creased an amount equal to the head of the pump, 20 ft of water. P_f, the minimum pressure, equals 29 plus 20, or 49 ft of water, gage, or 83 ft of water, absolute. The required volume by Equation 4 is

$$V_t = \frac{35.4}{\frac{34}{83} - \frac{34}{103.3}} = 440 \text{ gal.}$$

Example 6: Determine the size of expansion tank required when it is connected as shown in *D*, Fig. 17.

Solution: The expansion tank is located at the top of the system with the result that the height of the system has no effect on the required minimum pressure, P_f. However, the tank is located far enough from the pump so that friction loss in the piping between the pump and the tank must be considered in determining the pressure effect of pump operation on system pressures. Assume that the tank is located at a point such that the friction loss between the tank connection to the system and the suction of the pump is 8 ft, with the resistance in the return riser to the boiler still considered negligible.

The pressure in the expansion tank remains the same whether the pump runs or not. Therefore, since 8 ft of friction loss exists between the expansion tank and the pump suction at the top of the return riser, the pressure in the expansion tank must be increased by that amount to maintain a positive air venting pressure at that point.

P_f, the minimum pressure in the tank should be the sum of 4 ft for positive venting pressure and 8 ft for pump effect, or 12 ft water, gage, which is 46 ft of water, absolute. Since the pump is located between the expansion tank connection and the boiler, P_o, the maximum pressure *in the tank*, must be less than the operating pressure of the relief valve by an amount equal to the effect of pump operation on the boiler pressure. In this case, the effect of the pump is reduced by the friction loss between the expansion tank and the boiler. The head of the pump, 20 ft, less friction as discussed, 8 ft, is equal to 12 ft. The height of the system is 25 ft. The sum of the pump head and the building height effect is 37 ft.

P_o, then, is 69.3 less 37, which is 32.3 ft of water, gage, or 66.3 ft of water, absolute. Other factors remain as discussed in the other examples. Substituting in Equation 4 the required expansion tank size is:

$$V_t = \frac{35.4}{\frac{34}{46} - \frac{34}{66.3}} = 157 \text{ gal.}$$

In *Examples 4, 5,* and *6,* the calculated size of the expansion tank has been indicated. It is customary practice to select a standard tank size not less than that calculated.

The two following important factors in tank sizing have not been illustrated in the *Examples 4* to *6*:

1. *Use of compressed air to increase the amount of air in the tank.* This factor affects the value of P_o by increasing it above atmospheric pressure. The use of compressed air to *charge* the expansion tank reduces the required tank volume.

2. *Effect of a design maximum temperature higher than 212 F.* The effect of design temperatures above 212 as used by some designers is given in the discussion of *A*, Fig. 17. It is possible to obtain proper operation of the expansion tank without adding the pressure required to maintain liquid water at temperatures in excess of 212 F. Two things are necessary on this basis of design: (*a*) the pressure increase in the system as the temperature increases from 40 F to 212 F and to the final design temperature must be sufficient to keep the pressure above that corresponding to the temperature of the water in order to prevent boiling and (*b*) the operating personnel for the system must be instructed regarding the proper pressure for various system temperatures in order that proper pressure control of the system may be maintained. An automatic fill valve cannot be used to maintain the minimum pressure for such a system.

In small systems where the volume of water is small and where the pressures due to pump and static heads are low, expansion tanks are small and no critical problems are encountered. However, for large systems the size of the expansion tank and the problems of pressure control can become critical. The following means of reducing expansion tank size and establishing satisfactory pressure control may be investigated in addition to the methods discussed under *A* to *D*, Fig. 17:

1. Compressed air, if available, can be admitted to the expansion tank to obtain the desired pressure.

2. The head of the pump may be reduced by the use of larger pipe sizes, or greater design temperature drop.

3. The boiler may be constructed for pressures higher than 30 psig.

4. The steam boiler may be used with a steam-to-water heat exchanger to heat the water circulated.

The point of connection of the expansion tank to the system should be studied carefully to guard against the possibility of isolating the tank from a hot boiler or any part of the system by normal operation of automatic, check, or manual valves.

BOILER ROOM PIPING

The arrangement of equipment, its capacity, and the piping arrangement for its connection will vary, depending upon the size and characteristics of the systems which it serves. Most of the principles involved in these arrangements have been discussed. Fig. 18 shows the piping and specialties considered necessary for the most basic system. The *ASME Low Pressure Heating Boiler Code* requires that provision must be made for draining a closed expansion tank without emptying the system. A valve is commonly included in the expansion piping to the tank but it must not close a connection to the safety relief valve. Fig. 19 shows a more elaborate multizone system. Most systems will fall between these extremes as the engineer fits the design to the requirements of the installation.

One device in boiler piping which facilitates elimination of air before it can enter the mains is the dip tube. Air will separate from the water in a heating system at a point where the velocity and pressure are the lowest and where the temperature is the highest. Although the pressure at the boiler is generally high, it is a logical place to perform the separation. Fig. 18 shows the use of a dip tube. This extension of the outlet pipe forms a dead space at the highest and hottest part of the boiler. The air will tend to separate from the

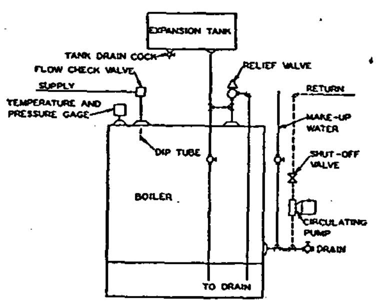

Fig. 18. . . . Basic Boiler Connections for a Hot Water System

water in this space. The air can be conducted to the expansion tank by a connection from the tank to the highest point of the boiler (see Fig. 18). The connecting pipe should be as direct as possible and be pitched upward continuously to the tank. If the expansion tank is not connected directly to the boiler, an automatic air vent valve should be installed at the high point of the boiler, instead.

In general, the manufacturer's recommendation on the number of outlets to be used for a particular boiler for a given application should be followed. This applies also to return connections.

The prevention of thermal shock through proper use of return connections should be considered in piping arrangement. Where more than one pump are used for circulation, the discharge of the pumps should be joined before being discharged into the boiler. A check valve should be installed in the discharge of each pump, unless another method of preventing backflow through the pump circuit is provided. Where temperatures higher than normal are maintained in the boiler, the connection of the return to the boiler should follow the manufacturer's recommendations for such service.

Where a multiple boiler installation is used, provisions should be made to prevent the bypassing of water through a boiler which is not being maintained at control temperature. In some cases this provision takes the form of automatic control valves interlocked with the boiler temperature control to be open only when the temperature in the particular boiler is being maintained at operating conditions. In other cases, manual valves are installed in the boiler returns and opened only when the burner switch which places the firing device at the command of the boiler temperature control is in the *ON* position.

Weighted check valves, or flow check valves, should be installed in the supply piping from the boiler to prevent gravity circulation during periods when the circulating pumps are not operating. If the piping is arranged with separate supplies to individual zones, a weighted check valve should be installed in the supply piping to each zone.

THE USE OF STEAM WITH HOT WATER HEATING SYSTEMS

The use of a steam boiler or district steam with a converter (heat exchanger) has many advantages for tall buildings. The piping for the steam used in this type of a system should follow the principles outlined in Chapter 6, Steam Heating Systems. In tall buildings the system can be zoned vertically as shown in Fig. 20, that is, with a given number of floors per zone and a converter for each zone. This type of design makes the limitation of maximum pressure in the system possible. With a converter-type system, the volume of water in the boiler is not a part of the volume of water causing thermal expansion in the system. Since the boiler in a hot water system may hold 30 to 50 percent of the total water volume of the system, the reduction in the size of the expansion tank and the problems involved therewith are of major importance.

The use of steam in extended-surface coils for heating air will often be more desirable in a system where steam is available. This type of installation will result in less expensive coils, and simplified coil controls.

TEMPERATURE CONTROL

Methods of temperature control for hot water heating systems, including zone controls, are covered in Chapter 13 of the 1961 Guide And Data Book.

SYSTEM ADJUSTMENT

Two common methods of determining the effects of capacity adjustment are: the measurement of space tempera-

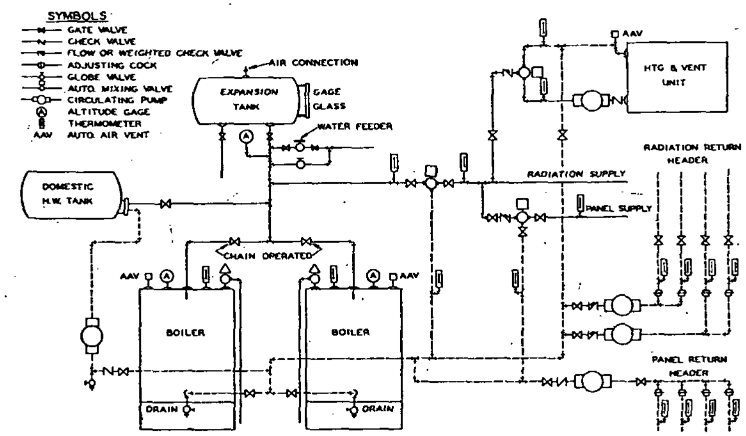

Fig. 19. . . . Boiler Piping for Multiple-Zone Multiple-Purpose Heating System