split-phase type or of the capacitor-start (or two-value capacitor) type.

For starting the split-phase type of motor, two methods are generally acceptable. In one method a thermally-operated time delay is used. When the motor is started, a contact which is normally closed applies power to the starting winding. A thermal element which controls these contacts is in series with the motor and carries line current. Due to the current flow through this element, it is heated until, after a definite period of time, it is warmed sufficiently to open the contacts and remove power from the starting winding. The running current then heats the element enough to keep the contacts open. The setting of the time for the starting contacts to open is determined by tests on the system components, i.e., the relay, the motor, and the compressor, and is based on a prediction of the amount of time delay required to bring the motor up to speed.

The second method of starting split-phase motors utilizes a series-coil or current-operated relay. This device is affected indirectly by motor speed.

In this type of connection, a relay coil carries the line current going to the motor. When the motor is started, the inrush current to the running winding, passing through the relay coil, causes the contacts to close, and applies power to the starting winding. As the motor comes up to speed, the current decreases until at a definite calibrated value of current corresponding to a preselected speed, the magnetic force of the coil diminishes to a point which allows the contacts to open to remove power from the starting winding.

Capacitor-start and *two-value-capacitor hermetically-sealed* motors are usually started with a voltage-type relay. In this method of starting the relay coil is connected in parallel with the starting winding. When power is applied to the line, the relay does not operate because it is calibrated to operate on a higher voltage. As the motor comes up to speed, the voltage across the starting winding and relay coil increases in proportion to the motor speed. At a definite voltage corresponding to a preselected speed, the relay operates and opens its contacts, thereby opening the starting-winding circuit. The relay then keeps these contacts open because there is sufficient voltage induced in the starting winding, when the motor is running, to hold the relay in the open contact position.

CONTROL FOR ALTERNATING-CURRENT MOTORS

Squirrel-cage motors are usually started at line voltage where power company limitations permit. In sizes up to 5 hp at 220 volts, or 7½ hp at 440 volts, polyphase motors may be started by means of manual switches having overload current elements for motor protection. In larger ratings a linestarter is usually provided with either an additional safety switch or circuit breaker for disconnecting and short-circuit protection. Reduced-voltage starting may be used when the current inrush on full voltage exceeds the limitations set by the power company. The magnitude of this inrush current is entirely independent of the load on the motor, and is the same whether the motor is lightly loaded or heavily loaded.

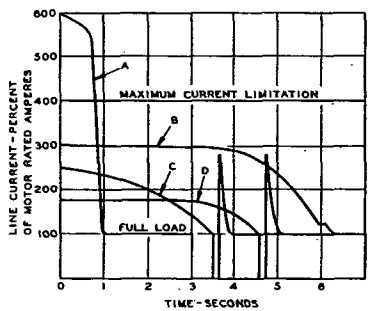
Restrictions on starting current may limit the maximum current inrush or may limit the increments of current inrush which may be drawn on each step. Table 7 shows a comparison of the various methods of reduced-voltage starting. The choice may depend upon the limitation to be met. Fig. 5 shows examples for maximum current limitations. Fig. 6 shows examples for increment limitations. The increment starters would not be satisfactory for meeting maximum current limitations as they exceed the maximum value before the motor reaches full speed. Both Curves *B* and *C* of Fig. 6 would be satisfactory if the increment limitation were 400 percent but only the starter illustrated by Curve *C* would meet a limitation of 200 percent increments.

When increment starters are used, the motor may not develop enough torque to start until the last step. Fig. 6 shows that with the resistor step starter the motor does not start until Step 3 or after 2 seconds on Curve *C*. Part-winding motors may start and then stall at about half speed until the second step which applies full torque.

Table 7 .... Comparison of Squirrel-Cage and Synchronous Motor Starting Methods

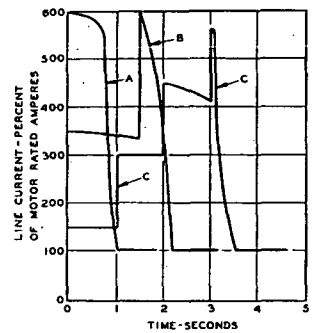
Type of Starter	Percent of Motor Rated Values		
	Voltage	Starting Torque	Line Current
Full Voltage Starter	100	100	100
Autotransformer			
80 percent tap	80	64	68
65 percent tap	65	42	46
50 percent tap	50	25	30
Resistor, single step	80	64	80
Reactor			
50 percent tap	50	25	50
45 percent tap	45	20	45
37.5 percent tap	37.5	14	37.5
Part Winding	60*	50*	60*
Star-delta	58	33	33

* Varies with portion of winding used.



Curve A—Full Voltage Starter
Curve B—Reactor 50 Percent Tap
Curve C—Autotransformer 65 Percent Tap

Fig. 5 .... Starters for Maximum Current Limitations

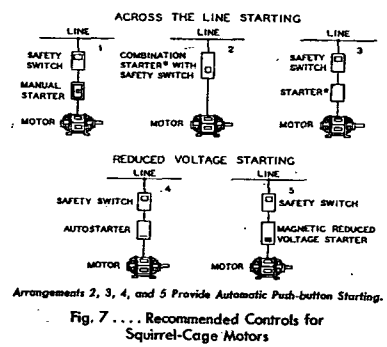


Curve A—Full Voltage Starter
Curve B—Part Winding Starter
Curve C—4-Step Resistor Increment Starter

Fig. 6 .... Starters for Increment Limitations

The load inertia WK^2 may also affect the selection of reduced current starting method since the reduced torques may not be sufficient to accelerate the load without overheating the motor or in the case of synchronous motors, may not reach sufficient speed to pull into synchronous speed. In these cases the solution may be to use the wound-rotor induction motor or some means of reducing the load such as suction dampers on compressors. Fig. 7 illustrates recommended control practice for squirrel-cage motors.

Wound-rotor motors require control of both primary and secondary circuits. The primary* control may be the same as for squirrel-cage motors, manual or magnetic, at full voltage. Secondary* control provides means of varying secondary resistance for starting and speed control. The secondary controller should be specified for starting duty only, or for speed regulating duty. If the secondary controller is to be used for speed-regulating duty, the percent speed reduction, the number of speed control points, and the type of load (variable or constant torque) should be specified. Fig. 8 illustrates recommended control practice for wound-rotor motors.



Arrangements 2, 3, 4, and 5 Provide Automatic Push-button Starting.

Fig. 7 .... Recommended Controls for Squirrel-Cage Motors

Synchronous motor starters should provide pull-out protection, automatic synchronization or automatic stopping of the motor after pull-out, and assurance of complete starting sequence, as well as overload and low-voltage protection. The control may be either magnetic or semi-magnetic at full or reduced voltage. Semi-magnetic starters provide automatic field control, but require hand operation for closing the line contactors to start and transfer to full voltage.

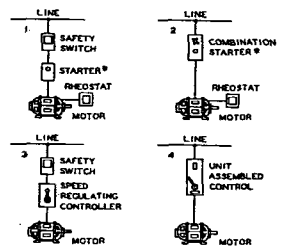


Fig. 8 .... Recommended Controls for Wound-Rotor Motors

In applying reduced-voltage starters to synchronous motors it should be remembered that, since these motors are started on damper windings and function during the acceleration period similarly to squirrel-cage motors, the starting torque varies as the square of the applied voltage. Consideration should be given to insure development of sufficient motor torque to accelerate the load.

Multi-speed control may be either manual or magnetic, and at full or reduced voltage. When using automatic magnetic control with two-, three-, and four-speed separate winding or consequent-pole motors, control may be obtained from a remote point by means of a push button master switch. The various speeds of the motor are obtained from the master switch by simply depressing the correct push button. This is known as selective speed control. It is commonly used in the smaller theater installations where the fan and motor are located backstage and the speed control is located in the lobby.

Multi-speed motor controllers may be provided with compelling relays which make is necessary for the operator to press the first speed button before regulating the motor to the desired speed. This ensures that the motor is always started at low speed before adjusting to a higher speed.

Timing relays which provide for automatic acceleration may be used for control. With this feature the motor will always start at low speed and automatically accelerate to the desired speed. Decelerating relays may be used to reduce the shock effect of the braking action on the motor and drive when the speed is reduced from a higher to a lower speed.

Single-phase motor control usually consists only of an across-the-line starter, either manual or magnetic. In some

*Refer to Glossary at end of chapter.