but some walls are complicated by the inclusion of metal, for instance, and tests for conductance are required. The apparatus is required to accommodate large specimens representing actual construction. The shielded hot box apparatus was developed for this purpose.[47] Specimens for the apparatus at the National Bureau of Standards are 5 ft long and 8 ft high, while others require different sizes, some larger, others smaller.

The guarded hot box is described in the A.S.H.V.E. Standard Test Code for Heat Transmission through Walls.[47] The apparatus consists essentially of three boxes: a cold box, cooled by a refrigerating machine; a hot box, heated electrically; and a metering box also heated electrically. Each box has an open side to be placed against the specimen. The cold box is clamped against one side of the specimen, and the hot box against the other. The hot box encloses the metering box and is kept at the same temperature to minimize heat exchanges to or from the metering box, except through the specimen. The electric energy necessary to heat the metering box is measured, converted to Btu per hour, and divided by the area and the temperature difference through the wall, from surface to surface, to yield the conductance of the wall. The transmittance or U-value of the wall is then computed by means of the surface coefficients from Chapter 9.

The Nicholls heat flow meter is sometimes useful for measuring steady heat flow through a wall or other building member.[48] In essence, this meter consists of a plate or slab of material of known thermal resistance having attached thermocouples on both sides. For use, the device is pressed against or cemented to the wall to be tested. At steady state, the temperature difference through the slab, measured with the thermocouples, with the known thermal resistance of the slab, indicates the heat flow through the slab and hence, through the wall covered by it. For best results, such meters are calibrated by means of a guarded hot plate or other suitable apparatus. The chief precaution is to assure that the heat flow is steady at the time of measurement.

EVALUATION OF THE THERMAL ENVIRONMENT

Advocates of radiant heating emphasize the fact that comfort depends on radiant heat exchanges, as well as air temperature. For this reason several instruments have been devised to evaluate the comfort or warmth of rooms, taking radiant as well as convective effects into account. Prominent among these are the eupatheoscope, the globe thermometer, the thermal integrator and the heated globe.[49,50] Descriptions are contained in the references, and are omitted here because these devices are not widely used in America for several reasons, among which is the fact that radiant heating with high temperature sources is not a chief method of comfort heating in this country.

COMBUSTION ANALYSIS

There are two approaches to the problem of measuring the capacities of fuel burning devices, such as boilers and furnaces. The direct or calorimetric test consists in measuring the change in enthalpy or heat content of the fluid, air or water, heated by the device and multiplying by the flow rate in pounds per hour to arrive at the capacity in Btu per hour.[51] The indirect test consists in determining the heat lost in the flue gases and deducting it from the heat evolved by combustion of the fuel.[52] A heat balance consists in the simultaneous application of both tests to the same device. The indirect test almost invariably indicates the greater capacity,

and the difference is credited to radiation from the boiler or furnace casing and *unaccounted for loss.*

In the case of some small equipment, the expense of the direct test is not considered justifiable, and the indirect test is relied upon with an arbitrary *radiation and unaccounted for* factor.[52]

Flue Gas Analysis

The Orsat apparatus is commonly used for analyzing flue gases. In its ordinary form, it consists of three pipettes and a means for isolating a sample of flue gas in a graduate. After measuring, the sample is expelled from the graduate into the first pipette where the carbon dioxide is extracted by potassium hydroxide. The sample is then remeasured and successively passed into the second and third pipettes, where the oxygen and the carbon monoxide are respectively extracted by potassium pyrogallate and cuprous chloride.

For field testing and burner adjustment, simpler portable devices are available for carbon dioxide determination only. From curves, based on typical hydrogen content of several common fuels, efficiencies may be

Table 1. Ringelmann Smoke Chart Spacings

Number of Card	Thickness of Lines, mm	Distance in Clear Between lines, mm
1	1.0	9.0
2	2.3	7.7
3	3.7	6.3
4	5.5	4.5

estimated from the carbon dioxide value obtained. More elaborate laboratory equipment is sometimes provided for precise determination of carbon monoxide content by burning the carbon monoxide to carbon dioxide in presence of a catalyst.[53, 54] In large plants, carbon dioxide recorders are used to obtain a continuous indication of the plant's efficiency.[55]

SMOKE DENSITY MEASUREMENTS

Ringelmann charts are widely used for evaluating the density of smoke discharged from chimneys or stacks, and smoke ordinances are based on them in some cities. Each chart is composed of a series of crossed black lines on white paper which, at a distance of about 50 ft, is visually compared with the smoke under observation. Four charts are used with different degrees of blackness as shown in Table 1. The smoke density is specified by Ringelmann numbers from 1 to 4.

The photoelectric cell is used in some apparatus developed for smoke density recording in large plants. The same device is included in the testing equipment for domestic oil burners described in *National Bureau of Standards*, Commercial Standard CS75-42.[56] Under *Laboratory Tests* this publication contains the following section: "Smoke Determination.—After combustion has reached equilibrium, the amount of smoke in the flue gases, when viewed lengthwise through 4 feet of the smoke pipe in accordance with the *Underwriters' Laboratories, Inc.*, Standard for Domestic Oil Burners (Subject 296), March 1934 and subsequent revisions, shall not reduce the output of a standard photoelectric cell from 9 microamperes, with a clear