DISTRICT HEATING HANDBOOK

THIRD EDITION

A MANUAL OF DISTRICT HEATING PRACTICE

A DESCRIPTION OF THE DISTRICT HEATING INDUSTRY

A GUIDE TO MODERN COMMERCIAL EQUIPMENT

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CHAPTER 15

HOT WATER FOR DISTRICT HEATING

INTRODUCTION

Commercial District Heating in the United States is confined almost entirely to the manufacture, distribution, and sale of steam. Engineering and economic considerations at the time these systems were built led to the selection of steam as the heat-carrying medium. However, it is not to be construed that steam is the only method by which heat can be distributed over long distances. Hot water has been used and is being used today where economic conditions are favorable and where good engineering practice dictates. It is the purpose of this chapter to treat the subject of hot water for district heating very generally; to bring to attention that it can be and is being used; and to emphasize the latest trends in this method of heat distribution for district heating.

LOW-PRESSURE HOT-WATER SYSTEMS

The use of low-pressure hot-water distribution systems—below 200 F—has been practically discontinued for district heating in the United States in favor of steam. The reasons for this are numerous. Some of the more important ones are as follows:

If tall buildings are to be served, extremely high pressures must be carried in the distribution system or the consumer must provide pumping facilities.

Hot water requires a two-pipe street distribution system.

Hot-water distribution systems are less convenient to repair and more consumers are affected when a shutdown of a portion of the system is required. To repair leaks or connect new consumers to the street mains the affected lines must be drained and service to all consumers in the affected area discontinued. It is possible to by-pass the affected area if provision has been made with adequate cross connections and sufficient valves. This additional equipment increases the cost of a system which is already high in investment.

Capital investment for a hot-water distribution system is generally higher than for an equivalent steam system because of the dual piping required for supply and return mains. The investment should not be assumed to be double, however, since steam traps and pressure-reducing valves are eliminated.

Because of these evident disadvantages most district heating systems built in the United States within the past twenty-five years use steam. Those using hot water are generally systems supplying small groups of comparatively low buildings of the institutional type.

HIGH-PRESSURE, HIGH-TEMPERATURE WATER SYSTEMS

In Europe, economic conditions have stimulated the growth of district heating. Fuel is scarce and expensive. This justifies increased investment in the system. High-pressure, high-temperature water—275 to 400 F—as the heat-distributing medium seems to be one answer to this problem. High-pressure, high-temperature water has become very popular in Europe, particularly in the industrial field, and is being used to some extent in this country, especially where it can be combined with electric power generation. According to one eminent authority in Great Britain[1]—"*In Europe many industrial heating plants have been changed over from steam to high-pressure hot water. For a district heating plant such a conversion is, however, hardly possible because of the great capital expenditure involved.*"

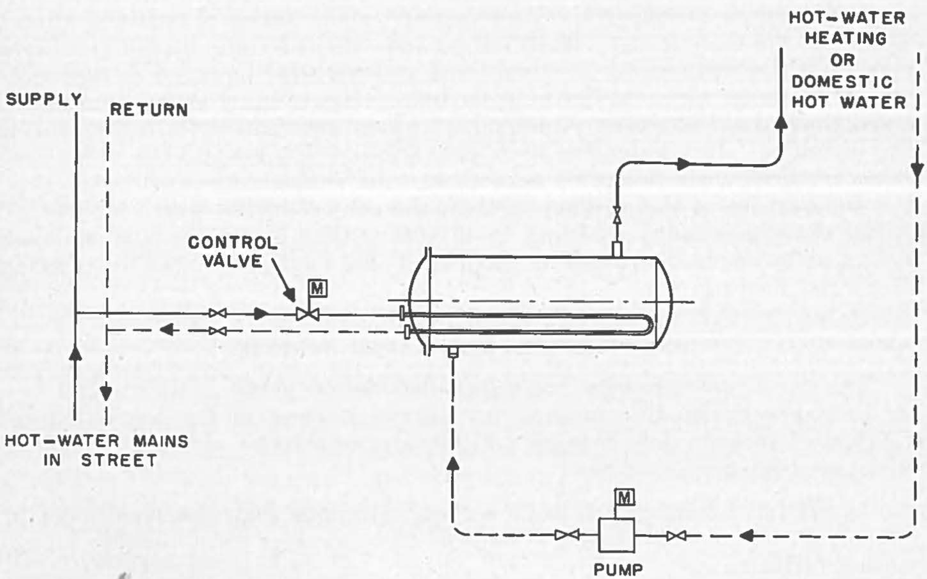


FIG. 1—Heat Exchanger and Piping Arrangement Where High-Temperature, High-Pressure Water Is Available in the Street Mains to Provide Low-Pressure Hot Water for Space Heating and Process Use

A high-pressure, high-temperature water system uses either water heated under pressure in a boiler up to 400 F or water raised to this temperature by means of a heat exchanger with steam as the heating medium. Where power generation is desirable, steam from the boilers is expanded through exhaust or extraction type turbines into single or multiple stage exchangers which heat the water to the desired conditions. From the heat exchangers the condensed steam is returned to the boiler in a closed system. The heated water is circulated through the distribution system by means of pumps and returned to the heat exchanger through its closed system.

The manner in which this hot water is used at the consumer's premises depends on several factors which can be evaluated in each case. If the consumer can use the high-pressure, high-temperature water, it can be piped directly from the street main and connected to his equipment. This probably

[1] A. E. Margolis, Kennedy and Donkin, Consulting Engineers, 12 Caxton Street, London, S.W. 1.

would be the case of an industrial user or where heating equipment, such as unit heaters, are designed for this purpose. Where high pressure is required at moderate temperatures, the water from the street main may be mixed with some of the return water from the consumer's system to obtain the desired temperature before it goes to the heat-consuming unit. Probably the most widely used method is to pipe the water from the street to a heat exchanger in which either low-pressure steam is generated or low-temperature water is

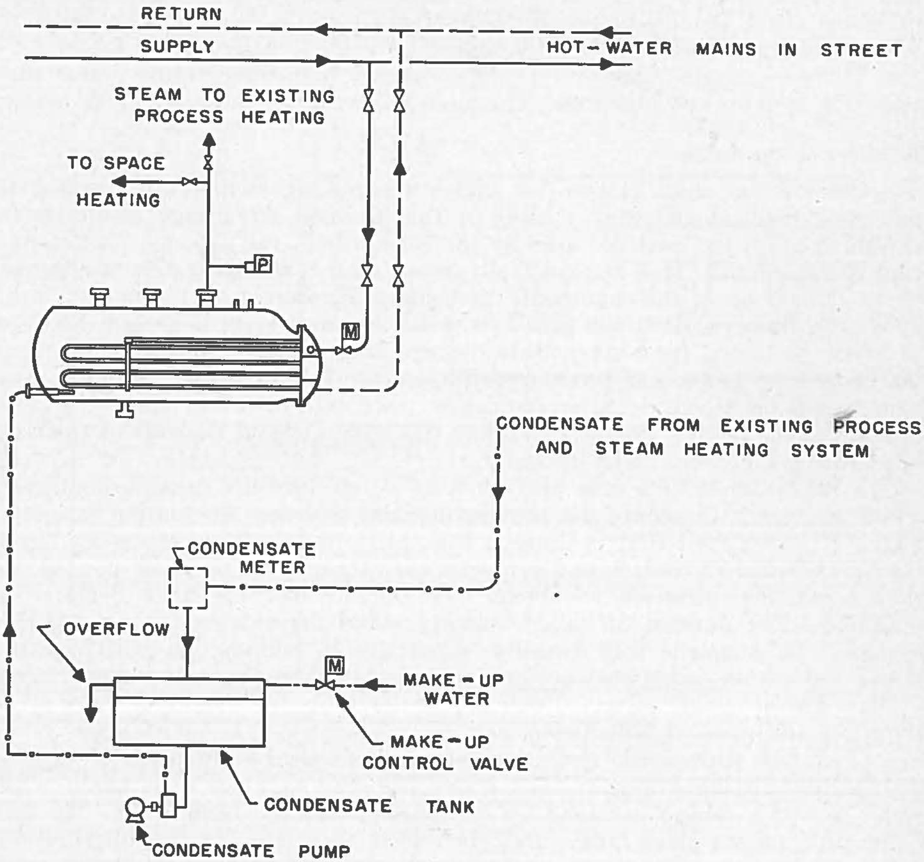


Fig. 2—Heat Exchanger and Piping Arrangement Where High-Temperature, High-Pressure Water Is Available in the Street Mains to Provide Steam for Space Heating and Process Use

heated. Low-pressure hot water may be desirable for the space-heating system and steam for process work. These can both be obtained readily through the use of two heat exchangers, one generating steam and the other hot water. This type of system is very flexible and could be advantageous under the right conditions.

Fig. 1 shows a simple arrangement where high-pressure, high-temperature water from the street main flows to a heat exchanger which provides low-pressure hot water for space heating or service water heating.

Fig. 2 shows another arrangement where low-pressure steam is generated in a heat exchanger to furnish steam for space heating and process work.

In the past, steam distribution for district heating has had a marked advantage over hot water because of the ease of metering the quantity used. Steam condensate meters were developed to a high degree of accuracy and reliability. No such meter was available for metering hot water. However, meters have been developed in Europe which measure the quantity of water and the temperature difference between supply and return and record the total quantity of heat units consumed. Unfortunately, they are so expensive to purchase that sometimes a single meter must be used for a group of buildings and the total Btu divided among the consumers according to an estimate. In other instances a single temperature-difference recorder is used in conjunction with a hot-water meter on each premises.

The advantages claimed for high-pressure, high-temperature water distribution systems are numerous. The more important of these are given below.

Economy of Operation

One of the chief claims for high-pressure, high-temperature water is increased thermal efficiency. Most of this thermal advantage results from returning all of the heat not used by the consumer or lost through pipe radiation to the plant. This apparent advantage over a steam system would not be so great if all of the condensate were likewise returned to the boiler plant. It is true, however, that the heat lost in the steam system is greater because of losses sustained from condensate drained from steam mains and in steam discharged by traps and accessory equipment. In the United States it has usually not been considered economically justifiable to return all of the condensate to the plant. The cost of doing this would exceed the cost of treating and heating the boiler make-up water.

A hot-water system may also serve as a high-pressure heat accumulator, which enables it to supply the heating demand with less fluctuation in boiler load. It is reported that in Europe the entire distribution system is raised to the maximum pressure and temperature at night or off-peak periods so that a leveling effect on the boiler load at the morning peak demand is obtained. The amount of boiler capacity saved depends on the size of the system. To augment this capacity, especially in conjunction with electric power generation, large heat accumulators installed at strategic points in the system are of great value. Reducing peaks in boiler steaming rates also improves the over-all boiler efficiency.

Operating with closed circuits means the practical elimination of expensive water-treating systems. The water is used over and over again with small amounts added to make up for losses resulting from leaks. In the boiler this means clean tubes and good heat transfer. In the distribution system, heating, and process equipment it means practical elimination of internal corrosion resulting from entrained gases.

Water temperature and rate of water flow to the system can be controlled at the plant. Individual controls on heating systems and process equipment can be applied readily.

Smaller Pipe Sizes

Smaller pipe sizes can be used to transmit the same amount of heat with high-pressure, high-temperature water than with low- or medium-pressure steam. The pipe size depends on the pressure and temperature drops for which the system is designed. Temperature drops as high as 200 F can be applied successfully in a hot-water system. However, two-pipe distribution piping is required in a hot-water system, whereas only one pipe is required in a steam distribution system. Relative heat-carrying capacities of various sizes of pipe for the two media cannot be given except in actual design cases because of the many factors involved. Fig. 3 shows a comparison of pipe sizes for steam and hot water for transmitting the same amount of heat, 200,000,000 Btu per hr. These are actual design figures for a heating system under construction in northern United States.

It is important to note that the pressure drop allowed for steam in this design is 25 psi for two miles of pipe, or approximately 0.24 psi per 100 ft. Under these conditions the high-pressure, high-temperature water lines can be significantly smaller. Many steam systems in the United States are designed to operate at considerably higher pressure drops, some as high as 1 psi per

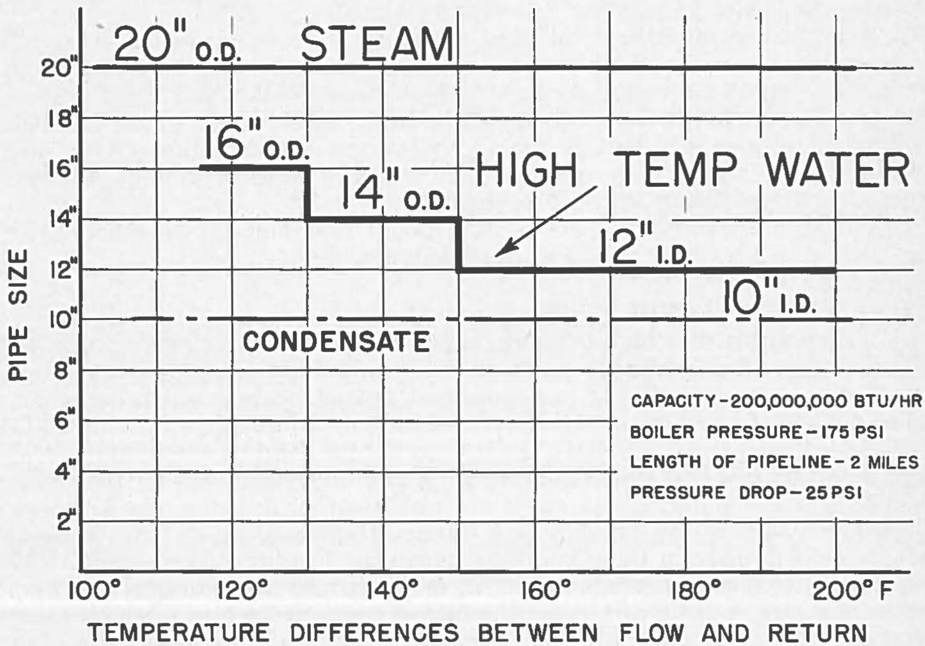


FIG. 3—Comparison Between Pipe Sizes for Steam and Hot Water for Transmitting 200,000,000 Btu per Hour Under the Conditions Stated[1]

100 ft. With a pressure drop of 1 psi per 100 ft, a 16-in. steam line could be used to transmit the same heat quantity. The advantage is still in favor of the water line but is not as great as is indicated by the chart.

Ease of Installation

In a high-pressure, high-temperature water system, pipe can be laid to follow the contour of the ground since no grade is required as in the case of steam. Also the low points need not be dripped. These are advantages both in construction and maintenance.

The elevation of hot-water pipes in buildings can be changed as often as may be required to suit the installation. The pipes can be placed in the open instead of in inaccessible spaces, underground, or in trenches as is often

[1] By American Hydrotherm Corporation, New York, N. Y.

required with steam supply and return lines. For this reason the pipes are usually more accessible for maintenance.

Savings in Special Applications

Some of the more important advantages claimed for high-pressure, high-temperature water as a heat distributing medium have been pointed out. In addition to these, other advantages are claimed for specialized industrial applications. High-pressure, high-temperature water installations have been made in industrial plants such as for wool processing, cotton and rayon finishing, and rubber manufacturing. Operating and maintenance results are reported to be very satisfactory, and where this type of system has replaced a steam system, savings of 25 per cent have been claimed.

A typical installation consists of a high-pressure steam boiler supplying a turbine. Steam is extracted or exhausted from the turbine to heat the water in a high-temperature generator. Hot water is taken from this generator and circulated through the system, which, in a rubber plant, includes equipment such as all types of presses, vulcanizers and radiators. After giving up heat to the process equipment the water is returned through a closed system to the generator where it is reheated.

For such applications there is little doubt that high-pressure hot water has a definite advantage as a heat distributing medium.

Use in Commercial District Heating

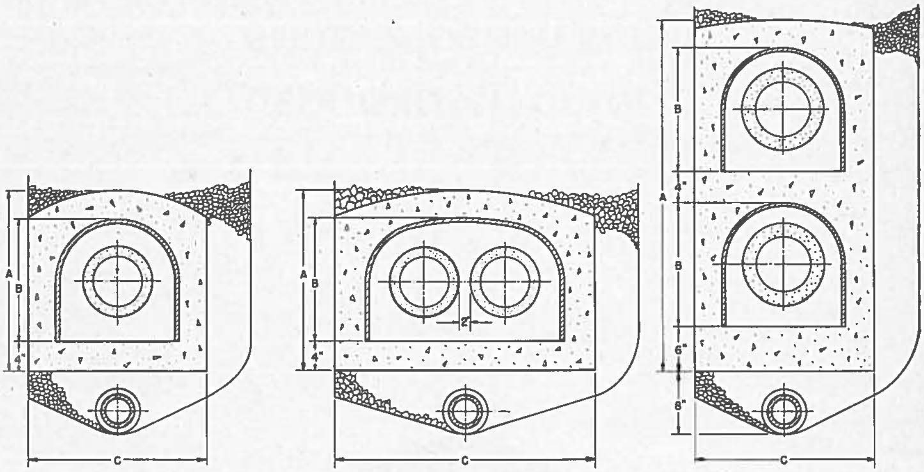
It is possible that high-pressure, high-temperature water might work out economically when applied to a new district heating system. There are, however, considerations involved in commercial district heating which are somewhat different from those applying to industrial, institutional, or housing units.

Commercial district heating usually serves the larger metropolitan areas with multi-storied and low buildings with many diversified uses for the space. Many of these buildings at one time had their own boiler plants which furnished steam or low-pressure hot water. High-pressure hot water could not be used directly in these buildings unless the heating systems were redesigned and changed to accommodate it, or provisions made to generate low-pressure steam or hot water using the high-pressure hot water as the heating medium. This, however, does not appear to be practical, because the cost of converting to district heating would in either case become excessive.

In many large cities the problem of finding space in the streets to install utility lines is quite serious. The dual piping for supplying and returning the hot water would require a conduit of considerable size and form a prohibitive barrier for other utilities in the street. This is based on the assumption that the conduit used would be of a design similar to the conduit shown in Fig. 4. It is claimed that prefabricated conduit would occupy much less space and would be preferable; however, unless hot-water pipes would be considerably smaller than the steam, dual piping would require more space and usually furnish a greater problem than would one pipe.

As already mentioned, another problem arises when using high-pressure, high-temperature water in connecting new customers or making repairs to the main and return lines of the distribution system. When shutting down a portion of the system the pressure must be relieved first and the water then drained. Relieving the pressure is similar to doing so with a steam line, but draining the high-temperature water poses a problem. Many large cities prohibit the dumping of high-temperature water in the sewers and suitable drainage provisions are not always available.

High-pressure, high-temperature water in the consumer's building appears to be more hazardous than steam at 30 psi or lower. Many district heating systems supply steam to consumers at these low pressures.



MAIN	4"	6"	8"	10"	12"	16"
A	20½"	22⅜"	24⅜"	26¼"	28⅛"	31⅜"
B	12½"	14⅜"	16⅜"	18¼"	20⅛"	23⅜"
C	20¼"	22⅜"	24⅝"	26¾"	29¼"	32½"

STEAM MAIN CONSTRUCTION

MAIN	4"	6"	8"	10"	12"	16"
A	20½"	22⅜"	24⅜"	26¼"	28½"	31⅜"
B	12½"	14⅜"	16⅜"	18¼"	20⅛"	23⅜"
C	31"	35⅛"	39"	43"	46⅞"	53"

HOT-WATER SUPPLY AND RETURN MAINS HORIZONTAL

MAIN	4"	6"	8"	10"	12"	16"
A	37"	41¼"	45¾"	50¼"	53¾"	61½"
B	11½"	13⅝"	15⅞"	18⅛"	19⅞"	23¾"
C	19¾"	21⅞"	24⅛"	26¼"	28¾"	32"

HOT-WATER SUPPLY AND RETURN MAINS VERTICAL

FIG. 4—Comparison of Conduit Cross Sections for District Heating by Steam and High-Pressure, High-Temperature Hot Water

Conclusions

High-pressure, high-temperature water has some definite advantages and, when good engineering practice indicates, it should be given serious consideration. It does not appear, however, that it will displace existing steam systems because of the large capital expenditure for conversion. However, the scarcity or high cost of fuel may at some time change the economic balance to such an extent that the apparent savings may outweigh the disadvantages.