

IEEE Standard Requirements for AC High-Voltage Air Switches Rated Above 1000 V

IEEE Power & Energy Society

Sponsored by the
Switchgear Committee

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

IEEE Std C37.30.1™-2011

23 March 2012

IEEE Standard Requirements for AC High-Voltage Air Switches Rated Above 1000 V

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Switchgear Committee
of the
IEEE Power & Energy Society

Approved 7 December 2011

IEEE-SA Standards Board

Abstract: Required ratings, construction requirements, design test requirements, applications, and suggested practices for all high-voltage enclosed indoor and outdoor and nonenclosed indoor and outdoor switches rated above 1000 V are specified. This includes ratings and requirements for such switches as disconnecting, selector, horn-gap, and grounding for manual and power operation, except for interrupter switches, distribution-enclosed single-pole air switches, and distribution cutouts fitted with disconnecting blades.

Keywords: high-voltage switches, IEEE C37.30.1, indoor switches, outdoor switches

The Institute of Electrical and Electronics Engineers, Inc.
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PDF: ISBN 978-0-7381-7157-9 STD97189
Print: ISBN 978-0-7381-7182-1 STDPD97189

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Introduction

This introduction is not part of IEEE Std C37.30.1-2011, IEEE Standard Requirements for AC High-Voltage Air Switches Rated Above 1000 V.

This standard is intended to be a consolidation of the following standards: IEEE Std C37.30™-1997, ANSI C37.32-2002, IEEE Std C37.34™-1994, IEEE Std C37.35™-1995, IEEE Std C37.36b™-1990, and IEEE Std C37.37™-1996. This standard incorporates relevant material from earlier standards and replaces IEEE Std C37.30, ANSI C37.32, IEEE Std C37.34, IEEE Std C37.35, IEEE Std C37.36b, and IEEE Std C37.37. In addition, the Consolidation of C37.3x Series Working Group has strived to make minimal technical changes to the text from these standards. This consolidation effort is the first phase of a two-part process to facilitate harmonization of the IEEE C37.30 series of standards with existing International Electrotechnical Commission (IEC) documents covering switch devices. The second phase of the process will be to incorporate technical changes where needed and to harmonize with IEC standards.

This comprehensive document is the consummation of efforts of the Consolidation of C37.3x Series Working Group of the High Voltage Switches Subcommittee of the IEEE Switchgear Committee.

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Gary Haynes
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Janusz Zawadzki

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

William J. Ackerman
Steven Alexanderson
Chris Ambrose
J. Angelis
Stan Arnot
Adam Bagby
R. Paul Barnett
W. J. Bill Bergman
Steven Bezner
Wallace Binder
Michael Bio
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C. Erven
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Saumen Kundu
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1. Overview

1.1 Scope

This standard covers preferred ratings; construction and testing requirements; and application, loading, installation, operation, and maintenance guidelines for all high-voltage enclosed and nonenclosed, indoor and outdoor air switches rated in excess of 1000 V. This includes such switch types as disconnect, horn-gap, fault-initiation, and ground for manual or power operation. The following switch types are not covered by this standard: interrupter switches, distribution cutouts fitted with disconnecting blades, and switches used in metal-enclosed and pad-mounted switchgear. This standard also does not apply to load-break separable insulated connectors, circuit breakers, circuit switchers, or reclosers.

1.2 Purpose

The purpose of this standard is to provide a basic standard for air switches.

2. Normative references

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

ANSI C29.1, American National Standard for Electrical Power Insulators—Test Methods.¹

ANSI C29.8, American National Standard for Wet-Process Porcelain Insulators—Apparatus, Cap and Pin Type.

ANSI C29.9, American National Standard for Wet-Process Porcelain Insulators—Apparatus, Post Type.

ANSI C63.2-2009, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications.

IEC 60815, Guide for the Selection of Insulators in Respect of Polluted Conditions.²

IEEE Std C2[®]-2007, National Electrical Safety Code[®] (NESC[®]).³

IEEE Std 4[™], IEEE Standard Techniques for High-Voltage Testing.^{4,5}

IEEE Std 142[™]-2007, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (*Green Book*[™]).

IEEE Std 1247[™], IEEE Standard for Interrupter Switches for Alternating Current, Rated Above 1000 V.

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

IEEE Std C37.100.1[™], IEEE Standard of Common Requirements for High-Voltage Power Switchgear Rated Above 1000 V.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms and Definitions*⁶ should be consulted for terms not defined in this clause.

air switch: A switching device designed to close and open one or more electric circuits by means of guided separable contacts that separate in air. The switching device may be equipped with arcing horns.

allowable continuous current class (ACCC) designation (of an air switch): A code that identifies the composite curve relating the loadability factor (LF) of the switch to the ambient temperature θ_a as determined by the limiting switch part class designations.

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⁶ *IEEE Standards Dictionary: Glossary of Terms and Definitions* is available at <http://shop.ieee.org>.

arcing horn: One of a pair of diverging electrodes on which an arc is extended to the point of extinction after the main contacts of the switching device have parted.

distribution class: A descriptive term used to denote application, restriction, or both to the part of an electric system between the substation and the customer.

enclosed switch: A switch designated for operation within a housing restricting heat transfer to the external medium.

horn-gap switch: A switch provided with arcing horns.

indoor switch: A switch designated for operation inside buildings or weather-resistant enclosures that do not restrict heat transfer to the ambient atmosphere.

loadability factor (LF): The ratio of allowable continuous current at a given ambient temperature to rated current.

loadability: The ratio of allowable continuous current at 25 °C ambient temperature to rated continuous current.

observable temperature rise: The steady-state temperature rise of any part of the switch above ambient temperature.

outdoor switch: Switches designated for operation outside buildings or enclosures. Outdoor switches may be exposed to the weather. Outdoor switches experience no restriction of heat transfer to the ambient atmosphere.

peak withstand current: The maximum instantaneous current at the major peak of an offset power frequency sinusoidal current that a switch is required to carry.

power frequency: The frequency at which a device or system is designed to operate.

rated fault-making current: The maximum root-mean-square (rms) power frequency current, expressed in symmetrical amperes, that the switch shall be required to make and carry at its rated maximum voltage for a specified duration. For transient currents, such as fault initiation and capacitive discharge, the rated making current shall be the current available from the circuit without the influence of the switching device.

short-time (symmetrical) withstand current: An abnormal power frequency current, the initial portion of which may have a dc offset, expressed in root-mean-square (rms) symmetrical amperes, that a switch is required to carry.

short-time (symmetrical) withstand current duration: The maximum duration of short-time (symmetrical) withstand current that a switch is required to carry.

station class: A descriptive term used to denote application or restriction or both to generating stations, switching stations, substations, and transmission lines.

switch part class designation: A code that identifies the curve that relates the loadability factor (LF) of a switch part material and function to the ambient temperature θ_a .

visible corona (as applies to an air switch): A luminous discharge due to ionization of the air surrounding an air switch and caused by a voltage gradient exceeding a certain critical value.

4. Service conditions

4.1 Usual service conditions

High-voltage switches conforming to this standard shall be suitable for operation at or within their ratings, provided that

- a) The ambient temperature (temperature of the surrounding air) is within the range of $-30\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$.
- b) The altitude does not exceed 1000 m (3300 ft).
- c) The wind velocity does not exceed 37 m/s (80 mi/h).

NOTE 1—This wind velocity will produce a pressure of approximately 770 N/m^2 (16 lbf/ft^2) of projected area on cylindrical surfaces (see NEMA SG 6-2000 [B20]).^{7,8}

NOTE 2—The interrupting ability of some switches that rely on a rapidly increasing external air gap for circuit interruption (such as whip arcing horns) may be influenced by local wind velocity and direction.

4.1.1 Outdoor switch

Switches designated as outdoor switches shall be suitable for operation outside buildings or enclosures. Outdoor switches may be exposed to the weather including icing conditions. They experience no restriction of heat transfer to the ambient atmosphere.

4.1.2 Indoor switch

Switches designated as indoor switches shall be suitable for operation inside buildings or weather-resistant enclosures. If an indoor switch is designed for weather-resistant enclosures, it shall also be considered an enclosed switch. If an indoor switch is designed for operation inside buildings, in a manner that does not restrict heat transfer to the ambient atmosphere, it shall be considered an indoor switch only.

4.1.3 Enclosed switch

Switches designated as enclosed switches shall be suitable for operation inside a housing that restricts heat transfer to the ambient atmosphere. Enclosed switches may also be suitable for use in enclosures filled with a dielectric media other than air, e.g., oil or sulfur hexafluoride (SF_6).

4.2 Unusual service conditions

Where other unusual conditions exist, they should be brought to the attention of the parties responsible for the design and application of the equipment. Examples of such conditions include the following:

- Operation in high altitudes. Equipment that depends on air for its insulating and cooling medium will have a higher temperature rise and a lower dielectric strength when operating at higher altitudes than when operating at lower altitudes. For altitudes above 1000 m (3300 ft), correction

⁷ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

⁸ The numbers in brackets correspond to the numbers in the bibliography in Annex G.

factors should be applied to the switch ratings. Altitude correction factors are specified in IEEE Std C37.100.1.⁹

- Contamination, such as damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moistures or dripping water.
- Abnormal vibration, shocks, earthquakes, or tilting.
- Excessively high or low ambient temperatures.
- Unusual transportation or storage conditions.
- Unusual space limitations.
- Unusual operating duty, frequency of operation, difficulty of maintenance, poor current waveform (high harmonic content), unbalanced voltage, or special insulation requirements.
- The application of an outdoor switch, indoor switch, or an enclosed switch for other purposes, which may include concerns regarding weather exposure and restricted heat transfer; see Table 1.

Table 1—Applications that may be considered unusual

Type of switch	Switch exposed to weather	Installation with restricted heat transfer
Outdoor Switch	Usual	Unusual
Indoor Switch	Unusual	Unusual
Enclosed Switch	Unusual	Usual

5. Description of ratings and capabilities

Subclauses 5.1 through 5.16 generally define the ratings and capabilities that switches may be required to have. The switch manufacturer can build a switch product that meets any combination of the ratings, or alternately, other apparatus standards may require a specific set of ratings. The ratings of equipment covered by this standard include the items marked with an “X” in Table 2. The preferred values for ratings and capabilities are found in Clause 6. The test procedures to establish the ratings and capabilities are found in Clause 8.

Table 2—Switch ratings and required tests

Switch rating	Switch ^a		
	Disconnecting	Fault-initiating	Grounding
	(1)	(2)	(3)
Rated power frequency	X	X	X
Rated maximum voltage	X	X	X
Rated continuous current	X	—	—
Rated dielectric withstand voltages	X	X	X
Rated lightning impulse withstand (basic impulse insulation level (BIL))	X	X	X
Rated switching impulse withstand (for rated maximum voltage of 362 kV and above)	X	X	X
Rated power frequency dry withstand	X	X	X

⁹ Information on references can be found in Clause 2.

Table 2—Switch ratings and required tests (*continued*)

Switch rating	Switch ^a		
	Disconnecting	Fault-initiating	Grounding
	(1)	(2)	(3)
Rated power frequency wet withstand (outdoor)	X	X	X
Rated power frequency dew withstand (indoor)	X	X	X
Rated peak-withstand current	X	O	X
Rated short-time (symmetrical) withstand current	X	O	X
Rated short-time (symmetrical) withstand current duration	X	O	X
Rated mechanical operations	X	—	X
Rated mechanical terminal load	X	X	X
Rated ice-breaking ability—manual (outdoor)	O	O	O
Rated ice-breaking ability—power: single attempt opening and closing (outdoor)	O	O	O
Rated ice-breaking ability—power: single attempt opening, multiple attempt closing (outdoor)	O	—	O
Rated load-making current	O	—	O
Rated fault-making current	—	X	—

^a “X” indicates required rating; “O” indicates optional rating; “—” indicates not applicable.

5.1 Rated power frequency

The rated power frequency is the fundamental steady-state supply voltage frequency at which the switch is designed to operate. Typical power frequencies are 50 Hz and 60 Hz.

5.2 Rated voltage

5.2.1 Rated maximum voltage

The rated maximum voltage of a switch is the highest root-mean-square (rms) line-to-line voltage of rated power frequency for which the switch is designed to operate.

Specific requirements keyed to the rated maximum voltage are as follows:

- Interrupting ratings
- Making current ratings
- Limit of corona voltage and radio-influence voltage (RIV)
- Ratings at which switching surge tests are required

5.3 Rated withstand voltages

The rated withstand voltages are the voltages of the appropriate wave shape, magnitude, and duration that the switch shall withstand under specified conditions without damage to the insulating materials.

5.3.1 Rated power frequency withstand voltage

The rated power frequency withstand voltage is the rms value of the sinusoidal waveform of rated power frequency.

5.3.1.1 Rated power frequency dry withstand voltage

The rated power frequency dry withstand voltage is a rated power frequency withstand voltage that the switch is required to withstand for a duration of 60 s under dry conditions.

Insulation between the live parts of a switch and ground shall withstand 100% of the rated power frequency dry withstand voltage.

Insulation across the open gap of air switches shall withstand 110% of the rated power frequency dry withstand voltage.

5.3.1.2 Rated power frequency wet withstand voltage

The rated power frequency wet withstand voltage is the power frequency withstand voltage that an outdoor switch is required to withstand for a duration of 10 s under wet (rain) conditions. There are no power frequency wet withstand requirements for indoor or enclosed switches.

Insulation between the live parts of an outdoor switch and ground shall withstand 100% of the rated power frequency wet withstand voltage.

5.3.1.3 Rated power frequency dew withstand voltage

The rated power frequency dew withstand voltage is the power frequency withstand voltage that an indoor or an enclosed switch is required to withstand, without flashover or damage to any insulation, for a duration of 10 s with dew (condensate) over the switch's solid insulation.

Insulation between the live parts and ground shall withstand 100% of the rated power frequency dew withstand voltage.

If the open gap of an enclosed switch is effectively bridged by a solid insulation, a dew withstand test shall be made, and the open gap shall withstand 100% of the rated power frequency dew withstand voltage.

There is no power frequency dew withstand requirement for outdoor switches.

5.3.2 Rated lightning impulse withstand voltage

The rated lightning impulse withstand voltage is the peak value of 1.2/50 μ s positive and negative impulses that the switch shall be required to withstand.

Insulation between the live parts of a switch and ground shall withstand 100% of the rated lightning impulse withstand voltage.

Insulation across the open gap of air switches shall withstand 110% of the rated lightning impulse withstand voltage.

NOTE—Conformance to this rating does not necessarily provide assurance that a switch with 110% withstand across the open gap will always flash over to ground instead of across open gaps. Where surge protection of the gap is required, switch insulators may be equipped with rod gaps or similar protective devices.

5.3.3 Rated switching impulse withstand voltage

The rated switching impulse withstand voltage is the peak value of 250/2500 μ s positive and negative impulses that the switch shall be required to withstand. There are no rated switching impulse withstand requirements for switches with rated maximum voltage less than 362 kV.

Insulation between the live parts of a switch and ground shall withstand 100% of the rated switching impulse withstand voltage.

Insulation across the open gap of air switches shall withstand switching impulse voltages listed in Table 5 (in 6.6).

5.4 Rated continuous current

The rated continuous current is the maximum current the switch shall be required to carry continuously under usual service conditions without exceeding specified temperature limits, as shown in Table 3. The current is in rms amperes at rated power frequency.

Table 3—Temperature limitations for air switches, enclosed and nonenclosed

Switch part	Allowable maximum temperature, θ_{max} (°C)	Nonenclosed indoor and outdoor switches		Enclosed indoor and outdoor switches	
		Limit of observable temperature rise at rated current, θ_r (°C) ^a	Switch part class designation	Limit of observable temperature rise at rated current, θ_r (°C)	Switch part class designation
	(1)	(2)	(3)	(4)	(5)
(a) Contacts in air ^b					
(1) Copper or copper alloy	75	33	BO2	20	QO ₃ 3
(2) Copper or copper alloy to silver or silver alloy, or equivalent	90	43	DO4	33	RO4
(3) Silver, silver alloy, or equivalent	105	53	FO6	43	TO6
(4) Other ^c	—	—	—	—	—
(b) Conducting mechanical joints					
(1) Copper or aluminum	90	43	DO4	33	RO4
(2) Silver, silver alloy, or equivalent	105	53	FO6	57	TO6
(3) Other ^c	—	—	—	—	—
(c) Switch terminals with bolted connections	90	43	DO4	33	RO4
(d) Welded or brazed joints or equivalent	105	53	FO6	43	TO6
(e) Other current-carrying parts					
(1) Copper or copper alloy castings	105	53	FO6	43	TO6
(2) Hard drawn copper parts ^d	80	37	CO3	25	PO ₂ 2

Table 3—Temperature limitations for air switches, enclosed and nonenclosed (*continued*)

Switch part	Allowable maximum temperature, θ_{max} (°C)	Nonenclosed indoor and outdoor switches		Enclosed indoor and outdoor switches	
		Limit of observable temperature rise at rated current, θ_r (°C) ^a	Switch part class designation	Limit of observable temperature rise at rated current, θ_r (°C)	Switch part class designation
	(1)	(2)	(3)	(4)	(5)
(3) Heat-treated aluminum alloy parts	105	53	FO6	43	TO6
(4) Woven-wire flexible connectors	75	33	BO2	20	QO ₃ 3
(5) Other materials ^c	—	—	—	—	—
(f) Insulator caps and pins and bushing caps	110	57	GO7	47	UO7
(g) Current-carrying parts in contact with insulating materials					
(1) Insulation class 90 °C	80	37	CO3	25	PO ₂ 2
(2) Insulation class 105 °C	95	47	EO5	43	SO5
(3) Insulation class 130 °C	120	63	HO8	60	VO8
(4) Insulation class 155 °C	145	80	IO9	77	WO9
(5) Insulation class 180 °C	170	97	JO10	93	XO10
(6) Insulation class 220 °C	210	123	KO11	120	YO11
(7) Oil ^e	90	43	DO4	33	RO4
(8) SF ₆	350	307	—	297	—
(h) Nonenergizable parts subjected to contact by personnel					
(1) Handled by operator ^f	50	10	—	10	—
(2) Accessible to operator ^f	70	30	—	30	—
(3) Not accessible to operator ^g	—	—	—	—	—
(i) Entire switch limited to 30 °C rise					
(1) Outdoor	70	30	AO1	—	—
(2) Indoor	85	—	—	30	NO1

^a The limit of observable temperature rise listed in this column is suitable for use in rating switches for application in enclosures of IEEE Std C37.20.2™-1999 [B8] and IEEE Std C37.20.3™-1987 [B9], if the corresponding allowable maximum temperature listed in column 1 is not exceeded when in the enclosure. These temperature rises are chosen to give a loadability of 1.22 at 25 °C.

^b Contacts as used here include (a) stationary and moving contacts that engage and disengage and (b) contacts that have relative movement but remain engaged.

^c Other materials may become available for contacts, conducting mechanical joints, and other current-carrying parts that have a different allowable maximum temperature, θ_{max} . Their limit of observable temperature rise at rated continuous current, θ_r , shall be related to their θ_{max} , in accordance with 5.4.

^d If annealing will not impair switch operation or reduce ability to meet any of the ratings, 105 °C may be used for θ_{max} and the corresponding increase in θ_r as determined in 5.4.

^e The top oil (upper-layer) temperature shall not exceed 80 °C total. The 90 °C value refers to the hottest-spot temperature of parts where they contact the oil.

^f It is assumed that any parts handled by or accessible to an operator will be in ambient air with a temperature that does not exceed 40 °C.

^g The maximum temperature of any nonenergizable part that is not accessible to the operator shall not exceed a temperature that will necessitate maintenance or replacement of parts during the life of the switch.

5.4.1 Allowable continuous current

The allowable continuous current of a switch at specific ambient temperature is the maximum alternating current, in rms amperes at rated frequency, that a switch will carry without exceeding the allowable maximum temperature for any of its parts, as listed in column 1 of Table 3.

The allowable continuous current may be determined from Equation (1).

$$I_a = I_r \left(\frac{\theta_{\max} - \theta_a}{\theta_r} \right)^{0.5} \quad (1)$$

where

- θ_a is ambient temperature (°C)
- I_a is allowable continuous current at ambient temperature, θ_a
- I_r is rated continuous current
- $\theta_{\max}$ is allowable maximum temperature (°C) of switch part, from Table 3
- θ_r is limit of observable temperature rise (°C) at rated current of switch part, from Table 3

5.4.2 Loadability

The loadability of an air switch is the ratio of allowable continuous current, at 25 °C ambient temperature, to rated current.

NOTE—Loadability is a measure of the allowable continuous current over the average of ambient temperatures from 10 °C to 40 °C for the air surrounding air switches. The loadability of 30 °C rise switches of previous standards is 1.22 at 25 °C. The limits of observable temperature rise at rated current in Table 3 have been selected to maintain a minimum 1.22 loadability at 25 °C.

The loadability of switches used in enclosures is covered by other standards and is the ratio of allowable continuous current, at 25 °C ambient temperature outside the enclosure, to rated current. This loadability may be different from 1.22.

5.4.3 Switch part class designation

The switch part class designation of a switch is a code that identifies the curve that relates the loadability factor, LF , of the switch to the ambient temperature, θ_a . This factor is determined by the allowable maximum temperature, $\theta_{\max}$, and the limit of observable temperature rise, θ_r , using the formula in Equation (2).

$$LF = \frac{I_a}{I_r} = \left(\frac{\theta_{\max} - \theta_a}{\theta_r} \right)^{0.5} \quad (2)$$

The switch part class designations are given in Table 3. Refer to Annex C for application curves.

5.4.4 Allowable continuous current class (ACCC) designation

The ACCC designation of an air switch is a code that identifies the composite curve relating the loadability factor, LF , of the switch to the ambient temperature, θ_a , as determined by the limiting switch part class designations. The first term of the ACCC designation is obtained from the first letter of the class designation of the switch part having the lowest limit of observable temperature rise. The middle term is the letter O, designating loadability at 25 °C ambient temperature. The last term is obtained from the numeral of the class designation of the switch part having the highest limit of observable temperature rise.

5.4.5 Limits of observable temperature

The maximum value of observable temperature rise of any part of a switch, when tested in accordance with Clause 8, is given in Table 3.

The limit of observable temperature rise, θ_r , at rated current shall be determined from either Equation (3) or Equation (4) to maintain an air switch loadability of 1.22.

$$\text{For nonenclosed switches, } \theta_r = \left(\frac{\theta_{\max} - \theta_n}{1.5} \right) \quad (3)$$

$$\text{For enclosed switches, the lesser of } \theta_r = \left(\frac{\theta_{\max} - \theta_{e1}}{1.5} \right) \text{ or } \theta_r = \theta_{\max} - \theta_{e2} \quad (4)$$

where

- θ_n is 25 °C, the standard ambient temperature
- θ_{e1} is 40 °C
- θ_{e2} is 55 °C
- $\theta_{\max}$ is allowable maximum temperature (°C) of switch part, from Table 3
- 1.5 is $(1.22)^2$, where 1.22 is loadability of switch at θ_n

5.5 Rated short-time withstand current

The rated short-time withstand current has two associated ratings:

- a) Rated peak withstand current, which is a measure of the switch's ability to withstand the magnetic forces associated with a short circuit
- b) Rated short-time (symmetrical) withstand current duration, which is a measure of the switch's ability to withstand the heat generated by a short-time current

The relationship between peak withstand current and short-time (symmetrical) withstand current is based on an approximate X/R of 17 for 60 Hz applications and X/R of 14 for 50 Hz applications. This leads to a peak current to rms symmetrical current ratio of 2.6 for 60 Hz and 2.5 for 50 Hz.

5.5.1 Rated peak withstand current

The rated peak withstand current is the maximum instantaneous current at the major peak of an offset rated power frequency current, having a total duration of not less than 0.166 s, which the switch shall be required to carry while in the closed position.

5.5.2 Rated short-time (symmetrical) withstand current duration

The rated short-time (symmetrical) withstand current duration is the maximum duration for which the switch shall be required to carry rated short-time (symmetrical) withstand current while in the closed state.

5.6 Rated fault-making current

Only switches that have the closing speed independent of operating personnel can have a fault-making current rating. Switches that have the closing speed dependent on operating personnel may have a fault-making current capability, which indicates that successful circuit closing is dependent upon proper operation of the switch. Nameplates of switches with a fault-making current capability shall have a caution that references the switch's instruction manual and indicates that successful circuit closing is dependent upon proper operation of the switch.

5.7 Visible corona-free voltage

The visible corona onset voltage is the line-to-ground voltage at which there is an onset of visible plumes or spikes under dark conditions.

5.8 Radio-influence voltage (RIV) limit

The RIV limit is the maximum allowable RIV, at a specified detection frequency and at a specified distance, produced by a switch when energized at a specified voltage at rated power frequency. The limits of RIV are given in column 6 of Table 4 (in 6.6).

5.9 Partial discharge limits

This item is currently under study and is intended to appear in a subsequent revision to this standard.

5.10 Rated ice-breaking ability

The rated ice-breaking ability is the maximum thickness of ice, as defined by the ice-loading test of 8.5, under which the switch shall be required to successfully open or close.

5.11 Rated mechanical operations

The rated mechanical operations is the minimum number of mechanical operating cycles that a switch shall be required to perform without requiring maintenance or adjustment. An operating cycle shall be one close operation and one open operation. For outdoor switches, a specified number of operations must be accomplished with various terminal loads.

5.12 Rated mechanical terminal load

The rated mechanical terminal load is the static force, equivalent to an external mechanical load and applied at each terminal in specified directions, that a switch shall withstand while stationary and during operation.

5.13 Rated control voltage

The rated control voltage is the nominal voltage for which a power-operated mechanism is designed to operate.

5.14 Rated closing time (for power-operated switches)

The rated closing time of a switch is the specified interval in a closing operation between the energizing of the close coil, at the lower limit of the rated control-voltage range, and the making of the current-making switch contacts.

5.15 Switching endurance—fault-initiating switch

The expected switching endurance of a fault-initiating switch is the number of closing operations, at rated making current, that a switch is capable of performing when it is new and tested at its rated making current. After the last rated closing operation, the switch must be capable of being opened.

5.16 Rated load-making current

The rated load-making current of a switch is the highest prospective rms current that a switch shall be required to make and carry at its rated maximum voltage.

NOTE—Preferred ratings and testing requirements have not been established at this time. Consult manufacturer for this information.

6. Preferred ratings

Preferred ratings for outdoor, indoor, and enclosed switches are given in 6.1 through 6.4.

Preferred ratings for switch accessories are given in 6.5.

All the tables and the figure relating to these preferred ratings (i.e., Table 4 through Table 13 and Figure 1) are presented in 6.6.

The ratings designated in this standard and in reference standards are preferred and are not considered restrictive. Nonpreferred ratings based on performance are acceptable under the provisions of this standard when accepted by the equipment user.

6.1 Outdoor switches—preferred ratings

6.1.1 Station class outdoor air disconnect switches

6.1.1.1 Voltage and current

The preferred voltage, continuous current, and withstand current ratings at the rated power frequency of 60 Hz or 50 Hz are given in Table 4, Table 5, and Table 6.

6.1.1.2 Short-time withstand current duration

The preferred short-time (symmetrical) withstand current durations are given in footnote a of Table 6, with allowable I^2t variations given in 8.3.5.1.

6.1.1.3 Peak withstand current duration

The preferred peak withstand current duration is given in footnote b of Table 6.

6.1.1.4 Ice-breaking ability

If an outdoor switch has an ice-breaking rating, the preferred ratings shall be 10 mm (3/8 in) and 20 mm (3/4 in). A switch that has successfully passed the ice test and is rated for a given thickness of ice is also rated for lesser thicknesses.

6.1.1.5 Mechanical operations

The preferred mechanical operation rating shall be 1000 operations: 900 close-open cycles without terminal loading and 100 close-open cycles with terminal loading as specified in 8.6.2.2. Refer to Table 13 for rated control voltages for power-operated switches and 8.6.2.4 for number of operations at minimum and maximum control voltage.

6.1.1.6 Terminal loading

The preferred mechanical terminal loadings are given in Table 7.

6.1.1.7 Dielectric test voltages

6.1.1.7.1 Energized parts to ground

Outdoor switches in either the open or closed positions shall withstand the voltages specified in column 2, column 3, and column 4 of Table 4. See footnote a of Table 4 and Table 5 for switching impulse ratings.

6.1.1.7.2 Open-gap withstand

The air gap of outdoor air switches, when in the fully open position, shall withstand voltages that are 110% of the rated lightning impulse dry withstand and the power frequency dry withstand voltages given in column 2 and column 3 of Table 4. For switches rated 362 kV and higher, the open gap shall also withstand the switching impulse voltages specified in Table 5.

6.1.1.7.3 Corona and radio-influence test voltage limits

Switches rated 123 kV and higher, when tested under dark conditions at the voltage levels specified in column 5 of Table 4, shall be free of visible plumes or spikes. The limits of RIV are given in column 6 of Table 4. Refer to 8.7 and 8.8 of this standard and to Annex A of NEMA CC1.

6.1.2 Distribution class outdoor air disconnect switches

6.1.2.1 Voltage and current

The preferred voltage, continuous current, and withstand current ratings at the rated power frequency of 60 Hz or 50 Hz are given in Table 8 and Table 9.

6.1.2.2 Short-time withstand current duration

The preferred short-time (symmetrical) withstand current durations are given in footnote a of Table 9, with allowable I^2t variations given in 8.3.5.1.

6.1.2.3 Peak withstand current duration

The preferred peak withstand current duration is given in footnote b of Table 9.

6.1.2.4 Ice-breaking ability

Refer to 6.1.1.4 for preferred ice-breaking ratings.

6.1.2.5 Mechanical operations

The preferred number of mechanical operations shall be as specified in 6.1.1.5.

6.1.2.6 Terminal loading

The preferred mechanical terminal loading is given in Table 7.

6.1.2.7 Dielectric test voltages

6.1.2.7.1 Energized parts to ground

Outdoor switches in either the open or closed positions shall withstand the voltages specified in column 2, column 3, and column 4 of Table 8.

6.1.2.7.2 Open-gap withstand

The air gap of outdoor switches, when in the fully open position, shall withstand voltages that are 110% of the rated lightning impulse dry withstand and the power frequency dry withstand voltages given in column 2 and column 3 of Table 8.

6.1.2.7.3 Corona and radio-influence test voltage limits

Switches rated below 123 kV have no corona voltage requirements or RIV requirements.

6.2 Indoor air switches—preferred ratings

6.2.1 Voltage and current

The preferred voltage and preferred continuous and withstand current ratings at the rated power frequency of 60 Hz or 50 Hz are given in Table 10 and Table 11.

6.2.2 Short-time withstand current duration

The preferred short-time (symmetrical) current withstand durations are given in footnote a of Table 11, with allowable I^2t variations given in 8.3.5.1.

6.2.3 Peak withstand current duration

The preferred peak withstand current duration is given in footnote b of Table 11.

6.2.4 Mechanical operations

The preferred number of mechanical operations shall be as given in 6.1.1.5.

6.2.5 Terminal loading

Presently, there are no preferred mechanical terminal loadings for indoor switches.

6.2.6 Dielectric test voltages

6.2.6.1 Energized parts to ground

Indoor air switches, in either the open or closed positions, shall withstand the dielectric test voltages specified in column 2, column 3, and column 4 of Table 10.

6.2.6.2 Open-gap withstand

The air gap of indoor air switches, when in the fully open position, shall be such that the open gap or gaps will withstand a test voltage that is 110% of the lightning impulse dry and power frequency dry withstand test voltages specified in column 2 and column 4 of Table 10.

6.2.6.3 Corona and radio-influence test voltage limits

Switches rated below 123 kV have no corona voltage requirements or RIV requirements.

6.3 Grounding air switches—preferred ratings

6.3.1 Voltage and current

The preferred voltage and withstand current ratings at the rated power frequency of 60 Hz or 50 Hz are given in Table 4, Table 6, Table 8, and Table 9 for outdoor switches and Table 10 and Table 11 for indoor switches. Grounding switches have no continuous current ratings but have withstand current ratings that may be equal to or less than the disconnect switch rating.

6.3.2 Short-time withstand current duration

The preferred short-time (symmetrical) withstand current durations are given in footnote a of Table 6, Table 9, and Table 11, with allowable I^2t variations given in 8.3.5.1.

6.3.3 Peak withstand current duration

The preferred peak withstand current duration is given in footnote b of Table 6, Table 9, and Table 11.

6.3.4 Ice-breaking ability

Refer to 6.1.1.4 for preferred ratings for outdoor grounding switches. Indoor grounding switches have no ice-breaking requirements.

6.3.5 Corona and radio-influence test voltage limits

Switches rated 123 kV and higher, when tested under dark conditions at the voltage levels specified in column 5 of Table 4, shall be free of visible plumes or spikes. The limits of RIV are given in column 6 of Table 4. Refer to 8.7 and 8.8 of this standard and to Annex A of NEMA CC 1 for testing procedures.

6.4 Fault-initiating switches—preferred ratings

The preferred fault-making current ratings of fault-initiating switches at the rated power frequency of 60 Hz or 50 Hz are given in Table 12.

6.4.1 Short-time withstand current duration

The preferred short-time (symmetrical) withstand current durations are given in footnote a of Table 12, with allowable I^2t variations given in 8.3.5.1.

6.4.2 Peak withstand current duration

The preferred peak withstand current duration is given in footnote b of Table 12.

6.4.3 Preferred closing time

The preferred closing time, which includes blade travel to close the switch, shall not exceed 0.5 s.

6.4.4 Operating life expectancies

The expected switching endurance of a fault-initiating switch is the number of closing operations, at rated making current, that a switch is capable of performing when it is new and tested at its rated making current. After the last rated closing operation, the switch must be capable of being opened. The manufacturer should be consulted for operating life expectancies for fault-initiating switches.

6.4.5 Corona and radio-influence test voltage limits

Switches rated 123 kV and higher, when tested under dark conditions at the voltage levels specified in column 5 of Table 4, shall be free of visible plumes or spikes. The limits of RIV are given in column 6 of Table 4. Refer to 8.7 and 8.8 of this standard and to Annex A of NEMA CC 1 for testing procedures.

6.5 Switch accessories—preferred ratings

6.5.1 Power-operated mechanisms

6.5.1.1 Rated control voltages

The rated control voltages and their ranges for power-operated mechanisms used on high-voltage air switches shall be as shown in Table 13. Operating, auxiliary, and tripping functions shall perform satisfactorily when control voltages are within the ranges given in that table.

6.5.1.2 Voltage range measurement conditions

Voltage measurements shall be made at the control power input terminals of the mechanism. Maximum voltages are measured at no-load and minimum voltages are measured with operating current flowing.

NOTE—Maximum voltage at no load recognizes battery charging and equalizing techniques. Control circuits must dielectrically withstand the higher voltage, which also occurs if maximum voltage is maintained with operating current flowing. It is not necessary to maintain the higher voltage level as long as the voltage remains within the specified range. This obviates the need for a higher than maximum voltage to maintain the stated maximum voltage with operating current flowing. However, the minimum voltage must be maintained with operating current flowing to verify proper operation.

6.5.1.3 Torque requirements

Power-operated mechanisms shall develop the manufacturer's rated torque when operating at the preferred rated voltages given in Table 13.

6.5.1.4 Power-operated mechanism characteristics

Motor-operating mechanisms for outdoor switches shall have a torque at the output shaft under minimum operating voltage adequate to operate the switch under rated ice conditions. Operating time and torque value required should be in accordance with the manufacturer's recommendation.

6.6 Preferred ratings tables and figure

Table 4—Preferred voltage ratings for station class outdoor air switches

Line number	Rated ^c maximum voltage (rms kV)	Rated withstand voltage			Corona voltage & RIV	
		Lightning impulse (kV peak)	Power frequency (rms kV)		Test ^a voltage (rms kV)	Limit of RIV ^b (μV @ 1 MHz)
			Dry 1 min	Wet 10 s		
	(1)	(2)	(3)	(4)	(5)	(6)
1	8.3	95	38	30	—	—
2	15.5	110	50	45	—	—
3	27	150	70	60	—	—
4	38	200	95	80	—	—
5	48.3	250	120	100	—	—
6	72.5	250	120	100	—	—
7		350*	175	145	—	—
8	123	350	175	145	78	500
9		450	235	190	78	500
10		550*	280	230	78	500
11	145	350	175	145	92	500
12		450	235	190	92	500
13		550	280	230	92	500
14		650*	335	275	92	500
15	170	450	235	190	108	500
16		550	280	230	108	500
17		650	335	275	108	500
18		750*	385	315	108	500
19	245	550	280	230	156	500
20		650	335	275	156	500
21		750	385	315	156	500
22		900*	465	385	156	500
23		1050	545	455	156	500

Table 4—Preferred voltage ratings for station class outdoor air switches (*continued*)

Line number	Rated ^c maximum voltage (rms kV)	Rated withstand voltage			Corona voltage & RIV	
		Lightning impulse (kV peak)	Power frequency (rms kV)		Test ^a voltage (rms kV)	Limit of RIV ^b (μV @ 1 MHz)
			Dry 1 min	Wet 10 s		
	(1)	(2)	(3)	(4)	(5)	(6)
24	362	1050	545	455	230	500
25		1300*	610	525	230	500
26	550	1550	710	620	349	500
27		1800*	810	710	349	500
28	800	2050	940	830	508	750

NOTE 1—For switches rated 362 kV and higher, see Table 5 for values of rated switching impulse withstand voltages.
NOTE 2—Modern arrester technology enables use of lower lightning impulse rated equipment in some applications. The traditional values are indicated with an asterisk (*).

^a The test voltages are 110% of the rated maximum line-to-neutral voltage. It is not necessary to retest switches previously tested and acceptable at 105%. It is not necessary to retest switches previously rated at 121 kV, 169 kV, and 242 kV.

^b If equipment of any given rated maximum voltage is used on a circuit of higher voltage rating, the RIV limit and test voltage for the equipment shall be that corresponding to the rated maximum voltage of the circuit.

^c The switches listed in line 19 through line 28 are intended for application on systems effectively grounded as defined in IEEE Std 142-2007.

Table 5—Preferred switching impulse withstand voltage for station class outdoor air switches

Line number (from Table 4)	Rated maximum voltage (rms kV)	Rated lightning impulse withstand (kV peak)	Switching impulse withstand voltage (kV peak)	
			To ground ^a	Across open gap ^b
	(1)	(2)	(3)	(4)
24	362	1050	750	655 + (295)
25	362	1300	885	825 + (295)
26	550	1550	1050	880 + (450)
27	550	1800	1150	1000 + (450)
28	800	2050	1300	1000 + (650)

^a Line-to-ground insulation strength is based on 97.7% probability of withstand where the standard deviation is 6%. See 8.1.4.7.

^b Values in parenthesis are 60 Hz bias voltages expressed in kV peak units (column 1 voltage $\times \sqrt{2}/\sqrt{3}$). The summation of this opposite polarity bias voltage and the associated open-gap switching impulse voltage is equal to a 97.7% probability of line-to-ground flashover (CFO + 2σ), where CFO is critical flashover. See 8.1.4.7.