less than 75 percent, based on the total heating value of the gas.[4] These efficiencies are based upon Equation 10.

Design Considerations

Some factors important in the design of gas heaters are:

1. Proper design of the burner head, port sizes, and locations so that the flame will not lift, float, or flash back, and be excessively noisy in operation.

2. Proper venting of combustion chamber.

3. Protection of valve handles to prevent excessive temperature rise during operation.

4. Insulation and baffling of heater to prevent overheating of walls and floor.

INSTALLATION OF SPACE HEATERS

The two most important considerations involved in the installation of a space heater are safety and chimney draft. The items of chimney details and flue connections which should have special attention are outlined in Chapter 36, Chimneys and Draft Calculations. Proper installation of recessed gas heaters should be made according to *American Standard Installation of Gas Appliances and Gas Piping* (ASA Z21.30-1959). In all cases, it is recommended that installation be made in accordance with the current *National Building Code.*

REFERENCES

[1] *I = B = R Testing and Rating Code for Low Pressure Cast-Iron Heating Boilers* (Institute of Boiler and Radiator Manufacturers, June, 1958).

[2] Testing and rating code for boiler-burner units (*Engineering Standards Part II*, Mechanical Contractors Association of America, 1956).

[3] *I = B = R Ratings for Cast-Iron Boilers* (Institute of Boiler and Radiator Manufacturers, May 10, 1955).

[4] Net load recommendations for heating boilers (*Engineering Standards Part II*, Mechanical Contractors Association of America, 1956).

[5] *Comfort Heating* (American Gas Association, 1938, p. 35).

[6] *Gravity Code and Manual for the Design and Installation of Gravity Warm Air Heating Systems* (National Warm Air Heating and Air Conditioning Association, Manual No. 5, 5th ed.).

[7] B. A. Landry and R. A. Sherman: Development of a design of smokeless stove for bituminous coal (*ASME* Annual Meeting, 1948).

[8] *American Standard Approval Requirements for Gas-Fired Room Heaters* (American Standards Association, Z21.11, 1956, with addenda Z21.11a-1957 and Z21.11b-1958).

[9] *American Standard Approval Requirements for Central Heating Gas Appliances Volume IV, Gravity and Fan Type Vented Recessed Heaters*, (ASA Z21.13.4, 1958).

[10] *American Standard Listing Requirements for: Automatic Pilots* (Z21.20, 1951); *Gas Appliance Thermostats* (Z21.23, 1940); *Domestic Gas Appliance Pressure Regulators* (Z21.18, 1956); *Automatic Valves for Gas Appliances* (Z21.21, 1952); (American Standards Association).

CHAPTER 36

CHIMNEYS AND DRAFT CALCULATIONS

Draft Definitions, Theoretical Natural Draft, Factors Affecting Natural Draft, Available Draft, Required Draft; Industrial Chimneys, Available Draft for the Industrial Chimney, Determining Industrial Chimney Sizes; Residential Chimneys, Available Draft for Residential Chimneys, Chimney Sizes for Heating and Process Boilers, Short Chimneys, Determining Residential Chimney Sizes, Draft Requirements of Appliances, Gas Appliance Venting; Recommendations of the National Board of Fire Underwriters, General Considerations

DRAFT is the pressure difference associated with the movement of flue gases through a flue or chimney. Natural draft is caused and measured by the difference in weight of a column of flue gas within the flue and a corresponding column of air of equal dimension outside the flue. Natural draft is always negative and is expressed in inches of water gage.

When the movement of air is supplied by a fan, the draft is said to be forced or induced. When the fan is located so as to push the flue gases through the flue, the draft is forced. When the fan is located so as to draw the flue gases through the flue, the draft is induced.

THEORETICAL NATURAL DRAFT

Theoretical natural draft is produced solely by the difference in weight of the column of flue gases within the flue and that of a corresponding column of air of equal dimensions outside the flue. In the determination of theoretical natural draft, no allowance is made for friction or other positive or negative effects. Theoretical natural draft is expressed by the following formula:

$$D_t = 2.96\,HB_o\left(\frac{\rho_o}{T_o} - \frac{\rho_c}{T_c}\right) \qquad (1)$$

where

D_t = theoretical draft, inches of water.
H = height of flue or chimney, feet.
B_o = barometric pressure, inches of mercury.
ρ_o = density of air at 0 F and 1 atmosphere pressure, pounds per cubic foot.
ρ_c = density of flue gas at 0 F and 1 atmosphere pressure, pounds per cubic foot.
T_o = temperature of air surrounding the chimney, Fahrenheit absolute.
T_c = temperature of the gases, average or effective, in the chimney, Fahrenheit absolute.

Theoretical natural draft may also be expressed by the following simplified formula in which it is assumed that the densities of the flue gas and of the air are equal at the same temperature and pressure:

$$D_t = \frac{\rho H(T_c - T_o)}{5.2T_c} \qquad (2)$$

where

ρ = mean density of atmospheric air, pounds per cubic foot.

FACTORS AFFECTING NATURAL DRAFT

As indicated in both Equations 1 and 2, the theoretical natural draft is directly proportional to the height of the flue and is dependent upon the absolute mean temperature of the gases within the flue. It is also directly proportional to the density of the air outside the flue although the effect of this factor is minor.

The formulas for theoretical natural draft are based on mean or average temperature which is one half of the sum of the entering and exit temperature. Since the difference in exit and entering temperatures, or the temperature gradient in the flue, is due to the escape of heat through the walls of the flue and chimney, the heat transfer characteristics of the chimney construction affect draft. Heat transfer is also affected by the rate of flow of the flue gases through the flue so that draft is also affected directly.

The flow of flue gases through the flue is retarded by friction which varies directly with the friction coefficient of the flue surface, and with the rate of flue-gas flow. The friction loss may be estimated by means of one of the formulas for ducts such as the Fanning equation or it may be estimated with sufficient accuracy by the method used for air ducts. (See Chapter 21.)

The height of the flue is measured from the point of entrance of the flue gases to the top of the flue. With no wind to produce an aspirating effect and with no obstruction such as a rain cap at the top of the flue, the column of flue gases may extend upward above the top of the flue for several feet. The effect of this column may be sufficient to overcome the negative or retarding effect of friction and to cause the observed draft to exceed the theoretical draft. This added effect has been measured in some test work. A wind blowing across the top of the flue may also produce an aspirating effect sufficient to overcome the effect of friction and to cause the observed draft to exceed the theoretical. Both of these effects are transient and unreliable and should not be considered in determining the proper design of a chimney.

AVAILABLE DRAFT

The available draft produced by any chimney is equal to the theoretical natural draft minus the friction loss. Given the height, the heat transfer characteristics of the chimney construction, the entering temperature of the flue gases and their volume, and the friction coefficient of the flue and its dimensions, the available draft is readily calculable.

The efficiency of a chimney is defined as the ratio of the observed draft or available draft, produced by the chimney