



IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee

386TM

IEEE
3 Park Avenue
New York, NY 10016-5997, USA

1 March 2007

IEEE Std 386TM-2006
(Revision of IEEE Std 386-1995)

IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V

Sponsor

**Insulated Conductors Committee
of the
IEEE Power Engineering Society**

Approved 15 September 2006

IEEE-SA Standards Board

Abstract: Definitions, service conditions, ratings, interchangeable construction features, and tests are established for loadbreak and deadbreak separable insulated connector systems rated above 600 V and, 600 A or less, for use on power distribution systems.

Keywords: deadbreak connector, elbow connector, loadbreak connector, power distribution systems, separable conductor, separable insulated connector systems

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2007 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 1 March 2007. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

Print: ISBN 0-7381-5219-6 SH95570
PDF: ISBN 0-7381-5220-X SS95570

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS.**”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

This introduction is not part of IEEE Std 386-2006, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.

This standard was developed in response to a need created by the rapid expansion of underground distribution systems. A key element that allowed this expansion to become a reality is the separable insulated connector. This device provides for simple and inexpensive connection and switching to transformers and other equipment used in underground distribution.

When separable insulated connectors became available, the Institute of Electrical and Electronics Engineers (IEEE) and the National Electrical Manufacturers Association (NEMA) worked cooperatively to develop a document that defined the interfaces, ratings, and test conditions for the device. The success of that cooperative effort is apparent from both the vast number of these devices now in interchangeable use in the field and their enviable safety record.

This cooperative effort continues due to the ongoing upgrading and changing nature of these underground systems and products. The recent cooperative effort has been provided by the ANSI C119.2 Subcommittee and the IEEE Working Group on Separable Connectors under the auspices of the Insulated Conductors Committee of the IEEE Power Engineering Society.

This revision reflects the following major additions:

- Definitions of new and previously omitted connector components
- Overload current ratings for deadbreak connectors
- Optional color coding for 200 A loadbreak connectors
- Clarification of interchangeability requirements
- Bushing well stud torque withstand requirement
- Thermal cycle withstand test for non-elastomeric components
- Stacking dimensions for 200 A deadbreak and 600 A deadbreak connectors
- Test table reviewed to indicate sequence of tests
- Operating procedures for switching test expanded
- Trial-use guide for testing separable connector lubricants
- Operating interface ac withstand test for 200 A loadbreak connectors

For information on the application of separable connectors, refer to IEEE Std 1215™-2001 [B9].^a

^a The numbers in brackets correspond to those of the bibliography in Annex C.

Notice to users

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/updates/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: <http://standards.ieee.org/reading/ieee/interp/index.html>.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents or patent applications for which a license may be required to implement an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Participants

At the time this standard was completed, the NEMA Primary Connector Committee, 8CC-IV, had the following membership:

Frank M. Stepniak, Chair
Vince A. Baclawski, Secretariat

Roy Jazowski

John Makal
Carl Wentzel

Tiebin Zhao

At the time this standard was completed, the joint IEEE Power Engineering Society, Insulated Conductors Committee, B16W—Revision of IEEE Std 386 Working Group and ANSI C119.2 Subcommittee on Separable Insulated Connectors had the following membership:

Frank M. Stepniak, Chair
Harry Hayes, Vice Chair
Vince A. Baclawski, Secretariat

Darren Barnett
Ed Bradley
Dave Britton
Thomas Champion
Jack Cherry
Russ Dantzler
Robert Gear
Stan Heyer
Trung Hiu
Stan Howell

Roy Jazowski
Gael Kennedy
Albert Kong
Glenn Luzzi
John Makal
Greg Mastoras
Rachel Mosier
Denis Pratt
Ewell (Tim) Robeson

Roger Schoneman
Bruce Shattuck
John Spence
Wes Spencer
Greg Stano
Tim Wall
Dennis Wedam
Carl Wentzel
Sanford Yoder
Tiebin Zhao

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Marcos Andrade
Kenneth Bow
Harvey Bowles
Vern Buchholz
William Byrd
Thomas Callsen
Mary Capelli-Schellpfeffer
Michael Clodfeder
R. Daubert
Larry Davis
Frank Denbrock
John Densley
Mark Drabkin
John DuPont
Dana Dufield
Guru Dutt Dhingra
Stephen Early
Marcia Eblen
Gary Engmann
Michael Faulkenberry
Jorge Fernandez-Daher
Marcel Fortin

Robert Fulcomer
Robert Gear
David Gilmer
Ron Greenthaler
Randall Groves
Richie Harp
Jeffrey Hartenberger
Steven Hensley
Dennis Horwitz
David Jackson
Edward Jankowich
Robert Keefe
Gael R. Kennedy
Yuri Khersonsky
Hermann Koch
Edwin Kramer
Gregory Luri
Glenn Luzzi
John Makal
James Medek
Steven Meiners

John Merando
G. Michel
Shantanu Nandi
Gary L. Nissen
Neal Parker
Michael Pehosh
Dave Singleton
Michael Smalley
James Smith
Gregory Stano
Brian Steinbrecher
Frank M. Stepniak
John Teixeira
William Thue
Carl Wall
Daniel Ward
Lee Welch
Carl Wentzel
James Wilson
Jan Zawadzki
Tiebin Zhao
Donald W. Zipse

When the IEEE-SA Standards Board approved this standard on 15 September 2006, it had the following membership:

Steve M. Mills, *Chair*
Richard H. Hulett, *Vice Chair*
Don Wright, *Past Chair*
Judith Gorman, *Secretary*

Mark D. Bowman
Dennis B. Brophy
William R. Goldbach
Arnold M. Greenspan
Robert M. Grow
Joanna N. Guenin
Julian Forster*
Mark S. Halpin

Kenneth S. Hanus
William B. Hopf
Joseph L. Koepfinger*
David J. Law
Daleep C. Mohla
T. W. Olsen
Glenn Parsons
Ronald C. Petersen
Tom A. Prevost

Greg Ratta
Robby Robson
Anne-Marie Sahazizian
Virginia Sulzberger
Malcolm V. Thaden
Richard L. Townsend
Walter Weigel
Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Alan H. Cookson, *NIST Representative*

Catherine Berger
IEEE Standards Editor

William Ash
IEEE Standards Program Manager, Technical Program Development

Contents

1. Scope	1
2. Normative references.....	1
3. Definitions	2
4. Service conditions	6
4.1 Usual service conditions	6
4.2 Unusual service conditions	6
5. Ratings and characteristics	7
5.1 Voltage ratings and characteristics	7
5.2 Current ratings and characteristics.....	7
6. Construction	8
6.1 Identification.....	8
6.2 Operating means	9
6.3 Shielding.....	9
6.4 Interchangeability	9
6.5 Test point.....	10
6.6 Hold-down bails	10
6.7 Bushing well stud torque withstand	10
6.8 Thermal cycle withstand.....	10
7. Testing	27
7.1 Production tests.....	27
7.2 Design tests.....	27
7.3 Test conditions.....	27
7.4 Partial discharge test.....	27
7.5 Dielectric tests	28
7.6 Short-time current test	29
7.7 Switching test	29
7.8 Fault-closure test.....	32
7.9 Current-cycling test for uninsulated components of 600 A connectors.....	32
7.10 Current-cycling test for 200 A insulated connectors	33
7.11 Current-cycling test for 600 A insulated connectors	36
7.12 Accelerated sealing life test.....	37
7.13 Cable pull-out test (tensile strength).....	37
7.14 Operating-force test	37
7.15 Operating-eye test.....	38
7.16 Test point cap test.....	38
7.17 Test point tests.....	38
7.18 Shielding test	39
7.19 Bushing well stud torque test.....	39
7.20 Thermal cycle withstand test	39

Annex A (informative) Trial use guide for testing of separable connector lubricants.....	41
A.1 Test for lubricants used on separable insulated connector interfaces	41
A.2 Operating force test.....	41
A.3 Accelerated aging test.....	41
A.4 Dielectric tests	42
A.5 Switching test.....	42
A.6 Compatibility	42
A.7 Physical properties.....	42
Annex B (informative) Operating interface ac withstand test	44
Annex C (informative) Bibliography.....	46

IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V

1. Scope

This standard establishes definitions, service conditions, ratings, interchangeable construction features, and tests for loadbreak and deadbreak separable insulated connector systems rated above 600 V, 600 A or less, for use on power distribution systems.

2. Normative references

The following referenced documents are indispensable for the application of this document. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C119.4, Electrical Connectors-Connectors for Use between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Connectors.¹

ANSI/ASQC Z1.4, Sampling Procedures and Tables for Inspection by Attributes.

ASTM F467, Standard Specification for Nonferrous Nuts for General Use.²

IEEE Std 4™, IEEE Standard Techniques for High-Voltage Testing.^{3,4}

IEEE Std 592™, IEEE Standard for Exposed Semiconducting Shields on High-Voltage Cable Joints and Separable Insulated Connectors.

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/>).

² ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

³ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁴ The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

3. Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B7]⁵ should be referenced for terms not defined in this clause.

The following definitions are the intended meanings of terms used in this standard or associated with separable insulated connector systems. Figure 1, Figure 2, Figure 16, Figure 17, and Figure 18 show typical components of separable insulated connectors. The term *connector* as used in this standard means separable insulated connector.

3.1 arc quenching rod: An ablative material added to the end of a probe that serves to pressurize and cool the arc and help deionize the arc by products while approaching current zero, assisting in the arc interruption process.

3.2 arc ring: Material inserted between the metal contact area of a loadbreak probe and the arc quenching rod for the purpose of limiting arc damage to the probe metal.

NOTE—See Figure 8 and Figure 9.⁶

3.3 bushing extender: A connector that provides two in-line elbow interfaces.

3.4 bushing insert: A connector component intended for insertion into a bushing well designed for use with another connector component, such as an elbow.

NOTE—See Figure 1.

3.5 bushing well: An apparatus bushing having a cavity for insertion of connector component, such as a bushing insert.

NOTE—See Figure 1.

3.6 bushing well plug: An accessory device designed to electrically insulate, electrically shield, and mechanically seal a bushing well.

3.7 cable adapter: A connector component that fits over the insulation of the cable increasing its diameter to properly mate with the cable accessory.

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

3.9 connecting plug: A connector that provides two in-line bushing interfaces.

3.10 continuous current rating: The designated rms alternating or direct current that the connector can carry continuously under specified conditions.

⁵ The numbers in brackets correspond to those of the bibliography in Annex C.

⁶ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

3.11 dead-front bushing arrester: An insulated and shielded surge protective device with a bushing operating interface.

3.12 dead-front elbow arrester: An insulated and shielded surge protective device with an elbow operating interface.

3.13 elbow: A connector component for connecting a power cable to a bushing, so designed that when assembled with the bushing, the axes of the cable and bushing are perpendicular.

NOTE—See Figure 1 and Figure 2.

3.14 feed-thru bushing insert: An accessory device with two electrically interconnected bushing interfaces that can be installed into a bushing well.

3.15 feed-thru parking bushing: An accessory device with two electrically interconnected bushing interfaces that can be installed into a parking stand.

3.16 grounding parking bushing: An accessory device designed to electrically ground and mechanically seal a de-energized power cable terminated with an elbow and to be installed into a parking stand.

3.17 grounding tab: A projection on a connector component or accessory device designed for the placement of a drain wire for the purpose of grounding the outer shield of the device.

3.18 insulated cap: An accessory device designed to electrically insulate, electrically shield, and mechanically seal a bushing insert or integral bushing.

3.19 insulated parking bushing: An accessory device designed to electrically insulate, electrically shield, and mechanically seal a power cable terminated with an elbow and to be installed into a parking stand.

3.20 insulated plug: An accessory device designed to electrically insulate, electrically shield, and mechanically seal an elbow interface.

3.21 integral bushing: An apparatus bushing designed for use with another connector component, such as an elbow.

NOTE—See Figure 1 and Figure 2.

3.22 loadbreak connector: A connector designed to close and interrupt rated load current or less on energized circuits under specified conditions.

3.23 maximum voltage rating: The highest phase-to-ground voltage (rms) for single phase systems or phase-to-ground and phase-to-phase voltage (rms) for three phase systems at which a connector is designed to operate.

3.24 multi-way junction: An accessory device with two or more interconnected bushing and/or bushing well interfaces.

3.25 operating eye: An integral part of an elbow or other accessory device designed for the attachment of a live-line tool used to handle or operate the device.

3.26 operating interface: The surfaces at which a connector is normally separated.

NOTE—See Figure 1 and Figure 2.

3.27 parking stand feed-thru well: A multi-way junction device consisting of interconnected bushing wells that can be mounted in a parking stand.

3.28 probe: The internal, separable, current carrying part of an elbow, tee connector, or insulated cap (usually in the form of a metal rod or bolt) that connects the conductor compression lug to the bushing portion of the separable connector.

3.29 reducing tap plug: An accessory device designed for the transition of a 600 A deadbreak system to a 200 A deadbreak or loadbreak system.

3.30 reducing tap well: A connector that provides a transition from a 600 A elbow to a 200 A bushing well.

3.31 separable insulated connector: A fully insulated and shielded system for terminating and electrically connecting an insulated power cable to electrical apparatus, other power cables, or both, so designed that the electrical connection can be readily established or broken by engaging or separating the connector at the operating interface.

NOTE—See Figure 1 and Figure 2.

3.32 short-time current rating: The designated rms current that a connector can carry for a specified, limited period of time under specified conditions.

3.33 straight plug: An in-line connector that provides a transition from a cable to a bushing interface.

3.34 straight receptacle: An in-line connector that provides a transition from a cable to an elbow interface.

3.35 tee connector: A receptacle connector component for connecting a power cable to two in-line bushing interfaces, so designed that the axes of the cable and bushing interfaces are perpendicular.

NOTE—See Figure 2.

3.36 test point: A capacitively coupled terminal for use with voltage sensing devices.

NOTE—See Figure 1 and Figure 2.

3.37 test point cap: A shielded cover for the capacitive test point.

3.38 withstand voltage: The specified voltage that, under specified conditions, can be applied to insulation without causing flashover or puncture.

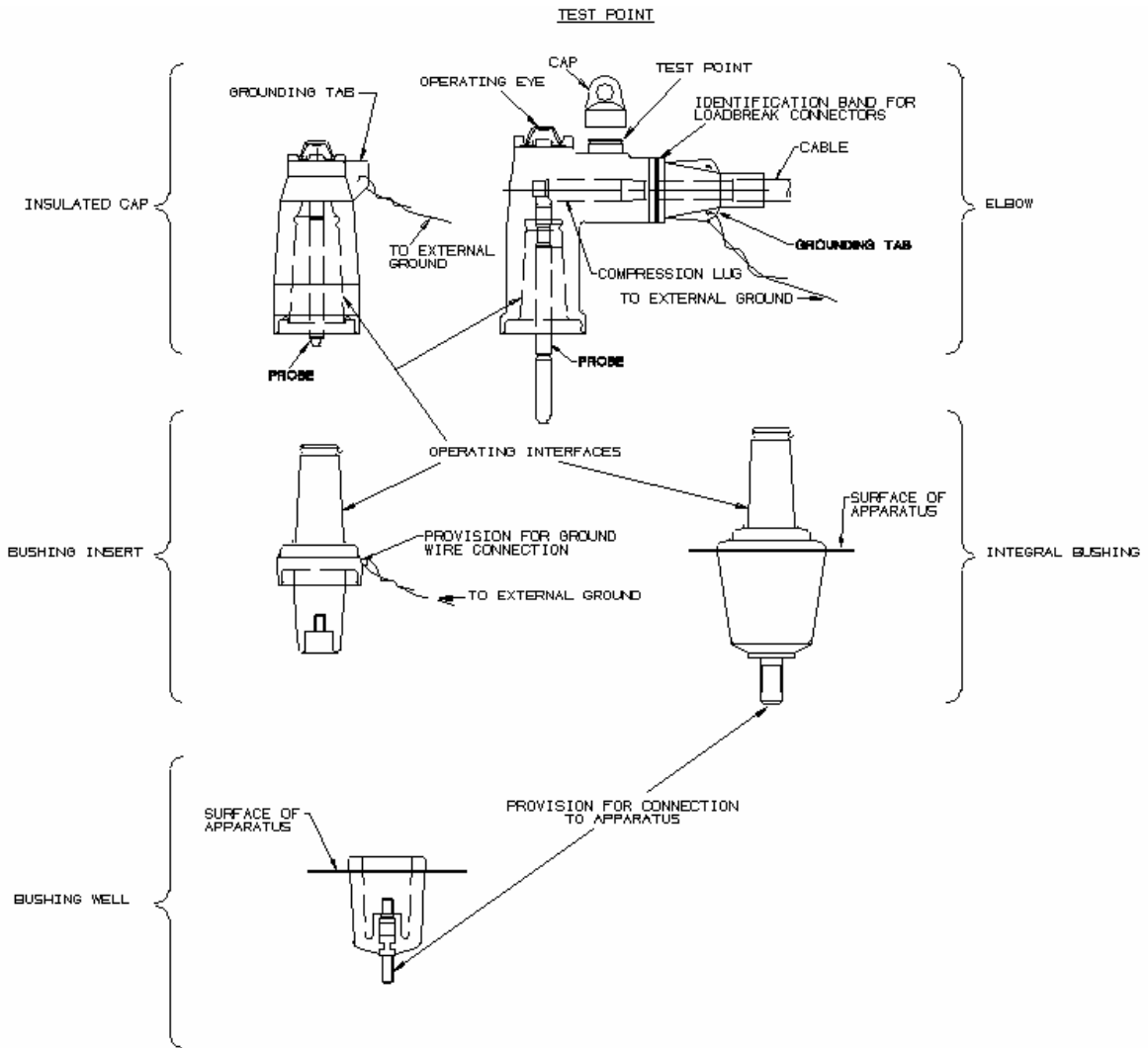


Figure 1—Typical components of 200 A separable insulated connector system

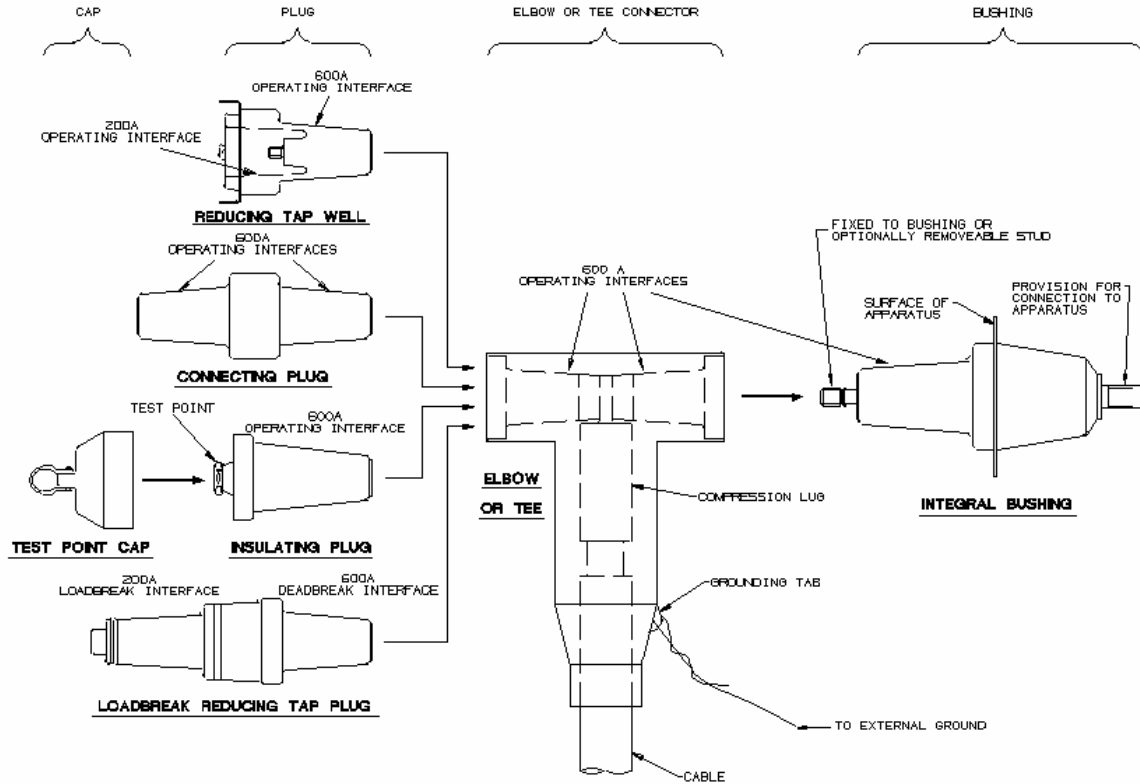


Figure 2—Typical components of 600 A separable insulated connector system

4. Service conditions

4.1 Usual service conditions

Connectors shall be suitable for use under the following service conditions:

- a) In air, including exposure to direct sunlight
- b) Buried in earth
- c) Intermittently or continuously submerged in water at a depth not exceeding 1.8 m (6 ft)
- d) Environmental temperatures within the range of $-40\text{ }^{\circ}\text{C}$ to $+65\text{ }^{\circ}\text{C}$ (loadbreak connectors can be closed and separated within the range of $-20\text{ }^{\circ}\text{C}$ to $+65\text{ }^{\circ}\text{C}$)
- e) Altitudes not exceeding 1800 m (6000 ft) above sea level (applicable to loadbreak connectors only)

4.2 Unusual service conditions

Conditions other than those listed in 4.1 are considered to be unusual. (The manufacturer should be consulted for recommendations.)

5. Ratings and characteristics

5.1 Voltage ratings and characteristics

The voltage ratings and characteristics of connectors shall be in accordance with Table 1.

Table 1—Voltage ratings and characteristics

Maximum voltage rating (kV rms) ^a	Withstand voltages			
	BIL and full wave (kV crest)	AC 60 Hz for 1 min (kV rms)	DC for 15 min (kV)	Minimum partial discharge (kV rms) ^b
8.3 ^c	95	34	53	11
8.3/14.4 ^d	95	34	53	11
15.2 ^c	125	40	78	19
15.2/26.3 ^d	125	40	78	19
21.1 ^c	150	50	103	26
21.1/36.6 ^d	150	50	103	26

^a The highest steady-state voltage across the open contacts that a loadbreak connector is rated to switch is the maximum phase-to-ground rms voltage for phase-to-ground rated devices or the maximum phase-to-phase rms voltage for phase-to-ground/phase-to-phase rated devices.

^b Based on a sensitivity of 3 pC (see 7.4).

^c Phase-to-ground.

^d Phase-to-ground/phase-to-phase.

5.2 Current ratings and characteristics

The current ratings and characteristics of connectors shall be in accordance with Table 2.

Table 2—Current ratings and characteristics

Connector type	Continuous current rating (A rms) ^a	Switching current rating (A rms)	Overload current ^{a, b, c} 4 hour rating (A rms)	Fault-closure current rating ^d			Short-time current rating		
				A rms, sym	Duration (s)	Min x/r	A rms, sym	Duration (s)	Min x/r
Loadbreak	200	200	—	10 000	0.17	6	10 000	0.17	6
							3 500	3.00	6
Deadbreak	200	—	300	—	—	—	10 000	0.17	6
							3 500	3.00	6
Deadbreak	600	—	900	—	—	—	25 000	0.17	20
							10 000	3.00	20

^a In general, the overload capability of a connector exceeds its continuous current rating. Overload capability varies with environment, cable sizes, etc. The connector manufacturer's recommendations should be obtained for the particular combination involved.

^b Consult the manufacturer for ratings that exceed those listed in Table 2.

^c One overload cycle during a 24 h period.

^d Applicable to loadbreak connectors only. Equipment to which these assemblies are affixed may have lower safe limits of current performance.

6. Construction

6.1 Identification

Mating components of a separable insulated connector shall be permanently (for example, ink stamped, branded, or molded in) and legibly identified with the following information:

- a) Manufacturer's identification
 - 1) Company name or logo
 - 2) Part identification
 - 3) Date of manufacture
- b) Continuous current rating (when applicable)
- c) Maximum voltage rating
 - 1) 200 A and 600 A deadbreak connectors:
Identify with the maximum phase-to-ground voltage rating.
 - 2) 200 A loadbreak connectors:
Three-phase: Identify with the maximum phase-to-ground/phase-to-phase voltage rating.
Single-phase: Identify with the maximum phase-to-ground voltage rating.
- d) Cable insulation diameter range (when applicable)
- e) Whether loadbreak or deadbreak (when applicable). In addition to the word "LOADBREAK," elbows of loadbreak connectors shall have the following markings:
 - 1) Connectors with a phase-to-ground voltage rating shall be identified with a removable white band from 13 mm to 32 mm (0.5 in to 1.25 in) wide, located on the cable entrance portion of the connector not less than 25 mm (1.00 in) from the cable entrance. The removable band shall be clearly visible from the normal operating position, and affixed to minimize its accidental dislodgment.
 - 2) Connectors with both phase-to-ground and phase-to-phase voltage ratings shall be identified with a removable white band from 13 mm to 32 mm (0.5 in to 1.25 in) wide, having a centered black stripe 4.8 mm \pm 1.6 mm (0.188 in \pm 0.062 in) in width located on the cable entrance portion of the connector not less than 25 mm (1.00 in) from the cable entrance. The removable band shall be clearly visible from the normal operating position, and affixed to minimize its accidental dislodgment.
- f) Color-coding: In addition to the white bands of item e) of this subclause, 200 A loadbreak connectors may, at the option of the manufacturer, be identified by a color as specified in Table 3.

Table 3—200 A loadbreak connector color code (optional)

Voltage rating (kV rms)	Reference figure	Color
8.3/14.4	5	Red
15.2/26.3	7	Blue
21.1	7	Off White
21.1	9	Tan
21.1/36.6	7	Gold
21.1/36.6	8	Purple

6.2 Operating means

Connectors shall be operable by means of a suitable live-line tool that clamps the elbow so that operation is along the probe axis. The required operating force over the environmental range of $-20\text{ }^{\circ}\text{C}$ to $+65\text{ }^{\circ}\text{C}$ shall be as follows (see 7.14).

- a) 222 N to 890 N (50 lbf to 200 lbf) for connectors without hold-down bails
- b) 44 N to 890 N (10 lbf to 200 lbf) for connectors with hold-down bails

If an operating eye is provided, it shall support a 14 N·m (120 lbf-in) rotational force and shall support a static operating force as shown in Table 4:

Table 4—Static operating force

Connector type	Force	
	N	lbf
Deadbreak elbow	1334	300
Loadbreak elbow	2224	500
Grounding elbow	1779	400
Insulated cap	2224	500

6.3 Shielding

Connectors shall have an electrically conductive shield and, where required, shall have provision for connecting an external ground to the shield. Except for nonelastomeric components, connectors shall meet the requirements of IEEE Std 592.⁷

6.4 Interchangeability

6.4.1 Complete interchangeability

- a) Complete interchangeability implies that parts from one manufacturer when mated with parts of another manufacturer meet all the applicable requirements of this standard.
- b) Complete interchangeability is demonstrated when:
 - 1) A part meets the design test requirements when tested with any mating part meeting the dimensional requirements of this standard.
 - 2) In addition, 200 A loadbreak connectors must demonstrate conformance with switching (7.7) and fault close (7.8) test requirements when tested with intermixed bushings and elbows of different manufacturers.

⁷ For information on references, see Clause 2.

6.4.2 Limited interchangeability

Limited interchangeability applies only to 200 A loadbreak connectors and shall be demonstrated by compliance with all the requirements in 6.4.1, complete interchangeability, except for the switching (7.7) and fault close (7.8) test requirements.

6.4.3 Interface dimensions

The dimensions of operating and bushing well interfaces shall be in accordance with Figure 3 through Figure 15.

6.4.4 Stacking dimensions

Upon request, each manufacturer shall supply the dimensions in Figure 16, Figure 17, and Figure 18. The stacking, "S," dimensions enable users to determine the dimensional effect of stacking components. The mounting, "M," dimensions enable users to determine the depth that a bushing well or integral bushing projects into the apparatus on which it is mounted. A mounting, "M," dimension is also provided for multi-way junction brackets.

6.5 Test point

Test points are optional and may be specified on either loadbreak or deadbreak elbows.

6.5.1 Capacitance

Test points shall be capacitively coupled to the conductor system and shield of the connector.

The capacitance between the test point and the conductor system shall be at least 1.0 pF. The ratio of the capacitance between test point and shield to the capacitance between test point and conductor system shall not exceed 12.0. These values shall be verified by tests when conducted in accordance with 7.17.1.

6.5.2 Cap removal force

The force required to remove the test-point cap shall be within the range of 36 N to 218 N (8 lbf to 49 lbf). The cap operating eye shall be capable of withstanding a static operating force of 445 N (100 lbf) over the environmental temperature range of $-20\text{ }^{\circ}\text{C}$ to $+65\text{ }^{\circ}\text{C}$ (see 7.16.1).

6.6 Hold-down bails

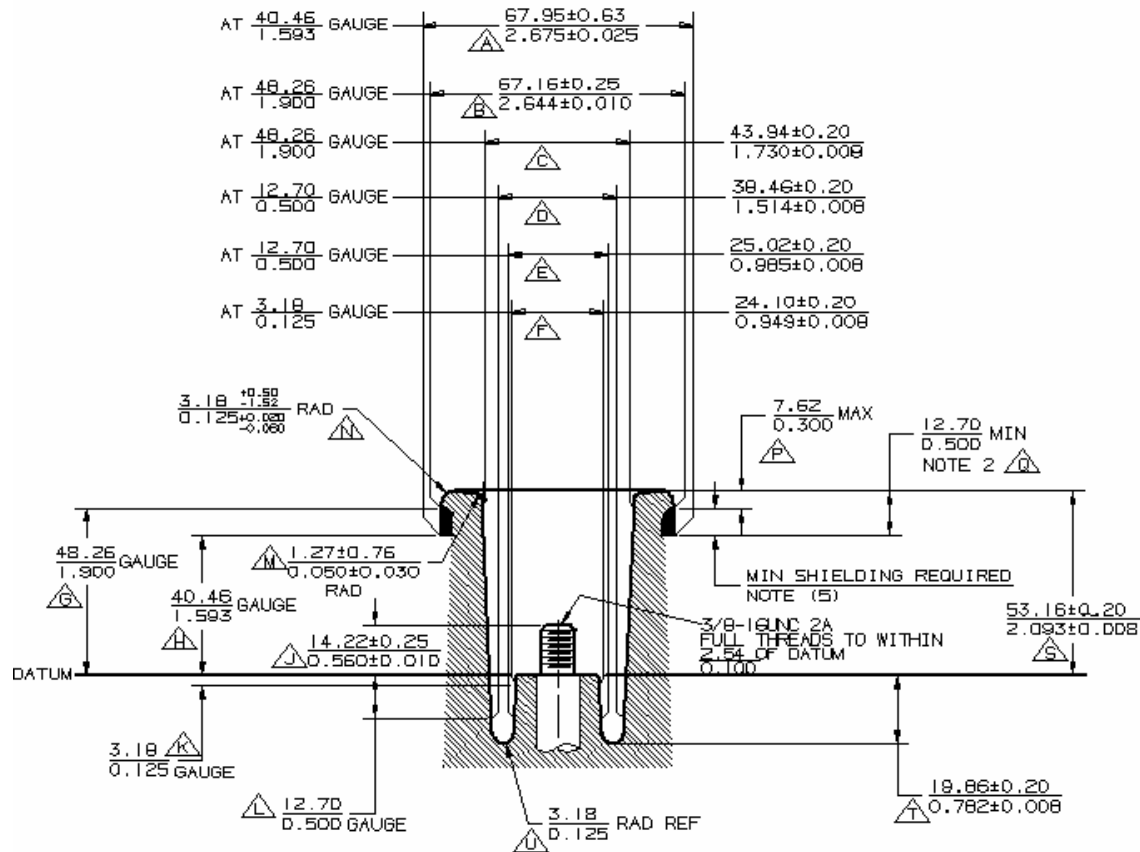
Dimensions, materials, and performance criteria are not specified in this standard.

6.7 Bushing well stud torque withstand

The 3/8"-16 threaded stud in the bushing well shall withstand a minimum torque of 23 N·m (17 ft·lbf) without stripping or fracturing (see 7.19).

6.8 Thermal cycle withstand

Non-elastomeric connector components shall withstand temperature cycling from $-40\text{ }^{\circ}\text{C}$ to $+130\text{ }^{\circ}\text{C}$ without cracking, breaking, or impairing the ability to meet the other requirements of this standard when tested according to the procedure in 7.20.



NOTE 1—Diameters C, D, E, and F to be concentric with pitch diameter of threads on stud within 0.25/0.010 TIR (total indicator reading).

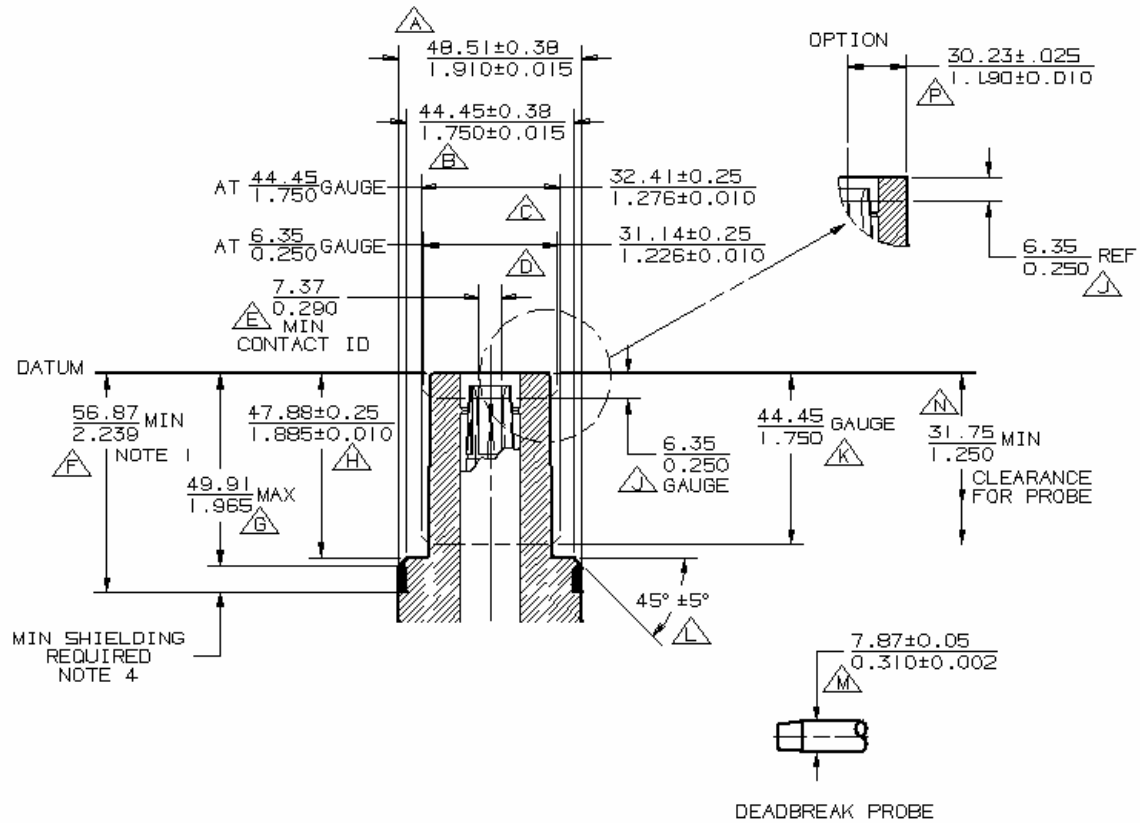
NOTE 2—Clearance for mating parts.

NOTE 3—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 4— Δ —Alphabetical dimensional identification.

NOTE 5—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulation portion, except for bushing wells that have internal shielding.

Figure 3—200 A bushing well interface, 8.3 kV, 15.2 kV, and 21.1 kV



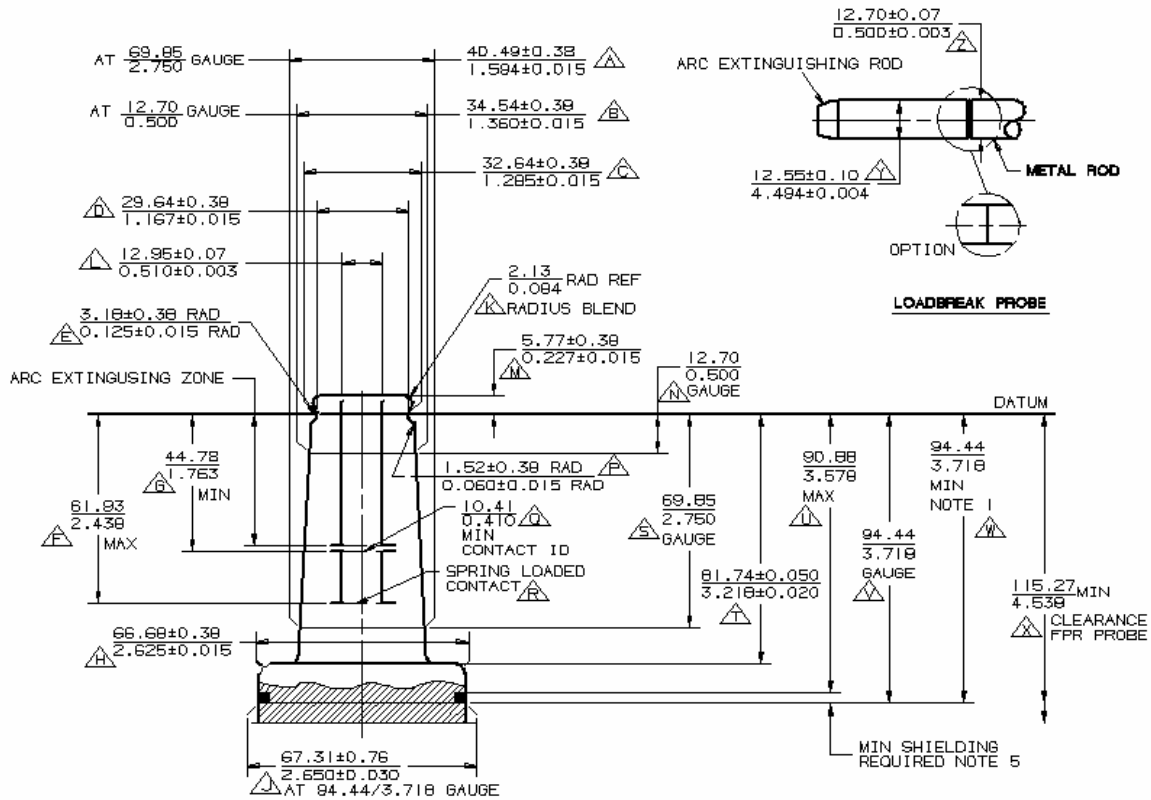
NOTE 1—Clearance for mating parts.

NOTE 2—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3— Δ —Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulation portion, except for bushings that have internal shielding.

Figure 4—200 A deadbreak interface, 8.3 kV and 15.2 kV



NOTE 1—Clearance for mating parts.

NOTE 2—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

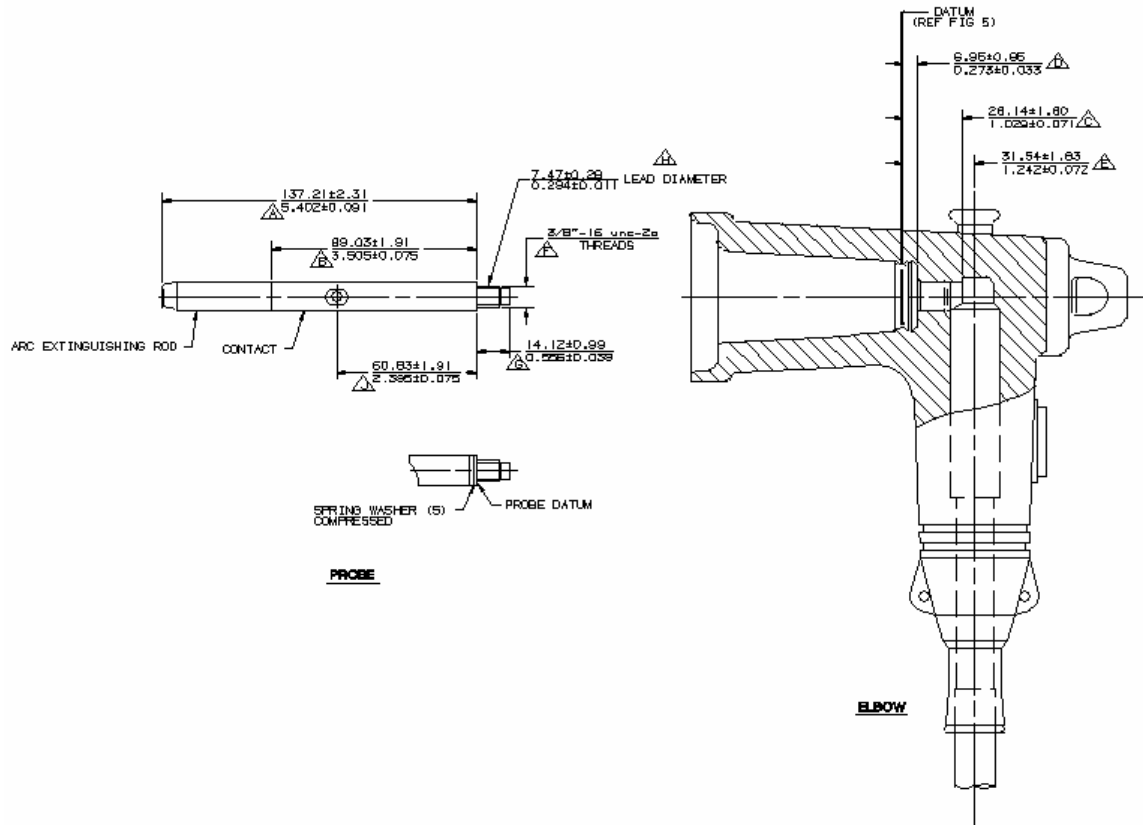
NOTE 3— Δ —Alphabetical dimensional identification.

NOTE 4—Probe and elbow—See Figure 6.

NOTE 5—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulation portion, except for bushings that have internal shielding.

NOTE 6—Minimum overlap for mating parts.

Figure 5—200 A loadbreak interface, 8.3 kV and 8.3 kV/14.4 kV

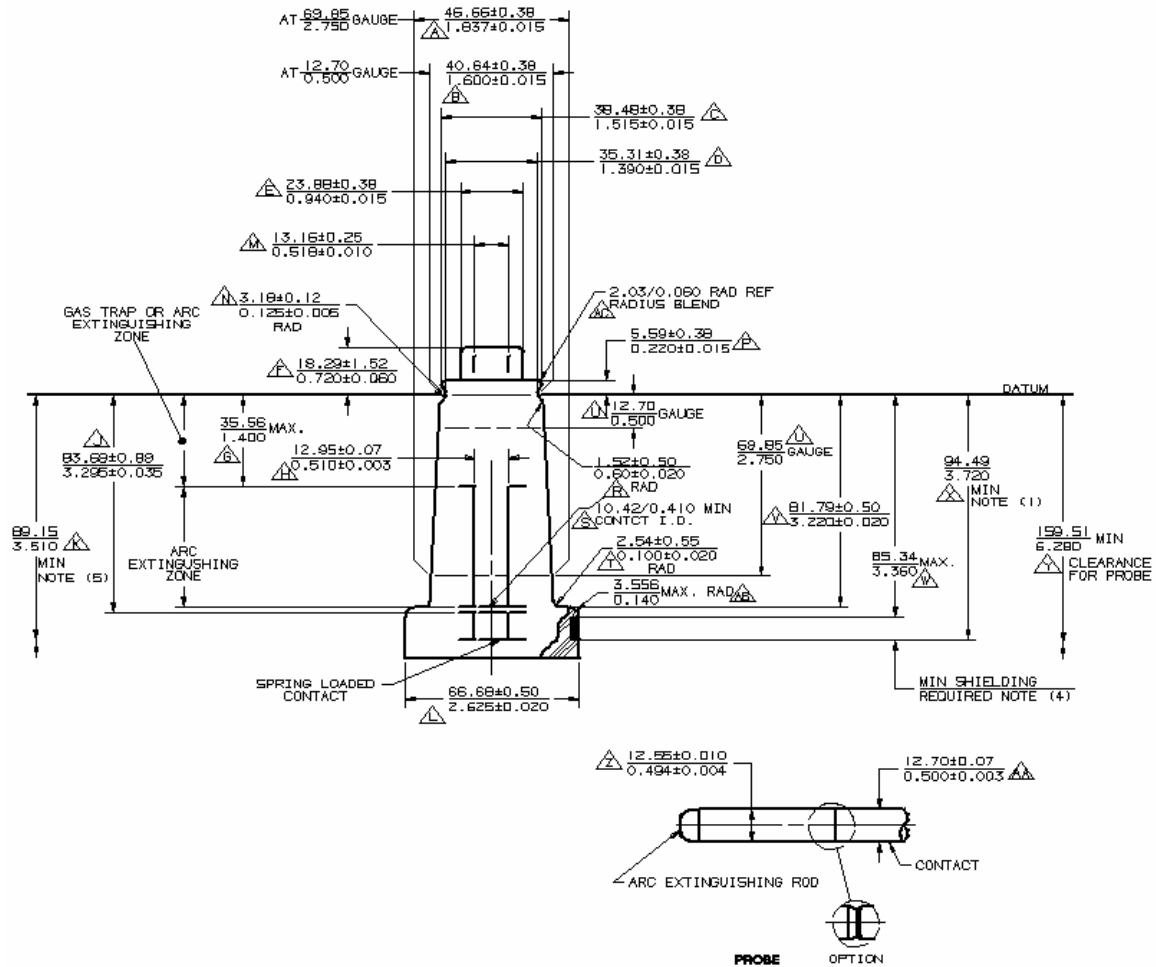


NOTE 1—For bushing, see Figure 5.

NOTE 2—Dimensions; mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

Figure 6—200 A loadbreak probe and elbow, 8.3 kV and 8.3 kV/14.4 kV



NOTE 1—Clearance for mating parts.

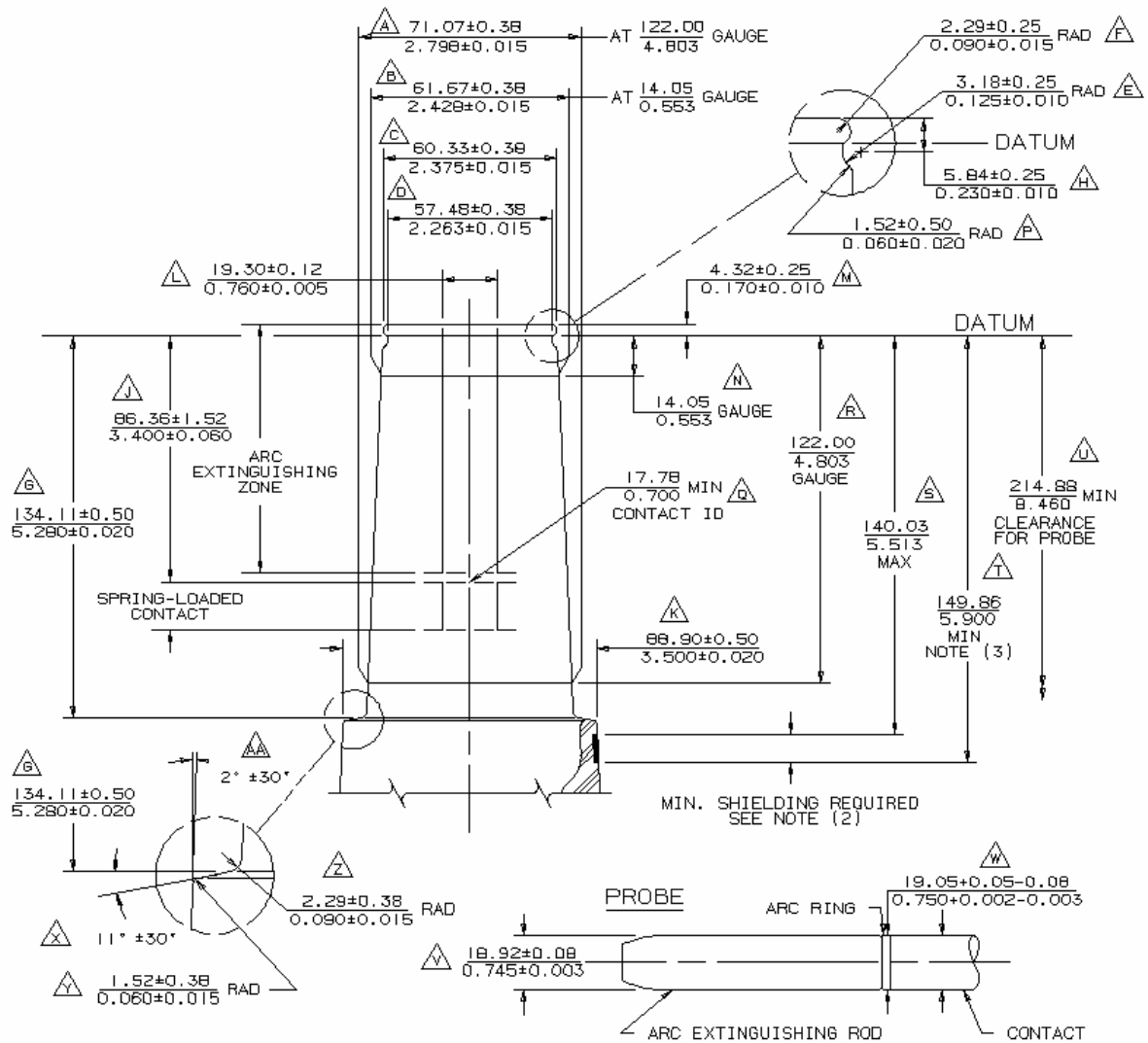
NOTE 2—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulation portion, except for bushings that have internal shielding.

NOTE 5—Minimum overlap for mating parts.

**Figure 7—200 A loadbreak interface, 15.2 kV and 15.2 kV/26.3 kV;
 200 A loadbreak interface no. 2, 21.1 kV and 21.1 kV/36.6 kV**

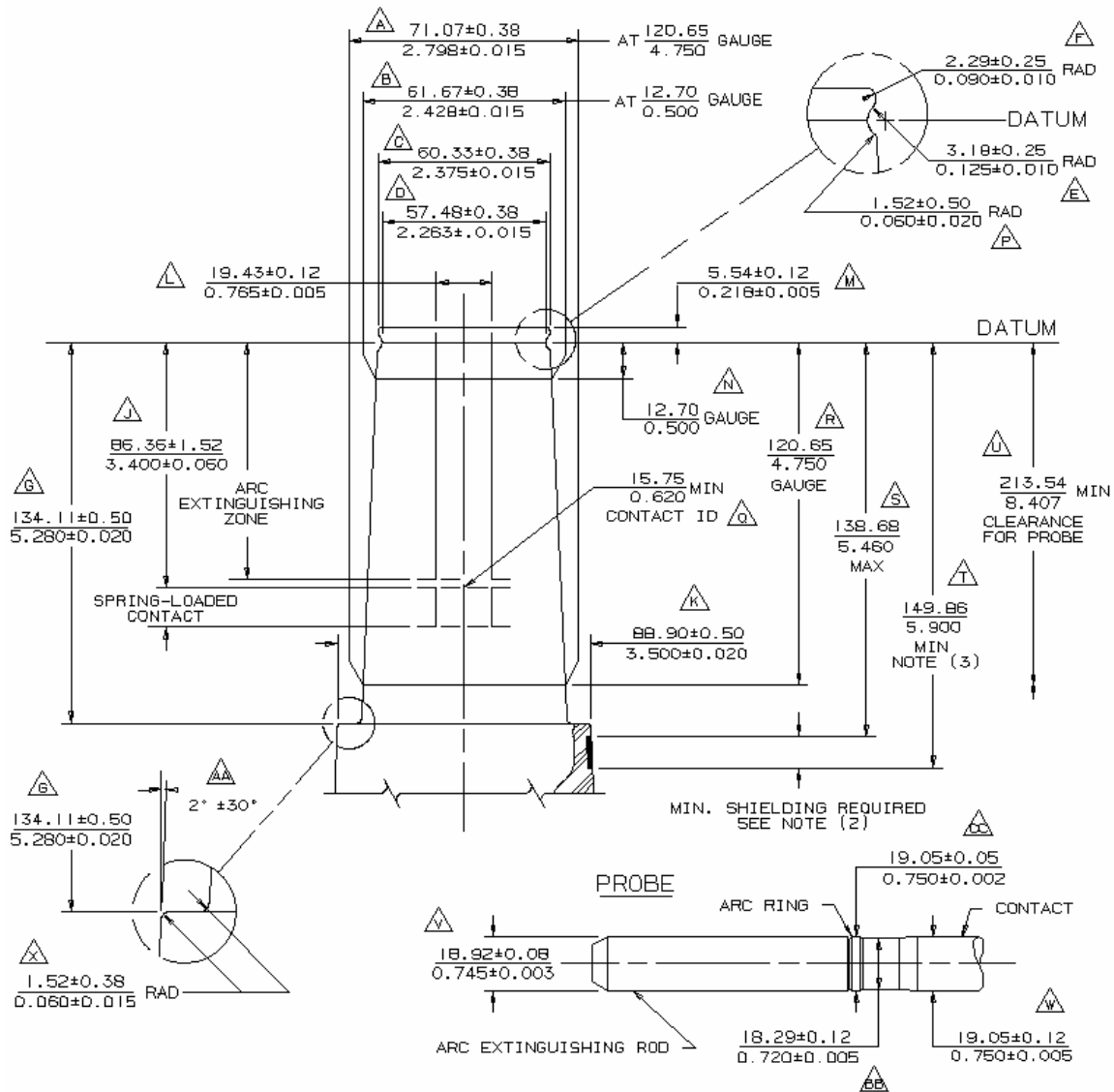


NOTE 1—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 2—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulation portion, except for bushings that have internal shielding.

NOTE 3—Minimum overlap for mating parts.

Figure 8—200 A loadbreak interface no. 1A, 21.1 kV/36.6 kV

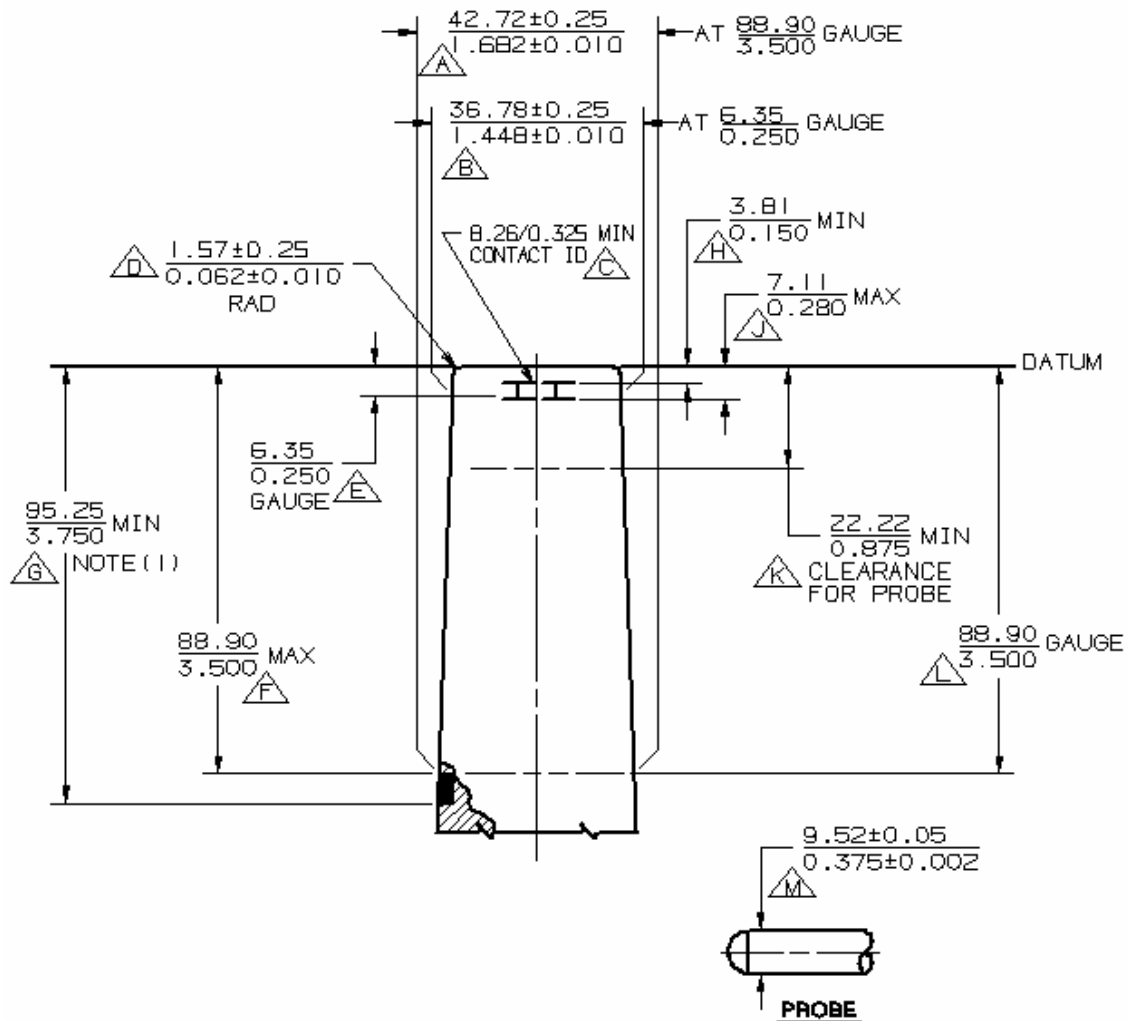


NOTE 1—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 2—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulation portion, except for bushings that have internal shielding.

NOTE 3—Minimum overlap for mating parts.

Figure 9—200 A loadbreak interface no. 1B, 21.1 kV



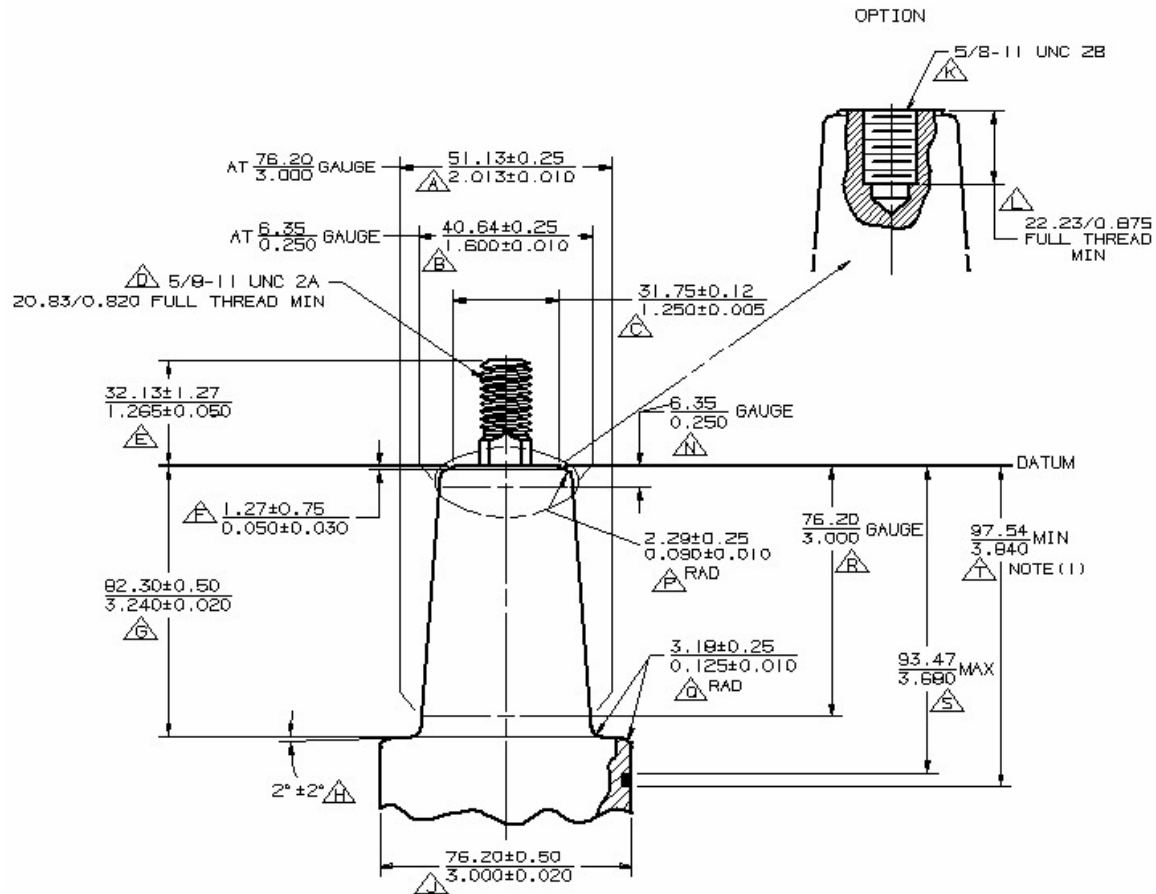
NOTE 1—Clearance for mating parts.

NOTE 2—Dimensions mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulated portion.

Figure 10—200 A deadbreak interface, 21.1 kV



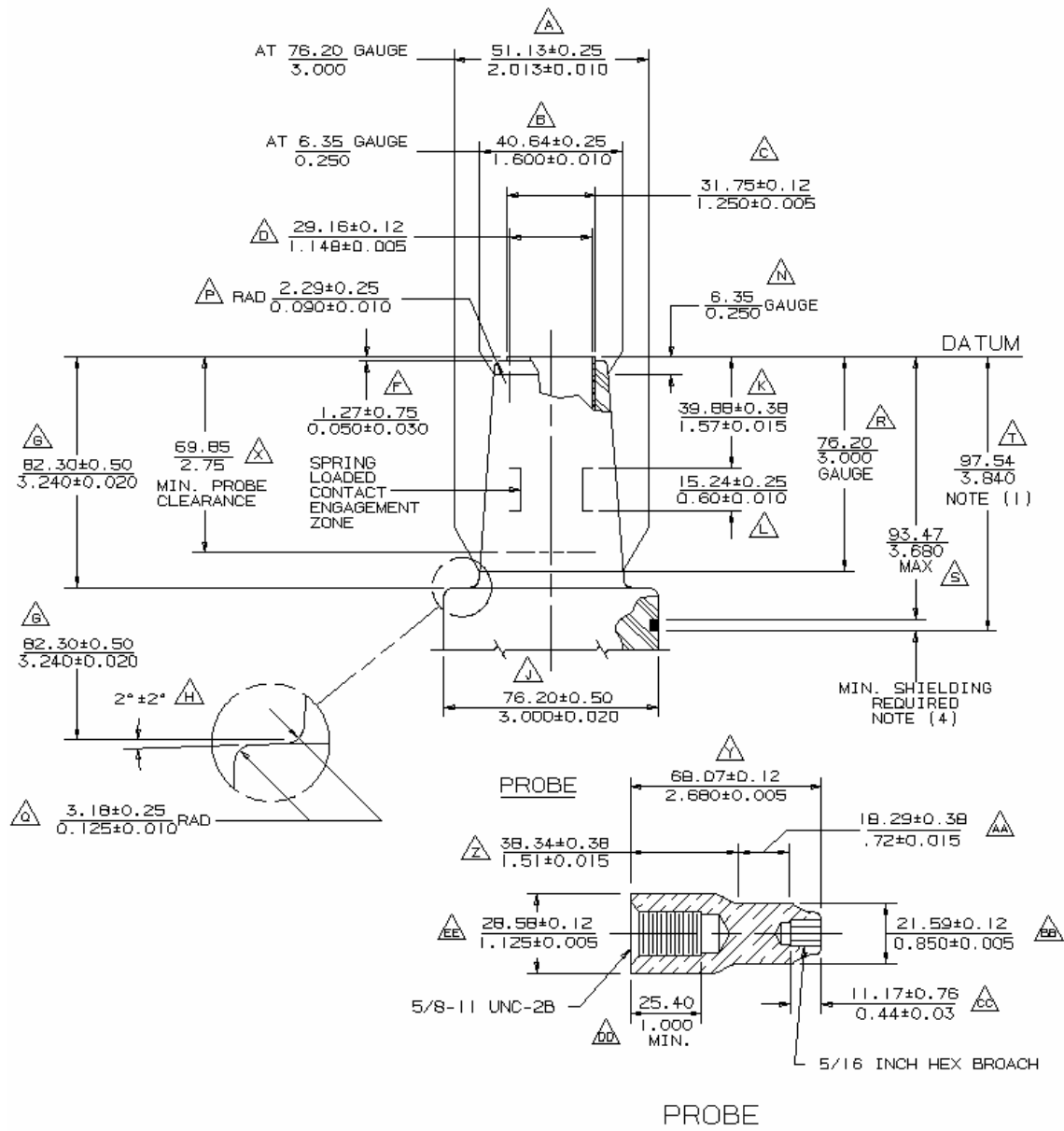
NOTE 1—Clearance for mating parts.

NOTE 2—Dimensions mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulated portion except for bushings that have internal shielding.

Figure 11—600 A deadbreak interface no. 1, 8.3 kV and 15.2 kV



NOTE 1—Clearance for mating parts.

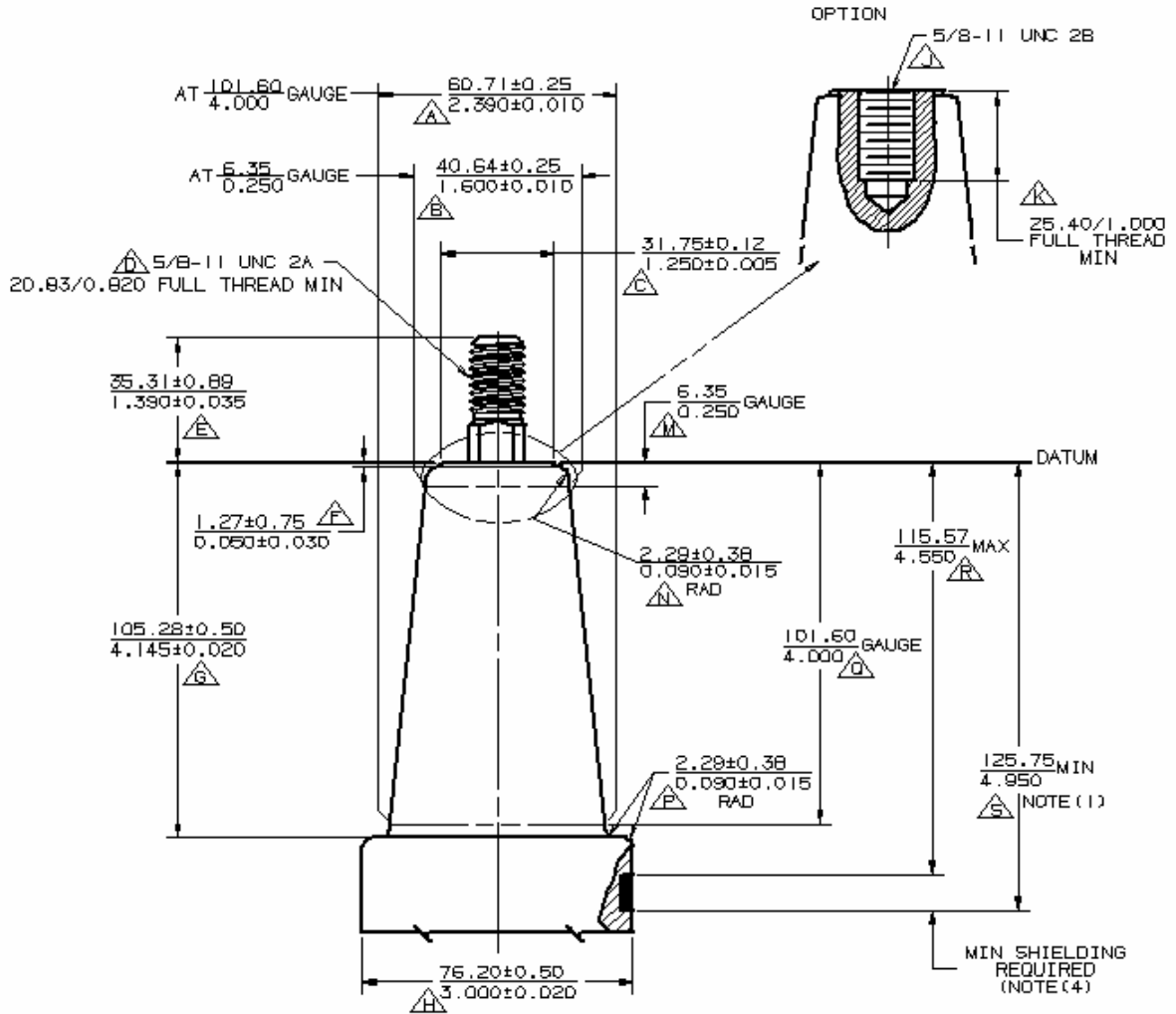
NOTE 2—Dimensions mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulated portion except for bushings that have internal shielding.

NOTE 5—Operating bracket must be consistent with datum.

Figure 12—600 A deadbreak interface no. 2, 8.3 kV and 15.2 kV



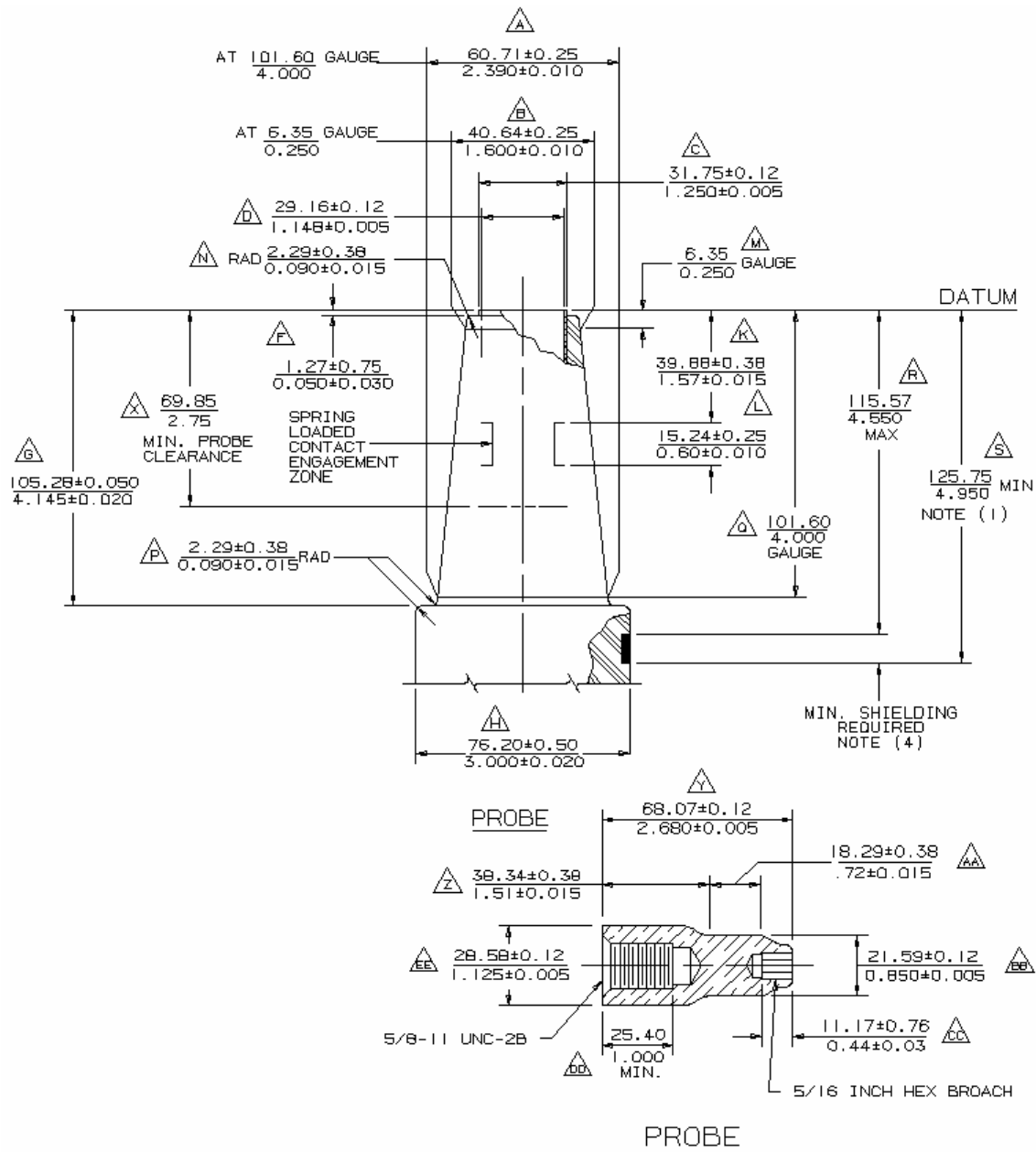
NOTE 1—Clearance for mating parts.

NOTE 2—Dimensions mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulated portion except for bushings that have internal shielding.

Figure 13—600 A deadbreak interface no. 1, 21.1 kV



NOTE 1—Clearance for mating parts.

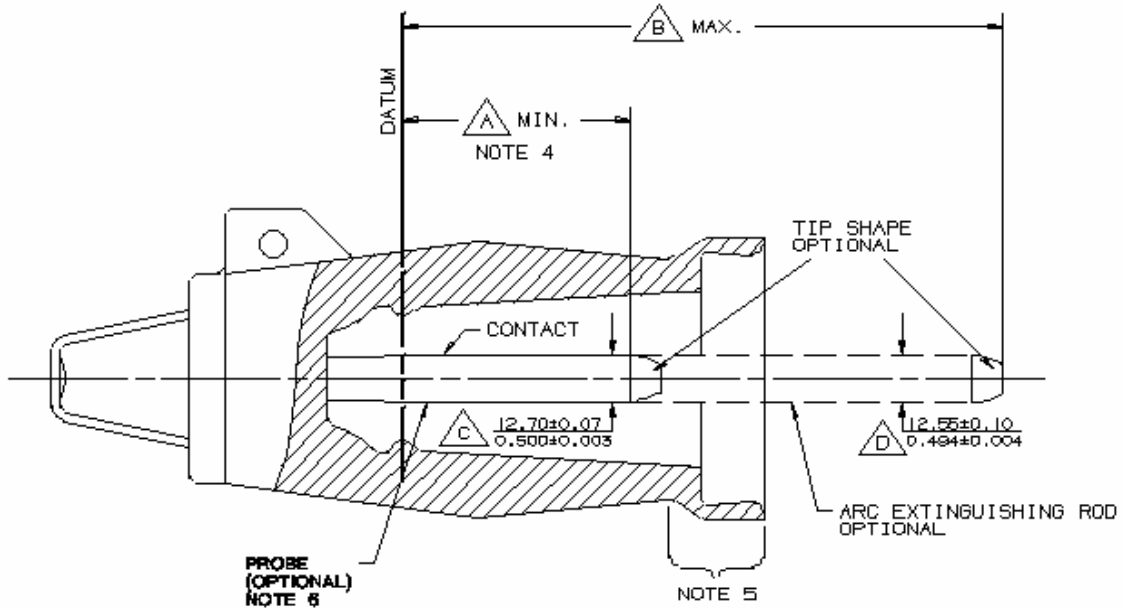
NOTE 2—Dimensions mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3—Δ—Alphabetical dimensional identification.

NOTE 4—The diameter of the shielded portion shall at no point be less than the largest diameter of the insulated portion except for bushings that have internal shielding.

NOTE 5—Operating bracket must be consistent with datum.

Figure 14—600 A deadbreak interface no. 2, 21.1 kV



RATING	A (MIN.)	B (MAX.)
8.3kV	$\frac{59.69}{2.35}$	$\frac{113.28}{4.46}$
15.2kV	$\frac{97.03}{3.82}$	$\frac{157.48}{6.20}$

NOTE 1—For bushings, see Figure 5 and Figure 7.

NOTE 2—Dimensions: mm/in; $\frac{\text{mm}}{\text{in}}$.

NOTE 3— Δ —Alphabetical dimensional identification.

NOTE 4—Dimension A is the minimum length of 0.500 ± 0.003 (12.70 mm \pm 0.007 mm) diameter contact. Conductive probe segment shown.

NOTE 5—Conductive or nonconductive cuff optional.

NOTE 6—Manufacturer should be contacted regarding interchangeability of caps without probes. Caps without probes may not meet the corona extinction levels of this standard when mated with certain bushing designs.

Figure 15—Insulated cap for 200 A loadbreak interface, 8.3 kV and 15.2 kV

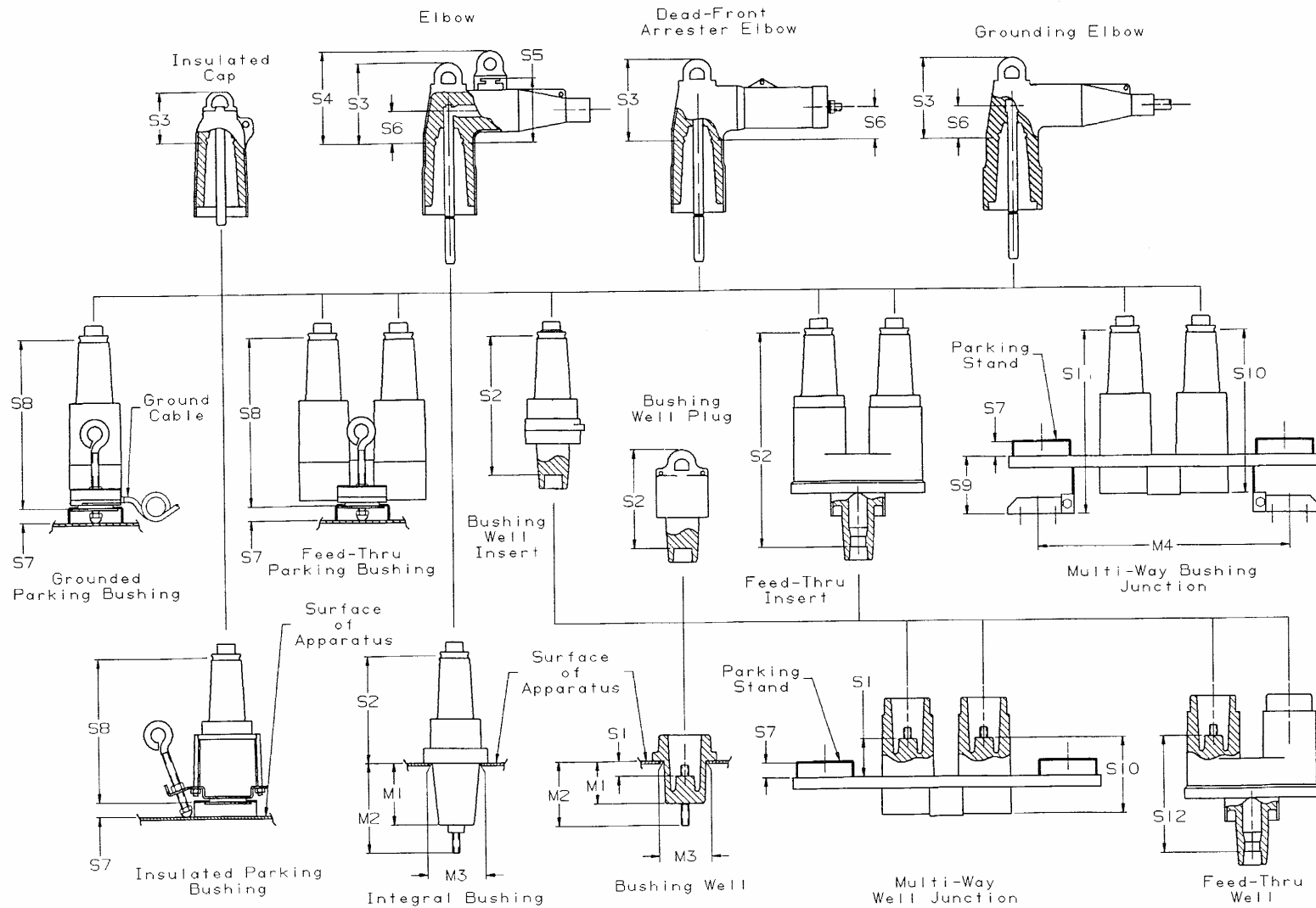


Figure 16—Stacking dimensions for 200 A loadbreak separable insulated connector system

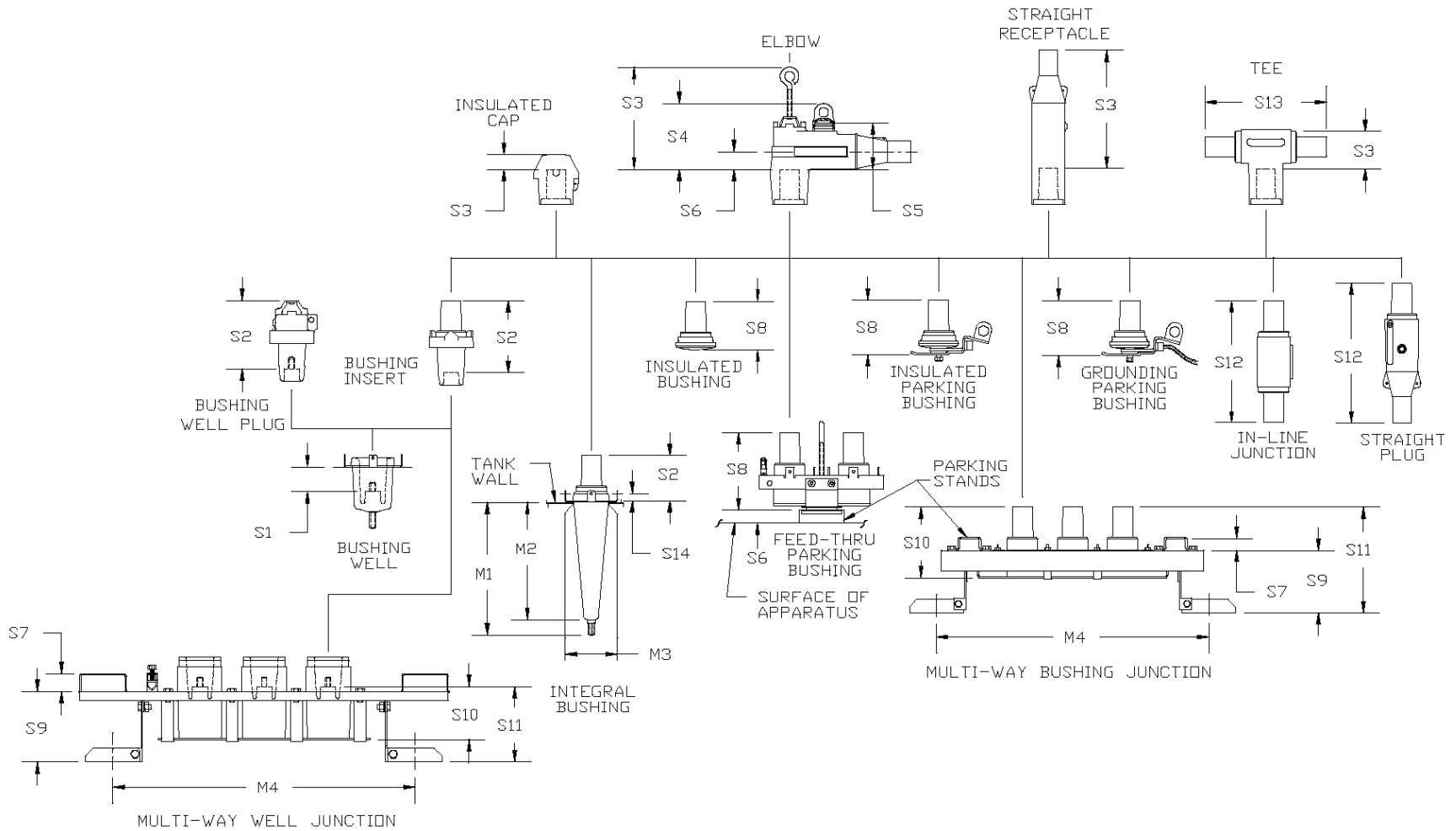


Figure 17—Stacking dimensions for 200 A deadbreak separable insulated connector system

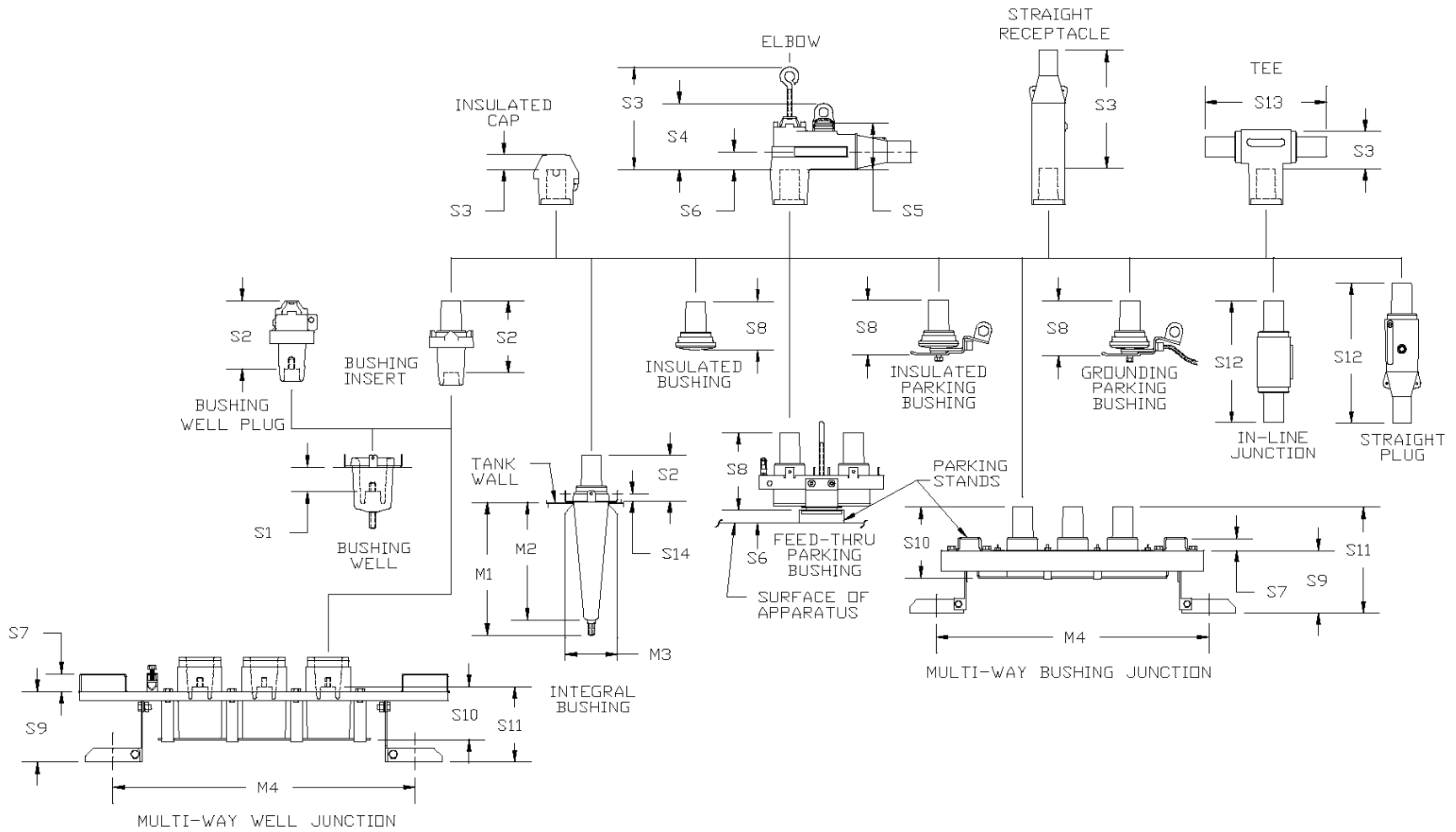


Figure 18—Stacking dimensions for 600 A deadbreak separable insulated connector system

7. Testing

7.1 Production tests

The following production tests shall be performed by the manufacturer on all connector components except ground bushings and grounding elbows:

- a) Partial discharge test (see 7.4)
- b) AC withstand or full-wave impulse withstand voltage (see 7.5.1 and 7.5.3)
- c) Test-point voltage test if applicable (see 7.17.2)

Connectors shall be properly assembled with actual or simulated components that duplicate the fit and voltage stress distribution of the actual components.

Bushing wells may be sample tested in accordance with ANSI/ASQC Z1.4 with an acceptable quality level of 2.5% using the normal inspection level.

7.2 Design tests

The design tests listed in Table 5 shall be performed by the manufacturer to demonstrate compliance of the design with this standard. Design tests shall be performed using actual connector system components assembled according to the manufacturer's instructions and using those materials supplied in the manufacturer's packaging.

7.3 Test conditions

The following test conditions shall apply unless otherwise specified:

- a) All parts that are normally grounded shall be connected to the ground of the test circuit
- b) Ambient temperature shall be in the range of 0 °C to +40 °C
- c) All ac voltages shall have a frequency of 60 Hz \pm 5% and sine wave shape of acceptable commercial standards as defined in IEEE Std 4
- d) Voltages shall be measured in accordance with IEEE Std 4

7.4 Partial discharge test

The purpose of this test is to verify that the partial discharge minimum extinction voltage of the specimen is not less than the value given in Table 1.

The test voltage shall be raised to 20% above the partial discharge minimum extinction voltage specified in Table 1. If the partial discharge peak value exceeds 3 pC, the test voltage shall be lowered to the partial discharge minimum extinction voltage specified in Table 1 and shall be maintained at this level for at least 3 s but not more than 60 s. Partial discharge readings taken during the interval 3 s to 60 s shall not exceed 3 pC peak.

Table 5—Design tests

Design test		Sequence ^a			Individual
		A	B	C	
		No. samples ^b	10	4	30
Reference					
Thermal cycle withstand	7.20	X ^d			
Partial discharge test	7.4	X	X		
AC withstand voltage	7.5.1	X	X ^e		
DC withstand voltage	7.5.2	X			
Impulse withstand voltage	7.5.3	X	X ^e		
Short-time current	7.6				X
Switching	7.7			X	
Fault-closure	7.8			X	
Current cycling	7.9 to 7.11				X
Accelerated sealing life test	7.12		X		
Cable pull-out (tensile strength)	7.13				X
Operating force	7.14				X
Operating eye	7.15				X
Test point cap	7.16				X
Test point	7.17	X ^c	X ^c		
Shielding	7.18				X
Bushing well stud torque	7.19				X
Impulse withstand voltage	7.5.3		X		

^a Sequence A = dielectric tests sequence.

Sequence B = accelerated life tests sequence.

Sequence C = switching tests sequence.

^b No failures are permitted except for switching and fault-closure tests in which none are permitted in 10 consecutive samples of a maximum lot size of 30.

^c Where applicable.

^d Applicable to non-elastomeric components.

^e May substitute impulse withstand voltage 7.5.3 for ac withstand voltage 7.5.1.

7.5 Dielectric tests

The purpose of these tests is to verify that the insulation of the test specimen will withstand the voltages shown in Table 1.

The test voltage shall be applied to the parts of the connector that are energized in service.

The test point, if any, shall be grounded during these tests.

7.5.1 AC withstand voltage test

The test voltage shall be raised to the value specified in Table 1 in not more than 30 s. The connector shall withstand the specified test voltage for 1 min without flashover or puncture.

7.5.2 DC withstand voltage test

The test voltage shall have a negative polarity (i.e., the negative terminal is connected to the test specimen) and shall be raised to the value specified in Table 1 in not more than 30 s. The connector shall withstand the specified test voltage for 15 min without flashover or puncture.

7.5.3 Impulse withstand voltage test (BIL)

The test voltage shall be 1.2/50 μ s wave having the crest value (BIL) specified in Table 1. The wave shape shall meet the requirements of IEEE Std 4. The wave shape tolerance shall be as shown in Table 6.

Prior to application of the first full-wave impulse, preconditioning pulses at 50% and then at 75% of the BIL and full-wave value shown in Table 1 may be applied to the closed connector. During a change of polarity, the preconditioning pulse sequence may again be applied.

The closed connector shall withstand three positive and three negative full-wave impulses without flashover or puncture. When the impulse withstand test is used as a production test, the connector shall withstand one full-wave impulse of each polarity without the application of preconditioning pulses.

Table 6—Impulse wave shape tolerances

Measured quantity	Tolerance (%)
Crest value	± 3
Front time	± 30
Time to half value	± 20
Nominal rate of rise of wavefront	± 20

7.6 Short-time current test

The purpose of this test is to verify that the connector is capable of withstanding short-time current of the magnitudes and durations shown in Table 2.

The connector shall be mounted in a manner approximating service conditions. Hold-down bails shall be used with 200 A deadbreak elbows.

Short-time current tests may be made at any voltage up to the rated voltage of the connector.

The rms value of the first major loop of a current wave shall be not less than the value specified in Table 2 multiplied by 1.3 ($X/R = 6$) for 200 A connectors or 1.6 ($X/R = 20$) for 600 A connectors. The magnitude shall be measured in accordance with IEEE Std C37.09 [B10].

Connectors shall withstand the current without separation of interfaces or impairing the ability to meet the other requirements of the standard.

7.7 Switching test

This test is applicable to loadbreak connectors only. The purpose of this test is to verify that the loadbreak connector is capable of closing and interrupting the rated switching current given in Table 2.

The connector shall withstand ten complete switching operations under the conditions listed in Figure 19 and Table 7 without arcing to ground or impairing its ability to meet the other requirements of this standard. A complete switching operation shall consist of connecting and disconnecting. Appropriate ground-fault detection equipment shall be used for all tests. The last switching operation shall be recorded by an oscillogram.

Table 7—Voltage conditions for switching test

Connector voltage rating (kV rms) ^a	Figure 19 test voltage		Test circuit diagram required (see Figure 19)
	V ₁	V ₂	
8.3	8.3	—	C
8.3/14.4	14.4	8.3	A or B
15.2	15.2	—	C
15.2/26.3	26.3	15.2	A or B
21.1	21.1	—	C
21.1/36.6	36.6	21.1	A or B

^a The highest steady-state voltage across the open contacts that a loadbreak connector is rated to switch is the maximum phase-to-ground rms voltage for phase-to-ground rated devices and the maximum phase-to-phase rms voltage for phase-to-ground/phase-to-phase rated devices.

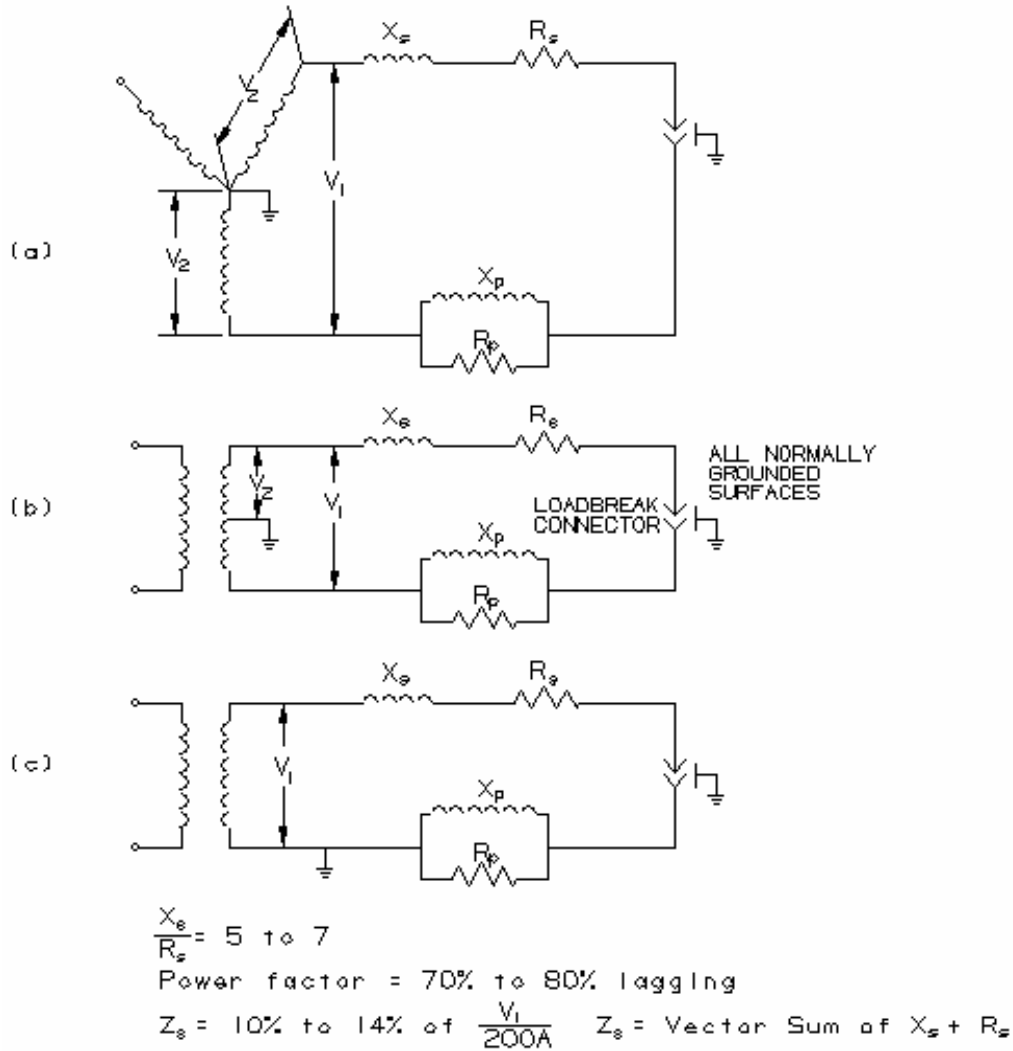
7.7.1 Mounting preparation of loadbreak connectors for switching tests

The connector shall be mounted with all normally grounded parts grounded in a manner closely approximating normal service conditions. Adjacent grounds, in the form of connector systems of the same type as the one being tested, shall be mounted and appropriately grounded on each side of the connector under test at the distance shown in Table 8. If hold-down bails are used, these shall be installed as in normal service.

Table 8—Elbow spacing for switching and fault-closure tests

Connector voltage rating (kV rms)	Maximum center-to-center spacing	
	mm	in
8.3	83	3-1/4
8.3/14.4	83	3-1/4
15.2	102	4
15.2/26.3	102	4
21.1	140	5-1/2
21.1/36.6	140	5-1/2

NOTE—Tests shall be conducted with adjacent grounds exposed as in normal service.



NOTE 1—Care shall be exercised in the selection and connection of instrument transformers to ensure that they will not significantly alter the wave shape, magnitude, or duration of transient voltages or current normally associated with the test circuit.

NOTE 2—The switching rating may be achieved with the test circuit.

NOTE 3—Series impedance, which may include source impedance, may appear on either side of the loadbreak connector.

NOTE 4—Transformer loading that represents normal service conditions can be used for switching.

Figure 19—Circuit diagrams for switching current tests

7.7.2 Operating procedures for switching test

The loadbreak connector under test shall be operated manually using a suitable live-line tool or an equivalent mechanical actuator. The operator shall maintain a minimum dwell time of 5 s after the probe is positioned in the arc extinguishing area of its mating part. The operator shall perform the closing and opening operations using a positive, continuous motion so as not to tease the contacts. Mechanical actuators shall be designed to perform switching operations at velocities typical of human operators.

The test samples shall be operated using the series or parallel method of switching. The test samples are connected in series for the series method with two operators performing the switching. One operator closes one of the samples while the other operator opens the other test sample. For the parallel method of switching, one operator is used and a rapid make/break operation is performed on one or more samples connected in parallel. The preferred method of switching for all third party certification interchangeability tests shall be the parallel method of switching. All manufacturers shall state in their test reports the method of switching used.

Time between closing and opening of the test connector shall allow steady-state voltage and current conditions to be achieved prior to opening. Successive switching operations of the same test connector shall be performed at a time interval of not less than 1 min. Manufacturers may test their own products under conditions of a reduced time interval.

7.8 Fault-closure test

This test is applicable to loadbreak connectors only. The purpose of the test is to verify that the connector is capable of closing on the fault current given in Table 2.

Fault-closure tests shall be conducted on connectors from the lot that has passed the switching test (7.7). Any connector from this lot that has successfully completed ten switching operations may be used in the fault-closure test and shall be used in the same sequence in both tests. The test conditions shall be as shown in Table 9 and Figure 20. At least one connector shall be closed at an instant when the voltage is 80% or more of its peak value.

Table 9—Voltage conditions for fault-closure test

Connector voltage rating (kV rms)	Figure 20 test voltage (kV rms)		Test circuit diagram required (see Figure 20)
	V ₁	V ₂	
8.3	8.3	—	(b)
8.3/14.4	14.4	4.2	(a)
15.2	15.2	—	(b)
15.2/26.3	26.3	7.6	(a)
21.1	21.1	—	(b)
21.1/36.6	36.6	10.6	(a)

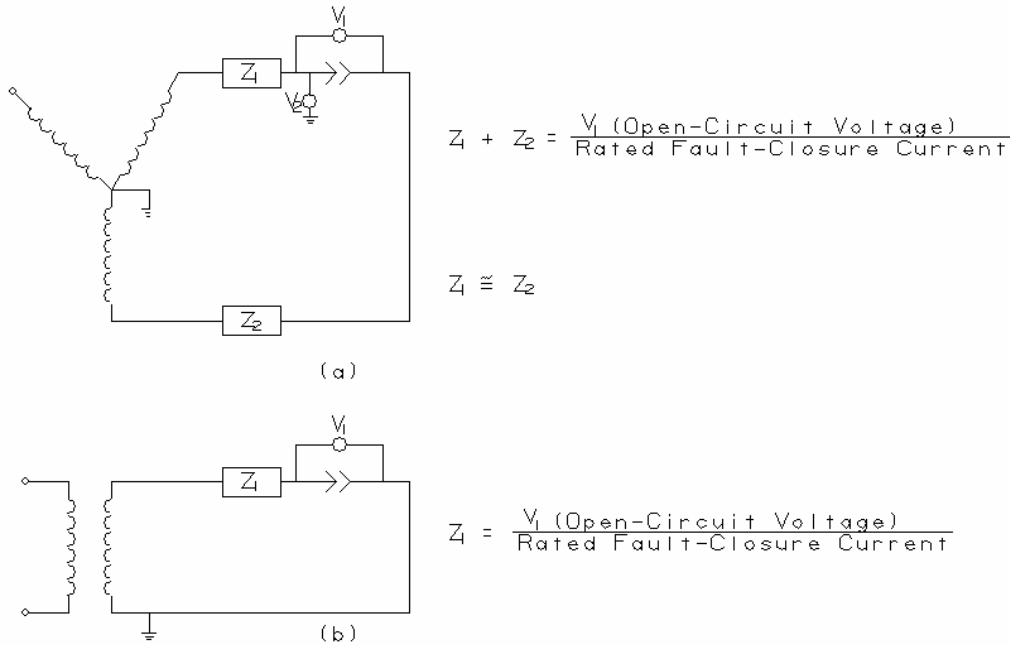
The sample lot will have successfully passed the fault-closure test if ten consecutive samples meet the following criteria:

- a) Oscillograms show no external ground current
- b) All parts remain within the closed connector assembly

Connectors need not be operable after this test. Mounting preparation of the loadbreak connector shall be the same as specified in 7.7.1.

7.9 Current-cycling test for uninsulated components of 600 A connectors

The purpose of this test is to demonstrate the ability of the uninsulated components of the connector system to maintain their required continuous current-carrying capability when subjected to cyclical loads.



NOTE—Any circuit that duplicates the voltages V_1 and V_2 and the conditions in Table 2 is acceptable for conducting the fault-closure test.

V_1 is the required voltage across contacts prior to flow of fault current.

V_2 is the required voltage from each contact to all normally grounded surfaces during flow of fault current

Figure 20—Circuit diagrams for fault-closure tests

Tests shall be conducted in accordance with ANSI C119.4. A 750 kcmil aluminum conductor shall be used for 600 A connectors.

The test shall be made without insulation on the conductor or current-carrying parts of the connector to avoid any deterioration of the insulation that may otherwise occur at the maximum temperature of this test.

The conductor system shall meet the requirements given for Class A connectors in ANSI C119.4.

7.10 Current-cycling test for 200 A insulated connectors

7.10.1 Accelerated thermal test

The purpose of this accelerated test is to demonstrate that 200 A insulated connectors can carry rated current under usual service conditions. Successful completion of the test listed below shall be considered as evidence that the connector meets its rating.

A control cable, used for the purpose of obtaining conductor temperature, shall be installed in the heat cycle loop between two equalizers. Its length shall be 183 cm (72 in). The control cable shall be the same type and size as the cable used to join the connectors under test.

Four connectors shall be assembled in series on AWG No 1/0 insulated aluminum conductors having a length of 91 cm (36 in). The cable insulation thickness shall be selected according to its voltage class (see Table 10).

Equalizers used shall be in accordance with ANSI C119.4.

Table 10—Cable insulation thickness for 7.10 and 7.11

Voltage rating (kV rms)	Cable insulation thickness (mil)
15	175 to 220
25	260 to 280
35	345

The bushing bus shall be a flat, rectangular, bus bar 356 mm (14 in) long, 102 mm (4 in) wide, and 10 mm (3/8 in) thick. The bushing wells shall be mounted 31 cm (12 in) apart centered along the midline of the bus bar. The bushing well studs shall be tightened to the bus bar using an installation torque of 9 N·m ± 1 N·m (80 lbf·in ± 10 lbf·in).

Unless otherwise specified by the manufacturers, the elbow male contact probe shall be threaded into the elbow compression lug using an installation torque of 9 N·m ± 1 N·m (80 lbf·in ± 10 lbf·in).

Current-cycling tests shall be conducted at an ambient temperature of 15 °C to 35 °C in a space free of drafts.

The current-cycle amperes shall be adjusted during the current-on period of the first five cycles to result in a steady-state temperature rise of 100 °C to 105 °C on the control conductor. This current shall then be used during the remainder of the test current-on periods, regardless of the temperature of the control conductor.

The test shall consist of 50 current cycles, with the current on 4 h and off 2 h for each cycle. At the end of each current-on cycle, the assembly shall be de-energized and within 3 min be submerged in water at 5 °C ± 5 °C for the remainder of the current-off cycle. At the end of the 10th, 25th and 40th cycles (± 2 cycles), after the samples have returned to room temperature, a short time ac current of 3500 A ± 300 A rms shall be applied to each sample for a minimum of 3 s.

The temperature of at least the following current transfer points shall be measured at the end of each cycle with the current on:

- a) Probe to compression lug
- b) Probe to female contact
- c) Female contact structure to metallic housing (piston contact)
- d) Between bushing insert and bushing well.

These temperatures shall not exceed the temperature of the control conductor.

The temperature differences between the control conductor and the connector shall show a condition of stability from the fifth cycle to the end of the test. Stability is indicated when the change in the individual differences is not more than 10 °C from the average of the measured differences in this interval for this connector.

The dc resistance of the connector system shall be measured at the end of cycles 10, 20, 30, 40, and 50 (± 2 cycles). The dc resistance measurements shall be made between the elbow cable equalizer and the bushing stud after the connector system has stabilized at ambient temperature. Ambient temperature shall be measured by devices located within 61 cm (2 ft.) of the test loop but in a location that minimizes the effect of thermal convection. The ambient temperature shall be recorded at the same time as each set of

resistance measurements, and the resistance shall be corrected to 20 °C. The dc resistance shall be stable over the period of measurement. Stability is achieved when any resistance measurement, including allowance for instrument accuracy, does not vary more than $\pm 5\%$ from the average of all the measurements in this interval.

7.10.2 Thermal test with off-axis operation

The purpose of this test is to demonstrate that loadbreak and deadbreak 200 A connectors can carry rated load current after being subjected to an off-axis operating force. Successful completion of these tests shall be considered as evidence that the connector meets its rating.

Each connector shall be subjected to six cycles, each consisting of a mechanical operation as specified in 7.10.2.1 and current cycling as specified in 7.10.2.2.

The elbow shall be disassembled with a 12.7 mm (0.5 in) wide pulling band, as shown in Figure 21 for application of an off-axis force. Grounding tabs or other obstructions may be removed to apply the pulling band. No provision is made for an off-axis closing force since it is not consistently reproducible.

Four connectors shall be assembled in series on AWG No. 1/0 insulated aluminum conductors having a length of 91 cm (36 in). The cable insulation thickness shall be selected according to its voltage class (see Table 10).

7.10.2.1 Mechanical operation

The elbow shall be rotated about the probe axis a minimum of 10° in both the clockwise and counterclockwise directions by means of a suitable live-line tool. The tool shall be approximately parallel with the axis of the probe.

The connector shall then be opened five times with the force applied to the pulling band and closed five times with the force applied to the operating eye. The force required to open or close the elbow shall be parallel to the axis of the probe. The applied force shall be sufficient to completely close the connector.

7.10.2.2 Current cycling test

A control cable, used for the purpose of obtaining conductor temperature, shall be installed in the current-cycling loop between two equalizers. Its length shall be 183 cm (72 in). The control cable shall be the same type and size as the cable used to join the connectors under test.

The current shall be adjusted so that the temperature on the conductor of the control cable is $90\text{ °C} \pm 5\text{ °C}$. The current shall be applied for eight continuous cycles, each cycle consisting of 3 h on and 3 h off.

Equalizers used shall be in accordance with ANSI C119.4.

Current-cycling tests shall be conducted at an ambient temperature of 15 °C to 35 °C in a space free of drafts.

The temperature shall be measured by thermocouples located as follows:

- a) At the compression lug
- b) At the approximate midpoint of the bushing contact or as near thereto as practical
- c) On the conductor surface at the midpoint of the control cable

The temperature at location a) and location b) shall not exceed the temperature of the conductor of the cable at location c).

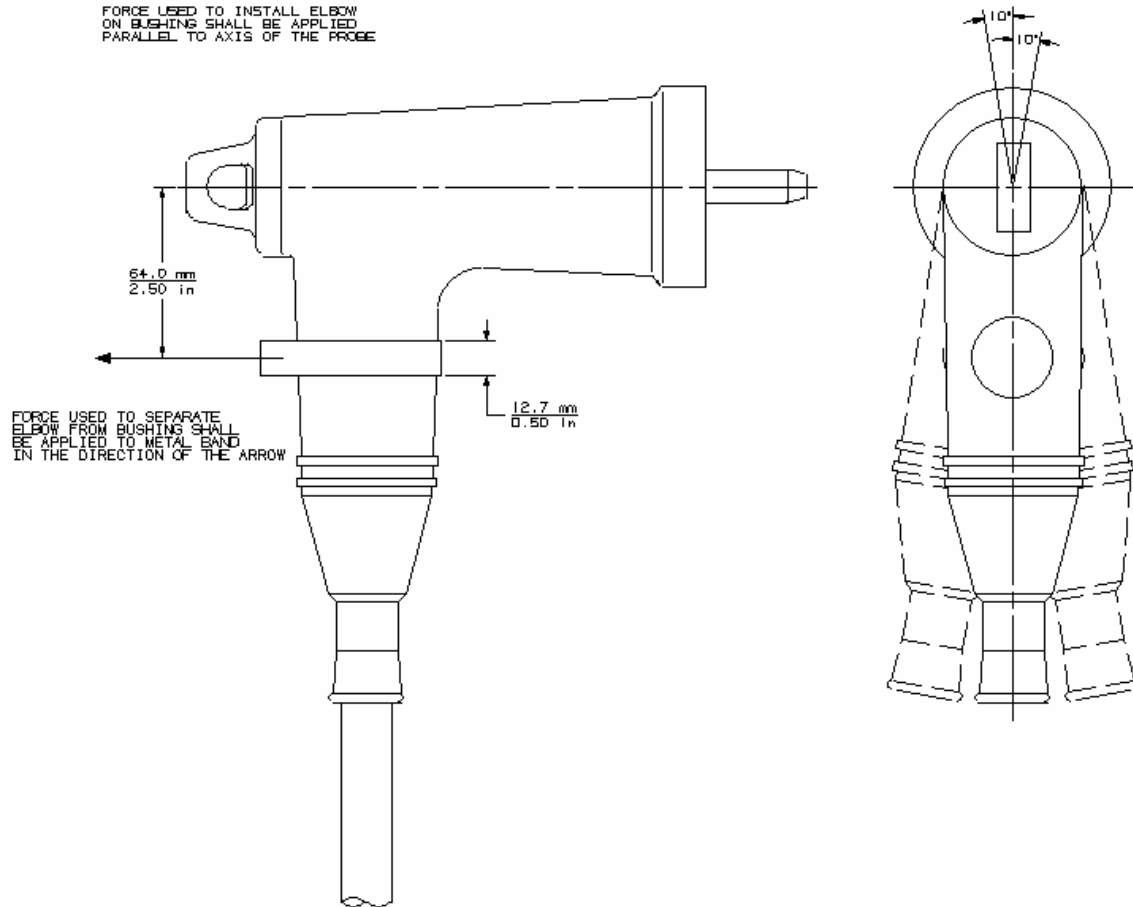


Figure 21—Operating-force test for 7.10.2

7.11 Current-cycling test for 600 A insulated connectors

The purpose of this test is to demonstrate that 600 A insulated connectors can carry rated current under usual service conditions. Successful completion of the test listed within this subclause shall be considered as evidence that the connector meets its rating.

A control cable, used for the purpose of obtaining conductor temperature, shall be installed in the current-cycling loop between two equalizers. Its length shall be 183 cm (72 in). The control cable shall be the same type as the cable used to join the connectors under test.

Four connectors shall be assembled in series on 750 kcmil insulated aluminum conductors having a length of 91 cm (36 in). The cable insulation thickness shall be selected according to its voltage class (see Table 10).

Equalizers used shall be in accordance with ANSI C119.4.

Current-cycling tests shall be conducted at an ambient temperature of 15 °C to 35 °C in a space free of drafts.

The current-cycle amperes shall be adjusted to result in a steady-state temperature of 90 °C ± 5 °C on the surface of the conductor of the control cable. The temperature shall be measured at the approximate center of the control cable.

The test shall consist of 50 current cycles, with the current on 6 h and off 6 h for each cycle. The temperature of the hottest spot of the connector shall be measured every ten cycles and shall not exceed the temperature of the conductor of the control cable.

7.12 Accelerated sealing life test

The purpose of this test is to demonstrate that the connector can maintain a long-term seal at all interfaces to prevent the entrance of moisture.

Four samples shall be assembled on AWG No. 1/0 aluminum conductors for 200 A connectors and 750 kcmil aluminum conductors for 600 A connectors.

The cable shall be compatible with the thermal conditions of this test. A mandrel simulating the test cable may be substituted during the oven aging portion of this test.

The four connector assemblies shall be placed in an oven having 121 °C temperature and remain there for three weeks. After this time has elapsed, the four samples shall be removed from the oven and each operated once by using the operating eye or an appropriate location on the axis of the separable interface.

The four connector assemblies shall then be subjected to 50 cycles of the following sequence of operations:

- a) The assemblies shall be heated in air using sufficient current to raise the temperature of the conductor of the control cable to $90\text{ °C} \pm 5\text{ °C}$ for the following time period:
 - 1) 200 A connectors: 1 h
 - 2) 600 A connectors: 4 h
- b) The assemblies shall be de-energized and within 3 min, submerged in $25\text{ °C} \pm 10\text{ °C}$ conductive water (5000 Ω -cm maximum) to a depth of 30 cm (1 ft) for the following time periods:
 - 1) 200 A connectors: 1 h
 - 2) 600 A connectors: 2 h

After the 50th cycle, the connector and cable assembly shall withstand a design impulse test (see 7.5.3).

The test point, if provided, shall be capable of passing the voltage test specified in 7.17.2.

7.13 Cable pull-out test (tensile strength)

The purpose of this test is to determine if the connection between the cable conductor and compression lug of the connector is capable of withstanding a tensile force of 890 N (200 lbf).

The compression lug shall be held in a manner that will not affect the strength of the connection. The tensile force shall be applied to the cable conductor.

The connection shall withstand the applied force for 1 min without impairing the connector's ability to meet the other requirements of this standard.

7.14 Operating-force test

The purpose of this test is to demonstrate that the force necessary to operate a connector meets the requirements of 6.2.

The elbow shall be assembled with a probe and compression lug and the connector system shall be lubricated in accordance with the manufacturer's instructions.

The temperature of the components shall be $-20\text{ }^{\circ}\text{C}$, $+25\text{ }^{\circ}\text{C}$, and $+65\text{ }^{\circ}\text{C}$, respectively, for three separate tests. Each test shall consist of closing and then reopening the connector within 10 min. The force shall be applied to the operating eye parallel to the axis of the probe at a rate of 13 cm/min (5 in/min).

The forces required to open or close the connector shall be within the ranges specified in 6.2.

7.15 Operating-eye test

The purpose of this test is to demonstrate that the operating eye meets the requirements of 6.2 at $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

A tensile force shall be gradually applied to the operating eye in the direction of normal operation. The operating eye shall withstand the force for 1 min.

A rotational force shall be applied with a suitable live-line tool to the operating eye in a clockwise direction and in a counter-clockwise direction.

Some distortion of the operating eye is acceptable provided the connector is serviceable after the test and meets the partial discharge requirement specified in Table 1.

7.16 Test point cap test

The purpose of this test is to demonstrate that the removal force of the test point cap meets the requirements of 6.5.2 and the cap operating eye is capable of withstanding the maximum operating force.

7.16.1 Test point cap operating-force test

A tensile force shall be gradually applied to the test point cap in the direction parallel with the probe axis at $-20\text{ }^{\circ}\text{C}$, $+25\text{ }^{\circ}\text{C}$, and $+65\text{ }^{\circ}\text{C}$.

The force required to remove the test point cap shall be within the range specified in 6.5.2.

7.16.2 Test point cap operating withstand test

A tensile force of 445 N (100 lbf) shall be applied to the test point cap operating eye for 1 min at $-20\text{ }^{\circ}\text{C}$, $+25\text{ }^{\circ}\text{C}$, and $+65\text{ }^{\circ}\text{C}$.

Some distortion of the operating eye is acceptable provided the test point cap is serviceable after the test.

7.17 Test point tests

7.17.1 Test point capacitance test

The purpose of this test is to verify that the capacitance values of the test point meet the requirements of 6.5.1.

The connector shall be installed on a cable of the type for which it is designed to operate, and the shielding shall be grounded in the normal manner. The capacitances from test point to cable and test point to ground shall be measured with suitable instruments and proper shielding techniques.

The measured values shall be within the tolerances specified in 6.5.1.

7.17.2 Test point voltage test

The purpose of this test is to ensure proper operation of the test point.

A test voltage shall be applied to the conductor system of the connector. The response of a suitable sensing device on the test point shall indicate an energized condition.

7.18 Shielding test

The purpose of this test is to demonstrate that the shielding meets the requirements of 6.3. The test procedure shall be in accordance with IEEE Std 592.

7.19 Bushing well stud torque test

The purpose of this test is to demonstrate that the threaded stud in the bushing well shall withstand the minimum torque specified in 6.7.

Four bushing wells shall be tested. A minimum of 2 brass 9.5 mm (0.375 in) diameter flat washers shall be assembled to the bushing well stud to act as spacers. The maximum combined height of the spacer washers shall not exceed 4.0 mm (0.16 in). No lubrication shall be applied. A torsional force shall be applied to a 3/8-16 UNC brass heavy hex nut (ASTM F-467) assembled to the bushing well stud.

The four bushing wells shall withstand the stud torque specified in 6.7 without fracture or stripping.

7.20 Thermal cycle withstand test

The purpose of this test is to demonstrate that non-elastomeric separable connector components can withstand the stresses of an accelerated thermal cycle test.

Bushing well and reducing tap well samples shall be thermal cycled with mating parts installed.

Ten thermal cycles shall be conducted in air. The temperature cycles shall comply with the thermal cycle profile shown in Figure 22. The temperature extremes shall have a tolerance of $\pm 5^\circ\text{C}$.

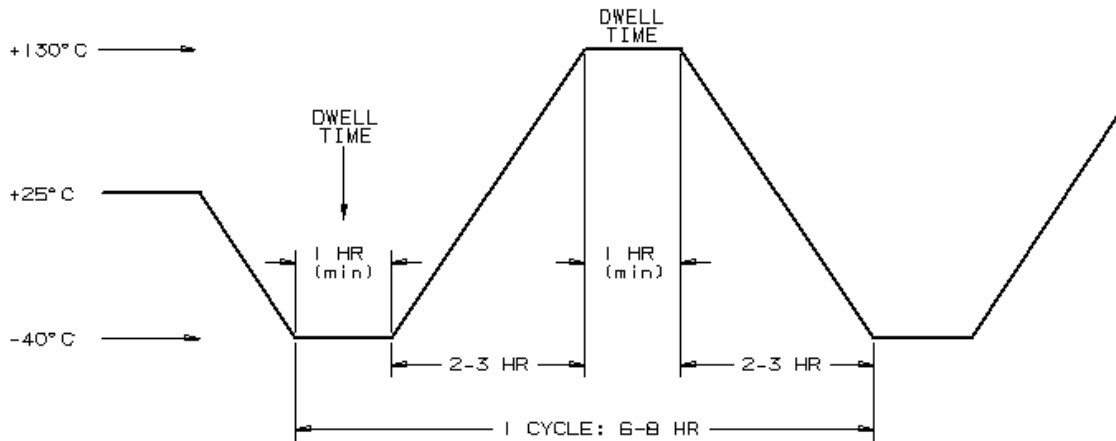


Figure 22—Thermal cycle profile

After completion of the thermal cycles the non-elastomeric components shall be tested to the applicable dielectric withstand test levels for the following:

- Partial discharge test 7.4
- AC withstand voltage 7.5.1

The aged mating parts may be replaced with new mating parts for the dielectric tests.

Ten samples shall withstand the thermal cycle test without cracking or breaking and shall meet the requirements of the corona voltage level and ac withstand voltage tests.

Annex A

(informative)

Trial use guide for testing of separable connector lubricants

A.1 Test for lubricants used on separable insulated connector interfaces

The purpose of these tests is to demonstrate that the lubricant used on the interfaces of separable insulated connectors will meet the electrical and mechanical requirements of this standard. The specified test requirements are intended to demonstrate that the lubricant is acceptable for application to all separable insulated connector components.

A.2 Operating force test

The purpose of this test is to demonstrate that interfaces of separable insulated connectors lubricated with a specific lubricant meet the operating force requirements as specified in 6.2.

The lubricant shall be applied to the mating interfaces of four 15.2/26.3 kV rated loadbreak elbow and bushing insert (Figure 7) assemblies. The amount of lubricant applied shall be as specified by the separable connector manufacturer.

Operating force tests shall be performed on the four connector assemblies per the specified procedures in 7.14.

The forces required to open and close the connector shall be within the range for loadbreak elbows specified in item a) of 6.2.

A.3 Accelerated aging test

The purpose of this test is to demonstrate that thermally aged separable insulated connectors lubricated with a specific lubricant are capable of being operated within the limits specified in this section.

The lubricant shall be applied to the mating interfaces of four 15.2/26.3 kV rated loadbreak elbow and bushing insert (Figure 7) assemblies. The amount of lubricant applied shall be as specified by the separable connector manufacturer.

An operating force test shall be conducted at $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ per the procedures specified in 7.14 to determine the initial opening value for each assembly.

The four elbow and bushing insert assemblies shall be reassembled and then placed in an oven having a temperature of $121\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and remain there for 20 weeks. The four samples shall then be removed from the oven and allowed to cool until they stabilize at $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$. An operating force test shall then be conducted per the procedures specified in 7.14 to determine the opening force value for each assembly.

The four sample average of the opening force at $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ shall not exceed 1334 N (300 lbf).

The lubricant should also be evaluated by testing the cold temperature (i.e., $-20\text{ }^{\circ}\text{C}$) operating forces of aged connectors. At this time insufficient data is available to establish test requirements.

A.4 Dielectric tests

The purpose of this test is to demonstrate that interfaces of separable insulated connectors lubricated with a specific lubricant meet the electrical requirements of this standard.

The lubricant shall be applied to the mating interfaces of ten 15.2/26.3 kV rated loadbreak elbow and bushing insert (Figure 7) assemblies. The amount of lubricant applied shall be as specified by the separable connector manufacturer.

The ten connector assemblies shall be tested to the applicable dielectric withstand levels for the following:

- Partial discharge test 7.4
- AC withstand voltage 7.5.1
- DC withstand voltage 7.5.2
- Impulse withstand voltage 7.5.3

All ten assemblies shall meet the electrical requirements for a 15.2/26.3 kV connector system as specified in Table 1.

A.5 Switching test

The purpose of this test is to demonstrate that the switching performance of loadbreak separable insulated connectors is maintained when a specific lubricant is applied to the mating interfaces. Grease formulations having dimethyl or phenyl silicone base oils are exempt from the switching test requirement. This exception is based on the over 30 years of acceptable switching performance of loadbreak connectors lubricated with silicone greases.

The lubricant shall be applied to the mating interfaces of 15.2/26.3 kV rated loadbreak elbow and bushing insert (Figure 7) assemblies. The amount of lubricant applied shall be as specified by the separable connector manufacturer.

The connector assemblies shall be switched per the specified procedures of 7.7.

Ten consecutive connector assemblies out of a maximum of 30 samples shall meet the switching requirements as specified in 7.7 when closing and interrupting the rated switching current given in Table 2.

A.6 Compatibility

The manufacturer shall demonstrate that the lubricant is compatible with the separable connector and cable materials. The dielectric strength, dielectric constant, dissipation factor, volume resistivity, and elongation properties shall be considered.

A.7 Physical properties

The purpose of this list is to serve only as a guide for the physical properties generally required of a lubricant intended for use on the mating interfaces of separable connectors. Approval of a lubricant is achieved by demonstrating compliance with the requirements detailed in A.1 through A.6.

Table A.1—Lubricant properties

Physical property	Value	Test method
Temperature range	−40 °C to +150 °C	
Penetration (worked 60 times)	260 to 300 at 25 °C 220 to 300 at −20 °C	ASTM D1403-97 [B4]
Dielectric strength (minimum)	500 V/mil	ASTM D149-97 [B1]
Volume resistivity (minimum)	1×10^{13} Ω-cm	ASTM D257-99 [B3]
Dielectric constant	2.5 to 4.0 at 2kHz	ASTM D150-98 [B2]
Dissipation factor (maximum)	0.007 at 1kHz	ASTM D150-98 [B2]
Bleed (maximum)	6%	FTM 791-321.3-1986 [B6] 100 °C for 1000 h
	6%	ASTM D1742-94 [B5] IP121 100 g wt. 40 °C for 1000 h
Evaporation (maximum)	6%	FTM 791-321.3-1986 [B6] 100 °C for 1000 h

Annex B

(informative)

Operating interface ac withstand test

This test is applicable to loadbreak connectors only. The procedure defined in this annex is for 25 kV class connectors. For 35kV class connectors, the manufacturer shall report the test procedure, test levels, and conditions used.

The purpose of this test is to demonstrate that loadbreak separable connectors are capable of performing an opening operation under high operating force, low temperature, elevated voltage, and zero load current conditions without a flashover to ground. 200 A loadbreak connectors designed to prevent partial vacuum induced switching flashovers shall pass the requirements of this test.

If necessary, the 200 A operating interfaces can be cleaned with a laboratory grade of isopropyl alcohol (2-propanol). After cleaning, the samples shall dry for a minimum of 15 min before assembly to ensure the cleaning solvent has evaporated from the interface.

Further preparation of the samples shall follow Option A or Option B.

- *Option A:* The 200 A operating interfaces shall be free of any lubrication. Assemble 16 loadbreak elbows with test cable installed and 16 insulated caps onto bushing inserts at an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$.
- *Option B:* The 200 A operating interfaces shall be lubricated according to the manufacturer's instructions with the complete contents of the packet of silicone grease supplied with the elbow or insulated cap. Assemble 16 loadbreak elbows with test cable installed and 16 insulated caps onto bushing inserts at an ambient temperature of $25\text{ °C} \pm 5\text{ °C}$. Heat age all samples at $120\text{ °C} \pm 5\text{ °C}$ for three weeks.

The preparation and aging option used shall clearly be identified in the test report. After Option A or Option B, chill the connector assemblies in a cold chamber at -20 °C to -25 °C for a minimum of 16 h. For 12 of the 16 samples of each type, remove one connector assembly at a time from the cold chamber and mount the assembly to a grounded test stand. Attach ground leads to the external shields of the connector. Adjacent grounds are not required.

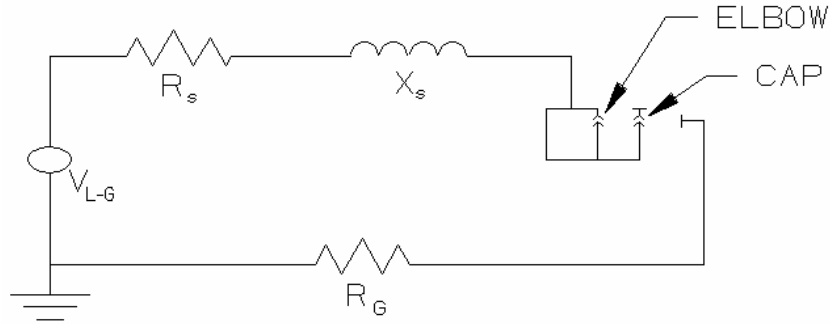
The test circuit parameters shall be in accordance with Figure B.1. Actual circuit parameters used shall be reported.

Separate the elbow (or insulated cap) of the connector assembly from the bushing within 10 min after removal from the cold chamber. The opening operation shall be performed with a positive continuous motion applied manually or by a mechanical actuator with an average operating speed during the initial 2.5 cm (1.0 in) of travel of $89\text{ cm/s} \pm 13\text{ cm/s}$ ($35\text{ in/s} \pm 5\text{ in/s}$). The force shall be applied to the operating eye of the connector using a suitable live-line tool or equivalent device.

Each of the 12 consecutive connector assemblies shall withstand one opening operation under the specified conditions without flashover to ground or impairment of the connector's ability to meet the other requirements of this standard.

The connector component designed to prevent partial vacuum switching flashovers must also demonstrate the ability to meet the requirements of this test when tested with mating components from other manufacturers.

Measure the opening force of the four remaining samples of each type. Within 10 min after removal from the cold chamber, a force shall be applied to the operating eye parallel to the axis of the probe at a rate of 13 cm/s (5 in/s). The average opening force for the four samples shall be between 1334 N and 2224 N (300 lbf and 500 lbf).



Circuit Parameters

$$V_{L-G} = 1.75 \times \text{rated line-to-ground voltage, minimum}$$
$$Z_S = R_S + X_S$$
$$X_S / R_S = 5.0 - 7.0$$
$$Z_S \geq 0.10 \times R_G$$
$$I_F = V_{L-G} / (Z_S + R_G) \geq 50A$$

Figure B.1—Circuit diagram for operating interface dielectric test

Annex C

(informative)

Bibliography

[B1] ASTM D149-97, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.

[B2] ASTM D150-98, Standard Test Method for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation.

[B3] ASTM D257-99, Standard Test Methods for DC Resistance or Conductance of Insulating Materials.

[B4] ASTM D1403-97, Standard Test Methods for Cone Penetration of Lubricating Grease Using One-Quarter and One-Half Scale Cone Equipment.

[B5] ASTM D1742-94, Standard Test Method for Oil Separation from Lubricating Grease During Storage.

[B6] FTM 791-321.3-1986, Federal Test Method for Oil Separation from Lubricating Grease (Static Technique).

[B7] IEEE 100™, The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition.^{8,9}

[B8] IEEE Std 1210™-1996, Standard Tests for Determining Compatibility of Cable Pulling Lubricants with Wire and Cable.

[B9] IEEE Std 1215™-2000, IEEE Guide for the Application of Separable Insulated Connectors.

[B10] IEEE Std C37.09™-1999, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

[B11] IEEE Std C62.11™-1999 (Reaff 1994), IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits

[B12] NEMA CC4-1986 (R1992), 8.3 kV and 8.3/14.4 kV Probe for Separable Insulated Loadbreak Connectors.¹⁰

[B13] Weitz, G. C., "Recommendations for the evaluation of alternative solvents used for electrical cable cleaning," *IEEE/PES Transmission and Distribution Conference and Exposition Proceedings*, Los Angeles, CA, pp. 667–671, Sept. 15–20, 1996.

⁸ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁹ The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

¹⁰ NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).