers, and in every sense "fit and proper" persons to belong to the Institution. The lines are gradually drawn tighter over the entrance of students each year, the entrance requirement is now as nearly martriculation as it can be without examination.

In 1889 a series of "regulations of the Council as to the preliminary education of candidates seeking admission as Students" was issued, which sets forth that "on and after the 1st of June of

* Proc. Inst. C. E. Vol. LXVIII, p. 10.
† Proc. Inst. C. E. Vol. LXXI, p. 227.

that year Students shall produce evidence of "a competent knowledge of the subjects of general education specified in the following list." The list which forms the pamphlet, gives also a list of Universities, public educational establishments which include special preparation for the engineering profession, and public examining bodies and examinations recognized by the Council. The report for that year announces the republication in extended form of the mémoire issued in 1870 entitled "The education and status of Civil Engineers in the United Kingdom and Foreign Countries."*

This list was published in September, 1891, and is extensively circulated; it gives a full list of the various educational bodies in the Empire which the Institution is prepared to recognize, as giving fit and proper training to engineering students, quotes at some length from addresses by many of the eminent engineers who have filled the presidential chair and others, from 1865 to 1886; but makes no advance toward encouraging the students to hope for a degree similar to that conferred in law, medicine, arts or theology.

The Institution has gone as far as restrictions and all other methods short of actual matriculation or entrance examination can be carried. In 1886 it announces in a foot note, in the annual report of Council, "The use of the simple letters C.E, is expressly discountenanced by the Institution as not founded on any qualification and as being calculated to mislead" and three years afterwards defines its position as follows :— †

"There is no object in limiting its members, as is the custom in some exclusive bodies; for the Institution always "has opened —and it is hoped will always open—its doors to all professional men who have an honest title to be entered on the register; but it refrains from augmenting its numbers by the admission of persons who are merely attracted to it for their own advantage; and the Council above all things, desires to make it understood that membership in the Institution is a real guarantee of professional standing, and (as far as possible) also of the personal character of those on whom it is conferred." ‡

* Proc. Inst. C. E. CII, p. 197.

† Proc. Inst. C. E. Voi. LXXXVI, p. 168.

‡ Proc. Inst. C. E. Vol. CII, p. 193.

ACTION BY INST. C. E. IRELAND.

The Institution of Civil Engineers of Ireland, too, has turned its attention to this question. In his annual address as President, in 1887, Mr. John Griffiths gives the professional status a prominent place.* He quotes Colonel Burgoyne their first President, who said at their first meeting in 1835.

"You are well aware, that in spite of the efforts of many able and eminent men, the profession has been at a low ebb in Ireland. Persons without education or skill have been frequently employed in operations of importance, and the consequence has been, as might have been anticipated, bad or injudicious works, wasteful or fruitless expenditure. It will be your effort to prevent the recurrence of these evils, and you are now adopting the measure best calculated to enable you to do so with effect, by organizing a society for your own improvement."

Mr. Griffiths then continues:

"In Ireland there are special inducements for unqualified persons to call themselves Civil Engineers, and the letters 'C. E.' after a man's name are of themselves sufficient justification for grave suspicion as to professional qualifications. * * *

"It is difficult to understand why a man's qualification for the title of C. E. should not be determined by the profession to which he aspires to belong, as in the case of law and medicine. We are too much disposed in this age of competitive examinations to hand over to examining bodies, a function which, I believe, should be administered by the profession itself through some accredited organization of its own. For want of this both our own and the Indian Governments have been obliged to resort to the selection of men for their works by means of examinations, which tend to place these appointments in the hands of inexperienced men, fresh from their colleges, and practically exclude those who are in the practice of their profession. That appears to me an undesirable state of affairs and not conducive to public good or the credit of the profession.

"What I wish particularly to urge is that no such training can take the place of actual experience on works, and that degrees and certificates, however creditable as proofs of a young man's diligence, afford no proof of his capacity as an engineer. Till

* Proc. Inst. C. E., Ireland, Vol. XIX, p. 37 et seq.

engaged on work it is impossible to say whether he possesses administrative or constructive ability, or those most essential attributes of an engineer, common sense, power of observation and tact in the management of men. I freely admit that most of these are natural gifts, which may be possessed by a young man who has had no practical training, but it is not till he comes in daily contact with actual work and workingmen, that it can be proved he does possess them."

Referring to Government appointments, Mr. Griffiths does not think a man should be admitted to examination unless he could shew practical professional training, in which case the examinations would be restricted to purely professional subjects, due credit being given for experience on works of magnitude. "With professional men of eminence as examiners, I believe such a course would be productive of much good, and place at their country's service experienced men, in place of the crammed recruits who have to learn their profession, if they ever do learn it, at the expense of the nation."

Western Society of Civil Engineers.

Mr. L. E. Cooley in his presidential address to the Western Society of Engineers touches up the profession after the following manner :—*

"The early engineer of this country was a species of scientific or skilled tramp, with a precarious tenure of position measured by the work in progress. He furnished his employer with the skill of his trade without questioning public policy or the best solution, in other words, the engineer was a tool who assumed his employer to be responsible. The conscientious engineer was always industriously working himself out of a job, was in the position of the man who saws vigorously at the limb on which he sits.

"Much of this character the profession retains to-day, but the growth of professional spirit and the enlightenment of the employer is working a change. The engineer is assuming more the position of counsellor, is more the executive factor in the conduct of large operations, is retained more as an adviser on the staff of industrial enterprises. All this gives stability, material

* Engineering Record, Vol. XXIII, p. 208.

rewards and independence, gives the engineer a fixed abiding place and makes him a factor in the community in which he lives, enables him to develop the social qualities which he needs and leads to that pre-eminence enjoyed by our profession in older lands.

"What are the duties of the engineer as a citizen, and what is to be his future relation to the machine of civilization?

"The engineer is a man of too much breadth, is too cosmopolitan to organize anything in the nature of a professional trades union, to go even as far as has the doctor, the preacher or the lawyer; but in his association unwritten laws of ethics will crystallize the profession, will broaden its interests and sympathies, he will become a factor which is recognized for the general good of the community, and with public regard he may achieve those higher ambitions which are for the welfare of the state.

"I regret sometimes that the engineer is not more assertive of his prerogatives among men, and console myself with the reflection that his broad comprehension of "forces and materials," the ever varying phenomena flowing from fixed principles, the inscrutable law which he recognizes behind all, makes him modest, makes him tolerant of the egotism and the petty strifes of men, the arrogance of whose purse-string is the patent of nobility."

Engineering Status by Degree.

On this continent where there are many schools of engineering, the graduate seems destined to have scant justice meted out to his talents and mental acquirements. There are many engineers of standing, whose experience ought to enable them to place a fitting value on a properly college trained engineer. Several technical and professional journals have given attention to this subject; one of, if not the most powerful and influential journal, *Engineering News*, had an editorial article headed Professional degrees granted by Colleges, (Vol. XXII, p. 252, Sept. 14th. 1889). It sets forth its views as follows: "We know of no principle of ethics which makes a lie any more respectable for being solemnly engrossed on parchment and certified to by a President and faculty; and the plain truth of the matter is that the certifying that boys who have been four years 'at school are civil engineers, or mechanical engineers, or engineers of mines or sanitary engineers' is a lie out of the whole cloth, and known to be such by those who certify to it. If so, it is a demoralizing and injurious practice which ought to be stopped. The excuse for it, is of course, that there is no actual deception; that it is well understood that the degree actually means no more than that its holder has given four years to studying the given profession, and that the same objections hold to the time-honoured 'M. D.' for physicians.

"But granting the degree to be a proper one for our miscalled 'doctors,' it does not follow that it is a proper one for any kind of engineering students.

"Engineering is a practical profession. The student cannot learn it, by however long study at school, as he can astronomy, surveying, painting, chemistry, or (with sufficient hospital practice) medicine; he must have experience in the actual practice of his profession. Therefore the whole tribe of 'C.E.' degrees are intrinsically and especially improper, failing some years of practice. We hope we shall become in time sufficiently civilized to abolish them."

Argument in favor of Close Profession.

There is now presented to the reader a consensus of opinion from both worlds,—the old and the new,—which can be accepted as coming from the highest sources, wherein is found a generally expressed belief that the professional status has to be raised out of a quagmire in which it has been found. How to do so is the problem, the solution of which has called forth considerable divergence of opinion and evidenced an unexpressed desire for something the various bodies long for but are afraid to suggest.

The Institution of Civil Engineers raises its standard by making the entry qualification as rigid as possible; it aims at improving the educational status of its lowest grade (the Student) in which very commendable success has been attained, it provides for its youngest members with thoughtful solicitude, by encouraging them to read papers, some of which are sometimes found worthy of being published in its Proceedings, and by giving rewards of a substantial nature for original communications prepared by students. Once (in 1881) it suggested that Students should be examined by examiners appointed by the Council, before being admitted; the revolutionary principle embodied in such a proposal seems to have frightened their conservative ideas; it is abandoned, no further reference is made to it. Some years after a little soft soap is thrown out to the profession, in a flattering form of words; the Institution opens its doors to all who are honestly entitled to be entered on the register, it refrains from augmenting its membership list by admitting persons who desire to belong to it for their own advantage, and above all things "desires to make it understood that membership in the Institution is a real guarantee of professional standing, and (as far as possible) also of the personal character of those on whom it is conferred."

The president of the Irish Society of Civil Engineers in his address, leads one to hope he favoured the mental culture of the engineer; however, he fails lamentably, and sinks into the everlasting slough of the "Practical engineer." "Practical" let him be by all means, but "practical" he must be, only through the door of thorough education, his foundation must be thorough theoretical knowledge of his subject, his structure practice, and the bond experience.

The president of the Western Society of Civil Engineers hits the nail straight on the head, he need not have said "the *early engineer* was a species of scientific or skilled tramp," he could easily have applied the expression to the present day. His opening is charming, the whole address well worth study, the conclusion a very neatly turned compliment, his argument can be summed up by using some of his own words "too much breadth and too cosmopolitan." There is too much of the "tramp" about this writer, cosmopolitanism is a very good quality but it lacks Nationalism. Professional union has nothing of the trades union about it, closer union will have a healthy lasting effect on the profession. It is the extreme breadth and cosmopolitan character of the men engaged in the profession which makes us a set of tramps. There is hardly an engineer in the Dominion who will not rush into print, gladly, to give professional advice, or impart for nothing, with a little judicious self advertising, opinions which ought to be paid for. The public know this thoroughly and make good use of it. The expression "professional tramp" is one which suits the situation admirably.

The Professional journal quoted mildly sneers throughout its whole article at the assumption of a degree by any man and especially by an engineer. It is not necessary to follow the article through the whole of the argument, it concludes by saying "engineering is a practical profession" that the "student must have experience in the actual practice of his profession" and that "C. E. degrees are intrinsically and especially improper failing some years of practice." How absurd it is for men who are themselves university men, who owe their position to their higher education, to write in the above strain; when they commenced their editorial career, were they any less entitled to be called "editors" because they had not had many years of experience?

So long as the designation "C. E." is derived from college, and the holder bases all his claims and rights to that alone, neglecting to extend his experience by practice, then the degree is "especially improper." In what place can one find such a young man, what is the universal experience? Is it not that the degree is the greatest incentive to acquirement of practical knowledge? The present writer knows not of a single case in which the college bred lad has failed to follow up theory by practice, and in his experience the graduate picks up his practical knowledge quicker and in more practical form than the merely "practical engineer."

Professional Apathy.

The whole aim of technical education has been missed by the profession, those who were in a position to recognize its advantages appear to have deliberately blinded themselves to it in the early days; a prejudice has been formed which gives a direct contradiction in practical life, to all the written and published expressions of interest in the advancement of education and technical lines.

There is a remarkable conflict at present, between the public and the profession. The former recognise the necessity of improved education; in the most open handed manner, by public and private benefactions, engineering education is being advanced; the profession accepts all the gifts given to it, and places the best men obtainable in these chairs, and then fails in its duty. It affects to be deeply sensible of the advantages conferred on its younger members through this generous action of the public, takes all it can get, and sedulously avoids giving any return.

When it is asked to accept the college graduate, to extend the right hand of fellowship to him and admit him into the sphere in which his life should now be cast, the profession drops him, because he has had " no practical experience," and sinks into its depressingly lethargic condition of admiration and demand for the "Practical man." Whatever may have been the triumphs of the profession in other lines, its recognition of the higher education of its younger members, cannot be classed among them.

The present *laisser aller* condition cannot exist much longer, the public will waken up to their rights and will demand of the profession a suitable acknowledgment of their services and interest; large sums have been expended in endowing and equipping schools of engineering by the governments of the Dominion and the several provinces and by private benefactors. The graduates of these are a credit to the institutions from which they emerge, the writer cheerfully bears testimony to his appreciation of the training given at some of the colleges, the young men he has employed have all turned out well. The courses of instruction are being enlarged, the magnificent benefactions of one gentleman will soon place in Montreal one of the most fully and perfectly equipped engineering schools and laboratories to be found anywhere.

Responsibility of the Profession.

The fruits of all of these colleges—graduates—have to be acknowledged somewhere, the fit place is in the profession, the proper mode is by a society of men in that profession, who being incorporated and legally chartered, have conferred on them, the necessary powers to carry on these graduates by making them conform to certain standards, which would place them at given gradations in the Society, each of which would be equivalent to a degree, and have a commercial value. The degree thus obtained would be the "practical" evidence the profession is groping for. If anybody will calmly consider the future of engineering, with a view to making a forecast of probabilities, he will soon convince himself that the engineer of the future will be altogether a thinking man; rule of thumb is being rapidly banished, the new forces we are called upon to deal with, require the highest mental culture and education; these will go hand in hand with observation, and in spite of his "degree" the engineer of the next generation will in no sense fall short of his progenitors as A PRACTICAL MAN.

The writer formed his opinions about the ultimate aim of all engineering societies, 15 years ago, he has not had occasion to change them; the unexpressed desire, one may almost say—will, of the profession is towards higher attainments in its members, and the recognition of them by a properly constituted professional body. Universities and colleges may grant degrees in arts, medicine or law, the holder of a degree obtains no professional advantage until he is admitted to professional standing by a corporate body, duly qualified and entitled to do so. The feeling has grown rapidly in the Dominion in the last five years that professional standing must be recognized, and a qualification obtained whereby a man's standing can be established. The architects of the Provinces of Quebec and Ontario have organized; in British Columbia a movement for organization is on foot; the Provincial Land Surveyors of the Province of Ontario have had increased power granted to them by legislation and they are now endeavouring to get a charter to enable them as a body to license their practitioners, instead of being licensed by the Government.

The formation of a close profession will not be injurious to the engineering interests, or to the public. It is not yet 25 years since the medical profession in the Province of Ontario, obtained a charter; no injury has arisen to the public from the formation of this into a profession: it would take only a few minutes to satisfy any sceptic that the movement has been of the greatest benefit to everybody. The several Provinces have each their law societies, they are all close corporations. Who ever heard of importing leading counsel from the United States to plead a cause in any Canadian court, who has suffered in any way from this arrangement? Can anyone say that the cause of justice is badly served because the members of the Canadian bar do not practice in the United States courts? Does public health suffer because American physicians do not have branch offices in Canada? Who can say that these distinctive cordons have provoked bad feeling between the respective professions in each of these two countries? On the contrary we know that the very best and friendly relations exist between these professions. The formation of these professions into such close corporations has been attended with the very best results to every one, of inestimable benefit in elevating the morale of the practitioners, the movement has resulted in incalculable benefit to the public.

Undignified Tactics.

The writer has good grounds for saying that there is a strong feeling in the profession, for closer union: if a poll were tried the favourable expression of opinion would be surprising. Nothing can be more unsatisfactory than the present professional status, in no class of men calling themselves a profession of learned men is there so little of self-respect, dignity and *entente cordiale.* Physicians are generally credited with having less brotherly love towards each other than any other profession; still with it all one member does not try to cut into his neighbour's practice, take patients away from him or offer to perform operations at a lower rate. Barristers or solicitors do not fight for clients nor do Counsel tender to take briefs for the pleasure of cutting out a neighbour. What does the engineer do? Who can deny that there is about as much wire pulling and log rolling among engineers as among the vendors of patent articles; corporations all know it and make full use of it; they either make engineers bid directly against each other, get advice for nothing through the public press, or set them to work directly, and indirectly, to cut down each other's fees. As the profession stands to-day, it is almost a trade; men advertise themselves either in the public press, or by circular, or by flooding the country with copies of every report they write, they have themselves interviewed and described as "eminent," "well known," "experts," &c., and yet condescend to practices to which these very words reprobate. The Institution of Civil Engineers says that "membership in the Institution is a real guarantee of professional standing and (so far as possible) also of the personal character of those on whom it is conferred"; membership in our Society also, as well as the kindred one in the United States, should be taken to have a like influence and value, which should exert a much more elevating tone and effect on the members, than it appears to do.

The profession in the British Empire is certainly influenced by the Institution, membership in it carries weight all over the Empire and on the Continent of Europe. The writer notices with satisfaction that of late years Canadian engineers have felt the benefit of connection with the Institution. Next to the Institution, the American Society has claimed and still attracts many Canadian Engineers; the qualifications for this Society are of such an order as to give its members a standing similar to that of the Institution. The effect of membership in one or both of these Societies has not had the improving and high moral tone on the Canadian members it seems to have on members resident in the United States and elsewhere, so far as the writer's experience extends. There is too much advertising, puffing, still hunting and conduct which connection with one of these societies alone should lead a man to abhor, how much more then should his self respect rise if he belongs to more than one? The medical profession in Ontario set a very good example when they wisely and properly decided against advertising; they do not even allow the insertion of a professional card in any newspaper.

In the legal profession, the system of advertising exists to a limited extent, chiefly in the form of professional cards. In the practice of both these professions, one finds no tenders asked for surgical operations or family practice, nor do learned Counsel cut fees or swagger over their cases won.

Duty of the Society.

It lies fairly within the limits of the Canadian Society of Civil Engineers to consider what obligations fall upon it, in connection with the future of the younger members. It is abundantly proven from the foregoing argument that the weight of opinion is against the bare degree, which granted by a college or university confers no acknowledged professional standing. The writer looks on this as a matter of regret, the possession of a degree is evidence of education and training in special lines of knowledge. The medical student obtains his right of entry into his profession through his degree, to obtain which, he has passed the required standards laid down by the corporation or corporate body into which he is to be admitted; the examinations to which he has been subjected being conducted by that body. His value as a practitioner rests upon himself as taught in the school of experience. The same course applies to the young engineer, the majority of the profession look with kindly feelings on the graduate, the day is passed in which he is classed as a ninconpoop, and his theoretical training discounted.

There are now so many schools of engineering in the Dominion supported out of public and private funds, it will soon be incumbent on the profession to take cognizance of their work, and declare in a more marked manner than has yet been attempted, that the degrees of these schools, under certain conditions, give the holder the full qualified entry into the professsion, through the door of the CANADIAN SOCIETY OF CIVIL ENGINEERS.

Why delay any longer in acknowledging the fitness of thorough education as the basis of engineering proficiency? Hold out the right hand of friendship to the student and tell him that the gateway of his future life is open to him by the diplomas of the CANADIAN SOCIETY OF CIVIL ENGINEERS, granted to him after he has passed such standards and appeared before such examiners as the Society shall determine.

This proposition may startle the average mind, there will be plenty of objection taken, and numbers of critics on all sides will proclaim that the Society has nothing to do with education — as the Institution told the writer it was not an educational body — to all of which the writer has only one answer, the whole drift of our Society and all Engineering Societies is educational. We write papers, we discuss, the whole object is mental improvement.

The Society has given evidence of its interest in our younger members, by admitting them to a recognized grade or standing, and gives further proof of interest by asking them to hold Students' meetings and read papers, some of which have already been found worthy of a place in our Proceedings.

The Society need have no fear of its standing being affected, if it assumes the position and powers of such bodies as the medical or legal profession, or the Church. None of these suffer from granting degrees.

The CANADIAN SOCIETY OF CIVIL ENGINEERS has had a remarkable record since its organization; it is making itself felt in the land; membership in it is being acknowledged as the rank of an engineer's standing; the outside world has given it a place among learned bodies; it now lies with the members to extend that influence, and to raise the tone of the profession to the standard it is entitled to, as the foremost of all the learned and scientific professions in the world.

DISCUSSION.

Mr. W. J. Sproule.

Mr. Sproule said Mr. Macdougall's paper is opportune, the subject having been much discussed recently in technical journals, and it seems to be yearly pressing itself more urgently on the attention of Civil Engineers. The discussion referred to plainly indicates the unsatisfactory state of the profession. Remedies have been sought and doubtless recently a majority of the profession in Canada have not only entertained but seriously considered the question, of seeking remedial conditions by legislation. No properly directed effort has yet been made in this direction, probably because the project has not been heretofore generally endorsed by the more influential though, numerically speaking, minor portion of the profession. Mr. Macdougall has shown that the parent and greatest society of Engineers, the English Institution, has on several occasions recognized the need of more stringent requirements for entering the profession—an educational standing, virtually equivalent to an examination—and the need of restricting or discountenancing the assumption of the title of C. E. by unqualified persons. It will probably be admitted that the mild advice given on this point has been disregarded and that the profession has been humiliated, has lost prestige and respect, and the public injured by incompetent persons acting as Civil Engineers. Surely the profession claims sufficient intelligence and integrity to use power with discretion and for the interests of the general public as well as for their own benefit. The profession is the only competent judge of the qualifications necessary for a Civil Engineer, and it is difficult to understand what evil result could arise from the profession being empowered to certify to those who are qualified and to refuse such certification to those who are not. If it were made illegal to make official use of the title of Civil Engineer without such certificate probably no further restriction would be needed and the charlatan who now preys on the brains of honest men would gradually disappear from the profession. The speaker advocates that an endeavor be made to secure such power, and earnestly desires that this Society may take action with a view of becoming a professional court of highest appeal, so to speak, for the Dominion, and a respected central institution for the several incorporated bodies, since such incorporation comes under the jurisdiction of the Provincial Legislatures.

Mr. Blackwell said it seemed to him in thinking over this question that in carrying out Mr. Macdougall's views the great point which offered difficulties and which the members of the English Society saw, at least he thinks they saw, is the question of pupilage. You cannot overlook the question of pupilage. Some of our greatest Engineers have learned their profession by this pupilage system better than they could have learned it from any college. For instance take the queston of building reservoirs, etc.—A young man who goes into the office of an Engineer and who makes this his special work and practice for a term of years; the consequence is that he gets good appointments and gets pushed along in this particular branch of his profession without the assistance of College Degrees, and that seems to the speaker to be the cause of the delay of any advancement being made in the direction which Mr. Macdougall has spoken of in his paper. **Mr. K. W. Blackwell.**

You cannot overlook this special pupilage system, such as you find in England, and while it does not actually exist in Canada yet it reflects its influence here to a large extent.

Again, if it be conceded that at the present time the best appointments in the profession are in the hands of gentlemen who have been pupils of engineers in practice and who have never taken College Degrees, that fact in itself is a very strong inducement to young men to seek to enter the employment or offices of engineers in good practice rather than to go to an Engineering College.

In the future no doubt while many will go in for College Degrees, many will continue to follow the Pupilage System and the speaker fails to see how the line can be drawn.

Mr. Irwin said the speaker being a member of two close corporations, viz: the Association of Dominion Land Surveyors and the Corporation of Land Surveyors of the Province of Quebec, has had at any rate some experience of their working. Certainly the standing of the Land Surveyors in this Province has improved since the present corporation began to hold the examin- **Mr. H. Irwin.**

ations as they are now conducted, and in the future no uneducated man will be admitted to practice.

There is no doubt, but that it would be much better if some means could be devised whereby unqualified persons would be prevented from styling themselves ' Civil Engineers." One of the greatest obstacles to this is that the definition of a Civil Engineer according to By-Law No. 3 covers almost too much. The miner who, without any education or experience as a Civil Engineer, dams up a river and turns a stream of water on a gravel bank to wash it down in the search for gold, is certainly " directing one of the great powers of nature for the use of man." The speaker is of opinion that no one who has not had a good education in the theory of whatever branch of Engineering he professes to belong to, should be permitted to call himself a Civil Engineer, at a time when education is so easily obtained.

Mr. Blackwell instances the case of a pupil in a large engineering firm who might become a very good Engineer in a particular branch and thereby command a high salary, with no knowledge of theory. The speaker thinks in such case that without a good education he would neither have any right to call himself a Civil Engineer, nor would he be able to apply his practical knowledge to the best advantage.

One of the principal arguments in favor of close corporations for Land Surveyors is, that when acting as such they have to protect the interests of third parties, such as owners of lands adjoining those they are measuring, or purchases of properties. Now, Engineers also who are employed by Governments or public corporations have also to look after the interests of the public in general, and therefore, on the same line of reasoning such Engineers should be duly qualified for their work. The question then comes in, who is to be the judge of such qualifications? Unfortunately we see cases all over the country, where the principal qualification seems to be " ability to pass bad work, and not to see boodling going on." The less a man knows of his work therefore, the better he will suit those who have the spending of public money. Complaint is often made, and justly, that Engineers are little thought of in this country, whereas in Europe they are considered to belong to the foremost of the learned professions, and it is thought that the remedy would be found in a close corporation. The speaker thinks that if the Civil Engineers of this country would have more respect for each other, the public would learn to respect them more. There are too many unseemly and unprofessional controversies in the newspapers, and members of this Society too often try to get positions or work that rightly belongs, through order of promotion or otherwise, to fellow members.

Since this Society has been formed to advance the profession generally, the speaker thinks that it should be no hardship to forbid anyone who is not a member to style himself a Civil Engineer, or to make membership of the Society a necessary qualification for holding any public office, and also to exclude for the future from the Society all uneducated men.

Mr. Dawson said the suggestion in Mr. Macdougall's paper with regard to defining more clearly the standing of Civil Engineers, could be carried out in a consistent way if the Canadian Society were willing to consider an Engineering Degree as title for membership in the Society, and were then to grade the membership according to the amount of experience gained in the practice of the profession. In this way the public would be better able to appreciate the standing of a Civil Engineer. Mr. W. B. Dawson.

Mr. Walbank said he was afraid that the idea of making the profession a close corporation would be almost out of the question. In the first place, the Dominion Government would have no power to legislate for the Provinces; each Provincial parliament would have to legislate for itself. He thought that if the question were started by the Province of Quebec it would simply mean that the Ontario men could not come down and practice here nor for us to practice in Ontario. It would be a pity to curtail our sphere of usefulness. If the Society would look after the ballot box, and have only good men elected, and raise the standard of qualification, it would tend to raise the status of the profession just as well as any close corporation. The speaker saw no need for a close corporation of engineers any more than for the merchants, bricklayers or others. He did not mean to draw a comparison between engineers, merchants and bricklayers, but he simply meant that he saw no more reason why the Civil Engineers should be incorporated than the others. If it could be made a Dominion affair, if the whole Dominion of Canada could be incorporated as a close corporation, he would be in favour of if, but he thought they would be doing far more harm Mr. W. McLea Walbank.

than good by making the profession a close corporation for one Province. As he had said before, if the standard of admission and necessary qualifications were raised he thought it would answer the purpose just as well as any close corporation.

Mr. A. Brittain Mr. Brittain said Mr. Macdougall's paper on "The Professional Status" forcibly brings out the fact that since the foundation of the Institution of Civil Engineers, which may be considered the recognized birth of Civil Engineering, a provision for scientific teaching and technical training has been provided that makes meetings of a Society like this unnecessary, because their object, as stated in the By-Laws of this Society, viz: "to facilitate the acquirement and interchange of professional knowledge" is now accomplished by special training.

That these meetings are not considered specially advantageous is demonstrated by their small attendance.

The Civil Engineer is necessarily a servant; the fact of his having a proprietary interest in any of the plant or material used upon work designed or supervised by him impairs the value of his opinion on that work, both with the party carrying it out and the party furnishing the money. As Chief Engineer to a railway or other commercial company he must modify his plans in accordance with the requirements of that company or their financial resources, and as a subordinate engineer he must modify his plans in accordance with the views of his Chief, who may have special reasons that cannot be given for conducting work in a particular manner.

A Civil Engineer is supposed to have a natural aptitude for precision, quickened by the study of mathematics; such a mind and training is not usually adapted for money making, in which the speculative is such an important factor; therefore an important phase of the question is, would making Civil Engineering a close profession, entrance to which could only be through an accredited organization of its own, tend to place it on a more remunerative and therefore improved basis?

If this be decided in the negative little advantage will be gained by pursuing the subject any further.

If it be decided in the affirmative the next question might be.—What should be the standard of education and practical experience required for membership, so as to entitle it to the confidence of the public?

There are difficulties in the way, especially in the Dominion, owing to Provincial laws and vested interest, but the speaker thinks they are over estimated. France has successfully grappled with the subject, greatly to the advantage of members of the profession, and the munificence of our citizens has placed the means in this city of an unrivalled technical education; something therefore should be done in the interest of the numerous young men who will avail themselves of it, and who may enter an honourable, but not lucrative calling.

The speaker agrees with the views of the author, and thinks that the profession would be improved by making it a close one, and, as he has endeavored to show, as the original object of this Society is now unnecessary, owing to the before mentioned provision of our citizens, this Society might with advantage take up the question.

Mr. Torrance said it seemed to him that they could not do better in reference to the matter than support the action of our Toronto members. By referring the matter to Council for investigation the Society would soon be placed in possession of valuable information as to the existence of any legal or other difficulties in the way of forming a close engineering profession, somewhat similar to those establish by the legal and medical professions. Mr. J. F. Torrance.

In the divergent land laws and systems of measurement established in Ontario and Quebec we see ample reason for the Land Surveyors incorporating under provincial charters. But in all other branches of the profession, the speaker fails to see any reason why a central examining body should not license its graduates to practice their profession throughout the length and breadth of the Dominion. Are not our materials, the labour market and the climate much the same at Ottawa in Ontario as at Montreal? The same remark holds good of Toronto, Victoria, of Halifax and St. John.

If it is necessary for the long established communities of the old world to have some protection against imposition at the hands of incompetent Engineers, the need of such protection must be twice as evident in the scattered and poorly educated community of our Dominion. In every municipality we see men in authority called upon to grant engineering franchises or to design and superintend extensive systems of municipal engineering who have not received the rudiments of any technical training at school, and whose life long pursuits have not qualified them in any way to pass judgment upon such questions. But they are compelled to sit in judgment on grave engineering questions, often with but little warning. If they are honest in their desire to serve their community intelligently they should seek professional advice. But in the absence of any barriers against quacks and charlatans posing before the public as Engineers, how are these municipal counsellors and aldermen to know the wise from the pretender, the honorable and conscientious master of his profession from the loud-voiced impudent charlatan ?

The speaker contends that the strongest arguments in favor of erecting barriers against the indiscriminate entrance into the profession of all who chose to thrust themselves upon the public, exist in the young and inexperienced communities of our Dominion. If the need for such a system is felt by many of the best Engineers in Great Britain and Ireland and elsewhere, the unanimous action of our Toronto members shows that the need is pressing itself strongly upon the attention of many of our ablest members.

No branch of our profession stands in more need of a thorough purging than the mining section. While no country in the world is richer in mineral wealth than Canada, the speaker feels justified in asserting that in no other country are capitalists as suspicious of mining enterprises as they are here. It is vexatious to hear many of our ablest financiers and professional men calmly advance as an indisputable proposition the assertion that *all* mining investments are more risky than other business enterprises. They do not seem to have the slightest suspicion that there may be good and judicious investments in mines as well as in railroads. They do not seem to think it necessary to enquire into the character of professional training of men that offer to open their mines and place in their hands a sure bonanza. If an unsuccessful grocer shouts loudly enough in the journals his disinterested (?) advice to "keep your eye on the Kootenay," he is likely to draw tens of thousands out of the pockets of Montrealers with scant prospect of any return, while trained mining engineers may waste months vainly seeking to obtain some attention to a rational proposal for exploiting our mineral deposits nearer home.

It will be a good thing for Canada if the establishment of an educated profession of Civil Engineers can help to restore Canadian confidence in our vast mineral wealth, and can aid Canadian capital to secure proper returns upon judicious investments in properly supervised mining and metallurgical enterprises.

Correspondence from Mr. C. M. Odell,—

Mr. Odell said he wished to express himself as agreeing with Mr. Macdougall in his remarks on "Undignified Tactics." The writer has opened an office in the town of North Sydney, C.B., and is fighting an uphill battle for existence, and the inclined plane is rendered all the more steep through the unprofessional conduct of some of the members of the profession who should know better. **Mr. C. M. Odell**

DISCUSSION BY TORONTO MEMBERS.

Mr. Gray agreed cordially with the sentiments of the writer; he had a short time ago, met with an article in which very similar views were expressed, which he would now read. They appear in an article in "Engineering Magazine" for February, 1892, written by Mr. Oberlin Smith, Past Presdt. Am. Soc. Mech. Engrs. Towards the end of the article Mr. Smith says: **Mr. H. A. Gray**

"In conclusion, we may perhaps well consider one of the most practical points at issue, viz.: What authority is to decide the question asked in the title of this essay? Such authority cannot be the public at large, nor can it be the individual himself upon whom judgment is to be passed, who may perhaps be prematurely anxious to write an "E," accompanied by some other prefixed letters, at the end of his name. It has been suggested that some time our general Government will have become prepared to take in hand such matters of national consequence as this—fixing the definitions and limitations of some of the most important professions, perhaps regulating the same through various universities that might be made competent to confer certain degrees upon individuals possessing certain different qualifications. Obviously the titles of engineers should be regulated as fully as in such professions as law and medicine, for the common purpose in all of preventing the danger incident to that quackery which threatens to damage and rob clients seeking professional experts. All this does not mean that none but college-bred men should enter the ranks of engineering. It merely means that some system of examining boards, properly constituted and controlled, should pass upon the knowledge, practical as well as theoretical, of those who publish themselves as ready to give important technical advice, and to spend the money of their clients.

"Until such time as there shall be some unification in regard to this matter, the best way to begin a reform in our own profession is probably through the great engineering societies acting in conjunction with the important colleges, and strongly urging uniformity in the matter of officially expressing their opinions regarding qualifications in candidates for practical professional life. In seeking analogies among other professions, it would appear that there is probably less quackery among the lawyers than among clergymen and physicians. This may be due to an especially thorough organization, in the way of bar associations, which help to maintain a desirable *esprit de corps* among their members. We all know how many lay-preachers and quack-doctors and medicine-makers there are to whom it is outrageous that we should ever be allowed to trust our spiritual and corporal welfare. These men should be compelled to attain to a certain standard of education and experience before being allowed to practice independently—as should lawyers and engineers.

"If we glance over the actual status of the engineering organizations in the United States we shall find the four great national societies, in the Am. Soc. C. E., 39 years old; the Am. Inst. of Min. Engrs., 20 years old; the Am. Soc. of Mech. Engrs, 11 years old, and the Am. Inst. of Elect. Engrs., 7 years old. Their total aggregate membership is about 5,400, some 1,200 of which are juniors, associates, etc. In addition to these we find the Am. Inst. of Archts., the U. S. Naval Inst. and several railroad and electrical associations, besides over 40 local engineering societies and railway clubs, some of which cover a section of territory embracing more than one city, and others of which are confined to particular cities with their suburbs. It is much to be regretted that for certain purposes of a general character, where the interests of the profession would be advanced by unity of action, there cannot be some national organization which would cover all the ground, or else some federation of the present societies, acting at certain times for certain objects, for the benefit of all."

Some common organization is, I think, bound to come in the future, and this will undoubtedly become a nucleus of authority which will, in the estimation of the public, develop into a tribunal capable of deciding the questions here discussed.

Mr. Meadows said he considered the degree of C. E. of our School of Science (Toronto) and in other places should carry as much weight as the M.D. degree; he feared if the power of conferring degrees were left to the Society it might lead to its being a machine, and so miss its chance of being useful to the whole profession; and he also feared that Canadian degrees would supplant those of English and Irish Universities and Coopers Hill, to the detriment of the holder of these degrees. Mr. J. Meadows

Mr. Ellis said we need not fear that a close corporation would do the profession harm; it has not done so in the legal profession; if our various provincial law societies examine their students, there is no reason why the Can. Soc. C. E. should not do so also. There would be an advantage in the degree of the Society, it would permit a man to practice in any part of the Dominion. Mr. H. D. Ellis.

Mr. Marani, said before the degree of C. E. is granted by this School, the student undergoes a thorough training in theoretical and practical work, he passes examinations and gets certificates in surveying, drawing and other subjects, in which he has practical work as well as theory. After three years' experience in practice in railway, electrical, sanitary, hydraulic or other public work, he is again examined before he gets his degree. It would give the profession greater weight, and both the students and public would be benefited, if the Can. Soc. C. E. could control the profession and be the only degree-conferring body. Mr. C. J. Marani.

Mr. Brough said we must not mix up medicine and engineering; the M.D. can learn enough from books or in school without going out of the college; the Engineer is different, he wants and must have practical experience. A degree granted by the Society would be of incalculable benefit, and the only real recognition of an engineer's standing. Mr. W. C. Brough.

Mr. Armstrong supported the views of the writer. As a practical evidence of his concurrence with the writer, he would beg leave to move, Mr. H. W. D. Armstrong.

That the views expressed by Mr. Alan Macdougall in his paper entitled "The Professional Status, a plea for a close corporation" be endorsed by this meeting, and that a copy of said resolution be forwarded to the Secretary of the Can. Soc. C. E., Montreal, to be presented at the next annual meeting of the Society, with the view of obtaining the necessary legislation to that end."

Mr. H. E. C. Carry.

Mr. Carry had much pleasure in seconding the motion. The paper interests us all deeply; and he hoped sincerely something would be done soon to put the profession on a proper foundation. A young man should not wait for experience before he got work; he might be examined by the Council and get a degree which would enable him to become an Assist.-Engineer; after passing certain rules to be hereafter arranged by the Council, he could come up for the necessary examination to place him in the highest rank of the Society.

Friday, 6th May.

JOHN KENNEDY, President, in the Chair.

Paper No. 65.

SNOW ON RAILROADS.

HOW TO PREPARE FOR, AND HOW TO DEAL WITH IT.

By J. W. Harkom, M. Can. Soc. C. E.

The effect of a snowfall is felt in the traffic movement on railroads in inverse proportion to the means adopted to prepare for it, the greatest inconvenience being felt in localities where it seldom occurs; consequently a fall considered light in one place has the effect of entirely stopping traffic in others. Various causes go to exaggerate the effect in the southern parts of the snow belt, where snow is more difficult to deal with by reason of the character of the fall, and because of the packing or solidifying which follows attempts to move it.

The subject may be considered under four heads:

I. The behaviour of snow under varying conditions of atmosphere and temperature.

II. The manner in which resistance is offered to its removal.

III. The various methods for keeping the road bed clear of snow.

IV. The best way to deal with snow obstructions.

I. The numerous ways in which snow falls and settles may be classified as follows:—

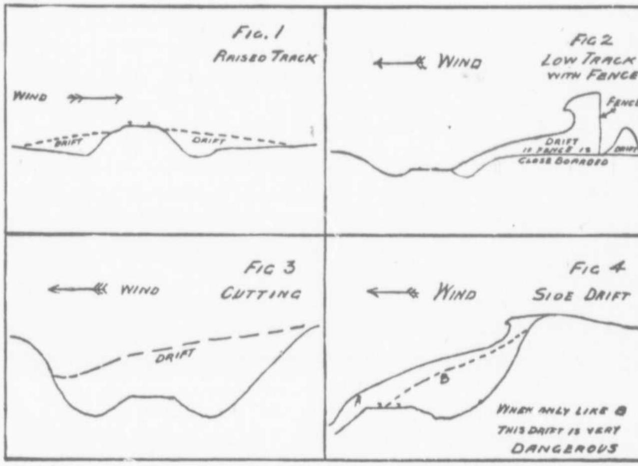
(*a.*) Quietly and steadily at a comparatively high temperature, flakes damp and soft.

(*b.*) Similarly at a low temperature, flakes hard, generally small.

(*c.*) Passing apparently through a current of colder air than that in which formed, with high wind which results in drifts. In such a case the small flakes harden separately, and being free are easily drifted.

(*d.*) One in which the flakes reach the ground apparently through a milder stream of air hardly sufficient to thaw, and when settled freeze into a mass owing to the chilling influence of the earth.

(*e.*) Lastly a damp fall followed by a slight thaw after low temperature upon very cold ground; this is the cause of ice forming under the snow, and is the worst condition to deal with. The different ways in which drifts form are illustrated by Figs. 1, 2, 3 and 4.



II. Falls such as described in (I *a.*), although greater in bulk, are the easiest to remove when railways are properly equipped, occurring most frequently at the commencement of a winter, and the fall being of uniform depth, pushing the snow aside is sufficient to open a road. The greatest difficulty in dealing with such snow is, its eddying into the ash pan of firebox, reducing both draught and steam. What to do with the snow after it has been forced aside, will be treated in part IV.

The fall described in (I *b.*) is frequently more troublesome if its depth exceeds a couple of inches, as it fills the rail flanges (so called) and makes it difficult for the wheels of engines and cars to touch the rail and get the proper adhesion and smooth running surface.

When a fall like (I *c.*) occurs, the season being advanced and a surface of hard smooth snow, (specially after a thaw and subsequent drop in temperature) is offered for it to drift over, the trouble begins. Every bush, post, hillock, fence, out obstruction of any kind, or out hollow offering a lee side, collects the drifting snow. Railway cuttings offer the best opportunity for deep drifts to gather and are sometimes known to get "full," and when in that condition, are difficult to deal with, especially in the small hours of the night. When such cuttings lie parallel with the wind, little or no trouble results, it being when the snow is blown across that they offer the best opportunity for drifts to lodge.

In localities where a road curves considerably, a change of wind has in a couple of hours been known to clear out blocked cuttings and to fill others which were clear.

The seemingly erratic manner in which drifts form, and the low temperatures at time of formation offer great difficulties to their prevention or removal. The filling of the "flanges" referred to under (I *b.*) is an awkward matter to deal with, and will occur with the lightest fall, and even when no snow has recently fallen, being caused by the disintegration of previously formed drifts and by the breaking off of small particles of ice from partially thawed snow. This trouble will be specially considered in the latter portion of this paper.

A fall as described in (I *d.*) is happily not frequent, chiefly occurring towards the end of a winter, and in open country rather than in a wooded or hilly one, it being necessary to the formation of such drifts that the wind should have a clear sweep and unchecked velocity to move the snow; when packed as described it is like stone to deal with, huge drifts being able to carry any weight without breaking through, the ordinary wooden shovel being useless for moving it. These are the drifts which cause the most derailments, and being often "side drifts" so called from their covering the road bed unequally, sometimes many feet high on one side and a few inches on the other, are very dangerous. Even when of uniform depth across the track they do great damage, allowing engine wheels and ploughs to roll or slide up them rather than break through to the rail, and "ditching" is a common result. Another very dangerous kind of drift may be included under this heading, viz, when earthen banks (generally sand) have been exposed by thaws, wind and snow sweeping over gather particles, which mingling with the snow, form a very solid and difficult obstruction to remove.

In the case of falls like (I *e.*) the packed matter when not cleared by proper appliances, is dangerous, ice being formed on rails after the passage of wheels. Where drainage is bad the ice forms sooner, and when formed nothing but a man with a pick-axe or similar appliance will remove it.

III. The methods of dealing with snow may be divided into two classes, viz: "preventive" and "curative". Of the former, many brilliant propositions have been heard, including the warming of the roadbed by steampipes to thaw the snow as it comes to rest. That in general use is a "snow fence."

Snow sheds are used in many places, but they may be classed with fences.

When building a railway in a snowy district, care is now generally taken to raise the roadbed above the general level of the ground. Three feet to rail level is sufficient, and even a less height has given good results.

Of "cures" there are two forms, viz., snow-ploughs and snow-scrapers.

There are four kinds of ploughs, viz.:

1. Independent ploughs, pushed by an engine.
2. "Rotary" or machine ploughs.
3. Wing ploughs.
4. Nose ploughs built on engines.

Of scrapers there are two chief types, viz: 1st. That placed on the pilot of engine, and 2nd. that built on a car and when in use towed behind a train.

"Prevention being better than cure" the snow fence stands first in merit among the successful methods of dealing with snow. The best fence for this purpose is a hedge row of small evergreen trees. The common balsam or cedar is recommended, and when planted in three or four rows — the trees in one row covering the intervals in the other — the result is a snow fence that will never fail.

As the trees require some years growth to act efficiently they should at first be supplemented by an outside close board fence. The Lombardy poplar has been used on account of its quick growth, but its branches are not close enough to the ground to make a perfect snow fence.

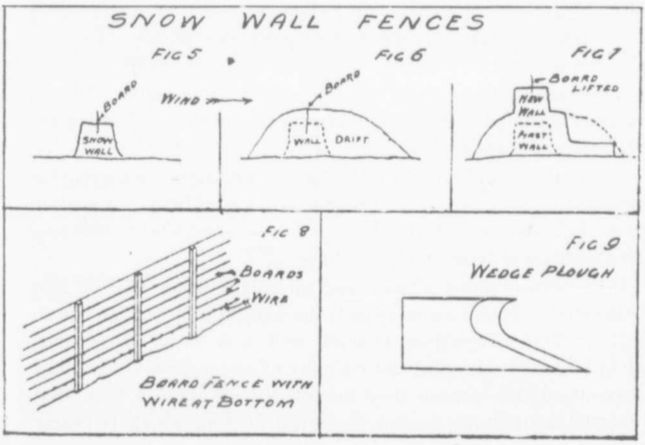
The location of any snow fence is necessarily governed by the direction of prevailing winds, and the general features of the ground, but—to be effective—it should never be within fifty feet of the centre of the track, thus giving room clear of the roadbed for the formation of the drift.

Excellent results have been attained by the setting up of temporary fences at greater distances than this, and in very bad places a good plan is to set up a double line, one hundred feet apart.

Snow walls have been cheaply built and with good effect, but in strong winds they are liable to be levelled and their tops blown away. To prevent this the author suggests the topping of a snow wall with a board nailed to a couple of stakes. When the drift reaches the top of the board it should be raised to a higher level. See fig. 5, 6 and 7.

As a rule "second line fences" are not needed to meet the first storm, so that plenty of material is available to construct at small expense in this way a second line of defence to meet future storms.

Should the snow on the ground melt away the wall will still remain for some time, ready to meet the next storm, and in the spring it is a light matter to break it up, thus preventing any retardation of vegetation.



Portable wooden fences, in the shape of strong hurdles, are excellent auxiliaries of this class, both for "first" and "second line" fences.

Snow fences built of wood are liable to destruction from fire in dry grass or bush clearing, but they can be protected by raising the boards about a foot from the ground, and stringing a wire to make good this space against sheep, etc. See fig. 8.

The bottom opening does not lessen the efficiency of the fence as the first snow fall generally fills the gap, or snow can be thrown there by the trackmen before the season of heavy drifts sets in.

Snow sheds are of two distinct classes, one to cover a deep cutting (generally rock) the other, along the side of a hill or mountain, to guard against slides or avalanches. The former is a simple matter, no very great strains having to be allowed for, a strong roof truss is usually sufficient. In the latter class they call for careful design and construction, so that when tested they may carry great weight and offer no obstacle to the sliding clear of snow, ice and stones.

The author has not thought it necessary to enter here into the construction of snowsheds, the general principles—laid down above—being sufficient for this paper. It should not however be forgotten that the hauling of trains within any such sheds is a matter of trouble and difficulty, as the rail in them is often "bad," either "greasy" in summer or "frosty" in winter, and keeping the track to surface increases the trackman's duties. There is also the fire risk.

There are portions of railway in the Rocky mountains where in summer the road is carried round outside the sheds, showing the preference for open track.

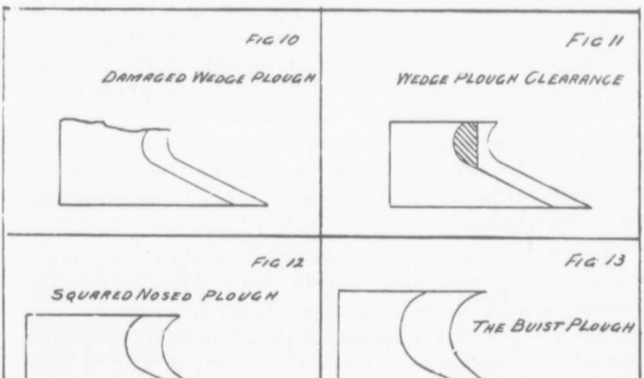
The author emphatically endorses the principle of *keeping the snow off* the road as the best way to work a railway. A certain amount of snow on the banks is a benefit, materially reducing the ill effects of frost on the road bed.

In discussing ploughs those used on single track will be first considered. The accepted type is the wedge or V nose shown in Fig. 9. This plough does its work well in an even fall of snow up to two feet deep, but the majority of them do not *clear* snow of greater depth because they cannot dispose of more than that quantity through the curved discharge at top, which is nearly always too small. The deeply drifted snow either piles on top of the plough or breaking it off (see Fig. 10) falls close to the channel cut out and so back upon the track. Another fault in construction is that the V nose leads the snow to the side of the plough too soon, delivering it too close to the track.

The idea of the original designers appears to have been, to turn a furrow, as a farmer in his field; but snow should be first lifted and then delivered at the side as far from the track as possible. To secure this the roadmasters call for *fast running.*

To assist such ploughs to deliver snow far from the track the curved delivery should be of greater capacity, and a practical rule for design would be to make it at least one half the total depth of plough, for it must be remembered that to do the work intended it has to pass to each side one half of the snow the plough runs through. A brief consideration will show that for a plough ten feet wide working in snow three feet deep, the area of this portion (shaded in Fig. 11) should be fifteen square feet, or the snow will go over top or fall at sides of plough and close to track.

A better design of plough has been coming into use of late years in which the nose is square instead of V shaped, and the best snow clearing under the author's observation has been done by them (see Fig. 12.) This design is much safer, as it will lift



a side drift, and when one side is full will pass the snow to the opposite side. The author has had personal experience with a plough of this pattern for ten years, and it never failed in any kind of drift, or got off the track.

Variations have been made in the shape of the centre of plough front, notably in the Buist plough (see Fig. 13) which combines in its shape two of the points necessary for effective working pointed out in the foregoing, viz: a full clearance for delivery and the square nose.

The author considers the hollowing of the front or raising the sides (shown by dotted lines) to be objectionable, as it confines the snow too much.

A pattern of plough much in favor on some roads is a large wing plough, which can be used for breaking a road first and afterwards for widening the snow banks and scraping the rail. They generally have in front a moveable apron for scraping flanges.

This plough is very high, has a square nose, and an unusually high delivery (see Fig. 14.) Excellent work has been done with them, but they must be run at high speed, which, in front of an engine, is open to serious objection.

Although there have been many other designs, the above are the only kinds which need be mentioned here.

We now come to machine ploughs. Of these the only one worth considering is the "rotary," and with it wonderful work has been done, but it should never be lost sight of, that although unrivalled for emptying a full cutting, the cutting should not have been allowed to get full. Descriptions of the "rotary" are so numerous that space need not be taken to describe it here. Its progress is slow, but it does its work effectively. It is expensive to operate, but less so and leaves its work in a better shape than "a shovel brigade."

The "wing plough" is the most effective ally a road master nas, in moving snow back from the track after the ordinary breaking plough has passed through. It is constructed (see Fig. 15) much as an ordinary square nose plough in front, except that generally its nose has an iron apron moveable at will, to clear switches and crossings. When the apron point is lowered it cuts hard snow a little below the rail level. The "wings" proper are huge doors hung on sides and operated from within, and when fully extended press back the snow on each side to a width of fifteen feet. The wings are usually operated manually, by rack and pinion, under signal received from a "look-out" man.

The author has for two winters had a winged plough operated by compressed air, each wing being connected by a rod and piston, to a ten inch cylinder, having a motion of three feet, sufficient to fully extend the wings and allow them to return home to sides of plough. The return pull is secured by two cylinders of the same size working with a shorter stroke coupled close to the hinge of the wing. Air pressure is admitted to each wing by a three way cock, handled by the look-out man.

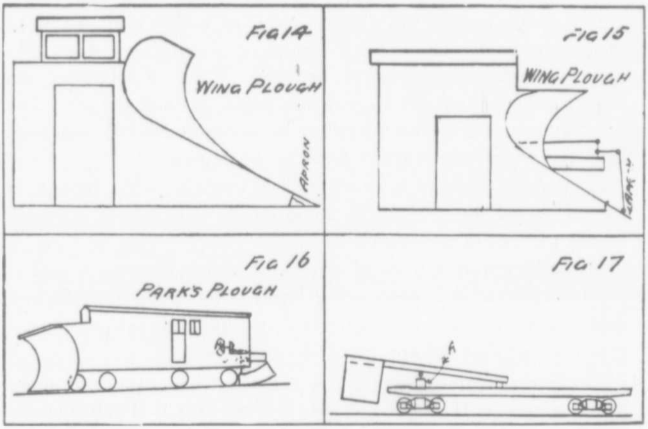
One great advantage claimed for compressed air is that should a drift be too heavy, the wings instead of being held out until the pinion, its dog, or the rack breaks, or the engine is stuck, will close in, until the pressures equalize. Then if necessary the plough is backed up and another run taken to finish the job. The working pressure on the wings can be so regulated that resistance need not exceed the tractive force of the engine.

It has been assumed in the foregoing that the wing plough is hauled behind the locomotive, as no plough with men in it should be run in front of an engine.

Using an apron in front of a wing plough in opening a road is very dangerous, the apron being liable to be raised by drifts and derailment follows. It is after the road has been opened for engine passage that the apron will do good work.

Another machine plough, the "Parks," has been for many years in use on the Grand Trunk Railway, but it is only a heavy scraper, and its construction in front is such that it must leave the track in a deep side drift, the author therefore considers it should be classed among scrapers, not among ploughs. The front as will be seen (see fig. 16) offers no opportunity for snow to pass from one side to the other, and in a deep drift the wedging action of the Y front forces the wheels off the track. In a couple of feet of snow with no banks, it is effective, but being a machine plough men have to ride in it, and it should not be run in front of an engine. It becomes, therefore, for practical purposes only a scraper, but it is the very best of scrapers. The hinged portion shewn by dotted lines (lifted by a screw from inside) is heavy, and furnished with shoes to ride the rail and guide it. The track "flanges" (so called) are effectually cleared out, and such other parts as may be arranged for by the shape of the cutting edges of the scraper.

Next in order as a scraper, but called a plough, may be noticed an arrangement patented in Michigan, (see fig. 17). It consists of a flat car (pushed by an engine) carrying a long hinged beam. Attached to its free end in front of the car is a V shaped plough or scraper, which is raised or lowered by an air cylinder at A. The whole affair is only fit for work which can be done quite as well and without risk by the "Temple" scraper, with which the Grand Trunk Railway Company equip their engines, and which is always ready for service.



On double track ploughs there is little to be said, their system of working being in practice far from perfect.

The Boston & Albany Railroad ran (the author believes) some years ago a plough with a moveable nose hung vertically, (see fig. 18) by means of which snow could be thrown to either side, at will. But that did not clean out the space between the tracks, and the trouble of throwing snow from one track to the other still remained, as well as the objectionable ridge in the centre. This will be dealt with later.

The common shape of the double track plough is that shown in fig. 19, and is built with a square nose. This practically shovels up all the snow in front, passing it to the outside of track. The matter of clearance (see fig. 19) is of great importance in this plough, but has apparently not received the attention deserved, as the clearance instead of being double that required in a single track plough is, so far as the author has noticed, no greater than that given to single ploughs. The question of working these and other ploughs on double—and even four—tracks will be considered at the end of this paper.

Of fixed or engine nose ploughs there are a variety, and some have been patented. They are generally of sheet iron with square nose, and of shape shown in fig. 20, practically a large shovel.

An objection to this class is that they are troublesome when the engine backs up, gathering snow underneath, and eventually either stalling the engine or breaking the plough.

One plough of this kind is arranged over an ordinary pilot to allow the "Temple" scraper to be used.

The author has given much attention to engine ploughs. Fig. 21 illustrates one built and successfully running (worked both forward and backward) on the Drummond Counties Railway, Province of Quebec, during two winters.

It is found that the guards on the sides of the engine truck keep the snow out of the plough when backing up, and a heavy triangular scraper hung underneath at the front end, made an

FIG 18

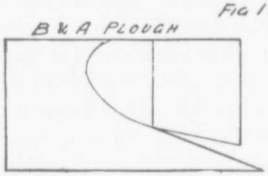


FIG 19

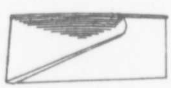


FIG 20

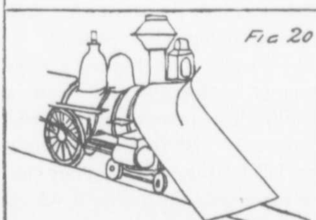
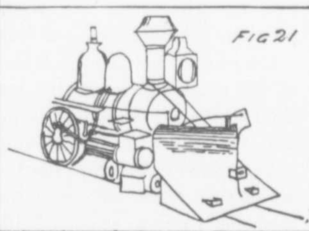


FIG 21



excellent road. Last winter (March 1891) one of these ploughs assisted by an engine broke through, near Barrie, Ontario, at one run, a drift a quarter of a mile long and from four to six feet deep, although only designed to work its way through two or three feet of snow. The square front of the plough has been found to give the greatest safety, no case of derailment in any kind of drift having been experienced. For several winters on the Arthabaska and Doucet's Landing Branch, Grand Trunk Railway, one of these ploughs did good work keeping that track open, the train always getting through. During the same storms the greatest difficulty was experienced on the Quebec main line.

Another kind of nose plough much used years ago is shown in fig. 22. It is not a good thing to use when the snow is deeper than its top, because it acts as a harpoon, offering great resistance to backing out of a drift, requiring much shovel work to clear it so as to admit of backing without the whole affair being torn off. It also gathers snow underneath in backing up.

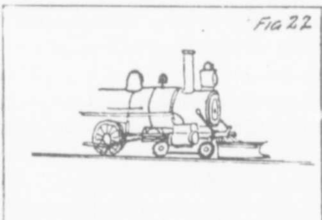
We next come to scrapers; considering first those used on engines. There have been two kinds used on the Grand Trunk Railway as noticed by the author. The first was the "Goulette," the design of an intelligent conductor, who no doubt had many times, in the early days taken his turn at holding the shovel on the rail in front of an engine to help it up a grade in stormy weather. His design—which was to hold the shovel mechanically—has been superseded by the "Temple" scraper (Fig. 23) fitted to the pilots of engines. This consists of an iron body hinged loosely at the front end, and lifted off or lowered to the rail by an arm on a crank shaft worked by the engineman from the cab. To this body is attached a steel blade hung by hinges at the top, and held in a vertical position when working by two steel springs, thus allowing the blade in case of being accidentally run on to a switch or other obstruction to give way or slide over it. The author has seen these scrapers do work that had previously been considered work for an independent plough.

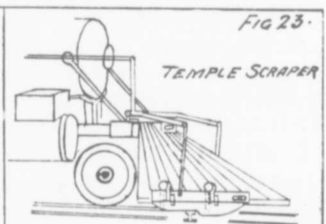
Care has to be taken in fitting the scrapers that they are always of the same figure on the bottom of blades, and that when on the rail the whole stands level, failing this precaution they will not work alike, the work being unevenly distributed, by reason of some having to scrape hard snow left by the others. They cannot do such work, and hence the scraper gets the discredit which is properly due to want of uniformity and care in fitting.

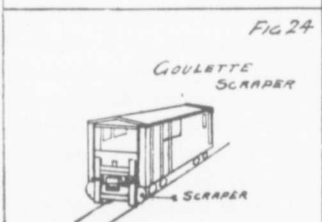
We next come to the scraper fixed to a car and worked at the rear of the train. The "Goulette" scraper (Fig. 24) is a crude arrangement of heavy moulded blade set at an angle to the rail and shaped to cut a space ten inches wide, one inch and a half below rail level inside the rails and down to rail level outside the rails. It is operated by a man moving a heavy lever attached to the framework carrying the scrapers, a set being fitted on each end of the car outside the wheels, so that running in either direction, the last thing on the train is the scraper and no serious damage is likely to result from failure to lift it at switches, crossings, etc., as not infrequently happens on account of the uncomfortable position of the man working it.

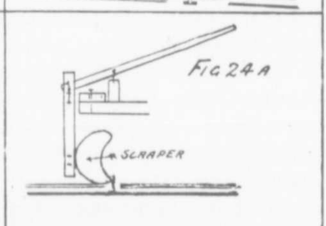
The Maine Central Railway has improved on this arrangement, putting the scraper in the centre of the car and working it by men in the body of car, which is a better position for the "look-out."

A similar construction on the Portland Division, Grand Trunk Railway, under the supervision of the author has done its work well for years, with comfort to the men and without derailment. The arrangement for working is more convenient, certain and rapid in action, and the scraper is so made that on striking a switch or crossing plank, it only breaks off the part below the









rail. This cannot throw a wheel off, and the injury can be repaired in a few minutes.

The author has heard of scrapers of this class being used on the American Pacific Railroads in the Rocky Mountains which are operated by compressed air. Doubtless they did good work, air being quick and sure in its action.

Having concluded the descriptive part we will now take up Section IV. or the best way to deal with snow obstructions.

IV. As already noticed in this paper the author advocates preventive methods.

The question of cuts and fills will always in uneven country have in connection with first cost a very important part in governing the profile of a road, at the same time in the case of roads liable to be visited by snow the avoidance of snow troubles should be taken into consideration. and where possible cuttings should be made wide and shallow to give room for drifting. On prairies the rails should be three feet above ground level, then neither snow fences, nor snow ploughs will be required, engine scrapers with an occasional trip of the car scraper being sufficient to thoroughly clean out the flanges.

In summer the snow clearing apparatus should be overhauled and repaired; the snow fences attended to, and fresh fences ready for use where experience has shown them to be necessary. All should be ready for use by the second week in October. Fences are by far the cheapest method of dealing with snow, they require no wages, and do better work than a gang of men shovelling. The latter, unless great expense is incurred in casting the snow a long distance back, only aggravate the difficulties of future storms. Intelligent, and thorough observation of the prevailing winds will assist in locating fences, which as before stated should be put well back from the track, and not necessarily placed parallel with it. Such preparations being made, the approach of winter and its snow storms can be met without anxiety. Knowing that all possible has been done to keep snow off, it only remains for the intelligence department to watch "old probs.", and when his predictions are being verified, to see that freight trains are not started without a fair probability of their reaching their destination.

When it is known that a heavy storm is commencing, start no freights, and make arrangements to run ploughs ahead of passenger trains to keep the road open. This enables freight trains to be started out directly the storm abates, and on the first sign of abatement, preparations should be made to shovel out sidings and switches to prevent delay. As a rule, work of this kind done during a storm is wasted.

There are many days in winter when full summer loads can be hauled, but in bad weather it is not economy to load engines to the sticking point.

A careful and thorough system of telegraphic reports of weather from all parts of the line, in addition to the meteorological predictions, should be enforced; train loads and movements can then be safely arranged.

However, let us suppose that in spite of all precautions a heavy block has occurred, that some cutting has drifted full, the ordinary plough has failed to make its way through, and assistance is asked for. Intelligent action is then necessary to prevent damage to rolling stock. It has only too often been the practice to put extra engines on and try to ram the plough through, usually resulting in smashing it and the engines. A good rule is "that what one engine and plough cannot go through is not safe to run at."

In coupling ploughs to engines it is necessary to couple closely with small short links to allow the plough to break away from the engine in case it jumps the track. These small links are not to be used for pulling the ploughs but only in pushing. Sometimes if the snow is soft and damp, although deep, two or three engines moving at a walking pace can push a plough through it safely, but if the temperature is low that cannot be done, the drifted snow being so hard that one might as well try to dig the cutting out of the original earth by the same means. Under these conditions the "rotary" if on hand will do good work. If the drift is not more than six or seven feet deep, the line can be opened quickly, by taking a gang of men and setting to work in pairs about fifteen feet apart, to dig cuts *across* the track about twelve feet wide and just long enough for themselves to work in, going down till they find the rail, and leaving it bare for a couple of feet in length. Two hours of this kind of work with a gang of twenty men will prepare for opening a long cutting. When all is ready the plough will at every opening get relief and the engine a chance to work. The cut being opened it should be widened in preparation for another storm. Unless this widening is done at once there is no certainty that the cut will not soon be worse than the previous storm left it.

A roadmaster should never neglect the widening of snow cuttings and the levelling down of banks close to the rail. The wing plough is a good auxiliary for this work, but frequently where the rotary is not used snow must be carried away on flat cars.

The clearing out of the mouths of culverts to admit the free passage of melted snow is very necessary, and general freedom of drainage requires attention. Thaws and rain are often sudden, and as promptly followed by fall in temperature tending to freeze the road solid in a short time.

When ice has formed on the track it can only be removed by the pickaxe. No plough or scraper can clean the rails, and any attempts to force engines over or through it before a thaw has thoroughly set in, must result in disaster. Resort must be had to hand labor to clean the rails and flanges, and is a costly undertaking.

A serious problem has presented itself of late years in dealing with snow on roads of two or more parallel tracks.

The New York Central has had unpleasant experiences of this nature, the trouble being that the removal of snow from one track threw it on to the other unless side ploughs were used, and even in that case a ridge is left between tracks, helping the formation of fresh drifts.

To successfully deal with this the author suggests the following system:—Starting out with the theory that in clearing a line of snow between any two given points (whether on single or double track) no trains should be on that portion of the line while the clearing is in progress. Assuming that it is desired to clear a "section" of snow and that at each divisional terminus there is held in reserve a complete equipment; it is necessary to note the direction of the wind in order that the ploughs may start from that end of the road which will give the action of the side ploughs the assistance of the wind in carrying all the loose snow stirred up to the same side as the plough is putting it. For example sake we will take it for granted that a storm is blowing from the North, on a double track running East and West, and that the practice is to use the left hand track, consequently the side ploughs are built to throw snow to that side.

In this case the ploughs should run from the East to the West, and the first "section" — say twenty or thirty miles — secured clear of trains.

Both tracks being clear of trains, running orders West are first given on the eastbound or north track to one plough to the end of the selected "section."

This plough being the ordinary square nosed plough is pushed by the engine, the hauled wing plough follows later to force back the bank on the north side and to clear the most of the centre between tracks, thowing this snow well over on to the south track, helping the second side plough to move it further south and by a wing plough following to force back the bank on the south side. (See sketch, fig. 25.)

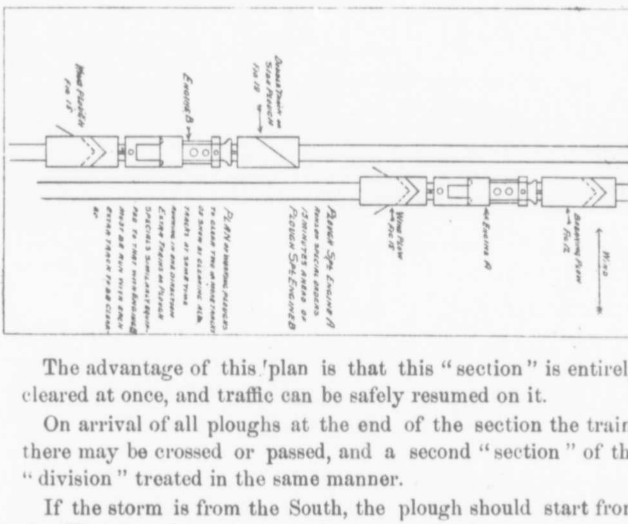


Fig. 25

The advantage of this plan is that this "section" is entirely cleared at once, and traffic can be safely resumed on it.

On arrival of all ploughs at the end of the section the trains there may be crossed or passed, and a second "section" of the "division" treated in the same manner.

If the storm is from the South, the plough should start from the West, but although not unknown, southerly storms are not frequent.

If it is the practice to use the right hand track to run on, the ploughs would start from the west end with a northerly storm.

If the storm is due East or West, and the road has not very much curvature it would be found that not much trouble would result, but still both tracks should be cleared—so to speak — at the same time, by the plough on the wrong track being run fifteen minutes ahead of the other in all cases.

In the case of four track railroads four sets of ploughs are required to be worked in a similar manner to the above, viz: one breaking plough, three side ploughs and four wing ploughs. After considerable thought and experience, the author considers this to be the best, if not the only way to promptly and effectively clear anything more than a single track railway of snow.

With the following, which is not claimed as original nor as applicable only to the subject under consideration, the author concludes: "To keep a railway clear of snow eternal vigilance is the price of safety." Without that all appliances are useless.

Friday, 20th May.

A. BRITTAIN, M. Can. Soc. C. E., in the Chair.

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

MEMBER.

MARIE JOSEPH ETIENNE LUDOVIC DE LA VALLÉE POUSSIN.

ASSOCIATE MEMBERS.

EDWARD FREY BALL.	CHARLES DE BLOIS GREEN.
CHARLES GARDEN.	THOMAS ROBERT HENDERSON.
ALVAH SEYMOUR GOING.	WILLIAM A. HENDRY.

STUDENTS.

MATTHEW FORTESCUE.

The following was transferred from the class of Associate Members to that of Members :—

HENRY IRWIN.

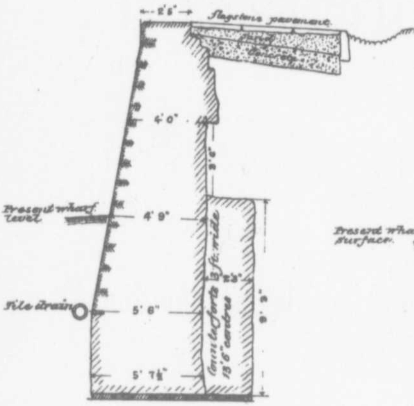
The following was transferred from the class of Students to that of Associate Members :—

ARTHUR HENRY BOULTON.

The discussions of Mr. Macdougall's paper on the "Professional Status," and of Mr. Harkom's paper on "Snow on Railroads," occupied the evening.

AN OLD REVETMENT WALL.

By W. J. SPROULE, Ma. E.



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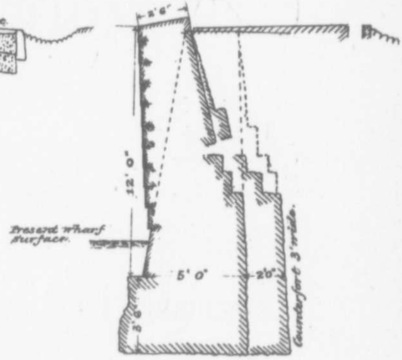
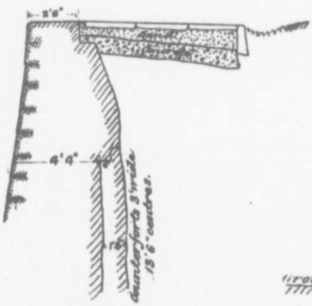


BUILT 1840-41.



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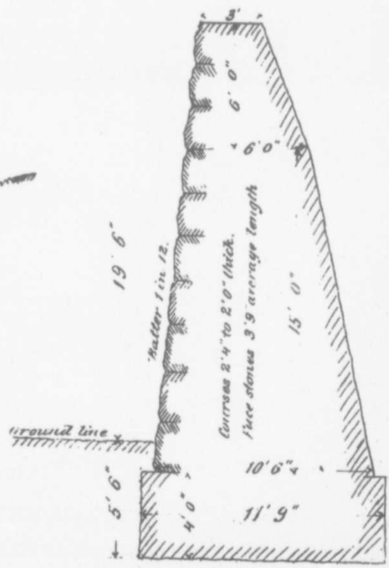

CAN. PAC. RY. REVETMENT WALL
MONTREAL HARBOUR

BUILT 1884.