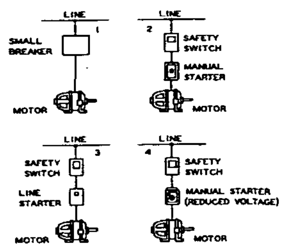
cases it is desirable also to provide a disconnect switch. Fig. 9 illustrates the recommended controls.

MOTOR RATING

The rating of an electric motor depends upon the total temperature which the motor attains under operating conditions. This total temperature depends on both the ambient temperature and the temperature rise of the motor. As motor temperature rise is in turn determined by the ability of the motor to dissipate heat, circulation to the motor should not be restricted. Improper selection of motors with regard to temperature ratings may result in high motor operating temperatures and accompanying reduction in motor life.

FUNCTIONS OF CONTROL EQUIPMENT FOR MOTORS

In general, control equipment for all types of motors should provide (1) means of disconnecting the motor and controller from the power supply, (2) means for starting the



Arrangements 2, 3, and 4 are optional for motors up to 7½ hp, 220 volts.

Fig. 9 .... Recommended Controls for Single-Phase Motors

motor, (3) overload protection for the motor, (4) protection against low voltage, and (5) means for varying the motor speed.

Full-voltage starting for motors is preferable because of its lower first cost and simplicity of control. Except for d-c machines, most motors are mechanically and electrically designed for full-voltage starting. The starting inrush current, however, is limited in many cases by regulations of power companies because of the voltage fluctuations which may be caused by heavy current surges. It is therefore often necessary to reduce the starting current below that obtained by across-the-line starting. The power supplier should be consulted to determine the allowable inrush current for any given location.

The choice between full-voltage and reduced-voltage starting is governed almost entirely by inrush current limitations. The starting torque of all motors varies with the starting current, and it is therefore necessary to insure that the motor is supplied with sufficient current to develop enough torque to accelerate the load.

In present practice *overload protection of motors is obtained* by use of thermal-overload inverse-time-limit type protection. The usual setting of such protection devices is not to exceed 125 percent of rated full load current for open 40 C deg rise motors, and not to exceed 115 percent of rated full-load current for all other motors, the element tripping after a definite interval of time. The *National Electrical Code* requires the addition of fuses or circuit breakers to protect the overload elements from severe short-circuit currents.

Two types of protection are available against low voltage at the motor terminals. One type, called low-voltage release, permits the motor line contactor to drop out on low voltage and to close again when the voltage returns to normal, thereby restarting the motor when the abnormal condition is ended. The second type, called low-voltage protection, causes the motor line contactor to drop out on low voltage, but prevents restarting when the voltage returns to normal except by the action of an operator. This latter type of protection is desirable where it is necessary for the operator to make initial starting adjustments on the machine.

Manual control for an alternating- or a direct-current motor is usually located near the motor. When so located an operator must be present to start and stop or change the speed of the motor by operating the control mechanism. Manual control is sometimes employed only as a device to give overload protection, and another device is employed to start and stop the motor. Manual control is used particularly on small motors which operate unit heaters, small blowers, and room coolers in an air-conditioning system. In other cases manual control in the form of drums, when used with multi-speed motors, is used only as a speed setting device, while the starting and stopping functions operate automatically through thermostats and pressure switches.

Because of the increasing complexity of air-conditioning systems, the equipment is operated preferably by automatic control, and less dependence is placed on manual operation and regulation.

Automatic control of motor starters may be accomplished by the use of remote push button stations, by a thermostat, float switch, pressure regulator, or other similar pilot devices. An added advantage of automatic control is that the main wiring for the starter may be installed near the motor, while the starter may be operated by a remote control device.

GLOSSARY

General Definitions

NEMA is the abbreviation for the National Electrical Manufacturers Association.

AEIC is the abbreviation for the Association of Edison Illuminating Companies.

EEI is the abbreviation for the Edison Electric Institute.

Speed Regulation (d-c motors) is the change in speed between no load and full load, expressed in percent of full-load speed; for example, a motor having a no-load speed of 1200 rpm and a full-load speed of 1140 rpm would have a speed regulation of 5.26 percent.

Slip (a-c induction motors) is the difference between the motor speed and synchronous speed expressed in percent of synchronous speed, e.g., a 1200-rpm motor operating at 1140 rpm would have a slip of 5 percent.

Torque is an expression of the turning effort developed by the motor at the shaft, and is usually expressed in ounce-feet for fractional horsepower motors, and in pound-feet for motors of larger ratings.

Primary is the term usually applied to the high voltage or line side of a transformer or motor. In the case of the wound rotor motor the primary is the stator winding.

Secondary is the term usually applied to the low voltage or load side of a transformer or motor. In the case of the wound rotor motor the secondary is the rotor winding.

NEMA Classification by Mechanical Protection and Method of Cooling

These classifications are from NEMA publications MGI-1.20 and MGI-1.21.

Open Machine

An open machine is one having ventilating openings which permit passage of external cooling air over and around the windings of the machine.

a. *Drip-proof Machine*. An open machine in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine at any angle not greater than 15 degrees from the vertical cannot enter the machine either directly or by striking and running along a horizontal or inwardly inclined surface of the machine.

b. *Splash-proof Machine*. An open machine in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine or coming towards it in a straight line at any angle not greater than 100 degrees from the vertical cannot enter the machine either directly or by striking and running along a surface of the machine.

c. *Semi-guarded Machine*. An open machine in which part of the ventilating openings in the machine, usually in the top half, are guarded as in the case of a "guarded machine" but the others are left open.

d. *Guarded Machine*. An open machine in which all openings giving direct access to live or rotating parts (except smooth shafts) are limited in size by the design of the structural parts or by screens, grilles, expanded metal, etc., to prevent accidental contact with such parts. Such openings shall not permit the passage of a cylindrical rod ½ inch in diameter, except that, where the distance from the guard to the live or rotating parts is more than 4 inches, they shall not permit the passage of a cylindrical rod ¾ inch in diameter.

e. *Drip-proof Fully Guarded Machine*. A drip-proof machine whose ventilating openings are guarded in accordance with paragraph d.

f. *Open Externally-ventilated Machine*. A machine ventilated by means of a separate motor-driven blower mounted on the machine enclosure. Mechanical protection may be as defined in paragraphs a to e, inclusive.

g. *Open Pipe-ventilated Machine*. An open machine except that openings for the admission of the ventilating air are so arranged that inlet ducts or pipes can be connected to them. This air may be circulated by means integral with the machine or by means external to and not a part of the machine. In the latter case, this machine is sometimes known as separately- or forced-ventilated machine. Enclosures may be as defined in par. a to e, inclusive.

h. *Weather-protected Machine. Type I*—A. An open machine with its ventilating passages so constructed as to minimize the entrance of rain, snow and air-borne particles to the electric parts and having its ventilated openings so constructed as to prevent the passage of a cylindrical rod ¾ in. in diameter.

Type II—A machine having, in addition to the enclosure defined for a weather-protected Type I machine, its ventilating passages at both intake and discharge so arranged that high-velocity air and air-borne particles blown into the machine by storms or high winds can be discharged without entering the internal ventilating passages leading directly to the electric parts of the machine itself. The normal path of the ventilating air which enters the electric parts of the machine shall be so arranged by baffling or separate housings as to provide at least three abrupt changes in direction, none of which shall be less than 90 deg. In addition, an area of low velocity not exceeding 600 fpm shall be provided in the intake air path to minimize the possibility of moisture or dirt being carried into the electric parts of the machine.

Totally-enclosed Machine

A totally-enclosed machine is one so enclosed as to prevent the free exchange of air between the inside and the outside of the case but not sufficiently enclosed to be termed air-tight.

a. *Totally-enclosed Nonventilated Machine*. A totally-enclosed machine which is not equipped for cooling by means external to the enclosing parts.

b. *Totally-enclosed Fan-cooled Machine*. A totally-enclosed machine equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.

c. *Explosion-proof Machine*. A totally-enclosed machine whose enclosure is designed and constructed to withstand an explosion of a specified gas or vapor which may occur within it and to prevent the ignition of the specified gas or vapor surrounding the machine by sparks, flashes or explosions of the specified gas or vapor which may occur within the machine casing.

Note—See National Electrical Code Article 500—For Hazardous Locations, Class I, Groups A, B, C or D.

d. *Dust-ignition-proof Machine*. A totally-enclosed machine whose enclosure is designed and constructed in a manner which will exclude ignitable amounts of dust or amounts which might affect performance or rating, and which will not permit arcs, sparks, or heat otherwise generated or liberated inside of the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specific dust on or in the vicinity of the enclosure.

Note I—Successful operation of this type of machine requires avoidance of overheating from such causes as excessive overloads, stalling or accumulation of excessive quantities of dust on the machine.

Note II—See National Electrical Code Article 500—For Hazardous *Locations, Class II, Groups E, F or G.*

e. *Water-proof Machine*. A totally-enclosed machine so constructed that it will exclude water applied in the form of a stream from a hose, except that leakage may occur around the shaft provided it is prevented from entering the oil reservoir and provision is made for automatically draining the machine. The means for automatic draining may be a check valve or a tapped hole at the lowest part of the frame which will serve for application of a drain pipe.

Note—A common form of test for a water-proof machine is to play on the machine a stream of water from a hose with a one-inch nozzle delivering at least 65 gpm from a distance of about 10 ft, from any direction, and for a period of not less than 5 min.

f. *Totally-enclosed Pipe-ventilated Machine*. A totally-enclosed pipe-ventilated machine is a totally-enclosed machine except for openings so arranged that inlet and outlet ducts or pipes may be connected to them for the admission and discharge of the ventilating air. This air may be circulated by means integral with the machine or by means external to and not a part of the machine. In the latter case, these machines shall be known as separately- or forced-ventilated machines.

g. *Totally-enclosed Water-cooled Machine*. A totally-enclosed machine which is cooled by circulating water, the water or water conductors coming in direct contact with the machine parts.

h. *Totally-enclosed Water-air-cooled Machine*. A totally-enclosed machine which is cooled by circulating air which, in turn, is cooled by circulating water. It is provided with a water-cooled heat exchanger for cooling the ventilating air and a fan or fans, integral with the rotor shaft or separate, for circulating the ventilating air.

i. *Totally-enclosed Air-to-air cooled Machine*. A totally-enclosed machine which is cooled by circulating the internal air through a heat exchanger which, in turn, is cooled by circulating external air. It is provided with an air-to-air heat exchanger for cooling the ventilating air and a fan or fans, integral with the rotor shaft or separate, for circulating the internal air and a separate fan for circulating the external air.

j. *Totally-enclosed, Fan-cooled Guarded Machine*. A totally-enclosed, fan-cooled machine in which all openings giving direct access to the fan are limited in size by the design of the structural parts or by screens, grilles, expanded metal, etc., to prevent accidental contact with the fan. Such openings shall not permit the passage of a cylindrical rod ½ in. in diameter except that,