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CONTINENTAL PRACTICE[1]

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1. GENERAL REVIEW

The development of district heating on the continent after the war of 1914-18 has been facilitated by the shortage and high cost of coal. In 1921, the Hamburg Electricity Company and a leading heating firm formed a company for public heat supply. The success of this company encouraged many towns in the following years to take up district heating. Many plants were on a small scale, owing to the economic limitations of district heating at that time.

The predominant method of heating on the continent is by slow combustion stoves with a thermal efficiency of 40 to 50 per cent. as compared with 20-25 per cent. for open coal fires in this country. In consequence of this, the saving that can be attained by the introduction of central heating installations is less than would be the case in this country. Moreover, the installation of central heating in an existing building involves many difficulties, and as a rule a district heating plant had to be designed for the heat supply of existing central heating plants only. Evidently, heat could not be distributed in streets where only one out of ten buildings could take the supply. No service, even electricity supply, could be run under such conditions. It is also obvious that a district heating service could only be successful if the heat was supplied at a lower rate than the cost from central heating boilers.

This explains why the district heating service had at first to be limited to favourable areas of a town with an adequate proportion of central heating installations. The conditions improved steadily because central heating, partly due to district heating, became more popular in the following years. All new office buildings and almost all new blocks of flats were fitted with central heating systems.

According to my experience as Manager of the District Heating Company in Hamburg and as the engineer responsible for many other schemes in Germany and other countries, the new service has been appreciated everywhere for its convenience, cleanliness, low cost and reliability. During my management of the District Heating Company for 12 years, it happened only once that the supply to a few consumers had to be interrupted, owing to the flooding of the basements. The Fire Brigade isolated the section because of the escaping vapour from one basement due to the flood water vaporising where in contact with the steam main. It would have been much worse if the old central heating boilers had been kept in service.

According to a report of the Association of Electricity Undertakings, there were in Germany in 1936, 28 district heating plants for public supply of heat. This figure does not include numerous central station heating plants for housing estates. The heat distribution systems were as follows:—

	Plants
Steam	16
High pressure hot water	3
Low pressure hot water	3
Steam and hot water	6

In 1936, the total heat sent out amounted to 5.14×10^{12} BThU.

The success of district heating in Germany can be judged from the data published by a well known authority—Dr. Wellmann, V.D.I., Journal, 15th November, 1941, according to which new district heating plants for four towns were sanctioned and partly carried out for an annual supply of 30.5×10^{12} BThU, about six times as much as from all pre-war plants.[2]

(1) A paper presented by the author, Life Member of NDHA, during Joint Session 2 on District Heating of the "Fuel and the Future" conference sponsored by the British Ministry of Fuel and Power in London, October 8, 9 and 10, 1946 and printed here by the kind permission of the Ministry and the author.

(2) The Growth of District Heating in Russia and Germany, by A. E. Margolis—Engineering, October 8th, 1943.

The development of district heating in the Soviet Union has been even more remarkable. It was started on a very small scale, with only two consumers, in Leningrad in 1924-25. In 1938 the total heat distribution system of Leningrad had already been extended to 44 miles, and the heat sent out in that year amounted to 3.3×10^{12} BThU. At the beginning of 1939 the total capacity of generating sets with heat supply for space heating and process work in the U. S. S. R. amounted to 1,747,000 kW., and the total heat sent out in 1939 was 87.5×10^{12} BThU.

According to the Five Years' Plan of 1938-42, which was interrupted by the War, the capacity of all thermal power stations had to be increased by 7 million kW. of which 5 million kW. were to be installed with back-pressure or extraction turbines for heat supply. The heat-electric capacity would then have been 47.5 per cent. of the total steam driven electric generating capacity in the U. S. S. R.

In 1939, the total number of district heating plants in the U. S. S. R., including industrial plants with heat supplied to outside buildings, amounted to about 160. It is often said that the extent of these district heating plants is comparatively small. True, the length of the heat distribution systems and the number of consumers is very small indeed. According to the data on district heating for the ten leading cities(3) the total length of their heat distribution systems amounted to 136 miles, out of which about 120 miles were by means of hot water. The total number of consumers was only 1,063, although the number of connected buildings was much greater. This shows that the supply of heat is still limited to large buildings and factories. On the other hand, it shows how great is the demand for low grade heat, and it indicates the wide scope for the future development of district heating.

District heating has also been adopted in other countries, such as Denmark, Holland, France and Czechoslovakia. The heat-electric station at Brno is of special interest, as it supplies steam to the majority of the textile and chemical factories of the town and to many buildings, for process work and heating. The Vatican City should also be mentioned as the only City on the continent with a centralized heat supply throughout, and supplied from a heat-electric station.

2. COMBINED HEAT AND POWER GENERATION

The rate of growth of district heating on the continent in recent years has been much greater than in the U. S. A. It is due first of all to the fact that the cost of plant, especially of the heat transmission and distribution systems, and the cost of labour as well, are lower on the continent and the cost of coal is higher than in the U. S. A. The main reason is, however, that American plants are operating as a rule with straight steam supply. In contrast to continental practice, combined heat and power generation is seldom applied in the U. S. A.

The growth of district heating in the U. S. A. in the eighties and nineties of the last century coincided with the erection of numerous light and power stations which, at that time, were built with exhaust steam engines. It was a comparatively easy job to make use of the available exhaust steam for heating buildings in the neighborhood of the power station. There was no need for returning the condensate, and the balancing of the heat and power loads was a simple matter. With the rapid growth of the electric power demand at the beginning of this century, the old primitive stations were hopelessly outpaced by large condensing stations. Such stations were located so as best to meet the requirements for cooling water and fuel delivery, and the comparatively small district heating plants had either to close down or to change over to live steam distribution. But even under favourable conditions combined heat and power generation is not so efficient as on the continent. This is due partly to steam distribution, but mainly to the poor load factor of the back-pressure electricity generating sets, and high operating costs.

In contrast, the development of district heating on the continent has been based predominately on combined heat and power generation. It started at a time when the superior-

(3) District Heating in Russia, by A. E. Margolis. The Steam Engineer. February and March 1941.

ity of large condensing sets was a well established fact. It had often to be started from the older power stations which were conveniently located in regard to the heat supply area, but had comparatively poor boiler plants and high working costs. Combined heat and power generation has not only the advantage of saving coal but also of reducing considerably the cost of boiler plant, its attendance and maintenance, as compared with straight heat supply. Old power stations with high working costs which, from the standpoint of power generation would have to be scrapped, could again be run economically when used in addition for heat supply. However, the greatest efficiency of combined heat and power generation can only be attained in modern stations. Great effort has therefore to be made, firstly, to extend district heating to the magnitude of electric power generation, and secondly, as we shall see later, to balance the variations of the heat and power loads and to adapt the supply of heat to the requirements of electric power generation.

3. DEVELOPMENT OF DISTRICT HEATING IN HAMBURG

In Hamburg I started district heating from the oldest power station in October, 1921. In 1924, a second power station was given over to the District Heating Company. In 1929, all rights for district heating were acquired by the Electricity Company, and a third power station was put into service for heat supply. Finally, in 1933, the heat distribution system was connected to a comparatively modern power station located in Tiefstack outside the built up area of Hamburg, with a generating capacity of 85.000 kW. but with a working pressure of only 200 lbs. per sq. in. Two new high pressure boilers of 220,000 lbs. per hour, each with a working pressure of 1,700 lbs. per sq. in., and two back-pressure sets of 11,000 kW., each exhausting at the pressure of the old boiler plant, were installed. The exhaust steam was transmitted over a distance of 2.2 miles to the third power station where it was used again for generation, and the exhaust steam of about 40 lbs. per sq. in. was supplied to the network of the district heating plant. The existing back-pressure set was of 4,000 kW. only, but the generating capacity of the station could be increased to a total of 20,000 kW.

The steam main of 28-inch bore was designed for a transmission of 550,000 lbs. of steam per hour at 200 lbs. per sq. in. and 660° F. When transmitting 220,000 lb. per hour, a test showed that the drop in temperature was 54°, corresponding to only 22° F. at full load, and the loss of heat to less than 1 per cent. over a distance of 2.2 miles. It demonstrates the fact that heat can be supplied from stations outside a city, if the demand is sufficiently large.

It is noticeable how closely the development of district heating has been following that of electric power supply. After the erection of the Tiefstack power station, the older power stations were taken out of commission and converted into transformer stations. Similarly, after the erection of the steam main from the Tiefstack power station, the boiler plants of the two oldest power stations were taken out of commission and the power stations converted into sub-stations. The higher rate of growth of district heating is demonstrated by the fact that, from the commencement of electricity generation in Hamburg, it took 35 years before a plant of the type to be seen at Tiefstack could be realised; whereas a comparable development in district heating has been accomplished in 12 years. During this period the annual heat supply rose from 36×10^9 BThU to 960×10^9 BThU. It rose to 1210×10^9 BThU in the year 1937-38 and, according to the latest information, to 1600×10^9 BThU in the year 1941-42.

In Charlottenburg, district heating was started in 1926 from a modern power station with a boiler plant working at 500 lbs. per sq. in. In Leipzig, Dresden, Barmen and Brno the new main power stations were erected for electricity and heat supply. In the Soviet Union this development took place on a much larger scale.

4. HEAT DISTRIBUTION

Most of the plants in Western Europe were built for steam distribution. This was due to the large number of steam central heating installations which could be easily connected to a steam distribution system. Hot water heating plants had to be connected by means of calorifiers. The heat supplied could be easily metered by means of condensate meters. In contrast with American practice, the condensate was always returned to the boiler plants to be used as feed water. With due precaution steel pipes can be used for the condensate and the danger of corrosion eliminated.

The disadvantage of steam distribution is the reduction in electric power output of the back-pressure sets and the high, almost prohibitive cost of steam storage. A further disadvantage is the high cost of connections for small heating installations.

From the standpoint of power generation, the low pressure hot water distribution system is the most efficient. The heating water replaces the cooling water of a condensing station, and the total latent heat of the steam is regained in the simplest way and at a very low back-pressure. The cost of a heat-electric station for low temperature heat distribution, when properly designed, does not exceed the cost of a condensing station. Low pressure hot water distribution is very suitable when all existing central heating systems are carried out by means of hot water. It has been successfully applied for the heating of 4,000 flats in Steglitz, a suburb of Berlin, with a three main system for heating and hot tap water supply.

The connection of steam heating installations to a hot water distribution system is possible if the temperature of the circulating water is raised. This affects, however, the electric power output, and the increase in temperature of the water should for this reason be as low as possible. Moreover, this increases the quantity of circulating water, the size of mains and the cost of calorifiers.(4)

In Dresden a three-main hot water distribution system was installed in 1927-29. It consisted of two flow mains, one with a hot water temperature of 285 F., the other one with hot water at 260 F., and a common return main. All heating installations were connected by means of calorifiers, the steam heating systems using flow water of 285 F. and the water heating system flow water at 260 F. In later years a system of injecting high temperature flow water to the water of the heating systems was tried out and proved to be successful.

Hot water distribution with a flow water temperature of 275 F. and higher, and injection of flow water to the heating systems, was applied on a very large scale in the Soviet Union. Hot water distribution has been chosen for reasons of the increased electric power output, without giving sufficient consideration to the shortage of experienced engineers and skilled labour. According to the Russian literature it resulted in many unpleasant breakdowns. Under such labour conditions steam distribution systems have the great advantage that repairs can be carried out in a very short time, whereas, for the repair of hot water mains, much time is lost for drainage and refilling.

When the heat distribution systems are placed in conduits and due regard is given to the welding and expansion of mains, temperature stress, venting and so on, the reliability of a district heating service is greater than that of any other service. The provision of conduits and of expansion protects the mains against any movement of the soil, and breakdowns as in the case of cold water or gas mains are actually excluded. All simplified methods, by burying the pipes direct in the ground, are done at the sacrifice of the reliability of service and should be applied with the utmost care. Most careful consideration should also be given to the method of heat insulation, which cannot be dealt with here.

5. BALANCING OF HEAT AND POWER LOADS

The co-ordination of heat and power generation depends upon balancing the variations of the heat and power loads, and a short review of the methods adopted should be of some interest.

Method (a). By back-pressure and condensing sets working in parallel.—This is the most expensive method, because the capacity of the back-pressure sets is not available on mild days at the time of the electric peak, and the load factor of the back-pressure sets is comparatively poor. The cost of the back-pressure sets must

(4) Superheated Hot Water from the standpoint of District Heating, by A. E. Margolis. The Journal of the Institution of Heating and Ventilating Engineers, April, 1938.

therefore be allocated to district heating. This was the case in Hamburg when 2,000 and 4,000 kW back-pressure sets were installed before heat storage was available.

Method (b). By back-pressure and low pressure condensing sets in series. The exhaust steam of the back-pressure sets, when not required for heating, is supplied to a low pressure condensing set. This method was at first applied in Kiel in 1922-23, and later in Leipzig and Brno. It improves considerably the value and load factor of the back-pressure sets, and the additional cost of the low pressure condensing set is much lower than that of a parallel high pressure independent condensing set or sets.

Method (c). By the use of pass-out steam. Pass-out turbines were extensively used in the Soviet Union. The cost of turbo-alternators is lower than that of separate condensing and back-pressure sets. The overall steam consumption, owing to the great variation of the heating load, is, however, much higher than with back-pressure sets. According to a report to the Academy of Science in the U. S. S. R. in 1943, the overall steam consumption was in many cases as high as for normal condensing sets without pass-out.(5)

Method (d). By hot water storage combined with any form of heat-electric station. In the case of hot water distribution, heat storage in large capacity hot water accumulators is the most efficient method of balancing the variation of heat and power loads. Both services can be run independently of each other, and the back-pressure generating sets can be designed either for peak load or base load.

In Hamburg a hot water accumulator with a storage capacity of 400×10^6 BThU was installed in 1929-30, for the hot water distribution system. After that I could always run the back-pressure sets of 2,000 kW and 4,000 kW installed in two stations, situated at a distance of four miles from each other, in accordance with the requirements of the electric load. Any surplus exhaust steam or deficiency in heat was made good by the accumulator. The average heat losses of the Hamburg accumulator amounted to only 0.04 per cent. per hour.

The application of the large capacity hot water accumulator for heat-electric stations makes possible the use of electric heating on a very large scale(6) but, owing to the limitation of time, it cannot be dealt with here. Similarly, the treatment of the very promising co-ordination of heat-electric stations with heat pump plants must be excluded from this paper.

6. CONCLUSION

To sum up, District Heating is the final stage in the development of central heating. Central heating is now generally adopted for Government and Communal Buildings, for factories, offices and the better class dwellings. There cannot be any doubt that with the steady improvement of living conditions central heating would become as general as electric lighting, because it so greatly improves the comfort of living. Therefore, the general introduction of district heating is bound to come, because it gives an ideal and cheap service and because it has the additional advantage of eliminating most of the smoke nuisance and of saving very great quantities of coal. The development of district heating on the Continent shows that its general adoption depends upon co-ordination of heat and power generation which widens the economic basis of both heat and power supply and by which the greatest quantities in coal are saved. The increasing difficulties in mining and the steady rise in the cost of coal makes this development a problem of paramount importance.

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(5) The Principles of Operation and Design of Heatification, by L. A. Melentiev (in Russian). Proceedings of the Academy of Science in U. S. S. R., No. 3, 1943.

(6) An Outline District Heating Scheme for London, by A. E. Margolis, Engineering, March 26, 1944.