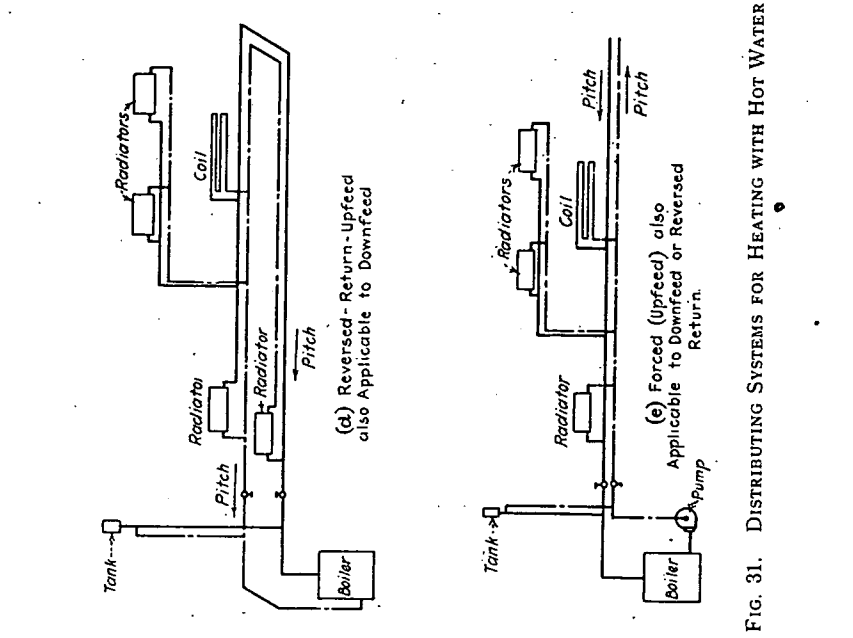
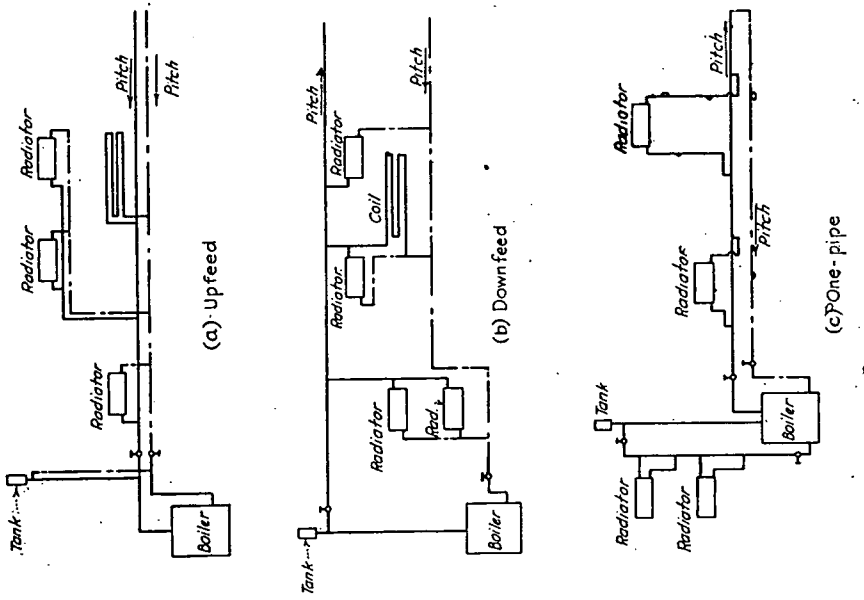


FIG. 31. DISTRIBUTING SYSTEMS FOR HEATING WITH HOT WATER



15 lb. per square inch is maintained in the highest radiator and if, in an open system, the expansion tank is located 15 x 2.4 or 36 ft. above the highest radiator, the two systems will be alike so far as pressure and boiling points are concerned.

Since water is only very slightly compressible (a change in pressure of 10 lb. per square inch will produce a change in volume of about 1 in 33,000) its density and its coefficient of friction may be considered independent of pressure and hence the laws governing pressure heads and friction heads are also independent of pressure and are the same for closed systems as for open systems.

PRESSURE HEAD

The force maintaining circulation is sometimes expressed in pounds per square inch but more generally in terms of the height of a column of water which would produce this pressure, *i. e.* in feet of water, millinches of water, etc. The height of such a column of water is the *Pressure Head.*

FRICTION HEAD

The forces resisting circulation are the frictional resistances in the heater, the radiators, the pipe lines, the several fittings and valves, and in the water itself. These resisting forces are also expressed in terms of water column. The height of this column is the *Frictional Head.*

Tests by Professor F. E. Giesecke demonstrate that the friction head for new commercial black iron pipe of American manufacture is

$$h = 83\ V^{1.88}\ d - 0.04\ d - 1.275$$

where

h = friction head, per foot of pipe, in millinches of water,
V = velocity, in ft. per sec.
d = actual internal diameter of pipe, in inches.

It has been found by experiment that the friction of water in commercial black iron pipe varies, approximately, as the 1.8 power of the velocity and that the friction in fittings, valves, and in radiator and heater inlets and outlets varies, approximately, as the square of the velocity of the water in a pipe having the same nominal size as such fitting, valve, etc. It is, therefore, impossible, to express with accuracy the friction in a pipe fitting in terms of the friction in the pipe. For example, if the friction in an elbow is equal to the friction in 3 ft. of pipe, when the velocity of the water is 1 ft. per second, the friction in the elbow will be equal to that in 4.1 ft. of pipe when the velocity is 5 ft. per second, and equal to that in 2.2 ft. of pipe when the velocity is 1/5 ft. per second.

It is possible, however, to express, with sufficient accuracy, the friction in one pipe-fitting in terms of the friction in any other pipe-fitting or in any valve. For example, if the friction in one open globe valve is equal to that in twelve elbows, when the velocity is 1 ft. per second, the same relation will exist at all other velocities, if the friction varies as the