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District Heating in Denmark

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Copenhagen

The first district heating systems in Denmark were commenced in the capital, Copenhagen, in 1925. At that time there were two old electric power stations within the city, the Gothersgade Station and the Eastern Station, chiefly acting as reserves for the H. D. Oersted Works, a big power station which had just been built at the Souther Harbour. The working pressure of the boilers of the two old power stations was 12 atm (176 psi). Since these boilers were reserves, and since the consumption of electric power in December was a maximum in the afternoon while the heat consumption was a maximum in the morning hours, by the end of January and in February the old boilers could supply a considerable amount of heat, without the power reserve being reduced too much.

At that time a study was made to establish power-heat production, utilizing first the boiler steam for production in back-pressure or exhaust steam turbines, and thereafter the low-pressure steam to heat circulating water for the heating of various buildings in the city. The existing boiler pressure of 12 atm (176 psi) was, however, too low for obtaining an economic profit from power-heat production. Furthermore, many of the first consumers—hospitals, industries, etc., were to be supplied with heat for special purposes requiring a higher temperature than could conveniently be used for circulating hot water.

The result of the considerations was that steam was used for a considerable part of the district heating systems. It was supplied at pressures of up to 12 atm (176 psi), while circulating water was used for a minor part of the systems, the flow temperature being up to 100 C (212 F).

In 1931 district heating was augmented by steam from the H. C. Oersted Works where the boiler pressure is 25 atm (368 psi). It was decided to supply boiler steam for district heating without combining it with power production. The steam mains have been calculated for a working pressure of 25 atm (368 psi) and a temperature of 400 C (752 F). The steam passes through reducing valves so that its pressure varies between 12 and 20 atm (176-294 psi) according to the season.

In 1933 developments necessitated an extension of the boilers at the Gothersgade Works. It was decided to build a plant with 50 atm (735 psi) boiler pressure and furnished with back-pressure turbines with a back-pressure of 6-12 atm (88-176 psi), the back-pressure being regulated according to the pressure required by the district heating system. Since then the greater part of the heat supplied from this station originates at the combined power-heat plant, so that from about 47 atm (691 psi) pressure at the turbine stop-valves, the steam expands in the turbine to 6-12 atm (88-176 psi), and thereafter is conducted to the district heating network. Besides the actual boiler plant at this works, 4 vertical Ruths steam accumulators for a maximum pressure of 13 atm (191 psi) were installed in 1929.

Now erection of a new Eastern power-heat works in the "Kalkbraenderi" harbour to replace the old Eastern Works, is being planned. This new works is designed for a working pressure of 115 atm (1691 psi). Steam for district heating is to be taken from the turbines at a pressure of 8-16 atm (118-235 psi). The network of the old Eastern Works is to be connected to the steam network of the new station so that the boilers at the old plants may be put out of operation. Furthermore, it is intended to establish a considerable network for supply of heat by hot water. The heat for this system will be taken as steam from the turbines with pressure about 0.5—1.5 atm (7-21 psi) absolute pressure, and the steam will be conducted to heat exchangers, where the circulating water will be heated.

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OPERATING STATISTICS FOR DISTRICT HEATING UTILITIES IN DENMARK

City and Population (See "a")	Method of Production	Circulating Medium	Maximum Pipe Diameter Inches (See "b")	Length of Mains Miles (See "b")	Number of Consumers	Consumption—Steam Equivalent	
						Max/Hr Lb (See "b")	Per Year M Lb (See "b")
Copenhagen 732,000	Steam and back-pressure steam	Steam and Hot Water	10	21.4	402	787,518	991,000
Frederiksberg 114,000	Steam	Steam and Hot Water	6	5.2	32	88,775	210,000
Aarhus, Heating 111,000	Exhaust Steam	Hot Water	18	13.0	558	285,961	438,000
Aarhus, Industry	Steam	Steam	5	1.8	13	42,956	110,000
Odense 94,000	Steam, exhaust steam and back-pressure steam	Hot Water	16	4.4	354	123,139	190,000
Esbjerg 45,000	Back pressure steam	Hot Water	12	6.9	314	81,820	131,000
Randers 37,000	Diesel Engine and back-pressure steam	Hot Water	12	11.6	491	144,003	246,000
Slagelse 18,000	Diesel Engine and steam	Hot Water	8	6.9	49	12,273	19,000
Ronne 12,000	Diesel Engine and boilers	Hot Water	6	0.4	27	2,864	
Faaborg 5,000	Diesel Engine and boilers	Hot Water	4½	0.3	8	3,273	7,000
Silkeborg 22,000	Diesel Engine and boilers	Hot Water	6	0.3	10	2,455	
Svendborg 22,000	Diesel Engine	Hot Water	7	0.2	5	4,091	11,000

"a" In each instance the municipality is the owner of the system except in Esbjerg, where the South-West Jutland Electric Works is the owner.
"b" Metric system figures replaced by English equivalents at NDHA Headquarters. 1 Lb assumed equivalent to 970 Btu.

Further, an extension of the H. C. Oersted Works, designed for the same boiler pressure as in the new Eastern power-heat plant, is being planned, so that also there combined power-heat production will be established.

Aarhus

In 1928 a power-heat plant was erected at Aarhus in connection with a considerable extension of the local power station. The boiler pressure is 25 atm (368 psi), and the steam expands through exhaust turbines so that it can be taken at a pressure corresponding to the hot water temperature to be maintained. Also a boiler for 80 atm (1176 psi) pressure was built, the steam from which expands through a topping turbine to 25 atm (368 psi), whereafter it is conducted to the 25 atm (368 psi) system.

The greater part of the heat supplied by the Aarhus plant is distributed by circulating hot water, although part of the heat is delivered as steam for industrial purposes. At Aarhus a hot water accumulator is used for smoothing the load of the hot-water system.

Randers

The District Heating System at Randers was established in 1931 in connection with the Diesel engine at the electric power station. The cooling water from the engine was used as circulating heating water, and furthermore part of the heat contained in the combustion gases was utilized, the heat from the gases being transmitted to the circulating water in a "Riggas" calorifier. In periods, where the Diesel engine could not supply sufficient heat, the heat could be supplemented by heating the circulating water in a steam heated exchanger, the steam being taken from the 15 atm (221 psi) boiler at the works. In 1935 the steam power plant of the works was extended by a steam turbine, so that the circulating water could be heated by exhaust steam from the turbine. In 1936 an old turbine was converted into a back-pressure turbine so that the heat of the back-pressure steam could be utilized for heating the circulating water; finally in 1943 the plant was extended with a new back-pressure turbine. Furthermore a hot-water accumulator has been erected. The entire amount of heat sold is delivered as circulating hot water.

Esbjerg

At Esbjerg the district heating was commenced in 1927. Also at this place a start was made to utilize waste heat from Diesel engines. Since then the plant has been extended with a back-pressure turbine connected to the 25 atm (368 psi) steam boiler of the works.

A very considerable part of the district heat being delivered in Denmark, is produced in connection with the generation of electricity, and due to the difficult fuel conditions in the country where practically the entire supply must be obtained from abroad, the development of utilization of waste heat will continue in the future.

Other Towns

District heating plants are to be found in a number of other Danish towns. The table above gives the most important data of some of these plants.

It should be added that due to difficulties in delivery of fuel, the consumption of heat has been restricted. In prewar years the consumption in Copenhagen was usually 60 per cent higher than stated in the table.

Since the war a very rapid increase in the number of district heating consumers has taken place in the more important towns, a development which is still continuing; but this progress is in many cases being counteracted by the scarcity of materials and labor.

All hot-water distribution mains are steel pipes. To begin with, the condensing mains for the Copenhagen district heating plants were copper pipes, but later on steel pipes were used.

All the water plants are low-pressure systems with open expansion tank. In accordance with seasonal requirements the flow temperature is 65-100 C (149-212 F), and some of the plants have been calculated for a future increase in the flow temperature to 115 C (239 F).

The greater part of the pipes are laid in square concrete conduits, and in most cases Cell-Concrete has been used for insulation. The Cell-Concrete is poured into the concrete conduit and fills it entirely.

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"b" Metric system figures replaced by English equivalents at NDHA Headquarters. 1 Lb assumed equivalent to 970 Btu.

Measurement of District Heating Service in Denmark

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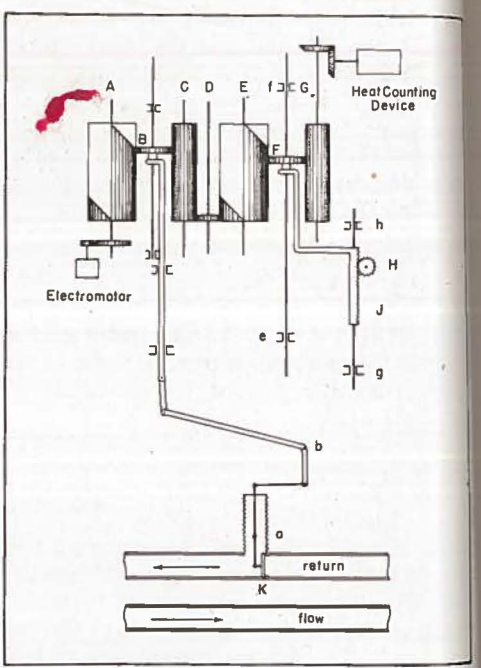
When heat is distributed through steam, the consumers must as a rule collect the condensate from the delivered steam and pump it back to the works. Then the quantity supplied is ascertained through a condensation meter (an open rotary type-meter) in the condensate line above the condensate recovery receiver tank. For a few big consumers steam meters have been installed.

When heat is distributed through circulating hot water, the amount of water circulating in the consumers' heating systems is measured, and this amount is multiplied by the decline in temperature of the water.

In Copenhagen this measuring is effected by a rotary meter or a Woltmann meter in the return line, and a double thermograph with temperature indicator in the flow pipe as well as in the return pipe is used. The water meter is read every tenth day, and the thermograph ribbon is cut off simultaneously. By means of the thermograph ribbon the average temperature difference between flow and return water in the ten day period in question is determined and this average is multiplied by the corresponding quantity of water. This method is satisfactory in case of fairly regular operation. For special irregular operation several intermediate readings of the meter must be made, so that the ten-day period can be divided into shorter periods. These intermediate readings are made by the local boilerman.

As long as heat-meters were obtainable, such meters were used in most of the other Danish towns. In the type of meters used, the momentary amount of circulating water is automatically multiplied by the temperature difference of flow and return water. The meter type usually employed is shown schematically on the enclosed drawing. The meter is fitted on the return



pipe. The amount of water is measured by a throttle flap "K", the displacement of which is proportional to the rate of circulation. By rod system suspended at "a" and "b", the movement of the throttle flap is transmitted to the cog-wheel "B", which can move along a vertical axel. Tightness between the lever arm operating the rod system and the return pipe is obtained by an elastic junction box of corrugated copper. Through a gear connection, a fixed-speed electromotor operates a cylinder "A" with toothed surface, the teeth being cut after a helical line.

When the throttle flap "K" is closed, the cog-wheel "B" is in its top position, and is just

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out of mesh with the teeth on "A". Gradually as "K" opens corresponding to the water flow, "B" moves downwards, whereby it passes into mesh with "A", and the more "B" moves downwards, the more teeth it will catch on "A". The amount of circulating water will, therefore, be proportional to the number of revolutions of "B'. Besides, "B" is in mesh with a toothed cylinder "C", a cog-wheel "D" and a cylinder "E", the number of revolutions of which is thus proportional to the amount of water. The temperatures of flow and return water are recorded by fluid filled containers inserted in the two pipes, and through capillary tubes and a special mechanism the measurement of the temperature is transferred to a cog wheel "H", the number of revolutions of the latter thus being proportional to the difference in temperature. The cog-wheel "H" operates a rack "J", which can move vertically, being kept in position by the guides "g" and "h". The rack is connected to a cog-wheel "F", so that the difference in temperature determines the height at which "F" is engaging "E". When the difference in temperature is zero, the cog-wheel is in its top position, and it is just out of contact with "E". When the difference in temperature rises, "F" moves downwards and catches "E", and the more "F" slides downwards, the longer the period of contact per revolution of "E" will be. "E's" number of revolutions being proportional to the amount of water, the cog-wheel "F" will rotate proportionally to the product of the amount of water and the difference in temperature. "F" is also in mesh with the cog-wheel "G" which, through a gear transmission, carries the rotation to a counting device. The principle of this type of meter is correct, but the design is not satisfactory as might be wanted, and it requires careful attendance and frequent adjustment.

During and since the war it has been impossible to procure a sufficient number of meters. In some cases the scarcity has been remedied, however, by using one heat meter for a group of buildings, and the cost of the heat thus measured has been distributed between the buildings in question in proportion to the amount of water circulating in the individual houses, which amount of water is measured by a meter of the Woltmann or rotary type. This way of distribution is, however, rather unsatisfactory.

SECTION NEWS

NEW ENGLAND SECTION

The annual fall meeting of the New England Section of NDHA was held in the auditorium of the Boston Edison Company at 39 Boylston St., Boston, on the evening of October 6, 1948.

Chairman George K. Saurwein of the Cambridge Steam Corporation presided. Ralph Prescott of the Taunton Municipal Lighting Plant read the paper "Corrosion of Underground Steam Line Supports" by Messrs. Collins, Schlachter and Winans of Detroit. President Henry L. Martin gave the highlights of the Operating Statistics Report for 1947. Chairman Saurwein presented the paper "American and European Viewpoints on the Combined Operation of Electric and Steam Service" by Ward F. Davidson of New York. Copies of the paper "Forecasting New York System Steam Loads" by T. P. Brown, Jr., of New York, were given to all present.

Section dues for the year were set and the following elected to office:

Chairman . . . . George H. Gowdy
Cambridge Steam Corporation

Vice-Chairman . . . Donald F. Blair
Stone and Webster Company

Secretary . . . . Ferdinand F. Hawley
Boston Edison Company

Treasurer . . . . . A. L. Dutton
Boston Edison Company

Members of Board

Donald F. Kavanaugh — G. Dana Kenyon
George K. Saurwein — R. A. Spence

PACIFIC SECTION

A meeting of this Section was held during the first week in September in Seattle, Wash. A detailed report of the Section activities has not been received at Headquarters.