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THE KENDALL SQUARE STATION

A Combination Steam-Heating and Electric-Generating Plant

R. D. Stauffer

(In this paper the author describes the Cambridge, Mass., company's new steam-electric plant equipment and tunnels and explains why they were built.)

INTRODUCTION

Several years ago, when the Kendall Square plant was projected, the Cambridge Electric Light Company had only sufficient generating facilities to produce about half of its kilowatt-hour requirements. The Boston Edison Company supplied the other half of these requirements. For a number of years, the Cambridge company was able to purchase this substantial portion of its requirements at an attractive price. However, after the war period, when the loads of all utility companies were showing a rapid increase, the Boston Edison Company found it necessary to add capacity to its system at high post-war construction costs, and, therefore, it was no longer in a position to offer power to Cambridge at the attractive price which prevailed before the war.

The Cambridge Gas Light Company, an associate company of the Cambridge Electric Light Company, has its gas plant located in East Cambridge, adjacent to the Charles River basin. A portion of this plant site, facing the Basin to the east, and bordering on Broad Canal to the south, was unoccupied, and was an ideal location for a new generating plant. In addition to its being at the best possible available location in the Cambridge franchise area, it was situated in an industrial area, surrounded by many manufacturing plants, requiring large blocks of electric power and process steam. This made it possible to provide a combination steam-heating and electric-generating plant, which could furnish both services. As all engineers know, electric power can be produced a great deal more cheaply if the heat in the exhaust steam can be sold, instead of being dissipated in the cooling water supplied to the condenser.

The Cambridge Steam Corporation, also an associate company, had for some years been furnishing process steam to some of the manufacturing plants in the area, this steam being supplied from the gas works' boiler plant. This meant that the new plant could take over the steam load of the gas works, as well as the steam customers already being supplied from this plant.

Immediately after it was announced that the plant was to be built, a twenty-year contract was secured for both electric power and steam supply from one of the large neighboring industrial companies, who had for years supplied its electric and steam requirements from its own plant. Since then, many of the other manufacturing plants have been connected or have applied for steam service.

The plant is located so that, with a minimum of expense and construction, it is tied directly into the 13,800 volt underground system of the Electric Company. This eliminates the need for a step-up substation, which is usually a part of a generating station. The location of the plant makes it possible to receive coal or fuel oil by rail, barge, or truck.

The initial unit of the plant will have two boilers, each having a rated capacity of 200,000 lb per hr of steam, and one turbine-generator unit, having a capability of 20,000 kw. The plant is designed for operation at 1300 psi at the turbine throttle, and 900 F total steam temperature.

PLANT DESCRIPTION

The plant is designed to burn either pulverized coal or fuel oil, depending upon price and availability of these fuels. Coal-handling facilities are provided, which include an unloading track hopper and an inclined belt to a crusher and transfer house. The crusher can be used, should there be run-of-mine coal, or by-passed with slack coal. A second inclined belt conveyor carries the coal to a coal bunker in the Station. From the bunker, coal is fed to Babcock and Wilcox pulverizers, two of which are provided for each boiler. The boilers are of Babcock and Wilcox manufacture and are of the Stamford type, having a large furnace volume. The furnace is entirely water-cooled, having touching tubes. Each boiler is provided with a superheater, economizer, and air preheater. Gases from the boiler units pass through a Cottrell electrostatic precipitator to the induced-draft fans, and then to the brick chimney. Oil storage facilities include a 1,250,000 gallon storage tank, adjacent to the plant with a heater at the tank, and oil pump and heater facilities in the plant.

A Westinghouse turbine-generator, having a capability of 20,000 kw, and having a direct-connected exciter is provided. The turbine exhausts to a Westinghouse condenser having the usual auxiliaries, including vertical circulating-water pumps. The turbine is of the extraction-condensing type, taking steam at the throttle at 1300 psi and 900 F, and exhausting to the condenser at 29 in. of vacuum. An automatic extraction opening, at 200 psi, supplies the required amount of send-out steam to the steam distribution system. In this way, full electrical load is carried on the generator regardless of the amount of steam required for the steam-distribution system.

Since the industrial plants supplied with steam are not able to return condensate in the full amount of the steam supplied to them, a large amount of make-up water must be provided. For this purpose, Cambridge city water is treated by a Cochrane hot-process water-treating plant, complete with filters, treating tanks, and all auxiliaries. The water-treating equipment is guaranteed to produce water of sufficient purity for the high-pressure boilers. Two Cochrane deaerating feed-water heaters are provided, which receive condensate from the surface condenser, as well as the make-up water from the water-treating plant. In the deaerators, water is heated to about 215 F, and from these heaters it goes to the boiler-feed pumps, which pump the water through two closed feed-water heaters on the way to the boilers. The first heater receiving the water at 215 F heats it to about 273 F, and the second heater raises it from this temperature to about 383 F.

HEAT BALANCE

The large percentage of make-up required for this plant had a very decided bearing on the heat balance selected. Studies indicated that the best method of taking care of the large exhaust-steam requirement was to provide sufficient steam-turbine auxiliaries to produce the required amount of steam. These auxiliary turbines receive steam at 200 psi taken from the same steam mains as the send-out steam. The three boiler-feed pumps are turbine driven, the turbines exhausting at 3 psi into the deaerating heaters and the hot process softeners. The turbines driving the induced-draft fans, and those driving the turbine oil pumps, exhaust at 35 psi into the low-pressure closed heater. The high-pressure heater receives 200 psi steam directly from the send-out main.

The boilers blow down into a flash tank, steam going to the hot-process softeners, and condensate flows to a blow-down heat exchanger, which heats the make-up water on its way to the water-treating equipment.

BUILDING

Power-plant buildings to house the equipment are usually too expensive. They generally cost approximately 25 per cent of the total cost of the project and, in these days of high cost of construction, frequently amount to an even larger percentage. As construction costs have doubled since prewar days, and utility rates have remained the same or, in some cases, have been reduced, it is doubly important that new projects be made as economical as possible, especially in the case of the plant building or other items of equipment which do not contribute to the efficiency of the plant.

Since the Kendall Square plant is located on a parkway, facing the Charles River basin, it was essential that the building be attractive, to be in keeping with other buildings being erected in the area. This meant that the problem was to make an attractive building as economical as possible. In addition, the building had to be waterproof, to withstand the northeast storms common to the area. To accomplish these goals, it was decided to use Dri-Speed wall tile of buff color, and to make the walls only 8 in. thick. This required that they be carried on spandrel beams at least every 20 feet. However, the normal floor and platform levels in the plant occur about every 20 feet, so that the provision of the spandrel beams did not present a difficult problem.

STEAM TUNNELS

In order to reach the larger steam customers, it was necessary to construct a steam main for a distance of about 3,000 feet. The main is located underground, running through the gas works' property and in the sidewalk area of one of Cambridge's streets, crossing other streets on the way. At each intersection, provision was made for branch-line connections for future extensions. It was determined that one 16 in. steam main, and one 8 in. return would be provided initially, with additional space for a second 16 in. steam main in the future. Initial design of the tunnel provided for a rectangular reinforced-concrete conduit 4′-10½″ in width and 7′-0″ high. Preliminary estimates covering the concrete tunnel construction indicated that it should cost about $75.00 per linear foot. After about 700 feet had been constructed, a check made on the cost showed that it would cost between $100.00 and $125.00 per foot. At this point, it was decided to discontinue constructing any further rectangular reinforced-concrete tunnel, and use instead a flat conduit with removable cover in certain places, and a precast concrete pipe for other areas. The flat conduit was used for street crossings, where there were interferences by sewer, water, or other utility services and, in other locations where the top surfaces could be disturbed in the future and the covers lifted for maintenance or for the installation of the future 16 in. steam main. In other locations, a 5-ft diameter precast concrete pipe was used as a tunnel which will permit installation of the future steam main.

The plant is arranged so that it can readily be extended for additional boiler and turbine equipment. The second turbine unit is scheduled for delivery in August of next year. This means that construction will be started on extending the turbine room and electrical bay early next Spring.

J. C. Butler: Does the paper show costs, including breakdowns of plant equipment and building costs per pound of capacity?

R. D. Stauffer: No, I merely tried to hit the high spots. Incidentally though, costs have gone up as everybody knows these days, so when we designed this plant we started to make it an oil-burning one to save the cost of the coal- and ash-handling equipment, precipitators and pulverizers. When we began ordering equipment there was a three-year delivery on turbines. We did not order any of the coal-handling and burning equipment which costs around half a million dollars until two years had gone by and we had just about a year left which would permit us to get delivery on the coal equipment.

A year or more ago you could not beg or borrow oil for burning under boilers. There was just enough for gas manufacturing and other purposes, so we had to put in coal equipment. We just got it all erected when oil suddenly became very plentiful with a corresponding reduction in price. We are now buying oil which costs us delivered in barges about $1.71 a barrel and if we bought coal it would cost something over $11 per ton, so you can see that the coal-handling equipment is not going to get much use for the first couple of years.

John P. Gallagher: How many men do you figure to operate the plant?

R. D. Stauffer: We have in mind four operators per shift, a plant chemist and a chief, and when we burn coal we probably will have two additional. This does not include the maintenance crew which will be shared with the older station.

John P. Gallagher: Will the blow down be continuous or intermittent?

R. D. Stauffer: We expect it will have to be continuous.

John P. Gallagher: How about gas temperatures? You said water at 385 F.

R. D. Stauffer: There will be air preheaters after the economizers so we expect the exit-gas temperature to get down to 325 F.

John P. Gallagher: What will be the efficiency?

R. D. Stauffer: Just about 86 or 87 per cent.

John P. Gallagher: What will be the cost per kw of capacity?

R. D. Stauffer: With the first turbine unit we have twice the required amount of boiler capacity. A 20,000 kw turbine will not require more than 200,000 lb of steam per hour, which is the capacity of one boiler. Since there are two boilers of this capacity, the extra boiler is chargeable to steam heating. I would say the cost with the extra boiler capacity right now will be about $250 per kw, but after the second turbine is installed the cost will be down to about $140 per kw of capacity. We are not going to add a third boiler for some time, for with the gas-works steam plant there for backup we will not need a third boiler until the steam load increases quite materially.

John P. Gallagher: Did you save on your condenser?

R. D. Stauffer: Yes. There is only a 13,000 square-foot one.

John P. Gallagher: Normally this would be good for about 13,000 kw.

R. D. Stauffer: Roughly, yes, but we always will bleed steam for auxiliaries so it is big enough.

Albert R. Mumford: Since the Btu rate is less than 6000, what proportion of your throttle steam are you bleeding and do you hope to maintain that proportion?

R. D. Stauffer: That Btu rate was at maximum steam send-out. That is the reason it is so low. We expect it to vary from that point to about 9200 Btu per kwhr, depending on how much steam is being used for send-out. Of course that will vary between summer and winter, Sundays and weekdays, etc. Maximum steam send-out is about 200,000 lb per hour.

The turbine generator is designed so that we can get full electrical load on the generator with no steam bled for send-out, in which case more steam is condensed or we can get full kw load with the maximum bleed to send-out and only a very minimum of steam to the condenser.

Carl D. Zimmerman: Is the electric load controlled mainly due to the steam send-out and how is it fitted in with other stations?

R. D. Stauffer: I should point out that this plant is not operating yet. We expect to put steam through the turbine next week. So far we have one boiler operating. We expect to control it entirely on the electrical end. This will be the most efficient unit we have and when the electric load is available it will run at full load. We will bleed whatever steam is required.

E. E. Dubry: Suppose the turbine is down, how do you use the 1500 psi boiler pressure?

R. D. Stauffer: We have a pressure-reducing and desuperheating station for that purpose and then, as I said before, we have the gas-works plant which we will keep for awhile as back-up. After next year when we have the second turbine we hope not to have the two turbines out at one time.

J. C. Butler: What do you expect to get for steam being sold from this station?

R. D. Stauffer: That is a little difficult to answer because we have a steam rate that has a demand and energy feature and it will depend entirely on the load factor for the particular customer. What we will try to do, since condensing-plant efficiency is less in the summer when circulating water is warm, is to secure additional steam load at that time, but it is the time of year when most people use the least. To encourage steam use in summer for air conditioning and other processes we have made a rate that has quite a heavy demand feature. To answer your question I would say that with coal cost at $8, it might run somewhere between 70 cents and 90 cents per million Btu unit depending on the load factor.

J. Edwin Koch: What percentage of operating costs do you figure on charging to steam sales?

R. D. Stauffer: What we expect is that the steam revenue will pay the Steam Corporation its operating expenses and fixed charges plus a very small overhead, and all the rest of the revenue will go to the Electric Company.

Chairman Prestwich: Thank you, Mr. Stauffer for a very good and an enlightening paper. When a new installation is completed and placed in commercial operation by a company, it is of much interest to the industry to have a knowledge of it and of its idiosyncracies as an aid in engineering studies of proposed equipment.

Next, R. G. Felger, Assistant Superintendent of Central Heating in charge of heating plants and coaling plants of The Detroit Edison Company, will describe one of their recent installations in his paper, "The Detroit Edison Company Installs a 200,000 Pound per Hour Boiler." Mr. Felger.

...Mr. Felger then presented his prepared paper...

THE DETROIT EDISON COMPANY INSTALLS A 200,000 POUND OUTPUT BOILER

R. G. Felger

(In this paper the author describes how a boiler having a capacity of 230,000 lb per hour was installed in an existing plant in a space that was originally planned for a boiler having a capacity of 95,000 lb per hr.)

The Willis Avenue Heating Plant is now the oldest plant in the central heating system of The Detroit Edison Company. Prior to 1903, when the Central Heating Company was formed, this plant had been operating as an electric power station. Later it was decided to utilize the exhaust steam from the generating units for heating buildings in the neighborhood. This was the beginning of the Central Heating Company. A franchise was obtained from the City, permitting the Company to