Circuit Voltage

Molded case circuit breakers are rated by voltage class and should be applied only to system voltages within their rating. The voltage rating is determined by the maximum voltage that can be applied across its terminals, the type of distribution system and how the breaker is applied in the system.

Circuit breakers listed for use at 120/240 volts may be applied on 120/240 volt grounded systems. For applications on 240 volt ungrounded systems apply only circuit breakers rated 240 volts (with no "slash" rating) or higher.

Circuit breakers rated 277/480 volts are suitable for application on 277/480 volt grounded wye systems and are not for application on 480 volt ungrounded delta systems. Apply circuit breakers rated 480 volts (with no "slash" rating) or higher on 480 volt ungrounded delta systems.

UL 489 provides standards for testing the individual poles of 2-pole and 3-pole MCCBs. The test current is generally lower than the interrupting rating of the MCCB. This capability is necessary for breakers applied on corner-grounded delta systems where single line-to-ground faults may be interrupted by only a single pole of a circuit breaker with full line-to-line voltage across that single interrupting pole. MCCBs should not be used on circuits where the available fault current exceeds the level at which individual poles were short circuit tested at line-to-line voltage.

Note: On all three-phase Delta, grounded B Phase applications, refer to Eaton.

Circuit Frequency

The tripping characteristics of most molded case circuit breakers remain virtually constant when applied to frequencies of 50 and 60 hertz. On higher frequency applications, molded case circuit breakers must usually be specially calibrated and/or derated. The amount of derating depends upon the frame size and ampere rating as well as the current frequency. In general, the higher the ampere rating in a given frame size, the greater the derating required.

Thermal-magnetic molded case circuit breakers applied at frequencies above 60 hertz could require that individual consideration be given to thermal performance, magnetic performance and interrupting capabilities.

Electronic trip units are usually calibrated for 50/60 hertz, although operation at higher frequencies is achievable with the use of special derating factors and specially sized cable or bus.

Avoid making circuit breaker performance assumptions on applications above 60 hertz. Consult Eaton for any Cutler-Hammer molded case circuit breaker above 60 hertz.

Continuous Ampere Rating

Molded case circuit breakers are rated in rms amperes at a specific ambient. This ampere rating is the continuous current they will carry in the ambient temperature for which they are calibrated. Cutler-Hammer thermal-magnetic breakers are calibrated for an ambient temperature 40°C (104°F) which is the average temperature within an enclosure; thus, they minimize the need for derating. If the enclosure ambient is known to exceed 40°C, the breaker used should either be especially calibrated for that ambient, or be derated accordingly.

In accordance with the National Electrical Code, all circuit breakers are derated to 80% for continuous loads except electronic trip unit circuit breakers that have been tested and marked for 100% application.

The selection of a specific ampere rating for a given application is dependent upon the type of load and duty cycle, and is governed by the National Electrical Code. In general, the NEC requires overcurrent protection at the supply and at points where wire sizes are reduced. It further states that the conductors be protected in accordance with their current carrying capacity, but lists exceptions for applications such as motor circuits where a larger rating is often required to override motor inrush currents.

Cable Selection

UL listed circuit breakers rated 125 A or less shall be marked as being suitable for 60°C (140°F), 75°C (167°F) only or 60/75°C (140/167°F) wire. All Cutler-Hammer listed breakers rated 125 A or less are marked 60/75°C. All UL listed circuit breakers rated over 125 A are suitable for 75°C conductors. Conductors rated for higher temperatures may be used, but must not be loaded to carry more current than the 75°C ampacity of that size conductor for equipment marked or rated 75°C or the 60°C ampacity of that size conductor for equipment marked or rated 60°C. However, the full 90°C (194°F) ampacity may be used when applying derating factors, so long as the actual load does not exceed the lower of the derated ampacity or the 75°C or 60°C ampacity that applies.

Circuit Breaker Sizing Considerations

The following paragraphs outline pertinent information from the NEC according to the type of load and duty cycle.

A. Service

A service includes the conductors and equipment for delivering electrical energy from the supply system to the wiring system of the premises served.

NEC Article 230 contains the many requirements for services of 600 volts or less including the sizing, location and overcurrent protection of conductors, disconnect means, permissible number of disconnects, grounding of conductors, and ground fault protection requirements of service equipment.

B. Feeder Circuits

A feeder is composed of the conductors of a wiring system between the service equipment or the generator switchboard of an isolated plant and the branch circuit overcurrent device.

NEC Article 220: Where a feeder supplies continuous loads or any combination of continuous and noncontinuous loads, the rating of the overcurrent device shall not be less than the noncontinuous load plus 125% of the continuous load.

Exception: Where the assembly including the overcurrent devices protecting the feeder(s) are listed for operation at 100% of their rating, neither the ampere rating of the overcurrent device nor the ampacity of the feeder conductors shall be less than the sum of the continuous load plus the noncontinuous load.

Only breakers listed for 100% application, and so labeled, can be applied under the exception (for example, type CKD). Breakers without 100% application listing and label are applied under (B) above, or at 80% of rating.

NEC Article 430: Breakers for feeders having mixed loads; i.e., heating (lighting and heat appliances) and motors, should have ratings suitable for carrying the heating loads plus the capacity required by the motor loads.

NEC Article 430: Breakers for motor feeders shall have a rating not greater than the sum of the highest breaker rating of any of its branches and the full load currents of all other motors served by the feeder.

C. Branch Circuits

A branch circuit is the portion of a wiring system extending beyond the final overcurrent device protecting the circuit.

(1) Lighting Circuits (NEC Article 310)
These are protected in accordance with the conductor ratings as given. High wattage incandescent lamp loads may result in abnormally high inrush currents that must be taken into account to avoid nuisance tripping. The lamp manufacturer should be consulted for data relative to the inrush currents.

(2) Motor Circuits (NEC Article 430)
Breakers are primarily intended for the protection of conductors, motor control apparatus and motors against short circuits and ground fault conditions.

On motor overloads, the motor overcurrent device will open the circuit before the correctly applied breaker. Currents higher than the locked rotor value will be interrupted by the breakers, protecting the circuit from these heavy fault currents. The breaker must not trip on normal starting.

While breakers may be applied for motor running overcurrent protection when the requirements of Article 430 of the NEC are met, these applications are not recommended for Eaton's Cutler-Hammer breakers and, therefore, this discussion is confined to the use of a breaker as a circuit protector.

For many applications, particularly those where starting behavior of the motor is unknown, the NEC maximum rules are followed. Usually, lower rated breakers can be used successfully. This is further discussed under motor circuit application and motor application tables.

Motor Circuit Application (NEC Article 430): The breaker must have a continuous rating of not less than 115% of the motor full load current. Before applying a breaker, one should check to determine the effect of any of the following conditions: High ambient temperature, heating within breaker enclosure due to grouping of current consuming devices, frequent motor starting, and lengthy motor acceleration period.

Breaker Rating or Setting (NEC Article 430): The motor branch circuit overcurrent device shall be capable of the motor. The required protection shall be considered as being obtained when the overcurrent device has a rating or setting not exceeding the values given in **Table 28.1-106**, reference NEC Article 430).

An instantaneous trip circuit breaker (without time delay) shall be used only if adjustable and if part of a combination controller having overcurrent protection in each conductor and the combination is especially approved for the purpose. In the event a breaker chosen on this basis still does not allow motor starting, a higher rating is permitted by the code. See Exceptions listed with **Table 28.1-106**.

Due to the infinite number of motor-and-load combinations and because comparable breakers of different manufacture have different tripping characteristics, NEC motor circuit breaker rules are of a general nature and are set up as maximum boundaries. Protection is considered satisfactory if the breaker rating does not exceed the figure allowed by the NEC requirements. Although Cutler-Hammer breakers rated less than the NEC maximum values may be applied in most cases. Many operating engineers select breakers on the basis of the NEC maximum rules simply because consideration of other factors is not usually necessary, or to ensure motor starting when the starting behavior of the motor is not known. **Tables 28.1-106** and **28.1-107** are adapted from Article 430 of NEC.

When a certain motor is standard for a given job, as on a volume produced machine tool, it is practical (and often more economical) to select a breaker for closer protection than one chosen on the basis of NEC maximum rules.

Circuit breakers are not horsepower rated. Unlike switches, circuit breakers are not horsepower rated because they are able to safely interrupt currents far in excess of the locked rotor value for any motor with which they may be applied. This ability is recognized in the NEC as stated in paragraph 430.109 and is proven by the Underwriters' tests described in UL bulletin number 489, *Standard for Branch Circuit and Service Circuit Breakers*.

For example, a breaker must pass the UL overload test consisting of breaking a current 600% of its ampere ratings. As motor branch circuit breaker ratings are usually 125 to 250% of motor full-load currents, this test establishes the ability of the breaker to more than interrupt locked rotor currents. Following the overload test and others, the breaker is called upon to successfully clear its rated short circuit current which is a minimum of 5000 amperes. This also is many times higher than motor locked rotor current. Because by definition a circuit breaker is required to "open under abnormal conditions...without injury to itself", the breaker must still be in operating condition after the test.

Application Information

Table 28.1-106. Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground Fault Protective Devices — NEC Table 430.52

Type of Motor	Percent of Full Load Current ①	
	Instantaneous Trip Breaker	Inverse Time Breaker
Single-Phase Motors	800	250
ac Polyphase Motors other than Wound Rotor		
Squirrel Cage:		
Other than Design B Energy Efficient	800	250
Design B Energy Efficient	1100	250
Synchronous	800	250
Wound Rotor	800	150
Direct-Current (Constant Voltage)	250	150

① For certain exceptions to the values specified, see Sections 430.52 through 430.54. The values given in the last column also cover the ratings of nonadjustable inverse time types of circuit breakers that may be modified as in Section 430.52, Exceptions No. 1 and No. 2. Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc., that start unloaded, do not require a fuse rating or circuit breaker setting in excess of 200 percent of full load current.

Table 28.1-107. Full-Load Current Three-Phase Alternating-Current Motors — NEC Table 430.250 ②

Hp	Induction Type Squirrel-Cage and Wound-Rotor Amperes							Synchronous Type Unity Power Factor ③ Amperes			
	115 Volts	200 Volts	208 Volts	230 Volts	460 Volts	575 Volts	2300 Volts	230 Volts	460 Volts	575 Volts	2300 Volts
1/2	4.4	2.5	2.4	2.2	1.1	0.9	—	—	—	—	—
3/4	6.4	3.7	3.5	3.2	1.6	1.3	—	—	—	—	—
1	8.4	4.8	4.6	4.2	2.1	1.7	—	—	—	—	—
1-1/2	12.0	6.9	6.6	6.0	3.0	2.4	—	—	—	—	—
2	13.6	7.8	7.5	6.8	3.4	2.7	—	—	—	—	—
3	—	11.0	10.6	9.6	4.8	3.9	—	—	—	—	—
5	—	17.5	16.7	15.2	7.6	6.1	—	—	—	—	—
7-1⁄2	—	25.3	24.2	22	11	9	—	—	—	—	—
10	—	32.2	30.8	28	14	11	—	—	—	—	—
15	—	48.3	46.2	42	21	17	—	—	—	—	—
20	—	62.1	59.4	54	27	22	—	—	—	—	—
25	—	78.2	74.8	68	34	27	—	53	26	21	—
30	—	92	88	80	40	32	—	63	32	26	—
40	—	120	114	104	52	41	—	83	41	33	—
50	—	150	143	130	65	52	—	104	52	42	—
60	—	177	169	154	77	62	16	123	61	49	12
75	—	221	211	192	96	77	20	155	78	62	15
100	—	285	273	248	124	99	26	202	101	81	20
125	—	359	343	312	156	125	31	253	126	101	25
150	—	414	396	360	180	144	37	302	151	121	30
200	—	552	528	480	240	192	49	400	201	161	40
250	—	—	—	—	302	242	60	—	—	—	—
300	—	—	—	—	361	289	72	—	—	—	—
350	—	—	—	—	414	336	83	—	—	—	—
400	—	—	—	—	477	382	95	—	—	—	—
450	—	—	—	—	515	412	103	—	—	—	—
500	—	—	—	—	590	472	118	—	—	—	—

② The following values of full load currents are typical for motors running at speeds usual for belted motors and motors with normal torque characteristics. The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.

③ For 90 and 80 percent power factor, the above figures shall be multiplied by 1.1 and 1.25 respectively.

C. Capacitor Protection (NEC Article 460)

In normal applications, breakers rated about 150% of capacitor rated currents are recommended. This factor allows for switching surges, and possible overcurrent due to overvoltage and harmonic currents. Such selection fully meets the NEC requirements in 460.8 for a conductor and disconnect to be rated not less than 135% capacitor rating. Where the operating currents exceed 135% of rated current due to harmonic components, service conditions may require the selection of a breaker with a higher current rating.

For application in ambients higher than the rated ambient of the breaker, the breaker derating table should be checked to determine the rating of the breaker required to meet the minimum of 135% capacitor rating.

Circuit breakers and switches for use with capacitor must have a current rating in excess of rated capacitor current to provide for overcurrent from overvoltages at fundamental frequency and harmonic currents. The following percent of the capacitor-rated current should be used:

Fused and unfused switches. . . . 165%

Enclosed Molded Case Circuit Breaker (Includes additional de-rating for enclosures) 150%

Air circuit breakers. 135%

Contactors:

Open type 135%

Enclosed type 150%

Refer to Section 37 for specific sizing of protective devices by kvar rating.

E. Transformer Protection (NEC Article 450) Primary

Each transformer 600 volts or less shall be protected by an individual overcurrent device on the primary side. Rated or set at not more than 125% of the rated primary current of the transformer.

Exception No. 1: Where the rated primary currents of a transformer is 9 amperes or more and 125% of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher standard rating described in Section 240 shall be permitted. Where the rated primary current is less than 9 amperes, an overcurrent device rated or set at not more than 167% of the primary current shall be permitted.

Where the rated primary current is less than 2 amperes, an overcurrent device rated or set at not more than 300% shall be permitted.

Exception No. 2: An individual overcurrent device shall not be required where the primary circuit overcurrent device provides the protection specified in this Section.

Exception No. 3: As provided in (b) (2) below.

(2) Primary and Secondary

A transformer 600 volts or less having an overcurrent device on the secondary side rated or set at not more than 125% of the rated secondary current on the transformer shall not be required to have an individual overcurrent device on the primary side if the primary feeder overcurrent device is rated or set at a current value not more than 250% of the rated primary current of the transformer.

A transformer 600 volts or less, equipped with coordinated thermal overload protection by the manufacturer and arranged to interrupt the primary current, shall not be required to have an individual overcurrent device on the primary side if the primary feeder overcurrent device is rated or set at a current value not more than 6 times the rated current of the transformer for transformers having more than 6% impedance and not more than 4 times the rated current of the transformer for transformers having more than 6 but not more than 10% impedance.

Exception 4: Where the rated secondary current of a transformer is 9 amperes or more and 125% of this current does not correspond to a standard rating of a fuse or nonadjustable circuit breaker, the next higher standard rating described in Section 240 shall be permitted.

Where the rated secondary current is less than 9 amperes, an overcurrent device rated or set at not more than 167% of the rated secondary current shall be permitted. Closer protection can be provided by breakers having shunt trips actuated by a temperature sensing device imbedded in transformer windings.

Table 28.1-108. Single-Phase Primary Protection When Secondary Protection Provided

kVA	208 V		240 V		277 V		480 V		600 V	
	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip
2	10	20	8	20	7	15	5	10	4	—
3	14	30	13	30	11	20	6	15	5	10
5	24	50	21	50	18	40	10	20	8	20
7.5	36	70	31	60	27	50	16	30	13	30
10	48	100	42	80	36	70	21	40	17	40
15	72	150	63	125	54	100	31	60	25	50
25	120	225	104	200	90	175	52	100	42	100
37.5	180	350	156	300	135	250	78	150	63	150
50	240	450	208	400	181	350	104	200	83	150
75	361	700	313	600	271	500	156	300	125	250
100	481	1000	417	800	361	700	208	400	167	350
167	803	1600	696	1200	603	1200	348	700	278	600
250	1202	2000	1042	1600	903	1600	521	800	417	800
333	1601	3000	1388	2000	1202	2000	694	1200	555	800
500	2404	3200	2083	3000	1805	2500	1042	1600	833	1200

Table 28.1-109. Single-Phase Secondary Protection When Primary Protection Provided

kVA	208 V		240 V		277 V		480 V	
	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip
2	10	15	8	15	—	—	—	—
3	14	20	13	20	11	15	—	—
5	24	30	21	30	18	25	10	15
7.5	36	45	31	40	27	35	16	20
10	48	60	42	60	36	50	21	30
15	72	90	63	80	54	70	31	40
25	120	150	104	150	90	150	52	70
37.5	180	225	156	200	135	175	78	100
50	240	300	208	300	181	225	104	150
75	361	450	313	400	271	350	156	200
100	481	600	417	600	361	450	208	300
167	803	1000	696	900	603	800	348	450
250	1202	1600	1042	1400	903	1200	521	700
333	1601	2000	1388	1800	1202	1600	694	900
500	2404	3000	2083	3000	1805	2500	1042	1400

Table 28.1-110. Three-Phase Primary Protection When Secondary Protection Provided

kVA	240 V		480 V		600 V	
	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip
3	7	15	—	—	—	—
6	14	30	7	15	6	15
9	22	40	11	25	9	20
15	36	70	18	40	14	30
30	72	150	36	70	29	60
37.5	90	200	45	90	36	70
45	108	200	54	110	43	90
50	120	225	60	120	48	100
75	180	350	90	200	72	150
112.5	271	500	135	250	108	200
150	361	700	180	350	144	300
225	541	1000	271	500	217	400
300	722	1000	361	600	289	500
500	1203	2000	601	800	481	700
7550	1804	2500	902	1200	722	1000
1000	2406	4000	1203	2000	962	1600

Table 28.1-111. Three-Phase Secondary Protection When Primary Protection Provided

kVA	208 V		240 V		480 V		600 V	
	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip	FLA	Breaker Trip
3	8	10	7	10	—	—	—	—
6	17	20	14	20	7	10	—	—
9	25	35	22	30	11	15	9	10
15	42	60	36	45	18	25	14	20
30	83	110	72	100	36	45	29	40
37.5	104	150	90	125	45	60	36	50
45	125	175	108	150	54	70	43	60
50	139	175	120	175	60	80	48	60
75	208	300	180	225	90	125	72	90
112.5	312	400	271	350	135	175	108	150
150	416	600	361	500	180	225	144	200
225	652	800	541	700	271	350	217	300
300	833	1200	722	900	361	500	289	400
500	1388	1800	1203	1500	601	800	481	600
750	2082	3000	1804	2500	902	1200	722	900
1000	2776	3500	2406	3000	1203	1600	962	1200

Interrupting Rating

The maximum amount of fault current supplied by a system can be calculated at any point in that system. One rule must be followed for applying the correct circuit breaker.

The interrupting rating of the breaker must be equal to or greater than the amount of fault current that can be delivered at that point in the system where the breaker is applied.

The interrupting rating of the breaker is the maximum amount of fault current it can safely interrupt without damaging itself. A breaker's interrupting rating always decreases as the voltage increases. Interrupting rating is one of the most critical factors in the breaker selection process.

Number of Poles

The number of poles in the breaker is determined by the type of distribution system. A pole is required for each hot conductor, but usually not for the neutral conductor, except in certain special applications.

In general, a 1-pole breaker may be used on grounded neutral systems for single-phase applications and a 3-pole breaker on 3-phase applications. There are instances, however, where 2-pole breakers are necessary on single-phase systems and 4-pole breakers on 3-phase systems to interrupt the neutral. Certain dc voltage applications also use special multi-pole configurations.

Fixed or Interchangeable Trip Unit

Reverse Feed Applications (Power Supply to Load Side)

Often due to physical equipment arrangements in panelboards and switchboards, it is desirable to reverse feed a molded case circuit breaker. For this application, circuit breakers must be tested and listed accordingly. For safety reasons, thermal-magnetic circuit breakers having interchangeable trip units are not acceptable for this application, and are, therefore, marked "Line" and "Load" on the cover. Where circuit breakers are so marked, the power source conductors must be connected to the "Line" end terminations.

Circuit breakers suitable for reverse feed application generally have sealed covers and not marked "Line" and "Load" and are UL listed.

Unusual Operating Conditions

Trip Unit Temperatures

Eaton's Cutler-Hammer Thermal-magnetic circuit breakers are temperature sensitive. At ambient temperatures below 40°C (104ºF), circuit breakers carry more current than their continuous current rating. Nuisance tripping is not a problem under these lower temperature conditions, although consideration should be given to closer protection coordination to compensate for the additional current carrying capability. In addition, the actual mechanical operation of the breaker could be affected if the ambient temperature is significantly below the 40°C standard.

For ambient temperatures above 40°C, breakers will carry less current than their continuous current rating. This condition promotes nuisance tripping and can create unacceptable temperature conditions at the terminals. Under this condition, the circuit breaker should be recalibrated for the higher ambient temperature.

Electronic trip units are insensitive to ambient temperatures within a certain temperature range. The temperature range for most Cutler-Hammer electronic trip units is -20°C to +55°C (-4ºF to 131ºF). However, at very low ambient temperatures, the mechanical parts of the breaker could require special treatment, such as the use of special lubricants. If the ambient temperature exceeds 40°C significantly, damage to the electronic circuitry and other components could result. Eaton includes temperature protective circuits in its designs to initiate a tripping operation and provide self-protection, should the internal temperature rise to an unsafe level.

Circuit Breaker Temperatures

The temperature of the air surrounding a circuit breaker is the ambient temperature. For some years, all molded case circuit breakers were calibrated for 25°C (77°F). This ambient temperature was not very representative of the conditions in which most molded case circuit breakers were applied, namely in an enclosure. In the mid-1960s, industry standards were changed to make all standard breakers calibrated to a 40°C ambient temperature. For any ambient temperature application above or below 40°C, it is recommended that the breaker manufacturer be consulted as to any possible re-rating, recalibration or special procedures, before the circuit breaker is selected and applied.

Table 28.1-112. Derating Chart for Non-Compensated Thermal-Magnetic Breakers Calibrated for 40°C

Breaker Ampere Rating at 40°C	Ampere Rating		
	25°C (77°F)	50°C (122°F)	60°C (140°F)
F-Frame/E125-Frame			
15	17	13	11
20	22	18	16
25	32	21	16
30	33	27	24
35	41	32	27
40	45	34	29
50	55	46	42
60	66	56	52
70	77	65	60
90	99	84	78
100	110	94	87
125	137	116	105
150	165	138	125
J-Frame/JG-Frame			
70	79	63	55
90	102	81	71
100	115	89	76
125	140	114	102
150	171	134	116
175	200	156	134
200	230	178	153
225	252	205	183
250	281	227	201
K-Frame			
100	121	90	79
125	145	116	106
150	188	132	111
175	210	159	141
200	243	180	157
225	255	212	198
250	294	230	208
300	364	270	236
350	412	322	291
400	471	368	333
L-Frame/LG-Frame			
300	330	276	252
350	385	325	301
400	440	372	340
500	550	468	435
600	660	564	525
M-Frame			
300	332	277	252
350	388	322	292
400	444	368	334
450	495	418	383
500	550	468	435
600	660	564	525
700	770	658	613
800	880	754	704

Moisture — Corrosion

High moisture content and/or the presence of corrosive elements can result in damage to key operating components and/or severely compromise the breaker's operational integrity. As is the case with all electrical equipment, this type of condition or environment should be avoided. Good electrical practice dictates that electrical equipment always be applied in a clean environment, free of moisture and corrosion. If such operating conditions cannot be avoided, special treatment of the circuit breaker should be considered to minimize the possibility of operational problems. Most Cutler-Hammer molded case circuit breaker cases are molded from glass polyester which does not support the growth of fungus. In addition, a special moisture and fungus-resisting treatment is recommended for any parts that are susceptible to the growth of fungus. In areas where daily temperature changes have a tendency to cause condensation, the inclusion of space heaters in the enclosure is the best preventative measure. The manufacturer should be consulted if either one of these operational environments is likely to exist. Consider the addition of a Cutler-Hammer C799 series oxidation inhibiting capsule in the assembly.

Altitude

Low voltage circuit breakers must be progressively derated for voltage, current carrying and interrupting rating at altitudes above 6,000 feet (1,829 m). The thinner air at higher altitudes reduces cooling and dielectric characteristics compared to the denser air found at lower altitudes. Refer to Eaton for additional application details.

Shock/Vibration

Where high shock is an anticipated condition, hi-shock Navy type breakers are recommended. Molded case circuit breakers can be supplied to meet the following marine specifications: U.S. Coast Guard CFR 46, ABS – American Bureau of Shipping, IEEE 45, UL 489 Supplement SA Marine, and UL 489 Supplemental SB Naval.

Special Applications

Molded Case Breakers for Application on Resistance Welding Circuits

Short circuit protection for resistance welding devices can be obtained by properly applying instantaneous trip molded case circuit breakers.

Note: Instantaneous only breakers for welding application are intended for application within the welding equipment not as feeder breakers to welding machines.

These breakers permit normally high welding currents, but trip instantaneously if a short circuit develops. These breakers include standard molded case circuit breaker features such as trip-free operation, deadfront and single-phase protection. Because the breakers are resettable after tipping, replacement costs and downtime are minimized.

Duty Cycle is based on the one minute averaging time of the breaker, and can be determined as follows:

$$\text{Duty Cycle} = \frac{\text{Weld Time} \times 100}{\text{Weld Time} + \text{Off Time}}$$

"During-weld" amperes can be obtained from the welder manufacturer, or as follows:

$$\text{During-weld Amperes} = \frac{\text{During-weld kVA} \times 1000}{\text{Voltage}}$$

Interrupting capacity of the breaker should be within the maximum available at the point of application. Refer to Eaton for additional application details.

Mining Service Circuit Breakers

The full line of mining service circuit breakers includes 1000Y/577 Vac ratings. Mining breakers are available with a full line of accessories. These special purpose circuit breakers are designed specifically for underground trailing cable application per MSHA 30 CFR 75.

Engine Generator Circuit Breakers

Engine generator molded case circuit breakers are designed specifically for application on diesel engine powered standby generators where high interrupting circuit breakers are not required. Engine generator circuit breakers conform to UL 489, CSA and IEC 947-2.

Molded Case Switches

The molded case switch is used when a compact, high capacity disconnect switch is required. It provides no overcurrent protection, overload or low level fault. The MCS is equipped with a high instantaneous magnetic fixed trip unit. The fixed magnetic trip is factory preset to interrupt high fault currents at or above its preset level. MCS is self protecting within its withstand rating. The molded case switch accepts the same accessories as the equivalent thermal-magnetic circuit breaker. See **Table 28.1-114**.

Application and Replacement of Breakers

Apply and replace breakers prudently, within the design and operating parameters of the power system. Use the following tables to select the size and type of Series C® Circuit Breaker needed to fit virtually any application in series connected and other protective systems. Series C Breakers are highly compatible across ratings, capacities and characteristic; prudent replacements are as important as initial selection.

Unusual Mounting Configurations

Generally, circuit breakers may be mounted in any position, up or down, horizontal or vertical, without affecting the tripping characteristics or interrupting rating. However, mounting circuit breakers in a vertical position with the "ON" position other than "UP" will be in violation of Article 240-81 of the National Electrical Code.

Table 28.1-113. Endurance Test per UL 489

Ampere Rating	Operations		
	Full Load	No Load	Per Minute
0 – 100	6000	4000	6
101 – 225	4000	4000	5
226 – 600	1000	5000	4
601 – 800	500	3000	1
801 – 2500	500	2000	1
2501 – 4000	400	1100	1

Table 28.1-114. Molded Case Switch Short Circuit Current Ratings at 60 Hz Only (Maximum Fault Current at Which Device can be Applied in kAIC)

MCS Frame	Ampere Rating	Short Circuit Current Rating			
		240 V	480 V	600 V	250 Vdc
GD	100	65	22	—	10
EHD	100	18	14	—	10
FD	150	65	25	18	10
HFD	150	100	65	25	22
JD	250	65	25	18	10
HJD	250	100	65	25	22
DK	400	65	—	—	10
KD	400	65	35	25	10
HKD	400	100	65	35	22
LD	600	65	35	25	10
HLD	600	100	65	35	25
MDL	800	42	35	22	20
HMDL	800	100	65	35	25
ND	1200	65	50	25	—
HND	1200	100	65	35	—
RD	2000	125	65	50	—
EGK	125	100	65	—	42
JGK	250	100	65	35	42
LGK	600	100	65	35	42
NGK	1200	100	65	35	—
RGK	2000	125	65	50	—

DC Circuit Breakers

UL listed Eaton's Cutler-Hammer DC Molded Case Circuit Breakers are for use in general dc circuits. They are also used in ungrounded battery supply circuits of UPS systems which provide continuous reliable ac power to computer-controlled applications for financial institutions and telecommunications. These devices are an excellent alternative to molded case switches and fuses because they are easier to install and require less maintenance.

All DC breakers are designed specifically for use in ungrounded dc circuits. The various dc voltage ratings are obtained by connecting one, two, three or four poles in series as noted. Connection diagrams are shown on the breaker nameplate. The DC breakers use the same internal and external accessories as the standard breakers for ac application.

Molded case circuit breakers for transportation application requiring 750 Vdc are available 15 through 2500 amperes with 20 kA interrupting capacity at 750 Vdc. Breakers require 4 poles in series for 750 Vdc application. However, 750 V is not a UL rating. Dimensions are the same as the standard thermal-magnetic equivalent.

Interrupting Capacity Ratings

Table 28.1-115. UL 489 Interrupting Capacity Ratings

Circuit Breaker Type	Frame	Interrupting Capacity (Symmetrical kA)			
		Volts dc ①			
		125 ②	250 ③	600 ④	750 ⑤
HFDDC	150	42	42	35	42
HJDDC	250	42	42	35	42
HKDDC	400	42	42	35	42
HLDDC	600	42	42	35	20
HMDLDC	800	42	42	35	—
NBDC	1200	42	50	50	20
PBDC	2500	42	75	75	30 (3-Pole)

① dc ratings apply to substantially non-inductive circuits. 8 millisecond time constant.
② 1-pole in series.
③ 2-poles in series.
④ 3-poles in series.
⑤ 4 poles in series. Not a UL listed voltage rating.

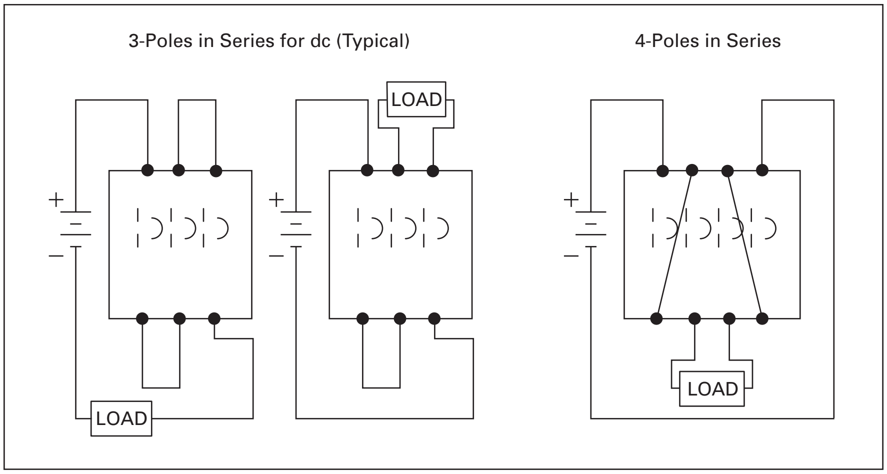


Figure 28.1-7. Series Connection Diagrams for 600 Volts dc Application
Note: Use rated cable per NEC. Connect to terminals as per breaker nameplate.

Application of Cutler-Hammer Molded Case Circuit Breakers to 400 – 415 Hz Systems

Eaton's Cutler-Hammer molded case circuit breakers, including breakers with electronic trip units, can be applied for overcurrent protection on 400 – 415 Hz systems. Commonly used to power computer installations, 400 – 415 Hz systems are also employed in conjunction with certain aircraft, military and other specialty equipment.

This publication contains guidelines to applying Cutler-Hammer molded case circuit breakers on 400 – 415 Hz systems.

Circuit Breaker Derating Required

Table 28.1-116, lists the maximum continuous current carrying capacity at 400 – 415 Hz of Cutler-Hammer molded case circuit breakers. Due to the increased resistance of the copper sections resulting from the skin effect produced by eddy currents at 400 – 415 Hz, circuit breakers in many cases require derating.

The thermal derating on these devices is based upon 100%, 3-phase application in open air in a maximum of 40°C (104°F) with 4 feet (1.2 m) of the specified cable 75°C (167°F) of bus at the line and load side. Additional derating of not less than 20% will be required if the circuit breaker is to be utilized in an enclosure. Further derating may be required if the enclosure contains other heat generating devices or if the ambient temperatures exceed 40°C.

Table 28.1-116. Continuous Current of 400 Hz Breakers

Breaker Frame Series	Maximum Continuous Amperes at 60 Hz	400 – 415 Hz Application ①		
		Maximum Continuous Amperes	Cable/Bus Bar (Per Phase)	Terminals (Fixed Front) Catalog or Style Number
EHD, FDB, FD, HFD	15 20 25	15 20 25	1 #12 Cu 1 #12 Cu 1 #12 Cu	**624B100G02** **624B100G02** **624B100G02**
	30 35 40	30 35 40	1 #10 Cu 1 #10 Cu 1 #8 Cu	**624B100G02** **624B100G02** **624B100G02**
	50 70 90	45 65 85	1 #6 Cu 1 #4 Cu 1 #2 Cu	**624B100G02** **624B100G02** **624B100G02**
	100 125 ② 150 ②	95 115 135	1 #1 Cu 1 – 1/0 Cu 1 – 1/0 Cu	**624B100G17** **624B100G17** **624B100G17**
JDB, JD, HJD	70 90 100	60 80 90	1 #4 Cu 1 #2 Cu 1 #1 Cu	**T250KB** **T250KB** **T250KB**
	125 150 175	100 125 150	1 – 1/0 Cu 1 – 1/0 Cu 1 – 2/0 Cu	**T250KB** **T250KB** **T250KB**
	200 225 250	160 200 200	1 – 3/0 Cu 1 – 4/0 Cu 1 – 250 kcmil Cu	**T250KB** **T250KB** **T250KB**
KDB, KD, HKD	125 150 175	100 125 150	1 – 1/0 Cu 1 – 1/0 Cu 1 – 2/0 Cu	**T300K** **T300K** **T300K**
	200 225 250	160 180 200	1 – 3/0 Cu 1 – 4/0 Cu 1 – 250 kcmil Cu	**T300K** **T300K** **T300K**
	300 350 400	225 275 300	1 – 350 kcmil Cu 1 – 500 kcmil Cu 2 – 3/0 Cu	**T300K** **T350K** **T400K**
LDB, LD, HLD	250 300 350	210 240 275	1 – 250 kcmil Cu 1 – 350 kcmil Cu 1 – 500 kcmil Cu	**T600LA** **T600LA** **T600LA**
	400 500 600	310 370 425	2 – 250 kcmil Cu 2 – 350 kcmil Cu 2 – 500 kcmil Cu	**T600LA** **T600LA** **T600LA**
LD with Digitrip RMS 310	300 600	300 500	2 – 250 kcmil Cu 2 – 350 kcmil Cu	**T401LA** **T401LA**
MDL with Digitrip RMS 310	400 500 600	340 405 470	2 – 3/0 Cu 2 – 300 kcmil Cu 2 – 350 kcmil Cu	**T600MA1** **T600MA1** **T600MA1**
	700 800	355 400	2 – 4/0 Cu 2 – 300 kcmil Cu	**T800MA1** **T800MA1**
ND with Digitrip RMS 310	1200	700 750 850	3 – 300 kcmil Cu 3 – 350 kcmil Cu 4 – 350 kcmil Cu	**T1000NBI** **T1000NBI** **T1200NBI**
RD with Digitrip RMS 310	2000	1500	4-1/2 x 4 Cu	Rear Connected Cu T-Bar

① The calibration of these breakers and the tolerance percentages of the time-current curves are the same as at 60 Hz.
② FD and HFD only.

Cable and Bus Sizing

The cable and bus sizes to be utilized at 400 – 415 Hz are not based on standard National Electrical Code tables for 60 Hz application. Larger cross sections are necessary at 400 – 415 Hz to avoid exceeding component temperature limits. All bus bars specified are based upon mounting the bars in the vertical plane to allow maximum air flow. All bus bars are spaced at a minimum of 1/4-inch (6.35 mm) apart. Mounting of bus bars in the horizontal plane will necessitate additional drafting. Edgewise orientation of the bus may change the maximum ratings indicated. If additional information is required for other connections of cable or bus, contact the Eaton Technical Resource Center.

Interrupting Capacity

400 – 415 Hz interrupting capacities of the Cutler-Hammer molded case circuit breakers found in **Table 28.1-117**.

Application Recommendations

It is recommended that thermal indicating devices such as "tempi plates" be placed on the line and load terminals or T-connectors of the center pole. These are usually the hottest terminals with a balanced load. A maximum temperature of 90°C (50°C over a maximum ambient of 40°C) would verify the maximum rating for the particular application. Temperature profiles taken on these breakers can be correlated to ensure that the hottest points within the breaker are within the required temperature limits. A thermal cutoff switch can also be used to actuate a shunt trip to open the breaker if the thermal limits are exceeded. Consult the Eaton Technical Resource Center for further information on special applications.

400 – 415 Hz Breakers

When required, molded case circuit breakers may be factory calibrated for 400 – 415 Hz application. These breakers are specially labeled for 400 – 415 Hz usage and their nameplate current rating will include the necessary derating factor. The highest "Maximum Continuous Amperes" rating at 400 – 415 Hz found in Tables A and B is approximately equal to the highest specially calibrated 400 – 415 Hz nameplate amperes rating available for a given frame size. The EHD, FDB and FD frames have style numbers designated for breakers calibrated at 400 – 415 Hz. Contact the Eaton Technical Resource Center for ordering information on other Cutler-Hammer breakers to be applied in 400 – 415 Hz systems.

Table 28.1-117. Interrupting Capacities of 400 Hz Breakers

Breaker Frame Series	Estimated 400 – 415 Hz Interrupting Capacities ①② (rms Symmetrical Amperes)		
	240 V	480 V	600 V
Thermal Magnetic			
EHD	3,600	2,800	—
FDB	3,600	2,800	2,800
FD, HFD	13,000	5,000	3,600
JDB, JD	8,000	7,000	7,000
HJD	14,000	10,000	7,000
KDB, KD, HKD	21,000	11,000	8,000
LDB, LD	14,000	10,000	7,000
HLD	21,000	11,000	8,000
MD	14,000	10,000	7,000
Electronic Trip Units			
KD, LD, MDL, ND	14,000	10,000	7,000
HLD, HMDL	21,000	11,000	8,000
HND	21,000	16,000	8,000
RD	40,000	33,000	33,000

① The above interrupting ratings are estimates based on the design parameters and operating characteristics of each breaker as well as on the limited amount of test data thus far available for circuit breakers applied to 400 – 415 Hz systems.
② Not UL listed.

100% Rated Circuit Breakers

The amount of protection designed into a distribution system is often based on economics. However, each project should be furnished with a reliable distribution system that delivers the most effective protection possible for each investment dollar.

Reliable and economic system design can be usually achieved with Eaton's Cutler-Hammer circuit breakers that are UL listed for application at 100% of their ratings — instead of standard breakers that in actual use are applied at 80% of their frame ratings in an enclosure.

The concept between a system design using standard breakers and that using 100% rated breakers is uncomplicated — but there are no shortcut methods for determining which design (and devices) is the best choice for a given system. Good engineering practice requires a careful system analysis beginning with the lowest feeder and concluding with the main device.

Also included in the system analysis must be all present and future factors that could affect the size and/or quantity of the breakers and associated hardware, such as switchboard bus, busway, cable and conduit. Other factors to consider are loads (continuous and noncontinuous) and system expansions and transformers with provisions for forced air cooling.

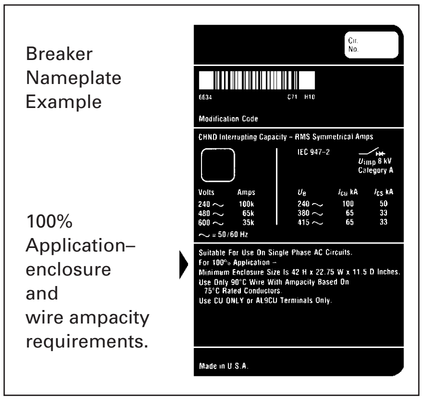


Figure 28.1-8. Breaker Nameplate

A 100% rated breaker receives its UL listing based on tests conducted in a minimum size enclosure with minimum ventilation (if required) and minimum cable sizes, as stated on this nameplate example. All Cutler-Hammer 100% rated breakers have standard electronic trip units.

The NEC

The rules and intent of the National Electrical Code governing the use of standard or 100% rated breakers must be understood before recommending or applying such devices.

Section 210.20(A) Continuous and Noncontinuous Loads of the National Electrical Code addresses differences between applications of standard rated breakers and 100% rated breakers. (Significant sections are in bold face type.)

> "Where a feeder supplies continuous loads or any combination of continuous and noncontinuous loads, the rating of the overcurrent device shall not be less than **the noncontinuous load plus 125% of the continuous load**."
>
> The minimum circuit conductor size without the application of any ampacity adjustment or correction factors shall have an allowable ampacity equal to or greater than the noncontinuous load plus 125% of the continuous load.
>
> "Exception: Where the assembly including the overcurrent devices protecting the feeder(s) are listed for operation at 100% of their rating, neither the ampere rating of the overcurrent device nor the ampacity of the feeder conductors shall be less than the **sum of the continuous load plus the noncontinuous load**."

Figure 28.1-9. NEC Reference

Section 210.20(A) covers standard breakers, and the exception 100% rated breakers. NEC Section 210.20(A) and the Section 210.20(A) exception can be expressed by these formulas:

Standard 80% Rated Design
Noncontinuous Load +
125% of the Continuous Load
= Total Minimum Load

Special 100% Rated Design
Noncontinuous Load +
Continuous Load
= Total Minimum Load

The necessity for these NEC requirements results from circuit breaker testing procedures.

A molded case circuit breaker is tested in open air to verify its nameplate ampere rating. The nameplate specifies a value of current the circuit breaker is rated to carry continuously without tripping within specific operating temperature guidelines.

In most instances, a breaker is applied in an enclosure and performance could be adversely affected by slow heat dissipation and temperature rise. These factors must be considered regarding the ability of the breaker to comply with its nameplate ampere rating.

Testing Conditions and Operating Conditions

There are distinct differences between these conditions that are addressed in the NEC Section 210.20(A) by introducing an overcurrent device and associated hardware sizing factor. The sizing factor ensures reliable equipment performance under realistic conditions. Section 210.20(A) is the key to making the best system design choice.

For feeders, Section 215.2(A) addresses the rating of all overcurrent devices that have been tested in open air but are applied in an enclosure. The thermal response of an overcurrent device applied in an enclosure will usually be faster than in open air, thus dictating the 125% requirement.

The exception allows for properly tested and listed overcurrent devices to be applied at 100% of their nameplate rating.

There is a Difference Between 100% Rated Breakers and 100% Rated Assemblies

Special attention should be given to the word "assembly" in the NEC Exception. Normally, an assembly is listed for 100% operation only after being successfully tested as an assembly per UL requirements.

For an assembly to receive a 100% rated UL listing, it must be tested separately by UL project engineers. Panelboards are tested to UL 67, switchboards tested to UL 891.

Installing 100% rated breakers in an assembly does not automatically make it acceptable for a 100% rating.

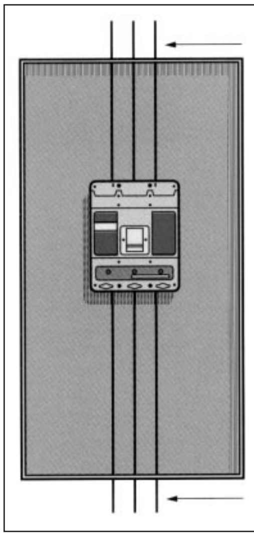


Figure 28.1-10. Conductor Requirements

Table 28.1-118. The Application — These Examples Illustrate the Cost Savings when the 100% Rated Approach is Utilized ①

A visual comparison of breaker, bus and cable sizes in the Three-Phase Distribution System examples (line diagrams) reveals how a 100% rated system design can provide cost savings.					
Load	**Feeder #1**	**Feeder #2**	**Feeder #3**	**Main**	**Description**
Continuous	400 A	800 A	0	1200 A	Three-Phase Distribution System Line Diagrams
Noncontinuous	200 A	0	1000 A	1200 A	

① Selection of either a 100% rated design or standard design must result from a system analysis beginning with the lowest feeder and concluding with the system's main device. For these system examples, assume that all assembly testing has been successfully completed and either the 100% rated design or standard design can be selected. Each system is hypothetical and either approach will meet safety requirements. Loads were arbitrarily selected. The load table includes the calculations for minimum total loads in conformance with NEC Section 210.20(A).

Table 28.1-119. Available 100% Rated Circuit Breakers

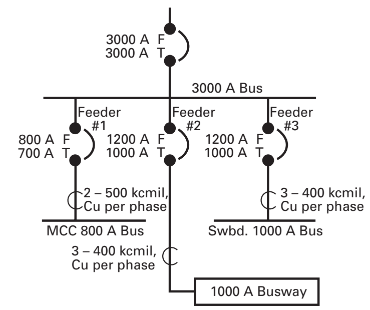
Frames	Rating at 480 V	Trip Units
K-Frame 125/250/400 A Minimum Enclosure Size 24 x 15 x 6-inches (609.6 x 381.0 x 152.4 mm)	CKD 35 kA CHKD 65 kA	Digitrip 310
L-Frame 125/250/400/600 A Minimum Enclosure Size with Ventilation 24 x 15 x 6-inches (609.6 x 381.0 x 152.4 mm)	CLD 35 kA CHLD 65 kA CLDC 100 kA	Digitrip OPTIM
L-Frame 600 A Minimum Enclosure Size with Ventilation 24 x 15 x 6-inches (609.6 x 381.0 x 152.4 mm)	CLD 35 kA CHLD 65 kA CLDC 100 kA	Digitrip 310
M-Frame 800 A Minimum Enclosure Size with Ventilation 42 x 18 x 7.5-inches (1066.8 x 457.2 x 190.5 mm)	CMDL 50 kA CHMDL 65 kA	Digitrip 310
N-Frame 800/1200 A Minimum Enclosure Size with Ventilation 42 x 22.75 x 11.5-inches (1066.8 x 577.9 x 292.1 mm)	CND 50 kA CHND 65 kA CNDC 100 kA	Digitrip OPTIM
N-Frame 800/1200 A Minimum Enclosure Size with Ventilation 42 x 22.75 x 11.5-inches (1066.8 x 577.9 x 292.1 mm)	CND 50 kA CHND 65 kA CNDC 100 kA	Digitrip 310
R-Frame 1600/2000 A Minimum Enclosure Size with Ventilation 21.5 x 18 x 13-inches (546.1 x 457.2 x 330.2 mm) ②	CRD 65 kA CRDC 100 kA	Digitrip OPTIM
R-Frame 1600/2000 A Minimum Enclosure Size with Ventilation 21.5 x 18 x 13-inches (546.1 x 457.2 x 330.2 mm) ②	CRD 65 kA CRDC 100 kA	Digitrip 510/610/810/910
R-Frame 1600/2000 A Minimum Enclosure Size with Ventilation 21.5 x 18 x 13-inches (546.1 x 457.2 x 330.2 mm) ②	CRD 65 kA CRDC 100 kA	Digitrip 310
JG-Frame Minimum Enclosure Size 24 x 15 x 6-inches (609.6 x 381.0 x 152.4 mm)	JGE-C 25 kA JGS-C 35 kA JGH-C 65 kA JGC-C 100 kA	Digitrip 310+
LG-Frame Minimum Enclosure Size with Ventilation 24 x 15 x 6-inches (609.6 x 381.0 x 152.4 mm)	LGE-C 35 kA LGS-C 50 kA LGH-C 65 kA LGC-C 100 kA	Digitrip 310+

② Use with 9-inch (228.6 mm) Tee connector.

Table 28.1-120. Standard 80% Rated Design

Noncontinuous Load + 125% of the Continuous Load = Total Minimum Load				
Calculation per NEC of Minimum Total Load ①	200 + (1.25) (400) =700 A	0 + (1.25) (800) =1000 A	1000 + 0 = 1000 A	2700 A ①
Breaker Frame (F) Trip (T) Rating	(F) (T) 800 A ②/700 A	(F) (T) 1200 A ②/1000 A	(F) (T) 1200A ②/1000 A	(F) (T) 3000 A ②/3000 A
Bus/Cable Rating	**800 A** ②	1000 A	1000 A	3000 A ②

Line Diagram

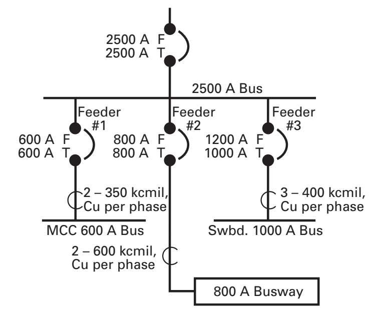


① (Noncontinuous Load) + (125%) (Continuous Load) per NEC Section 210.20(A).
② Nearest standard size, not less than calculated value.

Table 28.1-121. Standard 100% Rated Design

Noncontinuous Load + Continuous Load = Total Minimum Load				
Calculation per NEC of Minimum Total Load ③	200 + 400 = 600 A	0 + 800 = 800 A	1000 + 0 = 1000 A	2400 A ④
Breaker Frame (F) Trip (T) Rating	(F) (T) 600 A/600 A	(F) (T) 800 A/800 A	(F) (T) 1200 A ⑤/1000 A	(F) (T) 2500 A ⑤/2500 A
Bus/Cable Rating	600 A	800 A	1000 A	2500 A ⑤

Line Diagram



③ (Noncontinuous Load) + (Continuous Load) per NEC Section 210.20(A) Exception.
④ Sum of all NEC calculated minimum feeder loads.
⑤ Nearest standard size, not less than calculated value.

Table 28.1-122. The Result — Savings in Both Switchboard and Cable Costs

Design	Minimum Total Load (Amperes)				Rated Breaker
Standard	700	1000	1000	2700	100% Rated Breaker Systems Save Money: Significant economic advantages — in lower rated and sized breakers, less cable, and significant reductions in equipment floor and wall space — can be realized when the results of a systems analysis favor the 100% rated design approach.
100% Rated	600	800	1000	2400	
Results	The standard design requires higher rated, more expensive breaker and bus. Although the minimum total load is 700 amperes, most breakers and hardware are available only in standard sizes requiring even more expensive "nearest standard size" breakers and hardware.	Dramatic economic advantages are achieved by using the 100% rated design. Substantial savings result from using an 800 ampere busway and significant savings are also provided by the smaller breaker frame and cable size.	Calculations indicate either approach results in the same size breaker and hardware. A 100% rated breaker would be more expensive although the final decision could rest on whether or not future load growth is anticipated.	The 100% approach provides significant economic advantages. It not only permits use of the smaller size 2500 ampere breaker (nearest standard size) and main bus. Eaton offers a 2500 ampere frame breaker which further enhances the economic value of the 100% rated design.	

Series Rated Systems

Under most circumstances, selection of a series rated system will reduce initial cost and size, since downstream breakers are not fully rated for the prospective short circuit fault current at their point of application. The interrupting rating of the upstream breaker must always be equal to or greater than the available fault current at its line terminals. In addition, downstream breakers must have been tested in combination with the upstream breaker and shown to be protected by the upstream breaker at the assigned series rated interrupting rating. The net result is that the system can be assigned a "series rated" or "integrated" rating higher than the rating of the downstream breaker when it is tested or applied alone. Design of the system and selection of breakers is based on short circuit interruption test specified and witnessed by UL.

Because of their blow-open design, most molded case circuit breakers are current limiting to some degree. In a series rated application and in the event of a major fault, both upstream and downstream breakers open, protecting the lower-rated downstream devices by limiting the let-through current.

To develop a series rated protective system, it is suggested that the design engineer, after completing preliminary steps:

- Define available fault current at the line side terminals of the upstream breaker.
- Select an upstream breaker with an interrupting rating equal to or greater than the available fault current.
- Verify the series tested interrupting ratings of the selected combination of breakers by referring to the tables in this section.
- Confirm, during installation, that the correct breakers have been selected by checking the nameplates appearing on the end-use equipment.

Evaluating the Protection Systems

Designed properly, all three systems protect electrical equipment with equal effectiveness. But initial cost and continuity of service can vary widely depending on the inherent characteristics of the system, and on the design philosophy adopted.

Fully Rated System

A fully rated system is typically less costly than a selectively coordinated system and more costly than a series rated system. All breakers are rated for full fault current at their point of application in accordance with the National Electrical Code. The continuity of service provided by the system is less than with a selectively coordinated system, and can be more than a series rated system.

Selectively Coordinated System

A selectively coordinated system is the most costly of the three. All breakers are fully rated and upstream breakers must have adequate short-time delay adjusting capabilities. Continuity of service is the highest possible.

Series Rated System

A series rated system is the least costly. The upstream breaker is always fully rated, but the interrupting ratings of downstream breakers are normally lower. Service continuity can be acceptable after initial start-up, since the lower-level arcing faults most likely occur after that time can be cleared by the downstream breaker alone. However, under high fault conditions, both the upstream and downstream breakers would open, eliminating service to the affected portion of the system.

National Electrical Code Requirements

Requirements of the National Electrical Code for short circuit ratings may now be met by equipment that is marked with ratings adequate for the available fault current at their point of application in the electrical system. Refer to the current NEC for specific requirements.

General Discussion

Available Short Circuit Current. Service equipment shall be suitable for the short circuit current available at its supply terminal.

Approval. The conductors and equipment required or permitted by the Code shall be acceptable only if approved. See Examination of Equipment for Safety and Examination, Identification, Installation and Use of Equipment. See definitions of "Approved," "Identified," "Labeled" and "Listed."

Examination, Identification, Installation and Use of Equipment

1. Examination: In judging equipment, considerations such as the following should be evaluated.
   a. Suitability for installation and use in conformity with the provisions of this Code. Suitability of equipment use may be identified by a description marked on or provided with a product to identify the suitability of the product for a specific purpose, environment or application. Suitability of equipment may be evidenced by listing or labeling.
   b. Mechanical strength and durability, including, for parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.
   c. Wire-ending and connection space.
   d. Electrical insulation.
   e. Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service.
   f. Arcing effects.
   g. Classification by type, size, voltage, current capacity and specific use.
   h. Other factors which contribute to the practical safeguarding of persons using or likely to come in contact with the equipment.
2. Installation and Use: Listed or labeled equipment shall be used or installed in accordance with any instructions included in the listing or labeling.

Interrupting Rating

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

Circuit Impedance and Other Characteristics

The overcurrent protective devices, the total impedance, the component short circuit withstanding ratings, and other characteristics of the circuit to be protected shall be so selected and coordinated as to permit the circuit protective devices used to clear a fault without the occurrence of extensive damage to the electrical components of the circuit. This fault shall be assumed to be either two or more of the circuit conductors, or between any circuit conductor and the grounding conductor or enclosing metal raceway.

Motor Contribution

The fault current contribution of motors connected between series rated breakers must be considered. Article 240.86(C) in the 2005 edition of the National Electrical Code states that for series ratings the sum of the motor, full-load currents cannot exceed 1% of the interrupting rating of the lower-rated circuit breaker. The actual fault current contribution from induction motors is about 4 times their full-load current (impedance value of 25%). For example, if the downstream branch circuit breakers used in a series rated combination have an interrupting rating of 14,000 amperes rms symmetrical for a 480 volt system, the maximum full-load current of motors connected to that panel from the branch circuit breakers is 140 amperes (1%). For typical induction motors this is equivalent to a total horsepower at 480 volts of approximately 115 horsepower.

Design/Test Considerations for Series Coordinated Circuit Breakers

Test Procedures for all Cutler-Hammer molded case circuit breakers intended for application in series connected systems are in full compliance with all applicable paragraphs of the latest edition of UL 489.

Note: For further information, see IEEE Standards 141, 242 and 446.

The entire system is tested, since such tests are the only way to correctly verify the performance of overcurrent devices under short circuit conditions.

Calibration, interruption, trip-out and dielectric withstand tests are performed. Breakers in their as-received condition are used for the interrupting and intermediate interrupting capability tests. If agreeable to concerned parties, previously tested samples may be used. The interrupting rating of the line-side circuit breaker is equal to or greater than the maximum available fault current on the distribution system at its point of intended application.

Tests comply also with the intent of the proposed revisions to applicable IEC documents.

Tests are completed in a well-defined sequence:

- Interrupting tests.
- Intermediate interrupting tests.
- Trip-out tests.
- Dielectric voltage-withstand tests.

Eaton's Cutler-Hammer Series C Circuit Breakers intended for application in series rated systems are subjected, in the following sequence, to interrupting ability, intermediate interrupting ability, trip-out, and dielectric voltage-withstand tests.

During testing of the series rated circuit breakers, each breaker is mounted in the smallest enclosure in which it is to be used; openings in the enclosure do not exceed 10% of its total external area, and there are no openings directly opposite a vent in a circuit breaker case. The two enclosures are connected by a 12-inch (304.8 mm) conduit of any diameter. Each lead from test terminals to the line-side breaker is less than 4 feet (1.2 m) per breaker(s), and each load shorting the load-side breaker(s) is sized based on the rating of the load-side breaker. The combined length of the lead from the line-side overcurrent protective device of the load-side breaker and from the load-side breaker to the shorting point, is less than 4 feet (1.2 m) per pole.

Exception: the breakers may be mounted in the end-use equipment that will contain them and is marked for use with the series combination. The load-side breaker is positioned as close as possible to the line-side breaker(s). Line and load leads are less than 4 feet (1.2 m).

A fuse is connected between the enclosure and line terminal of the pole least likely to arc to the enclosure, or the neutral, if the breaker is rated 120/240 or 480Y/277 Vac. The connection to the load-side of the limiting impedance is #10 AWG copper wire less than 6 feet (1.8 m) long. The fuse is a 30 A non-renewable type acceptable for branch circuit protection; its voltage rating is not less than the rating of the device, and its interrupting rating is not less than the available current.

1. Interrupting tests:
   a. The test circuit is closed on the series combination with all breakers fully closed; and
   b. The load-side breaker is closed on the circuit while the line-side breaker is fully closed.

Note: Random closing is used in all 3-phase tests. When the circuit is closed on the combination, closing is controlled in single-phase tests so that closing occurs within ten electrical degrees of the zero-point of the supply voltage wave.

2. *Intermediate interrupting tests* at the specified available current and maximum voltage. Procedures are identical to those described in 1a and 1b (above) but at the maximum current level that causes the load-side breaker to open, but not the line-side breaker. If the line-side breaker is current-limiting, the series combination shall be evaluated in the region below its current- limiting threshold. (There is no need for these tests if the current is less than the interrupting rating on the load-side breaker.)
3. *Trip-out tests* of the load-side breaker at 250% of the marked ampere rating.
4. *Dielectric voltage-withstand tests* verify that the breaker can withstand, without breakdown, a 60 (48 – 62) Hz essentially sinusoidal potential for one minute.

Series Connected Ratings: Cutler-Hammer Circuit Breakers

A wide range of breakers and combinations in the Eaton's Cutler-Hammer line is available that has been tested in accordance with UL procedures for series connected ratings: individually enclosed breakers in series with main lug panelboards, main breakers integral with branch breakers in panelboards, in switchboards, and in meter centers. You can rely on the enclosed data for applications with other undefined distribution equipment where series application ratings can be an advantage.

Circuit Breaker/Circuit Breaker series rated combinations are listed by Underwriters Laboratories in their *Component Directory* (Yellow Book) under "Circuit Breakers — Series Connected."

The series combinations shown in the UL Yellow Book are UL recognized component ratings only. Consult the equipment manufacturer for applicable UL recognized assembly combinations.

Specific series ratings tested combinations in assemblies can be found in **Section 22** for Panelboards and in **Section 26** for Residential Products such as meter stacks and loadcenters. Both circuit-breaker-to-circuit-breaker and fuse-to-circuit-breaker upstream/downstream series rating tables are provided. The assemblies series ratings tables are also on the Eaton Web site (www.EatonElectrical.com). Search for document 1C96944H02 "Panelboard and Switchboards Series Ratings Information Manual."

Circuit Breaker Identification

Marking of all Eaton's Cutler-Hammer circuit breakers is clear for easy identification of type, rating and operating status. Nameplates are color-coded for immediate identification of rating, and a color-coded bar identifies the type and interrupting rating at common application voltages. Operating status is indicated clearly by the position of the handle and color-coded flags. On and off positions are identified by English words and international symbols.

Scientists and engineers at the Eaton Testing Laboratory ensure that Cutler-Hammer circuit breakers are the most reliable and develop new concepts and improvements in breaker design. Designs and reliability are verified, products are improved continuously and qualified to meet UL, NEMA and other standards. In addition, engineers from any breaker or panelboard manufacturer can work along-side their peers from Eaton to test their products in the lab.

The consolidated nameplate on all breakers provides complete identification and rating information in a format that is easy to read and understand.

The interrupting rating of the series combination is never permitted to be marked on the downstream breaker. However, the series rating may be marked on panelboards in which the combination has been tested and listed if:

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

Marking of Panelboards

Marking of panelboards conforms to the latest edition of UL 67. Markings are clear and understandable, and include the short circuit rating in rms amperes; maximum voltage rating for each short circuit rating; a statement indicating that additional or replacement devices shall be of the same type and of equal or greater interrupting capacity; and, when applicable, the identity of combinations of integral and branch circuit overcurrent devices that are required when applying the marked short circuit current rating.

Fuses

Fuses can be used instead of circuit breakers in fully rated, selectively coordinated and series connected protection systems. See the tables in the back of this brochure for fuse breakout data applied to series connected designs.

Don't apply fuses using the up-over-down method, which has been recommended by some fuse manufacturers for sizing a current-limiting fuse that protects a downstream molded case circuit breaker with a specified rms symmetrical interrupting rating. The method can lead to erroneous and unsafe conclusions, and should not be used.

Example: Assume a specific type of current-limiting fuse rated 2000 A. Then using the figure below:

1. Draw a vertical line from the prospective short circuit current of 200 kA to intersect the "typical peak let-through curve at "A."
2. Draw a horizontal line left from Point "A" to intersect the "prospective peak" curve at "B."
3. Drop a vertical line from "B" to intersect the horizontal axis and read the recommended rating, 65 kA rms, concluding that a circuit breaker with a 65 kA interrupting capacity will be protected by a specified 2000 A current-limiting fuse.

This conclusion is wrong when the downstream service has a blow-open contact assembly, as does a molded case circuit breaker or similar device. It may be valid when the current-limiting fuse is sized to protect a passive bus bar system.

The reason: The up-over-down method ignores dynamic impedance (the inherent current-limiting of the downstream molded case circuit breaker). Such impedance is developed directly by the forces of the let-through current created when the contacts are blown open.

For proper application of current-limiting fuses, always refer to recommendations by the manufacturer of the circuit breaker, which are based on actual test data.

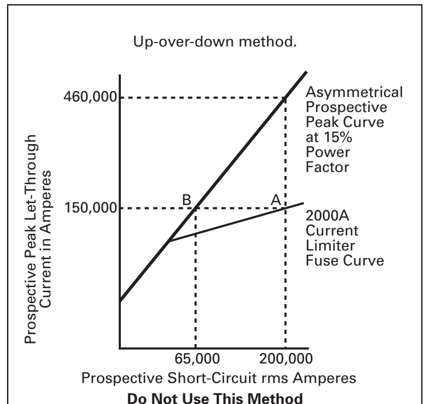


Figure 28.1-11. Up-Over-Down Misapplication

Application and Replacement of Breakers

Apply and replace breakers prudently, within the design and operating parameters of the power system. Use the following tables to select the size and type of circuit breaker needed to fit virtually any application in series rated and other protective systems. Breakers are highly-compatible across ratings, capacities and characteristic; prudent replacements are as important as initial selection.