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REPORT OF HOT WATER COMMITTEE

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EUROPEAN HOT WATER HEATING PRACTICES

By F. L. Witsell, Chairman

In view of the decreasing popularity of hot water as a heat transfer medium for district heating projects in the United States, and a simultaneous increase in popularity of the same system in Europe, this Committee has endeavored to gather and summarize all available data on European heating practice, in an effort to ascertain the reasons underlying this decided difference in opinion as to the relative advantages of steam and hot water distribution. The growth of our industry from its inception to the present day, made possible by the use of steam as a heat transfer medium, is too well known to be discussed here. However, a brief review of European plants and practice, drawn from the data that we have been able to assemble, will serve to emphasize fundamental differences in European and American practice.

The first European attempt at central station heating dates back to approximately 1900, when a state owned power plant was erected in Dresden, Germany, to supply several governmental buildings with electrical energy and steam heat. Several other projects patterned after the Dresden system followed in later years, all using exhaust steam as a heat transfer medium. As the result of extensive study by German engineers, these systems were eventually converted to hot water circulation in order to improve the thermal efficiency of the plants.

Herein lies the major factor in influencing European engineers in favor of hot water distribution. Electric generation is regarded as inseparable from the heating process, and only minor plants serving exceptionally small systems are without electric generating equipment. Also, almost without exception, systems of this nature are owned by the state or municipality in which they are located, to the exclusion of private enterprise. Under government supervision, heating systems are designed in accordance with a long-term plan of national economy, with the object of satisfying the combined heat and power demands of the consumer with the minimum fuel expenditure, and acceptance of the service by the consumer is sometimes compulsory, as in Paris, where isolated plants are excluded from the area served, by ordinance, and in Russia, wherein all activities are under control of the central planning committee of the Soviet Union.

Due to the greater economy of large turbines, steam extraction is preferred to the operation of the smaller, base-load, back-pressure units.

The expansion of steam from relatively high initial pressures to pressures at or near atmosphere results in maximum electrical generation per unit of steam; however, steam expanded to these pressures is unsuited to transmission over the relatively long distances encountered in European projects. The use of hot water as a heat transfer medium solves the problem of heat distribution in a satisfactory manner, permitting substantial reduction in pipe sizes; and delivery of the heating medium to remote consumers with minimum temperature loss. The duplex piping required for hot water distribution is not considered disadvantageous by European engineers, who regard the condensate return line as an indispensable part of the steam distribution system, and who view the American practice of wasting the condensation as uneconomic in principle.

Three major factors have caused hot water heating to incur the disfavor of American engineers, namely: the inability to serve process loads, requiring temperatures in excess of 212 degrees; the lack of suitable metering equipment to determine the consumers use for billing purposes, and the difficulties encountered in serving high buildings. European engineers have successfully solved these difficulties through the distribution of superheated water at temperatures of 285 degrees or above, obtained by stage heating and the extraction of limited quantities of relatively high pressure steam, and by the development and application of satisfactory heat unit meters that permit service to be rendered on a metered basis. High buildings do not offer the difficulties found in America, but the problem can be satisfactorily solved, as witnessed by the installation in the Cities Service Building in New York.

In examining the whole problem from the European engineers' point of view, that is, the generation and distribution of electric energy and heating service from a central station with minimum fuel expenditure, we find that the use of high steam pressures for heat distribution is regarded as uneconomical, because the distribution of live steam taken directly from the boilers excludes the possibility of electric generation. Also, that steam extracted from the turbines at pressures sufficiently high to permit the use of economical pipe sizes results in lowered electric generation per unit of steam, and is regarded with equal disfavor, and that the construction of a steam distribution system designed to transmit steam exhausted or extracted at low pressures and to return the condensation, involves a capital expenditure equal to or greater than that required for an equivalent hot water system. Further, a reduction in primary boiler surface below that required with an equivalent steam distribution system is permissible, as the water rate of the turbines is substantially lowered by extracting steam for the heating process at the lowest pressure consistent with the circulating water temperatures required. Coupled with the fact that all condensation is available for boiler feed, and that the difficulties commonly associated with hot water heating by American engineers have been satisfactorily solved, the European engineer considered the two systems as equal from the standpoint of capital expenditure and distribution difficulties, and bases his decision on thermal efficiencies, wherein hot water distribution is decidedly superior.

It is to be borne in mind that the trend toward hot water heating in Europe is of comparatively recent origin, and that before the advent of high steam pressure, extraction turbines and suitable metering apparatus, together with the long-term national economy programs formulated by post-war governments, hot water heating had no marked advantage over steam as a heat transfer medium. Also, that steam transmission is in general use over relatively short distances, to industries requiring higher temperatures for process purposes than can be obtained from superheated water, although the use of live steam taken directly from the boilers is, in general, regarded as uneconomical.

In order to illustrate some of the outstanding achievements in hot water heating that have been attained by European engineers during the last ten years, the Committee has studied the replies received in response to a questionnaire broadcast to the designers and operators of Europe's outstanding heating systems. The character of ownership and the engineering and economic theory that predicates the European engineers' choice of methods to be used in heat distribution have been sufficiently discussed, and indicate reasonably well the representative opinion in regard to the relative merits of the two methods of heat distribution. A brief description of one or two of the outstanding systems, wherein these theories have been placed in practice, will serve to illustrate the sharp difference which exists in heating practices there and in the United States.

In 1925 the city of Dresden decided to enlarge the municipal plant, absorb the state plant previously mentioned in this paper, and to exclude private electric concerns from the city. A new boiler house was constructed in 1927, housing five new boilers of 3,280 sq ft each, operating at 544 lb pressure and 770° F steam temperature. Electricity was generated by extraction turbines, and several new units of the same design were added to care for the increased load requirements. To secure the maximum thermal efficiency in the new plant, it was decided that the heating business would be entered on a large scale. Accordingly, 16,000 ft of new line was constructed, in addition to the state heating system that had been previously expanded to serve business other than buildings controlled by the state. In place of the two pipe (flow and return) system, three pipes were used, so valved and interconnected that any one of the three lines can serve as either flow or return, permitting repairs at any time to any section. Eighty lb per sq in. static pressure is insured by open tanks of 21,000 gal capacity, located 200 ft above the high point of the distribution lines, and a closed tank, provided with an automatic make-up line is installed at lower level, with 75-lb air pressure held above the level of the water in the tank. The outgoing temperature is held constant at 284° F, and the return temperature drops as low as 117°. Under these temperature conditions, 1 cu ft of water is capable of carrying 7,000 Btu. Present friction head is 37 lb, and when the system is fully loaded, will be increased to 80 lb.

Four centrifugal pumps are provided, with a combined capacity of 3,000 gpm. Automatic by-pass valves are used to pass water to the return line in case of low suction pressure. The return water is preheated by four heat exchangers, having a total capacity under maximum conditions of return water temperature of 90 million Btu per hr when supplied with steam bled from the turbines at 26 lb pressure. The final temperature of 284° F is reached by using two booster heaters having a total capacity of 20 million Btu, supplied by bled steam at 200 lb pressure. Approximately 85 per cent of the heating is done in the first stage. Condensate is stored in open tanks, blanketed with steam to prevent the absorption of oxygen.

No circulating water passes through the customer's piping, as heat exchangers are provided in all cases. When the customer has a steam system, the water line in the exchanger is lowered to provide for steam generation. Loss of circulating water due to leaks in customers' systems is thus avoided.

All services are metered by the Samson heat unit meter, mechanically measuring and integrating the flow and temperature difference, and reading directly in British thermal units. The total heat demand on the new municipal system was 10,000 M Btu per hr in 1928, and rose to 67,200 M Btu per hr in 1930-31.

The foregoing description of the Dresden system may be considered as typical of present-day European hot water heating practice. The Russian achievements in the same field have been most remarkable. The first hot water main in Moscow was laid in 1930, and the present length of the heating system has now reached 15 miles, the total length of pipes being about 38 miles, pipe sizes ranging from 4 to 18 in. About eleven miles of this system distributes hot water, the remainder carrying process steam to near-by plants. The maximum load on the hot water system is 400 million Btu per hr, and the total quantity of heat which will be supplied by the Moscow system in 1934 will amount to the equivalent of one and one-fifth million tons of steam, and consequently within the brief span of four years the Moscow ststem will stand third in size among the heating systems of the world.

The rated capacity of the bleeder and back-pressure turbines installed at the Moscow plants was 64,000 kw on January 1, 1934, and will be increased to 113,000 kw installed by the end of the year.

The Leningrad system was started in 1924-25, and has 21 miles of conduit, of which 18 miles are hot water lines. Nearly all of the most important public and historical buildings of the city are connected to the hot water system and use yearly an amount of hot water corresponding in heating value to 700 million lb of steam, and approximately an equal amount of steam is transmitted to industries for process purposes. The Russian systems are reported to have worked continuously since their installation, and to have proven their efficiency from both technical and economical viewpoints.

The Committee has, in this paper, endeavored to assemble data that is representative of present-day European preference and practice. It is not to be inferred that hot water distribution is practiced to the exclusion of steam, for systems using steam for distribution still outnumber those distributing hot water in Europe.

We are deeply indebted to the European engineers for their replies to our questionnaire, and to Mr. Arthur J. Slade and Mr. J. R. Mason, of the American District Steam Co. for their assistance in obtaining the data from which this report was written.