

are voluntary. Those for electrical equipment used in the air conditioning and refrigerating industries are listed in Chapter 71. Of special importance in the United States and Canada are the *National Electrical Code (NEC)* and the *Canadian Electrical Code, Part I*, respectively.

The *National Electrical Code* is Volume 5 of the *National Fire Protection Code*, and contains the minimum recommendations considered necessary to make electrical installations and equipment safe. All interested industry organizations, insurance and enforcement groups, and the public are represented on the committees preparing and revising this code, to fulfill the requirements necessary for adoption by the American Standards Association. The *National Electrical Code* is not mandatory. Mandatory status is obtained only when it is made part of local ordinances or by the regulations of insurance companies. The electrical codes of practically all communities in the United States are based upon it.

Underwriters' Laboratories, Inc., is a non-profit organization sponsored by the National Board of Fire Underwriters, which promulgates standards for various types of equipment. Underwriters' standards for electrical equipment cover construction and performance for the safety of such equipment, and interpret requirements to insure compliance with the intent of the NEC. A complete list of available standards may be obtained from Underwriters' Laboratories which also examines and tests equipment and publishes lists of equipment which has passed these tests and therefore bears the U/L labels. The lists and labels are recognized by local authorities.

The *Canadian Electrical Code, Part I*, is a standard of the Canadian Standards Association. It is also a voluntary code with minimum requirements for electrical installations in buildings of every kind.

The *Canadian Electrical Code, Part II*, contains specifications for construction and performance of electrical equipment in compliance with Part I. Specifications for different materials and equipment have been published, and the complete list may be obtained from the Canadian Standards Association. Underwriters' Laboratories standards and standards of the Canadian Standards Association for electrical equipment are similar so that equipment designed to meet the requirements of one code may also meet the requirements of the other. However, there is not complete agreement between the codes and consequently individual standards must be checked when designing equipment for use in both countries.

Approvals Laboratories of the Canadian Standards Association examine and test material and equipment for compliance with the *Canadian Electrical Code*.

Copies of electrical standards may be obtained directly from the sponsoring organizations. (See Chapter 71.)

### DOMESTIC REFRIGERATION

Motors used in domestic refrigeration range from approximately 1/100 hp fan motors to 1/2 hp compressor motors. These motors are in most cases controlled directly by the system controls, which may be thermostats, timers, pressure switches, or other automatic control devices. Practically all standard production motors in the United States and other countries are single-phase motors, for operation on 115 and 230 volts single-phase a-c.

### Motors

Compressor motors in most domestic refrigerators are hermetically-sealed. They are either split-phase, capacitor-start, or permanent-split-capacitor motors. Split-phase and

permanent-split-capacitor motors are suitable for compressors requiring medium or low starting torques. Capacitor-start and special split-phase motors develop high starting torque. Performance characteristics are given in Table 4.

Domestic refrigerators may or may not have a mechanical air moving device. Those that do generally employ a shaded-pole motor. (See Table 4.)

Because of their hermetic design, it is neither possible nor necessary to service compressor motors. On the other hand, fan motors are accessible and must be occasionally serviced in accordance with manufacturer's instructions.

### Motor Control

**Starting Switches.** To start a single-phase induction motor of the split-phase or capacitor-start type, a switch is needed to disconnect the starting winding or the capacitor circuit after the motor has been accelerated to approximately 70 percent of synchronous speed.

In open type motors, centrifugal switches are used and operate at predetermined motor speeds. In hermetic compressors, electrical arcing cannot be tolerated. Therefore, switches in motors for hermetic compressors must be hermetically-sealed, or they must be located outside the compressor shell. Economic considerations have frequently led to the use of external switches.

**Starting Relays.** Both magnetic and thermal relays are also used for starting split-phase motors. They are located outside the compressor shell. Relays usually respond to the current in the main winding, in order to take advantage of the main winding current vs speed characteristics of the motor. The current-speed curve varies with line voltage, so that the starting relay must be selected for the range of voltage likely to be encountered in service. Ratings established by the compressor manufacturer in cooperation with the motor manufacturer should not be changed because this may result in undesirable starting characteristics.

The starting methods by use of relays are:

1. **Starting method using thermally-operated relay.** 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.

2. **Starting method using current-operated relay.** 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.

### Motor Protection

Motors for domestic refrigerator and freezer compressors are protected by thermal protectors mounted directly on the outside of the compressor shell. These protectors carry the full motor line current. The protector size is based on a contact rating which is adequate to interrupt the stalled current of the motor on continuous cycling. Cycling-life requirements are based on specifications established by Underwriters' Laboratories in the United States and the Canadian Standards Association in Canada. Both standards require 15 days of continuous cycling and a 72-hour heating test with locked rotor.

Table 4 . . . Characteristics of Various Types of Single-phase a-c Motors

|                               | Split-Phase<br>General-Purpose        | Split-Phase<br>High-Start | Permanent-<br>Split-Capacitor | Capacitor-Start<br>Induction-Run | Shaded-Pole               | Capacitor-Start<br>Capacitor-Run |
|-------------------------------|---------------------------------------|---------------------------|-------------------------------|----------------------------------|---------------------------|----------------------------------|
| Connection diagram            |                                       |                           |                               |                                  |                           |                                  |
| Speed torque curves           |                                       |                           |                               |                                  |                           |                                  |
| Starting method               | Relay                                 | Relay                     | None                          | Relay                            | None                      | Relay                            |
| HP ratings                    | 1/100-1/2                             | 1/100-1/2                 | 1/100-5                       | 1/100-1/2                        | 1/100-1/2                 | 1/100-6                          |
| Full load speeds at 60 cycles | 3450-1725                             | 3450-1725                 | 3450-1725                     | 3450-1725                        | 3100-1550<br>1000         | 3500-1750                        |
| Torque                        | Moderate<br>Locked rotor<br>Breakdown | High<br>High              | Low<br>Moderate               | Very High<br>High                | Low<br>Low                | High<br>High                     |
| Speed classification          | Constant                              | Constant                  | Constant                      | Constant                         | Constant or<br>Adjustable | Constant                         |
| Full load power factor        | Moderate                              | Moderate                  | High                          | Moderate                         | Moderate                  | High                             |

Thermal protectors are responsive to temperature as well as electric current. Application is made and protector rating determined by the compressor manufacturer in cooperation with the protector manufacturer. Any change in protector rating after the proper application has been made, may result in either over-protection and frequent trip-out or under-protection and burn-out of the motor windings.

Connections to protector terminals should not be changed and no additional connections should be made to the terminals, because any change in the heat added to or removed from the terminal will affect the rating of the protector.

Open type air-moving motors, which are usually small fractional horsepower motors, are protected by self-impedance, thermostats, or thermal protectors. Shaded-pole motors can be impedance-protected. These motors are designed liberally with regard to iron, and the high impedance of the windings is used to limit motor current and, consequently, winding temperature. (See Underwriters' Laboratories requirements for impedance-protected motors.)

Most air-moving motors are protected by thermostats and thermal protectors, operating in response to motor winding temperature, or motor temperature and motor current. The protector is part of the motor itself. The nameplate of the motor is marked in accordance with the requirements of the approval agency.

Starting relays and protectors for hermetically-sealed compressor motors normally do not require any maintenance other than to make sure that electrical connections are tight. Protectors for open motors do not require any maintenance.

### ROOM AIR CONDITIONERS

Room air conditioners have compressor motors ranging from 1/4 hp to 3 hp, and fan motors ranging from 1/4 hp to 1/2 hp. Motors are in most cases controlled directly by the system controls, such as thermostats, timers, pressure switches,

or other automatic devices. Single-phase motors using 115 and 230 standard voltage are most common.

### Motors

Most compressor motors for room air conditioners are permanent-split-capacitor or capacitor-start, capacitor-run motors in hermetically sealed systems. Permanent-split-capacitor motors provide an economical approach to the problem of maintaining low-current draw on a 115-volt circuit. Performance data are given in Table 4.

The necessity for low-current-draw on a 115-volt circuit, also makes it necessary to use permanent-split-capacitor motors for the fans of room air conditioners. Where current-draw is no problem, shaded-pole motors are used.

Hermetic design makes it impossible and unnecessary to service compressor motors. Fan motors are accessible, and should be occasionally serviced in accordance with manufacturer's instructions.

### Motor Control

**Starting Switches.** Permanent-split-capacitor motors do not require a starting switch, because the starting winding with its capacitor is designed to remain permanently connected to the motor circuit. Capacitor-start induction-run, and capacitor-start capacitor-run motors, have at least one capacitor, which is in the circuit only during the start of the motor. Therefore, it is necessary to disconnect the starting winding or the starting capacitor as soon as the motor has reached full speed.

**Starting Relays.** Both thermally-operated and current-operated relays may be used (see previous section on Domestic Refrigeration for a description of these relays).

Capacitor-start hermetically-sealed motors above 1/4 hp are usually started with a voltage-type relay. In this method of