Instead of proportioning the ducts as outlined in the preceding paragraph it is more usual in practice to proportion all the ducts so that they have the same velocity as that used in the longest duct and to balance the system by employing dampers in the shorter ducts.

Return duct systems are designed making use of the same principles as those used in the design of supply duct systems. In this case the design may be based on the volume of air corresponding to the density of air existing in the return ducts, or in order to provide a factor for air leakage, it may be based on the same volume as used for the supply ducts.

11. Determine frictional resistance in:

a. Supply side of system as outlined in Item 10.
b. Return side of system as outlined in Item 10.
c. Furnace units, casing or hood, which is usually considered as equivalent to 0.03 to 0.10 in. of water.
d. Accessories such as washers or air filters, from manufacturer's data.
e. Inlet and outlet registers and grilles[7].
f. Other accessory equipment such as cooling coils, from manufacturer's data.

The requirements in the Tentative Code for Testing Oil-Fired Fan-Furnace Units give static pressure loss requirements, *external* to the units as:

0 to 800 cfm = 0.12 in.
800 to 1600 cfm = 0.20 in.
1600 to 3000 cfm = 0.24 in.
3000 to 6000 cfm = 0.30 in.

Choose a fan which, according to its manufacturer's rating, is capable of delivering a volume of air, expressed in cubic feet per minute, against a frictional resistance, expressed in inches of water, computed by adding together the items listed in the preceding discussion. In practice it is recommended that liberal allowances should be made so that the fan will be capable of delivering air against pressures that may not have been foreseen during the design of the duct system.

12. Select a furnace capable of delivering heat at the register outlets equal to the total heat loss of the structure to be heated. Equation 4 may be used for coal burning furnaces:

$$G = \frac{H}{f \times p \times E_1 \times E_2 [1 + 0.02 (R - 20)]} \qquad (4)$$

where

G = required grate area, square feet.
H = total heat loss from building, Btu per hour.
f = calorific value of coal, Btu per pound.
p = combustion rate, pounds of fuel per square foot of grate per hour.
E_1 = furnace efficiency based on heat available at bonnet.
E_2 = efficiency of transmission based on ratio of heat delivered at register to heat available at bonnet.
R = ratio of heating surface to grate area.

Equation 4 is not applicable to ratios less than 15 to 1. Higher ratios as a rule provide lower flue gas temperatures and higher efficiencies. In practice it is customary to use these constants: f = 12,000 (for specific values, see Table 5, Chapter 8); p = 7.5 lb; E_1 = 0.65 (lower efficiency must be used with highly volatile solid fuel); and E_2 = 0.85.

The foregoing procedure for determining the size of the furnace to be used applies to continuously heated buildings.

13. Although intermittently heated buildings usually have their heat losses computed according to the standard rules for determining such losses, these rules do not take into account the heat which will be absorbed by the cold material of the building after the air is raised in temperature. This heat absorption must be added to the normal heat loss of the building to determine the load which the heating plant must carry through the warming-up process. It is customary to increase the normal heat loss figure by from 50 to 150 per cent depending upon the heat capacity of the construction material, the higher percentage applying to materials of high heat capacity such as concrete and brick.

[7]Pressure Losses in Registers and Stackheads in Forced Warm Air Heating, by A. P. Kratz and S. Konzo (University of Illinois, *Engineering Experiment Station Bulletin* No. 342).

14. Follow the same methods for an oil furnace as for coal where a conversion unit is to be used, making sure that the ratio of heating surface to grate area exceeds 20 to 1. If it does not, a size larger furnace should be selected. Use the manufacturer's Btu ratings of furnaces designed for exclusive use with oil.

15. The selection of the proper size gas furnace for a constantly heated building can be easily made by using Equation 5:

$$R = \frac{H}{0.85} \qquad (5)$$

where

H = total heat loss from building, Btu per hour.
R = output rating of the furnace, Btu per hour.

In the case of converted warm air furnaces a slightly different procedure is necessary, as the Btu input to the conversion burner must be selected rather than the furnace output. The proper sizing may be done by means of Equation 6:

$$I = 1.68\, H \qquad (6)$$

where I = Btu per hour input.

The factor 1.68 is the multiplier necessary to care for a 15 per cent heat loss in the distributing ducts and an efficiency of 70 per cent in the conversion burner.

16. Specify location and type of all dampers in both supply air and return air sides of system. Specify controls including location of all thermostats. Arrange for proper control of humidifying equipment.

HEAVY DUTY FAN FURNACES

Fan furnaces for large commercial and industrial buildings, churches, schools, etc., are available in sizes ranging from 300,000 to 3,000,000 Btu per hour per unit. Heavy duty furnace heaters may be arranged in battery combinations of one or more units.

Most manufacturers of heavy duty furnaces rate their furnaces in Btu per hour and also in the number of square feet of heating surface. Conservative practice indicates that at no time in the heating-up period should the furnace surface be required to emit more than an average of 3500 Btu per square foot. A higher rate of heat emission tends to increase the heat loss up the chimney, and raise fuel consumption, to shorten the life of the furnace, and to overheat the air. The ratio of heating surface to grate area on furnaces for this type of work should never be less than 30 to 1 and as indicated previously may run as high as 50 to 1.

Control of temperature is secured through (1) controlling the quantity of heated air entering the room, (2) using mixing dampers, or (3) regulating the fuel supply.

The design of heavy duty fan furnace heating systems is in many respects similar to that of the central fan heating systems described in Chapter 20. Ducts are designed by the method outlined in Chapter 31.

HUMIDIFICATION

Temperatures and relative humidities should be governed within the limits of the generally accepted standards. (See Chapters 2 and 26.)

Water evaporating pans are usually located in air which has been heated by contact with the heating surfaces. To change water into vapor capable of being carried in an air stream as part of the mixture, about 1000 Btu per pound are required. There is a trend in present practice toward heating the water in addition to heating the air. Equipment for doing this may make use of sprays, or it may take the form of water circulating coils placed within the combustion chamber and connected by pipes to the humidifier pans where a constant water level is maintained by some separate float device. (See Chapter 26.)