TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL. XII., PART I.

JANUARY TO JUNE,
1898.

Montreal:
PRINTED FOR THE SOCIETY
BY JOHN LOVELL & SON.
1898.

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CONTENTS.

ILLUSTRATIONS.

PROCEEDINGS.

INSTRUCTIONS FOR PREPARING PAPERS, ETC.

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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.

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Thursday, 17th February.

Duncan MacPherson, Member of Council, in the Chair.

Messrs. W. McNab and G. H. Duggan having been appointed scrutineers of the ballot reported the following elected :

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ALLAN KILBIE STUART,	JAMES STANLEY VINDIN.

STUDENT.

WILLIAM BEAUMONT ANDERSON.

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

GEORGE KYLE ADDIE,	HENRY BLACK STUART.

Paper No. 126.

THE "MAIN GUT" LIFT SPAN ON THE NORTHERN AND WESTERN RAILWAY, NEWFOUNDLAND.

By W. CHASE THOMSON, A.M.CAN.SOC.C.E.

The Main Gut, Bay St. George, on the line of the Northern and Western Railway, Newfoundland, is crossed by a bridge consisting of one two-hundred-foot span, two seventy-five-foot spans, one seventy-three-foot span and a thirty-five-foot lift span, in all about five hundred feet (see Fig. 1),—designed and built by the Dominion Bridge Co. (Limited.) This paper, however, will treat only of the "lift" and adjacent seventy-three-foot spans, which are certainly uncommon, and it is hoped that a description of them will be of interest to the members of this Society.

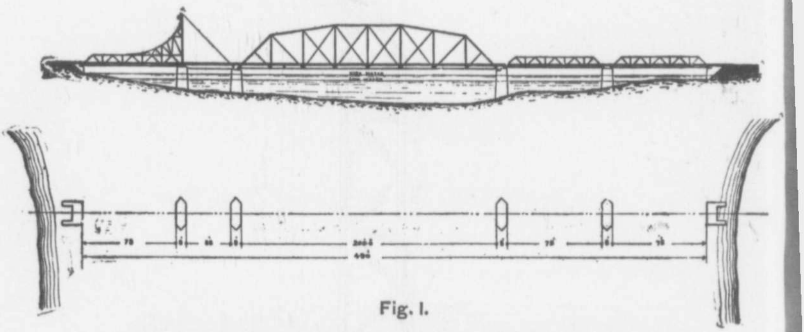


Fig. I.

There is little, if any, navigation at this point, but the Newfoundland Government required a clear opening of thirty-five feet, with a depth of water of thirteen feet; so, taking into consideration the extra expense for building a circular pier in this depth of water, which would have been necessary if an ordinary swing span had been built, it was found more economical to adopt a lift span, which would have the additional advantage of being practically a fixed span when closed.

The general dimensions and mechanism are shewn in Fig. 2, so it will only be necessary to explain the process of determining the counter-weight and the curve of its track, keeping it in equilibrium during all periods of opening or closing; also the stresses in tower and fixed span caused by this counter-weight.

From the general conditions of equilibrium, the weight of lift span into the vertical rise of its centre of gravity at any instant must equal the counter-weight into its vertical fall; or, in other words, the vertical fall of counter-weight corresponding to any position of lift span must equal

$$\frac{\text{weight of lift span} \times \text{rise of centre of gravity}}{\text{counter-weight}}$$

Supposing the chains to weigh nothing, the centre of counter-weight roller will be found on the intersection of a curve inscribed by end of chain attached to counter-weight and a horizontal line at height just determined; and the centre of gravity of lift span and counter-weight will always be found on the same horizontal line. The weight of chain, however, alters these positions somewhat, as will be seen presently.

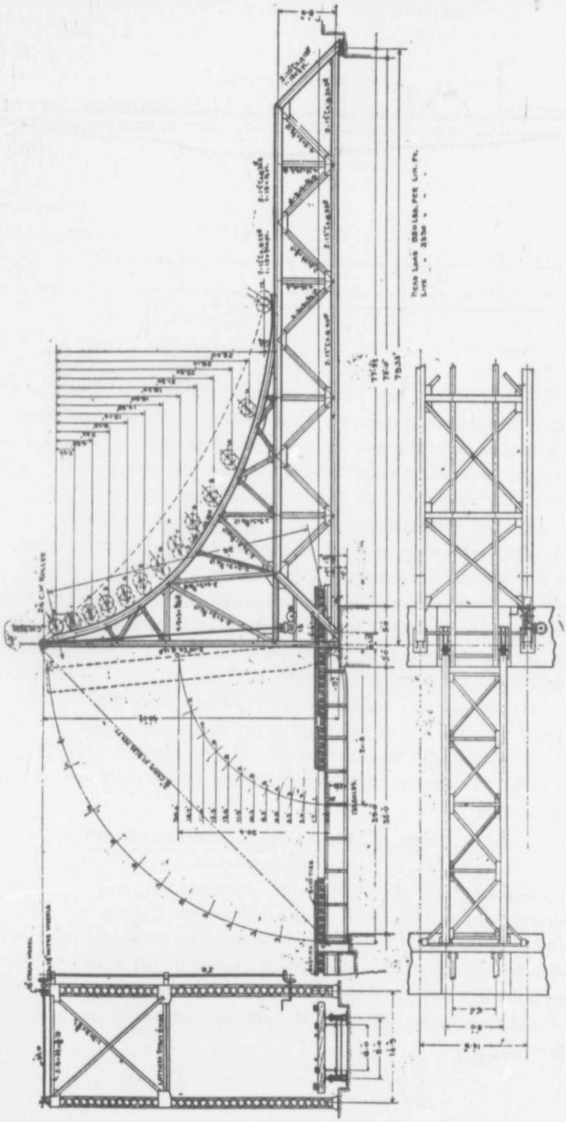


Fig. 2.

The actual operations for determining the curve of counter-weight track were as follows: First, the weight of lift span, including ties, rails, etc., was found to be 26,700 lbs., or 13,350 lbs. on each girder; the distance of its centre of gravity horizontally from hinge was 20.8 ft. and from bottom of girder 2.55 ft. Next, the total vertical rise of the centre of gravity of span, viz., 20.4 ft., was divided into twelve equal spaces of 1.7 ft. each, and the corresponding vertical fall of counter-weight was computed for the different positions, allowance being made for weight of chain at eight pounds per foot as follows:

Weight of Chain.

Position	End adjacent to Lift Span	End adjacent to counter weight.
0	55 × 8 = 440 lbs.	3 × 8 = 24 lbs.
1	53 × 8 = 424 "	5 × 8 = 40 "
2	50 × 8 = 400 "	8 × 8 = 64 "
3	48 × 8 = 384 "	10 × 8 = 80 "
4	45 × 8 = 360 "	13 × 8 = 104 "
5	42 × 8 = 336 "	16 × 8 = 128 "
6	39 × 8 = 312 "	19 × 8 = 152 "
7	36 × 8 = 288 "	22 × 8 = 176 "
8	32 × 8 = 256 "	26 × 8 = 208 "
9	28 × 8 = 224 "	30 × 8 = 240 "
10	23 × 8 = 184 "	35 × 8 = 280 "
11	17 × 8 = 136 "	41 × 8 = 328 "
12	4 × 8 = 32 "	54 × 8 = 432 "

Vertical Fall of Counter-weight for the Different Positions of Lift Span

Position	Lift Span Chain Rise C. W. Chain.	Ordinates.
0	$(13350 + 440) \times 0 = 9530y + 24\frac{y}{2}$	$y =$ 0.00 feet.
1	$(13350 + 424) \times 1.7 = 9530y + 40\frac{y}{2}$	$y =$ 2.45 "
2	$(13350 + 400) \times 3.4 = 9530y + 64\frac{y}{2}$	$y =$ 4.88 "
3	$(13350 + 386) \times 5.1 = 9530y + 80\frac{y}{2}$	$y =$ 7.32 "
4	$(13350 + 360) \times 6.8 = 9530y + 104\frac{y}{2}$	$y =$ 9.73 "
5	$(13350 + 336) \times 8.5 = 9530y + 128\frac{y}{2}$	$y =$ 12.14 "
6	$(13350 + 312) \times 10.2 = 9530y + 152\frac{y}{2}$	$y =$ 14.55 "
7	$(13350 + 288) \times 11.9 = 9530y + 176\frac{y}{2}$	$y =$ 16.90 "
8	$(13350 + 256) \times 13.6 = 9530y + 208\frac{y}{2}$	$y =$ 19.20 "
9	$(13350 + 224) \times 15.3 = 9530y + 240\frac{y}{2}$	$y =$ 21.50 "
10	$(13350 + 184) \times 17.0 = 9530y + 280\frac{y}{2}$	$y =$ 23.80 "
11	$(13350 + 136) \times 18.7 = 9530y + 328\frac{y}{2}$	$y =$ 26.00 "
12	$(13350 + 32) \times 20.4 = 9530y + 432\frac{y}{2}$	$y =$ 28.00 "

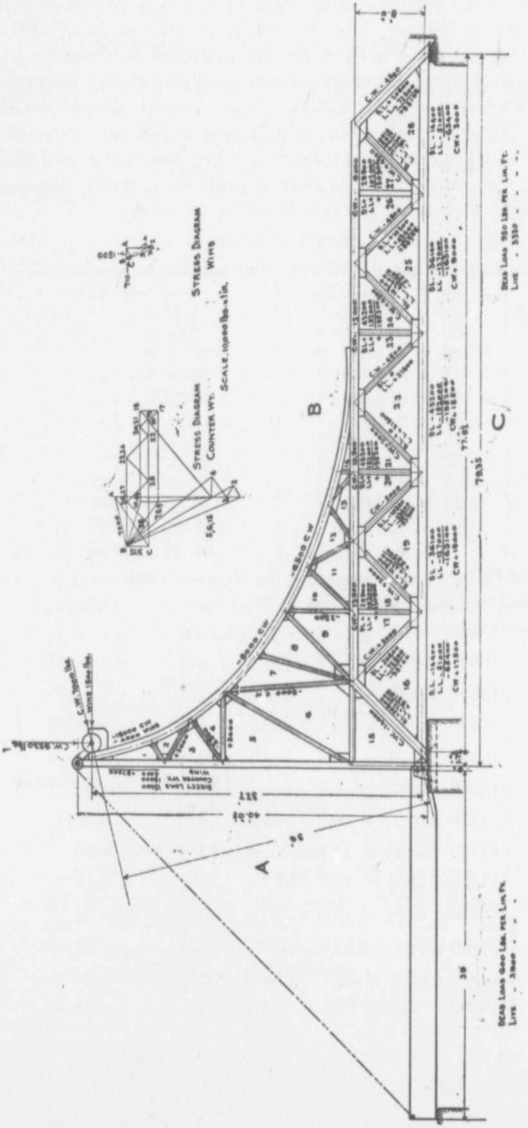

A
B
C
Stress Diagram
Counter Wt.
Stress Diagram
Wind
Scale, 10000 lbs. = 1 in.
C.W. 7000 lbs.
Wind 1800 lbs.
C.W. 8530 lbs.
Direct Load 15600
Counter Wt. 13600
Wind
-18000 C.W
-8000 C.W
-8500 C.W
40.0
35.0
77.81
79.35
36
Dead Load 950 Lbs. per Lin. Ft.
Live " 3330 " " "
Dead Load 600 Lbs. per Lin. Ft.
Live " 3800 " " "

Fig. 3.

In the above equations it is assumed that, at any period during the process of opening, the centre of gravity of chain on side of tower adjacent to lift span rises the same amount as that of lift span; whereas, on the other side of tower that the centre of gravity of chain falls only one-half that of counter-weight. Position 12 determines the amount of counter-weight.

The next operation was to take a piece of very fine wire to represent the chain. A pin was stuck into the point of attachment to girder, to which one end of the wire was made fast. The wire was then passed over a sheave at the top of the tower, and the other end made fast to a pin stuck in the centre of counter-weight roller, thus obtaining length of chain. Then, with a pencil point in loop, at counter-weight end of wire, curves were described intersecting horizontal lines which were determined by the above ordinates. These intersections located the centre of counter-weight rollers for the twelve different positions of lift span.

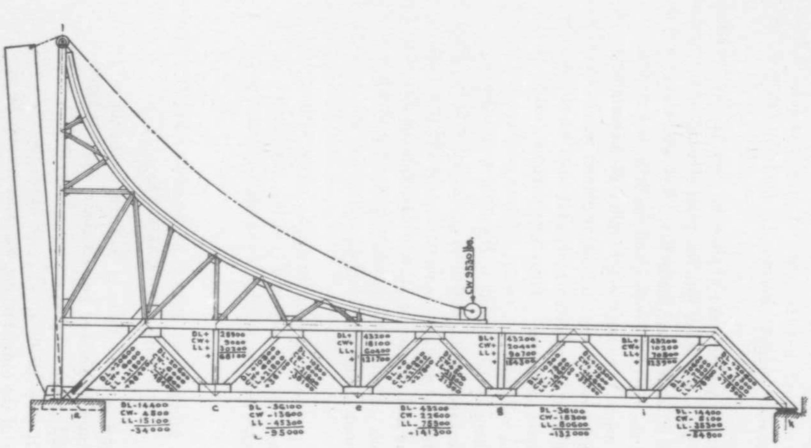
It might be thought that the sag in the chain would shorten it so as materially to affect the results, but this sag was found to be only about four-tenths of a foot for position 11, shortening the effective length of the chain about one inch; and for all previous positions this shortening was inappreciable. Position 12, however, gave a sag of 4.5 feet. This shortened the chain about nine inches, and was of course taken into account.

The various positions of counter weight roller without correction for chain, as well as the corrected position, are shewn in Fig. 2; thus it will be seen that the weight of the chain affects the curve very considerably.

STRESSES IN TOWER AND FIXED SPAN FROM COUNTER-WEIGHT AND WIND PRESSURE.

When the draw is closed there is a force at the top of tower, the resultant of counter-weight and pull on chain, equal to 7,000 lbs. This force was treated graphically as shewn in Fig. 3, first having found the reaction B C = $7000 \times \frac{36}{79.33} = 3175$ lbs. To simplify the operation, some of the tower bracing was considered to be omitted. In addition to the above, stresses from a wind pressure of 50 lbs. per square foot on tower were also determined.

The stresses in the main truss members, as found above, were generally less than those caused by dead load, and of opposite kind; therefore they were only taken into consideration when they exceeded the



DEAD LOAD 950 LBS. PER LIN. FT.
LIVE " 3330 " " " ", FROM g TO k ONLY.

Fig. 4.

latter. The maximum stresses, draw closed, are shewn in Fig. 3. When the draw is open, the counter-weight rests on top cord of fixed span a little past the centre, and the train load cannot proceed beyond this point. The maximum stresses under these conditions are shewn in Fig. 4, and, as may be seen, are considerably less than stresses for draw closed, except in one of the centre web members.

COUNTER-WEIGHT.

The counter-weight is carried in a box, the sides of which are made of 20″ I-beams; the ends are made of plates 1¼″ thick; and the bottom of ½″ plates stiffened by angles. The box is suspended by a shaft 6 inches in diameter, which passes through its end plates. At each end of shaft is a cast iron roller 24 inches in diameter. These rollers travel on the curved tracks, which are made of 10″ channels, 9″ back to back, and latticed on underside. The total amount of counter-weight, including box rollers, etc., is 19,060 lbs.

OPERATING MACHINERY.

The bridge is opened and closed by means of a crank at one side of tower, the power being transmitted by shafting and gearing to its top, and there turning a horizontal shaft. On this shaft are keyed two 15-inch chain wheels into which engage the chains connecting counter-weight with end of lift span.

TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE I

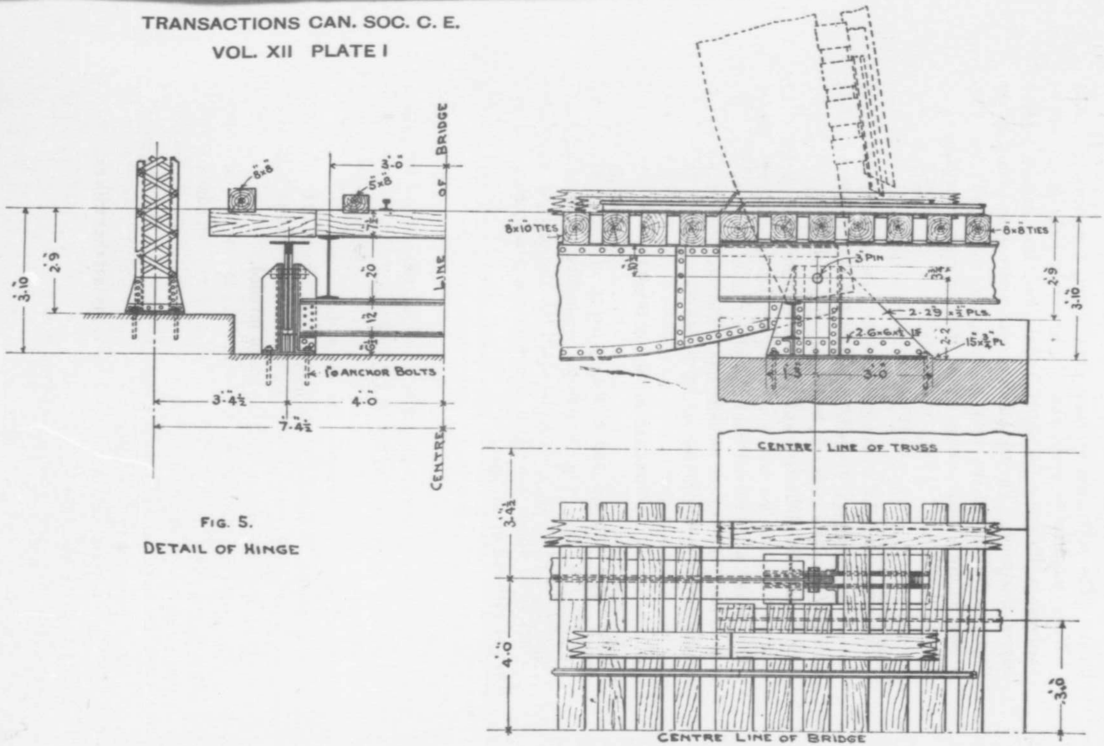


FIG. 5.
DETAIL OF HINGE

Thursday, 10th March.

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

Paper No. 127.

ELECTRICAL POWER TRANSMISSIONS.

By R. A. Ross, E.E., M.Can.Soc.C.E.

The subject of electric power transmissions over long distances has for the last few years been the field in which the most prominent electrical engineers have found a scope for their energies, and the advance in consequence has been most marked. So much so that, while four years ago there was not a power scheme of any magnitude, at the present they are numbered by the score, and are of such size as to utilize an immense amount of power formerly unavailable.

A noteworthy point in modern plants is the similarity of the methods in use, especially in America, which is always more given to standardization than are European countries. The several types of alternating transmission have practically crystallized into two standard forms remarkably alike in detail and equally applicable to most cases.

The controversies over the relative merits of direct and alternating current for transmission purposes have been settled, and the latter having come out victorious is now carrying the war into the hitherto undisputed territory of the former, namely, the application to general motor purposes, and the results are not doubtful.

With the application of alternating current motors to traction purposes, which appears to be not far distant, the last territory held exclusively by the direct current will have been invaded.

The reason for this state of things is not far to seek, as the alternating system which formerly was applicable only to incandescent lighting has recently made such strides as to prove itself more generally useful for all purposes of transmission and for most cases of distribution than is the direct current system.

This triumph of the alternating is due to the fact that with extremely simple and durable apparatus, the power is so readily transformed into that form which meets the requirements of most cases.

The efficiency and durability of the newer types of apparatus is such as to leave but scant room for improvement, and it appears probable that unless some fundamental discovery is made which will render present types entirely obsolete, these forms will persist for some time to come.

Accompanying this standardization of apparatus has come a remarkable decrease in first cost and maintenance charges affecting the interest and depreciation accounts correspondingly, and resulting in decreased cost of power to the consumer.

In consequence we may expect to see the field of steam generation for many purposes invaded by the simpler, cheaper and more cleanly electric power.

If we may judge by present indications, the next phase of the problem to be attacked will be the adaptation for railway purposes of power from large water falls. This only awaits the development of a satisfactory motor for alternating traction purposes, and, from the reports of several recent installations in Europe and the statements of prominent traction engineers in this country, the day of the alternating railway motor for use on the longer railways is not far distant.

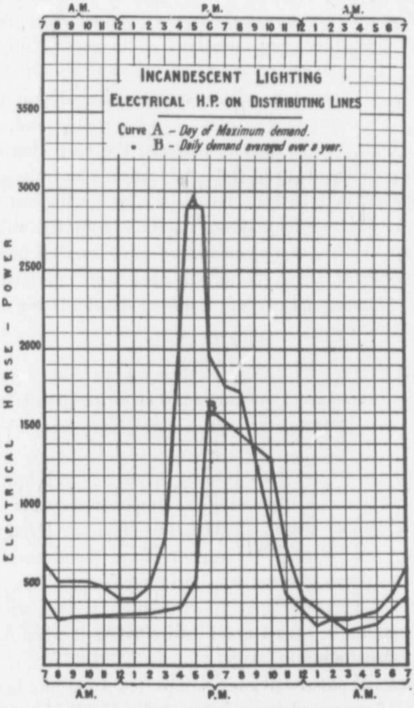
To illustrate the methods adopted in transmission work, a few of the larger plants in operation or building are given below.

	System.	Distance.	Voltage.	Horse-power.	
Brescia,	Direct cur.	12	15,000	700	
Pomona,	Single phase.	29	10,000	800	
Fresno,	Three phase.	35	11,000	1,400	
Lauffen,	“ “	100	30,000	300	Experimental
Portland,	“ “	12	6,000	5,000	
Ogden,	“ “	38	16,000	3 000	
Three Rivers,	Two phase.	17	12,000	600	
Kootenay,	Three phase.		20,000	2,000	Building
Hamilton, Ont.	Two phase.	38	20,000	3,000	“
Lachine,	Three phase.	5	4,400	20,000	
Chambly,	Two phase.	16	12,500	20,000	Building

With one exception these are all alternating plants, and it will be noticed that Canada is well to the fore, as might be expected from the almost unlimited powers available. Montreal stands at the head of the world so far as transmitted power is concerned, and it appears probable that the two magnificent schemes at present under construction will find an ample market in the city and vicinity.

Montreal's demands, covering as they do the whole field of consumption of power for street railway, incandescent and arc lighting, and motor power, offer a good example for illustrative purposes, and it has been deemed advisable to give point to the discussion to follow by reference to the demands existing here at the present time, without reference to future necessities, as these will no doubt be much of the same kind.

With this end in view, the following curves have been drawn, showing the demands for all classes of power at the present time for the twenty-four hours.



The higher curve in each case shows the maximum demand during the year, and the lower the average load at each hour of the day for the year.

From these demands the transmission scheme will be figured, but necessarily in a general way for illustrative purposes.

The problem consists in laying down the power in the city to suit the demands in the most complete way as regards economy, efficiency and suitability.

As these demands affect the transmission by their nature, as well as by their amount, they must be considered briefly before taking up the transmission proper.

INCANDESCENT LIGHTING.

The demand curves shown have been figured from the actual curves of one of the present stations in the city, with an allowance for the loads of the other operating companies; in all to cover 100,000 lights wired up.

To meet this demand it will be readily granted that direct current is unsuitable, owing to the distances to be covered, and alternating currents of single, two or three phase are the only alternative, any of these being readily obtained from the transmission voltage by means of static transformers to feed the distribution at a voltage of say 2,000, which is considered safe for city work. This potential will of course be again reduced before entering customers' premises, thus involving two sets of transformers. This system will also cover interior lighting by alternating arc lamps, and perhaps a few small alternating motors.

ARC LIGHTING.

The demand curves for the arc lighting have been figured on the supposition that there are 2,000 arc lamps on series circuits in the city, lighted from dusk to dawn, the curves in this case being elevated into straight lines.

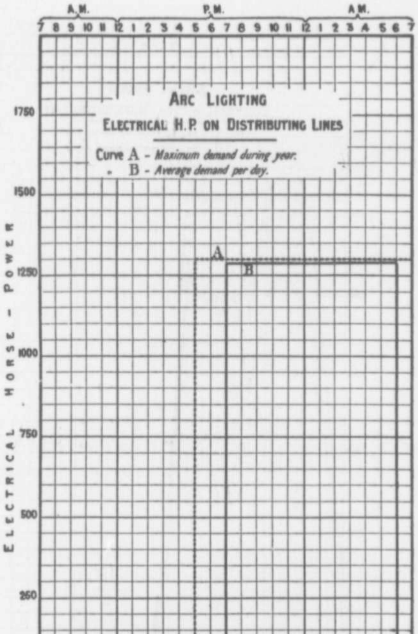
For this service several plans present themselves as below.

(1) By rectifying the alternating transmission currents into direct through the agency of rectifiers, which are simply revolving commutators driven by small synchronous motors from the transmission line, and using this current in the present series arc lamp. This system has been in use for a short time in several European staions, with varying results. It appears to have a great future before it when it has come through the present doubtful stage.

(2) By means of alternating arc lamps fed from the incandescent circuits. This system, while perfectly applicable for interior lighting where each unit is treated as an incandescent lamp and turned on or off at will, is not so suitable for street lighting, as it does not lend itself to ready control from the station. Further, as the light distribution

of alternating current lamps is inferior per watt of consumption to that of direct, it becomes more expensive in operation.

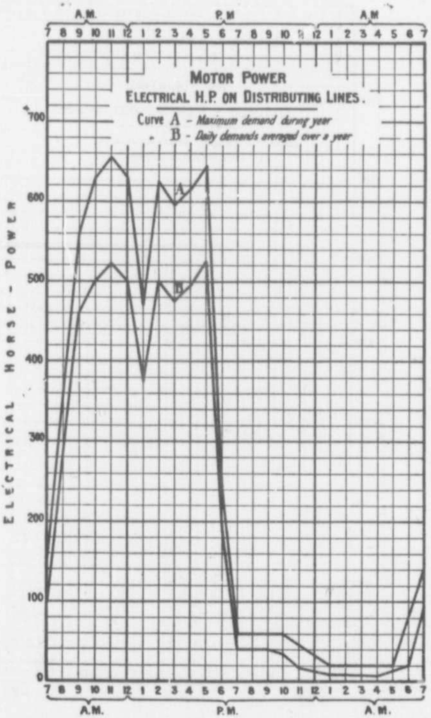
(3) The series arc system as at present used, with motors instead of engines to drive the dynamos, while necessitating more apparatus than either of the others, is more simple and controllable in operation, and will be accepted for illustration. The number of units necessary to cover the 2,000 lights will be 16 if of 125 lights each, which is about as high as is available per machine. If these were coupled in pairs to 200 H. P. motors, the units would be 8, and the addition of a spare would make a total of nine, which should be ample for present demands.



MOTOR POWER.

Either alternating or direct current motors are suitable for general work, but, where variable speeds are necessary as for elevator purposes the direct is at the present time the only one available. The cost of the former is also higher at the present time. The advantages of the alternating motor distribution are, less cost of circuits, greater simplicity of apparatus, and the ability to reach outlying demands at small cost, and that it involves no special apparatus in the distributing station other than the necessary lowering transformers.

As the objections to the alternating (on the score of price and unsuitability where speed regulation is required) appear to be within

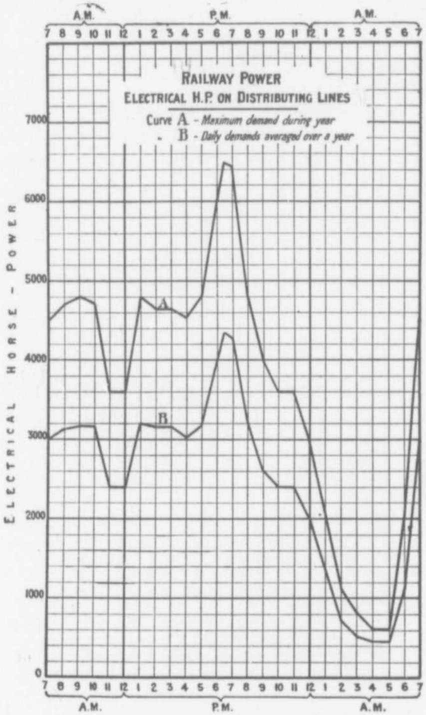


reach of correction in the near future, that method will be adopted for this case.

The demand curves are based upon the actual load curves of one of the present stations, with allowance for the other operating companies' loads. In all it represents about 1,100 H. P. of motors installed, to be driven from a two or three phase motor circuit, fed directly through reducing transformers from the transmission line, at a voltage of say 2,000, and again reduced by individual transformers at the motors.

RAILWAY POWER.

These curves are the actual records for the past year for the railway company's plant. As at the present time only direct current motors



are applicable to this purpose, means must be adopted for transforming the alternating to direct current for the trolley circuit. This is easily accomplished by means of rotary transformers with small loss.

These rotaries are practically direct current generators, with collector rings through which the alternating current flows to the windings driving the machine as a motor, while from the commutator connected to the same windings the direct current, which has been commutated from the alternating, flows to the trolley line.

TOTAL DEMANDS.

The load for all classes of demands is given to the last curve, which is formed from the others, and shows the period of the greatest station activity to be about six p. m.

It is evident that apparatus must be installed to meet this maximum demand, while the average output could be met by a much smaller plant.

The interest and depreciation charges on plant, which forms such a considerable percentage of the cost of the output, is a constant no matter what that output may be, so that, when it is possible to fill up the hollows in the curve by the sale of additional power during periods of light load, which shall not be operative during the period of heavy demand, the cost of this addition is only that of additional coal in steam stations, and in water powers is nothing, and for this reason may be disposed of at low rates.

The table below illustrates the ratio of plant installed to the output column, one giving the average output per hour figured from the curves for a year, and column two the plant installed to meet maximum demands, while the third shows the ratio between them.

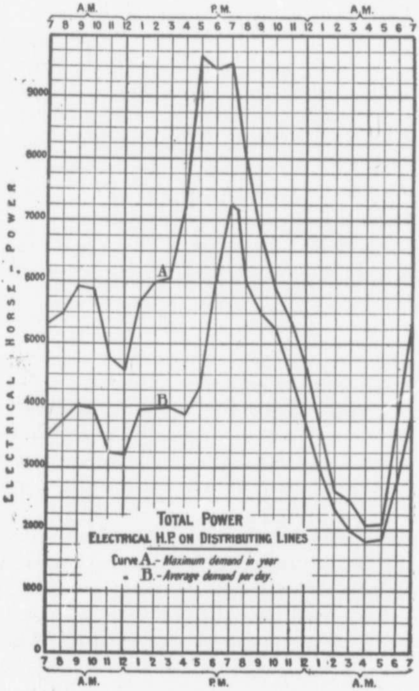
	Incandescent.	Arc.	Motor Power.	Street Ry.	Total.
Average E. H. P., per hour..........	604	650	218	2,430	3,902
Max. E. H. P. required..............	2,925	1,300	656	6,450	11,331
Ratio output to capacity............	20.6%	50%	33.3%	37.7%	34.4%

It will be seen that the output is only about one third of that possible with the plant which must be installed. To dispose of the remaining two-thirds is the ambition of every station manager.

It is just here that the storage battery finds its best field in steam station, but in waterpower plants it has no place unless the plant be loaded to its full capacity, and an increase is desired which the water available will not admit of.

As an illustration of what is to be expected, the above case is useful, but so simple a case seldom occurs in practice, as instead of having the curves of actual demand the engineer usually has to draw upon his educated imagination for these, guided by his experience with similar plants.

Having determined the amount of power required for the various demands, and fixed upon the best method of distribution to meet those demands, the problem of the transmission may be taken up intelligently point by point.



GENERAL SYSTEM.

Considering the direct current as out of the question for large transmission purposes, three different alternating systems present themselves, namely, single two and three phase. The first we are thoroughly familiar with, owing to its use in the purely lighting stations where it is entirely satisfactory, but when it is necessary to distribute power for motor purposes it fails owing to the fact chiefly that single phase motors while practicable are not found suitable in operation as they are not readily started from rest.

The question therefore hinges upon the point of relative superiority of the two and three phase systems.

So far as apparatus is concerned, these two systems are about on a par for all practical purposes when designed for the same conditions of opera tion, but for the line the three phase has the best of the argument, the transmission copper being reduced 25 p. c. This point of superiority, however, looses much of its effect, for it is possible to use two phase apparatus at both ends of the line, and by means of suitable transformers change from two to three phase for the transmission, in which case the capacity of the transformers used must be slightly increased, as some of the copper is partially inactive when coupled up for change of phase.

For this reason the three phase will be adopted in the case under consideration as being probably the cheaper in first cost and equal in efficiency.

VOLTAGE OF TRANSMISSION.

As the copper in the circuit varies inversely as the square of the voltage for the same loss and distance, the advantage of high voltage becomes apparent. Conversely with the same distance and copper, the loss in line may be reduced in proportion to the square of the proportionate increase, or the distance may be increased directly as the increase, and any combination of these may be attained by simply raising the voltage.

On the other hand, the apparatus installed must be designed to resist the effects of the increase on the insulation, and greater precautions are necessary to maintain it in operative condition. The cost will also be somewhat greater where especially high voltages are used.

The highest voltage in practical operation at the present time so far as I am aware is at Ogden, Utah, where 16,000 is used with raising transformers.

The highest generated directly on the machine without the aid of transformers is 12,000 at the Chambly plant. There are several now building however, which contemplate a line voltage of 20,000, and we may expect to see this figure increased from time to time as methods of insulation improve.

It is well to remember that the apparatus will be called upon to resist much more than the normal pressure, owing to conditions of load to opening of circuits under load, and to lightning, so that a large factor of safety is essential where high voltage is desired.

PERIODICITY.

In former years a high periodicity of 120 to 133 per second was general, being suitable for lighting purposes, and by reason of the high period, transformer costs were low. With the advent of the alternating motor and of long transmission lines the periodicity dropped to 60, which is now the standard in America. In Europe, however, the tendency is to go even lower, and each maker of apparatus appears to have his own standard.

The lowest possible where incandescent lighting is to be done is 25, for at this alternation the fluctuations are just visible in the light.

The effects of lowering the periodicity are to decrease induction effects, which are always objectionable, simplify and cheapen the motor equipment and to increase somewhat the cost of transformers.

It would appear that for general transmission work, which involves the use of much power for motors, that a lower alternation would have met the case speeds better, but as 60 periods has been universally adopted on this continent it will probably be maintained for some time.

REGULATION.

Owing to the copper losses and induction effects at various loads on the system from the generator shaft to the lamps or motors, the generator voltage must be raised as the load increases. It is very desirable that this increase be kept as low as possible, so that a continual adjustment of the voltage which would render the lights unsteady is unnecessary.

To this end the copper losses, and especially the induction effects, must be kept within bounds. The first involves only the cost of the copper, the latter depends upon the nature of the demands and the relative positions of the copper conductors. The induction of lines and apparatus has an effect somewhat similar to that of the inertia of water in long pipes, and causes the current to lag behind the voltage, necessitating a large output of volt-amperes to produce watts, and, as lines and apparatus must be of sufficient capacity to carry the useless increase of current and the generator to allow for the useless additional volts, an increased capacity of plant is necessary.

These induction effects may have a larger influence on the regulation than the necessary copper losses, and should be carefully watched.

It is well to bear in mind, however, that the increased volt-ampere readings do not represent additional power consumption, as would be the case in direct current, as they have to be multiplied by the cosine of the angle of lag (which is always less than unity) to give the true power.

Poor regulation therefore cuts down the capacity of the plant, and renders it difficult to maintain the voltage constant under varying loads.

Having thus sketched the main points, which affect the general working of the plants, the apparatus may be taken up in detail.

DISTRIBUTING STATION.

The reducing transformers necessary for lowering the line voltage to that suitable for the incandescent distribution, arc light motors, and rotary transformers for railway service, must be of the highest grade to stand the high line potential, as well as the increases of voltage to which they may be subjected under certain conditions. Of course the efficiency should be of the highest and the regulation good. As the heat developed is great, an air blast or circulation of cool oil is provided.

The rotary transformers which form such a large part of the load in this case partake both of the nature of alternating motors and of direct current generators. As an alternating current motor of synchronous type they must be self starting, and in consequence are of either two or three phase.

As a generator they must, at the speed established by the synchronous motor part, give the necessary direct current at the proper voltage for the trolley line. as both the motor action and the voltage generation take place in the one set of armature windings, and as the fields are common to both there is a certain ratio of impressed alternating voltage to direct voltage at the commutator, which is constant, and any change of field strength alters the direct current voltage only indirectly by causing a leading or lagging current in the transmission lines, thus giving more or less volts to the alternating side of the machine.

Owing to this effect of over or under excitation of the rotary upon the line currents, causing them to lead or lag behind the voltage, this apparatus may be arranged to keep the current and voltage of the line in phase, thus doing away with the troubles from lagging currents which so unfavourably affect the system in the matter of regulation. On the other hand, where there is no necessity for close regulation, the line induction is encouraged, and is found useful in overcompounding the direct current side of the rotary automatically, thus giving the rise of voltage with load so desirable in railway work.

In the present case, if the lighting and railway loads be carried upon separate lines, the latter arrangement is desirable, as the lighting will have good regulation while the railway service will over compound automatically.

The total load for railway needs being 6,450 E. H. P., and the average from 7 a. m. to 9 p. m. being 3,000 E. H. P., seven units of 1,000 E. H. P. should cover the demands, and the machines in operation should have a good load factor.

For the arc light demands, as before stated, eight units would be sufficient. The motors may be either synchronous or induction, the former preferably as they may be useful in assisting the regulation of the incandescent lighting service by proper excitation, as their loads do not fluctuate.

This apparatus, with the necessary switchboard and instruments for the high potential receiving and lower potential distributing circuits, completes the distributing station equipment.

TRANSMISSION LINE.

The line is usually the weakest link in the chain, being exposed to the weather, and not under that careful supervision which is given to the rest of the plant.

The pole line as a supporting structure must of course be of the solidest to stand the strains imposed not only by the weight of copper, but in these latitudes by a great weight of ice also, which if assisted by a gale will try the best work to the utmost.

Poles of cedar, pine, or chestnut of very heavy section are necessary for this work. They should be set in concrete or broken stone and heavily guyed on curves, or in certain positions double poles with heavy cross arms between should be used.

The insulators for high potential work are universally made of porcelain, as that material weathers better than glass and is not so hygroscopic.

This porcelain should be so thoroughly vitrified as to exhibit a fracture like glass when broken, otherwise it will absorb moisture and break down.

To minimize surface leakage, which, if severe, may burn off the pins, the surface over which it has to take place is made as long and of as small surface as possible. To assist in reducing this leakage, insulators with oil in grooves, over the surface of which the leakage must take place, have been tried and found to work well when the oil surface is clean, but in operation dirt accumulates and troubles ensue so that the plain porcelain insulator of large insulating surface and high resistance to piercing is now the standard.

The copper circuits are of bare copper, as weather-proof insulation at high voltages is perfectly useless. The cross section of the copper being of course so proportioned as to give the loss determined upon as suitable for the conditions existing. These conditions depend upon the cost of the power, the amount available and the demands. The loss may be reduced to any extent by the use of more copper, but unless there is a demand for the power saved, which will pay interest and depreciation on the additional cost of circuits, no economy results.

On the other hand, the copper may be reduced and the losses increased, but only within the bounds set by the demands of good regulation.

In practice a loss of 15 per cent. is seldom exceeded, and a very common allowance is from 7 per cent. to 10 per cent.

Several effects manifest themselves in alternating lines which do not exist on those of direct current systems, and they deserve the closest attention in planning the system. While the actual losses in direct and alternating work are about the same under the same conditions, the drop in voltage in the former is a measure of that loss, while in the latter it may be no indication.

In fact, it is possible to so arrange the circuits in some cases of alternating work as to have a greater voltage at the end of the circuit than is generated at the station, but this does not indicate that the line generates power of itself; it simply means that, while the self-induction and capacity of the line and load raises the voltage, much as a water ram in a pipe line raises the pressure, it at the same time throws the current out of phase with that voltage, and the real power is that obtained by the multiplication of the apparent volt-amperes by the cosine of the angle of lag introduced. It is therefore only possible to read the power indications on a watt-meter, which instrument takes account of this angle while the volt and ampere meter readings which are used to determine direct current power are not reliable for the alternating.

This increase of voltage may under certain conditions become so serious as to endanger the insulation of line and apparatus.

In most cases it is advisable to reduce the induction as much as possible, and to effect this the wires on opposite sides of the circuit are strung as closely together as is consistent with safety, and several wires of equivalent cross section used rather than a smaller number of larger area.

To do away with unbalancing of the phases of the system, the circuits should be strung symmetrically, which is effected in the case of two phase lines by placing the going and returning wires of each phase on the opposite ends of the diagonal of a square, and in three phase ines by stringing the three conductors at the corners of an equilateral triangle.

As lightning may cause trouble, not only by direct stroke, but by the accumulation of static electricity upon the lines, means must be provided for getting rid of it safely. To this end, guard lines of barbed wire are strung above the circuits, and these are grounded at frequent intervals.

GENERATING PLANT.

The apparatus in this part of the plant consists of the water wheels, generator, raising transformers and switchboard apparatus.

Regarding the latter two, the same remarks apply as were made regarding similar apparatus in the distributing station.

As to the generators, their size is usually limited by the power of the water wheel units, and their speed by the wheel speed unless gearing be used.

The usual method of attacking the question with direct connected units is to arrange for as powerful wheels as is possible consistent with having the proper size units to handle the load properly, and designing the generators to suit the wheels as regards size and speed.

Vertical turbines with the rotating part of the generator revolving in a horizontal plane are usual, but, in several recent plants, horizontal turbines are used direct connected to the generators, which in that case are below the crest of the dam and above the tail-race by an amount determined by the height of the draft tube. The first system introduces footstep bearings, which are always more or less objectionable, but removes the delicate armature windings from chance of damage by water. The second places the generator at the mercy of water-tight bulkheads and stuffing-boxes.

As to the voltage to be generated upon the machines, if raising transformers are used, this is of little consequence unless from a machine designer's point of view, as the transformers will have equal efficiency at any ratio of transformation.

Where the transmission voltage is not dangerously high, it is of course preferable to do away with these transformers, and generate directly on the machine.

In deciding this point it must be kept in mind that the failure of a transformer through the breaking down of insulation is a much less serious matter than that of a generator, which is less likely to occur when that apparatus is of low voltage. Owing, however, to improved types of generators, we may expect to see raising transformers dispensed with in many cases where they would have been deemed indispensable with older types.

In specifications drawn up for the generating apparatus, the following points are strongly insisted upon:—

(1) That the heating of any part shall not exceed a certain specified temperature after a certain length of run at full load and an additional time at a certain specified overload.

(2) That the efficiency at full load, three quarters, one half, and one quarter loads, shall be guaranteed by the tenderer and proved by test.

(3) That the regulation of the generator shall be within a certain per centage at full non-inductive load.

(4) That the insulation of any part of the machine shall not break down under a specified voltage which is high enough to allow of a good factor of safety over the normal pressure.

Although it is impossible to specify limits for these requirements which will suit every case, it may be said generally that the allowable increase of temperatures for large generators ranges from thirty to forty degrees centigrade. The full load efficiency from ninety-four to ninety six per cent. The regulation depends upon whether the machine is compound wound or not. In the former case the regulation may be anything for which the compounding is set, and in the latter from three to ten per cent.

The test voltage applied ranges from three to ten times the operative, the former factor for high voltage machines, the latter for lower voltages.

The modern generator being either of the inductor, or revolving field type, in which the high potential armature windings are stationary, lends itself to high voltage generation, as the insulation spaces may be increased largely without rendering the machines unwieldy, for the reason that the armature wires are distributed over the outside ring where space is more abundant, and the vibration of running, which abrades, and finally breaks down the insulation on the older revolving armature types is largely absent in the newer machines.

Having sketched in a general way the points to be considered and determined upon the general features of the transmission, we may take up the figuring of lines, efficiencies and horse-powers to be generated.

To do this, certain assumptions must be made as to the allowable efficiencies of the line and apparatus at various loads. This has been done in the tables below. As regards the apparatus, commercial efficiencies have been assumed, which are usual for this class of work, and will be guaranteed by the manufacturers. The line efficiencies are what would be usually allowed, considering the copper as designed for those efficiencies at maximum demand.

	Loads.			
Transmission (generator to sub-station).	100%	75%	50%	25%
Generators.	96	95	94	90
Line.	90	92.5	95	97.5
Raising and lowering transformers.	96	95	94	90
Total efficiency of transmission.	83	83	84	79
Incandescent (distribution to lamps).				
Primary distribution at 2,000 volts.	96	97	98	99
Large reducing transformers.	97	97.5	97	95
Secondary distribution to lamps.	97	98	98.5	99
Total efficiency of distribution.	91	92.5	93.5	93
Arc Lighting (distribution to lamps).				
Efficiency of motor.	92			
Efficiency of arc machine.	86			
Efficiency of line distribution to lamps.	93			
Total efficiency of distribution.	72.6			
Power Circuit (distribution to motors).				
Efficiency of lines.	90	92.5	95	97.5
Efficiency of transformers.	96	95	94	92
Total efficiency of distribution.	86.4	88	87	89.7

Railway Power (distribution to motors).				
Efficiency of rotary transformers.	96	96	95	90
Efficiency of distributing lines to motors.	80	85	90	95
Total efficiency of distribution.	76.8	81.6	85.5	85.5

From these efficiencies of line and apparatus the whole power necessary for all the maximum demands may be transmitted at an efficiency of 80 p. c. from the generator shaft to the distributing lines in the city.

The total efficiency at full load from the generator shaft to the lamps, railway and stationary motors, is 68 p. c., and under the average running conditions would be not less than 70 p. c.

These figures illustrate the remarkable efficiency of electrical transmission even on such a mixed and varying load. It will be noticed that at varying loads the efficiencies are not very different, owing to the fact that, while the apparatus falls off, the line increases in efficiency, thus maintaining a balance.

In fact, under light loads the efficiency is higher than under heavy, and is actually higher than given in the totals, because the tables consider the whole plant as operating at fractional load, while in actual running the apparatus would be kept at full load by shutting down units as the load dropped, thus raising the efficiency. The figure of 68 p. c. therefore may be safely taken as the lowest to be met with during the course of the year, and as it holds only for the peak of the load will not affect the average efficiency materially.

The date assumed or calculated for the transmission is given below. The power is that necessary at the distributing lines to take care of the maximum demands as shown on the curve of total power. The power factor is assumed to be 100 p. c. for the class of load considered, loss in transformers 4 p. c., in line 10 p. c., which is not too high for the peak of the load, as this is what the line is designed for.

Electrical H. P. required at end of transmission line	11946
Voltage of transmission at end of transmission line	15000
Periodicity or complete cycles per second	60
Distance transmitted in miles	10
Power factor assumed p. c.	100
Loss in transformers p. c.	4
Loss in line p. c.	10

System of transmission—Three phase.

Figuring the transmission on the above assumptions the actual electrical horse-power at the generator terminals is 13623, while the apparent horse-power as read by volts and amperes is 13862. In other words, while the real loss in the transmission is 14 p. c. of the power required at the end of the line, the apparent loss is 16 p. c. This shows a high power factor for the whole system, and is obtained by a non-inductive load on a line well subdivided, and with the wires properly placed.

To illustrate the effect of an inductive load upon the amount of apparatus necessary, another line with a load power factor of 90 p. c. has been figured, the other conditions remaining the same as before. This, while having the same losses as in the first case, requires 17327 apparent horse-power at the generator, necessitating an increase of generating apparatus of 25 p. c., or, in case the plant were installed, it would cut down its capacity 20 p. c., and would decrease that of the distributing apparatus 10 p. c.

Were it not for these induction effects the problem would be as simple as in the case of direct current work, but as it is, they affect the matter to a very great degree, and require the most careful consideration to arrive at even a fair approximation to actual results.

Considering the fact that this power is laid down from the wheels with such simple machinery with but at most one revolving part, and therefore requiring no attention when once started, it is not surprising that electricity should have monopolized the field. The efforts at the present time to transmit to longer distances will be successful in proportion as the knowledge of insulating methods increase ; and, from the rapidity with which the present voltages have been attained from the lower formerly prevailing, it is not difficult to foresee the time when this country which is so rich in waterpower will be literally covered with power lines for all purposes. The possibilities in the way of covering an increased territory by raising the voltage may be illustrated by the plant considered above, where, with 15000 volt and 14 p. c. loss, the power covers a radius of ten miles in all directions. If the voltage were doubled, and the same loss allowed, the radius would be 40 miles, and the territory covered would be sixteen times as great. In other words the area served will vary as the fourth power of the ratio of increase of voltage. The question of the advisability of transmitting from a distance the natural power available in preference to generation at the centre of distribution by steam power requires the most careful attention. The cost of the power laid down on the consumer's premises is made up of two items, namely, fixed charges and operating expenses. The first includes interest and depreciation on the plant, the second coal and supplies, attendance, etc. The saving by the adoption of waterpower is in coal and supplies, and perhaps a small part of the labour, provided the plant cost is the same. Should, however, the increase in the cost of the transmission scheme exceed that of the steam sufficiently to eat up the saving in interest and depreciation on the increased cost of plant, there is nothing to be said in favour of the transmission.

If there is no cheapening of cost, the steam plant has the advantage of the greater reliability in lines and apparatus, as no high voltages need be used, and there is no risk of troubles with waterpower during the winter such as exist to a greater or less extent in this climate.

In many cases, however, where the waterpower improvement can be made with small outlay per horse-power rendered available, the gain may be large. It is not so large, however, as seems to be the idea of the public which considers a waterpower as capable of producing power for nothing, entirely ignoring the capitalization necessary for development.

The transmission and utilization of electric power has advanced beyond the experimental stage, and is not now surrounded with that mystery which used to obscure the financial facts, and the more it is considered as a commercial article depending upon the laws of supply and demand for its existence, the more will its usefulness become apparent to the consumer and its financial security appeal to the capitalist.

Thursday, 24th March.

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

G. H. Duggan and J. M. McCarthy having been appointed scrutineers of the ballot, declared the following elected:

Member.

Alexander Mitchell.

Associate Members.

Charles Albert Bigger, Joseph Wilbrod Fraser,
Lewis Skaife.

Students.

George Alphonse Bachaud,
Frank Lorne Campbell Bond,
Raoul de B. Corriveau,
Thomas Tweedie Irving,
Homer Morton Jaquays,
James Hector Parent,
Henri D. Parizeau,
Frank Townsend St. George,
Henry Luxmore St. George,
Richard T. Gough,
Louis Frederick Gagnon.

Associates.

Henry Frederic Duck, Daniel Nicoll Armstrong.

Transferred from class of Student to class of Associate Member:

Charles Cuthbert Worsfold.

Paper No. 128.

METERS.

By W. C. Brough, M.Can.Soc.C.E.

A question which so often agitates the minds of engineers and other officials of municipalities is how to supply the corporation with a sufficient quantity of pure water for domestic, manufacturing and fire protection purposes; and after this supply is procured, how to maintain and increase it in sufficient quantities as the population, and consequently the demand, increases.

As a general rule this is not a question of so much importance in small towns as in cities, where excessive expense in pumping, and perhaps filtration as well as wastefulness have to be considered.

There are three means usually resorted to, to prevent waste, viz.: stringent by-laws, house to house inspection, and the use of meters. It is the latter means to which special reference will be made.

I consider I am justified in saying that if people were more honest, meters would be more widely used, for honest people have no objection to pay for that which they receive, and people who object to meters are those who wish to take advantage of receiving more than they pay for.

From my experience, people who receive their water through meters pay less in proportion than those who do not, that is if the latter only use the amount they are supposed to, and which with moderate carefulness and honesty they should.

But this carefulness and honesty would prevent immoderate use, the allowance of leaky plumbing, and the inexcusable practice of allowing taps to run at night in winter to prevent freezing, instead of turning the water off at the cellar tap.

It was only a short time ago that I heard a person complaining of the water bill, saying, " I cannot understand why we have to pay for water, as it is one of nature's gifts." In response I remarked that although it was a gift of nature, and that we all had the privilege of going to the lake (or other source of supply) and helping ourselves, if we wanted to save the trouble of bringing back with us all that we required, and instead have it delivered in our houses, we should be satisfied to pay for the delivery.

The majority of consumers know nothing about foot-pound duty, nor do they seem able to grasp the idea that each gallon of water delivered means a certain consumption of fuel, labour and wear and tear of plant; that the plant originally cost a large sum of money and is continually requiring additions and improvements, as well as responsible management and watchfulness.

All these necessitate a revenue for maintenance which is a sufficient reason why a charge should be made for the delivery of nature's gift. And in order to reduce the expenses and distribute the charges evenly amongst the population I advocate the use of meters.

What I wish to emphasize is that each consumer should pay his equal and just share of the revenue, viz., that an equal amount be paid by each taker for each gallon used or wasted, and that the just should not suffer for the unjust, or that the former will have to pay extra in proportion to compensate for the delinquencies of the latter.

Some of the arguments against the adoption of meters are, inefficiency, inaccuracy and the expenses involved in keeping them.

First, referring to the last objection, their cost is comparatively trivial, and would be more than compensated for by saving in waste and inspection. For instance, say a $\frac{5}{8}$ inch meter, which is large enough for an ordinary household, costs about $16.00, and with proper care lasts twenty years. The interest and sinking fund for twenty years at 5 per cent. equals less than $1.60 per year, or making full allowance for repairs fifteen cents per month.

The management may supply the meter and charge this rental, or the consumer purchase the meter himself.

As to inefficiency and inaccuracy, I will give a schedule of results of tests made by me, refuting these charges, provided a proper meter be chosen for service and one that will fulfil the following requirements.

1. It should register with a suitable degree of accuracy the quantity of water delivered at every rate of flow from that of the maximum capacity of the service pipe to a rate so small as to discourage theft. The admissible error is usually placed at from 2 to 5 per cent.

2. This degree of accuracy should be permanent, i. e., the meter should not be subject to any change seriously affecting its accuracy by wear; by slight deposit of sediment. Sudden opening and closing of the house faucets should not lead to any considerable error in registration.

3. The introduction of the meter should not materially affect the delivery of the service pipe, i. e., should cause no serious loss of effective head or pressure.

4. The price should be small and the necessary repairs inexpensive. Most prominent amongst the classes of meters used are the oscillating piston, the rotary piston and the velocity meters.

The meters tested by me, and the results of which are given in the schedule, were of the rotary piston type, of very simple construction and easily comprehended by a man of but slight mechanical ability, and can, therefore, be re-adjusted with little trouble or expense, without removal from the service pipe, as all the parts are interchangeable, put together with set-screws not riveted.

I made twelve separate tests, eleven of which were with three different $\frac{5}{8}$-inch meters and with streams $\frac{1}{2}$-inch and $\frac{1}{8}$-inch and $\frac{1}{16}$ inch capacity. The twelfth was with an ordinary service faucet as commonly used in cities, in order to decide the loss of head or pressure caused by the introduction of the meter.

Referring to the qualities of a meter, first, it will be seen, by looking at the schedule, that all the results of the tests made prove the meters are well within the limit of admissible error. (The meters tested were chosen at random from a large number. And, further, by looking at the number of cogs used in the cog-gear in tests Nos. 1, 2, 3, 7, 8 and 9, it will be seen that meters of this type can be regulated by changing the number of cogs nearly as accurately as a watch.

I first tried a meter with 29, then 31, and finally 30 cogs, until I regulated it down to the very small error of only two quarts in every hundred gallons, or, in other words, a difference of a gallon and a half per day for the usual consumption per capita of the inhabitants.

This difference is that between the amount registered by meter and the amount computed from weight at a certain temperature.

Again, tests No. 3 (29 cogs) and 6 were made with $\frac{5}{8}$ inch meters and $\frac{1}{8}$-inch streams, still showing particularly good results, although in the first case the meter had not been adjusted with the proper number of cogs. Also, in test No. 9, with $\frac{1}{16}$ inch stream, the meter was out less than half of one per cent., showing that the registration was very accurate.

Under the second requisite of a meter, durability, I am able to say but little from personal experience, as I have only been interested in such matters for a comparatively short time. The meter longest in use of which I can speak with authority is one of twelve years trial, which shows very slight signs of wear; however, people who have had much longer experience than I, testify to their lasting qualities.

As to the opening and closing of the faucets suddenly and frequently affecting the registration, I will refer to test No. 11, during which, while five cubic feet were running, I closed off and turned on the water suddenly seven times, with no detrimental effect, as shown by comparing this test with No. 10 test; both being made with the same meter.

Now, coming to the third qualification, the introduction of a meter should not materially affect the delivery. By again referring to the schedule, one will observe that the average time occupied in running five cubic feet through the meters to be 7 minutes and 42 seconds, while through a tap without a meter attached (test 12) it took seven minutes and twenty-one seconds in running 31.2 gallons, about a wine barrel full, showing very little obstruction to the force of flow.

The fourth requisite, being the consideration of first cost and cost of repairs, has been referred to in this article before.

After completing these tests, I examined an old meter which I was told had been condemned and put out of use, as it had been reported that it would not register and was the worst meter ever owned by a special water department. The outside of the meter was rusty and covered with mud, however; on the inside it was clean and showed no appreciable signs of wear. On examination of the parts, I found that the set screw supposed to hold the lever moved by the spindle of the piston was loose, and consequently the piston revolved without turning the spindle of the clock gear, and without turning the registering hands.

I also found that the spindle of the clock gear was bent. I tightened the screws, straightened the spindle, put the meter together, attached it to the service pipe, turned on the water, and found the meter to register.

By this I claim that the meter had been neglected and not examined as it should have been, and was condemned unjustly, as I believe is often the case, when we hear the charge of inefficiency and inaccuracy being brought up as an argument against the use of meters.

In conclusion, in reference to another charge of inefficiency of meters, namely, that sometimes they will allow water to pass through them without registering the amount. Of course they are supposed always to register correctly, but, on the other hand, is it not more advisable to lose a small amount of water in this way than to have the water stop running when the meter stops registering? For if the meter does not register, the amount of water consumed can be very accurately computed by comparison with previous amounts registered, and I believe that it would be better for a city to lose a little water by the non-registering of a comparatively few meters than by the wholesale waste that always goes on when meters are not in use; and also to lose the water by a meter not registering the amount flowing through it than to have the flow stop simultaneously with the registration, for in that case numerous accidents might occur by the explosion of boilers or heating apparatus.

METER TESTS.

No. of Tests.	Size of Meter.	Size of Stream	Registration at		Weight of Tank at		Temperature.	Amount of water run by	
			Start.	Finish.	Start.	Finish.		Registration	Weight.
					Lbs.	Lbs.	Dg. F.	Cub. ft.	Cub. ft.
1	⅝ inch	½ inch	11 cub.ft.	16 cub.ft.	57½	362¾	47	5	4.89
2	"	½	$21\frac{1}{10}$ "	$26\frac{1}{10}$ "	57½	362¾	46	5	4.89
3	"	⅛	$26\frac{2}{10}$ "	$31\frac{2}{10}$ "	58	362¾	46	5	4.88
4	"	½	$13\frac{1}{10}$ "	$18\frac{1}{10}$ "	57	370½	48	5	5.02
5	"	½	$18\frac{1}{10}$ "	$23\frac{1}{10}$ "	57¼	371	47	5	5.02
6	"	⅛	$23\frac{1}{10}$ "	$28\frac{1}{10}$ "	57¾	367½	48	5	4.97
7	"	½	00 "	5 "	57¾	381	49	5	5.17
8	"	½	00 "	5 "	57½	372	49	5	5.03
9	"	$\frac{1}{10}$	5 "	7 "	—	—	49	2	2.01
10	"	½	$5\frac{1}{10}$ "	$10\frac{1}{10}$ "	57½	367¾	49	5	4.97
11	"	½	$10\frac{1}{10}$ "	$15\frac{1}{10}$ "	57½	367¾	50	5	4.97
12	"	½	....	....	57½	367¾	50	....	4.97

Water pressure during test.	Time of		No. of Meter.	Total time running.	No. of Cogs in Clock-gear.	Difference between registration and weight measured in gallons p.c. in favor of	
	Start.	Finish.				Consumer p.c.	WaterDept.p.c.
Lbs.	h. m. s.	h. m. s.		h. m. s.			
80	5~02~00	5~09~37	15,156	0~7~57	29	....	2.2
80	....	....	15,166	....	29	....	2.2
80	....	....	15,166	....	29	....	2.4
75	4~27~30	4~35~00	22,096	0~7~30	......	0.38	....
75 to 77	11~51~00	11~58~30	22,096	0~7~30	......	0.38	....
75 to 40 to 20	....	....	22,096	....	......	....	0.028
77	3~22~00	3~24~52	15,166	0~7~52	31	3.39	....
75	....	....	15,166	....	30	0.57	....
75	....	....	15,166	....	30	0.48	....
70 to 77	....	....	22,072	....	36	....	0.028
78	....	....	22,072	....	36	....	0.028
78	5~36~00	5~43~21	....	0~7~21	......	....	....

Thursday, 7th April.

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

The Secretary read a letter from Mr. W. E. Davis, General Passenger Agent of the Grand Trunk Railway, announcing that he was presenting the Society with two steel engravings of the Suspension Bridge and the new Steel Arch at Niagara Falls.

A donation was also received from Mr. Rudolph Hering, M.Can. Soc.C.E., consisting of pamphlets, by himself, on different systems of sewage and water supply.

Paper No. 129.

NOTES ON BELTING.

By G. R. MacLeod, Stud. Can.Soc.C.E.

The principal materials used for belting are leather, rubber and cotton, and of these leather is probably the most commonly used on account of the fact that it is very efficient and wears well. But, inasmuch as it is more expensive than rubber or cotton, and in view of the fact that under conditions of moisture and great heat it is unserviceable, it is frequently replaced by the less efficient materials.

The belt is subject to failure in as many places as there are joints, and as leather essentially consists of short strips of about 5 feet in length, the necessity of joining it in various ways is another great drawback to its universal use. Some methods of connecting these strips make the joints almost as strong as the solid leather, but the presence of the joint may cause the belt to fail, not from tension, but from a tendency to wear or crack at that point.

The best leather belts are made from oak-tanned ox hide, the strongest part of the hide being the back. The grain or hair side of the leather is put next to the pulley. It would appear at first sight as if this were a mistake, since the grain side is the smoother and would therefore give less friction.

Mr. Arthur Achard of Geneva, in a paper before the Inst. Mech. Engineers, 1881, says:

" If the belt is wide, a partial vacuum is produced between the belt and the rim of the pulley, by the aid of an adequate velocity, which causes the atmospheric pressure to press the belt close against the pulley. An adhesion is thereby produced, which is totally independent of friction, and enables the tension to be considerably reduced." This is very important, because the less the tension on the belt the less will be the friction on bearings, and hence the greater power derived. A wide thin belt is therefore better than a narrow thick one, and this is so, not only for the reason that it gives less tension on the belt, but because it also gives greater flexibility.

Mr. D. A. Low in his "Machine Designing" also states that the smooth side is the better "because it gives greater driving power," reasoning probably in the same way as Mr. Achard.

Mr. J. Tullis of Glasgow, however, states that the belt will last longer if the grain side is out, and that coatings of courier's dubbin and oil will make the flesh side as smooth as the other.

Rubber belting is superior to leather in damp places. The part of the belt that gives it strength is not the rubber, but the cotton framework.

It is made by taking a wide strip of cotton duck and folding it into as many plies as desired, with rubber in between, and a thicker coating of rubber on the outer side.

The rubber, of course, is in a liquid state when applied to the cotton, and when the belt is finished it consists of a strong solid flexible belt, having the appearance of solid rubber.

There is almost no limit to the length that can be made all in one piece, so that there is only one joint in any piece of belt in use. Even this can be avoided by ordering an endless belt for special cases. The manufactured product is usually very uniform in quality. Extremes of heat and cold have very little effect on it, and it has very little tendency to slip on the pulley. It should be kept free from all *animal* oils or grease, as these are injurious to the rubber

Cotton belting is quite a favourite. It can be made stronger than leather of the same cross-section, and of great length without joints. It is better than leather in moist places and is less expensive. It was formerly made in the same way as cotton-and-rubber belting; that is, by laying one ply of cotton duck on top of another till the desired thickness was attained, and then sewing the whole together. The more modern method is to make the whole thickness together at one operation, each ply being interwoven with the one next to it.

An improvement on the plain cotton belt is made by soaking it in a mixture of red lead and linseed oil. This process has the same effect as it has in preserving wood. The cotton belt is then more efficient in moist places or in conditions which are found very unfavourable to the use of leather or even rubber. Some modifications of this kind of belt are made by substituting for part of the cotton a woof of hair and other materials. An example of this is the "Camel Brand," tests of which are reported below.

Gutta percha has been used as a substitute for rubber, and has been found to be a very efficient protection to the cotton. Tests have been made of a special brand of this called "Balata belting." It is manufactured in England, and has a rather thick coating of gutta percha on the outer side, and thin layers between the layers of cotton, while the side next the pulley is coated with a solution called "Balata."

STRESSES IN BELTS.

Belts are subject to two kinds of stress, viz., tension and bending.

The more serious strain is caused by bending round the pulleys. If the pulleys are small, the only way is to use the most flexible material. This will probably be the cheapest in the long run.

A good rule is given by Lineham in his "Mechanical Engineering," viz :—The distance centre to centre of pulleys should not be less than six times the diameter of the larger pulley.

It is a very important matter that the edges of the belt should wear well. If the edge is not good, it will soon become frayed by contact with the rim of the pulley, and will cause failure of the belt. The best edges are on good oak tan leather, and on rubber. The structure of the latter (folding) together with a strong covering of rubber secures a good compact edge.

Creep in belts is due to the belt stretching on the tight side, and if the belt stretches easily this is very serious. For every foot of belt that goes *on* the driver, less than a foot goes *off* and goes on to the follower. If the diameters of the pulleys were equal, the driver would make a greater number of revolutions in unit time than the follower would. Hence, if there is much stretch in the belt there is a loss of speed. This loss amounts to 1 per cent. to 3 per cent., depending on the elasticity of the belt. Since the tension on the belt is kept as low as possible to prevent too much friction on bearings of the pulleys, the belt that is least extensible at low tensions is the one which is most valuable in the matter of tensile strength.

JOINTS AND FASTENINGS.

Joints form the weak feature of belts, so far as tensile strength and wear is concerned, especially in the case of leather belting. They are of two kinds, (*a*) permanent, (*b*) temporary.

Permanent joints take many different forms. In leather belting, the most common is the laced joint. A lap joint splice is made, and cemented together; then two or three rows of rawhide lacing are put in. The holes for the lacing are not punched, but two sharp cuts are made for each stitch. The cuts should lie diagonally so as to injure the longitudinal fibres as little as possible. Copper rivets and various kinds of metal fasteners are used as a substitute for lacing, being more easily and quickly put on. But these all show a tendency, more or less, to cut or crack the leather, and are inferior to the spliced, cemented and laced joint.

For temporary joints, either thin strips of wrought iron or rawhide lacing are used, the latter being the more common.

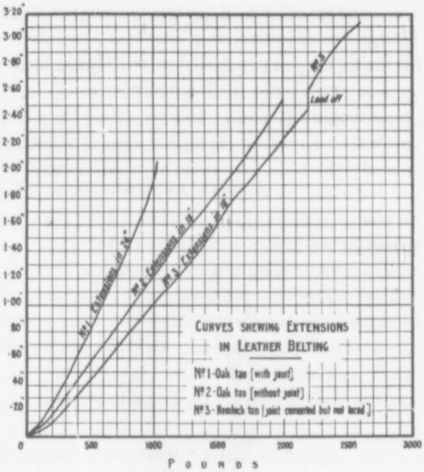
The best joints of this kind are made by squaring the ends of belt to be joined, and making one or more parallel rows of holes across the belt. The holes are usually round punched; awl-holes are not so good. It is better to have only one strand of lace in each hole, and the lacing should not cross on itself, especially on the side next the pulley.

RESULTS OF TESTS.

The following are the result of tests made in McGill College Testing Laboratory in 1896-97. The curves for the different kinds of belting show the total extensions for the various loads. When the specimen slipped from the jaws the load had to be taken off and begun again. This shows as a break in the curve. But the general direction of the curve after reloading is the same as before, although it may be continued in a higher position on the paper. The machine used was the Emery Testing Machine. When pressure from the accumulator is admitted gradually, the curve of extensions is quite smooth and regular; but when the machine is fed rapidly the extensions are less; this becomes more noticeable in belt testing. It shows as a sharp change in the curve, but when the feed is again better regulated, the curve resumes its former course. In some cases, of course, these sharp changes in the curve may be due to lack of uniformity in the material, particularly in the case of belting composed of cotton and hair.

Extensions were read at every 200 lbs. increase of load, except in some of the larger specimens, where readings were taken every 500 lbs. increase.

Leather Belting.—Specimens were procured from D. K. McLaren & Co., Montreal.



No. 1.—English oak tan leather.

Width 2 inches. Sectional area 0.453 sq. in.

Weight 0.213 lbs. per lineal foot.

Cost 23c. per foot.

Total stretch in 24 inches was 2.15 in. = 9 p.c.

Permanent stretch 0.2 p.c.

Maximum strength 2,210 lbs. per sq. in.

This specimen contained a joint, spliced, cemented and laced in the same manner as first example described under *Joints.* It broke straight across the middle of the joint.

No. 2.—Same belt as No. 1 but without joint.

Maximum strength, 4,640 lbs. per sq. in.

This shows that the strength of the joint is about one-half the strength of the solid belt.

No. 3.—Hemlock tan leather.
Width $3\frac{1}{2}$ inches.
Sectional area .798 sq. in.
Weight .206 lbs. per foot.
Cost 43c. per foot.

Total extension was 3.11 inches in 18 in. = 18.3 p.c. This specimen had a cement splice without lace or rivets. It failed at 3,300 lbs. per sq. in.

Fracture took place, not in the joint, but immediately at its edge.

A solid piece of this belt stood 4,000 lbs. per sq. in.

An unlaced cemented joint is stronger than a laced one, but lacing is necessary where the belt is exposed to heat or moisture.

RUBBER BELTING.

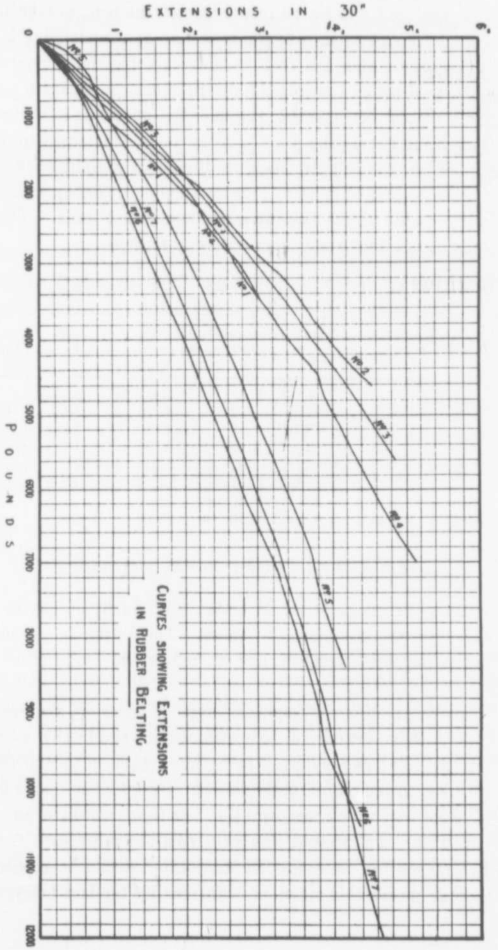
The specimens tested were manufactured by the Canadian Rubber Co. of Montreal.

Fig. 3

The curve of extensions is almost a straight line with a slight tendency to turn upwards immediately before fracture. This straight line indicates that the extensions are about the same for each increment of load and hence that the material is very uniform. Another fact that shows the uniformity of the material is that the fracture in each case was clear and straight across the belt. It was not a tear but a break.

The method of measuring the extensions is as follows:—

Two pencil lines are ruled square across the belt exactly 30 inches apart. A scale graduated to hundredths of an inch is clamped with one end at the lower mark, by means of a short piece of steel with a bent head thus ┌──── ; this piece is clamped to the scale and the two together are clamped to the belt, so that the end of the scale is exactly at the pencil line.



CURVES SHOWING EXTENSIONS IN RUBBER BELTING

A long steel pointer, also having a bent end, is clamped at the other mark. As the belt stretches, this pointer moves along the scale, thus giving the amount of stretch which can be read quickly to hundredths by means of a magnifying glass.

The sketch (Fig. 3) is a section of the jaws for holding the specimen, A piece of steel rod *a* is placed in the loop of the belt, to take up the pressure from the two rods *b b*, whose section is a semicircle; *b b* are fitted into grooves and are free to move, so that the pressure from them is always directed towards the centre of *a*. A separate piece of belting *c* is placed between the jaw and the specimen to protect the latter from being cut by the jaws. Four bolts *d* are used to tighten the jaws. When the belt stretches, its thickness is diminished. The bolts are then tightened more to prevent slipping. The jaws are connected to the piston of the ram by a ball and socket joint. They can thus adjust themselves to any unevenness in tension.

TABLE SHOWING RESULTS OF TESTS OF RUBBER BELTING.

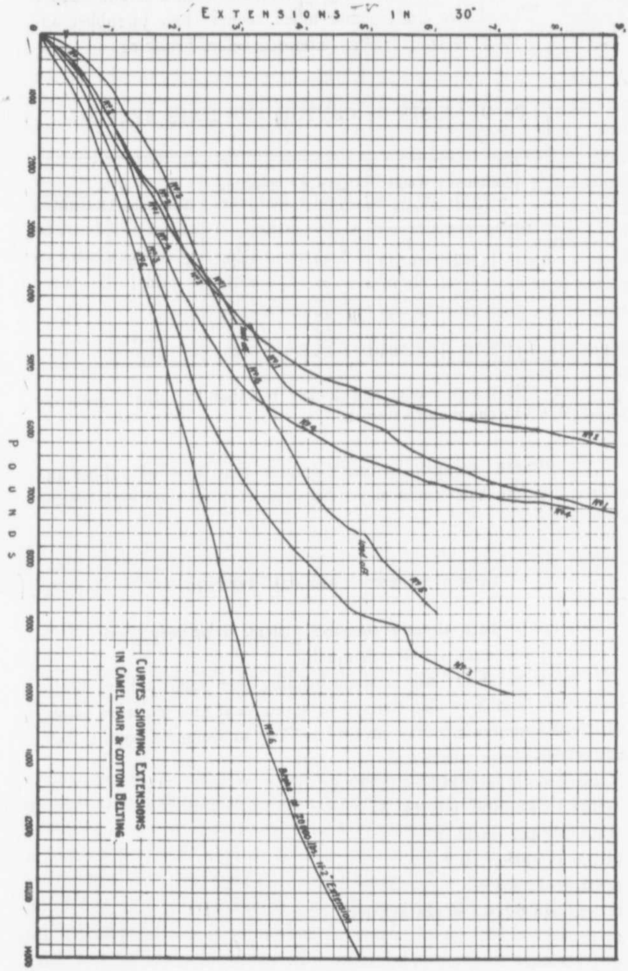
Specimen No.	Width.	Sectional Area, sq. in.	Weight per lineal foot.	Cost per lineal foot.	Breaking load per sq. in.	Total Extension.	Permanent Extension.
	ins.		lbs.	$ c.	lbs.	p.c.	p.c.
1	4	.840	0.477	.42	4170	10.0	0.13
2	5	1.100	0.635	.52	4270	14.9	3.3
3	6	1.505	0.844	.62	3790	16.4	3.0
4	8	1.920	1.032	.84	3700	17.0	1.9
5	10	2.587	1.143	1.07	3320	13.9	1.6
6	12	2.995	1.281	1.30	3540	14.5	2.4
7	14	3.440	1.812	1.54	3620	15.8	2.0

REDDAWAY'S PATENT CAMEL BELTING.

This belting is made partly of cotton and partly of coarse camel hair, said to be the combings of camels. The cotton is the material which forms the chief strength, and therefore the longitudinal fibres are cotton.

The hair yarn forms a woof, although in some of the specimens tested there were strands of hair running longitudinally as well as transversely. The two materials being interwoven in several plies, the belt is soaked in red paint and allowed to dry. The paint forms a good body coating, which protects the belt from moisture and makes it very durable. To prevent the belt from becoming stiff and hard, an occasional coating of castor oil and tallow should be applied; but any *resinous* mixture is injurious. In making the lace holes, a sharp

awl should be used instead of a punch, as the latter cuts the threads and thus weakens the belt.



CURVES SHOWING EXTENSIONS IN CAMEL HAIR & COTTON BELTING.

A glance at the curves shows that for small loads the extensions are uniform, and even have a tendency to decrease until a certain limit is reached. The elastic limit comes much sooner than in rubber and leather, and there is an enormous extension before breaking.

RESULTS OF TESTS OF COTTON AND HAIR BELTING.

Specimen No.	Width.	Sectional Area sq. in.	Weight per lineal foot.	Cost per lineal foot.	Breaking load per sq. in.	Total Extension.	Permanent Extension.
	ins.		lbs.	$ c.	lbs.	p.c.	p.c.
1	4.4	1.262	0.572	.33	5960	31.9	11.6
2	5.1	1.220	0.599	.39	5570	35.1	4.5
3	6.1	1.710	0.800	1.00	5900	24.5	7.1
4	6.0	1.31	0.599	.48	5650	27.6	12.9
5	6.0	1.83	0.781	.58	5360	20.6	....
6	12.2	3.78	1.705	1.33	5160	38.0	19.3

NOTE.—No. 3 is a heavier and thicker belt than the others, described as "double" by the manufacturers.

The ultimate strength is much greater than that of rubber and leather, but the belt would never be submitted to such high tension while in use.

DICK'S PATENT "BALATA BELTING."

This kind of belt, already described, seems to be very good. It is very strong and does not stretch much.

The gutta percha is said to stand bending over small pulleys better than rubber, and it is also claimed to stand heat and moisture better.

It has cheapness in its favour, and is likely to become a popular belt. Only one specimen was tested.

Section $4.45'' + 0.22'' = 0.979$ sq. in.
Weight .433 lbs. per lin. ft.
Cost 46c per lineal ft.
Total extension 15.7 p.c.
Permanent 4.4 p.c.
Max. load 5210 lbs. per sq. in.

TABLE SHOWING COMPARATIVE VALUES OF BELTS.

KIND OF BELT.	Ultimate Strength.		Total stretch.	Stretch at 400 lbs. per sq. in.	Permanent set.
	Per sq. in.	P r lb. per ft.			
			p.c.	p.c.	p.c.
Leather................	4320	12200	10.5 to 18.3	1.0	0.5
Rubber	3773	7296	14.6	2.2	2.05
"Camel".............	5860	12050	29.6	2.25	13.1
"Balata"	5210	11750	15.7	1.16	4.4

The column, 'strength per lb. per ft.' gives a fair idea of the proportionate driving power that can be got out of the same weight of different kinds of belt.

The last two columns show the comparative values with regard to stretch.

PRICES.

Leather,	10c	per ft. for	1″	belt to	$12.00	per ft.	for	72″
Rubber,	21c	"	2″	"	6.72	"		52″
"Camel,"	12c	"	2″	"	1.33	"		12″
"Balata,"	21c	"	2″	"	1.30	"		12″

The "Camel" belting is by far the strongest, but it also stretches most. *Where it can be used*, the leather is the most economical, although it is very expensive in large widths. It is the lightest, and less power is lost by stretch.

The gutta percha comes next for lightness and driving power, and would therefore seem to be the most serviceable belt of all. But it is hardly fair to come to such a conclusion where only one specimen is tested.

Thursday, 21st April.

E. **Marceau**, Member of Council, in the Chair.

Paper No. 130.

WIND STRESSES IN A THREE-HINGED ARCH.

By F. P. Shearwood, A.M.Can.Soc.C.E.

The practical importance of the subject of stresses produced by wind pressure in structural designing, as well as the fact that the information to be found in text books concerning these stresses in arched bridges is exceedingly limited, seems a sufficient reason for presenting to the members of this Society what appears to be a satisfactory method of computing them in the three-hinged type.

Simply stated the problem is this: In a three-hinged arch without top laterals to find the magnitude and direction of the forces acting at the abutments. Having found these, the other stresses can readily be discovered by Graphic Statics, or some equally well-known method.

Up to the present time there has not been to the writer's knowledge any satisfactory solution of this problem offered to the profession, and, in the attempt to solve it or any question of the same nature, co-operation and discussion seem to be the conditions of establishing the true explanation. In this, as in all branches of engineering science, the problems of to-day may become the accepted facts of to-morrow, which, though simple in themselves, will be of value in general practice.

The amount of labour expended on the solution of this problem may seem to be comparatively insignificant, and the results obtained, satisfactory as they are, may appear at first sight of trivial practical importance. That such is not the case will be seen when some of the various complications and conditions of the problem have been examined.

The problem first presented itself in an arch recently built by the Dominion Bridge Company, in a rather exposed situation. In providing for the wind forces it was at once seen that the complications of overturning and lateral forces throughout the system produced stresses difficult to determine. All available text books were silent on the subject, and an exact solution did not present itself. It was thought, however, that close, or at all events safe results, would be obtained by

considering the horizontal truss to be a continuous girder of varying cross-section in so far as the dead load stress at the crown would counterbalance the tension on the leeward chord, by providing for stresses produced by the two extreme conditions, viz: the horizontal truss considered with no moments at the centre, and also with no moments at the abutments. The tipping force to be worked out separately and considered as turning about each panel point as follows:

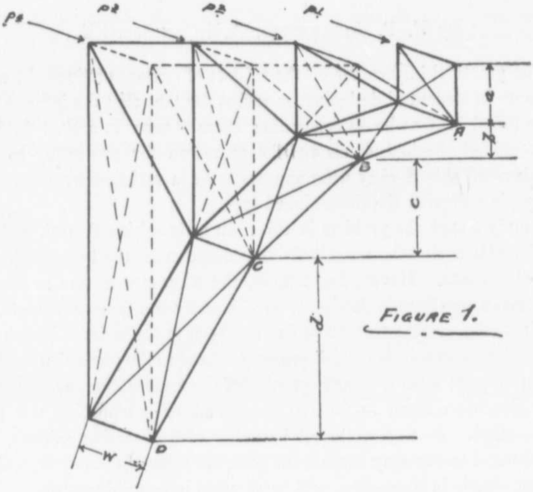


FIGURE 1.

In Fig. 1 where the load

$$\text{At } A = P^1 \times \frac{a}{w}$$

$$\text{At } B = P^2 \times \frac{a+b}{w} + P^1 \times \frac{b}{w}$$

$$\text{At } C = P^3 \times \frac{a+b+c}{w} + \left\{ (P^1 + P^2)\left(\frac{c}{w}\right) \right\}$$

$$\text{At } D = P^4 \times \frac{a+b+c+d}{w} + \left\{ (P^1 + P^2 + P^3)\left(\frac{d}{w}\right) \right\}$$

in which w = the width of the arch at the point considered.

These quantities were treated as vertical loads in the ordinary way. Combining for each member the tipping stresses thus found with whichever horizontal condition gave the maximum, the stresses were found to be so great, and in consequence the section of the chords so largely increased, that it was considered expedient to spend much time and labour in discovering the true method of solution.

Perhaps the most difficult part of the problem was to realize that each half of the arch was a simple span so far as the vertical loads are concerned, inasmuch as the vertical components of the reactions are determined by the distance of the load from each abutment, and the direction of one reaction is unalterable. It was also difficult to perceive where to apply the loads created by the tipping action of the wind, and the method shown above seemed to be correct; but, once having proved that each half arch was a simple span in itself, the half arch *A C* can in Fig. 2 be replaced by any other simple frame without altering the reaction at *A* and *C*.

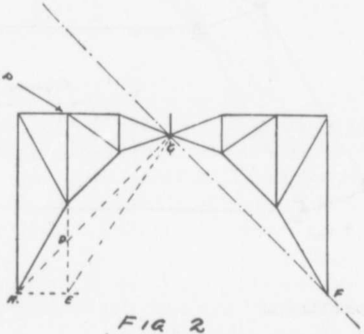


FIG 2

Let the truss *ADCBE* with a braced tower supported at *E* replace one half arch. In this it is clear that the whole tipping load is applied at *E*, and the vertical components of the reactions at *A* and *F* are in inverse ratio to their distances from *E*, and the direction of the reaction at *F* must pass through *C*, therefore that at *A* is also known.

Such were some of the difficulties encountered before arriving at what is believed to be the correct solution as follows:—

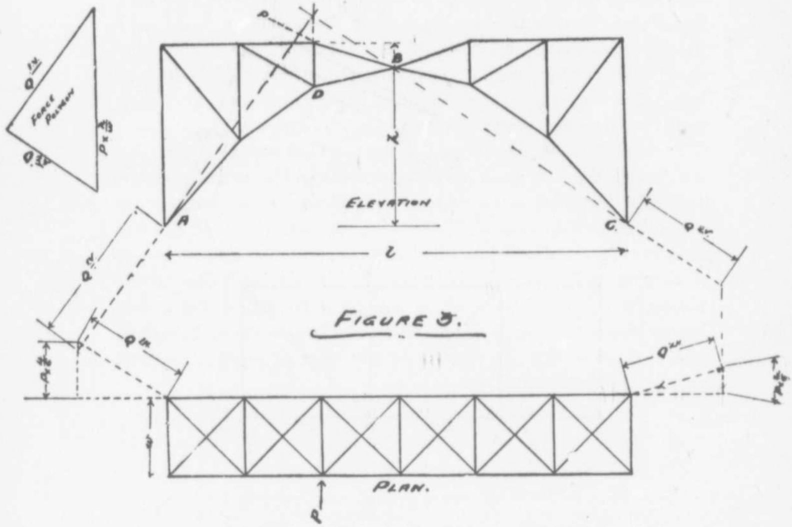


FIGURE 3.

In the three-hinged arch as portrayed in Fig. 3 no vertical moments can occur at the crown or abutments, and consequently the force polygon as seen in elevation must pass through these points. If we apply any horizontal force P, an uplift is created at the abutments of the windward arch and a corresponding reaction at the abutments of the leeward arch.

Considering the leeward trusses, the line of reaction Q^{2v} must pass through C and B, and Q^{1v} must meet that line vertically above or below D, where the force P is applied.

Turning now to the horizontal truss in the lower chords, as shown in plan of Fig. 3, the force P is resisted by the two abutment reactions, Q^{1h}, Q^{2h}, but this must be in such a plane that no alteration is made in Q^{1v}, Q^{2v}, as seen in elevation; for, if these are altered, the condition to produce zero moments at the hinges will not be maintained, and so the reactions can only be as shown in Fig. 3.

A simple illustration of the above solution is obtained from Fig. 4, where we can replace the arch (shown in the dotted lines), by the straight chords AB, BC, without altering the stresses at the hinges in any way.

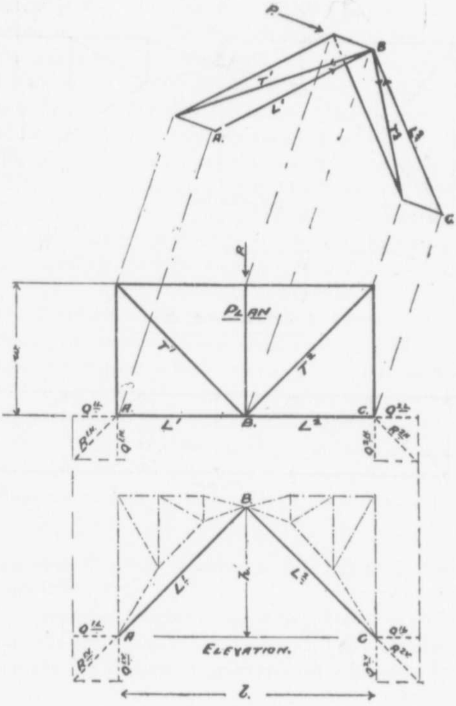


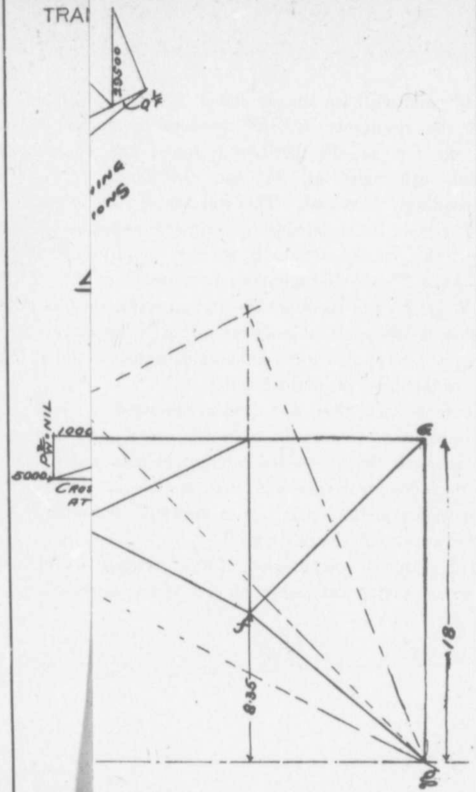
FIGURE 4.

Suppose a horizontal load P is applied at the crown B, the vertical reaction will be $\frac{P \times h}{w \times 2}$ at each abutment, and the longitudinal will be $\frac{\frac{P}{2} \times \frac{l}{2}}{h}$ The resultant falls in the plane of the straight line drawn from A to B, which produces a direct stress in $L^1 L^2$, equal to the reaction R^{1v}, R^{2v}.

Now, considering the horizontal forces, P is resisted by the horizontal reactions, Q^{1h}, Q^{2h}, and we have already found Q^{1L}, Q^{2L}. Combining these, we find the resultants R^{1h}, R^{2h}, produce no moment at B. Assume that, so far as the horizontal forces are concerned, that a moment can exist at B, then the forces Q^{1L}, Q^{2L} must be correspondingly decreased. This will decrease the stresses in L^1 L^2, but T^1 T^2 remain the same, since Q^{1h} and Q^{2h} cannot be altered. Considering now the forces acting at B, we have longtitudinal components of $T^1 + L^2 = T^2 + L^1$. But the vertical components of $T^1 + T^2$ no longer balance $L^1 + L^2$, and there are no external loads, and the arch from construction is incapable of resisting vertical moments at this point ; therefore it is not possible to maintain equilibrium and at the same time to alter the direction of the reaction.

From this it seems clear that any moment produced in the horizontal truss also produces a moment in the vertical truss, and the essential conditions are such that no vertical moment is produced at the crown, and the reactions for the above loadings are the only ones which produce zero moments at the hinges ; it is therefore concluded that the horizontal forces can only be as shown.

The method of graphical computation of wind stresses is fully explained on the accompanying plate, where an arch of very simple form is considered.

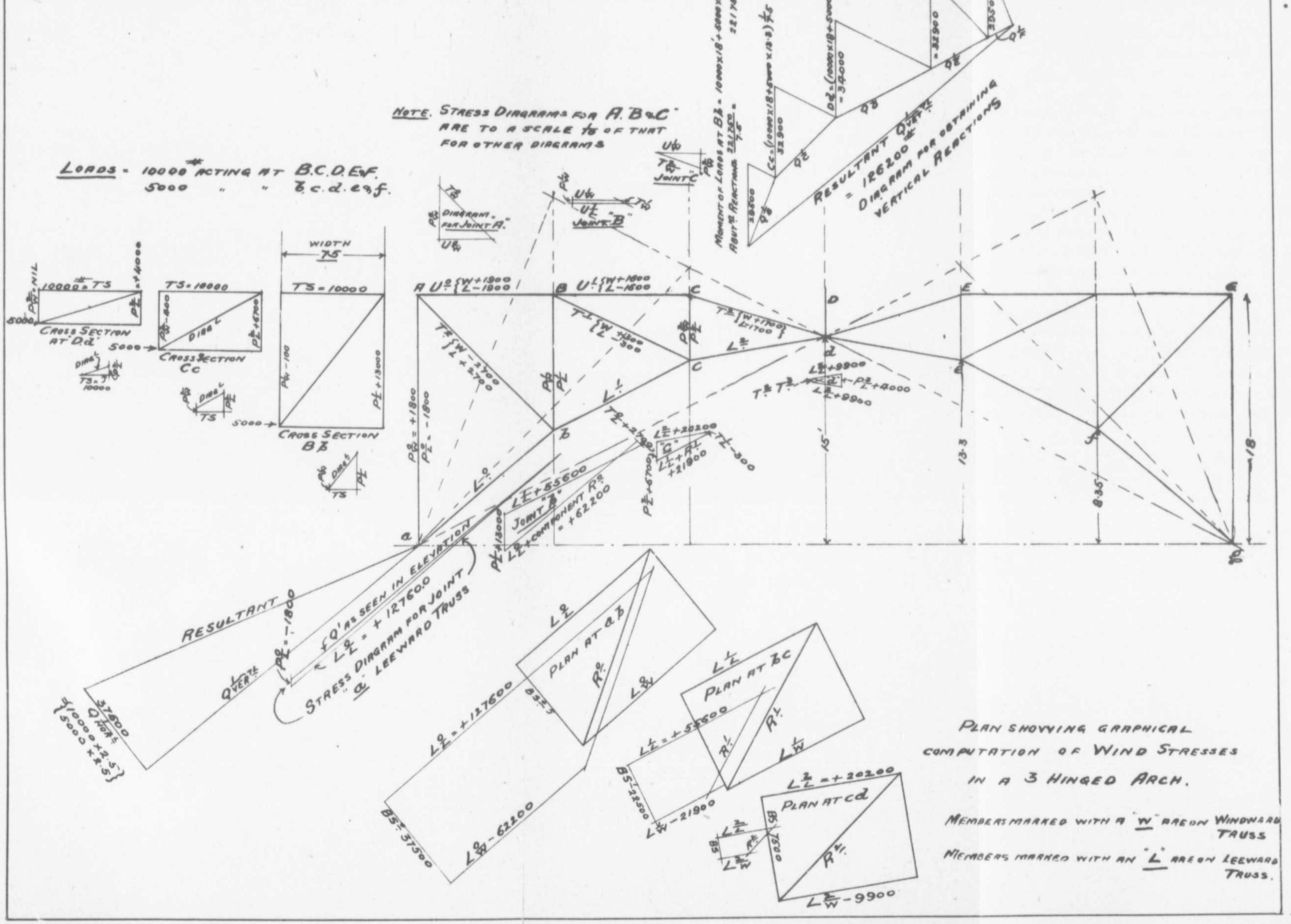


AN SHOWING GRAPHICAL
TATION OF WIND STRESSES
N A 3 HINGED ARCH.

BERS MARKED WITH A "W" ARE ON WINDWARD TRUSS

BERS MARKED WITH AN "L" ARE ON LEEWARD TRUSS.

TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE II



PLAN SHOWING GRAPHICAL COMPUTATION OF WIND STRESSES IN A 3 HINGED ARCH.

MEMBERS MARKED WITH A "W" ARE ON WINDWARD TRUSS

MEMBERS MARKED WITH AN "L" ARE ON LEEWARD TRUSS.

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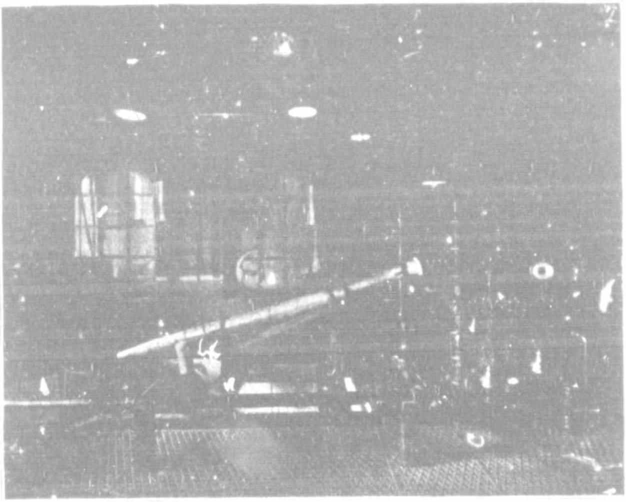


Thursday, 5th May.

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

An announcement was made as to an invitation from the "Société des Ingénieurs Civils de la France" to the Members of this Society to attend the Anniversary celebration during the coming year.

Paper No. 131.

HYDRAULIC LABORATORY, McGILL UNIVERSITY.

By Henry T. Bovey, M.Inst.C.E., LL.D., etc., and
J. T. Farmer, Ma.E.

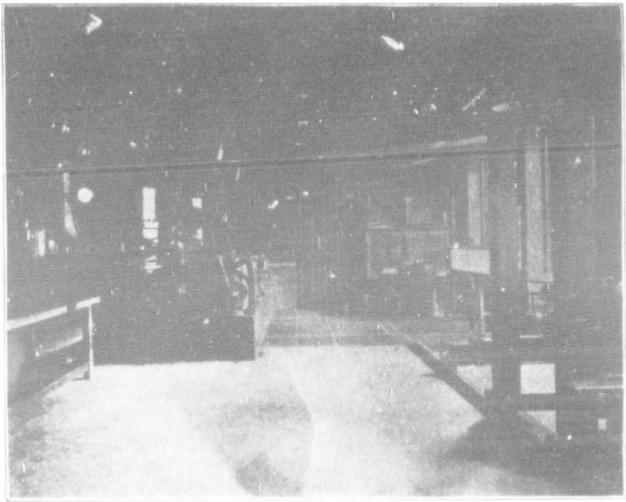
General Description.—The laboratory is 39 feet in length and 31 feet in width. On the north side, near the centre, stands the Experimental Tank, having its base on a level with the bottom of a flume.

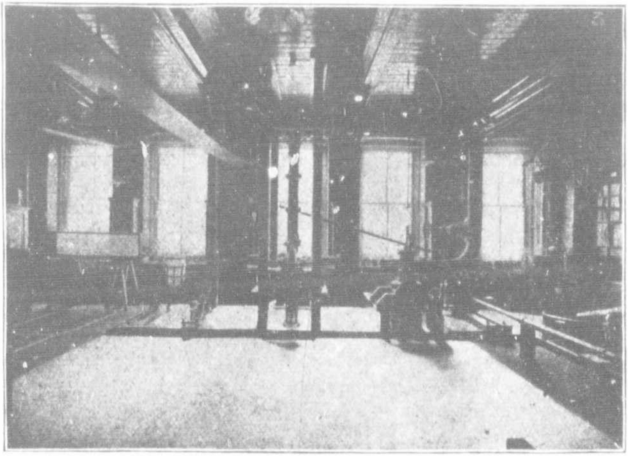
The flume, which is 5 feet wide and 3 feet 6 inches deep, runs from the tank and terminates in an adjustable weir. The water flowing through the flume may pass over or under the weir and may run to waste or may be made to pass into five large carefully calibrated tanks, 8 inches below the floor level and ranged in series on the south side of the Laboratory. The covering of the tanks is on the level, and indeed forms part of the floor.

Over the easternmost of the tanks stands the Experimental Pump on a base formed of suitably designed carrying girders or trunks.

On the west side, at convenient points along the flume, are the following pieces of apparatus :—A 16 inch Pelton Wheel, with brake attachments, a Turbine Tester of special design and an Experimental Centrifugal Pump. Along the west wall is fitted up a Rife Hydraulic Ram with all the necessary pipes and tanks for experimental work. The pumps are driven from a line of 3½ inch steel shafting near and running parallel with the east side of the Laboratory. The shafting is operated by a 100 H. P. Mackintosh & Seymour high-speed horizontal engine, standing in an adjoining room. By means of an electromagnetic coupling, designed by Prof. Carus-Wilson, and connected with a switch conveniently placed near the Experimental Pump, the main shaft can be almost instantaneously thrown in and out of gear and without sudden impact or shock, as the circular armature permits a partial rotation until the resistance is overcome. A 90 H. P. automatic recording transmission Dynamometer is placed on the shaft between the magnetic coupling and the nearest point at which power is transmitted. An 8 inch line of piping makes a complete circuit of the Laboratory near the ceiling. The several pumps and motors are connected with this circuit, and the movement of the water is controlled by suitably placed 8 inch straightway valves, branch tees, elbows, etc. By means of a short vertical length of 8 inch piping, terminating in a goose-neck, the pumps can be made to discharge into the top of the experimental tank from which the water passes into the flume, then into the large tanks, and is thus again available for supply. The whole of the water used in the Laboratory is drawn from the city high level reservoir, which gives at the base of the tank a pressure of more than 120 lbs. per square inch. The city service is connected with the 8 inch circuit, which can therefore, if desired, be made to act as a supply pipe to the turbines and other motors. Provision is also made for connecting the latter directly with the city service. The pumps and motors all discharge into the flume and the water then passes over the weir where the volume of discharge can be measured. If the volume is not too great it can be at once measured by passing the water into the large calibrated tanks.

The weir may be used the whole width of the flume without side contractions, but by means of suitable checks one or more side contractions can be introduced and the width of the weir diminished to any required extent, or the weir may be subdivided into two or more independent weirs. A large number of experiments have already been made to determine the co-efficient of discharge with and without side contractions and with different depths of water over the weir lip. The results will be given as soon as the experiments have been completed. The water may be conveyed to any one of the five tanks through an iron channel provided with properly placed manholes, and the five tanks can all be connected together by means of a 10 inch pipe running along the bottom of a deep trough next the wall, and having the necessary valves and 6 inch branches communicating with the several tanks. The water may also be run to waste through this 10 inch pipe. In this channel and next the weir there is a flap-door with edges inclined at 45° to the vertical. The edges of the gap closed by the door are also inclined at 45° to the vertical, and the fit between the





door and gap has been made as perfect as practicable. An India-rubber cord is inserted in an endless groove running along the centre line of the edges, so that when the door is closed and pressed home it is absolutely water-tight. The door can be instantaneously opened and closed by means of a lever and a system of links acting as a toggle-joint, and each movement is recorded by an electrical chronograph. In any given experiment the door is opened and the water allowed to run to waste until the head over the weir lip is steady, when at a signal the door is instantaneously closed, when the water is conveyed by the channel into any or all of the tanks.

The stand-pipe for the fire-hose rises vertically at the back of the tank and extends to the full height of the building. At the base it is provided with a number of unions varying in size from 6 to 1 inch, and to these unions are attached the lines of piping for pipe-flow experiments. The position of the stand pipe was selected so as to allow of straight lengths of more than 400 feet of pipe being used.

To secure a uniform pressure a Locke Regulator has been provided which responds, though slowly, to a variation in the pressure.

A special piece of apparatus for hose testing has been placed in the south-west corner of the Laboratory. It is connected by hydraulic piping with the Blake pressure pumps in the Testing Laboratory. A large number of tests have been made on the strength and on the longitudinal and circumferential extensibility of different varieties of hose, which in the great majority of cases was in lengths of 50 feet. The pressure, which often exceeded 800 lbs. per square inch, was directly indicated by a standard Crosby Gauge, while the time and pressure were also registered automatically by a recording gauge specially designed for this work.

Of the remaining apparatus the following may be briefly noticed :

A glass tank, 72 inches by 18 inches by 12 inches, with circular diaphragm chamber at one end. This serves to illustrate vortex ring motion, and also, with the aid of glass tubes with flared ends and of different diameters, the critical velocity and other stream line phenomena.

Inverted glass domes, with an orifice in the bottom, with which are demonstrated the phenomena of circular and spiral vortex motion, of the invertion of the vein, etc.

A series of very carefully made nozzles with a perfectly smooth bore, and having pressure gauge attachments at each end. Each nozzle is 36 inches in length between the gauge connections, and has a taper corresponding to a diameter, varying from 3 inches to $2\frac{3}{4}$ inches in the largest to 3 inches to $\frac{1}{2}$ inch in the smallest.

A series of sixty hydrostatic gauges, each with a range of 20 lbs. and embracing pressures up to 140 lbs. per square inch. The gauges are graduated to tenths of a pound, and the range of every gauge is overlapped by the two consecutive gauges.

A mercury column, 27 feet in height, is fixed to the north wall near the experimental tank, and in addition to this there are several small portable mercury columns, which are used in the experiments for determining the resistance to flow in small pipes due to elbows, bends, convolutions, etc. These pipes are 13 in number, have a smooth bore and are $\frac{3}{8}$ inch in diameter.

The Laboratory is also supplied with a Venturi and other piston and rotary meters, a number of hook gauges, Darcy's improved Pitot tube, brass standard gallon, quart and litre measures with glass strikes, etc., etc.

Measuring Tanks.—There are several copper measures of capacities varying from 10 to 100 gallons. They have been carefully calibrated, and the calibrations are frequently checked. When in use they are placed upon a plane-table with adjustable feet so that a true level can be always maintained.

Each of the large tanks already referred to is 6 feet by 3 feet 6 inches by 9 feet deep, and discharges into the 10 inch header through a 6 inch straightway valve. Each tank is also connected with a separate vertical 4 inch brass pipe, in which the water freely rises and falls with the water in the tank. This forms the float chamber. These tanks have been carefully calibrated, and the contents can be readily measured to within the sixteenth of a gallon. The float is attached to a vertical $\frac{3}{16}$ inch brass rod with a pointer at the upper end, indicating on a brass plate the quantity of water in a tank. A fine cord, fastened to the top of the rod, rises vertically, passes around a frictionless pulley, and carries a constant weight at the end which counterbalances the rod, etc., keeps the cord taut, and so prevents the pointer from rubbing against the plate.

Experimental Tank.—The tank is of cast iron, is 28 feet in height, square in section, and has a sectional area of 25 square feet. Every care was taken to make the inside surfaces of the tank walls perfectly flush, and to this end the flanges, by which the several sections were bolted together, were placed on the outside. At first the water discharged from the tank was replaced by water admitted into the top of the tank through a hose terminating in a rose submerged just below the surface. Although the utmost care had been taken in the design of this rose to reduce the eddy motion at efflux to a minmum, there was always an appreciable disturbance. The hose was therefore extended until the rose rested on the bottom of the tank, 8 feet below the orifice; with this arrangement a series of orifice-flow experiments were made (the time in each case being the mean of that given by two stop-watches), and the values of the co efficient of discharge are given in the following tables:

TRIANGULAR ORIFICE OF .05 SQ. IN. AREA AND REMAINING ORIFICES OF .0625 SQ. INS. AREA.

Head in feet.	Circular.		Equilateral triangle with horizontal base uppermost.		Square with vertical sides.		Rectangle with vertical sides equal to four times the width.		Rectangle with vertical sides equal to sixteen times the width.	
	T	S	T	S	T	S	T	S	T	S
1.	678	620	657	631	643	627	662	640	688	671
2.	618	613	646	623	631	621	643	629	655	657
4.	610	605	628	616	620	615	631	620	642	643
6.	607	601	628	613	615	612	627	616	634	636
8.	606	601	621	610	613	609	624	613	631	632
10.	604	600	618	608	612	608	621	613	629	629
12.	603	598	617	607	611	607	621	611	626	627
14.	602	598	617	607	610	606	620	610	623	625
16.	602	598	616	606	609	606	619	609	622	625
18.	601	597	615	605	607	605	618	608	622	623
20.	601	597	615	605	607	604	618	608	621	622

ORIFICES OF .197 SQ. IN. IN AREA.

Head in feet.	Circular.		Equilateral triangle with horizontal side uppermost.		Square with vertical sides.		Square with diagonal vertical.	Rectangle with vertical sides equal to four times the width.		Rectangle with vertical sides equal to one quarter the width.	Rectangle with vertical sides equal to sixteen times the width.	Rectangle with vertical sides equal to one sixteenth the width.
	T	S	T	S	T	S	S	T	S	S	S	S
1.	624	618	627	627	623	628	623	635	640	641	658	659
2.	616	611	620	621	613	621	619	626	633	632	646	646
4.	610	607	615	615	606	617	614	619	629	629	637	637
6.	607	605	613	613	604	614	612	616	625	627	634	633
8.	606	604	612	612	603	612	612	614	625	625	631	631
10.	606	604	611	611	602	610	611	612	624	623	630	629
12.	605	603	611	611	601	610	611	611	622	622	627	626
14.	604	603	610	610	600	610	609	611	622	621	624	625
16.	606	602	610	610	600	610	609	610	620	621	624	624
18.	605	602	610	610	600	610	609	609	620	620	623	623
20.	604	601	609	609	600	610	609	602	620	620	622	622

N.B.—In the above Tables T indicates a thickness of plate of ,16 -in., and S indicates that the orifice is sharp-edged.

The presence of the hose in the tank was not satisfactory, as it necessarily interfered with the stream-line motion, and therefore affected to a greater or less extent the values of the co-efficient of discharge. The hose was discarded, and the water is now admitted into a 3 inch chamber extending right across the bottom of the tank and containing perforations on the lower surface through which the water flows to the bottom and is there deflected upwards. Twelve inches above the bottom the water is made to pass through a baffle-plate perforated with $\frac{3}{8}$ in. holes, and 6 inches higher there is a second baffle-plate also perforated with $\frac{3}{8}$ in. holes. In order to equalize as much as possible the flow from all points, the pitch of the holes in the upper plate was determined by the projections on a horizontal plane of equal distances on a sphere of 10 ft. diar. with its centre at the centre of the orifice of discharge.

There are two outlet pipes for fast and slow discharge, and there are two inflow pipes, the one 3 ins. and the other $1\frac{1}{2}$ ins. in diameter. Each of these pipes is controlled by a stop-valve.

With this new arrangement, the time being taken by an electric chronograph, the following values for the co-efficient of discharge have been deduced for sharp-edged orifices :—

Head in feet.	Circular.	Square		Rectangular Ratio of sides 4 : 1.		Rectangular Ratio of sides 16 : 1.		Triangular.
		Sides vertical	Diagonals vertical.	Long side vertical.	Long side horizontal	Long side vertical.	Long side horizontal	
1	.6199	.6267	.6276	.6419	.6430	.6633	.6644	.6359
2.	.6131	.6204	.6277	.6335	.6355	.6503	.6510	.6280
4.	.6081	.6162	.6177	.6281	.6293	.6409	.6415	.6228
6	.6073	.6137	.6156	.6255	.6266	.6368	.6372	.6202
8.	.6056	.6127	.6138	.6234	.6252	.6342	.6346	.6189
10.	.6050	.6116	.6132	.6224	.6240	.6323	.6327	.6183
12.	.6040	.6109	.6123	.6217	.6230	.6311	.6314	.6177
14.	.6038	.6104	.6118	.6207	.6222	.6304	.6304	.6176
16.	.6032	.6099	.6113	.6203	.6215	.6301	.6298	.6171
18.	.6031	.6096	.6110	.6200	.6212	.6299	.6293	.6163
20.	. .029	.6094	.6108	.6198	.6210	.6291	.6285	.6160

The manner in which the head of water in the tank is defined is both simple and effective. A glass tube of $1\frac{1}{2}$ in. diar. is fixed to the tank by brackets and extends from the top to the bottom. On one side of the gauge there is a brass scale graduated from a zero point in the same horizontal plane as the centre of the orifice of discharge. A carrier with a horizontal wire passing in front of the gauge slides up and down, and any required head is obtained by bringing the necessary scale graduation, the surface of the water in the gauge, the wire and its reflection in a mirror at the back of the gauge, into the same horizontal plane. There is a second indicator on the opposite side of the tank consisting of a float attached to an ordinary water-proof silk fishing line passing over a large light frictionless pulley and then vertically downwards in front of the tank. The cord is kept taut by a weight at the bottom, and carries a friction tight pointer which can be easily and rapidly adjusted to indicate any required mark on a brass plate fixed in a convenient position on the tank face, so that the operator working the valves has it constantly under observation. As soon as the head of water in the tank has been determined by means of the glass gauge, the pointer is moved into position opposite the mark, and is kept there throughout the experiment. This obviates the necessity of constantly watching the level of the water in the gauge, which, on account of the height of the tank, is often very inconvenient and troublesome. Occasionally, however, it is advisable to check the position of the pointer by observing the water-level in the gauge, as the cord-indicator is extremely sensitive, and the cord itself necessarily varies slightly in length, so that small errors might otherwise be introduced.

The head of water is brought to any required level by means of a three-way valve through which the water can either be admitted or may be allowed to escape. The valve is provided with a long vertical spindle, upon which handles are arranged at different points in such manner that one can be easily reached and operated from any position in the height of the tank. Close to the cord indicator and within the reach of the operator there is a $\frac{1}{4}$-inch pipe with valve, which is useful for a fine adjustment when the inflow is only slightly in excess of the discharge.

The values of the co-efficient of discharge (c_d) were calculated from the usual formula.

$$c_d = \frac{Q}{At\sqrt{2gh}}$$

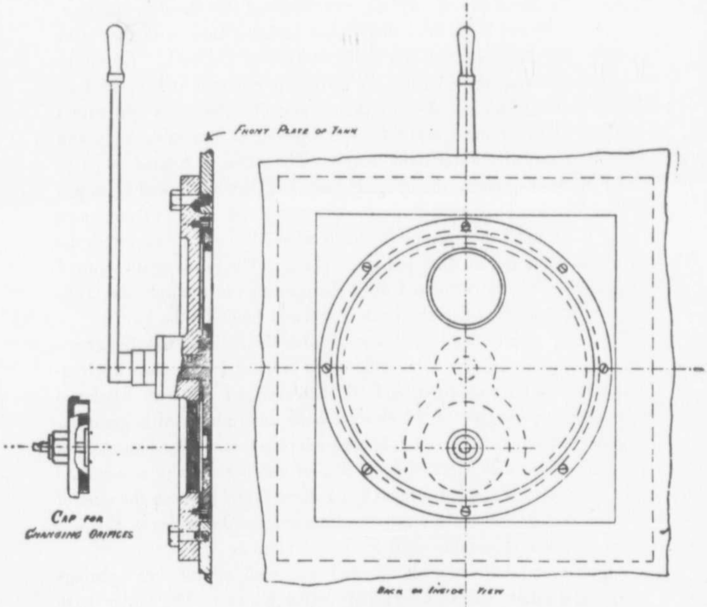
The area (A) of each orifice was practically the same and equivalent to the area of a circle of $\frac{1}{2}$-inch diameter, or .19635 sq. inches.

The value of g (= 32.176) used in every case was that obtained for Montreal by Commandant Deforges in 1893.

At least two sets of measurements were made for each head, and the mean was adopted as correct if the results did not differ by more than 3 in 10,000.

The possible errors in the several factors of the above formula have been computed to be as follows :

	For 20-ft. head.	For 1-ft. head.
Error in Q	20 in 100,000	20 in 100,000
" A	10 "	10 "
" t	5 "	1 "
" g	2 "	2 "
" h	1 "	20 "



CIRCULAR VALVE
OF EXPERIMENTAL TANK
Designed by F. Walbycombe.

Perhaps the most important feature of the tank is the valve arrangement. The valve is a gun-metal disc ¾-in. in thickness and 24-ins. in diameter, fitted into a recess of the same dimensions in a cast iron cover plate, with gun metal bearing faces, forming a water-tight joint for the face of the disc. This cover plate or body is bolted to an opening in the front of the tank, and the inner faces of the cover plate or disc are flush with the inner surface of the tank.

In the disc and on opposite sides of the centre there are two screwed openings, the one 3-ins. and the other 7-ins. in diameter. By rotating the disc each opening can be made concentric with a screwed 7½-in. opening in the body of the valve. The disc is rotated by means of a spindle through its centre, passing through a gland in the front of the valve body and operated by a lever on the outside. Gun metal bushes, with the required orifices, are screwed into the disc openings, and when screwed home have their inner surfaces flush with the valve surface, and therefore with the inside surface of the tank. By means of a simple device, these bushes can be readily removed and replaced by others without the loss of more than a pint of water. A cap with a central gland is screwed into the 7½-in. opening of the valve body and forms a practically water-tight cover. The valve is rotated so as to bring the bush opposite the opening, and it is then unscrewed by means of a special key projecting through the cap gland. The valve is now turned back until the opening is closed when the cap is unscrewed, the bush taken out and another put in its place. The cap is again screwed into position, the valve rotated until the openings in the disc and tank-side are concentric, when the bush is screwed home by the key.

The utmost care has been taken to form the orifices with the greatest possible accuracy. The orifices are worked in the discs approximately to the sizes required, and are then stamped out with hardened steel punches, the sizes of which have been determined with great exactness by means of Brown & Sharpe micrometers. The diameters of the orifices are also checked by a Rogers' comparator and a standard scale. In some cases a discrepancy has been found between the sizes of the die and its orifice, but the size obtained for the orifice is the one which has been invariably used in the calculations.

A gun metal bush or shell, screwed into each of the two openings in the main disc, carries a series of orifice plates. The larger bush takes plates with openings up to 4-ins. in diameter, and the smaller bush takes plates with openings up to 1¾-in. in diameter. The plates are provided with a shouldered edge which fits against the corresponding rim of the bush and are screwed with the orifice in any required position by means of an annular screwed ring fitting the interior surface of the bushing. The orifice plates are gun metal discs, 4½-ins. in diameter by ¼-in. thick for the large bush and 2-ins. in diameter by ⅛-in. thick for the small bush.

Each of the larger orifices, from 4-ins. to 6-ins. diameter, is made in a separate bush which fits the 7-in. opening, and any of which can be easily taken out and replaced.

In "co-efficient of discharge" experiments, the water, on leaving the orifice, passes either to waste or to the measuring tank, through a bifurcated galvanized iron tubing, supported in a pivoted frame. The water is first run to waste through one of the branches until a steady head has been obtained, and the frame is then rapidly swung through a small angle by means of a lever, when the water passes through the other branch to the tank. As soon as the tank is sufficiently full, the frame is swung back and the water again runs to waste. In the forward and return movements, the lever makes and breaks an electric contact, the interval of time occupied by an experiment being registered by a chronograph.

In "co-efficient of velocity" experiments, the position of the jet from an orifice is defined by vertical measurements from a straight-edge, supported horizontally above the jet by a bracket on the tank face at one end and at the other on a bearing, which admits of a vertical adjustment.

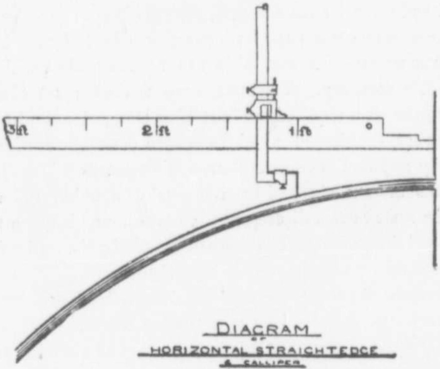
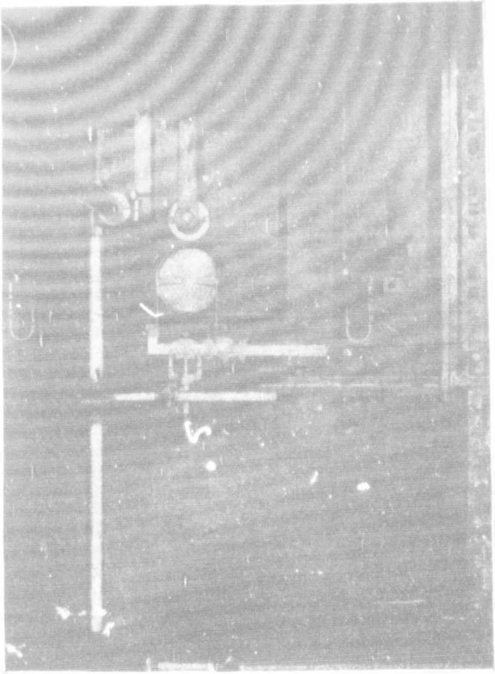


DIAGRAM
OF
HORIZONTAL STRAIGHTEDGE
& CALLIPER
FOR MEASURING
DEFLECTION OF JET.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The steel straight-edge is $5\frac{1}{2}$-ft. in length, $2\frac{1}{2}$-ins. in depth, $\frac{3}{8}$-in. in width and is graduated so as to give the horizontal distances from the inner face of the orifice plate. The vertical ordinates are measured by a Vernier caliper specially adapted for the purpose. The flat face of the movable limb is made to rest upon the upper surface of the straight-edge, and the caliper arm hangs vertically. A bent piece of wire, with a needle-point, is clamped to the other limb, and by means of the screw adjustment, can be readily moved until it just, touches the upper or lower surface of the jet.

The sectional dimensions of the jet are determined by the jet measurer.

One end of a horizontal 2-in. bar is attached to the front of the tank and the other is supported on a frame bolted to the sides of the flume. A split cross-head, or sleeve, slides along this bar and may be clamped by a tightening screw in any desired position. Upon the cross-head there is another split boss, or sleeve, through which a second bar passes at right angles to the first, and carries a similar cross-head to that on the 2-in. bar, so that provision is made for a rough adjustment in a vertical plane. Through the latter cross-head passes a smaller bar, and along this bar slides a third adjustable cross-head, or caliper-holder, by which the caliper can be swung round and receive its final adjustment. For the measurements a 12-inch Brown & Sharpe Vernier caliper is used. A capstan head rod is clamped to each leg and can be swivelled through any angle. Steel needle pointers are inserted in the heads, and are clamped in such position as may be required. In making a measurement the steel points are first made to touch and the corresponding readings taken. The points are then separated by sliding the caliper heads apart, and the whole apparatus is moved into position. The points are finally adjusted so as to touch the surfaces of the jet at opposite points, and readings are again taken. From the two sets of readings the transverse dimension of the jet can be at once determined.

With this apparatus, jet measurements can be made to the one-thousandth of an inch, and at any point between 72 inches and $\frac{1}{8}$-in. from the inner edge of the orifice plate, but rigidity is most essential.

Impact Apparatus.—This apparatus was constructed for the purpose of determining the force with which jets from orifices, nozzles, etc., impinge upon veins of different forms and sizes. (See Fig. 1, p. 85.)

A massive cast-iron bracket, 8-ft in length, has one end securely bolted to the front of the tank, and the other supported by a vertical tie-rod from one of the oak beams in the ceiling. The upper surface is provided with accurately planed slides, which are set level about 5-ft. above the orifice axis. If, from any cause, the end of the bracket farthest from the tank is found to be too high or too low, the error can be corrected by loosening or tightening the nut on the tie-rod.

The balance proper is carried by a sliding frame which can be moved horizontally into any position along the bracket by means of a rack and pinion actuated by a sprocket wheel with chain. At one end the frame has two equal arms with a common horizontal axis parallel to the bracket, and each arm has a stop on its lower surface which serves to limit the oscillation of the balance.

The balance, in its mean position, consists of a main trunk with horizontal axis rigidly connected with a vertical slotted arm and with two equal horizontal arms at one end. The common axis of the latter is horizontal and perpendicular to the axis of the main trunk. The hardened steel knife edges of the balance are 4-ft. centre to centre and rest in hardened steel Vees inserted in the ends of the sliding frame on each side of the bracket. The bottom of each Vee is in the same horizontal line (called the axis of the Vees) at right angles to the bracket.

A bar with the upper portion graduated in inches and tenths has a slot in the lower portion, which is bent into a circular segment of 9½-ins. radius. The bar slides along the slot in the vertical arm of the balance. A radial block, with the holder into which the several vanes are screwed, moves along the slot in the circular segment, and may be clamped in any required position, the angular deviations from the vertical being shown by graduations on the segment. The centre of this segment in every case coincides with the central point of impact on a vane, is in the vertical axis of the balance arm and is also vertically below the axis of the Vees. Thus the jet can always be made to strike the vane both centrally and normally.

The scale pan hangs from a knife-edge at one end of the horizontal arms of the balance, while to the other end is attached a fine pointer which indicates the angular movement of the balance on a graduated arc fixed to the sliding frame. The balance is in its mid-position when the pointer is opposite the zero mark.

When a vane has been secured in any given position, the preliminary adjustment of the balance is effected by moving a heavy cast iron disc along a horizontal screw fixed into the main trunk. The sensitiveness of the balance is also increased or diminished by raising or lowering heavy weights on two vertical screws in the top of the trunk.

Assume that the adjustments have all been made and that the jet now impinges normally upon a vane.

Let W be the weight required in the scale pan to bring the balance back into its mid-position.

Let F_a be the *actual* force of impact determined by the balance.

Let F_t be the *theoretical* force of impact deduced by the ordinary formulæ.

Then the ratio $\frac{F_a}{F_t} = c_i$ may be called the co-efficient of impact.

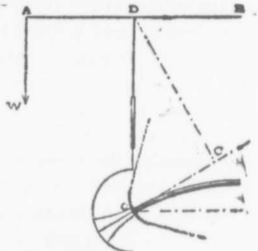


DIAGRAM OF IMPACT BALANCE.

Let y be the vertical distance of the central point of impact below the horizontal axis of the orifice, which is 36 ins. below the axis of the Vees. The distance between this axis and the point of suspension of the scale-pan is 24 ins.

Let ϕ be the angle through which the water is turned on the vane.

Let θ be the angle which the tangent to the path of the jet at the point of impact makes with the horizontal.

Let h be the head over an orifice of sectional area A.

Then,

$$F_a \cos\theta\,(36 + y) = W\,24$$

and

$$\begin{aligned} F_t \cos\theta &= 2\,w\,c_c\,c_v^2\,Ah\,(1-\cos\phi) \\ &= 2\,w\,c_d\,c_v\,A\,h\,(1-\cos\phi) \\ &= 4\,w\,c_d\,c_v\,A\,h\,sin^2\frac{\phi}{2} \end{aligned}$$

w being the specific weight of the water and c_c, c_v and c_d the coefficients of contraction, velocity and discharge, respectively.

Thus c_i the co-efficient of impact

$$= \frac{F_a}{F_t} = \frac{6\,W}{wc_dc_v\,Ah\ sin^2\frac{\phi}{2}(36+y)}$$

For a flat vane and taking $w = 62\frac{1}{2}$ lbs. per cub. feet,

$$c_i = \frac{.192\,W}{c_d c_v\,A\,h\,(36+y)}$$

A very few co-efficient of velocity (c) experiments gave the following results :

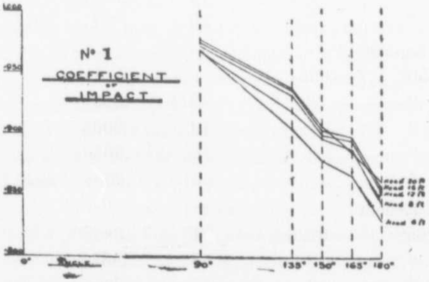
Head in feet.	Co-efficient of velocity (c^v.)
4	.9950
8	.9960
12	.9957
16	.9960
20	.9954

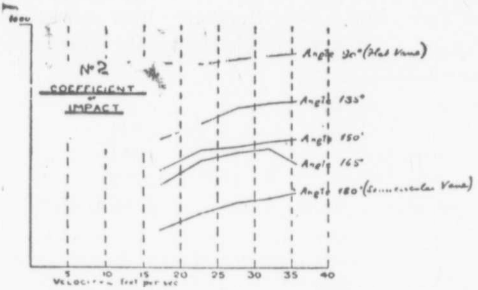
The mean of the values of c_v, namely .9956, is the value used in calculating by means of the above formula, the values of the co-efficient of impact given in the accompanying table:

I. Vanes with smooth polished surfaces.

Form of Vane	Surface area in sq. ft.	Head over orifice in ft.	Co-efficient of impact (c_i) diar. of orifice being		
			.5-in.	.6769 in.	1.0002 in.
Flat	.0491	4	.9691		
"	"	8	.9684		
"	"	12	.9725		
"	"	16	.9749		
"	"	20	.9767	.9777	.9723
Circular segment of 135°	.0575	4	.9048		
"	"	8	.9189		
"	"	12	.9319		
"	"	16	.9360		
"	"	20	.9377	.9677	.9777
Circular segment of 150°	.0654	4	.8789		
"	"	8	.8969		
"	"	12	.9004		
"	"	16	.9036		
"	"	20	.9068	.9520	.9561
Circular segment of 165°	.0780	4	.8668		
"	"	8	.8877		
"	"	12	.8955		
"	"	16	.8982		
"	"	20	.8861	.9360	.9560

Form of Vane	Surface area in sq. ft.	Head over orifice in ft.	Co-efficient of impact (c) diar. of orifice being .5-in.	.6769 in.	1.0002 in.
Circular segment of 180°	.0982	4	.8297		
"	"	8	.8454		
"	"	12	.8544		
"	"	16	.8572		
"	"	20	.8623	.9219	.9685
II. Vanes with surfaces rough as cast.					
Flat	.0491	4	1.0168		
"	"	8	1.0276		
"	"	12	1.0343		
"	"	16	1.0411		
"	"	20	1.038	1.0295	1.0179
Circular segment of 180°	.0982	4	.7447		
"	"	8	.7527		
"	"	12	.7570		
"	"	16	.7593		
"	"	20	.7567	.8467	.9203





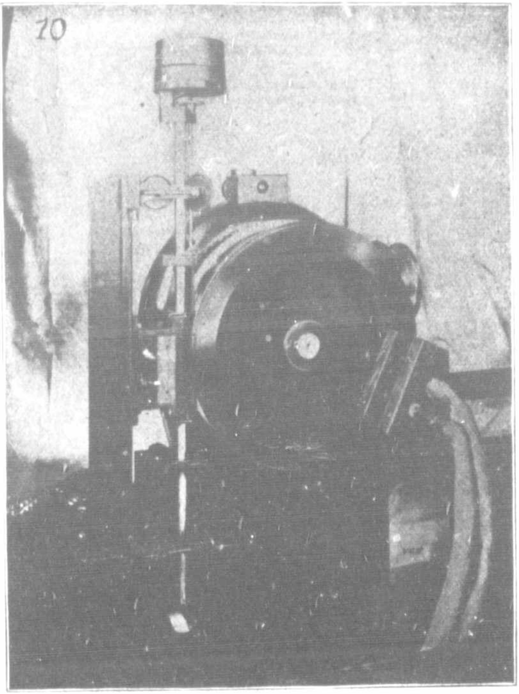
In the above diagrams, fig. 1 represents the variation of the c_i for different angles of deflection.

The results obtained for each head or velocity are combined into a curve.

The angle of deflection denotes the total angle through which the direction of motion of the water is turned, i.e., 90° for a flat vane; 180° for a hemispherical vane.

Fig. 2 shows the variation of the coefficient c_i with the head or velocity of the impinging stream. The curve indicates the value for each angle of deflection. The general indication of the curves is that the co-efficient increases with the velocity.

The *Testing of Motors, Gauges* and *Pressure Chamber*. In motor testing it is of importance to know the pressure of the water at certain points in the supply (or delivery) pipe, and, generally speaking, it is impracticable to employ either a mercury or a water gauge. The pressure is therefore observed by standard Bourdon gauges, of small individual range, which are frequently tested, a record being made of the errors. The method usually adopted to diminish the oscillating effect in the gauge due to fluctuation in the flow is to connect the bore of the pipe with an annular chamber by a number of small holes. In the McGill Laboratory these holes have been replaced by a continuous opening around the bore, less than .005 inch in width, with the obvious result of obtaining a better mean pressure. Similar chambers are also being used in experiments on the resistance of bends to flow. There are four sets of bends of 1 in., 1½ in., 2 in. and 3 in. diar., and each set consists of 30 bends, 10 having a radius of *one* diameter, 10 of *two*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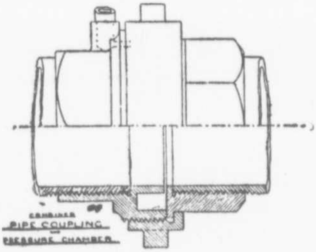


diameters and 10 of *four* diameters. At the central cross-section of each bend, provision is also made for ascertaining the pressure, either by a mercury column or by a gauge, at the extremities of the radii to the outer and inner surfaces of the bore. The chambers for the bends are combined with union couplings, of the same bore, which allow the attached part to be swivelled through any required angle.

Speed Indicators.—The speed of the motor is taken by a revolution counter and also by a tachometer. A sliding slotted sleeve at one end of main shaft of the motor can be made to engage with the spindle of the revolution counter, which can therefore be readily thrown in and out of gear at the commencement and end of a test, and the readings can be taken at leisure. The tachometer is supported on a bracket fixed to the motor frame, and is driven by a cord passing over a pulley on the motor shaft.

Brake.—Besides a Halpin brake of 50 H.P. capacity, the laboratory is equipped with a friction brake which has been designed by Mr. Withycombe, the superintendent, and which can be used with wheels both of the horizontal and the vertical type. It possesses many novel features of which the most important are :—

First, that it is self-adjusting and

Second, that a single direct weighing gives the total drag.

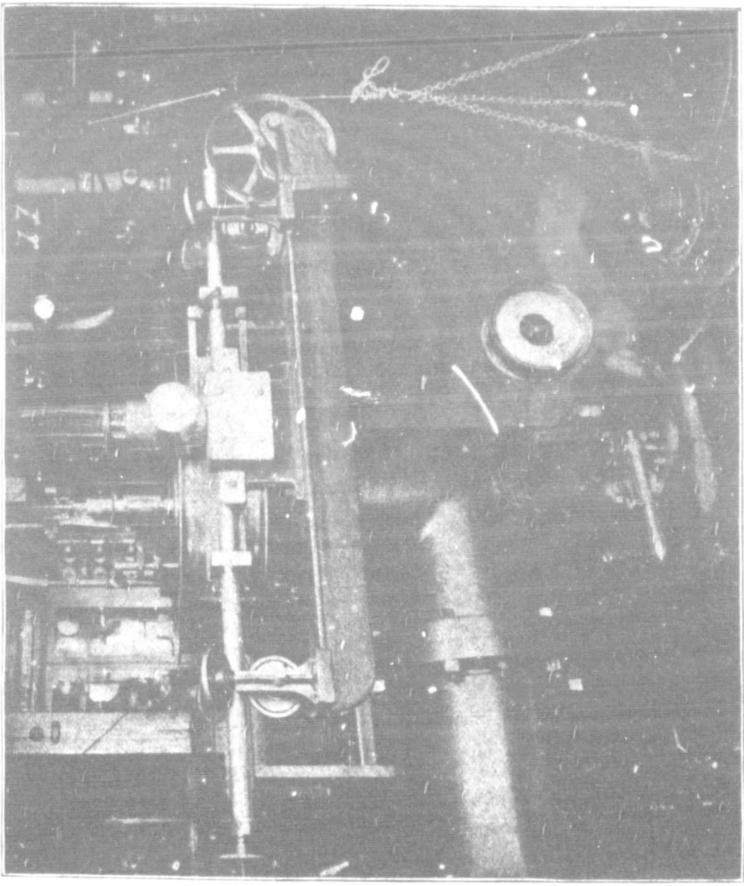
The brake wheel is of cast-iron and turned inside and out. The outer and inner surfaces of the rim are shrouded, the shrouding on one side being formed by the solid disc connecting the rim with the boss. A stream of water is delivered tangentially into the channel inside the wheel through a narrow rectangular mouthpiece of nearly the same width as the channel. The surplus water is carried away by a scoop of somewhat similar form but reverse in action. The tight portion of the brake band is of leather, and the slack portion consists of two strips of copper. In the mean position, each portion embraces about one-half of the circumference of the pulley, and its end is attached to a lug projecting from a rod. The lug to which the slack portion is joined is capable of sliding along the rod and, by means of a screw, can be adjusted so as to increase the slack tension as desired and therefore to produce any required total drag. The rod in the direction of its length has a practically frictionless range of 5 inches, which corresponds to a variation of about 16° in the angle of band contact. The resultant force along the rod is the difference between the tight and slack tensions, and measures the drag. The force is balanced by dead weights which are placed in a tray at the top of the rod for a vertical wheel and, if the wheel is horizontal, in a scale-pan suspended by a cord which passes over a frictionless pulley and is attached to the head on the rod.

If, from some cause, the band friction should increase, the drag would also increase, and there would be a corresponding movement of the rod. Thus, a portion of the leather band would be unwrapped, while an equal portion of the copper band would be brought into contact. But the frictional co-efficient for leather exceeds that for copper, so that the drag would be less and would continue to diminish until it again balanced the weight. The reverse, of course, would be true, if the band-friction should diminish. The rod would move in the opposite direction, an excess of the leather band would be brought into contact and the drag would continually increase until equilibrium was again restored.

Hence, within a certain range, the band will find a position of equilibrium, although the friction may vary, and the total drag will then be measured by the dead weight in the tray or in the scale-pan.

If the movement of the rod should be so great that it may come against one of the stops provided to limit its action, the drag can be re-adjusted by means of the screw attachment. This, however, is very unlikely to happen, as the range already allowed is sufficient to admit of a large variation in the value of the co-efficient of friction. It has been found that the best results are obtained by running the wheel without any lubricant on the rim ; care should be taken to protect the rim from water or oil, which would necessarily produce a considerable variation in the frictional resistance.

This brake has been in use only a few months, but in the several trials which have been made it has fully realized the expectations that



had been formed of its efficiency. It has been employed in measuring directly off the jack shaft the power developed by a 6 in. turbine with vertical axis and a 16 in. Pelton wheel with horizontal axis.

It may be noted that the weight of the rod and connected parts has been made exactly 10 lbs., which, of course, forms part of the dead weight in the case of a vertical wheel.

Measurement of Water.—The whole of the water is discharged into the flume, and passes over the weir into the large calibrated tanks. If the quantity is too great to be measured in the tanks, the water is run to waste and the discharge calculated from the normal weir formula. Co-efficients of discharge have been found for various depths over the lip, and the co-efficient for any particular depth can be very approximately determined by interpolation. The depth over the lip is obtained by means of the " depthing " apparatus, which consists of a deep girder stretching across the flume and carrying three hook gauges with Verniers which read to .001 inch.

Centrifugal Pump.—The Centrifugal Pump is erected over the flume in a framework which allows it to be raised or lowered so that the heights of suction and discharge may be varied at will. For this purpose the piping is made in interchangeable lengths of 2 feet. The pump is driven by a 9 inch belt and discharges into the ceiling circuit already described. From this circuit the water is delivered into the top of the Experimental Tank, flows into the adjoining flume, passes over an intercepting weir for calibration and is then again conveyed along the flume to the pump. Thus, the same water can be used over and over again.

Turbine Tester.—The turbine is supported upon an annular flange bolted to the bottom of a cast-iron cylinder. An 8-inch tee is secured to the crown of the cylinder, and a cover with a specially designed gland is bolted to the upper flange of the tee. The jack-shaft passes through this gland, which forms an almost frictionless bearing. No packing is required, as provision has been made for carrying away any slight leakage that might occur. The jack-shaft passes through a piece of pipe screwed to the bottom of the cover and extending downwards to the cylinder, so that it is protected from the impulsive effect of the inflowing water. The supply pipe is connected with the horizontal branch of the tee, and the entrance of the water is controlled by an 8 inch straight-way valve placed at some distance from the opening.

The gates of the turbine, for example, one of the New American inward and downward flow type, are worked by means of a shaft extending from a pinion geared to the toothed quadrant and passing through a gland in the crown of the cylinder. The upper end of the shaft is provided with a handle and pointer, which indicates on a graduated quadrant the extent of the gate opening.

Suitable pressure gauge connections have been arranged in the upper and lower parts of the cylinder.

The power of the turbine is determined by the friction-brake already described.

Experimental Pump.—This pump is of the vertical triple throw single acting plunger type, and is driven by two 10 inch double leather belts running on 48 inch pulleys formed on the outer cranks, or discs. The plungers are 7 ins. in diameter and have an 18 inch stroke. The approximate maximum delivery is estimated to be 1,000 gallons per minute when the pump is running at a speed of 150 revolutions per minute against a pressure of 120 lbs. per sq. inch. The suction valve chambers are placed directly over the calibrating tank nearest the east wall, and draw the water from this tank through two 10-inch suction pipes. Each discharge valve chamber is directly connected with a 12 inch header, which discharges into the 8 inch ceiling circuit. The water may be made to flow in almost a direct line to the point of discharge, or it may be made to pass around the three sides of a rectangle so that the effect of the additional bends and increased length of piping may be estimated. The water flows into the experimental tank at a point 20 feet above the level of the discharge valves.

One of the features of the pump is the provision made that the valves can be taken out and replaced by others of a different type. The valves at present in sitû are a Riedler valve and two others with groups of 36 circular disc valves of 1$\frac{5}{8}$ inches diameter in each.

In addition to the usual pressure gauges, tachometer and revolution counter, the pump is fitted with a specially designed continuous triple indicator apparatus, which autographically records during any given time of a trial the speed, variation and duration of the valve chamber pressure at any point of the stroke. Sight holes are provided for observing the movement of the valves and indicators for recording their lift. A special recording gauge also registers the pressure in the delivery pipe.

As the pump is for experimental work, it has been made unusually heavy, its total weight being about 55,000 lbs. The plungers, valves and valve seats, all internal screws, nuts, etc., are of bronze, and weigh more than 3,700 lbs.

DISCUSSION ON PAPER ON HYDRAULIC LABORATORY AT McGILL—SUGGESTION OF HYDRAULIC DATA STILL REQUIRED.

By W. Bell Dawson, M.Can.Soc.C. E.

In the investigation of the movement of currents in the ocean, some questions arise which are strictly of a hydraulic character. In most cases, even in the deeper parts of the Gulf of St. Lawrence, the currents do not extend to the bottom; and they thus constitute a body of water flowing over a water bed. In the most pronounced and permanent of the currents in the Gulf of St. Lawrence, there is seldom any movement appreciable below 50 or 60 fathoms, whereas the total depth is often 100 to 200 fathoms.

The co-efficient required in the study of the problem *is in the friction of water on itself.* This brings up the question, " Is it admitted that in pipes and smooth open channels a film of water adheres to the side, and that the co-efficients of friction as now determined are in reality values for the friction of water on itself; if not, can a satisfactory value be arrived at, by laboratory experiments, for this kind of friction?"

Another kindred problem is the effect of wind upon water. In nearly all cases, in the currents which I have investigated, their movement consists of three elements: (1) A tendency to move dominantly in some one direction, as a permanent set; (2) a tidal element which occasions a reversal of direction or a veer in direction, during the tidal period; (3) a wind drift or set, due to the action of the dominant wind at the time.

These three effects are superposed in the result as observed; and to separate them it is first necessary to deal with the wind influence, and either to eliminate it, or to reduce it to calculation; and thus to allow for it in the resultant movement of the current as obtained from observation. The other two elements can then be more readily distinguished and separated from each other; and the analysis of the movement will thus be obtained. The co-efficient required for this purpose is the friction of *air upon water.* In the actual case at sea there is always wave motion produced at the same time; but there does not seem to be good reason to suppose that this affects the result in any essential way. It may be a question, however, whether the co-efficient required could be determined by laboratory experiments; but if it could, its value would be of the first importance in such investigations.

The complete problem requiring solution may be stated as follows:

1st.—In the case of a confined body of water (lake, pond or tank) what will be the water slope maintained by a wind blowing steadily with a given velocity? From this a co-efficient of friction could be deduced for air upon water.

2nd.—In the case of a body of water unlimited in extent and depth, under the action of a wind of a constant velocity for a given length of time, what surface velocity will be produced in the water, and to what depth will the movement extend?

It is evident that to answer this last question, the friction of air upon water and of water upon itself must both be known. The latter co-efficient would also enable the rate of decrease in the movement to be computed as a function of the depth.

In determining these co-efficients it could not be assumed in advance that they would be constant at all velocities. The friction of the air upon the water would be likely to vary with the density of the air, but the variation might not be marked within the ordinary range of barsometric pressure. In the case of water upon itself, the co-efficient would probably vary little with the velocity except at very low speeds, at which water might become appreciable in its influence. It is not to be expected that the pressure, due to depth, would have any effect upon the co-efficient. On the other hand, the density of the water, as between fresh and salt water, would influence the result wherever the question of inertia or momentum came into play.

The determination of the co-efficients here indicated would evidently be of much advantage in the investigation of marine currents; as it is not possible, otherwise, to separate satisfactorily the wind disturbance in the current from the two other elements above indicated, which contribute to the actual or combined result, which comes under direct observation.

TIDAL SURVEY DEPARTMENT,
Ottawa, April 2nd, 1898.

Thursday, 19th May.

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

J. M. McCarthy, J. G. LeGrand and G. R. MacLeod having been appointed Scrutineers of the Ballot, announced the following elected:

Members.

Frederick Adam Hamilton, Henry Szlapka,
Charles Wilford West.

Associate Members.

John Murphy, Arthur St Laurent.

Student.

Alfred George Tully LeFevre.

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

Frederick William Cowie, Alfred Paverly Walker.

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

W. P. Morrison, John Irvine.

Paper No. 132.

COMMERCIAL ASPECT OF ELECTRICAL TRANSMISSIONS.

By George White-Fraser, M.Can.Soc.C.E.

All engineering works are means to ends, and where those ends are the attaining of some commercial advantage it will probably be easily acknowledged that their features should be regulated by the same considerations as govern the general policy of the enterprise in connection with which they are undertaken. By "engineering works" is meant any matter that at any stage of its progress comes under the professional consideration of an engineer, professing any branch of Engineering—Civil, Mechanical, Electrical or other. There are, no doubt, certain classes of enterprise in which safety to life and property or the attaining of a sanitary advantage are the chief factors in prescribing their general features; but in that class, already large, and becoming more popular every day, which forms the subject of this paper, dollars and cents are the objects sought, and dollars and cents should decide every question. Probably in no branch of engineering is it so true as in the Electrical, that the engineer has to work "to order" in every case, and, galling as it may be to do so, obey the inevitable decree of the dollar. This sometimes imposes the most apparently paradoxical conditions, discouraging to the progressive manufacturer as well as very distasteful to the engineer. And yet if engineering be, as is here contended, the means towards an end, it should bear that end loyally in view, and, having established correct premises, concede logical conclusions. The comparative success or failure of many commercial enterprises depends on the formulation of a broad general policy, and while many minor details, both of policy and management, may be modified from time to time to meet new conditions as they arise, the original construction has much the same effect as "fixing a negative," *i.e.*, any inaccuracies or flaws are permanent in their effect. The great importance therefore of a wise formulation of policy and of engineering to suit will be evident. An Electrical Power Transmission enterprise must be regarded as simply a commercial venture—an investment; and the duty of the engineer is, broadly, to so arrange the engineering as that the greatest possible profit may accrue on the least possible capital outlay. The terms "possible profit" and "possible outlay" are here taken as relative, not as absolute. A class of construction costing absolutely the lowest sum possible would not be the best investment (save under very exceptional conditions) owing to the probable high cost of maintenance, while on the other hand the superior machinery and solid construction that most engineers would prefer (regardless of cost) might by its very excellence impose such interest and other fixed charges on the investment as would overbalance the saving in maintenance. The dollar is an important factor here. Most extensive enterprises raise money on bonds, and the charges on those bonds, compared with estimated cost of maintenance, will have an important influence in deciding the general character of work in respect of its absolute intrinsic excellence. The cheapness of money in Europe in connection with the low price of labour, accounts for the solid and lasting construction there in vogue. The object of this paper being to show that every enterprise should be considered on its special merits, it would seem a little inconsistent to attempt to generalize. It may, however, be granted that those factors of principal importance as affecting the ratio of net profits to investment are interest, maintenance and wages' charges—that is, the fixed expenses. In water power transmissions there are very few variable expenses; where fuel is the source of energy, the problem contains an added factor. The above ratio, or, in short, dividends can be increased—other things being equal—by either lowering first cost for the same business done, or by doing more business on the same investment. This is a rather simple-looking proposition, but it opens up a field for careful consideration that presents many complicated features.

Probably the most important factor in formulating the general engineering line is the relative value of money and power. Is it better business in any particular case to spend money in order to save power and have it to sell, or to expend power (and have less to sell) in order to save money, and so diminish fixed charges? Here in Montreal are two immense water powers, and also a very large field for the sale of power. As good steam coal is not expensive, the cost of steam power is not prohibitive, and electrical power generated by the water power must be sold under the cost of steam power, and therefore at a very reasonable figure. There being probably more than sufficient water to supply all the probable demand for power, it is evident that water can be wasted if thereby money can be saved, and that it is the better policy to try and do the same amount of business with smaller investment than to endeavour to do more at an increased expenditure. Under these circumstances it is plain that the price of machinery and apparatus is certainly of equal importance to its efficiency, and that machinery of less intrinsic excellence (granted to be mechanically strong and probably durable) may be the better investment, if its price is sufficiently lower than that of other apparatus actually much more efficient. It is a logical conclusion, although a disagreeable one, that there are conditions easily conceivable where the "Farmer's" wheel, inefficient, clumsy and antiquated though it may be, is actually under the circumstances a better investment than the latest and finest result of modern scientific research. And the same is true of the electrical equipment. Take, however, the case of a mining country, where the mines themselves are far up the sides of the mountains, and the only available water power far below, in the valley, where wood fuel is almost exhausted and coal is enormously expensive, and has to be carried on mule back. Our own mining locations in British Columbia are rapidly approximating to these conditions, and instances will not be hard to find where more power could be sold than can be generated, and at very high prices. Here conditions are completely reversed. Power can be sold at considerably higher figures than it costs to generate, and money can usually be obtained at reasonable interest, so that the best business policy, and therefore the best engineering, is to develop and save every possible H. P. by the use of the most efficient machinery, etc., although at large cost. Instances are not rare where fair coal costs $20 per ton at the mine, which means for 6 days' working per week, 24 hours a day, 50 weeks per year, that steam power in medium sized mints will cost not less than $250 per annum per H. P. for fuel alone. Or, with coal at $15, working 20 hours per day, makes $180 as the cost of a H. P. year, not including charges for wages, maintenance, etc. Assuming then that $100 can be obtained per H. P. year, electrical, and that the cost of saving one H. P. by the use of higher class machinery (electrical) is $100 invested (surely a liberal amount), on which the fixed charge for interest, sinking fund, depreciation, etc., are as high as 25 p.c., the business view of the situation becomes, each H.P. saved for sale out of the various electrical and mechanical losses, by using such more expensive machinery, means investing $100 at 75 p.c. interest. This is, of course, a case that will not frequently arise in practice; but with different data it often does. Between these two extremes of low selling price and plenty of water, and high selling price and not more than sufficient water, comes a great variety of intermediaries, each presenting special features. In the average case, however, where there is neither a large excess of water, nor a high selling price for power, there will arise a particular point entering as a factor into the general consideration, which may be stated somewhat as follows:—

"Any decrease in first cost consequent on purchasing less efficient machinery or on reducing cost of transmission line can only be effected at the price of wasting power, which has a saleable value. This means that profits are relinquished in order to reduce expenses, and it is plain that there must be some point where a still further reduction of expenses can only be effected by such a curtailing of profits as that sale value of the total power, dissipated as above, shall be greater than the total saving in expenses thereby effected. Good engineering will mean the arranging of all the details so that the economical mean may be reached, where the least practical annual expense may be effected by means of the least practical expenditure of power." Every case contains this factor.

The details of an Electrical Power Transmission that can be so varied at will as to affect first cost are the voltage and the " drop; " but the same commercial basis also limits engineering here.

In any particular case, the cost of transmission copper varies inversely as the square of the transmitting voltage; or doubling the pressure quarters the cost of copper for the same distance, drop, and power transmitted. Hence it is evident that the higher the voltage used the less the investment for copper will require to be. When, however, the pressure is raised beyond a certain point, this advantage is largely offset by the fact that a high pressure requires a special class of transforming and insulating apparatus entailing very considerable expense. While generators can be built to deliver very high voltages without any transforming device, still it is hardly advisable to construct them for higher than 5,000 to 6,000 volts, so that if higher than this is desired it becomes necessary to use step-up transformers at the generating end and step-downs at the receiving end. These will cost certainly not much under $15 per pair per H. P. Further, while up to any medium voltage—say 5,000 volts—the ordinary glass insulators and inexpensive form of line construction will be generally sufficient in any ordinary climate; beyond this point it becomes necessary to use special insulators, which, when pressures greatly in excess of 10,000 volts are employed, will cost not less than $1.00 each for really satisfactory articles. Hence, it is easily seen that the employment of a high pressure entails such an expense that the copper saving may not be sufficient to warrant it; nor is it always possible to keep on raising pressure until an economy results, for the reasons that mechanical considerations forbid the use of wire smaller than about 25,000 circ. mils. for suspension; and the upper limit of pressure seems to be placed at present at less than 20,000 volts, owing to leakage and other troubles which tend to increase with the pressure. To transmit 1,000 H. P. over 5 miles at 5,000 volts, with 10 per cent. drop 3-phase—requires 22½ tons copper, costing probably $6,750; the size of wire being 145,800 circ. mils. Raising the pressure to about 12,000 volts will reduce the size of copper to 23,000 circ. mils., reduce the weight to 3.6 tons, and the cost to $1,080.00, making a difference in favour of the higher voltage of $5,670. The step-up and down transformers required with this high pressure will, however, more than balance this saving. In order that they should just balance, these transformers should be obtainable at $2.84 per H. P., which is out of the question. It is impracticable to raise the pressure still further, or to increase the "drop," as 23,000 C. M. is already below the prudent minimum size for line wire. And this is leaving the extra cost of high voltage insulators out of consideration as being rather small—about $400 against the high voltage. It is a simple matter to calculate the minimum distance at which, with above data, it would be equally economical to transmit with low volts and save expense of transformers; or, with high pressure, using transformers and saving copper. Bearing in mind that for the same pressure, horse-power and drop, the weight, and therefore the cost, of copper varies as the square of the distance. First assume the actual number of volts in the drop to be the same in both cases, and the total horse-power constant, then the amperes vary inversely as the pressure; and if we take

$l =$ the given distance (in the above case $= 5$ miles).

$a =$ the amperes corresponding to the low pressure H. P. (in the above $= 150$).

$l' =$ required distance at which the high and low pressure weights are equal.

$a' =$ the amperes corresponding to the raised pressure (in above $= 62\frac{1}{2}$.)

$d =$ the actual number of volts dropped (in the above low pressure case $= 500'$).

$T =$ total cost of transformers.

$K =$ constant depending on cost of copper.

then, $l' = \dfrac{K\,l\,a - T\,d}{K\,a'}$

If, on the other hand, we take the H. P. as constant, the pressure and therefore the amperes, variable, and the drop to remain the same *per centage* of pressure, then using the same notation as above, with the following additions:

$v =$ pressure corresponding to a (in above $5{,}000v$).

$v' =$ pressure corresponding to a' (in above $12{,}000v$).

$d =$ drop in pressure, expressed as "percentage."

then $l' = \dfrac{K\,l\,a\,v' - T\,v\,v'\,d}{K\,a'\,v}$

Several other calculations may be made, based more or less on the above data—some being rather more complicated. For instance, given a certain distance, what is the maximum economical H. P. that can be transmitted without using transformers; or stated conversely, at what H. P. will it pay to incur the extra expense of transformers. In the above formulæ no account is taken of the cost of insulators which will have the effect of increasing "l."

The determining of the most economical voltage has inseparably connected with it a factor which deserves most careful consideration. We have seen how a high pressure is not always, and of necessity, an economy, and have assumed a particular case as basis for a calculation. The "drop" was taken at ten per cent. of the voltage in both cases; but this "drop," its amount—whether expressed in actual volts or in percentage—should also be decided on a commercial basis. The "drop" along a line means simply pressure, and therefore power dissipated, and therefore lost. It can be made large, or small, by using (other things being equal) less or more copper; but, while it can be so varied as to considerably effect the *first cost* of a transmission, and therefore the fixed charges, it must not be forgotten that it can considerably affect also the income. All other things being equal, the quantity of copper required varies inversely as the drop; therefore it is evident that the larger the amount of power dissipated in overcoming the ohmic resistance of the lines, or the larger the drop, the smaller will be the investment for copper and the less the fixed charges against the business. But at the same time power costs money to develop, and generally has some commercial value, and the value of the power lost in "drop" should be placed against the saving in copper investment. In the above case we assumed 10 per cent. drop, that is we dissipated 100 H. P. in the lines. But whether 10 per cent., or more, or less, is the most advantageous drop depends on the sale value of power and on the value of money. Assume that bonds are saleable at 4 p.c. par, that 5 p.c. is laid by for sinking fund, and that all the power that can be laid down can be sold for $30 per H. P. year. And further assume that the water power has a maximum not greater than the demand for power. This case will frequently arise where a large mill is situated on a medium power, and the power has a value to the mill of anything less than the cost of producing it by steam. By reducing the drop to 5 p.c. or dissipating only 50 H. P., the other 50 H. P. is saved, and will be worth on these assumptions $1,500 for sale or use. The copper required with this smaller drop will be an extra 22 tons and cost an extra $6,750; so the result of saving 50 H. P. is making $1,500 a year on a $6,750 investment roughly speaking. But if the distance were three times as great, and the value of a horse-power were only $20 per year, there would be a very different result, viz., only $1,000 a year on an investment of nearly $20,000, or 5 °, which is only about sufficient to pay the interest on the bonds, and therefore no saving. It might, however, appear that while $20 per year would be the value of water power as compared with steam power, the increase in the quantity of the article to be manufactured, attained by saving the 50 H. P., might be sufficient to result in a commercial advantage in that way, so that the matter is still further complicated by the consideration of what can be done with the power saved. It seems, therefore, a very reasonable proposition that commercial considerations have a paramount influence in deciding the engineering lines. It is usually accepted without criticism that the most efficient machinery is the best; but there is no necessary consequence, unless a special meaning is given to the term "best" from the commercial point of view, that machinery is the best that makes the largest profit on its investment. If this be accepted, then at once its price becomes important, and difference in prices may be so considerable that the actually less efficient plant may be the better investment, more especially so where steam is employed. It is not unusual to have a choice among electrical generators (more particularly in smaller sizes) where the efficiencies range from 88 p.c. to 94 p.c., and the lowest price is 75 p.c. of the highest. The one offering the best investment must be determined after a calculation of the money value of the difference in efficiencies in connection with the first cost and probable maintenance percentage. Efficiency has a greater effect in determining comparative value, as the cost of fuel becomes greater as is evident from the following considerations. One per cent. difference in efficiency means one ton of coal saved out of every 100 tons; and, as this saving goes on continuously, the value of the 1 per cent. efficiency is the capitalized value of the ton of coal; or, with coal at $3 and money worth 6 p.c., and a plant consuming 1,000 tons of coal every year with 90 p. c. efficiency, another plant with 91 p. c. efficiency would be an equally good investment, although it cost $500 more; or, with coal at $4 and money worth 5 p. c. although it cost $800 more; but, if coal cost $2 and money were worth 6 p.c., it would be worth only $330 more as an investment. So that if in the above three cases the 90 p. c. efficiency plant were purchasable for $600, or $900, or $400, then the actually less valuable plant from the engineering point of view would be the more valuable from the commercial. In ordinary sized lighting plants the question of initial pressure is not usually a factor, as high voltage is not possible. But the "drop" should be considered, and is very considerably limited by the requirements of good service. Such drop as is allowed should be placed almost entirely between the generating station and the main centre of distribution, where compensations can be allowed by the regulating devices at the dynamos. Its amount is here governed as above, by the cost of generating power, as compared with the cost of money, for if fuel is cheap and money dear, then a large drop is more economical than it would be where fuel was expensive and money obtainable at small interest. Thus in the municipal enterprises which seem to be becoming popular, where the security for bonds is good, and therefore their interest low, it is generally economical to allow a larger drop than where a private individual owns the enterprise. It is plain that the principles above enunciated are capable of application in every case, and although the issues may be comparatively small, still the main object of engineering must be to carry out the idea of securing the most profitable investment.

ADDITIONS AND CORRECTIONS.

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Hamilton, F. A	151 Hollis St., Halifax, N.S.	March 19, 1898
Mitchell, Alex	1237 Majestic Bdg., Detroit	March 24, 1898
Stewart, Alex. F	Bloemfontein, S. Africa	Dec. 9, 1897
Szlapka, Henry	Hamilton Bridge Co., Hamilton, Ont	May 19, 1898
West, Charles W	Halifax, N.S	May 19, 1898

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Belanger, Ernest	Room 51, Street Ry. Bldg., Montreal	March 8, 1898
Bonnin, Prof. A	132 St. James St., Montreal	June 14, 1898
Doré, J. Emil	379 St. Hubert St., Montreal	March 8, 1898
Dufresne, L. A	17 St. James St., Montreal	March 8, 1898
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Murray, W. A	17 St John Street, Montreal	Feb. 8, 1898
Murphy, John J	Prov. Engineers Dept., Halifax, N.S	May 19, 1898
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ST. GEORGE, F. T	1148 Dorchester St., Montreal	March 24, 1898
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WATEROUS, C. A		May 19, 1898

TRANSFERRED FROM CLASS OF ASSOCIATE MEMBER TO CLASS OF MEMBER.

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WALKER, ALFRED P	C.P.R., Toronto	May 19, 1898

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