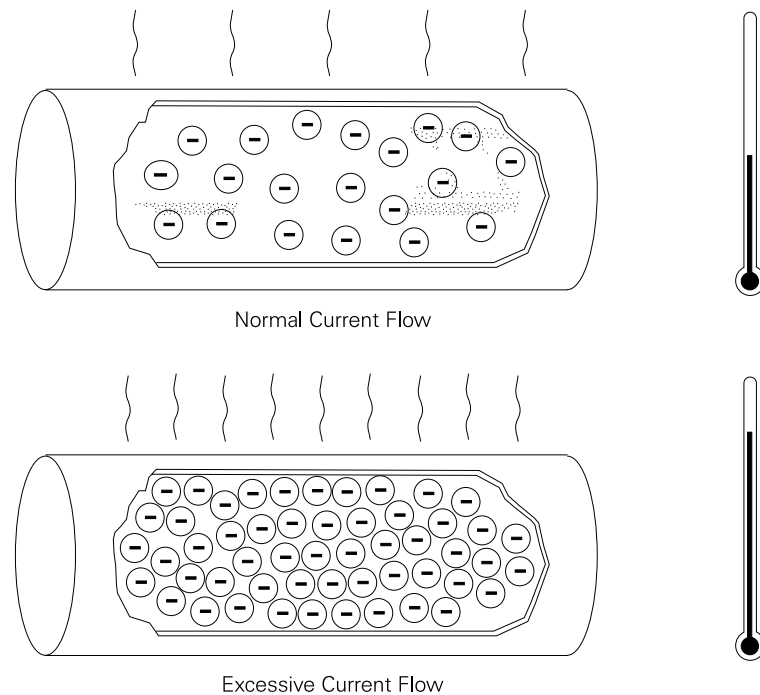


Overload Protection

Before discussing specific control components, it is necessary to review what an overload is and what steps can be taken to limit the damage an overload can cause.

Current and Temperature

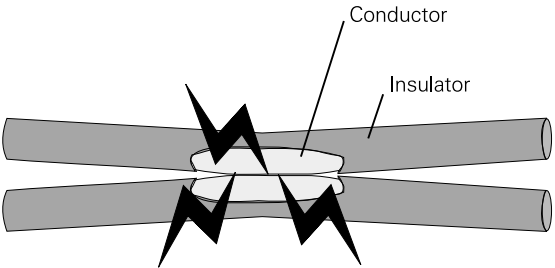
Current flow in a conductor always generates heat due to resistance. The greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Overcurrent protection devices are used to protect conductors from excessive current flow. Thermal overload relays are designed to protect the conductors (windings) in a motor. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating.



Excessive current is referred to as overcurrent. The *National Electrical Code®* defines overcurrent as *any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault* (Article 100-definitions).

Short Circuits

When two bare conductors touch, a short circuit occurs. When a short circuit occurs, resistance drops to almost zero. Short-circuit current can be thousands of times higher than normal operating current.



Ohm's Law demonstrates the relationship of current, voltage, and resistance. For example, a 240 volt motor with 24 ohms of resistance would normally draw 10 amps of current.

$$I = \frac{E}{R}$$

$$I = \frac{240}{24}$$

$$I = 10 \text{ amps}$$

When a short circuit develops, resistance drops. If resistance drops to 24 milliohms, current will be 10,000 amps.

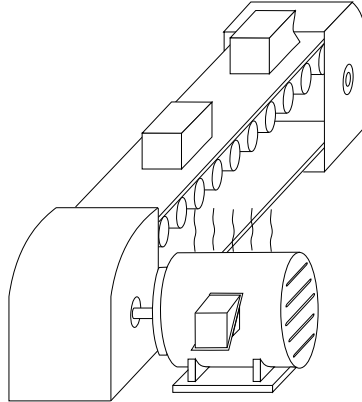
$$I = \frac{240}{0.024}$$

$$I = 10,000 \text{ amps}$$

The heat generated by this current will cause extensive damage to connected equipment and conductors. This dangerous current must be interrupted immediately when a short circuit occurs.

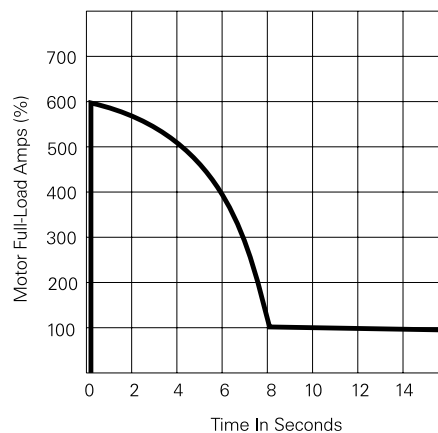
Overload Conditions

An overload occurs when too many devices are operated on a single circuit or a piece of electrical equipment is made to work harder than it is designed for. For example, a motor rated for 10 amperes may draw 20, 30, or more amperes in an overload condition. In the following illustration a package has become jammed on a conveyor causing the motor to work harder and draw more current. Because the motor is drawing more current it heats up. Damage will occur to the motor in a short time if the problem is not corrected or the circuit is not shut down by the overload relay.



Temporary Overload Due to Starting Current

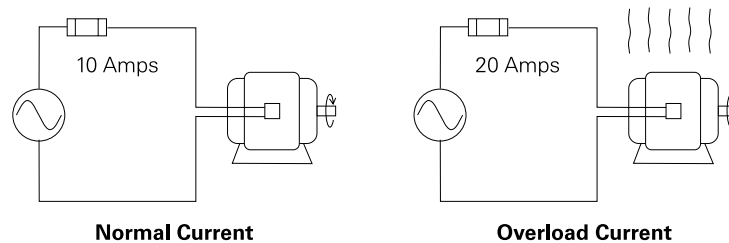
Electric motors are rated according to the amount of current they will draw at full load. When most motors start, they draw current in excess of the motor's full-load current rating. Motors are designed to tolerate this overload current for a short period of time. Many motors require 6 times (600%) the full-load current rating to start. Some newer, high-efficiency motors may require higher starting currents. As the motor accelerates to operating speed, the current drops off quickly. The time it takes for a motor to accelerate to operating speed depends on the operating characteristics of the motor and the driven load. A motor, for example, might require 600% of full-load current and take 8 seconds to reach operating speed.



Overload Protection

Fuses and circuit breakers are protective devices used to protect circuits against short circuits, ground faults, and overloads. In the event of a short circuit, a properly sized fuse or circuit breaker will immediately open the circuit.

There is, however, a dilemma that occurs when applying fuses and circuit breakers in motor control circuits. The protective device must be capable of allowing the motor to exceed its full-load rating for a short time. Otherwise, the motor will trip each time it is started. In this situation it is possible for a motor to encounter an overload condition which does not draw enough current to open the fuse or trip the circuit breaker. This overload condition could easily cause enough heat to damage the motor. In the next section we will see how overload relays are used to solve this problem.



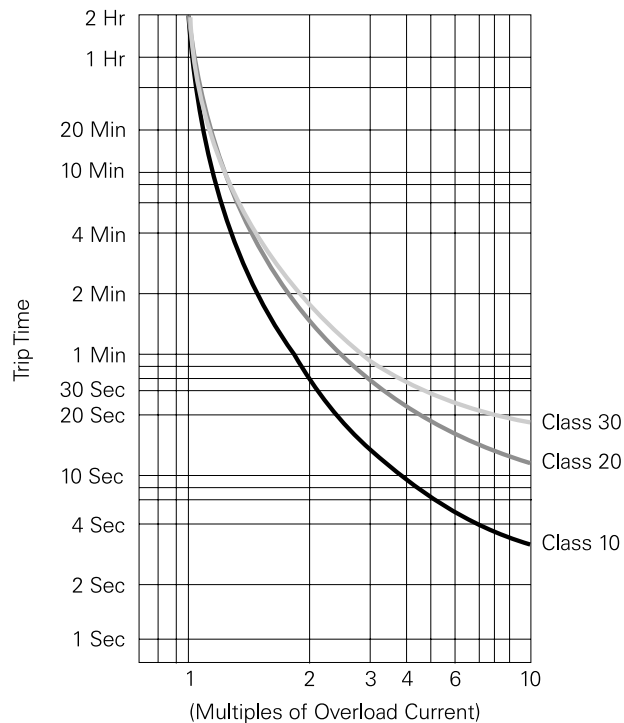
Overload Relays

Overload relays are designed to meet the special protective needs of motor control circuits. Overload relays:

- allow harmless temporary overloads, such as motor starting, without disrupting the circuit
- will trip and open a circuit if current is high enough to cause motor damage over a period of time
- can be reset once the overload is removed

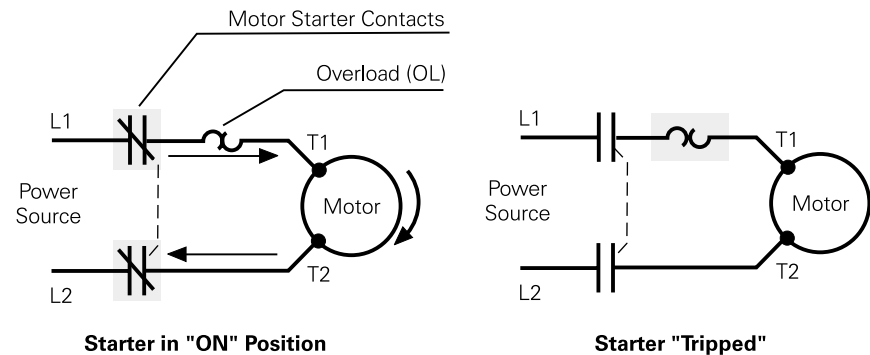
Trip Class

Overload relays are rated by a trip class, which defines the length of time it will take for the relay to trip in an overload condition. The most common trip classes are Class 10, Class 20 and Class 30. Class 10, for example, has to trip the motor off line in 10 seconds or less at 600% of the full load amps. This is usually sufficient time for the motor to reach full speed. Many industrial loads, particularly high inertia loads, use Class 30. Siemens standard overload relays are Class 10 or Class 20 with Class 30 available with some starters.



Overload Relay in a Motor Circuit

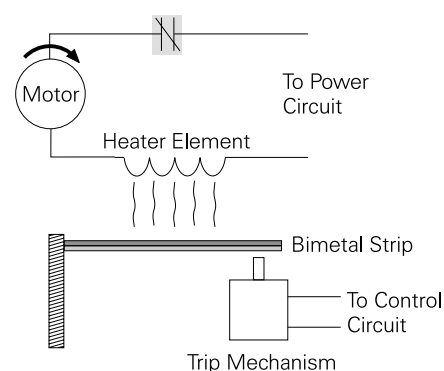
The following illustration shows a motor circuit with a manual starter and overloads. Current flows through the overloads while the motor is running. Excess current will cause the overload to trip at a predetermined level, opening the circuit between the power source and the motor. After a predetermined amount of time the starter can be reset. When the cause of the overload has been identified and corrected the motor can be restarted.



Bimetal Overloads

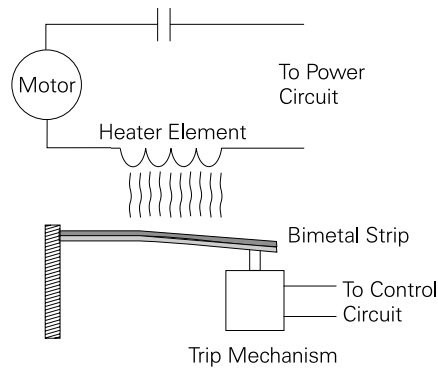
Overload protection is accomplished with the use of a bimetal strip. This component consists of a small heater element wired in series with the motor and a bimetal strip that can be used as a trip lever. A bimetal strip is made of two dissimilar metals bonded together. The two metals have different thermal expansion characteristics, so the bimetal bends at a given rate when heated.

Under normal operating conditions the heat generated by the heater element will be insufficient to cause the bimetal strip to bend enough to trip the overload relay.



Normal Current Flow

As current rises, heat also rises. The hotter the bimetal becomes, the more it bends. In an overload condition the heat generated from the heater will cause the bimetal strip to bend until the mechanism is tripped, stopping the motor.



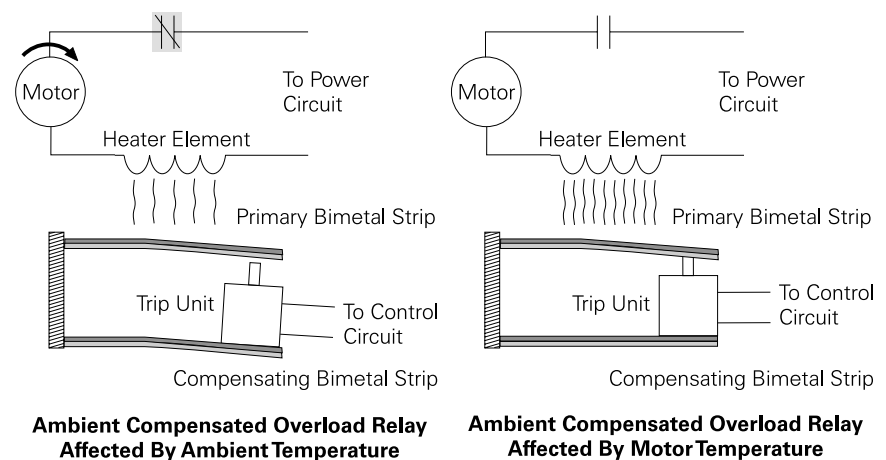
Overload Condition

Some overload relays that are equipped with a bimetal strip are designed to automatically reset the circuit when the bimetal strip has cooled and reshaped itself, restarting the motor. If the cause of the overload still exists, the motor will trip again and reset at given intervals. Care must be exercised in the selection of this type of overload as repeated cycling will eventually damage the motor.

Ambient Compensated Overload Relay

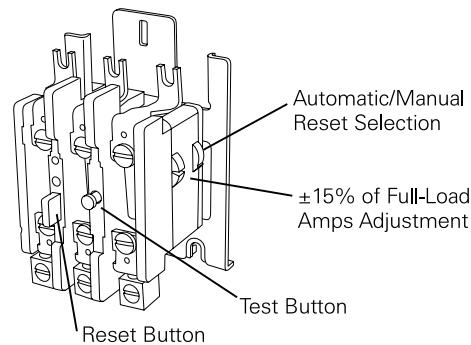
In certain applications, such as a submersible pump, the motor may be installed in a location having a constant ambient temperature. The motor control, along with the overload relay, may be installed in a location with a varying ambient temperature. The trip point of the overload relay will vary with the temperature of the surrounding air as well as current flowing through the motor. This can lead to premature and nuisance tripping.

Ambient compensated overload relays are designed to overcome this problem. A compensated bimetal strip is used along with a primary bimetal strip. As the ambient temperature changes, both bimetal strips will bend equally and the overload relay will not trip the motor. However, current flow through the motor and the heater element will affect the primary bimetal strip. In the event of an overload condition the primary bimetal strip will engage the trip unit.



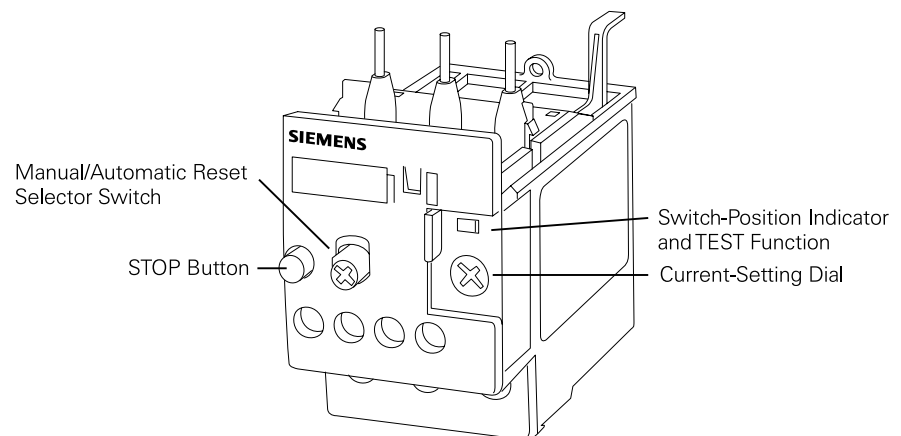
Class 48 Bimetal Ambient Compensated Overload Relay

The Class 48 bimetal ambient compensated overload relay is available in single-pole or three-pole designs. Unlike the melting alloy overload relay, the bimetal ambient compensated overload relay can be set for manual or self-resetting operation. An adjustment dial located on the unit allows the ampere trip setting to be adjusted by $\pm 15\%$. The bimetal ambient compensated overload relay heater elements are available in Class 20 or Class 10 ratings. A normally open or normally closed auxiliary contact is available as an option.



SIRIUS 3RU11 Overload Relay

The Siemens SIRIUS 3RU11 is a bimetal type of overload relay with the heater elements as an integral part of the design. The unit comes with a Class 10 trip as standard. The SIRIUS 3RU11 features manual or automatic reset, adjustable current settings, and ambient compensation. A switch-position indicator also incorporates a test function which is used to simulate a tripped overload relay. A normally open and a normally closed auxiliary contact are included.

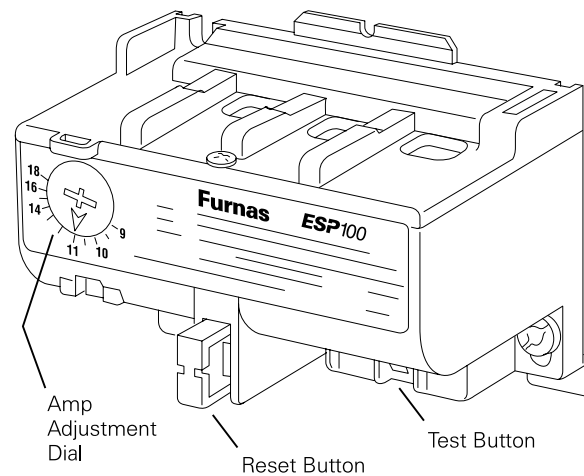


Electronic Overload Relays

Electronic overload relays are another option for motor protection. The features and benefits of electronic overload relays vary but there are a few common traits. One advantage offered by electronic overload relays is a heaterless design. This reduces installation cost and the need to stock a variety of heaters to match motor ratings. Electronic relays offer phase loss protection. If a power phase is lost, motor windings can burn out very quickly. Electronic overload relays can detect a phase loss and disconnect the motor from the power source. This feature is not available on mechanical types of overload relays.

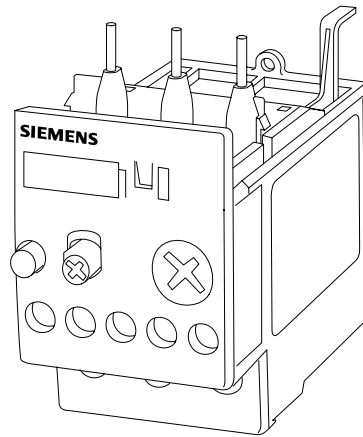
Furnas ESP 100 Electronic Overload Relay

A single ESP100 overload relay replaces at least six size ranges of heaters. Instead of installing heaters the full-load amperes (FLA) of the motor is set with a dial. The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amperes. NEMA Class 10, 20, and 30 trip curves are available for a variety of applications. The relay comes in either a manual or self-resetting version. Auxiliary contacts are available as an option.



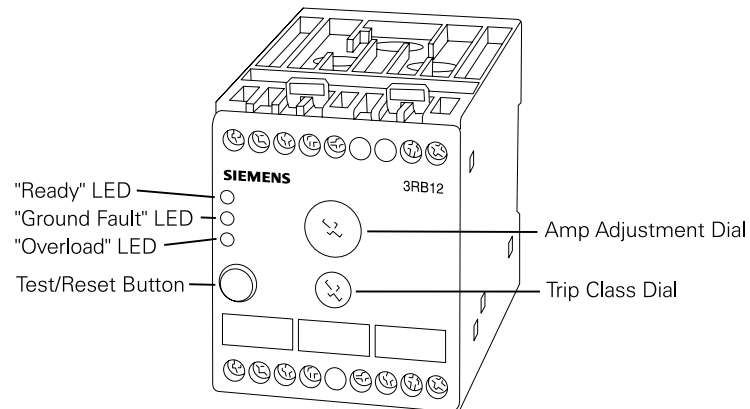
**Siemens 3RB10
Electronic Overload Relay**

The Siemens SIRIUS 3RB10 is an electronic overload relay with a design very similar to the ESP 100. The unit comes with a Class 10 or Class 20 trip. The 3RB10 features manual or automatic reset, adjustable current settings, and ambient compensation. A switch-position indicator also incorporates a test function which is used to simulate a tripped overload relay. A normally open and a normally closed auxiliary contact are included.



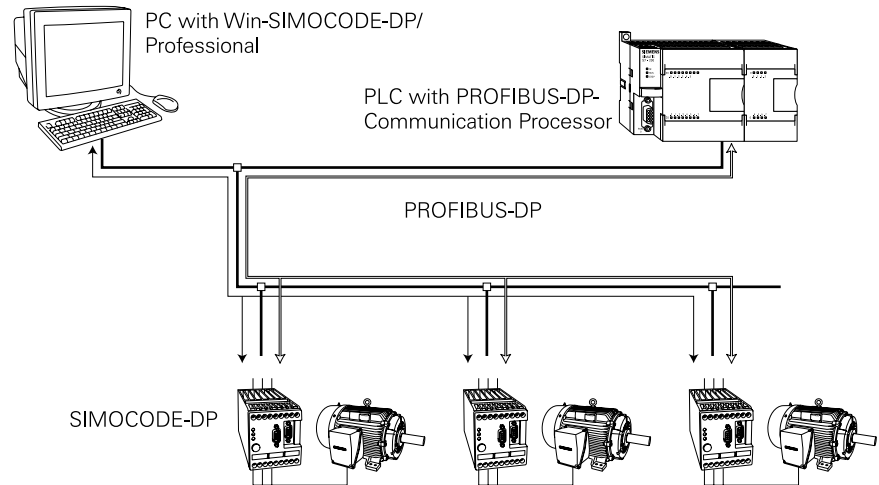
**Siemens 3RB12
Electronic Overload Relay**

In addition to heaterless construction and phase loss protection, the 3RB12 offers ground fault protection, phase unbalance, LED displays (ready, ground fault, and overload), automatic reset with remote capability, and selectable trip classes (5, 10, 15, 20, 25, or 30). The 3RB12 is self-monitoring and is provided with 2 normally open and 2 normally closed isolated auxiliary contacts.



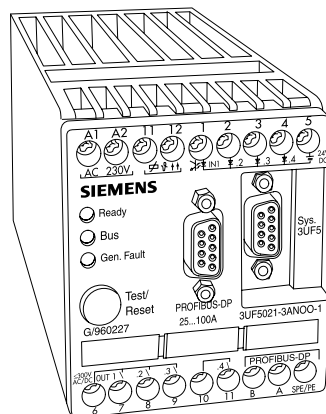
PROFIBUS DP

In any complex process the need for rapid information flow is critical. PROFIBUS DP is an open communication system based upon international standards developed through industry associations. PROFIBUS DP allows the connection of several field devices, such as SIMOCODE-DP, on a single bus for communication to a PLC or computer. PROFIBUS DP is suitable as a replacement for costly parallel wiring.



3UF5 SIMOCODE-DP

The 3UF5 SIMOCODE-DP overload relay integrates with PROFIBUS-DP. SIMOCODE-DP protects the load against overload, phase failure, ground fault, and current imbalance. SIMOCODE-DP can be parametrized, controlled, observed, and tested from a central source such as a PC with Win-SIMOCODE-DP/Professional installed, or a PLC with a PROFIBUS-DP communication processor. The 3UF50 basic unit can also be used as an autonomous solid-state overload relay for motor protection. A trip class in six steps from Class 5 to Class 30 can be selected. The basic unit (shown) is supplied with four inputs and four outputs. An available expansion unit provides eight additional inputs and four additional outputs.

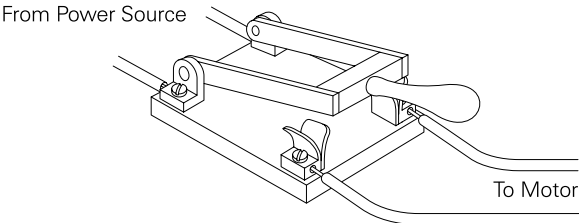


Review 3

1. With an increase in current, heat will _____ .
 - a. increase
 - b. decrease
 - c. remain the same
2. The *National Electrical Code*® defines overcurrent as *any current in _____ of the rated current of equipment or the ampacity of a conductor.*
3. An _____ occurs when electrical equipment is required to work harder than it is rated.
4. A Class _____ overload relay will trip an overloaded motor offline within 10 seconds at six times full-load amps.
 - a. 10
 - b. 20
 - c. 30
5. A _____ strip uses two dissimilar metals bonded together.

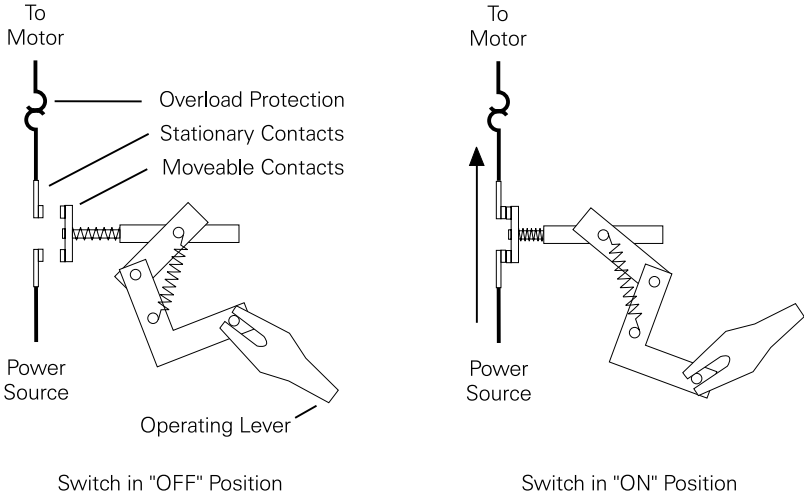
Manual Control

Manual control, as the name implies, are devices operated by hand. A simple knife switch, like the one shown in the following illustration, was the first manual-control device used to start and stop motors. The knife switch was eventually replaced with improved control designs, such as manual and magnetic starters.



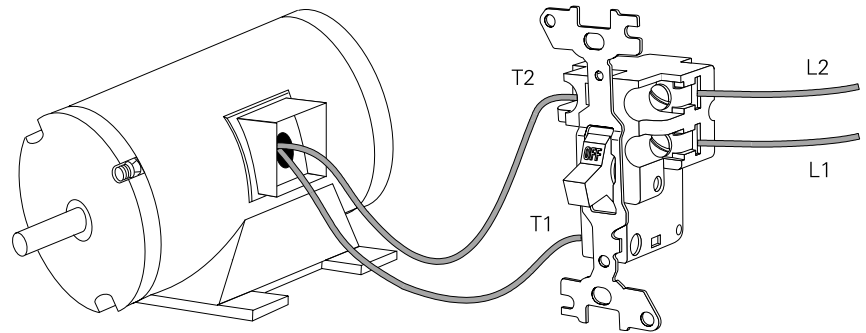
Basic Operation

The *National Electrical Code*® requires that a motor control device must also protect the motor from destroying itself under overload conditions. Manual starters, therefore, consist of a manual contactor, such as a simple switch mechanism, and a device for overload protection. The following diagram illustrates a single-pole manual motor starter. Each set of contacts is called a pole. A starter with two sets of contacts would be called a two-pole starter.

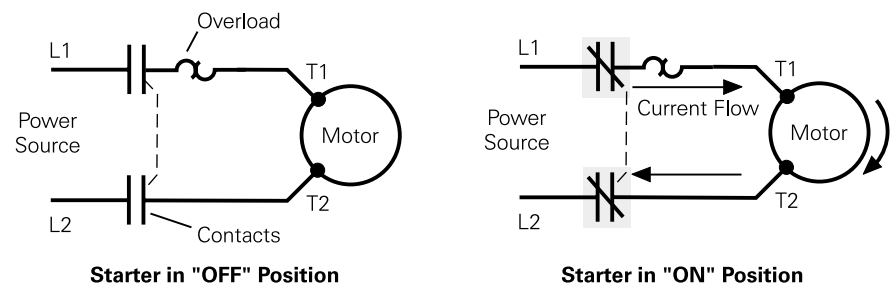


Two-Pole Manual Starter

Starters are connected between the power source and the load. For example, a two-pole or single-phase motor starter is connected to a motor. When the switch is in the "OFF" position, the contacts are open preventing current flow to the motor from the power source. When the switch is in the "ON" position, the contacts are closed and current flows from the power source (L1), through the motor, returning to the power source (L2).



This is represented with a line drawing and symbols as illustrated in the following drawing.

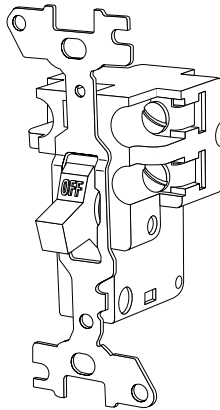


Low Voltage Protection

Some manual motor starters offer low-voltage protection (LVP) as an option. LVP will automatically remove power from the motor when incoming power drops or is interrupted. The starter must be manually reset when power is restored. This protects personnel from potential injury caused by machinery that may otherwise automatically restart when power is restored.

SMF Fractional-Horsepower Manual Starters

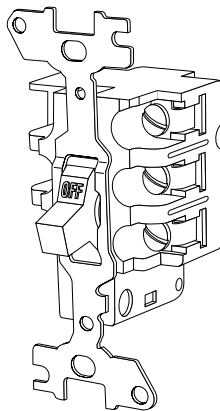
Siemens SMF fractional-horsepower starters provide overload protection and manual "ON/OFF" control for small motors. SMF starters are available in one- or two-pole versions suitable for AC motors up to 1 HP and 277 VAC. The two-pole version is suitable for DC motors up to 3/4 HP and 230 VDC. SMF manual starters are available in a variety of enclosures. A two-speed version is available.



Two-Pole Manual Starter

MMS and MRS Manual Switches

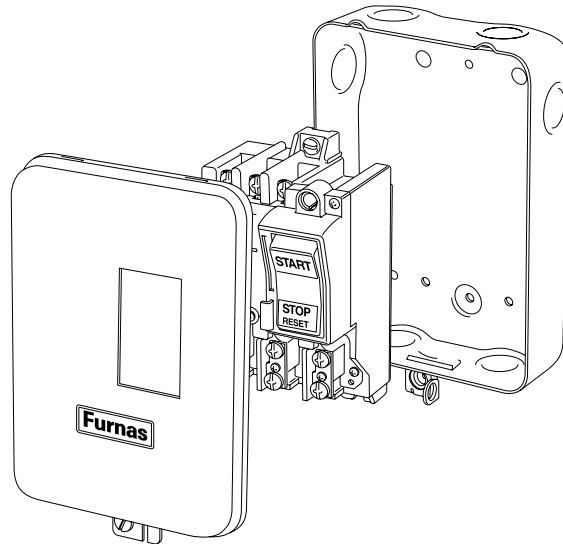
Siemens MMS and MRS manual switches are similar to SMF starters but do not provide overload protection. MMS and MRS switches only provide manual "ON/OFF" control of single- or three-phase AC motors where overload protection is provided separately. These devices are suitable for use with three-phase AC motors up to 10 HP and 600 VAC and up to 1-1/2 HP and 230 VDC. The MMS and MRS manual switches are available in various enclosures. Two-speed and reversing versions are available.



Three-Pole Manual Switch

Furnas Class 11 Manual Starter and Manual Contactor

Furnas Class 11 manual starters use a melting-alloy overload relay with interchangeable heater elements and a manual reset. It has a maximum rating of 10 HP at 460 VAC (3Ø) and 5 HP at 230 VAC (1Ø). Class 11 manual starters are available in a complete line of general-purpose and industrial-duty enclosures. Class 11 manual starters may also be furnished with a low-voltage protection circuit. Class 11 manual contactors provide no overload protection.

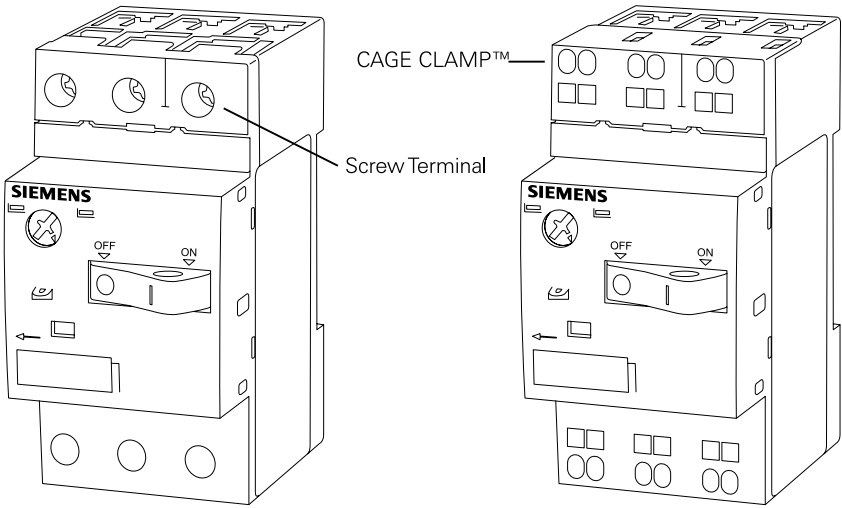


3RV10 Motor Starter Protectors

3RV10 motor starter protectors (MSPs) are part of the Siemens SIRIUS 3R motor control product line. A thermal overload with a bimetal strip is used to provide overload protection with the 3RV10 motor starter protector. 3RV10 MSPs come in four frame sizes: 3RV101, 3RV102, 3RV103, and 3RV104.

Frame	Max Current at 460 VAC	Max HP at 460 VAC
3RV101	12 Amps	7.5
3RV102	25 Amps	20
3RV103	50 Amps	40
3RV104	100 Amps	75

The 3RV101 is available in both screw-terminal and CAGE CLAMP™ versions. The 3RV102, 3RV103, and 3RV104 are available with screw terminals.

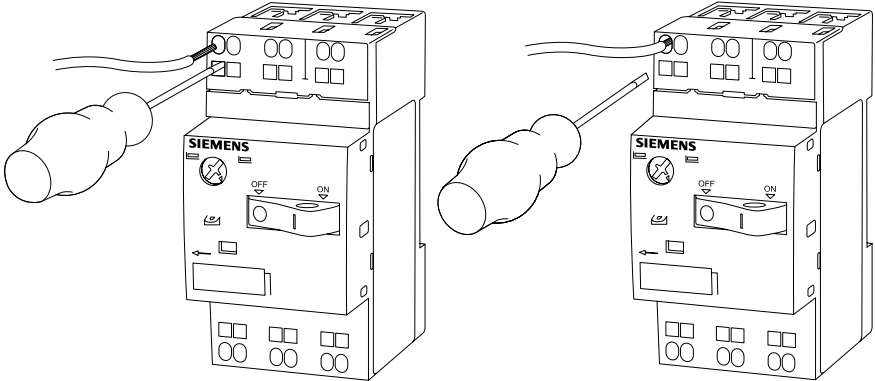


3RV101 with Screw Terminal

3RV101 with Cage Clamp

CAGE CLAMP™

The CAGE CLAMP™ is available on many Siemens SIRIUS 3R products including the MSPs. To connect a wire, simply push an electrician blade screwdriver into the appropriate portal, insert the stripped end of the wire into the portal directly above, remove the screwdriver, and the wire is securely connected. CAGE CLAMP™ devices are especially beneficial in installations that are subject to vibration.

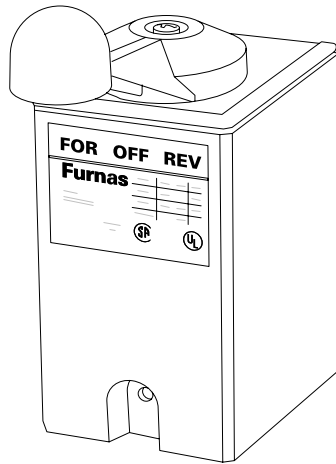


Enclosures and Options

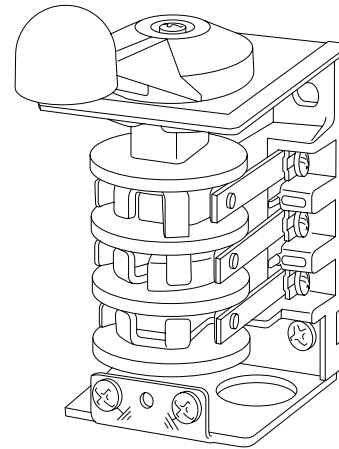
Siemens 3RV10 MSPs are available in a variety of enclosures. Several options, such as indicator lights, are also available.

Reversing Drum Controller

Manually operated drum controllers, like the Furnas Class 58 reversing drum controller, stop and change direction of reversible AC motors. Overload protection is not provided by the reversing drum controller and must be supplied by an external means. The Furnas Class 58 reversing drum controller is rated for 10 HP at 460 VAC. Another style of drum switch is used to change speed of multi-speed motors.



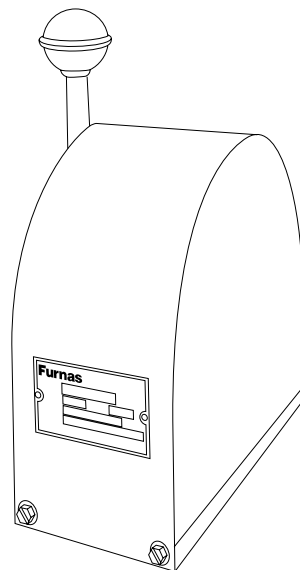
Reversing Drum Controller



**Reversing Drum Controller
With Cover Removed**

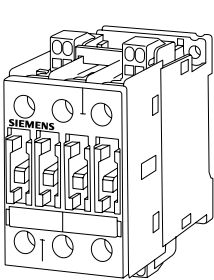
Master Switch

The Furnas Class 53 master switches provide single-handle control of hoists, cranes, oven pushers, and other equipment requiring speed steps of wound rotor or direct-current motors. Master switches are available with momentary or maintained contacts and up to five speed settings.

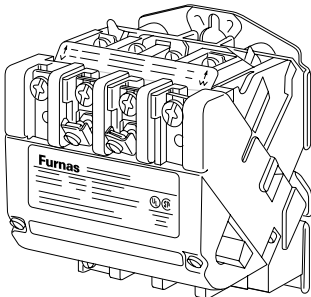


Magnetic Contactors and Starters

Most motor applications require the use of remote control devices to start and stop the motor. Magnetic contactors, similar to the ones shown below, are commonly used to provide this function. Contactors are also used to control distribution of power in lighting and heating circuits.



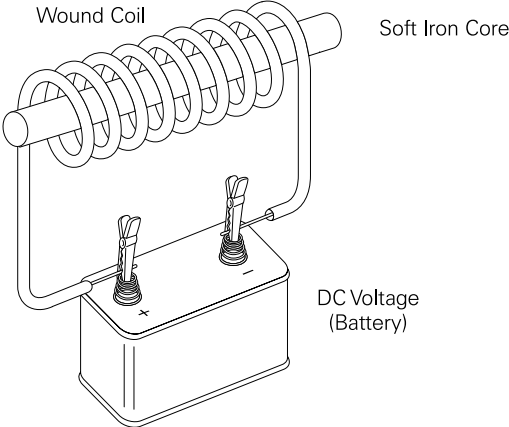
Sirius 3R



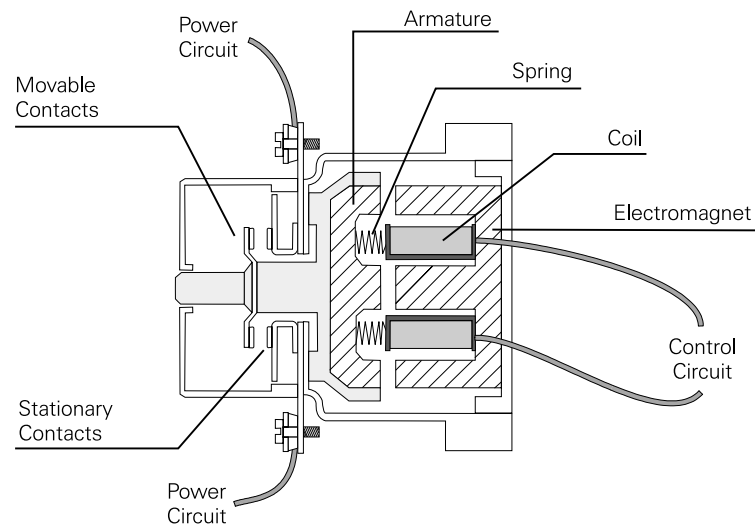
INNOVA Series

Basic Contactor Operation

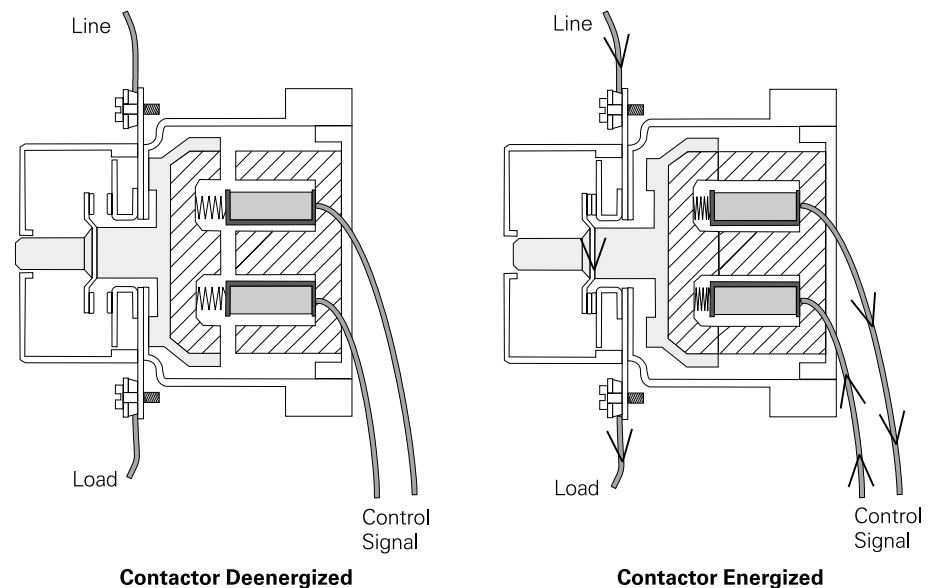
Magnetic contactors operate utilizing electromagnetic principles. A simple electromagnet can be fashioned by winding a wire around a soft iron core. When a DC voltage is applied to the wire, the iron becomes magnetic. When the DC voltage is removed from the wire, the iron returns to its nonmagnetic state. This principle is used to operate magnetic contactors.



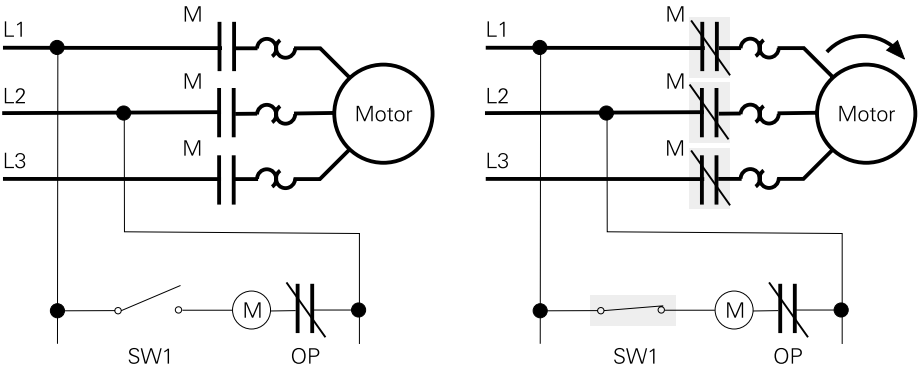
The following illustration shows the interior of a basic contactor. There are two circuits involved in the operation of a contactor: the control circuit and the power circuit. The control circuit is connected to the coil of an electromagnet, and the power circuit is connected to the stationary contacts.



The operation of this electromagnet is similar to the operation of the electromagnet we made by wrapping wire around a soft iron core. When power is supplied to the coil from the control circuit, a magnetic field is produced magnetizing the electromagnet. The magnetic field attracts the armature to the magnet, which in turn closes the contacts. With the contacts closed, current flows through the power circuit from the line to the load. When the electromagnet's coil is deenergized, the magnetic field collapses and the movable contacts open under spring pressure. Current no longer flows through the power circuit.

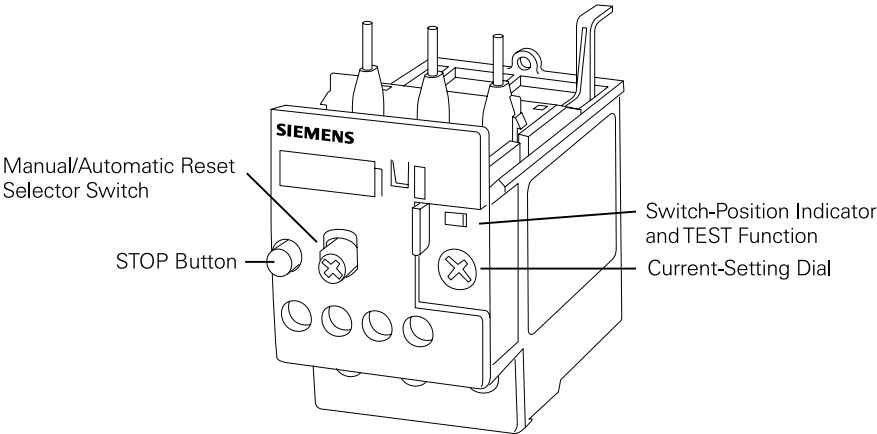


The following schematic shows the electromagnetic coil of a contactor connected to the control circuit through a switch (SW1). The contacts of the contactor are connected in the power circuit to the AC line and a three-phase motor. When SW1 is closed, the electromagnetic coil is energized, closing the "M" contacts and applying power to the motor. Opening SW1 deenergizes the coil and the "M" contacts open, removing power from the motor.



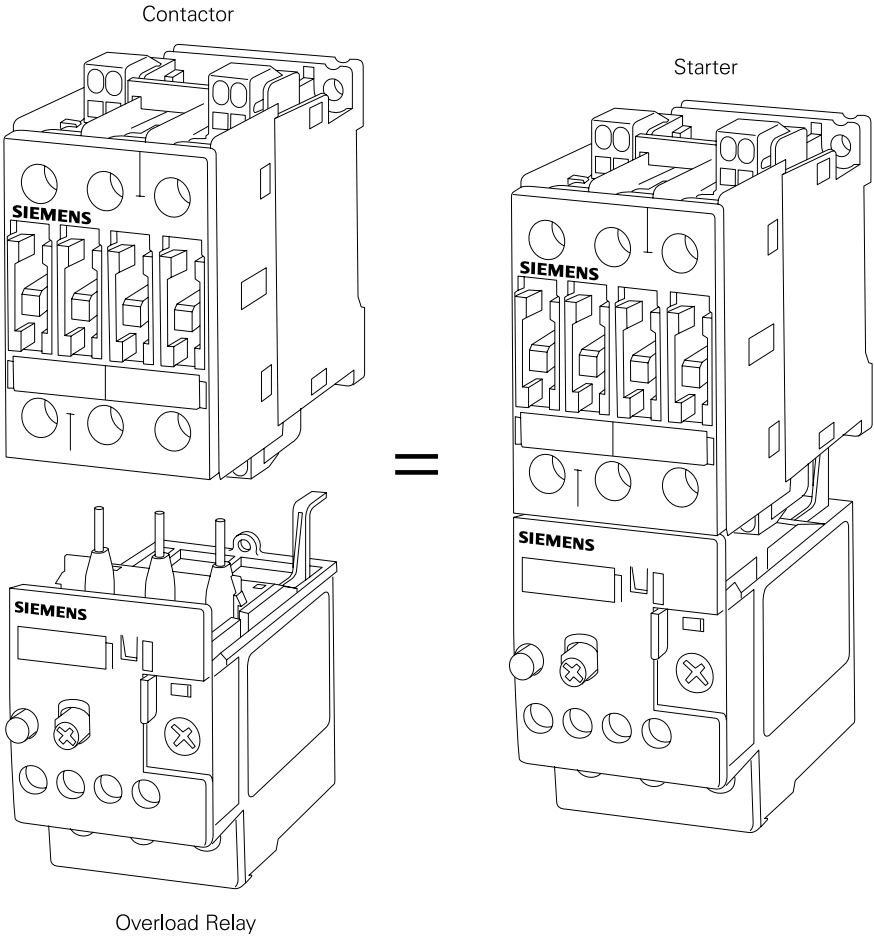
Overload Relay

Contactors are used to control power in a variety of applications. When applied in motor-control applications, contactors can only start and stop motors. Contactors cannot sense when the motor is being loaded beyond its rated conditions. They provide no overload protection. Most motor applications require overload protection. However, some smaller-rated motors have overload protection built into the motor (such as a household garbage disposal). Overload relays, similar to the one shown below, provide this protection. The operating principle, using heaters and bimetal strips, is similar to the overloads discussed previously.



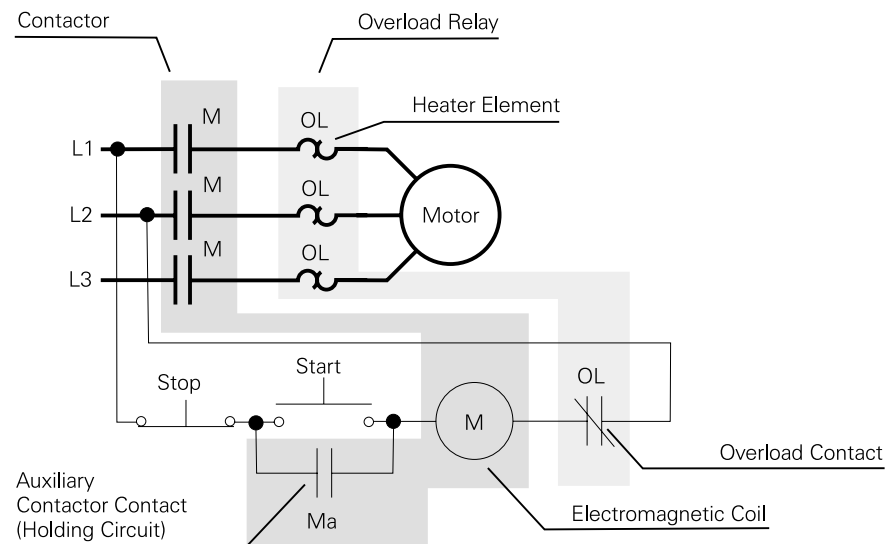
Motor Starter

Contactors and overload relays are separate control devices. When a contactor is combined with an overload relay, it is called a motor starter.



Motor Starter in a Control Circuit

The following diagram shows the electrical relationship of the contactor and overload relay. The contactor, highlighted with the darker grey, includes the electromagnetic coil, the main motor contacts, and the auxiliary contacts. The overload relay, highlighted by the lighter grey, includes the "OL" heaters and overload contacts. The contactor and the overload relay have additional contacts, referred to as auxiliary contacts, for use in the control circuit. In this circuit a normally closed "OL" contact has been placed in series with the "M" contactor coil and L2. A normally open "M" auxiliary contact ("Ma") has been placed in parallel with the "Start" pushbutton.



Review 4

1. A starter with two sets of contacts would be called a _____-pole starter.
2. _____ will automatically disconnect power from the motor when incoming power drops or is interrupted.
3. The Furnas Class 11 motor starter protects motors up to _____ HP at 460 VAC and _____ HP at 230 VAC.
4. The 3RV102 motor starter protector protects motors up to _____ HP at 460 VAC.
5. When a contactor is combined with an overload relay, it is called a _____ .