SELECTION AND APPLICATION OF LOW-VOLTAGE POWER CIRCUIT BREAKERS FOR LIGHTING, DISTRIBUTION AND POWER CIRCUITS

RATING AND SERVICE CONDITIONS
PROTECTIVE DEVICES AND OTHER DEVICES
APPLICATION GENERAL
OPERATING CHARACTERISTICS

An air circuit breaker is a device for interrupting a circuit in air between separable contacts under normal or abnormal conditions.

The proper application of a low-voltage power circuit breaker requires a knowledge of the circuit breaker ratings and the conditions under which the circuit breaker is to be used. With this knowledge it is possible to select the proper circuit breaker for the requirements of the application in question.

RATING AND SERVICE CONDITIONS

RATING

The rating of a circuit breaker is a designated limit of operating characteristics based upon definite conditions. The rating of a low-voltage power circuit breaker includes the following items:

(a) Rated voltage.
(b) Rated maximum design voltage.
(c) Rated maximum voltage.
(d) Rated frequency.
(e) Rated continuous current.
(f) Rated short-time current.
(g) Rated short-circuit current (interrupting rating).
(h) Rated control voltage.

Rated Voltage:

The **rated voltage** is described in three (3) different ways:

1. Rated voltage.
2. Rated maximum design voltage.
3. Rated maximum voltage.

(a) The **rated voltage** for a circuit breaker is the same as the nominal voltage which is considered to be 240, 480 and 600 volts.

(b) The **rated maximum design voltage** is the highest voltage at which the circuit breaker shall be required to operate. Circuit breakers of the 600 volt class shall have a rated maximum design voltage of 630 volts.

(c) The **rated maximum voltage** is the maximum voltage at which the breaker shall be required to interrupt its rated short circuit current. These circuit breakers shall have maximum voltages of 250, 500 and 630 volts corresponding to rated volts of 240, 480 and 600 volts and shall be required to interrupt short circuit currents as given in Section 9.1.1, Table 1, page 2.

Rated Frequency:

The **rated frequency** is the frequency of the circuit for which the circuit breaker is designed.

Rated Continuous Current:

The **rated continuous current** is the designated limit in rms amperes or direct current amperes which the circuit breaker will carry continuously. Low voltage power circuit breakers shall have a continuous current rating in the open based on a temperature rise at the terminal connections not exceeding 40 C. A continuous current rating of an enclosed low voltage power circuit breaker is such that the maximum temperature rise is based on an average air inside the enclosure which does not exceed the standard 40 C. ambient by more than 15 C. These continuous current carrying ratings are based on the use of silver-faced or equivalent contact surfaces and all other terminal connection surfaces are welded, brazed, soldered or silver-surfaced or the equivalent. Under any conditions the continuous current rating cannot exceed the coil rating used. See Section 9.1.3, Table 2, page 6.

Rated Short-Time Current:

The **rated short-time current** of a low voltage power circuit breaker is the rms symmetrical current at rated maximum voltage at ½ cycle after fault initiation, which

the circuit breaker is required to carry for two periods of ½ second duration each with a 15 second interval of zero current between the ½ second periods. For the short-time current rating of these breakers, refer to Section 9.1.3, Table 6, page 7, which gives the current in rms symmetrical amperes based on the following test procedure, operating duty, and performance.

Circuit breakers without direct-acting overcurrent trip devices shall be given a short-time current rating, expressed in amperes.

Test Procedure:

The rated short-time current rms amperes shall be determined by measuring the current flow in a test circuit as follows:

The circuit breaker shall be short-circuited or omitted.

The test circuit used shall be a 60 cycle rms sinusoidal current at rated maximum voltage calculated in accordance with American Standard C37.5.

Current shall be measured ½ cycle after initiation of current flow. The test circuit shall have a power factor not greater than 15% (X/R ratio of 6.6 or greater) with series X and R connected in series with the circuit breaker. The alternating component of current at the end of 30 cycles or ½ second shall not be less than 80% of the a-c component at the end of the first half cycle. Two tests shall be made of ½ second duration with a 15 second interval of zero current between tests. The test shall be performed on a three-pole breaker using a three-phase circuit. After the performance of the test the circuit breaker shall be capable of carrying rated continuous current without exceeding the rated temperature rise for the various parts and shall be capable of meeting a short-circuit current rating.

Rated Short-Circuit Current (Interrupting Rating):

The **rated short-circuit current** of the circuit breaker is the highest current, rms, at rated maximum voltage which the breaker is required to interrupt during the operating duties specified and with a normal frequency recovery voltage equal to the rated maximum voltage. The short-circuit current rating shall be given in rms symmetrical current, one-half cycle after fault inception, at the rated voltage of the circuit breaker. It shall be based on the following test procedure, operating duty and performance.

Test Procedure:

The symmetrical current shall be determined by measuring the current flow in a test circuit as follows:

The symmetrical current which verifies the short circuit rating shall be determined by calculating the test circuit with the circuit breaker short-circuited or omitted, and shall be measured at ½ cycle after inception of the current flow in the test circuit. This current shall be calculated in accordance with American Standard C37.5. The test circuit shall have a power factor not greater than 15% with a X/R ratio of 6.6 or greater and series connected.

The transient characteristics of the test circuit shall be such that the alternating component of the current at the end of ½ second shall not be less than 80% of the alternating component of the current at the end of the first half cycle. The test circuit voltage prior to the initiation of current flow shall be the rated maximum voltage. On three-phase test, either the power source or fault connection shall be grounded, but not both.

Operating Duty:

The **operating duty** for a breaker shall consist of an open operation followed by a 15-second interval and then a close, open operation.

Performance:

At the end of any performance at or within its interrupting rating, the circuit breaker shall be in the following condition:

The circuit breaker shall be substantially in the same mechanical condition as before the test. The circuit breaker shall be capable of withstanding a dielectric test of 60% of the required test voltage which is 2,200 volts for one minute for 600 volt equipment. The circuit breaker shall also be capable of carrying a rated continuous current, without exceeding the allowable temperature rise, and it shall be capable of operating automatically within the manufacturer's specified time limits at 300% calibrated point.

SERVICE CONDITIONS:

The **service conditions** affecting low-voltage power circuit breakers include the following:

(a) Ambient temperature.
(b) Altitude.
(c) Unusual service conditions.

Ambient Temperature:

Low-voltage power circuit breakers are for use within their rating where the outside ambient temperature does not exceed 40C.

Altitudes:

Low-voltage power circuit breakers are for use within their rating where the altitude does not exceed 3,300 feet (1,000 meters). Operation above this may affect the dielectric, the voltage and the current rating. For the appropriate rating factor for altitudes above 3,300 feet, see Section 9.1.3, Table 3, page 6.

Unusual Service Conditions:

Unusual service conditions may require unusual construction or operation, and these should be brought to the attention of those responsible for the application, manufacture and operation of the circuit breaker. Wherever possible, steps should be taken at the site of the installation to nullify the deleterious poisonous effects of unusual service conditions. Among such unusual conditions are:

(a) Exposure to damaging fumes or vapor.
(b) Exposure to steam.
(c) Exposure to salt air.
(d) Exposure to oil vapors.
(e) Exposure to dripping moisture.
(f) Exposure to hot and humid climate.
(g) Seasonal or infrequent use.
(h) Exposure to extreme temperatures or sudden changes in temperatures.
(i) Exposure to excessive dust, abrasive dust, magnetic or metallic dust.
(j) Exposure to explosive mixtures of dust or gases.
(k) Exposure to water in the form of a stream such as is used for cleaning, etc.
(l) Subject to submersion.
(m) Exposure to abnormal vibration, shocks or tilting.
(n) Exposure to unusual transportation or storage.
(o) Unusual space limitations.
(p) Unusual insulation requirements.
(q) Unusual configuration of enclosing rooms, causing hot air pockets, rooms not having normal ventilation or rooms containing large amounts of magnetic material.
(r) Unusual operating duty, frequency of operation or difficulty of maintenance.
(s) Operation at unstable control voltages.
(t) Unusual or special operation requirements.
(u) Exposure to extreme sun temperatures.

PROTECTIVE DEVICES AND OTHER DEVICES

PROTECTIVE DEVICES

DIRECT-ACTING TRIP DEVICES
UNDERVOLTAGE TRIP DEVICE

OTHER DEVICES

SHUNT TRIP DEVICE
AUXILIARY SWITCHES
ALARM SWITCHES
ALARM CONTACTS
INTERLOCKED CIRCUIT BREAKERS

A complete line of circuit breakers insofar as voltage current and interrupting ratings are concerned is not enough. The adaptability of the circuit breakers to installation requirements depends upon the completeness of protective and other devices available and their design and construction from a practical viewpoint.

These requirements are met with various types of devices such as direct acting trips, undervoltage trips, shunt trips, auxiliary switches, alarm switches, mechanical interlocks and other special features.

DIRECT-ACTING TRIP DEVICES

The following direct acting trip devices are applicable to series direct-acting trip or transformer direct-acting trip:

(a) **Instantaneous Direct-Acting Trip:** An instantaneous direct-acting trip is one which functions magnetically above a predetermined value of current without any intentional delayed action.

(b) **Delayed Direct-Acting Trip:** A delayed direct acting trip is one which functions above a predetermined value of overcurrent with an intentional delayed action.

(c) **Dual Direct-Acting Trip:** A dual direct-acting trip is one which combines the function of a magnetic instantaneous direct acting trip and a delayed direct acting trip.

(d) **Selective Direct-Acting Trip:** A selective direct-acting trip is one which functions with an intentional delayed action at all values of current between a predetermined value and the rated interrupting current of the circuit breaker with which it is associated. It will automatically reset when the current is reduced within a prescribed time to a value within the rated continuous current.

(e) **Dual Selective Direct-Acting Trip:** A dual selective direct-acting trip is one which combines the function of a selective direct acting trip and a delayed direct acting trip.

Instantaneous Direct-Acting Trip: Instantaneous direct-acting trip consists of a laminated-iron electromagnet and a pivoted armature which cooperates with it. Calibration is provided by spring loading the armature to increase the pick up point. A calibrated scale indicating the tripping current values is provided. The electromag-

net is energized by the current flowing in the circuit protected by the breaker. When load conditions are such that the current flowing is less than that for which the armature is set to pick up, the armature remains stationary. If the current exceeds the value corresponding to the setting of the armature, the armature is forcibly drawn by magnetic action against the magnet. Just before the armature reaches the magnet it acts with impact on the latch holding the circuit breaker closed, and releases it instantly. The armature has a free preliminary movement before striking the restraining latch, insuring positive action. The action of the armature is independent of latch friction or any other element which might unfavorably influence accuracy.

For short-circuit currents it is possible to calibrate from 500 to 1500% of the ampere rating of the circuit breaker, and the device is normally set at approximately 1000%.

This device is available on circuit breakers up to and including 4000 amperes with series direct acting tripping and 5000 to 6000 amperes a-c with transformer direct acting trip.

Selective Direct-Acting Trip (short-time)—Mechanical: The construction and operation of the selective direct-acting trip is the same as the instantaneous direct-acting trip device with the addition of a timing device which measures in cycles. This cycle-timer measures time by the inertia of an oscillating member, actuated by a toothed wheel which is actuated in turn by the armature. The armature has a fixed gap with tension springs for calibration. Three fixed bands, minimum, intermediate and maximum, are obtained by changing the length of the lever arm actuating the cycle-timer. See Time Current Curves for Time Characteristics.

The calibration range of tripping adjustment is 400 to 1000% of the ampere rating of the circuit breaker, and the device is normally set at 400%.

This device is available on circuit breakers with continuous current ratings up to and including 4000 amperes with series direct acting trip and 5000 to 6000 amperes with transformer direct acting trip.

Delayed Direct-Acting Trip (long-time)—Displacement Type: The construction and operation of the displacement type direct-acting trip device is the same as for the instantaneous direct-acting trip device with the addition of a time delay device. The armature has a fixed gap with tension springs for calibration. The time delay device consists of a silicone-oil-filled dashpot in which the oil must be displaced from one side of a piston to the other side, before tripping can take place.

After the piston has completed not more than one-half its full stroke, it moves into a low pressure area which permits the armature to act with impact. The amount of delay is determined by the distance that the piston moves in the high pressure area. This distance is adjustable. Due to a highly responsive check valve, the armature is not purposely delayed on resetting which takes place quickly. After each reset the device requires the full pick-up current to cause the armature to start another tripping stroke.

For overload conditions the calibration range of tripping adjustment can be from 50 to 125% of the coil rating of the circuit breaker, or from 80 to 160% of the coil rating, and is normally set at 100%.

This device is available on circuit breakers up to and including 4000 amperes with series direct acting tripping and 5000 to 6000 amperes with transformer direct acting trip.

Dual-Magnetic (General Purpose) Direct-Acting Trip —Displacement Type: This device combines the functions of an instantaneous direct-acting trip with a delayed long-time direct acting trip of the displacement type. See preceding material for calibration and description.

Dual Selective Direct-Acting Trip — Displacement Type: The dual selective direct-acting trip combines the functions of the selective short-time direct-acting trip with a delayed long-time direct-acting trip of the displacement type. See preceding material for calibration and description.

UNDERVOLTAGE TRIP DEVICE

Undervoltage tripping is the tripping of a low voltage power circuit breaker from a trip coil responsive to a decrease in voltage below a predetermined value of main circuit voltage. The dropout voltage is approximately 30–60% of the circuit voltage. Pick up voltage is approximately 80% of coil voltage rating. The devices are not adjustable for pickup or dropout voltage.

Instantaneous: In the undervoltage device a coil which surrounds an electromagnet is connected directly to the line and attracts a pivoted armature. The armature is spring loaded. When the voltage on the coil falls below a certain value, the magnetic pull on the armature is reduced and the armature moves to the open air gap position aided by a spring. The force of the spring is at the same time transmitted to the tripping bar and the latch is released to trip the breaker.

Time Delay: When it is required that the breaker remain closed for a short interval following voltage failure, the addition of a time delay device is available and added to the device previously described. Its addition delays the operation of the undervoltage feature for an adjustable time interval. If the normal circuit conditions do not return during the interval, the undervoltage device will trip the circuit breaker.

SHUNT TRIP DEVICE

Shunt trip is the tripping of an air circuit breaker by means of a trip coil energized from a source of power, the trip coil circuit being closed through a relay, switch, or other means. This device consists of a tripping magnet and armature. When the circuit is energized, the tripping magnet operates the armature which releases the latch and opens the breaker. In order to prevent the operating coil of the shunt trip device from

burning out, following the opening of the breaker, an auxiliary contact is provided to disconnect the coil from the circuit as the breaker opens.

AUXILIARY SWITCHES

Type L: This auxiliary switch consists of an enclosed drum-type switch with either four, six or eight contacts. The fixed contact elements consist of metal blades permanently fastened to a molded insulating case. The rotary elements have an opening in the form of a star so that they may be mounted on a square shaft. The contacts in the rotary elements have a lead or lag of 22 degrees, allowing them to be placed in any 3 positions 22 degrees apart. Thus any set of contacts may be made not only circuit-closing or circuit-opening but early-closing, late-closing, early-opening or late-opening, giving great flexibility in carrying out various control schemes.

ALARM SWITCHES

When a circuit breaker opens by means of a protective device it is sometimes desirable to have an alarm circuit, warning the operator that the circuit breaker has opened by other than normal operation.

On the type K-225, K-600, K-1600, K-2000, K-3000 and K-4000 circuit breakers this is accomplished by using a two contact auxiliary switch which is operated by the automatic trip indicator. The alarm switch is reset by pushing the trip indicator button back to the reset position. Opening of the breaker by the protective device leaves the contacts in the alarm position until they are manually reset.

This alarm circuit should be energized until someone resets the circuit breaker.

For any electrically operated circuit breaker controlled from one remote point, the alarm circuit can be accomplished by furnishing a "slip" contact on the control switch. This together with a "b" contact on the standard auxiliary switch meets all the conditions of an alarm circuit. The circuit is reset by turning the handle of the control switch to the trip position, opening the "slip" contact.

ALARM CONTACTS

Before a circuit breaker is opened by means of a protective device it is sometimes desirable to give a warning signal that an overload exists. This can be done by having the long time overload armature close a set of alarm contacts instead of tripping the breaker. This is usually done on only one pole of the circuit breaker, leaving the protective devices on the other two poles set to trip the circuit breaker at higher values of overload. The instantaneous trips are not changed.

INTERLOCKED CIRCUIT BREAKERS

Two circuit breakers can be mechanically interlocked so that only one breaker may be closed at one time but both may be open at any one time.

Mechanical: Mechanically interlocked circuit breakers are so arranged that when one breaker is closed the other breaker is mechanically blocked in the open position against any normal closing effort. Breakers to be interlocked may be in either a vertical or horizontal alignment but mounted in adjacent compartments.

Key Interlocks: The "Kirk" type of key interlock may be used to interlock two breakers. A key must be in the breaker interlock before a breaker can be closed and the key cannot be removed until the breaker is tripped open. The key can then be removed to the other breaker interlock to permit closing of that breaker.

To interlock more than two breakers a key exchange is recommended.

Electrical Interlock: Circuit breakers can have their control circuits so arranged that they are electrically interlocked.

APPLICATION—GENERAL

GENERAL

The maximum system voltage applied to a low voltage power circuit breaker can in no case exceed the listed voltage rating of the breakers.

The ampere rating can in no case be less than the maximum current which the breaker will be called upon to carry continuously, including any 1 or 2 hour overload rating. It also should not be less than the continuous current carrying capacity of the apparatus connected to it. For motors the rating should be related to the continuous and starting current ratings of the motor.

Circuit breakers can be used for intermittent loads where the breaker is required to carry a current higher than its continuous rating, periodically, for short intervals. The combined effects of these higher currents must be integrated and such cases should receive special engineering consideration.

The interrupting capacity must be sufficient for the maximum short circuit current possible. Cascading is permitted with large air circuit breakers.

Protective devices should be selected to fit the particular application. Normal direct acting, temporary direct acting, abnormal direct acting, undervoltage, and other conditions should be carefully considered.

Other devices should be selected as required.

Consideration should be given to any unusual service conditions.

VOLTAGE RATINGS

Standard voltage ratings are as follows:

TABLE 1

Volts Ac		
Type	Voltage Rating	Maximum Design Rating
K-225 K-600 K-1600 K-2000 K-3000 K-4000	600-480-240	630-500-250

CONTINUOUS CURRENT RATINGS

Standard continuous current ratings, with series trips, are as follows:

TABLE 2

Type	Maximum Coil Ratings Amperes
K-225	20, 40, 70, 125, **225**
K-600	40, 70, 125, 225, 400, **600**
K-1600	225, 400, 800, **1600**
K-2000	400, 800, 1600, **2000**
K-3000	2500, **3000**
K-4000	**4000**

SHORT-TIME RATINGS

The short-time rating of low-voltage power circuit breakers without direct-acting trip devices, *i. e.* for relay tripping, is equal to its 600-volt interrupting rating. Circuit breakers with instantaneous trip in the fault current range require no short time rating. Breakers using selective trip have a further limitation as to the minimum coil that may be used. The minimum coil values are shown in Table 6.

RATINGS AT VARIOUS ALTITUDES

When low voltage power circuit breakers are used at altitudes above 3300 feet, the dielectric, the voltage and the current ratings shall be multiplied by the following factors to obtain the new ratings for the altitude at which the breakers will be used.

TABLE 3

Altitude	Correction Factors			
Feet	Interrupting Capacity	Voltage	Current	Dielectric
3300	1.00	1.00	1.00	1.00
5000	1.00	.95	.99	.95
10000	1.00	.80	.96	.80
20000	1.00	.56	.90	.56

DIELECTRIC TEST VOLTAGES

The dielectric test voltage for low-voltage power circuit breakers, except as otherwise specified, are applied for 60 seconds at volts as follows:

TABLE 4

Rated Voltage of Breaker Ac	*Dielectric Test Voltage Volts Ac
	Breakers for Standard Applications
600	2200

* When tested in the field, the test voltage should be equal to 75 percent of the value given in the table.

OPERATING TIMES

The closing, opening and interrupting times of a circuit breaker are as follows:

(a) The closing time of a circuit breaker is the interval between the energizing of the close coil and the touching of the arcing contacts at rated control voltage. Where a closing relay is used with an electrically operated circuit breaker, the closing time includes the time consumed in the operation of the closing relay.

(b) The opening time of a circuit breaker is the interval existing between the energizing of the trip coil at rated voltage and the parting of the arcing contacts of the circuit breaker.

(c) The interrupting time of a circuit breaker is the interval existing between the energizing of the trip coil at rated voltage and the interruption of the circuit. This is the summation of the opening time and the arcing time. If the tripping current of the circuit breaker is large enough to require the use of an individual auxiliary relay, the interrupting time includes the time consumed in the operation of such auxiliary relay.

(d) The interrupting time of a circuit breaker using direct acting trip device is the time from start of short circuit until arc interruption.

INTERRUPTING CURRENT RATINGS

A. The interrupting rating of a low-voltage power circuit breaker with direct-acting instantaneous tripping, when used with the series trip coil pickup settings indicated, shall be as follows:

TABLE 5

Type	600 Volt Interrupting Rating Rms Symmetrical Amperes†	Range of Pickup Settings—Amperes
K-225	14000	12 to 225
K-600	22000	20 to 600
K-1600	42000	120 to 1600
K-2000	55000	250 to 2000
K-3000	65000	1600 to 3000
K-4000	85000	2000 to 4000

† For interrupting ratings at other than 600 volts see Section 9.1.1 Table 1.

B. The interrupting ratings of low-voltage power circuit breakers with delayed direct-acting trip, when used with series trip coil pickup settings indicated, shall be as follows:

TABLE 6

Type Ac	Short-Time and Interrupting Rating Rms Sym. Amperes	Range of Pickup Settings—Amperes		
		Short-Time Delay		
		Minimum	Intermediate	Maximum
K-225	14000	72–225	72–225	120–225
K-600	22000	120–600	120–600	200–600
K-1600	42000	240–1600	240–1600	400–1600
K-2000	55000	240–2000	240–2000	400–2000
K-3000	65000	1600–3000	1600–3000	1600–3000
K-4000	85000	3200–4000	3200–4000	3200–4000

The interrupting ratings given in the above Table are based on maximum, intermediate and minimum short-time delay bands associated with selective direct-acting trip devices and for relays, wherein the maximum delay shall not exceed ½ second.

C. All interrupting ratings given above are based on the circuit breakers being enclosed and for all voltages up to and including rated maximum design voltage.

Circuit breakers having series trip coils with pickup setting lower than the minimum listed for its interrupting rating will have an interrupting rating corresponding to the largest interrupting rating under which that coil size is listed.

When circuit breakers are equipped with relays for tripping instead of a series trip coil, consideration must be given to the breakers short-time current rating which may be the limiting factor.

BREAKER RATING FACTORS FOR RECLOSING SERVICE

The standard duty cycle on fault currents is 0–15 second-CO.

The interrupting ratings of large air circuit breakers must be reduced for operating duties other than the standard duty cycle to enable them to meet the required standard of interrupting performances. Additional CO unit operations or reducing the standard 15-second time interval increases the duty on the contacts and the interrupter and a derating factor should then be applied. At the present time there are no derating factors established. Such applications should be referred to the factory.

REPETITIVE DUTY

Power operated low-voltage power circuit breakers, when operating under usual service conditions, should be capable of performing a certain number of operations.

The number of operations is dependent upon whether the breaker is opening under no-load, load, non-fault, fault or large inrush conditions.

The following Table 7 gives the number of operations under several combinations of circuit conditions. The operating conditions and the permissible effect upon the breakers are given in the paragraphs below the table. All paragraphs listed for each column must be considered.

All parts of a circuit breaker that function during a normal operation shall be included. Other parts, such as overload coils, that function only during infrequent abnormal circuit conditions shall be excluded.

TABLE 7

1		2	Number of Operations				
			3	4	5	6	7
Circuit Breaker Designation		No. of Operations between Servicing Para. No. 1	No Load Mechanical	Full Load Non-Fault	Full Load Fault	Inrush Non-Fault	Inrush Fault
Type	Interrupting Rating Amperes		Para. Nos. 2, 5, 6, 7, 8, 9	Para. Nos. 3, 5, 6, 7, 8, 10	Para. Nos. 3, 5, 6, 7, 8, 9, 11	Para. Nos. 4, 5, 6, 7, 8, 10	Para. Nos. 4, 5, 6, 7, 8, 9, 11
K-225	14000	2500	25000	5000	4000	3500	2500
K-600	22000	1750	25000	3500	2800	2500	1750
K-1600	42000	500	8000	1000	800	750	500
K-2000	55000	500	8000	1000	800	750	500
K-3000	65000	250	3000	500	400	—	—
K-4000	85000	250	3000	500	400	—	—

Servicing:

(1) Servicing shall consist of adjusting, cleaning, lubricating, tightening, etc., as recommended by the manufacturer. The number of operations listed are a basis of servicing at intervals of six months or less.

Circuit Conditions:

(2) When closing and opening no load.

(3) When closing and opening currents up to the continuous current rating of the circuit breaker at voltages up to the maximum design voltage and at 80% pf or higher.

(4) When closing currents up to 600% and opening currents up to 100% (80% pf or higher) of the continuous current rating of the circuit breaker at voltages up to the maximum design voltage.

When closing currents up to 600% and opening currents up to 600% (45–50% pf) of the continuous current rating of the circuit breaker at voltages up to the maximum design voltage, reduce the number of operations shown in columns 6 and 7 to 5% of number listed.

Operating Conditions:

(5) With rated control voltage applied.

(6) Frequency of operation not to exceed 20 in 10 minutes or 30 in one hour. Rectifiers or other auxiliary devices may further limit the frequency of operations.

(7) Servicing at no greater intervals than shown in Column 2 of Table 7.

Condition of the Circuit Breaker After the Operations Shown In the Table:

(8) No major parts shall have been replaced except as qualified in paragraph 11.

(9) Circuit breaker shall be in a condition to meet all of its current, voltage and one opening test at rated short circuit current.

(10) The circuit breaker shall be in a condition to meet all its current and voltage ratings but not necessarily its interrupting rating.

Operation Under Fault Conditions:

(11) If a fault operation occurs before the completion of the permissible number of operations, it is not to be inferred that the breaker can again meet its interrupting rating or complete its number of operations without servicing or making repairs if necessary.

SHORT-TIME OVERLOAD RATING

Circuit breakers are rated upon a maximum basis. They are circuit interrupters and protective devices, and, as such, may be called upon at any time to successfully remove from service other equipment or circuits. Furthermore, after such a circuit interruption, their current carrying ability may be materially reduced. Because of these conditions, which differ from those for generators, motors, transformers, and similar apparatus, it is not practical to establish standard overload or thermal ratings.

STANDARD RATED CONTROL VOLTAGES

Standard rated voltages and their ranges for control and power supply of the operating mechanisms of large air circuit breakers measured at the terminals of the mechanisms with full current flowing shall be as follows:

TABLE 8

Rated Voltage	Closing Voltage Range	Tripping Voltage Range
Volts—Direct Current[1]		
48	—	28–60
125	90–130	70–140
250	180–260	140–280
Volts—Alternating Current		
115	95–125	95–125
230	190–250	190–250
460	380–500	380–500

[1] Control from exciter circuits is not recommended.

MANUAL AND ELECTRIC OPERATION

A circuit breaker should be operated so that the contacts close quickly and positively. The two types of manual close are dependent and independent operation. Dependent operation exists when the contact speed of closing is a function of how fast the close handle is operated. Independent operation exists when contact closing speed is not a function of the close handle motion. With dependent manual operation, hesitancy in closing may cause undue burning of the contacts and if a short-circuit exists, the results may be excessive arcing and other disturbances which may cause severe damage to the breaker.

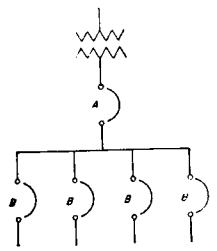
(1) **Dependent manually-operated** circuit breakers shall be limited to applications where the following conditions exist:
   (a) For dead-front and individually-enclosed circuit breakers equipped with instantaneous trip devices where the short-circuit requirements do not exceed 42,000 rms symmetrical amperes at 600 volts, 50,000 rms symmetrical amperes at 480 volts, and 65,000 rms symmetrical amperes at 240 volts.
   (b) For dead-front and individually-enclosed circuit breakers equipped with instantaneous trip devices where the maximum instantaneous trip setting does not exceed 15,000 rms symmetrical amperes.
   (c) For all circuit breakers equipped with selective overcurrent trip devices where the delayed tripping requirements do not exceed 15,000 rms symmetrical amperes.
   (d) For all circuit breakers without direct-acting overcurrent trip devices where the interrupting requirements do not exceed 15,000 rms symmetrical amperes.

(2) **Independent manually-operated** or electrically-operated circuit breakers shall be used in applications described under (1) preceding as well as applications exceeding the values listed up to the breaker ratings, except that only power-operated circuit breakers operated from a remote position shall be used when the following conditions exist:
   (a) When circuit breakers are subjected to fault currents in excess of their interrupting ratings (cascade).
   (b) For circuit breakers applied without enclosures where the interrupting requirements exceed 10,000 rms symmetrical amperes.

CASCADING

Where continuity of service is not required, properly selected circuit breakers may be used in cascade arrangement. Circuit breakers are considered to be in cascade when two low voltage air circuit breakers are connected in series in a distribution system, and the circuit breakers beyond those nearest to the source are applied in the following correlated manner. Such a typical circuit is illustrated in the following Figure 1:

Figure 1



In this cascade arrangement, circuit breakers toward the source are provided with instantaneous tripping devices for current values which may occur for faults beyond other circuit breakers nearer the load. Hence, circuit breakers in the series other than the circuit breaker closest to a fault may trip and interrupt loads on other than the faulty circuit. Such arrangements are used only where the consequent possible sacrifice in service continuity is acceptable and when the increased hazard to personnel and equipment is recognized by those responsible for such application and operation.

Cascading shall be limited to two steps of interrupting rating.

   (a) The interrupting rating of circuit breaker A nearest the source of power shall be equal to at least 100 percent of the short-circuit current as calculated. The circuit breaker in this step shall be equipped with instantaneous trips set to trip at a value of current that will give back-up protection whenever the circuit breaker in the next lower step carries current greater than 80 percent of its interrupting rating.
   (b) The circuit breaker or breakers B in the second step shall be selected so that the calculated short-circuit current through the first step plus motor contribution in the second step, will not exceed the rms symmetrical interrupting ratings shown in Table 9.

   For the second step of a 2-step cascade, the circuit breakers shall have an instantaneous trip set above the starting inrush current of the load.

TABLE 9

Fault Current Limitations for Two-Step Cascading Application of Low-Voltage Power Circuit Breakers

Line No.	Frame Size Amperes	600 Volts	480 Volts	240 Volts
1	225	25000	42000	50000
2	600	42000	60000	85000
3	1600	85000	85000	100000
4	2000	85000	85000	130000
5	3000	85000	85000	130000
6	4000	85000	85000	130000

Example: Figure 1

Transformer is 1500 kva, rated 480 volt, 3 phase, 60 cycle, on low voltage side.

Transformer reactance is 5.75%.

Short-circuit current (unlimited primary source) =

$$\text{Full load current} \times \frac{100}{\%\text{ transformer impedance}}$$

$$\frac{\text{KVA} \times 1000}{\text{E}\sqrt{3}} \times \frac{100}{\%\text{ transformer impedance}}$$

$$\frac{1500 \times 1000}{480 \times 1.732} \times \frac{100}{5.75} = 31380$$

Motor contribution (without specific data assume 100%) =

4 × transformer full load current

$$4 \times 1800 = \frac{7200}{38580}$$

I.C. required for breaker "A"

Full load capacity required for breaker A, 1800 amps. Therefore, A is a 2000 ampere K-2000 breaker

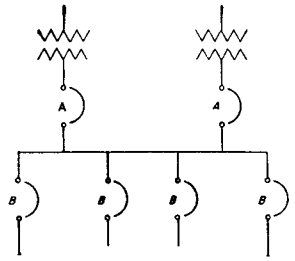
with more I.C. than the circuit requires. Breaker B may be a K-225, because its I.C. rating, (42,000), is greater than 38,580 per Table 9.

Breaker A is given an instantaneous trip calibration of 80% of 22000, or approximately 17,500 amperes.

Breaker B is given an instantaneous trip calibration suitable for its own circuit.

Another typical circuit which requires consideration is shown in the following Figure 2:

Figure 2



This is similar to Figure 1 except there are two sources of power, operated in parallel, each protected by its own breaker A.

Both breakers A must have interrupting ratings fully adequate for their respective sources. Proper cascading now is contingent on A (both breakers) opening to back up breaker B. In estimating the minimum interrupting rating for breaker B, the current fed into a fault below B by the two sources must be considered. Breaker B is considered the second stage of the cascade, and the first stage includes the two breakers A acting together. In such a circuit, the settings of the instantaneous trips must be carefully considered. Both breakers A must trip instantaneously before the total current through breaker B reaches 80% of the interrupting rating of B.

Example: Figure 2

Each transformer is 750 kva, rated 480 volts, 3 phase, 60 cycles on low voltage side.
Transformer reactance is 5.75%.
The motor load is 600-hp (induction type).
Synchronous motor load—zero.

Short circuit current (unlimited primary source) from two transformers in parallel =

$$\frac{1500000}{480 \times 1.732} \times \frac{100}{5.75} = 31380 \text{ rms amps.}$$

Motor contribution—
4 × 750 (Motor full load current) = 3000
Total short circuit = 34380 (two transformers).

Single transformer full load current is

$$\frac{750000}{480 \times 1.732} = 900 \text{ amperes.}$$

Short circuit on one "A" breaker is

$$900 \times \frac{100}{5.75} = 15690 \text{ amperes.}$$

Therefore, the K-1600 is selected for breaker A because of the continuous current requirement.

Breaker B may be applied as a K-225 because (42,000 interrupting rating) is greater than 34380. However, each A breaker is equipped with an instantaneous trip set at not more than one-half of 80% of 22000, or approximately 8500 amps.

In a cascade arrangement, all the breakers are usually in the same switchgear assembly. Any impedance between the members is considered negligible, and the short-circuit current calculated for the location is considered equally applicable to all.

When mounted in more than one switchboard having bus or cable connections between them the impedance of this connection may be taken into account, and if taken into account, a new cascade set-up for the second switchboard may be established.

Cascading cannot be extended to include the power air circuit breaker on the high side of a transformer.

Cascading is permitted with modern breakers in an enclosed switchboard. It is not recommended for live front breakers or individually enclosed breaker.

Breakers with relays and shunt trip may not be used in a cascade arrangement since their time of operation is too long.

All circuit breakers subjected to fault currents in excess of their interrupting rating shall be electrically operated from a remote position only, to provide protection for the operator when closing against fault current.

The operation of circuit breakers in excess of their interrupting rating is limited to one interruption, after which inspection or replacement may be required.

Where cascading is proposed, recommendations shall be obtained from the manufacturer in order to insure proper co-ordination between circuit breakers.

Cascade arrangement of circuit breakers cannot be regarded as applicable in all cases. In this arrangement, all members of the cascade must open at the same time. This may interfere with continuity of service on circuits not involved in the fault. Cascading is used for saving of space and material where its limitations permit and where properly co-ordinated circuit breakers are available.

. Types K-225, K-600, K-1600, K-2000, K-3000 and K-4000 circuit breakers are suitable for cascading. Molded case type ET circuit breakers are not suitable for cascading with these breakers.

SELECTIVE TRIPPING

Where continuity of service is desired, selective tripping arrangements of full-rated circuit breakers are required. Selective direct acting trip is the application of circuit breakers in series so that, of the circuit breakers carrying fault currents, only the one nearest the fault opens to remove the overcurrent. Such a circuit is illustrated in Figure 3:

Properly selected low-voltage power circuit breakers may be applied on low-voltage circuits to obtain selective tripping. The following requirements shall be observed:

(a) Each air circuit breaker A, B, C and D must have an interrupting rating equal to or greater than the available fault current at the point of application.

(b) Except for the breaker farthest removed from the source of power, each air circuit breaker must have a short-time delay with a short-time rating equal to or greater than the available current at the point of application.

(c) The time-current characteristic of each air circuit breaker at all values of available overcurrent, shall be such as to insure that the circuit breaker nearest the fault shall function to remove the overcurrent conditions. Those nearer the source of power shall remain closed and continue to carry the remaining load current.

(d) To insure that each circuit breaker shall function to meet these requirements, the time-current characteristics of associated circuit breakers must not overlap. The pickup settings and time delay bands of both the long-time and short-time delay elements must be properly selected.

(e) Dependent manually-operated circuit breakers shall be limited to application in which delayed tripping requirements do not exceed 15,000 amperes or 15 times the coil rating, whichever is greater.

(f) The time-current characteristics of circuit breakers in a selective system shall be such that four circuit breakers may be operated selectively in series when required. One of these shall be a load circuit breaker equipped with an instantaneous trip element.

Operation of selective tripping may require coordination with the rest of the system. As an example, the low voltage side of a transformer bank requires that, in the application of relays or fuses on the high voltage side, proper co-ordinating steps should be taken.

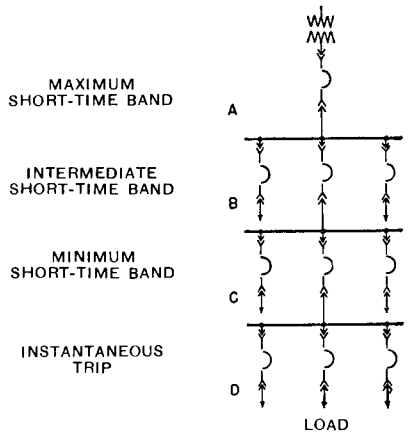
Breakers with selective tripping are permitted only with modern breakers in enclosed switchboards.

Breakers with relays and shunt trips may be used providing the total interrupting time (including breaker time) does not exceed ½ second.

Molded case type ET air circuit breakers with instantaneous trip may be used in the last step of the selective trip arrangement provided they have the required interrupting capacity.

Types K-4000, K-3000, K-2000, K-1600, K-600, K-225 and ET (molded case) circuit breakers are suitable for selective tripping.

Figure 3



The operating characteristics of direct acting trip devices on low voltage power circuit breakers are shown on the following TD curves.

TABLE 9

Breaker	Overload Dual Magnetic	Characteristics			TD Curve for Direct-Acting Trip Devices*
		Long-Time	Short-Time	Instantaneous	
K-225 K-600 K-1600 K-2000	OD-3	50–125%		500–1500%	TD-6693
	OD-4	80–160%	400–1000%		TD-6694
	OD-5	80–160%	400–1000%	500–1500%	TD-6695
	OD-6	80–160%		500–1500%	TD-6695
	OD-7			500–1500%	None
	OD-8			80–250%	None
K-3000 K-4000	OD-300	50–125%		500–1500%	TD-6693
	OD-400	80–160%	400–1000%		TD-6694
	OD-500	80–160%	400–1000%	500–1500%	TD-6695
	OD-600	80–160%		500–1500%	TD-6695
	OD-700			500–1500%	None
	OD-800			80–250%	None

* See Section 9.1.3, Pages 12, 13 and 14.

GENERAL-PURPOSE DIRECT-ACTING TRIP DEVICES
I-T-E Type OD-3 for K-225 through K-2000, OD-300 for K-3000 and K-4000

Breaker Frame Type	Maximum Continuous Coil Rating	Long-Time Adjustable Pickup Points						Instantaneous Adjustable Pickup Points			
		1	2	3	4	5	6	1	2	3	4
K-225	20	—	12	15	18	20	25	75	125	200	300
K-225 K-600	40	20	25	30	—	40	50	150	250	400	600
K-225 K-600	70	40	—	50	60	70	90	250	500	750	1100
K-225 K-600	125	70	—	90	100	125	160	450	800	1200	1900
K-225 K-600 K-1600	225	120	150	175	200	225	285	750	1500	2400	3400
K-600 K-1600 K-2000	400	—	250	300	350	400*	500	1250	2000	4000	6000
K-600	600	—	400	—	500	600	750	2500	4000	6000	9000
K-1600 K-2000	800	400	500	600	—	800	1000	2500	5000	8000	12000
K-1600 K-2000	1600	800	1000	1200	—	1600	2000	5000	10000	16000	24000
K-2000	2000	—	1200	1600	1800	2000	2500	10000	15000	20000	30000
K-3000	3000	1600	2000	—	2500	3000	3800	10000	20000	28000	36000
K-4000	4000	2000	—	3000	3500	4000	5000	20000	30000	40000	48000

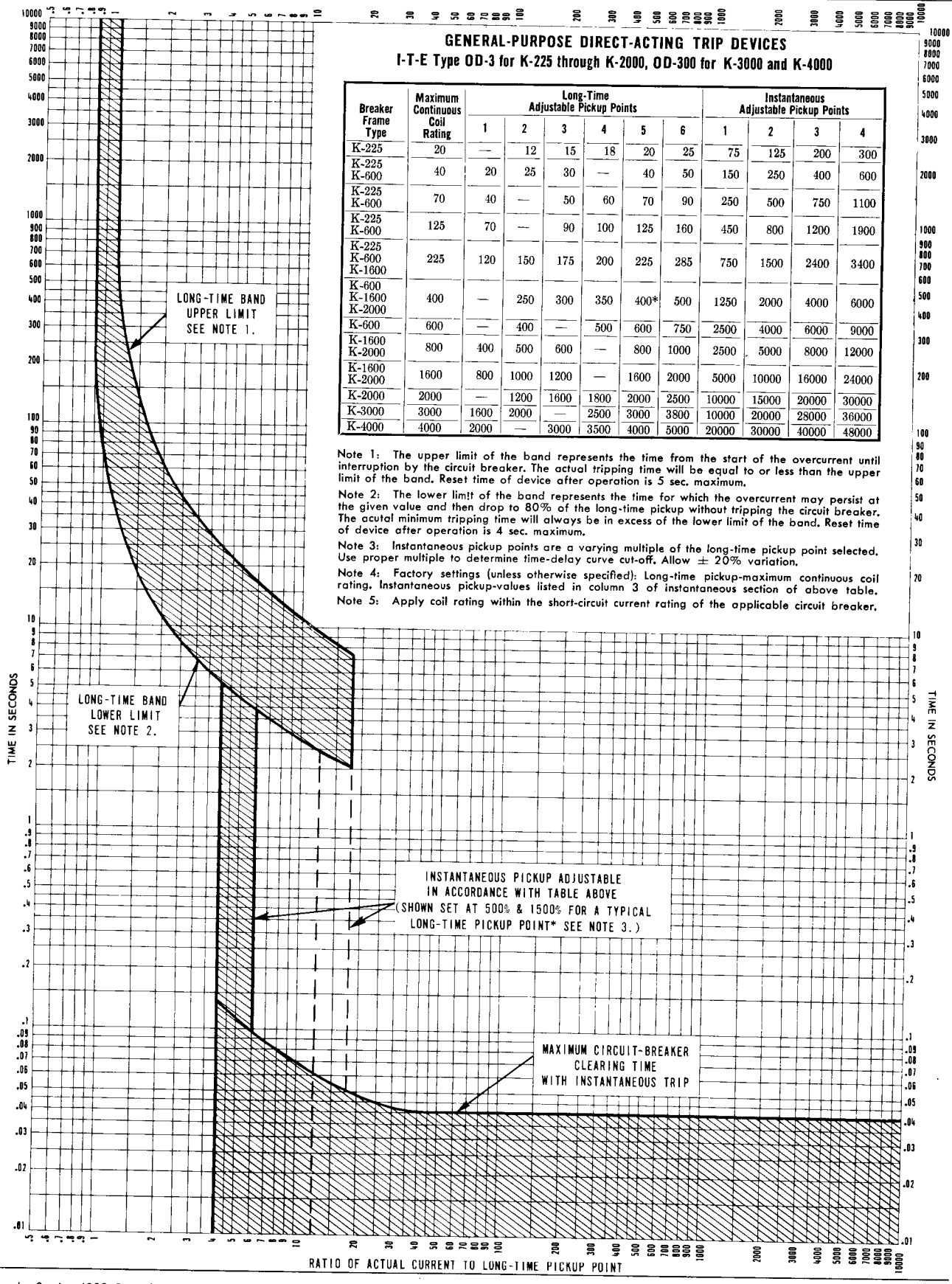
Note 1: The upper limit of the band represents the time from the start of the overcurrent until interruption by the circuit breaker. The actual tripping time will be equal to or less than the upper limit of the band. Reset time of device after operation is 5 sec. maximum.

Note 2: The lower limit of the band represents the time for which the overcurrent may persist at the given value and then drop to 80% of the long-time pickup without tripping the circuit breaker. The acutal minimum tripping time will always be in excess of the lower limit of the band. Reset time of device after operation is 4 sec. maximum.

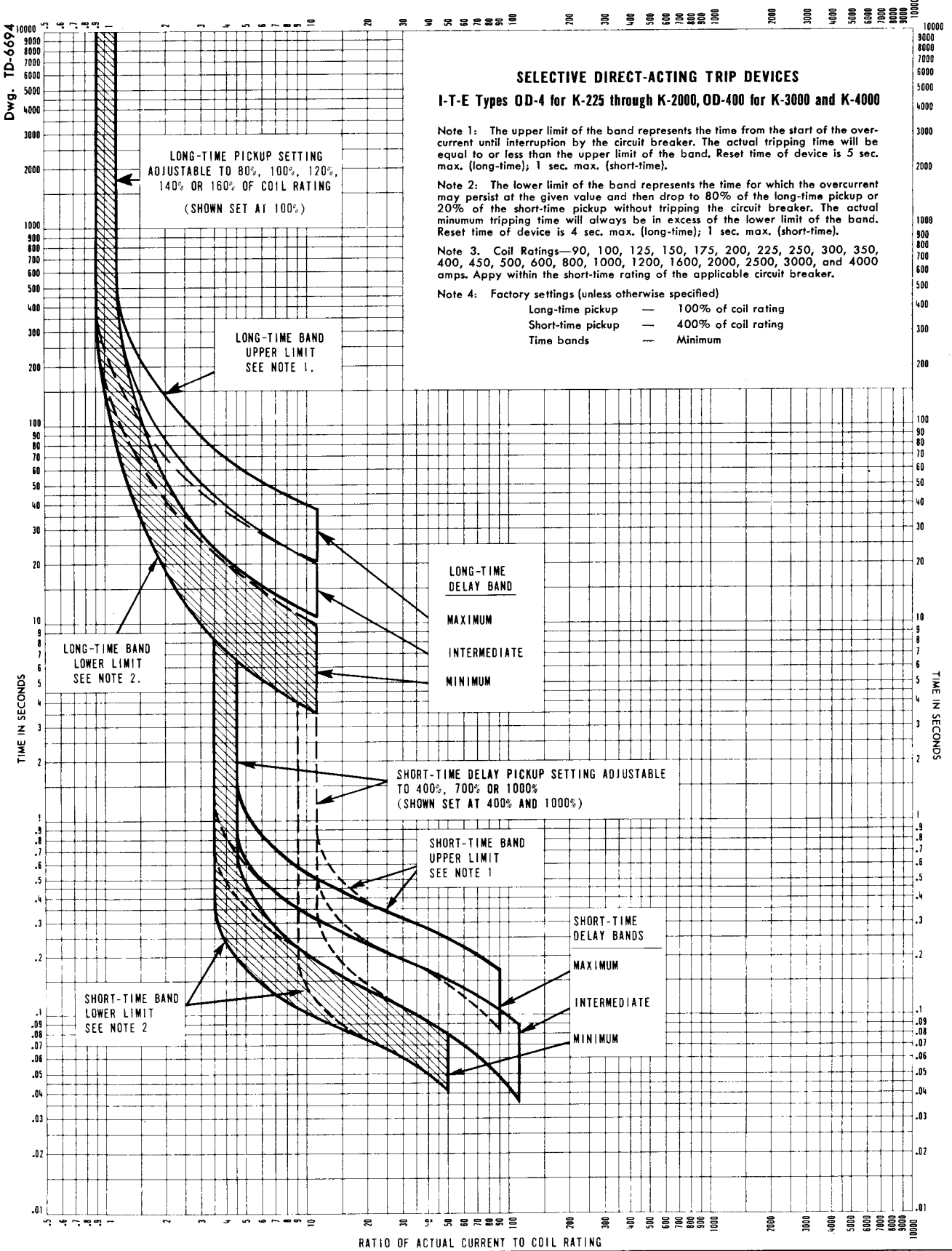
Note 3: Instantaneous pickup points are a varying multiple of the long-time pickup point selected. Use proper multiple to determine time-delay curve cut-off. Allow ± 20% variation.

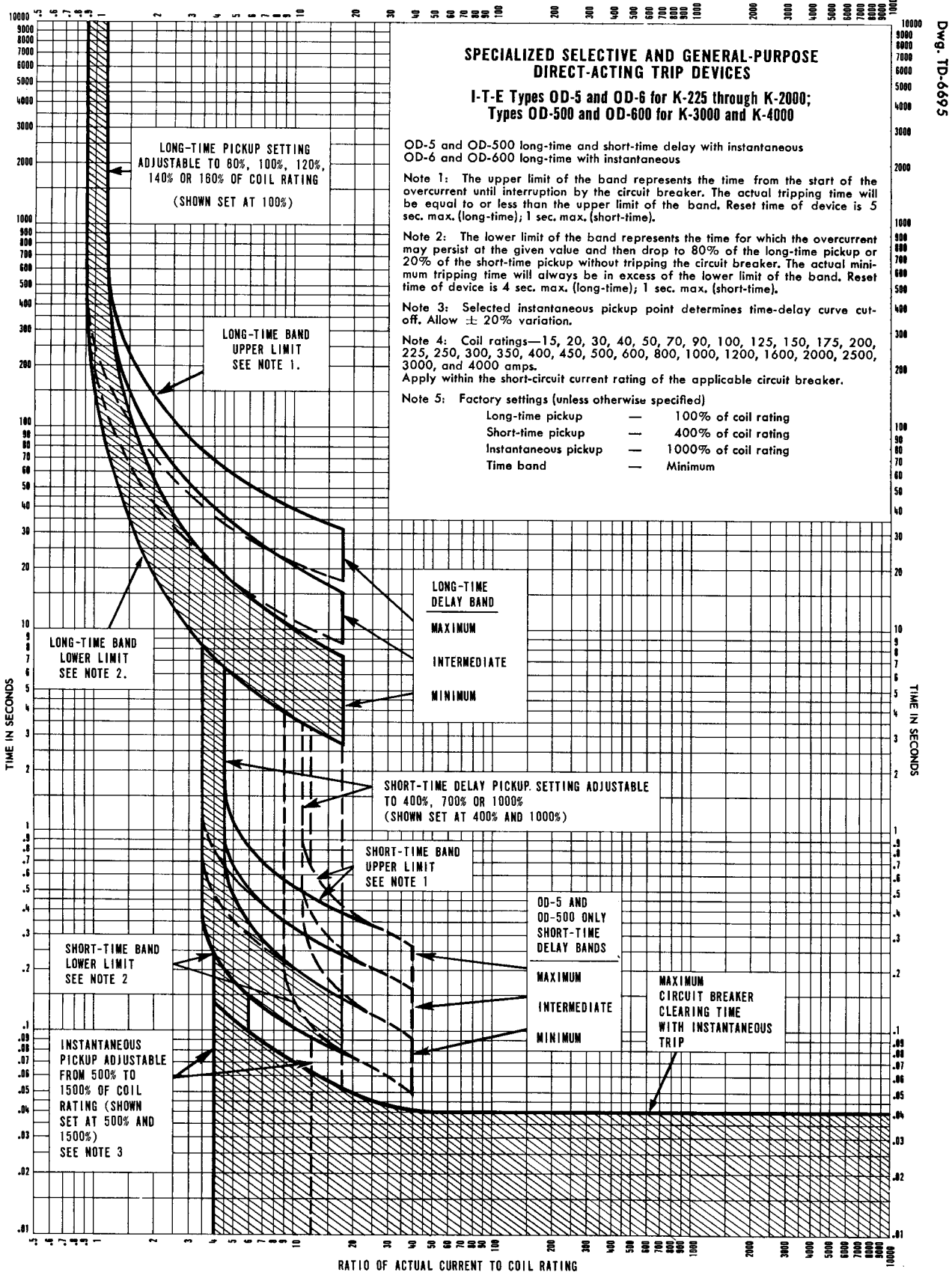
Note 4: Factory settings (unless otherwise specified): Long-time pickup-maximum continuous coil rating. Instantaneous pickup-values listed in column 3 of instantaneous section of above table.

Note 5: Apply coil rating within the short-circuit current rating of the applicable circuit breaker.



Dwg. TD-6693


Dwg. TD-6694
SELECTIVE DIRECT-ACTING TRIP DEVICES
I-T-E Types OD-4 for K-225 through K-2000, OD-400 for K-3000 and K-4000
Note 1: The upper limit of the band represents the time from the start of the overcurrent until interruption by the circuit breaker. The actual tripping time will be equal to or less than the upper limit of the band. Reset time of device is 5 sec. max. (long-time); 1 sec. max. (short-time).
Note 2: The lower limit of the band represents the time for which the overcurrent may persist at the given value and then drop to 80% of the long-time pickup or 20% of the short-time pickup without tripping the circuit breaker. The actual minumum tripping time will always be in excess of the lower limit of the band. Reset time of device is 4 sec. max. (long-time); 1 sec. max. (short-time).
Note 3. Coil Ratings—90, 100, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 800, 1000, 1200, 1600, 2000, 2500, 3000, and 4000 amps. Appy within the short-time rating of the applicable circuit breaker.
Note 4: Factory settings (unless otherwise specified)
Long-time pickup — 100% of coil rating
Short-time pickup — 400% of coil rating
Time bands — Minimum
LONG-TIME PICKUP SETTING ADJUSTABLE TO 80%, 100%, 120%, 140% OR 160% OF COIL RATING
(SHOWN SET AT 100%)
LONG-TIME BAND UPPER LIMIT SEE NOTE 1.
LONG-TIME BAND LOWER LIMIT SEE NOTE 2.
LONG-TIME DELAY BAND
MAXIMUM
INTERMEDIATE
MINIMUM
SHORT-TIME DELAY PICKUP SETTING ADJUSTABLE TO 400%, 700% OR 1000%
(SHOWN SET AT 400% AND 1000%)
SHORT-TIME BAND UPPER LIMIT SEE NOTE 1
SHORT-TIME BAND LOWER LIMIT SEE NOTE 2
SHORT-TIME DELAY BANDS
MAXIMUM
INTERMEDIATE
MINIMUM
TIME IN SECONDS
TIME IN SECONDS
RATIO OF ACTUAL CURRENT TO COIL RATING


SPECIALIZED SELECTIVE AND GENERAL-PURPOSE DIRECT-ACTING TRIP DEVICES
I-T-E Types OD-5 and OD-6 for K-225 through K-2000; Types OD-500 and OD-600 for K-3000 and K-4000
OD-5 and OD-500 long-time and short-time delay with instantaneous
OD-6 and OD-600 long-time with instantaneous
Note 1: The upper limit of the band represents the time from the start of the overcurrent until interruption by the circuit breaker. The actual tripping time will be equal to or less than the upper limit of the band. Reset time of device is 5 sec. max. (long-time); 1 sec. max. (short-time).
Note 2: The lower limit of the band represents the time for which the overcurrent may persist at the given value and then drop to 80% of the long-time pickup or 20% of the short-time pickup without tripping the circuit breaker. The actual minimum tripping time will always be in excess of the lower limit of the band. Reset time of device is 4 sec. max. (long-time); 1 sec. max. (short-time).
Note 3: Selected instantaneous pickup point determines time-delay curve cut-off. Allow ± 20% variation.
Note 4: Coil ratings—15, 20, 30, 40, 50, 70, 90, 100, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 800, 1000, 1200, 1600, 2000, 2500, 3000, and 4000 amps.
Apply within the short-circuit current rating of the applicable circuit breaker.
Note 5: Factory settings (unless otherwise specified)
Long-time pickup — 100% of coil rating
Short-time pickup — 400% of coil rating
Instantaneous pickup — 1000% of coil rating
Time band — Minimum
LONG-TIME PICKUP SETTING ADJUSTABLE TO 80%, 100%, 120%, 140% OR 160% OF COIL RATING (SHOWN SET AT 100%)
LONG-TIME BAND UPPER LIMIT SEE NOTE 1.
LONG-TIME BAND LOWER LIMIT SEE NOTE 2.
LONG-TIME DELAY BAND
MAXIMUM
INTERMEDIATE
MINIMUM
SHORT-TIME DELAY PICKUP SETTING ADJUSTABLE TO 400%, 700% OR 1000% (SHOWN SET AT 400% AND 1000%)
SHORT-TIME BAND UPPER LIMIT SEE NOTE 1
SHORT-TIME BAND LOWER LIMIT SEE NOTE 2
OD-5 AND OD-500 ONLY SHORT-TIME DELAY BANDS
MAXIMUM
INTERMEDIATE
MINIMUM
INSTANTANEOUS PICKUP ADJUSTABLE FROM 500% TO 1500% OF COIL RATING (SHOWN SET AT 500% AND 1500%) SEE NOTE 3
MAXIMUM CIRCUIT BREAKER CLEARING TIME WITH INSTANTANEOUS TRIP
TIME IN SECONDS
TIME IN SECONDS
RATIO OF ACTUAL CURRENT TO COIL RATING
Dwg. TD-6695