DISTRICT HEATING
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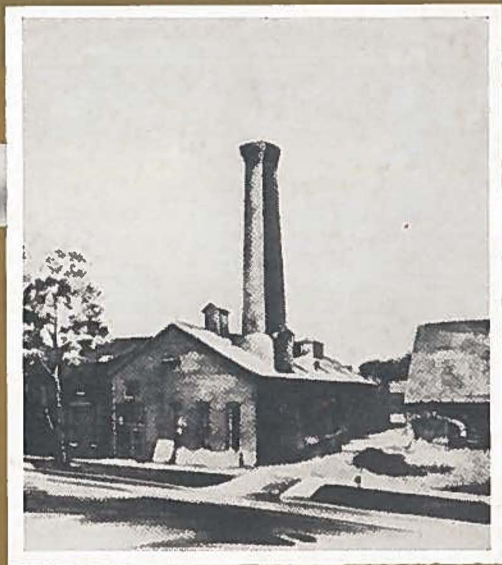

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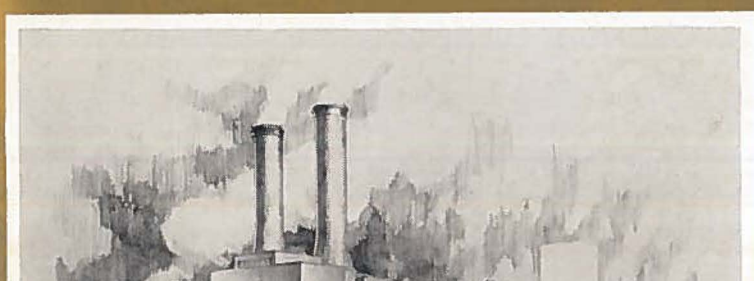

NATIONAL DISTRICT HEATING ASSOCIATION
NDHA

District Heating in Copenhagen, Denmark

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General Description

District heating service was started in Copenhagen in 1925, after electricity production had been centralized in a new plant and the boiler plants of the old power houses, therefore, became available for the supply of heat. Two small warm-water systems were established, but soon other customers requiring a higher temperature than could be supplied through warm water wanted service, and it was decided then that further development should utilize steam distribution. The existing boilers in the old power houses were for only kg/cm² (170 psig) pressure and back pressure operation, therefore, could not be established.

In 1933 one of the old plants had to be extended, and for the first time combined power-heat generation was established by installing boilers for 45 kg/cm² (640 psig) pressure and 400 C (752 F) steam temperature and 7000 kw in back pressure turbines.

At the end of the last war new generating capacity for electric supply was needed. An investigation was made to determine if the new plant should be combined with a further development of the district heating system. As a result of the investigation it was decided that combined power-heat generation and district heating should be developed as fas as possible, that warm water distribution should be used where possible, that a new power station for combined operation should be erected, and that the existing main generating station should be modernized and changed to combined operation.

The main reasons for this decision were that the increasing costs of fuel made combined operation more attractive, and that Denmark has to import practically all fuels needed, which makes their saving of some importance.

Heat is now supplied from three stations: (1) a new maintenance station, Svanemollevaerket, built recently and designed specifically for power-heat generation, (2) another main generating station, H. C. Orsted Vaerket, an older station now being modernized with high-pressure boilers and back-pressure turbines, and (3) an older plant serving peak load purposes both for electricity and district heating.

A flow diagram for the new station, Svanemollevaerket, is shown in Fig. 1. Steam conditions at the high-pressure-turbine throttles are 110 kg/cm² and 510 C (1562 psig and 950 F). The steam

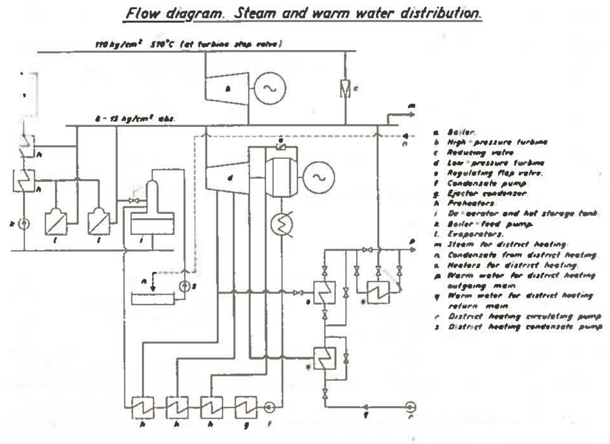

FIG. 1—Flow Diagram. Steam and Warm-Water Distribution.

temperature was limited to this value as, at the time of making the decisions, materials for higher temperatures were not readily available in Europe. Reheating was not deemed feasible for this special design. Two back-pressure turbines totalling 60,000 kw are installed. The back-pressure can be varied between 8 and 15 kg/cm² (114–213 psig) depending upon the requirements of the heating system. At those pressures the steam will still have a superheat suitable for the heating system. The back-pressure steam not being used for district heating, for feed-water heating, and for the evaporation of make-up water is utilized in low-pressure turbines of which there are two, totalling 42,000 kw. Besides three extraction points for feed-water heating these machines also have two extraction points for heating the circulating water of the warm-water district heating system. At full turbine load the first heater gets steam at a maximum of 0.8 kg/cm² abs (11.4 psi abs), which makes it possible to heat the circulating water to about

85 C (185 F), and the second heater gets steam at about 2.4 kg/cm^2 abs (34.1 psi abs), whereby the temperature of the circulating water may be further increased to about 100 C (212 F).

If a still higher temperature is required the circulating water may be passed through a third heater receiving steam from the 8-15 kg/cm^2 steam system and in which the water may be heated to 115 C (239 F). For the greater part of the year, in fact for all but about 1,000 hours, heating in the first heater only is necessary. The temperature of the water is regulated primarily by using one or two heaters and, if necessary, by partly bypassing one of the heaters on the water side. At part load on the turbine the pressure at the tap-off may not be sufficient to give the desired temperature. In such case this pressure may be increased by throttling the flow of steam to the last stages of the turbine by means of a flap-valve installed as indicated on the diagram.

The development of the district heating system through the years will be apparent from Fig. 2, which shows the connected load and the annual sales of heat.

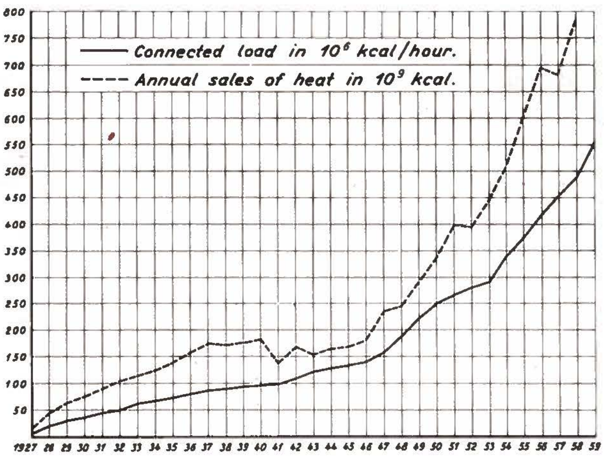

FIG. 2—Connected Load and Annual Sales.

The city of Copenhagen has about 753,000 inhabitants. Fig. 3 is a map of the city showing the extent of the district heating system. Heating mains and buildings served are shown in black. The heating system extends about 5 km (3.1 miles) from the generating stations. The principal data are given in Table I.

Table I

Number of customers	1,240
Total connected load	555 · 10^6 kcal/hour
Total sales, year 1957/58, steam	639,400 · 10^6 kcal
Total sales, year 1957/58, warm water	143,600 · 10^6 kcal
Hours use at connected load	1,601 hours
Length of mains	103.2 km (64.1 miles)
Maximum size of mains	400 mm (16")

FIG. 3—Copenhagen District Heating System.

The maximum load varies with the severity of the weather, and reaches a value of 0.8 times the total connected load in severe winters (−15 C).

About 85 per cent of the heat sold comes from power-heat generation. For the fiscal year 1957/58 the total sale of heat was 783,000 · 10^6 kcal (3,121,000 · 10^6 Btu) and the total back-pressure power generated 126 million kwh. Considerably more power is generated when using warm-water circulation, as will be apparent from Table II, which gives average data for the year 1957/58 from two of our plants.

Table II

		Warm Water Distribution	Steam Distribution	
Average steam pressure at turbine throttle	kg/cm²	110	110	45
Average steam pressure at turbine throttle	C	504	504	380
Average back pressure at turbine exhaust	kg/cm²	9.7	9.7	10.0
Average steam temperature at turbine exhaust	C	266	266	275
Average circulating water temperature				
outgoing	C	80		
returning	C	58		
Power generated per 10^6 kcal heat sold	kwh net	340	162	110

The power generated is net, that is after subtracting all auxiliary power and power for circulating pumps and condensate pumps. The figures for the 110 kg/cm² plant will be improved, as the heating load increases, as the plant is laid out to supply about 200 per cent more heat than is sold at present.

The climatic conditions in the country are such that the normal heating season has a duration of about 250 days, from the latter part of September to about the middle of May. Extreme cold weather is unusual, heating systems normally being calculated on the basis of a maximum outdoor temperature of −15 C (+5 F). The approximate load duration curve for the heating system is shown in Fig. 4; it is apparent that maximum loads are only short peaks, and that loads above 50 per cent of maximum are probable in less than 1,000 hours per year.

Heat Distribution System

Heat is supplied for house heating and for industrial purposes. Until some years ago steam only was used for distribution except in two small areas; but when making the investigation mentioned before we came to the conclusion that

Duration curve for district heating load.

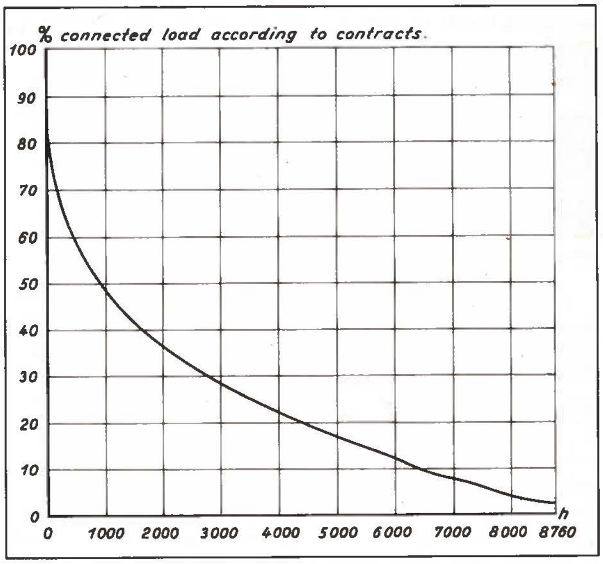

FIG. 4—Duration Curve for District Heating Load.

warm-water distribution should be used as far as possible. Warm water gives a simpler piping system than steam (less expansion and no drainage problems), and the maintenance costs of the system are smaller. With combined power-heat generation a further advantage is obtained with warm-water distribution, as the kwh generated for a given amount of heat sold is about twice that obtained with steam distribution (see Table II). The principal objection to warm water has so far been the question of metering; with the meters now available this problem should be solved.

While warm water with the temperature used here is satisfactory for house heating purposes, usually it cannot meet all heat requirements of industrial undertakings, hospitals, and hotels. To take care of this group of customers, the existing steam distribution is being maintained, and is also being further extended into areas, in which there is a reasonable demand for heat at a higher temperature. Warm-water distribution is used in residential districts. Only one service is available in a district.

Steam System

Steam is sent out from the plant with a pressure varying between 8 and about 15 kg/cm² (114 and 213 psig), depending on the heating load, in order to get the largest possible back-pressure generation. Certain minimum pressures must be kept at certain points in the distribution system. In order to reduce condensation in the mains, steam is sent out with a certain degree of superheat.

Heating of buildings is always done by warm water. The steam is, therefore, supplied to a heat exchanger, in which the circulating water is heated up to the desired temperature. A storage-type heater is used for preparing hot service water.

Condensate from the heaters is returned through a condensate meter to a small storage tank and pumped back to the power plant by an automatic pump.

Where steam is supplied for industrial purposes, pure condensate is collected as far as possible and pumped back to the power plant. In a few cases where the danger of contamination is considered large, evaporator plants have been installed at the customer, thus keeping the two systems separated.

From our experience returning the condensate to the power plants has been a paying proposition so far as it is normally clean enough to be used as boiler feed water. In the older plants up to 640 psig pressure this system has operated for a number of years with no difficulties. In the new high-pressure plant, 110 kg/cm² (1562 psig), which has been in operation now for six years, there has been some difficulties in keeping the water clean enough, mainly, we believe, due to the fact that so many new heating lines have been placed in service. A very close check must be kept on each returning condensate line, and at the least sign of contamination the condensate is dumped until the fault is located and corrected. To reduce the possible loss of condensate we have in one section installed two condensate lines for each outgoing steam main, one line being used for condensate that is believed to be clean under all cirmustances, and the other for condensate that may be contaminated. Our records for Svanemollevaerket show that for the last year about 92 per cent of the condensate was returned.

Warm Water System

The warm-water system is operated with an outgoing temperature varying between 70 and 115 C (158 and 239 F) depending upon the weather. The minimum temperature is determined from the desired temperature of the warm-water house service and may be carried for about half the year. In mild winters the temperature need not be above about 95 C (203 F) and even in severe weather temperatures above 100 C (212 F) will be necessary for short periods only.

The amount of heat sent out is regulated by varying the temperature and the volume of water circulated.

The water is circulated at such pressure that it may be used directly in the radiators of the houses; the maximum allowable pressure is 6.5 kg/cm² (92 psig) and the mean pressure of the system, i.e. the average of the pressure in the outgoing and returning pipes, measured at the station, is kept at about 3.5 kg/cm² (50 psig). In some older installations the radiators are not capable of withstanding the maximum pressure of 6.5 kg/cm² with a reasonable degree of safety; in such cases a pressure-reducing valve is installed. Radiators are now available, both in cast iron and steel plate, which are tested at 10 kg/cm² (142 psig) pressure, and which are used for all new installations served by district heating.

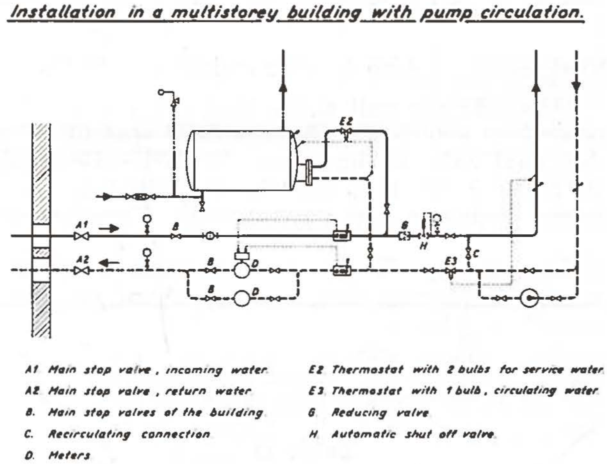

FIG. 5—Installation in a Multistory Building with Pump Station Circulation.

Fig. 5 shows a diagram of the installation in a multistory building with pump circulation. Water from the district heating mains enter at A_1. A branch is taken off to the storage heater for house service water and next the water enters the circulating system to the radiators. If the radiators are of the old type, which may not be able to stand the full pressure, a pressure-reducing valve (G) and an automatic shut-off valve (H) are installed. This last valve will shut off the line by increased pressure in case the pressure-reducing valve fails.

The temperature of the house service water is regulated automatically by thermostats (E_2) in the service-water tank and in the return line.

The temperature of the incoming water may be higher than required for the water to the radiators, the system, therefore, is equipped with a recirculating connection (C) through which the returning water may be recirculated to regulate the water temperature to the radiators. Regulation is accomplished by a valve (E_3) thermostatically controlled by the temperature of the water to the radiators. If desired, the system can be made fully automatic, the temperature of the circulating water being controlled by outside temperature and the temperature of different sections of the building (for instance, north and south side). As mentioned before, water is sent out with a maximum temperature of 115 C (239 F). This relatively high temperature, which is too high for direct circulation, is possible only because of this recirculating device. The advantage of the system is that it enables an increased cooling of the circulating water, thus reducing—for a given sale of heat—the volume of water circulated, the size of street mains as well as the power for pumping. In the contracts it is stipulated that the cooling of the water, i.e. the temperature difference between incoming and outgoing water, at the customer shall be at least 25 C (45 F) and that the temperature of the return water must not exceed 70 C (158 F). The return water is metered at D and leaves the customer at A_2. Two meters are shown in the diagram, one for winter and one for summer use. Fig. 6 shows a photo of such an installation.

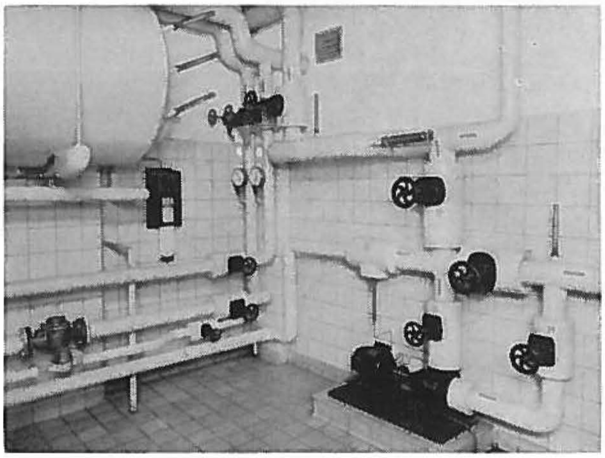

FIG. 6—Warm Water Installation.

The largest size of street mains used in 400 mm (16 in.) diameters. In other towns in Denmark larger mains, up to 600 mm (24 in.) diameter are in use.

The warm-water system at present extends out to about 3 km (1.86 miles) from the plant. This distance cannot be increased very much without installing booster pumps in the system.

Maintenance

The first street mains laid down more than 30 years ago are still in use and generally in good condition. It is apparent that the maintenance work is less on the hot-water-distribution system than on the steam system. Our data, however, are not sufficient to give definite figures. On the steam system the condensate lines were at first laid in copper pipes welded together. The welds proved to be a weak point requiring considerable maintenance. For the last about 25 years steel pipes has been used also for condensate lines with satisfactory results.

The cell-concrete insulation mentioned later has been very satisfactory. It is, of course, necessary that the duct and pipes are dry, which means that the drainage system must be effective.

A measure of the conditions of the system is the maintenance costs and the losses. The annual maintenance costs for the whole district heating system has as an average for the last two years been 6,800 kroner per km pipe line ($1,586 per mile) with a downward tendency. The heat losses in the system determined as the difference between the heat bought from the power plants and the heat paid for by the customers has for the last two years been 12.7 per cent based on heat sent out.

(Continued in July Issue)

Have You Heard . . .

FLORHAM PARK, N. J.

On a 675-acre site Esso Research and Engineering Company is building an office building, prototype building, service building, two gatehouses and a sewage treatment and disposal plant—the initial construction of a modern research center. All heating, air conditioning, power and communication lines are run underground. Over 500 tons of Gilsulate will be used for insulating and protecting the underground steam pipes.

BUFFALO, N. Y.

A laboratory has solved the problem of increasing hot water volume without adding costly heating installations by installing mixers to existing steam and cold water lines. Style D Steam and Water Mixer, made by the Powers Regulator Company, Skokie, Ill. was used. It automatically mixes water and steam to deliver water at any temperature desired by the user. In the laboratory, the mixer combines cold city water with 100-lb steam to provide water averaging 140 F, but can also provide water at temperatures as low as 50 F and as high as 200 F.

Mrs. Elva B. Webb

Office Secretary, N.D.H.A.
from
August 1939 to September 1957