vacua is preferable since the higher the vacuum the greater is the accuracy in the distribution of steam through the system, particularly in mild weather. A pump capable of producing up to 25 in. of vacuum on the system is used in such cases. A controller is placed on the pump so that the vacuum or absolute pressure carried in the returns can be maintained at a certain amount below that existing in the line to insure circulation.

The traps are designed to operate in high vacuum. It is apparent that this system differs from the ordinary vacuum system by having a vacuum on both sides of the system, instead of only on the return side, in order to secure control of the heat emission from the radiators and thus to control

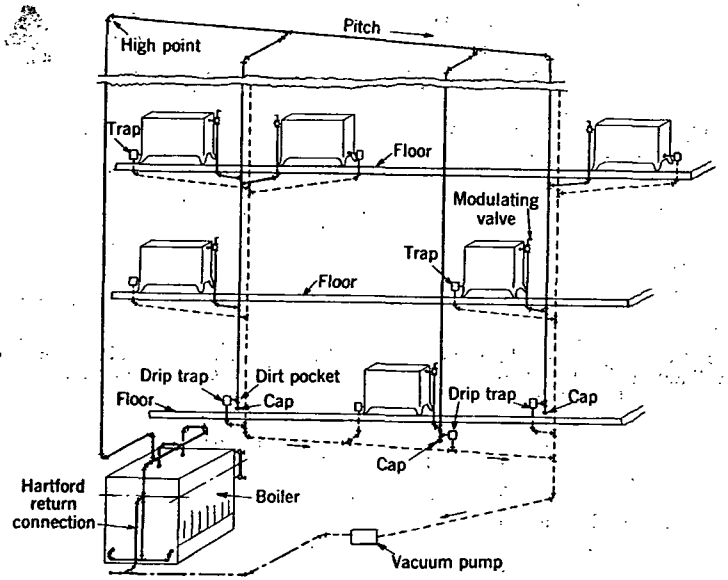

FIG. 18. TYPICAL DOWN-FEED VACUUM SYSTEM

the temperature in the building. These systems permit the heat output from the steam mains and risers to be diminished as the weather becomes milder, thus giving control to this portion of a heating system. The decrease in condensation in the piping as the temperature of the steam is reduced under a vacuum is a measure of the saving in heat loss from piping resulting from steam circulation at sub-atmospheric pressures as compared with circulation at sub-atmospheric pressure. The system can be operated in the same manner as the ordinary vacuum system when desired.

In the vacuum system, steam pressure above that of the atmosphere exists in the supply mains and radiators practically at all times. In the sub-atmospheric system, steam pressure exists in the steam main and radiators only during the most severe weather, while under average winter temperatures the steam is under a partial vacuum which in mild

weather may reach as high as 25 in. after which further reduction in heat output is obtained by partially filling the radiation with steam.

This vacuum is partially self-induced by the condensation of the steam in the system due to the supply of steam being furnished through the control which admits it, and it being proportioned to balance the existing heat loss. 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 drips which will operate satisfactorily at any pressure from 5 lb gage to 26 in. of vacuum.

The control valve is either a special pressure-reducing valve which may be controlled manually, or a control valve or combustion equipment which may be operated thermostatically from points selected in the building. The vacuum pump regulator is simply a diaphragm so arranged that, when the vacuum in the return line is insufficient to hold the desired difference in pressure between the steam and return sides of the system, the vacuum pump is automatically started and the vacuum increased to the necessary amount. The actual pressure difference maintained between the two sides of the system is only enough to secure adequate circulation and is often about 2 in. of mercury. This fixed pressure difference between the supply and return sides of the system results in practically constant circulation under all pressure conditions.

In order to distribute the steam equally when the system is being warmed up and also to reduce the amount of steam delivered to the radiators on mild days, orifice plates are used in the graduated radiator control valves. A definite, nearly constant, relation exists between the supply and return pressure differential at various points throughout the system which promotes proportionate steam distribution between the various radiators. The heat emitted from the radiators in mild weather and under conditions of high vacuum is not only reduced in proportion to the difference in the steam temperature between that for 2 lb gage and for 25 in. of vacuum but it is reduced still further by a reduction in the amount of steam which can pass through the orifice when the steam is expanded due to the vacuum. This renders possible the control of heat emission from the radiators to a point not indicated entirely by the difference in steam temperatures, but far beyond it.

Sub-atmospheric operation has advantages even where individual thermostatic radiator control is installed. By operating the system with steam temperatures in parallel with the outside temperature requirements, a large part of the load is removed from the temperature control system, it makes fewer operations and the radiator follows an even temperature without fluctuating from extreme hot to extreme cold.

The high-vacuum pumps on this system are equipped with receivers having float control so that the pump can be placed on a receiver-return-pump basis at night if desired so no high vacuum will be carried. One radical difference between this system and the ordinary vacuum system is that no lifts can be made in the return line, except at the vacuum pump.