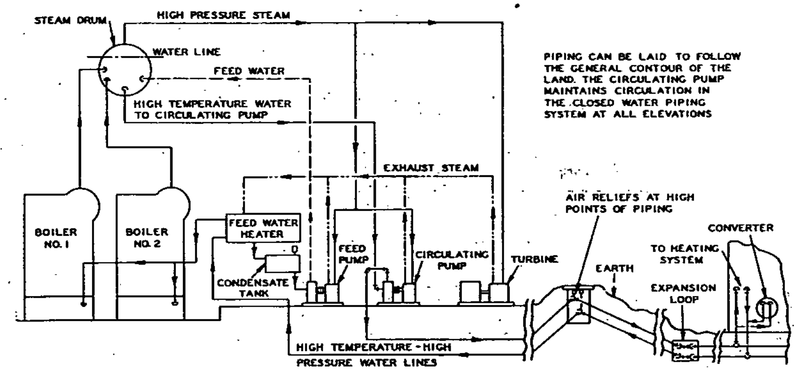

Fig. 2 .... Profile of High-Temperature Water System

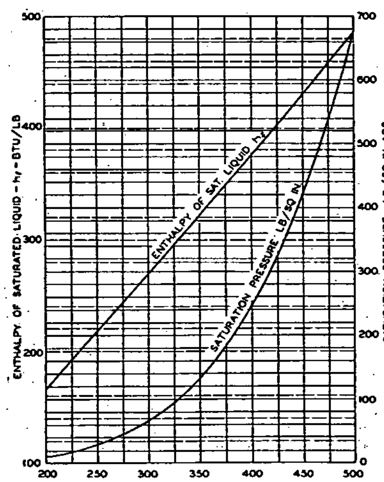

Fig. 3 .... Relation of Saturation Pressure and Enthalpy to Water Temperature

by the system design and elevation characteristics to values between 300 F to 325 F. Most systems are being designed with the system circulating pump in the supply line and with a steam drum for pressurization, expansion, and temperature control. In this type of system, 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 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.

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., 1936 edition.

Elevation effects and the pressures required to prevent the flashing of water to 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.

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

1. Temperature vs pressure at saturation (see Fig. 3).
2. Density or specific volume (v_s) vs temperature.
3. Enthalpy or sensible heat (h_f) vs temperature.
4. Viscosity vs temperature.

The relation of temperature and pressure, specific volume, and enthalpy are all discussed in Chapter 3. Data for the normal temperature-pressure ranges are given in Table 3 of Chapter 3. The properties of water for the range 212 F to 400 F are shown in Table 1.

Water temperatures of 350 to 400 F requiring 250 psig working pressure will largely be limited to district and institutional installations. In such applications the heat quantities and distances to be covered usually justify the added cost of the heavier pipe, fittings and special valves.

Boilers

The boiler plants of the larger high-temperature water systems are comparable to boiler plants of power generating stations operating within the same pressure range. The boilers should be selected for size and type in keeping with the load and design pressures. Both steam for power or processing and high-temperature water for heating may be supplied from the same boiler plant. The load is determined by the heat required for:

1. Space heating and winter air conditioning.
2. Generated steam required for power.
3. Water heating or heat processes.

The boilers may be water-tube, horizontal return-tube or Scotch marine type, and may be equipped with any conventional fuel-firing apparatus. Water-tube boilers are favored for higher pressure ranges—200 psig and upward. Boilers may be of either forced circulation or gravity circulation type. The circulating pump of forced circulation boilers must operate continuously during operation of the boiler. Water-tube boilers frequently require separate vessels for the pressure cushions, depending on the volume of the steam drum relative to system requirements. When systems using fire-tube boilers are cushioned by steam, expansion space may be available within the boiler itself.[1] A separate vessel usually is used when the system is cushioned by air or other gas.

Proper distribution of return water and of water flow is essential in all types of boilers to prevent tube failures due to overheating or unequal expansion in boiler tubes.

Expansion Pressure Cushion

Four methods are used to produce and maintain the necessary pressures on the system:

1. A steam cushion in the steam space of the boiler or a steam drum.
2. A separate expansion tank for steam pressurizing.
3. Compression tank with compressed air or an inert gas.
4. An automatic pressure pump.[2, 3, 4]

A steam cushion or a pneumatic cushion is generally favored because it may also accommodate the expansion. The *steam-cushion* method for maintaining pressure above the water level in the boiler requires space to accommodate the expansion of the water volume within the system when heated to the system operating temperature. Systems which do not use steam for maintaining the required pressure, or in which the boiler steam space is inadequate to accommodate the change in water volume, will require additional tanks or steam drums for expansion.

The arrangement of the tanks for pneumatic cushioning is similar to the closed expansion tanks when air pressures are used for cushioning or pressurizing. A suitable means of balancing or a connection from the bottom of the tank should be made to the main system return header. (See Fig. 4.)

A major problem when pressurizing by steam is to maintain a proper boiler water level while providing for the change in water volume due to expansion and contraction. Boiler water level and flow connections should be designed to utilize the steam drum in adjusting to changes in water

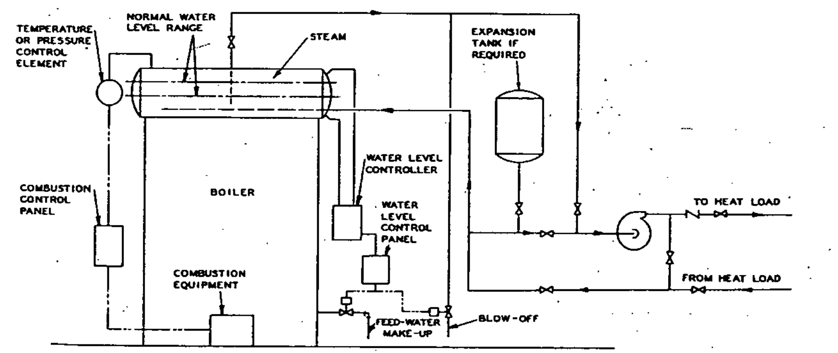

Fig. 4 .... Schematic Arrangement of Combustion and Feed-Water Controls