Online Continuing Education for Professional Engineers
Since 2009

HV Substation Equipment: Outdoor Air Switches

PDH Credits:

2 PDH

Course No.:

ASW101

Publication Source:

USDA – Rural Utilities Service

"RUS Bulletin: Design Guide for Rural Electrical Substations"
Pub. #RUS 1724E-300

Release Date:
June 2001

DISCLAIMER:

All course materials available on this website are not to be construed as a representation or warranty on the part of Online-PDH, or other persons and/or organizations named herein. All course literature is for reference purposes only, and should not be used as a substitute for competent, professional engineering council. Use or application of any information herein, should be done so at the discretion of a licensed professional engineer in that given field of expertise. Any person(s) making use of this information, herein, does so at their own risk and assumes any and all liabilities arising therefrom.

Copyright © 2009 Online-PDH - All Rights Reserved
1265 San Juan Dr. - Merritt Island, FL 32952
Phone: 321-501-5601

5.7 AIR SWITCHES

5.7.1 General

This section deals with high-voltage air switches used in substations. Items discussed include applicable national standards, types of air switches, various constructions of outdoor air switches, service conditions, ratings, and tests.

The general function of an air switch is as stated in ANSI/IEEE Std. C37.100: "A switching device designed to close and open one or more electrical circuits by means of guided separable contacts that separate in air." Air, at atmospheric pressure, is also the insulating medium between contacts in the open position.

Many varieties of air switches have been developed to fulfill special user requirements. RUS IP 202-1, "List of Materials Acceptable for Use on Systems of RUS Electrification Borrowers," contains both fully accepted and conditionally accepted types of air switches and should be consulted whenever air switches are required.

All varieties of air switches used in a cooperative's substations need to generally conform to all applicable national standards and guides. The principal standards and guides for air switches are the following:

- ANSI Std. C29.1, "Test Methods for Electrical Power Insulators"
- ANSI Std. C29.8, "Wet-Process Porcelain Insulators (Apparatus, Cap and Pin Type)"
- ANSI Std. C29.9, "Wet-Process Porcelain Insulators (Apparatus, Post Type)"
- ANSI Std. C29.10, "Wet-Process Porcelain Insulators (Indoor Apparatus Type)"
- ANSI Std. C37.32, "Standard for Switchgear—High-Voltage Air Switches, Bus Supports, and Switch Accessories—Schedules of Preferred Ratings, Manufacturing Specifications and Application Guide"
- ANSI/IEEE Std. C37.100, "IEEE Standard Definitions for Power Switchgear"
- IEEE Std. C37.34, "Test Code for High-Voltage Air Switches"
- IEEE Std. C37.35, "Guide for the Application, Installation, Operation and Maintenance of High-Voltage Air Disconnecting and Load-Interrupter Switches"
- NEMA Std. SG-6, "Power Switching Equipment"

5.7.2 Types of Air Switches

The main types of air switches are determined by and named according to their application. Standard definitions, according to ANSI/IEEE Std. C37.100, describe their general functions.

5.7.2.1 Disconnecting or Isolating Switch (Disconnector, Isolator): "A mechanical switching device used for changing the connections in a circuit, or for isolating a circuit or equipment from the source of power." This switch "is required to carry normal load current continuously and, also, abnormal or short-circuit currents for short intervals as specified. It is also required to open or close circuits either when negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the switch poles occurs."

5.7.2.1.1 Typical Applications:

a. Circuit breaker isolation
b. Power transformer isolation
c. Voltage transformer disconnecting
d. Equipment bypassing
e. Bus sectionalizing

NOTE: Where the current to be broken or made is not negligible, a horn-gap switch (see Section 5.7.2.3) should be used.

5.7.2.2 Grounding Switch: "A mechanical switching device by means of which a circuit or piece of apparatus may be electrically connected to ground." Grounding switches are often mounted on the jaw or hinge end of disconnecting or horn-gap switches. See Figure 5-22.

5.7.2.2.1 Typical Applications:

a. To ground buses or circuits (for safe maintenance) after they are first isolated
b. To intentionally ground a circuit (using an automatic high-speed device) in order to activate a remote protective relaying scheme

5.7.2.3 Horn-Gap Switch: "A switch provided with arcing horns." See Figure 5-23.

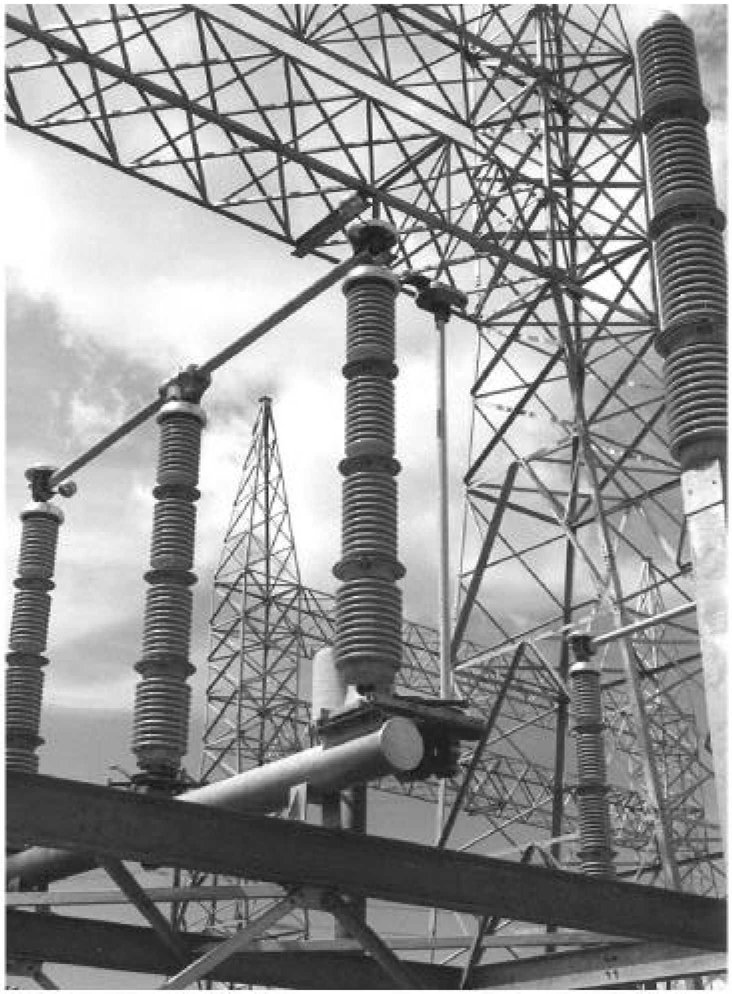


Figure 5-22: Horizontally Mounted Double Break Switch with Grounding Switch.
Courtesy of Tuley & Associates, Inc.

Figure 5-23: Horizontally Mounted Double-Break Switch. Note arcing horns and corona shields at blade contact points. Courtesy of Tuley & Associates, Inc.

5.7.2.3.1 Typical Application: To de-energize or energize a circuit that possesses some limited amount of magnetic or capacitive energy, such as transformer exciting current or line charging current. The arcing horns protect the main contacts during opening or closing and enhance the ability of the switch to perform its task.

NOTE: Where the amount of current to be broken or made is not clearly within the switch's capability, consult the manufacturer or use an interrupter switch (see Section 5.7.2.4).

5.7.2.4 Interrupter Switch: "An air switch, equipped with an interrupter, for making or breaking specified currents, or both." "The nature of the current made or broken, or both, may be indicated by suitable prefix, that is, load interrupter switch, fault interrupter switch, capacitor current interrupter switch, etc." Typical applications are indicated by the above-named prefixes. See Figure 5-24.

Figure 5-24: Horizontally Mounted Vertical-Break Interrupter Switch.
Courtesy of Tuley & Associates, Inc.

5.7.2.5 Selector Switch: "One arranged to permit connecting a conductor to any one of a number of other conductors." In substation applications, it is unlikely that more than two conductors would be subject to selection.

5.7.2.5.1 Typical Applications:

a. To connect a potential device to either of two buses
b. To perform a joint disconnecting and grounding function

5.7.3 Various Constructions of Outdoor Air Switches

Outdoor air switches are constructed in many different styles or construction classifications. Preferred standard ratings are listed in Tables 5-38, 5-39, and 5-40. A pictorial representation of each classification is shown at the bottom of Table 5-39. The various constructions are described below and include ANSI/IEEE Std. C37.100 definitions (in quotation marks) where appropriate.

Table 5-38: Preferred Voltage Ratings for Station Class Outdoor Air Switches. Ref. ANSI Std. C37.32-1996, Table 1. Reproduced with permission of the National Electrical Manufacturers Association.

Line Number	Rated Maximum Voltage kV rms	Rated Withstand Voltage: Lightning Impulse[1] kV peak	Rated Withstand Voltage: Power Frequency kV rms: Dry 1 Minute	Rated Withstand Voltage: Power Frequency kV rms: Wet 10 Seconds	Corona and Radio Influences Test Voltages: Test[2] Voltage kV rms	Corona and Radio Influences Test Voltages: Limit of RIV[3] mV @ 1 MHz
	(1)	(2)	(3)	(4)	(5)	(6)
1	8.25	95	35	30	—	—
2	15.5	110	50	45	—	—
3	25.8	150	70	60	—	—
4	38.0	200	95	80	—	—
5	48.3	250	120	100	—	—
6	72.5	250	120	100	—	—
7	72.5	**350**[4]	175	145	—	—
8	121	350	175	145	77	500
9	121	450	235	190	77	500
10	121	**550**[4]	280	230	77	500
11	145	350	175	145	92	500
12	145	450	235	190	92	500
13	145	550	280	230	92	500
14	145	**650**[4]	335	275	92	500
15	169	450	235	190	107	500
16	169	550	280	230	107	500
17	169	650	335	275	107	500
18	169	**750**[4]	385	315	107	500
19	242[5)]	550	280	230	154	500
20	242[5)]	650	335	275	154	500
21	242[5)]	750	385	315	154	500
22	242[5)]	**900**[4]	465	385	154	500
23	242[5)]	1050	545	455	154	500
24	362	1050	545	455	230	500
25	362	**1300**[4]	610	525	230	500
26	550	1550	710	620	349	500
27	550	**1800**[4]	810	710	349	500
28	800	2050	940	830	508	750

NOTES:
(1) For switches rated 362 kV and higher, see table 2 [Table 5-39] for values of rated switching impulse withstand voltages.
(2) 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%.
(3) If equipment of any given rated maximum voltage is used on a circuit of a higher voltage rating, the radio influence voltage limit and test voltage for the equipment shall be that corresponding to the rated maximum voltage of the circuit.
(4) Modern arrester technology enables use of lower lightning impulse rated equipment in some applications. The traditional values are shown in bold font.
(5) The switches listed in lines 19 through 28 are intended for application on systems effectively grounded as defined in ANSI/ IEEE Std. 142.

Table 5-39: Preferred Switching Impulse Withstand Voltage for Station Class Outdoor Air Switches. Ref. ANSI Std. C37.32-1996, Table 2.
Reproduced with permission of the National Electrical Manufacturers Association.

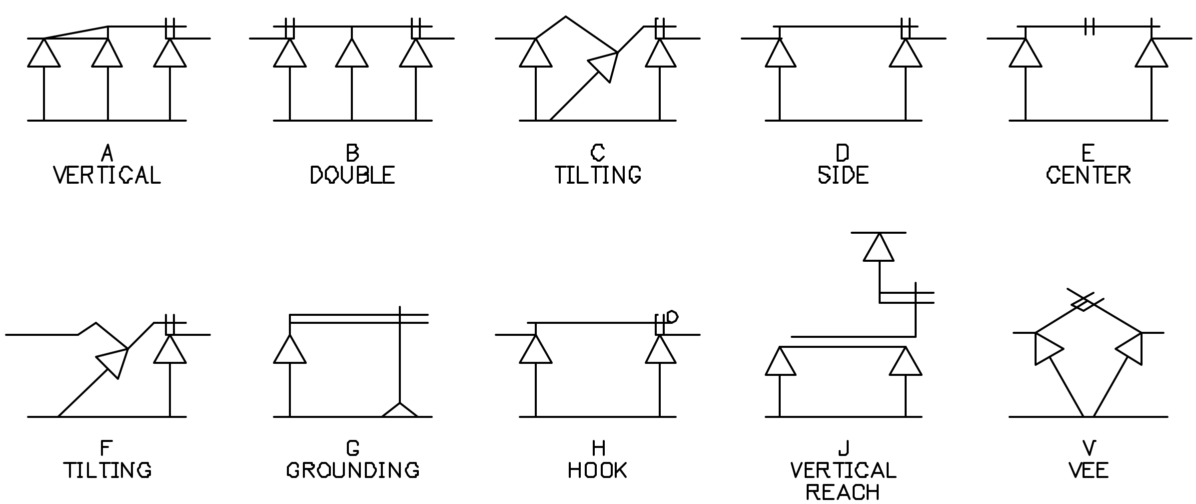
Line Number (from table 1 [Table 5-38])	Rated Maximum Voltage kV rms	Rated Lightning Impulse kV Peak	Switching Impulse Withstand Voltage kV Peak	
			To Ground[1]	Across Open Gap[2]
	(1)	(2)	(3)	(4)
24	362	1050	750	655 + (295)
25	362	1300	885	825 + (295)
26	550	1550	1050	880 + (450)
27	550	1800	1150	1000 + (450)
28	800	2050	1300	1000 + (650)

NOTES:
(1) Line-to-ground insulation strength is based upon 97.7 percent probability of withstand where the standard deviation is 6 percent. See ANSI Std. C37.34, 4.4.7.

(2) Values in parenthesis are 60 Hz bias voltages expressed in kV_p units (column 1 voltage * $\sqrt{2}/\sqrt{3}$).

The summation of this opposite polarity bias voltage and the associated open gap switching impulse voltage is equal to a 97.7 percent probability of line-to-ground flashover (CFO + 2). See C37.34, 4.4.8.

CONSTRUCTION CLASSIFICATIONS



Ref. ANSI Std. C37.32 – 1996, Annex B, Figure B–1. Reproduced with permission of the National Electrical Manufacturers Association.

Table 5-40: Preferred Continuous and Withstand Currents for Station Class Outdoor Air Switches. Ref. ANSI Std. C37.32-1996, Table 3.
Reproduced with permission of the National Electrical Manufacturers Association.

Line Number	Continuous Current Rating Amps (1)	Withstand Currents	
		Short-Time Withstand (Symmetrical) kA (2)	Peak Withstand kA (3)
1	600	25	65
2	1200	38	99
3	1600	44	114
4	2000	44	114
5	2000	63	164
6	3000	63	164
7	3000	75	195
8	4000	75	195

NOTES:
(1) The ratio of the peak withstand current to short-time (symmetrical) withstand current is 2.6.
(2) Rated duration of the short-time (symmetrical) withstand current is 3 seconds with allowable I^2t variations given in IEEE C37.34.
(3) Rated duration of the peak withstand current test is 167 milliseconds.
(4) Peak withstand current (kA) ≅ 1.625 times the rms asymmetrical momentary current (kA). Switches previously rated at 40, 61, 70, 100, and 120 kA rms asymmetrical momentary are closely equivalent to the above peak withstand current ratings and do not require retesting.

5.7.3.1 Vertical Break Switch (Construction Classification A): "One in which the travel of the blade is in a plane perpendicular to the plane of the mounting base. The blade in the closed position is parallel to the mounting base." The hinge end includes two insulators, one of which is caused to rotate by the operating mechanism and thereby open and close the blade. See Figure 5-25.

Figure 5.-25: Vertically Mounted Vertical-Break Switch. Courtesy of Tuley & Associates, Inc.

5.7.3.2 Double Break Switch (Construction Classification B): "One that opens a conductor of a circuit at two points." The center insulator stack rotates to accomplish the opening and closing operation. See Figure 5-23.

5.7.3.3 Tilting-Insulator Switch (Construction Classifications C & F): "One in which the opening and closing travel of the blade is accomplished by a tilting movement of one or more of the insulators supporting the conducting parts of the switch." This type of switch is seldom used today. However, this switch is still in service on many existing installations. It is included here since it will be necessary to modify or replace such switches on occasion. See Figure 5-26.

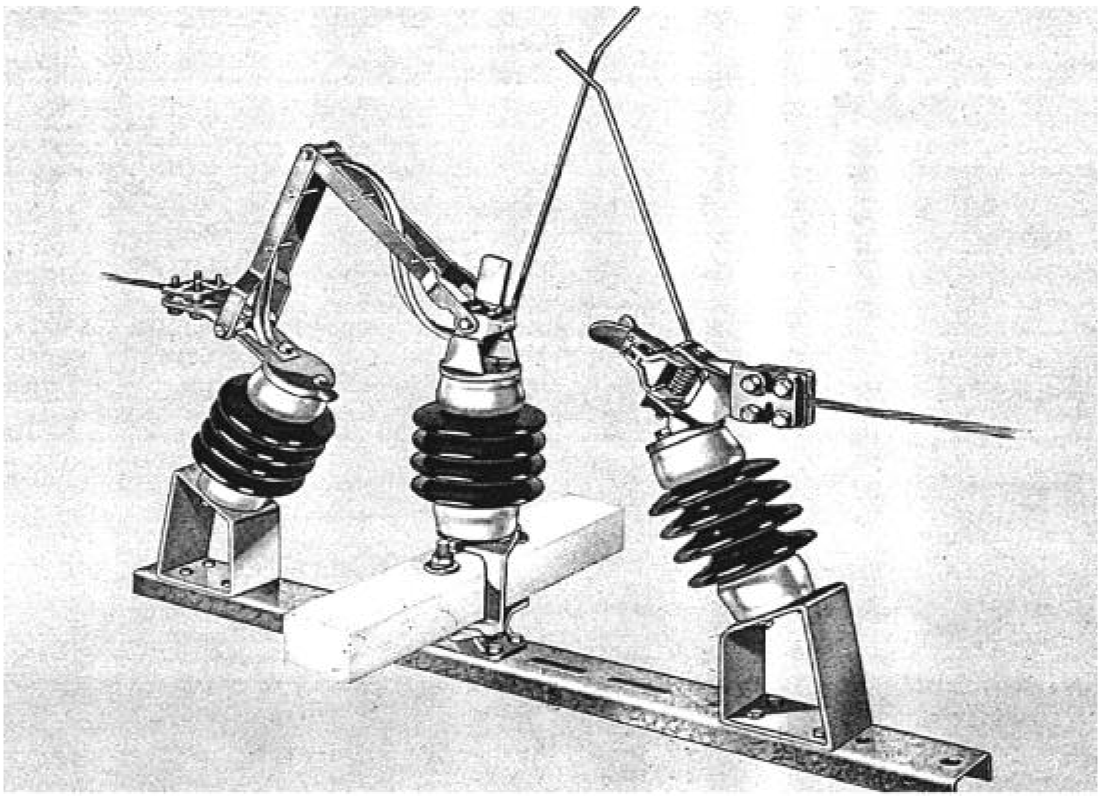


Figure 5-26: Tilting Insulator Switch. Courtesy of Kearney.

5.7.3.4 Side-Break Switch (Construction Classification D): "One in which the travel of the blade is in a plane parallel to the base of the switch." The hinge-end insulator rotates to accomplish the opening and closing operation. See Figure 5-27.

5.7.3.5 Center-Break Switch (Construction Classification E): One in which travel of the blade is in a plane parallel to the base of the switch and that opens in the center at only one point. Both insulators rotate to accomplish the opening and closing operation. See Figure 5-28.

5.7.3.6 Grounding Switch (Construction Classification G): As noted in Section 5.7.2.2, "a mechanical switching device by means of which a circuit or piece of apparatus may be electrically connected to ground." The pictorial representation in Table 5-39 shows a type where an insulated blade, connected to a bus or a piece of equipment, is made to contact ground. Some types use a normally grounded blade, which is made to contact the bus or equipment to be grounded. See Figure 5-22.

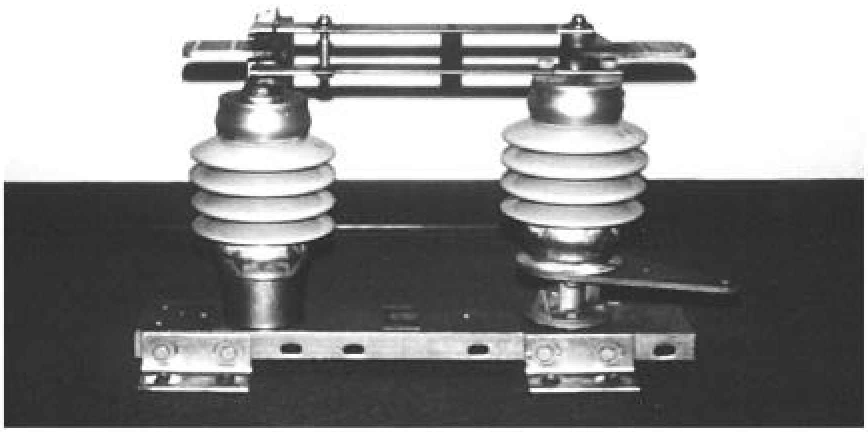


Figure 5-27: Single Side-Break Switch. Courtesy of Southern States, Inc.

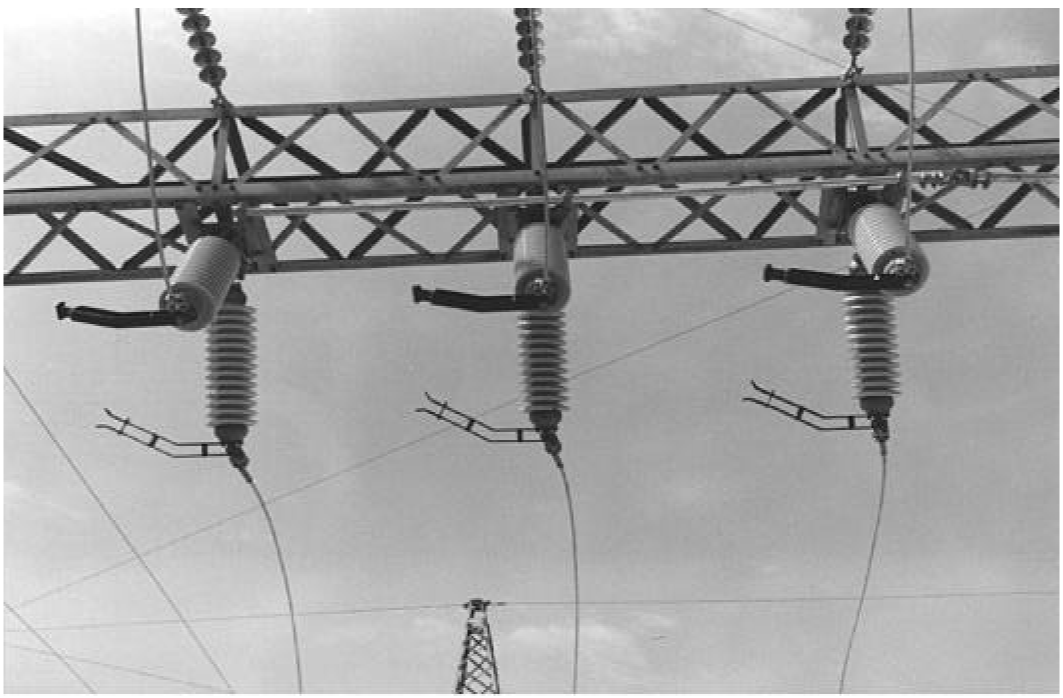


Figure 5-28: Underhung Center-Break V-Switch. Courtesy of Tuley & Associates, Inc.

5.7.3.7 Hook Stick Switch (Construction Classification H): One that is opened manually by means of a switch stick. Both insulators remain stationary when the blade, hinged at one end, is unlatched and opened or closed by the switch stick. These are single-pole (single-phase) switches. See Figure 5-29.

5.7.3.8 Vertical Reach Switch (Construction Classification J): "One in which the stationary contact is supported by a structure separate from the hinge mounting base. The blade in the closed position is perpendicular to the hinge mounting base." See Figure 5-30.

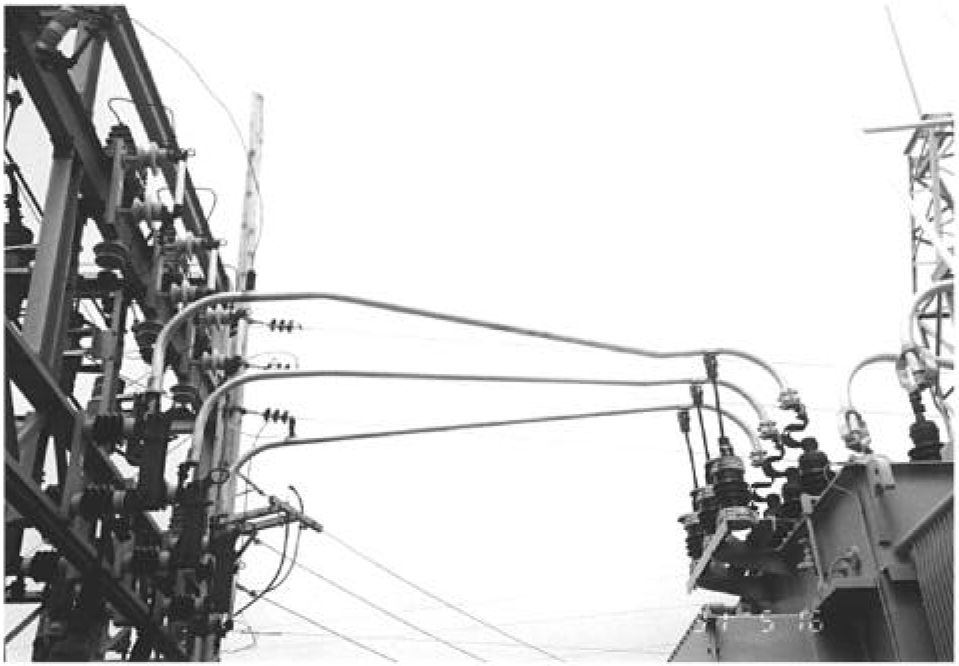


Figure 5-29: Hook Stick Switches on Structure at Termination of Bus from Transformer (Coffeyville, Kansas)

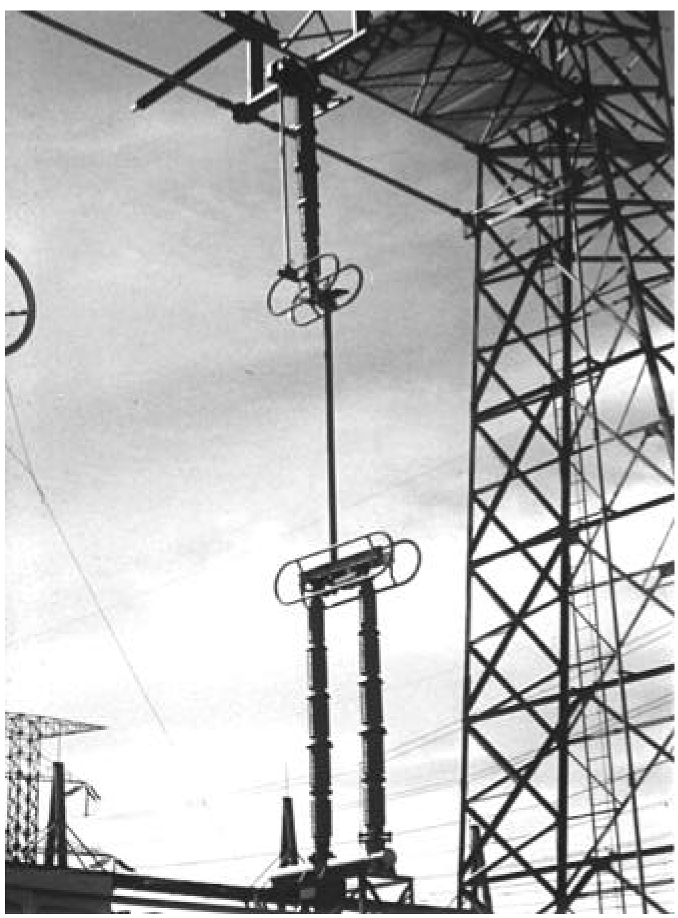


Figure 5-30: Vertical Reach Switch. Courtesy of Southern States, Inc.

5.7.4 Usual Service Conditions

The ratings of all high-voltage air switches covered by the standards are based on the following.

5.7.4.1 Temperature: Ambient temperature of cooling air over the switch is within the range of -30°C to +40°C for non-enclosed indoor or outdoor switches. Ambient temperature of cooling air over the switch does not exceed 55°C for enclosed indoor or outdoor switches. Maximum ambient temperature outside the enclosure does not exceed 40°C.

5.7.4.2 Altitude: Altitude does not exceed 1000 meters (3300 feet). Correction factors should be applied above 1000 meters as shown in Table 5-41.

Table 5-41: Altitude Correction Factors for High-Voltage Air Switches. Ref. ANSI/IEEE Std. C37.30–1992, Table 1. Copyright © 1992. IEEE. All rights reserved.

Altitude		Altitude Correction Factor To Be Applied to:	
		Rated Withstand Voltage	Current Rating*
Feet	Meters	Col.1	Col. 2
3300	1000	1.00	1.00
4000	1200	0.98	0.995
5000	1500	0.95	0.99
6000	1800	0.92	0.985
7000	2100	0.89	0.98
8000	2400	0.86	0.97
9000	2700	0.83	0.965
10000	3000	0.80	0.96
12000	3600	0.75	0.95
14000	4200	0.70	0.935
16000	4800	0.65	0.925
18000	5400	0.61	0.91
20000	6000	0.56	0.90

NOTE 1: This table is being reviewed. Check later revisions of standard for values.
* For maximum ambient of 40°C for non-enclosed switches and 40°C outside the enclosure for enclosed switches.

5.7.5 Ratings

5.7.5.1 General: The various ratings covered by the ANSI Standards for the several types of air break switches are indicated by an "X" in Table 5-42. All these ratings are defined in ANSI/IEEE Std. C37.100. However, the main rating definitions applicable to "disconnecting switches" will be repeated here for convenience since this is the most common air switch used in substations. For the most part, the ratings repeated here also apply to the other switch types.

Table 5-42: Switch Ratings and Required Tests. Ref. IEEE C37.30-1997, Table 1.
Copyright © 1997. IEEE. All rights reserved.

Switch Rating	Disconnecting Switch	Interrupter Switch	Fault-Initiating Switch	Grounding Switch
	Column 1	Column 2	Column 3	Column 4
Rated power frequency	X	X	X	X
Rated maximum voltage	X	X	X	X
Rated continuous current	X	X	—	—
Rated dielectric withstand voltages	X	X	X	X
Rated lightning-impulse withstand (BIL)	X	X	X	X
Rated switching-impulse withstand (for rated maximum voltage of 362 kV and above)	X	X	X	X
Rated power frequency dry withstand	X	X	X	X
Rated power frequency wet withstand (outdoor)	X	X	X	X
Rated dew power frequency withstand (indoor)	X	X	X	X
Rated peak-withstand current	X	X	O	X
Rated short-time (symmetrical) withstand current	X	X	O	X
Rated short-time (symmetrical) withstand current duration	X	X	O	X
Rated mechanical operations	X	X	—	X
Rated mechanical terminal load	X	X	X	X
Rated ice-break ability – manual (outdoor)	X	X	X	X
Rated ice-break ability – power: single attempt opening and closing (outdoor)	X	X	X	X
Rated ice-break ability – power: single attempt opening, multiple attempt closing (outdoor)	X	X	—	X
Rated load-making current	O	X	—	X
Rated fault-making current		—	X	O
Rated switching parameters [a]				
Rated capacitance-switching overvoltage ratio[a]	—	X[b]	—	—
Rated minimum differential-capacitance voltage[a]	—		—	—
Rated maximum differential-capacitance voltage[a]	—	X[b]	—	—
Rated load-interrupting current and expected switching endurance[a]	—	O[c]	—	—
Rated unload transformer interrupting current and expected switching endurance[a]	—	O[c]	—	—
Rated single-capacitance interrupting current and expected switching endurance[a]	—	O[c]	—	—
Rated parallel-connected capacitance-switching current and expected switching endurance[a]	—	O[c]	—	—

NOTES: ”X” indicates required rating; “O” indicates optional rating; “—” indicates not applicable.
[a] Relates to interrupter switches and will be superseded by IEEE PC37.39 when it is completed and approved.
[b] Required if the interrupter switch has capacitance-switching ratings.
[c] At least one current-interrupting rating is required for interrupter switches.

5.7.5.2 Disconnecting Switch Ratings

5.7.5.2.1 Rated Voltage: Rated voltage "is the highest nominal system voltage on which it is intended to be applied."

5.7.5.2.2 Rated Maximum Voltage: Rated maximum voltage "is the highest rms voltage at which the device is designed to operate."

5.7.5.2.3 Rated Continuous Current: Rated continuous current "is the maximum direct current, or rms current, in amperes at rated frequency which it will carry continuously without exceeding the limit of observable temperature rise."

NOTE: Allowable continuous current at a "specific ambient temperature is the maximum direct or alternating current in amperes, rms at rated frequency which it will carry without exceeding the allowable temperature for any of its parts as listed in Column 1" of Table 5-43.

The allowable continuous current may be determined using Equation 5-5:

Equation 5-5

$$I_A = I_R\left(\frac{\theta_{max} - \theta_A}{\theta_r}\right)^{\frac{1}{2}}$$

Where:

- θ_A = Ambient temperature (°C)
- I_A = Allowable continuous current at θ_A
- I_R = Rated continuous current
- θ_{max} = Allowable temperature of switch part from Table 5-43
- θ_r = Limit of observable temperature rise (°C) at rated current of switch part from Table 5-43

The values of θ_r in Table 5-43 have been selected (when the switch is tested in accordance with Section 6 of IEEE Std. C37.34) to maintain a loadability of 1.22 at 25°C (77°F) where:

> Loadability of a non-enclosed air switch is the ratio of allowable continuous current at 25°C (77°F) ambient temperature to rated current. The loadability of an enclosed air switch is the ratio of allowable continuous current at 40°C (104°F) inside ambient temperature to rated current.

Users in colder climates and those with maximum load currents, known to occur during ambients lower than 40°C (104°F), should carefully consider the possible cost benefits from taking advantage of allowable continuous currents when selecting the continuous current rating of any air break switch. In such applications, a lower continuous current rating may be sufficient, compared to a rating based strictly on the maximum direct, or rms alternating current, of the circuit in question.

Table 5-43: Temperature Limitations for Air Switches. IEEE Std. C37.30–1997, Table 2.
Copyright © 1997. IEEE. All rights reserved.

		Nonenclosed Indoor and Outdoor Switches		Enclosed Indoor and Outdoor Switches	
	Allowable Max Temperature, θ_{max} (°C)	Limit of Observable Temperature Rise and Rated Current (θ_r) (°C) (see Note 1)	Switch Part Class Designation	Limit of Observable Temperature Rise at Rated Current, θ_r (°C)	Switch Part Class Designation
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
(1) Contacts in air (see Note 2)					
(a) Copper or copper alloy	75	33	BO2	20	QO$_3$3
(b) Copper or copper alloy to silver or silver alloy, or equivalent	90	43	DO4	33	RO4
(c) Silver, silver alloy, or equivalent	105	53	FO6	43	TO6
(d) Other (see Note 3)	—	—	—	—	—
(2) Conducting mechanical joints					
(a) Copper or aluminum	90	43	DO4	33	RO4
(b) Silver, silver alloy, or equivalent	105	67	FO6	57	TO6
(c) Other (see Note 3)	—	—	—	—	—
(3) Switch terminals with bolted connections	90	43	DO4	33	RO4
(4) Welded or brazed joints or equivalent	105	53	FO6	43	TO6
(5) Other current-carrying parts					
(a) Copper or copper alloy castings	105	53	FO6	43	TO6
(b) Hard drawn copper parts (see Note 4)	80	37	CO3	25	PO$_2$2
(c) Heat treated aluminum alloy parts	105	53	FO6	43	TO6
(d) Woven wire flexible connectors	75	33	BO2	20	QO$_3$3
(e) Other materials (see Note 3)	—	—	—	—	—
(6) Insulator caps and pins and bushing caps	110	57	GO7	47	UO7
(7) Current-carrying parts in contact with insulation materials					
(a) Insulation Class 90°C	90	43	CO3	33	PO$_2$2
(b) Insulation Class 105°C	105	53	EO5	43	SO5
(c) Insulation Class 130°C	130	70	HO8	60	VO8
(d) Insulation Class 155°C	155	87	IO9	77	WO9
(e) Insulation Class 180°C	180	103	JO10	93	XO10
(f) Insulation Class 220°C	220	130	KO11	120	YO11
(g) Oil (see Note 5)	90	43	DO4	33	RO4
(h) SF_6	350	307	—	297	—
(8) Nonenergizable parts subjected to contact by personnel					
(a) Handled by operator (see Note 6)	50	10	—	10	—
(b) Accessible to operator (see Note 6)	70	30	—	30	—
(c) Not accessible to operator (see Note 7)	—	—	—	—	—
(9) Entire switch in accordance with IEEE C37.30-1992					
(a) Outdoor	70	30	AO1	—	—
(b) Indoor	85	—	—	30	NO1

NOTES to Table 2:

(1) The limit of observable temperature rise listed in this column is suitable for use in rating switches for application in enclosures of IEEE C37.20.2–1993 and IEEE C37.20.3-1987, 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 23°C.

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

(3) 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.

(4) 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.

(5) 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.

(6) It is assumed that any parts handled by or accessible to an operator will be in ambient air not to exceed 40°C.

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

5.7.5.2.4 Rated Short-Time Current (Momentary and Three Second)

5.7.5.2.4.1 Rated momentary current "is the rms total current which the switch shall be required to carry for at least one cycle. The current shall be the rms value, including the direct-current component, during the maximum cycle as determined from the envelope of the current wave, and the test period shall be at least ten cycles."

5.7.5.2.4.2 Rated three-second current is the rms total current, including any direct current component, that the switch shall be required to carry for three seconds.

5.7.5.2.5 Rated Withstand Voltage: Rated withstand voltage "shall be the voltage which the device has to withstand without flashover or other electric failure when voltage is applied under specified conditions." The standard low-frequency wet and dry and 1.2 x 50 microsecond impulse withstand voltages are listed in ANSI Std. C37.32.

5.7.5.2.6 Preferred Ratings: The preferred ratings of voltage, continuous current, short-time current ratings, dielectric withstand voltages, and radio influence test voltages of various constructions of outdoor air switches (at 60 Hz) shall be in accordance with Tables 5-38, 5-39, and 5-40.

5.7.6 Other Requirements

5.7.6.1 Insulators: Insulators used need to have sufficient strength to withstand the magnetic forces produced by the rated momentary current ratings specified in Table 5-40.

An approximation of the electromagnetic force exerted between two current-carrying conductors is given by Equation 5-6 (from ANSI Std. C37.32):

Equation 5-6

$$F = M\left(\frac{5.4 \times I^2}{S \times 10^7}\right)$$

Where:

F = Pounds per foot of conductor
M = Multiplying factor (determined from Table 5-44)
I = Short-circuit maximum peak current in amperes in accordance with Table 5-44
S = Spacing between centerlines of conductors in inches

The force calculated from the above operation will, in most cases, be conservative, tending to compensate for the neglect of resonant forces. It should, therefore, be reasonably accurate for the majority of practical situations.

Table 5-44: Multiplying Factor (M) for Calculation of Electromagnetic Forces.
Ref. ANSI Std. C37.32–1996, Annex A.3.2.
Reproduced with permission of the National Electrical Manufacturers Association.

Circuit	Amperes (I) Expressed as	Multiplying Factor (M)
dc	maximum peak	1.0
ac, 3-phase	maximum peak	0.866
ac, 3-phase	rms asymmetrical	$(0.866 \times 1.63^2) = 2.3$
ac, 3-phase	rms symmetrical	$(0.866 \times 2.82^2) = 6.9$
1 phase of 3-phase or 1-phase	maximum peak	1.0
1 phase of 3-phase or 1-phase	rms asymmetrical	$(1.63^2) = 2.66$
1 phase of 3-phase or 1-phase	rms symmetrical	$(2.82^2) = 8.0$

5.7.6.2 Terminal Loadings: Terminal pad loadings should be in accordance with Table 5-45.

The arrangement of bolt hole centerlines in terminal pads should be in accordance with Figure 5-31. Holes should accommodate bolts ½ inch (12.7 mm) in diameter.

1. Two or more interleaved 4-hole pad configurations can be used as shown in Figure 5-31(b) (of ANSI Std. C37.32-1996).

2. All dimensions are in inches and millimeters.

Table 5-45: Terminal Loadings for High-Voltage Switches. Ref. ANSI Std. C37.32-1996, Table 2. Reproduced with permission of the National Electrical Manufacturers Association.

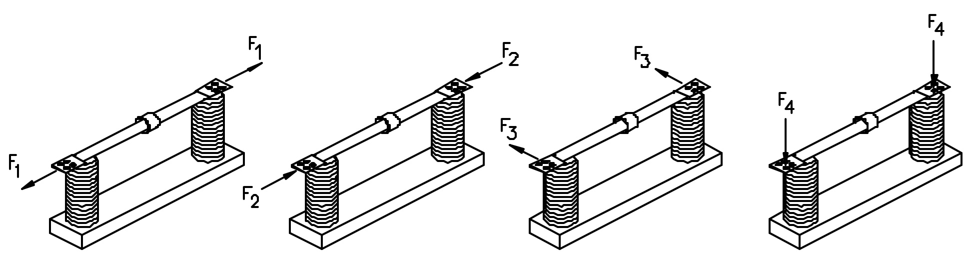
Line Number	Maximum voltage kV	Current rating amps	F_1 and F_2 lbs	(N)	F_3 lbs	(N)	F_4 lbs	(N)
	(1)	(2)	(3)		(4)		(5)	
1	4.8–72.5	200-1200	90	(400)	30	(130)	30	(130)
2		>2000	90	(400)	30	(130)	30	(130)
3	121–169	600–1600	120	(530)	40	(180)	110	(490)
4		>2000	120	(530)	40	(180)	250	(1110)
5	242–362	1200–1600	180	(800)	60	(270)	375	(1670)
6		>2000	230	(1020)	75	(330)	685	(3040)
7	≥500	All	450	(2000)	150	(670)	750	(3330)

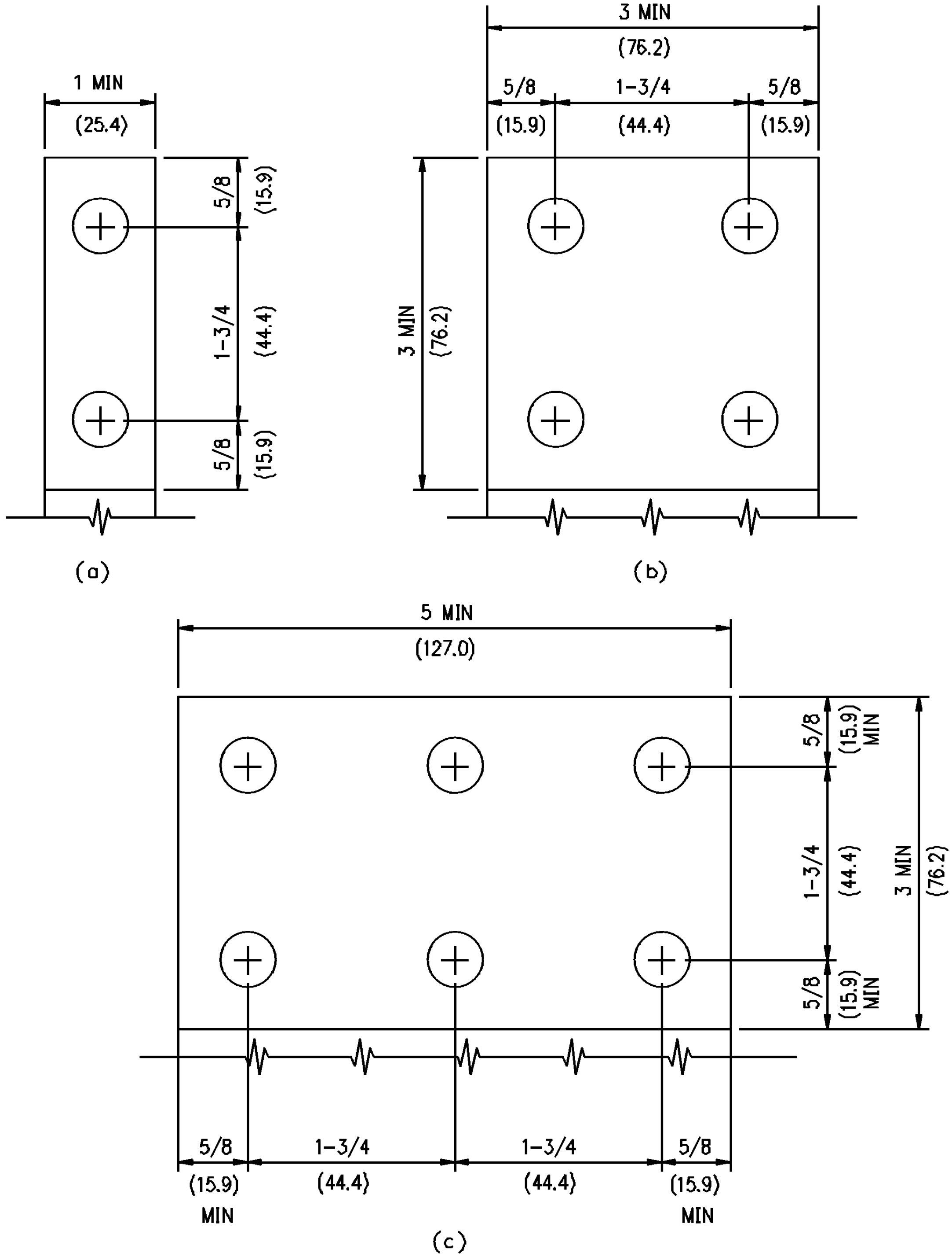
NOTES:

(1) Terminal pad loading F_1, F_2, F_3, and F_4 incorporate considerations for typical weights of connected bus conductors having ice and wind loads, expansion loads, and limited moment forces. It is recommended that the manufacturer be consulted on forces that exceed those given in the table. These higher forces may be due to long bus spans rigidly connected to switches, extra high short circuit current forces, bus spans other than aluminum tube conductors, and other forces not considered.

(2) These loadings were derived for the mechanical operations requirement of IEEE C37.34, Clause 11 and do not necessarily represent the mechanical loading limit on terminals. Consult the manufacturer when actual valves are needed.

(3) At 242 kV and above, F_4 forces may be reduced by 40% for switches with hinged or pivoting-type terminal pads.





1. TWO OR MORE INTERLEAVED 4-HOLE PAD CONFIGURATIONS CAN BE USED AS SHOWN IN FIGURE 1(b).
2. ALL DIMENSIONS ARE IN INCHES AND MILLIMETERS.

Figure 5-31: Arrangement of Bolt Hole Centerlines in Terminal Pads. Ref. ANSI Std. C37.32-1996, Figure 1. Reproduced with permission of the National Electrical Manufacturers Association.

5.7.6.3 Outdoor Air Switch Break Length: The length of break of outdoor air switches, when in the full open position, shall be such that the open gap or gaps will withstand a test voltage that is 10 percent in excess of the low-frequency impulse and dry withstand test voltages given in Table 5-38.

5.7.6.4 Break Distances and Spacing: The minimum metal-to-metal single-pole break distances and the single-pole centerline-to-centerline spacing of insulator columns needs to be as specified in Table 5-46 (see page 317 of this bulletin).

5.7.6.5 Base Mounting Holes: Base mounting holes for outdoor air switches shall be as specified in Table 5-47.

Table 5-47: Station-Class Outdoor Air Switches Preferred Mounting Hole Spacing for 600-, 1200-, and 1600-Ampere Switches. Ref. ANSI Std. C37.32-1996, Table 7. Reproduced with permission of the National Electrical Manufacturers Association.

Line No.	Rated Max. Voltage kV rms	Hook stick			Single side break			Vertical break		
		A In. (mm)	B In.	B (mm)	A In. (mm)	B Inches	B (mm)	A In. (mm)	B In.	B (mm)
	(1)	(2)	(3)		(4)	(5)		(6)	(7)	
1	8.25	18 (457)	2 or 7	(50.8 or 178)	24 (610)	3 or 7	(76.2 or 178)	36 (914)	3 or 7	(76.2 or 178)
2	15.5	21 (533)	2 or 7		24 (610)	3 or 7		36 (914)	3 or 7	
3	25.8	24 (610)	2 or 7		27 (686)	3 or 7		39 (991)	3 or 7	
4	38.0	30 (762)	2 or 7		33 (838)	3 or 8-1/4	(76.2 or 210)	48 (1220)	3 or 8-1/4	(76.2 or 210)
5	48.3	39 (991)	3 or 8-1/4	(76.2 or 210)	39 (991)	3 or 8-1/4		54 (1370)	3 or 8-1/4	
6	72.5	51 (1290)	3 or 8-1/4		51 (1290)	3 or 8-1/4		69 (1750)	3 or 8-1/4	
7	121	66 (1680)	3 or 8-1/4		72 (1830)	8-1/4	(210)	87 (2210)	8-1/4	(210)
8	145	78 (1980)	3 or 8-1/4		84 (2130)	8-1/4		99 (2510)	8-1/4	
9	169	90 (2290)	8-1/4	(210)	96 (2440)	8-1/4		111 (2820)	8-1/4	

NOTES:
(1) "A" is the dimension along the length of the base and "B" is the dimension along the width of the base in inches.
(2) Dimensions for switches above 169 kV have not yet been established.
(3) Millimeter values approximate 25.4 mm per inch.

5.7.6.6 Phase Spacing: Phase spacing (pole spacing), centerline-to-centerline, for outdoor air switches needs to be as specified in Table 5-48.

Table 5-46: Station-Class Outdoor Air Switch—Pole Unit Dimensions. Ref. ANSI Std. C37.32-1996, Table 6.
Reproduced with permission of the National Electrical Manufacturers Association.

Line Nos.	Rated Maximum Voltage kV rms	Rated Lightning Impulse Withstand Voltage kV Peak	Length of Break Minimum Metal-to-Metal[1]				Insulator Centerline-to-Centerline Phase Spacing Inches Minimum[1] (mm)							
			Single Break Distance		Double Break Distance		Single Break Insulator Strength				Double Break Insulator Strength			
			Inches	(mm)	Inches	(mm)	Standard		High		Standard		High	
	(1)	(2)	(3)		(4)		(5)		(6)		(7)		(8)	
1	8.3	95	7	(178)	--		12	(305)	15	(381)	--		--	
2	15.5	110	10	(254)	--		15	(381)	18	(457)	--		--	
3	25.8	150	12	(305)	--		18	(457)	21	(533)	--		--	
4	38.0	200	18	(457)	12	(305)	24	(610)	27	(686)	18	(457)	21	(533)
5	48.3	250	22	(559)	15	(381)	30	(762)	33	(838)	23	(585)	24	(610)
6	72.5	250	22	(559)	15	(381)	30	(762)	33	(838)	23	(585)	24	(616)
7	72.5	350	32	(813)	22	(559)	42	(1067)	45	(1140)	30	(762)	34	(864)
8	121	350	32	(813)	22	(559)	42	(1067)	45	(1140)	30	(762)	34	(864)
9	121	450	See Note 2		See Note 2		51	(1295)	54	(1370)	35	(889)	—	
10	121	550	50	(1270)	32	(813)	60	(1520)	—		42	(1067)	—	
11	145	350	32	(813)	22	(559)	42	(1067)	45	(1140)	30	(762)	34	(864)
12	145	450	See Note 2		See Note 2		51	(1295)	54	(1370)	35	(889)	—	
13	145	550	50	(1270)	32	(813)	60	(1520)	—		42	(1067)	—	
14	145	650	60	(1520)	38	(965)	72	(1830)	—		48	(1220)	—	
15	169	450	See Note 2		See Note 2		51	(1295)	54	(1370)	35	(889)	—	
16	169	550	50	(1270)	32	(813)	60	(1520)	—		42	(1067)	—	
17	169	650	60	(1520)	38	(965)	72	(1830)	—		48	(1220)	—	
18	169	750	68	(1730)	44	(1120)	84	(2130)	—		54	(1370)	—	
19	242	550	50	(1270)	32	(813)	60	(1520)	—		42	(1067)	—	
20	242	650	60	(1520)	38	(965)	72	(1830)	—		48	(1220)	—	
21	242	750	68	(1730)	44	(1120)	84	(2130)	—		54	(1370)	—	
22	242	900	84	(2130)	50	(1270)	96	(2440)	—		68	(1730)	—	
23	242	1050	104	(2640)	57	(1450)	116	(2950)	—		75	(1900)	—	
24	362	1050	104	(2640)	57	(1450)	116	(2950)	—		75	(1900)	—	
25	362	1300	120	(3050)	66	(1680)	132	(3350)	—		84	(2130)	—	
26	550	1550	See Note 2		—		See Note 2		—		—		—	
27	550	1800	See Note 2		—		See Note 2		—		—		—	
28	800	2050	—		—		—		—		—		—	

NOTES:

1. The design of some switches may be such that the minimum metal-to-metal distance and the centerline-to-centerline spacing conflict. Where this occurs, the minimum metal-to-metal distance should be used. Minimum metal-to-metal distances may be modified provided proof of performance is substantiated by dielectric tests.
2. Values have not yet been established.

Table 5-48: Phase Spacing and Ground Clearance for Station-Class Outdoor Air Switches and Bus Supports. Ref. ANSI Std. C37.32–1996, Table 5. Reproduced with permission of the National Electrical Manufacturers Association.

Line No.	Rated Max. Voltage	Rated Lightning Withstand Voltage[1]	Min. Metal-to-Metal Distance Disconnecting Switches, Bus Supports, and Rigid Conductors[2]		Ground Clearance[3]				Centerline-to-Centerline Phase Spacing[4]					
					Recommended		Minimum		Vertical Break Disconnecting Switches and Bus Supports		Side Break (Horizontal Break) Disconnecting Switches		All Horn Gap Switches (Vertical and Side Break)	
	kV rms	kV Peak	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm
	(1)	(2)	(3)		(4)		(5)		(6)		(7)		(8)	
1	8.25	95	7	178	7.5	191	6	152	18	457	30	762	36	914
2	15.5	110	12	305	10	254	7	178	24	610	30	762	36	914
3	25.8	150	15	381	12	305	10	254	30	762	36	914	48	1220
4	38.0	200	18	457	15	381	13	330	36	914	48	1220	60	1520
5	48.3	250	21	533	18	457	17	432	48	1220	60	1520	72	1830
6	72.5	250	21	533	18	457	17	432	48	1220	60	1520	72	1830
7	72.5	**350**	31	787	29	737	25	635	60	1520	72	1830	84	2130
8	121	350	31	787	29	737	25	635	60	1520	72	1830	84	2130
9	121	450	44	1118	39	991	34	846	72	1830	91	2310	103	2620
10	121	**550**	53	1350	47	1193	42	1067	84	2130	108	2740	120	3050
11	145	350	31	787	29	737	25	635	60	1520	72	1830	84	2130
12	145	450	44	1118	39	991	34	846	72	1830	91	2310	103	2620
13	145	550	53	1350	47	1193	42	1067	84	2130	108	2740	120	3050
14	145	**650**	63	1600	52.5	1333	50	1270	96	2440	132	3350	144	3660
15	169	450	44	1118	39	991	34	846	72	1830	91	2310	103	2620
16	169	550	53	1350	47	1193	42	1067	84	2130	108	2740	120	3050
17	169	650	63	1600	52.5	1333	50	1270	96	2440	132	3350	144	3660
18	169	**750**	72	1830	61.5	1562	58	1473	108	2740	156	3960	168	4270
19	242	550	53	1350	47	1193	42	1067	84	2130	108	2740	120	3050
20	242	650	63	1600	52.5	1333	50	1270	96	2440	132	3350	144	3660
21	242	750	72	1830	61.5	1562	58	1473	108	2740	156	3960	168	4270
22	242	**900**	89	2260	76	1930	71	1803	132	3350	192	4870	192	4870
23	242	1050	105	2670	90.5	2299	83	2108	156	3960	216	5500	216	5500
24	362	1050	105	2670	90.5	2299	84	2134	156	3960	216	5500	216	5500
25	362	**1300**	119	3020	106	2692	104	2642	174	4430	See Note 5		240	6100
26	550	1550	See Note 5		See Note 5		124	3150	See Note 5		See Note 5		300	7620
27	550	**1800**	See Note 5		See Note 5		144	3658	See Note 5		See Note 5		324	8230
28	800	2050	See Note 5		See Note 5		166	4216	See Note 5		See Note 5		600	15240

(1) Close lightning arrester coordination may allow lower lightning impulse values. Traditional values shown in bold font.
(2) Minimum metal-to-metal distance may be modified providing proof of performance is substantiated by dielectric test.
(3) Ground clearances for switches with voltages 362 kV and above are based on switching surge voltage levels. Refer to bibliography, Annex C [of ANSI Std. C37.32-1996].
(4) The phase spacings in columns 6, 7, and 8 are recommended values. Overall width of switch and bus support energized parts, angle of opening of side-break switches, etc., may allow a reduction in phase spacing dependent upon voltage concentration on sharp projections. Resultant metal-to-metal distances between phase energized parts should not be less than that shown in Column 3.
(5) Values not yet established.

5.7.6.7 Ratings and Requirements for Switches: Preferred ratings and other requirements for indoor air switches, grounding switches, fault initiating switches and load interrupter switches are listed in ANSI Std. C37.32, Sections 5 through 8, respectively. Tables 5-49 through 5-51 list ratings and requirements applicable to indoor air switches and grounding switches.

Table 5-49: Preferred Ratings for Indoor Air Switches. Ref. ANSI Std. C37.32-1996, Table 12. Reproduced with permission of the National Electrical Manufacturers Association.

Line No.	Rated Max. Voltage kV rms	Rated Withstand Voltage			Continuous Current Rating (Amperes, rms)								
		Impulse Lightning kV Peak	Power Frequency kV rms		200	400	600	1200	2000	3000	4000	5000	6000
			Dew 10 Sec.	Dry 1 Min.	Short-time (symmetrical) current ratings, thousands of amperes rms [1]								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	4.8	60	15	19	12.5	12.5	25	38	50	63	--	--	--
2	8.25	75	24	26	12.5	12.5	25	38	50	63	75	100	125
3	15.0	95	26	36	12.5	12.5	25	38	50	63	75	100	125
4	15.5	110	30	50	12.5	12.5	25	38	50	63	75	100	125
5	25.8	125	40	60	—	12.5	25	38	50	63	75	100	—
6	38.0	150	—	80	—	12.5	25	38	50	63	75	—	—

[1] Short-time current ratings include a momentary current rating and a 3-second current rating, based on the test conditions described in Section 5 of ANSI/ IEEE C37.34. Divide the momentary current rating by 1.6 to obtain the 3-second ratings.

NOTES:

(1) Withstand current ratings include a peak withstand current rating as well as a short-time (symmetrical) withstand current rating as shown.

(2) The ratio of the peak withstand current to short-time (symmetrical) withstand current is 2.6.

(3) Rated duration of the short-time (symmetrical) withstand current is three (3) seconds with allowable I^2t variations given in IEEE C37.34.

(4) Rated duration of the peak withstand current test is 167 milliseconds.

Table 5-50: Indoor Air Switches and Bus Supports—Phase Spacing and Length of Break.
Ref. ANSI Std. C37.32-1996, Table 13.
Reproduced with permission of the National Electrical Manufacturers Association.

Line No.	Rated Max. Voltage kV rms	Phase Spacing Minimum Metal-to-Metal Clearance Disconnecting Air Switches and Bus Supports Inches[1)]		Length of Break Minimum Metal-to-Metal Single-Break Distances Inches [(2)]	
	(1)	(2)		(3)	
		Inches	(mm)	Inches	(mm)
1	4.8	4- 1/2	(114)	4-1/2	(114)
2	8.25	6	(152)	6	(152)
3	15.0	7-1/2	(190)	7-1/2	(190)
4	15.5	9	(229)	9	(229)
5	25.8	13	(330)	13	(330)
6	38.0	18	(457)	18	(457)

NOTE – Millimeter values approximate 25.4 mm per inch.

(1) Barriers may be used to provide additional safety during operation by preventing accidental contact with live parts. The provision of adequate insulating barriers may allow a modification of these clearances. These minimum clearances may be modified provided proof of performance is substantiated by dielectric test (with due consideration to the effects of electromagnetic forces) in accordance with the values shown in columns 2 and 4 of table 12. When indoor switches are mounted in equipment covered by other standards, minimum clearances may be modified by such standards.

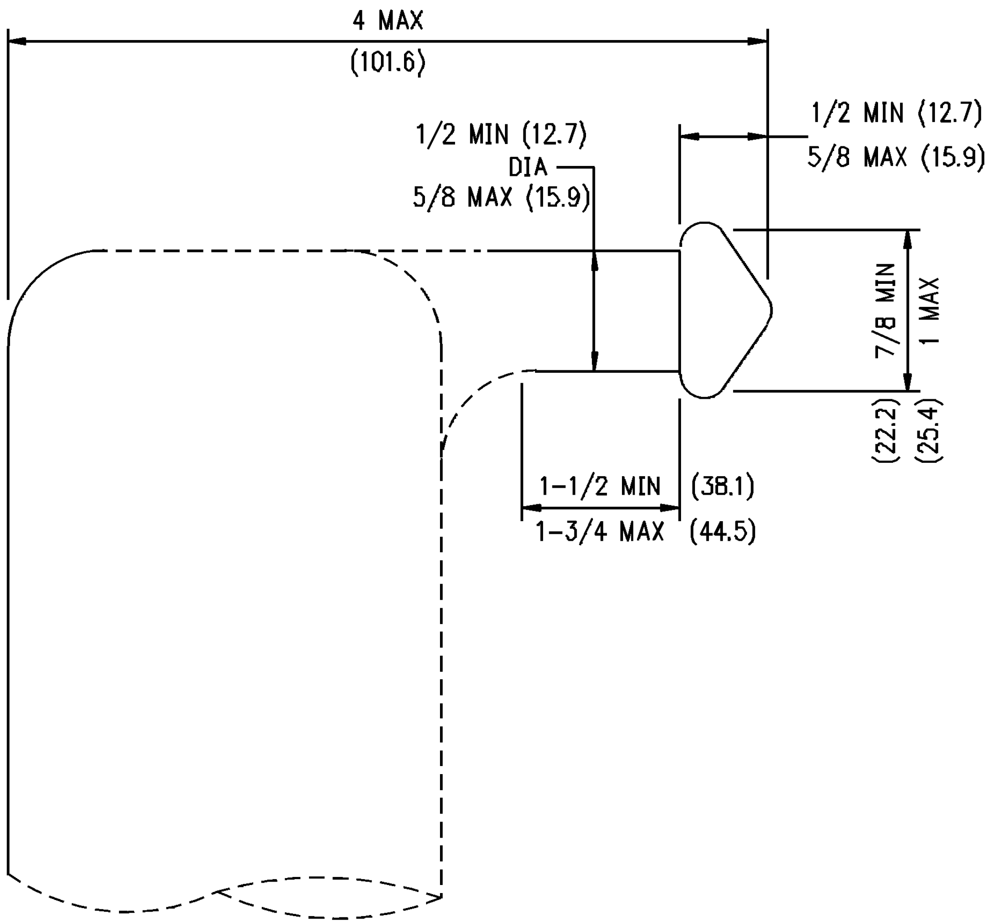
(2) Minimum metal-to-metal distances may be modified from the values listed above provided proof of performance is substantiated by the dielectric test in accordance with Clause 4 of IEEE C37.34.

Table 5-51: Grounding Switch Electrical Clearance.
Ref. ANSI Std. C37.32-1996, Table 14.
Reproduced with permission of the National Electrical Manufacturers Association.

Line No.	Rated Maximum Voltage kV rms	Rated Lightning Impulse Withstand Voltage kV Peak	Minimum Gap – Ground Switches to Live Parts	
			inches	mm
	(1)	(2)	(3)	
INDOOR				
1	4.8	60	2.0	50.8
2	8.25	75	2.0	50.8
3	15.0	95	2.0	50.8
4	15.5	110	2.0	50.8
5	25.8	125	3.0	76.2
6	38.0	150	4.0	102
DISTRIBUTION CLASS OUTDOOR				
7	8.25	75	2.0	50.8
8	15.0	95	2.0	50.8
9	27.0	125	3.0	76.2
10	38.0	150	4.0	102
STATION CLASS OUTDOOR				
11	8.25	95	2.0	50.8
12	15.5	110	2.0	50.8
13	25.8	150	4.0	102
14	38.0	200	6.0	152
15	48.3	250	9.5	241
16	72.5	250	9.5	241
17	72.5	350	14	367
18	121	350	14	367
19	121	450	18	457
20	121	550	22	559
21	145	350	14	367
22	145	450	18	457
23	145	550	22	559
24	145	650	27	686
25	169	450	18	457
26	169	550	22	559
27	169	650	27	686
28	169	750	31	787
29	242	550	22	559
30	242	650	27	686
31	242	750	31	787
32	242	900	38	965
33	242	1050	44	1118
34	362	1050	47	1194
35	362	1300	50	1270
36	550	1550	75	1905
37	550	1800	85	2159
38	800	2050	112	2845

NOTE – These gap distances are not a requirement for grounding blades that operate in a plane perpendicular to the main switch base.

5.7.6.8 Outdoor Air Switch Hook Dimensions: Outdoor air switch hook dimensions shall be in accordance with Figure 5-32.



NOTES:
1. All dimensions are in inches (millimeter values are approximate).
2. Dimensions that are not shown are optional.

Figure 5-32: Outdoor Air Switch Hook Dimensions. Ref. ANSI Std. C37.32-1996, Figure 2. Reproduced with permission of the National Electrical Manufacturers Association.

5.7.7 Mounting Considerations

5.7.7.1 Supports: Air switches should be mounted on supports strong enough to ensure that current carrying contacts mate properly when opened and closed, since considerable reaction forces are exerted on the supports during operation.

5.7.7.2 Orientation: Whenever possible, air switches should be oriented so that the blade is dead when the switch is open.

5.7.7.3 Mounting Arrangement: The intended mounting arrangement of air break switches should be made known to the manufacturer so that the insulators will be properly assembled.

5.7.8 References

ANSI Std. C29.1, “Test Methods for Electrical Power Insulators.”

ANSI Std. C29.8, “Wet-Process Porcelain Insulators (Apparatus, Cap and Pin Type).”

ANSI Std. C29.9, “Wet-Process Porcelain Insulators (Apparatus, Post Type).”

ANSI Std. 29.10, “Wet-Process Porcelain Insulators (Indoor Apparatus Type).”

ANSI Std. C37.32, “Standard for Switchgear—High-Voltage Air Switches, Bus Supports, and Switch Accessories-Schedules of Preferred Ratings, Manufacturing Specifications and Application Guide.”

ANSI Std. C37.33, “High-Voltage Air Switches—Rated Control Voltages and Their Ranges.”

ANSI/IEEE Std. C37.100, “Standard Definitions for Power Switchgear.”

ANSI/IEEE Std. 142, “IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book).”

IEEE Std. C37.30, “Standard Requirements for High-Voltage Air Switches.”

IEEE Std. C37.34, “Test Code for High-Voltage Air Switches.”

IEEE Std. C37.35, “Guide for the Application, Installation, and Operation and Maintenance of High-Voltage Air Disconnecting and Load-Interrupter Switches.”

NEMA Std. SG-6, “Power Switching Equipment.”

RUS IP 202-1, “List of Materials Acceptable for Use on Systems of RUS Electrification Borrowers.”