the sphere and the thermostat-operated switch, is also used for controlling room conditions.

Fig. 4 shows a typical *electronic control* system. The electronic control system operates the circulator in cycles. It varies the flow of water to the panel in proportion to the heat demand, as measured from room, outdoor, and panel conditions. A low limit immersion thermostat, set to maintain desired water temperature in the boiler, starts the burner. A high limit immersion thermostat is set to stop the burner at maximum desired boiler water temperature. A manual by-pass, as shown, is desirable to prevent the flow of water into the panel at temperatures in excess of design conditions.

Circuit Balance

In addition to a thermostatically controlled device for modulating the temperature of the circulating water, it is advantageous to insert in each circuit a locked flow control or adjustable resistance to give uniform conditions throughout all rooms. Owing to unforeseen difficulties with varying frictional losses in pipes, emission factor, and exposures, it is an advantage to be able to regulate permanently the flow through each circuit by means of a key operated valve as indicated in Fig. 3.

Compensation for Increase of MRT

Due to the increase in MRT (mean radiant temperature) within a panel heated space, which necessarily takes place as the heating load increases, the air temperature should theoretically be lowered to maintain comfort. In ordinary structures, with normal infiltration loads, the required reduction in air temperature is not great and a conventional fixed control point room thermostat may be used. If a large infiltration load exists, or if untempered mechanical ventilation is employed, a thermostat with variable control point should be considered. Because of the relationship between MRT and air temperature in the space (and the variable MRT from point to point in the space) a conventional type of room thermostat (either fixed or variable control point as previously determined) measuring principally air temperature, should provide simple and satisfactory control.

Lowered Night Temperature

In general, lowered night temperature control is not recommended with *heavy* panels, though it may be satisfactory with *light* panels.

INDICATING AND RECORDING EQUIPMENT

In addition to the automatic control of temperature and humidity conditions, visual indication and permanent chart records of the variables involved, are desirable. They provide an accurate check on the performance of the system, both from the standpoint of conditions maintained, and cost of operation. Instruments are available to provide accurate records of these variables such as pressure, temperature, humidity, flow, and CO_2, which go to make up a complete heating or air conditioning system. In some cases the control equipment is provided with indicating or recording mechanisms, by means of which the performance of the controls may be observed or recorded, and in other cases, separate instruments are used for the purpose.

CHAPTER 40

MOTORS AND MOTOR CONTROLS

Fundamentals of Motor Selection; Alternating Current Motors, Types and Control Equipment; Motor Rating; Functions of Motor Control Equipment; Glossary of Motor Terms, Enclosures, Speed Classification and Mounting

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 are divided into two general classifications, *alternating-current* or *direct-current*, depending on the power source to be used.

FUNDAMENTALS OF MOTOR SELECTION

The following characteristics of the *power supply* should be determined: (1) whether current is alternating or direct, (2) voltage, (3) alternating current phase, (4) alternating current frequency, (5) voltage regulation, (6) continuity of power.

1. *A-C vs. D-C Systems*. For most applications, a-c supply is satisfactory since suitable performance can usually be obtained with a-c motors and control. Where special characteristics, such as an extra wide speed range and severe accelerating or reversing duty are involved, conversion by means of motor generator sets, by rectifiers, or in special cases by converters, may be justified.

2. *Voltage*. Standard conditions of voltage and frequency are the values listed on the name plate of the motor. Reasonable horsepower design limits are given in Table 1. Power lines are often given voltage ratings known as *nominal system voltages* which are numerically slightly different from the standardized motor voltages.

3. *Phases*. Three-phase power supply is most desirable, but only single phase is offered for most residential and rural districts.

4. *Frequency*. Sixty-cycle systems predominate in the United States. In foreign countries, 50-cycle systems are common and nominal system voltages are frequently different.

5. *Voltage Regulation*. The voltage regulation of the power supply should be known in order to select motors which will deliver sufficient torque even with the probable drop in voltage, to start and carry the load. All induction motor torques and synchronous-motor starting and pull-in torques vary as the square of the voltage.

6. *Continuity of Power*. Dips in voltage from switching or other line disturbances may necessitate time-delay undervoltage protection, and, in case of synchronous-motors, high torque designs and resynchronizing control. Sustained low voltage may necessitate higher torque motors.

The following characteristics of the *driven machine* should be determined: (1) mechanical arrangement including position of motor and shaft, portability desired, drive connection, and space limitations; (2) speed range desired; (3) horsepower requirement; (4) torque; (5) inertia; and (6) frequency of starting.

1. *Mechanical Arrangement*. Arrangement of the driven machine usually determines whether a *horizontal* or *vertical* motor is needed. Horizontal motors are more generally available and less expensive; most grease-lubricated ball-bearing motors will operate in either position. Fractional-horsepower waste-packed sleeve-bearing