



IEEE Recommended Practice for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults

IEEE Power and Energy Society

Developed by the
Switchgear Committee

IEEE Std C37.20.7™-2024
(Revision of IEEE Std C37.20.7-2017)

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IEEE SA Standards Board

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Abstract: Procedures for testing and evaluating the performance of switchgear for internal arcing faults are covered by this recommended practice. A method of identifying the capabilities of this equipment is given. Service conditions, installation, and application of equipment are also discussed. As used in this document, the term *switchgear* is used as a general term covering switching and interrupting devices and their combination with associated control, instrumentation, metering, protective and regulating devices, assemblies of those devices with associated interconnections, accessories, and supporting structures used primarily in conjunction with the generation, transmission, distribution, and conversion of electrical power.

Keywords: accessibility, arc, arc-resistant, bus, compartment, IEEE C37.20.7™, internal arcing fault, medium-voltage controllers, metal-clad switchgear, metal-enclosed bus, metal-enclosed gas-insulated switchgear, metal-enclosed interrupter switchgear, metal-enclosed low-voltage power circuit breaker switchgear, metal-enclosed switchgear, motor control centers, overpressure, protection, switchboard

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Participants

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Dan Hrncir, *Chair*
John Kaminski, *Vice Chair*

Paul Barnhart	Keith Flowers	Eduardo Ramirez
Francis Beauchemin	Christopher French	Bettoni
David Beseda	Sahadev Gohil	Tony Ricciuti
Russell Boyce	Lou Grahor	Jeffery Ricker
Robert Burns	Jack Harley	Mark Roberson
Ted Burse	Ron Hartzel	Leonel Santos
Dan Busilan	Tom Hawkins	Todd Sauve
Eldridge Byron	Jared Hines	Victor Savulyak
Clint Carne	Jason Hollander	Garett Sims
Matthew Claxton	Chad Kennedy	Paul Sullivan
Bob Cohn	Mike Lafond	Donnie Swing
Fiori Coziuc	Henning Milnikel	Marcelo Valdes
Randall Creach	Darryl Moser	Michael Wactor
Federico Di Michele	Terry Neighbours	Matthew Westerdale
Doug Edwards	Owen Parks	Torsten Wirz
Michael Flack	Paul Rakus	Terry Woodyard
Sergio Flores		Mina Youssef

The following members of the individual Standards Association balloting group voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention.

Charles Ball	Gary Haynes	Sumitabha Pal
Thomas Barnes	Jared Hines	Bansi Patel
Paul Barnhart	Werner Hoelzl	Paul Rakus
Steven Bezner	Dan Hrncir	Samala Santosh Reddy
Russell Boyce	Richard Jackson	Pierre Riffon
Robert Burns	Laszlo Kadar	Ryandi Ryandi
Ted Burse	Uwe Kaltenborn	Leonel Santos
Paul Cardinal	John Kaminski	Todd Sauve
Nancy Chilton	John Kay	Bartien Sayogo
Robert Cohn	Thomas Keels	Oleksandr Sergeyenko
Fiori Coziuc	Yuri Khersonsky	Devki Sharma
Kurniawan Diharja	Boris Kogan	Garett Sims
Louis Doucet	Jim Kulchisky	Wayne Stec
Neal Dowling	Michael Lafond	Donald Swing
Edgar Dullni	Karl Lai	David Tepen
Donald Dunn	Chung-Yiu Lam	Truett Thompson
Douglas J. Edwards	Robert Lau	Wayne Timm
Tanner Esco	Wang Lei	Francois Trichon
Sergio Flores	Jeffrey Lord	John Vergis
Carl Fredericks	Colby Lovins	Lanyi Wang
Kamal Garg	Greg Luri	Jeffrey Ward
Shubhanker Garg	William McBride	John Webb
Sahadev Gohil	Kevin McGlown	Terry Woodyard
Lou Grahor	Darryl Moser	Dean Yager
Paul Hamer	Terry Neighbours	Mina Youssef
John Harley	Arthur Neubauer	Matthew Zeedyk
Thomas Hawkins	Joe Nims	Danish Zia

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Hao Hu
Yousef Kimiagar
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Howard Li
Xiaohui Liu
John Haiying Lu
Kevin W. Lu
Hiroshi Mano

Paul Nikolich
Robby Robson
Lei Wang
F. Keith Waters
Sha Wei
Philip B. Winston
Don Wright

*Member Emeritus

Introduction

This introduction is not part of IEEE Std C37.20.7-2024, IEEE Recommended Practice for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults.

This revision incorporates many changes to the 2017 version. Some of the changes are listed below, but it is recommended that the user review the document in its entirety.

- The first notable revision is the changing of this document from a *guide* to a *recommended practice*. By definition, a *guide* gives alternative approaches; this document gives a singular recommended approach for testing internal arc faults and, thus, better fits the *recommended practice* definition.
- Extensive work was completed to better define test sample configuration for equipment that will be installed over a volume of air. Examples include cable vault, cable tunnel, and so forth.
- The *Test current* subclause (5.3.4) added details on how to test equipment utilizing IEEE Std 386™ or EN-50181 cable terminations.
- In *Current-limiting devices* (5.3.6.3), additional details are given on the test requirements for these devices.
- *Burn indicator placement* (5.5.2) received significant changes as well, trying to more clearly define the requirements for the indicators and indicator stands. In this clause, several figures are added to more clearly communicate the required placement of the stands around many different configurations of test objects.
- Subclause 6.2.2 was added to *Test report* (6.2), describing additional information required in the test report for protective devices. Examples include: current-limiting fuses and interrupt switches. This also added additional information on the nameplate.
- In Annex C, a required label is defined that is to be applied to accessibility suffix B compartment doors or covers. In Annex L, additional details are given in *Calibration* (L.3.2.1).

The standards, recommended practice, and guides in the IEEE Std C37™ series⁶ have been developed over a period of many years through the cooperative efforts of users, specifiers, manufacturers, and other interested parties. The original development of the 2001 edition of this guide rests heavily on Annex AA of IEC 298-1981⁷ and Amendment 1: 1994.

In the 1970s, principally in Europe, interest in evaluating electrical equipment under conditions of internal arcing emerged. As a result, a draft Annex AA to IEC 298 “A.C. Metal-Enclosed Switchgear and Controlgear for Rated Voltages Above 1 kV and Up to and Including 52 kV” was issued by the IEC in 1981 and revised in 1990. It was redesignated IEC 62271-200 and revised in 2003 and 2011.

Subsequent to the creation of IEC 298, IEC subcommittee 17D issued Technical Report IEC/TR 1641 in 1996 (now redesignated as IEC/TR 61641) entitled “Enclosed Low-Voltage Switchgear and Controlgear Assemblies—Guide for Testing Under Conditions of Arcing Due to Internal Fault.”

Knowledge of the arc resistance testing guide in IEC 298 spread to North America, and it was used as the basis for EEMAC G14-1, 1987, “Procedure for Testing the Resistance of Metalclad Switchgear Under Conditions of Arcing Due to an Internal Fault.” EEMAC G14-1 incorporated improvements in knowledge and understanding in over a decade of use of Annex AA of IEC 298 in Europe.

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⁷IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

Failure within a switchgear assembly, whether from a defect, an unusual service condition, lack of maintenance, or misoperation, may initiate an internal arc. There is little likelihood of an internal arc in equipment meeting the requirements of IEEE Std C37.20.1™, IEEE Std C37.20.2™, IEEE Std C37.20.3™, IEEE Std C37.20.9™, IEEE Std C37.23™, UL 347, UL 845, or UL 891. There is even less likelihood of an internal arc in equipment that has insulated bus, compartmentalization, barriers, and interlocks, such as those described in IEEE Std C37.20.2; however, the possibility cannot be disregarded completely. The intent of this recommended practice is to address the testing procedure for internal arcing faults in switchgear.

Even when arc-resistant construction is specified, it is strongly recommended that supplemental power system protection be provided. This supplemental protection should limit the total energy that can be delivered in the event of internal arcing faults. This protection can be provided in a variety of ways, depending on the nature of the system. Among the forms of protection that may be appropriate are current-limiting fuses, current-limiting circuit breakers, zone differential or bus differential relaying, ground differential protection, or arc-sensing systems sensitive to light or pressure effects that accompany internal arcing faults. The objective of such protection is to cause the interruption of all sources of power to the arcing fault in a time interval that is shorter than the rated arcing duration capability demonstrated by the tests contained within this document (see 4.4).

In addition to supplemental power system protection, adequate personal protective equipment is required, as all hazards associated with an internal arcing fault are not eliminated when equipment tested to this recommended practice is used.

In this document, the term switchgear is used in its broadest sense (see definition of *switchgear* in [Clause 3](#)) and is not restricted only to equipment as described in IEEE Std C37.20.1, IEEE Std C37.20.2, or IEEE Std C37.20.3.

Contents

1. Overview	12
1.1 Scope	12
1.2 Word usage	12
1.3 Background	13
2. Normative references	16
3. Definitions	16
4. Ratings	18
4.1 General	18
4.2 Accessibility type	18
4.3 Internal arcing short-circuit current	18
4.4 Arcing duration	19
5. Tests	19
5.1 General	19
5.2 Test sample configuration (general considerations for all equipment)	19
5.3 Test conditions	21
5.4 Arc initiation	28
5.5 Burn indicators (for observing the thermal effects of gases)	29
6. Assessment	36
6.1 Assessment of test results	36
6.2 Test report	37
6.3 Nameplate	38
7. Application considerations	39
7.1 General	39
7.2 Potential areas for arcing	39
7.3 Design changes	39
7.4 Equipment maintenance	39
Annex A (informative) Bibliography	40
Annex B (informative) Application guide	41
Annex C (normative) Supplemental ratings	50
Annex D (normative) Metal-enclosed low-voltage power circuit breaker switchgear (IEEE Std C37.20.1) ..	53
Annex E (normative) Metal-clad switchgear (IEEE Std C37.20.2)	57
Annex F (normative) Metal-enclosed interrupter switchgear (IEEE Std C37.20.3)	61
Annex G (informative) Outdoor equipment	64
Annex H (normative) Motor control centers (UL 845)	69
Annex I (normative) Medium-voltage ac controllers (UL 347)	73
Annex J (normative) Switchboards (UL 891)	76
Annex K (normative) Metal-enclosed bus (IEEE Std C37.23)	80
Annex L (normative) Metal enclosed switchgear incorporating gas-insulating systems (IEEE Std C37.20.9) ..	87

IEEE Recommended Practice for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults

1. Overview

1.1 Scope

This recommended practice establishes methods by which equipment may be tested for resistance to the effects of arcing due to an internal fault. Equipment types covered in this recommended practice include metal-enclosed switchgear as defined by IEEE Std C37.20.1™, IEEE Std C37.20.2™, IEEE Std C37.20.3™ and IEEE Std C37.20.9™; metal-enclosed bus as defined by IEEE Std C37.23™; medium-voltage ac controllers as defined by UL 347; motor control centers as defined by UL 845; switchboards as defined by UL 891; and metal-enclosed medium-voltage air-insulated circuit breakers for outdoor application defined by IEEE Std C37.04™ (see note).⁸ This recommended practice applies only to equipment utilizing air or other insulating gas as the primary insulation medium and rated 52 kV ac or below. It applies to both indoor and outdoor equipment; however, special consideration should be given to the building size and construction for indoor applications (not fully addressed by this document).

The tests and assessments described in this recommended practice are only applicable to arcing faults occurring entirely in air within the enclosure when doors and covers are properly secured in accordance with the rated accessibility type. This recommended practice does not apply to arcing faults that occur within components of the equipment, such as instrument transformers, sealed interrupting devices, fuses, and so on.

Designs that meet the requirements of this recommended practice will be referred to as *arc-resistant*.

NOTE—These circuit breakers are sometimes referred to as dead-tank circuit breakers.⁹

1.2 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{10,11}

⁸Information on references can be found in [Clause 2](#).

⁹Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the recommended practice.

¹⁰The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

¹¹The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

1.3 Background

1.3.1 Consequences of internal arc faults

Switchgear is designed to withstand the worst-case mechanical forces between conductors, which occur when a short circuit occurs directly on the load terminals of the switchgear. This condition is referred to as a *bolted fault*, a short-circuit condition that assumes zero impedance exists at the point of the fault. The ability of switchgear to withstand the effects of the bolted fault is demonstrated in the short-time withstand current tests and the short-circuit current withstand tests as required by the specific equipment standard or the corresponding tests in the relevant standards for other equipment types. When a bolted fault occurs, the voltage at the fault is essentially zero, and the fault energy is dissipated throughout the entire system from the source to the fault location.

The occurrence of arcing inside switchgear produces a variety of physical phenomena that are very different from the bolted fault. For example, the arc energy that results from an arc developed in air or other insulating gas will cause a sudden pressure increase inside the enclosure and localized overheating. As a result, both severe mechanical and thermal stresses occur on the equipment. Moreover, the materials involved in or exposed to the arc may produce hot decomposition products, either gaseous or particulate, which may be discharged to the outside of the enclosure.

The procedures outlined in this recommended practice make it possible to evaluate the effect of abnormal internal pressure acting on properly latched or secured covers, doors, inspection windows, and so on. The procedures also take into consideration the thermal effects of the arc on the enclosure and of ejected hot gases and glowing particles.

1.3.2 Equipment qualified to this recommended practice

The use of equipment qualified to this recommended practice is intended to provide an additional degree of protection to the personnel performing normal operating duties in close proximity to the equipment while the equipment is operating under normal conditions. To qualify for an arc-resistant rating, the equipment shall fulfill the criteria in 6.1 of this recommended practice in any state that exists during the equipment's normal operations. For the purpose of this recommended practice, normal operations include duties such as opening or closing switching devices, connecting and disconnecting withdrawable parts, reading of measuring instruments and monitoring equipment, and so on. Therefore, if performing any normal operation requires that any cover be removed and/or any door be opened, the test described in Clause 5 shall be carried out with the cover and/or door removed. Removing or replacing active primary components (e.g., fuses or any other removable primary component) and activities required to carry out maintenance work are not considered to be normal operations.

Such equipment cannot ensure total personnel protection under all circumstances that may exist at the time of an internal arcing fault. Furthermore, it is not intended to provide this additional degree of protection to operating personnel who in the normal performance of their duties would be required to alter the equipment from its normal operating condition. The areas where an additional degree of protection is provided for each accessibility type are defined in 4.2. Access areas above or below the switchgear are not included. Examples

of personnel activities or installation conditions not covered by this recommended practice include, but are not limited to the following:

- a) Personnel on top of or above the switchgear for maintenance or cleaning
- b) Any activity requiring personnel to be elevated above the base level of the switchgear, that is, use of a ladder, lift, or on a catwalk
- c) Switchgear installed on an open grating
- d) Installations over a vault large enough for personnel to enter

Some guidance is given for testing where the switchgear is mounted over an open volume not belonging to the switchgear, for example, to allow access for cable entry. These inclusions address both closed-bottom switchgear construction, not reliant on the open volume for arc exhaust or pressure relief, and open-bottom switchgear construction, reliant on the open volume for arc exhaust or pressure relief, but do not address all possible configurations, nor do they imply that the area below the equipment is rated in any way for accessibility as described in [Clause 4](#).

Equipment qualified to this recommended practice does not ensure total protection to persons in the general vicinity of the equipment in the event of an internal arcing fault. The user is advised to review the information in the application guide found in [Annex B](#) and to follow the equipment manufacturer's installation instructions to assure proper equipment performance.

The selection of equipment qualified to this recommended practice does not imply protection from equipment damage or ensure continued operation without disruption to electrical service. It is expected that switchgear involved in an internal arcing fault will require rework or replacement before being returned to service.

The equipment qualified by this recommended practice is tested as a solidly grounded system to produce a maximum effect of circulating fault current within the test specimen metallic structure and ground bus. Equipment qualified by this recommended practice may be applied on solidly grounded, resistance, or reactance grounded, and ungrounded systems.

1.3.3 Application of this recommended practice

This recommended practice is intended to assist in the selection of applicable test points and test procedures to analyze equipment under the stress of an internal arcing fault. It is not intended to provide design information for the manufacture of arc-resistant switchgear.

This recommended practice is applicable to ac equipment only and does not address arcing in the dc equipment described in IEEE Std C37.20.1 or IEEE Std C37.23.

This recommended practice does not cover all effects that may constitute a risk, such as the release of toxic materials and excessive sound pressure, nor does it consider the effects on building construction (see [Annex B](#)).

The user should take into consideration the possibility of the emission of significant arc gases from the equipment in the event of an internal fault. Adequate provisions for dealing with these by-products should be considered.

As indicated in [1.1](#), this recommended practice addresses arc faults that occur entirely in air or an insulating gas within the enclosure, and it does not address abnormal arcing within components. This restriction is imposed by considerations of testing and practicality. Such component failures, especially liquid-filled components, are excluded because of the difficulty in designing tests that could be performed consistently. This restriction should not reduce the usefulness of results of tests conducted in accordance with this recommended practice

for evaluating the performance of switchgear, but it is recognized that failure of components may cause failure of the assembly to meet the assessment criteria of 6.1.

This document is classified as a *recommended practice* since use of this recommended practice is not mandatory for all equipment. However, when testing for resistance to internal arcing is required in accordance with this document, the requirements of this document are mandatory.

1.3.4 Relevance of tests

1.3.4.1 General

The arcing fault tests described in this recommended practice are intended to assist in assessing the ability of the equipment to withstand the effects of an internal arcing fault. It should be realized that it is not possible to simulate all conditions that can produce internal arcing faults in service and that the arc does not always behave in a repeatable manner. It follows that an assembly proven by such tests cannot be guaranteed to withstand all internal arcing faults that may occur in service.

1.3.4.2 Extension of design test results

The validity of the results of a test carried out in a functional unit of a particular design of switchgear can be extended to another one, provided that the original test was more onerous and the latter can be considered as similar to the one(s) tested in the following aspects, and can therefore be considered in the same “family of design”:

- a) Dimensions
- b) Structure and strength of the enclosure
- c) Partition architecture (see [Clause 3](#) for definition)
- d) Performance of the pressure-relief device, if any
- e) Insulation system

A test performed at a given voltage, current, and duration is generally valid for lower values of current, voltage, and duration except when the equipment is protected by a current-limiting device, where the device performance is sensitive to voltage and current. This does not imply that longer durations are possible at lower currents.

1.3.4.3 Extensibility of ratings

It is not possible to calculate the permissible arcing duration for a current that differs from that used in the test. The maximum pressure during the arcing event will generally not decrease with a shorter arcing time, and there is no agreed-upon rule according to which the rated arcing duration may be increased (by calculation) for applications with a lower fault current.

1.3.4.4 Components and accessories

The results of arcing fault tests described in this recommended practice apply to the overall switchgear system tested with various components in place. Components such as viewing panels, infrared windows, handles, relays and meters, specialized hardware, and so forth that are qualified by test on a single design are qualified only on that design to the extent described in 1.3.4.2 for a family of designs. The qualification of the component is not transportable to other designs unless it can be shown that all relevant parameters are equal to or better when compared to the original tested sample. The component itself cannot be deemed “arc-resistant” and, therefore, may not be applied in other designs outside the original family of designs without a qualifying analysis or additional testing.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std C37.04™, IEEE Standard for Ratings and Requirements for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V.^{12,13}

IEEE Std C37.20.1™, IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear.

IEEE Std C37.20.2™, IEEE Standard for Metal-Clad Switchgear.

IEEE Std C37.20.3™, IEEE Standard for Metal-Enclosed Interrupter Switchgear Rated above 1 kV AC up to and Including 48.3 kV AC.

IEEE C37.20.9™, IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems.

IEEE Std C37.20.10™, IEEE Standard for Definitions for AC (52 kV and below) and DC (3.2 kV and below) Switchgear Assemblies.

IEEE Std C37.23™, IEEE Standard for Metal-Enclosed Bus.

IEEE Std 386™, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Rated 2.5 kV through 35 kV.

UL 347, Medium-Voltage AC Contactors, Controllers, and Control Centers.¹⁴

UL 845, Motor Control Centers.

UL 891, Switchboards.

3. Definitions

For the purposes of this document, the following terms and definitions apply.

When multiple definitions exist, the definitions shall be evaluated in the following priority:

- a) Definitions embedded in this Standard shall be used.
- b) For terms not defined within this standard, the definitions within IEEE Std C37.20.10 shall be used.

¹²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

¹³The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

¹⁴UL publications are available from Underwriters Laboratories (<https://www.ul.com/>).

- c) For terms not defined in either this Standard or IEEE Std C37.20.10, the *IEEE Standards Dictionary Online* should be consulted.¹⁵

The definitions of terms contained in this standard, or in other standards referred to in this standard, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject matter treated in this standard.

applied insulation: Insulation that is conformal to the shape of the conductor, and bonded to the conductor in such a way that removal requires destroying or otherwise damaging the insulation. Typical examples of such insulations are epoxies or polymers applied by fluidized bed or liquid dip processes that are applied at the factory. Specifically excluded from this definition are tape and all types of boots or slip-on insulation that are field installed and/or removable in the field, and any field-applied spray-on insulation, conformal coatings, or shrink tubing.

arc-resistant switchgear: Equipment designed to withstand the effects of an internal arcing fault as indicated by successfully meeting the test requirements of IEEE Std C37.20.7™.

components: Any device connected to the primary circuit and intended for use within the confines of the switchgear enclosure. Examples include the main interrupting or switching device, voltage transformers, and control power transformers.

current-limiting circuit breaker: A circuit breaker that does not employ a fusible element and, when operating within its current-limiting range, limits the let-through I^2t to a value less than the I^2t of a half-cycle wave of the symmetrical prospective current.

floor: The level, relative to the foundation, at which the operator is standing during normal operation of the equipment.

foundation: The structure on which the equipment under test rests and that simulates the manufacturer's installation recommendations. At the discretion of the manufacturer, the equipment under test may be fastened to the foundation.

functional unit: Part of metal-enclosed switchgear that comprises all components of the primary and control circuits that contribute to the fulfillment of a single function.

NOTE—Functional units may be distinguished according to the function for which they are intended, for example, incoming unit or feeder unit.

internal arcing fault: An unintentional discharge of electrical energy in air or insulating gas within the confines of a switchgear enclosure.

internal arcing short-circuit current: The maximum value of the rms symmetrical prospective fault current applied to the equipment under conditions of an arcing fault for the rated arcing duration specified by the manufacturer.

isolated compartment: A compartment that is physically sealed from the effects of an internal arcing fault in adjacent compartments.

partition architecture: The physical arrangement of barriers or parts of the switchgear enclosure used for separating one compartment from other compartments or used to create any venting configurations for pressure relief.

¹⁵IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

pressure-relief device: Any opening, covered or uncovered that is designed to exhaust the overpressure from an internal arcing fault from the confines of the switchgear enclosure or specific compartment of the switchgear enclosure.

switchgear: A general term covering switching and interrupting devices and their combination with associated control, instrumentation, metering, protective and regulating devices, assemblies of those devices with associated interconnections, accessories, and supporting structures used primarily in conjunction with the generation, transmission, distribution, and conversion of electrical power.¹⁶

4. Ratings

4.1 General

An IEEE recommended practice cannot mandate or define equipment ratings. This recommended practice is intended to establish a level of performance for the equipment under specific conditions. Although these conditions are not an equipment rating, they are the basis of the equipment evaluation described in this recommended practice and are listed in the ratings clause for convenience.

4.2 Accessibility type

A distinction is made between two levels of accessibility to switchgear assemblies. These levels correspond directly to the burn indicator placement given in 5.5.2 and are as follows:

- *Type 1:* Switchgear with arc-resistant designs or features at the freely accessible front of the equipment only.
- *Type 2:* Switchgear with arc-resistant designs or features at the freely accessible exterior (front, back, and sides) of the equipment only.

The accessibility shall be designated by selecting the Type (either Type 1 or Type 2) and by adding the appropriate suffix to designate the specific performance features tested. For the basic test described in this recommended practice, a suffix of “A” is used, that is, Type 1A or Type 2A, to identify the basic rating. Additional performance features and the suffixes that designate them are found in Annex C.

4.3 Internal arcing short-circuit current

The internal arcing short-circuit current is the prospective fault current value to be used for testing. The preferred value of the internal arcing short-circuit current is the rated short-time current of the equipment. For equipment that does not have a rated short-time current, the preferred value for the internal arcing short-circuit current shall be the rated short-circuit current. Where fuses or current-limiting circuit breakers are intended to provide current-limiting protection for the equipment, it shall be noted that a protective device is required for this rating by a mark on the nameplate (see 6.3). Notwithstanding the aforementioned, the vertical section containing the current-limiting device shall be subject to the internal arcing short-circuit current testing procedure on the incoming terminals of the protective device to determine the maximum internal arcing short-circuit current for the vertical section with no protection. An additional test shall be made on the vertical section downstream from the protective device to determine the maximum internal arcing short-circuit current for the vertical section when the current-limiting device is not operating in its current-limiting range. The maximum internal arcing short-circuit current rating tested without the current-limiting device installed shall be noted on the nameplate (see 6.3).

¹⁶In this document, the term *switchgear* is used in its broadest sense and is not restricted only to equipment as described in IEEE Std C37.20.1, IEEE Std C37.20.2, or IEEE Std C37.20.3.

4.4 Arcing duration

The rated arcing duration is the period of time the equipment can experience the effects of an internal arcing fault and meet the requirements specified by this recommended practice in 6.1. Where the duration is limited by protective devices, those devices shall be identified on the equipment nameplate. See 5.3.6.3 and 5.3.6.4 for testing with device-limited current or duration and 6.3 for nameplate marking.

The preferred rated arcing duration for each type of equipment addressed by this recommended practice is found in the annex for the specific type of equipment.

Although any value of rated arcing duration is permitted, the minimum recommended duration is 0.1 s. It is generally considered unnecessary to test for durations longer than 1.0 s.

5. Tests

5.1 General

The general test arrangements and procedures are described in this clause. Details specific to a type of equipment covered by this recommended practice are found in the annex section for that type of equipment. Both the information found in this clause and the information found in the appropriate annex is required to define the test sample and perform the arc fault testing.

5.2 Test sample configuration (general considerations for all equipment)

In the choice of test specimen configuration, the following points should be considered:

- a) The test should be carried out on a compartment(s) not previously subjected to internal arcing.
- b) The mounting arrangements of the test specimen should be as prescribed by the manufacturer.
- c) The configuration of each vertical section should be as follows:
 - 1) The vertical section(s) should be fully equipped. Mockups of major internal components are permitted, provided they have the same volume and external material as the original items, and they do not affect the main and grounding circuits or improve the physical conditions within the test sample with regard to overpressure and gas leakage. It is not necessary to have every component used within a section represented; that is, stress cones, cables, and arresters may be omitted from the cable compartment if they do not provide significant reductions in volume or an impediment to venting. Mockups of switching devices in the current path for the compartment under evaluation are permitted only if they are as follows:
 - i) Use conductors and connections representative of those found on the switching device
 - ii) Are mounted or held in the enclosure in the same way as the switching device, and
 - iii) Have no modifications altering the potential gas escape points found in the actual device.

For example, a circuit breaker may be replaced with a dummy breaker with the same primary disconnecting devices and conductor size, racking mechanism, grounding means, and similar front cover. It is not necessary to have the full operating mechanism, components, wiring, interrupters, and so forth, found inside the circuit breaker housing.
 - 2) The compartments within the vertical section should be representative of the minimum volume used for the maximum size component and the maximum unbraced wall surface used by the design. The sample should contain the maximum amount of openings (total area) designed for equipment ventilation and the minimum amount of openings (total area) designed for arc fault pressure relief.

- 3) All ventilation openings used for equipment cooling and designed to close during an overpressure event shall be open and functional before starting the test.
- 4) If the equipment is intended for use with specific control devices, such as relays and meters, mounted on exposed doors or covers that are not for isolated compartments designated for low-voltage control or instrumentation, a representative sample or mockup of these devices should be present on the test specimen and the method of mounting any mockups should match the standard mounting method for the actual device.

If the design of the equipment is intended for use with a variety of control devices mounted on exposed doors or covers that are not for isolated compartments designated for low-voltage control or instrumentation, the conditions experienced during the tests on the exposed doors or covers shall be measured (pressure and deflection) for use in evaluating the suitability of devices to be located on those doors or covers.

See [Annex C](#) (suffix B) for an alternative test method for isolated compartments designated for instrumentation and control. For compartments tested to the requirements of suffix B or suffix C (see [Annex C](#)) and having no primary circuit components in the compartment, there are no further restrictions for components mounted on covers or doors of such compartments.

The equipment-specific annexes may also contain guidance on special treatment of isolated compartments designated for instrument and control devices.

- 5) Any openings created in the equipment as a result of manufacturing, assembly, or modification that have an intentional covering, plug, or similar device may have that device installed. Openings that do not have intentional coverings may not be blocked in any way for this test.
 - 6) Surfaces of components and the enclosure that are exposed to the arc should be finished using the surface-finishing methods (paint, plating, insulating materials, etc.) intended for service.
- d) The normal ground point(s) of the test specimen shall be connected to the test supply neutral through an adequate conductor; also see [5.3.2](#).
 - e) The arc should be initiated in a way that is representative of faults that could occur under service conditions and normal activities associated with the equipment. See [7.2](#) and the appropriate annex for typical locations for arc initiation.

For the purpose of this recommended practice, normal operating conditions means the conditions of metal-enclosed switchgear required to carry out operations, such as opening or closing switching devices, connecting and disconnecting withdrawable parts, reading of measuring instruments and monitoring equipment, and so on. Therefore, when normal operations require that any cover be removed and/or any door be opened in a compartment containing a primary circuit component, the test shall be carried out with the cover and/or door removed so it does not interfere with placement of burn indicators.

Removing or replacing active components (e.g., fuses or any other removable primary component) and activities required to carry out maintenance work are not considered to be normal operations.

- f) Whether the equipment is for indoor or outdoor installation, the test arrangement should simulate room or surrounding conditions in a manner that enables the manufacturer to provide application guidelines that consider the following:
 - 1) Distance to adjacent walls
 - 2) Ceiling height
 - 3) Any obstruction located near the equipment that may deflect hot gas into an area defined by the accessibility type
 - 4) Any openings beneath the equipment (e.g., for a cable vault) that may allow hot gas to escape into an area defined by the accessibility type:

If the design incorporates an exhaust system that will vent pressure directly out of the room, no room simulation is necessary.

The minimum extension past the perimeter of the enclosure for the test sample exhaust system shall be 2 m. When the duct is intended to have a cover, for weatherproof designs or segregation, this cover shall be present for the test. The duct cover is not considered part of the unit under test, but is required to verify the equipment functionality as the duct and cover may create venting restrictions that will influence the performance of the equipment.

- g) When the equipment employs a single expansion chamber intended to vent abnormal internal pressure from multiple compartments, the expansion chamber should be representative of the smallest volume chamber used by the design.
- h) Each variation in bus phase spacing (energized surface to energized surface) and clearance to ground (energized surface to grounded surface) should be tested in each compartment, except for configurations where only the size and/or quantity of bus changes. In these configurations, a representative enclosure may be tested using the smallest physical bus size to produce the greatest phase-to-phase and phase-to-ground clearances. If the greatest phase-to-phase and phase-to-ground clearances result in a premature extinction of the arc, the smallest clearances shall also be tested. See 5.3.3 and 5.3.6.2 for guidance in voltage selection and premature arc extinction requirements.
- i) In the case of switchgear consisting of extensible (modular) stand-alone units, the test specimen shall consist of two units connected together as in service. Testing shall be made in all compartments of the end of the switchgear adjacent to the burn indicators. However, if a substantial difference (to be declared by the manufacturer) in strength exists between the joining sides of adjacent units and the side forming the end of the switchgear, three units shall be used and the test of the different compartments shall be repeated in the central unit.

If tunnels or ducts are used to channel arc products across more than one vertical section before exiting the sample, one test shall be performed with an internal duct length of at least 2 m beyond the section in which the arc is initiated.

A stand-alone unit is an assembly that may contain within a single common enclosure one or more functional units in horizontal or vertical arrangement (tier).

- j) When the switchgear assembly employs blowers or fans to supplement convective air flow through a compartment for cooling purposes (i.e., forced ventilation), a single test shall be made as follows:
 - 1) For equipment with a rated maximum voltage greater than 1000 V, the fan(s) shall be operating and all associated ventilation shall be open.
 - 2) For equipment rated 1000 V or less, the fans shall be turned off and all ventilation in its normal (fan off) state.
- k) Viewing panes and similar devices that have a permanently mounted (hinged or bolted) protective cover required to be closed to maintain the arc-resistant rating shall have the cover in place and properly secured for these tests.

5.3 Test conditions

5.3.1 General

The tests should be performed as a three-phase test for three-phase equipment, except for tests on switchgear with segregated phases if no mutual influence between the segregated phase compartments is likely and on equipment utilizing cable terminations as defined by IEEE Std 386 or EN-50181. Single-phase devices should be tested phase to ground. Polyphase devices that are designed such that the phases do not share a common insulating medium and, therefore, cannot interact in an arcing fault may be tested as a single-phase device or as a polyphase device with each phase connected phase to ground. Three-phase devices using IEEE Std 386 or

EN-50181 cable terminations are tested utilizing a three-phase test source with the fault initiated between two of the three phases.

The test circuit is calibrated with prospective current. The current calibration location is based on the test voltage as follows:

- a) When the tests are performed at full voltage, the prospective test current calibration shall be made at the incoming terminals of the test sample or at the laboratory supply terminals (as indicated in 5.3.4).
- b) When the tests are performed at reduced voltage on equipment where the power circuit is contained in a sealed compartment or where the compartment under test is, at the discretion of the manufacturer, not readily accessible in a testing laboratory for placement of the calibration shorting bar and subsequent removal and replacement with the arc initiation wire, two samples may be used: The actual test sample in which the arc-initiation wire is placed at the appropriate location and a second sample for the current calibration whose primary circuit components are identical to the primary circuit components of the test sample. The shorting bar for calibration shall be placed at the closest point beyond the arc initiation point.

The physical size of the test sample can affect the current path and, therefore, the peak current delivered to the test point. The test sample size shall be limited as described in item i) of 5.2, or in the annex specific to that type of equipment, to reduce the effects of internal impedance.

Each compartment design of a vertical section containing a main circuit component and having an exposed front, back, or side to be assessed for a particular accessibility type shall be tested.

5.3.2 Supply circuit

The neutral of the supply system shall be grounded or connected to the ground bus of the switchgear assembly by a separate bus. If the neutral is grounded, the ground bus of the switchgear assembly shall also be grounded. If the neutral of the supply system is connected to the switchgear assembly by a separate bus, the switchgear assembly may be isolated from earth as required by the laboratory.

This requirement recognizes that test laboratories may not allow the flow of intentional ground fault current due to safety and/or instrumentation concerns.

These connections shall not materially alter the test conditions.

The test source shall be connected as follows:

- a) *For a cable compartment:* Supply from the bus, through the feeder switching device.
- b) *For a bus compartment:* The supply connections shall not introduce any opening in the compartment under test and are as follows:
 - 1) If barriers are fitted to create separated bus compartments between functional units, the supply shall be made through one barrier.
 - 2) If the bus compartment is common for the whole switchgear, the supply shall be made through the main switching device located at one end of the switchgear.
 - 3) In case of non-symmetrical designs of bus compartment, the most onerous internal arc initiation should be considered, with respect to arc energy and burn-through.
- c) *For the main switching device compartment:* Supply from the bus, with the device in closed position.

- d) *For a compartment with several main circuit components inside:* Supply through one available set of incoming connections, with all switching devices in closed position, except for grounding switches, if any, which shall be in open position.

5.3.3 Test voltage

The preferred value for test voltage is the rated maximum voltage of the equipment.

If the equipment has a dual voltage rating and contains voltage-sensitive components, both voltage ratings shall be tested.

Where full-voltage testing is not possible due to laboratory constraints, a reduced voltage may be used. To reduce the chances of premature arc extinction, the voltage chosen should be the highest possible voltage available at the required test current. It is suggested that the reduced value be no less than 60% of the rated maximum voltage for the equipment, however this will vary based on phase spacing, insulation medium, bus shape, etc., and lower voltages may provide acceptable results.

Reduced-voltage testing is not allowed as follows:

- a) For equipment rated 5 kV or lower.
- b) When the performance of the protective means utilized is voltage sensitive (example: current-limiting fuse).

5.3.4 Test current

5.3.4.1 Overview

For equipment designs capable of using either cable or bus as the line and load connections, the prospective short-circuit current is calibrated in accordance with [5.3.4.2](#).

5.3.4.2 Cable connection

For equipment using cable only as the line and load connections, it may not be practical to apply a shorting bar at the entrance to the equipment. In this case, the prospective short-circuit current may be calibrated at the laboratory supply terminals as follows:

- a) For tests at rated maximum voltage, where the cables used as the incoming connection (from the laboratory supply terminals to the sample) are no longer than 2.4 m (8 ft) and are as follows:
 - 1) The circuit is rated 25 000 A or less, the calibration value of the prospective current shall be not less than 100% of the rated internal arcing short-circuit current when measured at the laboratory supply terminals.
 - 2) The circuit is rated between 25 001 A and 50 000 A, the calibration value of the prospective current shall be not less than 105% of the rated internal arcing short-circuit current when measured at the laboratory supply terminals.
 - 3) The circuit is rated between 50 001 A and 200 000 A, the calibration value of the prospective current shall be not less than 110% of the rated internal arcing short-circuit current when measured at the laboratory supply terminals.
- b) For tests at rated maximum voltage, where the cables used as the incoming connection (from the laboratory supply terminals to the sample) are longer than 2.4 m (8 ft), the following applies:
 - 1) The calibration value of the prospective current shall not be less than 100% of the rated internal arcing short-circuit current with a shorting bar connected to the end of incoming cables or other

location where appropriate bolted connection can be made with full length of cables included. If same set of cables cannot be used after calibration, a set of identical cables can be used for actual test(s) without repeating calibration.

- c) For tests made at reduced voltage on medium-voltage equipment connected using only cables for the line and load connections:
 - 1) Cables shall be applied to the outgoing terminals to the phases under test and shorted together at the ends. The cables may be shorted together using a shorting bar having equal or greater cross-sectional area as the cables.
 - 2) The calibration current value shall be at least 100% of the rated internal arcing short-circuit current for equipment.
- d) Compartments covered by Case 3 (5.4.2.4), that is, with IEEE Std 386 or EN-50181 cable terminations shall be tested using a three-phase circuit, with a two-phase fault initiated between two adjacent phases.
 - 1) Provisions for connection of the arc initiation wire are to be made as follows:
 - i) For outer-cone connections, the phase(s) to be tested shall be fitted with lugs without insulation.
 - ii) For inner-cone connections, the insulation directly below the cable plug(s) shall be perforated or partially removed, or bolt(s) shall be installed in the cones of the phase(s) to be tested.

The supply circuit shall be three-phase, with all three phases energized to allow the fault to become three-phase should it escalate.

The test current shall be calibrated for 87% of the rated internal arcing short-circuit current at the two phases where the arc will be initiated.

The actual current during the arcing test will be approximately 87% of the specified internal arcing short-circuit current, assuming that the arc does not evolve into a three-phase fault or a phase-to-ground fault.

Should the two-phase fault escalate to a three-phase fault, the test is deemed invalid and shall be repeated as a three-phase test at 100% rated internal arcing short-circuit current.

Following the test involving a two-phase fault on a three-phase circuit, an additional single-phase test shall be conducted. The arc shall be initiated between the phase nearest to grounded metal and ground. The test current shall be calibrated for 87% of the rated internal arcing short-circuit current.

- 2) The additional single-phase test is not required if the following two conditions are met:
 - i) The two-phase fault using a three-phase circuit evolves into a phase-to-ground fault, and the ground current is 20% or more of the calibrated current, and
 - ii) The ground bus (and the grounding switch if applicable) have been tested in accordance to 7.6 of IEEE Std C37.20.9-2019.

Once the circuit is calibrated, the shorting bars are removed and arcing tests are performed.

The test current parameters specific to each type of equipment and protective device utilized are found in the annex for the equipment type.

5.3.4.3 Calibration

The calibration current value (prospective current value) available to the test sample during calibration shall be the value of the internal arcing short-circuit current as specified in 4.3, comprising a peak and symmetrical component value. It is recognized that it may not be possible to deliver the exact values required due to the inherent characteristics of the test laboratory. When this is the case, the peak current level shall be met and the symmetrical value is allowed to be reduced with the test duration extended to obtain the required arc energy for the rating. The criteria for prospective current calibration are as follows:

- *AC component:* The short-circuit current for which the switchgear is specified with respect to arcing should be set to the desired internal arcing short-circuit current. The current should remain constant. If the capability of the test laboratory does not permit this, the test shall be extended until the integral of the ac component of the current is equal to (or greater than) the value specified by $I \times t$ (proportional to the arc energy) for the desired rating of internal arcing short-circuit current and arcing duration. The test duration may be extended to not more than 125% of the desired rated arcing duration.
- *DC component:* The instant of closing should be chosen so that the prospective value of the peak current flowing in one of the outer phases is the calculated peak value based on the rated internal arcing short-circuit current multiplied by the factor identified in the annex applicable to the product type.

The calibrated value shall not be less than the calculated peak current value. In the case of two-phase initiation of the arc, the instant of closing shall be chosen to provide the maximum possible dc component.

5.3.4.4 Actual test current

The actual current delivered to the test point will be reduced by the impedance of the arc and the test sample. If the voltage at the start of the test is lower than the maximum rated voltage, the arc shall not extinguish prior to the completion of the intended test duration (see 5.3.6 for exceptions and guidance on test duration).

5.3.5 Frequency of the test supply

The duration of the test should be considered when setting the frequency of the test current. The arc energy is significantly affected by frequency when the arc duration is less than 50 ms. Where fast-acting protective devices will limit the rated arcing duration (duration of test arc) to 50 ms or less, the frequency at the beginning of the test shall be the rated frequency of the equipment $\pm 10\%$ and the frequency should not decay by more than 8% over the test duration.

For a rated arcing duration greater than 50 ms, the frequency at the beginning of the test shall be the rated frequency of the equipment $\pm 20\%$. Frequency decay is not critical for testing with test durations greater than 50 ms.

5.3.6 Duration of the test

5.3.6.1 Overview

The duration of the test is the rated arcing duration (see 4.4). The preferred duration for this test is found in the annex for each equipment type.

Protective devices that limit current or duration may be applied in incoming compartments to protect the downstream compartments of the switchgear assembly. The compartment containing the incoming terminal of the protective device shall be tested at the rated internal arcing short-circuit current and the rated arcing duration in accordance with 5.3.6.2. Compartments on the load side of the protective device shall be tested in accordance with 5.3.6.3 and 5.3.6.4, based on the type of protective device. A designation shall be placed on the equipment nameplate indicating that the rating is achieved using a protective device (see 6.3).

5.3.6.2 No protective device

The fault current should flow for the intended duration at the rated power frequency (as described in 5.3.5) for the equipment.

The arc should not extinguish before the intended arcing duration for the test has elapsed. It is recognized that some equipment may incorporate design features intended to extinguish arcing at maximum rated voltage.

Should the arc in a test sample extinguish prior to completion of the rated arcing duration with the test voltage set in accordance with 5.3.3 to the maximum rated voltage of the equipment, the test is considered valid if the following conditions are met:

- a) The prospective test calibration current requirements of 5.3.4.3 are met.
- b) There are no other phase configurations for this design having smaller phase-to-phase or phase-to-ground clearances. This includes distance created by the insulation system. If there are configurations with smaller clearances, the test shall be repeated with the minimum clearance.

Should the arc extinguish prior to completion of the rated arcing duration with a reduced test voltage, a second test shall be performed at full voltage and reduced current for the same intended arcing duration. The calibration current during the second (reduced current) test shall be no less than 60% of the rated internal arcing short-circuit current. If the arc extinguishes prematurely and the extinguishing time is no longer than the extinguishing time of the first test plus one cycle, the first test is considered valid and the intended arcing duration may be applied for the original internal arcing short-circuit current value. The test voltage shall be maintained for the intended duration during both tests. The rated arc duration shall be marked with the abbreviation “SE” on the nameplate to indicate self-extinguishing, followed by the duration measured in the first test.

In the event that the repeat test fails to meet the performance criteria of 6.1, neither configuration shall be judged as having met the criteria for achieving the rating being demonstrated.

5.3.6.3 Current-limiting devices

5.3.6.3.1 Overview

Compartments or functional units protected by current limiting devices (see B.2.4.2) require multiple tests as indicated in 5.3.6.3.2, 5.3.6.3.3, and 5.3.6.3.4.

Depending upon the technology employed, it may be necessary to test the equipment completely as both a fuse (see 5.3.6.3.2) and as a current-limiting circuit breaker (see 5.3.6.3.3).

If the enclosure housing the protective device has not been previously tested to prove its arc fault rating, a test shall be performed on the enclosure in accordance with 5.3.6.2. This test shall be performed with the arc initiating wire across the incoming terminals of the protective device. A successful test validates the vertical section or compartment that contains the protective device.

NOTE—An enclosure containing a protective device that is not integral or close-coupled to the arc resistant enclosure under test need not be tested in accordance with 5.3.6.2.

5.3.6.3.2 Fuses

The fuse type that causes the highest cut-off current (let-through current) shall be used in Test 1 (see 5.3.6.3.4) and to determine the values for Test 2 (see 5.3.6.3.4). The tests shall be performed at the rated maximum voltage of the equipment. Further, the effects of using current-limiting devices that employ pyrotechnic means

to commutate current to a current-limiting fuse should be considered when developing test plans for equipment utilizing such devices.

The X/R ratio of the test circuit will be different based on the rated maximum voltage of the equipment. See the equipment specific annex for values.

5.3.6.3.3 Current-limiting circuit breakers

The device rating with the highest rated current shall be used in Test 1 (see 5.3.6.3.4) and to determine the values for Test 2 (see 5.3.6.3.4). The tests shall be performed at the rated maximum voltage of the equipment.

5.3.6.3.4 Testing with current-limiting devices

The test sample shall consist of two enclosure sections, equipped with the protective device in section 1 and the compartment under test in section 2.

For all configurations of vertical sections intended to be protected by the current-limiting device, Test 1 and Test 2 shall be performed as follows:

- *Test 1:* The laboratory connections shall be made in section 1. The test circuit shall be calibrated for the rated internal arcing short circuit current and for the preferred rated arcing duration found in the equipment annex. The actual current level and duration of the current flow will be controlled by the protective device.

The arc initiating wire shall be placed in the enclosure under test at the locations described in the specific equipment annex. The current shall flow until the protective device operates. The supply voltage shall be maintained for the full duration of the preferred rated arcing duration for the specific type of equipment.

- *Test 2:* The arc energy released during longer duration tests may not be predictable by short-circuit I^2t values published by the fuse manufacturer. In the case of current limiting fuses, the maximum arc energy may occur at current levels below the maximum interrupting rating.

To test for greater arc energy conditions that may occur when current-limiting devices are used, an additional test shall be conducted. The intent of this test is to subject the equipment to a combination of current and time that falls on the time-current curve below the current-limiting mode or to the left of the time-current curve, typical of the values that could be experienced in operation. Combinations of current and time that fall to the right of the time-current curve are outside the scope of this testing.

The prospective test current shall be calibrated to a +5%/–0% tolerance for the current value obtained from the device time-current characteristic curve for the maximum rated protective device, at the point on the curve where the clearing time is equal to the preferred rated arcing duration found in the specific equipment annex. The preferred arcing duration need not be exceeded unless the specific application requires a longer duration.

To assure that the maximum energy condition is met, the test shall be carried out with the protective device either bypassed or replaced with conductors of negligible impedance.

The arc initiating wire shall be placed in the enclosure under test at the point furthest away from the incoming terminals on the three-phase power circuit. The current shall flow for the intended duration (premature arc extinction is not allowed).

5.3.6.4 Duration-limiting devices

The arc shall sustain until the protective device operates. The test voltage shall be maintained for the intended duration.