

Fuel Utilization

A combustion rate of from 5 to 8 lb of coal per (square foot of grate) (hour) is recommended for residential furnaces. A higher combustion rate is permissible with larger furnaces for buildings other than residences, depending upon the ratio of grate surface to heating surface, firing period, and available draft.

In residential furnaces for coal burning, the ratio of heating surface to grate area will average about 20 to 1; in commercial sizes the ratio may be as high as 50 to 1, depending on fuel and draft. Furnaces may be installed singly, each furnace with its own fan, or in batteries of a number of furnaces, using one or more fans.

Where oil fuel is used, care must be exercised in selecting the proper size and type of burner for the particular size and type of furnace used. Furnaces for burning oil fuel are usually designed for blow-through installations so that the pressure in the air space is higher than that in the combustion chamber or flues. The National Warm Air Heating and Air Conditioning Association has prepared a *Tentative Code for Testing and Rating of Oil-Fired Furnaces*. Compact fan-furnace-burner units are available, suitable for basement, closet, or attic installations.

Gas-fired forced air furnaces should conform in construction and performance to A.G.A. Approval Requirements.

Heavy Duty Fan Furnaces

Fan furnaces for large commercial and industrial buildings, churches, schools, etc., are available in sizes ranging from 300,000 to 6,000,000 Btu per (hour) (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 indicate the number of square feet of heating surface. Limitations on temperature of flue gases, heat exchanger, and casing as well as carbon monoxide and air temperature rise are also factors in establishing ratings for these units. These limits are shown in the *ASHRAE Code for Testing and Rating Heavy Duty Furnaces and Direct-Fired Unit Heaters*.

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 19. Ducts are designed by the method outlined in Chapter 21.

MATERIALS AND CONSTRUCTION

Both cast-iron and steel furnaces are made in capacities ranging from those for small insulated residence application with inputs of 40,000 Btu per hour or less, to capacities as large as 600,000 Btu per hour.

Cast-iron furnaces are usually constructed with a minimum sectional thickness of $\frac{1}{4}$ in., and effectively resist high temperatures and corrosion. They usually have a fairly large heat capacity because of their mass, which provides a distinct fly wheel or carry-over heating effect.

In steel furnaces welding, riveting, or both are used to join the formed metal. The use of steel castings, however, is rare, because of the cost, and because high stresses are not encountered in normal furnace construction. Steel furnaces have low heat capacities as a result of their relatively low mass and, therefore, deliver heat rapidly on demand.

FURNACE RATING

Rating Equations for Gravity Warm Air Furnaces*

Until a method of testing and rating gravity warm air furnaces has been developed, the following empirical rating equations are recommended by the National Warm Air Heating and Air Conditioning Association.

Gravity warm air furnaces of conventional design, having ratios (of heating surface to grate area) of 15 to 1 or greater, and having a ratio of casing area to face area not less than 0.4, are rated by the following equations:

1. *Hand-fired furnaces converted to Stoker, Gas, or Oil Firing.*

$$\text{Bonnet Capacity in Btu per hour} = 1785 \times S \times 1.333 \quad (2)$$

2. *Hand-fired furnaces, with ratios of heating surface to grate area greater than 15 to 1 and less than 25 to 1.*

$$\text{Bonnet Capacity in Btu per hour} = 1785 \times S \times 1.333 \quad (3)$$

3. *Hand-fired furnaces with ratios of heating surface to grate area in excess of 25 to 1.*

$$\text{Bonnet Capacity in Btu per hour} = 1785 \times 25 \times G \times 1.333 \quad (4)$$

where

S = heating surface, in square feet.

G = actual grate area, in square feet.

The *Register Delivery Rating* is equal to $0.75 \times (\text{Bonnet Capacity})$. The *Leader Pipe Rating* in square inches, formerly used as a rating unit, may be found by dividing the *Register Delivery Rating* by 136.

Heating Surface of Furnace

Prime heating surface is defined* as surface above the top of the grate having hot gases or live fuel on one side and circulating air over the other, and in all cases is measured on the exterior or air side. The areas of the outer casing, the inner liner, and any radiation shields shall not be considered as heating surface.

In determining the amount of heating surface, extended surfaces are considered to be prime heating surface subject to the following limitations:

1. Extended heating surface may consist of fins, ribs, webs, lugs, or other projections from the prime heating surface. Projections less than $\frac{1}{4}$ in. thick at the base, and extending more than 1 in. from the prime surface are classified as fins.

2. Integral fins are continuously welded to, or cast as a part of, the prime heating surface. Both sides are included as heating surface, subject to the following allowances:

Distance from prime surface.....	1st in.	2nd in.	3rd in.	Over 3 in.
Ratio of effective area to total area.....	0.40	0.30	0.20	None

3. Non-integral fins are spot welded to, or otherwise held in line contact with, the prime heating surface. Both sides are included as heating surface, subject to the following allowances:

Distance from prime surface.....	1st in.	2nd in.	3rd in.	Over 3 in.
Ratio of effective area to total area.....	0.30	0.20	0.15	None

Heating Boilers, Furnaces, Space Heaters

4. In the case of ribs, webs, or lugs more than $\frac{1}{4}$ in. thick at the base and extending less than 1 in. from the prime surface, the entire surface in contact with circulating air is included as heating surface.

5. In the case of ribs, webs, or lugs more than $\frac{1}{4}$ in. thick at the base and extending more than 1 in. from the prime heating surface, the areas of both sides of the first inch are included as prime heating surface. The portions projecting beyond 1 in. are treated as integral fins.

Grate Area

Grate area is defined* and treated for purpose of rating as follows:

1. The *nominal grate area* is defined as the total cross-sectional area of the bottom of the firepot. In steel furnaces the nominal grate area is the cross-sectional area inside the firebrick lining.

2. The *actual grate area*, used for calculating the ratios of heating surface to grate area, is the nominal grate area minus certain areas that cannot be considered as part of the grate itself. The following rules govern these deductions: (1) If a solid, continuous ledge extends around the grate and inside the firepot, any area of this ledge extending inside of a circle, the diameter of which is 1 in. less than the diameter of the bottom of the firepot, shall be deducted. (2) If separate, solid projections extend from the firepot towards the grate, the areas of any portions of these projections extending inside of a circle, the diameter of which is 3 in. less than the diameter of the bottom of the firepot, shall be deducted. (3) In the case of grates which are inclined, or are conical, the projected area is the same as the nominal grate area. The latter should, therefore, be used after making any necessary deductions.

Ratings for Forced Air Furnaces

For solid-fuel-burning, forced air furnaces having bonnet capacities between 80,000 and 250,000 Btu per hour, no standard method of test has been accepted, although eventually such codes will be developed. The National Warm Air Heating and Air Conditioning Association recommends the following empirical equations for use in rating solid fuel forced air furnaces:

1. *Hand-fired furnaces converted to Stoker, Gas, or Oil Firing.*

$$\text{Bonnet Capacity in Btu per hour} = 2265 \times S \times 1.177 \quad (5)$$

2. *Hand-fired furnaces, with ratios of heating surface to grate area greater than 15 to 1 and less than 25 to 1.*

$$\text{Bonnet Capacity in Btu per hour} = 2265 \times S \times 1.177 \quad (6)$$

3. *Hand-fired furnaces with ratios of heating surface to grate area in excess of 25 to 1.*

$$\text{Bonnet Capacity in Btu per hour} = 2265 \times 25 \times G \times 1.177 \quad (7)$$

where

S = heating surface, in square feet.

G = actual grate area, in square feet.

The *Register Delivery Rating* is equal to $0.85 \times (\text{Bonnet Capacity})$.

The following testing and rating codes have been generally accepted in the industry:

Commercial Standard CS-109-44 for rating solid-fuel-burning, forced air furnaces having bonnet outputs of 80,000 Btu per hour or less. This provides a method of rating small coal-fired forced air furnaces by test.

A Tentative Code for Testing Oil-Fired Furnaces. This code has been adopted by the National Warm Air Heating and Air Conditioning Association for rating oil-fired furnaces by test.

The American Gas Association method of rating gas-fired furnaces on performance under tests. This is described in the *Approval Requirements for Central Heating Gas Appliances—Vol. II, Gravity and Forced Air Central Furnaces*, Z21.13.2.

Commercial Standard 113-51 is a method of rating oil-burning floor furnaces by test.

Commercial Standard CS 104-49 is a method of rating warm air furnaces equipped with pot-type oil burners by test.

Various codes covering the construction and performance of appliances as related to fire hazards have been developed by Underwriter Laboratories, Inc. In addition, there are many municipal codes which regulate construction and installation of furnace equipment.

The yardstick of the National Warm Air Heating and Air Conditioning Association provides criteria for evaluating a furnace design and installation against industry accepted standards.

FURNACE EFFICIENCY

Rating formulas of the National Warm Air Heating and Air Conditioning Association are based on 55 percent efficiency for gravity coal furnaces and 65 percent efficiency for forced air coal furnaces. In the tentative *Oil Testing Code* the contemplated minimum efficiency is 70 percent for oil-fired forced air furnaces. Gravity gas furnaces approved by the American Gas Association are assigned a rating based on 75 percent efficiency. All forced-air gas-fired furnaces approved by American Gas Association are assigned a rating based on 80 percent efficiency.

DESIGN CONSIDERATIONS

Considerations of prime importance in the design of warm air furnaces and some general suggestions to be observed in connection with each, are as follows:

1. Adequate heat transfer surface.

- Heat transfer rates of 2000 to 4500 Btu per (hour) (square foot) of heating surface may be obtained without unduly high metal temperatures. With some types of design somewhat higher rates are acceptable.
- Fins, pins, and bosses are frequently used to add surface and to break down superficial gas films, both on gas-to-metal and metal-to-air surfaces.
- Surface and stack (flue gas) temperatures are good indications of the amount and effectiveness of the heating surfaces.

2. Safe and efficient combustion of fuel.

- Proper mixture of fuel and air is necessary for efficient combustion. This necessitates careful attention to the design of grates, nozzles, burners, air inlet areas and location, and combustion chamber baffling.
- Regulation of the quantity and the distribution of the air for combustion should be provided by use of check dampers, draft regulators, draft hoods, air shutters, and air orifices.
- Total draft loss through appliances should not exceed that available from chimneys which would normally be obtainable in the size of building which the appliance will supply with heat.
- The use of ignition safety devices such as safety pilots, hold-fire controls, and the like is recommended.

3. Fuel capacity of appliances.

- With solid fuels adequate coal capacity should be provided for at least 5 hr of operation at the maximum rated combustion rate.

4. Adequate circulation of air over heating surface.

- In gravity furnaces, free air space between casing and heat exchanger should be great enough to permit free flow over all surfaces.
- Forced air furnace design must include fans having proper capacity and suitable performance characteristics. Internal static pressures must be minimized without losing the advantages of high-velocity circulation over the heat exchanger surfaces.
- The air flow over the heating surface must be directed to obtain maximum efficiency and to eliminate hot spots and air noises.