the casing above the level of the grate in the furnace. To accomplish this the shoe must be wide.

Tests of six different systems of cold air returns, Fig. 6, made at the University of Illinois[2], resulted in the following conclusions:

1. In general, somewhat better room temperature conditions may be obtained by returning the air from positions near the cold walls.
2. Friction and turbulence in elaborate return duct systems retard the flow of air, and may seriously reduce furnace efficiency, and lessen the advantages of such a design.
3. The cross-sectional duct-area is not the only measure of effectiveness. Friction and turbulence may operate to make the air flow out of all proportion to the various duct areas.

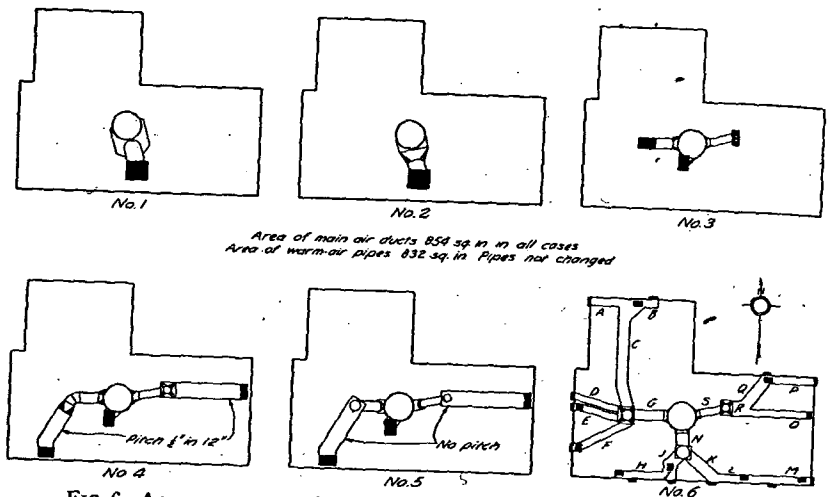

FIG. 6. ARRANGEMENT OF COLD AIR RETURNS FOR THE SIX INSTALLATIONS

FURNACE CAPACITY

The size of furnace should, of course, be such as will provide the necessary air heating capacity, usually expressed in square inches of leader pipe area, and at the same time provide a grate of the proper area to burn the necessary fuel at a reasonable chimney draft. The total leader pipe area required is easily obtained by finding the sum of the leader pipe areas as already designated.

The grate area will depend on several factors of which four are very important. First of all, the air temperature at the register for which the plant has been designed must be determined. Usually, this temperature is taken as 175 F. Second in importance is the combustion rate, *which must always correspond with the register air temperature*, as is shown by reference to a set of typical furnace performance curves (Fig. 7) for a cast-iron circular radiator furnace with a 23-in. diameter grate and 50-in. diameter casing. The conditions shown on these curves which seem to

[2]Investigation of Warm-Air Furnaces and Heating Systems, Part *N*, by A. C. Willard, A. P. Kratz and V. S. Day (University of Illinois *Engineering Experiment Station Bulletin No.* 189).

approximate nearest to the 175 F register warm-air temperature are—combustion rate, 7 lb; warm-air register temperature, 173 F; efficiency of the furnace, 58.5 per cent. The third factor is efficiency, which, in turn, is a function of the combustion rate varying with it as shown by the efficiency curve of Fig. 7. The fourth factor is the heat value per pound of fuel burned, which was 12,790 Btu, but is not shown on the curves since it was constant for all combustion rates.

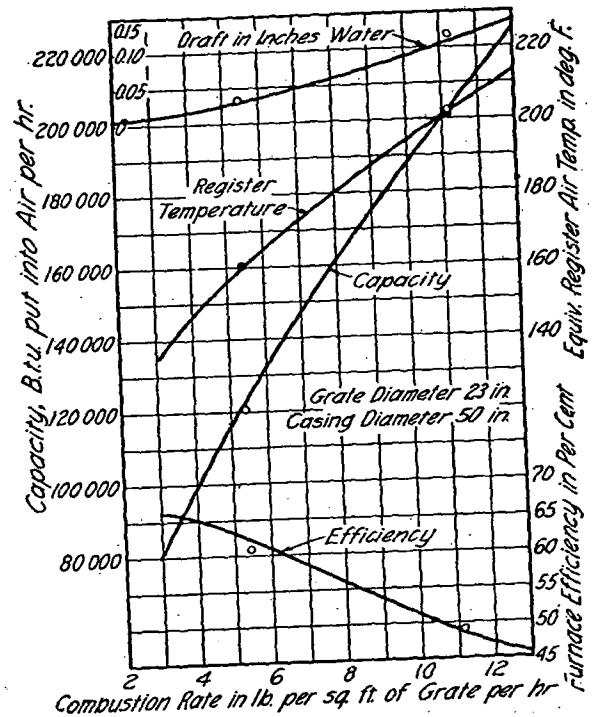

FIG. 7. TYPICAL PERFORMANCE CURVES FOR A WARM AIR FURNACE AND INSTALLATION IN A THREE-STORY TEN LEADER PLANT, OPERATING ON RECIRCULATED AIR

From the relation existing between these factors it is found (Fig. 7) that the capacity of the furnace under test is 147,750 Btu per hour for the total grate, which gives the capacity at the furnace bonnet per square foot of grate as 51,200 Btu and per square inch of grate as 356 Btu per hour.

Suppose it is desired to select a furnace to deliver air to the rooms at a register temperature approximating 160 F rather than 175 F. Referring to the curves, the relation is—combustion rate, 5.5 lb; register warm-air temperature, 160 F; and efficiency of the furnace, 62 per cent. Under this condition the capacity of the furnace at the furnace bonnet per square foot of grate area is 43,200 Btu per hour, and per square inch of grate it is 300 Btu per hour. From these performance values, the grate area for any