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IEEE Guide for the Application of Separable Insulated Connectors

IEEE Power Engineering Society

Sponsored by the
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IEEE Std 1215-2001™

IEEE Guide for the Application of Separable Insulated Connectors

Sponsor

Transmission & Distribution Committee
of the
IEEE Power Engineering Society

Approved 10 October 2001

IEEE-SA Standards Board

Abstract: This guide provides general information on the application and operation of separable connectors. It is intended to be basic, and supplement the manufacturer's specific recommendations and established utility practices.
Keywords: connectors, power distribution, switchgear

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Introduction

(This introduction is not a part of IEEE Std 1215-2001, IEEE Guide for the Application of Separable Insulated Connectors.)

This document is the first IEEE guide issued that addresses the application and operation of separable insulated connectors. This application guide is the product of close collaboration between representatives of both users and manufacturers of separable connectors. The Separable Connectors Working Group of the Insulated Connector Committee provided valuable input to this guide.

This application guide is intended to be used in concert with ANSI/IEEE Std 386-1995,[a] which defines the ratings, construction specifications, service conditions, and qualification tests for separable insulated connectors.

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[a]Information on references can be found in Clause 2.

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Contents

1. Overview 1

1.1 Scope 1

2. References 1

3. Definitions 2

3.1 Cautions, notes, and warnings 2
3.2 Parts of a bushing 2
3.3 Parts of a bushing well 3
3.4 Parts of an elbow 3
3.5 Separable connectors 3
3.6 Tools 4

4. Design considerations 4

4.1 Systems 4
4.2 Environmental 7

5. Construction and installation 8

5.1 Use of loadbreak versus deadbreak 8
5.2 Grounding of components and shields 8
5.3 Lubrication 9
5.4 Tightening requirements 10
5.5 Elbow/bushing assembly 11
5.6 Compression lugs 11
5.7 Solvents 12
5.8 Cleanliness (avoiding contamination) 13
5.9 Cable training 15
5.10 Clearances for operation 15
5.11 Operator/bushing location 16
5.12 Stacking 600 A Tees 16

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6. Operation 17

6.1 Use of loadbreak versus deadbreak 17

6.2 Deadbreak operating practices 17

6.3 Loadbreak operating practices 18

6.4 Capacitive test point 22

6.5 Switching 23

6.6 Fault duty 25

6.7 Use of accessories 26

6.8 Grounding accessories 29

6.9 Inspection of separable connectors 30

Annex A (informative) Bibliography 31

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IEEE Guide for the Application of Separable Insulated Connectors

1. Overview

This guide covers the application of separable connectors—rated 601 V and above, 600 A or less—for use on power distribution systems. Included are design considerations and guidelines for the construction, installation, and operation of 200 A loadbreak connectors and for 200 A and 600 A deadbreak (non-loadbreak) connectors.

This guide is intended as a supplement to the training in high-voltage electrical equipment, established safe operating procedures, and the manufacturer's instructions for the application of separable insulated connectors. Installers and operators of separable connectors require formal training in the use of high-voltage electrical equipment. It is the user's responsibility to establish safe operating procedures and provide training. The manufacturers are required to provide installation and operating instructions for their products.

1.1 Scope

This guide provides general information on the application and operation of separable connectors. It is intended to be basic, and to supplement the manufacturer's specific recommendations and established utility practices.

2. References

This guide shall be used in conjunction with the following publications. If the following standards are superseded by an approved revision, the revision shall apply.

ANSI C2-1997, National Electrical Safety Code, American National Standards Institute.[1]

ANSI/IEEE Std 386-1995, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.

[1]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

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ANSI/IEEE Std 516-1995, IEEE Guide for Maintenance Methods on Energized Power Lines.

ASTM F 855-1997, Standard Specifications for Temporary Protective Grounds to Be Used on De-energized Electrical Power Lines and Equipment.[2]

CFR 29 Part 1910.269, Occupational Safety and Health Standards—Electric Power Generation, Transmission, and Distribution.[3]

IEEE Std C62.22-1997, IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems.[4]

NEMA CC 4-1986 (Reaff 1992), 8.3 kV and 8.3/14.4 kV Probe for Separable Insulated Loadbreak Connectors.[5]

NFPA 70-2002, National Electrical Code® (NEC®).[6]

3. Definitions

For the purposes of this Guide, the following terms and definitions apply. IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition, [B1][7] should be referenced for terms not defined in this clause. Also refer to the definitions and terms listed in ANSI/IEEE Std 386-1995.

3.1 Cautions, notes, and warnings

3.1.1 caution: A potentially hazardous situation which, if not avoided, may result in minor or moderate injuries. It may also be used to alert against unsafe practices.

3.1.2 note: Provides additional information or explanation on a topic.

3.1.3 warning: A potentially hazardous situation which, if not avoided, could result in serious injury or death.

3.2 Parts of a bushing

3.2.1 bore: The inner channel of the bushing into which the elbow probe is inserted.

3.2.2 canister: The support tube that forms the inner wall of a bushing. In a loadbreak bushing, the piston slides along the wall of the canister during a fault-close operation.

3.2.3 finger contact: The female contact of a separable connector bushing into which the elbow probe is inserted to make an electrical connection.

[2]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).
[3]CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (http://www.access.gpo.gov/).
[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[5]NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (http://global.ihs.com/).
[6]The NEC is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, USA (http://www.nfpa.org/). Copies are also available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[7]The numbers in brackets correspond to those of the bibliography in Annex A.

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3.2.4 nose: The part of a loadbreak bushing constituting the elbow probe entrance. The nose section can include a plastic cap or valve assembly with O-ring seals on the exterior end of the bore. The locking ring on the bushing mating interface is also included.

3.2.5 piston: The movable contact assembly within a separable connector bushing that allows the snuffer tube and finger contact to move outward in the event of a fault-close operation. This contact is typically located near the bottom end of the snuffer tube. The finger contact is generally threaded into the piston. The piston contact slides on the metal canister that forms the internal wall of the bushing.

3.2.6 shoulder: The step at the base of the mating interface on the exterior surface of a bushing where the elbow cuff overlaps the bushing to provide a watertight seal.

3.2.7 snuffer tube: The tubular part of a loadbreak separable connector bushing into which the elbow probe is inserted. This tube contains both the arc quenching material essential for circuit interruption and the female part of the main current contact.

3.2.8 stop ring: A feature that limits the outward motion of the piston during fault-close operation of a bushing.

3.3 Parts of a bushing well

3.3.1 stud: A threaded metal rod located in the bushing well that mates into the base section of a bushing insert.

3.4 Parts of an elbow

3.4.1 arc follower: The polymeric tip on the apparatus end of a loadbreak elbow probe that decomposes when exposed to an electric arc. Decomposition of the arc follower material aids in cooling the arc and deionizing the hot gases produced during circuit interruption.

3.4.2 compression lug: The internal current carrying part of an elbow designed for the transition of the current path from the cable conductor to the probe.

3.4.3 housing: The molded polymer shell consisting of the insulation, insulation shield, and conductor shield of an elbow. The housing encloses the probe and compression lug.

3.4.4 probe: The male contact on an elbow or protective cap, typically in the form of a metal rod.

3.5 Separable connectors

3.5.1 component: An individual assembly within a separable connector system. Individual components of a separable connector system include: elbows, bushings, junctions, caps, bushing wells, plugs, etc.

3.5.2 mating interface: The surfaces on a separable connector that are designed to provide an interference fit between two parts of the connector system. Typically, these surfaces require application of a lubricant and form either rubber-to-rubber or rubber-to-nonelastomeric contacting surfaces.

3.5.3 part: A subassembly of a separable connector component. For example, the individual parts of an elbow (a type of separable connector component) include a molded polymer housing, a compression lug, and a probe.

3.5.4 types: Separable connectors are classified into three types; 200 A loadbreak, 200 A deadbreak, and 600 A deadbreak.

3.5.5 shipping cap: A plastic cover that is used during transport to prevent contamination of the mating interface and internal parts. A shipping cap is not designed for installation on an energized circuit.

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3.6 Tools

3.6.1 live-line tool: An insulating tool, typically made of fiberglass, that is designed for use on, or in the vicinity of, high-voltage equipment. As used in the context of this standard, the live-line tool additionally provides a means of mechanically attaching to and locking onto the pulling eye of a separable connector and provides a means of transferring mechanical force between two or more points. Common names for live-line tools used to operate separable connectors include shotgun stick, switching stick, clamp stick, shotgun tool, etc.

3.6.2 probe wrench: A tool designed for use in installing the probe into the compression lug of an elbow. Some types include a mechanism for limiting the maximum torque applied during installation of the probe.

4. Design considerations

4.1 Systems

4.1.1 Underground distribution systems

Numerous types of distribution systems exist. In North America, the most common type of distribution system is the three-phase, four-wire multigrounded-neutral system. This system consists of three-phase conductors and a neutral conductor. The neutral conductor is grounded to earth at numerous locations. In most cases, the source supplying three-phase, four-wire distribution circuits is a wye-connected transformer with the neutral solidly connected to earth. Where the source is a delta-connected transformer, a grounding or zigzag transformer of sufficiently low impedance to limit the phase-to-ground voltages is also installed. To provide single-phase service, transformers are connected between one phase conductor and neutral.

Another distribution system is the three-phase, three-wire ungrounded system. This system consists of only three phase conductors. The source supplying these systems is either delta- or wye-connected transformers. To provide single-phase service, transformers are connected between two of the phases.

Continuous operating voltage across the separable connector is not to exceed the rated line-to-ground voltage.

4.1.2 Single-phase versus three-phase rating

Unlike cable voltage ratings, separable connector voltage ratings are based on the maximum line-to-ground voltage of the circuit and the maximum line-to-line voltage. Consequently, separable connectors are marked with either a single or a dual rating. For example, a separable connector with a single rating of 8.3 kV is suitable for use on single-phase circuits where the maximum phase-to-ground voltage is 8.3 kV or less. The single rating is the maximum voltage allowed across the connector insulation from the conductor to the insulation shield. Since the insulation shield is grounded, this is the maximum phase-to-ground voltage. Both deadbreak and loadbreak connectors can be single rated. For loadbreak connectors that are single rated, the normal recovery voltage across the contacts during a loadbreak operation cannot exceed the single rating (8.3 kV in the example). Consequently, loadbreak separable connectors with a single rating can be applied on single-phase circuits where the transformers are connected line-to-ground.

Only loadbreak separable connectors are dual rated because the second rating number is the maximum voltage that can appear across the contacts of a connector. These connectors are referred to as three-phase rated because they can withstand the higher voltage that will appear across the contacts when

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opening a delta-connected circuit. For example, a separable connector with a rating of 8.3/14.4 kV can be applied on circuits where the phase-to-ground voltage does not exceed 8.3 kV (the number to the left of the slash in the rating) and the normal recovery voltage across the contacts during a loadbreak operation does not exceed 14.4 kV (the number to the right of the slash in the rating). Thus, dual- or three-phase rated separable connectors can be applied on delta or wye three-phase circuits or on a single-phase circuit where the respective voltages appearing on the connector are less than or equal to the ratings.

CAUTION
Surge protection levels used on multigrounded-neutral systems differ from those used on ungrounded systems. Ensure that the BIL rating of the separable connector is adequate for the surge protection level of the system.

4.1.3 200 A loadbreak versus deadbreak

There are two types of 200 A rated connectors: loadbreak and deadbreak. A loadbreak connector is designed to close or interrupt current on energized circuits. A deadbreak connector is designed to be separated and engaged on de-energized circuits only.

The basic connector system for both types consists of an elbow connected to a cable and either a bushing insert or integral bushing connected to the apparatus. Other connector components are available to form taps, dead ends, grounds, and installation points for fuses or circuit breakers. These connectors have sliding contacts that enable easy separation and engagement. Some components are provided with an operating eye for live-line tool operation.

4.1.4 600 A versus 200 A

There are two continuous current ratings for separable insulated connectors: 200 A and 600 A. To achieve the maximum connector ratings, the thermal environment and cable conductor size must be considered. Air temperature surrounding the connector; i.e., apparatus enclosure temperature, must be limited to 65 °C. The cable conductor must be sized to carry the rated current based on the cable temperature rating and thermal operating environment, i.e., direct buried, duct, free air, etc. If higher current ratings are required, consult the manufacturer.

Various components allow interconnection of 200 A and 600 A connectors. When components of different current ratings are connected together, CAUTION should be exercised not to exceed the ratings of the 200 A connector system.

4.1.5 Component shields

The shield on separable connector components is the outer semiconducting or conducting layer. When grounded, it serves three purposes:

1) It ensures controlled electrical stress within the component insulation.
2) It shields high voltages from contact, providing deadfront operation.
3) It enhances the safety of the connector system.

The result of improper shield grounding on separable connectors is the accumulation of electrical charges on the shield surface as a result of capacitive coupling across the component insulation. A voltage differential will appear that can present a static change exposure to personnel or lead to discharges and erosion of material at the connector interfaces. During a switching operation, the accumulated charge changes the voltage stress pattern across the separating connector. A sudden

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electrical discharge or arc can occur, which ionizes the surrounding air at the discharge site. The ionized air lowers the interface dielectric strength, which can result in a phase-to-ground flashover. Failure to ground shields properly is a frequently encountered reason for flashover failure of elbows, protective caps, and parking bushings.

In a typical application, silicone grease is used as a lubricant on the mating interface of separable connector components. However, the grease also serves as an electrical insulator. Silicone grease can isolate a component from ground if the grounding provisions are not used. Similarly, the paint on a transformer tank or other enclosure can isolate a bushing or well from ground. When this occurs, the semiconducting shield on the connector component becomes one plate in a series-parallel connected capacitive voltage divider. The cable conductor and the cable insulation shield form other plates of the capacitor assembly. Depending on the capacitance ratios, significant voltages can appear on the insulation shield. The worst-case condition can occur when several shields, connected in series, are not properly grounded. This will place a higher percentage of the total capacitance in the junctions separating the respective shields, increasing the voltage drop across the exterior surface of the components.

The capacitive coupling phenomenon is illustrated in Figure 1. The capacitances shown in the illustration will be shorted if the shields on two adjacent components are connected to ground. Voltage drops in the circuit will be isolated across the component insulation and will not appear across the silicone grease within the mating interface.

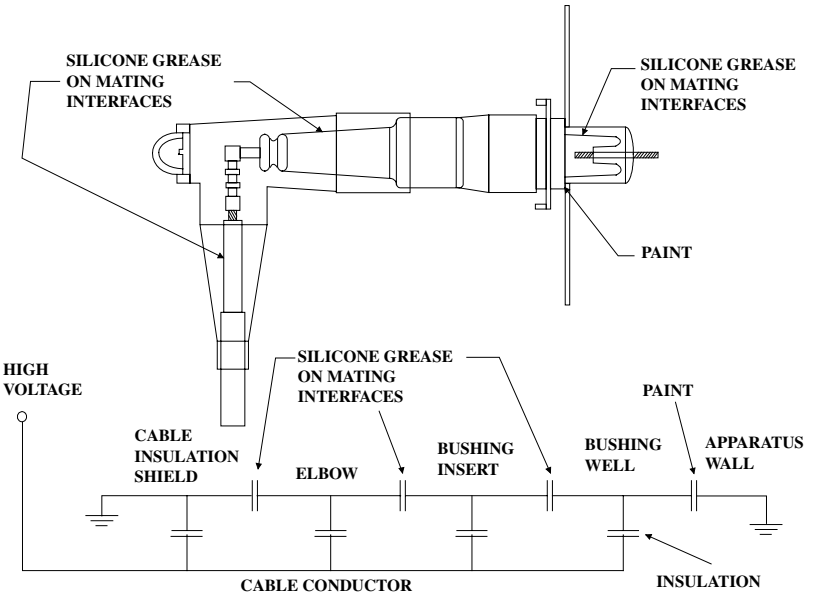


Figure 1—Voltage divider effect of capacitive coupling across components

4.1.6 Overload rating

An overload rating for separable insulated connector components is the allowed current level for a limited time period beyond the specified continuous current of the connector.

4.1.6.1 200 A loadbreak systems

Loadbreak separable connectors do not have an overload rating. The 200 A loadbreak connectors are limited to 200 A continuous current to prevent switching operations at current levels that exceed the capability of the connector system.

If uncertainty exists regarding overload capability, the user should consult the manufacturer.

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4.1.6.2 200 A and 600 A deadbreak systems

Deadbreak connectors typically have a 4-h overload rating as follows:

—200 A rated components: 300 A, rms
—600 A rated components: 900 A, rms

These ratings are based on an ambient temperature of 25 °C. Actual ratings are published in manufacturers' catalogs. If uncertainty exists, consult the manufacturer.

4.1.7 Interchangeability

Interchangeability is defined as the intermixing of mating separable connector components from different manufacturers. Included in the definition are elbows, bushings, plugs, caps, parking stands, etc. The definition does not include the intermixing of individual parts within a component.

Interchangeability applies to components having the same current rating, voltage rating (including single-phase or three-phase), interface size, and loadbreak or deadbreak. The interface sizes are detailed in the figures shown in ANSI/IEEE Std 386-1995. Generally, the bushing dimensions are specified. Because of the elasticity in ethylene propylene diene monomer (EPDM) rubber, the mating elbow or protective cap will have slightly different dimensions to ensure a proper fit with the bushing.

ANSI/IEEE Std 386-1995 defines two types of interchangeability. Complete interchangeability requires compliance with all applicable requirements of the standard. Limited interchangeability excludes the requirements of switching and fault close for loadbreak connectors. In cases where uncertainty exists regarding interchangeability, the user should contact the component manufacturer.

4.2 Environmental

4.2.1 Environment

Separable connectors are designed for use in environments where the air temperature is within the range of −40 °C to +65 °C. Loadbreak separable connectors can typically be closed and opened when temperatures are within the range of −20 °C to +65 °C. Separable connectors can be continuously submerged in water to a depth of 2 m when fully mated.

CAUTION
Loadbreak separable connectors cannot be switched under water.

The area immediately around the loadbreak connector must be free of moisture and debris such as plant growth, ant hills, and wasp nests prior to switching. The cable must be clear of obstructions and free to move. If debris or dirt is not easily removed, the circuit should be de-energized before attempting to operate the connector.

While performing switching, the operator should take care to keep the exposed interfaces free of moisture, dirt, and other contaminants.

NOTE—The air temperature range corresponds to −40 °F to +149 °F. The operating temperature range for opening and closing is −4 °F +149 °F. Separable connectors can be continuously submerged in water to a depth of 6 ft when fully mated.

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4.2.2 Ultraviolet exposure

Separable connectors can generally be exposed to direct sunlight. The external shielding of separable connectors is generally a semiconductive, carbon-filled, EPDM rubber. The carbon fillers in the semiconducting shield provide adequate resistance to ultraviolet radiation.

CAUTION
Some bushing and bushing well materials traditionally used with separable connectors are adversely affected when exposed to direct sunlight for long periods of time. Contact the separable connector manufacturer for the device being installed to ensure the assembly can withstand continued exposure to direct sunlight.

4.2.3 Exposure to hydrocarbons

The polymers used in separable connectors are not compatible with oil, gasoline, and other hydrocarbon compounds. Separable connectors with prolonged exposure to hydrocarbons must be de-energized and replaced.

The most common means of contaminating a separable connector with a hydrocarbon compound occurs when the bayonet fuse is removed from a padmounted transformer. Oil can easily drip from the end of the fuse onto the separable connector. Protection should be provided to keep this type of contamination from occurring. If contamination occurs, it should be wiped off immediately. Consult the manufacturer for applications where hydrocarbon contamination cannot be avoided.

5. Construction and installation

The manufacturer's instructions should always be followed regarding the installation and use of separable connectors.

5.1 Use of loadbreak versus deadbreak

Loadbreak separable connectors are rated for switching energized circuits with load currents up to 200 A. They have a fault-close rating of 10 kA (symmetrical) for 10 cycles. Deadbreak separable connectors have no loadbreak or fault-close capabilities. The 200 A rated deadbreak elbows are mechanically fastened to their respective apparatus (switches, transformers, etc.) using hold-down bails. The bails maintain connector assembly, preventing inadvertent separation. Deadbreak connectors must be provided with an alternate switching device. The 600 A rated deadbreak connectors bolt together and do not use bails. Loadbreak elbows normally are not used with bails because of potential interference with switching operations. Loadbreak elbows are held in place by an integral locking system and do not require the use of hold-down bails.

Loadbreak elbows are identified by an identification band around the cable entrance. A single-phase rated elbow has a solid white band. A three-phase rated elbow has a white band with a center black stripe. Refer to ANSI/IEEE Std 386-1995 for further information. Deadbreak connectors have no identification band.

5.2 Grounding of components and shields

The grounding provisions on all components of a separable connector system should be connected to a solidly grounded conductor. This includes all separable connector components that have a conductive

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outer insulation shield. Grounding is typically accomplished by connecting a strand of cable neutral wire to the grounding provision or by connecting a drain wire from the grounding provision to a driven ground rod within the apparatus enclosure. If the ampacity of the cable neutral is critical, use an additional drain wire to connect the grounding provision to the ground rod. Typical grounding provisions include a molded grounding tab with a hole or eye for insertion of a wire lead, a port hole connector bolted to a mounting plate, or a braided wire lead. The grounding lead or wire is referred to as a *drain wire* because grounding of the shield prevents the accumulation of charge on the component shield, draining that charge to ground.

CAUTION
The shield must not be connected in series with the system ground circuit. The shield is not designed to carry neutral current.

On molded rubber components, the eye of the grounding tab may have a thin membrane across the opening. This membrane must be punctured when a wire is inserted through the grounding tab. The end of the wire should be pulled through, bent around, and wrapped tightly back on itself. This will ensure good electrical contact with the rubber. Exercise CAUTION, however, not to tear through the wall of the eye. A minimum wire size of #14 AWG copper is generally recommended for shield grounding.

Exercise CAUTION when selecting the ground attachment point for drain wires, especially if the wire is uninsulated. Avoid the possibility of a drain wire contacting an energized secondary bus or energized primary cables during switching operations. This is especially important on components that come equipped with braided drain wires. Such wires are typically provided on protective caps or bushing well plugs. Braided wires tend to be longer than drain wire connections made with a concentric neutral strand and they are much more flexible, allowing them to move more freely. Drain wires should be trained in a manner that does not interfere with the operation of the separable connector. The lead should be routed to maintain the maximum clearance possible away from the separable interface of the connector system. If there is a possibility of a drain wire contacting an energized conductor during a switching operation, apply appropriate protective cover-up equipment, such as insulating blankets or hoses. This is particularly important when switching in a single-phase transformer where the primary and secondary cables are in the same compartment. Protective cover-up of the secondary terminals and cables can prevent an accidental contact of the drain wire with an energized conductor.

The outer edge of the bushing well, where the cuff on the bushing insert contacts the well, is typically conductive. This surface should be solidly grounded either by connecting a ground wire to the mounting flange or by ensuring electrical contact between the mounting flange and the apparatus tank. In some cases, paint on the flange mounting studs and/or the tank wall can provide a thin layer of insulation. It might be necessary to remove some paint to ensure good electrical contact.

5.3 Lubrication

5.3.1 Reasons to lubricate

The purpose of the lubricant used on separable connectors is to reduce the assembly force during initial installation and to provide longer term lubrication of the mating interface, easing connector operations. The mating surfaces of separable connectors have to be lubricated properly to facilitate complete mechanical assembly of the parts. Although the lubricant provides water-sealing capabilities, it should not be used as the sole means for providing protection from moisture. The molded fittings of the separable connector are designed for a tight fit that will seal out moisture.

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5.3.2 How to lubricate

Use an insulating lubricant (typically a silicone grease) approved by the separable connector manufacturer. The lubricant is provided with the connector kit or purchased as a separate item. Aerosol lubricants are not recommended. Failure to use the proper lubricant and application procedure can result in seizure or electrical failure of the connector mating interfaces.

Apply lubricant to all mating surfaces, including the nose and shoulder areas of bushings. The inner surface of the elbow cuff should also be lubricated.

Whenever lubricant is applied by hand, the device(s) to be lubricated shall be electrically isolated and de-energized. The condition of the circuit should be verified and grounding applied in accordance with the required work practices of your company.

WARNING
Never attempt to lubricate energized separable connectors by hand.

The lubricant should be applied evenly to the mating interfaces in a manner that achieves a thin uniform coating. Do not over apply, as excess grease can prevent proper installation. Excessive grease application can result in an elbow backing off a bushing.

Excessive lubrication of the bushing well interface can prevent bottoming of the bushing insert on the stud of the bushing well. This can lead to overheating of the connector or breakage of the bushing well stud. The most successful lubrication technique is to apply a thin, uniform coating of lubricant to the interface on both the bushing well and the bushing insert. Because this interface initially makes contact at approximately the midpoint of the interface, lubricant is wiped in both directions. Lubricating only one interface will cause half of the interface to be wiped dry during assembly, making it difficult to tell when the components are fully seated.

CAUTION
Do not apply additional lubricant to the bore of a bushing. The lubricant can be carried down inside the bushing, contaminating the arc quenching materials and the current carrying contacts. This can lead to failure of the connector.

For connectors having test points, remove the test point cap and lubricate the mating surfaces of the cap and the test point.

The cable insulation and the cable entrance area inside the elbow have to be lubricated before sliding the elbow onto the cable. Use a back-and-forth twisting motion until the elbow cannot advance any further onto the cable. Rotate the elbow until it is aligned for proper insertion of the threaded probe.

To relubricate energized components, make use of de-energized components such as insulated parking bushings, multiway junctions, or protective caps. Apply lubricant to the mating interface of the de-energized component. Then, mate the de-energized component with the energized component following appropriate safety procedures and using the correct live-line tools and equipment.

5.4 Tightening requirements

5.4.1 200 A connectors

5.4.1.1 Bushing insert to bushing well stud

In preparation for installing the bushing insert into the bushing well, lubricate the mating interfaces as indicated in 5.3.2. Inspect the bushing well to ensure the stud is in place, tight, and in good condition.

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Studs are either permanently fixed into the bushing well or they can be replaceable. Place the threaded end of the insert into the well and align the insert onto the well stud. For manual assembly, turn the insert in a clockwise direction until you feel it bottom on the well stud. A sudden increase in the torque necessary to turn the insert will be detected. If a sudden decrease in torque is detected, remove the bushing and inspect for either a broken stud or stripped threads. If an assembly tool is used, follow the manufacturer's instructions for tightening.

5.4.1.2 Elbow probe to compression lug

The probe (male contact) should be preassembled into the threads of the compression lug prior to crimping to ensure proper thread engagement. Insert the threaded end of the probe (male) into the threaded (female) end of the compression lug and engage the threads. Turn the probe by hand until it becomes snug in the compression lug. If resistance is encountered when first engaging the threads, do not continue. Remove the probe and check the threads for damage. If there is no observable damage, realign the probe with the compression lug threads, and retighten. If the threads are damaged, replace both the compression lug and the probe. Ensure that the compression lug, probe, and bushing bore are properly aligned for unobstructed operation of the separable connector.

Remove the probe and install the elbow housing onto the cable. Align the housing to center the threads on the end of the compression lug with the probe opening. Insert the probe into the compression lug and hand tighten as previously described. Complete the installation by using an approved wrench (see manufacturer's instructions) to tighten the probe securely onto the compression lug.

5.4.2 600 A connectors

To assemble 600 A rated separable connectors, refer to the manufacturer's installation instructions.

5.5 Elbow/bushing assembly

Typically, the cuff of a properly assembled elbow extends 10 to 15 mm beyond the shoulder at the base of the bushing mating interface. In general, cuff overlap should not be used as a positive indicator of a fully assembled elbow. Seating indicators are available. Consult the manufacturer on their use and to determine if proper indication is achieved when intermixed components from different manufacturers are used.

A loadbreak elbow is secured to the bushing by engaging a locking ring at the upper end of the elbow mating interface with a mating groove on the nose of the bushing. A proper close operation using a live-line tool will ensure engagement of this locking ring. Full engagement can be checked by a slight tug on the live-line tool, ensuring that the elbow does not slide off the bushing freely. For 200 A deadbreak elbows, proper seating is achieved by use of the hold-down bail and bracket. Tighten the bail in accordance with the manufacturer's recommendations.

Refer to the manufacturer's installation and operating instructions for further information.

5.6 Compression lugs

Refer to the manufacturer's installation instructions for recommendations on crimping tools and dies required for proper installation of the compression lug.

After preparing the cable, clean the conductor using a stainless steel wire brush or other approved procedure. Immediately insert the conductor into the compression lug. The lug should contain an inhibitor designed to limit further conductor oxidation and penetrate any oxidation still present.

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Before crimping, align the compression lug on the conductor so that the flat contact area faces the bushing. Follow the manufacturer's or user's crimping instructions. Evenly distribute the proper number of crimps across the marked portion of the compression lug barrel. Depending on the die type used in assembly, it may be necessary to rotate the compression tool 90° or 180° to eliminate curvature of the compression lug barrel. After crimping operation, remove any flashing that could damage the separable connector insulation when the elbow housing is slipped onto the cable. Wipe off excess inhibitor to prevent getting any on either the separable connector or the cable insulation during assembly. Inhibitor on the insulation surface acts as a conductive contaminant.

Follow recommended practices when installing the compression lug on strand-filled conductors. Modern strand-fill materials typically do not have to be removed from the conductor strands before installation of the compression lug.

5.7 Solvents

The banning of many common, chlorinated solvents has prompted questions about the proper application of newer solvents used to clean separable connector components. The objective is to remove contaminants effectively without producing adverse effects on the semiconducting compounds or the insulation surface. To achieve this objective, the solvent must be able to remove the contaminants commonly encountered on separable connector components, including dirt, silicone grease, and carbon deposits.

Inhibited 1,1,1-trichloroethane (methyl chloroform) was the solvent of choice for use on the EPDM rubber insulation of separable connectors before it was banned. However, trichloroethane was not recommended for use on the semiconducting shields. Banning of the chlorinated solvents has forced both manufacturers and users to take a hard look at actual requirements in many of the applications where solvents have been used.

Trichloroethane is an extremely active solvent. It produces swelling in EPDM rubber on a short-term basis and with long-term exposure will significantly degrade the polymer. Its successful use stemmed primarily from the rapid evaporation rate, resulting in the solvent being in contact with the rubber surface for a very short time. Trichloroethane left virtually no solvent residue and drying time was not a concern.

Many of the newer solvents replacing trichloroethane are hydrocarbon based. These solvents are typically not as effective at removing silicone grease or some of the other contaminants. Greater effort might be required to clean the polymer surface. In addition, these solvents have a much slower evaporation rate, which places them in contact with the rubber for a longer time. Although they do not attack the rubber as actively as trichloroethane, their longer exposure time can result in a greater overall adverse effect on the rubber polymer. Consequently, the newer solvents should be dried from the surface of the insulation using a clean, lint-free towel or rag. Drying should be completed as soon as the surface has been effectively cleaned and before assembly.

The use of a hydrocarbon-based cleaner would seem to be undesirable because of the known adverse effects of hydrocarbon-based oils on the physical and electrical characteristics of EPDM rubber. However, the relatively limited exposure of the polymer to the solvent during a cleaning operation makes limited use of a hydrocarbon-based solvent acceptable.

Most solvents recommended for cleaning cable insulation are generally not recommended for cleaning the semiconductive outer insulation shield on separable connectors. These solvents can remove carbon from the shielding material and produce swelling that increases the separation between the carbon grains embedded in the shield polymer. Both of these actions cause an increase in the shield volume resistivity that is an undesirable effect.

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A simple, easily obtained cleaner for semiconductive shielding materials is a lightweight, low-viscosity silicone oil. Such oils can be obtained in either aerosol cans or in bottles as a liquid. The product is sometimes listed as a mold release agent. The lightweight oil is very effective at dissolving the primary surface contaminants: dirt, silicone grease, and carbon. However, some CAUTION is required in selecting an appropriate product, particularly in the aerosol form. The silicone oil is frequently mixed with a carrier or with a propellant that can produce an adverse effect on the EPDM rubber. A Material Safety Data Sheet (MSDS) should be obtained from the solvent manufacturer to assist in the identification of compounds that can produce adverse effects. Consult the separable connector manufacturer for specific recommendations or request compatibility testing for compliance with the requirements of appropriate industry standards.

Lightweight silicone oils either in the liquid or aerosol form ARE NOT RECOMMENDED for use in cleaning or lubricating the mating insulating surfaces on separable connectors. Lightweight oils will migrate out of the interface, allowing the surfaces to bond together. When sprayed as an aerosol, condensation of moisture can occur as a result of the cooling effect produced by the expanding gas propellant. Any moisture condensing on an insulating surface will contaminate the surface and can lead to surface tracking or an interface flashover.

In addition to cleaning effectiveness and compatibility, other solvent characteristics can affect the usefulness of a solvent in a particular application. Solvent characteristics to consider include toxicity, vapor density relative to air, flashpoint, flammability, disposal requirements, personal protective equipment required, and Occupational Safety and Health Administration (OSHA) mandated permissible exposure limits (CFR 29 Part 1910.269). If the solvent is to be applied in a manhole or confined space where air circulation is limited, the density relative to air is important since the solvent vapor should not displace breathable oxygen from the enclosure. In addition, the level of solvent in the air should remain below the permissible exposure limits. Flammability and flashpoint will be important if an electric arc or an open flame could ignite the solvent. For example, alcohol is an effective cleaning solvent, but its vapors are highly flammable.

Manufacturers of solvents have attempted to address these concerns in many ways, including the use of special product packaging methods. Some solvents can be obtained on premoistened towelettes. Packaging of the towelettes limits exposure to the solvent until the packaging is opened. The amount of solvent on each towelette is limited, keeping personnel exposure below OSHA mandated limits (CFR 29 Part 1910.269) while delivering the solvent directly to the desired area of application.

A standard has been published by the National Electrical Manufacturers Association (NEMA) specifying requirements for solvents used to clean the arc follower on the male probe contact of loadbreak separable connectors. These requirements are contained in NEMA Standard CC 4-1986.

5.8 Cleanliness (avoiding contamination)

When working with high voltages imposed across either an interface or across an external surface, the cleanliness of the surface is EXTREMELY IMPORTANT. Conductive contaminants can increase leakage currents, causing an increase in power loss and higher operating temperatures. Conductive contaminants can also change the electrical stress distribution. Control of electrical stress along a mating interface, either during steady-state operation or during a switching operation, is extremely important to the functioning of many separable connector devices. An increase in leakage current or alteration of the electrical stress distribution can lead to an interface flashover or to an insulation puncture.

Even the presence of nonconductive contaminants can produce adverse effects. The fit along a mating interface typically depends on an interference between the mating surfaces where the outer component

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of the interface applies an inward pressure, hoop stress, that keeps the interface tight. This serves two purposes. First, it helps to keep moisture out. If moisture were to get into the interface, it could easily contain conductive contaminants that can lead to a flashover. Second, the dielectric strength along a tightly fitting interface is higher than along a loosely fitting interface that can contain air pockets. Consequently, a tight fitting interface will have improved voltage withstand characteristics. Non-conductive contaminants, such as sand or dirt, can separate the interface, creating small air pockets around the contaminant grains. This will lower the dielectric strength and provide a path for moisture entry.

Some materials can be nonconductive contaminants until exposed to humidity in the air. The humidity can be absorbed by the contaminant, creating ionic solutions that are highly conductive.

There is an industry trend to make high-voltage apparatus and components more compact and easy to operate. As this trend continues, the importance of cleanliness in the assembly and operation of these devices will increase.

When cleaning high-voltage components, consider the type of wipes used both to apply solvents and to dry the insulation surface. Lint-free towels or rags are recommended that are free of chemicals or compounds that form ionic solutions when wet. Some brands of paper towels can leave behind wood fibers that absorb moisture. The wet wood fibers can provide a conductive path that can lead to an interface flashover. ALWAYS wipe in a manner that minimizes the possibility of contaminating the insulating surfaces. When using a solvent to clean insulation, take care not to wipe across a semiconducting material. Work from the insulation up to the edge of other layers that can introduce contamination. To clean all the way to the edge, make a final wipe from the insulation perpendicularly across the edge before discarding the wipe.

An environment that is conducive to cleanliness is not always available for the preparation of cable ends and field assembly of separable connectors. Take the steps necessary to avoid common contamination problems. Avoid the introduction of moisture and contaminants onto an interface or inside of a component. Moisture is not only conductive, but it can also cause corrosion to form on the electrical contacts. If a component must be installed while it is raining, protect the work area with a tarpaulin or take other appropriate measures. In hot climates, the perspiration from personnel working on the installation can be a serious source of contamination. Perspiration not only provides moisture, but also the salt in perspiration is highly conductive and corrosive.

Place protective equipment in positions to limit the possibility of contaminants entering the work area. Rubber blankets can be used to isolate the assembly area from dirt, moisture, and other natural contaminants such as grasses and insects. Blankets can also be used to lay out components for easy access in the assembly area while keeping them clean and protected.

Keep tools and cover-up apparatus clean and in good condition. Do not transfer contaminants from a poorly maintained tool onto the insulation surface.

Inspect the insulation surface for any evidence of contamination before proceeding with assembly of the connector. Look for any contaminants that may be transferred from adjacent surfaces or materials during the installation process. The inhibitor squeezed from the end of a compression lug can be a source of interface contamination. Some of these inhibitors contain highly conductive metal particles or sand as an abrasive agent. Remove excess inhibitor from the edge of the compression lug once it is installed. This will prevent smearing the inhibitor down the insulation surface when, for example, an elbow is pushed onto the end of the cable.

Some separable connector components can be reused or moved from one site to another. Store these components and transport them in a manner that will ensure they remain clean. Protective caps and plugs should be covered with a protective cap or mated with another component that provides

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an effective seal. In all cases, components should be inspected and, if necessary, cleaned before each use.

5.9 Cable training

In the initial design of an underground distribution system, the designer must allow for the operation and maintenance of the cable and the separable connectors. Adequate slack is needed to allow for installation, switching, isolating, and grounding of the cable and related hardware, including making up the connection to the ground bus or to a ground rod. Sufficient slack should be provided to ensure that thermal expansion and contraction of the cable circuit leading to the apparatus does not place undue downward force on the connectors that could crack bushings or bushing wells. Downward tension on a cable could also prevent the operator from withdrawing an elbow probe completely from a bushing or prevent the operator from reinserting an elbow probe once it has been removed.

The bending radius of the cable must be considered and is dependent on the size and construction of the cable. Generally, the bending radius is a minimum of 8 to 12 times the outside diameter of the cable. If there is any question about bending radius, the cable manufacturer should be contacted. It is good practice to ensure that the cable can move through an arc defined by the position of the various separable connector components within the apparatus, and by the position of the cable entrance into the switching compartment. Care should be taken not to introduce curvature into the elbow when training cable. It should not be forgotten that cables elongate when heated by increasing load current. Thermally induced elongation can cause additional bending of the cable depending on the installation configuration.

The person installing 200 A or 600 A separable connectors should always follow the manufacturer's instructions and recommendations. Cable preparation is an important factor in the safe and reliable operation of the separable connector. The cable should be as straight as possible to allow for proper installation of the separable connector. Proper cable training or positioning will also aid the operator by making it easier to switch an elbow when performing operation and maintenance procedures.

Cable installation practices vary, depending on the chosen construction design. Typical installation practices include cable in conduit, direct buried cable, or a combination of both. In rural areas the apparatus (transformers, switches, etc.) are typically padmounted, while in urban areas they can be submersible in vault-type applications. When separable connectors are to be installed within a low-profile transformer, the primary cable should be trained to the outside and in front of the secondary cables to allow for operation of the elbows. In vault-type construction, extra care should be taken in the racking of the cable and separable connectors. The weight of the cable, if not supported, can place the elbow and bushing under mechanical stress that could lead to failure.

Thought should be given to the operation of separable connectors in cold climates. Depending on the size and type of cable being used, the cable will not be as flexible in colder climates. In submersible applications when the temperature drops below freezing, ice can form. Therefore, extra care in cable racking and support is required to accommodate the added weight on the cable and the separable connectors. Ground settling and frost heaving should be considered. The ground should be tamped down if the earth is excessively disturbed or nonconfined. A shifted padmount apparatus can result in excess mechanical force on the connector assemblies if there is insufficient slack in the cables.

5.10 Clearances for operation

Underground distribution system design should anticipate the operational and maintenance requirements that will come into effect after construction. Adequate clearance should be provided for the operation of live-line tools, related tools, and equipment. Clearances are specified by the utility in their safety and work procedures, local codes, and/or ordinances. Pertinent national codes

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include: ANSI C2-1997, NFPA 70-2002, Federal Register, OSHA Rules and Regulations (Occupational Safety and Health Administration) including CFR 29 Part 1910.269; and ANSI/IEEE Std 516-1995.

A basic requirement when preparing to switch a loadbreak separable connector is to have the appropriate physical workspace with sufficient clearance from adjacent obstructions to permit unrestricted motion of the operator, live-line tools, and the connector. With the compartment doors of a transformer or switchgear open, there should not be any shrubbery, buildings, or other obstructions within the length of the live-line tool plus sufficient operating space. The operator should be able to stand in a location where the separable connector can be operated in a straight line along the device axis, preferably at a height that is comfortable for the operator. Solid footing should be available with space to step either forward or backward. The surface the operator stands on should be flat without tripping hazards or loose material.

Ensure that there is adequate cable length and freedom of cable motion to allow uninterrupted operation of the separable connector system. If the cable length is short or other cables are interfering with motion of the separable connector, the probe can jam in the connector at a partially open position. This can prevent circuit interruption and result in failure of the connector. Positioning of the cable, separable connectors, and accessory parking stands should be designed to fall on the arc of motion limited by cable length.

5.11 Operator/bushing location

The bushing height shall be in such a position as to be operable for switching. Care should be taken during design to allow the operator to remove an elbow properly and park it on an appropriate device (an insulated parking bushing, multiway junction, etc.). Operators performing switching shall position themselves relative to the elbow and bushing so that they can perform the switching operation safely and effectively. Operators should have secure footing to prevent injury to themselves and others.

In subsurface applications where switching is to be performed from outside the vault or substructure, operators should be in a position to remove an elbow properly and park it on an insulated parking bushing safely and effectively. The bushing and elbow configuration should be at an angle to the operator to allow for the straightest possible removal and reinstallation of the elbow. This may mean that the connector is installed at an upward angle to facilitate proper switching. Proper racking of the cable should be addressed to prevent excessive weight on the connectors and other components. Proper racking aids in performing necessary switching operations.

5.12 Stacking 600 A Tees

The 600 A separable insulated connector system is designed to splice cables, as well as connect cables to apparatus. A connecting plug is used to join one elbow to the next through the operating interfaces. This arrangement can be extended to join multiple elbows, providing a junction that creates multiple taps on a feeder. The number of joined elbows typically does not exceed four, but this is not necessarily the limit. The limit is established by both current and mechanical support considerations. The maximum continuous current rating is 600 A for any one elbow and shall not be exceeded.

As an example, a junction of seven elbows is possible if the feeder elbow is limited to 600 A and each of six taps is limited to 100 A. This example is based on continuous current only. To use such an arrangement, mechanical support of both the elbows and adjoining cables is essential. The weight of unsupported cable can be substantial, based on the cable's length and size. Forces applied to the elbows can bend connections and cause loosening torque. Electromagnetically induced force caused by fault current and thermal expansion of the cable circuit are two other factors to consider.

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For example, a fault current of 25 kA fed into one cable and out another parallel cable separated by 20 cm will produce a force of approximately 625 N/m of cable length pushing the cables apart. Under this condition, a moment of force is generated about the connection point. It is, therefore, important not only to support cable weight, but also to secure the cable to prevent movement. A recommended point for securing the cable is near its entrance into the elbow.

NOTE—As stated previously in metric units, this information in customary units would be as follows: If the cables are separated by 8 in, the force will be approximately 42 lb/ft of cable length.

To achieve the proper assembly torque during installation, it is important to follow the manufacturer's instructions. This usually means torquing each elbow connection individually rather than torquing a multi-elbow assembly from one end to the other.

6. Operation

6.1 Use of loadbreak versus deadbreak

Deadbreak connectors must be de-energized before operating and be mechanically secured with bails when connected. Deadbreak connectors shall not be energized unless the parts are fully assembled in accordance with manufacturer's instructions. The 200 A loadbreak connectors do not require a bail and can be used for energized operation in connecting and disconnecting apparatus. When connecting (energizing) apparatus with a 200 A loadbreak connector, the available fault current shall not exceed the 10 kA rating of the connector. Both loadbreak and deadbreak connectors can be isolated using insulated protective caps, plugs, and insulated parking bushings. Optional accessories allow system grounding, testing, bypass, surge protection, the use of current-limiting fuses, and circuit breakers. Additional taps can be provided using multiway junctions. Live-line tools should be used to operate these connectors.

6.2 Deadbreak operating practices

Prior to separating a 200 A or 600 A deadbreak connector, verify that the circuit is de-energized. Typical methods of ensuring a circuit is de-energized include the use of an approved voltage detection device on the capacitive test point of an elbow, a spiking tool, or a test rod. Grounding and component removal procedures will vary by utility and are based on established work practices as well as the type of separable connector components stocked. Examples of typical methods used for different types of deadbreak components are described in 6.2.1 and 6.2.2.

6.2.1 200 A or 600 A deadbreak connector with a capacitive test point

Remove the test point cap using a live-line tool. In order to obtain a reliable reading, ensure that the test point is clean and free of contamination and moisture. Check for voltage on the test point using an approved detection device, the operation of which should be tested on a known energized circuit immediately before and after the voltage test. Attach the clamp end of an approved grounding device, such as a grounding elbow, to a solidly grounded connection point. This may be a driven ground rod or the system neutral conductor. With an indication of no voltage, proceed with the grounding operation. On 200 A rated systems, remove the hold-down bail. To ground the elbow side of the circuit, use a live-line tool to remove the elbow and park it on a multiway junction. A second test for voltage can be performed by inserting a test rod into the opposite end of the multiway junction. Bringing the end of the live-line tool near the test rod will produce a buzz or discharge if the circuit is energized. Do not proceed with grounding until the circuit is known to be de-energized. To ground the cable side of the connection, connect the grounding elbow to an available position on the multiway

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junction. To ground the bushing side of the connection, connect the grounding elbow to the bushing. On a de-energized 600 A rated system, the insulated plug can be removed from the elbow and replaced with a reducing tap plug using live-line tools. Use of the reducing tap plug allows 200 A rated grounding components to be used for system grounding. A 600 A grounding bushing is available. The elbow can be transferred to the grounding bushing and the insulated plug replaced.

6.2.2 200 A or 600 A deadbreak connector without a capacitive test point

Without a capacitive test point, other means of determining the presence of voltage must be applied prior to opening the connector. Utility practices vary widely in this situation. Some utilities require that all circuits in the work area be de-energized at a switching device. This switching device can provide some means of voltage detection and can also create a visible air break and grounding point. A portable external device can be used to detect circuit voltage. These devices are sometimes called *tick tracers* because they emit a clicking sound when in proximity to voltage or current fields above a given threshold. Care should be exercised in using these devices on shielded power cable systems, however, because the electric field is contained within the cable and accessories by the insulation shielding. Some utilities require spiking of the cable. In this procedure, a grounded pin is driven through either the cable or the accessory insulation and into the conductor. Once the condition of the circuit has been adequately determined, the connector is opened and a grounding procedure similar to that previously described is followed.

WARNING
When performing a grounding operation, the ground clamp end of the lead on the grounding elbow should be the first connection made before beginning the grounding operation and the last connection removed when completing the work and preparing to restore the circuit to service.

6.3 Loadbreak operating practices

6.3.1 Proper operation using live-line tools

When operating in-service separable connectors, a quick and firm continuous pulling or pushing action is recommended to overcome the mechanical forces resisting switching operations. Slow switching speed can result in arcing across the mating contacts, which can expel ionized gases into the mating interface and damage the mating contacts. This could compromise the ability of the separable connector to provide a complete electrical path. Slow switching speed can also result in an incomplete mating of the rubber interfaces, allowing moisture intrusion and inhibiting the ability of the connector to provide a tight interfacial seal. There are numerous types of live-line tools available for the installation and removal of separable connectors. Prior to beginning work, the operator should be familiar with the operation of the live-line tool chosen for use in accomplishing the particular task.

A clamping-style live-line tool, called a *shotgun stick*, is commonly used for removal and installation of separable connectors. This type of live-line tool attaches to the pulling eye of the elbow or insulated protective cap for switching of the separable connector. In using a live-line tool, the force exerted on the separable connector is determined by the force applied to the tool by the operator. Another type of live-line tool that can assist the operator in applying this force employs an impact or slide-hammer mechanism. The impact-type tool facilitates removal and installation of an elbow or protective cap by providing momentum via the slide hammer, which is sufficient to overcome the mechanical resistance to connector operation.

The length of the specified live-line tool is typically based on the minimum distance required to withstand a specified voltage level, plus a distance for properly gripping the tool and a safety factor. If a connector arcs to ground during a switching operation, the resulting flash can ionize the

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surrounding air, reducing the dielectric strength across a portion of the tool's surface. Fault current magnitude and duration are important considerations when choosing the length of a live-line tool. Consult the company's safe work practices for the required live-line tool length for each particular application.

Refer to ANSI/IEEE Std 516-1995 for the care and maintenance of live-line tools and to determine the minimum approach distance. In addition to using a live-line tool when operating separable connectors, the operator should also use personal protective equipment (PPE) in accordance with CFR 29 Part 1910.269 and the company's safe work practices.

Live-line tools, such as ratchet tools, that limit the separation speed during the critical arc extinction time, are not recommended. Tools that are not designed for quick operation and those that pull at an angle off the centerline of the probe axis are not recommended for removal or installation of separable connectors.

6.3.2 Loadbreak switching practices

Loadbreak separable connectors are inexpensive and reliable devices for switching of distribution circuits. Laboratory testing and field experience show that loadbreak separable connectors can successfully interrupt a range of load currents from less than 1 A up to 200 A at rated voltage or less. However, the success and safety of a switching operation is dependent on use of the proper tools and techniques.

Proper operating tools and safety equipment should be available and in use. Separable connectors are designed and tested to interrupt load currents safely and close into faults up to their ratings. However, the possibility exists that they could fail during energized operations, resulting in a flashover to ground. The severity of the flashover depends on a number of factors, including the available fault current and the type of overcurrent protection on the circuit.

To minimize the exposure of operating personnel to such events, appropriate combinations of distance, live-line tools, and PPE must be used. Users shall follow established safe work practices that are based on system design and the types of approved safety equipment available. Users should also consider the recommendations of the separable connector manufacturer.

The operator should not be looking directly at the connector during the moment of circuit interruption or connection. Positive control of the connector and cable should be maintained at all times. The operator should have a means of isolating an energized conductor readily available and convenient. Companies that operate separable connectors can have other requirements, including the wearing of hard hats, rubber gloves, protective eyewear, arm guards, flame-retardant clothing, and/or rubber overshoes. Follow the recommendations of the operating company.

Separable connector interfaces tend to stick as the lubricant ages. Before separating the connector, a slight clockwise rotation of the live-line tool is recommended. Counterclockwise rotation is not recommended because the probe or bushing insert may loosen at internal threaded joints, resulting in a poor electrical connection. The success of the rotation procedure is dependent on the condition of the interface lubricant.

Separate the connector in a smooth, continuous motion at the maximum speed the operator can comfortably control. The live-line tool used during switching operations should be held to one side of the operator's torso.

If the connector will not separate, rotate the live-line tool attached to the component pulling eye through a wider clockwise angle. Try opening the connector again. If the connector still will not separate, do not apply excessive force. The connector is most likely damaged. The circuit will have to be de-energized and the connector removed by other means.

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If possible, the connector probe and mating interfaces should be inspected for evidence of contamination, damaged parts, or dried lubricants. Damaged or defective components should be replaced. Contaminants should be removed using an appropriate solvent. Dried lubricants should be cleaned from the interface and replaced with fresh lubricant. An easy method of relubricating an interface on an energized component is to mate it temporarily with either a protective cap or an insulated parking bushing that has fresh lubricant on the mating surface.

Closing or mating of two separable connectors should be done in a smooth, continuous motion at the maximum speed the operator can comfortably control. It is easy to ensure proper engagement of the probe into the mating bushing if the components are initially aligned by placing the probe tip into the nose of the bushing. This is called the *dwell position*. The probe tip can temporarily be inserted 25–50 mm without damaging the components or creating the possibility of a flashover. Consult the manufacturer's instructions for determination of the dwell position for the particular connector. Once alignment is achieved, the connector should be immediately closed. Exercise CAUTION not to pull back on the live-line tool. Backward motion could allow the probe to drop out of the bushing bore.

Separable connectors are not designed to remain in the dwell position for an extended period of time. Mechanical damage can occur or, if the circuit is energized, electrical failure could eventually result. Once in the dwell position, immediately close the connector.

Energized loadbreak separable connectors should ALWAYS be operated using an approved live-line tool. De-energized loadbreak separable connectors should also be operated using a live-line tool for three reasons. First, this ensures that mechanical forces on the connector are applied at the pulling eye, preventing possible damage to the compression lug caused by off-axis loading. Second, this ensures personnel safety should the circuit actually be energized. Third, this ensures full seating of the connector with engagement of the locking rings. Some separable connector designs have an indicator to show when the mating component is properly seated. Safety precautions of the operating company should be followed to ensure personnel safety and apparatus protection.

Deadbreak connectors should be operated using a live-line tool. Operating forces on deadbreak connectors should be applied along the pulling eye axis, not in the area of the cable or the cable entrance, to prevent mechanical damage to the compression lug and probe. The safety precautions of the operating company should be followed to ensure that a deadbreak connector is not switched on an energized circuit.

Loadbreak separable connector components depend on expendable materials to ensure successful interruption of the arc produced when switching high-voltage and high-current electrical contacts. These materials have a finite life. Each operation of the connector reduces that life by vaporizing materials within the connector. The life of a loadbreak separable connector is dependent on the number of operations, the magnitude of the current interrupted, and the phase angle. The graph in Figure 2 provides an indication of the operational life of a loadbreak separable connector.

DO NOT apply separable connectors in situations where routine switching is required for maintenance purposes or for system control. A duty-rated switch should be used in these applications.

Although separable connectors have a fault duty rating, the components are not designed for repeated closings in an effort to locate system faults, otherwise known as *fault chasing*. The fault close rating is a one-time rating intended to ensure that operating personnel will not be exposed to the hazards of an explosive failure or an arc. Closing in on a fault with a separable connector can result in damage to the connector components that could lead to component failure, if reused. When a separable connector is closed on a fault, the bushing and elbow should be replaced. When a fault closure occurs, the snuffer tube of the bushing will extend outward. However, in some bushing designs, snuffer tube extension can occur during routine switching operations. The manufacturer should be contacted to determine the operating characteristics of the specific bushing design purchased.

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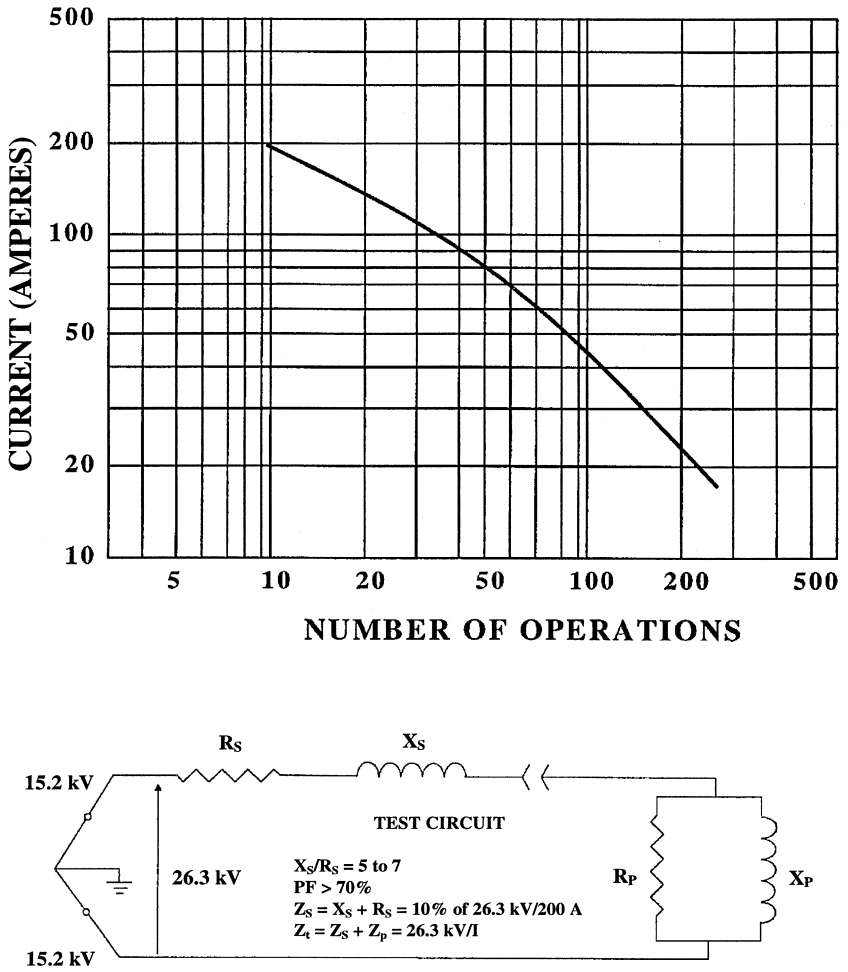


Figure 2—Switching operations for various currents with circuit power factors above 70%

Separable connectors depend on the application of mechanical force to produce component separation. The bushing component is intended to be rigidly fixed, while the elbow component is movable with an attachment point for application of the appropriate live-line tool. Bushings, multiway junctions, and insulated parking bushings must be clamped or rigidly fixed to a solid base. This base should not move under the application of typically expected operating forces that can exceed 2225 N. When an accessory parking stand is used, be sure that the separable connector is locked in the parking stand before attempting operation of the connector. DO NOT operate an elbow on an unmounted multiway junction or insulated parking bushing. Opening a separable connector on an unsecured transformer or terminating cabinet could cause the apparatus to move.

Separable connectors interrupt high voltages and currents in a very compact space. In the fully mated and locked position, they can successfully function at rated load current and voltage up to a depth of 2 m of water. However, SEPARABLE CONNECTORS ARE NOT DESIGNED TO INTERRUPT A CIRCUIT OR BE SWITCHED UNDER WATER. When preparing to operate a connector in a situation where moisture is present, such as during a rainstorm, take steps to ensure that the connector will remain dry. Use a tarpaulin or other means to ensure that the mating interface does not become contaminated with moisture.

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6.3.3 Loadbreak grounding practices

Typical examples of removal/grounding procedures for loadbreak connectors are as follows:

— Place the desired accessory device (multiway junction, insulated parking bushing, etc.) on the accessory parking stand using an approved live-line tool. Make sure the insulation shield on the accessory device is grounded by connecting a minimum #14 AWG wire from the device grounding eye or lug to a solidly grounded connection point such as a driven ground rod or a system neutral. Operate the connector in accordance with the loadbreak switching practices specified in 6.3.2.

— To use a multiway junction or feed-thru as a ground point, remove the protective caps from the bushings of the multiway junction. Clean the bushing surfaces and coat the interfaces with the recommended lubricant. Tighten the junction in its parking stand by rotating the eyebolt in a clockwise direction until the junction is snug (repeat for each multiway junction). Do not overtighten the eyebolt. Connect the clamp end of the lead on each grounding elbow to system ground. Remove one loadbreak elbow from its apparatus bushing and install it on the multiway junction. Perform a voltage test using a test rod or a capacitive test point and the appropriate voltage sensing device. Ensure the circuit is de-energized. Follow the manufacturer's instructions to ensure the voltage sensing device is working properly. If using a test rod, bring the end of the live-line tool near the test rod. A buzz or discharge can be heard if the circuit is energized. Once confirmation of a de-energized circuit has been obtained, insert a grounding elbow into one of the bushings of each multiway junction using a live-line tool.

WARNING
When performing a grounding operation, the ground clamp end of the lead on the grounding elbow should be the first connection made before beginning the grounding operation and the last connection removed when completing the work and preparing to restore the circuit to service.

6.4 Capacitive test point

The capacitive test point is an option available on many types of accessories. The test point is a terminal capacitively coupled to the cable conductor and is integrally molded into the insulation of the cable accessory. The terminal is commonly made of either metal or a conductive plastic. Insulation is provided to isolate the terminal from the external semiconductive insulation shield.

A semiconductive elastomeric (rubber) cap is provided to cover, protect, and shield the terminal during steady-state operation. The capacitive test point should not remain in an unshielded condition for an extended period of time. Allowing a capacitive test point to remain uncovered and unshielded for an extended period of time can result in the contamination of the insulation around the test point. A contaminated test point can result in electrical discharges between the test point and ground shield of the connector, which would erode the surrounding insulation and lead to a connector failure. A contaminated test point could also result in a false de-energized reading of the voltage sensing device.

The protective cap should be replaced after a voltage measurement is complete. Permanently mounted voltage sensing devices or fault indicators should be shielded. Test point protective caps and other test point accessories should always be operated using a live-line tool.

The capacitive test point can be used to determine if the separable connector and its attached circuit are energized or de-energized. The test point cap is removed using a live-line tool. A high-impedance voltage sensing device specifically designed for this application is used to measure the presence or absence of voltage on the test point terminal.

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CAUTION
Improper meters or meters that are set to make a direct voltage measurement may not indicate voltage on the test point of an energized connector.

Ensure a proper test point reading as follows:

— Operate the test point voltage sensing device in accordance with the manufacturer's operating instructions. Ensure proper meter settings for voltage range, direct voltage measurement, and test point.
— Verify the condition of batteries used in the voltage sensing device.
— If possible, verify operation of the voltage sensing device on a known energized circuit to ensure the device is working properly.
— Verify the circuit of interest is energized using the voltage sensing device prior to de-energizing the circuit.
— De-energize the circuit.
— Verify that the circuit is de-energized using the voltage sensing device.
— Reverify operation of the voltage sensing device on a known energized circuit to ensure the device is still working.

The capacitive test point characteristics are specified in ANSI/IEEE Std 386-1995. These characteristics are broad in nature because of the common dimensional variances in manufacturing. The capacitive test point is not sufficiently accurate, nor is it intended for, actual voltage measurements or phasing operations. Consult the separable connector manufacturer if phasing is required.

Care shall be taken to keep the insulation around the test point terminal clean and dry. The distance between the terminal and the grounded external insulation shield is short and can be bridged by contaminants. If the terminal is shorted by contaminants, it will give a false de-energized indication when tested. The test point cap must always be in place when the test point is not in use. Do not use the capacitive test point for voltage detection if the terminal has not been covered by a cap. A fresh coating of lubricant shall be applied to the test point cap each time it is installed or reinstalled on the test point.

CAUTION
Operators should use safe operating practices, even if a no-voltage condition is indicated on the test point terminal. A reading of no voltage from the test point should not be the only indication of a de-energized circuit obtained before touching the connector. Other procedures can include direct voltage testing or grounding using a live-line tool.

The capacitive test point may serve as a mount for faulted circuit indicators and voltage indicator devices. Refer to the application guide for faulted circuit indicators or the appropriate device installation instructions.

6.5 Switching

6.5.1 Cable switching

Loadbreak separable connectors have successfully switched up to 32 km of cable. No problems are anticipated switching the capacitance associated with cable length, provided that the load current on the cable is 200 A or less.

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6.5.2 Capacitor switching

The use of loadbreak separable connectors to energize or de-energize capacitors is not allowed under any circumstances. Loadbreak separable connectors are not designed to interrupt purely reactive loads. Some other means of interrupting the highly reactive load of a capacitor, such as an oil or vacuum switch, has to be employed. Prior to operating a separable connector on a capacitor loaded circuit, tests should be performed to ensure that the switching device has interrupted the reactive current.

6.5.3 Radial and loop switching

Underground distribution cable systems can be operated in either a loop or a radial configuration. A radial circuit connects one or more loads on a cable run extending outward from a source. Should a failure or a need for circuit reconfiguration create an interruption in service to the load, the cable configuration does not allow the load to be served from an alternate source. Equipment must be repaired, replaced, or added before the circuit can be restored.

In a loop configuration, flexibility is available. Loop circuits typically operate with a normally open point where alternate sources are isolated by an open switch or a separable connector that provides visible separation of the two sources. Alternate circuit connections can be made using apparatus already in place. The alternate connection may provide power from the same source as the original circuit or provide power from a different source. The steps required to change the circuit configuration depend on the phase and voltage relationship of the sources, the location of any component failures that may have created a circuit fault, and/or other reasons for changing a circuit configuration.

Open-loop switching occurs when a circuit or a portion of a circuit is totally isolated from one source before being connected to the alternate source.

Another method of switching loop circuits is called *closed-loop switching*. In this method, the circuit is reconfigured without interrupting service to the load. Items to consider under this type of switching are described in 6.3.2.

When loadbreak separable connectors are used in open-loop or closed-loop switching, consideration shall be given to the magnitude and phase relationship of the voltage present across the connector.

6.5.4 Ferroresonance

Ferroresonance is a phenomenon that can result in transient overvoltages. It can occur when performing single-phase switching on a three-phase circuit. Ferroresonance typically occurs when one or two open phases result in energizing cable capacitance through the nonlinear magnetizing impedance of a transformer. A resonant condition is established where energy oscillates back and forth between the inductance of the transformer and the capacitance of the cable. Significant overvoltages can be generated that may lead to component failure or flashover. The likelihood of ferroresonance occurring increases with increasing system voltage. It is typically difficult to predict when ferroresonance may occur during a switching operation because of the constant changes that take place in the configuration and length of distribution cable circuits. However, once a ferroresonance condition occurs, there are several things that can be done to minimize the possibility of a reoccurrence.

Methods for avoiding ferroresonance include the use of three-phase gang switches, use of grounded wye-grounded wye transformers, changing the location of switching points or transformers to eliminate the impedance balance, applying a resistive load to the transformer of 15% or more of rating before switching, etc. Ferroresonance can be easily mitigated on a loop-fed system because of the ability to move a normally open point without single-phase switching a three-phase transformer.

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6.6 Fault duty

Fault duty defines the short-time current rating for loadbreak and deadbreak connectors and the fault-close current rating for loadbreak connectors.

6.6.1 Through-faults

The short-time current is the through-fault current rating of an assembled separable connector. A through-fault within the amplitude and duration limits of the ratings will not harm the connector. There is no limit on the number of through-faults provided that there is sufficient time between faults for the connector temperature to return to its normal load current condition. Repetitive faults can, however, cause overheating that could damage the connector and cable. The short-time or through-fault current ratings for 200 A and 600 A rated separable connectors are provided in ANSI/IEEE Std 386-1995.

The fault-close current rating of a loadbreak separable connector is the same as its short-time current rating. However, the number of fault-close operations is limited to one. The difference between a through-fault and a fault close involves the state of the connector system at the time the fault current is conducted through the separable connector. In a through-fault, the connector contacts are mated and fully seated at the time of fault current conduction. In a fault close, the contacts are being closed to connect an energized circuit onto a circuit that contains a fault. Short-circuit current will flow through the connector system and arcing will occur across the mating contacts. Loadbreak separable connectors are limited to a single fault-close operation because arcing across the mating contacts vaporizes metal from the contact surfaces and erodes the arc-quenching materials within the connector. This could damage the contacts and may produce carbon, which can contaminate internal and external interfaces. The fault-close capability of loadbreak separable connectors is provided as a safety feature in the event of an accidental closure on a fault. Closure on known faults is not recommended.

For proper application and safe operation of separable insulated connectors, circuit protection must be designed to limit fault currents to be within the amplitude and duration of the connector ratings.

6.6.2 Fault close

If a separable connector is closed into a fault, one must assume that some damage has occurred to the connector or that the performance characteristics of the connector have changed. Both the elbow and bushing exposed to a fault-close operation should be replaced. Replacement of the elbow and bushing should occur even if personnel operating the elbow were successful in closing on the fault. The connector components should be de-energized and replaced. Internal damage could be present that is not visible externally. Reuse of a separable connector exposed to a fault-close operation can result in connector failure.

6.6.3 Use of current-limiting fuses

The use of current-limiting fuses in conjunction with loadbreak separable connectors limits the available energy under fault conditions. Proper coordination of device ratings is required in this application. Consult the manufacturer for recommendations.

6.6.4 Fault chasing

Separable connectors should not be used in an attempt to locate or chase faults. Connectors should be used for their intended purpose: to terminate extruded solid dielectric cables and to connect and

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disconnect loads up to the device rating. Separable connectors should not be abused or used in any way that might provide a false sense of safety for the operating personnel.

Fault location is more appropriately performed using faulted circuit indicators or test equipment designed to locate circuit faults.

6.7 Use of accessories

6.7.1 General

The separable insulated connector system consists of different voltage classes (15 kV, 25 kV, and 35 kV), a multitude of accessories, and various interfaces. The user of this guide should be aware of the differences in the various accessories and should only combine compatible devices. In general, the different interfaces do not permit the interchange of incompatible accessories.

The manufacturer's instructions regarding the installation and use of accessories should always be followed. Safe work practices should be followed at all times. The user should be trained in the proper use of the various accessories.

The accessories should be stored to prevent damage and contamination. Like other tools, accessories should be routinely inspected before and after use.

CAUTION
Do not operate connectors that are not securely mounted. Inspect connector assemblies before and after use. Replace connectors that are found to be damaged.

6.7.2 Multiway junctions and feed-thrus

Multiway junctions and feed-thrus are accessories available with either a vertical or horizontal mounting. The user should select the mounting based on the space and application requirements.

Multiway junctions are used with other accessories to bypass transformers, to isolate energized cables, to ground cables, to test cables, and to provide surge protection. A live-line tool should be used to install and remove multiway junctions. The lifting eye or locking bolt is designed for ease of operation and handling with use of a live-line tool. After the multiway junction is placed into the parking stand, the locking bolt should be tightened to prevent the junction from becoming dislodged during use.

The metal mounting bracket for the multiway junction might not make electrical contact with the apparatus on which it is installed because of the insulating properties of the coatings present. Paint on the apparatus tank can provide an electrically insulating layer. A drain wire should be attached to the accessory's mounting bracket and to a driven ground rod.

Precautions regarding multiway junctions and feed-thrus include:

— Bushings on this accessory are internally connected. Energizing any bushing on the bus results in energizing all bushings on the bus.
— Shipping caps (dust covers) used to keep bushing interfaces clean during transport and handling should be removed immediately before installing the multiway junction or feed-thru. Do not leave shipping caps (dust covers) on energized bushings. The caps are not voltage rated.
— Whenever an energized bushing is exposed or whenever a bushing could become energized, the bushing should be covered with an insulated cap. Before installing the insulated cap, the cap

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drain wire should be securely connected to the ground rod or a grounded conductor. The insulated cap and all other accessories should be installed and removed using a live-line tool.
— All drain and ground wires should be trained so as not to interfere or come into contact with energized parts.
— For safety reasons, personnel operating the connector should verify that the bushing is de-energized before attaching a ground.

6.7.3 Insulated parking bushings

Insulated parking bushings are used to provide an insulated and isolated connection point for the elbow. A live-line tool should be used to install and remove insulated parking bushings. The lifting eye or locking bolt is designed for ease of installation using a live-line tool. After the insulated parking bushing is placed into the parking stand, the locking bolt should be tightened to prevent the bushing from becoming dislodged during use.

Whenever separable connector components are mated, care should be taken to ensure that the mating components are securely mounted. A slight tug on the pulling eye helps to determine whether or not the component is securely attached. Components should be installed and removed using a live-line tool.

6.7.4 Deadfront arresters

6.7.4.1 General

Shielded, fully submersible surge arresters are available for use with other 200 A separable connector components. These are available in three styles: elbow, parking bushing, and bushing insert arresters. Arresters are used where lightning and switching surge protection is desired for transformers, cable, apparatus, and other underground circuit components. Surge arresters are typically applied at the end of a radial circuit or on both sides of the open point in a loop circuit. Installation at this location helps to limit overvoltages caused by reflections, protect the attached apparatus, and extend cable life. Proper voltage selection and coordination with arresters at the riser pole can prevent the occurrence of voltage doubling on the underground system. ANSI/IEEE Std 1299/C62.22.1-1996 provides guidance on the application of surge arresters to protect insulated, shielded electric power cable systems [B4].

Like other separable connector components, separable connector surge arresters are deadfront devices designed for operation using live-line tools. Separable connector arresters generally employ metal oxide varistor (MOV) technology coupled with a housing of premolded rubber. The arrester provides overvoltage protection in a fully shielded, submersible, deadfront device.

The ground lead for a separable connector arrester has to be connected to the driven ground rod before the arrester is connected to an energized line. In addition, a drain wire should be connected from the grounding tab on the separable connector arrester to a grounding point.

WARNING
The ground rod attachment should be the first connection made and the last connection removed when installing, replacing, or removing a separable connector arrester.

6.7.4.2 Elbow arrester

Elbow arresters can be installed on a multiway junction, a feed-thru, or an apparatus bushing. Ensure that all interfaces are clean and that lubricant has been applied to the elbow interface prior to installation. If the elbow arrester is being installed on an energized circuit, the operator should position

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the arrester so that it is aligned with the bushing and then turn away while thrusting the arrester onto the bushing. After installation, a slight tug should be applied to ensure proper seating of the elbow arrester onto the bushing.

A live-line tool should always be used when installing and removing elbow arresters. Care should be taken to avoid bending or twisting the arrester body.

6.7.4.3 Parking bushing arrester

The parking bushing arrester can be used instead of the multiway junction and an elbow arrester at the circuit normal open points.

The parking bushing arrester should be installed and removed using a live-line tool. The mating interface of the arrester should be kept clean and should be lubricated prior to installing an elbow. Position the elbow probe into the end of the parking bushing arrester until a slight resistance is felt. The operator should turn away from the connector assembly while thrusting the elbow onto the arrester. A slight tug should be applied to ensure proper seating of the elbow on the parking bushing arrester.

6.7.4.4 Bushing insert arrester

The bushing insert arrester may be used instead of a bushing insert. The arrester can be used to provide a mounting position for a loadbreak elbow in addition to its protective functions.

The bushing insert arrester has to be installed on de-energized apparatus. The mating interfaces have to be kept clean. Lubricate the mating interface prior to installation. The bushing insert arrester should be hand tightened into the bushing well. Prior to installing the arrester, the ground lead has to be attached to the driven ground rod. Additionally, a drain wire should be connected from the grounding tab on the arrester to a grounding point. When re-energizing the circuit, the operator should turn away from the bushing insert arrester.

Whenever a bushing arrester is installed or removed from a bushing well, the apparatus shall be de-energized.

6.7.5 Protective cap

Protective caps insulate, shield, and completely seal the bushing interface. Protective caps should be installed and removed using a live-line tool. All installed bushings not mated to another separable connector component should be covered with a protective cap.

Prior to installation, the interface of the protective cap should be cleaned and lubricated. The drain wire used to maintain ground potential on the semiconductive shield of the cap should be attached to a grounding point. The drain wire should not be disconnected until the protective cap has been removed from the bushing. Care should be taken to ensure that the protective cap is securely attached to the bushing. A slight tug on the protective cap, using a live-line tool, can determine if the cap is securely attached.

6.7.6 Bushing shipping cap

Bushing shipping caps (sometimes called *dust covers*) are placed on all bushing interfaces by the manufacturer to maintain a contamination-free surface. These caps shall never be left on bushings that could become energized. Shipping caps are not designed to withstand circuit operating voltages and have to be removed and replaced with the proper separable connector.

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6.8 Grounding accessories

Several types of separable connectors are available for grounding cables and padmounted apparatus. Use of the proper grounding accessories is important to ensure that the separable connector remains connected and is able to sustain the connector-rated fault current. Separable connector components should comply with the short-time current requirements of ANSI/IEEE Std 386-1995. Refer to ASTM F 855-1997 for requirements for the grounding cables and connecting clamps. Care should be taken, however, to verify that the apparatus to be grounded is de-energized before proceeding to install grounding accessories.

The 200 A loadbreak grounding elbows and grounded parking bushings are preferred over other types of grounding devices. These devices are fully rated for through-faults and for one fault-close operation, offering enhanced safety compared to other methods of grounding.

CAUTION
The ground lead on a grounding accessory should be attached to a solidly grounded connection point such as a driven ground rod. The ground attachment should be the first connection made and the last connection removed when installing, replacing, or removing a grounding accessory.

Grounding accessories should be inspected before, during, and after use. Follow the inspection procedures outlined in 6.9. In addition, ensure that grounding accessories are not damaged and that continuity is present across the grounding path. The inspection should check for broken conductor strands in the ground lead (particularly at the edge of connectors and at the attachment point to the grounding device), loose connections, and corrosion.

The leads on grounding accessories are typically very flexible, being made of a large number of small conductor strands. Breakage of the conductor strands can reduce the fault current capability of the connector. Areas where mechanical stress is placed on the conductor strands should be carefully inspected. A bulge under the insulating jacket can be an indicator of conductor damage. When using grounding accessories, consider what could happen to the ground lead should the device become connected to an energized circuit. The magnetic field produced by fault current can generate mechanical forces that would push a coiled ground lead apart or push the ground lead away from the involved phase conductor. It may be desirable to restrain such motion. Generally, the shorter the ground lead, the better. Not only will there be less lead to move, but the impedance of the grounding path will also be reduced.

Grounding accessories are typically colored either a bright orange or yellow to distinguish them from other separable connector components.

Always verify that the circuit or apparatus to be grounded is de-energized before proceeding with connection of the grounding devices.

6.8.1 Test rod

Test rods are for use in voltage testing. Test rods are not recommended for grounding.

CAUTION
The mechanical forces produced by the magnetic field generated during a fault can expel an unrestrained test rod from a bushing.

6.8.2 Grounding elbow

Grounding elbows are available as either deadbreak or loadbreak devices. The connector will be a fully functional elbow with a ground lead attached at the normal cable position.

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6.8.3 Grounded parking bushing

Grounded parking bushings are available as either deadbreak or loadbreak devices. The connector will be a fully functional parking bushing with a ground lead attached at the base.

6.9 Inspection of separable connectors

6.9.1 Condition after switching

Separable connectors should be inspected prior to and during the course of an operation to insure continued safe and reliable operation. Inspection should be based on user experience and system reliability requirements. Inspections should always be performed as dictated by safe work practices. The guidelines in 6.9.2 and 6.9.3 provide information on commonly used inspection techniques.

The mating interfaces on all separable connector components should be maintained in a clean and contaminant-free condition. There should be no evidence of tracking, carbon, or foreign materials. Any abnormal conditions should be corrected following the manufacturer's recommendations.

6.9.2 Elbows

Elbows should have clean mating interfaces. There should be no evidence of tracking, burns, punctures, material erosion, or carbon deposits on the outer surface of the elbow housing.

For loadbreak elbows, under normal operation, the probe arc follower and contact surfaces might exhibit fine scoring and/or minor pitting. Slight pitting is common on the edge of the metal contact surface directly behind the arc follower. A very slight amount of carbon could be present on the surface of the arc follower. The arc follower is normally white with a dull surface appearance. If the surface of the arc follower is covered with carbon deposits, or material is eroded from the surface, or the surface appears to have a glossy finish, both the elbow and the mating bushing should be replaced.

For deadbreak elbows the metal probe and threaded components should be undamaged and free of pitting, corrosion, contaminants, burrs, and filings.

6.9.3 Bushings

For loadbreak connectors, the condition of the elbow probe is an indicator of the condition within the mating bushing. Like the elbow, bushings should not show any evidence of tracking, carbon deposits, burns, punctures, or contamination of the mating interfaces. For deadbreak bushings the metal contacts and threaded components should be undamaged and free of pitting, corrosion, contaminants, burrs, and filings.

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Annex A

(informative)

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