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Electrification of St Clair Tunnel

.. The Central .. Railway and Engineering .... Club .... of Canada

OFFICIAL PROCEEDINGS

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PROCEEDINGS OF THE CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA MEETING.

Rossin House, Toronto, November 17th, 1908.

The President, Mr.McRae, occupied the chair.

Chairman,—

It is now ten minutes after 8 o'clock and we will call the meeting to order.

The first order of business is, reading of minutes of previous meeting. The minutes of previous meeting have been put into printed form in our monthly journal, and every member having been provided with a copy, therefore it will be in order for somebody to move their adoption.

Moved by Mr. Acton Burrows and seconded by Mr. Bly, that minutes of previous meeting be taken as read.

Chairman,—

The second order of business is, remarks of the president. The only remarks I have to make to-night is to tender my apology to the Club for not being present at the last two meetings. I was unavoidably away from the city and could not attend. I also wish to tender my thanks to the officers who so kindly and efficiently filled the chair on those two occasions.

I have a complaint from the secretary that there are some members of the Association who have not paid up their dues for the year 1908. This is the last month of our financial year, and it is most advisable that those who have not paid up their dues should do so at once, and those who can exert any influence on those who were active members formerly, to come back into the fold again, the Club at large, will appreciate it very much.

There is hardly a meeting which has taken place that your attention has not been called to the necessity of filling out the attendance cards which have been placed on the chairs. The secretary informs me, that, without exception, at every meeting there are a great many members who do not fill out the cards. It is not only the members but the visitors who overlook filling out these cards. It is very important that these cards be filled out, and I trust that when my tenure of office is through, my successor will not have the trouble with this matter that I have had.

Mr. Burrows,—

I think it would be a very good plan for some one to go around and ask each member for his card while he is sitting there.

Chairman,—

That is the duty of the members of the Reception Committee.

Mr. Burrows,

I think it would be a good idea to fill out the cards now.

Chairman,—

The next order of business is, announcement of new members.

NEW MEMBERS.

Mr. H. F. Game, Machinist, G.T.R. shops, Toronto.

Mr. B. J. Markle, Superintendent Dominion Bridge Co., Toronto.

Mr. Geo. F. Milne, Inspector of Machinery, Canadian Inspection Co., Toronto.

Mr. M. R. Griffiths, Manager Electrical Department, Canadian H. W. Johns Manville Co., Toronto.

Mr. E. Blackstone, Machinist, Consumers Gas Co., Toronto.

Mr. J. E. Wiese, Superintendent of Boiler Shop, Canada Foundry, Toronto.

Mr. W. R. Maynard, Storeman G.T.R., Stratford.

Mr. H. Cross, Blacksmith, Consumers Gas Co., Toronto.

MEMBERS PRESENT.

T. J. Ward.	J. H. Morrison.	D. W. Robb.
D. Walsh.	W. McKay.	J. Clements.
P. McCabe.	J. F. Campbell.	T. T. Black.
D. C. Hallowell.	A. E. Hawker.	J. W. McLintock.
W. J. Bird.	H. D. Campbell.	J. P. McKelvie.
Acton Burrows.	A. M. Wickens.	G. D. Bly.
W. A. Hare.	J. O. B. Latour.	J. M. Downer.
B. J. Markle.	J. Bernard.	I. Jefferis.
J. Hay.	S. Price.	S. W. Price.
W. Poulter.	M. Walker.	E. B. Allen.
W. H. Bowie.	W. Dyer.	J. Duguid.
J. W. Griffin.	W. A. Nixon.	W. S. Cowan.
J. G. Hyde.	E. Logan.	J. Irwin.
J. Barker.	G. Shand.	H. Cross.
J. McWater.	C. L. Worth.	J. Kyle.
L. S. Hyde.	J. Dodds.	J. C. Garden.
F. Burrows.	F. Smith.	N. MacNicol.
F. R. Wickson.	J. C. Armer.	G. Black.
A. G. McLellan.	H. G. Fletcher.	W. H. Farrel.

Chairman,—

The Executive Committee in session to-night, has approved of the election of these gentlemen to membership in this Club.

Chairman,—

No. 11, in the order of business, is the appointment of committees. According to Section 10, page 6, of the by-laws, a nominating committee of five shall be elected, who shall present at the Annual Meeting nominees for each office to be filled; it shall be the privilege of any member of the Club to nominate other candidates, the nominees receiving the highest number of votes for each office, to be declared elected.

That is the duty we have to perform to-night. In connection with this, I may say, gentlemen, that the Executive deem it advisable that a representative from each of the industries be represented as far as possible within the number of five, should be elected to this Committee, for the purpose of selecting nominees for the ensuing year. We now declare the meeting open to receive nominations for this committee.

Mr. Geo. Baldwin, moved by Mr. Wickens and seconded by Mr. Hare.

Mr. I. Jeffries, moved by Mr. Worth, and seconded by Mr. J. Hay.

Mr. A. M. Wickens, moved by Mr. Burrows and seconded by Mr. Bly.

Mr. E. Logan, moved by Mr. Poulter and seconded by Mr. Worth.

Mr. W. A. Hare, moved by Mr. Downer and seconded by Mr. Bowie.

Chairman,—

Gentlemen, these are members who have been nominated for this Committee. What is your pleasure? Carried.

Chairman,—

We have been favored with an excellent paper by Mr. W. D. Hall, Superintendent of the St. Clair Tunnel. Unfortunately Mr. Hall is unable to be here to-night, which is a great disappointment to us all. In the absence of Mr. Hall, I will ask Mr. Bly to read his paper, if Mr. Bly will kindly favor us.

Mr. Bly,—

Mr. Chairman, I will do the best I can. I only got a copy of the paper at noon to-day and scarcely had time to look it over, consequently I am at a loss and know very little about the St. Clair Tunnel. I have been through it twice, and that is about the extent of my knowledge of the electrification of the St. Clair Tunnel. When the secretary asked me to read it, I did not know what I could say, and suggested the names of several gentlemen who would be more able to do justice to the paper and Mr. Hall than I. However, I will do the best I can, if you will bear with me.

Chairman,—

I assure you we will not be hard on you, Mr. Bly.

Mr. Bly,—

As far as the discussion is concerned, you will have to discuss it among yourselves without Mr. Hall to cross-question you. I think it would be out of place for me to discuss the paper in Mr. Hall's absence in the way he would undertake to discuss it, therefore, I will read it as it is. If there is anything which you do not understand and I can explain, I will do the best I can. No doubt there are a number here to-night who know more about it than I do. As regards the electric locomotive, I do not know anything about that part of it. My locomotives are screwed down to the earth, they only stand still and tread.

ELECTRIFICATION OF ST. CLAIR TUNNEL.

BY MR. W. D. HALL, SUPERINTENDENT ST. CLAIR TUNNEL.

The St. Clair Tunnel was commenced in September, 1888, completed for freight traffic in October, 1891, and for passenger service in December, 1891. The length of the tunnel is about 6,032 feet, and the approaches thereto 5,603 feet. The internal diameter is 19 ft. 10 in. It consists of cast iron rings 18 inches wide, each ring containing thirteen segments and a key piece. The weight of the iron is about 56,000,000 pounds.

The steam locomotives formerly used for hauling trains through the tunnel had ten drive wheels, and could haul a train of about 700 tons up the 2 per cent. grade. The electric locomotives have increased the capacity about one third, being capable of handling a one thousand ton train up the 2 per cent. grade at ten miles per hour. Under the present conditions of operation with the electric locomotives, the tunnel ventilation is perfect, whereas, with the steam locomotives difficulty was experienced on account of the accumulation of coal gas. The tunnel is now whitewashed and well lighted throughout, making a trip through it a pleasing experience, whether on a train or on foot. The electric locomotives have been in regular 24 hour service since May 17th of the present year, and for about two months previous to this they were operated for approximately 18 hours each day.

The inauguration of the electric service has brought about a considerable reduction in the coal bill, but sufficient time has not elapsed to enable a comparison to be made with the cost of steam operation.

The engineers and firemen formerly used for operating the steam locomotives have been educated to operate the electric locomotives, and are meeting with success in their new occupation.

Both freight and passenger trains are now controlled by air brakes. The trains are operated at a much more uniform speed and, although much heavier trains are hauled, a "break loose" due to the pulling out of draw bars, etc., is an exception.

Each locomotive consists of two half units coupled. Each half unit has three axles, each with a geared, single phase, 250 h.p., 240 volt, commutating series motor. A half unit weighs 62½ tons, the entire locomotive weighing 125 tons and geared for 50,000 pounds draw bar pull at 10 miles per hour, which gives approximately full load with a 1,000 ton train on a 2 per cent. grade. These locomotives can give a maximum draw bar pull of 80,000 pounds, but this, of course, would be excessive for the average draft gear. The multiple unit system of control is employed, the switches of which are operated by air pistons whose valves are controlled by electro magnets which receive current through the master controller from a set of storage batteries which are charged from a small motor generator set on the locomotive. The quadrant of the master controller has 20 notches, 17 of which are running positions, the other three being known as switching notches and are used when coupling up trains, or at times when slow speed is desired. When two or more locomotives are connected together, all are operated from one controller.

The equipment of each half unit consists of the pantagraph which makes electric contact with the trolley lines, the auto-transformer, switch groups, control system, three main motors, electrically driven air compressor, electrically driven fan or blower, wiring and meters, air brake and hand brake equipment, electro-pneumatic and mechanical sanders and lighting and heating circuits.

The locomotive frames are of the rigid outside bar type and consist of two cast steel side frames, joined at the ends by cast steel bumper girders and reinforced by cross braces at two intermediate points. The main journal boxes are carried in the side frames in recesses fitted with gibb and wedges.

The driving wheels are 62 inches in diameter and are built up with steel centres and steel tires secured in place with double "Mansel" retaining rings.

The entire weight of the locomotive is on the three pairs of drivers.

The cab is built of sheet steel with Z-bar frame built up on an angle iron base frame.

The auxiliary apparatus is arranged on each side of the cab. leaving a comparatively wide aisle between.

Trap doors are provided above each of the three motors to make them accessible.

A master controller and set of brake valves are mounted at each end of the cab so that the locomotive may be operated from either end.

Heavy currents are carried from one piece of apparatus to another in the cab by means of corded copper rods, while the smaller currents are carried by rubber insulated wire placed in iron conduit.

The motors are connected in multiple, and are so arranged that any one or two motors can be disconnected in the event of trouble.

The cut-out switches are designated by numbers and are mounted on the end of the reverse group.

The blower supplies air for ventilating the motors and auto-transformers and also for cooling the air compressor heads.

The continuous capacity of the motors under forced ventilation is 750 amperes at 235 volts. The motors are supported by the axles on one side and by a nose suspension on the other.

The control system for each half unit consists of one 3,300 volt auto-transformer, three preventive coils, a train line relay, three switch groups, two master controllers, two small storage batteries and a small motor generator set.

The main auto-transformer is located on the side of the cab near its centre. It is connected to the trolley by a high tension cable through an oil circuit breaker provided with a no voltage release protective relay. In case the locomotive should leave the rails and the frame thus become insulated from the ground, this relay would cause the circuit breaker to open and remain open until the ground connection to the locomotive frame had been re-established and the circuit breaker re-set; the three preventive coils are located directly over the blower in No. 1 end of the cab and provide a means of stepping from one transformer tap to another without producing a short circuit in the transformer, or an open circuit to the motors; at the same time, they serve to distribute the motor current among the four switches in the transformer switch groups.

The train line relay is located between the transformer switch groups, its purpose being to enable a number of the wires leading from the master controllers to be used twice, thus cutting down the number of control wires required between locomotives and at the same time shortening the length of the controller drum.

There are three switch groups on each half unit, two being transformer groups and the third the reverse group. The transformer groups are located above the transformer with the train line relay between them. Each group consists of ten electro-pneumatically operated switches. The function of these groups is to connect the motors to the various taps on the auto-transformer to give the requisite speed regulation. These switch groups being very close to the transformer, the leads between the two pieces of apparatus are very short. The third switch group is located on the opposite side of the locomotive and consists of twelve electro-pneumatically operated switches. The switches in this group control the direction in which the locomotive is run; there are four of these switches for each motor, two for operating in the forward direction and two for reversing.

The master controller is so placed that the engineer can have a clear view ahead from his seat and, at the same time, can operate the controller and brake valve handles. Each master controller has two interlocking handles, one being the operating handle and the other the reversing handle. The master controller operates the various switches in the switch group by current from the 20 volt storage battery circuit. In the operation of the locomotive, the controller can be left in any of the seventeen running notches as there is no resistance to overheat and burn out. The engineer is guided in the operation of the controller by an ammeter mounted directly before him in the cab. In the event of the engineer moving his controller handle too fast, the circuit breaker will open and cannot be re-set until he has moved the controller handle to the "off" position.

Across the top of the controller are located a number of push buttons which, when pressed, operate respectively, the pneumatic bell ringer, pneumatic sanders, circuit breaker re-set and pantagraph trolley. Foot pedals are within reach of the engineer's foot which also serve to operate the bell and sanders.

There is no doubt but that we will find the largest item in connection with the general overhauling of the locomotives will be the turning of tires and the painting. There should be far less tire wear than with the steam locomotives because there is seldom any slipping of the wheels. It has been stated that with the electric locomotives the wear is only one thirty-second of an inch for 30,000 miles run as compared with 8,000 or 9,000 for the steam locomotives.

The inspection of an electric locomotive consumes more time than that required for a steam locomotive, owing to the greater number of parts requiring attention, but this is, perhaps, offset owing to the fact that the inspections are not so frequent.

Upon a locomotive going to the shop for inspection, the dust is blown out of the electrical apparatus by an air blast; all motors, brushes, commutators, controllers and the entire control system are examined and cleaned; the air brake system is also inspected and tested and, if found necessary, the pantagraph shoe is renewed, at the same time all journals are examined and oiled and the sand boxes refilled.

DISTRIBUTION SYSTEM.

All cables leaving the Power House are taken into the tunnel through a vertical, concrete shaft containing the various cable ducts. This concrete shaft is directly over the tunnel at the south side of the Power House, near the bank of the St. Clair River at Port Huron, and the locomotive feeders tap the trolley and rail at this point. The trolley extends a distance of about 3.7 miles and where passing through the tunnel, is supported by insulators secured to the roof; these insulators are known as the "barrel" type and support two steel messenger cables at a distance of about three inches from the tunnel shell and these, in turn, support the two trolley wires, which are about six inches lower. The insulators are twelve feet apart.

In the tunnel cuts and in the yards, a single catenary construction is employed; this consists of a heavy steel messenger cable which is supported by insulators on steel bridges which span the tracks and from these cables the trolley is hung by vertical hangers made of galvanized iron pipe cut in varying lengths and so distributed as to avoid any sag in the trolley lines. The trolley is staggered, or diverted from a straight line, in order to distribute the wear on the pantagraph shoes when a locomotive is passing under it. In addition to the locomotive feeders, there are two, three phase cables for the tunnel lights and motor driven pumps in the tunnel, two for the three pumps at the tunnel portal, Port Huron, and two for the three pumps at the tunnel portal, Sarnia, and power feeders and arc light feeders for light and power in the tunnel yards, engine houses and passenger stations at Port Huron and Sarnia. These cables are carried through the tunnel in concrete duct lines built on each side of the tunnel; paper insulated, lead sheathed cables are employed.

The tunnel is lighted by 480 16 c.p. incandescent lamps, spaced 25 feet apart on each side and alternated so as to bring a light every 12½ feet. The transformers for this lighting deliver current at 440 volts.

There are a number of indicating lightning arresters connected to the aerial lines and, so far, these have given satisfactory results except that slight inconvenience has been felt at times due to birds perching on the arcing tips and thus causing a short circuit.

On account of 25 cycle current being employed, it was deemed advisable to operate all arc lamps through the medium of a mercury vapor rectifier.

Power Station.

The Power Station is situated on the bank of the St. Clair River at Port Huron, Mich. It is constructed of concrete to the level of the turbine room floor and above this are paving blocks, corniced and coped with concrete. The roof consists of cinder concrete and is almost flat, only sufficient slope being allowed to permit of proper drainage. The turbine room is lofty and well lighted with incandescent lamps supported by artistic wall brackets and Nernst lamps supported by the roof trusses above the crane girders. The walls are lined with white enamel brick to a height of 8 feet from the floor and above this is sand lime brick. In the front of the building are the superintendent's office, switch board room and engineers' room, each of which is finished in black oak, the offices being furnished with mission style furniture to match.

The turbine room contains two 1,250 k.w. Westinghouse-Parsons 3 phase, 25 cycle, 3,300 volt turbo-generators, two barometric condensers, two engine driven exciters, one motor driven exciter and two dry air pumps.

The turbine room basement contains two engine driven circulating pumps of the turbine type, one house pump, two engine driven stoker fans, the transformer room, (which also contains the mercury vapor rectifier for the arc lights) a store room and a lavatory.

The auxiliary apparatus can be seen from the turbine room floor.

The boiler room floor is on the same level as the turbine room basement and contains four Babcock & Wilcox water tube boilers of 400 nominal horse power each, they have three drums and are equipped with Jones' Underfeed Stokers. There are two boiler feed pumps and an independently fired superheater which is equipped with an automatic regulator for controlling the steam temperature.

Above, and in front of the boilers, are concrete coal bunkers capable of storing 500 tons of coal which is fed through spouts to the stoker hoppers and superheater. The main steam header furnishes steam at a pressure of 200 pounds and in addition to this is a steam header carrying a pressure of 125 pounds for operating the auxiliary engines. The reduction in steam pressure is made through the medium of automatic reducing valves.

The two boiler feed pumps take their supply from wells which catch the water from the condenser discharge; before reaching the boilers, the feed water passes through vertical feed water heaters which receive the exhaust steam from auxiliaries.

The smoke stack is of concrete with a rectangular brick base, its height is about 175 feet.

When operating condensing air is prevented from entering the turbine glands by a water seal and in order to avoid a possibility of these seals being broken as a result of the failure of the house pump, we connected the pump discharge line and the city water service together, but placed a check valve in the city line so that in the event of a pump failure the check valve opens and city water is supplied without interruption; this was made possible owing to the fact that the pump maintains a higher pressure than the city mains.

The load factor is necessarily poor, but the station was designed to meet the tunnel conditions and its economy is all that might be expected from a single track, heavy grade load.

THE SINGLE PHASE RAILWAY MOTOR.

It may be of interest to you to learn something of the operation of the single phase motors which we are using at the St. Clair Tunnel; I will, therefore, endeavor, in a few words, to make this plain.

It is our experience with the direct current series motor that if the direction of current in both armature and field be changed, the armature will continue to revolve in the same direction; so, too, with alternating current in the motor and with the armature and field in series, the direction of rotation will not change with reversals of the alternating current and the armature will revolve just as it does with direct current.

So far as the production of mechanical energy is concerned, the action of the motor is practically the same whether direct or alternating current is used, in fact alternating current, as such, is not essential to the operation of these single phase motors; they have been developed so that they operate satisfactorily in spite of certain difficulties inherent in the alternating current, so that they have the proper speed characteristics for railway work.

The direct current series motor may be considered a special case of the more general alternating current motor, for, while the alternating current motor makes an equally successful direct current motor, the reverse is not true. The changes in voltage, load, etc., have corresponding effect on speed and torque in the alternating current motor as similar changes in the direct current motor; the practical operation of the two motors is therefore the same. The alternating current motor is started by lowering the voltage through the medium of auto-transformers and the motors are reversed by inter-changing either the field or armature connections as in the ordinary railway motor.

While, in general, the alternating current series motor works on the same principles as the corresponding direct current motor, several things happen inside of the former by reason of the varying magnetic field produced by the alternating current, that are not found in the direct current motor. The characteristics of the alternating current motor are:

(1) An e.m.f. generated in the armature winding by the alternating magnetic field, in addition to the e.m.f. generated by the rotation of the armature.

(2) A local current generated in the armature coils, short circuited by the brushes due to this e.m.f.

(3) An iron loss occurring in the entire magnetic circuit, due to the alternating magnetic field.

(4) An active e.m.f. existing between the turns of the field coils which may be termed the counter e.m.f. of the field coils.

With an alternating magnetic field there are two distinct e.m.f.'s generated in the armature coils, first by the movement of the coil through the field with a maximum value when the coil is parallel to the lines of force and a zero value when the coil is at right angles to these lines — and the second by the alternating magnetism, with the maximum value occurring when the coil is at right angles to the lines of force and a zero value when the coil is parallel to these lines. The first, or mechanically generated e.m.f. is proportional to the speed; the second, or electrically generated e.m.f. is proportional to the current frequency. While these two e.m.f.'s exist in the armature winding, only one, the mechanically generated e.m.f. appears at the terminals of the motor. So far as the external circuit is concerned, the electrically generated e.m.f. neutralizes itself and plays no part in determining the current taken by the motor, but at each brush there is a local circuit in which the electrically generated e.m.f. is not neutralized; a current results, which, if not prevented, affects commutation and increases motor loss; this, however, has been taken care of in the design of the motors so that the operation is quite satisfactory.

The external appearance of the single phase motor in general is similar to that of direct current motors; the construction, however, is slightly different in that the entire magnetic part of the field is laminated, the field being built up of annular punchings with poles projecting radically inward. The punchings are held together in a steel frame, the armature being put in or taken out through the ends. The armature is also similar in appearance to the armatures of direct current railway motors.

There is very little tendency to flash across between brushes or from the brushes to the frame of the motor and the commutation is very satisfactory, the sparking being so slight as to be barely noticable.

The operation of direct current railway systems has been very satisfactory for two main reasons: first, because the direct current series motor, owing to its variable field, has speed torque characteristics which make it particularly suitable for traction work and, secondly, because only a single trolley is necessary. The direct current railway system has, however, some disadvantages, the most serious of which, perhaps, is the comparatively low trolley voltage which is necessary. This feature has hampered, to a considerable extent the development of such roads. Owing to the ease and economy of voltage transformation with alternating current, the use of alternating current motors permits of a high trolley voltage and at the same time a low voltage at the motors, since a transformer can readily be placed on the locomotive to reduce this trolley voltage for use at the motors. The alternating current railway system possesses the two main advantages of the direct current system, since the motor has the same speed torque characteristics as the direct current series motor and single phase circuits require only one trolley. In addition to possessing these two advantages, the alternating current system overcomes a number of limitations. With the alternating current the arrangement of high trolley voltage giving economy of transmission and low motor voltage giving minimum motor trouble, can be obtained by means of a transformer on the locomotive.

Long distance roads can be supplied with transformer stations instead of rotary converter sub-stations and contain no synchronous or moving machinery. The omission of synchronous machinery renders the service less liable to interruption, since momentary short circuits or similar troubles which might interrupt the service where synchronous apparatus is used, would in many cases cause no interruption in a system where such apparatus was not used and in case of a shut-down from any cause, service in a system without synchronous apparatus can be resumed more quickly than in the case of one in which it is necessary to synchronize a number of rotary converters before power can be put on the line. Owing to the ease and economy of voltage transformation with alternating current, any desired voltage may be applied to the motors without the use of resistance, motors may thus be run at full speed, or at any lower speed, and the power consumption at all speeds will be proportional to the energy actually expended in driving the locomotive, so that, since there are no rheostats, there will be no rheostatic loss. With the use of alternating current, electrolysis is practically eliminated.

In concluding this description of the various features of the single phase railway system as used at the St. Clair Tunnel, it should be borne in mind that the advantages accruing from this system are due primarily to the use of alternating current, rather than to any advantages of the alternating current railway motor over the direct current railway motor.

My aim being to give you a general outline of the electrification scheme employed for handling traffic through the St. Clair Tunnel, I will refrain from going further into the details of the apparatus employed.

SERVICE.

The tunnel service is carried out by the aid of block signals, telegraph and telephones.

The Westinghouse Electric and Manufacturing Company were the general contractors and Mr. B. J. Arnold was the consulting engineer for the railway company.

Chairman,—

Mr. Burrows, I believe you are a recent arrival from the scene of the fray, and as usual, will no doubt have something interesting to say on this question.

Mr. Burrows,—

I have listened with a great deal of pleasure to this paper, and it is of greater interest to me because I was afforded an opportunity last week, through the kindness of the management of the Grand Trunk Railway, of being present at the official inspection of that electrical plant. I have never spent a more interesting day in my life than at the opening of the tunnel. I would advise you all when you get a chance, to go through the tunnel and look over the plant, not only the electric zone but the power house as well.

The greatest advantage, which struck me when going through the tunnel, was the elimination of the element of danger, especially in the operation of passenger trains. Referring to a few remarks which I made when there: We all remember the sad accident which occurred at the tunnel several years ago, in which several lives were lost. The other day we travelled through the tunnel, leaving Port Huron at 1 o'clock, and went through on a train of flat cars, which had been fitted up with railings around them and seats from passenger coaches. We went through the tunnel at a fairly slow rate of speed, and I must say it was beautifully lighted. It was lighted as well as any of the streets in Toronto at night. In fact, I suggested to Mr. Davis, Passenger Traffic Manager of the Grand Trunk, to start moonlight excursions through the tunnel in the summer time, as it would be an interesting ride and would cool off the passengers.

Another important matter is the efficiency of the tunnel in the large number of trains which can be handled. Then again, I will show you, in a few minutes, that there is much greater economy with the electric locomotive now than with the old steam locomotive.

One of the most interesting persons present that day in connection with the functions, was Mr. Joseph Hobson, an engineer who is second to none in point of achievement in the United States or Canada. I think I can say, without being at all disparaging, that what Mr. Hobson carried out the work of building the tunnel itself—was wonderful. He had not modern tools to work with, and the difficulties were enormous, hydraulic work and concrete work were in their infancy. Mr. Hobson said in responding to the toast to his health, that he felt, very often, like throwing up the task. As you know a very extensive power plant had to be maintained.

Mr. Hall's paper is a very interesting one, and is a good description of the plant, etc. I have a little data here which, if I am not taking too much time, I would read supplementary to Mr. Hall's paper. I think it will be interesting to steam railway and mechanical men, especially. The data has been prepared by Mr. H. L. Kirker, Resident Engineer of the Westinghouse Co.

Electrification has increased the capacity of the St. Clair Tunnel fully thirty per cent., it has removed a serious handicap from the passenger service and reduced the operating expenses.

The electric locomotives handle 1,000 ton trains where the steam locomotives handled 700 ton trains. The electric locomotives climb the 2% grades with these trains at 10 miles per hour, where the steam locomotives were barely able to pull out at 3 miles per hour. Under electric conditions the average time from summit to summit is 10 minutes and the average number of cars per train is 27.3, and this number can be increased. Under steam conditions the average time from summit to summit was 15 minutes, and the average number of cars per train was 19.7. During the first 24 hours of continuous electric service 1,529 freight cars and the usual number of passenger trains were put through the tunnel. This was done without any attempt to establish a record. The record under steam conditions (exclusive of one for which extraordinary preparations were made) was 1,501 freight cars and the usual number of passenger trains. The average number of freight cars per day in January 1908 (steam service) was 937, the average in February was 682, in March 923. The low average in February was due mainly to snow blockades resulting from the eleven blizzards that occurred during that month. During the first half of March the business that offered exceeded the capacity of the tunnel. Just after the middle of March an 18 hour per day electric service was instituted. The first time the service was carried through 24 hours (March 23), the result indicated above was obtained. For several years past the business offered during the season of closed lake navigation has at times exceeded the capacity of the tunnel. With the electric service the capacity of the tunnel exceeds the capacity of the terminals. A run can be made through the tunnel every fifteen minutes. Assuming 70 per cent. of these runs to be freight and the average number of cars per train to be thirty, the total is 2,016 freight cars per day, which is more than 30 per cent. greater than was the steam capacity of the tunnel.

The electric locomotives have transformed the atmospheric conditions of the tunnel. The air has been cleared of the exhaust steam and gases of combustion. The tunnel is now as clean and well lighted as a city street, and the air is as pure as the St. Clair River air. Air brakes can now be used on all trains. With the steam service hand brakes had to be used on freight trains. Had the air brakes been used a break-in-two in the tunnel would have held the engine in the tunnel beyond the danger limit. Fortunately no accident ever occurred to a passenger train during the eighteen years of steam service. There have been of course numerous break-in-twos and occasional derailments with freight trains, some of which accidents were accompanied with results that gave the tunnel a sinister reputation. With the electric service the tunnel trip is a safe and comfortable one. Moreover, the elimination of the exhaust steam and the corroding fumes has done away with what was a source of depreciation on the passenger rolling stock. A further saving in operation has been effected, due to the fact that the electric locomotives are less severe on the rails than the steam locomotives were.

The fuel bills for the locomotives during the last six months of steam service averaged $4,956.00 per month. The fuel bill for the first six months of the electric service averaged $1,152.60 per month. Hard coal costing $6.00 per ton was used on the steam locomotives, bituminous coal costing $2.00 per ton is used in the tunnel power station. The maintenance of the steam locomotives averaged 13.6 cents per locomotive mile. The maintenance of the electric locomotives during the first six months of service was 4.3 cents per locomotive mile. There has been a fifteen per cent. reduction in the total wages paid to locomotive crews and 23 per cent. reduction in the total wages paid to train crews. The first six months of electric operation shows a 44 per cent. reduction on the cost of steam operation.

The electric locomotives have handled the entire tunnel service since May 17th, 1908, prior to which date there were two months of 18 hours per day electric service and prior to which period there was some preliminary electric operation. The transition period occupied about ten weeks, continuous electric service not being inaugurated until the men and equipment were thoroughly seasoned. Gradual transition was of course but common prudence, as the results have abundantly proved. The change-over was made with practically no interference to traffic, and the new service has been a success from the start. But each of the five original locomotives has made more than 23,000 miles. The wear on the gears is inappreciable, and the pinions, from present indications, will each make 50,000 miles. Main motor brushes are making 15,000 miles and the pantagraph shoes average 2,000, some have made 3,400 miles. The life of the brake shoes has been quite variable, however. The original shoes made from 5,000 to 6,000 miles.

Steel shoes have been found to be quite unsatisfactory. Various kinds of cast iron shoes are now being tried. Their life is ranging from 400 to 2,000 miles. The commutation of the motors is good. The control system is practically troubleless. There has been some weeding out of defects that were not discovered during the test, but the amount has been small. Two main motors and one auxiliary motor have failed. The trouble in each instance seems to have been due to defective workmanship. During the last six months there have been thirty-four delays to traffic, nine of which were chargeable to the electric locomotive. The power consumption for passenger service is averaging about thirty-eight watt hours per ton mile, and for the freight service about thirty-five watts per ton mile. Trouble with the overhead construction outside the tunnel has been limited to several lightening arrester failures and the replacement of some three or four trolley ears. In the tunnel but two insulators have failed since the commencement of the service. On one occasion the trolley wire was burnt in two through the careless resetting of the pantagraph of a work train locomotive standing in the tunnel. On another occasion a box car with an extraordinary high hand brake wheel grounded the tunnel trolley. The trolley breaker cleared the trouble and no damage to the construction resulted. The wear on the trolley wire is insignificant.

The chairman has just handed me the following extract from a press article:—

Electric headlights are provided, as well as lights for the illumination of the interior of the cab and the dials of the indicating instruments. The heating of the cab is provided for by means of standard electric heaters. Heat is also available for drying sand stored in sand boxes. In general the M.C.B. standards have been conformed with in so far as couplers, wheel treads, etc., are concerned. The general dimensions of the half-units are as follows:

Length over all, 23 ft. 6 ins.

Height from top of rail to top of roof, 13 ft.

Height from top of rail to top of pantograph bow when lowered, 14 ft. 11 ins.

Width of cab over all, 9 ft. 8 ins.

Total weight of locomotive half-unit, fully equipped, 67½ tons.

(This weight is practically evenly divided over three drivers)

Weight of complete locomotive unit, 135 tons.

Length of rigid wheel base, 16 ft.

Diameter of driving wheels, 62 ins.

Normal speed of train ascending 2 per cent. grade (miles per hour) 10 miles

Normal speed on level tracks (miles per hour), 25 to 30.

Chairman,—

Mr. Wickens, have you something to say on this subject?

Mr. Wickens,—

From what has been said to-night it seems to show that the steam locomotive is doomed. It looks as though the day will come when we will have electric railroads out and out. In fact it shows the electric locomotive as being more efficient than the steam locomotive, whose weight has increased so much that it is difficult to keep the tracks in repair under its weight. The starting of trains is very hard on all parts of the steam locomotive, but from reports on the comparison of the two locomotives in this tunnel (taking into consideration the grade of 2 per cent.) it shows conclusively that many of the troubles which have been connected with the steam locomotive, have been eliminated entirely by the use of the electric locomotive. Besides this, the cost of operation seems to be reduced to a great extent, and perhaps the cost has not been reduced yet as far as it may be. For instance, they are using the turbine with superheated steam. I think it is safe to say, that it would give better steam economy in the end, if they used reciprocating engines and put in low pressure turbines, because more steam would get converted into mechanical work better than any other way. It is quite likely that the cost of operation of this plant would be considerably reduced if the steam equipment was built in that particular way in the powerhouse. Then as far as the electric construction of these locomotives is concerned, the use of the alternating current in single phase, they have reached practically the desideratim as far as we know.

They have also got rid of many of the troubles connected with the direct current, and they have adopted the system as used for long distances. When you use the alternating current at high voltage, you can send it a longer distance on a smaller wire with a less drop.

We may expect to see all locomotives, in time, run by electricity, unless Edison gives us something better. However, when we were boys we thought the electric light was an impossibility. Then again we are now seeing the wireless telegram flashed across the ocean. Now these things seemed to us, years, ago, just as impossible as what Edison is now trying to do—get power from coal direct. Now that the electrification of the St. Clair tunnel has proved perfectly successful, it will be only the fore-runner of other things as marvellous along these lines.

I will not take up your time regarding the construction of these locomotives, as I do not know anything about them. However, I feel that I would like to spend a day on one of them.

Chairman,—

We have with us to-night, Mr. D. W. Robb, of the Robb Engineering Co. We shall be glad to hear from Mr. Robb.

Mr. Robb,—

I have been very much interested in the paper. It is certainly very interesting, and while I have read accounts of this work, yet I have not had an opportunity to visit the St. Clair Tunnel since its electrification. I remember the former conditions of it, having gone through it on several occasions, and remember of the accident a number of years ago. Of course this is particularly interesting to steam men because it shows, as Mr. Wickens has already said, what may be done in way of stationary engines or turbines. Of course it brings us one step nearer to the electrification of railways, although a good deal has already been done, when you consider the work that has been done on the New York Central and its suburban lines, also the work done at other places. Of course this is something new and was done under very hard conditions.

Chairman,—

Mr. Robb, I am sure we are all pleased to have you with us to-night, and to hear your remarks.

We should also like to hear from Mr. McKay.

Mr. McKay,—

I do not think I can say anything more than has been said to-night. Mr. Robb being in town, I thought it would be interesting for him to hear this paper read on the electrification of the tunnel. I was very anxious, myself, that he should come with me to-night, as this is my first visit to the association, and I thought I would like a little protection. However, you all look very good, and as you have not done anything serious to my friend, Mr. Wickens, I think I may feel safe.

I was through the tunnel several times years ago, and can testify as to the dangers of the place, however, I am pleased to hear that you have, at last, got rid of the many difficulties formerly attending it.

I think some of the comparisons look rather rosy. Of course they are comparing the development of the locomotive to-day with those built as long back as Mr. Wickens can remember. Then again there is a difference in the kind of coal used. I remember the time when the firemen on the old steam locomotives had great trouble in keeping the grates covered. Now they are built to use a cheaper grade of coal. I think myself, as Mr. Wickens has already said, that they could still do better, if they used a different type of engine in their power house. However, I am pleased indeed to know that they have succeeded as well as they have, and hope sometime to visit the tunnel and be able to say more about it.

Thanking you for the attention.

Chairman,—

Mr. Duguid, of Stratford, is here, and perhaps he would like to say a few words.

Mr. Duguid,—

You cannot expect me to say very much regarding the electrification of the St. Clair Tunnel. I have only visited the roundhouse there on business and not in connection with the tunnel, and when it comes to the question of electricity, you cannot expect me to express my views the same as some of these other gentlemen. To discuss the paper intelligently I would have to take sometime to study it up. Because I am in the employ of the Grand Trunk Railway at Stratford, you should not infer that I know anything about the St. Clair Tunnel. No doubt there are a great many gentlemen in the room who are better able to discuss the paper. During the last eighteen months we have had a hard proposition on our hands at Stratford, which has kept us busy. I practically know nothing about the tunnel and therefore cannot say anything about it.

Chairman,—

Probably it is possible that Mr. Hall will be here at our next meeting, and if there is any questions which you may care to ask, and which cannot be answered by some of our members in the room, if you will keep these questions until the next meeting, I am sure Mr. Hall will be glad to answer same for you. Between now and the next meeting you can look up the different questions you wish to ask.

We are greatly indebted to Mr. Hall for this very fine paper which has been presented to us to-night. I am sure we all enjoyed it.

Probably it might be in order for me to say something being an electric traction man. I do not bother my head about the operation of the power department. I have found that of late years the electric traction business is becoming divided up into a number of propositions all coupled into the one profession, very much in the same manner as the medical profession. That is, the man who looks after the production of power, and the man who looks after the rolling stock, have their hands full in their own respective departments. My advice to any person who intends studying up this question, is to select some particular line of the business and follow that up particularly. Mr. Burrows and Mr. Wickens have taken away a great deal of my thunder.

I find it necessary that I must leave you, and would ask our vice-president, Mr. Burrows, to take the chair and relieve me of the duty.

It will be very good order to pass a vote of thanks to the writer of this paper.

Chairman,—

I think we ought to act on the president's suggestion and pass a vote of thanks to Mr. Hall. I would be very glad if somebody would propose a vote of thanks to Mr. Hall, who has gone to a great deal of trouble in the preparation of this paper.

Mr. Black,—

I am very pleased to hear that the tunnel is now completed, and it is not necessary now to pull down the windows and be in darkness until you come out on the other side.

It gives me very much pleasure in moving a vote of thanks to Mr. Hall for his fine paper. Seconded by Mr. Jeffris.

Chairman,—

You have heard the resolution before you; what is your pleasure in the matter? Carried.

Chairman,—

The secretary will write Mr. Hall and express to him our vote of thanks, and also invite him to visit us.

I think we also should pass a vote of thanks to Mr. Bly for filling up the breach and reading the paper. I wish to move a vote of thanks to Mr. Bly.

Mr. Bird,—

I have very much pleasure in seconding the motion. Although I was a little late in coming, yet I have enjoyed the evening.

Chairman,—

Mr. Bly, I have pleasure in expressing to you the vote of thanks of the Club.

Mr. Bly,—

Thank you, Mr. Chairman, and gentlemen, for the vote of thanks, which I accept on behalf of Mr. Hall, who has taken so much trouble to prepare the paper which I have read to you. I hope that in the near future we shall hear from Mr. Hall himself.

Chairman,—

I think that practically disposes of the business for to-night. I suppose everybody has signed the attendance cards.

The president has already spoken to you of the payment of fees which are in arrears. I feel rather diffident in speaking of this, but I think we can offer the excuse—that is to try and increase the membership. We have done very well for a new Club. Of course we are laboring under difficulties in starting a railway club here, whereas in Montreal it is the headquarters of two large railroads. However, if every member would go away to-night with the resolution to bring in a new member, it will help a great deal.

Of course you have heard the nomination of members for the committee, but I would like to say that these recommendations are not in any way binding on the Club.

At our next meeting on the 22nd of December, the annual election of officers takes place. Our good friend, Mr. Wickens, notwithstanding the hard things Mr. McKay has said about him to-night, is going to give us a paper, and we hope to have a good turn out. Above all things we should start on time like the trains do. At least they start out on time even though they do not always arrive on time.

The next order of business is, adjournment of meeting.

Moved by Mr. McLintock and seconded by Mr. Brown, that meeting be adjourned.