The *National Warm Air Heating and Air Conditioning Association* recommends empirical equations similar to Equations 2, 3 and 4 for gravity furnaces, except that a constant of 2265 is used in place of the 1785.

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

Commercial Standards 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 based upon performance under tests. This is described in the Approval Requirements for Central Heating Gas Appliances.

Commercial Standards 113-44 is a method of rating oil-burning floor furnaces by test.

Commercial Standard CS 104-43 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 [10] 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 formulae of the *National Warm Air Heating and Air Conditioning Association* are based on 55 per cent efficiency for gravity coal furnaces and 65 per cent efficiency for forced air coal furnaces. In the tentative Oil Testing Code the contemplated minimum efficiency is 70 per cent for oil fired forced air furnaces. Gravity gas furnaces approved by the *American Gas Association* are assigned a rating based on 75 per cent efficiency. All *forced air gas-fired furnaces* approved by *American Gas Association* are assigned a rating based on 80 per cent 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.*

   a. Heat transfer rates of 2,000 to 4,500 Btu per (hour) (square foot) of heating surface may be obtained without unduly high metal temperatures.

   b. 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.

   c. 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.*

   a. 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.

   b. 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.

   c. 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.

   d. The use of ignition safety devices such as safety pilots, hold-fire controls, and the like is recommended.

3. *Fuel Capacity of Appliance.*

   a. 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.*

   a. In gravity furnaces, free air space between casing and heat exchanger should be great enough to permit free flow over all surfaces.

   b. Forced air furnace design must include fans having proper capacity and having performance characteristics. Internal static pressures must be minimized without losing the advantages of high velocity circulation over the heat exchanger surfaces.

   c. The air flow over the heating surface must be directed to obtain maximum efficiency and to eliminate hot spots and air noises.

   d. Air velocities at bonnet should not be much in excess of 1,000 fpm and air temperature distribution at the furnace outlet should be uniform within approximately ± 30 deg.

5. *Durability.*

   a. A minimum metal weight for gas-fired heat exchangers is established at No. 20 U. S. Gage for plain carbon steel by the *A.G.A.* Approval Requirements for Central Heating Gas Appliances with some municipal codes specifying 18 gage. Cast-iron sectional thicknesses of ¼ in. to ⅜ in. are recommended.

   b. Added strength and reinforced designs may be required to preclude damage in shipment, burning out from overfiring, or corrosion from condensation.

   c. Maximum heat exchanger surface temperatures which may be used vary with the metal. The *American Gas Association* Approval Requirements for Central Heating Gas Appliances specify a maximum of 875 F for cast-iron or steel gas furnaces, and the Bureau of Standards CS 109-44 Code for Forced Air Solid Fuel-Burning Furnaces specifies 1000 F as a maximum surface temperature. These temperatures define the range in which oxidation of non-alloy ferrous metal begins. The use of proper alloy additions increases the temperature resistance properties of metals.

   d. Casing temperatures should be controlled so that they do not become hazards to burn those who touch them, or to create fires.

6. *Serviceability.*

   a. Those parts of the furnace which may be subject to soot, fly-ash, or condensation deposits, should be accessible for cleaning.

   b. Parts which may require adjustments or replacements, such as grates, baffles, liners, controls, should be removable.

   c. Furnaces should be so designed that they can be installed with a minimum of difficulty.

7. *Control.*

   a. Thermostatic controls of various types should be used to correlate space temperatures with unit operation.

   b. Controls should be provided wherever possible, to prevent the occurrence of excessive temperatures or other conditions in any part of the unit which might cause unsafe operation.

8. *General design considerations.*

   a. Furnace casings are normally constructed of formed and painted sheet steel or of galvanized iron. The casing should be protection from excessive radiation losses and temperatures by use of insulation or sheet steel air space liners. Liners should extend from the grate level to the top of the furnace and should be spaced from 1 in. to 1½ in. from the outer casing.