CENTRAL ELECTRIC LIGHT AND POWER STATIONS.

PART II.—TECHNICAL.

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TECHNICAL ASPECTS OF THE PERIOD.

GENERAL CONDITIONS.

The first Census Office report on central electric light and power stations for 1902 contained a historical review of their development and of the apparatus which had been employed up to that time or was then in use. The descriptions then given included some of the earlier stations, as well as dynamos, engines, motors, transformers, arc and incandescent lamps, meters, and other appliances. The next report (that of 1907) embraced data of the same general character, and the present report may therefore be considered as a continuation in its discussion of the evolution that has taken place since 1907.

The general statistics that have been presented in the preceding chapters of this report contain in themselves evidence of the changes which have taken place, and the remarks which will now be made on the technique of the industry will only serve to illustrate even more strikingly the incessant advances that characterize the electric art so preeminently. It stands to reason that an industry which has doubled itself in the two five-year periods within the time covered by the work of the Bureau of the Census is far from having reached a position of equilibrium, while there are no indications that this rate of increase has any tendency to fall off. Electric lighting is still the one great field in which electrical energy generated by central stations is employed, but more particularly within the last five years the application of the electric motor has been broadened and universalized, while a number of kindred arts, all based upon the consumption of electricity, have grown apace, increasing enormously the percentage of the miscellaneous sources from which central station income is derived. Detailed reference to these aspects of the industry will be made later. The interesting fact develops in connection with this greater increase of electric service to the public, that its cost has steadily decreased during the census periods referred to, while the cost of living has steadily increased. A typical example may be cited from the statistics of Massachusetts between 1904 and 1912, based upon the reports of the State Board of Gas and Electric Light Commissioners, which show that while in the seven years the cost of living predicated upon current market prices had risen 37 per cent, the rates for electricity had been reduced about 17 per cent. In other words, while the cost of food, coal, shoes, household equipment, etc., had increased over one-third in the seven years, the cost to the public of a very large proportion of its light and power furnished by public utilities had been lowered one-sixth.

Three remarkable developments are associated with the period 1907–1912, as contrasted with those of antecedent date, although the results are probably only a continued exemplification of the trend of the art and the irresistible push of the forces that have made it what it is as a centralized source of supply.

Consolidation of central stations.—One of these conditions of development has been the marked tendency toward central station consolidation. The process was never more active than during the period 1907–1912, taking on chiefly two aspects. In the earlier days of the industry it was only natural that a company operating within a small area in a given city or district should reach out with its circuits and cover additional territory or should merge in some way with other competitive companies covering the same region or municipality, in order to secure the economies and efficiencies which come from the operation of a large plant as compared with that of a small one. Hence there are very few cities or towns in the United States to-day where competitive central stations exist, the vast majority of them being under unified control but subject to the regulation of public-service commissions as to their rates, capital, conditions of service, and other features of the work. Some of these city systems have expanded so as to embrace large contiguous areas far beyond the original city limits. In the case of the Boston Edison Co., which supplied electricity originally to only one-eighth of a square mile, the area embraced by the circuits of the same company is now 700 square miles. The same principle has been given another application in the bringing together under one management of a large number of extraurban central station properties whose areas of service march together.

The Public Service Co. of New Jersey furnished electricity, gas, or electric street railway service, in 1912, to 202 municipalities in the state with a total population of 2,028,947, of which 173 communities with a population of 1,947,199 were supplied with electricity for light, heat, power, etc. It is unquestionably true that in all these places the quality, price, and continuity of the service were superior to what could be obtained through a number of small and often struggling local enterprises.

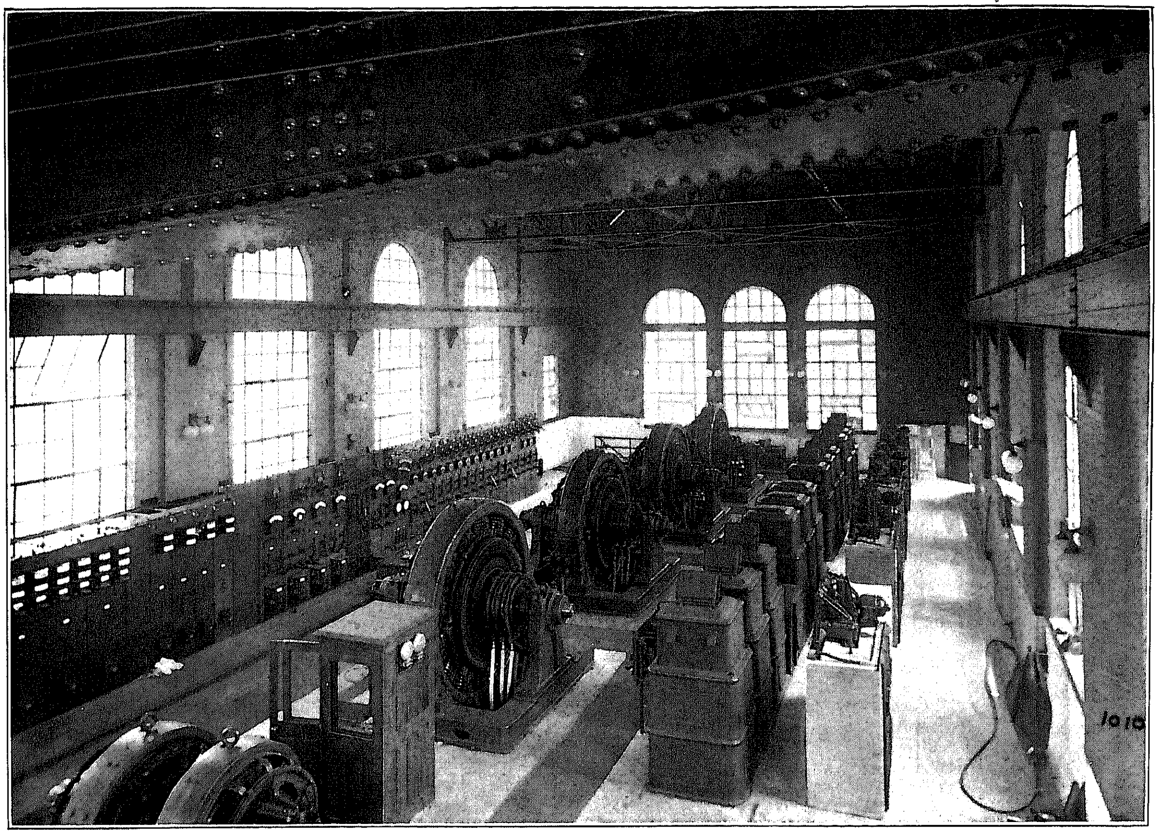
Equally notable in respect to extent and comprehension of system is the Pacific Gas & Electric Co. of California, which in 1912 was the owner or operator of plants and properties in 30 counties in central California, furnishing electric light and power to 187 communities, besides supplying gas, water, and street railway service in many of these or other places. The area covered was approximately 37,700 square miles, with a population in 1910 of 1,325,000, or about 55 per cent of that of the entire state. The electric generating capacity at the census of 1912 was 192,573 horsepower, of which 92,973 horsepower was hydroelectric, and the water-power capacity was being increased by a 53,300 horsepower plant then under construction. The total earnings of the company in 1911 were $14,500,000. In 1910 it had already 1,408 miles of high-tension transmission line, 950 miles of distributing transmission line, and 167 miles of underground cable in the central district of San Francisco.

The state of Illinois affords another example of what has been done in this respect. The Central Illinois Public Service Co. at the end of 1912 was serving 87 communities which were originally supplied by no fewer than 49 separate generating plants under nearly as many distinct managements.[1] This number had rapidly been reduced by consolidation to eight, which in turn were to be reduced to four, capable of generating all the needed energy. The advantages of such interconnected operation are best illustrated by the example of the Lake County district, Illinois, where this unified service effected a decrease in production costs from 7.08 cents per kilowatt hour to 2.87 cents per kilowatt hour, a saving of 4.21 cents per unit. The average price of electrical energy to the consumer was reduced by this process from 9.4 cents to 7.7 cents per kilowatt hour. The consumption per capita increased also from 40 kilowatt hours to 85. These figures and others were presented by President Samuel Insull, of the Commonwealth Edison Co., before the Franklin Institute in March, 1913, at which time he also called attention to the economies effected by the use of electricity in the operation of coal mines and in the farming districts in the state of Illinois. There were also other economies of a striking nature. A survey of central station plants in smaller Illinois towns showed that the plant-equipment reserves ranged from 15 to 82 per cent, yet the reliability of such service was always questionable. Although the maximum demands of various uses described totaled 305,000 kilowatts, the simultaneous maximum load on a unified system reaching these customers would be but 225,000 kilowatts. Such a system would show a load factor of about 48.7 per cent. Replacing the 437,530 kilowatts in small-plant capacity necessary to furnish the indicated service, with a unified system (allowing 20 per cent capacity reserve above the 225,000 kilowatts of maximum demand), a saving was shown as follows: 437,530 kilowatts in small plants, at $100 per kilowatt, $43,753,000; 270,000 kilowatts, unified, at $75 per kilowatt, $20,250,000, making a saving in investment of $23,503,000. In addition to this tremendous saving in plant investment there would be similar economies in operation, although it would be difficult to give a fair estimate of these without assuming special conditions, for under conditions of individual plant operation it is hardly conceivable that there could be obtained, either at all or on anything approaching a similar scale, such applications of electric service as unified operation makes possible.

Holding companies.—The other tendency of the period in the way of unification has been that exemplified in the creation of "holding" companies, now so much under discussion, whereby unrelated properties distributed widely over several states have been brought together under one central control and management, one of the objects and results being to invite capital by averaging the profits and losses over a wider area so that the risk of "putting all the eggs in one basket" is minimized or abolished. The number of commercial central stations in the United States in 1912 is given as 3,659. According to an authentic table,[2] the results of an investigation into the control or ownership of central stations in cities having a population of 5,000 or more showed 1,159 communities, in 528 of which syndicated properties of one kind or another were given service. It is not the intention here to discuss the political aspects of this problem, but to point out that under such centralized management there have invariably followed a renovation and enlargement of the properties, the installation of new apparatus, increase in service and facilities, and supervision by men of higher ability or attainments, each of whom is expert in his chosen field, furnishing, therefore, talent utterly beyond the power of a small plant to hire or retain. It is because of results shown in unification of the one kind or other that in such states as New York, where there are some 321 central station plants, it has been contended that the efficiency would be much higher and the cost of service to the public much lower if there were only 40 such plants, or even only 10. The distribution of electrical energy from this minimized

[1] National Electric Light Association, Report on Progress, 1913.

[2] Electrical World, Sept. 28, 1912.



1. 60-CYCLE ROTARY CONVERTERS, CLEVELAND RAILWAYS CO., CLEVELAND, OHIO.

2. STEAM TURBO-GENERATORS, LONG ISLAND RAILWAYS, LONG ISLAND CITY, N. Y.

(Face p. 112.)

number is easy of practice under modern methods of power transmission, and not at all necessarily dependent upon hydroelectrical development. It has been pointed out, for example, that in some of the small communities at the eastern end of Long Island, New York, coal costing the central station company only $1.15 per ton at the pit's mouth comes with a burden of $2.65 per ton freight charges when it reaches the company's coal bin, so that the best price the company can make to its customers is about 18 cents per kilowatt hour. The same little system fed from a substation could be operated much more economically from a large transmission plant at tidewater midway of the island, supplying a large area, or even from the steam-generating system of the Brooklyn Edison Co. at the western end of the island, 100 miles away.

Utilization of water power.—One further aspect of the enormous increase in the industry during the period 1902–1912 is the utilization of water power as a source of primary energy supply in driving the electrical generators. It is to be noted from the general table on the statistics of the continental United States that the number of water wheels employed more than doubled and that their horsepower increased 463.6 per cent, or from 438,472 horsepower in 1902 to 2,471,081 in 1912. During the same period the horsepower of steam engines and turbines in the industry increased only 254.7 per cent, or barely half as much. Such figures, however, do not reveal the full extent of the tremendous development that has taken place in some states. Thus the statistics of North and South Carolina are nothing short of extraordinary. The increase in North Carolina in water-wheel capacity in the 10 years reached 2,500 per cent, while in South Carolina the increase amounted to not less than 1,614 per cent. The increase in North Carolina in the horsepower capacity of the stationary motors, served almost wholly from these water-power systems, was 3,356 per cent in the 10 years 1902 to 1912. In view of such figures, which have various implications as to their bearing on the art and science of power transmission, it is easy to understand the rapid development of many industries in the South requiring crude energy in large quantities.

Relationship between central stations and electric railways.—The interrelations, already close between the central station industry and electric street railway systems, have been much more strongly knitted by these developments in large power production, although not quite in the manner revealed in earlier reports. At one time there was a marked tendency toward the consolidation of lighting and traction properties, largely with the object of merging their power plants to secure higher economy in operation. Greater efficiencies were secured without doubt, but it has often been contended that the general quality of the service from the lighting circuits was not improved; or that the preoccupation of the management in the anxieties of running street cars hindered the light and power part of the business from receiving the full attention it required in order to give satisfaction to the public and grow at the highest rate attainable. Be this as it may, it is now certainly the fact that there is an increasing disposition to treat the matter the other way around, the street or interurban railway abandoning its own generation of current and buying it in bulk from the local central station. Chicago has been notably a leader in this development, and the Commonwealth Edison Co., which has steadily maintained that it is uneconomical to supply a given territory by more than one system of electrical energy transmission, has for several years supplied all the power requirements of the Chicago city railways and part of those of the elevated railways and the Chicago railways. Thus the railway portion of the total output of energy has become a very large percentage of the whole and is growing rapidly. But there are many other places where the same change has occurred, as, for example, in Cleveland, Ohio, where the Cleveland Railway Co. in 1912–13 put out of commission two large plants of nearly 5,000 horsepower in steam engines, and is now purchasing 60-cycle alternating current from the Cleveland Electric Illuminating Co., converting it into direct current for use on the street car lines, through 1,500-kilowatt rotaries, with the supplement of storage batteries. Even more striking is the instance of Philadelphia, where for some time past the Philadelphia Electric Co. has been feeding a load of 35,000 horsepower daily to the Philadelphia Rapid Transit Co. Adopting the same method, the Pennsylvania Railroad has made a contract with the Philadelphia Electric Co. for the energy used in the electrification of its lines between Broad Street station and Paoli, and also between Broad street station and Chestnut Hill. The contract is for five years. At the beginning the Pennsylvania Railroad will use about 4,500 horsepower, a minimum of 3,750 kilowatts with a load factor of 25 per cent being specified. The energy is to be furnished for the main line to Paoli and any addition or extension thereto, the railroad company reserving the right to call on the Philadelphia Electric Co. for any additional power that may be necessary for its general system from time to time. With the completion of the present work as planned, the Pennsylvania Railroad will have 32 miles of electrified lines in the Philadelphia suburban district.

The significant importance of this contract is that it carries with it a solution of one of the great difficulties encountered in the electrification of the steam railroads of the country. If each of the railroads were to put in its own power plants an enormous outlay in the aggregate would be necessary, and they are not in such financial position as to assume this burden, in spite of the conceded gains in volume and density of traffic due to electrification. But the lines in most parts of the country pass through towns and cities which already have large central stations capable of furnishing this energy to the respective sections of the track. In other districts where the population is sparse the lines are frequently near water-power transmission networks that could be tapped for this additional service. This latter work has, indeed, already been taken up in the Far West, and in the meantime, through the intermediary of the local central station system at Baltimore, some of the energy from the huge hydroelectric plant on the Susquehanna River, 40 miles away, is being fed into the circuits of the Baltimore & Ohio Railroad.

STEAM POWER.

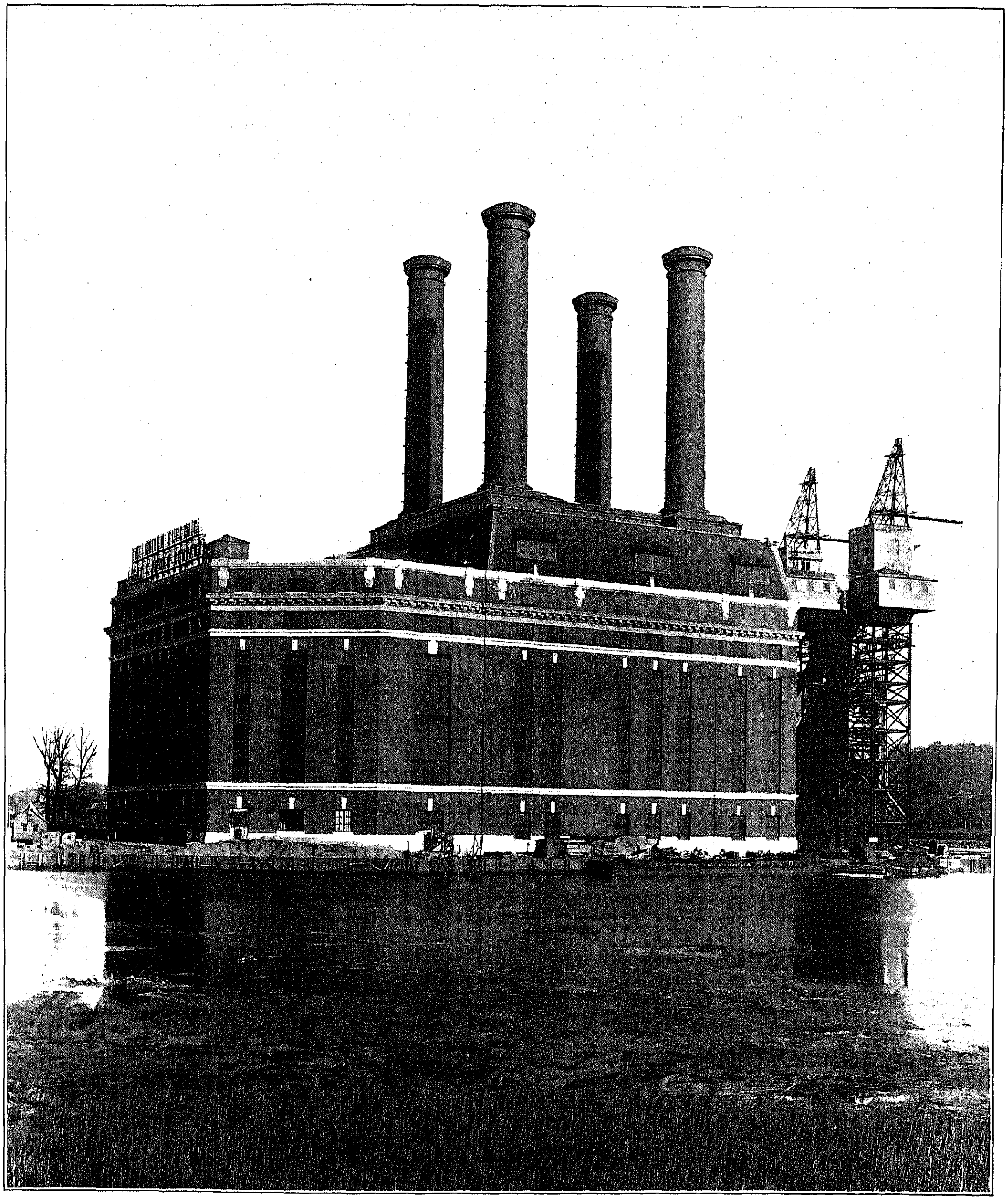
The general conditions as to steam power are discussed in Chapter III, and bear emphatic testimony to the vogue and supremacy of the steam turbine in central station work. Steam will probably remain the chief prime power for driving the generators of the industry, but the fact is not to be overlooked that while the total steam engine equipment in 1912 was 4,946,532 horsepower, that of the water wheels was 2,471,081 horsepower, and showed a gain in the 10 years of 463.6 per cent, while the steam increase was 254.7 per cent. The proportion of central station service given in urban communities is very large, and demands absolute reliability and continuity. Hence the exclusive use of water power is out of the question, and there is a growing practice of associating heavy steam-reserve equipment with hydroelectric installations, if only as an assurance of uninterrupted supply. A factory or a metallurgical plant might conceivably be deprived of power even for hours without serious loss or discomfort to any one. A train may be late and inflict temporary inconvenience upon only a comparatively few persons by its delay; but no large community likes to run the risk of being deprived suddenly, even for a short time, of its light, heat, and power. Thus few great central station systems to-day, however dependable may be their hydroelectric plants, are without a fair percentage of steam stand-by, if the companies are responsible for the continuous service of a considerable population; and hence the very increase of hydroelectric development generally brings with it an increase in steam plant that is reflected in these returns.

Tendency toward greater efficiency.—A general summary of existing conditions in steam central stations was made before the Association of Edison Illuminating Companies in September, 1911, by President T. E. Murray, dealing with reliability of service, operating economy, and structural excellence. Larger boilers have come into vogue, and the evolution of boiler furnaces is such that fuels heretofore considered worthless can now be burned to advantage. Stokers are less automatic but more efficient than formerly, and the growing scarcity of steam sizes of anthracite, rendering a greater use of bituminous coal necessary, carries with it a wider adoption of the mechanical stoker. The steam-piping systems in use are designed on the unit plan, with interconnecting mains and steam speeds of 12,000 feet a minute. Steam pressures still remain between 175 and 200 pounds, and the use of superheated steam is becoming more general. A great improvement in boiler feeding has followed the use of the centrifugal pump and accurate water meters, and open heaters and forced draft are most widely employed in later stations. The steam turbine has supplanted the reciprocating engine in large stations, and it is very doubtful if any more large reciprocating units will be installed for power-station purposes. Coming to the electrical equipment, the design is largely influenced by the character of the load and the distance to which energy is to be transmitted. In busbar arrangements, standard practice favors the group method of generator and feeder connections having two sets of busbars sectionalized at one or more points by switches. For bus and switch compartment work concrete is coming largely into use, but brick makes a more finished construction, while for high-tension switches, and for flooring high-tension compartments, soapstone is still the best available material.

The improvements made in protective devices and instruments for switchboards are noted, as well as methods of control which have worked well in practice, especially in stations having system operators or load dispatchers. As to operating costs, Mr. Murray stated that attention to station economics with large units and careful design has resulted in a station cost which is gradually approaching a minimum. He divided the cost of a fair-size station per kilowatt as follows:

	Per cent.
Total	100
Building structure	30
Boilers, furnaces, and boiler room auxiliaries	20
Turbines, generators, and condensers with auxiliaries	25
Piping systems	10
Switchboard and other electrical work	7
Miscellaneous small items not otherwise included	8

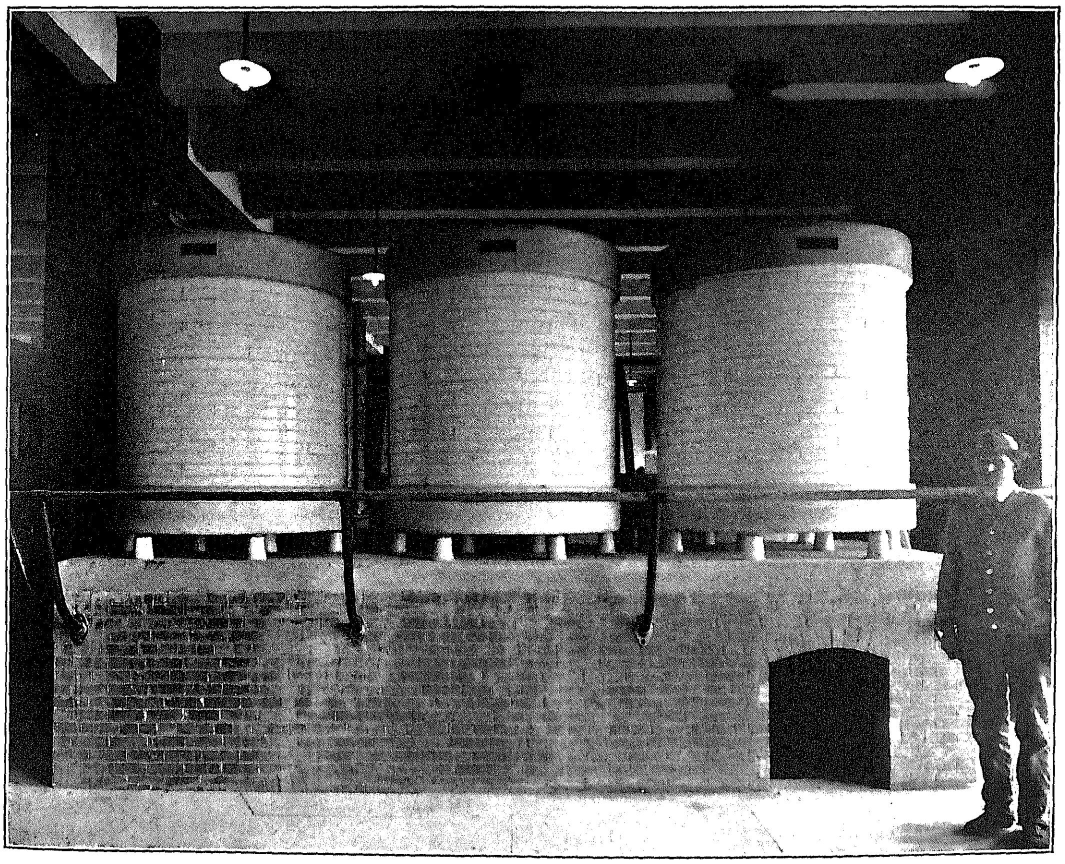
The importance of striving after a low cost of construction per kilowatt of station capacity will be appreciated when it is considered that the effect of a saving in the station investment cost of $5 per kilowatt is equivalent to an annual saving in the coal bill of 12 per cent with coal at $3 a ton, where a fixed annual charge on the investment of 14 per cent is allowed to cover interest, depreciation, and taxes. It would appear, according to Mr. Murray, who spoke from a vast experience, that further gains must come from advances in the direction of reduction in cost, increase of output, and improvement in the load factor under which the stations operate, rather than in the efficiency of the individual units.



NEW GENERATING STATION, UNITED ELECTRIC LIGHT AND POWER CO., NEW YORK CITY.

(Face p. 114.)

1. GENERATING ROOM.



2. REACTANCES.

Facilities for obtaining coal and water.—Other aspects of the situation were noted by Mr. I. E. Moultrop, in the winter of 1912–13, before the Worcester (Mass.) Polytechnic Institute. It had been found, for example, that in the design of a large station wharf privileges having a channel of ample depth for coal carriers of large size and the avoidance of drawbridge tolls are important factors, and that an inland plant should, so far as possible, not be dependent upon a single railroad for its supply of coal. The coal-storage facilities should permit the holding of at least a month's fuel supply at all times and three months' supply in winter, to guard against interruptions. The supply of circulating water should be almost unlimited in a plant of great size. At the South Boston plant of the Boston Edison Co., with seven units in operation, 10,000,000 gallons of circulating water per hour were required to maintain the vacuum. The practice of drawing such water from a channel rather than from shallow places in a harbor is highly desirable. Although the cost of land is not the factor it used to be in connection with large stations, on account of the tendency to locate such plants outside the centers of cities, the burden of fixed charges carried by the real estate investment in plants of very high capacity is a factor to be considered with some care. While it is always possible to build a plant in a new location when the demand for service necessitates it, it is more desirable to extend a well located existing station, as this does not require a new operating organization or new coal-storage and wharfing facilities.

Boilers.—Water-tube boilers are the only kind suitable for large stations, and Mr. Moultrop held that units of from 500 horsepower to 750 horsepower rating are as large as is desirable. Engineers are not agreed regarding the desirability of very high-power boiler units, although these have made excellent records in the Delray station of the Detroit Edison Co. and in European plants. Large boilers complicate the question of spare equipment and are liable to the same troubles as the smaller units, so that a larger percentage of the total steaming capacity is taken from service in case of trouble with a boiler of large size. As to the general design of a central station and the selection of its equipment, Mr. Moultrop indicated the flexibility of methods and range of selection in an art already well standardized by stating that in a recent case as many as 25 preliminary station designs were made with the assistance and for the criticism of the operating department to which the station would have to be entrusted.

In connection with the resort to larger boiler units that should correspond in some degree to the larger turbo-generators in steam stations—a practice which, as the preceding paragraph shows, is not deemed fundamentally essential—reference should be made here to the 10 huge water-tube boilers installed in 1911–12 by the Detroit Edison Co. at its Delray plant on the river front. Each of these great units is rated at 2,365 boiler horsepower, on the assumed basis of 10 square feet of heating surface per horsepower, or 30 pounds of steam per horsepower hour. The Delray boilers have been tested up to 214 per cent of full load, which is equivalent to generating steam at about 7 pounds per hour per square foot—not an excessive evaporation for boilers in modern practice. Ordinarily the units carry 6,000 kilowatts to 7,000 kilowatts each. This load increases to 8,000 kilowatts per boiler during the peak periods, and for short durations has reached 11,000 kilowatts. Each boiler is 36 feet high, 30 feet wide, and 28 feet deep, being fired from both ends. The three huge steam drums are connected with the two mud drums by no fewer than 1,564 3¾-inch tubes. Each boiler has four water columns and an even dozen safety valves designed to relieve the pressure if it rises above the normal steam condition of 205-pound pressure and 150-degree superheat. At normal rating the big units have shown a combined thermal efficiency of 80 per cent (about 89 per cent being the maximum possible value), and this observed efficiency decreased only to 76 per cent at 100 per cent overload. It is held that the remarkable economies obtained could hardly be traced to exceptional flue temperatures or any other furnace conditions differing materially from ordinary experience. But the large units decrease the usual proportion of radiation losses, and, with their single huge fires, enable the closest attention to be given to the one bed. Labor costs are thus reduced correspondingly and the boiler-room layout is simplified and cheapened. The boilers themselves cost less per unit of rating than similar small units. Difficulties with furnace brickwork have apparently been solved as rapidly as they presented themselves. A series of tests on two of the Delray units was carried out under the direction of Dr. D. S. Jacobus, and formed the subject of a paper presented by him at the annual meeting of the American Society of Mechanical Engineers.[1] The test required the services of 50 men working in eight-hour shifts for six weeks. During this time 5,000 tons of coal and 45,000 tons of water were measured. The results obtained show that with the two kinds of stokers the combined efficiency of both boiler and furnace ranges from 80 per cent at slightly below normal rating to about 76 per cent at double rating. Such results are attributed not less to the skill employed in the test, the expertness of the stokers, and the careful selection of the fuel, than to the design and size of the boilers.

Size and power of turbines.—The notable feature in generating units in the last census period has been the increase in the size of the turbines as well as in the speed of revolution. At the time the present text went through the press the size of units had been carried to the highest point reached in the order given by the Philadelphia

[1] Journal, American Society of Mechanical Engineers, November, 1911, p. 1437, et seq.

Electric Co. for two machines rated at 30,000 and 35,000 kilowatts, respectively, and with increasing rotative speeds even this is not regarded as at all the limit in capacity. The smaller of these units would supply the adjacent state of Delaware with all the current needed by all its public utility companies. In the meantime, the largest actual unit is one rated at 25,000 kilowatts, with a maximum rating of 40,000 horsepower, contracted for in England, 1911–12, by the Commonwealth Edison Co. of Chicago. This unit is of the horizontal type, the low-pressure end being double-flow. The unit is 75 feet long and 18 feet wide, with a speed of 750 revolutions per minute, the generating part being 25-cycle, 3-phase, 4,500-volt. The exciter is carried on the shaft, and the auxiliaries are of rotary type, electrically driven. This compares with a unit of 30,000 kilowatts of American manufacture ordered by the Interborough Co. (subway) of New York City, the high-pressure element being a single-flow turbine operating at 1,500 revolutions per minute, and the low pressure element being a double-flow turbine operating at 750 revolutions per minute. Another horizontal turbo-generator unit of American make, ordered by the Commonwealth Edison Co. for the Northwest station, is of 30,000-kilowatt capacity. The exciter will be installed on the shaft of the machine, and the over-all length of the unit will be 60.5 feet. The width is 18.4 feet, and the height 14 feet. The generator part is a 9,000-volt, 25-cycle, 3-phase machine, operating at a speed of 1,500 revolutions per minute, and designed for an output of 1,925 amperes per phase. The turbine is to be operated at a steam pressure of 230 pounds, with a supertemperature of 200 degrees Fahrenheit. The weight of the entire unit is about 1,000,000 pounds.

Meanwhile some very large units have been put in actual operation in steam central stations, as, for instance, in the Waterside plant of the New York Edison Co. on the East River, where in November, 1911, the first of three 20,000 kilowatt turbo-generators was installed. These generators are 4-pole, 3-phase, 25-cycle, wound for 6,600 volts. The normal speed is 750 revolutions per minute. They are direct-connected to six-stage vertical turbines, designed to operate on 175-pound gauge pressure, with a back pressure of 1½ pounds absolute in the exhaust chamber, and with steam superheated 100 degrees Fahrenheit. The steam consumption in pounds per kilowatt hour under these conditions is guaranteed to be as follows:

LOAD IN KILOWATTS.	Steam, pounds per kilowatt hour.	Total steam per hour, pounds.
10,000	15	150,000
15,000	14.4	216,000
20,000	15	300,000

The dimensions of the base of the machine are 17 feet 6 inches by 17 feet. The height above the base is 35 feet 7 inches, and the height of the foundation above the basement floor is 10 feet. Each machine weighs, approximately, 420 tons, the revolving parts weighing 112 tons. The runners are 13 feet in diameter, and the total number of steam buckets they contain is 7,200. It is interesting to note that the area occupied by one of the 20,000-kilowatt units is 297 square feet. The area occupied by the single 3,500-kilowatt engine-generator unit of the type displaced is 918 square feet, so that the unit generates, approximately, eighteen times as much power as the old reciprocating engine per unit of area occupied. Assuming that the turbine is fully loaded all day and that there is an evaporation of 9 pounds of water per 1 pound of coal, the unit will require 7,200,000 pounds of steam a day, and about 400 tons of coal.

While awaiting the installation of its huge new units above referred to, the Chicago Commonwealth Edison Co. had put into operation in the winter of 1911–12 its Northwest station with units of 20,000-kilowatt capacity. These are spaced 44 feet apart. The steam turbines are six-stage machines, and each one has 7,392 buckets. The outside diameter of the sixth wheel is 13 feet 2 inches, and it has a peripheral velocity of over 500 feet a second, or about 6 miles a minute. The guaranteed steam consumption, with steam at 250-pound pressure and 100-degree superheat, is 14 pounds per kilowatt hour at loads of 10,000 kilowatts and 13.45 pounds at a load of 15,000 kilowatts.

Combustion tests.—Two types of boilers are used at the Northwest station, one with a vertical pass for the hot gases and one with a horizontal gas pass. The purpose of using the two types is to give a thorough test to determine which is the better, with the idea of insuring practically perfect, therefore practically smokeless, combustion. Each boiler should be able to generate 30,000 pounds of steam an hour, and this requires a rate of coal burning of 4,500 pounds an hour under each boiler, so that in each second of time 300 cubic feet of air passes through the grate. With 60 boilers, all running at the maximum rate, the amount of air entering the grates each minute would be over 1,000,000 cubic feet. To avoid unpleasant drafts of cold air in winter, provision is made to admit air directly under the grates from the train shed below.

Use of lignite and low-grade coal.—The creation of the numerous hydroelectric plants included in this report has been of incalculable benefit not only in the utilization of resources hitherto utterly wasted, but in directing attention to the higher economies possible in the use of fuel, and to the employment of grades of coal regarded previously as too low in calorific values. The central stations of the country have played a large part in this branch of "conservation," and it is interesting to note how the ascending prices for anthracite and bituminous coal have thrown them back on lignite where this happens to be obtainable within a reasonable hauling range. The Denver Gas & Electric Co. may be cited as one instance of a large system utilizing lignite within "striking distance," as well as being an example of the large use of hydroelectric energy transmitted from remote water powers. A notable example of fuel economy has been witnessed in Pennsylvania in the creation of a large electric plant whose operation is based entirely on the use near the pit mouth of coal that is undesirable for transportation. Coal available commercially is sent away by track, but the residue is now being made by electrical methods equally serviceable for light, heat, and power over large local areas and with a minimization of the waste hitherto represented by huge culm piles.

As to the utilization of low-grade fuel, economical methods for the combustion of the brown lignite found in parts of North and South Dakota and Montana have received the attention of Government investigators. In a 40-page pamphlet, prepared by Messrs. D. T. Randall and Henry Kreisinger, of the United States Geological Survey, the results of a series of tests are presented and analyzed. The authors conclude that the combination of boiler and furnace setting which they describe gives good results with North Dakota lignite, and they state that steam can be produced with a fuel efficiency of 55 to 58 per cent of all the heat in the coal. They experienced no difficulty in working the boiler to full capacity. Equally good or perhaps better results could be obtained by the use of mechanical stokers. Although this fuel is generally considered unsatisfactory, they concluded that it might be used with fair economy under boilers at their full rated capacity.

The subject of the utilization of lignite received special attention at the meeting in 1912 of the Southwestern Electrical Association, at San Antonio, Tex., when many central station managers testified as to their success in its use, especially as compared with oil. Mr. E. W. Kellogg, of El Paso, declared that while the ordinary run of mine-slack refuse coal, averaging 10,500 heat units per pound, gave a dense black smoke when burned on ordinary grates, the Colgate lignite was practically smokeless, showing economies expressed in cents per kilowatt hour very much higher than those obtained with even the highest grade of steaming coal. Mr. R. C. Brooks, of Dallas, explained that lignite was usually not adapted for burning on automatic stokers, since it required a stronger draft than that ordinarily afforded. While it produced more ash, it was nevertheless found to be a satisfactory fuel, and at $1.33 per ton, delivered, compared well with Oklahoma coal at $5 per ton. The Texas lignite had to be transported about 65 miles, and in even that distance suffered considerable reduction in size through slacking. Mr. W. S. Rathell, of Waco, related the results of some comparative tests of lignite and oil made on a 150-horsepower boiler, six-hour periods being adopted. These tests showed 1 ton of McAlester slack to equal 3 barrels of fuel oil, while 1 ton of Rockdale lignite equaled 2.25 barrels of oil. Lignite-burning boilers had the disadvantage that they could not be forced. There was also an objectionable tendency to slacking in the lignite. As the result of all these drawbacks, the local company found it necessary to carry auxiliary fuel, fearing to depend upon the lignite coal alone. Chain grates for burning lignite were installed, but without success. The slow ignition of the fuel made it impossible to keep up steam pressure. An excessive amount of labor was also required in removing ashes, etc. Even when protected from the weather by sheds and roofs, lignite slacked and then ignited from spontaneous combustion. Mr. A. E. Judge, of Tyler, reported that his company had been burning lignite with success for three years, having changed from oil when the latter reached $3 a barrel to lignite at $1.90 per ton, with an incidental saving of about one-third of the fuel expense. At the outset lump lignite was used, but slack was afterward purchased at $1.40 per ton, about 10 per cent more being required to produce the equivalent heating effects of the large size. The fuel was burned under forced blast on a special grate having many small holes. The use of lignite had about doubled the cost of labor, so that the net saving of lignite over oil represented the difference between $1,000 and $600 per month in operating expense. From every viewpoint lignite had proved a success, and there had been no trouble in forcing the boilers thus fired up to loads well beyond their normal rating.

Dr. A. C. Scott, of Dallas, called attention to the marked difference in the qualities of lignite mined in different sections of Texas. The ash content of such lignite was of the greatest importance in producer operation. The combustion of lignite containing 7,500 to 8,000 heat units, at 60 per cent efficiency and $1.50 per ton, was about equivalent to oil fired at 75 per cent efficiency, the oil containing 18,500 heat units and costing $1 per barrel. The heat-unit value of lignite varied, however, with the conditions of mining, transit, etc. For the proper combustion of lignite, the grate bars should be at least 24 inches from the boiler shell, the exact distance depending on the moisture content of the fuel. Troubles with lignite as fuel had been due chiefly to slow burning, but this difficulty could be solved by mixing the fuel with bituminous material of a higher grade. Thus a half-and-half mixture of lignite and McAlester slack burned very well. To get full steaming capacity it was advisable to provide a Dutch-oven furnace and a high stack. The cost of handling lignite had averaged on test from 8 to 12 cents per ton, suggesting the employment of some simple and efficient conveyor. Comparing oil at 93 cents per barrel with lignite at $1.15, there was a saving shown in favor of oil.

Mr. John A. Walker, of San Angelo, told how his company had changed to lignite after oil rose in price from 95 cents a barrel to $1.15. After trying lignite for 18 months the use of oil was resumed, owing to the trouble of handling the lignite, which had to be hauled 1½ miles at an expense of $150 a month. Prof. F. C. Bolton stated that the three years' experience at the Texas Agricultural and Mechanical College had proved oil at $1 per barrel to be a less expensive fuel than lignite at $1.50 per ton. When available, lignite screenings were cheaper than either. Mr. Frank E. Scoville, of Laredo, said that while lignite required a larger boiler equipment for the same output, it was his experience while operating a plant at Austin that this low-grade fuel was more satisfactory and cheaper than cannel coal mined only 26 miles away. Another speaker declared, however, that wherever lignite was used some auxiliary means must be provided for forcing the boilers, and that some mechanical device had to be arranged for conveying the fuel from the cars to the furnaces.

Storage of coal.—Coal storage has necessarily received the attention of central station managers, as will have been gathered from various statements already noted above; and huge piles are now to be noted within the vicinity of modern plants. The adoption of underwater coal storage is one of the newer developments of the central station industry. Coal which is in open-air storage even six months may lose as much as 25 per cent of its fuel value, while there is always the tendency to spontaneous combustion. Coal can be stored under water, however, almost indefinitely without loss of its fuel value, and such storage offers an opportunity for holding large coal reserves almost indefinitely against a time of need. With this idea of guarding against strike or other shortage, and following expensive experience, the Omaha (Nebr.) Electric Light & Power Co. built in 1911-12 a large under-water storage pit capable of holding 10,000 tons, with the bunker contents enough for three months' operation of its 13,000-kilowatt plant. This storage pit measures 100 feet by 116 feet in plan and is 22 feet deep below the water level, which is in turn 23 feet below the crane runway. It will submerge 7,000 tons of coal, while 3,000 tons more can be piled on above the water level. The coal is unloaded from cars run alongside the pit by means of a grab bucket carried on a crane of 145-foot span. The coal car track passes directly above the hoppers leading to the coal crushers, which in turn discharge into the conveyors elevating the fuel to the overhead bunkers. This arrangement provides that the ordinary route of the fuel is from the cars to the boiler room, the storage pit always being kept filled with a fixed quantity of coal. The pit is of reinforced concrete and is carried on 400 piles at 5-foot centers driven to bedrock 19 feet to 30 feet below the semiliquid quicksand. The presence of this quicksand made it necessary to reinforce the structure for both internal and external pressures to prevent collapse of the pit when empty. The piles are capped with 2-foot 6-inch concrete slabs, reducing the stresses in the pit floor, which is 12 inches thick. Besides the steel reinforcing in the floor, old rails have been embedded in the concrete at 1-foot distances, their heads being flush with the waterproofed floor surface, to serve as an armor against the impact of the bucket when removing coal from the pit. The side walls are 4 feet thick at the bottom, tapering to 2 feet 6 inches at the top. The pit has been so constructed as to be capable of extension in both directions as the generating plant grows. Spanning the pit and the crusher hoppers, a total width of 145 feet, is a 5-ton bucket crane. This crane is made up of two girders 12 feet apart, between which runs the trolley carriage with its 2-cubic-yard bucket. The bridge is propelled by a 45-horsepower motor at 300 feet per minute, and the trolley is operated at a similar speed by a 16-horsepower motor. The main hoisting is performed by two motors, one of 45-horsepower and the other of 30-horsepower rating, giving a hoisting speed of 120 feet per minute. With this crane bucket a 50-ton car has been unloaded in 20 minutes. The cost of each handling of the coal is estimated to be about 4 mills per ton, whether from car to pit or from pit to crusher hoppers.

On account of the muddy sediment of the Missouri River, on the banks of which the plant stands, waste water from the plant supply (which has been allowed to settle in sediment basins) is used to fill the coal-storage pit. For draining the pit, outlets fitted with valves are provided just above the sewer level, so that the water can be drained to this point by gravity, beyond which the pump used to fill the pit can be brought into service for the purpose of discharging its contents into the sewer. This Omaha under-water coal-storage pit is estimated to have cost about $70,000, a part of this being due to the unusual and difficult conditions of quicksand on which the pit had to be foundationed.

A similar plant was built a little later by the Indianapolis Light & Heat Co., which stores 15,000 tons under water, while 15,000 tons more are just above water. The bin is 100 feet by 300 feet, and there is a depth of more than 20 feet below the water line. The concrete on the bottom and sides is 1 foot to 18 inches thick, reinforced with twisted steel; and the bottom has in addition a system of T-rail. The rail top stands half an inch above the surface of the concrete, and the rail is laid lengthwise of the bin, 18 inches from center to center; the intention being to protect the concrete from being destroyed by a lowered bucket when it is scraping for coal. A track runs across the top of the bin with a locomotive hoisting crane. The bin was excavated in plain gravel, and cost about $28,000, there being left gravel worth $4,000 available for other purposes, making the net cost $24,000.

Use of gas and oil as fuel.—An interesting plant in respect to fuel used is that of the Kansas Gas & Electric Co., at Wichita, whose capacity in 1911–12 of 8,750 kilowatts was based upon gas burning or oil burning, while the design permitted additions, if necessary later, for coal burning. The plant comprised turbogenerators and alternators. There were four boilers of the tubular type, each with 5,680 square feet of heating surface. The boiler furnaces were equipped with both oil burners and gas burners. They had very large combustion chambers and were of unusual size. They were fired from under the rear of the boilers on the side facing the turbine room, so that the turbine-room attendant might also care for the boilers, if necessary. There was a steel stack 14 feet in diameter and 199 feet 6 inches in height above the boiler-room floor, with the breeching placed in the base of the stack in such a manner that it would not be necessary to disturb it in case the station was equipped later for burning coal.

About four years ago, following the advent of natural gas into the city, the Fort Smith (Ark.) Light & Traction Co. began the use of this fuel instead of coal for its steam-driven generating station. Auxiliary provision had been made also for burning oil in case of low pressure or accident to the gas-supply lines. The cost of operation with gas at 8 cents per 1,000 cubic feet had been found to be just about equal to that of coal formerly purchased at $1.20 to $1.45 per ton. With the use of gas, however, there had resulted important savings in the cost of handling coal and ashes and in labor generally.

Magnitude and importance of central station work done by steam power.—Before passing on to a consideration of other forms of power, it is only proper to close this section of the report by noting how large and important the work done by steam remains in comparison. The table below shows the outputs, peak loads, and load factors of the central stations in Chicago, New York, Philadelphia, Boston, and Brooklyn for 1912.

SYSTEM.	DATA ON LARGE GENERATING SYSTEMS.			
	Peak load in kilowatts.	Date of peak load.	Yearly output in kilowatt hours.	Yearly load factor of system—per cent.
Commonwealth Edison	233,000	Dec. 11	799,000,000	43–44
New York Edison [1]	189,726	Dec. 20	513,926,429	30.8
New York Edison	210,813	Dec. 23	[2] 619,290,064	[2] 33.4
Philadelphia Electric [3]	65,489	Dec. 23	183,969,655	32
Boston Edison	60,143	Dec. 18	161,702,955	30.6
Brooklyn Edison	42,500	Dec. 17	125,770,000	33.7

[1] Exclusive of service to railroads.
[2] Including railroad load estimated for entire year.
[3] Philadelphia only.

The Commonwealth Edison system had the highest peak load and the largest output of the central station systems, owing to its great railroad load. The New York Edison Co. took over the load of the Third Avenue Railroad Co., approximating 28,000 kilowatts, but too late to make any impression on the yearly output. In this connection the output of the Niagara Falls Power Co. and the Canadian Niagara Power Co., which virtually constitute a single system, the stations being operated in parallel, is of interest. The peak load on that system occurred on March 8, 1912, and was 115,900 kilowatts. The output for the year, however, was 868,392,750 kilowatt hours, and the load factor of the system (ratio of yearly average to highest peak in year) was 82.29 per cent, making it in point of output the largest system in the world. The figures, however, did not reflect natural conditions at Niagara Falls. During most of the year the output of each of the plants was rigidly limited by the restrictions of the Burton Act, and during several months a part of the Buffalo load was supplied from the plant of the Toronto Power Co., at Niagara Falls, Ontario. Figures for the total output of Niagara would run far beyond those quoted, but at the best would show that the steam generation of electrical energy is comparable on terms of equality.

In regard to electric current transmission, it is also to be noted that steam central stations have demonstrated their ability to operate in this field successfully in a most surprising manner, and that it has been seriously suggested that electrical energy production wherever possible will take place at the pit mouth. To indicate what this might mean, it is sufficient to quote some figures given in his presidential address in November, 1910, before the British Institution of Electrical Engineers, by Mr. S. Z. de Ferranti, who suggested that there was feasibility, economy, efficiency, and greater public wealth in taking the 150,000,000 tons of coal then used in England miscellaneously and turning it all into electrical energy. He would furnish 131,400,000,000 kilowatt hours at a 60 per cent load factor from plants of a normal capacity of 25,000,000 kilowatts, and would group that apparatus into 100 stations, each of a capacity of a quarter of a million kilowatts, in 10 units of 25,000-kilowatt capacity each. The generating and distributing plants would require only 500,000,000 pounds sterling ($2,500,000,000). Instead of using up 150,000,000 tons of coal, these plants would require only 60,000,000, and taking all items into account Mr. Ferranti estimated that the public could be profitably served with current in some instances as low as one-fourth cent per kilowatt hour.

Meantime a good deal of just such work has been done in the United States. One example is furnished by the Empire District Electric Co., operating in the zinc and lead mining district of Missouri and Kansas, which at the time of this report had in service 9 generating stations, 19 substations, 100 miles of 33,000-volt transmission lines, and an equal mileage of 2,300-volt distribution circuits. It served, besides, the running needs of a scattered community of more than 150,000 people and 165 miles of interurban railway. This service of itself is not remarkable, but that it should grow and prosper where gas can be had for 25 cents per 1,000 cubic feet and coal is somewhere about $2 per ton speaks volumes for the practical advantages of electric power. Mining, however, involves peculiar conditions in the use of power, and experience has shown that under the circumstances of average use the power costs in mining run abnormally high. For instance, in one case of mine pumping it was found that even with fuel gas at only 12.5 cents per 1,000 cubic feet the actual fuel cost per 1,000 gallons pumped rose to 4.8 cents. When the steam pump was discarded and an electric pump was installed in its place, the cost for the power fell to 8.3 mills per 1,000 gallons. In addition to more than 100 pumping installations, many motor-driven air compressors were in use, with hoists and other equipment, bringing the total connected motor load up to about 25,000 horsepower.

Another instance is furnished from Iowa, where in 1909 the Bullock Public Service Co. bought the electric light plants at Missouri Valley, with a population of 3,000; Blair, Nebr., 3,500 population, distant 15 miles; and Logan, Iowa, 2,000 population, 9 miles distant. None of these plants were able to pay any returns on the respective investments. They were replaced by a modern plant of a 625-kilovolt-ampere steam turboalternator installed at Missouri Valley, and 16,500-volt transmission lines were built to Logan and Blair, with a 2-mile branch from the Logan line to Magnolia, Iowa, 300 population. A number of enterprising farmers who had been operating a gasoline plant built a 2-mile line to connect with the 2,300-volt local distribution in Missouri Valley for 24-hour service. At Missouri Valley 2,300-volt, 3-phase service was used for the local distribution, and at Blair and Logan 1,150 volts.

At a meeting of the American Institute of Electrical Engineers in Pittsburgh early in 1913 it was stated that the West Penn system had during 1912 no fewer than 76 coal mines on its circuits with an aggregate load of 14,831 horsepower, each mine finding it more economical to use central station energy than to generate electricity for itself. Another case is that of the Luzerne County Gas & Electric Co., at Kingston, Pa., which presents the very unusual condition of an electrical system, covering some 30 square miles of territory right in the heart of a coal-mining region, selling a great deal of electrical energy to the mines and buying coal locally at current prices. It is in effect hauling coal from the mines and delivering back electric energy more cheaply than it can be generated at the mine mouth. A somewhat singular set of circumstances led to the unusual results noted. To begin with, the coal costs from $1.10 to $1.30 per ton, delivered. The refuse and screenings available at the mouth of the mine would be cheaper than the buckwheat used, yet it appears that, on investigating the relative economies, the saving by using the cheaper coal had been found not so great as might be anticipated. In some instances this result was due to the scarcity of water supply at the mouth of the ordinary mine, and still more chargeable to the difficulty of utilizing very cheap fuel on a small scale. The economical burning of culm and similar fuel requires conveying apparatus on a large scale and can be best done in a plant much larger than the ordinary mine would require. Hence the central plant can afford to utilize cheap coal hauled from near-by mines and then distribute electrical energy back to the mines at a profit to all concerned. The coal is hauled to the station in carts and dumped into a large concrete coal bin, from which a motor-driven conveyor distributes it to the boiler room. It is not even burned on automatic stokers, nor are the ashes disposed of automatically, although an ash-conveying system has been installed. The operating conditions make the success of the plant in energy distribution all the more remarkable. The cost of fuel per ton is so low that any difference secured by a more expensive plant would make the economy a questionable one until the plant had to carry a much greater load. The requirements necessary with coal selling at $3 or $4 prove uneconomical with coal at $1.25.

Carrying out the same idea of a transmission system based on steam-driven generators, the Interstate Light & Power Co. went into operation in 1910 in the zinc and lead mining field in southwestern Wisconsin with a plant near Galena, on the Fever River, Illinois. This plant of 3,000-kilowatt steam-driven alternators delivered energy at 33,000 volts, 60 cycles, over 27 miles of line to three substations across the Wisconsin line, from which 2,300–4,000-volt secondaries fed a large number of mines through local transformers reducing to 220 volts. The region thus covered economically and successfully embraces over 200 square miles of hilly and rough country, where difficult haulage made the price of fuel extremely high, and where the local water was notoriously bad for boiler supply. Energy was sold at the mines on a scale of 8 cents down to 2 cents for all in excess of 80,000 kilowatt hours. A minimum charge was made of $1 per month per horsepower of connected load. The average rate secured by a mine consuming from 500,000 to 600,000 kilowatt hours was about 2.7 cents per kilowatt hour.

GAS AND OIL PLANTS.

Increase during 10-year period.—As the general statistics show, there has been a very large increase in the use of gas and oil engines in the central station industry, with percentage gains of 576.4 in number and 811.5 per cent in horsepower during the 10-year period. The figures for 1912 are 1,116 engines with a capacity of 111,035 horsepower. It will be noted the average units are not large.

Gas-producer plants.—Apparently no notable features require comment as to the use of engines dependent on illuminating gas, but other types have developed features of interest. Reference has been made to the use of lignite coal directly under the boilers of many central stations; but it has also been employed in gas-producer plants for gas engines, in spite of the trouble reported from plants required to meet sudden increases of load. The response of the producer to an increased demand for gas if the load rises quickly is generally sluggish, and the engine will therefore suffer from insufficient supply. This tendency of the lignite producer to balk under irregular load conditions has stood in the way of wider application where its low fuel costs and other advantages make it very useful.

In discussing the lignite producer before the Southwestern Electrical Association convention in 1911, Mr. W. B. Head, general manager of the Stephenville, Tex., Light & Water Co., recounted his own satisfactory experience during four years' operation, 24 hours daily, of a 100-horsepower updraft producer plant doing both electric lighting and water pumping. The performance of this equipment he characterized as unqualifiedly successful, whatever troubles were met with having been of a purely mechanical nature, such as might occur with any internal-combustion engine. The Stephenville plant had been run continuously 24 hours per day, except Sundays, when it was shut down 12 hours for overhauling. The cost of fuel, at 80 per cent load factor, had averaged under 5 mills per kilowatt hour. Unlike steam plants of equivalent sizes, producer plants of even very small ratings share the high efficiencies and the economies of the larger sizes.

The Blooming Grove (Tex.) Ice & Electric Co. had had a 60-horsepower lignite producer-engine plant in operation during the past three years. The early experiences were quite disappointing, and for a time the plant was virtually a failure, minor misadjustments or broken parts, the causes of which were often apparently undiscoverable, resulting in refusals to start or run; but in 1912 the plant was reported as being in satisfactory operation. Night electric lighting service for 100 customers and the town water supply were furnished by the producer engine, the waterworks pumps being run during the night hours after the evening peak had been passed. The plant equipment comprised a 60-horsepower gas producer providing fuel gas for a vertical, double 12-inch by 13-inch cylinder engine running at 290 revolutions per minute. A 35-kilowatt, 2,200-volt, 60-cycle, single-phase alternator was belted to the engine flywheel, and from clutch-driven extensions of the engine shaft the air-lift compressor and high-duty water pumps were driven. Lignite from the Beargrass, Tex., field had been used in the producer. This fuel cost about $1 a ton at the mine and $2.10 a ton laid down at the plant when contracted for in quantities. For this had been substituted Malacoff lignite from a nearer and newly developed field, costing $1.40 per ton laid down. The plant required about 1,500 pounds of lignite per 12- to 14-hour night's run, and about 20 carloads were used per year. During four to five months of the summer the plant was run 24 hours per day.

Natural gas.—There are various natural gas central stations in different parts of the country, but it is more particularly, perhaps, in the Southwest that one expects to find them. A successful small station of the kind is that of the Independence Electric Co., at Independence, Kans., a 775-kilowatt plant which in 1912 contained three different types of gas engines. In spite of cheap natural gas a number of the local industries were operated from the lines of the electric company, whose connected day load in motors was larger than its evening lighting peak. Under the average operating conditions of the Independence plant during a 30-day test, including periods of light as well as full loading, a kilowatt hour was produced for every 20 cubic feet of gas taken by the engines. This natural gas from the Oklahoma fields had a fuel value of about 950 pound Fahrenheit heat units per cubic foot. Under conditions of ½ to 60 per cent load at the time of another test, the engine produced a horsepower hour on 11.75 cubic feet of gas.

Oil engines.—With regard to oil engines, the data for the plant of the Citizens Electric Light & Power Co. of Lebanon, Ind., are of interest. Its self-igniting engines of the Diesel type had been in operation over six years in 1912. The principal equipment of the station comprised two 225-horsepower, 164-revolutions-per-minute, 3-cylinder engines, direct-connected to 160 kilovolt-ampere, 2,300-volt, 60-cycle, 3-phase alternators, and a 125-horsepower, 83-kilovolt-ampere, 225-revolutions-per-minute unit of similar type. The last of the larger units was installed in 1907, the other two engines having been in service since 1905. Each set was arranged with its own belt-driven exciter, and one engine could also be belted to an air compressor in the main engine room; but the compressed air for the plant was principally supplied by two motor-driven compressors in an adjoining room. At the rear of the plant building was the cooling tower for reducing the temperature of the engine-jacket water.

The fuel used in the engines was a partly refined heavy oil, testing 30° Baumé and containing about 19,000 pound-Fahrenheit heat units. From it the sulphur and other materials were removed. The oil cost 2.75 cents per gallon delivered in tank cars to the 11,000-gallon underground storage container, 30 feet south of the plant. The engines derived their immediate fuel supply from two 30-gallon steel tanks within the station, into which the oil was pumped by hand from the underground reservoir once every hour. The quantity of oil fed was exceedingly small. Under ordinary conditions the engines consumed from 10 gallons to 20 gallons of oil per hour, and produced 10 kilowatt hours per gallon of oil. The cost of producing a kilowatt hour in the Lebanon plant had averaged 2.8 mills for fuel oil alone and 1.9 mills for labor. Three men were employed about the station, but one of them gave only half of his time to the operation of the plant, having also outdoor charge of making arc-lamp renewals, overhead repairs, etc. Lubricating oil and waste averaged 0.2 mill per kilowatt hour.

The plant had an excellent load factor, its total output averaging about 41 per cent of the 24-hour equivalent of its maximum demand. During the eight hours of the working day its load due to motors averaged 78 per cent of its evening peak. Among the profitable power services supplied by this station was the city waterworks pumping plant, whose 60-horse power load occurred 18 hours daily during off-peak periods; a 25-horsepower planing mill, a 50-horsepower flour mill, and 60 horsepower in motors in a cream-separator factory. There was a total of 518 horsepower connected in 3-phase motors.

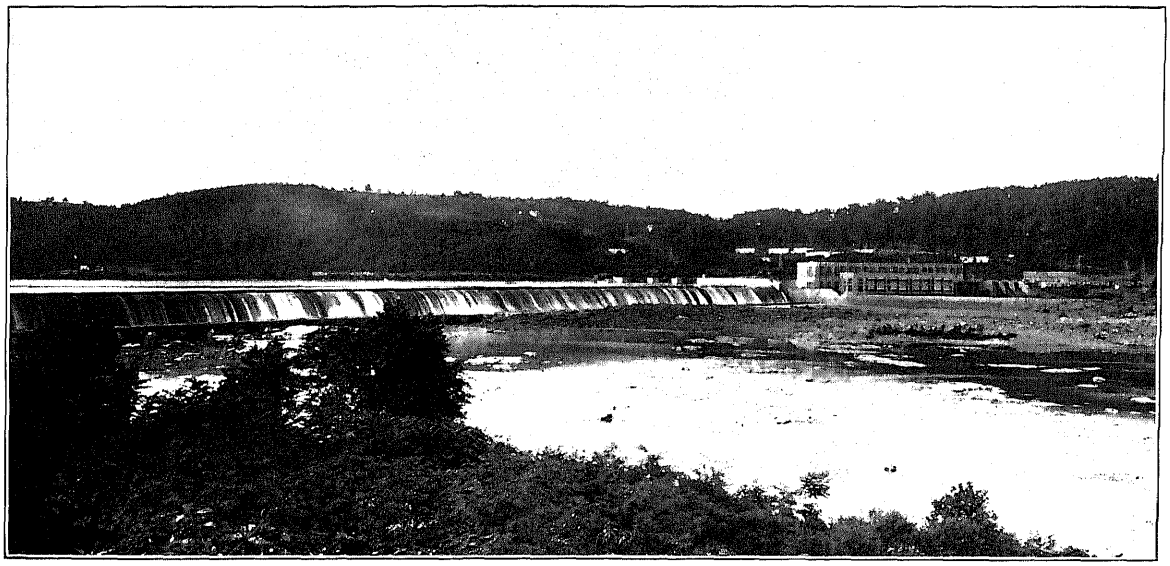
WATER POWER.

The remarkable extent of the development of water power in central station systems and transmission enterprises has already been referred to. It is true that the increase of such capacity applied separately to electric railways as shown by the statistics of that industry was no less than 859 per cent, but the total water power used by electric railways in 1912 was only 471,307 horsepower, as compared with 2,471,081 horsepower for central stations. This indicates that the railways as such have not gone in for the development of hydroelectric energy of their own on a large scale devoted specifically to street-car operation; a fact further established by the significant disclosure that with 6,000,000,000 kilowatt hours of current produced by railway power plants, nearly half as much more was purchased. Undoubtedly a large part of that came from central station steam plants, as in Chicago, New York, Boston, or Philadelphia, but a considerable proportion was taken from the hydroelectric systems whose output is embraced in this report, in the development of which, however, utilization in some degree by street railways was a factor. Thus the production of electrical energy at Niagara is registered entirely in the central station report, but the current itself not only is used in the operation of the local street railways, but is delivered for traction purposes at Buffalo, Rochester, Syracuse, and other points.

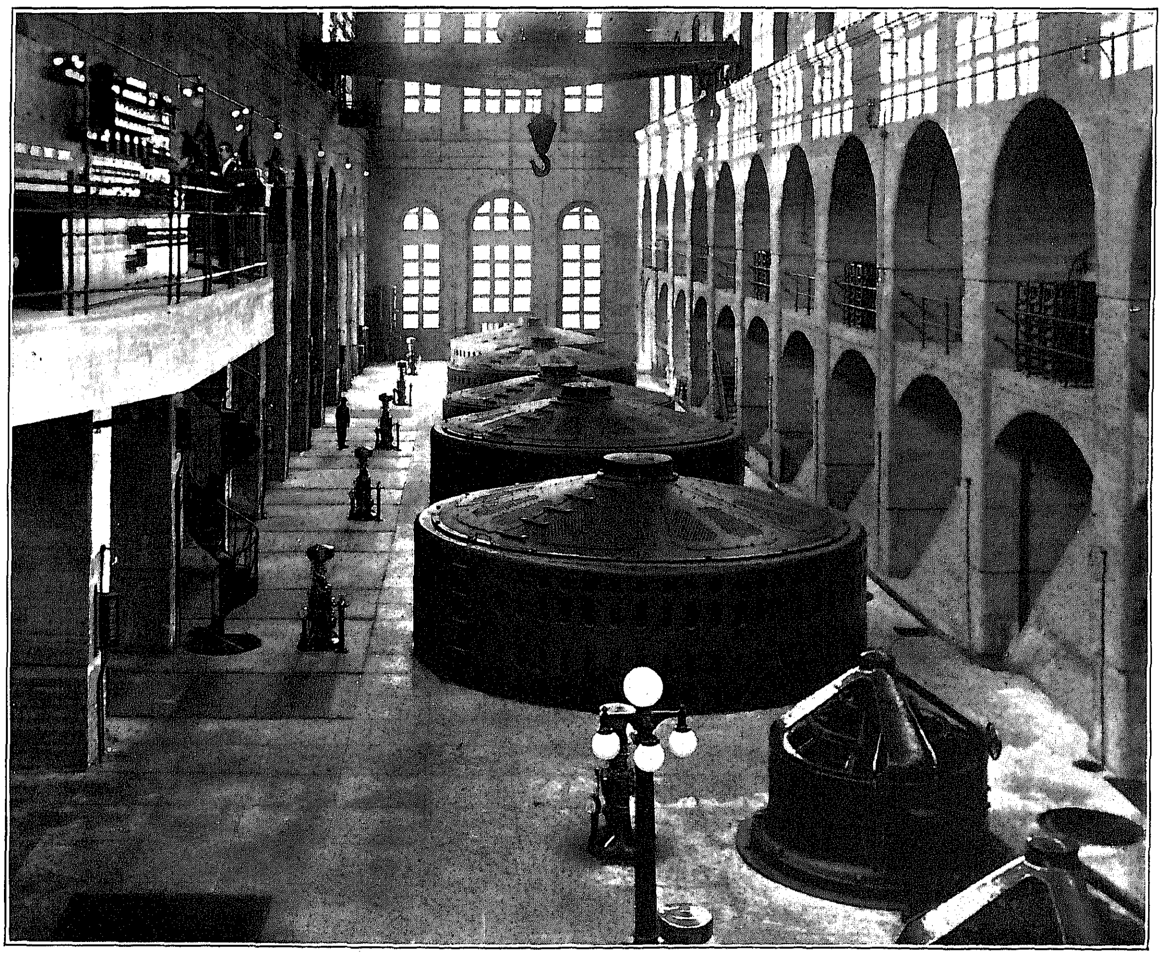
While the period covered by this report included some extraordinarily large and important enterprises, to which attention will now be called, it is worthy of note that few such have been of recent origin, one reason being that their construction and maintenance has proven in many cases expensive and unprofitable, as exemplified by two of the undertakings whose large financial requirements had much to do with the panic of 1907. It is also maintained that the restrictions and onerous regulations thrown around water-power development of later years with the idea of protecting the public have operated as a severe check, driving away capital that at best has had a poor return from this form of investment, and thus leaving the powers to remain wasted and the water still to flow idly to the sea. This is not the place to discuss the various political features of the "conservation" movement, but there is an obvious relation between the advance and perfection of such an art and the manner in which the investor is invited or repelled. If one feature more than any other could be said to arrest the gaze of the observer in the central station field to-day, it would be that of the consolidation into one system of numerous small plants in a given territory, requiring the application to ordinary central station operation of the principles and practices that hitherto have applied to pure power-transmission systems. It was the habit, only a few years ago, to think of central stations and of power-transmission systems as things apart. To-day, so swift is the march of events and improvement in the field, the two arts are found overlapping, blended, merged, and the whole revolution is predicated upon the conservation and utilization of hitherto wasted resources of power, upon the greater economy possible in dealing with existing equipment, and upon cheaper, better service to the public. At the water-power conference of the National Electric Light Association held in New York in April, 1911, and addressed by Secretary of the Interior Fisher, it was stated by the chairman, Mr. Henry L. Doherty, that over 33,000,000 unreservoired horsepower of hydroelectric energy still awaited development in the United States, and that at least $200,000,000 a year could be saved in coal, but that $7,000,000,000 would be required to create the necessary plants.

Pennsylvania Water Power Co.—The notable water-power plants of the period have been of both high and low head. One of the most striking is that of the Pennsylvania Water & Power Co. at McCalls Ferry, Holtwood, Pa., on the Susquehanna River, which, next to the St. Lawrence, is the largest stream flowing into the North Atlantic, drains 27,000 square miles, and takes up the annual precipitation over that area of approximately 42 inches. One of the largest in the

PENNSYLVANIA WATER AND POWER CO., McCALLS FERRY, PA.

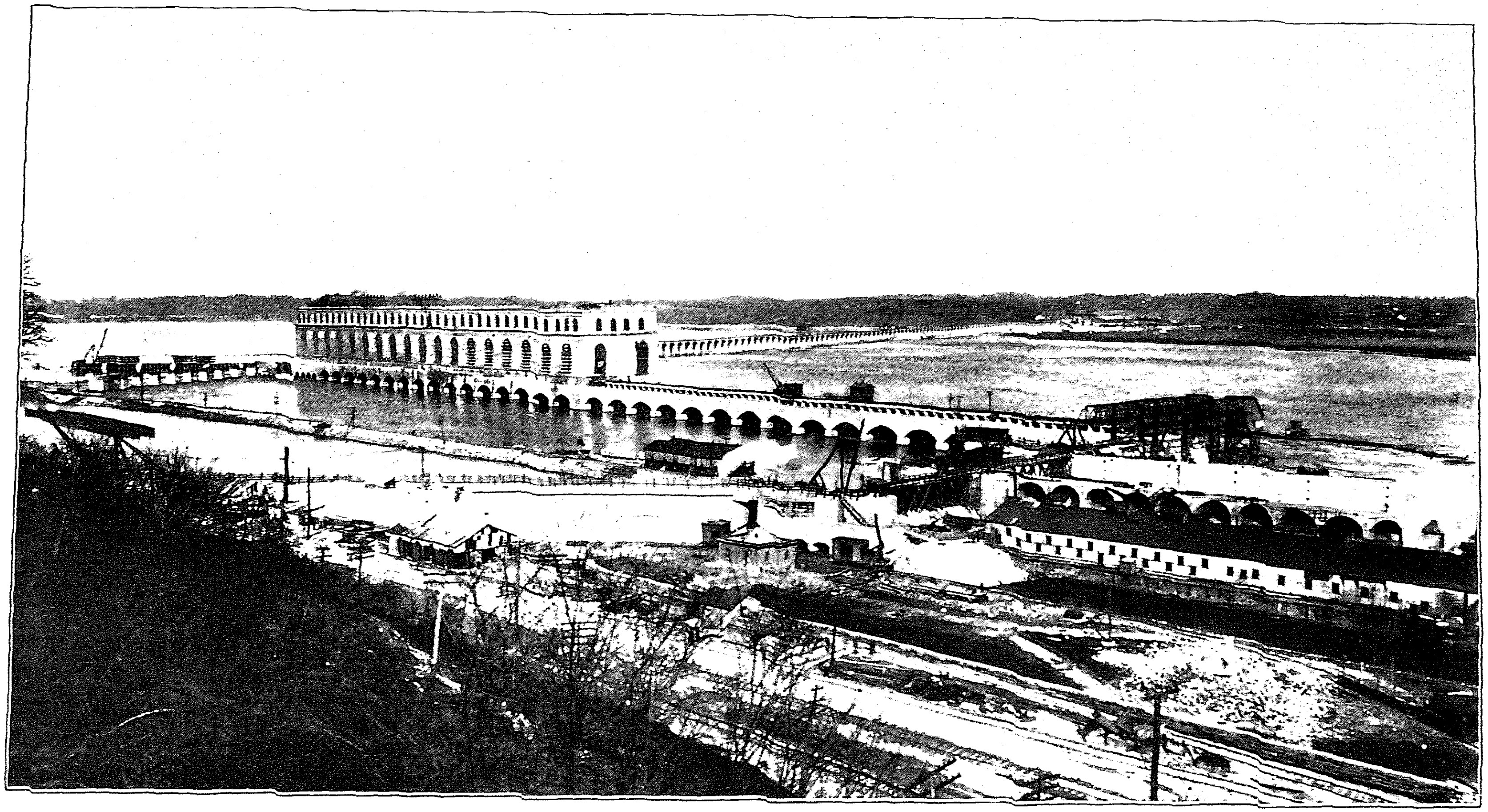


1. POWER HOUSE, SUSQUEHANNA RIVER.



2. GENERATING STATION, FIRST FIVE MAIN GENERATORS.

(Face p. 122.)



POWER HOUSE, MISSISSIPPI RIVER POWER CO., KEOKUK, IOWA.

world, the dam is half a mile in length, and is built of solid reinforced concrete with an average height of 55 feet and a base width of 65 feet. The storage reservoir thus formed covers an area of more than 3 square miles. The power house is also built of reinforced concrete at the easterly end of the dam, and is itself no less than 500 feet long, providing space for 10 hydroelectric units with a total maximum capacity of 120,000 horsepower, 7 being installed. The first five water wheels were of the vertical type, 15,300 horsepower each, and the later ones, of the same type, have by change of design been carried to 18,000 horsepower each. The generators are 3-phase, 25-cycle, 11,000-volt, the largest having a capacity of 12,000 kilowatts each, with the water wheels at 94 revolutions per minute under 53 feet head and 80 per cent gate opening. These are unusually large units for hydroelectric work.

Within a radius of 75 miles of the plant over 750,000 horsepower is being developed by steam, indicating the size of the market to be supplied. A large amount of power has been supplied to the Consolidated Gas, Electric Light & Power Co. and the United Railways & Electric Co. of Baltimore, 40 miles away, as well as to the Baltimore & Ohio Railroad. The Edison Electric Co. at Lancaster, Pa., 20 miles away, is also supplied. The first transmission line to Baltimore on a 100-foot right of way has 500 steel towers ranging in height from 58 to 120 feet, carrying two 70,000-volt circuits each consisting of three aluminum cables. This line is to be duplicated, owing to the rapid increase in demand for energy. The receiving substation in Baltimore has transformer capacity to handle 80,000 horsepower and provision for an ultimate 100,000 horsepower.

Mississippi River electrical development at Keokuk, Iowa.—The completion of this immense hydroelectric enterprise, involving an expenditure of about $25,-000,000, was one of the notable engineering achievements of 1912–13. The plant of the Mississippi River Power Co. at Keokuk, Iowa, is one of the largest that have ever been undertaken in this country and ranks highest among the plants of its kind in the world. It is located at the foot of the Des Moines Rapids, a dam having been constructed across the river between the cities of Keokuk, Iowa, and Hamilton, Ill., and the power house erected on the Iowa side. The history of the project of developing power from the Des Moines Rapids dates back as far as 1848, but no success attended the various attempts until in 1899, when the Keokuk & Hamilton Water Power Co. was organized, with a capital of about $2,500, raised by the sale of stock. The city councils of Keokuk and Hamilton were applied to for help, and by unanimous consent of the citizens $7,500 was appropriated and turned over to the promoting company, every cent of which has been paid back to the city treasuries. With these funds at their disposal further investigations were carried on, and Congress was applied to for a franchise, which was granted early in 1905 after a thorough investigation to safeguard the rights of the public. In the early part of 1910 sufficient capital had been assured for the larger enterprise, and the actual work on the construction was started on January 5, 1910, just 30 days before the franchise expired. The Mississippi River Power Co. was formed in the spring of 1911 to succeed the old Keokuk & Hamilton Water Power Co., and is now the owner of the entire plant and equipment. Current was delivered to St. Louis on July 1, 1913, as provided by contract made long before this water-power development was even an assured project.

The ultimate capacity is 300,000 horsepower. The present power-house installation comprises only one-half of the final equipment, although the substructure of the building is complete for the second section, which will be erected as soon as the demand for additional power warrants it. Several transmission lines have been erected, one 110,000-volt line covering the territory along the river as far south as St. Louis, 144 miles from Keokuk; one 66,000-volt line from Meppen to Alton; two 33,000-volt lines, one to Hannibal and one to Quincy; and one 11,000-volt line covering the territory up the river to Burlington. The bulk of the present energy is disposed of in St. Louis, where 60,000 horsepower is contracted for on a 99-year lease.

The plant consists of the dam across the river, the power house, a navigation dock and dry dock, a retaining wall for protecting the railroad tracks, and an ice fender—all one concrete mass with a total linear dimension of 2½ miles. One of the restrictions made by the Government when granting the franchise was that a deep waterway must be maintained, the old locks, dry dock, and canal being submerged under many feet of water with the new development. A lock and dry dock had therefore to be built by the water-power company and ceded free of cost to the Government, which has complete ownership of them. The lock, 400 feet long and 110 feet wide, is one of the largest in existence, the width being the same as that of the Panama Canal locks. Power for operating both the lock and dry dock, as well as the machine shops, is also furnished free from a separate turbine-driven air-compressor plant built by the company and turned over to the Government.

The dam is of the gravity type, built of mass concrete without reinforcement and keyed down into the limestone bottom of the river about 5 feet. The structure, including the east and west abutments, has a total length of 4,649 feet, a width of 29 feet at the top and 42 feet at the bottom, and a height from the bottom averaging about 53 feet. It comprises 119 equal spans, consisting of arches supported on piers between which the spillway sections are placed. The structure therefore acts as both a bridge and a dam, with the water flowing over the spillways beneath the arches. The piers are 6 feet wide, and the spillway sections 30 feet long and about 32 feet high. In designing this dam the extreme variations in the stream flow of the river had to be provided for, varying from a minimum of 20,000 cubic feet per second to a maximum of 372,500 cubic feet. While the normal operating head is 32 feet, this will vary from 21 to 39 feet from high to low water.

It was also necessary to limit the water level above the dam to prevent flooding of such land as had not been included in the flowage lands. The height of the spillway has therefore been designed to take care of the limit of the upper level. In order to keep the water above the dam at a constant level with smaller flow, steel gates have been provided on top of all the spillways. In extreme high-water periods these gates are all open, while at lower stages a sufficient number will be closed to maintain the pool above the dam at the proper level. The spillway gates are built of steel truss framework faced with steel plates, and they are raised or lowered by means of two electrically operated derricks, traveling on a track on top of the dam. Two standard-gauge railroad tracks previously used for construction are also located on the dam and serve the gates. The erection of this dam across the Mississippi River at Keokuk has formed a lake which covers an area of approximately 43,000 acres. It extends 65 miles upstream to Burlington, Iowa, and varies in width from 1 to 3 miles. Navigation for this distance, which formerly was very difficult during low-water periods, has therefore been greatly benefited.

The power house is located some distance from the Iowa shore, the intervening space forming the forebay. It lies almost parallel with the river, and the water runs through the intakes and draft tubes nearly at right angles to the river flow, resuming its normal direction in the tailrace, which is excavated in the river bed from the upper end of the power house along its entire length and for some distance beyond the downstream end.

The total length of the power house is 1,708 feet. It has been completed to its full height on the forebay side for the entire plant, including the future extension, while on the river side the downstream half has been built above high water. It includes, however, the draft-tube openings for the future units.

The width of the building is 132 feet 10 inches, and the total height 177 feet 6 inches, of which the height of the substructure to the generator floor is 70 feet and to the transformer floor 78 feet. The height of the generator room is 68 feet, which gives ample head room for the traveling cranes, and makes it possible to take out the turbine runners with their shafts and carry them to the repair shop at the end of the generator room.

To gain head, and in order that the draft tubes might always be covered with water, the power-house foundation has been extended down in the bedrock of the river about 25 feet below the limestone bottom. The substructure is built entirely of concrete, the intake, scroll chambers, and draft tubes being moulded in. It contains 211,400 cubic yards of concrete.

The superstructure is a reinforced concrete building of massive, dignified design, containing four floors. The generator room is located on the main floor along the river side. The exciter sets and transformers are installed in compartments in the center of the building, while the gateroom occupies the shore side of the building. The floor level for the exciter, transformer, and gate rooms is 8 feet higher than the floor of the generator room. For the low-tension switches, busbars, and reactances, there are provided two narrow mezzanine floors in the center of the building. Except at the ends, where additions are built out over the generator room to accommodate offices and store rooms, the fourth floor extends for the entire length of the building on the shoreward side only. This floor contains the switchboard-control room, the 110,000-volt switches, busbars, and lightning arresters.

From the forebay the water enters each turbine through four intakes converging into a scroll chamber moulded in the concrete around the turbine. The design of this spiral-formed scroll chamber and the intakes has been made very carefully in order to insure an equal velocity and force of the water all around the circumference of the wheel and thus obtain the highest efficiency possible. Three of the intakes for each turbine are entirely separate from the fourth, uniting in a common passage some distance from the scroll chamber for passing the water to the farther side of the wheel, while the fourth intake supplies the water to the near side. The scroll chamber has an average diameter of 39 feet and a height of 22 feet.

The outer openings of the intakes, which are 7½ feet wide by 22 feet high, are provided with steel gates sliding in cast-iron guides. For raising these gates, as well as the screens, a 75-ton traveling crane is provided, running the full length of the gatehouse. For lowering the gates, however, there is a separate brake mechanism for each gate. The water from the turbines is discharged to the tailrace through concrete draft tubes. These are about 60 feet long, gradually curved from a vertical to a horizontal direction. The foundations at their outlets are about 25 feet below the normal river bed. The draft tubes have a diameter of 18 feet at the wheels, but their cross section changes from a circular shape at this point to an oval at the outlet, the tailrace openings measuring 22 feet 8 inches in height by 40 feet 2 inches in width. This enlargement and change in shape is calculated to reduce the discharge velocity

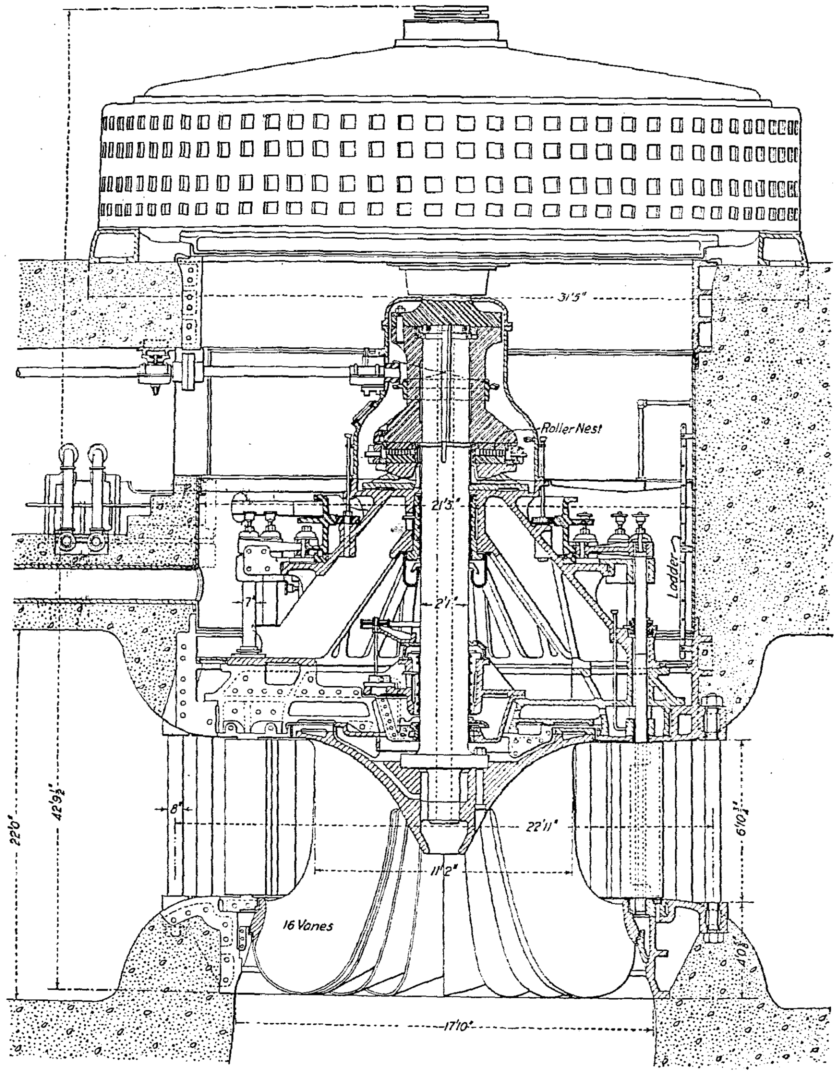
MISSISSIPPI RIVER POWER CO., KEOKUK, IOWA.

1. GENERATING STATION.

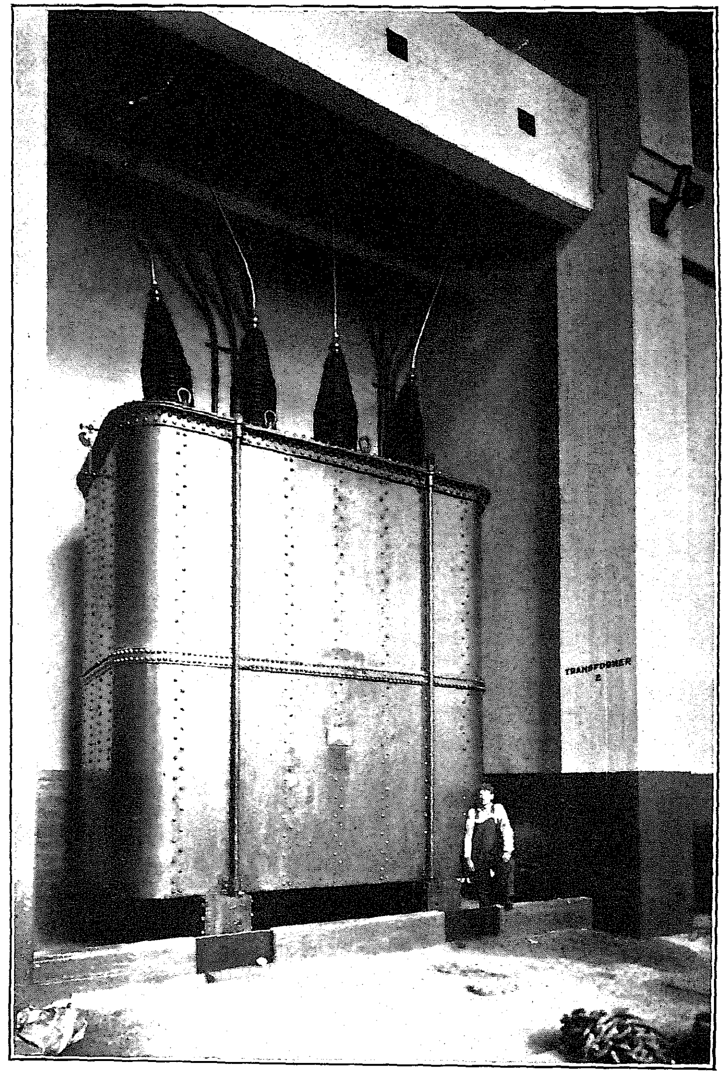
2. CONTROL SWITCHBOARD.

(Face p. 124.)

MISSISSIPPI RIVER POWER CO., KEOKUK, IOWA.



1. CROSS SECTION OF 10,000-HORSEPOWER VERTICAL SHAFT SINGLE RUNNER TURBINE.



2. NINE THOUSAND KILOWATT-AMPERE TRANSFORMER (110,000 Y 11,000).

of the water to four feet per second at the outlet into the tailrace.

The initial installation comprises 15 turbines of the vertical single-runner type with a normal rating of 10,000 horsepower each, based on a head of 32 feet. Their design is, however, such that they will operate efficiently with a head varying from 21 to 39 feet. The actual speed is 57.7 revolutions per minute, the specific speed 338, and the maximum efficiency at normal head about 88 per cent.

The turbine itself is placed at the bottom of a large concrete-encased steel cylinder called the pit liner. Bolted to the upper and lower ends of this steel shell are large cast-iron rings, weighing 30 to 40 tons each, which support the entire weight of the unit, or approximately 1,000,000 pounds. Each turbine has 20 cast-steel guide vanes, which are placed just below the pit-liner cylinder between two heavy cast-iron foundation rings, which are separated by 8-inch bolts.

Each runner has 16 vanes, the outside diameter at the bottom being approximately 17 feet and at the top 12½ feet, the length being 11 feet. The runner is mounted on a forged-steel shaft, which has a diameter of 25 inches and is coupled to the generator shaft above. The weight of each runner alone is 64 tons, while the weight of the total revolving element, including the water thrust and the generator field, is 275 tons. This weight is carried by a thrust bearing at the top of the wheel and below the generator, the bearing being supported from the upper foundation ring. Two guide bearings are also provided for each turbine unit. Two different kinds of thrust bearings are used. Twelve of the units are equipped with combination oil-pressure and roller bearing. Under normal operation, oil is forced between the two bearing faces at 225-pound pressure, separating these by a thin film of oil, on which the revolving element is supported. However, if for any reason the oil pressure or supply should fail, the upper bearing plate will settle down on a set of oil-immersed steel rollers, which will then carry the weight of the rotating element without interrupting the operation. The three remaining thrust bearings require lubrication at only atmospheric pressure.

For lubricating the pressure-type thrust bearings each unit is provided with a separate triplex oil pump chain-driven from the governor shafts and having a capacity of 150 gallons per minute at 225-pound pressure. A central oil-supply system for the thrust bearings is also installed, to be used in case of emergency. This consists of two motor-driven triplex oil-pressure pumps located in the main pump room and pipes to the different bearings.

The lubricating oil for the guide bearings is furnished by either two water-wheel driven or two motor-driven pumps. The oil is pumped to large tanks, whence it flows by gravity to the bearings and thence to reservoirs under the lower bearings. From the reservoirs it is pumped to the filtering and central supply tanks.

The oil can also be simultaneously pumped directly to the bearings and the gravity tanks. Revolving indicators, designed on the principle of water meters, are inserted in the piping leading to the guide bearings of each unit. These indicators are so adjusted that a certain number of revolutions correspond to a certain quantity of oil. Thermometers have been inserted in the ingoing and outgoing oil-supply pipes for each unit.

In addition to the main units there are two smaller turbines for driving the auxiliary generators furnishing power to the motor-driven exciters. These turbines, of the vertical type, have a capacity of 2,200 horsepower and a speed of 125 revolutions per minute.

The regulation of each turbine is accomplished by a specially designed oil-pressure governor, the balanced guide vanes being controlled through an exposed operating mechanism from the actuators, which are located on the generator floor in front of each unit. The operating mechanism consists of a rocker ring carried on ball bearings and connected by links to the cranks on the guide vane stems. The rocker ring is operated by means of piston rods from two high-pressure regulating cylinders, which, together with the relay valves, are located on the thrust-bearing floor. Under 200-pound oil pressure, these cylinders develop 250,000 foot-pounds, and the oil pressure is furnished by a separate induction motor-driven triplex pump for each unit. This pump and motor, as well as the accumulator and receiving tanks, are also installed on the thrust-bearing floor. By means of automatic control the pump is started up if the pressure falls below 140 pounds and continues to run until it has reached 180 pounds. The speed-control element and the anti-racing devices are installed in the governor pedestals on the main floor, and the governor fly balls are driven mechanically from a countershaft. On the governor pedestals are mounted various gauges indicating the oil pressure, the gate opening, and the speed, while the automatic regulation can be changed over to hand control if desired. The governor mechanism is also equipped with a motor connected electrically to the control switchboard, in order that the switchboard operator can control the speed of any unit when synchronizing. The governors maintain the speed steady within one-half of 1 per cent, and on decrease in load bring the speed to normal within five seconds.

The 15 main generators are located directly above the turbines and are spaced along the generator room 48 feet apart. Two auxiliary generators are equipped with direct-connected exciters mounted on top of the units, while the individual exciters for the main generators are motor-driven, the sets being installed in compartments on the same level as the gatehouse floor, 8 feet above the generator room. These exciter compartments are entirely open toward the generator room, and openings are further provided in the partitions between the compartments, thus affording a continuous passage through the whole length of the exciter gallery. The auxiliary exciter, lighting and power transformers, as well as the auxiliary switchboards, are all located in compartments on this gallery, facing the generator room.

The large main transformers are installed on the same floor level and back of the exciter sets, in compartments opening toward the gatehouse. The low-tension busbars and oil switches are located above these compartments.

The high-tension room occupies almost the entire top floor of the gateroom section of the building, at the same elevation as the roof of the generator room, and divided into a number of compartments, or, rather, rooms, for separating the various high-tension switches, lightning arresters, connections, etc. The outgoing lines run through bushings to the roof structure, to which the long river spans are anchored. These roof structures also support the line-disconnecting switches and the lightning-arrester horn gaps, while the arrester tanks are installed on the high-tension switch-room floor.

The control switchboards are located in a large room at the south end of the high-tension switch-room floor, entirely shut off from the generator room; but, by descending a short flight of stairs to an inspection gallery, a view of the entire generator floor is obtained. All the pumps for water, vacuum, and air-compressor systems are located in the tunnel below the transformers.

The present installation comprises the 15 main units of the 3-phase, 25-cycle, vertical revolving-field type, having 52 poles and operating at a normal speed of 57.7 revolutions per minute. They have a maximum continuous rating of 9,000 kilovolt-amperes, at 11,000 volts, and when operating at 80 per cent power-factor the temperature rise will not exceed 50 degrees Centigrade on the armature winding measured by resistance or temperature coils placed in the armature slots between the top and bottom coils, 50 degrees Centigrade on the field winding measured by resistance, or 50 degrees Centigrade on all other parts measured by thermometer. The machines are designed for a high internal reactance, limiting the instantaneous short-circuit current to about five times the normal value. At the same time they have an inherent regulation of approximately 8 per cent at unity power factor and 20 per cent at 80 per cent power factor.

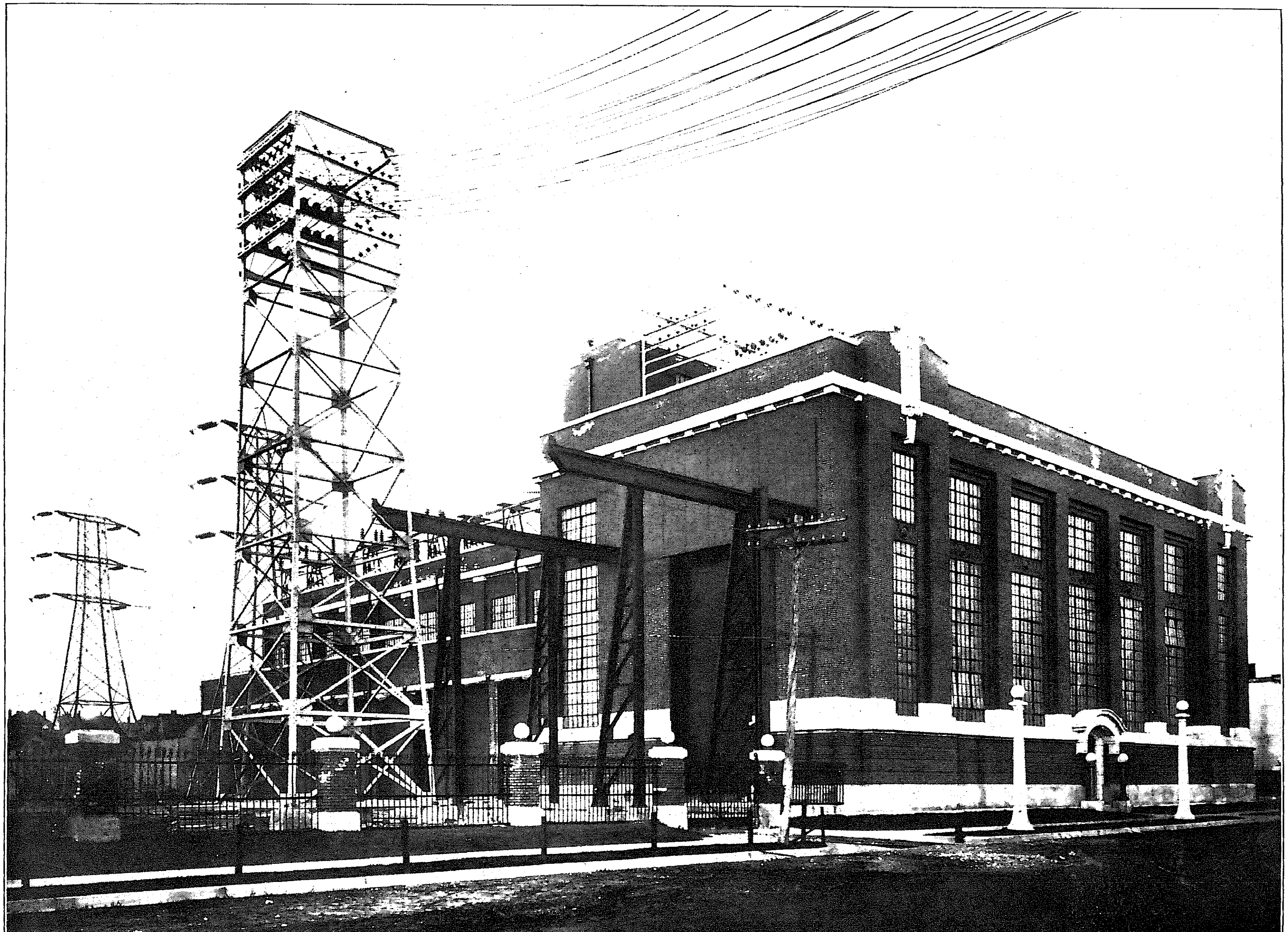
The system of excitation is of unusual interest. In order to obtain the greatest flexibility, each generating unit is provided with a separate exciter. These are motor-driven and operate at a much higher speed than would have been possible with direct-connected units. The exciter sets receive their driving power normally from an entirely independent source, consisting of two auxiliary water-wheel driven alternators feeding into a set of busbars which run the full length of the station; sectionalizing switches being provided only in the middle so that if desired the bus can be divided into two sections with one auxiliary alternator connected to each. The exciter sets can also be fed from the main bus, four step-down transformers being provided for this purpose. They connect the main bus with a second auxiliary exciter bus, sectionalized in four groups with one transformer for each group. Connections can also be established, in case of emergency, with one of the duplicate storage batteries used ordinarily for the operation of the oil switches.

The two auxiliary alternators are equipped with individual direct-connected exciters, and regulators serve to keep the auxiliary bus voltage constant. Besides supplying the exciter sets, energy is also normally taken from this bus for the power and lighting of the station.

The field current is conducted directly from the motor-driven exciters to their respective generators, the commutator brushes of the former simply being connected to the collector ring brushes of the latter, with solenoid-operated field switches inserted in one of the leads. The regulation is accomplished by adjusting the fields of the individual exciters, thus eliminating large field rheostats and energy losses in the main field circuits. Each exciter is provided with its own regulator, and parallel operation with compensation for cross currents is obtained by means of current and potential transformers which are installed in the generator leads and connected 90 degrees out of phase with each other.

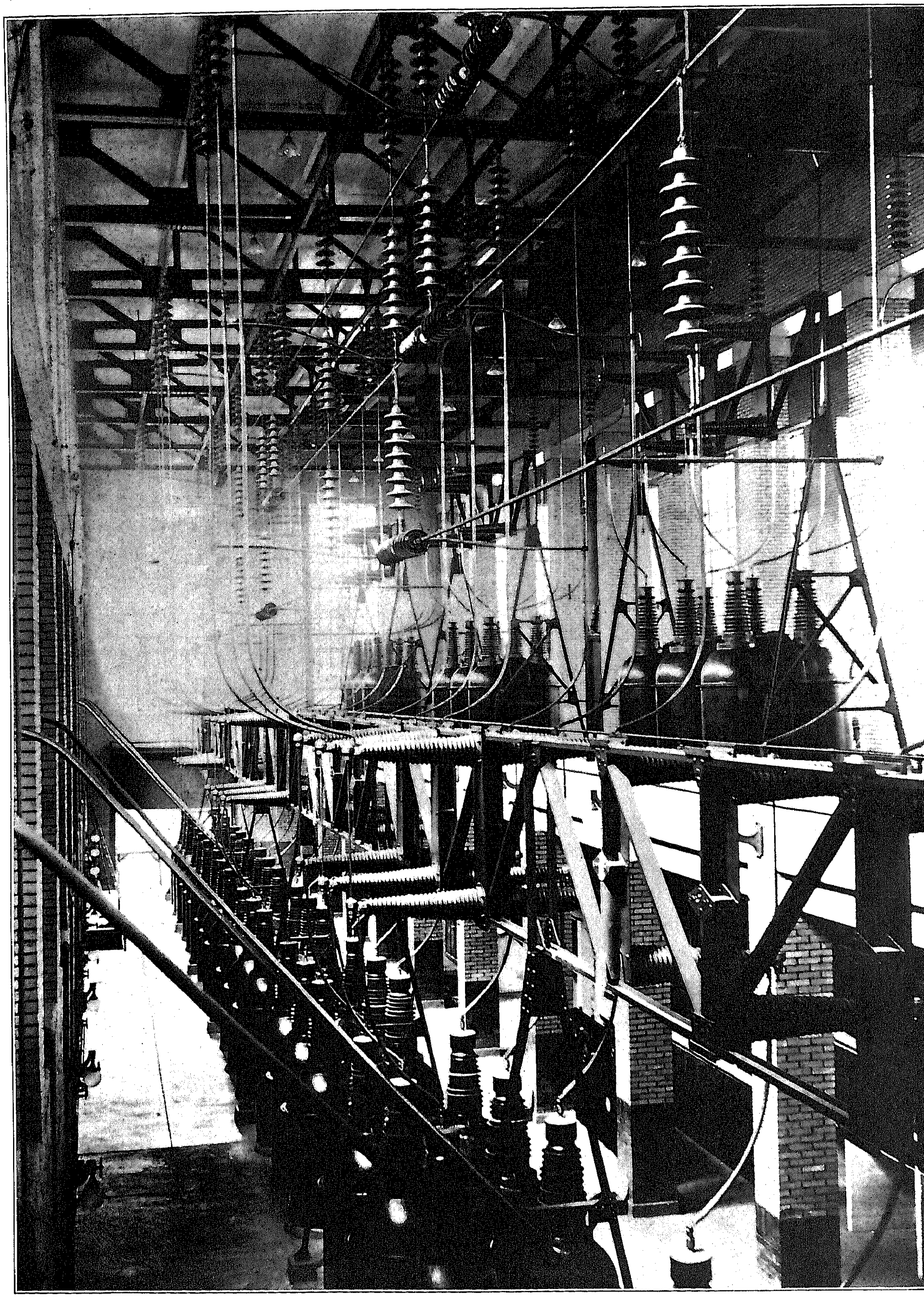
The two auxiliary alternators are of the vertical type direct connected to water wheels. They have a maximum continuous rating of 2,000 kilovolt amperes at 460 volts and operate normally at 125 revolutions per minute. Their general design is the same as that of the main units, with the exception that each is equipped with a direct-connected exciter mounted on the upper bearing bracket so that the machines can be started as self-contained units. The upper bearing bracket also supports a roller thrust bearing which carries the weight of the total revolving element, including the water-wheel runner and the water thrust.

There are nine main 3-phase oil-insulated water-cooled transformers of the shell-type construction, with a maximum continuous rating of 9,000 kilovolt amperes and a temperature rise not exceeding 50 degrees Centigrade based on an ingoing water quantity of 46 gallons per minute at a temperature of 27 degrees Centigrade. The low-tension, 11,000-volt winding is delta connected, and the high-tension 110,000-volt winding Y connected. The high-voltage winding is very heavily insulated and has been submitted to a one-minute high-potential test of 250,000 volts from primary to secondary and core, and across the full winding, while the high-tension bushings have



ST. LOUIS SUBSTATION, ELECTRIC COMPANY OF MISSOURI—ELECTRIC CURRENT GENERATED BY THE MISSISSIPPI RIVER POWER CO. AT KEOKUK, IOWA.

(Face p. 126.)



HIGH TENSION SWITCHING EQUIPMENT, ST. LOUIS SUBSTATION, ELECTRIC COMPANY OF MISSOURI.

been tested at 450,000 volts. The efficiency of the transformers at normal load is approximately 98.5 per cent; the regulation at unity power factor is 1.3 per cent, and the reactance 5.7 per cent. The supporting framework, which holds the core and coils together, is built of structural I-beams, channels, and angles. The tanks are made of boiler plate reinforced by numerous ribs and designed to withstand atmospheric pressure. The top covers are provided with gaskets, making the transformers practically air-tight. However, a 4-inch overflow pipe is provided and sealed with oil-paper gaskets. The cover, core, and leads can be lifted out of the tanks without detaching any parts, while the whole unit rests on a wheeled truck which permits moving the transformer from its compartment out into the gatehouse where it may be handled by the crane.

The cooling coils are of 1½-inch wrought-iron pipe, each coil being made up in three sections, the total length being 1,834 feet. They are designed to withstand a water pressure of 500 pounds per square inch. The water for cooling purposes is pumped from the gatehouse by motor-driven centrifugal pumps, after which it is filtered and led to the cooling coils. A duplicate system of piping is provided, the valves and visible discharge nozzles being mounted back of the transformer compartments on the walls facing the generator room.

Each transformer requires about 10,000 gallons of insulating oil, and a complete piping system with pumping equipments has been installed for handling this between the cars, tanks, and the various transformers. Large storage tanks for both filtered and unfiltered oil are installed in separate compartments in the lower tunnel below high tailrace water level, the tanks being embedded in sand as a fire protection. Each transformer occupies a floor space of approximately 9 feet by 16 feet. The height to the top of the cover is 18 feet 6 inches, and to the top of the high-tension leads 24 feet 3 inches. The weight of the complete transformer units, including the oil, is 246,000 pounds.

The contract entered into to supply 60,000 horsepower of electric energy to the public utilities of St. Louis is very elaborate. The base rate made is $18 a horsepower year at 60 per cent load factor. However, by an interesting provision, it is agreed that there shall be a revaluation every 10 years, made by arbitrators, if necessary, to fix anew the rate for electrical energy according to the fluctuation in the market price for coal as determined by taking the average for a term of two years before the date of revaluation. The base rate for coal is taken as $1.42 a ton. For each increase or decrease of 1 cent in the price of coal a corresponding increase or decrease of one-half of 1 per cent shall be made in the price of the hydroelectric energy. Thus, if in 10 years the price of coal has gone up 20 cents a ton, the price of the energy delivered in St. Louis will be advanced 10 per cent, making it at that time $19.80 a horsepower year. Similarly, a reduction in the price of coal will mean a reduction in the price of electricity under the St. Louis contract, which is for a term of 99 years.

Other low heads.—The report of 1905 described a plant of 21 feet head belonging to the Indiana and Michigan Electric Co. on the St. Joseph River, Michigan. On the same river the same company has obtained 2,000 horsepower from a 10-foot-fall plant near Buchanan. The concrete dam has a spillway 396 feet in length, its sill creating a head of 10 feet above the tailrace. The generating plant is housed in a brick structure 272 feet long on a massive concrete foundation forming part of the dam.

In October, 1911, an interesting plant was put in operation under an 11-foot head at Marseilles, Ill., supplying energy to half a dozen lighting systems as well as to 125 miles of interurban railway. The Marseilles plant utilizes water from the Illinois River, which was first dammed at that point some 40 years ago. Power is still supplied to local industries from the fall thus made available and also to this new plant. The difficulties in utilizing so low a head for hydroelectric work are the very low speed of the wheels, if the individual wheels are to be of any considerable power, and the regulation, which becomes increasingly difficult as the head falls. There is also very frequently extreme trouble from "drowning out" the wheels during times of flood, and extraordinary means have often to be taken to secure anything like uniform speed of the wheels on account of the variable head. In this particular instance the trouble from variable head was less than would be found in many comparable plants. With only 11-foot head available, large horizontal turbines were practically out of the question. It has been not unusual in such cases to install several turbines with vertical shafts connected by beveled gears to a common driving shaft by which, either directly or indirectly, the generator is driven. In this way it becomes possible to combine several fairly high-speed wheels on a single generator which can then be of normal construction and speed. The objections to this plan are the loss of efficiency in the gearing and the amount of space taken. Such construction calls for costly mechanical equipment and a loss of energy in the gears greater than would ordinarily be found in a change of the design in the dynamo to adapt it to lower speed. European practice has gradually drifted away from this construction for hydroelectric work toward the use of special very low-speed generators, direct-connected to the water wheel on the vertical shaft. In the Marseilles power house this later plan of operation has been adopted with admirable results. The old hydraulic equipment did not lend itself readily to this arrangement and there was installed in the new power house along the old lines, three 62-inch turbines being geared to a common horizontal shaft driving a single generator, in such groups as fully to utilize the old equipment. The later units are of 320 kilovolt-amperes each. The generators are of a typical umbrella type, each directly driven from a 74-inch vertical-shaft turbine at 75 revolutions per minute. One specially interesting feature of the equipment is the means taken to support the weight of the revolving parts, necessarily considerable, since in addition to the runner of the turbine the rotor of the generator is some 10 feet in diameter. The low head and considerable weight were unfavorable to the use of the ordinary water-step support, and in this case the entire weight of the revolving parts is taken on a roller bearing, oil-lubricated, at the top of the umbrella. In other words, the rotor and the runner are hung from a thrust bearing at the top of the unit, where they can be inspected with the greatest readiness. The arrangement is such that the rotor and, if necessary, the runner can be easily lifted out by the traveling crane. Each individual turbine is controlled by a quick-acting governor, operated by pressure oil and controlled by a push-button switch on the main board, so that the speed of the machines can be very easily adjusted for the purpose of synchronizing.

A plant with 13-foot head was started in July, 1910, in north-central Kansas by the Rocky Ford Milling & Power Co., securing 800 kilowatts in capacity from 3-cycle, 60-volt generators, delivered into the city of Manhattan, 3 miles away, at a pressure of 6,600 volts to a local distributor, the Manhattan Light, Ice & Power Co., which maintains its steam plant as a standby. The generating company does not sell its energy outright to the distributing company, but accepts as its payment a fixed proportion of the amount paid by the consumer at his prevailing rate. By this arrangement the distributor pays all the charges for getting the current delivered to the retail purchaser, as well as for selling, metering, billing, and other local expenses.

Water power development in Atlantic seaboard and East South Central states.—In the Atlantic seaboard states the medium water-power heads have found their development, while on the Pacific slope extremely high heads are not uncommon. The census period has witnessed several important developments both in New England and south of the national capital. In New England the conspicuous example is the Connecticut River Transmission Co., which, beginning a few years ago with a plant on the river at Vernon, Vt., of 20,000 horsepower, has grown into a large enterprise, reaching through its circuits such cities as Fitchburg, Clinton, and Worcester, Mass., and Providence, R. I., with energy developed at a series of plants all capable of feeding into the common transmission network, in which the line pressure runs up to 120,000 volts.

The Southern Power Co. has long been a leader in electrical power development and transmission, and its work has been instrumental not only in stimulating a great variety of industries in North and South Carolina, but in setting an example to other sections of the country. This company now has operating voltages of 100,000 and transmits energy to a distance of 210 miles, a range exceeded slightly at probably only one or two other points within the United States, and nowhere else in the world.

An interesting southern plant which went into operation during 1911–12 is the third installation of the North Carolina Electrical Power Co., of Asheville, N. C., on the French Broad River, 25 miles northwest of that city, in the mountains. The normal rating of the plant is 5,000 horsepower, and it represents in round figures an expenditure of $500,000, or $100 per horsepower. To make a suitable site it was necessary to raise and rebuild 2.5 miles of the track of the Southern Railway, which skirts the river at this point. The track at the dam was raised 20 feet higher than the old roadbed, the total excavation amounting to about 60,000 cubic yards, 80 per cent of which was of solid granite. The change in roadbed alone cost $75,000 and required one year to complete. All of the relocation work was done without interference with traffic, although there were operated over this line an average of from 30 to 40 trains per day. The dam is 530 feet long, 30 feet high, 43.75 feet thick at the base and 11 feet at the top. It is built of very heavy concrete, the large stones in some instances representing 5 cubic yards. The downstream face of the dam is curved in such a manner as to insure that the water will always cling to the surface and prevent the formation of a vacuum under the falling sheet. In the dam, next to the power house, are two circular mud gates, 7 feet in diameter, which are opened and closed by an electrically driven pump in the power house. The gates and cylinders are entirely submerged. The four penstock gates are among the largest cast-iron gates made; each gate covers a clear opening of 18 feet by 7.25 feet, and weighs 13 tons; and they are operated in pairs by an electric motor. There are two 1,875-kilowatt, 3-phase units, 60-cycle, 6,600 volts, with vertical shafts, the exciters being on top of the alternators. For transmission the electromotive force is stepped up to 66,000 volts. Duplicate transmission lines have been built on private right of way, one on the west side and the other on the east side of the river, to Plant No. 2, 6 miles northwest of Asheville, where there is a substation for distributing energy to Asheville, Canton, and other places. The other two hydroelectric plants owned by the company develop 4,000 horsepower, all of which has been utilized in Asheville.

One of the most notable of the recent hydroelectric developments in the South is that of the Ocmulgee River by the Central Georgia Power Co., at Lloyds Shoals, Ga., midway between the cities of Atlanta and Macon, where four streams, the South, Yellow, Alcovy, and Tussahaw Rivers, unite the liquid resources of a huge watershed and afford an unusually vast reservoir capacity. The reservoir itself has an area of some

4,000 acres, estimated to contain at least 3,000,000,000 cubic feet of water, and the water has been backed up by its creation for a distance of 15 miles. The dam is 11 feet wide at the crest, 95 feet wide at the base, and 1,710 feet between the abutments. It is erected between two high bluffs, which with the river bed are of solid gray granite. The power house, integral with the dam, is 200 feet long, while the spillway occupies 728 feet. The power house is a brick and steel structure, designed for six main generator units of 3,000 kilowatts, at 60 cycles. The voltage of 2,300 is stepped up to 63,000 for the long-distance transmission service over 41 miles to Forsyth and Macon on the south and 18 miles to Griffin on the north. Steel-tower transmission lines are used, the towers being on an average 500 feet apart. The right of way, which is owned by the company, is 100 feet wide and entirely cleared of standing timber. The Central Georgia Co. is a wholesaler, delivering to customers in a field where there is widely diversified industry requiring energy in considerable blocks, for cotton mills, cottonseed-oil mills, breweries, flour mills, fertilizer factories, packing plants, brick fields, knitting mills, railway plants, etc.

Another notable southern installation of the period is the 27,000-horsepower hydroelectric plant of the Eastern Tennessee Power Co. on the Ocoee River at Parksville, Tenn. The dam, built of concrete, is 840 feet long at the crest and is from 115 to 125 feet thick at the base, with a spillway 362 feet in length. The water enters the penstocks at a point about 30 feet below the crest. The main building of the power house, 165 feet long and 35 feet wide, situated immediately below the dam, of which its superstructure is an integral part, contains five main generating units, each rated at 5,400 horsepower when operating under 98 feet head at 360 revolutions per minute. The energy is generated at 2,300 volts, the electromotive force being raised to 66,000 volts by transformers housed in a wing at the north of the main building. In addition to the 27,000 horsepower available from this plant, provision for a secondary development of 11,000 horsepower at Parksville has been made by building two openings in the dam, to which penstocks leading to a power station about 400 feet below the dam will be attached. The energy available from this source will be used as a reserve to the main plant. Besides these plants, a second development of 20,000 horsepower has been under construction on the Ocoee River, the available water-power resources of which aggregate 75,000 horsepower. Energy is transmitted at 66,000 volts over two 3-phase circuits to Cleveland, Tenn., a distance of 13 miles from the plant; and from the switching station in Cleveland, where the lines separate, the energy is carried over single-circuit wood-pole lines 26 miles west to Chattanooga, Tenn., 85 miles northeast to Knoxville, Tenn., and 75 miles south to Rome, Ga.

High-head water-power plants.—Examples of low-head and medium-head hydroelectric plants are found chiefly in the Central, Eastern, and Southern states, and it is to the Pacific slope that one looks for the high-head systems and the more spectacular instances of power transmission. One such system is that of the Arizona Power Co., which has no great river flow to depend upon, but uses water direct from springs. Such a plant is quite exceptional. The source of power is the overflow from springs at Fossil Creek, which pour from unknown subterranean depths in Gila County, Ariz. These springs are heavily mineralized, so that the deposit from them coats the surroundings in a way that suggested the name. On investigation they proved to yield a flow which, except when temporarily swollen by one of the rare rainfalls of the region, remains absolutely constant year in and year out at 43 cubic feet per second. This is not a large quantity, but, backed by a drop of 1,600 feet, it makes a power with large possibilities. In the present development the whole of the head has not been utilized, since by employing the lower 1,100 feet it was feasible to utilize a small basin having an area of about 28 acres as a storage reservoir. Under this plan the power-house site, which, while, hydraulically speaking, upon Fossil Creek, is actually on the Verde River at a point where it is more convenient to drop the water into the river than at the actual confluence of Fossil Creek with the Verde. To the west and southwest, at a distance of 50 or 60 miles, are Prescott, Ariz., and an important mining district eager for cheap power. To get the water from the head works to the power house involved covering a distance of 38,000 feet, of which 12,000 feet is in reinforced concrete flume, 11,000 feet of concrete tunnels, 7,500 feet of steel gravity siphon (part of it on four long steel bridges) and 2,200 feet of wooden flume on trestles, the remainder being of reinforced concrete and steel piping, taking up the pitch downward to the power house. The power house itself contains three 1,800-kilowatt generating units with the customary electrical equipment for a line pressure of 45,000 volts, which is carried over 75 miles of steel-tower transmission line. One of the interesting features of the plant is the use of a large amount of reinforced concrete flume, to which the constructors were driven by the rocky nature of the ground. The smoothness of the flume is a very material advantage, particularly where the flow is rapid, inasmuch as the coefficient of friction is reported to be a good deal less than for ordinary ditches or the wooden flumes so extensively used on the Pacific coast. The storage reservoir is a very important feature of the undertaking. It is 5 miles from the head works and on the line of the concrete flume, and can be drawn off at an average depth of 10 feet over 28 acres, yielding sufficient capacity to run the entire plant for $3\frac{1}{2}$ days at the average steady flow of the stream. Below the lake, 5,600 feet of the hydraulic way next to it is a concrete-lined tunnel through the mountain, and the rest is reinforced concrete and steel pipe. The power house is installed with three 1,800-kilowatt generating units each driven by a 3,000-horsepower impulse water wheel, and the arrangement of the station is exactly as if three stations, each of one unit, were independently located at different points along the transmission line. The wheels have needle-valve regulation. The only switches are those on the high-tension side of the transformers. For purposes of distribution the line voltage is reduced to 11,000 volts in the substations, and energy is delivered to customers at 400 volts, 60-cycle, 3-phase. One mining company alone takes 2,000 horsepower.

Another unusual western plant, though not one of extremely high head, was put into commission in 1912, utilizing a head of 181 feet from the Thousand Springs, rising from lava beds in Idaho. Practically the whole state of Idaho and parts of Utah and Nevada are overlaid with a great lava sheet which covers the sedimentary rock, in some places to a depth of several hundred feet. This lava rock, now hardened and more or less impervious to water, lies on a sandstone equally impervious. But in the plane of contact between these two formations, underground streams are collected and flow for miles without meeting the light of day. In southwestern Idaho, where the Snake River has cut its channel more than 300 feet deep through the 100-foot surface layer of igneous lava, and then through the softer sedimentary rocks for 200 feet or more, egress is afforded for one of these underground rivers in a curious way. For a distance of nearly half a mile along the side of the canyon the water pours out into view from the plane of the lava contact, forming the famous Thousand Springs. The source of the water itself is unknown and certainly is not within 100 miles of the point where it emerges from its underground channel. The stream has an average flow of about 750 cubic feet per second and is very uniform in character, varying little during the seasons of the year. From the level where it emerges, 100 feet below the top of the canyon, a head of 181 feet is available down to the Snake River, which flows below, and here a 3,000-horsepower water-power plant has been constructed, with provision for extensions to 12,000 horsepower to utilize the full flow of the springs. Many different attempts have been made in earlier years to collect and utilize the flow from the Thousand Springs, but without success, owing to the peculiar nature of the problem, the difficulty of foundationing structures on the side of the cliff, and the long contact outlet of the water. The solution of the problem was the erection of a concrete canal wall on the side of the cliff at the outflow level. This wall is 400 feet long and in places 16 feet high. It forms a canal 20 feet wide, whose other side is the native cliff, and in which the water from the numerous spring outlets is collected. At one end for a distance of 150 feet the canal is widened out to 40 feet, forming a forebay opening to the penstocks which lead to the power house, nearly 200 feet below. The Thousand Springs development is capable of furnishing 12,000 horsepower. The initial machinery consists of two 1,500-horsepower units, spiral scroll-case water wheels, operating under the head of 181 feet, driving 2,300-volt, 60-cycle, 3-phase alternators. No gate valves are provided for the penstock tubes, but quick-closing head gates are inserted at the tops of the pipes. These head gates are hoisted by worm-geared motors, although it is possible to close them almost instantaneously from the power-house floor, by means of a tripping rope allowing them to fall and shut. From the alternators the electromotive force of the 2,300-volt, 60-cycle energy is stepped up to 40,000 volts for transmission to Idaho points, where the energy is chiefly used for irrigation pumping. The hydroelectric site is 8 miles south of Windell, Idaho, on the Snake River.

The "tying in" of hydroelectric plants with irrigation systems is also one of the newer and interesting features of work in the far West and on the Pacific coast. One example may suffice. For a number of years the Davis & Weber Counties Canal Co. has operated an extensive irrigation system supplying a large district near Ogden, Utah. By means of a canal extending far up the famous Weber Canyon and paralleling the Union Pacific Railroad's right of way, water is diverted from the Weber River and led out through a concreted channel, which for miles skirts the foothills and marginal slopes of the lower river, supplying water to the farms below and beyond. Realizing the water-power possibilities of the original irrigation system, it was found feasible to develop over 13,000 horsepower with the 200-foot head available between the canal and the river. Of this total capacity, an initial installation of 3,750 horsepower has now been completed. At the point selected as the most advantageous for this development the river flows on the far side of an old broad flood-plain (now rich farm land), bringing the natural discharge channel more than half a mile from the hillside canal. The water-power plant was accordingly located at about the midpoint of this 2,800-foot distance, being supplied through steel penstocks 1,400 feet in length, while a tailpiece of about the same length had to be excavated to connect the turbine shaft tubes with the river. In many respects the Riverdale plant is therefore unique, having huge steel penstocks of extraordinary length under full hydraulic head, and special features of design to control and withstand the remarkable normal and impact forces involved in these great moving masses of water. Utilizing its own available resources to the limit, the plant also "borrows" the flow of an independent irrigation ditch, later returning it to the lower channel by means of a centrifugal pump after extracting the net energy of nearly 200 feet of fall, which would otherwise be wasted. In spite of the difficult natural conditions to be overcome, and the completeness and excellence of its equipment, the plant has been erected at a very low cost, said to have been less than $45 per kilowatt.

The point of diversion of the main irrigation-ditch supply is in the Weber Canyon, 8 miles from the power house. The 30-foot channel has been concreted, rendering it waterproof and permitting higher velocities of stream flow without danger of "washing" the sides. Originally 325 cubic feet per second was the water allowance granted the irrigation company, but this quantity has since been augmented by additional fillings of 300 cubic feet per second. These amounts do not include, however, the 18 cubic feet per second obtained from the Riverdale ditch, which passes the plant. From September 15 to April 15, 643 cubic feet per second is thus available for waterpower use. During the remaining months of the year, which constitutes the irrigation season, only 318 cubic feet can be taken.

The initial installation comprised two principal water-wheel units, one of 2,500-kilowatt and the other of 1,250-kilowatt rating. Each is separately supplied from the gatehouse through its own steel tube, 1,400 feet in length. To form the forebay, the 30-foot concrete-lined canal on the side of the hill has been widened to 60 feet for a distance of 250 feet, providing a basin which is in part closed on the plant side by the gatehouse. This concrete and brick structure provides four penstock openings, including two other outlets for additional 2,500-kilowatt units in the future. Trash racks protect the intakes of the present penstocks, which can be closed, respectively, by 96-inch and 72-inch sluice gates, operated by 3-horsepower induction motors. These gates work under 19-foot head and can be manipulated from the power house or from the gatehouse itself, as desired. In the first 400 feet the penstock tubes drop 173 feet, reaching the flood-plain surface, on which they are carried, practically level, for nearly 1,000 feet to the power house.

Perhaps the most spectacular work embraced within the present census period, and fitly closing it, is that of the Big Creek development in central California carried out by the Pacific Light & Power Corporation. In addition to involving the highest voltage for transmission over the longest distance yet attempted, the installation possesses many features of interest from the purely hydraulic standpoint. It is 175 miles from San Francisco and 240 miles from Los Angeles, and the elevation is about 7,000 feet. In the total installation a fall of 4,000 feet will be utilized to generate 120,000 kilowatts for the system of the Pacific Light & Power Corporation, which already has an aggregate equipment rating of 70,000 kilovolt-amperes in six hydroelectric and three steam plants, and serves a population of 400,000 in Los Angeles and surrounding cities, including Pasadena, Riverside, and San Bernardino. The scheme involves the construction of two power houses, each with an ultimate equipment of 60,000 horsepower in four wheels, of which two are installed initially; and the plants can be operated independently. The generating units are 3-phase, 6,600-volt machines driven by two overhung impulse wheels on the same shaft. The combined rating of the two wheels of each unit is 20,000 horsepower. The current is to be stepped up to 150,000 volts for the line of 240 miles, which will consist of a double set of steel towers, each supporting three steel-cored aluminum conductors arranged horizontally. The line stands largely on a private right of way, and the plant is located in the Sierra National Forest, about 70 miles west of Fresno, the permit granted by the United States Department of Agriculture being the most important thus far issued.

The annual rainfall of the Big Creek watershed is more than 80 inches for an average year, and the run-off is equivalent to at least 50 inches. Three gravity-section concrete dams, two 100 feet and the third 164 feet in height, close all the natural openings in the basin. These dams are built upon solid granite formation, the construction material, with the exception of the cement, being available close at hand. Upon leaving the basin, Big Creek drops about 4,000 feet within a distance of 6 miles. With such a great difference in elevation, and with a reservoir to equalize the flow of the stream, a comparatively small amount of water is necessary for hydroelectric development. If there were no inflow for five months, it would probably be possible to operate during that period on storage alone, assuming a 50 per cent load factor. From the reservoir the water is led southwest through a 4,000-foot tunnel cut in solid granite to a steel flow pipe, which continues 6,800 feet along the surface to the mountainside above Big Creek. Here the water enters pressure pipes and drops about 2,100 feet through the wheels of power house No. 1 to the forebay of a second tunnel formed by a dam 70 feet in height, built across the bed of the creek. Tunnel No. 2 carries the water through solid granite to the crest of the gorge, about 4 miles southwest of power house No. 1. From the outlet of this tunnel the water enters pressure pipes and falls about 1,900 feet to power house No. 2. It will be possible to generate about the same power at each of the plants, as the forebay of the second tunnel is located at a point just below the juncture of Pitman and Big creeks, and the additional supply of water increases the power available at station No. 2 and in a measure compensates for the difference in static heads at the two plants. On November 8, 1913, the plant went into operation, transmitting 18,000 horsepower to Los Angeles at a pressure of 135,000 volts.

The Southern Sierras Power Co., a subsidiary company of the Nevada-California Power Co., of Denver, Colo., completed in 1912 a double, 3-phase, high-tension, steel-tower transmission line northward from its San Bernardino, Cal., plant, through the Owens River Valley for a distance of 236 miles to Bishop, Inyo County, where the company has two hydroelectric developments with an aggregate rating of 4,000 horsepower. The Southern Sierras Power Co. owns and operates a 5,000-horsepower steam turbo-generating and distributing system at San Bernardino, the distributing system at Corona, Cal., and also an 80-mile distributing system covering the San Bernardino, Riverside, Corona, San Jacinto, and Perris Valley districts, embracing a thickly settled territory of at least 50,000 population. The hydroelectric stations are on Bishop Creek, a tributary of the Owens River. One of the stations, which is already in operation, has a rating of 2,000 horsepower, while another of the same rating has recently been constructed.

At Long Lake, west of Spokane (Wash.), there has been under construction a new plant for the Washington Water Power Co., with the highest spillway dam in the world. It is 200 feet in total height, a fall of 170 feet has been created, and a storage lake 23 miles in length and averaging three-eighths of a mile in width has been made. Considering only 15 feet of storage, the water thus held for reserve amounts to 2,695,000,000 cubic feet, all of which is available not only for the Long Lake plant, but also for the older one at Little Falls. The dam is unique in at least two important particulars. Owing to the topography it has not been considered feasible to provide a spillway for flood waters except over the dam itself. This means that the dam is not only higher than any other spillway dam now in existence, but will at times of flood carry about 10 feet of water over its crest. It has been determined to hold the low-water level of the lake at the same level as at high water. This will be accomplished by the use of three roller dams of German type mounted upon the crest of the spillway, Each roller is 65 feet long and 19 feet deep, and will be operated by suitable power mechanism. The plant will consist of an ultimate installation of four 13,900-kilovolt-ampere generators having a continuous overload capacity of 25 per cent, each generator being connected to a water wheel rated at 22,500 horsepower. These are the largest water wheels ever built. The Washington Water Power Co., for which this new plant is needed, supplies electrical energy to Spokane, Wash., as well as to all the towns and cities in the Inland Empire within a territory extending approximately 100 miles west, north, and south of that city. It has 534 miles of 60,000-volt transmission line, two sections of which feed the Coeur d'Alene mining district in Idaho, the largest producing lead-mining center in the world. From Spokane to Wallace, Idaho, two independent lines traversing different routes carry the electrical energy to the center of the extensive lead-mining district, nearly 100 miles east of its point of generation. Another high-tension line extends south for nearly 65 miles into the fruit-raising Palouse country, one of the great wheat belts of the Northwest. From this line the towns along the route are lighted, flour mills are operated, and electricity is distributed for general use. Still another line extends 117 miles into the Big Bend country contiguous to the Columbia River, a rich fruit-growing and wheat-raising addition to the older Palouse country. The line to the north extends as far as Newport in the lumber region, traversing also a part of the state of Idaho. In Spokane the energy is distributed for the operation of over 24 miles of interurban electric railways and 88 miles of city lines, the company's two interurban lines connecting Spokane with Cheney and Medical Lake. The Great Northern Railroad shops are among the many industrial establishments supplied in Spokane from its circuits. The system generates a large part of its energy from water power at the very heart of the city, and has other sources of supply, as at Post Falls, Idaho, and more recently at Little Falls, Wash., 30 miles west of Spokane, with 20,500-kilowatt capacity.

Attention may be called to the automatic pumping station at the Mill Creek, Utah, plant of the Knight Consolidated Power Co., a singularly clever and ingenious method of conserving water supply in a territory where water is precious and the available amount is limited. This plant, working on the somewhat scant and variable supply of a mountain stream, fortunately rendering available a head of over 1,000 feet, at certain seasons of the year found itself painfully short of water. Had there been a second stream available, it would have paid to go to considerable expense to add its flow to that of the primary source of power. This has often been done to meet the exigencies of increasing load and stationary water supply. In this case no such auxiliary stream was available at or near the level of the main supply. A group of springs, however, at a lower level gave hope of additional water in useful quantity, and the bold expedient was adopted of pumping this supply to the level of the main headworks by electric power. A cubic foot of water which one can drop more than 1,000 feet onto the wheels below by pumping it less than 150 feet is not a source of energy to be held in contempt. The project as actually carried out involves an automatic pumping station driven by an induction motor coupled directly to a centrifugal pump capable of delivering 3.5 cubic feet of water per second against a head of 138 feet. The little pumping plant requires no attention. The result is very interesting. Except in May and June, when the primary water supply outruns the capacity of the pipe line, it pays to pump the spring water. At normal load it takes 67 kilowatts to deliver the 3.5 cubic feet per second at the upper level, and this quantity of water represents 237 kilowatts at the generators below. There is therefore obtainable, at merely the expense of the pumping plant, 170 additional kilowatts for 10 months in the year, amounting to a yearly output of nearly 1,250,000 kilowatt hours. It is sufficiently obvious that this additional supply, as large as that delivered by the central station in many a small eastern city, is a valuable asset. In point of fact, the saving is more than enough to pay for the pumping plant in a single year. It is an extraordinary case of "hoisting yourself by your jack boots," which only electricity could do in this fashion.

Development work done by U.S. Reclamation Service.—It is not perhaps generally recognized that the United States Reclamation Service work has carried with it a great deal of incidental power development. The following is from an article[1] by Mr. C. J. Blanchard, of the Service:

In the working out of a definite plan for the utilization of our natural resources and particularly the water powers, only one Federal bureau has been actually engaged in the engineering work of developing power. The Reclamation Service, organized in 1902 for the purpose of making habitable large areas of irrigable public lands, has constructed a number of power plants and has launched the Government in the power-producing business in several localities. Originally the idea of power development was solely for the purpose of pumping water to lands above the reach of the gravity canals, but wise management decreed when there was demand for surplus power that all such power which could be economically developed should be provided for in the construction of the plant. In this way the Government has found itself in the field as a maker and seller of electric power. It is a rather advanced step in the governmental activities, but no one has yet seriously questioned its practicability and certainly no one can gainsay its success financially.

The following table shows the present condition as well as the possibilities of power development on the reclamation projects:

PROJECT.	Horse-power devel-oped.	Possible horse-power.
Total	27,670	394,845
Arizona, Salt River	9,030	20,000
Arizona, Yuma		600
California, Orland		(1)
Colorado, Uncompahgre		10,000
Colorado, Grand Valley		2,000
Idaho, Boise	3,000	3,000
Idaho, Minidoka	10,000	30,000
Montana, Huntley	380	380
Montana, Lower Yellowstone		290
Montana, Sun River		(1)
Montana, Flathead		300,000
Nebraska-Wyoming, North Platte		(1)
Nevada, Truckee-Carson	1,660	8,000
New Mexico, Rio Grande		(1)
North Dakota, Williston	3,000	3,000
Oregon, Klamath		(1)
Oregon, Umatilla		75
Utah, Strawberry Valley	1,600	3,500
Washington, Yakima		15,000
Wyoming, Shoshone		(1)

[1] Not determined.

Discussing all these general conditions, and some of the data already presented, it is remarked by a leading expert, Dr. Louis Bell:[2]

A conspicuous item of the year in hydraulics was the sensational performance of the 6,000-horsepower turbines for the Appalachian Power Co. These wheels under test reached the highest point of full-load efficiency that has yet been recorded, 93.7 per cent, and at moderate loads still showed efficiencies well above those heretofore recorded for wheels under similar conditions. This remarkable performance resulted in an efficiency of 88 per cent from water to busbars, again a record figure well maintained at more moderate loads. The point of the matter seems to be that with wheels working under sufficient head to give a fairly normal design remarkable efficiencies can be obtained provided the output is sufficiently great. Wheels operating under freak conditions of speed or head can not be expected to do so well, yet it is very evident that wheel design on the whole has been so far improved within the past few years as to reduce greatly all the losses save those which must be classified as physically unavoidable. Another plant worthy of special notice on account of the hydraulic situation is that of Hale's Bar, on the Tennessee River. Here the fundamental difficulty is variable head, and in this case the variation between low water and flood is from 40 feet to as low as 19 feet. This very uncomfortable situation was met by placing three turbines on each vertical generator shaft, two of them being used together at times of fairly high head and moderate flow, and the third added only when the head is reduced by flood conditions. This is, of course, an extreme of variable head, but no better solution of the difficulty has been devised than this of multiple wheels. When the head is sufficiently high, placing them separately on the shaft, as at Hale's Bar, is the natural arrangement. The arrangement tried on one of the well-known Swiss plants, a composite runner with three sets of buckets arranged radially to meet the difficulty of extreme low head, has not yet been used in America. Nor has the scheme, tried years ago in one of the plants on the Willamette, of an additional turbine coupled to a separate shaft for low-head work connected to the dynamo shaft by pulleys and a wide belt, been repeated elsewhere.

[1] Scientific American, Apr. 5, 1913.
[2] Electrical World, Jan. 3, 1914.

TRANSMISSION SYSTEMS.

The transmission lines themselves have necessarily been the subject of much consideration in recent years, involving many technical problems, aside from those associated with rights of way, relationship to other electrical circuits of lower voltage, and the crossing of steam railway tracks. Incidentally, details have already been given in the foregoing text as to some of the lines, and a valuable table is herewith presented which affords a survey of the whole situation of the development during the census period 1907–1912 and its results during 1913. Owing to its great range there may be incidental minor errors or omissions, but its broad survey may be taken as comprehensively correct.

Increase in voltage.—The significant fact brought out by this table is the remarkable advance in the voltage or pressure of current on the circuits. A few years ago, pressures of 10,000 or 15,000 volts for transmission were regarded as extreme, but the table assumes that anything below 70,000 volts is now merely for "distribution" and should not be included in "transmission." In line with this is the ruling of the state commission of Virginia, which in dealing with a proposal to carry a 110,000-volt line along a railroad right of way, decided favorably as to its feasibility and safety. It has become altogether a matter of proper construction. The whole tendency has been toward the placing of these high-voltage circuits on steel towers, but a great many lines in the pressures below 70,000 volts are carried on wooden poles.

Tower and line construction and installation.—A typical steel-tower installation at high voltage was that put in operation in 1911 for 135,000-volt transmission from Au Sable to Flint, Mich., 125 miles away, and also to Battle Creek, 65 miles farther, tying in at various other points to the 44,000-volt network spread out over southern and central Michigan. The transmission line comprises a single 3-phase circuit of three No. 9 copper wires carried on suspension-type insulators hung from the cross arms of 55-foot steel towers. Two braced bracket arms extend from one side and one arm from the other, carrying the wires at the apices of a tipped isosceles triangle with a 12-foot base and 17-foot sides. The lowest wire is 40 feet above the ground. The suspension insulators to be used have eight disks linked in series, each disk having been tested to withstand 75,000 volts continuously, and 100,000 volts for a brief period. Each complete eight-disk porcelain insulator measures 52 inches from the tower hook to the line conductor.

A clear right of way into each substation was purchased for the 135,000-volt lines. At the substation the end wall of the building is apparently cut away, leaving only a hanging pediment which serves as a rain shield to protect the vertically downward entries of the wires through bushings in a horizontal shell carried by a second wall several feet inside the building line. The high-tension lines are delta connected to the transformers, subjecting the insulation to the entire 135,000-volt stress. It appears that a line of such high insulation is little injured by lightning strokes. In fact, the 110,000-volt Grand Rapids line has given less trouble than many others of much lower potential in the system, and although afforded no lightning protection, has operated through the most severe storms without interruption.

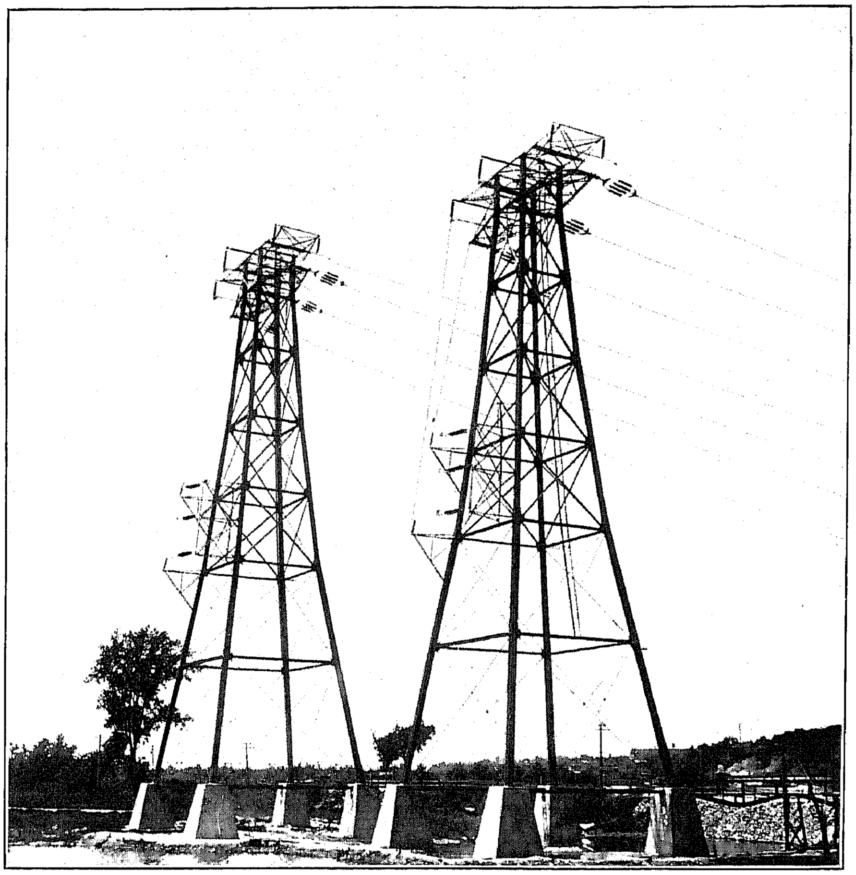
During 1912 the Central Colorado Power Co. adopted a wooden transmission-tower construction for a new 70-mile line at 100,000 volts. Each tower comprises one 45-foot and one 40-foot pole, which are set into the ground to a depth of 5 feet 6 inches. At the ground the poles are separated by a distance of 17 feet 6 inches, and converge to a distance of 11 feet at a level 35 feet above the ground. The cross arm is formed of a pair of 4-inch, 5¼-pound steel channels bolted together at their ends and inclosing the poles as a bow spring. Although pinned to the poles by through bolts, the spring pressure of these deflected channels is sufficient to hold them securely in position. A 10-inch spacing block is inserted at the mid-point of the bow, and the channels are braced to the poles with 4-foot knee pieces. These towers are spaced at 500-foot intervals throughout the 70-mile line. The arrangement of the suspension insulators places all 3-phase wires in the same plane. The ground wire is carried at a distance of nearly 8 feet from the nearest conductor. At each pole a ground tap is run down under staples and wrapped in a spiral about the pole butt to provide a permanent earth connection. The Central Colorado Co. has used a construction similar to this in some of its 13,000-volt lines, where the bow-spring cross arms are formed of two 6-inch by 6-inch hardwood members. With this construction, spans as long as 1,100 feet have been used.

Another special modification used on these 13,000-volt lines, where it is desirable to avoid guying against the fierce winds that prevail in the region, has been an A-frame arrangement. Two 30-foot poles are erected 30 feet apart, at an angle of 30 degrees with the perpendicular, forming an equilateral triangle. The frame is linked and braced by ⅝-inch bolts extending through plate crosspieces. At distances 6 feet down each pole, measured from the apex of the frame, provision is made for attaching strain insulators, the jumpers between spans passing around the poles. The top wire is then attached to the frame crosspiece, while the lower conductors clear the ground by 20 feet. This construction has been used in a mountainous country for a distance of nearly 3 miles, the maximum of the 47 spans being 1,100 feet.

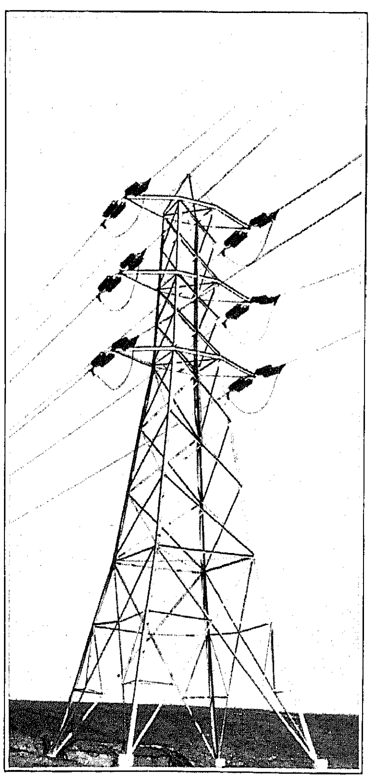
Some idea of the general conditions prevailing in high-voltage "distribution," as distinguished from "transmission," may be formed from the 1912 report of the committee on electrical transmission of the Ohio Electric Light Association, comprising information as to a number of lines operating at from 6,600 to 33,000 volts in Ohio, Indiana, and Kentucky. The committee reported that the practical working radius of 2,300-volt transmission was very limited, being about 1 mile for 25 cycles and 3,700 feet for 60 cycles, when the wire is loaded to its carrying capacity and the pressure drop is 10 per cent. The transmission-line design centered on the operating voltage. A good rule was 1,000 volts per mile of line. For example, a 6-mile line would require 6,000 volts. The usual spacings were summarized as follows:

VOLTS.	Minimum spacing, inches.	Maximum spacing, inches.
6,600	12	48
13,200	18	36
22,000	30	36
33,000	36	72

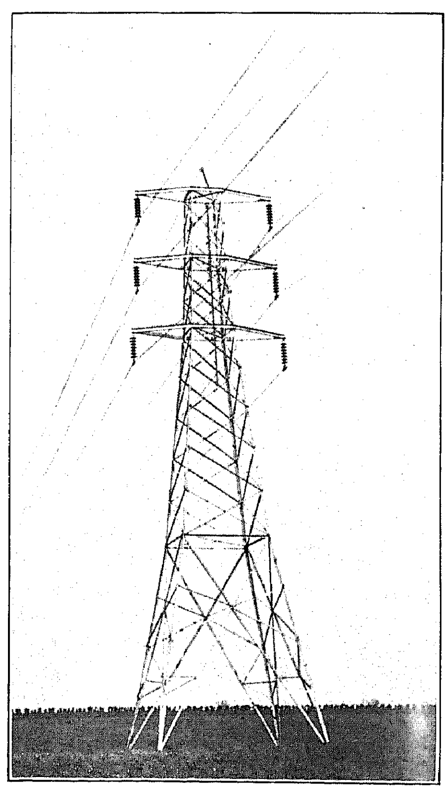
The greater the number of provisions against lightning, the better the possibility of uninterrupted service. The aluminum-cell arrester had proved very efficient. It not only afforded a path to ground for lightning but aided in removing all internal line disturbances. However, this arrester had the disadvantage of the necessity for charging it each day, thus making its efficacy dependent on the operator. The multi-gap arrester



1. 135-FOOT RIVER-CROSSING TOWERS.



2. DEAD END TOWERS.



3. STANDARD TOWERS.

(Face p. 134.)

also relieved surges and was found very effective up to 13,200 volts. Ground wire was placed at the top of the line structure so that it had a shade angle of 45 degrees to the outside conductors. It might be a ⅜-inch stranded galvanized plow steel or bimetallic wire. The ideal construction comprised ground wires at the highest points of the poles and aluminum-cell arresters at both ends of the line and in the center.

Transmission work in recent years has seen the introduction of a great deal of aluminum for the circuits, its use being naturally controlled more or less by the ruling price for copper. In some instances the newer metal is associated with steel as a core, the same practice being followed also with copper. In the Big Creek-Los Angeles transmission, 241 miles of double circuit, the use of very large steel-core aluminum conductors is to be noted. Following the usual practice of the day, the area of the steel in these cables is approximately one-seventh that of the aluminum, there being seven steel wires around which are stranded 54 aluminum wires, giving the cable a diameter of 950 millimeters. The critical current pressure with this conductor on a 17-foot spacing would be 210,000 volts, so that there is an ample margin against the dangerous formation of "corona" at the normal voltage of the transmission at 150,000; while with copper the spacing between the circuits would be 30 feet to secure the same factor of safety. The Pacific Gas & Electric Co. in California, in carrying out extensions during 1912–13, has made frequent use of aluminum, one of the most important instances being its Drum-Cordelia line. Copper has been used for the conductors on the sea coast and in regions where sleet and snow are most encountered, but elsewhere the line is built of 19-strand aluminum, No. 5 B. & S. gauge. The standard transmission-tower spacing is 800 feet on the level, with which there is no unusual sag with aluminum if freedom from sleet is enjoyed.

Suspension insulators have virtually abolished pin insulators for high-voltage transmission lines, and they are now used exclusively, the practical limit of the pin insulator being about 60,000 volts. The suspension type came into use in 1905 and marks a radical change in methods of operation. In the pin-insulator line, the conductor is held rigidly at every insulator, so that the lateral and longitudinal movement of the conductor is resisted at every point of support, with results that may be seen of all men after a severe snowstorm or a deposition of sleet. Time and again the telegraphic and telephonic systems of the country over large areas have been paralyzed and prostrated by the snapping of the wires or the breakage of the cross arms and poles. Suspension insulators are, however, except at dead-end connections, free to move in all directions, but what is thus gained in flexibility and safety has to be compensated for in large clearance spaces. The displacement of the wires in high winds is dangerous mechanically and electrically, so that longer cross arms are needed, and the height and cost of towers are increased.

Outdoor substations.—The development of outdoor substations has been one of the marked features of the period, associated with long-distance transmission work. The problem of furnishing electricity to isolated communities and consumers has received much attention and is now generally recognized as a serious and important undertaking. There never has been any question as to the desirabliity of giving service to outlying territories, providing the investment and maintenance charges were such that a fair return could be expected. Prior to the building of transmission networks and high-tension distribution feeders radiating from central points to small communities, the cost of lines to reach the small consumer, combined with the high cost per kilowatt of switching and protective equipment, practically closed a field now open to development. The situation, therefore, is improved, as the consolidation and unification of central-station systems have resulted in a large mileage of transmission lines passing through the districts ready and waiting for electrical service. The problem has resolved itself into the building of lines from a large-capacity centralized plant to definite points where loads of suitable characteristics to justify the expense can be secured. From these high-tension feeders, branches extend along the way, to farms, mills, stone quarries, grain elevators, irrigation projects, railways, pumping installations, dairy farms, canning factories, brick or tile plants, excavating shovels, etc.

The small generating station supplying a town or village is necessarily at a distinct disadvantage in the generation and distribution of electricity as compared with the larger stations, as the economy is low. This condition is due to the small quantity of power generated, the poor load factor, and the fact that the size of the enterprise does not justify the employment of high-class engineers or operators. The small generating station is therefore being quite generally superseded by a substation, supplied from a high-tension transmission line serving a number of communities. With one or more small towns as a nucleus, the transmission line is built—the first step toward supplying an entire district or even a county from a centralized plant. The supply of power along the main transmission lines has thus become a comparatively simple matter, aided largely by the outdoor substation, reducing the investment required and therewith the cost of the current furnished.

In this class of work the wooden-pole outdoor substation is extensively used. The steel-tower equipment has, however, many advantages and its use is steadily increasing. This is especially true since manufacturers have designed stations with proper equipment for quickly, easily, and cheaply handling heavy transformers. The development of switch gear which will not freeze has also had an important bearing on substation equipment. Improvements in high-tension chemical fuses have been pushed, and the general tendency in all the outdoor equipment has been toward simplicity and cheapness. The operation of outdoor transformers is held to be no longer experimental. In general the type is similar to that for indoor use, except that the cover and the leads are designed to shed moisture and furnish higher factors of safety by superior insulation.

It was to take care of small isolated loads that the development of the outdoor substation began, and these have afforded its greatest field to date. Complete outdoor installations up to several hundred kilovolt-amperes have enabled service to be given to isolated customers and small communities which otherwise could not be profitably served directly from the main transmission lines. It is possible to locate such substations almost anywhere, the structural and foundation requirements varying with conditions. The high-tension switching is usually limited to air-break types, instead of the costly oil switches, while lightning protection is afforded by either the electrolytic lightning arrester or the simpler horn type. Most of these installations have been free from elaborate secondary control, that provided, if any, being of the simplest type and established in weatherproof housings.

The application of the outdoor substation has been carried to large-capacity installations. The substation thus combines not only the functions of a switching station, but that of supplying a large load to a community. With substations of this character, involving attendance, it is necessary to provide a suitable building designed for at least part of the installation. What part of the high-tension apparatus may properly be installed out of doors depends largely on the saving thereby effected. The actual outdoor apparatus must be provided for separately, and a combination of the indoor and outdoor substation will in many cases prove most advantageous. In some cases it is feasible to place the whole outfit out of doors, including the low-tension control equipment, provided the latter is not extensive, but in most cases it is questionable whether the operating conditions permit this extreme. In cases where attendance is required it is believed advisable to install the secondary equipment outdoors. The manner of installing the outdoor equipment depends, of course, upon the size and importance of the layout. In general, the incoming and outgoing lines must have proper terminal structures for connection and distribution to the banks of transformers. The transformers themselves are provided with solid foundations, preferably of concrete, so designed that they may be removed on rails, and provision should be made for heating the cases if climatic conditions require it, while the piping for oil or water must be carefully considered.

A most important detail of the outdoor installation is that of providing proper facilities for repairing damaged apparatus, and large substations provide some shelter where such repairs can properly be made.

The space occupied by the outdoor installation is, of course, large, and adequate provision must be made for preventing anyone from coming in contact with the equipment. The element of safety to employees and the public can not be neglected, especially in view of the fact that the equipment of outdoor installations represented at the end of 1913 no less than 300,000 kilovolt-amperes in high-tension outdoor transformers.[1]

Many illustrations of this class of work might be cited. Among the most recent were two substations installed in 1912–13 by the Amherst (Mass.) Power Co.[2] Of these, one is located at Chicopee and the other at Agawam, Mass., both being supplied from the company's double-circuit, 60-cycle, 3-phase, 66,000-volt transmission line extending from Turners Falls to Springfield, Mass. Each station is of an ultimate 10,000-kilovolt-ampere capacity. In these plants all the high-tension switching apparatus for 66,000 volts and the transformers are out of doors. The low-tension apparatus at 13,200 volts is indoors, as well as apparatus at Agawam distributing at 2,300 volts. The control switchboards and instruments, motor-generator sets, etc., are not developed to the point where it is practical to operate them outside, but it is remarkable that in the exacting climate of New England such a general plan as this can be carried out with a considerable saving in first cost of the substation and no increase in operating expense. The note may be made that oil transformers of the radiator type are used. In outdoor transformers the oil freezes at −15 degrees Centigrade. Steps are taken to keep the temperature of the oil above that point by connecting the apparatus that may be standing idle to the busbar on the low-tension side from about January 1 to March 10 each year, thus securing artificial heat. The transformers and oil switches are connected by a complete piping system to a two-compartment oil tank buried in the ground, so that oil can be drained from any transformer or oil switch into its respective compartment of the oil tank and thence can be pumped through a portable oil-filter press back into the transformers or switches. Alarm thermometers on the transformers are connected to bells in the station. There is installed in the cover of each transformer a small heating unit taking 200 watts at 110 volts. The object of this unit is to keep the air in the top of the transformer, and especially the spare transformer when not excited, a little above the temperature of the air outside, so that in the process of "breathing," which is sure to be present to some extent in any large trans-

[1] Proceedings, American Institute of Electrical Engineers, February, 1914. Macomber.

[2] Proceedings, American Institute of Electrical Engineers, February, 1914. F. L. Hunt.

former subjected to varying temperatures, the air taken in, even though heavily laden with moisture, will have that moisture vaporized by coming in contact with the warmer air inside, rather than further condensed by coming in contact with cooler air inside, which would occur if there were no artificial heat inside the cover of the transformer.

When it becomes necessary to disassemble a transformer it is rolled on to a transfer truck upon which it is run into a compartment at one end of the substation where a hoist is available of sufficient capacity to lift and remove the core. Switch hooks, used for operating the disconnecting switches outdoors, are fitted with a copper cone at about the middle of the handle, the cone being grounded when the hook is to be used. All the outdoor aluminum lightning-arrester cans are painted white to overcome a difficulty experienced in climates where the absorption of the sun's heat by dark-colored cans has raised the temperature of the electrolyte of the arrester to a point where it was damaged. Two coats of white paint on these cans have been sufficient to keep the temperature of the arresters below the danger point in these installations, up to the present time. The same treatment may be applied with similar results to the transformers where excessive temperatures are reached on account of the sun's direct rays. The winter-weather test of these substations has been satisfactory in frost, sleet, and snow.

Each outdoor station is surrounded by an iron picket fence and all the equipment is set on concrete foundations extending below frost line and about 15 inches (38.1 centimeters) above the final level of the ground. Thus far in the operation of these stations nothing has occurred which indicates any important point of disadvantage in the outdoor arrangement, except that some difficulty was at first experienced in keeping the joints of the cooling radiators on the transformers oil-tight, due to the wide range in temperature to which they were subjected every 24 hours. The design of these radiators was changed, and the new radiators have thus far stood the test of wide temperature changes without developing leaks.

Outdoor apparatus is also used on this system at several of the local consumers' substations, where energy is delivered to factories, mills, etc., at 13,000 volts and stepped down to 2,300, 550, 440, or other voltages. The transformers are connected to the 13,200-volt circuit through combination horn-gap arresters and choke coils, and horn-gap disconnecting switches, and the power is metered at 13,200 volts by the use of outdoor potential transformers, indoor current transformers under shelter, and a meter in a box with glass cover. The tower stands approximately 20 feet high, the bottom of the transformers being about 10 feet from the ground.

STORAGE BATTERIES.

The use of storage batteries by central stations has continued to extend, and some of these equipments are of extraordinary size. The Consolidated Gas Electric Light & Power Co., of Baltimore, Md., possesses what is held to be the largest single storage-battery installation in the world, the next largest being owned by the New York Edison Co. The Baltimore company has a large steam station at Westport, just on the outskirts of Baltimore. It is also the largest user of the transmitted energy generated by the Pennsylvania Water & Power Co., at Holtwood, Pa., on the Susquehanna River, reference to which has already been made. Ordinarily the greater part of the load in Baltimore is carried by the hydroelectric station at Holtwood, a 40-mile transmission line connecting the terminal receiving station at Highlandtown, Md., with the generating station. In order to safeguard its customers against interrupted supply in case of mishap to the hydroelectric station at Holtwood, to the transmission line, or to the steam station at Westport, it was decided to install the battery. The battery house adjoins the substation of the company on McClellan Street, Baltimore, and was especially designed and constructed for the battery and its equipment. Provision has been made for an additional story to accommodate another battery of similar size, if necessary. The battery comprises 152 cells, each of which contains 133 lead plates. The cells are arranged in four rows and are covered with heavy glass plates. The total weight of the equipment is 616.5 tons. The battery is kept connected to the busbars supplying the direct-current service, and in the event of any interruption can immediately assume the load so as to carry it without interruption to the service. It will deliver 44,000 amperes at 250 volts for six minutes, or 11,000 amperes for one hour. The capacity at the six-minute rate is 11,000 kilowatts. The battery is thus able to carry the entire direct-current load on the system for a period varying from 10 minutes to several hours, depending on the magnitude of the load at the time of discharge.

ARC LAMPS.

It will have been noted that in the statistics for the estimated number of lamps wired for service the total of arc lamps in 1912 was only 505,395, as compared with 555,713 in 1907, thus indicating a 9.1 per cent falling off in that short period, although the whole 10 years showed an increase of 31 per cent. These figures of decline embrace a most interesting chapter in electrical history, and are eloquent as to the rapid changes now going on in the central station art. It is true that in the 10 years the number of arcs operated from municipal plants increased 80.8 per cent, and that from 1907 to 1912 they increased from 82,940 to 91,851, but this is simply a proof that the municipal plants for well-known inherent reasons do not respond so quickly in any of their enterprises as does private capital to advances in invention and industrial art, but follow the more conservative method of adding to an old plant rather than adopting the policy of scrapping it because the apparatus has become obsolete. Usually bonds have been issued for the installation, and the natural tendency is to keep as much of the plant going as possible until full amortization has occurred. In an industry like the central station, where one invention or improvement succeeds another in swift and even startling succession, it becomes imperative to make these advances in order to give the public better and cheaper service with the latest appliances even if relatively new machinery has to be scrapped and new capital risked. Obsolescence plays a large part in the field of electric light and power. It is not to be understood, however, that the municipal lighting systems have fallen behind quite as these figures would indicate, for many of the lamps enumerated are of the later modern types evolved during the period.

The development of the arc lamp as a street illuminant has been treated in earlier central station reports, and an account of the later arcs will be found in the census report on manufactures—Electrical machinery, apparatus, and supplies—for the Thirteenth Census. It may be remembered that single and double carbon, direct-current, open-arc lamps run in series from a constant-current arc generator were at first the base of the whole lighting industry, and they are still in use in some places. Series arcs run from alternating-current machines were little patronized on account of their lower efficiency. Constant-potential direct-current and alternating-current open arcs were in extensive use for a time, not as a part of civic lighting but for auxiliary illumination. About the close of the last century most of the plain open arcs were replaced by inclosed-arc lamps, having an inner globe chamber around the carbons, and were favored on account of their longer carbon life, steadier light, and lower cost and time for trimming, these qualities offsetting a lower efficiency. The direct-current series inclosed arcs were operated from arc dynamos of the old type at higher wattage and the alternating-current lamps were run from constant-current transformers. This latter transformer system has had a very wide use, but has lately been superseded in a large degree by "luminous-arc" lamps on series circuits supplied by mercury rectifiers and constant-current transformers. The use of constant-potential flaming arcs is also increasing. The alternating-current series inclosed-carbon arc lamp of 6.6 amperes has done the bulk of American street lighting for many years in the recent past, while more lately the 4-ampere, 300-watt magnetite or luminous arc has been successful in replacing the carbon arc, giving an available 300 candlepower; the titanium arc of 400 candlepower and 200 watts also making a place for itself. It is here that the issue for supremacy has been joined with the novel large gas-filled mazda or tungsten incandescent street lamps giving 400 candlepower at 300 watts, as compared with the former reigning favorites, especially the old inclosed arc with about 175 mean spherical candlepower. In discussing these changes, the well-known authority, Dr. C. P. Steinmetz, in a recent article,[1] gives a table of relative efficiencies of the various candlepower of illuminants:

RELATIVE EFFICIENCY OF VARIOUS CANDLEPOWER OF ILLUMINANTS.

200 MEAN SPH. C-P.		300 MEAN SPH. C-P.		400 MEAN SPH. C-P.		500 MEAN SPH. C-P.		1,000 MEAN SPH. C-P.	
Type.	Watt.	Type.	Watt.	Type.	Watt.	Type.	Watt.	Type.	Watt.
A-c. carbon	490	A-c. carbon	620	Mazda	620	Standard magnetite	400	Gas-filled mazda	780
D-c. carbon	380	D-c. carbon	480	Standard magnetite	350	Gas-filled mazda	390	Standard magnetite	700
Mazda	310	Mazda	470	Gas-filled mazda	310	Special magnetite	350	Special magnetite	550
		Standard magnetite	300	Special magnetite	290	White flame	350	White flame	520
		Special magnetite	250	Titanium	210	Yellow flame	280	Yellow flame	400
						Titanium	250	Titanium	360

Dr. Steinmetz also says:

There is a general desire for more light, but more still is the desire for cheaper lighting, and there is a much greater appreciation of getting a reasonable increase of illumination—50 to 100 per cent—at a reduced cost to the city, than there is of getting much more light at the same price; while even a very great increase of light, if accompanied by an increased cost, is rarely acceptable in street lighting, except in special cases of decorative lighting, of white way lighting, etc.; and such special application naturally represents only a small part of the country's lighting. This is well illustrated by the experience of the arc-lighting industry. When the arc-lighting engineers became so interested in "large units" as to lose some interest in the low-power high-efficiency arcs and began to push the big luminous or flame arcs, the replacement of the 175-candlepower inclosed-carbon arc by low-power luminous arcs, which had been going on rapidly before, practically stopped, and the country turned to the mazda incandescent lamp, which offered lower power and therefore cheaper units.

It will certainly be very interesting, therefore, to see where the arc lamp is placed relatively at the close of the period 1912–1917, but obviously meantime there is being a great deal of work done with over half a million of these large units in service. Much of this work with the flaming arc is for commercial purposes, but there are many excellent street-lighting systems

[1] General Electric Review, Vol. XVII, No. 3, March, 1914.

with the other modern arcs, one of the best being notably that with the 6.6-ampere luminous arc in the central section of the city of Washington along Pennsylvania Avenue, the same city having also a system of incandescent street lighting. Figures of interest are given by Mr. Walter C. Allen, the electrical engineer of the District of Columbia, for the main avenue, as follows, as to lighting with the luminous arcs:

Length of roadway on center line, 6,356 feet.
Width of roadway, 109 feet.
Square feet of roadway, 692,804 feet.
Number of lamps, 123.
Total watts at 520 each, 63,960.
Annual maintenance cost ($97.50 each), $11,992.50.
Watts per linear foot, 10.06.
Watts per square foot, 0.0923.
Cost to maintain per linear foot, $1.886.
Cost to maintain per square foot, $0.0173.

The cost of installation is estimated to be $170 per unit, exclusive of the posts, ribbed frames, glass, and special parts, which are furnished by the District and cost as follows:

	Cost.
Cast-iron post	$26.90
Cast aluminum ribbed spherical frame	37.50
Special parts	3.00
Total	67.40

The work of installing the cables, erecting the posts, etc., was done by the Potomac Electric Power Co. at its own expense. The company also maintains the lamps at the rate of $97.50 each per annum, less $4.40 deducted as interest and depreciation on the municipally owned posts, in accordance with the acts of Congress establishing rates for street lighting in the District of Columbia.

Another recent installation of similar character was that made by the Lynn (Mass.) Gas & Electric Co. for the Massachusetts Metropolitan Park Commission along two miles of the North Shore Boulevard, with 40 luminous arcs, operating on a 4-ampere rectifier circuit and consuming about 300 watts each. The lamps are carried on slender iron posts 18 feet high, spaced from 200 to 300 feet apart. They give, at a less cost, some twelve times the illumination of the gasoline lamps previously used.

This resort to low posts for the modern arcs is becoming quite general, having been inaugurated in 1912 at New Haven, Conn., when a "White Way," comprising two of the principal business streets, was dedicated with most impressive ceremonies, and a slogan sign, "Old Elms but New Ideas," was flashed upon the gaze of over 100,000 enthusiastic celebrants. The "boulevard" luminous arc was then put in service for the first time, with 78 "inverted" 6.6-ampere lamps, on 11.5-foot posts, spaced at intervals averaging 87 feet, and staggered on opposite sides of the two streets. By "inverted" is meant that the globe of the lamp is placed above the mechanism instead of below it, as usual. The effect of the illumination is most pleasing and satisfactory, and the installation has marked the point of a new departure in an effective response of the modern arc on low posts to the ornamental street lighting with tungstens that has threatened the old supremacy of the arc outdoors. The minimum illumination is estimated at about 2 foot-candles, which is quite high by street-lighting standards.

In other parts of the country the progress of the luminous and other arcs for street lighting is quite noticeable. The city of Baltimore now has 365 or more luminous arcs on ornamental posts distributed over 2½ miles of business streets, in an area comprising nearly 50 blocks, the lamps being of the inverted type rated at 6.6 amperes. The posts are 14.5 feet high. The merchants paid the initial cost of the lamps, the Consolidated Gas Electric Light & Power Co. obtaining this money from the city and the latter collecting from the merchants. The lamps and posts erected represent an investment of approximately $105 each, and are spaced from 50 feet up, according to the amount of money collected, which ranged from approximately $2 a front foot to $1.20 a front foot.

The city of Rochester, N. Y., may be mentioned as one which had 86 of the same type of 6.6-ampere magnetite arcs installed during 1912 in East Avenue, one of the finest residential streets, running from the center of the town to the city line, the lamps being placed 200 feet feet apart and staggered. The cost was borne partly by local assessment on the abutting property, and the rest came out of the general lighting fund.

Omaha, Nebr., has completed the installation of 140 10-ampere flaming-arc lamps, placed four to the 350-foot block on downtown thoroughfares. In each block the lamps, two on a side, are so staggered as to bring one unit to every 90 feet of street length. They are hung from ornamental gooseneck arms 20 feet above the street surface. In each block it was found possible to use one of the two former lamp-posts in its existing position, moving the other to a new location to conform to the installation of the two new posts per block. The Omaha Electric Light & Power Co. installed the entire system, including conduit, cable, posts, labor, and repaving, for $15,000. This, of course, was exclusive of the lamps themselves, which cost $32 each. The Omaha company is under contract to do the city lighting for $75 to $85 per lamp year, but as the city receives a rebate in the form of a lighting assessment of 3 per cent of the company's gross income, besides a 3 per cent occupation tax payable into the general fund, the net cost per lamp year is but $68 to $70. The system is to be extended to outlying districts.

The adoption of a new lighting system for Federal Street, Pittsburgh, Pa., was brought about by the influence of the local North Side Board of Trade. The grade of Federal Street had been raised considerably in order to place it above the flood level. With the street in a much better condition than previously, it was decided to complete the improvements with an efficient lighting system. After an investigation of the subject, a long-burning flaming-arc lamp was adopted. This was the lamp used to illuminate the hall at Baltimore where the latest Democratic national convention was held nominating President Wilson. There are installed 90 lamps in all, each with the commercial rating of 3,000 candlepower. The street is 48 feet wide and the lamps are placed 60 feet apart. They are hung on ornamental poles of colonial pattern, 25 feet high, with ornamental goosenecks.

The lighting of the luminous-arc lamp standards in Utica, N. Y., in 1912 was made the basis of a public celebration. The installation, which is fed from the circuits of the Utica Gas & Electric Co., consists of 66 inverted-type luminous-arc lamps rated at 6.6 amperes and installed on cast-iron posts spaced 85 feet apart along both sides of Genesee Street, from Bragg Square to the first block above the city hall, a distance of about one-half mile. The lamps were installed at the expense of the merchants and business men along this section of the street, and their maintenance after January 1, 1913, falls to the city under the regular contract for street lighting.

Houston, Tex., and Missoula, Mont., may be cited as examples of places where the new magnetite lighting has been coupled with the use of the trolley poles. In the summer of 1912 the Houston (Tex.) Lighting & Power Co. completed the installation of 80 handsome iron poles carrying 4-ampere magnetite arc lamps which furnished illumination for the business district of the city. These poles are of an attractive design, originated locally and built to conform in base pattern with the new trolley poles in the business streets, in some cases combination poles being used for both railway and lighting purposes. The standard arc-lamp poles are, respectively, 6 inches, 5 inches, and 4 inches in diameter, tapering in three sections. The combination trolley and arc-lamp poles are 8 inches, 7 inches, and 6 inches in section and weigh 800 pounds each. Three-inch pipe forms the gooseneck, the lamp itself being suspended with the arc 19 feet above the roadway. There are four lamps to each 330-foot block in the downtown section, the posts being staggered so that each corner is lighted by two lamps, while the greatest mid-block distance between lamps is about 110 feet. Lead-covered, paper-insulated No. 6 single conductor cable is used to convey the current to the lamps. The lamps are trimmed with the aid of a ladder wagon. Alba globes are used to diffuse the direct rays of the 4-ampere magnetite arcs, but these have been replaced in some cases with clear glass to increase the light from the lamps. At Missoula the 100-foot-wide main street, Higgins Avenue, is lighted for a distance of nearly one mile by 6.6-ampere magnetite arcs of the inverted type carried on trolley-pole brackets at 100-foot intervals, the lamps being held up by 24-inch straight bracket arms 18 feet from the street surface. The erection of the system was facilitated, it is said, by the Montana state law which provides for the creation of special lighting-improvement districts. The law specifies that "the portion of the entire cost of erecting and maintaining posts and of the annual maintenance of lamps therein in such district, not less than one-fourth nor more than three-fourths, as shall be determined by the city council, shall be borne by property embraced within said district abutting upon some portion of the street or avenue within such district to be lighted." To create such an improvement district requires the consent of 51 per cent of the abutting property holders, in addition to an ordinance passed by the local city government. The Missoula Light & Water Co., however, went even further in its initiative, offering to assume the entire expense of installation on the assurance of a three-year contract for the lighting. The proposition was accepted without opposition, and the introduction of the system has already led to a strong demand throughout the city for better street lighting everywhere. That is really what all our cities need, for the standard of street illumination is still at a low point.

Other instances of the new street lighting could be mentioned here, the installations in some cases having been made in record time, but those just given must suffice. It may be noted that in Chicago, outside of street lighting, the South Side Park Commission is using 280 flaming arcs of 7.5 amperes to replace the former inclosed carbon arc lamps at important boulevard and drive intersections, adding to the safety of travel on foot or by vehicle and saving the turf from invasion. Until a short time ago the streets of Chicago were very badly lighted by the municipal plant with lamps of an old type poorly installed, but recent changes are putting that city in the front rank of progress as to arc lighting, a transition having been made to flaming arcs, of which two or three types are used. Several thousand have been installed, and a total of not less than 62,000 is proposed. This is a notable advance. In the residence section these arcs are installed, one at every street intersection and alley, and under no circumstances more than 350 feet apart. These are hung 22 to 23 feet from the sidewalk. In the business section two lamps are placed at every street intersection, and one at each alley intersection, and never more than 250 feet apart. The lamps in this section are 25 feet above the sidewalk. The lamp is carried on a 30-inch bracket, with automatic series cut-outs, and is lowered for trimming, the lowering gear being entirely concealed.

Very many attempts have been made to light large outdoor spaces by means of plain carbon-fed arc lamps, but the newer attempts are based upon the use of flaming arcs with the modern impregnated carbon. The effect is different in the extreme, and, according to all reports, much more successful. Two of the examples are furnished by Chicago. In July, 1910, a military tournament was given at night in an arena 400 by 600 feet, surrounded by tiers of seats about 100 feet deep, making a total of about 11 acres. The seats accommodated 40,000 people. This vast open space was illuminated by eighty 550-watt flaming arcs, hung 50 feet between centers, in 10 spans of 8 each. They were suspended by drop wires at a uniform height of 35 feet above the arena from 600-foot twin spans of steel messenger wire passing over 50-foot poles set back of the seats and guyed from the tops of 40-foot poles, which in turn were anchored. The lamps were fed with 60-cycle current, two in series across each side of a 110–220-volt 3-wire circuit supplied from a temporary transformer installation. In the arena nearly 3,000 soldiers took part in all kinds of drills and evolutions twice daily, and every one, including the soldiers, seemed very well pleased with the quality and intensity of the evening illumination. An average intensity of about 1 foot-candle was obtained, the lights being concentrated above the arena. Readings at the center of the field gave an average of 1.35 foot-candle illumination. The energy consumption was about 0.18 watt per square foot. The work was done by the local Commonwealth Edison Co.

Although opal globes were used in this experiment, some inconvenience from glare was experienced, and another effect, even on a clear night after rain, was that of a luminous mist over the arena, due to the dust. Both conditions seemed susceptible of improvement. Another attempt along different lines was made at Chicago in August of 1910 at the new American League Baseball Park, where the low score of 3 to 0 for the game showed how effective the illumination was. The park contains about 8 acres and seats about 32,000 persons, with the usual spaces allotted to the stands and the "diamond." The total installation consisted of 20 powerful flaming arcs with 1¼-inch carbons taking about 100 amperes each. Ten of the lamps were placed on 80-foot towers or on the grandstand roof, and the other 10 were placed around the park about 7 feet above the ground and were used only when the game was played. Of the high lamps two were placed on a 30-foot tower over the right pavilion flanking the grandstand, and two similarly over the left pavilion. The preponderance of light was on the first-base side, where most of the plays are made. This scenic lighting was supplemented by service lighting to the extent of 150 tungsten lamps of 100 watts placed in passageways and exits. The total load was about 250 kilowatts.

It should be added that high poles or standards for arc lamps are still in vogue, and they are of increasing beauty, serving as ornaments to the street instead of as disfigurements, as was so often the case in earlier years. Many separate arc pole lines have been abolished by the joint use of trolley poles.

INCANDESCENT LAMPS.

Street lighting.—Street lighting by incandescent lamps is so intimately connected with arc street lighting and has developed so enormously of recent years in competition with the older method that it is fitting to discuss it here, taking up later the incandescent lamp itself. There is nothing new about street lighting by incandescent lamps. It goes back to an early stage of the art. But the differences in practice have been radical. The primitive illumination of this type was attempted with small units, single carbon-filament lamps carried on brackets. Much of this lighting still prevails, although marked improvement has been seen in the adoption of metallic-filament single lamps placed on low posts or standards of wood, metal, or concrete; and the streets of numerous rural or suburban communities are lighted in this manner. The great change has come about chiefly through the adoption of group or clustered lamps on low standards; and now the introduction of the much larger tungsten units, ranging up as high as from 300 to 5,000 candle-power, has injected new elements for consideration into the vexing problem of what is really best to-day for street illumination. These larger, high-power incandescent units are, however, mounted on tall poles in the same manner as the familiar large arc lamps, and, while some have thus been tried on streets and in parks, no regular installations could be cited up to the time the present report went to press. The use of tungsten-lamp street lights on single posts and in clustered standards had begun at the time of the last report and was referred to therein. Later examples show how extensive has since been this development. A special report of the National Electric Light Association of June, 1911, gives a list of no fewer than 84 cities in which ornamental posts for incandescent street lighting had then been installed. The example was cited of Atlanta, Ga., where the system illuminated a length of street approximately 13,000 feet and included 239 handsome low posts, each carrying five 100-watt tungsten lamps in opal-glass globes.

At Warren, Ohio, up to about 1909-10, the city streets were lighted with open arcs, and the municipality then considered changing to inclosed, but the local company intervened with some suggestions and demonstrations as to tungsten posts, and finally a new contract was made for series tungstens on a 10-year basis, the company to install and operate the entire system. It seemed only natural that a great incandescent lamp manufacturing center should thus use its own product. The installation is divided into the residential and the downtown systems. In the former there are 355, 90, and 175 street series lamps of 40, 60, and 80 candlepower, respectively. All the units are equipped with reflectors and are suspended by gooseneck brackets from wooden poles arranged in a straight line along one side of each residential street. In the spacing of these units, in the residential district one lamp is located at each street intersection and the intervening distance between corner lamps is divided so that the spacing is as uniform as possible. This varies, however, from 100 to 300 feet in the different streets, depending on the traffic demands and to some extent on the foliage of the shade trees. The lamps are 14 feet above the pavement, and they are suspended 3 feet beyond the curb line over the road. The illumination in the residential districts is highly satisfactory and is far superior to that furnished by the former open arcs. The lighting of the downtown streets is ornamental. Sixty-two 3-lamp iron standards, each supporting 2 pendant lamps and 1 upright, are employed on the principal business streets, while around the central park 22 single-lamp standards are located. At the entrance of the courthouse, on the north side of the park, two 5-lamp standards are situated, one on either side of the approach. All upright lamps (except nineteen 60-candlepower lamps on the single-lamp standards) are rated at 80 candlepower and are surrounded by 14-inch globes, while 12-inch globes are used on the 40-candlepower pendant lamps. The spacing of the 3-lamp standards is uniform in each street, but varies from 65 to 75 feet in different streets; that of the single-lamp standards is from 65 to 85 feet. The corner standards at street intersections are set where the street lines extended meet the curb lines; thus there are eight of these standards at each intersection.

Each ornamental standard is anchored to a 2½-foot cube of concrete, the center of which is placed 18 inches back from the curb line in the business streets, thus allowing the outside pendant lamp to be hung directly above the face of the curb. The wiring of the standards is all underground. The contract specifies the following prices per annum to the lighting company for maintaining the three sizes of lamps in the two systems and under the two operating schedules. The cost of installation is taken care of in these prices.

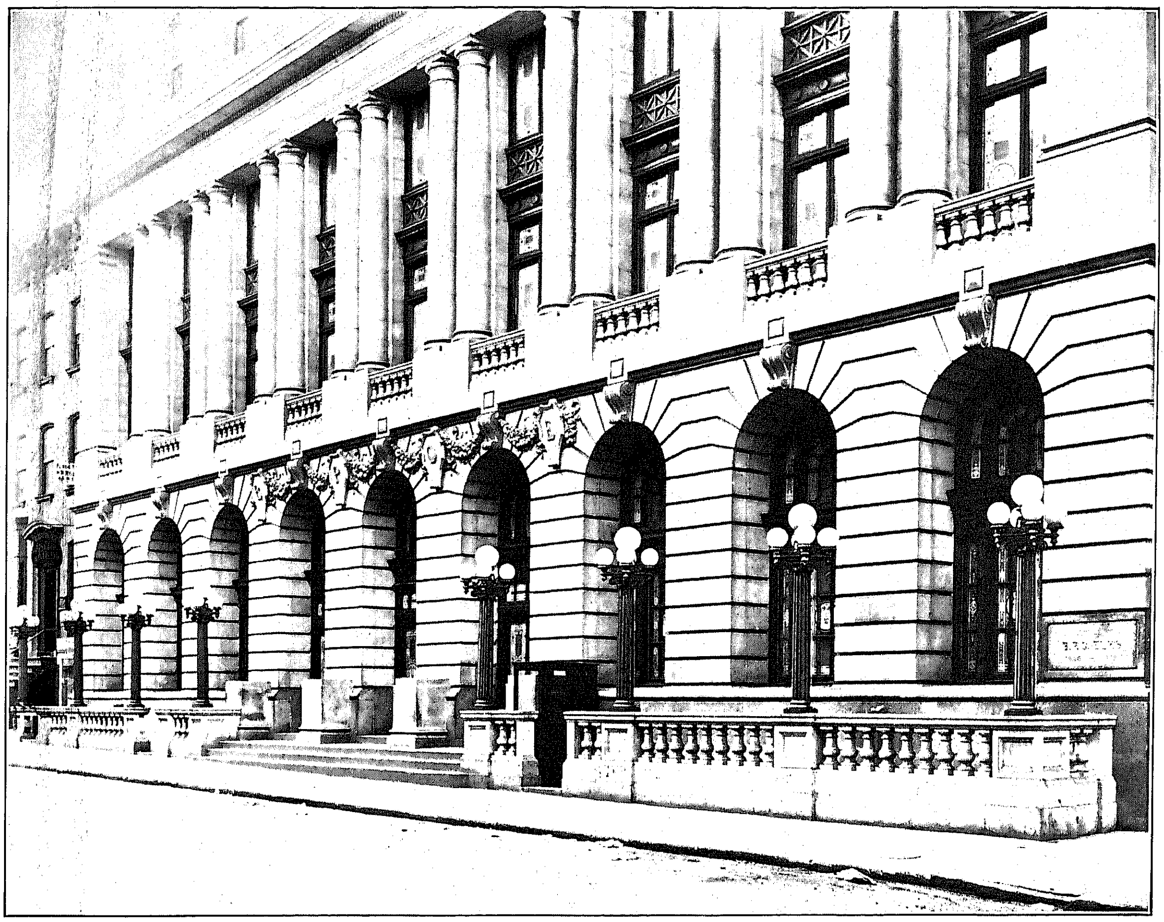
SIZE OF LAMP.	ORNAMENTAL.		Residential, all night.
	All night.	Midnight.	
40 candlepower	....	$12.00	$13.50
60 candlepower	$19.50	14.50	19.50
80 candlepower	23.00	18.00	23.00

Included in the cost of installation, that of the standards, bases, conduits, and wire was as follows: 5-lamp standards, $40; 3-lamp standards, $36.50; 1-lamp standards, $30. These figures are based on one standard of each kind, exclusive of lamps, globes, sockets, etc. The 3,065 feet of steel-armored cable cost 36 cents per foot and an additional 5 cents per foot for laying. The lead cable, of which there was 4,550 feet, cost 21½ cents per foot, and the bases for the 86 posts were estimated at $3.50 each. The fiber conduit laid cost 51 cents per foot, and the total cost of the globes was approximately $1 each.

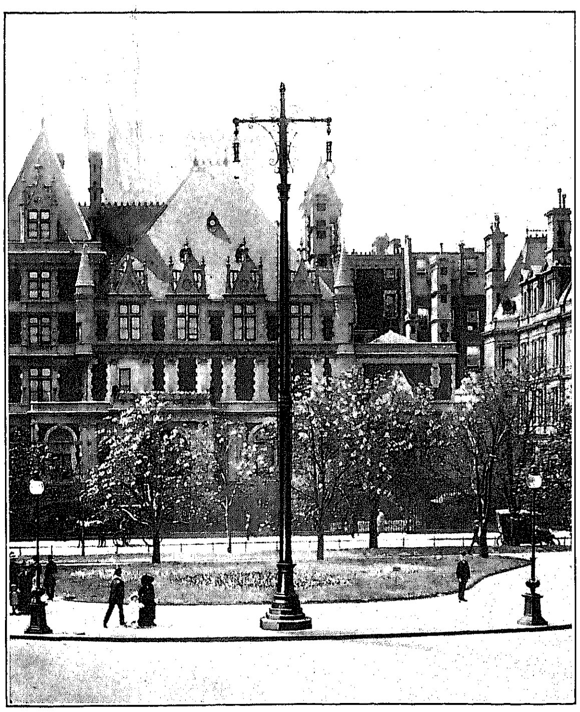
In the old open-arc lighting system there were 161 units, consuming 500 watts each and operating on 9.6 amperes. Seventy-one of these lamps burned on all-night schedule and the remainder till midnight, in the former case the city paying the central station $80 each and in the latter $55 each a year.

In 1911 a number of concrete posts for tungsten lamps were set up at Ann Arbor, Mich., in the effort to secure somewhat cheaper construction. The cost was $7.47 per pole. The posts are 25 feet long, 8 inches in diameter at the base and 5 inches at the top, and are reinforced with four ⅜-inch steel rods, one at each corner. Complete, the posts weigh 1,185 pounds each. Six inches from their tops single arms or buck arms are cast into the concrete, 1½ by ⅝ by 18 inch steel angles being used. These arms are bored for ⅝-inch bolts, which support the insulators carrying the line wires. Nineteen feet from the butt of the pole, three ½-inch bolts are cast into the concrete for carrying the lamp bracket. The posts are set 5 feet into the ground, bringing the lamp 12 feet above the curb. On each post is stenciled the number of the lamp and its circuit. The wooden forms required for the construction of these poles cost $200 to build, $155 of which was for lumber and mill work. A concrete mixture of one part Portland cement, two parts sand, and four parts ½-inch crushed limestone was used, the cement being mixed wet and poured and troweled in the form.

Another treatment of the "ornamental street lighting" idea, which is more or less typical of this kind of work, is found at Des Moines. The city agrees to pay for the operation of the top lamps in the clusters on the curb-lighting posts from dusk to midnight, the energy used between midnight and dawn by the lamp being donated by the Des Moines Electric Co. Up to the close of 1912 the electric service company, assisted by "booster" organizations, had put in position in Des Moines 440 curb lighting posts, each supporting five 100-watt tungsten lamps in translucent white-glass globes. One of these globes surmounts the post and four are suspended from brackets. The original arrangement was that merchants or abutting property owners should pay the electric service company for posts and equipment at the rate of $60 for each post, with a monthly operating and maintenance charge of



1. FIVE-LIGHT CLUSTER LAMP PILLARS, ELKS CLUB, NEW YORK CITY.



2. TWO ALBA FLAMING LAMPS, 45 FEET ABOVE SIDEWALK, PLAZA, FIFTY-NINTH STREET, NEW YORK CITY.

3. LAMP PILLARS ON BOARD WALK, ATLANTIC CITY, N. J.

(Face p. 142.)

$5.80 per post. In the event of failure to pay the monthly charge the electricity was cut off.

The retail merchants then started a movement to cause the city to take over the 440 electroliers and pay for their operation and maintenance as street lighting. They were not successful in securing all they asked for, but they did obtain a substantial reduction as the result of an arrangement by which the merchants, the city, and the company agreed to share the burden. The initial cost of the installation of new posts, $60, remains as before. However, the city agrees to pay $12 a year for the lighting and maintenance of each top lamp from dusk until midnight. The cost of this service from midnight until dawn is assumed by the company. The merchants agree to pay $43.68 a year, or $3.64 a month, for the operation and maintenance of the four other lamps from dusk until midnight. The posts are spaced 44 feet apart, so that the cost to each merchant having 22 feet frontage is only $1.82 a month. The electric service company's total revenue from each post, operating the lamps as related, is $55.68 a year. In order to get revenue to pay for the top lamps on the curb-lighting posts, the city discontinues entirely the ordinary street-lighting arc lamps at street intersections in the districts affected. After midnight the street lighting is thus confined entirely to these top lamps, which are thought to afford sufficient light for the purpose.

Chicago is a striking example of this newer development in street lighting. Taking figures published in September, 1912, it would appear that 3,000 privately owned street-lighting posts were then being operated by the Commonwealth Edison Co., which has devoted special attention to securing this class of contracts in outlying business centers. A load of about 1,200 kilowatts was thus connected and in use for this kind of public illumination, the cost of which was defrayed by abutting merchants. Of the total number of posts, 85 per cent were installed under the company's regular two-year contract, by the terms of which the central station company erected and maintained the installation, operating it a given number of hours daily, for a fixed sum, collectible weekly from the individual merchants or from the neighborhood business men's associations. About 500 posts were served on a meter basis, the customers installing their own equipment and purchasing energy from the Commonwealth Co. at a fixed kilowatt-hour rate.

The rates for this ornamental street lighting, under the standard two-year contract, are as follows for posts each carrying a single 250-watt tungsten lamp or four 60-watt tungsten lamps:

	Per lamp-post per week.
Dusk to 10 p. m. 6 nights and dusk to midnight 1 night per week	$1.75
Dusk to 11 p. m. 6 nights and dusk to midnight 1 night per week	1.85
Dusk to midnight 7 nights per week	1.95
Dusk to 1 a. m. 7 nights per week	2.10

For posts equipped with five 60-watt lamps the schedule is:

	Per lamp-post per week.
Dusk to 10 p. m. 6 nights and dusk to midnight 1 night per week	$2.00
Dusk to 11 p. m. 6 nights and dusk to midnight 1 night per week	2.13
Dusk to midnight 7 nights per week	2.25
Dusk to 1 a. m. 7 nights per week	2.37

These charges are payable weekly and are subject to a discount of 25 cents per post if paid within three days from date of bill. After the original term of the two-year contract has expired, the service may be continued, if desired, at a cost of 66.7 per cent of the above-listed rates. Lamps are switched on and off at the specified hours by the company's patrolmen. Changes in posts or wiring are made at the expense of the customer. In outlying districts the lines of the Commonwealth Edison Co. follow the alleys, and to reach the street-lighting installation taps are brought across the customers' premises to the curb, a group of three or four posts being served in this way from each tap.

It may be noted that Chicago exemplifies the use of various styles of post, including concrete, also the single-unit type with one lamp, with a decided tendency toward the cluster fixture.

Kansas City may also be quoted as an example of work in this direction. Seven miles of its downtown streets are lighted by 1,500 trolley-post brackets, each carrying three 150-watt tungsten lamps in a single clear-glass inclosing globe, besides one 16-candlepower carbon unit pointed upward. For several years a more ornamental fixture has been sought, and as the result of competitive exhibits an official design has been selected. To this pattern all installations are required to conform in order to receive a city permit. The patterns have been acquired by the city, so that the manufacture of the posts is thrown open to all. While of course local property owners can in no way be forced to substitute for their present fixtures posts of the newer design, it is the plan that, as from time to time new installations are erected or old ones replaced, these approved patterns shall be employed, with the result that ultimately a uniform ornamental lighting system will be in use throughout the entire city.

The designs accepted from the competitive exhibits submitted include both complete 5-lamp standards and bracket arms for trolley posts. The standards to be used on streets without trolley lines are of slender and graceful proportions and carry five upturned 100-watt lamps 13 feet above the sidewalk. The post base is 13 inches in diameter, and the distance measured across the pairs of 10-inch globes is 2 feet 10 inches. Delivered at the curb and completely equipped, these 5-lamp standards cost $50 each. This outlay is met by the abutting property owners. The Kansas City Electric Light Co. makes the installations and is paid by the city $32.50 per post per year. The selection of the designs was made by a committee representing local improvement associations, the Municipal Art League, and city officials.

A pleasing modification or variation of the low-post plan has been afforded in one or two cities, of which Minneapolis may be cited as an example. Its downtown streets have been rendered attractive during daylight hours by the greenery of flower baskets, which grace a number of the curb-lighting posts. This ornamentation of the tungsten standards is due to a general movement, encouraged by the Minneapolis Civic and Commerce Association, to decorate the business section with "hanging gardens," window boxes, flower baskets, etc. A special container is arranged to fit over the top of the 5-lamp standard, and in this flowers, ferns, and trailing vines are planted, producing a charming effect. The cost of equipping such a post is about $6 the first year and $4.50 annually thereafter. This outlay has in each case been defrayed by the abutting property owner or tenant. In the Minneapolis instance these bits of green which fleck the downtown streets in summer time have given to the town the appropriate title of "The City of Hanging Gardens."

Many general questions have naturally been involved in the change to incandescent street lighting, outside of the technical problems. Those who have made such installations have met with frequent objection raised by the storekeeper at the corner liable to payment on a curb-foot basis for both his narrow front on the main street and his longer front on the side street. The difficulties thus created proved almost fatal to the plans for tungsten curb fixtures at Great Falls, Mont., where the corner-property objectors refused to go into the agreement. An adjustment was finally secured, however, by installing 32-candlepower lamps in the alleys behind the stores, and charging these lamps to the mid-block occupants on the same curb-foot basis as in front. The conduits for the curb fixtures are fed through overhead lines in the alleys adjoining the main street, so that it was a simple matter to install 32-candlepower graphitized carbon-filament lamps and reflectors on wooden poles. The presence of these alley lamps has also a positive police value in preventing depredations on merchants' stores from the rear. Under the arrangement, the cost of erecting and operating the lamps is borne on a footage basis in which both front street and alley frontings are counted equally, the discrepancy between the corner and mid-block occupants being reduced to a point where the former were all satisfied to come in. Eighty posts, each carrying four 60-watt till-midnight lamps and one 100-watt all-night lamp, have been installed. The posts are of an elaborate type manufactured locally and cost $135 each, completely installed. The Great Falls Electric Properties operate the entire system, including the alley lamps, at the rate of $6 per curb post per month. There are two of the alley lamps to each block, located at points one-third the distance between streets. Under a Montana statute, the cost of building and operating this ornamental lighting system is borne one-half by the city government, one-third by the abutting owners and tenants, and one-sixth by the street railway company, the latter being required by law to contribute this amount to the lighting of streets traversed by its cars.

The tungsten lamp.—The report of 1907 bore evidence to the place already made for itself by the tungsten, or as it is now quite generally known, the "Mazda" lamp. Its inroads since 1907 upon the field previously occupied by the carbon-filament lamp have been remarkable; as exemplified in one respect by the data given in preceding pages as to its adoption for street lighting, where, however, it was in competition with the old-fashioned arc lamp. A very rapid development of interior and domestic electric lighting by central stations has gone on throughout the census period, due in part to the development of the incandescent lamp and in part also to the increased economy of central station service and the lower price of current. Of course, the tungsten lamp is by no means the only one in use, as will be shown, but it has been the leader in improvement, and a few of its advances may be referred to briefly. The pressed tungsten-filament lamp was introduced commercially in this country about 1907, the filament being then made by squirting the material through a die. The stronger drawn-wire filament soon followed in 1910, being made from tungsten wire drawn from bars of the pure metal. A reduction in the size of the glass bulb was made possible by improvements in methods of manufacture, and there was a great decrease in the depreciation of candlepower throughout the life of the lamp, due to lessened blackening of the bulb. A higher vacuum was obtained by chemical methods, the use of a chemical making it possible to obtain a much better exhaust than with the pumps alone. The efficiency of representative types of tungsten lamps rose as follows:

YEAR.	Efficiency—Watts per candle.	YEAR.	Efficiency—Watts per candle.
1907	1.25	1911	1.18
1908	1.25	1912	1.15
1909	1.25	1913	1.12
1910	1.20		

At the Cooperstown, N. Y., convention in September 1913, of the Association of Edison Illuminating Companies, large tungsten lamps from 350-candlepower to 5,000 candlepower with chemical "vacuum getters"—such as nitrogen gas, upon which considerable antecedent experimental work had been done—were exhibited for the first time, having the low record consumption of 0.5 watt per candle in the largest units.

In the period 1907-1912 the tungsten lamp rose from 10 per cent of the total American output of incandescent lamps to 39.94 per cent, while carbon-filament lamps fell from 93.27 per cent to 25.47 per cent. In the same period the approximate average candlepower of all incandescent lamps rose from 19 in 1907 to 29 in 1912.[1] The price of the lamp went down in still greater proportion, the 40-watt lamp being listed at $1.50 in 1907 and at 45 cents in 1912. The number of all lamps sold in the United States in 1912 is placed at 90,000,000, being an increase from 1907 to 1912 of 41.7 per cent.[2] The proportions of carbon and tungsten filament lamps have already been noted. But graphitized carbon-filament lamps represented no less than 33.59 per cent of the total in 1912, the tantalum metallic-filament constituting only 1 per cent. It is interesting to note in this connection that under date of May 1, 1913, the Treasury Department of the United States issued an order covering instructions for the use of incandescent lamps which set forth that after that date "gem" or graphitized lamps of any description would not be used, thus adopting the tungsten lamp exclusively for the purposes of the National Government.

In the earlier pressed-filament process and in the initial stage of the tungsten wire-drawing process, it was commercially impossible, on account of the high price that would result from a sufficiently close selection, to make filaments of the exact amperage desired. It was necessary, therefore, in lamps intended for series-burning service, to make them as nearly as possible of the correct amperage, photometer them to determine the current necessary to produce the correct efficiency, and then to sort them out into narrow ampere ranges. Only lamps of the same ampere range were suitable to burn in series together. It was necessary, therefore, to use extreme care that each customer always received lamps selected for his range of service. In cases of errors in photometry, poor sorting or accidental mixing, customers received lamps of widely different amperages, which when burning in the same series naturally produced ununiform candlepower and variable, short lives. Improvements in the wire-drawing process have made it possible to select wire that will produce lamps of approximately exact amperages. Hence it is possible now to have, instead of a range of amperages for each size of lamps, a single current rating for each size. For instance, in the case of the 6.6 ampere, 40-candlepower street-series lamp, where it was formerly necessary to have ampere ranges corresponding to 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, and 6.9 amperes and always to supply each customer with lamps from a single one of these ranges, it is now possible to make all lamps of this size almost exactly 6.6 amperes. This improvement applies to all lamps intended for street-series service and series-burning sign service, and has been productive of greatly improved results in both cases. It has also made possible the adoption of only five standard amperages for street-series circuits, namely, 3.5, 4.5, 5.5, 6.6, and 7.5 amperes. All central station companies are adjusting their street-series lighting circuits to one of these standard current values.

Electric signs.—One of the most interesting developments of recent years in the incandescent-lamp field has been the growth of sign lighting. The use of the electric sign is universal, and the more prominent thoroughfares in every American city of any size or pretensions to activity are ablaze after dark with large and small signs, many of them being of the "flashing" type, and some of them being built up with several thousand lamps. The estimate was made in 1912 that there were at that time installed on central station circuits no fewer than 80,000 electric signs, which, at an average of 100 lamps, would represent 8,000,000 lamps. These signs for commercial purposes have been supplemented by a large number in a special class, of the "slogan" type. Cities in all parts of the country have placed signs of this character near the railroad track, or in other conspicuous places, so as to catch the eye, emphasizing the desirability of the city as a business or manufacturing center or as a home. The sign of this character at Toledo, Ohio, is the largest of its kind in the world. It flashes an express train at full speed, then a lake steamer, and finally advises the traveler that "You can do better in Toledo." It weighs 25 tons and is 75 feet long and 68 feet high. There are 7,000 tungsten lamps of 10 watts each in this sign. As a usual thing, the lamps used in signs are smaller and of lower candlepower than those employed for illumination.

Display illumination.—A further development in incandescent lighting of this nature has been seen in its employment as a means of outlining large edifices at night, either permanently or for special occasions. Perhaps the most conspicuous example that could be cited was the illumination of St. Patrick's Cathedral, New York City, on the return from Rome, in January, 1912, of Archbishop Farley after he had been raised to the cardinalate. The pride of the citizens and the joy of the parishioners found admirable expression in one of the most beautiful nightly spectacles the city has ever seen. The lighting plan included all of the vertical and horizontal lines, the arches, windows, buttresses, and doors, as well as the two great spires and the crosses surmounting them, 340 feet above the asphalt of Fifth Avenue. In addition, there was outlined over the main entrance in various colored lamps the coat-of-arms of the cardinal, a shamrock with two eagle heads to the left and

[1] Presidential address, Millar, Illuminating Engineering Society, September, 1913.

[2] Report of Lamp Committee, National Electric Light Association, June, 1913.

two doves on the right. A special system of cables was used extensively on the spires, and there, during the bitterly cold weather, the steeplejacks working on the job were clad with electric heating-pad jackets in circuit with the lights, to keep them warm. Some twenty-seven thousand 8-candlepower lamps and 20 miles of wire were required in outlining the building. A mile of independent low-tension feeders was run underground from the New York Edison Co.'s substation at Fifty-third Street and Sixth Avenue to and around the cathedral to supply the energy. Surrounding the cathedral were arranged twenty-four 5-lamp gilded tungsten standards equipped with 150-watt lamps. By means of control from the substation the illumination was brought up gradually from a dim glow to a full blaze of glory. Special lighting was also arranged temporarily for the interior of the cathedral. Forty-watt tungstens replaced the two thousand and one hundred 16-candlepower carbon-filament lamps, and the seven great chandeliers, 130 feet above the floor, five in the nave and one in each of the transepts, were lowered for greater effect. The lamps around the columns were also changed. The sanctuary illumination was modified to accentuate the beauty of the marble altar and reredos, the altar itself remaining untouched.

VAPOR LAMPS.

Vacuum-tube lamps of various kinds were noted in the 1907 report, and they have since then made a place for themselves in the art which would apparently indicate their ability to survive, in competition with other illuminants, or in association with them, as exemplified in the Allegheny County Soldiers' Memorial at Pittsburgh. This fine building, somewhat suggestive of Grant's Tomb or that of Halicarnassus, cost $1,500,000. Its lighting cost about $60,000, or only 4 per cent of the total, but is a very large part of the decorative scheme. At night the façade is illuminated by the light of the mercury vapor tubes inside, with marvelous effectiveness. Within, tungsten lamps are used very brilliantly in the corridors. The main room is the auditorium, 110 by 120 feet and 65 feet from the center of the floor to the ceiling. It seats 3,000 persons. Here all lighting is indirect through an elaborate glass septum, divided into panels. Tungsten lamps of 50.5-kilowatt consumption radiate more than 50,500 candlepower. The 444 dim stars in the ceiling are represented by 25-watt carbon lamps; the bright stars are represented by 129 tungstens of 40-watts. These lamps are carried in plaster rosettes helping to accentuate the larger elements. The central panel is outlined in rosy pink by the vacuum tube which incloses it. There are nine centers which consist of circular panels of rich pierced plaster ornament, above each of which are suspended two 18-ampere flaming arcs. A group of glass sashes is arranged around each of these arc panels and forms a series of geometrical surfaces. Each of the main rectangular panels, comprising a flaming-arc center and its group of sashes, is framed by a nitrogen vapor tube, with a reflector that projects the light through an encircling slot, so that each panel is banded by rose-colored light. Glass panels are located close to the side walls, one over each window, and over each is a parabolic reflector containing a 400-watt mercury vapor lamp. The light from these sources is directed against the walls of the room, and through the windows, and is so softened by the panel glass as to acquire a pale sky-blue tone. The effect of this ceiling may perhaps be compared with that which would be furnished by a vast luminous canopy in Persian rug tints. Fixtures would have cost as much, but could not have given any such illumination. The lighting is so controlled that any feature can be used singly, and the qualities of moonlight, dawn, early morning, high noon, and sunset are all obtainable at will. In all, 30 different effects are available. Five systems of electric lighting are employed for single effects or in a harmonious whole. The people who did this were not afraid of color and knew how to use it. As Mr. Henry Hornbostel, of the firm of architects responsible for the design of the building, has said, the time has come for abandoning certain traditions relative to illumination and for establishing new ideals, especially concerning color combinations.

The quartz lamp.—A newcomer of the period has been the quartz mercury arc lamp, which is distinguished from its immediate predecessor, the glass mercury arc, by the fact that, by reason of the change in the material of the tube itself, a considerably larger amount of energy can be concentrated in a given space for illumination, with a higher potential drop per unit length of tube, a higher mercury vapor pressure, and a higher temperature. All this leads to a greater efficiency of light production. The greater concentration of energy is made possible by the employment of quartz, a material of far higher melting point than even the most refractory glass that can now be obtained, as the envelope. The two classes of lamps are similar in utilizing the principle of the passage of an electric current through mercury vapor to produce light, but they differ not only in the character of the container but in the pressure of the vapor, the temperature of the arc, the color of the light, and other incidental features. Quartz as a refractory substance for vessels and tubes in laboratory work has been used for a number of years, but it is only the advent of the high-pressure mercury vapor lamp that has made a demand for it on a large scale. With a mercury vapor lamp operating at a pressure of one atmosphere, it has been calculated that the temperature at the center of the arc is between 4,000 degrees and 6,000 degrees centigrade.

Ordinary lead glass will soften at about 300 degrees. The quartz used in these new lamps is made in Europe by fusing the tubes from rock crystal. It is extremely hard, being 7 on a scale where the diamond rates as 10. It is transparent and practically colorless.[1] The operation of the quartz lamp on commercial-line circuits from central stations supplying direct current offers no serious difficulties, and lamps are being manufactured for 110-, 220-, or 550-volt direct-current circuits, the 220-volt lamp being the more generally used. The best value of the quartz tube as a light source is given as 0.4 watt in specific consumption of energy per mean spherical candlepower. The color of the light, according to measurement with the Ives colorimeter, is closely the same in average as that of daylight. Some quartz lamps have already been introduced abroad in street lighting, and in this country a number of small street-lighting installations have been made in cooperation with business men's associations, but the field has been narrowed by the absence of lamps that could be operated in series or with an alternating current.

The neon tube.—The last addition to the lighting resources of the central station art is the neon tube of Claude, a French physicist, which has already been exhibited before the central station bodies of this country but has not entered into actual service here. It employs the very rare gas neon, which forms a constituent part of the atmosphere and is now obtained in commercial quantities as a by-product of the preparation of liquid oxygen from air. The ordinary tubes are about 6 meters in length and give 900 spherical candlepower with a specific consumption of 0.72 watt per candlepower. The light is of a warm orange color, entirely lacking in blue rays, just as the ordinary mercury arc is lacking in red rays.

USE OF CURRENT FOR POWER.

The significant fact appears from the returns that while the total central station income from light, heat, and power increased 240.9 per cent in the census period 1902–1912, the number of stationary motors served increased 330.9 per cent and their horsepower capacity 843.1 per cent. This is altogether independent of the large percentage of income derived from the supply of current for street-railway service, already noted. Moreover, while the average gain is very high, it falls extraordinarily short of the gain in some individual states in electric-power work, due wholly to the development of hydroelectric power plants and the incidental transmission and distribution. It is when one turns to the statistics of the two neighboring states of North and South Carolina that the unprecedented extent of hydroelectric development emerges. Going back a dozen years, these two states were utterly undistinguished in the arts of the central station industry and power transmission. Since 1902 the income of central station plants in South Carolina has risen from $387,010 to $4,499,800 in 1912, a percentage increase of 1,063. In addition, the water-wheel capacity has increased 1,614 per cent, the station output 1,836 per cent, and the stationary-motor capacity 2,274 per cent. North Carolina rivals these figures in some respects, and, astounding as it may seem, eclipses them in others. The income there rose from $250,133 in 1902 to $1,458,786 in 1912, which is only 483.2 per cent for the period, an average of 48 per cent per annum, but the water-wheel capacity increased from 1,920 to 49,951 horsepower, or 2,502 per cent, and the capacity of stationary motors rose from 950 to 32,830 horsepower, or 3,356 per cent. It is doubtful if there is anything to equal such data in present-day development in America. There can not be many industries expanding at an average rate of 335 per cent per annum for a term of 10 years. It could hardly be expected as within human probability that such rates of advance could be maintained, especially in these two states. And yet, in September, 1911, Mr. G. K. Hutchins, of the Columbus, Ga., Power Co., in a discussion of this subject, reported a large percentage of cotton mills still operated entirely by steam power; while Mr. F. P. Catchings, of the Georgia Power Co., stated that only about 25 per cent of the cotton mills in North Carolina were driven wholly by electricity.

Operation of textile mills.—Among the distinctive features of the electric drive mentioned by Messrs. Hutchins and Catchings is the great flexibility it introduces into all departments of the mill, thus permitting the various processes to be kept balanced, and affording economical means in any department for overtime work which might be required for the finishing of special orders. Not only does the constant and uniform speed serve to secure a better quality of product, but experience has shown that there is obtained a substantial increase in product, conservatively estimated at an average of 10 per cent. The textile mill affords a very satisfactory demand for energy throughout its running hours, and furnishes an attractive day load for any central station of sufficient size to handle this class of business. Five textile mills in which the average of maximum demand was taken for a 12-month period showed a ratio of demand to the motor rating installed varying from 71 to 96 per cent.

Cotton ginning.—In like manner the cotton gin has loomed up as a desirable load for southern plants. In general, electric companies in the South and Southwest have avoided cotton-ginning loads on account of their comparatively heavy demand during only a few months in the year, overlapping the winter lighting season. The

[1] The Mercury Vapor Arc Lamp, Trans., Illuminating Engineers' Society, Pittsburgh, 1913, Evans.

cotton-ginning season usually begins in August or September and lasts through December, running much of this period 24 hours a day, the latter part coming at a time, however, when the capacity of generators is needed for the evening peaks. In the case of a 65-horsepower cotton gin at Coalgate, Okla., motor-driven by the local central station, not only does the electric company consider this good business, but the gin, though in the midst of a coal-mining section, has been able to reduce its total operating expenses from 50 cents down to 30 cents per bale, with energy at 4 cents per kilowatt hour. This gin has a capacity of about 1 bale each 10 minutes when running continuously. With electric drive the heavy boiler operating and upkeep costs have been eliminated, together with the boiler-room force, leaving only one gin-stand man and one packer to operate the plant. The gin usually begins operation August 15 and runs until about the first of the year. The heaviest cotton-ginning season is near the middle of this period, when the gin is sometimes run 24 hours per day. At other times the ginning load by agreement is kept off the peak period of the lighting plant, being operated principally during daylight hours.

Special uses.—These details as to one industry might well serve as an example or illustration of what is happening all along the line in the operation of the innumerable industries of the United States, and it is in reality only possible here to refer to such typical applications, where a whole industry is affected, or to special cases where the electric motor makes possible and economically successful that which could not previously be attempted. An admirable presentation of the value of the power load for central stations was made in September, 1911, before the Vermont Electrical Association by Mr. F. M. Kimball, who outlined the value of some of the special uses to which electrical energy is being put, as follows: For driving printing machinery, because of its qualities of cleanliness, variation in speed, safety, and economy; for running elevators, where electrical devices for securing control in speed and direction of movement are more simple and effective than when any mechanical drive is used; for operating woodworking machinery, requiring essentially a high rate of speed; in stores, markets, and jewelry shops, and by opticians; in shipyards and erecting works, in conjunction with machine tools that can be carried to various portions of floor or yard; for driving fans and exhausters, bellows, etc.; by bakers and confectioners, with whom perfect cleanliness is highly desirable; in pumping water for irrigation; in lumbering operations, enabling portable mills to be operated anywhere on the cut; in small refrigerating apparatus; on docks, to move and load merchandise; in building operations, to raise material; in cash-carrier systems in stores; for driving laundry machinery; in hotels, etc.; for quarry work, in drilling. The capacity of motors Mr. Kimball placed as not far from 1,000,000 horsepower in the United States alone.

Large users of electric power are indeed increasing rapidly in number, sometimes in new fields and quite often in old. In the summer of 1911, for example, the Worcester (Mass.) Pressed Steel Co. contracted with the Connecticut River Transmission Co. to supply current for 600 horsepower in motors, with a 24-hour load, using 3-phase, 60-cycle, 13,000-volt current, lowered to 500 volts. A large number of other and more extensive steel-plant installations could be cited. Mining operations by electricity are exemplified by the Empire District Electric Co., of Joplin, Mo., giving service the same year with 2,300-volt motors in no fewer than 125 different mines, for pumping, hoisting, and other operations; the company having at that time 37,000 horsepower of generating capacity for all services and a motor load of not less than 16,500 horsepower, all energy being sold on a horsepower basis and on a demand schedule. A somewhat analogous service is the operation of oil-well pumps by central stations. Near Folsom, W. Va., a number of motor-driven oil wells have been in operation several years. Central station service has been introduced among the wells of the Kern River and Los Angeles fields in California, where more than 300 motors were at work in 1912, resulting in a saving of half the former cost of steam drive. On the basis of 233 wells served the saving in operating expenses was nearly $120,000 per annum.

Pumping water.—Water pumping for large and small communities is another of the newer fields of importance. For example, the Niagara River has been made to pump itself electrically for the water supply of the city of Niagara Falls, N. Y. Motor-driven centrifugal pumps lift the water from the seething river and deliver it to settling beds, from which it passes to the street mains. The plant in 1911–12 was capable of delivering 13,000,000 gallons per day. Some waterworks figures were given before the Michigan Electrical Association in 1911 by Mr. F. D. Spencer, of Cheboygan, who cited a number of examples with the data of electrical consumption for 1,000 gallons pumped. One company operating a triplex pump driven by a 35-horsepower motor and pumping against 100-foot head reported an average consumption of 700 watt hours per 1,000 gallons pumped. Another company operating a motor-driven deep-well plunger pump reported a consumption of 1,333 watt hours per 1,000 gallons pumped against a head of 120 feet. Another plant reported a consumption of 1,220 watt hours per 1,000 gallons pumped by a motor-driven deep-well plunger pump lifting 110 feet.

At Coalgate, Okla., the water supply for the 4,000 population is lifted from 250-foot wells by one 50-horsepower motor-driven compressor supplying air-lift pumps and one 15-horsepower deep-well pump.

The reservoir level is maintained by a 25-horsepower centrifugal pump capable of delivering 300 gallons per minute. Tests made by Mr. H. L. Reager, manager of the local central station company, show that about 1.25 watt hours are required by the deep-well pump for every gallon lifted. As this means a considerable saving over the air lifts, the town decided to replace the latter by deep-well pumps. The pumping station is 5 miles from the town and the powerhouse, and the attendant who takes care of the pumps augments his income by farming. All of the motors are 2,300-volt machines. Ordinarily the pumps are operated from 3 p. m. to 5 p. m. and for several hours in the early morning beginning at 12 midnight. The town pays 4 cents per kilowatt hour for its pumping service, from which the central station derives an income of about $500 a month.

The water of Webb City and Carterville, Mo., is similarly supplied by motor-driven pumps. The joint waterworks company serving the two nearby communities has installed five double-plunger deep-well pumps, each capable of delivering 500 gallons per minute from the 300-foot depth and driven by 25-horsepower 25-cycle motors. The pumps discharge into a 5,000,000-gallon reservoir. Energy for the waterworks is purchased from the system of the Empire District Electric Co. at the rate of $1.25 per month for each horsepower connected, plus 1½ cents per kilowatt hour consumed.

The extreme flexibility of motor drive is again shown by a Louisville installation which furnishes water from a well of special quality to a brewery 3,040 feet distant. This brewery is located on the dry bed of Ballards Creek, from which its supply was formerly obtained, but, with the use of the creek water for other industrial purposes at points above, recourse was had to the well above mentioned, the water of which is found especially valuable for use in the brewing plant. This water is raised by an air lift and is then conveyed 3,040 feet from the well to the brewery by a 15-horsepower, 3-phase induction motor-driven centrifugal pump capable of delivering 200 gallons per minute. Electric service is supplied from the lines of the Kentucky Electric Co.

The Kansas City Electric Light Co. gives service under contract to Armour & Co. in pumping 18,000,000 gallons of water per 24 hours for the latter's local packing plant. For several years the electric company furnished the packing plant 6,000,000 gallons daily from a motor-driven pump on a barge anchored in the Kansas River near its generating station. The permanent installation for delivering the larger quantity comprises a 500-horsepower, 6,600-volt, 25-cycle motor, driving a single-stage centrifugal pump. This equipment is located in the basement of the company's operating station. The pump delivers into a 30-inch pipe leading to the packing plant, against a hydrostatic head of 111 feet. This water is used principally for cooling purposes in the refrigerating plants, and is required in nearly uniform quantities throughout the 24 hours.

Before leaving this topic it is only right to note that the huge cofferdam around the wreck of the battleship *Maine* in Havana Harbor was emptied by three large centrifugal pumps each driven by electric motor and mounted on a barge. The electrical energy for this unique pumping service was furnished through submarine cable by the local Havana Lighting Co., an American institution.

An unusual pumping performance is that of marsh drainage along the Illinois River. The Pekin and La Marsh Drainage District consists of about 2,500 acres of land along the Illinois River, near Pekin, protected from overflow by a dike on the river bank running back to the bluffs at both ends of the district. This area is in charge of drainage commissioners, who drain the land and keep it in condition for cultivation by pumping the water from the inclosure over the dike into the river. Thus at all stages of the river the land is available for agriculture. The first pumping plant in connection with this drainage system was driven by steam engines, but, as the cost proved too high, the engines were superseded by gas engines supplied from a producer plant. After a year's service the gas-engine equipment was in its turn replaced by electric motors supplied with energy from the local central station companies.

Suction dredging.—In the Susquehanna River there accumulate large deposits of anthracite washed down by every spring freshet, the greatest deposits occurring at Plymouth and Northumberland. These are reclaimed for use by the local central stations. At Plymouth a barge equipped with motors of 190 horsepower has a centrifugal pump which sucks coal from the bed of the river and forces it with the water through a long pipe line to the shore, where the coal is dumped. The pump can suck up 50 tons of coal an hour.

Another kind of river pumping is exemplified at St. Louis, where in April, 1912, work began on a dike 40 feet high and three miles long to protect the lower sections of East St. Louis against the inroads of the Mississippi River. With current taken from a local plant through a submarine cable, a dredge with an 800-horsepower electric motor handles 15,000 cubic yards of wet material per day, sucking it from a maximum depth of 35 feet and lifting it to the extreme height of the dike wall. The pumping dredge is equipped also with other apparatus including a 250-horsepower rock-cutting machine electrically driven.

Flour milling.—The operation of flour mills has become a large part of electric-motor application, with notable economy and increase in efficiency. In 1879 the famous Queen Bee flour mill was built at Sioux Falls, S. Dak., at a cost of $500,000, but was shut down a year later on account of transportation troubles. It stood idle until 1912 when it was found that motor drive for it with central station current was possible and profitable. When first operated with an ordinary 800-horsepower water-wheel plant its capacity was 800 barrels of flour per day. Now, with only 485 horsepower of electric motors, its capacity is 1,200 barrels.

Sewage disposal.—Oklahoma City, Okla., in 1912, contracted with the Oklahoma Gas & Electric Co. for 130 horsepower to be used for the electrolytic disposal of the city sewage. A 75-horsepower purification plant has been installed in the Packingtown district. The scheme of sewage purification used is similar to that at Santa Monica, Cal. There would appear to be a large, wholly new field of central station activity in this direction.

Street paving.—The city of Leavenworth, Kans., began to repave a prominent business street, and let a contract for that purpose to a paving firm, which used a steam engine to run the paving machinery. Complaints from residents on the street soon followed on account of the smoke, dirt, and noise from the engine, and the Leavenworth Light, Heat & Power Co. finally induced the contractor to rent a motor for the power service. A 15-horsepower motor to run the paving machine was mounted on a wagon, the machine and wagon being moved three times a week; and as the company's lines were on the street where the paving was being done, connection to the service wires was easily changed, the meter and starting box being carried on the wagon with the motor. As the use of the steam engine had caused some delay, working nights was suggested to the contractor, and twelve 100-watt tungsten lamps on portable poles were installed to furnish light for the night work. The contractors were much gratified with the change to electricity.

Wood working.—The introduction of central station energy into wood-working plants has often proved difficult and is a subject of much discussion. It may therefore be noted that a large stave mill at Galveston, Tex., which formerly burned its refuse in its own 100-horsepower steam plant, is now operated by 40 horsepower in electric motors using central station service. This motor drive costs the mill $60 to $65 a month at 4 cents per kilowatt hour, while it sells to the local gas company the refuse formerly burned, for $1.15 per ton delivered, or about $150 per month. The gas company utilizes the oak shavings and refuse for fuel in its water-gas plant, replacing oil that formerly cost $400 to $500 a month.

Telpherages.—It has long been evident that one of the seriously neglected fields of central station is that of operating docks, piers, and railway freight yards, many managers not being aware, apparently, that practical "telpherage" systems and other devices are in use whereby package freight, and even bulk material, are handled successfully; thus opening up an enormous demand for apparatus and energy. As an example, the fact may be cited that at New Orleans and Mobile the United Fruit Co. makes use of motor-driven machines of the marine-leg type for unloading the bunches of bananas from the holds of vessels, thus saving much time, loss, labor, and damage in comparison with hand unloading. On some other docks, as noted in previous reports, the overhead telpherage system, as on the New York river fronts, has found adoption.

At the two southern ports named, from an extension boom projecting over the water's edge a 35-foot vertical marine leg is dropped into the hatch of the vessel drawn up to the wharf. Sprocket wheels on the marine leg and stationary portions of the unloader carry a pair of chains 4 feet apart, between which, on cross-bars, is attached a canvas strip so arranged with slack as to form pockets at 3-foot intervals. The four machines at New Orleans have 92 pocket belts, and each is driven by its own 15-horsepower induction motor. These machines have individual equipments for unloading 2,500 bunches of bananas per hour, the bunches weighing from 60 pounds to 120 pounds each. In the hold of the vessel the conveyors are filled from three levels, each loading into every third pocket of the conveyor, the speed of which is, of course, too high to permit filling successive pockets from a single position. After reaching the back or dock end of the conveyor, the pocket-chain passes over a straight roller which discharges the bananas gently onto a moving belt running back to the cars where the fruit is loaded for rail shipment. At New Orleans the Mississippi River level varies periodically by about 14 feet, and the unloaders must accommodate themselves to this variation, as well as be able to reach the hatches of any ordinary vessel. The suspended marine leg is supported from an auxiliary boom hinged to the main boom, so that, by making a jackknife bend, practically any hatch level or distance from the wharf can be negotiated. The manipulation of the booms and hoists and the side travel of the huge machine along the dock front are all controlled by friction clutches on the main conveyor-motor shaft. Within three to five minutes after the vessel's hatches are made ready, the machines can be located in position and unloading begun. The four machines at New Orleans working together can unload 10,000 bunches per hour. Besides expediting the work of unloading and saving labor, the machines effect their most important economy in preventing damage to the fruit. Energy to operate the unloaders at New Orleans is taken through cables and plug connections on the dock from the lines of the New Orleans Railway & Light Co. The machines at Mobile are supplied with energy by the Mobile Electric Co.

In similar manner the New York Edison Co. has entered into contract with the United Fruit Co. to supply current to its steamers when at their docks in

New York, to be used for operating cargo winches and for other purposes. This lessens the amount of steam equipment necessary to be kept in operation and facilitates speedy handling of the cargo.

Ice manufacture.—The manufacture of ice, either in combination central station plants or through the supply of electrical energy to ice factories, has become an important industry. An interesting example of both businesses being carried on under one management is that of the Kentucky Traction & Terminal Co., of Lexington, which takes the condensate from its surface condensers, reboils and filters it, and uses it in making artificial ice. The plant is of 5,000-kilowatt capacity. Besides supplying the local Lexington utilities, the new turbine station transmits 33,000-volt, 60-cycle energy to railway substations at Paris, Frankfort, and Nicholasville, and to combination railway and lighting substations at Versailles and Georgetown. Sixty to seventy-five tons of ice are turned out daily at the central power house, to be sold directly to retail dealers or held in storage against the heavy summer demand.

Another interesting example is the Durham, N. C., Traction Co., with a combination of lighting, traction, and ice-making. The condensation from the engines is sufficient to make 100 tons of ice a day. The water from the reboiler is forced through four coolers and then through a set of three cloth filters. It passes thence through a set of charcoal-brick filters and three batteries of charcoal and silica-sand filters, whence it reaches the pre-cooler. The latter is a double-pipe arrangement in a tank, wherein ammonia is expanded directly, so that the water on its way to the freezing cans reaches a temperature of 40 degrees Fahrenheit, or lower. There is a storage tank which is also piped with coils sufficient to maintain the temperature of the water a few degrees above freezing before it reaches the cans. With a new tank room, 295 cans in the whole system can be produced, making it possible to manufacture 100 tons of ice a day if necessary. The storage room, in which provision is made for 150 tons of ice without stacking, is piped for direct expansion and is insulated with 4 inches of cork covered with cement. The cork is laid in 2-inch tiers, between which is a ½-inch coating of cement, while the cork on the ceiling and floor is laid in asphalt. Ice is handled by means of a pneumatic hoist and hand-operated crane. The steam from the Corliss engine is first passed through a 36-inch self-dumping oil trap or separator, which is said to be effective in removing the oil from the steam. The ice is retailed by the company at the rate of 40 cents per 100 pounds in small pieces, and 30 cents per 100 pounds in cakes. If two cakes are sold at one delivery, the rate is 25 cents per 100 pounds.

Before the Kansas Electrical Association in September, 1911, Mr. W. E. Sweezey, of Junction City, Kans., gave some interesting data as to combination ice plants. He had had over nine years' experience in combination-plant operation and at that time had a 35-ton plant in connection with his station. The same boilers did the work of both plants, the demand of each varying almost inversely as that of the other. The figures of coal consumption submitted show how the sum of the two demands was nearly constant, one increasing almost exactly as the other fell off. The following tabular statement shows the tons of coal burned and the amounts of electricity and ice produced during six typical months of winter and summer.

	June.	July.	August.	November.	December.	January.
Tons of coal burned	670	675	700	580	620	600
Kilowatt hours generated	108,780	111,710	122,500	146,430	162,121	155,160
Tons of ice made	965	1,055	1,050	112	54	32

In the Junction City plant the same engineers and firemen were employed the year around, as the coal burned and energy converted were practically uniform throughout the 12 months. The only extra labor required by the ice plant was for "pulling" the cakes from the cans, which for the 35-ton outfit cost about $5 a day, amounting to about 25 cents per ton of ice. As a result, the average cost of producing a kilowatt hour in summer, when the output was decreased by 33 per cent, was almost exactly the same as during the heavy loads of the winter months.

As to ice plants operated from central station circuits, some figures on the quantity of energy consumed during the year by several refrigerating installations were given by Mr. W. C. Anderson, of the Canton Electric Co., before the Ohio Electric Light Association, in July, 1911. Of the 10 such installations then in operation in Canton, several had been in use for 8 or 9 years. Below is given the consumption, in kilowatt hours, of each of the six of these plants which are so metered as to give results available for comparison.

Ice Plants Operated from Central Station Circuits—Energy Consumption of Refrigerator Installation.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Refrigerator installation:						
Tons refrigeration	3	3	5	3	5	3
Motor horsepower	7½	10	20	7½	26	16
Energy consumption:						
Kilowatt hours—						
January	146	646	1,950	....	51	516
February	70	733	2,210	....	34	120
March	112	846	2,070	286	102	892
April	322	1,627	2,600	1,528	1,240	2,168
May	247	1,654	2,850	1,622	1,139	1,928
June	403	2,826	3,600	2,050	1,069	1,976
July	343	4,718	6,040	2,062	2,649	1,978
August	540	5,633	5,590	2,060	2,518	2,212
September	591	4,174	4,790	1,712	2,100	2,200
October	576	2,145	4,200	1,476	1,639	2,052
November	453	1,161	2,630	804	944	1,540
December	335	229	3,310	....	936	264

At the meeting of the Illinois Electrical Association, October, 1912, Mr. J. G. Learned reported that the

Commonwealth Edison Co. then had 2,000-kilowatt capacity connected in ice making. Local ice manufacturers could make ice electrically at a lower cost per ton than the cost of natural ice brought from the near-by Wisconsin lakes. One Chicago ice factory had an electrical load factor of 85 to 90 per cent and turned out its product at 48 to 52 cents per ton, in competition with lake ice costing 55 to 60 cents per ton. Mr. Learned urged central stations to encourage raw-water ice making. The Lincoln Ice Co., Chicago, had an installation of about 450 horsepower in alternating-current motors used to drive compressors, pumps, hoists, etc. This plant had a capacity for producing 120 tons of ice every 24 hours, and was operated throughout by electrical energy. Filtered water from Lake Michigan was used to make the ice. An 80-ton plant at South State and Forty-third Streets had an electric-motor equipment with a rating of about 350 horsepower. Both plants operated 24 hours a day in the summer. They bought electrical energy from the electric-service company on the "off-peak schedule," by which a reduced rate was offered in consideration of the fact that the consumer agreed not to take electricity between the hours of 4 p. m. and 8 p. m. during the months of November, December, and January. By reason of the continuous demand and concessions made in the off-peak schedule, the ice makers were able to obtain a very low rate for electrical energy, namely, about 1 cent a kilowatt hour.

Creamery work.—The O'Neill (Nebr.) Light & Power Co. carries on the unique combination of an electric-light plant and a creamery business. The combination of these two industries made it possible to install an electric-light plant where otherwise the enterprise would probably be of an unprofitable character. The motive power is a 45-horsepower Corliss engine belted to a line shaft. From this line shaft is driven a 50-kilowatt, 3-phase, 2,300-volt alternator at 900 revolutions per minute. For the creamery business there is belted to the line shaft a 10-ton refrigerating machine. The other machinery for the butter and ice-cream making is also driven by the line shaft. The establishment has a capacity of one car of butter per week and 300 gallons of ice cream per day.

CENTRAL STATION STEAM AND HOT-WATER HEATING AND SUPPLY OF STEAM FOR POWER.

Steam heating.—There are a great many central station systems that combine steam heating with their electrical operations, and this would appear to be a growing branch of the industry. Other kindred conditions have developed and have been worked out. The laundry comes midway between the power and the heating load of a station, especially where there is the opportunity to use exhaust steam, a field of work into which central station companies are throwing themselves with energy and success. For instance, in a Minnesota city of 4,500 inhabitants, where the central station has 175 kilowatts in generating equipment driven by Corliss engines, and does a steam-heating business during the winter, summer use for its exhaust steam is provided by heating water for a steam laundry, three hotels, three barber shops, and two apartment buildings. As the plant is operated with a back pressure of from 2 to 3.5 pounds per square inch, winter and summer, this water-heating business is found of great service in helping to carry the plant over the light-load summer period. The steam laundry is the best user of exhaust steam during the summer period. It is located adjacent to the electric plant and is supplied with exhaust steam for water heating through a 3-inch lagged pipe line, and with live steam for its large mangle through a 1-inch high-pressure steam line. The large mangle, two washing machines, and a centrifugal drier are all driven by electric motors, and electric heat is used for the flat-irons and collar machine. The electricity consumed for heating purposes and for motors has averaged about 615 kilowatt hours per month. Steam is sold by meter at an average rate of 70 cents per 1,000 pounds of condensation. The income for the steam used by the drier, mangle, water heater, and several small machines has averaged $22.75 per month. The heating of water for barber shops, flat buildings, and hotels near the plant was also found to be a profitable adjunct of the regular summer service.

The relation of the central station industry to the field of steam heating and hot-water heating is not yet very well defined, but there is already a good deal of relationship and interaction, because obviously the supply of such heat is often necessary within the area covered by the electrical circuits, and a building which requires light and power has also corresponding necessities for heat or hot water in the winter months, or even all through the year. Hot-water supply by central stations so far is a negligible quantity, but there is already a large amount of steam heating. In the report of the committee on steam heating, of the National Electric Light Association, presented at the Seattle, Wash., meeting in 1912, Mr. A. D. Spencer recited the experience of the Central Heating Co. of Detroit, Mich., which operated two stations for heating, one using live steam exclusively and the other depending to a considerable extent upon the exhaust steam from the engines of an electric light and power station. The total number of heating companies in the United States in 1912 was about 250. The National Electric Light Association is particularly interested in those systems, operated in connection with electric supply systems, which either utilize exhaust steam from the generating plants or maintain separate live-steam plants.

These plants are operated either for direct profit by the utilization of exhaust steam (which may be considered a by-product), or on account of the electrical business which can be secured only when heat also is furnished.

Many heating companies, Mr. Spencer said, are not directly profitable. In many cases where profits are claimed it can be shown that no proper separation of costs has been made. Even where costs are separated such items as depreciation are seldom included. Overhead expenses, such as clerical labor, superintendence, plant charges, etc., are often charged entirely to the electrical division. Many companies which at first used exhaust steam only, have become practically live-steam companies, owing to the growth of their heating business. As heating loads and electrical loads have entirely different characteristics and do not coordinate well, it is necessary to restrict the heating service to a point where only a small part of the total exhaust steam available is used, if the use of live steam is to be avoided. As the heating company generally finds it difficult to refuse new business, if it intends fully to occupy the field, growth is inevitable.

Rates.—Heating business can be secured at rates equivalent to the cost to the consumer operating his own plant. Possibly slightly higher rates can be charged, because of the convenience of the service. Residences and small business places, which pay higher prices for coal, should be charged more than larger buildings where engineers are employed and where the coal cost is about equal to that paid by the heating company. As those private plants have no distribution investment and no distribution heat losses, it is hard for the heating company to compete at a profitable rate. In residence districts profitable rates undoubtedly could be charged.

Steam costs, like electric costs, can be divided into service (per customer) costs, capacity (per square foot radiation) costs, and output (per thousand pounds steam) costs. As heating load factors are substantially the same for all customers, it is fair to ignore the capacity costs and to consider costs as made up of service costs and output costs. Rates should be made up of a service charge and a charge for steam used; or at least the system of rates should be such as automatically to cover both elements of cost. This is generally taken care of by a sliding scale of rates which reduces the cost per thousand pounds of steam as the consumption increases. The rates cover all costs, including a proper proportion of overhead charges, interest charges, and depreciation. The last item is very important, as steam-distribution systems are found to be subject to rather rapid deterioration.

Hot-water heating systems use flat rates, as it is impossible to meter the service. Some steam heating systems use flat rates, but the tendency is toward meter rates, which are desirable, as they charge each customer for actual heat used, and do not penalize one customer for the waste of another. They also tend to cause economy in the use of heat, thus permitting the company to serve its customers at lower rates. Flat rates are usually based on the radiation area connected. Under this system it is necessary for the heating company to supervise all installations and specify the amount of radiation required.

Meter rates are based on the pounds of steam condensed. Under this system, supervision of installation is desirable only as a matter of policy to insure satisfied customers. The meter system introduces an element of cost and annoyance in the maintenance of the condensation meters, which are subject to severe operating conditions and are a source of much trouble.

A report received by the committee above named from the New York Steam Co. stated that in its experience the average building uses 25 per cent less steam when operating on a meter than when operating on a flat rate. This has to a considerable extent been borne out by the experience of the heating company in Chicago, which has already transferred several of its customers from a flat-rate to a meter basis. One of the largest office buildings in the country, erected in Chicago, with approximately 90,000 square feet of radiating surface, closed a contract with the heating company for steam service on a meter basis.

Steam power.—High-pressure service for power has proved very unsatisfactory in Detroit, mainly by reason of the inability to meter the service properly and the necessity of keeping the mains alive during the summer months. The service already on the system has gradually been disconnected, and new customers have not been encouraged. Where meters are used it is found desirable to maintain a somewhat elaborate system of inspections. The conditions under which the meters operate are severe. Heat, moisture, and dirt are always present. Defective traps may allow steam to get to the meters. No meter has been found which operates satisfactorily under such conditions without frequent attention. Many smaller companies read and inspect the meters daily. In larger systems this becomes impracticable. In Detroit meters are read every five days. Meters found out of order are promptly repaired. All readings are checked, and sudden decreases in consumption are followed up by inspections. A system of monthly inspections of the large meters is being inaugurated in order to remedy troubles before any revenue is lost. Every summer all meters are overhauled and put into first-class condition.

Customer's installation.—The point of greatest weakness in a district heating system is in the customer's installation. Regulating valves stick, causing too low or too high pressure; traps stick, flooding the system or allowing a leakage of steam into the basement; automatic air valves fail to operate, causing the radiators to fill with air; strainers clog, causing flooded installations; valves leak and ruin floors and ceilings. For these reasons it is essential to maintain a patrol service, in order to keep customers satisfied. It is generally found desirable to have small repairs and adjustments made by the patrol man, rather than to ask the customer to hire a steamfitter. Such repairs are charged at cost of material used. It is found that many customers require considerable assistance and education before they are able to regulate systems satisfactorily. On flat-rate systems, elaborate specifications for customers' installations are essential. On meter systems, certain points are covered by specifications for the protection of the heating company and to insure the satisfaction of the customer.

Decentralized plants.—Another class of steam heating, namely, that from decentralized steam plants, is used by central station companies only in a few large cities, where a great amount of radiating surface is located within very small areas. In Boston and Philadelphia some of these small block-heating plants are operated by the local electric light and power companies, while in New York and in Chicago they are operated by independent steam-heating companies, which cooperate with the electric light and power companies.

ELECTRICITY IN AGRICULTURE.

Power, lighting, and heating.—The use of electricity on the farm has been pursued and developed with extraordinary rapidity in recent years. The chief reasons are the extension of power-transmission circuits from central stations in cities, and the establishment of distribution networks in connection with hydroelectric enterprises looking for patronage of every description. The variety of uses to which electricity can be put on the farm is surprising. Not only are there all the usual services and conveniences utilized by the dweller in the city, but there are many others relating specifically to farm work. The report of the Committee on Electricity in Rural Districts of the National Electric Light Association made in June, 1913, enumerated 50 uses for electricity in the farmhouse itself, 30 applications for electric-motor drive to barn and field machinery, and 20 uses in the dairy. Even this does not exhaust the list, which omits all the work connected with irrigation and with many industries carried on in country districts, such as fruit-canning, digging sand and gravel, and the operation of stone quarries and of sawmills, creameries, gristmills, etc.

Concrete examples of this significant development exemplify what is being done all over the country. At the meeting of the Illinois State Electrical Association in 1911, this subject was brought up, and some most interesting statistics were presented. Mr. E. L. Brown, of Elmwood, Ill., described his local system comprising 30 miles of transmission lines connecting 8 small towns and supplying about 50 farms. Mr. R. H. Abbott, of Petersburg, Ill., described his service to farmers along the route of a 16,500-volt, single-phase transmission line, with step-down transformers lowering to 2,400 volts for the primary distribution. All transformers, poles, lines, lightning arresters, etc., were owned by the farmers, each of whom paid a minimum charge of $2 per month.

An interesting example is furnished by the work done on the Bacon farm, near Grand Forks, N. Dak., where the energy is supplied by the Red River Power Co. A gasoline engine was formerly the prime mover, but now a 3-phase motor mounted on a portable truck supplies all the service. In like manner, at the Bellows farm, of 640 acres, 4½ miles from Maryville, Mo., not only is electric light for the house and barns obtained from the local electric-light company, but a 20-horsepower induction motor on skids is moved around the place and can be connected at several points in and about the barns and silos where work is to be done. The 3-phase, 60-cycle, 2,300-volt transmission line, with painted poles and creosoted butts, was built by the company at the expense of Mr. Bellows, costing about $425. There are nine points at which the motor can be put directly at work. At Montrose, Colo., the local company has a special lighting circuit nearly 6 miles long, built by itself, to reach a group of large fruit ranches west of the city. There are no fewer than 38 such customers, with 14 transformers, of 3 to 5 kilowatt capacity each. The line consists of a single-phase circuit of No. 6 copper on glass insulators, with wooden poles and cross arms, the poles being Idaho 30-foot cedar with 6-inch tops, and set in concrete foundations to a depth of 18 inches, the pole bottoms reaching a depth of 5.5 feet. The cost of the line, with arresters, transformers, and meters, was $800 per mile.

As to the line material, Mr. Theodore Bass, of Farmington, Ill., at the Illinois meeting noted above, described a service to a group of three farms supplied with energy from his 16,500-volt transmission line. The farmers hauled and erected the poles, paying $200 for the high-tension step-down transformer and the three distributing transformers. Iron wire is used for secondaries. Mr. W. G. Austin, of Effingham, reported the successful operation of a 7-horsepower motor at the end of a mile of 2,200-volt line of No. 10 iron wire. Another member stated he had constructed 32 miles of 1,000-volt line, using No. 6 hard-drawn copper wire on 30-foot poles, at a cost of from $150 to $200 per mile.

With regard to the work of the Petersburg (Ill.) Electric Light Co., when the news became known of its plans to build a 16,500-volt transmission line to Greenview and Mason City, a number of farmers along the way served notice on the company that if they could have the privilege of taking service at the town rates, the right of way for the proposed line would be furnished free of cost. With this inducement to supply electricity to neighboring farms, Mr. R. H. Abbott, president of the company, made arrangements to install several step-down transformer substations along the line, reducing to 2,400 volts for distribution to the farms. These single-phase, high-tension transformers are mounted in small houses built on 25-foot poles and are protected only by fuses. At the beginning of 1912, two such substations had thus been erected, one feeding a 2-mile, 2,300-volt line supplying four farmers, and one a 2-mile line for two farmers. The 2,300-volt lines are of No. 6 hard-drawn copper wire carried on 6,600-volt porcelain insulators on 25-foot poles set 40 to the mile, and the regular distributing transformers are equipped with both lightning arresters and 2,300-volt fuses. All of the transformers, poles, lines, arresters, etc., are owned by the customers, so that the company is without investment on their account. A minimum bill of $2 per month is charged each customer, the regular Petersburg schedule applying to the energy consumed. The farmers appreciate the service, and several have fitted up their places with electrical equipment, installing pumps, motors, fans, irons, bathroom heaters, and other appliances.

At Liberty, Ind., the Liberty Light & Power Co. in 1912 furnished electric lighting service from its 32 miles of 13,200-volt and 6,600-volt transmission lines to a number of farmers in the vicinity. The farm owners in the neighborhood of Liberty and Richmond are very prosperous, but were using their electric service only for lighting. The company made a minimum "transformer-loss" charge of $1 a month for each customer. During the winter months, however, some of the farm bills averaged $2 to $2.50, the rate for energy being 13 cents per kilowatt hour. Tungsten lamps were used for general illumination in the farmhouses, the commoner carbon lamps being employed in the barns and outbuildings.

Irrigation and pumping.—An important and somewhat distinct branch of this work has been that relating to irrigation and pumping. A good deal of this work has been done in the West, based on windmills, gas engines, etc.; but with the combination of wells, internal-combustion engines, and ditches a failure, the agriculturist took up the previously neglected electrical pumping. The aggressive policy of certain central stations in building the necessary pole lines to reach such loads has resulted in many interesting and very profitable installations of motor-operated pumps. An installation of this kind is that of Mr. M. A. Lunn, near Denver, Colo. In this case 80 acres were supplied with all the water necessary to change dry, arid land to fertile, productive soil. A 35-horsepower, 3-phase, 220-volt motor is belted to a centrifugal pump which is connected to two lines of 12-inch pipe. The pump is capable of delivering 1,100 gallons per minute against a head of 50 feet. The water is pumped in two directions to discharge points 1,320 feet north and 1,320 feet south, respectively, of the pump house; and from the height of 50 feet it is allowed to flow by gravity through ditches over the adjoining fields. The 13,000-volt transmission lines are tapped for this service, the pressure being reduced to 220 volts at the pump house. All the water used is secured through fillings made on seepage and underflow in a stream known as Dry Creek, an earthen breastwork serving to collect the water flowing in the creek and such seepage as the lands situated on higher levels may supply. The results of the installation have been not only satisfactory but highly gratifying to the consumer.

Even more interesting, because more extensive in its sphere of influence, is the work to which attention is drawn by Mr. C. H. Williams, of the Northern Colorado Power Co., whose system relies on energy from coal, with steam turbines, and whose territory extends from Denver, on the south, to Cheyenne, Wyo., on the north, and from the foothills of the Rockies to a line 50 miles eastward on the plains. All through this arid belt, where rainfall is light and surface water rather unreliable, irrigation is a great stimulus to cultivation and crop values, and the company has gone thoroughly into it. One part of its work is to reach the underflow by electric pumping. The generating plant is 13,200 volts, 3 phase, 60 cycles. For the transmission 44,000 volts pressure is used on the main line, with branches at 13,200 volts, 6,600 volts, and 2,300 volts. The system already built reaches 32 towns in the center of the richest agricultural district in northern Colorado. The lines are run on wooden poles, 40 to the mile, with substations and switching stations about 20 miles apart on the main line, so arranged that any substation can be cut out without interrupting the service. All the territory covered has a copious underflow. The wells dug for irrigation are peculiar. They are either circular or rectangular in form, with concrete curbings lowered to reach down to the water-bearing strata. The pump is submerged and the vertical shaft run up to a framing which carries either a motor with vertical shaft directly coupled or a pulley belted to a motor placed in a housing at the side of the well. The lift being but moderate, centrifugal pumps are used, driven by 2,300-volt motors. During the pumping season of 1910 careful tests were made on 57 pumping plants, with approximately the following results: With an irrigation plant arranged to supply a quarter-section of 160 acres, lifting through a 25-foot head, the average investment required is $7.45 per acre. The cost of operation varies from $1.75 to $2.25 per acre-foot; that is, a foot of artificial rainfall per acre can be obtained for this modest sum. Over much of the territory this additional foot is all that is required, although in other places 2 feet may be necessary. Allowing 10 per cent as fixed charge on the pumping investment, the ultimate cost to the farmer for an acre-foot amounts to only about $2.75. This is much lower than the ordinary cost of water rights and their maintenance, with the additional advantage that the water is always available just when it is needed. The gain by this ability to regulate the time of flow to the condition of the crops has led to not a little pumping by farmers who already have water rights. Besides the use of electricity for pumping, a considerable amount of auxiliary farm machinery is operated in the same manner.

In 1912 over 60 miles of secondary distribution lines were built through the rich and productive farming country of the Sacramento and San Joaquin Valleys, near Stockton, Cal., by the Western States Gas & Electric Co. This system had then a connected load of nearly 2,000 horsepower in the irrigation and farm service of some 700 ranchers. The network of secondary lines, built at an outlay of $90,000, covers 80 square miles of the best farming country, and has been laid out with extensions in view which will cover 2,000 square miles. Irrigation forms an important part of farming operations in this region, the addition of water to the land multiplying its productiveness from two to ten times. Irrigation plants operated by central station service are always ready for use, and are started and stopped with no more effort than is required for the throwing of a switch. Such power service is, of course, a great boon to the small farmer. The rates for electric service are as follows: First 1,000 kilowatt hours, 3 cents per kilowatt hour; second 1,000 kilowatt hours, 2.5 cents; third 1,000 kilowatt hours, 2 cents; fourth 1,000 kilowatt hours, 1.5 cents. Great crops of asparagus, celery, potatoes, onions, beans, grapes, and deciduous fruits are made possible. Within three months, in the summer and fall of 1912, 1,500 horsepower, mostly in small motors driving irrigating plants, had been connected to the lines.

At the meeting of the New England section of the National Electric Light Association in October, 1912, many references were made to the application of electricity to the farm in the East. A paper read by Mr. C. H. Miles, of the Boston Edison Co., referred to its famous tent exhibit. This traveling "circus" comprises all kinds of farm apparatus driven by electricity, and is moved from place to place in a large suburban and rural territory. It is estimated that, by irrigation, land in New England can be made to yield from 50 to 100 per cent more in crops than by depending solely upon natural water supplies. Growers of market-garden products in Arlington, less than 10 miles from Boston, are using land worth $1,000 per acre. The Edison Co. replaced a steam-pumping installation in that town with a 25-horsepower motor driving a centrifugal pump at 3,600 revolutions per minute and pumping about 200 gallons of water per minute against 90-pound pressure. The cost of this energy is but little more than was formerly paid for attendance on the steam pump, and about 30 per cent more water is delivered at a moment's notice. The water in this installation is used through open hose and a series of small nozzles placed horizontally in a supply pipe fixed about 2 feet above the ground, the application of the water thus resembling natural rainfall. During the very dry period in June and July of 1912, the plant was in constant operation and the cost of energy was only about $4 per month per acre.

Miscellaneous uses.—Mr. H. D. Larrabee, Montpelier, Vt., emphasized the advantageous conditions of his territory in the application of electric energy to farming. In the Montpelier district, in one case, a 2,300-volt line was extended 3.5 miles, 40 rural customers being supplied with energy, chiefly for lighting. Thirty-one electric flatirons were sold in two months. In other instances, where motors of from 1-horsepower to 3-horsepower rating were installed for farm service, a 2.5-kilowatt pole-type transformer and a 20-ampere meter were installed at each place. Mr. Eugene Farmer, of Oak Bluffs, Mass., described an educational campaign conducted by the Vineyard Lighting Co. to induce more of the people in its territory to take up agricultural and fruit-raising pursuits. Courses in farming had been added to the high-school curriculum at Martha's Vineyard. At one representative plant a motor-driven pump was operated between midnight and dawn on one section of the farm after another in rotation, thus giving an artificial shower on each section every fifth night. Such service enabled liquid insecticides and fertilizers to be sprayed as and when required. Mr. Taylor, of Poughkeepsie, N. Y., cited the extension of a central station 2,500-volt circuit 1.5 miles to serve 35 farmers, which resulted in the shutting down of six old windmills, the installation, besides lamps, of electric washing machines, fireless cookers, and flatirons, as well as an electric incubator, and the operation of the usual electrically driven farm apparatus. On one model farm with 50 cows a 2-horsepower motor had been installed with a milking outfit. A 9-cent kilowatt-hour power rate was in force.

Egg incubation.—This section should properly include egg incubation, as an increasing number of poultry farms are being electrified. The size of some of the electrical incubators is astonishing. Muskogee, Okla., has one of 30,000-egg capacity, said to be the largest incubator in the world. The growth of the chicks is artificially forced by electric light. Use of motor-driven blowers to circulate the air heated by natural-gas burners has made possible the compact construction of this hatchery, the egg trays of which are superimposed on racks, 20 deep. Five thousand eggs can thus be handled and hatched in a space 2 feet by 4 feet by 4 feet, requiring only about one-tenth of the area and air volume demanded by the old-style incubators. After hatching has begun, trays with high sides are substituted for the incubating trays, each high-side tray occupying the same space as two of the ordinary trays. Although the idea of converting the whole building into a hatchery with superimposed open trays for the eggs is not new, the use of a motor-driven blower at Muskogee to force the evenly heated air to all parts of the tray racks has, for the first time, made this method practicable on a large scale. Humidity of the air is regulated by passing it over open pans of water. A simple thermostat controls the natural-gas supply to the burners through a mercurial valve, keeping the temperature in the incubator constant at 100 degrees. It is stated that chickens thus raised live three electric-light days during two ordinary days of sunshine, so that the 4-week-old electric chicken will far outweigh the sunshine chicken, whose hours of feeding capacity gave it only a 67 per cent load factor, for in the runways the scheme substitutes eight-hour periods of light and darkness. Under the old system of brooding the chicken was idle 8 hours out of the 24, as it could eat all the food it wanted in 8 hours and digest it in another 8. Thus it is evident 8 hours between one dawn and the next were wasted by the improvident chicken, reckless of its short life. No information has been forthcoming as to the effect on the flavor of the chicken working at a 100 per cent load factor, but any inequality can doubtless be rectified by broiling it electrically. The local company finds a steady load in the incubator supply.

Details of an electric incubator at New Orleans, which was put into service with an initial capacity of 6,000 eggs, were made public during 1912–13. It is 40 feet long and 5 feet wide, with 40 compartments, each with a capacity of 150 eggs. The cost of operation is put at 50 cents per compartment per hatch, with various incidental advantages over the former methods.

ELECTRIC VEHICLES.

The more extensive use of the electric automobile has provided a new source of income for the central station, and the service is apparently only at its beginning. According to President W. H. Blood, of the Electric Vehicle Association of America, in 1911-12 there was invested in this country not less than $10,000,000 in electric trucks and $30,000,000 in electric pleasure vehicles; and a production of at least 15,000 electrics of all types was estimated for 1913. A very large proportion of these machines were supplied with charging current from central station circuits. It is only natural, therefore, that throughout the country an effort has been made to develop this new class of business and build up the vehicle "load." The opportunity thus offered is enormous. At the meeting of the Illinois Electrical Association in 1912 it was stated by Mr. George Jones that if half the horses in use in Chicago were replaced by electric vehicles, the central station load created would amount to 94,000,000 kilowatt hours per annum As such vehicles are usually charged late at night, when the ordinary demand for current is small, no additional investment in central station apparatus would be necessary, and this "off peak" business would improve the general load factor about 13 per cent.

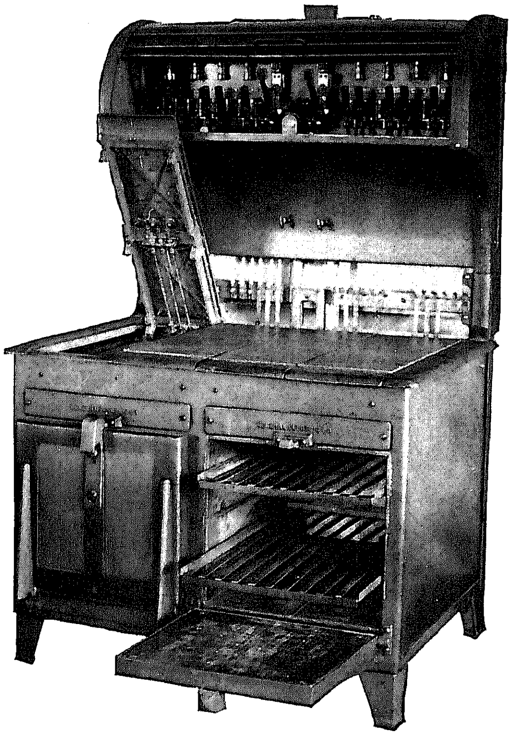
In a paper read before the National Electric Light Association in June, 1913, by Mr. E. E. Witherby, the following remarkable figures were given as to the increase of electric commercial trucks in use in Chicago: November, 1910, 80; November, 1911, 150; April, 1912, 263; November, 1912, 365; January, 1913, 523; May, 1913, 647. One department store in Chicago had in use or on order 139 vehicles, while one brewery in New York had 112 large trucks. At the Brewers' Congress in Boston in October, 1912, one of the speakers stated that electric trucks were saving his company over $80,000 per annum in delivery service. At the end of 1912 the city of Denver had one electric pleasure vehicle for every 217 inhabitants, probably the "record," and due wholly to the energetic campaign for the introduction of electrics made by the Denver Gas & Electric Co. In Boston and all the other large cities the central station companies not only have put in operation large "fleets" of electrics for their own use, but have undertaken, at heavy advertising expense, the education of the public in the use of these vehicles. Some of the companies have themselves equipped electric garages for the convenience of consumers, but in general the conduct of that part of the business is left to private garages, the central station company merely selling current to such institutions or to individuals. An example of the general practice was given before the Electric Vehicle Association in October, 1912, in a paper on the situation in Denver, Colo., by Dr. M. Ekstromer. The Denver Gas & Electric Co.'s rate to private garages on the off-peak basis is a minimum monthly charge of $5, plus 4 cents per kilowatt hour over and above the minimum, with a 10 per cent discount. "Peak charging" at times when other demands are pressing raises the minimum to $7.50 per month. For public garages the rates are about 3 cents, with discounts based upon quantity. Early in 1910 the company established a department of electric-vehicle and storage-battery engineering, which has since done much to standardize garage practice, educate users in the proper care of equipment, assemble and utilize cost data, and promote cooperation among dealers. The company sells no vehicles directly and maintains impartiality between the competitive makes in its territory. An attractive monthly publication is mailed free to all owners of pleasure and commercial electric cars and also to merchants owning and operating gasoline or horse-drawn vehicles and trucks. In June, 1910, there were 3 commercial and 480 electric pleasure vehicles in the city, but in the fall of 1912 no fewer than 57 commercial electric vehicles were in service or on order and 850 pleasure vehicles of the electric type were in service. The vehicle load then called for 2,160,000 kilowatt hours, yielding a revenue of about $64,800 per year. The estimated increase in the next two years was 300 per cent. One coal company, which, according to the Denver Gas & Electric Co., has had exceptional opportunity for studying its electric delivery service, employs a car which hauled 435 tons of coal in one month, a daily average of 18.3 tons. The largest amount of coal hauled in a single day by the truck amounted to 22.1 tons. It covered 63 miles in one day, and the record number of trips was seven. The truck was in service 229 hours, but it was engaged in hauling only 126 hours, 103 hours being required to load coal and unload it. The total mileage for the machine for the whole month was 1,005 miles. It took 119 trips, averaging 8½ miles each, to accomplish that distance.

Use by United States Government.—The Government itself has made considerable use already of electric vehicles, charged chiefly from central station circuits. Among the Federal establishments in Washington which own and operate such vehicles may be mentioned the Navy and Treasury Departments, the Insular Bureau, and the Government Printing Office. Most notable is the work done in New York City through the last census period and down to the present moment in the local post-office service by some 30 machines. Twelve of these electric trucks have made deliveries from 19 postal substations in New York to addressees of large and heavy packages sent through the parcel post. This service was begun with the inauguration of the parcel post, 7 vehicles having been used during the first months, 15 for a subsequent period, and later, by reason of changes in the system, the 12 mentioned. During the month of December, 1913, in 27 days these machines traveled 7,111 miles and delivered 98,243 parcels. At this rate the parcel-post truck fleet covered an average distance of 263 miles per day, or 22 miles per individual vehicle. These trucks, it should be noted, have, however, capacities of 45 miles per charge. Deliveries were made at the rate of 3,628 parcels per day, or about 303 per day per vehicle. The average distance traveled per package delivered was 0.0724 mile, or 382 feet. At the rental paid by the Government for this delivery service the average cost per parcel was 3.3 cents, not including, however, the salary of the carrier who accompanied the truck on its rounds and made the actual deliveries. In addition to the trucks just mentioned, a number of large electric machines are used for mail haulage between the New York City depots and postal stations. Some of these cars have been in service five or six years, having been used 24 hours per day and every day in the year during much of this period. Such mail service is one of the most exacting to which motor trucks can be applied.

Fire apparatus.—An interesting application of a special character is that to fire apparatus, as exemplified in the equipment of the ladder truck and combination wagon for the Springfield, Mass., fire department, current being supplied by the local United Electric Light Co. The truck carries a total length of 325 feet in ladders and a crew of seven men, and has four 3-horsepower motors and 80 cells of 17-plate battery, the outfit weighing complete 10 tons and making 15 miles at full speed on a single charge. The truck has a guaranteed maximum speed of 20 miles per hour on a level roadway. On a test run it has ascended a 12 per cent grade at a speed of 8 miles per hour. The combination wagon carries a 40-gallon chemical tank, 200 feet of chemical hose, and 1,000 feet of regular fire hose. It is driven by four 3-horsepower motors and weighs 7 tons, having a speed guaranty of 30 miles an hour. Its battery equipment is the same as that of the ladder truck. On a 12 per cent grade it has made a measured speed of 12 miles an hour. Three electrically driven hose wagons were ordered in 1911 by the city authorities. The initial cost of the motor-driven ladder truck was about $12,000. A first-class horse outfit costs about $5,500, but the annual cost of operation by horses is far greater than with electricity. Three horses can not be maintained in the condition necessary for fire department service on less than $1,000 per year. The single item of shoeing horses with the best rubber pads costs at least $4 per month per horse. The small cost of energy at about 3 cents per kilowatt hour is noteworthy, and even if a life of but a single year should be obtained from the battery there would still be a margin of nearly 50 per cent in favor of electricity.

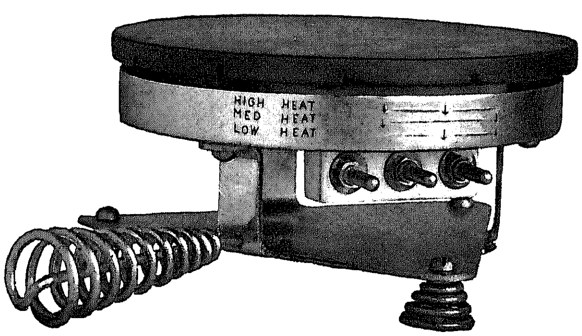
The general relation of the central station industry to the electric vehicle was summed up by Mr. Arthur Williams, then its president, in an address before the Electric Vehicle Association in January, 1913. Ten years ago the price of energy for charging averaged about 23 cents per kilowatt hour throughout the United States, compared with from 3 to 5 cents in 1913. Meanwhile, the price of gasoline has risen and higher prices are probable. Electrical energy tends to fall

ELECTRIC COOKING.

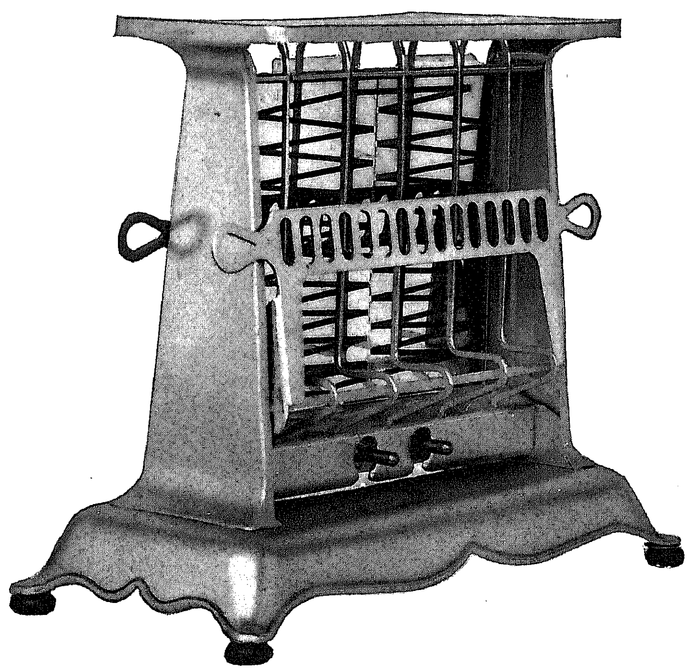


1. HOTEL RANGE.

2. HOUSE RANGE.



3. THREE-HEAT FLAT UNIT STOVE.



4. RADIANT TOASTER, 550 WATTS.

(Face p. 158.)

still lower in price, particularly for "off-peak" loads. Mr. Williams brought out the fact that an investigation of the battery-charging load curve in New York, with special reference to the express business, showed that, with no restrictions on the use of energy, demand was not made for a single kilowatt hour before 7 p. m., in spite of a total consumption at the rate of 1,000,000 kilowatt hours a year. The off-peak character of the load is thoroughly established, so far as the central station as a source of current is concerned.

ELECTRIC HEATING AND COOKING.

Notable advances have been made in the five years in the introduction and perfection of a great variety of apparatus for electric heating and cooking in the home, as well as for a wide range of industries where special and intense concentrated applications of heat are desirable. Some of these have been referred to incidentally in the foregoing text. The best way of exemplifying what has been done in the respective fields is to cite a few typical examples, simply noting as significant of changing conditions that in several small western communities, where there is hardly any other need for a day supply of current, so many electric flatirons are in use that the local central station operates specially on "wash days" to furnish them with current during daylight hours.

In connection with the installation of an electric range in his residence, Mr. Charles H. Williams, general manager of the Northern Colorado Power Co., Denver, in 1911–12 made a thorough study of the cost of electric cooking for a family of six persons for a period of 10 days. Energy was supplied from the commercial circuits of the Denver Gas & Electric Co. The range is suited for 220-volt service and has two 10-ampere and three 20-ampere switches controlling corresponding baking and stove circuits. The table below gives the character of meal, materials cooked, maximum demand in kilowatts, consumption of energy in kilowatt hours, and cost per meal, the data commencing with the installation of the electric range. The cost of electrical energy is placed at 5 cents per kilowatt hour. Records were taken by a pen-recording wattmeter which was carefully calibrated with an instrument of precision. Much care was taken to keep the range absolutely free from dirt during the progress of the cooking tests.

Experience showed that some electrical energy was lost in changing from one heat to another in order to regulate the temperature properly. It was found that after the oven was once heated, baking could be done at small cost. Roughly, the cost of electric cooking varied from 3 cents to 10 cents per day per person upon the basis of the above rate per kilowatt hour.

COST OF ELECTRIC COOKING, FAMILY OF SIX, AT 5 CENTS PER KILOWATT HOUR.

MEAL.	Materials cooked or heated by electric range.	Maximum demand in kilowatts.	Kilowatt hours required.	Cost (cents).
Dinner	4.5-pound roast lamb; baked white and sweet potatoes; baked rice pudding.	2.40	2.70	13.50
Breakfast	Oatmeal; 8 baked apples; coffee	2.24	2.50	12.50
Lunch	Stewed prunes; tea; potatoes for yeast	0.60	0.87	4.30
Dinner	(Clock mechanism disconnected)	......	......	......
Breakfast	Oatmeal; coffee; kettle of water	2.46	1.40	7.00
Lunch	Warming potatoes; finnan haddie warmed; tea.	2.20	0.65	3.25
Dinner	3.5-pound veal roast; baked sweet potatoes; 10 baked apples; baked Irish potatoes.	2.80	4.35	21.75
Evening	Cooking oatmeal	1.00	0.47	2.35
Breakfast	Warming oatmeal; coffee	0.68	0.55	2.75
	Testing oven, raising temperature from cold to hot.	1.40	0.70	3.50
Dinner	Stewing 4.5-pound chicken; boiled potatoes; toast.	2.08	2.00	10.00
Breakfast	Baked apples, 8; oatmeal; coffee; baking bread; stewing prunes.	2.60	3.20	16.00
Lunch	Boiled potatoes; coffee; 3-pound pot roast	......	3.15	15.75
	Warming coffee for laundress, 2 p. m.	0.05	0.10	0.50
Dinner	Boiled sweet potatoes; baked potatoes; baked corn bread.	2.40	2.75	13.75
Breakfast	Coffee; oatmeal	1.00	0.55	2.75
Dinner	Beef stew; carrots; potatoes; prune stew	2.00	2.50	12.50
Breakfast	Baked apples; oatmeal	2.48	2.55	12.70
Lunch	Warming meat and coffee	1.40	0.70	3.50
	Baking three loaves graham bread	1.28	1.35	6.75
Dinner	Chicken stew, 4.5 pounds; cranberries, 1 quart; potatoes, boiled (6 large).	1.00	2.15	10.75
Breakfast	Baked apples; oatmeal; coffee	2.50	3.25	16.25
Lunch	Warming meat; coffee	1.60	0.35	1.75
Dinner	Meat pie; potatoes boiled	2.20	2.50	12.50
Breakfast	Oatmeal; coffee	0.60	0.60	3.00
Lunch	Warming meat; coffee; potatoes for yeast	0.90	0.60	3.00
Dinner	Baked finnan haddie; boiled potatoes; baked apple; cream sauce.	2.60	3.50	17.50
Breakfast	Baked apple; oatmeal; coffee	1.00	0.50	2.50

Unsuspected economies are found in the use of electric cooking and heating, as for example in the lessened shrinkage of joints of meat, as compared with those cooked in gas or coal ranges. The saving on a pound of meat thus cooked with all its juices will pay for enough, or more than enough current to leave the consumer on the right side of the balance sheet. A cheaper grade of coffee can be so prepared in an electric percolator as to be superior to more expensive coffees prepared in the usual way. Mrs. W. E. Sweezey, wife of the manager of the Junction City (Kans.) Electric Light Co., in a paper read before the Kansas State Electrical Convention, September, 1911, in telling of her own experience with electric cooking, stated that she had found 30-cent percolator coffee all that could be desired and had given up the use of the 40-cent grade, thus saving $3.90 a year in her coffee bills. Mrs. Sweezey determined to make a test of the energy consumed by her electric cooking range. On the day in question, after a breakfast of bacon and eggs, toast, and coffee, a dinner of fried chicken with gravy, hot biscuits, baked sweet potatoes, mashed potatoes, peach pie, and coffee, and a warmed-over supper, the total consumption shown by the meter was only 3 kilowatt hours.

Several institutions now do their cooking entirely by electricity, among which may be mentioned the Engineers Club at St. Louis and the jail at White Plains, N. Y. The Engineers Club in New York City has had a large electric grill in use for over 10 years.

Commercial bakeries.—It has been several years since samples of flour in the large flour mills were tested electrically, but out of those tests has grown the development of the electric bread bakery, as well as the electric baking of crackers and biscuits, some factories using this method exclusively. One bakery at Milwaukee, Wis., may be noted. It began with a 10-kilowatt outfit, but in 1912 had installed a 30-kilowatt, 360-loaf oven, because experience showed that, compared with the ordinary coal-heated apparatus, the electric oven had the advantages of saving coal and ash storage space, the expense, labor, dirt, and annoyance due to handling coal and ashes, unpleasant heat in the workrooms, etc. The electric ovens, which are built on the multistory plan, occupy only one-fifth the space of the old ovens, and can be started up much more quickly, attaining a baking temperature within 45 minutes after the heat is applied. The new 360-loaf oven has a maximum demand of 30 kilowatts and a running demand of 20 kilowatts. It is in use 20 hours a day, assuring a consumption of about 20,000 kilowatt hours per month. Under these conditions the bakeshop enjoys a rate for current of 2¾ cents to 3 cents per kilowatt hour, the energy cost for baking amounting to about ⅛ cent per loaf. Wheat bread requires 30 minutes to bake, so that the large oven will produce 720 loaves per hour, or 14,400 per day. Rye bread requires a higher temperature, the "medium" heat, for "maintaining," and the "high" heat during 45 minutes for baking. It was proposed at the date given to install an additional and much larger apparatus, giving a total capacity of more than 15,000 electrically baked loaves per day. Electricity is used generally for other operations throughout the bakery, motor-driven dough mixers, cake mixers, and the like, being employed for preparing the flour, etc. The current has even been applied to the inclosed chafing-dish heating units and to the frying pots in which the lard and cottonseed oil are kept boiling for dipping doughnuts. It is the common practice to heat these pots over open flames, and if the hot oil boils over bad fires may result. The application of electric heat removes this danger and helps to lower the insurance rates, which discriminate in favor of electric heating.

MISCELLANEOUS USES AND SERVICES.

Electro chemistry and metallurgy.—It would be difficult to name a trade or industry carried on in the United States in which electricity from central station circuits is not now employed in one form or another. Some of the larger group uses have been indicated or described in the foregoing text. The number could be added to indefinitely, with illustrations from many unsuspected quarters. It is known, for example, that the fields of electro chemistry and metallurgy have broadened extensively in the last few years, but not all the instances of work of this character have yet come to light. Quite incidentally, for example, at the Denver convention of the American Electro Chemical Society, in September, 1913, Prof. J. W. Richards stated, apropos of making steel castings for the mining industry, by means of the electric furnace:

> I will cite a little plant 12 miles from Bethlehem, Pa., that is operating on a local power supply, using the power between 12 o'clock at night and 4 in the afternoon, paying 1 cent per kilowatt hour, melting cold charges of all sorts of scrap iron and steel and making steel castings for the trade in competition with open-hearth castings.

It was stated at the same meeting that the Detroit Edison Co. had established a rate of about $50 per kilowatt per year for electric furnaces; and that in the manufacture of ferro-alloys electrically several hydroelectric plants had energy for sale at a rate of 3 cents per kilowatt hour, or $27 per kilowatt year, on the basis of nine months' guaranteed delivery, and delivery of one-third or one-fourth the full amount during the three months of low water. In 1911 one central station company reported that it was supplying 22 electric furnaces with an aggregate demand of 7,500 kilowatts. The possibilities in this direction are being closely studied, and that progress has been generally made, or perhaps a revolution begun, in the steel industry, involving in future the consumption of vast quantities of electrical energy, may be inferred from the fact that in 1912–13 no fewer than 100 electric steel-making furnaces were in operation. The total rating was 350 tons, requiring an energy consumption of 50,000 kilowatts. The largest single rating of American "arc" furnaces for this work was 15 tons. Corresponding work has been done in many other branches of metallurgy and chemistry.

Curing meats, etc.—One of the miscellaneous uses of electrical current is in the more speedy curing, aging, or ripening of various materials, both liquid and solid, ranging from whisky to hides. The newest of these processes is the curing of meats. A Cincinnati packer discovered that if 60-cycle alternating current be passed through the brine containing hams, the pores of the meat are opened to the fluid and the hams can be completely cured in from 30 to 35 days. This effects a considerable saving in plant space, material, labor, and investment, and the product obtained equals in all respects the naturally pickled ham. The green hams to be cured are piled on trays in wooden vats, 16 feet by 4 feet by 5 feet, each vat holding about 5,000 pounds of meat. At the ends of the vats are the electrodes, each set comprising five 3½-inch carbon cylinders 4 feet long, inclosed in unglazed 6-inch tubular tiles. After the hams are in position the brine, held at a temperature of 34 degrees to 36 degrees Fahrenheit, is turned into the vat and kept circulating by motor-driven pumps on the floor below. From the switchboard a current strength of 30 amperes to 35 amperes, 60-cycle alternating, is turned through the vat, the drop in potential between the opposite sets of electrodes being about 40 volts. This discharge is usually continued throughout the pickling period of a month or more, although experiments seem to show that equally good results are obtained by using the current flow alternately 24 hours on and 24 hours off. In the same way bacon, which ordinarily requires 18 to 20 days, can be completely cured in 3 or 4 days. The plant has had 10 of these 5,000-pound electric vats in continuous service. The curing vats had been in use nearly a year in 1912, and are the result of nearly four years' experimenting. During the course of these tests, direct current was first used, but the products of electrolysis liberated at the electrodes fouled the solution and caused changes in its composition. With alternating current these effects are avoided, but the pore-opening action remains.

Use by physicians and dentists.—A very large field of central station service has been found among physicians, especially those in the electrotherapeutic group, with numerous appliances needing current. Mention must also be made of the requirements of dentistry. In the larger cities the number of physicians and dentists on the circuits can be counted by hundreds. Their work is supplemented by a great deal done in hospitals, and by the purification of water and milk and the sterilization of sewage and other material containing bacteria. Great advances have been made in recent years in the production on the spot of ozone by small machines operated electrically from central station circuits, and these may be found in schoolrooms, banks, theaters, meeting halls, and similar places.

Other special uses.—The use of lifting magnets may also be noted as an invasion of fields of work left previously to mere mechanical apparatus or to manual labor. One of the most notable instances in recent years was the use of such magnets for lifting 15,000 tons of nails, hoops, etc., from a sunken barge in the Mississippi River at New Orleans. The current to energize the "lifters" was supplied from the circuits of the local central station company.

A large proportion of the telegraph and telephone offices now derive from central station systems the prime electrical energy required for the operations of their apparatus and lines, the current being transformed in various ways to suit the conditions of service.

Electric heating finds its way in an unexpected manner into the printing office, and many instances could be noted. Thus, for drying "rush" work rapidly so that it can be delivered or made ready at once for printing on the other side without offsetting, the Bradley & Gilbert Co., printers, of Louisville, Ky., make use of a drying cabinet containing a 770-watt electric heater. This heater sits in the lower compartment of the 5-foot by 3-foot case, and above it, on a light tray of wood slats, the sheets to be dried are placed. Sheets which would require lying undisturbed 24 hours at ordinary room temperatures are thoroughly dried in the cabinet in 30 to 60 minutes and are then ready for handling of any kind. Twenty-five or fewer sheets may be laid on top of each other without offsetting in the drying cabinet, and, of course, this drying space could be increased without additional expense by multiplying the number of trays. So much printing work is required in a hurry, that such an electric drying cabinet is a valuable addition to any printing establishment.

Electric toasters are ordinarily an equipment of the breakfast table, but have been applied by the Brooklyn Edison Co., N. Y., to the curling of feathers for local milliners.

One of the applications of electric heat on the Pacific coast has been the drying of fruit; another, the speedy ripening of walnuts. Seven to ten days are required to ripen walnuts in the open air and sunshine after picking. With electric heat, the time has been reduced to 24 hours.

Electric heat from central station circuits has been applied in crematories at Oakland and Pasadena, Cal. The body is placed in an individual retort. The temperature rises inside of an hour to 2,000 degrees, the organic products undergoing distillation. In another hour nothing remains but mineral matter and ash on a clean tray. There is an entire absence of noise, dirt, or flame, and it is stated that at a charge of $50 per cremation, a substantial profit is shown in this unique service.

After the fire which destroyed the huge Equitable Building in New York City, thousands of bonds, stock certificates, and other securities were dried by electric heat. Many of the banks in New York and other cities have installed electric wax melters.

REGULATION AND RATES.

The recognition and extension of the principle of the control of public utilities by public-service commissions constitute one of the most striking features of American political development in recent years, state after state having fallen into line since the initiative was taken in Massachusetts, Wisconsin, and New York. In most of the states, therefore, the central station industry is now carried on under the supervision of such an authority clothed usually with large powers over the issuance of securities, the standards of service, the disposal of complaints, the regulation of rates, and the control of competition. There has already grown up a vast mass of rulings, decisions, and general literature, constituting in itself a library of liberal proportions, all bearing upon these problems. The difficulties involved in shaping an industry to the requirements of 30 or 40 different commissions can be easily conceived. Some of the public utilities affected find it necessary to issue for the information of operating companies abstracts of rulings and decisions that concern them.

The Wisconsin Railroad Commission.—At the meeting of the Wisconsin Electrical Association in January, 1911, Mr. Edwin S. Mack made a useful summary of the principles the Wisconsin Railroad Commission had recognized or established. The commission had then been in service more than five years, during three years of which it had had jurisdiction over electric light companies. Its decisions and opinions then occupied five printed volumes, in addition to its annual reports. Besides work of a routine character, such as the answering of questions and acting as general counsel and mentor to utilities, the duties of the commission are of two kinds: (1) The setting of standards of service, and (2) the adjustment of disputed cases and service and rate complaints. Good service to the public is exacted by the commission, and if, upon investigation of a case, it finds an increase of rates necessary to enable good service to be rendered, it is disposed to order such an increase. The adjustment of rate cases involves study of many factors. From the gross earnings the operating expenses, including the taxes, must be subtracted, while the rate of depreciation due to age and wear, the reasonableness of return, the correct capital on which to base return, and the percentages allowable for interest and profit must all be determined. In addition to this, costs must be properly proportioned among the various classes of service so that each of these classes shall pay its share. The figures for the gross earnings and operating expenses are usually obtained from the company's books, verified by examination and study of the property in operation.

In considering the amount to be taken as the basis of return it is pointed out that different principles apply from those applicable to property with an open market value. The principal may be taken as the funded debt or bond issue, plus the capital stock and investments. If necessary to appraise the tangible property, the apprisal may be based upon (1) original cost, including additions, or (2) cost of reproduction new, or (3) present value—that is, reproduction value less depreciation. Added into this, of course, are the "service" value, engineering, etc., necessary to make of the integral parts an efficient mechanism.

The "actual total investment" is generally taken as the basis for rate making, when it can be shown that the expenditures have all been prudent compared with the present value of the investment, and that ordinary business sagacity has been employed. When excessive or imprudent investments, not commensurate with the value of service to the customer, have been made, a corresponding reduction is ordered in the basic amount. All values, whether gifts, surplus earnings, or new capital, are considered by the commission as actual parts of the investment. The sale of bonds is recognized as the modern method of raising capital, and bond discounts are viewed as proper items of cost.

"Cost of going value"—that is, the expenditure or deficit involved before the business reaches a profitable condition, with organization perfected, customers connected, and harmonious operation throughout its mechanism—is also regarded as an item of the investment. The cost of going value is computed by a curve chart which traces the elements of the company's business during the first year, given over to construction; the second year, when partial operation began; and the following years, during which the business expanded normally, the income finally exceeding the expenses and netting a profit. Interest at the rate of 6 or 7 per cent is allowed on going value, the higher figure where the service is good, and it can be shown that the plant was not built ahead of public needs or in an excessively expensive or unwise manner, that there are no present prospects of profits, and that the past management has not been incompetent. Obviously, according to the commission's doctrine, public utilities can not retrieve errors or losses as private enterprises can. When a good return has been earned continuously from the beginning of work no cost of going value is considered or allowed by the commission.

When the investment in the property is not ascertainable, or it becomes necessary to check or approximate such investment, recourse is had to the appraisal of the elements of the property by the valuation staff of the commission. This staff was originally formed for the tax commission's service, on the Michigan plan, but now serves that commission and the railroad commission jointly.

Added to the sum of the costs of the elements of the plant as appraised, a general allowance of 10 to 12 per cent is usually made for the expenses of combining them in "harmonious operation." Of the usual 12 per cent allowance, which applies to all but store supplies and paving, 5 per cent is credited to engineering, 4 per cent to interest during construction, and 3 per cent to legal expenses, commissions, and contingencies. The Wisconsin commission usually places this total at 10 to 12 per cent, although many engineers figure 15 to 20 per cent for these expenses. In addition to this percentage, stores and supplies, as part of the working capital, have been allowed up to 1.5 per cent in some cases. The depreciation factors for getting present values are obtained from curve sheets issued by the commission showing various rates of depreciation applicable to elements suffering from different degrees of wear and obsolescence.

The commission has refused to place a capita value on "successful good judgment," as employed in locating a site for a plant, allowing only for the sum actually spent. Allowance has been made, however, for nonoperating property held under reserve or emergency, but not for scrap or superabundant equipment. "Good will" has not been recognized—although the effect of "ill will" has certainly been apparent in cases before the commission. Franchises are treated as having value, but not a value to be respected in rate making. The commission has distinguished carefully the elements of interest and profit, allowing for the first a "reasonable" rate of return, after which the surplus becomes profit. The commission has frequently allowed 8 per cent for electrical concerns, while water companies can get an allowance of but 7 or 6, and municipal plants are limited to 4. There has been a tendency to lose sight of the separate parts of a business in consideration of the whole, although this is contrary to sound cost-distribution methods. The cost of service is generally held to control the rates charged, although this has been modified in the case of small customers, so as not to make it prohibitive. So far as possible, consumers who use current for but a short time daily pay an amount on the fixed costs proportional to their demand, and an amount on the variable costs proportional to their actual use or consumption.

At the Conference of Governors held at Spring Lake, N. J., September, 1911, Gov. McGovern, of Wisconsin, made an interesting address on the routine administration and results of the Wisconsin commission law. The genuinely constructive and enduring character of this method of control is best demonstrated, he held, by the fact that while the people have gained enormously, the utilities have not suffered. On the contrary, they have prospered as never before. Lower rates have not been followed by diminished income, but, by inviting larger patronage, have resulted instead in an actual increase in revenues. To the utilities, therefore, the net outcome has been a gain. As evidence of the prosperity under commission regulation, the last annual report of the Wisconsin commission showed that during the year the operating revenues of electric utilities increased 20 per cent, their net income 29 per cent, and new construction for the year 145 per cent. The operating revenues of water utilities meanwhile increased 7 per cent, their income 13 per cent, and new construction 24 per cent. Gas utilities increased their operating revenues 3 per cent, their net income 15 per cent, and new construction 24 per cent. Telephone utilities increased their operating revenue 11 per cent, their net income 9 per cent, and construction for the year 14 per cent. Railway and traction lines on the average increased their operating revenues 13 per cent, their net income 8 per cent, and construction 8 per cent.

How these results are possible may be illustrated by the case of the Madison Gas & Electric Co. In March, 1910, this company's schedule of rates, based as it was entirely upon the energy consumed, was abolished, and there was substituted a new schedule which took into consideration the elements of installation and classes of consumers, as well as the amount of energy used. In actual experience the form of rate schedule is as important as the rate per unit; and it is the policy of the commission to devise schedules which, while avoiding discrimination and unjust charges, will at the same time encourage extension of the service and thereby decrease the cost per unit. After one year's operation under the new schedule another investigation was made, and it was found that, compared with 1909, the last full year in which the old rates were in effect, the output of the electric plant had increased over 16 per cent, the gross earnings nearly 13 per cent, and the net earnings 24 per cent, while expenses increased less than 3 per cent. Compared with 1907, the number of consumers in the residence class had increased 34 per cent, the number of lamps connected 54 per cent, the kilowatt hours sold 70 per cent, and revenue 35 per cent. Here, however, is the important point: After a year's operation under the commission's schedule, it was found that the business had so increased that it was possible to effect a further reduction of 2 cents per kilowatt hour in the primary rate.

General effect of regulation on public utilities.—The general effect of legislation on public utilities and the effect of commission control are summed up for the census period by Mr. W. J. Hagenah, a well-known authority, as follows:

The year 1912 will always be of historic importance, not because of the growth of utility control, but because of the more important reason that during this year the substantial results of state supervision which have accrued during the last five years have become generally apparent and the policy of public regulation of utilities recognized as successful. Present conditions give definite promise of the early completion of the third stage of the economic cycle, from which the public utility will emerge greater because of its increased efficiency, more popular because of the diversified ways in which its service has become a public necessity, and more firmly established because of the confidence which it commands and the resulting distribution of its securities among the investors of relatively small means. Less than five years ago the rapid increase of regulatory statutes was regarded with mixed sentiments of fear and approval. The legal power to regulate was recognized, but the ability of a public swayed by misconception and prejudices to lodge such power with men of trained minds and judicial temperament, and to create commissions which would occupy positions of dignity and respect not unlike that of a court, was seriously questioned. It was feared that capable men could not be secured for such services, that the commissions would become subservient to politics, and that capital would grow timid and seek other fields of investment. Events of 1912 have proved these fears to be groundless and have justified the confidence in the public. Unfortunately not all those who possess the power to regulate public utilities are imbued with the judicial spirit which their office demands, and occasionally decisions are rendered which give evidence that considerations of political expediency have not been overlooked. Generally such conditions will be found in the first efforts at regulation, or may be accounted for in the same manner that a popular but incompetent individual is sometimes elected to public office, but, on the whole, our utility regulating authorities are composed of men who fairly represent the sentiment of the public, and that sentiment is one which seeks to do justice. The year will therefore be remembered as the period when confidence in public regulation was established, when the justice of regulatory statutes was generally accepted, and when capital frankly sought the profits and the protection which this doctrine affords. No other year in the history of the industry has witnessed such gigantic strides in the development and extension of utility services. The new capital invested in public utilities during 1912 exceeds by far that of any other year. Not only is this true of American capital, but the safety and general attractiveness of the American utility security has appealed to the wealth of Europe, and the present year has witnessed the shipment to this country of funds conservatively estimated to be in excess of $100,000,000 for investment in public utility issues.

When the majority of the public utility laws were drawn up, the fact was recognized that if public service corporations were to be controlled and regulated, they must at the same time be protected. In general, this protection is afforded in two ways—(1) protection from the ruinous effects of aggressive competition where circumstances do not warrant a second utility, and (2) assurance of a reasonable rate of return upon an equitable valuation to reward an adequate service rendered. The first is made possible through the agency of the "convenience and necessity law," which is operative in most states under commission control. The law recognizes that a public service corporation is, in its very nature, monopolistic in character, and protects it from competition except where the public welfare demands the existence of a second utility. The utility commission in administering the law determines whether such a second utility is necessary or not. This provision, as Chairman Roemer, of the Wisconsin commission, has put it, is not intended as auxiliary to the power of the commission to enforce rates and service, as is sometimes erroneously assumed, but is a remedy of last resort and may be applied only in exceptional cases. In Wisconsin not a single certificate of convenience and necessity has ever been granted to a new competitive electric central station, although several requests for such have been made. Under this law it is impossible, practically, for a municipality to operate its own plant in competition with an existing private plant. Under certain conditions the municipality has the right through the law to purchase the private plant at a valuation fixed by the commission. Very few municipalities have availed themselves of this opportunity, for experience has shown that where the public can obtain through its authorities in the commission all the advantages of public ownership, without any of the risks or disadvantages, it is good policy to keep out of a hazardous investment.

In harmony with this general point of view, the public-service commission of Kansas in 1812 handed down a decision protecting a local central station company. Under the law of 1911 no utility can operate until a certificate has been obtained from the commission that public convenience and necessity will be subserved by permitting it to enter the field where another utility of the same kind already exists. The Parsons Railway & Light Co., according to the evidence, was giving satisfactory service from an adequate plant, but an application was made for permission to enter the territory and compete. The commission said that the obvious purpose of the law was to prevent a duplication of utilities under such circumstances, and it denied the certificate.

In like manner the public-service commission of the second district, New York state, issued a decision in the matter of the application of the Red Hook Light & Power Co., defining the legitimate limits of competition and protecting a public utility already occupying a given field. In this case the Red Hook Light & Power Co. applied to the commission, under section 68 of the public-service commission law, for permission to construct an electric plant and a gas plant in the city of Hudson, and to exercise a certain franchise therefor granted by the common council and mayor of that city. The application was denied upon the following grounds:

1. That another electrical and gas corporation was already giving electric and gas service to the city of Hudson.

2. That the service rendered by such other corporation had not been shown by the applicant to be not satisfactory to the public and of such character that a competing company should be admitted into the city.

3. That the contention of the applicant that the other company did not have a franchise in the city of Hudson was one which would not take into consideration that the existing company was in fact occupying the city, and that if it were not there lawfully the remedy lay with the courts and not with the commission.

The same stand was taken in March, 1913, by the Board of Gas and Electric Light Commissioners of Massachusetts. The selectmen of Barnstable had given permission to the Barnstable Co. to put up lines in the town of Hyannis, but the territory was already covered by the Buzzards Bay Electric Co. as to rights granted and as to actual service. To let in the new company would create competition in a large part of the island of Martha's Vineyard. "It is not merely a question as to which of the two companies shall do the business in the town of Barnstable, but whether to the company already there a second company for the same purpose shall be added, so that there shall be two companies engaged in the same business in the same territory." The commission found that the old company was giving good and adequate service and should not be disturbed. "Under all the conditions, in the opinion of the board, it does not appear that the public necessity and convenience require the admission of the Barnstable Electric Co.;" and the appeal against it by the old efficient company that was thus to be raided was sustained and the order of the selectmen was annulled.

In another decision of the same board a different question came up, involving the ability or right of a municipal plant to sell at lower prices than a private utility. It appeared that the Groton municipal plant's cost of production, according to a calculation for the year ended March 1, 1912, was 16.43 cents per kilowatt hour. This figure included operating expense, interest on the investment at 3⅞ per cent, and depreciation at 5 per cent. In the face of this cost figure the town petitioned for a permit allowing it to sell energy for commercial lighting at 12 cents per kilowatt hour. In addition to pointing out the fact that such a course would be contrary to law, the commission in refusing the petition made the observation that "a supply to private consumers for less than cost compels all other taxpayers, many of whom may be unable to obtain the service for their own use, to pay for the special advantages enjoyed by a few."

. An interesting state of affairs in Milwaukee was disposed of by a decision of the Wisconsin commission, which practically threw over the shoulders of the Milwaukee Electric Railway & Light Co. a cloak of protection, by requiring other companies that had been let in under the old theory of competition or had been competitive as "block" systems to adjust their rates to a uniform basis and revise their methods of doing business so as to conform to the requirements and policies of the commission. In doing this, the commission took occasion to point out the many evils of competition in the public-utility business, as well as the bad consequences that result from such an unnecessary duplication of equipment.

Discrimination in rates.—One of the most important cases brought before a public-service commission has been that of the New York Edison Co., in regard to complaints on the ground that it had unduly favored large customers with low rates, at the expense of the small customer, with the obvious result, of course, that isolated plants had been shut down or shut out. The Edison Co. filed with the commission a long reply, which, in several respects, is a noteworthy treatise on the rate question as a whole. The cost of supplying electrical energy is stated to consist largely of three elements, namely, fixed charges, customer or stand-by charge, and operating expenses or running costs, in accordance with the view generally accepted by rate experts. But the calculation of the cost of supplying a given customer is declared to be a hopeless task, although the cost of supplying a particular class may be approximated without great difficulty. Fourteen general principles are laid down as essential in preparing any rate schedule, which go to show that while the cost of service is an important consideration it is not wholly controlling, and commercial expediency must always be consulted. Rule 8 brings this out forcibly:

> It is not sufficient that a system of rates be theoretically sound. It must get and hold the business and be simple enough to be understandable by the consumer.

As to the small consumer, Vice President Lieb of the company stated to the commission that the average 10-cent or retail customer, who never uses in excess of 250 kilowatt hours monthly, and represents nearly 80 per cent of all the commercial customers on the company's books, was being supplied below the average cost for service and at a direct loss to the company. As a result of the rate reductions put into effect by the company on July 1, 1911, there was a total decrease in revenue from all sources in the 12 months ended July 31, 1912, of approximately $1,250,000, of which $850,000, or about 70 per cent, went to the benefit of the small lighting customer. Investigation by the company showed that there was no appreciable stimulation in new business as a result of the new rates, which confirmed its past experience as to the futility of relying upon any considerable increase in new business and revenue over the usual natural growth to offset the direct loss of revenue attendant upon the introduction of lower rates. Under the new schedule the average return had been reduced from 7.39 cents per kilowatt hour to 6.87 cents per kilowatt hour, or by approximately 7.03 per cent on all the regular commercial business of the company.

In justification of the general policy of giving a lower rate per kilowatt hour to the motor-service customers than to the retail lighting customers, Mr. Lieb drew attention to the relative costs of supplying these classes of service. In the case of the New York Edison Co., the service connection for the smaller consumer represented an investment of over $65, or more than $542 per kilowatt, while a connection to a larger consumer represented an amount per kilowatt which decreased with increase in the size of the installation until, with an installation of 500 kilowatts or over, the cost of service connections became insignificant and the burden of fixed charges on this feature of the investment was reduced to a minimum. Attention was also called by the company to the fact that the average consumption and income per meter and per customer were continually decreasing for all classes of customers. Average consumption had decreased from 213 kilowatt hours for the year ended July 31, 1908, to 181 kilowatt hours for the year ended July 31, 1912. This decrease was ascribed to several causes, of which the constant extension of the company's service to smaller residences and apartments, by virtue of the lower rates, and the greater extent to which tungsten lamps were used were probably the most important.

The minimum charge.—An important feature in rate systems has been the very common practice of central station companies in making a "minimum charge" per month for their service, or, as it is also sometimes called, a "meter rental." The amount represents a maintenance or "readiness to serve" charge, based upon the idea of requiring each consumer to bear some part of the burden of furnishing the commodity. The practice applies in other utilities than the electric, and prevails in gas and water supply. An average charge is $1 per month minimum, but rates as low as 50 and 75 cents per month are not uncommon, all being returned in service that may be demanded. There are various court decisions and commission rulings on the subject. The railroad commission of California went so far as to authorize the Mount Whitney Power & Electric Co. to put into effect a meter contract or regulation providing for a minimum charge of $24 per year. The Arizona Corporation Commission in September, 1912, ruled in favor of a charge of $1.50 per month, "and in no case shall said charge be made except in case the electricity consumed in any month, charged for at the regular rates, shall be less than the sum of $1.50, and in such case no charge will be made for the electricity consumed."

A ruling of the Massachusetts Board of Gas and Electric Light Commissioners in 1910 as to the minimum charge of the Edison Electric Illuminating Co. of Boston is significant in regard to this matter and may be quoted:

It is conceded on all sides that a public service corporation is entitled to secure from its customers as a whole a sufficient revenue by which it may live and prosper; and where, as in this case, it has a business well established, the imposition of such a charge is probably of more consequence to the general body of its customers than to the company itself. In other words, the interests of the company and those actual users of electricity who are dependent on the company for their supply are so far identical that it is desirable from the standpoint of both, perhaps more emphatically from that of such consumers, that the company's business shall expand and develop along profitable rather than unprofitable lines, so far at least as may be consistent with a proper regard to the company's duty as a public servant. Electricity is fast becoming one of the common conveniences and even necessities of life, and the board believes that it should be made available to a much larger portion of the community than it now is. But, in view of the constant advancement in the art, and of the large investment incident to placing wires underground in many cities, a too rapid expansion of the company's business in directions where, under present conditions, there is no substantial demand may perhaps hinder, rather than help, that promotion of its use which the board believes is on the whole so desirable. It is largely because of these considerations that the board reached the conclusion that for the present it ought not to require the discontinuance of some minimum charge.

If such a charge is to be permitted, its amount is a matter of expediency respecting which the board is not inclined to interfere, unless the manner of its imposition tends to work a real hardship upon small customers, and so become a palpable evasion of the company's public duty. Respecting the present charge the board is convinced that no increase in amount should be allowed, and that a smaller amount might be desirable.

If the company shall continue to impose a minimum monthly charge upon its customers who pay the prevailing maximum net price, such charge shall not exceed $1 per month per meter; and if on any thirtieth day of June it shall appear that a customer has, by reason of said charge, paid or become liable to pay during the year immediately preceding an amount exceeding the minimum monthly charge multiplied by the number of months in which he has been a customer, and an average price for electricity supplied by meter exceeding the prevailing maximum net price per kilowatt hour, the company shall refund all such excess; provided, however, that nothing in this recommendation shall be construed to require the company to render its service at an average charge per month less than the minimum monthly charge, or at an average price per kilowatt hour less than the prevailing maximum net rate.

The New Jersey Board of Public Utilities, one of the more recent creations in the commission field, placed on record January 16, 1912, the following conclusions as to the minimum charge:

First. That a minimum charge is a reasonable rule or regulation for an electric-lighting company to make.

Second. That the making of this charge by the month is just and reasonable, and is really more equitable than if the charge were made by the year.

Third. That a charge of $1 per month "per plant for installation" is just and reasonable, but that a charge of $1 per meter is excessive where more than one meter is installed. A minimum charge of 50 cents per month per meter is not excessive or unreasonable for each additional meter installed on the same premises, for the same customer, supplied through the same service.

Fourth. That where a customer requests that service be discontinued for a period of at least one month or more, the minimum charge should be waived during such period.

Fifth. That where a customer requires the service for a limited period only, a reasonable charge may be made for the work of connecting and disconnecting the service at the beginning and end of the short period.

The minimum charge is part of the rate schedule, and should be incorporated with it whenever it is compiled for examination by the public.

As to electric-motor service the ruling held that a minimum charge of 50 cents per horsepower per month was not excessive or unreasonable. It might work out as an apparent hardship to a few small consumers who used their equipment but a very short time, in some cases not more than four or five hours a month. The fact could not be lost sight of, however, that the supply of electric power was strictly a commercial proposition, that to relieve one customer from the payment of any considerable portion of the cost would merely result in transferring the burden to other customers, and that such a transfer did not appear to be justified. The board, therefore, determined that in connection with the sale of electricity for power purposes the minimum charge of 50 cents per horsepower per month established by a company furnishing such service was not excessive or unreasonable. It was further ruled that the smallest minimum charge made in connection with electric-power service, $1 per month, was not excessive or unreasonable.

In the state of Washington the public service commission in a ruling of November 16, 1912, held that a minimum charge is a reasonable practice which tends to distribute equitably the cost of operating and maintaining the plant among all patrons who, by reason of their service connections, are in a position to make demand upon the company for service. It was set forth that the practice of collecting a minimum charge of this character was sanctioned by custom and authority, and was followed by the city of Seattle with respect to its municipally owned water and lighting systems.

The Wisconsin Railroad Commission has rendered many decisions on this subject, and it would be difficult and, indeed, unnecessary here to compile all of them. But, as usual with that pioneer body, they go to the heart of the problem. In the appeal of the Lancaster Electric Light Co. several points were raised. Application was made by the company for authority to put in effect a minimum rate of $1 per month. An analysis of the operating expenses showed that the consumer costs to the company amounted to 46 cents per meter per month. In addition to this amount, if a customer consumed two kilowatt hours per month, the value of current used at the rate charged, 12½ cents per kilowatt hour, would be 25 cents per month. The minimum bill, therefore, must be high enough to cover these fixed costs and also the average value of current used by the class of customers who, in general, consume the smallest amount of current. Under the circumstances, the proposed minimum of $1 per month would be unnecessarily high, and a minimum monthly bill of 75 cents would be reasonable and just. The company was authorized to put such a rate into effect. The commission said:

As repeatedly stated by this commission, the minimum bill rests, for its justification, upon certain expenses which are incurred by a utility because of its being in a position to serve. In other words, the minimum bill for an electric lighting utility may be greater than the amount which would be derived from the consumer in question if he were charged merely for the current used at regular rates, and this is due to the fact that the utility incurs certain expenses because of its readiness to furnish current to the consumer, irrespective of whether or not he actually uses current. These expenses are such as arise because of the consumer's premises being connected to the lines of the utility, and may be determined with a considerable degree of accuracy.

In a similar case in 1911 as to the Bloomer electric light plant the commission said:

The operating expense of an electric plant includes several items which vary with or are proportional to the number of metered consumers. The expense of reading meters, maintaining meters, delivering bills, and carrying the customers' accounts are expenses which bear little or no relation to the current sold. These costs go on month by month, whether the consumers use much or little current. Interest, taxes, and depreciation on the investment represented in the meter are expenses which the plant must bear and which it rightly expects to have returned to it. By adding the direct consumer expenses to the fixed charges on the meter investment and also making a sufficient allowance for the current which will be consumed under the minimum bill, the minimum charge may be definitely determined.

The Ohio law of 1911 says in this respect:

Nothing in this act shall be taken to prohibit a public utility from providing for a minimum charge for service to be rendered unless such minimum charge is made or prohibited by the terms of the franchise, grant, or ordinance under which such public utility is operated.

Heating and cooking rates.—Special attention has been paid by central stations in recent years, as already noted, to the development of electric heating and cooking, and it has been sought to encourage this class of service by a lower rate. There might be mentioned a number of interesting examples of the results of energetic campaigns by the central stations to annex this business, applying to all kinds of apparatus used in the household. One illustration, however, must suffice. Early in the summer of 1912 there was begun by the commercial departments of the Great Shoshone & Twin Falls Water Power Co. and the Southern Idaho Water Power Co., of Pocatello, Idaho, a campaign of advertising, publicity, and education of the public in the use of electricity for cooking purposes. Newspaper advertising was followed by a rapid succession of circular letters, tending to interest the public further in the advantages of the electric range over fuel-burning stoves. Public demonstrations of electric cooking were held, and the people turned out by the hundreds. At one exhibition in Twin Falls more than 1,000 visited the display rooms in one day, and each was served with a small portion of a daintily prepared, electrically cooked food. The demonstrations were followed up by well-planned solicitations for the sale of electric ranges among consumers.

During the fall of 1912 about 60 complete electric ranges of various sizes were sold. A carload of 125 ranges was ordered later during the winter, and practically all of this shipment was disposed of in advance. Five hotels and several restaurants and bakeries discarded all kitchen fuel and are using electricity exclusively for cooking and baking purposes. One of the incidental obstacles was the difficulty experienced in finding a market for the old fuel ranges.

The two companies adopted a rate of 2.5 cents per kilowatt hour for energy used for domestic cooking. For commercial cooking the guarantee-rate schedule is as follows:

Monthly guarantee per kilowatt connected.	Rate per kilowatt hour (cents).
$1.50	2.0
2.00	1.5
2.50	1.4
3.00	1.2
3.50	1.0

From the records of the company it would appear that the average income from the domestic cooking ranges installed prior to April 1, 1913, was $3.89 per range per month.

Herewith is given a group of rates in various cities where special schedules for electric heating and cooking have been put in force. The rates quoted are those under which service was given in 1912.

Atlanta, Ga.—The ordinary power rate ranged from 6 cents per kilowatt hour to 3 cents per kilowatt hour, but special consideration was given in the matter of estimated demand, which was figured at 50 per cent of the connected load.

Altoona, Pa.—Four and half cents per kilowatt hour on separate meter.

Boston, Mass.—Miscellaneous rates for cooking and heating and other uses; 10 cents per kilowatt hour for the first 20 kilowatt hours per month; 3 cents per kilowatt hour for excess use. Minimum charge, $12 per year. Under certain off-peak conditions and for large consumption the rate for over 2,000 kilowatt hours was reduced to 2 cents per kilowatt hour.

Des Moines, Iowa.—Four and half cents per kilowatt hour on separate meter.

Detroit, Mich.—The maximum power rate, 4 cents per kilowatt hour, was used.

Duluth, Minn.—Rate for cooking and heating, vacuum cleaners, and washing machines, 3 cents per kilowatt hour, less 20 per cent prompt payment discount. Minimum charge, $1 per month.

Kansas City, Mo.—Cooking rate 4½ cents per kilowatt hour. Separate meter used.

Los Angeles, Cal.—Five cents per kilowatt hour, with separate meter. Minimum charge, $3 per month.

Memphis, Tenn.—One dollar and fifty cents per month per kilowatt of demand, plus 3 cents per kilowatt hour.

Omaha, Nebr.—Cooking rate, 6 cents per kilowatt hour; 5 per cent discount if complete cooking outfit was installed. No heating rate.

Portland, Oreg.—Four cents per kilowatt hour. Minimum charge, $1 per month.

Redding, Cal.—Three cents per kilowatt hour for the first 100 kilowatt hours per month; 2½ cents for the next 100 kilowatt hours per month; 2 cents for the next 100 kilowatt hours per month; 1½ cents for excess over 300 kilowatt hours per month. Minimum charge, $1 per month. Approved by the California Railroad Commission.

Salt Lake City, Utah.—Six and six-tenths cents per kilowatt hour with separate meter. Minimum charge, $2 per month. Prompt payment discount, 10 per cent on all charges, including minimum.

Seattle, Wash.—Three cents per kilowatt hour with separate meter. Minimum charge, $2 per month.

Spokane, Wash.—The industrial rate, 5 cents per kilowatt hour.

Springfield, Mass.—Heating rate, 6 cents per kilowatt hour. No cooking rate.

Superior, Wis.—Five cents per kilowatt hour for the first 50 kilowatt hours per month. Four cents per kilowatt hour excess use.

The Mount Whitney Power & Electric Co., Visalia, Cal., operating two water-power plants and two steam plants, with circuits covering the greater part of Tulare County and extending into Kern County, had developed an irrigation pumping load to a point where it became the main part of the company's business, which left a very large winter valley in the yearly load curve. To correct this, after thorough investigation the company in 1912 sought the domestic heating and cooking business, adjusting the prices as experience indicated, and developed a very successful service in that field. It is expected that within the next few years electricity for cooking and heating will be quite as universally used in this locality as it is now for lighting and pumping. The rates were worked out to fit the conditions, as follows: It was deemed reasonable to obtain the lighting rate of 9 cents per kilowatt hour for the current used for lighting, about 3 cents per kilowatt hour for cooking, and 1 cent per kilowatt hour for heating. To reduce the investment in meters and the cost of handling accounts, one meter is used for each residence, and these rates are combined by using a sliding schedule, each section to cover the average consumption of its class of service. The resultant existing rates are:

Combination lighting, cooking, and heating.—Ten and one-half cents per kilowatt hour for first 20 kilowatt hours per month; 3.5 cents per kilowatt hour for next 150 kilowatt hours per month; 1 cent per kilowatt hour for excess over 170 kilowatt hours per month.

Prompt payment discount, 15 per cent on bills paid within 10 days.

Minimum charge, $2 per month.

Heating.—(Lights registered on separate meter) available for residences and business houses and offices, 3.5 cents per kilowatt hour for first 150 kilowatt hours per month; 1 cent per kilowatt hour for excess over 150 kilowatt hours per month.

Prompt payment discount, 15 per cent on bills paid within 10 days.

Minimum charge, $1 per month.

Cooking.—Available for hotels and restaurants, 3.5 cents per kilowatt hour.

Prompt payment discount, 15 per cent on bills paid within 10 days.

Flat rate.—Available to all consumers for water or other heaters operating continuously, $8.30 per kilowatt per month.

Prompt payment discount, 15 per cent on bills paid within 10 days.

Electric vehicle rates.—Intermediate between the schedules just cited and those for very large power consumers are those which apply to electric vehicles, in regard to which a wide range of practice exists, the aim being to build up a demand for current in the "off-peak" hours of the night, when the generating plant would otherwise be called upon for a relatively small amount of current. A garage put in operation in Chicago in 1912 is an example of an effort to make the charge equitable to the customer. The rate there is divided into two portions—a fixed charge of $20 per month for storage, maintenance, and oiling; and a second charge for power at the rate of 4.5 cents per kilowatt hour for the first 300 kilowatt hours and 4 cents after that limit has been passed.

In the report of the committee on rates and charging stations presented at the Chicago convention of the Electric Vehicle Association of America, October, 1913, it was stated that up to that time very little advance had been made by the public garages toward providing a separate scale of rates for the current used, the prevalent practice being a monthly rate depending upon the size of the vehicle, or a flat price per charge, regardless of the quantity taken. Out of 128 answers to the committee's questions, the reports from only 31 cities indicated that the garages in their districts were metering the current.

The committee reported that the average for a total of 91 of the largest cities in the country showed a rate of 3.007 cents per kilowatt hour paid by public garages, and 5.338 cents by private garages.

Some of the central station companies maintain garages or storage-battery service for which special rates are in vogue. Thus the Hartford (Conn.) Electric Light Co. buys, maintains, installs, and charges in the customer's truck all the batteries needed for its continuous operation. For this service the company charges a flat rate of from $15 to $60 per month, depending on the size of the truck, to which is added a mileage charge of from 1½ cents to 7 cents, depending upon the capacity of the truck and the miles traveled per month.

The report above referred to gives the electric vehicle current-supply rates from 128 central stations arranged alphabetically. It will be necessary to quote only a few of these as typical. The wholesale rate is given on the first line; the retail rate on the second.

Akron, Ohio	3c. to 1.5c. per kwh.; minimum $1 per kw. No cash discount.
	5c. flat per kwh.; minimum $1 per kw. No cash discount.
Allentown, Pa	8c. to 2.6c per kwh.; minimum 50c. per hp. 10 per cent cash discount.
	8c. to 2.6c. per kwh.; minimum 50c. per hp. 10 per cent cash discount.
Atlanta, Ga	5c. to 1.5c. per kwh.; minimum $1.11. 10 per cent cash discount.
	5c. to 3c. per kwh.; minimum $1.66. 10 per cent cash discount.
Aurora, Ill	$1 per hp. plus 4c. to 2.5c. per kwh.; minimum $3.
	$1 per hp. plus 4c. to 2.5c. per kwh.; minimum $3.
Auburn, N. Y	$1 Demand plus 4c. to 1.5c. per kwh.; minimum $1.
	$1 per hp. plus 4c. per kwh.; minimum $2. 10 per cent discount.
Baltimore, Md	4c. per kwh; minimum $5 for each vehicle.
	5c. per kwh.; minimum $5.
Binghamton, N. Y	$2.50 kw. of demand plus 1c. per kwh.
	First 100 kwh. 5.5c.; excess 3.33c., less 10 per cent; minimum $4.
Bloomington, Ill	3c. net per kwh.; minimum $5.
	5c. net per kwh.; minimum $5.
Boston, Mass	10c. to 2c. per kwh.; minimum 75c. per meter.
	10c. to 3c. per kwh. with discounts additional; minimum 75c.
Bridgeport, Conn	7c. per 100 kwh., or less to 3.25c. for 4,800 kwh. or over; minimum per hp. $1.50 to 50c.
	7c. per 100 kwh., or less to 3.25c. for 4,800 kwh. or over; minimum per hp. $1.50 to 50c.
Brockton, Mass	10c. to 4c. per kwh.; minimum $1. 10 per cent discount.
	7c. per kwh.; minimum $1. 10 per cent discount.
Brooklyn, N. Y	10c. to 3c. per kwh.; minimum $1 hp. Quantity discount.
	10c. to 3c. per kwh.; minimum $1 hp. Quantity discount.
	Flat rate 5c. per kwh. No minimum. No discount.
	Flat rate 5c. per kwh. No minimum. No discount.
Buffalo, N. Y	Primary charge $3.25 to $2.50 per kw.; second charge 1.5 to 1c. per kwh. Discount 25c. kw.
	8c. to 1.5c. per kwh.; minimum $1. Discount 1c. per kwh.
Cambridge, Mass	5 5/9c. to 2½c. per kwh.; minimum $1 per hp. Discount 10 per cent 15 days.
	5 5/9c. to 2½c. per kwh.; minimum $1 per hp. Discount 10 per cent 15 days.
Canton, Ohio	Maximum 6c.; average 3c. per kwh.
	Maximum 6c.; average 4c. per kwh.
Chattanooga, Tenn	5c. to 2c. per kwh.; minimum $1.053 per hp. Discount 5 per cent.
	5c. to 2c. per kwh.; minimum $1.053 per hp. Discount 5 per cent.
Chicago, Ill	Guaranteed maximum rate 4½c. per kwh.; minimum 50c. per hp. connected.
	11c. to 6c. and 4c. per kwh., less 1c. for cash, minimum 50c. per hp. connected.
Chicago (suburbs)	Direct-current, primary 50 kw. at $1.40, excess at 90c.: secondary 5c. to 9c. Discount 10 per cent secondary charge.
	11c. to 6c. and 4c. per kwh., less 1c. for cash; minimum $1.50 per charge plug.
Clinton, Iowa	Flat rate 5c. per kwh.
	Flat rate 5c. per kwh.
Colorado Springs, Colo	Fixed charge 50c. per hp. connected, plus 7c. to .77c per kwh. 10 per cent discount; minimum $1 hp.
	11c. per kwh., less 45 per cent discount; minimum $5.
Council Bluffs, Iowa	6c. per kwh., less 10 per cent discount; no minimum.
	6c. per kwh., less 10 per cent discount; no minimum.
Dallas, Tex	5c. to 3 1/3c. per kwh., less 10 per cent. Discount 50c. hp. Connected minimum.
	5c. to 3 1/3c. per kwh., less 10 per cent. Discount 50c. hp. Connected minimum.
Danville, Ill	5c. to 2c. per kwh. Must be used during off-peak hours.
	Flat rate 5c. per kwh.; minimum $5.
Dayton, Ohio	4.2c to 3c. per kwh., according to hours use of demand, 5 per cent discount.
	6.6c. to 5.4c. per kwh., less 5 per cent; no minimum.
Denver, Colo	$1 hp, plus 4c. kwh., less 10 per cent; also $2 per hp., plus $1.75, less 10 to 15 per cent discount.
	Flat rate 4c. per kwh., less 10 per cent; minimum from $5 to $12.50.
Des Moines, Iowa	5c. to 3c. per kwh., depending upon hours use of capacity, 5 per cent discount; minimum $2.50.
	5c. to 3c. per kwh., depending upon hours use of capacity, 5 per cent discount; minimum $2.50.
Detroit, Mich	Flat rate 3c. kwh., less 5 per cent or demand $3 per kwh. plus 1c. to 6c. per kwh.; minimum $1.
	Flat rate 4c. per kwh., less 5 per cent discount; minimum $1.
	Flat rate 2c. per kwh.
	Do not sell to private garages.
Dover, N. H	Flat rate 4c. per kwh. net.
	Flat rate 4c. per kwh. net.
Dubuque, Iowa	Flat rate 6c. per kwh., less 1c.; minimum $1 hp.
	10c. per kwh. down, according to quantity; minimum $1 per hp.
Duluth, Minn	3c. per kwh., less 20 per cent discount; minimum $15 per month.
	6c. per kwh., less 20 per cent discount; minimum $4 per month.
Elmira, N. Y	7c. to 2c. per kwh.
	7c. to 2c. per kwh.
Erie, Pa	3c. per kwh., less 5 per cent; minimum 75c. month.
	5c. per kwh., less 5 per cent; minimum 75c. month.
Evansville, Ind	Fixed charges $2 net per active kw., plus 1c. per kwh.
	5c. to 2½c. per kwh., less 10 per cent; minimum 50c. per hp.
Fall River, Mass	6c. to 1½c. per kwh., less 10 per cent; minimum $1 per hp.
	6c. to 1½c. per kwh., less 10 per cent; minimum $1 per hp.
Fort Smith, Ark	5c. to 1.99c. per kwh.
	5c. to 1.99c. per kwh.
Fort Worth, Tex	5c. to 3c. per kwh.; minimum $1.
	5c. to 3c. per kwh.; minimum $1.

Supply and rates to railways.—As typical of the heavy power contracts and rates made by central station companies may be given in abstract the terms agreed to between the Great Falls (Mont.) Power Co. and the Chicago, Milwaukee & Puget Sound Railway in 1912–13. The plans for the electrification of the railway, from Harlowton, Mont., to Avery, Idaho, a distance of 440 miles, include the supply of wholesale power from the Great Falls Power Co., Great Falls, Mont., with plants at Rainbow Falls and Black Eagle Falls on the Missouri River. The railway company agreed to electrify its line between Harlowton and Deer

Lodge, Mont., a distance of 238 miles, before January 1, 1918, and also to buy from the power company electric energy at the rate of 10,000 kilowatts, maximum demand, for the full period of the 99-year agreement, but two years' notice is to be given the power company as to the time when delivery must begin. The railway company has several options for more power, up to a total rate of 25,000 kilowatts, maximum demand, the agreement as to this additional demand being as follows: Not less than 4,000 kilowatts, nor more than 8,000 kilowatts, if called for prior to January 1, 1923; not less than 3,500 kilowatts, nor more than 7,000 kilowatts, if called for at any time between January 1, 1918, and January 1, 1928, if at least 6,300 kilowatts additional has been called for prior to January 1, 1923. Additional energy, when once called for, as above, will be supplied for the entire remaining term of the contract.

Delivery of energy will be made to not more than five receiving substations between Deer Lodge and Harlowton, at 50,000 volts or 100,000 volts, three-phase, 60 cycles, alternating current. The railway substations are to contain sufficient synchronous machinery to secure a power factor of at least 80 per cent. The power company will have the right to install regulators in the substations, for the operation of synchronous machinery, in such manner as to receive any power factor between 80 per cent leading and 80 per cent lagging. The rate of energy will be 5.36 mills per kilowatt hour, subject to a minimum bill, after the first year of service, equivalent to 60 per cent of all the energy contracted for. The power company is also required to pay the Federal Government a tax of 5 mills per 1,000 kilowatt hours for all energy delivered over transmission lines crossing the public domain.

This region is mountainous, embracing some very heavy grades, and it is estimated that electrical operation will result in large economies as compared with operation by steam locomotives using expensive fuel.

Rate schedules.—Herewith are appended a number of typical rate schedules from various American cities, which have been reduced to uniformity, enabling better comparison, on the basis of the scale or schedule provided by the rate research committee of the National Electric Light Association; but before presenting them it is desirable to exhibit the general conditions as to average rates prevailing in 1912 in 30 representative cities of the United States.

Of the 30 cities, 1 had a population of less than 25,000, 9 had populations between 25,000 and 50,000, 8 between 50,000 and 100,000, 7 between 100,000 and 200,000, 4 between 200,000 and 500,000, and 1 in excess of 1,000,000.

It is perhaps better to summarize the rates of some of the larger cities for 1913–14, instead of attempting to present all the voluminous schedules. Even from this brief synopsis, which follows the tabular statement, the complexity of the tariffs dealt with may be inferred, but, whatever the method employed, the aim of the companies has naturally been to cultivate and develop the universal use of electricity.

AVERAGE RATES FOR CENTRAL STATION SERVICE IN THIRTY CITIES.

INSTALLATION.	Connected load (kilowatts).	Maximum demand (kilowatts).	Monthly consumption (kilowatt hours).	Average rate per kilowatt hour (cents).
Residence, large	3.0	2.2	127	9.1
Residence, small	0.6	0.5	27	9.4
Retail store, large	7.0	7.0	1,126	6.3
Retail store, small	0.5	0.5	67	8.1
Drug store	1.5	1.5	200	7.4
Saloon	1.5	1.5	377	6.4
Church	5.0	5.0	156	8.7
Industrial, 1 motor	1.5	2.0	109	6.6
Industrial, 2 motors	3.7	5.0	286	6.0
Industrial, 3 motors	10.3	10.0	244	6.7
Industrial, 8 motors	18.7	25.0	3,318	3.2
Industrial, 20 motors	59.7	50.0	4,180	3.5

Boston.—Steam only. Meter rate, 10 cents per kilowatt hour. No discount; lamps free. Minimum, $9 per year. State regulation fixed 12-cent rate; present rate reduced by company.

New York.—Steam only. Block rate, 10 cents first 250 kilowatt hours; 9 cents next 250; 8 cents next 250; 7 cents next 250; 6 cents next 500; 5 cents excess over 1,500 kilowatt hours. No discount; lamps free. No minimum charge.

Buffalo.—All Niagara water power. Wright demand, 7 cents first 60 kilowatt hours' use per month; 4 cents next 120 kilowatt hours; 1.5 for excess. Maximum demand, residence one-quarter connected load; commercial one-half connected load. Minimum charge, $12 per year. No lamp renewals; no discount. Rate fixed by state commission. Pending court review, commission has allowed company to charge one-half cent additional on use over 60 hours.

Philadelphia.—All steam. Alternating current, overhead, 10 cents straight line meter rate. Direct current, underground, 12-cent straight line meter rate. Free lamps; no discount up to $10. Minimum charge, $1 per month. State commission has not regulated rates.

Baltimore.—Susquehanna water power, steam auxiliary. Eight and one-half cents per kilowatt hour, meter rate. Minimum charge $12 per year. Free lamps; no discount. Rate fixed by state commission after complete investigation.

Washington.—All steam. Wright demand, 10 cents first 120 kilowatt hours per month; 5 cents excess kilowatt hour; minimum charge $1; lamps free. Delay payment penalty 1 cent per kilowatt hour. District commission has not regulated rates.

Chicago.—All steam. Wright demand, 11 cents first 30 kilowatt hours' use per month; 6 cents next 30 kilowatt hours' use per month, 4 cents excess kilowatt hours. Maximum demand estimated percentage of connected load up to 30 lights; measured by indicators over 30 lights. Lamps free; no minimum charge; prompt payment discount 1 cent per kilowatt hour. Rates fixed by state council 1913 for five years.

Cleveland.—All steam. Wright demand, 10 cents first 36 kilowatt hours use assessed maximum demand, 5 cents next 30 hours, 3 cents excess kilowatt hours. No discount; no minimum, free lamps. State commission can not regulate rates in first instance. City council early in 1914 voted flat uniform 3-cent rate. Old rate still prevails under the law.

Cincinnati.—All steam. Load factor rate based on hours use of 70 per cent connected load. Base 10 cents per kilowatt hour, 40 hours use, 9½ cents; 90 hours use, 7 cents; 180 hours use, 5½ cents; 270 hours use, 5 cents. No free lamp renewals; no discount. Minimum charge $1. State commission has no jurisdiction over rates in first instance.

St. Louis.—Keokuk water power, steam auxiliary. Nine and one-half cents net per kilowatt hour. Residence Wright demand, room basis, 10 cents per kilowatt hour first 4 kilowatt hours for each of first four rooms plus 2½ kilowatt hours for each additional room; 6 cents for excess used. Minimum $1 per month; discount 5 per cent; free lamps. Rate ordinance fixed by state commission at 9½ cents upset by court. Company voluntarily reduced rates to maximum fixed by the commission. State commission has not regulated.

Kansas City.—All steam. Nine cents per kilowatt hour; no discount; minimum charge $1 per month. State commission has not regulated rates, but city appealed to commission to fix rates.

Denver.—Water power, steam auxiliary. Doherty rate, customer charge $9 per year; demand charge $36 per year per kilowatt connected; energy charge 5 cents per kilowatt hour; discount 10 per cent. Free lamps.

Rate schedules in detail.—Below are given in greater detail the typical rates of some other cities which illustrate the general practice in different parts of the country. The information is from the Rate Research, a publication issued by the National Electric Light Association and devoted to the compilation of this class of data.

Omaha, Nebr.—The Omaha Electric Light & Power Co.
Green Bay, Wis.—Green Bay Gas & Electric Co.
Norristown and Conshohocken, Pa.—The Counties Gas & Electric Co.
Superior, Wis.—The Superior Water Light & Power Co.
Madison, Wis.—Madison Gas & Electric Co.
Watertown, N. Y.—The Watertown Light & Power Co.
Pittsfield, Mass.—Pittsfield Electric Co.
Evansville, Ind.—The Evansville Public Service Co.
Meadville, Pa.—People's Incandescent Light Co.
Southern California.—Southern California Edison Co.
Bridgeport, Conn.—The United Illuminating Co.
Idaho.—Utah Power & Light Co.
Brooklyn, N. Y.—The Flatbush Gas Co.
New Glarus, Wis.—New Glarus Municipal Electric Light and Water Plant.
Hartford, Conn.—Hartford Electric Light Co.
Marquette, Mich.—Light and Power Commission.
Marshall, Mich.—Electric and Water Works Department.

Omaha, Nebr.—The Omaha Electric Light & Power Co. has published the following lighting rate (effective July 1, 1913) and power rate (effective Oct. 1, 1913):

LIGHTING RATE.

Character of service.—Effective for commercial and residence lighting. The secondary lighting rate of 6 cents per unit (k w h.) is effective for all electrical heating devices and the charging of storage batteries designed for use in electric vehicles.

Rate.—Twelve cents per kilowatt hour for the first 30 hours' use per month of maximum demand; 6 cents per kilowatt hour for excess use.

Determination of demand.—Commercial lighting: Active load, 100 per cent of total connected load. Residence lighting: Active load, 60 per cent of total connected load.

Prompt payment discount.—Five per cent discount on total bill if paid within 10 days from date.

Minimum charge.—For regular service, none. For emergency or throw-over service, $1 per month per kilowatt of capacity connected to the service lines, and for no less a period than one year.

Lamp renewals.—Standard carbon or gem incandescent lamps will be furnished and renewed only on customer's premises without additional charge (to customers entitled to free lamp renewals) in standard sizes of 4 c. p. 20 watts, 10 c. p. 30 watts, 16 c. p. 50 watts, 32 c. p. 100 watts, either clear or frosted.

RETAIL POWER RATE.

Rate.—Nine cents gross per kilowatt hour for the first 200 kilowatt hours per month; 5 cents net per kilowatt hour for the next 400 kilowatt hours per month; 3 cents net per kilowatt hour for the next 2,600 kilowatt hours per month; 2 cents net per kilowatt hour for all excess kilowatt hours per month.

Discount.—One cent per kilowatt hour on first 200 if paid within 10 days from date.

Minimum charge.—For regular service, $3 per month. For emergency service or throw-over service, $1 per kilowatt of capacity connected to the service lines, and for no less a period than one year.

WHOLESALE POWER RATE.

Character of service.—This rate is designed to apply to large industrial enterprise using 3-phase 60-cycle alternating current and requiring long hours' use of power apparatus (where the guarantee of a minimum income of $140 per month to the company is warranted under a long term contract).

Rate.—Demand charge: $1.25 per month per kilowatt of capacity connected, for installations of over 150 horsepower. Energy charge: One cent per kilowatt hour.

Determination of demand.—The demand is considered as the total of capacity connected.

Discounts.—None.

Minimum charge.—One hundred and forty dollars per month.

Green Bay, Wis.—City of Green Bay *v.* Green Bay Gas & Electric Co., decision of the Wisconsin Railroad Commission, establishing gas and electric rates, July 11, 1913. The electric rates fixed by the commission are as follows:

GENERAL LIGHTING RATE.

For all lighting service furnished residences, business places, and public buildings including incidental use of appliances for heating and power measured by the same meter:

Rate.—Ten cents net or eleven cents gross per kilowatt hour for the first 30 kilo watt hours per month per active kilowatt connected. Eight cents net or nine cents gross per kilowatt hour for the next 60 kilowatt hours per month per active kilowatt connected. Four cents net or five cents gross per kilowatt hour for all use in excess of 90 kilowatt hours per month per active kilowatt connected. For all signs, outlines, and window lighting on a yearly contract basis five cents net or six cents gross per active 50-watt lamp or its equivalent per month plus four cents net or five cents gross per kilowatt hour for current consumed as estimated according to the schedule of lighting hours.

Determination of active connected load.—The active load shall be determined as ordered for Class A, B, C, E, and F in In re Madison Gas & Electric Co. (7 W. R. C. R. 152, 167).

Minimum charge.—One dollar net or $1.10 gross per month per meter.

Prompt payment discount.—The difference between the gross and net rates shall constitute a discount for prompt payment of bills.

Terms and conditions.—For the reconnection of meters for the same consumer on the same premises, a charge of $1 per meter shall be made. Where the company is unable to read meter, after reasonable effort, the fact shall be plainly indicated on the monthly bill, the minimum charge shall be assessed and the differences shall be adjusted with the consumer when meter is again read.

Norristown and Conshohocken, Pa.—The Counties Gas & Electric Co. rates, effective December 31, 1913:

NORRISTOWN AND CONSHOHOCKEN.

Electric lighting.

Rate.—Ten cents per kilowatt hour for the first 200 kilowatt hours per month; 7 cents per kilowatt hour for the next 50 kilowatt hours per month; 5 cents per kilowatt hour for the next 100 kilowatt hours per month; 4 cents per kilowatt hour for over 350 kilowatt hours per month.

Discount.—Bills to be rendered at 1 cent per kilowatt hour above the foregoing rates and subject to a discount of 1 cent per kilowatt hour if paid at the office of the company within 10 days after presentation.

Minimum charge.—One dollar and fifty cents per meter per month.

Electric power.

Rate.—Ten cents per kilowatt hour for the first 100 kilowatt hours per month; 7 cents per kilowatt hour for the next 100 kilowatt hours per month; 6 cents per kilowatt hour for the next 100 kilowatt hours per month; 5 cents per kilowatt hour for the next 100 kilowatt hours per month; 4 cents per kilowatt hour for the next 400 kilowatt hours per month; 3 cents per kilowatt hour for the next 500 kilowatt hours per month; 2 cents per kilowatt hour for over 1,300 kilowatt hours per month.

Discount.—Bills to be rendered at 1 cent per kilowatt hour above the foregoing rates and subject to a discount of 1 cent per kilowatt hour if paid at the office of the company within 10 days after presentation. When the current consumption for any month computed at the aforesaid rates exceeds $75, the consumer shall be entitled to a further discount at 10 per cent thereon, provided the amount of such further discount shall not reduce the amount due for such consumption to an amount less than $75.

Supplementary discount.—No. 1: Where the company supplies the consumer with electric energy at the primary voltage of its distribution line, and the consumer furnishes the necessary transformers, a further discount of 5 per cent will be allowed from the monthly bill, figured at the aforesaid rate.

No. 2: If the power factor on the entire load, due to a lagging current is maintained at 95 per cent or better, a further discount of 5 per cent will be allowed on bills figured at the aforesaid rate.

Minimum charge.—No bill submitted on this schedule less than $2. If the connected load of a consumer is more than 2 horsepower the minimum charge shall be $1 per horsepower for all connected load.

MAIN LINE.

The following rates apply to consumers on company's distribution lines suitable for supplying service demanded:

Electric lighting.

Rate.—Ten cents per kilowatt hour for the first 200 kilowatt hours per month; 7 cents per kilowatt hour for the next 50 kilowatt hours per month; 5 cents per kilowatt hour for the next 100 kilowatt hours per month; 4 cents per kilowatt hour for over 350 kilowatt hours per month.

Minimum charge.—One dollar per meter per month.

Electric power.

Rate.—Ten cents per kilowatt hour for 100 kilowatt hours per month; 9 cents per kilowatt hour for 101 to 300 kilowatt hours per month; 8 cents per kilowatt hour for 301 to 600 kilowatt hours per month; 7 cents per kilowatt hour for 601 to 1,000 kilowatt hours per month; 6 cents per kilowatt hour for 1,001 to 1,500 kilowatt hours per month; 5 cents per kilowatt hour for 1,501 to 2,000 kilowatt hours per month, 4 cents per kilowatt hour for 2,001 to 2,500 kilowatt hours per month; 3 cents per kilowatt hour for over 2,500 kilowatt hours per month; 2½ cents per kilowatt hour for 10,000 or more kilowatt hours per month.

Minimum charge.—No bill submitted under this schedule less than $1. If the connected load of a consumer is more than 1 horsepower the minimum charge shall be $1 per horsepower for all connected load.

CONSHOHOCKEN.

Demand rate.—Ten cents per kilowatt hour for the first 20 kilowatt hours per month per horsepower; 6 cents per kilowatt hour for the first 100 kilowatt hours per month in excess of the above; 4 cents per kilowatt hour for the next 900 kilowatt hours per month; 2½ cents per kilowatt hour for over 1,000 kilowatt hours per month.

Rating of demand.—Under 10 horsepower demand, connected load; from 10 horsepower to 50 horsepower in one motor, 90 per cent connected load; from 10 horsepower to 50 horsepower in more than one motor, 80 per cent connected load. Over 50 horsepower demand obtained from curve-drawing instruments, when the demand will be taken as the highest average demand during any five consecutive minutes during the month.

Minimum charge.—No bill submitted on this schedule less than $1.

SUPERIOR, WIS. (population 40,384).—The Superior Water, Light & Power Co. rates, effective January 1, 1914, are as follows:

RESIDENCE LIGHTING RATE.

For all electric energy furnished residences, dwellings, flats, and private boarding houses for lighting. This service may include energy for other uses than lighting, where appliances of not over 600 watts capacity, each, are employed, whose aggregate demand does not require special wiring or enlarged meter or transformer capacity.

Rate.—Ten and one-half cents per kilowatt hour for all or part of first 6 kilowatt hours used per month in house having 3 rooms or less, plus 2 kilowatt hours for each additional room; 8½ cents per kilowatt hour for all or part of next 6 kilowatt hours used per month in house having 3 rooms or less, plus 3 kilowatt hours for each additional room; 6 cents per kilowatt hour for all energy used in excess of 12 kilowatt hours per month in house having 3 rooms or less, plus 5 kilowatt hours for each additional room.

Determination of rooms.—In applying the above rate, the count of rooms is to be made on the so-called real estate agents' rental basis (which excludes bathrooms, hallways, and unfinished attics and basements), except that rooms having an area of more than 300 square feet will count as two rooms. Where two or more room exceed 300 square feet each, only one extra room will be counted for each 300 square eet of excess area.

Minimum charge.—One- to 5-room house or flat, 50 cents, plus 10 cents for each additional room.

The following is a tabulation of above rate:

NUMBER OF ROOMS.	1–3	4	5	6	7	8	9	10	11	12	13	Add for each additional room.
	KILOWATT HOURS.											
Rate per kilowatt hour:												
10½ cents, first.	6	8	10	12	14	16	18	20	22	24	26	2
8½ cents, next.	6	9	12	15	18	21	24	27	30	33	36	3
6 cents, all over	12	17	22	27	32	37	42	47	52	57	62	5
Minimum monthly bill	$0.50	$0.50	$0.50	$0.60	$0.70	$0.80	$0.90	$1.00	$1.10	$1.20	$1.30	$0.10

Prompt payment discount.—One cent per kilowatt hour when paid on or before 10 a. m. on 16th and one-half cent per kilowatt hour when paid later than this, but not later than 10 a. m. on the 26th of month following that for which bill is rendered. When the 15th or 16th falls on a Sunday or holiday, discounts allowed until 10 a. m. on the 17th; and until 10 a. m. on the 27th, when the 25th or 26th falls on a Sunday or holiday.

Lamp renewals.—Lamps may be purchased from the company at prices as published. No allowance for lamps returned. The company assumes no responsibility for lamps after they have been delivered to the consumer.

Term of contract.—This agreement shall remain in force for the term stated, if any, and in any event, for the full period during which service is taken and until three days after receipt at the company's office of written notice from the consumer of his wish to discontinue. A term contract may be required when special investment is required in order to furnish service.

Terms and conditions.—When electric mains pass in front of a house, a charge of $5 is made for the labor cost of running service wires. When two or more houses are connected at the same time, by extending a single service drop from house to house and when the distance between the houses is less than 20 feet, the charges are as follows: Two houses, $7.50; three houses, $9; four houses, $10; five houses, $11.

COMMERCIAL LIGHTING RATE.

This service may include energy for other uses than lighting when motors or other appliances of not over 750 watts capacity each and not over 1,500 watts aggregate capacity are used.

Rate.—Ten and one-half cents per kilowatt hour for all or part of first 3 kilowatt hours used per month per 100 watts of active load; 8½ cents per kilowatt hour for all, or part of next 6 kilowatt hours used per month per 100 watts of active load; 6 cents per kilowatt hour for all current used in excess of 9 kilowatt hours per month per 100 watts of active load.

Determination of active connected load.—Active connected load shall in every case be a percentage of total connected load consisting of lamps, appliances, etc., installed upon consumers' premises, and shall be fixed as follows:

Class A: Window, sign, basement salesroom, and outside decorative lighting, 66⅔ per cent of the total connected load shall be deemed active.

Class B: Stores, offices, etc., 70 per cent of the total connected load shall be deemed active when such load is equal to or less than 2½ kilowatts; 55 per cent of such connected load over and above 2½ kilowatts shall be deemed active, provided that lamps used exclusively in space devoted to the storing of goods shall be treated as 20 per cent active and shall not be included in the 2½ kilowatts specified above.

Class C: Public buildings, churches, hotels, factories, 55 per cent of the total connected load shall be deemed active.

In classes A, B, and C, the minimum connected load to be used in figuring active load shall be 200 watts.

Prompt payment discount.—Same as for residence lighting.

Note: On bills owed by the United States of America, the State of Wisconsin, the county of Douglas, and the city of Superior, an additional 30 days' time is allowed without forfeiture of discount.

Quantity discounts.—First 250 kilowatt hours per month, discount, none; second 250 kilowatt hours per month, discount, 0.5 cent per kilowatt hour; third 250 kilowatt hours per month, discount, 1 cent per kilowatt hour; fourth 250 kilowatt hours per month, discount, 1.5 cents per kilowatt hour; fifth 250 kilowatt hours per month discount, 2 cents per kilowatt hour; sixth 250 kilowatt hours per month, discount, 2.5 cents per kilowatt hour; seventh 250 kilowatt hours per month, discount, 3 cents per kilowatt hour; all additional consumption, discount 1.5 cents per kilowatt hour. The average discounts are as follows: Monthly consumption of 500 kilowatt hours, average discount, 0.25 cent per kilowatt hour; monthly consumption of 750 kilowatt hours, average discount, 0.5 cent per kilowatt hour; monthly consumption of 1,000 kilowatt hours, average discount, 0.75 cent per kilowatt hour; monthly consumption of 1,250 kilowatt hours, average discount, 1 cent per kilowatt hour; monthly consumption of 1,500 kilowatt hours, average discount, 1.25 cents per kilowatt hour; monthly consumption of 1,750 kilowatt hours and over, average discount, 1.5 cents per kilowatt hour.

Minimum charge.—Net 50 cents per month for 500 watts or less of connected load, plus 5 cents for each additional 50 watts connected.

Lamp renewals.—Same as for residence lighting.

Term of contract.—Same as for residence lighting.

MADISON, WIS. (population 25,531).—The Madison & Gas Electric Co. rate schedule as of November 30, 1913:

GENERAL LIGHTING RATE.

Rate.—Eleven cents gross or 10 cents net per kilowatt hour for the first 30 hours' use per month of active connected load; 7 cents gross or 6 cents net per kilowatt hour for the next 60 hours' use per month of active connected load; 3 cents gross or 2 cents net per kilowatt hour for all excess use per month of active connected load.

Determination of active connected load.—Active connected load shall in each case be a fixed percentage of the total connected load, consisting of lamps, appliances, etc., installed upon the consumers' premises.

Prompt payment discount.—The difference between the gross and net rates or 1 cent per kilowatt hour shall constitute a discount for payment before the 13th day of the month following the last day of meter reading.

Minimum charge.—One dollar net per month per meter.

Lamp renewals.—Company shall renew burned-out or badly dimmed carbon filament lamps of the type originally furnished or installed by the company when returned unbroken to its office. Charges for the maintenance and replacement of other illuminants shall be reasonable and in accordance with the schedule of charges filed with the railroad commission.

Terms and conditions.—For the reconnection of meters for the same consumer upon the premises a charge of $2 is deemed reasonable.

POWER RATES.

To any single consumer signing the company's standard forms of contract provided for service for three years or more and located within the residence districts adjacent to the company's 3-phase A. C. power lines, the charge for A. C. electric power service shall be computed upon the following basis:

Rate.—Demand charge: Twenty-eight dollars per year for each kilowatt of demand of the first 10 kilowatts; $18 per year for each kilowatt of demand of the next 90 kilowatts; $9 per year for each kilowatt of demand in excess of 100 kilowatts.

Energy charge: Two and one-half cents gross or 2 cents net per kilowatt hour for the first 500 kilowatt hours consumed during the month; 1½ cents gross or 1 cent net per kilowatt hour for the next 1,000, kilowatt hours consumed during the month; 1 cent gross or ⅔ cent net per kilowatt hour for all energy consumed during any month in excess of 1,500 kilowatt hours.

WATERTOWN, N. Y. (population 26,730).—The Watertown Light & Power Co. schedule revised as of January 1, 1914.

LIGHTING RATES.

Rate.—Rates are named varying with hours and tenths of hours use per month from 11 cents gross, per kilowatt hour, for the first hours' use of consumer's demand, to 7.5 cents gross, per kilowatt hour for 8 hours' use of consumer's demand, 7 cents gross, per kilowatt hour for 13 hours' use of consumer's demand, and 6.3 cents gross, per kilowatt hour for 24 hours' use of consumer's demand, etc.

Determination of assessed demand.—The consumer's demand is assessed from an inspection of the consumer's lamps and appliances connected and use is made of the following table when watts consumption is not marked on label or name plate: Two candlepower carbon lamps, 13 watts; 4 candlepower carbon lamps, 22 watts; 8 candlepower carbon lamps, 32 watts; 10 candlepower carbon lamps, 35 watts; 16 candlepower carbon lamps, 50 watts; 20 candlepower carbon lamps, 70 watts; 24 candlepower carbon lamps, 84 watts; 32 candlepower carbon lamps, 112 watts; empty-sockets that may be used, 40 watts; inclosed arc lamps, 550 watts. Three-fourths of the whole connected load as obtained is taken as the basis on which to render bills with a minimum connected load of one-half kilowatts.

Quantity discounts.—Ten per cent discount on bills amounting to from $50 to $75 per month; 15 per cent discount on bills amounting to from $75.01 to $100 per month; 20 per cent discount on bills amounting to from $100.01 to $125 per month; 25 per cent discount on bills amounting to from $125.01 to $150 per month; and 30 per cent discount on bills amounting to over $150 per month.

Prompt payment discount.—A discount of 2 cents per kilowatt hour is allowed if bills are paid on or before the discount date named on the bill.

Minimum charge.—One dollar per month per consumer.

Terms and conditions.—Two or more business places owned by the same person or company will be considered as one in rendering bills if so desired, but in such cases the total connected load will be used as a basis instead of three-fourths of the connected load. Anyone who owns and uses a lighting plant and requires connection to our system will be charged a minimum of $1 per month per kilowatt connected load as a breakdown service charge.

PITTSFIELD, MASS. (population 32,121).—The following is the rate schedule of the Pittsfield Electric Co.:

RESIDENCE LIGHTING RATE.

Rate.—Twelve cents per kilowatt hour for the first kilowatt hour used per month per 25-watt lamp connected; 8 cents per kilowatt hour for all excess use. The minimum capacity that will be provided is 500 watts.

Prompt payment discount.—Ten per cent discount is allowed on bills if paid on or before the 15th of the month in which the bill is rendered, provided there exists no unpaid balance of previous months.

Minimum charge.—For any month that the meter for lighting service does not register at least 8 kilowatt hours, no bill for current will be rendered, but a net charge of 50 cents for maintenance of service will be made. If in any 12 consecutive months ending January 1 the consumption of electricity at regular rates, less discount equals $9 or more, a rebate will be made of amounts paid for maintenance of service as specified above.

Terms and conditions.—For each meter installed where customer is not on the company's books, a deposit will be required equal to one month's bill, or $3 for residence. The company will pay 4 per cent interest on same annually, deposit to be returned when the meter is removed.

COOKING RATES.

To encourage the use of electric flatirons, ranges, and other household appliances, the company recommends the installation of a special heating circuit so that the current used by these devices may be registered on a separate meter.

Rate.—Four cents per kilowatt hour is made a special flat rate for this class of service.

Minimum charge.—A minimum charge of $1 per month is required.

COMMERCIAL LIGHTING RATE.

For stores and places of business in congested section of city:

Rate.—Twelve cents per kilowatt hour for the first 30 hours' use per month of consumer's demand; 8 cents per kilowatt hour for the next 50 hours' use per month of consumer's demand; 6 cents per kilowatt hour for the next 100 hours' use per month of consumer's demand; 5 cents per kilowatt hour for all over 180 hours' use per month of consumer's demand.

Determination of demand.—Connected load not in excess of 1, 2, 3.5, 5, 7.5, 10, 15, 20, 25, 30, 40, or 50 kilowatts. Basis of demand, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, or 15 kilowatts. The minimum capacity that will be provided is 1 kilowatt.

Prompt payment discount.—Same as in residence lighting.

Terms and conditions.—For each meter installed where customer is not on the company's books, a deposit will be required equal to one month's bill, or $5 per store.

EVANSVILLE, IND. (population 69,647).—The Evansville Public Service Co. schedule taking as the maximum rate 7½ cents per kilowatt hour, prescribed as the rate for light and power in the franchise rendered the company, made effective the following rates January 1, 1913:

RESIDENCE LIGHTING RATES.

Rate.—Seven and one half cents per kilowatt hour for the first 100 kilowatt hours consumed per month; 7 cents per kilowatt hour for the next 100 kilowatt hours; 6½ cents per kilowatt hour for the next 100 kilowatt hours; 6 cents per kilowatt hour for the next 100 kilowatt hours; 5½ cents per kilowatt hour for the next 100 kilowatt hours; 5 cents per kilowatt hour for the next 100 kilowatt hours; 4½ cents per kilowatt hour for the next 100 kilowatt hours; 4 cents per kilowatt hour for the next 100 kilowatt hours; 3¾ cents per kilowatt hour for all over 800 kilowatt hours consumed per month.

Prompt payment discount.—Ten per cent if bill is paid on or before the 12th day of the month succeeding that month for which bill is rendered.

Minimum charge.—One dollar net per consumer per month.

COMMERCIAL LIGHTING RATES.

Regular Rate.

Same schedule as for residence lighting.

Optional Rate.

Under this schedule, stores and commercial establishments of every character will be billed, if they so elect by contract for lighting service.

Rate.—Fixed charge plus energy charge. Fixed charge: Two dollars and fifty cents net or $2.77 gross per active kilowatt per month.

Energy charge: Three cents net or 3⅓ cents gross per kilowatt hour for the first 90 hours' use per month of active connected load; 2 cents net or 2.22 cents gross per kilowatt hour for all energy use in excess of 90 hours' use per month of the active connected load.

Determination of active connected load.—Class A: Banks, office buildings, professional establishments, wholesale and retail merchandise establishments, etc., the following percentage of the connected load shall be deemed active: 90 per cent of the first 2 kilowatts, 80 per cent of the next 3 kilowatts, 60 per cent of all over 5 kilowatts.

Class B: Department stores, hotels and office buildings where company sells service to the building as one customer, but not including stores on the first floor, the following per cent of the connected load shall be deemed active: 70 per cent of the first 5 kilowatts, 50 per cent of the next 5 kilowatts, 30 per cent of all over 10 kilowatts.

Class C: Vaudeville theaters, moving-picture shows, etc., the following percentage of connected load shall be deemed active: 60 per cent of the first 5 kilowatts, 40 per cent of all over 5 kilowatts.

For 40-week theaters, 33⅓ per cent of connected load, and for summer parks, and all similar transient customers, 100 per cent of the connected load, shall be deemed active.

Prompt payment discount.—The difference between the gross and net rates will constitute a discount for prompt payment on bills paid on or before the twelfth day of the month.

POWER RATES.

Regular Rate.

Rate.—Five cents per kilowatt hour for the first 300 kilowatt hours per month; 4½ cents per kilowatt hour for the next 300 kilowatt hours per month; 4 cents per kilowatt hour for the next 300 kilowatt hours per month; 3½ cents per kilowatt hour for the next 300 kilowatt hours per month; 3 cents per kilowatt hours for the next 300 kilowatt hours per month; 2½ cents per kilowatt hour for all over 1,500 kilowatt hours per month.

Prompt payment discount.—Ten per cent if bill is paid on or before the 12th day of the month succeeding the month for which bill is rendered.

Minimum charge.—Fifty cents net per horsepower connected per month.

Optional Rate.

Rate.—Fixed charge plus energy charge. Fixed charge: Two dollars net or $2.22 gross per active kilowatt per month.

Energy charge: One cent net or 1.11 cents gross per kilowatt hour for all current consumed.

Prompt payment discount.—Same as in regular rate.

Additional 50 per cent discount from fixed charge allowed for off-peak power users.

Active connected load.—The following percentage of total nominal rated capacity of motor or motors installed shall be deemed active: ninety per cent of the first 5 horsepower of connected load, 80 per cent of the next 5 horsepower of connected load, 70 per cent of the next 20 horsepower of connected load, 60 per cent of the next 20 horsepower of connected load, 50 per cent of all over 50 horsepower of connected load.

MEADVILLE, PA. (population 12,780).—The following is the rate schedule of the Peoples' Incandescent Light Co., effective January 1, 1914:

RETAIL LIGHT SERVICE.

Available for and applying to all consumers using the company's standard lighting service, applicable especially to residence lighting and other lighting service where average monthly consumption is low.

Rate.—Ten cents per kilowatt hour.

Prompt payment discount.—Discount of 10 per cent if paid on or before the 10th day of each month.

Minimum charge.—One dollar per month per consumer.

Terms and conditions.—A cash deposit of $3 will be required with each service application when customer is not a property owner, or when monthly service charges are not guaranteed by a responsible party. The company reserves the right to discontinue service in case of failure of customer to make prompt payment of bills when due, or in case of violation of the rules and regulations of the company governing use of the electric service.

WHOLESALE LIGHTING SERVICE.

Available for and applying to all consumers using the company's standard lighting service, and especially applicable to commercial lighting and other lighting service where average monthly consumption warrants a minimum charge of $2.

Rate.—Ten cents per kilowatt hour for the first 10 kilowatt hours per month; 8 cents per kilowatt hour for the next 20 kilowatt hours per month, 6 cents per kilowatt hour for the next 70 kilowatt hours per month, 5 cents per kilowatt hour for the next 900 kilowatt hours per month, 4 cents per kilowatt hour for all over 1,000 kilowatt hours per month.

Prompt payment discount.—Discount of 5 per cent if paid on or before the 10th day of each month.

Minimum charge.—Two dollars per month per consumer.

Terms and conditions.—Same as in retail lighting service except that $5 is required as a cash deposit.

SIGN AND WINDOW LIGHTING.

Available for consumers using the company's standard lighting service for sign, window, and display lighting. This service is turned on and off by the company and will be operated between dusk and 11 p. m. each day.

Rate.—One cent per watt per month for each watt installed.

Prompt payment discount.—Five per cent if paid on or before 10th day of each month.

Minimum charge.—One dollar per month per consumer.

Terms and conditions.—Same as for retail lighting service.

COOKING AND HEATING SERVICE.

Available for all consumers using the company's standard service for heating and cooking purposes and offering a special low rate to consumers desiring to use electric cooking utensils and heating devices.

Rate.—Four cents per kilowatt hour.

Prompt payment discount.—Five per cent if paid on or before the 10th day of each month.

Minimum charge.—One dollar per month per consumer.

Terms and conditions.—Same as for retail lighting service.

GENERAL POWER SERVICE.

Available for all power consumers using the company's standard service.

Rate.—Unit charge: Five cents per kilowatt hour for all use less than 250 kilowatt hours per month; 4½ cents per kilowatt hour for 250 kilowatt hours per month; 4 cents per kilowatt hour for 500 kilowatt hours per month; 3½ cents per kilowatt hour for 1,000 kilowatt hours per month; 2½ cents per kilowatt hour for 2,000 kilowatt hours per month; 2¼ cents per kilowatt hour for 3,000 kilowatt hours per month; 2 cents per kilowatt hour for 5,000 kilowatt hours per month; 1¾ cents per kilowatt hour for 10,000 kilowatt hours per month; 1½ cents per kilowatt hour for 20,000 kilowatt hours per month. For amounts between those named above, charge will be made at rate given for next larger amount. Demand charge: Where unit consumption exceeds 2,000 kilowatt hours per month a monthly charge of $1 per kilowatt demand will be made in addition to unit charge as named above.

Determination of demand.—Where installation does not exceed 15 kilowatts the maximum monthly demand will be the actual installed demand. Where installation exceeds 15 kilowatts the maximum monthly demand will be determined by maximum demand meters.

Prompt payment discount.—Five per cent if paid on or before the 10th day of each month.

Minimum charge.—One dollar per month per kilowatt demand, provided that in no case an amount will be charged less than $2.

Terms and conditions.—A cash deposit of $10 will be required with each service application when the customer is not a property owner or when monthly service charges are not guaranteed by a responsible party.

RESERVE OR BREAKDOWN SERVICE.

Rate.—In accordance with previous schedules herein named as conditions and requirements of consumers may demand.

Minimum charge.—One dollar per month per kilowatt of installed demand.

Terms and conditions.—Same as for general power service.

SOUTHERN CALIFORNIA.—The Southern California Edison Co. has filed with the California Railroad Commission a new schedule for electric lighting service which applies in Los Angeles, Riverside, San Bernardino, and Orange Counties, except in the cities of Los Angeles and Pasadena. This schedule becomes effective March 1, 1914.

Rate.—Seven cents per kilowatt hour for the first 100 kilowatt hours per month; 6½ cents per kilowatt hour for the next 200 kilowatt hours per month; 6 cents per kilowatt hour for the next 200 kilowatt hours per month; 5½ cents per kilowatt hour for the next 500 kilowatt hours per month; 5 cents per kilowatt hour for the next 1,000 kilowatt hours per month; 4 cents per kilowatt hour for the next 1,000 kilowatt hours per month; 3 cents per kilowatt hour for the next 2,000 kilowatt hours per month; 2½ cents per kilowatt hour for all over 5,000 kilowatt hours per month.

Minimum charge.—One dollar per month.

Lamp renewals.—Free renewals of Gem metalized filament lamps of 8-candlepower and over.

BRIDGEPORT, CONN. (population 102,054).—The United Illuminating Co. now charges the following rates for electric light and power:

LIGHTING RATES.

Rate.—Eight cents per kilowatt hour.

Quantity discounts.—Five per cent less for 400 kilowatt hours or more per month; 10 per cent less for 600 kilowatt hours or more per month; 15 per cent less for 800 kilowatt hours or more per month; 20 per cent less for 1,600 kilowatt hours or more per month; 25 per cent less for 2,400 kilowatt hours or more per month; 30 per cent less for 3,200 kilowatt hours or more per month; 35 per cent less for 4,000 kilowatt hours or more per month.

Minimum charge.—Twelve dollars per year per meter.

Lamp renewals.—The above rate includes free renewal of standard Gem metalized filament lamps.

POWER RATES.

Rate.—Six cents per horsepower hour for less than 50 horsepower hours per month; 5 cents per horsepower hour for 50 horsepower hours or more per month 4.5 cents for 100 or more; 4.25 cents for 200 or more; 4 cents for 400 or more; 3.75 cents for 600 or more; 3.5 cents for 800 or more; 3.3 cents for 1,200 or more; 3.1 cents for 1,600 or more; 2.9 for 2,400 or more; 2.7 cents for 3,600 or more; 2.5 cents for 4,800 or more; 2.3 cents for 6,000 or more; 2.1 cents for 8,000 or more; 1.9 cents for 10,000 or more; 1.8 cents for 15,000 or more; 1.7 cents for 20,000 or more; 1.6 cents for 30,000 or more; and 1.5 cents per horsepower hour for 40,000 horsepower hours or more per month.

Minimum charge.—One dollar per month for ½ horsepower installed, $1.50 per month for 1 horsepower installed, $2 per month for 2 horsepower installed, $2.50 per month for 3 horsepower installed, $3 per month for 4 horsepower installed, $4 per month for 5 horsepower installed, $4 per month for 7½ horsepower installed, $5 per month for 10 horsepower installed, 50 cents per horsepower per month for all over 10 horsepower installed.

IDAHO.—The Utah Power & Light Co. has put into effect in its Idaho territory the following schedule, effective March 1, 1914:

LIGHTING—METER RATE.

Rate.—Ten cents per kilowatt hour for the first 60 hours' use per month of customer's demand, 7 cents per kilowatt hour for all additional hours' use per month of customer's demand.

Determination of demand.—Customer's demand in the above shall be calculated as a percentage of the connected lighting load in accordance with the following classification:

Class 1: Any customer with less than five interior lights; also sign and outline lighting, displays, windows, hallways, and public lights of buildings (these are figured separately from the balance of the installation), 100 per cent.

Class 2: Art stores, banks, barber shops, bakeries, book stores, bowling alleys, cafés, cigar stores, clothing stores, clubs, coffee and tea stores, commission houses, confectionery stores, dance halls, department stores, dressmaking and millinery stores, drug stores, dry goods stores, florists, furniture stores, furnishings stores, groceries, hardware stores, hat stores, hotels and rooming houses, lodge halls, meat markets, moving-picture theaters, photographers' studios, public halls, railroad business, restaurants, saloons, shoe-shining parlors, shoe stores, telegraph and telephone business, theaters, wholesale liquor and wine stores, general stores, 85 per cent.

Class 3: Apartment houses, automobile stores and garages, bicycle and electrical shops, breweries, business offices, churches, cleaning and dyeing shops, engraving and printing shops, express companies, hospitals, jewelry stores, laundries, livery stables and barns, loan offices, manufactories, machine, carpenter and blacksmith shops, music and piano stores, paint shops, pool and billiard halls, public buildings, publishing establishments, residences, schools, tailor shops, undertakers' establishments, warehouses, wholesale houses, 70 per cent.

Prompt payment discount.—A discount of 10 per cent on all metered bills for retail lighting and retail power service will be given, provided such bills are paid in full on or before 10 days from date rendered; and provided further that no previous bills remain unpaid. Failure to receive bills will not entitle the customer to discount.

Minimum charge.—A minimum monthly charge of $1 net shall apply.

Terms and conditions.—The company will furnish the necessary meters which will be maintained by and remain the property of the company. Any meter registering within 2 per cent either way from normal is to be considered satisfactory. If the company's measuring instruments shall fail to register, the account for the period during which stoppage occurred, shall be made up and settled on the basis of previous days of like use. Property owners will ordinarily not be required to make any meter deposits covering electrical service to property owned and occupied by them. Customers occupying rented premises, even though they may own other property, will be required to pay a deposit covering the furnishings of electric service to the premises occupied, on the basis of an estimated 60 days' bill; it being understood, however, that for residential customers said deposit shall in no case be less than $2.50 nor greater than $5. The company will pay interest on meter deposits at the rate of 8 per cent per annum.

HEATING AND COOKING—METER RATE.

This schedule is for alternating current service supplied at 110, 220, or 440 volts, for heating and cooking purposes only, and measured by a separate meter.

Rate.—Four cents per kilowatt hour for the first 50 kilowatt hours of monthly consumption, 3 cents per kilowatt hour for all additional kilowatt hours of monthly consumption.

Prompt payment discount.—A discount of 10 per cent on all metered bills for retail lighting and retail power service will be given, provided such bills are paid in full on or before 10 days from date rendered; and provided further that no previous bills remain unpaid. Failure to receive bills will not entitle customer to discount.

Minimum charge.—A minimum monthly charge of $2 net shall apply.

Terms and conditions.—Same as in lighting, meter rate.

RETAIL POWER—METER RATE.

This schedule is for alternating current service supplied for power purposes only (including irrigation), for installations aggregating 50 horsepower or less, and measured by a single meter.

Rate.—For delivery at 110, 220, or 440 volts: Five cents per kilowatt hour for the first 60 hours' use per month of customer's connected load, 3 cents per kilowatt hour for all additional hours' use per month of customer's connected load.

For delivery at 2,300, 4,000, 6,600, or 11,000 volts: Four cents per kilowatt hour for the first 60 hours' use per month of customer's connected load, 2 cents per kilowatt hour for all additional hours' use per month of customer's connected load.

Prompt payment discount.—A discount of 10 per cent on all metered bills for retail lighting and retail power service will be given, provided such bills are paid in full on or before 10 days from date rendered, and provided further that no previous bills remain unpaid. Failure to receive bills will not entitle the customer to discount.

Minimum charge.—A minimum monthly charge of $1 net per horsepower of connected load shall apply.

Terms and conditions.—Same as in lighting, meter rate.

IRRIGATION POWER—FLAT RATE.

This schedule is for alternating current service supplied for irrigation power purposes only, for installations aggregating 50 horsepower or less.

Rate.—For delivery at 110, 220, or 440 volts: Five dollars per month per horsepower of customer's connected load.

For delivery at 2,300, 4,000, 6,600, or 11,000 volts: Four dollars and fifty cents per month per horsepower of customer's connected load.

Prompt payment discount.—A discount of 10 per cent on all metered bills for retail lighting and retail power service will be given, provided such bills are paid in full on or before 10 days from date rendered; and provided further, that no previous bills shall remain unpaid. Failure to receive bills will not entitle customers to receive discount.

Term.—Charges shall continue as long as customer's apparatus is connected to company's line or until company receives written notice to disconnect. This schedule is for a minimum period of three consecutive months per season.

Terms and conditions.—Same as in lighting, meter rate.

WHOLESALE POWER—METER RATE.

This schedule is for alternating current service supplied for power purposes only (including irrigation) for installations aggregating more than 50 horsepower and measured by a single meter of each kind needed.

Rate.—For delivery at 110, 220, or 440 volts: Demand charge, $1.33⅓ per month per kilowatt of customer's demand; energy charge, 1.8 cents per kilowatt hour.

For delivery at 2,300, 4,000, 6,600, or 11,000 volts: Demand charge, $1.33⅓ per month per kilowatt of customer's demand; energy charge, 1.5 cents per kilowatt hour.

For delivery at 44,000 volts: Demand charge, $1.33⅓ per month per kilowatt of customer's demand; energy charge, 1.3 cents per kilowatt hour.

Determination of demand.—Customer's demand in the above shall be determined by periodic tests, or by suitable permanent meters, or in any other mutually satisfactory manner.

Discounts.—The following quantity discounts on the total monthly bill shall apply: First $400 or fractional part thereof, net; next $400 or fractional part thereof, 15 per cent; next $400 or fractional part thereof, 30 per cent; all in excess of $1,200, 45 per cent.

Minimum charge.—A minimum monthly charge of $1 net per horsepower of connected load shall apply.

BROOKLYN, N. Y.—The Flatbush Gas Co., Borough of Brooklyn (Twenty-ninth ward only), Greater New York, has been granted special permission by the New York Public Service Commision (first district) to put into effect seven days after publication a supplement to its schedule of rates for power purposes. In its application the company stated that it had a request from an ice manufacturer for the supply of electric current for power purposes in quantities so large that it was necessary to extend the old scale of discounts to make a rate for the prospective consumer. The present rate is:

Rate.—Twelve cents per kilowatt hour for first 800 kilowatt hours per month; 10 cents per kilowatt hour for from 800 to 1,200 kilowatt hours per month; 8 cents per kilowatt hour for from 1,200 to 2,000 kilowatt hours per month; 7 cents per kilowatt hour for excess over 2,000 kilowatt hours per month.

Discounts.—On monthly bills for 100 horsepower hours and over (less than 200), 20 per cent; 200 horsepower hours and over (less than 400), 25 per cent; 400 horsepower hours and over (less than 600), 30 per cent; 600 horsepower hours and over (less than 800), 35 per cent; 800 horsepower hours and over (less than 1,000), 40 per cent; 1,000 horsepower hours and over (less than 1,500), 45 per cent; 1,500 horsepower hours and over (less than 5,000), 50 per cent; 5,000 horsepower hours and over (less than 10,000), 55 per cent; 10,000 horsepower hours and over (less than 15,000), 60 per cent; 15,000 horsepower hours and over (less than 20,000), 65 per cent; 20,000 horsepower hours and over (less than 25,000), 70 per cent; 25,000 horsepower hours and over (less than 35,000), 75 per cent; 35,000 horsepower hours and over (less than 55,000), 80 per cent; 55,000 horsepower hours and over (less than 80,000), 81¼ per cent; 80,000 horsepower hours and over, 83⅓ per cent.

These discounts were already in use up to 55 per cent on monthly consumption of 5,000 horsepower hours and over. The new supplement authorized by the commission extends the sliding scale of discounts up to 83⅓ per cent, as above.

NEW GLARUS, WIS.—Application of the New Glarus (population 708) Municipal Electric Light & Water Plant for authority to increase its rates. Decision of the Wisconsin Railroad Commission, increasing the rates, November 22, 1912. Application was made for permission to increase electric rates on the ground that the rate then in effect, which was a flat one of 8 cents per kilowatt hour, did not meet expenses. The commission made a valuation of the property and an analysis of the revenues and expenditures, also a careful apportionment as between the electric and water plants and between the different departments of electric service. All free service was ordered to be discontinued, and the following rates were established:

COMMERCIAL LIGHTING.

Rate.—Customer charge: Twenty-five cents per meter per month.

Energy charge: Eleven cents per kilowatt hour.

Prompt payment discount.—One cent per kilowatt hour for payment within 15 days.

COMMERCIAL POWER.

Demand charge.—One dollar per rated horsepower per month.

Prompt payment discount.—Twenty-five cents per rated horsepower for payment within 15 days.

Energy charge.—Six cents net per kilowatt hour for first 30 hours use of connected load per month, 4 cents net per kilowatt hour for excess over 30 hours use of connected load per month.

STREET LIGHTING.

Rate, to be credited to plant.—Fifty dollars per 640-watt arc per year, $25 per 250-watt tungsten lamp per year. (Moonlight schedule till 11 p. m., 1,100 hours annually.)

HARTFORD, CONN.—The schedule of the Hartford Electric Light Co., effective December 1, 1912, comprises a residence rate that is not available for business purposes, a cooking rate not available for power, and a power rate not available for cooking.

RESIDENCE LIGHTING.

Available for all consumers using the company's standard service.

Rate.—Nine cents per kilowatt hour.

Prompt payment discount.—Five per cent when bills are paid on or before 10 days after their respective dates.

Minimum charge.—None.

Lamp renewals.—The rate given above includes the renewal of standard metallized filament lamps and tungsten lamps of 250 watts and over, when burned-out lamps are returned unbroken.

Standard riders.—None given.

Term of contract.—None given.

Terms and conditions.—See contract form.

SCHEDULE A—RESIDENCE LIGHTING.

1. On meter.—Current for residence lighting will be furnished to customers signing contract embodying the company's terms and conditions at the rate of 9 cents per kilowatt hour, less 5 per cent for 10 days' cash payment.

2. Flat rate.—Customers may, at their option, sign a flat-rate contract for not less than one year for low-voltage tungsten lighting under the following schedule: Ten-candlepower lamps, $1 per month; each additional 10-candlepower lamp, 6 cents per month, less 5 per cent for 10 days' cash payment. Ten to 20 candlepower lamps, $1.50 per month; each additional 20-candlepower lamp, 12 cents per month, less 5 per cent for 10 days' cash payment.

SCHEDULE B—WHOLESALE LIGHTING.

On meter.—Current for commercial lighting will be furnished customers signing contract embodying company's terms and conditions according to the following schedule:

Monthly consumption.—For the first 500 kilowatt hours, 9 cents per kilowatt hour; for any part of next 1,000 kilowatt hours, 7 cents per kilowatt hour; for any part of next 2,500 kilowatt hours, 4 cents per kilowatt hour; for any part of next 6,000 kilowatt hours, 3½ cents per kilowatt hour; for all excess, 2½ cents per kilowatt hour.

Under this contract the following discounts from the gross bill for long-burning hours will be allowed: Thirty-five per cent for over 350 hours' use of installed load per month, 30 per cent for over 280 hours' use of installed load per month, 25 per cent for over 230 hours' use of installed load per month, 20 per cent for over 195 hours' use of installed load per month, 15 per cent for over 165 hours' use of installed load per month, 10 per cent for over 140 hours' use of installed load per month, 5 per cent for over 115 hours' use of installed load per month, 2 per cent for over 100 hours' use of installed load per month.

A further discount of 5 per cent for 10 days' cash payment will also be allowed.

Flat rate.—Flat-rate contract, based upon meter schedule and subject to revision at the expiration of one year, will be given to customers desiring to contract for a definite number of hours' use of installed load. This rate will include lamp renewals up to a normal amount for the contracted hours of burning.

SCHEDULE C—POWER.

Current for wholesale power purposes will be furnished to regular users of power upon signing contract embodying the company's terms and conditions according to the following schedule:

Monthly consumption.—For the first 500 kilowatt hours, 4½ cents per kilowatt hour; for any part of next 1,000 kilowatt hours, 3½ cents per kilowatt hour; for any part of next 3,500 kilowatt hours, 2¾ cents per kilowatt hour; for any part of next 65,000 kilowatt hours, 1½ cents per kilowatt hour; for all excess, 1⅓ cents per kilowatt hour.

These rates are for power only. Energy used directly or indirectly for lighting purposes must be metered separately, and billed at lighting rates, except that for any month when the energy used for power exceeds 90 per cent of the total the amount of energy used for lighting will be included with that for power, and the total billed at power rates.

SCHEDULE D—NIGHT POWER.

[Current used for power at night.]

In order to encourage the use of power at night any customer contracting for energy under either the power or cooking schedule, upon a guaranty of a minimum payment of $20 per month, for their night power, will be allowed a discount of 40 per cent on such a fraction of their total power as is used between the hours of 10 p. m. and 7 a. m. The company will install special meters for recording this power without charge, provided the demand for such night power amounts to at least 10 per cent of the total.

SCHEDULE E—COOKING.

The company will furnish energy for operating cooking and heating apparatus to customers signing contract embodying the company's terms and conditions at the rate of 3 cents per kilowatt-hour on a guaranteed minimum payment of $1 per month. This schedule may be used in residences to include such other household appliances as flatirons, cleaners, etc., as may be desired, in addition to the cooking apparatus contracted for.

SCHEDULE F—AUXILIARY SERVICE.

The company will maintain a service for supplying electric current as a reserve, auxiliary, or breakdown to a private generating plant, provided the customer guarantees a minimum monthly payment for this service of $3 per kilowatt per month for the first 25 kilowatts contracted for; $2 per kilowatt per month for the next 75 kilowatts contracted for; $1.50 per kilowatt per month for the next 100 kilowatts contracted for. Current will be delivered at customer's switchboard and billed monthly according to regular light or power schedules, subject to above minimum monthly payments. No lamp renewals are supplied under this schedule.

SCHEDULE G—SPECIAL APPLICATIONS.

In order to encourage novel uses of electric current, the company is prepared to investigate any proposed installations, and to quote low experimental rates thereon, subject to revision at the expiration of one year's contract.

MARQUETTE, MICH. (population 11,503).—Light and Power Commission. This is a large water-power plant, the full power available being greater than all present uses. The following new schedule of rates was put into effect March 1, 1913:

LIGHTING RATES.

Rate.—Five cents per kilowatt hour for first 200 kilowatt hours per month; 4 cents per kilowatt hour for next 100 kilowatt hours per month; 3 cents per kilowatt hour for next 100 kilowatt hours per month; 2 cents per kilowatt hour for excess over 400 kilowatt hours per month.

POWER RATES.

Rate.—Three cents per kilowatt hour for first 200 kilowatt hours per month; 2 cents per kilowatt hour for next 200 kilowatt hours per month; 1 cent per kilowatt hour for excess over 400 kilowatt hours per month.

STREET LIGHTING.

Rate.—Sixty dollars per year per 7.5-ampere inclosed arc lamp (all night schedule).

MARSHALL, MICH.—Electric and Water Works Department. The present electric rates are:

RESIDENCE LIGHTING.

Rate.—Five cents per kilowatt hour.
Prompt payment discount.—Ten per cent if paid within 16 days
Minimum charge.—Fifty cents per month.

COMMERCIAL LIGHTING.

Rate.—Four cents per kilowatt hour.
Prompt payment discount.—Ten per cent if paid within 16 days.
Minimum charge.—Fifty cents per month.

STREET LIGHTING.

Thirty-five dollars per 6.6-ampere arc light per year, $10 per tungsten light (average 68 watts), (all-night schedule).