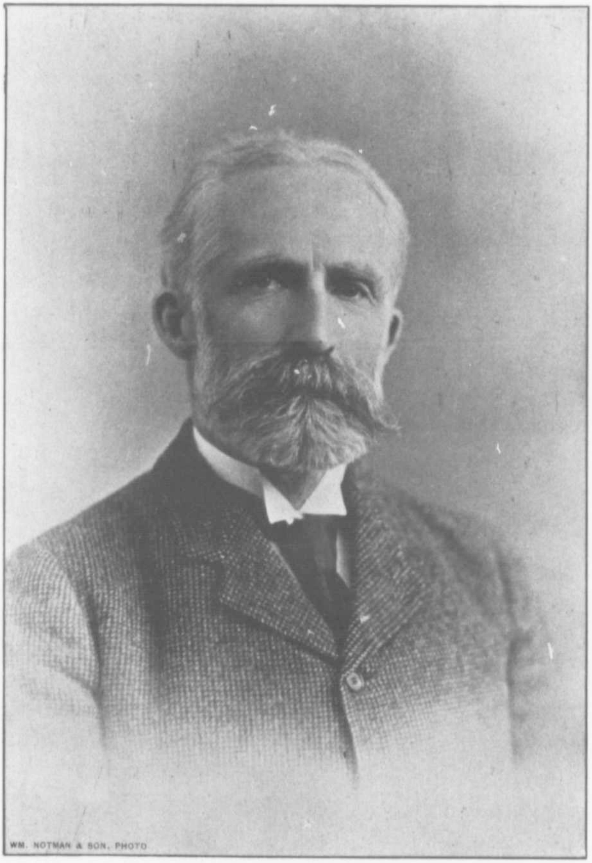


WM. NOTMAN & SON, PHOTO

Yours faithfully
J. Alex. Hutchison

TRANSACTIONS

OF

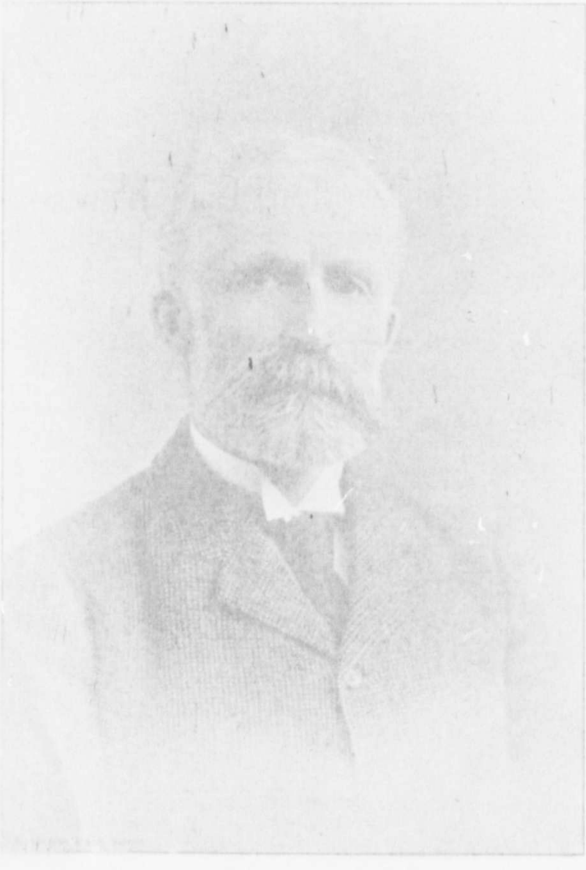
The Canadian Society of Civil Engineers.

VOL. VIII., PART I.

JANUARY TO JUNE,

1894.

Montreal:
PRINTED FOR THE SOCIETY
BY JOHN LOVELL & SON.
1894.



Yours faithfully
Alex. Atteson

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—*By-Law No.* 47.

CONTENTS.

INSTRUCTIONS FOR PREPARING PAPERS, ETC.

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

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

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

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

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

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

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mbers of ouncil..	F. N. Gisborne. E. P. Hannaford. W. T. Jennings. S. Keefer. L. Lesage. H. D. Lumsden. A. Macdougall. H. F. Perley. H. Peters. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Scheriber. H. Wallis.	H. Abbott. F. R. F. Brown. F. N. Gisborne. J. Hobson. W. T. Jennings. J. Kennedy. L. Lesage. A. Macdougall. H. A. F. Macleod. M. Murphy. P. A. Peterson. H. S. Poole. H. N. Ruttan. P. W. St. George. C. Scheriber.	G. F. Baillairge. J. D. Barnett. K. W. Blackwell. St. G. J. Boswell. F. R. F. Brown. G. C. Cuningham. E. Gilpin. F. N. Gisborne. W. T. Jennings. G. A. Keefer. J. Kennedy. M. Murphy. B. D. McConnell. E. Wragge. J. A. Vanier.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. W. T. Jennings. G. A. Keefer. H. G. C. Ketchum. T. Monro. G. H. Massy. P. A. Peterson. H. N. Ruttan. P. W. St. George. J. W. Trutch. E. Wragge.	W. P. Anderson. J. D. Barnett. F. R. F. Brown. K. W. Blackwell. C. E. W. Dodwell. H. Donkin. F. N. Gisborne. E. A. Hoare. J. Hobson. W. T. Jennings. T. Monro. P. A. Peterson. H. N. Ruttan. P. W. St. George. Sir J. W. Trutch.	J. D. Barnett. K. W. Blackwell. H. T. Bovey. H. J. Cambie. C. E. W. Dodwell. F. C. Gamble. F. N. Gisborne. E. A. Hoare. Jos. Hobson. C. H. Keefer. H. G. C. Ketchum. H. D. Lumsden. A. Macdougall. H. N. Ruttan. P. W. St. George.	J. D. Barnett. St. Geo. Boswell. H. T. Bovey. F. R. F. Brown. G. C. Cuningham. C. K. Domville. C. H. Keefer. H. D. Lumsden. A. Macdougall. E. Mohun. G. A. Mountain. H. S. Poole. Frank R. Redpath. Thomas Ridout. P. W. St. George.	H. Abbott. P. S. Archibald. J. D. Barnett. H. T. Bovey. O. Chanute. G. C. Cuningham. H. Donkin. G. H. Duggan. J. Galbraith. G. H. Garden. Wm. Haskins. H. A. F. MacLeod. H. Peters. H. N. Ruttan. L. A. Vallee.
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retary..	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey.	H. T. Bovey. C. H. McLeod.	C. H. McLeod.	C. H. McLeod.	C. H. McLeod.
asurer..		H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	H. Wallis.	K. W. Blackwell.
rarian....	……………	F. Chadwick.	F. Chadwick.	F. Chadwick.	F. Chadwick. Wm. McNab.	Wm. McNab.	Wm. McNab.	Wm. McNab.

Thursday, 18th January.

P. Alex. Peterson, President, in the chair.

Paper No. 86.

CONCUSSION IN SEWER PIPES.

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

The writer desires to lay before you what he believes to be an unrecognised source of danger to pipes, under certain conditions, during the construction of sewers.

In Victoria, B.C., about 2000 feet of 20 inch pipe were laid, and before many weeks had elapsed it was found that a very considerable number were broken.

Examination showed that near a ventilator or a manhole on a straight line the pipes were intact; while in a manhole on a curve they were sometimes fractured. In rock tunnel, where there was open space above the pipes and clear entrance to a manhole, the pipes were undamaged, while after being back filled in earth, near which blasting had been necessary, they were sometimes cracked.

The natural inference in the first place was, of course, that this result was due to improper laying and insufficient tamping; but it was felt that the damage could not be attributed to such a cause.

The pipes had been tested for crushing (while unsupported at the sides) up to 2500 lbs. per lineal foot without fracture; an inspector was present when each pipe was laid, whose duty it was to see the back filling properly tamped, while the work was frequently visited, at uncertain intervals, by the engineers and chief inspector. Further, it was found that in work performed by the same men, when the superincumbent weight was far in excess of that above the broken pipes, no damage had been done.

Mr. G. A. Keefer, Mr. E. A. Wilmot, Mr. E. G. Tilton and the writer finally came to the conclusion that the damage arose from concussion caused by the blasting in the trenches and tunnels beyond where the pipes had been laid, and this conclusion appeared to be justified by the facts before narrated.

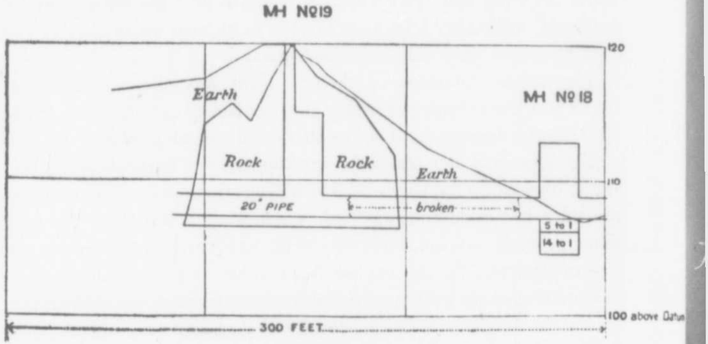
It should be explained that between 60 and 70 p. c. of this pipe was laid through solid trap rock, nearly all in tunnel. This tunnel was unfilled for the sake of access, and there was consequently an open space above the pipes. The rock was intensely hard. With a day and night shift the progress was only 5 feet a week to the face. The charges were heavy, and the air was naturally driven out of the tunnel with great force.

Since the discovery was made, all pipes in the neighbourhood of blasting have been stopped at their upper ends and covered with sacks of earth, and no pipe has been laid into the lower end of a tunnel until the latter had been driven through. These precautions proved successful, and no further damage was done.

The total cost of replacing the injured pipes was about $1700, which was paid by the contractor before the final acceptance of the work.

The writer has often heard of sewer pipes being found broken after the work had been taken off the contractor's hands, the cost in these cases falling upon the City, and the blame upon the contractor. Is it not possible that in some instances, at all events, the breakage might be due to concussion?

The profile below may be taken as typical of the other points where breakage occurred.



The pipe between MH. 18 and MH. 19 was laid in open trench from MH. 18 to within about 20 feet of MH. 19, and back filled before the blasting above and below MH. 19 was completed.

At MH. 18 there was clear opening to the outer air, and the pipes near that opening were undamaged.

The results were similar at other points where breakage occurred; the ventilators apparently relieving the pressure, and a few lengths of pipe on each side of them were undamaged.

Had the trench not been filled in, the author's theory is that no damage would have been done, as the pressure outside and in would have been equalised.

As a case apparently in point, the author was informed by the contractor that, when about to fire a shot at the outlet, he and the inspector took shelter in the valve chamber, a small concrete building, from which a 22″ steel pipe, set in concrete, was laid about 370 feet, and about 25 feet beyond its end the shot was fired in open trench. The concussion caused a violent shock to them both, they being at the time opposite though above and ten feet away from the upper end of the pipe.

We know that in tunnel work a heavy shot can cause a considerable shock several hundred feet away in spite of numerous shafts.

CORRESPONDENCE.

r. Rust.

Mr. C. H. Rust is very much interested in Mr. Mohun's paper, as the writer has had a very large experience in the construction of pipe sewers in Toronto, and in a great many cases has found the pipes broken on an examination being made some months after the completion of the sewer. Our private drain inspectors in making connections occasionally report cracked pipes. The city has no pipe sewer of greater diameter than $18^{\text{in.}}$ and all fractures so far have been entirely with $18^{\text{in.}}$ pipes. No $15^{\text{in.}}$ or $12^{\text{in.}}$ have been found broken. We have for some years past discontinued laying $18^{\text{in.}}$ pipes, and with $15^{\text{in.}}$ pipes we almost invariably fill the haunches in with concrete. The percentage of breakages appears to be greater with pipes laid in sand when the fracture appears, generally, to commence at a manhole and continues along the line of pipe for a number of feet. The cracks invariably extend the whole length of the pipe, and in a great many cases upon being taken out, the pipe will fall into four equal pieces. Although these pipes are cracked, the writer very rarely found a complete collapse of the sewer. His conclusion as to these breakages is that in sand the timber to support the sides is generally carried down below the pipe, and in removing the timbers, the sides of the trench have fallen in, and the result is a cracked pipe. In clay trenches the breakage is caused by neglecting to have the pipes properly embedded, and carelessness in tamping the sides. From the experience we have gained, it appears that the $18^{\text{in.}}$ pipe is not made of a sufficient thickness to withstand shocks. The Toronto specifications call for the following thicknesses : $12^{\text{in.}}$ in diameter, $1^{\text{in.}}$ thick ; $15^{\text{in.}}$, $1\frac{1}{4}^{\text{in.}}$; $18^{\text{in.}}$, $1\frac{1}{2}^{\text{in.}}$

Mr. Mohun does not state whether he has had any experience in pipes of a less diameter than $20^{\text{in.}}$ From the experience we have had here, the writer is inclined to think that the breakages mentioned in Mr. Mohun's paper may have been caused by negligence in tamping the sides or in not placing the pipes on a cushion of sand or concrete when laid in rock.

In 1889 an examination was made of a number of pipe sewers in various parts of Toronto. Altogether, 24 were inspected at various points. The results were as follows: 21 18^{in} sewers were examined, of which 14 were laid with American pipe. Of these, 5 were found with cracked pipes. Seven $18^{\text{in.}}$ drains were examined, which were laid with Scotch pipe. Of this number three drains were found with damaged pipes. Four $15^{\text{in.}}$ sewers were examined, all of which were found in good condition.

Mr.Macdougall

Mr. Alan MacDougall said he had corresponded with the author for further information than given in the paper. The experience was a novel one. The injured pipes appear to have been near a manhole in the rock tunnel ; the trench appears to have been filled up, and the only outlet for the compressed air was through the pipe ; the pipe acting somewhat like the bore of a great gun, or a gun barrel, discharged the air into the manhole where it had not free vent. The force of the concussion was felt in the manhole, and appeared to react on the pipe at a point a few feet back from the manhole. The air must have been confined in the manhole, the cover possibly being in place ; the greatest force of the concussion re-acted on the pipe, and destroyed it. The later experience of the author of the paper bears evidence in favour of his hypothesis. After the ends of the pipes were stopped up, and no air had access to the pipes, no further breakages occurred.

DISCUSSION.

Mr. Smith. Mr. C. B. Smith remarked that Mr. Rust's discussion recalled a similar experience of his own in the Southern States. Double strength sewer pipe is freely used in place of culverts on railroads, and on one piece of work the speaker had charge of, where hundreds of Blackmer and Post sewer pipe culverts were so constructed, only two failed; these were found to be split longitudinally from end to end in, almost exactly, quarters. These two pipes were founded on soft rock with rings let down, and carefully rammed on both sides up to the middle, while all the others were on softer foundation, similarly laid. After taking the broken pipes out, about 6 inches of clay was rammed on the bottom, and the pipes laid on this cushion; no further trouble was experienced, which would lead one to conclude that possibly Mr. Mohun's pipes were on too hard a foundation for the side support given. The speaker would also like information as to the reason for making the contractor replace, at his own expense, pipes which he, Mr. Mohun, claimed were well laid and properly inspected, and which failed admittedly, through unforeseen and doubtful causes. Would not the fact of the contractor being made to replace the broken work go to indicate that poor workmanship was the real cause of the failures?

Mr. Irwin. Mr. Irwin said: Mr. Mohun does not state precisely how the pipes were broken by the concussion; but from the additions made to the paper after it was first read, it might be assumed that the breakage was caused by internal pressure in the pipes and not by jarring, since he remarks, near the end of the paper, that ventilators relieved the *pressure* and that a few lengths on each side remained undamaged.

From the third clause of the paper, as first printed, the writer concluded that in rock tunnel the pipes were undamaged, and that it was when the pipes were *laid in earth* near which blasting was necessary, that they were cracked, and supposed that the blasting which did the damage was at the bottom of an open cut, the holes being vertical; this seemed improbable. The later information received, however, shows that the blasting which broke the pipes was in tunnel, the holes being horizontal, and the result of an explosion was to force the air suddenly through the pipes, since the liberated gases were bound to find an outlet.

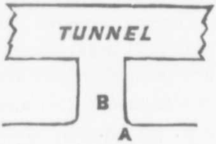
Had the blasting been in open cut in the bottom of the trench, the displacement of the air would have been mostly upwards, and it is unlikely that any damage would have been done.

It does not seem certain, however, that the breakage was due to the *bursting* of the pipes, for the air was free to travel along them to the outlet, and the writer thinks it is just as likely to have been caused by the sudden jar of the explosion.

A short time ago the writer saw several pipes in a waggon load, broken during cartage, from the jarring caused by the roughness of the road; and yet the same make of pipes delivered by train, carried trains with only about three feet of earth above them, as did also the balance of the load delivered by waggon. There is no information given as to how the pipes were laid where left uncovered in a rock tunnel, nor is it clear whether any of the pipes laid in this way were broken, yet one would suppose that more pipes would be cracked in such places than where carefully bedded in soft earth, and well tamped; however, since some 60 per cent. of the pipes were laid in tunnel, it may be assumed that some have been broken.

As illustrating the curious effects of explosions of dynamite in some cases, the writer would add that he knows of a well authenticated incident which happened not long ago.

A short heading had been driven into the face of a rock bluff, and a tunnel had been commenced at right angles to the heading in each direction, as shown in the sketch below. A stove was placed at the mouth of the heading (at A) and a man was standing just inside the heading (at B) and was thawing dynamite cartridges on the stove, while just outside, beyond the stove, were several boxes of dynamite, amounting to over 200 pounds.



A cartridge on the stove blew up and exploded the whole of the stock of dynamite. The man was thrown on his back, but received no permanent injuries, though he was deaf for two or three weeks and was in hospital during that time.

It was supposed that the force of the explosion, on the rock floor, was upwards and outwards, and that the confined air in the heading and short tunnel acted as a cushion receiving a certain amount of pressure, probably considerably reduced by the upward direction of the explosion.

Mr. Peterson. Mr. Peterson said that Mr. Mohun had neglected to mention a great many points that are required in order to properly explain the question under discussion. He thought that Mr. Mohun should have furnished a plan showing the nature of the work done, where the blasts were made, where the cracks occurred, etc., etc. He thought it would be difficult, without this information, to come to any conclusion in the matter. He was inclined to think, however, that improper laying had more to do with the cracks in the sewer pipes than the blasting, and suggested that the Secretary should write to Mr. Mohun for further information before closing the discussion.*

Mr. Wallis. Mr. Wallis remembered an explosion occurring near the Grand Trunk Railway engine shed at Stratford in 1879. Every window in the shed was broken, those on the side nearest the point of explosion being blown inwards and on the side opposite outwards in relation to the shed. Seventeen cars near to the one in which the explosion took place were blown to splinters, the axles being broken or twisted, and some of them being found several hundred feet away. The car which contained the explosive was wrecked beyond recognition, and at the place where it stood was a hole almost sufficiently large to have contained the car. The explosive was intended for blasting operations under water, and its active agent was said to have been nitro-glycerine.

Mr. Leonard. Mr. R. W. Leonard said :—It is apparent that the blasting in the tunnel heading acted in the same manner as the explosion in a gun, the shock of discharge being directed fairly at the open end of the pipe already laid. The sudden pressure caused them to burst just as the gun bursts if too weak to stand the strain.

With regard to Mr. Irwin's remarks on the capacity of the human body to safely withstand heavy pressure suddenly applied, we may consider the case of a submarine diver down below one hundred feet of water. He safely withstands for a lengthened period an absolute pressure of about 65 lbs. per sq. in. The pressure within the limit of safety may or may not be greater when applied for a second or two only, but even 65 lbs. per sq. in. suddenly applied and as suddenly reversed in direction (as is the case in an explosion) is sufficient to wreck a pretty strong structure, though it may not cause loss of life to a person who escapes injury by flying missiles.

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* NOTE.—These remarks are on the paper as first presented. The sketch with accompanying notes were added subsequently.

Mr. W. McLea Walbank said he thought there was hardly sufficient information given by the author of the paper to enable him to arrive at a satisfactory solution as to the cause of the cracks referred to. They might have been caused by imperfectly bedding the pipes, for example—the faucet resting on ground and the remainder of the pipe unsupported when the weight of the earth filling above might cause the cracks referred to; but without more detailed information on the subject, any conclusion we might draw would be valueless.* Mr. Walbank.

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* NOTE.—These remarks are on the paper as first presented. The sketch with accompanying notes were subsequently added.

REPLY TO DISCUSSION.

Mr. Mohun in reply said he regrets the deficiency of information referred to in the discussion. It must, however, be remembered that the result not having been anticipated, the available data upon which the theory advanced has been based really consists of but little more than the fact that pipes were cracked in the filled trenches in the vicinity of blasting operations.

The investigation made by Messrs. Keefer, Wilmot, Tilton and the writer, shortly after the damage was discovered, convinced them that the breakage did not result—except possibly in some isolated instance—from improper laying or back filling.

Every precaution was taken to ensure the full bedding of and solid back filling round the pipes. No pipe was laid except in the presence of an inspector ; the works were daily and hourly visited by the Chief and Resident Engineers and Chief Inspector. At the commencement of the contract, all sub-inspectors did their work under continuous supervision, until it was ascertained that they thoroughly understood their duties. No portion when laid was allowed to be covered up until after examination. In some places where breakage was subsequently found to have occurred, the writer was present when the pipes were laid, and knows that they were properly tamped with fine, dry material. A transverse groove was in all cases cut to receive the socket, which was not tamped until the pipe had been bedded for its full length between sockets. In rock the trench was excavated to an extra depth of six inches, and then brought up to grade with 14 to 1 concrete of fine shingle and sand. This concrete was carried up to the haunch, and well rammed round the pipe with a curved T shaped iron ; the pipes were similarly bedded where bad material had to be removed. These points the writer had intended to refer to in a future paper on the sewerage system of Victoria. It may be added that by far the greater part of the blasting was on the line of the 20″ in. pipe.

Mr. Irwin is right in assuming that no pipes were broken in tunnels or open trenches where the air had room for expansion. The blasts assumed to be the cause of damage were fired both in tunnel and in open trench.

The writer is confident that if his instructions were faithfully carried out,—and he has no reason to doubt it,—no damaged pipe was lowered into the trench. The pipes were individually tested: 1st When received at the Corporation yard; 2nd, when delivered to the contractor's teamster; 3rd, when delivered at the trench.

The writer believes he is correct in stating that no injury whatever was done to pipes in open tunnel whether laid before or after the blasting was completed. And no pipes were damaged by blasting or otherwise after their open ends had been protected by sacks of earth.

The contract provided that on the completion of the work, any damage from any source whatever should be made good by the contractor, who had further to maintain every portion of the works in working order for an additional period of six months. The latter provision was more particularly intended to apply to the settlement of street surfaces. During this term of maintenance a little work had to be performed on the streets, but the sewers themselves worked then, and for over a year to the present time without any stoppages or the slightest hitch of any kind. Owing to the limited number of houses connected at the early stage of their existence, the writer was at first somewhat doubtful whether they would remain self-cleansing without more flushing than will be required ultimately when they are performing their full duty; they, have, however, proved entirely self-cleansing, since the sand, etc., accumulated during construction was removed.

It is with some diffidence that the writer has ventured to submit to the Society a theory, novel at least to him, and he has only done so under the full conviction that, whether the damage is in this case due to the cause suggested or not, a source of danger has been indicated which is worthy of the attention of engineers.

Thursday, 25th January.

P. W. St. George, Vice-President, in the Chair.

Paper No. 87.

THE MANUFACTURE AND USES OF WIRE.

By W. E. L. Dyer, Stud. Can. Soc. C.E.

The manufacture of wire is of considerable antiquity, and dates back to 1500 B.C., where its manufacture is mentioned in Exodus, chapt. xxxix. 3, where it is said that "they did beat the gold into thin plates and cut it into wires." Mention is also made, about 800 B.C., in the Odyssey, Bk. viii, to a net wrought out of iron by the god Vulcan.

Since then, however, the manufacture of wire and the uses to which it may be put have increased so much, that to-day it is one of the most important and useful of manufactures.

The physical properties required to make useful wire are possessed by only a limited number of metals, among the most useful of which are iron, steel, copper, platinum and gold.

The thinnest wire has been made from gold which has been drawn down to $\frac{1}{5000}$ in. in diameter, and platinum has been made $\frac{1}{3000}$ in. in diameter. These metals were covered with silver during the drawing, and this was afterwards dissolved off with Nitric Acid. The greatest quantities, however, are manufactured from steel and copper.

Wire was originally made by beating the metal into long plates which were then cut into continuous strips and afterwards rounded by hammering. To-day, wire is made by a process known as "cold drawing," which was introduced from Germany into Great Britain about the middle of the 17th century, and wire may be made of any shape and useful size, the section depending only on the class of work to which it is going to be applied.

Wire is drawn out of "wire rods" which are rolled from billets weighing from 100 lbs. upwards. The billet is prepared for drawing with special care, and it must be of the best material for the smaller sizes of wire. The billets are passed through a series of rolls varying in speed and in diameter, so that the slack caused by the difference in length due to the difference in diameter of the rod may be taken up. The diameter of the rolls is usually from 8 to 12 inches, and are driven at the rate of from 450 to 500 revs. per min. The peripheries of the rolls are formed with different shaped grooves, such as from square to oval, oval to round, round to square, and so on, for the purpose of obtaining compactness in the metal. After passing through ten or twelve different rolls called "passes," the rod is wound in "hanks" ready for the wire drawer, who makes them into wire by the process of "cold drawing."

This is done by drawing the rod through a perforated plate called the "draw-plate," which is a disc of hard steel pierced with a series of holes corresponding in aperture with the size and section of the wire to be made. The holes are funnel-shaped, being wider at the side where the metal enters and tapering to their small diameter at the other face. The friction of the wire passing through the plate tends to enlarge the hole, and care must be taken to keep the wire greased when it is passing through the plate, otherwise the hole will tend to enlarge and the wire will not be uniform. When very great uniformity is required, holes are cut through rubies or similar hard stones, and the metal is drawn through these. To get the wire through the plate, a point is put on each rod either by hammering or in a pointing machine. The rods are then cleansed by being washed in a bath of dilute sulphuric acid, and afterwards immersed in lime water to give a drawing surface, and finally they are dried by being heated in a suitable chamber. A wire-drawing machine consists of a drum *A* mounted on a vertical axis *B*. In front of the drum is placed the draw-plate *D*, which is clamped to the bench in a suitable position.

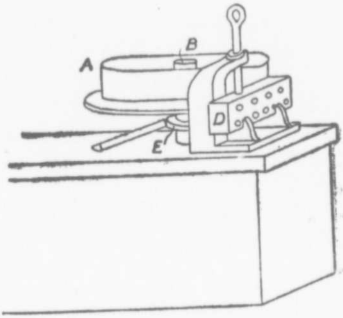


FIG. 1

Pincers are used to take hold of the tapered end of the rod inserted in the hole of the plate, and they are so fixed that they are forced backwards by the revolving cam E fixed on the spindle B. When a sufficient length of the rod has been drawn through to be fixed to the drum, the machine is started and the drawing continued, care being taken to keep the wire well lubricated. The moment of resistance in drawing No. 10 and No. 11 wire, as got by experiments made for Thurston, is about 350 ft. lbs., and the velocity of the wire is about 4.2 ft. per sec. Larger wire is drawn at a lower speed, reaching a minimum at 2.5 ft. per sec., and the smaller sizes are drawn at speeds running up to about 8.4 ft. per sec.

The resistance offered by wire in passing through the draw-plate varies with the size of wire, quality of metal and the arrangement of the blocks. An approximate value for good wire is given by the formula

$$P = \frac{30}{.250 - d}$$

Where P is the pull and d the diameter of the wire.

During the drawing, the wire usually becomes hard and brittle, and to remove this so that the drawing may be continued it is necessary to anneal the wire. The number of times the wire has to be annealed depends on the quality and the diameter of the wire. Zinc is the only metal which when being drawn becomes very soft and ductile, but this is removed by being kept in boiling water for some time, during which it becomes brittle. Annealing consists in heating the wire in "annealing pots," which are metal chambers into which the wire is placed and hermetically sealed. For several hours it is kept at a red heat and then allowed to slowly cool. The temperature is kept up by burning gas round the annealing pits, and the temperature inside of them is about 1450° F.

The effect of annealing steel wire is to lessen the tenacity but to greatly increase the ductility, as will be seen by referring to Kirkaldy's tests, which show that hard steel wire will stand 120,976 lbs. per sq. in. in tension, and annealed wire will stand only 74,637 lbs. per sq. in. in tension.

Hard wire will stand only 22.4 complete turns in 5″, while annealed wire will stand 79 complete turns in 5″.

During annealing a slight expansion takes place, which removes the coating, so that the protection coating must be renewed after annealing; and to prevent oxidation during annealing the wire should be heated in a non-oxidising atmosphere or in the presence of some flux.

To protect the surface of wire from oxidation it is usually galvanised, tinned or coppered.

Galvanising wire consists in coating the wire with metallic zinc, which is done by drawing the wire, which has previously been thoroughly cleansed, through a bath of molten zinc called " spelter," and by this means it retains a metallic film. The zinc is kept liquid at a temperature of 775 ° F. by a furnace placed beneath the bath. As the wire leaves the spelter, it passes through sand to remove the superfluous zinc which adheres to it.

To tin wire, hanks are dipped into the molten tin and the superfluous tin is shaken off, and a bright surface given by being drawn through one or more holes in the draw-plate.

To copper wire the hanks are steeped in a solution of sulphate of copper, and a film of copper is deposited on the wire. The wire is then drawn a few holes, as in tinning, to give it a bright, polished surface.

Among the many uses to which wire may be put, wire rope, chain, nails, screws, coat and hat hooks, cotter pins, netting, and hooks and eyes, may be considered among the most useful. Wire rope is said to have originated in Germany, where they were first used as the supporting ropes of the Geneva bridge. These ropes were only a number of parallel wires bound with a number of finer wires, and were manufactured by hand on rope walks. The rope manufactured to-day usually consists of six " strands," which are made up of six wires twisted round a hemp core by suitable machinery. The bobbins containing the wire are set in the periphery of a larger frame, like a cage, which revolves round an axis placed either horizontally or vertically. The wire, from the bobbins, is passed through apertures provided in the annular framing and nozzle plate running in the head-stock bearing, and thence are carried through the fixed closing block or die to the draw off drum. The core, which is composed of either hemp or soft iron, is drawn in centrally from the back of the machine through the tubular horizontal shaft, and as the machine revolves and the core is drawn along, the wires are twisted spirally round it. The bobbins are so placed that the wires are concentrated at the nozzle plate and drawn through the closing die at a very small angle, and any slack which may take place due to the unequal running of the bobbins is kept back by the closing die. The bobbins are controlled by an eccentric motion which always keeps them in a vertical position, thus preventing any individual twisting of the wires. The machine used for twisting the strands together is called a closing machine, and is the same as the stranding machine, differing only in the number of bobbins and the rate at which it is run.

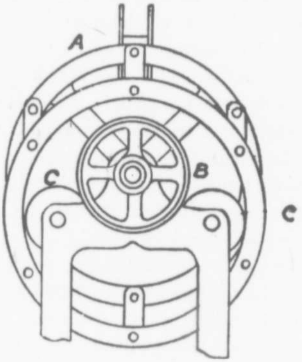


FIG. 2

A simple way of keeping the bobbins perpendicular is shown in Fig. 2. The spinner *A* is attached to the hollow shaft which is turned by a belt acting on the pulley *B*, the speed being about 50 revolutions per minute.

On the rim of the spinner and to the end of the rods holding the bobbins are attached cranks in a perpendicular position to an iron ring. The weight of the ring keeps the bobbins always in an upright position, thus preventing any individual twisting of the wires. The wire on the bobbins weighs from 400 to 600 lbs. The two rollers *C C* are to prevent any lateral motion of the ring. Tension is put on a cord which passes round a pulley on each bobbin by a spring, and thus prevents the too rapid feeding of the wire.

The size of wire rope varies from about $\frac{3}{4}''$ to $7''$ in diameter, and there is no useful size which is not either made or can be made. Care must be taken that the strands are twisted around one another in the closing machine in a direction opposite to that of the individual wires in the strands. Strands are usually twisted up to the left, and rope is closed to the right.

The principal uses to which wire rope may be put are probably that of hauling cars on the streets or out of mines and for the transmission of power to a distance. The advantages possessed by wire rope over other ropes are that they last longer if properly used, they are stronger, and a very great amount of power can be transmitted with comparatively light gearing if they are run at their highest practicable velocity, which is about 100 ft. per sec.

On account of the stiffness of wire ropes, pulleys with large diameters must be used to diminish the bending action and reduce the loss of works due to journal friction. If the distance is very great to which the power is to be transmitted, it is divided into stations or relays, each station being provided with a horizontal shaft upon which is fixed a double grooved pulley. Care must be taken that the rope does not touch the ground between the relays. Sometimes relays are made over 600 ft., but usually they are placed every 400 or 500 ft. apart. The loss is estimated at 2.5 per cent + 1 per cent. for every 1000 yards of distance, and the weight per lineal foot is about 1.34 d^2 where d is the diameter of the rope.

Wire nails are rapidly supplanting those pressed out of iron, and in their favour it may be said that they hold better throughout their length although they require less force to start them. The wire nail is also very much easier to drive into wood, and is not liable to split the wood as is the case with pressed nails. In the manufacture of wire nails, the wire is straightened by means of rollers placed as in Fig. 3, and fed into the machine where dies grip it, while the head is knocked up by a spring bolt mechanism operated by a cam placed on the main shaft. It is then cut off by dies and ejected from the machine.

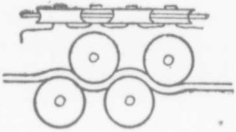


FIG. 3

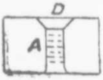


FIG. 4

The rollers which straighten the wire have to be regulated by means of a screw placed on the top, and by which the rollers may be loosened so that they may be pushed further apart or closer together, as the case may be.

The dies which hold the wire while the head of the nail is being formed are made like Fig. 4. The indentations *A* hold the wire and prevent it from slipping while the hammer strikes the wire, causing it to fill up the countersunk part of the die *D*.

The dies which cut the wire off to the correct length are formed as in Fig. 5. These dies are fitted into two arms, which are worked by a cam on the main shaft, and cut the nail off in a four-sided tapering point, the angle of which is about 15° or 20°.

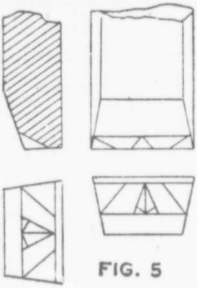


FIG. 5

Wire is being largely used in the manufacture of coat and hat hooks, and these hooks are very largely used because of the easy way they may be put in place.

In the manufacture of these hooks there are seven steps necessary. The first step is to straighten the wire and cut it off into suitable lengths, the straightening part of the machine being made up in Fig. 6. The next step is bending it into the form of Fig. 7 ; a press is then used to form an indentation at one end, as shown in Fig. 7 *A*.

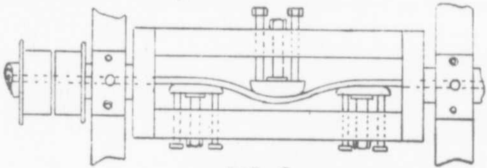


FIG 6

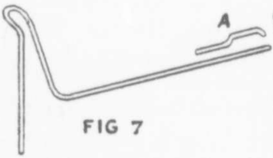


FIG 7

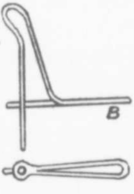


FIG. 8

FIG. 9

Next, the end with the indentation is bent over, thus doubling itself, and the indentation lies on the wire as in Fig. 8.

The indentation is now bent round the wire by means of a press, thus forming a very strong support.

The end *B* of the hook is bent up as in Fig. 9, and lastly a thread is cut on the end *C*, thus completing the hook. The thread is cut by a machine which works automatically, and consists of sets of dies or cutters. The first set of cutters commences the thread, and the next set does a little more, and so on till the thread is finished, when the hook is discharged from the machine, and it is only necessary to wash it and japan it, if desired, to put the hook on the market.

Cotter pins are usually made of half round steel wire, and are formed as in Fig. 10.

The wire enters the machine between rollers, which straighten it, and is fed by a clamp which holds it and moves it along the required length, which is a little more than twice the length of the pin. A knife, which is worked by a cam on the main shaft, cuts the wire, while a pin, with a vertical and horizontal motion, catches the wire, drawing it in between two dies which close on it, thus pressing it into shape and holding it long enough for a rapidly revolving cutter, worked by a cam, to trim off the end of the pin, and giving it a hemispherical finish which enables it to be easily driven into place. The jaws are then suddenly released, and the pin falls out of the machine.

In the manufacture of screws the wire is straightened in the usual manner between rollers, and "screw-blanks" are stamped out by machinery similar to that used in the manufacture of nails, differing only in the manner of cutting off the wire. The first step is to fix the head of the screw, and this is done by a machine which works automatically. The blank is held in a chuck, and rapidly rotated, while a chisel worked by a cam comes up and cuts the head down to size. The chuck stops, and a rotating circular saw comes up with a vertical and horizontal motion and cuts a groove in the head. The chuck rotates again and the chisel comes up, taking off the bur which was formed by the saw.

The blanks are then taken to the threading machine, which also feeds automatically and is a very complicated arrangement of cams and gears. The head is held in a chuck and rotated, while a chisel with a horizontal motion takes the point of the screw, then it is fed a little forward and a longer cut taken. The number of cuts taken is usually six, the last cut running the whole length of the thread and finishing it. After the sixth cut the chisel goes back, the screw is thrown out of the machine and another blank taken in. The screw is then cleaned by being shaken with leather shavings or sawdust, which puts a bright finish on it. The chisel, while the thread is being cut, is kept cool by means of soda water, which also gives a good cutting surface.

In the manufacture of wire chains the wire is passed between rollers and fed into the machine by a clamp, which has a horizontal motion derived from a cam working on an arm which may be altered, thus regulating the feed, and thus the length of wire which may be fed into the machine. The wire is cut off by a knife worked by a cam, while a pair of jaws with dies fitted into the end, and moving with a lateral motion, bend the wire pressing it round a vertical spindle which has a diameter equal to the inside diameter of the link. Another jaw clamps the two ends and folds them over one side of the clamp, forming the other end of the link.

The wire is now fed into the machine again, and passes through the last made eye. The jaw which has been holding the link is suddenly released, allowing the link to fall out, but it is prevented from going to the ground by the wire passed through the link.

When single wire chain is being made, there is only one end to be bent over, so that the only change necessary is the die in the clamp which bends the wire over.

In the manufacture of hooks and eyes, the eyes are formed in a very simple manner. The wire is straightened between rollers and fed into the machine by an arm working on a clamp. A hammer with a vertical motion strikes the end of the wire, forming an indentation, as in Fig. 11 ; then another hammer with a horizontal motion strikes the end and bends it over, thus forming the eye, as in Fig. 12.

A knife operated by a cam then cuts the wire, and the eye falls out of the machine.

A thread is then cut by a machine on the end of the eye.

The hooks require to be handled five times. The wire is straightened and cut off into the required length by a machine similar to that used for coat and hat hooks. The wire is then pointed at one end by a cutter, while the wire is held in a clamp, the machine feeding and emptying itself automatically. The wire is then pressed into the shape of Fig. 13 by hammers moving vertically and horizontally. The other end then has an indentation pressed out similar to Fig. 11. An eye is then put over the indentation, and the press, with a horizontal motion, bends the indentation over, thus finishing the hook, which is like Fig. 14.

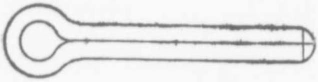


FIG. 10

FIG. 11

FIG. 12

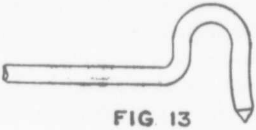


FIG. 13

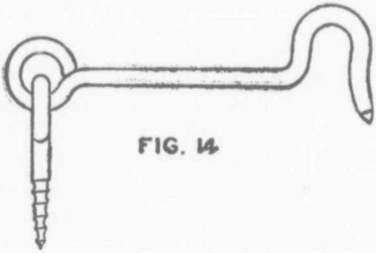


FIG. 14

Thursday, 1st February.

P. W. St. George, Vice-President, in the Chair.

Paper No. 88.

RAILWAY TURNOUTS.

By H. K. Wicksteed, M.Can.Soc.C.E.

Having had occasion to lay out a railway terminal yard not long ago, and being cramped for room and steel, and having frogs of only 2 or 3 numbers on hand, which, out of respect for the shareholders' pockets, he felt bound to use up if possible rather than have others made, the writer had quite a lot of figuring and scheming to do, and was struck with the utter inadequacy of the pocket-book tables and formulas.

In the first place, all the books with which he is familiar take a slide rail swinging on its heel through an angle of from 45 minutes to 3° as a point, or rather a line of departure, and with this as a tangent and the swinging end as P.C. start a curve running to the frog and proceed to investigate its form and length. This always has seemed to the writer wrong and clumsy, not only in theory but in practice. In the first place, the slide-rail is not a rigid bar, and no matter how well lubricated its bearings, a steel rail 24 to 28 ft. long will spring slightly in being thrown, and instead of forming a tangent to the lead there is an arc from the heel to toe and then a sharp elbow in the reverse direction.—(See Plate I.)

In the second place, the wheel path, even should it conform with that intended, is not theoretically or practically the most perfect. A sharp change in direction, necessitating an angular movement of the car truck about its center, then a piece of straight line necessitating a second movement in the opposite direction, and lastly a curve necessitating a third slight movement in the same direction as the first. Practically, I believe all these movements are rendered unnecessary by play between rail and flange, and a bodily transverse sliding on the rail; but, however they take place, here is a source of increased wear and tear and resistance.

Thirdly, the lead required is unnecessarily long, which means increased yard room and more steel than absolutely wanted; and lastly, and by no means unimportant, the mathematical formulas are so complex, that to my knowledge no engineer tries to figure them for himself, but takes what he can from the tables and leaves the balance to the foreman's eye, if indeed he troubles about the matter at all beyond pointing out the position of the head-block. Take, for instance, the following for the very simplest problem of all—to find the frog distance having given the throw of switch and frog angle, etc., copied verbatim from Trautwine's pocket-book:

$$\text{Frog distance} = 2\,(\text{gauge}-\text{throw}) \times \frac{\text{cotan switch angle} \times \text{cotan frog}}{\text{cotan switch angle} + \text{cotan frog}}$$

$$= \frac{2\,(\text{gauge}-\text{throw})}{\text{sin frog angle} + \text{sin switch angle.}}$$

It will be noticed that the denominators of the fractions preclude the use of logarithmic functions.

The writer asked one very painstaking and competent engineer of long experience, whom he found one day superintending the laying down of a double throw switch with somewhat unusual elements, how he obtained the positions of frogs, etc. He replied that he got them all by scale from a plot on a large scale—graphically, in fact, which is the way Trautwine recommends. Now, the author is far from being opposed to graphic methods, and is especially fond of them in his own practice; but in the case of complicated switch and turnout problems, the graphic method (except as a check on final results when it is invaluable) is extremely tedious, and necessitates a large amount of trial and error work, plenty of paper and table room and lots of time. A man cannot have all these things with him in the field, and more time is wasted in going to his office perhaps 30 or 40 miles and coming back with the results.

For above mentioned reasons, the writer long ago came to the conclusion that the lead of the turnout should be circular from the heel of switch to the point of the frog, the slide rail being part of the circular curve instead of external to it, and being bent around stop spikes driven into the ties to this circular form. So far, so good; and he believes that this is not only his own practice but that of many others. Now to find the frog distance. Let A, Fig. 2, be the frog, and a its angle. Produce its line to meet the opposite rail at P, then AP.C $= a$. Let g represent the gauge of track

$$AP = g.\ \text{cosec}\ a \text{ or } \frac{g}{\sin a}$$

but A.P. is the subtangent of the circular arc AB, and the angle being small the arc and chord are for practical purposes equal to one another, and also to the sum of the subtangents = 2 AP = frog dist.

Frog distance, $$F = \frac{2\,g}{\sin a} \quad (1)$$

Now the number of the frog is the reciprocal of the chord of the angle, or in small angles such as generally occur on railways practically of its sine. Thus a No. 10 frog has a chord or sine of $\frac{1}{10}$.

Hence approximately the frog distance

$$F = 2\,N\,g. \quad (2)$$

g being taken as 4.7 feet, a No. 10 frog will then have a frog distance of 94 feet. We shall see further on how well this agrees with another formula obtained in a different way.

F in this and subsequent formulas and equations means the distance of frog point from the heel of the switch instead of from the toe, as in the pocket-book tables we have quoted.

This last distance we shall refer to as the lead, and denote by the letter L. The length of slide rail we will call S.

g is the gauge, usually 4.7 ft.

T is the throw of switch, usually 5 inches, which for simplicity and with ample accuracy we may consider as ·4 ft.

Now to obtain the length of slide rail S. Take the diagram in Fig. 3, a simple turnout with a 1 in 10 frog. For such a small arc as 94 ft. we may consider the curve as being a parabola, and that the offsets from the tangent are proportional to the squares of the distances from the heel of switch or point of curvature.

Now at the toe we have an offset by hypothesis of T, or .4 ft. At the frog we have the gauge or 4.7 ft.

Hence $$\frac{S^2}{F^2} = \frac{T}{g}$$

$$S^2 = F^2 \left(\frac{T}{g}\right)$$

and $$S = F\sqrt{\frac{T}{g}} \quad (3)$$

For all ordinary railway cases T and G are constants

and $$\sqrt{\frac{T}{G}} = \cdot 29$$

Hence $$S = \cdot 29\ F \quad (4)$$

or in Fig. 3 $S = \cdot 29 \times 94 = 27.3$tfeet.

These three equations:

$$F = \frac{29}{\sin a} = 2\,N\,g = \frac{9.4}{\sin a} \text{ or } 9.4\,N$$

$$S = .29\ F$$

and $$L = F - s \qquad (5)$$

will solve all the simpler problems of single throw turnout, but in the double and treble throw something more is wanted. It was cases like Figs. 4 and 5 which set the writer thinking on the following lines.

Returning to Fig. 3 again, the offset from the tangent at the end of a 100 feet chord of a 1° curve is 0.87 ft., and increases proportionally to the degree of curvature. Hence for a curve of D° it will be .87 D and as above for any other distance (within moderate limits) from the point of curvature, it will be for n feet

$$.87\ D \times \left(\frac{n}{100}\right)^2$$

The total deflection in degrees at the end of this distance will be $\frac{Dn.}{100}$

Then for Fig. 3 we have $\left(\frac{F}{100}\right)^2 \times .87\ D = g \quad (a)$

$$\text{and} \quad \frac{F}{100} \times D = a \ (b)$$

$$\text{From } (a) \text{ and } (b)\ F^2D = \frac{10000\,g}{.87} \text{ and } F\,D = 100\,a$$

$$\therefore\ F^2D = 100\ a\ F$$

$$\text{therefore } 100\ a\ F = \frac{10000\,g}{.87}$$

$$F = \frac{100\ g}{.87\ a} = 115\ \frac{g}{a} \quad (6).$$

Substituting in (b) $\frac{100\ g}{.87\ a} \times \frac{D}{100} = a \quad D = .87\ \frac{a^2}{g} \quad (7).$

Substituting for—a and g—the same values as before, viz.:—1 in 10 or 5°.75—and — 4.7 ft., we get:

$F = 94$ ft. as before
$D = 6°.12$ or $6°\ 07'$
and $S = 27$ ft.
$L = 67$ ft.

Comparing with Trautwine's tables, we find for a 26 ft. slide rail, a lead of 72.7 or $F = 98.7$.

and $R = 877$ or $D = 6^\circ\ 30'$

We have therefore saved 4·7 ft. of lead or 9·4 ft. of steel, and got a slightly easier curve on it.

Lower down in the same table we will find that, with a 16 ft. slide rail, we will have a lead of 67.8 and a curvature of 6° 15′ practically the same as above, but with an angle at the heel of 1° 30′, which is rather abrupt for high speeds and certainly not as desirable as a continuous curve.

Let us now take up Fig. 4, a three throw switch with two 1 in 10 frogs, on the main line. We wish to determine the longitudinal position of the third frog. We have given the curvature $D = 6^\circ.12$ the offset for which for 100 ft. or $0 = .87\ D = 5.3$ ft. (from the tables).

Since the third frog is evidently in the centre of the gauge, we have the total offset $= \frac{1}{2}$ g or 2.35, hence the equation

$$\left(\frac{F_1}{100}\right)^2 \times 5.3 = 2.35$$

$$F_1^2 = 4434$$

$$F_1 = 66.6$$

$$L_1 = 40 \text{ (nearly)}$$

This last problem can of course be readily solved by a drawing, but not without considerable construction work and labour.

The following Fig. 5 is not quite so simple, but it is probably a better arrangement because no two frogs come opposite one other, and there is no point on the main line unprotected by a guard rail as there is in Fig. 4.

The frog in north rail, Fig. 4, being 1 in 8 from equation (2), we get:

$$F = 2\ Ng = 2 \times 8 \times 4.7 = 75.2 \text{ ft.}$$

from (4) $S = .29\,F = 75.2 \times .29 = 21.8$, say 22 ft.

$$(5)\quad L = F - S = 75.2 \times 22 = 53.2$$

$$(7)\quad D = .87\ \frac{a^2}{g} = \frac{.87 \times (7.16)^2}{4.7} = 9^\circ.49 \text{ or } 9^\circ\ 30' \text{ nearly.}$$

Now, to determine the position of the third frog, which is not now in the centre of track. The tangential offset for the south curve is as above, 5.3, for the north 8.3. If F be the frog distance on the north line, F + 6 will be that on the south, the switch being 6 ft. longer. This we may say, before going further, involves no difficulty in practice, the spikes on the north side being driven 6 ft., or 3 ties, nearer the toe than on the south.

Now we have for the distance of the frog from the north rail the expression $\left(\frac{F + 6}{100}\right)^2 \times 5.3$

from the south rail the expression $\left(\frac{F}{100}\right)^2 \times 8.3$

But the sum of these two is the gauge.

Whence we get the equation :—

$$\left(\frac{F + 6}{100}\right)^2 \times 5.3 + \left(\frac{F}{100}\right)^2 \times 8.3 = 4.7$$

$$\text{Simplifying—}(F^2 + 12\,F + 36)\,5.3 + 8.3\,F^2 = 47000$$

$$13.6\,F^2 + 63.6\,F = 47000—191 = 46809$$

$$F^2 + 4.68\,F + (2.34)^2 = 3442 + 5.5 = 3447.5$$

$$F + 2.34 = 58.71$$

$$F = 56.4$$

$$F + 6 = 62.4$$

$$L = 34.4$$

This determines the longitudinal position—substituting the above values in the expressions

$\left(\frac{F + 6}{100}\right)^2 \times 5.3$ and $\left(\frac{F}{100}\right)^2 \times 8.3$—we get the values.

Distance from north rail............	2.06
" " south "	2.64
	4.70

The angle of the frog will be the sum of the deflections of the two turnouts.

$$a = \frac{F}{100} \times 9.5 + \frac{F + 6}{100} \times 6.12$$

$$= \frac{15.6\,F + 36.6}{100} = 9^\circ.16 \text{ or } 9^\circ\,10'$$

A No. 6 frog, pinched a little with the crow or rail bender and with the point set back a trifle from the theoretical as obtained above, will fit the place quite well in practice; but if we wish to be very exact about it, the following analysis of the problem in Fig. 6, a double throw both on same side of main line will suggest a means of calculating. This is not a common combination, but it actually, or rather one almost identical with it, occurred in the writer's practice. One turnout was for a main siding and the other for a Y, and in order to save room and switch frames and unnecessary complication it was decided to start both from the same headblock. The main turnout was already laid with a 67 ft. lead and a 1 in 10 frog, as in Fig. 3. We had on hand a No. 6 and a No. 10 frog, which we desired to use. Putting the 1 in 6 first in the main line we get from equation (2)

$$F = 2g \times N = 9.4 \times 6 = 56.4,$$

or as in such an obtuse angle as 9° 32′ the sine and chord commence to differ appreciably—we may take the more exact value by (1) :

$$F = \frac{2g}{\sin a} = \frac{9.4}{\sin 9^\circ\ 32'} = 56.8$$

T is in this case 10 inches or .83 ft.

Substituting in (3) $s = F \sqrt{\frac{T}{g}} = 23.8$

$$\frac{F\ D}{100} = a, \text{ therefore } D = \frac{100\ a}{F} \pm (8)$$

$$= 16^\circ.78 \text{ or } 16^\circ\ 44'$$

We have still to obtain the position of the 1 in 10 frog—between the two turnout rails. Let x be the unknown distance from the point of the last one considered (the 1 in 6), and D the curvature per 100 ft. over this piece x.

Then $\frac{x\ D}{100}$ will be the deflection of the south turnout between the two frogs, and the total deflection from main line to point of 1 in 10 frog will be $\frac{x\ D}{100} + 9^\circ\ 32'$. On the north turnout the deflection to same point will be that for a distance $27 + 33 + x = x + 60$, and will be represented by the expression $\frac{x + 60}{100} \times 6^\circ.12$. But by hypothesis the difference between these is the angle of the frog or 5° 44′ hence the equation :

$$\frac{x\ D}{100} + 9^\circ.53 - 6.12\ \frac{x + 60}{100} = 5^\circ.73$$

$$x\ D + 953 - 6.12\ x - 367 = 573$$

$$x\ D = 6.12\ x - 13$$

$$D = \frac{6.12\ x - 13}{x}$$

Again we have for the lateral position of the frog from south rail of main line :—

on the north turnout $\left(\frac{x + 60}{100}\right)^2 \times 5.3$

on the south turnout $x \sin 9^\circ\, 32' + .87\ \mathrm{D} \left(\frac{x}{100}\right)^2$

$$\text{equating } \frac{(60+x)^2 \times 5.3}{10000} = .1656\, x + \frac{.87\ \mathrm{D}\, x^2}{10000}$$

$$(60+x)^2 \times 5.3 = 1656\ x + .87\ \mathrm{D}\, x^2$$

$$19080 + 636\, x + 5.3\ x^2 = 1656\, x + .87\ \mathrm{D}\, x^2$$

substituting the value of D in terms of x above.

$$5.3\, x^2 + 636\, x + 19080 = .87\, x^2 \times \frac{6.1\, x - 13}{x} + 1656\, x$$

$$= 5.3\, x^2 - 11.3\, x + 1656\, x$$

$$1009\, x = 19080$$

$$x = 18.9.$$

Substituting in the equation for D in terms of x above

$$\mathrm{D} = \frac{6.1\, x - 13}{x} = \frac{115.3 - 13}{18.9} = 5^\circ.41 \text{ or } 5^\circ\ 25'$$

Substituting in the expression for the offset or lateral position of the frog point, we have :

$$0 = \left(\frac{60+x}{100}\right)^2 5.3 = .789^2 \times 5.3 = 3.3 \text{ ft.}$$

Fig. 7 is a combination of the arrangements in Figs. 5 and 6, and is an example of a 4 throw switch, something not often seen in actual practice. For reasons explained further on, it would not be advisable to break up the sharp curve forming the lead of south turnout by inserting another frog. A 1 in 8 has therefore been instituted.

Making $\mathrm{F} = 75.2,\ \mathrm{D} = 9^\circ\ 30',\ \mathrm{S} = 31.6,\ \mathrm{L} = 43.6$

The only element left not solved as in the preceding is the position of frog between the extreme north and south turnouts and its angle.

Both tracks have now a curvature of $9^\circ.30$. $0 = 8.3$, but one curve starts 10 ft. behind the other. We have then the equation :—

$$\left\{\left(\frac{\mathrm{F}}{100}\right)^2 + \left(\frac{\mathrm{F}+10}{100}\right)^2\right\} \times 8.3 = 4.7$$

$$2\ \mathrm{F}^2 + 20\ \mathrm{F} + 100 = \frac{47000}{8.3} = 5662$$

$$\mathrm{F}^2 + 10\ \mathrm{F} + (5)^2 = 2831 - 50 + 25 = 2806.$$

$$\mathrm{F} + 5 = 53$$

$$\mathrm{F} = 48 \qquad \mathrm{L} = 26$$

Distance from south rail and main line as above

$$\frac{\mathrm{F}^2 \times 8.3}{10000} = 1.9 \text{ ft. or } 1'\ 11''$$

For the angle of frog we have:

$$a = \frac{2\ F + 10}{100}\ 9.5 = 10^\circ.07 \text{ or } 10^\circ\ 04'$$

It is quite possible to add a fifth track making a 5 throw switch; but as it necessitates 4 extra frogs and 8 guard rails, the extra complexity and cost will generally outweigh the advantages of convenience in operation.

Some of the writer's mathematical contemporaries, who discussed the transition curve, will, he feels sure, be dissatisfied with some of the above methods, because they are not precise. For the sake of simplicity in resulting formulas he has treated the curve of the turnout at one moment as a circular arc and at the next as a parabolic. He has assumed the sum of the subtangents as being equal to chord, and the co-sine of a considerable angle as being unity. His answer to them is that a difference of a few inches in the lead on either side will make no difference whatever in the practical utility of the results; and as frogs are made in a forge and machine shop, and not by a mathematical instrument maker, the errors in them will often amount to more than those due to the want of precision in the formulas. And, further, whether the curve be circular, parabolic or something a little different from either, matters not one particle, provided the radius of curvature is nearly constant and there are no sharp angles or breaks in it. The methods and formulas given above have been repeatedly tested in practice, and found to yield good results in every case.

On the other hand, some of the practical men will say that it is useless to spend time and figures on such work, and that a foreman with a good eye will run them out by himself just as truly as can be done by the engineer. The writer has been a good deal with track men, and has repeatedly officiated as foreman himself, and believes he has as true an eye as most. He has found that, if left to themselves, they will make, even the best of them, the most surprising errors, not of inches but of feet, in the simplest problems, such as in Fig. 3. The track layer, who is judged mainly by the quantity of work he does, will almost invariably get his leads too short; and the section-foreman, who is judged by the quality, and who sees the failings of his predecessor's work, is almost invariably impressed with the necessity for very long leads, and acts accordingly. As a matter of fact, a lead extremely long necessitates a sharp kink somewhere, just as an extremely short one does, and is only a trifle less objectionable and unsightly. Such problems as have been solved in the preceding with the use of only one unknown quantity may generally be worked out on the ground by any tolerably intelligent man by stakes and tape measurement, in some such way as Trautwine suggests, but this is merely a graphical solution on a full sized drawing. On a road where trains are passing and sometimes standing every few minutes, it will not be found a very economical method, especially when half a dozen or more men are waiting to go to work; and in any case it is a longer operation than the algebraic solutions given above. The problems above, in which we have used two unknowns, are almost indeterminate on the ground, except by the method of successive trials and approximations, which also is not economical of time.

Given the position of frogs and toe of switch, and almost any foreman may be trusted to make as fair a line as need be, especially if he bears in mind that at half the frog distance the offset from main line is just one quarter the gauge.

The whole subject is precisely one of those involving the commonplace details of a railway, which are so often neglected as too simple and well understood to be worth the attention of a first-class engineer. I have instanced one engineer who did not think so. These everyday details, if only because they are so often repeated, are those which really have most to do with the safe and economical operation of a railway; and I think the writer need make no apology for a further explanation of his deeming it worth while to study the question and to lay the results before the engineering fraternity.

Split switches are displacing the old-fashioned stub switches we have heretofore been considering for any service involving high speed. The advantage is of course the continuity of the rails and the absence of jar and jerk. The objections are higher cost and that they are not susceptible of being worked into 3 and 4 throw turnouts, hence they will probably never displace them altogether. The split switch differs essentially from the stub, in having a moveable rail planed down to a bevel edge having an angle of from 1 to 2 degrees, and moving into position alongside its neighbour instead of *vis-à-vis* to its end. There is thus an inevitable angle as in the stub switches discussed in the pocket books. As it is impracticable to bring this bevelling to an actual feather-edge, the virtual point is a foot or so back of the actual. For convenience of calculation and other practical reasons, which need not be gone into here, but which may be understood from a study of the diagram of the position of the wheels of an ordinary 8-wheeled engine on a curve (Fig. 8), the writer's practice is to consider this angle as merely an elbow in the continuous turnout curve, as worked out in the first example, Fig. 3, and the virtual point as the intersection point of the subtangents corresponding to the angle. If, as in Fig. 1, the frog angle be 1 in 10, the curve 6° and the angle of fly-rail 1° 30′, we shall have these subtangents 12.5 ft. each, the P. C. will therefore be 12.5 ft. back of the virtual, or 13.5 ft. from the actual point of the fly-rail, and the inner edge of this last must be straight for $11\frac{1}{2}$ ft., after which it will be bent to the curve of the turnout. Its total length must be at least sufficient to secure the necessary clearance for the wheel flanges, which we have heretofore taken at .4 ft. For an angle of 1° 30′ this will be 15 ft. and for 2° 11 ft. The total frog distance in Fig. 3 was 94 ft. Subtracting 13.5, we get 80.5 for the length of lead.

With these considerations borne in mind, the various problems for 2 and 3 throw turnouts may be worked just as in the case of stub switches. The writer has already said that 3 throw turnouts are impossible with the split switches, but it is quite common to find a double turnout arranged as in Fig. 9, with one switch a little ahead of the other. Except that the distances are longer, this is a precisely similar case to that in Fig. 5. The writer has already alluded to the diagram in Fig. 8. It is introduced for the sake of demonstrating the objection to a frog in the middle of a sharp curve. The leading driver will inevitably strike the elbow, if indeed it does not ride over it; and the trailer will wrench the guard rail badly. The truck wheels traverse well enough, and as both drivers tend towards the inside rail, the point of frog is easily taken care of. Hence, while the lead may be made fairly sharp with safety, there should always be a piece of straight or easy curve beyond the frog, hence the flattening in Fig. 6 in the south turnout between the 1 in 6 and 1 in 10 frogs. In regard to guard rails, they will be seen in the older roads made so as to be parallel with the main rail for quite a distance, with a sharp kink at each end. Fig. 10 *a*. These are required to be made in the forge. The writer has always been in the habit of making them as in Fig. 10 *b*, leading the stray wheel gradually into its proper line and then letting it go immediately the point of frog is passed. These can be made on the ground in a few minutes with a jim-crow and cold chisel, and he is glad to see them coming into general use.

If, as the writer believes, the methods and principles enunciated above have never been used in connection with turnout problems except by himself, he thinks the maintenance of way engineer will be well repaid by a study of them, as he has himself been in the increased rapidity with which he can arrive at accurate results, and (which is perhaps of more consequence) in clean cut easy curves and turnouts.

Inasmuch as the equations often involve large numbers, squares and square roots, he can never be far astray in plotting the results afterwards as a check on the arithmetical work. It is much easier and takes less time to plot a result than to arrive at it graphically; and as an evidence of its being worth while to employ some means of locating frogs and switches before going to work, it is only necessary to point out one or two of the many clumsy, ill-fitting ones which any tyro can detect in almost any large yard as the result of haphazard work under no system whatever.

DISCUSSION.

Mr. Irwin.

Mr. Irwin thinks that Mr. Wicksteed must be referring to some rather old books when he finds them giving formulæ or rules for turnouts based on straight swinging rails or switch rails. Trautwine's Pocket-book, edition of 1883, and all later editions, style straight switch rails as "old practice."

The tables in Parsons' "Track," edition of 1886, are based on curved switch rails; and Shunk's Pocket-book, edition of 1890, gives tables for both straight and curved switch rails.

The formula for frog distance, quoted from Trautwine, does not appear in the later editions, and there appears to be a misprint or error in the reduced formula, which should be

$$\frac{2\,(\text{gauge} - \text{throw})}{\tan \text{frog angle} + \tan \text{switch angle}}.$$

This of course reduces readily to

$$\frac{2\,(\text{gauge} - \text{throw}) \times \cos \text{frog angle} \times \cos \text{switch angle}}{\sin\,(\text{frog angle} + \text{switch angle})}$$

which is adapted to calculation by logarithms.

The formula (2), $F = 2\,N.g.$, is given in Trautwine, edition of 1883, and seems to have been used for some time; indeed this and some other very useful formulæ may be found in *Engineering News* of the 11th January last, on page 33.

The speaker notices that Mr. Wicksteed has recourse to the parabola to get the offsets to the curve proportional to the squares of the distances along the tangent. Instead of assuming the curve approximately a parabola, it would seem to be simpler to state that for a flat circular arc the offsets vary approximately as the squares of the distances on the tangent, since in a flat arc, of radius $= R$, chord $= 2\,s$ and rise $= r$, $s^2 = 2\,R\,r$.

The speaker quite agrees with Mr. Wicksteed, however, that a difference of a few inches (and often a difference of a few feet) is of very little practical importance in the length of the lead, which might just as well be on a transition curve as not.

As for the length of the switch rail, or sliding rail, it does not seem to be necessary to make it more than about 24 feet so as to leave enough to spike down out of a 30 foot rail. Mr. Wicksteed's formula No. 7, $D = \cdot 87 \times \frac{a^2}{g}$, does not seem quite so handy as the formula given in the number of *Engineering News* above referred to, viz. :—$D^\circ = \frac{600}{n^2}$, which, when $n = 10$, gives $D = 6^\circ$ instead of $6^\circ\ 07'$ as by Mr. Wicksteed's formula, the more exact formula when $T = 0'{\cdot}4$ and $g = 4'{\cdot}7$ being $\frac{608}{n^2}$.

The speaker thinks that Mr. Wicksteed has deduced his formulæ in a much neater and more practical style than that to be found in most books on the subject, and that the entire paper is worthy of the study of those who wish to be well posted on the subject.

Mr. Wicksteed's formula for length of switch rail, viz. :— $S = \cdot 29 \times F$ is perhaps simpler if reduced to give S in terms of N by substituting $\cdot 94 \times N$ for F, from which we get $S = 2{\cdot}73 \times N$.

There are thus three formulæ for F, S and D in terms of N only, viz. :—

$$\begin{array}{llll} (1) & F = 9{\cdot}4 \times N & & \\ (2) & S = 2{\cdot}73 \times N & \text{and if } N = 10 & \left\{\begin{array}{l} F = 94' \\ S = 27'{\cdot}3 \\ D = 6^\circ\ 05' \end{array}\right. \\ (3) & D^\circ = \dfrac{608}{N^2} & & \end{array}$$

to which add (4) Radius of turn-out curve $= 9{\cdot}4 \times N^2$

The throw being taken as $0'{\cdot}4$ and the gauge as $4'{\cdot}7$. If the gauge be $4'{\cdot}75$ and the throw $0'{\cdot}42$, the formulæ would be slightly changed as below, viz. :—

$$\begin{array}{llll} (1a) & F = 9{\cdot}5 \times N & & \\ (2a) & S = 2{\cdot}85 \times N & \text{and if } N = 10 & \left\{\begin{array}{l} F = 95' \\ S = 28'{\cdot}5 \\ D^\circ = 6^\circ\ 02' \end{array}\right. \\ (3a) & D^\circ = \dfrac{603}{N^2} & & \end{array}$$

(4*a*) $R = 9{\cdot}5 \times N^2$

the values given by Mr. Wicksteed being $F = 94'$, $S = 27'{\cdot}3$ and $D = 6^\circ\ 07'$, all three being practically the same.

In Shunk's Pocket-book, edition of 1890, there are two tables of quantities required in laying out curves: one calculated for a straight moving rail and the other for a curved moving rail. These tables are calculated for various lengths of moving rail, and are the most complete the speaker has seen.

The speaker thinks that the 6° 30′, quoted as taken from Trautwine's tables, is probably for the old style of switch with a straight switch rail.

Mr. MacPherson

Mr. D. MacPherson said the author of the interesting paper on Railway Turnouts has put into simple formulæ most of the cases to be met with in practice, but he surely is not justified in assuming that the current books, and most members of the profession, still adhere to the ancient method of starting a turnout curve at the toe of a stub switch rail. The writer has an 1885 edition of Trautwine, in which the improved method advocated by the author of the paper is fully set forth, and most of the necessary formulæ are given, though they are not in as simple a form as those given in the paper.

The frog distances given by Trautwine are almost identical with those deduced from the author's formula $F = 2\ N\,g$ which he only claims to be approximate ; but for a 1 in 10 frog this formula would give $F = 94'{\cdot}16$, and worked out mathematically, the chord is $94'{\cdot}14$, which surely might be called absolutely correct in practice.

In the example given to find position of central frog in Fig. 5, the author takes from tables $5'{\cdot}3$ as the offset from tangent, for a chord of $100'$ of a $6°\ 12'$ curve. This does not appear sufficiently close when dealing with the lateral position of the frog point, as the offset is really $5'{\cdot}39$, which would give a difference of $\frac{6}{16}$ inch laterally in the given frog distance of $56'$, and the frog point would be that much out of line, which would give it a serious blow every time a truck passed. The writer cannot either see the advantage of thus using leads of different lengths in a three throw turnout, for it necessitates two guard rails more than when equal leads are used, and in latter case the wing rail of each frog always forms a guard for the point of the opposite frog. Most of the author's formulæ appear sufficiently accurate for practical purposes, but the writer cannot agree with his general statement that the fact of frogs being often inaccurately made is any reason for using only approximate formulæ for laying them. The formula and the frog might vary in the same direction, and thus cause a very appreciable error. All main line frogs should be tested for accuracy, and none used which were not true.

With regard to form of guard rail advocated by the author as shown at "*b* fig. 10," this being one continuous curve, a flange bearing against it would be changing its direction up to the very point of frog, and would not pass the point when moving in a direction parallel to the main rail, which parallel direction is desirable.

The standard guard rail in use on the Canadian Pacific Railway has a straight portion in the centre 3′ 6″ long or 1′ 9″ on each side of the frog point, and then curves off easily towards each end.

The long straight guard rail with sharp bend at each end, as shown at "*a* fig. 10," would be very objectionable for fast main line service.

Mr. C. B. Smith said: It did not appear that any allowance had been made for the straight frog; there must necessarily be 5 feet straight in the frog itself, and, over and above, a curve cannot be ended exactly at an angle plate or any other fastening, therefore he thought it best to allow 6 or 7 feet straight at that point. Again, a switch rail, in split switches, is straight; it must be; this is therefore a tangent to the curve. These two facts narrow a curve down considerably. The practice he had met with had been to establish standard frogs and lengths of moveable rails for use on the road, then draw large size diagrams which will fix the lead, etc. He did not see how one set of tables could be well adapted to both leads of stub and split switches. Mr. Smith.

Any road will get along with two numbers of frogs very nicely, say No. 7 and No. 9, and with one or two lengths of moveable rails; and, as trackmen never cut rails unless obliged to, it will be found that two rails short or full length are put in between the heel of the switch and end of frog; the lead must take care of itself. A little care in the selection of rails will make this do very well indeed for a No. 7, No. 8 or No. 9 frog, in which the correct distance with 24 foot split switch rail would be 49 feet, 54 feet, and 60½ feet respectively to the end of the solid frog.

Mr. Wicksteed said:—Replying to Mr. Irwin's criticisms, the author thanks him heartily for his corrections, which seem on every point to be just. He (the writer) has used his own methods and formulæ for several years, and was not aware that Trautwine had published the newer formula based on the circular slide rail until within the last few weeks. Nearly 20 years ago the writer remembers discussing with some other engineers the wisdom of the old method of a straight slide rail tangential to the curve of the lead, and as a result he abandoned it for the circular form, but the formulas in the paper were not deduced until some years later.

In reply to Mr. McPherson, he would say that the more acute the angle of the frog the more nearly exact is the formula $F = 2Ng$ — with the blunter frogs such as are practicable in the case of 4-wheel switching engines, and on narrower gauges of track the formula is not so nearly exact as in the case of the 1 in 10 frog he gives as an instance.

Mr. McPherson is evidently well versed in modern methods, but the writer believes that a great number of the older members of the profession still adhere to the straight tangential slide rail. In the case of ill made frogs, the proper method would evidently be to take the angle as it actually is, and make the lead to correspond, instead of assuming it correct and giving it the lead, for which it was intended, hence the reason for fully understanding the theory of the matter and the evolution of formulas to meet such cases. The C.P.R. standard guard rail is a very good one, but the writer thinks that if he studies some of the older and more conservative roads he will find the form A, Fig. 10, to be the rule.

To Mr. Smith the author would say that 5 to 7 feet of straight line in any curve of moderate radius will not materially break the line of the curve, and may be neglected in computation. If Mr. Smith will read the portion of the paper dealing with split switches again, he will find the writer has dealt with the question of straight parts of "fly" or switch rails, and explained how he adapts the one set of formulas to turnouts of either pattern.

Mr. McPherson has called attention to a fancied error in the offset used in one of the examples. The curve in question was 6°.12 or 6° 07′, not 6° 12′, as Mr. McPherson has taken it. The offset for a 6° 05′ curve, which the author took as being near enough for his purpose, is 5.308, practically 5.3 as assumed.

Friday, 9th February.

G. C. Cuningham, Member of Council, in the Chair.

Paper No. 89.

METAMORPHIC AREAS OF KEEWATIN.

STUDENT'S PAPER.

By J. C. Gwillim.

The district, or rather region, which is under consideration lies in the Laurentian country north of the C.P.R. and the Lake of the Woods; throughout this region there are more or less isolated patches of altered sedimentary rocks. These rocks are plainly of aqueous origin, and are quite distinct from the crystalline body mass in which they occur. They are of much the same character as the Lake of the Woods formation, without being of as great extent individually. No traces of superficial igneous action was observed in any of the areas, all metamorphism having apparently taken place under conditions of great pressure as well as of heat.

The sketch map (Plate 9) accompanying this essay is taken from a chart of surveys by Mr. D. B. Dowling of the Geological Survey, and contains many improvements and additions upon the older maps of this region,—the result of careful exploration and survey during last summer. It will be readily seen how greatly the crystalline rocks predominate, leaving but occasional patches of what must once have been a great sedimentary formation over-lying the whole country. The exploration and survey of this district began at Wabigoon. It was continued northwards to the head waters of the Berens River and Cat Lake. Several independent excursions were made into the different water-ways of this region, giving us a much more comprehensive knowledge of the extent and position of the metamorphic rocks, together with their relations to the regional gneiss which everywhere flanks them in.

The Huronian areas seem to thin out as one goes northwards from the line of railway, until the height of land between the Winnipeg River drainage and that of the Beren's River and Albany form a natural boundary to the main district in which they occur.

As these metamorphic areas are not large, it is possible to observe their contact with the more crystalline rocks in many places, except that this region is heavily wooded, causing an obstruction to the clear definition of contact lines. Moreover, such a state of things contributes to hasten decomposition of the rocky floor, so that one does not find here the same bright and fresh exposures of rock as are met with on L. Winnipeg, where the reef rocks are continually being washed by waves. Besides this, being of a more basic character than the latter, they have suffered greater chemical decomposition since the ice sheet passed away.

The appearance here and there of highly inclined schists cropping out beside the water's edge gives one too little data upon which to form elaborate theories of bedding surfaces and the constitution of anticlines and synclines.

The first band of these altered Huronian rocks is noticed some four miles north of Wabigoon Tank, and it is found to occur in a chain of long narrow lakes trending to the N. E.

The chief of these lakes is Lake Minnitakie, and strikes south-westerly. Its shores are lined by a coating of nearly vertical schists. These schists and the deep narrow lake conform to one another in a remarkable manner, and what was noticed here is fully borne out by further exploration, in going to shew that there is a close relation between the strike of the schists and the longer areas of the lake basins. Although in some cases we find lakes which do not run south-westerly or with the strike of the rocks, such lakes will generally be found to occupy basins which are of a more crystalline character. Lac Seul is a notable example of such a crystalline basin. Still, as Dr. Lawson pointed out in his report of the Lake of the Woods district, the basins of water are, as a rule, lined by a coating of more or less soft and easily cleavable schists.

Deep bays trend off from Lake Minnitakie, and these probably occupy former areas of easily decomposed rock, or rock which offered but little resistance to the all-pervading ice action which is so plainly marked on every rounded bed of rock in all the country northwards of the International Line.

Between the northern limits of Lake Minnitakie and Lac Seul, there is a local height of land. At this point the schists give place to rocks of a more crystalline character. These continue on until Lac Seul is reached, and they predominate in all the Lac Seul basins. As it was observed before, Lac Seul does not conform physically to the majority of lakes in this region, and from this fact we might have anticipated its geological character as being of a different order. This surmise would be quite correct, for with the exception of a few very small patches of hornblendic schists the whole lake basin is gneissic.

The lamination of this gneiss is generally south-westerly to north-westerly, and is often of a porphyritic character. At some points near the H. B. post there are some hills of glacial sand and clay, 60 to 100 feet above the lake level.

Very little of its waters come in from the south, which would go to show that there is a local height of land not far back, the same barrier possibly as that one which constitutes the lip of the Red Lake basin further to the westward. Lac Seul empties at its western end by the English river, which river continues to run along a little north of the aforementioned barrier until its junction with the Mattawa, a river which drains the Red Lake region. The two combining form a very respectable river, which, after flowing a few miles southwards, pitches over the gneissic barrier by a succession of fine falls, until it finally joins the classic Winnipeg River and pours rapidly down into Lake Winnipeg. Between Lac Seul and Mattawa the gneisses become more contorted and more finely laminated, often curving visibly within a few yards, while many of the bands are garnitiferous. This apparent bedding of the gneiss is not very noticeably conformable to the course of the river. Indeed, the river itself is but a series of depressions filled with water, contracting here and there where heavier and more resisting rock has blocked the way. At these places the gneiss is well banded, and strikes directly across the stream which seems to spill over into a somewhat softer formation below it. The general strike of the gneiss along this part of the river is N.W., which is diagonally across it in the main. On reaching Mattawa the strike becomes more westerly, and further south it is fairly conformable with the course of the river.

On ascending the Mattawa river the schists are again met with; they occur as the outliers of the main metamorphic area lying about Red Lake. These are but in narrow bands alternating with gneiss, both of which formations are tilted at high angles to the south-east, and strike south-westerly.

In the chain of small lakes hereabouts one generally finds the western shores more schistose in character than the eastern ones, while islands occurring in the mid lake have a composite character, being mainly gneiss with inclusions of harsh hornblendic schist, or if of schist, ramifications of gneiss are seen to penetrate it in all directions. In every case it is the gneiss as a molten magma conforming to the irregularities of the Huronian, not *vice versa.*

Sometimes angular blocks of hornblendic schist may be seen scattered through the gneiss like pieces of mosaic, set in the more crystalline floor. These blocks may be found at great distances from the main bodies of the schist mass.

Some dykes of dark basic rock occur here, and a few veins of pegmatite or bosses of red feldspathic intrusions, but they appear to have had little effect in disturbing the position of the schists, cutting through indifferently at all angles, the most noticeable effect being a greater degree of crystalline form in the adjacent beds.

This stretch of alternating gneiss and schists continues until the eastern end of Red Lake, at which point beds of hard green schist occur. This is very much contorted, and is ramified by thin veins of quartz. Green rock of this nature is characteristic of much of the Huronian belt. Its position is usually next after the more highly altered hornblendic schists, being two places removed from the gneissic magma matter.

A section taken across the eastern end of Red Lake from the point where the river leaves it to the north-eastern bay by which it enters showed strike of the rocks very nearly north and south, being 180° to 200°, with a dip of from 85° to 75° west.

The chief characteristic of this portion of the lake is the occurrence of granite masses intruding through the schists. Just where the granite joins or comes in contact with the altered rocks is hard to find, for the igneous masses have so metamorphosed the beds of sedimentary rocks that they become almost identical in colour and texture, as seen without a microscope. Also new planes of strike or cleavage seem to have been induced in them, giving the whole a massive and block-like appearance, quite unlike the schistose structure of the rocks somewhat further removed from the seats of intrusion.

This gradation without a clear definition of contact does not occur in any other place noticed in this region. Usually the line of contact is very decisive, especially where the more feldspathic intrusive masses join the hornblende schists. At other places, owing perhaps to a similarity of colour, the line of contact is harder to see, but is just as definite, when one considers the texture of the adjacent rocks.

On leaving this lake by the river which enters the N. E. Bay, the formation again undergoes a transition from schists to bands of gneiss. The schists are sometimes weathered in a curious corrugated manner, just as a gigantic eozoon might appear when decalcified, leaving only the network of unattached mineral. The undecomposed surfaces are polished, and have almost a metallic lustre. The pits and canals between them are a few inches deep and often without decomposition colours. Dykes of granite pierce the schists in this vicinity ; as usual, they cause little or no deflection of the bedding, simply giving a more crystalline character and inducing new cleavage planes with a general massiveness. An expedition northernwards to Pegangeham Lake showed only crystalline rocks of a dark basic character. These constitute the height of land between the Red Lake basin and the Berens River and Albany.

The upper arms of the Berens River are in crystalline troughs, and it is not until on turning southwards after recrossing the height of land that Huronian rocks are again met with.

Immediately upon passing over the height of land, a series of long narrow lakes is traversed. These trend south-westerly and lie in a great basin of metamorphic rocks, stretching eastwards indefinitely. This trough is enclosed by rather high hills composed of nearly vertical schists running parallel with the water-way. These hills are higher than the granite masses observed on first entering the area, which seems odd if we regard the present contour of the surface as due to glacial action. Yet before becoming decomposed, these more easily broken schists may have offered as much resistance as the granite itself. Besides this, there is reason to believe that although the ice may have polished off rocks so smoothly that their constituents look like mosaic work, yet they did not absolutely plane off great depths by sheer weight and motion. They had probably an action more allied to the nature of sand-paper, not a rigid cutting surface.

The schists of this district are very varied and very interesting. Many of them are finely cleaved. Some are almost flinty in character. At one place there is a low reef of magnetic rock, a compound of iron and sulphur probably. This the Indians use as medicine, no doubt deriving benefit from the sulphurous fumes given off upon roasting it.

RED LAKE.

This lake is the chief and centre of the metamorphic areas. Schists of almost every colour, cleavage and hardness are found within its basin.

Besides the intrusive masses mentioned as occurring at the eastern end, there are granitic flanks upon either side of the lake, a little way back from the shores. Half way towards the west end the granite flank of the south turns in toward the lake and cuts across it.

the contact of the schists with it are decisive and well defined, without much of the mixing of the two as is usual upon the flanks of the altered areas.

At the western end, there is a rapid succession of beds, from massive-looking rocks holding roundish quartz crystals to soft chloritic schists. One narrow band of crystalline limestone is found here, the only one observed, neither is there any appreciable amount of quartzite, so that these rocks are not by any means perfectly analogous to the typical Huronian. Dr. Lawson, impressed with this difference of lithological character, called the Lake of the Woods series the "Keewatin" to distinguish them, and both of these areas correspond in most respects. There is a general turning of the strike from the east end of this lake, where it is north and south to S. W. and finally N. W. at the western end. This may be due to the pressure of the half-moon-shaped granitic flank which lies to the South.

At the contact line the schists conform to the boundaries of the main granitic or gneissic area.

METAMORPHISM.

All these occurrences of metamorphic rock seem to go to prove that there is no rule for their occurrence. The physical geography is in some measure a guide as to what may be expected, for owing either to peculiar bedding or greater ease of disintegration these areas are usually found to occur about lakes and water-ways. However, some of the most abrupt and conspicuous hills are also of schistoze character. The trend of the general strike is southwesterly, glaciation also is in the same direction. This is but a coincidence, yet it afforded a line of less resistance to the moving ice in the direction of cleavage, so it came about that deep longitudinal troughs were worn out. Granitic hills are rarely very abrupt or high in this region, but in the altered patches there is a much greater difference of heights between the lake surfaces and boundary hillsides. It is hard to give the gneiss a parentage; what it was originally can hardly be determined from its present occurrence in this district. Whatever it was or whatever it came from, it was most certainly in a molten or plastic condition when the metamorphic or Huronian rocks here came into their present relations to it. This is proved at every contact line where it has adapted itself to the fissures or fragments of the shattered sedimentary rocks.

Concerning the areas considered, the gneissic structure, although in finely laminated layers of alternate light or dark material, has a wonderful evenness over great distances; their strike and cleavage are almost always somewhat different from that of the schists, and they are definitely distinct from these both in texture and colour. Certainly at the contact the gneiss conforms, or the two conform rather—but this conformity does not extend far back, the gneiss having a broad banded trend of its own.

Considering the fact that at the main contact of the crystalline and metamorphic areas the schists are always found crushed and fractured, while the gneiss has insinuated itself through all, we are led to believe that at any rate the gneiss was in a semi-fluid condition and has since crystallised out into its distinctive mineral lands. One thing is certain, that this gneiss was quite soft before it became gneiss at all, and that if it were heated to such a degree as this softness implies, any original bedding or sedimentary characters which it may have had would be totally destroyed, so that we cannot regard the banding of these gneisses as the beds of original sedimentary rock.

Besides this, their area is so great, that if we take them vertical, as they are, we should have to account for such a thickness of strata that one can hardly credit the earth with at so early a period of its existence.

That this molten magma pushed the old beds of the Huronian up and down or side ways is to be seen by the great variations of strike where the metamorphosed areas are very limited. So various are these planes of striking that one is forced to conceive that the beds were burst up by the magma and then settled back, sinking sideways along the surface of least resistance, which would account for the high angles at which they dip and for their want of systematic arrangement in relation to one another. Lateral pressure then forced them together and gave the alternation of beds. The fact that there are definite beds is established in many places. At others there is no proof that the strike is not a cleavage plane induced by lateral pressure.

GLACIAL PHENOMENA.

A great moraine of over 200 feet high extends northwestwards along the southern shores of Trout Lake. This lake is wholly gneissic like Lac Seul. The chain of hills forming this moraine was first observed south of Red Lake. It was crossed again upon the head waters of the Berens River, and the Indians informed us that it ran all the way between these two points, and past Trout Lake. Their mass is made up of boulders and sand, no distinct beaches were observed upon the slopes, or any sign of stratification.

Upon Lac Seul there are high sand hills of stratified banded nature clearly laid down in water and during glacial times ; they rest upon a polished and striated floor of porphyritic gneiss, and are overlaid in their turn by great boulders. A few boulders occur in the sand mass, but there seems to be an absence of boulder transportation during its depositions. In a cliff of this sand and till, near the H.B. post, there is an interesting illustration of lateral pressure, due probably to floating ice. A thin stratum of fine till is folded most beautifully into a model series of anticlines and synclines, while the strata above and beneath it rest undisturbed.

The conditions necessary for the formation of these hills of glacial till would call for an extension of water which would totally submerge all barriers to the southwards, and give to Lake Agassiz a depth and extent much more vast than is at present conceded to it. Such conditions of surface level in this locality may, however, have prevailed, that these hills were deposited in a lake of only local extent. As the present elevation is, this could not have been so. Lac Seul itself is several hundred feet above the level of Lake Winnipeg. So that any glacial sea which submerged it must have stretched over all the country between, as the present elevation of land is disposed.

The glaciation of this district is mainly S. 40° to 50° W. It conforms to the shape and hardness of the rocky floor in some degree ; at places curving grooves may be seen to vary from S. 35° W. to S. 50° W. within a few feet. Evidently there were great local flexions of the ice sheet even to rotation, whereby great holes were gouged out, while soft schists have escaped in many places.

Upon the east shore of Lake Winnipeg there is a bank of Palæozoic sandstone as soft as clay ; this still stands amid a region of glacially polished crystalline rocks as a monument to geological possibility and proof of local relief and local pressure of the ice cap.

Thursday, 15th February.

S. I. Cunningham, Member of Council, in the Chair.

Paper No. 90.

LOCATION AND CONSTRUCTION OF THE GREAT NORTHERN RAILWAY IN THE ROCKY MOUNTAINS.

By Jas. H. Kennedy, M. Can. Soc. C.E.

The Great Northern Railway system, composed of the old St. Paul, Minneapolis & Manitoba, Montana Central, Eastern Minnesota, Fairhaven & Southern and other railways, under the control of Mr. J. J. Hill, is the last addition to the increasing number of transcontinental railways competing for business between the Pacific slope and the East. The surveys for the Pacific extension of this system were begun in the year 1889, and, with the exception of the Cascade tunnel construction were finished in 1892, so that by the use of a switchback in the Cascades, the line was opened for through business. This line is unique in being the only through line ever built over the Rocky Mountains without government aid either as a subsidy or land grant; and it is claimed to have advantages in the way of grades, distance, etc., over its competitors. This of course is the second line over the summit of the Rocky Mountains owned by this company, the other being from Helena to Butte City, Montana.

This paper is written with a view to giving the members of our Society a little information with respect to the details of the surveys and construction in the main range of the Rocky Mountains, with the hope of provoking a discussion that may elicit from others possessing it, more complete information, as well as to draw forth a comparison with the other transcontinental lines, or with similar work elsewhere; and let it be remembered that the information here intended to be given is limited to the Rocky Mountain section, or say to the part between Havre on the east and Kalispell on the west side of the range,—a distance of 260 miles. Of this 260 miles the first 150 from Havre to Blackfoot was mostly ordinary prairie work, and offers nothing specially interesting, except indeed the two high bridges crossing the Cutbank and Two Medicine Creeks. These bridges will be noticed later. Again, on the west side from Coram to Kalispell, 25 miles cannot be said to be mountain work, although quite as heavy in one or two places. That leaves an intermediate distance of some 85 miles that may fairly be called mountain work, and it is to this latter district that this paper is more particularly intended to apply. (See Map, Plate VI.)

The general route selected to be explored was through the Marias Pass and down the Flathead River to the Flathead Valley, and the exploration was made in the winter of 1889 and 1890 with great difficulty by an engineer on snow-shoes, aided by old trappers and hunters. The plan decided on was to start in from the west side of the range and follow up the middle fork of the Flathead River to as near as possible to the Marias Pass, and to return from the Pass by following down a creek, since called Summit Creek, some 12 miles to its outlet into the Middle Fork of the Flathead, thence down this latter river to the Flathead Valley. The difficulties and hardships met with in making this trip in midwinter with several feet of snow on the ground in the face of cold and hunger, and in which the participants were at one time feared to have been lost, cannot be very well described, but can be appreciated by those who subsequently passed over the same ground. The route, however, was reported as quite favourable, the elevation of the summit being about 5200 feet, with no insurmountable difficulties to be overcome.

The route leading up to the Pass from the East had been known for some time to be quite practicable, the writer being unable to say who explored it, or who discovered the Pass. It is claimed by some, however, that the Pass was known to the Indians for nearly a century, and had been used by traders of the Hudson Bay Company. Be that as it may, there is still to be found the evidence of an old and pretty well defined trail leading up towards the Pass from the west side, but it divides up and becomes so obscure in places that it is hardly possible for a stranger to follow it up. Indeed, a party who made the attempt was after 10 days search for the Pass compelled to return for a guide without having found it.

In the spring of 1890, three survey parties were placed in the field to make preliminary surveys. One party started westward from Havre. The second was started nearer the foot of the mountains to work westward, while the third was started from the west side of the range with instructions to work eastward up the middle fork of the Flathead river to meet the other party working westward in the mountains.

The progress of surveys in the mountains was necessarily slow on account of the difficulties to be overcome. Supplies had to be forwarded by pack train, and the trail had to be cleared, and in places graded. Again, the season was very wet; indeed it rained more or less every day from the 12th of May until the 4th of July. This kept the stream crossings so high that supplies had to be ferried on rafts and the horses had to swim. Another difficulty was the scarcity of horse feed, there being but a very few places where grass could be found at all; consequently, when the pack train arrived at camp with a cargo, it was always necessary, rain or shine, to move camp hurriedly, and get the horses out to feed as quickly as possible. This, of course, made moving camp very disagreeable, as the rain never omitted to pour on moving days. The two parties in the mountains met on the 30th of July, about 20 miles west of the summit, and, according to instructions, each turned and located back over its own preliminary.

On the prairie, of course, camp outfits and supplies were moved forward by wagons, but in the mountains the pack train was the only way practicable. The usual load for a pony or cayuse was from 150 to 200 lbs., and the average expense 75 cts. per day for each animal, with $60 per month for the "head packer," and $40 to $45 for each assistant. A man who doesn't understand the "diamond hitch," by which the pack is "cinched" to the horse, is useless with a pack train. This work was all done with hired animals, but it is very probable that it could be done as economically and in other ways more satisfactorily by purchasing the animals and placing an experienced man in charge of them.

There were a few places along Summit Creek and on the Flathead that showed evidence of former snowslides where the timber had been stripped off in streaks from the top of the mountain to the bottom; but there seemed to have been no slides of recent occurrence, and they had no influence on the location, the plan adopted being to make the location to suit the ground, and decide on the protection of the roadbed from snowslides afterwards if it should be found necessary. From the summit down Summit Creek, the fall is such that the grade (a 1.8 p.c.) crosses the Flathead at the mouth of the creek about 140 feet above the water, and the valley of the middle fork of the Flathead from here for a few miles down the river may be said to be reasonably straight. This valley, however, is about 120 feet above the water, and the stream meanders from side to side, so that at each point where the stream cuts into the side of its valley, there is a cut bank extending up the side to a higher bench. The work of carrying the survey lines over the face of some of these cut banks was both difficult and dangerous on account of the liability to slip down, and also on account of the stones that were continually dropping as they became loosened. The material was cemented gravel. Further down the river the rock closed in on both sides, forming a canon for several miles. Through this canon the grade line was carried about five feet above high water mark.

The following instructions for the location were given by the chief engineer, viz.:—

Limit of curvature,	10°
Shortest tangent,	200′

These limits were strictly adhered to during the location. There were no transition curves used, strictly speaking, in the location, but where practicable, the sharper curves had one or two stations at beginning and ending with twice the radius. For instance, a 10° curve would begin and end with a station or two of a 5 where there was room to get it in.

The following data were also laid down by the chief engineer as a guide in making location, viz.:

One foot in distance is worth $10.
" " rise and fall up to 10 ft. is worth nothing.
" " " " over 10 ft. " " $500.

Or in other words, a summit of 100 ft. is equal to a mile around.

One degree of curvature is worth $50, or that amount might be expended in order to eliminate one degree of curvature.

These, of course, were not intended to be very exact values for curvature, distance, or rise and fall; but considered to be somewhere near the truth, or near enough for all practical purposes; so that, by using these figures in calculating alternative locations, no very great error of judgment could take place in deciding which to adopt. These figures, with a list of approximate prices for rock, earth, bridging, tunneling, etc., were adhered to during the location, which was completed with the exception of a few minor revisions in January, 1891.

As to grades, suffice it to say that the summit is reached from the east with a maximum grade of one per cent. From Summit to Essex, about 14½ miles, there is a down grade of 1.8 per cent., and from Essex westward to and across the Flathead country, the maximum down grade is 0.8 per cent. with a maximum of 0·6 per cent. against west-bound traffic. Compensation for curvature at the rate of .04 per degree was used on all maximum grades.

In the fall of 1890, while the location in the mountains was progressing, a supply road was begun from each side of the range and carried to completion shortly after the completion of the location, or about the first of February, 1891. The weather during the early winter had been very favourable, and very little snow had fallen; otherwise it is doubtful if the supply road could have been completed that winter, as snow began to fall on the 1st February and continued until it was six or seven feet deep. It continued quite stormy until April. The supply road, however, was no sooner completed than contractors were on the ground engaged in hauling in supplies and opening up their heavy rockwork.

Construction operations were carried on simultaneously from both sides of the range. The necessary supplies for the west side had been shipped from St. Paul to Ravalli, a station on the Northern Pacific, west of Missoula, and hauled from there 30 miles to the foot of Flathead Lake. Thence taken by steamboat to Demersville, 60 miles, and stored there before the close of navigation on the Lake. Demersville thus became a distributing point for the work both east and west of the Flathead country.

Grading was classified under the four following heads: solid rock, loose rock, cemented gravel and earth; and the following may be quoted from the classification, viz.:

"Solid rock will include all rock in place (except slate, shale and sand rock, and disintegrated granite that can be removed without frequent drilling and blasting), and detached rocks or boulders which measure one cubic yard or more, in removing which it is necessary to resort to drilling and blasting.

"Loose rock will include all detached masses of rock measuring one cubic foot and less than one cubic yard, and all slate, shale, sand rock, and disintegrated granite, which can be removed by picks and bars without frequent drilling and blasting, although blasting will be occasionally resorted to.

"Cemented gravel will include compacted earth, hard pan, cemented gravel deposits, and all material, except solid rock and loose rock, as above described, which cannot practically be plowed.

"Earth will include all material in excavation of every description not embraced in the foregoing classifications for solid rock, loose rock, and cemented gravel.

"Embankment will include all borrowed material for formation of roadbed or for other embankments wherever required."

The free haul for earth was 300 feet, and for classified material 1000 feet. When the haul extended beyond 1000 feet, embankment price was added to the price paid for excavation.

The rock was not a very difficult material to handle in most cases. It varied from slate and sand rock to a hard brittle quartzite, and all tilted up to a dip of about 40 degrees to the northwest. There were a few instances of cemented gravel that were as difficult to remove as rock, or more so, where powder had to be used to shake up the material; but in general the material varied so that it was difficult at times to decide what classification should be given. The method adopted, however, was to classify the harder material as cemented gravel and the looser as earth, with a varying percentage of classified material according to hardness. It will be noticed that the specification for cemented gravel is somewhat elastic, and leaves considerable to the engineer's opinion as to what he considers "may practically be plowed."

While such a clause as the above in the specification very often enables an engineer to do justice by a contractor by giving him the benefit of the doubt when it might otherwise be impossible, nevertheless it has a tendency to induce contractors to take work at a price they know to be too low with the expectation of getting classified out by the engineer, and this is an evil that appears to be increasing more and more as competition becomes closer.

There are five tunnels in the district under consideration, all west of the summit. They vary in length from 180 to 780 feet, the total amounting to about 1,600 feet of tunneling. Of this, the whole, with the exception of about 150 feet, is timbered. There were no special difficulties connected with the tunnels, the whole being in rock, and sufficient timber was obtained close by. The timber used was hewn tamarack and red fir. Logging was of red fir 4″ × 6″. Tunnel work was let at a stated price per lineal foot for the standard dimensions, and when necessary to be enlarged for timbering the increase in size was paid for per cubic yard. Timbering was paid for at a rate per M. ft. B.M. The drilling was all done by hand. (See Standard Sections, Plate V.)

There are four high wooden bridges in the district under consideration: two on the east side of the range crossing the Cutbank and Two Medicine Creeks, and two crossings of the Flathead river on the western slope. The Cutbank bridge is about 1,200 feet long and 180 feet high, and consists of 4 spans of 120 feet each and the rest 16 feet spans. The Two Medicine bridge is probably one of the highest timber trestles ever erected, being 751 feet long and 211 feet high. It consists of one span of 120 feet, 4 spans of 40 feet each, and the rest 16 feet spans. This bridge contains about 750 M. ft. B.M. of timber. (See Plate VIII.) The two crossings of the Flathead river are 140 and 90 feet high respectively, and each contains 2 long spans and a number of 16 feet openings; but writing from memory, definite figures cannot be here given, and indeed it is possible some of the heights or lengths given may be found to be slightly in error.

The special features of these high trestles are continuous posts from foundation to cap, packed at every story with a 4″ + 12″ plank 6′ long. (See Plate VII.) The stories are all 17½ feet high, so as to permit the use of 18 feet lengths in posts, and also to avoid using too long pieces in the longitudinal and sway braces. Long timber is not very plentiful in Montana. The inside posts have a batter in order to afford a better system of bracing in the lower stories than could be had with plumb posts, and additional posts are inserted as the height increases. The assembling of the various parts is made in such a way that the trestle is easily raised piece by piece, and any piece can be removed without disturbing other parts of the bridge.

The floors are of 6 in. × 8 in. ties laid flat, and spaced 12 in. centre to centre. Inside and outside guard rails are used well notched down and bolted.

The timber was mostly cut and sawn by portable mills in the vicinity of the bridges. Red fir was used for all stringers, as it is by far the best timber for the purpose to be found in Montana. White pine is scarce, but Norway pine is more plentiful, and was used for posts and caps where fir was scarce.

Outside of those four large structures the smaller bridging and trestling was very light considering the rough character of the country. Fir timber was used for piling and stringers, and indeed it was used for all purposes when it could be had, which was not always the case.

The following is a partial list of the prices paid to contractors on this work:—

Solid rock	$ 0.90	to	$1.00	per cubic yard.
Loose "	0.35	to	0.40	" "
Cemented gravel	0.35			" "
Earth, etc.,	0.16			" "
Embankment	0.16			" "
Tunnel	40.00			per lin. ft., stan. sec.
Tunnel excavation	1.50			per cubic yard.

The latter item was for enlarging the standard section to admit the timbering when necessary. Ordinary labour cost $1.75 to $2.00 per day.

The above prices will no doubt be considered low in comparison with prices paid for similar work elsewhere, and it may be here said that while there were no fortunes made by contractors, it is believed that all or nearly all competent men pulled through with more or less to their credit. As before stated, the most serious drawback was the expense of hauling in supplies; consequently, the maintenance of the camps was a serious drain on the profits of the work.

In regard to the cost of the work, the writer regrets having no estimates at hand, with the exception of 20 miles between Nyack and Coram. The heaviest mile in this 20 was 43,000 cub. yds., and the average cost of grading for the 20 was $14,200 per mile, but in this is included three miles of a flat where the work was light, and which considerably reduces the average from what it otherwise would be to 30,000 cub. yds. per mile; from Nyack to Summit the quantities were considerably heavier.

In conclusion, it may be stated that Mr. E. H. Beckler of Helena, Mont., was chief engineer of this work; and his organization of his staff was this: the whole work was divided into divisions in charge of division engineers. These divisions were subdivided into residencies in charge of resident engineers, who reported to the division engineer; and each residency was subdivided into sections of 6 to 10 miles, with an assistant engineer in charge of each, who reported to the resident engineer. The length of these divisions and residencies of course varied considerably according to the difficulty of the work in that particular locality.

NOTE ADDED 1ST MARCH, 1894.

The drilling in both tunnels and open cuttings was done by hand, there not being a steam or electric drill on the district. The tunnels were all in rock, and were excavated in this way. An upper heading of about 7 feet high was carried forward and kept several feet ahead of the bench. In this heading the timber plates were carefully set in varying lengths depending on circumstances, and the arch timbers and lagging put in place; after which the space around the arch was well packed with rock or cordwood. The sills and posts were placed afterwards according as the bench was removed to admit them. The specification called for rock packing around the timbers, but contractors preferred to use cordwood instead, and they were allowed to do so by furnishing the wood at their own expense. The wood is much more convenient for handling than rock, and probably as good in every way. The timbers were kept protected from getting shattered by shots and flying rocks by slabs of wood spiked to their faces; but occasionally a timber would get shattered so that it would be necessary to remove it, no matter what care was taken to protect it.

The bench was always kept up as close to the heading as possible, so that as much as possible of the material shot from the heading would fall clear of the bench, thus avoiding the labour of removing it. This item of clearing off the bench after a shot is often important.

About 16 drillers, or say 7 men in the heading and 9 on the bench, is as great a force as can be worked advantageously at one time. This was the force worked in No. 4 tunnel, which was worked from one end only. This was probably the most difficult tunnel to work, and working the usual hours per day the monthly progress was from 30 to 35 feet.

It was not always necessary to keep the timbering in place close up to the workmen. In one case the timber was not put in place until the excavation was completed; and had not the timber been on the ground and framed before the completion of the excavation, it might not have been used at all, as the roof turned out better than was expected. Material from tunnels was hauled out in ordinary carts.

Road-bed excavations were made 20 feet wide at grade and slopes, 1 to 5 in rock and generally 1 to 1 in earth; but this latter was not strictly adhered to in all cases, however, for various reasons. There is a class of hard pan or gumbo in places that was found to stand well at a slope steep enough to keep it dry, but at a slope flat enough to allow it to get wet, it became semi-fluid, and ran down upon the road-bed. Again, there are places where a 1 to 1 slope would run into the mountain side, the natural slope being about the same. In these cases steeper slopes were used.

The width of embankment for 5 feet and under was 14 feet, and for over 5 feet, 16 feet wide at grade; slopes 1½ to 1, except along streams, where they were made 2 to 1 for rip rap or slope wall. (See Plate VIII.)

The primary difference between these two classes is that slope wall is supposed to be hand placed and rip rap thrown down more roughly.

Prices ranged about $1.00 per c. y. for rip rap, and $1.50 for slope wall.

A considerable part of the grading was done by stationmen in small contracts of a few stations each; and on account of the difficulty of getting heavy plant into the country, and cost of maintaining horses, much of the material was hauled out of cuttings in "Swede carts;" that is an ordinary dumping cart turned about to run backward, and hauled by men, while one of them directs it from behind by a long pole which replaces the ordinary shafts. Others made "godevils" to run on rollers on a wooden track, while for short hauls others used trays to slide on greased poles. These "godevils" were hauled by horse power, of course.

Pile foundations were used where practicable to drive piles; and where they could not be driven on account of rock, cedar mud sills were set, or cribs were built and filled with rock. There were no special difficulties met with from the nature of the materials in foundations; of course it will be remembered that there were no heavy masonry piers or abutments erected. A detailed account of the foundations of the 4 large bridges cannot be given here with accuracy.

There were places on steep side hill where cribs or retaining walls were necessary to maintain the slope of embankment. These cribs were built of round logs according to the general plans (see Plate VIII), and were paid for at a stated price per lin. ft. of logs in structure when completed.

The track, a 68 lb. steel rail with 36 inch angle bars, with 6 bolts and hexagonal nuts, was laid with square joints and 16 ties to the rail. The rails were cut in 30 feet lengths with a number cut 29′ 6″ for inside of curves. These short rails had their ends painted at the mill, so they could be readily detected, and the tracklayers were furnished with a list of the curves and the number of short rails required for each. This was found to be an excellent plan to keep square joints, and the writer believes it to have been an original idea with Mr. Beckler, not having seen it elsewhere. The Holman track-laying machine was used, and the daily progress some days reached 160 stations. The rails, of course, were curved in the material yard and loaded on cars in the order required to fit the curves, without any assorting at the end of the track.

The ties used in the mountains were 7 inches thick, 7 inch face and 8 feet long, of fir and tamarac. The contract price was 25 cts. each, and, as stated, they were laid 16 to the rail, or 2,816 to the mile.

The grading was all done by Messrs. Shepard, Siems & Co., contractors of St. Paul. From Havre to the summit was done by contract, and from the summit west to the crossing of the Columbia River in Washington was done by the same firm on a percentage basis. The Railway Company thus retained an interest in the supply stores.

The prices given in this paper are those paid by Shepard, Siems & Co. to their sub-contractors west of the summit.

The timber was mostly furnished by the Boston & Montana Commercial Co. of Helena, and the structures were erected by Porter Bros. of St. Paul. Timber work was all done at a stated price per M. ft. B.M., but the writer is unable to give those prices with certainty.

DISCUSSION.

Mr. Leonard. Mr. R. W. Leonard said the specification regarding overhaul is rather unusual, and seems hardly fair to the contractor or to the company. The prices are exceptionally low as compared with prices which we are accustomed to pay in the West.

Mr. Smith. Mr. C. B. Smith said he would like to call attention to the specifications, which were similar to several he had worked under. They were very elastic, and the loose rock clause particularly covers a large class of materials very easily worked, while the solid rock clause could be similarly extended. He had worked under prices of 64 cts. for solid rock, 32 cts. for loose rock, and 16 cts. for earth which included hard pan. The whole thing was absurd, and contractors persisted in taking work at these prices, looking to the engineer to help them out by classifying.

He wished to heartily concur with the author on this question. He sincerely hoped that such objectionable prices would never get across the border, but that prices in Canada would be kept at such figures as would enable engineers to classify to the letter and at the same time to do justice to the contractor.

CORRESPONDENCE.

Mr. W. B. Mackenzie said :—Mr. Kennedy's paper is very interesting to railroad engineers. It appears to have been the desire of the Chief Engineer to locate the road in the best place and to construct it in a first class manner. Mr. Mackenzie.

The classifications of solid rock, loose rock, cemented gravel and earth appear to be excellent, with the exception that the upper limit for loose rock is too high. In the writer's opinion it should be placed at one half a cubic yard, or perhaps as low as one-third. Large boulders measuring over half a cubic yard are more troublesome to dispose of than solid rock, and should be classed as such.

Cemented gravel is a classification which should have appeared in our specifications at an earlier date. The writer has seen cemented clay and gravel more difficult to remove than solid rock, yet the contractor had to take earth price or nothing. In many parts of New Brunswick and Nova Scotia, only the first three or four feet below the surface, which is acted upon by the frost, can be called earth ; below that point it is all hard pan.

The writer believes the "schedule" system of letting railway work is preferable to the "lump sum" method. In the latter, the company either pays too much or the contractor loses too much ; the fair and reasonable price is seldom paid. Unless distribution profiles, full and complete quantities and detailed working-plans are furnished to intending contractors, as is done in England, offers on the "lump sum" method are simply guesses. To see the end from the beginning, through the fog and indefiniteness of an earth-embracing general specification and an outline plan and profile, as is sometimes attempted, is more than mortal man is equal to ; hence, offers are close, or wide of the mark, according to the inherited or self-acquired experience of the would-be contractor.

Too often the inexperienced man gets the work because his price is the lowest ; and, war being duly declared against the engineer, construction drags slowly along to a completion, which is satisfactory to no person in particular, and least of all to the contractor himself.

The schedule prices given in the paper for solid rock, 90c to $1.00 per

c. yd., appear remarkably low, considering that all the drilling was done by hand, and the price of ordinary labour $1.75 to $2.00 per day.

Making the rock slopes 1 to 5 in stratified rock, instead of 1 to 4, as is common, is a very good idea.

For the embankment along streams, it seems to the writer it would have been cheaper, and equally as good, to allow the earth to take its natural slope of 1½ to 1, and increase the thickness of the rip-rap and slope walls. To make the slopes 2 to 1 must have required considerable extra labour in placing the material. Plate X, Fig. 1, shows the section of a hand-laid slope wall 300 feet in length on a railway embankment built by the writer, along a harbour shore, which has been in use 9 years and is still in good condition.

The sectional outline of the timber crib retaining-wall is a good one. In its construction, however, the writer would suggest slight improvements as follows:

1. That the crib begin with a longitudinal at the bottom and end with one on top.

2. That the cross-ties be fastened to the longitudinals.

3. That a ballast-floor be placed on the second cross tie from the bottom.

4. That the crib be filled with stones above and below the ballast-floor.

5. That the cross ties be placed alternately instead of directly over each other.

Nos. 3 and 4 may not be needed in this particular case.

Two years ago the writer was called upon to design and build a surcharged crib retaining-wall. At that time he failed to find any literature on the subject. He has since, however, discovered that Prof. Harris of the Royal Military College treats the subject in his book, Vol. 2, p. 36.

The writer began by figuring out the weight of a cubic foot of cedar crib, filled with loose stones, which he made to be 67.6 lbs. He then constructed a number of trial sections having heights from 10 to 22 ft., and treated them graphically in the same way that he would a stone wall. He found that it was the tendency of the wall to slide forward which had to be guarded against, and not the overturning. Using a co-efficient of friction of 0.60 for wood on earth, he arrived at the following conclusion:—For surcharged retaining-walls of cedar cribwork filled with stones, earth backing weighing 106 lbs per c. ft.

If the mean width be made equal to the height, the front battered 1 in

8 and the back vertical, the factor of safety against sliding forward on its base will be about $1\frac{3}{4}$. The stability may be increased by sloping the bottom inwards.

For retaining-walls when backing is level with top of wall, earth backing weighing 106 lbs. per cubic foot.

If the mean width be made equal to 0.762 of the height, the front battered 1 in 8 and the back vertical, the factor of safety against sliding horizontally forward on its base will be 2. The stability may be increased by sloping the bottom inwards.

The section Fig. 2, Plate X, was designed in accordance with the first rule, to support a clay and gravel bank 350 ft. long; and the wall is standing perfectly. The writer's observations of the behaviour of crib retaining-walls lead him to think that the widths given above are not too great. Fig. 3, Plate X, shows the outline section of a crib retaining-wall lately built on the Harlem River. The bottom width is equal to the height and the top width is two thirds the height. It has one ballast floor, and is filled solid with stones.

Fig. 4, Plate X, shows the outline section of a crib filled with stones, built on the soft mud, and supporting railway tracks which, in the space of one year, moved forward bodily twenty feet, from the pressure of the level earth filling behind. The whole mud bottom moved outwards, carrying the crib with it, until a bank formed in front one-half the height of the crib. Fig. $4\frac{1}{2}$, Plate X, shows the outline of a timber crib filled with stones, 105 ft. long, which slid out 6 inches in the center, when the clay filling had reached a height of 8 ft. The wall was built on flatted mudsills laid close together on soft clay. The water carried the soapy clay in between the bottom of the crib and the mudsills, reducing the co-efficient of friction to about 0.25, and causing the crib to slide forward on the mudsills.

Fig. 5, Plate X, shows the outline section of a crib filled with stones, and protecting a railway bank on salt water, which stood perfectly where the foundation was good, but where it was soft, slid out ten feet and tilted inwards.

The writer recently designed and built a dry stone retaining-wall (surcharged) 11 ft. high to carry a waterway through a railway bank of sand and gravel. The different authorities consulted required for rectangular surcharged retaining-walls laid in cement, 11 ft. high, the following thicknesses:—

1. Jacobs	4.609 ft.	for cement masonry.
2. Tate	4.880	do

3. Vose	5.250 ft.	for cement masonry.
4. Baker	5.500	do
5. Latham	6.060	do
6. Col. Wurmbs	6.700	do
7. Trautwine	8.470 ft.	for dry rubble.

Taking the mean of Nos. 1 and 3, increasing the thickness one-quarter for drylaid rubble, putting a batter on front and back, so that the area of the cross section was unchanged, and sloping the bottom inwards, the section shown by Fig. 6, Plate X, was produced and built. The writer considers the wall none too heavy. The width at base is 0.84 of the height. The *Engineering News* of Jan. 26, 1893, says that the width of dry walls at the base, over the footings, should be nearly equal to the height. Many masonry constructions fail because their foundations are not designed to meet the requirements of the materials upon which they rest, and it is just in this particular that there will ever be ample room for the exercise of all the theoretical and practical knowledge which intelligent engineers can bring to bear upon the subject.

Masonry walls laid in cement, retaining earth level with their tops, if less than 4-10 of their height at the base, over the footings, will bulge or lean forward in ten or fifteen years, from the effects of water, frost, tremors, etc.

Fig. 7, Plate X, shows the section of an ordinary retaining-wall laid in cement, and supporting street traffic, which moved forward at the top $9\frac{5}{8}$ inches in 17 years. Between October, 1893, and May, 1894, it moved $\frac{3}{4}$ of an inch. Fig. 8, Plate X, shows the outline section of an ordinary retaining-wall laid in cement, for a railway bridge abutment, which was damaged to such an extent in 20 years that it became necessary to remove it. Fig. 9, Plate X, shows the outline section of a surcharged retaining-wall laid in lime and pointed with cement supporting the toe of a railway embankment, which bulged forward several inches in the first year.

Fig. 10, Plate X, shows the outline section of a dock wall supporting railway tracks and street traffic which in 10 years bulged forward $2\frac{1}{4}$ feet in several places, from the pressure of sand filling level with its top.

The section of the track ties mentioned in Mr Kennedy's paper, 7 inches by 7 inches, is an excellent one, and far preferable to the 6 in. × 8 in. ties so commonly used. A 6 inch tie is too thin. By the time an inch is adzed off in shimming, another inch of the lower surface decayed, and the remaining 4 inches has been badly damaged by repeated drivings of blunt and badly formed spikes, the tie is ready to break short off under a train, and the longer it is the sooner will it break. A great advantage in the 7 in. × 7 in. tie is that it can be made from a smaller tree, and will, therefore, cost less.

Mr. Kennedy in reply said:—The specification regarding overhaul, although unusual in Canada, is more common in the Western States, and all that can be said in its favour as far as the author can see, is that it saves the trouble of calculating overhaul in many cases. There certainly appears to be very little advantage visible to the contractor, who finds his embankment running out further than he expected. When the haul reached one thousand feet, the contractors were generally given permission to waste from the cutting and borrow to make the bank, if they found it more convenient, than continuing the haul from the cutting, and they always did so when good material was close at hand.

The specifications for loose and solid rock gave good satisfaction, and were well suited to the materials in that locality.

The greatest difficulty the engineers met with in classifying was with the cemented gravel where it was necessary to allow only a percentage of the classified material.

As regards the large bridges, the author wishes to say that the design of the packed post of that peculiar pattern originated with Mr. Beckler, to whom he is indebted for the following corrections of lengths that were given in the paper from memory. The Cut Bank bridge consists of sixteen feet spans in trestle bents, one span 120 feet Howe truss and five spans 40 feet Pony truss. The first crossing of Flathead River one span 150 feet Howe truss, one span Pony truss, balance 16 feet spans. Second crossing of Flathead River three spans 150 feet Howe truss each, balance 16 feet spans trestle.

In reply to Mr. McKenzie, he would say that in the few places where earth embankment was made along the Flathead River, there was little or no extra work required in making the slope two to one, as the current was rapid and washed out all the fine material as it was thrown into the water, leaving only the stones and coarse gravel, while the largest stones were rolled out into the stream and formed the rip-rap. Of course, all the material used contained a considerable percentage of stones, and the coarser was placed next the water, as far as possible. In this way some contractors made the rip-rap without much extra labour, and for which they were paid. He presumes they made it pay for any extra work in flattening the slope of the embankment, as there was no "kicking" on that score.

The author recognises the improvements suggested in the cribwork, especially that the crib should begin with a longitudinal in the bottom.

The general plans for cribs (Plate 8) were varied considerably to suit the particular places where used. There were none required or used of more than a very few feet in height. In one particular place, to ensure safety, a longitudinal was laid in a trench dug along the centre line of roadway, and long top cross ties were well notched down over it, and well spiked to the three longitudinals. This was thought an excellent plan.

The worst slide that occurred during construction was where a heavy embankment slid on the sloping face of the rock several feet below the natural surface. It was so close to the entrance to a tunnel that the alignment could not be changed, and the only remedy seemed to be to remove part of the embankment and build a trestle benching off the rock for each bent. The trestle was built, and, as far as the author knows, is a success. At another place, the embankment gradually settled for several days, and at the same time the flat below gradually moved until an island arose in the river which seemed to form a footing, and the settlement ceased and gave no further trouble.

Friday, 23rd February.

C. H. McLeod, Member of Council, in the Chair.

Paper No. 91.

SOME FEATURES IN THE EQUIPMENT AND RUNNING OF A STREET RAILWAY POWER-HOUSE.

STUDENT'S PAPER.

By Frank H. Pitcher, Assoc. M. Inst. E.E.

The power-house in view, viz., Coté street, of the M. S. Ry., so far as the building is concerned, consists simply of a light frame structure of the type known as "balloon." Being designed to protect the plant from the weather for only one or two years at the most, it was thought sufficient for making it fire and weather proof to merely tar and gravel the roof and cover the walls with sheet iron. The available floor space measures 105′ × 51′. This is divided into two by a partition, forming on the one side the engine and dynamo room, 59′ × 51′; on the other the boiler and coals room, 47′ × 51′.

The ventilation is good, being effected by two Sturtevant blowers situated in the dynamo room, which exhaust from there to the furnaces, thus keeping up a fair circulation in the former. In the design of a dynamo room, too much attention cannot be given to this question. Besides the heat from the engines, there is a constant radiation of heat from the armatures, fields and bearings of the generators which must at once be dissipated if the machines are to perform their proper functions.

EQUIPMENT.

The steam plant consists of five 250 horse-power locomotive boilers, duplicates of those used by the G.T.R. Co. on their locomotives. They are set up some 20′ from Coté street, the coal pit and fireman's platform intervening. The boilers are mounted on brick piers, one at each end, the back end having cast iron rollers under it to obviate straining the masonry on the expansion and contraction of the boilers.

Two tandem compound high speed engines known as "Ideal," made by the Harrisburg Foundry & Machine Works, Harrisburg, Pa., drive the generators, the latter being belted direct. These engines are built to indicate 500 horse-power each, running at 188 revs. per minute, with a boiler pressure of 120 lbs., and with condensers. In addition, there are the two blowers mentioned above, one Worthington pump for feeding the boilers or filling a tank with a 7000 gallon capacity, the latter for use on failure of city supply; also two feed heaters working on the exhaust in the usual way. The boilers being also arranged with injectors have three ways by which they may gain their water supply, which is ample precaution against possible failure.

The electric plant consists of two No. 80, 200 K. W. 500 volt Edison generators, speed 450 revs. per minute; two Westinghouse 200 K. W. 500 volt standard St. R.R. generators, speed 535 revs. per minute.

There is an ammeter in series with each machine, and in addition a main Weston ammeter, range 2000, working on the milli-voltmeter principle on the trolley bus bar. The voltmeter is a Weston range 600 connected between the trolley and ground bus bars. There is a Westinghouse automatic circuit breaker in the circuit of each machine, as well as a Westinghouse three-jawed switch. Fuse blocks are placed in each feeder, being arranged double, so that in the event of the blowing of a fuse in any particular feeder, the other, which is always fixed in multiple, may be at once thrown in; thus time is saved, and the danger of blowing the other fuses lessened.

Each machine is of course furnished with the usual rheostat in series with the shunt coils, by which the voltage of the generator is regulated.

All the machines throughout the system are connected in multiple. It is therefore highly essential that the generators of any power-house, as also each individual machine, before throwing in with the others on the line, be brought to the same potential as the latter. The device in this case for observing this uniform potential is due to the electrical engineer of the Company, Mr. Brenner.

The method is a zero one, and things are so arranged that when the main switch of the machine in question is open, a current generated by the latter is still flowing through the voltmeter, but in a reverse direction from that due to the line. When, therefore, the line and machine have an equal E. M. F., the voltmeter will read zero and the main switch may then be closed.

Briefly, it is accomplished as follows: A fine fuse is introduced on the main switch between the terminals of the ground wire, the ground brush is therefore always connected to the ground bus bar. The trolley brush is connected through the voltmeter to the trolley bus bar. It is at once obvious that the machine and line are sending their currents in opposite directions so as to oppose one another.

It may be mentioned here that besides the four machines at Coté street, there were two 200 K.W. Edisons at the Royal Electric Co.'s works and one at the Exhibition grounds. The seven machines worked together for most of the summer.

On first starting up the engines, a good deal of difficulty was experienced in getting the bearings to run without heating. This, however, in new high speed machinery seems inevitable. Great difficulty was found also in getting the governors, which are of the centrifugal type usual in high speed engines, to work satisfactorily. To adjust them so as to function properly under the great and continual variations of load, proved to be a hopeless task. A governor capable of compensating for the extraordinary variations common to all small roads would be a marvel. This road being at the time only about one-third completed was comparatively small, and therefore liable to frequent and wide variations of load not lessened by the hilly nature of the city.

Ordinarily a 16′ car on the level, equipped with two 25 horse-power Westinghouse motors, should take on an average no more than 40 or 50 ampères when loaded, but running empty up Windsor hill it takes 100 ampères.

To allow for these intermittent variations the practice is to use high speed engines with late cut-off and very heavy fly-wheels. This latter, however, only tides over the situation for a short time; for longer demands, the governors are supposed to work. As a matter of fact, with these large overloads, the governors cannot compensate. The result is, the engine slows down, the potential of the machines belted to it falls, and, as is often the case, the other engines govern better, or the generators belted to them are not so sensitive, *i.e.*, do not pick up their load so quickly; then the potential on the line will be higher than that of the machine at the brushes. The result is, the series coil overcomes the shunt, and the machine is reversed. This necessitates the throwing out of the armatures and giving the magnets an initial charge in the right direction, bringing the voltage up again to that of the line, and throwing the machine in once more. In the meantime, the overload caused by taking these machines out may be sufficient to throw the circuit breakers of the others, and thus the whole system becomes temporarily disabled, all the cars stopping and lights going out. To operate the system successfully, the engines and dynamos should be similar, *i.e.*, as to power, governing, etc.; and in the case of more than one station, the feed points of the different stations should be far enough apart to allow an appreciable drop between them.

In the case under consideration the conditions were by no means similar to the above. In the first place, the generators in Coté street power-house itself were far from being alike in respect to governing. The Westinghouse, owing to laminated pole pieces, were much more sensitive than the Edisons, which had very massive cast iron pole pieces. The eddy currents set up in the latter at a change of load would tend to oppose the change, and hence make the machine more sluggish; while in the former, these eddy currents being practically absent left the machine free to pick up at once any extra demand.

Another feature possessed by the Westinghouse machines, and one which probably contributes in a large measure to its sensitiveness, is its comparatively low self-induction. The four series coils are connected in multiple, and as the self-induction of any circuit— *i.e.*, the property possessed by the circuit to retard the rise of current when an E. M. F. is impressed upon it—varies directly as the resistance, and the current at the end of any time after the impression of the E. M. F. is inversely proportional to the self-induction, it will at once be seen that connecting the above coils in multiple, thereby diminishing the resistance and number of turns, lessens the time constant of the circuit. The latter is the time required for the current to rise to 0.634 of its full value, as determined by Ohm's law when the current becomes steady. It is therefore quite safe to say that the rapid action of these dynamos on a change of load depends to a great extent on the way the series coils are connected. On account of this, constant hand regulation was necessary in order to keep the circuit breakers in series with these sensitive machines from flying out. Then again the drop between the machines at the Royal and those at Coté street being far too small, gave rise to constant trouble. Under the above conditions, then, some of the machines bore the brunt of the sudden over-loads, and thereby endangered themselves and the engines.

It is doubtful therefore whether this extra sensitiveness is of any advantage in traction work, and in case of working dissimilar machines together, it is a decided disadvantage. In any case such machines are harder on the engines, causing sudden and violent strains, which are very detrimental to the life of the engine.

It is no disadvantage worth speaking of in traction work to have the voltage fall a little, and remain so for a short time; but it is a decided calamity to have the circuit breakers fly out and fuses go, causing the stopping of all cars on the line, till the circuit breakers are in again. In the case of a short circuit on the line caused by the trolley wire breaking and grounding, the inevitable result was a complete break all around, in spite of the fact that all available resistance was thrown into the shunt coils. The time required to bring all the machines to a common voltage and get them coupled in again so as to retain their circuits after one of these general breaks sometimes amounted to 5 or 10 minutes, which is quite an item in traction work, and interferes considerably with schedule time. There might perhaps have been some high resistance rheostat, which could have been thrown in with those already provided, so that in an emergency like the above the circuit could have been retained till the wire was raised, and thus the cars kept moving, though of course very slowly.

From a log book, in which were entered details of every day's run, including the average output per hour, it is found that the average rate of working for the month of August was less than 500 H.P., the nominal capacity of the station being 1000 H.P.

At times, however, the demand on the station reached 950, or even more than 1000 H.P., viz., at noon or 6 o'clock, and on occasions of any special event lying along the route of the R. R. Thus the station running 20 hours, viz., from 5 a.m. until 1 a.m. the following morning (the Royal running in the interim), was running at less than one-half its capacity for eighteen hours, or 9-10ths of the whole run, the efficiency of the engines and generators under these conditions being very much impaired, though that of the latter suffered very much less than the former.

The above average is not so low as in smaller stations, but still quite too low to insure economical running.

The average fuel and water consumption per day for the station was 13 tons of coal and 4000 gallons of water approximately,—engines running non-condensing of course.

In this country there has lately been suggested a scheme for getting over this difficulty, which makes the engines run nearer their full capacity, and under a constant load, thereby obtaining a higher efficiency than under the existing circumstances. It consists essentially in connecting in series between the trolley wire and the ground a sufficient number of accumulators of adequate capacity. In case of a small demand from the line, the engine will be kept at full load by having to charge up the cells, and when a larger supply is demanded by the line, the cells discharge, and hence the load on the engine and voltage of the line is kept approximately constant.

Of course this by itself will not give a perfectly constant load and potential, as the latter needed to charge the cells is greater than they can maintain on discharging.

In Europe the above combination of cells and generators has proved both practical and economical for central lighting stations, and at Zurich, Switzerland, where the gradients are considerable, two lines for traction work are in course of erection, which are to be operated on this method.

There were few accidents during the summer, an occasional melted crank pin bearing and two armature burn-outs being about all. Of the latter, the first was a result of carelessness on the part of the rewinders. The armature was an Edison which had been in use before, and said to have been burned out by lightning; however, it was repaired, and sent to Coté st., warranted as good as new. It tested all right with a magneto, showing no open circuits.

On starting up and exciting the machine, showers of melted solder were thrown from the neck of the armature about midway between the end of commutator and core. When it had reached the voltage of the line, which was at the time 450 volts, it was thrown in, at which the solder ceased to fly and the machine appeared to function properly. After half an hour it was taken out and allowed to run on open circuit for two hours, after which three coils were found to be burned out, and the commutator to have suffered considerably.

On investigating, it was found that in the neck of the armature (and on the opposite side from the present burn-out) there was a large hole partly filled with a mass of melted copper and solder, several coils being burned completely in two at that point; the chunk of metal making contact, however, and thus the magneto could not detect the break. The armature had to be wholly disconnected and splices made.

The other burn-out, which was rather a curious one, happened to the same armature. After having been repaired, it ran satisfactorily for perhaps six weeks, when, without much warning, up it went again, this time making a far more brilliant display then before. On taking out the armature, it was found that about one-half the conductors of the outside layer had been displaced through a very considerable angle. The bonding wires were perfectly sound and tight, the only objection to them being that they were too few. The wire bent slightly between these bands. The clearance was at best very small, far too much so;

and as the heating of the armature was pretty great, the latter as a whole expanded enough to allow the protruding loops of wire to rub against the inner surface of the pole pieces. Thus the insulation was abraded, and the coils short-circuited through the iron of the fields. The contact between the conductors and iron occurred also at the point where the field was most intense, as shown by the bright spots on the pole pieces at that point, and hence, when the short circuit occurred, the coils were at their maximum voltage. This of course was a totally ruined armature, and had to be wholly rewound.

No damage from lightning was sustained, there being no very severe storms except on two occasions, on which the lightning-arrester acted promptly and efficiently, short-circuiting the discharge to the ground. The current from the machine, however, which followed the arc was always sufficient to throw the automatic circuit breakers.

A great need of the station was a more efficient lighting arrangement. The one in use consisted of five incandescent lamps in series connected between the trolley and ground leads. On the occasion of overloads and the consequent fall of potential, the lamps often ceased to give any light whatever, merely burning a dull red. This was a great inconvenience, for it was just at such times that the closest watch had to be kept on the machines and instruments. Of course the five lamps in each car were subject to the same conditions, and behaved similarly. However, on the completion of the road, and when the full supply of power is attainable, this difficulty will doubtless be obviated.

The station has already been practically abandoned in favor of the permanent and main one on William st. This removal was no doubt hastened by an unfortunate wreck of one of the engines in the temporary station.

However, everything being considered, the short time allowed for construction, its extremely temporary nature, and the condition under which it worked, it would seem that the company have every reason to be satisfied with the results.

Thursday, 1st March.

P. ALEX. PETERSON, President, in the Chair.

Paper No 92.

THE DARTMOUTH, N.S., WATER AND SEWERAGE WORKS.

BY F. A. CREIGHTON, STUD. CAN. SOC. C. E.

In the year 1875 Mr. T. C. Keefer, M. Can. Soc.C.E., was called to Dartmouth, N.S., to report on the cost of a system of water-works for that town. The most feasible plan seemed to be a gravity system, supplied from Lamont and Topsail Lakes, a splendid natural reservoir situated among the hills, distant about three miles to the northeast of the town. Mr. Keefer had an extensive survey made of these lakes as well as of Loon Lake, which, as will be seen by the plan, is situated to the east of Topsail Lake and is distant from it about 1500 feet. Mr. Keefer reported with plans and estimates, and the matter was dropped for the time. The question of the introduction of water was raised from time to time, until finally in the latter part of the year 1889 Mr. E. H. Keating, M.I.C.E., at that time City Engineer of Halifax, was called upon to make plans and estimates for the immediate introduction of a water and sewerage system. When the estimates and plans were ready, a public meeting of ratepayers was called, which, however, was adjourned for one year. A meeting was held in January, 1891, when the ratepayers authorized the Council to ask permission of the Legislature to borrow the sum of $100,000 to introduce the water and sewerage systems into the town, and the works were finally begun in the fall of 1891.

WATER SUPPLY.

The plans of Messrs. Keefer and Keating were followed in the main and the water brought from Lamont and Topsail Lakes. (Plate III.)

These lakes are at an elevation of 225 feet above the mean tide level of Halifax Harbour, and have a combined watershed (exclusive of the lakes themselves) of 588 acres, mostly of thickly wooded land. The combined area of the lakes is 163 acres, Lamont being 22 and

Topsail 141 acres. The depth of the lakes ranges from 12 to 25 feet, and the bottom is for the most part gravelly, though the north end of Lamont Lake has a considerable area of muddy bottom.

The stream between the lakes was originally about 2 feet deep and 350 feet long, but this was enlarged to a canal 8 feet deep and 4 feet wide at the bottom, with the side slopes rip-rapped for their entire length.

Lamont and Topsail Lakes are capable of supplying to the town 750,000 gallons per diem, while for the present 250,000 is all that will be used. The storage capacity is 234,000,000 gallons.

The efficiency of these lakes may be more than doubled as soon as necessity arises, by the addition of Loon Lake, which, as has been mentioned above, is distant from Topsail about 1500 feet. This lake belongs to a different watershed from Topsail Lake. It was the reservoir of the old Shubenacadie canal, and is some 3 feet lower than Topsail. Before connecting Topsail and Loon Lakes the water level of Loon would of course have to be raised, which could be done by means of a dam about 150 feet long at the outlet at a cost of $500. It is proposed to connect the lakes by a 24 inch crock pipe, laid so as to take the overflow of Loon Lake. This pipe when laid as proposed can deliver, running full, some 2,600,000 gals. per diem, thus largely increasing the available water supply. The total cost of the connection is estimated at $5000.

DAM AND GATE HOUSE.

The dam and gate house are situated at the foot of Lamont Lake. The original dam was built to supply water for a grist mill, but the mill had not been in use for some years when the town took the lake for its supply. The old dam, which was built roughly with stones, brush, and other rubbish, was raised 2 or 3 feet and the gate house built in the front part. When the lakes rose, the dam was found to be leaking considerably. The different leaks were repaired as they appeared, but finally a trench 2½ feet wide was cut along the whole length of the dam, down to a bed of clay some 2 feet under the original ground surface, and filled with well puddled clay. This seemed to stop the leaks effectually, and no trouble was experienced till February 7, 1893, when it was found to be leaking about the waste-weir, and an examination showed as follows: It will be seen by the sketch how the waste-weir is constructed. It is 12 feet wide and set into the dam some 2½ feet. 6 in. × 8 in. timbers bedded in the clay are put in running across the weir 4 feet apart. These are planked over with 3 in. plank, caulked and run with tar to keep the water from making its way through to the clay. Another layer of 3 in. plank is put on as a protection from the sun when no water is running over the weir. Stakes are driven down in front at the lake end of the weir, and 3 in. plank extending 4 feet out on each side of the weir spiked to them. 6 in. × 6 in. timber sides are then put in, with the timbers well fastened together with ragbolts. Then clay is well rammed down in front of the apron and around the sides. A dry wall is built at the back of the dam under the weir, and loose rock thrown in behind to break the force of the water falling over.

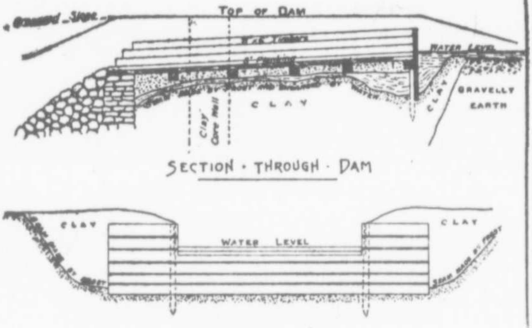
Frost Action.—It is known that as frost works down through clay it expands the clay, which of course must rise, and anything in the clay must of necessity rise with it. Thus it will be seen that as the frost found its way down past the apron in front of the dam, each plank, as the frost reached it, rose and separated from the one below it. In our case there were spaces of from $\frac{1}{2}$ to 1 inch between them, while the first short plank at the sides was separated from its neighbour fully 2 inches.

Then as frost goes down through clay there is always a space (usually half filled with ice needles) between the frozen ground on top and that unfrozen underneath. It will readily be seen that as soon as the frost had worked down below the water-level, the water would begin to find its way between the lifted planks in front, and along the seam made by the frost, and out into the stones behind the dam. It would not be long before the water would wear away a considerable quantity of the soft clay, and thus make a serious leak.

The state of the dam at Dartmouth was about as shown on the sketch. The ground at the side of the weir had risen by the action of the frost and taken the weir up with it. This left spaces between the planks, and the frost had then made a seam below the water mark admitting the water, which rapidly wore away the dam.

To repair this temporarily, the lake was dammed off in front of the weir, and the apron in front double planked, breaking joints. The planks were nailed on one side only, so that if the frost raised them again no harm would be done. Each plank would work against its neighbour and always keep a tight joint. Clay was then puddled in front and rammed back as far as possible under the weir. This stopped the leak, and about a week later the wood of the waste weir was taken out, the space filled up, and the weir removed further along to the end of the dam, where it has a gradual fall back to the tail race.

In the spring it is intended to carry the slope of the dam back some



SECTION · THROUGH · DAM

· FRONT · ELEVATION ·

Dartmouth, N.S. Water Supply

· PLAN · SHEWING · EFFECT · OF · FROST ·
· ON · CLAY · DAM ·

· Scale · 1/8 · inch · = 1 · foot ·

F. A. CREIGHTON., Stud. Can. Soc. C.E.

90 or 100 feet, which will give the inside of the dam a slope of about 20 to 1.

The Gate House.—The gate house is set in the front of the dam. The intake ditch is 6 feet wide at the bottom, with side slopes varying from almost perpendicular at the gate house to about 3 to 1 at the outer end. The sides are rip-rapped for the entire length. The ditch runs out into the lake about 125 feet to deep water on a level with the bottom of the gate house. The foundation and wing walls are built of rubble and cement masonry. When the lakes first filled up this wall was found to leak considerably, so a coating of cement concrete 4 inches thick was put on the inside; this did not stop it, so a similar coat was put on the outside, and this seemed to make the wall tight. After the lakes filled up a second time, however, a slight run of water came out of the end of the waste flume. This leak has not yet been located, but will probably be repaired as soon as the frost is out of the ground.

As will be seen by the plan of the gate house (see Plate) there are two sets of screens; they are of copper-gauze, and set 4 feet apart. The screen frames, as well as the sluices and guide timbers, are made of pitch pine. Some difficulty was experienced at first by these swelling on coming in contact with the water, but after being planed down they gave no more trouble.

The opening in front of the gate house is two feet wide, and runs the whole depth of the wall. This opening is covered with an iron grating to prevent sticks, loose ice, etc., from coming in contact with the screens.

The waste sluice at the back of the house, which may be used to drain off the lakes, is built 3 ft. high and 2 ft. wide; it is made of 6 in. × 6 in. hemlock, fastened together with rag bolts, and braced inside every 6 ft. The bottom floor is 8 ft. 9 in. below the high water level of the lake, and the top of the town supply pipe is 6 ft. 2 in. below the water level.

THE MAIN PIPE LINE.

The main pipe from the lakes to the town is 12,600 ft. long. It starts from the gate house with 20 in. pipe, which continues for about half a mile, where it is reduced to a 12 in. which runs a distance of 9,300 ft. to the town. In the line there are 3 blow offs and 3 air cocks. For a distance of 800 ft. just before the end of the 20 in. pipe there is a hill rising above the lake level; this had to be cut through to a depth of 23 ft. in order to get the pipe down to grade. At a place 1,300 ft. from the lake the trench bottom was found to be too soft to lay the 20 in. pipe on, so a platform of 2 in. plank was built for a distance of some 75 ft.

At the upper canal bridge (see Map, Plate II.) the 12 in. pipe is reduced to a 10 in., and a special left to take an 8 in. pipe down Portland st. to the lower canal bridge, thence across the bridge, to connect with the 6 in. pipe at the corner of Portland st. and Wilson lane. x This pipe will serve as a safeguard in case of the water having to be turned off the 10 in. pipe at present supplying the town.

The 10 in. pipe runs from the upper bridge 1,600 ft. along Ochterloney st. to Dundas st., where the distribution commences. This pipe is laid across Sullivan's pond. The pond was drained off for the purpose, and the pipe laid in a shallow trench in the bottom.

The main line as well as 1,500 ft. of the 10 in. pipe is jointed with wood instead of the ordinary lead joint. This has been proved to be quite as efficient a joint as lead, while the saving in cost, as will be seen later, is considerable.

x Victoria Road

The joint is made about as follows :—The staves are made of the best white pine, and are cut to the exact curve of the pipe for which they are intended. They are from 4 to 5 inches long and 3 inches wide, and about $\frac{1}{8}$ in. thicker than the space they are intended to fill. To make the joint, steel wedges are driven into the faucet under the pipe, so as to force the spigot of one pipe well up against the faucet of the other. Then the lower third of the faucet is filled with the staves, driven as tightly as a man can with a heavy hand hammer. The wedges are then taken out and driven in on top, so as to drive the pipe firmly down on the staves below, and the upper two-thirds of the staves first started in, and then driven firmly home with a hammer weighing 7 or 8 lbs. The staves are then forced apart with a small steel wedge, and pine wedges of the same material as the staves driven into the spaces. This makes a good tight joint, and in every way as lasting a one as lead ; but care must be taken in putting in the small wedges, to put in enough and drive them well home, as one of them left out means a considerable leak. If a wood joint does leak it will be seen that, on account of the wood swelling, it must tend to get better instead of worse, as would be the case with lead.

One great advantage of the wood joint over lead is that it can, if necessary, be made with as much as half of the pipe under water. This saved an expensive cofferdam in one place in Dartmouth, where the pipe had to cross a loose rock embankment across a pond—a distance of about 300 ft. Had lead joints been used, the pipe would have been laid along the side of the embankment and a cofferdam built to keep out the water.

Of course, before adopting wood joints, care must be taken to see that the castings are made reasonably smooth, as any projecting piece of iron on the faucet will peel off the stave as it is driven in, and thus cause a leak. In the pipe used in Dartmouth, some of the pipes were rather rough, and considerable trouble was found in getting some of the joints tight.

The following table will give about the saving effected in Dartmouth by the adoption of the wood joints :

Diam. of Pipe.	Cost including laying.		Saving per joint	No. joints.	Total saving.
	Wood.	Lead.			
	$ c.	$ c.	$ c.		$ c.
20 in.	1 38	2 30	92	205	188 60
12 in.	90	1 45	55	870	478 50
10 in.	77	1 25	48	125	60 00
					$727 10

This saving, together with the saving of the cost of the cofferdam referred to above, would dig up and repair a great many joints if they should happen to leak on account of wood not making so sure a joint as lead.

DISTRIBUTION.

The distribution system is shown in dotted line on the plan (Plate II.). The 10 in. pipe runs down Ochterloney st. as far as King st., where it is reduced to an 8 in.; this runs as far as Water st., then turns along Water st. as far as Stairs st. An 8 in. also branches off and runs along King st. as far as Portland st. The south end of Water st., Prince st., portions of King and Wentworth streets and Quarl and Portland streets are laid with 6 in. pipes. Boggs, Green, Dundas and part of Wentworth streets and Wilson's lane are laid with 4 in.

The following are the lengths of the different sizes of pipes in the town :

584 ft. 10 in. pipe.
1943 " 8 " "
6054 " 6 " "
2033 " 4 " "

The extensions shown on the plan will probably be made next summer (1893). This will include 3760 feet 8 in., 6250 feet 6 in., and 788 feet 4 in. pipe.

The pipes are all in 12 feet lengths, and are made by the Londonderry Iron Co. They have given every satisfaction, only 4 being broken on the main line, and when the pressure was put on in the town, only one broken pipe showed up, which was a 6 in. split for about 3 feet in the middle. The special castings were made by the Truro Foundry Co., and the valves are of the Ludlow pattern and made by Stevens & Burns, London, Ont.

The pipes in the town, with the exception of 300 feet of 6 in. and 250 feet of 8 in., are all jointed with lead. The pressure in the town was so great that it would have been difficult to make wood joints in the small pipes tight without having the water on to test them as they were laid. The difference in cost between wood and lead joints in the small pipe would have been very slight. The 300 feet of 6 inch pipe laid with wood is on Water st. from Ochterloney to Quarl, and has not shown a single leak though under a pressure of 95 lbs.

The dead ends and specials left for future extension were plugged with a wooden plug turned to the proper diameter and put in with an ordinary wood joint. These have stood very well. Out of twenty, only two, and these each under a pressure of from 90 to 95 lbs., have blown out.

The hydrants, of which there are 25, are made by the Burrell Johnston Iron Co., Yarmouth, N.S. The valve in this hydrant shuts against the pressure, is faced with leather, and shuts against a brass seat. The screw for working the spindle is at the top, working in a brass nut. They have two 2½ in. discharge nozzles, and are all connected with the main by 6 in. branches.

After the hydrants were set, it was found that through some mistake the nozzles would not fit the hose then used by the town. The cheapest way to overcome this difficulty was found to be to change the nozzles, which were of brass leaded into the top of the hydrants. To get them out, pieces of iron about 2 inches in diameter and 5 ins. long were heated in a portable forge, and one inserted in each nozzle. As they cooled, fresh ones were put in, and after being changed three times the nozzle usually dropped out, and the new ones were leaded right in. Three men with four iron lumps and a portable forge changed all the hydrant nozzles in the town in two days.

The cost of the hydrants in Dartmouth when set was about $50.00 each.

HOUSE SERVICES.

The house connections are all made with ½ inch lead pipe weighing 7 lbs. to the yard, and costing when laid in the trench about 12c. per foot. The trenching for house services was done by labourers at a contract price of 12c. per foot run, and men working at that price made very good wages. The lead pipe is taken from the main by a straight brass screw nipple. The corporation cocks are set in the sidewalk about a foot out from the side line of the street. The service boxes are on the extension pattern made of cast iron. All the service boxes, stopcock and nipples were made by Stevens & Burns. Connections between brass and lead were made by the ordinary compression joint.

The service-pipes were laid to a depth of 5 feet; this seems to be below frost level in Dartmouth, as no service-pipe has frozen up to date (March 16, 1893), and this has been an exceptionally cold winter. The average cost of a house service where there was no rock to contend with was about $10.

The *trenching* on the main line from the lakes to Pine street, as well as the pipe laying, was done by contract at the following prices per cubic yard: rock, $1.75; loose rock, 65c; and earth 27c. The refilling was done at the rate of 10cts. per cubic yard. As to the trenching in the town, see below.

The *pressure* in the town, as indicated by a gauge on the hydrants, varies from 75 to 91 lbs. This is sufficient to throw a good stream over any building in town without the aid of a fire engine.

SEWERAGE SYSTEM.

As will be seen by the plan (Plate II.), the sewerage of Dartmouth is divided into three separate systems, each having its own outfall. The principal outfall is that at North street, which will eventually drain most of the town north of Ochterloney street, though the area at present draining into it is only about 29 acres.

The outfall is a 20 in. × 30 in. concrete block egg-shaped sewer, extended out into the harbour 30 feet, with a circular wooden box 30 ins. in diameter with the sides 5 ins. thick. The main sewer of this system starts with a 12 in. pipe at the corner of Pine and Ochterloney streets, and runs down Ochterloney street 1188 feet, to King street, where it increases to 15 inches diam., running with that diameter 580 ft., as far as Water street. It then turns north along Water street as a 20 in. × 30 in. concrete sewer, and runs 280 feet to North st., and then turns down North street 221 feet to the outfall. The sewer receives branches from most of the cross streets on the way down, and will eventually drain them all. It can also drain Pine, part of Maple, and Beech streets with all their cross streets. This system can also be extended, from Stairs st. north along the Windmill Road about 1,000 feet, and also up Stairs st., to drain Church st. and the north ends of Prince, King and Wentworth streets.

The next system empties at Boggs st. This is capable of very little further extension. It at present drains 10½ acres. The outfall is of 15 in. crock pipe extended 18 feet into the harbour with a circular wooden box 16 in. diam., with the sides 4 in. thick. This system drains Water st. (south of Quarl), Prince st., Portland st. and Boggs st.

The other system, emptying at the foot of Wentworth st. into the canal, can be extended no further. It drains an area of 14.7 acres, the outlet is a 16 inch wooden box, sides 4 in. thick, and runs out into the stream 80 feet. This system drains most of Portland st. and half of Quarl st. with their several cross streets. At the corner of Dundas and Portland streets a cutting of 17 feet had to be made to overcome the rising ground from Wilson's lane to Dundas st.

The lengths of the different size sewers at present laid in the town are as follows:

500	feet	20 in. × 30 in.	concrete block	sewer.
1087	"	15 in.	vitrified salt glazed	sewer pipe.
4146	"	12 in.	do	do
4882	"	9 in.	do	do
475	"	6 in.	do	do

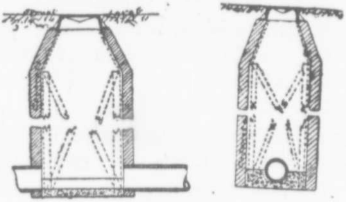
All the sewer pipe used was from the Standard Drain Pipe Co. of St. Johns, P.Q. The concrete sewer came from the city of Halifax at a cost of $1.30 per running foot, with an addition of $1 per ton truckage aad ferriage.

The Wooden Box Extensions to the Boggs and North street outfalls were made after the outfalls were built, it being thought advisable to extend them further out into the harbour so as to empty below low tide level and to keep sand, shingle, etc., from washing into the mouth of the sewer and clogging it up. The Wentworth st. outfall is entirely a wooden box run out into the stream 80 feet. This is not below low water, as when the tide is out the stream is only about 6 inches deep. The boxes are made of hemlock in pieces 12 to 18 feet long, narrowed on the inside so as to form a circle when laid together. A raft was first built having a frame of 6 in. × 8 in: timber, and planked with 2 in. planking; the box was then built right onto the raft, one piece being put on at a time and spiked securely to its neighbour. When the box was finished, a cribwork of 6 in. × 8 in. timbers was built up around the mouth to a level with the top of the box and extending back about 8 feet. The raft was then floated into position and the crib filled with stone to sink it. The whole raft and box was then covered over with stone, forming a solid wall as a protection from floating logs, etc. In the canal this wall runs half way across the stream so as to turn the full force of the current directly past the mouth of the sewer and carry the sewage right away.

In laying the sewers under water at the outfall, a cofferdam was built to keep out the water. Stakes were driven in, leaving a space of two feet between them; these were planked up on the inside, and the space between them filled with well rammed clay. This made a very tight dam, effectually keeping the water out until the necessary pipe and masonry had been laid. At the Boggs st. outfall the sewer pipe under water was laid in a bed of cement and covered with the same to a depth of 6 inches.

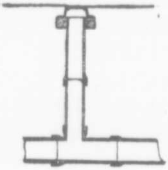
MANHOLES, VENTILATORS AND CATCH PITS.

Wherever two or more sewers meet, there is a manhole, and at every change of grade a lamphole and ventilator, so that there is no sewer in the town which is not open to thorough inspection.

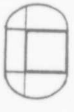


MANHOLE.

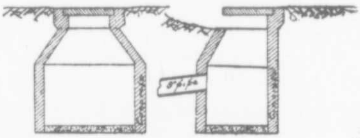
The catch basins are connected with the sewer by a 9 in. pipe always with a good fall. All catch basins and manholes are made of concrete instead of brick, which elsewhere is generally used for the purpose.



Ventilator.



Top View C. P. Mould.



Front Elevation. Long'l. Section.
CATCH-PIT.

The catch pits, of which there are 42, were designed by Mr. E. H. Keating, M.I.C.E., then city engineer of Halifax, now city engineer of Toronto. The moulds are made in sections fastened together on the inside by pieces of iron about 2 in × 4 in. and ⅛ in. thick, and common wood screws. The bottoms of the catch pits are 6 feet below the level of the sidewalks. The lower 3 feet 3 in., as will be seen by referring to the plan (Plate IV), is elliptical in shape, 4½ feet long × 3 feet wide; then they begin to narrow, and are 2 feet square at the top. The side away from the gutter is perpendicular, while the other side runs out under the gutter. The sides are 6 in. thick; the excavation is taken out, so as to leave a space of from 6 to 8 in. outside the mould. This space is filled with concrete to a height of 3 ft. 6 in., the connection with the sewer having been put in two feet from the bottom. After this, stones are built up around to keep the concrete of the proper thickness till it is built to a height of five feet. Then the top mould, having grooves for the reception of the concrete covers, are put on, and the top finished with a grout of 2 to 1 gravel and cement. After the concrete is set, a man goes inside with a screw-driver, takes the moulds apart, and passes them up piece by piece through the top. The mould is then put together and carted to the next hole. The bottom, which is of concrete with a stone foundation, is then put in. A catch pit of this kind can be built by three men in less than two days at a cost of about $30.

Man-holes being of different depths, a standard mould could not be made more than the two top feet. The remainder was made by a frame 3 ft. long x 4 ft. wide of 3 in. by 4 in. scantling braced in position and fastened with lag screws. 1½ inch boards were placed against the outside of the frame, and concrete rammed in against them. The top mould was then set on the posts of the frame and concreted up to the top, leaving the opening at the top 18 in. × 20 in. When the concrete is set, the moulds are taken apart from the inside and passed through the top. A cast-iron top with a moveable cover is then put on the concrete, and the bottom, which is of concrete having grooves for the flow of water, is put in, and the man-hole is completed. The cost of a man-hole of course depends entirely on the depth, but an average one, say about 8 or 9 feet deep, in Dartmouth costs about $40.00.

Some objection might be raised against the use of concrete for man-holes, on account of the heavy traffic on the streets being liable to break off the concrete. The traffic on the Dartmouth streets is very heavy, but no trouble of this kind has occurred as yet.

The ventilators or lamp-holes are made by a 9 in. crock pipe coming to within a foot of the surface, with a loose concrete collar set over it, about a foot from the ground surface and resting on the ground around the pipe. A round cast-iron top with a moveable cover is set on the collar as a protection to the pipe.

HOUSE DRAINAGE.

The house drains are all, except in the case of a double house, laid with 4 in. crock pipe. No grade is allowed less than 1 foot fall in 48 ft., and they are all laid to a good even grade. The junctions left at the main for house connections are 6 in. branches bevelled from the main pipe; these are reduced at the main to 4 in.

The main trap of most of the houses is the hand-hole trap as made by the Standard D. P. Co. This is set just outside the foundation wall, and has a 4 in. cast-iron pipe coming to the surface as fresh air shaft, to ventilate the main soil pipe inside the house.

TRENCHING.

Within the town, wherever there were both water and sewer pipes to be laid in the same street, they were laid in the same trench, the sewer pipe being 2 ft. to one side and from 2 to 10 ft. below the water pipe.

A trench intended for the reception of the two pipes was started at the top 5 ft. wide, and continued that width until it was 5½ ft. deep, then one side of the trench was dug down 3 ft. wide to the proper grade for the sewer. The sewer pipe was laid first, and the trench filled up to the level for the water pipe; then the water pipe was laid and the trench filled up.

After the water was turned on in the town, wherever there was any filling to be done, a hose was put on the nearest hydrant and the water turned into the trench. This settled the earth excellently, and saved much expense in men ramming in the trench and horses and carts to cart away surplus material. When an earth trench was filled in this way there was very rarely any earth at all to be carted away.

In the house connections, house-drains were usually placed in the same trench as the service pipe, always provided, however, that they were put 1½ ft. below the service pipe. It is the author's opinion that this has had a good deal to do with keeping many of the service pipes from freezing up. The last service that was put in was a combined trench, and had to be filled with frozen earth, and the water pipe froze up while the plumbers were at work at it. This was not discovered until after the trench was filled, so it was left a week or two before steps were taken to thaw it out. The people in the house, however, began to use the sink at once. About ten days after the trench was filled the water started of its own accord, and has been running ever since. The warm air in the sewer pipe actually thawed out the ground for a foot and a half around it, and started the water.

All the rock in the main trenches and in some of the house trenches, which was nearly vertically bedded slate, was taken out by contract with steam drills at a price of $4.00 per cubic yard. This might have been done somewhat more cheaply with hand-drills by day's labor, but it would probably have extended the work into the next year and cost more in the end. There was a great deal of rock in the town, and the steam drills, working night and day, took it out very quickly. There was removed in the town altogether about 2,650 cubic yards.

The cost of earth trenching, which was done by day's work, was from 30 to 35 cts. per yard, and refilling trenches from 10 to 15 cts.

In rock the trenches were taken out 6 ins. below grade, and filled up to grade with good, well rammed earth, making a good bed for the sewer to lie on.

The lightest grade for a sewer in the town is the 12 inch sewer on Ochterloney st. from Pine to Wentworth sts., a length of about 900 ft., falling at the rate of 0.435 per 100.

In connection with sewer ventilation the writer noticed that on frosty mornings warm air was escaping from the mouths of the catch-pits in the more elevated portions of the town, while if a piece of lighted paper were set in front of one of the lower catch-pits a strong current of air was seen to be drawn in. This, of course, is only the result of nature's law that warm air rises. As Dartmouth is rather hilly and most of the grades steep, this circulation would naturally, in cold weather, be very rapid, and serve as an excellent ventilation for the sewers. An opportunity has not yet occurred to notice the effect of this in warm weather, but it is supposed that there would be less circulation the more the temperature of the outside air became equal to that of the sewer.

This circulation might in very cold weather endanger the safety of the lower catch-pits on account of freezing the two feet of water always lying in the bottom. This matter has not yet been fully investigated, but as the weather in Dartmouth never remains cold for any great length of time, it is thought they will be tolerably safe.

The cost of the water service was about $59,370, and that of the sewers $30,970. The work was begun in the fall of 1891, under the direction of Mr. C. E. W. Dodwell, M.I.C.E., M.Can.Soc.C.E. In that year the pipe house and a great part of the main pipe line were built, also the sewer outfalls at North and Boggs streets, and some of the sewers laid. Mr. Dodwell resigned in November to accept another position when the work was taken charge of by Mr. W. G. Yorston, C.E. In the following year the remainder of the work was done, the last house service being filled up on December 31, 1892. The deep cutting about half a mile from the lake was done in the winter of 1891-92 and the main line finished in May, 1892. Owing to some delay in repairing the leaks on the line, the water was not finally turned on in the town until November 1st. It has remained on ever since, and given every satisfaction to the rate-payers, as is evidenced by the fact that at a public meeting held March 23, 1893, the town council was authorized to go to the Legislature for permission to borrow $35,000 to carry on the proposed extensions spoken of above.

Note added Feb. 12th, 1894:—During the summer of 1893, the following extensions were made to the water and sewerage systems: There were laid 14,500 ft. of water pipe, making a total now laid of about 7½ miles; also 10,200 ft. of sewers, making a total now laid of over 4 miles. 31 additional hydrants were set, making a total now in use of 55. The number of houses now connected with the water mains is 350, and those using the sewers number about 250. The work of trenching was done in small contracts, and cost on an average about as follows: Solid rock, $2.60 per cubic yard; loose rock, 50cts. per cubic yard; earth, 26cts. per cubic yard. The contractors seem to have done very well at these prices. Flush cocks, varying in size from ½ to 4 inches, have been placed at the dead-ends of most of the sewers; these are comparatively inexpensive, and are very effective in their work.

CORRESPONDENCE.

Mr. Gray.

Mr. H. A. Gray said he wished to correct an error which was evidently unintentional on the part of the author of this paper, in his statement that the source of the system of water works for the town of Dartmouth had been first recommended in the year 1875, by Mr. T. C. Keefer, M.Can.Soc.C.E., and afterwards approved of by Mr. E. H. Keating. By reference to the published report of the Town Council of Dartmouth in April, 1875, it will be seen that the writer explored all the lakes in the vicinity of that town, tested the water, X and under date April 26th, 1875, reported to the warden of Dartmouth, W. S. Symonds, in favour of obtaining the supply from Lamont and Topsail Lakes, and that on May 31st, 1875, he submitted detailed plans and estimates of cost of the work. In July, 1875, Mr. E. W. Jarvis, A.I.C.E., went over the work and calculations with the writer, and afterwards wrote a letter recommending the proposed scheme. Mr. Keefer, being consulted in the matter in the autumn of 1875, reported under date March 7th, 1876, recommending the same locality as a source of supply. The writer is much pleased to see that the scheme has now been so successfully carried out.

Mr. Mohun.

Mr. Mohun said:—The use of the concrete for the egg-shaped sewers, man-holes, etc., is likely to yield the most satisfactory results. About two years ago the writer constructed a concrete egg-shaped sewer over 9,000 feet long, which proved absolutely water-tight through its entire length as high as the springing line where one or two small leaks were found, and subsequently easily stopped; this sewer was constructed in the trench.

Mr. Creighton states "the concrete sewer came from the city of Halifax." Are we to understand that it was moulded in Halifax and shipped in sections? If so, were the invert blocks, sides, and arches moulded in separate pieces, and what precautions were taken to render the joints absolutely tight? It would also be interesting to know of what materials the concrete was formed, and in what proportions it was mixed.

Judging from the plan and the statement that the Wentworth street outfall at low water discharges into a stream 6 in. deep, the writer fears that the discharge at this point will, at no distant date, become an

x There is a reference in Hfx papers in the 1840's
or so about water being suggested for Dartmouth

intolerable nuisance. It is stated that the area tributary to this outlet is in round numbers 15 acres, and that this portion of the system can be extended no further. It appears to the writer that this is precisely one of those cases in which a different method from that obtaining in the larger areas might be advantageously adopted.

Assuming that the Boggs street outlet is unobjectionable, and that a proper grade from Wentworth street to that point cannot be obtained to discharge by gravitation, it would seem that the surface water might well discharge into the canal, leaving the sewage to be dealt with in another manner.

Taking the area at 15 acres, the population at 50 per acre, which is probably excessive, and the sewage at 5 gallons per head an hour, the quantity to be dealt with would only be 62½ gallons a minute, and this would not require to be raised apparently more than, say, 5 feet. The small power required might well be obtained from the water works.

Personally, the writer is strongly in favour of placing man-holes not only at the junctions of sewers, but also at all changes of direction whether horizontal or vertical.

The author states that "flush cocks varying in size from ½ to 4 inches have been placed at the dead ends of most of the sewers."

For the purpose of flushing, as that term is understood by the writer, *i.e.*, the sudden discharge of a considerable volume of water into the sewer, the use of small cocks, though while open maintaining a stream in the sewer, is hardly adapted to the purpose in view. It is possible that this, however, is only a temporary expedient. The upper ends of all sewers should, in the writer's opinion, be provided with automatic flush tanks.

It is observed that 6 inches diameter is the minimum size adopted. This question has been so often debated that it is unnecessary to recapitulate the arguments which have been advanced, but it is believed that the general concensus of engineering opinion is in favour of the 8 inch as the minimum size.

A very important point, which the writer, being totally ignorant of the local conditions prevailing, approaches with some diffidence, is the probable future condition at the North street outfall. From the plan, this outfall appears to be completely embayed, and the question arising in the writer's mind is whether the currents at different stages of the tide are sufficiently strong and have proper direction to remove the sewage from the water front. This question, however, can only be answered by one possessing local knowledge.

Mr. Alan Macdougall said:—It might not be considered *en règle* for a senior to comment on the paper of a student, the object of the students' papers being to elicit and bring out discussion from the students themselves; still, he could not pass over the opportunity of expressing his appreciation of the paper. It gives ample evidence of the capabilities of our student class, and it is a paper which will compare favourably with those written by the similar classes in some of the other great engineering societies. The publication of these papers in the Proceedings of a Society such as ours gives them prominence which they would not attain when published in a journal of a small local society. He trusted this paper would be an incentive to other students to present papers to the Society. He trusted that the students resident in Toronto would be able to spare sufficient time from their academic work to discuss the paper; he had offered to act as chairman at a meeting, and he had hopes of being able to forward a contribution to the discussion on this very interesting paper from the Toronto students. Mr. Macdougall

Mr. Creighton said: In reply to Mr. Gray, the writer wishes to say that the records of the town about the time that the water-works agitation started are in a very mixed up condition, and it is a very easy matter to make a mistake. The writer remembers seeing a report of Mr. Gray's, but was under the impression that it was later than that of Mr. Keefer. Mr. Creighton.

Regarding the concrete sewers, they were moulded in sections at the Halifax Poor Asylum, shipped to Dartmouth, and put together in the trench with Portland cement mortar mixed 2 to 1. A cross section of the sewer shows six pieces—one for the invert, two for the sides and three for the arch.

The blocks were laid so as to break joints. As to the proportions used in making the blocks, the figures are not at hand. But Mr. Doane, M.Can.Soc.C. E., city engineer of Halifax, will be able to furnish them.

The objections with regard to the Wentworth st. outfall are very easily overcome without resorting to the Boggs st. outfall, as suggested by Mr. Mohun. It is true that the stream is only 6 inches deep where the sewage enters it, but that depth only continues as far as the railway trestle shown on the plan, where it drops right off into deep water. The tide at the mouth of the sewer rises about 4 feet, but only rises up stream to a point about 100 feet below the lower canal bridge. When the tide is out, there is always a strong current past the mouth of the sewer, and it comes in so slowly that there is never any back current. It will also be noticed by the plans that the sewer is built pointing directly out into the harbour, so that if at any future date it should prove offensive, it is a very simple matter to run it out into deep water.

The mouth of the North st. outfall is not as deeply embayed as Mr. Mohun understands it to be. The wharves in the vicinity are built on piles, so that the water has a good chance to scour all round the mouth of the sewer. After a year's work there is no trace whatever of any sewage settling near it.

The flush-cocks spoken of are not temporary but a permanent work, and the writer is of opinion that if properly looked after, and taking expense and quantity of water used into consideration, they are quite as good as the automatic flush tank. It must be borne in mind that the rainfall in Dartmouth is considerable, and that goes a long way toward keeping the sewers in good condition. The very small cocks are only used at the top of short steep grades where they have very little work to do. There are about eight 4-inch cocks, but the majority are from 1½ to 2 inches. As these discharge under a pressure of from 60 to 90 lbs., it will be seen that a considerable flow of water can be obtained. Another use that has been found for these cocks is to open them slightly in very exposed places to keep up a flow in the dead end of a water-pipe in very cold weather. The *Engineering Record* of May 26th says that they are putting in the same cocks in Newton, Mass., though they do not seem to be doing it as effectually as was done in Dartmouth.

It was removed later as a menace to health
Swimming went on in summer all around that point

Thursday, 15th March.

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

Paper No. 93.

THE CONSTRUCTION OF A SMALL TUNNEL.

By J. G. G. Kerry, A. M. Can.Soc.C.E.

INTRODUCTION.

The West Virginia & Pittsburgh R.R., a feeder of the B. & O. system, was built to open up the sparsely settled and formerly inaccessible counties of Central West Virginia. Topographically, these counties show series of heavy narrow parallel ridges with deep dividing valleys; these ridges run roughly east and west, and are some of the many chains of mountains comprising the great Alleghany range; the valleys are drained by tributaries of the Great Kanawha River, one of the main feeders of the Ohio. The slopes of these ridges are short and rough, and the line in its general course due southward cuts directly across them, necessitating a difficult location with heavy grades and expensive work. At the divide between the Little Kanawha and Elk River valleys, it was found impossible to locate over the summit while maintaining the desired maximum grade of 1.5 per 100, and the tunnel whose construction is described in this paper was needed to pass this point.

The railroad was built by the West Virginia Improvement Co., of which Mr. J. A. Fickinger was Chief Engineer and Manager, and the contract for this work was let in January, 1891, to T. J. Steers & Co. of Weston, W.Va.

LOCATION.

As finally located, the line passes through the north approach cut and into the tunnel on a 7° 30′ curve, the P.T. of which lies some 40 ft. beyond the portal; the remainder of the tunnel and the south approach cut are on the tangent to this curve. The tunnel is built on a 0.25 per 100 grade falling to the southward, and is on the summit between two 1.50 per 100 grades. The portals were laid out so that the cut on centre line at the head of the portal slope would be 50 feet, the distance between them being 624 feet.

MATERIAL.

The material through which the tunnel was driven was a soft blue clay shale, nearly dry, and showing little stratification. This shale rapidly disintegrated on exposure to the air, and tunneling through it without timbering would have been dangerous if not impossible. The company not being prepared to line the tunnel throughout with masonry at the time of construction, it was necessary to use a system of timbering amply strong for several years' service and large enough to contain the masonry when it should be built. The unusually large excavation section shown in Fig. 1 (18.77 cub. yds. per lin. ft.) was rendered necessary by this double lining. The shale was overlaid with beds of heavy and strong sandstone dipping slightly toward the north, and so low that near the north portal some of the sandstone had to be blown down to make room for the timbering.

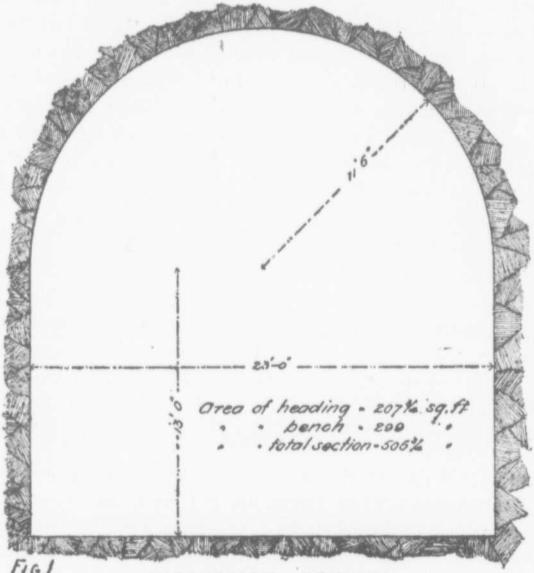


FIG. 1

EXCAVATION SECTION

METHOD OF EXCAVATION.

When the contractors had full forces, the excavation was carried on by day and night shifts, working ten hours each, from both ends of the tunnel. It was but rarely, however, that full forces were employed, as the adjacent grading was more backward than the tunnel and the men were drawn off to it. The excavation was all done by hand work, no special tunnel machinery being employed, and it was conducted on the general principle that nothing is so expensive in tunneling as a cave-in.

HEADING.

The shifts were divided into heading and bench gangs, the foreman of the bench gang being, however, subject to directions from the foreman of the heading. The heading gang consisted of a foreman, 8 miners, 6 muckers and a "nipper;" and its work was to excavate the material from the bottom of the wall-plates up (7.70 cub. yds. per lin. ft.), to place the wall-plates in position, to erect the arches upon them, and to lag and pack the same.

Coming back into the heading after a blast, the miners first pulled down all dangerous material from the roof, then cleared away enough of the debris of the blast to give themselves working room, and proceeded with the drilling. Three sets of holes (two wet and one dry) were usually drilled in the face of the heading; each set consisting of four holes about 4 ft. deep, the exact placing of each hole depending on the success of the last shot; twenty-four lin. ft. of hole was considered a day's work for two miners. The holes were loaded with from 4 to 6 sticks ($\frac{1}{3}$ lb.) of dynamite apiece, and fired by battery or fuse, as might

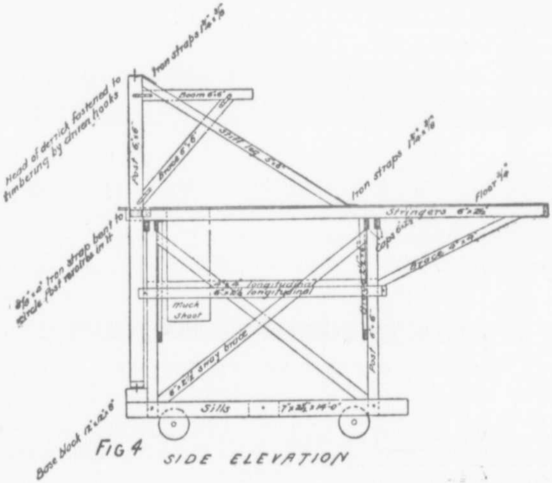
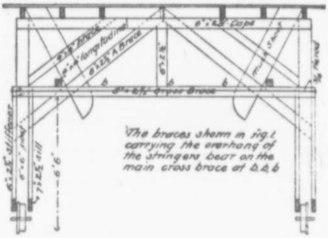


FIG 4 SIDE ELEVATION

be desired; as far as practicable, all blasts were fired at the end of the five hour spells, so that the dynamite fumes might dissipate during the idle hour; the average fall from a heading blast was 2½ ft.

While the drilling was progressing, the muckers cleaned up the heading, the scaffold car, Figs. 4, 5 and 6, being necessary for this purpose. This was a mounted platform, in height a little lower than the heading floor, and with its frame so arranged that dump cars could run right under it and be loaded through shoots from the platform above. It ran on a special track, and was provided with long detached planks which were laid from the platform to the heading floor, the muck being wheeled down them and dumped through the shoots. The car was provided with a small derrick for handling timber, lagging and packing.



The braces shown in fig. 1 carrying the overhang of the stringers bear on the main cross brace at b, b, b

FIG 5 FRONT ELEVATION

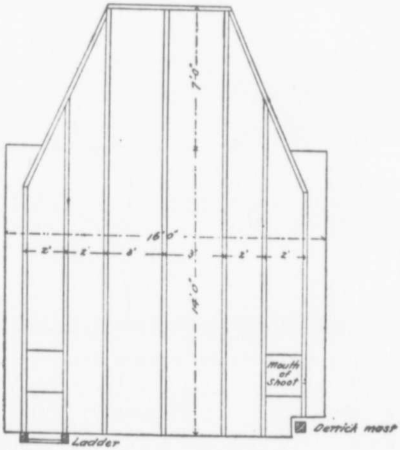


FIG 6 FLOOR PLAN

BENCH.

The bench gang consisted of a foreman, 8 drillers, 10 muckers and a "nipper;" and its work was to excavate the material remaining in the section (11.07 cub. yds. per lin. ft.), to place the plumb posts, and to lag and pack behind them.

After a bench blast, the whole gang was put at work cleaning off the rails of the scaffold car track, and pushing this up as way was made for it, it being always run back for safety before a blast. When the scaffold car was brought far enough ahead to communicate with the heading, the drillers cleared off places for their new set of holes, and went to work on them. The bench was shot down in four foot holds, two half-depth blasts being made for each hold; each blast consisted of four holes, two being centre holes and two drilled as nearly vertically under the inside edge of the wall-plate as possible; the charges were 10 sticks of dynamite to an outside hole and 15 to a centre one. The drilling and blasting of the bench though simple required skillful management, the points to be guarded against being, damage to plumb posts and arch timbers, danger of uncovering too great a length of the wall-plate at a single shot, and complete avoidance of any interference with the progress of the heading.

The muck was taken out to the dump in side-dumpers of about one yd. practical capacity run in trains of two, the heading muckers loading one through the scaffold car shoots, while the bench men loaded the other, the bench men having to clean up to the face of the bench before the next blast was ready. Where the rock shot down in large masses, progress was much aided by the use of stone flats mounted, so that the platforms were flush with the tops of their wheels, on to which heavy rock could be barred without blockholing or extra handling. The bench was kept about two wall-plate lengths behind the heading, and made the same average progress. This progress was about 2½ ft. per shift; the actual excavation was made at a rate of 5 ft. per shift, but as the time consumed in pointing down odd projections, timbering, lagging and packing being equal to that spent on rough excavation, the progress rate was only 2½ ft. per shift.

PROGRESS OF EXCAVATION.

The north heading started under on April 17th, the south heading being delayed by a heavy approach cut until June 3rd. No record was kept of the monthly progress, the irregularities of the forces and delays occasioned by lack of timber rendering all such records valueless.

The headings were holed on Sept. 17th, and the bench was finished by Oct. 15th, the work having been in progress for just six months. The heading was driven with great care, and no exceptional record was made until the night before the holing, when two gangs drove 20 ft. of heading of rapidly diminishing cross-section in a desperate effort to pierce the 24 feet remaining in the tunnel. The driving of the bench was of course limited by the heading, but after its completion the pick of the forces were placed on the bench, and with gangs increased to one foreman, 8 drillers, 12 muckers and nipper, the rate of progress rose to 3½ feet per shift, the bench being blown in 6 ft. holds.

DIFFICULTIES IN EXCAVATION.

No trouble was experienced with the bench anywhere, but the heading was frequently in bad ground. At the north portal the top of the heading passed into a shattered bed of sandstone rock, which could not be shot down without disturbing a considerable amount of material on the portal slope. Here a 6′ × 8′ drift was made under the sandstone, and the heading expanded to its full section and timbered at the second wall-plate, and the first wall-plate length was driven outwards, the shattered rock being caught up by timbers as quickly as the excavation was completed.

As the tunnel grade fell and the sandstone rose to the southward, the heading was soon clear of the sandstone, which made an admirable roof for a season. The shale had very little adhesion to the sandstone, and when the sandstone bed and the tunnel section separated, it soon proved itself not sufficiently strong to hold up across the span by coming down in heavy falls, which left the bottom of the sandstone exposed. The material between the bottom of the sandstone and the top of the section was accordingly excavated, until its thickness grew such that the cost of its removal became an item of considerable expense when it was determined to hold it in place. This material where removed was classified as "fallen material."

Up to this point the system had been to drive a full heading for a wall-plate length, and then timber it up. This was now changed, and the heading was driven with an arched longitudinal section having full height at the end of the preceding wall-plate, and being barely high enough at the end of the new wall-plate to admit of its being easily placed. The new wall-plate being in position, the excavation necessary for each of its imposed arches was made separately, each being erected, blocked and partially packed before the excavation for the succeeding one was commenced. The last arch being up, the heading was again driven forward for a new wall-plate. Side drifting to place the wall-plates, on which the arches were then built as in the method just described, was tried, but was almost immediately abandoned as more costly than that method.

It is only just to remark that, owing to the great care thus taken by the contractors in all doubtful places, neither fatality nor accidental interruption occurred during the progress of the work.

TIMBER.

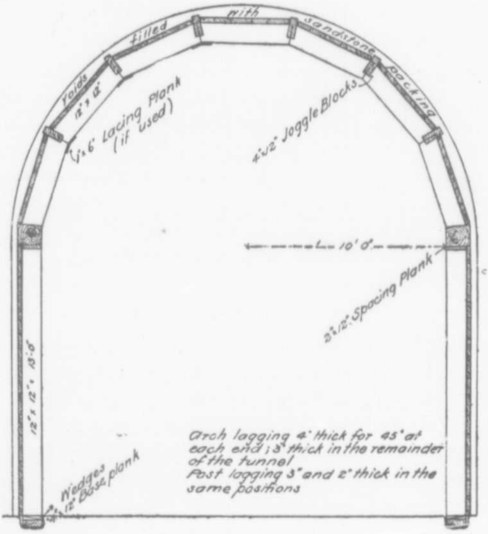


FIG 2 SECTION OF TIMBERING

The system of timbering is shown in Figs. 2 and 3. All timber was of white oak, and was carefully inspected; all sticks had to be in a thoroughly sound condition, and arch segments were rejected if they showed any sign of longitudinal cracking or splitting. The system of erection as follows :—

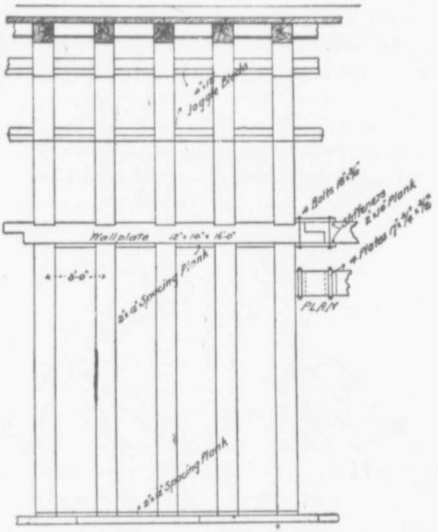


FIG 3 ELEVATION OF TIMBERING

HEADING TIMBER.

The heading being ready, a pair of wall-plates were brought in, and the engineers were sent for to superintend the placing of them. This operation is described further on. The wall-plates were 12″ × 14′ 16′ 0″, and as the theoretical springing of the arch was at the lower side of the wall-plate, radial beds were adzed on its upper side, to make bearings for the arch timbers; the wall-plates were jointed by halving for a foot at each end, and were made in pairs, right and left, so that the forward end when in position might always show the lower section of the half-joint, that being a material advantage in the placing of the plates. The wall-plates being in position and securely blocked against outward and downward movement, the joints were secured by tightening up the clamps. The detail of these clamps is shown in Fig. 3. Stiffening planks 2″ × 14″ × 2′ 0″ were placed above and below the jointed plates, and drawn against them by tightening up bolts working through pairs of transverse straps. These bolts and straps are entirely outside the timber, and comprise all the permanent iron in the tunnel.

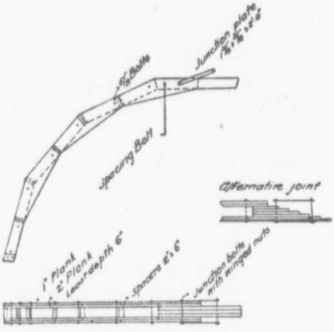


FIG 7 CENTRING FOR TIMBER ARCHES

The arches were erected on the segment centres shown in Fig. 7. The arches are of 12″×12″ timber, in seven segments, the segments being cut to template, and were erected by simply laying each segment in place on the centres. The centres were erected by jointing the two segments by the bolts shown in Fig. 7, and then blocking up their feet to proper position; the long hook shown in the same Fig. was driven into the preceding arch, and served to hold the frame in position at its proper spacing; the second system of segment joint there shown proved the better in practice, being more readily handled. The arch segments being up, they were blocked solidly from the roof against all upward and outward movement, and 4″ × 12″ joggle-blocks with 8″ shoulders were placed between consecutive arches at each joint. The centres were then withdrawn and the lagging commenced. The lagging was close-laid in lengths equal to the arch spacing, and the bottom piece bore on the projecting back of the wall-plate. All voids back of the lagging were filled with broken sandstone brought into the tunnel for the purpose, and hand-laid. The use of sandstone was insisted upon because it was feared that the shale would deteriorate in time and yield under pressure if used as packing, thus giving the masses above a chance to start moving. The lagging and packing were carried up simultaneously, the packing of the crown segment being completed from between the next arches; and the timbering was completed by nailing up the two lines of 1″×6″ lacing plank at each joint. These lacing planks were to protect the corners of the segments from blasts, and were torn down after the tunnel was completed. They had the demerit of hiding the condition of the joint, and were accordingly omitted in bad ground.

BENCH TIMBER.

As the bench was removed, the wall-plates were caught up on the plumb posts, due watch being kept that no length of the wall-plates was at any time left without ample support. The posts were underlaid by 4″ × 12″ plank in 6 feet lengths, and wedges bearing upon these planks were driven until the post took a full bearing against the wall-plate above. The posts were spaced by 2″ × 12″ plank at foot and head. The lagging and packing were carried up simultaneously from the floor level, but it was not considered necessary to keep this work right up as in the case of the arch logging, and it often fell considerably behind, the shale on such occasions proving itself amply strong to stand without support during the short period of exposure, the rate of disintegration being very slow in the unchanging atmosphere of the tunnel. No provision was made in this system for sidelong pressure, and no need of such provision was developed.

DIFFICULTIES AND ALTERATIONS OF TIMBERING.

The details of the system were varied to suit circumstances. The heaviest pressure (immediate and future) was anticipated at the portal, and the end wall-plates were accordingly carried well out, and all the ragged voids between the lagging and the portal slope filled with timber blocks; and for the first 45 ft. at the entrance 4″ lagging was used over the arch, and 3″ behind the plumb posts, these being reduced to 3″ and 2″ respectively for the remainder of the tunnel. The arch and plumb post spacing was 3 ft. centre to centre: a proposition to maintain the thickness of the lagging at the end of the first 45 ft. and to increase the tib spacing being considered and rejected.

As described hereafter, the wall-plates were set narrow, high and canted slightly inwards, the effect being to leave the segment joints open at the back and tight on the front, so that the joints would take a full bearing when the pressure came on and the edges yielded under it. Near the centre of the tunnel it was noticed that the joints of the arches on three wall-plates had opened at their lower edges indicating heavy downward pressure. The wall-plates were immediately dapped to receive extra arches; these were similar to the existing arches in every respect, except that one of the end segments was cut off short and wedges were placed between it and the wall-plate, by driving which the arch was forced to a full bearing against the lagging. For two wall-plates after this occurrence, seven arches were placed on a wall-plate instead of five;

but as the indications of pressure then ceased, the five were again adopted.

GRADE AND ALIGNMENT.

By reason of the general plan of construction necessarily adopted, the company had to excavate a large and expensive section ; but this section was reduced wherever practicable, and thus the clearance between the systems of lining was reduced to a minimum, necessitating very careful placing of the timbering. The wall-plates were the determining members of the timber system, and they were, therefore, placed by the engineering staff. The plan of operations was as follows :

Taking advantage of the fact that the main tangent in the tunnel passed out of the portal at the curved end well within the section, this line was established by five hubs, one over each portal, to serve as back-sights, one on the summit and one well away from each portal, in such position as to command a full view of it. These latter served as instrument stations, and from them the line could be run right into the heading when necessary. No permanent points were established in the tunnel, the line being always brought up from the outside points when required ; the P.T. was established temporarily and the curve run in from the tunnel tangent. The signal used in the tunnel was a small miner's lamp with a plumb bob hung below the centre of the flame. When the tunnel was smoky, recourse was had to the gasoline lamps used to light the tunnel. These were known as "electric torches," and had a long pendant arm of gas pipe terminating in a bend and a small circular nest of burners, the plumb bob being attached to the centre of this nest. On very bad days for seeing, the speediest method was to establish points on the tangents as far as could be readily seen, and then to move the instrument up into the heading, and get it into range with the points. When needed, the line was marked by a temporary point opposite the forward ends of the new wall-plates, the position of the last wall-plate being always tried as a check. The level was then set up in the heading, bench marks being established in the tunnel, and the wall-plate was alternately shifted in grade and alignment until both were satisfactory. A miner's lamp, held close to the face of the rod, proved sufficient to illuminate both it and the cross-hairs of the instrument. The wall-plates were normally set ½" narrow, ½" high, and canted slightly inwards, these allowances being made to provide for the unavoidable settlage under compression. When the heading was holed, the line and levels met within ¼ inch.

MEASUREMENT OF EXCAVATION.

At every set of timbers a regular series of offsets was taken by the inspector from the outside of the frame to the face of the rock, four measurements being made from each plumb post, one from every arch joint and one from the centre of each arch segment; the measurements of the sets on each wall-plate were averaged, and these averages were recorded as the measurements of that wall-plate length and the area and contents calculated therefrom; the recorded measurements read as if taken from the arch centre. The system of measurement proved very convenient; the step by step method of excavating and timbering would have seriously hampered any other system, but with this the inspector could always make his measurements whenever the excavation was complete and the timber frame in place, and the lagging and packing might immediately proceed. Any error in the relative placing of the timbers would, however, be reproduced in the measurements. These sections were taken as a precautionary measure, it being specified that the work would be paid for by theoretical dimensions.

COST.

The prices and costs were as follows:

11,726	cy. excavation at	$2.85	$33,419.10
742	packing	1.75	1,298.50
256	fallen material	1.25	320.00
303,000	ft. B.M.	30.00	9,090.00
	624 lin. ft. of tunnel		$44,127.60

these figures being contract prices, the actual cost being probably in the neighbourhood of $35,000. In the approaches the prices were solid rock, 80 cts. per cub. yd.; loose rock, 40 cts.; and earth, 20 cts. White oak timber was delivered on the ground for $15.00 per M., and cost $8.00 for framing. Common labour was worth $1.45 a day in the tunnel, and the miners were paid $1.75.

On considering the permanent stability of the tunnel, it was thought that if any ground movement should occur such as would bring heavy pressure upon the lining, it would be in the vicinity of the portals while the timbering would decay most rapidly at the same place. It was therefore determined to put in portals and to build the masonry for fifty feet at each end. The masonry section is shown in Fig. 8. It was built of red sandstone, very coarse in structure and well adapted to resist the action of heated gases. The side walls were laid in courses,

MASONRY.

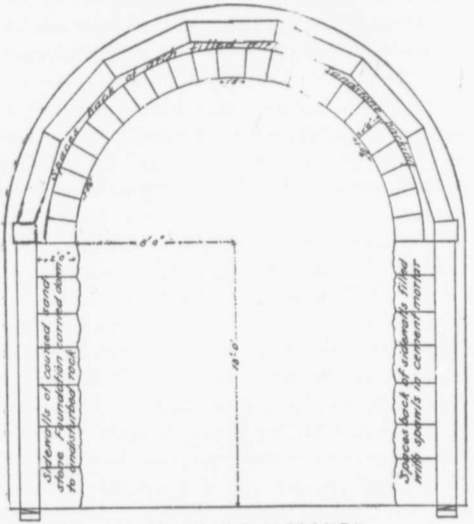


FIG 8 SECTION OF MASONRY

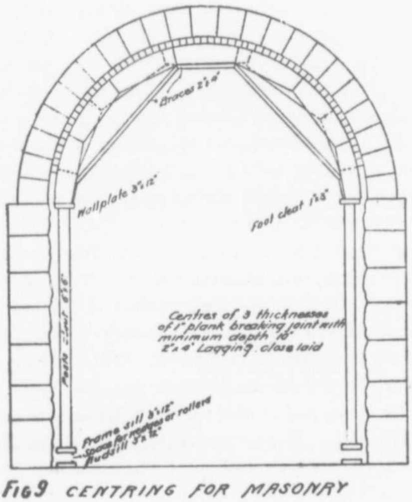


FIG 9 CENTRING FOR MASONRY

all stones being two feet or more thick, and the bottom courses were extended into the tunnel, so that the ends of the courses might be "yacked" off continuously from base to keystone, and the wall thus left in good condition for bonding on the resumption of work on the lining. The spaces between the plumb posts were filled with spawls in mortar. These walls were built with a small derrick set up without stiff-legs or guys, the pin at the top of the post being placed in an auger hole bored in the crown segment of one of the arches; and although the segment was not fastened in any way, the joint and lagging friction proved sufficient to overcome any stresses from the derrick tending to move the segment. The centering for the arch is shown in Fig. 9. The centres rested on a 3″ × 12″ wall-plate supported by rough 6″ × 6″ posts bearing on a 3″ × 12″ frame sill. The frame sill was carried by wedges working against a 3″ × 12″ mud-sill; the range of these wedges was large, so that the centres would be considerably lowered when the wedges were struck, and the whole section of centering might then be run ahead on small rollers placed on the mud-sill. With that purpose in view the posts were set far enough away from the side-walls to clear the quarry face projections of the stones, and the first few pieces of lagging were omitted on each side of the centre. The section of centering used was about 25 ft. long, the centres being spaced 3 ft. centre to centre; the centres were built of three thicknesses of 1″ plank breaking joint, and with a minimum depth at joint of 10 inches; the lagging was 2″ × 4″ laid on the flat; the consecutive posts were fastened together by irregular diagonal bracing. The masonry arch was 18″ deep, the voussoirs measuring 1′ 0¾″ on the intrados and the keystone 1′ 3″; all joints were ¼″; and the voids between the masonry and the timbering were packed with dry sandstone, hand laid. By reason of the impracticability of the ordinary methods of handling stone in the confined space between the lagging of the centres and the timbering of the tunnel, special methods had to be resorted to. The method employed was to leave an opening in the crown lagging of ample size to pass any of the arch stones; above this opening a piece or two of the tunnel lagging was removed, and an iron bar placed upon the timber arches. A set of blocks was attached to this bar, and with its aid the arch stones was run up till they passed through the lagging, when they were swung off on to it. The difficulty was to get headway enough for the blocks to work in. Gas pipe rollers were placed under the stone, and it was run along on its side until it came opposite its destination. It was then canted upright, there being room to cant the stones at the joints of the timber arch only, and a single rope was passed round it. Six men were needed to bring it to place, two holding back on the rope from the opposite side of the centering, two aiding the slipping of the stone and guarding its edges from spawling, and two masons being below to receive it, throw off the rope, and set the stone accurately, it requiring decided skill to bring the stone to its right place with an even mortar bed under it. The keystone was run into place dry and grouted. The head-wall of the portal was a rectangular block of masonry 25′ 0″ × 26′ 0″ × 4′ 0″. It was laid as firs class work, and the bond with the arch was made by creepers. It was held that it was necessary to support these head-walls by buttresses, it being known that unsupported head-walls in tunnels in the same section of the State had failed under a gradually increasing movement of the material on the portal slope, this movement sometimes only commencing years after the completion of the work. The buttresses built were 8′ 0″ × 3′ 0″ in plan, and were stepped back towards the head-walls commencing at the springing level.

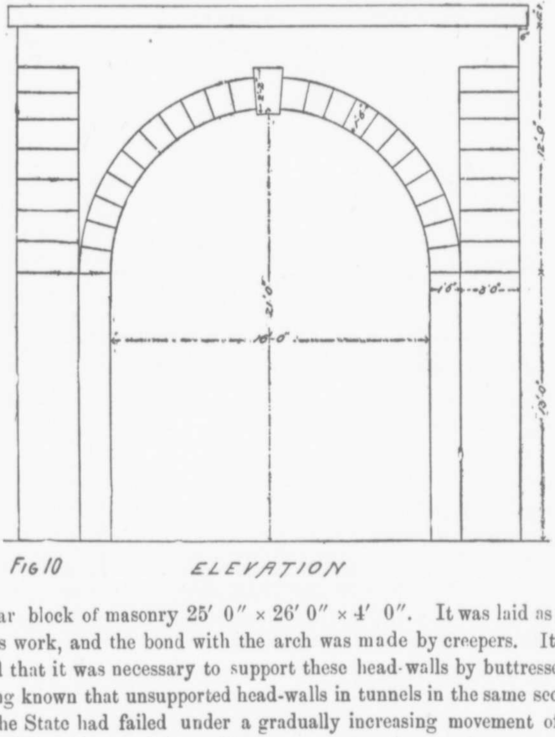


FIG 10 ELEVATION

The prices on this work were $9.00 a cub. yd. for portal masonry,

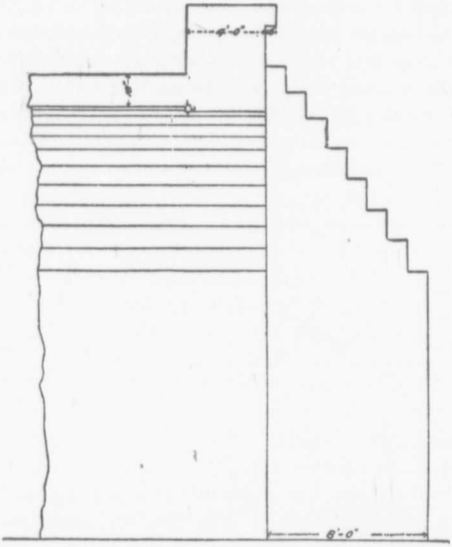


FIG 11 LONGITUDINAL SECTION

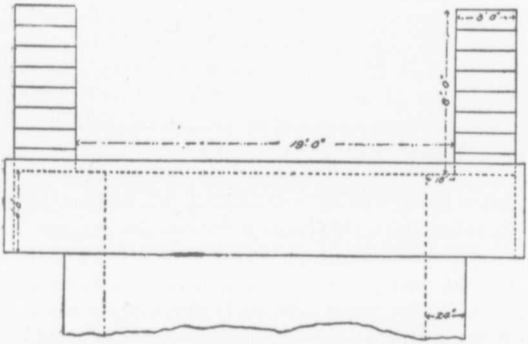


FIG 12

PLAN

$8.00 for side-walls, and $14.00 for arch sheeting. This cost was not included in the tunnel estimate before given, as the work was only partially done, and because the detail of the lining would probably be altered by the employment of a cheaper material when transportation facilities were obtained. The cost of one portal complete was:

76.5 cub. yds. portal masonry	@ $9.00	$688.50
6.1 arch masonry	@ 14.00	85.40
		$773.90

and the cost per lin. ft. of lining was:

Sidewalls	2.57 cub. yds.	@ $ 8.00	$20.56
Arch	1.53	@ 14.00	21.42
Packing	1.19	@ 1.75	2.08
Lining per lin. ft.			$44.06

In the estimate before given the cost of excavation, timbering, etc., was $44,127.60 for 624 ft., so that the total cost per lin. ft. of completed tunnel would be (excluding portals, fallen material, etc.):

Excavation	$53.55
Packing	2.08
Timbering	14.57
Side-walls	20.56
Arch	21.42
Packing	2.08
	$114.26

The whole work was carried through in a style that was entirely satisfactory to the chief engineer. Mr. Jos. N. Allston was resident engineer in charge, and the management of the construction was in the hands of Mr. John E. Dougher of T. J. Steers & Co., and most of the practical points in the system above described were an outcome of his great experience as a tunnel builder.

Thursday, 29th March.

P. Alex. Peterson, President, in the Chair.

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

Member.

Cyrus Carroll.

Associate Members.

William L. Leslie,
J. Grant MacGregor,
William Geo. Warner.

Associate.

Harry Wilson.

Students.

John D. Black,
W. F. Carter,
Theo. Denis,
G. S. Dobson,
W. R. Dougall,
Alex. R. Dufresne,
W. E. L. Dyer,
Jas. B. Godwin,
O. C. Hart,
Gerald J. Lonergan,
A. J. McPherson,
H. M. MacKay,
Chas. H. Mitchell,
A. L. Mudge,
Wm. M. Ogilvie,
Paul E. Parent,
Carl Reinhardt,
John H. Larmonth,
Frank T. St. George.

The discussion on "Concussion in Sewer Pipes" and on "Dartmouth Water and Sewerage Works" occupied the evening.

Thursday, 12th April.

P. ALEX. PETERSON, President, in the chair.

Paper No. 94.

CEMENT MORTARS IN FREEZING WEATHER.

BY M. J. BUTLER.

In considering what is best to be done when it is found necessary to carry on masonry work in freezing weather, if one searches the records of cement mortars found in the Proceedings of the various Engineering Societies, in the standard text-books used as a guide in the practice of the Profession, it will be found that the verdict is "don't do it." Failures in the past can be, no doubt, traceable to the effects of frost; nevertheless, success may be had by taking the necessary precautions.

In the late fall of 1892 the writer was compelled to construct about 600 cubic yards of masonry. After consulting all available sources for information and precedents, added the following clause to the specifications governing the works under his direction :—

" No masonry will be allowed to be laid in freezing weather unless so "ordered by the engineer, in which case the following precautions " shall be taken :—The stones shall be warmed to remove any ice from " the surface, and the mortar mixed with brine made as follows :—Dis- " solve one pound of salt in 18 gallons of water when the temperature " is 32° F, and add one ounce of salt for every degree the temperature " is below 30° F, or enough salt, whatever the temperature, to prevent " freezing."*

" The sand shall be heated sufficiently to thaw any frozen particles."

Cement and salt were furnished by the Railway Co.

In the actual carrying on of the work the steps taken were as follows :—

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* Quoted by J. J. R. Croes, Transactions American Society of Civil Engineers, Vol. XVI, p. 84, and there credited to the Royal Engineers ; see also Baker's Treatise on Masonry Construction, page 543.

CEMENT.

A careful chemical analysis of the cement supplied showed the following composition :—

Lime	60.15
Silica	24.30
Alumin. and Iron Oxid.	10.78
Magnesia	1.18
Alkalies	1.60

FINENESS.

Seven per cent. residue was left on a standard sieve of 10,000 meshes to the square inch, 60 per cent. of which passed through a sieve of 22,000 meshes to the square inch.

TENSILE STRENGTH.

Samples prepared with 25 per cent. of water, and pressed with the fingers into the moulds, when allowed one day in air and six days in water, broke with an average tensile strain of 350 lbs. to the square inch.

HOT TEST.

All the cement used was carefully submitted to the boiling test in thin pats on glass. None of the samples showed any cracks, and but one or two left the glass.

SAND.

The sand used was clean, rather coarse, sharp river sand, very nearly all silica.

Knowing from the success of the hot test that there was no danger to be feared from " blowing," all the brine was made with very hot water. The sand was kept as hot as possible. The stones were not heated, but care was taken to see that no ice was on them.

During the construction of the work the temperature varied between 39° above to 10° below zero F.

The whole work was carried forward to successful completion, and was and is satisfactory in every respect, no small credit being due to the contractor for the care and skill he showed in pushing on the work under very unfavourable conditions.

Another case where the masonry work was being built under the same specification, and where the contractor was obliged to furnish the salt, it was found that insufficient salt was used, and that as a consequence the outer portion of the mortar bed, about three inches back from the face, in the following spring was of about the consistency of leached ashes, which had to be raked out and replaced with fresh Portland cement mortar; the inner part of the mortar bed was set hard and solid—doubtless the outer portion froze solid, the inner being protected from the severe frost by the overlying stone and at the edge by the parts destroyed.

Another case where natural cement was used in stuccoing a building, having been put on in a coat about one inch thick, failed entirely. In fact, natural cements will not stand frost in the sense herein implied.

During the construction of the Kansas City Bridge,* "the béton, consisting of eight parts limestone, was broken to pass through a three-inch ring, two of sand and three of cement. It is an interesting fact that both masonry and béton were laid in the above works in the severe winter months by the use of hot sand and hot water. At the Quincy Bridge, during the coldest weather, each stone was held over a brazier of charcoal to draw out the frost. The mortar thus used was found the following spring to be as hard and perfect as any on the work."

During the construction of the Chignecto Ship Railway in Nova Scotia, some experiments were tried, which seemed to show a reduction in strength in the samples submitted to the testing machine.† Doubtless the effect of frost on small samples, from the fact that it will penetrate the whole mass, is more serious than in actual works where the effects will be confined to the outer edges of the mortar beds.

In the construction of the works of a lock at the St. Mary's Falls Canal,‡ in 1877, it was found that Portland cement mortars satisfactorily withstood the effects of frost, but that natural cement mortars were disintegrated to the depth of 3 or 4 inches ; in the same locality a Portland cement concrete which froze solid proved satisfactory.

The sample tests with various quantities of salt used in the above mentioned work go to show that the strength of the mortar increased with the quantity of salt used.

The Austrian Society of Civil Engineers & Architects§ have recently investigated the question of masonry construction in freezing weather. "During a temperature below 26° F, 14 brick walls were built, each 3

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* Manual for Railroad Engineers, by Geo. L. Vose.

† Proceedings Inst. C. E., Vol. CVII.

‡ Transac. Amer. Soc. C.E., Vol. XVI, pp. 79 et seq.

§ Engineering News, 1894, p. 253, Vol. XXXI.

"ft. 4 ins. long, 6 ft. 8 in. high, and 10 in. thick. The following mor-" tars were used :

"(1) Common fat lime mortar, (2) Roman cement mortar, (3) Port-" land cement mortar, (4) 1 of Portland cement to 2 of lime, (5) "cement and slag mortar. All these mortars were tried over with cold "water and once with warm water (77° F), and some of them were tried "with a 7 per cent. cold salt solution. Two walls were also built with "a frost-proof mortar,—Patent Hausleitner.

"The first three mortars were also tested on nine rubble masonry "walls, the same length and height as the brick walls, and 15 ins. thick. "The water was used with the same variations as above. Half of each "wall was covered with boards, and the covered half showed in each "case somewhat better results.

"After three months the walls were examined; wherever lime had been used, either alone or with cement, the result was a failure.

"The use of Roman cement gave different results according as it "was used on brick or stone.

"Portland cement with cold salt solution and frost-proof cement " 'Patent Hausleitner' were the only mortars which gave perfect satis-"faction, and these were in good order when used as exterior finish."

Inasmuch as we in Canada are debarred from construction about four months in each year, if it be unsafe to build masonry work, it is considered important to show that with proper materials properly handled there need be no fear to use Portland cement mortar on account of cold weather; and in the hope that the resulting discussion will bring out many precedents the foregoing notes have been prepared.

DISCUSSION.

Mr. Leonard.

Mr. R. W. Leonard said :—Mr. Butler has contributed a valuable paper on one of the most important subjects to be considered by the Canadian Civil Engineer.

"Mahan's Civil Engineering," p. 72, says: "Béton is injured by freezing before it has had time to set." "The effect of freezing on newly made béton is to detach a thin scale from the exposed surface ... but the injury does not extend into the mass of the material unless the *frost* is very intense." Also on p. 263 he says, in speaking of common lime mortar: "Mortar which is exposed to the action of frost before it has set will be so much damaged as to impair entirely its properties."

Common experience in building heavy masonry in Canada of late years shows that heavy masonry may be laid in Portland cement mortar in the coldest weather with perfect safety. The precautions usually taken are simply to warm the sand sufficiently to prevent the mortar from freezing while laying, and to clean the stones of all ice and frozen mud by steam hose or otherwise.

The writer has seen brick walls laid successfully in common lime mortar in cold weather, and believes it is not an uncommon practice in Norway and Sweden. In this case the brick should be heated as well as the mortar. In building such a wall in winter there is considerable danger of the sun thawing one side of the wall while the other side remains frozen, and thus throwing the wall out of plumb or entirely overthrowing it.

It appears to the writer that the effect of frost on mortar is mechanical rather than chemical, and that if a mortar can be preserved from freezing until partially set, or if when once frozen it remains so until set (if it is possible for the mortar to set while frozen), that frost will injure it but slightly, if at all. On the contrary, if successively frozen and thawed before setting, the mechanical effect will be to reduce the mortar to the "consistency of leached ashes." This theory will account for the result which Mr. Butler instances, both in the pointing of the masonry wall and also in stuccoing the building spoken of and in the failure of their walls.

Mr. Butler implies that salt is a necessity in laying masonry in freezing weather. The experience of many masonry works built in winter in Canada without salt does not bear this out, and it is questionable if salt is of material advantage in laying masonry in winter. The writer would instance one case where a stone wall laid in very severe weather was tested the following summer with a heavy head of water against it, without developing a sign of a leak, and no salt was used. (Niagara Falls Park River Railway Co. Power House.)

On the effect of salt in mortar, there is a variety of opinions amongst the authorities, as the following quotations will show. Gillmore's Limes, Hydraulic Cements and Mortars, p. 169 says: "The strength of mortars is considerably impaired by using sea water for mixing them;" proved by transverse tests. The results of 3,500 tests of 7 brands of natural and Portland cements with different percentages of salt described in *Engineering News*, November 21st, 1891, and also of 2531 tests of 15 brands of cement (described in *Engineering News,* December 30th, 1890), tested by Mr. John Gartland, 1889-90, at Governor's Island, N. Y. Harbour, give grounds for the following conclusions :—"Cement mixed with sea water gains considerably in strength during the first few weeks, but that it does not hold out;" and "The gain also seems to be greater and more permanent with the Portland than with the natural cements." "The effect of using a ten per cent. solution seems not so good as with a three per cent." Experiments made by Col. Totten on various mortars made from materials in general use in the United States led to the conclusion that "Fresh water gave better results than salt water." (Appendix to General Treussart's work on Hydraulic and Common Mortars.) Results of numerous experiments by Mr. Grant in England on Portland cement are: "Salt water is as good for mixing with Portland cement as fresh water." Mahan's Civil Engineering, p. 189, draws the conclusion that "Sea water is nearly as good as fresh water for mixing Portland cements, but injures the Rosendale and all argillo-magnesian cements very considerably."

One effect of salt in mortar is to cause an efflorescence which is undesirable in some works. We know that the effect of saccharine matter is to increase the strength of some mortars, and it would seem that some substance may be found of economic value in materially strengthening mortar, whether lime or cement.

Mr. Smith. Mr. C. B. Smith said that the opportunity had been afforded him last winter of making some experiments at McGill College on the effect of frost on mortars.

He had made mixtures in four series.

The first series was treated as in ordinary laboratory tests, the second series was treated similarly, except that it was not that of immersion but confinement in damp air; the third series was exposed, after setting, to frost for the whole period (2 months); the fourth series was exposed as quickly as possible to frost, and left there continuously.

These series were carried through mixtures of Portland cement, neat 1 to 1, 2 to 1 and 3 to 1, also natural cement neat and 1 to 1.

The Portland cement mortars all gave the highest tests on the 1st series, next on the 2nd series, next on the 4th series, and lowest of all on the 3rd series. Thus pointing out three facts: first, that such mortar exposed to frost immediately is stronger than if exposed after it has set, the probable reason being that in the first case the *structure* not being formed, the mixture is not so much injured as when the weak structural form has just been assumed, but still containing some moisture for the frost to act on.

The second fact is that a Portland cement mortar will set in low temperatures in spite of the frost effect (provided the materials are of ordinary temperature), and that it does not need salt.

The third fact is that cement testing, as practised, is favorable to Portland cements, as it gives the highest results with immersion.

Coming to the natural cement mortars, under the same conditions, very different results were obtained. The first noticeable one was that the mixtures exposed at once to frost crumbled to pieces.

The second result is that if it is given time to set (4 to 8 hours) as against about 40 min. with the quick setting Portland, that it is quite capable of standing the frost and gives very high results.

The third feature is that the tests in damp air are higher than when immersed, and here again we see that standard cement-testing is against the natural cement.

It would seem reasonable that when cements are to be compared, they should be compared under conditions similar to that in which they are to be used; and in work not to be immersed for some time, the natural cement would show up much better than when the comparison is made with submerged specimens; this advantage or disadvantage would probably disappear if immersion did not take place for some months.

These exposures took place in temperatures ranging from +10°F. to —6°F., and in the lowest one only (—6°F.) did the Portland cement mortar show any effect of the frost, the fractures in this group being rather irregular. The exposures were all for two months in December and January and February, during which time, on very rare occasions only, the temperature rose to 32°F. for a few hours at midday.

Mr. Lordly.

Mr. H. R. Lordly said that quite an extensive series of experiments on the freezing effect on cement mortars had been in progress at the College of Civil Engineering, Cornell University, for several years past.

In one series, of which he possessed data, briquettes with and without salt were exposed to the action of frost for 24 hours. At the end of that time they were brought into the laboratory, thawed out, and placed in water along with a set of briquettes of the same cement which had been mixed at the same time as those frozen, but kept in the laboratory. The temperature of the laboratory was 68° F., of the water 65° F.

At the end of one, four and thirteen weeks these briquettes were tested for tensile strength, and on comparing the results it was found that those which had been frozen broke at a point of from 17 to 26 per cent. less than those unfrozen, at the end of 13 weeks. Those with salt gave a higher tensile strength than those without it, although in one or two brands of cement no appreciable benefit was derived from its use.

For these tests just mentioned the mortar was one of sand to one of cement, with water equal to 30 per cent. of the cement, by weight. When salt was used, the proportion was one per cent. of the whole, thus:—

Cement	43.4	per cent.
Sand	43.4	" "
Water	12.2	" "
Salt	1.0	" "
	100.0	" "

In the case of magnesium cement mortars it was found that after being frozen for 24 hours, at a temperature of zero degrees Fahr., before allowing it to set, reduced the strength by from 25 to 40 per cent. below that kept at a temperature of 65° F.

A Portland cement of good quality did not appear to suffer any permanent loss of strength, the setting being retarded only, as the material will not set at freezing temperature.

With natural cements some are more or less injured, and in their case some curious instances are worthy of note. A number of briquettes of natural cement mortar, the same proportions as those already mentioned, were mixed outside when the temperature was 8° above zero, the water being 42° and the cement 40° F. Some of these briquettes were brought in as soon as made, and when tested at the end of thirteen weeks, having being kept in water, gave results about 7° per cent. higher than briquettes of similar material, mixed in air at 68° and water 65° F., and kept in water of the same temperature.

Also, those briquettes which were mixed out of doors at the same temperature as the former, and then frozen for 24 hours, gave higher results than those mixed indoors and then frozen for 24 hours.

In another instance a natural cement, mixed with salt, gave a result very much higher than the same cement mixed without salt and not frozen. This latter was a quick setting cement supposed to contain an excess of lime, which may partly account for the results obtained.

Of course these last cases were the exception, not the rule. They go to prove, however, that the results obtained from experiment as to the freezing effect on cement mortars are not by any means conclusive.

Prof. F. P. Spaulding, who has charge of the cement laboratory at Cornell University, in a communication to the speaker says :—

"My own experiments upon this subject, as well as the results of "others in the same line, show that there are so many circumstances "which may affect the action of cement mortar that the drawing of "any general conclusions as to the effect of frost is a matter of difficulty. A small briquette tested for frost effect may show no loss of "strength due to having been frozen, and yet the same mortar used in "a wall during freezing weather may be ruined by frost. Such a "case has come under my own observation during the past season. "This may be attributed to the fact that the injury to mortar from "freezing is not usually due to any depreciation in the strength of the "cement, although loss of strength sometimes occurs, but to the disrupting action of the unequal expansion caused by freezing. This "injury is also, I think, more commonly due to freezing after, than "before, setting. Natural cement mortars subjected to severe freezing, or alternate freezing and thawing, before it has attained sufficient "strength to resist disruption, is commonly injured by frost.

"My results have, in general, being quite favourable to the use of salt "which prevents freezing and any consequent change of volume. I "have not found that mortar containing salt would set at freezing "temperatures, it simply remains soft until warm enough to set. "Salt also seems to accelerate the hardening process, causing a mortar "containing it to gain full strength more quickly than it otherwise "would. This effect is much more noticeable upon natural than upon

"Portland cements, and it may have had an influence in many in-
"stances where the use of salt has seemed to prevent injury to work in
"cold weather."

Prof. Spaulding also states "that he has always found mixing cement with hot water to be detrimental," but that "heating the stone to be used in the masonry has the same effect as warming the air in which the mortar is set."

Regarding the use of salt, the speaker would like to refer to a paper already mentioned by Mr. Butler.* In the discussion on this paper several engineers of experience in the matter testified to the benefit derived from the use of salt, and the words of one engineer are worth quoting, viz.:—"That he had occasion to examine the masonry referred
"to by another member, built upon the line of the Erie Canal. This
"masonry was the retaining wall of the West Shore Railroad, where it
"runs along the canal. When it was first laid in very cold weather,
"without the proper use of salt, it gave way and got into very bad
"condition. Directions were then given and carried out for using a
"strong solution of salt for mixing the mortar, one barrel of brine
"being mixed when another was being used for mortar. The result
"has been very satisfactory, and the masonry is in excellent condition
"yet."

The speaker has of late examined many of the articles on cements and concretes published in various Proceedings, Transactions, etc., and believed a record would show more failures due to poor cement, a surplus of magnesium, and poor mixing of the mortar, than from the direct effect of frost.

He thought it was to be regretted that more of the older members of the Society had not brought forward some information as to their practical experience in the matter. The President narrated his experience, at a former meeting, in which he stated that he had carried on work during freezing weather, and had not, so far, found any injurious effects from frost. In the work mentioned, salt was used, and he, the President, expressed his opinion that, with a little extra care, cement work might be carried on during winter months with perfect safety, thereby agreeing with those engineers who had had a similar experience in the United States.

One member had spoken of adding lime to the cement mortar to "warm it." This was quite frequently done in mortars for ordinary

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* Trans. Am. Soc. C.E., Vol. XVI.

building purposes, but no authority could be found that would countenance any addition of lime in cement mortars or concretes for engineering constructions where strength and durability are necessary.

Mr. MacPherson.

Mr. MacPherson wanted to know what the salt was used for; and if salt was used to prevent freezing, why was warm water used? He said he had used mortar in freezing weather, but had never used salt.

Mr. Peterson.

The President, Mr. Peterson, in closing the debate, said that he wished to thank Mr. Butler for his timely paper on cement mortars in freezing weather; for though some engineers laid masonry all through the winter, it was the exception rather than the rule to do so; and he knows of engineers on large works who would not allow a yard of masonry to be laid after the temperature was below freezing. It was only in 1877 on the Quebec, Montreal, Ottawa & Occidental Railway, that he had learned that masonry laid in winter was quite as good as when in summer. All masonry on this line, previous to his taking charge as Chief Engineer, had been laid in natural Hull cement, which he found had not set, and in many cases the work had to be taken down, so he had decided to adopt Portland cement for all masonry to be laid in the future. In November, 1877, the piers of the Gatineau bridge were nearly up to high water, when extremely cold weather set in; and as it was important that these piers should be finished as early as possible in the spring, they were carried up above high water, when the thermometer was nearly at zero,—it being understood that, if the cement did not set, the masonry would be taken down. The spring opened early, and there was time to examine the masonry thoroughly before high water, when it was found that the cement was set so hard that it was impossible to lift a stone or even to remove any of the cement. So the piers were carried up at once, and a great deal of time saved. Since that time he had never, even in the very coldest weather, quit laying masonry when using Portland cement.

He had put in concrete foundations in deep water in mid winter, had pumped out the caissons and found the concrete set perfectly hard. Masonry had been built upon these concrete foundations, and the mortar in the following spring was perfectly set, and so hard that it was difficult to remove any portion of it in order to do the pointing.

In constructing the elevator foundations in Montreal in the winter, a large portion of the work was done in the winter; some of the walls were only four feet thick and all the piers were four feet square. Work was carried on upon these walls and piers at all times when the weather would permit men to work out of doors. As most of this work was to be covered up, the outer joints of the stones were not left open, but were smoothly plastered over. In the following spring a thin scale, about as thick as a sheet of writing paper, came off. The remainder of the cement was nearly as hard as stone, and when cutting some notches in the walls which were required for joists, the cement mortar was found to be nearly as hard as the stone. He stated that, during the same winter, in order to test the setting qualities of Portland cement when mixed as concrete and thoroughly exposed to the action of the frost, he mixed three half-barrels of concrete, viz.: one with cold water, cold sand and cold stone; another with warm sand, warm water and warm stone; and another with cold stone, cold sand and cold salt water. These materials, after being thoroughly mixed, were put into Portland cement barrels, cut in two, and left exposed to the frost. In the following spring the staves of the barrels were removed, when the concrete was found to be thoroughly set with no loose portions on the outside, and it was only with difficulty that any part could be broken off with a heavy sledge hammer such as masons use for breaking lime stone. The most careful examination failed to show any difference between these three samples.

He stated in conclusion that he had laid a great many thousand yards of masonry in winter; and that while it was always more economical to do such work in summer, he considered that the quality of the work done in winter was equal to work done in summer. He trusted, however, that some members of the Society, who have been for years engaged in building lock masonry with natural cements, would give their experience with regard to its use in winter. His own experience went to show that it was unsafe to use any natural cement during freezing weather.

Mr. Butler. Mr. Butler in reply to the discussion said the quotations from Prof. F. P. Spaulding, of Cornell University, "that he has always "found mixing cement with hot water to be detrimental, but that heating the stone to be used in the masonry has the same effect as warming the air in which the mortar is set," would go to show that the Professor has been unfortunate in his cement. The well-known hot water test for over-limed cements is the only reliable method for determining a safe cement, and unless our cement will stand the hot water test, it would be folly to use hot sand, hot water or heated stones. The effect of adding salt is to practically raise the boiling point of water and to lower the freezing point, hence heated brine will retain the heat longer than heated water, and it may be that sufficient time will be gained by the use of salt to permit the mortar to set hard enough to resist the disintegrating effects of frosts.

Thursday, 26th April.

P. ALEX. PETERSON, President, in the chair.

Paper No. 95.

SOME APPLICATIONS OF ELECTRIC MOTORS.

By FRED. A. BOWMAN, B.E., A.M. Can. Soc. C.E., A.M. Am. Inst. E.E.

The intention is in this paper to deal with the subject more from the standpoint of the civil or mechanical engineer than from that of the electrical. A sketch of the method of applying motors to different kinds of work will be given with data regarding the power called for.

Among the electrical papers that have been read before this Society, one by Mr. Thornberry gives an historical sketch of the dynamo, and one by Mr. Lawson describes the methods employed and advances made in the various systems of electric lighting. The writer will therefore make his historical notes brief.

The history of the electric motor goes back to the discovery by Faraday, in 1821, of electro-magnetic rotation, and the invention, in 1823, by Barlow of his rotating wheel. In 1840 Thomas Davenport built a motor in New York, which was used to drive a printing-press. The publication of a periodical called *Electromagnet* was begun by him, the printing being done in this press, but only two numbers were issued.

The fact that one dynamo used as a generator can be employed to give motion to another connected to it as a motor seems to have been first discovered at the Vienna Exhibition in 1873. Some of the earliest applications of this principle on a commercial scale were made at the sugar works in Sermaize by Messrs. Chrétien and Felix. In 1878 M. Felix installed a chaplet lift in these works for unloading beet root from the vessels, by which means a saving of 10 per cent. in labour was effected.

In the following year it was decided to employ the engine at the works in the slack time which occurs during part of the year in the beet sugar industry, to furnish electric power for ploughing the fields in the neighbourhood. The system employed was the same as in steam ploughing, a motor being placed on a trolley at each side of the field. The motors worked the drums on which the steel rope drawing the plough was wound and unwound, and also furnishing power for the forward motion of the trolleys. The speed of the plough was 55 feet per minute, and the work done was at the rate of 200 square feet per minute. This is about the same as would be done by a five or six horse-power Fowler steam-tackle.

The advantages of electric motors for use in driving the machinery in small industries are efficiency, reduced cost of attendance, cleanliness, reduced fire risk, and economy of power. Small engines and boilers are troublesome, calling for an amount of care and attention that is almost constant, independent of the power generated. The attention given is generally of the unskilled kind that reduces the efficiency of the plant below the low percentage inseparable from small units. The dirt and heat from a steam plant is always an annoyance and often a serious drawback. The risk from fire is of course greatly increased in any case by the presence of a steam boiler. The electric motor does not possess these disadvantages. As built by the best makers to-day, it has, except in the case of the very small sizes,[1] a very high efficiency. There is no dirt, heat or smell; it calls for a minimum of attention, occupies little floor space, or, as will be shown presently, none at all. It is economical of power, as when stopped there is no consumption of energy. If properly installed, it is absolutely safe as regards fire risk.

In the case of large factories with long lines of shafting, and these distributed on several floors in separate buildings, there is a great loss of power in driving by belting from floor to floor, and in having either separate boilers in each building or lines of steam pipes from a central battery of boilers.

With electric motors, one or more can be placed on each floor, and thus all or only a part of the shafting can be driven, according as it is called for.

In the case of accident, a line of shafting can be stopped almost instantly—a matter oftentimes of life or death. Transmission of power by shafting from room to room necessitates holes in partition walls that are a serious source of danger in the case of fire.

The ordinary method of driving shafting is by belting from the motor pulley; but in a few instances railway motors have been used, geared directly to the line shaft in the same way as to a car axle, the motor being bolted to the ceiling timbers.

In the case of a long line of shafting, unless it is tolerably certain that it will be in constant use throughout its whole length, it is better to divide it into two or more lengths, with a motor to each. If economic handling of material will admit of it, those machines which are least used can be then grouped on one motor and those more used on another. This grouping often proves very convenient and economical where a night shift works on certain kinds of work only, and nothing need be kept running except the machines directly needed.

The belt from motor to shaft should be as nearly horizontal as possible, as most stationary motors run at a speed considerably higher than that of the shafting they drive; consequently, the driving pulley and arc of contact are small. Light double leather belts will be found most suitable for this work.

In cases where floor space is valuable, or it is impossible to place the motor anywhere but directly under the shaft, it is better to place it on a platform slung from the ceiling by iron rods, at such a height that the motor shaft will be on a level with the shaft to be driven. The rods must be considerably larger than is necessary to support the weight in order to give the necessary stiffness to withstand the pull of the belt. The platform must be wide enough to permit of a man standing comfortably alongside of one side of the motor, at least to tend and clean it. The switch and starting apparatus may be placed in any convenient location. A light iron ladder can be attached to the platform, and, if necessary, it can be made to fold up and be pulled up to the ceiling when not in use.

The following examples from actual practice will show what size of motors have been installed to do certain kinds of work, and under what unsatisfactory conditions they will continue to do it.

A Thomson-Houston shunt wound motor of 35 horse-power in a large machine shop drives a grind-stone, 18 planers 8′ by 2′ bed, 3 milling machines "No. 3 Brainard" 12″ by 28″ bed, 1 speed lathe, 3 shapers 12″ by 20″. The motor runs 1,150 revs. per minute, the driven shaft at the usual speed of line shafting for this class of work. The belt is an 8″ double leather. The average distance from centre of motor pulley to centre of shaft is 20′ 10,″ making an angle of 24° with the horizon.

In the same shop a similar motor of 10 horse-power drives four 20″ drill presses, one 12″ ditto, one boring machine boring up to 6″ hole, one speed lathe, one milling machine 12″ by 18″ bed, one splining machine 12″ stroke, and one large slotting machine. It is on a platform such as has been described. The motor pulley is 8″ diam. by 6″ face with $1\frac{3}{4}$″ bore, and runs 1,600 revs. per minute. The driven pulley is 51″ diam by 8″ face with $2\frac{7}{16}$″ bore, and runs 245 revs. per minute. The distance from centre to centre of pulleys is 15′ and the belt runs horizontally. The following case shows what a motor will stand. A 5 horse-power Thomson-Houston shunt wound motor was used to drive a No. 4 Sturtevant blower in blacksmith shop, with 18 fires. Both were on a platform slung from the ceiling, the motor shaft being coupled directly to the blower shaft and running at 1,800 revs. per minute. The platform was almost directly over a large tempering furnace. The heat, smoke and dust to which it was exposed can only be realized by those who have had occasion to travel among the roof timbers of a large forge shop in full operation. The field coils and pole pieces on a hot summer's day were too hot to put your hand on. A similar 10 horse-power motor in the same shop was also mounted on a platform, but in a somewhat cooler corner. It drove a grindstone, a large pair of Beaudry shears and a Bradley helve hammer. The motor pulley was 9″ diam. by 6″ face with $1\frac{3}{4}$″ bore, with a speed of 1,600 revs. per minute. The driven pulley was 32″ diam. by $6\frac{1}{2}$″ face, with $2\frac{7}{16}$″ bore, with a speed of 442 revs. per minute. The belt 6″ wide with a distance between centres of 18′ 7,″ and running horizontally.

In a carpenter and pattern shop a 20 horse-power Thomson-Houston motor drives eleven circular saws, two grindstones, eight speed lathes, one drill press 5″ swing, one 8″ swing, one jig-saw, one moulding machine, one mortizing machine, three planers, two band saws, one engine lathe 6′ bed, one shaper 12″ stroke. These machines are distributed over two floors, the motor being on the lower one. The motor pulley is 10″ diam. by 7″ face with 2″ bore, and a speed of 1,300 revs. per minute. The pulley on the line shaft is 48″ diam. by $8\frac{1}{2}$″ face with $2\frac{7}{16}$″ bore and a speed of 264 revs. per minute. The distance from centre to centre of pulleys is 12′ 6″ at an angle of 57° with the horizon. An 8″ belt is used.

Messrs. Martin & Warneck's flouring mill at Ottawa is driven by a 100 kilowalt (133 horse-power) motor built by the Royal Electric Co. It is of the four pole type, and is run on a 500 volt circuit. It is situated one mile from the power station, and runs continuously for 24 hours per day and six days per week, stopping for Sundays only. The motor pulley is $23\frac{1}{2}$″ diam. by 20″ face, driving a jack shaft 18′ feet away by an 18″ belt. The mill was previously driven by a steam engine, and the motor is belted to the original jack shaft. The machines driven consist of fifteen sets of 9″ × 24″ rolls, four purifiers, three scourers, one separator, four centrifugal reels, eight octagon reels

16′ long; in addition, there is a grain elevator separate from the mill, 84′ high, with a capacity of 1,200 bushels an hour. Experiments show that it requires a minimum of 75 horse-power to drive the mill, when it is once started and everything going right. The extra power is called for when there comes a " choke " and for starting up.

Electricity has come to be so largely used as a motive power for freight and passenger elevators and hoists, that several firms in the United States and at least one in Canada make a specialty of them. The cleanliness, compactness and ease of regulation of the electric motor adapt it admirably to this class of work, where the floor space available is often if not generally limited.

In small shops where an elevator works between two or three floors only, a simple stationary motor is belted to a countershaft that drives the drum, the attendant does not travel on the elevator, and the ordinary starting apparatus suffices. For the larger passenger and freight elevators, the motor and hoisting mechanism are all on one bed plate, and connected to each other by spur or worm gearing. Lately the Sprague-Pratt elevator for high speed passenger service has been brought out, in which multiplying sheaves are used as in hydraulic systems, but instead of a ram a screw driver by the motor operates the sheaves. In other cases motors are used to drive the pumps for hydraulic systems. This partakes more of pumping than elevator work.

To control the speed and to stop and start a hand line is generally run up and down the shaft, passing through the car as in other systems, and moving the controlling apparatus through suitable gear. This system has the advantage that the elevator can be worked either from the car or from any floor. Another system that can only be worked by an attendant on the car consists in running two bare copper wires up and down the shaft and to have the current regulator on the car. Sliding contacts attached to the car take the current from one wire, pass it through the regulator and into the other wire, by which it is conveyed to the motor.

Portable electric hoists should be carefully considered by all who have to handle heavy goods in warehouses or on wharves. They are small and compact, can be mounted on low truck wheels, and moved about a warehouse floor to wherever a pull on a rope is called for, or run out on a dock to unload cargoes. The supply of current is provided for in a very simple manner. Wires are carried from the source of supply of current to various points in and round the buildings, and terminate in small locked boxes. The hoist is furnished with a convenient length of flexible conductors which are quickly attached by suitable clips to the terminals in the nearest box.

At one of the largest refineries at Greenpoint, Brooklyn, N.Y., there is a long range of wharf and warehouses for the reception and storage of raw sugar, much of which comes in lighters which have no hoisting gear of their own. Portable electric hoists are used for the unloading of these vessels. Terminal boxes are arranged at suitable places along the walls of the warehouses so as not to necessitate too great a length of cable. The cable is allowed to lie on the ground, a board being laid each side of it as would be done with a hose, if there is to be much crossing of it with trucks. Power is furnished by a 220 volt dynamo on the premises. The hoists were built by the Lidgerwood Co., and fitted with 10 horse-power motors. The motor is geared to the shaft of the drum, and the connection between shaft and drum for hoisting is through a band clutch. The lowering is done by a brake. There are two hand levers,—one working the motor regulator, the other the clutch. The brake is worked by a foot lever.

The writer had the privilege of making a test run of half a day with the first of these installed at these works and unloaded a lighter of sugar with it. Three bags weighing over 3 cwt. each were placed in the sling at each lift. The lifts averaged 1000 lbs. each. There was no gain in hoisting more, as the three were just a truck load for a porter.

As the hold was cleared directly under the hatchway, the hoisting rope with some 20 ft. of chain attached was hauled in to where the bags lay. The machine had then to haul them to the hatchway with the chain dragging on the inner edge of the deck before the actual lift began.

Only two hitches occurred, once the hook caught the deck, and the hoist, failing to lift the lighter, started to climb the rope; the second hitch was due to the drum and friction clutch being new and a little stiff, and in consequence the rope did not pay out quite as easily as the stevedores wished when being taken back to the hold. So during the writer's temporary absence the captain of the lighter carefully *greased the face of the band of the clutch.* It took some little time to find out why a clutch that until now had held the heaviest loads with a reasonable pull of one hand suddenly called for the united strength of both arms to make it take hold at all.

At the wharves of Sanderson & Sons, Brooklyn, where the Wilson

Line steamers lie, there are nine hoists in use, of the same pattern as the one just described. It has recently been stated that the whole bill for repairs on these for 2½ years has been $2.75 per hoist.

There are several points that should be carefully looked to in the design of an electric hoist. The armature of the motor must be waterproof. The resistance box and all wires must be so placed that oil from the bearings cannot drop on them, as, falling on the former, it is apt to catch fire, as the resistances are hot from the passage of the current and on the latter it ruins the insulation. This detail of location of parts would appear to be almost self-evident, but is mentioned, as the writer had trouble with both these faults in a hoist built by a leading electric company. The foot plate of the break lever should be of good size; they are sometimes made so small that a man with a large foot cannot get it far enough on to apply his weight properly; it should also be as near the ground as is practicable. In order to work a brake quickly and lower the load to just where it is wanted the operator must not have to raise his foot high. He must be able to apply his whole weight without raising the other foot off the ground. The lever can be placed as low as needed, and hinged so that it can be raised out of the way when moving the hoist from place to place.

Were the advantages of these little hoists more thoroughly realized by engineers and contractors, they would soon be largely used wherever hoisting, pulling and hauling are to be done. Compact, strong and easily handled, they can be hauled about anywhere and used for hoisting material in or out of place, for shifting cars at freight sheds, or for hauling cars from face to dumping ground in excavation work or quarries. Those who have never handled them do not realize what a well built electric motor will stand in the way of overload and general abuse. When one sees as the writer has a 15 horse-power motor exert a force of 40 horse-power for a few moments, and a 25 horse-power run at 35 horse-power for 10 hours a day for several weeks, he becomes convinced that electric motors have passed the experimental stage and taken their place as thoroughly reliable machines.

Another branch of hoisting work to which electricity lends itself most admirably is that of travelling and jib cranes. Of course the designs of these are as numerous as the builders, but the leading practice in the case of travelling cranes is to employ not less than three motors, *i.e.*, one for each motion. A one-motor crane has very little advantage over one driven by ropes or a square shaft. The same complication of clutches is required as in the latter cases; and unless the motor is very large, only one motion can be performed at a time. When three motors are used, one is placed on the bridge near one end, and works the longitudinal travel of the crane. This is usually done by gearing the motor to a shaft running the length of the bridge and driving the truck wheels at each end. The other two motors are placed on the trolley: one of them works the tranverse motion and the other does the hoisting. All the controlling is done from the cage attached to the bridge in which is a small switchboard and the levers or hand-wheels for controlling the motions. This arrangement permits of the three motions being carried on together.

The current is generally transmitted to the switchboard from bare wires stretched the length of the travel over the crane. Trolley wheels on flexible arms carry the current from the wires to the switchboard in the same way as the trolley arm on electric street railway cars. The current comes from the generator by one wire, goes to the motors, and returns by the other wire. To get the current to the motors on the trolley, bare copper strips or wires are stretched along the bridge, and sliding contacts on the trolley take off the current. Occasionally a flexible cable is used to connect the switchboard and the motors on the trolley, but this is inconvenient, as means have to be provided for taking up the slack in the cable as the trolley moves to and fro. The connection between the armature shaft of the motor and the hoisting drum is either by spur gearing or endless screw and worm wheel. One of the great advantages of electricty for this heavy crane work is that there is no great muscular power called for to work the regulating levers. No matter how great the power transmitted, the only force the operator has to exert is that necessary to overcome the light rubbing friction in the contacts of the regulator, consequently, great delicacy of movement is obtained, and a weight of one hundred tons can be moved only one-sixteenth of an inch in any direction. This is unattainable where the operator has to exert considerable force to throw clutches in and out of gear. It is important to this delicacy of motion that there be as little lost motion as possible in the motion of the regulators. In many cases the arm that moves over the contacts of the regulator is held in a slot in such a way, that as soon as it moves off the last contact it drops to the lower end of the slot, thus making a quicker break than the hand motion alone would, and preventing the formation of an arc between itself and the last contact. There is a serious objection to this arrangement, for if the operator throws off this current with a quick jerk, as he often will in rapid work, the arm may strike the other end of the slot with sufficient force to make it rebound on to the contact, and start the crane unexpectedly. The writer prefers hand levers for moving the regulators with a notched quadrant and pawl similar to the reverse lever of a locomotive. One notch at the "off" position is all that is needed, as when at work the hand is rarely removed from the lever; and if it is, the friction is enough to keep it in place. Hand wheels are often used, and permit of very nice handling of the various motions, but do not sufficiently indicate the position of the regulator.

The switchboard in the cage should be made of incombustible material, such as slate or marble, and should be provided with a double pole switch, so arranged as to cut off the current from all the motor circuits. Suitable safety fuses should be placed in the circuit to each motor.

Magnetic brakes are often placed on the hoisting gear. They are applied by a heavy weight or strong spring, but are held off while the motor is in motion by a magnet round which the main current passes on its way to the motor. In this way anything which intentionally or accidentally interrupts the current to the motor destroys the power of the magnet and permits the brake to act.

Mr. H. Ward Leonard proposes a system for driving crane motors, hoists, elevators, etc., in which a small generator is used for each motor. The regulating devices, instead of controlling the motor directly, alter the field strength of the generator, and thus vary the pressure at which the current is supplied, and, consequently, the speed of the motor. Reversing is accomplished by reversing the magnetism of the generator.

As examples of large cranes may be mentioned one erected by the Morgan Engineering Co., in the testing house of the General Electric Company's factory at Lynn, Mass. The span is 45 ft. and the capacity of the crane 20 tons. A 10 horse-power railway motor is used for the longitudinal travel of the bridge. A similar motor is mounted on the trolley for hoisting, and one of 3 horse-power for the cross travel of the trolley. There are two cranes of 100 tons capacity each, built by Wm. Sellers & Co., in the Baldwin Locomotive Works.

The writer believes that electric jib cranes could be substituted with great advantage for the large steam cranes now used on engineering works.

Take, for instance, a dry dock or canal lock. There will be a track laid all round the work on which steam cranes will travel, excavating the material or placing the blocks of stone in place. Each of these is provided with an independent boiler and one or two engines, and calls for a skilled man to run it. Somewhere near at hand there will be another boiler to supply steam for drills and pumps. All these small engines and boilers are a great source of waste and expense. The cranes do a great deal of work that is a very light load on their engines, and it is well known that the efficiency of a steam engine at half load is less than that of an electric motor under the same circumstances. One larger engine driving a dynamo could supply power to all the various machines used. A light trolley wire suspended over the track would convey power to the cranes, and cables would carry the current to pumps and drills with a fraction of the loss there is in carrying steam the same distance by pipes and hose.

DISCUSSION.

Mr. A. E. Childs said, the excellent paper by Mr. Bowman, treating of some applications of electric motors, is worthy the attention of the members of the Society who are interested in the application of small powers directly to the work to be done. Mr. Bowman has treated the subject in a systematic way, which indicates that he has given the paper considerable thought and attention. Mr. Childs.

Mr. Bowman mentions the installation of an electric lift in the sugar works of Messrs. Chrétien & Félix. There is no doubt that sugar refineries all over America have also made great progress in the applications of electricity to the handling of their product. One of the largest of these installations is that at the Spreckles Sugar Refinery, in Philadelphia. The most interesting application of electricity in these large refining works is the electric overhead travelling double-rail carriers. One large pier, having sufficient space for the unloading of the cargoes of five vessels, simultaneously, is roofed over, and under this roof is placed the system of overhead rail-supporting carriers. This overhead system has switches, sidings, loops and all the various turnouts and applications as in an ordinary tramway. The sugar is discharged from the vessels, is carried to the various sugar houses, for direct refining or storage. The carrier itself weighs 2500 pounds, and is capable of lifting its own weight. The carriers were built by the McMyler Manufacturing Company, of Cleveland, Ohio, the motors for the carriers being supplied by the Westinghouse Electric & Manufacturing Company, of Pittsburgh, Penna. These motors have a capacity of 4 H.P. each, and are of the Manchester type. The operator in the overhead carrier has a comfortable seat, and can control the rising, lowering or horizontal motion of the carrier with great ease and precision. The voltage of the line is about 250, the power being supplied by a Westinghouse generator driven by a Westinghouse automatic engine, of the latter of which the Spreckles Sugar Refining Company have eighty-two doing the work of the refinery. Mr. Bowman mentions that in the case of Chrétien & Félix, a saving of 10 per cent. is effected; but Mr. Charles Watson, superintendent of the Spreckles Sugar Refinery, claims a saving of 50 per cent. over their former method of handling the sugar. Altogether, this installation is probably the most remarkable and complete of its kind, in America at least, and the writer is unaware of any plant which has a larger capacity or greater usefulness.

The author of the paper also refers to the application of motors to long lines of shafting in large factories. In this connection it may be interesting to the members of the Society to know, that in the case of the new factories and the new buildings of the manufacturing plant of the Westinghouse Electric & Manufacturing Company, now being erected at Brinton, near Pittsburgh, Pa., the electric method of distributing power all over the works will be applied in a most thorough manner. A central station will be established, and power will be supplied to each of the departments, where it will be distributed to the lines of shafting in the cases of the smaller machines; and in case of the large and heavy machines, and machine tools, the motors will be placed directly on the machines themselves, thus doing away with all line shafting whatever. This arrangement will save the additional expense of a great deal of overhead shafting, as well as the cost of maintaining this shafting, which is always a serious item, and in addition to this there will be a great saving in efficiency, since the loss due to transmission of power by means of belts will be done away with, and the more economical method of using electricity will be applied. One of the principal sources of saving will be the fact that the boiler plant will be located at one point, as well as the engines and generators. In all factories which have been built previous to the present era of electric transmission, the boilers and engines have been located at several points, generally, involving long lines of steam piping and long transmission by belting. It will be readily seen that in the case where electricity is used, the entire thing is greatly simplified, and the cost of maintenance largely reduced.

The most important branch which the author of the paper has dwelt upon is the application of electric motors to travelling cranes. The most complete plant of travelling cranes is that mentioned by Mr. Bowman as being at the Baldwin Locomotive Works, in Philadelphia. These cranes were built by Wm. Sellers & Co., Philadelphia, and the electrical equipment is that of the Westinghouse Company. It is very interesting to watch the operation of these large cranes, as they pick up with apparent ease the largest locomotives built by this Company. The shock on the generator when one of these locomotives is raised is very severe, and the needles of the ammeters on the switchboard will swing around at such a rate that it is impossible to see what the starting current is when the load comes upon the enormous cranes. This fact in itself speaks highly for the generators and motors which have to stand such severe work.

A very interesting application of electric motors, which the author of the paper has not mentioned, is the application of railroad type motors to rolling mills. At the Carnegie rolling mills in Pittsburgh, the Westinghouse Company has installed a complete electric plant for operating the rolls. The motors are 30 H. P. each, there being four motors to each set of rolls. The motors reverse the train of rolls on each table each time that the bloom passes through the rolls ; at the same time the other two motors raise or lower the tables, as the case may be, to bring the rail or beam, or whatever the product may be, within the line of opening between the rolls. The Carnegie Company state that by the application of these motors to their rolling mill, the output has been increased from two hundred tons to three hundred tons per working day, a gain of 50 per cent. in the manufacturing capacity of the mill. This application has been so satisfactory that other rolling mills in the country are following the lead taken by Carnegie, Phipps & Co., of Pittsburgh.

In addition to these applications, electric motors are now being used for girder hoists, slitting shears, foundry cranes, transfer hoists and machines of that class.

There is one more application which the author of the paper has not taken up, and that is the charging of furnaces by means of electric motors. This application is one of the most recent, and it is now having the serious consideration of several well-known iron and steel companies, and in the near future will no doubt be amply described in the technical papers.

Thursday, 10th May.

MR. W. J. SPROULE, Member, in the chair.

The discussion on Mr. M. J. Butler's paper on "Cement Mortars, &c.," occupied the evening.

Friday, May 25th.

G. H. Garden, Member of Council, in the Chair.

Paper No. 96.

THEORY OF THE ACTION OF PUMPS.

By Professor J. T. Nicolson, B.Sc., M.Can.Soc.C.E.

This paper is, in the main, a compilation from scattered memoirs (mostly German) on the subjects in question, and, save for incidental novelties of treatment, contains nothing original.

It is offered to this Society first, because the secretary informed the author last week he would be pleased to have a paper for this evening; and secondly, because Past President Mr. Kennedy thought it would be of value to have Bach's celebrated experiments recorded in the Society's proceedings. They are accordingly embodied in Sect. III. It is proposed to give an account of Bach's and Riedler's later experiments on pumps themselves to the Society in a future paper.

The paper is divided into three parts: The first part is devoted to the consideration of the forces acting and resistances experienced during the suction stroke of a single acting pump without and with a vacuum-vessel; the second part deals with the nature and action of valves; and the third gives the results of Bach's experiments as above mentioned.

Parts IV, V, and VI, to be offered at a future time, will contain the investigation of the delivery stroke, the experiments of Riedler and Bach, leading to the determinations of the limiting speed of pumps, and some suggestions as to the direction for future experiments on the subject.

The symbols used in this paper are as follows:

G = Weight of one cub. ft. of fluid to be pumped.
g = acceleration due to gravity.
A = area of pump bucket or plunger.
a = area of suction pipe.
v = speed of plunger at any instant.
$\dot{v}$ = acceleration of same at same instant.
u = speed of water in suction main at same instant.

$\dot{u}$ = acceleration of water in suction main at same instant.

l = length of suction main.

l_1 = length of suction main between pump chamber and vacuum-vessel.

l_2 = length of suction main from vacuum vessel to suction well.

h_s = vertical distance from water level in well to bottom of stroke.

x = distance of plunger from bottom of stroke at instant considered.

S = length of stroke.

B = pressure in pounds per sq. in. corresponding to barometric pressure.

F_1 = average force required to act on the plunger in order to overcome weight.

F_2 = average force required to act on the plunger in order to overcome inertia.

F_3 = average force required to act on the plunger in order to overcome friction.

c = fraction of stroke giving a volume equivalent to clearance.

PART I.--THE SUCTION STROKE.

The work done by the atmosphere while forcing the fluid up the lift-main during the suction stroke consists of three parts: that required to raise the water merely against gravity; that required to overcome the force of inertia; and that required to be expended on prejudicial hydraulic resistances.

SECTION 1.—WORK AGAINST GRAVITY.

The work expended per stroke in merely raising the water may be estimated as follows:

The force acting on the suction pipe is $G\,a\,(h_s + x)$, and acts through a distance $\frac{A}{a}dx$ when the plunger rises the amount dx. The work done during the upward stroke is therefore

$$F_1\,S = \int_0^s G\,A\,(h_s + x)dx = G\,A\,S\left(h_s + \frac{S}{2}\right) \ldots\ldots(1)$$

SECTION 2.—WORK AGAINST INERTIA FORCES.

If the water in the suction pipe is at rest, and then receives a velocity u, an amount of work equivalent to $\frac{Mu^2}{2g}$ foot lbs., the kinetic

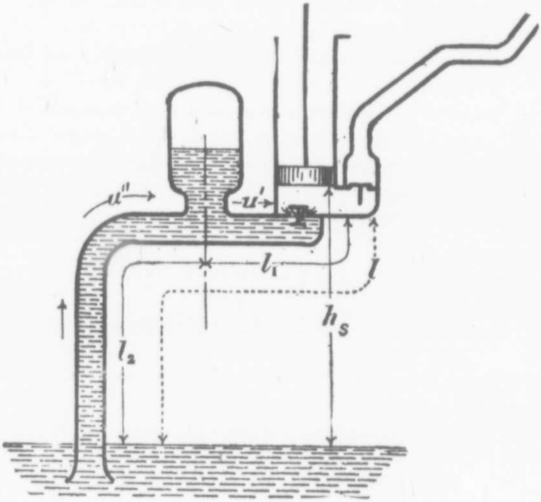


Fig. 1.

energy of the mass of water M must be expended. If it have initially a velocity u_1 and this is to be increased to u_2, the amount of work to be expended must be the equivalent of the difference of the kinetic energies before and after alteration of speed of the water; or in symbols

$$\frac{M\ (u_2^2 - u_1^2)}{2g}.$$

Should u_1 be greater than u_2, work need not be expended upon, but will be done by the fluid; and if $u_2 = u_1$, no work need be done.

In applying these principles, there are three different masses of water, the effects of whose inertia are to be considered.

(*a*) A weight of water $G\ A\ dx$ which enters the suction pipe from the well while the plunger describes the space dx, and receives the velocity u which obtains in that pipe at the instant considered. A work in foot lbs. equivalent to $\frac{G\ A\ u^2\ dx}{2g}$ is necessary to effect this; and can be performed by a force $\frac{G\ A\ u^2}{2g}$ moving through a distance dx.

(*b*) The weight of water $G\,a\,l$ which is contained in the suction pipe of a single acting pump without a vacuum vessel which is at rest at the beginning of the stroke.

If there be a vacuum vessel, the water contained in that part of the suction pipe between this and the well is continuously in motion, while that part which lies between pump chamber and vacuum vessel comes to rest during the return stroke. If the piston acceleration be $\dot{v}$ and that of the fluid in the suction pipe $\dot{u}$, then the work $\frac{G\,a\,l\,\dot{u}\,dx}{g}$ must be expended while the plunger describes the distance dx. This is performed by a force $\frac{G\,a\,l\,\dot{u}}{g}$.

(*c*) The weight of water $G\,A\,(x + c\,S)$ contained at the moment in the pump chamber must also be accelerated, and an amount :— $\frac{G\,A\,(x + c\,S)\,\dot{v}\,dx}{g}$ foot lbs. of work must be expended while the plunger travels the distance dx.

The force $\frac{G\,A\,(x + c\,S)\,\dot{v}}{g}$ acting through dx will accomplish this.

At the instant considered, then, there is required an amount of work to overcome the inertia of the three masses of fluid, as follows :

$$\left[\frac{G\,A\,u^2}{2g} + \frac{G\,a\,l\,\dot{u}}{g} + \frac{G\,A\,(x + c\,S)\,\dot{v}}{g}\right]dx$$

or since $A\,\dot{v} = a\,\dot{u}$.

$$\frac{GA}{g}\left[\frac{u^2}{2} + (l+x+c\,S)\,\dot{v}\right]dx.$$

The work done during the whole stroke is therefore

$$F_2\,S = \frac{G\,A}{g}\int_0^s \left[\frac{u^2}{2} + (l + x + c\,S)\,\dot{v}\right]dx \;\ldots\ldots..(2)$$

an integral which can be easily found for certain kinds of motion of the plunger, as we shall see.

The force which must at any instant be exerted on the fluid during the suction stroke is obviously

$$\frac{G\,A}{g}\left[\frac{u^2}{2} + (l+x+c\,S)\,\dot{v}\right]$$

where u, x, and $\dot{v}$ are variables.

SECTION 3.—WORK AGAINST HYDRAULIC RESISTANCE.

The prejudicial hydraulic resistances acting during the suction stroke occur: at the entrance to the suction pipe; at the foot valve, if any; by pipe friction and variation of section or direction in the suction pipe and the pump chamber; and at the suction valve.

If h_r be the total head lost in resistances, then a force $G\,a\,h_r$ must be exerted on account of these resistances; and since, while the plunger travels a distance dx, this force will have to move through $\frac{A}{a}\,dx$, the work then done will be

$$G\,a\,h_r\,\frac{A}{a}dx = G\,A\,h_r\,dx$$

h_r may also be put equal to $\frac{\zeta u^2}{2g}$; where ζ is an experimental constant, and is made up of the following five component parts:

ζ_1 for entrance to suction pipe.
ζ_2 for flow through foot valve.
ζ_3 for flow through suction pipe.
ζ_4 for flow through suction valve.
ζ_5 for motion in pump chamber.

The work required to overcome these resistances may thus be written:

$$G\,A\,(\zeta_1 + \zeta_2 + \zeta_3 + \zeta_4 + \zeta_5)\frac{u^2}{2g}\,dx \qquad \text{for the travel } dx.$$

and for the whole stroke:

$$F_3\,S = GA\Big(\Sigma(\zeta)\Big)\int_o^s \frac{u^2}{2g}\,dx \text{ ....(3)}$$

SECTION 4.

The pressure of the external atmosphere must be capable of overcoming all these opposing forces at every moment; or at all events the work done during the stroke by the atmosphere must be at least equal to the sum of all the opposing quantities of work. The distance moved through by this atmospheric force during the suction stroke S is $S\frac{A}{a}$; so that if B be the pressure in pounds per square inch corresponding to the height of the barometer, we must have

$$G\,B\,a\,S\,\frac{A}{a} \geqq (F_1 + F_2 + F_3)\,S$$

$$\text{or } G\,B\,A\,S \geqq G\,A\left(h_s + \frac{S}{2}\right)S$$
$$+ \frac{GA}{g}\int_o^s\left[\frac{u}{2}^2 + (l + x + c\,S)\,\dot{v}\right]dx$$
$$+ GA\left(\zeta_1 + \zeta_2 + \zeta_3 + \zeta_4 + \zeta_5\right)\int_0^s \frac{u^2}{2g}dx \;.\;\ldots(4)$$

The force GAB must at every moment be equal to or greater than

$$G\,A\,(h_s + x) + \frac{GA}{g}\left[\frac{u}{2}^2 + (l + x + c\,S)\;\dot{v}\right] + \frac{GA}{2g}\left[\Sigma\;(\zeta)\;\right]u^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Obviously $Av = au$; and $A\dot{v} = a\dot{u}$ if the law of continuity holds.

The condition expressed in (5) is best investigated graphically; and for this purpose we may write it thus

$$B - \left[(h_s + x) + \left(\frac{u^2}{2g} + \frac{l + x + c\,S}{g}\dot{v}\right) + \Sigma\,(\zeta)\,\frac{u^2}{2g}\right]$$
$$\geqq 0 \ldots\ldots\ \ldots\ldots (5a)$$

$$\text{or } B - \left[(h_s + x) + \frac{l + x + c\,S}{g}\dot{v} + \left(1 + \Sigma(\zeta)\right)\frac{u^2}{2g}\right]$$
$$\geqq 0 \ldots\ldots\ldots\ldots\ldots\ldots(5a)$$

In Fig. 2 let AB represent the stroke of the plunger and let A be the lowest position. We may now shew graphically the values of the terms in expression $(5a)$ by setting up from AB their numerical amounts expressed in feet of water; positive quantities upwards, negative downwards.

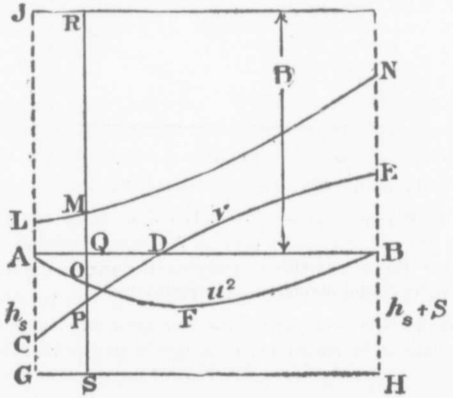


Fig. 2.

The constant atmospheric pressure is first represented by the straight line drawn so that $AJ = BK = B$. The lift $(h_s + x)$ will be represented by the slightly inclined line, when $AG = h_s$, and $BH = (h_s + S)$. The term involving $\dot{v}$ the acceleration of the plunger will be shown by such a curve as *CDE*; while that involving u^2 and composed of resistances at entrance and during transit through the suction pipe by the graph *AFB*.

For any given piston position, as *Q*; if *MR* be taken equal to the sum of *QS*, *QP*, and *QO*; then *MQ* represents the excess of the force due to atmospheric pressure over the resisting forces of gravity, inertia, and hydraulic resistance. If *LN* be the locus of all such points as *M*, it represents the resultant curve of pressure on the under side of the plunger. So long as all the points in *LN* lie above *AB*, (5*a*) is satisfied. If the curve intersects *AB* as in Fig. 3, the plunger leaves the water behind as at *T*; and is struck a blow by it when it catches up again after *U*.

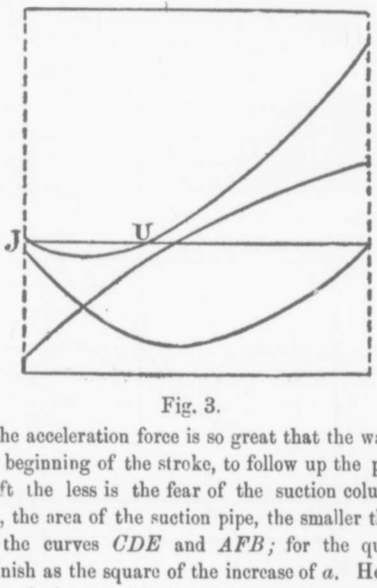


Fig. 3.

In Fig. 4, the acceleration force is so great that the water is unable, even from the beginning of the stroke, to follow up the plunger. The smaller the lift the less is the fear of the suction column breaking. The greater *a*, the area of the suction pipe, the smaller the importance attaching to the curves *CDE* and *AFB*; for the quantities they represent diminish as the square of the increase of *a*. Hence the speed of the pump may be increased by increasing the diameter of the suction pipe. The greater l is, the length of the lift main, the smaller must be the speed of the plunger. With high piston speed and a not very excessive pressure in the force main, the pressure in the pump chamber may, towards the end of the stroke, become so great as to open the discharge valve and force water to flow through, before the plunger gets to the top of the stroke. This is represented in Fig. 5.

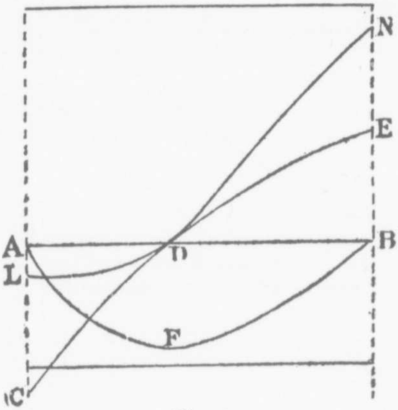


Fig. 4.

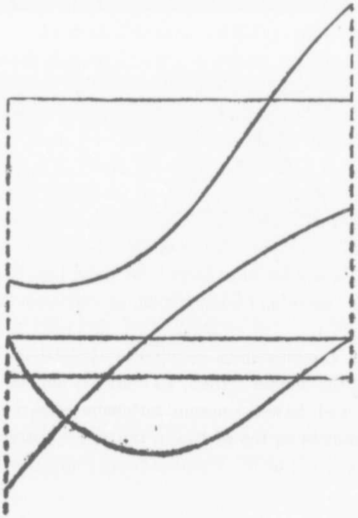


Fig. 5.

In drawing these curves for a crank driven pump, it is usually sufficiently accurate to neglect the obliquity of the connecting rod, when CE becomes a straight line, and AFB a curve of sines, as shown in Fig. 6.

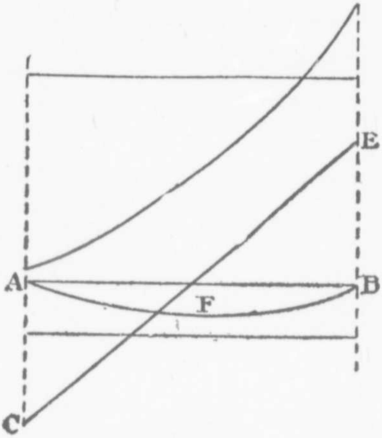


Fig. 6.

From the above considerations and diagrams, it is seen that a considerable portion of the available atmospheric head is required at the beginning of the suction stroke for the purpose of merely accelerating the mass of water in the lift main. This in fact determines the maximum plunger speed with given values of the pump dimensions; and for long lift-mains the allowable speed must be very small.

To overcome this difficulty, a vacuum vessel is inserted in the main in order to insure an inflow from the well as nearly steady as possible. The mass of water to be accelerated at the commencement of the suction stroke is then reduced to that between this vessel and the plunger; so that instead of l in the above equations we must insert l_1 (the distance between vacuum vessel and plunger), which can usually be made very small.

If the vacuum vessel be sufficiently large, the pressure in it will alter but little during the double stroke, so that the motion of the entering fluid between it and the well becomes very approximately uniform.

The work expended on the inertia of the water entering the suction pipe is again given out at the vacuum vessel; and then is effective in accelerating the fluid between it and the pump chamber, when it comes to rest at the end of the down stroke.

The work necessary to overcome the inertia of the water entering the suction pipe with uniform velocity u'' is obviously $\dfrac{GAS\,(u'')^2}{2g}$

If l_2 be the length of lift main from vacuum chamber to well, the work spent against hydraulic resistance will be $GAS\,\zeta''\,\dfrac{(u'')^2}{2g}$; where $\zeta'' = \zeta_1 + \zeta_2 + \zeta_3'' + \zeta_5''$ refers to the length l_2

In the length l_1 between vacuum vessel and pump chamber, an amount of work

$$GAS\,\zeta'\int_0^s \frac{(u)^2}{2g}\,dx$$

must be spent; since here u' is variable.

Also here $\zeta' = \zeta'_1 + \zeta'_3 + \zeta_4 + \zeta_5$ where ζ'_1 is the coefficient of resistance at the entrance to the pipe leading from vacuum to pump chamber; ζ'_3 for the friction in the latter corresponding to the length l.

When a vacuum vessel is fitted, we have only to change equ. (5*a*) into the expression

$$B-\left[(h^s + x) + \frac{l_1 + x + c\,S}{g}\dot{v} + (1 + \zeta'')\frac{(u'')^2}{2g} + \zeta\frac{(u')}{2g}\right]^3 \geqq \ldots\ldots\ldots\ldots\ldots \quad (5b)$$

PART II.—VALVES.

In this paper we concern ourselves only with automatic valves: those, *i.e.*, which open and close under the influence of fluid pressure.

During the lifting of the valve, and after completion of the stroke, water flows through the opening so made, by reason of the difference of pressures above and below the valve, and keeps it open. If now the velocity of the water diminishes to nothing, the valve should gradually close, and should touch its seat exactly at the moment when the speed of the water becomes nothing; otherwise a return flow of water will take place through the unclosed valve for an instant. This is to be avoided not only because of the diminution of delivery thereby occasioned, but also on account of its effect in destroying smoothness of working.

If it be the suction-valve which closes too late, the plunger will have described a short distance x of its return stroke before the valve touches its seat. When this does happen, the discharge valve has to be struck open and the mass of water on the other side of it accelerated; and since the acceleration is a maximum with crank driven pumps at the end of the stroke, the effect of this description of even a small value of x will produce a blow in the pump chamber, which will be the more severe the later the suction valve closes and the greater the mass of water to be accelerated.

A similar, if not usually as great, effect is produced when the delivery valve closes after the plunger has begun to perform its return stroke.

In order to obtain a timeous closing of the valves, other forces must be introduced besides those of fluid pressure; and three kinds of valves may be distinguished:

(*a*) *Gravity loaded valves*, when gravity alone acts;

(*b*) *Spring loaded valves*, when the elasticity of the valve itself or of another body is employed; and

(*c*) *Gravity and spring loaded valves*, when both kinds of force are essential.

A valve is spring loaded only when the specific gravity of the valve is unity.

Gravity can often be made to effect correctly timed closure; but when heavy valves are in question with large inertia effects recourse, must be had to springs.

SECTION 1.—GRAVITY VALVES.

At the moment when the valve begins to close, its weight in water W, must be a little greater than P, the difference of the forces exerted on its sides by the fluid streaming past it, which we shall call the *valve head.*

P is a function of (see Fig. 7) a_1 a_2 (the lower and upper areas); p_1, p_2; the lift h, the velocity u with which the water is flowing through d, at the beginning of closure; of the size and shape of the valve box, and of construction and finish of the valve.

The pressure in the fluid between valve and seat is not known at present; but assuming it to be but little different from p_2, and that the valve box is large enough to have no influence on P, we may write with sufficient accuracy for the valve head

$$P = (p_1 - p_2)\, a_1 + \frac{k u_1^{\,2}}{2g}\, G a_1 \ldots\ldots (11)$$

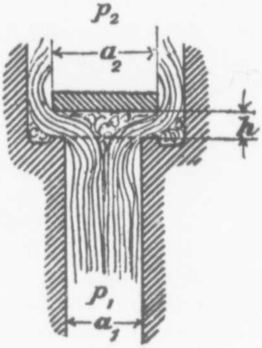


Fig. 7.

This may be shown as follows :

The force tending to keep up the valve is the difference of the lower and upper pressures acting on the area of underside of valve, together with the force required to change the momentum of the water flowing through.

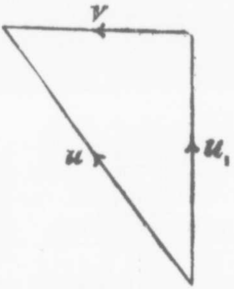


Fig. 8.

In Fig. 8, if u_1 and v represent the initial and final velocities of the water passing the valve, the change of velocity is represented by u.

If a mass of water M impinges against the valve per second, the force required to give this a volocity u in a second is $F = \frac{Mu}{g}$ lbs. The vertical component of this force is

$$F_v = \frac{Mu}{g}\frac{u_1}{u} = \frac{Mu}{g} = \frac{Mu}{g}.$$

In other words, the force acting on this account on the valve is that required to destroy the vertical speed of the water passing. Now,

$$M = Ga_1 u_1.$$

Hence $F_v = n \dfrac{Ga_1 u_1^2}{g}$ where n is a co-efficient allowing for friction, etc. Putting $K = 2n$ we may write:—

$$F_v = K \frac{u_1^2}{2g} Ga_1$$

which justifies the form of (11); K being a co-efficient to be determined by experiment, and depending for its value upon the final direction of the stream, the breadth of the valve seat, and nature of the valve.

The greater the weight of the valve the more readily it will close; on the other hand, the less it will lift at maximum flow, and the greater resistance will it offer to the passage of the water. When the distance from valve to well is great, prompt closure must on this account be somewhat sacrificed in order to diminish the prejudicial hydraulic resistance. A return flow is then inevitable through the valve; and what must be carefully attended to is the securing of as direct and energetic an action on the upper side of the valve due to this return flow as possible.

Such an arrangement as shown in Fig. 9, where the water is discharged through the side channel A, and where the return flow from A rather tends to lift or jam the valve than to close it, is by all means to be avoided.

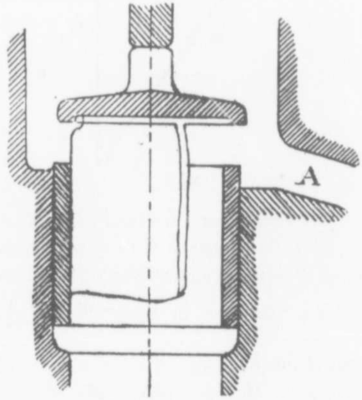


Fig. 9.

The kinetic energy per pound of the water passing between valve and seat is $\frac{v^2}{2g}$ if v is its velocity there. Now this kinetic energy is due to $\frac{ku_1{}^2}{2g}$ that part of $\frac{u_1{}^2}{2g}$ which it still retains, and $\frac{p_1 - p_2}{G}$ the head equivalent to the difference of pressures below and above.

$$\text{hence } v = C_v \sqrt{k\,u_1{}^2 + 2g\frac{p_1 - p_2}{G}}$$

where C_v is the coefficient of velocity.

Assuming the co-efficient of contraction in the area a under the valve to be unity, we shall therefore have

$$\left[a_1\,u_1 = c\,qh\sqrt{[\,ku_1{}^2 + 2g\frac{p_1 - p_2}{G}}\right] \ldots\ldots\ldots$$

Where c is the co-efficient of discharge and $q = \pi d_1$

Hence

$$p_1 - p_2 = \left[\left(\frac{a_1\,u_1}{c\,q\,h}\right)\right]^2 \frac{G}{2g} - \frac{k\,u_1^2}{2g}\,G$$

$$= G\,\frac{u_1{}^2}{2g}\left[\,\left(\frac{a_1}{c\,q\,u}\right)^2 - k\right.$$

Substituting in (11) the valve head is:

$$P = Ga_1\,\frac{u_1{}^2}{2g}\left[\left(\frac{a_1}{c\,q\,h}\right)^2 + K - k\right]$$

Or putting f for $K - k$, the weight of the valve in the fluid,

$$W \underset{>}{=} P = Ga_1\,\frac{u_1{}^2}{2g}\left[\left(\frac{a_1}{c\,q\,h}\right)^2 + f\right] \ldots\ldots\ldots(12)$$

SECTION 2.—SPRING AND GRAVITY VALVES.

1. *Opening.*—At the instant of opening the forces acting on the valve are $a_1\,p_1 + a\,p$ upwards (where $a = \frac{\pi}{4}\left(d_2^2 - d_1^2\right)$ and p is the mean pressure in the space between valve and seat); and $a^2\,p_2 + W + F$ downward (where F is the force due to the spring; and W the valve's weight in water).

The equation of motion of the valve is therefore

$$a_1\,(p_1 - p_2) - a\,(p_2 - p) - W - F = \frac{W + G\,V}{g}a = \frac{W}{g}\,\frac{\gamma}{\gamma - 1}\,a$$

Where a is the acceleration and V the volume of the valves and γ is the specific gravity.

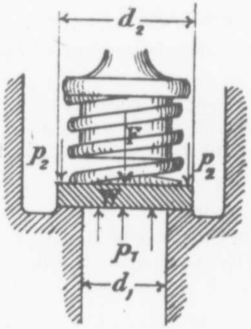


Fig. 10.

Hence if $\frac{W}{g} \frac{\gamma}{\gamma - 1}$ be denoted by M; the following is an expression for the acceleration :

$$a = \frac{a_1 (p_1 - p_2)}{M} - \left[\frac{d}{M} (p_2 - p) + \frac{\gamma - 1}{\gamma} g + \frac{F}{M}\right] \text{......(13)}$$

From which it is seen that the acceleration increases with difference of pressures $(p_1 - p_2)$; and diminishes as the mass of the valve, the spring loading, and the area of valve seat increase. The last only so long as $p_2 - p$ is positive, which is probably the case with high speed pumps as a vacuum must obtain for an instant when the valve lifts quickly at first.

Assuming as small a value as possible for $p - p$ (since the smaller this is, the greater may the suction head be), and constant, the time required to lift the valve a given amount will be shorter the smaller its mass, the less the initial spring-load, and the smaller the valve seat area.

The conditions for equilibrium of the valve are obtained by putting $a = 0$ in (13) ; then

$$a_1 (p_1 - p_2) - a (p_2 - p) - W - F = 0$$

$$\text{or, } p_1 - p_2 = \frac{a}{a_1} (p_2 - p) + \frac{W +}{a} F \text{......... (14)}$$

$p_1 - p_2$ may be called the *valve load.*

SECTION 3.—HYDRAULIC RESISTANCES WHEN OPEN.

The hydraulic resistances opposed by the valve to the passage of the fluid, the sum of which we call the *valve resistance*, may be enumerated as follows :

That caused (*a*) by the change of direction of the stream.

(*b*) by the change of velocity occasioned by passing from area a_1 to area hq.

(*c*) by friction against the underside of the valve and valve seat.

(*d*) by change of direction and sectional area in the valve box.

and (*g*) in the case of a valve guided from below, by the changes of direction, and sectional area of stream as well as the friction against the surfaces of the guiding bodies.

The present state of the science of hydro-dynamics is unable to give rational expressions for these actions separately ; we must be content with a summarisation.

For any given valve in a properly constructed seat and box, we may in this way take the resistance as consisting of a part proportional to the velocity-head $\frac{u^2}{2g}$, and another part proportional to the velocity-head $\frac{v^2}{2g}$ where u and v are the velocities through seat and between valve and seat respectively, so that the total valve resistance will be measured by

$$\zeta \frac{u^2}{2g} = \zeta_1 \frac{u^2}{2g} + \zeta_2 \frac{v^2}{2g} \text{ ....(15)}$$

where ζ is the co-efficient of resistance of the valve, and ζ_1 and ζ experimental co-efficients. Now

$$u\, a_1 = c_c\, v\, hq, \text{ or } v = u \frac{a_1}{c_c\, hq}$$

where c is the co-efficient of contraction, hence (15) may be written :

$$\zeta \frac{u^2}{2g} = \frac{u^2}{2g} \left[\zeta_1 + \frac{\zeta_2}{c_c^2} \left(\frac{a_1}{hq} \right)^2 \right] \text{ ....(16).}$$

$$\text{or } \zeta = \zeta_1 + \frac{\zeta_2}{c_c^2} \left(\frac{a_1}{hq} \right)^2 \text{ .... (16}a\text{)}$$

For the valves here discussed $a_1 = \frac{\pi}{4} d^2$, and for valves guided on top $q = \pi d$, hence (16*a*) becomes

$$\zeta = \zeta^1 + \frac{\zeta_2}{16 c_c^2} \left(\frac{d}{h} \right)^2 \text{ .... (17)}$$

Putting β for $\frac{\zeta_2}{16 c_c^2}$

$$\zeta = \zeta_1 + \beta \left(\frac{d}{h} \right)^2 \text{ ....(18)}$$

SECTION 4.—VALVE-LOAD OR VALVE-HEAD WHEN OPEN.

Using the equation of continuity of flow we may similarly simplify equ. (12) for the valve head, which becomes :

$$P = G\,a^1\ \frac{u^2}{2g}\left[f + \left(\frac{d}{4\,c\,h}\right)^2\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots(12a)$$

Equations (18) and (12*a*) were first given by Bach in [illegible] treatise on Fire Engines in 1883; and they were experimentally tested as to their validity, and for the determination of their co-efficients by him in 1884.

PART III.—BACH'S EXPERIMENTS.

In this section a succinct account of the results of Bach's experiments is given; for the methods and apparatus used by him, see his treatise "Versuche über Ventilbelastung u. Ventilwiderstand," Berlin, Julius Springer, 1884.

(*a*) Plate-valve, guided above, and plane under side (Fig. 11).

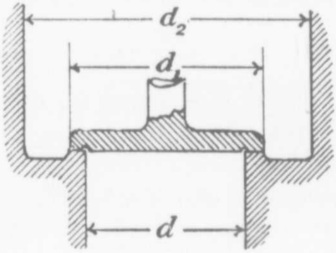


Fig. 11.

With this construction of valve were determined the interdependence of valve-load, valve resistance, and valve lift, and the relations between valve load and speed of water.

Another similar valve with larger seat area was used to determine the effect of this quantity.

The dimensions were $d = 50$ mm., $d_1 = 60$ mm., $d_2 = 90$ mm.

The variation of P with the lift h when the head under which water flowed through was kept constant, for values of h between $\frac{d}{10}$ and $\frac{d}{4}$ may be expressed by

$$P = 1000\ a^1\ \frac{u^2}{2g}\left[2.5 + \left(\frac{d}{4 \times 0.62h}\right)^2\right] \quad \ldots(19)$$

f being $= 2.5$ and $c - 0.62$.

The variation of ζ with the lift h are expressed by equation (18); with $\zeta_1 = 0.55$ and $\beta = 0.15$; so that

$$\zeta = 0.55 + 0.15 \left(\frac{d}{h} \right)^2 \quad \text{..........................} (20)$$

for ordinary values of the lift between $\frac{d}{10}$ and $\frac{d.}{4}$

For a valve as in Fig. 11, but with the dimensions $d = 50$ mm. $d_1 = 74$ mm., $d = 100$ min. that is a broader seat-area:

$$f = 5.15 \text{ and } c = 0.605.$$

so that (19) is

$$P = 1000\, a_1 \frac{u^2}{2g} \Big[5.15 + \frac{d}{4 \times 0{\cdot}605\, h} \Big)^2 \Big] \text{.......} (19a)$$

Also ζ_1 becomes 1.1 and β 0.155 so that (20) reads

$$\zeta = 1.1 + 0.155 \left(\frac{d}{h} \right)^2 \quad \text{..........................} (20a)$$

(*b*) Valve concave downwards, guided above, as shown by Fig. 12

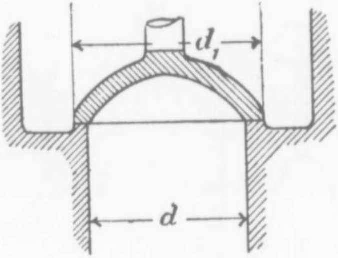


Fig. 12.

In this case in equation (12*a*) we get $f = 2.34$, and $c = 0.63$.

For Fig. 11 we had

$f = 2.5$ and $c = 0.62$; so that we see that under similar conditions Fig. 11 requires a somewhat greater valve load than Fig. 12, contrary to what we should have expected.

With this valve ζ_1 becomes $= 0.65$ and $\beta = 0.132$, so that comparing with equation (20), it is seen that ζ_1 is greater and B less with a concave than with a flat valve. On the whole, the co-efficient o resistance ζ comes out smaller, for lifts from $\frac{d}{10}$ to $\frac{d}{4}$, for concave than for plane valves.

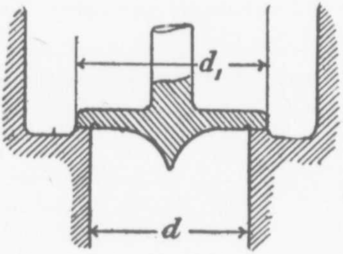


Fig. 13.

(*c*) Valve convex downwards ; guided above. Fig. 13.

Here the co-efficients in equation (12*a*) and (18) are almost identical with those for a flat bottomed valve given in equations (19) and (20).

(*d*) Valves with guiding ribs below, as shown by Fig. 14.

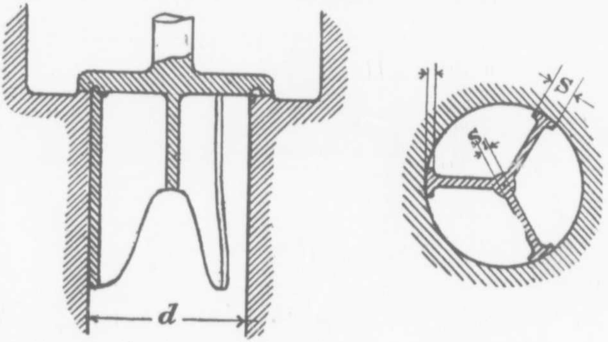


Fig. 14.

Here the area through the valve seat is diminished 12. 9 per cent. by the guide feathers.

If the number of ribs be i, then $p = \pi d - is$, so that equ. (12*a*) becomes :—

$$P = 1000\, a_1 \quad \frac{u^2}{2g}\left[\; f + \left(\frac{a_1}{ch(\pi\, d - is)}\right)^2\right] \ldots .(21)$$

and the constants obtained from experiment were $f = 2.18 + c = 0.553$.

Also instead of equ. (18) we have here

$$\zeta = \zeta_1 + B\, \left(\frac{d^2}{(\pi d - is)h}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots (22)$$

and for ordering lifts we may write $\zeta_1 = 1.35$ and $B = 1.7$.

PRACTICAL RULES.

Taking P as the valve load, or the force with which the opened valve must be loaded in order to maintain its equilibrium against the streaming fluid:--

d = dia of valve seat (v. Fig. 11).
$a = \pi d_2$ = area through do
h = lift of valve.
i = number of guide ribs, for clack valve.
s = breadth of same (v. Fig. 4).
b = radial breadth of valve or seat facing $= \frac{1}{2}(d_1 - d)$ (Fig. 11).
u = speed of flow through a.
g = acceleration due to gravity $=32.2$.
ζ = co-effi. of resistance of the valve; so that head lost by resistance through the valve is $\zeta \frac{u^2}{2g}$. and ζ_1 β, γ, f, c, experimental co-efficients.

Then with the foot and the pound as units we have:

$$P = 62{\cdot}4\, a\, \frac{u_2}{2g} \left[\ \ + \left(\frac{d}{4\,ch}\right)^2\right] \text{ .... (I)}$$

$$P = 62{\cdot}4 a \frac{u^2}{2g} \left[f + \left(\frac{a}{c(\pi d - is)h}\right)^2\right] \text{.........(II)}$$

$$\zeta = \zeta_1 + \beta\left(\frac{d}{h}\right)^2 \text{ ....(III)}$$

$$\zeta = \zeta_1 + \beta\left(\frac{d^2}{(\pi d - is)\, h}\right)^2 \text{ ....(IV)}$$

With the following values of constants:

1.—FOR PLATE VALVE AS IN FIG. 11.

In Equ. I, take $f = 2{\cdot}5 + 19\, \frac{b - 0{\cdot}1d}{d}$ for breadths of b from $\frac{d}{10}$ to $\frac{d}{4}$; $c = 0{\cdot}60$ to $0{\cdot}63$.

In Equ. III take $\zeta_1 = 0{\cdot}55 + \frac{4\,b - 0{\cdot}1d}{d}$ with b as above.
$\beta = 0{\cdot}15$ to $0{\cdot}16$.

Any deviation from a plane underside makes but little difference on the co-efficients; but it may be noted that ζ_1 is smaller for the valve in Fig. 12 and larger for Fig. 13 than for Fig. 11. The breadth of valve or eat face is much more influential than the form of thelower surface of the valve.

2.—FOR PLATE VALVES WITH GUIDE RIBS, AS IN FIG. 14.

Use Equ. II with valves of f and of c 10 p.c. less than for those for valves guided above, and Equ. IV with valves of ζ_1 from 0.8 to 1.6 greater than those in § 1 corresponding to a diminution of sectional area from 13 to 20 p. c.; and valves of β from 1.7 to 1.75. The co-efficient of resistance ζ is of course very considerably greater with valves guided below.

RAILWAY TURNOUTS
BY H. K. WICKSTEED.

TRANS. CAN. SOC. C.E.
VOL. VIII. PLATE I.

Fig. 1.

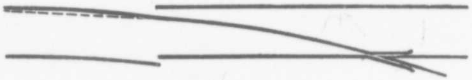


Fig. 2

Fig 3

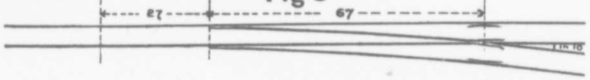


Fig. 4

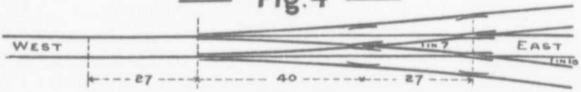


Fig. 5

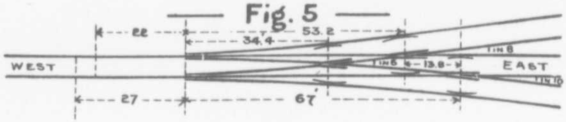


Fig. 6

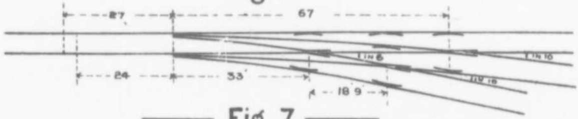


Fig. 7

Fig. 8.

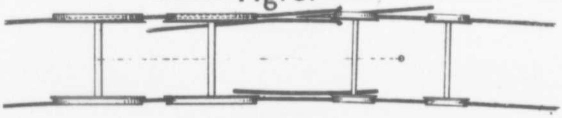


Fig. 9

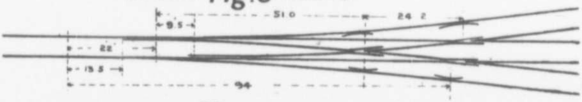
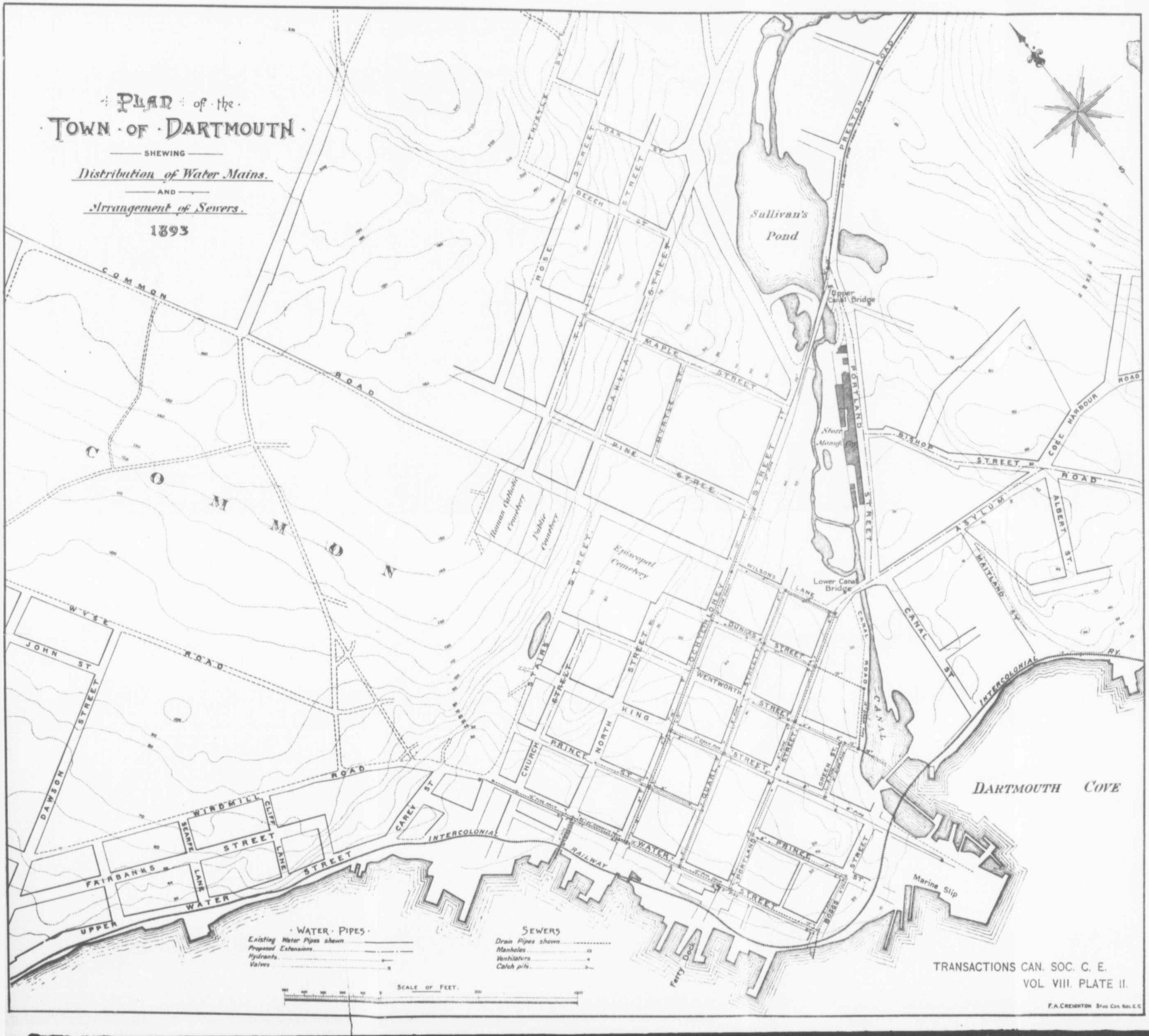
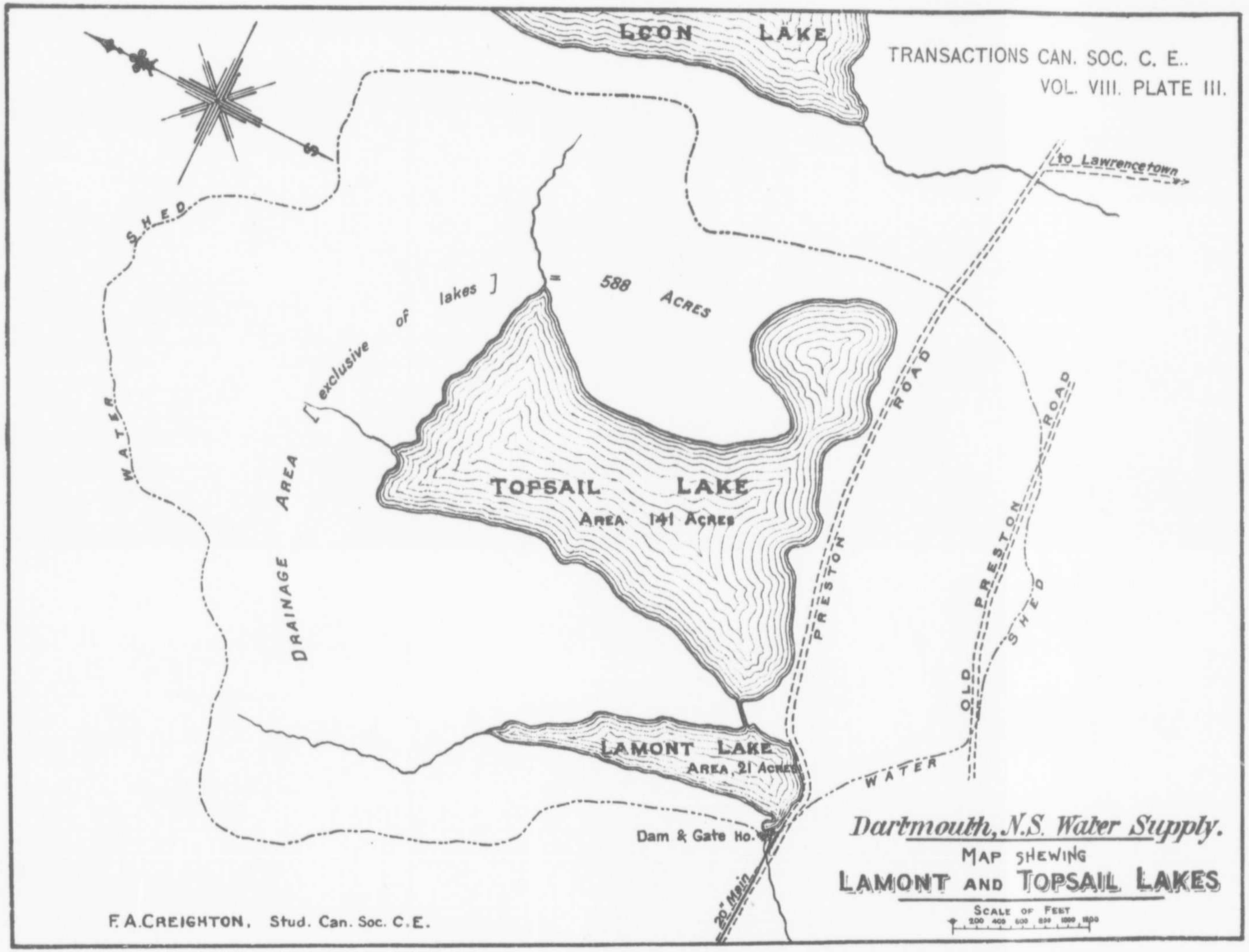


Fig 10



TRANSACTIONS CAN. SOC. C. E.
VOL. VIII. PLATE II.

TRANSACTIONS CAN. SOC. C. E.
VOL. VIII. PLATE III.



Dartmouth, N.S. Water Supply.

MAP SHEWING

LAMONT AND TOPSAIL LAKES

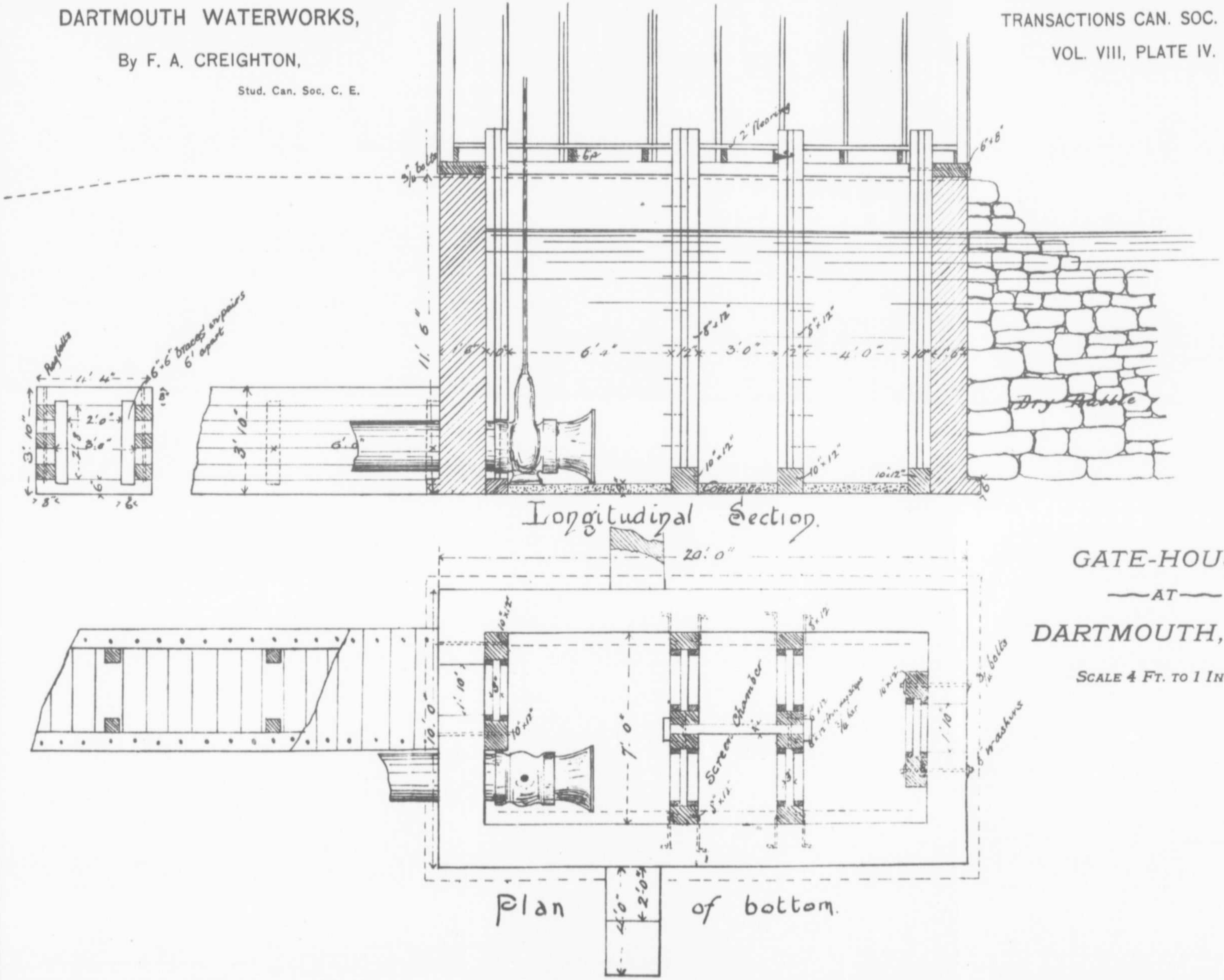
F. A. CREIGHTON, Stud. Can. Soc. C. E.

DARTMOUTH WATERWORKS,

By F. A. CREIGHTON,

Stud. Can. Soc. C. E.

TRANSACTIONS CAN. SOC. C. E.
VOL. VIII, PLATE IV.



GATE-HOUSE

—AT—

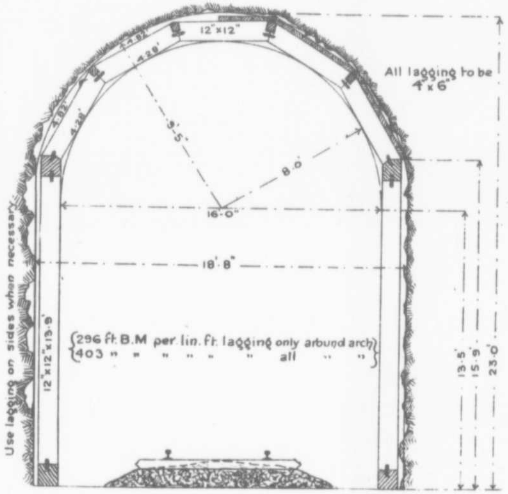
DARTMOUTH, N. S.

SCALE 4 FT. TO 1 INCH.

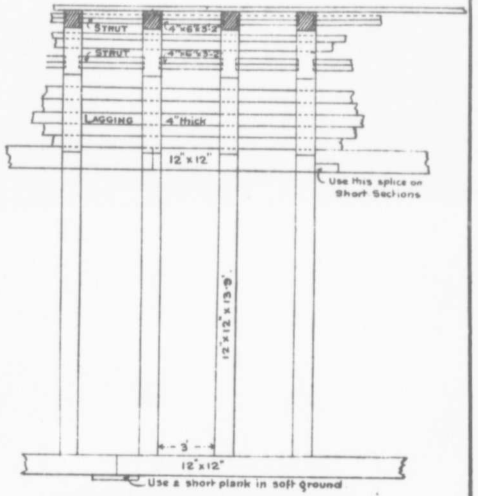
GREAT NORTHERN RAILWAY

STANDARD SECTIONS FOR TUNNELS

SOLID ROCK SECTION
11·07 Cub. Yds. per lineal foot.



TIMBERED SECTION
14·585 Cub. Yds. per lineal foot.



LONGITUDINAL SECTION

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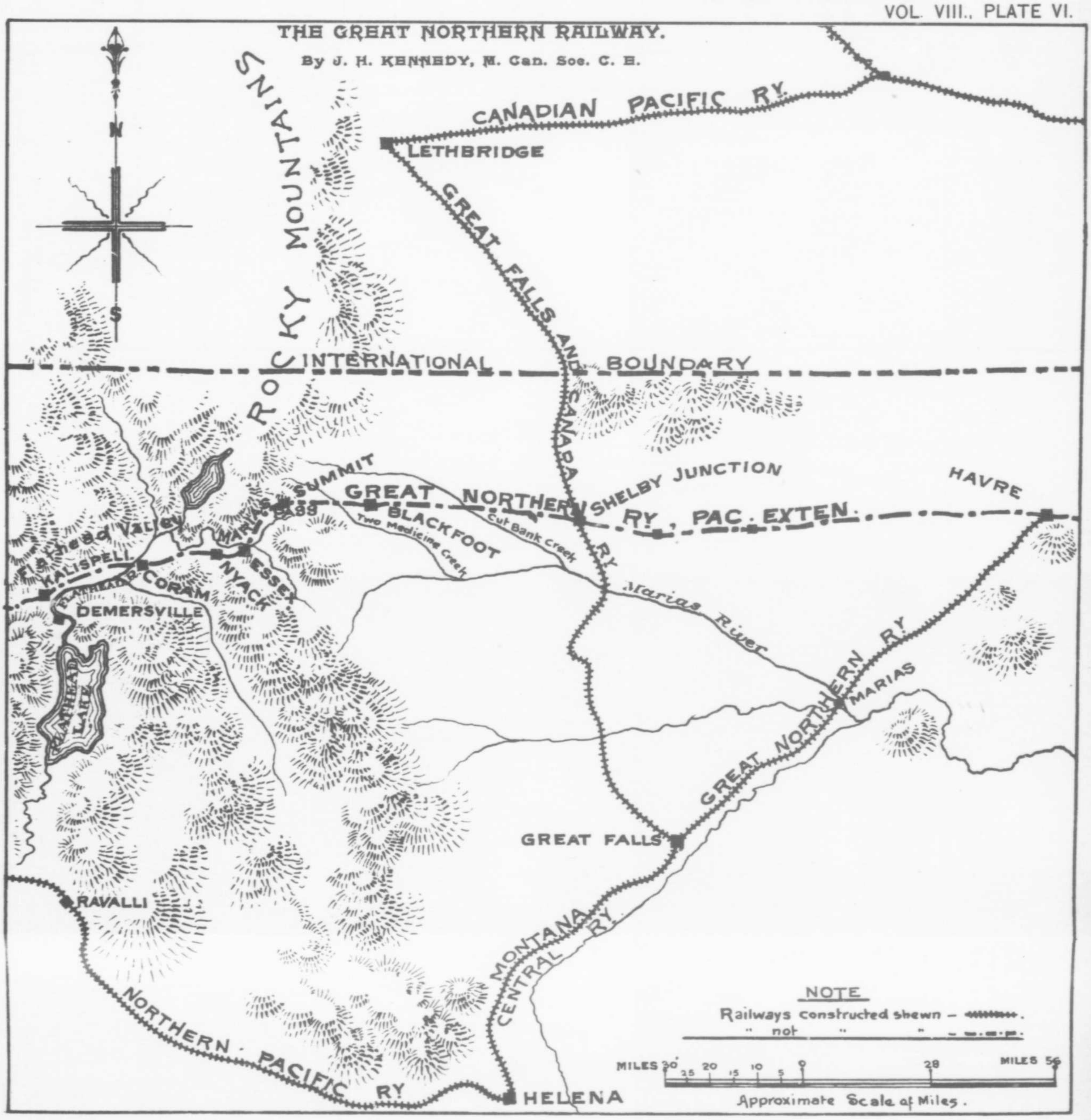
VOL. VIII., PLATE VI.



THE GREAT NORTHERN RAILWAY.

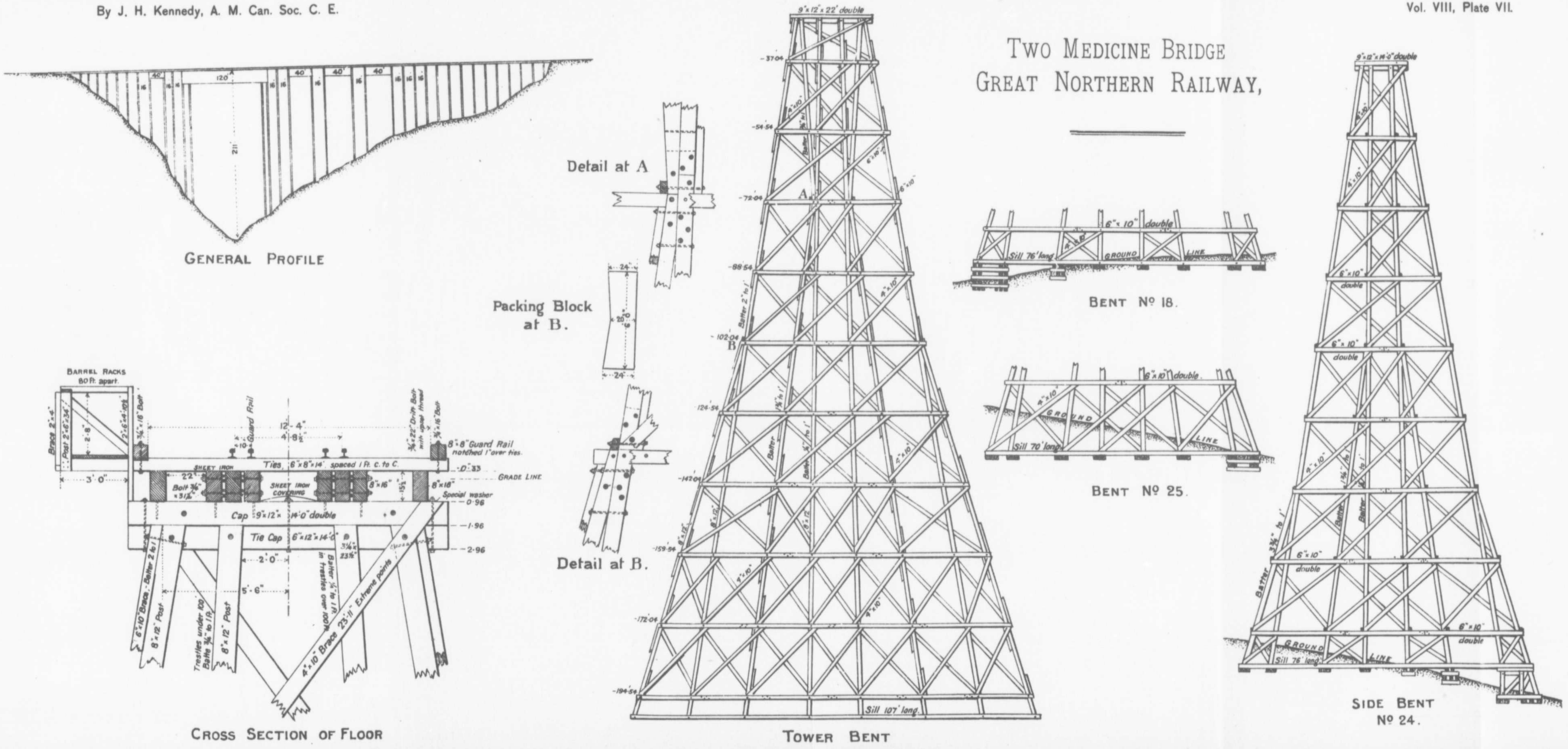
By J. H. KENNEDY, M. Can. Soc. C. E.

THE GREAT NORTHERN RAILWAY,

By J. H. Kennedy, A. M. Can. Soc. C. E.

TRANSACTIONS CAN. SOC. C. E.
Vol. VIII, Plate VII.

TWO MEDICINE BRIDGE GREAT NORTHERN RAILWAY,



GENERAL PROFILE

CROSS SECTION OF FLOOR

Detail at A

Packing Block at B.

Detail at B.

TOWER BENT

BENT Nº 18.

BENT Nº 25.

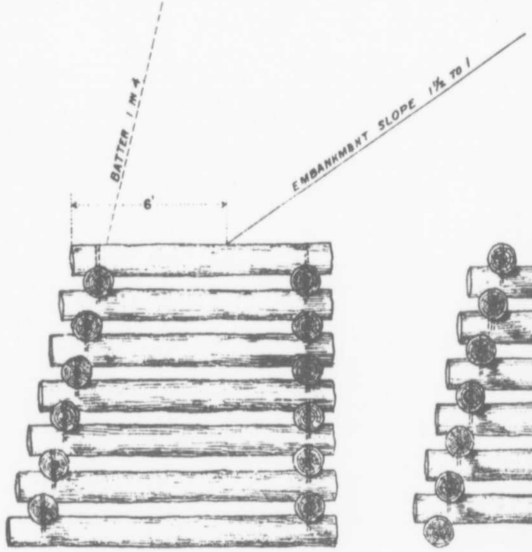
SIDE BENT Nº 24.

TRANSACTIONS CAN. SOC. C. E.
Vol. VIII, Plate VIII.

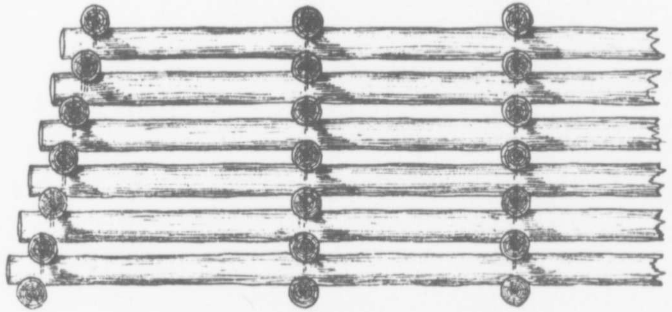
GREAT NORTHERN RAILWAY,
PACIFIC EXTENSION

BY JAS. H. KENNEDY, A. M. Can. Soc. C. E.

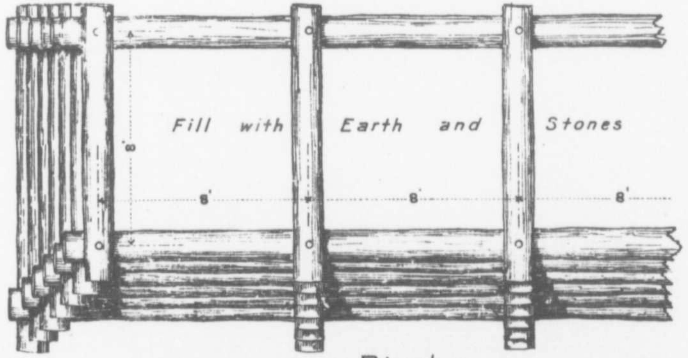
GENERAL PLANS.



· END · ELEVATION ·



· SIDE · ELEVATION ·



· PLAN ·

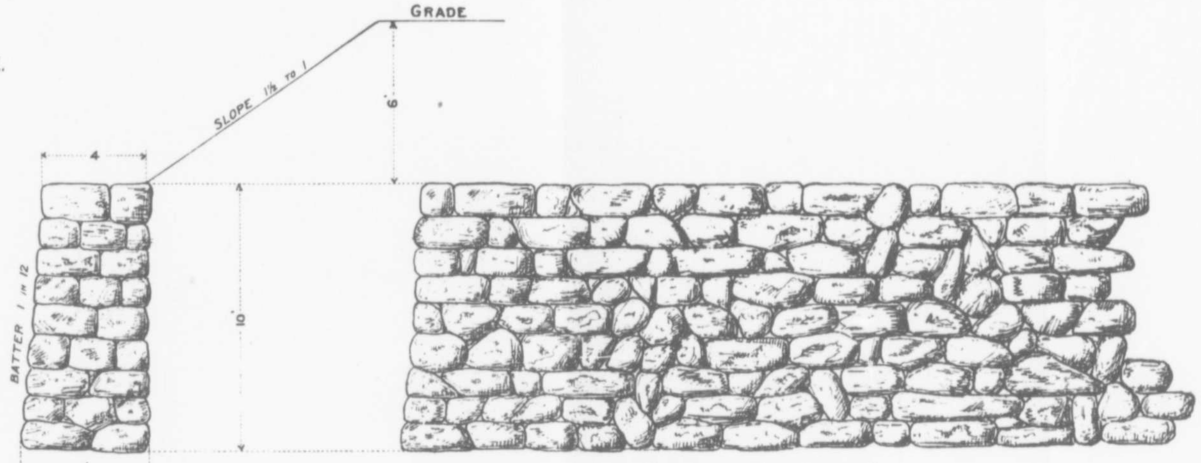
· PLANS · FOR ·
· LOG · RETAINING · CRIBS ·

NOTE.

Tops of Cribs to be 6 ft or more below Grade except along side of Streams where Grade is not sufficiently above High Water to permit this to be done.

Make width at Base so that Crib will be not less than 8 ft. widr at the top.

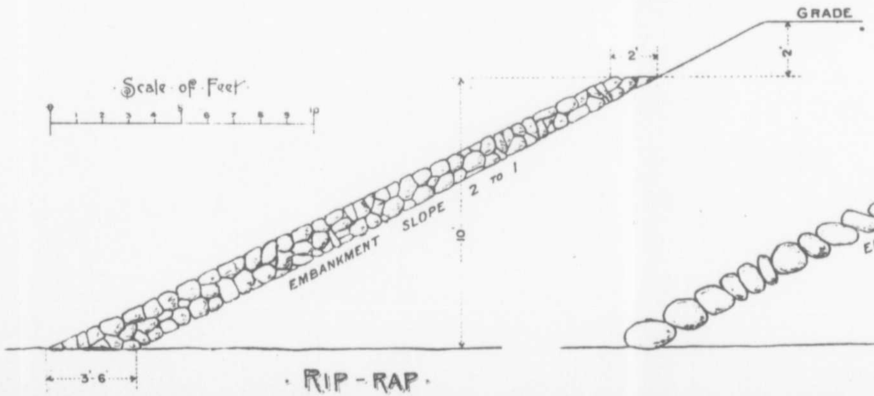
Logs to be secured with tree-nails not less than 2" in diameter and 18" long.



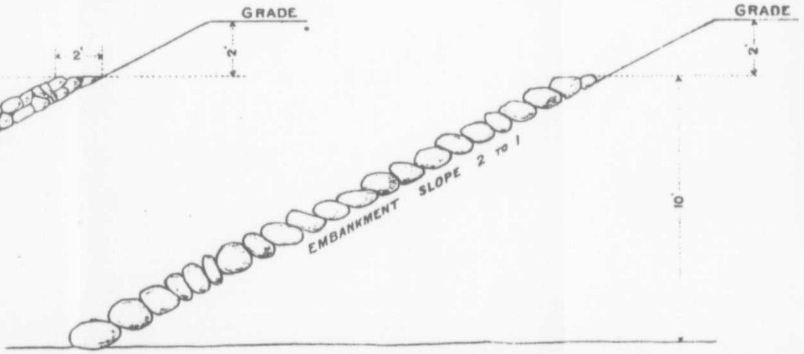
· END · ELEVATION ·

· FRONT · ELEVATION ·

· DRY · LAID · ROCK · RETAINING · WALL ·



· RIP - RAP ·



· SLOPE · WALL ·

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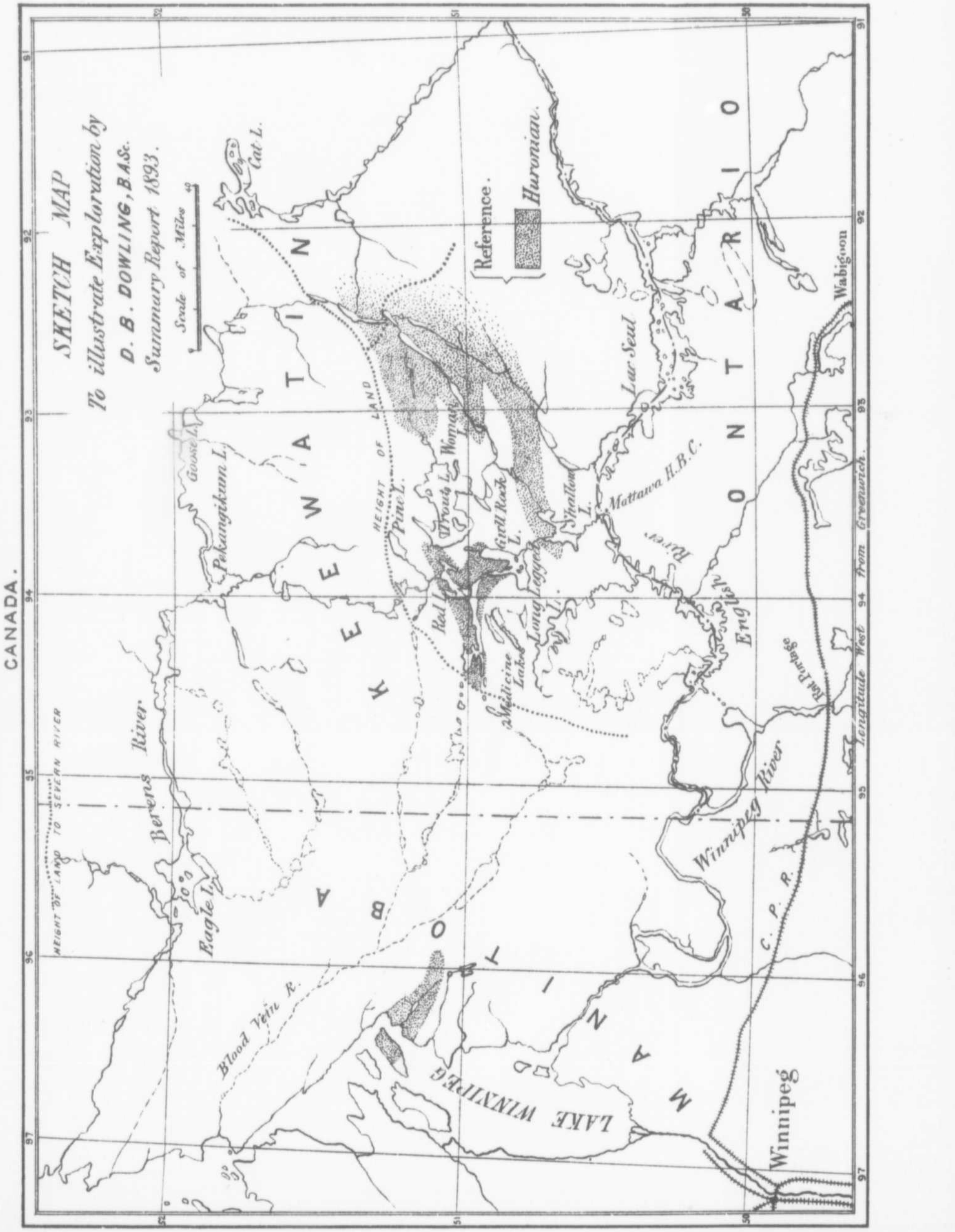
Trans. Can. Soc. C. E. Vol. VIII. Plate IX.

"Metamorphic Areas of Keewatin" by J. C. Gwillim, Stud. Can. Soc. C. E.

GEOLOGICAL SURVEY DEPARTMENT,
CANADA.



TRANSACTIONS CAN. SOC. C. E.
VOL. VIII. PLATE X.

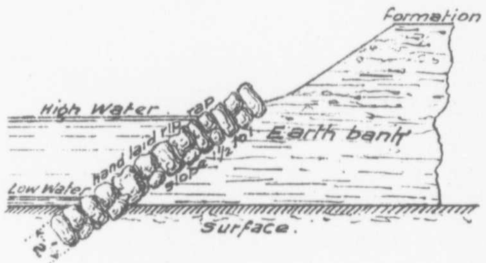


FIG. 1.

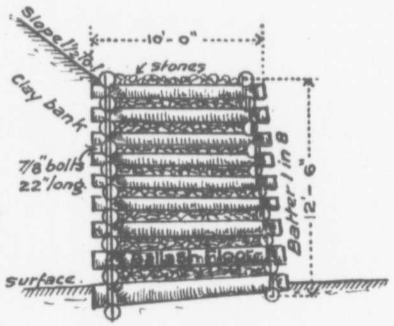


FIG. 2.

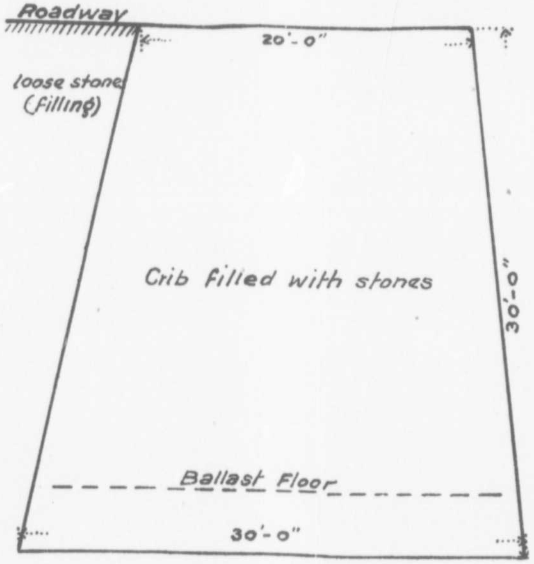


FIG. 3.

FIG. 4.

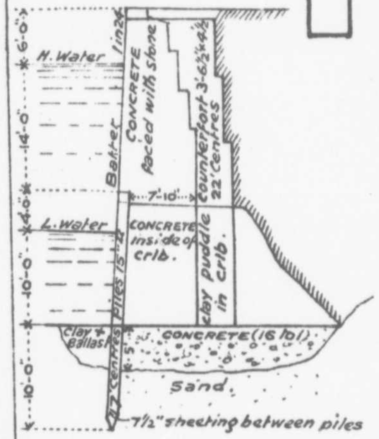
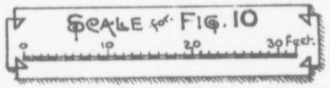


FIG 10



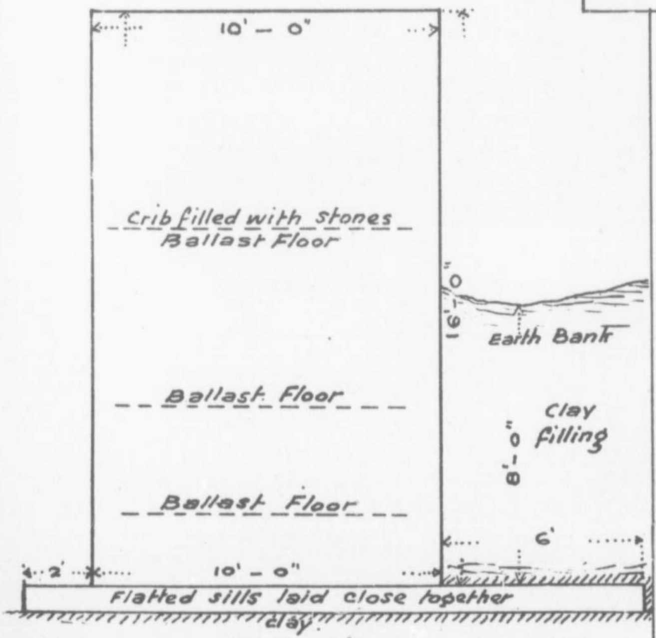


FIG. 4½.

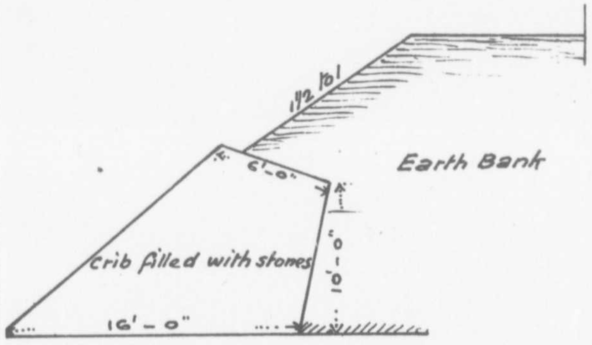


FIG. 5

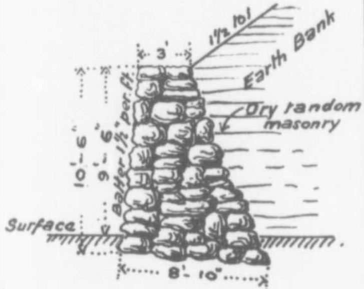


FIG. 6.

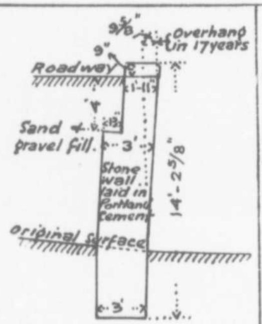


FIG. 7.

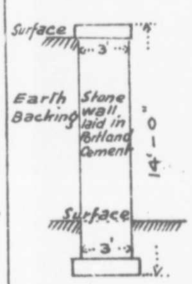


FIG. 8

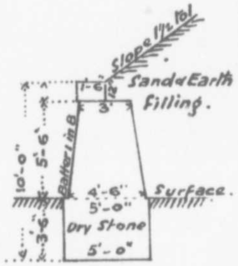


FIG. 9.