NEMA AB*3 91 ■ 6470247 0503714 563 ■

STANDARDS PUBLICATION NO. AB 3

nema

Molded Case Circuit Breakers and their Application

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

AB 3

MOLDED CASE CIRCUIT BREAKERS AND THEIR APPLICATION

Published by

National Electrical Manufacturers Association
2101 L Street, N.W.,
Washington, D.C. 20037

©1992 by National Electrical Manufacturers Association

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

TABLE OF CONTENTS

Page

Foreword i
Scope i

Section 1 REFERENCED STANDARDS AND DEFINITIONS

References 1
General Definitions 3
Molded Case Circuit Breaker 3
Molded Case Switch 3
Purpose of Overcurrent Protective Devices 3

Section 2 AVAILABLE TYPES OF MOLDED CASE CIRCUIT BREAKERS

General Usage Classifications 5
Residential 5
Industrial/Commercial 5
Tripping Means 5
Thermal Magnetic 5
Dual Magnetic 5
Solid-State (Electronic) 5
Specific Purpose Classifications 5
High Capacity Circuit Breaker 5
Integrally-Fused Circuit Breaker 5
Current-Limiting Circuit Breaker 5
Switching Duty Circuit Breaker (SWD) 5
Instantaneous Only Circuit Breaker (Motor Circuit Protector or Circuit Interrupter) 5
Heating, Air Conditioning, and Refrigeration Circuit Breaker (HACR) 5
Marine Circuit Breakers 6
U.S. Navy Circuit Breakers 6
Mining Circuit Breakers 6

Section 3 AVAILABLE VARIATIONS IN MOLDED CASE CIRCUIT BREAKERS

Construction Variations 7
Circuit Breaker 7
Frame 7
Trip Unit 7
Mechanism 7
Pole 7
Installation Variations 7
External Conductor Connections 7
Mounting Arrangements 7
Handle Orientation 8

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Reverse Feed Circuit Breakers 8
Specific Application Circuit Breakers 8
Accessories 8

Section 4 MOLDED CASE CIRCUIT BREAKER RATINGS
Ampere Ratings 9
Voltage Ratings 9
Interrupting Ratings 9
Frequency 9

Section 5 SELECTION OF MOLDED CASE CIRCUIT BREAKERS
Preliminary Considerations 11
Electrical Parameters 11
User Requirements 11
Environmental Conditions 11
National Electrical Code 12
General Considerations for Molded Case Circuit 12
Breaker Application 12
General Requirements 12
The Main Circuit Breaker 12
The Feeder Circuit Breaker 12
The Branch Circuit Breaker 13
Load Requirement Considerations 13
Continuous Duty, General Purpose Load 16
Lighting Loads 16
Heating, Air Conditioning, and Refrigeration Loads 16
Motor Loads 16
Specific Considerations for Molded Case Circuit Breaker Applications 16
Conductor Selection 16
Terminations 16
Single-Phasing Protection 17
Time-Current Curves 17
Selective Coordination 20
Series Application 23
Capacitor Switching 25
Motor Loads 25
Heating, Air Conditioning, and Refrigeration (HACR) Type Circuit Breakers 26
Nuclear Power Generating Station Equipment
Qualifications 26
Other Considerations for Specific Applications 26
Current-Limiting 26
Ground Fault Protection 28
Molded Case Switches 33

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Section 6 CODES AND STANDARDS AFFECTING MOLDED CASE CIRCUIT BREAKERS
United States Standards 35
NEMA Standards Publication AB 1 35
NEMA Standards Publication AB 4 35
Underwriters Laboratories Inc. UL 489 35
Underwriters Laboratories Inc. UL 943 35
NFPA 70 35
NFPA 70B 35
NFPA 70E 35
Federal Specification W-C-375 B/GEN 35
IEEE Publication 323 35
Other Applicable Codes and Standards 36
International Standards 36
IEC 947-1 36
IEC 947-2 36
IEC 898 36
National Standards of Other Countries 36
Canadian Standards Association (CSA) 36
German Standard (VDE) 36
Standard Association of Australia (SAA) 36

Section 7 PREVENTIVE MAINTENANCE AND FIELD TESTING
Normal Preventive Maintenance 37

Appendix A Abbreviations, Definitions, and Symbols 39

Appendix B UL Requirements for Molded Case Circuit Breakers 43

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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. To assure a meaningful publication, copies were sent during the draft stage to a number of individuals and organizations in the public and private sector having an interest in or responsibility for the purchase, testing, application, use, or inspection of this product category. Their resultant comments and suggestions provided a vital user and general interest input prior to final NEMA approval and resulted in a number of substantive changes being made in this publication. As future major revisions to this publication are proposed, it is intended to offer the same or similar individuals or organizations a further opportunity to participate in the development of this publication.

This publication will be periodically reviewed by the Molded Case Breaker Section of NEMA for any revisions necessary to keep it up to date with advancing technology. Proposed or recommended revisions should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Suite 300
Washington, D.C. 20037

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 volts ac, 50/60Hz, 1200V dc, 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 abbreviations N.E.C., N.E. Code, or Code appear they shall be understood to mean the National Electrical Code.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

MOLDED CASE CIRCUIT BREAKERS AND THEIR APPLICATION

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.

Section 1
REFERENCED STANDARDS & DEFINITIONS

1.1 REFERENCES

The reader is referred to the following supplementary reference material. Copies are available from the sources indicated.

American National Standards Institute
1430 Broadway
New York, NY 10018

ANSI/IEEE Std. 344-1987	*IEEE Recommended Practices for Seismic Qualifications of Class 1E Equipment for Nuclear Power Generating Stations*
ANSI/IEEE Std. 446-1987	*IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE Orange Book)*
ANSI/IEEE Std. 649-1980	*Qualifying Class 1E Motor Control Centers for Nuclear Power Generating Stations*
ANSI/IEEE Std. 650-1979	*IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations*
ANSI/NEMA 250-1985	*Enclosures for Electrical Equipment (1000 Volts Maximum)*
ANSI/NFPA 20-1990	*Centrifugal Fire Pumps*
ANSI/NFPA 70-1990	*National Electrical Code*
ANSI/NFPA 70B-1990	*Electrical Equipment Maintenance, Recommended Practice for*
ANSI/NFPA 70E-1988	*Electrical Safety Requirements for Employee Work Places*
ANSI/NFPA 302-1984	*Fire Protection Standard for Pleasure and Commercial Motor Craft*

British Standards Institute
2 Park Street
London, W1A2BS

3871-1965 (Amended August 1968 and November 1974)	*Specifications for Miniature & Molded Case Circuit Breakers*

Canadian Standards Association
178 Rexdale Blvd.
Rexdale, Ontario, Canada M9W1R3

CSA C22.2 #5-1986	*Molded Case Circuit Breakers*

Institute of Electrical and Electronics Engineers, Inc.
Publication Sales Department
445 Hoes Lane
Piscataway, NJ 08854
(See also ANSI/IEEE Standards listed above.)

ANSI/IEEE Std. 141-1986	*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*

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

International Electrotechnical Commission
- Central Office of -
3, rue de Varembe
Geneva, Switzerland

American National Standards Institute
1430 Broadway
New York, New York 10018

IEC-898	*Circuit Breakers for Overcurrent Protection for Household and Similar Installations*
IEC-947-1	*Low Voltage Switchgear and Controlgear -Part 1: General Rules*
IEC-947-2	*Low Voltage Switchgear and Controlgear -Part 2: Circuit Breakers*

National Electrical Manufacturers Association
2101 L Street, N.W., Suite 300
Washington, D.C. 20037

(See also ANSI/NEMA Standards listed above.)

NEMA AB 1-1986	*Molded Case Circuit Breakers*
NEMA PB 2.2-1989	*Application Guide for Ground Fault Protective Devices for Equipment*
NEMA 280-1984	*Application Guide for Ground Fault Circuit Interrupters*

National Fire Protection Association
Publications Sales Department
Batterymarch Park
Quincy, MA 02269

(See ANSI/NFPA Standards listed above.)

Standards Association of Australia
Standards House
80 Arthur St.
North Sidney, MSW, Australia

AS 2184-1985	*Molded Case Circuit Breakers (up to and including 600VAC and 250 VDC) (Interrupting Ratings of 10 Ka and more)*
AS 3111-1983	*Approval and Test Specification for Miniature Overcurrent Circuit Breakers*

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

UL 489 (1988 Edition including Revisions through June 1990)	*Molded-Case Circuit Breakers and Circuit-Breaker Enclosures*
UL 943-1985	*Gound Fault Circuit Interrupters*
UL 1053 (1988 Edition including Revisions through December 1989)	*Ground Fault Sensing and Relaying Equipment*
UL 1087 (1986 Edition including Revisions through November 1987)	*Molded Case Switches*

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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

WC 375-GEN-1975
MIL-C-17361D (SH)-1977
MIL-C-17588D (SH)-1981

Federal Specification—Circuit Breakers, Molded Case: Branch Circuit and Service Circuit Breaker, Air, Electric, Insulated Enclosure (Shipboard Use)
Circuit Breakers (Automatic—ALB) And Switch, Toggle (Circuit Breaker, Non-Automatic--NIB) Air, Insulating Housing, 125 Volts and Below AC or DC (Naval Shipboard Use)
USCG Electrical Systems Regulations, Subchapter S (33 CFR, Part 183) USCG Electrical Engineering Regulations, Subchapter J (46 CFR, Parts 110-113)

Verband Deutscher Electrotechnicker (VDE) e.V
21 Strasse Mannallee
6 Frankfurt a.M., Germany

VDE 0660-1982

Regulations for Low Voltage Switchgear Part 1/8.69 Regulations for Switches for Rated Voltages Up To 1000 VA And Up To 3000 VDC And for Control Switches And Contactors Up To 1000 VAC

1.2 GENERAL DEFINITIONS

NOTE: For a more detailed listing of definitions, symbols, and abbreviations, see Appendix A.

1.2.1 Molded Case Circuit Breaker

A molded case circuit breaker is a device, assembled as an integral unit in a supporting and enclosing housing of insulating material, designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent, without injury to itself when properly applied within its rating.

1.2.2 Molded Case Switch

A molded case switch is a device assembled as an integral unit in a supporting and enclosing housing of insulating material designed to open and close a circuit by nonautomatic means.

It is stressed that molded case switches are not overcurrent protective devices and have no overload, short-circuit, or high-level ground fault protection capabilities within their specified withstand rating. Some molded case switches are provided with instantaneous trip mechanisms for the sole purpose of self protection against faults at levels below their short circuit withstand rating.

Having demonstrated by test their capability of making and breaking load currents of six times their marked ampere rating when switched, these switches can be applied, where horsepower ratings are specified, up to the maximum value of their continuous current rating.

1.3 PURPOSE OF OVERCURRENT PROTECTIVE DEVICES

Overcurrent protective devices are intended to protect electrical systems from extensive damage which can be caused when the components are subjected to electrical currents greater than those for which the systems are intended.

The electrical system components include electrical wire and cable, transformers, electrical controls, electrical distribution equipment, and utilization equipment such as motors, electrical machinery, electrical appliances, lighting, and so forth.

Overcurrent protective devices are intended to protect against one or more of the following:

1. Overloads;
2. Short Circuits; including High-Level Ground Faults.

Molded case circuit breakers are a type of overcurrent protective device that is commonly used to protect circuit conductors.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Section 2
AVAILABLE TYPES OF MOLDED CASE CIRCUIT BREAKERS

2.1 GENERAL USAGE CATEGORIES

2.1.1 Residential

Single or two-pole thermal-magnetic or magnetic (dashpot or hydraulic) circuit breakers rated 225 amperes or less, 120 volts ac or 120/240 volts ac and having interrupting ratings of 22,000 amperes rms symmetrical or less are usually categorized as residential circuit breakers.

2.1.2 Industrial/Commercial

Circuit breakers with ratings other than those covered under "residential" are usually categorized as industrial/commercial circuit breakers.

2.2 TRIPPING MEANS

2.2.1 Thermal-Magnetic

The device provides 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 to cause the breaker to trip or open mechanically. The larger the overload, the faster the tripping of the breaker; the smaller the overload, the longer it takes the breaker to trip. This is commonly called the inverse time principle.

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

2.2.2 Dual Magnetic (Dashpot) (Hydraulic)

On overload, the device operates on an inverse time principle by utilizing a magnetic coil surrounding a plunger which 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)

On overload, the device operates on the inverse time principle. Current sensors are utilized in each pole of the breaker to sense the current. The electronic circuitry measures and times the output from the current sensors. On overloads and short-circuits, the electronic circuitry initiates tripping of the breaker. Also, this type of device may provide low-level ground fault protection.

2.3 SPECIFIC PURPOSE CATEGORIES

2.3.1 High Capacity Circuit Breakers

The principle of operation in high capacity breakers is similar to the standard thermal-magnetic or electronic breaker. However, its current interrupting capability is much higher.

2.3.2 Integrally-Fused Circuit Breaker

This type of breaker is a combination of a thermal magnetic breaker and coordinated current limiters (high-fault protectors) contained within the same molded housing. The current limiters prevent the development of the maximum prospective short-circuit current in the circuit. With this combination, much higher interrupting ratings are possible than those for standard and high capacity breakers.

2.3.3 Current-Limiting Circuit Breaker

A type of 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.

2.3.4 Switching Duty Circuit Breaker (SWD)

A type of circuit breaker rated 15 or 20 amperes intended to switch 277 volts or less fluorescent lighting loads on a regular basis. These breakers are marked "SWD," (Reference Section 240-83(d) of the National Electrical Code).

2.3.5 Instantaneous Trip Only Circuit Breaker (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 shall be permitted to include a transient dampening action to ride through initial motor transients (see section 430-52 [FPN] of the National Electrical Code). 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 Breaker (HACR)

The National Electrical Code permits the use of inverse-time circuit breakers to protect multimotor and combination-load installations involved in heating, air conditioning and refrigerating (HACR) equipment provided the breakers have been listed for group installation and marked

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

"Listed HACR Type" (Reference Section 430-53(c) of the National Electrical Code.

2.3.7 Marine Circuit Breakers

These breakers are intended to be applied on board a boat or ship. Applicable requirements are NFPA 302, applicable publications of the American Boat and Yacht Council, Inc., IEEE specifications 45, sub-chapters S and J of regulations of the U.S. Coast Guard and UL 489, supplement paragraphs S1 through S10.

2.3.8 U.S. Navy Circuit Breakers

These circuit breakers are intended for installation aboard U.S. Naval ships and conform to military specifications MIL-C-17361 and MIL-C-17588; or UL 489 Supplement A.

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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Section 3
AVAILABLE VARIATIONS IN MOLDED CASE CIRCUIT BREAKERS

3.1 CONSTRUCTIONAL VARIATIONS

3.1.1 Circuit Breaker

A circuit breaker is a device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent, without injury to itself when properly applied within its rating.

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 Trip Unit

A trip unit is an assembly installed within the circuit breaker frame that causes the breaker to open automatically under overload or short-circuit. The trip unit may utilize thermal magnetic, dual magnetic or electronic sensing means.

Trip units operate such that an overload or fault on any one pole will cause all poles to open simultaneously to prevent single phasing.

Trip units may be fixed or interchangeable. The continuous current rating of circuit breakers with interchangeable trip units can be changed in the field. Circuit breakers with fixed electromechanical trip units have fixed continuous current ratings. Generally, in the larger frame size breakers, the instantaneous trip setting is field adjustable.

Electronic trip units, either fixed or interchangeable, may have any or all of the following types of time current adjustments: long time pick-up or ampere setting, long time delay, short time pick-up, short time delay, instantaneous pick-up, ground fault pick-up, or ground fault time delay.

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 for tripping.

The closing operations are usually performed by one of two methods. The most prevalent is the overcenter toggle type of mechanism which closes the breaker contacts by a manual movement of the breaker handle. The manual opening of the contact is also actuated by the movement of the breaker handle. This manual closing may be directly dependent (slow make) or independent (quick make) of the closing speed of the operator's movement of the 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 mechanically tied together through the mechanism, such that all poles operate together. Two single-pole circuit breakers may be mounted in a single housing without a mechanical tie.

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 conductors that plug into the panelboard main bus.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Plug-in connections for accessory wiring may also be provided. The circuit breaker may 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 removable element may be readily removed from the stationary portion with a racking mechanism without unbolting the current-carrying connections or mounting supports.

The drawout racking mechanism will permit 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 housing 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 may 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 housing portion of the drawout assembly and signals the movement of the circuit breaker between the "connected" and "test" positions.

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, will not be more than 6-1/2 feet (1.95 meters) above the floor or working platform. An exception to this is circuit breaker busway plugs, which can be hookstick operated.

3.4 REVERSE FEED CIRCUIT BREAKERS

UL 489 specifies that a circuit breaker shall be marked "line" and "load" except for circuit breakers which have been tested and found acceptable for reversed line and load connection.

3.5 SPECIFIC APPLICATION CIRCUIT BREAKERS

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 in a combination of these characteristics. The manufacturer should be consulted regarding specific, non-standard, applications.

3.6 ACCESSORIES

Accessories are devices added to breakers that perform secondary functions. Some accessories, such as shunt trip releases, under-voltage releases, and auxiliary switches may be internally mounted; while electrical operators, mechanical interlocks, handle locking devices, and so forth, are generally externally mounted.

Most external accessories are suitable for field installation. Some internal accessories may be field installable in interchangeable trip type circuit breakers. UL does place restrictions on the installation of internal accessories in the field. Therefore, the manufacturer should be consulted for specific instructions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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 (Section 240-6) 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.

EXCEPTION: 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, 120/240, 240, 277, 480Y/277, 480, 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.

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 (1ø–3ø) to indicate their suitability.

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

4.3 INTERRUPTING RATINGS

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

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

4.4 FREQUENCY

Molded case circuit breakers may be used for ac or dc applications as defined and marked by the manufacturer; ac circuit breakers are rated for use on 50/60Hz systems unless otherwise noted.

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

For applications of ac breakers at frequencies other than 50/60 Hertz, such as 400 Hertz, the manufacturer must be consulted.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

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

1. System Voltage Rating—Phase-to-Phase and Phase-to-Neutral Where Applicable
2. System Phasing—Single or Multiphase
3. System Loads—Values and Types
4. System Frequency
5. Proposed Use In System—Main, Feeder, Branch Circuit, and so forth
6. Available Short Circuit Current
7. 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, and 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

Molded case circuit breakers are calibrated at 100 percent of rated current in open air for a given ambient temperature (usually 25°C (77°F) or 40°C (104°F)). 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 rerated 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

Molded case circuit breakers are designed to perform satisfactorily under clean air conditions where relative humidity does not exceed 50 percent at a maximum temperature of + 40°C (104°F).

Higher relative humidities are permitted at lower temperatures, e.g. 90 percent at +20°C(68°F). Care should be taken where moderate condensation may occasionally occur due to variations in temperature.

For atmospheres having a higher moisture content and temperature or where fungus growth is prevalent, or both, 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.

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

At altitudes above 6600 feet (2000 meters), molded case circuit breakers should be progressively derated for voltage or interrupting capabilities, or both.

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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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

Where equipment is intended to break current at other than fault levels, it should have an interrupting rating at system 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.

Some other performance requirements to be considered include:

- Ground Fault Requirements, for Equipment Protection under NEC Sections 215-10, 230-95, and 240-13.
- Health Care Facility Feeder Selectivity Requirements for Equipment Ground Fault Protection under Section 517-17(b)
- Fire Pump Circuit Breakers under Section 230-90(a), Exception No. 4
- Circuit Breakers used as Switches in Fluorescent Lighting Circuits—Under NEC Section 240-83(d)(SWD)
- Circuit Breakers used for Group Motor Overcurrent Protection under NEC Section 430-53(c)(HACR)

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 breaker 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.

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.

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

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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.

If ground fault protection is required 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.

This additional level of ground fault protection is mentioned in the fine print note (FPN) of NEC Section 230-95, where maximum continuity of electrical service is necessary for general installations and is mandatory for health care facilities per NEC Section 517-17.

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.

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.

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

If ground fault protection is required 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.

This additional level of ground fault protection is mentioned in the fine print note (FPN) of NEC Section 230-95 where maximum continuity of electrical service is necessary.

For specific 15 and 20 ampere, 125 volt single phase receptacle circuits, as defined in NEC Section 210-8, the user should select ground fault circuit interrupters equipped to provide personnel protection.

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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

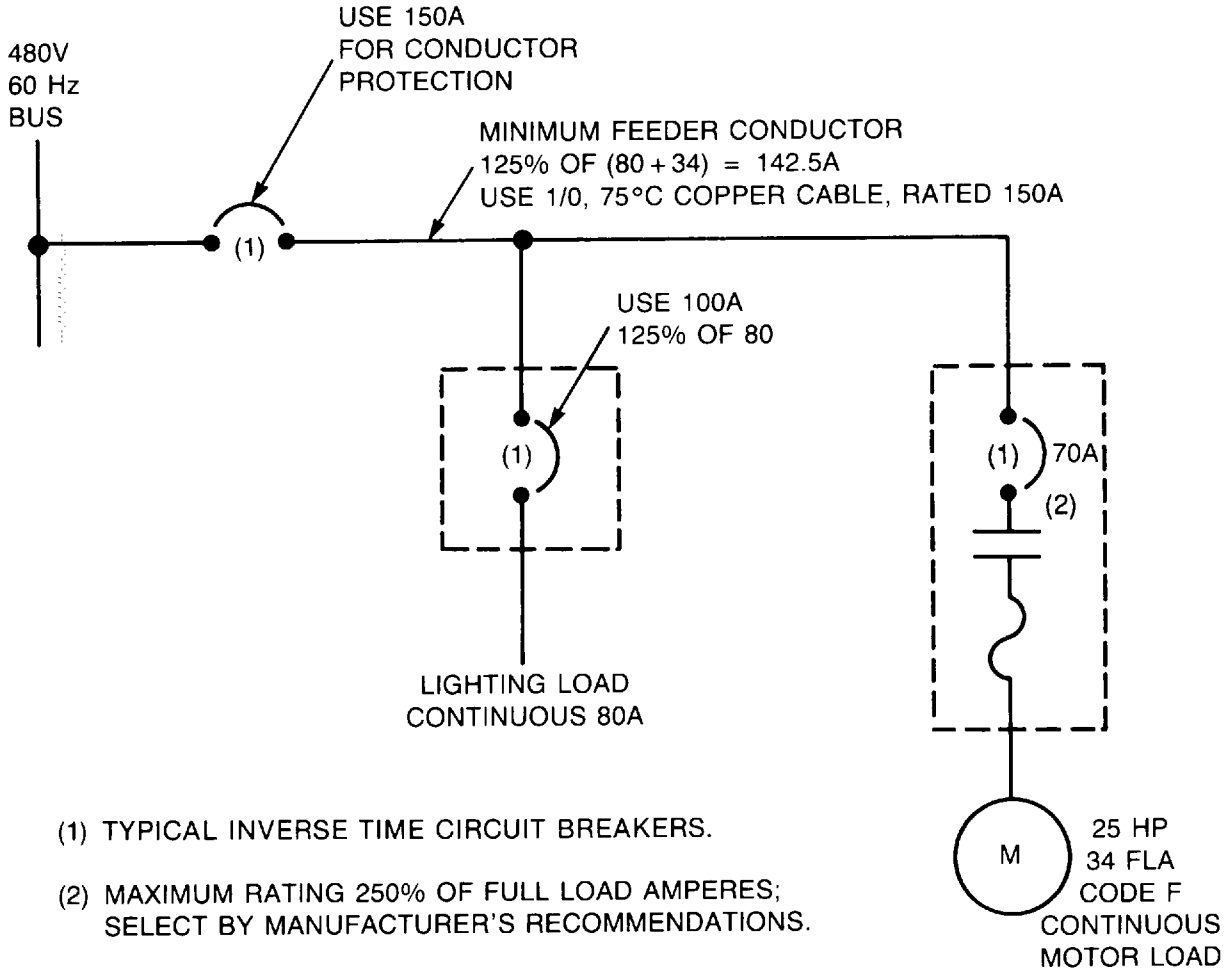


Figure 5-1
TYPICAL FEEDER CIRCUIT
(LIGHTING LOAD AND SINGLE FIXED MOTOR LOAD)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

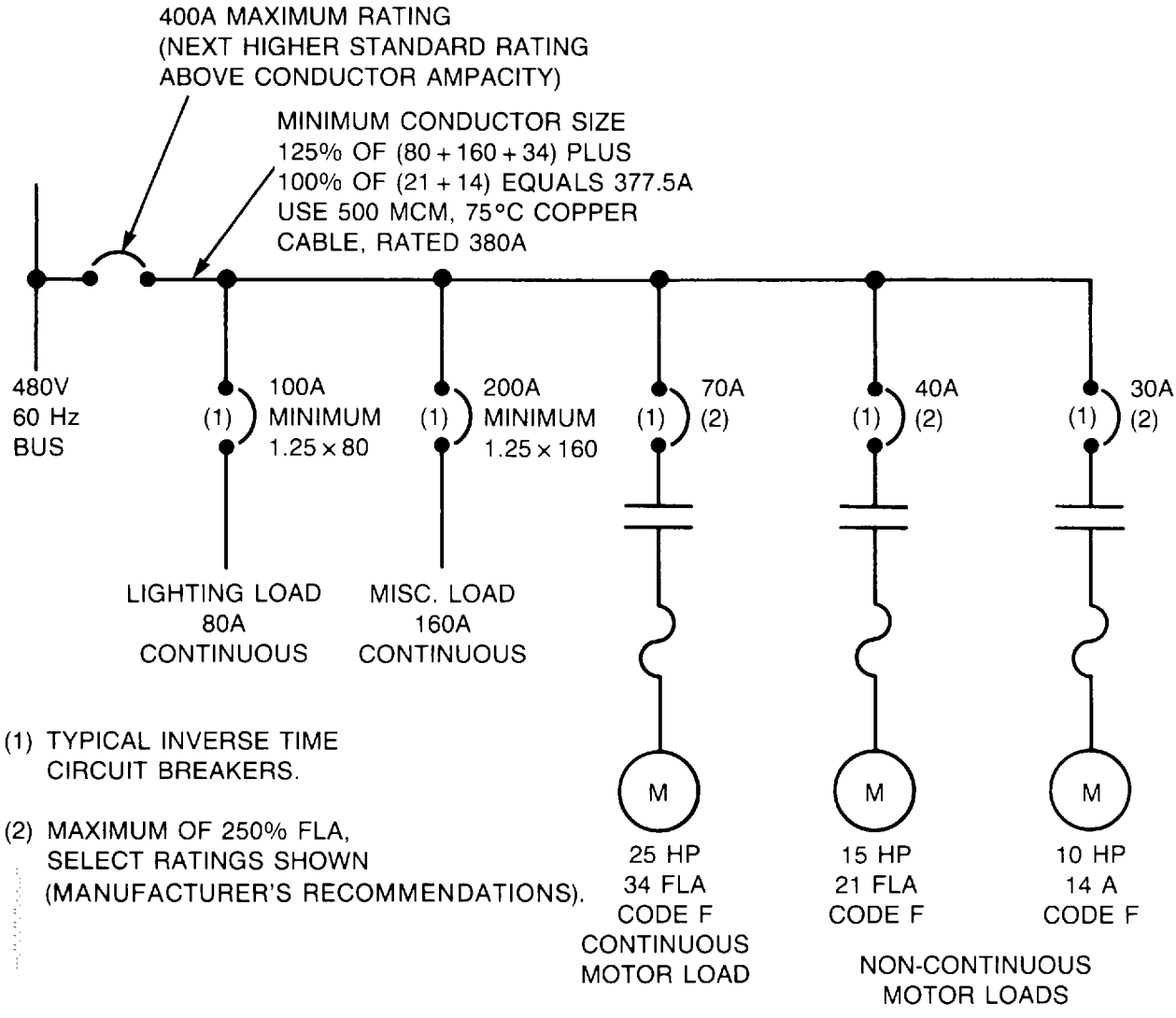


Figure 5-2
TYPICAL FEEDER CIRCUIT
(COMBINATION AND MULTIPLE MOTOR LOADS)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

5.3.1 Continuous Duty, General Purpose Load

Selection of a standard inverse time circuit breaker, sized 125 percent of the continuous load current is usually recommended. There are cases where it might be desirable to use a circuit breaker rated to carry 100 percent of its rated current continuously. Breakers rated for this application are specifically marked.

5.3.2 Lighting Loads

For circuits involving the switching of fluorescent lighting loads, there are breakers especially designed and tested for that purpose. These breakers are marked "SWD."

For high intensity discharge lighting, high wattage security lighting and other special lighting applications, the circuit breaker manufacturers can recommend devices designed for the purpose.

5.3.3 Heating, Air Conditioning, and Refrigeration Loads

Select circuit breakers marked "HACR" which are designed, tested, and listed for the multi-motor and combination loads encountered in heating, air conditioning, and refrigeration equipment.

5.3.4 Motor Loads

Since motor loads are so important and prevalent in industrial and commercial applications, they are covered separately in 5.4.8.

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.

5.4.1.1 TEMPERATURE RATING OF CONDUCTOR

The manufacturer's specific recommendations for insulated conductors to be used with breakers are: breakers rated 125 amperes or less are calibrated to use 60°C rated wire, unless otherwise marked; breakers rated above 125 amperes are calibrated to use 75°C rated wire.

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.

Copper (Cu) and Aluminum (Al) are the most widely used conductor materials. The ampacities of most commonly used insulated conductors are listed separately 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.

A Word of Caution! The standards that determine the size of conductors inside a factory-wired assembly may be different from the standards used for branch circuits. Therefore, the size of the factory wiring should not be used to determine the size of the branch circuit wiring.

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 be 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.

Cables should be terminated according to the instructions furnished by the manufacturer. Particular care should be taken not to exceed the recommended stripping length to avoid the possibility of reduced electrical clearances. Terminal connections should be torqued according to the marked requirement on the circuit breaker or to other specifications provided by the manufacturer.

Terminal wire connectors are available which are suitable for use with both copper and aluminum and are marked Al/Cu. Special care should be taken to follow the manufacturer's installation instructions.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

5.4.3 Single-Phasing Protection

A three-phase motor running without current in one phase is said to be "single-phasing."

When a multipole circuit breaker opens, all poles open simultaneously thus preventing "single-phasing." Single-phasing conditions can cause shock hazard, motor overheating, and other equipment damage.

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 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:

1. Nonadjustable
   - Fixed Ampere Setting
   - Fixed Long Time
   - Fixed Instantaneous
2. Partially Adjustable
   - Fixed Ampere Setting
   - Fixed Long Time
   - Adjustable Instantaneous
3. Fully Adjustable
   - Long Time Pick-Up or Ampere Setting
   - Long Time Delay
   - Short Time Pick-Up
   - Short Time Delay
   - Instantaneous Pick-Up
   - Ground Fault Pick-Up
   - 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').

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 point 'A'), 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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

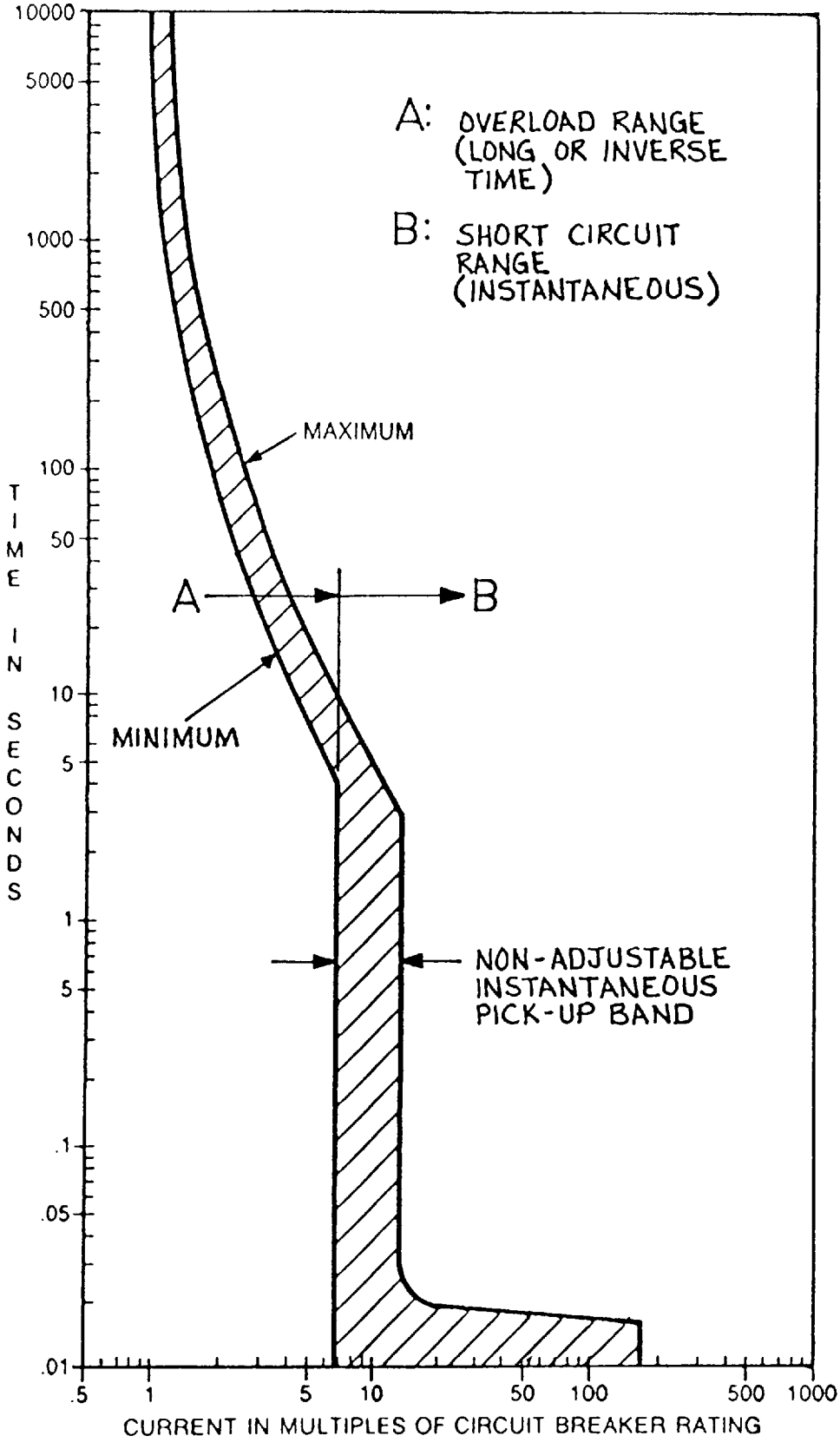


Figure 5-3
TYPICAL TIME-CURRENT CURVE FOR NON-ADJUSTABLE MOLDED CASE CIRCUIT BREAKERS (100A)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

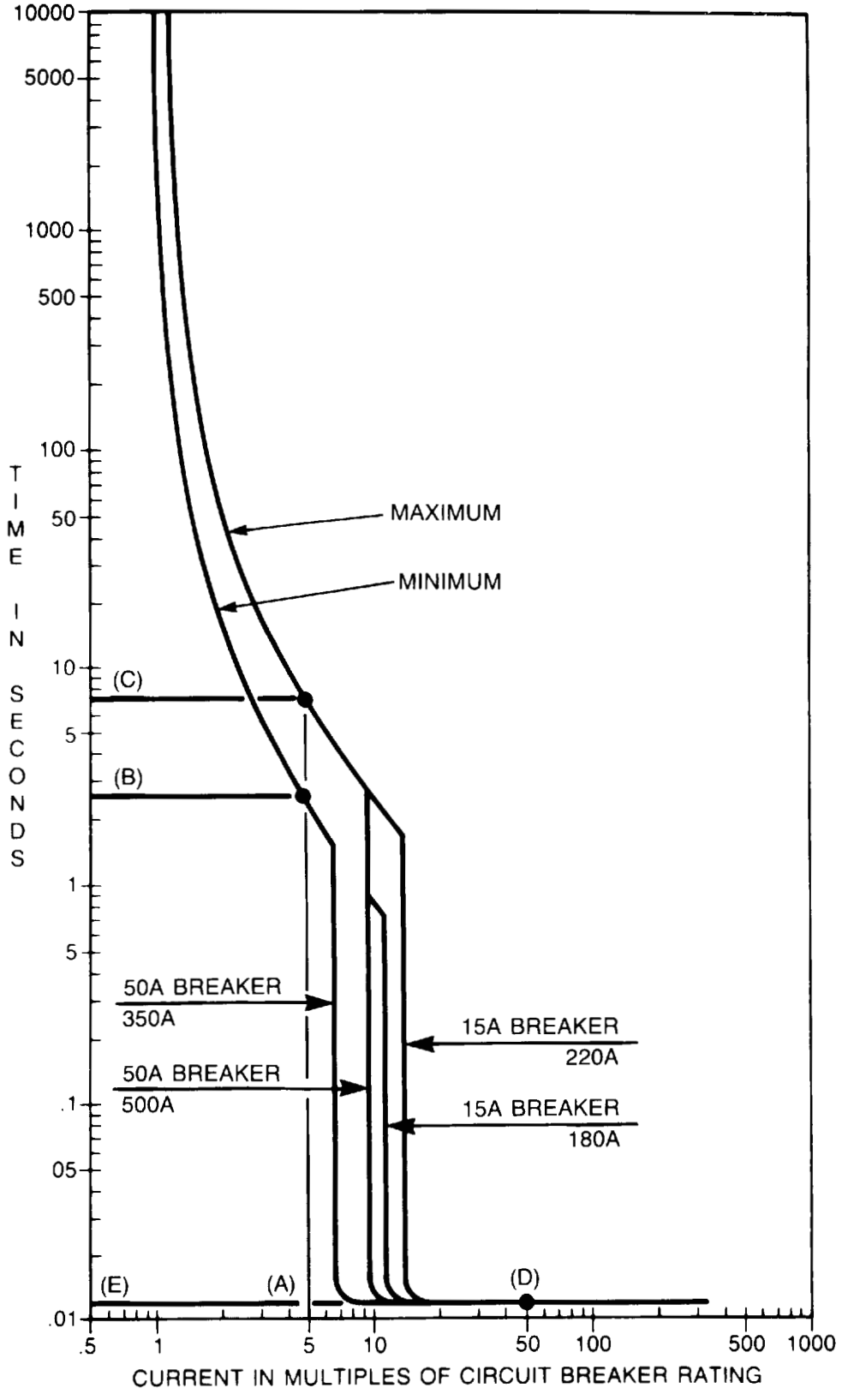


Figure 5-4
SAMPLE TIME-CURRENT CURVE
15A AND 50A CIRCUIT BREAKERS

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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).

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:

1. The preliminary power distribution plan should be developed from the substation or service equipment through the utilization equipment areas.
2. The requirements for standby or emergency power supplies, including any automatic transfer equipment, should be determined.
3. 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.
4. A preliminary short-circuit study should be conducted to determine required equipment interrupting ratings.
5. 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:

1. IEEE Std. 141 (Red Book)
2. IEEE Std. 242 (Buff Book)
3. IEEE Std. 446 (Orange Book)
4. 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.

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

Given

1. Single-line diagram with utility supply parameters as illustrated in Figure 5-8;
2. 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;
3. Feeder circuit breaker (F) rated 600 amperes;
4. Downstream branch breaker (B), thermal-magnetic type, rated 100 amperes with time-current curve per Figure 5-3; and

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

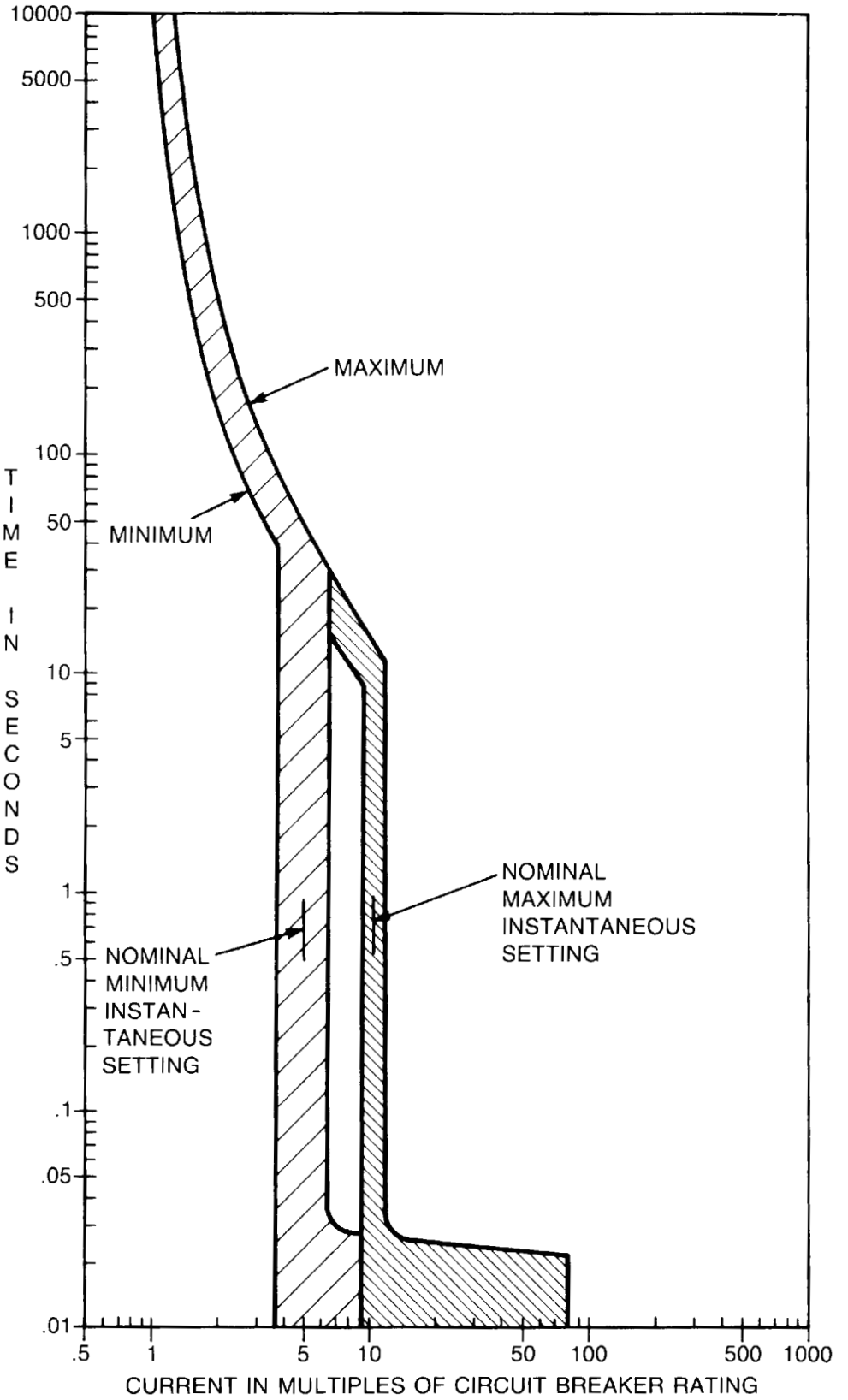


Figure 5-5
TYPICAL TIME-CURRENT CURVE FOR ADJUSTABLE INSTANTANEOUS MOLDED CASE CIRCUIT BREAKERS

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

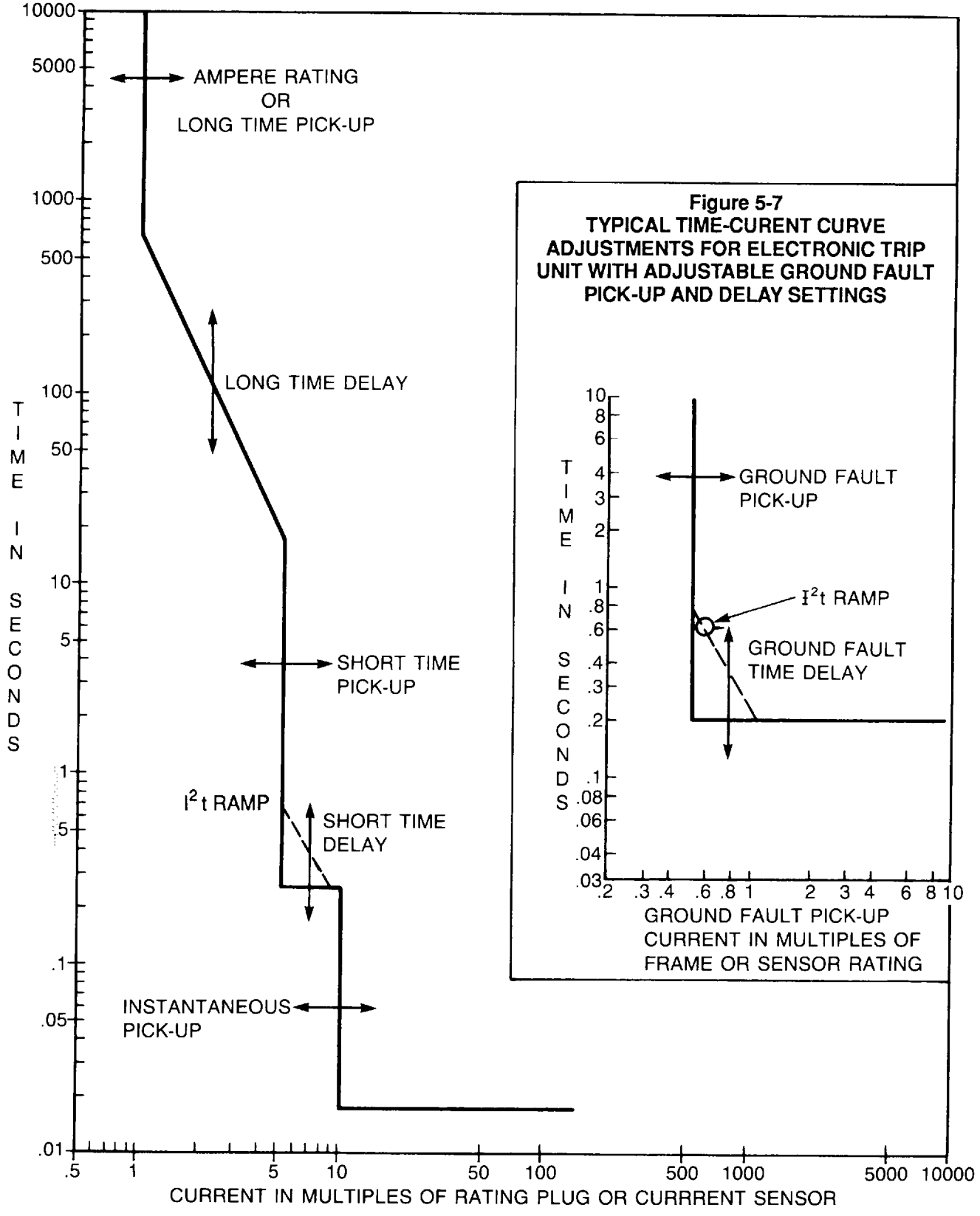


Figure 5-7
TYPICAL TIME-CURENT CURVE ADJUSTMENTS FOR ELECTRONIC TRIP UNIT WITH ADJUSTABLE GROUND FAULT PICK-UP AND DELAY SETTINGS

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

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

5. 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

1. Main circuit breaker (M) with rating and time-current adjustments required for selective coordination with the given boundary protective devices: "A" and "B."
2. Feeder circuit breaker (F) with rating and time; current adjustments required for selective coordination with the given boundary protective devices: "M" and "B."
3. 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 220-10(b)(exception). The rating will comply with Table 450-3(a)(2)(b) 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)(1) 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.

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. 5.)

Ground fault settings for circuit breakers "M" and "F" are shown under separate curves "MG" 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 preset 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.

5.4.7 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 fully complies with the requirements of Section 110-9.

Series Tested—Combination Method

CAUTION

THE USE OF *NON-TESTED* FUSE/BREAKER SERIES COMBINATIONS CAN CAUSE PERSONAL INJURY OR EQUIPMENT DAMAGE, OR BOTH. ONLY

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

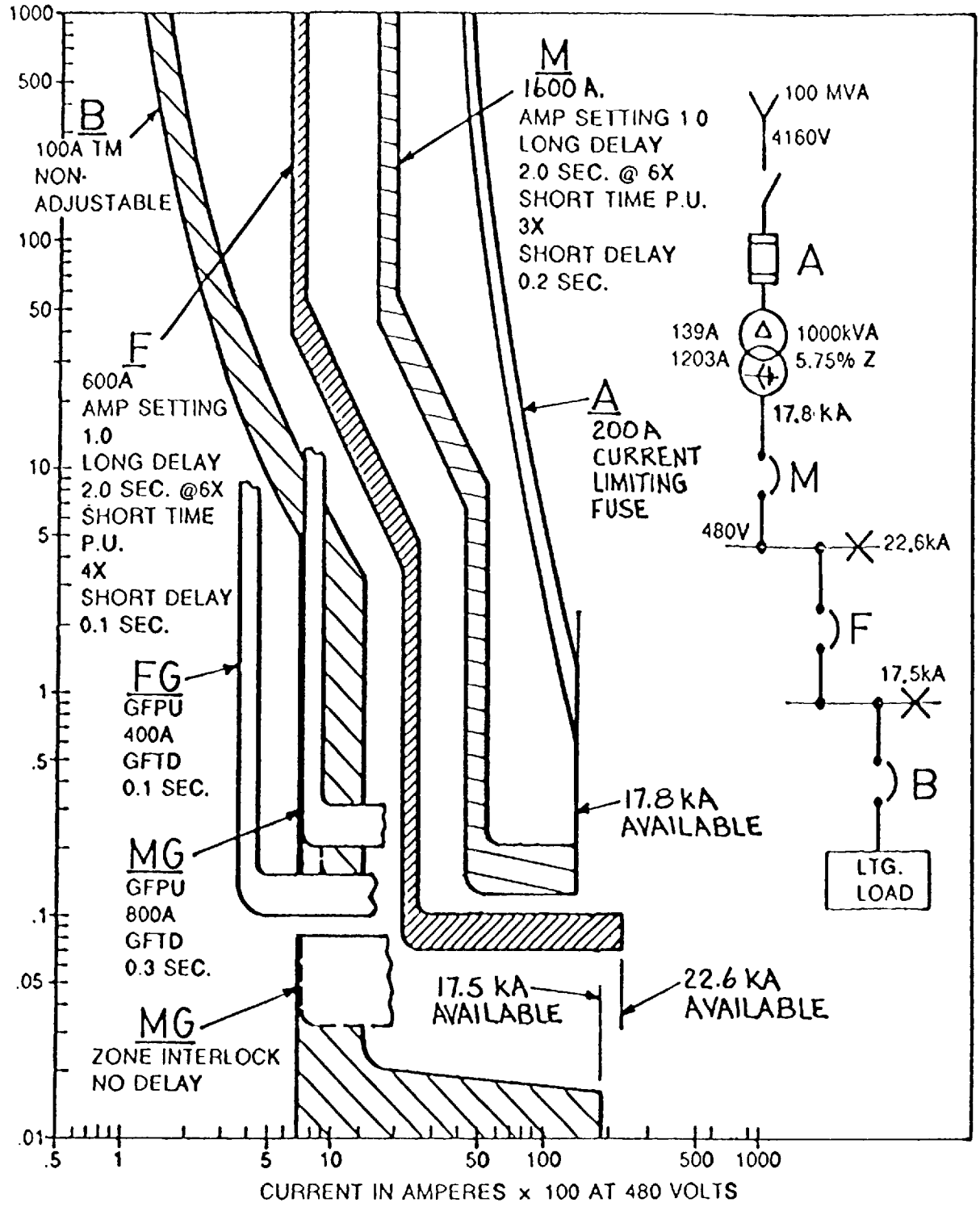


Figure 5-8
TYPICAL SYSTEM—SELECTIVELY COORDINATED

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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.

Proper care should be taken in designing systems with significant motor loads to ensure that the proposed application does not exceed the series rating due to motor fault current contributions.

Section 110-9 defines the interrupting rating requirements for electrical installations as follows: "Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the system voltage and the current which is available at the line terminals of the equipment."

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 which 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:

1. The upstream circuit breaker or fuses are installed in the panelboard as a main breaker; or
2. 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:

1. The available fault current at the line side terminals of the upstream circuit breaker or fuses should be determined.
2. 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.
3. 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 RATED SYSTEM."
4. 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.

5.4.8 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

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

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 often allows the use of a smaller frame size 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.

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

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 "Listed HACR Type" 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.

5.4.11 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:

1. Standard 323
2. Standard 344
3. Standard 649
4. 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 which 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, namely:

1. Molded case circuit breaker with integrally mounted current limiters
2. Molded case circuit breaker with close-coupled externally mounted current limiters
3. Molded case circuit breaker with electromechanical means for limiting fault currents without replaceable fuse elements.

For the purpose of this publication, categories 1 and 2 above cover molded case circuit breakers with current

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

limiters (high fault protectors) or fuses unique to the product and not general purpose current limiters (high fault protectors) or fuses which may be used with other devices.

Any device considered "current-limiting," will substantially limit the peak let-through current (I_p) 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 (I_p2). 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.

The selection of the proper current-limiting devices is not a simple matter. The manufacturers of current-limiting devices normally publish the I_p 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

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 which ensures 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 which 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.

5.5.1.2 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.

Current-limiting circuit breakers have been developed using a variety of mechanical concepts to limit the let-through current to satisfy the fundamental definition of current-limiting without the use of the fuses. These methods include both single and double break contact arrangements with repulsion loops as well as commutation systems.

For individual breakers tested alone, manufacturers publish peak let-through current (I_p) and energy (I^2t) curves. In addition, extensive testing has been done with downstream circuit breakers of a variety of types and ratings and I_p and I^2t curves with these results have also been publish-

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

ed. Typical curves of these types are illustrated in Figures 5-9 and 5-10.

Since application ratings and details vary between suppliers, consult the manufacturer for specific application recommendations.

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:

1. Ground fault protection for equipment
2. 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 milliampere current range. Devices which 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.

5.5.2.1 GROUND FAULT PROTECTION FOR EQUIPMENT

A. General. This subject has been well documented in recent years. Two publications worthy of review are as follows:

1. NEMA Standard Publication PB 2.2
2. IEEE Std. 242. Chapter 7 covers ground fault protection.

Any document on this subject should stress the following factors:

1. The need for ground fault protection, for example, arcing ground faults
2. Applicable performance standards and Code requirements
3. Methods of detecting ground faults
4. Types and arrangements of distribution systems with recommended detection; schemes for each
5. Coordination examples

The referenced documents thoroughly cover each of these topics. For simplicity, this document's discussion of Ground Fault Protection of Equipment will be limited to 600 volts and to the most common type of system covered by the National Electrical Code, for example, the solidly grounded wye.

B. Code Requirements. The National Electrical Code, under Sections 215-10, 230-95, and 240-13, requires that ground fault protection of equipment be provided when all the following conditions exist:

1. Solidly grounded wye systems
2. More than 150 volts to ground but not exceeding 600 volts phase-to-phase
3. Disconnects rated 1000 amperes or more for services, feeders, or mains for a building or structure.

Ground fault protection is not required on a feeder or building or structure disconnect if such protection is provided on the line side.

Two safety related exceptions to these requirements are as follows:

1. In a continuous industrial process where a nonorderly shutdown will introduce additional or increased hazards
2. Fire pump installations

There are several other items in this Code section that should be reviewed in detail by the reader. These non-mandatory items, in fine print notes, should be considered:

1. Ground Fault Protection for Equipment (GFP) may be desirable for disconnects rated less than 1000 amperes.
2. GFP, as required in this Code section, does not provide any protection for ground faults on the line side of the service disconnect means. It serves only to limit arcing damage on the load side.
3. The addition of GFP on service equipment will necessitate reviewing the overall wiring system for proper selective overcurrent protective coordination. Additional downstream GFP installation may be required where continuity of service is necessary.
4. When GFP is supplied on the service disconnect and an interconnection is made with another supply system, other devices or means may be needed to assure proper ground fault sensing.

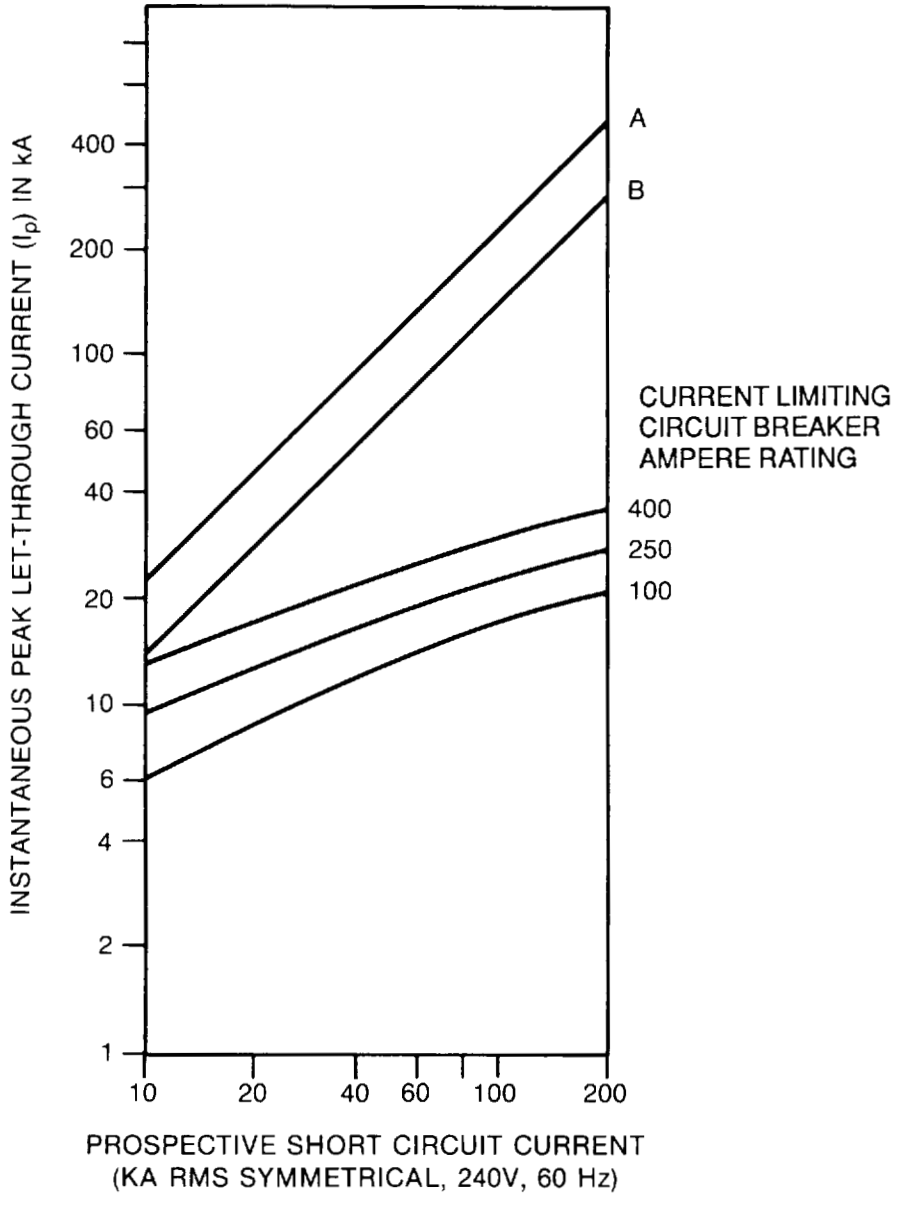
Any time that GFP is supplied for services rated 600 volts or less, the maximum allowed setting is 1200 amperes. The time-current curve may be designed to allow for a one second delay for ground faults equal to or greater than 3000 amperes.

Any time that GFP is provided in line with the requirements of Section 230-95, it must be performance tested when first installed. The test shall be conducted with approved instructions provided with the equipment. Written records must be made available to the authority having jurisdiction.

In addition to the basic service entrance requirements as outlined above, Section 517-17 defines the following additional requirements:

1. Where GFP is required on main service disconnects per Section 230-95 of the National Electrical Code, it should also be provided in the next level of feeders downstream toward the load (See 517-17-a)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale



A = MAXIMUM ASYMMETRICAL PEAK AT 15% POWER FACTOR
(2.3 × RMS SYMMETRICAL)

B = MAXIMUM SYMMETRICAL PEAK (1.414 × RMS SYMMETRICAL)

Figure 5-9
TYPICAL CURRENT LIMITING CIRCUIT BREAKERS

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

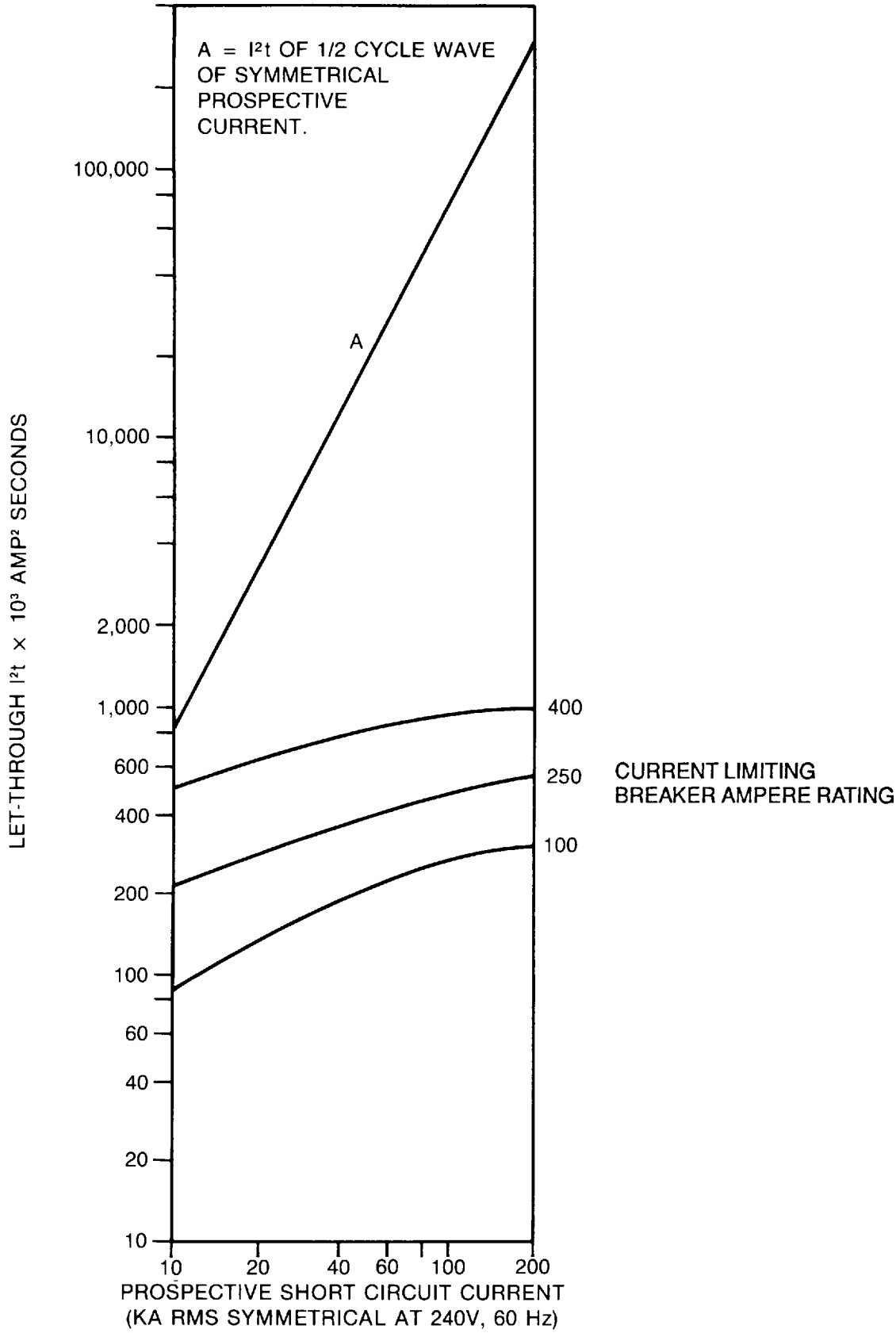


Figure 5-10
TYPICAL CURRENT LIMITING CIRCUIT BREAKERS

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

2. When provided on these two levels, a separation in time of 6 cycles (0.1 seconds) shall be provided between the service and feeder ground fault tripping bands. Operating time of the disconnect devices shall be considered to achieve 100 percent selectivity (See 517-17-b).

C. Electronic Trip Units. Molded case circuit breakers are available with integral ground fault protection using electronic trip units to enable a user to comply with the requirements of the National Electrical Code. Where integral GFP is not available, as in thermal-magnetic circuit breakers, normally available shunt trip devices can be applied with separately mounted GFP relay systems to accomplish the same end results.

D. Zone Selective Interlocking. When multiple levels of GFP are provided in a distribution system to provide continuity of service for downstream locations, selective coordination on ground fault is ordinarily obtained by adjusting the current pick-up or, more importantly, the time delay settings of the upstream and downstream devices. This will ensure that the device nearest to the ground fault operates to clear the fault first.

In addition to the required time-current curve shaping characteristics supplied with available GFP systems, zone selective interlocking circuitry is also available to limit system damage for upstream fault zones. See a typical example illustrated in Figure 5-11.

In Figure 5-11, as an example, GFP has been provided to achieve maximum service continuity on three levels; main, feeders and branch circuits. To achieve selective ground fault coordination, typical pickup and time delay settings have been selected as illustrated.

Each successive upstream device has been set at a higher time delay value. This provides, for example, that circuit breaker "B2" will trip first for a fault at "P3" and devices "F2" and "M" will operate only as back-up devices. This requires increasingly higher time values for each upstream device so that false tripping does not occur and maximum continuity of service is maintained. Under this concept, should a ground fault occur at point "P1," the main circuit breaker "M" could not operate in less than 0.5 second for an arcing ground fault in its zone. Thus, less damage would occur if a faster trip time was available.

The use of zone selective interlocking overcomes this application difficulty and greatly reduces the amount of damage that could otherwise occur for an upstream fault such as at points "P2" or "P1." Zone selective interlocking operates in this manner.

1. Each GFP device in a zone interlock system must be provided with zone interlocking circuitry.
2. Each GFP device is set with appropriate time-current settings to achieve ground fault selectivity as typically illustrated in Figure 5-11.
3. Each level of GFP device is interconnected to the next level GFP device closer to the power source.
4. Each GFP device will operate with "no intentional time delay" for a ground fault within its immediate zone regardless of its preset time delay setting. This will enable the protective device to clear the fault in its zone in the fastest time possible, thus limiting the maximum damage level.
5. For any downstream fault, in the next lower zone, the protective device first sensing the fault will transmit a restraining signal to all upstream devices causing them to respond to their preset time delay settings. A typical time-current adjustment curve is shown in Figure 5-7 with a typical coordination example shown in Figure 5-11.

E. Selection Guidelines. A wide range of molded case circuit breakers are available with a variety of features, settings and configurations of time-current curves to satisfy the application requirements of the National Electrical Code, or system designer, or both. Consult the manufacturer for specific product details. In general, when selecting or applying molded case circuit breakers, the following characteristics relating to ground fault protection of equipment should be defined:

1. Type of system involved
   a. solidly grounded wye
   b. other
2. Number of conductors
   a. 3 ph., 4 wire
      1) with phase to neutral loads
      2) without phase to neutral loads
   b. 3 ph., 3 wire
      — with no neutral
3. Type of distribution system involved
   a. Simple radial
      1) single supply source
      2) single ground
   b. Complex
      1) multiple supply sources
      2) single or multiple ground points
4. Method of ground fault sensing employed
   a. Vectorial summation
      1) residual
      2) zero sequence (core balance)
   b. Ground return—sensor on grounding electrode
   c. Differential
5. Levels of protection
   a. single
   b. multiple
      1) with zone interlocking

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

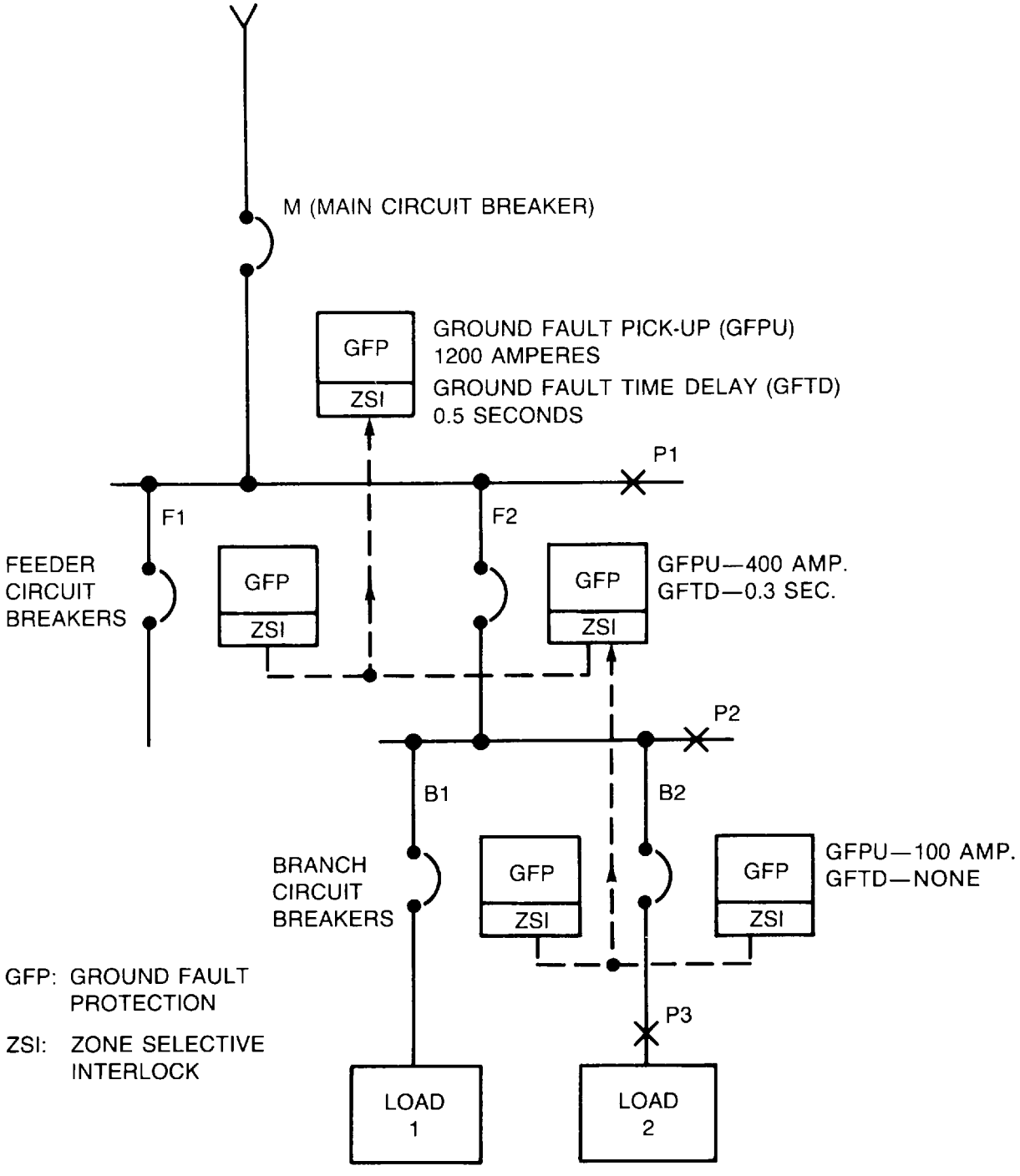


Figure 5-11
TYPICAL MULTILEVEL GROUND FAULT PROTECTION

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

2) without zone interlocking

6. Time-current characteristics settings
   a. Pick-up
   b. Time delay
   c. Type time-current curve
      1) fixed or adjustable
      2) inverse or flat response
7. Optional features
   a. field test provisions
      1) integral
      2) separate
   b. ground fault alarms
      1) integral
      2) remote

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. A typical schematic diagram is illustrated in Figure 5-12.

All GFCI's are provided with a push button actuated test circuit which 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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

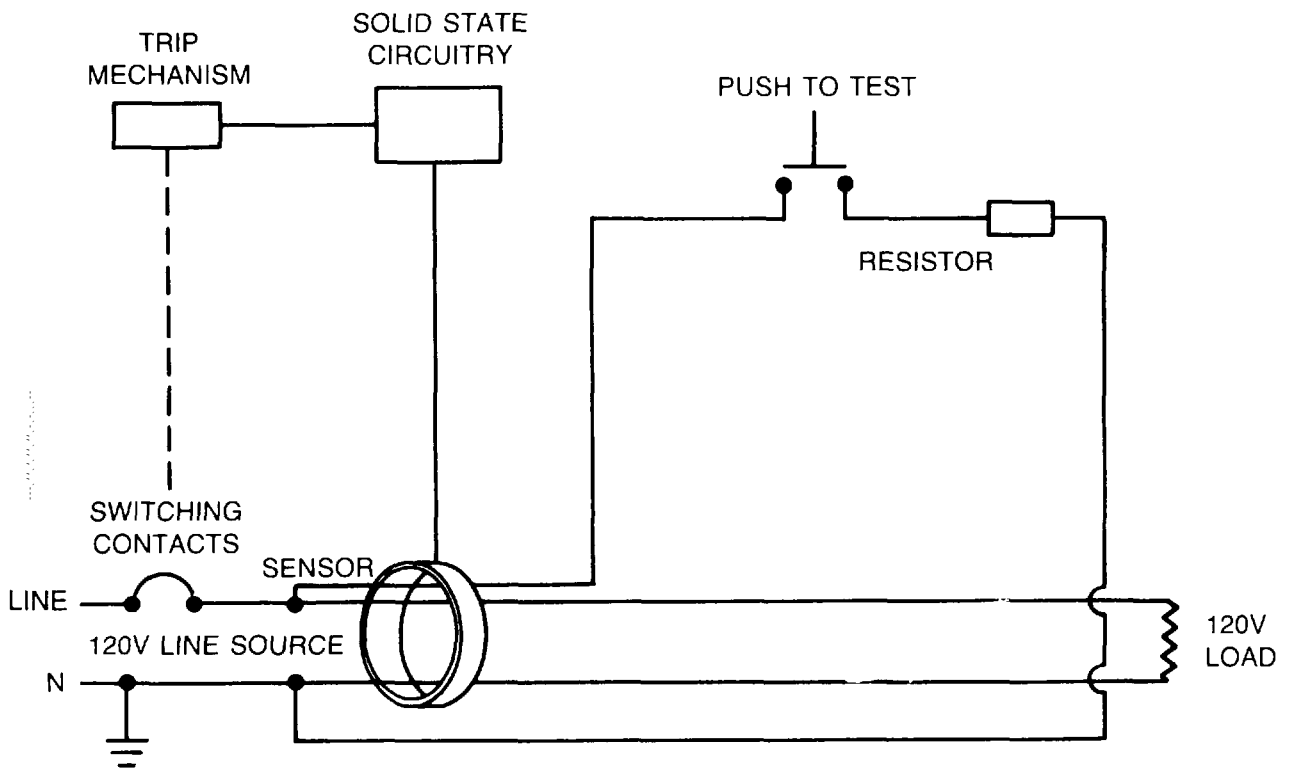


Figure 5-12
TYPICAL GROUND FAULT CIRCUIT INTERRUPTER
SCHEMATIC DIAGRAM

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Section 6
CODES AND STANDARDS AFFECTING MOLDED CASE CIRCUIT BREAKERS

A standard generally defines a product with reference to construction, dimensions, tolerances, safety, operating characteristics, performance, quality, rating, testing, and the service for which designed. There are several standards for molded case circuit breakers, and it should be noted that conformance with one standard does not necessarily imply conformance with other standards. Consult the manufacturer.

6.1 UNITED STATES STANDARDS

6.1.1 NEMA Standards Publication AB 1

This publication includes standards for ratings, tests and performance, manufacturing, markings and warning labels, applications for breakers and enclosures, and accessories for breakers.

These standards are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting the proper circuit breaker for specific needs.

6.1.2 Underwriters Laboratories Inc. UL 489

This standard for safety includes requirements for construction, performance, ratings, and markings for molded case circuit breakers and circuit breaker ground fault circuit interrupters, circuit breaker accessories, and circuit breaker enclosures.

These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience and are revised as necessary.

6.1.3 Underwriters Laboratories Inc. UL 943

This standard for safety includes requirements for construction, performance, ratings, and markings for GFCIs.

6.1.4 NFPA 70

The National Electrical Code contains provisions for the practical safeguarding of persons and property from hazards arising from the use of electricity.

Although the National Electrical Code is not mandatory, it is intended to be suitable for mandatory applications by governmental bodies exercising legal jurisdiction over electrical installations and for use by insurance inspectors. The National Electrical Code is sponsored by the National Fire Protection Association and is revised every three years.

6.1.5 NFPA 70B

The purpose of this recommended practice is to provide guidelines that will help to reduce hazard to life and property that can result from failure or malfunction of industrial-type electrical systems and equipment. This practice explains the functions, requirements, and economic considerations that can be used to establish an effective Electrical Preventive Maintenance (EPM) program.

6.1.6 NFPA 70E

This standard addresses those electrical safety requirements for employee workplaces that are necessary for the practical safeguarding of employees in their pursuit of gainful employment.

6.1.7 UL 1087

This standard describes the requirements for molded case switches that are assembled as an integral unit in a supporting and enclosed housing of insulated materials with a maximum rating of 600V, and 6000 A. This standard also covers accessory devices that may be installed in or on a molded case switch to perform a secondary function to the primary function of the switch.

6.1.8 NFPA 20

This document deals with the selection and installation of pumps supplying water for private fire protection. Items considered include water supplies, suction, discharge and auxiliary equipment, power supplies, electric drive and control, internal combustion engine drive and control, steam turbine drive and control, acceptance tests, operation and maintenance.

6.1.9 Federal Specification W-C-375 B/GEN

This specification is for the use of all Federal agencies and covers molded case circuit breakers for service entrance, feeder, meter service, or branch circuit protection and rated up to 4,000 amperes, 600 volts ac, 60 Hz.

Generally, circuit breakers conforming to the requirements of UL 489 are considered qualified for inclusion on the Federal agencies qualified product list.

6.1.10 IEEE Publication 323

This document describes the basic requirements for qualifying Class 1E equipment and interfaces that are to be used in nuclear power generating stations. The requirements presented include the principles, procedures, and methods of qualification. These qualification requirements, when met, will confirm the adequacy of the equip-

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

ment design under normal, abnormal, design basis event, post design basis event, and containment test conditions for the performance of Class 1E functions.

6.2 OTHER APPLICABLE CODES AND STANDARDS

Most cities and states in the U.S. have adopted some type of electrical code. These codes are usually a specific edition of the National Electrical Code with or without modification. For specifics, the local municipality should be contacted.

6.3 INTERNATIONAL STANDARDS

Some of the more important standards pertaining to molded case circuit breakers are:

6.3.1 IEC 947-1 — Low Voltage Switchgear and Controlgear - Part 1: General Rules

6.3.2 IEC 947-2 — Low Voltage Switchgear and Controlgear - Part 2: Circuit Breakers

6.3.3 IEC 898 — Circuit Breakers for Overcurrent Protection for Household and Similar Installations

NOTE: IEC (International Electrotechnical Commission) is the world organization for establishing international electrical and electronic standards for the purpose of international unification.

6.4 NATIONAL STANDARDS OF OTHER COUNTRIES

The following is a partial listing of other national standards applicable to circuit breakers:

6.4.1 Canadian Standards Association (CSA)

CSA C22.2 No. 5 - Molded Case Circuit Breakers

6.4.2 British Standard 3871—Parts 1 & 2

Specifications for Miniature and Molded Case Circuit Breakers Part 1-1965—Miniature Air Break Circuit

Breakers for AC Circuits

6.4.3 German Standard—VDE 0660 Part 1

Regulations for Low Voltage Switchgear Part 1/8.69

Regulations for Switches for Rated Voltages up to 1000 VA and up to 3000 VDC and for Control Switches and Contactors up to 1000 VAC

6.4.4 Standards Association of Australia (SAA)

AS 2184 - Molded Case Circuit Breakers (up to and including 600 VAC and 250 VDC) (Interrupting Ratings of 10 Ka and more)

AS 3111 - Approval and Test Specification for Miniature Overcurrent Circuit Breakers

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Section 7
PREVENTIVE MAINTENANCE AND FIELD TESTING

7.1 Normal Preventive Maintenance

WARNING: HAZARDOUS VOLTAGES IN ELECTRICAL EQUIPMENT CAN CAUSE SEVERE PERSONAL INJURY OR DEATH.

UNLESS OTHERWISE SPECIFIED IN THIS PUBLICATION, INSPECTION, PREVENTIVE MAINTENANCE AND TESTING MUST ALWAYS BE PERFORMED ON EQUIPMENT WHICH IS DE-ENERGIZED. VERIFY THAT THERE IS NO VOLTAGE PRESENT ON INCOMING LINE TERMINALS (OR ON CONTROL POWER TERMINALS, IF PRESENT) AND BETWEEN THESE TERMINALS AND GROUND TO POSITIVELY ASCERTAIN THAT THE EQUIPMENT IS TOTALLY DE-ENERGIZED. THE DISCONNECTING OR ISOLATING MEANS ON THE LINE SIDE OF THE DEVICES BEING CHECKED OR TESTED SHOULD BE LOCKED IN THE "OFF" POSITION TO ASSURE THAT THE EQUIPMENT WILL REMAIN DE-ENERGIZED DURING THESE PROCEDURES.

SAFETY RELATED WORK PRACTICES DESCRIBED IN NFPA 70E-1988, PART II SHOULD BE FOLLOWED AT ALL TIMES.

Under normal conditions, properly applied molded case circuit breakers require maintenance only for verification of environmental conditions of the installation and of the enclosure type used for the circumstances.

However, a number of industrial users have requested guidance regarding inspection and preventive maintenance guidelines which could be carried out on a regularly scheduled basis. In that regard, see NEMA Standards Publication AB 4.

Molded case circuit breakers undergo extensive submittal testing under UL 489 prior to listing, and then production line calibration and testing during manufacture as well as regularly scheduled UL witnessed follow-up testing during the production life of the product.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

APPENDIX A
ABBREVIATIONS, DEFINITIONS, 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
E	Voltage
F	Fahrenheit
Hz	Frequency in Cycles per second Hertz
I	Current
|	Closed (on) position (International Standard Marking)
I_p	Peak current
I^2t	Amperes squared seconds
I_{cs}	Rated service short-circuit breaking capacity (IEC)
I_n	Rated uninterrupted current (IEC)
I_{cw}	Rated short time withstand current (IEC)
KCMIL	Thousand circular mils (same as MCM)
L	Inductance (Henrys)
MCM	Thousand circular mils (same as KCMIL)
M	Meter
M_A	Ratio of Asymmetrical to Symmetrical Current (3-phase)
M_M	Ratio of Asymmetrical to Symmetrical Current (1-phase)
mm	Millimeter
ms	Millisecond
N	Neutral
O	Breaking operation, circuit breaker
o	Open (off) position (International Standard Marking)
R	Resistance OHMS, in general
R_1	OHMS, cold
R_2	Resistance OHMS, hot
RH	Rubber covered conductor, heat resistant, rated 75°C
rms	Root mean square
SWD	Switching duty
T	Tripping time or time
t	Time interval
T_1	Temperature—Celsius degrees, cold
T_2	Temperature—Celsius degrees, hot
TC	Thermocouple
THW	Thermoplastic covered conductor, moisture and heat resistant, rated 75°C
TW	Thermoplastic covered conductor, moisture resistant, rated 60°C
U_e	Rated operational voltage (IEC)
U_i	Rated insulation voltage (IEC)
V	Voltage
Z	Impedance
ø	Phase
ø	Angle between voltage vector and current vector
I_{cu}	Rated ultimate short-circuit breaking capacity (IEC)

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

DEFINITIONS

Accessories—auxiliary devices that may be installed in or on a circuit breaker which perform a secondary function to the primary function of a circuit breaker.

Adjustable Instantaneous Release (Trip)—that part of an overcurrent trip element which contains a means that can be adjusted to trip a breaker instantaneously at various values of current within a predetermined range of currents.

Air Circuit Breaker—one in which the interruption occurs in air.

Alarm Switch (Switching Device)—an auxiliary switch that operates to open or close a circuit when the circuit breaker trips. An alarm switch does not operate when the breaker is turned "on" and "off."

Ambient-Compensated Circuit Breaker—one in which means are provided for partially or completely neutralizing the effect of ambient temperature upon the overload tripping characteristics.

Ambient Temperature—the average temperature of the surrounding medium that comes in contact with the breaker. For an enclosed device, it is the average temperature of the medium outside the enclosure.

Auxiliary Switch—a switch which is mechanically operated by the main device for signaling, interlocking, or other purposes.

NOTE: Auxiliary switch contacts are normally designated as "a" or "b" as indicated below:

"a" contacts—are open when the breaker or switch contacts are open and are closed when the circuit breaker or switch contacts are closed.

"b" contacts—are closed when the breaker or switch contacts are open and are open when the circuit breaker or switch contacts are closed.

Calibration Setting—the adjustment of the release mechanism of a circuit breaker to make the breaker perform in accordance with its prescribed characteristics.

Calibration Test—one which is made at a selected percentage or multiple of the marked current rating of the circuit breaker to verify the tripping characteristics of the 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 injury to itself when properly applied within its rating.

Circuit Breaker Enclosure—an enclosure intended to house a single circuit breaker (single or multipole).

Cross-Over Current of an integrally Fused Circuit Breaker—the current at which the opening operation 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 time-current trip characteristic curve.

Current-Limiting Circuit Breaker—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.

Dielectric Withstand Voltage Tests—tests made to determine the ability of the insulating materials and spacings used to withstand overvoltages without flashover or breakdown under specified conditions.

Drawout-Mounted Circuit Breaker—an assembly of a circuit breaker together with a supporting structure so constructed that the breaker is supported and can be moved between the main circuit Connected and Disconnected position without unbolting connections or mounting supports.

The stationary portion of the drawout assembly includes self-supporting primary circuit terminals and may include an interlocking means which permits movement of the breaker between the main circuit connected and disconnected positions only when the breaker contacts are in the open position.

Electrical Operator—an electrical controlling device which may be used to open, close, or reset a circuit breaker or switch.

Enclosure—a surrounding case constructed to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree to the enclosed equipment against specified environmental conditions.

Endurance Test—one which is made to determine compliance with a specified number of mechanical and electrical operations.

Fixed Instantaneous Release (Trip)—that part of an overcurrent release element which contains a nonadjustable means that is set to trip a breaker instantaneously at or above a predetermined value of current.

Frame—an assembly consisting of all parts of a circuit breaker except an interchangeable trip unit.

Frame Size—applies to a group of molded case circuit breakers which are physically interchangeable with each other. Frame size is expressed in amperes and corresponds to the largest ampere rating available in the group.

Front-Connected Circuit Breaker—one in which the terminals for connecting or disconnecting conductors are accessible from the front of the breaker.

Ground Fault Circuit Breaker — a circuit breaker which performs all normal circuit breaker functions and also

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

trips when a fault current to ground exceeds some predetermined value.

NOTE: The ground fault current sensing means may or may not be integral with the circuit breaker.

Handle Block—a device which provides for a positive means of retaining the breaker (or switch) handle in a desired position.

Integrally-Fused Circuit Breaker—one in which coordinated fuses (high fault protectors) are connected in series with the release (trip) elements of the circuit breaker and are mounted within the housing of the circuit breaker.

Instantaneous—a qualifying term indicating that no delay is purposely introduced in the automatic tripping of the circuit breaker.

Interchangeable Trip Unit—a trip unit which can be interchanged by a user among circuit breaker frames of the same design.

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.

Marine Circuit Breaker—a circuit breaker designed and constructed to meet special requirements for marine use.

Mechanical Interlock—a device which interlocks two or more circuit breakers or molded case switches together so that only selected ones can be closed at the same time.

Mechanism—

a) An External operating mechanism of a breaker or switch is a mechanism which engages the handle of a circuit breaker mounted within an enclosure and provides a manual means for operating the circuit breaker from outside the enclosure.

b) An Internal mechanism of a breaker or switch is a mechanism by which the main contacts of a circuit breaker are actuated.

Molded Case Circuit Breaker—one which 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 breaker with two or more poles which provide two or more separate conducting paths in which the poles are insulated from each other.

Naval Breaker—a circuit breaker designed and constructed to meet special requirements for naval use.

Neutral (or Solid Neutral)—an assembly consisting of an appropriate number of terminals providing for the connection of the grounded 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 service grounding conductor.

Overcurrent Release (Trip)—a component, which, for a given pole of a circuit breaker, detects overcurrent and transmits the energy necessary to trip the breaker automatically. It can actuate the breaker operating mechanism directly or can form part of a trip unit.

Pick-Up Point—the rms current level at which the circuit breaker tripping function is initiated.

Pole (of a Circuit Breaker or Switch)—that portion of a breaker or switch associated exclusively with one electrically separated conducting path of its main circuit.

Rated Control Voltage—the designated voltage which is to be applied to the closing or tripping devices to open or close a breaker or switch. It is allowed to vary above or below the rated control voltage within a specified range.

Rated Frequency—the service frequency of the circuit for which the breaker or switch is designed and tested.

Rated Insulation Voltage (U_i)—the value of voltage to which dielectric voltage tests and creepage distances are referred. In no case shall the maximum rated operational voltage exceed the rated insulation voltage.

Rating—the designated limit(s) of the operating characteristic(s) of a device.

Release—a mechanism within the circuit breaker, which responds to overcurrents by tripping the breaker.

Rear-Connected Circuit Breaker—one in which the current-carrying conductors are connected to terminals accessible from the rear of the breaker.

Service Conditions—the conditions under which a breaker or switch is to be applied.

Service Equipment—the necessary equipment, usually consisting of a circuit breaker, or switch and fuses, and their accessories, located near the point of entrance of supply conductors to a building and intended to constitute the main control and means of disconnecting the supply to that building.

Short Time Delay—a qualifying term indicating a purposely introduced delayed tripping action. The short time delay action can have either definite or inverse time characteristics.

Shunt-Trip Device—a release mechanism energized by a source of voltage which can be derived either from the main circuit or from an independent source.

"Trip-Free"—a qualifying term indicating that the circuit breaker contacts cannot be held in the closed position by the operating means during the trip command conditions.

Tripping—the opening of a circuit breaker by actuation of the release mechanism.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

Trip Unit of a Circuit Breaker—a self contained portion of a circuit breaker which actuates the mechanism that opens the circuit breaker contacts automatically.

Undervoltage Release—a release mechanism which causes a circuit breaker to open automatically if the control voltage falls below a predetermined value.

Withstand Current (I_{cw})—the assigned rms symmetrical or dc current that a circuit breaker or molded case switch can carry in the closed positon for a specified time.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

APPENDIX B
UL REQUIREMENTS FOR MOLDED CASE CIRCUIT BREAKERS

B1.1 SIGNIFICANCE OF A UL LISTED PRODUCT

A UL label on a molded case circuit breaker means that the breaker has met the basic requirements for circuit breakers covered by Underwriters Laboratories Inc. (Standard UL 489).

A 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.

Highlights of performance requirements as contained in UL 489 are listed below:

B1.1.1 Performance Requirements for Molded Case Circuit Breakers: Initial Submittal to UL

After a new breaker has been designed, it is 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."

B2.1 FAULT-CURRENT CIRCUIT TESTS

B2.1.1 Limited Available Fault-Current Circuit Tests

UL 489 requires that the following tests be performed:

1. **200 Percent Calibration.** Each pole of the circuit breaker must trip within a specified time limit when carrying 200 percent of its continuous current rating.
2. **135 Percent Calibration.** With all of the poles connected in series, the circuit breaker must trip within a specified time limit when carrying 135 percent of its continuous current rating.
3. **Adjustable Instantaneous Response Calibration.** If the circuit breaker has an adjustable instantaneous tripping means, then it must trip within a specified percentage of the marked tripping current.
4. **Overload.** The circuit breaker is operated making and breaking 600 percent of its rated current, but not less than 150 amperes. For breakers through 1600 amperes, the number of 600 percent operations is 50. For larger breakers to 3000 amperes, the number of operations is at least 25.
5. **Tungsten-Filament-Lamp Load.** Circuit breakers rated 50 amperes or less and 125 or 125/250 volts or less are closed into a tungsten-filament-lamp load to ensure the breaker contacts do not weld.
6. **Temperature Rise.** While carrying 100 perecent of rated current after the overload test, the circuit breaker mounted in open air, or in enclosures for 100 percent rated devices, is checked for temperature rise and must be within specified limits at terminations and other critical locations.
7. **Endurance.** The circuit breaker must complete successfully the following number of operations:

FRAME SIZE	FULL LOAD	NO LOAD	NUMBER PER MINUTE
0–100	6,000	4,000	6
101–225	4,000	4,000	5
226–600	1,000	5,000	4
601–800	500	3,000	1
801–2500	500	2,000	1
2501–6000	400	1,100	1

8. **Recalibration Test.** Both the 200 percent and 135 percent calibration tests are repeated.
9. **Short-Circuit.** For breakers rated 240 volts and up a minimum of two short-circuit tests per pole and one with all the poles connected. For a three-pole breaker, this means a minimum of seven short-circuit tests. For breakers rated 120/240 volts, a minimum of 3 tests are made with all poles connected. The short-circuit current, ranges from a minimum of 5000 amperes, minimum available fault current, to 70,000 amperes, depending on breaker frame size and whether individual poles are being tested or whether all poles are connected in test. Depending on the test sequence selected by the manufacturer, an additional low-level short circuit test may be required after endurance testing. The circuit breaker is to be connected to the test circuit using wire correctly sized for the rating of the circuit breakers. The line leads shall not be more than 4 feet long and the load leads shall not be more than 10 inches long.
10. **Trip Out.** The 200 percent calibration test is repeated following the short-circuit tests.
11. **Dielectric.** The circuit breaker must withstand for one minute twice-rated voltage plus 1000 volts:
    a. Between line and load terminals with the breaker in the open and tripped positions,
    b. Between poles when the breaker is closed, and
    c. Between live parts and ground, with the breaker in the open and closed positions.

During the test program, no conditioning of the breaker can take place and at the conclusion of the test sequence, there cannot be any failure of functional parts.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

B2.1.2 High Available Fault-Current Circuit Tests

High Fault-Current Test: After qualifying a set of breakers to the standard tests, a manufacturer may submit additional circuit breaker samples for the tests on higher than standard fault-currents.

The performance tests for breakers for use on high-available-fault currents are:

1. 200 percent calibration test
2. Short-circuit test at the marked interrupting rating,
3. 250 percent calibration test, and
4. Dielectric withstand test (Same as under "Standard Tests" except that the voltage is twice rated voltage but not less than 900 volts).

With successful performance, the circuit breakers will then be marked or labeled with the current-interrupting rating or ratings.

B3.1 Switching Duty (SWD)

After qualifying a set of breakers to the limited available fault-current circuit tests, a manufacturer may submit additional samples for the tests for switching duty. The SWD listing applies to 277 volts or less, 15 and 20 ampere breakers only. The breakers are subjected to special temperature rise tests at predetermined times during the specified endurance operation. Upon successful completion, the breakers can be marked SWD.

B4.1 Performance Requirements

B4.1.1 Performance Requirements for Instantaneous Trip Only Breakers

The test sequence for verification of design performance is:

1. Verification of calibration
2. Overload
3. Temperature rise
4. Endurance
5. Short circuit
6. Re-Verification of Calibration
7. Dielectric

Tests are the same as under the limited available fault current program except that during short circuit tests, burnout of the magnetic trip coil is acceptable, when the device is tested alone. However, when tested in series with intended overload relays or equivalent in sequence, coil burnout is not permitted.

Instantaneous trip only breakers are not intended for use on service entrance feeders, as branch or service circuit breakers. Therefore, these breakers are recognized under the UL component program; and the final acceptance by UL of these breakers is dependent upon their use in complete equipment submitted to UL.

B4.1.2 Performance Requirements for Molded Case Switches

Since molded case switches are derivatives of molded case circuit breakers, some testing of the switches is identical to that for breakers. These tests include a 600 percent overload performance test.

B5.1 UL LISTED PRODUCTS

UL listed products are designed to fully comply with all the construction and performance requirements of the category. Inverse time type circuit breakers can be a UL listed product.

B5.2 RECOGNIZED COMPONENT

Recognized components are devices which 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.

B5.3 UL CLASSIFIED CIRCUIT BREAKER

A circuit breaker identified by the manufacturer of the circuit breaker as suitable for use in a specified panelboard in lieu of a specified circuit breaker.

B5.4 UL CLASSIFIED TO IEC

UL classified to IEC devices are devices which have been tested in accordance with specific IEC (International Electrotechnical Commission) publications.

B6.1 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 three test sequences (X, Y, and Z) are listed below:

Sequence X. Conducted quarterly on breakers of frame size 200 amperes or less and annually on breakers of frame size over 200 amperes.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS

Not for Resale

Calibration—200 percent
—135 percent
Overload
Calibration at 100 percent
Temperature
Dielectric

Sequence Y. Conducted quarterly on breakers of frame size 200 amperes or less and annually on breakers of frame size over 200 amperes.

Calibration—200 percent
Endurance—Load
—No Load
Recalibration—200 percent
—135 percent
Short circuit—200 percent
Trip out
Dielectric

Sequence Z. Conducted semi-annually on breakers of frame size 150 amperes or less and annually on breakers of frame size over 150 amperes.

Calibration—200 percent
Short Circuit
Trip Out—200 percent
Dielectric

The biennial tests are conducted on circuit breakers that have interruption 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.

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.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

NEMA STANDARDIZATION BACKGROUND

The purpose of NEMA Standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Standardization Policies and Procedures, p. 1)

Definition of a Standard

A Standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 8)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 7 & 16)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to authorized engineering information and not to procedures required for compliance with the standard.

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale

MOLDED CASE BREAKER SECTION
OF THE
NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

MEMBER COMPANIES

ABB Control, Inc.
Wichita Falls, TX 76306

American Circuit Breaker Corporation
Albemarle, NC 28001

Challenger Electrical Equipment Corp.
Malvern, PA 19355

Eaton Corporation
Cutler-Hammer Products
Milwaukee, WI 53216

GE
Plainville, CT 06062

Klockner Moeller Corporation
Franklin, MA 02038

Merlin Gerin, Inc.
Smyrna, GA 30082

Siemens Distribution Equipment Business
Siemens Energy and Automation, Inc.
Charlottesville, VA 22906

Siemens Energy & Automation, Inc.
Tucker, GA 30084

Square D Company
Palatine, IL 60067

Unicorn Electrical Products
Anaheim, CA 92806

Westinghouse Electric Corporation
Pittsburgh, PA 15220

Copyright National Electrical Manufacturers Association
Provided by IHS under license with NEMA
No reproduction or networking permitted without license from IHS
Not for Resale