SECONDARY UNIT SUBSTATIONS

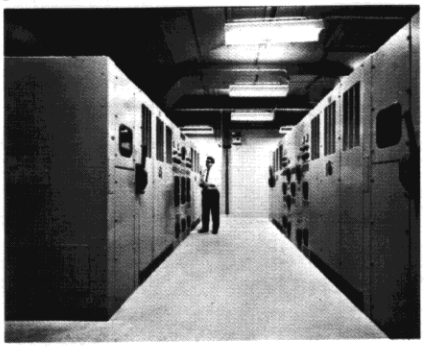
including Low-Voltage Metal-Enclosed Switchgear with Drawout K-LINE® and K-DON® Power Circuit Breakers

Bulletin 10.2–1C

112½ — 2500 kVA
Primary Voltage: 2.4 kV — 13.8 kV
Secondary Voltage: 208/120 — 600 Volts
Indoor or Outdoor Sheltered-Aisle, Walk-In
Liquid, Ventilated or Sealed-Dry Transformers

I-T-E SECONDARY UNIT SUBSTATIONS

Indoor Secondary Unit Substation consisting of Air Interrupter Switch, Askarel Transformer and Low-Voltage Switchgear.



Indoor Secondary Unit Substation consisting of Air Interrupter Switch, Ventilated-Dry Transformer and Low-Voltage Switchgear.

Outdoor Secondary Unit Substation installation.

WHAT IS A UNIT SUBSTATION?

A unit substation is a substation consisting primarily of one or more transformers which are mechanically and electrically connected to, and coordinated in design with, one or more switchgear or motor control assemblies, or combinations thereof.

SECONDARY UNIT SUBSTATION

A secondary unit substation is a unit substation in which the outgoing low-voltage section is rated below 1000 volts. Principal areas of application include use in industrial plants, electric power generating stations, and commercial buildings.

An articulated secondary unit substation is a common type of secondary unit substation consisting of:

- An incoming line section which provides for the connection of one or more incoming high-voltage circuits, each of which may or may not be provided with a switching device or a switching and interrupting device.
- A transformer section which includes one or more transformers.
- An outgoing section which provides for the connection of one or more outgoing feeders, each of which is provided with a switching and interrupting device.

These sections are normally subassemblies intended for connection in the field.

PURPOSE OF SECONDARY UNIT SUBSTATIONS

The trend towards location of electrical distribution systems close to the center of loads has become very prevalent in recent years. The secondary unit substation is compatible with this systems design concept because the wide array of components to select from allows tailoring it to your exact application needs. For example, the availability of askarel-filled and dry type transformers permit installation of secondary unit substations in buildings close to the load without the need of costly fire containment equipment. Secondary unit substations provide other benefits and advantages over older distribution methods:

- Reduced power losses.
- Improved continuity of service.
- Increased flexibility.
- Better voltage regulation.
- Less installation expense.
- Efficient space utilization.

FEATURES OF I-T-E SECONDARY UNIT SUBSTATIONS

I-T-E has been designing, engineering and manufacturing secondary unit substations since 1943. Throughout this long history of product manufacture, I-T-E has established itself as a reliable supplier of secondary unit substations. Some salient features of I-T-E secondary unit substations are:

- Lower transformer and switchgear weight.
- Reduced floor space.
- Increased personnel safety.
- Coordinated engineering.
- Simplified purchasing.
- Prompt delivery.
- Design flexibility.

INDEX — SECONDARY UNIT SUBSTATIONS

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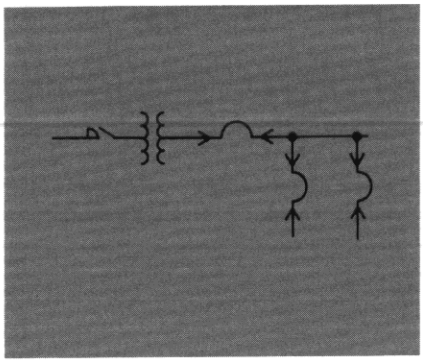
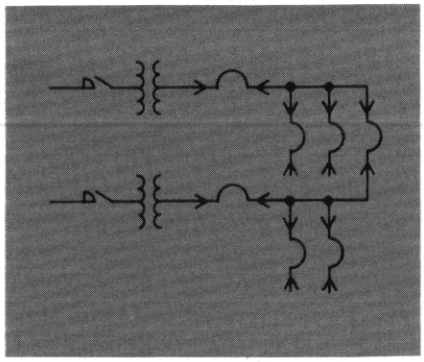
SELECT THE SYSTEM



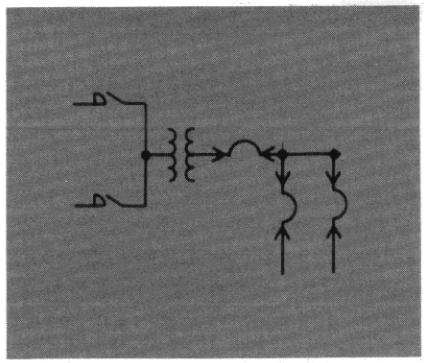
RADIAL

This system generally has a single incoming primary device, single stepdown transformer and an outgoing section for the connection of one or more outgoing power circuit breakers.



SECONDARY-SELECTIVE

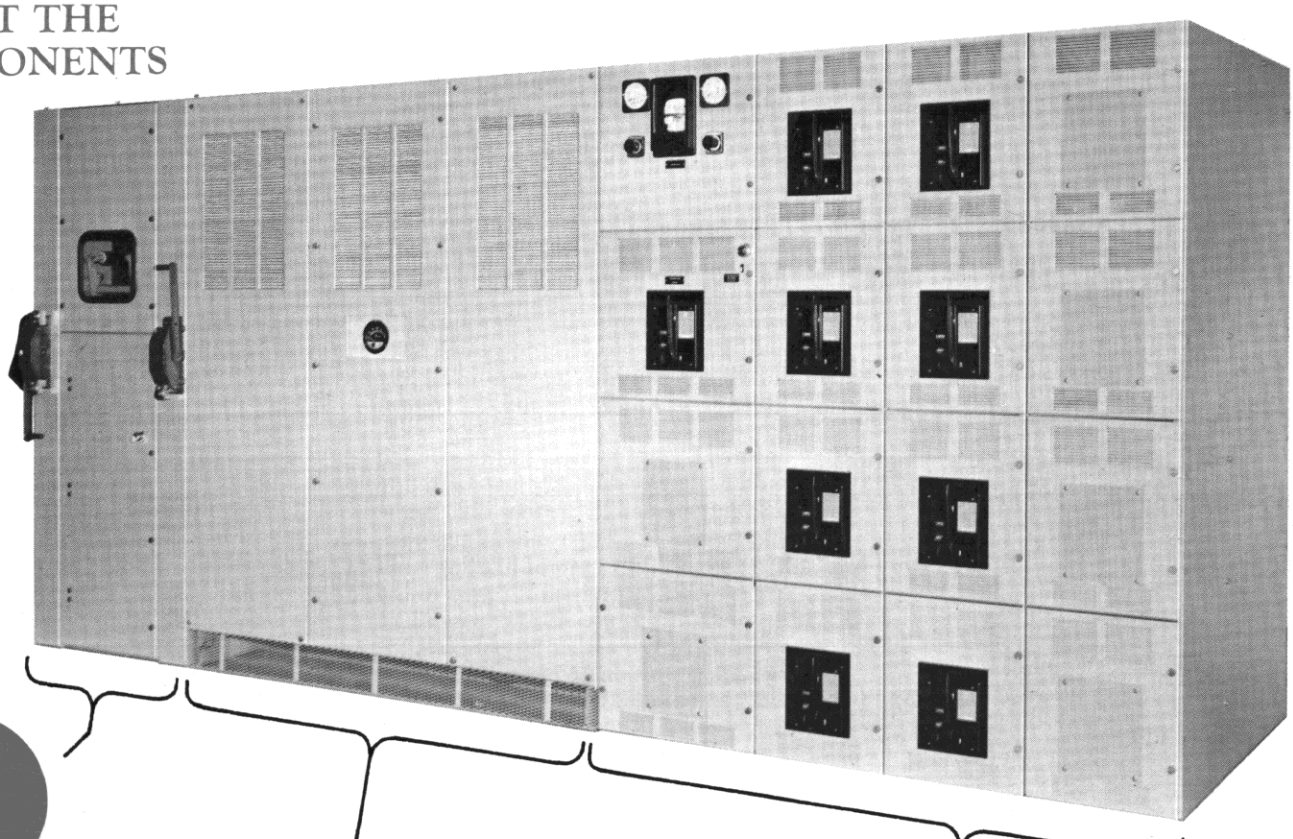
This system generally has two incoming primary devices and two stepdown transformers. The outgoing side of each transformer is connected to a separate bus through a power circuit breaker. The two sections of bus are connected by a normally open power circuit breaker. Each bus has one or more outgoing power circuit breakers.

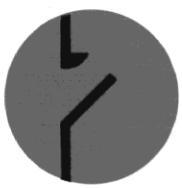


PRIMARY-SELECTIVE

This system contains two incoming primary devices connected to a single stepdown transformer and an outgoing section for the connection of one or more outgoing power circuit breakers.

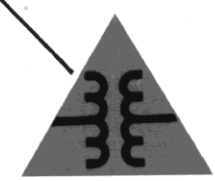
SELECT THE COMPONENTS





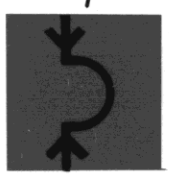
INCOMING LINE SECTION

Air Interrupter Switch
  Fused or Unfused
  Single or Duplex
Air Interrupter Selector Switch
  Fused or Unfused
Air Terminal Chamber
Liquid Interrupter or Disconnect Switch
Oil Cutouts
  Fused or Unfused
Metal-Clad Switchgear



TRANSFORMER SECTION

Liquid-Immersed
  Askarel
  Oil
Ventilated-Dry
Sealed-Dry, Gas-Filled



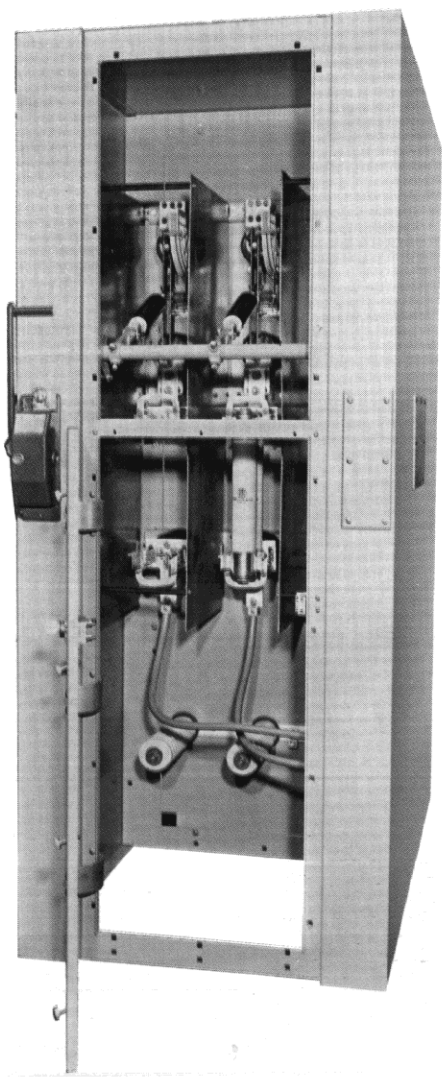
OUTGOING SECTION

Low-Voltage, Metal-Enclosed Switchgear
Drawout Air-Magnetic Power Circuit
  Breakers, Fused or Unfused
Plug-in Molded-Case Circuit Breakers

INCOMING LINE SECTION

TABLE 1 — AIR INTERRUPTER SWITCH RATINGS

Nominal Voltage Rating, kV	Maximum Continuous Current Rating, A	Fault Closing Rating, kA Asym.	
		Switch Unfused	Switch Fused
4.8	600	40	Fuse Interrupting Rating (see Table 35, Page 32)
7.2	600	40	
13.8	600	40	

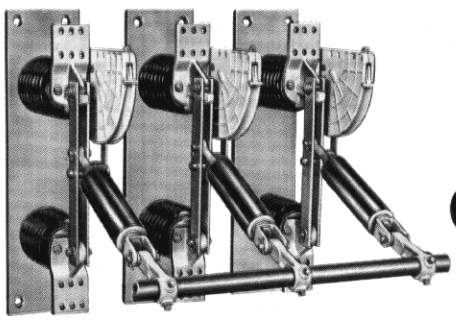


Indoor Air Interrupter Switch

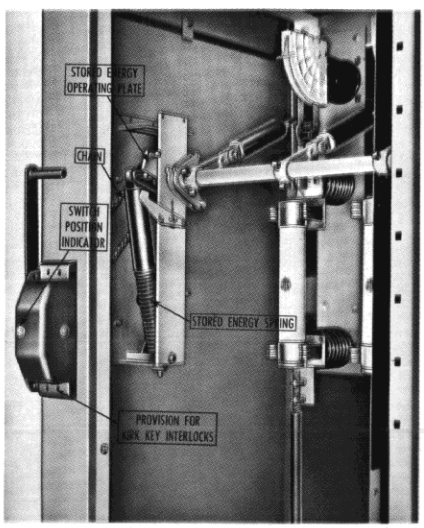
AIR INTERRUPTER SWITCH— SINGLE OR DUPLEX

The I-T-E type HPL-C air interrupter switch is a stationary mounted, three-pole, two-position (on-off) device which utilizes a snap-action quick-make, quick-break blade in combination with an arc chute for safe closing and interruption. It is available with or without current-limiting fuses. Visual indication through the safety-glass front window and on the handle mechanism shows the blade position. Fused switches are Kirk™ key interlocked to prevent opening of the fuse door while the switch is in the closed position. I-T-E type CL-13 current-limiting fuses are provided as standard. Fused or unfused switches are available with or without lightning arresters, can be equipped with cable lugs or potheads, and can be arranged for top or bottom entrance. (Lightning arresters are required for use with ventilated-dry type transformers).

Duplex switches are also available, consisting of two Kirk key-interlocked switches located side by side. These various switch assemblies are available in both indoor and outdoor construction, and can be applied to Secondary Selective or Primary Selective Systems.



Three-Phase HPL-C Switch Assembly.



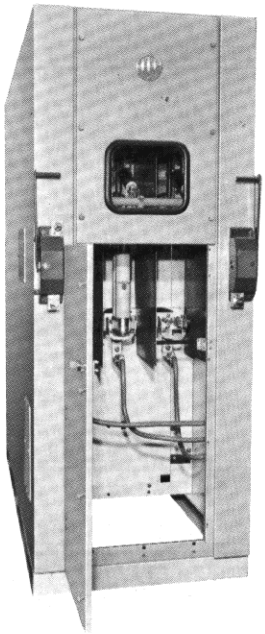
Stored-Energy Operating Mechanism.

Note: For complete information on HPL-C switches see I-T-E Bulletin 1630-1; for CL-13 fuses see I-T-E Bulletin 14.1-1.

AIR INTERRUPTER SELECTOR SWITCH

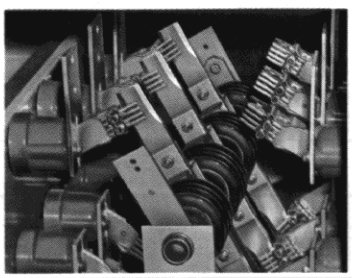
The air interrupter selector switch consists of a stationary rear-mounted, three-pole, two-position (Line 1—Line 2) switch, in series with a three-pole, two position (on-off) I-T-E type HPL-C interrupter switch. Visual indication on the front-mounted handle mechanism indicates Line 1 or Line 2.

The selector switch is Kirk™ key interlocked with the interrupter switch to prevent switching of lines with the load connected.

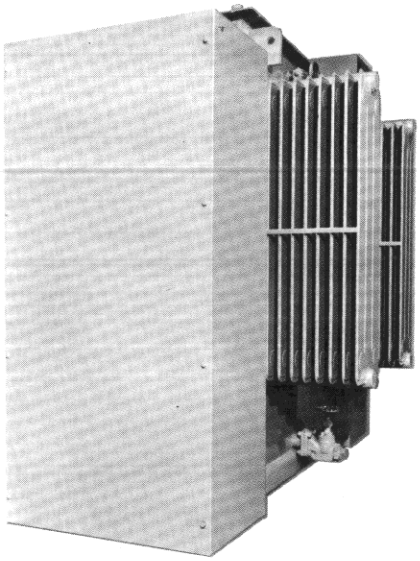


Fused arrangements are Kirk key interlocked to prevent opening of the fuse door while the interrupter switch is in the closed position. I-T-E type CL-13 current-limiting fuses are provided as standard. Fused or unfused switches are available with or without lightning arresters. Equipment may be supplied with cable lugs or potheads and arranged for top or bottom entrance. (Lightning arresters are required for use with ventilated-dry type transformers.

The selector arrangement is available in both indoor and outdoor construction, and is generally installed in Primary Selective systems.

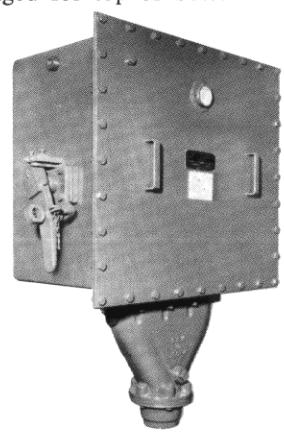


Cutaway of 3-pole selector switch shows blade positioned for connection to one incoming line.



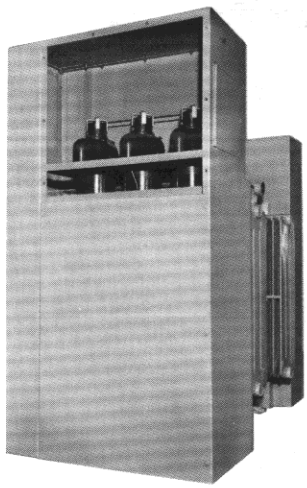
AIR TERMINAL CHAMBERS

Floor-mounted air terminal chambers come equipped with cable lugs or potheads and are directly connected to the high-voltage side of the transformer. They are available in indoor or outdoor construction, and can be arranged for top or bottom entrance.



LIQUID INTERRUPTER OR DISCONNECT SWITCH (OIL-ASKAREL)

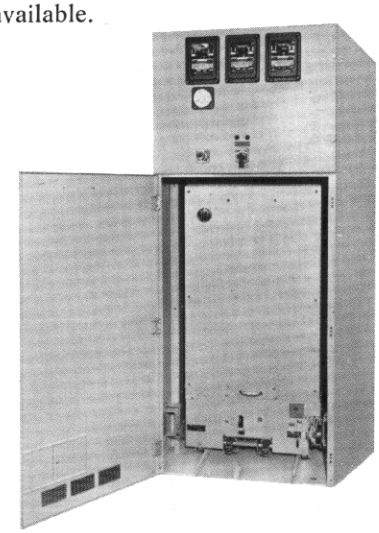
These switches can be provided on liquid-immersed transformers only. They are three-pole, two- or three-position assemblies. The switch enclosure is welded or bolted directly to the transformer tank. When oil filled, the switch can interrupt load currents up to 400 amperes. When filled with askarel, the switch has no interrupting capacity, but can be used as a disconnect switch to break magnetizing currents up to 10 amperes for five operations. After this the askarel must be replaced. Potheads are always provided for cable terminations. Oil or askarel is shipped in a separate container to eliminate the need of draining the switch to make cable connections.



OIL CUTOUTS— FUSED OR UNFUSED

Oil cutouts are supplied mounted in an air terminal chamber and have provisions for terminating one three-phase incoming cable. When fused, application of oil cutouts are limited to 500kVA at 2400 volts and 750kVA at 4160 volts and 1000kVA at 13.8kV. Unfused application as disconnects are limited to 750kVA at 2400 volts or 1000kVA at 4160 volts and 2000kVA at 13.8kV. Values are based on applying fuses at twice the full-load current rating of the transformer.

Indoor or outdoor construction is available.



METAL-CLAD SWITCHGEAR

For the ultimate in primary protection and personnel safety, specify I-T-E type HK metal-clad switchgear with stored-energy, drawout power circuit breakers.

HK switchgear is available for systems ratings of 4.16, 7.2 and 13.8kV, 75 to 1000MVA. For complete information on this type equipment, refer to I-T-E Bulletin 8.2-1.

TRANSFORMER SECTION

GENERAL

A complete line of secondary unit substation transformers is offered by I-T-E. Table 2 lists standard transformer ratings for the liquid-immersed (oil or askarel), ventilated-dry and sealed-dry units. Transformer dimensions and weights are given on pages 27 through 29. Additional application data may be found on page 34.

LIQUID-IMMERSED TRANSFORMERS

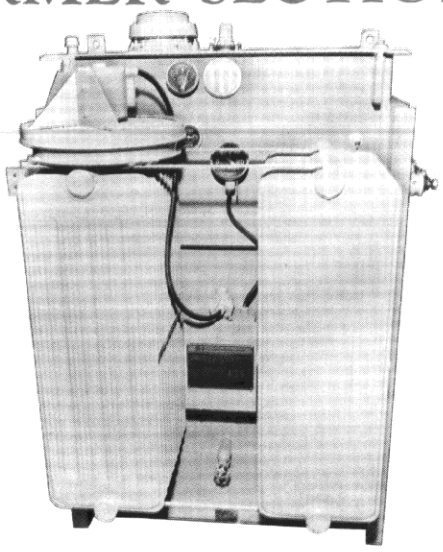
Liquid-immersed transformers have their core and coil immersed in either a flammable mineral oil or askarel—a synthetic nonflammable insulating liquid which, when decomposed by an electric arc, evolves only non-explosive gaseous mixtures. The oil-immersed transformer is generally applied outdoors to guard against possible fire hazard. If used indoors, the transformer should be located in a fire vault. It is operated at 65°C rise and features lighter weight and compact size, with an improved radiator design for more efficient cooling. The askarel-immersed transformer is similar in construction and features to the oil-immersed type, except for the insulating liquid. It is intended primarily for indoor application, but can be used outdoors near building walls or on roofs.

VENTILATED-DRY TRANSFORMER

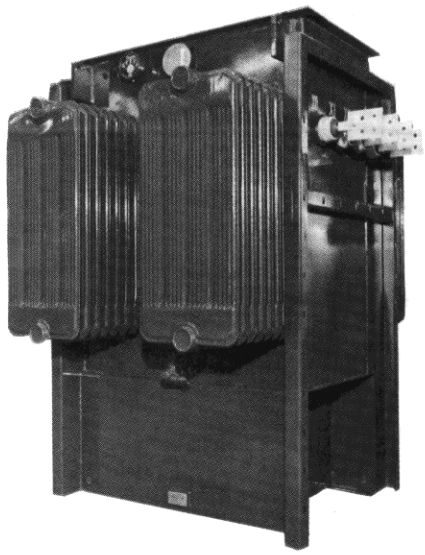
A ventilated-dry transformer is one in which the windings are freely ventilated to the air outside the transformer enclosure. I-T-E ventilated-dry transformers utilize a superior moisture-resistant insulation system designed to operate at 150°C rise. Other features of ventilated-dry transformers are reduced size and weight; and, fire, explosion and toxic resistance.

SEALED-DRY TRANSFORMER

The windings of standard I-T-E sealed-dry transformers are immersed in a fluorocarbon gas, C_2F_6, which is contained in a sealed tank which prevents intermingling with outside air. The gas acts as an efficient heat transfer and dielectric medium. Sealed-dry transformers are generally applied indoors but can be utilized outdoors if there is no exposure to lightning, and assuming adequate protection against excessive impulse voltage is provided.



Indoor (Askarel)



Outdoor (Oil)

LIQUID-IMMERSED TRANSFORMERS

- Lighter weight
- Less floor space
- Constant bushing height
- Proven radiator design
- Proven insulation system
- Low operating temperature
- Minimum losses
- Low sound level

TABLE 2 — STANDARD TRANSFORMER RATINGS

TYPE	Primary Voltage Delta	kVA 3-Phase Self-Cooled	kVA 3-Phase Forced-Air Cooled	SECONDARY VOLTAGE 208Y/120 240 delta	SECONDARY VOLTAGE 480Y/277 480 delta	Standard Impedance*	NEMA Sound Level, db Self-Cooled	NEMA Sound Level, db Forced-Air Cooled
Liquid-Immersed Oil or Askarel 65°C Rise †	2400	112½	—	x	x	2.25‡	55	—
	4160	150	—	x	x	3.0‡	55	—
	4800	225	—	x	x	4.5	55	—
	6900	300	—	x	x	5.0	55	—
	7200	500	—	x	x	5.0	56	—
	12000	750	862	x	x	5.75	58	67
	12470	1000	1150	x	x	5.75	58	67
	13200	1000	1150		x	8.0	58	67
	13800	1500	1725		x	5.75	60	67
		2000	2300		x	5.75	61	67
		2500	3125		x	5.75	62	67
Ventilated-Dry 150°C Rise †	2400	112½	—	x	x	3.0‡	50	—
	4160	150	—	x	x	3.5‡	50	—
	4800	225	—	x	x	4.5	55	—
	6900	300	—	x	x	5.0	55	—
	7200	500	667	x	x	5.0	60	67
	12000	750	1000	x	x	5.75	64	67
	12470	1000	1333	x	x	5.75	64	68
	13200	1000	1333		x	8.0	64	68
	13800	1500	2000		x	5.75	65	69
		2000	2666		x	5.75	66	71
		2500	3333		x	5.75	68	71
Sealed-Dry Hexafluoro-ethane (C_2F_6) Gas-Filled 150°C Rise †	2400	300		x	x	5.0	57	—
	4160	500		x	x	5.0	59	—
	4800	750		x	x	5.75	63	—
	6900	1000		x	x	5.75	63	—
	7200	1000	—		x	8.0	63	—
	12000	1500			x	5.75	64	—
	12470	2000			x	5.75	65	—
	13200	2500			x	5.75	66	—
	13800							

* Standard impedance tolerance is ±7½%.

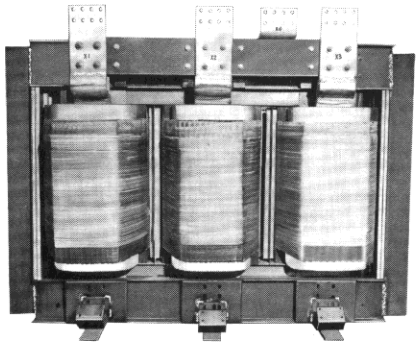
† Average ambient temperature of 30°C.

‡ Transformers with impedances of 4.0% or less are designed to withstand 25 times normal current for two seconds.

CHARACTERISTICS COMPARISON

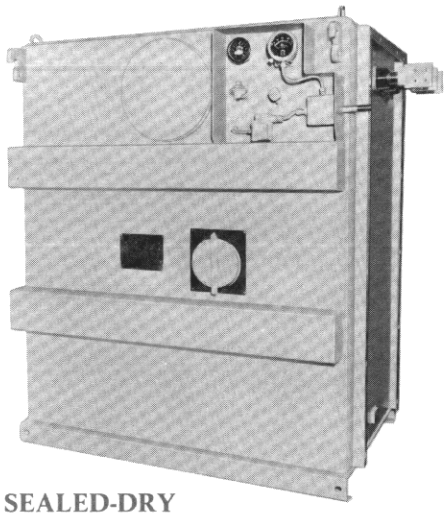
Table 3 below provides an easily comprehensible framework for comparing pertinent capabilities of liquid-immersed, ventilated-dry and sealed-dry transformers. A standard oil-immersed transformer rated 1500 kVA, 13.8 kV to 480 volt, was chosen as the base transformer because of its common usage in secondary unit substations. Approximate values of various base transformer characteristics are as follows:

Sound level (self-cooled)—60db
Weight—8,600 lbs.
Floor space—53″ Wide x 87″ Deep
Height—82½ inches



VENTILATED-DRY TRANSFORMER

- Moisture-resistant insulating materials
- Reduced size and weight
- Indoor application
- Toxic resistant
- Fire and explosion resistant



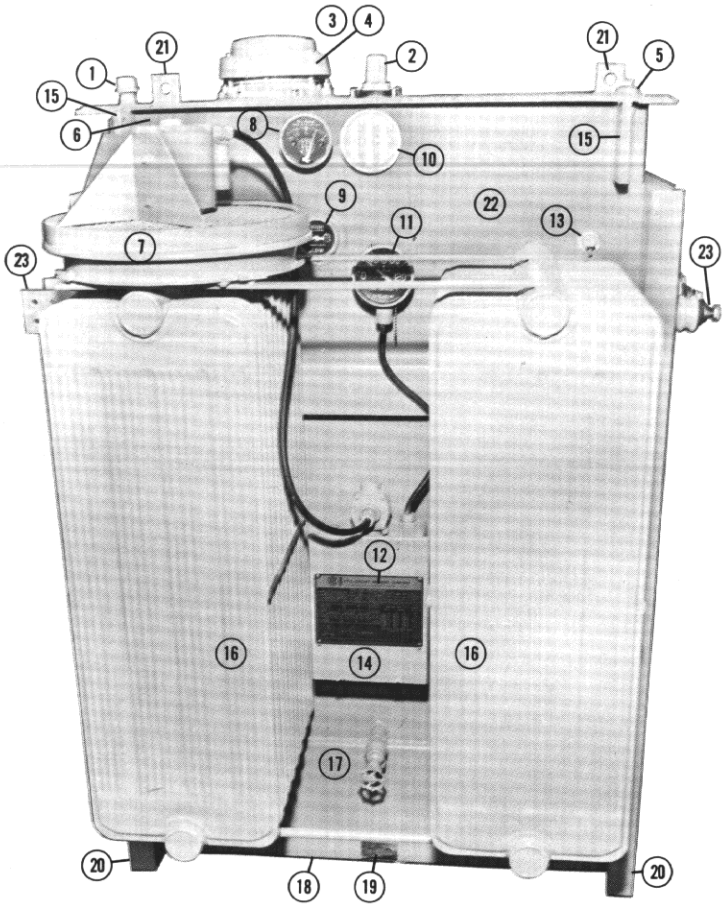
SEALED-DRY TRANSFORMER

- Hexafluoroethane gas (C_2F_6)
- Higher dielectric
- Higher impulse levels
- Faster heat transfer
- Minimum maintenance
- Compact design
- Toxic resistant
- Fire and explosion resistant

TABLE 3 — COMPARISON OF CHARACTERISTICS OF LIQUID-IMMERSED AND DRY-TYPE TRANSFORMERS
1500 kVA, 15 kV to 480 Volts, Oil-Immersed Transformer as Base (See above)

Characteristics	Liquid-Immersed 65°C Rise		Ventilated-Dry 150°C Rise	Sealed-Dry 150°C Rise
	Oil	Askarel	Air	Gas (C_2F_6)
Insulation Type	Class A	Class A	Class H	Class H
Impulse Strength	95 kV	95 kV	50 kV	95 kV
Losses @ operating temp.* No Load Full Load	 100% 100%	 100% 100%	 185% 134%	 150% 113%
Maximum Voltage Class	15 kV	15 kV	15 kV	15 kV
Temperature Ratings: Average Rise°, C Hottest Spot Rise°, C	 65 80	 65 80	 150 180	 150 180
Sound Level	100%	100%	108%	106%
Weights	100%	120%	75%	133%
Dimensions: Floor Space Height	100% 100%	100% 102%	80% 109%	110% 122%
Application: Indoor, Outdoor	Indoor (vault only) Outdoor	Indoor Outdoor	Indoor	Indoor Outdoor†
Fire, Explosion Resistant	No	Yes	Yes	Yes
Toxic Resistant	No	No	Yes	Yes
Maintenance: Liquid Cleaning Internal External	Yes No Normal	Yes No Normal	No Yes Occasionally	No No Minimum
Precautions before energizing after shutdown to dry insulation	None	None	Yes	None
Cost	100%	125%	125%	200%

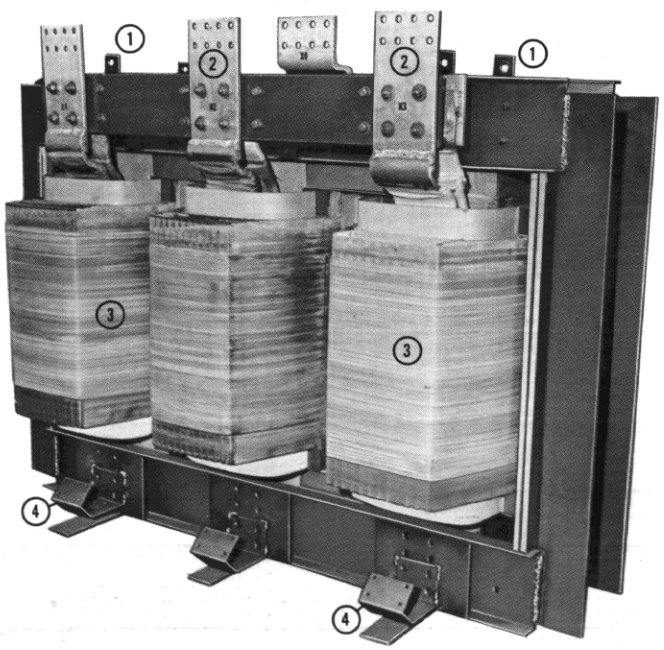
Note: Values stated are approximate average and subject to variation with kVA size, kV rating, etc.
* Operating temperatures: 85°C for liquid, 170°C for ventilated and sealed-dry types.
† Applicable for all types of installations assuming no exposure to lightning, and assuming adequate protection against impulse voltage.



Askarel-Immersed
Transformer-Indoor

LIQUID-IMMERSED TRANSFORMERS

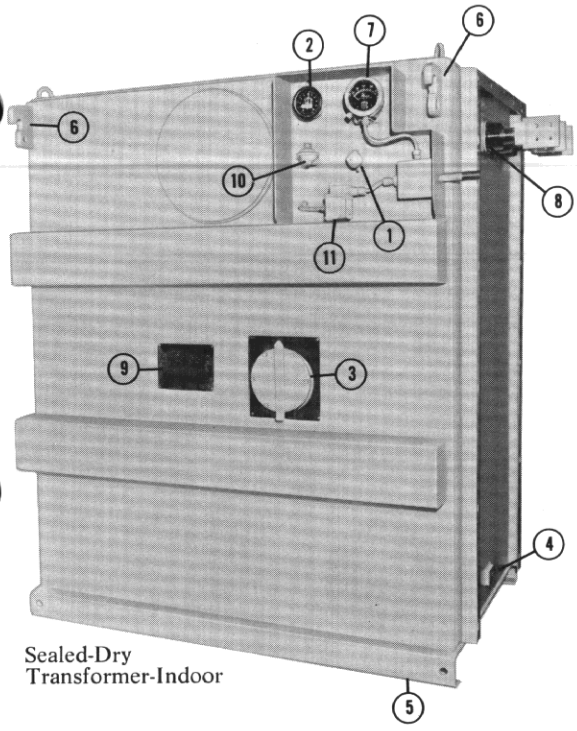
① 1″ fill pipe and filter-press connection
② Tap-changer handle
③ Handhole (not shown)
④ Mechanical relief device (Askarel only)
⑤ 1″ vent plug
⑥ Pressure test device (not shown)
⑦ Fan (optional)
⑧ Pressure-vacuum gauge
⑨ Magnetic liquid-level gauge
⑩ I-T-E monogram
⑪ Dial-type thermometer
⑫ Diagrammatic nameplate
⑬ Liquid sampling valve (Askarel only)
⑭ Terminal box for fan control (optional)
⑮ Transformer lifting eyes
⑯ Radiators
⑰ 1″ drain valve and sampling device (Oil only)
⑱ Base for jacking and skidding
⑲ Ground pad
⑳ Close-coupled molding
㉑ Lifting eyes for cover only
㉒ Tank
㉓ Low-voltage terminals



Ventilated-Dry
Transformer
Core and Coils Only

VENTILATED-DRY TRANSFORMERS

① Lifting eyes on upper core clamp
② Secondary low-voltage connections
③ High-voltage winding
④ Mounting provisions for future fans



Sealed-Dry
Transformer-Indoor

SEALED-DRY TRANSFORMERS

① Filling and sampling valve
② Pressure-vacuum gauge
③ No-load, externally-operated tap changer*
④ Ground pad
⑤ Skid base with provision for jacking and towing
⑥ Transformer lifting hooks
⑦ Hot-spot indicator (optional)
⑧ Hermetically-sealed bushings
⑨ Diagrammatic nameplate
⑩ Pressure-relief valve
⑪ Pressure switch

*Accessible under sealed cover

Typical Radiator Fan Installation—
Liquid-Immersed Transformer.

PROVISIONS FOR FUTURE FORCED-AIR COOLING

All liquid-immersed transformers, 750kVA and above, and ventilated-dry transformers 500kVA and above, have provisions for the future installations of fans for forced-air cooled operation.
These provisions include:

1. Full forced-air cooled capacity in all current-carrying parts, including high-and low-voltage bushings.
2. Provision for mounting the balance of required equipment in the field.
3. Provision for the future automatic control of the fans as follows:
   a. Liquid-immersed units—provision for incorporating the thermometer relay for control of the future fans from top liquid temperature.
   b. Ventilated-dry units—provision only for mounting winding-temperature relay for control of future fans.

STANDARD PRODUCTION ELECTRICAL TESTS

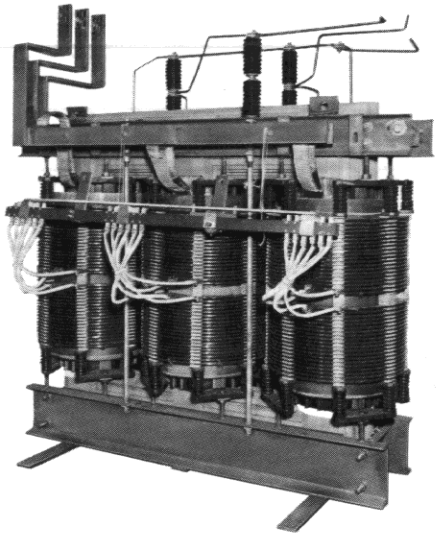
Winding resistance test
Ratio test
Polarity and phase-relation test
No-load loss test
Excitation current test
Impedance and load-loss test
Applied potential test
Induced potential test

OPTIONAL ACCESSORIES

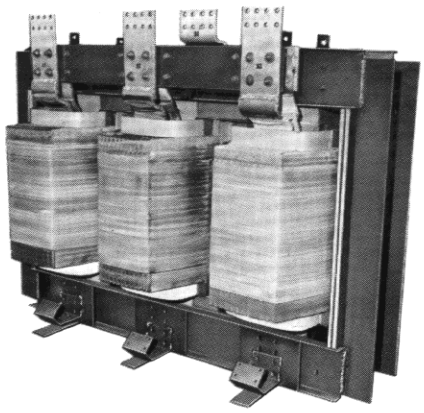
Winding-temperature equipment
Gas absorbers for askarel-filled transformers
Tap changer interlocks for liquid-immersed and sealed-dry transformers
Alarm contacts for:
  Thermometer
  Liquid-level gauges
  Pressure-relief device
Sudden-pressure relay on liquid-immersed transformers

DETAILS OF CONSTRUCTION—LIQUID-IMMERSED AND DRY TRANSFORMERS

Core Assembly—Liquid-Immersed Transformer



Core and Coils—Sealed-Dry Transformer



Core and Coils—Ventilated-Dry Transformer

CORE CONSTRUCTION

The core of each I-T-E transformer is made of non-aging, high-permeability, grain-oriented, cold-rolled, silicon steel specifically processed for consistently low losses.

The thin-gauge laminations are sheared with special high-quality shear blades in such a manner that the flux path will be aligned with the axis of highest permeability in the steel. Each lamination is flat and free from burrs and is inorganically insulated on both surfaces to minimize eddy-current loss.

Laminations are hand stacked on a specially designed tables which ensures flatness and prevents the introduction of bending stresses while the finished core is being set in an upright position. Careful positioning of each lamination produces close fitting lap and butt joints to further minimize core loss and noise.

Core legs are assemblies of laminations with cross sections designed to accommodate the coils with the optimum combination of high space factor and coolant flow.

The upper and lower core yokes are rigidly clamped by welded assemblies of steel members consistent with bracing and supporting requirements. Core clamps are chemically cleaned to remove any dirt or impurities from the forming and welding operations. This assures that only clean, bright metal will be in contact with the cooling medium. Core clamps on ventilated-dry transformers are steel grit blasted to remove mill scale and slag. Then the core assembly is painted to insure against oxidation. Core clamps and all structural parts are insulated to prevent local circulating currents and are solidly bonded to ground and to the core to prevent development of potential in any part.

COIL CONSTRUCTION

I-T-E regards the coils as the most important part of the transformer. The coil is of rectangular construction with sheet-wound aluminum secondary windings and insulated, wire-wound primary windings. This construction meets the following requirements:

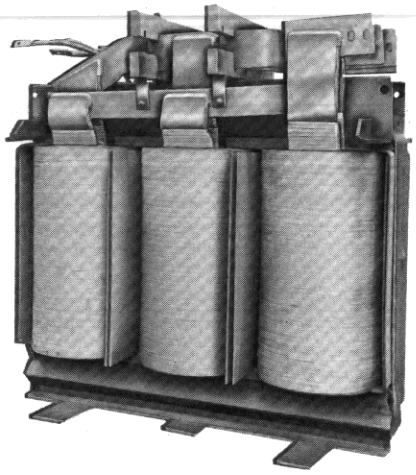
STRESSES—Axial short-circuit stresses are virtually eliminated by the use of sheet-wound secondary and wire-wound primary windings with no interleaved components. I-T-E coils are, therefore, wound with the secondary coil nearest the core and supported by a strong insulating cylinder. The primary coil is then wound on top of the secondary coil. A suitable insulating full-length barrier is provided between the two coils, consisting of spacers and sheet insulation built up to the proper thickness. The coil wire is wound tightly and uniformly thru a tension device to insure maximum strength.

COOLING—The coils are equipped with cooling channels in order to dissipate the heat generated in the coils. This is accomplished by insertion of corrugated or other suitable duct-spacing material, depending on design.

CURRENT CARRYING ABILITY—The current density in the individual conductors of the coil is not greater than permitted by the proper cooling of the coil. Secondary coils are made of sheet conductor properly insulated to maintain maximum efficiency and cooling.

TAPS—Tap leads or terminals are secured to the winding at their proper location, without breaking the continuity of the winding.

LIQUID-IMMERSED TRANSFORMERS



Core and Coils—Liquid-Immersed Transformer

INSULATING MATERIAL

All insulating materials used have been thoroughly tested and proven with respect to their electrical and mechanical characteristics and are stable at operating temperatures and compatible with the cooling medium.

In liquid-filled transformers, the insulation system is thermally upgraded. It is chemically modified to resist the effects of high temperature. The improved insulation enables the new, compact transformers to maintain full load-carrying ability at their higher operating temperature without affecting life expectancy.

Thermally-upgraded pressboard insulation is used for coil spacers, both longitudinal and radial, as well as ends. It is also used between layers and between high- and low-voltage coils. The porosity of the insulating materials permits the insulating liquid to penetrate the insulating materials giving it a high dielectric strength.

Figure 1 below compares the absolute value of toughness, measured in inch-pounds, of thermally-upgraded insulation and untreated electrical-grade kraft.

As shown by the curve, the initial toughness of the new insulation after drying and oil impregnating is 97% higher than that of electrical-grade kraft, and a substantial improvement in toughness is maintained during aging at 150°C.

TRANSFORMER SUPERSTRUCTURE

The superstructure consists of the secondary bus bars with their associated connections to the secondary coil leads, the tap changer and the supporting channels for the primary leads. Secondary bus bars are held in alignment by wooden spacers. Through-bolts bind the spacers securely together. The primary leads are supported in pressboard channels.

The complete superstructure is preassembled and installed on the transformer.

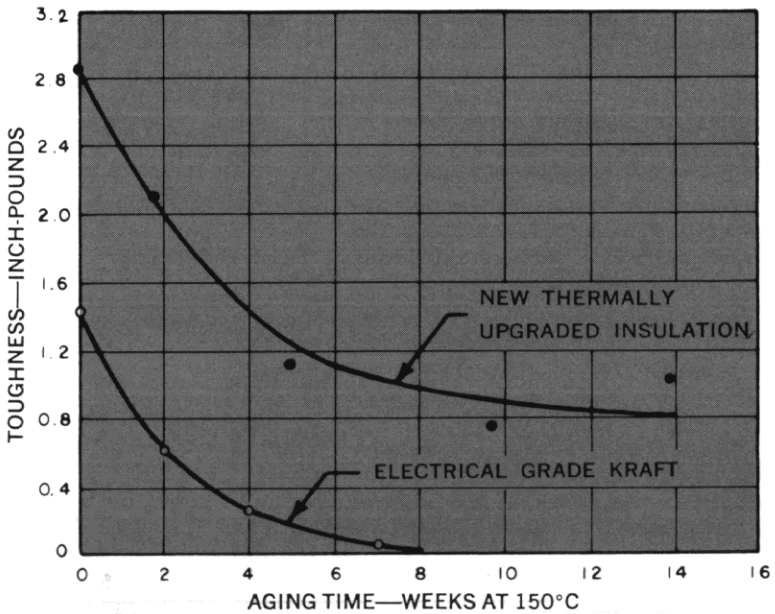
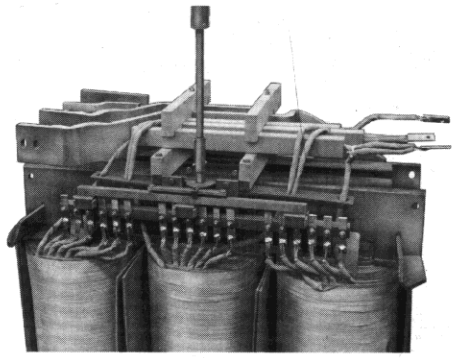


Figure 1—Comparison of absolute values for toughness of new thermally-upgraded insulation vs electrical-grade kraft

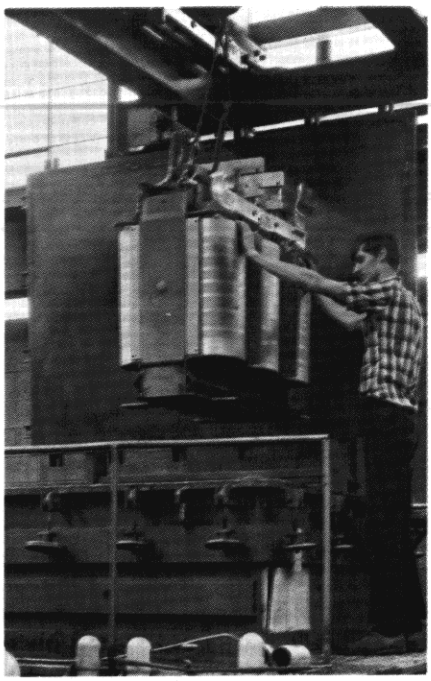


Tap Changer—Liquid-Immersed Transformer

TAP CHANGER

The tap changer is the in-line type, consisting of an insulated bar on which are mounted three-sets of six stationary contacts. Bridging two stationary contacts of each set are two self-aligning, spring-loaded movable contacts. The movable contacts are driven by a common insulated bar by means of a gear and rack thru an externally-operated, tap-changer handle.

LIQUID-IMMERSED TRANSFORMER

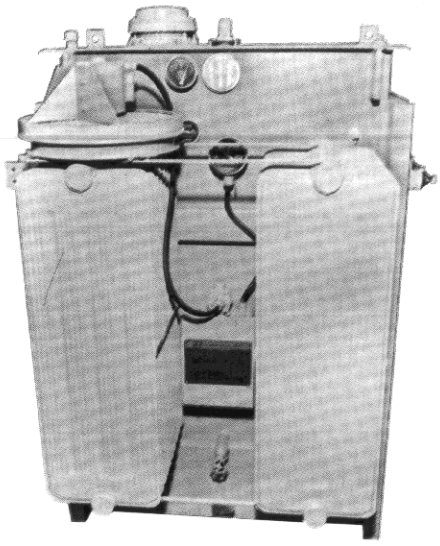


DRYING OF CORE AND COIL

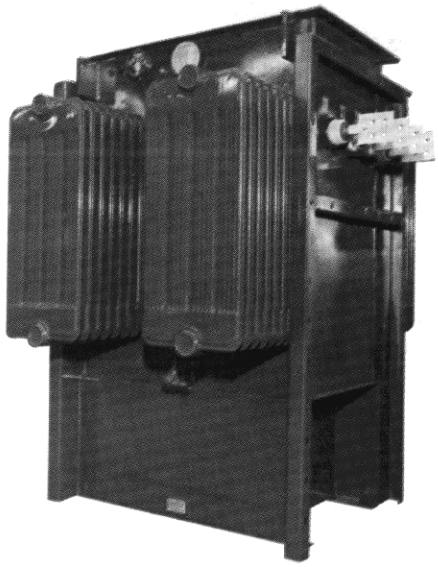
An important step in the manufacturing process of liquid-immersed transformers is the drying of the core and coil assembly prior to tanking. The core and coil is heated in an oven to 105°C.

During the drying, the insulating materials give up moisture and therefore shrink in dimensions. While the core and coil are still hot, the core and coil clamping fixture is tightened and the core is welded solidly together.

The core and coil assembly is then vacuum impregnated in an insulation liquid, to fill all voids and remove any remaining moisture. It is then lowered into its tank and the connection between coil and core and tank are then made. The braces to the tank are secured and the tank is filled with liquid while the transformer is still warm. The cover is welded in place and the transformer is ready for tests.



Askarel-Immersed Transformer—Indoor



Oil-Immersed Transformer—Outdoor

TANK

The transformer tank is fabricated of heavy-gauge steel plates. A minimum number of plates are used to reduce the number of welded seams.

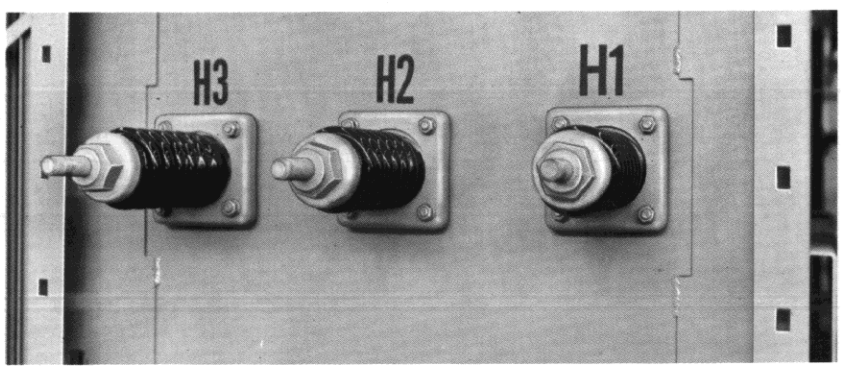
The tank base is fabricated of formed steel to receive and transmit the core and coil weight to the mounting pad or foundation and provides for skidding or rolling in any direction. Facilities for jacking are at the ends of the base.

Formed structural members are welded to the side walls so that the complete tank will be sufficiently reinforced to withstand a test of 7.5 pounds per square inch pressure. This will prevent permanent tank distortion during operation or pressure testing. The top of the tank is further strengthened by a flange which is used as a welding ring for securing the tank cover. An asbestos-type gasket is provided between the reinforced cover and the top flange and is compressed during the welding operation to prevent weld spatter from entering the tank. Lifting hooks are provided at the corners of the tank to permit the finished transformer, complete with liquid, to be handled by a crane.

Adequate radiation surface is provided by radiators to assure that the temperature rise of the cooling liquid will not exceed the specified limit when the transformer is continuously operated at rated full load.

The entire tank is chemically cleaned before painting to remove any oil, dirt or other impurities from the forming and welding operation. Each tank is painted with a rust inhibiter prime coat and two finish coats in accordance with ANSI standards. The use of individual mounted porcelain bushings, bolted and gasketed to the tank wall, assures reliable leak-free service. They are easily externally removed from the tank for transformer maintenance.

Porcelain bushings



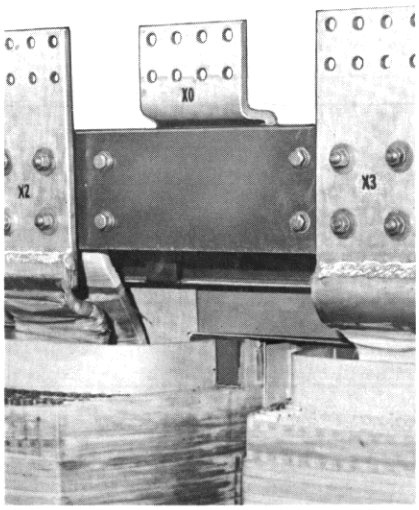
INSULATING MATERIAL

All insulating materials used have been thoroughly tested and proven with respect to their electrical and mechanical characteristics and are stable at operating temperatures and compatible with the cooling medium. In dry-type 150°C transformers, the wire is paper wrapped. Spacers and packout are suitable class H materials. Layer insulation is Nomex M and mica. These insulation materials will withstand the high operating temperature permitted in this type of transformer.

IMPREGNATION OF COILS

All coils are first dried in spring-loaded compression fixtures in temperature-controlled ovens to relieve stresses and assure proper dimensions. They are next impregnated with silicone varnish under vacuum. The vacuum helps avoid tiny air pockets where corona might start, or where moisture and dirt might penetrate the coils and coil insulation. It gives the highest dielectric strength possible. Finally they are returned to the ovens to give the varnish a thorough curing.

VENTILATED-DRY

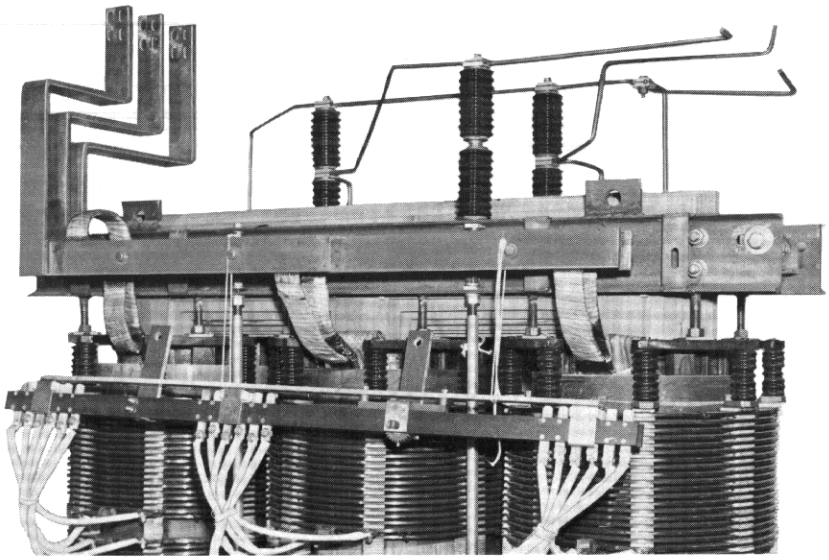


Bus Assembly—Ventilated-Dry Transformer

BUS ASSEMBLY

The low-voltage bus is mounted to the upper core clamp of the transformer. The primary connections from the high-voltage compartment are made directly to a terminal board. Tap connections are changed manually.

SEALED-DRY



Tap Changer and Internal Bus Assembly

BUS ASSEMBLY

A superstructure, mounted on the transformer upper core clamp, contains all of the secondary and primary bus and associated insulators and connections to the high- and low-voltage coil leads. Both high- and low-voltage bus ends are then clamped or bolted to the transformer bushings.

TAP CHANGER

The tap changer is the in-line type similar in construction to that used on liquid-immersed transformers. It is operated through an externally-operated mechanism which prevents the loss of pressure.

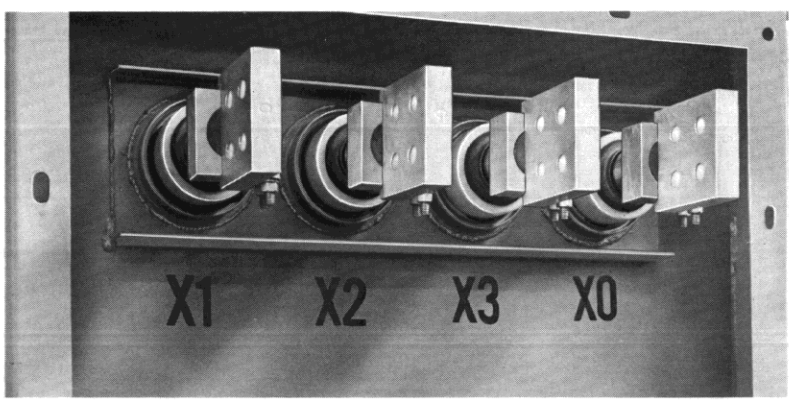
C_2F_6 FLUOROCARBON GAS

The new hexafluoroethane (C_2F_6) gas has a dielectric strength of approximately 2.8 compared with air as a base of 1.0. This higher dielectric strength results in higher basic impulse levels than nitrogen-filled or ventilated-dry type units.

As a heat-transfer medium, the higher molecular weight and lower viscosity of hexafluoroethane make it more efficient than nitrogen. This results in faster heat transfer from the transformer core and coils to the tank walls and permits a lighter, more compact design.

TANK

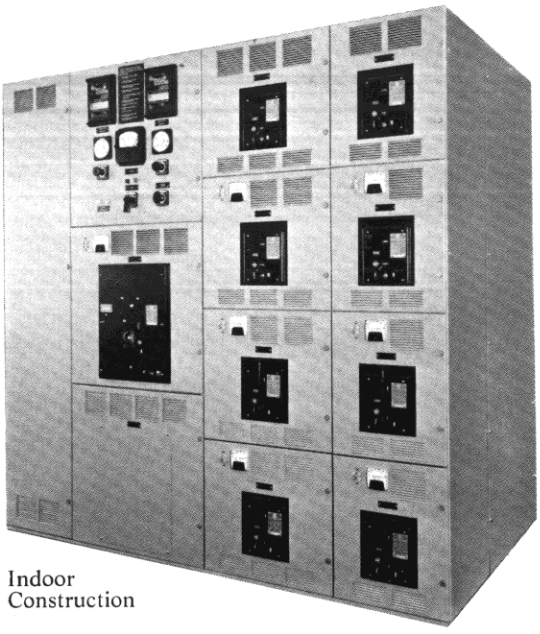
The tank on the sealed-dry transformer is similar in construction to the liquid-immersed type. It, however, is designed to withstand 15 lbs. pressure or vacuum. Other features include: protected instrumentation, external stiffeners and hermetically-sealed glass bushings.



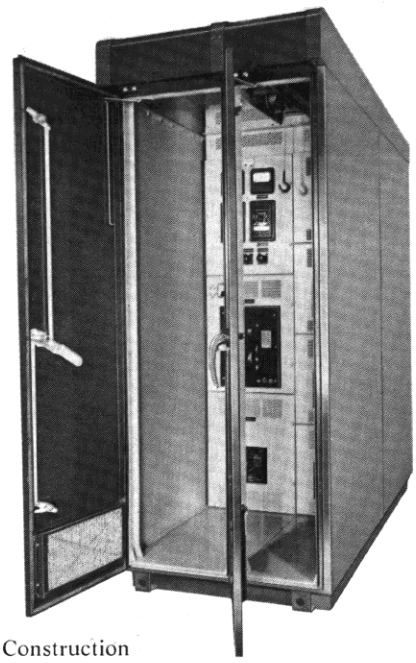
Glass bushings

OUTGOING SECTION

LOW-VOLTAGE SWITCHBOARD



Indoor Construction



Weatherproof Walk-In Construction

Compact I-T-E low-voltage metal-enclosed, drawout switchgear features time-tested, field-proven manually or electrically operated stored-energy K-LINE® and K-DON® air-magnetic power circuit breakers. The standard design offers various size circuit breakers mounted in 4-high compartments (see page 30 for low-voltage switchgear arrangements). In addition, modern insulating materials with high strength-to-weight ratios allow significant reduction in weight and floor space.

INDOOR CONSTRUCTION

Free-standing, indoor units offer complete isolation of breaker and instrument compartments. The versatility of compartments, frames and breaker ratings enables meeting your exact application requirements. Notice the semi-flush circuit breaker handles do not project into the aisle, thereby reducing accidental breakage or false tripping. Also each feeder may be equipped with a panel-mounted ammeter and pushbutton phase selector for convenient reading.

WEATHERPROOF WALK-IN CONSTRUCTION

Weatherproof walk-in construction provides all-weather protection when the switchboard must be located outdoors. The same arrangement principles are used in weatherproof as in standard indoor construction. In addition, this construction provides approximately three feet of aisle space on the breaker side to protect equipment and personnel from inclement weather. Also provided are large areas at the top and bottom of each frame for cable entry. Large working area is provided in the rear compartment for pulling and connecting cables.

Standard outdoor construction provides:

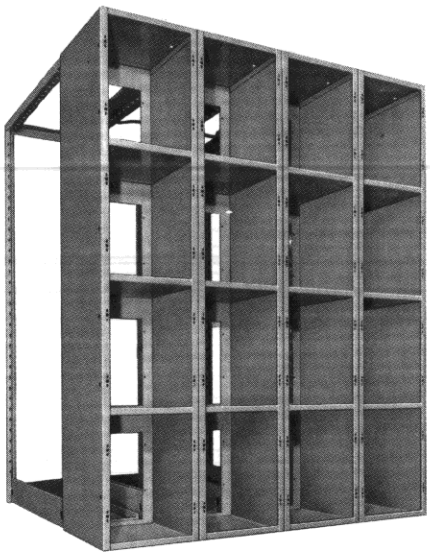
1. Manually-operated lifting device.
2. Filtered louvers and vents, front and rear.
3. Strip heaters to reduce condensation.
4. Convenience outlets and interior lighting.
5. Weatherproof gasketing throughout.

A control-power transformer may be mounted in an auxiliary compartment, if required, to furnish power to outlets and strip heaters.

TABLE 4 — SWITCHBOARD RATINGS

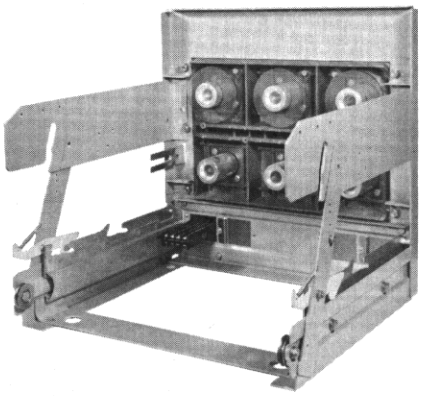
Switchboard Construction	① Circuit Breaker Type	Nominal Voltage Rating, V	Maximum Design Voltage, V	② Maximum Continuous Current Rating, A	Insulation Levels, kV		Limit of Hottest Spot	
					Power Frequency Withstand (rms)	Impulse Withstand	Temp. Rise (°C)	Total Temp. (°C)
Indoor	K-LINE	Up to 600	Up to 630	Up to 4000	2.2 2.2 2.2	—	65	105
Outdoor	K-DON	Up to 600	Up to 630	Up to 1600	2.2 2.2 2.2	—	65	105

① Available breaker ratings are listed on Page 18, Tables 5 and 6. ② Available breaker continuous current ratings are listed on Page 18, Tables 5 and 6.



SWITCHBOARD FRAME

Individual frame consists of a bus and cable area and up to four circuit breaker compartments. Switchboards are assemblies of multiple individual frames. Each frame is welded in a fixture which assures rigid construction, strong enough to support switching equipment. Frames are erected and securely bolted to each other. This type of construction permits versatility in selecting unit sizes for shipment and duplicate manufacturing ensures complete interchangeability in field installations.



CIRCUIT BREAKER CRADLE

A cradle comprises main and secondary separable contacts, current transformers (if required) and all other drawout mechanisms in a complete jig-welded rigid assembly. There is no dependence upon the switchboard frame for any critical alignment. Any size cradle can be installed into any compartment of its own size or larger. Blank compartments not required for other functions may be converted to a circuit breaker compartment by the installation of a cradle and necessary riser bus modifications or additions to the switchboard.

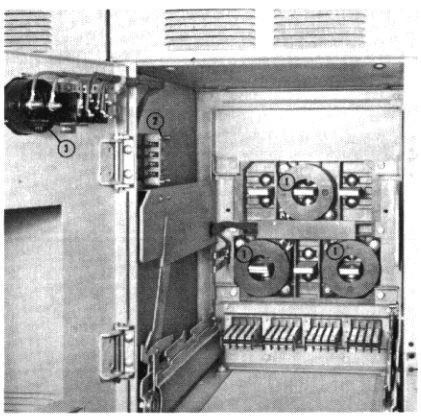
CIRCUIT-BREAKER COMPARTMENT

All individual circuit-breaker compartments are isolated from each other and from the bus area. Front door louvered grilles are scientifically designed to allow full air circulation. Hinged doors are flanged for greater rigidity. Hinges are completely concealed by being mounted inside the enclosure, and are adjustable for perfect door alignment. A removable pin within the hinge assembly provides easy door removal. Knurled panel screws fit easily into floating retainer nuts for quick, easy alignment. These screws offer the utmost in safety in keeping the doors securely closed even under the most severe fault conditions.

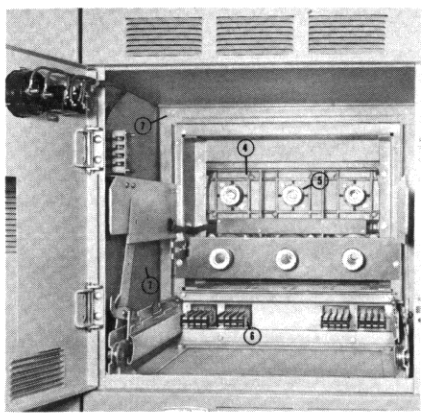
Control separable contacts are tiered, upper and lower, so you can mount twice as many within the narrower dimensions—as many as 32 in each compartment. This means auxiliary circuits for your use. Standardized wiring of circuit breakers and devices to particular terminals makes maintenance far easier. Notice also that the control contacts are located at the bottom where they are safe. They are front removable to make replacement or modification easily accomplished from within the circuit-breaker compartment.

Front-Mounted Current Transformers

Fully-insulated, high-dielectric epoxy-molded toroidal current transformers are located on the stationary primary leads within the circuit-breaker compartment. Convenient location and accessibility makes changing a minor maintenance procedure. Standard low-voltage current transformers have metering accuracies in conformance with ANS C37.20. Current transformer short-circuiting block has safe, convenient location. It is placed at front of circuit-breaker compartment and can be easily reached with circuit breaker still in compartment.



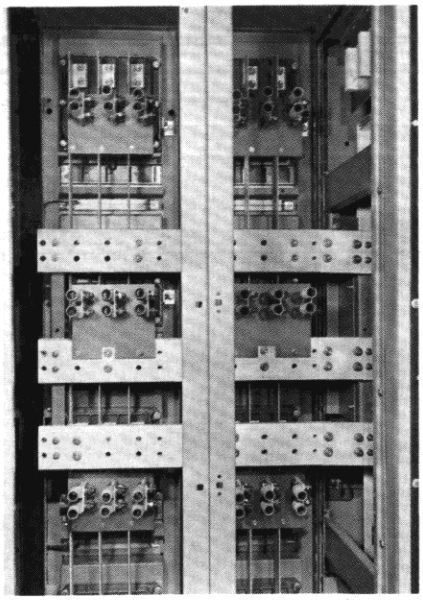
K-600 Compartment



K-DON-1600 Compartment

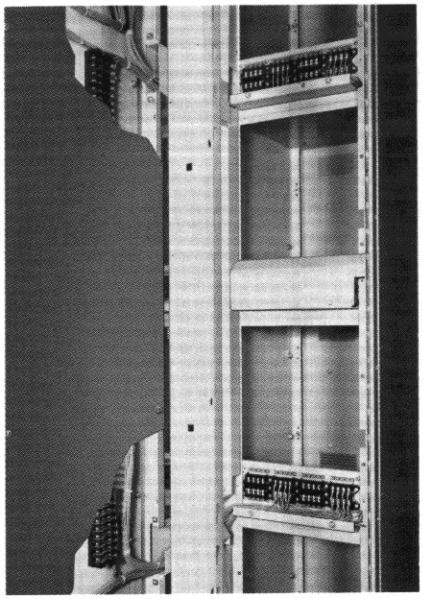
① Current transformers are front mounted and easily accessible from the circuit-breaker compartment.
② Current transformer short-circuiting block is conveniently located behind circuit-breaker compartment door.
③ Feeder ammeter is located directly on feeder compartment door for easy reading and space saving. Rear view of ammeter is shown.
④ Modern polyester-glass insulation system is used throughout switchboard.
⑤ Stationary primary leads mate with movable primary leads mounted on circuit breaker.
⑥ Secondary disconnects are removable from the front for ease of accessibility.
⑦ Complete compartment isolation is provided between each K-LINE® or K-DON® circuit breaker and main bus compartment.

BUS AND CABLE COMPARTMENT



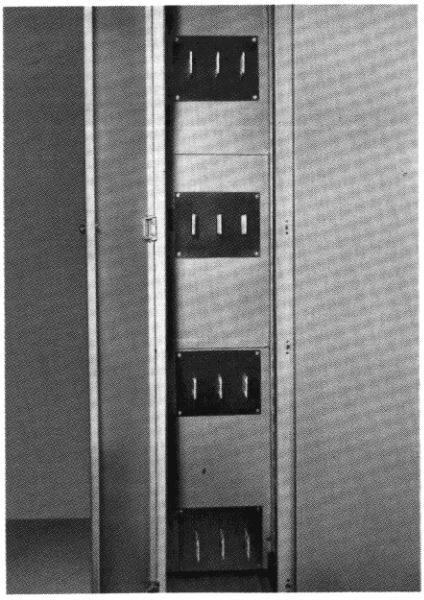
POLYESTER-GLASS INSULATION SYSTEM

All insulating parts of the switchboard are made of high-strength polyester glass. Each insulated part is specially designed in shape and strength to fulfill its part of a totally integrated insulation system.



ENCLOSED SECONDARY WIRING TROUGHS (optional)

All secondary wiring and terminal blocks located in the bus compartment are enclosed in completely covered metal troughs to afford complete isolation from the switchboard bus.

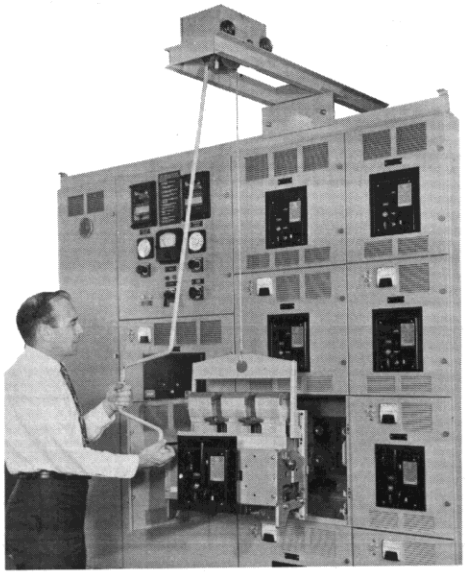


REAR BARRIERS (optional)

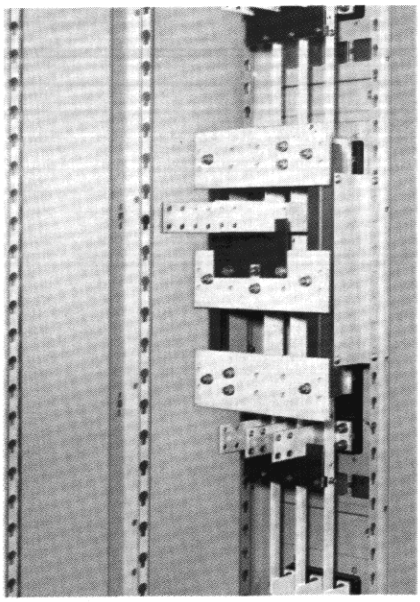
For those who prefer to have a completely isolated cable area, rear barriers are available. The primary leads are extended through slotted polyester-glass inserts which are mounted in a solidly-grounded metal isolating panel. Note that hinged rear doors are standard.

OVERHEAD LIFT DEVICE

For ease of handling K-LINE circuit breakers, a traveling overhead lift device can be provided. This device is supported from the front section of the switchboard assembly and will not affect any incoming power or control cables at the rear bus section. The hoist can be moved the full length of the switchboard and with the aid of a lifting yoke, the breaker can be lifted from the floor or from the completely withdrawn breaker cradle. Lifting power is provided through a removable hand-crank, worm-driven mechanism and sturdy flexible cable. Although the driving mechanism is designed for easy hand operation, the weight of the breaker cannot accidently move the mechanism even when the crank is unattended or removed.



Overhead Lift Device on Indoor Switchgear



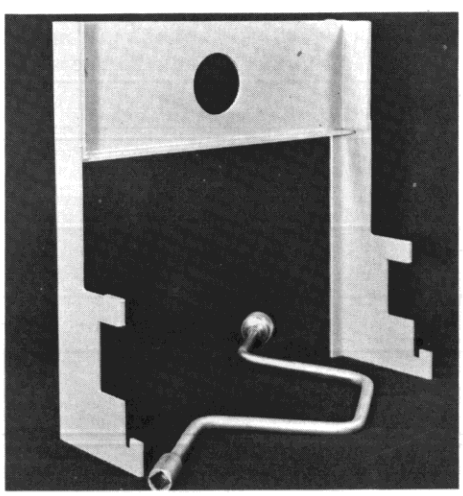
VERTICAL BUS ARRANGEMENT

The three-phase main horizontal bus is vertically arranged one above the other and is located as close to front of switchboard as possible, providing large area for auxiliary equipment and cable makeup. Vertical mounting of bus provides maximum ventilation, and freedom from dust. Bus is designed for an allowable temperature rise of 65°C above an average 40°C ambient. All insulating parts of the switchboard are made of *high-strength polyester-glass.* Each insulated part is specially designed in shape and strength to fulfill its part of a truly integrated insulation system. A section of the top sheet of each frame is removable to facilitate installation of overhead conduit and cable. All rear leads are easily accessible for simple connection with a minimum of cable bending.

Aluminum bus is silver-plated and is braced against movement in any direction under all possible short-circuit conditions. Pre-slotted mounting members permit flexibility to add mounting supports when required in the field for incoming cables, etc. Vertical risers connecting breakers to the main bus are welded for space saving. The connections of the vertical risers to the main bus and breaker terminals are bolted.

ACCESSORIES

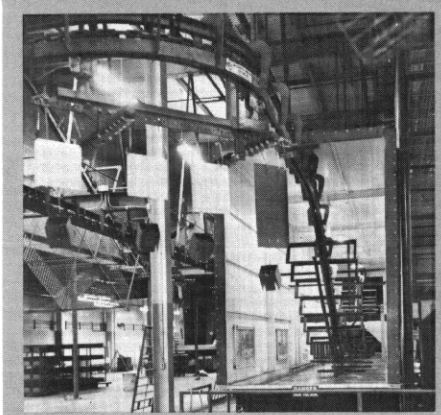
Each factory-assembled switchboard is shipped with circuit-breaker racking crank and lifting yoke as standard accessories. A maintenance handle for manual spring charging is included on electrically-operated breakers only.



A PAINT FINISH TO MATCH TRADITIONAL I-T-E QUALITY

- **Smooth, uniform paint finish**
- **Complete paint penetration**
- **Corrosion-resistant**
- **Electro-chemical bonding of paint to metal**
- **Long-lasting paint finish**

All standard low-voltage switchboard frames are painted by an automated, industry-first electro-deposition paint process. This multi-stage cleaning and painting operation is automatically controlled to provide uniform paint thickness throughout. The metal frame is completely immersed in a huge, electrically charged "gray river" of light gray, ANSI #61, epoxy enamel paint. Current flow from paint to part immediately bonds the epoxy paint to every exposed surface of the metal. Termed "electrocoating", this process provides an attractive and durable paint finish of the highest quality.



Switchboard Being Immersed in "Gray River"

The electrocoating process entails preparation of the metal and application of the color coat. The metal receives a series of alternate alkaline cleansing and water rinse operations, followed by a phosphatizing treatment. After the metal is properly prepared, the frame is immersed in light gray, ANSI #61, epoxy enamel paint for a specified time period. Following another water rinse, the paint finish is baked dry.

All standard switchboard frames and other metal work used in outdoor switchgear are painted in the manner described. In addition, the weatherproof enclosure for outdoor low-voltage switchgear also receives a spray application of dark gray, ANSI #24, baked acrylic enamel.

POWER CIRCUIT BREAKERS

TABLE 5 — K-LINE® POWER CIRCUIT BREAKER RATINGS

① Circuit Breaker Type	Maximum Continuous Current Rating, A	Interrupting Capacity, Symmetrical RMS Amperes		
		240 Volts	480 Volts	600 Volts
K-225	225	25,000	22,000	14,000
K-600	600	42,000	30,000	22,000
K-1600	1600	65,000	50,000	42,000
K-2000	2000	85,000	65,000	55,000
K-3000	3000	85,000	65,000	65,000
K-4000	4000	130,000	85,000	85,000
K-600S	600	42,000	30,000	22,000
K-1600S	1600	65,000	50,000	42,000
K-2000S	2000	85,000	65,000	55,000
K-3000S	3000	85,000	65,000	65,000
K-4000S	4000	130,000	85,000	85,000

① K-LINE breakers equipped with a POWER-SHIELD solid-state overcurrent trip device have their normal designations suffixed with an S.

K-LINE®

K-LINE circuit breakers have been developed for the protection of feeder circuits and for use as main breakers where the interruption requirements are within the ratings shown in Table 5.

This modern line of low-voltage, air-magnetic, drawout power circuit breakers offers a selection of either manually or electrically (motor charged) operated spring-closing mechanisms, which provide positive quick-make operation. K-LINE circuit breakers can be provided with either a direct-acting, electro-mechanical or a solid-state overcurrent trip device. They are compact and come equipped with many other features which are particularly adaptable to general low-voltage switchgear applications.

For application information on K-LINE circuit breakers, refer to pages 35 and 36.

K-DON®

The K-DON circuit breaker is a compact, versatile protective device which incorporates all of the features of the K-LINE circuit breaker and the current-limiting characteristics of the Amp-Trap† fuse. The current-limiting fuses are integrally mounted on, and physically connected in series with, the breaker. Each K-DON circuit breaker is equipped with an anti-single-phase device to prevent single phasing. No external tripping power is required to operate the anti-single-phase device.

The circuit breaker performs its normal function of time delay and instantaneous tripping throughout its entire range of interrupting capacity. When properly applied, the fuse takes over protection for currents at or above the circuit-breaker short-circuit current rating up to 200,000 amperes. For currents within the circuit-breaker interrupting capability, the fuse will not open unnecessarily thus saving nuisance replacements. This system affords vast flexibility in applying pin-point protection to any type of electrical apparatus. For application information on K-DON circuit breakers, refer to Pages 37-41.

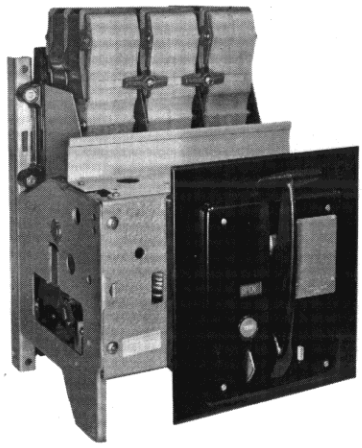
† Registered Trademark—Chase-Shawmut Co.

TABLE 6 — K-DON® POWER CIRCUIT BREAKER RATINGS①

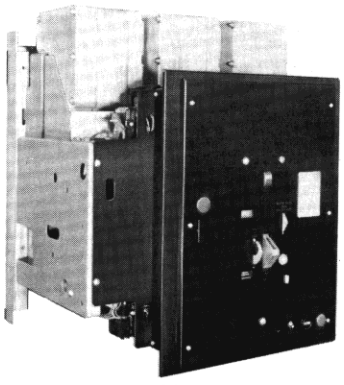
② Circuit Breaker Type	Maximum Continuous Current Rating, A	Interrupting Capacity, Symmetrical RMS Amperes
		240, 480, and 600 Volts
K-DON-600	600	200,000
K-DON-1600	1600	200,000
K-DON-600S	600	200,000
K-DON-1600S	1600	200,000

① Fused circuit breakers with 2000, 3000 and 4000A continuous current ratings are available with separately mounted, drawout, current-limiting fuses. Refer to Page 30 for arrangement information and Page 40 for application data.

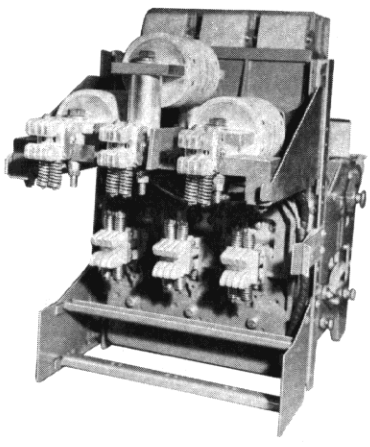
② K-DON breakers equipped with a POWER-SHIELD solid-state overcurrent trip device have their normal designations suffixed with an S.



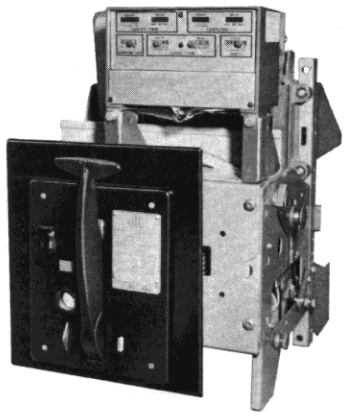
Manually Operated K-600



Electrically Operated K-3000

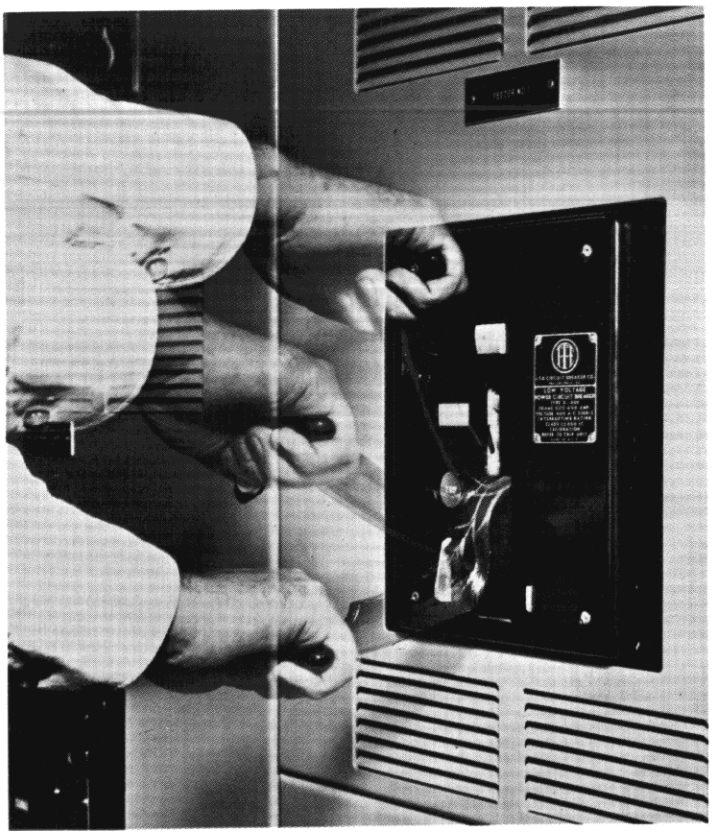


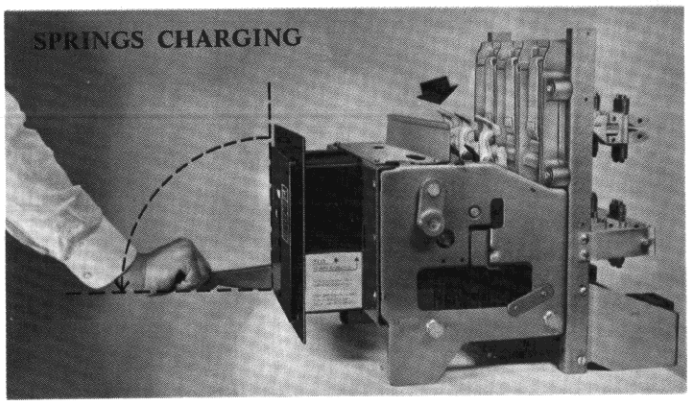
Rear View Manually Operated K-Don-600

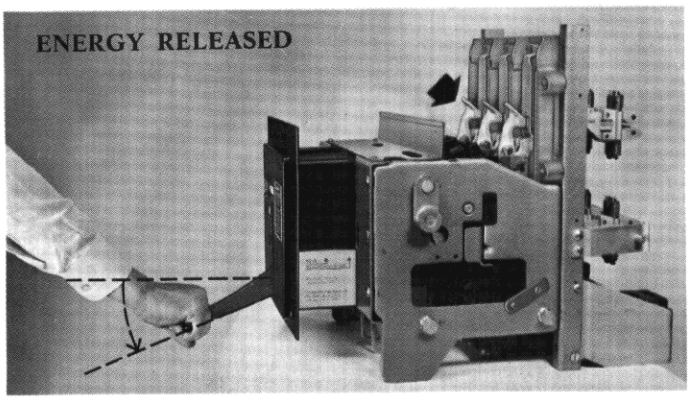


Manually Operated K-Don-600S

Manual Stored-Energy Gives Quick-Make, Quick-Break Operation







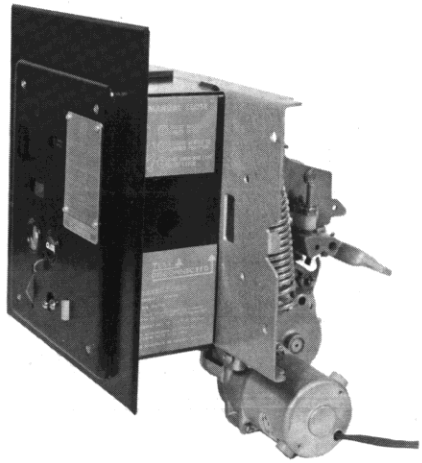
LESS UPKEEP, LONGER CONTACT LIFE

Manually-charged, stored-energy breakers offer many advantages to its users. Of primary importance is the added safety for operating personnel. This quick-make mechanism also provides longer contact and breaker life and increases the scope of application for manual breakers. K-LINE® breakers cannot be teased into the closed position. A pair of powerful springs actually close the contacts. For breakers with frame size ratings from 225 through 2000 amperes, the operator simply supplies energy to the device by pulling the semi-flush closing handle downward to approximately 100°. The initial 90° fully charges the closing springs and the remaining motion releases the spring energy to drive the contacts into the closed position by a smooth cam action. The fully-charged springs develop sufficient energy to close and latch the breaker safely under any conditions within the breaker rating. A flush-mounted manual trip button is located on the easily-accessible breaker escutcheon. It is also equipped with a hand-reset automatic trip indicator which provides for visual indication of automatic trip operation.

ELECTRICAL OPERATION

All K-LINE circuit breakers are also available with motor-charged, stored-energy closing mechanisms to be used when remote control or local electrical control is required. The normal control power required by this mechanism is only a fraction of the power requirement for a solenoid closing mechanism.

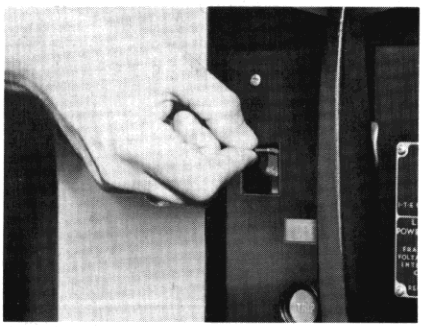
A fractional-horsepower motor with enclosed speed-reduction gears provides the closing energy. The high-torque, high-speed output easily charges the powerful closing springs. The springs are retained in a fully-charged condition until the energy is required for closing. Upon tripping, the springs are again recharged automatically by the mechanism. An emergency charging handle is provided for manual charging if control power is lost. A manual closing lever on the escutcheon permits simple manual close with the compartment door closed. All stored-energy springs are automatically discharged for safe breaker maintenance when the circuit breaker is racked to the disconnect position.



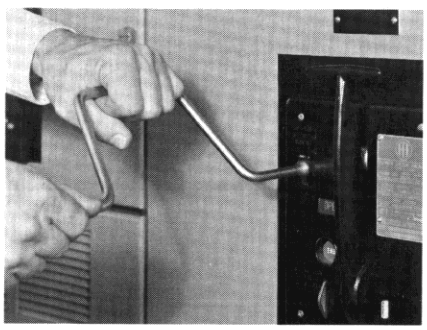
SAFE, EFFICIENT, CLOSED-DOOR DRAWOUT

The circuit-breaker compartment door need never be opened while moving the K-LINE® circuit breaker from the completely connected through test into the disconnected position. Unique construction reduces I-T-E switchgear to three basic components: frame, breaker and a removable cradle on which the breaker rolls for drawout. The mechanism permits racking the breaker into connected, test and disconnected positions without ever opening the compartment door. It facilitates testing and maintenance and promotes safe operation. A lift shutter is provided on the breaker escutcheon which permits insertion of a racking crank to move the breaker. It is completely interlocked, i.e., the shutter cannot be lifted while the circuit breaker is closed and the circuit breaker cannot be closed while the shutter is lifted. When open, the breaker can be padlocked in the connected, test or disconnected positions. When padlocked, the breaker cannot be closed or moved to any other position.

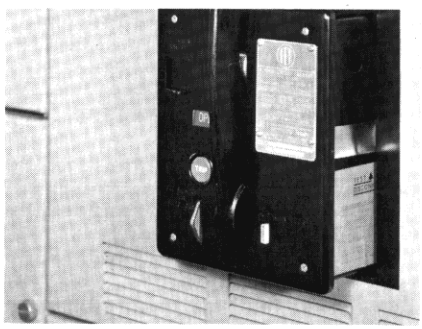
The extendable escutcheon mounted on the circuit breaker slides through an opening into the compartment door while the spring-loaded cover plate surrounding the escutcheon is held in place by the door. Visual indication on the side of the breaker denotes all three positions. Compartment doors may be opened, if desired, when the breaker is in any position. To remove the breaker from its compartment, it must be racked to the fully-disconnected position, the door opened and the breaker pulled manually to the fully-withdrawn position while it is supported by extending sliding rails. At this point the breaker may be lifted directly from the rails by means of an overhead lift device and moved with a transfer truck or be handled completely with a combination lift device and transfer truck.



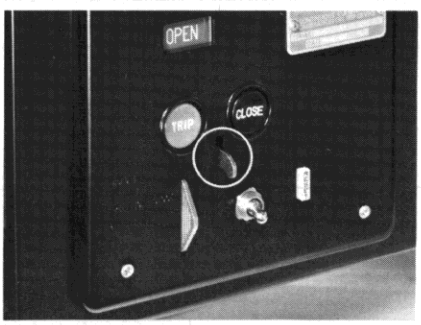
LIFT SHUTTER must be raised to insert breaker racking crank. It cannot be raised when breaker contacts are closed.



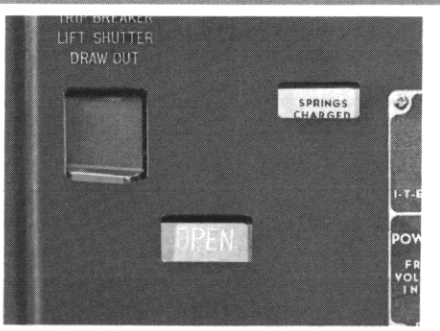
INSERT CRANK to move breaker between positions. Crank cannot be inserted without raising lift shutter.



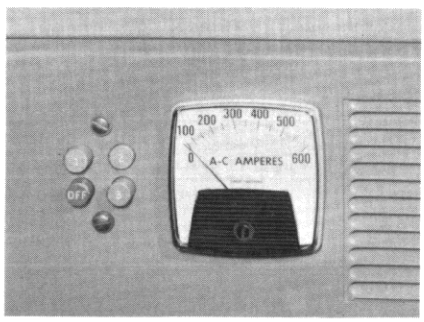
READ BREAKER POSITION from target on the right side of escutcheon. When breaker is in disconnected, test or connected positions, lift shutter will close. Breaker contacts cannot be closed until lift shutter is closed.



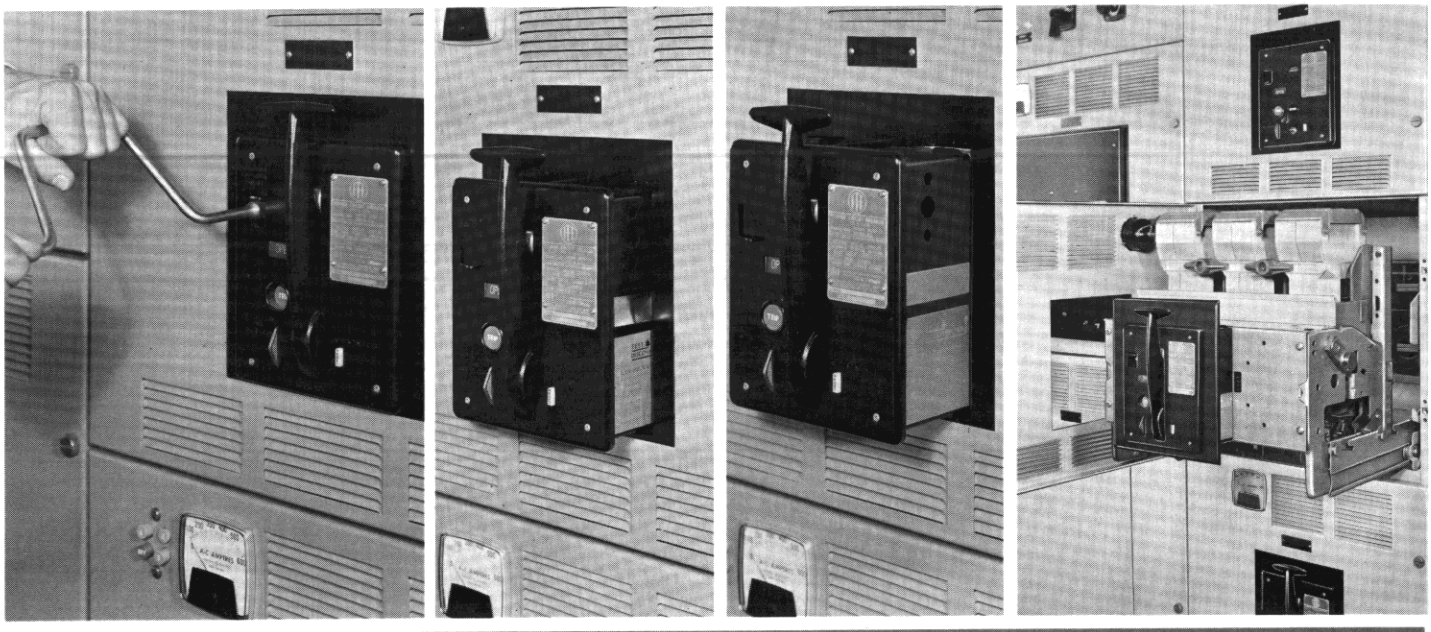
MANUAL CLOSING LEVER. All electrically operated breakers can be closed manually with the compartment door closed, if control power is lost, by simply pulling the closing lever. Closing springs can also be charged manually with a hand lever.



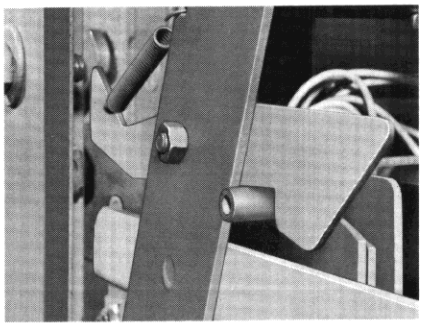
SPRING-CHARGED INDICATOR shows condition of stored-energy springs on electrically-operated breakers.
OPEN-CLOSED INDICATOR visually shows position of breaker contacts directly on front of escutcheon.



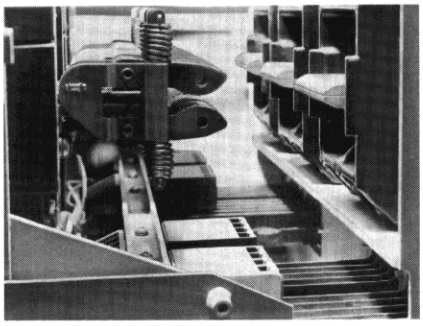
FEEDER AMMETER. Each feeder compartment can be equipped with a door-mounted ammeter and push-button switch for easy, convenient reading and space saving.



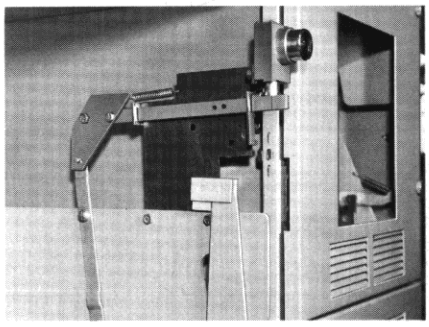
CONNECTED ..... TEST ..... DISCONNECTED ..... FULLY WITHDRAWN .....



RAIL LATCH prevents breaker from rolling off track when breaker is fully withdrawn. Latch must be released to lift breaker from rails.

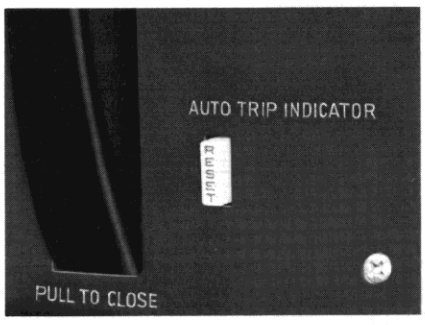


PRIMARY, SECONDARY AND GROUND CONTACTS on the circuit breaker mate sequentially in a straight-line motion with counterparts within the switchboard. This insures proper breaker operation at each position.

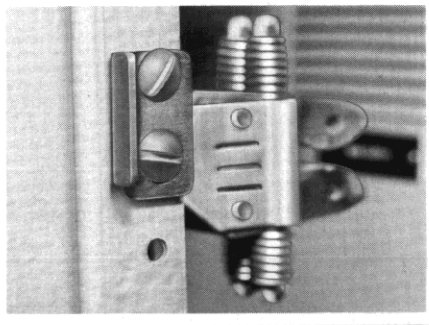


KIRK™ KEY INTERLOCKS offer an unlimited number of interlocking arrangements between all components of the switchgear. They are particularly adaptable to sequential operations or prevention of unauthorized operation.

PADLOCK PROVISION. The circuit breaker, when open, can be padlocked (with up to three locks) in all three positions. When padlocked, it cannot be closed or moved to any other position.



AUTOMATIC-TRIP INDICATOR gives visual indication when the breaker has tripped from a fault or other overcurrent conditions.



INTERFERENCE KEY on the breaker mates with slot on cradle allowing only the proper rated breaker to be inserted into the compartment. It is virtually impossible to insert a lower rating into any compartment.

OD—ELECTRO-MECHANICAL OVERCURRENT TRIP DEVICE

K-LINE® type OD electro-mechanical overcurrent trip devices have been designed to provide dependable performance with virtually noiseless and vibration-free operation. I-T-E low-voltage power circuit breakers equipped with this rugged device are available in any desired combination of long-time delay, short-time delay and instantaneous tripping. Each overload is individually calibrated, tested and certified by Quality Control to assure "as designed" performance and service.

OD-3 and OD-300 Dual-Magnetic Direct-Acting Trip Device

The OD-3 and OD-300 are fully adjustable, dual-magnetic overcurrent trip devices. They employ a dual armature. One is connected to an oil-displacement dashpot to provide long-time delay. A second armature provides instantaneous trip characteristics. The overload on each pole has independent adjustment for long-time delay pick-up, instantaneous pick-up, and the amount of time delay. It is a self-contained, direct-acting, electro-mechanical device which depends on its own circuit for tripping power. No external tripping power is required.

Expanded-range calibration is incorporated to provide a greater number of usable calibrated long-time pick-up settings. Conventional trip devices provide only two calibrated pick-up settings (80% and 100%) which may be used continuously without excessive overheating. Table 61, page 43, shows the increased number of calibrated long-time pick-up settings within 100% of the continuous current rating of each trip coil. This feature permits a user to select a device with a trip coil rating which provides adequate protection for present power requirements and also permits an increase in capacity by means of simple adjustments.

A wide range of adjustment makes this rugged unit ideal for protection of motors and equipment which require close protection.

Production units have been subjected to more than 4,000,000 welding type pulse test cycles without failure—thus proving a long-life design! OD-3 and OD-300 units now in service have proven themselves in many difficult application including heavy-duty welding circuits.

OD-4 and OD-400 Dual-Selective Direct-Acting Trip Devices

The OD-4 and OD-400 direct-acting trip devices combine the fluid-displacement type time delay with mechanical-escapement time delay to provide a composite time-delay device in which it is possible to closely control the time-delay over a range of current values from normal load current to the full interrupting current rating.

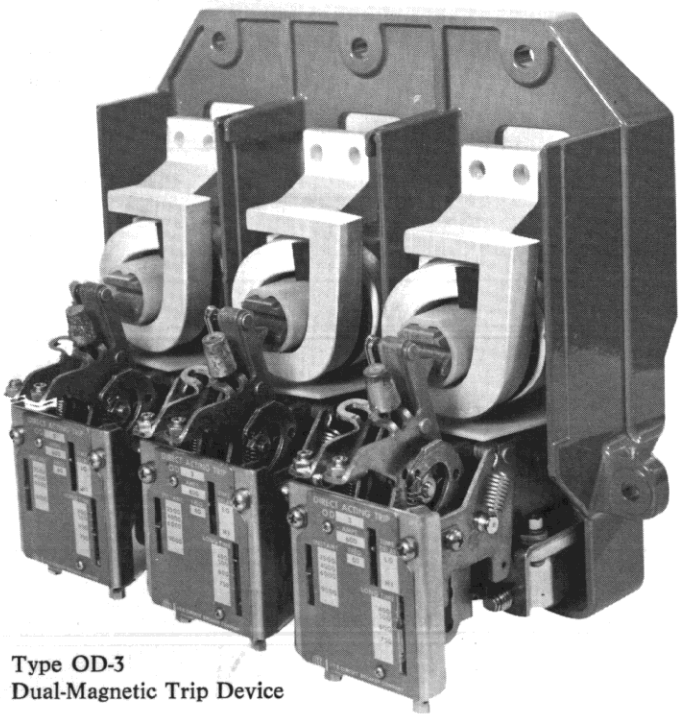
This allows the direct-acting trip devices of circuit breakers in series to be set so as to permit selective tripping of the circuit breaker closest to the fault. Thus maximum continuity of electrical service may be provided where such continuity is mandatory.

EASY TO ADJUST

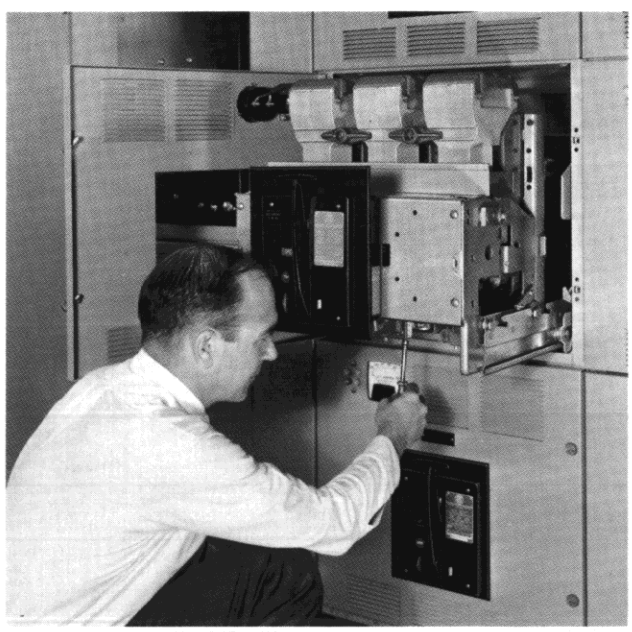
Trip devices are clearly visible and within easy reach from the front of the circuit breaker. Even on electrically-operated circuit breakers, they are readily accessible to the operator for quick, easy adjustment.

EASY TO SERVICE

The three-phase overcurrent trip device assembly is mounted on a one-piece, impact-resistant polyester glass molding for breaker sizes up to K-600. On larger size breakers the overcurrent trip device assembly consists of three individual units. If repair or replacement is required, the assembly is easily removed from the back of the breaker. Associated devices need not be disturbed.



Type OD-3
Dual-Magnetic Trip Device



Adjusting and servicing OD device is simple and convenient.

POWER-SHIELD™—SOLID-STATE OVERCURRENT TRIP DEVICE

GENERAL INFORMATION

POWER-SHIELD is a three-phase solid-state, overcurrent trip device designed for low-voltage power system protection against damage caused by overload and short-circuit conditions. It can be integrally mounted on K-LINE® and K-DON® low-voltage power circuit breakers. The logic assembly of the POWER-SHIELD system is mounted on the shelf above and behind the breaker escutcheon for easy accessibility to the control panel. POWER-SHIELD is suitable for application on low-voltage circuits rated up to 600V ac, 50/60 Hertz. Available standard types and their related trip functions are shown in Table 63, page 44.

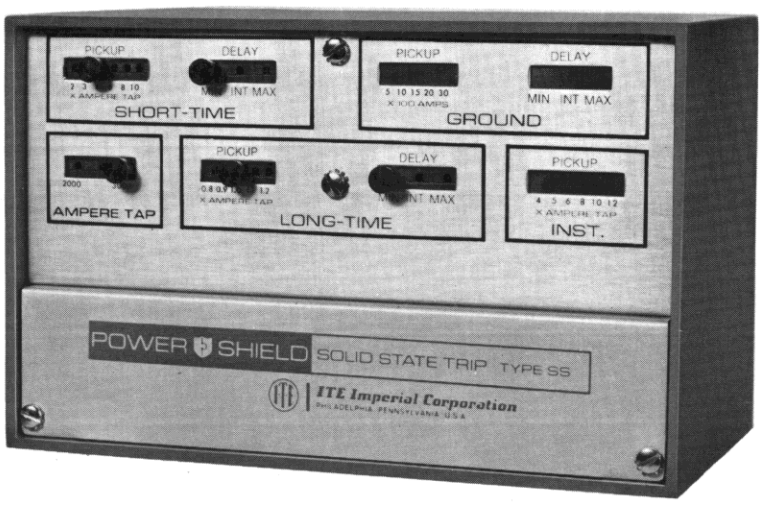
The POWER-SHIELD solid-state overcurrent trip system consists of current sensors, logic assembly, magnetic latch release and interconnecting wiring. There are two current sensors mounted on the breaker lower base molding around each primary conductor. One sensor supplies the logic assembly with a signal current proportional to the primary current, and is referred to as the signal sensor. The other sensor, designated the power supply sensor, supplies the power required to operate the magnetic-latch release and solid-state circuitry. The logic assembly contains the circuitry and various tap-blocks used to set the overcurrent trip levels and time delays. The magnetic-latch release is similar in function to a shunt-trip device, but is powered by the fault current through the power-supply sensors, and is actuated by the logic assembly system.

SIMPLE TAP CHANGING

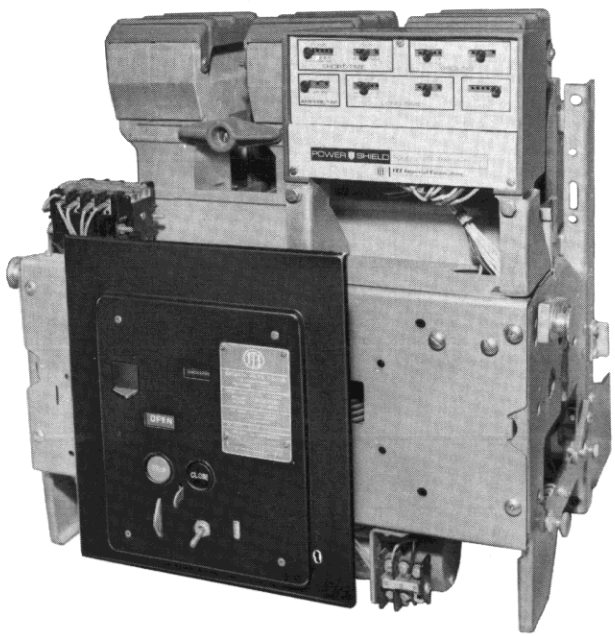
The wide rating range of each device, coupled with its simplified field adjustment, allows almost unlimited load growth within each breaker frame size. Only seven different sizes are required for the full range of 40 thru 4000 amperes (see page 44). Field setting is accomplished by insertion of tap plugs into the front of the logic unit. All settings are made in this fashion, including the **ampere tap** which selects the continuous rating of the current sensor. This setting is shown directly in primary amperes, giving the user a positive indication of the continuous current rating of his circuit breaker. The long-time, short-time and instantaneous functions are then adjusted by tap plugs which are a percentage of this ampere tap setting. In addition, three time-delay bands, minimum, intermediate and maximum can be selected for both the long-time and short-time functions. All time-current curves are straight lines, asymptotic at the pick-up point to produce optimum coordination with other protective devices. Coordination is made even more positive by the wide separation between all time-delay bands.

GROUND-FAULT PROTECTION

POWER-SHIELD is available with multiple ampere taps for a wide range of pick-up currents. The ground function can be included in the logic assembly for those applications in which it is desirable to protect the system against faults to ground. These are often damaging arcing faults which result in current magnitudes below the pick-up of the long-time trip function. 3-wire applications with ground protection do not require any additional sensors. For 4-wire applications, one ground sensor is remotely mounted around the neutral conductor and is wired to the logic assembly through a breaker secondary disconnect. The ground function is tap selected directly in amperes, and is independent of the ampere tap setting.



Front view of SS-4 POWER-SHIELD logic assembly.



Front view of K-2000S electrically operated breaker equipped with SS-5G POWER-SHIELD unit.

GROUND-SHIELD®

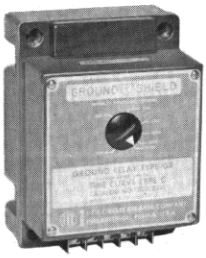
Fast, Sensitive Ground-Fault Protection System

The I-T-E GROUND-SHIELD® Ground-Fault Protection System offers fast, sensitive protection against ground faults including destructive, low-magnitude, arcing ground faults in solid- and resistance-grounded distribution systems. It consists of a special-design, core-balancing current transformer (sensor) and a low-burden, solid-state ground relay.

The ground sensors are available with small- or large-window configurations designed to enclose all phase and neutral bus or cable conductors. Standard round current sensors are available up to an 8″ diameter; standard rectangular sensors have a maximum 16″ x 20″ opening. Split-core current sensors are also now available from I-T-E in sizes up to 8″ in diameter. They provide added flexibility to all GROUND-SHIELD systems by facilitating installation on existing cable circuits without disturbing present connections.

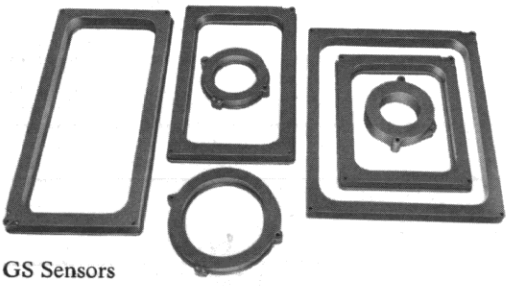
The GROUND-SHIELD current sensor will respond only to ground fault currents. Balanced or unbalanced load currents, and two-phase or three-phase short circuits not involving a ground return conductor, will have no effect on the sensor. Two relay systems are available, one with 5 ampere minimum sensitivity, and one with 200 ampere minimum sensitivity. The 5A system includes the GR-5 relay with 5-50A pick-up adjustment and is used for protection of individual loads such as motors and transformers. On high-resistance grounded systems the 5-50A relay is used for both circuit and load protection. The 200 ampere system includes the GR-200 relay with 200-2000A pick-up adjustment and is used for circuit protection.

The 5A system provides 5 time-current curves of definite time shape. The times for the GR-5 relay are 2, 6, 12, 18, and 24 cycles. Five time-current characteristics are available for the 200A system. The times for the GR-200 relay are 6, 12, 18, 24, and 30 cycles. All relay calibrations are in primary amperes. Tripping of the desired breaker (coordination) is obtained by applying relays with successively faster curves, progressing from source to load circuits. Relays are available for surface mounting or semi-flush panel mounting.

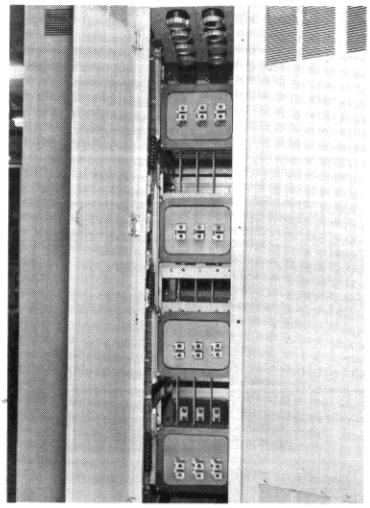


GR-200, Surface Case

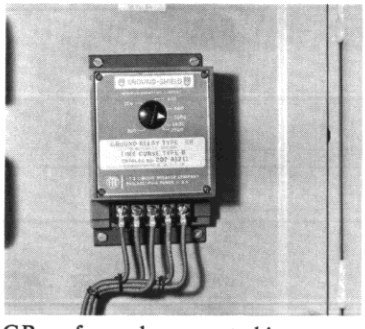
GR-5, Drawout Case



GS Sensors

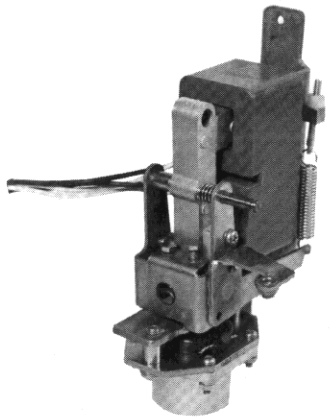


GS sensors mounted in cable compartment.

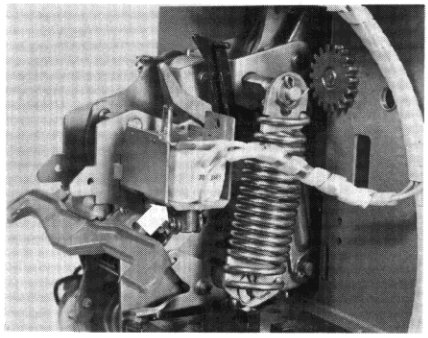


GR surface relay mounted in instrument compartment.

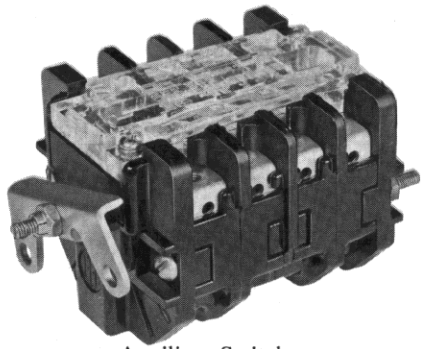
BREAKER COMPONENTS



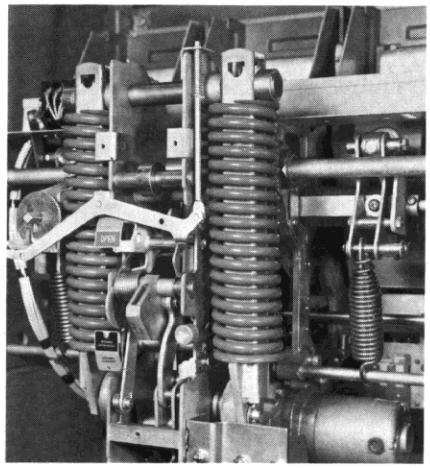
Undervoltage Trip Device



Shunt Trip Device



Auxiliary Switch



K-3000 Motor Charged Stored-energy Operating Mechanism

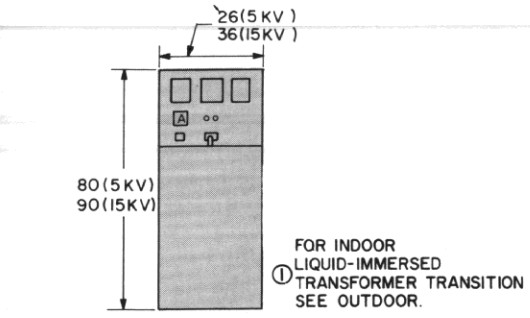
FEATURES OF STORED-ENERGY K-LINE® AND K-DON® CIRCUIT BREAKERS

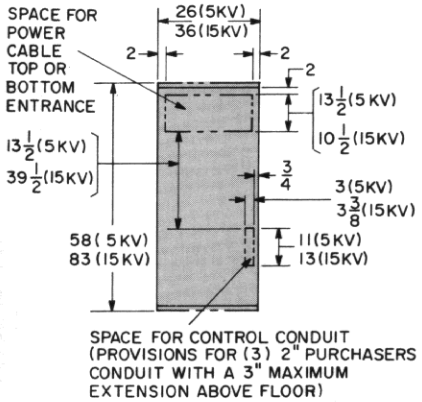
	STANDARD FEATURES INCLUDE:	K-225 K-600 K-1600 K-2000	K-3000 K-4000	K-DON-600 1600	K-600S K-1600S K-2000S	K-3000S K-4000S	K-DON-600S K-DON-1600S
MANUALLY OPERATED	Springs charged and breaker closed with manual handle	X	No	X	X	No	X
	Springs charged only with manual handle	No	X	No	No	X	No
	Manual close lever—door closed	No	X	No	No	X	No
	Springs-charged indicator	No	X	No	No	X	No
ELECTRICALLY OPERATED	Springs charged with motor—after trip	X	X	X	X	X	X
	Electrical closing release	X	X	X	X	X	X
	Manual close lever—door closed	X	X	X	X	X	X
	Shunt-trip device	X	X	X	X	X	X
	Control relay	X	X	X	X	X	X
	Charging-motor disconnect switch	X	X	X	X	X	X
	Springs-charged indicator	X	X	X	X	X	X
	Secondary disconnects (operating and test position)	X	X	X	X	X	X
	4-Contact auxiliary switch	X	X	X	X	X	X
	Provision for manual spring charge	X (Door Open)	X (Door Closed)	X (Door Open)	X (Door Open)	X (Door Closed)	X (Door Open)
MANUALLY OR ELECTRICALLY OPERATED	Manual trip button	X	X	X	X	X	X
	Breaker contact-position indicator	X	X	X	X	X	X
	Breaker racking-position indicator	X	X	X	X	X	X
	Racking interlock (breaker must be open prior to racking)	X	X	X	X	X	X
	Positive racking stops	No	X	No	No	X	No
	Padlock hasp—up to three locks (locks breaker trip-free and in position)	X	X	X	X	X	X
	Breaker interchangeability interlock	X	X	X	X	X	X
	Direct-acting overcurrent trip devices (dual-magnetic, other combinations, except dual-selective)	X	X	X	No	No	No
	Solid-State overcurrent trip device (long-time and instantaneous, SS-3)	No	No	No	X	X	X
	Automatic trip indicator (overcurrent and undervoltage trip)	X	X	X	X	X	X
	Primary disconnects—(operating position only)	X	X	X	X	X	X
	Ground disconnect—(operating and test position only)	X	X	X	X	X	X
	Manual slow-close provision	X	X	X	X	X	X
	Actuator to discharge springs on withdrawal from switchboard	X	X	X	X	X	X
	Amp-trap, current-limiting fuses	No	No	X	No	No	X
	Anti-single-phase device	No	No	X	No	No	X
ADDITIONAL OPTIONAL FEATURES (E.O. or M.O. except as noted)	Local electrical trip button—(on escutcheon)	X	X	X	X	X	X
	Shunt trip with 4-contact auxiliary switch (2 spares)—M.O. only	X	X	X	X	X	X
	Dual-selective, direct-acting overcurrent trip device	X	X	X	No	No	No
	Solid-State overcurrent trip device (Dual-Selective, SS-4 and SS-5)	No	No	No	X	X	X
	Mechanical lockout on automatic trip (reset by indicator)						
	—Overcurrent and undervoltage trip	X	X	X	X	X	X
	—Overcurrent alone (special trip for undervoltage)	X	X	X	X	X	X
	Alarm switches—1 N.O. and 1 N.C. (reset by indicator)						
	—Overcurrent and undervoltage trip	X	X	X	X	X	X
	—Overcurrent alone (special trip for undervoltage)	X	X	X	X	X	X
	Auxiliary switches—spares						
	—4 or 8 Contacts—E.O. only	X	X	X	X	X	X
	—4, 8 or 12 Contacts—M.O. only	X	X	X	X	X	X
	Undervoltage-trip device						
	—Instantaneous	X	X	X	X	X	X
	—Time delay—Adjustable 0 - 15 sec.	X	X	X	X	X	X
	Operation counter	X	X	X	X	X	X
	Remote electrical-close release—M.O. only	No	X	No	No	X	No
	Wiring change to charge springs when breaker closes	X	X	X	X	X	X
	Hinged door interlock—door locked when breaker closed	X	X	X	X	X	X
	Mechanical-transfer interlock—two breakers using flexible cable arrangement	X	X	X	X	X	X
	Additional secondary disconnects up to 32 maximum total	X	X	X	X	X	X
	Secondary disconnects—operating and/or test position only	X	X	X	X	X	X
	Key interlocks—switchboard mounted—2 maximum	X	X	X	X	X	X
STANDARD ACCESSORIES	Racking crank	X	X	X	X	X	X
	Lifting yoke	X	X	X	X	X	X
	Maintenance spring-charge handle—E.O. only	X	X	X	X	X	X
	Slow-close bracket	No	X	No	No	X	No
OPTIONAL ACCESSORIES	Transfer and lift truck	X	X	X	X	X	X
	Overhead lift device—(standard outdoor)	X	X	X	X	X	X
	Floor dolly	X	X	X	X	X	X

DIMENSIONS ▲

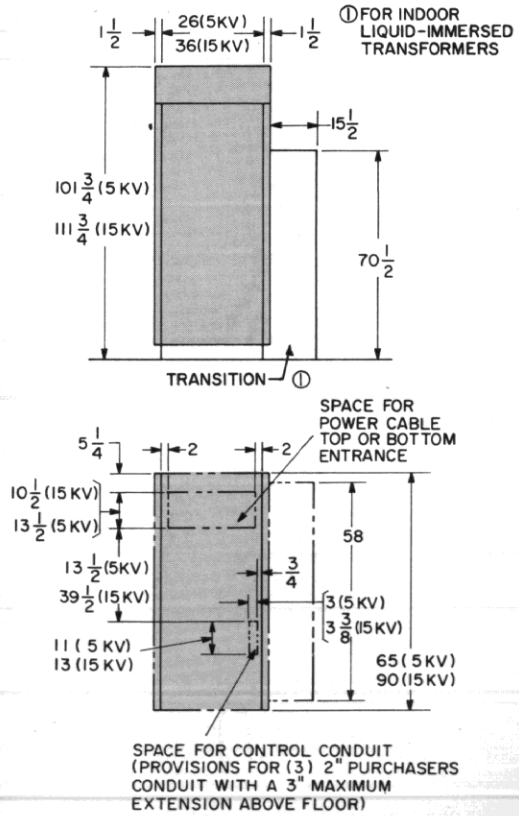
METAL-CLAD SWITCHGEAR

Indoor





Outdoor



OIL CUTOUTS

Indoor — Outdoor

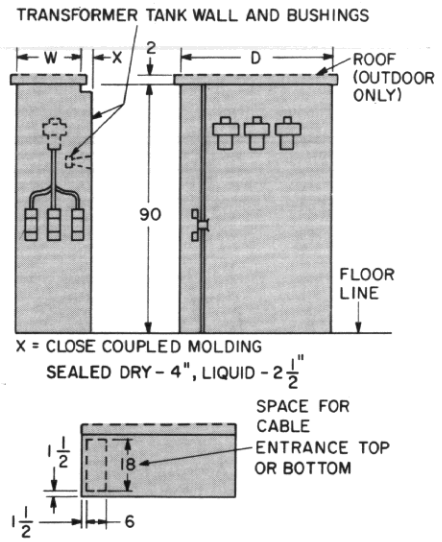
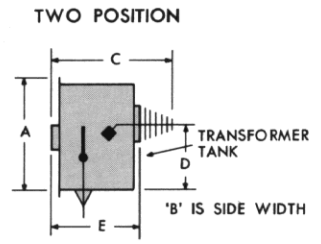


TABLE 7 — OIL CUTOUTS

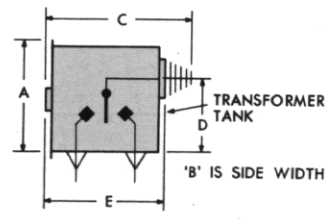
Device	Liquid		Ventilated and Sealed-Dry	
	W	D	W	D
5 kV — 100, 200A	22½	48	21	48
5 kV — 300A 15 kV — 100, 200A	44½	58	43	58

LIQUID SWITCHES

Indoor — Outdoor



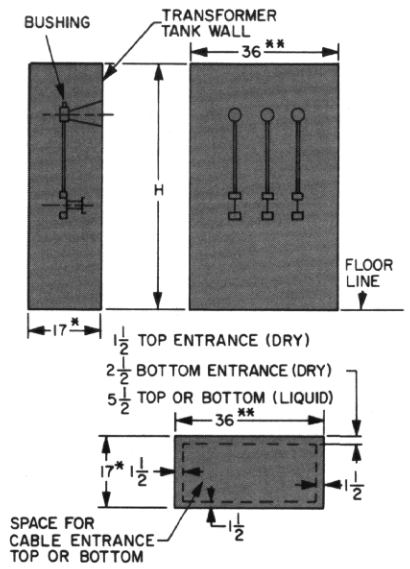
kV	A	B	C	D	E
5	21⅛	30½	23	13¾	17⅜
15	26	34½	24	16¼	18⅜



kV	A	B	C	D	E
5	22⅛	28	25¾	14¾	20¼
15	26	32	28¾	17¼	23⅛

AIR TERMINAL CHAMBER

Indoor — Outdoor

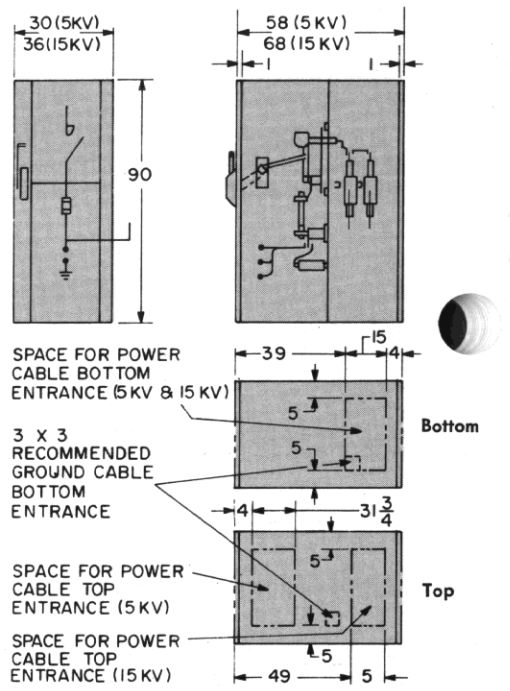


*ADD 1" ON ALL VENTILATED-DRY TRANSFORMERS
**WHEN USED WITH VENTILATED-DRY TRANSFORMER-MATCH TRANSFORMER DEPTH

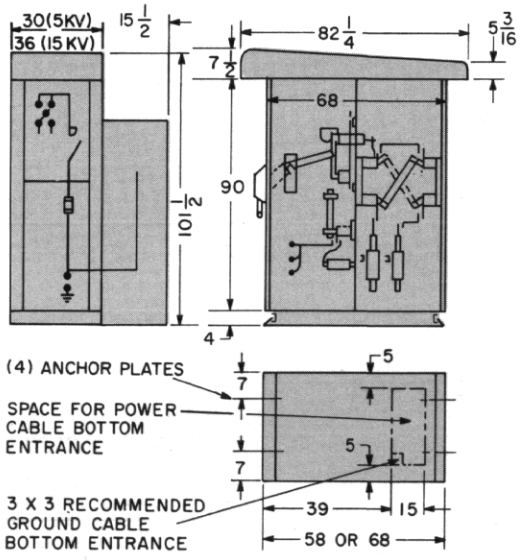
TABLE 8 — AIR TERMINAL CHAMBER

Trsfr. Dim.		Liquid H		Sealed-Dry H		Vent.-Dry H
kVA	kV	Bott Entr	Top Entr	Bott Entr	Top Entr	Top or Bott Entrance
225-500	5	70	94	80	90	90
	15				100	
750-1000	5	70	94	80	90	
	15				100	
1500-2500	5	70	94	80	100	
	15				110	

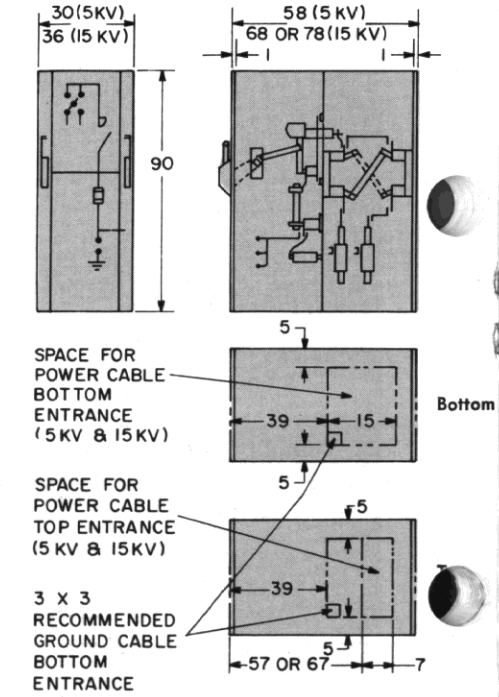
AIR INTERRUPTER SWITCH—Indoor



SELECTOR SWITCH—Outdoor

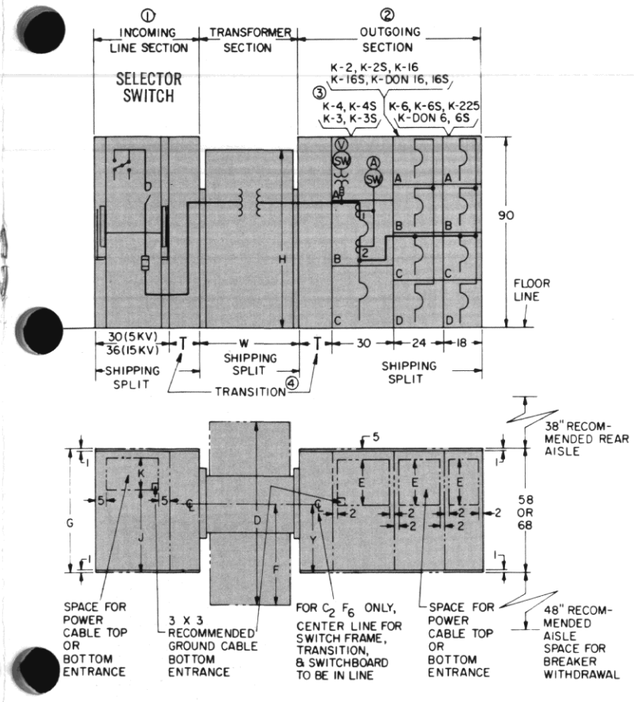


SELECTOR SWITCH—Indoor



▲ **Dimensions are in inches. They are approximate and should not be used for construction.**

LIQUID (ASKAREL) AND SEALED-DRY—Indoor



VENTILATED-DRY—Indoor

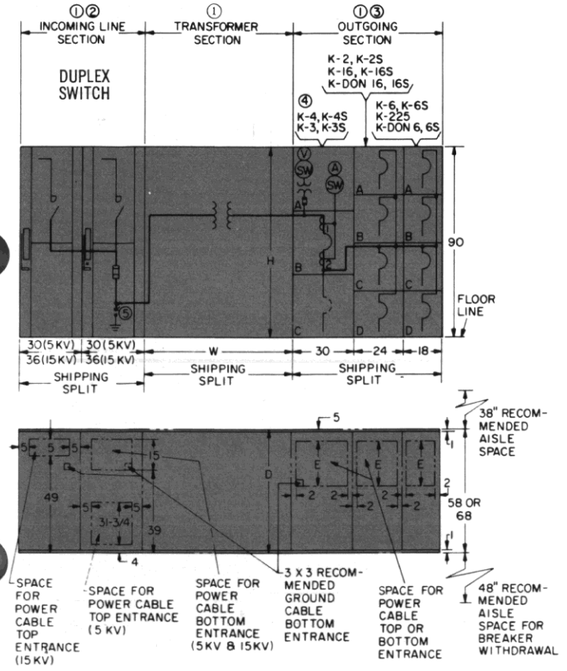


TABLE 9 — AIR INTERRUPTER SELECTOR SWITCH

Voltage	Cable Entrance	G	J	K
5kV	Bottom	58	39	15
5kV	Top	68	57	7
15kV	Bottom	68	39	15
15kV	Top	78	67	7

① Incoming Section (15kV) must be 68" deep when furnished with 2 - 3/c potheads for top entrance.
② When main bus is over 4000 amperes, consult I-T-E district sales office.
③ K4000 (2-45" high compartments) breaker located in bottom compartment.
④ Transition units are supplied assembled to the Incoming Line Section and Outgoing Section.

TABLE 13 — VENTILATED-DRY (VU-9)—150°C RISE

kVA	Incoming Section	Dimensions, in. W†	H	D
112½ to 300	5 kV or 15 kV	42	90	58
500 to 1000		54		58
1500 and 2000		60		68
2500		60		78

† A 12" wide transition unit must be supplied when no main breaker is used.

TABLE 14 — LOW-VOLTAGE SWITCHGEAR

Circuit Breaker Type	Frame Width Inches	"E" Dimension Without Main Bus Barrier		With Main Bus Barrier		Feeder with Ground Sensor		Neutral 3φ4w with Main Bus Barrier†	
		Switchboard Depth, in.							
		58	68	58	68	58	68	58	68
K3 & K3S, K4 & K4S	30	21*	31*	12	22	—	17½	7½	17½
K2 & K2S, K16 & K16S	24	21	31	12	22	—	17½	7½	17½
K-225 K6 & K6S,	18	21	31	12	22	—	17½	7½	17½
K-DON 16 & 16S	24	16½	26½	—	17½	—	13	—	13
K-DON 6 & 6S	18	16½	26½	—	17½	—	13	—	13

* With bottom entrance to K-3000 in compartment C, subtract 6".
† For main breaker unit or with K-3000 in compartment C.

① Incoming, Transformer and Outgoing Sections will always have their fronts aligned.
② Incoming Section (15 kV) must be 68" deep when furnished with 2—3/c potheads for top entrance.
③ When main bus is over 4000 amperes, consult I-T-E district sales office.
④ K-4000 (2-45" high compartments) breaker located in bottom compartment.
⑤ Distribution-type lightning arresters are always required.

TABLE 10 — ASKAREL AND SEALED-DRY

kVA	Incoming Section	Askarel (LU-8) 65°C Rise W	H	D	F	T	Sealed-Dry (GU-1) 150°C Rise W	H	D	T
112½	5 kV	45½	76½	34	17½	15½	—	—	—	14
	15 kV						—	—	—	
150	5 kV	45½	76½	34	17½		—	—	—	
	15 kV						—	—	—	
225	5 kV	45½	76½	38	17½		—	—	—	
	15 kV						—	—	—	
300	5 kV	45½	75½	47	18		72	70¼	48	
	15 kV								52	
500	5 kV	45½	76½	52½	30		72	80¼	48	
	15 kV						76		54	
750	5 kV	48½	80½	62*	39		74		50	
	15 kV						78		54	
1000	5 kV	Δ 48½	79	70*	39		78	90¼	52	
	15 kV						82		56	
1500	5 kV	53	84½	87	47½		86	100¼	54	
	15 kV						88		58	
2000	5 kV	53	82	97	48½		88		56	
	15 kV						92		60	
2500	5 kV	53	87	99	49½		92	110¼	58	
	15 kV						96		62	

* For 208Y/120 volts application, add 8".
Δ For 8% impedance, add 4½".

LIQUID (OIL & ASKAREL) Outdoor

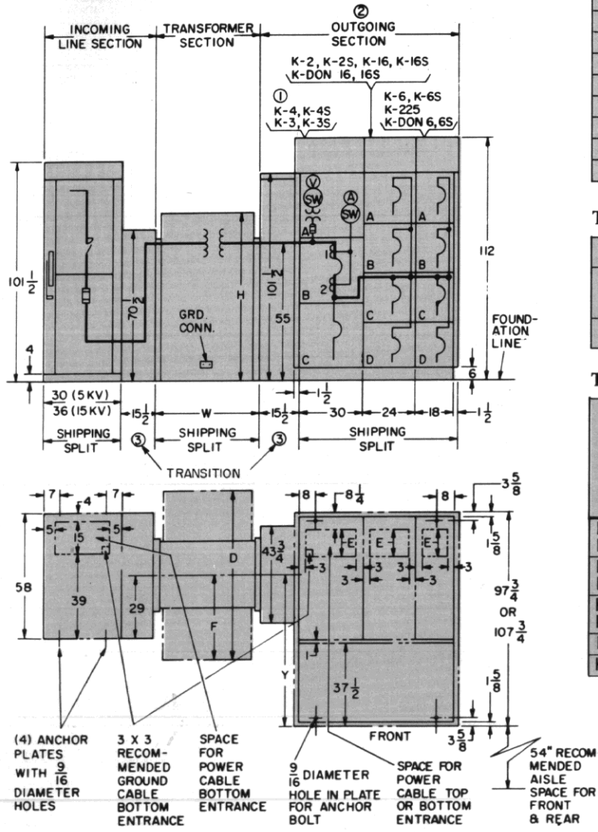


TABLE 11 — LOW-VOLTAGE SWITCHGEAR

"Y" Dimension	
Without Main Breaker with K-LINE® Feeders With Main Breaker with K-LINE or K-DON Feeders	32
Without Main Breaker with K-DON® Feeders	36½

TABLE 12 — LOW-VOLTAGE SWITCHGEAR

Circuit Breaker Type	Frame Width, in.	"E" Dimension Without Main Bus Barrier		With Main Bus Barrier		Feeder Ground Sensor	
		Switchboard Depth, in.					
		58	68	58	68	58	68
K3 & K3S, K4 & K4S	30	21*	31*	12†	22†	—	17½
K2 & K2S, K16 & K16S	24	21	31	12	22	—	17½
K6 & K6S, K-225	18	21	31	12	22	—	17½
K-DON 6, 6S	18	16½	26½	—	17½	—	13
K-DON 16, 16S	24	16½	26½	—	17½	—	13

* With bottom entrance to K-3000 in compartment C, subtract 6".
† With K-3000 in compartment C & 3φ, 4w system, subtract 4½".

TABLE 15 — OIL & ASKAREL (LU-8) –65°C RISE

kVA	W	H OIL	H ASK.	D	F
112½	45½	74½	76½	34	17½
150	45½	74½	76½	34	17½
225	45½	74½	76½	38	17½
300	45½	73½	75½	47	18
500	45½	74½	76½	52½	30
750	48½	78½	80½	62	39
1000	48½	77	79	70	39
1500	53	82½	84½	87	47½
2000	53	80	82	97	48½
2500	53	85	87	99	49½

TABLE 16 — LOW-VOLTAGE SWITCHGEAR

"Y" Dimension	
Without Main Breaker with K-LINE Feeders With Main Breaker with K-LINE or K-DON Feeders	69½
Without Main Breaker with K-DON Feeders	74

TABLE 17 — LOW-VOLTAGE SWITCHGEAR

Circuit Breaker Type	Frame Width	"E" Dimension Without Main Bus Barrier		With Main Bus Barrier		Feeder with Ground Sensor	
		Switchboard Depth, in.					
		97¾	107¾	97¾	107¾	97¾	107¾
K3 & K3S, K4 & K4S	30	18*	18*	11†	18†	—	13½
K2 & K2S, K16 & K16S	24	18	18	11	18	—	13½
K6 & K6S, K-225	18	18	18	11	18	—	13½
K-DON 6 & 6S	18	15½	18	—	16½	—	12
K-DON 16 & 16S	24	15½	18	—	16½	—	12

* With bottom entrance to K-3000 in compartment C subtract 6".
† With K-3000 in compartment C & 3φ 4w system subtract 4½".

① K-4000 (2-45" high compartments) breaker located in bottom compartment.
② When main bus is over 4000 amperes, consult I-T-E district sales office.
③ Transitions shipped disassembled.

WEIGHTS

INCOMING LINE SECTION

TABLE 18 — PRIMARY DEVICE WEIGHTS, LBS.

Type Primary Device	Depth, in. Indoor 58	Depth, in. Indoor 68	Depth, in. Outdoor 58	Depth, in. Outdoor 68	3 Fuses	3 L.A.	1-3/c 3-1/c Pothead
5 kV Unfused Switch	900	1000	1350	—	200	50	100
15 kV Unfused Switch	1200	1300	1800	—			
5 kV Unfused Selector	1100	1200	1550	—			
15 kV Unfused Selector	—	1600	—	2250			
Air Terminal Chamber	400						
Liquid Switches	2-Position		3-Position				
5 kV	450		500				
15 kV	515		640				
Oil Fused Cutout 5 kV—100, 200A	900						
Oil Fused Cutout 5 kV—300A 15 kV—100, 200A	1300						

TABLE 19 — METAL-CLAD SWITCHGEAR WEIGHTS, LBS.

Circuit Breaker Type	Cont. Current, A	Breaker Weight	Depth Indoor 56″	Depth Outdoor 65″	End Panels
5HK75	1200	550	1325	1690	545
5HK250	1200	560	1325	1690	
5HK250	2000	580	1458	1823	
5HK350	1200	750	1400	1790	590
5HK350	2000	760	1533	1923	
			81″	**90″**	775
7.5HK500	1200	995	2170	2675	
7.5HK500	2000	1005	2411	2916	
15HK500	1200	985	2170	2675	
15HK500	2000	1005	2411	2916	
			89″	**98″**	835
15HK750	1200	1345	2260	2778	
15HK750	2000	1355	2501	3019	

AUXILIARY EQUIPMENT

5HK–Potential transformer, drawout unit with 3 PT's—216 lbs.
15HK–Potential transformer, drawout unit with 3 PT's—515 lbs.
5 & 15 kV–Stationary-mounted, control-power transformers to 15 kVA—305 lbs.
5HK–Drawout fuse unit—160 lbs.
15HK–Drawout fuse unit—295 lbs.

TRANSFORMER SECTION

TABLE 20 — TRANSFORMER WEIGHTS, LBS.

Transformer Type	Volts, kV	TRANSFORMER kVA *	300	500	750	1000	1500	2000	2500
Ventilated-Dry	5 or 15	2200	2200	3000	3800	4900	6400	7900	10025
Liquid-Askarel	5 or 15	3700	4100	5100	6900	7500	10300	11800	13800
Liquid-Oil		3100	3400	4300	5800	6400	8600	10000	11600
Sealed-Dry	5	—	4200	6000	6800	8250	11000	11000	15800
	15	—	4800	6400	7200	8850	11500	13700	16500

*112½ through 225 kVA.

OUTGOING SECTION

TABLE 21 — LOW-VOLTAGE SWITCHGEAR WEIGHTS, LBS.

Type Unit	Frame Width, Inches	Switchgear Depth, in. Indoor 58	Indoor 68	Outdoor 97¾	Outdoor 107¾
*K-225, K-6 & 6S, K-DON 6 & 6S	18	750	850	1300	1420
		900	1000	1450	1570
*K-16 & 16S, K-2 & 2S, K-DON 16 & 16S	24	1000	1200	1650	1880
*K-3 & 3S, K-4 & 4S	30	1550	1750	2300	2535
		1600	1800	2350	2585
Auxiliary Units (Bus Transition) Includes Bus	18	700	800	1250	1370
	24	800	900	1450	1580
	30	900	1000	1650	1785
End Panels	1½	—		1000 Per Swbd	1125 Per Swbd
Overhead Lifting Device	—	100 Per Switchboard			
†Terminal Block Pans	—	110			
Main Bus Barriers	18	65			
	24	90			
	30	110			

*Switchboard only. Does not include breakers. For breaker weights, see Table 23.
†For electrically operated circuit breakers.

TABLE 22—TRANSITION UNIT WEIGHTS, LBS.

14″ Switchgear Depth 58″	14″ Switchgear Depth 68″	15½″ Indoor	15½″ Outdoor
400	450	425	475

TABLE 23—CIRCUIT BREAKER WEIGHTS, LBS.

Type	Manual Operation	Electrical Operation
K-225	102	123
K-6 & 6S	112	133
K-16 & 16S	185	206
K-2 & 2S	204	225
K-DON 6 & 6S	142	163
K-DON 16 & 16S	264	285
K-3 & 3S	520	548
K-4 & 4S	533	561

ARRANGEMENTS – OUTGOING SECTION

TWO-HIGH

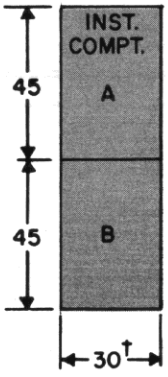


TABLE 24

Each 30" Wide x 45" High Compartment Can Be Fitted With	
Quan.	Type
1	K-4000 Compt. B
1*	Drawout Fuse Compt. A
1	KP, HP, HR, CP or CR (All Stationary Only)
2	HM or CM
4	KM or CJ
6	JJ, JL or HJ
12	FJ or CF
20	EF, EH or HE

* Fuse size 6000A. 4000A maximum continuous current rating.
† Power Co. metering compt. 40".

THREE-HIGH

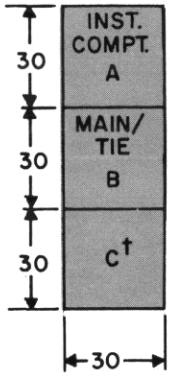


TABLE 25

Each 30" Wide x 30" High Compartment Can Be Fitted With	
Quan.	Type
1•	K-2000 Compt. C
1•	K-3000 Compt. C
1	K-3000 Compt. B
1*	Drawout Fuses Compt. B
1	KP, HP, HR, CP, or CR (All Stationary Only)
2	KM, HM, CJ or CM
4	JJ, JL or HJ
8	FJ or CF
12	EH, EF or HE

• When used with drawout fuse units.
* Fuse sizes 3000-4000A (K-2000).
Fuse sizes 4000-6000A (K-3000).
3000A maximum continuous current rating.
† Can be equipped with any lower rated breaker.

FOUR-HIGH

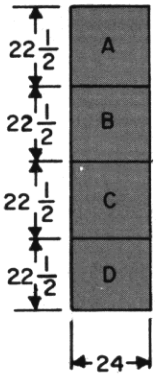


TABLE 26

Each 24" Wide x 22½" High Compartment Can Be Fitted With	
Quan.	Type
1	K-16
1	KD-16
1	K-2
1	KP, HP or HR (All Stationary Only)
2	JJ, JL, KM, HJ or CJ
4	FJ or CF
8	EF, EH or HE

LEGEND

K-6 = K-225, K-600 & K-600S
K-16 = K-1600 & K-1600S
K-2 = K-2000 & K-2000S
KD-6 = K-DON-600 & K-DON-600S
KD-16 = K-DON-1600 & K-DON-1600S

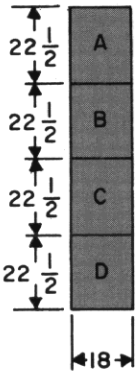


TABLE 27

Each 18" Wide x 22½" High Compartment Can Be Fitted With	
Quan.	Type
1	K-6
1	KD-6
1	JJ, JL, KM, HJ or CJ
3	FJ or CF
6	EF, EH or HE

NOTES:
All frames may be fitted with the same size circuit breaker in each compartment except as follows:
1—Only one K-2000 breaker in each 24" wide frame.
2—Main and Tie must be located in compartment B.

Preferred arrangement for the same size breakers in each 18" or 24" W compartment is as follows:

No. of same size circuit breakers	Compartment
1	B
2	B, C
3	B, C, D

TABLE 28 — K-6, K-16 AND K-2 ARRANGEMENTS

Compt.	Type Breaker													
A	K-16	K-6	K-6	K-6	K-16	K-6	K-6	—	—	—	—	—	—	—
B	K-2	K-2	K-2	K-2	K-2	K-2	K-2	K-2	K-2	K-2	K-2	K-2	—	—
C	K-16	K-16	K-16	K-6	K-16	K-16	K-6	K-16	K-16	K-6	K-16	K-6	K-2	K-2
D	K-16	K-16	K-6	K-6	—	—	—	K-16	K-6	K-6	—	—	K-16	K-6

TABLE 29 — K-6 AND K-16 ARRANGEMENTS

Compt.	Type Breaker								
A	K-6	K-6	K-6	K-6	K-6	—	—	—	—
B	K-16	K-16	K-16	K-16	K-16	K-16	K-16	—	K-16
C	K-16	K-16	K-6	K-16	K-6	K-16	K-6	K-16	K-6
D	K-16	K-6	K-6	—	—	K-6	K-6	K-6	—

TABLE 30 — KD-6 AND K-16 ARRANGEMENTS

Compt.	Type Breaker								
A	KD-6	KD-6	KD-6	KD-6	KD-6	—	—	—	—
B	K-16	K-16	K-16	K-16	K-16	K-16	K-16	—	K-16
C	K-16	K-16	KD-6	K-16	KD-6	K-16	KD-6	K-16	KD-6
D	K-16	KD-6	KD-6	—	—	KD-6	KD-6	KD-6	—

TABLE 31 — KD-6 AND KD-16 ARRANGEMENTS

Compt.	Type Breaker								
A	KD-6	KD-6	KD-6	KD-6	KD-6	—	—	—	—
B	KD-16	KD-16	KD-16	KD-16	KD-16	KD-16	KD-16	—	KD-16
C	KD-16	KD-16	KD-6	KD-16	KD-6	KD-16	KD-6	KD-16	KD-6
D	KD-16	KD-6	KD-6	—	—	KD-6	KD-6	KD-6	—

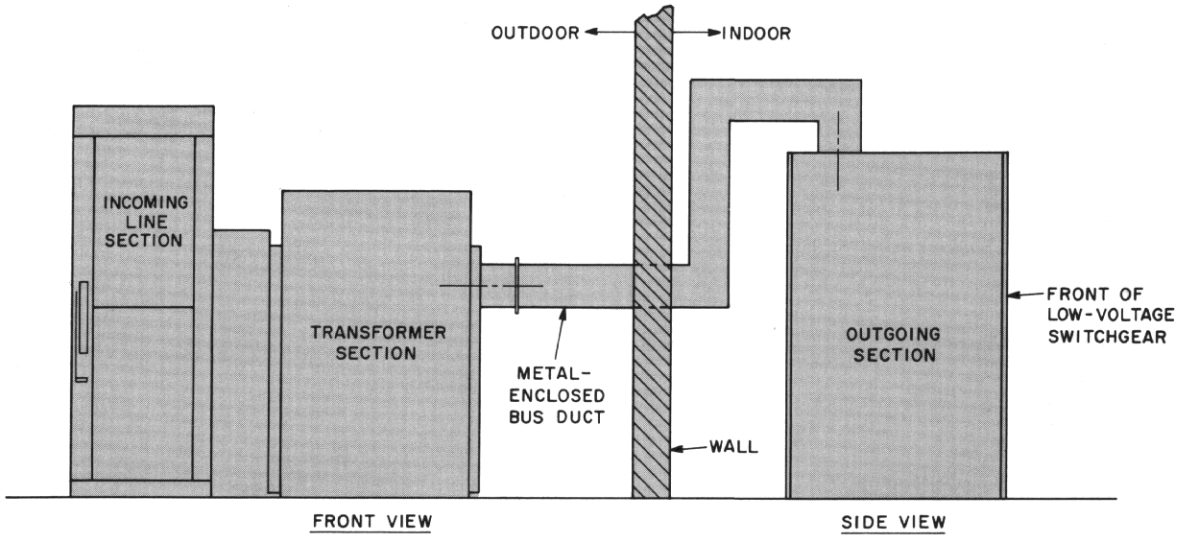
TABLE 32 — K-16, K-2 AND KD-6 ARRANGEMENTS

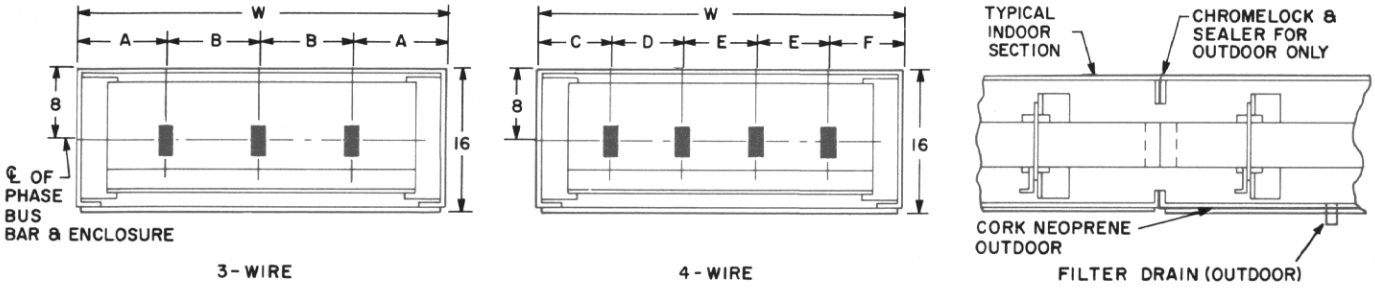
Compt.	Type Breaker								
A	KD-6	KD-6	KD-6	KD-6	KD-6	—	—	—	—
B	K-2	K-2	K-2	K-2	K-2	K-2	K-2	K-2	—
C	K-16	K-16	KD-6	K-16	KD-6	K-16	KD-6	KD-6	K-2
D	K-16	KD-6	KD-6	—	—	KD-6	KD-6	—	KD-6

METAL-ENCLOSED BUS DUCT

I-T-E low-voltage metal-enclosed bus duct is available in continuous current ratings of 600A through 3000A at 600 volts. Standard construction includes silver-plated aluminum bus mounted on polyester-glass bus supports. Outdoor bus duct is weatherproofed and is provided with heaters to reduce condensation.

- Indoor or outdoor construction
- 3- or 4-wire
- Polyester-glass bus supports
- Silver-plated aluminum bus
- Removable access cover





TYPICAL SECTION VIEWS

TABLE 33 — INDOOR-OUTDOOR 600-3000 Amperes

Type	Dimensions							Current Rating, A	Housing Material	Cover Material
	W	A	B	C	D	E	F			
3-Wire	22	6	5	—	—	—	—	600-2000	12 Ga. Steel	600-1600A 12 Ga. Steel
3-Wire Split Phase	34	8	9	—	—	—	—	3000	11 Ga. Steel	
4-Wire 50%–100% Neutral	27	—	—	6	5	5	6	600-2000	12 Ga. Steel	
4-Wire Split Phase 50% Neutral	39	—	—	6	7	9	8	3000	11 Ga. Steel	2000-3000A ⅛" Aluminum
4-Wire Split Phase 100% Neutral	43	—	—	8	9	9	8	3000	11 Ga. Steel	

SELECTION AND APPLICATION

INCOMING LINE SECTION

AIR INTERRUPTER SWITCHES

TABLE 34 — AIR INTERRUPTER SWITCH RATINGS (Fused or Unfused)

Voltage Rating				Current Rating				Interrupting Life on Close-Open Duty Cycle Number of Interruptions					Fault Closing With Spring Operator	
Nominal kV	Max. Design kV	Withstand		Continuous Current, A	At kV	10 Cycle Momentary Rms Asym. kA	4 Sec. Short-Time Rms Sym. kA	At kV	Power Factor	200A	400A	600A	Unfused Rms Asym. kA	Fused
		60 Cycle kV	Impulse kV											
4.8	5.5	19	60	600	5.5	61	38	5.5	0.8	1000	1000	300	40	Fuse Interrupting Rating
7.2/13.8	14.5	36	95	600	14.5			14.5		800	400	300		

TABLE 35 — CL-13 CURRENT-LIMITING FUSE RATINGS, (50/60 Hertz) Non-Disconnect Type

System kV, L-L	Interrupting Rating		Fuse kV
	MVA Sym.	kA Asym.	
2.4	250	96	4.8
4.16	430	96	4.8
4.8	500	96	4.8
6.9	480	64	14.4
7.2	500	64	14.4

System kV, L-L	Interrupting Rating		Fuse kV
	MVA Sym.	kA Asym.	
11.5	800	64	14.4
12.0	830	64	14.4
12.47	860	64	14.4
13.2	910	64	14.4
13.8	995	64	14.4
14.4	1000	64	14.4

TABLE 36A — POWER FUSE SELECTION①

System kV, L-L		2.4				4.16				4.8				6.9				7.2			
Transformer		I F.L.	Fuse Size			I. F.L.	Fuse Size			I F.L.	Fuse Size			I F.L.	Fuse Size			I F.L.	Fuse Size		
kVA②	Impedance③		Min.	133%	Max.		Min.	133%	Max.		Min.	133%	Max.		Min.	133%	Max.		Min.	133%	Max.
112.5	4.5	27	40E	40E	65E	16	25E	25E	40E	14	20E	20E	30E	9	15E	15E	20E	9	15E	15E	20E
150	4.5	36	40E	50E	80E	21	40E	40E	50E	19	30E	30E	40E	12	20E	20E	30E	12	20E	20E	30E
225	4.5	54	65E	80E	125E	31	40E	40E	65E	27	40E	40E	65E	19	30E	30E	40E	18	30E	30E	40E
300	5.0	72	100E	100E	150E	42	50E	65E	100E	36	50E	50E	80E	25	40E	40E	50E	24	40E	40E	50E
500	5.0	120	125E	200E	250E	69	80E	100E	125E	60	80E	80E	125E	42	50E	65E	80E	40	50E	65E	80E
750	5.75	180	200E	250E	300E	104	125E	150E	200E	90	100E	125E	150E	63	80E	100E	100E	60	80E	100E	100E
1000	8.0	241	250E	300E	300E	139	150E	150E	150E	120	125E	150E	150E	84	100E	100E	100E	80	100E	100E	100E
1000	5.75	241	250E	300E	400E	139	150E	200E	250E	120	125E	200E	200E	84	100E	125E	150E	80	100E	125E	125E
1500	5.75	361	400E	—	—	208	250E	300E	300E	180	200E	250E	300E	126	150E	200E	200E	120	125E	200E	200E
2000	5.75	—	—	—	—	278	300E	400E	400E	241	250E	400E	400E	167	200E	200E	200E	160	200E	200E	200E
2500	5.75	—	—	—	—	348	400E	—	—	300	400E	400E	400E	209	—	—	—	201	—	—	—

① Minimum fuse size shown will clear transformer magnetizing inrush current. 133% fuse size permits overload operation of transformer up to 133% of rating. Maximum fuse size provides transformer fault protection for phase-phase, 3-phase and phase-ground faults on secondary windings of standard 3-phase transformers. Suffix E denotes NEMA standard fuse rated 30°C rise above 40°C average ambient.

② The self-cooled kVA rating of the transformer as shown above should be used in selection of fuse size on forced-air cooled transformer applications. Also, on such applications, the 133% fuse size must be chosen for proper coordination.

③ Per cent impedance on self-cooled kVA base.

TABLE 36B– POWER FUSE SELECTION①

System kV, L-L		11.5				12.0				12.47				13.2				13.8				14.4			
Transformer		I	Fuse Size			I	Fuse Size			I	Fuse Size			I	Fuse Size			I	Fuse Size			I	Fuse Size		
kVA②	Imp.③	F.L.	Min.	133%	Max.	F.L.	Min.	133%	Max.	F.L.	Min.	133%	Max.	F.L.	Min.	133%	Max.	F.L.	Min.	133%	Max.	F.L.	Min.	133%	Max.
112.5	4.5	5.7	10E	10E	10E	5.4	10E	10E	10E	5.2	10E	10E	10E	4.9	10E	10E	10E	4.7	10E	10E	10E	4.5	10E	10E	10E
150	4.5	7.5	15E	15E	15E	7	15E	15E	15E	7	15E	15E	15E	6.6	10E	10E	15E	6.2	10E	10E	15E	6	10E	10E	15E
225	4.5	11.2	20E	20E	25E	10.8	20E	20E	25E	10.4	20E	20E	25E	9.8	15E	15E	20E	9.4	15E	15E	20E	9	15E	15E	20E
300	5.0	15	25E	25E	30E	14.4	25E	25E	30E	14	25E	25E	30E	13	20E	20E	30E	12.6	20E	20E	25E	12	20E	20E	25E
500	5.0	25	40E	40E	50E	24	40E	40E	50E	23	40E	40E	50E	22	40E	40E	50E	21	40E	40E	40E	20	30E	30E	40E
750	5.75	38	50E	50E	65E	36	40E	50E	65E	35	40E	50E	65E	33	40E	50E	65E	32	40E	50E	50E	30	40E	50E	50E
1000	8.0	50	65E	65E	65E	48	65E	65E	65E	46	65E	65E	65E	44	65E	65E	65E	42	50E	50E	50E	40	50E	50E	50E
1000	5.75	50	65E	65E	80E	48	65E	80E	80E	46	65E	65E	80E	44	50E	65E	80E	42	50E	65E	80E	40	50E	65E	80E
1500	5.75	75	100E	100E	125E	72	100E	100E	125E	70	80E	100E	125E	66	80E	100E	100E	63	80E	100E	100E	60	80E	100E	100E
2000	5.75	101	125E	150E	150E	96	125E	150E	150E	92	100E	125E	150E	88	100E	125E	150E	84	100E	125E	150E	80	100E	125E	125E
2500	5.75	126	150E	200E	200E	120	125E	200E	200E	116	125E	200E	200E	109	125E	150E	150E	105	125E	150E	150E	100	125E	150E	150E

① Minimum fuse size shown will clear transformer magnetizing inrush current. 133% fuse size permits overload operation of transformer up to 133% of rating. Maximum fuse size provides transformer fault protection for phase-phase, 3-phase and phase-ground faults on secondary windings of standard 3-phase transformers. Suffix E denotes NEMA standard fuse rated 30°C rise above 40°C average ambient.

② The self-cooled kVA rating of the transformer as shown above should be used in selection of fuse size on forced-air cooled transformer applications. Also, on such applications, the 133% fuse size must be chosen for proper coordination.

③ Per cent impedance on self-cooled kVA base.

OIL CUTOUTS

TABLE 37 — FUSE INTERRUPTING RATINGS

Nominal Full Winding Voltage	Fuse Interrupting Rating		kVA Limitations	
	Amperes (rms) Asymmetrical	Equivalent MVA Symmetrical	Fused	Unfused
2.4	10,000	42	500	750
4.16	10,000	72	750	1000
13.8	4,000	99	1000	2000

LIQUID SWITCH

TABLE 38 — RATINGS

Voltage Rating, kV	Maximum Continuous Current Rating, A	Interrupting Capacity, A	
		Oil-filled	Askarel-filled
5	400	400	①
15	400	400	①

① When liquid switch is askarel-filled, it has no interrupting capacity. It can break magnetizing currents of up to 10A for five times without replacement.

METAL-CLAD SWITCHGEAR

TABLE 39 — HK CIRCUIT BREAKER RATINGS

Circuit Breaker Type	5HK-75	5HK-250	5HK-350	7.5HK-500	15HK-500
Current Ratings (Continuous)	1200A	1200 & 2000A	1200 & 3000A	1200 & 2000A	1200 & 2000A
Rated MVA (Sym)	75	250	350	500	500
Current, Close & Latch	20000A	60000A‡	80000A	70000A	40000A†
Current, 3 Sec.	12500A	37500A	50000A	44000A	25000A
Voltage, Rated kV	4.16	4.16	4.16	7.2	13.8
Voltage, Max. Design kV	4.76	4.76	4.76	8.25	15.0
Voltage, Min. at Rated MVA	3.5	3.85	4.0	6.6	11.5
I.C. at Rated kV	10500A	35000A	48600A	40000A	21000A
I.C. at Max. kV	9100A	30300A	42400A	35000A	19300A
I.C. at Min. kV	12500A	37500A	50000A	44000A	25000A

†60,000 A Momentary Available ‡80,000 A Momentary Available

Note: For complete application information on I-T-E Metal-Clad Switchgear, refer to I-T-E Bulletin 8.2-1.

TABLE 40 — CIRCUIT BREAKER RATINGS

Circuit Breaker Type	5HK	7.5 & 15 HK
60 Cycle Withstand	19 kV	36 kV
BIL	60 kV	95 kV
Interrupting Time (0-100% IC)	5 cycles	5 cycles
Average Closing Time	4.5 cycles	7.5 cycles
Average Tripping Time	1.5 cycles	1.5 cycles
Spring Charging Time—Max.	2 seconds	2 seconds

TRANSFORMER SECTION

TABLE 41 — STANDARD TRANSFORMER RATINGS

TYPE	Primary Voltage Delta	kVA 3-Phase Self-Cooled	kVA 3-Phase Forced-Air Cooled	SECONDARY VOLTAGE 208Y/120 240 delta	SECONDARY VOLTAGE 480Y/277 480 delta	Standard Impedance*	NEMA Sound Level, db Self-Cooled	NEMA Sound Level, db Forced-Air Cooled
Liquid-Immersed Oil or Askarel 65°C Rise †	2400	112½	—	X	X	2.25‡	55	—
	4160	150	—	X	X	3.0‡	55	—
	4800	225	—	X	X	4.5	55	—
	6900	300	—	X	X	5.0	55	—
	7200	500	—	X	X	5.0	56	—
	12000	750	862	X	X	5.75	58	67
	12470	1000	1150	X	X	5.75	58	67
	13200	1000	1150		X	8.0	58	67
	13800	1500	1725		X	5.75	60	67
		2000	2300		X	5.75	61	67
		2500	3125		X	5.75	62	67
Ventilated-Dry 150°C Rise †	2400	112½	—	X	X	3.0‡	50	—
	4160	150	—	X	X	3.5‡	50	—
	4800	225	—	X	X	4.5	55	—
	6900	300	—	X	X	5.0	55	—
	7200	500	667	X	X	5.0	60	67
	12000	750	1000	X	X	5.75	64	67
	12470	1000	1333	X	X	5.75	64	68
	13200	1000	1333		X	8.0	64	68
	13800	1500	2000		X	5.75	65	69
		2000	2666		X	5.75	66	71
		2500	3333		X	5.75	68	71
Sealed-Dry Hexafluoro-ethane (C_2F_6) Gas-Filled 150°C Rise †	2400	300		X	X	5.0	57	—
	4160	500		X	X	5.0	59	—
	4800	750		X	X	5.75	63	—
	6900	1000		X	X	5.75	63	—
	7200	1000			X	8.0	63	—
	12000	1500			X	5.75	64	—
	12470	2000			X	5.75	65	—
	13200	2500			X	5.75	66	—
	13800							

* Standard impedance tolerance is ±7½%.
† Average ambient temperature of 30°C.
‡ Transformers with impedances of 4.0% or less are designed to withstand 25 times normal current for two seconds.

TABLE 42 — LIGHTNING ARRESTERS

kV Rating of Arrester	Line to Line kV Ungrounded System	Line to Line kV Grounded System
Station and Intermediate Type ①		
3	2.4	4.16
6	4.8	7.2
9	7.2	12.47
12	11.5	13.8
15	13.8	18.0
Distribution Type②		
3	3.0	4.5
6	6.0	9.0
9	9.0	12.8
12	12.0	15.0
15	15.0	18.0

① For use with liquid-immersed and sealed-dry transformers.
② Distribution type arresters with special characteristics are furnished as standard on ventilated-dry transformers.

TABLE 44 — TEMPERATURE GUARANTEES

Transformer Type	Ambient*	Rise†	Hot Spot Rise
Liquid-immersed	30°C	65°C	80°C
Ventilated-dry	30°C	150°C	180°C
Sealed-dry	30°C	150°C	180°C

Altitudes must not exceed 1000 meters or 3300 feet.
* The temperature of the cooling air (ambient temperature) must not exceed 40°C and the average temperature of the cooling air for any 24-hour period must not exceed 30°C.
† Degrees rise is the average winding temperature rise by resistance. See NEMA Standard TR-1 and ANS C57.12.00.

TABLE 43 — DIELECTRIC TESTS

Transformer Type	Voltage Class, kV	Applied Test 60 Cycle All kVA Ratings	Basic Impulse Levels 1.2 x 50 ms	Induced Test 7200 Cycles, All kVA Ratings
Liquid-Immersed or Sealed-Dry	1.2	10 kV	30 kV	Twice normal voltage
	2.5	15 kV	45 kV	
	5.0	19 kV	60 kV	
	8.66	26 kV	75 kV	
	15.0	34 kV	95 kV	
Ventilated-Dry	1.2	4 kV	10 kV	Twice normal voltage
	2.5	10 kV	20 kV	
	5.0	12 kV	25 kV	
	8.66	19 kV	35 kV	
	15.0	31 kV	50 kV	

TABLE 45 — STANDARD HIGH-VOLTAGE TAPS

Rated Voltage	Rated kVA HV Taps, Volts			
2400	2520	2460	2340	2280
4160	4360	4260	4055	3950
4800	5040	4920	4680	4560
6900	7245	7070	6730	6555
7200	7560	7380	7020	6840
12000	12600	12300	11700	11400
12470	13095	12780	12160	11845
13200	13860	13530	12870	12540
13800	14400	14100	13500	13200

OUTGOING SECTION—K-LINE® CIRCUIT BREAKERS

TABLE 46 — K-LINE CIRCUIT BREAKER RATINGS

① Circuit Breaker Type	A-C Volts	Frame Size, A	Symmetrical Interrupting Rating With: Instantaneous Trip, A	Symmetrical Interrupting Rating With: Delayed Trip, A	Symmetrical Close and Latch & 30-Cycle Short-Time Rating, A	② Symmetrical Fault Current Limit 2-Step Cascade, A
K-225	208 and 240	225	25,000	14,000	14,000	25,000
K-600		600	42,000	22,000	22,000	42,000
K-1600		1,600	65,000	50,000	50,000	65,000
K-2000		2,000	85,000	55,000	55,000	85,000
K-3000		3,000	85,000	65,000	65,000	85,000
K-4000		4,000	130,000	85,000	85,000	130,000
K-225	480	225	22,000	14,000	14,000	22,000
K-600		600	30,000	22,000	22,000	30,000
K-1600		1,600	50,000	50,000	50,000	50,000
K-2000		2,000	65,000	55,000	55,000	65,000
K-3000		3,000	65,000	65,000	65,000	65,000
K-4000		4,000	85,000	85,000	85,000	85,000
K-225	600	225	14,000	14,000	14,000	14,000
K-600		600	22,000	22,000	22,000	22,000
K-1600		1,600	42,000	42,000	42,000	42,000
K-2000		2,000	55,000	55,000	55,000	55,000
K-3000		3,000	65,000	65,000	65,000	65,000
K-4000		4,000	85,000	85,000	85,000	85,000

① Recommended maximum continuous current rating of largest feeder breaker in per cent of transformer (self-cooled) rated current, when primary power fuses are included is 40% for current-limiting type and 50% for non-current-limiting type.

TABLE 47 — K-LINE S CIRCUIT BREAKER RATINGS

① Circuit Breaker Type	A-C Volts	Frame Size, A	Symmetrical Interrupting Rating With: Instantaneous Trip, A	Symmetrical Interrupting Rating With: Delayed Trip, A	Symmetrical Close and Latch & 30-Cycle Short-Time Rating, A	② Symmetrical Fault Current Limit 2-Step Cascade, A
K-600S	208 and 240	600	42,000	22,000	22,000	42,000
K-1600S		1,600	65,000	50,000	50,000	65,000
K-2000S		2,000	85,000	55,000	55,000	85,000
K-3000S		3,000	85,000	65,000	65,000	85,000
K-4000S		4,000	130,000	85,000	85,000	130,000
K-600S	480	600	30,000	22,000	22,000	30,000
K-1600S		1,600	50,000	50,000	50,000	50,000
K-2000S		2,000	65,000	55,000	55,000	65,000
K-3000S		3,000	65,000	65,000	65,000	65,000
K-4000S		4,000	85,000	85,000	85,000	85,000
K-600S	600	600	22,000	22,000	22,000	22,000
K-1600S		1,600	42,000	42,000	42,000	42,000
K-2000S		2,000	55,000	55,000	55,000	55,000
K-3000S		3,000	65,000	65,000	65,000	65,000
K-4000S		4,000	85,000	85,000	85,000	85,000

② It is the intention of the industry to eliminate cascading. Pending revision of ANS C37.13-1963 (R1969) to accomplish this, the fault-current limitations for 2-step cascade have been made the same as the short-circuit ratings with instantaneous trips.

SELECTION OF LOW-VOLTAGE POWER CIRCUIT BREAKERS IN LOW-VOLTAGE DRAWOUT SWITCHGEAR†

SELECTION OF BREAKER TRIPPING CHARACTERISTICS

The degree of service continuity available from a low-voltage distribution system depends on the degree of coordination between circuit-breaker tripping characteristics.

Three methods of tripping coordination are in general use, each representing a different degree of service continuity and of initial cost.

These methods, or systems, combine breaker ratings and tripping characteristics as follows:

FULLY-RATED SYSTEM

A fully-rated system is one in which both the main and feeder breakers have adequate interrupting capacity for the fault current available at the point of application.

All breakers are equipped with long-time delay and instantaneous overcurrent trips. Ordinarily only the breaker nearest the fault will open. The main breaker will trip, however, when the fault current exceeds its instantaneous trip setting, and service continuity may be lost.

CASCADED SYSTEM

A cascaded system is one in which only the main breaker has adequate interrupting capacity. Feeder breakers with inadequate interrupting capacity may be used provided the main breaker trips instantaneously to protect them when the fault current reaches a dangerous level.

All breakers are equipped with long-time delay and instantaneous trips. The main (back-up) breaker is set to trip instantaneously when the fault current through the backed-up feeder breaker exceeds 80% of the feeder breaker interrupting capacity.

The cascaded system offers a minimum initial cost when maximum continuity of service is not required.

SELECTIVE SYSTEM

A selective system is one in which both the main and feeder breakers have adequate interrupting capacity for the fault current available at the point of application.

The main breaker is equipped with overcurrent trip devices having long-time delay and short-time delay functions. The feeder breakers are equipped with overcurrent trip devices having long-time delay and instantaneous functions unless they are required to be selective with other protective devices nearer the load. In this case, the feeders are equipped with trip devices having both long-time and short-time delay.

In a selective system, only the breaker nearest the fault trips. Service continuity is thus maintained through all other breakers.

The main breaker trips only on a bus fault.

The selective system offers a maximum of service continuity, with a slightly higher initial cost than the fully-rated or cascaded systems.

SELECTION OF BREAKER TYPE

The following three basic factors determine the selection of a breaker after a decision has been reached on the type of system required:

System voltage and frequency
Continuous current
Available fault current

† Selection and application information is for low-voltage power circuit breakers equipped with OD direct-acting, electro-mechanical overcurrent trip devices. In general, however, these application rules apply to breakers with POWER-SHIELD™ solid-state overcurrent trip devices except for differences in available ampere taps and long-time, short-time and instantaneous pick-up settings.

USE OF APPLICATION TABLES

Application Tables 48A, B and C provide for proper selection of the circuit-breaker type required. They should be used as follows:

Use Table 48A for a fully-rated system
Use Table 48B for a cascaded system
Use Table 48C for a selective system

Having chosen the right table, refer to that part of it which covers the system voltage.

Look for the horizontal line listing an available fault current nearest the one required at the point of application (let the nearest one be higher, rather than lower than the exact fault current needed).

Then select the circuit-breaker type listed where the Available Fault Current line crosses the vertical column headed with the wording: Load Continuous Current Rating.

TABLE 48A—FULLY-RATED SYSTEM

Manually-charged, stored-energy-closed circuit breakers may be applied within their 600 v, 480 v, or 240 v interrupting rating, provided their instantaneous trips are set below their short-time ratings.

System Voltage and Frequency	Available Fault Current, Symmetrical RMS Amperes
501 to 630V 25-60 Hertz	14000
	22000
	42000
	55000
	65000
	85000
251 to 500V 50-60 Hertz	22000
	30000
	50000
	65000
	85000
Up to 250V 50-60 Hertz	25000
	42000
	65000
	85000
	130000

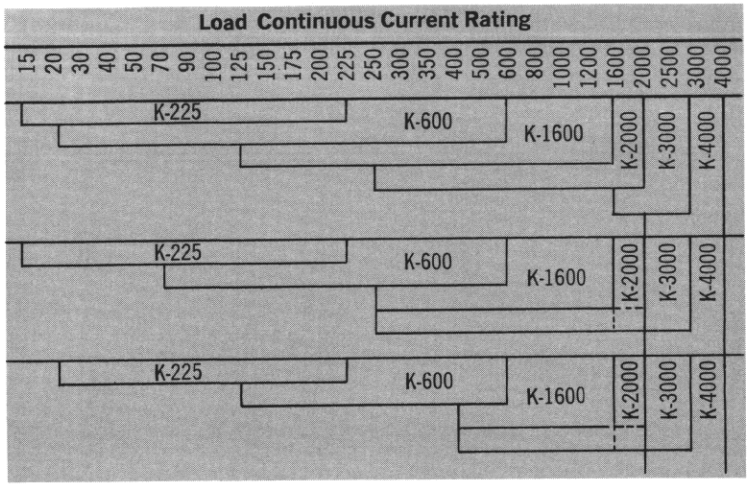


TABLE 48B—SECOND-STEP CASCADED SYSTEM

(First-Step Cascaded System—same as Fully Rated)

Circuit breakers subjected to fault currents in excess of their interrupting ratings are to be electrically operated and are to be controlled from a position other than in front of the breaker to provide protection for the operator when the breaker is closed against a fault current.

System Voltage and Frequency	Available Fault Current, Symmetrical RMS Amperes
481 to 600V 25-60 Hertz	25000
	42000
	85000
	85000
	85000
241 to 480V 50-60 Hertz	42000
	60000
	85000
	85000
	85000
Up to 240V 50-60 Hertz	50000
	85000
	100000
	130000
	130000

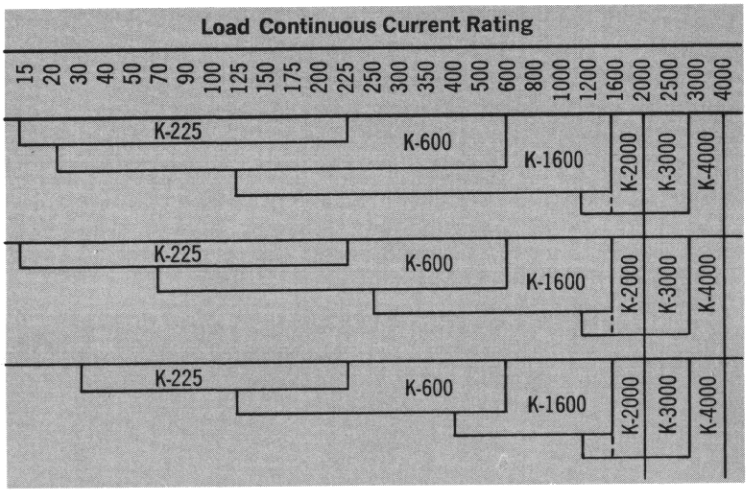
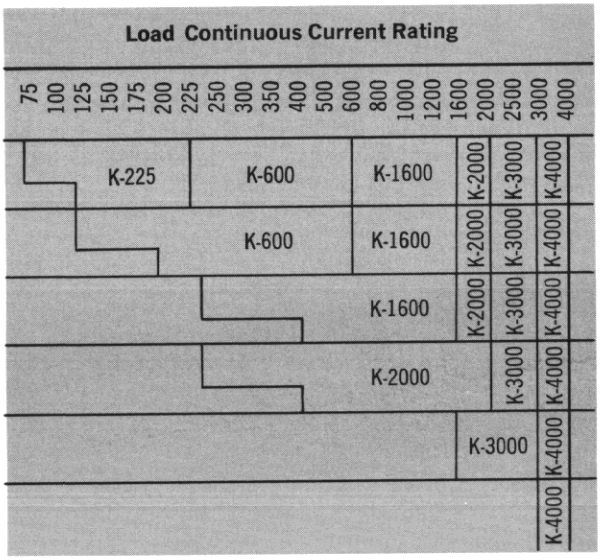


TABLE 48C—SELECTIVE SYSTEM

The manually-charged, stored-energy-closed circuit breakers with delayed trip may be applied within their short-time ratings.

System Voltage and Frequency	Available Fault Current, Symmetrical RMS Amperes	Short-Time Delay Band
Up to 600V 50-60 Hertz	14000	Minimum Intermediate Maximum
	22000	Minimum Intermediate Maximum
	42000*	Minimum Intermediate Maximum
	55000	Minimum Intermediate Maximum
	65000	Minimum Intermediate Maximum
	85000	Minimum Intermediate Maximum



* 50,000 at 480 and 240 volts.

K-DON® CIRCUIT BREAKERS

TABLE 49 — K-DON BREAKER RATINGS

Circuit Breaker Type	Frame Size, A	Voltage A C	Maximum Continuous Current, A	Maximum Interrupting Symmetrical Rating, Rms Amperes	Range of Circuit Breaker Pickup, A	Amp-trap Continuous Rating, A
K-DON-600 K-DON-1600	600 1600	up to 600 up to 600	600 1600	200,000 200,000	40-600 120-1600	300-1200 300-2500
K-DON-600S K-DON-1600S	600 1600	up to 600 up to 600	600 1600	200,000 200,000	40-600 200-1600	300-1200 600-2500

The following step by step procedure is to be used as a guide for proper circuit breaker and fuse selection.

A. CIRCUIT-BREAKER SELECTION

1—Determine the system short-circuit capacity in symmetrical rms amperes.

2—Determine from Table 50 columns 3, 4 and 5 respectively the approximate continuous current rating and the time-delay and instantaneous overcurrent trip settings.

3—Select from Tables 51* or 52, columns 1, 2, 3 and 4 respectively the frame size, proper coil rating, time-delay and instantaneous settings as follows:

(a) When there is a choice of breaker frame size the larger will provide maximum flexibility in case of load growth.

(b) The coil rating should be equal to or greater than the value determined in Table 50, column 3.

(c) Time-delay setting should be set at a value nearest to that determined in Table 50, column 4.

(d) Instantaneous setting should be set at a value nearest to that determined in Table 50, column 5. However, this value may have to be adjusted downward to coordinate with Amp-trap† to be selected in step B.

*Table 51 is to be used for K-DON breakers with electro-mechanical overcurrent trip devices; Table 52 is for K-DON breakers with solid-state overcurrent trip device.

†Registered Trademark—Chase-Shawmut Co.

TABLE 50 — CIRCUIT-BREAKER APPLICATION

1		2	3	4	5
Type of Application		Purpose of Circuit Breaker	Continuous Current Rating of Circuit Breaker	Settings of Overcurrent Trip Device	
				Time-Delay	Instantaneous
Service entrance (general)		(a) To protect source transformer windings from overheating, due to overload of fault current flow. (b) To protect circuit conductors from effects of overcurrent flow. (c) To provide safe and rapid means for connecting and disconnecting of load circuit.	Based upon 125% of the transformer current rating	125% of the transformer current rating	1000% of circuit-breaker current rating
Service feeder (general)		(a) To protect circuit conductors from effects of overcurrent flow. (b) To protect connected electrical equipment from effects of fault current flow.	Based upon 115% of estimated load current	115% of estimated load current	1000% of circuit-breaker current rating
BRANCH CIRCUITS (GENERAL)	Individual motor circuit	(a) To protect motor windings from overheating due to overcurrent or fault current flow. (b) To protect circuit conductors and other connected electrical equipment from overload or fault current flow. (c) To provide safe and rapid means of connecting and disconnecting motor circuit.	Based upon 115% of rated full-load current of motor	115% of rated full-load current of motor	1000% of circuit-breaker current rating
	Group motor circuit	(a) To protect circuit conductors from overheating. (b) To protect circuit conductors, motor windings and other connected electrical equipment from fault current flow. (c) To provide safe and rapid means of connecting and disconnecting common motor circuit from supply source.	Based upon 115% of largest motor full-load current plus sum of other motor currents	100% of circuit-breaker current rating	1000% of circuit-breaker current rating
	Combined motor and lighting circuit	(a) To protect circuit conductors from overheating. (b) To protect circuit conductors, motor windings and other connected electrical equipment from fault current flow. (c) To provide safe and rapid means of connecting and disconnecting common load circuit from supply source.	Based upon 115% of largest motor full-load current plus sum of other motor and lighting load currents	100% of circuit-breaker current rating	1000% of circuit-breaker current rating
	Lighting circuit	(a) To protect circuit conductors from effects of overload or fault current flow. (b) To provide safe and rapid means of connecting and disconnecting lighting circuit from supply source.	Based upon 125% of estimated maximum lighting current	100% of circuit-breaker current rating	1000% of circuit-breaker current rating

K-DON® CIRCUIT BREAKERS

B. AMP-TRAP† SELECTION

Table 51 or 52 is to be used for selecting the correct fuse sizes to coordinate with the instantaneous setting of the overload device to provide proper coordination between the circuit breaker and fuse. It was developed to provide the greatest range of coordination possible, taking advantage of maximum fuse sizes whose let-thru current can be withstood by the circuit breaker.

Figure 3, Page 41, is a second aid in the selection of the proper Amp-Trap fuse sizes. However, Fig. 3 is not to be used as the only criterion if, as in the case of molded-case circuit breakers, there is an I^2t limitation in the equipment to be protected by the fuse (See Figure 4).

There are two basic considerations in selecting an Amp-Trap fuse size.

1—The peak let-thru current must not exceed 2.3 times the symmetrical short-circuit withstand of the equipment to be protected by the K-DON circuit breaker.

a. If the equipment protected by the circuit breaker has a symmetrical short-circuit withstand rating at least equal to that of the circuit breaker,* fuse size selection may be made by using Table 51 or 52.

b. If the equipment protected by the circuit breaker has a symmetrical short-circuit withstand rating less than the circuit breaker, Fig. 3 must be used to determine the maximum fuse size.

Draw a vertical line on Fig. 3 representing the available symmetrical RMS amperes. Establish the intersection of this line with the peak amperes that the equipment is capable of withstanding. The fuse size represented by the fuse let-thru curve passing below this intersection is the maximum fuse size that should be used. Of course, the smallest fuse size, consistent with coordination, provides the best protection.

2—The second consideration is that the fuse size coordinates with the circuit-breaker overload time-current characteristic. Proper application of Table 51 or 52 and their associated notes will assure coordination and, therefore, avoid needless fuse replacements for current levels within the interrupting rating of the breaker.

For application using special instantaneous settings, a breaker-fuse coordination curve should be drawn.

Fuse curves are normally plotted with time as the ordinate and current in amperes as the abscissa. However, the abscissa of the overcurrent device time-current curves is the ratio of actual current to current tap or to coil rating or to pickup setting. There are so many combinations of settings as to render it completely impractical to publish general coordination curves for fuses and overcurrent trip devices.

When it is desired to plot specific coordination curves, the following procedure is suggested.

a. Replot the overcurrent device curve using actual amperes as the abscissa based on pick-up settings selected. The curves may be moved right or left to accommodate settings not plotted on published curves. A transparent overlay is helpful in this procedure.

b. Enter the fuse melting time-current curve from Figure 4, Page 41, on this newly plotted overcurrent device curve and examine for proper coordination.

c. When fuse size is dictated by protection needs, the fuse curve should be plotted first and the overcurrent device settings are then determined by trial and error, by replotting the overcurrent device cuves.

NOTES:

① Maximum allowable fuse sizes listed in Tables 51 or 52 are based on an available RMS symmetrical short-circuit current of 200kA. If available current is less than 200kA larger fuse sizes may be used based on let-thru of Figure 3 as illustrated in the following table. **Note that this does not apply to K-DON breakers equipped with solid-state trip.**

Frame Size	600	600	1600
Avail. kA	130	85	100
Max. Fuse Size, Amps.	1600	2000	3000

② When fused circuit breakers are used on high-inrush circuits such as motor starting, for extended periods, the maximum allowable fuse size from Tables 51 or 52 should be used regardless of instantaneous setting. Otherwise these fuses and other unblown fuses, after a short-circuit, may have melting times less than "when new". In this case, fuse replacement should be considered if the coordination is critical.

C. APPLYING LOW-VOLTAGE POWER CIRCUIT BREAKERS WITH SEPARATELY MOUNTED CURRENT LIMITING FUSES

(Note that this applies to the K-2000, K-3000 and K-4000 only. Lower rated breakers (not K-225) will be coordinated in the same manner as the K-DON breakers in Tables 51 or 52.

The interrupting capability of the proper combination of low-voltage power circuit breakers and current-limiting fuses is appreciably higher than the capability of the circuit breaker alone. The following guidelines are offered for combining Chase-Shawmut Amp-Trap current-limiting fuses, NEMA Class L, with modern I-T-E low-voltage power circuit breakers:

1—Avoid or at least minimize overlap of time-current characteristics (fuse vs. overcurrent device) at currents less than the circuit-breaker interrupting rating to keep needless fuse blowing to a minimum. Adding a short-time element often helps to obtain coordination.

2—The total clearing time of the fuse must be equal to or less than the total clearing time of the circuit breaker at a current equal to the interrupting rating of the circuit breaker at the voltage of the application.

3—The peak let-through current of the fuse must not exceed 2.3 times the withstand rating of the circuit breaker.†

4—The fuses should preferably be on the source side of the circuit breaker. When this is not possible, the two should be located as close as practical to each other, and the installation should minimize the exposure to a fault between the breaker and the fuse.

NOTE:

In order to obtain selective protection when fuses are applied in series, it is necessary that the fuse nearer the source have a current rating at least two times that of the fuse nearer the load, providing that both fuses are Chase-Shawmut Class L. The two-times ratio is applied to fuse ratings up to 2000A, but for fuse ratings of 2500A to 6000A the ratio may be reduced to 1½ times.

† Registered Trademark—Chase Shawmut Co.

* K-DON-600, 42,000A Sym; K-DON-1600, 65,000A Sym.

† K-2000 — 85,000A, Sym.
K-3000 — 130,000A, Sym.
K-4000 — 130,000A, Sym.

TABLE 51 — K-DON COORDINATION (ELECTRO-MECHANICAL)

Circuit Breaker Type	Breaker Coil Rating, A	Long-Time Pickup Settings, A	Instantaneous Pickup Settings,③ A	Coordinating Fuse Size, A (See Note 1) Min.	Max.
1	2	3	4	5	
K-DON-600	70	40, 50, 60, 70 or 90	250	300	600
			500	300	600
			750	300	600
			1100	300	600
	125	70, 90, 100, 125 or 160	450	300	800
			800	300	800
			1200	400	800
			1900	600	800
	225	120, 150, 175, 200, 225 or 285	750	300	1200
			1500	400	1200
			2400	600	1200
			3400	1000	1200
	400	250, 300, 350, 400 or 500	1250	400	1200
			2000	600	1200
			4000	1200	1200
			6000	See Note 2	
	600	400, 500, 600 or 750*	2500	800	1200
			4000	1200	1200
			6000	See Note 2	
			9000	See Note 2	
K-DON-1600	225	120, 150, 175, 200, 225 or 285	750	300	1600
			1500	400	1600
			2400	600	1600
			3400	1000	1600
	400	250, 300, 350, 400 or 500	1250	400	2500
			2000	600	2500
			4000	1200	2500
			6000	1600	2500
	800	400, 500, 600, 800 or 1000	2500	800	2500
			5000	1600	2500
			8000	2500	2500
			12000	See Note 2	
	1600	800, 1000, 1200, 1600 or 2000*	5000	2500	2500
			10000	2500	2500
			16000	See Note 2	
			24000	See Note 2	

* Setting above coil rating is available for coordination, if needed, but is not thermally self protecting.

TABLE 52 — K-DON COORDINATION (SOLID-STATE)

Circuit Breaker Type		Breaker AMPERE TAP Settings, A	Long-Time Pickup Settings, (X Ampere Tap) A	Instantaneous Pickup Settings, (X Ampere Tap) A	Coordinating Fuse Size, A (See Notes 1 & 5) Min.	Max.
1		2	3	4	5	
K-DON-600S	SENSOR RANGE	50, 70, 100	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	300	1200
		150	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	300	1200
					400	1200
		225	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	400	1200
					600	1200
	SENSOR RANGE	250	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	600	1200
					800	1200
		400	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	800	1200
					1000	1200
		600	0.8, 0.9, 1.0, 1.1† or 1.2†	4, 5, 6, 8, 10 or 12	1200	1200
					See Note 2	
K-DON-1600S	SENSOR RANGE	250	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	600	2500
					800	2500
		400	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	800	2500
					1000	2500
		600	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	1200	2500
					1600	2500
	SENSOR RANGE	600	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	1200	2500
					1600	2500
		1000	0.8, 0.9, 1.0, 1.1 or 1.2	4, 5, 6, 8, 10 or 12	2000	2500
					2500	2500
		1600	0.8, 0.9, 1.0, 1.1† or 1.2†	4, 5, 6, 8, 10 or 12	2500	2500
					See Note 2	

† Setting above maximum ampere-tap rating is available for coordination, if needed, but is not thermally self protecting.

NOTES TO TABLES 51 AND 52:

① The minimum fuse size column indicates the minimum fuse size that will coordinate with the instantaneous trip setting directly along side it at the 100% long-time pickup setting. Even though a lower fuse size might appear to coordinate by use of minimum or intermediate time bands or lower instantaneous setting or lower long-time pickup setting, a fuse size lower than listed is not recommended.

② The maximum fuse for the frame size will not coordinate with the instantaneous trip setting listed. (See Note 4.)

③ The instantaneous setting selected should not be less than five nor more than fifteen times the long-time pickup setting selected.

④ When the selected settings and indicated fuse size will not coordinate, the following applies:

a. Determine the degree of overlap by drawing a breaker-fuse coordination curve.

b. If the degree of overlap is not deemed critical (low probability of needless fuse blowing), accept the overlap.

c. If the degree of overlap is deemed critical, utilize a short-time delay element in conjunction with the long-time and instantaneous elements to achieve coordination.

⑤ For the solid-state device the coordinating fuse size is based on the ampere-tap setting. If a higher tap setting is planned for future load growth, the maximum fuse size for the sensor range should be used to maintain proper coordination.

Tables 53 and 54 can be used along with the notes of Table 51 and 52 to assure coordination. Table 53 is to be used when applying separately fused circuit breakers with electro-mechanical overcurrent trips.

TABLE 53 —
COORDINATION OF SEPARATELY MOUNTED FUSES AND BREAKERS (Electro-Mechanical)

Circuit Breaker Type	Breaker Coil Rating, A	Long-Time Pickup Settings, A	Instantaneous Pickup Settings, A	Coordinating Fuse Size (See Table 51, Note 1) Min.	Max.
K-2000	2000	1200, 1600, 1800, 2000 or 2500*	10,000	3000	3000
			15,000	See Note A	
			20,000	See Note A	
			30,000	See Note A	
K-3000	3000	1600, 2000, 2500, 3000 or 3800*	10,000	4000	6000
			20,000	6000	6000
			28,000	See Table 51, Note 2	
			36,000	See Table 51, Note 2	
K-4000	4000	2000, 3000, 3500, 4000 or 5000*	20,000	6000	6000
			30,000	See Table 51, Note 2	
			40,000	See Table 51, Note 2	
			48,000	See Table 51, Note 2	

* Setting above coil rating is available for coordination, if needed, but is not thermally self protecting.

Table 54 is for separately fused circuit breakers with solid-state overcurrent trip devices.

TABLE 54 —
COORDINATION OF SEPARATELY MOUNTED FUSES AND BREAKERS (Solid-State)

Circuit Breaker Type		Breaker AMP-ERE TAP Set. A	Long-Time Pickup Settings, (X Ampere Tap) A	Instantaneous Pickup Settings, (X Ampere Tap) A	Coordinating Fuse Size (See Table 51, Note 1) Min.	Max.
K-2000S	SENSOR RANGE	800	0.8, 0.9,	4, 5, 6, 8, 10, 12	2000	3000
		1200	1.0, 1.1†	4, 5, 6, 8, 10, 12	3000	3000
		2000	or 1.2†	4, 5, 6	3000	3000
		2000		8, 10, 12	See Note A	
K-3000S		2000	0.8, 0.9,	4, 5, 6, 8, 10, 12	5000	6000
		3000	1.0, 1.1†	4, 5, 6, 8	6000	6000
		3000	or 1.2†	10, 12	See Table 51, Note 2	
K-4000S		3000	0.8, 0.9,	4, 5, 6, 8	6000	6000
		3000	1.0, 1.1†	10, 12	See Table 51, Note 2	
		4000	or 1.2†	4, 5, 6	6000	6000
		4000		8, 10, 12	See Table 51, Note 2	

† Setting above maximum ampere-tap rating is available for coordination, if needed, but is not thermally self protecting.

A. Maximum fuse sizes listed are based on an available RMS symmetrical short-circuit current of 200kA. However, if the available current is only 115kA, a 4000A fuse may be used with the K-2000S breaker frame size for coordination with a higher instantaneous setting.

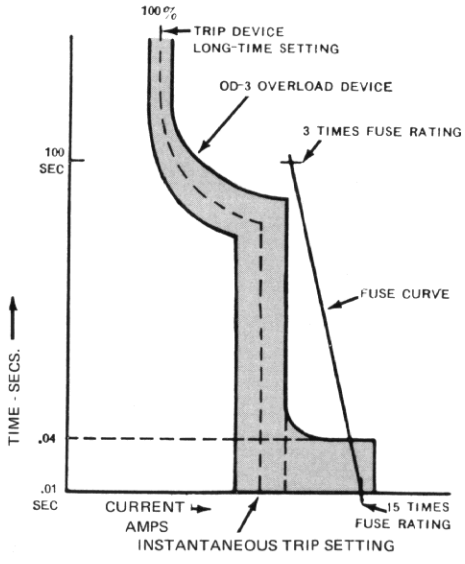


Figure 2—Typical Breaker Amp-Trap Coordination Curve

TABLE 57 — CIRCUIT BREAKER CONTROL-POWER REQUIREMENTS

Circuit Breaker Type	Nominal Control Voltage	Average Closing-Motor Current, A	Shunt-Trip Current, A	Closing-Relay Current, A		Closing-Circuit Voltage Range, Volts	Trip-Circuit Voltage Range, Volts	Recommended Control Circuit Fuse Size, A
				Anti-Pump	Release			
K-225	120 V ac	10	6.5	.15	1.5	95-127	50-127	10
K-600, S	240 V ac	5	1.15	.075	.75	190-254	190-254	10
K-1600, S	48 V dc	25	3.14	.11	1.33	35-60	28-60	15
K-2000, S	125 V dc	10	1.3	.06	.7	90-140	70-140	10
K-DON-600, S	250 V dc	5	.65	.03	.3	180-280	140-280	10
K-DON-1600, S								
	120 V ac	10	10.0	.15	4.0	95-127	50-127	10
K-3000, S	240 V ac	5	1.84	.075	1.84	190-254	190-254	10
and	48 V dc	25	5.0	.11	5.0	35-60	28-60	15
K-4000, S	125 V dc	10	2.0	.06	2.0	90-140	70-140	10
	250 V dc	5	1.0	.03	1.0	180-280	140-280	10

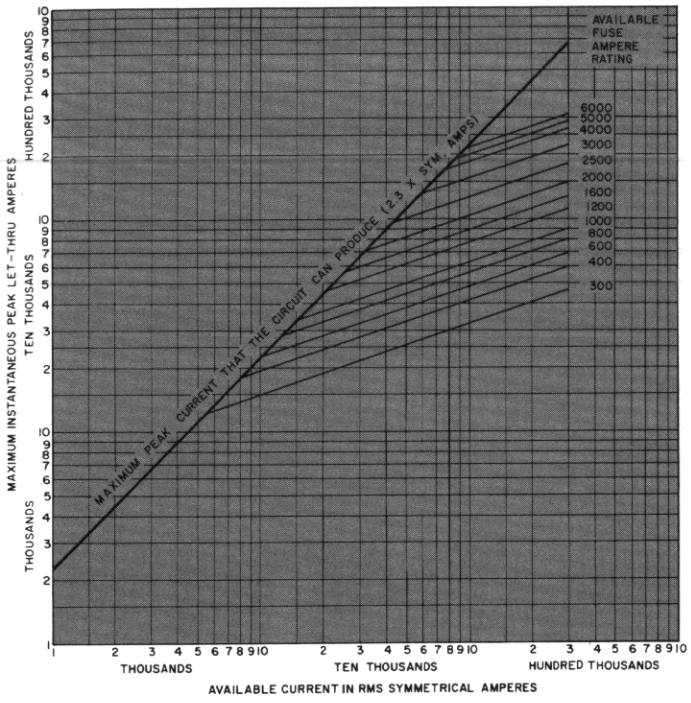


Figure 3—Amp-Trap Let-Thru Curves

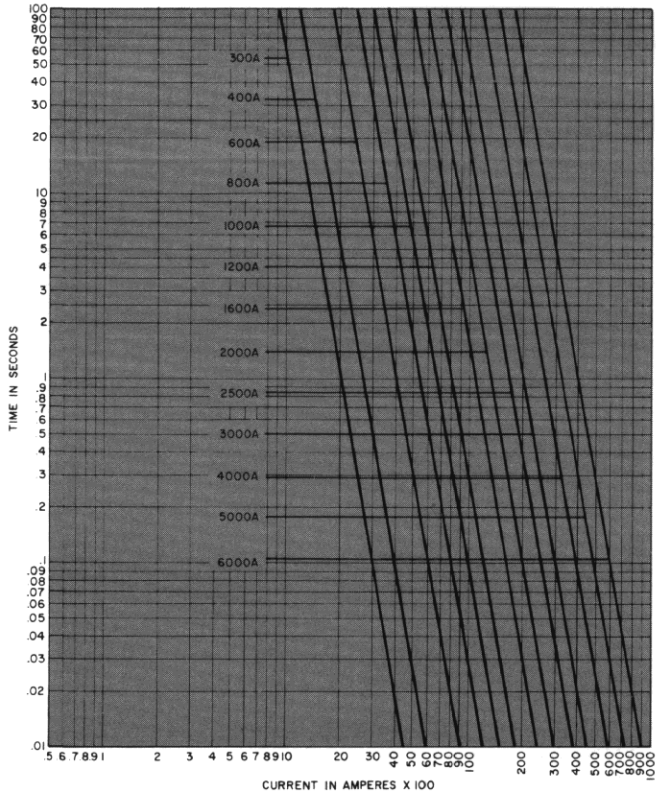


Figure 4—Melting Time-Current Characteristic Curves

TABLE 55— PROTECTION OF MOLDED-CASE CIRCUIT BREAKERS IN SWITCHBOARDS, MOTOR CONTROL CENTERS AND PANELBOARDS*

Molded Case Circuit Breaker		K-DON-600		K-DON-1600	
Type	Trip Rating, A	Maximum Coil Rating, A	Maximum Amp-Trap Rating, A	Maximum Coil Rating, A	Maximum Amp-Trap Rating, A
EF	15-100	225	300	—	—
FJ	70-150	400	400	—	—
	175-225			400	400
JL	70-125	600	1000	800	1000
	150-225				
	250-400				
KM	250-275	600	1000	800	1000
	300-800	—	—		
HE	15-50	600	800	—	—
	70-100			800	800
HJ	125	600	1200	800	1200
	150-175				
	225-400				
HM	400-800	—	—	800	1200

TABLE 56— PROTECTION OF LOW-IMPEDANCE BUS DUCT SYSTEMS*

Bus Duct	K-DON-600		K-DON-1600	
Ampere Rating	Maximum Coil Rating, A	Maximum Amp-Trap Rating, A	Maximum Coil Rating, A	Maximum Amp-Trap Rating, A
Plug-In Type				
225	400	300	—	—
400	600	1200	—	—
600	600	2500	800	2500
800	—	—	1600	2500
1000	—	—	1600	2500
1200	—	—	1600	2500
1350	—	—	1600	2500
1600	—	—	1600	2500
Feeder-Type				
800	—	—	1600	2500
1000	—	—	1600	2500
1200	—	—	1600	2500
1350	—	—	1600	2500
1600	—	—	1600	2500

*Based on available short-circuit current of 100,000 amperes at 480 volts. For available fault currents above 100,000 amperes symmetrical, consult I-T-E district sales office.

TABLE 58 —UNDERVOLTAGE TRIP DEVICE*

Nominal Control Voltage	Current at Rated Volts, A	Minimum Pick-up Voltage Value, Volts	Dropout Voltage Values, Volts	
			Minimum	Maximum
120 V ac	.48	92	39	69
240 V ac	.24	184	69	138
480 V ac	.12	384	144	288
125 V dc	.17	100	37	75
250 V dc	.086	200	75	150

* Applicable to K-LINE and K-DON power circuit breakers.

OD—ELECTRO-MECHANICAL OVERCURRENT TRIP DEVICE

GENERAL-PURPOSE, DUAL-MAGNETIC DIRECT-ACTING OVERCURRENT TRIP DEVICE (OD-3 AND OD-300)

This device combines long-time delay (50-125% of coil rating) and instantaneous (500-1500% of coil rating). It can be used in almost any feeder application including welding and motor circuits.

DUAL-SELECTIVE, DIRECT-ACTING OVERCURRENT TRIP DEVICE (OD-4 AND OD-400)

This device combines long-time delay (80-160% of coil rating) and short-time delay (400-1000% of coil rating). Its prime application is for use on selective-tripping systems where service continuity is of major significance.

SPECIALIZED-SELECTIVE AND GENERAL-PURPOSE, DUAL-MAGNETIC DIRECT-ACTING OVERCURRENT TRIP DEVICES (OD-5, OD-500, OD-6 AND OD-600)

The OD-5 and OD-500 combine long-time delay (80 to 160% of coil rating), short-time delay (400-1000% of coil rating) and instantaneous (500-1500% of coil rating). The OD-5 and 500 is a modified selective device. The addition of the instantaneous trip allows it to be applied above the short-time rating while sacrificing only a minor degree of selectivity.

The OD-6 and OD-600 are similar to the OD-3 and OD-300 general-purpose devices except for the more limited range of the long-time pickup.

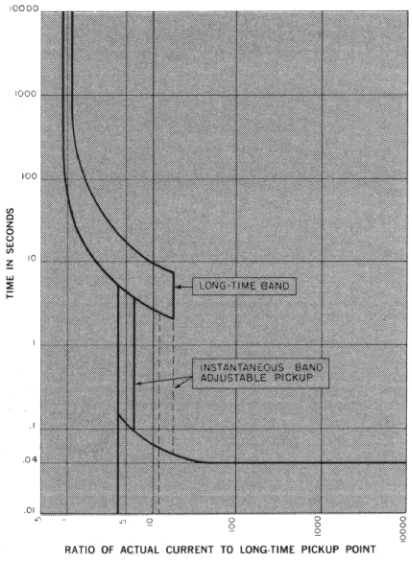


Figure 5—General Purpose Types OD-3 and OD-300

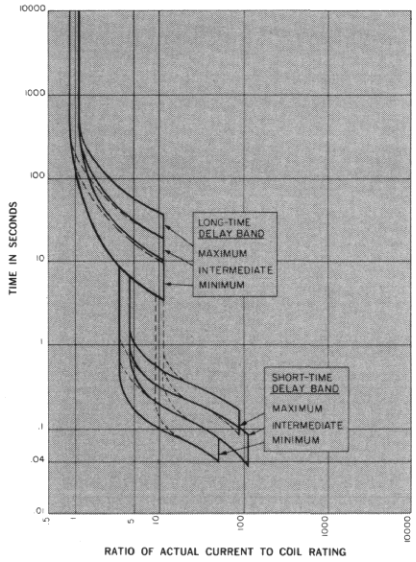


Figure 6—Dual Selective Types OD-4 and OD-400

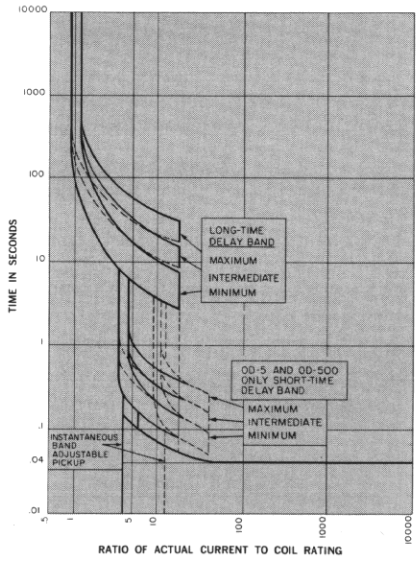


Figure 7—Specialized Selective Types OD-5, 500 and OD-6, 600

Note: Each individual OD device operates within ±10% of its pickup setting. This narrow ±10% band will always fall within the wider bands shown in Figures 5, 6 and 7.

TABLE 59 — OD ELECTRO-MECHANICAL APPLICATION PARAMETERS

Circuit Breaker Type	A-C Volts	Frame Size, A	Direct-Acting Trip Devices				
			Maximum Coil Rating, A	Minimum Coil Ratings with			
				Cascade or Inst. Trip, A (OD-3)	Delayed Trip (OD-4)		
					Minimum Band, A	Intermediate Band, A	Maximum Band, A
K-225	208 and 240	225	225	40	90	90	150
K-600		600	600	225	150	150	250
K-1600		1,600	1,600	800	300	300	500
K-2000		2,000	2,000	800	300	300	500
K-3000		3,000	3,000	3000	3000	3000	3000
K-4000		4,000	4,000	4000	4000	4000	4000
K-225	480	225	225	20	90	90	150
K-600		600	600	125	150	150	250
K-1600		1,600	1,600	400	300	300	500
K-2000		2,000	2,000	400	300	300	500
K-3000		3,000	3,000	3000	3000	3000	3000
K-4000		4,000	4,000	4000	4000	4000	4000
K-225	600	225	225	20	90	90	150
K-600		600	600	40	150	150	250
K-1600		1,600	1,600	225	300	300	500
K-2000		2,000	2,000	400	300	300	500
K-3000		3,000	3,000	3000	3000	3000	3000
K-4000		4,000	4,000	4000	4000	4000	4000

TABLE 60 —
DUAL-MAGNETIC, DUAL-SELECTIVE AND INSTANTANEOUS ELECTRO-MECHANICAL OVERCURRENT-TRIP-DEVICE CHARACTERISTICS

Circuit Breaker Type	Trip Device Type	Characteristic		
		Long-Time	Short-Time	Instantaneous
K-225 K-600 K-1600 K-2000	OD-3	50-125%		500-1500%
	OD-4	80-160%	400-1000%	
	OD-5	80-160%	400-1000%	500-1500%
	OD-6	80-160%		500-1500%
	OD-7			500-1500%
	OD-8			80-250%
K-3000 K-4000	OD-300	50-125%		500-1200%
	OD-400	80-160%	400-1000%	
	OD-500	80-160%	400-1000%	500-1200%
	OD-600	80-160%		500-1200%
	OD-700			500-1200%
	OD-800			80-250%

TABLE 62 —
TYPES OD-4, 400 THRU OD-8, 800 COIL RATINGS

Circuit Breaker Type	OD-4,400① Coil Ratings, A
K-225	90 100 125
K-225 K-600	150 175 200 225
K-600	250
K-600 K-1600 K-2000	300 350 400 450 500 600
K-1600 K-2000	800 1000 1200 1600
K-2000	2000
K-3000	2500 * 3000
K-4000	4000

Circuit Breaker Type	OD-5,500, 6,600, 7,700 and 8,800 Coil Ratings, A②
K-225	15 20
K-225 K-600	30 40 50 70 90 100 125
K-225 K-600 K-1600	150 175 200 225
K-600-1600	250
K-600 K-1600 K-2000	300 350 400 450 500 600
K-1600 K-2000	800 1000 1200 1600
K-2000	2000
K-3000	2500 3000
K-4000	4000

①Refer to Table 59 for application parameters.
②Refer to I-T-E district sales office for application parameters.
* Adjustable down to 1600A.

TABLE 61 —
TYPE OD-3 AND OD-300 DUAL-MAGNETIC ELECTRO-MECHANICAL OVERCURRENT-TRIP-DEVICE PICK-UP POINTS

Circuit Breaker Type	Maximum① Continuous Coil Rating, A	Adjustable Long-Time Delay Pickup Points, A	Adjustable Instantaneous Pickup Points, A
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

①Refer to Table 59 for application parameters.
* Setting above maximum ampere tap rating and breaker frame size is available for coordination, if needed, but is not thermally self-protecting.

POWER-SHIELD™—SOLID-STATE TRIP DEVICE

Figure 8—General Purpose (SS-3) Time-Current Characteristics

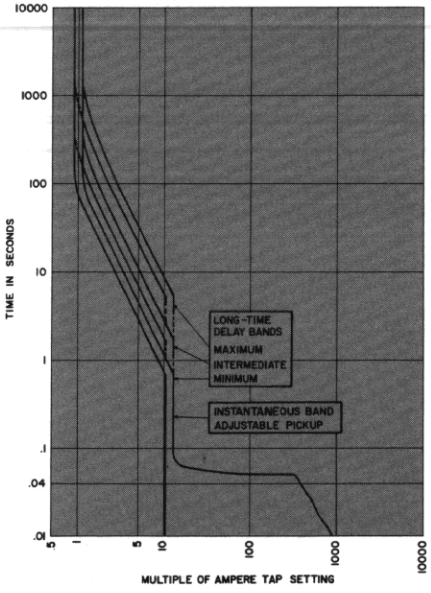


Figure 9—Dual Selective (SS-4 and SS-5) Time-Current Characteristics

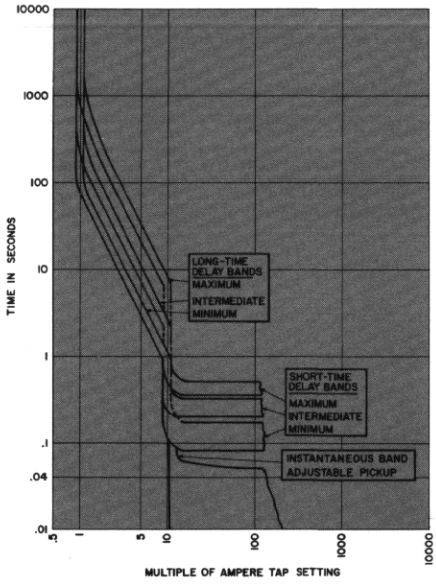


Figure 10—Ground Time-Current Characteristics

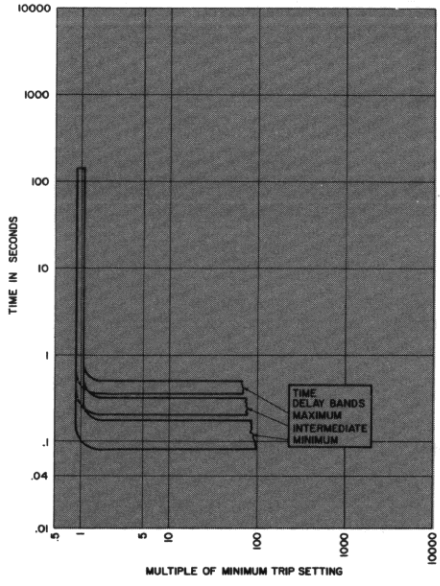


TABLE 63 — STANDARD TYPES

Type	Designation	Trip Functions
SS-3:	General Purpose	Long-time; Instantaneous
SS-4:	Dual Selective	Long-time; Short-time
SS-5:	Triple Selective	Long-time; Short-time; Instantaneous
SS-3G	—	Same as SS-3, with Ground (3- or 4-wire)
SS-4G	—	Same as SS-4, with Ground (3- or 4-wire)
SS-5G	—	Same as SS-5, with Ground (3- or 4-wire)

TABLE 65 — TIME-DELAY CHARACTERISTICS

Trip Function	Time-Delay Band	Time Delay
Long-Time	Maximum Intermediate Minimum	15 seconds† 5 seconds† 2 seconds†
Short-Time	Maximum Intermediate Minimum	0.35 seconds§ (21 cycles) 0.20 seconds§ (12 cycles) 0.08 seconds§ (4.8 cycles)
Instantaneous	Maximum Intermediate Minimum	No Intentional Delay
Ground	Maximum Intermediate Minimum	0.35 seconds§ (21 cycles) 0.20 seconds§ (12 cycles) 0.08 seconds§ (4.8 cycles)

† Measured at six (6) times ampere-tap setting and at the lower limit of maximum, intermediate or minimum long-time time delay bands.

§ Measured at the lower limit of maximum, intermediate, or minimum short-time and ground time delay bands at any point above pick-up.

TABLE 64 — PHASE AMPERE TAP AND GROUND PICK-UP RANGES

Circuit Breaker Type		Available Ampere Tap Settings, A	Pick-Up Range† Long-Time (Times Ampere Tap Setting)	Short-Time (Times Ampere Tap Setting)	Instantaneous (Times Ampere Tap Setting)	Ground X100A
K-600S	Sensor Range	50 70 100 150 225	0.8 0.9 1.0 1.1* 1.2*	2 3 4 6 8 10	4 5 6 8 10 12	1 2 3 4 5 6
		250 400 600				
K-1600S		250 400 600	0.8 0.9 1.0 1.1* 1.2*	2 3 4 6 8 10	4 5 6 8 10 12	1 2 3 4 6
		600 1000 1600				3 6 9 12 18
K-2000S		800 1200 2000	0.8 0.9 1.0 1.1* 1.2*	2 3 4 6 8 10	4 5 6 8 10 12	3 6 9 12 18
K-3000S		2000 3000	0.8 0.9 1.0 1.1* 1.2*	2 3 4 6 8 10	4 5 6 8 10 12	5 10 15 20 30
K-4000S		3000 4000	0.8 0.9 1.0 1.1* 1.2*	2 3 4 6 8 10	4 5 6 8 10 12	5 10 15 20 30

* Setting above maximum breaker frame size is available for coordination, if needed, but is not thermally self-protecting.

† The tolerance on all calibrated pick-up settings for long-time, short-time, instantaneous and ground functions is ±10% through the temperature range of −20°C to 55°C.

GROUND-SHIELD® GROUND-FAULT PROTECTION APPLICATION

TIME-CURRENT CHARACTERISTICS

The time-current curves shown in Figures 11 & 12 are designed to provide maximum protection against ground faults with minimum disturbance to unfaulted circuits. Use GR-5 relay for all individual loads (such as motors and transformers) and for high-resistance grounded systems. Use GR-200 relay for main, feeder and branch circuits on solidly or low-resistance ground systems.

INTERRUPTER TYPES

Common interrupting devices which can be used with ground-fault relays are (1) high-voltage power circuit breakers, (2) low-voltage power circuit breakers, (3) molded-case circuit breakers, (4) service protectors, (5) contactors, and (6) certain load-break, switch-fuse combinations. First, care should be taken to insure that the switch interrupting rating is sufficient to handle ground faults of all magnitudes which would be cleared faster than the associated fuse maximum clearing curve. Also, it is necessary that the interrupter switch be equipped with a fast shunt-tripping mechanism and ability to interrupt the ground fault within several cycles from energization of trip coil. Circuit breaker and fuse combinations equipped with shunt-trip coils are well adapted to the GROUND-SHIELD Protection System.

BASIC NEED FOR GROUND-SHIELD

The basic need for ground-fault protection in low-voltage systems is illustrated in Figure 13. Shown is a 1000 kVA service transformer with a 1600-ampere main breaker (with typical long-time and short-time characteristics) and fuse. A 1500A ground fault (Point I) on the 480Y/277 grounded neutral system would not be detected by this breaker. A 4000A ground fault (Point II) could persist for about 33 seconds even if the minimum long-time band were used. An 8,000 ampere ground fault (Point III) would be cleared within about .2 to .4 seconds by the short-time device, assuming it is present, otherwise, between 8 to 20 seconds would elapse before the fault is cleared. For the assumed 8,000A fault, even though the current values are the calculated result using all source, circuit and arc impedances, the actual RMS current values passing through the circuit breaker can be considerably lower. This is because of the spasmodic nature of the fault caused by (1) arc elongating blow-out effects, (2) physical flexing of cables and some bus structures due to mechanical stresses, (3) self-clearing attempts and arc re-ignition, and (4) shifting of the arc terminals from point to point on the grounded enclosure (as well as on the faulted conductors for non-insulated construction). All of these effects tend to reduce the RMS value of fault currents. Figure 13 also illustrates that a ground fault which would normally produce 8,000A under stabilized conditions and which results in an effective value of only 4000A (Point II) would have a max. clearing time of 33 seconds instead of the normally expected max. of .4 seconds.

Other fault interrupting devices such as fuses (Note from Figure 13 that a 1600A fuse takes 5 minutes to clear a 4000A fault) which have far slower operating times as low fault currents, have even a greater need for supplementary ground-fault protection. Most of these devices have time-current characteristics which delay tripping for about 100 seconds for fault currents 200% to 300% of normal continuous-current rating.

Note the interrupting time for a curve C, GR-200 relay would be about .2 seconds on a 4000 ampere ground fault and less than .4 seconds on a 1500 ampere ground fault.

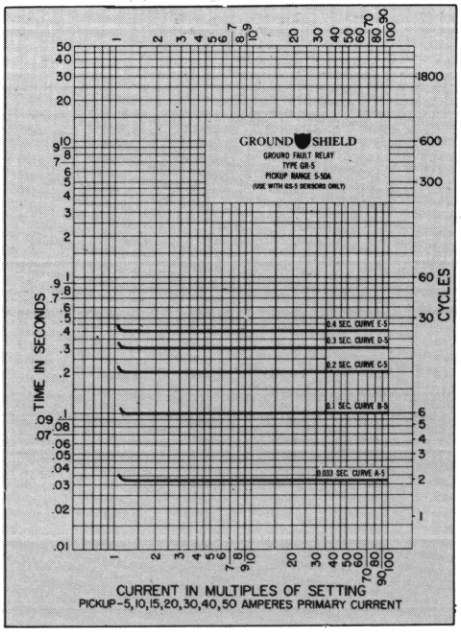


Figure 11—GR-5 Time-Current Characteristics

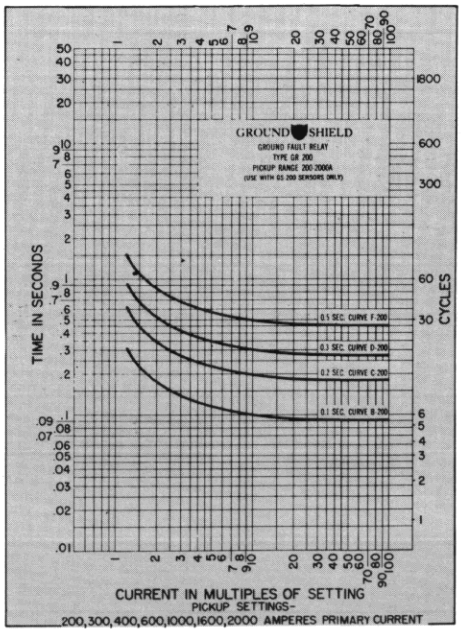


Figure 12—GR-200 Time-Current Characteristics

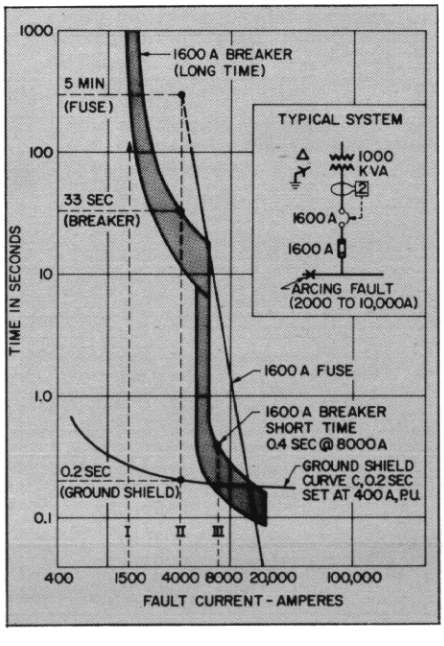


Figure 13—Ground-Shield System Coordination Curves

Note: For complete application information. on I-T-E GROUND-SHIELD, refer to I-T-E Bulletin 18.1.3-1.

MOLDED-CASE CIRCUIT BREAKERS

TABLE 66 — MOLDED-CASE BREAKER RATINGS

Max. Amperes A-C Max. Voltage	Circuit Breaker Frame	Current Continuous Amperes	A-C Volts	Maximum Interrupting Rating Sym. Rms Amperes	3-Pole Circuit Breaker (not including mounting) Size, Inches
100 Amp 480 Volt	EH†	15–100	240 480	14,000 14,000	W 4½ H 6 D 3 19/32
100 Amp 600 Volt	EF†	15–100	240 480 600	18,000 14,000 14,000	W 4½ H 6 D 3 19/32
	HE†	15–100	240 480 600	65,000 25,000 18,000	W 4½ H 6 D 3 19/32
	CE† Cordon	15–100	240 480 600	200,000 100,000 100,000	W 4½ H 9 D 3 19/32
225 Amp 600 Volt	FJ†	70–225	240 480 600	22,000 18,000 14,000	W 4½ H 10 D 4 1/16
400 Amp 600 Volt	JJ†	250–400	240 480 600	42,000 30,000 22,000	W 9 H 11 D 4 1/16
	JL*	70–400	240 480 600	42,000 30,000 22,000	W 9 H 11 D 4 1/16
	HJ	125–400	240 480 600	65,000 35,000 25,000	W 9 H 11 D 4 1/16
	CJ Cordon	150–400	240 480 600	200,000 100,000 100,000	W 9 H 15 3/16 D 5 7/16
800 Amp 600 Volt	KM	250–800	240 480 600	42,000 30,000 22,000	W 9 H 15½ D 4 1/16
	HM	400–800	240 480 600	65,000 35,000 25,000	W 9 H 22 D 5¾
	CM Cordon	400–800	240 480 600	200,000 100,000 100,000	W 9 H 26 29/32 D 6⅞
1200 Amp 600 Volt	KP	600–1200	240 480 600	42,000 30,000 22,000	W 9 H 15½ D 4¾
1600 Amp 600 Volt	HP	600–1600	240 480 600	65,000 50,000 42,000	W 9 H 15½ D 4¾
	CP Cordon	800–1600	240 480 600	200,000 100,000 100,000	W 9 H 21 D 4¾
2000 Amp 600 Volt	HR	1800–2000	240 480 600	65,000 50,000 42,000	W 9 H 15½ D 4¾
	CR Cordon	1800–2000	240 480 600	200,000 100,000 100,000	W 9 H 21 7/16 D 4¾

† Non-interchangeable trip.

* 70, 90 and 100 ampere breakers have interrupting ratings of 30,000 amperes asymmetrical, 25,000 amperes symmetrical at 240 volts ac; 25,000 amperes asymmetrical, 22,000 amperes symmetrical at 480 and 600 volts ac; 10,000 amperes at 250 volts dc.

TABLE 67 — LOW-VOLTAGE POWER CIRCUIT BREAKER APPLICATION — 208 VOLTS

Transformer Rating, 3-ph kVA and Impedance Per Cent	Primary System Max. Short-Circuit kVA	Normal Load Continuous Current, A	Short-Circuit Current Total RMS Symmetrical Amperes			Minimum Frame Size Air Circuit Breaker Recommended			
						M*	C	I	S
			Transformer Alone	Motor Load‡	Combined	Main Breaker	Cascaded Feeder	Feeder with Instant. Trip	Feeder with Selective Trip
112.5 2.25%§	50,000 100,000 150,000 250,000 500,000	312	13,160 13,480 13,640 13,760 13,840	600	13,770 14,080 14,240 14,330 14,440	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
150 3.00%§	50,000 100,000 150,000 250,000 500,000	416	11,280 11,580 11,640 11,820 12,000	800	12,080 12,380 12,440 12,620 12,800	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
225 4.5%	50,000 100,000 150,000 250,000 500,000	625	12,640 13,120 13,360 13,600 13,760	1200	13,840 14,320 14,560 14,800 14,960	K-1600 K-1600S	K-225 K-600S	K-225 K-600S	K-225 K-600S K-600 K-600S
300 5.0%	50,000 100,000 150,000 250,000 500,000	834	14,880 15,680 16,000 16,240 16,400	1700	16,580 17,380 17,700 17,940 18,100	K-1600 K-1600S	K-225 K-600S	K-225 K-600S	K-600 K-600S
500 5.0%	50,000 100,000 150,000 250,000 500,000	1388	23,120 25,200 26,000 26,640 27,200	2800	25,920 28,000 28,800 29,440 30,000	K-1600 K-1600S †	K-600 K-600S	K-600 K-600S	K-1600 K-1600S
750 5.75%	50,000 100,000 150,000 250,000 500,000	2080	28,640 32,000 33,360 34,400 35,280	4200	32,840 36,200 37,560 38,600 39,480	K-3000 K-3000S	K-600 K-600S	K-600 K-600S	K-1600 K-1600S
1000 5.75%	50,000 100,000 150,000 250,000 500,000	2780	35,840 41,120 43,360 45,200 46,720	5600	41,440 46,720 48,960 50,800 52,320	K-3000 K-3000S †	K-600 or K-600S K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S K-2000, S

240 VOLTS

112.5 2.25%§	50,000 100,000 150,000 250,000 500,000	271	9,600 11,680 11,840 11,920 12,020	1100	10,700 12,780 12,940 13,020 13,120	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
150 3.00%§	50,000 100,000 150,000 250,000 500,000	361	11,280 15,480 15,680 15,760 15,920	1400	12,680 16,880 17,080 17,160 17,320	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
225 4.5%	50,000 100,000 150,000 250,000 500,000	541	11,120 11,640 11,840 12,020 12,160	2200	13,320 13,840 14,040 14,220 14,360	K-600 K-600S †	K-225 K-600S	K-225 K-600S	K-225 K-600S K-600 K-600S
300 5.0%	50,000 100,000 150,000 250,000 500,000	722	12,880 13,600 13,920 14,080 14,320	2900	15,780 16,500 16,820 16,980 17,220	K-1600 K-1600S	K-225 K-600S	K-225 K-600S	K-600 K-600S
500 5.0%	50,000 100,000 150,000 250,000 500,000	1203	20,080 21,840 22,560 23,120 23,600	4800	24,880 26,640 27,360 27,920 28,400	K-1600 K-1600S	K-225, K-600S K-600 K-600S	K-600 K-600S	K-1600 K-1600S
750 5.75%	50,000 100,000 150,000 250,000 500,000	1804	24,960 27,760 28,880 29,920 30,640	7200	32,160 34,960 36,080 37,120 37,840	K-2000 K-2000S †	K-600 K-600S	K-600 K-600S	K-1600 K-1600S
1000 5.75%	50,000 100,000 150,000 250,000 500,000	2406	31,120 35,680 37,520 39,120 41,360	9600	40,720 45,280 47,120 48,720 50,960	K-3000 K-3000S	K-600 or K-600S K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S K-2000, S

* The transformer main secondary breakers are in most cases determined by continuous current instead of fault current. For this reason breakers in the M column are usually larger than those listed in the I column. The values listed in the M column allow a breaker continuous rating approximately 25% above the transformer self-cooled full-load current. If the transformer has a fan cooled rating a main secondary breaker larger than indicated by column M may be required.

§ Short-circuit currents are calculated with impedances shown applying to liquid-immersed transformers only. Refer to Table 41, Page 34, for ventilated-dry type impedances.

‡ Motor load contribution for 208 volts is based on 50%. 240 volt application table is based on 100% motor load contribution.

† These circuit breakers are applied at less than 25% above transformer full-load rating. If 25% is required, use the next larger frame size.

TABLE 68 — LOW-VOLTAGE POWER CIRCUIT BREAKER APPLICATION — 480 VOLTS

Transformer Rating, 3-ph kVA and Impedance Per Cent	Primary System Max. Short-Circuit kVA	Normal Load Continuous Current, A	Short-Circuit Current Total RMS Symmetrical Amperes			Minimum Frame Size Air Circuit Breaker Recommended			
						M*	C	I	S
			Transformer Alone	100% Motor Load	Combined	Main Breaker	Cascaded Feeder	Feeder with Instant. Trip	Feeder with Selective Trip
112.5 2.25%§	50,000 100,000 150,000 250,000 500,000	135	5,720 5,840 5,880 5,960 6,000	500	6,220 6,340 6,380 6,460 6,500	K-225 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
150 3.0%§	50,000 100,000 150,000 250,000 500,000	180	5,400 5,790 5,865 5,895 5,955	700	6,100 6,490 6,565 6,595 6,655	K-225 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
225 4.5%	50,000 100,000 150,000 250,000 500,000	271	5,460 5,720 5,800 5,900 6,790	1100	6,560 6,820 6,900 7,000 7,890	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
300 5.0%	50,000 100,000 150,000 250,000 500,000	361	6,480 6,800 6,960 7,040 7,120	1400	7,880 8,200 8,360 8,440 8,520	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
500 5.0%	50,000 100,000 150,000 250,000 500,000	601	10,000 10,960 11,280 11,600 11,840	2400	12,400 13,360 13,680 14,000 14,240	K-1600 K-1600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
							K-600 or K-600S		
750 5.75%	50,000 100,000 150,000 250,000 500,000	902	12,400 13,840 14,480 14,960 15,360	3600	16,000 17,440 18,080 18,560 18,960	K-1600 K-1600S	K-225 K-600S	K-225 K-600S	K-600 K-600S
1000 5.75%	50,000 100,000 150,000 250,000 500,000	1203	15,600 17,920 18,800 19,600 20,240	4800	20,400 22,720 23,600 24,400 25,040	K-1600 K-1600S	K-225 or K-600S		K-600, S
							K-600 K-600S	K-600 K-600S	K-1600 K-1600S
1000 8.0%	50,000 100,000 150,000 250,000 500,000	1203	12,030 13,350 13,980 14,315 14,555	4800	16,830 18,150 18,750 19,115 19,355	K-1600 K-1600S	K-225 K-600S	K-225 K-600S	K-600 K-600S
1500 5.75%	50,000 100,000 150,000 250,000 500,000	1804	20,640 24,960 26,800 28,480 29,840	7200	27,840 32,160 34,000 35,680 37,040	K-2000 K-2000S †	K-600 or K-600S		
							K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S
2000 5.75%	50,000 100,000 150,000 250,000 500,000	2406	24,720 30,560 34,080 36,720 38,960	9600	34,320 40,160 43,680 46,320 48,560	K-3000 K-3000S	K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S
2500 5.75%	50,000 100,000 150,000 250,000 500,000	3010	27,900 36,300 40,400 44,500 48,100	12000	39,900 48,300 52,400 56,500 62,100	K-4000 K-4000S	K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S
								K-2000 or K-2000S	
								K-2000 K-2000S	K-3000 K-3000S

* The transformer main secondary breakers are in most cases determined by continuous current instead of fault current. For this reason breakers in the M column are usually larger than those listed in the I column. The values listed in the M column allow a breaker continuous rating approximately 25% above the transformer self-cooled full-load current. If the transformer has a fan cooled rating a main secondary breaker larger than indicated by column M may be required.

§ Short-circuit currents are calculated with impedances shown applying to liquid-immersed transformers only. Refer to Table 41, Page 34, for ventilated-dry type impedances.

† These circuit breakers are applied at less than 25% above transformer full-load rating. If 25% is required, use the next larger frame size.

TABLE 69 — LOW-VOLTAGE POWER CIRCUIT BREAKER APPLICATION — 600 VOLTS

Transformer Rating, 3-ph kVA and Impedance Per Cent	Primary System Max. Short-Circuit kVA	Normal Load Continuous Current, A	Short-Circuit Current Total RMS Symmetrical Amperes			Minimum Frame Size Air Circuit Breaker Recommended			
						M*	C	I	S
			Transformer Alone	100% Motor Load	Combined	Main Breaker	Cascaded Feeder	Feeder with Instant. Trip	Feeder with Selective Trip
112.5 2.25%§	50,000 100,000 150,000 250,000 500,000	108	4,580 4,680 4,720 4,760 4,780	400	4,980 5,080 5,120 5,160 5,180	K-225 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
150 3.00%§	50,000 100,000 150,000 250,000 500,000	144	4,500 4,650 4,695 4,740 4,770	600	5,100 5,250 5,295 5,340 5,370	K-225 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
225 4.5%	50,000 100,000 150,000 250,000 500,000	217	4,380 4,590 4,670 4,730 4,770	900	5,280 5,490 5,570 5,630 5,670	K-225 K-600S †	K-225 K-600S	K-225 K-600S	K-225 K-600S
300 5.0%	50,000 100,000 150,000 250,000 500,000	289	5,160 5,450 5,560 5,640 5,710	1200	6,360 6,650 6,760 6,840 6,910	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
500 5.0%	50,000 100,000 150,000 250,000 500,000	481	8,020 8,740 9,020 9,250 9,430	1900	9,920 10,640 10,920 11,150 11,330	K-600 K-600S	K-225 K-600S	K-225 K-600S	K-225 K-600S
750 5.75%	50,000 100,000 150,000 250,000 500,000	722	9,960 11,110 11,550 11,930 12,240	2900	12,860 14,010 14,450 14,830 15,140	K-1600 K-1600S	K-225 or K-600S K-600 K-600S	K-600 K600S	K-600 K-600S
1000 5.75%	50,000 100,000 150,000 250,000 500,000	962	12,410 14,250 14,980 15,640 16,170	3800	16,210 18,050 18,780 19,440 19,970	K-1600 K-1600S	K-600 K-600S	K-600 K-600S	K-600 K-600S
1500 5.75%	50,000 100,000 150,000 250,000 500,000	1444	16,500 19,920 21,390 22,740 23,870	5800	22,300 25,720 27,190 28,540 29,670	K-2000 K-2000S	K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S
2000 5.75%	50,000 100,000 150,000 250,000 500,000	1924	19,730 24,830 27,180 29,370 31,280	7700	27,430 32,530 34,880 37,070 38,980	K-2000 K-2000S	K-1600 K-1600S	K-1600 K-1600S	K-1600 K-1600S
2500 5.75%	50,000 100,000 150,000 250,000 500,000	2406	22,380 29,160 32,430 35,640 38,500	9600	31,980 38,760 42,030 45,240 48,100	K-3000 K-3000S	K-1600 K-1600S K-2000 K-2000S	K-1600 K-1600S K-2000 K-2000S	K-1600 K-1600S K-2000 K-2000S

* The transformer main secondary breakers are in most cases determined by continuous current instead of fault current. For this reason breakers in the M column are usually larger than those listed in the I column. The values listed in the M column allow a breaker continuous rating approximately 25% above the transformer self-cooled full-load current. If the transformer has a fan cooled rating a main secondary breaker larger than indicated by column M may be required.

§ Short-circuit currents are calculated with impedances shown applying to liquid-immersed transformers only. Refer to Table 41, Page 34, for ventilated-dry type impedances.

† These circuit breakers are applied at less than 25% above transformer full-load rating. If 25% is required, use the next larger frame size.

SHORT-CIRCUIT CURRENTS IN LOW-VOLTAGE SYSTEMS

To determine the interrupting-capacity requirements of low-voltage, air-magnetic power circuit breakers it is necessary to obtain information, at the point of application, of the short-circuit condition of every part of a distribution system. A set of 32 curves (available on request) provides a graphical means of determining the value of short-circuit currents and the corresponding power factor for various sizes of transformers and various voltages, in combination with different sizes and lengths of cable. In Tables 72 and 73 are given the multiplying factors to use in obtaining the asymmetrical values of current at different power factors.

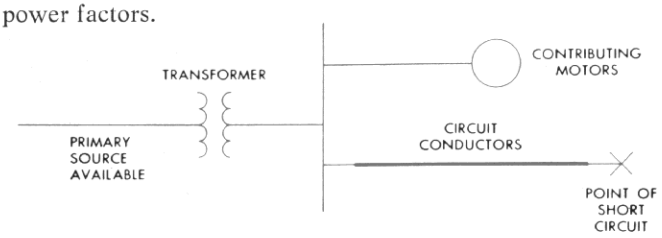


Figure 14

In the study diagrammed above, these basic characteristics are assumed:

1. Primary source available is 500 MVA at the primary of the transformer, with a source circuit X/R ratio of 25.
2. Transformer kVA covers a range of nine standard sizes; 150, 225, 300, 500, 750, 1000, 1500, 2000, 2500.
3. Distribution voltages of 208, 240, 480, and 600 v are assumed; 3-phase, 60 Hertz.
4. Transformer impedances are 4½% up through 500 kVA and 5½% for 750 kVA and higher, less the standard allowable tolerance of ±7½%. X/R ratios are selected from data furnished by numerous transformer manufacturers from which the characteristics in Table 70 (following) are calculated. The data is based on liquid-immersed, self-cooled transformers. Dry-type transformers generally have higher reactances, and the results of this study should be conservative for systems in which they are used.
5. Motor impedance is based on an equivalent reactance of 25 and an X/R ratio of 6.
6. Feeder conductors chosen are at least 115% of the size normally required for the standard frame sizes of low-voltage, air-magnetic power circuit breakers. Calculations in this study are based on 3-phase conductors, of minimum insulation thickness, in magnetic ducts. Table 71 gives the conductor sizes and alternate arrangements for which this study can be used.
7. Short-circuit duty can be read direct from the set of 32 curves. The short-circuit current available, in symmetrical amperes, and the corresponding short-circuit power factor are shown for any distance, in circuit feet, from the terminals of the transformer up to 5000 ft. These values include the current contributed by the connected motors.
8. Asymmetrical short-circuit currents, if desired, can be found from the symmetrical values above by using a multiplying factor read from Figure 15 and corresponding to the short-circuit power factor at the point of fault. Use the multiplying factor from Curve M_A to find the average 3-phase asymmetrical amperes and Curve M_M to find the maximum asymmetrical amperes in one phase with the greatest possible offset. For accurate values of M_A and M_M, use the values in Table 72.
9. Short-circuit current at the terminals of transformers may be determined from Table 73. This gives the symmetrical rms amperes, the 3-phase average asymmetrical rms amperes, and the maximum obtainable asymmetrical rms amperes in one phase at the terminals.

TABLE 70— TRANSFORMER CHARACTERISTICS

Transformer Rating kVA	X/R	R (%)	X (%)	Z (%)
150	3.24	1.23	4.0	4.19
225	3.35	1.19	4.0	4.17
300	3.50	1.14	4.0	4.16
500	3.84	1.04	4.0	4.12
750	5.45	0.94	5.1	5.19
1000	5.70	0.89	5.1	5.19
1500	6.15	0.83	5.1	5.18
2000	6.63	0.77	5.1	5.17
2500	7.18	0.71	5.1	5.15

TABLE 71— CIRCUIT CONDUCTORS

Circuit Rating Amperes	Conductor Size	Conductor Insulation	Alternate Conductor Sizes
50	# 4 AWG	Type R	—
100	# 0 AWG	Type R	—
225	250 MCM	Type RH	—
400	2-250 MCM	Type RH	—
600	2-500 MCM	Type RH	3-# 4/0 AWG
600	2-500 MCM	Type RH	4-# 2/0 AWG
1600	4-750 MCM	Type RH	3-2000 MCM
1600	4-750 MCM	Type RH	5-400 MCM
1600	4-750 MCM	Type RH	6-300 MCM

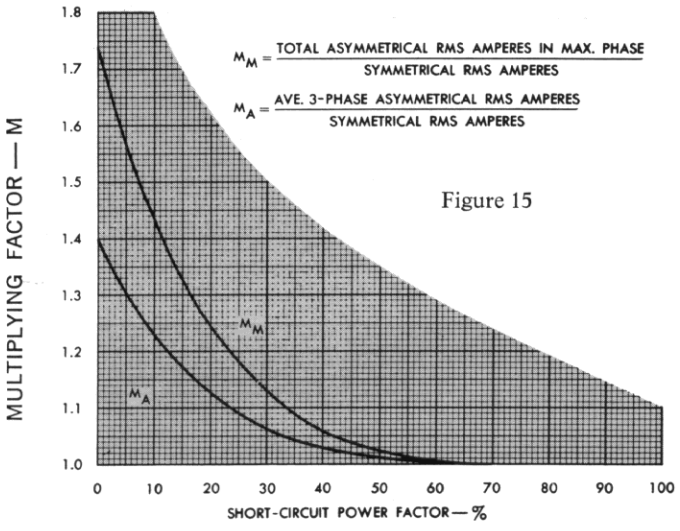


Figure 15

Multiplying Factors to obtain short-circuit asymmetrical current from symmetrical values, at an instant ½ cycle (60 cycle basis) after initiation of a fault.

TABLE 72 — SHORT-CIRCUIT MULTIPLYING FACTORS

Short-Circuit Power Factor Per Cent	Short Circuit X/R Ratio	Multiplying Factor: Maximum 1-Phase RMS Amperes at ½ Cycle (Curve M_M)	Multiplying Factor: Average 3-Phase RMS Amperes at ½ Cycle (Curve M_A)	Short-Circuit Power Factor Per Cent	Short Circuit X/R Ratio	Multiplying Factor: Maximum 1-Phase RMS Amperes at ½ Cycle (Curve M_M)	Multiplying Factor: Average 3-Phase RMS Amperes at ½ Cycle (Curve M_A)
0	∞	1.732	1.394	29	3.3001	1.139	1.070
1	100.00	1.696	1.374	30	3.1798	1.130	1.066
2	49.993	1.665	1.355	31	3.0669	1.121	1.062
3	33.322	1.630	1.336	32	2.9608	1.113	1.057
4	24.979	1.598	1.318	33	2.8606	1.105	1.053
5	19.974	1.568	1.301	34	2.7660	1.098	1.049
6	16.623	1.540	1.285	35	2.6764	1.091	1.046
7	14.251	1.511	1.270	36	2.5916	1.084	1.043
8	12.460	1.485	1.256	37	2.5109	1.078	1.039
8.5	11.723	1.473	1.248	38	2.4341	1.073	1.036
9	11.066	1.460	1.241	39	2.3611	1.068	1.033
10	9.9501	1.436	1.229	40	2.2913	1.062	1.031
11	9.0354	1.413	1.216	41	2.2246	1.057	1.028
12	8.2733	1.391	1.204	42	2.1608	1.053	1.026
13	7.6271	1.372	1.193	43	2.0996	1.049	1.024
14	7.0721	1.350	1.182	44	2.0409	1.045	1.022
15	6.5912	1.330	1.171	45	1.9845	1.041	1.020
16	6.1695	1.312	1.161	46	1.9303	1.038	1.019
17	5.7967	1.294	1.152	47	1.8780	1.034	1.017
18	5.4649	1.277	1.143	48	1.8277	1.031	1.016
19	5.1672	1.262	1.135	49	1.7791	1.029	1.014
20	4.8990	1.247	1.127	50	1.7321	1.026	1.013
21	4.6557	1.232	1.119	55	1.5185	1.015	1.008
22	4.4341	1.218	1.112	60	1.3333	1.009	1.004
23	4.2313	1.205	1.105	65	1.1691	1.004	1.002
24	4.0450	1.192	1.099	70	1.0202	1.002	1.001
25	3.8730	1.181	1.093	75	0.8819	1.0008	1.0004
26	3.7138	1.170	1.087	80	0.7500	1.0002	1.00005
27	3.5661	1.159	1.081	85	0.6198	1.00004	1.00002
28	3.4286	1.149	1.075	100	0.0000	1.00000	1.00000

TABLE 73 — SHORT-CIRCUIT CURRENTS

Transformer kVA	Short-Circuit Power Factor at Terminals All Voltages Per Cent	Multiplying Factor to Obtain Asym. RMS Amperes at ½ Cycle: Average 3-Phase	Multiplying Factor to Obtain Asym. RMS Amperes at ½ Cycle: Maximum Offset Phase	Short-Circuit Current at Transformer Terminals — Amperes: Sym RMS	3-Phase Average Asym. RMS	Maximum Offset Phase Asym. RMS	Sym. RMS	3-Phase Average Asym. RMS	Maximum Offset Phase Asym. RMS
				208 VOLTS			240 VOLTS		
150	27.4	1.079	1.155	11550	12410	13280	9980	10770	11530
225	26.6	1.083	1.165	17220	18650	20060	14940	16180	17400
300	25.6	1.089	1.174	23000	25050	27000	19970	21750	23440
500	23.6	1.101	1.197	38200	42060	45730	33100	36440	39620
750	17.5	1.148	1.286	47200	54180	60700	40900	46950	52600
1000	16.62	1.155	1.301	62700	72420	81570	54400	62830	70770
1500	15.57	1.165	1.320	92400	107650	121970	80100	93320	105730
2000	14.54	1.176	1.339	121800	143240	163100	105600	124200	141320
				480 VOLTS			600 VOLTS		
150	27.4	1.079	1.155	4990	5380	5760	3990	4300	4610
225	26.6	1.083	1.165	7470	8090	8700	5980	6480	6970
300	25.6	1.089	1.174	9985	10870	11720	7990	8700	9380
500	23.6	1.101	1.197	16550	18220	19810	13230	14570	15840
750	17.5	1.148	1.286	20450	23480	26300	16360	18780	21040
1000	16.62	1.155	1.301	27200	31420	35390	21750	25120	28300
1500	15.57	1.165	1.320	40050	46660	52870	32050	37340	42300
2000	14.54	1.176	1.339	52800	62080	70700	42200	49630	56500
2500	13.53	1.186	1.358	66700	79100	90600	53300	63200	72400

GUIDE SPECIFICATIONS FOR SECONDARY UNIT SUBSTATIONS

NOTE: Blue color and italics denotes information to be supplied by purchaser regarding either:
- Choice of alternates
- Addition of optional features
- Specific information

SCOPE

These specifications cover a complete (indoor) (outdoor) secondary unit substation from the incoming line terminals to the outgoing feeder terminals.

SECTIONS

The substation will have the following sections:
1. Incoming line section with ( ) incoming primary circuit(s).
2. Transforming section consisting of ( ) transformer(s).
3. Outgoing section which will provide for ( ) outgoing feeders provided with low-voltage power circuit breaker(s).

GENERAL ARRANGEMENT

The accompanying sketch No. _____ indicates orientation of equipment only, not construction details.

RATINGS

The ratings of the substation will be:

Self-Cooled rating ..... _____ kVA
Fan-Cooled rating ..... _____ kVA
Frequency ..... 60 Hertz
Number of Phases 3
( ) incoming (3) (4)-wire circuit(s) .... _____ kV
( ) outgoing (3) (4)-wire circuit(s) .... _____ volts

INCOMING LINE SECTION
(2-POSITION, ON-OFF) (3-POSITION, LINE 1-OFF-LINE 2) (FUSED) (UNFUSED) AIR INTERRUPTER SWITCH(ES)

This section shall consist of a floor-mounted, formed welded metal enclosure close-coupled to the transformer section and equipped with:

( )—3-pole, 2-position, gang-operated, load-interrupter switch, type HPL-C, rated 600 amperes, _____ kV, interrupting capacity 600 amperes.

( )—*3-pole, 2-position selector switch, interlocked and in series with the air interrupter switch.*

( )—*Power fuses, current-limiting type CL-13 _____ kV, _____ amperes continuous, to be located between the switch and the transformer. The fuse door to be interlocked with the switch handle to prevent opening while the switch is in the closed position.*

( )—*Lightning arresters rated (3) (6) (9) (12) (15) kV.*

_____ size cable to enter from (above) (below) and terminate in _____ *clamp-type lugs per phase or* (1-3/C) (2-3/C) (3-1/C) (6-1/C) *pothead*(s). *Pothead*(s) *to be provided with* _____ *fitting for cables with the following specifications:* _____ *kV size,* _____ *insulation,* _____ *O.D. over insulation,* _____ *O.D. conductor,* _____ *O.D. overall.*

LIQUID (INTERRUPTER) (DISCONNECT) SWITCH(ES)

This section shall consist of non-fused, oil-insulated, load-interrupter switch, mounted on transformer tank. This switch to be 3-pole (2) (3)*-position device rated* _____ *amperes continuous at* _____ kV.

This section shall consist of non-fused, askarel-insulated, disconnecting switch, mounted on transformer tank. The switch shall be capable of breaking transformer magnetizing current and the askarel shall be of the type designed for this operation. This switch to be 3-pole (2) (3)*-position device rated* _____ *amperes continuous at* _____ kV.

_____ size cable to enter from (above) (below) and terminate in (1-3/C) (2-3/C) (3-1/C) (6-1/C) pothead(s). Pothead(s) to be provided with _____ fitting cables with the following specifications: _____ kV size, _____ insulation, _____ O.D. over insulation, _____ O.D. conductor, _____ O.D. overall.

OIL FUSE CUTOUTS

This section shall consist of 3-gang-operated oil fuse cutouts, mounted in an air-filled terminal chamber directly connected to the transformer tank wall. Cut-outs are to be 2-position and rated _____ amperes continuous at _____ kV.

_____ size cable to enter from (above) (below) and terminate in _____ *clamp-type lugs per phase or* (1-3/C) (2-3/C) (3-1/C) (6-1/C) *pothead*(s), *Pothead*(s) *to be provided with* _____ *fitting for cables with following specifications:* _____ kV *size,* _____ *insulation,* _____ *O.D. over insulation,* _____ *O.D. conductor,* _____ *O.D. overall.*

AIR TERMINAL CHAMBER

This section shall consist of a full-height air terminal chamber directly connected to the high-voltage side of the transformer. It shall be rated _____ kV. _____ size cable to enter from (above) (below) and terminate in _____ *clamp-type lugs per phase or* (1-3/C) (2-3/C) (3-1/C) (6-1/C) *pothead*(s). *Pothead*(s) *to be provided with* _____ *fitting for cables with the following* specifications: _____ kV size, _____ insulation, _____ *O.D. over insulation,* _____ *O.D. conductor,* _____ *O.D. overall.*

METAL-CLAD SWITCHGEAR

( )—Metal-clad switchgear unit.

( )—(4.16) (7.2) (13.8) kV air circuit breaker, _____ amp, 3-pole, electrically-operated, stored-energy.

State Control Voltage Requirements.

( )—Set of insulated main bus, _____ amp.

( )—Current transformers, _____/5, ratio.

( )—Overcurrent relays, instantaneous and time.

( )—Breaker control switch with red and green indicating lights.

( )—Ammeter, 0- _____ scale.

( )—Ammeter transfer switch.

( )—Voltmeter.

( )—Voltmeter transfer switch.

( )—Drawout potential transformers, _____ -120 volt ratio.

_____ size cable to enter from (above) (below) and terminate in _____ clamp-type lugs per phase or (1-3/C) (2-3/C) (3-1/C) (6-1/C) *pothead*(s). *Pothead*(s) to be provided with _____ fitting for cables with the following specifications: _____ kV size, _____ insulation, _____ O.D. over insulation, _____ O.D. conductor, _____ O.D. overall.

TRANSFORMER SECTION
LIQUID-IMMERSED TYPES (OIL) (ASKAREL)—(OA) (OA/FA)

Transformer shall be (Oil) (Askarel)-insulated, 3-phase, 60 Hertz, (self-cooled) (forced-air cooled) with a temperature rating not to exceed a 65°C rise above 30°C average ambient.

Rated _____ kVA, with delta primary of _____ kV and a secondary of _____ volts (Delta) (Wye). Provide four (4) approximately 2½% full capacity taps in the high-voltage winding, two above and two below normal, brought out to an externally-operated, deenergized tap changer. Tap changer handle to be capable of being locked in any tap position.

Transformer base construction to be of the fabricated type and suitable for using rollers or skidding in any direction.

Transformer to be factory tested as prescribed by ANSI and NEMA Standards. All NEMA standard accessories are to be provided.

VENTILATED-DRY TYPE—(AA) (AA/FA)

Transformer shall be a ventilated-dry type, indoor construction, 3-phase, 60 Hertz, (self-cooled) (forced-air cooled) with a temperature rating not to exceed a 150°C rise above 30°C average ambient.

Rated _____ kVA, with a delta primary of _____ kV and a secondary of _____ volts (Delta) (Wye). Provide four (4) approximately 2½% full capacity taps in the high-voltage winding, two above and two below normal, brought out through studs, complete with bolted flexible links for deenergized tap-changing operation, made accessible through a removable panel on the transformer enclosure.

Transformer base construction to be of the fabricated type and suitable for using rollers or skidding in any direction.

Transformer to be factory tested as prescribed by ANSI and NEMA standards. All NEMA standard accessories are to be provided.

Necessary winding-temperature equipment for control of fans.

Shall have provision for future fan cooling.

SEALED-DRY, GAS-FILLED—TYPE AA

Transformer shall be sealed-dry type, gas-filled, 3-phase, 60 Hertz, self-cooled, with a temperature rating not to exceed a 150°C rise above a 30°C average ambient.

Rated _____ kVA, with a delta primary of _____ kV and a secondary of _____ volts (Delta) (Wye). Provide four (4) approximately 2½% full capacity taps in the high-voltage winding, two above and two below normal, brought out to an externally-operated, deenergized tap changer. Tap changer cover to be capable of being bolted in any tap position.

Transformer base construction to be of the fabricated type and suitable for using rollers or skidding in any direction.

Transformer to be factory tested as prescribed by ANSI and NEMA Standards. All NEMA standard accessories are to be provided.

OUTGOING SECTION

This section shall consist of one metal-enclosed (indoor) (outdoor) switchgear assembly, drawout type, rated 600 V a-c and arranged for _____ volt service on a _____ volt 3-phase (3) (4)-wire (grounded) (ungrounded) system. It shall be designed, factory assembled and tested in accordance with the latest applicable IEEE, NEMA and ANSI standards.

SWITCHBOARD (indoor) (outdoor)

Switchboard shall consist of sufficient vertical frames to house the number of circuits specified below, with a minimum number of empty spaces remaining. Each individual frame shall be divided into a front breaker section and a rear bus section isolated by steel panels. In addition, each circuit-breaker compartment shall be completely isolated from adjacent compartment by steel panels. All surfaces shall be phosphate treated and painted with an oven baked, corrosion-resistant epoxy enamel finish. Color of finish shall be light gray, ANSI No. 61.

SWITCHBOARD (outdoor only)

Switchboard shall be of the walk-in weatherproof type with gasketing throughout. Sufficient filtered louvers and screened vents shall be provided to afford adequate ventilation. Sufficient strip heaters shall be provided. Interior lighting and convenience outlets shall be furnished in the aisle space. A manually-operated lifting device running the full length of the walk-in aisle shall be provided for easy handling of breakers. Suitable undercoating shall be applied to prevent corrosion. All exterior surfaces shall receive one additional finish coat of oven baked, corrosion-resistant acrylic enamel paint. The color of the finish coat shall be dark gray, ANSI No. 24.

BUS

A single main bus shall extend through all frames of the switchboard, with interconnections to the circuit breakers in each individual frame. All bus shall be silver-plated aluminum. The main bus shall be of the same current rating as the main circuit breaker or the power source. It shall be braced to withstand stresses resulting from the maximum short-circuit current available. Minimum bracing to be 50,000 amperes symmetrical.

DISCONNECTING DEVICES & DRAWOUT MECHANISM

The breakers shall be of the drawout type, provided with self-aligning disconnecting devices, with the disconnecting fingers mounted on the breaker for ease of maintenance. The drawout mechanism shall hold the circuit breaker rigidly in the fully-connected, test and fully-disconnected positions. Interlocks shall be provided that will prevent moving the circuit breaker from the fully-connected, test or fully-disconnected positions, unless the breaker is open. Interlocks shall prevent closing the breaker between any of these positions. Provision shall be made for padlocking the breaker open and in any of the positions noted above.

CIRCUIT BREAKERS

Air circuit breakers shall be three pole, each pole equipped with a (electro-mechanical, direct-acting) (solid state) overcurrent tripping device providing adjustable overcurrent and (instantaneous) short-circuit protection. All (manually) (electrically) operated breakers shall be equipped with (manual) (motor) charged stored-energy closing mechanism to provide quick-make operation.

The drawout mechanism shall be designed so that the breaker can be racked to any position without opening the door, for maximum protection to operating personnel.

A hasp on the breaker escutcheon shall be provided that can receive up to three padlocks when the breaker is in the open position, positively preventing unauthorized closing or racking of the breaker. A manual trip button and external breaker position indicator shall be provided.

THE FOLLOWING EQUIPMENT SHALL BE SUPPLIED:

_____ main secondary breaker(s), _____ amp maximum continuous current, _____ amp interrupting capacity at _____ V ac, (manually) (electrically) operated.

_____ tie breaker(s), _____ amp maximum continuous current, _____ amp interrupting capacity at _____ V ac, (manually) (electrically) operated.

_____ feeder breaker(s), _____ amp maximum continuous current, _____ amp interrupting capacity at _____ V ac, (manually) (electrically) operated.

_____ feeder breaker(s), _____ amp maximum continuous current, _____ amp interrupting capacity at _____ V ac, (manually) (electrically) operated.

_____ space(s) for future breaker(s), _____ maximum continuous current, _____ amp interrupting capacity at _____ V ac, (manually) (electrically) operated.

_____ control-power transformer(s) for electrically operated breaker(s).

TRANSFORMER SECONDARY METERING

_____ *voltmeter*(s), *with 3-phase transfer switch.*

_____ *ammeter with 3-phase transfer switch.*

_____ *watthour meter*(s), (two) (three)*-element, (with) (without) demand attachment.*

_____ *current transformer*(s), ____/5 *or suitable rating.*

_____ *potential transformer*(s), *suitable rating.*

FEEDER METERING

_____ *ammeter*(s), *with 3-phase transfer switch.*

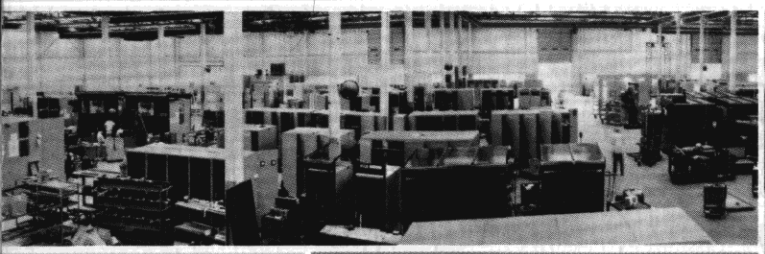
_____ *watthour meter*(s), (two) (three) *element.*

_____ *current transformer*(s), ____/5 *or suitable rating.*

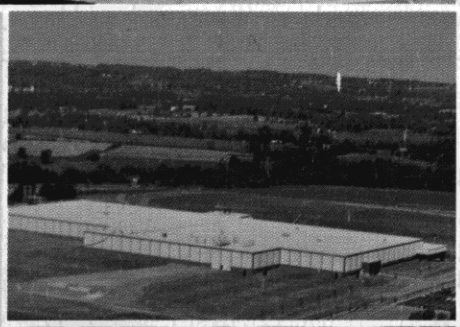
BUS DUCT—Switchboard Tie

Bus shall be non-segregated phase, metal-enclosed (indoor) (outdoor), *rated 600 Volts _____ amperes, 3-phase,* (3) (4)*-wire. 60 Hertz and shall consist of silver-plated aluminum conductors, insulated supports and housing.*

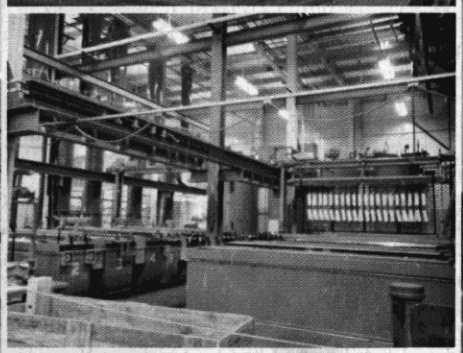
The Switchgear Division of I-T-E Imperial Corporation's Power Equipment Group manufactures and assembles switchboards for low-voltage metal-enclosed switchgear in its ultra-modern plant located at Chalfont (suburban Philadelphia), Pa. Material flow through this facility is optimized by its single story construction, permitting raw stock input at one end of the building, complete manufacture and testing, and final product shipment from the other end.



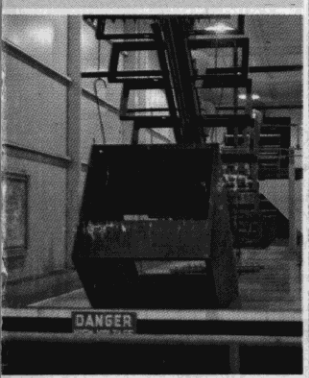
Final assembly work in process at Chalfont facility.



Aerial view of 300,000 sq. ft. Switchboard manufacturing plant located near Chalfont, Pa.



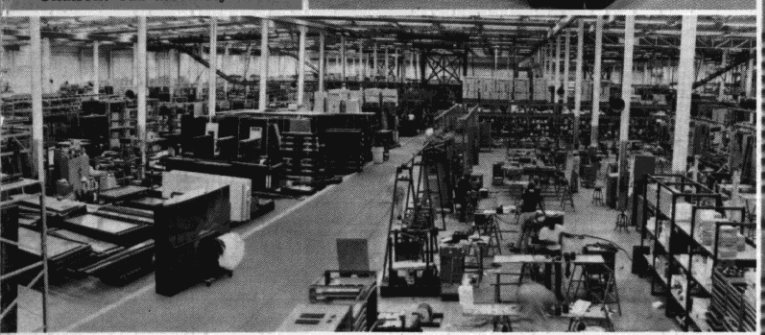
Fully automated electro-plating system produces all silver-plated bus used in low-voltage metal-enclosed switchgear.

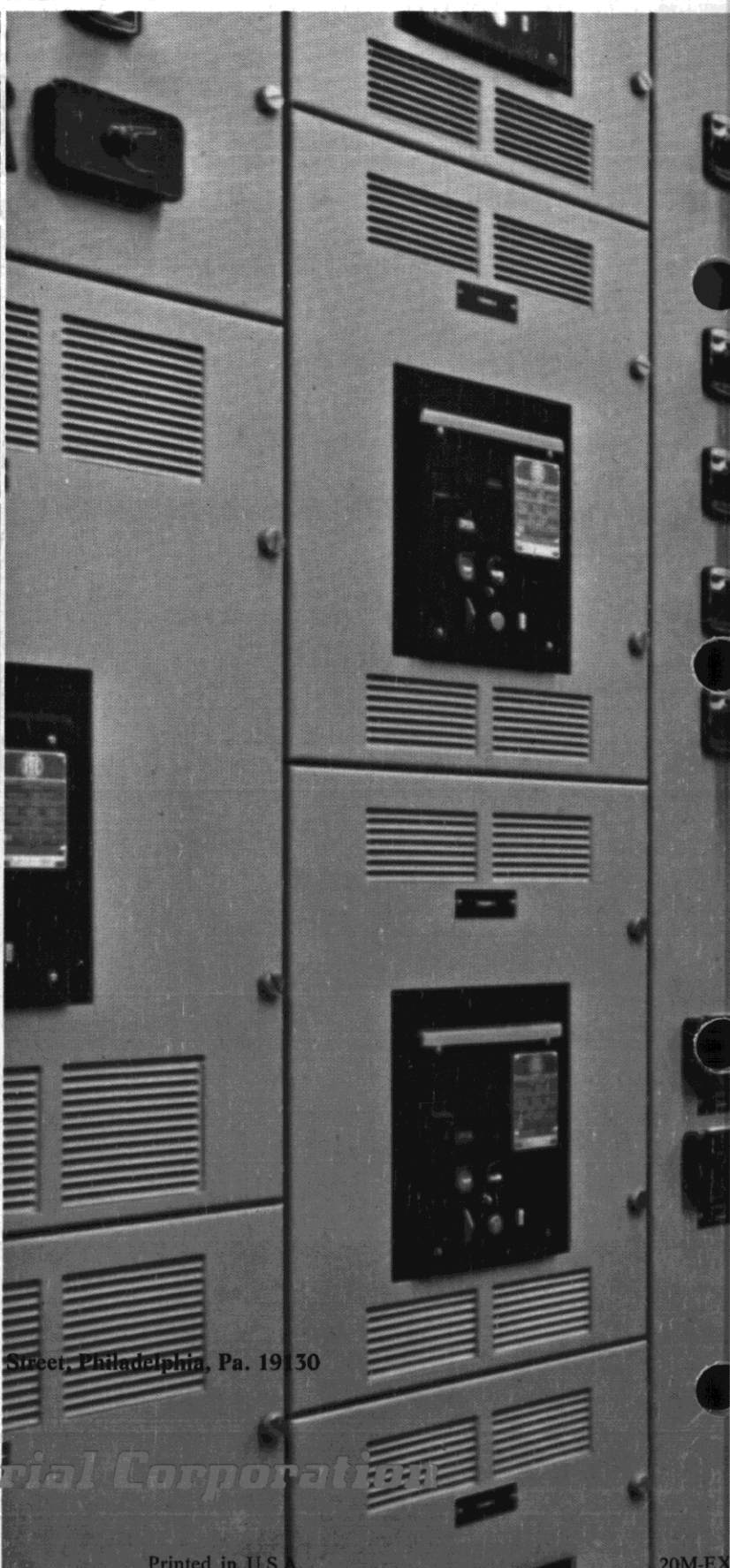


New fully automated "electro-coating" paint equipment in operation.

Numerically-controlled Wiedemann turret type metal press.

Chalfont sub-assembly area.





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