d. Air velocities at bonnet should not be much in excess of 1000 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 as 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 *National 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 by burning those who touch them, or by creating 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 which might cause unsafe operation in any part of the unit.

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.
   b. The hood or bonnet of the casing above the furnace should be as high as basement conditions will allow, to form a plenum chamber over the top of the furnace. This tends to equalize the pressure and temperature of the air leaving the bonnet through the various openings. It is generally considered advisable to take off the warm air pipes from the side of the bonnet near the top, as this method of take-off allows the use of a higher bonnet and thus provides a larger plenum chamber.
   c. Warm air outlet and return air connections should be designed so that the ductwork may be easily attached. A ⅞ in. flange is normally used for this purpose.
   d. Suitable provision should be made in appliances so that the controls and humidifiers may be installed in the proper location. When these auxiliary units are installed in the ductwork, detailed instructions should be provided to insure their proper location.
   e. The flue connection should be of integral flue pipe size, and provision should be made to attach the flue pipe to the flue outlet of the furnace.

HUMIDIFICATION EQUIPMENT

Evaporating pans are usually located in the outlet air. There is a present trend toward heating the water. 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. All humidifiers require provision for removal of dirt and lime.

SPACE HEATERS

Space heaters may be classified in several ways, such as:

1. By the type of fuel used as coal, wood, gas, and fuel oil.

2. According to the method of heat distribution as circulators or radiant types. A radiant heater is one in which the heat exchanger surface is exposed directly to the room atmosphere, and the generated heat is dissipated primarily by radiation. A circulating heater is essentially a jacketed radiant heater from which circulation of room air is promoted by the chimney effect caused by the movement of air passing upward between the jacket and heat exchanger surface.

3. According to method of design for particular fuel types, such as: (a) surface-fired and magazine-feed for solid fuels, (b) vaporizing pot-type and blue-flame heater for oil, and (c) vented and unvented heaters for gas. (The type of gas burner design, such as injection, yellow flame, power, and pressure, may also be mentioned.)

SOLID FUEL-FIRED HEATERS

Surface-fired heaters normally have a front firing door and are operated with relatively shallow fuel beds. A magazine-feed heater includes a deep reservoir of fuel to lengthen the attention intervals. In a true magazine-feed heater the rate of fuel ignition would be equal to the rate of burning; and self-feeding should operate to move the unburned fuel by gravity flow from the magazine section into the hearth area. However, the ideal balance between rate of ignition and rate of burning is virtually impossible to attain for any solid fuel under normal usage, although self-feeding may be obtained with wood and some free burning coals. Thus, a magazine-type space heater is essentially a deep surface-fired heater, its principal difference from other heaters being increased fuel capacity.

Materials and Construction

There is no accepted code governing the construction of solid-fuel-burning space heaters. In past years cast iron was used predominantly in the construction of coal and wood heaters, with the exception of the so-called *airtight* heaters designed as low-cost wood-burning units with little consideration for long life, and stoves were priced on a poundage basis. The present trend is toward fabricated steel parts and welded assemblies, although cast iron is still used for grates, firebox liners, and parts subject to high temperatures. Refractory firebox liners are also used quite extensively.

Formed sheet steel is used predominantly for the outer jacket of circulator heaters, although heaters with outer casings formed from cast iron are still readily available. Circulator cabinets normally have surfaces finished with a porcelain enamel, while the casing of a radiant heater is finished with an air-dried japan or a baked enamel.

Both welding and stove bolts are used in unit assembly, and stove cement is used on section joints to prevent air leakage. This latter is extremely important to obtain a low rate of combustion when desired.

Testing and Rating

There is no accepted code governing the method of testing and rating solid fuel space heaters. A tentative procedure, TS-3443, has been issued by the Division of Trade Standards, National Bureau of Standards, but is based on use of anthracite as a rating fuel, although bituminous coals are used predominantly as heating fuels. This procedure, which has been the basis of published ratings, consists of determining the heater output, expressed in Btu per hour, by the indirect method. The measurable heat losses: (1) loss due to moisture in the fuel, (2) loss due to heat in the dry flue gases, (3) loss due to unburned carbon monoxide, and (4) loss due to unburned combustible in the ash and refuse, are measured by test. The total of these four measurable losses, plus an assumed value for unaccounted for losses, are then subtracted from the heat input. The difference multiplied by the burning rate in pounds per hour is the heater output.

When using anthracite as the rating fuel, the unaccounted for loss has been assumed to be zero. It has been accepted practice to use a 20 percent allowance for the unaccounted for losses when burning a bituminous coal. The value of this factor has been under study and, although test work is incomplete, a value of 12 percent of the heat input has been determined as representing the losses due to smoke and unburned hydrocarbons for a surface-fired heater, when burning a high volatile bituminous coal.

No allowance is made for a radiation loss, as this is useful heat.

Design Considerations

Some important considerations in the design of solid-fuel space heaters are:

1. Suitable protection by baffling or insulation against overheating of floors and walls. Although there are no industry-accepted standards by which floor and wall temperatures may be determined, some indication of heater performance, with regard to overheating, may be found by the use of the corner booth test arrangement described in *National Bureau of Standards Commercial Standard* CS 103-43 and *Underwriters Laboratories Standard*, Subject 896, mentioned in following section on Oil Heaters.

2. Tight heater construction to prevent air leakage, and to enable maintenance of a suitably low minimum burning rate. This includes a ground, paper tight joint between the ashpit door and door frame.

3. Sufficient free air space, between the casing and heat exchanger of circulating heaters, to permit free air flow over all surfaces and maintain a suitably low casing temperature.

4. Protection of all metal parts from deterioration due to high temperature. This may be accomplished by: (a) fabrication of certain parts from cast iron or an alloy iron, (b) protection by a refractory liner, (c) use of high temperature enamel coatings, (d) directing air against hot spots.

5. Proper admission of secondary air to complete the combustion process. Care should be taken to prevent this air from also functioning as primary air.

6. Strength in assembly to prevent transportation and use damage.

Considerable work has been directed toward improvement of the performance of bituminous coal-fired space heaters, with particular reference to smokeless operation under conditions of normal operation such as obtained in homes. A smokeless coal heater has been developed by Bituminous Coal Research, Inc., wherein smokeless combustion is obtained by admitting secondary air through a narrow slot, extending from side to side, above the edge of the fuel bed where the gas leaves to enter a vertical gas passage.[8] Complete mixing of the volatile material, released from the coal in the magazine, with the secondary air supplied is obtained as both streams pass under the bottom of the arch. Complete combustion results from this intimate mixing in a region which maintains itself at high temperatures even during banking periods.

OIL HEATERS

Vaporizing pot-type oil heaters consist of: (1) a metal pot in the bottom of which the oil is vaporized, the vapors burning at or near the top of the pot and (2) a secondary combustion chamber, or heat exchanger, in which combustion is completed. The flue connection is made to this chamber or through a second heat exchanger which may be of the diving-flue type installed to increase efficiency. The burner may be designed for operation both with and without mechanical draft.

Blue-flame oil burners differ from the pot-type variety in that removable perforated sleeves are provided above an oil pan instead of a metal pot, and lighting rings or kindlers are used for easy lighting.

Both types of oil burners operate by the burning of the oil vapor rather than the oil itself, the oil being first fed to a chamber in which the oil is entirely vaporized, then mixed with air introduced through suitably located ports and burning at the top of the pot or perforated sleeves. Such heaters are designed to burn No. 1 oil (See Table 4, Chapter 33) or kerosine (coal oil). At no time should oil heavier than that for which the burner is designed be used, as heavier oils may cause excessive carbonization in the burner or fuel feed line.

Materials and Construction

Formed sheet steel and welded assemblies are used primarily in oil heater construction. Standards governing construction which have been generally accepted are:

1. *Commercial Standard for Flue-Connected Oil-Burning Space Heaters Equipped with Vaporizing Pot-Type Burners*, CS101-43 (National Bureau of Standards).

2. *Standard for Oil-burning Stoves*, Subject 896 (Underwriters' Laboratories, Inc.).

3. *Standard for Construction and Performance of Oil Burners for Installation in Stoves and Ranges*, Subject 865 (Underwriters' Laboratories, Inc.).

Some states or municipalities have codes which apply locally, but these usually apply primarily to installation, and the Underwriters' Laboratories label of approval is sufficient to cover acceptance of the unit.

Testing and Rating

Commercial Standard CS101-43 is intended to provide a uniform standard method for ascertaining the maximum practical heat output in Btu per hour of flue-connected oil-burning space heaters under approximately normal service conditions. This method is based upon the following equations:

$$H_r = A - B \tag{8}$$

and

$$E = H_r/A \tag{9}$$

where

A = total heat of fuel used.
B = heat lost in flue gases.
H_r = net heat delivered to the room.
E = unit efficiency.