to control. The coordination of the building design with the type of system and arrangement of controls should be considered during the planning stages. The following considerations are recommended:

1. Only groups of areas which have similar load characteristics should be served from a heating or cooling system under the control of a single zone. Rooms or areas having dissimilar load conditions should have individual controls.

The smaller the controlled area, the better will be the control obtained and the more nearly will the desirable individual room control be achieved.

2. A system that employs constant air volume with variable air temperature is more satisfactorily controlled than one that requires throttling of air volumes in order to achieve temperature regulation.

3. Heating and cooling coils should be carefully selected to avoid oversizing where light loads can be expected so that accurate temperature control can be achieved without *hunting* or *short-cycling* (oscillations from high to low temperatures).

4. Stratification of air in ducts must be prevented where no turbulence occurs after the coils or mixing dampers and where branch ducts receive air of different temperatures.

5. When pre-heat or tempering coils are employed they should be of the internal distributing tube or non-freeze type and in cold climates it may also be desirable to use face and by-pass dampers, with constant steam supply to the coil, in preference to throttling valves for temperature regulation.

6. Wherever automatically controlled dampers are used, those with adjacent blades opposed rather than parallel to each other will obtain the more uniform distribution.

7. When the relative humidity of the air is to be controlled it is always desirable to provide some means of reheating the saturated air.

8. Short-cycling of refrigeration equipment should be avoided by (a) providing capacity reduction or automatic unloading of the compressor to match the minimum load, (b) controlling the temperature of the condenser water, (c) providing artificial load, or (d) providing storage capacity for the system.[5,6]

9. Good air distribution and adequate diffusion of the air entering a space are necessary. Return air grilles should be located as an aid to proper distribution. Temperature control devices cannot prevent drafts nor can they be expected to compensate for poor design.

10. Radiator valves and valves for heating coils must not be oversized if close control is to be expected. For large capacity services multiple valves should be used. Where two valves are used, one should be sized for ⅓ and one for ⅔ of the steam requirement, and arranged for sequence operation.

11. Adequate space must be allowed for the equipment. Dampers should not be placed too close to coils and space must be allocated for the damper operators. Valves and their operators must be accessible for inspection and attention. Duct thermostats must be placed in a representative unstratified mixture of the air being controlled or if this is impossible, long averaging bulbs must be used. Humidifier pans should be placed down-stream from the source of heat. Coils must not be placed too close to either the inlet or the outlet of fans.

12. Space controllers must be placed in a space where they will measure the variables they are to control and where the condition is representative of the whole space. If the return air duct is used to represent space conditions the controllers should normally be located as near the space as possible.

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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 motive power. 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