life and other objectionable results. To avoid these effects reduced voltage starters are used. However, the starting limitations vary with the various power companies and the starting requirements should be checked in each locality.

PILOT CONTROLS

In selecting pilot control devices to operate in conjunction with either manual or automatic motor control, it is necessary that they be classified as follows:

1. *Two Wire Control.* Some thermostats, float switches, and pressure regulators provide two wire control which gives low voltage release. A three position off-on automatic pilot switch can be used in connection with this method and thus provide manual control. With a low voltage (12 or 20 volt) control circuit it is desirable to use a low voltage thermostat. When this type of thermostat is used it will be found that a saving in the wiring cost results. When using the low voltage thermostat on a control circuit a relay and transformer panel should be used instead of the low voltage coil on the starter.

2. *Three Wire Control.* Other types of thermostats, float switches and pressure regulators are of the three wire, low voltage type and are used in conjunction with a control circuit relay for controlling the operation of motors. Momentary contact start and stop push button stations are usually furnished as standard accessories with automatic starters, which give low voltage protection. This control cannot be used in combination with two wire pilot devices.

In selecting manual control for an alternating or a direct current motor, the common practice is to locate the control near the motor. When the control is installed at the motor, an operator must be present to start and stop or change the speed of the motor by operating the control mechanism. Sometimes manual control is 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 multispeed motors, is only used as a speed setting device with the starting and stopping functions operated automatically through thermostats, and pressure switches.

Because of the increasing complexity of air conditioning systems, heating, ventilating and air conditioning equipment is being operated on automatic control with less dependence 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 control device located elsewhere. In the majority of air conditioning installations, requiring motors 1 hp and larger, two or three phase alternating current is usually supplied.

DIRECT CURRENT MOTOR CONTROLS

Air conditioning installations using direct current power now are used only where alternating current is not available. Direct current motors

are always started through starters, which are devices using a resistance to be put in series with the armature circuit during starting only, the resistance being gradually cut out as the motor comes up to speed. The starting current is held within safe limits by the use of the resistance. The speed of a direct current motor may be regulated by several methods:

1. Speed adjustment by field control—by using a device with resistance to be put in series with the field winding. After the motor has been started to be used to increase the speed of the motor above full field speed.

2. Speed adjustment by armature control—by using devices with resistance to be put in series with the armature circuit to beused to reduce the speed of the motor below full field or normal speed.

3. Combinations of field and armature control, so that the starting, field control, or armature control may be combined in a single unit.

4. Speed adjustment by variable voltage control—by using a source of variable voltage a wide speed range from 16:1 and less can be obtained. Speed above basic motor speed is obtained by field control and below by reduced armature voltage. In the smaller range of motor sizes complete equipments are available for this type of control. In the ranges up to 30 hp this is accomplished by a small motor generator set. Below 7½ hp variable voltage speed control can be obtained through the use of electronic tubes for rectification and control functions.

Field control is usually preferred, depending on the size of the installation. For example, if a direct current motor were required with speed regulation between 1200 and 600 rpm, a choice of supplying a 1200 rpm motor with armature control or a 600 rpm motor with field control, both giving the same speed variation would be possible. While the 1200 rpm motor with armature control is lower in first cost than the 600 rpm motor with field control, the cost of operating the 600 rpm motor with field control is less and will save the difference in first cost over a period of time depending on the size of installation. A wide speed variation can be easily obtained in a direct current motor by using a combination of field and armature control.

SQUIRREL-CAGE MOTOR CONTROL

To meet the requirements of various drives of an air conditioning system, three types of squirrel-cage, two or three phase motors may be used: (1) normal torque, normal starting current, (2) normal torque, low starting current, and (3) high torque, low starting current.

Because of the large current inrush of the normal torque, normal starting current motor, some central stations usually require current limiting starting equipment on such motors above 7½ hp. To meet the starting current requirements, manual or automatic current limiting reduced voltage controllers are used. These controllers are equipped with voltage taps, the 65 per cent tap being regularly furnished when the starter leaves the factory. Motors 7½ hp and smaller have starting currents within the requirements of central stations and manual or magnetic, full voltage control may be used in all cases.

The normal torque, low starting current motor has a starting current which is approximately 20 per cent less than the normal current motor on full voltage and within the required current limits on 30 hp sizes and smaller. This motor, therefore, lends itself to across-the-line control because no current limiting equipment is necessary.