# PROCEEDINGS

OF THE

SEVENTEENTH ANNUAL CONVENTION

OF

# The National District Heating Association

HELD IN

NIAGARA FALLS, NEW YORK

June 1, 2, 3, 4, 1926

PUBLISHED BY THE ASSOCIATION

D. L. GASKILL, *Secretary.* H. R. WETHERELL, *Technical Secretary.*

## EXHAUST HEATING IN ROCHESTER, N. Y.

The Rochester Gas and Electric Corporation, following the recommendation of Mr. Rodger De Wolf, Chief Operating Engineer, is the first to enter the field of exhaust heating upon the basis of modern ideas as described herein. The new system is designed to supply low-pressure exhaust steam for heating and high pressure for process. In the initial installation will be two pulverized fuel fired boilers with a capacity of 120,000 lb. steam per hour at 375 lb. pressure. A 2500 kw. non-condensing turbo-alternator will be operated during the heating season. Steam at 375 lb. and 100 degrees super-heat will be expanded down to from 5 to 15 lb. depending upon the heating load, after which it will be reheated in a steam superheater to about 40 degrees superheat for evaporating the moisture in the exhaust. Ultimately a second 4000 K. W. turbine with additional boilers will be installed giving a total peak capacity of 236,000 lb. per hour, or, 590,000,000 lb. per year sold. The annual output of energy will be 20,000,000 kw. hr., 88.5 per cent of all available steam being passed through the turbines. A high pressure line carrying 100 lb. for process steam will be installed in the same underground conduit with the low pressure piping. Figure 9 shows the characteristics of turbines to be used. Figure 21 represents graphically the method of operating two turbines requiring all steam up to 172,000 lb. per hour, the balance or peak load of short duration being supplied by live steam. A temperature load duration curve is employed, the integrated area thereunder being the total annual steam send out. Figures 22 and 23 give turbine steam consumption data. The total steam generated at the boilers will be 678,000,000 lb. annually, the net sales being 87 per cent of gross generated; including turbine consumption.

67,800,000 lb. will be sent out at high pressure, leaving 610,200 lb. available for turbines of which 88.5 per cent or 539,950 lbs. will be utilized corresponding to a water rate of 24.5 lb. per kw. hr.

FIGURE 21

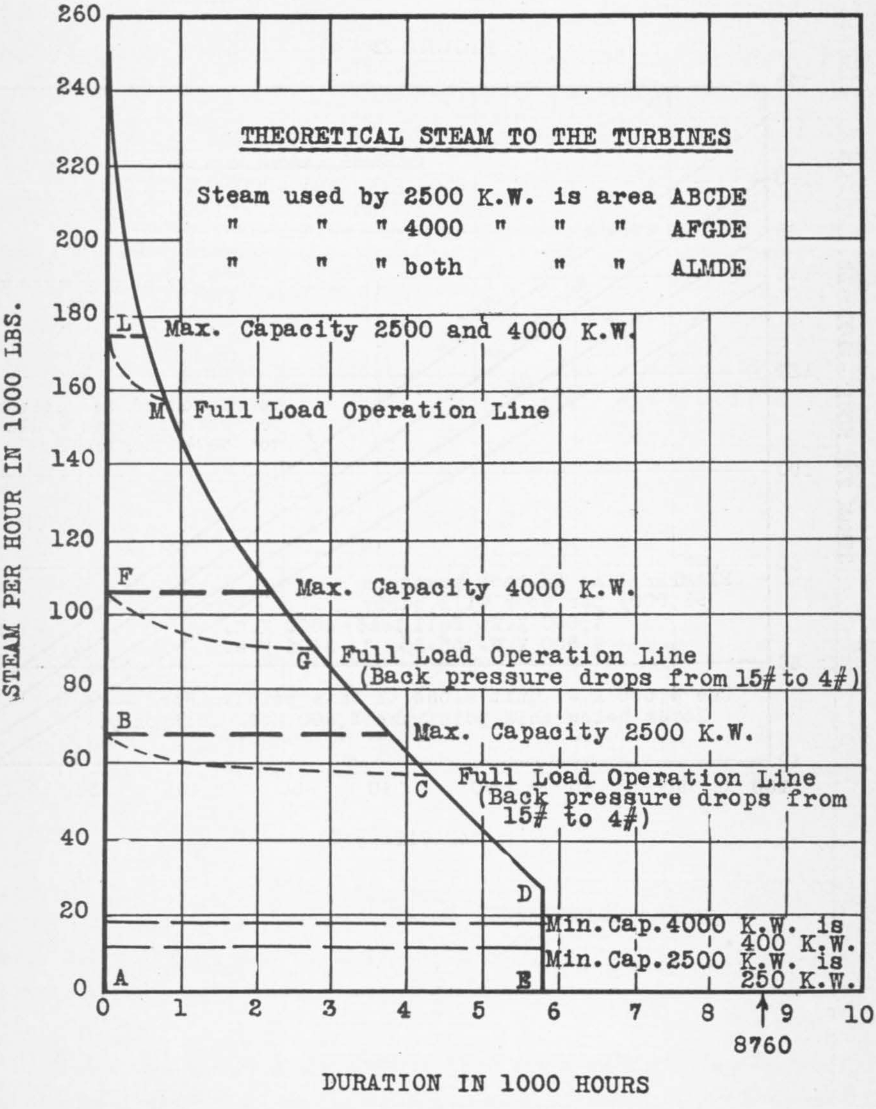

THEORETICAL STEAM TO THE TURBINES
Steam used by 2500 K.W. is area ABCDE
" " " 4000 " " " AFGDE
" " " both " " " ALMDE
Max. Capacity 2500 and 4000 K.W.
Full Load Operation Line
Max. Capacity 4000 K.W.
Full Load Operation Line (Back pressure drops from 15# to 4#)
Max. Capacity 2500 K.W.
Full Load Operation Line (Back pressure drops from 15# to 4#)
Min. Cap. 4000 K.W. is 400 K.W.
Min. Cap. 2500 K.W. is 250 K.W.
L
M
F
G
B
C
D
A
E
STEAM PER HOUR IN 1000 LBS.
0
20
40
60
80
100
120
140
160
180
200
220
240
260
0 1 2 3 4 5 6 7 8 9 10
8760
DURATION IN 1000 HOURS

FIGURE 22

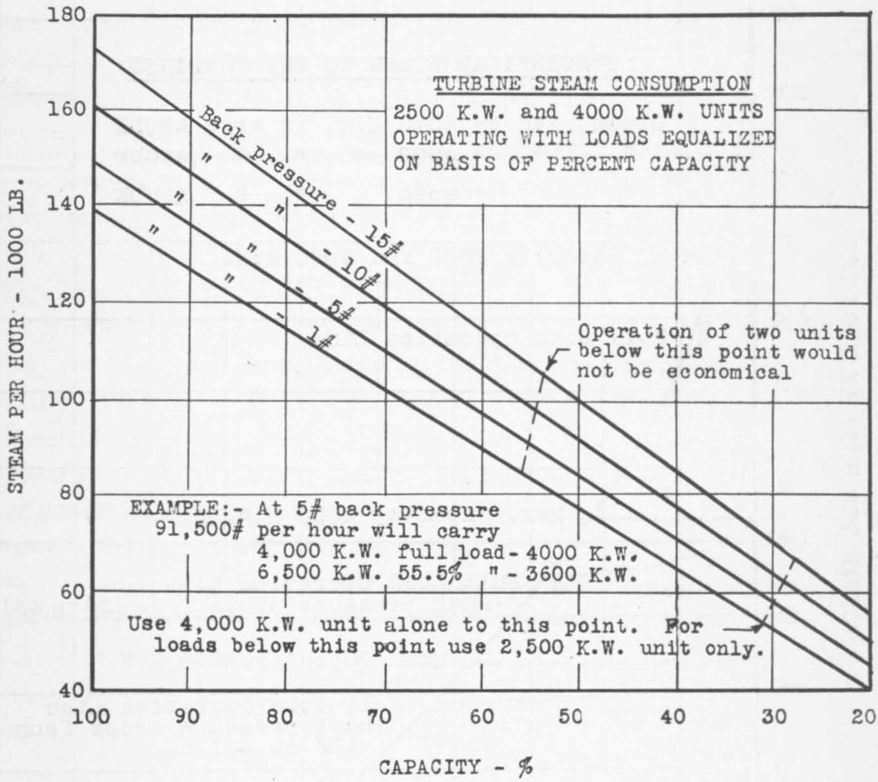

TURBINE STEAM CONSUMPTION
2500 K.W. and 4000 K.W. UNITS
OPERATING WITH LOADS EQUALIZED
ON BASIS OF PERCENT CAPACITY
Back pressure - 15#
" " - 10#
" " - 5#
" " - 1#
Operation of two units below this point would not be economical
EXAMPLE:- At 5# back pressure
91,500# per hour will carry
4,000 K.W. full load - 4000 K.W.
6,500 K.W. 55.5% " - 3600 K.W.
Use 4,000 K.W. unit alone to this point. For loads below this point use 2,500 K.W. unit only.
STEAM PER HOUR - 1000 LB.
180
160
140
120
100
80
60
40
100
90
80
70
60
50
40
30
20
CAPACITY - %

FIGURE 23

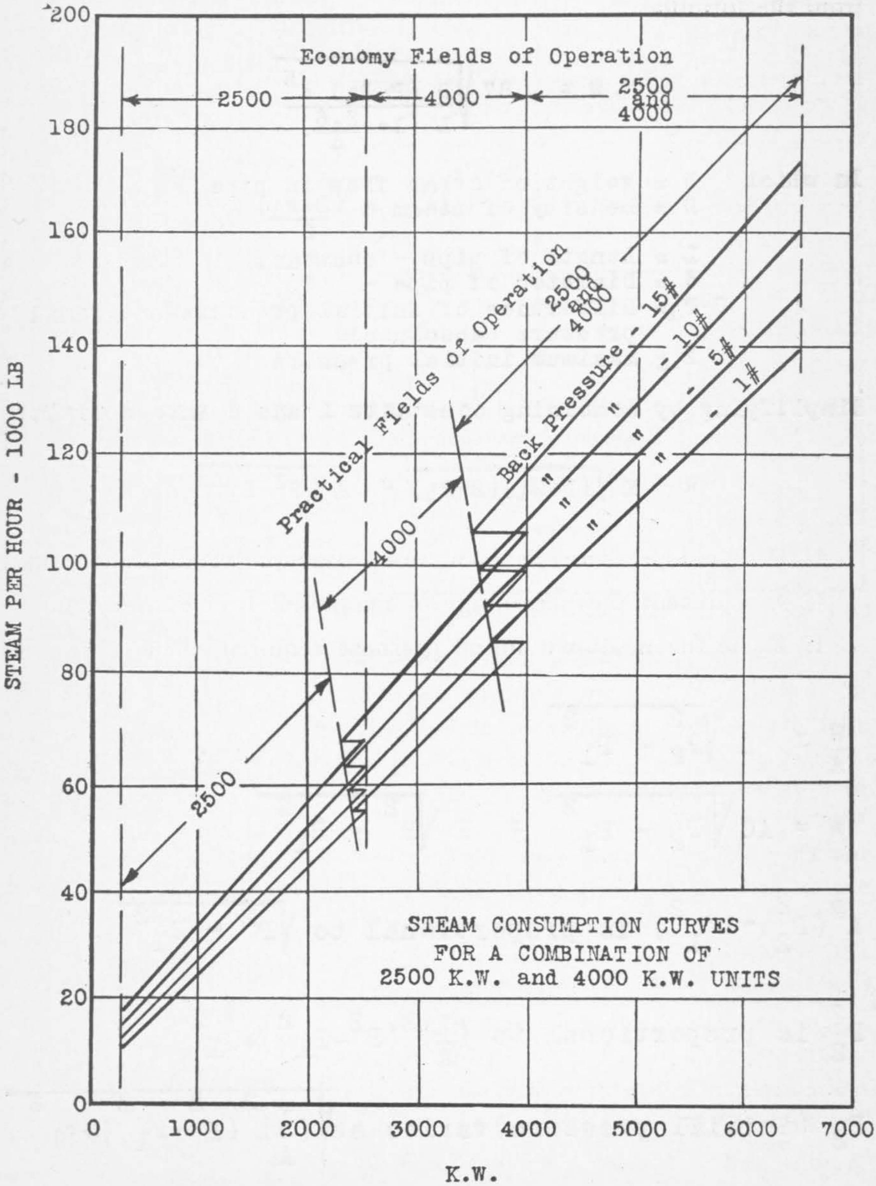

Economy Fields of Operation
2500
4000
2500 and 4000
Practical Fields of Operation
2500 and 4000
4000
2500
Back Pressure - 15#
" - 10#
" - 5#
" - 1#
STEAM CONSUMPTION CURVES
FOR A COMBINATION OF
2500 K.W. and 4000 K.W. UNITS
STEAM PER HOUR - 1000 LB
K.W.
0
20
40
60
80
100
120
140
160
180
200
1000
2000
3000
4000
5000
6000
7000

Figure 24 is a load-pressure diagram which Mr. De Wolf derives from the formula:

$$W = 87\sqrt{\frac{D\,(P-P_1)\,d^5}{L\,(1+\frac{3.6}{d})}}$$

In which
- $W$ = Weight of steam flow in pipe
- $D$ = Density of steam @ $\frac{(P+P_1)}{2}$
- $L$ = Length of pipe - constant
- $d$ = Diameter of pipe - "
- $P-P_1$ = Difference of initial pressure and final pressure (absolute)
- $P$ = Maximum initial pressure

Simplifying by combining constants L and d into constant K

$$W = K\sqrt{(P+P_1)(P-P_1)} = K\sqrt{P^2-P_1^2}$$

If $P_1$ (final pressure) is maintained constant at all loads, and
If A represent the percentage of maximum load carried, and
If $P_2$ be the unknown initial pressure required, then

$$\frac{W}{A} = C\sqrt{P_2^2 - P_1^2}$$

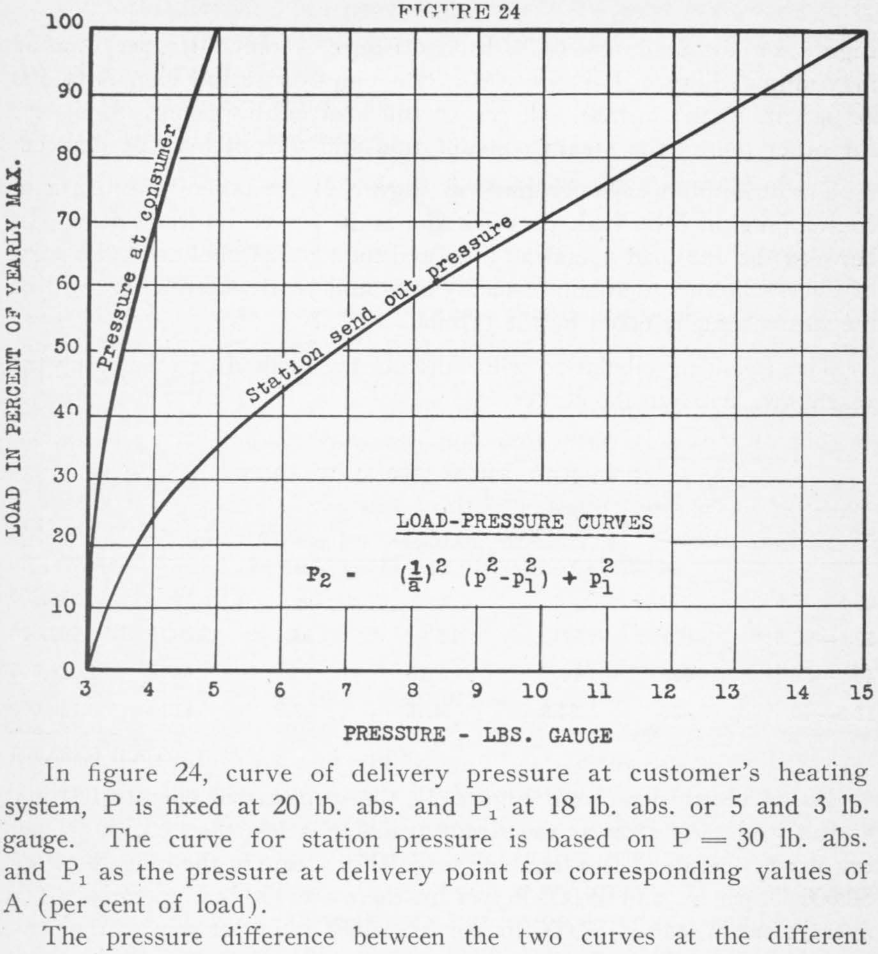
$$W = AC\sqrt{P_2^2 - P_1^2} = K\sqrt{P^2 - P_1^2}$$

$A^2(P_2^2 - P_1^2)$ is proportional to $\sqrt{P^2 - P_1^2}$

$P_2^2$ is proportional to $(\frac{1}{A})^2(P^2-P_1^2)+P_1^2$

$P_2$ (initial pressure) varies as $\sqrt{(\frac{1}{A})^2(P^2-P_1^2)+P_1^2}$

FIGURE 24




In figure 24, curve of delivery pressure at customer's heating system, P is fixed at 20 lb. abs. and $P_1$ at 18 lb. abs. or 5 and 3 lb. gauge. The curve for station pressure is based on P = 30 lb. abs. and $P_1$ as the pressure at delivery point for corresponding values of A (per cent of load).

The pressure difference between the two curves at the different percentages of load, gives the pressure drop through the line if the maximum drop is 10 lbs.

At the peak load, assuming 15 lbs. maximum back pressure, the 2500 K. W. turbine can handle 67,500 lb. per hr. With less demand for steam the velocity in the distribution line will decrease, requiring less pressure gradient and consequently lower back pressure; under which condition the turbine has a lower water rate, consuming less steam per kw. hr. For example at 8.6 lb. back pressure the unit will use only 61,500 lb. steam per hr. to carry full load. Referring to

Figure 24, the load at 8.6 lb. back pressure is only 61.5 per cent of maximum. Figure 9 shows steam consumption at full load is 61,500 lb. per hr. so the turbine will run at full load at this point. Similarly, for other points the steam consumption and output may be derived.

The minimum capacity lines in Figure 21 are taken for the steam consumption at 5 lb. back pressure and at 10 per cent turbine load. In between the full load operation lines and the vertical lines from the point of intersection of minimum capacity lines and yearly steam curve will be the steam actually taken by the turbine.

The following tabulation will illustrate the method of calculating the yearly kw. hr. from the curves.

K W. HRS. FROM 2500 K. W. UNIT

| Range of Steam Load M Lbs. Hr. | Hours At That Load | Average Steam Load M Lbs. Per Hr. | Back Pressure | Turbine Load % | K. W. Rate | Kw. Hrs. Per Year |
|---|---|---|---|---|---|---|
| 65.5—75.0 | 100 | ........ | .......... | 100 | 2,500 | 250,000 |
| 50 —65.5 | 450 | 57 | 11 | 88 | 2,200 | 992,000 |
| 40 —50 | 600 | 44 | 8.15 | 67 | 1,680 | 1,010,000 |
| 12.3—40 | 3,850 | 24.3 | 4.75 | 32.5 | 813 | 3,130,000 |
| | | | | | Total | 5,382,000 |

As an illustration, from Figure 21, the turbine will operate 100 hrs. at full load. As soon as the steam available is less than 65,500 lb. per hr., it will operate at less than full load. For steam in the range between 50,000 lb. per hr. and 65,000 lb. per hr. there are 450 hrs. operation. The average steam load is 57,000 lb. per hr. which is 76 per cent of the peak load which gives a back pressure on the turbine of 11 lb. The turbine with 57,000 lb. steam per hr. will operate at 88 per cent of full load if the back pressure is 11 lb., giving an output of 2200 K. W. for 450 hrs., or 992,000 kw. hrs. This method is applied also when the second unit of 4000 K. W. capacity is installed, and results in an ultimate output of 22,000,000 kw. hrs. in the sixth year's operation.

These calculations are purely theortical and it remains to be seen whether the results will be equaled or exceeded. The economy in this system is very marked when compared with live steam only.

(Great Applause.)

*President Shultz:* Gentlemen, this splendid report is before you for discussion. It seems to me that it is of very vital significance to us and it ought to have the fullest discussion, not only of those who are what you might say friendly towards the plan, but also those who may have some doubts about its advisability.

*Mr. Wetherell:* Mr. President referring to the operation of heating plants generating electricity as a by-product, I have in mind two cities located geographically about seventy-five miles apart, pretty good-sized cities, that prior to two years ago were operated as combination electric and heating plants. The load on these plants, particularly the electric load, grew to such a point that it made it necessary to either increase the capacity of those plants or build a super-power plant to supply both of them. That super-power plant has been completed now and it is operated as a wholesale company and sells electric current to the two other companies.

Then the question came up as to how they would operate the old plants, which were still to be operated, and on what basis. In one case the heating load happened to be almost equal to the electric load and it was decided to operate that plant as a heating station, the heating department taking over the entire operation of the station and fixed charges, and sell the electric current to the wholesale company at the price that the wholesale company was charging the electric department for the electricity that they supplied. That plant, of course, will be operated only in the winter time and will be shut down in the summer.

In the other case, the electric load was much greater than the heating load, due to a large amount of power business in that locality, and there were quite a few, probably three or four, pretty good-sized straight-condensing units in the plant. If that plant were turned over to the heating department, of course, it would be a burden on it and it would have to be operated anyway for the electric load, because there wasn't enough capacity in the super-power plant to take care of the whole thing. So they decided to turn that plant over to the wholesale company. That wholesale company now sells steam to the heating department and electricity to the electrical department at the same price it sold to the other people.

In both cases particular conditions which surrounded them worked out to very good advantage.

*Mr. Walker:* Mr. Chairman, I want to congratulate Mr. Orr and his Committee on this excellent report, which is the most interesting I have read for some time. I like particularly the manner in which the various opinions are presented here without any attempt by the Committee to settle what is going to be a much-discussed problem for a long time.

There are a few points I wanted to call attention to. It is suggested that boiler plants in the customers' buildings be used as peak-load capacity. Mr. Orr has had lots more experience along that line than we have in Detroit, but I would like to ask him to tell us honestly, now, if that is a feasible thing. We tried once to start up a customer's plant in cold weather, and after we had assembled our operating staff and after Mr. Dubry had gotten the boiler feed line tied down so it didn't jump all over the place, we found that the cold spell was over and the plant didn't do us much good.

I would like to call attention to Figure 13, which was taken from the study that was made of the turbine in Detroit. You will note in Figure 13 the maximum energy is obtained from the steam when the back pressure on the turbine is seventy-five pounds. That is because the amount of energy that you can extract depends upon the relation between the quantity of steam and the pressure drop through the turbine, and it so happens that for that particular feeder the maximum occurs at seventy-five pounds back pressure. It would be different for a feeder with a different characteristic.

The matter of the superheating of the exhaust and the charge for the moisture sent out in the exhaust is quite an intricate question. Mr. DeWolf will tell you that superheating the outgoing steam will reduce the line losses, and that is a very possible thing, but you must also remember that if you supply a customer superheated steam, providing you meter the condensation, you are only charging him on the basis of saturated steam, and it costs you more, obviously, to supply him superheated steam.

We felt in Detroit that we didn't need to charge against the operation of the turbine the heat which was absorbed by it which would otherwise go out as superheat, because we felt that the superheat was of little value.

On the matter of credit for installed capacity, I would just like to put this thought to you: it is only my idea and I don't ask anybody else to accept it. It seems to me that you cannot allow credit to your heating plant turbine in any specific case unless you can actually reduce the budget for your electrical power plant extension, and you can't do that unless the heating-plant turbine is of the same order of size as the turbines in the power plant, because you cannot reduce the actual number of units in the power plant. For a theoretical analysis such as this, the method used is, of course, correct.

Then there is the matter of the energy value, which Mr. Orr terms the secondary value. The report suggests that the credit be based upon the average operating and maintenance cost for the total amount of current generated in the main electrical generating stations. The common method of analyzing electrical costs, which I don't think has ever been disputed, is to divide the operating and maintenance costs into what are called standing costs and running costs, the standing costs consisting of the charges that are not proportional to the amount of electricity generated, and the running costs consisting of those that are proportional to the amount of electricity generated, and which would include most of the coal cost and such items but would not include such items as labor, unless it could be shown. In this case it was that their amounts would be definitely altered by a variation in the amount of electricity generated.

*President Shultz:* Is there any other discussion?

*Mr. Stevenson:* I do not have any criticism, but, inasmuch as this report has been necessarily discussed so much in outline, I want to call attention to and read a paragraph that seems to me to be the high point of the entire report. It is stated, "Experience in industrial progress bears out the thought that a point may be attained where further concentration becomes a disadvantage,—" He is speaking there of concentrating electric energies. "—and this has given rise to the idea that as an electrical utility grows, a limited capacity (which might be deemed peak capacity) in turbo-generating units, operating non-condensing and housed in strategic locations closely adjacent to a densely built business district, could be installed, with resultant mutual economic advantage to the electric and heating utilities,—."

This entire report reads almost like it were made up to apply to Pittsburgh particularly, and I simply want to point out that paragraph which seems to me ndicates the direction in which real progress is going to be made in future years in more economically combining electrical and heating utilities.

*Mr. DeWolf:* Mr. President, at one place Mr. Orr says, "—and the heating company should receive from the electric company a sum equal to the value of such power on the basis of the electric company's fixed charges and cost of generation at its most efficient plant." I want to very thoroughly commend Mr. Orr on pretty nearly everything else in the report except this, which is about the only point wherein I differ with him. It is a very excellent report. What I would suggest is the substitution of the words "of the power displaced" for "at its most efficient plant." Now, some of these kilowatt hours that you generate during the period of your peak load of the year are displacing kilowatt hours that would otherwise be generated in the oldest and most inefficient plant that the electric company possesses, because that is generally where the top part of your winter peak is carried. Therefore, there is a certain part of this kilowatt hour credit that should be put in at a figure higher than the cost of generating that power in your most efficient plant, and I think this point should be taken into consideration.

On the next page Mr. Orr has gone a good deal further than we did in Rochester in the capacity credit that he allows. He has a figure there of $23.00 per kilowatt. We used a figure of approximately half that. We did not make the 1.16 allowance which he gives in the first paragraph, nor did we use as high a figure as $125.00 per kilowatt for your condensing equipment, nor did we allow any decrease in transmission-system investment. As a matter of fact, I don't think you are justified in allowing any decrease in your transmission-equipment investment unless your non-condensing generating equipment, your turbine, is installed in duplicate, because, although the reliability of the non-condensing turbine is very much greater than the reliability of the condensing turbine, with its auxiliary equipment, nevertheless, we wouldn't feel like leaving a downtown district dependent during the peak load periods upon only one machine or one way of getting current into that district. Therefore, you either have to put the investment, or a good part of it, into your electrical transmission system to get this power into the downtown district or you have to put your non-condensing turbine capacity in in duplicate.

In this combination of electric with heating load I think we have the most notable advance that has been made in the heating industry in some years. We are, I think, going to be forced into that situation by the development in efficiency of power generation in both large and small plants, and we are going to have to use a method of supplying our power and steam demands which is essentially a complete substitute for the isolated plant with which we have to compete, and in order to compete nowadays on a profitable basis, we have got to give ourselves every advantage in the combination of these two classes of business which the best type of isolated plant gets through such combination.

I won't go into a description now of the Rochester plant or the Rochester system, because Mr. Woodruff is going to give you a paper on that later on as part of the Operating Committee's report. I will say, in general, that our operation this first season has borne out our expectations. We are now making an analysis of our cost of operation.

Mr. Orr gave some figures in regard to the credit that you get from the kilowatt hours generated and the difference between the cost of exhaust steam to your customer and the cost of live steam. Those figures he gives on page 59, showing in the case of 650 and 400 pound plants a difference of about 16 cents per thousand pounds. Our investigations of our operating costs for the past season indicate that we can give the steam a credit of from five to something over twenty cents per thousand pounds, depending upon the load factor on which it is operated.

One interesting point in the table on page 7 is that the decreased cost of the exhaust steam on 400-pound pressure is only about a cent and one-half less than the decreased cost of the exhaust steam if you go to the 650-pound boiler. In other words, the marginal cost of the additional 250 pounds pressure in your plant only increases the net reduction in your cost of steam to the consumer about ten per cent.

I didn't catch all that Mr. Walker said. He brought up one subject that has long been a subject of controversy, namely, superheated steam in your distribution system. I suppose we were along about the first to use it, and we have heard many discussions on the floor of this Covention with regard to it, whether you should or shouldn't use it. My final argument on all of these discussions is that by the time you get through with twelve months' operation, I think the Rochester Company shows a lower loss between the amount of steam leaving the station and the amount of steam accounted for on our customers' meters than any other company in the country. Now, I don't think that we are metering our steam any better than anybody else; I don't think that we are keeping the incidental leaks down any better than anybody else, and therefore, by a process of elimination, the only thing that I see that brings it about is superheating the steam.

In the new plants that we have just built we take the exhaust steam from the turbine and put it through a reheater to which heat is supplied by means of high-pressure steam passing into a coil in this heater. This is designed to give us about 40 degrees superheat on the steam as it leaves the station, and, as nearly as we can figure it out, 40 degrees of superheat will give us about zero degrees of superheat to the average customer. Now, the fellow right next to the plant is going to get some superheat and the fellow at the far end of the line is going to get a little condensation, but, on the whole, we try to average that out so it will meet Mr. Walker's condition of not supplying any more heat energy to the customer than we get paid for, if we can help it.

Mr. Walker also spoke about the size of the units. I didn't catch all that he had to say there, but it apparently dealt with the effect of the size of these units upon whether you should or should not give an electrical credit for the KW of capacity. Personally, I don't see any reason why the size of the unit or the fact that it is a relatively small unit should influence us at all in that credit. As an electrical operating man, I would rather have 30,000 kilowatts of capacity in three or four machines, provided I could get the same efficiency of power generation out of them, than I would in one, because, if any accident occurs to the one machine, you lose your entire 30,000; with the others you lose only a part of it. Now, that idea is unattainable in the straight electric generating plants, but it is obtainable in this combination of steam and electric business.

There is one further development which with us is an older development than the new station. I said that this combination of electric and heating business was a relatively new development. We are, I think, the only company in the country operating a large condensing electric generating plant and supplying a large heating system with steam from the same boiler room that supplies the condensing electric turbines. Where such a combination is physically possible, it is the ideal combination. We have kept track, for instance, of the load factor in our turbine room and our boiler room for a number of years. Last year the average yearly load factor in the turbine room was in the neighborhood of 26 per cent, I think The boiler room was in the neighborhood of 46 per cent. This means that every pound of steam that was generated, that went into the condensing electric turbines, was generated at a lower cost than it would ever have been possible to have generated that steam with the straight electric load alone.

We have another advantage in that say 75 per cent of the heating load can be dropped off our system, practically, for a period of twenty minutes or half an hour, at least, with no inconvenience to our heating customers. In other words, if we have 250,000 or 300,000 pounds of steam an hour going out into our low-pressure heating system around this plant which is equipped with condensing turbines, and we are operating our electric system in parallel with hydro-electric generation or transmitted power and lose our transmitted power, we can drop our heating customers off and take 200,000 or 250,000 pounds of steam and put it into our condensing turbines for a period of half an hour without disturbing our heating customers at all, and that half-hour period is a regular life-saver in enabling us to get the rest of our electric generating equipment into commission to carry the load that our transmission system dropped.

*Mr. Walker:* Mr. Chairman, I don't like to speak twice on one subject, but I don't think I made myself clear about the effect of the size of the heating-plant turbine. I didn't mean so much the size of the individual units, but rather the aggregate capacity that could be installed in the heating plant. Unless that aggregate capacity is such that it will actually allow you to decrease the investment in the main electric generating stations either by decreasing the number or size of the units or by postponing for an appreciable time the installation of a new unit, then I don't see how you can properly take credit for it; that is, I don't see how you can take credit for saving an investment when you haven't saved it at all but simply have an additional investment in the heating plant.

*Mr. DeWolf:* Mr. President, may I say another word on that? When any of us reach the point where we have to put in another main turbine, we will say a 30,000 KW unit, that turbine is installed at such a point in your load growth that its first function is really to displace some of your older equipment and give you spare capacity to take care of your growing load before that load actually gets on your system. You may have capacity in your heating KW turbines of only half of that 30,000, but that half capacity delays the day when you have to put the investment into your 30,000 KW unit just that much longer, and during that period of delay you are certainly entitled to the fixed cost on the non-condensing equipment.

If we were in the situation where, just as soon as you put your 30,000 KW unit in, your system load immediately increased up to the point where you could use all of that 30,000 KW, at a high load factor, and at the same time not discontinue the use of all of the equipment that you had in at the time you put the 30,000 KW unit in, then the question of fixed charges on your non-condensing turbine would be very much overstressed; but such a condition never arises. It seems to me that we are going along on the step process, and as you go from one step to the next there is a period in each one of those steps where you are justified in giving the non-condensing machine credit for those fixed charges, and those periods will cover the bulk of the time.

*Mr. Seiter:* I just wanted to call attention to Item 2 on that tabulation on page 54 which may be a misprint. They have the peak sent out in thousand pounds per hour as 1,940,000,000, which, I assume, should be 1,940,000 pounds per hour.

Also on this matter of superheat, it is natural to suppose that if we put sufficient superheat into the steam which is going into the distribution system, that the line loss will be reduced. In fact, if sufficient were put in, the condensation losses could practically be eliminated altogether. So any real basis of comparison should be based on a cost of 1,000 pounds of steam metered, eliminating other items which may have tended to reduce the cost in the meantime.

*Mr. Day:* Mr. Chairman, Mr. DeWolf makes the statement that it is possible to drop a heating load for fifteen or twenty minutes or a half hour without causing the consumers any distress. Of course, it can be done in the case of an emergency, if it has to be, possibly with less trouble than dropping the electric load, but at the same time, in the case of hotels or similar buildings, where you are heating the domestic hot water, it is a rather serious proposition sometimes to even drop it for a half hour; so I don't think that that should be given too much emphasis.

*Mr. DeWolf:* Mr. President, when I was speaking of the heating load, I mean the steam used directly for house-heating purposes. I wouldn't recommend for a moment dropping any other kind of a load. In Rochester we use mostly high-pressure and low-pressure mains, so that we can drop the heating load. Any building has enough heat-storage capacity in it so you can shut the steam off the radiators for a period of half an hour and your customers would hardly know that it was off. When it comes to shutting the steam off from the kitchens, etc., trouble generally results.

*President Shultz:* Is there further discussion?

*Mr. Wilder:* Mr. President, I think it would be well to emphasize the competitive advantage which the Central Station gains when they can supply a heating service as well as an electric service. I remember well about fifteen years ago when competition with the isolated plant was very severe and it required a lot of good engineering and a lot of good talking to displace the isolated plants that were then in operation or that were proposed. During the period of the War coal prices and labor prices and the cost of apparatus rose to such a point that hardly anyone could afford to put in an isolated plant, if they could purchase electric energy, regardless of the heating load. But that condition, happily from the standpoint of the man who is selling electric power, is not continuing. Coal is going down; labor, to be sure, has not dropped to any great extent, and whether it will in the future or not I hesitate to predict, but I wouldn't be at all surprised if it did drop some; the cost of apparatus is going down some, so that the competition between the Central Station service and the isolated plant is becoming more severe than it was three or four years ago.

Don't forget this, that if steam is not supplied, the owner of the building or factory, whatever it is, must put in a boiler plant and he must build a big stack, he must assign very definite and valuable space for his boilers and for his coal bunkers, and when he has done all that, it is very easy for him to say, "Well, here is a little space that we can't use for anything else and we will just put an electric generator in here and generate our own electricity." There is no question but that the ability to supply a combined service is a great advantage to the electric company.

*President Shultz:* Is there any further discussion? This is a very important subject—it ought to be very fully discussed.

*Mr Kastens:* Mr. President, I wonder if we couldn't have an opportunity to look over this paper more thoroughly and discuss it at some later session.

*President Shultz:* Maybe we can work that out, although our program is pretty full.

Is there any further discussion? Mr. Caleb, you have something in Kansas City, haven't you, of this sort? Have you anything to offer?

*Mr. Caleb:* Mr. President, in this report there is a short statement about our condition and method of coperation, and some of the gentlemen have spoken in favor and some against the proposed system or plan of operating an electric generating plant in connection with a heating system. The plan as it is worked out is applicable to only a very few cases in this country. In our own case we have a comparatively new electric generating plant, with an installed capacity of 130,000 KW, and we pull a peak, a normal winter peak, of upwards of 80,000 kilowatts on the electric system. Our heating system has a demand, in boiler horsepower, of about 15,000, and an installed generating capacity of about 5,000 KW. Now, it is hard for me, from our experience, to see just what credit we could ask for by going to the management and saying, "Here we have 5,000 KW in generating equipment that could be used economically for perhaps two or three months of the year in case of trouble at your big generating plants." At our generating plant the original units were 20,000, the new ones are 30,000 KW. It is my idea that the engineers and the management of the electrical department would say, "If we need standby equipment and should have a failure of our main plant, your little 5,000 KW is rather a small part."

One other way of looking at it, and we do this, is that we operate a downtown Edison system, and it is very important to maintain the 220 direct voltage service. This is served by four or five new automatic substations that are highly reliable. So far, in over two years, we have never had any trouble. But the demand on that system is about 15,000 KW: the system is all tied together, and in case of failure of the electric system, our heating turbines could not possibly have any effect on pulling that load; so that it just works back to the same question of whether the heating department is entitled to credit for standby equipment. That is the way we look at this particular subject. Of course, we do operate the system and will continue to do so, but when we compare production costs with the production costs in the large generating plant the showing is not too favorable.

Our heating plant, compared with other plants in the country, is probably seventh or eighth in size. In places where the heating plant could be combined with the main generating plant so that the two systems could be served by one boiler house as Mr. DeWolf speaks of, the results will probably be entirely different. When the generating plant is located at a distance on a river or source of circulating water and the boiler house has to be duplicated uptown, as in our case, the back-pressure generating plant has keen competition.

*President Shultz:* Any further discussion? There is one point that we ought to bear in mind in a consideration of this subject which Mr. Orr brought out in one of his charts. A good bit of the difficulty of considering what part the generation of electricity by the steam-heating department would play in the whole Edison system is due to the comparatively very small amount of steam that we sell now. Mr. Orr's figures show that in Chicago, in our Loop District, the output of steam for heating would be greater than the output of electricity, and this is the stage in which we are building up to the time when the heating business will be sufficiently large so that these theoretical advantages that this report points out will be apparent to everybody.

I was rather interested in noting the change in attitude on the part of our own people towards this idea, although they haven't as yet switched around to the point where they are willing to put it in. But it used to be that they wouldn't talk to you about it; but the change in attitude comes, I think, as much, or more, from the sales department than it does from the engineering department, because the sales department can see quite clearly the advantage it would be to them to have the joint supplying of steam and of electricity.

Just one little point. I think it might help us in discussing this with our electrical friends if we would talk about it as the by-product generation of electricity rather than the old term of by-product generation of steam. The isolated plant used to sell steam as a by-product, and what we are talking about now is electricity as a by-product.

Mr. Orr, will you close the discussion?

*Mr. Orr:* I would like to see Mr. Kastens' idea carried out if we can give some further time at a later session and have everybody glance through this report in the meantime. I don't believe you have had much opportunity so far to really read it. There are a great many points that have been raised by the various gentlemen here that have really been covered in this report, although I had no time to read them.

Mr. Walker's first question was with regard to that paragraph on operating customers' heating plants. Well, that is probably an unimportant point. In Chicago, as large and wonderful as it is, we still have an antiquated heating system, and that is the only method we have of operating customers' heating plants, so we think, probably, we can get along. We have the feed lines tied up pretty well. (Laughter.) For example, we just analyzed the situation and we have a peak load divided among the four separate plants of about 12,000 horsepower now. We could tie that in very nicely with 30,000 horsepower in an outside station and utilize those stations for a few months in the year with a very low investment charge and a very favorable set-up for the entire year in connection with a new plant. In other words, we would operate a new heating system at a very high load factor and utilize these small plants as peak capacity.

The question of superheating the steam I believe Mr. DeWolf covered. In the high back-pressure operation there is a slight amount of superheat. In the case analyzed here it shows about 27 degrees of superheat as the steam exhausts from the turbine blades. Therefore, it would be unnecessary to put in a re-superheater. Mr. DeWolf didn't explain it, but I believe he uses a new system of re-superheating, using steam instead of a re-superheat boiler.

Now, as the report brings out, this question of capacity credit is very much debatable, but the point is that we have got to sell this idea to the electric company in order to bring our costs down, and whether they will grant that credit or not is really immaterial in the long run. The saving of heat is there regardless of whether they admit it in black or white or not, and they can't lose by it.

Mr. DeWolf's question about the secondary energy charge being based on the most efficient plant is pretty well taken; that is covered in another paragraph which I did not read. In reality, I don't believe that it should be based on the most efficient plant. During the highest peak, half-hour load, there are any number of small stations, antiquated stations you might call them, that have to be brought into service, and the cost of that energy is many times what it is in the latest generating stations.

I believe that is all I have to say.

*President Shultz:* I would like to make one suggestion in regard to this paper. It seems to me that whereas this subject touches so closely upon the operation of the electric stations, we ought to get this paper before the electric operating men, and I think it would be very helpful if the member companies here would secure from Mr. Gaskill some extra copies and distribute them to your electrical operating men. I think it is rather interesting to notice that the men in our Association, like Mr. DeWolf and Mr. Walker, who represent both sides of the problem, are the ones who can see the most in this theory.

We are getting along very nicely with the schedule of our program, and I feel confident that we will have some time Friday morning for a further discussion of this report, so if you will look through it between now and then, we will give you some time for further discussion.

We still have a few moments and I am going to ask Mr. March, the Chairman of the Hot Water Committee, if he is here, who stated his report was fairly short, to present that report now. Is Mr. March here? Mr. March evidently isn't here so we will have to pass it over to the regular order of business.

I would like to announce the Committee on Resolutions. Unfortunately, we have had some deaths among our members and there are probably other matters that ought to be covered by resolution. The Resolutions Committee will consist of:

Mr. E. L. Wilder, Rochester;
Mr. Davis S. Boyden, Boston;
Mr. D. L. Gaskill, Greenville;

and I will ask them to prepare such resolutions as we should present at this Convention.

*Secretary Gaskill:* I have a telegram that I want to read. Some of you met Mr. Margolis, of Hamburg, Germany, who is very much interested in the work of the heating companies of this Association. He belongs to it as a Class C member, and yesterday morning, just before the Executive Committee was in session, we received this cable from him: "Very best wishes for a successful Convention. Margolis." That was sent from Hamburg, Germany. Mr. Margolis has contributed to our program and a magnificent set of photographs came in this morning to the President. I have a balopticon here at the hotel which I want to get some boys to get busy and set up immediately after this session is over, and I think we will be able, if the balopticon works all right, to show those photographs this evening in the talk.

*President Shultz:* Mr. Gaskill said that he always got the last word at you; he forgot it was the privilege of the presiding officer to say, "The meeting now stands adjourned."

Adjourned at 4.40 P. M.

tives of the Duquesne Light Company, are not in the class that have to be sold on steam heating. They are already sold. That being the case and the condition that we are in, emerging from old plants into a new plant, puts us, so to speak, in the position of entering into a new era of steam-heating business. Our new heating plant, just alongside the old one, is designed sufficiently large to take care of the entire downtown triangle of Pittsburgh. The capacity of this plant when completed will be about 1,100,000 pounds, with one large boiler as a spare.

We are particularly interested in the by-product of electric generation in Pittsburgh. As I remarked this afternoon, the story of by-product electric generation as presented by Mr. Orr seems almost like reciting our own story. We are sold on it one hundred per cent, and it is hard for us to see how any could object if they have all the facts. We feel that customers in and around Pittsburgh are also becoming more and more sold to the idea of a steam rate based on the actual value of steam rather than the old idea of steam as a by-product of electricity. With these conditions existing, we feel that it is perfectly legitimate to say that the steam business is healthy and we have every reason to believe that we may expect great things of it. (Applause.)

*President Shultz:* Mr. DeWolf will now present the story of the Rochester developments. Mr. DeWolf. (Applause.)

*Mr. DeWolf:* What Mr. Stevenson has just said about the Pittsburgh situation applies to a very large extent to Rochester, and the points that Mr. Orr brought out in his very excellent report this afternoon show some of the reasons why we in Rochester decided to go into this business as we have.

I've heard in recent years a great deal about the advantages of interconnection between different electric companies, and our executives appreciate those advantages very much better than they did a few years ago. The interconnection between the electrical business and the business of steam heating is, to my mind, just as important as the interconnection between electrical properties, and we can make just as great savings, relatively, through such interconnection as can be made in our super-power systems of which we hear so much.

I think that the companies in the electrical and steam business,—and those who are not in the steam business are going to get into it,—are now facing an era of competition which will be very different from the competition that we have had in the past fifteen or twenty years in getting electrical business. Our competition in getting electrical business in the past has been principally with isolated steam plants which were designed from fifteen to twenty years ago, and we had to supply power at a cost as low or lower than those plants could supply the power to their industrial or downtown building establishments.

We have now developed the production of power in our own power plants to a very much more economical point than it was fifteen or twenty years ago, and the consulting engineer who is building the isolated plant hasn't stood still in the meantime, and he is not going to stand still in the next five or ten years; and, as I say, looking into the future, we feel that we are coming into an era of competition that will be more severe than we have had in the past. Powdered fuel, high pressures, and the other advancements that we have made in our own plants are going to be copied by the isolated plant, and if we are not in a position to take advantage of the same combinations of load and the same operating economies that the isolated plant will be in a position to make, we are going to lose not only heating business, but we are going to lose electric load business.

In Rochester we feel very thoroughly convinced that these conditions are facing us. I might say that we are considering a case now of a large industrial power user. It is not a question with that user as to whether the new plant that he will have to have on account of the growth of his business is going to be purely a heating plant or a heating and generating plant; if he builds the plant, it will be a heating and generating plant. The only question is as to whether he is going to build a plant at all or whether we will furnish him everything that he would have to get out of his own isolated plant.

I think we are also coming into a new era of methods of central station heating. Mr. Orr's report has brought out very clearly the advantages of the combination of electric generation along with the heating business. Pittsburgh and ourselves are fully in accord on that point. I think we are going to see the use of materially higher pressures than we have in the past and the possible development of the distribution system along lines somewhat parallel to our electrical distribution system. That is, we will have high-pressure feeders which will supply steam as a feeder line only, not as a service line, to different points in the system, and I believe it is thoroughly practical to put a turbine on the end of those feeder lines, exhaust that turbine into your low-pressure system, and operate that turbine without any operators.

Our distribution system in Rochester, which we put in last year, was designed along somewhat different lines than usual. We have laid out a two-pipe system, high pressure and low pressure. The low-pressure system is designed to carry about 80 per cent of the maximum heating peak that we will get; the other 20 per cent will be carried on the high-pressure system, the high-pressure system feeding into the low-pressure system at the far end of the low-pressure lines through reducing valves. In this type of design, what you really do is to decrease the size of your low-pressure system below what it would be if it were a straight low-pressure system, increase the size of your high-pressure system above what it would be if you used it solely for supplying the absolutely necessary high-pressure steam of the district, and by this means I think you get a cheaper combination than you would get in any other way of supplying the district with both high pressure and low pressure.

The plant in Rochester has not been in operation long enough to give you any very accurate figures. In general, it is performing as we expected. We have shown that we can put steam into the distribution system at the plant when that plant is operating at a load somewhere near the designed load, at a total cost, including all plant losses, plant auxiliaries, etc., of not more than thirty cents per thousand pounds.

Among the advantages that the electric utility derives from a combination with steam heating I might enumerate some as follows: In the first place, the heating peak comes on at the same time of year as the peak on your electric system. Therefore, when you put in your non-condensing generating plant, the capacity that you put into that non-condens ng plant is available for the generation of electricity during the peak load of the year. With the modern types of non-condensing turbines that have been recently developed we can get very efficient production of power in this way.

The turbine installed in Rochester is an 11-stage machine, and we can get from 35 to 40 kilowatt hours per thousand pounds of steam delivered to the turbine; and this, in turn, means that on the usual load factor that you get on your heating business you will generate about 77 or 80 thousand kilowatt hours per year per thousand pounds of peak send-out on your low-pressure heating system. Now, you can turn that power out at considerably less than 5,000 B. T. U.'s per kilowatt hour, and that has the mercury turbine or anything else that we have developed up to date backed clear out of the picture; and I don't think that our utility managers can afford to overlook the economies that can be gotten through generation of this type, even though the total generation may not be a large percentage of the total generation of the electric utility.

Another advantage which can be gained in certain cases is due to the location at which you can put in these non-condensing units. We have built this plant in Rochester as an electric substation, as well as a steam-generating plant, and that electric substation is tied in to the 220-volt distribution system at that point. We supply from this substation certain large buildings in that district and we feel that we are giving the electrical customers in that district a considerable advantage in that we have provided automatic equipment so that in case of a major system disturbance on our electric system, which would result in a shut-down or partial shut-down of our electric system, this substation, together with its non-condensing turbine, will automatically cut loose from the rest of the electric system and will continue to give electric service to that district into which it is feeding directly through the low-voltage distribution system coming out of that station. That, in certain types of buildings where the danger due to loss of light or loss of power, with possible panics and so on, is an advantage that we feel is quite important.

We expect to go ahead with our development in Rochester. We are figuring on new developments, not only in this downtown district, but also in the industrial manufacturing district. In an industrial district of this character you have a somewhat different condition from the downtown district, particularly if you are fortunate enough to have some manufacturers who use a large amount of steam for process work. If this is the case, you can get load factors on your plant that are materially better than the load factor of a straight heating plant, because your plant in the industrial district will be supplying steam for the industrial process work 12 months out of the year and very often 24 hours a day for six or seven days out of the week.

This brings us, then, to another phase of this problem, which is that your rate system must be made such that when you come to go into an industrial district of this character, which has a load with a materially better load factor, your rate system must take care of the situation so that you give the industrial user a rate that is somewhat lower than you give in the downtown district, with its poor load factor. With such a rate system—and I think that the consumers in such a district will be willing to pay a fair rate—I see no reason why it is not entirely practical to go ahead with the development of plants feeding relatively small areas and perhaps widely distributed from each other, a sort of a decentralized system of steam and power generation.

In the plant feeding the industrial district you have the same advantage, so far as the generation of power in that plant is concerned, that you have in the downtown district, and you can furthermore give your industrial customers in that district a greater protection to their service through the connection of this heating plant on to their electric load, so that in case of a disturbance on the main electrical system their service will continue from the steam plant without interruption. (Applause.)

*President Shultz:* I will now ask Mr. Butler to read the short paper which Mr. Margolis has sent us on "Central Heating in Germany." Mr. Butler.

*Mr. Butler:* I will first read Mr. Margolis' letter to Mr. Shultz.

"Mr. Earle Shultz, President,
"National District Heating Association,
"Convention of the N. D. H. A.,
"Niagara Falls, N. Y.
"Dear Sir:

"When sailing home from the U. S. A., I had the intention of writing an account of district heating in Germany for you as soon as possible. But, on arriving, I found the conditions worse than I could imagine. I had such a lot to do and so many troubles that I did not find the time to gather my English knowledge in a logical article. So please excuse the delay and do not think I have forgotten my American friends; on the contrary, I often think of the interesting plants and of the great kindness I found everywhere in your wonderful country.

"I send you herewith a short account of district heating in Germany, with pictures and catalogues that may be of interest to you. Another article, explaining why the combined plants are preferred in Germany, will follow.

"I am sorry I cannot join you at the Convention, but my thoughts are with you, and I send you my best wishes for great success in your work.

Mr. Woodruff, of Rochester, has written a splendid report on the Rochester Plant, which I am sure you will all enjoy, so I will call upon Mr. Woodruff, of Rochester, to give his paper.

*Mr. Woodruff:* I can't give you the page number, because this report hasn't been printed yet. We were waiting for further information and didn't have time to get it to the press.

Late in the fall of 1924, after a careful study of conditions, the Rochester Gas & Electric Corporation decided to build a central station heating plant to serve the business section of the City of Rochester. A plot of land approximately 225 feet long and 65 feet wide was obtained. This land is centrally located with respect to the territory to be served, and runs from one street to another. The present plant occupies approximately half of the plot. The remaining half will be used for a duplicate plant as soon as load conditions warrant its erection.

In obtaining data on which to base the design of the plant, a very close study was made of the records of the company's Station No. 3, from which for many years steam has been furnished for heating and industrial purposes to a large industrial area adjacent to the station.

From these records load duration curves were plotted and a very accurate analysis of heating conditions in the City of Rochester was made.

The design of the station, which was done by the company's own Engineering Department, under the general direction of Mr. R. D. DeWolf, was made from this analysis.

Construction work was started March 1, 1925, and the plant was first put in operation October 15, 1925.

Due to the fact that the plant has been in operation but a short time, and also to the fact that it was, through necessity, put into operation before the full complement of instruments and gauges, by means of which the operation of the station will be checked, were installed, very little operating data is available. Therefore, this paper must necessarily be somewhat of a plant description. However, such operating data as we can consider authentic will be interspersed throughout the paper.

Due to the lack of railroad facilities, the coal is brought to the plant in trucks. The trucks upon arrival at the plant are driven upon a turntable which turns them to the proper position for dumping. The coal is dumped into the basement bunkers, of which there are two. These bunkers are of reinforced concrete and have a capacity of 400 tons each. The plant is not equipped with crushing or weighing apparatus. The crushing and weighing is done at one of the other stations.

From these basement bunkers the coal is delivered by means of chutes to two twenty-five ton apron conveyors; these convey coal to two twenty-five ton belt conveyors, which carry it in a direction at right angles to the apron conveyors and deliver it to a bucket conveyor which, in turn, elevates it to a three hundred ton cast iron bunker in the top of the building. The apron conveyors run over magnetic pulleys which remove such tramp iron as may be present. From an operating standpoint this coal handling equipment has been very satisfactory; no maintenance has as yet been necessary, and there are no indications that trouble may be expected.

The conveyors are all motor driven, and are equipped with interlocks so that the apron conveyor cannot be started unless the bucket conveyor is in operation.

From the bunker the coal flows through chutes, by gravity, to the feeders, which deliver it to the pulverizing mills. These feeders, which are of the roll type, are driven by constant speed motors, the amount of coal fed being regulated by means of a ratchet and pawl. The pawl is equipped with a magnetic lift, which is operated automatically to prevent further feeding of coal in case of an overload in the mill or a mill shutdown.

Some trouble was at first experienced with these feeders not feeding uniformly. This was remedied by putting a spring on the leveling plate. This spring maintains a constant pressure on the plate and keeps a constant thickness of coal on the rolls.

The pulverizing mills, of which there are three to the boiler, are of the impact or hammer type. Two of these mills have a capacity of 7,000 pounds of coal per hour, and one has a capacity of 2,000 pounds per hour. They are driven by constant speed A. C. motors, and will pulverize sufficient coal to operate the boilers at 400 per cent of rating.

The small mill has a feeder and exhauster built in as an integral part of the mill, while the large mills have separate exhausters mounted on the floor above the mills. The exhausters are driven by variable speed slip ring motors. The speed of these motors is varied as the rate of coal feeding changes, and very close regulation can be obtained.

Maintenance has been found to be much higher on the small mills than on the large. It has been found necessary on the small mills to change the hammers after approximately each 600 tons of coal pulverized. The large mills have pulverized to date over 2,600 tons of coal with no maintenance. It is estimated that over 4,500 tons can be pulverized before hammer replacement will be necessary.

The coal passes from the mills through a classifier to the exhausters. The air that sweeps the mills and carries the coal is preheated, and at some loads represents 30 per cent of the air necessary for combustion. At rated loads on the mills 15 per cent of the air necessary for combustion is used.

The coal and air mixture is delivered from the exhausters to the burners in 12 inch pipes. These pipes are in the form of a gooseneck. This construction was necessary, as the burners are arranged for vertical firing. As there are two burners to each large mill, it was found necessary to Y the pipe, one branch going to each burner. Considerable trouble was at first experienced in dividing the coal stream so that each burner would be getting an equal share of coal. This trouble was largely eliminated by placing a venturi nozzle in the main pipe just above the Y. The stream of coal and air passing through the venturi throat is split in the exact center by means of a thin plate. Tests show that regardless of the amount of coal and air flowing, it is divided fairly accurately and that each burner gets approximately an equal share of the mixture.

The burners are mounted on steel work and discharge vertically through the boiler arch. The burner of the small mill is on the centerline of the boiler, with the burners for the large mills located symmetrically about the same centerline. This gives a uniform flame distribution in the furnace with any of the mills in operation.

The arch is of special design, DeWolf construction being used. It is rigidly supported on four I-beams, and the vertically inclined portion is flexibly supported by rods so that the slab can swing in or out or rotate around the suspension to take care of the expansion of the arch itself or of the boiler. This feature eliminates a source of trouble in boiler settings, namely, that of keeping a good seal between the arch and the boiler. The motion referred to keeps the vertical arch always in contact with the boiler drums and with the horizontal portion of the arch.

The furnace walls are built of the same special DeWolf brick as is used in the arch, with the exception of the first three feet at the bottom, which is built of standard brick. The design of the side walls is somewhat of a departure from standard practice inasmuch as the lower 16 feet are corbeled in toward the furnace, the remainder of the wall being vertical. This is done to eliminate slag adherence. This feature of design has proven satisfactory, no trouble has been experienced from slag adhesion.

The furnaces have a total volume of approximately 10,000 cubic feet, or about .9 cubic feet per 10 square feet of boiler heating surface. The front portion of the side walls is 30 feet 6 inches high, and on the sides back of the arch, 41½ feet high. The design of the brick used is such as to provide that construction expansion, and repairs may be made at any point without disturbing the remainder of the wall. Six inch I-beams carry the weight of the walls in vertical sections 32 inches high, each section carried on an angle clip riveted to the I-beam. Any one of these 32 inch vertical sections can be removed without disturbing the one above or below it.

After the brickwork was in place, the entire inside of the furnace was Gunited. A layer of high temperature cement about ¼ inch thick was used. This made a very tight furnace, and to date shows no signs of failure.

This special furnace construction is particularly adaptable to design for furnishing preheated air. Secondary air openings are provided in the upper half of the front wall between each pair of 6-inch I-beams, the space between these I-beams being blocked off at mid-height. The secondary air for combustion is taken in at the bottom of the side walls, passes up through the space between the 6-inch I-beams to an air duct, which conveys the air to a duct along the front wall. Damper control is provided in this duct across the front of the furnace so that the air entering the space between the 6-inch I-beam and the front wall can be controlled.

Secondary air openings are also provided in six of the spaces between the 6-inch I-beams in the lower portion of the front wall. The air for these is taken in at the bottom of the front wall, dampers being provided in each vertical duct between the I-beams. The remaining eight vertical ducts between the I-beams in the lower portion of the front wall are connected to a common air duct from which preheated air is delivered to the pulverizing mill. Because of supplying this preheated air to the mill very wet coal can be pulverized without difficulty.

This preheated air was of so much assistance in handling wet coal and appeared to give so much better combustion, that an effort was made to increase the preheat. With the preheating done in the manner just described, the air came to the mills when carrying an average rating at 125 degrees F. Higher ratings gave higher preheat temperatures.

The temperature of the preheated air was satisfactorily increased by means of a home-made experimental preheater. This preheater was made by putting a sheet metal casing around the boiler uptake. The air is drawn down between this casing and the uptake. This increased the preheat 30 degrees F. at 100 per cent rating, and has proven so satisfactory that designs are under way to make a more adaptable and efficient preheater.

The side and rear walls of the furnace are equipped with water screen tubes. These tubes are a part of the boiler circulation.

The boilers, which are of the vertical water tube type, were manufactured by the Bigelow Company. They have a water heating surface of 11,219 square feet, and are five units deep; the front three units are eight wide, and the rear, two six wide. The rear six units comprise the economizer section.

By making the boiler narrower at the rear than at the front, more uniform gas velocity throughout the boiler is obtained.

The water screen receives water by means of 2 8-inch down-takes taken from the bottom of the D unit by means of 4-inch nipples, one down-take at each side of the boiler. These down-takes supply water to both side and rear water screens.

The side wall screens have at each side of the boiler, at the bottom of the furnace, an 8-inch header; from this header 10 4-inch tubes 26 feet 2 inches long, spaced on 18½-inch centers, go up to an 8-inch header on each side of the furnace at the top. These headers lead up to the top drum of the C units, and are connected by means of 8 4-inch nipples.

The rear water screen is composed of 2 8-inch headers, and has 7 4-inch tubes passing up the rear wall, spaced on 29-inch centers. These tubes run to junction boxes back of the A units. These junction boxes are connected to the top drum of the A units by 7 3¼-inch tubes. These tubes pass up between the front row of A units in such a manner as to replace the standard baffle. All water screen tubes are located ½ inch clear from inside of furnace wall.

The gases, after passing through the boiler, are carried by means of a vertical up-take to the low pressure economizer. The economizers are of the baffled type and have 4,707 square feet of surface. From these economizers the gases pass to an induced draft fan. A by-pass is also supplied, which carries the gases directly to the stack. The induced draft fans are supplied with a rather unusual drive. A 15 H. P. motor drives the fan from about 250 per cent of boiler rating to about 300 per cent of rating, natural draft being used up to 250 per cent of rating. Above 300 per cent rating a 75 H. P. motor drives the fan up to 400 per cent rating. Slip-ring variable speed motors are used, driving through spur gears.

The smaller motor is in gear at all times; a magnet clutch is provided between the large motor and the gear, and it remains disconnected except at high ratings. When the small motor is driven above synchronous speed, it is automatically disconnected from the line by a reverse power relay.

It has been found necessary to use the induced draft but once since the station was put in operation. The stack draft operating through the by-pass ordinarily being sufficient. The stack, which is of reinforced concrete construction, is 9 feet in diameter and rests on the roof steel 82 feet above the street level. The height of the stack above the roof is 170 feet, thus giving approximately 240 feet of effective stack height.

The ashes are removed by means of a steam jet ash conveyor, all the ashes from various points being brought to a main receiving tank. Three hoppers are supplied for ash collection, one under the furnace, one in rear of boiler, and one under the economizer. The one under the furnace is equipped with a hydraulic gate. The ashes are dumped into a receiving hopper and thence removed to the main tank by means of the steam jet ash conveyor. The steam jet conveyor acts directly as the hoppers under the boiler and economizer.

Considerable ash is deposited in the base of the stack and in the horizontal run of the flue along the roof of the building. Attempts have been made to remove this by means of the steam jet conveyor, but this has proven ineffectual. Designs are being made for a scraper conveyor to do this work.

Trouble was at first experienced with this steam jet conveyor, but after a proper nozzle was designed and leakage cut, it functioned satisfactorily.

The water used is the regular city water, and of such quality, that any treating system was thought to be unnecessary. Careful examination of boilers, valves, traps, steam lines, etc., indicates that this assumption was correct.

A large tank in the basement receives the returns from the heating system, which amounts to from 25 to 35 per cent of the water used. The make-up also enters this tank. From this tank the water is pumped by means of low head pumps to the low pressure economizer. Two pumps are supplied for this surface, one motor and one steam turbine driven.

The pumps deliver the water directly to the economizers, which are somewhat novel in that they are designed to carry a maximum of 15 to 20 pounds pressure. The discharge headers of the economizers are connected to a tank which is placed directly above the economizer. In the tank there is a float which controls a valve in the line from the pump to the economizer and maintains a constant level in the tanks. Originally these tanks were designed to be vented into the main low pressure heating system, but it was found that at no time was there sufficient steam generated in the economizers to necessitate this, and they are now vented to the atmosphere.

This method of controlling water to economizer and tanks has been somewhat modified from its original installation. Originally the float valves were arranged to shut the water completely off from the tanks when the demand was small. Trouble was experienced from the valves tending to stick in closed position. In order to eliminate this hazard, a pipe line was run from the tanks at the level of normal water line to the tank in the basement. The valve was then so arranged that it could not shut the water off entirely, the water flowing in excess of the demand passing through this pipe to the basement tank.

From the economizer tanks the water flows to centrifugal boiler feed pumps, one motor driven 300 gallons per minute, and one steam driven 500 gallons per minute. These pumps are designed for 500 pounds pressure, but normally operate at 450 pounds. These pumps deliver the water to the boiler through feed water regulators.

The boilers generate steam at 375 pounds gauge, and are equipped with superheaters which give the steam 100 degrees of superheat, or a total temperature of 540 degrees.

From the boilers the steam goes to the main header. Two lines, one 8 inch and one 6 inch, go to the distribution system. The pressure in the 6-inch line is 100 pounds, and in the 8-inch line, 130 pounds. The pressure reduction in these lines from that of the main header is accomplished by means of reducing valves.

The steam for the low pressure system goes to the main turbine except at very low loads, when it is passed through reducing valves. The reduction from 375 pounds to 7 pounds is accomplished in passing through only one reducing valve.

The main turbine is located in the basement, and has a capacity of 3,000 K. W. generating at 4,150 volts and 60 cycles, and is designated to discharge steam at from five to twenty pounds back pressure.

The amount of load carried on the turbine is regulated from the back pressure, and varies as the steam demand on the system. This is accomplished by means of a pressure regulator acting on the governor of the turbine. The turbine is designed to operate automatically without constant supervision. Automatic devices are installed so that in case the lubricating oil reaches too high a temperature or the pump fails to deliver oil or the generator overheats or the machine is thrown out of balance and vibrates, the unit will be automatically shut down and disconnected from the bus. In this event, the reducing valves supply steam to the low pressure system.

The exhaust of the turbine passes through a coil reheater. High pressure steam is used for supplying the heat. Tests show that the temperature of the steam leaving the reheater is 40 degrees to fifty degrees higher than on entering. By supplying this superheat to the low pressure system, the condensation losses are materially reduced and gives steam of a quality that can be used for some industrial purposes.

The condensation from the high pressure steam used in reheating is trapped to the return tank.

All joints on the high pressure lines are of the Sargol welded type, and special heat treated bolts are used for all the flanges. This method of making joints has proven very satisfactory.

All of the operating equipment is located on one floor. This allows a minimum of operating labor, one man and a helper being sufficient. On the operating floor are located the exhausters for the large pulverizing mills, the coal feeders for the large mills, the boiler feed pumps, the control for the induced draft fans, and the necessary switchboard and instrument panels for the operation of each individual boiler and its equipment. The control panels are grouped so that one operator can easily handle all the equipment. The control panels include the usual pressure instruments, draft gauges, meters, $CO_2$ Recorders, etc. From this control point, the water glasses of the boiler are also visible. The control floor is nearly on a level with the top of the boiler. The water level in the glasses can be very easily seen. The condition of the fires can also be seen from this floor, observation being taken through the burners.

Smoke indicators are also supplied, by means of which the operator can observe the conditions of the stack without leaving the control floor.

This station has met the designers' expectations with reference to flexibility in carrying light and heavy loads. One boiler has been operated at ratings as high as 86,000 pounds of steam per hour and as low as 6,000 pounds per hour. The mill sizes were selected with this in view. It was originally expected that the 2,000 pound mill would carry the load up to a certain point, and then one of the large mills would be cut in. In actual practice it was found that there was a gap between the upper limit of the 2,000 pound mill and the lower limit of the 7,000 pound mill. This variance seemed to be caused by a burner condition. To correct this, the burners of one of the large mills were equipped with adjustable tips by means of which the opening at the tip of the burner could be varied. This accomplished the required results, and since the change was made no trouble has been experienced from this source. When light loads were carried with only the small burner in operation, some trouble was experienced from loss of ignition and failure to burn the larger particles. Studies of the situation disclosed the fact that the secondary air entering through the front wall was causing the trouble. Arrangements were made whereby all of the air for combustion was admitted through and around the burners, all of the dampers admitting air through the front wall being closed and precaution taken to cut down the leakage through the setting. Since this has been done, the equipment has performed with gratifying results on light loads.

Considerable experimenting was done on the mills to determine the best setting of the classifier sleeve and the proper air flow through the mills. These two factors determine the fineness of the coal leaving the mills. It is extremely difficult to get an accurate sample of the pulverized coal with this type of mill. In conducting these experiments samples were taken by means of a pitot tube traverse of the exhauster discharge. This method, while not accurate, furnishes a convenient method of checking conditions of mills. Any change in mills, such as wear or breakage, shows up as change of fineness of the coal.

Samples are analyzed by means of a Rotap Machine.

After the air flow and classifier sleeve was adjusted, coal of such fineness as to give good results in firing was obtained. Observation showed that the amount of coarse coal, i. e., that which would not pass through a 30-mesh screen, was very low.

The power consumption and time in service of the mills for the month of April is as follows:

| | No. 1 Boiler | No. 2 Boiler |
|---|---|---|
| Small mill operated | 255 hrs. | 458 hrs. |
| Large mills operated | 221 hrs. | 454 hrs. |
| Total hours operation | 476 hrs. | 912 hrs. |
| Total coal burned | 455 tons | 928 tons |
| K. W. H. used by mill exhauster and feeder | 8,710 | 15,770 |
| K. W. H. per ton | 19.2 | 17 |
| Average feed per hour | .96 tons | 1.02 tons |
| Per cent rating on boiler | 72.8 | 97.2 |

Weekly average figures taken during the same month are as follows:

| | | | |
|---|---|---|---|
| Small mill operated | 166 hrs. | 167 hrs. | 144 hrs. |
| Large mills operated | 168 hrs. | 167 hrs. | 152 hrs. |
| Total hours operation | 334 hrs. | 334 hrs. | 296 hrs. |
| Coal burned | 367 tons | 345.7 tons | 395.5 tons |
| K. W. H. used | 6,040 | 3,680 | 5,300 |
| K. W. H. per ton | 16.5 | 16.4 | 18 |
| Average feed per hour | 1.1 tons | 1.04 tons | 1 ton |

This load is distributed 75 per cent to the mill and 25 per cent to the fan.

It will be noted in these tables that the mills were operated at very low capacities. The rated capacity of the mills is 9,000 lbs. per hour, while the average load was slightly over 2,000 lbs. per hour.

This power consumption is very good considering the operating conditions. The power consumption will be materially bettered when larger loads are carried.

A representative heat balance with a boiler operating at 150 per cent rating is as follows:

| | |
|---|---|
| $CO_2$—14%. | |
| B. T. U. per lb. of coal as fired | 13,400 |
| Temperature of entering condensate | 192 degrees |
| Temperature of entering make-up | 83 degrees |
| Temperature of feed entering economizer | 110 degrees |
| Temperature of feed leaving economizer | 145 degrees |
| Average pressure | 325 pounds |
| Average superheat | 75 degrees |
| B. T. U. per lb. of steam | 1,257 |
| Net B. T. U. added by econ, boiler and superheater | 1,179 |
| Temperature of air entering furnace | 90 deg. F. |
| Temperature of gas leaving boiler | 425 degrees |
| Temperature of gas leaving economizer | 260 degrees |
| Evaporation of 8.5 pounds of steam per pound of coal. | |

The evaporation obtained from January 1 to May 1 averaged 8.02 pounds of steam per pound of coal.

This record was taken during the time when the station was partially under construction and, as has been stated, before proper instruments were installed, and at very light loads for considerable of the time, and while it is not high, it leads the designers to be optimistic as to the efficiencies that can be obtained in the future.

The steam send-out of the station has been distributed as follows: 20 per cent to the high pressure lines, 80 per cent to the low pressure lines.

The steam entering the turbine contains 1,285 B. T. U.; when exhausted, it contains 1,139 B. T. U. at 7 pound back pressure 98 per cent quality; in reheating it gains 35 to 40 B. T. U.

The distribution system consists of high and low pressure lines with a return line for the condensate. The low pressure line is designed to take care of approximately 80 per cent of the maximum demand when the outside temperature drops to zero. The other 20 per cent is supplied through the high pressure system by means of reducing valves at the far ends of the system. This method reduces the investment in the low pressure system and gives a relatively inexpensive method of taking care of peak loads of short duration.

The high pressure and low pressure steam pipes, and return lines, are enclosed in a concrete duct. Both steam lines are insulated with a laminated type of all-asbestos insulation, the return line being left bare. In addition to three pipe systems, a single low pressure line has been built through a district requiring low pressure steam only.

The maximum station output to date is as follows:

| | |
|---|---|
| Maximum month's steam output | 30,186,000 pounds |
| Maximum day's steam output | 1,300,000 pounds |
| Peak load over period of 15 minutes | 86,000 pounds |
| Peak load over period of 1 hour | 78,000 pounds |
| Maximum day's K. W. generation | 27,000 |

On the whole, this station is quite satisfactory to its designers.

Due to the type of architecture employed, which harmonizes with the surrounding buildings, its smokeless and noiseless operation—to get noiseless operation the machines are mounted on cork foundations—the plant, although it is in the center of the business district and adjacent to the city's finest hotels, has been accepted by the people of the city as a valuable addition to the section. (Applause.)

*Chairman Seiter:* There is a very large amount of data massed in this report, and all of the papers have been of extreme interest. The tests which were run on air heaters are particularly interesting, in that preheaters have not generally been used in this country. We find, however, that in England they are used quite generally and very successfully. There services there should warrant more study in this country.

Is there further discussion?

*Mr. Felger:* I have just a few words to say in closing. We have made a heating plant questionnaire that is completed and isn't included in our report at the present time. It will be taken up by the Executive Committee to find out just how this will be treated. But I wanted to mention this because I know there are some here who have contributed to this questionnaire, and I suppose they are wondering why we haven't said anything about it.

Thank you. (Applause.)