

**IEEE Standard Design Tests
for High-Voltage Fuses, Distribution
Enclosed Single-Pole Air Switches, Fuse
Disconnecting Switches, and Accessories**

Sponsor
**Switchgear Committee
of the
IEEE Power Engineering Society**

Secretariat
**Institute of Electrical and Electronics Engineers, Inc
National Electrical Manufacturers Association**

Approved March 10, 1988
IEEE Standards Board

© Copyright 1989 by

**The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017-2394, USA**

*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 Technical Committees of the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Board. Members of the committees serve voluntarily and without compensation. They are not necessarily members of the Institute. The standards developed within IEEE represent a consensus of the broad expertise on the subject within the Institute as well as those activities outside of IEEE which have expressed an interest in participating in the development of the standard.

Use of an IEEE Standard is wholly voluntary. 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 once 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.

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.

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 all 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 technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE Standards Board
345 East 47th Street
New York, NY 10017
USA

IEEE Standards documents are adopted by the Institute of Electrical and Electronics Engineers without regard to whether their adoption may involve patents on articles, materials, or processes. Such adoption does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the standards documents.

Foreword

(This Foreword is not a part of ANSI/IEEE C37.41-1988, IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.)

This standard is a revision of ANSI C37.41-1981 to bring it up to date and in line with present day requirements for high-voltage fuses and switches. The expanded coverage of interrupting tests for Distribution Cutouts, Power Fuses and Current Limiting Fuses broadens its applicability.

This standard was prepared by the IEEE Subcommittee on High-Voltage Fuses with cooperation from the C37 Subcommittee on High-Voltage Fuses and NEMA.

This standard is one of a series of complementary American National Standards covering various types of high-voltage fuses and switches, so arranged that certain of the standards apply to all devices while each of the other standards provide additional specifications for a particular device. For any device ANSI/IEEE C37.40-1981, ANSI/IEEE C87.41-1981 plus the additional standard covering that device constitute a complete standard for the device. In addition, ANSI/IEEE C37.48-1987 is an application, operation, and maintenance guide for all the devices.

The following American National Standards make up this series:

ANSI/IEEE C37.40-1981 (1987), Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories

ANSI/IEEE C37.41-1988, Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories

ANSI C37.42-1981 (R 1987),¹ Specifications for Distribution Cutouts and Fuse Links

ANSI C37.44-1981 (R 1987), Specifications for Distribution Oil Cutouts and Fuse Links

ANSI C37.45-1981 (R 1987), Specifications for Distribution Enclosed Single-Pole Air Switches

ANSI C37.46-1981 (R 1987), Specifications for Power Fuses and Fuse Disconnecting Switches

ANSI C37.47-1981 (R 1987), Specifications for Distribution Fuse Disconnecting Switches, Fuse Supports, and Current Limiting Fuses

ANSI/IEEE C37.48-1987, Guide for Application, Operation, and Maintenance of Distribution Cutouts and Fuse Links, Secondary Fuses, Distribution Enclosed Single-Pole Air Switches, Power Fuses, Fuse Disconnecting Switches, and Accessories

The American National Standards Committee on Power Switchgear, C37, which reviewed and approved this standard, had the following personnel at the time of approval:

W. E. Laubach, *Chairman*

A. K. McCabe, *Executive Vice-Chairman, High Voltage*

D. L. Swindler, *Executive Vice-Chairman, IEC*

S. H. Telander, *Executive Vice-Chairman, Low Voltage*

C. H. White, *Secretary*

M. B. Williams, *Program Administrator*

<i>Organization Represented</i>	<i>Name of Representative</i>
Association of Iron and Steel Engineers	J. M. Tillman
Electric Light and Power Group	G. R. Brandenberger (Alt)
	T. E. Bruck (Alt)
	R. L. Capra
	H. D. Hendrix
	D. T. Weston
	D. A. Ditzler
	J. M. Provanzana
	D. E. Soffrin (Alt)
Institute of Electrical and Electronics Engineers	S. C. Atkinson (Alt)
	W. F. Hoenigman
	D. G. Kumbera (Alt)
	D. M. Larson
	H. W. Mikulecky
	E. W. Schmunk
	L. A. Schwalbe
National Electrical Manufacturers Association	T. C. Burtnett
	R. A. McMaster
	R. H. Miller
	H. L. Miller (Alt)
	R. O. D. Whitt
Testing Lab Group	L. Frier
	W. T. O'Grady
	R. W. Seelbach (Alt)
Tennessee Valley Authority	R. B. Rotton
U.S. Department of the Army	W. M. Jones
U.S. Department of the Navy	R. L. Clark
U. S. Department of the Interior, Bureau of Reclamation	J. W. Reif
U. S. Department of Agriculture	H. L. Bowles
Western Area Power Authority	G. D. Birney

The High-Voltage Fuse Subcommittee that prepared and approved this Standard had the following personnel:

J. R. Beard, *Chairman*

C. J. Ahrano
R. H. Arndt
J. J. Burke
C. J. Burland
R. F. Burnett
F. Calderon
F. L. Cameron
R. L. Capra
C. S. Cleale
W. R. Crooks

H. E. Foelker
C. C. Hamerla
S. F. Hassler
M. Hirakami
W. J. Huber
D. H. Klohr
T. S. Lauber
J. R. Marek
H. W. Mikulecky
F. J. Muench
V. N. Narancic

J. G. Leach, *Secretary*

H. M. Pflanz
R. Ranjan
H. R. Reid
H. F. Reynolds
T. E. Royster
W. R. Rueth
J. G. St. Clair
E. W. Schmunk
H. E. Swanson
A. C. Westrom

When the IEEE Standards Board approved this standard on March 10, 1988, it had the following membership:

Donald C. Fleckenstein, *Chairman*

Marco Migliaro, *Vice Chairman*

Andrew G. Salem, *Secretary*

Arthur A. Blaisdell
Fletcher J. Buckley
James M. Daly
Stephen R. Dillon
Eugene P. Fogarty
Thomas L. Hannan
Kenneth D. Hendrix
Theodore W. Hissey, Jr

Jack M. Kinn
Frank D. Kirschner
Frank C. Kitzantides
Joseph L. Koepfinger *
Irving Kolodny
Edward Lohse
John E. May, Jr
Lawrence V. McCall

L. Bruce McClung
Richard E. Mosher
L. John Rackine
Gary S. Robinson
Frank L. Rose
Helen M. Wood
Karl H. Zaininger
Donald W. Zipse

*Member Emeritus

Contents

SECTION	PAGE
1. Scope and References	7
1.1 Scope	7
1.2 References	7
2. Design Tests	7
3. Common Test Practices	10
3.1 General Test Conditions	10
3.2 Condition of Device to be Tested	10
3.3 Mounting of Specimen and Grounding	10
3.4 Frequency and Wave Shape of Test Voltage	10
4. Dielectric Tests	10
4.1 Test Practices	10
4.2 Test Procedures	11
5. Expendable Cap Static Relief Pressure Tests	12
5.1 Test Practices	12
5.2 Test Procedure	12
6. Interrupting Tests	12
6.1 Test Practices	12
6.2 Test Samples	12
6.3 Characteristics of the Test Circuit	12
6.4 Determination of Available Short-Circuit Current of Test Circuit	13
6.5 Tests on the Device	17
6.6 Description of Interrupting Performance Tests	17
6.7 Condition After Interrupting Performance Tests	22
6.8 Tests for Current-Limiting Fuses in Enclosures	23
7. Load-Break Tests	24
7.1 Test Practices	25
7.2 Test Procedure	25
7.3 Condition of Device After Test	25
8. Making Current Tests (Oil Fuse Cutouts)	26
8.1 Test Practices	26
8.2 Test Procedure	26
9. Radio-Influence Tests	26
9.1 Test Practices	26
9.2 Test Equipment and Procedure	27
9.3 Interpretation of Tests	27
10. Short-Time Current Tests	27
10.1 Test Practices	27
10.2 Test Procedures	28
11. Temperature-Rise Tests	28
11.1 Test Practices	28
11.2 Test Procedure	28
12. Time-Current Tests	29
12.1 Test Practices	29
12.2 Test Procedures	29
12.3 Presentation of Data	30
13. Mechanical Design Tests for Distribution Cutouts	30

SECTION	PAGE
13.1 Mechanical Operation Tests for Distribution Open Fuse Cutouts Under New, Clean Conditions	30
13.2 Thermal Cycle Tests for Distribution Open Fuse Cutouts	30
13.3 Torque Test	31

FIGURES

Fig 1 Alternate Test Circuit for Series 3 Test on Current-Limiting Fuses	21
Fig 2a Typical Lagging Power Factor Test Circuit	25
Fig 2b Typical Leading Power Factor Test Circuit	25

TABLES

Table 1 Design Tests	8
Table 2 Interrupting Performance Tests — Power Fuses (Except Current-Limiting)	9
Table 3 Interrupting Performance Tests — Power Fuses (Except Current-Limiting) (Use with Table 2)	13
Table 4 Minimum X/R Ratio for Test Series 5 for Power Fuses (Except Current-Limiting)	13
Table 5 Interrupting Performance Tests — Single-Voltage-Rated Distribution Cutouts (Except Oil Cutouts and Open Link Cutouts)	14
Table 6 Interrupting Performance Tests — Single-Voltage-Rated Distribution Cutouts (Except Oil Cutouts and Open Link Cutouts) (Use with Table 5)	15
Table 7 Minimum X/R Ratios for Distribution Cutout Interrupting Tests	15
Table 8 Interrupting Performance Tests — Slant-Voltage-Rated (Multiple-Voltage-Rated) Distribution Cutouts	16
Table 9 Interrupting Performance Tests — Slant-Voltage-Rated (Multiple-Voltage-Rated) Distribution Cutouts (Use with Table 8)	17
Table 10 Interrupting Performance Tests — Current Limiting Power and Distribution Fuses	18
Table 11 Interrupting Performance Tests — Current-Limiting Power and Distribution Fuses (Use with Table 10)	19
Table 12 Size and Length of Bare Conductors for Specified Tests	19
Table 13 Interrupting Test Requirements for a Homogeneous Series of Fuse Units	20

APPENDIXES

Appendix A Recommended Methods for Determining the Value of a Sinusoidal Current Wave and a Normal-Frequency Recovery Voltage	33
Appendix B Recommended Method for Determining the Equivalent Steady-State RMS Current for Plotting Time-Current Curves	37
Appendix C Simplified Fault Current Calculation	38
Appendix D Transient Recovery Voltage Parameters	39

APPENDIX FIGURES

Fig A1 Method for Determining the RMS Value of a Symmetrical Sinusoidal Wave	33
Fig A2 Method for Determining the RMS Value of an Asymmetrical Sinusoidal Wave	33
Fig A3 Chart for Determining the RMS Value of an Asymmetrical Sinusoidal Wave	34
Fig A4 A Scale for Measuring the RMS Value of an Asymmetrical Sinusoidal Wave	35
Fig A5 Curves for Determining from a Single Loop of a Displaced Sinusoidal Wave, the RMS Value of the Wave Integrated over a Complete Cycle or over the Single Loop	36
Fig A6 Determination of Normal-Frequency Recovery Voltage	36
Fig C1 Relation of X/R Ratio to Multiplication Factor	38
Fig D1 Typical Test Circuits	40
Fig D2 Peak Factor Determination from Current-Injection Test Record	41
Fig D3 Peak Factor Determination from Fault-Interruption Test Record	42

IEEE Standard Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories

1. Scope and References

1.1 Scope. This standard applies to tests for high-voltage fuses (above 600 V), distribution enclosed single-pole air switches, fuse disconnecting switches, and accessories (for alternating-current distribution systems) as follows:

- (1) Enclosed, open, and open-link types of distribution cutouts and fuses
- (2) Distribution current-limiting fuses
- (3) Distribution oil cutouts
- (4) Distribution enclosed single-pole air switches
- (5) Power fuses, including current-limiting types
- (6) Outdoor and indoor fuse disconnecting switches
- (7) Fuse supports, fuse mountings, fuse hooks, fuse tongs, and fuse links, all of the type used exclusively with products listed in (1) through (6), above
- (8) Removable switch blades for products listed in (1) through (3), above

1.2 References. When the following American National Standards referred to in this standard are superseded by a revision approved by the American National Standards Institute, the revision shall apply.

[1] ANSI C37.42-1981, American National Standard Specifications for Distribution Cutouts and Fuse Links.¹

[2] ANSI C37.44-1981 (R 1987), American National Standard Specifications for Distribution Oil Cutouts and Fuse Links.

[3] ANSI C37.45-1981 (R 1987), American National Standard Specifications for Distribution Enclosed Single-Pole Air Switches.

¹ANSI publications are available from the Sales Department of the American National Standards Institute, 1430 Broadway, New York, NY 10018.

[4] ANSI C37.46-1981 (R 1987), American National Standard Specifications for Power Fuses and Fuse Disconnecting Switches.

[5] ANSI C37.47-1981, American National Standard Specifications for Distribution Fuse Disconnecting Switches, Fuse Supports, and Current-Limiting Fuses.

[6] ANSI C63.2-1987, American National Standard Specifications for Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 1 GHz.

[7] ANSI/IEEE C37.40-1981 (R 1987), IEEE Standard Service Conditions and Definitions for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories.

[8] ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.²

2. Design Tests

2.1 The design tests to be conducted upon completion of a design or following a change that affects the performance are specified in the following standards:

- ANSI C37.42-1981 (R 1987) [1]³
- ANSI C37.44-1981 (R 1987) [2]
- ANSI C37.45-1981 (R 1987) [3]
- ANSI C37.46-1981 (R 1987) [4]
- ANSI C37.47-1981 (R 1987) [5]

2.2 Table 1 summarizes these tests.

²ANSI/IEEE publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08854-1331.

³The numbers in brackets correspond to the references listed in 1.2 of this standard.

Table 1
Design Tests

Design Test Given in Following Sections of this Standard	ANSI C37.42-1981 [1]		ANSI C37.44-1981 [2]		ANSI C37.45-1981 [3]	ANSI C37.46-1981 [4]	ANSI C37.47-1981 [5]
	Distribution Enclosed, Open, and Open-Link Cutouts		Distribution Oil Cutouts		Distri- bution Enclosed Air Switches	Power Fuse Supports and Fuse Units	Distribution Fuse Supports and Current- Limiting Fuses
	Fuse Cutouts	Discon- necting Cutouts	Fuse Cutouts	Discon- necting Cutouts			
4 Dielectric	X	X	X	X	X	X	X
5 Expendable cap bursting test	Δ	—	—	—	—	—	—
6 Interrupting	X	—	—	—	—	X	X
7 Load break	X°	+	X	X	—	—	—
8 Making current	—	—	X*	—	—	—	—
9 Radio influence	X	X	X	X	X	X	X
10 Short-time current	—	X	—	—	X	—	—
11 Temperature rise	X	X	X	X	X	X	X
12 Time current	—	—	—	—	—	X	X

X Test required.

Δ Only on expensible caps for expensible cap cutouts.

† On open-link fuse only.

X* Only on load-break cutouts having means provided for breaking load currents.

X* The distribution oil cutout combines the functions of a current-interrupting and a load-switching device and thus requires making a current test.

Table 2
Interrupting Performance Tests — Power Fuses (Except Current-Limiting)
(Parameters of Test Circuits and Tests)

Parameters	Test Series					
	1	2(4)	3	4	5	6
Power frequency recovery voltage	87% of Rated Maximum +5% Voltage -0%					
Transient recovery voltage	Rated Maximum Voltage +5% -0%					
Prospective (available) current — rms symmetrical	See Table 3					
	Rated Interrupting Current +5% -0%	From 87% to 91% Rated Interrupting Current	From 60% to 70% Rated Interrupting Current	From 20% to 30% Rated Interrupting Current	From 400 A to 500 A (1) (2)	From 2.7 to 3.3 Times Link or Fuse Unit Rating (2)
X/R ratio (power factor)	X/R Not Less than 15; Power Factor Not More than 6.7%					
Making angle related to voltage zero — degrees	1st Test: From -5 to +15 2nd Test: From 85 to 105 3rd Test: From 130 to 150					
Current rating of fuse link or fuse unit	Mini- mum	Maxi- mum	Mini- mum	Maxi- mum	Mini- mum	Maximum
Number of tests	3	3	3	3	1	2
Number of tests on each fuse employing refill units or fuse links (3)	3	3	3	3	4	
Number of tests on each nonrenewable fuse	1	1	1	1	1	1
Duration of power frequency recovery voltage after interruption	Not Less than Dropout Time or 0.1 s, Whichever is Greater					
	Not Less than 10 min					
	Not Less than 1 min					

NOTES: (1) If the values are lower than those of Series 6, test Series 5 need not be made.
 (2) If the test involves a melting time appreciably higher than 2 s, the current may be increased to obtain a melting time of approximately 2 s.
 (3) After each test, the refill unit or fuse link and expendable cap (if used) shall be replaced. Any exhaust control device normally field replaceable shall be replaced as follows:
 Test Series 1, 2, and 3: Replace after each test
 Test Series 4, 5, and 6: Replace after each series of tests
 (4) If Series 1 tests are made at 100% of rated maximum voltage, Series 2 tests need not be made.
 (5) The transient recovery voltage for this test circuit shall be critically damped. Shunting the load reactance with a resistance having a value equal to approximately 40 times the value of the reactance is usually adequate to critically damp the circuit. However, if this value does not result in critical damping, the resistance can be reduced to achieve critical damping. For testing convenience, an oscillatory TRV may be acceptable with the agreement of the manufacturer. Critical damping is obtained when:

$$R = \frac{f_0}{2fn} X \quad \text{where}$$

$$f_0 = \text{natural frequency of test circuit without damping}$$

$$fn = \text{power frequency}$$

$$X = \text{reactance of the circuit at power frequency}$$

3. Common Test Practices

3.1 General Test Conditions. Test conditions prevailing at the test site shall conform to usual service conditions in accordance with 2.1 of ANSI/IEEE C37.40-1981 (R 1987) [7], except that temperature rise tests shall be conducted within the ambient temperature range of 10 °C (50 °F) to 40 °C (104 °F).

3.2 Condition of Device to be Tested. The device shall be new and in good condition, and tests shall be applied before the device is put into commercial service, unless otherwise specified.

3.3 Mounting of Specimen and Grounding

3.3.1 Mounting of Power Fuses. The fuse equipment shall be mounted on a structure in the normal service position or positions for which it is designed, and with the base grounded.

3.3.2 Mounting of Distribution Cutouts and Enclosed Air Switches. Distribution enclosed, open and open-link cutouts and enclosed air switches, shall be mounted on a wood crossarm which measures 8.9 cm × 11.4 cm (3½ in × 4½ in) in cross section and shall be mounted in the position normally used in service.

Distribution oil cutouts shall be mounted on a rigid structure in the position normally used in service.

3.3.3 Grounding of Distribution Cutouts and Enclosed Air Switches. The fuse mounting bracket or housing shall be grounded by a lead attached to the housing or to the mounting bracket on the side of the crossarm opposite the fuse support.

3.3.4 Lead Connections of Distribution Cutouts. The source side lead shall be connected to the upper terminal of the cutout and the load side lead to the lower terminal when interrupting tests are being performed.

3.4 Frequency and Wave Shape of Test Voltage

3.4.1 Normal-Frequency Tests. The frequency for all normal-frequency tests shall be either 50 Hz or 60 Hz with limits of plus or minus 2 Hz, except as otherwise specified. A sine wave of acceptable commercial standards shall be applied to the device. For definition of the wave shape see ANSI/IEEE Std 4-1978 [8].

3.4.2 Impulse Tests. The wave shape and application of the 1.2/50 μs full wave test voltage is described in ANSI/IEEE Std 4-1978 [8] and shall have the following limits for design tests.

The impulse test wave shall have a virtual front time equal to or less than 1.2 μs, a crest voltage equal to or exceeding the rated full wave impulse withstand voltage and a time to the 50% value of the crest voltage on the tail equal to or greater than 50 μs.

NOTES: (1) For fuses designed and tested prior to the time of issuance of this new requirement, the impulse voltage limit wave shape is 1.5/40 μs. The manufacturer has the option of assigning a 1.2/50 μs rating on the basis of a prior design test with a minus 20% tail tolerance (time to 50% of crest voltage). For fuses designed and tested after the issuance of the new requirement, the impulse voltage limit wave shape is 1.2/50 μs.

(2) In the event that laboratory limitations are encountered due to the capacitance of the test fuse, then the maximum rise achievable may be used if it is mutually acceptable to the user and the manufacturer.

4. Dielectric Tests

4.1 Test Practices. Dielectric test practices shall be as specified in Section 3 and as follows.

4.1.1 Electrical Connections

4.1.1.1 Distribution Enclosed, Open, and Open-Link Cutouts. Electrical connections shall be made by means of AWG No 6, or equivalent solid bare wire, inserted in each terminal.

4.1.1.1.1 Connector Dimensions. These bare wires shall project horizontally, at least 30.5 cm (12 in) from the terminals, in a straight line approximately parallel to the face of the crossarm or steel structure and in such a manner as not to decrease the withstand value. Any necessary bends may be made at the terminals. For enclosed cutouts (and air switches), the bare wires shall be located approximately in the center of the entrance holes.

4.1.1.1.2 Terminal-to-Ground Tests. The test lead connections shall be made to one of the wires projecting from the terminals and to all groundable metal parts, with the fuse holder, including the conducting element (fuse link) or equivalent, or the blade in the closed position.

4.1.1.1.3 Terminal-to-Terminal Tests. The test lead connections shall be made to the wire projecting from the top terminal, with wire to the bottom terminal grounded and with the fuse holder or blade in the open position. The hanger shall not be grounded as specified in 3.3.3.

4.1.1.2 Distribution Enclosed Air Switches. Electrical connections shall be made by means of an AWG 2/0, or equivalent stranded bare wire, inserted in each terminal.

The specifications in 4.1.1.1.1, 4.1.1.1.2, and 4.1.1.1.3 also apply to distribution enclosed air switches.

4.1.1.3 Distribution Oil Cutouts. Electrical connections shall be made by means of an AWG No 6, or equivalent solid bare wire, connected to each terminal, to the end of the full length of insulated cables furnished with the cutout, or to the end of an insulated cable attached to the terminal in accordance with the manufacturer's instructions. Entrance terminals requiring taping or compound filling shall be assembled and taped or filled in accordance with the manufacturer's instructions. The connections projecting from the cutout shall not approach the metal parts of the cutout closer than a projection of the center line of the entrance terminal. Insulated conductors shall terminate 30.5 cm or more (12 in) from any grounded metal member of the terminal or of a cable sheathing attached to the grounded metal member in the normal assembly thereof.

4.1.1.3.1 Terminal-to-Ground Tests. The test lead connections shall be made to one of the wires projecting from the terminals and to all groundable metal parts, with the fuse carrier, including the conducting element (fuse link) or the blade in the closed position.

4.1.1.4 Power Fuses and Fuse Disconnecting Switches. Power fuse electrical connections shall be made by means of a bare wire inserted in each terminal.

4.1.1.4.1 Conductor Position. These conductors shall project from the terminals of the fuse in substantially a straight line parallel to the fuse unit or fuse holder for an unsupported distance of at least the break distance of the fuse.

4.1.1.4.2 Terminal-to-Ground Tests. The test lead connections shall be made to one of the wires projecting from the terminals and to all groundable metal parts, with the fuse unit or fuse holder, including the conducting element (fuse link) or equivalent, or the switch blade in the closed position.

4.1.1.4.3 Terminal-to-Terminal Tests (Test for Break Distances to Demonstrate Ability to Withstand 10% Higher Voltage). The test lead connection shall be made to the wire projecting from the upper terminal, with the wire connected to the lower terminal grounded and with the fuse unit, fuse holder, or switch blade in one of the following positions:

- (1) For fuse disconnecting switches, in the fully open position
- (2) For dropout power fuses, with the fuse holder or fuse unit in the dropout position
- (3) For nondropout power fuses with the fuse holder or fuse unit removed from the support

A power fuse or fuse disconnecting switch rated 72.5 kV and above shall be equipped with standard strength insulator units, and one or more insulator units identical to those supporting the current-carrying parts, shall be added to each of the insulator supports or columns (only for the test).

A power fuse or fuse disconnecting switch rated 48.3 kV or below shall be mounted with its base insulated from a grounded metal structure by means of insulator units identical to those assembled on the fuse. In the case of a rear-connected indoor power fuse bus, support insulators of equivalent electrical characteristics shall be used to support the base (only for the test).

NOTE: Successful completion of these tests does not necessarily ensure that a fuse support or fuse disconnecting switch when open will always flashover to ground instead of across the open gap.

4.1.2 Temperature (See 3.1)

4.1.3 Measurement of Voltage. The voltage for dielectric tests shall be measured in accordance with ANSI/IEEE Std 4-1978 [8].

4.2 Test Procedures. Dielectric tests shall be conducted as follows.

4.2.1 Normal-Frequency Dry-Withstand Voltage Tests

4.2.1.1 Test Voltage and Time. The test voltage specified for the device, with appropriate atmospheric corrections, shall be applied to the specimen for 1 min without flashover or damage to the insulating material.

4.2.1.2 Voltage Application. Seventy-five percent of the rated dry-withstand voltage may be applied in one step and gradually raised to the required value in not less than 5 s and not more than 30 s.

4.2.1.3 Correction of Test Voltage to Standard Conditions. The specified withstand voltage as given for standard atmospheric conditions shall be corrected for the existing atmospheric conditions at the time of the test. This correction shall be made in accordance with ANSI/IEEE Std 4-1978 [8].

4.2.2 Normal-Frequency Wet-Withstand Voltage Tests on Outdoor Devices

4.2.2.1 Test Voltage and Time. The test voltage specified for the device, with appropriate atmospheric corrections, shall be applied to the specimen for 10 s without flashover or damage to the insulating material.

4.2.2.2 Precipitation. See 1.3.3 of ANSI/IEEE Std 4-1978 [8].

The water shall be projected downward toward the front of the device and at an angle of 45° to the vertical and horizontal planes of the crossarm so that the spray strikes equally on the front and on one side wall of the device.

4.2.2.3 Voltage Application. Seventy-five percent of the rated wet-withstand voltage may be applied in one step and gradually raised to the required value in not less than 5 s and not more than 30 s.

4.2.2.4 Correction of Test Voltage to Standard Conditions. The specified wet-withstand voltage shall be corrected to standard air density in accordance with ANSI/IEEE Std 4-1978 [8]. Corrections for relative humidity shall not be made on wet-withstand tests.

4.2.3 Normal-Frequency Dew-Withstand Voltage Tests on Indoor Devices

4.2.3.1 Test Voltage and Time. The test voltage specified for the device, with appropriate atmospheric corrections, shall be applied to the specimen for 10 s without flashover or damage to the insulating material.

4.2.3.2 Procedure. Thoroughly clean the insulation of the device. Place the cleaned device in a cold chamber (refrigerator) having temperature of -10 °C to -15 °C (14 °F to 5 °F) until it is thoroughly cooled (may take 10 h to 12 h). Then mount the device, as specified in 3.3, in a test chamber having a normal temperature of 22 °C to 25 °C (72 °F to 77 °F) and a humidity of approximately 100%. When the device is completely covered with dew, immediately apply the test voltage as specified in 4.2.3.1 and 4.2.3.3.

4.2.3.3 Voltage Application. Seventy-five percent of the rated dew-withstand voltage may be applied in one step and gradually raised to the required value in not less than 5 s and not more than 30 s.

4.2.3.4 Correction of the Test Voltage to Standard Conditions. The specified dew-withstand voltage shall be corrected to standard air density in accordance with ANSI/IEEE Std 4-1978 [8]. Correction for relative humidity shall not be made in dew-withstand tests.

4.2.4 Impulse-Withstand Voltage Tests

4.2.4.1 General. Withstand voltage tests are made to determine that the test specimen is capable of withstanding a specified impulse voltage without disruptive discharge.

4.2.4.2 Procedure. Withstand voltage tests shall be made with an impulse of that polarity (usually the positive) that produces the lower withstand voltage on the test specimen. Three consecutive impulses shall be applied to the test

specimen. The crest voltage of each shall be not less than the specified withstand voltage properly corrected.

4.2.4.3 Correction of Test Voltage to Standard Conditions. The specified impulse-withstand voltage as given for standard atmospheric conditions shall be corrected for the existing atmospheric conditions at the time of test. Such corrections shall be made in accordance with ANSI/IEEE Std 4-1978 [8].

4.2.4.4 Interpretation of Tests. If a disruptive discharge does not occur during any of the three consecutive impulses, the specimen shall be considered as having met the test. If two or three of the applied impulse waves cause disruptive discharge, the test specimen shall be considered as having failed the test. If only one of the three applied impulses causes disruptive discharge, three additional impulses shall be applied. If disruptive discharge does not occur on any of these three additional impulses, the specimen shall be considered to have met the test.

5. Expendable Cap Static Relief Pressure Tests

5.1 Test Practices. The test specimen shall be tested without a fuse link. It shall be mounted and a means provided for exerting a prescribed test pressure through the medium of a liquid.

5.2 Test Procedure. The test pressure shall be transmitted through the medium of a liquid and shall be exerted against the entire area of the pressure-responsive section.

6. Interrupting Tests

6.1 Test Practices. Interrupting test practices shall be as specified in Section 3 and as follows.

6.2 Test Samples. In making tests on renewable fuses use fuse links or refill units of the same manufacture as the fuses, fuse links, fuse holders or fuse units or as recommended by the manufacturer.

6.3 Characteristics of the Test Circuit. The interrupting tests shall be made on a single phase alternating-current circuit. The circuit elements used to control the current and X/R ratio shall be in series with each other and the fuse, except where damping resistors are allowed. The testing

Table 3
Use With Table 2: Interrupting Performance Tests — Power Fuses
(Except Current-Limiting)

Rated Maximum Voltage kV*	Inherent TRV Parameters of the Test Circuit			
	Test Series 1, 2, 3, 4		Test Series 5	
	kHz +10% -0% (f)	Peak Factor +10% -0% ①	kHz +10% -0% (f)	Peak Factor +10% -0% ①
2.8	8.5	1.4	38	1.45
5.5	6.0	1.4	29	1.55
8.3	4.7	1.4	19	1.65
15.5	3.2	1.4	18	1.65
25.8	2.1	1.4	12	1.65
38	1.6	1.4	8	1.65

* For rated maximum voltages above 38 kV, the TRV parameters of the test circuit are not specified. Appropriate values may be selected by mutual agreement between user and manufacturer.

$$\textcircled{1} \text{ peak factor} = \frac{\text{TRV peak in kV}}{\sqrt{2} \times \text{power frequency recovery voltage in kV} \times \sin(\arctan X/R)}$$

X/R is not less than 15 for test Series 1, 2, 3, 4
 X/R is value from Table 4 for test Series 5

NOTE: Peak factor should be determined based upon a symmetrical fault (symmetrical current):

$$\text{TRV envelope specified is 1-cos shape, with time-to-crest} = \frac{10^3}{2 \times f \text{ in kHz}} \mu\text{s}$$

$$\begin{aligned} \text{RRRV; volts/microsecond} &= \frac{\text{TRV peak}}{\text{time-to-peak}} \\ &= 2 \sqrt{2} \times \text{power frequency recovery voltage in kV} \times \sin(\arctan X/R) \times \text{peak factor} \times f \text{ in kHz} \end{aligned}$$

Table 4
Minimum X/R Ratio for
Test Series 5 for Power Fuses
(Except Current-Limiting)
(See Table 2)

Test Voltage (kV)	Minimum X/R Ratio
2.8	1.1
5.5	1.1
8.3	1.2
15.5	6.0
25.8	6.0
38.0	7.0
48.3	8.0
72.5	10.0
121.0	13.0
145.0	14.0
169.0	15.0

circuit frequency shall be rated frequency ± 2 Hz. If 60 Hz test facilities are not available, tests at 50 Hz ± 2 Hz are acceptable for verifying 60 Hz ratings.⁴

⁴ 50 Hz tests may produce lower peak let-through currents, but may let through more I^2t than 60 Hz tests.

The parameters of the test circuits are specified in Tables 5 through 13. Typical test circuits are shown in Appendix D, Fig D1, (a) and (b). Methods of determining TRV parameters are shown in Appendix D. Overvoltage protective equipment used on the test circuit shall be such that no sparkover occurs during the normal interrupting operation of the fuse.

6.4 Determination of Available Short-Circuit Current of Test Circuit. Short-circuit the device properly connected in the test circuit with a connection⁵ having negligible impedance and applying the power at the point of the voltage wave that produces maximum offset in the first loop. Where desirable, and where the circuit will be cleared within the first loop of available current, the power applied may be with reduced voltage. Where this is done, the available current shall be

⁵ A fuse link may be used as the short-circuiting means, provided it is of sufficient capacity so that melting does not occur in the first major current loop.