

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, February 27th, 1895.

The 94th meeting of the INSTITUTE was held this date at 12 West 31st Street, and was called to order at 8 p. m. by President Houston.

THE PRESIDENT :—In the absence of Mr. Pope, our Secretary, who is unfortunately ill, Prof. Crocker has kindly offered to act as Secretary. The Secretary will please read the minutes of the last meeting.

Prof. Crocker read the minutes of the last meeting, and on motion they were adopted. He also read the following list of associate members elected and transferred at the council meeting in the afternoon.

Name.	Address.	Endorsed by
ANSON, FRANKLIN ROBERT	Manager, Salem Consolidated Street Railway Co., Salem, Ore.	F. L. Dame. P. S. Malcolm. W. C. Cheney.
CUMNER, ARTHUR B.	Senior Member, firm of Cumner, Craig & Co, 69 Broad Street, Boston, Mass.	S. S. Wheeler. F. B. Crocker. Geo. M. Phelps.
LECONTE, JOSEPH NISBET	Instructor in Electrical Engineering, State University, Berkeley, Cal.	C. L. Cory. F. F. Barbour. W. Meredith.
LOEWENHERZ, HERMANN	Mechanical Engineer, Met. Tel. and Tel. Co., 18 Cortlandt St., New York City; residence, 311 Hudson St., Hoboken, N. J.	Jos. Wetzler. Jno. J. Carty. T. C. Martin.
MACCULLOCH, ROBERT C.	Manager, Jos. Lough Electric Co., 503 Fifth Ave.; residence, 482 J. Lexington Ave., New York City.	H. W. Weller. G. Kirkegaard. R. W. Pope.
MAYER, MAXWELL M.	Manufacturer of Dynamos and Motors, 411 107th St., E. R.; residence, 242 E. 114th St., New York City.	A. L. Riker. O. P. Loomis. Jos. Wetzler.
NYHAN, J. T.	Superintendent and Electrician, Macon and Indian Spring Electric Railway, Macon, Ga.	W. F. D. Crane. Edw. Caldwell. R. W. Pope.
PADDOCK, B. C., JR.	Assistant in Generating Dept., Edison Elec. Illuminating Co. of Boston; residence, Brookline, Mass.	F. A. Pattison. Henry Floy. F. W. Erickson.

PRINCE, J. LLOYD	Engineer, 868 Flatbush Ave., Flatbush, N. Y.	F. B. Crocker. Max Osterberg. W. H. Freedman.
REDMAN, GEO. A.	General Supt., Electric Dept., Brush Elec. Light Co., and Rochester Gas and Elec. Co., Rochester, N. Y.	F. A. Scheffler T. C. Martin. H. A. Foster.
SWENSON, BERNARD VICTOR	Instructor in Electrical Engineer- ing, University of Illinois, Cham- paign, Ill.	D. W. Shea. Sam'l Sheldon. Townsend Wolcott.
Total 11.		

TRANSFERRED FROM ASSOCIATE TO FULL MEMBERSHIP.

Approved by Board of Examiners, December 17, 1894.

CROSBY, JAMES WELLINGTON	Electrical Engineer, Hix, Crosby & Co., New York City.
HIX, E. RANDOLPH	Firm of Hix, Crosby & Co., New York City.
BILLBERG, C. O. C.	Electrical Engineer, 3200 Arch St., Philadelphia, Pa.
CRAIG, JAMES HALLY	Firm of Cumner, Craig & Co., Boston, Mass.
SHAW, EDWIN C.	Manager, Akron General Electric Co., Akron, O.
Total 5.	

Prof. Crocker also stated that the Council had decided to have the general meeting for this year held at Niagara Falls on Tuesday, June 18th, and had also changed a rule of the Council so that in the future ten gentlemen may be transferred from associate to full membership at any one meeting, instead of five. Heretofore the limit had been five, which necessitated keeping applicants on the list for a long time, and this change was thought necessary in view of the growth of the INSTITUTE.

THE PRESIDENT:—If there is no business which the INSTITUTE wishes to transact at this time, we will proceed to the paper of the evening, "Notes on Recent Electrical Engineering Development in France and England." It is not necessary to introduce to you Mr. H. Ward Leonard, who is so well known by all of us.

Mr. Leonard read the following paper.

NOTES ON RECENT ELECTRICAL ENGINEERING DEVELOPMENTS IN FRANCE AND ENGLAND.

BY H. WARD LEONARD.

INTRODUCTION.

As a result of inspecting some of the most interesting of the developments in the field of electrical engineering during a recent trip to France and England, and as a result also of having met many of the engineers responsible for these recent developments, I find it difficult to reach a conclusion as to whether we, or our contemporaries across the water are ahead in the electrical engineering race.

Of course when one attempts to compare the electric developments of the respective countries commercially, we are in the same position as the "America" was in the historic yacht race, "there is no second;" but considering the recent electrical development from an engineering standpoint we are rapidly losing the lead we have thus far held.

Although I have always felt that so-called fundamental patents and the resulting enormous aggregations of capital and engineering talent under one management, were a millstone around the neck of our profession, I have never before had the opportunity of seeing positive and unmistakable evidence of it such as this visit abroad showed me.

In the beginning of electric lighting, both arc and incandescent, we led the world from an engineering standpoint, and were years ahead of any other country. But what has been done in this country in the way of a remarkable electrical engineering development since Edison started his first three-wire system at Sunbury, Pa., in July, 1883, and Westinghouse established his alter-

nating system with 1,000-volt primary and 50-volt secondary a few years later, and Sprague started the Richmond electric road? A moment's thought will, I think, make you all realize that the practical development of electrical engineering improvements is almost impossible against the opposition of the gigantic corporations in that field, and that corporations having such a large portion of their capital represented by patents will not wish to see the practical trial of a promising improvement which they do not control, and which may depreciate the value of the methods they control or claim to control. It is in just this way that we are losing ground when compared with England and France.

We undoubtedly have the best three-wire central station plants in the world, also the best alternating system converting from 1,000 to 50 volts. But what other kind of central stations have we to point to? Practically none.

We have 500-volt continuous current electric railways galore, and we operate such railways at distances for which 2,000 volts should be used instead of 500, and after investing more money in copper per car than the entire cost of the electrical equipment, we still lose twice as much energy as is commercial in the line.

Is there a large electric railway system in this country which as an electrical transmission of power is a credit to our profession? Not one.

In France, and even more in England, one is forcibly impressed by the many kinds of central stations being tried. Many of them may seem almost sure to prove commercially unsuccessful, but who can say which one may not prove the "Sunbury" of an enormous electrical engineering development?

No capital or patents can prevent the slow development of evolution, but I fear that under the existing conditions we shall have to content ourselves with drawing pictures of what might be done, and watch the continued introduction of the three-wire system of 1883, the 1,000 to 50-volt alternating system of about 1887 and the continuous current 500-volt railway system of 1887, while our engineering friends abroad keep trying not only their own ideas, but the ideas of many of us from this side because they have the necessary encouragement and opportunity to do so, while we have not.

I have learned on this hurried trip abroad of many applications of inventions of American engineers which have proven very

successful and which although patented, described and advertised in this country, were taken up first by English or French engineers notwithstanding their well known prejudice against American inventions.

ALTERNATING CURRENT PRACTICE.

In England one of the first things which impresses an engineer is the total absence practically of a 50-volt secondary for alternating systems. It is the general practice in England of late to use a three-wire secondary with 100 volts on each side. I believe that every engineer who has ever given the subject a thought, knows that there was no excuse except patents for a 50-volt two-wire secondary originally, and no excuse except the inertia and prejudice of large corporations for continuing to put in the two-wire 50-volt secondary to-day.

MANUFACTURING AND ENGINEERING.

In England there is a multitude of medium size concerns, manufacturing electrical apparatus, and the competition is mainly on ideas, and not the cost of dynamos per kilowatt. It is surprising to find that generators and motors are much cheaper in the United States than in either England or France, notwithstanding their advantages over us as to cheaper raw materials and labor.

The manufacturers abroad generally consider the consulting electrical engineers as entirely unnecessary in view of the multiplicity of schemes which every plant brings forth from the various manufacturers, but I believe that a great deal of benefit has been and is being accomplished in England, by virtue of the custom of placing in the hands of good consulting electrical engineers the design, for instance, of a large central station plant to be built by a city itself.

Has a central station of this kind ever been built in this country? I think not; that is, a central station built according to advice from a good consulting engineer who was free to select the good features, and eliminate the bad features of the various systems known to the art. Imagine a central station combining apparatus and methods of the General Electric, Westinghouse, and Siemens and Halske all in one system, also taking advantage of other good ideas from the United States and abroad. Who can doubt that it would be better than could be built by using only the patents and apparatus controlled by some one company.

Many will answer that all the best engineers are in the employ of the leading companies, and the consulting engineers available are incompetent commercially, and there is a great deal of force in this argument; but even if true, it certainly merely emphasizes the difficulty of getting a practical trial in this country of promising ideas in the electrical field unless they be controlled by one of the would-be-monopolists.

ROTARY TRANSFORMERS.

Rotary transformers are used in several stations in England for a continuous current high potential multiple arc distribution, the secondary being a three-wire system as usual. Such a plant is in use at Oxford. At Brighton and several other places the standard 220-volt continuous current three-wire system is supplemented for distant lighting and in newly occupied territory by the alternating system using about 2,000 volts in the primary, and a 220-volt three-wire secondary.

This alternating plant supplies the distant and scattered lighting during the period of heavy load, and during the period of light load (about three-quarters of the whole time) this distant lighting is supplied directly from the 220-volt three-wire system by switching the secondary circuit from the converter to the regular three-wire system.

Mr. Arthur J. Wright who installed this system first at Brighton, spoke of it to me as an American invention not patented in England, a description of which he had read in the American electrical journals, and was much surprised to learn that none of the central station companies had made use of it in the United States, as it was proving of the greatest value to him in his plant.

STEAM ENGINES.

I believe we are ahead of England and France in the designing of dynamos and engines. Their workmanship leaves nothing to be desired, but giving consideration to amount of material used, efficiency and design, I think we are in advance of them.

One of the most surprising things to me was to see the almost universal use of engines which we would consider had practically no governor. That is, engines using slow acting throttling governors instead of the triumphs of engineering skill which are so common in this country. Not since 1883 have I seen such

poor governors as I found generally used abroad in the finest and most recent stations, and upon engines which are almost perfection itself as regards manufacture.

THE PARSONS STEAM TURBINE.

The Parsons steam turbine was one of the most interesting things I saw in England. These steam turbines are direct coupled to dynamos, and in sizes of 350 k. w. revolve at 3,000 revolutions per minute, and of course run at higher speed in smaller sizes. The space occupied by a 350 k. w. outfit is over all about twenty-five feet long, five feet wide and including governor about seven feet high. These turbine plants when running at these high speeds are entirely free from vibration and are not even bolted down, but are supported by three pedestals, one near each end and one at the middle. There are some seven or eight bearings all in line, and a continuous stream of oil is forced through the bearings by a small pump driven by a worm on the main shaft.

The bearings used are extremely simple and very ingenious. The shaft runs in a gun-metal sleeve of about the usual dimensions, but between this sleeve and the surface of the pillow block are three cylinders of thin sheet brass concentric with the shaft, and sliding loosely over the gun-metal sleeve. The gun-metal sleeve is prevented from turning by a lug projecting down at one end into a hole in the pillow-block. The entire box being filled with oil, it will be seen that the shaft is free to vibrate slightly in every direction as it revolves, and that the viscosity of the oil tends to damp any such vibration. The three thin surrounding sleeves are perforated by a hole of about $\frac{1}{8}$ inch at about every two inches, so that the oil can work freely between these sleeves. The Parsons steam turbine uses the steam expansively as a reciprocating engine does. The steam at about 125 lbs., and preferably superheated, is led into the center of a cylindrical chamber in which the moving parts revolve. There are three of these chambers. In the first chamber the steam is expanded down partially, and thence goes to a second similar chamber and finally to a third one, which last chamber leads to the condenser. In each of these chambers the steam in its passage from the admission to the exhaust has to pass some thousands of small blades or teeth which project from the surface of the disks a fraction of an inch. The amount of steam used and its expansion, will de-

pend upon the clearance, and the number of these turbine disks it has to pass in getting to its exhaust. It will be evident that the friction of the engine is less than that of a reciprocating engine, and that the condensation losses should be less. Also full advantage can be taken of high pressure and especially of superheated steam, for the difficulties of proper lubrication and packing in the presence of high temperature steam in a reciprocating engine do not apply to this engine.

Tests by Professors Ewing and Kennedy indicate that this turbine when in perfect condition has an efficiency of one k.w. hour in electrical energy produced by 28 lbs. of feed water, the turbine being operated condensing. This is equivalent to about 15.7 pounds of water per indicated horse-power per hour, and I understood that in a recent competition, a guarantee was made by Mr. Parsons which was equivalent to about 13 pounds per indicated horse-power per hour, and that his guarantee was lower than that of the best triple compound condensing engines of the reciprocating type which were in the competition. At Newcastle-on-Tyne I saw a central station of about 25,000 lights operated solely by these steam turbines, and which has been in operation since 1890 and has been earning and declaring dividends ever since it started. An interesting fact as to this Newcastle station is that all of the conductors are laid underground and consist of vulcanized rubber cables drawn into cast-iron pipes which are gas and water tight, and through which chemically dried air is forced from the station by a blower.

There are over six miles of piping and over 25 miles of cable, and after five years operation Mr. Parsons states that they have not had a single instance of failure of insulation, explosion or other trouble with the underground system.

THE LAVAL STEAM TURBINE

Before leaving the subject of steam turbines, I will describe the Laval steam turbine of which I saw a number in the works of the manufacturers, Breguet & Co. of Paris. This steam turbine differs radically from the Parsons. The power is derived from the momentum of a jet of steam impinging upon buckets near the periphery of a disk, so that the machine is somewhat comparable to the Pelton water wheel. The steam, which is preferably used at a high pressure and exhausting into a vacuum, is expanded in a nozzle before reaching the disk, and reaches the buckets of

the disk fully expanded, and hence moving at a very high velocity which the inventor claims is 3000 feet per second for steam at 85 lbs. per square inch, exhausting into the air, and 3700 feet exhausting into vacuum. The nozzle makes a very slight angle with the plane of the disk. The admission of steam is controlled by a centrifugal throttling governor. The number of revolutions of the disk per minute varies from about 30,000 to 15,000 in sizes from 5 to 50 horse power. The buckets are milled out of a solid disk of steel just inside of the periphery, so as to leave a solid band on the circumference. The edges of the buckets are quite sharp. The disk in the case of a 50-horse power turbine is about $\frac{1}{2}$ in. thick. This disk is mounted on a small steel flexible shaft at a point about $\frac{1}{3}$ from one end. At the high speeds in question, a body tends to revolve about an axis through the center of gravity, and since it is impracticable to make the center of gravity absolutely coincident with a straight line joining the bearings, Mr. Laval has used a flexible shaft so that the disk is free to assume such a position as to revolve practically around an axis, through the center of gravity, and consequently the disk revolves with perfect smoothness and without any trouble at the bearings at these enormous speeds.

No successful way has been perfected as yet for operating a dynamo directly at these speeds, and so Mr. Laval gears from his turbine shaft to two dynamo shafts, one on each side of the turbine shaft, by means of double helical gears beautifully cut, which reduce 10 to 1, and upon these two driven shafts are placed the dynamo armatures, two driven shafts being used so as to balance the side thrust on the bearing of the turbine shaft. The Laval people claim as high efficiency as that of any steam engine of the same horse-power, and there seems no good reason to doubt their ability to secure such an efficiency which they guarantee fully and specifically.

A careful test made at Stockholm in 1893, showed an efficiency of 20 pounds of water per horse-power hour with steam at 113 pounds initial pressure and used condensing. The weight of this turbine is about 30 pounds per horse-power in a size of about 30 horse-power.

The simplicity of this steam engine, also its theory and practical design in detail are most beautiful, and it seems likely to become an important factor in the electrical field. What is needed is a generator of electricity directly driven by, or preferably con-

stituting a part of, the revolving disk, and here is food for considerable thought.

FIVE-WIRE SYSTEM.

At Manchester I saw the five-wire plant designed by Dr. Hopkinson and recently installed. I inspected the central station for a few minutes only, as unfortunately those most familiar with the principal features of the system were absent at the time of my visit. The dynamos were bipolar machines driven from vertical engines by means of link belts with idlers. I cannot say that I was favorably impressed with the generating plans or distribution system, as far as I could judge of them in such a brief observation.

LIVERPOOL ELECTRIC RAILWAY.

At Liverpool I investigated the overhead electric railway. The overhead structure, the motors, methods of collecting the current, etc., were exceedingly well designed and constructed, and gave evidence of good working. The central station apparatus and design was not, however, up to the standard of work here in recent electric railways.

The series parallel control is used, but no rheostat, the designer seeming to realize that it might just as well be left out, and the equivalent resistance secured in the windings of the motors themselves, with less apparatus and no appreciable difference in economy or control.

ENGLISH CENTRAL STATIONS.

In London I visited several central stations of which I will mention two. The first is that of the Metropolitan Electrical Supply Co. This company has an enormous area allotted to it. I will explain right here, that both in London and Paris the authorities follow the plan of granting to several different central station companies—supply companies as they term them—the exclusive right to a certain section of the city. No such company can run into any other company's section. At the central station of the Metropolitan company, I found four Parsons steam turbine units of 350 k.w. each, running at 3,000 revolutions per minute. These steam turbines had been in operation only a short time when I saw them, and had been installed for the reason that the central station had been enjoined by the courts from operating the reciprocating

engines formerly in use because of the vibration they caused. I was informed that the vibration was particularly troublesome and difficult to overcome, because the central station was built upon made land, above the bed of a former river and that the ground was boggy and transmitted any vibration in the most surprising manner. I inquired as to the working of the steam turbines and was informed that they were not able to detect any difference in their coal consumption compared with the compound condensing reciprocating engines formerly in use. I found that an accident had happened to one of the steam turbines by which it had lost all of the blades in one of the three chambers, which reduced its capacity and efficiency considerably, but did not put it out of service entirely.

The other London central station I shall refer to, is that of the City of London Company. This company supplies the heart of London, that is the old "City of London," which is without doubt the best central station territory in the world, on account of the wealthy nature of the customers, the substantial character of the buildings, and especially because of the peculiarly dismal foggy weather in London. While I was there, artificial light was required almost as much by day as by night. This central station is beautifully located on the south bank of the Thames, near the center of lighting, and is a fine example of the best that can be done to-day with the alternating system under such conditions. I do not believe it would be possible to find less excuse for the use of the alternating system than in this station, and yet I expect it will pay, for it can hardly fail to earn money under such extraordinarily favorable conditions for lighting.

But I need hardly say that they have no motors except toys, and but few of them; and when I remember that in Chicago 40 per cent. of the connecting load is motors and that this percentage is rising all the time, it seems evident that the City of London Co., is terribly handicapped by the use of the alternating current. However, they have a 2,000-volt three-wire secondary, and operate the dynamos all on multiple-arc which is certainly using the alternating current to the best advantage. Aside from the use of the alternating current under these conditions, it is difficult to say anything in criticism of the central station.

The plant is arranged on the panel system, which Mr. Mordey says originated with him, and which is thoroughly carried out in this station, for each panel or section across the building com-

prises an independent unit including a boiler, engine, dynamo, and switchboard for 500 k.w. The engines are vertical and direct-coupled to the Mordey alternators. The switchboards are entirely novel in design, being cast-iron pyramids about ten feet high, standing clear from the wall and having all of the conductors inside, with the instruments, etc., mounted on the front face. While very finely finished and ornamental, I could not but think that the vital parts would be more difficult to inspect and repair in case of emergency, than in our recent switchboard practice.

One detail of electrical construction in which the foreign practice seems very backward is the rheostats. In this magnificent station in the City of London, for instance, and in many other places I saw rheostats made by winding german silver wire on a slab of slate, which was then mounted on insulators horizontally on a table, and a slider arranged to move over the surface of the resistance wire itself, which was thoroughly exposed.

Another detail in which we are certainly in advance of foreign practice is our instrument work, for which we must thank Mr. Weston solely. I saw many fine instruments while abroad, but they seemed to be more suited for a physical laboratory than a central station, the substantial, compact, permanent features of the Weston instrument, with its readable scale and dead beat index were conspicuous to me by their absence.

FRENCH CENTRAL STATIONS.

In France the most interesting central station I saw was in Paris where I visited a sub-station designed for a capacity of 30,000 lights. The sub-station was supplied from a distant central station by means of a constant current of 250 amperes, all devices on this current being in series and the total E. M. F. running as high as 6,000 volts at times.

In the sub-station were rotary transformers, the primary ends of which were series wound motors and all being in series. The secondaries of these rotary transformers as generators, fed a five-wire system of conductors, and in multiple-arc with these generators across the five-wire system, was a bank of storage batteries. The lamps used were 110 volts; some of the rotary transformers had 110-volt secondaries, four of such secondaries being in series so as to make the five-wire system complete independently of the batteries. Other of the rotary transformers had 440-volt

secondaries and fed the outside conductors only. On each rotary transformer was a rheostat which was in multiple with the series wound field and which by a step-by-step movement similar to that of the old U. S. automatic regulator, controlled the strength of the series field so as to keep the E. M. F. in the secondary, constant; the controlling magnet of the automatic being across the secondary of constant E. M. F.

The storage battery plant was well designed and seemed to be in good order. It was as clumsy and seemed as full of troublesome possibilities as those we have on this side of the water. It had capacity for 8,000 10 c. p. lamps for three hours and cost about \$30,000, weighed about 400,000 pounds and occupied a space about 32 x 50 feet. This cost means about \$107 per k.w. of output which seems a pretty high price to pay for a plant to generate electrical energy to-day, especially when it probably has an efficiency at three hours' discharge not above 60 per cent. Such a storage battery must be compared in cost with the cost of boilers, engines and dynamos per kilowatt, which would cost perhaps \$50 per kilowatt, and whose efficiency would be 100 per cent. as compared with the 60 per cent. efficiency of the storage battery, since the storage battery must derive its energy from a steam plant first. The craze for storage batteries as the universal panacea for electrical troubles which we have all read so much about in connection with European practice, seems to be on the wane, if I may judge from the statements of the engineers, rather than the storage battery manufacturers, but when we remember that in France and England they do not know what a healthy motor load means, we need not be surprised at the claims of inefficiency for stations which do not use batteries, and hence run their boiler, engine, and dynamo for most of the 24 hours practically without load.

IMPORTANCE OF THE LOAD FACTOR IN CENTRAL STATIONS.

All central station people have known for years that the most profitable consumers were those who used their lamps for the greatest number of hours.

In other words, that the net profit due to a consumer was largely dependent upon the relation between his average load and his maximum load, which Mr. Crompton in England has aptly called the "load factor." Yet, while appreciating this fact, central station companies make their rates dependent upon the

kilowatt hours used, and independent of the maximum kilowatts used.

Mr. Arthur Wright at Brighton in England, deserves the credit, as far as I know, for having first given commercial recognition to this load factor of the consumer. Mr. Wright supplies each consumer not only with a meter which registers the kilowatt hours used, but also a second meter of simple construction which registers the maximum kilowatts used at any time during the month, and the discount which the consumer gets is very largely due to the relation between his average and his maximum kilowatts.

Suppose that there are two customers connected to a central station and that the monthly readings show that each has used 900 kilowatt hours. By the usual practice in this country the bill would be the same, yet one bill may be due to the use of one and one-quarter kilowatts for 24 hours per day, and for 30 days per month, and the second bill may be due to the use of 30 kilowatts, an average of one hour per day for 30 days per month. That is, the first bill may be due to a steady load, such as a few lamps in a basement of a hotel or a ventilating fan, while the second bill may be due to a larger load of lamps used only occasionally, as in an office building or an electric elevator requiring 30 k.w. for a few seconds to start it up, and after starting requiring only 15 k.w.

With the same 900 k.w. hours per month for the two cases, the central station company should charge at least five times as much for the case having the elevator and small load factor, as in the other case.

It is a fact not generally appreciated that in any central station the cost of producing a kilowatt hour can be divided into two portions, one of which, such as interest on cost, depreciation, salaries, a small part of the labor and coal, vary with the kilowatt capacity of the plant, that is proportionately to the maximum load, and are independent of the number of kilowatt hours produced, and the other portion of the cost of producing 1 k.w. hour represented by the larger portion of the coal, labor, water, etc., is dependent upon the number of kilowatt hours produced, and is independent of the maximum load.

The fact about this matter which is least appreciated is, that the portion of the total cost of 1 k.w. hour produced, which depends upon the maximum load, is about two-thirds of the

total cost, and the part dependent upon the output is only about one-third.

In a modern central station 1 k.w. of its capacity represents about \$300 invested. Consider the two consumers cited above. Both loads are in use at the time of maximum daily load. For the elevator, the central station has to provide an investment of \$9,000, for the ventilating fan \$375. Assuming interest, depreciation and similar charges, at 10 per cent. we have \$900 to deduct from our gross earnings in the elevator case, before we reach net profits, and \$37.50 in the other case.

Suppose we get 10 cents per kilowatt hour in each case, and that the cost of production independent of general expenses, interest depreciation, etc., is 50 per cent. of the gross receipts, etc.

This would mean that if we get 10 cents for each kilowatt hour in both cases, our gross revenue would be \$90 per month in each case, and our gross profit \$45.00 per month, or \$540 per year in each case. But in the elevator case we have interest and depreciation charges of \$900 a year, and hence have actually lost considerable money in supplying this customer, while in the other case we have made a net profit of over \$500 per annum.

We would have to charge more than ten times the rate per kilowatt hour to the elevator, that we charge to the ventilating fan to make the same net profit on \$1.00 of capital invested.

This load factor is a most vital question, and it is the difference in load factors in English and American central stations which makes storage batteries commercially possible there, and impossible here.

The average load factor of an English central station is less than 15 per cent., and even in London in December it is only 33 per cent., while in most American cities the load factor which averages 40 per cent. will in December in many cases be above 50 per cent.

This difference is due almost wholly to our motor load, which is an almost unknown quantity abroad. With a 15 per cent. load factor a storage battery may pay, but not with a load factor of 40 per cent., especially when the load factor in our central stations is rising each year.

If central station companies would offer such a discount due to load factor as to warrant an individual customer in installing at his own expense a storage plant which he would charge at the minimum rate per kilowatt hour by a steady current for twenty-four hours per day, and then used this stored energy to

supply his periodical demands for an occasionally very large rate of energy, I believe it is possible that the central station companies, the storage battery companies and the consumers might all derive a profit from the arrangement. I have no doubt that a central station company could afford to make a rate of four cents per kilowatt hour for a continuous service night and day, and make a satisfactory profit, while it would surely lose money in supplying an elevator, such as described above, even at fifteen cents per kilowatt hour.

I believe that the following schedule of rates fairly represents the charges per kilowatt hour that should be made to customers of various load factors.

Load Factor.	Rate per kw. hour in cents.	Resultant gross in- come per annum per kw. of plant.
5	30	\$131.40
10	20	175.20
15	16	210.24
20	13	227.76
25	11.2	245.28
30	10	262.80
35	9.2	281.07
40	8.5	297.84
50	7	306.60
60	6	315.36
70	5.3	325.00
80	4.8	336.38
90	4.4	346.89
100	4	350.40

It must be noticed that this argument would lose most of its force if the maximum load of the consumer did not occur at the time of day when the maximum load was upon the central station; but in elevators, and similar loads which call for their maximum load in starting up every few seconds, the maximum loads will not only occur together occasionally, but this will sometimes occur at the time of maximum load on the central station, and when this accumulated load is put upon the central station, the kilowatts must be there to meet the demand.

ELECTRIC HEATING.

I saw evidences of a very healthy demand for electrically heated devices while abroad. In London the principal central station company is running at its own expense a show room for the education of the public in this line, and several manufacturers of electric heaters told me the demand was very satisfactory, and promised a good future.

THE HEILMANN LOCOMOTIVE.

In France I examined what I considered the most important electrical engineering development of all that I saw. It was the Heilmann electric locomotive. Having been for some years past a firm believer in the merit of this machine, and having been in correspondence with Mr. Brown, Mr. Heilmann's electrical engineer, as to an invention of mine used in this locomotive for the first time on a large scale, I was especially interested in it, and my hearers will please discount as they may think necessary my description of the advantages of a locomotive using my system of control.

The locomotive I saw was the first one built, and was not in service when I was there. It had run 2200 miles commercially, however, and as a result of the performance of this first locomotive which was 600 H. P., there are now building two locomotives of 1500 H. P. each, which it is expected will go into commercial service about June next.

This electric locomotive carries its own central station with it. It is really a complete central station on wheels, with its power used for propelling itself. Speaking from memory, I should say the length over all was about 50 feet. The locomotive is mounted upon two bogies each having four axles, so that the weight of the locomotive is borne by 16 wheels, each of which is about 45 inches in diameter. A platform made of heavy iron girders runs the whole length of the locomotive, and is supported upon two pivots one at the center of each bogie. Upon this platform is mounted the coal, water, boiler, engine, dynamo, etc., so that it will be noticed every pound of material is used upon the drivers and therefore becomes effective for tractive purposes.

The entire weight of the locomotive is 114 long tons; that is, about 15,500 pounds per driving wheel, which is about the same as our standard practice in this country. With a tractive coefficient of .2 this means a drawbar pull of 50,000 pounds and assuming friction at six pounds per ton, we find that 50,000 drawbar pull would enable us to pull 1900 tons on a one per cent. grade at a low speed, say 15 miles per hour, and would give us ample drawbar pull for handling a 200-ton train at any speed thus far seriously discussed.

Most engineers who have heard of the Heilmann locomotive have derisively dismissed it from their minds as a ridiculous monstrosity of a crazy Frenchman, but I have for some time

believed, and am now convinced, that you will in the immediate future be bound to give this machine the most respectful consideration. I find that the impression prevails generally, that the modern steam locomotive is really a very perfect and efficient machine. This I think is far from being true. The efficiency of a boiler depends largely upon how perfect the combustion is, and with forced draft we can realize an efficiency of 80 per cent. with very perfectly designed boilers, provided we do not attempt to burn more than about 40 pounds of coal per square foot of grate surface per hour. But the maximum duty of boilers in locomotive practice such as for the highest speed service, involves the use of nearly 200 pounds of coal per square foot of grate surface, and I need hardly say that forcing the boiler in this way results in a terrible inefficiency. To produce an indicated horse-power in a steam locomotive at highest speeds to-day probably requires at least twice as much coal as is required in first-class stationary or marine boilers. This is the first place where Mr. Heilmann is able to show an economy; he is able to carry a larger boiler, and hence does not have to crowd it to such a wasteful point.

But regardless of an abundant supply of steam from the boiler we find ourselves greatly limited in power for steam locomotive practice at high speed, because of the wire-drawing of the steam, and difficulty of properly exhausting when we run our locomotive at its highest speed. The maximum drawbar pull obtainable when running at the highest speed, is only about half that obtainable at slow speed, no matter how much steam we have at command, or at what cut-off we work. Heilmann avoids this difficulty as we shall see presently.

Another matter of most serious importance is the tremendously destructive effect upon the roadbed and upon the locomotive itself, of the unbalanced vertical component of the motion of the counter-balance weight of the steam locomotive, and also the shouldering effect of the locomotive tending to spread the rails. Probably at least one-third of the cost of maintenance of the roadbed and the locomotive for high-speed service could be traced directly to this destructive "hammer blow" and side thrust. Both of these effects which become very troublesome as we go to the higher speeds, are entirely absent in the electric locomotive.

Having now pointed out the weaknesses of the steam locomotive which develop most forcibly as we increase in speed, I will

describe the construction of the Heilmann locomotive and point out how those difficulties are obviated by the electric locomotive.

The steam engine is compound, well-balanced, and directly coupled on its shaft is the electric generator. A four-pole single reduction motor of the ironclad type is geared to each of the eight axles, and the motors which are series wound are in multiple with each other across the brushes of the generator armature. As the motor field must have a fair degree of saturation to prevent sparking when the locomotive is running light and pulling no train, it will be evident that under all operating conditions, the motor fields are constant, and fully saturated, which makes them entirely sparkless. The field of the generator is separately excited by means of a small auxiliary engine and constant potential dynamo, which also supplies the electric lights needed. The main engine has a fixed cut-off at the most economical point, say one-quarter stroke and its speed is adjusted by the throttle.

The engine in practice is varied in speed from perhaps 50 to 500 revolutions, and the strength of the generator field from zero to its maximum strength. It will be noticed that all the steam is used expansively at a fixed cut-off, and Mr. Heilmann lays great stress on this, although I myself would prefer an automatic engine running at a constant speed, and I believe that he would, if he could get as good ones abroad as we can in this country. For starting, an almost unlimited torque is secured by gradually increasing the generator field strength and speed, which sends a current through the motors, rising smoothly from zero to that current sufficient to start the motor armature. If we leave the field controller and throttle in this initial position, our train will start smoothly, and will continue to move slowly, using the full current, but producing the current with about 50 volts or one-tenth of the full voltage, and we will be producing this power, about one-tenth of that required at full speed, by a steam engine using steam expansively instead of, as in the steam locomotive, full stroke. But of course we desire to accelerate the train rapidly, so we keep on manipulating the field controller and throttle, until we finally have the engine driving the generator at full speed in a field of full strength, which will of course represent the full power of the locomotive. When we reach a grade requiring three times the torque required on the level, we weaken the field to one-third of its full strength. We will then move up the grade at about one-third

of the speed on the level while using the same power as was required on the level.

It will be noticed that under the electrical arrangement on this locomotive, the electric energy is used in such a manner that its voltage is varied in proportion to the speed desired, and the amperes are in proportion to the torque required, so that the electrical energy produced is utilized in the most efficient manner possible.

Since this method of control of mine has been repeatedly criticized before this INSTITUTE on the score that a generator of such size and type when used as described would spark disastrously, I beg leave to say that I scrutinized most carefully the commutator of the generator which had supplied the current during the locomotive's 2200 miles service, and I never saw a commutator and brushes in more perfect condition, and the engineer assured me that under no circumstances had there been any sparking whatever. I regret that my method of control does not fit the generally accepted self-induction theory of sparking, but am forced to conclude that as something is evidently wrong, it must be the theory which fails to agree with the facts.

An electric locomotive of this kind would probably cost for the first few about \$30,000, each being equipped with a 1500-horse-power boiler of our best marine type, and one of our best automatic cut-off compound engines directly coupled to a modern multipolar generator. I believe that a locomotive of this type could be built which would be able to pull 50 per cent. more weight than any of the present steam locomotives, and that it could pull the same weight at 50 per cent. higher speed. I think this type of electric locomotive is the stepping stone between the steam locomotive and the electric locomotive operated from a distant central station.

To properly try the experiment of operating a high speed locomotive of 1500-horse-power from a central station would undoubtedly cost nearly a million dollars. To try it with a locomotive of the Heilmann type would cost not more than \$50,000 and if it proved successful, it is not much of a step to replace the boiler and constant speed steam engine with the moving contact and constant speed electric motor for driving the generator already tested and proven satisfactory.