

exhaust steam are now entirely worked out as turbines as well as piston engines. Trials have been made lately for the utilization of flue gases of boilers, blast furnace gases, exhaust gas of gas-engines, etc., and these trials give satisfactory results, but the company which exploits these patents is not yet ready to put the machines on the market.

I should like to show you a very interesting diagram; you see here upon the upper side of the drawing the general disposition of a steam plant: boiler, steam engine and waste-heat engine; the diagram below shows in per cent. of the heat energy produced in the boiler the amount of energy developed in the steam engine and in the waste-heat engine and the losses which occur during this process. According to this, 12 per cent. of the original heat is utilized in the steam engine and 4 per cent. in the waste-heat engine; 2 per cent. is lost in the ashes, 7 per cent. by radiation from the boiler, 22 per cent. goes in the flue gases, where 6 per cent. is recovered by the economizer and 16 per cent. escapes through the chimney, 2 per cent. is lost in the piping from the boiler to the steam engine, 2 per cent. radiated from the steam engine,  $1\frac{1}{2}$  per cent. in the steam piping to the vaporizer and  $53\frac{1}{2}$  per cent. is lost in the cooling water.

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#### DISCUSSION AT PHILADELPHIA, May 11, 1903.

CHAIRMAN HERING:—The papers are now open for general discussion.

MR. WM. C. L. EGLIN:—There are one or two points on which I differ with Mr. Torchio, particularly on the question of opening both the oil-switches in series. It seems to me it would be much better to open first one switch and if that fails open the second, for the reason that the arc introduced by the failure of the first switch will very materially reduce the load to be opened by the second switch. It is possible, in opening both together, that both might explode and form an arc which, of course, could not be put out under many conditions without shutting down the generator.

Mr. Lardner speaks of large versus small stations. I cannot agree in any way with the author of this paper in connection with stations for light and power. In the first place the location of the central station is perhaps the most important single feature of the system. A desirable or a perfect location is

extremely hard to get in any large city, and it is becoming more difficult every year. At first it was generally supposed we could go any distance with a high tension station, but that is not true. You must be reasonably close to your load center, especially if you expect to use underground distribution or transmission. You have to depend on water facilities, coal facilities and railroad facilities. To take care of the requirements of such a station, you need an area of greater length than the ordinary city block; that is, you need a station which can be extended in length for future requirements without being cut up by streets. In my opinion it is essential that the entire equipment of a central station of this kind should be on parallel lines; that is to say, the boiler room, the engine room, engine room equipment, steam piping equipment, coal apparatus and switchboard apparatus should be in parallel lines, so that every lineal foot will give one lineal foot for additional requirements. That means that the station will be narrow and long. The station that the Philadelphia company has started and completed—the first section—has possibly a growth of fourteen hundred feet in length. That is possibly double the length of any other station talked of, although it will only have a little more capacity in that length than some of the other stations.

The location of the substation is not at all as important as the generating station, for the reason that you have only one or two things to consider—one or two classes of apparatus to be considered. In the substation you may say you want only the electrical machinery. In Mr. Junkerfeld's division of the cost of real estate and generating apparatus in the central station he gives it as 35 to 45 per cent. That is probably a little high; but even at 30 per cent., that would represent several millions of dollars, in a large city. The transmission system is from 3 to 6 per cent., and the substations, including real estate, from 10 to 15 per cent.; so that the substation cost is small and it is divided into a large number of units. The substation can be placed in almost any kind of building.

The point in turbines versus engines that seems to have escaped the attention of the authors is the light load efficiency. It is well known that the steam engine efficiency is greatest at from 80 to 100 per cent. of the full-load. With a turbine the light load efficiency is very high. In the maximum there is very little difference between half-load and full-load, and even a very high efficiency on a quarter-load. This makes the actual efficiency of the plant very much higher than with steam engines.

The question of storage-batteries as auxiliaries depends entirely on the conditions of the service. Where maximum reliability and continuity of service are not necessary, a storage-battery can be omitted. In the case of the substation feeding into a low-tension network, as in the Edison station, a storage-battery is just as essential as the converter or any other part of the equipment of the substation. In the event of an accident in which part of the load is thrown off, the part of the load lost from-

the substation is transferred to the next substation, making trouble at that point. The storage-battery will tide these difficulties over, and in a system where continuity of service is of the first consideration, I believe that the engineer should invariably specify a certain proportion of storage-battery.

MR. HORATIO A. FOSTER:—It seems to me the original subject that was set before this meeting has been somewhat changed. As I remember, the subject was to be the tendency of the development of the modern central station. It seems to me that this might be called a discussion of the central station in very large cities, which of course is very important. I might say a little something about the tendency of the development in the smaller stations in the hundreds of towns outside of the large cities, which I think is quite as important as that in the large cities. Of course in the large cities also we have another point, and that is the difficulty of defining a central station. We have many plants in the larger buildings which are substantially central stations in themselves, plants that deliver a current to a large and wide area far ahead of the current delivered in many of the large central stations, so-called.

Another point that I hardly think has been given due consideration is a comparison of the cost of current in any of these large cities. Take New York City, for instance, they are comparing the cost delivered from the new station with the cost delivered from stations they had previously, and not with the cost of the separate stations. I would like to learn the cost of current delivered to the lamp or to the mains or to the railway network as developed by the modern style of single station. With the large amount of high-tension cable, costly conduit, and costly distribution in every way, as compared with that of a duplication of stations; that is, of a few good large stations which are located nearer the centres of distribution and therefore eliminate most of the costly distribution.

CHAIRMAN HERING:—I am pleased to hear what a number of the speakers had to say about the advantages of motor generators over rotary converters, because about two and a half years ago, in a paper read before the INSTITUTE, I called attention to this, but it intimated then that I was not at all in fashion, and that the rotary was the only proper thing to use. It seems now, however, that this fashion has changed. I often think there is altogether too much fashion in such matters, particularly in this country where we are too apt to follow the leaders blindly.

Mr. Lardner says the direct current dynamos are ruled out by the use of turbines. It seems to me he is not quite right in this; just as the turbine is the ideal engine, so the unipolar machine is an ideal continuous current dynamo, and the two seem to go well together. Unipolar machines have never been developed like the others, but that is no reason why they never will be, now that the very high speed turbine exists. The difficulty seems to lie in leading the current off from the edge of a disc which has an enormously high peripheral velocity.

MR. HEWITT:—There is one point I forgot to speak of when on my feet before and that is the possibility of offsetting the economies of a station by arranging it in a disadvantageous way, or by placing in too many auxiliaries. In two stations with which I am familiar—one a non-condensing station and the other a condensing, with equal loads, the cost per k.w. hour is almost identical. The entire economy gained by condensing in one case is offset by the fact that it requires enough additional men to offset the saving in coal; so that the cost per kilowatt hour is the same. If you place auxiliaries in the basement or in out-of-the-way places you have got to have some man to operate them. For traction work, anyhow, I can speak positively that the simpler the station is in all its parts the cheaper it will be to operate.

MR. TORCHIO:—I believe that the only direct question in reference to my paper was the opinion expressed by Mr. Eglin that it was desirable not to open the two switches in series at the same time, reserving the second switch for hand operation, in case the first is blown up, as the arc would reduce the current in the short circuit. I differ with Mr. Eglin. I think where the first switch blows up and the arc is maintained across the metal of the oil-can, the resistance of the arc will make practically no difference in the amount of current in the short circuit, and if it is necessary to open the second switch by hand, it might just as well open in the first place.

Although not bearing directly on my paper, I want, while I am speaking, to take issue to the statement made about the undesirability of one central generating station in New York, in the case of the lighting company. The lighting company was a few years ago operating several low-tension stations throughout the city, but when it came to the point of extending them they found difficulties in the cost of real estate, in not being able to obtain condensing water, in the question of operating steam stations in partly residential or business sections on account of complaints of neighbors objecting to noise, smoke, ashes, etc. To locate a direct current station along the water front was practically an impossibility, on account of local conditions, the water front being one mile or over a mile away from the centre of heavy distribution. The operation of several stations would also have added to the cost of operations and also materially to the amount of taxes which the company would have been liable for, and other reasons.

The whole question, of course, boils down to the point that we want to deliver one kilowatt to the customer for the least cost, but in this cost we must include all items of expense, besides the purely production cost. I believe, however, that people not closely familiar with the development of these stations, have wrong impressions about the relative importance of the different factors entering into the problem, and it seems, from the remarks I often hear, that undue prominence is given to certain

features of the system, and amount of losses and efficiency, and also cost of transmission cables and transforming apparatus. For instance, Mr. Hewitt to-night placed emphasis on the high cost of installation for high-tension cables. In paper-insulated cables as generally used the cost of paper bears a small proportion to the total cost of the cables.

In this discussion of multiplicity of stations I do not really follow the idea of the gentlemen advocating several low-tension stations. If they mean that these stations have to supply separate districts, it seems to me that if something serious happened to one station it will leave that district without light. That the large direct current stations are open to the criticism of breaking down, has been proved by several shut-downs of large stations due to short circuits, fires, bursting of steam pipes, or other reasons, so that in a measure the criticisms made to one alternating current station applies also to the independent stations.

As to the statement of Mr. Foster that rotary converters are the source of numerous troubles, I believe he qualified the statement when he said that it applies to high frequency rotaries. In all our experience with 25-cycle rotaries we have not found this type of apparatus to be more troublesome to operate than similar direct current apparatus.

Mr. Foster has stated that in large cities the development of power service is somewhat handicapped on account of the Underwriters imposing heavy restrictions to the installation of proper pumping apparatus which cannot be obtained from electric driven pumps. I think that the electric pump can be operated as satisfactorily as a steam pump, and this has been conclusively proved by the extensive use of electric pumping in the California plants, where they do extensive pumping with practically very little attention to the apparatus. The fact that in New York City there are from sixty to seventy thousand horse power for a great variety of commercial uses proves that the central stations are not very much handicapped in securing power customers.

Motor generators sets have been referred to. I imagine that the speakers had reference to induction motor generator sets, not synchronous motor generator sets. As I said before, I do not find any reason to pay more for this apparatus when you can get just as satisfactory results from rotary converters, as the latter is about 25% cheaper than the motor generator sets, and the efficiency is higher.

About the steam turbines with d.c. unipolar machines, I do not believe that this type of apparatus would be applicable in large cities, for many reasons. The unipolar machines are not capable of being designed for large quantities and commercially high-voltages. As far as my experience goes with the unipolar machines I find that it is very difficult to get rid of the heat,

requiring forced ventilation, also it is difficult to collect the current by ordinary brushes. The fact also that the units would be of small capacity would be a handicap to the use of unipolar generators as I think that the steam turbine in small sizes does not bear the same economical advantages to the reciprocating engine as the large steam turbine compared with a large engine. When there will be a more complete line of development in steam turbines most probably the cost will diminish, but at present the small steam turbine does not hold the relative economical advantages compared with the reciprocating engines as in the case of large turbines.

MR. PAUL SPENCER:—I was interested in the remarks of Mr. Hewitt and Mr. Foster, particularly in what they had to say in regard to the advantages of a number of stations as compared with one large station. It seems to me that these papers read to-night were written particularly on New York plants, and the engineering features therein described, while perfectly applicable to the New York situation, do not necessarily bear on the development of central stations throughout the country. There is some danger, I think, in engineers throughout the country being very largely influenced by what is done in situations like New York, and in adopting what is done there for stations where the practice would not fit conditions so well. We are rather apt to follow fads and fashions, and an engineer, in laying out a station, likes to have the latest and most up-to-date appliances. In the smaller and more extended situations, I would agree with Mr. Hewitt and Mr. Foster, that more than one station generating at the service and voltage to be distributed would in many cases be cheaper in first cost and more economical in operation than one large station from which the current would have to be transmitted and converted before being distributed.

MR. HEWITT:—Perhaps I did not make myself clear in regard to the cost of cable. What I had in mind was in the ground return we eliminate one cable altogether, or at most use a piece of bare copper; so that in estimating the cost of high-tension cables for conduit work, as I stated before, the figures I have made showing the cost of the extra cable, will offset the saving in copper for moderate distances.

In regard to the duplication of stations—I should have stated that of course it is taken for granted that these stations will be connected by ample tie lines. On the map the blue wafers represent the Philadelphia Rapid Transit Company's plants. They are all connected together, either directly or indirectly by tie line cables, so that it is possible to shift the load from the lower part of the city out as far as Ogontz, if necessary. The red ones are the lighting stations, and the green represent stations that do not belong to the Rapid Transit Company.

MR. TORCHIO:—Do the tie lines transmit the full output of the station?

MR. HEWITT:—It might be so arranged. In this particular case it would not be so, although it is possible to shut down any particular one of the stations without affecting the cars to any great extent, because the more important stations have two and some as high as four different tie lines. One station, for instance, in the centre of the city is connected directly to four other stations and indirectly to a fifth one.

MR. TORCHIO:—The remark I made when I was reading my paper is this: it must not be understood that the people in New York do not appreciate that conditions will determine the best lay-out to be made, and I wish to state that the same engineers that have had to do the designing in the lighting plants in New York have also been advising the traction company where they have used direct current machines to have them install large current machines of three thousand kilowatts. There are quite a number in the same station along side of alternating current machines, and also they added in existing stations large direct current units. That was only because the conditions allowed. They had plenty of facilities for coal, and in other distributions it makes that condition like Philadelphia.

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