IEEE PC37.100.1™/D9
Draft Standard of Common Requirements for High Voltage Power Switchgear Rated Above 1000 V

Prepared by the Common Requirements Working Group of the

Switchgear Committee

Abstract: This Standard collects the common requirements that are in many IEEE Power Switchgear Standards. These include: Service Conditions, Design (type) Tests, Design and Construction, Production (routine) Tests and Ratings.
Keywords: Common Requirements, Design tests, Production tests, Ratings, Service Conditions, Switchgear

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Introduction

(This introduction is not part of IEEE PC37.100.1/D9, Draft Standard for Common Requirements for High Voltage Power Switchgear Rated Above 1000 V.)

This is a new standard written specifically to collect into one document the requirements that are common in many IEEE Power Switchgear Standards. It follows the concept already in place in IEC 62271-1. In some cases, the requirements are equivalent to those in several existing switchgear standards; in other cases, they represent a compromise among two or more standards that have minor (or moderate) differences in the requirement. Still other requirements are taken from the latest draft of IEC 62271-1.

One distinct exception is the treatment of altitude correction factors or air density correction factors. This standard introduces a departure from the historical approach for altitude correction factors as they apply to applications above 1000 m. Refer to 2.2.1 and Annex B for these details.

The expected benefits of this concept is to reduce many of the minor inconsistencies among the various switchgear standards and, where differences must remain, to have them highlighted by exception to these common requirements.

It is the intention of the IEEE Switchgear Committee that the relevant [switchgear] standards will adopt the provisions of this standard by normative reference. Specific clauses may be adopted (a) without exception (the default), (b) with exceptions, (c) with additional requirements or a combination of (b) and (c), as deemed appropriate to the relevant standard. Refer to informative Annex A for specific recommendations for use with a relevant standard.

Note: IEC TC17 SC17A MT34 is currently developing IEC 62271-1. When the IEC 62271-1 standard is issued, it will replace IEC 60694.

In an effort to promote harmonization, this standard is formatted similar to the IEC Standard.

Patents

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

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(To be supplied by IEEE)

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

(To be supplied by IEEE)

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Draft Standard for Common Requirements for High Voltage Power Switchgear Rated Above 1000 V

1. Overview

1.1 Scope

This standard applies to alternating current switchgear, designed for both indoor and outdoor installation and for operation at service frequencies up to and including 60 Hz on systems having voltages above 1000 V.

Application of this standard shall be indicated by normative reference to C37.100.1-20xx in the relevant equipment standard on a section or clause-by-clause basis. Refer to Annex A. The inclusion of this standard as a normative reference shall not imply that all of the requirements contained herein apply as a default. In the absence of a normative reference, this standard shall be considered informative only[1]. In case of a conflict in requirements, the requirements of the relevant equipment standard shall prevail.

NOTE 1— [2]In general, this standard applies to all high voltage power switchgear designed to IEEE C37 series. Exceptions include low- voltage standards (less than 1 000 V), and protective relay standards.

NOTE 2—For the use of this document, “High Voltage” (ref IEV 601-01-27) [3] is the rated voltage above 1 kV. However, the term “Medium Voltage” (ref IEV 601-01-28) is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV.

NOTE 3—There are many common requirements found in the IEEE C37 Switchgear Standards. These include service conditions, ratings such as temperature rise limits, and test methods. This common requirements standard is provided to promote standardization of the requirements and to simplify the maintenance of these standards.

1.2 Normative references

[1] This standard cannot be applied retroactively to an existing relevant equipment standard.
[2] Notes in text, tables, and figures are given for information only, and do not contain requirements needed to implement the standard.
[3] IEV refers to the International Electrotechnical Vocabulary and may be found in IEC 60050(xxx). See Annex K

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.
References to IEC standards are either informative or offer an alternative to an IEEE standard. The user is cautioned that the IEEE standard and the IEC standard, while comparable, may not be equivalent. The use of an IEC standard should be based on agreement among the user, the manufacturer, and the certifying test laboratory. Use of an IEC standard for a design (type) test should be noted in the test report.

ANSI C29.1, Test Methods for Electrical Power Insulators [4]

ANSI C37.85, Alternating-Current High-voltage Power Vacuum Interrupters – Safety Requirements for X-Radiation Limits Interrupters Used in Power Switchgear, X-Radiation Limits for AC High-Voltage Power Vacuum

ANSI C63.2, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz – Specifications

ANSI/IEC AS 60529, Degrees of protection provided by enclosures (IP Code)

ANSI/NEMA MG1, Motors and Generators

ASTM D2472, Standard Specification for Sulfur Hexafluoride [5]

CISPR 11 (EN 55011), Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment [6]

IEC 85, Electrical insulation - Thermal classification [7]

IEC 60060-1, High-voltage test techniques. Part 1: General definitions and test requirements

IEC 60417, Graphical symbols for use on equipment

IEC 60694:2002, Common Specifications for high voltage switchgear and controlgear standards

IEC 61166, High-voltage alternating circuit breakers – Guide for seismic qualification of high-voltage alternating circuit breakers.

IEEE Std 1™, Recommended Practice – General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation [8] [9]

IEEE Std 141™ Red Book, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants
IEEE Std 4™, IEEE Standard Techniques for High Voltage Testing.

IEEE Std 4a™, Amendment to IEEE Standard Techniques for High Voltage Testing

[4] ANSI documents are available from the American National Standard Institute, 1430 Broadway, New York, NY 10018
[5] ASTM documents are available from the (IEEE Editor to complete)
[6] CISPR publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/)
[7] IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org)
[8] The IEEE standards or products referred to in Clause 1.2 are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated
[9] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/)

IEEE Std 1125™, IEEE Guide for Moisture Measurement and Control in SF6 Gas-Insulated Equipment

IEEE Std 1291™, IEEE Guide for Partial Discharge Measurements in Power Switchgear

IEEE Std C1313.1™, IEEE Standard for Insulation Coordination - Definitions, Principles, and Rules

IEEE Std C1313.2™, IEEE Guide for the Application of Insulation Coordination

IEEE Std C37.06™, AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities

IEEE Std C37.010™, IEEE Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

IEEE Std C37.21, IEEE Standard for Control Switchboards

IEEE Std C37.24™, IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

IEEE Std C37.81™, IEEE Guide for Seismic Qualification for Class 1E Metal-Enclosed Power Switchgear

IEEE Std C37.90.1™, IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus

IEEE Std C37.100™, IEEE Standard Definitions for Power Switchgear

IEEE Std C57.19.01™, IEEE Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings

IEEE Std C57.106™, IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment

IEEE Std 693™, IEEE Recommended Practices for Seismic Design of Substations

NEMA CC 1, Electric Power Connection for Substations [10]

NEMA 107, Methods of Measurement of Radio Influence Voltage (RIV) of High Voltage Apparatus

Other International standards are referenced in this standard. These references are to be considered informative; they are listed in Annex K.

2. Normal (usual) and special (unusual) service conditions

Unless otherwise specified, switchgear, including the operating devices and the auxiliary equipment which form an integral part of them, are intended to be used in accordance with their rated characteristics and the normal (usual) service conditions listed in 2.1.

If any of the actual service condition requirements differ from these normal (usual) service conditions, switchgear and associated operating devices and auxiliary equipment shall be designed to comply with any special conditions required by the user, or appropriate application arrangements shall be made. (See clause 2.2).

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

NOTE—Appropriate action should also be taken to ensure proper operation of other components, such as relays.

2.1 Normal (usual) service conditions

2.1.1 Indoor switchgear

a) The ambient air temperature does not exceed 40 °C. The minimum ambient air temperature is -30 °C for class "minus 30 indoor".

b) The influence of solar radiation may be neglected.

c) The altitude does not exceed 1000 m above sea level. (Switchgear ratings are based on sea level. See Annex B for considerations at application above sea level).

d) The ambient air is not significantly polluted and would be classified as having pollution level I "light" according to Table C.1 of Annex C.

e) The conditions of humidity are as follows:

— The average value of the relative humidity, measured over a period of 24 h, does not exceed 95%.

— The average value of the relative humidity, over a period of one month, does not exceed 90%,

For these conditions, condensation may occasionally occur.

NOTE 1—Condensation can be expected where sudden temperature changes occur in periods of high humidity.

NOTE 2—To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed and tested for such conditions should be used.

NOTE 3— Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear. Condensation may also be due to ground level rainwater or for underground applications, from incoming cable raceways connected to switchgear.

f) Vibration due to causes external to the switchgear and controlgear or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the Low Performance Level defined in IEEE 693. The manufacturer will assume that, in the absence of specific requirements from the user, there are none. [11]

2.1.2 Outdoor switchgear

a) The ambient air temperature does not exceed 40 °C. The minimum ambient air temperature is -30 °C for class "minus 30 outdoor".

Rapid temperature changes should be taken into account.

b) Solar radiation as much as 1 044 W/m^2 (a clear day at noon). The specific latitude of location should be considered. See IEEE C37.24 for details on evaluating the effects of solar radiation.

NOTE— Under certain conditions of solar radiation appropriate measures, e.g. roofing, forced ventilation, etc. may be necessary, or derating may be used in order not to exceed the specified allowable temperature rises.

[11] The interpretation of the term "insignificant" is the responsibility of the user or specifier of the equipment. Either the user is not concerned with seismic events, or his analysis shows that the risk is "insignificant".

c) The altitude does not exceed 1000 m above sea level. (Switchgear ratings are based on sea level. See Annex B for considerations at application above sea level).

d) The ambient air may be polluted by dust, smoke, corrosive gas vapors or salt. The pollution does not exceed the pollution level II – medium according to Table C.1 of Annex C.

e) The ice coating, particularly for equipment with exposed movable parts, does not exceed 1 mm. Refer to the relevant equipment standards for specific ice ratings and requirements.

NOTE—Typical ice classes are: 1 mm for class 1, 10 mm for class 10 and 20 mm for class 20.

f) The wind speed does not exceed 40 m/s (144 km/h) (90 mi/h). [12]

g) The presence of condensation and/or precipitation should be taken into account.

NOTE—Characteristics of precipitation are defined in IEEE Std 4 and IEEE Std 4a.

h) Vibration due to causes external to the switchgear or earth tremors are insignificant relative to the normal operating duties of the equipment and do not exceed the Low Performance Level defined in IEEE 693. The manufacturer will assume that, in absence of specific requirements from the user, there are none. [13]

2.2 Special (unusual) service conditions for both indoor and outdoor switchgear

When switchgear may be used under conditions that are different from the normal service conditions given in 2.1.1 and 2.1.2, the user's requirements should refer to standardized steps as follows:

2.2.1 Altitude

The basis of rating for switchgear is Standard Temperature and Pressure, commonly known as sea level conditions. Historically, switchgear has been successfully applied at altitudes up to 1,000 m without the use of an altitude correction factor.

For installations at an altitude higher than 1 000 m, the required insulation withstand level of external insulation at the service location shall be determined by multiplying the rated insulation levels at sea level by a factor Ka in accordance with Figure 1.

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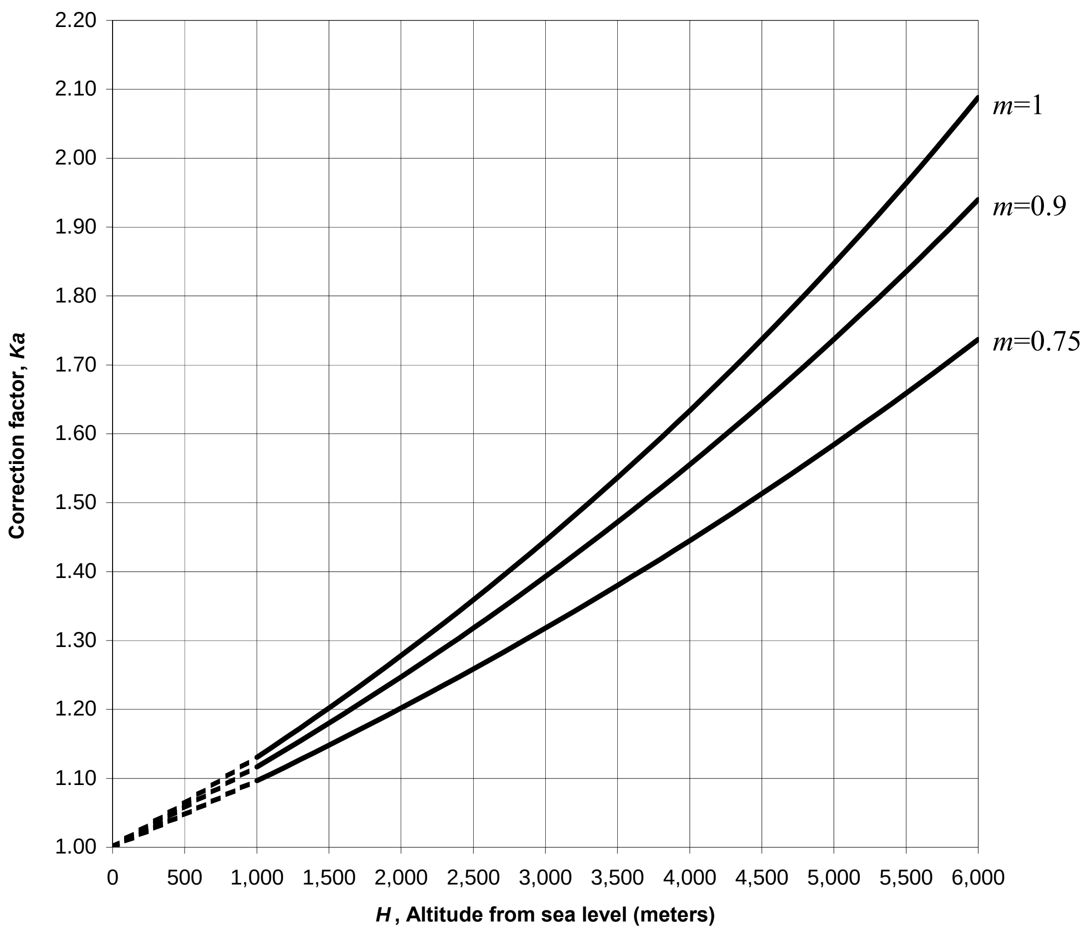
[12] Actual conversion: 40 m/s = 89.48 miles per hour; 40.2 m/s= 90 miles per hour
[13] See footnote 11.



The altitude correction factor can be calculated with the following equation taken from IEC 60071-2 paragraph 4.2.2.

$$K_a = e^{m\left(\frac{H}{8150}\right)}$$

where

H is the altitude in meters

m is taken as fixed value in each case for simplification as follows:

m = 1 for power-frequency, lightning impulse and phase-to-phase switching impulse voltages.

m = 0.9 for longitudinal switching impulse voltage (i.e. across the isolation gap)

m = 0.75 for phase-to-earth switching impulse voltage.

Figure 1 Altitude correction factor

2.2.2 Exposure to excessive pollution

For installation in a location with polluted ambient air, a pollution level from Annex C, Table C.1 should be selected.

2.2.3 Temperature and humidity

For installation in a location where the ambient temperature can be outside the normal (usual) service condition range stated in clause 2.1.1 and 2.1.2, the preferred ranges of minimum and maximum temperature to be specified should be selected from one of the following:

a) -40 °C and +40 °C for cold climates (class "minus 40 outdoor" or class "minus 40 indoor")

b) -50 °C and +40 °C for very cold climates (class "minus 50 outdoor")

c) -15 °C and +50 °C for hot climates

d) -5 °C and +55 °C for very hot climates

NOTE 1—IEC Switchgear standards have preferred special (unusual) service conditions for minimum and maximum temperature of -50 °C and +40 °C for very cold climates and -5 °C and +55 °C for very hot climates.

NOTE 2—Humidity varies widely throughout application locations, seasons and daily conditions. Users should be aware that, like relative air density discussed in Annex B, extreme humidity conditions (arid or desert environments) might affect the dielectric strength of air. Users should consult IEEE Std. 4 for humidity correction that may be appropriate in their specific application.

The use of apparatus in an ambient temperature lower than –30 °C or higher than 40 °C shall be considered as special. Temperatures below –30 °C create a harsh environment for switchgear. Many users in colder climates routinely experience -50 °C temperatures. The following should be considered for low ambient temperature environments:

— Operating times may be slower than rated times.

— Wax precipitation of insulating oil "cloud point" may occur where the oil becomes extremely viscous, creating excessive drag.

— Humidity in air system freezes, sticking operating and blast valves.

— Liquefaction of sulfur hexafluoride (SF6) may occur, necessitating derating of interrupting ratings and dielectric ratings unless heaters are utilized.

— Embrittlement of plastics, composites, and metals may lead to failure during breaker or switching device operation.

— Hydraulic or pneumatic equipment, including fluid dampers, may be affected.

— Special lubricants may be required to prevent sluggishness or freezing of bearings.

— Density and pressure switches may malfunction or may be out of range.

— Heaters for the mechanism or gas may be required.

In certain regions with frequent occurrence of warm humid winds, sudden changes of temperature and/or atmospheric pressure may occur, resulting in condensation even indoors. In tropical indoor conditions, the average value of relative humidity measured during a period of 24 h can be as high as 98%.

2.2.4 Exposure to abnormal vibration, shock, or tilting

Standard switchgear is designed for mounting on substantially level structures free from vibration, shock, or tilting. Where any of these abnormal conditions exists, recommendations for the particular application should be obtained from the manufacturer.

For installations where earthquakes are likely to occur, the user should specify a severity level in accordance with IEEE 693. [14] For nuclear Class 1E equipment, the user should specify a level in accordance with IEEE C37.81. Other unusual forms of vibration such as close proximity to mine blasting or mobile applications should be identified. The user should specify the operational requirements, including whether functionality must be maintained

— Before and after the seismic event or

— Before, during, and after the seismic event

NOTE—Any value of earthquake resistance is a special (unusual) service condition. If there is any concern for seismic capability, the condition must be analyzed and the severity level specified in accordance with IEEE 693.

2.2.5 Other Special (unusual) service conditions

2.2.5.1 Exposure to damaging fumes, vapor, steam, oil vapors, salt air, and hot and humid climate

a) Provision may be necessary to avoid condensation on all electrical insulation and current-carrying parts.

b) Insulation and bushings with extra creep distance may be required.

c) In cases where particular exposure represents a hazard to insulation integrity, special maintenance including insulator washing may be necessary.

d) Materials resistant to fungus growth may be required.

e) Installation in a positive pressure room system with appropriate filtration equipment may be required.

f) Installation of heaters in mechanism cabinets and indoor switchgear may be required.

2.2.5.2 Exposure to excessive dust or abrasive, magnetic, or metallic dust

a) Totally enclosed non-ventilated equipment or compartments may be necessary.

b) Where current-carrying equipment designed for ventilated operation is enclosed in a non-ventilated compartment, derating may be necessary.

c) Installation in a positive pressure room with appropriate filtration equipment may be necessary.

2.2.5.3 Exposure to explosive mixtures of dust or gases

Standard switchgear is not designed for use in explosive atmospheres. For this type of service, special consideration should be given in conjunction with requirements of applicable regulatory bodies so that acceptable equipment is selected.

2.2.5.4 Unusual space limitations

Unusual space limitations should be considered special.

[14] The severity level of earthquakes may also be determined in accordance with IEC 61166.

2.2.6 Other parameters

Any other unusual or special environmental, operational, or other conditions prevailing at the location where switchgear is to be placed in service should be identified.

NOTE—For other special environmental conditions, the user is referred to IEC 60721-1 [B15] [15]

3. Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE Std C37.100 should be referenced for terms not defined in this clause. For terms that are not listed in IEEE Std C37.100, users should refer to IEEE 100 *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B23]. An asterisk (*) indicates that at the time this standard was approved, there were no corresponding definitions in IEEE Std C37.100.

NOTE—The counterpart to IEEE Std C37.100 in IEC is the IEC 60050 series of standards. [B2], [B3], [B4], [B5], [B6]

3.1 Disconnector - A mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements. Note. - A disconnector is capable of opening and closing a circuit when either negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnector occurs. It is also capable of carrying currents under normal conditions and carrying for a specified time currents under abnormal conditions such as those of short circuit. (IEC 60050(441))

3.2 IP Coding*: A coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give additional information in connection with such protection. [3.4 of ANSI/IEC 60529]

3.3 Isolating distance*(of a pole of a mechanical switching device):

The clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position meeting the functional requirements specified for disconnectors. Clearance being the shortest path between the conductive parts. [16]

3.4 Non sustained disruptive discharge (NSDD)*: Disruptive discharge associated with current interruption, that does not result in the resumption of power frequency current or, in the case of capacitive current interruption does not result in current in the main load circuit.

3.5 Vacuum interrupter*: A switching component in which high-voltage electrical contacts operate in a highly evacuated, hermetically sealed environment.

NOTE—Refer to Annex H for additional information about terms used in this standard.

4. Ratings

The common ratings of switchgear, including their operating devices and auxiliary equipment, should be selected from the following:

a) Rated maximum voltage *(V)* or (U_r) [17]

b) Rated insulation level (*Ud*), (*Us*), (*Up*)

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[15] The numbers in brackets correspond to those of the bibliography in Annex K.

[16] This definition is a combination of three definitions taken from IEC 60050-441 [B4]. See Annex J.

[17] A listing of symbols for numerical variables or parameters used in this document is given in Annex H. In some cases, the IEEE symbol and the IEC symbol are not the same. In such cases, the IEEE symbol is listed first followed by the IEC symbol.

c) Rated power frequency *(f_r)*

d) Rated continuous current *(I_r)*

e) Rated short-time withstand current *(I_k)*

f) Rated peak withstand current *(I_p)*

g) Rated duration of short circuit *(t_k)*

h) Rated supply voltage of closing and opening devices and of auxiliary circuits *(U_a)*

i) Rated supply frequency of closing and opening devices and of auxiliary circuits

j) Rated pressure of compressed gas supply for insulation or operation.

NOTE—Other rated characteristics may be necessary and should be specified in the relevant equipment standards.

4.1 Rated maximum voltage (*V*) or *(U_r)*

The rated maximum voltage indicates the upper limit of the highest voltage of systems for which the switchgear is intended. The preferred values of rated maximum voltage are given in 4.1.1 and 4.1.2.

4.1.1 Range I for rated maximum voltages of 245 kV and below

Series A: (based on the current practice in North America and some other countries): 4.76 kV; 8.25 kV; 15 kV; 15.5 kV; 25.8 kV; 27 kV; 38 kV; 48.3 kV, 72.5 kV, 123 kV, 145 kV, 170 kV and 245 kV.

Series B: 3.6 kV; 7.2 kV; 12 kV; 17.5 kV; 24 kV; 36 kV; 52 kV; 72.5 kV; 100 kV; 123 kV; 145 kV; 170 kV and 245 kV.

NOTE 1—The series A voltages are applicable to North America and some other countries. The series B voltages are generally used outside North America. The series B voltages are the same as those identified as series I in IEC 60694 [B14] (62271.1-20xx). Voltages from both series are considered preferred in this standard.

NOTE 2—Refer to Annex I for proposed values of rated maximum voltages for future design.

4.1.2 Range II for rated maximum voltages above 245 kV

300 kV; 362 kV; 420 kV; 550 kV and 800 kV.

4.2 Rated insulation level, U_d, U_s, U_p

The rated insulation level of switchgear shall be selected from the values given in Table 1a, Table 1b, Table 2a and Table 2b.

In these tables, the withstand voltage applies at the standardized reference atmosphere (temperature (20 °C), pressure (101.3 kPa) and humidity (11 g/m3))[18] specified in IEEE Std 4, and IEEE Std 4a. Insulation withstand capability is affected by altitude. For special service conditions, see 2.2. and Annex B.

NOTE—For further information on insulation coordination, refer to IEEE 1313.1, IEEE 1313.2 or to IEC 60071-1 [B8] and IEC 60071-2 [B9].

[18] The standard reference atmosphere in English units is: temperature (68 °F), pressure (29.914 inches of Hg),and humidity (0.011 oz/ft^3).

The rated values for lightning impulse withstand voltage (U_p), switching impulse withstand voltage (U_s) (when applicable), and power frequency withstand voltage (U_d) shall be selected without crossing the horizontal marked lines in Table 1a, Table 1b, Table 2a and Table 2b.. The rated insulation level is specified by the rated lightning impulse withstand voltage phase to ground.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltages, the type of neutral grounding of the system and the type of overvoltage limiting devices. (See IEEE 1313.2) [19]

The "common values" as used in Table 1a and Table 1b apply to phase-to-ground, between phases and across the open switching device, if not otherwise specified in this standard. The withstand voltage values "across the isolating distance" are valid only for switching devices where the clearance between open contacts is designed to meet the functional requirements specified for disconnectors. For withdrawable devices, the isolating distance may be determined when the device is in the “disconnected” position. The term “common value” is used to make a distinction between the normal rating, where there is no intention to meet the added safety requirements for disconnectors, and the increased rating “across the isolating distance”, where the intention is to meet the added safety requirements for disconnectors. In the first case, the “common value” applies across the open switching device, i.e. the interrupting device. In the second case, the withstand value “across the isolating distance” may apply across the interrupting device or across an auxiliary disconnecting means, such as an auxiliary disconnecting switch or a withdrawable device.

[19] Or IEC 60071-2 [B9]

Table 1a——Rated insulation levels for rated maximum voltages of range I, series A [a]

Rated maximum voltage $V(U_r)$ kV (rms value)	Rated power frequency withstand voltage U_d kV (rms value			Rated lightning impulse withstand voltage U_p kV (peak value)		
	Common value [f]		Across the isolating distance [c]	Common value [f]	Across isolating distance [c]	2 µs Chopped Wave [b]
	Dry 1 min	Wet 10 sec [g]	Dry 1 min			
Col. 1	Col. 2	Col. 2a	Col. 3	Col. 4	Col. 5	Col. 6
4.76 [d]	19	- -	21	60	66	- -
8.25 [d]	36	- -	40	95	105	- -
8.25 [e]	38	30	42			- -
15 [d]	36	30	40	95	105	- -
15.5 [d]	50	45	55	110	121	142
15.5 [e]	50	45	55			
25.8 [d]	60	50	66	125	138	- -
				150	165	194
27.0 [d]	60	50	66	125	138	- -
27.0 [e]	70	60	77	150	165	- -
38 [d]	70	60	77	150	165	- -
	80	75	88	200	220	258
38 [e]	95	80	105	200	220	- -
48.3 [d]	105	95	- -	250	- -	322
48.3 [e]	120	100	132	250	275	- -
72.5 [d]	160	140	- -	350	- -	452
72.5 [e]	175	145	193	350	385	- -
123 [d]	260	230	- -	550	- -	710
123 [e]	280	230	308	550	605	- -
145 [d]	310	275	- -	650	- -	838
145 [e]	335	275	369	650	715	- -
170 [d]	365	315	- -	750	- -	968
170 [e]	385	315	424	750	825	- -
245 [d]	425	350	- -	900	- -	1160
245 [e]	465	385	512	900	990	- -

[a] For rated maximum voltages higher than 72.5 kV up to and including 245 kV, the values in Table 1b are also applicable.

[b] The 2 µs chopped wave test requirement only applies to outdoor breakers.

[c] Isolation of indoor circuits is normally achieved by withdrawing the removable switching device. Refer to relevant equipment standards for testing methods and requirements where this method of isolation is applicable.

[d] These ratings are generally applicable to switchgear equipment that is not used for isolation, e.g. high voltage circuit breakers and reclosers and may not include requirements across the isolation gap. Refer to relevant equipment standards for requirements across the isolation gap.

[e] These ratings are generally applicable to switchgear equipment that is used for circuit isolation, e.g. high voltage switches. Refer to relevant equipment standards.

[f] Common values are discussed in 4.2

[g] Power-frequency withstand tests under wet conditions are only required for outdoor switchgear.

Table 1b—— Rated insulation levels for rated maximum voltages of range I, series B

(Generally used outside of North America)

Rated voltage $V(U_r)$ kV (rms value)	Rated short-duration power-frequency withstand voltage[20] U_d kV (rms value)		Rated lightning impulse withstand voltage U_p kV (peak value)	
	Common value [a]	Across the Isolating distance	Common value [a]	Across the isolating distance
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
3.6	10	12	20	23
			40	46
7.2	20	23	40	46
			60	70
12	28	32	60	70
			75	85
17.5	38	45	75	85
			95	110
24	50	60	95	110
			125	145
36	70	80	145	165
			170	195
52	95	110	250	290
72.5	140	160	325	375
100	150	175	380	440
	185	210	450	520
123	185	210	450	520
	230	265	550	630
145	230	265	550	630
	275	315	650	750
170	275	315	650	750
	325	375	750	860
245	360	415	850	950
	395	460	950	1 050
	460	530	1 050	1 200

[a] Common values are discussed in 4.2

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[20] The term "short-duration power frequency withstand voltage" comes from the insulaton coordination standard, IEEE 1313.1. In paragraph 3.33, the term "standard power-frequency short-duration voltage shape" is defined as A sinusoidal voltage with frequency between 48 Hz and 62 Hz and duration of 60 s. A similar definition appears in IEC 60071-1, paragraph 3.18 a).

Table 2a— Rated insulation levels for range II

Rated maximum voltage $V(U_r)$ kV (rms value)	Rated power-frequency withstand voltage U_d kV (rms value)		Rated switching impulse withstand voltage U_s kV (peak value)		Rated lightning impulse withstand voltage U_p kV (peak value)		2 microseconds Chopped Wave withstand Voltage kV (Peak value)
	Phase-to-ground and between phases [a]	Across open switching device [b, c]	Phase-to-ground, breaker closed	Across open switching device [b, c]	Phase-to-ground and between phases	Across open switching device [b, c]	Across open switching device On one phase[b]
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
362	555	555	825	900	1300	1300	1680
550	860	890	1175	1300	1800	1800	2320
800	960	1056	1425	1500	2050	2050	2640

[a] Values of column (2) are applicable:
- i) For type tests, phase-to-ground, and
- ii) For routine tests, phase-to-ground, phase-to-phase, and across the open switching device

[b] Values of columns 3, 5, 7 and 8 are applicable for type tests only.
If the general arrangement of the three phase set results in a large distance between installed phases, dielectric withstand tests between phases are not required. If there is doubt, phase-to-phase tests are required, especially on a design with one common supporting frame for the three phases.

[c] Values across open switching device refer to the open interrupting gap. Refer to relevant equipment standards for ratings across the isolating distance where equipment is rated as an isolator.

Table 2b—Additional rated insulation levels for rated voltages of range II (Generally used outside of North America)

Rated voltage $V(U_r)$ (rms value)	Rated power-frequency withstand voltage U_d kV (rms value)		Rated switching impulse withstand voltage U_s kV (peak value)			Rated lightning impulse withstand voltage U_p kV (peak value)	
	Phase-to-ground and between phases [c]	Across open switching device and/or isolating distance [d]	Phase-to-ground and across open switching device	Between phases [d,e]	Across isolating distance [a,d]	Phase-to-ground and between phases	Across open switching device and/or isolating distance [b,d]
Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
300	380	435	750	1125	700(+245)	950	950(+170)
			850	1275		1050	1050(+170)
362	450	520	850	1275	800(+295)	1050	1050(+205)
			950	1425		1175	1175(+205)
420	520	610	950	1425	900(+345)	1300	1300(+240)
			1050	1575		1425	1425(+240)
550	620	800	1050	1680	900(+450)	1425	1425(+315)
			1175	1760		1550	1550(+315)
800	830	1150	1300	2210	1100(+650)	1800	1800(+455)
			1425	2420		2100	2100(+455)

[a] In column (6), values in brackets are the peak values of the power-frequency voltage $U_r\sqrt{2}/\sqrt{3}$ applied to the opposite terminal, (combined voltage).

[b] In column (8), values in brackets are the peak values of the power-frequency voltage 0,7 $U_r\sqrt{2}/\sqrt{3}$ applied to the opposite terminal, (combined voltage).

[c] Values of column (2) are applicable:

i) for type tests, phase-to-ground, and

ii) for routine tests, phase-to-ground, phase-to-phase, and across the open switching device.

[d] Values of columns 3, 5, 6 and 8 are applicable for type tests only.

[e] The values in column 5 are derived using the multiplying factors stated in Table 3 of IEC 60071-1.

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4.3 Rated power frequency (f_r)

The preferred values of the rated power frequency are 50 Hz and 60 Hz.

4.4 Rated continuous (normal) current and temperature rise

4.4.1 Rated continuous (normal) current (I_r)

The rated continuous current of switchgear is the rms value of the current that switchgear shall be able to carry continuously under specified conditions of use and behavior.
The values of rated continuous currents for new design should be selected from the R 10 series. [21] The R10 series comprises the numbers: 1, 1.25, 1.6, 2, 2.5, 3.15, 4, 5, 6.3, 8, and their products by 10^n. The historic values of 600 A, 1200 A, 3000 A, and 6000 A are also considered as preferred values.

NOTE—Rated currents for temporary or for intermittent duty are subject to agreement between manufacturer and user.

4.4.2 Temperature rise

The temperature rise of any part of switchgear shall not exceed the temperature rise limits specified in Table 3 under the conditions specified in the test clauses.

Equipment may be assigned an overload capability for higher than rated normal current for a temporary period provided the temperature does not exceed the maximum value temperature specified in Table 3.

Equipment may be assigned an overload capability for higher than rated normal currents based on a lower ambient temperature provided the temperature does not exceed the maximum value temperature specified in Table 3.

Refer to IEEE C37.010 for application information on overloads.

NOTE—In the case of a switch, the overload capability may exceed its breaking capability.

[21] The R10 series of numbers is described in IEC 60059. Each number in the series is approximately 125% greater than the preceding number.

Table 3—Limits of temperature and temperature rise for various parts, materials and dielectrics of high-voltage switchgear.

Nature of the part, of the material and of the dielectric (see points and notes below)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C K [22]
1 Contacts (see point 4)		
Bare-copper or bare-copper alloy		
- In air	75	35
- In SF_6 (sulfur hexafluoride (see point 5)	105	65
- In oil	80	40
Silver-coated or nickel-coated (see point 6)		
- In air	105	65
- In SF_6 (see point 5)	105	65
- In oil	90	50
Tin-coated (see point 6)		
- In air	90	50
- In SF_6 (see point 5)	90	50
- In oil	90	50
2 Connection, bolted or the equivalent (see point 4)		
Bare-copper, bare-copper alloy or bare-aluminum alloy		
- In air	90	50
- In SF_6 (see point 5)	115	75
- In oil	100	60
Silver-coated or nickel-coated		
- In air	115	75
- In SF_6 (see point 5)	115	75
- In oil	100	60
Tin-coated		
- In air	105	65
- In SF_6 (see point 5)	105	65
- In oil	100	60
3 All other contacts or connections made of bare metals or coated with other materials	(See point 7)	(See point 7)
4 Terminals for the connection to external conductors by screws or bolts (see points 8 and 14)	(See point 14)	(See point 14)
- Bare	90	50
- Silver, nickel or tin-coated	105	65
- Other coatings	(See point 7)	(See point 7)
5 Oil for oil switching devices (see points 9 and 10)	90	50
6 Metal parts acting as springs	(See point 11)	(See point 11)

[22] The symbol "K" for the kelvin is used in this standard to refer to a temperature increment. As a temperature increment (e.g. temperature rise) the kelvin is equal to the ºC, 1 K ≡ 1 ºC ≡1.8 ºF ; as temperature on a scale, 273.15 K ≡ 0 ºC ≡ 32 ºF and 0 K is absolute zero. The kelvin is written as "K" without the "º" degree symbol.

Nature of the part, of the material and of the dielectric (see points and notes below)	Maximum value	
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C K [22]
7 Materials used as insulation and metal parts in contact with insulation of the following classes (see point 12)		
- Y	90	50
- A	105	65
- E	120	80
- B	130	90
- F	155	115
- Enamel: oil base	100	60
synthetic	120	80
- H	180	140
- C other insulating material	(See point 13)	(See point 13)
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60
9 Accessible parts (See Note 3)		
- Expected to be touched in normal operation	50	
- Which need not be touched in normal operation ...	70	

NOTE 1--The points referred to in this table are those of 4.4.3.
NOTE 2--Refer to Annex J for a discussion of this table with respect to the comparable table in IEC 62271-1-20xx and to the requirements of several relevant equipment standards.
NOTE 3--The maximum value temperatures for group 9 are lower than those given in the comparable table in IEC 60694 (IEC 62272-1). See Annex J.

4.4.3 Particular points of Table 3

The following points are referred to in Table 3 and shall be considered as part of the table.

— Point 1: According to its function, the same part may belong to several categories as listed in Table 3. In this case the permissible maximum values of temperature and temperature rise to be considered are the lowest among the relevant categories.

— Point 2: For vacuum switching devices, the values of temperature and temperature rise limits are not applicable for parts in vacuum. The remaining parts shall not exceed the values of temperature and temperature rise given in Table 3.

— Point 3: Care shall be taken to ensure that no damage is caused to the surrounding insulating materials.

— Point 4: When engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be:

  — For contacts, those of the surface material having the lowest value permitted in item 1 of Table 3:

  — For connections, those of the surface material having the lowest value permitted in item 2 of Table 3.

— Point 5: SF_6 means pure SF_6 or a mixture of SF_6 and other oxygen-free gases.

NOTE 1—Due to the absence of oxygen, a harmonization of the limits of temperature for different contact and connection parts in the case of SF_6 switchgear appears appropriate. In accordance with IEC 60943 [B17], which gives guidance for the specification of permissible temperatures, the permissible temperature limits for bare copper and bare copper alloy parts can be equalized to the values for silver-coated or nickel-coated parts in the case of SF_6 atmospheres.

In the particular case of tin-coated parts, due to fretting corrosion effects (refer to IEC 60943) an increase of the permissible temperatures is not applicable, even under the oxygen-free conditions of SF_6. Therefore the initial values for tin-coated parts are kept.

NOTE 2—Temperature rises for bare copper and silver-coated contacts in SF_6 are under consideration.

— Point 6: The quality of the coated contacts shall be such that a continuous layer of coating material remains in the contact area.

a) After making and breaking test (if any);
b) After short-time withstand current test;
c) After the mechanical endurance test;

According to the relevant specifications for each equipment. Otherwise, the contacts shall be regarded as "bare".

— Point 7: When materials other than those given in Table 3 are used, their properties shall be considered, notably in order to determine the maximum permissible temperature rises.

— Point 8: The values of temperature and temperature rise are valid even if the conductor connected to the terminals is bare.

— Point 9: At the upper part of the oil

— Point 10: Special consideration should be given when low flash-point oil is used in regard to vaporization and oxidation.

— Point 11: The temperature shall not reach a value where the elasticity of the material is impaired.

— Point 12: Classes of insulating materials are those given in IEEE Std 1 or IEC 60694 (IEC 62271.1-20xx) Refer also to IEC 60085.

— Point 13: Limited only by the requirement not to cause any damage to surrounding parts.

— Point 14: These values are for connections to bare (un-insulated) cables or bus conductors. For connections to insulated cables, terminals shall not exceed 45 K rise or 85°C hottest spot total temperature when connected to 90˚C-rated cables rated for the full continuous (normal) current of the switchgear.

4.5 Rated short-time withstand current (I_k)

The rms value of the current that the switchgear can carry in the closed position during a specified short time under prescribed conditions of use and behavior.

The standard value of rated short-time withstand current for new design should be selected from the R 10 series specified in 4.4.1, and shall be equal to the short-circuit rating assigned to switchgear. The historic values of 6000 A and 12,000 A, are also considered as preferred values.

4.6 Rated peak withstand current (I_p)

The peak current associated with the first major loop of the rated short-time withstand current which switchgear can carry in the closed position under prescribed conditions of use and behavior.

The rated peak withstand current shall correspond to the rated frequency. For a rated frequency of 50 Hz and below it is equal to 2.5 times the rated short-time withstand current, and for a rated frequency of 60 Hz it is equal to 2.6 times the rated short-time withstand current.

Values higher than 2.5 or 2.6 times the rated short-time withstand current may be required according to the characteristics of the system. Under these conditions, a higher rating may be necessary.

NOTE 1—The peak factors cited above correspond to a circuit time constant (*L/R*) of 45 ms.

4.7 Rated duration of short-circuit (t_k)

The interval of time for which switchgear can carry, in the closed position, a current equal to its rated short-time withstand current.

Standard values of rated duration of short-circuit include: 0.5 s, 1 s, 2 s, and 3 s. Refer to the relevant equipment standard for this rating.

4.8 Rated supply voltage of closing and opening devices and of auxiliary and control circuits (U_a)

4.8.1 General

The supply voltage of closing and opening devices and auxiliary and control circuits shall be understood to mean the voltage measured at the circuit terminals of the apparatus itself during its operation, including, if necessary, the auxiliary resistors or accessories supplied or required by the manufacturer to be installed in series with it, but not including the conductors for the connection to the electricity supply.
The rated supply voltage should be selected from the standard values given in Table 4 and Table 5.

Table 4—Preferred Direct Current Rated Control Voltage and Ranges 1) 2) 3) 4) 5)

Nominal Voltage, V	Closing and Auxiliary Functions, V	Tripping Function, V
24 6)	--	14 - 28 7)
48 6)	38 - 56	28 - 56 7)
125	100 - 140	70 - 140
250	200 - 280	140 - 280

1 The numerical references, 1) 2) etc, referred to in the table are give in 4.8.2

2 Other notes or qualifications may apply; refer to relevant equipment standards.

Table 5—Preferred Alternating Current Rated Control Voltage and Ranges 1) 2) 3) 4) 8) 9)

Nominal Voltage (50/60 Hz) Phase, V	Closing, Tripping and Auxiliary Functions, V
120	104 - 127 9)
240	208 - 254 9)
480	416 - 508 9)
Polyphase	
208Y/120	180Y/104 - 220Y/127
240	208 - 254
480	416 - 508
480Y/277	416Y/240 – 508Y/292

1 The numerical references, 1) 2) etc, referred to in the table are give in 4.8.2

2 Other notes or qualifications may apply; refer to relevant equipment standards.

4.8.2 Qualifications applicable to Table 4 and Table 5

The following qualifying points are referred to in Table 4 and Table 5 and are required to complete the tables.

1) Electrically operated motors, contactors, solenoids, valves, and the like, need not carry a nameplate voltage rating that corresponds to the control voltage rating shown in the tables as long as these components perform the intended duty cycle (usually intermittent) in the voltage range specified.
2) Relays, motors, and other auxiliary equipment that function as a part of the control for a device shall be subject to the voltage limits imposed by this standard, whether mounted at the device or at a remote location.
3) In some applications, equipment may be exposed to control voltages exceeding those specified herein due to abnormal conditions such as abrupt changes in line loading. Such application requires specific study, and the manufacturer should be consulted. Also, applications containing solid-state control exposed continuously to control voltages approaching the upper limits of ranges specified herein require specific attention and the manufacturer should be consulted before application is made.
4) Voltage ranges apply to all closing and auxiliary devices when cold. Switchgear utilizing standard auxiliary relays for control functions may not comply at lower extremes of voltage ranges when relay coils are hot, as after repeated or continuous operation.
5) It is recommended that the coils of closing, auxiliary and tripping devices that are directly connected continually to one dc potential should be connected to the negative control bus so as to minimize electrolytic deterioration.
6) 24V or 48V tripping, closing, and auxiliary functions are recommended only when the device is located near the battery or where special effort is made to insure the adequacy of conductors between battery and control terminals.
7) Equipment having self-contained dc control sources shall operate over the range of 85% to 115% of nominal voltage and Table 4 shall not apply.

8) Includes supply for pump or compressor motors. Rated voltages for motors and their operating ranges are covered in ANSI/NEMA MG-1.

9) Includes heater circuits.

4.8.3 Tolerances

The tolerances of ac and dc power supplies in normal duty measured at the input of the auxiliary equipment are given by the range of values in Table 4 and Table 5.

4.8.4 Ripple voltage

In case of dc supply, the ripple voltage, that is the peak-to-peak value of the ac component of the supply voltage at the rated load, shall be limited to a value not greater than 5 % of the dc component. The voltage is measured at the supply terminals of the auxiliary equipment.

4.9 Rated supply frequency of closing and opening devices and of auxiliary circuits

The preferred values of rated supply frequency are dc, 50 Hz and 60 Hz.

4.10 Rated pressure of compressed gas supply for insulation and/or operation

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards and manufacturer's specifications.

4.11 Rated filling levels for insulation and/or operation

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards and manufacturer's specifications.

5. Design and construction

5.1 Requirements for liquids in switchgear

The equipment manufacturer shall specify the type and the required quantity and quality of the liquid to be used in switchgear and provide the user with necessary instructions for renewing the liquid and maintaining its required quantity and quality. This requirement does not apply to sealed pressure systems.

5.1.1 Liquid level

A device for checking the liquid level, preferably during service, with indication of minimum and maximum limits permissible for correct operation, shall be provided. This requirement is not applicable to dash-pots.

5.1.2 Liquid quality

Liquids for use in switchgear shall comply with the instructions of the equipment manufacturer.
For oil-filled switchgear, new insulating oil shall comply with IEEE C57.106 or IEC 60296 [B11].

5.2 Requirements for gases in switchgear

The equipment manufacturer shall specify the type and the required quantity, quality and density of the gas to be used in switchgear and provide the user with necessary instructions for renewing the gas and maintaining its required quantity and quality. This requirement does not apply to sealed pressure systems.

For sulfur hexafluoride (SF_6) -filled switchgear, new SF_6 shall comply with ASTM D2472-00 or IEC 60376 [B12].

In order to prevent condensation, the maximum allowable moisture content within gas-filled switchgear filled with gas at rated filling density for insulation ρ_{re} shall be such that the dew point is not higher than -5 °C for a measurement at 20 °C. Adequate correction shall be made for measurement made at other temperatures. For the measurement and determination of the dew point, refer to IEEE Std 1125 or IEC 60376 and IEC 60480 [B13].

Parts of high voltage switchgear housing compressed gas shall comply with the requirements specified in the relevant IEEE equipment standards.

NOTE—Attention is drawn to the need to comply with local regulations relevant to pressure vessels, e.g. ASME Boiler and Pressure Vessel Code.

5.3 Grounding of switchgear

Each switchgear shall be provided with reliable grounding provisions. Refer to the relevant equipment standards for specific requirements. Refer to NEMA CC1 for additional information and connector details.

5.4 Auxiliary and control equipment

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

5.5 Dependent power operation

A switching device arranged for dependent power operation with external energy supply shall be capable of making and/or breaking its rated short-circuit current (if any) when the voltage or the pressure of the power supply of the operating device is at the lower of the limits specified under 4.8 and 4.10 (the term "operating device" here embraces intermediate control relays and contactors where provided). If maximum closing and opening times are stated by the manufacturer, they shall not be exceeded.
Except for slow operation during maintenance, the main contacts shall only move under the action of the drive mechanism and in the designed manner. The closed or open position of the main contacts shall not change as a result of loss of the energy supply or the re-application of the energy supply after a loss of energy, to the closing and/or opening device.

5.6 Stored energy operation

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

5.7 Independent manual operation

The mechanism shall not reach the energy release point of a close operation if the switching device is in the closed state or of an open operation if it is open. This is to prevent the inadvertent, and potentially damaging, discharge of stored energy against an already closed or already open switching device.

It shall not be possible to progressively store energy by incomplete operations against an interlock, if supplied. During the operation, any movement of the contacts prior to release of the energy shall not reduce any electrically stressed gap to below that which will withstand rated insulation levels.

For a switching device with a short circuit making capacity but no short circuit current breaking capacity, a time delay [anti-reflex] shall be introduced between the closing and opening operation. This time delay shall be not less than the rated duration of the short circuit (refer to 4.7).

Note: The intention of this provision is to let the switch "ride out" the short-circuit in the closed position until a back-up device safely clears the fault.

5.8 Operation of releases

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

5.9 Low and high-pressure interlocking and monitoring devices

Where low-pressure or high-pressure interlocking devices are provided in operating mechanism systems, they shall be such that they can be set to operate at, or within, the appropriate limits of pressure stated by the manufacturer and with relevant IEEE standards.
Closed pressure systems filled with compressed gas for insulation and/or operation and having a minimum functional pressure for insulation and/or operation above 200 kPa (29 psi) (absolute pressure), shall be provided with pressure (or density) monitoring devices, to be continuously, or at least periodically, checked as part of the maintenance program, taking into account the relevant equipment standards. For switchgear having a minimum functional pressure not higher than 200 kPa (29 psi) (absolute pressure), such means should be subject to agreement between manufacturer and user.

5.10 Nameplates

Switchgear and their operating devices shall be provided with nameplates which contain the necessary information such as the name or mark of the manufacturer, the year of manufacture, the manufacturer's type designation, the serial number or equivalent, and the rated characteristics, as specified in the relevant equipment standards.
For outdoor switchgear, the nameplates and their methods of attachment shall be weather-proof and corrosion-proof.
If the switchgear consists of several poles with independent operating mechanisms, each pole shall be provided with a nameplate.
For an operating device combined with a switching device, it may be sufficient to use only one combined nameplate.
Technical characteristics on nameplates and/or in documents, which are common to several kinds of high-voltage switchgear, shall be represented by the same symbols. Such characteristics and their symbols are:

— Rated maximum voltage .... V or (U_r)

— Rated lightning impulse withstand voltage .... U_p

— Rated switching impulse withstand voltage .... U_s

— Rated power-frequency withstand voltage .... U_d

- Rated continuous current ....I_r
- Rated short-time withstand current ....I_k
- Rated peak withstand current ....I_p
- Rated frequency ....f_r
- Rated duration of short-circuit ....t_k
- Rated auxiliary voltage ....U_a
- Rated filling pressure (density) for insulation ....p_{re} (ρ_{re})
- Rated filling pressure (density) for operation ....p_{rm} (ρ_{rm})
- Alarm pressure (density) for insulation ....p_{ae} (ρ_{ae})
- Alarm pressure (density) for operation ....p_{am} (ρ_{am})
- Minimum functional pressure (density) for insulation ....p_{me} (ρ_{me})
- Minimum functional pressure (density) for operation ....p_{mm} (ρ_{mm})

The values to be used for U_p , U_s and U_d on nameplates are phase-to-ground values.

Other characteristics (such as type of gas or temperature class) being specified shall be represented by the symbols that are used in the relevant standards.

5.11 Interlocking devices

Interlocking devices between different components of equipment may be required for reasons of safety and/or convenience of operation (for example between a switching device and the associated grounding switch).

Switching devices, the incorrect operation of which can cause damage or which are used for assuring isolating distances, shall be provided with provision for locking facilities as specified to the manufacturer (for example, provision of padlocks).

5.12 Position indication

Clear and reliable indication shall be provided of the position of the contacts of the main circuit in case of non-visible contacts. It shall be possible to easily check the state of the position-indicating device when operating locally.

The color of the position-indicating device in the open, closed, or, where appropriate, grounded position, shall be in accordance with the requirements of the relevant equipment standards.

The closed position shall be marked, preferably with a "C" or the word "Closed". The open position shall be marked, preferably with an "O" or the word "Open". Alternatively, in the case of a multi-function device, the positions may be marked with graphical symbols for equipment of IEC 60417 .

5.13 Degrees of protection by enclosures

Degrees of protection according to ANSI/IEC 60529, shall be specified for all enclosures of high-voltage switchgear containing parts of the main circuit allowing penetration from outside as well as for enclosures for appropriate low-voltage control and/or auxiliary circuits and mechanical operating equipment of all high-voltage switchgear and switching devices.

The degrees of protection apply to the service condition of the equipment.

NOTE—The degrees of protection may be different for other conditions such as maintenance, testing, etc.

5.13.1 Protection of persons against access to hazardous parts and protection of the equipment against ingress of solid foreign objects (IP coding)

The degree of protection of persons provided by an enclosure against access to hazardous parts of the main circuit, control and/or auxiliary circuits and to any hazardous moving parts (other than smooth rotating shafts and slowly moving linkages) shall be indicated by means of a designation specified in Table 7.
The first characteristic numeral indicates the degree of protection provided by the enclosure with respect to persons, as well as of protection of the equipment inside the enclosure against ingress of solid foreign bodies.

If only the protection against access to hazardous parts is requested or if it is higher than that indicated by the first characteristic numeral, an additional letter may be used as in Table 7.

Table 7 gives details of objects that will be "excluded" from the enclosure for each of the degrees of protection. The term "excluded" implies that solid foreign objects will not fully enter the enclosure and that a part of the body or an object held by a person, either will not enter the enclosure or, if it enters, that adequate clearance will be maintained and no hazardous moving part will be touched.

Table 7 [23]—Degrees of protection

Degree of protection	Protection against ingress of solid foreign bodies	Protection against access to hazardous parts
IP1XB	Objects of 50 mm diameter and greater	Access with a finger (test-finger 12 mm diameter, 80 mm long)
IP2X	Objects of 12.5 mm diameter and greater	Access with a finger (test-finger 12 mm diameter, 80 mm long)
IP2XC	Objects of 12.5 mm diameter and greater	Access with a tool (test-rod 2.5 mm diameter, 100 mm long)
IP2XD	Objects of 12.5 mm diameter and greater	Access with a wire (test-wire 1.0 mm diameter, 100 mm long)
IP3X	Objects of 2.5 mm diameter and greater	Access with a tool (test-rod 2.5 mm diameter, 100 mm long)
IP3XD	Objects of 2.5 mm diameter and greater	Access with a wire (test-wire 1.0 mm diameter, 100 mm long)
IP4X	Objects of 1.0 mm diameter and greater	Access with a wire (test-wire 1.0 mm diameter, 100 mm long)
IP5X	Dust The ingress of dust is not totally prevented, but does not penetrate in a quantity or at a location such that it can interfere with satisfactory operation of apparatus or to impair safety.	Access with a wire (test-wire 1.0 mm diameter, 100 mm long)
NOTE 1 The designation of the degree of protection corresponds to ANSI/IEC 60529. NOTE 2 In the case of IP5X category 2 of 13.4 of ANSI/IEC 60529, is applicable. NOTE 3 If only the protection against access to hazardous parts is concerned, the additional letter is used and the first numeral is replaced by an X.		

[23] In order to preserve the coordination with IEC 62271.1, table number 6 is reserved for future use. It is intentionally omitted from this revision of C37.100.1. In IEC 62271.1, Table 6 covers classes of auxiliary contacts.

5.13.2 Protection against ingress of water (IP coding)

For equipment of indoor installation no degrees of protection against harmful ingress of water as per the second characteristic numeral of the IP-code is specified (second characteristic numeral X, example: IPXXC).

Equipment for outdoor installation provided with additional protection features against rain and other weather conditions shall be specified by means of the supplementary letter W placed after the second characteristic numeral, or after the additional letter, if any, example: IP2XCW.

5.13.3 Protection of equipment against mechanical impact under normal service conditions (IK coding)

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

5.14 Creepage distances for outdoor insulators

The minimum values for creepage distance under normal conditions of atmospheric contamination shall be as specified in Annex C for medium pollution level.

Guidelines for additional creepage under higher levels of pollution are also given in Annex C.

5.15 Gas and vacuum tightness

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

5.16 Liquid tightness

The following specifications apply to all switchgear that use liquids as insulating, or combined insulating and interrupting, or control medium with or without permanent pressure.

5.16.1 Controlled pressure systems for liquid

The tightness of controlled pressure systems for liquid is specified by the number of replenishments per day, N_{liq} or by the pressure drop, ΔP_{liq} without replenishment, both caused by the leakage rate F_{liq}.

The permissible values shall be given by the manufacturer.

5.16.2 Closed pressure systems for liquid

The tightness level of closed pressure systems for liquid, pressurized or not, shall be specified by the manufacturer.

5.16.3 Leakage rates for liquid

The leakage rate for liquid shall be indicated by the manufacturer. A clear distinction shall be made between internal and external tightness.

a) Total tightness: no liquid loss can be detected:

b) Relative tightness: slight loss is acceptable under the following conditions:

   1) The leakage rate, F_{liq} shall be less than the permissible leakage rate, F_p (liq).

   2) The leakage rate, F_{liq} shall not continuously increase with time or in the case of switching devices, with number of operations.

   3) The liquid leakage shall cause no malfunction of the switchgear, nor cause any injury to operators in the normal course of their duty.

5.17 Flammability

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

5.18 Electromagnetic compatibility (EMC)

The secondary system shall be able to withstand electromagnetic disturbances, stated in 6.9, without damage or malfunction.

This applies under normal operation and under switching conditions, including interruption of fault currents in the primary system.

The secondary system consists of:

— Control and auxiliary circuits, including circuits in central control cubicles, mounted at, adjacent to or inside the switchgear:

— Equipment for monitoring, diagnostics, etc. that is part of the switchgear:

— Circuits connected to the secondary terminals of instrument transformers that are part of the switchgear.

In many cases the secondary system may be divided into a number of major sub-assemblies, such as a central control cubicle of a circuit breaker, or a complete control cubicle of a circuit breaker in a GIS bay.

NOTE 1—General guidance regarding EMC and considerations to improve the electromagnetic compatibility is given in IEC 61000-5-1 [B21] and IEC 61000-5-2 [B22]. The magnitude of induced voltages in a secondary system depend both, on the secondary system itself and on conditions, such as grounding and rated voltage of the primary system.

5.19 X-ray emission

When subjected to high test voltages with the contacts open, vacuum switchgear may emit X-rays. In order to ensure that these are of an acceptable level, all vacuum switchgear shall comply with the provisions of ANSI C37.85.

6. Design (type) tests

The design (type) tests are for the purpose of proving the characteristics of switchgear, their operating devices and their auxiliary equipment.

6.1 Grouping of tests

The design (type) tests shall be carried out on a maximum of four test specimens unless otherwise specified.

NOTE—The rationale behind the specification of four test specimens is to give increased confidence to users that the switchgear tested is representative of that which will be delivered (in the limit, this would require all tests to be carried out on a single specimen), while allowing manufacturers to carry out testing at separate laboratories for different groups of tests.

Each test specimen of switchgear shall conform to drawings and be representative of its type and shall be subjected to one or more type tests.

For convenience of testing, the type tests may be grouped. An example of a possible grouping is shown in the Table 8 below.

Where additional type tests are necessary, these are specified in the relevant standard.

Table 8— Example of grouping of type tests

Group	Type-tests	Subclause
1	Dielectric tests on main, auxiliary and control circuits Radio interference test (RIV)	6.2 6.3
2	Measurement of resistance of the main current path Temperature rise tests	6.4 6.5
3	Short-time withstand current and peak withstand current tests Making and breaking tests	6.6 See relevant standard
4	Tests to verify the degrees of protection of enclosures Tightness tests (where applicable) Mechanical tests Environmental tests	6.7 6.8 } See relevant standard

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Each individual type test shall be made on complete switchgear in the condition as required for service (filled with the specified types and quantities of liquid or gas at specified pressure and temperature), on their operating devices and auxiliary equipment, all of which in principle should be in, or restored to, a new and clean condition at the beginning of each type test.

A test specimen is a complete switchgear when the poles are mechanically linked (i.e. one operating mechanism) or when the type tests are mainly three-pole tests. If this is not the case, a test specimen is one pole of the complete switchgear. Where permitted in the relevant standard, a test specimen may be a representative sub-assembly.

Reconditioning during individual type tests may be allowed, according to the relevant standard. The manufacturer shall provide a statement to the testing laboratory of those parts that may be renewed during the tests.

6.1.1 Information for identification of specimens

The manufacturer shall submit to the testing laboratory, drawings and other data containing sufficient information to unambiguously identify by type the essential details and parts of the switchgear presented for test. A summary list of the drawings and data schedules shall be supplied by the manufacturer and shall be uniquely referenced and shall contain a statement to the effect that the manufacturer guarantees that the drawings or data schedules listed are the correct version and truly represent the switchgear to be tested.

After completion of verification, the summary list shall be retained by the test laboratory. The detail drawings and other data should be returned to the manufacturer. The manufacturer shall maintain detailed design records of all component parts of the switchgear tested and shall ensure that these may be identified from information included in the drawings and data schedules.

NOTE—Manufacturers whose production systems have been certified for compliance with ISO 9001 [B27] satisfy the requirements for detailed design records.

The testing laboratory shall check that drawings and data schedules adequately represent the essential details and parts of the switchgear to be tested, but shall not be responsible for the accuracy of the detailed information.

Annex D specifies the particular drawings or data that is required to be submitted by the manufacturer to the test laboratory for identification of essential parts of switchgear.

An individual type test need not be repeated for a change of construction detail, if the manufacturer can demonstrate that this change does not influence the result of that individual type test.

6.1.2 Information to be included in design-test (type-test) reports

The results of all design (type-tests) shall be recorded in design-test (type-test) reports containing sufficient data to prove compliance with the ratings and the test clauses of the relevant standards and sufficient information shall be included so that the essential parts of the switchgear can be identified. In particular, the following information shall be included:

- Manufacturer;
- Type designation and serial number of switchgear tested;
- Rated characteristics of switchgear tested as specified in the relevant standard;
- General description (by manufacturer) of switchgear tested, including number of poles;
- Make, type, serial numbers and ratings of essential parts, where applicable (e.g. operating-mechanisms, interrupters, shunt impedances);
- General details of the supporting structure of the switching device or enclosed switchgear, of which the switching device forms an integral part;
- Details of the operating-mechanism and devices employed during tests, where applicable;
- Photographs to illustrate the condition of switchgear before and after test;
- Sufficient outline drawings and data schedules to represent the switchgear tested;
- Reference numbers of all drawings submitted to identify the essential parts of the switchgear tested;
- Details of the testing arrangements (including diagram of test circuit);
- Statements of the behavior of the switchgear during tests, its condition after tests and any parts renewed or reconditioned during the tests;
- Records of the test quantities during each test or test duty, as specified in the relevant standard.
- Dates the tests were conducted.

- Location and company name where the tests were conducted.
- Name of person responsible for conducting the tests.

NOTE 1—Some switchgear equipment may not be serialized (e.g. fuses). The relevant equipment standards should clarify by exception to portions of this clause.

NOTE 2—NSDDs may occur during the recovery voltage period following a breaking operation. Their number is of no significance to interpreting the performance of the device under test. They should only be reported in the test report in order to differentiate them from restrikes.

6.2 Dielectric tests

Dielectric tests of the switchgear shall be performed in compliance with IEEE Std 4 and IEEE Std 4a, or IEC 60060-1 [24] , unless otherwise specified in this standard or in the relevant product standard.

The tolerance for test value of the impulse voltage tests is +3%/-0

If correction factors are applied due to atmospheric conditions at the time of the test, it may be necessary to perform separate tests on equipment with non-atmospheric insulation paths in accordance with 6.2.12.

6.2.1 Ambient air conditions during tests

Reference shall be made to IEEE Std 4 and IEEE Std 4a regarding standard reference atmospheric conditions and atmospheric correction factors. Also refer to Annex B.

6.2.2 Wet test procedure

The external insulation of outdoor switchgear shall be subjected to wet withstand tests under the standard wet test procedure given in IEEE Standard 4 and IEEE Std 4a.

6.2.3 Conditions of switchgear during dielectric tests

Dielectric tests shall be made on completely assembled switchgear, as in service. The outside surfaces of insulating parts shall be in clean condition.

The switchgear shall be mounted for test with minimum clearances and height as specified by the manufacturer.

Equipment tested at one height above ground surface level will be deemed to be satisfactory if mounted at a greater height above ground surface level when in service.

When the distance between the poles of switchgear is not inherently fixed by the design, the distance between the poles for the test shall be the minimum value stated by the manufacturer.

When the manufacturer states that supplementary insulation such as tape or barriers is required to be used in service, such supplementary insulation shall also be used during the tests.

If arcing horns or rings are required for the purpose of system protection, they may be removed or their spacing increased for the purpose of the test. If they are required for voltage gradient distribution, they shall remain in position for the test.

[24] For purposes of tests described in clause 6.2 including its subclauses, IEC 60060-1 shall be considered equivalent to IEEE Std 4 and IEEE Std 4a.

For switchgear using compressed gas for insulation, dielectric tests shall be performed at minimum functional pressure (density) for insulation as specified by the manufacturer. The temperature and pressure of the gas during the tests shall be noted and recorded in the test report.

Caution: In the dielectric testing of switchgear incorporating vacuum switching devices, precautions should be taken to ensure that the level of possible emitted X-radiation is within safe limits. National safety codes may influence the safety measures established. Refer to ANSI C37.85.

6.2.4 Criteria to pass the test

a) Power frequency withstand voltage tests

   The switchgear has passed the test if no disruptive discharge occurs.

b) Impulse tests

   Impulse tests shall be performed by applying 3 consecutive impulses for each polarity at voltage levels equal to or greater than those that have been specified in Table 1b. The switchgear shall be considered to have passed the test if no disruptive discharge occurs. If one disruptive discharge occurs in the self-restoring part of the insulation, then 9 additional impulses of the same polarity shall be applied and if no additional disruptive discharges occur, the switchgear shall be considered to have passed the test.

NOTE—This is the preferred procedure when all three poles of a switchgear are tested. It is often referred to as the 3X9 procedure or Procedure C in IEEE Std 4 and IEC 60060-1 except that the IEC standard uses a +/-3% tolerance on the impulse voltage peak whereas IEEE uses a minus zero plus anything tolerance.

   As an alternate to the test described above, 15 consecutive lightning or switching impulses at the rated withstand voltage may be applied for each test condition and each polarity. The switchgear has passed the impulse tests if the following conditions are fulfilled:

   1) Each series has at least 15 tests;
   2) No disruptive discharges on non-self-restoring insulation shall occur. This is confirmed by 5 consecutive impulse withstands following the last disruptive discharge.
   3) The number of disruptive discharges shall not exceed two for each complete series.

This procedure leads to a maximum possible number of 25 impulses per series.

NOTE—This procedure is referred to as the 2/15 procedure or Procedure B in IEEE Std 4 and IEC 60060-1.

The determination of the location of the observed disruptive discharges can be done by the laboratory by dismantling and inspecting the equipment. If punctures of non-self-restoring insulation are observed, the switchgear has failed the test.

If it is proven that tests for one polarity give the most unfavorable results, it is permissible to perform the tests for this polarity only.

Some insulating materials retain a charge after an impulse test and for these cases care should be taken when reversing the polarity. To allow the discharge of insulating materials, the use of appropriate methods, such as the application of three impulses at about 80 % of the test voltage in the reverse polarity before the test, is recommended.

c) General comment

   When testing large switchgear, the part of equipment through which the test voltage is applied may be subjected to numerous test sequences to check the insulating properties of other down stream parts of equipment (circuit breakers, switches, etc). It is recommended that parts be

tested in sequence, starting with first connected part. When this part has passed the test according to the above-mentioned criteria, its qualification is not impaired by possible disruptive discharges that could occur in it during further tests on other parts.
These discharges may have been generated by accumulation of discharge probability with the increased number of voltage applications or by reflected voltage after a disruptive discharge at a remote location within the equipment. To reduce the probability of occurrence of these discharges in gas-filled equipment, the pressure of the already-tested parts may be increased after passing their tests.

6.2.5 Application of the test voltage and test conditions

Distinction must be made between the general case, where the three test voltages (phase-to-ground, between phases, and across open switching device) are the same, and the special cases of the isolating distance and of insulation between phases higher than phase to ground.

6.2.5.1 General case

With reference to Figure 2, which shows a diagram of connection of a three-pole switching device, the test voltage shall be applied according to the following Table 9:

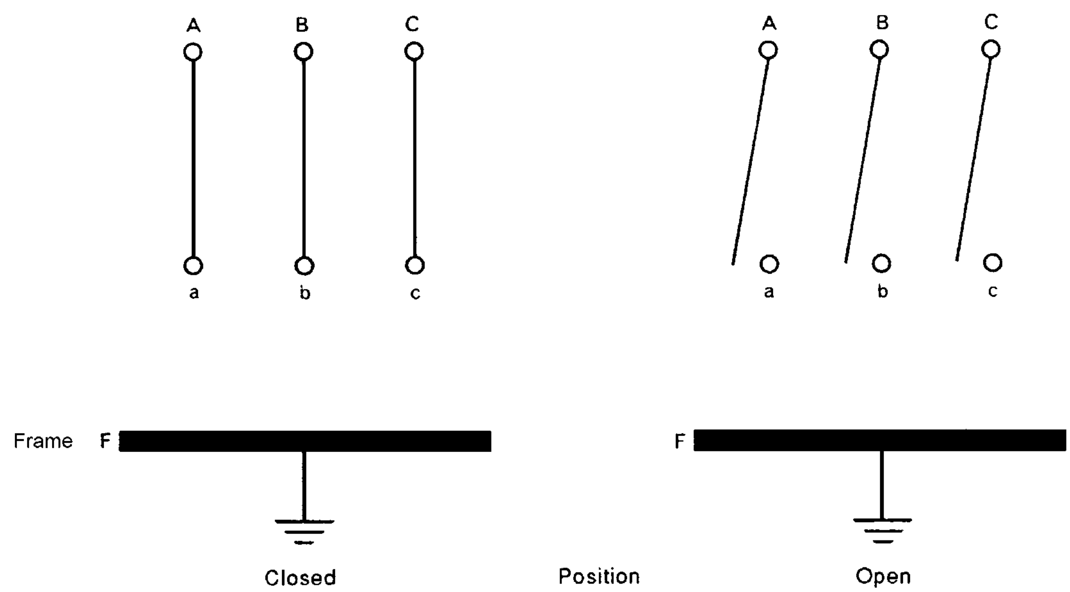

Figure 2— Diagram of connections of a three-pole switching device

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Table 9— Test conditions in general case

Test Condition	Switching device	Voltage applied to	Ground Connected to
1	Closed	Aa	BCbcF
2	Closed	Bb	ACacF
3	Closed	Cc	ABabF
4	Open	A	BCabcF
5	Open	B	ACabcF
6	Open	C	ABabcF
7	Open	a	ABCbcF
8	Open	b	ABCacF
9	Open	c	ABCabF

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In Table 9, test conditions 3, 6 and 9 may be omitted if the arrangement of the outer poles is symmetrical with respect to the center pole and the base. Test conditions 7, 8 and 9 may be omitted if the arrangement of the terminals of each pole is symmetrical with respect to the base.

In Table 9, test conditions 2, 3, 5, 6, 8, 9 may be omitted if the arrangement of the poles is fully symmetrical with respect to each other and to the frame. An example of this condition is symmetrical arrangement of three poles inside a cylindrical tank.

6.2.5.2 Special case

When the test voltage across the open switching device is higher than the phase-to-ground withstand voltage, different test methods may be used.

a) Method 1

1) Power frequency voltage tests

The tests shall be performed using two different voltage sources in out-of-phase conditions in order to obtain the specified test value. The voltage distribution is specified in 6.2.6.1 and in 6.2.7.1.

In this case, the test voltage across the open switching device (or isolating distance) shall be applied according to the following Table 10:

Table 10—Power-frequency test conditions [a,b]

Test Condition	Voltages applied to	Ground Connected to
1	A and a	BCbcF
2	B and b	ACacF
3	C and c	AbabF

[a] Test condition 3 may be omitted if the arrangement of the outer pole is symmetrical with respect the center pole and the frame.

[b] Test conditions 2 & 3 may be omitted if the arrangements of the poles is fully symmetrical with respect to each other an to the frame.

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In Table 10, Test condition 3 may be omitted if the arrangement of the outer poles is symmetrical with respect to the center pole and the base.

2) Impulse voltage tests

The rated impulse withstand voltage phase-to-ground constitutes the main part of the test voltage and is applied to one terminal; the complementary voltage is supplied by another voltage source of the opposite polarity and applied to the opposite terminal. This complementary voltage may be either another impulse voltage or the peak of a power frequency voltage. The other poles and the frame are grounded.

To take into account the influence of the impulse on the power-frequency voltage wave, caused by capacitive coupling between the two voltage circuits, the following test requirements shall be fulfilled: the sum of the voltage impulse peak and the complementary voltage at the instant of the peak value of the impulse shall be equal to the total test voltage required with a tolerance of +3 %. To achieve such a condition, the instantaneous power-frequency voltage or, the impulse voltage might be increased. The instantaneous power-frequency voltage may be increased up to, but no more than $(Ur)\sqrt{2}/\sqrt{3}$ for the lightning impulse tests, and not more than $(1.2)(Ur)\sqrt{2}/\sqrt{3}$ for the switching impulse tests.

The voltage drop can be greatly reduced by using a capacitor of a convenient value connected in parallel to the terminal of the power-frequency side.

The test voltage shall be applied according to Table 11:

Table 11— Impulse tests conditions - method 1

Test condition	Main part	Complementary part	Ground connected to
	Voltage applied to		
1	A	a	BbCcF
2	B	b	AaCcF
3	C	c	AaBbF
4	a	A	BbCcF
5	b	B	AaCcF
6	c	C	AaBbF

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In Table 11, test conditions 3 and 6 may be omitted if the arrangement of the outer poles is symmetrical with respect to the center pole and the base. Test conditions 4, 5 and 6 may be omitted if the arrangement of the terminals of each pole is symmetrical with respect to the base.

b) Method 2

When only one voltage source is used, the insulation across the open switching device (or isolating distance) may be tested as follows, for both power-frequency voltage tests and impulse voltage tests:

1) The total test voltage U_t is applied between one terminal and ground; the opposite terminal is grounded.

2) When the resulting voltage across the supporting insulation of the switching device would exceed the rated phase-to-ground withstand voltage, the frame is fixed at a partial voltage with respect to ground U_f, so that U_t - U_f is between 90 % and 100 % of the rated withstand voltage phase-to-ground.

3) If permitted, all terminals not under test and the frame may be insulated from earth, considering reference is made in 6.2.6 to the alternative method of 6.2.5.2.

Table 12 shows how to apply the different voltages.

Table 12—Impulse tests conditions - method 2

Test condition	Main part	Complementary part	Fixed at partial voltage U_f a)
	Voltage applied to		
1	A	a	BbCcF
2	B	b	AaCcF
3	C	c	AaBbF
4	a	A	BbCcF
5	b	B	AaCcF
6	c	C	AaBbF

a) If permitted by the relevant equipment standards, all terminals (not under test) and the frame may be insulated from ground.

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6.2.6 Tests of switchgear of $V \leq 245$ kV ($U_r \leq 245$ kV)

The tests shall be performed with the test voltages given in Table 1a) or Table 1b).

6.2.6.1 Power frequency voltage tests

Switchgear shall be subjected to power-frequency voltage withstand tests in accordance with IEEE Std 4 and IEEE Std 4a. The test voltage shall be raised for each test condition to the test value and maintained for 1 minute.
The tests shall be performed in dry conditions and also in wet conditions for external insulation of outdoor switchgear.

The isolating distance may be tested as follows:

— Method 1: In this case, neither of the two voltage values applied to the two terminals shall be less than one-third of the rated withstand voltage phase-to-ground:

— Method 2: for metal-enclosed gas-insulated switching device with a rated maximum voltage of less than 72.5 kV and for conventional switching device of any rated voltage the frame may be insulated from ground.

NOTE—Due to the large scatter of the results of power-frequency voltage wet tests for switchgear of rated maximum voltages equal to 170 kV and 245 kV, it is accepted to replace these tests by a wet 250/2500 ms switching impulse voltage test, with a peak value equal to 1.55 times the rms value of the specified power-frequency test voltage.

6.2.6.2 Lightning impulse voltage tests

Switchgear shall be subjected to lightning impulse voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1.2/50 ms according to IEEE Std 4 and IEEE Std 4a. The voltage levels shall be equal to or greater than those that are specified in Table 1b.

When testing a vacuum interrupter, some preliminary impulse tests may be performed at up to and including the rated withstand voltage. Breakdowns that are observed during these preliminary tests can be disregarded for the purposes of the withstand statistics used to determine pass or fail performance of the equipment.

When method 2 in 6.2.6.1 is used to test the isolating distance of metal-enclosed gas-insulated switching device with a rated maximum voltage of less than 72.5 kV and of conventional switching device of any rated voltage, the frame may be insulated from ground.

6.2.7 Tests of switchgear of rated maximum voltage of $V > 245$ kV ($U_r > 245$ kV)

In the closed position, the tests shall be performed in conditions 1, 2 and 3 of Table 9. In the open position, the tests shall be performed as stated below (but refer to 6.2.3). In addition, phase-to-phase switching impulse voltage tests shall be performed as stated below. The test voltages are given in Table 2a or Table 2b.

6.2.7.1 Power-frequency voltage tests

Switchgear shall be subjected to power-frequency voltage withstand tests in accordance with IEEE Std 4 and IEEE Std 4a. The test voltage shall be raised for each test condition to the test value and maintained for 1 min.

The tests shall be performed in dry conditions only.

The insulation across the open switching device or isolating distance may be tested with either method 1, 6.2.5.2 a) or method 2, 6.2.5.2 b). Whichever method is chosen, neither of the voltages applied between one terminal and the frame shall be higher than the rated maximum voltage *V or* (U_r).

NOTE—The manufacturer should be consulted if method 2 is used.

6.2.7.2 Switching impulse voltage tests

Switchgear shall be subjected to switching impulse voltage tests. The tests shall be performed with voltages of both polarities using the standardized switching impulse 250/2500 ms according to IEEE Std 4 and IEEE Std 4a. The voltage levels shall be equal to or greater than those that are specified in Table 2a or Table 2b. Wet tests shall be performed for outdoor switchgear only.

The isolating distance shall be tested with either method in 6.2.5.2.

The insulation between poles shall be tested in dry conditions only with a total test voltage given in column 5 of Table 2a and Table 2b, by either method in 6.2.5.2 above, The actual voltage distribution shall be as balanced as possible. Any unbalanced distribution of the total test voltage is more severe. When voltage components are different in shape or/and amplitude, the test shall be repeated reversing the connections.

6.2.7.3 Lightning impulse voltage tests

Switchgear shall be subjected to lightning impulse withstand voltage tests in dry conditions only. The tests shall be performed with voltages of both polarities using the standard lightning impulse 1.2/50 ms according to IEEE Std 4 and IEEE Std 4a. The voltage levels shall be equal to or greater than those that are specified in Table 2a or Table 2b.

6.2.8 Artificial pollution tests for outdoor insulators

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

6.2.9 Partial discharge tests

When requested by the relevant product standard, partial discharge tests shall be performed and the measurements made according to IEEE Std 1291 or IEC 60270 [B10].

NOTE—The term partial discharge covers all non-disruptive discharges, including corona that are partial discharges in air.

6.2.10 Dielectric tests on auxiliary and control circuits

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

6.2.11 Voltage test as condition check

When the insulating properties across open contacts of a switching device after the making, breaking and/or mechanical/electrical endurance tests cannot be verified by visual inspection with sufficient reliability, a power-frequency withstand voltage test in dry condition according to 6.2.6.1 and 6.2.7.1 across the open switching device at the following value of power frequency voltage may be appropriate if not otherwise stated in the relevant equipment standards.

For equipment with rated maximum voltages up to and including 245 kV:

— 80 % of the value in Table 1a or Table 1b, column 3 for disconnectors and switch-disconnectors (equipment with safety requirements) and 80 % of the value in column 2 for other equipment.

For equipment with rated maximum voltages from 300 kV and above:

— 100 % of the value in Table 2a or Table 2b, column 3 for disconnectors and switch-disconnectors (equipment with safety requirements):

— 80 % of the value in Table 2a or Table 2b, column 3 for other equipment.

NOTE 1—The reduction of the test voltage is motivated by the insulation coordination margin [25] in the rated test voltage values, which takes aging, wear and other normal deterioration into account, and by the statistical nature of the flash-over voltage.

[25] The term “insulation coordination margin” is sometimes stated as “Safety Margin” or “Safety Factor” in other standards.

NOTE 2—Condition-checking tests of the insulation to ground may be required for enclosed devices of certain design. In such cases a power-frequency test with 80 % of the values in column 2, of Table 1a, Table 1b, Table 2a, or Table 2b, should be performed.

NOTE 3—The relevant apparatus standard can specify that this condition-checking test is mandatory for certain types of equipment.

6.2.12 Insulation paths

When performing dielectric tests, two classes of insulation paths are to be considered:

a) Atmospheric paths: Paths entirely through atmospheric air, such as along the porcelain surface of an outdoor bushing.

b) Non-atmospheric paths: All other paths, such as through a gas or vacuum sealed from the atmosphere, through a liquid such as oil, through a solid, or through a combination thereof.

6.2.12.1 Non atmospheric paths

In order to meet the requirements for non atmospheric paths, at least three dry withstand tests must be accumulated at each polarity, at the rated lightning impulse and related chopped wave voltages (in addition to one dry power frequency withstand test), all without benefit of reduction of voltages due to correction factors. The purpose is to apply full stresses to these non-atmospheric paths; therefore, tests in which a flashover occurs through an atmospheric path may be ignored. It is permissible to raise the dielectric strength of the atmospheric paths by artificial means, such as an extra high-voltage shield or a corona ring. In some atmospheric conditions, it may be desirable to delay testing of the non-atmospheric paths until conditions improve.

6.2.12.2 Atmospheric paths

There is no separate atmospheric path requirement for the dry-power frequency test.

6.3 Radio influence voltage (RIV) test

These tests apply only when specified in the relevant standards. Switchgear shall be installed as stated in 6.2.3.

6.3.1 Test voltages and limits

Unless otherwise specified in the relevant standards, a test voltage of $(1.1)V/\sqrt{3}$ ($(1.1)Ur/\sqrt{3}$) shall be applied to the switchgear, with $V(U_r)$ being the rated maximum voltage of the switchgear. The measurement of the RIV shall then be made and recorded.

The switchgear shall be considered to have passed the test if the radio influence level at $(1.1)V/\sqrt{3}$ ($(1.1)Ur/\sqrt{3}$) does not exceed 2500 mV unless other test limits are specified in the relevant standards. Devices having two or more voltage ratings shall be tested on the basis of the highest voltage rating given on the nameplate.

6.3.2 Test conditions

6.3.2.1 Atmospheric conditions

Tests shall be conducted under atmospheric conditions prevailing at the time and place of test but it is recommended that tests be avoided when the water vapor pressure is below 0.67 kPa or above 2.00 kPa.

Since the effects of humidity and air density upon radio influence voltage are not definitely known, no correction factors are recommended for either at the present time. However, it is recommended that barometric pressure and dry and wet bulb thermometer readings be recorded so that, if suitable correction factors should be determined, they could be applied to previous measurements.

6.3.3 Test equipment and procedure

The equipment and general method used in making radio influence voltage tests shall be in accordance with the recommendations of NEMA 107 (methods) and ANSI C63.2 (equipment).

The measuring circuit shall preferably be tuned to a frequency within 10 % of 1.0 MHz, but other frequencies in the range of 0.5 MHz to 2 MHz may be used. The actual measuring frequency will be recorded. The test results shall be expressed in microvolts.

6.3.3.1 Procedure

The test voltage shall be applied as follows:

— In the closed position, between the terminals and the grounded base,

— In the open position, between one terminal and the other terminals connected to the grounded base, and then with the connections reversed if the switching device is not symmetrical.

The case, tank, base and other normally grounded parts shall be connected to ground.

6.3.4 Precautions

The following precautions should be observed when making radio influence voltage tests:

a) The device under test should be approximately the same temperature as the room in which the tests are made

b) The device under test should be dry and clean

c) The device under test should not have been subjected to dielectric tests within 2 hours prior to the radio influence voltage tests

d) In some cases it may be found that the radio influence voltage falls off after the rated power-frequency voltage has been applied for a short time. In such cases, it is allowed to pre-excite the device under test at normal operating voltage for a period not exceeding 5 minutes before proceeding with the tests.

e) Care should be taken to avoid influencing the measurements by grounded or ungrounded objects near the switchgear and to the test and measuring circuits.

Failure to follow the precautions noted above shall not be cause to disqualify a device that meets the specified test limits.

6.4 Measurement of the resistance of circuits

6.4.1 Main circuit

A measurement of the resistance of the main circuit shall be made for comparison between the switchgear type tested for temperature rise and all other switchgear of the same type subjected to routine (production) tests (see 7.3).

The measurement shall be made using a dc supply by measuring the voltage drop or resistance across the terminals of each pole. Special consideration shall be given to enclosed switchgear (see the relevant standards).

The current during the test shall be 25% of the rated continuous current or 100 A dc, whichever is lower. Experience shows that an increase of the main circuit resistance cannot alone be considered as reliable evidence of bad contacts or connections. In case of doubt, the test should be repeated with a higher current, as close as possible to the rated continuous current.

NOTE--For some equipment, the rated continuous current is less than 100 A.

The measurement of the dc voltage drop or the resistance shall be made before the temperature-rise test, with the switchgear at the ambient air temperature for a period of at least eight (8) hours, and after the temperature-rise test when the switchgear has cooled to a temperature nearly equal to the ambient air temperature. The measured resistances after the test shall not differ by more than 20% from the pre-test resistance

The measured value of the dc voltage drop or the resistance shall be given in the type-test report, as well as the general conditions during the test (current, ambient air temperature, points of measurement, etc.).

6.4.2 Auxiliary circuits

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

6.5 Temperature-rise tests

6.5.1 Conditions of the switchgear to be tested

The temperature-rise test of the main circuits shall be made on a new switching device with clean contacts, and, if applicable, filled with the appropriate liquid or gas at the minimum functional pressure (or density) for insulation prior to the test.

6.5.2 Arrangement of the equipment

The test shall be made in an environment substantially free from air currents, except those generated by heat from the switching device being tested. In practice, this condition is reached when the air velocity, measured before test, does not exceed 0.5 m/s.

For temperature-rise tests of parts other than auxiliary equipment, the switchgear and their accessories shall be mounted in all significant respects as in service, including all normal covers of any part of the switchgear, and shall be protected against undue external heating or cooling.

When the switchgear, according to the manufacturer’s instructions, may be installed in different positions, the temperature-rise tests shall be made in the most unfavorable position.

These tests shall be made on three-pole switchgear but may be made on a single-pole or on a single unit provided the influence of the other poles or units is negligible. This is the general case for non-enclosed switchgear. For three-pole switchgear with a rated continuous current not exceeding 1250 A, the tests may be made with all poles connected in series.

For particularly large switchgear for which the insulation to ground has no significant influence on temperature-rises, the insulation to ground may be reduced.

Temporary connections to the main circuit shall be such that no significant amount of heat is conducted away from, or conveyed to, the switchgear during the test. The temperature-rise at the terminals of the main circuit, and at the temporary connections at a distance of 1 m from the terminals, shall be measured. The difference of temperature-rise shall not exceed 5 K. The type and sizes of the temporary connections shall be recorded in the test report.

For three-pole switchgear, the test shall be made in a three-phase circuit with the exceptions mentioned above.

The test shall be made at the rated continuous current (I_r) of the switchgear. The supply current shall be practically sinusoidal.

Switchgear, with the exception of dc auxiliary equipment, shall be tested at rated frequency with a tolerance of +2 % and -5 % except as noted in the following two paragraphs. The test frequency shall be recorded in the test report.

Tests performed at 50 Hz on switching devices having no ferrous components adjacent to the current-carrying parts should be deemed to prove the performance of the switching device when rated 60 Hz, provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values.

When tests are performed at 60 Hz they should be considered valid for the same current rating with 50 Hz rated frequency.

The test shall be made over a period of time sufficient for the temperature-rise to reach a stable value. This condition is deemed to be obtained when the increase of temperature-rise does not exceed 1 K in 1 hour with readings being taken at not greater than 30-minute intervals. This criterion will normally be met after a test duration of five to six times the thermal time constant of the tested device.

6.5.3 Measurement of the temperature and the temperature-rise.

Precautions shall be taken to reduce the variations and the errors due to the time lag between the temperature of the switching device and the variations in the ambient air temperature.

For coils, the method of measuring the temperature-rise by variation of resistance shall normally be used. Other methods are permitted only if it is impractical to use the resistance method.

The temperature of the various parts other than coils for which limits are specified shall be measured with thermometers or thermocouples, or other sensitive devices of any suitable type, placed at the hottest accessible point. The temperature-rise shall be recorded at regular intervals throughout the test when the calculation of the thermal time constant is needed.

The surface temperature of a component immersed in a liquid dielectric shall be measured only by thermocouples attached to the surface of this component. The temperature of the liquid dielectric itself shall be measured in the upper layer of the dielectric.

For measurement with thermometers or thermocouples, the following precautions shall be taken:

a) The bulbs of the thermometers or thermocouples shall be protected against cooling from outside (dry clean wool, etc.). The protected area shall, however, be negligible compared with the cooling area of the apparatus under test;

b) Good heat conductivity between the thermometer or thermocouple and the surface of the part under test shall be ensured;

c) When bulb thermometers are employed in places where there is any varying magnetic field, it is recommended to use alcohol thermometers in preference to mercury thermometers, as the latter are more liable to be influenced under these conditions.

6.5.4 Ambient air temperature

The ambient air temperature is the average temperature of the air surrounding the switchgear (for enclosed switchgear, it is the air outside the enclosure). The ambient temperature shall be determined by taking the average of the readings of three measuring devices placed 300 mm to one side of the device and vertically located as follows:

For pole or frame mounted equipment	For enclosed equipment
— One 300 mm above the top of the device	— One level with the top of the equipment
— One 300 mm below the bottom of the device	— One 300 mm (12 in) above the floor
— One midway between the above two positions.	— One midway between the above two positions.

NOTE—Pole or frame-mounted equipment includes all equipment mounted above or off the floor or ground. Enclosed equipment includes metal clad, metal enclosed, and pad-mounted equipment that is normally installed on the floor or ground pad.

The thermometers or thermocouples shall be protected against air current and undue influence of heat.

NOTE—In order to avoid indication errors because of rapid temperature changes, the thermometers or thermocouples may be put into a suitable liquid such as oil in a suitable container or reliably attached to a suitable mass of metal.

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 hour.

The ambient air temperature during tests shall be more than +10 ºC but less than +40 ºC. No correction of the temperature-rise values shall be made for ambient air temperatures within this range.

6.5.5 Temperature-rise testing of the auxiliary and control equipment

The test is made with the specified supply (ac or dc), and for ac at its rated frequency (tolerance +2 %, -5 %).

Tests performed at 50 Hz on switching devices having no ferrous components adjacent to the current-carrying parts should be deemed to prove the performance of the switching device when rated 60 Hz provided that the temperature-rise values recorded during the tests at 50 Hz do not exceed 95 % of the maximum permissible values.

When tests are performed at 60 Hz they should be considered valid for the same current rating with 50 Hz rated frequency.

The auxiliary equipment shall be tested at its rated supply voltage (U_a) or at its rated current. The ac supply voltage shall be practically sinusoidal.

Continuous rated coils shall be tested over a period of time sufficient for the temperature-rise to reach a constant value. This condition is usually obtained when the variation does not exceed 1 K in 1 hour.

For circuits energized only during switching operations, the tests shall be made under the following conditions:

a) When the switching device has an automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the circuit shall be energized 10 times, for either 1 s or until the automatic breaking device operates, the interval between the instant of each energizing being 10 s or, if the construction of the switching device does not permit this, the lowest interval possible.

b) When the switching device has no automatic breaking device for interruption of the auxiliary circuit at the end of the operation, the test shall be made by energizing the circuit once for a duration of 15 s.

6.5.6 Interpretation of the temperature-rise tests

The temperature rise of the various parts of the switchgear or auxiliary equipment for which limits are specified, shall not exceed the values specified in Table 3. Otherwise, the switchgear shall be considered to have failed the test.

If the insulation of a coil is made of several different insulating materials, the permissible temperature rise of the coil shall be taken as that for the insulating material with the lowest limit of temperature rise.

If the switchgear is fitted with various equipment complying with particular standards (for example, rectifiers, motors, low-voltage switches, etc.), the temperature rise of such equipment shall not exceed the limits specified in the relevant standards.

6.6 Short-time withstand current and peak withstand current tests

Main circuits and, where applicable, the grounding circuits of the switchgear shall be subjected to tests to prove their ability to carry the rated peak withstand current and the rated short-time withstand current. The tests shall be made at the rated frequency with a tolerance of ±10 % at any suitable voltage and starting at any convenient ambient temperature.

At the option of the manufacturer and the testing laboratory, the two tests may be combined.
For convenience of testing, wider tolerances of the rated frequency may be necessary. If the deviations are appreciable, i.e. when switchgear rated for 50 Hz are tested at 60 Hz and vice versa, care should be taken in the interpretation of results.

6.6.1 Arrangement of the switchgear and of the test circuit

The switchgear shall be mounted on its own support or on an equivalent support and installed with its own operating device as far as necessary to make the test representative. It shall be in the closed position and fitted with clean contacts in new condition.

Each test shall be preceded by a no-load operation of the mechanical switching device and, with the exception of grounding switches, by measurement of the resistance of the main circuit, see 6.4.1.
The test may be made three-phase or single-phase. In the case of a single-phase test, the following shall apply:

— On a three-pole switchgear, the test shall be made on two adjacent poles;

— In the case of switchgear with separated poles, the test may be made either on two adjacent poles or on one pole with the return conductor at phase distance. If the distance between poles is not fixed by the design, the test shall be made at the minimum distance indicated by the manufacturer;

— Unless otherwise specified in the relevant equipment standards, the return conductor need not be taken into account, but in no case shall it be located closer to the tested pole than the minimum distance indicated for phase centers by the manufacturer.

The connections to the terminals of the switchgear shall be arranged in such a way as to avoid unrealistic stressing of the terminals. The distance between the terminals and the nearest supports of the conductors on both sides of the switchgear shall be in accordance with the instructions of the manufacturer.
The test arrangement shall be noted in the test report.

6.6.2 Test current and duration

The ac component of the test current shall be equal to the ac component of the rated short-time withstand current (I_k) of the switchgear. The peak current (for a three-phase circuit, the highest value in one of the outer phases) shall be not less than the rated peak withstand current (I_p) and shall not exceed it by more than 5 % without the consent of the manufacturer. The current in the other outer phase shall begin with a major loop.

For three-phase tests, the ac component of the current in any phase shall not vary from the average of the currents in the three phases by more than 10 %. The average of the rms values of the ac component of the tests currents shall be not less than the rated value.
The test current I_t shall, in principle, be applied for a time t_t not less than the rated duration t_k of short circuit.

If no other method to determine the value $I_t^2\ t_t$ is available, then it shall be determined from the oscillogram using the method of evaluating I_t given in Annex E. The value of $I_t^2\ t_t$ on test shall be not less than the value of $I_t^2\ t_k$ calculated from the rated short-time current (I_k) and the rated duration of short-circuit ($I_t^2\ t_k$), and shall not exceed this value by more than 10 % without the consent of the manufacturer.
When the characteristics of the test plant are such that the peak and rms values of test current specified above cannot be obtained in a test of the specified duration, the following deviations are permitted:

a) If the decrement of the short-circuit current of the test plant is such that the specified rms value, measured in accordance with Annex E or by an equivalent cannot be obtained for the rated duration without applying initially an excessively high current, the rms value of the test current may be permitted to fall below the specified value during the test and the duration of the test may be increased appropriately, provided that the value of the peak current is not less than that specified and the time is not more than twice the duration required with a maximum of 5 seconds for the equivalent $I_k^2 t_k$

b) If, in order to obtain the required peak current, the rms value of the current is increased above the specified value, the duration of the test may be reduced accordingly;

If two separate tests are made;

— For the peak withstand current test, the time during which the short-circuit current is applied shall be not less than 0.167 s;

— For the short-time withstand current test, the time during which the short-circuit current is applied shall be equal to the rated duration. However, deviation in time according to Item a) above is permitted.

6.6.3 Behavior of switchgear during test

All switchgear shall be capable of carrying their rated peak withstand current and their rated short-time withstand current without causing mechanical damage to any part or separation of the contacts.

It is recognized that, during the test, the temperature-rise of current-carrying and adjacent parts of the mechanical switching device may exceed the limits specified in Table 3. No temperature-rise limits are specified for the short-time current withstand tests but the maximum temperature reached should not be sufficient to cause significant damage to adjacent parts.

6.6.4 Conditions of switchgear after test

After the test, the switchgear shall not show significant deterioration, shall be capable of operating normally, carrying its rated normal current continuously without exceeding the temperature-rise limits specified in Table 3 and withstanding the rated dry power frequency withstand voltage specified under dielectric tests.

If the mechanical switching device has a rated making and/or breaking capacity, then the condition of the contacts shall not be such as to affect the performance materially at any making and/or breaking current up to its rated value.

The following is sufficient to check these requirements:

a) A no-load operation of the mechanical switching device shall be performed immediately after the test, and the contacts shall open at the first attempt.

b) The resistance of the main circuit shall be measured according to 6.4.1 (except for grounding switches). If the resistance has increased by more than 20 %, and if it is not possible to confirm the condition of the contacts by visual inspection, it may be appropriate to perform an additional temperature-rise test.

6.7 Verification of the degrees of protection provided by enclosures

6.7.1 Verification of the IP coding

In accordance with the requirements specified in clauses 11, 12, 13 and 15 of ANSI/IEC 60529, tests shall be performed on the enclosures of switchgear fully assembled as under service conditions. As real cable connections entering the enclosures are not normally installed for type tests, corresponding filler pieces shall be used. Transport units of switchgear shall be closed for the tests by covers providing identical protection qualities as for the joints.

When the supplementary letter W is used, indicating a supplementary requirement for weather conditions, a recommended test method is given in Annex F.

6.7.2 Mechanical impact test

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

6.8 Tightness Tests

The purpose of tightness tests is to demonstrate that the absolute leakage rate F does not exceed the specified value of the permissible leakage rate F_P.

If the test object is filled with a fluid different from the fluid used in service, an appropriate conversion of leakage rates shall be provided.

Where possible, the tests should be performed on a complete system at P_{re} (or ρ_{re}). If this is not practical, the tests may be performed on parts, components or sub-assemblies. In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart TC (see Annex G, Figure G.1). The possible leakages between sub-assemblies of different pressures shall also be taken into account.

The tightness test of switchgear containing a mechanical switching device shall be performed both in the closed and open position of the device, unless the leakage rate is independent of the position of the main contacts.

In general, only cumulative leakage measurements allow calculation of leakage rates.

The type test report should include such information as:

— A description of the object under test, including its internal volume and the nature of the filling gas or liquid;

— Whether the object under test is in the closed or open position (if applicable);

— The pressures and temperatures recorded at the beginning and end of the test and the number of replenishments (if any needed);

— The cut-in and cut-off pressure settings of the pressure (or density) control or monitoring device;

— An indication of the calibration of the meters used to detect leak rates;

— The results of the measurements;

— If applicable, the test gas and the conversion factor to assess the results.

The tightness tests shall be performed in connection with the tests required in the relevant standards, typically before and after the mechanical operation test or during the operation tests at extreme temperatures.

An increased leakage rate at extreme temperatures is acceptable, provided that this rate resets to a value not higher than the maximum permissible value at normal ambient air temperature. Refer to the relevant equipment standards for test requirements and permissible leakage rates at extreme temperatures.

6.8.1 Controlled pressure systems for gas

The relative leakage rate F_{rel} shall be checked by measuring the pressure drop ΔP over a time period, t that is of sufficient length to permit a determination of the pressure drop (within the filling and replenishing pressure range). A correction should be made to take into account the variation of ambient air temperature. During this period the replenishment device shall be inoperative.

$$F_{rel} = (\Delta P/p_r)(24/t)100 \text{ (\% per day)} \quad (1)$$

Alternatively, the number of replenishment operations per day (N):

$$N = (\Delta P/(p_r - p_m)(24/t) \quad (2)$$

Where:

p_r is the rated filling pressure, p_{re} or p_{rm} as the case may be
p_m is the measured filling pressure and
t is the test duration in hours.

NOTE—In order to maintain the linearity of the formula, ΔP should be of the same order of magnitude as p_r - p_m. Alternatively, the number of replenishment operations per day may be measured directly.

6.8.2 Closed pressure systems for gas

Due to comparatively small leakage rates of these systems, pressure drop measurements are not applicable. Other methods (examples are given in Annex G) may be used to measure the leakage rate *F*, which, in combination with the tightness coordination chart TC, allows one to calculate the relative leakage rate F_{rel}.

In general the test Q_m (See IEC 60068-2-17 [B7]) represents an adequate method to determine leakage in gas systems.

If the test object is filled with a test gas different from the gas used in service and/or at a test pressure different from the normal operating pressure, corrective factors defined by the manufacturer shall be used for calculations.

Since metering difficulties occur during low and high temperature tests, the procedure used may be to perform the tightness test at ambient temperature before and after the low and high temperature tests to determine if there has been a change.

Since leakage rate measurements in practice may have an inaccuracy of +50%, the tightness test is considered to be successful when the leakage rate F_P is achieved within the limits of +50%. The inaccuracy of measurement shall be taken into account when calculating the period of time between replenishments.

6.8.3 Sealed pressure systems

a) Switchgear using gas

Tightness tests on such switchgear and controlgear are performed in order to determine the expected operating life for the sealed pressure system.

The tests shall be performed according to 6.8.2.

b) Vacuum switchgear

A type test for tightness is not relevant for sealed vacuum interrupters and switches as the tightness of each interrupter and switch is verified during the manufacturing process. Sealed vacuum interrupters and switches are considered to have a zero leakage rate during their life. The manufacturer shall state the manufacture date (month, year) for each device. The manufacturer may, if appropriate, publish an expected minimum life in data sheets for vacuum interrupter models or groups of models..

6.8.4 Liquid tightness tests

The purpose of tightness tests is to demonstrate that the total system leakage rate F_{liq} does not exceed the specified value F_p (liq).

The object under test shall be as in service conditions with all its accessories and its normal fluid, mounted as close as possible as in service (framework, fixing).

The tightness tests shall be performed in connection with the tests required in the relevant equipment standards, typically before and after the mechanical operation test, during the operation tests at extreme temperatures or before and after the temperature-rise tests.

An increased leakage rate at extreme temperatures (if such tests are required in the relevant equipment standards) and/or during operations is acceptable, provided that this rate resets to the initial value after the temperature is returned to normal ambient air temperature and/or after the operations are performed. The increased temporary leakage rate shall not impair the safe operation of the switchgear.

The switchgear shall be observed over a period sufficient to determine a possible leak or the pressure drop ΔP. In this case, the calculations given in 6.8.1 are valid.

NOTE—Using liquids different from those in service or gas for the test is possible but requires justification by the manufacturer.

The test report should include such information as:

— A general description of the object under test:

— The number of operations performed:

— The nature and pressure(s) of the liquid:

— The ambient air temperature during test:

— The results with the switchgear device in closed and in open position where applicable

6.9 Electromagnetic compatibility tests

6.9.1 Emission tests

6.9.1.1 Emission tests on primary systems

For primary systems of switchgear in normal operation, without switching operations, the emission level is verified by means of the radio interference voltage test, see 6.3.

Emission caused by switching operations, including interruption of fault currents, is incidental. The frequency and level of such emission are considered to be part of the normal electromagnetic environment.

6.9.1.2 Emission tests on secondary systems

For secondary systems of switchgear, the EMC requirements and tests specified in this standard have precedence over other EMC specifications.

Electronic equipment, which is part of the secondary system, shall fulfill the requirements with regard to CISPR 11 [26][B1] for group 1, class A equipment. No other tests are specified. A 10 m measuring distance may be used instead of 30 m, by increasing the limit values by 10 dB.

6.9.2 Immunity tests on secondary systems

6.9.2.1 General

[26] CISPR is International Special Committee on Radio Interference, the acronym stands for the French Comite International Special des Perturbations Radioelectriques.

Secondary systems of switchgear shall be subjected to electromagnetic immunity tests if they include electronic equipment or components. In other cases no tests are required.

The following immunity tests are specified:

- Electrical fast transient/burst test (see 6.9.2.3). The test simulates the conditions caused by switching in the secondary circuit;
- Oscillatory wave immunity test (see 6.9.2.4). The test simulates the conditions caused by switching in the primary circuit.

NOTE—Other EMC immunity tests do exist, but are not specified in this case. Electrostatic discharge (ESD) tests are normally required on electronic equipment, and need not be repeated on complete secondary systems. Radiated field and magnetic field tests are considered to be relevant only in special cases. A compilation of EMC immunity tests is given in IEC 61000-4-1 [B18].

Example of a special case: -Electronic devices, placed in close vicinity of the bus bars of metal enclosed switchgear, may be influenced by magnetic fields. Supplementary arrangements may then be made in order to ensure electromagnetic compatibility.

6.9.2.2 Guidelines for immunity tests

Electromagnetic immunity tests should preferably be made on complete secondary systems. It is, however, also permissible to make separate tests on those major sub-assemblies that contain electronic equipment, in a realistic configuration.

NOTE—Even a moderate modification of the secondary system, such as a change of the cable layout, may change the properties in respect of high frequency disturbances.

Test voltage shall be applied only to the external interface of the secondary system or tested sub-assembly. If there is no external interface, i.e. if the secondary system is totally integrated into the switchgear, test voltage shall be applied to suitable terminals within the secondary system. The manufacturer shall choose such terminals.

6.9.2.3 Electrical fast transient/burst test

An electrical fast transient/burst test shall be performed in accordance with IEEE C37.90.1 or IEC 61000-4-4 [B19]. The test voltage shall be 4 kV.

NOTE—IEEE C37.90.1-2002 specifies a test voltage (magnitude) of 4 kV as the only choice. IEC 61000-4-4 (1995), provides for four test levels with 4 kV being the highest. IEC 62271.1 (20xx) may specify a lower (2 kV) test level.

6.9.2.4 Oscillatory wave immunity test

An oscillatory wave immunity test shall be performed, with shape and duration of the test voltage in accordance with IEEE C37.90.1 or IEC 61000-4-12 [B20].

Damped oscillatory wave tests shall be made at the following frequencies, with a tolerance of plus/minus 30 %:

- For secondary systems of GIS-equipment: 100 kHz, 1 MHz, 10 MHz, 50 MHz:
- In all other cases: 100 kHz, 1 MHz.

Tests shall be made for both common and differential (transfer) mode. For the common mode tests the voltage shall be 2.5 kV, and for the differential mode tests it shall be 1.0 kV.

NOTE—Disconnector operations in GIS may create surges with extremely steep wave fronts, hence the need for the test frequencies 10 and 50 MHz for GIS. Test procedures for these frequencies are under consideration.

6.9.2.5 Behavior of the secondary equipment during and after tests

The secondary system shall withstand each of the tests specified in 6.9.2.3 to 6.9.2.4 without permanent damage. After the tests it shall still be fully operative. Temporary loss of parts of the functionality is permitted at the electrical fast transient/burst test and at the oscillatory wave immunity test according to Table 16.

Table 16 [27]—Assessment criteria for transient disturbance immunity tests

Function	Criterion
Command and control	1
Measurement	2
Counting	1
Data transmission	2
Information and data storage protection	1
Processing on line off line	1 3
Monitoring	2
Man-machine interface	3
Self-diagnostic	2

Criteria of recommended severity level according to IEC 61000-4-1

1 Normal performance within the specification limits
2 Temporary degradation or loss of function or performance which is self-recoverable
3 Temporary degradation or loss of function or performance requiring operator intervention or system reset
4 Degradation or loss of function that is not recoverable, due to damage of equipment (components) or software, or loss of data.

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6.10 Additional tests on auxiliary and control circuits

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

6.11 X-Radiation procedure for vacuum interrupters

Testing shall be in accordance with ANSI C37.85.

7. Routine (production) tests

[27] In order to preserve the coordination with IEC 62271.1, table numbers 13, 14 and 15, are reserved for future use. They are intentionally omitted from this revision of C37.100.1.

The routine (production) tests are for the purpose of revealing faults in material or construction. They do not impair the properties and reliability of a test object. The routine tests shall be made wherever reasonably practical at the manufacturer's facility on each apparatus manufactured, to ensure that the product is in accordance with the equipment on which the type tests have been passed. By agreement, any routine test may be made on site.

The routine tests given in this standard comprise:

a) Dielectric test on the main circuit in accordance with 7.1:

b) Dielectric test on control and auxiliary circuits in accordance with 7.2:

c) Measurement of the resistance of the main circuit in accordance with 7.3:

d) Tightness test in accordance with 7.4:

e) Design and visual checks in accordance with 7.5.

Additional routine tests may be necessary and will be specified in the relevant IEEE equipment standards. When switchgear are not completely assembled before transport, separate tests shall be made on all transport units. In this event, the manufacturer shall demonstrate the validity of his test (example: leakage rate, test voltage, resistance of part of the main circuit).

Test reports of the routine tests are normally not necessary unless otherwise agreed upon between manufacturer and user.

7.1 Dielectric test on the main circuit

A dry, short-duration power-frequency voltage shall be applied. The test shall be made according to IEEE Std 4 and 6.2, on the complete apparatus or on each separate complete pole, or on each transport unit. Equipment shall be in new, clean and dry conditions.

The test voltage shall be that specified in column 2 of Table 1a, Table 1b, Table 2a or Table 2b according to the relevant IEEE equipment standards, or the applicable part thereof.

7.2 Dielectric test on auxiliary and control circuits

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

7.3 Measurement of the resistance of the main circuit

For the routine test, the dc voltage drop or resistance of each pole of the main circuit shall be measured under conditions as nearly as possible similar with regard to ambient air temperature and points of measurement to those under which the corresponding type test was made. The test current should be within the range stated in 6.4.1.

The measured resistance shall not exceed 1.2 R_u, where R_u is equal to the resistance measured before the design (type) temperature-rise test.

7.4 Tightness test

Routine tests shall be performed at normal ambient air temperature with the assembly filled at the pressure (or density) corresponding to the manufacturer's test practice. For gas filled systems sniffing may be used.

7.4.1 Controlled pressure systems for gas

Additional design and visual tests will be made as required to verify good manufacturing practice.

7.4.2 Closed pressure systems for gas

The test procedure corresponds to 6.8.2.

The test may be performed at different stages of the manufacturing process or of assembling on site, on parts, components and sub-assemblies, according to the tightness coordination chart TC, (Annex G, Table G.1)

7.4.3 Sealed pressure systems

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

7.4.4 Liquid tightness tests

At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards.

7.5 Design and visual checks

The Switchgear shall be checked to verify its compliance with the purchase specifications.

Annex A

(informative)

Recommendations for application of this standard to relevant switchgear standards

A.1 Introduction

Working groups responsible for the development or maintenance of relevant switchgear standards are encouraged to adopt the common requirements outlined in IEEE C37.100.1 by citing the standard as a normative reference. Some provisions may not apply to some equipment standards, therefore exceptions and/or deviations from these common requirements are allowed. These exceptions and/or deviations should be specifically noted in the relevant equipment standard. It is important, however, that no ambiguity exist within or between this common requirements standard and the relevant equipment standard.
In order to promote consistency in application, and to minimize the possibility of conflicting interpretation of the requirements, the following are guidelines to which implementers should adhere.

A.2 Normative reference

The scope of this standard (Clause 1) requires that the relevant equipment standard include the common requirements standard as a normative reference. This is normally accomplished by listing a dated reference to IEEE C37.100.1 in Clause 2 of the relevant equipment standard.
In order to distinguish between dated and undated reference standards, the following paragraph should be used as the introductory paragraph to Clause 2. It may be necessary to delete or change the old introductory paragraph(s) to avoid a conflict.
"The following referenced documents are indispensable for the application of this standard. For dated references, only the version cited applies. For undated references, the latest version of the referenced document (including any amendments or corrigenda) applies."

A.3 Default requirements

Once a normative reference is made to this common requirements standard, it does not mean or imply that all of the requirements of the common requirements standard apply to the relevant equipment standard as the default. The relevant equipment standard must explicitly state which parts of the common requirements standard apply.

In order to avoid any ambiguity or misunderstanding on this point, it is recommended that each clause or subclause of the relevant equipment standard begin with one of the following sentences (where 200X represents the approval year of the common requirements standard, as listed in the reference clause of the relevant equipment standard):

a) "Paragraph XX.AA of IEEE Std C37.100.1-200X applies ." when the requirements found in IEEE Std C37.100.1-200X are applicable without additions or modifications.

b) "Paragraph XX.AA of IEEE Std C37.100.1-200X applies with the following addition(s)." If the basic text found in IEEE Std C37.100.1-200X is relevant as published, but additional requirements are deemed necessary by the Working Group responsible for the revision, the Working Group can include these additional requirements as a normative inclusion to the body of the text.

c) "Paragraph XX.AA of IEEE Std C37.100.1-200X applies with the following modification(s)." If the basic text found in IEEE Std C37.100.1-200X is relevant as published, but minor changes to the basic requirements to make the text relevant are deemed necessary by the Working Group responsible for the revision, the Working Group can modify the basic requirements as a normative inclusion to the body of the text.

d) "Paragraph XX.AA of IEEE Std C37.100.1-200X does not apply." If the basic text found in IEEE Std C37.100.1-200X is not relevant as published, but requirements of a similar nature are deemed necessary by the Working Group responsible for the revision, the Working Group can include these similar requirements as a normative inclusion to the body of the text

Annex B

(normative)

Altitude correction factors

B.1 Basis of Altitude-Related Ratings for Switchgear

The altitude correction factors given in 2.2 are based on two factors. The first factor is that historically, insulation coordination has had enough margin to safely use equipment up to about 1 000 meters without further consideration. . The second factor is the actual physics of the behavior of the insulation withstand level of external insulation that is approximated by the equation given in Figure 1. This equation recognizes that the insulation withstand level of external insulation decreases with increasing altitude beginning at sea level, not at 1000 m. The background of this equation is given in IEEE 4 and IEC 60071-2.

B.2 Impact of Increased Altitude on Insulation Coordination

Air density (temperature and air pressure) varies from one place to another on the earth, and may also vary in the same place over time. Air density (temperature and air pressure) influences the dielectric strength of air, (see B.3). As a result, the testing for dielectric withstand voltages would vary and not be comparable. Therefore, it is necessary to define standard conditions for temperature and pressure in order to adjust for variations in air density from these standard conditions. The dielectric withstand voltages are adjusted to the standard reference atmosphere, also known as Normal Temperature and Pressure at Sea Level, (NTP) in order to provide comparable test results for all test objects regardless of test location and atmospheric conditions. This is standard laboratory test practice defined in both IEEE Std 4 and IEC 60060-2 where the Standard Reference Atmosphere is defined as t_0 = 20°C, b_0 = 101.3 kPa, and h_0 = 11 g/m3.

Since atmospheric pressure has the greatest influence on the dielectric strength of air and is related to the altitude (above sea level), adjustments or corrections for atmospheric air density conditions are usually referred to as “altitude correction” factors when selecting switchgear voltage ratings or insulation for a given application.

The following applies to altitude correction for switchgear:

— The basis of rating for all switchgear is the standard reference atmosphere or NTP, often referred to as sea level conditions.

— Correction for relative air density is required for any altitude (barometric pressure differing from 101.3 kPa) above sea level and any temperature differing from 20°C (68°F) and humidity differing from 11 g/m3. However, in view of the insulation coordination factors applied to the design of electrical power systems, switchgear has historically and successfully been applied at altitudes up to 1 000 m without applying an altitude correction factor.

— Test laboratories record actual atmospheric conditions and correct to NTP conditions when equipment is tested. A corrected test voltage may be used if atmospheric conditions differ materially from NTP conditions. For example, BIL is the rated impulse withstand voltage of equipment referenced to NTP conditions.

— Applications of switchgear at altitudes higher than about 1 000 m have historically required use of an altitude correction factor based on the change in air density from 1 000 m to the application site.

NOTE—The standard reference atmosphere and Normal Temperature and Pressure at Sea Level (NTP) are equivalent terms and are commonly referred to as "sea level" for convenience. They should not be confused with the terms

B.3 Impact of Increased Altitude on Insulation Coordination

The insulation coordination process requires coordination of lightning, switching and one-minute power frequency withstand voltages. IEEE 1313.1 and IEC 60071-1 specify the procedure for the selection of the withstand voltages for equipment. They also identify lists of preferred voltage ratings and their associated insulation levels. Switchgear standards generally follow these preferred values although not all combinations of the preferred values are available in the preferred ratings of switchgear.

IEEE 1313 refers to IEEE Std 4 for the selection of correction factors for altitude, electrode configuration and wave shape. IEC 60071 refers to IEC 60060 for similar information.

Traditionally, the altitude correction factor is only applied at altitudes above 1 000 m. This practice assumes that the insulation coordination factors applied in the insulation coordination process take care of any reduced insulation capability below 1 000 m. This historical practice has not made clear that air insulation is reduced for all applications above sea level, not just those above 1 000 m. For example, when the correction factor given in IEEE Std 4 and IEC 60060-1 for an altitude of 1 000 m is applied, the result is K_d = 0.885 or a degrading of the dielectric withstand voltages of 11.5%.

The decision to use historic insulation coordination factors (both internal and external margins) that allow the use of equipment up to 1 000 m without an altitude correction factor, must be made with full knowledge of the physics of relative air density and the resulting dielectric performance of air that occurs with increased altitude. Internal insulation generally is not sensitive to increasing altitude when the dielectric medium is contained in an enclosed interrupter, while external insulation is sensitive to altitude. The internal and external insulation characteristics in many historical products have been nearly equal near the altitude of 1 000 m.

B.4 Application at altitudes above sea level

Switchgear that depends on air for an insulating and cooling medium will have a higher temperature rise and a lower dielectric withstand capability when operated at altitudes above sea level. For applications at altitudes higher than sea level, the rated power frequency withstand voltage, the lightning impulse withstand voltage (BIL), and the continuous current rating of the assemblies should be corrected to obtain the modified ratings.

For insulation not exposed to ambient atmospheric pressure, the dielectric characteristics are identical at any altitude and no special precautions need to be taken. An example is the internal insulation of a sealed or pressurized interrupter.

NOTE 1—For low-voltage auxiliary and control equipment, no special precautions need to be taken if the altitude is 2000 m or less. For higher altitude see ANSI C37.21.

NOTE 2—For discussion of the conflicting testing requirements for internal and external insulation refer to IEEE Std 4.

The required withstand voltages for a particular application must take a number of factors into account. Two types of correction factors are the atmospheric correction factor, K_a and insulation coordination factors, K_s that take into account the differences between the actual in-service conditions of the insulation and those in the standard withstand tests.

Subclause 4.2.2 of IEC 60071-2 provides the equation for altitude correction factors based on the dependence of the atmospheric pressure on the altitude, that is relative air density.

$$K_a = e^{m\left(\frac{H}{8150}\right)} \tag{3}$$

Where

K_a altitude (or atmospheric) correction factor;

H altitude above sea level, in meters

m exponent. See Figure 1

When the altitude correction factors are applied starting at 1000 m, the historical correction factors, equation (3) becomes:

$$K_a = e^{m\left(\frac{(H-1000}{8150}\right)} \tag{4}$$

$$k_d = \frac{1}{K_a} \tag{5}$$

Where:

k_d relative air density correction factor [28]

Figure B.1 shows the three approaches to altitude correction factors. The first, a baseline in accordance with IEC 60071-2, where the correction factors start at sea level; the second, as used in this standard where correction factors start at 1000 m and follow the baseline to higher altitudes; and the third, the historical approach, where correction factors start at 1000 m but at a reduced correction level in accordance with equation " 4" above. Table B.1 lists the percent difference between the second and third approaches relative to the IEC 60071-2 baseline. It can be seen that in both approaches the difference is zero at sea level and increases to 12% at 1000 m. However, while the 12% difference continues for all altitudes above 1 000 m in the third (historical) approach, the difference above 1000 m is zero for the second approach as used in this standard.

NOTE—IEEE has traditionally considered the altitude correction factor to be a number equal to or less than 1.0 and the rated withstand voltage (at sea level) is multiplied by the correction factor to obtain reduced insulation strength at a higher altitude. In this standard, the altitude correction factor Ka is a number equal to or greater than 1.0 and the rated withstand voltage (at sea level) is divided by Ka to obtain the reduced insulation strength at a higher altitude

[28] The air density correction factor, K_d is defined in IEEE STD 4. IEC 60061-1 uses the symbol k_1. Note that K_a is equal to or greater than 1.0.

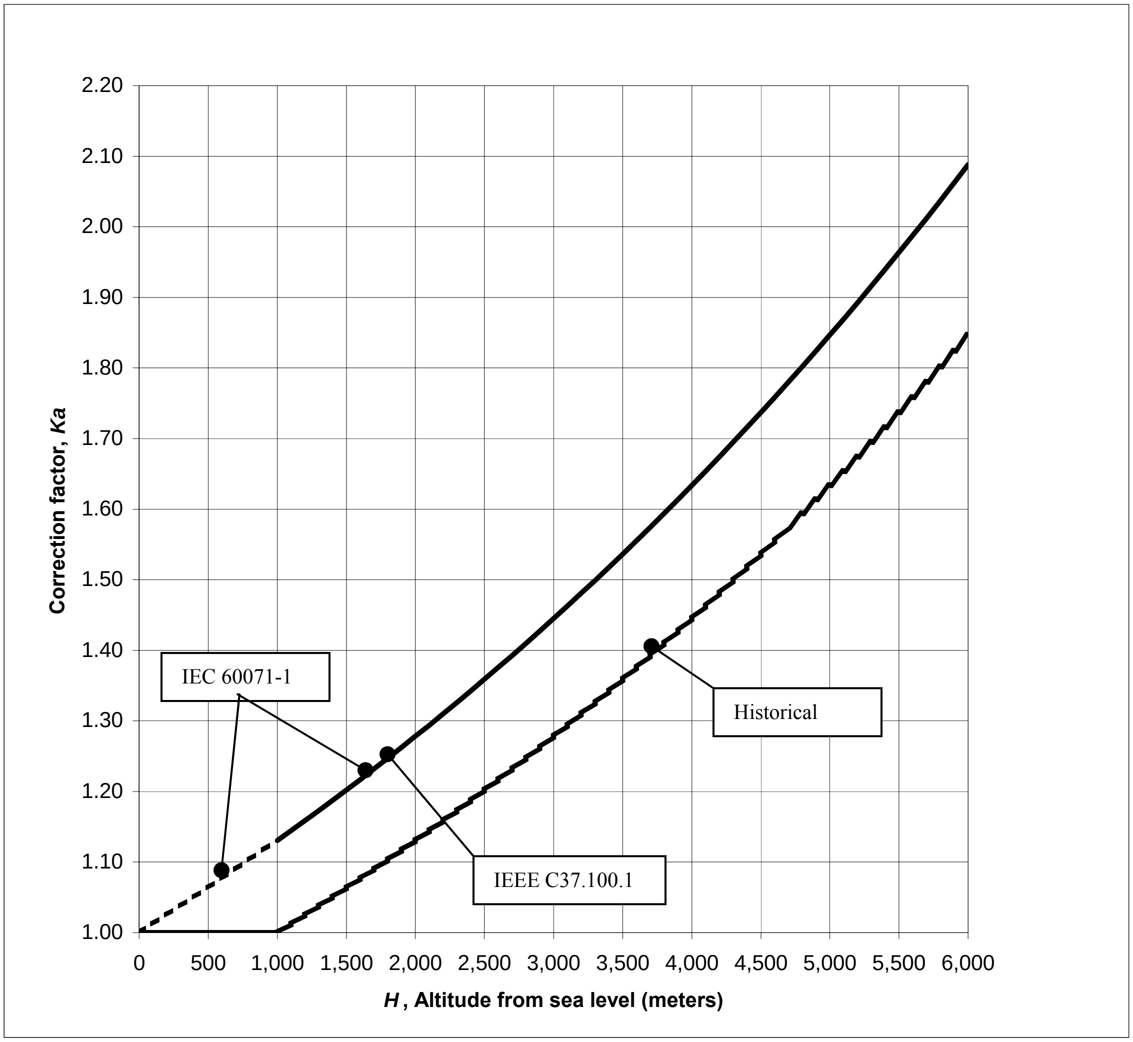


Figure B.1- Altitude Correction – Two Approaches
For m = 1

Percent difference relative to IEC 60071-1 for two approaches, $m = 1$		
Altitude (meters)	IEEE C37.100.1	Historical
0	0	0
200	2	2
400	5	5
600	7	7
800	9	9
1000	12	12
Above 1000	0	12

.

Table B.1- Percent Difference on Altitude Correction Factors

Annex C

(normative)

Exposure to pollution

C.1 General

The quality of ambient air with respect to pollution by dust, smoke, corrosive and/or flammable gases, vapors or salt is a consideration under normal and special service conditions (refer to clause 2 of this standard). This annex defines four levels of pollution as well as recommendations for the minimum specific creepage distance across external insulation.

C.2 Pollution levels

For purposes of standardization, four levels of pollution, light, medium, heavy, and very heavy, are qualitatively defined. The qualitative description is given in Table C.1 as an approximate description of some typical corresponding environments. Other extreme environmental conditions exist that merit further consideration, e.g., snow and ice in heavy pollution, heavy rain, and arid areas.

C.3 Minimum requirements for Switchgear

The minimum creepage distance expressed as a specific creepage in mm/kV are for the normal service conditions (i.e., light pollution level) of atmospheric contamination and altitudes up to 1000 m. This minimum creepage provides generally satisfactory service operation under these conditions.

For each level of pollution described in Table C.1, the corresponding minimum nominal specific creepage distance, in millimeters per kilovolt (phase-to-ground) of the highest voltage for equipment is given in Table C.2.

Experience has shown that the criterion of “minimum nominal specific creepage distance,” which implies linearity under pollution between withstand voltage and creepage distance, applies to most glass and ceramic insulators used on existing systems. Some insulators specially shaped for particular kinds of pollution may not satisfy these conditions even though they perform satisfactorily in service.

The specific creepage distance values given in Table C.2 apply to glass and ceramic insulators. Values for other materials are under consideration.

Table C.1— Environmental examples by pollution level

Pollution level	Examples of typical environments
I Light	Areas without industries and with low density of houses equipped with heating plants. Areas with low density of industries or houses but subjected to frequent winds and/or rainfall. Agricultural areas [a] Mountainous areas. All these areas shall be situated at least 10–20 km from the sea and shall not be exposed to winds directly from the sea. [b]
II Medium	Areas with industries not producing particularly polluting smoke and/or with average density of houses equipped with heating plants. Areas with high density of houses and/or industries but subjected to frequent winds and/or rainfall. Areas exposed to wind from the sea but not too close to the coast (at least several kilometers distant). [b]
III Heavy Areas	Areas with high density of industries and/or suburbs of large cities with high density of heating plants producing pollution. Area close to the sea or in any case exposed to relatively strong winds from the sea. [b]
IV Very heavy	Areas generally of moderate extent, subjected to conductive dusts and to industrial smoke producing particularly thick conductive deposits. Areas generally of moderate extent, very close to the coast and exposed to sea-spray or to very strong and polluting winds from the sea. Desert areas, characterized by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation.

[a] The use of fertilizers by spraying or the burning of crop residues can lead to a higher pollution level due to dispersal by wind.

[b] Distances from seacoast depend on the topography of the coastal area and on the extreme wind conditions.

Table C.2— Minimum nominal specific creepage distance by pollution level [29]

Pollution level	Minimum nominal specific creepage distance (mm/kV of line-to-line voltage)	Minimum nominal specific creepage distance (mm/kV of line-to-ground voltage)
Col. 1	Col. 2	Col. 3
I Light	16	28
II Medium	20	35
III Heavy	25	44
IV Very heavy	31	54

NOTES

1—In very lightly polluted areas, nominal specific creepage distances lower than 16 mm/kV can be used depending on the service experience. A specific creepage distance below 21 mm/kV is not recommended.

2—In the case of exceptional pollution severity, a nominal specific creepage distance of 31 mm/kV may not be adequate. Depending on service experience and/or on laboratory test results, a higher value of nominal specific creepage distance can be used, but in some instances the practicability of washing or greasing may have to be considered.

3—The specific creepage distance values given in this table are for insulators between phase and ground; they are the same as those given in IEC 60071-2 [B9] Table 1. The values are expressed both in terms the rated maximum voltage (line to line), column 2 and in terms of the equivalent voltage line-to-ground, column 3.

4—The specific creepage distance values given in this table apply to glass and ceramic insulators. Values for other materials are under consideration.

[29] Table C.2 is taken from IEC 60815 [B16] and C37.010 [B24].

Annex D

(normative)

Identification of test specimens

The following data and drawings, as applicable, shall be submitted by the manufacturer to the testing laboratory, in respect of each test sample (but not necessarily included in the test report). Information to be included in the test report is given in 6.1. 2.

D.1 Data

— Manufacturer's name;

— Type designation, ratings and serial number of apparatus;

— Outline description of apparatus (including number of poles, interlocking system, busbar system, grounding system, and the arc extinguishing process);

— Make, type, serial numbers, ratings of essential parts, where applicable (e.g. operating mechanisms, interrupters, shunt impedances, relays, fuse links, insulators);

— Rated characteristics of fuse links and protective devices;

— Whether the apparatus is intended for operation in the vertical upright, vertical inverted, and horizontal positions.

D.2 Drawings

Table D.1— Drawings

Drawings to be submitted	Drawing content (as applicable)
Single-line diagram of main circuit	Type designation of principal components
General layout NOTE - For an assembly it may be necessary to provide drawings of the complete assembly and of each switching device.	Overall dimensions Supporting structure Enclosure (s) Pressure-relief devices Conducting parts of main circuit Grounding conductors and grounding connections Electrical clearances: - (to ground, between open contacts): - (between poles). Location and dimensions of barriers between poles Location of grounded metallic screens, shutters or partitions in relation to lives parts Liquid insulation level Location and type designation of insulators Location and type designation of instrument transformers
Detailed drawings of insulators	Material Dimensions (including profile and creepage distances)
Arrangement drawings of cable boxes	Electrical clearances Principal dimensions Terminals Level or quantity and specifications of insulation in filled boxes Cable termination details
Detailed drawings of parts of the main circuit and associated components	Dimensions and material of principal parts Cross-sectional view through the axis of main and arcing contacts Travel of moving contacts Electrical clearance between open contacts Distance between point of contact separation and end of travel Assembly of fixed and moving contacts Details of terminals (dimensions, materials) Material and creepage distances of insulating parts
Detailed drawings of mechanisms (including coupling and operating mechanisms)	Arrangement and identity of main components of the kinematic chains to: - main contacts - auxiliary switches - pilot switches - position indication Latching device Assembly of mechanism Interlocking devices Identity of springs Control and auxiliary devices
Electrical diagram of auxiliary and control circuits (if applicable)	Type designation of all components

Annex E

(normative)

Determination of the equivalent rms value of a short-time current during a short circuit of a given duration

The method illustrated in Figure E.1 should be used to determine the short-time current (see 6.6.2).
The total time t_t of the test is divided into 10 equal parts by verticals 0 - 0.1 ... 1 and the rms value of the ac component of the current is measured at these verticals.
These values are designated:

$$Z_0, Z_1 \ldots Z_{10}$$

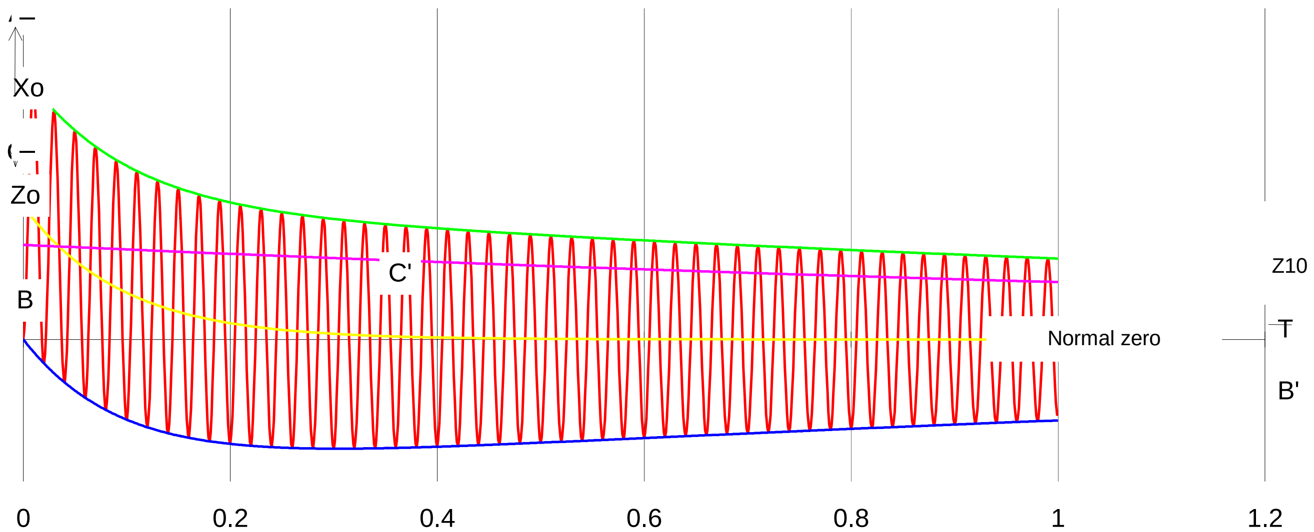
where:
$Z = X/\sqrt{2}$ and
X is the peak value of ac component of current. [30]

The equivalent RMS current during the time t_t is given by:

$$I_t = \sqrt{\frac{1}{30}\left(Z_0^2 + 4\left(Z_1^2 + Z_3^2 + Z_5^2 + Z_7^2 + Z_9^2\right) + 2\left(Z_2^2 + Z_4^2 + Z_6^2 + Z_8^2\right) + Z_{10}^2\right)} \qquad (6)$$

The dc component of current represented by CC' is not taken into account.

[30] The use of the letters "Z" and "X" in this annex represent values of current as illustrated in Figure E.1; they do not represent impedance as in traditional electrical engineering notation. This annex is consistent with Annex B of IEC 60694 and 62271-1, Ed 1 CDV 2006-02-06



AA' BB'	Envelopes of current wave
CC'	Displacement of current wave zero line from normal zero line at any instant.
Z0 .. Z10	RMS value of ac component of current at any instant measured from normal zero; dc component is neglected.
X0	Peak value of ac component of current at instant of initiating short-circuit.
BT -	Duration of short circuit.

Figure E.1— Determination of short-time current

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Annex F

(normative)

Method for the weatherproofing test for outdoor switchgear

The switchgear to be tested shall be fully equipped and complete with all covers, screens, bushings, etc., and placed in the area to be supplied with artificial precipitation. For switchgear comprising several functional units a minimum of two units shall be used to test the joints between them.

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the surfaces under test. The various parts of the switchgear may be tested separately, provided that a uniform spray is simultaneously applied also to both of the following:

1) The top surfaces from nozzles located at a suitable height:
2) The floor outside the equipment for a distance of 1 m in front of the parts under test with the equipment located at the minimum height above the floor level specified by the manufacturer.

Where the width of the equipment exceeds 3 m, the spray may be applied to 3 m wide sections in turn. Pressurized enclosures need not be submitted to artificial precipitation.

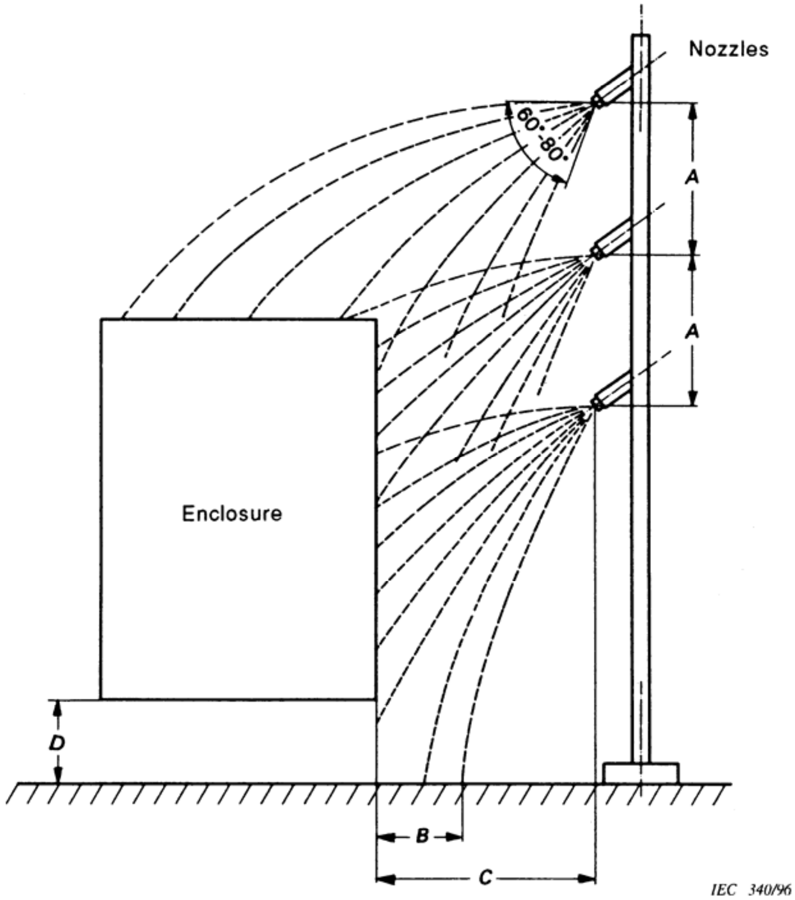
Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of 30 l/min ± 10 % (8.0 gpm +/- 0.8 gpm) at a pressure of 460 kPa ± 10 % (66 psi +/- 6 psi) and a spray angle of 60 ° to 80 °. The center lines of the nozzles shall be inclined downwards so that the top of the spray is horizontal as it is directed towards the surfaces being tested. It is convenient to arrange the nozzles on a vertical stand-pipe and to space them about 2 m apart (see test arrangement in Figure F.1).

The pressure in the feed pipe of the nozzles shall be 460 kPa ± 10 % (66 psi +/- 6 psi) under flow conditions. The rate at which water is applied to each surface under test shall be about 5 mm/min, and each surface so tested shall receive this rate of artificial precipitation for a duration of 5 min. The spray nozzles shall be at a distance between 2.5 m and 3 m from the nearest vertical surface under test.

NOTE—When a nozzle in accordance with Figure F.2 is used, the quantity of water is considered to be in accordance with this standard when the pressure is 460 kPa ± 10 % (66 psi +/- 6 psi).

After the test is completed, the equipment shall be inspected promptly to determine whether the following requirements have been met:

1) No water shall be visible on the insulation of the main and auxiliary circuits:
2) No water shall be visible on any internal electrical components and mechanisms of the equipment:
3) No significant accumulation of water shall be retained by the structure or other non-insulating parts (to minimize corrosion).



A	About 2 m
B	1 m
C	2,5 m to 3 m
D	Minimum height above floor

Figure F.1—Arrangement for weatherproofing test

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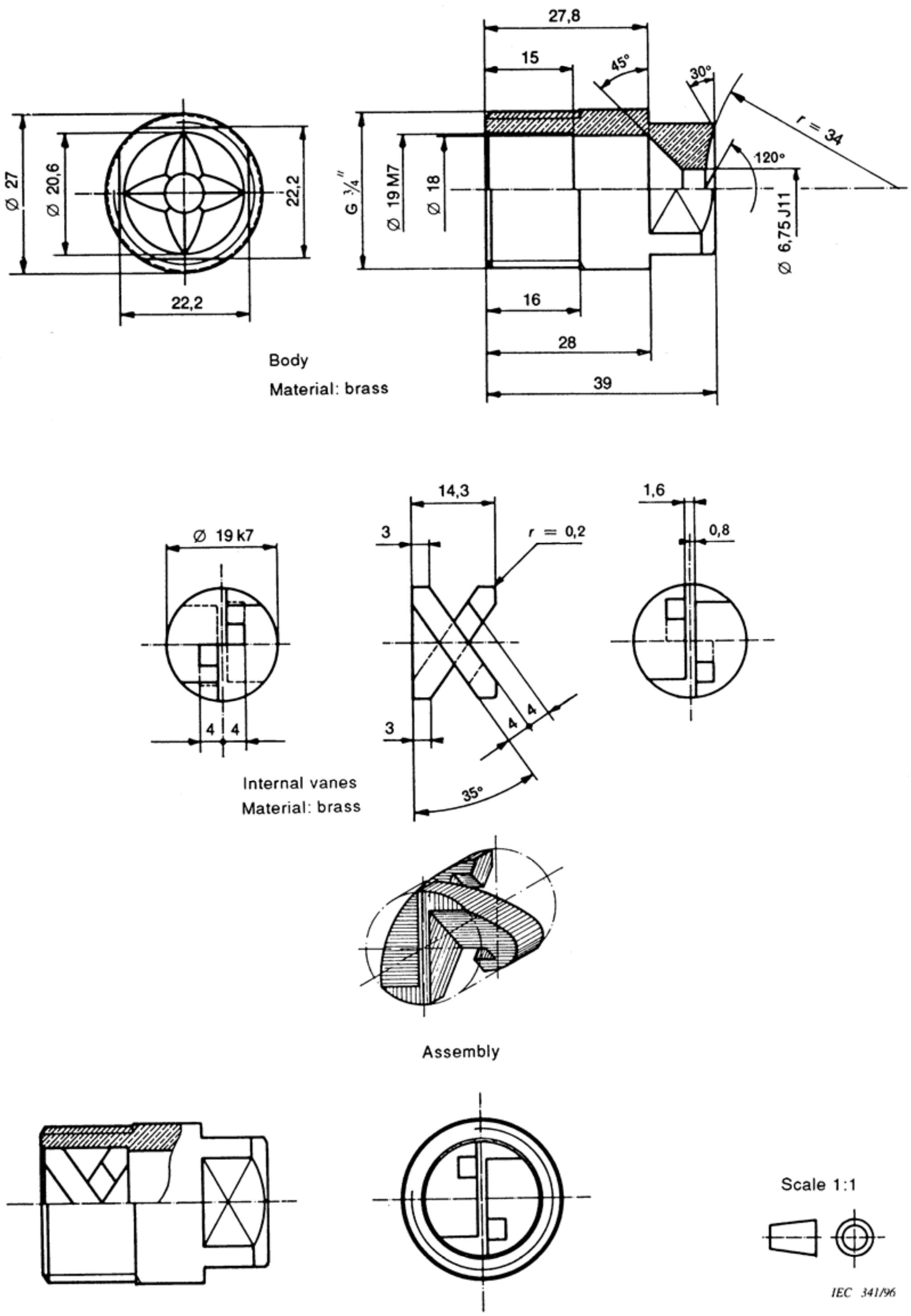

Figure F.2— Nozzle for weatherproofing test [1]

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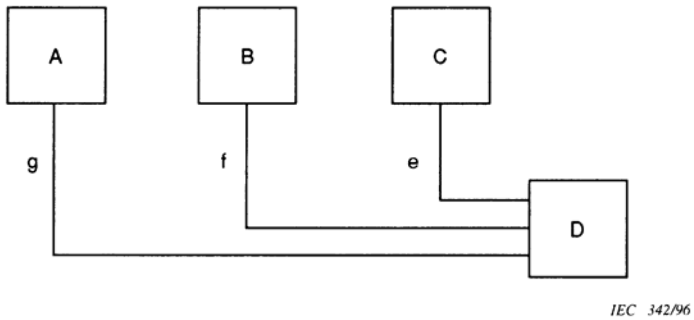
[1] Refer to Annex J for information about the ISO dimensions used in this figure.

Annex G

(informative)

Tightness (information, example and guidance)



Example:

Gas insulated metal-enclosed switchgear, single-phase encapsulated, circuit-breaker compartments of the three-phases connected to the same gas-system

Leakage rate of the system:

Compartment A	19 x 10^{-6} Pa x m^3/s
Compartment B	19 x 10^{-6} Pa x m^3/s
Compartment C	19 x 10^{-6} Pa x m^3/s
Control box D (including valves, gauges, monitoring devices).	2.3 x 10^{-6} Pa x m^3/s
Piping e	0.2 x 10^{-6} Pa x m^3/s
Piping f	0.2 x 10^{-6} Pa x m^3/s
Piping g	0.2 x 10^{-6} Pa x m^3/s
Complete system	59.9 x 10^{-6} Pa x m^3/s

Filling pressure P_{re}: 700 kPa (absolute)

Alarm pressure P_{ae}: 640 kPa (absolute)

Total internal volume 270 dm^3

$$F_{rel} = \frac{59.9 \cdot 10^{-6} \times 60 \times 60 \times 24 \times 365}{700 \cdot 10^{3} \times 270 \times 10^{-3}} \times 100 = 1.0 \text{ \% per year}$$

$$tr = \frac{(700 - 640) \times 10^{3} \times 270 \times 10^{-3}}{59.9 \cdot 10^{-6} \times 60 \times 60 \times 24 \times 365} = 8.5 \text{ years}$$

Table G.1— Example for a tightness coordination chart TC

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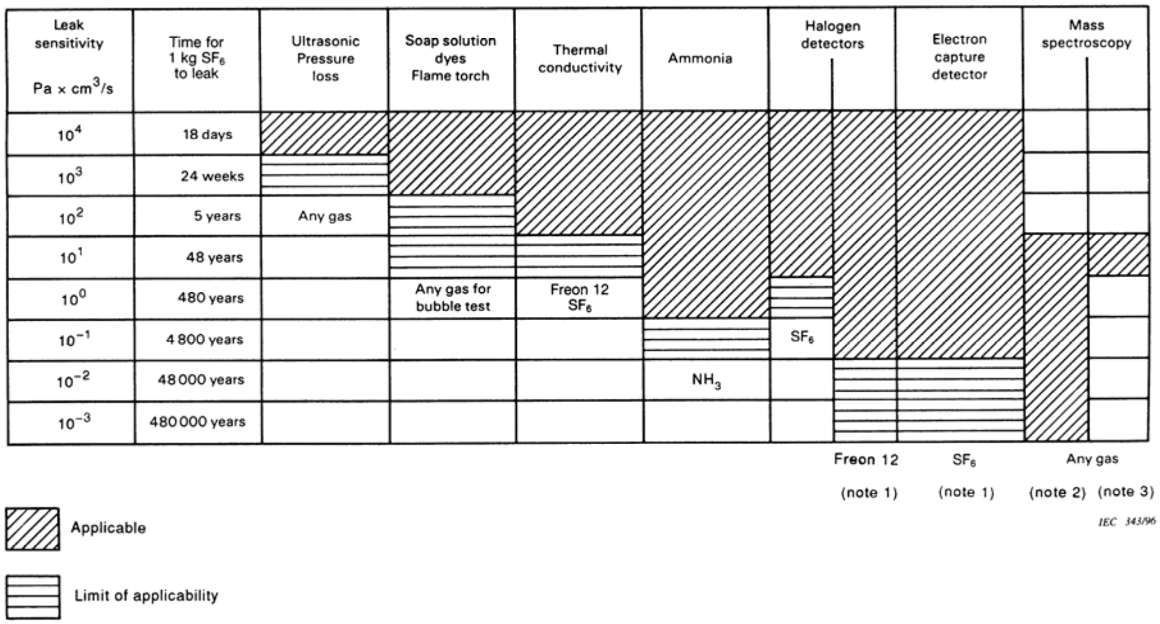

NOTE 1—Sniffing in good conditions. By integrated leakage measurement, better sensitivity can be achieved.

NOTE 2—By integrated leakage measurement.

NOTE 3—By sniffing.

Figure G.1— Sensitivity and applicability of different leak detection methods for tightness tests

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Annex H

(informative)

Symbols and related terminology

The following table provides a listing of the most common terms and their respective abbreviations as used in IEEE and IEC.

NOTE—the user is cautioned to the fact that some of the terms are very similar but have slightly different definitions between IEEE and IEC.

Abbreviations		Definition	Customary Units	Clause
IEEE	IEC			
V	U_r	Rated maximum voltage (IEEE); Rated voltage (IEC)	V RMS	4.1
none	U_p	Rated lightning impulse withstand voltage	V peak	4.2
none	I_r	Rated continuous current (IEEE); Rated normal current (IEC)	A RMS	4.4.1
none	not used	Rated momentary withstand current	kA asymmetrical	
none	I_p	Rated peak withstand current	kA peak	4.6
none	I_k	Rated short-time withstand current	kA symmetrical	4.5
none	t_k	Rated duration of short circuit	s	4.7
none	f_r	Rated power frequency	Hz	4.3
none	U_a	Rated supply voltage of closing and opening devices and of auxiliary circuits	V RMS	4.8
none	U_s	Rated switching impulse withstand voltage	V peak	4.2
none	U_d	Rated power frequency withstand voltage	V rms	4.2
none	p_r	Rated filling pressure		6.8.1
none	P_m	Measured filling pressure		6.8.1
none	$P_{re}(\rho_{re})$	Rated filling pressure (density) for insulation	Pa	5.10
none	$P_{rm}(\rho_{rm})$	Rated filling pressure (density) for operation		5.10
none	$P_{ae}(\rho_{ae})$	Alarm pressure (density) for insulation		5.10
none	$P_{am}(\rho_{am})$	Alarm pressure (density) for operation		5.10
none	$P_{me}(\rho_{me})$	Minimum functional pressure (density) for insulation		5.10
none	$P_{mm}(\rho_{mm})$	Minimum functional pressure (density) for operation		5.10
none	F	Absolute leakage rate (for gas and liquid filled systems)	$Pa \cdot m^3/s$	6.8

Abbreviations		Definition	Customary Units	Clause
IEEE	IEC			
none	F_p	Maximum permissible absolute leakage rate specified by manufacturer		6.8
none	F_{rel}	Absolute leakage rate related to the total amount of gas in the system at rated filling pressure (or density).	%/day or %/year	6.8.1
none	t_r	Time between replenishments to compensate for leakage rate F	See Figure G.1 Annex G	
Grounded	Effectively grounded/ earthed	System neutral is effectively connected to ground or earth		
Ungrounded	Non-effectively grounded/ earthed	System neutral is not connected to ground or earth		
Impedance grounded	Non-Solidly earthed	System neutral is connected through an impedance to ground or earth		

Table H.1— Comparison of IEEE and IEC Electrical terms and symbols

Note: The symbols and parameters that relate to transient recovery voltage (TRV) will be included in IEEE C37.04 b-200x. [B25]

Annex I

(informative)

Proposed values of rated maximum voltage for future design

I.1 Introduction

This proposal is focused on the series A and series B rated maximum voltages in 4.1.1 and rated insulation levels in Table 1a and Table 1b that have been taken from IEC 60694 Common Clauses. It is proposed that the design of future switchgear equipment focus on a set of voltages that are both rationalized and harmonized with those of IEC to represent world wide practice.

I.2 Range I for rated maximum voltages of 245 kV and below

3.6 kV - 5.5 kV -7.2 kV - 12 kV - 15.5 kV - 24 kV – 27 kV – 38 kV -
52 kV - 72.5 kV - 100 kV - 123 kV - 145 kV - 170 kV - 245 kV.

I.3 Rated insulation level

The rated insulation level of switchgear shall be selected from the values given in Table I.1.

Table I.1— Proposed rated insulation levels for rated voltages

Rated Maximum Voltage	Power Frequency Withstand		Lightning Impulse withstand	
$V(U_r)$ kV	Dry and Wet Common Value (U_d) kV	Across open Gap (Dry and Wet) kV	Full Wave Common Value (U_p) kV	Full Wave Across open Gap kV
3.6	10	12	20	23
			40	46
5.5	19	21	40	46
			60	70
7.2	20	23	40	46
			60	70
12	28	32	60	70
			75	85
			95	105
15.5	36	40	95	105
	45	50	110	125
24	50	60	95	110
			125	145
27	50	55	125	140
	60	66	150	165
38	60	66	150	165
	80	88	200	220
52	95	110	250	290
72.5	140	160	350	385
100	150	175	380	440
	185	210	450	520
123	185	210	450	520
	230	265	550	630
145	230	265	550	630
	275	315	650	750
170	275	315	650	750
	325	375	750	860
245	360	415	850	950
	395	430	900	990
	395	460	950	1050
	460	530	1050	1200

Annex J

(informative)

Notes on the development of C37.100.1

J.1 General

This annex documents some of the background history or rationale for selected parts of this standard.

J.2 Organization

With permission from the IEEE Editorial Staff, the organization of this Common Requirements Standard follows that of the IEC counterpart standard, IEC 60694 (IEC62271-1-20xx). Thus the clause numbering of this standard matches, clause for clause and table for table, the same topics set forth in the proposed IEC 62271-1. Furthermore, insofar as possible, the latest CDV draft of IEC SC17A MT34 has been reviewed and, where appropriate, the new, revised, or deleted material has been reflected in C37.100.1.

In several cases, material that is to be included in the IEC standard is not considered appropriate for this IEEE standard. Either the material does not apply to the IEEE document scope or was not considered sufficiently "common" for the relevant IEEE product standards. In order to preserve the "clause for clause" matching relationship between the two standards, this IEEE standard retains the same IEC clause number and heading but simply states:

"At the present time, there are no common requirements defined for this subject. Refer to the relevant equipment standards."

Subclause 4.10 and 4.11 are examples where this procedure is used.

In a similar manner, a table that appears in the IEC document but is not considered appropriate for this IEEE document is left out and its table number passed over. In the few cases where this occurs, the following table will bear a footnote stating:

"In order to preserve the coordination with IEC 62271.1, table number x is reserved for future use. It is intentionally omitted from this revision of C37.100.1."

Table 7 within subclause 5.13.1 is an example where this procedure is used.

The Working Group felt that these unusual steps would promote the harmonization effort between IEEE and IEC and would go a long way to facilitate the comparison of the two parallel standards.

J.3 Comments on selected topics

The following notes pertain to the clause, table, figure, or annex referenced.

- Subclause 1.1 – The scope of the standard, as the title implies, covers high voltage switchgear. In general, this is the IEEE C37 series of standards. However this is not an absolute because several of the C37 standards pertain to low voltage switchgear or to relays. Furthermore, there is no intention to exclude a standard outside the C37 series.
- Subclause 1.1 and Annex A – There was considerable concern within the Working Group and many of the IEEE Switchgear Section Members at large concerning the "forced" application of this horizontal standard. The wording of subclause 1.1, Footnote 1, and Annex A were carefully chosen to alleviate

these concerns. The only requirement is that this standard be used where applicable and appropriate. It is left to the working groups charged with the revision of the respective relevant equipment standards to adopt the provisions of these common (specifications) requirements, as they deem appropriate.

— Subclause 1.2 - In compliance with the 2005 IEEE Style Manual and IEC practice, the normative references are not dated unless the use of a particular dated version (revision) of that reference is required.

— Subclause 2.2.1 and Annex B – The approach to altitude correction factors has been changed to recognize the physics of relative air density and its effect on the dielectric withstand of an air gap. The long history of successful application of switchgear equipment up to 1 000 m without the application of relative air density (altitude) correction factors is also recognized.

The debate over this change examined several related issues:

a) The traditional or historical approach is not consistent with the true physical relationship between relative air density and the dielectric strength of an air gap, i.e. the change in relative air density between sea level and 1 000 m is significant when considered by itself.

b) The traditional or historical approach of disregarding correction factors up to 1000 m has been applied successfully for several decades. Other considerations, e.g. insulation coordination assumptions, design safety factors, support the practice of disregarding the change in relative air density between sea level and 1 000 m.

c) The new IEEE approach to the matter places it at odds with IEC standards for applications above 1000 m..

It is the hope of the WG that both IEEE and IEC can adopt this same approach in the near future.

— Subclause 2.2.3 – Special or unusual temperature conditions now include preferred ranges recognizing the needs in certain parts of the world. For example, the desert region of the United States routinely experiences an upper temperature of +50°C or +55°C but rarely sees temperatures below –15°C or –5°C. On the other end, regions in Canada routinely see temperatures down to –40°C or –50°C. It should be emphasized that these are special or unusual conditions when it comes to specifying equipment.

— Subclause 2.3.3 – Extreme humidity as a special or unusual service condition was debated by the WG. Very arid or desert regions of the earth can experience an absolute humidity that approaches zero. Under these conditions, IEEE Std 4 indicates that a correction factor of 10% to 12% might be appropriate. Rather than trying to take on this new topic and attempt to define a “normal humidity range”, the WG decided to add an informative note that will alert the user to this issue.

— Subclause 2.2.5 – This clause notes some “other special service conditions”. Emphasis is on “service” conditions, not storage, transport, application or system (network) related conditions. In general, the service conditions are limited to those controlled by the geographic location or by nature.

— Clause 3 – Since this is a common clause standard, it is not surprising that nearly all of the special terms used are defined in the IEEE C37.100 or the Authoritative Dictionary. In the Authoritative Dictionary of IEEE Standards Terms, there are multiple definitions provided for internal and external insulation. As used in this standard, the definitions below are considered more appropriate:

External insulation: The air insulation and the exposed surfaces of solid insulation of equipment, which are both subject to dielectric stresses and to the effects of atmospheric and other external conditions such as contamination, humidity, vermin, etc.

Internal insulation: Internal insulation comprises the internal solid, liquid, or gaseous elements of the insulation of equipment, which are protected from the effects of atmospheric and other external conditions such as contamination, humidity, vermin, etc.

— Clause 3.3 –The definition adopted in this standard for “isolating distance” is intended to be equivalent to the combination of three definitions from IEC 60050-441 with the exceptions noted below.

a) **441-17-35** - isolating distance (of a pole of a mechanical switching device)

The clearance between open contacts meeting the safety requirements specified for disconnectors.

b) **441-17-34** - clearance between open contacts

The total clearance between the contacts, or any conductive parts connected thereto, of a pole of a mechanical switching device in the open position.

c) **441-17-31 -** clearance

The distance between two conductive parts along a string stretched the shortest way between these conductive parts.

The IEC phrase, "clearance between open contacts" is replace by "clearance between the contacts, or any conductive parts connected thereto." Both IEC and IEEE agree that the reference to "safety requirements" is inappropriate and is replaced by "functional requirements." The result is a concise definition containing the essential elements and is complete, i.e. there is no need to refer to other definitions for a complete understanding of the term.

— Clause 4 and Annex H – Many symbols are introduced in this clause and listed in Annex H. Some of these are also being introduced in the 200x revisions to the HV circuit breaker standards, C37.04, .06, and .09. While the IEEE symbols are used where they exist, most of the symbols are harmonized with the IEC symbols and are new to IEEE.

— Clause 4, Table 1a: Table 1a has been changed to include values in column3 and column 5 for all rated voltages up and including 38 kV. The values "across the isolation gap" are generally 110% of the dry common value consistent with the HV Switch standards. Note (d) has been revised to refer the user to the relevant equipment standards for requirements across the isolation gap. These changes recognize the fact that some medium voltage equipment, such as Metal-Clad Switchgear, is tested across the isolation gap in the TEST position with the circuit breaker in the closed position.

— Subclause 4.4.2, subclause 4.4.3 and Table 3 – Limits of temperature rise. The preferred numbers for temperature rise and total temperature are intentionally harmonized with IEC and the latest revisions to the HV circuit breaker standards. It is recognized that some relevant equipment standards may not be able to adjust to these numbers. Exceptions to the table are allowed and expected. Table J.1 lists some of the exceptions or deviations from the IEC Common Requirements standard that are either included in Table 3 or are recognized in certain relevant equipment standards as noted. The table and notes list exceptions only, i.e. if a line or note from Table 3 or clause 4.4.3 is not mentioned, it was found to be in harmony with IEC. Equipment standards for HV switch, and gas-insulated substations are noted areas of further deviation.

Table J.1—Temperature Rise Exceptions/Differences

Nature of the part, of the material and of the dielectric (see notes below)	Maximum value: Temperature °C	Maximum value: Temperature rise at ambient air temperature not exceeding 40 °C K	Reference Standard (Note 1)
Col. 1	Col. 2	Col. 3	Col. 4
1 Contacts (see points 4 and 14)			
Bare-copper or bare-copper alloy			
- In air	75	35	
....	**70**	**30**	[C:155]
- In SF_6 (sulfur hexafluoride (see point 5)	105	65	
....	**90**	**50**	IEEE 1247/D5
Tin-coated (see point 6)			
- In SF_6 (see point 5)	90	50	
....	**105**	**65**	IEEE 1247/D5
2 Connection, bolted or the equivalent (see point 4)			
Bare-copper, bare-copper alloy or bare-aluminum alloy			
- In air	90	50	
....	**70**	**30**	C37.20.2, -.3
- In SF_6 (see point 5)	115	75	
....	**100**	**60**	IEEE 1247/D5
- In oil	100	60	
....	**80**	**40**	C37.40-2003
Silver-coated or nickel-coated			
- In air	115	75	
....	**125**	**85**	IEEE 1247/D5
....	**105**	**65**	C37.20.2,-.3
- In SF_6 (see point 5)	115	75	
....	**125**	**85**	IEEE 1247/D5
Tin-coated (see point 6)			
- In air	105	65	
....	**115**	**75**	IEEE 1247/D5
- In SF_6 (see point 5)	105	65	
....	**125**	**85**	IEEE 1247/D5
4 Terminals for the connection to external conductors by screws or bolts (see points 8 and 14)	**(see point 14)**	**(see point 14)**	See Note 3
5 Oil for oil switching devices (see points 9 and 10)	90	50	C37.60-2003 See Note 4
8 Any part of metal or of insulating material in contact with oil, except contacts	100	60	

Nature of the part, of the material and of the dielectric (see notes below)	**Maximum value**		**Reference Standard (Note 1)**
	Temperature °C	**Temperature rise at ambient air temperature not exceeding 40 °C K**	
9 Accessible parts - Expected to be touched in normal operation .... - Which need not be touched in normal operation ... - External surface of enclosures (public accessible enclosures only) .... - External surfaced not accessible to an operator in the normal course of duties.	Note 5 Note 6 **110** **105** **110**	 **70** **--** **--**	 C37.74-2003 IEEE 1247/D5 C37.20.2, -.3
10. Other current carrying parts - **Copper or copper alloy casting............................** **- Hard-drawn copper parts (Note 7)........................** **- Heat treated aluminum parts**................................	 **105** **80** **105**	 **65** **40** **65**	 IEEE 1247/D5 IEEE 1247/D5 IEEE 1247/D5

Nature of the part, of the material and of the dielectric (see notes below)	Maximum value		Reference Standard (Note 1)
	Temperature °C	Temperature rise at ambient air temperature not exceeding 40 °C K	

NOTE 1—Reference standards are C37.100.1 & IEC 62271-1 unless otherwise indicated; entries in **bold** represent the exceptions found in the standard listed in column 4.

NOTE 2—Reference to a "point" refers to the points listed in clause 4.4.3.

NOTE 3—Point 14 is added to Table 3: "These values are for connections to bare (un-insulated) cables or bus conductors. For connections to insulated cables, terminals shall not exceed 45 K rise or 85°C hottest spot total temperature when connected to 90˚C-rated cables rated for the full continuous (normal) current of the switchgear."

NOTE 4—C37.60-2003 qualifies oil temperature as follows: "The top oil (upper layer) temperature shall not exceed 40°C rise or 80°C total. The 50°C and 90°C values refer to the hottest spot temperature of parts in contact with oil."

NOTE 5—C37.04, C37.20.2, C37.20.3, and IEEE 1247 use different wording but they all specify a maximum temperature of 50°C. The IEC limit of 70°C is considered too high for the safety of operating personnel.

NOTE 6—C37.04, C37.20.2, C37.20.3, and IEEE 1247 use different wording but they all specify a maximum temperature of 70°C. The IEC limit of 80°C is considered too high for the safety of operating personnel.

NOTE 7—If annealing will not affect the performance of the switch, the total temperature and temperature rise over a 40 °C ambient for copper or copper alloy castings may be used.

NOTE 8—When the arcing contacts are bare copper contacts and are separate from but in parallel with the main contacts, the temperature rise of the main contacts and of the arcing contacts shall not exceed the values given in Table 3.

NOTE 9—Point 4 of clause 4.4.3 is not the same as given in IEC 62271-1:
"When engaging parts have different coatings or one part is of bare material, the permissible temperatures and temperature rises shall be:

— for contacts, those of the surface material having the lowest value permitted in item 1 of Table 3:
— for connections, those of the surface material having the **lowest** [IEC 62271-1 reads "highest"] value permitted in item 2 of Table 3.

On this point, the IEC community relies on its long and successfully experience. Lacking this experience or any supporting studies, the IEEE Switchgear has not endorsed this provision.

— Clause 5.13 – The WG decided to include the topic of degrees of protection by enclosures since it is receiving more attention in the industry and has been in the IEC common requirements document for some time. The WG also debated over the use of NEMA Std 250 as a reference as opposed to IEC 60529. The decision to use the IEC standard was made when it became ANSI/IEC 60529-2004 standard in November 2004.

— Clause 6.2.4 b) – The criteria to pass the impulse test has been under considerable debate in the IEEE and IEC communities, reference IEC SC 17, MT36 activities. The WG has taken the position that the 3x9 method or procedure C in IEEE Std 4 has served the industry well for many years. This method has been adopted across most of the IEEE switchgear standards over the past 10 years. Furthermore, some IEEE standards have recognized both the 3x9 (Procedure C) and the 2/15 (Procedure B) as acceptable test methods. Accordingly, this document recognizes both methods as well.

— Annex C – Pollution level III: A subtle change was made to the definition of pollution level III that makes it more consistent with the definition of pollution level II. The text changed from:

> "Areas with high density of industries **and** suburbs of large cities with high density of heating plants production pollution" to:

> "Areas with high density of industries **and/or** suburbs of large cities with high density of heating plants production pollution." (Emphasis added.)

Each of the two criteria should be sufficient to meet the definition of the pollution level. Although the new definition differs from IEEE C37.010-1999 and IEC 60815-1996, it is the hope of the WG that both IEEE and IEC will adopt this new definition in the near future.

— Annex F, Figure F.2: This figure borrowed from IEC 62271-1 is dimensioned in accordance with ISO metric practices. Refer to ISO 286-1, ISO system of limits and fits for details. [B26] Table J.2 provides a quick guide to the meaning of some of the less familiar dimensions shown in the figure.

Table J.2—Translation of ISO Dimensioning in Figure F.2

ISO designation (Figure F.2)	Meaning	Approximate English dimension
Ø 27 (typical)	27 mm diameter	1.06" dia.
Ø 19 M7	19 mm hole with a tolerance class of M7. See note	19 mm +0/-0.021 mm or 19 mm +0/-21 µm
Ø 6,75 J11	6.75 mm hole with a tolerance class of J11. See note	6.75 mm +/- 45 µm
Ø 19 k7	19 mm shaft (or outside diameter) with a tolerance class of k7. See note	19 mm +23/-2 µm

NOTE—The "M", "J", and "k" denote the position of the tolerance zone. Upper case letters are for holes, lower case letters are for shafts, The number following the tolerance zone letter denotes the standard tolerance grade. For additional information, refer to ISO 286-1, *ISO system of limits and fits*.

Annex K

(informative)

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