CHAPTER VIII.

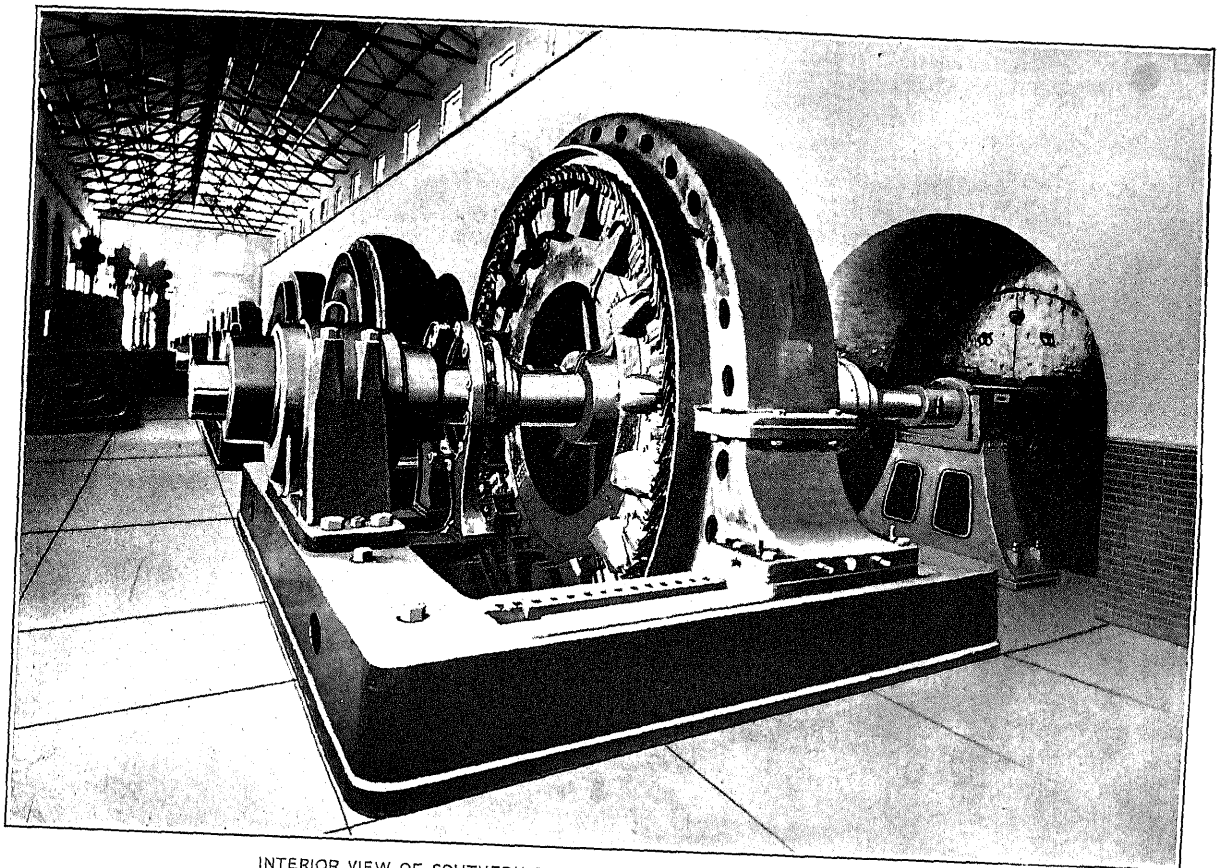
TECHNICAL ASPECTS OF THE PERIOD.

By Thomas Commerford Martin, Expert Special Agent.

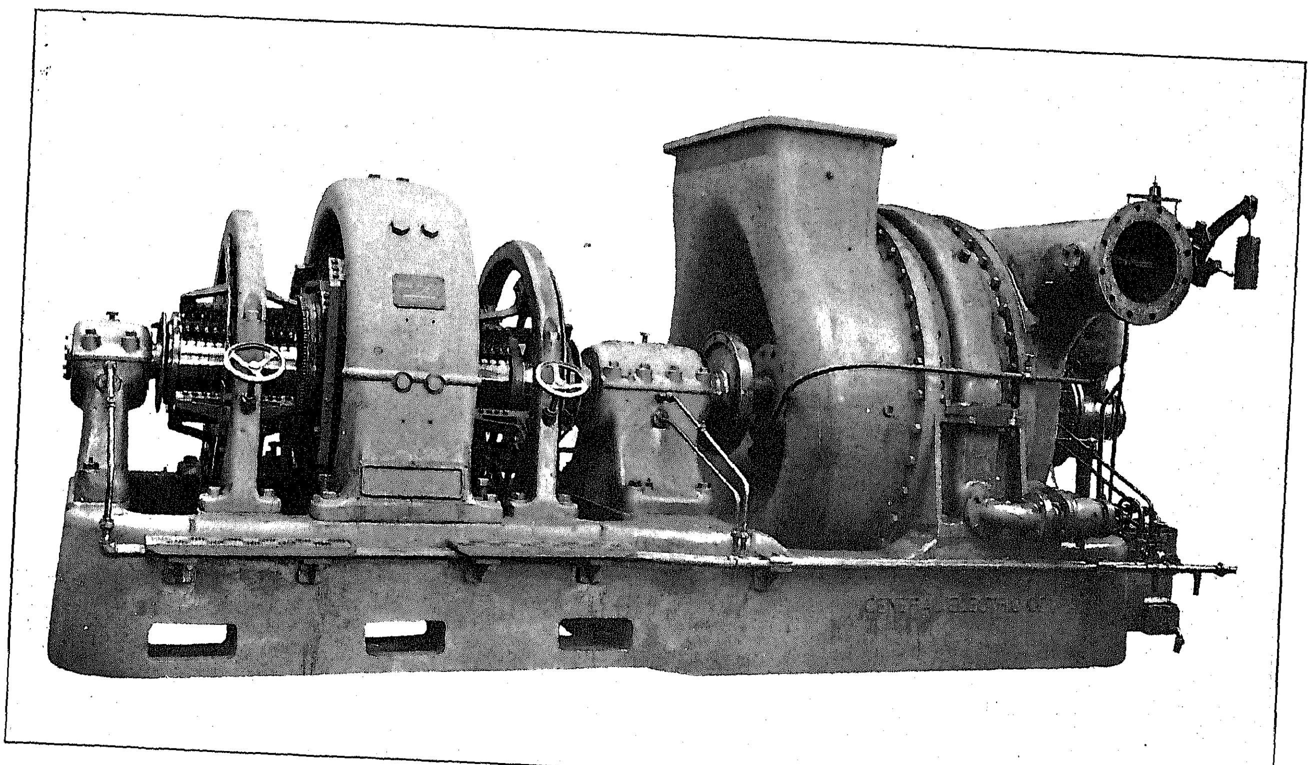
General conditions.—The report on central electric light and power stations for 1902 embraced a historical review of their development and discussed the apparatus in use at that time for the generation of electrical energy and for its distribution and consumption, including dynamos, motors, transformers, arc and incandescent lamps, and other appliances. It is not necessary, therefore, to consider again these phases in the growth of the electric light and power industry; and the present discussion will be limited to the evolution that has taken place since 1902. There have been changes in every branch of the industry, some of which have been extreme, and the approach of a few of which was indicated in the former report. In one or two instances the introduction of new methods or appliances was unexpected. The changes in the technical aspects of the industry have kept pace with those in its financial and physical aspects. Virtually doubling itself every five years, in the latter respects, the central-station industry displays as yet no symptoms of settling down into a condition of satisfaction with the present which would be obstructive of improvement. Indeed, the notable tendency toward the consolidation of small individual stations into large "systems" with extensive networks has brought with it the wholesale "scrapping" of plants and apparatus and the installation of generating and consuming appliances of far higher efficiency and economy, in order to meet the demand on the part of the public for cheaper and better service.

A typical case is that of the Boston Edison Company, whose system in 1885 covered an area of one-eighth of a square mile, and at present covers an area of 509 square miles—the increase being due chiefly to expansion during the period 1902–1907. The map presented herewith, showing some of its circuits, reveals the details of that vastly larger area in which it is now operating, within which lie 35 cities and towns of Massachusetts, with a combined population of approximately 1,000,000 inhabitants. Included in this territory are 2,197 miles of streets, 1,016 miles of which are covered by the lines of the company Within the region are 34,428 customers, requiring a supply of current up to 100,000 kilowatts, equivalent to two million 16-candlepower lamps. Originally the engines in the generating plant were of 90 horsepower, but they have been displaced by steam turbines of 16,000 horsepower each; while generators of 20-kilowatt capacity have been succeeded by generators of 12,000-kilowatt capacity. All this development has taken place within a period of about twenty-five years, and similar development is shown in other large centers of population, such as those served by the Public Service Corporation in New Jersey and the Pacific Gas and Electric Company in California.

Another salient feature of the period 1902–1907 is the increasing resort to water power as a source of primary energy. The statistics in Chapter III on power equipment show that the number of steam engines, including steam turbines, in central stations increased from 5,930 in 1902, with a total of 1,379,941 horsepower, to 7,206 in 1907, with 2,627,450 horsepower. Practically all these engines were located within the corporate limits of towns and cities, and the increase in capacity during the five-year period was nearly 100 per cent. But the development in water power due to the establishment of perhaps not less than 300 hydro-electric power transmission enterprises is much more striking. The water wheels reported show an increase from 1,390 in 1902 to 2,481 in 1907, while their capacity increased from 438,472 horsepower to 1,349,087 horsepower, more than threefold. It is not to be understood that all this hydro-electric power is specifically employed in central station lighting and power, as a great deal of it is furnished to electric railways and isolated mills and mines. But the power-transmission company is generically a central-station plant, and all such companies and systems are included in the present statistics where they affect the totals and the analytic deductions in many important respects, as, for example, in the average price obtained per kilowatt hour. It is obvious, upon a moment's consideration, that a transmission company can sell its product at a lower rate than a central station which in its price per kilowatt hour to the customer has to include free supply of lamps, or arc carbons and globes, labor, inspection, etc. The apparent return per kilowatt hour as given in this report is thus too low, from the central-station standpoint, and would naturally be higher after the deduction of a very large but inde-



INTERIOR VIEW OF SOUTHERN POWER COMPANY'S HYDRO-ELECTRIC PLANT.



HORIZONTAL LOW-PRESSURE STEAM TURBINE AND GENERATOR.

terminate quantity of electrical energy sold in bulk by the power company, almost invariably at a price below what the same power would cost the receiving central-station company, or individual consumer, if it were produced by steam at or near the point of utilization.

This development of remote water powers for purposes of electrical transmission is recognized as one of the questions of the time, and was given special study by the conservation conference held at the White House in 1908, on invitation of President Roosevelt. In a report [1] to this conference, made by Mr. H. St. Clair Putnam, it was stated that of the total estimated power produced in the United States in 1907, about 26,000,000 horsepower was credited to steam engines, 800,000 horsepower to gas and oil engines, and 3,000,000 horsepower to water motors. It will be seen from these figures that nearly half the utilized water power of the country is subject to central-station conditions and control, and the proportion belonging to hydro-electric power is in reality much larger, as several hundred small electric plants not engaged in the sale of electricity, but connected with various manufactories, employ water power. Mr. Putnam said:

During the past few years there has been renewed interest in water powers on account of the practicability of their use for the generation of power and the electrical transmission of this power to distant markets. The great hydro-electric development at Niagara was the first large enterprise of this character and has demonstrated its practicability. The census of 1902 gives a partial list of long-distance hydro-electric plants developing power aggregating 600,000 horsepower; and this list can now be largely increased. Our most desirable water powers are being absorbed rapidly, and it becomes important, therefore, for us to take stock of our water resources and formulate plans for their control and proper utilization.

The recognition of the importance of water-power development has grown since the conference was held, and the proper methods of dealing with water powers and maintaining public control and interest in them have become a distinct problem for the National Government, as well as one of the topics most agitated in the press.

Steam power.—The figures in Chapter III show striking changes in the use of steam power in central stations since the report of 1902. At that time, owing to the fact that steam turbines had not been installed in any considerable degree, they were not reported separately. In the present report they are credited with 19.9 per cent of the total horsepower reported and 31.1 per cent of all the steam power. Few revolutions in the mechanical world have been more rapid and sweeping. The relative size of the units is also significant, for while the reciprocating engines averaged 265 horsepower in 1907, the turbines averaged 2,168 horsepower, or eight times as much.

[1] Proceedings of a Conference of Governors, published by authority of Congress, 1909, p. 292.

Only one or two of the recently equipped central stations with large generating units have installed reciprocating engines. The most notable instance is the Redondo generating station of the Pacific Light and Power Company of California, which has been equipped with reciprocating engines of the latest type. The plant has a nominal rating of 15,000 kilowatts in three equal units, which generate current at the extremely high electro-motive force of 18,000 volts, for which the dynamos are wound. There are three 34 and 70 inch by 56 inch combined double horizontal and vertical compound side-crank automatic engines, each direct-connected to one of the 50-cycle 3-phase alternators of the fly-wheel type. The fuel used is crude petroleum. On a total output of not less than 60,000 kilowatt hours per 19.5 hours running for fifteen days, there being 4.5 hours of "stand-by" idleness each day, the contractor guaranteed an output of 170 kilowatt hours per barrel of oil weighing 334 pounds, each pound delivering 18,500 British thermal units. The actual test showed 252.8 kilowatt hours per barrel; and a bonus of $363,310 was earned by the contractor as a result of this remarkable economy and efficiency. It is stated that the first cost of the plant did not exceed by 5 per cent that of a steam-turbine plant.

No other large new central station with reciprocating engines can be named. The whole drift seems to be toward large steam turbines or large gas engines, where water power is not available, or even as a reserve where the uncertainty of water power renders some auxiliary power necessary. Chicago and New York have both furnished examples. The New York Edison Company now has both its great Waterside stations in operation side by side on the East River, with an aggregate maximum rating of 330,000 horsepower, in 24 units of 169,500 kilowatts. Waterside No. 2 began operations in November, 1906, and although reciprocating units were first contemplated, it now contains six 8,000-kilowatt vertical turbo-generators, two 7,500-kilowatt horizontal turbine units, and two 14,000-kilowatt vertical units, which comprise the entire equipment of this huge station. Waterside No. 1, which began operations in October, 1901, and was intended to hold sixteen 3,500-kilowatt reciprocating engine units, has now eleven such units, together with three 10,000-kilowatt and two 5,000-kilowatt vertical turbine units.

The new Quarry Street station of the Commonwealth Edison Company of Chicago, constructed just across the south branch of the Chicago River from the Fisk Street station, illustrated in the report of 1902, constitutes, with its initial rating of 28,000 kilowatts in two units, a fit supplement to the latter station, the pioneer great steam turbine power house in this country. It is significant of the rapid march of events that the first four turbo-generators in the Fisk Street station, only five years old, were replaced in the summer of 1909 by an equal number of 12,000-

kilowatt units, which change increases the Fisk Street station rating by 22,000 kilowatts without any addition in the boiler room except the extension of two stacks and slightly increased grate surface.

A further development in the use of primary power has been the practice in high-pressure steam generating plants to resort to low-pressure steam turbines which run on the exhaust steam of reciprocating engines, and this practice appears to have been quite successful. In a paper on the subject[1] read at Atlantic City in June, 1909, before the National Electric Light Association, Mr. C. H. Smoot cited several instances, and said: "I strongly suggest that owners of noncondensing plants consider the opportunity of utilizing the exhaust of their reciprocating engines in low-pressure steam turbines, and thereby adopt a method of rejuvenating their plants by one of the most efficient methods of developing power from steam."

Oil engines.—The Pittsfield (Mass.) Electric Company has put in regular service an interesting oil-driven plant to supplement its older steam plant, which also does a large exhaust-steam heating business in the cold season. The fuel used is crude petroleum. A side track of the Boston and Albany Railroad extends parallel to the north wall of the station, and all the fuel oil is handled upon this spur. Oil is stored outside the plant in three 6,000-gallon tanks. These tanks are filled by gravity from the oil cars run upon the siding, and from the tanks the oil is piped into the basement of the power house. Water for cooling the jackets and bearings of the machinery in the station is drawn from a neighboring pond through an 18-inch pipe, which terminates in a well about 60 feet inland from the shore. From the well a triplex pump in the basement draws and delivers the water as needed in the plant.

The generating unit is a 350-kilowatt, 60-cycle, 2,300-volt, 2-phase revolving-field alternator mounted on a shaft midway between two 16-inch by 24-inch 3-cylinder oil engines. The normal speed of this unit is 164 revolutions per minute. It is governed by by-passing the oil supply back into the suction side of the oil pump. In general design and appearance the engine follows the lines of a vertical inclosed type of steam engine. The action is on the 4-stroke cycle, but the engine differs from all previous internal-combustion engines in compressing a full charge of air to a point above the igniting point of the fuel, whether liquid or gaseous, and then injecting this fuel for a certain period, variable according to the load, into this red-hot air, where it burns under controlled limits of temperature and pressure. The cylinder operation is therefore one of combustion rather than explosion. Each engine is rated at 225 horsepower, weighs 80,000 pounds, and has the following over-all dimensions: Floor space, 9 feet 6 inches by 16 feet 6 inches; height, 12 feet. Foundation dimensions: Width of top, 10 feet; bottom, 12 feet; length, 20 feet; height, 7 feet, 1 inch. The latter dimensions include the space required by a direct-connected engine-type generator.

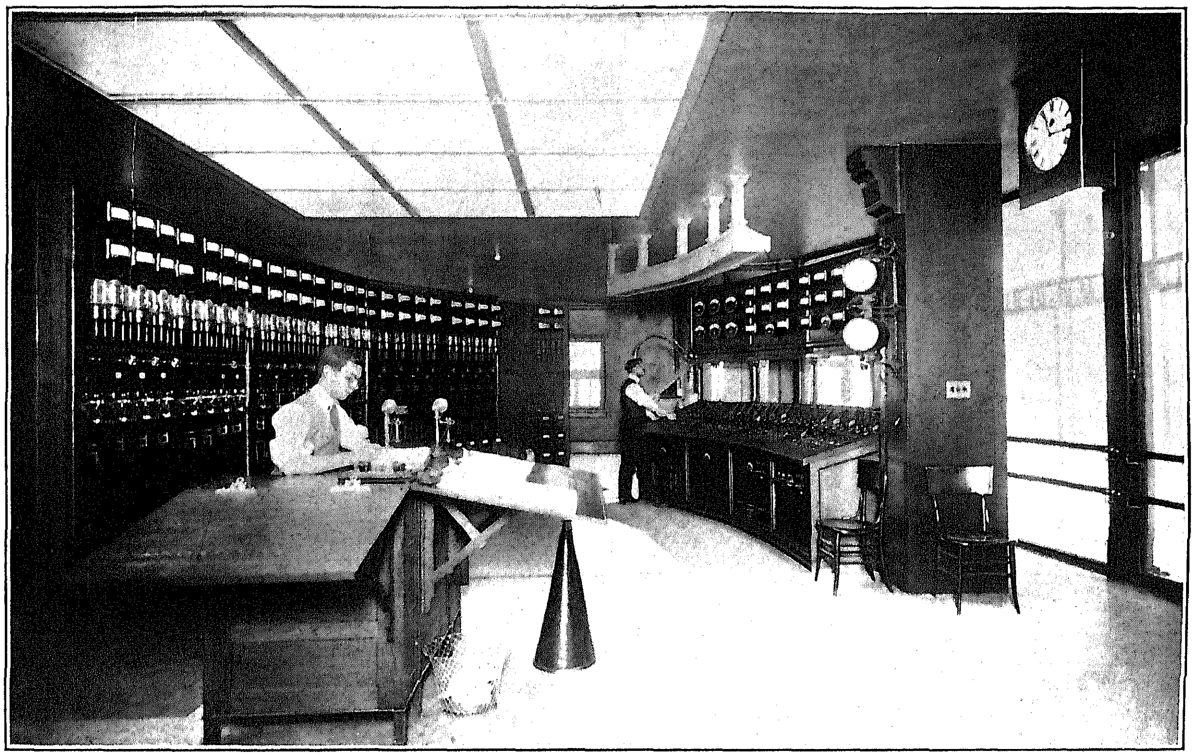
Gas engines.—A notable development in the generation of current has been the resort in San Francisco to very large gas engines by the California Gas and Electric Corporation. Its three engines, each of 5,333 horsepower, connected to the alternating-current generators, have the following dimensions: Length over all, 70 feet; width over all, 34 feet; weight of heaviest casting, 60 tons; diameters of cylinders, 42 inches; length of stroke, 60 inches; main journals, 30 inches diameter, 54 inches long; main crosshead gibs, 27 inches wide, 54 inches long; diameter of center of shaft, 38 inches; weight of fly wheel, 130,000 pounds; total weight of engine, fly wheel, and generator, 1,200,000 pounds. In general design and detail the gas engines resemble modern high-grade, massive steam engines. They are horizontal, twin-tandem, double-acting, 4-stroke cycle, giving two impulses to each crank per revolution. Each of the electric generating units can deliver 4,000 kilowatts at 13,000 volts, 25 cycles.

It is recognized that the gas engine itself is successful in large sizes for generating plants, but that the intrinsic efficiency of such plants depends on the gas producer, and upon the economical gasification of low grades of fuel. As has been said, the producer in its best form is the means of making available the high thermal efficiency of the gas engine to many central stations, and is the chief factor that warrants the installation of this type of prime mover at a greater installation cost than that of a steam plant. There are now producers on the market that can be relied upon to produce a satisfactory gas from many of the low grades of coal available in different sections of the country; and the result is shown, in part, in the increase in the number of gas engines from 165 in 1902 to 463 in 1907, and in their capacity from 12,181 horsepower to 55,828 horsepower.

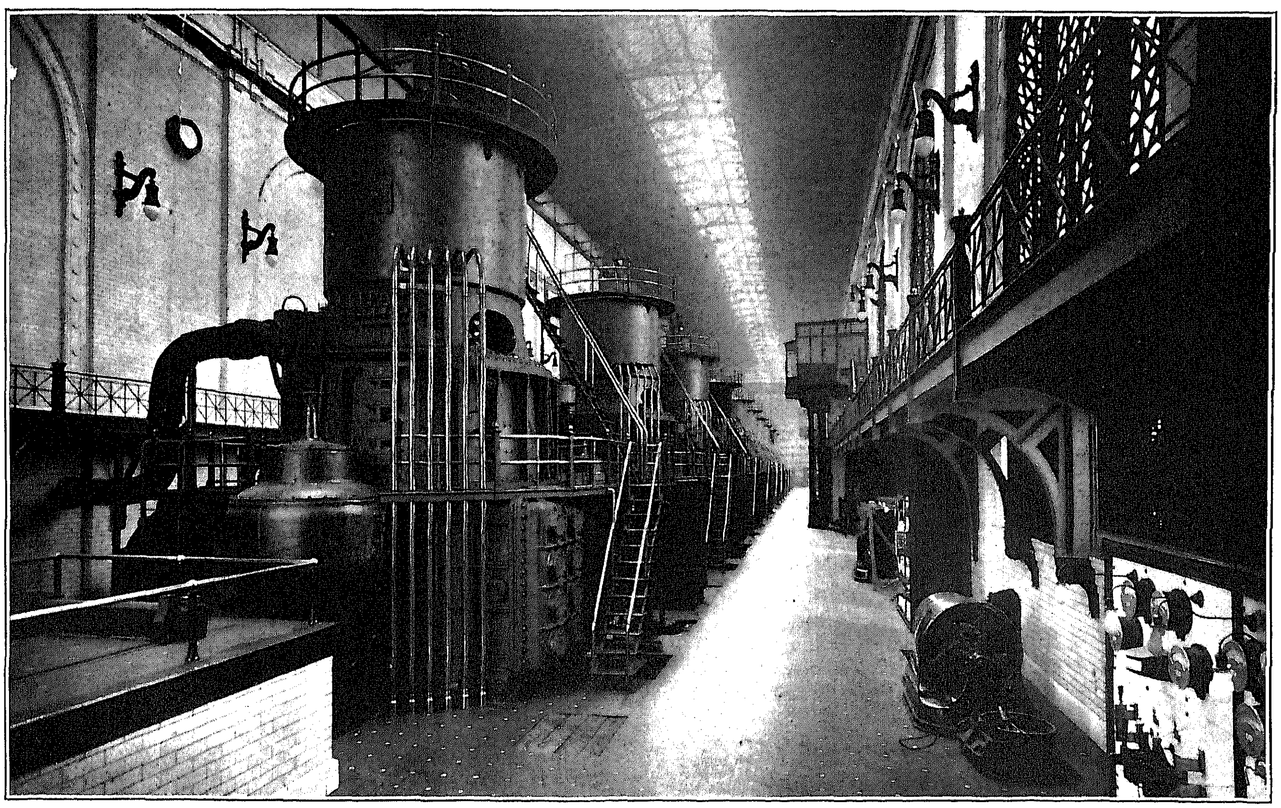
As an illustration of complex conditions, the Keene Gas and Electric Company, of Keene, N. H., may be cited, which uses gas, steam, and water power in three separate plants. The company's gas plant, distant only 1¼ miles from the business center, contains two 250-horsepower anthracite gas producers and three gas engines of the vertical three-cylinder type, the two smaller engines being each connected to an 80-kilowatt alternator, and the largest unit to a 110-kilowatt alternator. The fuel requirements are less than in a steam plant of equal capacity, and the fuel feeding and ash discharging for the producer are accomplished by the action of gravity alone.

Water power.—The statistics in Chapter III as to water power are clearly indicative of the general trend of practice. An immense increase is shown both in the number and size of water wheels. In 1902 there were 1,390 water wheels, having a capacity of 438,472

[1] Proceedings, National Electric Light Association, 1909, Vol. II, p. 232.



SWITCHBOARD ROOM, QUARRY STREET STATION, COMMONWEALTH EDISON COMPANY, CHICAGO.



STEAM TURBINE GENERATING PLANT, FISK STREET STATION, COMMONWEALTH EDISON COMPANY, CHICAGO.

horsepower, while in 1907 there were 2,481, having 1,349,087 horsepower. Thus the size per unit rose from an average of about 315 horsepower to 544 horsepower. The units are classified as "water wheels," but in practically every instance a more correct designation would be "turbine." In compiling the statistics, no attempt was made to differentiate between impulse and reaction types, or between installations as having horizontal or vertical shafts; although all these features have necessarily an intimate relationship to the character of the electrical generator associated with the driving wheel.

The most notable developments of the period 1902 to 1907 have been those at Niagara Falls and those in the Sierras of California; but in every part of the country where water powers lay undeveloped, enterprises on a large scale have been set on foot for the purpose of hydro-electric generation and power transmission. In fact, the period named may be regarded as one of great speculative activity in this respect, with the result that many plants have come into existence that remain unprofitable, either because the work has been too costly, because there is little market for the energy when developed, or because the problems of economical and uninterrupted transmission have not been mastered.

A water-power plant of somewhat unusual character is that of the Indiana and Michigan Electric Company, on the St. Joseph River at Berrien Springs, Mich., serving northwestern Indiana and southwestern Michigan. It was built during the intercensal period and placed in service during 1908, and is of the low-head system, capable of producing 7,200 kilowatts. The company has a total of 25,000 horsepower in its steam and water power plants, the four of the latter all being on the St. Joseph River. This river has a maximum flow of only about twenty-five times the minimum, and the actual head at Berrien is only 21 feet, gained by backing up the flow for more than 10 miles by a dam nearly one-third of a mile long, the back flow extending to the next plant above. The power house stands lengthwise to the dam. The low head made necessary considerable complication in the water-wheel plan. Each of the four generators installed is driven by a group of four pairs of wheels working under a normal head of 20 feet. The generators, rated at 1,800 kilowatts each, 60 cycles, are driven at 150 revolutions per minute. The river runs over and through a mass of glacial drift, with a hardpan bottom, and to prevent loss of water by flow under the apparent bottom of the river, a continuous line of sheet-steel piling was driven in clear across the river down to hardpan, under the upstream side of the dam; while a similar defense of mail was put across the downstream side to prevent any backwash. These elaborate precautions were taken primarily to prevent the passage of water under the dam or the scouring of the river bed below the latter, and thus preclude any possibility of undermining the structure.

Another plant of somewhat unusual character is that put in operation in 1907 by the Patapsco Electric and Manufacturing Company, of Ellicott City, Md., whose power house on the Patapsco River about 10 miles west of Baltimore is built entirely within the dam and is thus completely under water. The same structure thus serves both as dam and as power house; the available fall is utilized, and with slight modifications the suction force of the spillway water as it rushes over the mouth of the tailrace may be employed to increase the effective head by lowering the water level in the race well. With power houses as ordinarily constructed below the dam, the contrary effect obtains. Abundant natural light is had through windows located on the downstream side of the dam, beneath the falls, and natural ventilation is also provided. The generating alternators when under load furnish sufficient heat to dispel any dampness that may manifest itself; and, although somewhat restricted as to space, the power house is as comfortable as any other station building of like capabilities. The plant has a capacity of 600 kilowatts, with provision for another 300-kilowatt unit, and the electrical energy is employed for lamps and motors.

The structure represents the latest development in dam design. Heretofore, solid masonry has been considered the only safe and permanent device to impound water, reliance being placed on the enormous weight of the dam to resist the water pressure. At Ellicott City the water pressure is utilized to maintain the position of the dam, the upstream side being so proportioned and shaped that the weight of the water upon it equals the horizontal-pressure component. The dam is merely a shell in which the necessary rigidity and strength are secured by a very small fraction of the material needed in the old-style construction. The deck and apron are supported on buttresses and have a section just sufficient to resist bending under water pressure, a large factor of safety, of course, being allowed. The structure may be built in considerably less time than a solid dam, and the interior may be utilized, as in this instance, for housing the electrical equipment. In 1907 two plants of the same character as that at Ellicott City were begun, one at Delta, Pa., and the other on the Big Horn in Wyoming—each having a head of water of about 60 feet and developing about 1,500 kilowatts.

No inconsiderable amount of modern hydro-electric development in the West is associated with irrigation work. One of the most noteworthy and recent examples is connected with the Custer reservoir in San Miguel and Dolores counties, Colo., where a dam 110 feet high impounds 756,800 acre-feet of water, to be employed in power development and irrigation. Another work of this character, which has been under construction for some time and will be completed before April, 1910, is the Orchard Mesa irrigation project, extending from Grand Junction to Palisade, in the richest fruit district of Colorado.

During 1906–7 the municipality of Lynchburg, Va., installed a plant which is somewhat typical of the older methods, in that the current is not transmitted a long distance, and that the energy is employed for ordinary arc-lighting purposes. This plant utilizes the flow of the James River, and occupies an old pumping station that was part of the municipal waterworks before the new gravity system was introduced. An operating head of only 12 feet has been skillfully employed. The plant is laid out for the use of series alternating current, to avoid the use of transformers between the generators and the series circuits. The generating dynamos are 2-phase alternators designed to supply 15 amperes per phase at 4,200 volts. The arc lamps are supplied with 7.5 amperes at 80 volts. This gives two circuits per phase, with 50 lamps on each circuit, or 200 lamps per generator. An inductive regulator is placed in each circuit which will automatically maintain a constant current of 7.5 amperes through the lamps.

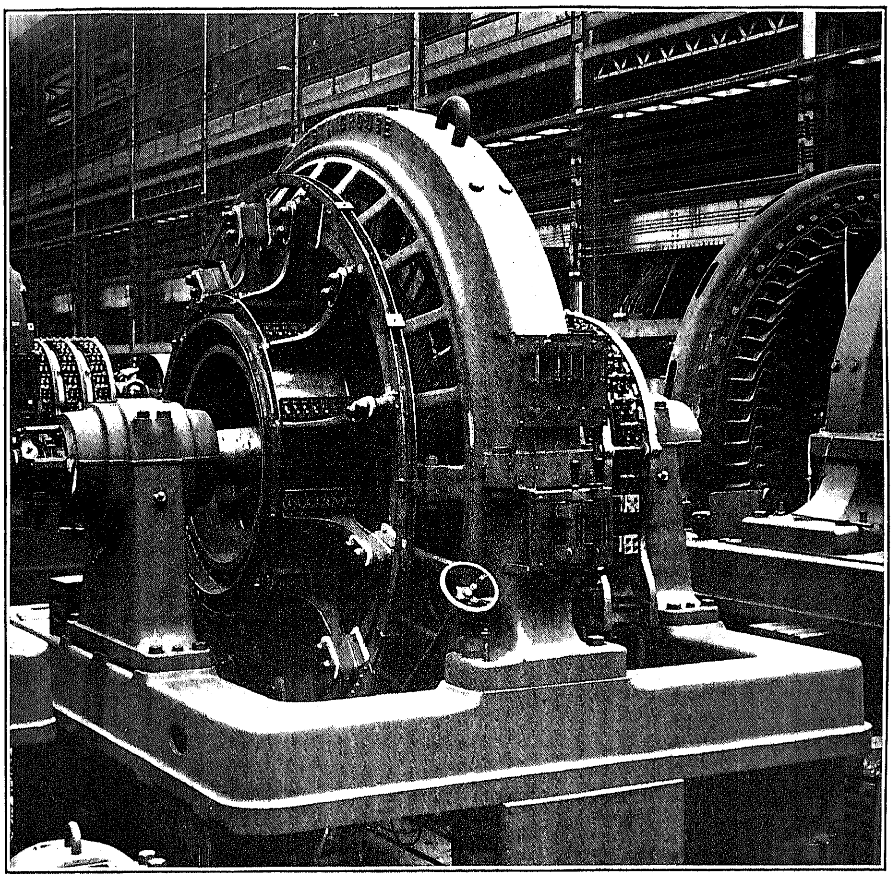
Niagara remains, of course, the preeminent example of hydro-electric development in the United States. Grouped around the great falls are seven generating stations, whose supply of electrical energy is in demand over a very large area of consumption. Figures reported for 1908–9[1] show that the energy from Niagara Falls is used at the rate of 126,800 horsepower for electro-chemical processes, 56,200 horsepower for railway service, 36,400 horsepower for lighting, and 54,640 horsepower for various industrial services, or a total of 274,040 horsepower. Since the water of Niagara Falls represents probably more than 5,000,000 horsepower, it would seem that only about 5 per cent of the available power is being utilized at present. As to the proportion of energy from Niagara Falls used locally as compared with that transmitted elsewhere, figures in the article referred to above show that 12,300 horsepower is transmitted more than 100 miles; 33,500 horsepower, 75 miles and less than 100; 3,100 horsepower, 50 miles and less than 75; 79,640 horsepower, 10 miles and less than 50; while 145,400 horsepower is used locally on the Canadian and New York sides of the falls. That is to say, somewhat more than 50 per cent of the energy actually utilized is employed locally, and almost all of this is used in industries that have been attracted to Niagara Falls by reason of the generating stations located there. Electro-chemical processes take 87 per cent of the energy that is consumed locally and 46 per cent of the total amount utilized.

What is believed to be the largest turbine of its type ever built is that put in operation during 1905–6 by the Seattle and Tacoma Company at its Snoqualmie Falls plant, 35 miles east of Seattle, Wash., a single-wheel turbine of 10,000 horsepower capacity. The 12,500 horsepower vertical turbines of the Electrical Development Company, the 10,000 horsepower horizontal turbines of the Ontario Power Company, and the 10,000 horsepower vertical turbines of the Canadian Niagara Power Company, all of which are at Niagara Falls, Ontario, are duplex machines, as each unit has two runners on a single shaft driving a single generator. The Snoqualmie Falls turbine, with but one wheel, therefore, represents by far the largest concentration of power yet accomplished in turbine water wheels. The turbine in question is employed in an enlargement of the Snoqualmie Falls plant to double its original capacity.

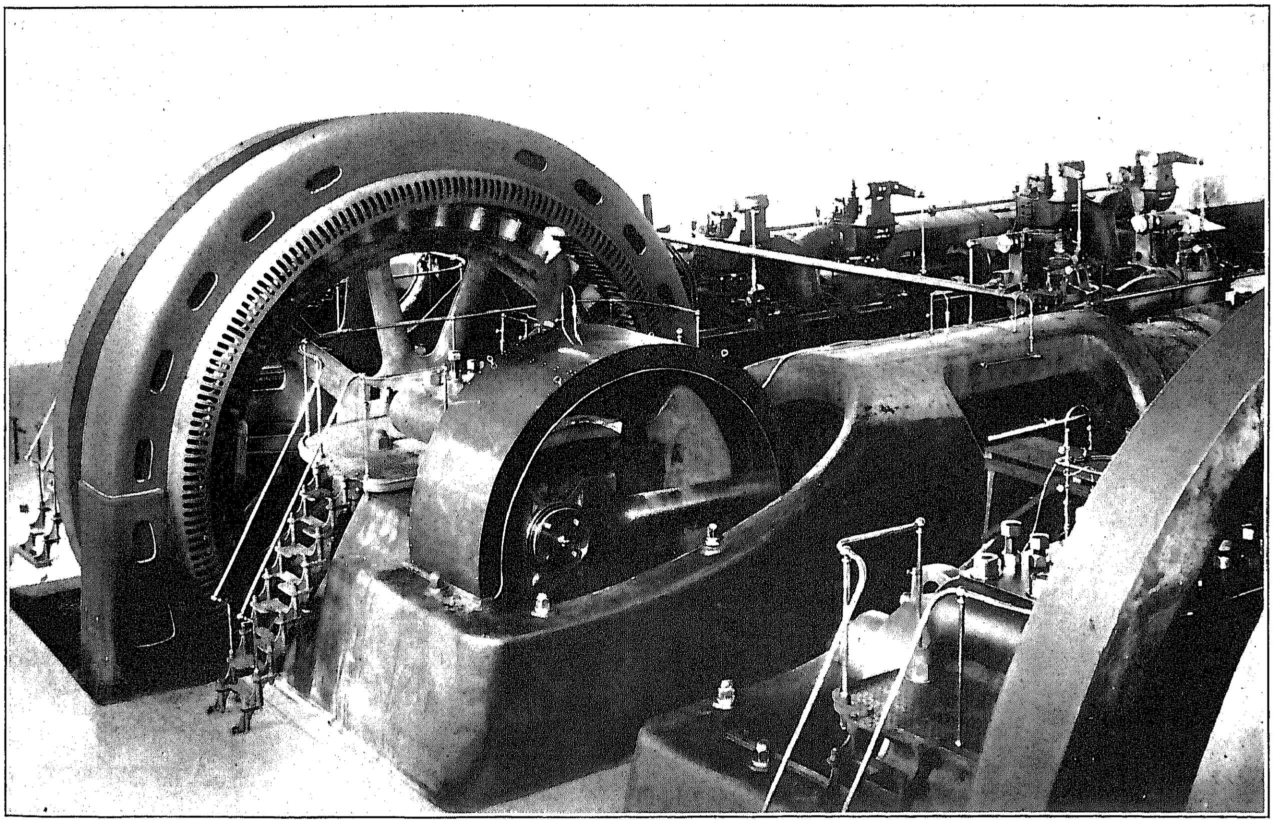
[1] Electrical World, October 21, 1909, p. 978 et seq.

Generators.—The statistics of Chapter III are very complete as to the generator, or dynamo, equipment of American central stations in 1907, and reveal clearly the changes that have taken place and are still in progress in the manner of generating electric current. At one time the central stations of the country were wholly on the basis of direct current for incandescent lighting, arc lighting, and motor supply, and direct-current generators predominated to the exclusion of any other type. Now the vast majority of stations are on the basis of alternating current, even if they deliver direct current to the consumption devices. As shown by Table 34, there were in use in 1907 for generating direct current, either of constant voltage or of constant amperage, 5,365 dynamos of a total capacity of 487,452 kilowatts, as compared with 6,808 machines of 2,221,773 kilowatts capacity employed to generate alternating current. In 1902 the alternating-current dynamo was already in the lead as to capacity, though somewhat inferior as to number; but the five years witnessed a remarkable diminution in the number and capacity of dynamos of constant amperage designed strictly for the old arc-lighting service, and in reality capable of nothing else. The number fell off from 3,539 to 1,685, and the capacity from 145,866 kilowatts to 80,992 kilowatts; and it is probable that during the period in question few, if any, new machines of the old type were built. If there were any new machines intended specifically for arc-lighting purposes, they will be found in the alternating-current group, where their presence tended to keep down the average capacity per unit to 326 kilowatts, although this is far above the average per alternating unit shown for 1902, which was below 144 kilowatts.

Thus the interesting and significant fact emerges that although the generator capacity in the five years more than doubled, rising from 1,212,235 kilowatts to 2,709,225, the number of dynamos actually declined from 12,484 to 12,173. How far this concentration will go it is hard to say, but the tendency is plainly visible. At the beginning of 1908, for example, there were 345 central stations in New York state. It has been conservatively estimated that with the methods and apparatus now in use for generating, transmitting, and distributing current, the whole state could be much more economically and efficiently supplied from 10 stations each with a radius of about 50 miles. This being true, it is obvious that hundreds of the smaller dynamos would disappear and their work be



1,500-KILOWATT ROTARY CONVERTER.



GENERATOR CONNECTED TO LARGE GAS ENGINE, SAN FRANCISCO.

done by relatively few machines of greatly increased capacity. The radical modifications of all kinds that would follow such a change in generating methods, which is entirely feasible, lie beyond the scope of this report.

Of late years there has been little development in the design of such direct-current machinery as is included in this report, and what has been done aims rather at refinement and perfection than the adoption of new ideas. All the real work of development is concentrated on the alternating-current types, especially those driven at high speed by steam turbines. The size of 3-phase alternating-current dynamos has been carried as high as 14,000 kilowatts, with an overload capacity 50 per cent above normal rating. These generators have a frequency of 25 cycles per second and produce current at 11,000 volts pressure, usually for delivery to rotary converters which so manipulate it as to make it possible for lamps and motors on the circuit to use direct current at a low safe pressure. Such a machine is capable of energizing to full brilliancy 560,000 tungsten incandescent lamps of 25 watts and 20 candlepower, giving a total light equal to 11,200,000 candles.

Where such a machine is to furnish current for lighting rather than for motors, it is usual to employ a frequency of 60 cycles, as with a lower frequency there is an appreciable flicker in the lights. Dynamos of such design are operated either horizontally or vertically, and either the armature or the field magnets may be revolved. A revolving-field generator of 14,000-kilowatt capacity is among more recent developments, operating at 6,600 volts, 60 cycles, 3-phase, direct-connected to the vertical shaft of a steam turbine running at a speed of 720 revolutions per minute. This huge machine has a peripheral speed of 18,300 feet per minute and an output per pole of 1,400 kilowatts, as compared with a peripheral speed of 8,000 feet per minute and an output per pole of 150 kilowatts in a reciprocating engine-driven alternator of the same capacity and frequency, operating at 75 revolutions per minute. The electrical and magnetic losses in the field and armature of such a machine of 14,000-kilowatt capacity amount to about 350 kilowatts, and to conduct this heat away from it in order to prevent local high temperature requires about 140,000 cubic feet of air per minute at usual dynamo-room temperatures. In order to regulate the movement of the ventilating air, the generator is entirely closed, with the exception of the intake and discharge openings at the top and bottom of the armature. Thus when the machine is running, its revolving field operates as a powerful fan. Air received through the openings in the ventilating hood is forced through passages provided in the field and the armature, and discharged at the openings in the base of the generator.

Now that so much of the current is generated by alternators, a large quantity of auxiliary apparatus is required of various forms. In the smaller plants the transformer capacity for lowering the potential is usually from 50 to 75 per cent greater than that of the generating apparatus, while in many of the larger systems, it is stated, the combined capacity of the converting and transforming apparatus is approximately three times as great as that of the generators. Transformers will be dealt with later; but reference may be made here to the apparatus which is of a generating character in design although it adds nothing to the capacity of the plant, simply rendering the energy produced more available for miscellaneous use. Thus current is often changed in voltage or phase and frequency changers have been widely adopted. These may be either synchronous or nonsynchronous, depending upon the degree to which exactitude in the change of frequency is carried. One part of the machine is motor, receiving the current to be changed, the other generating and delivering to the line the current produced or "manipulated." In recent work the vertical shaft type has been largely introduced in capacities of from 2,000 kilowatts upward. One machine designed for the Commonwealth Edison Company of Chicago, built while this report was in preparation, which changes from 25 to 60 cycles, is of not less than 6,666 kilovolt-ampere capacity, with 75 per cent load factor, and is probably the largest of its kind in existence.

While in a few cities the alternating current produced locally or received from a distance is used without any change to direct current, it would appear that in the consumption circuits and apparatus direct current is still preferred, in the standard voltages, from 110 up to 440. Because of this, the demand for "rotary converters," as they are called, is very large. These machines, of the synchronous type, have become the standard form of converting apparatus for low-frequency substations delivering low-pressure direct current to line. They receive the alternating current on one side and send out the direct on the other. Occasionally their place is taken by motor-generator sets in which there are two machines driving on the one horizontal shaft, the motor part of the device receiving the alternating current. This apparatus is, however, more in favor in Europe than in America. Probably the great majority of rotary converters enumerated in the present report are of the horizontal-shaft type, with collector rings at one side and the commutator on the other, but to meet the exigencies of limited floor space vertical shaft units have been manufactured, such as those of the 6-phase, 25-cycle, 250-volt, 2,500-kilowatt capacity designed for the New York Edison Company.

The extent to which apparatus of the auxiliary character described above may be needed, even for systems within city limits operating at pressures not to exceed 9,000 volts, can be inferred from the fact that at the end of 1907 the Commonwealth Edison Company of Chicago had a "peak-load" generating output of 119,250 kilowatts in three stations. It sent its electrical energy to no fewer than 33 substations of the system within the corporate limits and to 11 substations belonging to various railway companies taking current for the operation of their cars. The rotary-converter rating connected to the 115-volt and 250-volt direct-current network in the central part of the city aggregated 50,700 kilowatts. The alternating-current motor-generator frequency-changer sets, through which 60-cycle energy was supplied to outlying districts, aggregated 21,340 kilowatts. To this must be added the similar auxiliary equipment of the railways, making the formidable total of 122,940 kilowatts. It might be added incidentally that the system also included, for discharging into its direct-current network in the heart of the city, storage-battery plants fed through the rotaries, etc., aggregating over 18,000 kilowatts in output at a one-hour rate of discharge.

Transmission.—It has already been intimated in the preceding discussion that the development of the central-station industry has depended materially upon advances in transmission methods and apparatus. While this is true, little that is revolutionary has been developed during the period. In fact, one of the leading authorities, Dr. Louis Bell, discussing the subject early in 1908, said: "Much of the power-transmission work of the last five years has been of an unobtrusive character, mere extension, without material change of what had gone before."[1] Nevertheless, a survey of the progress made discloses conditions that were a few years ago hardly deemed to be within the range of possibility, and such widespread extension of transmission systems as to constitute a new industry and a new well-defined branch of engineering to which experts give their whole attention.

While the voltage of generators furnishing current for either long or short distance transmission has remained around 2,000 to 2,500 volts, the pressure on lines has been boldly carried from 10,000 volts up to 100,000, and the latter figure seems to be by no means the limit, since far higher potentials are being discussed or are under experiment, with serious thought of their ultimate adoption. The raising and lowering transformers appear to be equal to all the strains thus far put upon them. It has been a common practice to equip such high-voltage transformers with taps on the high-voltage side, so that they may be worked at 5 or 10 per cent below their full voltage. In the earlier stages of the industry separate transformers were used for each phase of a 2 or 3 phase system, but now composite 3-phase transformers are a common type, and no difficulty has been experienced in providing them for pressures of 100,000 volts and upward.

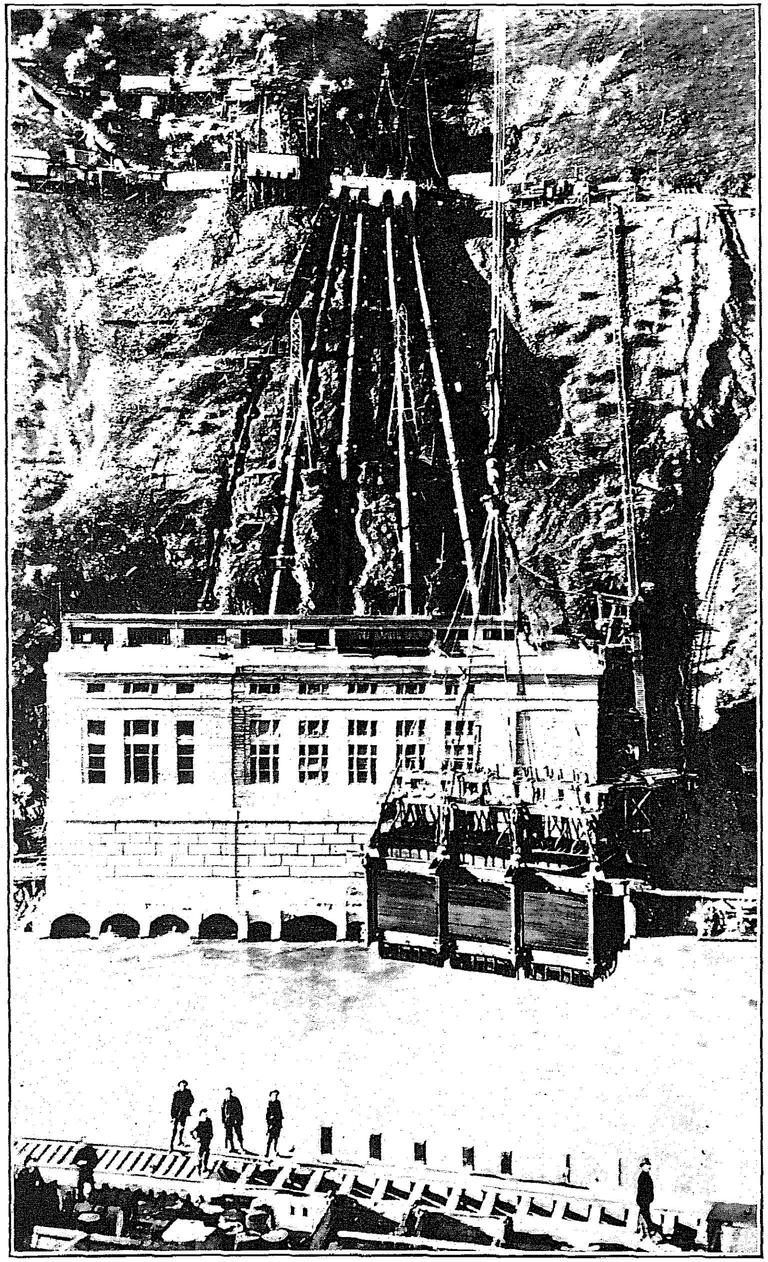
The circuits are usually of bare copper, and possibly the high price to which copper was carried in the "boom" period lasting up to 1907, about 25 cents per pound, may have had something to do with the effort to reduce the amount of copper in a line by raising the voltage. Aluminum has also been tried with success. The "pole lines" were originally of wood, as in the case of the first Niagara transmission to Buffalo, but steel poles and steel towers are now very general. The method of holding up the wires has varied. In California, with its dry climate, large pin-type porcelain insulators have been used with flaring "hoods" or "petticoats" to shed moisture, while another type is that of the suspension insulator. In the latter case several porcelain bells or drums, either plain or with concentric "petticoats," are strung together like reels on a thread, the uppermost insulator being carried by the cross-arm, and the lowest in the series supporting the transmission wire. The bells, of uniform size, ranging usually from 10 to 15 inches in diameter, are tied together by metallic links; and four or five of these bells in a bunch have a remarkable ability for standing up with very high voltage under all manner of adverse conditions of weather. The circuits are now more widely spaced, the separation averaging a foot per 10,000 volts; so that there is little risk of disturbance from anything except lightning. Many of the systems depend for lightning arresters upon "horn" or curved projecting ground wires of large dimensions; but others use multiple gap arresters, shunted to the ground from several points. A recent widely used type is an electrolytic lightning arrester which consists of aluminum cells, or jars, of large surface, stacked up in series.

It has already been noted that the standard frequency of transmission of alternating current is 60 cycles. At Niagara Falls this frequency of transmission began with 25 cycles, and is still maintained. The vast heterogeneous network of the Los Angeles (Cal.) Edison Company operates at 50 cycles. In an address[1] before the National Electric Light Association in 1906, Mr. R. H. Ballard stated that the Los Angeles system then included 110 miles of transmission line with 33,000 volts pressure; 300 miles of double-circuit transmission with 10,000 and 15,000 volts pressure; and 750 miles of transmission line with 2,200 volts pressure in the various cities and towns served by the system; and that there were no fewer than 22 communities to which the company gave electric service with energy from all manner of sources, including a plant on the Kern River transmitting energy at 75,000 volts to Los Angeles, 120 miles away. The longest American transmission system, however, is that in northern California, where the circuits reach 232 miles, from De Sabla, in the Sierras, to San Saulito.

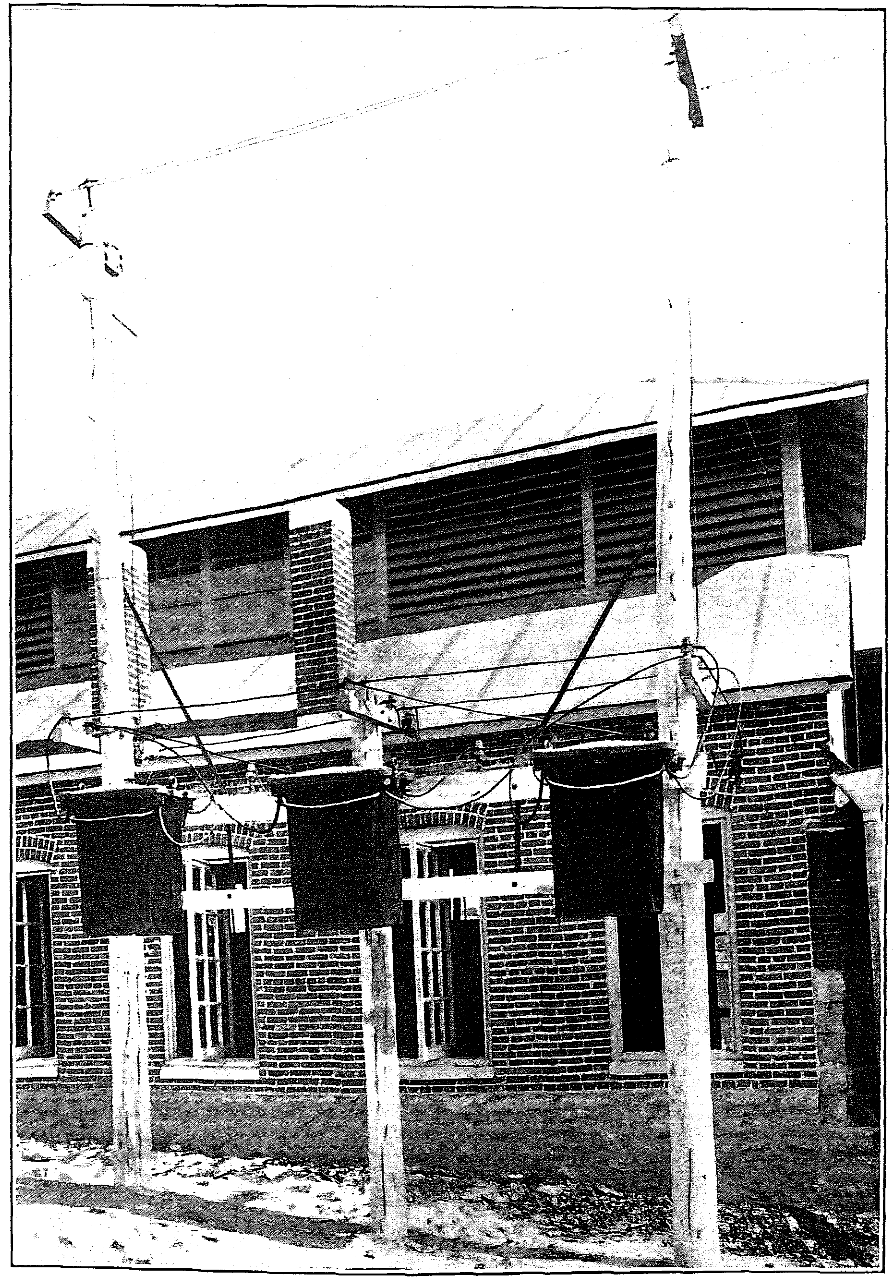
Another extremely long circuit is that from Niagara Falls to Syracuse, N. Y., a distance of 165 miles. The

[1] London Times, June 3, 1908.

[1] Proceedings, National Electric Light Association, 1906, Vol. I, p. 636 et seq.



CONVEYING A 10,000-KILOWATT, 100,000-VOLT TRANSFORMER WITHOUT CASE ACROSS THE FEATHER RIVER, CALIFORNIA.



METHOD OF MOUNTING DISTRIBUTION TRANSFORMERS ON POLES.

following description of this circuit is based on a paper [1] read by Mr. Ralph D. Mershon before the American Institute of Electrical Engineers in 1907. The system described is that of the Niagara, Lockport and Ontario Power Company, a purely transmission enterprise, buying its energy in bulk from the Ontario Power Company, which has a plant at the base of the Horseshoe Falls on the Canadian side, where the dynamos generate 3-phase, 25-cycle current at 12,000 volts, which is transmitted to the transforming station, the circuits crossing the river in the gorge below the whirlpool. The potential is stepped up from 12,000 to 62,500 volts for the transmission lines which run on a private right of way from Lockport to Mortimer, a distance of 57 miles, and have a capacity of 20,000 horsepower. From Mortimer to Syracuse, a distance of 81 miles, the line on the company's private right of way has a capacity of 10,000 horsepower. From Lockport to a point 11 miles east and thence south on private right of way to the West Shore Railroad, and thence on the West Shore right of way to Pittsford, is another line with a capacity of 20,000 horsepower. From Pittsford to Syracuse on the West Shore right of way is a 10,000-horsepower line. From Lockport south to Buffalo are two transmission lines on private way, each with a capacity of 30,000 horsepower. Emphasis is laid on the provision made for isolating the circuits like railroad rights of way, and thus insuring safer and surer work.

Steel towers are used almost entirely, generally what is known as the "windmill type," "tripod" or "quadruped," and constructed of either lap-welded pipe, or structural steel, galvanized. The standard length of span between towers is 220 feet in some parts, 550 feet in others; while an extreme length of 1,253 feet is reached and an extreme height of towers of 75 feet. Each line of towers or wooden structures carries only one 3-phase system. The main line conductors are of aluminum, except on a portion of the line between Mortimer and Syracuse, where copper was preferred because of the long spans. Crossing the Montezuma marsh, the big steel towers have their feet deeply embedded in concrete foundations.

Three sizes of cable of "line wire" are used for the main transmitting line. The largest cable of aluminum consists of 19 strands, having a total of 642,800 circular mils, equivalent to 400,000 circular mils copper. The areas of cross section of the other cables are respectively two-thirds and one-third that of the large one. The insulator used on all main-line construction, designed by Mr. Mershon, has unusual factors of safety as regards flashing, etc., and consists of three shells of porcelain nesting into each other and cemented together with neat Portland cement, the whole insulator being cemented in a similar manner to a steel pin before attachment to the tower. The insulator is 19 inches in total height and the upper "petticoat" has a diameter of 14.5 inches. The lines are most liberally provided with fuses to cut out the circuits in case of trouble, and with disconnecting switches and lightning arresters. Speaking of the elaborate arrangements for protection against lightning, Mr. Mershon says:

> Another feature out of the ordinary in connection with this station is the lightning-arrester equipment. This equipment is also out of doors and consists of a number of horn-type arresters mounted on wooden poles, in much the same manner as such arresters are ordinarily mounted. The installation differs, however, * * * in that, instead of there being only one pair of horns for each conductor, there are three such pairs. One pair is set for a comparatively low-striking electro-motive force and has in series with it a high resistance; the next pair is set for a higher-striking electro-motive force and has in series with it a lower resistance. A third pair is set for very high-striking electro-motive force and has in series with it a fuse. The theory on which these arresters are installed is that for ordinary slight static disturbances in the line, the arrester having the lower-striking electro-motive force will discharge, and since it has in series with it a comparatively high resistance, the resultant disturbance to the system due to the generated current which follows the discharge will be comparatively slight.

The Grand Rapids-Muskegon plant and system may also be cited. They were installed in 1906–7, with 66,000 volt transmission in circuits totaling about 75 miles, supplying the Grand Rapids Edison system, various interurban and local trolley railways, and several large industrial plants. In the following year 35 miles of steel-tower line were added, and the potential has since been raised to 80,000 and 100,000 volts with success. These later circuits use the suspension type of porcelain insulator. Five of these insulators are hung, horizontally, one above the other, like beads. Each is 10 inches across, and the rated voltage it will withstand is 23,000 volts per "link."

Distribution.—The standard methods of distribution have remained the same throughout the country, with occasional interesting variations for some particular purpose. It may be noted that the new metallic filament lamps favor the 110-115-volt circuits to which Americans have steadily adhered through many years. In the United States the 220-volt, 3-wire system is the rule, but in Europe, and especially in Great Britain, the 450-volt, 3-wire system is equally the rule. One system employs 110-volt lamps on each side of the neutral, and the other requires 225-volt lamps. It is obvious that copper economics are with the 450-volt system, but on the other hand, the lamp efficiencies are with the 220-volt system. In Europe, moreover, the standard lamp is 8-candlepower instead of 16-candlepower, and it is the fact that here again the lamp efficiencies are with the 110-volt lamp of the higher candlepower. It would seem, therefore, that there is no immediate prospect of a change of American distributing circuits from 220 to 450 volts on the 3-wire distributing networks, but that, on the contrary, the new lamps will find a wider market than heretofore while confirming the practice at 110 volts.

[1] Transactions of the American Institute of Electrical Engineers, vol. 26, Part II, p. 1273 et seq.

An interesting innovation is that made by the Toledo (Ohio) Gas, Electric and Heating Company, in the adoption of a 4,600-volt system of alternating-current distribution. The transformers on the system are wound for 4,600 primary and 110–220-volt, 3-wire, secondary distribution. Current is generated 3-phase, but the distribution is single-phase. The generators are star-connected with the neutral grounded. The transformers are delta-connected. In the construction unusual care has been taken to avoid trees by running the lines high. Insulators and fuses are, of course, more expensive than for the usual standard of 2,300 volts.

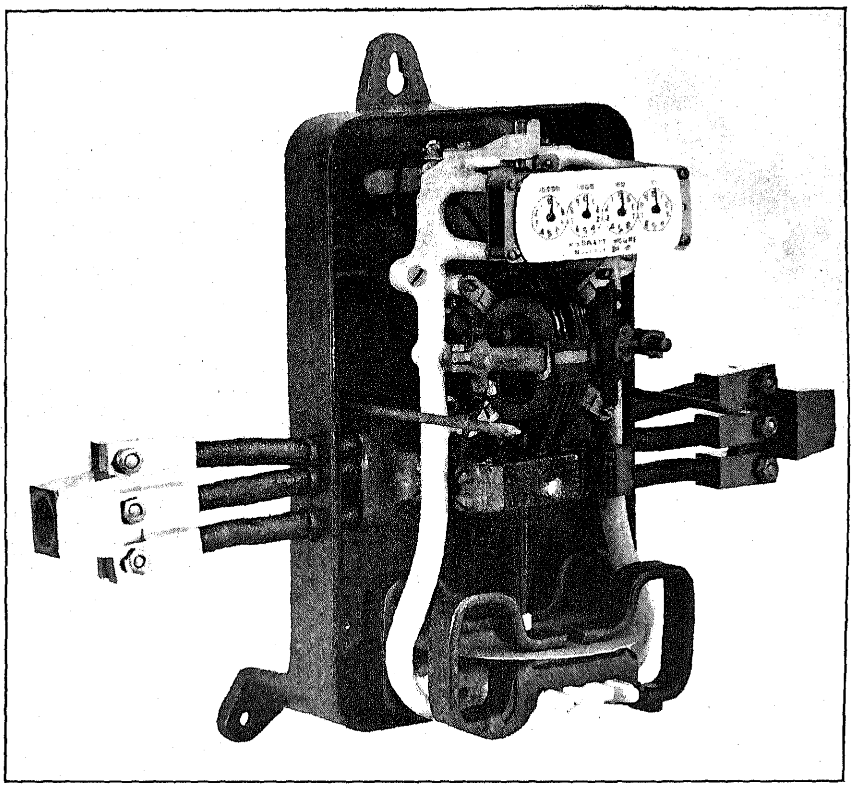
Another interesting change was that made during the intercensal period by the Denver Gas and Electric Company from direct to alternating current in territory just outside the business district of Denver, Colo. The company had for motor service a 220 and 440 volt, 3-wire, direct-current power distribution, most of the energy being used in and near the downtown district. The lighting distribution of the whole city is by single-phase feeder lines supplied from 3-phase bus bars at the power station. The direct-current motor feeders were becoming so long and the number of distant customers so large that an excessive amount of copper was called for. The decision was made to change the motor service outside of the downtown district to 3-phase, and to give customers new 3-phase induction motors in place of their direct-current motors. Most of the direct-current motors were sold at good prices. The direct-current copper taken down was worth enough to reduce materially the cost of the change. A puzzling question was to decide whether to use 220 or 440 volt motors. With 220-volt motors but one customer could usually be supplied from a bank of transformers, whereas with 440-volt motors and secondaries several in one locality could be supplied. The latter advantage was considered to be more than counterbalanced by the fact that with 220-volt motors standard lighting transformers could be used. The change was made without interrupting any customer's service.

The central station company in Detroit, Mich., on establishing its new plant at Delray, 4 miles from the business center, installed machinery for the generation and transmission of electrical energy at 4,600 volts, 3-phase, 60 cycles, and developed an extensive power service to factories direct by means of such current. Incidentally it may be mentioned that one of the reasons for placing this plant at Delray on the salt beds was that by using the exhaust steam of the power plant to evaporate the brine from the wells a very economical and profitable day load was secured.

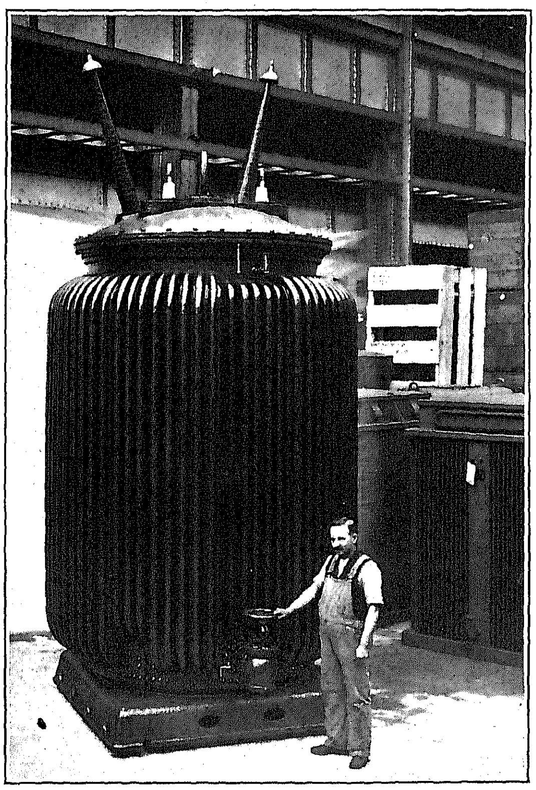
Transformers.—This class of apparatus, so necessary to power transmission by electricity, is also used largely in distribution circuits, and may therefore be properly considered at this point before taking up the "consumption devices," by which the electrical energy is used up in doing its work. Transformers were fully described in the previous report and in the reports on the manufacture of electrical apparatus,[1] and therefore need not be considered here in great detail. The most important features in the recent development of transmission methods have been the introduction of a large number of the modern transformers employed to "raise" and "lower" the voltage, and the adoption of composite 3-phasers instead of a separate transformer for each phase. The size is determined, of course, by the general capacity of the plant and the amount of energy passing out or in over the respective circuits. The Ontario Power Company, on the Canadian side of Niagara Falls, which delivers current for use over a large part of New York state south of Lake Ontario, employs transformers each of which has a capacity of 3,000 kilovolt amperes, and weighs, when filled with its insulating oil, approximately 50 tons. The current is received from the generators at 12,000 volts, and after being raised to 36,000 volts in the secondary winding, a line voltage of approximately 62,000 volts is secured by connecting the transformers two in series. At the Great Falls (South Carolina) power plant of the Southern Power Company the transformers are rated as of 2,000-kilowatt capacity. They are oil-insulated and water-cooled, and take 2,300-volt current from the generators, raising it to 44,000 volts for the line. By means of multiple connections inside or outside the transformer tank, 1,900, 2,000, 2,100, 10,000, and 22,000 volts can also be obtained. Oil for the transformers is furnished either by gravity or under pressure. Circulating water, for transformer-cooling purposes, is obtained by gravity. With a rise in temperature not exceeding 60° C., a circulation of 4 gallons of water per minute at full load is required; while with 5 gallons per minute and 1.25 load, the temperature will not exceed, by 55° C., that of the intake water during continuous operation. All the transformers are connected to a piping system by which carbonic acid gas can be admitted in case of fire.

As shown in Table 40 of Chapter III, main-station transformers were not enumerated in 1902, but in 1907 their number was reported as 1,577, with 592,708-kilowatt capacity, which is in itself a fair indication of the amount of "transmission" work done in the country. As was remarked in that chapter, there was little uniformity among the companies in the manner of reporting their miscellaneous equipment of this character. While the main-station transformers, therefore, are probably reported with fair accuracy, considerable doubt attaches to the statistics for what may be called the substation equipment, because here the border line to distributing apparatus in some instances is crossed. In Table 41 substation transformers to the number of 4,211 were reported for 1907, with 1,100,824-kilowatt capacity, while in

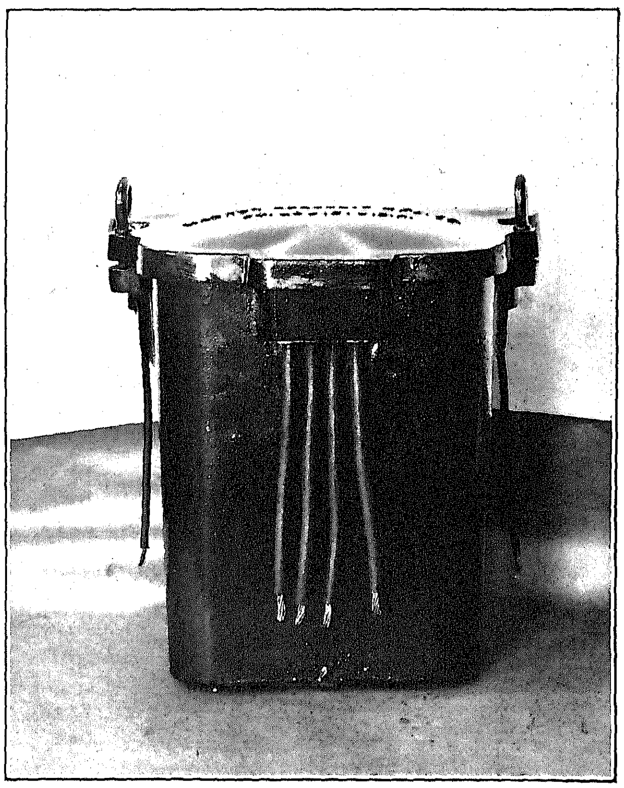
[1] Census Bulletin 245, Electrical Apparatus and Supplies, 1902, p. 10; Bulletin 73, 1905, p. 25.



400-AMPERE, 116 TO 120 VOLT METER UNCASED TO SHOW MECHANISM.



HIGH-VOLTAGE TRANSFORMER, SOUTHERN POWER COMPANY.



MODERN TYPE OF DISTRIBUTION TRANSFORMER.

1902 only 1,800, of 312,848-kilowatt capacity, were reported. It will be observed that the substation or receiving transformers are just about double the total capacity of the main-station transformers.

Three of the largest transformers in existence were manufactured during the year 1908–9 for the Great Western Power Company of California. The main power house of this company is located on the Feather River, near Oroville, in the county of Butte. The ultimate head of water developed is 525 feet, and 40,000 horsepower is transmitted at 100,000 volts to points along the coast 165 miles distant. The total weight of each of these monster transformers is 128,000 pounds, of which 40,000 pounds is due to the 5,000 gallons of oil used in each machine for cooling and insulating purposes. Each transformer is shaped like a giant wash boiler, stands 20 feet above the floor, and measures 9 by 18 feet. When these machines are working they each transform 10,444 kilowatts of electrical energy from a low voltage to a high voltage at the remarkably high efficiency of 98.6 per cent. The transformers for the Great Western Power Company are slightly larger than the six recently installed for the Great Northern Company of Duluth, Minn., which are in successful operation.

In Table 53 of Chapter IV the number of "distributing" transformers, or those on customers' circuits in 1907, is given as 299,489, with a total of 2,058,567-kilowatt capacity. There was a marked tendency toward an increase in size. The average capacity of these transformers more than doubled during the five years ending 1907, namely, from a little over 3 kilowatts to nearly 7. There has also been a great improvement in the construction of such transformers during the past five years. On this subject Mr. W. K. Layman[1] says:

Much of this improvement has been the result of a continuous and, recently, quite sharp improvement in the magnetic quality of sheet steel. The latest quality of transformer steel has been exploited under the various names of silicon steel, alloy steel, silico vanadium, and the like, with claims of individuality for each. The substantial fact is that these names are synonymous. They all refer to a quality of material in which the percentage of silicon has been greatly increased over that previously prevailing over the art. In chemical composition, the best material, as commonly employed in use to-day, shows the following analysis:

	New steel.	Old steel.
Combined carbon	0.070	0.080
Manganese	0.170	0.240
Sulphur	0.023	0.050
Silicon	3.700	0.094
Aluminum	1.314	0.050

It has been known from a very early date in the history of commercial transformers that silicon improves the quality of steel for transformer purposes, and some of the early technical writers explained the nonaging quality of impure steels, as compared with the pure, on the score of the presence of appreciable quantities of silicon. Manufacturing difficulties are said to have held back a quality of steel with as much as 3 per cent of silicon until about two years ago, when European mills began producing successfully this high silicon material, and very quickly its manufacture began here.

[1] Practical Aspects of Recent Improvements in Transformers, in Proceedings, National Electric Light Association, Vol. II, p. 220 et seq., 1909.

This change in chemical composition, together with special heat treatment by the manufacturer, has resulted in a marked improvement in the magnetic quality of the steel. The saving in internal energy losses with this material, as compared with the old, averages about 25 per cent. With this new material, if the weight is left the same, the performance will be greatly improved. If the performance remains unchanged, the weight is greatly reduced. Manufacturers have in general compromised between the two extremes and have built transformers lessened somewhat in weight but substantially improved in performance. Distributing transformers of modern type are usually for pole lines or for manholes, and differ in their adaptation to such specific use. If for pole-line service, the transformer is made as weatherproof as possible. If for manhole use, it is made water-tight or air-tight. As to the usual requirements, Mr. E. G. Reed said in a paper[1] read before the National Electric Light Association:

Standard transformers are made for only two voltages on the primary side—and in case of particular requirements a special transformer should be secured. For this reason modern commercial transformers are made for only two voltages on the primary side—that is, nominally 1,100 and 2,200 volts—and two voltages on the secondary—that is, nominally 110 and 220 volts. Standard transformers must be designed to operate at 1,100 volts, as well as at 2,200 volts, since there are still a number of stations using this voltage, though their number is decreasing. There is a limited demand for transformers with multiple-ratio taps on the primary winding, and sometimes for units having three secondary voltages. Such transformers can be secured for prices slightly higher than for the standard line. The demand for transformers having three secondary voltages arises from the convenience which at times results from having units which are interchangeable for light and power service. Lights are operated at nominally 110–220 volts, and motors at nominally 220–440 volts. The performance of the transformers with three secondary voltages is slightly inferior to that of the standard lines, which will probably more than offset the interchangeable feature. The increased complexity of the transformer provided with the numerous voltage combinations renders more likely a wrong connection when installing and the more chance of losing transformer by burn-out.

Storage batteries.—This class of apparatus has been found a necessary adjunct in most central stations or their substations in large cities, and is also found associated with many of the power-transmission systems. Persons familiar with the operation of storage batteries will appreciate the difficulties to be encountered in securing data as to number or capacity. While some figures are given in Table 40, Chapter III, as to number, which may be accepted as reasonably accurate, indicating a considerable increase in the number of cells, no effort has been made to report the

[1] Proceedings, National Electric Light Association, 1909, Vol. I, p. 581.

capacity, owing to the different methods in vogue of rating them or of employing their capacity.

At an earlier period batteries were used to even up the load on the generators in large central stations, but they are now used principally for emergency or "stand-by" service in substations and for carrying peaks of short duration. Their plates have therefore been designed to give the maximum output of energy for short and infrequent periods with a minimum first cost, upkeep, and space requirements. As a result the plates of later type will give nearly twice the output of the old plate, for twice the time, with a higher terminal voltage. Another development in such emergency service has been in connection with the auxiliary apparatus. End-cell switches that travel at high speed over the bars and are capable of carrying current up to 20,000 amperes for short periods have been successfully introduced. These switches can cut in or cut out from one to three cells per contact point, while carrying the maximum current, involving a great reduction in the cost of the copper conductor bars, since the number of runs from the end cells is reduced.

The use of batteries has enabled central stations to secure and execute large contracts for power that might otherwise have escaped them and fallen to isolated plants. In this connection Mr. Joseph Appleton, in a paper[1] read before the National Electric Light Association, says:

Equally important to the development of the emergency or stand-by battery comes the improved regulating features of storage batteries in connection with fluctuating direct and alternating-current power loads. The electrification of steam roads, and the increasing use of electrical energy in manufacturing plants, where large motors on fluctuating service are used, has necessitated the development of apparatus that will give a flexible control to the battery equipment and make it take that portion of the load, and that portion only, which gives the most efficient results as a whole to the substation or the power plant. Methods have been perfected which practically enable a selective control to be obtained, making the battery take any portion of the fluctuation desired for any predetermined time. For example, a battery equipment can be adjusted by this method to take the top part of the fluctuations only, not beginning to discharge until a predetermined portion of the fluctuation has been thrown on the generator or substation. It can be made to take the lower portion of the fluctuation, stopping at any desired point; or, further still, it can be made to take the first swing of the fluctuation, and then gradually throw the additional load caused by the fluctuation, up to any desired point, on to the generator or substation. With this apparatus any combination can be made to suit the capacity of the generating or rotary capacity with their overloads, so as to give the best net result to the system. This development of battery regulation is especially suited for such loads as are found in steel mills, the hardest kind of service for electrical apparatus which I believe exists.

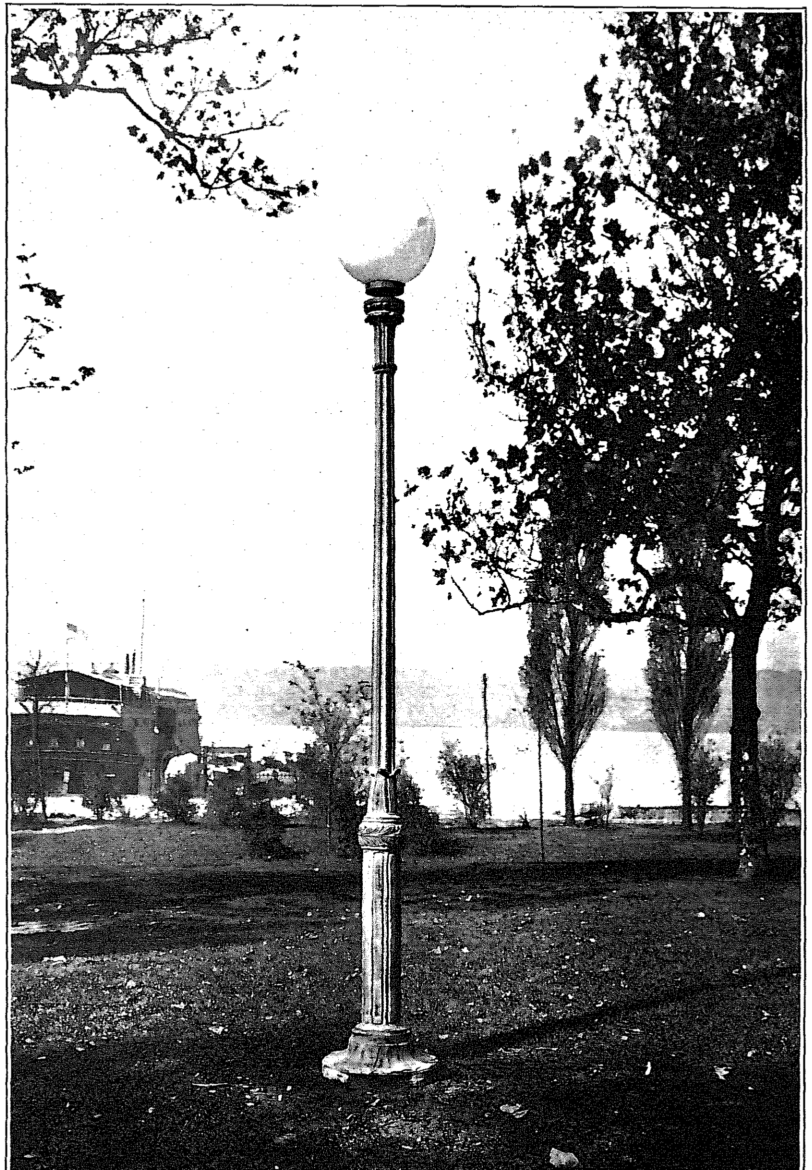
It should be noted here that the storage battery is constantly adding to the consumption of electrical energy through its use in vehicles of all kinds. Such batteries, charged directly from the circuits or through the intervention of mercury arc rectifiers and motor-generator sets, are numbered by thousands, and the income to the stations from this source is already large.

Arc lamps.—A very full account of the development of modern arc lamps up to 1907 will be found in the last census report on the manufacture of electrical apparatus, Bulletin 73. But the subsequent development has been very rapid and new types continue to be evolved. The nature of some of these changes has been quite fully discussed in Chapter IV, and the figures given there indicate the extent to which the old form of open arc was superseded by the inclosed type during the period 1902–1907. The evolution now going on is in the nature of a partial reversion to the open arc, and the abandonment of the inclosed, for outdoor service, while an intensified rivalry with new metallic filament incandescent lamps promises further advances in the direction of economy and efficiency.

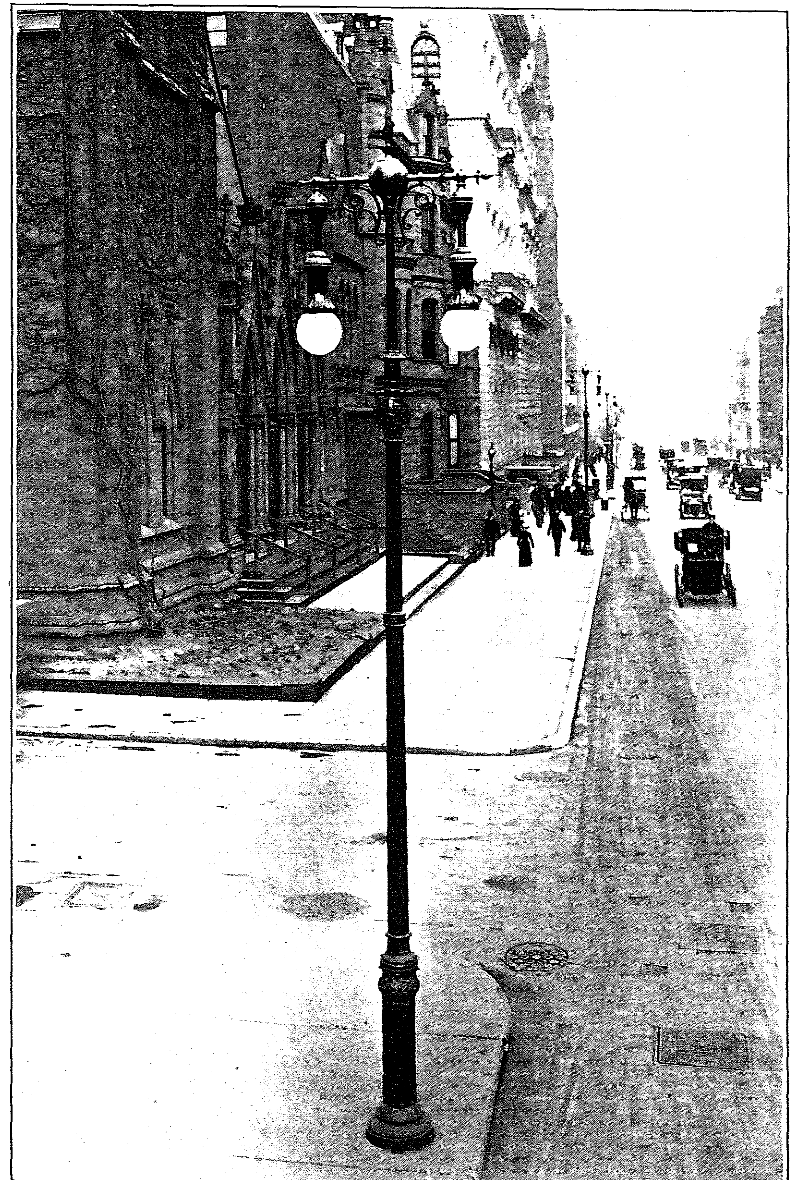
The resort to "flaming arcs" has been one of the most noteworthy and spectacular of the changes which the mere figures do not bring out, such lamps being adopted not merely for advertising purposes but for ordinary street illumination. Newark, N. J., affords an example that is strictly new and up-to-date in the special illumination of South Broad street with flaming arcs. This thoroughfare is no less than 100 feet wide, and the merchants on it were keen to secure more patronage. They formed an improvement association and have carried out an agreement with the Public Service Corporation, under which the city makes an allowance to the merchants equal to the sum paid to the company for the former inclosed arcs on the street. A system was laid out of permanent flaming arcs and of special supplementary incandescent lighting for the first two weeks. The arcs, of which there are 35, replacing 21 alternating-current inclosed arcs, are rated at 10,000 candlepower each, and are erected on poles along three blocks of the street, at a spacing of 60 feet. The new installation has been put in on a three-year basis of contract under which the lamps burn from dusk to dawn. The plan was such a brilliant success in all respects that steps were immediately taken to add two more blocks with an additional 15 arcs.

Flaming arc lamps are now being specified by engineers for municipalities and industrial-plant lighting, and naturally the question of maintenance cost is of prime importance. Two distinct types are now on the market, namely, the differential lamp and the so-called "gravity-feed" lamp. The differential lamp is generally adjusted to operate two lamps in series on 110-volt circuits, taking 10 amperes for the series, whereas the gravity-feed lamp, as a rule, is adjusted at 11 or 12 amperes. The differential lamp being taken as an example, the consumption of each lamp is 550 watts, which at an average cost of 2 cents per kilowatt-hour makes the cost $11 per 1,000 hours for current. The net cost of flaming arc-lamp carbons being taken as an example, the cost per trim per 1,000 hours, including labor, would be $8.50, making the total cost of trim

[1] Proceedings, National Electric Light Association, 1909, Vol. I, p. 195.



TUNGSTEN LIGHTING, RIVERSIDE DRIVE, NEW YORK CITY.



INCLOSED ARC-LIGHT LAMP-POSTS, FIFTH AVENUE, NEW YORK CITY.

and carbons $19.50 per 1,000 hours. The cost of repairs and globes per 1,000 hours may be figured at $2, to which $2 per 1,000 hours must be added for interest on the investment and depreciation, making a total of $23.50 per 1,000 hours of operation. At an average yearly operation of about 4,000 hours the cost would be $94 per year per lamp.

For municipal lighting the general plan of installing these lamps is to mount two lamps on one pole, as it simplifies the wiring problem over the plan of mounting one to a pole. The height of the lamps above the sidewalk should not be less than 25 feet, so as to secure a good distribution for their high candlepower.

At the annual convention in August, 1908, of the Ohio Electric Light Association, Mr. C. R. McKay, of the Toledo Railways and Light Company, read a paper in which he described an installation of 1,670 luminous magnetite arc lamps in regular service for street lighting at Toledo, Ohio. All the street lighting in Toledo is now done by means of such lamps, which for the most part are spaced approximately 600 feet apart in the residence and outlying districts of the city. In some other parts of the city, such as the principal shopping district, two lamps are placed on each pole and the poles are spaced 80 feet apart opposite to each other on each side of the street. The energy is generated by 25-cycle, 3-phase turbo-generators. To supply the arc lights, 37 constant-current transformers wound for 2,200 volts primary are installed, together with a corresponding number of mercury arc rectifiers and switchboard panels.

The lamps are generally hung over the center of the street intersections, at a height of approximately 25 feet, by means of suspension wires, and are lowered for trimming. The light in this type of lamp issues chiefly from the long arc itself rather than from the positive crater. It is therefore quite sensitive to rupture by drafts of air unless thoroughly protected by wind-proof casing and tight globes. Early difficulties with the upper electrode have been remedied by using copper of large diameter. The life of the lower electrode has been increased from 110 to over 160 hours. The lamps average from 320 to 324 watts per lamp, including line losses, as measured at the direct-current circuit terminal. The current is about 4 amperes. They take 38 per cent less energy per lamp than the 7.5-ampere alternating-current lamps they displaced. The residents of East Toledo gave unmistakable testimony to the superiority of the luminous arc over the 7.5-ampere inclosed-carbon arc, by objecting publicly to the use of the latter during a temporary interruption of the other circuit. The 1,670 lamps, distributed over 37 circuits, are trimmed by three trimmers, each provided with a horse and buggy. About 1 per cent of the lamps are usually in the shop for adjustment or repairs.

An interesting and novel feature of arc work is the "regenerative" inclosed flame, intended for streets and open spaces. If an ordinary flame arc were inclosed, the heavy fumes evolved from the impregnated carbons would soon form a deposit on the globe and obscure the arc. In this new lamp special means are provided for obtaining a circulation of the gases past the arc, and the light is produced mainly by raising such gases to the temperature of incandescence, and not merely by the combustion of chemicals in the arc. The spectrum of the light is a band-and-band line spectrum, which shows that the gases are in various stages of incandescence. About 15 grams of the associated composition are volatilized every hour, the gases rising from the positive crater through the arc. The lower carbon, which is the positive, is held in a fixed support. Surrounding the arc is a clear-glass cylinder, and outside this again is a translucent globe. The inner glass cylinder is in communication with two metal tubes, one on each side of the globe. There is a circulation of the hot gases up the central cylinder and down the other tubes, and the incandescent gases are carried around and subjected to the high temperature of the arc several times before finally condensing and settling in the outer tubes. The inner glass cylinder is kept perfectly clear of deposit for the greater part of its length, chiefly by the high temperature which prevents the gases condensing, but also probably by the strong direct draft past the arc. The upper negative carbon is an ordinary high-grade carbon. The lower stick is also of high-grade carbon, but is star-shaped in section. The grooves between the eight rays of the star are filled with the chemical composition, which is laid in in the form of a paste. The rods are then baked, and the paste expands into the pores of the carbon and fixes itself firmly into the grooves. The life of a single pair of carbons is over seventy hours. The light is of a yellow-white color, but modifications can be obtained by varying the nature of the composition on the positive carbon. The 550-watt size, taking 5.5 amperes at 100 volts, gives a mean hemispherical candlepower of 2,200.

Among the arc lamps in actual service on central-station circuits may be mentioned those with carbons of smaller diameter than usual, the object being to obtain a whiter and more efficient light, as well as its better distribution. Such lamps have a special adaptation to interior use, where they compete directly with incandescent and "glower" lamps. A typical lamp of this character has a lower negative carbon of large diameter, and a pair of upper positive carbons of small diameter, inclined at an angle to each other. The lower carbon is held in a fixed position while the two small upper carbons are arranged to "draw the arc" on starting, and feed downward as they are consumed. The arc is thus centered in one permanent position, making possible the use of a reflector to project the light entirely into the lower hemispherical plane of illumination. The arc is also inclosed by a large globe which restricts the access of air and brings about conditions similar to those which insure the long life of the carbons in an inclosed arc lamp.

Modifications in fixtures, globes, transformers, etc., to meet the changing conditions have necessarily been made, but as a general thing the manufacture of dynamos specifically for arc lighting, as in the early days, has ceased. The lamps now derive their supply of current from generators which operate a variety of other devices at the same time.

Incandescent lamps.—Data are given in Table 45 of Chapter IV as to the approximate number of incandescent lamps on the circuits of central-station plants, namely, 41,445,997 in 1907, or an increase over 1902 of 127.8 per cent. A large gain was shown also in the connections to electric-railway circuits, making a total of approximately 45,991,836 lamps connected. The grand total in the country could be given, however, only after ascertaining the data of isolated plants in office buildings, factories, steamships, and other similar private establishments, and such figures it is impracticable to obtain. Some authorities have assumed the connected lamps of such plants to equal in number those of the central stations, which seems rather improbable; but even if they do not, the total of consumption, assuming each lamp to be renewed once a year, is enormous.

A discussion of many features in the development of the incandescent lamp during the period will also be found in Chapter IV. Attention is there drawn to the nature of the data relating to lamps of 32-candlepower and 16-candlepower, the latter being the standard size. The introduction of metallic-filament lamps and other types has changed the importance and universality of such units, but the heterogeneity prevalent at the time of this report will doubtless settle down again to a limited number of standards by 1912, the probable year of the next electrical census. The varieties of one kind and another now run literally into the thousands, adding seriously to the cost of manufacture and carrying in stock, and it may be questioned whether the consumer is benefited in the end, by an illimitable freedom of choice, which often affects the construction of fixtures and the conditions of the supply circuits. What is involved in the transition may be inferred from the following comment:[1]

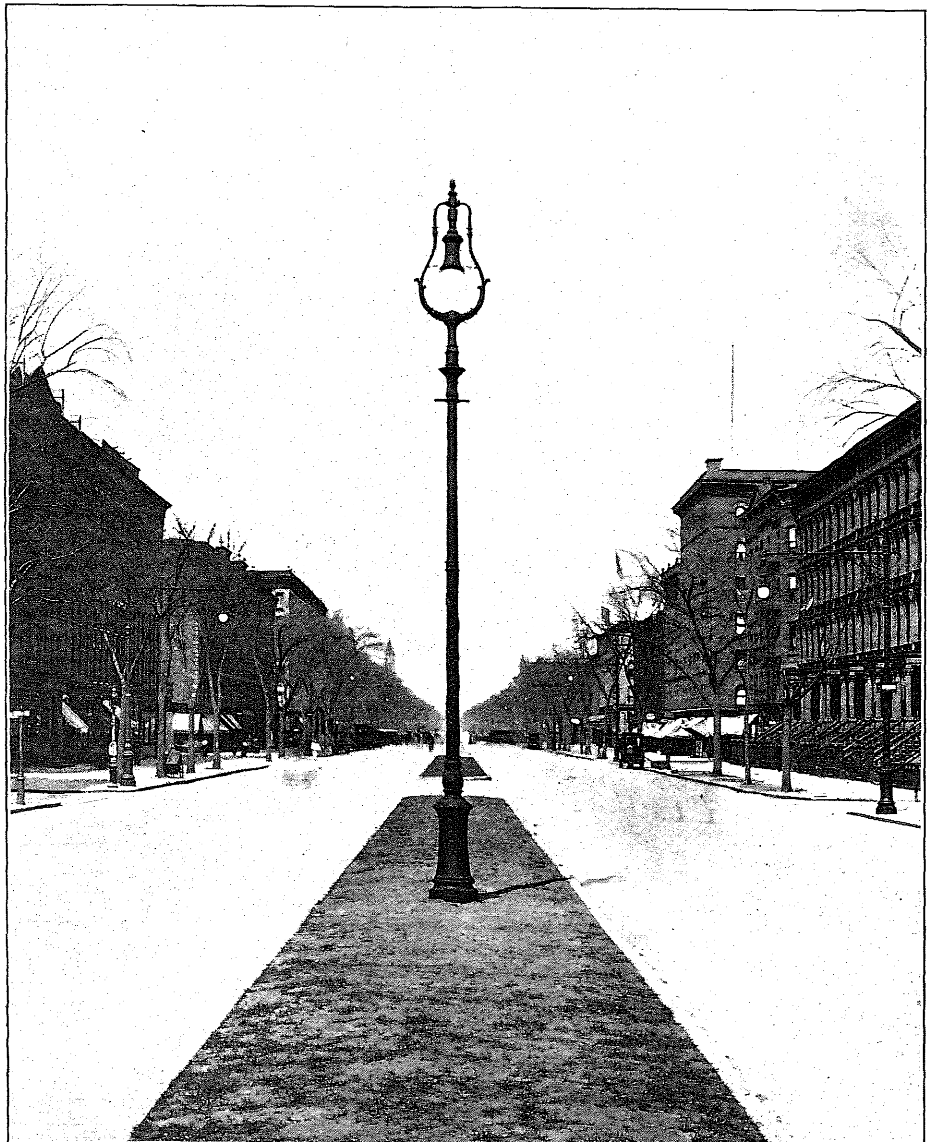
So many conditions are involved in a change from one set of fundamental apparatus to another, the period of transition must necessarily be long even if the expected improvements make good. The era of electric traction is well begun, but the steam locomotive, and even the horse car, still prevail. As a matter of fact, it is more interesting and practical to watch the actual incipient changes than to speculate on the possible scope of a whole revolution. For instance, there is an indication that a change in the art is upon us in the scarcity of old-style standard 32 and 50 candlepower lamps, due to the fact that makers are getting ready to discontinue their manufacture. The lamp manufacturers announced their intention some time ago of discontinuing the manufacture of the old common carbon-filament lamps in sizes of over 100 watts because of the advent of the new graphitized-filament lamp now commonly known as the "Gem," which latter, because of its higher efficiency, would be certain to supplant the old standard lamps even if the manufacture of the old lamps was not discontinued. But here comes in one of the prosaic points of detail. The position of the man who has an installation of standard 32-candlepower lamps with standard shade holders and who must substitute the new lamp, which is considerably larger in bulb and longer in neck than the old standard 32-candlepower lamp, is not a profitable one. The new lamp, as made, requires special shade holders when fitted with reflectors. The old standard shade holders leave the shade "high and dry" above the lamp bulb, defeating most of the purposes for which the shade may be intended. If the change to larger bulb lamps requiring different shade holders causes the owner at the same time to change to glassware that is suited to the purpose of most efficient illumination, the change in lamp sizes will have been a good thing aside from all questions of lamp efficiency.

The departure from the familiar form of carbon-filament lamp and the present popularity of the metallic-filament lamp are well described in a recent article by Prof. Albert F. Ganz.[1] It is pointed out that the early carbon-filament lamps required 5 to 6 watts per candle, but improvements in the manufacture of the filaments had, by about 1888, decreased this specific power consumption to 3.1 watts per candle. The high efficiency lamps, having a specific consumption of 3.1 watts per candle, could, however, be used only on circuits having close-voltage regulation, as otherwise the life of the lamp was greatly reduced. No radical improvements in carbon-filament lamps were made for over fifteen years, until about 1905, when the metallizing or graphitizing process for treating carbon filaments was developed. This process consists essentially in subjecting the carbon filament to the high temperature of an electric furnace with the result that the filament is partly or wholly graphitized. The filament is then "flashed" and subjected to the electric furnace for a second time. The graphitized or metallized carbon-filament lamp, known also under the trade name of "Gem" lamp, has a specific power consumption of 2.5 watts per candle, with the same normal life as the ordinary carbon-filament lamp. A further remarkable alteration produced in the carbon filament by the metallizing or graphitizing process is the change of the temperature coefficient of resistance from negative to positive, so that the treated filament behaves in this respect like a metal. This positive temperature coefficient makes the lamp much less influenced by fluctuations in the supply voltage.

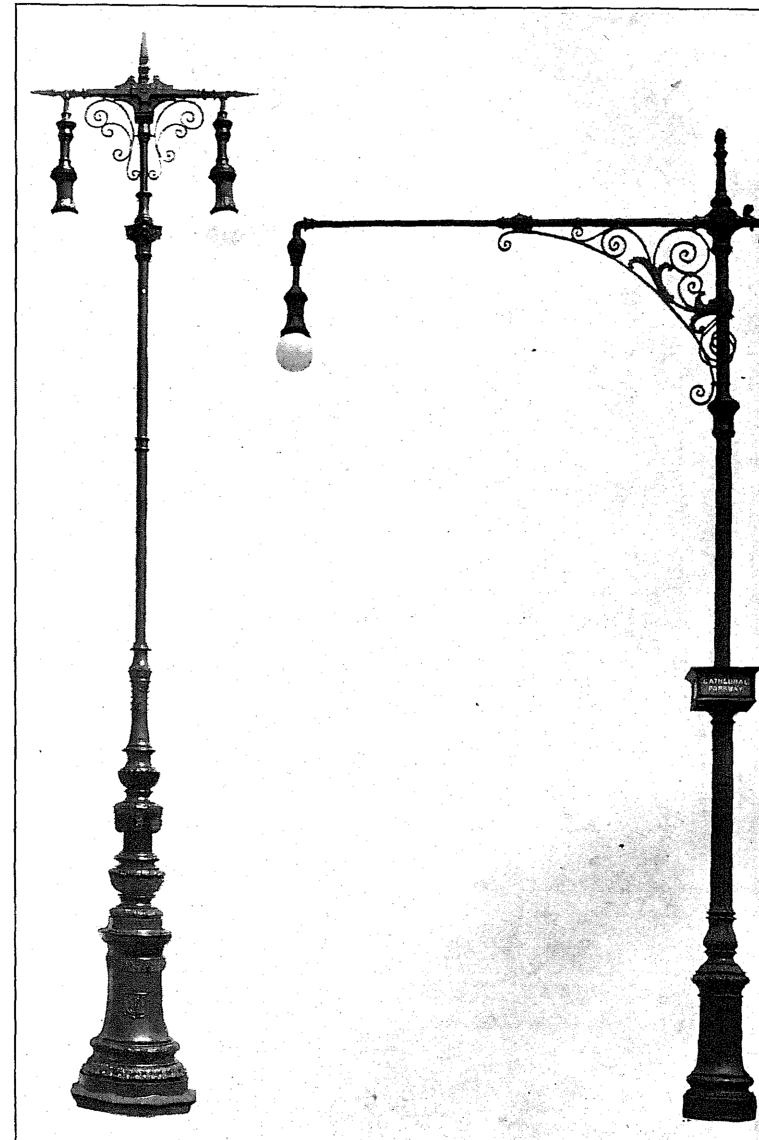
Meantime, incandescent lamps containing filaments of metal and giving efficiencies much higher than could be obtained with carbon have been introduced. Platinum was tried in the early stages of the manufacture, but was found not entirely satisfactory. Osmium was the first metal tried in the newer work, and a fairly satisfactory lamp, having a specific power consumption of 1.5 watts per candle, was obtained. A number of osmium lamps have, in fact, been used commercially in Germany, but the very limited available supply of

[1] Report of Committee on Progress, National Electric Light Association, 1907.

[1] American Gas Light Journal, July, 1909.



ARC LIGHTING ON SEVENTH AVENUE, NEW YORK CITY.



TYPES OF MODERN ARC-LIGHT POLES.

this metal has prevented the commercial introduction of this type on a large scale.

About the year 1904 lamps employing tantalum filaments were placed on the market, having an efficiency of about 2 watts per candle, with a useful life greater than that of the carbon-filament lamp on direct-current circuits. Processes were developed for producing pure ductile tantalum which was then drawn into fine wires for use in the lamps, and these tantalum lamps have come into considerable commercial use. A peculiarity of the tantalum lamp is that it has a short life when used on alternating current. The lamp is therefore inherently a direct-current lamp.

The following year incandescent lamps having filaments of tungsten were made in Germany. They had a specific consumption of about 1.25 watts per candle with a useful life claimed to be greater than that of the carbon-filament lamp, and worked equally well on both alternating and direct current. These lamps were quickly introduced on a large scale. The manufacture of tungsten lamps was also started in America about 1907, and they are now rapidly coming into use. Since tungsten is not ductile, the tungsten filaments can not be drawn into fine wires as in the case of tantalum. The production of a filament of tungsten, therefore, presents many difficulties, with the result that several different processes for producing these filaments have been developed. Since the specific resistance of tungsten is very much less than that of carbon, a filament of tungsten for a lamp to be operated at a given voltage must be very much thinner and longer than a carbon filament for the same voltage. For this reason tungsten filaments are admirably suited for heavy-current, low-voltage series lamps for use on constant-current circuits for street lighting. Multiple lamps for 110-volt constant potential circuits are now also manufactured in sizes down to 20-candlepower, but the filaments in these lamps are extremely small in diameter. When the tungsten filament is incandescent it is extremely soft, and the loops, especially those for high-voltage lamps, require supports to keep them in position. The first tungsten lamps were for this reason capable of operating only in a vertical downward position. The lamps have been so improved that they can now operate in any position. The high-voltage tungsten filament is, however, extremely fragile, and liable to break when subjected to vibration, so that these lamps are not yet suitable for places subjected to vibration, as, for instance, on trains or boats. In these latter places, however, the tantalum lamp and the low-voltage tungsten lamp are frequently used.

Both the tantalum and tungsten filaments have a positive temperature coefficient, and for this reason are less affected by fluctuations in line voltage than ordinary carbon filaments. The light given by tantalum and tungsten lamps is also much whiter than that given by carbon-filament lamps, owing to the higher temperature at which these filaments are operated. Another peculiarity of these metal-filament lamps is that they do not depreciate from their initial candlepower until the filament finally breaks. It is at times even possible to repair a ruptured tantalum or tungsten lamp filament by judiciously shaking the lamp with the current on, until the broken ends of the filament come in contact and are welded together by the intense local heat at the point of contact. Such a weld is frequently quite strong, enabling the lamp to continue in service for a considerable time.

The report of the lamp committee of the National Electric Light Association for 1909 brings out some interesting data as to conditions in regard to incandescent lamps in general during the period under review in the present report, based upon data from 200 of the largest central-station companies in the country. It is remarked that as to the general use of different types of lamps, the carbon-filament lamp was still the standard lamp, although the metallized-filament lamps were being used extensively by the companies, more than 60 per cent of those reporting having already used a considerable proportion of such lamps. Several of the larger companies proposed to abandon the standard carbon lamp entirely and furnish the metallized or Gem filament lamps for all their free renewals.

Tungsten lamps had also been in general use, about 75 per cent of the companies reporting that they had used such lamps, and of these in turn fully 75 per cent made extensive use of them and encouraged their introduction generally in their territories. The reports indicate considerable difficulties with the early lamps of this type, but a decided improvement in the later installations. The opinion is almost unanimous that the tungsten lamp is the best possible instrument for making satisfied customers and producing additional revenue. In the matter of incandescent street lighting, a small proportion of the companies reported changes to tungsten lamps, with apparently satisfactory results in all cases.

The number of companies using tantalum lamps was much smaller, about 20 per cent only, and the use of tantalum lamps was apparently becoming more restricted rather than extended. Free lamp renewals was the general practice, except in the case of very small companies and a few of the larger companies. Most of the companies that had furnished carbon lamps on a free-renewal basis were extending that policy to the metallized-filament lamps.

In the matter of delivering lamp renewals, about half of the companies required the customers to send for all lamps; about 10 per cent delivered all renewal lamps upon request of customers; and about 4 per cent made deliveries in accordance with a definite schedule for covering the territory systematically. The other companies encouraged customers to send for lamps, but also delivered upon request, subject to restrictions.

About 25 per cent of the companies making deliveries also placed the lamps in the sockets when requested. About 15 per cent of the companies had their free-renewal lamps marked for identification.

Most companies recognized the difficulty of preventing waste or loss of lamps without placing annoying restrictions upon the furnishing of lamps to customers, and about half the companies reporting kept a record of deliveries to individual customers and attempted, by means of such records, to avoid undue losses.

In the matter of renewing blackened and broken lamps, the general policy seemed to be to refuse to renew broken lamps, but to renew blackened lamps. In the matter of reserve stock, most of the companies carried a safe reserve, which in all the companies reporting would average about two months' supply. The prices charged for other than standard free-renewal lamps varied with the different companies from list prices to cost prices, with, on the whole, little uniformity between the companies.

At the January, 1908, meeting of the Pittsburg Section of the American Institute of Electrical Engineers the physical properties of the various forms of lamps then in use were summed up in the following table presented by Mr. A. J. Sweet:

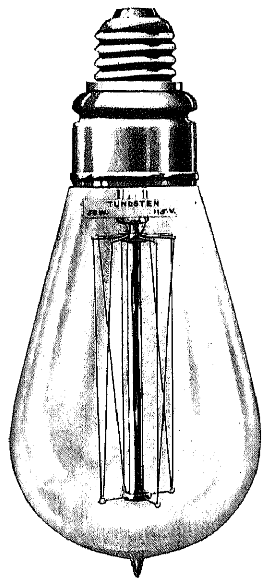
KIND OF LAMP.	Mean spherical candlepower.	Watts per candle.	Candle per K. W.
Common 56-watt carbon-filament incandescent lamp, rated at 3.5 watts per candle, 16 horizontal candlepower	13.2	4.24	236
Common 50-watt carbon-filament incandescent lamp, rated at 3.1 watts per candle, 16 horizontal candlepower	13.2	3.78	264
3-glower, 264-watt Nernst lamp	81.0	3.26	307
Gem, 125-watt, graphitized carbon-filament lamp of 50 horizontal candlepower	40.7	3.07	326
44-watt tantalum lamp, rated at 22 horizontal candlepower	16.0	2.75	364
Direct-current, 5.1-ampere inclosed arc on 110-volt circuit, 1.5-inch carbons	213.0	2.63	380
Alternating-current inclosed 5.7-ampere arc, taking 388 watts on 110-volt circuit, 0.5-inch carbons	152.0	2.55	392
60-watt, 110-volt tungsten-filament lamp, burning at 1.25 watts per horizontal candle	37.0	1.62	617
Luminous 8-ampere arc, 440-watt, two in series on 110-volt circuit	1,020.0	0.431	2,320

At the March, 1908, meeting of the New England Association of Electric Lighting Engineers, Mr. J. S. Whitaker, of the Rockingham County Light and Power Company, Portsmouth, N.H., read a paper on the introduction of the tungsten lamp. Citing a life test made upon an 80-candlepower, 115-volt lamp, he stated that it burned eight hundred and sixty-four hours continuously, with no perceptible change in color or diminution of light, though no photometer test was made. He instanced a small dry-goods store, which had originally an installation of incandescent lamps and gas arcs combined. Tungsten lamps were installed in the show windows and one wing, on free trial, with the result that an order was placed for a complete tungsten installation. The lighting cost to the merchant for December, 1907, was 20 per cent less than a year before. During seven months Mr. Whitaker purchased 850 tungsten lamps; of these 27 were broken in transit, 418 were installed, and 143 burned out. It was found that 75 per cent of the early "burn-outs" occurred in the first one hundred hours. Later lamps were better and more uniform. A charge of $1.75 each for 100-watt lamps was made to the consumer. This allowed for transportation and breakage. The company replaced all lamps not burning one hundred hours.

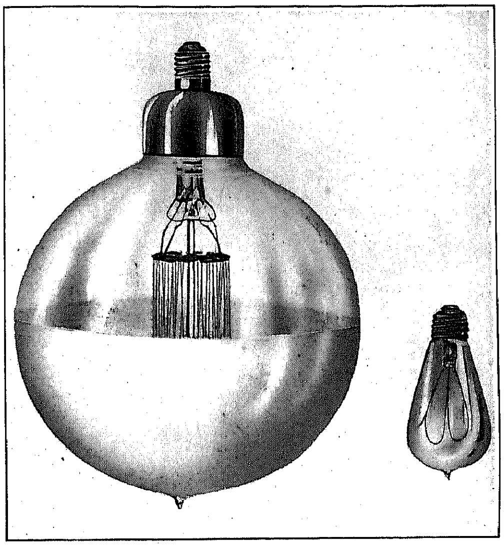
In the discussion Mr. Willcox, of Lowell, stated that a rental basis of 25 cents per month had been found satisfactory in meeting the gas-arc competition. Mr. Sands, of Haverhill, stated that he loaned the shades and reflectors in store installations of tungsten lamps; and if one was broken or lost, the customer paid for it. Mr. Cowles, of the Boston Edison Company, said that his company had installed about 1,200 80-candlepower tungsten lamps, charging an excess of $1.10, the lamp remaining the property of the company. The life appeared to be very good—thus far, at least seven hundred hours. The company placed the lamps in the sockets itself, pendant sockets being used. Mr. Hale, of the Boston company, said that most customers appeared to prefer the lamp installed with a clear shade, even though the company advised the use of a sand-blasted globe and etched shade. In Peabody, Mass., in order to meet gas-arc competition, 100-watt lamps were installed at a charge of $1.50 each, with a guarantee that the annual cost of renewals should not exceed $3 per lamp, which was the yearly rental charged by the gas company. In a bowling alley where formerly there was one gas lamp between each pair of alleys the tungsten lamps were placed, one over each alley, with reflectors adjusted to keep the light out of the eyes of the patrons, and to direct it onto the pins.

It may be added that since the date of the meeting last mentioned, all the points in favor of the tungsten lamp have been improved upon, including longer life, lower price, and less breakage in transit.

The number of cases of adoption of incandescent lamps for street lighting in the period has been remarkable, and the more noteworthy because a great deal of the new work is due to the efforts of merchants doing business along the streets illuminated rather than of the municipal authorities. In other words, it is another example of the stronger public spirit manifested in late years; and it may also be regarded as an evidence of the local pride which seeks to build up the community and its trade. Numerous concerted efforts have been made to enhance by such action the brilliancy and attractiveness of sections of particular thoroughfares or even of whole streets. This development is, moreover, particularly interesting as being in itself an evidence that the general lighting at such points is inadequate. Causing, as it does, too, an

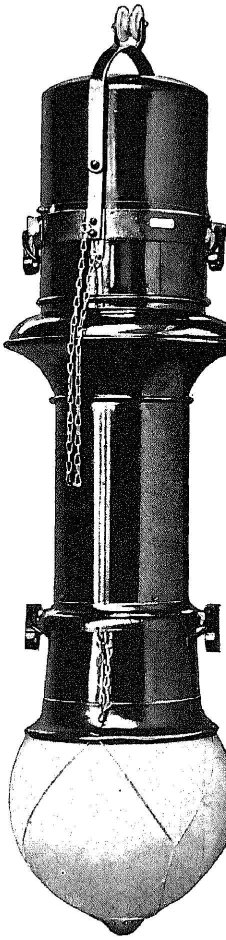


TYPE OF ORDINARY TUNGSTEN LAMP.



1,000-CANDLEPOWER TUNGSTEN LAMP COMPARED WITH ORDINARY 16-CANDLEPOWER CARBON LAMP.

INCLOSED ARC LAMP WITH ORNAMENTAL CASING FOR INDOOR SERVICE.



TYPE OF FLAMING-ARC LAMP.

accentuation of the surrounding gloom, it bids fair to be a factor in raising the general scale of street illumination.

A plan of extra lighting that has now become quite common is seen in arch lighting, of which there are many varieties. For example, Canal street, Grand Rapids, Mich., has been specially illuminated with series tungsten lamps, in 15 spans across the thoroughfare, each with 18 lamps of 60-candlepower, 75 watts. The spans are 100 feet apart, 110 feet in length, and the initial expense was $750 each for labor and material. Merchants paid for the work, and the cost of operation is so small that some of them are at an expense of only $1 per month. The effect has been marked, large crowds have been drawn, and, considered from all points of view, the installation seems to be very successful. On Monroe street, which is about 80 feet wide, 12 arches had been erected, 80 to 90 feet apart, with 14 tungstens on each; and 5 more arches were to follow.

Big Rapids has followed suit and has erected 7 arches, with plans for 5 more. Each arch has 10 tungstens of 60 candlepower in series. Half a dozen other small towns in Michigan have taken up the matter. A popular differentiation from the pipe arch is the stringing of a span wire from pole to pole or from building to building, the tungsten lamps being suspended from the span. It all means additional income for the station, but there are objections made to the "canopy" plan. It puts the lamps up so high that a considerable portion of the illumination is spent on the upper stories of the buildings. The overhead network of wiring is an obstruction to firemen, and there is damage in the case of high winds. The contrasting method of low posts close together has its warm advocates, not merely because of its more permanent character and appearance, but as a revenue producer. Thus, at Minneapolis, the Publicity Club has brought about the lighting of Nicolet avenue, the main street of the city, with 64 standards, 8 to the block, 4 on each side of the street. The cost has been met by assessing merchants $2 a front foot to cover installation and $1.25 a year per front foot for maintenance. The posts are of cast iron, standing 14 feet above the ground, and are ornamental. Each carries four 12-inch alabaster globes and one 16-inch, all in a vertical position, each containing one 100-watt tungsten lamp. The advantages of the vertical arrangement of the lamps are minimum breakage, greater cleanliness, and larger lighting area. Each post is connected to the Edison 3-wire direct-current system of underground lead-sheathed cable. The retail cost of the posts installed is put at $145 each, of which $85 is for foundry work and $60 for wiring, globes, lamps, and similar items. The Minneapolis General Electric Company runs the installation at a total inclusive charge of $78 per post per year. All five lamps are switched on by an electrolier key switch in the post base, and after midnight only the central lamp on top of the post is left to burn until daylight. As compared with a post system installed earlier at St. Paul, these standards are 2 feet higher and have arms 2 feet longer, while the tungsten lamp has added appreciably to the effective result obtained.

At Aurora, Ill., a somewhat similar scheme has been carried out, but there the tungsten lamps are carried in the downward burning position, except the central 60-watt one. No fewer than 173 posts have been installed, each carrying 3 lamps, except at each of the four corners of street intersections, where 5 lamps are used. The posts are 50 feet apart along each side of the street, on the curb line, one arm extending over the sidewalk, the other over the roadway. The plan originated with business men on the west side of the city, who organized the West Aurora Improvement Company. Proper ordinances were passed by the city council whereby the merchants could install and pay for the system and then turn it over to the city for maintenance and operation. Similar movements were started in other parts of the business district, and have culminated in a thorough lighting of the downtown section of the city. It is interesting to note that Aurora, in 1881, began at the other end of the methods of street illumination, with seven 150-foot towers, each carrying two large open arcs, high in the air, where they were imagined to give a "diffused moonlight," most of which in summer time at least, was intercepted from the sidewalks and roads by shade trees.

During the past four or five years there has been considerable advance in the use of electricity for the lighting of public parks, especially since the introduction of the tungsten lamp. In 1908 the New York Edison and allied companies developed a system of park lighting with tungstens and soon after placed large numbers of them in Riverside Park, on Riverside Drive, in Highbridge Park, and in St. Nicholas Park. These lamps are carried on ordinary posts at a height of over 10 feet from the ground. The lantern consists of three hinged interlocking sections, which provide socket and globe-holding devices, with means to clean and replace the lamps quickly as well as the reflectors and globes. To reach the posts, conduit and buried cable have been employed. The service switches control from 16 to 40 units equally balanced over the 3-wire network, and with slight modifications the system could be adapted to series alternating supply when used with a series transformer in either an arc or incandescent circuit. More recent modifications of this service include the lighting of Central Park with tungsten lamps.

In regard to street lighting it is interesting to note everywhere a greater interest in the beautiful aspect of the streets by day and night, and a desire not to spoil trees by bad trimming. At Los Angeles, Cal., the permits issued to the public-utility companies have printed on them in large type: "The trees must

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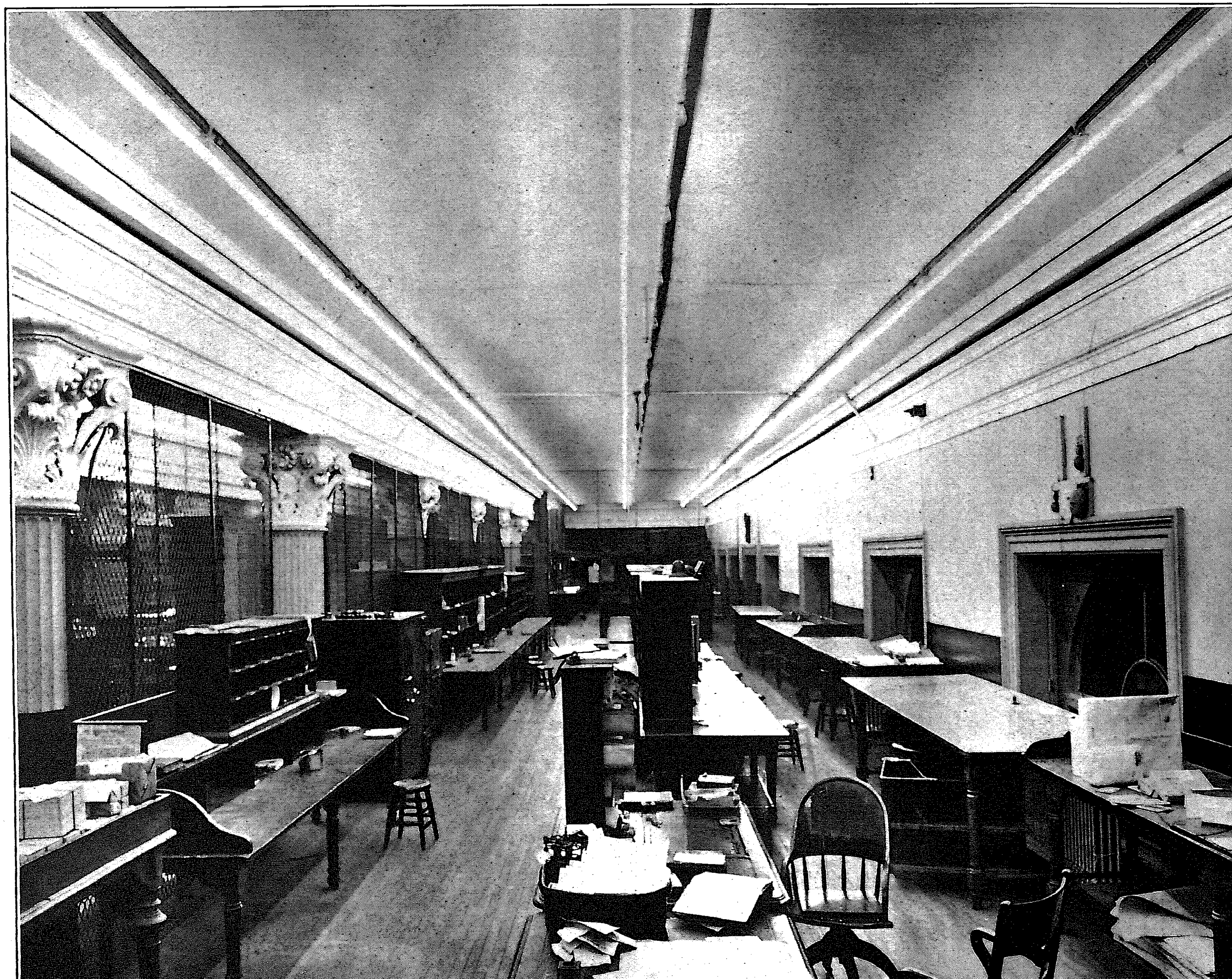
be trimmed so as to preserve their symmetry," and this has led trimmers to give some attention to the nature of the tree and the peculiarities of its growth. One of the problems of suburban and rural development of lighting has been how to connect up various dwellings without excessive expense and without marring the attractiveness of the streets and foliage trees by pole lines. In some cities there are alleyways that can be utilized, but most cities are without these. At Rochester, N. Y., the Railway and Light Company has met the difficulty by erecting a pole line on the back-yard boundary line; and the other utility companies cooperate in maintaining the system. The company has deeded to it by the owner the ground on which the pole is erected, together with the right of free access at all times, and in turn it places on the streets a handsome type of arc lamp with standard of bishop's crook or swanneck form. In running the mains to these back-yard poles, high-potential lines are taken underground to a transformer in the manhole nearest the street, and thence low-potential circuits are run to a manhole in the street opposite the pole lines, whence they branch and run underground to the end pole on either side. The mains are then brought up through conduit to the cross-arm. Service connections are made to the mains and brought in overhead to the rear of the houses, and the front of the property is left free from unsightly wires and service connections. The pole line extends from block to block, depending on the number of houses connected. No trouble has been experienced in getting the necessary concessions, as the plan is a benefit to the neighborhood.

Incidentally the tungsten lamp has already brought with it a number of auxiliary and supplemental devices and methods, such as socket adapters, reflectors, fixtures, and small transformers. In the new ballroom of the Hotel Astor, New York, where 1,200 people can dine or 2,500 can dance at one time, the lighting is done with some thousands of small low-volt tungsten lamps associated with small group transformers receiving current from motor-generator sets. At the twenty-fifth anniversary dinner of the American Institute of Electrical Engineers in the old ballroom of the same house in March, 1909, some 50 large tables were each beautifully illuminated with miniature tungsten lamps fed by a small storage battery set in a low metal vase on each table. Over the battery and lamps was placed a block of glass simulating ice, with a number of holes filled with water in which was set a mass of blush roses and maidenhair fern. The softly brilliant effect obtained would, it is said, have been impossible with carbon-filament lamps. Moreover, it was not necessary to wire each table for local lamps.

An evidence of the activity in the electric-lighting industry is the constant stream of novelties. Of these, the helion lamp is one for which an early commercial perfection is predicted. The carbon-silicon filament of this lamp has been brought to a point where it can be burned in open air at practically the specific consumption of an ordinary vacuum carbon lamp. An interesting quality of the filament is its extraordinary high specific resistance, which is nearly thirty times that of the carbon filament and several hundred times that of tungsten. Particles of it are so hard that they will scratch glass.

The present report includes data as to the extension of the use of Nernst or "glower" lamps. The introduction of the metallic-filament incandescent lamp has by no means operated to eliminate this lamp, which has many desirable features of its own. The vogue of the glower lamp is also due to the fact that new units have been developed, considerably better in efficiency than the old. Coincident with the improvements in the glower came the development of the single-glower renewal screw burner, making the renewal of the lamp the same practically as in standard incandescent practice. This has resulted in the introduction of the screw-burner principle into chandeliers; and the new fixtures of that type are characterized by economy of space and high illuminating power. A number of large stores and other establishments have adopted the glower form of illuminant. The Marshall Field store in Chicago, with 25 acres of floor space, is an example, the details of the lighting of which were made public in October, 1907, by Mr. F. J. Pearson, electrical engineer of the dry-goods company, from which report the following is taken:

Tests of various lighting systems were carried on over a period of eighteen months. While the illumination calculated from the photometric curves of individual lamps, as well as measurements of illumination at the counter level in the actual installations, was made use of in comparing results, far more value was attached to visual tests made by comparing the general appearance of large rooms or sections of rooms lighted in different ways. To show the multiplicity of requirements, it is stated that there were 350 sections in the store, nearly every one of which had a different class of goods, and therefore presented somewhat different requirements. It was therefore necessary, if uniformity throughout the store was to be secured, to select a compromise system which would meet fairly well all requirements. The general plan of testing the different illuminating systems offered by the different manufacturers was to take a large room about 150 by 250 feet, and equip one-half of it with one lighting system and the other half with another. This was thought to be the best way to bring before the non-technical public and the sales managers the relative effects and efficiencies of the various systems. Glower lamps on short chain pendants were finally selected for lighting the establishment, with an average illumination in the foot-candles as follows: All above the first floor, 2.5 to 3; the first basement, 3.5 to 4; second and third basements, shipping and packing departments, 2.25 to 2.5. Arc lamps were not seriously considered,



ROOM IN NEW YORK POST-OFFICE LIGHTED WITH VACUUM TUBES.

because it was stated that not 10 of the 350 section managers wanted to sell goods under them. The selection of the glower lamp was made because of low maintenance cost, color, and good general effect, as indicated by the preference of the management and the section managers.

The Moore tube system of vacuum lighting has also made progress, not only in the design of apparatus, but in the use of the tubes when provided with carbon dioxide, and is valuable in business establishments where color values are a main consideration. The long-loop tube system has been standardized into a "hair-pin" form, and there has also been developed a "straight-run" form, i. e., one end of the tube does not reenter the terminal box. The entire mezzanine floor of the New York Post-Office has been very successfully fitted up with tubes in 35 parallel rows, each 114 feet long, placed immediately against the ceiling.

Where the peculiar color is not objectionable, a large amount of miscellaneous lighting has been done with the mercury vapor lamp, which was in 1901 introduced to public notice by Dr. Peter Cooper Hewitt. He has since developed the same principle in the mercury arc rectifier, now also used largely to rectify alternating current into direct for various services, and especially for charging storage batteries. The lamp is a glass tube about 1 inch in diameter, on 110-volt circuits about 4 feet in length, and the light is obtained by vaporizing with the current the small quantity of mercury that the lamp holds. Dr. Louis Bell gives a specific consumption of 0.6 to 0.8 watt per equivalent candlepower for these lamps. The light is practically without red rays, but is strongly actinic and is therefore largely in use for photographic purposes. Mercury vapor lamps have been constructed with tubes bent into a circular form, so as to fit in a diffusing globe, and in some cases incandescent lamps have been added in the fixture for the purpose of supplying the red rays missing in the mercury vapor light. A prominent example of commercial lighting by units combining a mercury vapor lamp with a tungsten incandescent lamp is found in the editorial offices of the New York World, where 36 such units have been in use since May 1, 1908. Each combination consists of a mercury vapor tube bent into circular form of about 10 inches diameter, with a tungsten lamp in the center. The vapor tube and tungsten lamp are attached to an ornamental metal fixture provided with a white corrugated reflector and surrounded by a 16-inch holophane hemispherical globe. The combination lamp is designed to operate on the 120-volt circuit, and to take a current of 2 amperes, thereby consuming 240 watts. The vapor tube and tungsten lamps are connected in series, the vapor tube taking about 52 volts and the tungsten lamp about 58 volts. The remaining 10 volts are taken up by steadying inductance. An automatic device consisting of an inductance coil with a quick mercury break in vacuum, called a "shifter," is placed in the fixture for starting the lamp. Tests of the illumination produced by this installation, made by means of a luminometer, and of the power consumed, show that the candlepower of the tungsten lamp is about 80 and of the vapor lamp about 200. With a power consumption of 240 watts, this gives an equivalent specific power consumption of 0.86 watt per equivalent candle.

The quartz mercury vapor lamp has also become a commercial success and is in use in Germany. Its formidable powers of competition may be inferred from the fact that with the mercury arc playing in a quartz tube it is possible to raise the temperature very much higher than can be done in a glass tube. The maximum is reached at about 1 watt per candle, and afterwards the specific consumption decreases rapidly down to about 0.16 watt per candle.

Electric power.—As the statistics show, the intercensal period witnessed a phenomenal development in electric-power supply, or motor service. If it were not for their motor day load, many central-station companies would doubtless find themselves in difficulties. One problem, of course, is to prevent overlapping of the lighting and the motor loads, and this has been worked out in one way under the Gossler system as adopted in Montreal, Canada, and in various cities of the United States. In 1894 the Royal Electric Company of Montreal was supplying the equivalent of 14,700 16-candlepower lamps and 50 horsepower in motors; while the total number of its customers did not exceed 300, and none of the various heating appliances were heard of. In 1907 the Montreal Heat, Light and Power Company had connected to its system the equivalent of 450,000 16-candlepower lamps, about 37,000 horsepower in motors, and upward of 1,000 appliances for heating, cooking, refrigerating, and so forth. The company served upward of 13,000 consumers of electricity and about 50,000 consumers of gas, or a total of nearly 70,000 consumers. The nonpeak users under this system are encouraged by a special concession of rates. It was found that about 40 per cent of the company's customers could be shut off from obtaining energy at the time of peak load without detriment to them. Among the loads were 3,500 horsepower in cotton mills, which in order to obtain the concession start operation at 7 a. m. instead of 8, allow only half an hour for lunch, and are thus able to stop work at 4.30 p. m. The operatives in many instances prefer to work during these hours and go home early than to begin later and finish later. Among the off-peak customers were the various morning and afternoon newspapers, to which the company supplied upward of 400 horsepower. Another class of customers were the brickyards, which required a summer service exclusively, and secured a 50 per cent reduction from the regular rates on seven months' operation. The amount of horsepower involved was 600 to 700, used in driving casting machines, mixers, and conveyors. Other nonpeak users were the local water-power company, which used 1,200 horsepower in pumping drinking water; a railway-appliance company, which used 500 horsepower; cement works, which in 1909 used from 5,000 to 6,000 horsepower; and various wood yards. In the wood yards all the cutting was done during two or three hours of each day. The nonpeak rates were given to customers consuming relatively large amounts of power. An installation of 20 to 25 horsepower would be about the limit below which the nonpeak rate would not be granted. Extensions of the system have been carried out since the above data were obtained.

The extent to which electrical energy is now sold for power purposes is illustrated by the railway contracts made by the Commonwealth Edison Company of Chicago, which has been particularly energetic in reaching out for this class of business. Under the ten-year bulk contract with the Chicago City Railway, for example, the energy is supplied by the power company to the railway company in the form of a 3-phase, 25-cycle, 9,000-volt current. The railway company pays a minimum, primary, readiness-to-serve charge of $1.25 per kilowatt of demand per month. The kilowatts demanded are taken as 21,000 as a minimum for the first year of the contract and as much more as may be demanded. For the remaining nine years of the contract the railway company pays according to the following provisions for determining the maximum demand: The railway company's maximum demand in kilowatts for each month, upon which the primary charge is made, is determined by taking three consecutive days in the month, out of which there are selected two hours, of which one is the hour of greatest output in kilowatt hours in the first half of the day and the other the hour of greatest output in the second half of the day. The combined output for the six hours selected in the manner thus indicated must be greater than the combined output of six hours similarly selected from any other three consecutive days in the month. One-sixth of the aggregate number of kilowatt hours consumed by the railway company during the six hours selected is considered as the number of kilowatts constituting the railway's maximum demand. If the railway's maximum demand exceeds 21,000 kilowatts during the first year, the railway is to pay $1.25 per kilowatt of demand for each month for all in excess of the amount named.

The applications of electric motors on central-station circuits are now so numerous that it is useless to attempt to enumerate them all. The motors find employment in every industry and have seriously modified methods in some classes of work. A notable instance of their use outside of manufacture is furnished by the electrically operated high-pressure water systems for fire protection in the boroughs of Manhattan and Brooklyn, New York, for which the city appropriated over $5,000,000 for the whole work. The pumps are operated by induction motors, the aggregate rating for those installed in the four stations being 15,000 horsepower. Either salt or fresh water can be used, although up to the present time only the latter has been admitted to the mains. The systems are very extensive, that on Manhattan Island comprising about 63 miles of mains varying in diameter from 12 to 24 inches. The five pumping units in each station will deliver 5,000 gallons per minute against a discharge head of 300 pounds per square inch when operating at 750 revolutions per minute, with a suction lift not exceeding 20 feet. The pumps can be brought from standstill up to full speed in thirty seconds; and the company is under a contract penalty of $500 per minute if it fails in three minutes after an alarm is given to furnish the proper and adequate motor service. The readiness-to-serve charge is $24 per year per kilowatt of the kilowatt rating of the motors and 1½ cents per kilowatt hour for energy actually used.

The Brooklyn Edison Company receives $3,660 per month for its readiness to serve and 1½ cents per kilowatt hour for current used. The cost of the two Brooklyn stations and equipment was about $300,000. The interest on the city investment and cost of maintenance will approximate $78,000 yearly, while the reduction in insurance premiums in this borough is placed at $300,000 per annum. It is work like this that gives an idea of the loads that are being taken up to-day by large central-station systems throughout the country; and the $500-per-minute fine does not appall them, so reliable have such systems become.

A special example of the development of motor service from central stations during the intercensal period is found in its use for refrigerating, where the motor drives the localized cooling apparatus and the use of ice is dispensed with. Several plants of this kind are being operated in Philadelphia, ranging in capacity from a quarter ton of ice, driven by a 1-horsepower motor, up to 35 tons, driven by a 75-horsepower motor; and in some instances there are several units in the same plant. During 1907 the connected load of this character on the circuits of the Philadelphia Electric Company increased 217 per cent, represented by over 230 ice-tons capacity of refrigerating machinery. In the year named the company was operating refrigeration machines in saloons, grocery stores, residences, drug stores, dairies, butcher shops, and restaurants, and it has since added to this list the establishments of florists, candy makers, ice-cream makers, fish and game dealers, pork packers, hospitals, bottlers, and fruiterers, and the equipment for cooling drinking water in office buildings. The yearly bill has been found to vary from 4.3 to 9.2 times that for the highest month and from 5.5 to 14.8 times that for the month of June. This relation is modified somewhat by the differences in temperature of the different localities. Electricity is also employed to operate brine pumps and deep-well pumps, and the auxiliary-motor service of this kind connected in 1907 showed an increase of 284 per cent.

Early in 1907 one of Philadelphia's leading firms of florists decided to adopt mechanical refrigeration. They had a display case 16.5 feet long, 9 feet high, and 42 inches wide, embracing about 500 cubic feet, with three shelves, drawers below, and an ice bunker above. The flower jars and vases held probably 200 to 300 pounds of water, which was renewed daily. Four 16-candlepower lamps, placed so as not to be seen by the observer, were kept burning in the case above and in front, in order to illuminate the display properly. Openings in the floor of the main case permitted the cold air to circulate down to and around the smilax and other green stuff kept in the drawers below. Both doors and drawers were opened frequently, averaging probably four times per hour each. Under these conditions it was found necessary to use 500 to 700 pounds of ice each day to maintain a temperature of 44 or 45 degrees. The annoyance and inconvenience of handling were great, and the ice bill for one year was $501. A 1-ton plant driven by electric motor was installed at a cost of $1,000, and the first year's saving direct was $34.

Refrigeration suggests ventilation and the motor fan. Central-station companies have generally ceased to make any attempt to enumerate the fans on their circuits, though in some cities the figures are kept. In 1908 the companies in New York City reported that they had about 250,000 fans on their circuits, which furnished an appreciable and profitable day "load" during the summer months. The Philadelphia Electric Company estimated the number on its circuits at about 10,000, and a summer income from them of more than $20,000. St. Louis claimed at least 10,000 on central-station circuits; Providence, 5,000; Buffalo, 2,000; and Denver, 1,500.

The automobile load is a class of business in which, more or less directly, the modern central station supplies current to motors, several thousand machines now being operated by charging from the circuits. A typical example of what can be done is found in Toledo, Ohio, where the Railways and Light Company makes a charge of 3 cents per kilowatt hour to all public garages and repair shops, and 5 cents to private individuals, or a minimum bill of $3 per month to both classes. The result is that in Toledo there were in 1908 about 500 electric automobiles, and 9 public garages and 85 private ones using electricity. The company sold mercury arc rectifier sets at $230 for 30 amperes, including installation, and made a reduction of $20 when the owner installed the rectifier himself. The rectifier is said to cause an average reduction of about 40 per cent in kilowatt hours consumed as compared with charging through a rheostat. The income to the company was about $48 per year per vehicle in use in the city. One of the garages in the city could charge 48 vehicles at once, and 60 to 75 were charged by it in a single night. Its rates were $22.50 per month for charging, keeping, washing, and delivering an electric coupé. Another garage had some 80 vehicles on its regular list. It charged $20 per month for keeping up an open vehicle and $22.50 for a closed one.

Electric heating and cooking.—Great advances were made during the intercensal period 1902–1907 in the arts of electric heating and cooking, although the present report is practically without data of a statistical character in regard to the extent to which the various devices for these purposes have found a place on central-station circuits. For many years such apparatus was costly, easily deranged, and very uneconomical in its consumption of current; but these defects have been removed. While electric heating and cooking can not yet compare in general cheapness with older methods, including the use of gas, electricity has already made a place for itself in innumerable special instances and over a wide variety of industrial and domestic work. Moreover, the high efficiency metallic-filament incandescent lamps, by their smaller consumption of current, have put central-station managers on the alert to dispose of the surplus plant and electrical energy thus left idle on their hands. As a result there has been a really enormous stimulation of activity in this newer field. The progress that is being made may best be ascertained from the statements of some of the central-station operators who have studied the novel problems involved. One great advantage of electrical apparatus of this class is that it can be used with equal success on either direct or alternating current. It needs only to be fed with the proper amount of current from the supply circuits, without any particular adjustments except those for protection against fire and other accidents.

At the Ohio Electric Light Convention, held during the summer of 1907, Mr. M. E. Turner gave some interesting data about the use of electrical apparatus for cooking in Cleveland. He stated that it was not possible to obtain complete figures from all users, but the following reliable data were collected from 11 homes using complete cooking outfits:

ELECTRIC COOKING.	Number of residence.	Full months of use.	Average number of people cooked for.	Average kilowatt hours used per month.	Average per month per person.
Total, exclusively and in part			62	1,209	20
Exclusively	1	11	7	237	[1] 34
Exclusively	2	6	3	85	28
Exclusively	3	5	3	62	[2] 21
Exclusively	4	2	7	171	24
In part	5	1	3	34	11
In part	6	2	5	47	9
In part	7	2	7	68	10
In part	8	2	4	40	10
In part	9	4	6	34	6
In part	10	5	8	360	45
In part	11	1	9	71	8
Total exclusively			20	555	28
Total in part			42	654	16

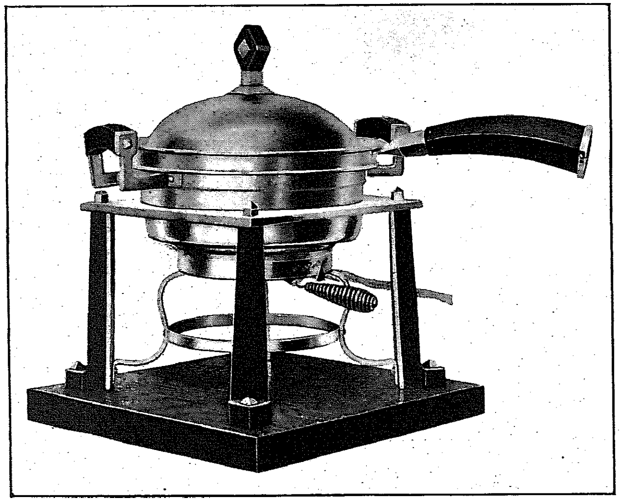
[1] Includes laundry ironing and water heating.
[2] Includes laundry ironing.

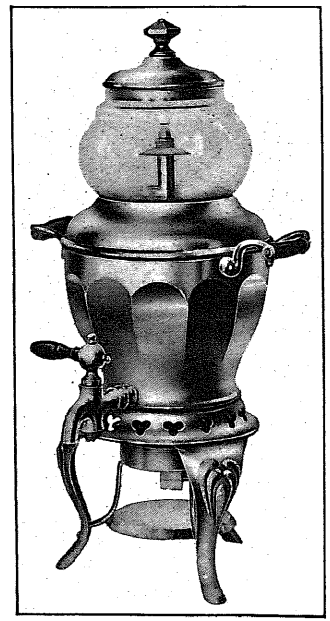
These figures indicate that with the growth of this branch of the business an increased energy consumption of from 100 to 200 kilowatt hours per residence per month may be expected. In Cleveland a two-rate method is used for billing residences, and the users of electric heating generally received the benefit of the secondary or lower rate. In fact, the cooking in all the 11 residences cited was done at a 5-cent rate. The expense under these conditions compares favorably with that for manufactured gas, and the fact that over 1,100 electrical-heating devices were sold in Cleveland by the local illuminating company alone during the twelve months preceding June, 1907, illustrates how popular electrical-energy consuming devices were becoming in the home. These sales were made through newspaper advertising and through the efforts of one salesman, and toward the close of the period named over 100 such devices a month were being sold without any direct solicitation. The results from June, 1907, down to the date of writing are equally striking.

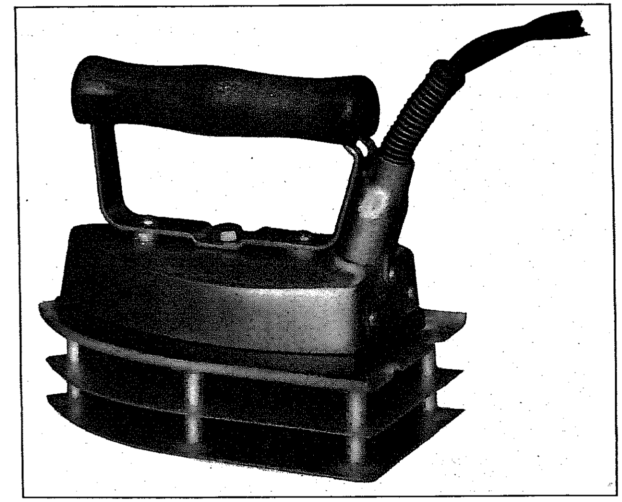
At the meeting of the Northwestern Electrical Association in Milwaukee during the spring of 1908, Mr. E. I. Callahan presented the advantages of an electric-heating load, and suggested some methods of securing it. He knew of no easier way by which companies could secure the desired result of getting more revenue with existing investment than by pushing the use of heating devices. Many of these devices, he claimed, were simple enough to be used in nearly every room in the house, by anyone, and could be connected to the usual receptacles provided. The central stations could usually supply 75 per cent of the load demand without providing increased transformer, meter, or plant capacity. He suggested that central stations not operating day circuits follow the example set by several managers, and for a trial start day circuits to operate all day on Tuesday, ironing day. Small motor loads would then spring up and the plants would soon be forced to operate every day in the week. As to soliciting business, he suggested that personal solicitation, although the most expensive advertising, was by far the most productive. He gave the results of cooking by electricity in his own home, in which for a period of a year the watt hours per person per meal averaged 264, with a maximum demand of about 2.8 kilowatts. Mr. J. R. Cravath, from his own experience, confirmed these figures, and stated that his maximum demand was about 3 kilowatts, inclusive of ironing. Mr. Korst, of Janesville, Wis., stated that about half of the residence customers of his company had flatirons, and that a very good revenue was derived from this source, especially during the summer months. He found, however, that when the bills crept up in the winter time, customers were apt to use their old irons heated on the coal ranges. In the summer many customers' bills, exclusive of the ironing, would fall below the $1 minimum per month. The use of the electric flatiron would bring the bills a little above $1, which would give the company more revenue, and better satisfy the customer because he thereby avoided paying for something he did not get. The flatiron also induced persons who were not previously customers to have their houses wired. Mr. R. N. Kimball, of Kenosha, Wis., said he had at first attempted to introduce flatirons by having a demonstrator in the office, but that he did not get much business that way. The demonstrator was then sent out to canvass the residences, and the results were very much better. Fully 75 per cent of the irons sent out on trial were kept and not returned to the office.

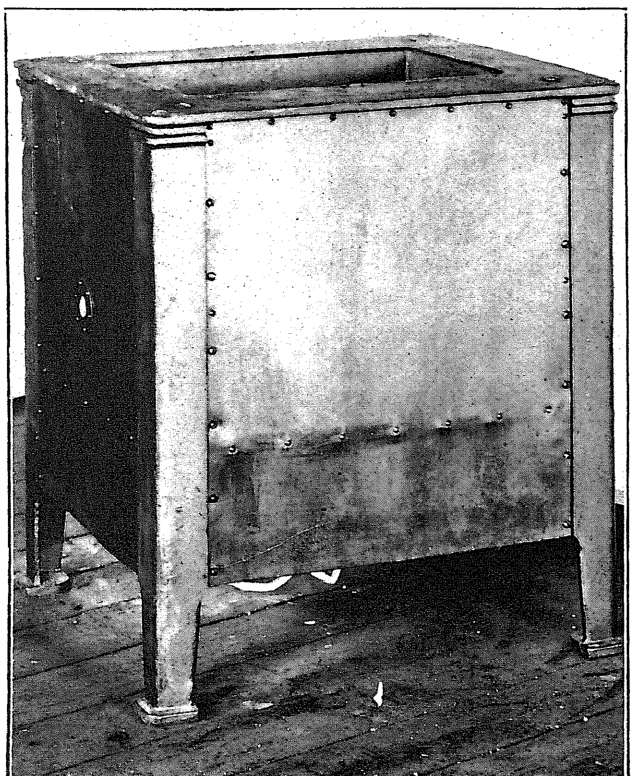
At its Grand Rapids convention in September, 1908, the Michigan Electric Association received the report of a special committee which had canvassed the central stations of the state as to the results obtained with electric heating and cooking. In general, the data as to progress were similar to those given above. Next to the flatiron in popularity and as income earners were the toasters, water heaters, and luminous radiators. Most stations reported the toasters and luminous radiators as equal in popularity, some of them having as many as 150 of each on their lines. The sale of chafing dishes, percolators, heating pads, and other devices seemed to be limited, either by reason of their first cost or infrequency of use.

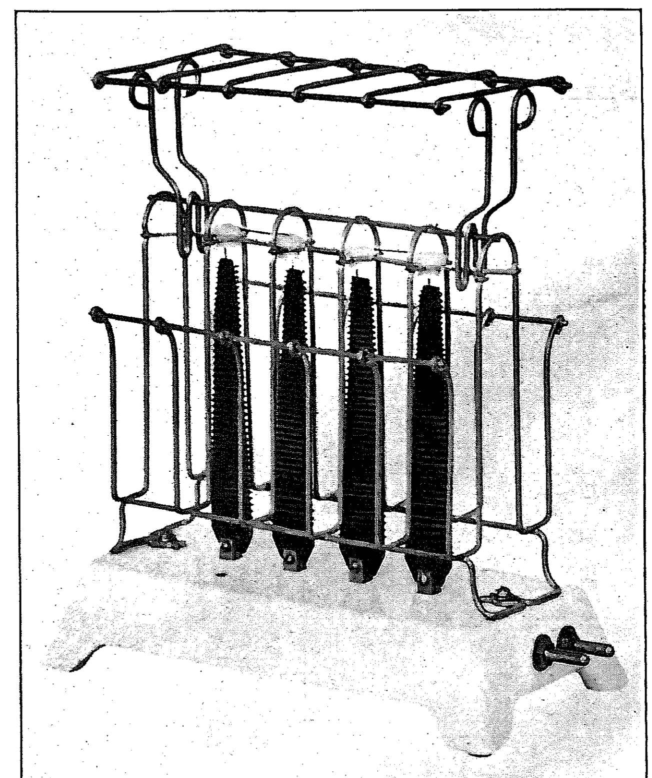
Another field of operations reported on by the committee named was that of the commercial heating of such appliances as gluepots, solder pots, soldering irons, and branding irons. Perhaps the greatest drawbacks to the introduction of electrical devices for the work indicated have been the high initial cost and the frequent burn-outs. Very few of the stations reported any great advances in the introduction of cooking outfits. For this the initial cost of the outfits and devices seemed to be mainly responsible, since even with such a rate inducement as 2.5 cents per kilowatt hour, as established at Sault Ste. Marie, no great amount of business was reported in this line. Other drawbacks to the electric-cooking outfit were its limited reserve capacity for the average family, and the inability of any yet known devices to heat enough water for the average household at anywhere near a reasonable price. The committee thought that before the electric-cooking outfit could be a success it would be necessary to furnish to the public devices that were not only fireproof, but more efficient, longer lived, and of lower initial cost. Tests had shown considerable saving by the use of the fireless cooker in connection with electric outfits, and many of the stations were already introducing and recommending them. Indeed the whole art was declared to be in a state of such rapid transition and improvement that criticisms valid at one time soon become of little weight.


TYPICAL ELECTRIC CHAFING DISH.


ELECTRIC COFFEE PERCOLATOR.


ELECTRIC FLATIRON.


ELECTRIC OIL-TEMPERING BATH.


ELECTRIC TOASTER WITH WARMING SHELF.

Electric meters.—According to the data given in Chapter IV on line equipment, there were 1,683,917 meters on central-station consumption circuits in 1907 as compared with 582,689 in 1902, the gain being not less than 189 per cent. If meters on electric-railway lighting systems are included, the number in 1907 was 1,897,803, representing a gain for the intercensal period of 196.9 per cent. Such figures furnish a clear indication of the rapidity with which the old practice of selling electricity on a flat-rate basis is being abandoned. It is true that a great deal of electricity is still sold by rough estimate, at an arbitrary price per lamp per year, or per horsepower of motor, and it is also true that modified flat-rate systems of payment have enjoyed some degree of favor; nevertheless, it is probable that no progressive central station of any size can be found that does not employ customers' meters, and the customers themselves, as a general rule, prefer to buy current that is measured. To show the importance attached to the subject, it may be mentioned that the report of the meter committee of the National Electric Light Association, presented in 1909, was a document[1] of over 300 pages; and to that exhaustive report special students of the subject are referred. The report was based on information received from the member companies, and included descriptive data concerning meters in general use on central-station consumption circuits.

The statistics in Chapter IV do not distinguish between types of meters or attempt to give their capacity. The answers given by the companies showed that some of them are still using the older commutator type of watt-hour meter, as well as the induction type of ampere-hour meter on alternating circuits. It was formerly considered that the commutator type of watt-hour meter was equally suitable for both direct and alternating current circuits; and, indeed, when the meter was properly "compensated," it did register with equal accuracy, in the majority of cases, on both kinds of service. At the present time the commutator type of meter is considered as a direct-current meter, while the induction watt-hour meter is regarded as preferable for alternating-current consumption circuits. It was found that while the ratio of meter capacity to connected load varied among the member companies, yet, considered as a whole, it was not far from 1 to 1—that is, 1 kilowatt of meter capacity is installed for each kilowatt capacity of connected load. It is but seldom that the peak load exceeds 30 to 60 per cent of the connected load and the generators seldom exceed 70 per cent of the connected load. It would appear from the following table that, on the average, the smaller companies had installed about 1.4 kilowatts of meter capacity for each kilowatt of generator capacity:

[1] Proceedings, National Electric Light Association, 1909, Vol. I, p. 257.

KIND OF SERVICE.	Number of meters.	METERS INSTALLED.		
		Average cost per meter.	Average capacity per meter in kilowatts.	Average cost per kilowatt of meter capacity.
Mostly residential	600	$11.75	0.91	$12.91
Mostly business	5,006	13.35	1.69	7.90
General	10,000	14.20	3.06	4.63
General	20,000	13.60	3.46	3.93

Assuming the cost of generators for smaller plants to average $12 per kilowatt and the cost of meters $8 per kilowatt, it will be seen that the cost of meters is not far below the cost of generators.

As an evidence of the effect of improved meter practice upon the average accuracy of meters, and the consequent influence on the revenue, the following table, received from a member company, was presented in the report referred to above. This company, supplying both alternating and direct current, replaced in all direct-current meters the stationary shunts with adjustable shunts, equipped all direct-current meters with diamond jewels, replaced all commutator meters on alternating-current circuits with induction meters, substituted modern meters for many of the older type, and improved its system of testing, with the following results:

YEAR.	Meters in service December 31.	Tenth load accuracy, per cent.	Heavy load accuracy, per cent.	Number of meters tested.	Per cent of meters tested.
1902	3,400	84.4	92.0	1,868	53.5
1903	4,165	81.5	94.0	2,980	71.5
1904	4,952	84.2	95.1	3,556	71.8
1905	5,861	87.9	96.1	4,044	69.0
1906	6,964	90.3	97.1	4,086	58.6
1907	8,060	92.2	97.5	6,942	86.1
1908	9,276	94.1	98.1	10,558	113.8

As indicative of the condition of meters not tested for from two to five years, the following table, showing the results of testing the 192 meters of a small company was also presented:

PER CENT.	LIGHT LOAD.		FULL LOAD.	
	Number of meters.	Per cent.	Number of meters.	Per cent.
Total	192	100.0	192	100.0
Above 20 fast	....	....	2	1.0
Between 10 and 20 fast	1	0.5	3	1.6
Between 4 and 10 fast	3	1.6	8	4.2
Between 2 and 4 fast	4	2.1	6	3.1
Between 2 slow and 2 fast	24	12.5	54	28.3
Between 2 and 4 slow	13	6.7	45	23.3
Between 4 and 10 slow	36	18.7	38	19.8
Between 10 and 20 slow	44	22.9	12	6.2
Over 20 slow	18	9.4	5	2.6
Not recording	49	25.6	19	9.9

It is evident from the above tables that the financial success of a company may be vitally dependent upon the testing of its meters, and it is obvious that the consumer has an equally large interest in securing the highest possible accuracy in the apparatus upon which alone the cost of service to him depends.

In Massachusetts a customer of an electric-light company or the company itself may apply to the Board of Gas and Electric Light Commissioners for an examination and test of any meter in use, the board furnishing the applicant with a certificate of the result of the test and the expense attached thereto. If the meter is inaccurate, the board may order the company to repair it or substitute an accurate one. All fees for examinations and tests are paid by the applicant, but if the examination is made at the request of the customer and the meter is found to register too fast, the electric-light company is responsible for the fees. The meter is deemed to be correct if it does not vary more than 5 per cent from the standard approved by the board. The inspector employed by the board receives a salary, together with necessary traveling and other expenses. The aggregate amount, however, must not exceed $3,000 in any year. Should the amount of compensation and expense exceed the amount of fees received, the excess is assessed upon and recovered from the electric-light companies. The board establishes rules and regulations, fixes standards, prescribes fees, and employs such means and methods for making examinations and tests of meters as in its judgment are most practicable, expedient, and economical. The fees charged for testing of various-sized meters in 1907–8 in New York, Massachusetts, and Canada are given in the accompanying table.

METER RATING.	RATES FOR TESTING WATT-HOUR METERS.			
	New York.	Massachusetts.	Canada.	
			Lamps.	Meters.
3 amperes	$1.00	$1.50	$0.75	$3.00
5 amperes	1.00	1.50	0.75	3.00
10 amperes	1.50	1.50	1.25	3.00
15 amperes	2.00	2.00	1.75	3.00
25 amperes	2.50	2.50	2.75	3.00
50 amperes	3.00	3.00	3.50	3.00
75 amperes	4.50	3.50	5.00	6.00
100 amperes	5.50	3.50	6.50	6.00
150 amperes	8.00	4.00	9.00	9.00
200 amperes	10.50	4.50	11.50	12.00
300 amperes	15.50	4.50	16.50	18.00
450 amperes	23.00	5.00	24.00	27.00
600 amperes	30.50	5.00	31.50	32.00
1,200 amperes	60.50	....	61.50	72.00

It will not be out of place here to note that by the provisions of the Canadian law a meter must be tested and stamped every five years. The meters to be tested are brought to the government inspection office, or in small towns and villages the test is conducted on the premises of the electric-light company. When a customer wants his meter tested, he notifies the electric-light company and requests it to send a qualified person to detach the meter from the mains so that it may be taken to the inspector's office. The inspector files with either the electric-light company or the customer, on payment of the proper fee, a certificate stating the result of the inspection, with such particulars as he may deem right to insert for the information and guidance of the persons concerned. Electrolytic meters in use may be continued unless objected to by the purchaser, but all renewals of meters must be made by the substitution of direct-reading types. No meter is passed which, when working at its full rating, varies more than 3 per cent from the legal standard unit of electricity, in favor of either the electric-light company or the consumer. Whenever a reading of a meter is taken by the electric-light company, the company must give a duplicate of such reading to the consumer. In every case the owner must keep the meter in good repair and is responsible for the due inspection thereof.

Legislation in this general direction has been made effective in the control over meters given to such new "public-service commissions" as those in Wisconsin and New York, and steps have been taken by these commissions for the full examination of all meters and meter complaints. A report made public in 1909 by the New York commission of the first district of tests conducted in New York City showed a remarkably satisfactory state of affairs as to the general accuracy of meters in the district. Under the public-service laws of New York an electric meter is allowed a variation of 4 per cent either way, while a gas meter is allowed only 2 per cent.

The latest rules of the public-service commission for the city of New York relative to testing electric meters are embodied in printed forms. Forms are included for reports on complaint, periodic, and office tests of meters. The complaint test is defined as a test made by an electrical corporation, upon the premises where the meter is installed, as the result of a complaint of the customer. A periodic meter test is a test made by an electrical corporation in the regular course of its business, upon the premises where the meter is installed, but not at the time of installation, which test is not made as the result of a complaint from the consumer nor by special direction of the corporation or one of its officers or employees. An office meter test is a test made by an electrical corporation, upon the premises where the meter is installed, by special direction of the corporation itself or of an officer or employee.

The rules require that every electrical corporation operating within the first district shall file with the public-service commission a monthly report, in the form prescribed, stating the results of all tests of electric meters tested for accuracy during the month. Such reports must be made for each calendar month and be filed not later than the 15th day of the following month.

All tests are required to be made with the meter in its permanent position on the consumer's premises, and under actual operating conditions as regards voltage, frequency, temperature, stray fields, and vibration. Where shunts, series transformers, or shunt transformers are used in connection with a meter, the meter must be tested from the line side of such apparatus when the voltage does not exceed 600. In periodic tests, where the line voltage exceeds 600 volts, the meter may be tested as a self-contained meter, and the ratio certificates of the transformers may be used in calculating the true line watts, provided the certificates are dated within the five years preceding the time the meter is tested. In compiaint and office tests the commission will accept the ratio certificates of the transformers, provided they are dated within the year preceding the time the meter is tested. When rotating standard meters are used the connections must be so arranged as to give the meter tester full control of the starting and stopping of the standard and at the same time allow him to count the revolutions of the meter under test.

Each meter must be tested independently, and no meter can be tested while connected in series with one or more other meters unless the potential circuit of each meter is so arranged as not to be fed through the field of any meter under test or rotating standard. All indicating and integrating instruments used as standard instruments in testing meters must be equipped with scales properly proportioned to the loads measured.

All meters must be adjusted so as to register with an error of not more than 1 per cent at light load and at full load, and both of these adjustments must be maintained in this condition as nearly as possible. All meters, whenever possible, are to be tested at three loads: One-tenth of the full rated capacity of the meter, normal load, and full rated capacity of the meter. The average of these tests obtained by multiplying the result of the test at normal load by three, adding the result of the tests at one-tenth capacity and full capacity, and dividing the total by five is deemed the condition of the meter, and such final average must be reported to the commission on the form prescribed by it. In an installation where it is impossible to obtain a load of 10 per cent of the rated capacity, or of 100 per cent of the rated capacity of the meter, tests are to be made at the nearest obtainable loads to 10 per cent and 100 per cent, respectively, of the rated capacity of the meter, and the values are to be given in the ratios.

The following classification, in percentage of installation, is used in determining normal test load:

A. Residence and apartment lighting	25 per cent
B. Elevator service	40 per cent
C. Factories (individual drive), churches, and offices.	45 per cent
D. Factories (shaft drive), theaters, clubs, entrances, hallways, and general store lighting	60 per cent
E. Saloons, restaurants, pumps, air compressors, ice machines, and moving-picture theaters	70 per cent
F. Sign and window lighting and blowers	100 per cent

When a meter is found to be connected to an installation consisting of two or more of the above classes of loads, the normal load used must be obtained by taking the average of the percentages for the classes so connected. Three tests are made at each load at which the meter is tested, but should any two fail to agree by 1 per cent, additional tests must be made until three results are obtained which do not vary one from another more than 1 per cent.

At Hartford, Conn., an interesting variation in meter practice has been worked out by the Hartford Electric Light Company, in connection with the introduction of the tungsten lamp in smaller sizes, designed for operation at 30 and 60 volts. Tests have shown that these low-voltage, extra high-efficiency lamps can be counted on for a life of at least two thousand hours. The filaments are tough and thick and will stand rough handling admirably. During the past two years several installations of these lamps have been made in residence service, and as a result the company is satisfied that it is advantageous to introduce them generally on its circuits. In order to handle the situation profitably, however, the company has worked out a plan of charging the customer for light used rather than billing on the usual basis of a price per kilowatt hour.

The plan consists in the substitution of a meter dial reading candlepower hours for the ordinary watt-hour dial of the ordinary induction meter and in charging the customer a rate of 0.025 cent per candlepower hour of service supplied. The customer pays the initial cost of installing the lamps, which is 20 cents apiece for either the 10, 20, or 30 candlepower, 30 or 60 volt lamps. Free renewals are given on all these lamps. The company installs an "economy coil," or compensator, in each residence to reduce the potential from that of the mains to 30 or 60 volts, as the case may be. This compensator has the advantage of absorbing the effect of voltage fluctuations on the high-tension lines back of the subway transformers from which secondary groups of loads are fed, and it is provided with multi-voltage taps for convenience. Mr. Dunham, president of the company, states:

> The whole system of meter measurement has gradually adjusted itself to a certain ratio between watts, or the power used in creating light, and the other costs entering into the production of the candlepower. This has been particularly the case with house lighting. The general average price of house lighting in the larger cities and in the older stations has become about 10 cents per kilowatt hour—that is, the whole cost of light is placed upon the kilowatt measurement, whereas more than one-half the cost consists of distribution management and "overhead" expenses. This is clearly shown by the fact that the same meter measurement of watts has an altogether different price when it is used simply as power. The price of power in the more modern stations and in the larger cities ranges from 2 to 6 cents per kilowatt hour, while the cost of light ranges from 4 to 12 cents, or about double the price of power, which would not be the fact if the customer paid for the same thing in both instances. For the power used the customer pays for the actual kilowatts, but for the light delivered the customer pays for the actual kilowatts used plus the various other expenses which have been attached by custom and necessity. This has placed all the stations in a peculiar relation to the old-fashioned watt-hour meters in regard to the new lamps, and they find themselves reduced in income, if they use the new lamps, to one-half of their old revenue. This can not be avoided except by changing the measuring instrument or by raising the price of the kilowatt hours used to double that charged for the old lamps, because the watt-hour meter measures a little less than half the actual cost of the candlepower.

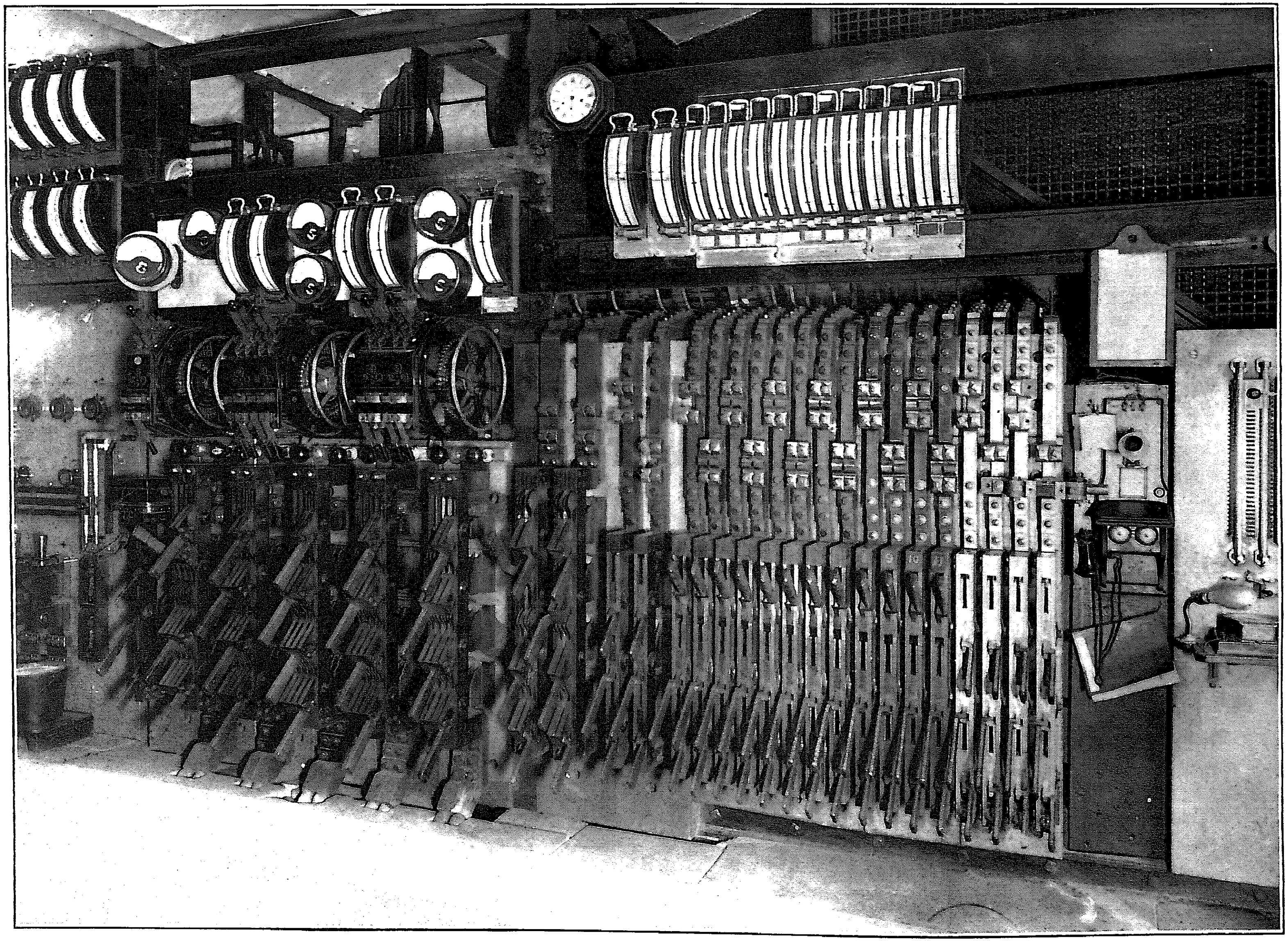
Regulation and rates.—Various references have already been made in this chapter to the subjects of rates and regulation. It is well understood that in their dealings with the communities served, central-station companies have always been governed by the local-franchise ordinances under which they operated. But these franchises have dealt more with questions of public-street lighting than with such a feature as service to the private consumer; and it is in the latter respect that most change is noticeable of recent years. The change has been carried furthest in those states where public-service commissions exist, whose authority and control over public-utility corporations have been generously amplified by the respective legislative bodies delegating such powers. These states are notably Massachusetts, Wisconsin, and New York, but it is significant that, as a matter of record, in almost every instance where the commissions have been appealed to, the actions or methods of the corporations have been sustained; or if modified, the underlying principle has been adhered to as based on reason and equity.

One of the most interesting recent cases is that in which the Wisconsin commission dealt with the application of the La Crosse Gas and Electric Company for the power to charge higher rates for electrical energy than had prevailed. The testimony and facts presented by the petitioner related mostly to the history of electric lighting in La Crosse, to the rates which the company was asking permission to establish, and to the various systems of fixed rates that were already in use. From the facts relating to the value of the plant and to its earnings and operating expenses, the commission said it was quite clear that the plant had not been a success as a producer of net earnings. This was especially true when some allowance was made for depreciation at 3 per cent. During the preceding two years the net earnings were not enough to pay any interest upon the investment nor even to meet ordinary depreciation charges, and so long as the rates charged for energy remained so low there was but little hope that the net earnings would increase. The decision included a discussion of one of the most important features of the problem—the cost to the company of serving each class of customers. It is not necessary to cite here the rates fixed, but the language of the decision is as follows:

It further appears that the proposed rates are somewhat lower than those charged in other cities, both inside and outside of this state. The comparisons we have made upon this point are quite extensive. They embrace at least 20 cities in Wisconsin and fully as many in other states. These facts are of considerable importance, not only to the petitioner but the people who are served by this company. The petitioner has duties as well as rights in this matter. While it is entitled to reasonable rates for service it renders, it has not the right to exact more than this. It must also see to it that the services it renders are adequate and that they meet all reasonable requirements in this respect. It is as important that the interests of the public it serves should be as fully protected as those of its own. The best rates are those that are based upon the cost. Each customer should, under ordinary conditions, contribute his just proportion of all the expenses, as well as of the interest upon the investment. From the foregoing examination of the facts involved in this case it appears to us that the rates submitted by the petitioner fairly meet the situation, and that they are just and reasonable. It has been determined, therefore, that these rates shall be put into effect, subject, however, to such revision as may be found necessary when the plants in question have been appraised, or for other reasons.

At Minneapolis the city officials held that the rates of the Minneapolis General Electric Company were too high, and that the same rate per kilowatt hour, except for quantity discounts, should be made for all consumers without regard to conditions of load. The company had put in force a system of rates under which customers having the best load-factors—that is, those using current the largest number of hours per day—were given much the lowest rates. It appears from the reports of the early stages of the Minneapolis controversy that the city officials were chiefly concerned with lowering the maximum rates charged by the company for short-hour business. Several expert investigations were made into the company's affairs, with the result that the correctness of the company's theory of readiness-to-serve charges in connection with electric light and power business was upheld. The experts all agreed that the rates given to any individual customer should be dependent upon the fixed charges on the investment necessary to serve him, plus his share of the operating expenses necessary to serve customers in his class, rather than on the average expense of serving all classes of customers. However, as a concession to the smaller customers, it seems to have been generally agreed, both by the company and by the experts, that the maximum rates should be a little lower than those to which the smaller short-hour customers would be strictly and scientifically entitled. This reduction from the maximum rates to small short-hour customers was advocated only on the ground that the many small consumers, by the consent of whom the company had the use of the streets and public alleys for the distribution of its current, were entitled to receive compensation in this way for the franchise, and that larger consumers were not entitled to receive such compensation in the same proportion.

The Minneapolis General Electric Company and the committee of the city council came to an agreement on electric light and power rates as a groundwork for an ordinance giving the company a thirty-year franchise and fixing the rates for electric light and power for the first year of the franchise. The city council originally passed an ordinance requiring a uniform rate of 8 cents per kilowatt hour, with discounts purely according to quantity. The company refused to recognize this ordinance, on the ground that it was unjust, inequitable, and confiscatory. The point of interest in the controversy is that a company was able to convince a council committee and citizens of



SECTION OF SWITCHBOARD, NEW YORK EDISON SYSTEM.

the fairness of a rate based on load-factor, and of the unfairness of a uniform rate per kilowatt hour for all classes of business.

The residence-lighting rate which was agreed upon is 9 cents per kilowatt hour for the first fifty-two hours' use per month of 40 per cent of the connected load, and 6.66 cents for all over that. Commercial lighting is at the same rate, except that the maximum demand as measured by maximum-demand meters is substituted for 40 per cent of the connected load. Maximum bills are 100 per cent of the connected load. Minimum bills are $1 per month per lighting customer. Retail motor service pays 7.5 cents per kilowatt hour for the first fifty-two hours per month of the customer's maximum demand, and 2.5 cents for all over that. The minimum bill is $1 per month per horsepower connected. The chief differences between these rates and the old rates of the company are that the maximum rate has been reduced on lighting from 12.6 cents for fifty-two hours' use of 60 per cent of the connected lamps to 9 cents for 40 per cent, and the minimum bill on motors reduced from $2 to $1 per horsepower. Free incandescent-lamp renewals and free arc-lamp maintenance have been abolished under the new rates. Quantity discounts from 5 to 25 per cent are to be allowed on accounts of from $50 to $250 per month.

Professor Cooley, one of the experts employed in the investigations, pointed out that light and power furnished under a limited-term franchise ought to cost the consumer more than that furnished under a perpetual franchise, because the company must figure upon paying off its bondholders and stockholders completely at the end of the limited-franchise period. A company could certainly float 4 per cent bonds on a perpetual franchise where with a limited franchise it would pay 5 per cent.

Rates were changed in one or two of the leading cities during 1907. The ordinance fixing the maximum rates to be charged by the Commonwealth Edison Company of Chicago, until 1912 was passed by the Chicago city council on March 23 of the former year. This company pays 3 per cent of its gross receipts to the city, in accordance with the franchise previously owned by the Commonwealth Electric Company. The rates are as follows: Up to July 31, 1908, 15 cents per kilowatt hour as a primary rate for energy used up to the equivalent of thirty hours' use of the consumers' maximum demand, and 9 cents per kilowatt hour as a secondary rate for all energy in excess of the foregoing amount. From August 1, 1908, to July 31, 1909, the maximum rate is 13 cents and the secondary rate 9 cents. From August 1, 1909, to July 31, 1912, the primary rate is 13 cents and the secondary rate 7 cents. A discount of 1 cent per kilowatt hour from the foregoing rates is to be allowed on all bills paid within ten days.

The Union Electric Light and Power Company, of St. Louis, has put in force a new system of rates, which differs considerably from the typical systems in use. It is founded on the belief that the value of the service rendered to any individual should, so far as practicable, be based on the cost of serving him, and not on the average cost of serving the entire body of consumers; and that as the cost of supplying current per kilowatt hour varies greatly with the different classes of service, so the price per kilowatt hour, in justice to the several users, should vary greatly to different customers. The company felt compelled to recognize the force of the argument of the customer who maintained that he was entitled to a lower average rate if he guaranteed $5 per horsepower per month than his neighbor who would guarantee only $1 per horsepower per month. At first a system of "special" contracts was adopted to meet this condition; but complaints of unequal discriminations led later to the substitution of a graduated schedule of rates. Under it the service is divided into a very much larger number of classes than was ever before attempted, and every consumer in the same class gets the same rate.

Each customer's rate is based on the minimum monthly guarantee he is willing to make per horsepower or per 50-watt lamp connected, and the rate is inversely proportional to the amount of the connected load. For example, the customer having fewer than 100 lamps pays 12 cents per kilowatt hour if he guarantees only 10 cents per month per lamp. By guaranteeing 45 cents per month per lamp he gets a rate of 10 cents per kilowatt hour, and by guaranteeing 65 cents per month per lamp, a rate of only 8 cents per kilowatt hour. Of the customers furnishing the 10-cent guarantee there are 15 subclasses, each with its own modified rate. The rate also declines as the number of connected lamps increases. For example, a customer guaranteeing 10 cents per month per lamp and having less than 100 lamps pays 12 cents per kilowatt hour. This rate is reduced by gradations until for 3,000 lamps or over, with a 10-cent-per-lamp guarantee, the rate is 6 cents per kilowatt hour. For the 45-cent-per-lamp guarantee the customer with fewer than 100 lamps pays 10 cents per kilowatt hour, while the customer with 3,000 lamps pays 5.2 cents per kilowatt hour.

All these rates are subject to discounts based on hours' use and quantity. The discount made according to the equivalent daily hours' use of the entire connected load starts with a 6 per cent discount for a kilowatt-hour consumption equivalent to one hour's use per day of the connected load, and rises by gradations to 25 per cent discount for a kilowatt-hour consumption equivalent to eighteen hours per day of the connected load. There is, also, in addition to this, a discount based on the amount of the bill, which is from 5 per cent on bills of under $10 to 56 per cent on bills of over $9,000 per month.

The motor rates are graded on the same plan. For a 1-horsepower motor customer they vary from 10 cents per kilowatt hour on a guarantee of $1 per month per horsepower to 5 cents per kilowatt hour on a guarantee of $7.50 per month per horsepower. The rate also depends on horsepower connected. Under the guarantee of $1 per month per horsepower the customer with over 500 horsepower gets a 5.5-cent rate. Under a guarantee of $2 per month per horsepower the rate is 4.5 cents. The rates for heating and cooking circuits in residences are 12 cents per kilowatt hour on a minimum monthly guarantee of $2, 11 cents on a $3 guarantee, 10 cents on a $4 guarantee, 9 cents on a $5 guarantee, 8 cents on a $7.50 guarantee, 7.5 cents on a $10 guarantee, and 7 cents on a $15 guarantee. On these cooking rates a discount is given according to the quantity of current consumed; on bills of $5 or under 5 per cent is deducted, and this per cent increases by 1 for each $1 of increase in the bills up to $15, at which point the discount is 15 per cent. For bills of over $25 the discount is 20 per cent.

In its annual report[1] for 1908 the Wisconsin commission said that it found the rates filed by the larger companies to be generally based on scientific considerations, but that those of the smaller companies partook of "every conceivable form and method of determination." Out of 119 companies reporting, 50 had no discriminatory rates, and 3 out of every 100 customers paid less than the schedule rates. The report went on to say: "Because a certain utility has more discriminations in effect than another does not mean in itself that it is following a vicious practice or is using unlawful methods. Most of the discriminations cited are remnants of a former period of unrestricted competition; others are the outgrowth of circumstances over which the utilities themselves have no control." In a recent address President Meyer of the commission said that the "sliding-scale arrangement is full of promise for the future," because "when the individual manager feels that with greater and keener application, with increased efficiency and economy, the rate of return on his investment will be increased, he is much more likely to aim toward efficiency and economy than he would if no such inducements were held out to him."

Both the Wisconsin and the New York commissions have sought to introduce a uniform classification of accounts for electric companies. Two sets of accounts are required in Wisconsin. In general, electric plants operating in cities of 10,000 inhabitants or over must keep at least the list of accounts prescribed in Class A, and all plants in cities of under 10,000 population must keep the accounts prescribed in Class B. Any changes or additions proposed by a company must be filed with the commission before the accounts in question are opened. At a meeting of the Northwestern Electrical Association the classification was spoken of in terms of approval by Mr. C. M. Duffy, comptroller of the Milwaukee Electric Railway and Light Company and chairman of the accounting committee of the association, who said that he did not understand how anyone engaged in the electric-lighting business would be willing to conduct it and know less about its finances than would be required by the commission. The fundamental principle of the accounting system is that all the costs of generating current shall be kept distinct from the other expenses. In New York state, also, both the commissions have put into force rules and systems for uniform accounting.

In New York City one of the features of the rate work of the public-service commission of the first district has been to make a more general provision for "breakdown" service. It has placed the price of this service at $30 per kilowatt of maximum demand, against which the real consumption is an offset at regular rates. In other words, the commission has recognized the inherent propriety of a stand-by readiness-to-serve charge. The commission of the first district made an exhaustive investigation of the contracts made by the companies, revealing a negligible number of special contracts—one or two hundred in scores of thousands—and many of these, as in other businesses, left over from a former management or other control. One of the acts of the commission has been to prohibit specifically any "undue or unreasonable preference" or advantage "to anybody, while no charge shall be made that is not in a filed schedule, nor shall any electrical corporation refund or remit in any manner or by any device any portion of the rates or charges so specified." It is obvious that the immediate effect of such a general policy is to compel companies to classify their customers more closely, so that all in any given group shall be treated alike. The fundamental fact is that very few cases are alike in all particulars. Even where like conditions exist, sometimes the parties in question can not be persuaded of it, and the companies have insisted on the impossibility of meeting the rules of the commission either as to publishing every little concession to a customer's wishes or as to strict conformity with all the terms prescribed for contracts. A brief on this point filed with the commission by the New York Edison Company pointed out that one of its most important forms of contracts was for supplying energy to large buildings by wholesale or in bulk. These contracts were largely the result of personal canvass and individual negotiation, and it was claimed that if the company was not permitted to modify the phrasing or minor details of such contracts to suit peculiar conditions its business would be seriously interfered with. The company stated that it did not seek to make special terms or give unusual privileges to particular customers, but simply to be permitted to

[1] Second Annual Report of the Railroad Commission of Wisconsin, 1908.

modify the contracts to suit different conditions. It desired only to extend to every customer any convenience or facility that the special conditions surrounding the service made practicable, provided that the peculiar features introduced into the contract did not modify the cost to the consumer, and provided that the company was prepared to extend the same privileges to all others who presented the same conditions. The company expressed itself as quite willing to accept and obey the order of the commission in so far as it prohibited any variation in charge, preference in rates, refunds, or special privileges, but it believed that special riders to the contracts with customers should be permitted to meet special conditions that did not affect the actual cost of furnishing the current, and it did not mean to discriminate in any way in favor of one customer as against another.

A valuable study of the whole subject of rates for electric energy is found in the decision of the Board of Gas and Electric Light Commissioners of Massachusetts in the matter of the complaint of the Public Franchise League against the Edison Electric Illuminating Company of Boston, filed May 29, 1908. In the opinion many of the points already discussed in this report, and others raised in the controversy, are given careful consideration. The Edison Electric Illuminating Company of Boston, like many other companies, has had a system of rates based upon "fixed costs" and "running costs," so as to charge each customer substantially the cost to it of supplying him, inclusive of a reasonable return on the investment—the basic method being known as the "maximum-demand" system. One of the various modifications of this system in use in America is the Doherty system, in operation in Denver and other cities. It is based fundamentally on the readiness-to-serve principle and aims at a more or less exact adjustment of the price to the consumer to the cost of producing that for which he contracts, and diverges widely from the idea of a uniform rate for all customers.