Under this condition the capacity of the furnace at the furnace bonnet per square foot of grate area is 43,300 B.t.u. per hour, and per square inch of grate it is 300 B.t.u. per hour. From these performance values, the grate area for any plant requirement will be, (allowing 20 per cent heat loss between furnace and registers):

$$\text{Grate area (175 deg. register temperature), square inches } \frac{1.2\ H}{356} = 0.0034H^* \quad (7)$$

$$\text{Grate Area (160 deg.), square inches } = \frac{1.2\ H}{300} = 0.0040H^* \quad (8)$$

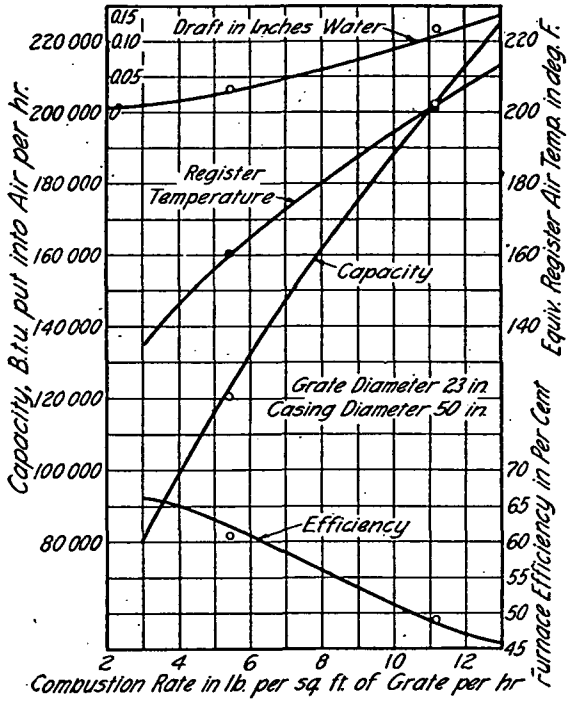

FIG. 54. TYPICAL PERFORMANCE CURVES FOR A WARM AIR FURNACE AND INSTALLATION IN A THREE-STORY TEN LEADER PLANT, OPERATING ON RECIRCULATED AIR

As a check upon the method of selection by performance curves, the method of selecting the furnace which has been in general use is as follows:

*Let H = B.t.u. heat loss from the entire house per hour = summation of all room losses $H_1 + H_2$ + etc. + the B.t.u. necessary to heat the fresh air if any, at intake. This fresh air loss in B.t.u. will be approximately 1.27 times the cubic feet of air admitted through the intake per hour on a zero day. For systems which recirculate all the air this value will be zero. For systems which have a fresh air intake, controlled by damper, this value might well be approximated, since this loss will probably be reduced to a minimum on a zero day. Assume for such cases, that the building loss is increased by 25 per cent, and that there is the usual 20 per cent loss between furnace and registers.

Let E = efficiency of the furnace
f = fuel value of the coal in B.t.u. per pound
p = pounds of coal burned per square foot of grate surface per hour and the formula then becomes

$$\text{Grate area, square inches } = \frac{1.2 \times 144\ H}{E\ f\ p} \text{ if all inside air} \quad (9)$$

For coal having a heat value of 12,000 B.t.u., a furnace having 60 per cent efficiency and 6 lb. of coal burned per sq. ft. of grate per hour, this becomes:

$$\text{Grate area, square inches } = \frac{1.2 \times 144\ H}{0.60 \times 12{,}000 \times 6} \text{ for all inside air} \quad (10)$$

The air temperature at the registers corresponding to the conditions covered by equation (10) would be approximately 160 deg. fahr. and for 175 deg. fahr. and 12,000 B.t.u. the combustion rate should be at least 7.5 lb. with an efficiency of about 57 per cent, using curves of Fig. 54 as a guide.

CHIMNEYS

The construction, location, height and area of the chimney to which the warm-air furnace is connected affect the operation of the entire heating system. Most residence chimneys are built of brick and may be either lined or unlined, but in either case the *walls must be air tight* and there should be *only one smoke opening* into the chimney. Cleanout, if provided, must be *absolutely air tight* when closed.

The walls of brick chimneys shall be not less than 3¾ in. thick (width of a standard size brick) and shall be lined with fire-clay flue lining. Fire-clay flue linings shall be manufactured from suitable refractory clay, either natural or compounded, and shall be adapted to withstand high temperatures and the action of flue gases. They shall be of standard commercial thickness but not less than ¾ in. All fire-clay flue linings shall meet the standard specification of the *Eastern Clay Products Association*. The flue sections shall be set in special mortar, and shall have the joints struck smooth on the inside. The masonry shall be built around each section of lining as it is placed, and all spaces between masonry and linings shall be completely filled with mortar. No broken flue lining shall be used. Flue linings shall start at least 4 in. below the bottom of smoke-pipe intakes of flues, and shall be continuous the entire heights of the flues and project at least 4 in. above chimney top to allow for a 2 in. projection of lining. The wash or splay shall be formed of a rich cement mortar. To improve the draft the wash surface should be concave wherever practical.

Flue lining may be omitted in brick chimneys, provided the walls of the chimneys are not less than 8 in. thick, and that the inner course shall be a refractory clay brick. All brick work shall be laid in spread mortar, with all joints push-filled. Exposed joints both inside and outside shall be struck smooth. No plaster lining shall be permitted.

Chimneys shall extend at least 3 ft. above flat roofs and 2 ft. above the ridges of peak roofs when such flat roofs or peaks are within 30 ft.