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Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Molded Case Circuit Breakers** and related products.

Upon completion of **Molded Case Circuit Breakers** you will be able to:

- Explain the need for circuit protection
- Identify various types of overcurrent protective devices
- Explain the basic electro-mechanical operation of a circuit breaker
- Identify various types of Siemens circuit breakers
- Identify circuit protection ratings for various types of Siemens circuit breakers
- Describe time-current characteristics on a time-current curve
- Explain the benefits and function of circuit breaker coordination
- Identify internal and external circuit breaker accessories
- Explain the difference between molded case circuit breakers and insulated case circuit breakers

This knowledge will help you better understand customer applications. In addition, you will be better able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** before attempting **Molded Case Circuit Breakers**. An understanding of many of the concepts covered in **Basics of Electricity** is required for **Molded Case Circuit Breakers**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

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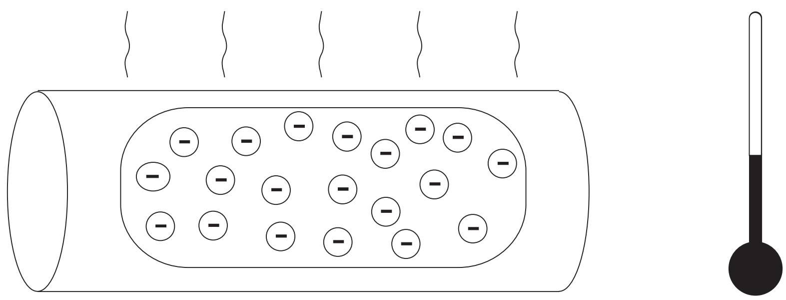
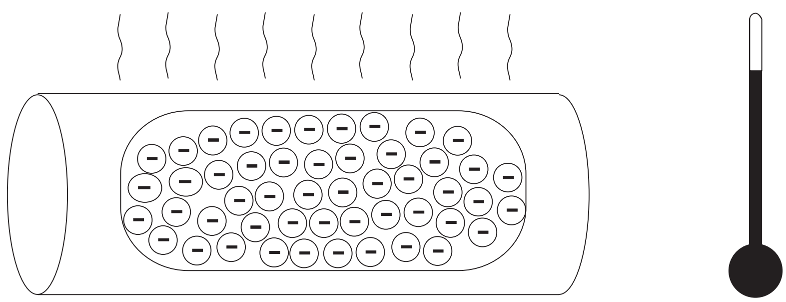
Need for Circuit Protection

Current and temperature

Current flow in a conductor always generates heat. 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, such as circuit breakers, are used to protect conductors from excessive current flow. 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.



Normal Current Flow



Excessive Current Flow

Excessive current is referred to as overcurrent. The National Electrical Code® (NEC®) 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).

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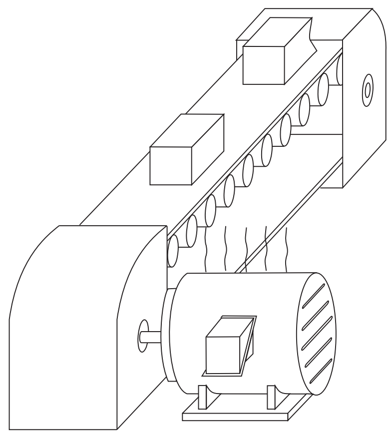
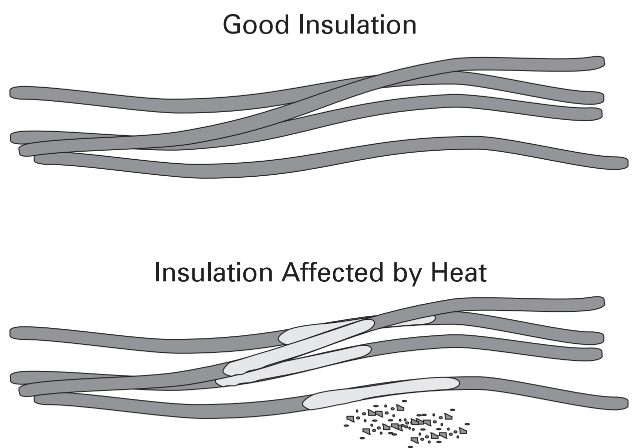
Overloads

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 amps may draw 20, 30, or more amps 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 shut down by the overcurrent protector.



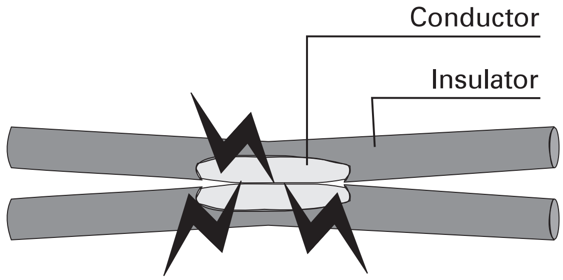
Conductor insulation

Motors, of course, are not the only devices that require circuit protection for an overload condition. Every circuit requires some form of protection against overcurrent. Heat is one of the major causes of insulation failure of any electrical component. High levels of heat can cause the insulation to breakdown and flake off, exposing conductors.



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 Ω of resistance would normally draw 10 amps of current.

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

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

$$I = 10 \ amps$$

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

$$I = \frac{240}{.024}$$

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

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.

Ampacities of insulated conductors

How hot an insulated conductor can get before it sustains damage needs to be known. As mentioned earlier, conductors are rated by how much current they can carry on a continuous basis, known as ampacity. The following illustration is from *NEC* Table 310-16. For example, a #8 American Wire Gauge (AWG) copper conductor with Type THW insulation is rated for 50 amps at 75° C . A #1 AWG copper conductor with Type THW insulation rated at 75° C can carry 130 amps. To avoid overloads and prevent insulation damage, it is necessary to keep the current from exceeding the conductor's continuous current rating.

TABLE 1-Ampacities of Insulated Conductors (From NEC Table 310-16)
Not More Than Three Insulated Conductors in Raceway
(Based on Ambient Temperatre of 30°C, 86°F)

	COPPER CONDUCTORS			
Size	60°C (140°F)	75°C (167°F)	85°C (186°F)	90°C (194°F)
AWG MCM	TYPES① RUW T TW UF	TYPES ① FEPW RH RHW RUH THW THWN XHHW USE ZW	TYPES V, MI	TYPES TA, TBS SA,AVB SIS FEP,① FEPB,① RHH,① THHN,① XHHW① ②
18	---	---	---	14
16	---	---	18	18
14	20①	20①	25	25①
12	25①	25①	30	30①
10	30	35①	40	40①
8	40	50	55	55
6	55	65	70	75
4	70	85	95	95
3	85	100	110	110
2	95	115	125	130
1	110	130	145	150
1/0	125	150	165	170
2/0	145	175	190	195
3/0	165	200	215	225
4/0	195	230	250	260

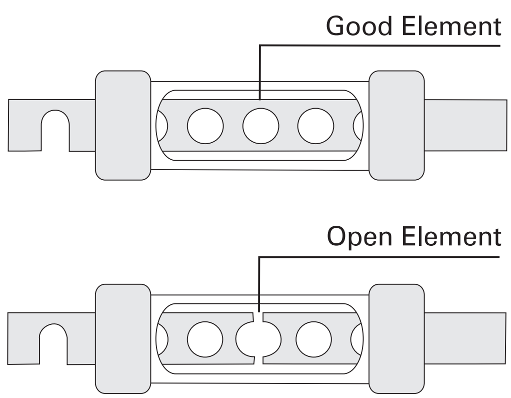
NEC Table 1 of Table 310-16 gives ampacities under two conditions: the raceway contains not more than three conductors and the ambient temperature is not more than 30° C (86° F). If either of these two conditions is exceeded, the values shown must be reduced using derating values provided by *NEC* (not shown here).

Types of Overcurrent Protective Devices

Circuit protection would be unnecessary if overloads and short circuits could be eliminated. Unfortunately, overloads and short circuits do occur. To protect a circuit against these currents, a protective device must determine when a fault condition develops and automatically disconnect the electrical equipment from the voltage source. An overcurrent protection device must be able to recognize the difference between overcurrents and short circuits and respond in the proper way. Slight overcurrents can be allowed to continue for some period of time, but as the current magnitude increases, the protection device must open faster. Short circuits must be interrupted instantly. Several devices are available to accomplish this.

Fuses

A fuse is a one-shot device. The heat produced by overcurrent causes the current carrying element to melt open, disconnecting the load from the source voltage.



Nontime-delay fuses

Nontime-delay fuses provide excellent short circuit protection. When an overcurrent occurs, heat builds up rapidly in the fuse. Nontime-delay fuses usually hold 500% of their rating for approximately one-fourth second, after which the current-carrying element melts. This means that these fuses cannot be used in motor circuits which often have inrush currents greater than 500%.

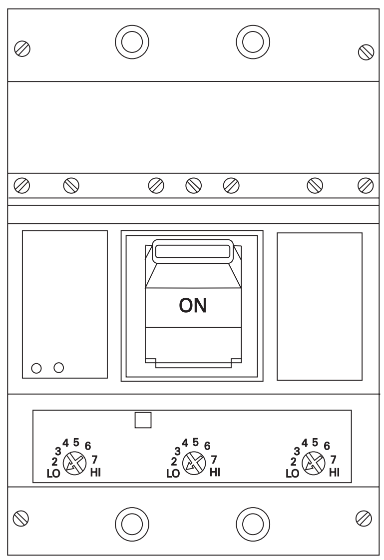
Time-delay fuses

Time-delay fuses provide overload and short circuit protection. Time-delay fuses usually allow five times the rated current for up to ten seconds to allow motors to start.

Circuit breakers

The *National Electrical Code* defines a circuit breaker as *a device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating*.

Circuit breakers provide a manual means of energizing and de-energizing a circuit. In addition, circuit breakers provide automatic overcurrent protection of a circuit. A circuit breaker allows a circuit to be reactivated quickly after a short circuit or overload is cleared. Unlike fuses which must be replaced when they open, a simple flip of the breaker's handle restores the circuit.

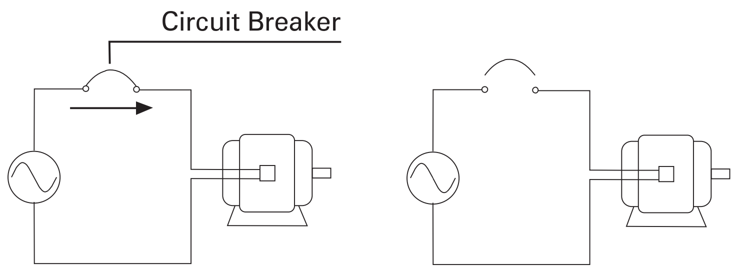


Circuit breakers:

- **SENSE** when an overcurrent occurs.
- **MEASURE** the amount of overcurrent.
- **ACT** by tripping the circuit breaker in a time frame necessary to prevent damage to itself and the associated load cables.

Circuit breaker operation in a simple circuit

In the following illustration an AC motor is connected through a circuit breaker to a voltage source. When the circuit breaker is closed, a complete path for current exists between the voltage source and the motor allowing the motor to run. Opening the circuit breaker breaks the path of current flow and the motor stops. The circuit breaker will open automatically during a fault, or can be manually opened. After the fault has been cleared, the breaker can be closed allowing the motor to operate.



Note: Article 240 in the *National Electrical Code* covers overcurrent protection. You are encouraged to become familiar with this material.

Review 1

1. With an increase in current, heat will

   a. increase
   b. decrease
   c. remain the same

2. Two causes of overcurrent are ___________ and ___________ .

3. A ___________ ___________ occurs when two bare conductors touch.

4. An ___________ occurs when electrical equipment is required to work harder than it is rated.

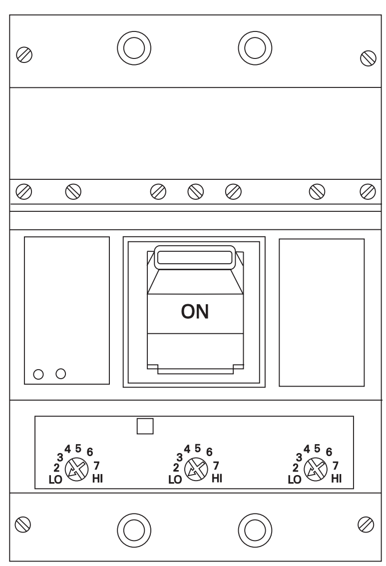
5. The three functions of a circuit breaker are ___________ , ___________ , and ___________ .

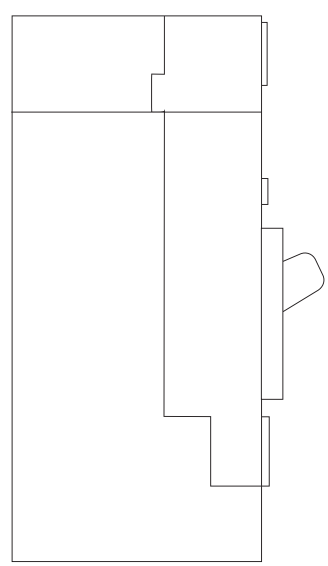
Circuit Breaker Design

The following section presents some basics of circuit breaker design. Variations to these design principles will be presented later in the course. Circuit breakers are constructed in five major components:

- Frame (Molded Case)
- Contacts
- Arc Chute Assembly
- Operating Mechanism
- Trip Unit

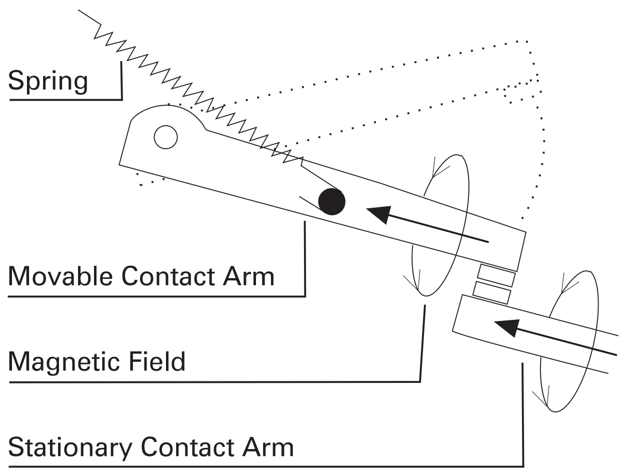
The frame provides an insulated housing to mount the circuit breaker components. The construction material is usually a thermal set plastic such as glass-polymer. The construction material can be a factor in determining the interruption rating of the circuit breaker. Frame ratings indicate several pieces of important information such as; maximum voltage, ampere rating, interrupting rating, and physical size.



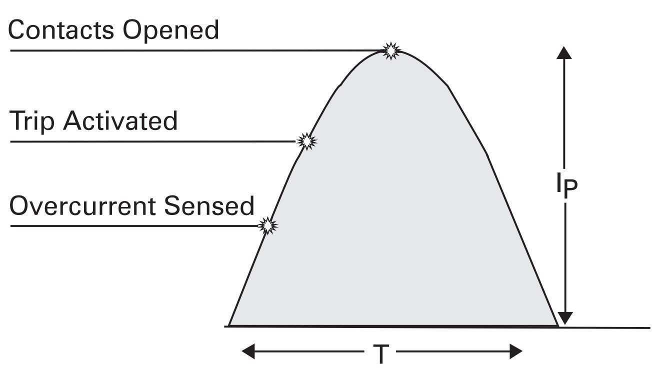


Straight-through contacts

Circuit breakers use contacts to break the circuit and stop the flow of energy. Some conventional circuit breakers use a straight-through contact arrangement. The electrical path through the contacts is a straight line. As discussed in **Basics of Electricity**, a magnetic field is developed around a current-carrying conductor. The magnetic fields developed around the contact arms of a straight-through contact arrangement have little or no effect on the contacts arms. During a fault, the contacts are only opened by the mechanical operation of the circuit breaker spring.

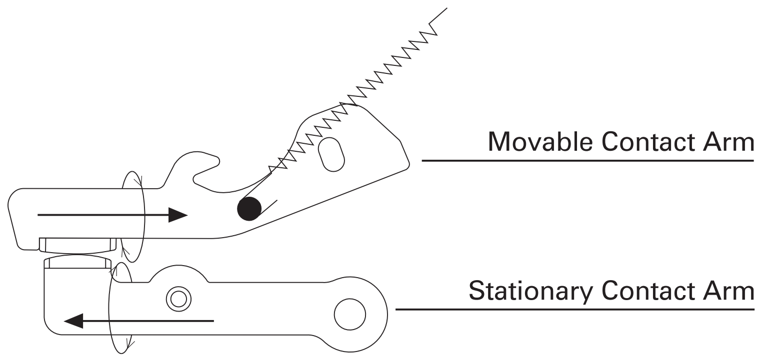


As mentioned earlier, current causes heat, which is destructive to electrical equipment. A rise in current causes a corresponding rise in heat. In reality, the thermal energy the circuit will see is proportional to the square of the current multiplied by the time the current flows (I^2T). This means that the higher the level of current, the shorter the time it takes for heat to damage equipment. In the following illustration, I_P represents the peak level the fault current rises before the breaker contacts open.

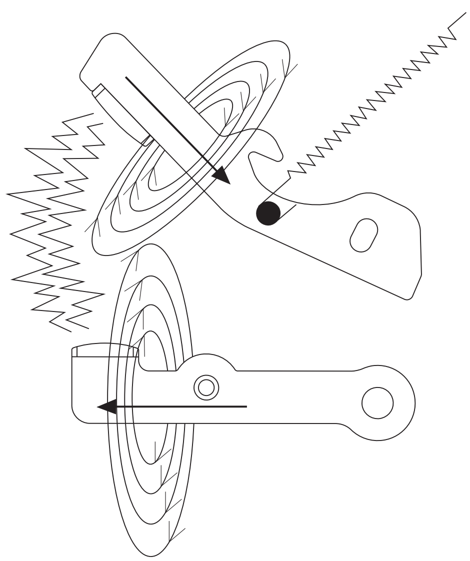


Blow-apart contacts

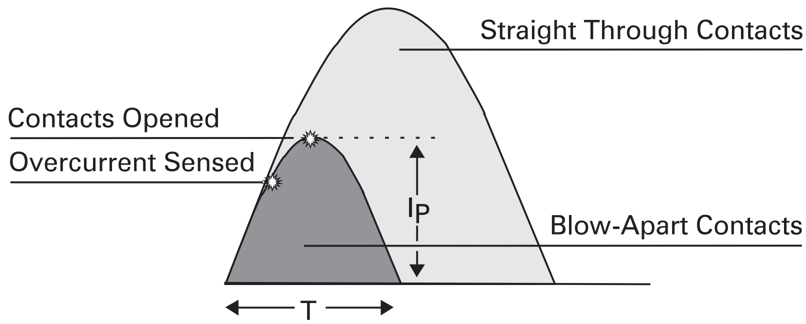
Siemens developed a design referred to as blow-apart contacts. With this design, the two contact arms are positioned parallel to each other as shown in the following illustration. As current flows through the contact arms, magnetic fields are set up around each arm. Because the current flow in one arm is opposite in direction to the current flow in the other arm, the two magnetic fields oppose each other. The strength of the magnetic field is directly proportional to the amount of current. During normal current conditions, the magnetic field is not strong enough to force the contacts apart.



When a fault develops, current increases which increases the strength of the magnetic field. The increased strength of the opposing magnetic fields actually helps to open the contacts faster by forcing them apart.

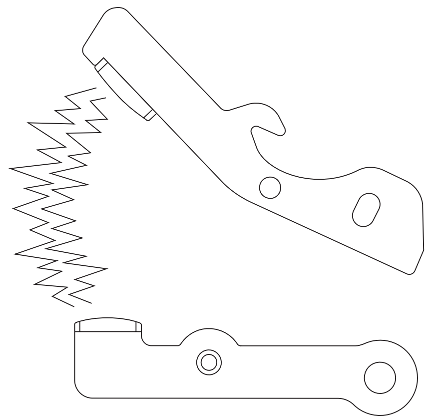


In comparison, the blow-apart contact design helps to open the contacts faster than the straight-through arrangement. I^2T is greatly reduced since arc extinguishment in less than 4 milliseconds is common with blow-apart contacts. This means that electrical equipment is exposed to less heat over a shorter period of time. The result is a higher degree of protection.

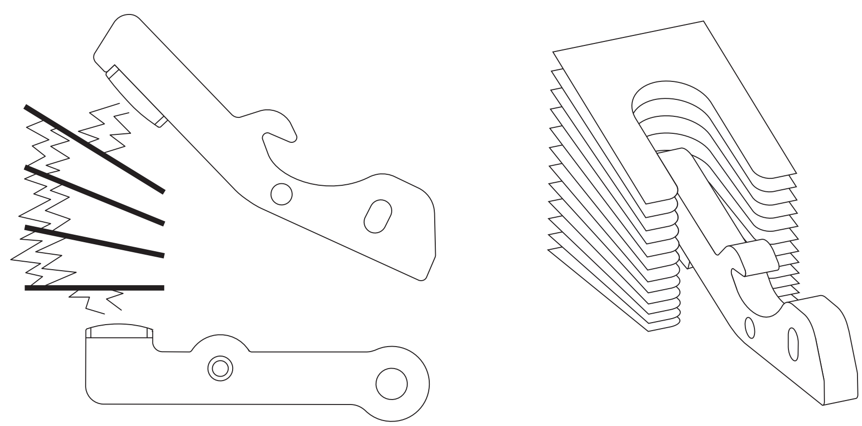


Arc chute assembly

As the contacts open a live circuit, current continues to flow for a short time by jumping the air space between the contacts in the form of an arc. When the contacts open far enough the arc is extinguished and the current flow stops.

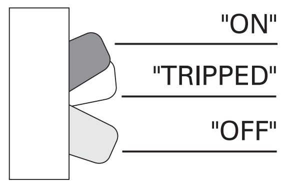


The arc can cause burning on the contacts. In addition, ionized gases form inside the molded case. If the arc isn't extinguished quickly the pressure from the ionized gases could cause the molded case to rupture. An arc chute assembly is used to quench the arc. This assembly is made up of several "U" shaped steel plates that surround the contacts. As the arc is developed it is drawn into the arc chute where it is divided into smaller arcs, which are extinguished faster.



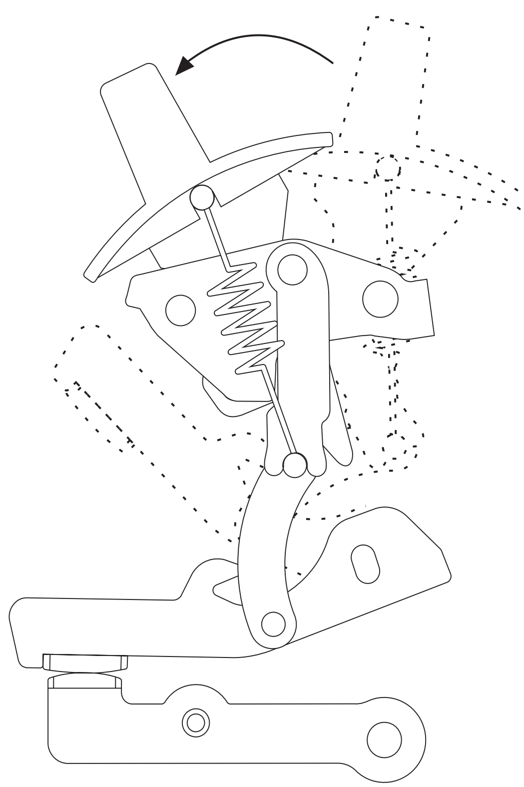
Operating handle

An operating handle is provided to manually open and close the contacts. Molded case circuit breakers (MCCBs) are trip free, meaning that they can't be prevented from tripping by holding or blocking the operating handle in the "ON" position. There are three positions of the operating handle: "ON" (contacts closed), "OFF" (contacts open), and "TRIPPED" (mechanism in tripped position). The circuit breaker is reset after a trip by moving the handle to the "OFF" position and then to the "ON" position.

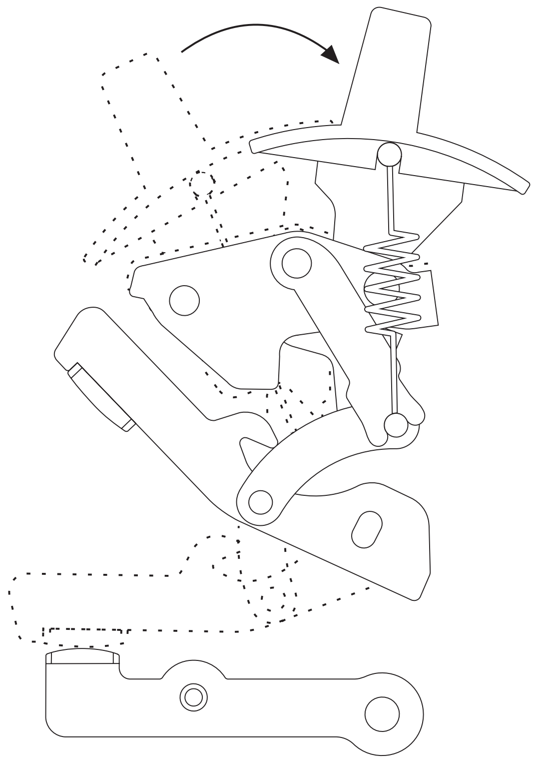


Operating mechanism

The operating handle is connected to the moveable contact arm through an operating mechanism. Siemens molded case circuit breakers use an over-center toggle mechanism that is a quick-make and quick-break design. In the following illustration, the operating handle is moved from the "OFF" to the "ON" position. In this process a spring begins to apply tension to the mechanism. When the handle is directly over the center the tension in the spring is strong enough to snap the contacts closed. This means that the speed of the contact closing and opening is independent of how fast the handle is operated.

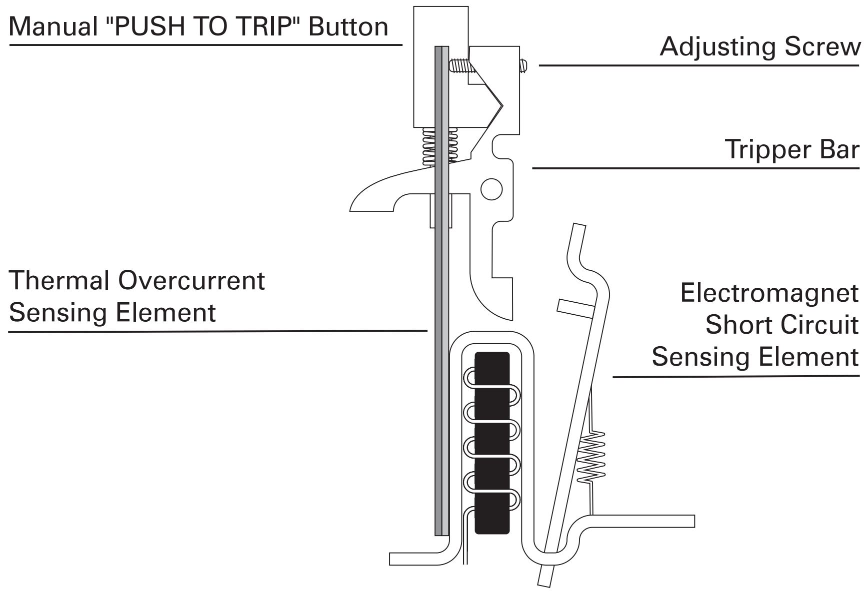


To open the contacts, the operating handle is moved from the “ON” to the “OFF” position. In this process a spring begins to apply tension to the mechanism. When the handle is directly over the center the tension in the spring is strong enough to snap the contacts open. As in closing the circuit breaker contacts, contact opening speed is independent of how fast the handle is operated.



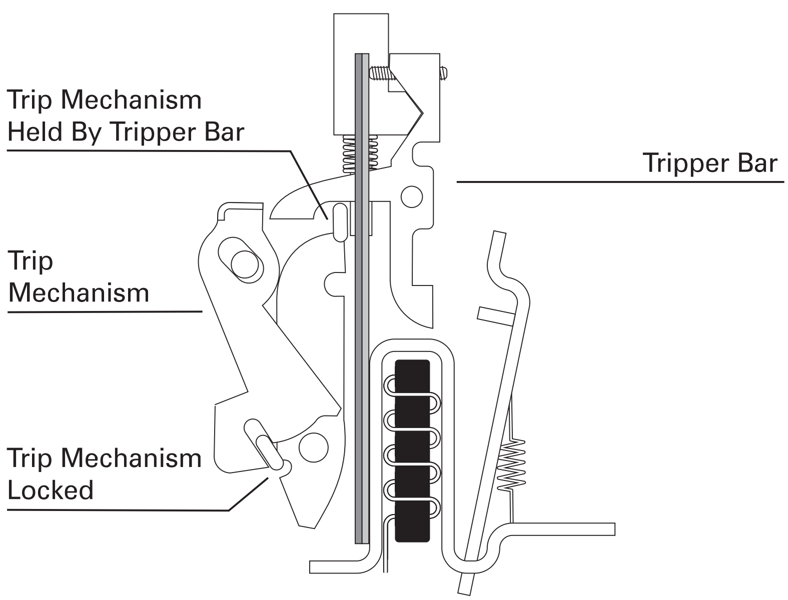
Trip unit

The trip unit is the "brain" of the circuit breaker. It consists of components that will automatically trip the circuit breaker when it senses an overload or short circuit. The tripper bar is moved by a manual "PUSH TO TRIP" button, a thermal overcurrent sensing element or an electromagnet.

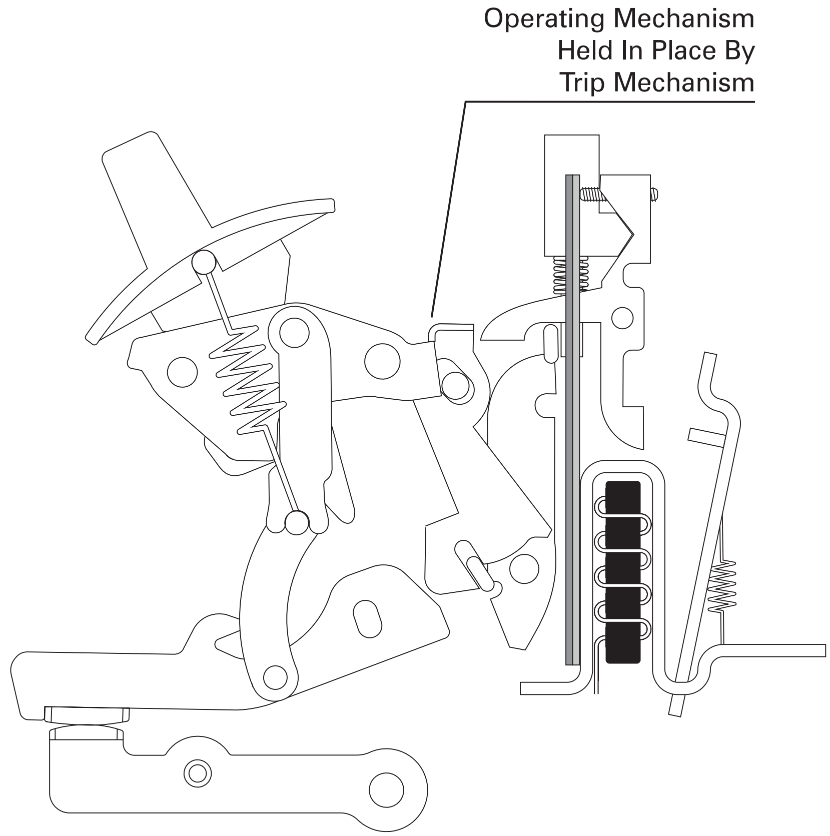


Trip mechanism

A trip mechanism is held in place by the tripper bar. As long as the tripper bar holds the trip mechanism, the mechanism remains firmly locked in place.

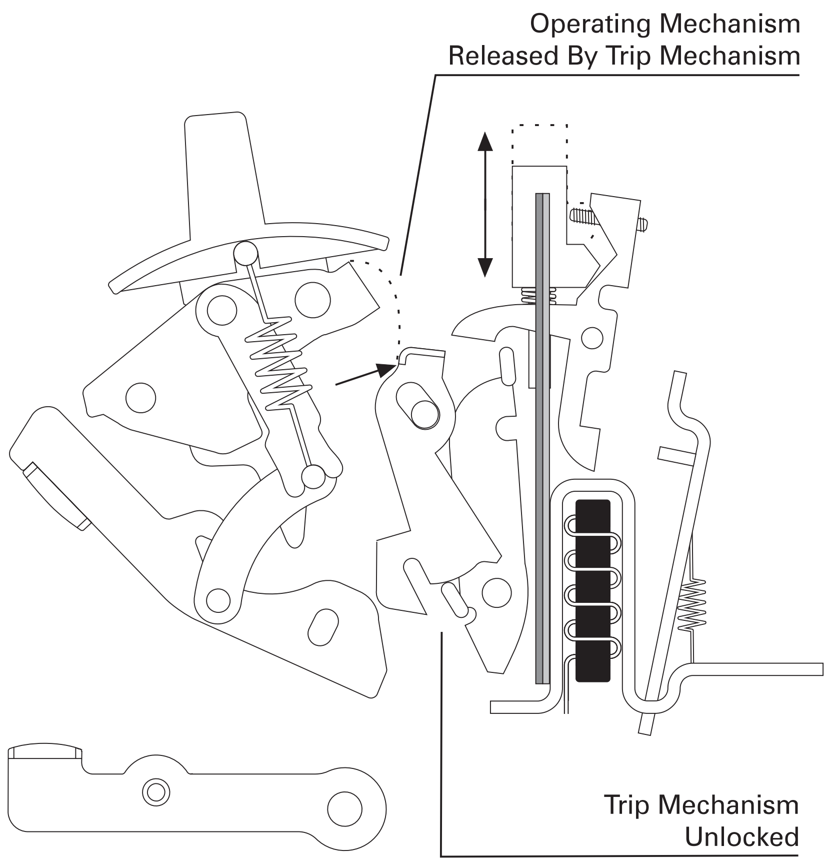


The operating mechanism is held in “ON” position by the trip mechanism. When a trip is activated, the trip mechanism releases the operating mechanism, which opens the contacts.



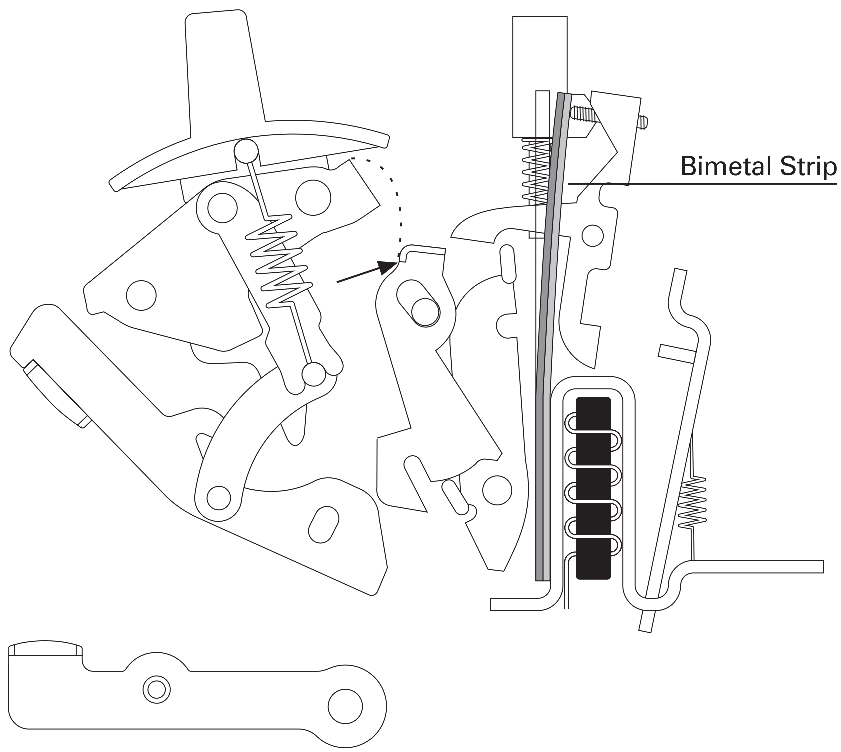
Manual trip

MCCBs, heavy duty and above, can be manually tripped by depressing the red “PUSH TO TRIP” button on the face of the circuit breaker. When the button is pressed the tripper bar rotates up and to the right. This allows the trip mechanism to “unlock” releasing the operating mechanism. The operating mechanism opens the contacts. The “PUSH TO TRIP” button also serves as a safety device by not allowing access to the circuit breaker interior in the “ON” position. If an attempt is made to remove the circuit breaker cover while the contacts are in the closed (“ON”) position, a spring located under the pushbutton will cause the button to lift up. This action will also trip the breaker.

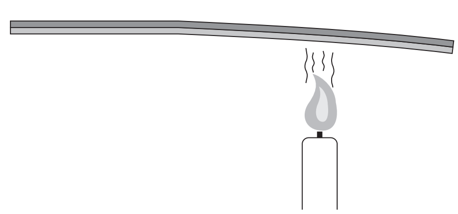


Overload trip

The overload trip unit senses and decides when to act by tripping the circuit breaker. Modern molded case circuit breakers have a lineage traceable to the Cutter Company, which came to be known as the I-T-E® Circuit Breaker Company in the late 1800s and early 1900s. The company introduced "Inverse Time Element" (I-T-E) circuit breakers in the United States. Simply stated, the higher the current, the shorter time it takes for the trip mechanism to activate. Modern thermal-magnetic circuit breakers generally employ a bimetal strip to sense overload conditions. When sufficient overcurrent flows through the circuit breaker's current path, heat build up causes the bimetal strip to bend. After bending a predetermined distance the bimetal strip makes contact with the tripper bar activating the trip mechanism.

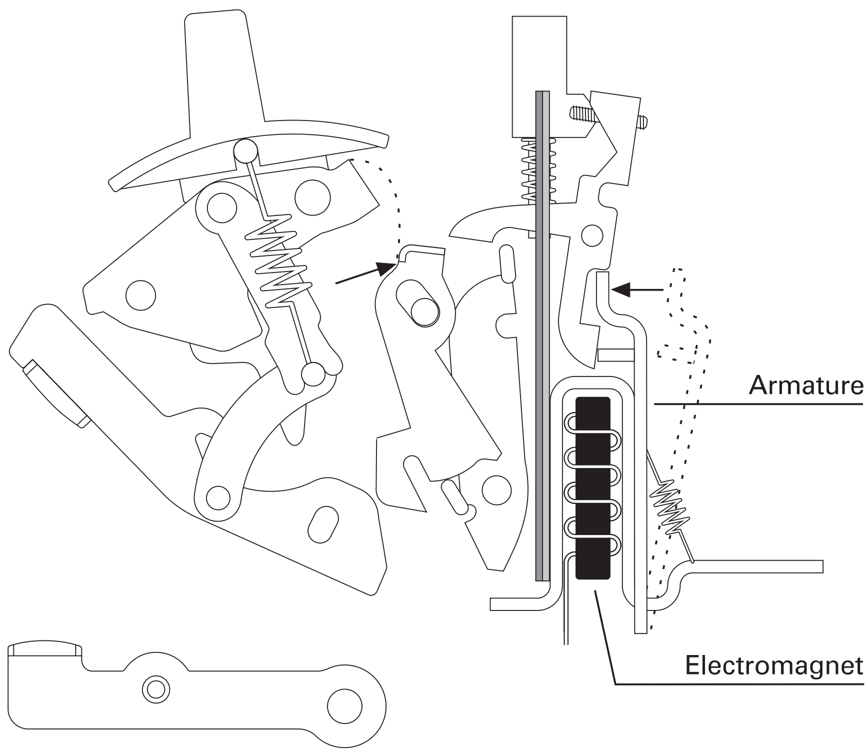


A bimetal strip is made of two dissimilar metals bonded together. The two metals have different thermal expansion characteristics, so the bimetal bends when heated. As current rises, heat also rises. The hotter the bimetal becomes the more it bends, until the mechanism is released.



Short circuit trip

Short circuit protection is accomplished with an electromagnet. This is referred to as the magnetic or instantaneous element. The electromagnet is connected in series with the overload bimetal strip. During normal current flow, or an overload, the magnetic field created by the electromagnet is not strong enough to attract the armature. When a short circuit current flows in the circuit, the magnetic field caused by the electromagnet attracts the electromagnet's armature. The armature hits the tripper bar rotating it up and to the right. This releases the trip mechanism and operating mechanism, opening the contacts. Once the circuit breaker is tripped current no longer flows through the electromagnet and the armature is released.



Review 2

1. Circuit breakers use ___________ to break the circuit and stop the flow of energy.

2. Siemens developed ___________ - ___________ contacts that greatly reduce the amount of time it takes for breaker contacts to open when a fault occurs.

3. The ___________ ___________ assembly reduces contact damage by dividing the arc into smaller segments which can be extinguished faster.

4. Siemens circuit breakers use an ___________ - ___________ toggle mechanism that is a quick-make and quick-break design.

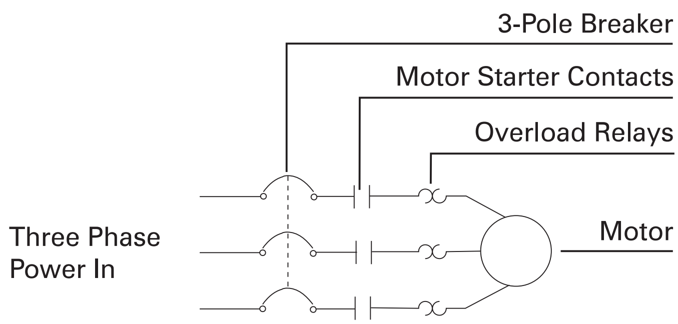
5. A ___________ strip uses two dissimilar metals bonded together.

6. An ___________ is used to sense a short circuit.

Types of Circuit Breakers

Instantaneous magnetic-trip-only circuit breakers

Instantaneous magnetic-trip-only circuit breakers do not provide overload protection and are used on motor circuits where overload protection is provided by a motor starter. The current level at which an instantaneous trip circuit breaker trips is adjustable. The name comes from the electromagnet used to sense short circuit current. The purpose of overload protection is to prevent the motor from operating beyond its full-load capability. In the schematic illustrated below, a motor is supplied through a 3-pole circuit breaker, motor starter contacts and separately supplied overload contacts. Heat generated from excessive current will cause the overload contacts to open, removing power from the motor.



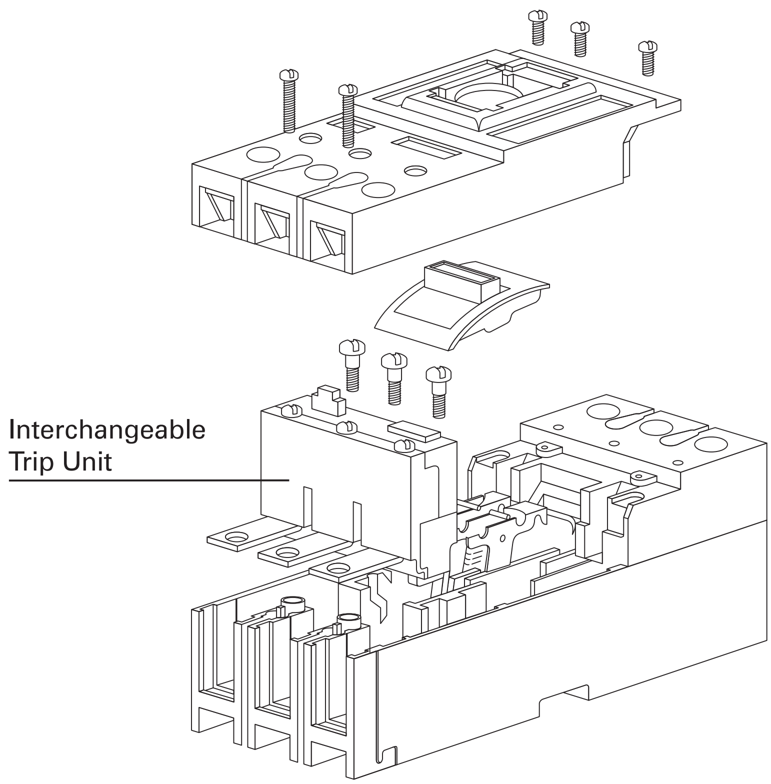
Thermal-magnetic circuit breakers

Thermal-magnetic circuit breakers have both overload and instantaneous trip features. When an overload condition exists, the excess current will generate heat, which is detected in the circuit breaker. After a short period of time, dependent on the rating of the breaker and amount of overload, the breaker will trip, disconnecting the load from the voltage source. If a short circuit occurs, the breaker responds instantaneously to the fault current and disconnects the circuit.

Interchangeable trip circuit breakers

The user does not have access to the trip unit on some circuit breakers. This means the trip unit cannot be changed with another. Interchangeable trip is actually a design feature that is available on some thermal-magnetic and some solid state breakers. The advantage of a breaker with an interchangeable trip unit is the user can change the continuous current rating of the breaker without replacing the breaker. This is done by replacing the trip unit with one of a different rating.

Note: Care must be exercised when considering interchangeable trip circuit breakers. A circuit breaker may be UL (Underwriters Laboratories, Inc.®) Listed for a specific interchangeable trip unit only. Circuit breaker frames are usually designed to prevent the installation of an improper trip unit size or type.

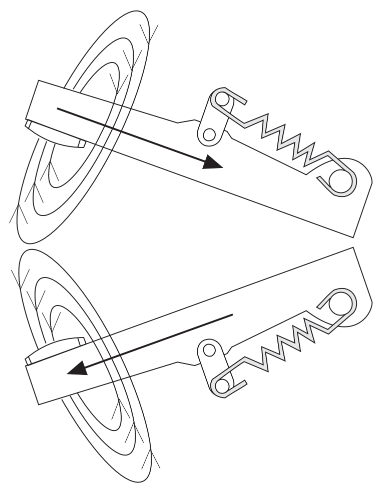


Molded case switch

Siemens molded case circuit breakers are available as a molded case switch. Molded case switches employ the same operating mechanism as the thermal magnetic and magnetic only units. A preset instantaneous function is factory installed to allow the switch to trip and protect itself at a high fault current, but the switch provides no thermal overload protection.

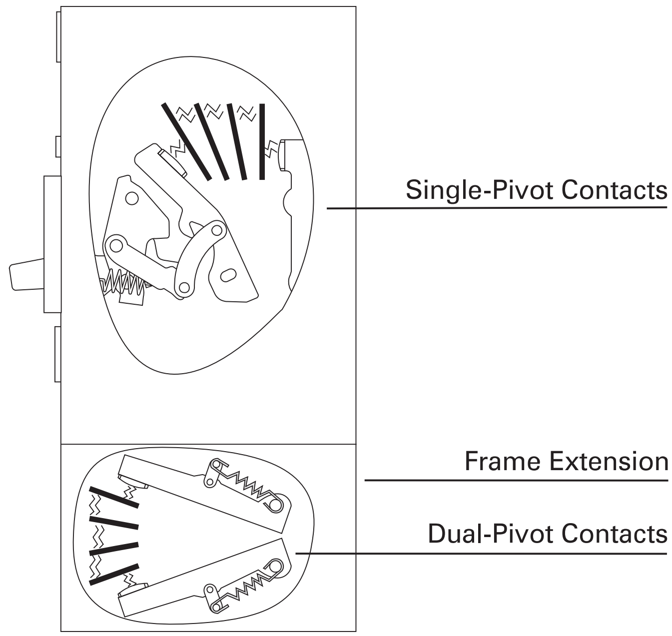
Current limiting circuit breakers

Many electrical distribution systems can deliver large short circuit currents to electrical equipment. This high current can cause extensive damage. Current limiting circuit breakers will reduce the current flowing in the faulted circuit to substantially less magnitude. This helps protect expensive equipment. One way to accomplish current limiting is with an additional set of contacts that feature two moveable arms. These are referred to as dual-pivot contacts, which separate even more quickly than the single-pivot contacts. The dual-pivot contacts are connected in series with the single-pivot contacts. As with the single-pivot design, current flows in opposite directions through the contact arms, creating a magnetic repulsion. As current increases, the magnetic repulsion force increases.



In an overload condition where current may only be one to six times normal current, the contacts remain closed until the breaker trips. In a short circuit condition fault current is extremely high, both sets of contact arms may open simultaneously, generating high impedance arcs. The contact gap of the dual-pivot contacts increases more rapidly, therefore generating arc impedance more rapidly. Once the arcs are extinguished, the dual-pivot contacts close on their own due to spring tension. The single-pivot contacts are held open by the breaker mechanism, which will have tripped during the fault and must be manually reset.

The frame on current limiting circuit breakers of this design is extended to allow room for the dual-pivot set of contacts. Siemens current limiting breakers are easily identified by a red label and can handle fault currents of up to 200,000 amps.

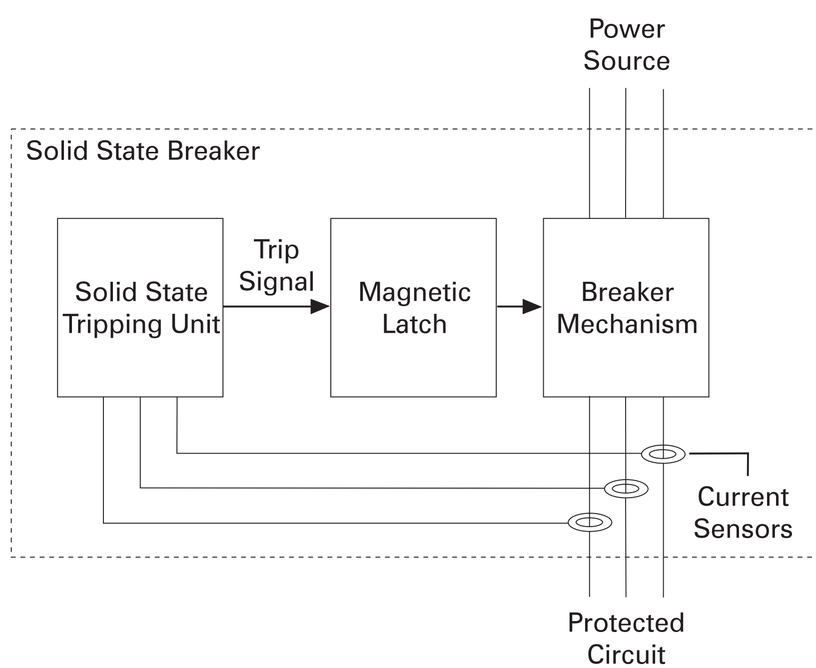


Solid state circuit breakers

Solid state circuit breakers function similarly to thermal-magnetic breakers. The basic breaker mechanism is still mechanical. The tripping unit is solid state. Siemens Sentron™ Series solid state breakers are referred to as Sensitrip® circuit breakers. As with the thermal-magnetic tripping unit, the Sensitrip circuit breaker tripping unit performs the following three functions:

- Senses magnitude of current flow
- Determines when current becomes excessive
- Determines when to send a trip signal to the breaker mechanism

Sensitrip circuit breakers use a microprocessor to execute numerous functions programmed in the unit. These units have a greater degree of accuracy and repeatability. Adjustments on the trip unit allow the user to select numerical values the microprocessor will use in performing protective functions. Current sensors mounted in the trip unit monitor the value of load current. The value of current is reduced to a low level and converted to a digital voltage, which is used by the microprocessor. The microprocessor continuously compares the line current with the value set by the user. When current exceeds a preset value for the selected time, the trip unit sends a signal to a magnetic latch. The magnetic latch opens the breaker's contacts, disconnecting the protected circuit from the power source.



Circuit Breaker Ratings

Ampere Rating

Every circuit breaker has a specific ampere rating. The ampere rating is the maximum continuous current a circuit breaker can carry without exceeding its rating. The main purpose of circuit breakers is to protect the conductor and equipment. As mentioned earlier, conductors are rated by how much current they can carry on a continuous basis, known as ampacity. As a general rule, the circuit breaker ampere rating should match the conductor ampacity. For example, if the conductor is rated for 20 amps, the circuit breaker should be rated for 20 amps. Siemens I-T-E® breakers are rated on the basis of using 60° C or 75° C conductors. This means that even if a conductor with a higher temperature rating were used, the ampacity of the conductor must be figured on its 60° C or 75° C rating.

There are some specific circumstances when the ampere rating is permitted to be greater than the current carrying capacity of the circuit. For example, motor and welder circuits can exceed conductor ampacity to allow for inrush currents and duty cycles within limits established by *NEC*.

Generally the ampere rating of a circuit breaker is selected at 125% of the continuous load current. This usually corresponds to the conductor ampacity which is also selected at 125% of continous load current. For example, a 125 amp circuit breaker would be selected for a load of 100 amps.

Voltage rating

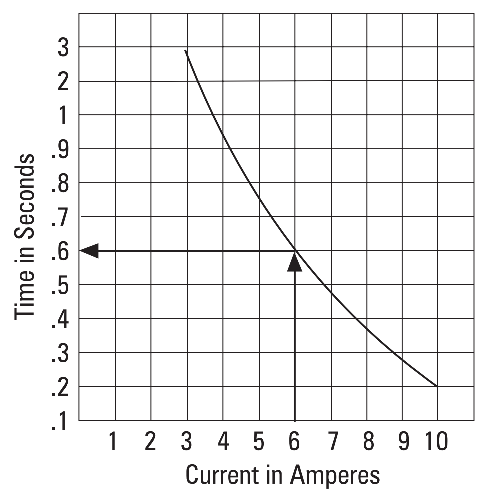
Circuit breakers are also rated according to the maximum voltage they can handle. The voltage rating of the circuit breaker must be at least equal to the circuit voltage. The voltage rating of a circuit breaker can be higher than the circuit voltage, but never lower. For example, a 480 VAC circuit breaker could be used on a 240 VAC circuit. A 240 VAC circuit breaker could not be used on a a 480 VAC circuit. The voltage rating is a function of the circuit breakers ability to suppress the internal arc that occurs when the circuit breaker's contacts open.

Current interrupting ratings

Circuit breakers are also rated according to the level of fault current they can interrupt. When applying a circuit breaker, one must be selected which can sustain the largest potential short circuit current which can occur in the selected application. Siemens circuit breakers have interrupting ratings from 10,000 to 200,000 amps. To find the interrupting rating of a specific circuit breaker refer to the Speedfax catalog.

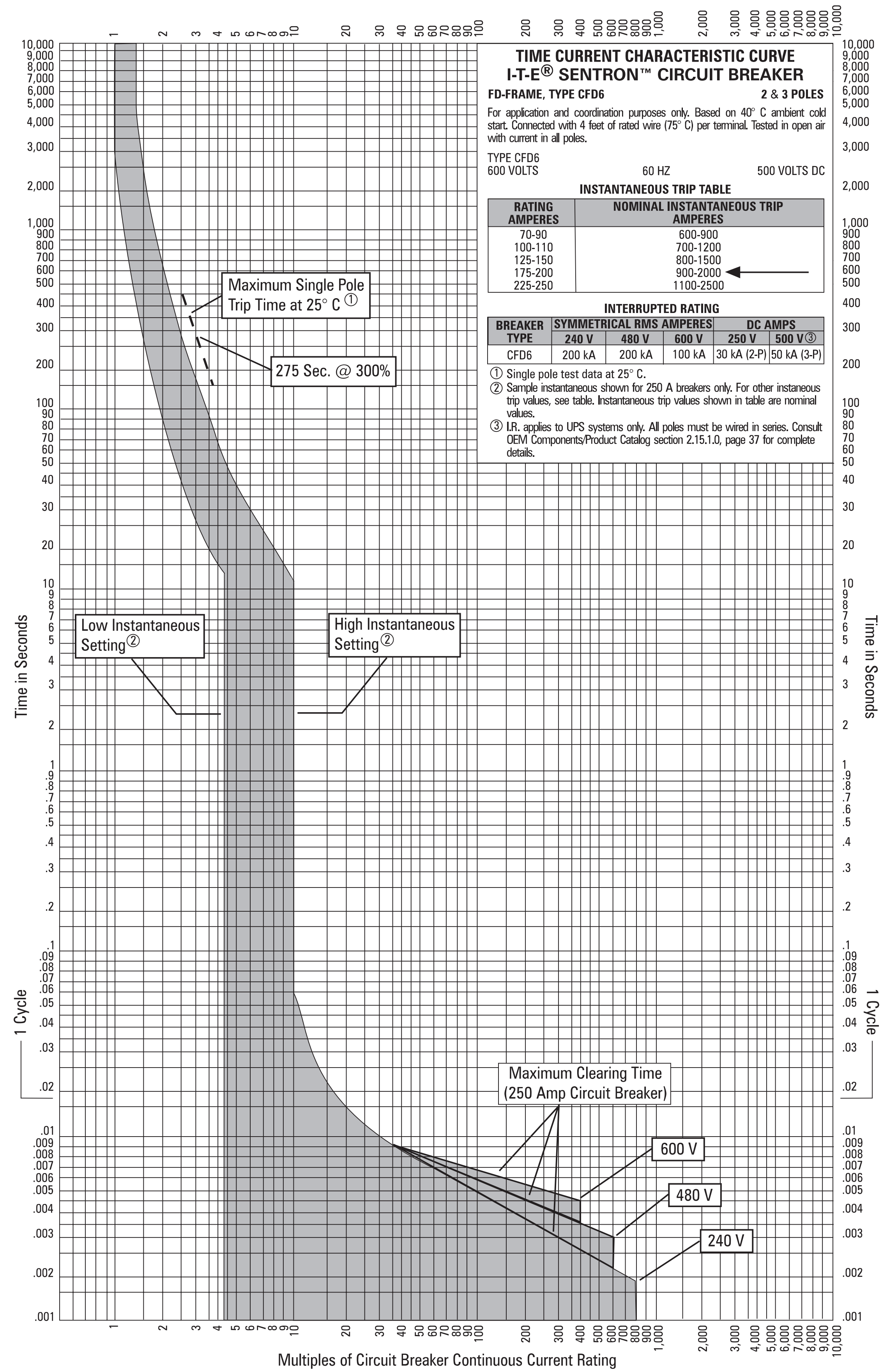
Time-Current Curves

Time-current curves, similar to the one shown on the following page, are used to show how fast a breaker will trip at any magnitude of current. The following illustration shows how a time-current curve works. The figures along the bottom (horizontal axis) represent current in amperes. The figures along the left side (vertical axis) represent time in seconds.



To determine how long a breaker will take to trip at a given current, find the level of current on the bottom of the graph. Draw a vertical line to the point where it intersects the curve. Then draw a horizontal line to the left side of the graph and find the time to trip. For example, in this illustration a circuit breaker will trip when current remains at 6 amps for .6 seconds. It can be seen that the higher the current, the shorter the time the circuit breaker will remain closed. It can be seen from the time-current curve on the following page that actual time-current curves are drawn on log-log paper, and the horizontal line is in multiples of the breaker's continuous current rating.

From the information box in the upper right hand corner, note that the time-current curve illustrated on the following page defines the operation of a CFD6 circuit breaker. For this example a 200 ampere trip unit is selected.



TIME CURRENT CHARACTERISTIC CURVE
I-T-E® SENTRON™ CIRCUIT BREAKER

FD-FRAME, TYPE CFD6 **2 & 3 POLES**

For application and coordination purposes only. Based on 40° C ambient cold start. Connected with 4 feet of rated wire (75° C) per terminal. Tested in open air with current in all poles.

TYPE CFD6
600 VOLTS 60 HZ 500 VOLTS DC

INSTANTANEOUS TRIP TABLE

RATING AMPERES	NOMINAL INSTANTANEOUS TRIP AMPERES
70-90	600-900
100-110	700-1200
125-150	800-1500
175-200	900-2000 ←
225-250	1100-2500

INTERRUPTED RATING

BREAKER TYPE	SYMMETRICAL RMS AMPERES			DC AMPS	
	240 V	480 V	600 V	250 V	500 V③
CFD6	200 kA	200 kA	100 kA	30 kA (2-P)	50 kA (3-P)

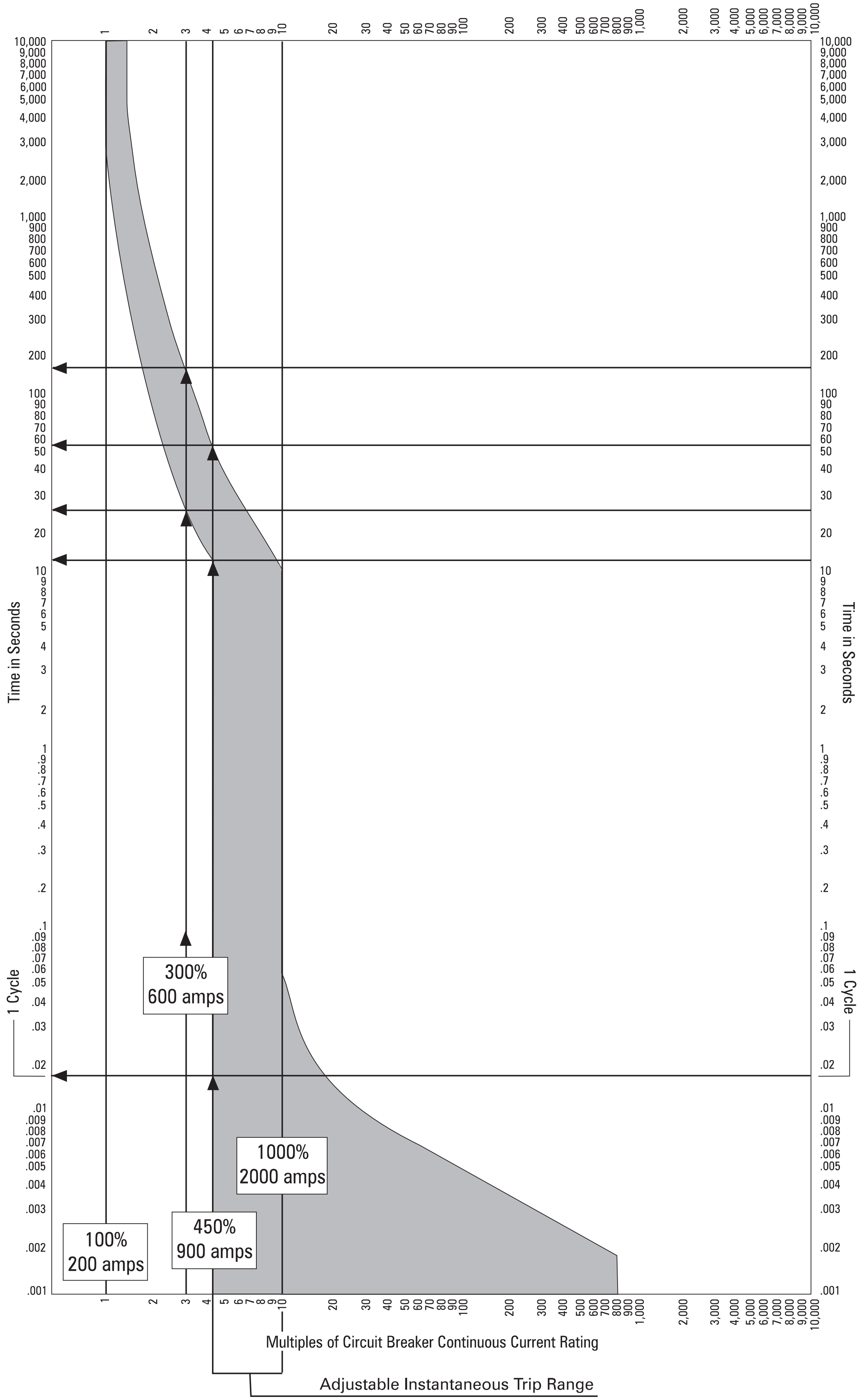
① Single pole test data at 25° C.
② Sample instantaneous shown for 250 A breakers only. For other instaneous trip values, see table. Instantaneous trip values shown in table are nominal values.
③ I.R. applies to UPS systems only. All poles must be wired in series. Consult OEM Components/Product Catalog section 2.15.1.0, page 37 for complete details.

Overload protection component of the time-current curve

The top part of the time-current curve shows the performance of the overload trip component of the circuit breaker. Time-current curves are shown as bands, and the actual performance of any one breaker can fall anywhere within the band. Using the example CFD6 breaker and 200 ampere trip unit, the time the breaker will trip for any given overload can easily be determined using the same procedure as previously discussed. For example, the breaker will trip between 25 seconds and 175 seconds at 600 amps with a 40°C ambient temperature, which is 3 times the the trip unit rating. This is illustrated by the time-current curve on the following page.

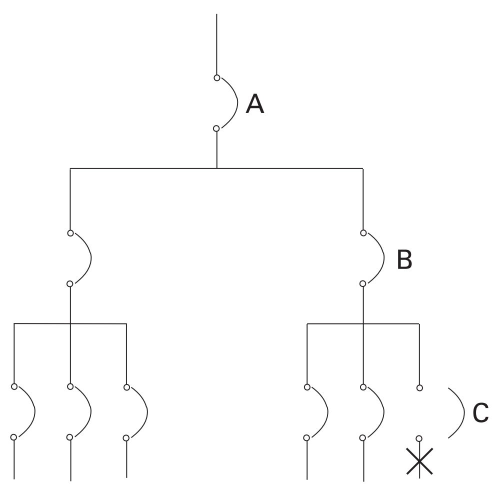
Instantaneous trip component of the time-current curve

The bottom part of the time-current curve shows the performance of the instantaneous trip component (short circuit) of the circuit breaker. The maximum clearing time (time it takes for breakers to completely open) decreases as current increases. This is because of the blow-apart contact design which utilizes the magnetic field built-up around the contacts. As current increases the magnetic field strength increases, which aids in opening the contacts. This circuit breaker has an adjustable instantaneous trip point from 900 A to 2000 A, which is 4.5 to 10 times the 200 A trip unit rating. If the trip point adjustment is set to minimum (900 A), and a fault current of 900 amps or greater occurs, the breaker will trip within 1 cycle (16.8 ms). If the trip point setting is set to maximum (2000 A), and a fault current of 900 amps occurs, the breaker will trip between approximately 12 and 55 seconds. A greater fault current will cause the breaker to trip faster.


Time in Seconds
Multiples of Circuit Breaker Continuous Current Rating
Adjustable Instantaneous Trip Range
1 Cycle
100%
200 amps
300%
600 amps
450%
900 amps
1000%
2000 amps

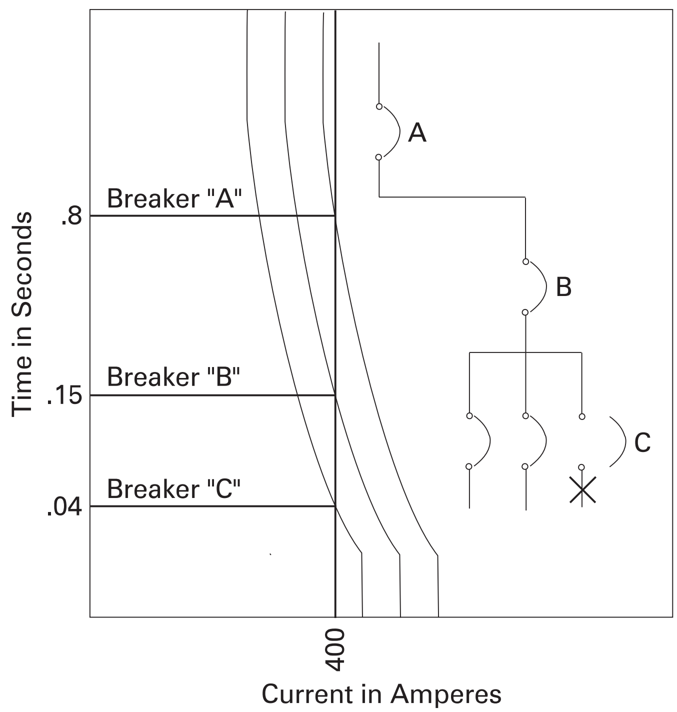
Selective Coordination

Selective coordination is the application of circuit protective devices in series such that under overload or fault conditions, only the upstream device nearest the fault will open. The rest of the devices remain closed, leaving other circuits unaffected. In the following example a short circuit has occurred in the circuit fed by branch circuit breaker “C”. Power is interrupted to equipment supplied by circuit breaker “C” only. All other circuits remain unaffected.



Using time-current curves to coordinate circuit breakers

Time current curves are useful for coordinating circuit breakers. If the trip curves of main breaker "A", feeder breaker "B", and branch breaker "C" are placed on the same graph, there should be no overlapping, indicating the breakers are coordinated. The three circuit breakers in the following example have been coordinated so that for any given fault value, the tripping time of each breaker is greater than the downstream breakers. In the following illustration circuit breaker "C" is set to trip if a 400 amp fault current remains for .04 seconds. Circuit breaker "B" will trip if the fault remains for .15 seconds, and circuit breaker "A" if the fault remains for .8 seconds. If a 400 amp fault occurs downstream from circuit breaker "C", it will trip first and clear the fault. Circuit breakers "A" and "B" will not trip.



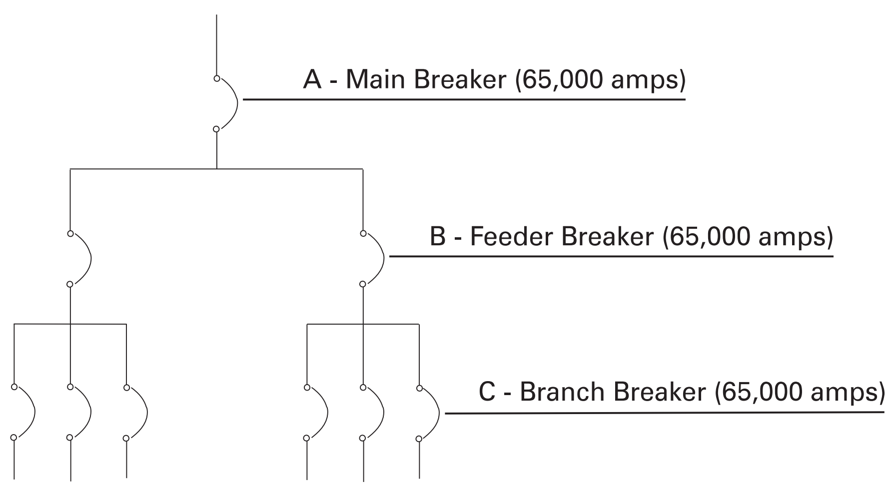
Series-Connected Systems

When selecting circuit breakers it is extremely important to know both the maximum continuous amperes and available fault current. This is true for any circuit breaker that is selected for any application. *NEC* article 110-9 states:

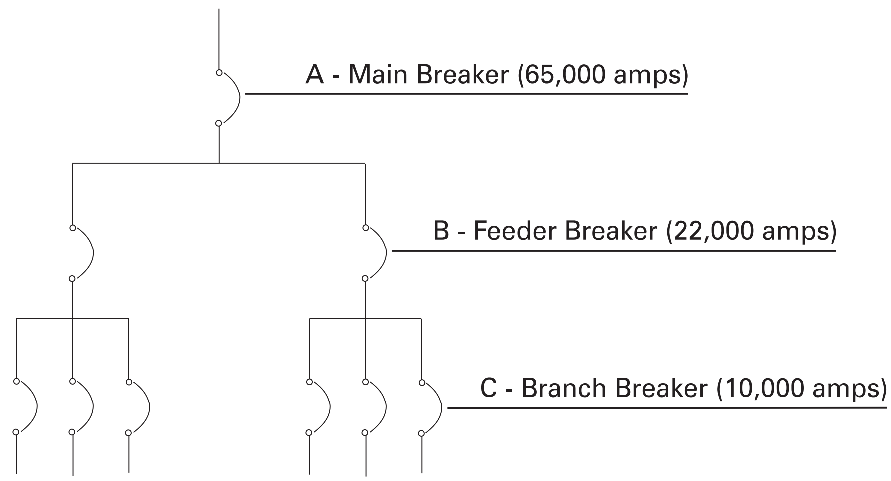
Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the system voltage and the current which is available at the line terminals of the equipment.

Equipment intended to break current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted.

There are two ways to meet this requirement. The first method is to select circuit breakers with individual ratings equal to or greater than the available fault current. This means that, in the case of a building with 65,000 amperes of fault current available at the service entrance, every circuit breaker must be rated at 65,000 amperes interrupting capacity (AIC).



The second method is to select circuit breakers with a series combination rating equal to or greater than the available fault current at the service entrance. The series-rated concept is that the main upstream breaker must have an interrupting rating equal to or greater than the available fault current of the system, but subsequent downstream breakers connected in series can be rated at lower values. For example, a building with 65,000 amperes of available fault current might only need the breaker at the service entrance to be rated at 65,000 AIC. Additional downstream breakers can be rated at lower values. The series combination must be tested and listed by UL.



Siemens series-rated breakers are listed under "Integrated Equipment Short Circuit Ratings" in the Siemens Speedfax® catalog, and in the UL "Recognized Components Directory" (yellow books) Volume 1. Your Siemens sales engineer can provide more information on Siemens series-rated circuit breakers.

Review 3

1. ____________ magnetic-trip-only circuit breakers protect against short circuits, but provide no overload protection.

2. ____________ magnetic circuit breakers have both overload and instantaneous trip features.

3. Siemens current limiting circuit breakers can interrupt up to ____________ amps.

4. The maximum continuous current a circuit breaker can carry is known as its ____________ rating.

5. The upper part of a time-current curve represents the ____________ ____________ component, while the lower part of a time-current curve represents the instantaneous trip component.

6. Circuit breaker ____________ will allow the circuit breaker supplying a circuit that faults to trip, but all upstream circuit breakers will remain unaffected.

Catalog Numbers

To help identify each type of circuit breaker, a catalog number is assigned. The catalog number provides a description of the circuit breaker. There are five parts to the standard I-T-E® molded case circuit breaker catalog number. The following figure illustrates a typical catalog number.

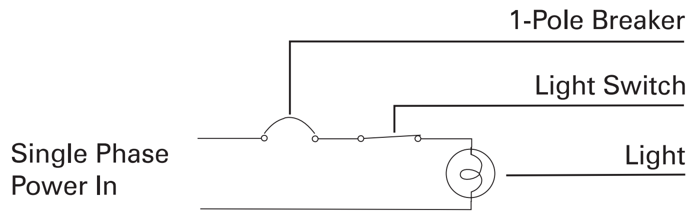
	Part 1	Part 2	Part 3	Part 4	Part 5
ED43B125A =	ED4	3	B	125	A

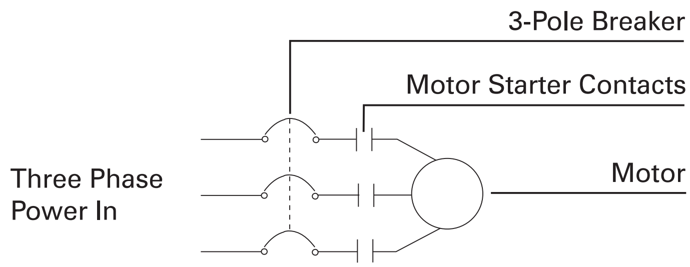
Part 1

Part 1 signifies the circuit breaker's frame type. There are four basic frame types available: normal duty, heavy duty, extra heavy duty, and fuseless current limiting. Most normal duty breakers are rated up to 240 VAC and have a maximum interrupting capacity of 10,000 or 22,000 amps. Heavy duty breakers have a stronger case. They are rated up to 600 VAC and have interrupting capacities up to 65,000 amps. This is the Sentron™ Series. There are eight basic Sentron Series frames: ED, FD, JD, LD, MD, ND, PD and RD. Extra heavy duty frames are rated up to 600 VAC and have interrupting capacities up to 100,000 amps. An extra heavy duty circuit breaker will have an "H" in the frame type designation. For example, a normal duty circuit breaker might be identified as QP. The same circuit breaker in an extra heavy duty frame will be identified as HQP. This is also true for the Sentron Series. For example, a heavy duty Sentron circuit breaker might be identified as FD6. The same Sentron circuit breaker in an extra heavy duty frame will be identified as HFD6. The same method is used to identify current limiting frames. For example, a current limiting circuit breaker in the ED6 frame will be identified as CED6.

Part 2

Part 2 indicates the number of poles on the circuit breaker. Sentron Series circuit breakers can be provided with 1, 2, or 3 poles. The number of poles reflects the number of ungrounded phases that are connected. For example, a 1-pole breaker might be used on a simple lighting circuit, and a 3-pole breaker might be used on a 3-phase AC motor.





Part 3

Part 3 identifies the style of breaker.

B = 40° C calibrated complete breaker
M = 50° C calibrated complete breaker
F = Breaker frame only
T = Trip unit calibrated for 40° C
W = Trip unit calibrated for 50° C
S = Molded case switch

Part 4

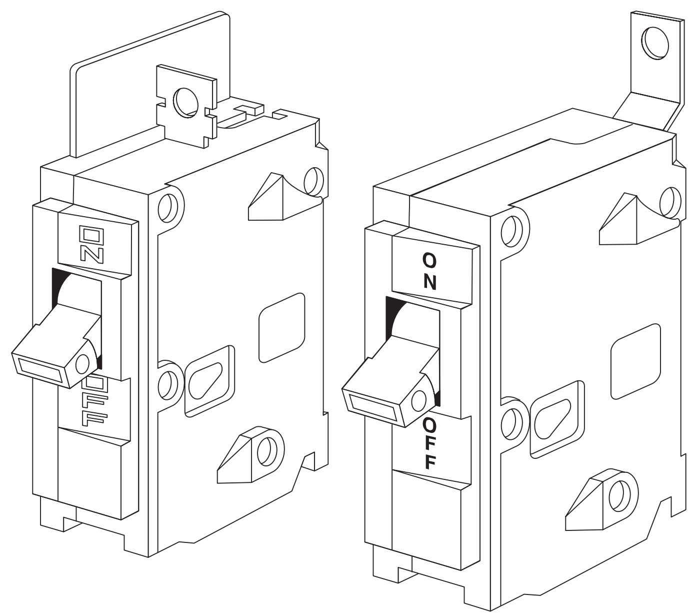
Part 4 shows the circuit breaker's continuous current rating. In the example shown on the previous page it is 125 amps.

Part 5

Part 5 indicates a special circuit breaker identifier, such as automatic switches.

Residential and Commercial Circuit Breakers

Siemens has several circuit breakers that are used in residential, commercial and light industrial applications. These circuit breakers are normally plug-in or bolt-on types that mount in load centers or panelboards. Other types are also available, for example, circuit breakers that mount on a DIN rail. There are several variations of circuit breakers, and this section will attempt to explain the most popular of them. The specific ratings for each circuit breaker can be found in the Speedfax® catalog.



EQ frame circuit breakers

EQ® frame circuit breakers, which includes QP, BL, and BQ type circuit breakers, are UL Listed for use with EQ load centers.

QP type plug-in circuit breakers

One type of circuit breaker that belongs to the EQ family is the QP plug-in breaker. Depending on the specific QP type circuit breaker, the following ratings are available:

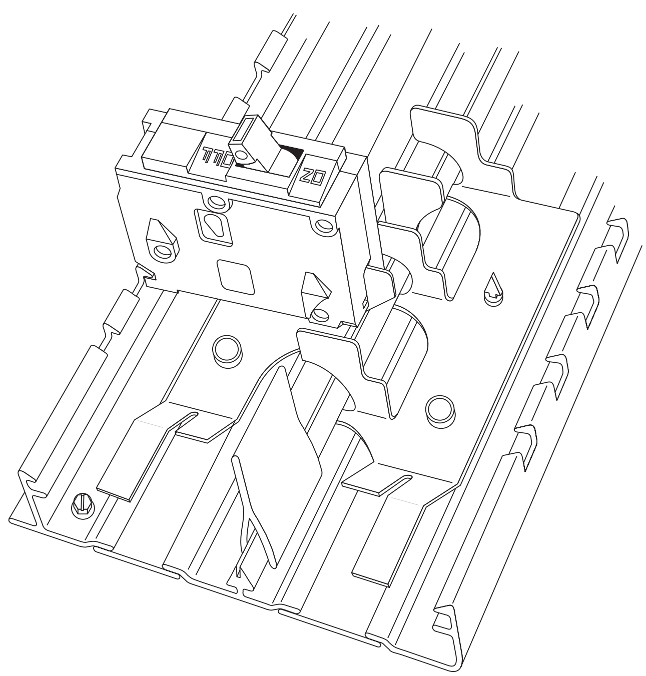
Interrupting rating	10,000, 22,000, or 65,000 amps
Continuous ampere rating	15-125 amps
Volts	120/240 VAC or 240 VAC
Number of poles	1, 2, or 3

For example, referring to the circuit breaker section of the Speedfax catalog, it can be seen that a 1-pole, 15 amp QP breaker, rated for an interrupting capacity of 10,000 amps at 120/240 VAC is a Q115. A 20 amp breaker is a Q120.

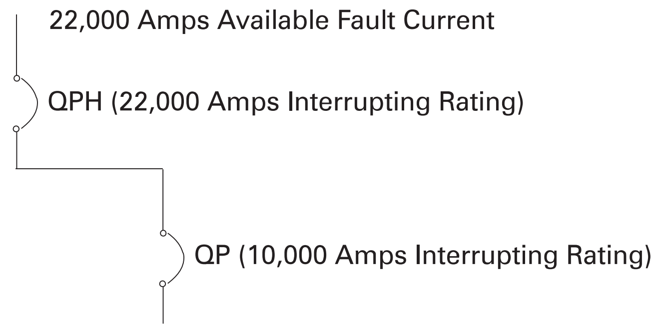
EQ 125A Frame - QP Plug-in (10,000A IR)

NON-INTERCHANGEABLE TRIP				
	1-Pole		2-Pole	
	120/240 VAC		120/240 VAC Common Trip	
Continuous Current Rating @ 40° C	Catalog Number	List Price	Catalog Number	List Price
15	Q115		Q215	
20	Q120		Q220	

The following illustration shows a QP 1-pole breaker installed in an interior from an EQ load center.

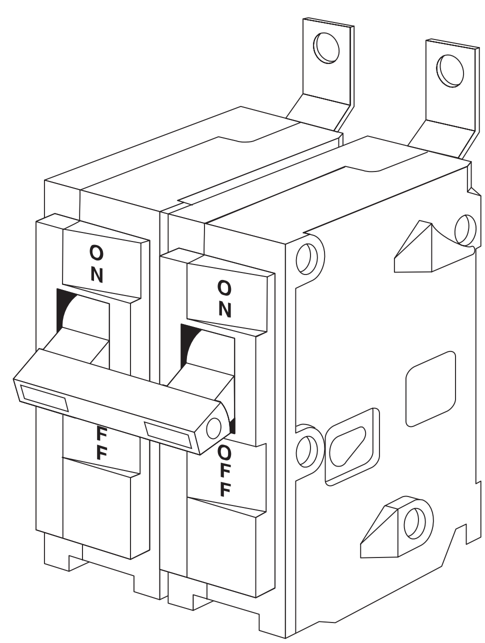


QP breakers can be used in single family homes where the available fault current does not normally exceed 10,000 amps. In some instances where fault current exceeds 10,000 amps, a QPH might be selected. In apartments, condominiums, and commercial buildings the available fault current is normally greater than 10,000 amps. Series-rated circuit breakers can be used. For example, a QPH feeder disconnect, with an interrupting capacity of 22,000 amps might be placed in front of a QP branch with an interrupting capacity of 10,000 amps. There are restrictions when using series-rated breakers. Refer to the Speedfax catalog for acceptable series-rated combinations.



BL and BQ type bolt-on circuit breakers

BL and BQ bolt-on breakers also belong to the EQ family. These breakers bolt directly to the power bus on panelboards in commercial and industrial applications, or the tab on the BQ can also be used to accept wire connectors.



BL 2-Pole

Depending on the specific BL type circuit breaker, the following ratings are available:

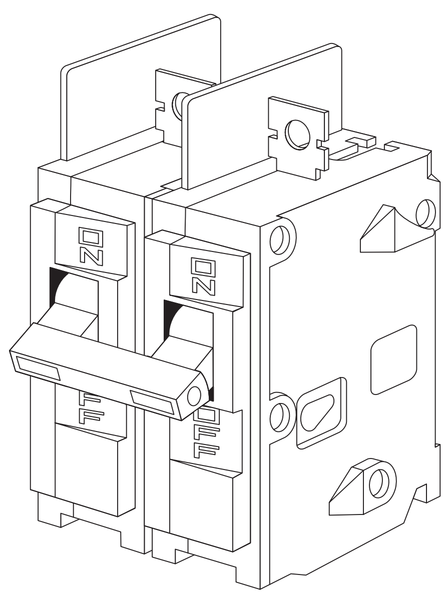
Interrupting rating	10,000, 22,000, or 65,000 amps
Continuous ampere rating	15-125 amps
Volts	120/240 VAC or 240 VAC
Number of poles	1, 2, or 3

For example, referring to the circuit breaker section of the Speedfax catalog, it can be seen that a 1-pole, 15 amp BLH breaker, rated for an interrupting capacity of 22,000 amps at 120/240 VAC is a B115H. A 20 amp breaker is a B120H.

EQ 125A Frame - BLH Low Tab Bolt-on (22,000A IR)

Continuous Current Rating @ 40° C	1-Pole		2-Pole	
	120/240 VAC		120/240 VAC Common Trip	
	Catalog Number	List Price	Catalog Number	List Price
15	B115H		B215H	
20	B120H		B220H	

Another bolt-on circuit breaker belonging to the EQ family is the BQ breaker. A BQ 2-pole breaker is illustrated below.



BQ 2-Pole

Depending on the specific BQ type circuit breaker, the following ratings are available:

Interrupting rating	10,000, 22,000, or 65,000 amps
Continuous ampere rating	15-125 amps
Volts	120/240 VAC or 240 VAC
Number of poles	1, 2, or 3

For example, referring to the circuit breaker section of the Speedfax catalog, it can be seen that a 2-pole, 20 amp BQ breaker, rated for an interrupting capacity of 10,000 amps at 120/240 VAC is a BQ2B020.

EQ 125A Frame - BQ Bolt-on (10,000A IR)

NON-INTERCHANGEABLE TRIP				
Continuous Current Rating @ 40° C	1-Pole		2-Pole	
	120/240 VAC		120/240 VAC Common Trip	
	Catalog Number	List Price	Catalog Number	List Price
15	BQ1B015		BQ2B015	
20	BQ1B020		BQ2B020	

BQD type circuit breakers

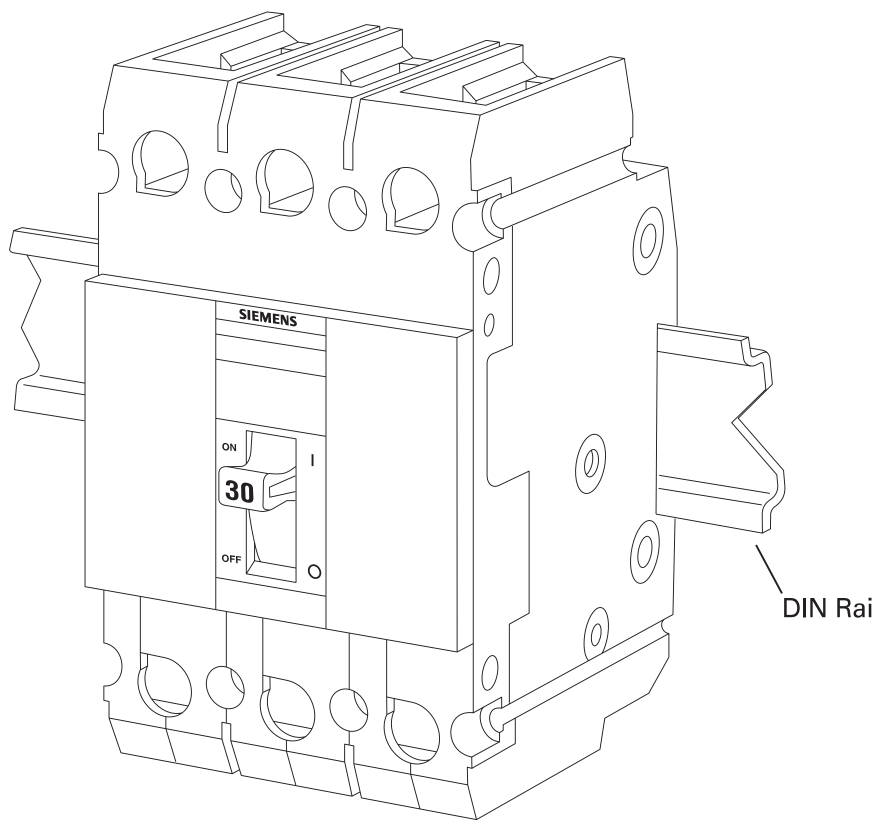
BQD type circuit breakers (not shown) are panel-mount-only for light industrial loads or 277 VAC lighting. Depending on the specific BQD type circuit breaker, the following ratings are available:

Interrupting rating	14,000 or 65,000 amps
Continuous ampere rating	15-100 amps
Volts	277 or 277/480 VAC
Number of poles	1, 2, or 3

CQD type circuit breakers

The CQD type circuit breaker is similar to the BQD, but mounts on a DIN rail. The one and two pole devices have a high intensity discharge (HID) rating for high pressure lighting. Depending on the specific CQD type circuit breaker, the following ratings are available:

Interrupting rating	14,000 or 65,000 amps
Continuous ampere rating	15-100 amps
Volts	120, 240, 277 or 277/480 VAC
Number of poles	1, 2, or 3

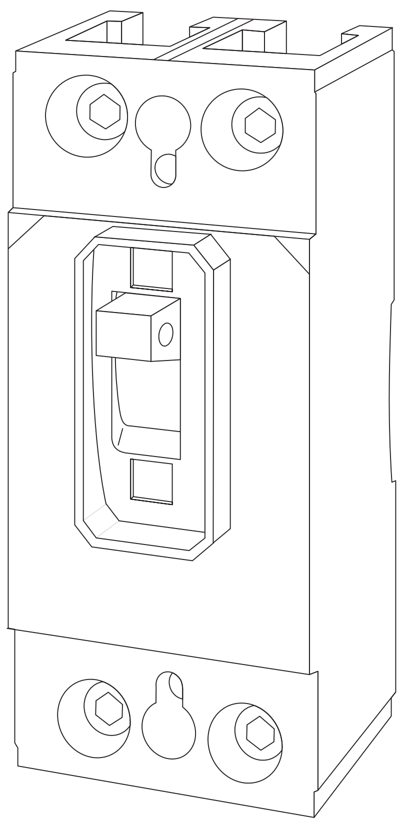


CQD 3-Pole

QJ type circuit breakers

QJ type circuit breakers can be used as main circuit breakers in EQ 3-phase load centers. They are also used as branch circuit breakers in commercial panelboards and switchboards. Depending on the specific QJ type circuit breaker, the following ratings are available:

Interrupting rating	10,000, 22,000, or 42,000 amps
Continuous ampere rating	60-225 amps
Volts	240 VAC
Number of poles	2 or 3

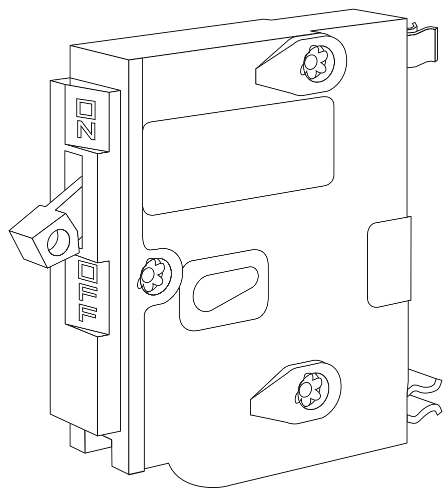


QJ 2-Pole

QD type plug-in circuit breakers for Square D load centers

The QD type circuit breakers are UL Classified for certain Square D Company load centers in place of Square D QO® circuit breakers. A panelboard compatibility list is packaged with each Siemens QD circuit breaker. Siemens QD circuit breakers are to be used only in those Square D panelboards shown on the compatibility list. Depending on the specific QD type circuit breaker, the following ratings are available:

Interrupting rating	10,000 amps
Continuous ampere rating	15-60 amps
Volts	120/240 VAC
Number of poles	1 or 2



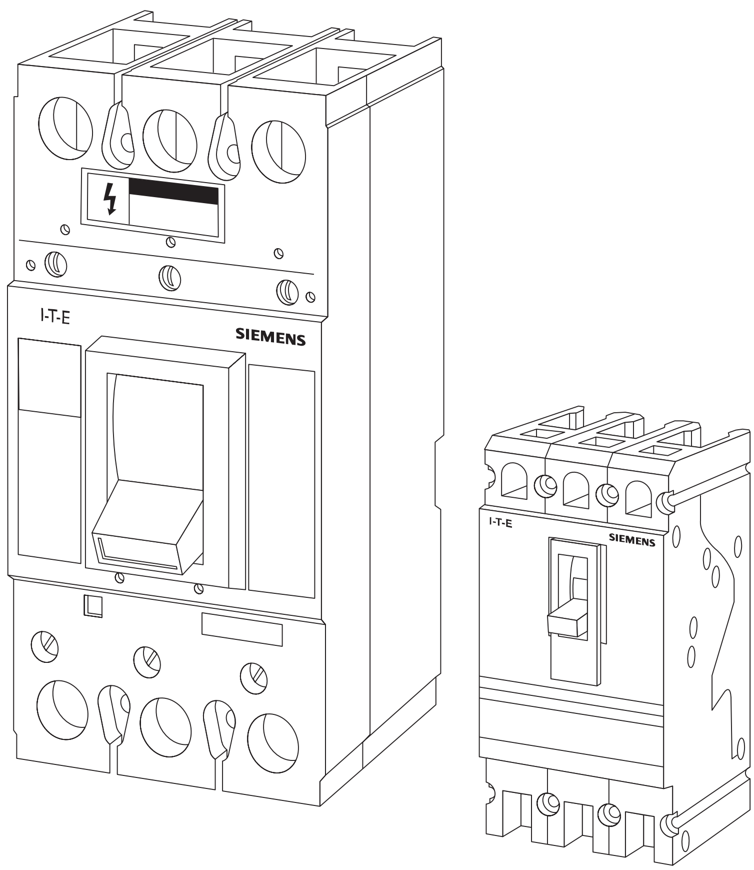
QD 1-Pole

Review 4

1. Part one (1) of the catalog number identifies the circuit breaker's __________ type.
2. An extra heavy duty FD6 type circuit breaker will be identified as __________ .
3. The continuous ampere range of the QP type circuit breakers is from __________ to __________ amps.
4. The Siemens type __________ circuit breaker can be used as a replacement for a Square D QO circuit breaker in certain Square D load centers.
5. The __________ type circuit breaker mounts on a DIN rail.

Sentron™ Series Circuit Breakers

Siemens Sentron™ Series circuit breakers are available in nine frame sizes: ED, FD, JD, LD, LMD, MD, ND, PD, and RD. Sentron Series circuit breakers have a wide range of uses in commercial and industrial applications, such as: combination motor starters, control centers, and distribution and power circuits in panelboards and switchboards, machine tools, resistance welder control panels, service entrance protection and main distribution feeder circuits in switchboards.



Ampere rating

Sentron Series breakers are available with ampere ratings from 125 to 2000 amps. Each frame is divided into specific ampere ratings. For example, in the following table it can be seen that the ED frame has a maximum continuous current range of 15 to 125 amps. When selecting a circuit breaker, refer to the Siemens Speedfax® catalog for specific product ratings.

Frame	Ampere Rating	Maximum Continuous Ampere Ranges
ED	125	15-125
FD	250	70-250
JD	400	200-400
LD	600	250-600
LMD	800	500-800
MD	800	500-800
ND	1200	800-1200
PD	1600	1200-1600
RD	2000	1800-2000

Voltage rating

Breakers are rated according to the maximum voltage they can handle. Sentron breakers are available with the voltage ratings shown below. It should be noted that breakers may be applied on systems with lower voltages than their maximum voltage rating, but never on systems above their maximum voltage ratings.

UL Voltage Ratings		IEC Voltage Ratings
120 VAC	125 VDC	220 VAC
240 VAC	250 VDC	240 VAC
277 VAC	500 VDC	380 VAC
480 VAC		415 VAC
600 VAC		500 VAC

Interrupting rating

The interrupting rating refers to the level of fault current that a breaker can safely interrupt. Sentron breakers are available with interrupting ratings from 10,000 to 200,000 amps. A color coded label system is used to identify the maximum interrupting rating.

Color Label	Interrupting Category	Voltage Range	Maximum Interrupting Current
Blue	Standard	240 - 600 VAC	65,000 amps
Black	High Interrupting	240 - 600 VAC	100,000 amps
Red	Current Limiting	240 - 600 VAC	200,000 amps

The easiest way to determine the interrupting rating of a specific circuit breaker is with the interrupting selector in the Speedfax catalog. For example, if a customer required a 100 amp Sentron Series circuit breaker capable of interrupting 10,000 amps at 240 VAC, the ED2 could be selected. However, if the customer required a 100 amp Sentron circuit breaker capable of interrupting 200,000 amps at 480 VAC, either the CED6 or the CFD6 could be selected. Another column, not shown here, references a page number where more detail can be found concerning the selected circuit breaker.

I-T-E® Molded Case Circuit Breakers

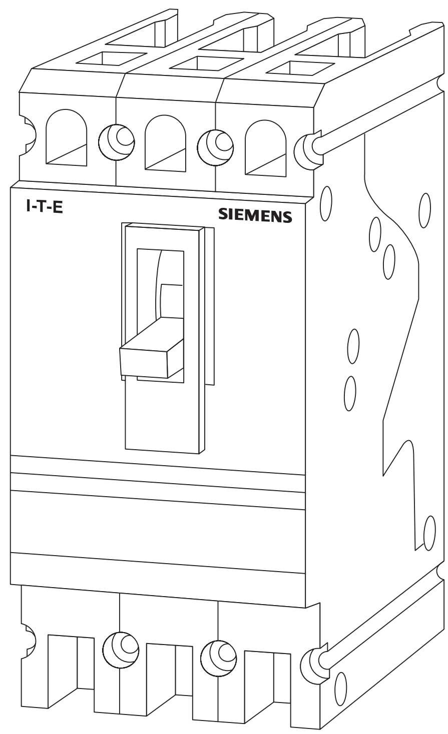
Selection/Application - Interrupting Selector

UL Interrupting Rating	Voltage Rating	Continuous Current	Breaker Type
10,000	120, 120/240	15-100	ED2
		15-125	QP, QT, BQ
		125-225	QPP
	240	15-100	ED2
		15-125	QP, BQ, BL
		60-225	QJ2
	277	15-30	BQC
200,000	240	15-125	CED6
		70-250	CFD6
		200-400	CJD6, SCJD6, HHJD6, HHJXD6
		450-600	CLD6, SCLD6, HHLD6, HHLXD6
		400-800	CMD6, SCMD6
		800-1200	CND6, SCND6
		1200-1600	CPD6
	480	15-125	CED6
		70-250	CFD6

ED frame Sentron circuit breakers

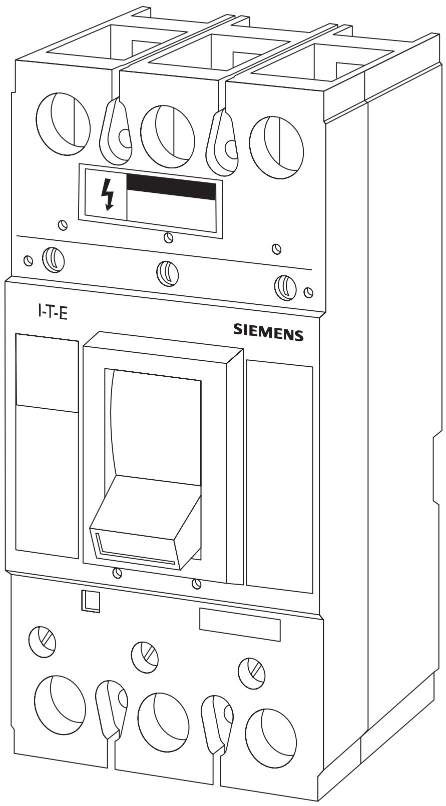
The ED frame circuit breaker is the smallest and least expensive circuit breaker in the Sentron Series family. Its frame ampere rating is 125 amps. ED frame circuit breakers are used in individual enclosures, switchboards, panelboards and load centers. ED frame circuit breakers are available as a molded case switch, instantaneous magnetic trip circuit breaker (motor circuit protection), or thermal magnetic circuit breaker which provides complete overload and short circuit protection. The trip circuit is non-interchangeable. Fixed instantaneous trip values are shown in the following chart:

Ampere Rating	Fixed Instantaneous Band
15-25 30-125	400-700 600-1000



Other Sentron Series circuit breakers

The other Sentron Series circuit breakers (FD, JD, LD, LMD, MD, ND, PD, and RD) range in frame size from 250 to 2000 amperes.



Some Sentron Series circuit breakers, like the JXD6 are UL listed for reverse feed applications. This means that power can be applied to the load side of the circuit breaker. Depending on the specific circuit breaker, Sentron Series circuit breakers are available as a molded case switch, instantaneous magnetic trip circuit breaker (motor circuit protection), or thermal magnetic circuit breaker which provides complete overload and short circuit protection.

Some circuit breakers, like the FD6 breaker have interchangeable trip units. Other circuit breakers, like the JXD6 have non-interchangeable trip units. The instantaneous trip values are externally adjustable. For example, a CFD6 circuit breaker with a 200 ampere trip unit was used during the time-current curve discussion. It can be seen from the following table that the trip unit can be adjusted in eight steps from 900 to 2000 amps.

Breaker Ampere Rating	Nominal Instantaneous Values							
	Low	2	3	4	5	6	7	High
70-90	600	640	690	730	770	810	850	900
100-110	700	770	840	920	990	1060	1140	1200
125-150	800	900	1000	1100	1200	1300	1400	1500
175-200	900	1060	1210	1370	1520	1780	1930	2000
225-250	1100	1300	1500	1700	1900	2100	2300	2500

Selecting a Sentron Series circuit breaker

Selecting a circuit breaker requires the use of the Siemens Speedfax catalog. Suppose a customer requested a Sentron Series interchangeable trip, 2-pole circuit breaker with a continuous ampere rating of 300 amps, capable of interrupting an available fault current of 35,000 amps at 600 volts. The first place to look would be the Interrupting Selector of the Speedfax catalog. It can be seen from the following example that there are four possible choices: HJD6, HJXD6, HLD6, and HLXD6.

I-T-E® Molded Case Circuit Breakers

Selection/Application - Interrupting Selector

UL Interrupting Rating	Voltage Rating	Continuous Current	Breaker Type
35,000	480	70-250 200-400 250-600 450-600	FXD6, FD6 JXD6, JD6, SJD6 LD6, SLD6 LXD6
	600	200-400	HJD6, HJXD6 HLD6, HLXD6

The next step would be to go to the Discount Schedule. The JD frame is a 400 ampere frame and the LD frame is a 600 ampere frame. If the customer does not need the larger frame, the JD frame will be a good choice. The right catalog number is HJD62B300.

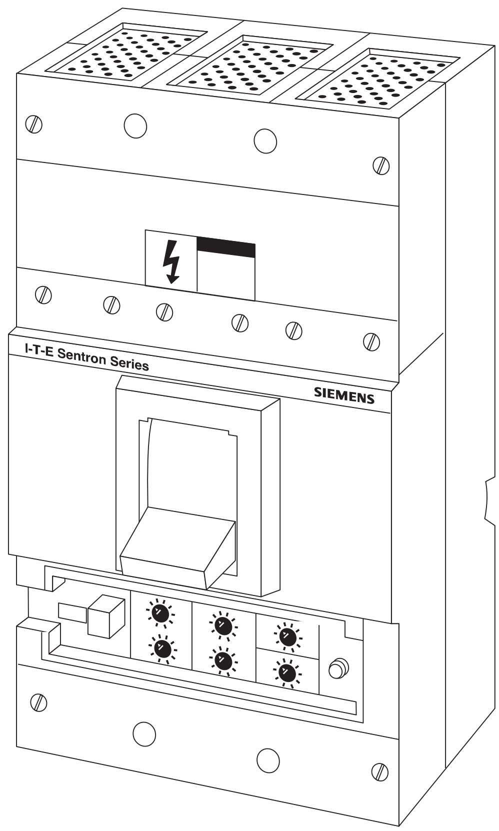
JD 400A Frame - Type HJD6

2-Pole 600 VAC, 250 VDC

Interchangeable Trip		
Continuous Current Rating @ 40° C	Complete Breaker Unassembled	
	Catalog Number	List Price
200	HJD62B200	
225	HJD62B225	
250	HJD62B250	
300	HJD62B300	

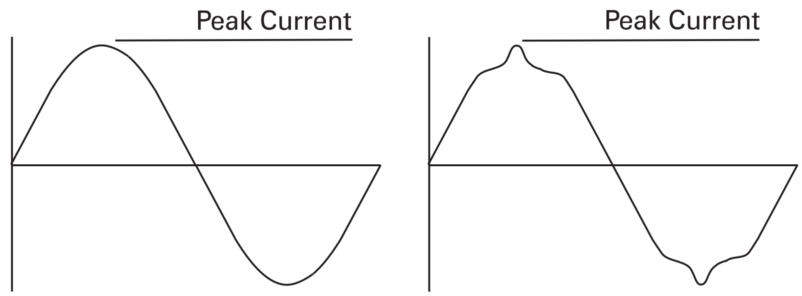
Sentron™ Series Digital Circuit Breakers

The Sentron™ Series circuit breakers are also available in a digital circuit breaker version, referred to as Sensitrip® III. Sensitrip III circuit breakers utilize a microcomputer which makes it possible to customize overcurrent protection which is matched exactly to the loads of an electrical system.



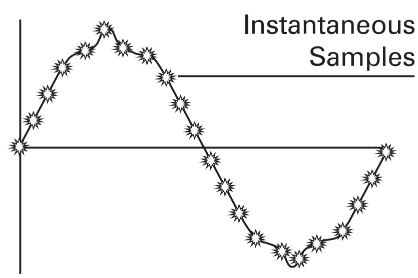
True RMS sensing

Some solid state circuit breakers react to peak currents of a sine wave. This method accurately measures the heating effect of the current on sine waves that are perfectly sinusodial. Frequently, however, sine waves are distorted due to harmonics on the line. When this happens, peak current measurement does not adequately evaluate the true heating effect of the current.



Sinusodial Wave   Distorted Wave

Sensitrip III digital circuit breakers use true RMS sensing to detect what is really happening with current. RMS (root-mean-square) current is the effective value of AC current. Sensitrip III RMS sensing capabilities take multiple, instantaneous "samples" of the actual current waveshape for a more accurate picture of its true heating value.



Being able to monitor true RMS current precisely is becoming more important in today's electrical distribution systems because of the increasing number of power electronic devices being used that can distort the waveform of the current. The microcomputer in Sensitrip III breakers samples the AC current waveform many times a second, converting each value into a digital representation. The microcomputer then uses the samples to calculate the true RMS value of the load current. This capability allows Sensitrip III breakers to perform faster, more efficiently and with repeatable accuracy.

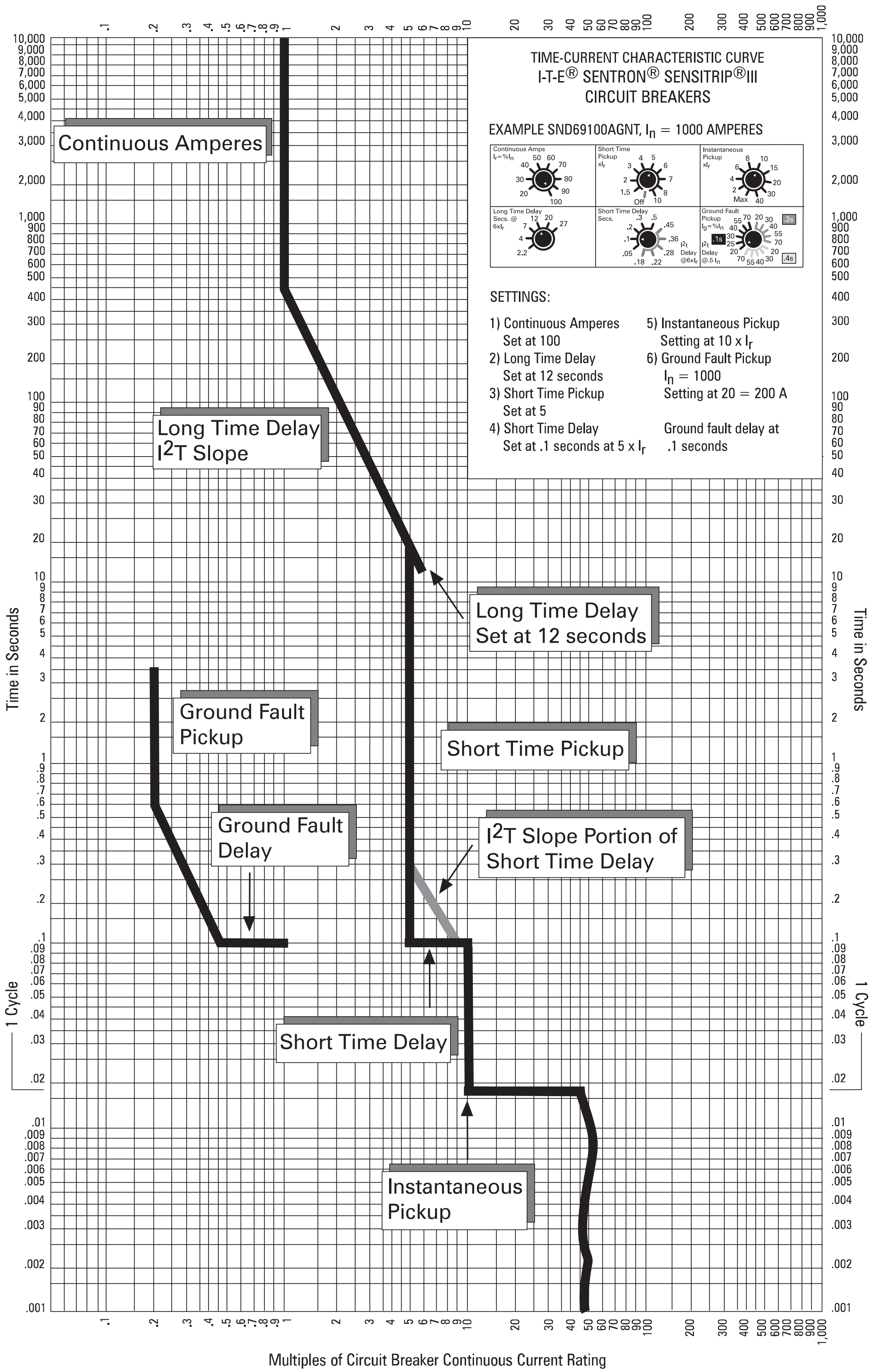
Maximum continuous ampere rating

Sensitrip III breakers are available in 400 through 1600 amp, 600 VAC and below, frames. A color label system is used to identify the interrupting category of the circuit breaker.

Blue = standard interrupting rating
Black = high interrupting rating
Red = current limiting

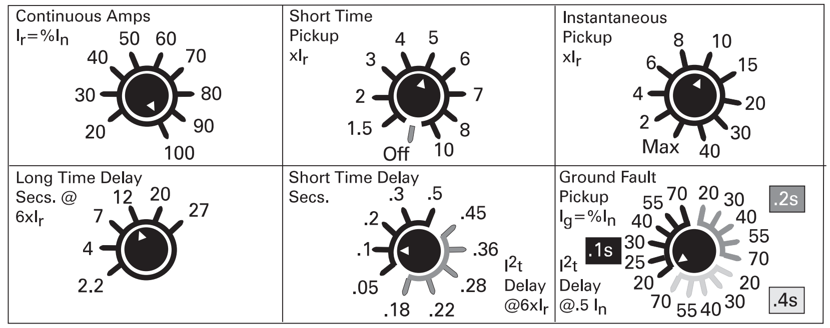
Frames are grouped according to maximum current. For example, it can be seen from the following table that a 1200 ampere frame Sensitrip III is available with 800, 1000, or 1200 maximum continuous amperes. Maximum continuous amperes is also referred to as <u>nominal</u> ampere rating (I_n).

Frame Size	Maximum Continuous Amperes I_n	Continuous Ampere Range I_r = % of I_n
400 A	200 300 400	40-200 60-300 80-400
600 A	300 400 500 600	60-300 80-400 100-500 120-600
800 A	600 700 800	120-600 140-700 160-800
1200 A	800 1000 1200	160-800 200-1000 240-1200
1600 A	1200 1400 1600	240-1200 280-1400 320-1600


TIME-CURRENT CHARACTERISTIC CURVE
I-T-E® SENTRON® SENSITRIP®III
CIRCUIT BREAKERS
EXAMPLE SND69100AGNT, I_n = 1000 AMPERES
SETTINGS:
1) Continuous Amperes Set at 100
2) Long Time Delay Set at 12 seconds
3) Short Time Pickup Set at 5
4) Short Time Delay Set at .1 seconds at 5 x I_r
5) Instantaneous Pickup Setting at 10 x I_r
6) Ground Fault Pickup I_n = 1000 Setting at 20 = 200 A
Ground fault delay at .1 seconds
Continuous Amperes
Long Time Delay I^2T Slope
Long Time Delay Set at 12 seconds
Ground Fault Pickup
Short Time Pickup
Ground Fault Delay
I^2T Slope Portion of Short Time Delay
Short Time Delay
Instantaneous Pickup
Time in Seconds
1 Cycle
Multiples of Circuit Breaker Continuous Current Rating

Adjustable functions

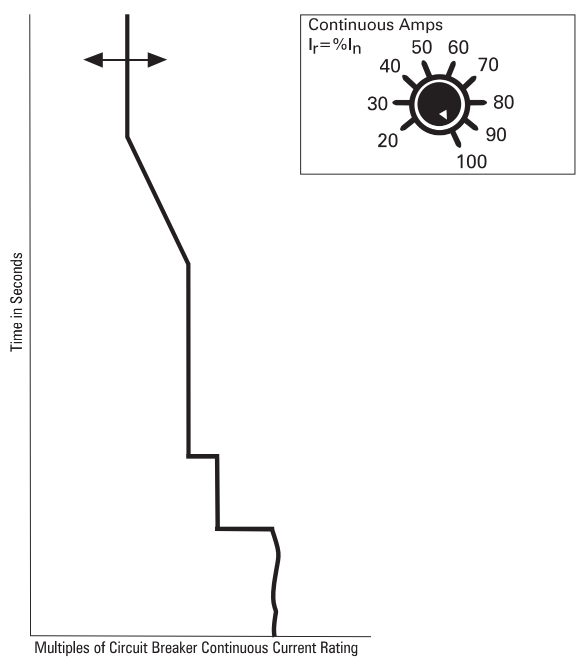
Curve shaping allows adjustment of individual circuit breakers for proper coordination between upstream and downstream devices. The basic adjustable functions are shown in the following illustration:



The time-current curve on the preceding page reflects one possible setup for a 1200 ampere frame Sensitrip III circuit breaker with a nominal (maximum continuous ampere) rating of 1000 amps. This time-current curve will be the basis for discussing the adjustable features of the Sensitrip III circuit breakers.

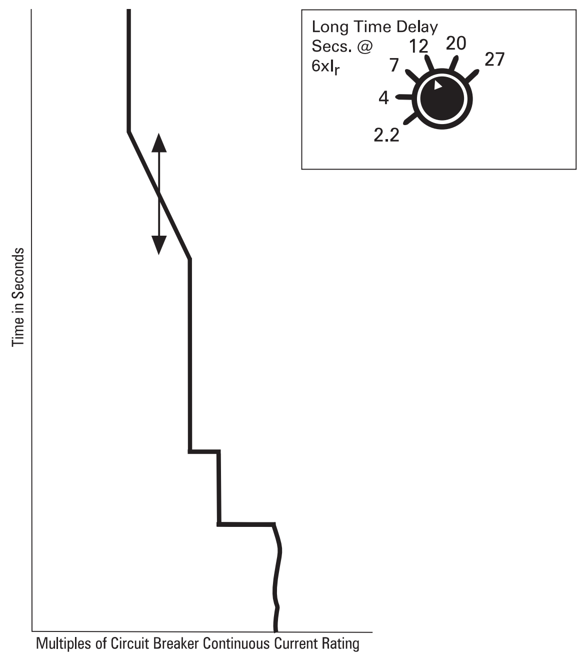
Continuous Amps (I_r)

Continuous Amps (I_r) varies the level of current the circuit breaker will carry without tripping. I_r is a percentage of the circuit breaker's nominal rating (I_n). Continuous amps can be adjusted from 20 to 100 percent of the circuit breaker's nominal rating. For example, a 1000 amp Sensitrip III breaker can be changed from 1000 amps to 800 amps by adjusting the breaker continuous amps setting to 80%.



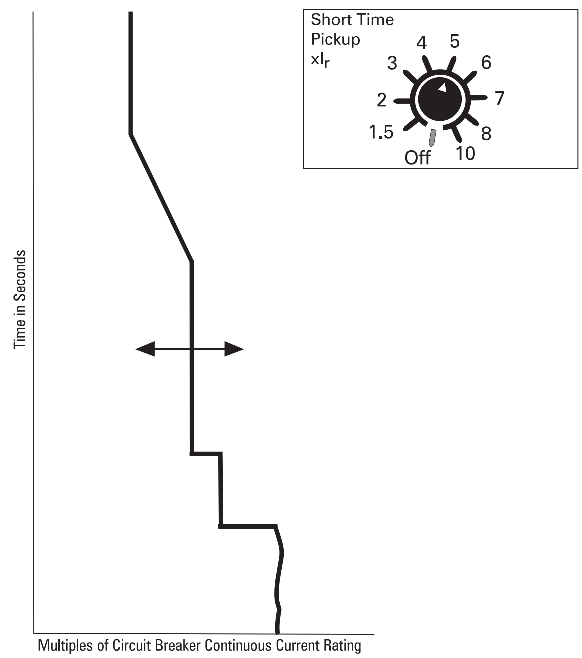
Long-time delay

Long-time delay causes the breaker to wait a certain amount of time to allow temporary inrush currents, such as those encountered when starting a motor, to pass without tripping. The adjustment is from 2.2 to 27 seconds at six times the continuous amps (I_r) setting. As shown below, the long-time delay effects the position of an I^2T slope. This means that lower levels of current will allow the breaker to remain online for longer periods of time.



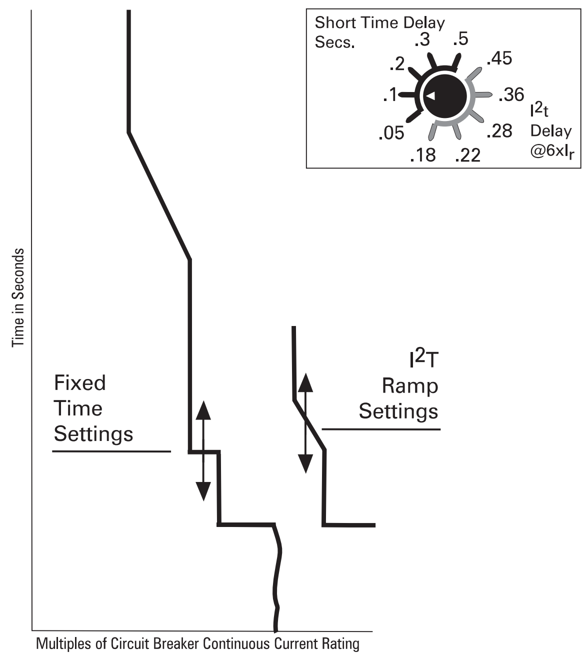
Short-time pickup

Short-time pickup is used for selective tripping. The short-time pickup function determines the amount of current the breaker will carry for a short period of time, allowing down-stream protective devices to clear short-circuits without tripping the upstream device. Short-time pickup is adjustable from 1.5 to 10 times the trip unit ampere setting (I_r). For example, a 1000 ampere frame can be adjusted to trip any-where from 1500 to 10,000 amps. The switch also has an "OFF" position to eliminate short-time pickup and short-time delay.



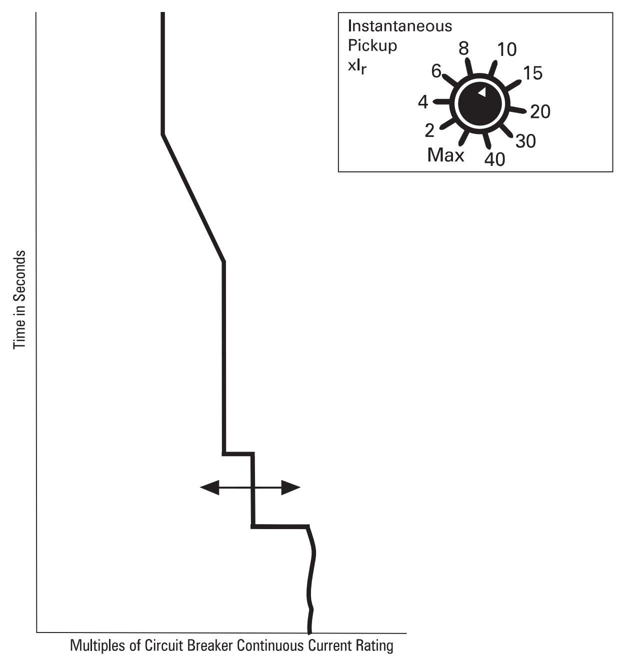
Short-time delay

Short-time delay, used in conjunction with short-time pickup, controls the time involved in postponing a short-time pickup trip. There are two modes: fixed time, or I^2T ramp. Fixed time is adjustable from .05 to .5 seconds. The I^2T ramp mode is adjustable from .18 seconds to .45 seconds, providing a short inverse time ramp. This allows better coordination with downstream thermal-magnetic circuit breakers and fuses. A fixed instantaneous trip point of 10,000 amps trips the breaker automatically and overrides any pre-programmed instructions .



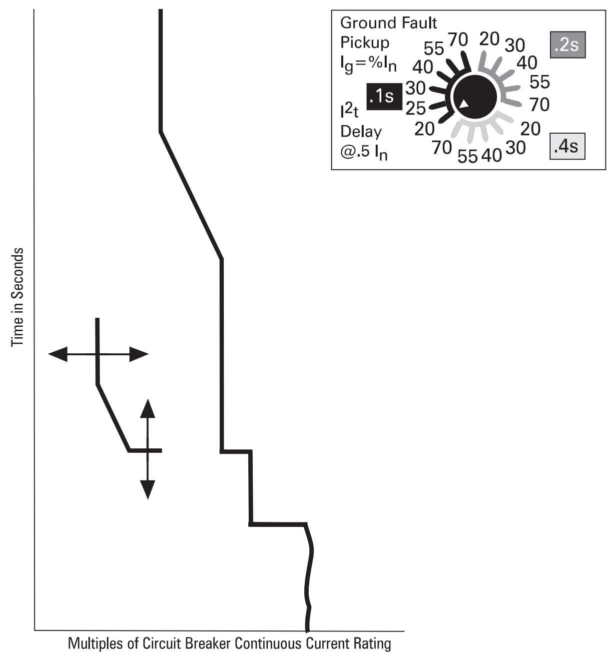
Instantaneous pickup

Instantaneous pickup is used to trip the circuit breaker with no intentional delay at any current between 2 and 40 times the breaker's continuous ampere setting (I_r). In this example instantaneous pickup has been set to 10 times the continuous amp setting, or 10,000 amps (10 x 1000) with a continuous amp setting of 1000 amps. In this case a higher setting would still trip at 10,000 amps due to a fixed instantaneous override of 10,000 amps which automatically trips the breaker regardless of the instantaneous pickup setting. If the continuous amp setting had been 300 amps, setting the instantaneous pickup at 10 would make the instantaneous setting equal to 3000 amps, well below the fixed instantaneous override.

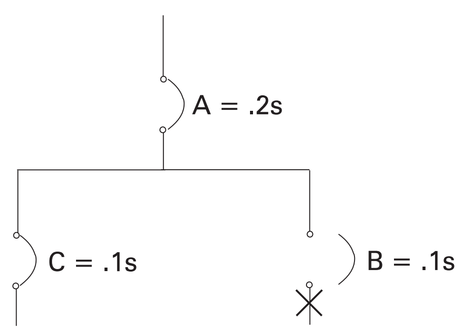


Ground fault pickup

Ground fault pickup controls the amount of ground fault current that will cause the breaker to interrupt the circuit. The adjustment can be set from 20 to 70% of the maximum breaker rating. In compliance with *NEC* 230-95, no trip point setting exceeds 1200 amps. The ground fault pickup is divided into three sections; .1s, .2s, and .4s. This feature adds a time delay of .1, .2, or .4 seconds to the breaker's trip when a ground fault occurs.



The ground fault pickup time delay feature is useful for circuit breaker coordination. In the following illustration, upstream breaker "A" has been set to .2s and downstream breakers "B" and "C" have been set to .1s. A ground fault occurring in the circuit supplied by "B" will trip the "B" breaker without disturbing "A" or "C".



Review 5

1. Sentron Series breakers are available in frame sizes from 125 to ___________ amps.

2. A ___________ color label is used to identify a current limiting Sentron Series breaker.

3. True ___________ sensing is an advantage of the Sentron Sensitrip III circuit breakers over thermal-magnetic breakers.

4. Setting the continuous amps setting of a Sensitrip III 1200 amp breaker to 50% changes the breaker's continuous current trip point to ___________ amps.

5. Long-time delay on a Sensitrip III is adjustable from ___________ to ___________ seconds.

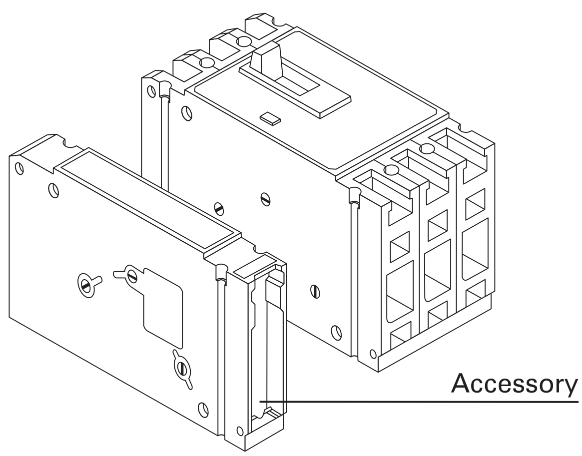
6. If a 1000 amp Sensitrip III breaker's continuous amps is set to 100% and instantaneous pickup is set to "8", the breaker will trip instantaneously (without intentional delay) at ___________ amps.

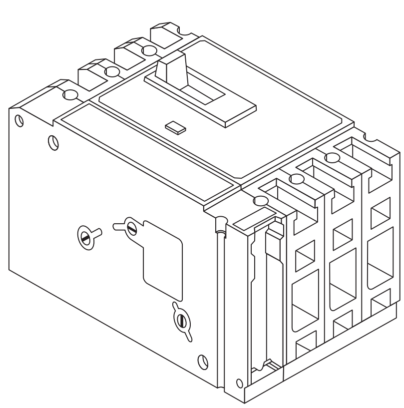
Internal Accessories

ED frame circuit breaker accessories

An accessory is an addition that adds to the performance of a circuit breaker or adapts the circuit breaker for specific application requirements. Various accessories are available for Siemens molded case circuit breakers. Internal accessories are used to modify a breaker's perfomance. The four internal accessories are shunt trip, undervoltage trip, auxiliary switches, and bell alarm.

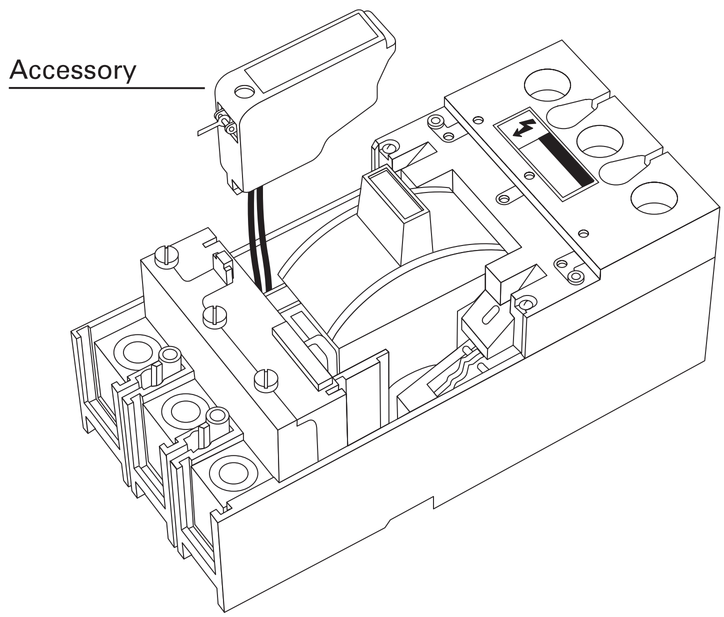
Mounting of internal accessories is handled differently for ED frame circuit breakers than for the other Sentron™ Series type circuit breakers. ED frame circuit breaker internal accessories are mounted on the side of the circuit breaker as shown in the following illustration.

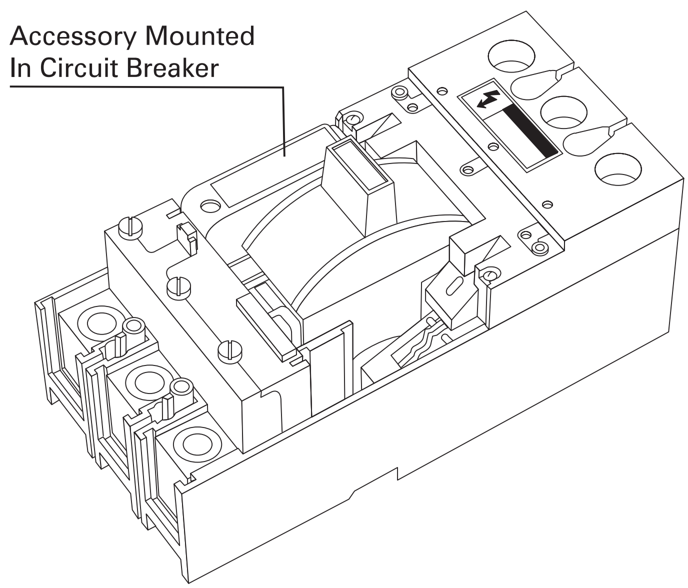




Other Sentron Series internal accessories

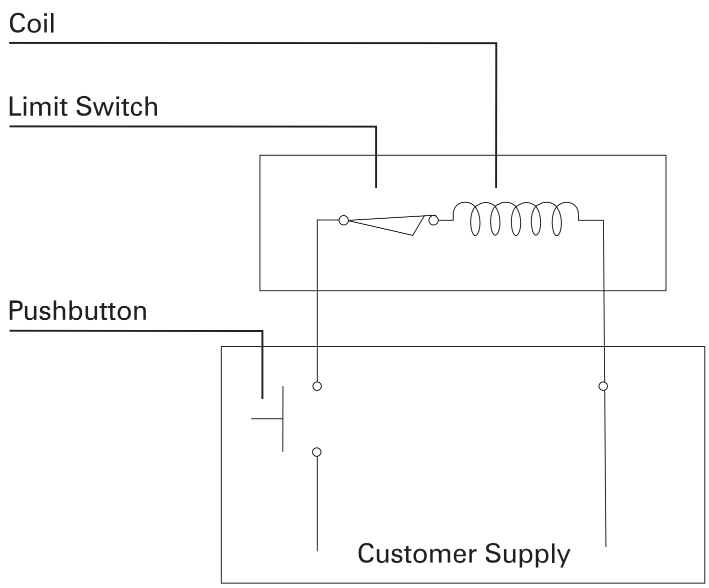
To mount internal accessories in all other Sentron Series circuit breakers, the cover is removed and the accessories installed as shown in the following illustrations.





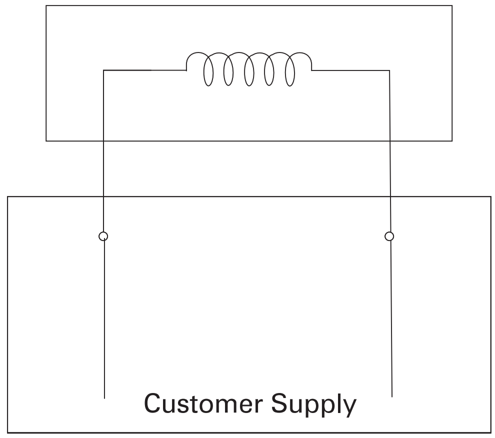
Shunt trip

It is sometimes necessary to trip a breaker from a remote location. For example, if someone were to get caught in a piece of machinery, anyone can push a "panic button" tripping the breaker. One or all critical circuit breakers may be tripped at the push of a button from a distant control point by use of a shunt trip device. The shunt trip device consists of a coil in series with a limit switch. When the circuit breaker contacts are closed the limit switch is closed. Depressing a customer-supplied pushbutton energizes the shunt trip coil, causing the breaker's mechanical latch to disengage the trip mechanism and opening the circuit breaker's contacts. When the circuit breaker's contacts open the limit switch also opens, removing power from the shunt trip coil. As with any trip the breaker must be reset manually.



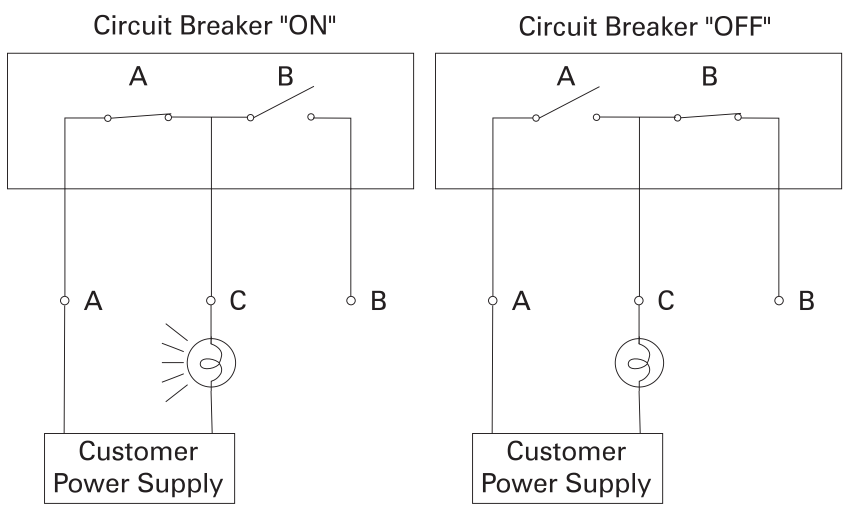
Undervoltage trip

The undervoltage trip device is designed to automatically trip the circuit breaker when the supply voltage drops to a low value (35-70% of nominal line voltage). The device also prevents the circuit breaker from being reclosed until the supply voltage returns to at least 85% of its normal level.



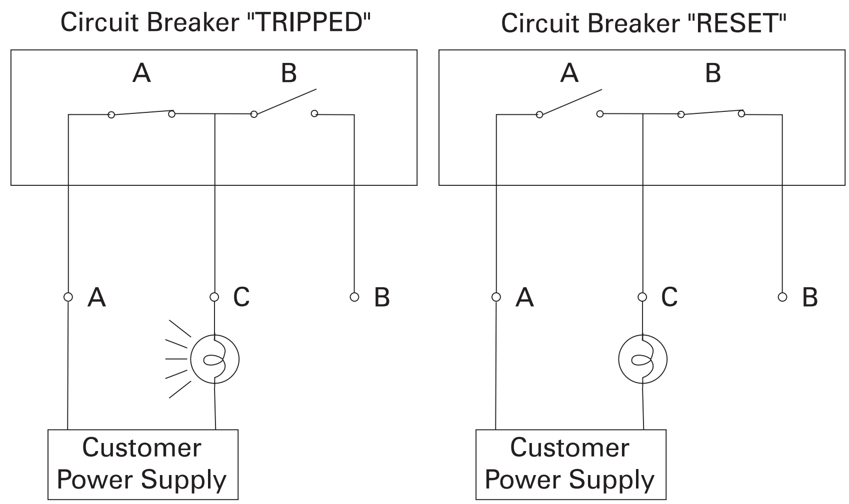
Auxiliary switch

An auxiliary switch consists of one set of normally open and one set of normally closed contacts. Contact "A" is open when the circuit breaker is in the "Off" or "Tripped" conditions. Contact "B" is closed when the circuit breaker is in the "Off" or "Tripped" conditions. This accessory is used to indicate whether a circuit breaker is on or off from a remote location. For example, in the following illustration an indicator light is connected to a customer's power supply through contact "A". When the circuit breaker is switched on, the light illuminates, indicating the circuit breaker's contacts are closed and the breaker is supplying power to the load. When the circuit breaker is switched off, contact "A" opens, turning the indicator light off.



Bell alarm switch

The alarm switch differs from the auxiliary switch in that it only functions when the circuit breaker trips. Opening and closing the circuit breaker by means of the operating handle does not affect the position of the alarm contacts. The “A” contact closes when the circuit breaker trips. The “B” contact opens when the circuit breaker trips. A horn or indicator light can be used to indicate the circuit breaker has tripped.



Accessory combinations

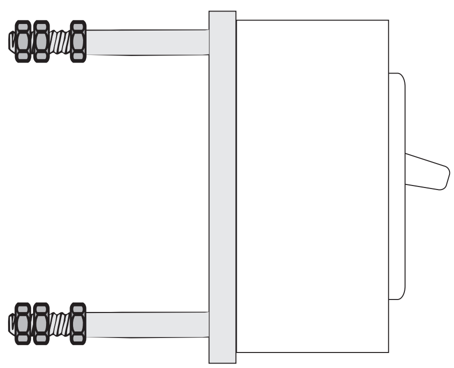
The maximum number of internal accessory combinations available for each breaker type is shown in the Speedfax catalog.

External Accessories

External accessories make circuit breakers suitable for specific applications. A variety of external accessories are available.

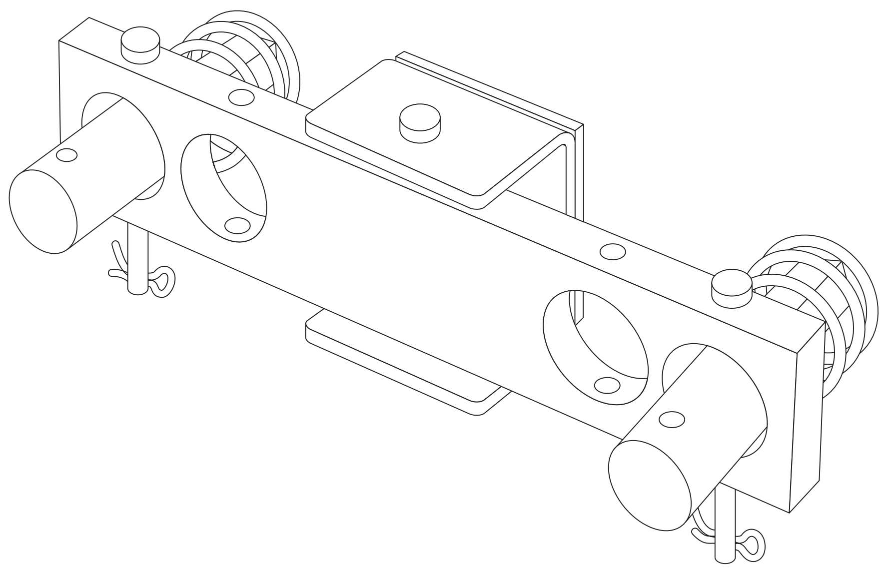
Rear connecting studs

Rear connecting studs are used for switchboard mounting of circuit breakers. Rear connecting studs are available in various lengths of either bus or cable connections.



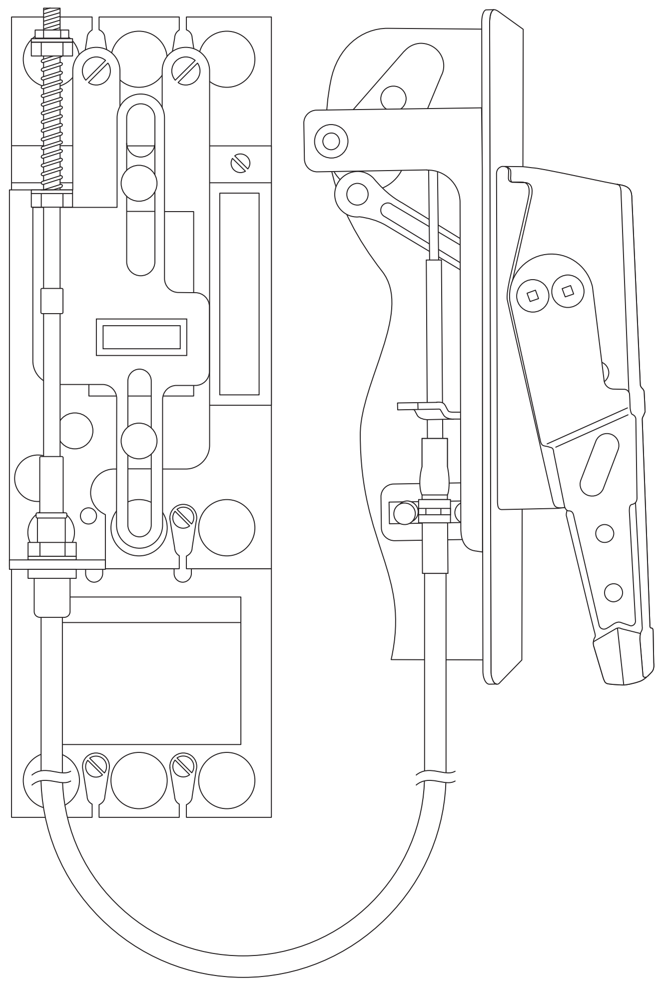
Mechanical interlock rocker arm

The rocker arm assembly is used to mechanically interlock two adjacent circuit breakers of the same frame configuration. Both circuit breakers can be open at the same time, but this allows only one breaker to be closed at any time.



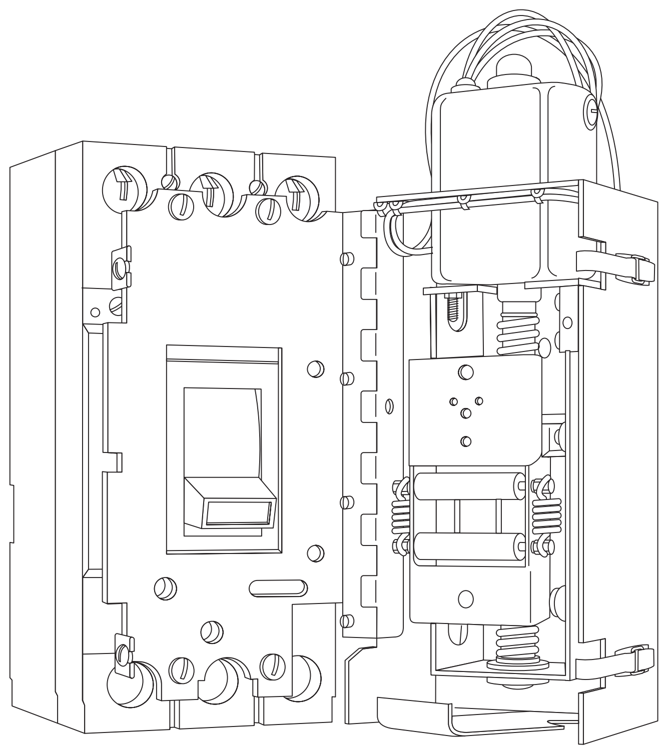
Max-Flex™ handle operator

The I-T-E® Max-Flex™ flange-mount handle operator is a flexible cable control device used for remote switching of a circuit breaker within an enclosure. The flexible cable is connected directly to the breaker switch handle at one end and a factory installed switch at the other end. The remote handle operator located on the enclosure is used to perform mechanical open/close switching operations. The cable comes in standard 3 or 4 foot lengths, however, lengths up to 20 feet can be ordered. When using a standard circuit breaker handle extension, it is necessary to exactly align the breaker with the extension. With the Max-Flex handle operator this exact alignment isn't necessary.



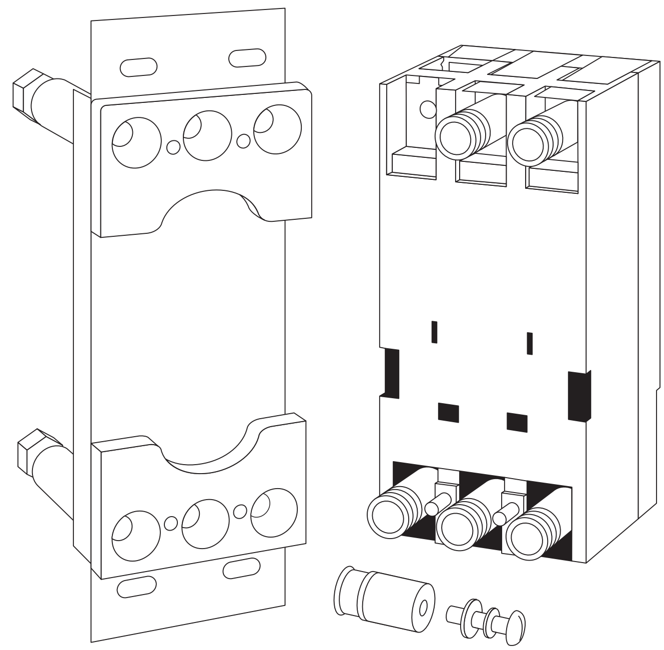
Telemand® electric motor operator

The I-T-E Telemand® electric motor operator is designed to open, close and reset a circuit breaker by remote control. It is mounted on the face of the circuit breaker so that it can engage the breaker's operating handle. The built-in motor is connected to remote pushbuttons. Pressing the "ON" pushbutton causes the electric motor to move the circuit breaker to the "ON" position. Pressing the "OFF" pushbutton causes the electric motor to move the circuit breaker to the "OFF" position. To reset the circuit breaker from the tripped position, press the "OFF" pushbutton to move the handle to the "OFF" position. Then press the "ON" pushbutton to the close the breaker contacts.



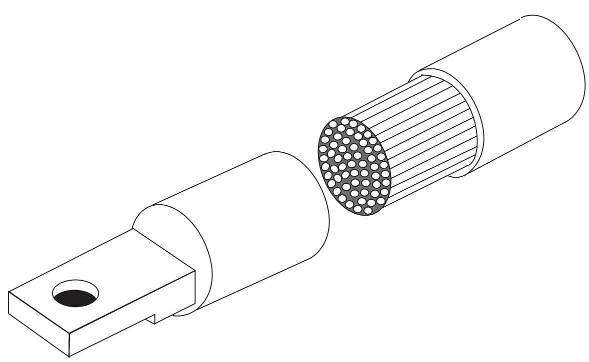
Plug-in assemblies

Plug-in mounting assemblies provide means for a quick change out of circuit breakers and molded case switches without disturbing the power connections.



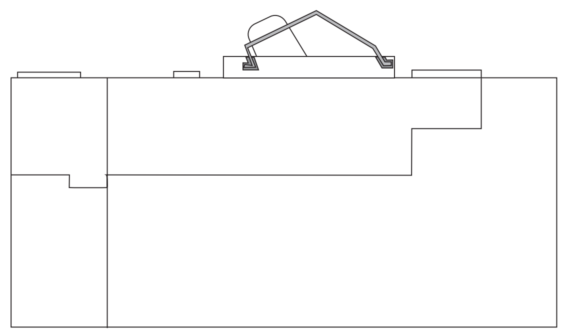
Terminal connectors

Various terminal connectors are available to permit easy front connection of either copper or aluminum insulated conductors to the terminal of a circuit breaker or molded case switch. Terminal connectors are designed and tested to accommodate the conductors or requirements outlined within the related UL standards.



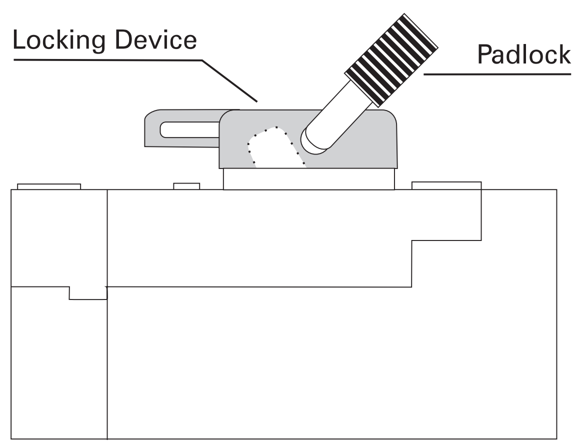
Handle blocking device

A handle blocking device is a non-lockable device that may be added to a circuit breaker to secure the handle in either the "ON" or "OFF" position. The device slides into slots provided on the circuit breaker. This device prevents accidental operation of the handle. The device will not prevent the circuit breaker from tripping when blocked in the "ON" position. The following illustration shows the handle blocked in the "ON" position.



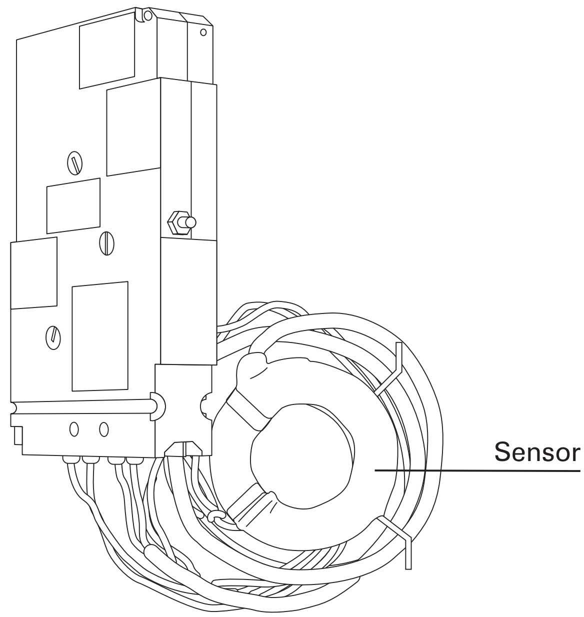
Handle padlocking device

The handle padlocking device is used to padlock the circuit breaker in the "ON" or "OFF" position. The device mounts over the handle and a customer supplied padlock is used to lock the handle. The breaker will still trip if locked in the "ON" position.



Ground fault sensor for ED frame circuit breakers

An external ground fault sensor is available for the ED frame circuit breakers. The relay functions to de-energize a circuit within an established period of time when the current to ground exceeds a predetermined value. This is done by detecting a 5 mA ± 1 mA or 30 mA ± 6mA current difference between two or more load conductors passing through the sensor.



Review 6

1. A ___________ - ___________ option is used when it is necessary to trip a breaker from a remote location, but cannot be used to reset the breaker.

2. An ___________ ___________ device is used to automatically trip a circuit breaker when the supply voltage drops.

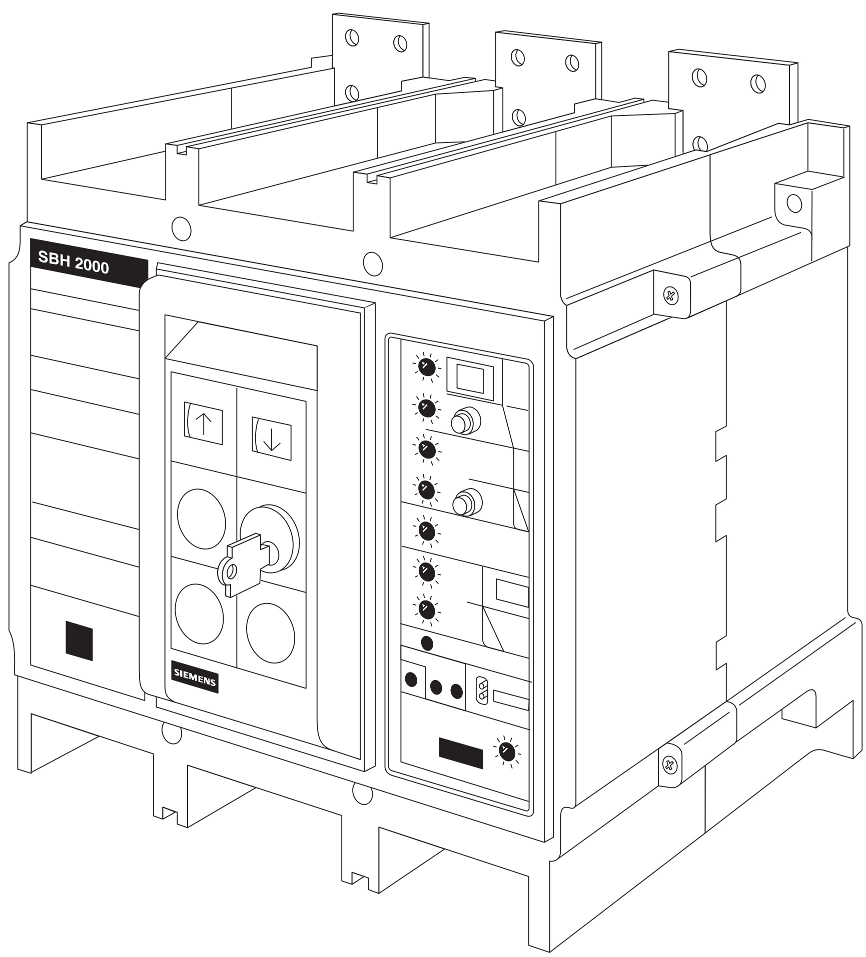
3. The advantage of the Max-Flex flange-mount handle operator versus a handle extender is that ___________ ___________ isn't necessary.

4. A ___________ ___________ is used to prevent two adjacent circuit breakers from being "ON" at the same time.

5. ___________ - ___________ mounting assemblies provide a means for a quick change out of circuit breakers without disturbing the power connections.

Insulated Case Circuit Breakers

The discussion to this point has been on molded case circuit breakers. Another type of circuit breaker is the low voltage air circuit breaker. Instead of having a molded case, the operating mechanism of a low voltage air circuit breaker is assembled on a metal frame for use in switchboards and switchgear. The components of a low voltage air breaker are larger and heavier for severe duty applications. Unlike molded case circuit breakers, low voltage air breakers have high short time withstand capabilites (breaker's ability to "ride through" a short circuit event). Molded case circuit breakers, on the other hand, have high interrupting ratings. A circuit breaker was needed that could supply high short time withstand and high interrupting ratings. Insulated Case circuit breakers (ICCBs) were designed to fill that need.



Ampere ratings

There are six frames: 800, 1200, 2000, 3200, 4000, and 5000 amps. Interchangeable rating plugs and a continuous current adjustment are provided with each trip unit. ICCBs can be applied in applications from 100 to 5000 amps through 600 VAC. The frame ampere rating is determined by the current sensors in the breaker.

Breaker Frame Size	Breaker Frame Ampere Ratings (I_n)
800 A	400 800
1200 A	1200
2000 A	1600 2000
3200 A	2500 3200
4000 A	2500 3200 4000
5000 A	5000

Interrupting ratings

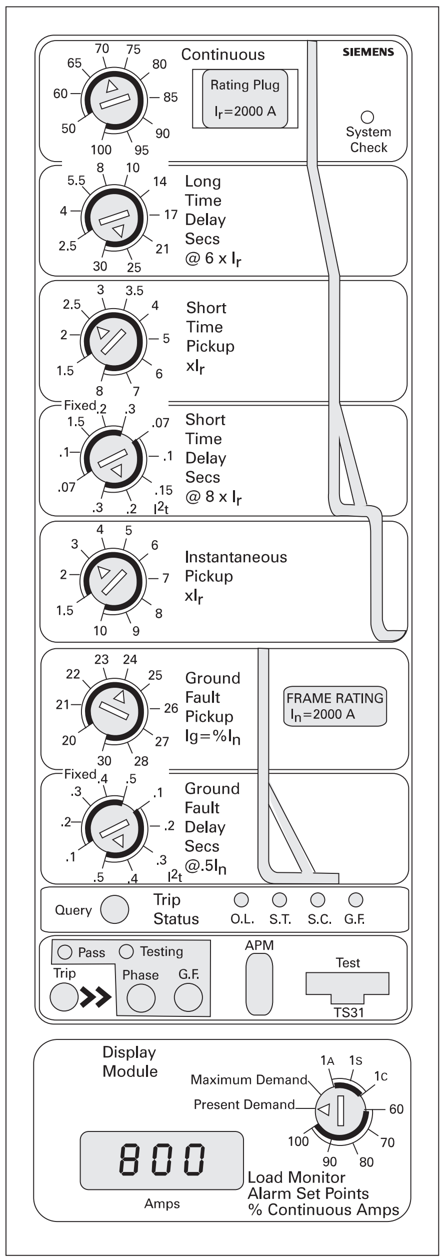
ICCBs use color coded labels to clearly identify the interrupting class of each breaker. A removable rating plug installed on the trip unit allows a user to select a current rating from 50 to 100 percent of the current sensor value. The following chart reflects the RMS ampere interrupting rating of Siemens insulated case circuit breakers.

Optional Ratings and Application Voltages	Breaker Frame Size		
	800 A 1200 A	2000 A	3200 A 4000 A 5000 A
Alternate AIR (Blue Label - "SBA")			
@ 240 VAC	65 kA	85 kA	NA
@ 480 VAC	65 kA	65 kA	NA
@ 600 VAC	42 kA	50 kA	NA
Standard AIR (Black Label - "SBS")			
@ 240 VAC	100 kA	100 kA	150 kA
@ 480 VAC	100 kA	100 kA	100 kA
@ 600 VAC	65 kA	65 kA	85 kA
High AIR (Red Label - "SBH")			
@ 240 VAC	200 kA	200 kA	200 kA
@ 480 VAC	150 kA	150 kA	150 kA
@ 600 VAC	100 kA	100 kA	100 kA
Short Time Ratings (30 cycles)	25 kA	35 kA	65 kA*

*Short Time Rating for 3200 A is 50 kA

ICCB Electronic Trip Unit

The electronic trip unit uses a microprocessor to execute the numerous functions programmed in the unit. The adjustments on the trip unit allow the user to select what values are to be used by the microprocessor in performing its protective function.

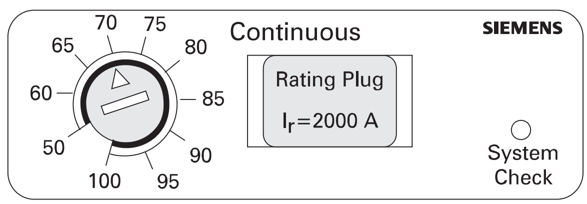


Interchangeable rating plugs

The trip unit is designed to use field interchangeable rating plugs. These rating plugs allow the effective ampere rating of the circuit breaker to be modified within a range of 50-100 percent of the breaker's frame ampere rating. The following table shows the trip unit rating plug values:

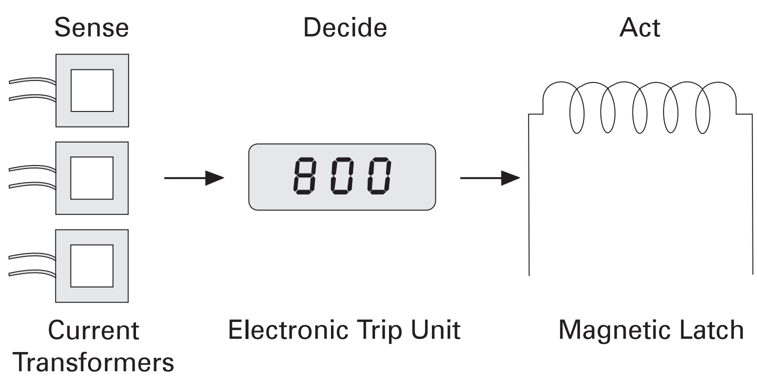
Breaker Frame Size	Frame Ampere Rating	Rating Plugs (Amperes)
800 A	400	200, 225, 250, 300, 350, 400
	800	400, 450, 500, 600, 700, 800
1200 A	1200	600, 700, 800, 1000, 1200
2000 A	1600	800, 1000, 1200, 1600
	2000	1000, 1200, 1600, 2000
3200 A	2500	1600, 2000, 2500
	3200	1600, 2000, 2500, 3000, 3200
4000 A	2500	1600, 2000, 2500
	3200	1600, 2000, 2500, 3000, 3200
	4000	2000, 2500, 3000, 3200, 4000
5000 A	5000	2500, 3000, 3200, 4000, 5000

The interchangeable rating plug is located at the top of the electronic trip unit.



Principle of operation

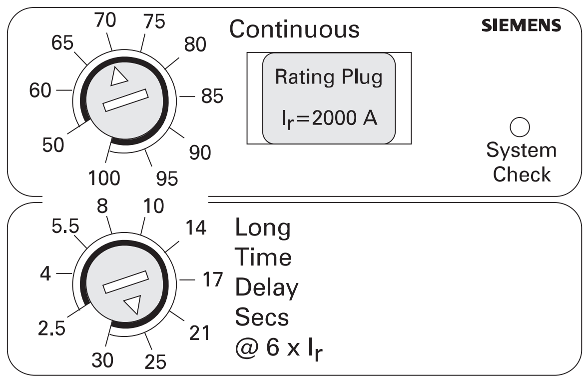
Current data is derived from current sensors (transformers) mounted in the breaker. The current signals from the transformers are converted to digital values in the trip unit. The electronic trip unit monitors current levels at an equivalent sampling rate of 353 samples per cycle per phase. It then decides when the circuit breaker should be tripped due to an overcurrent condition. A magnetic latch in the circuit breaker causes the breaker to trip when it receives a trip command from the electronic trip unit.



Continuous amps and long-time delay

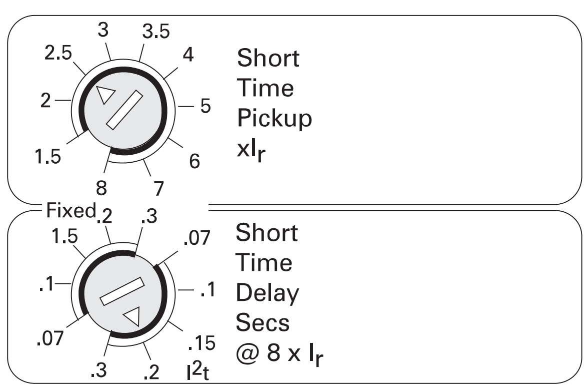
The continuous ampere adjustment sets the current level at which the breaker will continuously operate without tripping. For example, if a rating plug is 2000 amps and the continuous ampere adjustment is set to 50%, the breaker will continuously operate at current levels up to 1000 amps.

The long-time delay adjustment is used to set the tripping delay of the circuit breaker based on the magnitude of the overcurrent condition (6 times I_r). For example, if the rating plug is 2000 amps and long-time delay is set to 10 seconds, a fault current of 12,000 amps (6 x 2000) will cause the breaker to trip after 10 seconds. Long time is an inverse I^2t ramp function. This means the higher the current, the shorter the time the circuit breaker will remain "ON".



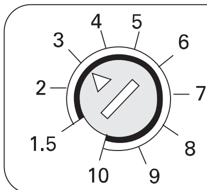
Short-time pickup and short-time delay

The short-time pickup adjustment is used to set the level of high current the breaker will carry for a short period of time without tripping. This adjustment is set in multiples of the value of the rating plug (I_r). Together with short-time delay, this adjustment allows downstream breakers time to clear short circuit faults without tripping upstream breakers. Short-time delay is used to set the time interval the breaker will wait before responding to the current value selected by short-time pickup. There are two modes of operation: fixed and I^2t. The I^2t delay has the characteristic of being inversely proportional to the square of the magnitude of the current. This means higher overcurrent conditions have shorter delays.



Instantaneous pickup and instantaneous override

The instantaneous pickup adjustment is used to set the current level at which the breaker will trip without an intentional time delay. Non-delayed tripping as a result of severe overcurrent minimizes potential damage to electrical systems and equipment. This adjustment is set in multiples of I_r.



An instantaneous override function is provided on all trip units. It is nominally set at the short-time rating of the respective breaker frame size. This allows the breaker to ride through high fault currents up to its short-time capability, however, it is self-protecting above these values.

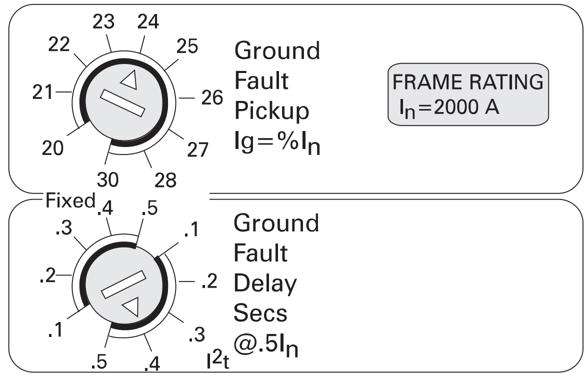
Breaker Frame Size	Short Time kA Rating (.500 seconds max.)
800 A	25
1200 A	25
2000 A	35
4000 A	65
5000 A	65

Ground fault pickup and ground fault delay

The ground fault pickup adjustment is used to set the level of ground current at which circuit interruption will be initiated. Together with ground fault delay, this adjustment allows selective tripping between main and feeder or other downstream breakers. The available ground fault pickup settings are given in the following table. In compliance with *NEC* 230-95, no trip point setting exceeds 1200 amps.

Frame Ampere Rating I_n	Available Setting % I_n									
400 A	20	25	30	40	50	60	70	80	90	100
800 A	20	25	30	40	50	60	70	80	90	100
1200 A	20	25	30	40	50	60	70	80	90	100
1600 A	20	26	32	38	44	50	56	62	68	75
2000 A	20	23	27	30	35	40	45	50	55	60
2500 A	20	23	26	29	32	35	38	41	44	48
3200 A	20	21	23	25	27	29	31	33	35	37
4000 A	20	21	22	23	24	25	26	27	28	30

The ground fault delay adjustment is used to set the time interval (in seconds) the breaker will wait before responding once the ground fault pickup level has been reached. There are two modes of operation: inverse time (I^2t) and fixed delay. Above 50 percent of the frame rating the inverse time delay reverts to a fixed delay of the same value.

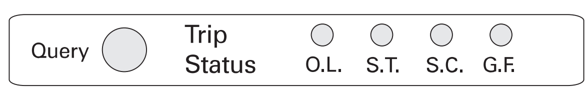


Trip status

The query button switch and trip status indicator lights provide the user a means for determining what type of fault caused the trip unit to trip the circuit breaker. Fault indicators are provided for:

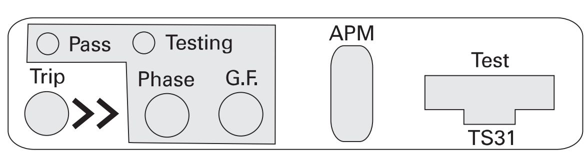
O.L. Overload or Long-Time Fault
S.T. Short-Time Fault
S.C. Short Circuit or Instantaneous Fault
G.F. Ground Fault

When a fault occurs the fault information is stored in the trip unit. When the Query button is pushed the appropriate fault indicator will light.



Integral test

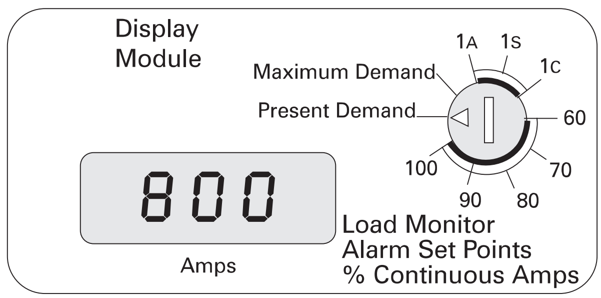
The integral test function enables the user to “exercise” the trip unit electronics, magnetic latch and breaker mechanism. The purpose of the test function is to provide the user with an easy means to conduct a “go/no go” type test before bringing the circuit breaker on-line.



Optional display module

The optional display module provides the features for allowing the user to locally monitor the phase currents. The display module plugs into the front of the trip unit. The load monitor alarm feature provides a local alarm display and an output signal for an external alarm when the average of the phase currents exceeds the alarm set point.

The current demand feature provides two ampere demand factors. The present demand setting displays the present ampere demand calculated on 15 minute intervals. The maximum demand setting displays the maximum ampere demand since last reset. To reset the maximum demand memory, the operator should simultaneously press the “Phase” and “G.F.” buttons on the integral test function.

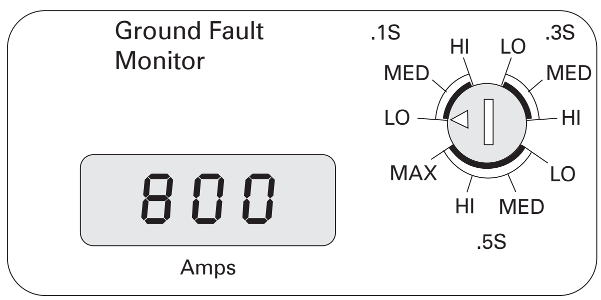


Ground fault monitor

The ground fault monitor allows the user to monitor ground fault current. The ground fault delays are divided into three time delay bands: 0.1, 0.3, and 0.5 seconds. There are three ground fault pickup levels available.

"LO" equals 20% of the frame rating.
"HI" equals the frame rating or 1200 A, whichever is less.
"MED" equals the average of "LO" and "HI".

The ground fault monitor displays the ground fault current in amps. When the ground fault current reaches a level 12% below the selected pickup setting the display will start to flash. When ground fault current reaches the selected setting the display will flash "OL". The ground fault monitor can be utilized with a display relay module or a remote indicator panel to provide a set of contacts for ground fault alarm. When used in conjunction with either of these devices and a shunt trip, the ground fault monitor can be used as ground fault sensing and relaying equipment per UL-1053.



Review 7

1. A red label ICCB at 480 VAC has an interrupting rating of ___________ kA.

2. A 600 amp rating plug is available in the ___________ and ___________ amp breaker frame sizes.

3. The trip unit monitors current levels at an equivalent sampling rate of ___________ samples per second.

4. Setting the continuous amp setting of a 1000 amp rating plug to 75% makes the ICCB a ___________ amp breaker.

5. In compliance with *NEC* 230-95, the maximum ground fault trip point setting of an ICCB is ___________ amps.

Review Answers

Review 1 1) a; 2) overloads, short circuits; 3) short circuit; 4) overload; 5) sense, measure, act.

Review 2 1) contacts; 2) blow-apart; 3) arc chute; 4) over-center; 5) bimetal; 6) electromagnet.

Review 3 1) instantaneous; 2) thermal; 3) 200,000; 4) ampere; 5) overload protection; 6) coordination.

Review 4 1) frame; 2) HFD6; 3) 15 to 125; 4) QD; 5) CQD.

Review 5 1) 2000; 2) red; 3) RMS; 4) 600; 5) 2.2 to 27; 6) 8000.

Review 6 1) shunt trip; 2) undervoltage trip; 3) exact alignment; 4) mechanical interlock; 5) plug-in.

Review 7 1) 150; 2) 800, 1200; 3) 353; 4) 750; 5) 1200.

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After completing the test, mail the answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

Questions

1. With an increase of current, temperature will

   a. decrease b. increase
   c. remain the same d. increase and decrease

2. The amount of current a conductor can carry on a continuous basis is known as

   a. ampacity b. instantaneous current
   c. peak current d. AWG

3. Overcurrent protection is covered by *NEC* article

   a. 110 b. 430
   c. 240 d. 384

4. A contact design which uses magnetic fields developed around the contacts to help force them apart during an overcurrent condition is known as

   a. straight-through b. single-pivot
   c. dual-pivot d. blow-apart

5. The operating mechanism in Siemens molded case circuit breakers is a/an ______ design.

   a. over-center b. normally open
   c. center-off d. normally closed

6. The "brain" of the circuit breaker is the

a.	arc chute	b.	frame
c.	trip unit	d.	operating mechanism

7. The type of circuit breaker that provides both overload and short circuit protection is a/an _______circuit breaker.

   a. instantaneous magnetic-trip-only
   b. interchangeable trip
   c. molded case switch
   d. thermal-magnetic

8. Siemens Sentron™ Series circuit breakers use a ______ label to identify a high interrupting category circuit breaker.

a.	black	b.	red
c.	blue	d.	yellow

9. The upper-most portion of a time-current curve shows the ______ performance of a circuit breaker.

   a. short circuit protection
   b. instantaneous trip
   c. continuous current
   d. current interrupting

10. The application of circuit protective devices in series, such that under overload or fault conditions, only the upstream device nearest the fault will open is known as

a.	series-rating	b.	selective coordination
c.	instantaneous trip	d.	current limiting

11. The maximum continuous ampere rating available for the BQ circuit breaker is

a.	15 amps	b.	100 amps
c.	50 amps	d.	125 amps

12. The QP circuit breaker is a/an _____ circuit breaker

a.	bolt-on	b.	Sentron Series
c.	plug-in	d.	insulated case

13. The type of circuit breaker that mounts on a DIN rail is

a.	BQD	b.	BL
c.	CQD	d.	BQC

14. The maximum continuous ampere range of an ND circuit breaker is

a.	15-125 amps	b.	200-400 amps
c.	800-1200 amps	d.	1800-2000 amps

15. True RMS sensing

a. measures peak currents only
b. provides more accurate picture of true heating
c. samples current every 1/2 second
d. measures peak voltages only

16. Which of the following adjustments is not available on a Sensitrip® III circuit breaker?

a.	continuous amps	b.	instantaneous delay
c.	long-time delay	d.	short-time delay

17. An accessory used to indicate a circuit breaker has tripped is a

a.	bell alarm switch	b.	undervoltage trip
c.	auxiliary switch	d.	shunt trip

18. A device used to allow only one of two adjacent circuit breakers to be closed at any time is a

a. mechanical interlock
b. Max-Flex™ handle operator
c. Telemand® electric motor operator
d. handle blocking device

19. Insulated case circuit breakers provide _______ interrupting ratings and _______ short-time withstand.

a.	high , poor	b.	low, excellent
c.	low, poor	d.	high, excellent

20. In compliance with *NEC* 230-95, no ground fault trip point setting can exceed ____ amps.

a.	1200	b.	10,000
c.	100,000	d.	200,000

Notes