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Canadian Society of Civil Engineers.

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To be read Thursday the 8th of May.

GENERATION AND DISTRIBUTION OF ELECTRICITY FOR LIGHT AND POWER;

MACHINES AND APPLIANCES THEREFOR; AND PARTICULARS OF SOME CANADIAN INSTALLATIONS.

By A. J. Lawson, M.Can.Soc.C.E., A.I.E.E., A.A.I.E.E.

Although hardly fourteen years have elapsed since the first application of electric arc lighting on a commercial scale, and only about nine years since the practical introduction of incandescent electric lighting, yet the production of electric currents by mechanical means had long before that time received much attention from men who had successfully solved that problem, and to whom our indebtedness is too often ignored. They were not patentees but inventors, and the splendid results of their labors were often freely given for the public benefit without thought of personal advantage. Greatest among these disinterested discoverers and benefactors was Michael Faraday, who in 1831 discovered the law of induction of currents and the principles of magneto electricity, and who published to the world his researches with the remark, "I have rather been desirous of discovering new facts and new "relations than of exalting those already obtained, being assured that "the latter would find their full development hereafter," a prophecy most amply fulfilled.

With the knowledge of Faraday's discoveries, Pixii of Paris constructed in 1832 the first appliance embodying the principle of magneto-electric induction, and for several years thereafter many inventors worked in the same field, but it was not until 1860, just 30 years ago, that Dr. Antonio Paccinotti, of Florence, invented the first generator of electricity, having an electro-magnetic field and an annular armature, — a machine which may be justly described as the prototype of all the dynamo-electric machines now known as Gramme armature dynamos. The exciting current, however, was not obtained from the machine itself, as is now the common practice in all continuous current generators, but was derived from a battery connected to the wires forming the field winding.

In 1866, the idea of a self-exciting dynamo suggested itself, almost simultaneously, to Mr. S. A. Varley of England and to Dr. Werner Siemens of Berlin, Germany. Mr. Varley patented his machine towards the close of that year, and the publication of that patent took place in July, 1867. In January, 1867, Dr. Siemens described publicly for the first time the dynamo-electric machine which he had invented the previous year. Sir Chas. Wheatstone also invented, about that time, a machine which was self-exciting, and which he had had constructed in the workshops of Mr. Augustus Stroh of London.

In 1870, Mr. Z. T. Gramme, of Paris, invented the armature winding which bears his name, and the commutator and connections thereto—one of the most important improvements in the development of dynamo-electric machinery.

In 1876, Mr. C. F. Brush, of Cleveland, Ohio, invented his arc light dynamo with cast-iron field magnets and cast-iron armature, a type of machine of which the first constructed is still running in Baltimore, and which, while closely resembling the Paccinotti and Gramme machines, had its distinctive peculiarities. From this machine and the series arc lamp, invented by Mr. Brush, may be said to date the commercial development of arc lighting; and it is probably to the interest evoked by the success which attended Mr. Brush's inventions that the present success of electric lighting generally is due.

In 1879, Mr. T. A. Edison, who had been engaged for some months in experimental work, produced a lamp, which gave rise to great expectations and much speculation. His experiments did not indeed result at that time in a commercial article, but they were the foundation of his success the following year, when he abandoned the attempt to use filaments of platinum iridium wire and resorted to carbon as the light-giving medium. But it was not until 1881, when he succeeded in obtaining a really durable incandescent lamp, that the application of electricity to domestic lighting became a possibility, and its adoption only a question of time.

Mr. J. W. Swan of England and Mr. W. E. Sawyer of New York, who had been experimenting on the same lines for probably a much longer period than Edison, both invented, about the same time, lamps embodying the elements of the success which afterwards attended their endeavours; but whilst to the three distinguished inventors mentioned is due the credit of the production of really commercial incandescent lamps, the fact that they were simply perfecting the ideas of other investigators, who had long previously experimented on the same lines, seems to have been generally lost sight of.

In September, 1882, the Edison station for the distribution of current to supply incandescent electric lights, located in Pear Street, New York, the first permanent station of its kind, was put into operation.

In 1870, not a single horse-power, whether produced by steam or water, was used for electric lighting, or for the manufacture of electric lighting apparatus, yet now it is estimated that out of a total of five and a quarter millions horse-power developed by steam engines and water wheels on this continent, half a million horse-power, or nearly ten per cent., is used in the production of electric current for the distribution of light and transmission of power, and in the manufacture of electrical machinery and appliances.

At the beginning of 1886, there were in the United States and Canada 450 local electric lighting companies operating central stations. At the beginning of 1887, the number had increased to 750; and at the beginning of 1889 to nearly 1,200; while in January, 1890, there were 1185 different companies operating central stations in the United States, 147 in Canada and 25 in Central America and Mexico, besides 266 gas companies, etc., engaged in electric lighting, making a total of no fewer than 1623.

At the end of 1886, there were 1,000 incandescent and nearly the same number of arc isolated plants. The number of private plants now in the United States is 3,925; in Canada and miscellaneous 196, and in Central America and Mexico 200; making a total of 4,300 isolated electric lighting plants, large and small.

The following was the condition of the arc lighting business at the beginning of the years mentioned:

Year.	Arc lamps in use.	Year.	Arc lamps in use.
1882	6,000	1886	96,000
1883	12,000	1887	150,000
1884	24,000	1888	115,000
1885	48,000	1889	210,000

while in 1890 the lamps in use number 235,000. Of these about 70,000 are of the Thomson-Houston manufacture, and 49,000 have been made by the Brush Electric Company.

Between November, 1886, and January, 1889, the number of incandescent lights in America more than quadrupled, increasing from 525-000 to 2,500,000. At the present time, there are fully 2,800,000 incandescent lamps in use. The estimated total capitalization of electric lighting and electric manufacturing companies in America at the present time is $250,000,000.

ELECTRIC LIGHTING IN CANADA.

Being one of the pioneers in construction of electric lighting plant in Canada, and the manufacturer or constructor of nearly 30 per cent. of the total capacity of incandescent lighting installations now in operation in the Dominion, the writer submits the following brief history of the process of the electrical industry in this country.

Ten years ago there was not a single electric light plant in operation in Canada. The first plants erected were Brush arc plants of small capacity. About the end of December, 1882, some Thomson-Houston arc lights were placed on exhibition in this City by the American Electric Illuminating Co., lighting St. James Street, Beaver Hall Hill, part of Dorchester street, and part of St. Lawrence Main street, but the first permanent installation for street lighting in Montreal was that supplied from a Brush dynamo owned by the Harbour Commissioners, who by this means lighted the Harbour, wharves and approaches.

In the Fall of 1883, some 50 are lights of the Hochhausen and Vandepoele systems were placed in the streets of Toronto, and Winnipeg also had some arc lights put into operation about the same time. In May, 1885, Ottawa adopted the Thomson-Houston arc light for its streets, replacing thereby both gas and oil, and in 1887 Quebec followed its example, and Halifax and other places followed suit.

In 1889, Montreal gave a contract for the electric lighting of the whole of its streets to the Royal Electric Co. for a period of five years, a portion of the city having been lighted by the same Company since 1886. Hamilton is now also lighted by the arc light, and St. John, N.B., has recently contracted for the lighting of the whole city, dividing the lighting between the companies operating the Thomson-Houston and the Brush systems, so that now the following cities may be said to have adopted exclusively the arc light in place of gas or oil:—Montreal, Ottawa, Quebec, Hamilton, London, Winnipeg, Victoria, Vancouver, Halifax, St. John, N.B., St. John's, N.F., Moncton and Sherbrooke, besides the majority of the towns throughout the Dominion, so that now comparatively little work remains to be done in arc lighting, incandescent lighting for residences and stores being the principal field remaining unoccupied, and there can be no question that the large majority of this work will be done on the alternating current system, which is so admirably fitted for the lighting of our widely-built cities and towns, and for the utilization of our numerous water powers for this purpose.

In 1882, two private installations of incandescent lights were made in the city of Montreal. The system employed was the Maxim, which was put into the St. Lawrence Hall and Bank of Montreal. So crude was the construction of these plants that they proved unsatisfactory, and after a very short time both were discontinued. In the St. Lawrence Hall only one lead was carried from the dynamos to the lamps, the return being made through gas and water pipes, a method which, it need hardly be pointed out, would not now be permitted by the Board of Fire Underwriters. The wire used in the Bank of Montreal for mains did not even have the coating of paint which would have gained for it the misnomer of "Underwriters wire," but was merely single cotton-wound magnet wire. This is not pointed out as reflecting in any way on the Maxim Co.: all companies' systems about that time were about equally crude.

In the fall of 1882, a contract was made for lighting the Canada Cotton Co.'s mill at Cornwall with the Edison light. A plant of 500 16 c. p. lamps capacity, constructed under the superintendence of Mr. Byllesby, now Vice-President of the Westinghouse Co., was started on the 28th day of February, 1883. In June, 1883, an exhibition Edison incandescence plant was placed in the "Mail" building, Toronto, but was subsequently discontinued.

The Montreal Cotton Co.'s mills at Valleyfield were next lighted in September of the same year, 800 lights being placed: which number was subsequently increased to about 1100 lights. The Canada Cotton Co.'s plant was also increased at the end of the year to 1200 lights, and it is now the largest private installation in Canada. In January of 1884, two competitive plants of small capacity were placed in the Parliament Buildings at Ottawa, for the lighting of which the writer furnished, in 1886, Edison machinery of a total capacity of 1000 lights.

The first incandescent electric light station in Canada was started at Victoria, B.C., in January, 1887, and was followed by that at Vancouver, B.C., completed in September of the same year. The distribution from both stations is on the three-wire system.

The station at Calgary, N.W.T., was completed and started in October, 1887, and in January, 1888, the station at Valleyfield, with overhead conductors—at that time the best constructed of all the Edison stations in Canada—was put into operation. For these four stations the writer supplied all the machinery.

The Cornwall station on the Westinghouse A. C. system, completed the same year, was the first A. C. station in Canada.

Toronto is the only place in which underground wires have yet been placed, but the Edison station, from which they are fed, has only lately been put into operation. It is the intention of the older Toronto Electric Light Co. to put under ground the wires for arc lights and for the alternating current plant about to be installed.

The Barrie central station, which the writer has constructed, is the latest completed central station plant, and the only one in the Dominion on the A. C. system carrying 2000 volts in the primary wires and nearly 100 volts in the secondaries, and it is one in which the highest quality of insulation, both of primary mains and house wiring, has been used.

At the present time there are 13,530 arc lights and about 74,000 incandescent lamps in use throughout the Dominion. There is hardly a village in Ontario, having a population of over three thousand inhabitants, which has not an electric light station of some kind in operation, and few of the important towns of the other Provinces are without electric lighting. Most of these it is true, are arc lighting stations, but about a dozen supply the incandescent light only, chiefly to stores and public buildings, the lighting of residences being yet scarcely entered upon. Several of the local companies which have hitherto supplied the arc light alone, or with a few incandescent lamps in series with their arcs, or in series multiple with them, have recently purchased and put into operation incandescence A. C. plants; and the various lighting companies formed for the supply of incandescent lights only, have also found it necessary in most cases to add arc lighting to their business, it having been sufficiently demonstrated that the incandescent light is unsuitable for street lighting, the public demanding from electric lighting, whether arc or incandescent, a much better illumination than is usually obtained from gas lighting, and in this respect the incandescent light has failed to meet the expectations even of its own advocates. The Edison municipal system has been used for street lighting on the Lachine Canal, and at Vancouver, Valleyfield, and Chatham, N.B., but is being replaced by arc lights in the two first-named places.

The principal electric lighting stations in Canada of which the capacity is 100 arc lamps of 2,000 nominal candle power or over, or 1,000 incandescent lamps of 16 candle power or more, are:—

Place.	No. of Arc Lights.	Inc. Lights 16 c. p.	System.
Barrie, Ont.	75	1,200	Ball Arc, Brush A. C. Incandescence.
Brockville, Ont	105	1,000	Ball and Reliance Arc, Slattery A. C. Incandescence.
Cornwall, Ont		1,300	Westinghouse A. C.
Gazette Printing Co., Montreal, Que.		1,350	Edison.
Halifax, N.S.	200	1,950	Thomson-Houston and Fuller Wood Arc, Slattery Incandescence.
"	250	1,400	Thomson Houston and Ball Arc and Westinghouse A.C. Incandescence
Hamilton, Ont	394	2,000	Thomson-Houston Arc, Westinghouse A. C. Incandescence.
London, Ont.	100		Thomson-Houston.
"	150		Ball.
Montreal, Que.	1,440	2,000	Thomson-Houston.
Ottawa, Ont.	522		Thomson-Houston.
"		1,000	Westinghouse A. C. and Weston series multiple.
Peterboro, Ont.	137		Thomson-Houston.
Quebec, Que.	692	1,000	Thomson-Houston.
St. Catharines, Ont.	105	215	Thomson-Houston Arc, Weston series multiple Incandescence.
Sherbrooke, Que.	167	500	Ball and Thomson-Houston Arc, and T.-H., A. C. Incandescence.
St. John, N.B.	325	1,000	Thomson-Houston.
"	205		Brush.
Toronto, Ont.	750	1,000	Hochhausen-Wright Arc, and T.-H. series Incandescence.
* "		10,000	Edison.
Truro, N.S.	60	1,800	Thomson-Houston Arc, Mather Inc.
Valleyfield, Que.		1,200	Edison.
Vancouver, B.C.	100	1,150	Thomson-Houston Arc, Edison Inc.
Victoria, B.C.	50	1,200	Ball Arc, Edison Incandescence.
Winnipeg, Man.	200	1,000	Brush and Thomson-Houston Arc, and T.-H. Incandescence.
* "		3,000	Edison.
Yarmouth, N.S.	100		Fuller Wood

* The two stations marked thus have the nominal capacity given here, but actually run at present about 20 per cent. of the number of lights at which they are rated.

The private installations of incandescent lights in Canada, having a dynamo capacity exceeding 600 lights of 16 c. p., are:—

Name of Owner.	No. of lamps 16 c. p.	System.
Canada Cotton Co., Cornwall, Ont.	1,250	Edison.
Montreal Cotton Co., Valleyfield, Que.	1,000	"
New York Life Co., Montreal, Que.	1,000	Brush.
Parliament Buildings, Ottawa, Ont.	1,000	Edison.
Stormont Cotton Co., Cornwall, Ont.	850	"
Gibson Cotton Co., Marysville, N.B.	850	"
Canadian Pacific Railway Station, Montreal.	800	Thomson-Houston.
Magog Print Co., Magog, Que.	700	Edison & Thomson Houston.
W. Bell & Co., Guelph, Ont.	600	Brush.

The following is a summary of the number of lights of the various systems now in operation in the Dominion:—

System.	Arc Lights.	Incandescent Lights.
Thomson-Houston	6,105	14,600
Edison	......	27,500
Ball	3,529	1,660
Brush	615	3,300
Hochhausen (Wright's improved)	750	......
Reliance	1,780	......
Westinghouse	......	6,850
Slattery	......	5,850
Craig	......	4,515
Mather	......	3,125
Weston	180	1,865
Fuller Wood	425	......
Other systems	150	1,500

ENGINES.

Whether the system to be employed be the low tension incandescent, the alternating current incandescent, or the high tension continuous current arc system, the three which are to-day practically the only ones operated to any extent in America, one of the chief points to be considered in the construction of a station is the economical generation and application of the prime power. Unfortunately in a great many cases where steam power is used, it was assumed in the early stages of electric station construction that any kind of steam plant would answer. Old slide valve engines which drove as antiquated machinery as themselves in machine shops, saw mills, woollen factories, and like places during the day were used at night for the running of electric light machinery, and very good reason naturally existed for the complaints made of the unsteadiness and unsatisfactory character of the lights supplied.

High-speed engines belted direct to the dynamos were next tried, and having been found to give much better results in point of steadiness, a number of builders, who had had no experience in such work, undertook the manufacture of this class of engines, and evidently tried to combine the old designs for agricultural engines, upon which their previous practice was based, with some of the principles embodied in the best class of engines sold in the United States for electric light purposes. The product was a mechanical curiosity, and a failure. It is safe to say that in not one of the Canadian shops building these engines in the early history of electric lighting in Canada was there a proper equipment for the manufacture of high-speed machines of any kind. No parts were made to gauge so that in the event of a break-down the broken part could be duplicated without sending it back to the shop as a model. A reaction soon afterwards set in in favour of slow-speed engines, especially for arc lighting, and at the present time, with few exceptions, engines of the Brown and Wheelock types are used in all arc light stations in Canada operated by steam power. For the running of incandescence plants, however, high-speed engines, mostly of American manufacture, have obtained the preference to which their excellent qualities and performance entitle them.

Brown engines furnish the motive power for the Central Stations in Montreal, Toronto and Winnipeg, both Brown and Wheelock engines are used in Halifax and London, and Wheelock engines in Hamilton, while Armington and Sims engines are the prime motors in the stations in St. Johns, N.F., St. John, N.B., Calgary, Alta., Vancouver and Victoria, B.C., and in the Parliament Buildings at Ottawa.

The economy of many stations could be increased by the intelligent use of the indicator, instead of trusting to the valves of engines being properly set by guess work, as is now so frequently the case.

BOILERS.

With the exception of the Royal Electric Co.'s east end station in Montreal, the ordinary horizontal fire tubular steam boiler has been used in every station. In that case the Babcock and Wilcox water tubular boiler is employed. In some cases the Jarvis setting has been adopted, but not to any great extent.

WATER POWERS.

At Quebec, power is obtained at the Falls of Montmorency, nine miles distant, to drive the Thomson-Houston arc dynamos and Thomson-Houston A. C. incandescence machines.

At Peterboro, water power is used to drive Thomson-Houston arc dynamos, from which 137 arc lights and a number of Bernstein incandescent lamps in series are supplied. At Barrie, Ont, a stream five miles distant from the town furnishes the power for both the arc and Brush A. C. incandescence plants.

Also in Ottawa, Cornwall, Smith's Falls, St. Catharines, Welland, Dunville, Thorold, Sault Ste. Marie, Sherbrooke, Joliette, Valleyfield, Almonte, for both factory and central station lighting, water furnishes the motive power.

ATTACHMENT OF DYNAMOS.

The dynamos are not coupled direct to engines in any of the Canadian stations. Ordinary double leather belting, made without seams or rivets, is generally used. In a few cases link leather belting has been tried, but the results have so far justified the opinion that this belting has been invented chiefly to find a market for scrap leather. Belting should not be overtaxed. One inch width of double leather belting running at a speed of 750 feet per minute will easily transmit one horse power, and at this tension will last a long time. Some dynamo manufacturers, in order to impose the belief that their machines use but little power, are in the habit of providing a much smaller margin than this per horse power. The only advantage, of which the contractor receives nearly the whole benefit, is that the first cost is decreased. The disadvantages, which affect the purchaser, are the necessary excessive tightness of the belt, and the consequent heating of journals, rapid wear of the belt, and large oil consumption. Rope driving may eventually be used as it has many advantages, but so far, with one exception in an isolated plant, the method has hitherto not been tried in Canada.

ARC LIGHTING SYSTEMS.

The arc lighting systems in use in Canada are the Thomson-Houston, Ball, Brush, Reliance, American or Fuller Wood, Hochhausen (Wright's improved) and Weston. The large majority of machines and lamps is of the Thomson-Houston and Ball systems.

As already mentioned, the Brush system was the first to be tried in the Dominion, but its sale was never pushed, and others took possession of the field. In the Thomson-Houston, in the Brush and in the Fuller Wood or American systems a current of 9.6 amperes is used, with a pressure varying according to the number of lamps in circuit. In the Ball system a current of 8 to 8½ amperes has been the standard, but lately that company have supplied several plants having a current of only four amperes, the lamps for which are nominally of 1,000 candle power each. In the Hochhausen-Wright system, a current of 10 amperes is used. In the Weston system the current is about 18 amperes, and the P. D. between the terminals of each lamp 25 volts. On account of the short arc and the consequent hissing the Weston lamp has not found general favour in this country. The regulation of the Thomson-Houston machine is excellent. The lamp also has the merits of simplicity of construction and steadiness in running. The feed is purely gravitational like the Brush feed, controlled by electro-magnetic action, there being no clock-work or gearing. It is not, however, quite so steady as some clock-work arc lamps, and requires the feed rod to be kept very clean in order to secure the proper working of the clutch. With the rack and pinion lamps this point is not of such importance, and the difference in the running of the two kinds of lamps sometimes observed may, to some extent, be due to the cleaning of the Thomson-Houston lamp rod having been neglected.

In regard to the rating of arc lamps some change seems to be desirable. At present lamps taking 48 volts and 9.6 amperes, lamps of the same voltage taking 10 amperes, and lamps of 50 volts and 8 amperes, are all compared the one with the other, and each is called 2,000 candle power, which is manifestly absurd. The current and pressure, or watts per lamp, should be given in all specifications, tenders and contracts.

STREET WIRING FOR ARC LIGHTS.

In wiring for arc plants, as is generally known, one wire of uniform section is carried from the machine to the lamps, where it is cut, and one end placed in the first binding post and the other in the second binding post, and so continued, the pressure falling on an average about 48 volts for each lamp in circuit, where the lamps, as is the general practice on this continent, are always run in series.

For lamps of 2,000 nominal candle power No. 6 wire American gauge, and for lamps of 1,200 nominal candle power No. 8 American gauge wire is used for the leads. Up to within the past two years, the insulation known as "Underwriters wire" was used, but lately this has given place to much superior quality. Unfortunately, there is still room for improvement even on the best which has yet been supplied in Canada.

SYSTEMS OF DISTRIBUTION FOR INCANDESCENT LIGHTING.

In the distribution of current for incandescent lighting from central stations the multiple arc two-wire system with low tension continuous currents was first used during 1882 and 1883.

In private installations at that time the tree system of wiring was usually followed, and it has not yet been entirely abandoned, although used in very few installations at the present date. In one station in the Maritime Provinces wired on this principle, the pressure varies from 125 volts at the lamps nearest the dynamo to 110 volts at the furthest point of distribution. But since 1884, very few stations indeed and few isolated plants of more than moderate size have been constructed on other than the feeder system of distribution.

A very short experience of distribution of the multiple arc system demonstrated that lights singly controlled could not be furnished economically by it at a greater distance from the central station than a quarter of a mile radius. The three-wire system, invented by Dr. John Hopkinson, and elaborated by Mr. Edison, was a temporary and partially successful solution of the difficulty, but this system, although it greatly reduced the quantity of copper necessary, only increased the radius of distribution on a paying basis by another quarter of a mile, and, while satisfactory for thickly populated towns, still left the distribution of light in suburban districts or openly built country towns as far from attainment as ever. The adoption of the alternating current system of distribution solved the difficulty.

The method of regulation first employed for the maintenance of equal pressure at the ends of the feeders in the three-wire system consisted of placing adjustable resistances or feeder equalizers in each circuit, more or less resistance being inserted by hand, according to the indications of the pressure indicators. Where the frames of such equalizers were made absolutely fireproof, such a system of regulations in small stations having only three or four sets of feeders radiating from it was in a measure unobjectionable, but when it came to the distribution of several hundreds, perhaps thousands, of amperes of current, through dozens of sets of feeders, the loss in these equalizers became a serious matter, and perfect regulation was difficult of attainment. In several cases also the heating of the equalizers was the origin of fires which resulted in the burning down of the stations, the destruction of the Edison stations in Boston and New York being a case in point. In recent practice these equalizers have not been used, but a method of interlacing the feeders as well as the distributing mains has been adopted, necessitating a somewhat larger outlay in conductors, but not involving, as in the other case, a loss of energy by the heating of useless resistance. With this interlacing the pressure at the lamps is much more nearly constant than under the old method.

At the price of labour and fuel and the selling prices current in this country, it may safely be said that the economical distribution of light or power, on the three-wire system, is limited to half a mile radius from the station in our most thickly populated towns. In both the United States and Canada distribution by this system has been carried out on a much wider area, for a limited number of lights and under special circumstances; but it is doubtful if there is a single city in Canada which will return any dividend on the investment to a company placing low tension wires carrying a pressure of even 300 volts underground, and there are not more than six cities in the whole Dominion which will yield any return on this system with overhead wires, unless the charges for electric lights be at least 50 per cent. more than the current prices for gas.

ALTERNATING CURRENT DISTRIBUTION.

In the method of distribution by high tension alternating currents, the converters, indicated by Fig. 1 and more practically explained by the specimens on the table, are placed in parallel circuit. As shown, the current from the dynamo does not enter the premises of the consumer but merely passes through the fine wire in alternately opposite directions, and generates, by induction, a current in the secondary or thick wire of the converter or transformer, which induced current is carried into the houses and through the lamps.

There are at present no alternating current motors in use developing large powers, but probably before many months machines will be supplied which will convert the electrical energy of alternating current into power with high efficiency. Ganz & Co., of Buda Pesth, have indeed nearly completed a station from which to distribute power by A. C. motors, and the Westinghouse Company are just completing a contract for A. C. motors for mine working. It is also the case that the A. C. system will not easily lend itself to the charging of storage batteries, without a complication of commutators and other apparatus. But there does not appear to be any demand for the charging of storage batteries except what can be supplied from continuous current stations or isolated plants now in operation, or for which special dynamos would not be best used separate and distinct from any other circuit.

ARC LIGHTING DYNAMOS.

Most of the dynamos used for arc lighting in America, and, it may be said, in the world, are of the Brush or Thomson-Houston types.

BRUSH ARC LIGHTING DYNAMO (FIG. 2).

These were first made with both armature and field cores of cast iron; but for some years past the armature has been built up of laminated hoop iron of good quality, a simple modification which raised the efficiency of the machine greatly, enabling the output to be increased 50 per cent. while running at the same speed as formerly. Upon the ing so formed the upper coils are wound. The 18-light machine weighs 1500 lbs., the 30-light machine 2500 lbs., and the 65-light machine 4800 lbs. complete.

The P. D. at lamp terminals is the same as in the Thomson-Houston system, 48 volts and the current is 9.6 amperes. The output of the first two sizes is 5.53 watts per lb. gross weight, and is 6.2 watts per lb. gross weight for the large machine. The respective speeds at full load are 1050, 950 and 805 revolutions per minute. In the 65-light machine the copper wire on the armature weighs 1340 lbs. and on the fields 1264 lbs., so that the output is 11.5 lbs. per lb. of the total weight of copper wire on the machine, and 22.35 watts per lb. of the copper wire on the armature.

THOMSON-HOUSTON ARC DYNAMO (FIG. 3).

In the Thomson-Houston dynamo the field is composed of two massive iron castings upon which the magnetising coils of copper wire are wound, and these castings are of such shape that they nearly completely encircle the armature, being fastened together over it by wrought-iron bolts, which form the yoke or keeper. The armature core is a spheroid built up of soft iron wire. Upon this core three coils of copper wire are wound, these being connected together at their inner ends, their outer ends being carried out and fastened to a three segment commutator. The regulation of the current, which in all arc lighting machines should be maintained constant, is performed by an electro-magnet which shifts the position of the brushes on the commutator, as fully described in Silvanus Thompson's "Dynamo Electric Machinery." The magnetism of this machine leaks outwardly to a considerable degree, which, of course, is a fault. There is also the objection to the form, that it is necessary, in case of breakdown of the armature, to dismantle the whole of the machine before the armature can be removed, and that that being done, in case a coil is burned out it is necessary to completely rewind the armature—in itself the work of several days.

The nominal 50-light Thomson-Houston machine will run 60 arc lamps of 2000 nominal candle power on a short circuit of wire; and speeded at 850 revolutions per minute, has a working E. M. F. of 2700 volts with a current of 9.6 amperes. Its total weight is 6200 lbs. The iron in the armature weighs 340 lbs., and the two cast-iron field cores weigh 2710 lbs. The weight of copper wire on the armature is 378 lbs. Its output is 4.18 watts per lb. of gross weight: 21.6 watts per lb. of copper wire on the machine, and 76.25 watts per lb. of armature wire.

BALL ARC DYNAMO (FIG. 4).

The Ball arc light dynamo has a Gramme ring armature, or rather two armatures running between blocks peculiarly placed one above one armature and the other under the other armature, and it has wrought-iron fields and pole pieces; in fact the whole machine frame is made of wrought-iron. It should, therefore, and does, weigh much less than other machines in which cast-iron is used. The 25-light machine weighs 990 lbs. and the 35-light machine 1180 lbs. complete. The current is $8\frac{1}{2}$ amperes, and the voltage per lamp 48. The output is 10.3 watts per lb. gross weight of the first machine and 11.97 watts per lb. of the 35-light machine. The weight of copper wire on the armatures of the 35-light dynamo (there being two in each machine) is 102 lbs., and on the fields 150 lbs. The output is thus 56.6 watts per lb. of copper on the machine and 140 watts per lb. of copper wire on the armature. The speed of the two machines mentioned is 1365 revolutions per minute and 1275 per minute respectively. The resistance of the field winding of the 35-light machine is 13 ohms, and of the winding of the two armatures 15 ohms.

The Ball Co. have recently made a machine intended for 80 arc lamps, of which the following are some of the particulars: Weight of the machine complete 3200 lbs.; current 10 amperes; E. M. F. 3750 volts; speed 940 revolutions per minute; wire on field 362 lbs. No. 10; on armatures 222 lbs. No. 15 B. & S. gauge; iron in each armature core $137\frac{1}{2}$ lbs. The output of this machine is 11.66 watts per lb. gross weight: 63.24 watts per lb. of copper wire on the machine, and 168.83 watts per lb. of copper wire on the armature.

TORONTO ARC DYNAMOS.

The machines made by the Toronto Electric Light Company for use in their own station are of the Hochhausen type, modified and improved by Mr. J. J. Wright, the Company's electrician and manager. The Company do not manufacture machines for sale, but make all their own arc light dynamos. Their standard type is a 40-light machine, 10 ampere current, average P.D. at binding posts of lamps 48 volts. The field is laid horizontally, being, it may be said, a Hochhausen machine laid on its side. The field cores are of wrought-iron, the frame and pole pieces of cast-iron. The cast-iron weighs 1200 lbs. in each machine. The field winding consists of 700 lbs. of No. 9 copper wire, and on the armature there are 180 lbs. of wire. The armatures are sectional, the coils being wound separately on moulds. Each armature has 18 coils with Gramme connections. The commutator consists of 18 segments, and is mounted on slate with an air space between the sections. The weight of the completed machine being 2400 lbs., the output is at the rate of 8 watts per lb. of wire on the armature, and 21.8 watts per lb. of the total copper wire on the machine. Mr. Wright in a communication on the subject sarcastically states: "Unlike "all other systems our armature coils sometimes burn out, and I have "adopted the sectional style to facilitate repairs. The power required "I have not accurately determined, but it is nearly $\frac{3}{4}$ horse power per "light—rather over than under—when working to full current and

"voltage. I adopt a few coils on armature rather than many, for while "the spark at brushes is larger, the increased simplicity of all parts "more than compensates."

WESTINGHOUSE A. C. ARC DYNAMO.

This dynamo, recently put upon the market, embodies several novel features. The frame of the 60-light arc machine is cast off the same patterns as the ordinary 750-light Westinghouse incandescence dynamo; and the only difference in the field windings is that the iron cores project through the coils to a greater extent than in the incandescent machine, the coils being shorter. The principal feature of the machine is the armature winding, which is almost entirely enveloped by the laminated iron discs forming the core, and is connected to two collecting collars as in the Westinghouse incandescence machines. The speed is 600 revolutions per minute, the periodicity being 50 cycles.

The lamp has two laminated wire cores, somewhat similar to the core of the Westinghouse ammeter, hung on a swinging arm, one of which plunges into the coarse wire series coil and the other into the fine wire shut coil. One carbon rod only is used, and the carbon itself is about $2\frac{1}{4}''$ wide by $\frac{7}{8}''$ thick. The lamp runs for 42 hours with one set of carbons. The P. D. at lamp terminals is 50 volt and the current 10 amperes. For lamps for inside use a converter is attached to the high-pressure street wires which transforms the current to 50 volts and 10 amperes, so that 50 volts is the maximum pressure entering a building. With the 60-light machine the lamps when required for street lighting only, may be run in series without the use of these converters. In the 125-light machine the current is 30 amperes and the total E. M. F. 2100 volts, and with this size converters are used for all the lamps, whether for street or interior lighting, which raise the voltage from 17 volts per lamp to 50 and reduce the current from 30 to 10 amperes. These are made to carry one, three, or five lights each.

The machines are started upon short circuit, and when fully excited a switch is opened and the lamps thereby thrown into circuit. With a sensitive ampere meter attached, the total change in the current when the lamps were thus placed in circuit, on a recent visit of the author's to one of the Westinghouse stations was less than two amperes, and this was only temporary. Provision is made by attachments on the dynamo and on the wires in the station to prevent the opening of the circuit.

LOW TENSION INCANDESCENCE DYNAMOS.

THE EDISON DYNAMO (FIG. 5).

The type of low tension machines which has found most favour on this continent is the Edison as modified and improved by Dr. Hopkinson, and further perfected at the Edison Machine Works. Between the machines made by the Edison Co. in America and the Edison-Hopkinson machine made by Mather & Platt of Manchester there is this difference: that the field cores of the Edison machine are made cylindrical and the armature core is still built up of iron discs bolted together; while the Edison Hopkinson machine has field cores, the section of which is a square between two half circles, and the armature discs are held together by nuts at each end of the core screwed on the shaft, thus giving the core a greater sectional area.

Take the Edison machines known as Nos. 10, 12 and 16 to illustrate the general construction of Edison dynamos, and their relative proportions and weights. The No. 10 machine is made for an E. M. F. of 125 volts and a current of 200 amperes, but is hardly ever run at more than 200 amperes and 110 volts except for central station work. The total weight of this, the best running of all the Edison dynamos, is 3570 lbs. The two cast-iron field blocks weigh 600 lbs. The field cores which, as in all Edison machines, are of wrought-iron, are each $10\frac{7}{8}''$ diameter by $16\frac{1}{4}''$ long, and are connected by a massive wrought-iron keeper $10\frac{1}{4}''$ wide by $8''$ deep by $26\frac{1}{2}''$ long. The field cores are wound with 220 lbs. of copper wire—110 lbs. on each limb. The wrought-iron in the armature weighs 220 lbs., the dimensions of the armature shell before winding is $8\frac{3}{4}''$ diameter by $16\frac{1}{2}''$ long, and the winding is a modified Siemens, taking 60 lbs. nett weight of copper wire. The diameter of the completed armature outside the bands is $9\frac{11}{16}''$ and the bore of the fields being $9\frac{15}{16}''$, there is a clearance of $\frac{1}{4}''$ all round. The speed of the machine is 1300 revolutions per minute. The resistance of the shunt coils is 37 ohms, and of the armature about .017 ohm cold, the shunt being thus about 2200 times the resistance of the armature. The output of this machine at 110 volts and 200 amperes is 6.13 watts per lb. gross weight, 77 watts per lb. of copper wire on the machine, and 333 watts per lb. of wire on the armature. There are 66 bars in the commutator.

The next two sizes will serve as a basis of comparison with the Royal Co.'s Thomson-Houston incandescence machine and the two Brush incandescence machines, of which the particulars are given further on.

The weights and dimensions of the No. 12 Edison dynamo are as follows:—complete machine 4340 lbs.; the cast-iron field blocks weigh 800 lbs.—400 lbs. each. The field cores are $20\frac{3}{4}$" long by $11\frac{1}{8}$" diameter. The keeper is $27\frac{1}{2}$" long, $11\frac{1}{8}$" wide and $8\frac{3}{4}$" deep. The armature core is $9\frac{11}{16}$" diameter, $18\frac{1}{4}$" long. When wound the armature is $10\frac{1}{8}$" diameter over bands, and the bore of the fields is $11\frac{1}{2}$", the clearance being 5-32" all round. 248 lbs. of wire are wound on the fields, and 84 lbs. of wire on the armature. The resistance of the shunt is 28.5 ohms and the resistance of the armature .011 ohm, or about 2600 times the resistance of the shunt. At 110 volts and 240 amperes the output per lb. gross weight is 6.08 watts; for each lb. of copper on the machine it is 79.5 watts, and for each lb. of copper on the armature 314.3 watts. The speed of the machine is 1200 revolutions, and there are 58 segments in the commutator.

The No. 16 machine made for a current of 320 amperes weighs 6800 lbs. The field cores are $12\frac{3}{4}$" [illegible]iameter by $23\frac{1}{2}$" in length. The keeper is $12\frac{3}{4}$" wide 10" deep [illegible]$2\frac{1}{2}$" long. The two cast-iron pole pieces weigh about 600 lbs. each, and are $28\frac{1}{2}$ inches in length, parallel with the shaft. The bore of fields is $12\frac{7}{16}$" diameter. The armature core is $11\frac{1}{16}$" diameter by $20\frac{1}{2}$" long, and when wound the finished armature is $12\frac{1}{4}$" over the bands, the clearance being thus $\frac{3}{32}$" all round. The weight of iron in the armature core is about 400 lbs., the nuinber of commutator segments is 52, and the speed is 1000 revolutions per minute. Each field limb is wound with 160 lbs. of copper wire—320 lbs. on both. The armature is wound with 133 lbs. of copper wire, one-third the weight of the iron disc core. The resistance of the shunt is 22.7 ohms, cold, and of the armature between opposite bars .009 ohm, the ratios being as 2500 to 1. As a shunt wound machine run at 110 volts and 320 amperes the output is 5.18 watts per lb. gross weight: 77.7 watts per lb. total copper wire, and 264.66 watts per lb. of wire on the armature. When compound wound the series winding of this machine is composed of 10 wires in parallel, making 5 complete spirals round each limb outside the shunt winding. Its resistance is .001 ohm.

The armature cores in all the Edison machines are built up of the softest disc iron .008" thick, separated by thin manilla paper, and every fifth disc is more widely separated from the next by several thicknesses of the same paper. In the three machines above mentioned there are two layers of wire on the armature, of which each section is once wound around the armature shell.

BRUSH LOW TENSION INCANDESCENCE MACHINES (FIG. 6).

The Brush incandescence machines are much lighter than the Edison for the same output. The new type which is being put upon the market has closed Gramme ring armatures connected to 60 segments in the commutator, the old type of machine with only eight armature segments as in the arc light machine having been recently abandoned. Of this new type of machine particulars have not yet been given. The old 250 ampere machine weighs 2300 lbs. The weight of iron in the armature, which is composed of laminated hoop iron, is 178 lbs., and the weight of iron in the fields is 400 lbs., the weight of copper on the armature is 148 lbs., shunt 360 lbs. and series coil 346 lbs. The gross weight of the 360 ampere machine is 3200 lbs. The weight of iron in the armature is 258 lbs. and the weight of copper is 184 lbs. On the fields there are 444 lbs. of copper in the shunt and 460 lbs. in the series coils. The output of the 250 ampere 105 volt machine is 11.4 watts per lb. gross weight: 30.73 watts per lb. of the total copper wire, and 177.36 watts per lb. of wire on the armature. For the 260 ampered 105 volt machine these figures are 11.81 watts per lb. gross weight; 41.81

watts per lb. of copper on machine, and 205.43 watts per lb. of copper on armature. The speeds are 1200 revolutions and 1100 revolutions per minute respectively.

The largest Brush machine as first made for the Cowles Smelting Co. of Lockport, N.Y., is equally adapted for the smelting of aluminum or the production of current for incandescent lights. Its capacity is 3200 amperes at 83 volts. It has 5124 lbs. of copper on the fields and 1600 lbs. of copper on the armature. The total weight of the machine is 22,000 lbs., and the output 12.07 watts per lb. gross weight: 37.5 watts per lb. of the total copper wire, and 166 watts per lb. of wire on the armature.

THOMSON-HOUSTON INCANDESCENCE DYNAMO (FIG. 7).

This incandescence machine, made in Canada by the Royal Electric Co., is very similar to an inverted Edison dynamo. The wrought-iron keeper is dispensed with, the bed casting forming the yoke between the field cores. The armatures are built up in the same manner as in the Edison machine, of wrought-iron discs, but thicker, and, instead of paper insulation between them, vulcanized fibre is used. The 250 ampere 110 volt Thomson machine weighs 5260 lbs. complete. The armature core is 14½″ long by 11½″ diameter, and is wound with 130¾ lbs. of No. 4 wire to 12¾″ diameter over the bands. The bore of the fields is 12″, thus allowing a clearance of ⅛″ all round the armature. There are 76 segments in the commutator. The field cores, which are of wrought-iron, are 10¾″ diameter by 12¾″ long, and are wound with 120½ lbs. of No. 15 wire, and the series coil of No. 8 wire weighs 62 lbs. The speed of the machine is 1300 revolutions per minute. The output is, therefore, at full load 5.23 watts per lb. gross weight: 87.79 watts per lb. of copper wire on the machine and 210.3 watts per lb. of wire on the armature. One peculiarity of this machine is the manner in which the series coils are wound over the armature itself and not over the field limbs as in other dynamos. The regulation of the machine is not perfect, but is fully equal to that of the compound wound Edison dynamos.

ALTERNATING CURRENT DYNAMO MACHINES.

WESTINGHOUSE DYNAMO (FIG. 8).

In a description of alternating current apparatus, the first place is due to the Westinghouse Electric Co., of Pittsburgh, organized in 1886, the pioneer on this Continent in the supply of the A. C. system of distribution of electricity.

In December last, 259 Westinghouse central stations were in operation with an aggregate capacity of 438,500 lights of 16 c. p. each, and at the present time there are 265 central stations, to which are connected 25,000 converters supplying current for 458,250 16 c. p. lamps.

The Westinghouse 1500-light machine weighs 9750 lbs. complete. The armature, which is built up of laminated discs of soft iron, is in the form of a hollow cylinder, 20⅞″ in diameter and 21″ long, and weighs 1440 lbs. It is wound with 30 lbs. of No. 10½ B. & S. gauge wire, and its weight complete is 1600 lbs., including the shaft. The total weight of the castings in the field, including the bed plate, is 6838 lbs. The weight of copper wire on the field bobbins, which are 12 in number, is 1257 lbs. The current from the machine at full load is 75 amperes, and the pressure 1050 volts. The output is thus 7.7 watts per lb. of gross weight: 58.27 watts per lb. of copper wire on the machine, 2500 watts per lb. of wire on the armature. The speed of the machine is 1375 revolutions per minute, and the periodicity 136. The exciting current is 14 amperes at 110 volts pressure, equivalent to 1540 watts, or nearly 2 E. H. P.

BRUSH A. C. DYNAMO (FIGS. 9 & 10).

The machine shown in the engravings is the 1000-light Brush alternator. Like all the Brush A. C. dynamos, it is intended to be run at from 2000 to 2200 volts. This size of machine delivering 30 amperes at that pressure runs at 1100 revolutions per minute at full load, at which it takes 100 H.P. to drive the alternator and exciter. The exciting current of 22 amperes and 135 volts is supplied by a small Brush arc light dynamo. The regulation is effected by sending part of the current from the exciting dynamo through a shunt box of varying resistances operated by hand. Very little regulation, however, is required, as the machine is nearly self-regulating from no load to maximum load. The armature (Fig. 10) is stationary and the fields revolve, this being the only A. C. machine in America so constructed. Such a construction has several advantages; in the first place the revolving part has only a low tension current passing through its coils, and being heavy and perfectly balanced acts as a fly wheel and regulator of the speed when from any cause there is a tendency in the prime motor to slacken speed. The wires from the switchboards are permanently attached to the ends of two coils of the armature. The armature coils are light and independently bolted to the ring, which holds them in position between the field bobbins. Should an accident happen to one of the armature sections, the latter may be replaced in five minutes by one man, the weight being only a little over 20 lbs. The armature core is composed of fibre in segments on which are wound copper ribbons insulated by silk and shellac. The total weight of the armature ribbon is 63 lbs., and of the complete machine 5120 lbs.

There are 12 cores of alternating polarity on each side of the field wound with 618 lbs. of copper wire. These cores are of wrought-iron bolted to two iron plates, and the weight of the twelve is 456 lbs. The nominal output of the machine, 60,000 watts, is at the rate of 11.71 watts per lb. gross weight: 88.1 watts per lb. of the total copper on armature and cores, and over 952 watts per lb. of the copper ribbon on the armature.

THE ROYAL ELECTRIC CO.'S DYNAMO (FIG. 11).

Sometimes the machines of the Royal Electric Co. for A. C. work are made with the exciter on the same shaft as shown in the cut, but more frequently the exciter is separate. In the 1200-light dynamo with separate exciter, the active iron in the fields weighs about 3400 lbs., and the iron rings of the armature (which is a hollow cylinder built up of laminated wrought iron) weigh 1250 lbs. The radial depth of these rings is 5". When turned up ready for winding the armature is 24⅝" diameter and 18¼" long. The diameter when wound is 25¼" over the bands, and, as the internal diameter of the field bobbins is 25½", there is a clearance of full ⅛" all round. The fields are wound with 845 lbs. of No. 8 B. & S. gauge wire; the armature winding consists of 32 lbs. of No. 11 B. & S. gauge wire. The speed of the machine is 1200 revolutions per minute, and the exciting current at full load is 24 amperes at 90 volts—say 2160 watts or nearly 3 E. H. P. The standard output of the machine is 70 amperes and 1020 volts, or 7.5 watts per lb. gross weight: 81.41 watts per lb. of the total copper wire and 2231 watts per lb. of the wire on the armature.

RATE OF ALTERNATION OR PERIODICITY.

In the Brush dynamo the periodicity is 110, while in the Fort Wayne, Westinghouse and Thomson-Houston machines the periodicity is from 125 to 136.

The European practice as to the rate shows considerable variation Messrs. Ganz & Co., of Buda Pesth, in the Ziperoowsky system use 42 cycles; Mr. Ferranti uses 68; Mr. Kapps works his machines at 80; and Mr. Mordey runs his at 100.

CONVERTERS.

WESTINGHOUSE CONVERTER (FIGS. 12 & 13).

The Westinghouse converter is of the shell type. In the 40-light converter, the core is built up of plates .017 inch thick, of which the total weight is 81 lbs. The primary winding of No. 16 wire weighs 10½ lbs., and the secondary wire is No. 3 gauge, 13¾ lbs. in weight. At 50 volts and 40 amperes this converter gives an output of 19.09 watts per lb. of active material. The P. D. between primary terminals required is 1000 volts, developing an E. M. F. of 50 volts at the terminals of the secondary coil.

Recent tests by Dr. Louis Duncan, of John Hopkins University, show 95 per cent. efficiency in a 40-light converter at full load, and only 84 watts loss with no load, and 90, 87.6, 83.3, and 70.7 per cent. efficiency in a 20 light converter at full, three quarter, half and quarter loads respectively.

THOMSON CONVERTER.

The Thomson converter, manufactured by the Royal Electric Company in this city, is similar in construction to the Westinghouse. The following are the particulars of the 30-light size: Iron discs, 108 lbs; primary wire, 920 feet No. 18 B. & S. gauge, 4⅞ lbs.; secondary wire, 44 feet No. 9 B. & S. gauge, 3⅞ lbs.; total active material, 116⅝ lbs.; case, 59½ lbs.; weight complete, 176 lbs.

BRUSH CONVERTER (FIG. 14).

The Brush 50-light converter is of the core pattern, like all the Brush converters with the exception of the two of smallest size. The iron wire in the core weighs 92 lbs., the primary wire weighs 20 lbs., and the secondary winding 11 lbs. At 100 volts and 30 amperes its output is thus 24.39 watts per lb. of active material. The case weighs 100 lbs. The 75-light converter core of iron wire weighs 115 lbs., primary winding of copper wire 21 lbs., and secondary winding 15 lbs. At 100 volts and 45 amperes the output is 29.8 watts per lb. of active material. The case weighs 110 lbs. These converters are made in standard sizes of 5, 10, 20, 30, 40, 50, 75, 125, 250 lights and up to 1000 lights capacity. They are also made for primary circuits of 1000 volts pressure with a ratio of conversion of 10 to 1 or 20 to 1. The core consists of the finest Swedish iron wire, insulated by cotton winding or braiding wound into an octagon form, by having pieces of wood placed under and through the coils, as shown. The secondary wires are then wound over the sections between the wood blocks with insulated pads between them and the iron wire at the corners. Over the corners of the secondary winding are placed other insulating pads, over which are then wound the fine primary wires.

There is thus an air space for insulation all round the different coils except at the corners where the wires lie on the insulating pads. The efficiency of a 75-light converter varies from 98 per cent., with 75 lights attached, to 93 per cent., with 38 lights.

METERS.

EDISON METER (FIGS. 15 and 16).

In the Edison system of distribution an electrolytic meter has been employed. A disadvantage connected with its use is that nobody except an employee of the company can find out what the meter has registered, and even he has to take every precaution in the washing and drying of the electrodes and in their accurate weighing in a chemical balance. This meter has been very extensively used, and has evidently given fair satisfaction, but the following statements from some of the superintendents of Edison stations show satisfaction is not general:

"The confidence is fully as great as in gas meters."

"They have as much confidence in the Edison meter as in the gas meter, and probably a little more."

"The meter to our customers is a blank, and it becomes a question of confidence in the meter man."

"Our meters here are a great deal of trouble owing to the number we have in use, but still we could not get along without them."

Sir D. Solomons, in the last edition of his work on electric lighting, describes the Edison meter as a thing of the past.

It is but fair to the Edison Company to say that they do not recommend their meters being used in stations of less than 1000 lights capacity.

THREE-WIRE ARON METER (FIGS. 17 and 18).

The Aron three-wire meter (Fig. 17) is used in all the large Edison stations, and by some other companies in Germany. It is a most admirable and reliable instrument, and it is one from which the consumer himself can learn what he is using. The one shown in Fig. 18 is applicable to the two-wire and A. C. systems. The registering apparatus consists of two sets of clockwork which will run forty days with one winding, but which it is intended to wind up every thirty days, when the readings are taken. The pendulum on the left is an ordinary pendulum uninfluenced by the current, but that on the right consists of a coil of very fine wire, which is connected direct to both the positive and negatives wires of the system, while one of the main wires, either the positive or negative, forms a solenoid, through which the main current passes, envelopping the fine wire pendulum core.

Before any current is passed through the meter, it should be tested in place to see that the pendulums swing synchronously. If they do not, the indications of one pendulum will gain upon those of the other. The exact adjustment to perfect synchronism is obtained by raising or lowering the weight on the left hand pendulum. If found correct the current is passed through the meter, and the right hand pendulum's movement being accelerated by the action of the current, causes the registering gear to work.

The chief obstacle in the way of the more general employment of this meter is its comparatively high first cost, but it appears to be worth the money.

WESTINGHOUSE METER (FIG. 19).

The Westinghouse meter is the one which has been most extensively used in America for the measurement of alternating currents, having been exclusively used in the Westinghouse stations, and being now largely used in those of other companies. About 1,200 are now in use. It is simply a small alternating current motor with registering gearing, and attached vanes placed on the shaft to retard the movement to a degree necessary for its adjustment and regulation. Its chief disadvantage is that it does not work readily with a small current, but as this tells against the company and not against the consumer, the latter will not probably have any objection to it. This meter will be better understood by examination of the sample on the table.

Alternating current meters have also been made by the Fort Wayne Electric Co. and the Thomson-Houston Electric Co.; but the latter is not yet on the market, and as the author has no experience of either he prefers not to describe them, and would refer members to the "Electrical World" or "Electrical Engineer" for full particulars.

STORAGE BATTERIES.

Storage batteries have not been applied on this continent to any such extent as they have been in Europe. Wherever they are employed except for propulsion of about a dozen street railway cars, perhaps fewer, it has been for the purpose of securing light after engines and dynamos have been stopped at night, and for railway car lighting. For the latter purpose they have not hitherto been a success, and have been discontinued on the Pennsylvania Road, on the Canada Atlantic and on the Grand Trunk Railways, the Julien battery having been used in these cases. On the Intercolonial Railway a great number of cars have been fitted up with these batteries, and it is said several additional charging stations are to be erected, it having been found that the two at present in operation, one at Levis and the other at Moncton, together with such current as may be obtained at Halifax, N.S., and Montreal, have been insufficient, or otherwise expressed, the capacity of the batteries supplied has not been enough to last during the runs between the various stations. The fact that the coal oil lamps, which were wisely left in position, are used on nearly every trip, proves the inadequateness of the batteries which have been supplied for this work.

Outside of these plants storage batteries have been used in five or six places in Canada, among which may be mentioned McGill College, the lights which we have here being run from a Gibson battery in the basement. The battery is charged from a small shunt wound dynamo driven by an Otto Gas engine made by Crossley Bros. of Manchester.

A PRIVATE INSTALLATION.

The same kind of plant and the same kind of battery are used in the residence of Mr. F. R. Redpath, the arrangement of which is shown in Figs. 20–23. The plant is in the basement of the house. The gas engine is an Otto made by Messrs. Schleicher, Schumm & Co., of Philadelphia, and is the steadiest running gas engine in Canada. Its weight, with two 54-inch fly wheels, is about 3200 lbs. It indicates 3.9 H. P., with a gas consumption of 26 cubic feet per H. P. per hour. Over the cylinder is a cast-iron saddle, on which the dynamo, a shunt wound machine made by Holmes & Co., of Newcastle-on-Tyne, is placed, there being just one quarter of an inch clearance between the rim of the fly wheels and the ends of the dynamo bed. Behind the dynamo and attached to the bed of the engine are two wrought-iron adjustable arms carrying the countershaft and idler pulley. The dynamo pulley is therefore between the idler and the fly wheel of the engine, is double crowned and is lapped over nearly the whole circumference by two belts as shown. The slip is less than 2 per cent. The speed of the machine is 180 revolutions per minute. The dynamo weighs 430 lbs., and the idler pulley and countershaft 100, so that the total weight of engine, dynamo and driving gear is 3800 lbs. A box 7′ 4″ × 2′ 8″ × 5′ 2″ would cover engine, dynamo, belting, idler pulley and countershaft, and the whole might be thus shipped to any distance completely set up ready for connection of gas and exhaust pipes. The arrangement of the plant was designed by Mr. Redpath, and is most compact and ingenious.

There are 42 cells of Gibson battery, capacity 150 ampere hours, and they are connected in two sets of 21 each in parallel, the changing current being 33 amperes at from 45 to 55 volts pressure. These cells are ranged on shelves in the engine room. The plates in this battery are placed horizontally instead of vertically as in other batteries, and have thus the advantage of being less liable to short circuiting through paste falling between them as it does in vertically arranged plates. A slight disadvantage is that the internal resistance is higher than some other forms of battery owing to the plates being further apart; but this is compensated for by the longer life of the Gibson, the makers guaranteeing to keep it in order for ten per cent. per annum of the first cost. The electrolyte used is dilute sulphuric acid with the addition of sulphate of soda, the density of the combined solution being 1.220. This battery will stand heavier charging than any other, and has frequently been charged with a current of 75 amperes; but the most economical practical charging rate is about 30 amperes. In charging the current is measured by Weston ammeter and the pressure by a Weston volt meter. There is also another Weston volt meter in the library upstairs, and underneath it a resistance switch of German silver in series with the battery, by which the pressure in discharging is regulated, as the battery, when first connected to the lamps after charging, is higher in E. M. F. than when nearly discharged, and the lamps used are of course of such voltage that they will give their full light at the lowest pressure to which the battery in practice is reduced. The maintenance of perfectly uniform light is thus under control from Mr. Redpath's arm chair.

This is the first and only complete private installation for residential lighting in Canada, and was first started five years ago, shortly after the visit of the British Association to this country.

VALLEYFIELD AND BARRIE CENTRAL STATIONS.

Let us describe briefly and compare these central stations, both constructed by the writer, and both of which are good samples of their respective class. Both have water power, but the first is on the Edison three-wire system and the second is a Brush A. C. plant. In Valleyfield the power is in the heart of the town and in the centre of distribution, so that it is in the most favourable position for economical distribution by low tension, and the wire used is as small in area as consistent with even voltage at the lamps and best efficiency of the plant. Both stations were built with rooms for the man in charge over the dynamo room. The running expenses are the same or about the same in both places. Probably no other stations of similar capacity in the world cost less to run, the total annual expense in each being less than $1600. The capacity of both stations is about the same, say 60,000 watts. The Valleyfield station complete cost $38,000, including building, water-wheels and flume. The Barrie station, including the same items, cost less than $22,000, including over $3000 for the wire leading into town for the station, five miles distant. In the Barrie station heavily insulated wire is used throughout the 24 miles of street wiring, and rubber-covered wire in all buildings, whereas bare wire is used at Valleyfield for street wiring, and fire and weatherproof wire for inside work. House wiring in Valleyfield is all cleat work, while most of that at Barrie is concealed, the lights in the latter place being principally in private houses placed on brass fixtures, while at Valleyfield drop cords are used exclusively. The pressure in the houses in Valleyfield is generally 220 volts, the three wires being carried in all cases where this system is used, in order to maintain as even a load as possible on both sides of the circuit. In Barrie the pressure is 93 volts on the lamps in the houses, and nothing higher than 98 volts can ever enter them. The charge for current averages at Valleyfield $9 per light a year, and at Barrie $7.50. This means that, making due allowance for all contingencies in both cases, the Barrie plant will pay its shareholders better than the Valleyfield plant will, while the customers pay $1.50 per light a year less. In the Barrie station Westinghouse meters are used on the premises of the largest consumers, and these can be read by the consumer as well as the meter man, the cost of operating the station is not increased, the man who attends to the wiring of the buildings in town and to collection of accounts taking the readings; while if the Edison meter be used at Valleyfield, another man will require to be employed to attend to the meters solely, and his wages will have to be added to the operating expense and thus reduce the net revenue.

The respective sizes of wire used in both stations is worthy of study. At Barrie the loss in the feeder is 14½ per cent. at full load, nearly the same as at Valleyfield. The length of feeder at Barrie is 10 miles for the complete circuit, and the size of wire No. 4 B. W. G. At Valleyfield the feeders are three in number and three in a set; the longest is less than two miles for the complete circuit, and the size of the outside wires No. 000 B. W. G. The No. 4 wire used at Barrie weighs 985 lbs. per mile, including insulation, and the No. 000 bare wire at Valleyfield weighs 2886 lbs. per mile.

It may be and has been said that in the one case you have a perfectly safe low tension system, while in the other, to use the pet phrase of the paid advocate of low tension, you have the "Death-dealing Alternating Current." That is admirable as a trade trick, but even the Edison Company now advertise that they are prepared to supply A. C. plant to all who desire it. Either there is less danger than they would have the public believe in the A. C. system, or they are ready to subordinate principle to pocket in the contest. To alter slightly a phrase from Dickens' "Holiday Romance," the Edison people have been advising the public to "Prohibit the use of the alternating current system on the ground of humanity as it makes ours too expensive." In an article on this subject, Sir William Thomson, the greatest living authority on electrical matters, says:

"*In passing I may remark that* 100 *volts in the house is perfectly* "*safe to the user, whether the current be alternating or continuous, as* "*is proved by large and varied experience in England.*"

It must be freely admitted that the accidents reported from New York were real and not invented for sensational purposes, but it must also be acknowledged that in no other city in the world is there such an organization as the Board of Electrical Control, to which appointments are made by political influence only, regardless of qualification, and one of whose advisers is, or was, an individual whose business it was for the past two years to discredit the alternating system, for which service he was well paid. In no other city in the States or Canada is there such bad construction of overhead conductors as there was in New York, and the under-ground construction there is nearly as dangerous on account of existing grounds on the wires and leakage of current, and the consequent liability to cause explosions of gas in subways as has already been repeatedly done, besides turning the paving stones into "a molten mass."

Furthermore, the insulation of the overhead wires, which have been in use in some cases over eight years, had rotted off, being of the quality known as "Underwriters," or "Undertakers" if you will.

Four deaths have occurred in the whole history of electric lighting in Canada from shocks of electricity, and two of these were the result of bad insulation of wires and faulty construction by a purchasing company doing its own work without employing anybody having any knowledge of the business, in order to cheapen the first cost of the plant, and which purchased a job lot of poorly insulated wire, and ran two dynamos in series with 100 arc lamps in circuit at a tension of nearly 5000 volts. The current used on that system was a continuous one, not a pulsating high tension current as stated in a circular which some of you may have received.

Thirty wires radiate from the Valleyfield stations. One pair carries the current from the Barrie station. In the Barrie station the pressure of primary current is the highest which has yet been used in this country, being about 2100 volts average on the feeder. This pressure is raised or lowered by increasing or decreasing the exciting current according to the load shown on the central station ammeter, which is graduated to single amperes, and is indicated by a Cardew volt meter, which, as elsewhere mentioned, is attached through a converter to the armature. Instead of having a compensator, as is used in the Westinghouse system, a table of loads and the corresponding pressures to be carried at the station is used. This method, though of course not absolutely perfect, owing to the rise of current with increase of voltage and vice versa, answers very well. The Cardew volt meter in the company's office in town, which is an excellent check upon the dynamo attendants' work, shows an average variation of two volts only in a night's run. The mains in town, which aggregate nearly 14 miles in length, are calculated for a loss of only 2 per cent. at full load, which gives a difference of ⅗ of a volt per lamp up or down from the standard. The house wires, which are insulated with rubber and tape, are calculated for one per cent. loss only at full load. As most of the lights are taken in private residences, where the whole number are hardly if ever in use at one time, the loss of light through resistance of the house wiring is practically nil.

MEASURING INSTRUMENTS.

The Ayrton and Perry instruments have been used to a very considerable extent in this country, and until recently were the most accurate of all really portable electrical measuring instruments. There is a sample on the table before you. They are only suited for direct currents, and are open to the objection that they have considerable friction and a high temperature error if kept in circuit, which they should never be except only for a few seconds when taking readings.

The Weston volt meter is shown in Figs. 24 and 25, and on the table are a volt meter and an ammeter of this type. These volt meters have the great advantage of extreme accuracy and very high resistance, averaging about 20,000 ohms, so that the quantity of current passing is extremely small. They may be kept continuously in circuit without any material variation in their readings. They require careful handling, of course, as do all electrical instruments, but they are the most accurate and reliable of all portable testing instruments for continuous currents. The volt meters contain a calibrating coil by which their constancy can be at all times tested. The writer has used quite a number of these instruments which he has checked with each other, and has sometimes compared the higher and lower scale by taking the P. D. difference between terminals of single cells of secondary batteries, and then, putting the whole of the cells in series, compared the reading of total E. M. F. of the battery. Several tests of this nature have come out within one quarter of a volt. The calibrations are in single volts on the higher scale, and thirtieths, twentieths or tenths of volts on the lower scale. The ammeters read to tenths of amperes in the small sizes. In both the divisions of the scale are so wide that one quarter of these values can be read with perfect ease.

For the most perfect readings by these instruments they should be set quite level, and 5 feet away from any other instrument, or from any mass of iron or steel, and so placed that the index will point due west when at the centre of the scale, but these precautions are not necessary for ordinary testing of pressure in buildings, as the error can never be more than ½ volt, if otherwise placed.

The Cardew volt meter (Fig. 26) is used for both direct and alternating currents, and is made to be used either vertically or horizontally.

The horizontal pattern has the advantage of being steadier than the vertical instrument owing to the disturbance caused by currents of air passing up the tube of the latter. All the more recent forms of this instrument have an adjusting screw outside of the case to bring the needle to zero, which should be done before the current is turned on. No adjustment should be made while the wire remains warm, as the section of the wire may be altered by any tension put upon it while in this condition and the calibration destroyed.

For alternating and direct currents Sir Wm. Thomson's latest instruments are the finest yet produced, but are more suited for standard or station than for use as testing instruments.

In the electrostatic instruments no current passes through the instrument at all, and so the conditions of a battery or dynamo on open circuit can be found with perfect accuracy. The electrical balances (Fig. 27) are adapted for both alternating and direct currents. To anybody desiring a fine standard laboratory or station set of large range, none are better than these instruments, expensive though they be. All stations for alternating current work should have a Cardew or Thomson volt meter, a portable Thomson multicellular electrostatic volt meter, for testing pressure in consumer's premises, etc., and a Thomson ampere gauge. For direct current stations Weston or Cardew volt meters for station work and line testing should be used, and Thomson ampere gauges for current measurement. The Westinghouse ammeter, an excellent instrument closely resembling the Thomson ampere gauge, is shown in Fig. 28, and the Edison ammeter in Fig. 29. For rough approximations the latter is a cheap and fairly accurate instrument.

TRANSMISSION OF POWER.

In his Address at the Annual Meeting, the President touched upon the subject of electrical transmission of power, mentioning the installation at the Chollar Mine, Virginia City, Nevada. There a Brush plant is used, as then stated, placed 1680 feet below the surface of the ground, in a chamber 50′ long × 25′ wide × 12′ high, hewn out of solid porphyry. The small stream of water, which drove the wheels at the surface of the mine,—was carried down through two iron pipes one 10″ and the other 8″ diameter, connected together at the bottom of the shaft by a Y into a single pipe 14″ diameter from which 6″ pipes lead to the Pelton water wheels' nozzles, and there develops sufficient energy through the dynamos to transmit to the surface through well insulated cables 450 H. P. The waste water is conveyed away through the Sutro Tunnel, pierced through the side of the mountain for the drainage of the mines—in itself a monument of engineering ability and Western enterprise. This is at present the largest installation in the world for transmission of power by stationary electric generators and motors.

About August last a generator and a motor of exactly the same type as those placed in the Chollar Mine were installed at Messrs. Barber & Co.'s Mills, Georgetown, Ont. The water of the Credit river was dammed over 2 miles below the mill, and a water wheel and shaft were placed in a building there along with the generator. A copper wire was carried back and attached to the motor, which develops 75 H. P. in the mill.

ELECTRIC RAILWAYS.

Four years ago there may be said to have been no electric railways in operation in America. Yet according to the most reliable sources of information there were 636½ miles of electrically equipped railways in operation and 700 miles under construction at the end of December, 1889: 1063 electric cars were then running and 771 cars were being equipped. The total number of completed roads was 107, and 85 were under construction. Of these roads two were running in Canada, their total length being 10 miles, and these were equipped with 10 motor cars. The first, at Windsor, Ont., with two miles of road and two cars, has now been at least four years in operation; the other is at St. Catharines, and the length of road is 8 miles, and it is equipped with 8 cars. Both roads use the Vandepoele system. The road at Victoria, B.C., is now running. The track is 4 miles long, with 4 motor cars. The Vancouver road, now approaching completion, is likewise 4 miles in length, and will be equipped with 4 motor cars. It will be running about the beginning of June. The Thomson-Houston system is used in both cities.

By far the largest amount of work in Electric railways had been done by the Thomson-Houston Co., and the Sprague Co. ranks next. The table given below shows the amount of work done by various companies and that under construction in January last.

ELECTRIC RAILWAYS.

In operation and under construction, Jan., 1890.

Name of System.	In operation. No. of Roads.	In operation. No. of Cars.	Under construction. No. of Roads.	Under construction. No. of Cars.
1 Thomson-Houston......	47	490	37	509
2 Sprague..................	35	408	33	218
3 Daft.......................	10	66	5	15
4 Van de Poele............	8	57	"	"
5 Short......................	3	17	1	5
6 Bentley-Knight..........	1	6	1	20
7 National Electric Ry. Co.	1	1	5	not given
8 Julien.....................	1	10	"	"
9 Fisher......................	1	4	2	not given
10 Henry.....................	1	4	"	"
11 Rae........................	"	"	1	4

STREET WIRING FOR ELECTRIC LIGHTING.

First, on account of the dangers of break down from heavy sleet storms, and the variation in tension of wire caused by the extremes of temperature experienced in Canada, poles should be placed not more than 135 feet apart, or say 40 to the mile. They should all be good, sound, straight cedar, 7 inches diameter at the top end and not less than 35 feet long, and should be set in the ground to a minimum depth of 6 feet and securely tamped. The cross arms should be of sound timber $4\frac{1}{2}'' \times 3\frac{1}{2}''$, well painted, and fixed in gains cut in the poles and secured thereto by lag screws 8" long, which would thus enter into the pole about $4\frac{1}{2}$ inches. They should never be attached by spikes only. Wherever telephone or telegraph wires run in the same streets, the poles should be of sufficient height to carry the electric light wires at least four feet above them. Bare wire for carrying either high or low tension currents in towns should be strictly prohibited.

None but the best double petticoat glass insulators should be used. The insulation of the wire should be both fire-proof and weather-proof, and be of such tough texture as to withstand abrasion should other wires by any means fall across the electric light wires.

For outside construction some of the English Board of Trade Regulations, which might be adopted with advantage in this country, are as follows, the numbers given being those of the Regulations:

1. An aerial conductor in any street shall not in any part thereof be at a less height from the ground than 20 feet, or when it crosses a street, 30 feet, or within six feet of any building for the purposes of supply.

2. Every support of aerial conductors shall be of durable material, and properly stayed against forces due to wind pressure, change of direction of the conductors or unequal lengths of span, and the conductors and suspending wires (if any) must be securely attached to insulators fixed to the supports. The factor of safety shall be at least 6, and for all other parts of the structure at least 12, taking the maximum possible wind pressure at 50 lbs. per square foot.

5. Every aerial conductor shall be protected by efficient lighting protectors.

6. Where any conductor crosses a street, the angle between such conductor and the direction of the street at the place of such crossing shall not be less than 60 degrees, and the spans shall be as short as possible.

7. Where any aerial conductor is erected so as to cross any other aerial conductor, or any suspended wire used, for purposes other than the supply of energy, precautions shall be taken by the owners of such crossing conductors against the possibility of that conductor coming into contact with the other conductors or wire, or of such other conductor or wire coming into contact with such crossing conductor by breakage or otherwise.

11. The insulation resistance of any circuit using high pressure aerial conductors, including all devices for producing, consuming or measuring energy connected to such circuit, shall be such that should any part of the circuit be put to earth the leakage current shall not exceed $\frac{1}{25}$ of an ampere in the case of alternating currents. Every such circuit containing high pressure conductors shall be fitted with an indicating device which shall continuously indicate if the insulation

resistance of either conductor fall below the conditions required by this regulation.

14. The owner of every aerial conductor shall be responsible for the efficiency of every support to which such conductor is attached.

15. Every aerial conductor, including its supports, and all the structural parts and electrical appliances and devices belonging to or connected with such conductors, shall be duly and efficiently supervised and maintained by and on behalf of the owners as regards both electrical and mechanical condition.

16. An aerial conductor shall not be permitted to remain erected after it has ceased to be used for the supply of energy unless the owners of such conductor intend, within a reasonable time, again to take it into use.

17. Every aerial conductor shall be placed and used with due regard to electric lines and works from time to time used or intended to be used, for the purpose of telegraphic communication, or the currents in such electric lines and works, and every reasonable means shall be employed in the placing and use of aerial conductors to prevent injurious affection, whether by induction or otherwise, to any such electric lines or works, or the currents therein.

The author considers that rules 7, 13, 14, 15, 16 and 17 should be equally binding upon telegraph and telephone companies whose wires are often as carelessly constructed as those of any electric light company, and have in consequence been quite as blameworthy for fires originating from electric currents.

HOUSE WIRING.

In the interior wiring, none but high class rubber insulated wire protected by an outer linen tape or other efficient covering should be used.

None but porcelain or slate base cut outs and switches should be allowed, and the sweating of drop wires for single lights on the main wires, such wires being afterwards twisted together and brought down to the lamp socket, should be prohibited.

Wherever lights are suspended by wires, stranded conductors, equal in area to No. 20 standard wire gauge, covered with a good solid rubber coating and protected on the outside by silk or cotton braiding, should be used, and where taken off from the main wires a porcelain rosette cut-out, such as the K. W. rosette, should in all cases be provided or a wood base rosette may be used, provided it is rendered fireproof.

No switches should be used which do not break contact quickly and automatically, or in which spring copper makes a connection; such copper is heated by the passage of a large current, and, by losing its hardness therefrom often fails to make good connection, and so may cause an arc to form. The Paiste switch is the only one at present made on this continent which fulfills these conditions.

Fuses for cut-outs should not be interchangeable with others of widely different capacity. Over-loading of wires first designed for lighter loads would then be impossible.

The joints in wires are preferably made with connectors such as the MacIntyre wire joint, as soldered joints on which acid has been used frequently corrode through the excess of acid not having been removed on completion of the soldering, and it has been the author's experience that ordinarily wiremen will not take the time or trouble to make a good joint with rosin as a flux.

It must be remembered that a low tension continuous current is more liable to cause a fire in case of short circuit between the main wires than an alternating current, owing to the connection which exists directly between the dynamo and the house wires, permitting the entrance into the house of an enormous current, while with the alternating current system the short circuiting of the secondary house wires will only result in the immediate melting of the fine wire fuse in the primary circuit of the converter. There should be no relaxation, therefore, of adopted regulations in favour of low tension direct systems on account of supposed greater safety, a thing which does not exist in their case, but both direct and alternating current systems should be treated alike so far as the wiring of consumers' premises is concerned, and the present standard should be raised, not lowered.

It should not be forgotten, that one of the most important elements in the attainment of perfect safety to everybody concerned is the employment by supply companies of properly qualified and experienced labour both for the construction and for the running of plants. It will be found to be very poor economy to employ bell hangers, plumbers and even shoemakers on work requiring considerable electrical and mechanical knowledge and clear judgment, as is done at the present time in some Canadian stations which might be mentioned, merely for the sake of saving two or three hundred dollars a year in wages, a sum which is much more than counterbalanced by the unsatisfactory results in the lighting and the additional cost of repairs. Nor should it be forgotten that a cheap and poorly constructed electric lighting plant is the worst of all possible investments.

To reassure the timid whose nerves have been so skilfully played upon by advocates of low tension systems, the following opinions of Sir William Thomson, Dr. John Hopkinson, Mr. W. H. Preece, Professor George Forbes and Monsieur E. Fesquet, handed in at recent meeting of the New-York Senate Committee on Electric Lighting, may be cited. These gentlemen, whose qualifications to speak authoritatively on the subject cannot be questioned, are practically unanimous in the opinion that the distribution by alternating currents can be and is safely carried out by underground or overhead wires at pressures of 2000 to 2500 volts; that absolute safety to the person can be and is obtained in the use of such currents; that there is less danger from fire from an alternating current system using converters than from a continuous low tension current connected direct from the dynamo to the consumers' premises (and the higher the tension in the primary the greater the safety in this respect); that on account of the small current and the consequently smaller area of copper wire required for its distribution, the alternating current had many advantages over all systems of low tension distribution; and that a properly constructed and mounted converter is in itself an effective protector to the user of electric illumination against danger from shock or fire.

In conclusion the opinion may be also hazarded that within the next ten years three-fourths of the incandescent electric lighting on this continent, following the example now set in Europe, will be carried out on the alternating current transformer system at increased rather than lower pressures than at present used, and that a large proportion of our mills and factories situated within five or even ten miles of water powers will be run by electric motors either driven direct by high tension continuous currents or by low tension alternating currents obtained through converters attached to primary conductors carrying a high tension and small current.

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