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Canadian Society of Civil Engineers.

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This Paper will be read on the evening of Thursday, May 17th.

ELECTRIC LIGHTING.

BY H. Y. THORNBERRY.

The object of this paper will be to give a brief résumé of Electric Lighting, of its discovery and development until the present time.

Very little was known of Electricity in 1790; yet from that year dates the discovery by Galvani of the electro-chemical action of two metals in the presence of moisture.

It was not until six years later that Volta devised the Voltaic Pile, the first source of a constant current of electricity.

It may be remarked as a queer coincidence that illuminating gas was discovered, and the possibility of making gas from coal demonstrated at a date almost coincident with the discovery of the galvanic current. It was not, however, until 1810, a Gas Company was formed for general lighting in London. It was in that year Sir Humphrey Davy discovered the Voltaic Arc.

So rapid, however, was the introduction of gas as an illuminant that 20 years had made it general, while the Electric Light had as yet only been born.

It must not, however, be supposed the want of progress in Electric Lighting was due to inactivity on the part of those from whom the world was to have the discoveries that were to make it a success.

Among the inventions of eminent men that led the way to electric lighting may be mentioned those of Arogo, who discovered the magnetizing effect of the galvanic current, and gave us the beautiful experiment termed the Arogo Disk.

Farada, in 1831, began his masterly researches, and gave the world his discovery of magnito-induction. In Farada's discovery, Electric Lighting takes its rise, and from his time date the inventions that have made it a possibility.

Following Farada, Pixi and Saxton produced the magneto-electric machine.

The Pixi machine is composed of a strong horseshoe permanent magnet, before the ends of which two spools of covered wire wound on U

his discovery of magnito-induction. In Farada's discovery, Electric

It was not until twenty years after Farada's discovery the first successful machine was produced, capable of sustaining the electric arc light.

Pacionotti is recorded as the first designer of a continuous current machine. Pacionotti conceived the method of revolving a continuous ring of iron before the poles of a strong magnet. The ring he divided into sections, with projecting teeth and wound on each section a coil of wire. On revolving the ring the polarity of each successive section or portion of the ring is changed, as it passes before the poles of the magnet, and currents are induced in each coil as it comes into the position of greatest magnetism. Instead of the alternating current of the Pixi machine we obtain in the Pacionotti dynamo a continuous current by means of a commutator or ring, divided into as many segments as there are sections in the revolving ring, each segment being connected to the corresponding spool of wire. The current is commuted and carried away by means of strips of copper resting on the commutator.

The action of this machine and of all continuous current dynamos may be likened to the familiar chain pump. The chain pump you will remember is operated by the revolution of an endless chain running over a wheel, and passing through a tube just large enough to admit the disk formed links, placed at intervals in the chain's length.

On revolving the chain, the disk links act as linkets bringing to the top of the tube a given amount of water on each revolution. The energy absorbed is proportional to the speed at which the chain travels and to the amount of water raised. In the Pacionotti dynamo each spool of wire acts as does the disk links on the chain, throwing into the electric circuit a given amount of electricity at every revolution.

The analogy is not quite true, but will serve as an illustration of the primary action occurring in the dynamo. The difference lies in the fact that the potential of the water raised remains constant, but the potential of the electric current produced increases as I have before stated directly as the speed.

In place of the permanent magnet used by Pixi, Pacionotti used the current generated by his machine to charge its own field magnets, the method now universally used in all continuous current machines. Pacionotti was followed soon after by Gramme who reinvented his ring, and by Siemens.

The action of the Gramme ring is in all respects the same as that of the Pacionotti ring. The Gramme ring differs only from the Pacionotti ring in the absence of teeth or projections on its periphery. The winding of the armature is greatly facilitated by the absence of the projections. The Gramme construction, because of its many advantages, has been adopted by several designers of dynamos. The Siemens armature, termed the drum armature, is used very largely by dynamo builders, because of the ease with which it can be wound. The Gramme and Siemens type of armature are more largely used than are any other designs.

The Brush armature follows the design of Pacionotti. One fourth of

projections. The Gramme construction, because of its many advantages,
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from 1 to 150 candles, and recently of 600 to 800 candles. Lamps o such high candle power have not heretofore been made. The economy of such a lamp remains to be established.

We have to-day another method of electric lighting, termed the alternating system. The method employed is to produce by an improved machine an alternating current of very high pressure, and to reduce or convert it to a low pressure suitable for house-lighting The conversion is for two purposes: on the score of economy, because by running the machine at a high pressure, a much smaller wire is necessary, and the current can be carried great distance at a comparatively small cost for wires, a large item in installing an Electric Light plant; safety, because a low pressure current is comparatively harmless.

In explanation of electric pressure, allow me to repeat a very apt illustration of the action of a dynamo machine forcing a current into a wire or series of wires.

It is this; the action is analogous to that of a force pump keeping up a pressure upon a line of hose pipe. Every point where leakage of the electric current occurs, and may liken to pin holes in the hose. Water leaking at innumerable pin holes reduces the pressure in the pipe, until perhaps the farthest end of the line of pipe receives no pressure at all. The higher the pump pressure at the source the greater the leakage at a given pin hole. So in handling the electric current we must provide against such leakages by making our conductors as perfect as possible, and to see that in no place does the wire come into contact with the limbs of a tree, or what not, that may convey a portion of the current pressure to the ground. We must, as engineers do, allow for a given loss of pressure due to the friction of the current traversing the conductor, and to reduce this loss of pressure or heat. We make our conductor as large as economy in outlay will permit.

The converter used in the alternating system is a well constructed induction coil. The construction in a simple form is as follows: a bundle of iron wires are wound on one end, with a spool of very fine wire, called the primary. On the reverse end with a spool of comparatively coarse wire tinned the secondary. To the primary wires are connected the wires from the Dynamo machine, and to the secondary, the wires leading to the lamps to be lighted.

The action in the coil is as follows: on every reversal of the charging-current, 200 and upward times per second, a reverse current is induced in the secondary wire by reason of the discharge and reversal of magnetism in the bundle of iron wires. The reversals of the current are so nearly continuous, no perceptible variation is discernable in the lamps.

The alternating current method of generating power has been applied to the electric arc light and to electric motors, making it a complete system, leaving nothing else to be lesired. A prediction was made at the last convention of Electric Light men, that the alternating system will eventually displace all other systems, by reason of the safety with which the current can be handled by the consumer. This is admitted of by reason of the conversion from a high to a low pressure entrance

The alternating current method of generating power has been applied
to the electric arc light and to electric motors, making it a complete

station. If a greater distance is found to be necessary for locating the station, the alternating system would most likely be selected.

These considerations apply to incandescent lighting alone. The limit of 1000 feet does not apply to what is termed the multiple series system.

In this system the pressure is constant, but four or five times as high as in the direct system.

The disadvantages are that when one lamp of a series of fire is wanted, the current for fire is consumed, creating something of a loss in power over the direct system.

If the system selected is to be an arc light system, the loss of power is not so serions a consideration. The arc light system and the alternating system are somewhat upon the same footing in that respect, in that both systems are run at high pressure. Everything remaining equal the higher the pressure the smaller the wire required to do a given current. The current into the pressure is a measure of the capacity for work.

One of the practical difficulties to be met is that of insulation; that is, to prevent a loss of current by leakage caused by moisture or contact of the wires with the limbs of trees, or other obstruction, capable of absorbing moisture. When it is impossible to clear shade trees, a specially covered water-proof wire is used. Carelessness or negligence in this respect has caused the burning of many fine shade trees in some instances of buildings.

In the early days of Electric Lighting cheapness in construction was the ruling feature. Electrical companies are to-day awakening to the fact that cheapness does not pay. Cheap construction means heavy maintenance, charges and a consequent reduction of profit. Cheap insulation means heavy leakage of the current and consequent loss of power, with danger, to life and property, and isalmost altogether. an absent feature of an Electric Light system as constructed to-day The tendency is toward the more expensive methods in every branch of the work, enlisting more public confidence in the utility of Electric Lighting in general.

The cost of maintainance is naturally of prime importance, and to the end that this item shall be as low as possible the most improved system of furnaces for the consumption of cheap fuel should be put in place. Leakages of every kind should be reduced to a minimum, economy in the lamp itself is of the greatest importance. Economy in this direction means economy at the coal pile. The decision as to the manufacture of lamp that shall be used will depend on the life and economy of the particular lamp, and on its capacity to maintain its candle power. Some incandescent lamps, retain more of the secluded gases than other makes, and consequently blacken in much less time.

The system to be adopted for any particular kind of lighting will depend upon the conditions under which it is to be operated. If the lighting is to be in a thickly settled portion of the city and near the station, the direct system would undoubtedly be selected. In direct lighting the three wire system has been adopted very largely, and results in a great economy in copper for conduction, increasing the construction

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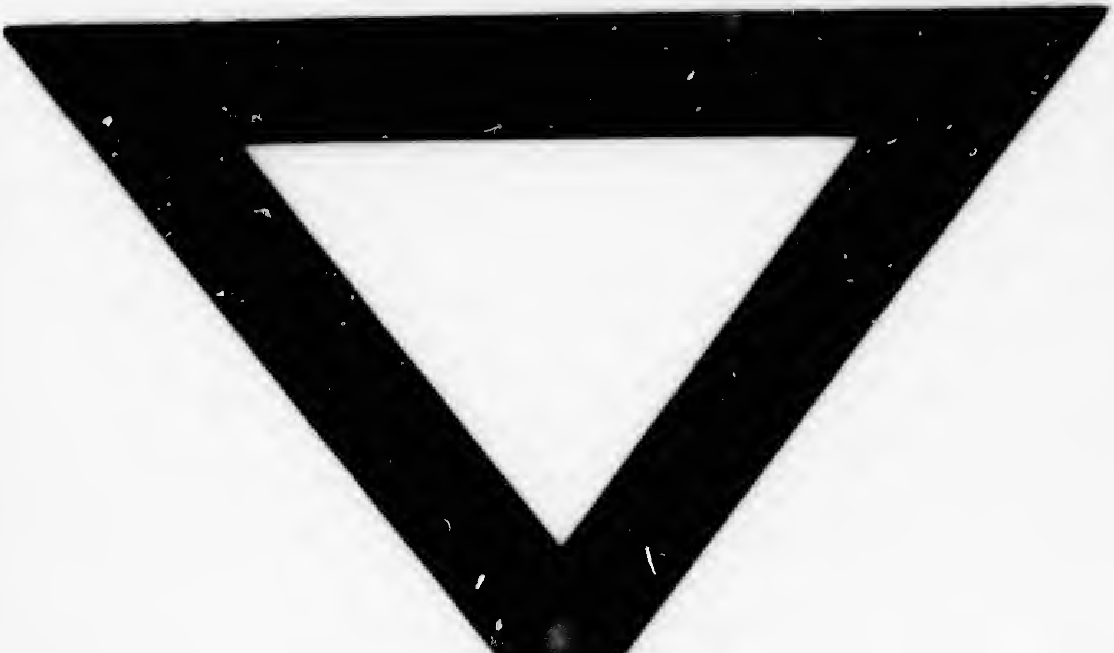

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Following Farada, Pixi and Saxton produced the magneto-electric machine.

The Pixi machine is composed of a strong horseshoe permanent magnet, before the ends of which two spools of covered wire wound on U shaped iron coves are made to revolve. In forming the U shaped magnet, one end of each spool cover is connected with an iron bar, the other end remaining free, and they thus form what is termed an electro magnet. At each half revolution or on every passage of the free ends of the spools, before the ends of the horseshoe magnet currents are induced in the spools, by reason of the magnetism imparted to the iron coves by the large permanent magnet, the currents alternating in direction at every passage, the strength of the current depending on the speed of the spools.

The explanation of the action I have referred to is as follows: between the free ends of any permanent magnet are continuously maintained lines of force so termed, made visible by the familiar experiment of placing iron filings on a glass plate over the poles of the magnet, and gently shaking the filings into position, when they assume the form of the passing lines of force or magnetism. When a single closed wire coill is passed from the weakest to the strongest part of a field of magnetic force, a current is generated in the wire. If we multiply the convolutions of the single coil 50 or 100 times, we can by one rotation of the drum on which the wire has been wound cut the lines of force 50 or 100 times, and remembering the strength of the current is proportiona to the speed and length of the wire (the strength of the magnet remain. ing the same), we thereby increase the pressure of the current as many times as there are turns of wire on the drum.

The lines of magnetism may be represented, though imperfectly, by the lines or rays of heat being radiated from a heated body. If we imagine a copper drum to be rotated in front of the heated body, and on the opposite side of the copper drum place a mass of metal kept at a low temperature, the copper drum on being rotated takes up a portion of the heat given off by the heated mass, and imparts that heat to the cold mass. The simile is this: a given amount of energy as heat is converted by the drum on each half-revolution. In the dynamo-machine a given amount of energy in the form of magnetism is converted on each half-revolution. The amount of energy converted depending upon the difference in potential energy represented in either case.

The simile is almost exact, for, in either case, the conditions remaining the same, the energy converted is proportional to the speed and to the work done.

Some ten years later than Pixi's invention, a compound Pixi machine was constructed, and gave Farada great pleasure. He saw in it the growing infant he had before given the world.

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The Brush armature follows the design of Pacionotti. One fourth of this armature is constantly out of connection and does no work.

Electric Lighting, to-day, is a business of such magnitude, ~~Mr. May~~ we may will be astonished at the rapidity of its growth. The principal cause of the sudden growth of a system practically in its infancy in 1878 may be ascribed to two causes: the Paris Exhibition and the Jablochkoff Electric Candle exhibited there. Machines we had, a practical electric lamp we had not. The Jablochkoff candle, so astonishingly simple, seemed destined to fill the vacancy, and caused a great revival of interest in Electric Lighting. The Jablochkoff candle, however, was not to fill the void. It remained for others to devise a lamp more suited for general use than was the Jablochkoff candle. The Jablochkoff candle is suited to the alternating current only, and never came into extended use because of its unsteady light.

On our side of the water new life was given to Electric Lighting by the invention of Brush, of Cleveland. His invention made it possible to sustain many lamps on one wire, a thing electricians said then could not be achieved.

In Arc lamps, before the time of Brush, a rock and pinion with a clockwork movement was the most reliable method in use for maintaining the carbon rods at a given distance from one another. In such a system, it was impossible to keep more than one lamp burning on one circuit from one machine.

Brush devised a very simple method termed a shunt, which forms a part of every lamp, making each lamp independent of each other lamp. Good lamps are now so perfect in action, it is impossible to see the movement of the carbon rods as it occurs.

Following Brush came many inventors, notably Weston, Maxima, Thomson and Houston, with all of whom you are doubtless familiar.

In incandescent lighting experimental attempts date to Page and Star in 1842. Sawyer and Man, in 1878, were undoubtedly the original inventors of the first successful incandescent lamp. The researches of Edison gave great stimulus to that branch of Electric Lighting.

The incandescent lamp is composed of a carbonized filament of Bamboo, chemically treated paper, or other suitable substance induced to the requisite thinness. The filament when ready for use is mounted in a suitable glass globe, in which a vacuum to the one-millionth atmosphere is then produced, and the globe hermetically sealed by a glass blower. The lamp is then mounted as you see them in use.

The incandescent form of lamp has been made of various candle power, The alternating current method of generating power has been applied to the electric arc light and to electric motors, making it a complete system, leaving nothing else to be desired. A prediction was made at the last convention of Electric Light men, that the alternating system will eventually displace all other systems, by reason of the safety with which the current can be handled by the consumer. This is admitted of by reason of the conversion from a high to a low pressure entrance to house or workshop.

Having given you a brief outline of some of the attempts in Electric Lighting, allow me to state the conditions under which it is necessary to construct a successful Electric Lighting system.

The first consideration in any system is the source of power.

If steam power is to be used, high-class engines are necessary to obtain regularity of speed. Slight variations in speed affect the brilliancy of the electric lamp very materially.

A second consideration in adopting steam is to divide the power so that a break-down shall not cause a dead stop of all the machinery. To accomplish this, considerable judgment should be used to so proportion the power, that the greatest economy shall be obtainable with all the varying head. The favorite method has been and is still to a large extent to use high speed automatic engines of moderate power.

Large stations are, however, in many places replacing the high speed engines with slow speed and condensing engines, thus obtaining greater economy. Independent condenser pumps have been adapted to a limited extent.

The experienced Electrical Engineer recognizes the fact that electric light is power, pure and simple, and he therefore aims at the most economical method of producing power, per se.

When water power is used, economy of power is not taken so much into consideration. The observations I have made as to a division of the source of power are as applicable, however, in the case of water-power as in the case of steam-power.

Having determined the kind of power to be used, the next consideration is the cost of the wiring or conductor for carrying the current. This will be determined by the cost of power and by the location of the station in relation to the districts to be lighted.

Having located the station and determined what power (or coal) will cost, we then determine the amount of power that can be economically lost in transmitting the current or in heating the wires. The balance is found when the cast of power lost is equalled by the interest on the money invested in construction and in the copper conductors.

Having determined this to equal, say, 10 p.c. of the energy developed by the dynamos, the calculation as to cost of wiring is easy.

The consideration of loss in power is one that presents itself the moment a station is proposed. The limit of distance as between the direct and the alternating system is in the neighborhood of 1,000 ft. from the candle power. Some incandescent lamps, retain more of the secluded gases than other makes, and consequently blacken in much less time.

The system to be adopted for any particular kind of lighting will depend upon the conditions under which it is to be operated. If the lighting is to be in a thickly settled portion of the city and near the station, the direct system would undoubtedly be selected. In direct lighting the three wire system has been adopted very largely, and results in a great economy in copper for conduction, increasing the construction account somewhat, however.

The alternating system has, however, a very decided advantage over the direct three wire system, requiring much less copper in construction.

If the lighting extends through a thickly settled district and a great distance from the station, the alternating system would unquestionably be selected.

If for street lighting alone, when large lights are to be placed at intervals only, the arc light system would be most desirable for this work; however the alternating system has of late come into prominence because of its flexibility. Small lights at shorter intervals give a more satisfactory distribution of light than does any system of large lamps, unless the large lights are multiplied so as to cover the territory sufficiently to prevent shadows. Of late the electrical accumulator has come into prominence as a method of storing electrical energy. While this system has become a valuable adjunct to systems already in place, I refer to isolated plants alone—it has not as yet proven economical enough to recommend itself for economical lighting. It is safe to say, however, the further development of this system of storage of power will undoubtedly be a valuable assistance to the electrical engineer.

Some figures as to the number of electric lights of various kinds in use in the United States may be interesting. The last estimate places the incandescent lamps at 1,750,000, an increase of 29 per cent. in the last year, and the arc lamps at 175,000, an increase of 29 per cent. also in the last year. This number of lamps are contained in 1000 central station and 3000 plants of various kinds, representing approximately $125,000,000 invested in a business that has been developed since 1878.

In concluding, allow me to express a sentiment I know you will echo, that is that evolution is a natural law, and applies no less to electrical inventions than in other branches of science. Every inventor has had his device or method improved by some one following him. Evolution is the guiding factor. The newly invented machine is never the perfected one. It was ever so and ever shall continue to be.

The present outlook for the future development of Electric Lighting and kindred Electrical appliances is very bright.

Astonishing strides have been made in the ten years since the Electric Light and Telephone have been given to the world, and who can say what developments in electrical research as great and [illegible]ter await us in the future.