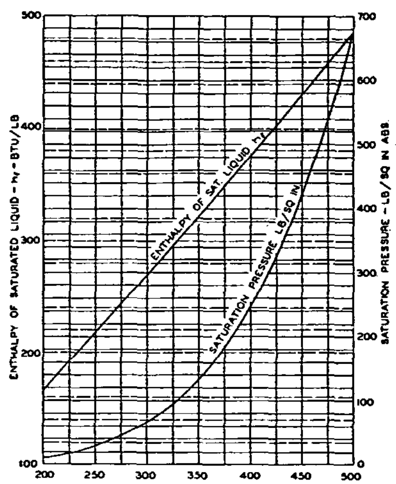

Fig. 2 .... Relation of Saturation Pressure and Enthalpy to Water Temperature

at a given minimum supply temperature continuously, while space heating may permit modulating the temperature as a function of the outdoor temperature or other climatic influences.

2. Temperature which must be obtained in the terminal unit.
3. Distance from heating plant to space or process requiring heat.
4. Terrain of land on which buildings are located.
5. Zoning requirements based on occupancy and load distribution.
6. Quantity and pressure of steam used for power equipment in central plant, if desired.
7. Variations in elevation within the system. These may make it desirable to locate the central station on the highest ground in order to maintain a maximum static pressure head on the system.

Theoretically, water temperatures up to about 350 F may be provided using equipment suitable for 125 psig, but practically, maximum water temperatures will be limited by the system design, pump heads, and elevation characteristics to values between 300 to 325 F. Water temperatures of 350 F to 420 F, requiring 250 to 300 psig working pressure, permit a greater temperature drop to be realized, and are employed where the savings resulting from the reduced pipe sizes offset the added cost of heavier fittings and equipment, or where the terminal units require the higher temperatures.

Most systems designed for steam pressurization have a steam drum through which the entire flow is taken, and which also serves as expansion vessel. A circulating pump is in the supply line taking water from the tank. The temperature of the water from the steam drum cannot exceed the temperature of the steam in the drum which corresponds to its pressure at saturation. The point of maximum pressure is at the discharge of the circulating pump. If, for example, this pressure is to be maintained below 125 psig, the pressure in the drum, corresponding to the water temperature, cannot exceed 125 psig minus the sum of the pump head and the pressure head due to the difference in elevation between the drum and the circulating pump. The steam drum (expansion tank) must be placed above the *high-temperature water generators.*

Many systems are designed for inert gas pressurization. In most of these systems, the pressurizing tank is connected to the system by a single balance line on the suction side of the circulating pump. *The circulating pump is located at the inlet* side of the high-temperature water generator. There is no flow through the pressurizing tank, and a reduced temperature will normally establish itself inside. This tank may be placed wherever *is most suitable in the central station. A special* characteristic of the gas-pressurized systems is the apparatus for creating and maintaining gas pressure inside the tank.

Of primary importance in the design and operation of the *high-temperature water system is the requirement of* maintaining at all points of the system a pressure which at all times, whether or not the system is in operation, exceeds the vapor pressure of the water. This may require limiting the water temperature, and *thereby the vapor pressure.*

Elevation effects, and the pressures required to prevent the flashing of water into steam in the supply system, can also limit the maximum water temperature that may be used, and *must therefore be studied in evaluating the temperature*-pressure relationships of the system.[1]

The properties of water which govern the features of the design are:

1. Temperature versus pressure at saturation. (See Fig. 2.)
2. Density or specific volume versus temperature.
3. Enthalpy or sensible heat versus temperature.
4. Viscosity versus temperature.

The relation of temperature and pressure, specific volume and enthalpy, are all available in the steam tables. The properties of water for the range 212 to 400 F are summarized in Table 1.

Direct-Fired High-Temperature Water Generators

Where the high-temperature water generators are direct-fired using conventional fuels, the central stations are comparable to steam boiler plants operating within the same pressure range. The generators should be selected for size and type in keeping with the load and design pressures, as well as the circulation requirements peculiar to high-temperature water. There are many systems in existence in which both steam for power or processing and high-temperature water are supplied from the same boiler; others in which steam is produced in boilers and used for generating high-temperature water; and again others where the burning fuel directly heats the water.

Table 1 .... Properties of Water (212 F to 400 F)

Temperature F	Pressure* Psia	Density Lb/Cu Ft	Specific Heat Btu/(Lb)(F)	Total Heat Above 32 F	
				Btu/Lb*	Btu/Cu Ft
212	14.70	59.81	1.007	180.07	10,770
220	17.19	59.63	1.009	188.13	11,216
230	20.78	59.38	1.010	198.23	11,770
240	24.97	59.10	1.012	208.34	12,313
250	29.83	58.82	1.015	218.48	12,851
260	35.43	58.51	1.017	228.64	13,378
270	41.86	58.24	1.020	238.84	13,910
280	49.20	57.94	1.022	249.06	14,430
290	57.56	57.64	1.025	259.31	14,947
300	67.01	57.31	1.032	269.59	15,450
310	77.68	56.98	1.035	279.92	15,950
320	89.66	56.66	1.040	290.28	16,437
330	103.06	56.31	1.042	300.68	16,931
340	118.01	55.96	1.047	311.13	17,409
350	134.63	55.59	1.052	321.63	17,879
360	153.04	55.22	1.057	332.18	18,343
370	173.37	54.85	1.062	342.79	18,802
380	195.77	54.47	1.070	353.45	19,252
390	220.37	54.05	1.077	364.17	19,681
400	247.31	53.65	1.085	374.97	20,117

* Reprinted by permission from *Thermodynamic Properties of Steam*, by J. H. Keenan and F. G. Keyes published by John Wiley and Sons, Inc., 1938 edition.

The high-temperature water generators may be of the water-tube or fire-tube type, and may be equipped with any conventional fuel firing apparatus. The water-tube type may have either forced circulation or gravity circulation, or a combination of both. The recirculating pumps of forced-circulation generators must operate continuously while the generator is being fired. Steam boilers relying on natural circulation may require internal baffling when used for high-temperature water generation. In Scotch Marine type boilers the problem of thermal shock caused by a sudden drop in the temperature of the return water impinging on the fire tubes must be considered. Forced circulation high-temperature water generators are generally of the once-through type and rely solely on pumps to achieve the circulation. Depending on the design they may require the use of internal orifices in the various circuits to apportion the water flow rates in proportion to the heat absorption rates. Circulation must be maintained at all times while the generator is being fired, and the flow rate must never be allowed to drop below a minimum indicated by the manufacturer.

Where gravity circulation type steam boilers are used for high-temperature water generation, the steam drum usually serves as expansion vessel.[2] In forced circulation type high-temperature water generators, a separate vessel into which all generators discharge is commonly used for maintaining the steam pressure cushion and for expansion. A separate vessel is usually used when the system is cushioned by an inert gas. Proper internal circulation is essential in all types of boilers to prevent tube failures due to over-heating or unequal expansion.

Pressurization

The method whereby the pressure is maintained above saturation should take into consideration the following factors:

1. The pressurization system should be relatively simple and incorporate a high degree of reliability. Loss of pressurization results in flashing within the system, which can lead to problems within pumps, generators, heat exchange devices, and the piping system.

2. The pressurization system should maintain the generally corrosion-free characteristics of hot water heating. Oxygen should be excluded from the system, both in the means of pressurization and in the operating cycle. This precludes the use of air as a pressurizing means. Cycles which periodically withdraw and reintroduce water should not be used.

3. The control of the pressurization system should maintain the inherently stable conditions of the high-temperature water cycle. Fluctuations in system pressure or temperature should be minimized by taking advantage of the thermal storage of the cycle. This will improve combustion efficiency through relatively steady firing rates.

4. The location of the compression tank used for pressurization has a great effect on the net positive suction head (NPSH) at the pumps and may limit the allowable friction losses of the piping system. Flexibility in the location of this tank is an advantage in adapting a HTW system to a given problem.

5. Proper safety devices for high and low water levels and excessive pressures should be incorporated in the compression system and interlocked with combustion safety and water flow rate controls.

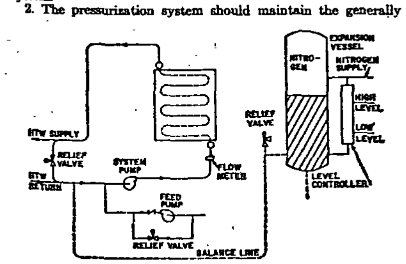

Fig. 3 .... Inert Gas Pressurization for One-Pump Type System

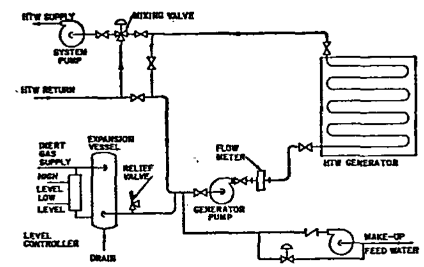

Fig. 4 .... Inert Gas Pressurization for Two-Pump Type System

There are a number of fundamental methods whereby pressure in a given hydraulic system may be kept at a desired level.[3,4]

1. An elevated storage tank is a simple means of pressurization, but due to the great heights required for the pressures encountered, this system is generally impractical.

2. A hydraulic pump may be used. However, difficulties in maintaining constant pressure-temperature relationship within the system, plus the withdrawal and reintroduction of system water make this system generally impractical. When pressurizing with a feed pump automatically operated by pressure control, a relief valve for the maximum system pressure is provided (see Figs. 3 and 4).[3] The pressure control is set to operate the feed pump and circulate water from the make-up tank to the system whenever the pressure falls to the regulator cut-in point, and to stop the pump when the cut-out point is reached. If the pressure increases to the relief valve setting, excess water will flow through the relief valve to the make-up water tank. Since this system is not entirely closed, the means for preventing the entry of corrosion-causing elements, principally oxygen, or for their elimination, should be considered.

3. Steam pressurization through the use of an expansion vessel which is separate from the HTW generator. The vessel must be above the HTW generators and connected in the supply water line from the generator. Water in the expansion vessel flashes to steam to maintain system pressure above the saturation point of the cooler water in the balance of the system. The circulating pump moves the water from the expansion vessel to the system and back to the generator. Since the system pump draws water from the bottom of the vessel, the vessel must be elevated to increase the net positive suction head to prevent cavitation or flashing in the pump suction. This arrangement is critical. To assist in the prevention of flashing, a bypass is provided from the HTW system return line to the pump suction. Cooler return water is then mixed with hotter water from the expansion vessel to give a resulting temperature below the corresponding saturation point in the vessel.