BUILDING ELECTRICAL SYSTEMS
EQUIPMENT AND DEVICES
SELECTION AND APPLICATION

CONTENTS PAGE

1. GENERAL

1.01 This section covers guidelines for the selection of equipment and devices for use in the electrical system. Equipment installed in telephone company buildings must, of course, comply with all applicable codes and standards.

1.02 Whenever this section is reissued, the reason(s) for reissue will be given in this paragraph.

2. CONDUCTORS

2.01 Conductors are the means by which current is carried through the electrical system. The function of conductors is to carry energy between the source and the utilization equipment. In carrying this energy, heat losses are generated and must be dissipated. The ability of conductors to dissipate these losses, which affects their current ratings (ampacity), depends on how the conductors are installed.

2.02 Conductors may be installed in raceways, underground conduit, cable trays, or may be directly buried.

2.03 When selecting conducter type and size, consideration should be given to the following:

- Load current
- Load cycling
- Overload requirement and duration
- Fault level
- Environment
- Voltage drop
- Material (copper or aluminum).

A. Wire

2.04 The standard of the American wire and cable industry is the American Wire Gauge (AWG). All wire sizes up to No. 0000 (also written No. 4/0) are expressed in AWG—the smaller the AWG number, the larger the size. (The No. 10 is a larger wire than No. 12 and smaller than No. 8.)

2.05 The No. 4/0 size is the largest AWG designation; beyond that, MCM (thousand circular mils) is used. In this designation, wire diameter increases with number, ie, 500 MCM is a larger wire (double the area) than 250 MCM. A circular mil is an artificial area measurement representing the square of the cable diameter when the diameter is expressed in mils (thousandths of an inch). Thus, a solid 1/2-inch diameter conductor is 500 mils in diameter (250,000 circular mils or 250 MCM in area).

2.06 Current-carrying capacity (or ampacity) is determined by the maximum operating temperature that insulation in insulated conductors can stand and by the maximum safe metal temperatures bare conductors can stand. For a given amount of current being carried, the operating temperature will depend on the thermal characteristics of the environment and the amount of heat generated.

2.07 The type of insulation must be suited to the particular application. Article 310 of the National Electric Code (NEC) covers the detailed application of insulation types and wire ampacity.

2.08 Both aluminum and copper conductors should be specified for all circuits above 200 amperes and over 25 feet in length with the selection of conductor type left to the contractor's option.

2.09 Leaving the conductor material to the contractor's option is desirable because of the great variations in the market prices of copper and aluminum and the experience level of the contractor using them.

2.10 Only the newer aluminum alloy wires (compact stranded) such as those trademarked "EXCELLOY*," or "STABILOY†" should be permitted.

2.11 Copper should be specified for all circuits under 25 feet or under 200 amperes. Aluminum might be appropriate for low-ampacity circuits if they are relatively long (over 300 feet).

2.12 Although color coding of conductors is no longer required by the NEC, the following is recommended:

(a) For 208Y/120 volts, use:

PHASE	COLOR
A	Black
B	Red
C	Blue
Neutral	White

(b) For 480Y/277 volts, use:

PHASE	COLOR
A	Yellow
B	Brown
C	Orange
Neutral	Gray

*Trademark of Aluminum Company of America.

†Registered trademark of Alcan Cable Division.

B. Busway

2.13 Two types of busway have had wide application in Bell System buildings for larger capacity circuits (above 800 amperes).

(a) Feeder busway has been used for service entrances and main feeders.

(b) Plug-in busway is often used for power risers in high-rise buildings.

2.14 Feeder busway has several serious disadvantages and should normally not be used in Bell System buildings. The large number of connections (joints at least every 10 feet) make it vulnerable to failure and are costly to maintain. Bell System experience has been that these joints are prone to failure. Feeder busway is also very costly when installed in an existing, congested environment. It must be designed for very long growth periods since it is not easily reinforced. Power tray cable or interlocked armored cable in a cable tray should be used instead of feeder busway for larger feeders.

2.15 While plug-in busway also has some of the above disadvantages, it can be a very convenient and economical facility for risers in high-rise buildings; there is no objection to its use for that purpose.

C. Flat Conductor Cable

2.16 Flat conductor cable is a complete wiring system for branch circuits that is designed for installation under carpet squares. This system includes flat conductor cable and associated shielding, connectors, terminations, adapters, boxes, and receptacles. Flat conductor cable consists of three or more flat copper conductors placed edge to edge, separated, and enclosed within an insulating assembly. This cable is covered by Article 328 of the NEC.

2.17 For receptacle outlets at individual desks, it is recommended that serious consideration be given to a flat conductor cable system instead of raised floors, underfloor raceways, "poke-through," power poles, etc. It is particularly appropriate where flat cable is also used under carpet for telephone distribution.

2.18 This wiring system is not expected to supplant the older methods entirely. However, it does have great potential because of its initial economy and for its easy adaptability to rearrangements. It is particularly appropriate for use in alterations and modernization of existing building space but should also be considered for new construction.

3. RACEWAYS

3.01 A raceway is any channel for holding conductors; it is designed solely for that purpose. Raceways may be constructed of metal or insulating material. The term raceway includes, but is not limited to:

- Rigid metal conduit
- Intermediate metal conduit (IMC)
- Rigid nonmetallic conduit
- Flexible metallic tubing
- Electrical metallic tubing (EMT)
- Flexible metal conduit (Greenfield)
- Surface raceways
- Underfloor raceways
- Cellular metal floor raceways
- Cellular concrete floor raceways
- Wireways
- Busways.

3.02 The purpose of a raceway is to:

(a) Support the conductors.

(b) Protect the enclosed conductors from mechanical injury and corrosion.

(c) Protect the surroundings against fire hazards due to overheating or arcing of the enclosed conductors.

3.03 The electrical designer should carefully evaluate the various circuit alternatives such as wire in conduit, armored cable or tray cable in cable tray, and plug-in busway. The choice of wiring method depends upon the specific conditions. Refer to Table A for recommended applications.

TABLE A

RECOMMENDED RACEWAYS

APPLICATION	RACEWAY	NOTES
Electric service — underground (primary and secondary)	Scheduled 40 polyvinyl chloride (PVC) using galvanized steel intermediate metal conduit (IMC) for elbow and vertical run at pole	Bury 30 inches below grade. Cover with plastic warning tape.
Buried in concrete or masonry	Galvanized steel IMC	Do not use aluminum.
Exposed indoors	Electrical metallic tubing (EMT) or cable tray	
In hollow partitions, hung ceilings, or under raised floors	EMT, flexible steel or type AC cable — (BX)	
Exposed outdoors	Schedule 40 PVC or aluminum	
Telephone entrance conduit	PVC—power and communication duct type "DB" per NEMA TC-6 Specification	
Site lighting	Schedule 40 PVC	
Attached to motor and/or vibrating equipment	Flexible metal conduit (Greenfield)	

3.04 Where more than two conduits are required (above 800 amperes), cable tray is recommended and should be specified in accordance with Article 318 of the NEC. Feeder busway is ***not*** recommended.

4. TERMINATIONS

4.01 A critical step in the installation of any electrical system is the proper termination of conductors to electrical components or other conductors. Properly installed terminations will ensure the reliability of the entire electrical system and will eliminate a major cause of electrical failures.

4.02 Aluminum cable shall be terminated with tin-plated aluminum compression lugs of the proper size with a suitable joint compound. Lugs and crimp dies shall be from the same manufacturer, Copper or bronze lugs, plated or unplated, shall not be used on aluminum cable.

4.03 Lugs or connectors ordinarily provided on approved devices (eg, circuit breakers, switches, etc) can be used to terminate copper conductors directly. Aluminum conductors should not be terminated directly on these devices; the conductor shall first be equipped with a crimp-type pin terminal.

4.04 The integrity of bolted connections is critically dependent upon the application of proper torque. Perhaps the best way to assure this is to specify torque-indicating nut or bolt assemblies, such as the TORK-NUT* assembly. This includes a breakaway nut, which shears off when the correct torque is applied. Where this is not applicable, torquing wrenches or screwdrivers must be used to ensure against loose or overtight connections.

*Trademark of Thomas and Betts Corp.

5. LOW-VOLTAGE SWITCHES

5.01 Low-voltage switches include safety switches, panelboard and switchboard devices, and large high-current (above 1200 amperes) power switches. A switch is an electrical device intended for on/off control of circuits and for isolation of equipment. These switches are rated as follows:

- Voltage
- Current
- Duty
- Fusibility
- Poles
- Throw
- Enclosure
- Mounting
- Type.

5.02 Where disconnect switches are required, use only heavy-duty safety switches; adjustable, magnetic trip-only molded-case circuit breakers; or fractional horsepower manual starters. For specific application, refer to Table B.

5.03 Large switches, from 1200 to 6000 amperes are of two types:

- Bolted pressure contact switch
- High-pressure contact switch.

These switches, when used as service entrance disconnects, shall be provided with electrical trip coils for remote operation by a manual trip station and/or ground fault relay.

5.04 All switches must be enclosed in an appropriate cabinet or switchboard. The National Electrical Manufacturers Association (NEMA) has standardized the nomenclature and application of such cabinets. (Refer to Table C.)

6. OVERCURRENT PROTECTION

6.01 Selecting protection for low-voltage systems (below 600 volts) involves some mandatory requirements that must be met but allow considerable room for choice. The rating of the overcurrent protective device must be sufficient and correct for the system being protected. These ratings include:

- Voltage
- Continuous current rating
- Fault-interrupting capacity
- Operating conditions
- Frequency.

The voltage of the protective device must meet or exceed the system voltage.

6.02 The continuous current rating of the overcurrent protective device must comply with the NEC, Articles 220-10 and 240, and protect conductors in accordance with their ampacities.

6.03 The fault current rating must comply with the NEC, Article 110-9, which states that equip-

TABLE B

APPLICATION OF MOTOR DISCONNECT SWITCHES

MOTOR HORSEPOWER (HP)*	TYPE
Fractional HP single-phase motors (1 or 2 poles)	Manual starters
Three phase up to 7-1/2 HP	Heavy-duty safety switch
Three phase over 7-1/2 HP	Adjustable magnetic trip-only, molded-case circuit breaker

*Or equivalent full load amperes per NEC Table 430-148 or 430-150.

TABLE C

NEMA ENCLOSURE DESIGNATIONS

TYPE	DESCRIPTION	APPLICATION
1A	General purpose dust resistant	Dry indoor locations
2	Dripproof	Indoor—subject to dripping
3R	Raintight, weatherproof	Exterior—vertical rain, sleet, and snow
4	Watertight	Driving rain and sleet
5	Dust-tight	Nonhazardous, dust-filled areas
6	Submersible	Self-explanatory
7-11	Hazardous	Hazardous and corrosive areas
12	Industrial	Indoor—dust, lint, oil, and moisture resistant; used in place of type 1 in industrial interiors.

ment intended to break current at fault levels shall have an interrupting rating sufficient for the system voltage and for the current available at the equipment terminals. Refer to Section 760-400-800*, Short Circuit Analysis, for details in performing fault-level calculations.

6.04 Operating conditions that must be considered include ambient temperature, duration of the load, moisture, dirt, physical location, vibration, and shock.

6.05 Frequencies other than 60 Hz may require derating or special calibration of the overcurrent protective device.

6.06 A ***properly*** selected overcurrent protective device prevents circuit overloading due to human error. This device also prevents development of conditions hazardous to life and property as a result of accidental faults, short circuits, and overloads. A complete overcurrent protective device can be defined by the following properties:

(a) The automatic interruption of overload or short-circuit current in excess of the device's current rating.

(b) The capability of the circuit to be manually opened safely under a load or short circuit up to its current rating

(c) The capability of the circuit to be manually closed into a load or short circuit within its current rating

6.07 To protect insulation, wiring, switches, and other apparatus from overload and short-circuit currents, automatic means for opening the circuit must be provided. The two most common devices employed are the fuse and the circuit breaker.

A. Fuses

6.08 The Underwriters Laboratories (UL), in conjunction with NEMA, has established standards for classifying fuses by letter rather than by type. The classification letter may designate interrupting rating; physical dimensions; degree of current limitation (maximum peak let-through current); and maximum clearing energy (I^2t) under specific test conditions. This letter may also indicate a combination of these characteristics. Table D contains a listing of fuse classifications. Tables E, F, and G contain the maximum peak let-through current (I_P) and clearing I^2t for class RK1, RK5, and L fuses, respectively.

6.09 Class J, K1, L, and T fuses are quite similar in current-limiting characteristics and afford

*Check Divisional Index 760 for availability.

TABLE D

FUSE CLASSIFICATION

VOLTAGE	FUSE TYPE CLASS	AMPERE RATING	INTERRUPTING RATING	NOTES
250	H	1-600	10,000	Not recommended
	K1 & K5	1-600	50,000 100,000 200,000	Physically interchangeable with class H
	RK1 & RK5	1-600	200,000	One-end rejection
300	T	1-600	200,000	Very small physical size and most current-limiting
600	H J	1-600 1-600	10,000 200,000	Not recommended
	K1 & K5	1-600	50,000 100,000 200,000	Physically interchangeable with class H
	RK1 & RK5	1-600	200,000	One-end rejection
	T	1-600	200,000	Very small physical size and most current-limiting
	CC	1-30	200,000	Small physical size
	L*	601-6,000	200,000	Bolt-in for service entrance

* Fuses with similar characteristics and mounting arrangements are also available in 300- and 400-ampere sizes although they are ***not*** UL listed sizes.

TABLE E

CLASS RK1 FUSES (NOTE)

CARTRIDGE SIZE (AMPERES)	BETWEEN THRESHOLD AND 50 KA		100 KA		200 KA	
	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
0-30	10	6	10	10	11	12
31-60	40	10	40	12	50	16
61-100	100	14	100	16	100	20
101-200	400	18	400	22	400	30
201-400	1200	33	1200	35	1600	50
401-600	3000	43	3000	50	4000	70

Note: UL Standard 198.4.

TABLE F

CLASS RK5 FUSES (NOTE)

CARTRIDGE SIZE (AMPERES)	BETWEEN THRESHOLD AND 50 KA		100 KA		200 KA	
	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$	$I^2t \times 10^3$	$I_p \times 10^3$
0-30	50	11	50	11	50	14
30-60	200	20	200	21	200	26
61-100	500	22	500	25	500	32
101-200	1,600	32	1,600	40	2,000	50
201-400	5,000	50	5,000	60	6,000	75
401-600	10,000	65	10,000	80	12,000	100

Note: UL Standard 198.4.

TABLE G

CLASS L FUSES (NOTE)

CARTRIDGE SIZE (AMPERES)	TEST FUSE RATING	50 KA		100 KA		200 KA	
		$I^2t \times 10^6$	$I_p \times 10^3$	$I^2t \times 10^6$	$I_p \times 10^3$	$I^2t \times 10^6$	$I_p \times 10^3$
601-800	800	10	80	10	80	10	80
801-1200	1200	12	80	12	80	15	120
1201-1600	1600	22	100	22	100	30	150
1601-2000	2000	35	110	35	120	40	165
2001-2500	2500	—	—	75	165	75	175
2501-3000	3000	—	—	100	175	100	200
3001-4000	4000	—	—	150	220	150	250
4001-5000	5000	—	—	350	—	350	300
5001-6000	6000	—	—	350	—	500	350

Note: UL Standard 198.2.

maximum current limitation. These fuses are specified by circuit breaker manufacturers for protection of circuit breakers against high-fault currents.

6.10 Class J and T fuses are very fast-acting fuses (no time delay) and must be used carefully if nuisance operation (fuse blowing) is to be avoided.

6.11 Class K5 fuses, while not as current limiting, are more economical than the above fuses and may be quite satisfactory for many applications where available short-circuit current is not too high.

B. Circuit Breakers

6.12 A circuit breaker is an electromechanical device that performs the same protective function as a fuse and, in addition, acts as a switch. Therefore, it can be used in place of a switch and fuse combination to both protect and disconnect a circuit. Circuit breakers can be divided into three main categories:

(a) ***Molded-case thermal-magnetic*** tripping breakers use bimetals and electromagnets to provide overload protection. This type of protective action is referred to as thermal magnetic.

Thermal trip is achieved through the use of a bimetal heated by the load current. Magnetic-trip action is achieved through the use of an electromagnet in series with the load current. The tripping action is known as inverse time characteristics, ie, a small overload takes a long time to operate the breaker. As the overload increases the tripping time decreases. At large overloads and short circuits, the breaker operates instantaneously. The distinguishing characteristics of these breakers are:

- Low cost
- Minimum maintenance required
- No long-time delay adjustment
- Adjustable instantaneous trip
- No short-time rating.

(b) ***Solid-state*** trip units are replacing thermal-magnetic trip units in some molded-case breakers. These are more accurate, permit some time delay adjustment, and provide for ground fault sensing.

(c) ***Power*** circuit breakers, sometimes called air circuit breakers (now available with insulated cases and solid-state trip units, similar to the newer molded-case breakers), are the most rugged, most versatile, and most expensive type. Their distinguishing characteristics are:

- High cost
- High interrupting capacity (HIC)
- Adjustable long-time, short-time, and instantaneous trip settings
- Integral ground fault protection option.

6.13 Although fuses and circuit breakers are overcurrent protective devices, their characteristics are quite different. Circuit breakers are complex mechanical devices that need periodic exercise, inspection, and maintenance. An inherent advantage of a circuit breaker is that it can be reset after tripping merely by operating its handle; it is not self-destructive on operation, as is the fuse. On the other hand, fuses are fail-safe devices that require little maintenance, and their current-limiting capability can be a great advantage.

6.14 The debate on fuses versus circuit breakers is ongoing. There are some applications only circuit breakers can satisfy, other applications only fuses can satisfy, and many applications in which either is satisfactory. The choice is dependent on other factors such as cost, size, and personal experience and prejudices. Sometimes a fuse/circuit breaker combination will provide required performance that neither can provide alone.

C. Application

6.15 Where circuit breakers are to be used, thermal-magnetic molded-case breakers should usually be specified throughout.

6.16 A principal feature of power circuit breakers is that they have short-time short-circuit ratings and thus can be used for selective or coordinated short-circuit protection. That is, the downstream breaker closest to the fault will always operate first, thereby eliminating the possibility of unnecessary service interruption on unaffected circuits.

6.17 Because of the lack of a demonstrated need for full coordination in most telephone company buildings, the higher cost power circuit breakers should be used only where their capability is really needed.

6.18 Specify interrupting capacity of all breakers. Do not require more interrupting capacity (IC) than necessary; the higher the interrupting capacity, the higher the price. Refer to Section 760-400-800, Short Circuit Analysis, for details on performing this study. See Table H for typical interrupting capacities of circuit breakers.

6.19 When current-limiting fuses are applied to the service entrance main, take full advantage of the lower interrupting capacity that might be permitted for the circuit breakers.

6.20 In large distribution systems, use current-limiting fuses to protect the circuit breakers in various sections of the switchboard, again allowing the use of circuit breakers with lower interrupting capacities. For protection of circuit breakers by fuses, refer to Fig. 1 and Fig. 2.

6.21 When using fuses, always specify fuses that are sized close to the initial loads expected,

TABLE H

INTERRUPTING RATINGS (NOTE)

FRAME		MOLDED CASE BREAKERS 240 VOLTS	MOLDED CASE BREAKERS 480 VOLTS
100A	Standard	18,000	14,000
	Heavy Duty	65,000	25,000
225A	Standard	25,000	22,000
	Heavy Duty	65,000	25,000
400A	Standard	42,000	30,000
	Heavy Duty	65,000	35,000
	HIC*	200,000	200,000
800A	Standard	42,000	30,000
	Heavy Duty	65,000	50,000
	HIC*	200,000	200,000
1200A	Standard	42,000	30,000
	Heavy Duty	65,000	50,000
	HIC*	200,000	200,000

Note: The interrupting ratings in this table are RMS amperes symmetrical. Values are typical although there is some variation among manufacturers.

* Includes integral current-limiting fuses.

with allowance for reasonable growth. Do not size for the ultimate loads, but plan to replace with larger fuses as growth occurs. By oversizing fuses initially, a great deal of protection and safety is lost.

6.22 Similarly, always set adjustable trips on circuit breakers to the lowest setting possible without causing nuisance tripping.

7. REFERENCES

7.01 The material in this section was based on the following references:

Industrial Power Systems Handbook—Beeman—McGraw-Hill, 1965

Recommended Practices for Electrical Power Distribution for Industrial Plants, IEEE STD 141-1976 "Red Book"

Recommended Practices for Electrical Power Distribution in Commerical Buildings, IEEE STD 241-1974 "Gray Book"

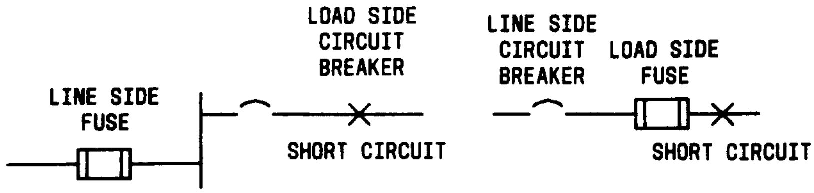
Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, IEEE STD 242-1975 "Buff Book"

Mechanical and Electrical Equipment for Buildings —McGuiness, Stein, Reynolds—Wiley Press, 6th Edition

Overcurrent Protection —Freund—McGraw-Hill 1980

National Fire Protection Association (NFPA) 70 National Electrical Code (NEC)

National Electrical Manufacturers Association (NEMA) Enclosures 250-1979

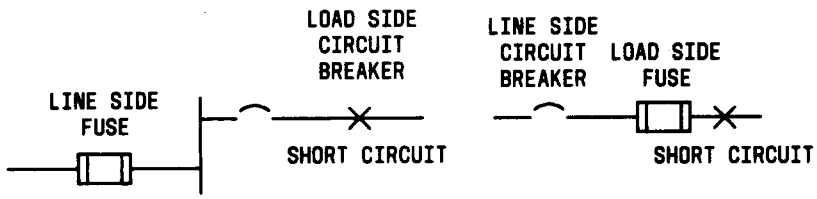


CIRCUIT BREAKER PROTECTION — STANDARD CIRCUIT BREAKERS (NOTE)

FRAME	AMPERE RATING	MINIMUM FUSE RATING		MAXIMUM FUSE RATING			
		CIRCUIT BREAKER INSTANTANEOUS SETTING		600 & 480 VAC		240 VAC	
		LOW	HIGH	LOAD SIDE	LINE SIDE	LOAD SIDE	LINE SIDE
50A (5000A IC)	15-20	—	50	—	—	—	200
	30-50	—	100	—	—	—	200
100A (7500-15000A IC)	15	—	70	200	300	400	400
	20-40	—	100	200	300	400	400
	50-100	—	200	200	300	400	400
225A (10000A IC)	125-225	—	400	—	—	400	400
225A (15000-25000A IC)	70-150	300	400	600	600	800	800
	175	300	400	600	1000	1000	1000
	200-225	300	600	600	1000	1000	1000
400A (25000-50000A IC)	70-125	300	400	800	1000	1000	1000
	150-175	300	400	800	1000	1000	1000
	200-225	300	600	800	1000	1000	1000
	250-300	400	600	800	1200	1200	1200
	350-400	600	800	800	1200	1200	1200
800A (25000-50000A IC)	125-175	300	400	800	1000	1000	1000
	200-225	300	600	800	1000	1000	1000
	250-275	400	600	800	1000	1000	1000
	300	400	600	800	1200	1200	1200
	350	600	800	800	1200	1200	1200
	400	600	800	1200	1200	1200	1200
	500-600	800	1200	1200	1200	1200	1200
	700-800	1000	1200	1200	1200	1200	1200

Note: The values listed above are typical for class J, L, T, or K1 current-limiting fuses on systems up to 100,000 RMS symmetrical amperes available. See breaker manufacturer for more specific details.

Fig. 1—Standard Circuit Breakers



CIRCUIT BREAKER PROTECTION — HIGH INTERRUPTING CAPACITY CIRCUIT BREAKERS (NOTE)

FRAME	AMPERE RATING	MINIMUM FUSE RATING		MAXIMUM FUSE RATING			
		CIRCUIT BREAKER INSTANTANEOUS SETTING		600 & 480 VAC		240 VAC	
		LOW	HIGH	LOAD SIDE	LINE SIDE	LOAD SIDE	LINE SIDE
100A (20000- 75000A IC)	15-20	—	70	400	600	1000	1000
	30-40	—	100	400	600	1000	1000
	50-70	—	200	600	800	1200	1200
	90-100	—	300	600	800	1200	1200
400A (30000- 75000A IC)	125	300	400	1200	1200	2000	2000
	150-175	300	400	1600	1600	2500	2500
	220-225	300	600	1600	2000	2500	2500
	250-300	400	600	1600	2000	2500	2500
	350-400	600	800	1600	2000	2500	2500
800A (30000- 75000A IC)	400	600	800	3000	3000	3000	3000
	500-600	800	1200	3000	3000	3000	3000
	700-800	1000	1200	3000	3000	3000	3000
1200 or 1600A (50000- 75000-IC)	800	1000	1200	3000	3000	3000	3000
	1000-1200	1600	2000	3000	3000	3000	3000
	1400-1600	2000	3000	3000	3000	3000	3000

Note: The values listed above are typical for class J, L, T, or K1 current-limiting fuses on systems up to 100,000 RMS symmetrical amperes available. See breaker manufacturer for more specific details.

Fig. 2—High-Interrupting Capacity Circuit Breakers