heated globe[36, 37]. These instruments were designed to obtain a quantitative measurement of the thermal exchange between the human body and its environment.

COMBUSTION ANALYSIS

The analysis of flue gases to determine completeness and efficiency of combustion is usually made chemically with the Orsat apparatus. This consists of a measuring burette, a leveling bottle, and three pipettes. Carbon dioxide is absorbed in the first pipette by potassium hydroxide, oxygen in the second by potassium pyrogallate, and carbon monoxide in the third by cuprous chloride. A known volume of gas is drawn in, and after each of the three absorptions the reduced volume is again measured in the burette. Pressure and temperature of the gas sample are kept constant while measuring. Several passes are made through each pipette which contains tubes or glass beads to increase the wetted surface. It is essential that each reaction be completed before the next reaction is started. Since the life of the reagents is limited, it is well to keep a record of the number of samples tested. Care is needed in operation to prevent the pulling of reagents out of the pipettes into the capillary tubing and burette. Many recording gas analyzers are available and are usually found in the larger plants.

Carbon Monoxide Measurement

A method of analyzing for low carbon monoxide concentrations completes the oxidation of the carbon monoxide in a known volume of sample, in the presence of a catalyst. The heat resulting is measured by a thermocouple calibrated in parts per 10,000 of carbon monoxide[38].

SMOKE DENSITY MEASUREMENTS

Smoke density may be judged by assigning to it the number of the Ringelmann Smoke Chart which appears to have the same color when observed at a distance of 50 ft. The charts are numbered 1 to 4 and are made of black lines cross-ruled on white as given in Table 1.

Apparatus using the photo-electric cell has been devised for recording smoke densities in large plants.

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

[36]Instruments and Methods for Recording Thermal Factors Affecting Human Comfort, by C. P. Yaglou, A. P. Kratz and C.-E. A. Winslow (Year Book, *American Journal Public Health*, 36-37).

[37]The Thermo-Integrator—A New Instrument for the Observation of Thermal Interchanges, by C.-E. A. Winslow and Leonard Greenburg (A.S.H.V.E. TRANSACTIONS, Vol. 41, 1935, p. 149).

[38]A Carbon Monoxide Recorder, by S. H. Katz, D. A. Reynolds, H. W. Frevert and J. J. Bloomfield *U. S. Bureau of Mines, Technical Paper* No. 355, 1926).

CHAPTER 36

Motors and Motor Controls

Direct Current Motors, Alternating Current Motors for Single Phase and Polyphase, Special Applications, Classification of Motors, Manual Control, Automatic Control, Pilot Controls, Direct Current Motor Control, Squirrel-Cage Motor Control, Multispeed Motor Control, Wound Rotor Motor Control, Single Phase Motor Control

THE electric motor, available in many different types suitable for various services, is now the most widely used form of prime mover. The equipment for starting, controlling and protecting these motors varies with the type and with the functions it is desired to attain. Motors used for heating, ventilating and air conditioning applications may be divided into two general classifications: (1) for use with direct current, and (2) for use with alternating current.

All driven machinery has certain torque characteristics which may vary with the speed, such as fans, which have sharply increasing torques with increasing speed. Others, such as reciprocating compressors, have a constant torque characteristic with changing speed, while still others such as stokers, may have rising torque with decreasing speed. Motors with suitable torque characteristics should be applied to the driven load.

All electric motors, as with nearly all machines, are rated on the basis of the total temperature which the motor attains under operating conditions as well as other characteristics. The motor temperature is a result of both the ambient temperature and temperature rise of the motor. The motor temperature rise is in turn determined by motor construction and motor losses. In selecting motors careful attention should be given to the ambient temperature, and rated motor rise in order that the resulting motor temperature does not exceed allowable total temperature, otherwise greatly shortened motor life will result. Consult motor manufacturers for allowable temperatures.

DIRECT CURRENT MOTORS

The three types of direct current motors available are: (1) shunt wound, (2) compound wound, and (3) series wound.

Shunt Wound motors, being suitable for application to fans, centrifugal pumps, or similar equipment, where the amount of starting torque required is relatively small, are used for the majority of applications in the field of heating, ventilating and air conditioning. They may be used on reciprocating pumps and compressors, if started under unloaded conditions.