NEMA AB 3

MOLDED CASE CIRCUIT BREAKERS AND THEIR APPLICATION

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Molded Case Circuit Breakers and Their Application

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Foreword

This standards publication is intended to provide a basis of common understanding within the electrical community concerning the proper application of molded case circuit breakers. User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
1300 N. 17th Street
Rosslyn, VA 22209

This standards publication was developed by the Molded Case Breaker Section of NEMA. Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the Molded Case Breaker Section was composed of the following members:

ABB Control, Inc.—Wichita Falls, TX
American Circuit Breaker Corp.—Albemarle, NC
Eaton Cutler-Hammer, Inc.—Pittsburgh, PA
General Electric—Plainville, CT
Moeller Electric Corporation—Franklin, MA
Siemens Energy & Automation, Inc.—Alpharetta, GA
Square D Company—Palatine, IL
Thomas & Betts Corporation—Memphis, TN

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Section 1
GENERAL

1.1 SCOPE

This application guide covers molded case circuit breakers and molded case switches, single-pole and multi-pole, fused and unfused, together with accessories used with them.

These circuit breakers and switches are assembled as integral units in supporting housings of insulating material and have rated voltages up to and including 1000 Vac, 50/60Hz, 1200 Vdc, and rated interrupting currents of 5000 Amperes or more.

This application guide addresses electrical systems with nominal ratings of 600 volts and below ac and dc, which represent the preponderance of the general use application.

Wherever the term “circuit breaker” or “breaker” is used in this publication, it is understood to mean “molded case circuit breaker.” Wherever the term “switch” is used in this publication, it is understood to mean “molded case switch.”

Wherever the abbreviation UL appears, it shall be understood to mean Underwriters Laboratories, Inc.

Wherever the abbreviation NEC or “Code” appear, they shall be understood to mean the *National Electrical Code*.

“NEC” and “*National Electrical Code*” are registered trademarks of the National Fire Protection Association.

With the exception of the definitions, and Appendix A and where mandatory requirements are indicated by such language as “shall,” “must,” and “such,” this document has been classified as Authorized Engineering Information.

1.2 REFERENCES

The reader is referred to the following supplementary reference material. Copies are available from the sources indicated. Standards with ANSI designations are also available from American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANCE
Av. Puente de Tecamachalco No. 6, Edificio Anexo
Seccion Fuentes, Lomas de Tecamachalco
53950 Naucalpan
Edo. de Mexico

NMX-J-266-ANCE — *Norma technica y de para interruptores automaticos en caja moldeada* (Electrical products - Molded case circuit breakers - Specifications and test methods.)

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Canadian Standards Association
178 Rexdale Blvd.
Etobicoke, Ontario, Canada M9WIR3

CSA C22.2 No. 5.1-M91	*Moulded Case Circuit Breakers*
CSA C22.2 No. 5.2-M90	*Moulded Case Switches*

Institute of Electrical and Electronics Engineers, Inc.
Publication Sales Department
445 Hoes Lane
Piscataway, NJ 08854

ANSI/IEEE Std. 141-1993	*IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book)*
ANSI/IEEE Std. 242-1986	*IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)*
IEEE Std. 323-1983	*Qualifying Class 1E Equipment for Nuclear Power Generating Stations – not found on IEEE web site*
ANSI/IEEE Std. 446-1995	*IEEE Recommended Practice for Emergency and Standby Power Systems for Indus-trial and Commercial Applications (IEEE Orange Book)*
ANSI/IEEE Std. 649-1980	*Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations--not found on IEEE web site*
ANSI/IEEE Std. 650-1990	*IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations*

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Rosslyn, Virginia 22209

ANSI/NEMA 250-1997	*Enclosures for Electrical Equipment (1000 Volts Maximum)*
NEMA PB 2.2-1999	*Application Guide for Ground Fault Protective Devices for Equipment*
NEMA 280-1990	*Application Guide for Ground Fault Circuit Interrupters*

National Fire Protection Association
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 20-1999	*Centrifugal Fire Pumps*
ANSI/NFPA 70-1999	*National Electrical Code*
ANSI/NFPA 70B-1998	*Recommended Practice for Electrical Equipment Maintenance*
ANSI/NFPA 70E-2000	*Electrical Safety Requirements for Employee Work Places*
ANSI/NFPA 302-1998	*Fire Protection Standard for Pleasure and Commercial Motor Craft*

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 489 (NEMA AB 1)	*Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures* (9^{th} Edition, 1996)
UL 943	*Ground Fault Circuit Interrupters* (3^{rd} Edition, 1993)

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UL1053	*Ground Fault Sensing and Relaying Equipment* (6^{th} Edition, 1999)
UL 1699	*Arc-Fault Circuit-Interrupters* (1^{st} Edition, 1999)

U.S. Government
Superintendent of Documents
Washington, DC 20402

WC 375-GEN-1975	*Federal Specification - Circuit Breakers, Molded Case: Branch Circuit and Service*

1.3 DEFINITIONS

accessories: Device that performs a secondary or minor duty as an adjunct or refinement to the primary or major duty of a molded case product.

accessory high-fault protector: A self-contained unit housing fuses or high-fault protectors. It is constructed for use with specific molded case products and to be connected directly to the load terminals of the molded case product.

adjustable circuit breaker: A circuit breaker that has adjustable time/current tripping characteristics. These may include (1) inverse-time (i.e., continuous current, long time, and/or short time), (2) instantaneous, and (3) ground-fault characteristics.

adjustable instantaneous release (trip): That part of an overcurrent trip element that can be adjusted to trip a circuit breaker instantaneously at various values of current within a predetermined range of currents.

alarm switch: A switch that operates to open or close a circuit upon the automatic opening of the molded case product with which it is associated.

ambient-compensated circuit breaker: A circuit breaker in which means are provided for partially or completely neutralizing the effect of ambient temperature upon the tripping characteristics.

ambient temperature: The temperature of the surrounding medium that comes in contact with the circuit breaker or switch. For an enclosed device, it is the temperature of the medium outside the enclosure.

arc-fault circuit-interrupter (AFCI): A device intended to mitigate the effects of arcing faults by functioning to de-energize the circuit when an arc-fault is detected.

auxiliary switch: A switch that is mechanically operated by the main device.

calibration: The factory adjustment of the release mechanism of a circuit breaker to make the circuit breaker perform in accordance with its prescribed characteristics.

calibration test: Verifies the tripping characteristics of a circuit breaker.

circuit breaker: 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 breaker and ground-fault circuit-interrupter (GFCI): A device that performs all normal circuit breaker functions and provides personnel protection against risk of electric shock as required by the

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National Electrical Code, the Canadian Electrical Code, and the Normas Tecnicas para Instalaciones Electricas (NTIE).

circuit breaker and secondary surge arrester: A device that performs all normal circuit breaker functions and provides protection against power-distribution system surge related damage to connected circuits and load-connected equipment.

circuit breaker and transient voltage surge suppressor: A device that performs all normal circuit breaker functions and that is intended to limit the maximum amplitude of transient voltage surges on power lines to specified values. It is not intended to function as a surge arrester.

circuit breaker with equipment ground-fault protection: A device that performs all normal circuit breaker functions and provides leakage current protection intended to reduce the likelihood of fire. It is not intended to function as a ground-fault circuit-interrupter.

circuit breaker enclosure: An enclosure intended to house a single, multipole, or two-single pole molded case products.

circuit breakers incorporating ground-fault protection for equipment: Circuit breakers that perform all normal circuit breaker functions and also trip when a fault current to ground exceeds a predetermined value.

class CTL circuit breaker: A circuit breaker that, because of its size or configuration, in conjunction with a class CTL panelboard, prevents more circuit breaker poles from being installed than the number for which the assembly is intended and rated.

close-open operation: A close operation followed immediately by an open operation without purposely delayed action. The letters "CO" signify this operation.

common trip circuit breaker: A multipole circuit breaker constructed so that all poles will open when any one or more poles open automatically.

cross-over current: The current of a fused circuit breaker at which the function of the fuse coincides with the operation of the trip mechanism of the circuit breaker, i.e., where the fuse clearing time curve crosses the circuit breaker trip characteristic curve.

current limiting circuit breaker: A circuit breaker that does not employ a fusible element and, when operating within its current-limiting range, limits the let-through I^2t to a value less than the I^2t of a 1/2-cycle wave of the symmetrical prospective current.

current limiting range: The rms symmetrical prospective currents between the threshold current and the maximum interrupting rating current.

current setting (I_r): The rms current an adjustable circuit breaker is set to carry continuously without tripping. It is normally expressed as a percentage (or multiple) of the rated current and is adjustable.

dielectric voltage-withstand test: A test that determines the ability of the insulating materials and spacings used to withstand overvoltages without breakdown under specified conditions.

drawout-mounted circuit breaker: An assembly of a circuit breaker together with a supporting structure constructed so that the circuit breaker is supported and can be moved to either the main circuit connected or disconnected position without the necessity of removing connections or mounting supports. The structure includes both self-supporting circuit terminals and an interlocking means that permits movement

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of the circuit breaker between the main circuit connected and disconnected positions only when the circuit breaker contacts are in the open position.

dynamic impedance: The arc impedance introduced into a circuit by the opening of the circuit breaker contacts during current interruption.

electrical operator: An electrical controlling device used to operate the mechanism of a circuit breaker in order to open, close, and, if applicable, reset the circuit breaker or switch.

endurance test: A test that determines compliance with a specified number of mechanical and electrical operations.

external operating mechanism: A mechanism that engages the handle of a circuit breaker and provides a manual means for operating the circuit breaker.

fixed instantaneous release (trip): That part of an overcurrent release element that contains a nonadjustable means that is set to trip a circuit breaker instantaneously above a predetermined value of current.

frame: An assembly consisting of all parts of a circuit breaker except an interchangeable trip unit.

frame size: A group of circuit breakers of similar physical configuration. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group. The same frame size designation may be applied to more than one group of circuit breakers.

fused circuit breaker: A circuit breaker that contains replaceable fuses or high-fault protectors assembled as an integral unit in a supportive environment and enclosed housing of insulating material.

fused molded case switch: A switch with integral replaceable fuses and high fault protectors assembled as an integral unit in a supportive and enclosed housing of insulating material.

ground-fault circuit-interrupter (GFCI): A device whose function is to interrupt the electric circuit to the load when a fault current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.

ground-fault delay: An intentional time delay in the tripping function of a circuit breaker when a ground-fault occurs.

ground-fault pickup setting: The nominal value of the ground-fault current at which the ground-fault delay function is initiated.

heating, air conditioning, and refrigeration (HACR) circuit breaker: A circuit breaker intended for use with multi-motor and combination loads such as are found in heating, air conditioning, and refrigeration equipment.

independent trip circuit breaker: A multipole circuit breaker constructed such that all poles are not intended to open when one or more poles open automatically.

instantaneous override: A fixed-current level at which an adjustable circuit breaker will override all settings and will trip instantaneously.

instantaneous pickup setting: The nominal value of current that an adjustable circuit breaker is set to trip instantaneously.

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instantaneous trip: A qualifying term indicating that no delay is purposely introduced in the automatic tripping of the circuit breaker.

instantaneous trip circuit breaker (motor circuit protector or circuit interrupter): A circuit interrupter that is intended to provide short circuit protection only. Although acting instantaneously under short circuit conditions, these circuit breakers shall be permitted to include a transient dampening action to ride through initial motor transients.

interchangeable trip unit: A trip unit that can be interchanged by a user among circuit breaker frames of the same design. See also **rating plug**.

internal mechanism: The means by which the main contacts of a circuit breaker are actuated.

interrupting rating: The highest current at rated voltage that a device is intended to interrupt under standard test conditions.

inverse time: A qualifying term indicating that there is a purposely introduced delayed tripping in which the delay decreases as the magnitude of the current increases.

I^2t (amperes squared seconds): An expression related to the circuit energy as a result of current flow. With respect to circuit breakers, the I^2t is expressed for the current flow between the initiation of the fault current and the clearing of the circuit.

lock-off device: A device that permits the circuit breaker to be locked in the OFF position.

long time delay: An intentional time delay in the overload tripping of an adjustable circuit breaker's inverse time characteristics. The position of the long time portion of the trip curve is normally referenced in seconds at 600 percent of the current setting (I_r).

long-time pickup: The current at which the long-time delay function is initiated.

mechanical interlock: A device or system that mechanically connects two or more circuit breakers or switches so that only selected ones can be closed at the same time.

molded case circuit breaker: A circuit breaker that is assembled as an integral unit in a supportive and enclosed housing of insulating material.

molded case switch: A device designed to open and close a circuit by nonautomatic means, assembled as an integral unit in a supportive and enclosed housing of insulating material.

multipole circuit breaker: A circuit breaker with two or more poles which provide two or more separate conducting paths.

neutral (or solid neutral): An assembly consisting of an appropriate number of terminals providing for the connection of the neutral conductors. When used as a component of service equipment, the neutral also includes (1) a means for making the required bonding connection between the neutral and the enclosure and (2) a terminal for the grounding electrode conductor.

open operation: The movement of the contacts from the closed to the open position. The letter "O" signifies this operation.

overcurrent release (trip): A release that operates when the current in the circuit breaker exceeds the release setting.

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overvoltage-trip release device: A trip mechanism that causes a circuit breaker to open automatically if the voltage across the terminals of the trip coil rises above a predetermined value.

peak current: The maximum instantaneous current that flows in a circuit.

pilot duty: The rating assigned to a relay or switch that controls the coil of another relay or switch.

pole: That portion of a circuit breaker or switch associated exclusively with one electrically separated conducting path of its main circuit.

prospective current (available current): Current that would flow in a circuit if a short circuit of negligible impedance were to occur at a given point.

rated control voltage: The designated voltage that is to be applied to the closing or tripping devices to open or close a circuit breaker or switch.

rated current (I_n): The marked current rating and maximum rms current a circuit breaker can carry continuously without tripping, and the maximum current the circuit breaker will carry without changing, deleting, or adding part(s) such as trip units and rating plugs. See current setting (I_r).

rated frequency: The service frequency of the circuit for which the circuit breaker is designed and tested.

rated voltage: The nominal rms voltage for which the circuit breaker is designed to operate.

rating: The designated limit(s) of the rated operating characteristic(s) of a device.

rating plug: A self-contained portion of a circuit breaker that is interchangeable and replaceable in a circuit breaker trip unit by the user. It sets the rated current (I_n) of the circuit breaker.

recovery voltage: The voltage that appears across the terminals of a pole of a circuit breaker upon interruption of the circuit.

remotely operated circuit breaker: A circuit breaker that contains an integral means to remotely open and close the circuit.

series rated (series connected): A group of overcurrent devices, connected in cascade, comprised of a circuit breaker or fuse main and one or more downstream circuit breakers that have been tested together to permit the branch or downstream circuit breakers to be applied on circuits where the available short circuit current exceeds the marked interrupting rating on the branch circuit breaker.

short-time delay: An intentional time delay in the tripping of a circuit breaker between the overload and the instantaneous pick up settings.

short-time pickup: The current at which the short-time delay function is initiated.

shunt-trip release device: A release mechanism energized by a source of voltage that may be derived either from the main circuit or from an independent source.

supervisory circuit: A feature included in a circuit breaker and ground-fault circuit-interrupter that provides a manual method for testing the device by simulating a ground fault.

SWD circuit breaker: A circuit breaker intended to switch fluorescent lighting loads on a regular basis.

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short circuit current rating: The maximum RMS prospective (available) current to which a device can be connected when protected by the specified overcurrent protective devices. The rating is expressed in amperes and volts.

threshold current: The rms symmetrical prospective current at the threshold of the current limiting range, where (1) the peak current let through in each phase is less than the peak of that symmetrical prospective current, and (2) the I^2t in each phase is less than the I^2t of a 1/2 cycle wave of the symmetrical prospective current.

trip-free circuit breaker: A circuit breaker designed so that the contacts cannot be held in the closed position by the operating means during trip command conditions.

tripping: The opening of a circuit breaker by actuation of the release mechanism.

trip unit: A self-contained portion of a circuit breaker that is interchangeable and replaceable in a circuit breaker frame by the user. It actuates the circuit breaker release mechanism and it sets the rated current (I_n) of the circuit breaker unless a rating plug is used. See **rating plug**.

undervoltage trip release: A release mechanism that causes a circuit breaker to open automatically if the control voltage falls below a predetermined value.

1.4 ABBREVIATIONS AND SYMBOLS

A	Amperes
ac	Alternating current
AWG	American wire gage
C	Celsius
CO	Making operation followed immediately by a breaking operation, circuit breaker
dc	Direct current
F	Fahrenheit
HACR	Heating, air conditioning, and refrigeration
HID	High intensity discharge
Hz	Frequency in cycles per second (hertz)
I	Current
I_n	Rated current
I_p	Peak current
I_r	Current setting
I^2t	Amperes squared seconds
kcmil	Thousand circular mils (same as mcm)
mcm	Thousand circular mils (same as kcmil)
m	Meter
mm	Millimeter
ms	Millisecond
N	Neutral
O	Breaking operation, circuit breaker
rms	Root mean square
SWD	Switching duty
t	Time
V	Voltage
Z	Impedance
ø	Phase
θ	Angle between voltage vector and current vector

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1.5 GENERAL APPLICATIONS

1.5.1 Purpose Of Circuit Breakers

Circuit breakers are intended to provide overcurrent protection for conductors and equipment by opening automatically before the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation. The parameters of this protection are outlined in *National Electrical Code*, Sections 240-2, 240-3, and 240-4.

1.5.2 Purpose Of Molded Case Switches

Molded case switches are intended to be used as a manual disconnecting means in a circuit. It is stressed that molded case switches are not overcurrent protective devices and have no overload, short circuit, or ground fault protection capabilities. Some molded case switches are provided with instantaneous trip mechanisms for the sole purpose of self protection in the event of a short circuit.

1.6 Field Testing

For field testing of molded case circuit breakers refer to NEMA Publication AB4-2001, *Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications*. If more detailed information is required, consult the manufacturer.

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Section 2
AVAILABLE TYPES OF MOLDED CASE CIRCUIT BREAKERS

2.1 GENERAL USAGE CATEGORIES

2.1.1 Residential

Residential circuit breakers are a general category that includes single and two-pole circuit breakers with ampere ratings of 225A or less, and with voltage ratings of 120Vac, 127Vac, 120/240Vac, and 240Vac. These breakers may also be used in industrial/commercial applications.

2.1.2 Industrial/Commercial

All three-pole circuit breakers and one and two-pole circuit breakers with ampere ratings over 225A and with voltage ratings above 240Vac are usually categorized as industrial/commercial circuit breakers. Some of these breakers may also be used in residential applications. Industrial/commercial circuit breakers are offered with ac ratings, combination ac/dc ratings, and dc ratings only.

2.2 TRIPPING MEANS

2.2.1 Thermal-Magnetic

These devices provide overload and short-circuit protection. Overload sensing and tripping is obtained through the use of a bimetal, which is heated by the load current. During an overload condition, the bimetal deflects unlatching the mechanism to cause the breaker to trip or open. As the overload current increases, the tripping time of the breaker decreases. This is referred to as the inverse time principle.

Short-circuit protection is obtained through electromagnetic action. If the fault current reaches a predetermined value, the breaker trips instantaneously.

Thermal magnetic circuit breakers usually have fixed continuous current ratings. Generally, in the larger frame size breakers, the instantaneous trip setting is field adjustable.

2.2.2 Dual Magnetic (Dashpot) (Hydraulic)

These devices provide overload and short-circuit protection. On overload, these devices operate~~s~~ on the inverse time principle by utilizing a magnetic coil surrounding a plunger that is restrained by air or liquid. As the magnetic field increases due to increased currents, the plunger increases its speed to unlatch the mechanism and open or trip the breaker in a shorter time.

Short-circuit protection by dual magnetic breakers is obtained through electromagnetic action. If the fault current reaches a predetermined value, the breaker trips instantaneously.

2.2.3 Electronic (Solid-State)

Electronic trip circuit breakers provide overload and short-circuit protection just as thermal-magnetic and dual magnetic breakers, but these breakers may also provide a variety of other protection schemes. These protection schemes may include ground fault protection, adjustable instantaneous trip, time delay tripping, and other tripping functions. The manufacturer should be consulted for available features.

Current sensors are utilized in each pole of the breaker to sense the current. The electronic circuitry measures the output from the current sensors and initiates tripping of the breaker.

Electronic trip circuit breakers generally have adjustable continuous current ratings.

NOTE—Circuit breakers equipped with such electronic means are suitable for ac systems only.

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2.3 SPECIFIC PURPOSE CATEGORIES

2.3.1 Remote Control Circuit Breakers

Remote control circuit breakers provide the normal functions of a circuit breaker and, in addition, can be switched remotely to turn the circuit “on” and “off.” Both overcurrent protection and remote control capability are combined within the same circuit breaker case.

2.3.2 Integrally-Fused Circuit Breakers

These devices employ high fault protectors which are similar to conventional current-limiting fuses but are designed, both physically and with time/current operating characteristics, for specific performance with the related circuit breaker.

Circuit breakers incorporating these high fault protectors also include overload and low level fault protection, thus combining the required protection elements for application on distribution circuits with higher available fault currents. These protective actions are coordinated so that unless a severe fault occurs, the high fault protector is unaffected and its replacement is not required. Historical data indicate that most system faults occur in the low fault level range.

High fault protectors are generally located within the molded case circuit breaker frame and separated from the sealed trip unit of the circuit breaker for easy access. An interlock is provided to ensure the opening of the circuit breaker contacts before the high fault protector cover can be removed. The possibility of single phasing is eliminated by designs that ensure simultaneous opening of all circuit breaker poles.

Additionally, many circuit breakers are equipped with a mechanical interlock, which prohibits the circuit breaker from closing with a missing high fault protector.

The continuous ampere rating of the circuit breaker is selected in the same manner as for a conventional molded case circuit breaker. Manufacturers generally provide a variety of high fault protector ratings with time/current characteristics for application with a variety of downstream devices. The selection of the individual high fault protectors should be made in strict accordance with the manufacturer's published literature to achieve the desired level of circuit protection.

Molded case circuit breakers with close-coupled, externally-mounted high fault protectors are applied in the same manner as those with integrally-mounted high fault protectors. If the high fault protector is properly applied, anti-single phasing is ensured by the coordinated tripping characteristics between the close-coupled high fault protector and the molded case circuit breakers. Whenever the high fault protector operates, the let-through energy will be sufficient to trip the breaker.

2.3.3 Current-Limiting Circuit Breakers

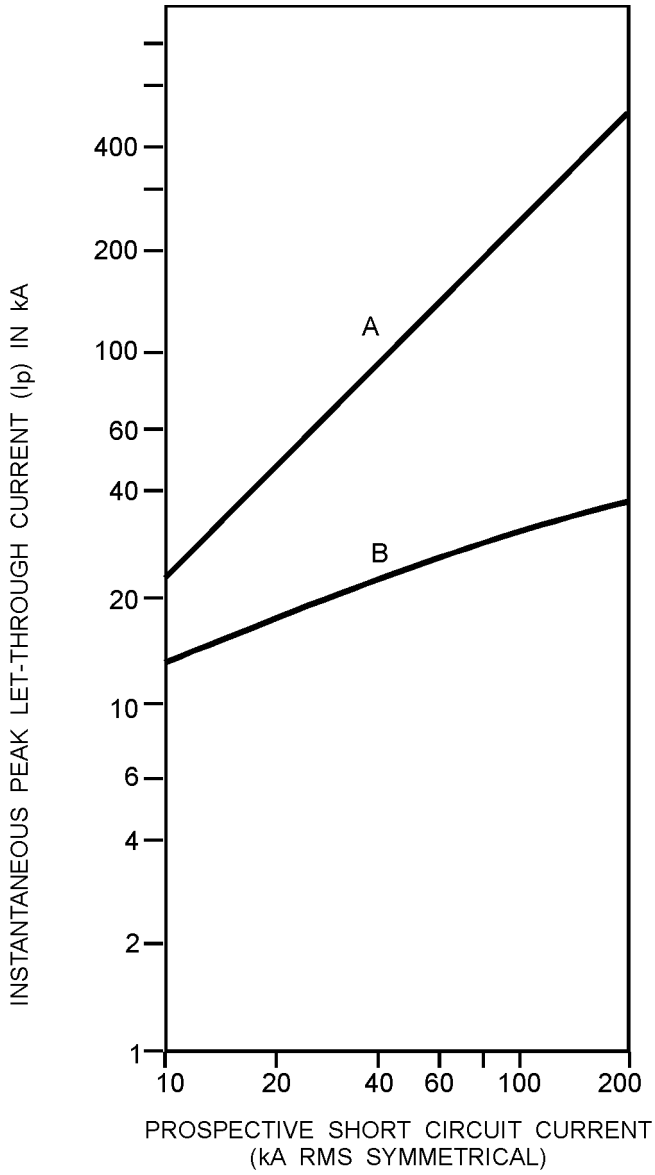
A current-limiting circuit breaker is a circuit breaker that does not employ a fusible element and that, when operating within its current-limiting range, limits the let-through I^2t to a value less than the I^2t of a 1/2 cycle wave of the symmetrical prospective current.

For individual breakers tested alone, manufacturers publish peak let-through current (Ip) and energy (I^2t) curves. Typical curves of these types are illustrated in Figures 2-1 and 2-2.

2.3.4 Switching Duty Circuit Breakers (SWD)

Switching Duty Circuit Breakers (SWD) are rated 15 or 20 amperes and are intended to switch 347 volts or less fluorescent lighting loads on a regular basis. These breakers are marked “SWD.”

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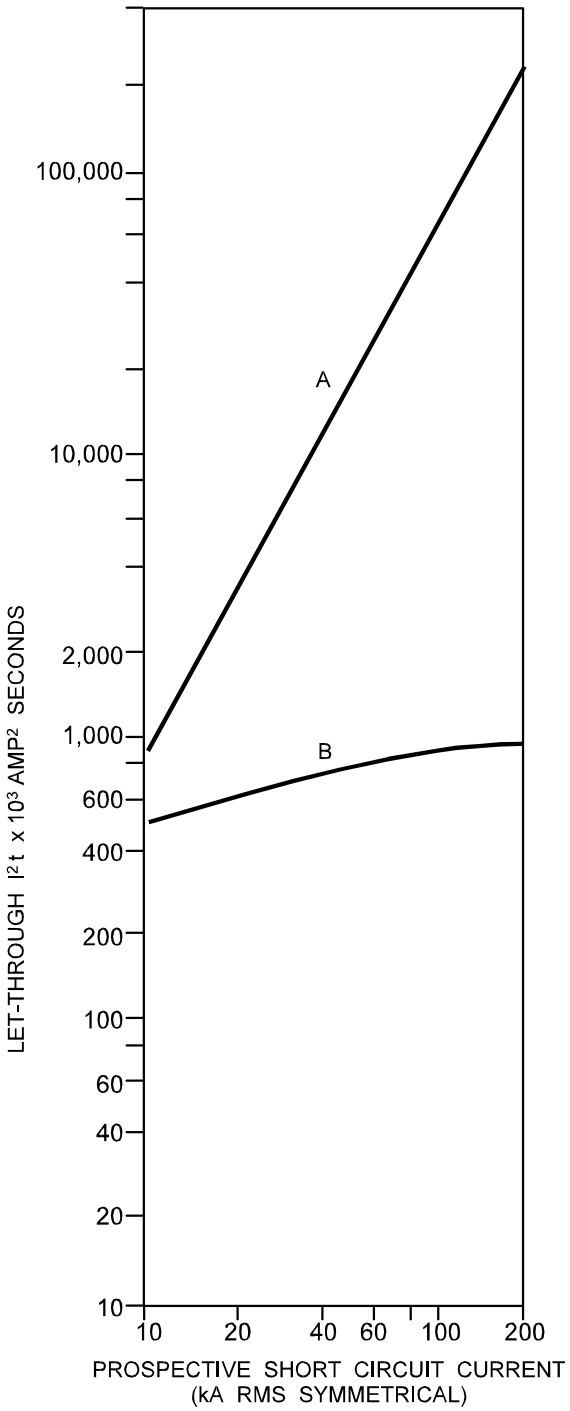


A = MAXIMUM PROSPECTIVE PEAK CURRENT

B = ACTUAL PEAK LET-THROUGH CURRENT OF CURRENT LIMITING BREAKER

Figure 2-1
TYPICAL CURRENT LIMITING CIRCUIT BREAKERS

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A = MAXIMUM PROSPECTIVE I^2t

B = ACTUAL I^2t LET-THROUGH OF CURRENT LIMITING BREAKER

Figure 2-2
TYPICAL CURRENT LIMITING CIRCUIT BREAKERS

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2.3.5 Instantaneous Trip Only Circuit Breakers (Motor Circuit Protector or Circuit Interrupter)

An instantaneous trip only circuit breaker is a circuit breaker intended to provide short-circuit protection only. Although acting instantaneously under short circuit conditions, instantaneous trip breakers are permitted to include a transient dampening action to ride through motor transients. Since external overload protection is required with these breakers, they cannot be used for branch circuit protection. These breakers are commonly used in motor circuits with motor starters in motor control centers and individual combination motor controllers.

2.3.6 Heating, Air Conditioning, and Refrigeration Circuit Breakers (HACR)

Section 430-53 of the *National Electrical Code* permits the use of an inverse-time circuit breaker as the branch-circuit protective device in multi-motor and combination load installations, commonly involved in heating, air conditioning, and refrigeration equipment, provided the circuit breaker has been listed for this purpose.

Molded case circuit breakers meeting the requirements will be marked "HACR Type" in conjunction with the listing mark to indicate their suitability for this specific use. Manufacturers of listed heating, air conditioning, and refrigeration equipment wishing to have their products identified for use with such a circuit breaker must mark their products indicating suitability for use with a breaker identified as a HACR Type.

2.3.7 Marine Circuit Breakers

These breakers are intended to be installed and used aboard a boat or vessel in accordance with the NFPA 302, applicable publications of the American Boat and Safety Council, Inc., the regulations of the U.S. Coast Guard, and UL 489, Supplement SA.

A marine breaker may be designated as ignition-protected. An ignition- protected device is a device or component constructed in such a manner that it will not ignite an explosive mixture of propane and air surrounding the device under normal operating conditions. An ignition-protected device is not necessarily "explosion-proof" as that term is applied to devices used on commercial vessels. See UL 489, Supplement SA for additional details.

2.3.8 Naval Circuit Breakers

These circuit breakers are intended for installation aboard non-combatant and auxiliary naval ships and conform to UL 489 Supplement SB.

2.3.9 Mining Circuit Breakers

These breakers are specifically designed for mining duty applications and permit the user to comply with mandatory mine safety standards.

2.3.10 High Intensity Discharge Lighting Circuit Breakers (HID)

For circuits involving the switching of high intensity discharge lighting loads, there are breakers especially designed and tested for that purpose. These breakers are marked HID and are rated 50 amperes maximum and 480 volts or less.

2.3.11 Ground Fault Circuit Interrupter (GFCI) Circuit Breakers

A type of circuit breaker that combines a standard circuit breaker and a ground fault circuit interrupter to provide overcurrent protection and protection against risk of electric shock as required by the *National Electrical Code*. These are 1-pole 120V ac and 2-pole 120/240V ac devices. Also refer to 5.5.2.2

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2.3.12 Circuit Breakers with Equipment Ground Fault Protection

These circuit breakers combine standard circuit breakers and equipment ground fault protective devices. These devices typically have 30mA trip levels and are for use in those applications required by the *National Electrical Code*. (See NEC Articles 426 and 427.) These devices do not provide protection against electric shock. Also refer to 5.5.2.1.2.

2.3.13 Classified Circuit Breakers

Classified circuit breakers are intended for use as alternates for specified circuit breakers for use with specified panelboards rated 225 amperes, 120/240V ac maximum where the available short-circuit current is 10kA, 120/240V ac maximum. These circuit breakers comply with Supplement SD of UL 489.

2.3.14 Circuit Breakers with Secondary Surge Arrester

These circuit breakers combine standard circuit breakers and secondary surge arresters to provide overcurrent protection and surge protection.

2.3.15 Circuit Breakers with Transient Voltage Surge Suppressor

These circuit breakers combine standard circuit breakers and transient voltage surge suppressors.

2.3.16 Circuit Breakers for Use With Uninterruptible Power Supplies

These are circuit breakers rated greater than 250V dc and intended for use with uninterruptible power supplies (UPS) and wired with 2- or 3-poles in series. These circuit breakers comply with the requirements of Supplement SC of UL 489.

2.3.17 Arc-Fault Circuit Interrupter (AFCI) Circuit Breakers

These circuit breakers combine standard circuit breakers and arc-fault circuit interrupters to detect hazardous arcing and interrupt the circuit in order to greatly reduce the potential of fire from an arc. These are 1-pole 120V ac devices. Also refer to 5.5.5

2.4 OTHER APPLICATIONS

Most manufacturers of circuit breakers can supply circuit breakers that vary in some degree from breakers manufactured to NEMA or UL standards. This variance could be in rating, calibration, accessories, mounting, or a combination of these characteristics. The manufacturer should be consulted regarding specific, non-standard applications.

2.5 SPECIAL PURPOSE CIRCUIT BREAKERS

There may be variations of the above categories with limitations of applications that will continue to meet UL requirements.

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Section 3
AVAILABLE VARIATIONS IN MOLDED CASE CIRCUIT BREAKERS

3.1 CONSTRUCTIONAL VARIATIONS

3.1.1 Circuit Breaker

A circuit breaker is the complete assembly of all parts of the device except for accessories.

3.1.2 Frame

A frame is an assembly consisting of all parts of a circuit breaker except an interchangeable trip unit or accessories. Frame size is given in amperes, which is normally the maximum ampere rating in a particular group. Circuit breakers of the same frame size are not necessarily physically interchangeable.

3.1.3 Interchangeable Trip Unit

An interchangeable trip unit is a field installable assembly that controls the tripping functions of the circuit breaker and that mounts within the circuit breaker frame. The trip unit may utilize thermal magnetic, dual magnetic, or electronic sensing means. Rating plugs are also considered as interchangeable units.

3.1.4 Mechanism

A breaker's mechanism is the operating means by which the main circuit breaker contacts are opened and closed. All breaker mechanisms utilize stored energy in springs for tripping.

The opening and closing operations are typically performed by one of two methods. The most prevalent is the over center toggle type of mechanism, which opens and closes the breaker contacts by a manual movement of the breaker handle. The second method, called "stored energy," is used on some of the larger breakers. With this method, the energy, stored in springs, may be released either manually or electrically to close the breaker contacts. The manual opening of the breaker is normally accomplished by releasing the energy stored in the trip mechanism. Breakers employing stored energy mechanisms are frequently used in applications requiring consistent, rapid closing capabilities.

3.1.5 Pole

A pole is the conducting path of a main contact. Circuit breakers are either single-pole, two-pole, three-pole, or four-pole with all poles electrically separated. Multi-pole breakers are normally common-trip construction with each pole mechanically tied together through the mechanism, such that all poles operate together. Two-pole circuit breakers may be independent trip construction with the handles on each pole mechanically connected but without a mechanical tie through the mechanism.

3.1.6 Accessories

Accessories are devices added to breakers that perform secondary functions. Accessories include items such as shunt trip releases, under-voltage releases, auxiliary switches, electrical operators, mechanical interlocks, handle locking devices, and so forth.

Most external accessories and some internal accessories are suitable for field installation. The manufacturer should be consulted for specific instructions.

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3.2 INSTALLATION VARIATIONS

3.2.1 External Conductor Connections

3.2.1.1 Front-Connected

A front-connected circuit breaker is one in which the terminals for connecting or disconnecting conductors are accessible from the front of the breaker.

3.2.1.2 Rear-Connected

A rear-connected circuit breaker is one in which the current-carrying conductors are connected to terminals accessible from the rear of the breaker

3.2.2 Mounting Arrangements

3.2.2.1 Stationary-Mounted

A stationary-mounted (fixed) circuit breaker is one that cannot be removed except by unbolting the current-carrying connections and mounting supports. Rigidly attached, external current-carrying conductors may be cable, threaded studs, or bus bars.

Stationary-mounted branch breakers used in panelboard construction usually have line side conductors bolted to the panelboard main bus.

3.2.2.2 Plug-In Mounted

A plug-in mounted circuit breaker is one that is installed in a manner that permits it to be readily removed from the supporting structure in which it is installed and from the line or load side stationary conductors, or both, to which it is attached.

Plug-in branch breakers used in panelboard construction have line side connectors that plug into the panelboard main bus.

The circuit breaker shall be equipped with a mechanical interlock that only permits the removal or insertion of the circuit breaker when its mechanism is in the "open” position.

3.2.2.3 Drawout Mounted

A drawout-mounted circuit breaker is one in which the circuit breaker may be readily removed from the stationary portion with a racking mechanism without unbolting the current carrying connections or mountings supports.

The drawout racking mechanism permits the circuit breaker to be in either the fully "connected" or "disconnected" positions and may provide a "test" position where the primary current carrying conductors are fully disconnected and separated by a safe distance from those in the stationary portion of the assembly and the accessory control wiring connections are "engaged" for "test" purposes.

The accessory control wiring may be automatically connected and disconnected with the action of the circuit breaker racking mechanism, or it may require a separate manual disconnecting operation.

The racking mechanism shall be equipped with a mechanical interlock that permits the movement of the circuit breaker into the “connected” position only with the circuit breaker in the “open” position.

a. Cell Position Switch—A cell position switch is a control accessory device that is used to signal the location of a circuit breaker within a drawout assembly. The device is mounted in the stationary portion of the drawout assembly and signals the movement of the circuit breaker between the “connected” and “test” positions.

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b. Shutter—A shutter is a device that is automatically operated to completely cover the stationary portion of the primary current-carrying conductors when the removable (draw-out) circuit breaker is either in the “test” or in the “disconnected” or “removed” positions.

3.3 HANDLE ORIENTATION

The *National Electrical Code* requires in Section 240-81 that where circuit breaker handles on switchboards or in panelboards are operated vertically, rather than rotationally or horizontally, the "up" position of the handle shall be the "on" position.

Section 380-8 requires that all switches and circuit breakers used as switches shall be located so that they may be operated from a readily accessible place. They shall be installed so that the center of the grip of the operating handle of the switch or circuit breaker, when in its highest position, which will not be more than 6 feet 7 inches (2.0 meters) above the floor or working platform. Exceptions to this are listed below**:**

a. Exception No. 1**:** On busway installations, fused switches and circuit breakers shall be permitted to be located at the same level as the busway. Suitable means shall be provided to operate the handle of the device from the floor.

b. Exception No. 2**:** Switches installed adjacent to motors, appliances, or other equipment that they supply shall be permitted to be located higher than specified in the foregoing and to be accessible by portable means.

c. Exception No. 3**:** Hookstick operable isolating switches shall be permitted at greater heights.

3.4 REVERSE FEED CIRCUIT BREAKERS

Circuit breakers, unless marked "line" and "load," have been tested and found acceptable for reverse feed applications.

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Section 4
MOLDED CASE CIRCUIT BREAKER RATINGS

4.1 AMPERE RATINGS

Standard ampere ratings for inverse time circuit breakers are included in the *National Electrical Code* (See Section 240-6(a)) as follows**:** 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000 amperes. The ampere rating of an adjustable trip circuit breaker is its maximum trip setting.

Section 240-6(b) applies to adjustable trip circuit breakers and notes that the rating is the maximum setting possible with an exception that circuit breakers that have removable and sealable covers over the adjusting means, or are located behind bolted equipment enclosure doors, or are located behind locked doors accessible only to qualified personnel, shall be permitted to have ampere ratings equal to the adjusted (set) long time pickup settings.

4.2 VOLTAGE RATINGS

For ac distribution systems, molded case circuit breakers are available with one or more of the following voltage ratings**:** 120, 127, 120/240, 240, 277, 480Y/277, 480, 347, 600Y/347, and 600 volts. For specific applications, voltage ratings to 1000 volts ac are available.

For dc application, molded case circuit breakers are available with one or more of the following voltage ratings**:** 125, 125/250, 250, 500, or 600 volts dc.

In accordance with Section 240-83(e) of the *National Electrical Code*, circuit breakers shall be marked with a voltage rating no less than the nominal system voltage that is indicative of their capability to interrupt fault currents between phases or phase-to-ground.

In accordance with Section 240-85 of the *National Electrical Code*, a circuit breaker with a straight voltage rating, e.g. 240 Vac may be applied in a circuit in which the nominal voltage between any conductors does not exceed the breaker's voltage rating.

A circuit breaker with a slash voltage rating, e.g. 120/240 Vac, may be applied in a circuit only in which the nominal voltage to ground from any conductor does not exceed the lower of the two values of the breaker's voltage rating and the nominal voltage between conductors does not exceed the higher value of the breaker's voltage rating.

Two-pole circuit breakers which are suitable for protecting three-phase, corner-grounded delta circuits are investigated and marked (1∅-3∅) to indicate their suitability.

For specific application or other voltage ratings, consult the manufacturer.

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4.3 INTERRUPTING RATINGS

Typical molded case circuit breaker interrupting ratings in ac rms symmetrical or dc Amperes are as follows**:**

5,000	25,000	65,000
7,500	30,000	70,000
10,000	35,000	85,000
14,000	42,000	100,000
18,000	45,000	125,000
20,000	50,000	150,000
22,000	60,000	200,000

4.4 FREQUENCY

Molded case circuit breakers may be used for ac or dc applications or both as marked by the manufacturer on the circuit breaker. Unless otherwise noted, ac circuit breakers are rated for use on 50/60Hz systems. Breakers for use on other systems, such as 400Hz, will be marked with the frequency.

CAUTION: Circuit breaker performance may be adversely affected by application at other than rated frequency.

4.5 POWER FACTOR CONSIDERATIONS

Normally the short circuit power factor of a system need not be considered when applying a molded case circuit breaker. This is based on the fact that the test circuit power factors on which the ratings have been established are considered low enough to cover most applications. Test circuits with lagging power factors no greater than in Table 4-1 are used to establish the rating.

When the power factor or X/R ratio for a specific system has been determined and is more inductive than that used to establish the interrupting rating, the multiplying factors shown in Table 4-2 (extracted from ANSI/IEEE Std 242) may be applied to the calculated, available short circuit current. These multiplying factors adjust the short circuit current to a value equal to the maximum transient offset in the initial half-cycle of short circuit current. It must be noted that these multiplying factors are based on calculated values for peak currents rather than on laboratory tests. Individual manufacturers may have additional information. As an example, consider a 225 A MCCB with a marked interrupting rating of 35kA to be applied on a circuit with a short circuit availability of 24kA and a power factor of 10%. Select the multiplying factor of 1.13 and multiply the 24kA value by it to arrive at the new short circuit value of 27.1kA. In this case, the MCCB is suitable for the 27.1kA short circuit because of its 35kA marked rating.

Table 4-1
TEST CIRCUITS WITH LAGGING POWER FACTORS

Available Short Circuit Current (rms sym amperes)	Lagging power factor (%)
10,000 or less	50
10,001–20,000	30
over 20,000	20

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Table 4-2
POWER FACTOR OR X/R RATIO

		MCCB Interrupting Rating (rms sym. amperes)		
		10,000 or less	10,001 to 20,000	over 20,000
Power Factor, %	X/R Ratio	Short Circuit Multiplying Factor		
4	24.98	1.62	1.37	1.23
5	19.97	1.59	1.35	1.22
6	16.64	1.57	1.33	1.20
7	14.25	1.55	1.31	1.18
8	12.46	1.53	1.29	1.16
9	11.07	1.51	1.28	1.15
10	9.95	1.49	1.26	1.13
11	9.04	1.47	1.24	1.12
12	8.27	1.45	1.23	1.10
13	7.63	1.43	1.21	1.09
14	7.07	1.41	1.20	1.08
15	6.59	1.39	1.18	1.06
16	6.17	1.38	1.17	1.05
17	5.8	1.36	1.15	1.04
18	5.49	1.35	1.14	1.02
19	5.17	1.33	1.13	1.01
20	4.9	1.31	1.11	1.00
21	4.86	1.31	1.11	1.00
22	4.43	1.28	1.09	1.00
23	4.23	1.27	1.08	1.00
24	4.05	1.26	1.06	1.00
25	3.87	1.24	1.05	1.00
26	3.71	1.23	1.04	1.00
27	3.57	1.22	1.03	1.00
28	3.43	1.20	1.02	1.00
29	3.3	1.19	1.01	1.00
30	3.18	1.18	1.00	1.00
35	2.68	1.13	1.00	1.00
40	2.29	1.08	1.00	1.00
45	1.98	1.04	1.00	1.00
50	1.73	1.00	1.00	1.00

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Section 5
SELECTION OF MOLDED CASE CIRCUIT BREAKERS

5.1 PRELIMINARY CONSIDERATIONS

Selection of the proper molded case circuit breaker depends on a thorough knowledge of the following system data**:**

5.1.1 Electrical Parameters

a. System voltage rating—phase-to-phase and phase-to-neutral where applicable
b. System phasing—single or multiphase
c. System loads—values and types
d. System frequency
e. Proposed use in system—main, feeder, branch circuit, and so forth
f. Available short circuit current
g. Continuous current and interrupting ratings required

5.1.2 User Requirements

User's requirements include application specifications, mode of operation, environmental and other service conditions, maintenance capabilities, and so forth.

5.1.3 Environmental Conditions

Environmental conditions include ambient temperature, altitude, humidity, vibration, mechanical shock, and any other specific environments concerned with marine or nuclear applications. Where any application considerations involve any of the following, consult the manufacturer.

5.1.3.1 Excessively High Or Low Ambient Temperatures

Thermal magnetic molded case circuit breakers are normally calibrated at 100 percent of rated current in open air for an ambient temperature of 40°C (104°F). Electronic trip circuit breakers and dual magnetic circuit breakers are not ambient sensitive. Where the ambient temperature is known to differ significantly from the calibration temperature, the breaker used should be specially calibrated for that ambient or be re-rated accordingly.

When the expected range of ambient air temperature around the circuit breaker is lower than -5°C (23°F) or higher than 40°C (104°F), breaker operation may be affected.

5.1.3.2 Humidity Conditions

Where fungus growth is prevalent, a special factory treatment may be required to resist moisture and fungi.

5.1.3.3 Corrosive Atmosphere

Where the atmosphere is heavily laden with corrosive salts, vapors, or fumes, molded case circuit breakers may require special corrosion-resistant finishes or enclosures, or both. For excessive or abrasive dust conditions, it is generally recommended that molded case circuit breakers be mounted in enclosures approved for that application. See ANSI/NEMA Standards Publication 250.

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5.1.3.4 Abnormal Vibration Or Mechanical Shock

Applications involving vibration or mechanical shock conditions should be referred to the manufacturer.

5.1.3.5 Altitude

Circuit breakers, when applied at altitudes greater than 2000 m (6600 ft), should have their continuous current and rated maximum voltage ratings multiplied by the correction factors shown in Table 5.1 to obtain values at which the application is made. The short-time and short-circuit interrupting ratings are not affected by altitude, and the short-circuit interrupting rating at the corrected voltage rating is equal to the short circuit interrupting rating at the uncorrected voltage rating.

Table 5.1
ALTITUDE RATING CORRECTION FACTORS

Altitude (ft./m)	Rated Continuous Current (A)	Rated Voltage (V)
<6600/<2000	1.00	1.00
8500/2600	.99	.95
13,000/3900	.96	.80

NOTE—Values for intermediate altitudes may be derived by linear interpolation.

5.1.3.6 Harmonics

Trip units are generally designed to be nonresponsive to load or circuit conditions that generate minor harmonic distortion. However, for certain load conditions, including phase controlled circuits, where the known load current wave shapes are nonsinusoidal, the manufacturer should be consulted for recommendations before application is made. Cyclic loads with sinusoidal wave shapes, such as occur in welding circuits, should also be reviewed with the manufacturer. Since welding loads are intermittent and produce an overload for a short period of time, standard inverse time breakers and electronic trip units equipped with memory circuits could initiate nuisance trip signals. The frequency or probability, or both, of this occurring will depend upon the "during weld" current and "duty cycle." Specific welding applications with known welding current parameters should be referred to the manufacturer. Memory circuit modifications may be required for circuit breakers with electronic trip units.

5.1.4 *National Electrical Code*

The selection of a specific ampere rating for a given application is dependent upon the type of load, duty cycle, and/or point of application. In general, the *National Electrical Code* requires overcurrent protection at the supply and at points where conductor sizes are reduced. Conductors shall be protected in accordance with their ampacities, but exceptions are allowed for applications such as motor circuits where a higher ampere rating is often required to carry motor inrush currents.

NEC Section 110-9 requires equipment intended to break current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that 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.

NEC Section 110-10 defines how the protective equipment along with the other circuit components shall perform when clearing a fault.

> **Circuit Impedance and Other Characteristics—**The overcurrent protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors, or between any circuit conductor

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and the grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section.

Some other performance requirements to be considered include**:**

a. Ground fault requirements, for equipment protection under NEC Sections 215-10, 230-95, and 240-13.
b. Health care facility feeder selectivity requirements for equipment ground fault protection under section 517-17(b).
c. Fire pump circuit breakers under section 230-90(a), exception no. 4.
d. Circuit breakers used as switches in fluorescent lighting circuits-under NEC Section 240-83(d)(swd).
e. Circuit breakers used for group motor overcurrent protection under NEC Section 430-53(c)(3).

NEC Section 430-109 allows the application of a circuit breaker as a disconnecting means provided the circuit breaker is a listed device. See 430-109(a)(4) for an instantaneous trip circuit breaker.

5.2 GENERAL CONSIDERATIONS FOR MOLDED CASE CIRCUIT BREAKER APPLICATION

5.2.1 General Requirements

In keeping with the user's specifications and single-line wiring diagram, the circuit beaker should be selected with the type of mounting arrangement, physical configuration, terminations, operating characteristics, and accessories required for the installation.

The circuit breaker selected should be the best suited for the available environmental surroundings and operating conditions.

The circuit breaker selected should satisfy all national and local code requirements while providing the maximum protection and greatest degree of reliability with minimum maintenance requirements.

5.2.2 The Main Circuit Breaker

The main circuit breaker in most installations generally means the main service circuit breaker. It is located near the point of entrance of the supply conductors to a building and is the main means of disconnecting the supply. A service includes conductors and equipment for delivering electrical power from the supply system to the distribution system of the premises served.

The ampere rating of the main service circuit breaker should be selected so that the rating will not be higher than the allowable ampacity of the service-entrance conductors in compliance with Section 230-90 of the *National Electrical Code*. The interrupting rating should be selected so that it will be equal to or greater than the available fault current at the supply terminals in compliance with NEC Section 110-9. The voltage and frequency ratings should be as required for the distribution system.

If the system and main service circuit breaker requirements fall within the parameters defined in NEC Section 230-95, the circuit breaker selected should have suitable integral ground fault protection or should be one that can operate in conjunction with separately mounted ground fault protection devices. For health care facilities see NEC Section 517-17.

The circuit breaker selected should be equipped with the appropriate short time rating or time/current tripping characteristics, or both, to provide the type of selective coordination required by the user's specifications.

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5.2.3 The Feeder Circuit Breaker

A feeder consists of all circuit conductors between the service equipment, or the source of a separately derived system, and the final branch-circuit overcurrent device.

The ampere rating of the feeder circuit breaker should be selected in accordance with Part B of Article 220 of the *National Electrical Code* so that the rating will be no less than the noncontinuous load plus 125 percent of the continuous load served.

EXCEPTION: Where the assembly including the feeder circuit breaker is UL listed for operation at 100 percent of its ampere rating, the circuit breaker ampere rating may be selected on the basis of the sum of the noncontinuous load plus the continuous load served.

Only circuit breakers that are listed and marked for 100 percent application and mounted in suitable enclosures may be applied in accordance with this exception. All other overcurrent devices are applied at 80 percent or less of their ampere rating for continuous loads (three hour or greater duration).

For a specific fixed motor load, as per the *National Electrical Code*, the ampere rating of the feeder circuit breaker should be selected so that it is no greater than the ampere rating for the largest branch circuit protective device (based on NEC Table 430-152) plus the sum of the full load currents of the other motors in the group (NEC Section 430-62).

On feeder circuits used for large capacity motor installations where future additions are expected, the ampere rating of the feeder circuit breaker should comply with the rated ampacity of the feeder conductors (NEC Section 430-62(b)).

Typical feeder circuits with lighting and single or multiple motor loads are shown in Figures 5-1 and 5-2. The interrupting rating should be equal to or greater than the available fault current at the line side terminals in compliance with NEC Section 110-9. The voltage and frequency ratings should be as required for the distribution system.

Where applicable, the use of listed series tested molded case circuit breaker combinations may be considered. See 5.4.6.

Ground fault protection may be required in accordance with NEC Section 215-10 or, for health care facilities, in accordance with NEC Section 517-17. If ground fault protection is provided on the main breaker as defined in NEC Section 230-95, consider the selection of a feeder circuit breaker with suitable integral ground fault protection or one that can operate in conjunction with separately mounted ground fault protective devices.

As may be required in the user's specifications, the circuit breaker selected should have the appropriate short time rating or time current tripping characteristics, or both, to provide the type of selective coordination required.

5.2.4 The Branch Circuit Breaker

A branch circuit is that portion of a distribution system extending beyond the final overcurrent device protecting the circuit. Branch circuits are intended to serve lighting, appliance, motor, and/or other single loads.

In general, the continuous load supplied by a branch circuit should not exceed 80 percent of the branch-circuit rating, unless the assembled equipment, including overcurrent devices, is approved for continuous operation at 100 percent of its ampere rating.

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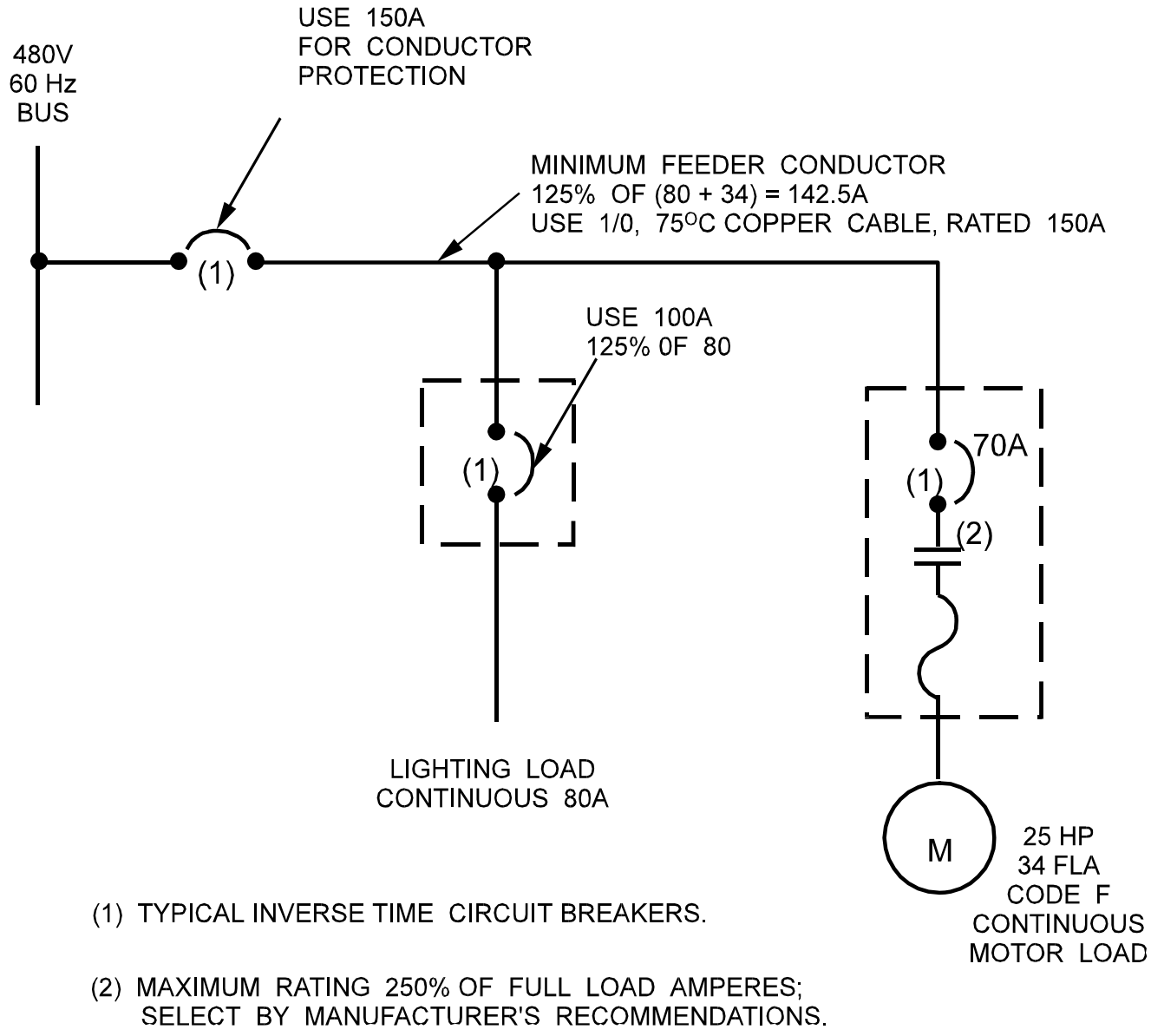


Figure 5-1
TYPICAL FEEDER CIRCUIT (LIGHTING LOAD AND SINGLE FIXED MOTOR LOAD)

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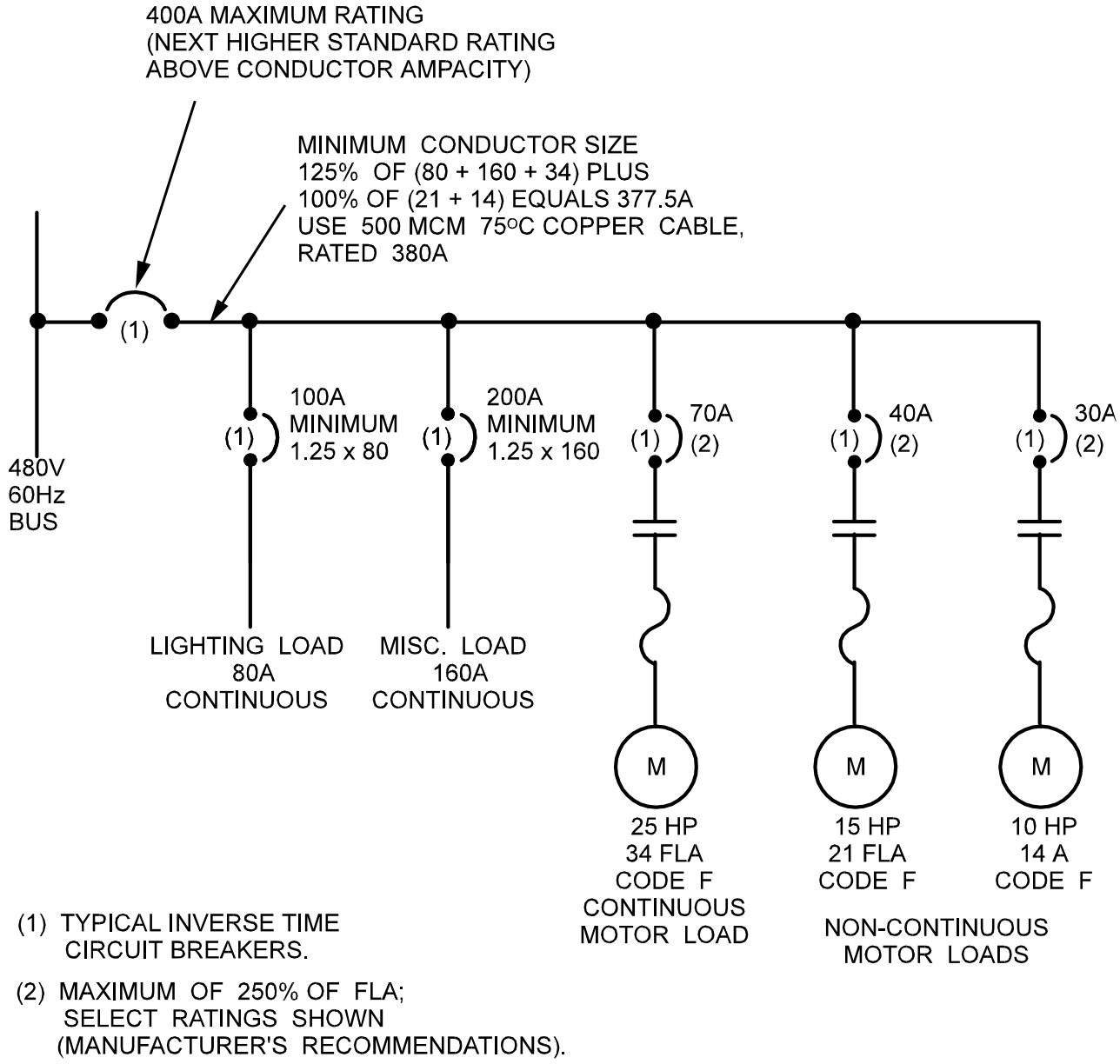


Figure 5-2
TYPICAL FEEDER CIRCUIT (COMBINATION AND MULTIPLE MOTOR LOADS)

The ampere rating of the circuit breaker should not exceed the specified values as shown in NEC Section 240-3 of the *National Electrical Code* for conductors; in NEC Section 240-2 for equipment; and in NEC Section 210-21 for outlet devices.

The interrupting rating of the branch circuit breaker should be equal to or greater than the available fault current at the line side terminals in compliance with Section 110-9. The voltage and frequency ratings should be as required for the distribution system.

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Where applicable, the use of listed series tested molded case circuit breaker combinations should be considered. See 5.4.6.

Ground fault protection may be required in accordance with NEC Section 240-13. If ground fault protection is provided on the main breaker, as defined in NEC Section 230-95, and is also included on the feeder breaker, the user should consider selecting a branch circuit breaker with suitable integral ground fault protection or one that can operate in conjunction with separately mounted ground fault protective devices.

For specific 15 and 20 ampere, 125 volt single phase receptacle circuits (see NEC Section 210-8, 305-6, and 550-8(b) for examples), and for items such as spas and hot tubs (see NEC Section 680-42), the user should select ground fault circuit interrupters (GFCI) equipped to provide personnel protection.

Some applications require circuit breakers with ground fault protection for equipment such as electric deicing and snow melting equipment as described in NEC Section 426-28.

5.3 LOAD REQUIREMENT CONSIDERATIONS

A paramount consideration in selecting a circuit breaker is the load. Attention should be given to the type of equipment comprising the load, the normal continuous/non-continuous current to be carried, the ON-OFF duty cycle, and so forth. There are load conditions that will call for the use of circuit breakers having time-current characteristics or other operating features, or both, fine-tuned for the particular application.

This list is not intended to cover all possible types of loads and combinations of loads, but the examples are cited to illustrate a few of the loading variations that should be considered. If there are any questions about the proper breaker for an application, contact the manufacturer of the circuit breaker or equipment, or both. The following are examples of loads frequently encountered**:**

NOTE—Pulsating loads, such as welders and phase controlled devices, require special considerations to prevent nuisance tripping. Consult the manufacturer.

5.3.1 Continuous Duty, General Purpose Load

Selection of a standard circuit breaker should be determined by adding 100 percent of the non-continuous load plus 125 percent of the continuous load. For a circuit breaker rated to carry 100 percent of its rated current continuously, it is only necessary to add the non-continuous current plus the continuous current. Breakers rated for 100 percent continuous current applications are specifically marked.

5.3.2 Lighting Loads

Refer to 2.3.4 and 2.3.10.

5.3.3 Heating, Air Conditioning, and Refrigeration Loads

Refer to 2.3.6.

5.3.4 Motor Loads

Since motor loads are so prevalent in industrial and commercial applications, they are covered separately in 5.4.9.

5.4 SPECIFIC CONSIDERATIONS FOR MOLDED CASE CIRCUIT BREAKER APPLICATIONS

5.4.1 Conductor Selection

The prime requisite of a molded case circuit breaker is to protect the circuit conductors. In order for the circuit breaker to provide this protection, the user should ensure that the breaker and conductors are properly matched.

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5.4.1.1 Temperature Rating Of Conductor

The *National Electrical Code* gives specific application rules to be followed for the temperature rating of conductors in Section 110-14(c).

It should be noted that some circuit breakers rated 125 amperes or less are marked 60°/75°C and are suitable for use with conductors of either temperature rating.

Wire rated for higher temperatures, such as 90°C, may be used if the conductor size is determined by either the 60°C or 75°C size, as appropriate.

In certain cases involving circuit breakers suitable for operation at 100% of their rating, 90°C conductors, sized in accordance with 75°C ampacity, are required. Refer to marking on the circuit breaker.

5.4.1.2 Conductor Ampacity

The circuit breaker will be marked to indicate the allowable conductor material, copper (Cu) and/or aluminum (Al), and the allowable sizes. The ampacities of most commonly used insulated conductors are listed in Tables 310-16 and 310-17 of the *National Electrical Code*.

In order to apply the tables correctly, consideration should be given to the correction factors in the footnotes and the notes that follow the tables.

CAUTION: The standards that determine the size of conductors inside a factory-wired assembly may be different from the standards used for field wiring. Therefore, the size of the factory wiring should not be used to determine the size of the field wiring. See NEC Section 310-1.

5.4.2 Terminations

Terminations provide the means of connecting the molded case circuit breaker to both the power source and the load. Due to the importance of electrical connections which can affect the performance of the molded case circuit breaker, consideration should be given to the proper selection, application, and installation of the molded case circuit breaker terminations.

Various methods of connection include bolted, plug-in, and terminal wire connectors (lugs). In some cases, more than one method will be used on the same molded case circuit breaker. For example, a breaker could have plug-in connections on one end to connect to a panelboard bus and terminal wire connectors on the other to connect to cables. Plug-in connectors should he used only with equipment specifically designed to accept them. When terminal wire connectors are used to connect the breaker, only those terminal wire connectors specified by the manufacturer for use with the molded case circuit breaker should be used. When alternate means of connection are desired, consult the manufacturer.

5.4.3 Single-Phasing Protection

A three-phase motor running without current in one phase is said to be “single-phasing.” Single-phasing conditions can cause shock hazard, motor overheating, and other equipment damage.

Most multipole circuit breakers are “common-trip” meaning that when a multipole circuit breaker opens, all poles open simultaneously thus preventing “single-phasing.”

5.4.4 Time-Current Curves

Manufacturers of molded case circuit breakers publish time-current curves that are used for coordination with overcurrent protection devices in distribution systems. Circuit protective devices that are selectively coordinated through normally encountered overcurrent ranges, with respect to their time-current curves, will enable the nearest protective device upstream from a fault condition to open first. This leaves the

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balance of the distribution system intact, and the greatest degree of service continuity will be maintained. Time-current curve types may be generally divided into categories determined by the type of trip unit employed in the circuit breaker and the type of adjustments available, including**:**

a. Nonadjustable
1. Fixed ampere setting
2. Fixed long time
3. Fixed instantaneous
b. Partially adjustable
1. Fixed ampere setting
2. Fixed long time
3. Adjustable instantaneous
c. Fully adjustable
    1. Long time pick-up or ampere setting
    2. Long time delay
    3. Short time pick-up
    4. Short time delay
    5. Instantaneous pick-up
    6. Ground fault pick-up
    7. Ground fault time delay

5.4.4.1 Nonadjustable

Circuit breakers are available with nonadjustable time-current characteristics. A typical curve for a 100 ampere, 2 and 3-pole, thermal-magnetic circuit breaker is shown in Figure 5-3. The curve is for application and coordination purposes only. It is based on 40°C ambient cold start when connected with 4 feet of rated wire per terminal. Calibration tests of the circuit breaker's inverse time characteristic are conducted in open air with current in all poles. (As a convenience for field testing, individual pole test data for 300 percent rated current at 25°C is generally shown by the manufacturer.)

In the upper or long-time portion of the curve, the delays are in seconds with shorter time delays as the current increases thus, the term "inverse time characteristic." As the current reaches the instantaneous range, the trip time decreases rapidly to where no intentional time delay occurs. Maximum and minimum trip times are shown across the trip range. Since the circuit breaker must carry 100 percent of its rated current in open air at 40°C (104°F) without tripping, it should be noted that the minimum trip time is shown on the plus side of 100 percent of the breaker ampere rating.

Since many time-current curves cover a range of continuous current ratings (such as from 90 to 150 amperes), the manufacturer should be consulted where specific time-current curves are required for close coordination purposes.

5.4.4.2 Using Breaker Time-Current Curves

NOTE —All examples refer to Figure 5-4.

Example No. 1

Assume a 15 ampere breaker with an instantaneous trip range of 180 amperes to 220 amperes mounted in an enclosure in normal room temperature.

Q**:** When will the breaker trip with an overload of 75 amperes?
A**:** Since 75 amperes is 5 times (point ‘A') the breaker rating (75 ÷ 15 = 5), the breaker will trip sometime between 2.5 seconds (point ‘B') and 7 seconds (point ‘C').

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Example No. 2

Assume motor starting current is 75 amperes for 10 seconds.

Q**:** Will a 15 ampere breaker allow a 10 hp, 460 volts ac motor to start without nuisance tripping on start-up?
A**:** Since 75 amperes motor-in-rush current is 5 times the breaker rating (75 ÷ 15 = 5), the breaker will trip between 2.5 seconds (point 'B') and 7 seconds (point 'C'). Therefore, the 15 amperes breaker will not allow the 10 hp motor to start.

Example No. 3

Assume a 50 ampere breaker with an instantaneous trip range of 350 amperes to 500 amperes mounted in an enclosure in normal room temperature.

Q**:** When will the breaker trip with an overload of 250 amperes?
A**:** Since 250 amperes is 5 times (point 'A') the breaker rating (250 ÷ 50 point 'A'), the breaker will trip sometime between 2.5 seconds (point 'B') and 7 seconds (point 'C'),
Q**:** Under a fault condition of limited value, for example, 2500 amperes, how fast will the circuit breaker trip?
A**:** Since the 2500 ampere fault current (point 'D') is beyond the instantaneous range of the breaker (500 amperes), the breaker, will trip instantaneously.

5.4.4.3 Partially Adjustable

Circuit breakers with frame ratings 225 amps and higher generally have fixed long time, but adjustable instantaneous settings. Except in the instantaneous range, the curve details are similar to the nonadjustable curve. A typical curve of a 400 amp, 2- and 3-pole, thermal-magnetic circuit breaker is shown in Figure 5-5. In the example, the instantaneous pick-up is adjustable from 5 to 10 times the continuous current rating.

5.4.4.4 Fully Adjustable

Molded case circuit breakers with established short time ratings and equipped with electronic trip units can be provided with a full range of adjustable time-current curve shaping characteristics. Example curves are shown in Figure 5-6 for the phase current adjustments and in Figure 5-7 for the ground fault current tripping adjustments.

Since the electronic trip units operate with current derived from current sensors and contain no thermally sensitive bimetals, the trip units are basically insensitive to ambient conditions. Since they are equipped with electronic components that have a recommended ambient range, the curves are generally applicable over a range of -20° to 55°C (-4°F to 131°F).

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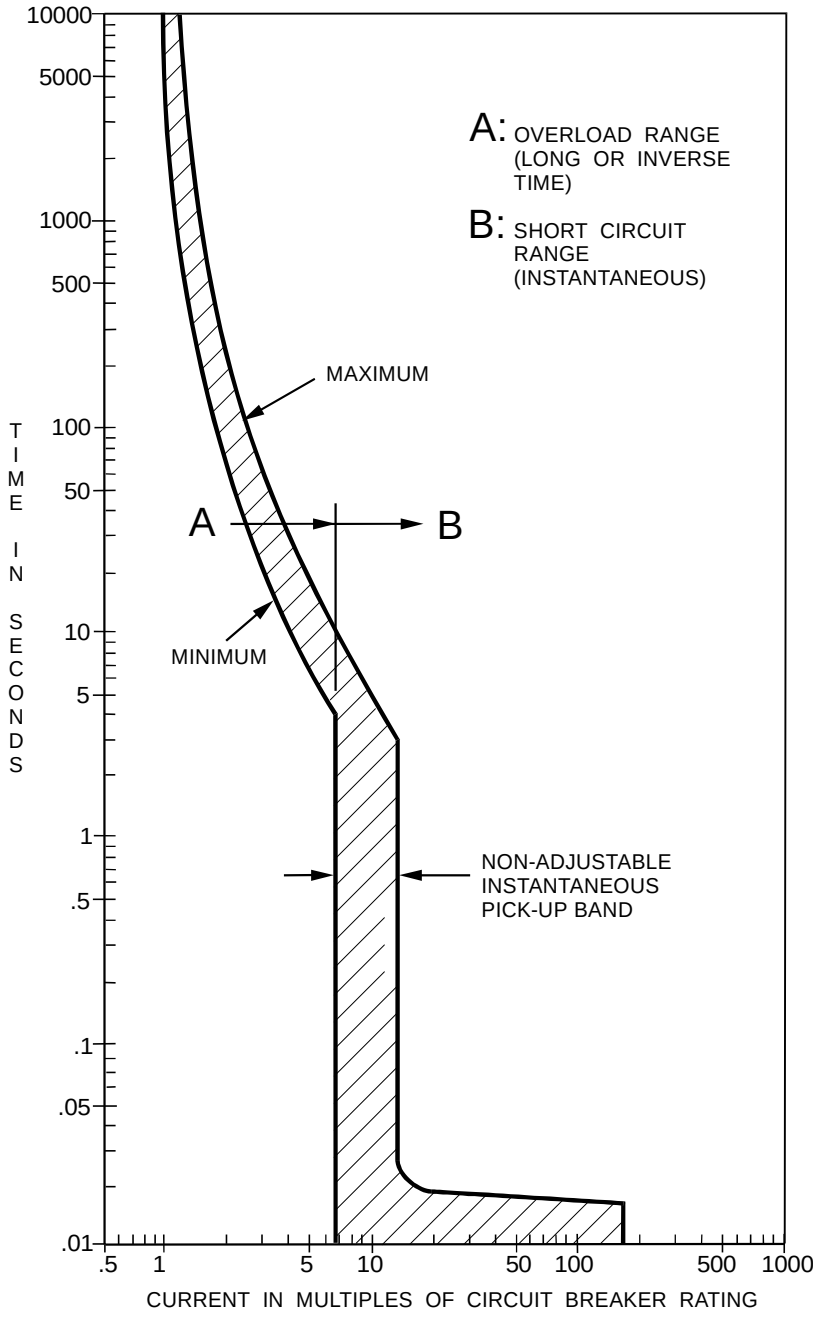


Figure 5-3
TYPICAL TIME-CURRENT CURVE FOR NON-ADJUSTABLE MOLDED CASE CIRCUIT BREAKERS (100A)

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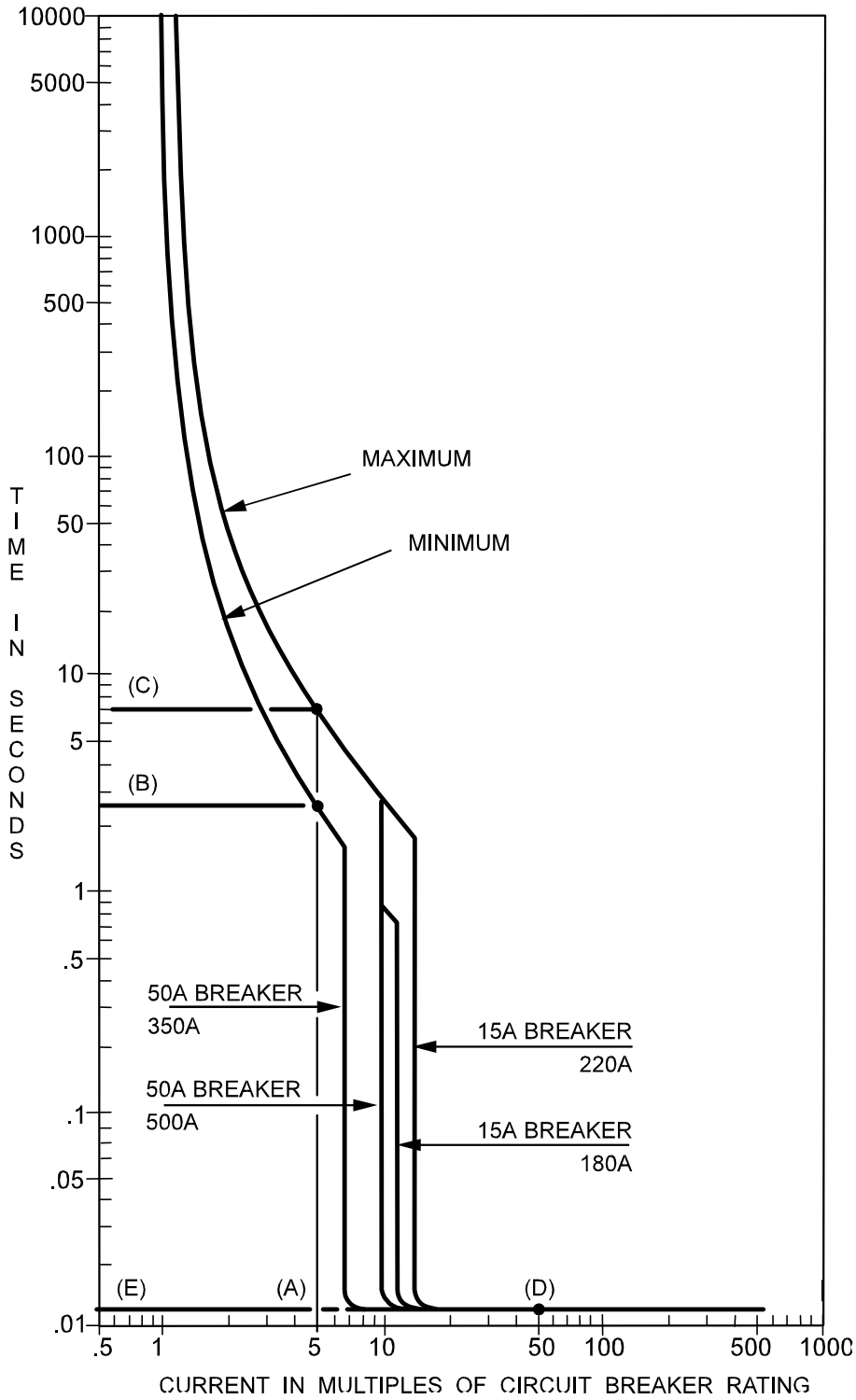


Figure 5-4
SAMPLE TIME-CURRENT CURVE 15A AND 50A CIRCUIT BREAKERS

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Electronic trip units may be equipped with either adjustable short time or adjustable instantaneous settings, or both, to suit application requirements. Trip units with only adjustable short time settings can be used to advantage in selectively coordinated distribution systems. Because of the reduced short time ratings compared to the normally high interrupting ratings, fixed override trip values are provided when the adjustable instantaneous setting is omitted.

Ground fault time-current curves are generally shown separately from the phase current adjustments. For services not exceeding 600 volts, the pick-up setting is limited to a maximum value of 1200 amperes in accordance with Section 230-95 of the *National Electrical Code*. Pick-up settings may be shown as a multiple of the frame rating, the continuous current rating, or in specific ampere settings, depending upon the manufacturer. Time delay settings are generally in steps to a maximum of 0.5 seconds. (See 5.4.5.)

When zone selective interlocking is provided, provisions are included to override the pre-set ground fault time delay for ground faults in the immediate zone of the breaker involved (see 5.5.2.1.4).

5.4.5 Selective Coordination

Selective coordination is the application of circuit protective devices in series in a manner that under fault conditions only the upstream device nearest to the fault will open to clear the circuit. This action enables the balance of the protective devices to remain closed, thus providing the user with the highest level of service continuity.

Time-current curves of molded case circuit breakers with adjustable time-current characteristics serve an important function in this system application.

Before any selectively coordinated distribution system can be developed, several systematic steps should be followed to ensure that the ultimate user's needs and desires are satisfied. Key development steps for the distribution, protection, and coordination of any industrial or commercial power system will involve the preliminary considerations outlined under 5.1 plus the following**:**

a. The preliminary power distribution plan should be developed from the substation or service equipment through the utilization equipment areas.
b. The requirements for standby or emergency power supplies, including any automatic transfer equipment, should be determined.
c. A preliminary single-line wiring diagram should be developed identifying such major electrical components as**:** service and distribution equipment, transformers, large motor loads, lighting, busways, cable routings, and so forth.
d. A preliminary short-circuit study should be conducted to determine required equipment interrupting ratings.
e. Detailed equipment selection coordination studies should follow.

To assist the system designer, there are a number of technical publications that can be used. References that contain detailed information on the above include the following**:**

a. IEEE Std. 141 (red book)
b. IEEE Std. 242 (buff book)
c. IEEE Std. 446 (orange book)
d. IEEE Std. 241 (gray book)

Molded case circuit breakers with electronic trip units generally have high interrupting ratings, short time withstand capabilities, and curve shaping adjustments that make them well suited for application in selectively coordinated systems.

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The following is an example of selective coordination using circuit breakers with electronic trip units:

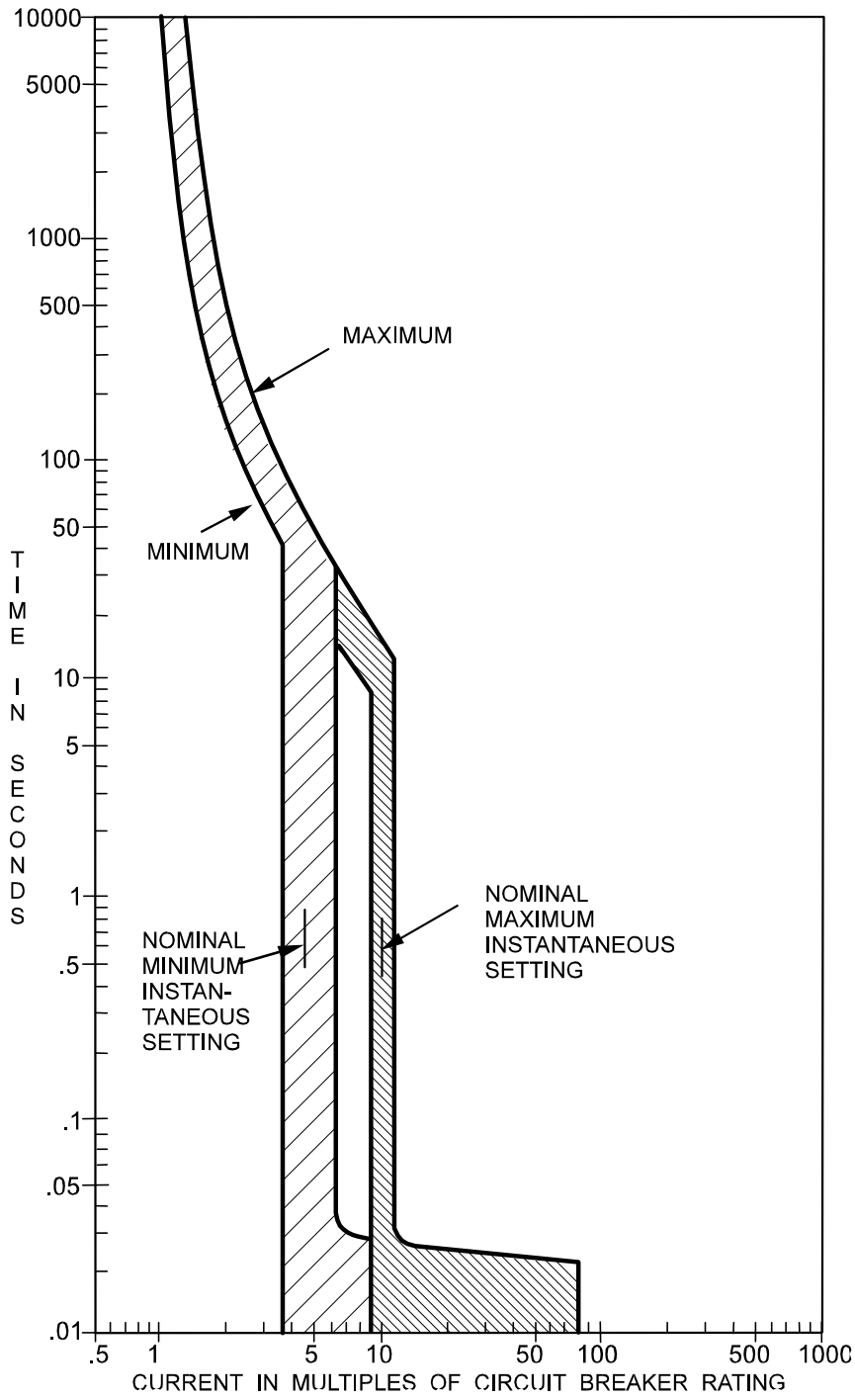


Figure 5-5
TYPICAL TIME-CURRENT CURVE FOR ADJUSTABLE INSTANTANEOUS MOLDED CASE CIRCUIT BREAKERS

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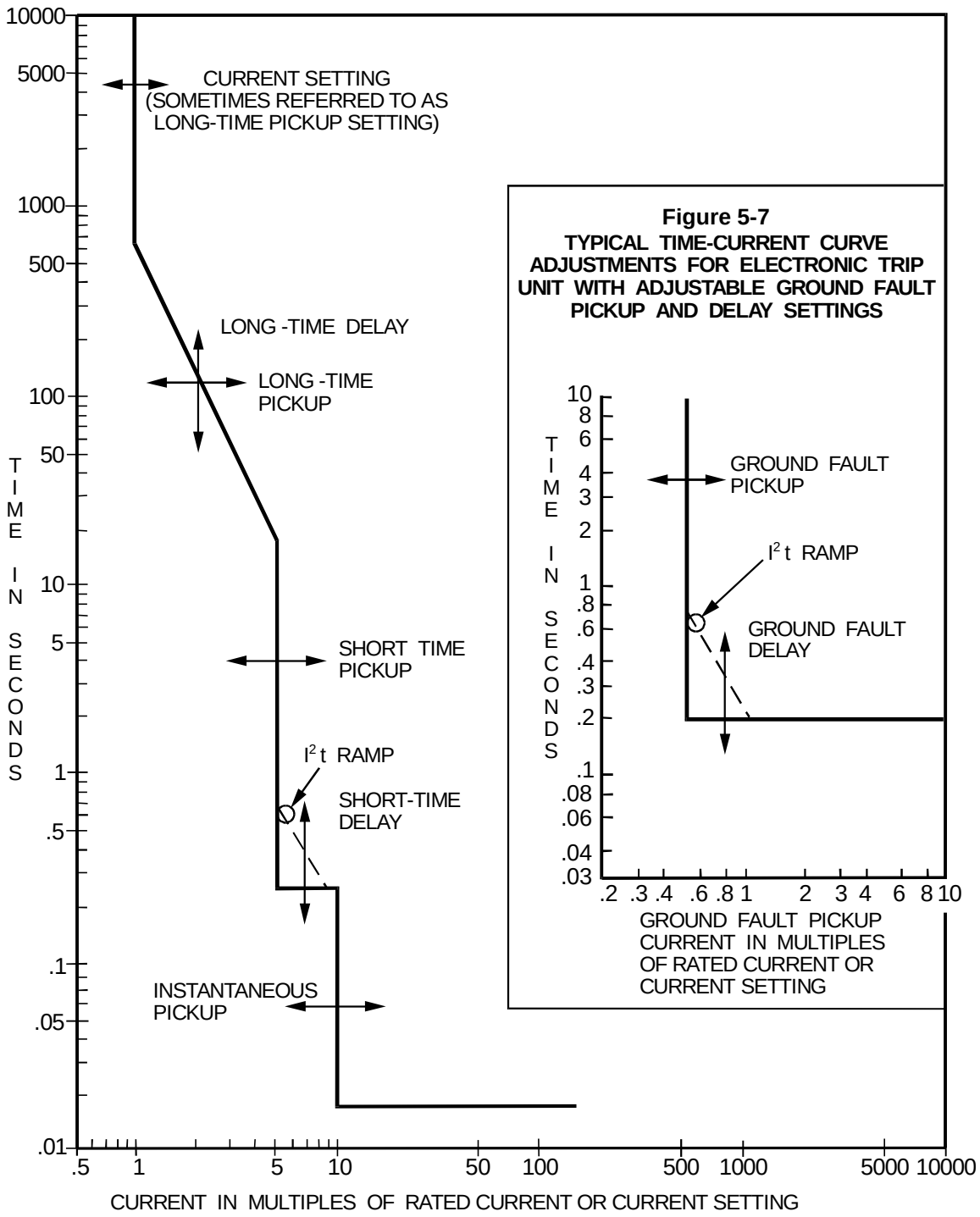


Figure 5-6
TYPICAL TIME-CURRENT CURVE ADJUSTMENTS FOR ELECTRONIC TRIP UNIT WITH ADJUSTABLE PHASE CURRENT SETTINGS

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Given

a. Single-line diagram with utility supply parameters as illustrated in Figure 5-8
b. High fault protector(s) or fuse(s) (A) of the type and rating recommended for the protection of the given transformer in accordance with Section 450-3 of the *National Electrical Code*
c. Feeder circuit breaker (F) rated 600 amperes
d. Downstream branch breaker (B), thermal-magnetic type, rated 100 amperes with time-current curve per Figure 5-3
e. Preliminary fault current study with values as indicated; for methods of calculation, refer to the IEEE Std. 141 (Red Book) or the manufacturer's literature, or both

Required

a. Main circuit breaker (M) with rating and time-current adjustments required for selective coordination with the given boundary protective devices**:** A and B
b. Feeder circuit breaker (F) with rating and time; current adjustments required for selective coordination with the given boundary protective devices**:** M and B
c. Coordinated, integral ground fault protection on devices M and F

Solution

The three requirements above clearly define a need that can be satisfied with two circuit breakers equipped with electronic trip units having integral ground fault protection. The interrupting ratings required are relatively low for today's modern circuit breakers, but the short time ratings are well suited for the given application.

The continuous current rating of the main circuit breaker (M) is selected as 1600 amperes, assuming a supervised installation. This circuit breaker may have a 100 percent application rating in accordance with Section 215-3 (exception). The rating will comply with Table 450-3(a), which permits continuous ratings to 250 percent for a supervised installation of the transformer secondary (1203 amperes) where primary fuse protection is supplied with a maximum rating of 300 percent of the transformer primary rating (139 amperes).

NOTE**:** Circuit breaker (M) ampere rating would be limited to 125% of the transformer secondary full load amperes per Table 450-3(a) for installations which are not supervised.

The interrupting rating of the main circuit breaker (M) should exceed 17.8 kA rms symmetrical at 480 volts.

The interrupting rating of the feeder breaker (F) shall exceed 22.6 kA rms symmetrical at 480 volts; this includes 100 percent motor contribution.

Molded case circuit breakers having the required features and ratings could have time-current curves similar to those illustrated in Figures 5-6 and 5-7. These types of circuit breakers have fixed override circuits with fixed instantaneous settings (which are based on their short time ratings) that are employed when the adjustable instantaneous settings are omitted for selective coordination.

Selected pick-up and time delay values for each circuit breaker are defined in Figure 5-8 under “M” and “F.” With the various settings available and the boundary conditions given, alternate phase current selections could have been made but the choices shown are a good compromise.

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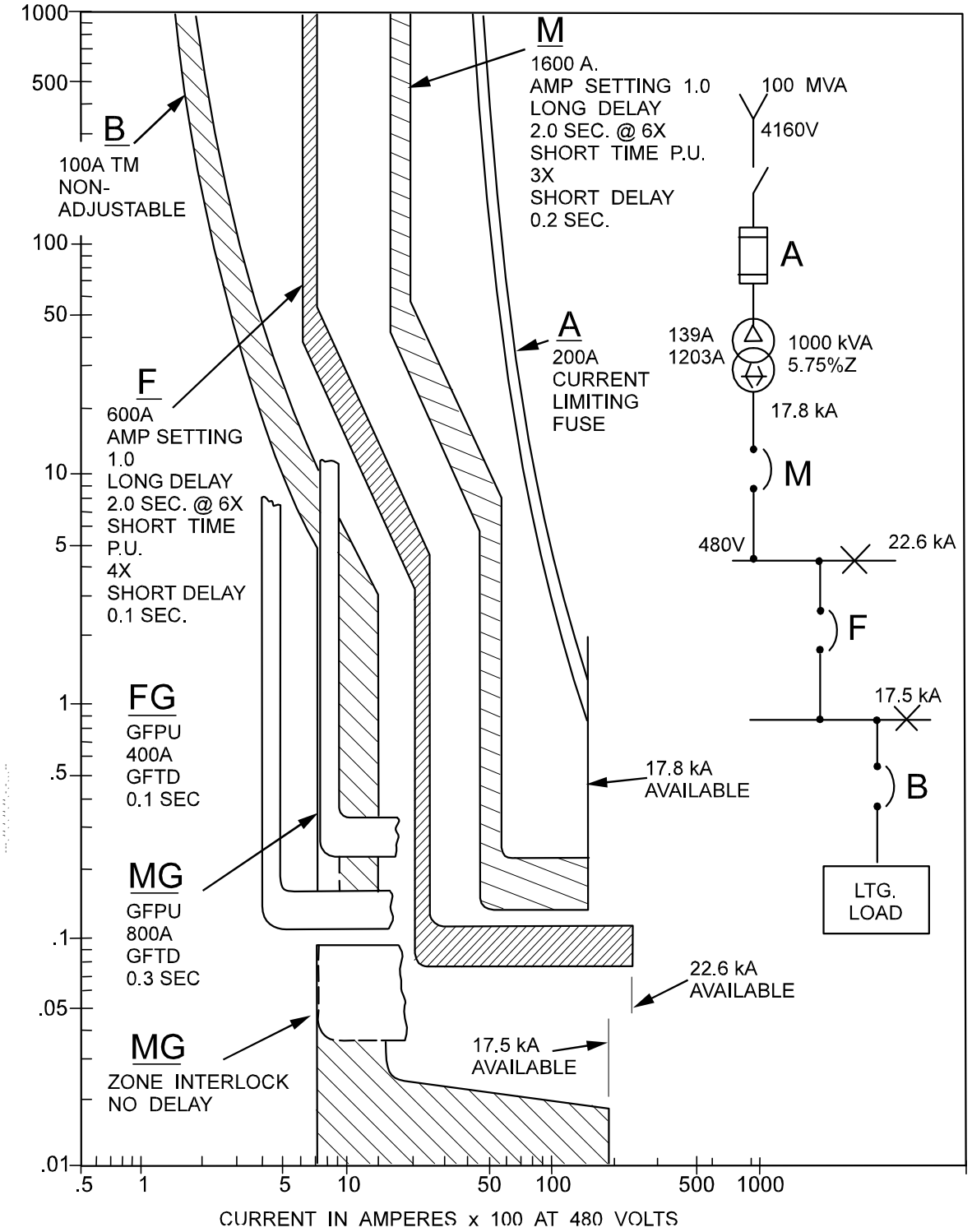


Figure 5-8
TYPICAL SYSTEM—SELECTIVELY COORDINATED

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When ground fault protection is required by NEC Section 230-95 for the main circuit breaker, it is not also required for the feeder circuit breaker, but is recommended where maximum continuity of service is desired. (See NEC Section 230-95, FPN No. 2.)

Ground fault settings for circuit breakers M and F are shown under separate curves M, G, and FG. Ground fault application details and recommended settings are shown in NEMA Standards Publication PB 2.2.

The ground fault selections shown follow the general recommendations of these guidelines. Selective coordination is achieved for all faults between the main and feeder circuits. For ground faults on the branch circuit (B) greater than 400 amperes and less than 1400 amperes, selectivity will be lost because circuit breaker F will open ahead of circuit breaker B. This was not a requirement in this example.

The zone interlocking between the main breaker (M) and the feeder breaker (F) will greatly reduce the probable damage level if a ground fault occurs in the system between the main and feeder circuit breakers. This is illustrated by the change in trip time indicated for “MG” for a downstream fault (0.2 second time delay) and a zone fault (no delay, for example, 0.08 seconds). Tripping on the downstream feeder breaker (F) is restrained to the pre-set time delay value of 0.1 second (FG) to give device “B” a chance to clear faults downstream of device B.

Conclusion

Selectively coordinated distribution systems can be effectively developed using molded case circuit breakers with electronic trip units equipped with integral ground fault protection. Because circuit breakers have a wide range of ratings and features, the manufacturer should be consulted.

5.4.6 Series Application

In electrical distribution systems, molded case circuit breakers may be applied in series with another overcurrent protective device in either of two methods and fully comply with the requirements of the *National Electrical Code*.

Fully Rated Method

Each circuit breaker should be selected with an interrupting rating equal to the available fault current at its line side terminals. This is the conventional method of applying circuit breakers, and it fully complies with the requirements of Section 110-9.

Series Tested-Combination Method (See Section 5.4.7 for explanation)

CAUTION: The use of *non-tested* fuse/breaker series combinations can cause personal injury or equipment damage, or both. Only *listed* series fuse/breaker combinations should be used.

Listed series fuse/breaker combinations will have been tested by the circuit breaker manufacturer. Fuse selections determined by other methods such as "up-over-down" or "up-over" should not be applied because these methods do not consider the "dynamic impedance" of the downstream circuit breaker.

Two or more circuit breakers or fuse/circuit breaker combinations should be selected that have been "tested in series" and listed for the available fault current at the line side terminals of the upstream device. This is an applications concept that meets the full intention of Section 110-9.

When used with motor loads on the bus between the two devices in the series, the sum of the motor loads on the bus should be no greater than 1% of the interrupting rating of the load side devices. Motor loads in residential applications do not exceed the 1%.

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Section 110-9 defines the interrupting rating requirements for electrical installations as follows**:** "Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment." Section 110-3(a)(1) indicates that the suitability of equipment may be evidenced by listing or labeling.

To implement these two basic requirements in the *National Electrical Code*, Underwriters Laboratories Inc. established in UL 489 a test sequence and performance criteria for molded case circuit breakers connected in series with other breakers or fuses. Tabulations of circuit breaker combinations that meet these requirements are published in the UL Recognized Component Directory.

In no case should a series combination of molded case circuit breakers or fuse/circuit breaker combinations be applied in a distribution system where the available fault current exceeds the marked interrupting rating of the upstream or line side circuit breaker or fuse. However, the interrupting rating of the individual downstream breaker in the combination may be exceeded if the combination has been tested at ratings equal to or greater than the available fault current at the point of application of the line side terminals of the upstream device.

The interrupting rating of the series combination is not permitted to be marked on the downstream circuit breaker. However, the end use equipment, such as a panelboard, in which the combination has been tested and listed, is marked with the series tested short circuit rating. This is permitted under two conditions**:**

a. The upstream circuit breaker or fuses are installed in the panelboard as a main breaker; or
b. The panelboard is main-lug-only type and is specifically marked to indicate the type and rating of the upstream listed series tested circuit breaker or fuses that must be applied with the panelboard.

To apply circuit breakers that have been series tested in a distribution system where the marked interrupting rating of the downstream device is exceeded, the following procedures should be observed**:**

a. The available fault current at the line side terminals of the upstream circuit breaker or fuses should be determined.
b. The circuit breaker or fuses selected as the upstream device should have an interrupting rating equal to or greater than the available fault current as determined in (1) above.
c. During installation, confirmation of the correct application can be verified by referring to the listing marks or nameplates, or both, appearing in the end use equipment. As required by NEC Section 110-22, any installation in which a series combination has been applied shall be marked by the installer "CAUTION-SERIES COMBINATION SYSTEM RATED __A. IDENTIFIED REPLACEMENT COMPONENTS REQUIRED."
d. The "Series Tested" interrupting rating of the selected combination may be verified by referring either to the UL recognized component directory or the manufacturer's literature.

NOTE—All combinations of circuit breakers or fuses and circuit breakers have not been tested and listed for series application. Only those ratings and combinations that can be verified should be used.

5.4.7 Dynamic Impedance

Arc impedance is introduced into a circuit by the opening of the circuit breaker contacts during current interruption. This arc impedance is referred to as dynamic impedance. The level of impedance and its rate of rise vary with the circuit breaker design. In general the faster a circuit breaker's contacts open the higher the impedance. The effect of dynamic impedance is that the circuit breaker limits the current flow in the circuit.

All molded case circuit breakers are capable of developing some degree of dynamic impedance under short circuit condition and thus can effectively limit the current flow. This is true whether the circuit breakers are identified as current limiting or not.

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The current limiting effect of the dynamic impedance can cause an unpredictable increase in the response time of the upstream device, therefore making it impossible to successfully select series combinations unless properly tested.

5.4.8 Capacitor Switching

5.4.8.1 General Purpose

Capacitors are used in low voltage distribution systems primarily to improve the overall power factor of the system. Requirements for capacitor applications are covered in Article 460 of the *National Electrical Code*.

5.4.8.2 Molded Case Circuit Breaker Ratings

Molded case circuit breakers should have voltage ratings adequate for the voltage of the capacitor system in which they are applied. The interrupting rating should be equal to or greater than the fault current available at the point of application. The continuous rating of the circuit breaker should be in excess of 135 percent of the maximum nameplate rating of the capacitor to be switched. Because of transient conditions which may occur during switching, manufacturers generally recommend values of 150 percent and above. Consult the manufacturer for specific recommendations.

5.4.9 Motor Loads

In selecting branch circuit protection for motor loads, it should be recognized that, while the circuit conductors should be protected from overcurrents due to overloaded circuits, short-circuits, and high-level ground faults, the branch circuit protective device should be able to carry the starting current of the motor without opening the circuit.

When a molded case circuit breaker is used as a protective device for a motor load, it can be either an instantaneous trip or a combination inverse-time/instantaneous trip type.

Instantaneous only circuit breakers are used only for short-circuit and high level ground fault protection. The *National Electrical Code* recognizes this type of breaker but allows its use, only if adjustable, and if part of a listed combination controller (See NEC Section 430-52(a)). The combination motor starter should have overload protection in each conductor.

The adjustable trip on these breakers should be set just above the starting current of the motor. This will afford the maximum short-circuit protection. One of the chief advantages of this type of breaker is that it provides short-circuit protection slightly above the instantaneous peak starting current of the motor.

Under 430-52(a), a FPN states that instantaneous trip only circuit breakers may be equipped with a damping means to accommodate a transient motor Inrush current without nuisance tripping.

Some motors have peak instantaneous starting characteristics higher than 13 times motor full load current (MFLC). Also some applications involving fast reversing, plugging, open transition, reduced voltage starting, or automatic supply transfer can cause very high peak starting currents. The motor and circuit breaker manufacturers should be consulted when applying breakers in these types of applications.

Another advantage of instantaneous-only breakers is that they can be sized at 115 percent of motor full load current, the minimum allowed by the *National Electrical Code*, without creating tripping problems on motor starting. This may allow the use of an instantaneous trip circuit breaker of smaller frame size than a thermal-magnetic circuit breaker.

An inverse time circuit breaker can be used to protect branch circuits feeding individual motors, groups of motors, or combinations of motors and other loads.

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The *National Electrical Code* requirements for motor branch-circuit short-circuit and ground-fault protection are contained in Article 430 (Part D). These are maximum values for branch-circuit protection device settings that define the limit of safe application. Where maximum protective device settings (ratings) are specified by the equipment manufacturer, they should not be exceeded.

5.4.10 Nuclear Power Generating Station Equipment Qualifications

Class 1E is the safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise are essential in preventing significant release of radioactive material to the environment. (See IEEE 323.)

The IEEE standards that relate to the qualification of Class 1E Equipment for nuclear power generating stations that could involve molded case circuit breakers include**:**

a. Standard 323
b. Standard 344
c. Standard 649
d. Standard 650

Any application of molded case circuit breakers requiring qualifications in line with these standards will be very special and should be referred to the manufacturer for recommendations.

5.5 OTHER CONSIDERATIONS FOR SPECIFIC APPLICATIONS

5.5.1 Current-Limiting

A general definition that includes a current-limiting circuit breaker has been established in Section 240-11 of the *National Electrical Code*. It is a device which, when interrupting currents in its current-limiting range, will reduce the current flow in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.

This is a generalized definition and could be used to cover the three common current-limiting design concepts used with molded case circuit breakers with

a. integrally mounted current limiters
b. close-coupled externally mounted current limiters
c. electro-mechanical means for limiting fault currents without replaceable fuse elements

For the purpose of this publication, categories a and b above cover molded case circuit breakers with current limiters (high fault protectors) or fuses unique to the product and not general purpose current limiters (high fault protectors) or fuses that may be used with other devices.

Any device considered "current-limiting" will substantially limit the peak let-through current (Ip) and thermal energy (I^2t) in responding to high level faults. The I^2t must be less than the I^2t of a 1/2-cycle wave of the symmetrical prospective current.

The forces exerted on the conductors in a distribution system, or circuit protective device, are related to the square of the peak let-through current (Ip^2). This is a main factor in determining the mechanical strength of a circuit component, including the molded housing, circuit conductors, wiring terminations, switchboard bus bracing, and so forth.

I^2t is a measure of the thermal let-through energy. This factor is directly related to the thermal capability of the system and its protective devices. It is used to determine minimum thermal conductor size, insulation limitations, and the capabilities of welded or brazed connections to remain intact.

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The selection of the proper current-limiting devices is not a simple matter. The manufacturers of current-limiting devices normally publish the Ip and I^2t let-through values of their circuit protective devices. However, care should be taken to choose devices, not only by their individual characteristics, but by their characteristics as influenced by the system within which they will be installed.

All current-limiting devices function as limiters within finite ranges of current values. Circuit impedance and other circuit parameters change during fault interruption due to the dynamic characteristics of downstream devices. Therefore, it is possible that the inherent current-limiting of a downstream current protective device could prevent a fault current from reaching the minimum current-limiting level of an upstream current-limiting device while still surpassing its own maximum interrupting rating. In a situation such as this, protection does not exist for the downstream device.

Therefore, because the circuit breaker manufacturer normally conducts actual system tests of these devices, the manufacturer's recommendations should be strictly followed.

5.5.1.1 Integrally Fused Circuit Breakers

Refer to 2.3.2.

5.5.1.2 Current-Limiting Circuit Breakers

Refer to 2.3.3.

5.5.2 Ground Fault Protection

The subject of ground fault protection is extensive but, for application simplicity, can be broadly separated into two major categories**:**

a. Ground fault protection for equipment
b. Ground fault protection for personnel

These two categories are covered by separate design and performance standards as well as separate sections of the *National Electrical Code*. Separate and distinctly different product types are available for each application category.

Personnel protection involves the protection of human life and, as such, requires sensitivity levels in the low (4-6) milliampere current range. Devices that provide this protection are called ground fault circuit interrupters (GFCI or GFI).

Ground fault protection for equipment (commonly referred to as GFP) is safety oriented, but from a different viewpoint. The protection of low voltage (600 volts) equipment allows sensitivity levels in the ampere range but also considers other user considerations, such as continuity of service, which can also be a very important safety factor. A new category of “circuit breaker with equipment ground fault protection” was recently established specifically for fixed outdoor deicing / snow-melting equipment and fixed heating equipment for pipelines and vessels as required in the *National Electrical Code*. The ground fault sensitivity level for these devices is typically 30 milliamperes.

5.5.2.1 Ground Fault Protection For Equipment

5.5.2.1.1 GFP (Ground Fault Protective) Devices

The NEMA Standards Publication PB 2.2 provides a thorough discussion of the applications of ground fault protective (GFP) equipment devices. Refer to this NEMA publication for details. *National Electrical Code* requirements for GFP devices are noted in Sections 215-10, 230-95, and 240-13.

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5.5.2.1.2 Circuit Breakers with Equipment Ground Fault Protection

Test requirements for a circuit breaker with equipment ground fault protection are covered in the UL 489 and UL 1053 standards. *National Electrical Code* requirements for a circuit breaker with ground fault protection are noted in Sections 426-28 and 427-22. Also refer to 2.3.12

5.5.2.2 Ground Fault Protection For Personnel (Circuit Breaker Type GFCI)

a. General Description

Circuit breaker type ground fault circuit interrupters (GFCIs) are standard inverse time type circuit breakers that also contain a differential current circuit that senses and initiates a tripping action on low-level ground fault conditions. These devices operate at 6mA maximum to protect personnel from ground fault currents. Circuit breaker GFCIs are normally used in load centers and panelboards to protect branch circuits in residential, commercial, and industrial applications.

The *National Electrical Code* requires GFCI protection in many places. These requirements can generally be met by the use of circuit breaker type ground fault circuit interrupters.

See NEMA Standards Publication 280 for additional information.

b. Available Ratings

Circuit breaker type GFCIs are normally rated 15, 20, 25, 30, 40, or 50 amperes, 120 volts ac, single-pole or 120/240 volts ac, two-pole. Application requirements are generally the same as for standard molded case circuit breakers. These devices are listed as Class "A" ground fault circuit interrupters and are required to operate at ground fault currents of 6 milliamps and greater.

c. Principle of Operation

In addition to providing personnel ground fault protection, a standard circuit breaker type ground fault circuit interrupter operates the same as any standard, inverse time circuit breaker providing circuit protection against overloads and high-level fault conditions. The ground fault sensing portion of the device responds only to ground faults which trigger the differential portion of the circuit.

All GFCIs are provided with a push button actuated test circuit that simulates a low-level ground fault to check the operating integrity of the device. Tests should be conducted monthly and a test record should be maintained.

For more detailed information on GFCIs, see NEMA Standards Publication 280.

5.5.3 Molded Case Switches

Molded case switches are used where compact high ampere rated switches are needed. The use of a circuit breaker design with its small operating mechanism and reduced size throughout makes a very compact switch possible. They contain circuit breaker arc interrupting and mechanism parts and have the ability to manually make and break motor locked rotor currents. They are assigned specific withstand ratings and are intended primarily for use as a disconnect device. Molded case switches may open automatically when subjected to short circuit fault levels below their withstand ratings. Short-circuit and overload protection on systems using molded case switches must be provided by an appropriate overcurrent device.

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5.5.4 Circuit Breakers Used on DC Systems

a. General

Molded case circuit breakers with dc ratings are typically applied in utility control systems, uninterruptible power systems, and telecommunication systems. Circuit breakers that are equipped with electronic trip units are typically not rated for use on dc systems since they utilize current transformers to sense the current.

b. DC Circuit Breakers Rated Up To 250 Vdc

Molded case circuit breakers with dc ratings up to 250 Vdc are certified to the basic requirements in the UL 489 standard. Comprehensive tests at fault current levels in ranges “A” and “B” of Figure 5 are conducted to evaluate the performance of the breaker to the ratings claimed.

c. DC Circuit Breakers Rated Above 250 Vdc

The UL 489 standard contains a supplement with requirements specifically for molded case circuit breakers with dc ratings above 250 Vdc for use in uninterruptible power supply (UPS) battery systems. Circuit breakers certified to these requirements are marked as being suitable only for use with UPS. The requirements are identical to the core UL 489 requirements with the following special points**:**

1. Nominal and Maximum (float) DC voltages—Considering that battery systems will float to a voltage above nominal when load is minimal, endurance and overload tests are done at the maximum (float) voltage. Also, the dielectric test levels are based on the maximum voltage. Both nominal and maximum voltages are marked on the circuit breaker.

2. Overload and endurance operations—For some frame sizes, the requirements for endurance and overload operations are reduced from those required of the general-application circuit breaker.

3. Pole Connections—Many circuit breakers used for dc circuit protection have the poles connected in series, especially for circuits above 250 Vdc. By connecting the poles in series, arc interruption is shared. Requirements for such connections are marked on the circuit breaker and in instructional information. Circuit breakers connected in this way are not generally suitable for use on systems with one polarity grounded. The reason is that a single ground fault could cause the full dc voltage to appear across one of the poles. These multi-pole connected circuit breakers will be marked for use only on ungrounded systems.

d. Dual-Rated AC/DC Breaker Performance

The performance of dual-rated ac/dc circuit breakers utilized on a dc circuit, as compared to the performance on an ac circuit, depends upon the level of fault current.

1. Overload Range—Refer to Figure 5-3. For fault current levels in the “A” range, the sensing element for a thermal-magnetic circuit breaker is a bimetal. Deflection of the bimetal is proportional to I^2 (rms). Deflection with dc will be the same as with the rms value of ac so that the time-current characteristic is the same for both ac and dc.

2. Short Circuit Range—Again refer to Figure 5-3. For fault currents at the lower end of the “B” range (approximately 4–12 times the circuit breaker rating) the electromagnetic feature of the circuit breaker is activated. The electromagnet responds to I_{peak} (instantaneous) rather than rms over some period. Under ac overcurrents, the armature of the electromagnet may “chatter,” knocking the latch partially off with each electrical cycle. With dc, however, the electromagnet force must be sufficient to unlatch the mechanism with a single force motion. The net effect is that the pickup band shown in Figure 5-3 shifts slightly to the right for the circuit breaker when applied on a dc circuit.

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For fault currents at the higher end of the “B” range (above 12 times the circuit breaker rating) the electromagnetic feature is also activated, but tripping time is essentially instantaneous. Actual circuit clearing time, however, depends on the circuit parameters and the particular design of the interruption section of the circuit breaker. Unless otherwise clarified by the manufacturer, the ac maximum clearing time shown on the time-current curve will also satisfy dc.

5.5.5 Arcing Fault Protection (Circuit Breaker Type AFCI)

a. General Description

Circuit breaker type arc-fault circuit interrupters (AFCIs) are standard inverse time type circuit breakers that also contain an arcing fault detection circuit that senses and initiates a tripping action when an arcing fault condition, which may cause a fire, is detected. Circuit breaker AFCIs are normally used in load centers to protect branch circuits in residential applications.

The *National Electrical Code* requires AFCI protection for the branch circuits supplying outlets installed in dwelling unit bedrooms. These requirements can generally be met by the use of circuit breaker type arc-fault circuit interrupters.

b. Available Ratings

Circuit breaker type AFCIs are rated 15 or 20 amperes, 120 volts ac, single-pole or 120/240 volts ac, two-pole. Application requirements are generally the same as for standard molded case circuit breakers.

c. Principle of Operation

In addition to mitigating the effects of arcing faults, a standard circuit breaker type arc-fault circuit interrupter operates the same as any standard, inverse time circuit breaker providing circuit protection against overloads and high-level fault conditions. The arc-fault sensing portion of the device responds only to arcing faults, which trigger the arcing fault detection portion of the circuit.

All AFCIs are provided with a push button actuated test circuit, which simulates an arcing fault to check the operating integrity of the device. Tests should be conducted monthly to verify that the unit remains functional. Units that no longer pass the test should be replaced.

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Appendix A
UL REQUIREMENTS FOR MOLDED CASE CIRCUIT BREAKERS

A.1 UL LISTED CIRCUIT BREAKERS

A UL Listed circuit breaker will have the words “Underwriters Laboratories Inc.” in various forms and/or a symbol comprised of the letters “UL” in a circle, together with the word “Listed” on the label. This marking means that the breaker has met the basic requirements for circuit breakers covered by Underwriters Laboratories Inc. (Standard UL 489). This UL label on a circuit breaker also means that the manufacturer's production is monitored at the factory by UL inspectors to assure continuing conformance to the UL performance requirements.

A.1.1 Performance: Initial Submittal to UL

After a new breaker has been designed, sets of samples are submitted to UL for a series of tests. At the discretion of the manufacturer, the tests shall be permitted to be performed sequentially, or in X,Y,Z sequencing as described under follow-up tests. Separate samples are submitted to the high available fault current test sequence.

A.1.2 Performance: Follow-up Tests

Underwriters Laboratories Inc. requires that continual testing be conducted on circuit breakers. These follow-up tests are scheduled on a regular, quarterly, semiannual, annual, and biennial basis.

The regular tests are conducted on a representative lot of breakers and consist of calibration checks, both 200 percent and 135 percent. The regular tests may also include a complete detailed inspection for constructional compliance. The regular tests may be conducted on any rating breaker and at any random time interval.

The quarterly, semiannual, and annual tests are generally conducted on the lowest and highest ratings of each family (similar construction) of circuit breakers. Three different types of test sequences (X, Y, and Z) are used. Each of these sequences is a portion of the full series of tests required for initial UL submittal. Each of these test sequences is conducted on a lot of new, unconditioned circuit breakers. The sequence of the tests in these groups is mandatory.

The UL follow-up testing begins with samples from the initial production run of a newly-labeled product. The samples from the initial production run are tested under the annual test program (Sequence X, Y, and Z). The timing of the follow-up program begins with this annual test.

The three test sequences (X, Y, and Z) are listed below**:**

a. Sequence X—Conducted quarterly on breakers of frame size 200 amperes or less and annually on breakers of frame size over 200 amperes.
   1. Calibration–200 percent
      –135 percent
   2. Overload
   3. Calibration at 100 percent
   4. Temperature
   5. Dielectric

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b. Sequence Y—Conducted quarterly on breakers of frame size 200 amperes or less and annually on breakers of frame size over 200 amperes.
   1. Calibration–200 percent
   2. Endurance–Load
      –No Load
   3. Recalibration–200 percent
      –135 percent
   4. Short circuit
   5. Trip out
   6. Dielectric

c. Sequence Z—Conducted semi-annually on breakers of frame size 150 amperes or less and annually on breakers of frame size over 150 amperes.
   1. Calibration–200 percent
   2. Short Circuit
   3. Trip Out–200 percent
   4. Dielectric

d. High-Available Fault Current Test Sequence

   For circuit breakers that have higher than standard interrupting ratings tests are conducted at the interrupting levels that represent maximum current, maximum voltage, and maximum kVA. These three levels are tested in rotation either two or three years apart. The sequence of these tests is 200 percent calibration, short circuit, 250 percent trip out, and dielectric.

A.2 UL RECOGNIZED COMPONENTS

A UL Recognized Component may bear an italicized “backward RU” symbol on the label. These are devices that must be used in combination with other designated products in order for the complete assembly to be suitable for UL listing. An example of a recognized component is an instantaneous only circuit breaker.

A.3 UL CLASSIFIED CIRCUIT BREAKERS

A UL Classified Circuit Breaker will be marked with the words “Underwriters Lab Inc.” in a straight line together with the word “CLASSIFIED” arranged in a semicircle form above, and the word “PRODUCT” arranged in a semicircle form below. This circuit breaker is identified by the manufacturer of the circuit breaker as suitable for use in a specified panelboard in lieu of a specified circuit breaker.

A.4 UL CLASSIFIED TO IEC CIRCUIT BREAKERS

A circuit breaker that has been evaluated by UL to an international standard only will have the symbol “UL” in a circle, the word “Classified” over the circle, and the words “Classified By Underwriters Laboratories Inc. in accordance with IEC Publication XXX” on the label. If the circuit breaker is also listed according to UL’s requirements, it will bear the UL Listing identification together with the words “Also classified by Underwriters Laboratories Inc. in accordance with IEC Publication XXX.”

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