steam pressure above that of the atmosphere exists in the supply mains and radiators practically at all times. In the sub-atmospheric system, atmospheric pressure of higher levels exists in the steam supply piping and radiators only during the most severe weather. Under average winter temperature the steam is under partial vacuum which in mild weather may reach as high as 25 in. Hg., after which further reduction in heat output is obtained by partially filling the radiation with steam.

The rate of steam supply is controlled by a control valve in the steam main or by thermostatically controlling the rate of steam production in the boiler. The control valve may be of the automatic *modulating* or *floating* type governed thermostatically from selected control points in the building or it may be a special pressure reducing valve which will maintain the desired sub-atmospheric pressures by continuous flow into the heating main. At all radiator supply tappings are radiator valves incorporating adjustable orifices or equipped with regulating orifice plates. The sizes of orifices used are larger than for orifice systems because for equal radiator sizes the volume flowing is larger. Radiator traps and drips are designed to operate at any pressure from 15 lb gage to 26 in. of Hg. Unit heaters, unit ventilators, cast-iron direct radiators and convectors may be used together in the sub-atmospheric system. A vacuum pump capable of operating at high partial vacua is preferable to promote accuracy in the distribution of steam throughout the system, particularly in mild weather. This vacuum is partially self induced by the condensation of the steam in the system under conditions of restricted supply for reduction of the radiator heat emission. The vacuum pump regulator is a diaphragm device subjected to the difference in pressure between the supply and return sides of the system. It starts the pump when the pressure drop through the system falls to a minimum and stops it when the pressure difference increases to a fixed maximum. The actual pressure difference (drop) maintained is only enough to secure adequate circulation and is often about 2 in. of Hg. The low pressure difference maintained permits the use of a wider range of sub-atmospheric pressure in the radiators and supply pipe and more precise control of distribution. This method of operation results in a diminution in heat output from steam mains and risers (as well as radiators) and gives a measure of control over this portion of the total system output. The decrease in condensation in the piping, as the temperature of the steam is reduced under vacuum, assists in securing control of building temperature and promoting economy. The orifices function to distribute steam proportionately when both complete and partial filling of the radiators is being employed in the cycle of heat output reduction. Individual thermostatic radiator control may be used with this system. With individual thermostatic radiator control the individual control makes fewer operations and the radiator follows a more even temperature without fluctuating from extreme hot to extreme cold, since operating the system with steam temperature inversely with the outside temperature removes a part of the load from the radiator temperature control.

The returns must grade downward constantly and uninterruptedly from the radiator return outlets to the inlet of the receiver of the vacuum pump. One radical difference between this system and the ordinary vacuum system is that no lifts should be made in the return line, except

at the vacuum pump. The receivers may be placed at a lower level than the pump and are equipped with float control so the pump may operate as a return pump during night operation. The system may be operated in the same manner as the ordinary vacuum system when desired.

To convert an ordinary vacuum return line system to a sub-atmospheric system, a control valve is inserted on the steam main near the boiler or the boiler is automatically controlled. The steam supply to each radiator is provided with a flow proportioning device, such as an orifice, a high-vacuum pump is substituted for the ordinary type and is supplied with a pressure difference control, and traps are placed on the radiators and drip points which will operate satisfactorily throughout the wide pressure and vacuum range.

Steam for heating domestic hot water should not be taken from the heating system side of the control valves of this system. It should be taken from the boiler header back of the control valve so that pressures sufficiently high for heating the water may be maintained on the heater. The sub-atmospheric method of heating can be used for the tempering and heating coils of ventilating and air conditioning systems. The flexible control of heat output secured by this method materially reduces the required size of by-pass around the heaters. Sub-atmospheric systems are proprietary.

ORIFICE SYSTEMS

Orifice systems of steam heating may have piping arrangements identical with vacuum systems. Some of these systems omit the radiator thermostatic traps but use thermostatic or combination float and thermostatic traps on all drip points. A return condensation pump with the receiver vented to atmosphere is generally used to return the condensation to the boiler, or place of final disposition, such as a feed water heater or hot well. They contemplate varying the heat emission from the radiators by varying the pressure maintained in the steam supply piping while the radiator pressure remains substantially equal to that of the atmosphere.

The principle on which they operate is based on the well known fact that the steam flow through an orifice will vary when the ratio of the absolute pressures on the two sides of the orifice exceeds 58 per cent. If the absolute pressure on the outlet side is less than 58 per cent of the absolute pressure on the inlet side, no further increase in flow will be obtained as a result of the increased pressure difference. If an orifice is so designed in size as to exactly fill a radiator with 2 lb gage on one side and ¼ lb gage on the other, the absolute pressure relation is:

$$\frac{14.7 + 0.25}{14.7 + 2.0} = 0.90 \text{ or } 90 \text{ per cent.}$$

Should the steam pressure be dropped to ¼ lb on the supply pipe, the pressure on each side of the orifice would be balanced and no steam flow would take place. From this it will be apparent that if an orifice of a given diameter will fill a given radiator with steam when there is a given pressure on the main, reducing this steam main pressure will permit filling various desired portion of the radiator down to the point where the main pressure equals the back pressure in the radiator provided the supply pipe pressures may be controlled sufficiently closely. If orifices are designed on