

1458™

IEEE Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded Case Circuit Breakers for Industrial Applications

IEEE Industry Applications Society

Sponsored by the
Petroleum and Chemical Industry Committee



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Petroleum and Chemical Industry Committee
of the
IEEE Industrial Applications Society

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Abstract: A recommended procedure for the selection, application, and determination of the remaining life in molded case circuit breaker is provided.

Keywords: available fault values, circuit breaker testing, molded case circuit breakers, molded case circuit breakers basics, molded case circuit breakers life, safety

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Introduction

This introduction is not part of IEEE Std 1458-2005, IEEE Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded Case Circuit Breakers for Industrial Applications.

This is a new standard that, for the first time, provides in one document the information that is necessary in order to select, apply, and determine the remaining life of molded case circuit breakers. This standard is intended to be used by para-professionals and is not a high-level engineering document.

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IEEE Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded Case Circuit Breakers for Industrial Applications

1. Overview

1.1 Scope

This standard provides a recommended procedure for the selection, application, and determination of the remaining life in molded case circuit breakers. This recommended procedure is safe and easily understood.

1.2 Purpose

Molded case circuit breakers are one of the most widely used circuit protection devices in low-voltage (less than 1000 volt) applications. In spite of their wide use in industry, the average person specifying, installing, operating and maintaining these devices has less than a complete understanding of them. The purpose of this document is to provide people who purchase or maintain molded case circuit breakers with a single document that includes the following information:

- How molded case circuit breakers operate
- How to correctly size and select molded case circuit breakers
- How to safely maintain molded case circuit breakers
- How to determine when a molded case circuit breaker must be replaced

2. Normative references

This standard shall be used in conjunction with the following publications. The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 242™, The Buff Book™—IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.^{1, 2}

IEEE Std 1015TM, The Blue BookTM—IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems.

3. Molded case circuit breaker basics

This clause describes the basic components of a molded case circuit breaker and how the components work.

3.1 Molded case circuit breaker basics

The topic of circuit breakers covers a very broad range of electrical devices, which have a number of things in common and an even larger number of dissimilar features and capabilities. The main groupings selected to cover circuit breakers are listed here as an introduction, without defining or explaining the individual groupings at this point:

- Circuit breakers in general
- Industrial molded case circuit breakers (600 V and below)
- Miniature circuit breakers (240 V and below)

Generally speaking, a circuit breaker is a device that:

- Provides protection
- Opens and closes
- Might be removable
- Might be fixed
- Might be installed by itself in an enclosure
- Might be installed with other equipment
- Is applied at many voltage levels

Circuit breaker definitions vary depending upon the source of the definition.

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

ANSI definition—A circuit breaker is defined as a mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit.

3.2 Circuit breakers in general

The premise is the same for both definitions and both are accurate, but the wording is quite different. The same is true with the many types of circuit breakers. Their general purpose is the same, but there are also a number of significant differences.

Circuit breakers come in what seems to be a never-ending array of sizes, designs, ratings, and functions (Figure 1). In general, a circuit breaker provides switching capabilities and protection against one or more overcurrent conditions. Examples of overcurrents are overloads, short circuits, and ground faults.

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The circuit breaker might be applied as an individual item in its own enclosure or utilized in conjunction with a wide variety of other equipment in a common enclosure. Depending upon such things as system voltage, type of circuit breaker, and specific application, circuit breakers in common enclosures with other devices might be called panelboards, switchboards, or switchgear, which are each specifically defined by a set of standards. They might even be referred to as just an assembly. An assembly could include some or all of the following: circuit breakers, control devices, metering devices, regulating devices, equipment interconnections, and supporting structures.

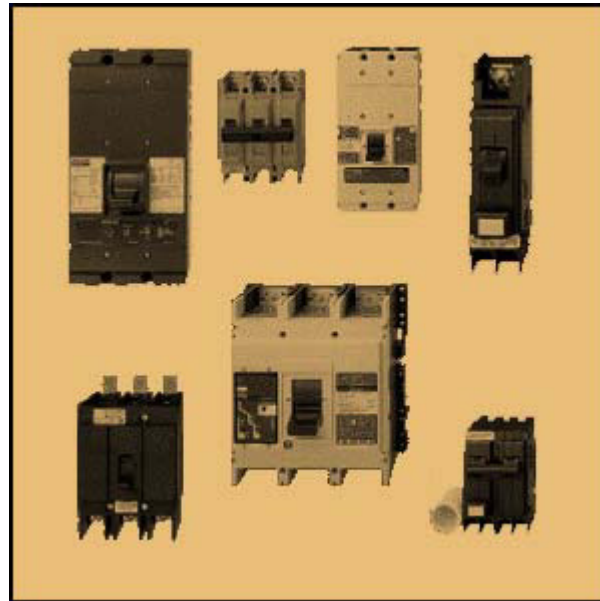


Figure 1—A broad range of circuit breakers

From a very broad perspective, all circuit breakers have the following common design and functional characteristics:

- Compliance with specific standards
- Set of open/close contacts
- Means to open and close the contacts
- Means to extinguish an arc
- Means to respond to overcurrents/commands
- Method for enclosing circuit breaker components
- Method for mounting circuit breaker

3.3 Circuit breaker standards

Circuit breakers are designed, built, and tested in accordance with one or more specific sets of standards. The applicable standards might be domestic, international, or both. These standards actually categorize particular types of circuit breakers. The governing standards are ANCE, ANSI, CSA, IEC, IEEE, NEMA, and UL. For a circuit breaker to be used, it shall comply with one or more specific sets of these standards.

3.4 Contacts open and close

Contacts in a circuit breaker provide a means for isolating or connecting a part of a circuit from or with the rest of the system. The contacts are like a wall switch that turns your lights on and off. In the case of a circuit breaker, however, the number of contacts depends upon the circuit breaker application. For example, a three pole circuit breaker applied on a three-phase electrical system would have three sets of contacts. In general, circuit breaker contacts are provided in sets, one set per phase. A contact set is usually comprised of a fixed part and a movable part. As a circuit breaker opens or closes, the fixed part of the contact maintains its position, while the movable part moves to close (make) or open (break) the contact.

3.5 Means to open and close contacts

Circuit breakers utilize some type of operating mechanism to open and close the contacts just discussed. This operating mechanism can be mechanical or electro-mechanical.

Depending upon the type of circuit breaker being considered, the operating mechanism could be called upon to

- Open and close the contacts manually
- Open and close the contacts on demand from a separate control or relay device
- Open the contacts automatically

3.5.1 Opening and closing contacts

Let's consider a three-phase circuit breaker of any kind. Designs are such that three sets of contacts open or close simultaneously. This means that all the contacts are linked together in some manner. This part of the mechanism might be connected mechanically in some fashion to a common handle. The handle, when operated, puts the mechanism into motion, and opens or closes the circuit breaker by opening or closing the contacts.

Circuit breakers, by virtue of their size and/or one or more standards requirements, need additional assistance to set the mechanism in motion and open or close the contacts as required. This additional assistance takes the form of opening or closing springs. Springs play a big role in the precise functioning of circuit breaker mechanisms. Springs are stretched or compressed to provide the energy necessary to assist with the proper opening or closing of the contacts.

A circuit breaker mechanism with spring assistance falls into one of the two following categories:

- Over-toggle type
- Stored-energy type

Over-toggle spring mechanisms are normally associated with molded case circuit breakers with two-step stored-energy types and insulated case and power circuit breakers.

3.5.2 Over-toggle

In a circuit breaker with an over-toggle mechanism, a manual handle on the circuit breaker is operated to set the mechanism in motion. The handle is moved to open or close the circuit breaker until a point is reached where the handle goes over-toggle (past the point of no return), and the spring-assisted mechanism automatically opens or closes the circuit breaker. This toggle mechanism is called the quick-make, quick-break type, meaning that the speed with which the contacts open or close is independent of how fast the handle is moved. A motor operator can be used to operate the handle automatically in lieu of manually going through the motion. The design is such that the circuit breaker would trip open when called upon to provide its expected protection, even if the manual handle were to be held in the ON (closed) position.

3.5.3 Two-step stored energy

The closing springs in this type of mechanism are used to store energy for use when needed. The process of storing energy and closing the circuit breaker is separated into the following two steps:

- 1) Closing springs are charged with the circuit breaker open. The circuit breaker is then closed.
- 2) The closing springs are re-charged with the circuit breaker closed providing for an open-close-open sequence.

Storing the energy in the springs is accomplished through the use of a manual-charging handle, an automatic means through the use of a small electric motor, or both. By having the ability to re-charge the closing springs, the circuit breaker can rapidly and remotely reclose after a fault. This ability to attempt a reclosure if a fault causes the circuit breaker to trip is designed to provide the user with a high degree of service continuity. Closing the circuit breaker can be accomplished by using a manual pushbutton or an electrical closing solenoid.

3.5.4 Electromagnetic assistance

Many molded case circuit breaker designs achieve high interrupting ratings by being designed to take full advantage of certain natural facts of physics to assist the operating mechanism with the opening process. This concept centers on a natural repulsion between two parallel conductors with current running in them in opposite directions.

While on the subject of the importance of the application of electromagnetic theory to circuit breaker design, it is appropriate to note that some new low-voltage power breaker designs take advantage of electromagnetic forces in both directions, opening and closing. Designs are such that the forces are used to help hold the contacts closed against a fault when required, and then reversed to assist with the opening process.

3.6 Means to extinguish an arc

An arc is defined as a discharge of electric current crossing a gap between two contacts. Arcs are formed when the contacts of a circuit breaker are opened under load. Arcs can be very destructive and vary greatly in size and intensity. The size of the arc depends on the amount of current present when the contacts are pulled apart. For example, the arc formed when a normal load current is broken would be insignificant in comparison to the arc formed when a short-circuit current is broken. Since arcs cannot be prevented, circuit breakers are designed to control them.

The heat associated with an arc creates an ionized gas environment. The bigger the arc, the more heat created. The more heat created, the more ionization that takes place. The more ionization, the better the conditions are for an arc to be maintained and grow. Obviously, this is the condition that must be dealt with quickly and effectively by a circuit breaker. The important thing to remember here is that the ability of the circuit breaker to control the arc is the key to its short-circuit interrupting capability. Of all overcurrent conditions, the short circuit is potentially the most devastating.

3.6.1 Current zero and arc extinguishing

When considering alternating current, it is important to note that there is no current flowing at each point zero (current zero) in the cycle. This is a very important aspect of arc extinguishing. With no current at point zero, conditions are optimal for preventing an arc from continuing.

3.6.2 Voltage and arc extinguishing

Voltage is also a very important consideration. Voltage tries to keep the current moving. It will keep pushing the current through point zero and give new life to the arc. Current does not take kindly to being stopped in

its tracks during the extinguishing of an arc. When an arc is stopped at current zero, the voltage will do its best to re-ignite the arc. Assuming it is unsuccessful, the built-up voltage pressure puts a great deal of potentially destructive stress on not only the device being used to extinguish the arc, the circuit breaker, but also the entire system. Equipment designs must take this possibility into account. Whether or not extinguishing of the arc is successful depends, in general, on the re-establishment of the dielectric strength of the gap between the open circuit breaker contacts. If the dielectric strength is greater than the voltage trying to re-ignite the arc, arc extinguishing will be successful. A dielectric is any insulating material between two conductors. The dielectric strength is the maximum voltage a dielectric can withstand without breaking down.

3.6.3 Arc extinguishing methods

In general, the control and extinction of an arc in molded case circuit breakers make use of one or more of the following four techniques:

- a) Arc extinguisher (chute)
- b) Break arc into smaller pieces
- c) Blow arc out with high-pressure gases
- d) Enclose contacts in non-conductive environments

Keep in mind that even though all of these four techniques are used, the arc extinguisher chute method is the predominantly used method of extinguishing the arc in molded case circuit breakers. This method cools and de-ionizes the arc at the same time, while it also contributes to the arc not being able to sustain itself.

3.6.4 Arc extinguisher (chute)

The function of the arc extinguisher is to control, divide, and extinguish an arc each time a breaker interrupts current. An arc extinguisher, therefore, dissipates arcs that result when the circuit breaker interrupts current flow. Each arc extinguisher consists of a stack of U-shaped steel plates held together by two insulating side plates. When an interruption occurs and the contacts separate, the current flow through the ionized region between the contacts induces a magnetic field around the arc and arc extinguisher. The resulting force drives the arc into the steel plates, de-ionizing the gas while dividing and cooling the arc.

Standard molded case circuit breakers utilize a linear current flow contact arrangement. A small blow-apart force between the contacts is generated under short-circuit conditions, which helps to open the contacts. The majority of the opening action, however, is caused by the mechanical energy stored in the trip mechanism itself.

Refinements have been made to the arc extinguisher, but not until the use of the reverse loop contact design have significant strides been made in the direction of improved arc extinguishing. The reverse loop design takes advantage of a principle of physics that describes what happens when current flows in essentially opposite paths. A much greater blow-apart force between the contacts is generated with the reverse loop design. This blow-apart force is directly proportional to the size of the fault current; the greater the fault, the greater the force. This force assists with rapid arc extinguishing by causing faster contact opening speeds. (See Figure 2.)

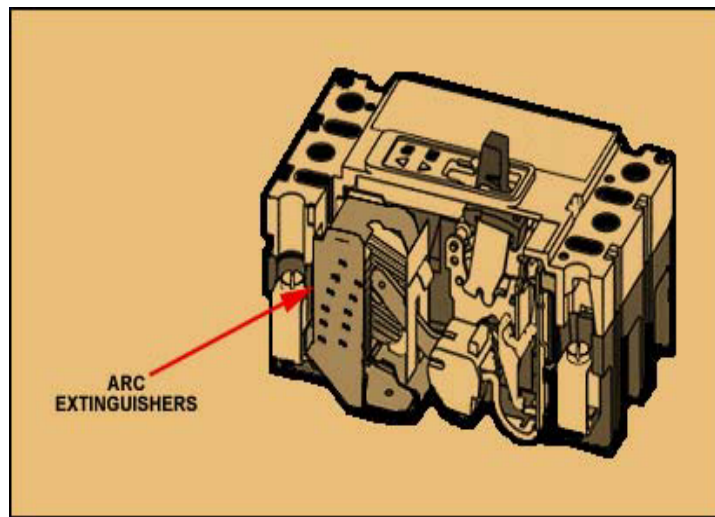


Figure 2—Arc extinguishers

3.7 Means to respond to overcurrents/commands

For a circuit breaker to be effective, a means must be provided that enables the circuit breaker to perform automatically or in response to a command. In order to accomplish this, generally, low-voltage circuit breakers are provided with integrally mounted devices called trip units.

3.7.1 Trip units

The function of the trip unit is to trigger the operating mechanism in the event of a prolonged overload or short-circuit current. To accomplish this, electromechanical (thermal magnetic) or electronic trip units are provided. (See Figure 3.) The traditional molded case circuit breaker has used electromechanical (thermal magnetic) trip units.

Protection is provided by combining a temperature-sensitive device with a current-sensitive electromagnetic device, both of which act mechanically on the trip mechanism. Molded case circuit breakers utilize one or a combination of different trip elements to provide the required circuit protection for a particular application. These trip elements protect against three conditions—thermal overloads, short circuits, and ground faults.

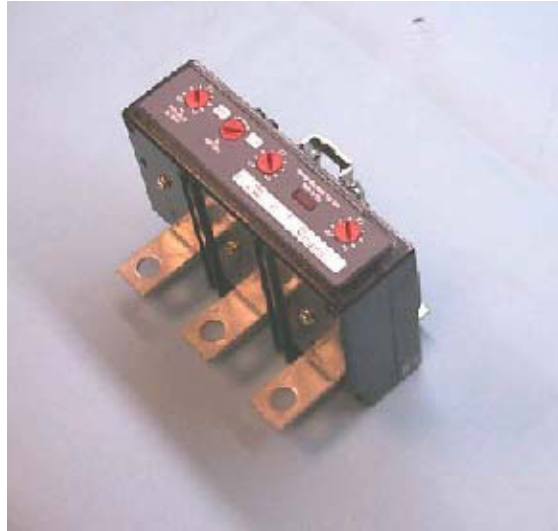


Figure 3—Trip unit

3.8 Method for enclosing circuit breaker components

The rigid circuit breaker frame provides a means by which all the required pieces and parts can be mounted and kept in place, ensuring the proper operation of the circuit breaker. The frame does more than just hold all the components together. It plays a critical role in the overall design's ability to comply with applicable standards. For example, the circuit breaker frame provides the rigidity and strength required to successfully deal with the interruption process and achieve the desired interrupting ratings. The frame's mechanical strength is sufficient to withstand the magnetic forces created by the square of the peak current, which could be quite large and potentially destructive. It also provides for insulation and isolation of the current path, offering personnel protection near the equipment during normal (no overcurrent) operation. Finally, the frame also provides a means by which the circuit breaker can be mounted and used. Molded case circuit breakers utilize molded insulating materials. Other low-voltage power circuit breakers and current medium voltage power circuit breakers are of a metal frame design.

3.8.1 Molded insulating material type

The primary functions of the molded case frame are to provide a rigid insulated housing to mount all of the circuit breaker components and deliver mechanical strength. Cases or frames are usually molded from a strong insulating material, such as glass-polyester or thermoset composite resins. Sizes vary according to the ampere rating of the circuit breaker. (See Figure 4.)

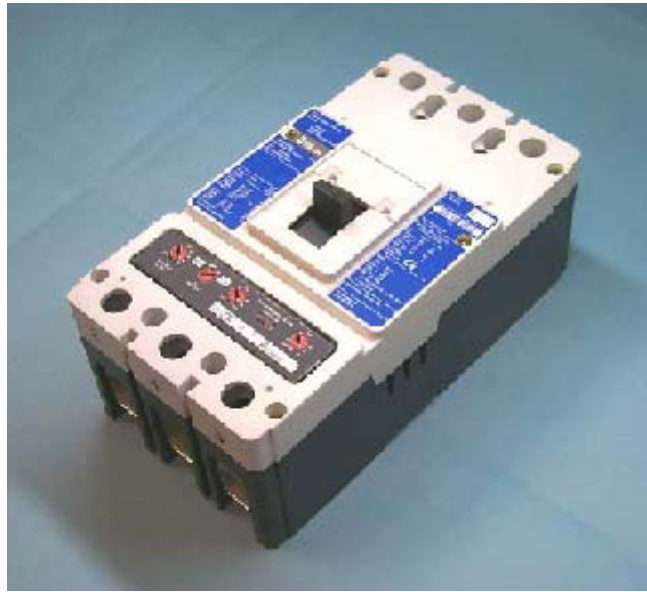


Figure 4—Molded insulating material type

3.9 Method for mounting circuit breaker

The mounting method is the way the circuit breaker is actually used in its individual enclosure or assembly. Circuit breakers, depending on the type and/or the particular application, are mounted for use in one of three basic ways:

- Fixed Mounted
- Removable
- Drawout

3.9.1 Fixed mounted

Generally speaking, a circuit breaker that is put into position in its individual enclosure or assembly and permanently bolted (fixed) in that position is considered a fixed mounted circuit breaker (Figure 5). To safely remove and/or replace a fixed circuit breaker, the power SHALL be removed from the circuit breaker and the bolted connections SHALL be undone.