Welcome to Module 8, covering molded case circuit breakers. In previous modules, you have learned about the fundamentals of circuit breakers (Module 5), medium voltage power circuit breakers (Module 6), and low voltage power circuit breakers (Module 7, 7+). In this module, we will specifically cover molded case circuit breakers (MCCBs): where they are used, their components and accessories.

This module is intended to be a continuation of the study of circuit breakers. You should have a good understanding of the concepts discussed in Module 5. Since various terms and phrases will be used in this module without providing further explanation, you might wish to review Module 5 before proceeding.

FIGURE 1: TYPICAL COLLECTION OF INDUSTRIAL AND MINIATURE MOLDED CASE CIRCUIT BREAKERS

Like the other modules in this series, this one presents small, manageable sections of new material followed by a series of questions about that material. Study the material carefully then answer the questions without referring back to what you’ve just read. You are the best judge of how well you grasp the material. Review the material as often as you think necessary. The most important thing is establishing a solid foundation to build on as you move from topic to topic and module to module.

A Note on Font Styles

Key points are in bold.

Glossary items are italicized the first time they appear.

Viewing the Glossary

You may view definitions of glossary items by clicking on terms and words that are underlined and italicized in the text. You may also browse the Glossary by clicking on the Glossary bookmark in the left-hand margin.
## WHAT YOU WILL LEARN

We'll **step through each of these topics** in detail:

<table>
<thead>
<tr>
<th>Section Title</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overview</td>
<td>3</td>
</tr>
<tr>
<td>What Are Molded Case Circuit Breakers?</td>
<td>3</td>
</tr>
<tr>
<td>Circuit Breaker Components</td>
<td>4</td>
</tr>
<tr>
<td>Frame</td>
<td>4</td>
</tr>
<tr>
<td>Operating Mechanism</td>
<td>5</td>
</tr>
<tr>
<td>Arc Extinguisher</td>
<td>5</td>
</tr>
<tr>
<td>Trip Unit</td>
<td>6</td>
</tr>
<tr>
<td>Review 1</td>
<td>8</td>
</tr>
<tr>
<td>Ratings and Environment</td>
<td>9</td>
</tr>
<tr>
<td>Ratings</td>
<td>9</td>
</tr>
<tr>
<td>Environment</td>
<td>10</td>
</tr>
<tr>
<td>Review 2</td>
<td>12</td>
</tr>
<tr>
<td>Motor Circuit Protectors</td>
<td>13</td>
</tr>
<tr>
<td>Fuse vs. Circuit Breaker</td>
<td>13</td>
</tr>
<tr>
<td>Components</td>
<td>14</td>
</tr>
<tr>
<td>How It Operates</td>
<td>15</td>
</tr>
<tr>
<td>Applications</td>
<td>16</td>
</tr>
<tr>
<td>Review 3</td>
<td>17</td>
</tr>
<tr>
<td>Accessories and Modifications</td>
<td>18</td>
</tr>
<tr>
<td>Operational Devices</td>
<td>18</td>
</tr>
<tr>
<td>Termination Devices</td>
<td>20</td>
</tr>
<tr>
<td>Review 4</td>
<td>25</td>
</tr>
<tr>
<td>Handle Operating Devices</td>
<td>26</td>
</tr>
<tr>
<td>Lock and Interlock Devices</td>
<td>28</td>
</tr>
<tr>
<td>Miscellaneous Devices</td>
<td>30</td>
</tr>
<tr>
<td>Mounting and Enclosures</td>
<td>31</td>
</tr>
<tr>
<td>Helping the Customer</td>
<td>33</td>
</tr>
<tr>
<td>Protecting Non-Motor Circuits</td>
<td>33</td>
</tr>
<tr>
<td>Protecting Motor Circuits</td>
<td>33</td>
</tr>
<tr>
<td>Review 5</td>
<td>34</td>
</tr>
<tr>
<td>Glossary</td>
<td>35</td>
</tr>
<tr>
<td>Review Answers</td>
<td>37</td>
</tr>
</tbody>
</table>
In Module 5, Fundamentals of Circuit Breakers, the definitions of a circuit breaker were given as follows:

- **NEMA** Definition – A circuit breaker is defined in NEMA standards as a device designed to open and close a circuit by non-automatic means, and to open the circuit automatically on a predetermined overcurrent, without injury to itself when properly applied within its rating.

- **ANSI** Definition – A circuit breaker is defined in ANSI standards as a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions, and also making and carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit.

The molded case circuit breaker is one of the two basic low voltage classes of circuit breakers. The other class is the low voltage power circuit breaker, which is covered in modules 7 and 7+.

**What Are Molded Case Circuit Breakers?**

Molded case circuit breakers are tested and rated according to the UL 489 Standard. Their current carrying parts, mechanisms and trip devices are completely contained within a molded case of insulating material. MCCBs are available in various frame sizes with various interrupting ratings for each frame size.

Molded case circuit breakers are designed to provide circuit protection for low voltage distribution systems. They protect connected devices against overloads and/or short circuits. They are used primarily in panelboards and switchboards where they are fixed mounted. Some of the larger MCCBs are available in drawout mount design.

Molded case circuit breakers are available with special features making them suitable for the protection of motor circuits when used in conjunction with a separate overload protection device. In these applications, they are often referred to as motor circuit protectors (MCPs).
Although there are many types of molded case circuit breakers manufactured, all are made up of five main components. These are:

- Molded Case or Frame
- Operating Mechanism
- Arc Extinguishers
- Contacts
- Trip Units

The function of the frame is to provide an insulated housing to mount all of the circuit breaker components. The frame is often of a glass-polyester material or thermoset composite resin that combines ruggedness and high dielectric strength in a compact design. The frame is also known as a molded case.

A frame designation is assigned for each different type and size of molded case. This designation is used to describe the breaker’s characteristics such as maximum voltage and current ratings. However, each manufacturer has their own identification system to account for the differences between breaker characteristics.
The **operating mechanism** is the means to open and close the contacts. The speed with which the contacts open or close is independent of how fast the handle is moved. This is known as **quick-make, quick-break**. The breaker cannot be prevented from tripping by holding the handle in the ON position. This is known as **trip-free**. The handle position indicates the status of the contacts — closed, open or tripped. When the contacts are in the tripped position, the handle is in a midway position.

**To restore service after the breaker trips, the handle must be moved first to the OFF position from its center tripped position.** Then the handle must be moved to the ON position. When breakers are mounted in a group, as in a panelboard, the distinct handle position clearly indicates the faulted circuit. Some breaker designs also incorporate a push-to-trip mechanism. This allows a manual means to trip the breaker and test the mechanism.

**Arc Extinguisher**  Whenever a circuit breaker interrupts current flow, an arc is created. The **function of the arc extinguisher is to confine and divide that arc, thereby extinguishing it**. Each arc extinguisher is made up of a stack of steel plates held together by two insulator plates. When an interruption occurs and the contacts separate, the current flow through the ionized region of the contacts induces a magnetic field around the arc and the arc extinguisher. (Module 5, “Fundamentals of Circuit Breakers,” covers this topic in detail.)

The lines of magnetic flux created around the arc and its force drives the arc into the steel plates. The gas goes through **deionization** and the arc divides, allowing it to cool.

Standard molded case circuit breakers use a linear current flow through the contacts. Under short circuit conditions, a small blow-apart force is created, which helps open the contacts. The majority of the opening action comes from mechanical energy stored in the trip mechanism itself. This is because the current in both contacts are going in the same direction and attract each other.

**FIGURE 3: ARC EXTINGUISHER IN OPERATION**

**FIGURE 4: LINEAR AND REVERSE LOOP CONTACTS**
MOLDED CASE CIRCUIT BREAKERS

Arc Extinguisher (continued)

Newer design breakers use a reverse loop of current flowing in essentially opposite paths. This creates a repulsion action and results in a greater blow-apart force. This force assists with rapid arc extinguishing by causing the contact to open faster. The force is directly proportional to the size of the **fault current**. The greater the fault, the greater the force, and the faster the contacts open.

Trip Unit

The **trip unit** is the brains of the circuit breaker. The function of the trip unit is to trip the operating mechanism in the event of a short circuit or a prolonged overload of current. Traditional molded case circuit breakers use electromechanical (thermal magnetic) trip units (Module 5 covers this in more detail). Protection is provided by combining a temperature sensitive device with a current sensitive electromagnetic device, both of which act mechanically on the trip mechanism. Electronic trip units are now available and they can provide much more sophisticated protection and monitoring.

Most molded case circuit breakers utilize one or more different trip elements to provide circuit protection for different applications. These trip elements protect against thermal overloads, short circuits and arcing ground faults.

Conventional MCCBs are available with either a **fixed** or **interchangeable electromechanical trip unit**. If a new trip rating is required for a **fixed trip** breaker, the entire breaker must be replaced. With an **interchangeable trip unit**, as its name implies, only the trip unit needs to be changed, up to the maximum current rating of the breaker frame. Interchangeable trip units are also called **rating plugs**. Some breakers offer interchangeability between electromechanical and electronic trip units within the same frame.

**To provide short circuit protection, electromechanical trip circuit breakers have adjustable magnetic elements.**

**To provide overload protection, electromechanical trip circuit breakers contain thermal trip elements.** Breakers using the combination of magnetic elements and thermal elements are often called thermal magnetic breakers.

Increasingly, molded case circuit breakers with conventional thermal magnetic trip units are being replaced by breakers with electronic trip units. These units provide increased accuracy and repeatability. Some units have built-in ground fault protection, removing the need for separate ground fault relays and **shunt trips**. Some units can also provide **system monitoring, data gathering and communication to energy management systems**.
In general, electronic trip systems are composed of three components:

- A current transformer (sensor) is used on each phase to monitor the current. It also reduces the current to the proper level for input to a printed circuit board.

- Electronic circuitry (printed circuit board) that interprets the input and makes a decision based on predetermined values. A decision to trip results in sending an output to the next component.

- A low power flux-transfer internal shunt trip that trips the breaker. This is typically a mechanical, spring loaded device held in place by a permanent magnet.

When a tripping signal is received from the electronic circuitry, the effects of the permanent magnet are momentarily counteracted by the tripping pulse, allowing the mechanical tripping action to take place. There is no need for an external source of tripping power, since the entire tripping system has very low power requirements.
MOLDED CASE CIRCUIT BREAKERS

REVIEW 1

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you’ve already read.

1. Molded case circuit breakers have their current carrying parts, mechanisms and trip devices completely contained within a molded case of insulating material.

   TRUE  FALSE

2. When the speed with which contacts open or close is independent of how fast the handle is moved, it is known as ____________, ______________.

3. To restore service after the breaker trips, the handle must first be moved to the full OFF position.

   TRUE  FALSE

4. The function of the arc extinguisher is to ___________ and ________ the arc.

5. To provide short circuit protection, electromechanical trip circuit breakers have ________________.

6. To provide overload protection, electromechanical trip circuit breakers have ________________.

7. Some electronic trip MCCBs can provide system monitoring, data gathering and ground fault protection.

   TRUE  FALSE
When selecting the proper circuit breaker for an application, the ratings and environment need to be considered.

The voltage rating of a circuit breaker is determined by the maximum voltage that can be applied across the terminals, the type of distribution system and how the breaker is being applied in the system.

The voltage system of 480Y/277V is the most common found in commercial and institutional buildings. It has a solidly grounded neutral. This system is also very prevalent in industrial plants and some high-rise residential buildings.

When a breaker is applied in a panelboard, it is important that it have the lowest possible voltage rating that will do the job and meet the specifications. It can save the customer a lot of money if the breaker is wisely chosen.

A 2-pole, 480/277V breaker can be used on this system because it is a three-phase, 4-wire, grounded system. The maximum line to ground voltage is 277 volts across one pole of the breaker.

That is not the case in a three-phase, 3-wire Delta system.

Here, a fault condition could occur that would allow the breaker to see the full 480V across one pole. UL requires that each pole of the breaker be rated to interrupt this full 480V.

The continuous current rating of a molded case circuit breaker is the amount of current it is designed to carry in open air. The breaker has a specific ampere rating and is ambient compensated. Most manufacturers calibrate their breakers for a 40°C (107°F) ambient. The National Electric Code (NEC) allows a breaker to be applied to a maximum of 80% of the breaker’s continuous current rating. Some manufacturers offer breakers that can be used at 100% if they are specifically designed and tested for such use. They must also specify the minimum size enclosure, ventilation needs and conductor size for the application.
The interrupt rating of a molded case circuit breaker is the amount of fault current it can safely interrupt without damaging itself. The interrupt rating must be equal to or greater than the amount of fault current available at the point in the system where the breaker is applied. The interrupt rating always decreases as the voltage increases. The interrupt rating is one of the most critical factors in the breaker selection process.

Most molded case circuit breakers retain the same tripping characteristics whether they are applied to a 50 Hz or 60 Hz system. On higher frequency systems, the breaker may need to be specially calibrated or derated. A molded case circuit breaker that has a thermal magnetic trip unit might not have the same thermal or magnetic performance at a higher frequency than 60 Hz. MCCBs with electronic trip units require special derating factors and cables or bus at higher frequencies.

The number of poles of a molded case circuit breaker is determined by the type of distribution system in which it is applied. Except in certain special applications, each hot conductor is considered a pole. For single-phase applications with a grounded neutral, a single-pole breaker can be used. Two-pole and three-pole breakers are used in three-phase systems.

FIGURE 8: TWO- AND THREE-POLE BREAKERS

Environment

Thermal magnetic breakers can be affected by large differences in the ambient temperature. At ambient temperatures below 40°C, the breaker carries more current than its continuous current rating. The mechanical operation of the breaker could be affected if the temperature is significantly below the 40°C standard. The breakers will carry less current than their continuous rating if the temperature is above 40°C, and could cause nuisance tripping. It could also cause unacceptable temperature conditions at the terminals of the breaker.
Electronic trip circuit breakers often have a wider temperature range (-20° – 55°C) and so are less susceptible to ambient temperature fluctuations. At very low temperatures, the mechanical parts of the trip unit could require special lubrication. At very high temperatures, the electronic circuitry components could be damaged. Some MCCBs with electronic trip units have special self-protection circuitry to trip, should the internal temperature rise to an unsafe level.

An atmosphere that has a high moisture content or the presence of corrosive elements should be avoided. Electrical equipment should be mounted in clean, dry environments. When moist conditions cannot be avoided, special fungus treatments may be needed. While the glass-polyester molded cases may not support the growth of fungus, terminals and other parts may. If changes in temperature create condensation, space heaters in the enclosures may be required.

Because the air is thinner at high altitude, it reduces the cooling and dielectric characteristics from those of denser air found at lower altitudes. Circuit breakers must be derated for voltage, current and interrupting ratings at altitudes above 6000 feet.

Special shock resistant breakers must be used for installations subject to high mechanical shock. Special installed anti-shock devices hold the trip bar latched under shock conditions, but don’t inhibit the proper functioning of the breaker for short circuits or overload conditions.

A large steel manufacturer was experiencing a lot of nuisance tripping of circuit breakers located near the smelting side of their factory.

Upon investigation, it was determined the circuit breakers had thermal magnetic trip units. The ambient temperature at that end of the factory was often around 110°F (43°C), particularly in the summer. The thermal magnetic breakers were only rated for 104°F (40°C).

The solution? They changed to breakers with electronic trip units that had a wider temperature range (up to 131°F/55°C) which easily handled the ambient heat, even on the hottest summer day.
MOLDED CASE CIRCUIT BREAKERS

REVIEW 2

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you’ve already read.

1. The voltage rating of a circuit breaker is the minimum voltage that can be applied across its terminals.

   TRUE    FALSE

2. The continuous current rating is the amount of current it is designed to carry in open air.

   TRUE    FALSE

3. The NEC allows a breaker to be applied to a maximum of ________% of its continuous current rating.

4. The interrupt rating of a breaker is the amount of fault current it can safely interrupt without damaging itself. TRUE    FALSE

5. For systems with higher than 60 Hz frequencies, the breaker may need to be specially calibrated or ________________.

6. The number of poles for a circuit breaker is determined by ________________________________.

7. Circuit breakers must be derated for voltage, current and interrupting ratings at altitudes above _________ feet.
Since special considerations need to be taken when using circuit breakers with motors, we will dedicate this section on their particular characteristics and applications.

Most faults on a motor circuit are caused by a breakdown of the insulation within the motor windings. The initial fault current is usually low when compared to the overall system capacity. However, because it causes an arcing condition, it could cascade and short out more and more of the motor windings. If the fault is allowed to continue, serious motor and starter damages occur, increasing repair costs. While fusible switches and thermal magnetic breakers can provide motor branch circuit protection, the level of protection is not as effective against this type of fault.

For this reason, the motor circuit protector was developed. A motor circuit protector (MCP) operates on a magnetic only principle. It has a specially designed current sensing coil in each of its three poles to provide sensitive low level protection. It can clear a fault faster than a fusible device. It does not, however, provide overload protection for the motor. As a result, a contactor with an overload relay or motor starter must be used in conjunction with the motor circuit protector. (See Module 19 for information on contactors, overload protection and starters.)

This chart shows the typical fault clearing time of a dual element fuse on low level faults. It required from 12 to 84 cycles to clear the fault. This test was based on a 3 hp motor with an FLA of approximately 4.2A. The short circuit was 150A, or 35 times the full load current. The fusible device had a 5A dual element fuse, sized at 120% the FLA. The NEC allows fuses to be sized up to 175% of motor full load current.

When an MCP rated at 7A was used, it was able to clear the fault in less than one cycle. It was set to trip at 51A, or approximately 12 times the full load current. The MCP also did not create a single-phasing condition, whereas the dual element fuse did. The fuse cleared the fault in phase B in only 12 cycles, but did not clear it in phases A and C until 22 cycles had elapsed.

In a single-phasing condition, the current to a motor in the remaining phases increases significantly above normal. This can lead to severe equipment damage. Because the motor circuit protector cleared the fault in all three phases in less than one cycle, the motor failure did not result in starting an electrical fire.
Components

The components of motor circuit protectors are very similar to molded case circuit breakers. They are:

- Molded Case
- Operating Mechanism
- Arc Extinguishers
- Contacts
- Trip Mechanism
- External Adjusting Mechanism

FIGURE 12: MOTOR CIRCUIT PROTECTOR COMPONENTS
How It Operates

Motor circuit protectors disconnect the motor load from an electrical supply under three conditions. They are:

- When the handle is switched to OFF.
- When an automatic trip operation occurs.
- When a manual trip is initiated with a push-to-trip button.

As with the molded case circuit breakers, the operating mechanism is a spring-loaded toggle that provides quick-make, quick-break and trip-free operation.

Its design provides an increased air gap between the stationary and moveable contacts when in the tripped position. This air gap results in greater arc extinguishing during contact opening and provides higher interrupt ratings.

The magnetic trip unit operates when a fault current exceeds the magnetic pickup setting. It consists of an electromagnetic coil and plunger assembly. Certain HMCPs also have a transient inrush trip suppression device. This allows the start-up of energy efficient motors without nuisance tripping the sensitive short circuit protection of the current sensing coil.

A tuned spring introduces a time delay of approximately 8 ms into the trip sequence under normal conditions. It allows the HMCP to ignore the initial high inrush current during the first half-cycle of start-up. A true fault current would supply a magnetic force to override the spring action and provide instantaneous tripping of the device.

Larger HMCPs (600A) and above may use electronic trip units to provide an adjustable three-phase instantaneous trip setting. At start-up, an electronic time delay acts as the inrush trip suppressor. However, any current in excess of the predetermined setting level, such as with a short circuit, would override the time delay and trip the HMCP.
How It Operates
(continued)

A trip setting adjustment allows for precise motor protection. Press in on a cam and turn the arrow until it is aligned with the required trip setting shown on the nameplate.

However, in keeping with NEC requirements, they cannot be set at more than 1300% of the motor full load current rating.

Applications

Motor circuit protectors can be used in combination starter units within a motor control center. They allow for protection against both low and high level fault currents without requiring current limiters. They can also be applied in stand-alone combination starters.

When properly sized, they can provide short circuit protection for resistance welding devices. The normal high welding currents can flow, but the HMCP trips instantaneously if a short circuit develops.

HMCPs can be used in panelboards. You can have both distribution branch circuit protection and protection of the motor circuits within the same enclosure.
Answer the following questions without referring to the material just presented.
Begin the next section when you are confident that you understand what you’ve already read.

1. Most faults on a motor circuit are caused by a breakdown of the insulation within the motor windings.
   TRUE      FALSE


3. An MCP provides overload protection for the motor.
   TRUE      FALSE

4. In a single-phasing condition, current to the motor in the remaining phases increases significantly.
   TRUE      FALSE

5. The operating mechanism provides quick-make, quick break and trip-free operation.
   TRUE      FALSE

6. The NEC allows an HMCP to be adjusted to a maximum of ________% of the motor FLA rating.

7. HMCPs cannot be used in panelboards.
   TRUE      FALSE
When a comparison is made between a fusible switch and a molded case circuit breaker, it is easy to see the application flexibility MCCBs provide. This is even more apparent when you look at the array of accessories and modifications available. We are going to review in general what is available with a brief explanation of their purpose and applications. We will not cover specific accessories for specific lines of breakers in this module.

We are going to divide our review into the following categories:

- Operational Devices
- Termination Devices
- Handle Operating Devices
- Lock and Interlock Devices
- Miscellaneous Devices

**Operational Devices**

A shunt trip provides remote controlled tripping of a molded case circuit breaker. A solenoid coil is remotely energized using a pilot device, such as a pushbutton. That moves the plunger to activate the trip bar of the breaker. At the same time, a cutoff switch operates which disconnects power to the solenoid so the coil doesn’t burn out. Often, pigtail leads are supplied for connecting the shunt trip to either an AC or DC control power source.

One application for a shunt trip is for use on a welding machine. Normal thermal overload protection is not practical because of the high, frequent cycling of the machine. Often, the machine is equipped with a thermistor to provide overload protection. The Normally Open (NO) contacts of the thermistor close when it reaches a preset temperature. The thermistor is connected to a shunt trip on a magnetic only circuit breaker. The breaker provides short circuit protection, the thermistor provides the overload protection.
An undervoltage release mechanism trips the breaker whenever the voltage falls below a predetermined level. These undervoltage release mechanisms (UVRs) come in two different styles:

The handle reset UVR (standard on current breakers) consists of a continuous rated solenoid with a plunger and tripping lever. The UVR mechanism is reset by a tripping lever when normal voltage has been restored, and the circuit breaker handle is moved to the reset OFF position. With no voltage applied to the UVR, the circuit breaker contacts will not touch when a closing operation is attempted.

An automatic reset UVR (standard replacement type breakers) has a tripping lever extension for resetting during the tripping action cycle. It works like the manual reset UVR except there is no plunger to be reset. When the breaker trips, it resets the UVR mechanism.

It is important to point out, that undervoltage release mechanisms are not designed to be used as circuit interlocks.

Due to long lengths of cables from power supplies in underground mining, low voltage conditions are common. To protect personnel and equipment, the circuit breaker trips. It cannot be energized until the power has been restored to at least 85% of the coil rating on the undervoltage release mechanism.

Providing circuit breaker main contact status, an auxiliary switch is mounted in the breaker. In this diagram, the contacts are shown as “a” and “b”. An “a” contact is open when the breaker is open or tripped. A “b” contact is closed when the breaker is open or tripped. The contacts are rated 120V for pilot duty.

If you wanted to give a visual indication that a circuit is energized, you could mount an indicating light on the panel. Using an auxiliary switch with an “a” contact would allow the light to be illuminated whenever the breaker is closed. When the breaker trips, the light goes off, letting you know the breaker has tripped or been opened.
**Operational Devices (continued)**

**Auxiliary switches can be used for circuit interlocking purposes.** The NEC requires that motor control circuits be disconnected from all sources of supply when the disconnect means is in the open position. For starters with common control, one circuit breaker would disconnect the voltage for both the power circuit and the control circuit. If the control circuit has a separate power supply, the circuit breaker would not disconnect that supply source. You could use separate disconnect means, or simply use an auxiliary switch in the breaker. When the breaker is open, the auxiliary opens the control circuit, disconnecting it from its supply source.

![Diagram of Circuit Breaker and Control Components](image)

**FIGURE 18: AUXILIARY CONTACTS DISCONNECT SEPARATE CONTROL POWER SOURCE**

**Alarm switches differ from auxiliary switches in that they function only when the breaker trips automatically.** The normally open contact of the switch closes when the breaker trips due to a short circuit, an overload condition, or when operated by a shunt trip. An indicating light, buzzer or bell can be placed in the circuit to provide indication that the circuit has tripped. When the breaker is reset, the alarm switch is reset. A manual opening of the circuit breaker does not affect the alarm switch contact.

**Termination Devices**

**Line and load terminals provide the means for connecting the circuit breaker to the power source and the load.** They are sized for various continuous current capabilities and wire types. Depending on the breaker, it may be supplied factory equipped with both line and load lugs, load terminals only, or line and load terminals for field installation.
Termination Devices (continued)

The terminal body is usually made of aluminum to accommodate aluminum or copper wire or cable. Terminals with copper or steel bodies are also available. Terminals are available that support single or multiple conductors.

A keeper nut slides onto the line or load conductor and acts as a threaded adapter to accept a ring terminal or other bolt-on connector.

A plug nut is used where screw connected ring terminals are preferred to connect cables to the breaker conductors. They are press-fit into the opening in the breaker terminal conductor.
Termination Devices (continued)

Endcap kits are used to connect bus bar or similar electrical connections.

Rear connected studs are available in different sizes to accommodate specific fixed mounted breaker applications and ratings. The breakers are front removable from switchboards and other equipment by unscrewing the nut that holds the stud to the breaker. Studs must be assembled in accordance with UL required clearances.

As with the rear connected studs, plug-in adapters simplify installation and front removal of the breaker from applications such as switchboards. Tulip-type connectors and threaded studs or flat bus bars are built into the molded support block and connect to the main bus.
Termination Devices (continued)

To connect circuit breaker terminals to the panelboard bus, panelboard connecting straps can be used. Since depth and bus spacing vary depending on type of panel and manufacturer, the panelboard builder should be consulted to determine the correct strap.

FIGURE 25: PANELBOARD CONNECTING STRAPS

So far, these termination devices have been a means for connection of the circuit breaker to the power source and load. The next few items offer terminal isolation and protection.

In motor control center applications, because of confined spaces, line side conductors are often custom fitted. Terminal end covers fit together with the circuit breaker case to form terminal compartments. This allows isolation of the discharged ionizing gasses that form during the tripping operation.

FIGURE 26: TERMINAL END COVERS

To provide protection against accidental contact with live line side terminations, terminal shields fasten over the front terminal access openings.

FIGURE 27: TERMINAL SHIELD
Termination Devices (continued)

Interphase barriers are high dielectric insulating plates that fit between the terminals to provide additional electrical clearance between circuit breaker poles.

Terminal covers provide the required electrical clearance between circuit breaker poles when extended terminals are used.
Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you’ve already read.

1. A shunt trip provides remote controlled tripping of a circuit breaker.
   
   **TRUE**       **FALSE**

2. An undervoltage release mechanism trips the breaker whenever the voltage _____________________ a predetermined level.

3. Auxiliary switches can be used for circuit interlocking.
   
   **TRUE**       **FALSE**

4. __________ and __________ terminals provide the means for connecting the circuit breaker to the power source and the load.

5. Interphase barriers provide additional electrical clearance between the circuit breaker poles.
   
   **TRUE**       **FALSE**
Handle operating devices provide indirect electrical or manual operation of the circuit breaker handle.

**Electrical operators provide complete remote control of a molded case circuit breaker by means of a pushbutton or similar pilot device.** When energized from a remote location, the operator mechanism moves the circuit breaker handle to either the ON or OFF position. Shunt trips and undervoltage release mechanisms can only be used to trip the breaker. Electrical operators deliver a positive switching action. In case of a power failure, means are provided for manual operation. They come in a variety of designs and, depending on the circuit breaker type, are mounted in different ways.

The newer designs are front mounted on the breaker cover and fit within the trim line of the circuit breaker. For smaller frame breakers, a solenoid is used. On larger frame sizes, a motor is used to provide the increased operational force required to move the breaker handle.

Some designs are side mounted and use an extended arm to move the circuit breaker handle. These older motor driven operators are not usually suitable for generator synchronizing because of the time it takes for operation.

Contemporary electrical operator designs, whether solenoid or motor driven, are capable of performing a closing operation in five cycles or less. This makes them very suitable for generator synchronizing applications.
Handle mechanisms allow for the manual operation of the circuit breaker toggle handle. These mechanical devices allow personnel to open and close the breaker without opening the enclosure in which the breaker is mounted. They come in a variety of designs for different applications and enclosure types.

The flex shaft type handle mechanism is an extra heavy-duty mechanism designed for mounting in flange-type enclosures. An operating handle, flexible shaft and mechanism are required for standard application.

Handle mechanisms are often designed to indicate the status of the circuit breaker since the breaker itself is often not visible when the handle operates. Some designs allow for protection against tampering, or to tag and lockout during maintenance. The unit shown here will accept up to three padlock shackles.

Rotary handle mechanisms mechanically transfer the rotating operation to the in-line toggle operation of the circuit breaker handle. Depending on their design, they may allow mounting an auxiliary switch on the handle for undervoltage release. Some devices are available with red handles and yellow background labels to meet local codes.
Lock and interlock devices are used to deter undesired circuit breaker operation and establish interlocked control systems. They do not interfere with the trip-free operation of the molded case circuit breaker.

The nonlockable handle block secures the breaker handle in either the ON or OFF position to prevent accidental operation.

The padlockable hasp mounts on the circuit breaker cover and will allow multiple padlocks to secure the handle in either the ON or OFF position.

The cylinder lock internally blocks the breaker trip bar in the tripped position. This prevents the breaker from being switched ON. However, use of a cylinder lock may reduce the interrupting rating of the breaker.
A key interlock is used to externally lock a circuit breaker handle in the OFF position. An extended deadbolt blocks movement of the breaker handle. The key is only removable in the locked position.

To prevent adjacent breakers from being switched to the ON position, a sliding bar interlock can be used. When the sliding bar handle is moved from one side to the other, a bar extends to alternately block the breaker handle.

Along the same lines, the walking beam interlock provides mechanical interlocking between breakers of the same pole configuration. It mounts on a bracket behind and between the breakers.
Certain molded case circuit breakers can have their interrupting rating increased to 200,000A symmetrical at up to 600V. The device used for this is called a current limiting attachment. It is bolted to the load end of the circuit breaker so that it will interrupt normal fault current up to 50 or more times the breaker’s continuous rating. The limiter will only trip when a very high fault is encountered. As the limiter trips, the breaker is also tripped magnetically, preventing a single-phasing condition.

A spring loaded indicator is on each pole of the limiter to identify the faulted phase. When a current limiter trips, it is an indication of a serious circuit problem that must be corrected before restoring service. To ensure the proper limiter is used with a compatible breaker, they are always of a noninterchangeable design.

Another device designed to protect personnel and equipment is the low level earth leakage (ground fault) protector. This device usually trips the circuit breaker through a shunt trip or undervoltage release mechanism when it detects a low level ground fault.
Generally, molded case circuit breakers can be mounted in any position. Mounting them up, down, horizontal or vertical does not affect the tripping or interrupting characteristics of the breaker. However, mounting them in a vertical position with the ON position as anything other than up, is in violation of National Electric Code.

In some cases because of the physical arrangement of a panelboard or switchboard, it is necessary to reverse feed a circuit breaker. The circuit breaker must be tested and listed accordingly for this type of application. Only breakers that have fixed trips can be used, and they usually have sealed covers. They often do not have “Line” and “Load” marked on the cover, so the power source can be connected to either the line or the load terminations.

In addition to being mounted in motor control centers, switchboards and panelboards, molded case circuit breakers are mounted individually in separate enclosures. The National Electric Code and local electric codes determine the proper selection of an enclosure type for a particular application. The National Electrical Manufacturers Association (NEMA) and the International Electro-technical Commission (IEC) have set standards for the protection of devices in various environmental situations. Enclosure types are rated to withstand water, dust, oil, and other environmental conditions. NEMA assigns Type classifications to enclosures. When an enclosure is rated a particular type, it means it is made of the specified materials and has passed specific tests. IEC also has tests and standards that enclosures must conform to. They assign an IP classification.

The most common types of enclosures are:

NEMA Type 1 (Conforms to IP40) – These enclosures are designed for indoor applications. They are suitable for installations where unusual conditions do not exist, but where a measure of protection from accidental contact is required. They are commonly used in commercial buildings and apartment buildings. They are often referred to as general purpose enclosures.
NEMA Type 3R (Conforms to IP52) – These enclosures are designed for outdoor use where falling rain, sleet or external ice might form. They have a gasket on the cover to keep out water. Some versions have a top hinged front cover which must be opened to gain access to the circuit breaker handle. Other versions have an external side operated handle mechanism. These enclosures are often referred to as raintight enclosures.

NEMA Type 4 (Conforms to IP65) – These enclosures are designed for use either indoors or outdoors. They provide protection from splashing water, wind blown dust or rain. They even protect the circuit breaker from hose directed water. They are well suited for application in dairies, breweries, paper mills, food processing plants and other process industries. These enclosures are often referred to as watertight enclosures.

NEMA Type 4X (Conforms to IP65) – These are much the same as the Type 4 except that they are made of gasketed, stainless steel. In some designs, they are made of a nonmetallic material. They provide better resistance to corrosion than the Type 4. Industries that have a high amount of corrosive liquids, require a high measure of hose-down cleaning, or are in a salt-water environment use these enclosures. They are often referred to as corrosion-proof enclosures.

NEMA Type 12 (Conforms to IP62) – These enclosures are designed for indoor use in dirty and dusty applications. They are constructed of sheet metal and provide protection from dripping liquids (non-corrosive), falling dirt and dust. A special NEMA 12K version provides knockouts for conduit. These enclosures are often referred to as dust-tight enclosures.

There are other ratings of enclosure types, but these are the most commonly used.
The selection of molded case circuit breakers is generally determined in two ways:

- For protection of non-motor circuits.
- For protection of motor circuits.

We will discuss protection of non-motor circuits first.

Non-motor circuit applications usually center around cable protection and require molded case circuit breakers with both overload and short circuit capabilities. They should be able to distinguish between harmless and destructive conditions, and function appropriately for its application. It is very important that the MCCB selected be adequately rated and equipped for all the electrical and physical conditions that are likely to exist when the system is energized.

The standard selection factors for molded case circuit breakers include:

- Voltage Rating
- Frequency
- Continuous Current Rating
- Interrupting Rating
- Number of Poles
- Fixed or Interchangeable Trip Unit
- Trip Unit Functions
- Accessories

The selection of an HMCP is based on the full load current of the motor it is to protect. Data shown in the National Electric Code (tables 430-148 and 430-150) list the full load currents of induction motors running at speeds normal for belted motors and with normal torque characteristics. However, actual motor nameplate ratings should be used for selecting the motor running overload protection.

Other considerations in the selection of HMCPs include:

- The ambient temperature outside the enclosure should not exceed 40°C (104°F).
- Infrequent starting, stopping and reversing of the motor.
- Motor accelerating time of 10 seconds or less.
- Locked rotor rating is a maximum of six times the motor FLA rating.
MOLDED CASE CIRCUIT BREAKERS

REVIEW 5

1. Electrical operating devices provide complete remote control of a molded case circuit breaker.
   TRUE    FALSE

2. Handle mechanisms are often designed to _________ _________ of the circuit breaker.

3. Rotary handle mechanisms mechanically transfer the rotating operation to the in-line toggle operation of the breaker handle.
   TRUE    FALSE

4. The padlockable hasp will allow securing the circuit breaker handle only in the OFF position.
   TRUE    FALSE

5. To prevent adjacent breakers from being switched to the ON position, you can use a ________________________________.

6. A current limiting attachment can increase a circuit breaker’s interrupting rating.
   TRUE    FALSE

7. _________ and ____________ determine which type of enclosure is used for a given application.
| **GLOSSARY** | **Ambient Compensated** | An electromechanical circuit breaker whose trip element is calibrated/adjusted to perform as required in a specific surrounding temperature condition. |
| **ANSI** | Abbreviation for American National Standards Institute. It does not develop standards, but functions as a coordinating body for the purpose of encouraging development and adoption of worthwhile standards. |
| **Arcing** | The discharge of electric current across a gap between two points. It occurs between breaker contacts each time a breaker interrupts a current. |
| **Bus** | The conductor(s), usually made of copper or aluminum, which carries the current and serves as a common connection for two or more circuits. |
| **Clearing Time (Circuit Breaker)** | The total elapsed time between the time the specified overcurrent causes a release device to be actuated and the instant of final arc extinction on all poles of the primary arcing contacts. |
| **Clearing Time (Fuse)** | The total elapsed time between the beginning of the specified overcurrent and the final interruption of the circuit. It is the sum of the melting time and the arcing time. |
| **Deionization** | The process of removing conduction ions, thus permitting arc extinction. |
| **Drawout Mount** | Breaker can be moved into or out of its structure without unbolting, often on a Racking mechanism. |
| **Fault Current** | The surge of amperage created during an electrical failing. |
| **Fixed Mounted** | The breaker is bolted into a fixed position with bus or cable mechanically bolted to breaker terminations. |
| **Fixed Trip** | The trip unit of the circuit breaker is set for a specific trip rating and cannot be adjusted if a new trip rating is needed. The circuit breaker must be replaced. |
| **IEC** | International Electro-technical Commission. |
| **Interchangeable Trip Unit** | If a new trip rating is required for an application, only the trip unit needs to be replaced, up to the maximum current rating of the breaker frame. |
| **Interrupt Rating** | The maximum short circuit current that an overcurrent protective device can safely interrupt. |
### MOLDED CASE CIRCUIT BREAKERS

**IP**
Ingress Protection: protection from the entry of dust, liquid, or other material into the enclosure and/or protection of human contact with live electrical parts.

**Knockouts**
Pre-stamped holes for the insertion of conduit or conductors into an enclosure.

**Low Level Fault**
Can range in magnitude from just above full load current to 10 or more times normal current. Does not usually cause noticeable damage immediately, but can lead to eventual problems.

**Molded Case Circuit Breaker**
A circuit breakers designed to provide circuit protection for low voltage distribution systems. Used primarily in panelboards and switchboards.

**NEC**
National Electric Code — a set of electrical installation standards applicable throughout the U.S. and published by the National Fire Protection Association. The NEC works with UL requirements and usually carry mandatory compliance.

**NEMA**

**Nuisance Tripping**
An unintentional trip at below set pickup currents, usually the result of circuit conditions or equipment applications.

**Quick-Make, Quick-Break**
Speed with which contacts open or close, regardless of the speed of handle operation.

**Rating Plug**
Used to change the continuous current rating of an electronic trip unit.

**Shunt Trip**
A device used to trip a circuit breaker remotely.

**Thermistor**
A temperature-sensitive resistor that changes its electrical resistance with a change in temperature.

**Trip-Free**
Breaker cannot be prevented from tripping, even when holding the handle in the ON position.

**Trip Unit**
Device that trips the operating mechanism in the event of a short circuit or overload condition.
MOLDED CASE CIRCUIT BREAKERS

REVIEW 1
ANSWERS
1. True
2. Quick-make; quick-break
3. True
4. Confine; divide
5. Adjustable magnetic elements
6. Thermal trip elements
7. True

REVIEW 2
ANSWERS
1. False
2. True
3. 80
4. True
5. Derated
6. The distribution system in which it is applied
7. 6000

REVIEW 3
ANSWERS
1. True
2. Magnetic only
3. False
4. True
5. True
6. 1300
7. False
MOLDED CASE CIRCUIT BREAKERS

REVIEW 4 ANSWERS
1. True
2. Falls below
3. True
4. Line; load
5. True

REVIEW 5 ANSWERS
1. True
2. Indicate status
3. True
4. False
5. Sliding bar interlock
6. True
7. NEC; local electric codes