valve handles about one-third of the total capacity and the other about two-thirds. They are controlled in sequence so that the small valve operates during periods of light load and the large valve begins to open only after the load exceeds the capacity of the small valve.

The steam piping from the valve to the coil inlet, and from the outlet to the trap should be the full size of the coil tapping or size specified by the manufacturer of the coil and should conform to good standard practice as illustrated in Chapter 21. It is very important that condensate be promptly drained from the coil. When the coil is at reduced pressure, as it will be much of the time, there will not be sufficient difference in pressure between the coil and the return line to obtain any lifting of the condensate.

THE CONTROL OF WATER FLOW

The capacity of a proportional valve for water service is not influenced by the supply water pressure but only by the pressure differential. If a certain water circuit has a total resistance of 30 psi at maximum flow, of which 1 psi is through the valve, the resistance of the rest of the circuit is 29 psi. When the valve is closed and there is no flow, the entire 30 psi resistance is across the valve. Thus the pressure drop across the valve increased by a ratio of 30:1 as the valve closed. This increase in pressure drop as the valve opening is decreased offsets partially the effect of closing the valve. It is obviously impracticable to design a water system such that there will be no increase in pressure drop across the valve as it closes. However, it is important to design the system, including the valve, in such a manner that the ratio of this increase in pressure drop as the valve closes is kept as low as possible. Thus, if the design pressure drop across the valve is 5 psi instead of 1 psi, the ratio of increase is only 6:1 instead of 30:1 and the performance of the valve will be improved accordingly. This discussion assumes a circuit in which the entire flow is controlled by a single valve. The same reasoning will apply to the more complicated systems involving a multiplicity of parallel circuits, each having a valve. In general it can be said that the pressure drop across a water valve at full flow should be a reasonable percentage of the resistance of the circuit in which the valve controls the flow. Due consideration should be given to any resultant increase in pumping head and operating costs.

Water circuits involving variable flow are subject to variable pressures in accordance with the pressure *vs* flow characteristic of the pump. On such circuits it is desirable to provide pressure control by means of a bypass connection around the pump. This bypass connection either has a spring-loaded relief valve, subject to the system pressure difference, or an automatic control valve operated by a differential pressure controller. The total resistance through the bypass connection at full flow should be equal to the total system resistance.

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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

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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