An American National Standard

IEEE Standard for Three-Phase, Manually Operated Subsurface Load Interrupting Switches for Alternating-Current Systems

Sponsor

Switchgear Committee
of the
IEEE Power Engineering Society

Secretariat

Institute of Electrical and Electronics Engineers
National Electrical Manufacturers Association

Approved June 23, 1983
Reaffirmed May 31, 1990
Reaffirmed December 13, 1994

IEEE Standards Board

Approved February 17, 1984
Reaffirmed October 8, 1990

American National Standards Institute

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

Use of an IEEE Standard is wholly voluntary. The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Futhermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least once every five years for revision or reaffirmation. When a document is more than five years old, and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of all concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason IEEE and the members of its technical committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

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

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

Foreword

(This Foreword is not a part of ANSI/IEEE C37.71-1984, IEEE Standard for Three-Phase, Manually Operated Subsurface Load-Interrupting Switches for Alternating-Current Systems.)

This standard is the culmination of over 12 years of effort. It has as its precursor the EEI guide for subsurface switches, which was published in 1972. The membership of the committee has changed many times over the period of time that this standard was written. Protocol dictates that only those persons who were members of the committee at the time of its approval have their names printed in the standard. However, many others have made valuable contributions, and the chairman appreciates the work and dedication of all those concerned.

The objective of this standard was to provide guidance in an area and at a time when the related products were in their early stages of development. With the passage of time, however, subsurface switches have reached their full function as a product. This standard will now serve as a benchmark to point the way to others who will have their opportunity to improve upon it.

This standard pertains to a type of apparatus that consists of a number of components. An objective at the time this standard was first proposed was that the dielectric ratings of the entire assembly be no less than the dielectric ratings of the switch portion of the unit. At the time of this writing, the dielectric ratings of the Separable Connector System are somewhat less than the stipulated dielectric ratings of the switch portion. It is the intent of the committee that if future developments produce Separable Connector Systems with enhanced ratings, then the dielectric ratings of the total switch assembly would be increased accordingly. It is not the function of standards to dictate product ratings; however, the committee recommends that appropriate groups consider the enhancement of the dielectric ratings of Separable Connector Systems.

The preparation of ANSI/IEEE C37.71-1984 was the cooperative work of the IEEE Joint Switchgear/Transmission and Distribution Committee Working Group for Pad-Mounted Switches and the ANSI C37 Working Group on Overhead, Pad-Mounted and Submersible Distribution Switches.

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

Organization Represented	*Name of Representative*
Association of American Railroads	
Association of Iron and Steel Engineers	J. M. Tillman
Electric Light and Power Group	D. O. Craghead R. L. Capra K. D. Hendrix R. L. Lindsey J. P. Markey (*Alt*) D. T. Weston
Institute of Electrical and Electronics Engineers	H. W. Mikulecky M. J. Beachy (*Alt*) G. Hanks C. A. Mathews (*Alt*) E. W. Schmunk C. A. Schwalbe G. W. Walsh C. E. Zanzie (*Alt*)
National Electrical Manufacturers Association	G. A. Wilson R. O. D. Whitt T. L. Fromm R. A. McMaster
Tennessee Valley Authorty	R. C. St. Clair
Testing Laboratory Group	L. Frier E. J. Huber R. W. Seelbach (*Alt*)
US Department of the Army Corps of Engineers	J. S. Robertson
US Department of the Interior, Bureau of Reclamation	R. H. Auerbach
US Department of the Navy, Naval Construction Batallion Center	R. L. Clark
Western Area Power Authority	G. D. Birney

At the time this standard was approved, the IEEE Joint Switchgear/Transmission and Distribution Committee Working Group for Pad-Mounted Switches had the following membership:

R. L. Capra *(Co-Chairman)*
C. A. Popeck *(Co-Chairman)*

J. J. Burke
L. V. Chabala
L. Clemons
G. W. Dolloff
R. L. Ensign
D. A. Granata
D. F. Hamilton
A. J. Kalvaitis (*Alt*)
D. G. Kumbera
P. C. Lyons
L. V. McCall
A. F. Parks
G. Perkins
J. C. W. Ransom
G. H. Taylor
F.D.Truban
C. L. Welter

The ANSI 37 Working Group on Overhead Pad-Mounted and Submersible Distribution Switches had the following membership:

C. A. Popeck, *Chair*

R. Ball	R. L. Gasnier	J. C. W. Ransom
P. Bergstrom	D. G. Kumbera	A. Salazar
J. J. Burke	K. E. Lloyd	J. H. Scott
R. L. Capra	M. Malia	G. W. Schneider
J. Cooper	R. W. Nelson	A. Tarkington
K. Elliott	A. F. Parks	F. Trayer
R. A. Few	G. O. Perkins	C. Welter
J. Fox	W. Perry	

At the time this standard was approved, the Reclosers and Sectionalizers Subcommittee of the IEEE Switchgear Committee had the following membership:

P. C. Lyons, *Chair*

M. J. Beachy	G. B. Fritz	J. C. W. Ransom
G. W. Dolloff	P. F. Johnson	D. R. Shapleigh
R. Donnelly	L. V. McCall	R. Singer
R. A. Few	A. F. Parks	B. F. Wirtz
G. Genest	C. A. Popeck	

The NEMA Technical Committee on Automatic Circuit Reclosers which prepared Tables 2 through 4 and approved this standard, had the following membership at the time of approval:

Robert A. Few, *Chair*

Dale H. Hagen	John G.Leach	Clarence L. Welter
David G. Kumbera	C. A. Popeck	D. F. Winter
	C. W. Ransom	

The C37 Subcommittee on Automatic Circuit Reclosers and Line Sectionalizers, which approved this standard, had the following membership at the time of approval:

B. H. Schultz, *Chair*

R. H. Arndt	R. A. Few	L. V. McCall
M. J. Beachy	P. F. Johnson	R. H. Miller
R. Bergstrom	D. G. Kumbera	R. W. Nelson
H. L. Caldwell	K. Lloyd	N. L. Paulson
R. L. Capra	P. C. Lyons	G. W. Schneider
G. W. Dolloff	J. P. Markey	B. F. Wirtz

When the IEEE Standards Board approved this standard on June 23, 1983, it had the following membership:

CLAUSE PAGE

CLAUSE PAGE

An American National Standard

IEEE Standard for Three-Phase, Manually Operated Subsurface Load Interrupting Switches for Alternating-Current Systems

1. Introduction

1.1 Scope

This standard applies to three-phase, group operated, 60 Hz, subsurface, load interrupting switches with maximum ratings of 600 A and 38 kV, and utilizing separable insulated connectors.

1.2 References

When the following standards referred to in this document are superseded by a revision, the latest revision shall apply.

[1] ANSI C37.85-1972 (R1978), American National Standard Safety Requirements for X-Radiation Limits for AC High-Voltage Power Vacuum Interrupters Used in Power Switchgear.[1]

[2] ANSI C57.12.26-1975, American National Standard Requirements for Pad-Mounted Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers for Use with Separable Insulated High-Voltage Connectors, High-Voltage; 24940 Grd Y/14,400 Volts and Below; 2500 kVa and Smaller.

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

[4] ANSI/IEEE Std 386-1977, Separable Insulated Connectors for Power Distribution Systems Above 600 V.

[5] ANSI/IEEE Std 454-1973 (R1979), Recommended Practice for the Detection and Measurement of Partial Discharges (Corona) During Dielectric Tests.

[6] ANSI/IEEE C37.09-1979, Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

[7] ANSI/IEEE C37.100-1981, IEEE Standard Definitions for Power Switchgear.

[1]ANSI Documents are available from the Sales Department, The American National Standards Institute, 1420 Broadway, New York, NY 10018.

2. Definitions

The definitions of terms contained in this standard, or in other standards referred to in this document, are not intended to embrace all the legitimate meanings of the terms. They are applicable only to the subject treated in this standard. For additional definitions see ANSI/IEEE C37.100-1981 [7].[2]

bus: (as used in this standard). A three-phase junction common to two or more ways.

subsurface switch: A submersible switching assembly suitable for application in a below-grade enclosure that does not allow space for personnel access.

surface operable: A term indicating that the switch and its accessories are operable from above grade.

way: A three-phase circuit entrance to a switching assembly.

switched way: A way connected to the bus through a three-pole, group operated switch.

tapped way: A way solidly connected to the bus.

NOTE — For clarification of definitions, see Fig 1.

3. Service Conditions

3.1 Unusual Service Conditions

Switches conforming to this standard shall be suitable for operation at their nameplate rating when:

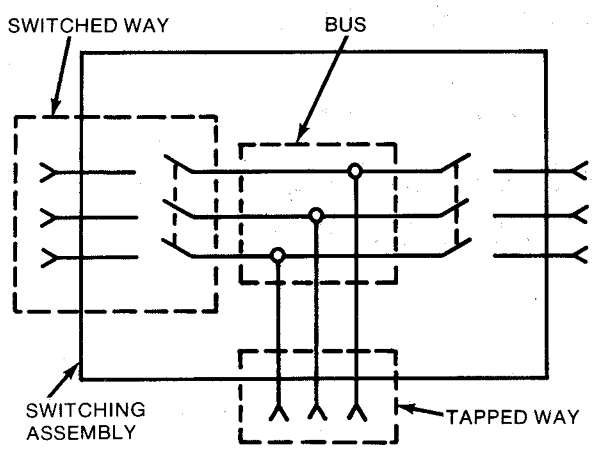


Figure 1— Example Using Definitions from Section 2. (3-Way Switching Assembly Shown)

1) The ambient air temperature within the below grade enclosure is not above 50°C or below –20°C.
2) The altitude does not exceed 3300 ft 1000 m).
3) The switch is installed in a below-grade enclosure subject to occasional flooding to a depth not exceeding 10 ft (3.03 m).

[2]The numbers in brackets correspond to those of the references in 1.2.

3.2 Unusual Service Conditions

3.2.1 Abnormal Ambient Temperatures

Switches may be applied at higher or lower ambient temperatures than specified, but performance may be affected. Special consideration shall be given to these applications.

3.2.2 Altitudes Above 3300 ft (1000 m)

Switches may be applied at altitudes higher than 3300 ft (1000 m). However, the basic impulse insulation level and rated maximum voltage of air insulated switches shall be multiplied individually by the correction factor shown in Table 1, column (3), to obtain values at which the application may be made.

In addition, the continuous current rating shall be multiplied by the correction factor shown in Table 1, column (4). However, switches designed for standard temperature rise may be used at normal current rating without exceeding total temperature limits, provided that the upper ambient temperature does not exceed the ambient allowed in 3.1 multiplied by the factor shown in Table 1, column (5). (Other ratings are not affected by altitude.)

3.2.3 Other Conditions That May Affect Design and Applications

Other existing unusual conditions should be brought to the manufacturer's attention. An unusual condition is considered to be any installation, application, or operation outside the requirements defined in this standard.

4. Ratings and Test Requirements

4.1 Rating Information

The ratings of subsurface switches shall include the following:

1) Rated frequency
2) Rated maximum voltage
3) Rated impulse withstand voltage
4) Rated continuous and load interrupting current
5) Rated momentary, making, and one second current
6) Rated cable charging interrupting current
7) Rated magnetizing interrupting current

Table 1— Altitude Correction

Altitude		Correction Factors to be Applied to		
Feet	Meters	Voltage Rating	Current Rating	Ambient Temperature
(Col 1)	(Col 2)	(Col 3)	(Col 4)	(Col 5)
3 300	1000	1.00	1.00	1.00
4 000	1200	0.98	0.99	0.99
5 000	1500	0.95	0.99	0.98
10 000	3000	0.80	0.96	0.92
16 000	4900	0.63	0.93	0.85

NOTE — Correction factors in Cols 4 and 5 shall not be applied simultaneously.

4.2 Voltage Ratings and Related Test Requirements

These ratings and requirements are detailed in Table 2.

4.3 Current Test Values

For detailed information, see Tables 3 and 4.

4.3.1 Conditions of Continuous Current Rating

(1) Switches are used under the usual service conditions defined in 3.1.

(2) Current ratings shall be based on the total temperature limits of the materials used for such parts. A temperature rise reference is given to permit testing at reduced ambient.

(3) Switches installed in non-ventilated, below-grade enclosures shall have their ratings based on a 40 °C ambient temperature outside the enclosure, with an ambient temperature rise of 10 °C inside the enclosure.

4.3.2 Limits of Observable Temperature Rise

At rated current, the observable hottest spot temperature rise of each of the various parts shall not exceed the following:

Contacts, Conducting Joints, Bushing Terminals, and Switch Insulation	Limit of Observable Hottest Spot Temperature Rise (°C)
Copper to Copper	20
Silver to silver or equivalent	
in air	55
in oil	40
Oil (2.5 cm) 1 inch below surface (top oil)	35
Class 90 °C Insulation	30
Class 105 °C Insulation	45
Class 130 °C Insulation	70
Class 155 °C Insulation	95
Class 180 °C Insulation	120
Class 220 °C Insulation	160

Table 2— Voltage Ratings and Related Test Requirements

Line No	Rated Maximum Voltage (kV)	Rated Withstand Impulse Voltage (kV)	Related Test Requirements: 60 Hz 1 Min Withstand			
			Design Test (kV, rms)	Production Test (kV, rms)	DC 15 Min Withstand (kV)	Minimum Partial Discharge (Corona) Extinction Voltage (kV, rms)
	(Col 1)	(Col 2)	(Col 3)	(Col 4)	(Col 5)	(Col 6)
1	15.5	95	35	34	53	11
2	27	125	60	40	78	19
3	38	150	70	50	103	26

NOTE — When performing field tests involving open contacts in a vacuum, the test should be performed in accordance with ANSI C37.85-1972 (R1978) [1].

Table 3— Continuous Load-Interrupting and Short-Time Current Test Values

Line No	Rated Maximum Voltage (kV)	Continuous Load- Interrupting Current (A)		Short-Time Current (A,* rms)					
				Class 1		Class 2		Class 3	
		Main Switch	Tap Switch	Sym	Asym	Sym	Asym	Sym	Asym
	(Col 1)	(Col 2)	(Col 3)	(Col 4)	(Col 5)	(Col 6)	(Col 7)	(Col 8)	(Col 9)
1	15.5	600	600	12 000	19 200	25 000	40 000	38 125	61 000
2	15.5	600	200	12 000	19 200	Not Applicable		Not Applicable	
3	15.5	200	200	10 000	16 000	Not Applicable		Not Applicable	
4	27	600	600	12 000	19 200	25 000	40 000	36 125	61 000
5	27	600	200	12 000	19 200	Not Applicable		Not Applicable	
6	27	200	200	10 000	16 000	Not Applicable		Not Applicable	
7	38	600	600	10 000	16 000	20 000	32 000	38 125	61 000
8	38	600	200	10 000	16 000	Not Applicable		Not Applicable	

*Short-time current ratings may be limited by the capabilities of bushings, connectors, or cables used on production switches. Design tests performed to substantiate the short-time values in Table 3 shall be made on switches with bushings, connectors, and cables of adequate capability.

Table 4— Cable Charging Interrupting and Magnetizing Interrupting Current Ratings

Line No	Rated Maximum Voltage (kV)	Continuous and Load Interrupting Current (A, rms)	Cable Charging Interrupting Current (A, rms)	Magnetizing Interrupting Current (A, rms)
	(Col 1)	(Col 2)	(Col 3)	(Col 4)
1	15.5	600	10	21
2	15.5	200	10	7
3	27	600	25	21
4	27	200	25	7
5	38	600	40	21
6	38	200	40	7

4.3.2.1 Notes on Observable Temperature Rise Limits

(1) When carrying rated continuous current, the steady state total temperature of the bushing terminals shall not exceed 75 °C for 200 A terminals and 90 °C for 600 A terminals.

(2) Contacts in other than oil or air may be operated at other temperatures, providing it can be shown by experience or tests that accelerated deterioration will not occur.

(3) For the purpose of establishing temperature limits, insulating materials shall be classified as follows:

a) *Class 90 Insulation*: Materials or combinations of materials such as cotton, silk, and paper without impregnation. Other materials or combinations of materials maybe included in this class if, by experience or accepted tests, they can be shown to be capable of operation at 90 °C.
b) *Class 105 Insulation*: Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid such as oil. Other materials or combinations of materials may be included in this class if, by experience or accepted tests, they can be shown to be capable of operation at 105 °C.
c) *Class 130 Insulation*: Materials or combinations of materials such as mica, glass fiber, asbestos, etc, with suitable bonding substances. Other materials or combinations of materials (not necessarily inorganic) may be included in this class if, by experience or accepted tests, they can be shown to be capable of operation at 130 °C.
d) *Class 155 Insulation*: Materials or combinations of materials such as mica, glass fiber, asbestos, etc, with suitable bonding substances. Other materials or combinations of materials (not necessarily inorganic) may be included in this class if, by experience or accepted tests, they can be shown to be capable of operation at 155 °C.
e) *Class 180 Insulation*: Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc, with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if, by experience or accepted tests, they can be shown to be capable of operation at 180 °C.
f) *Class 220 Insulation*: Materials or combinations of materials that by experience or accepted tests can be shown to be capable of operation at 220 °C.
g) *Over Class 220 Insulation*: Insulation that consists entirely of mica, porcelain, glass, quartz, and similar inorganic materials. Other materials or combinations of materials may be included in this class if, by experience or accepted tests, they can be shown to be capable of operation at temperatures over 220 °C.

4.3.2.2 Notes on Insulation

(1) Insulation is considered to be "impregnated" when a suitable substance provides a bond between components of the structure and also a degree of filling or surface-coverage sufficient to give adequate performance under the extremes of temperature, surface contamination (moisture, dirt, etc), and mechanical stress expected in service. The impregnant must not flow or deteriorate enough at operating temperature to seriously affect performance in service.

(2) The electrical and mechanical properties of the insulation must not be impaired by the prolonged application of the limiting insulation temperature permitted for the insulation class. The word "impaired" is here used in the sense of causing any change that could disqualify the insulating material from continuously performing its intended function, whether it is creepage spacing, mechanical support, or dielectric barrier action.

(3) In the preceding definitions, the words *accepted tests* are intended to refer to recognized test procedures established for thermal evaluation of materials by themselves or in simple combinations. Experience or test data, used in classifying insulating materials, are distinct from the experience or test data derived for the use of materials in complete insulation systems. The thermal endurance of complete systems may be determined by test procedures specified by the responsible technical committees. A material that is classified as suitable for a given temperature in the proceeding maybe found suitable for a different temperature, either higher or lower, by an insulation system test

procedure. For example, it has been found that some materials suitable for operation at one temperature in air may be suitable for a higher temperature when used in a system operated in an inert gas atmosphere.

(4) It is important to recognize that other characteristics, in addition to thermal endurance, such as mechanical strength and moisture resistance, are required in varying degrees in different applications for the successful use of insulating materials.

5. Design Tests

Design tests, sometimes called type tests, are those tests performed by the manufacturer to determine the adequacy of the design of a particular type, style, or model of equipment, or its component parts for meeting its assigned ratings, and for operating satisfactorily under normal service conditions or under special conditions, if specified, and may be used to demonstrate compliance with applicable standards of the industry.

Design tests are performed on representative apparatus or prototypes to verify the validity of design analysis and calculation methods, and to substantiate the ratings assigned to all other apparatus of basically the same design. These tests are not intended to be performed on every design or to be used as part of normal production. The applicable portion of these design tests may also be used to evaluate modifications of a previous design to assure that performance has not been adversely affected. Test data from previous similar designs may be used for current designs, where appropriate. Once made, tests need not be repeated unless the design is changed so as to modify performance.

5.1 General

5.1.1 Condition of Switch to Be Tested

The switch shall be new and in good condition.

5.1.2 Mounting of Specimen

The switch shall be mounted in the usual service position for which it is designed.

5.1.3 Frequency

The frequency of the supply voltage shall be 60 Hz +0 –20%.

5.1.4 Single-Phase Testing

Where single-phase testing is permitted (5.2.1 and 5.2.2) all such tests shall be performed on the same pole, with the other poles grounded.

5.1.5 Test Sequence

The following design tests are to be performed on the same switched way and in the sequence listed. However, the individual interrupting tests under (1) may be performed in any sequence, depending upon test facilities, but prior to the Momentary Current Test (2).

Maintenance shall not be performed on the switch during this sequence of tests. The insulating medium shall not be replaced, filtered, or reconditioned prior to the completion of test (4).

(1) Interrupting Current Tests	(5.2)
(a) Load Switching Tests	(5.2.1)
(b) Magnetizing Current Tests	(5.2.2)
(c) Cable Charging Current Tests	(5.2.3)
(2) Momentary Current Test	(5.3.1)
(3) Making Current Test	(5.3.2)
(4) 60 Hz Withstand Tests refer to Table 2, column (4)	(5.4.5)
(5) Thermal Runaway Test	(5.5.5)
(6) Mechanical Operation Test	(5.6)

5.1.6 Other Tests

The following design tests shall also be made, not necessarily on the same switch and in any sequence:

(1) 60 Hz Withstand Test, refer to Table 2, column (3)	(5.4.5)
(2) Impulse Withstand Tests	(5.4.4)
(3) Continuous Current Test	(5.5)
(4) Partial Discharge Level Test (Corona)	(5.7)
(5) DC Withstand Test	(5.8)
(6) One Second Current Test	(5.3.3)
(7) Pressure Tests	(5.9)

5.2 Interrupting Current Tests

The purpose of these tests is to verify that the switch is capable of closing and interrupting currents within its ratings.

5.2.1 Load Switching Tests

The switch shall be capable of switching all load currents, up to and including the rated continuous currents shown in Table 3, columns (2) and (3).

The switch shall be tested at currents in accordance with the following table:

Table 5— Load Switching

No of Operations		Test Current (Percentage of Rated Continuous Current)
Closing	Opening	
20	20	Not less than 100
30	30	40–60
10	10	5–20

Closing and opening operations shall be randomly timed. The tests shall be made at the rated maximum voltage of the switch on a three-phase circuit at 80% lagging power factor or less, using one of the circuits shown in Fig 2.

Where test facility circuit loading capability is limited, the tests at 5–20% and 40–60% current on a three-phase switch may be performed single-phase at 87% of the rated maximum voltage; however, the tests at not less than 100% current shall be made with circuit conditions specified in the preceding paragraph.

When single-phase tests are run at 5–20% and 40–60% current, the test sequence shall be run on each phase of the switch.

5.2.2 Magnetizing Current Tests

The switch shall be capable of closing and interrupting magnetizing current. The test circuit shall be as shown in Fig 3, and shall provide the steady-state current values shown in Table 4, column (4), (±20%). The test may be conducted single phase at 87% of rated maximum voltage.

The switch shall close and interrupt the specified current during a minimum of 10 randomly timed operations (30 randomly timed operations if tests are single phase, 10 operations on each pole). Sufficient time shall be allowed after closing to permit transients to subside.

Current measurement shall be made after transients have subsided, using an rms responding meter.

5.2.3 Cable Charging Current Tests

The switch shall be capable of closing and interrupting the rated cable charging current shown in Table 4, column (3). The test circuit shall be as shown in Fig 4. The neutral of the source and the neutral of the wye-connected capacitor bank are to be grounded.

The switch shall close and interrupt not less than the specified steady-state cable charging current during a minimum of 20 randomly timed operations. The maximum transient overvoltage produced during these tests shall not exceed 2.5 times the peak line-to-ground voltage.

5.3 Short-Time Current Tests

The purpose of these tests is to verify that the switch is capable of withstanding momentary, making, and one second currents (Table 3) to which the equipment may be exposed in partially overhead and underground circuits.

5.3.1 Momentary Current Test

5.3.1.1 Test Conditions

The switch shall have been previously subjected to the Interrupting Tests (5.2), and an additional 50 mechanical de-energized, close-open operations. Conductors used in this test shall be connected at right angles to the switch bushing.

Momentary current tests may be made at any voltage (above 50 V) up to rated voltage of the switch. Three-phase switches shall be tested on a three-phase circuit (see Fig 5).

5.3.1.2 Test Procedure

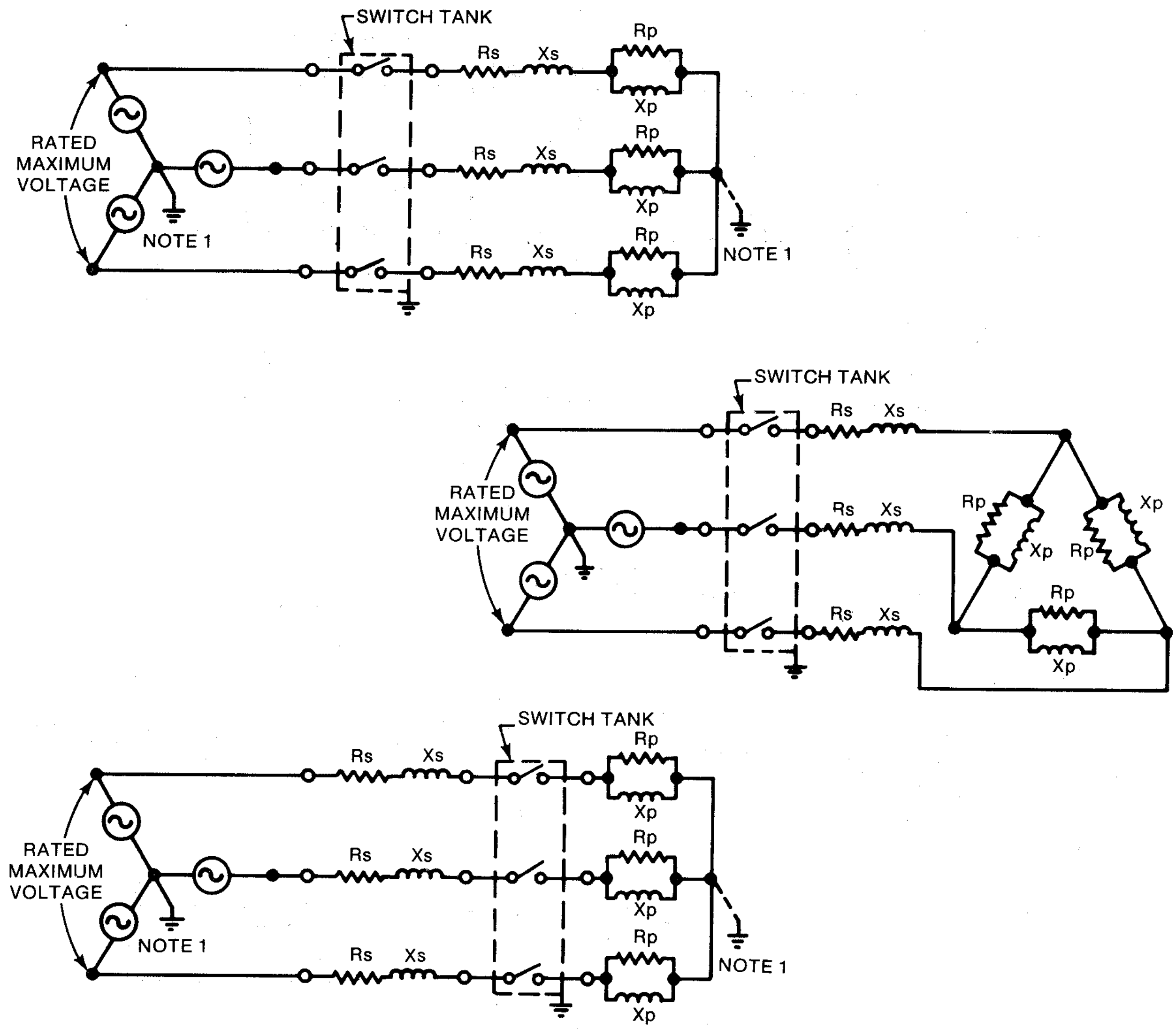
The switch shall withstand three sets of momentary tests. Each set shall include a sequence of three momentary surges with 10 seconds, ±1 second, between each of the three surges, to simulate typical reclosing operations. The duration of each surge shall not be less than 10 cycles.

The rms value of the first major current loop of the current wave of one phase of the first momentary surge of each set, shall be not less than the asymmetrical short-time current value in Table 3. The magnitude shall be measured in accordance with Section 7. of ANSI/IEEE C37.09-1979 [6].

5.3.2 Making Current Test

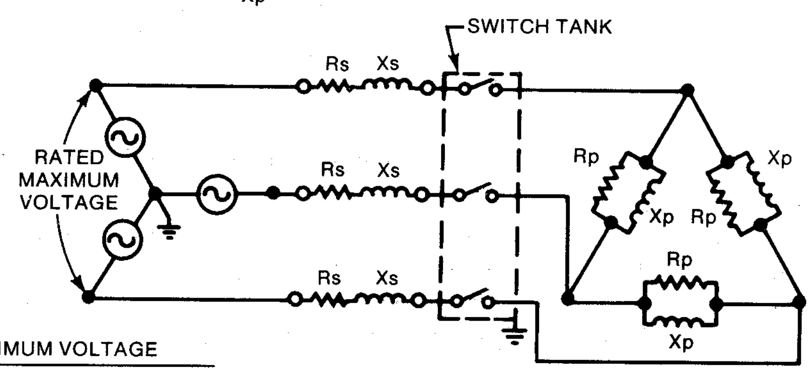
5.3.2.1 Test Conditions

The Making Current Test shall be conducted following the Momentary Current Test (5.3.1). Conductors used in this test shall be solidly connected at right angles to the switch bushing.



NOTE 1: EITHER THE NEUTRAL OF THE LOAD *OR* THE SOURCE MAY BE GROUNDED BUT *NOT* BOTH.

NOTE 2: ONCE CALCULATED FOR A SPECIFIC TEST SERIES, Z_s REMAINS THE SAME FOR THE REDUCED CURRENT INTERRUPTING TESTS.



$$Z_s = 10\% \text{ TO } 20\% \text{ OF } \frac{\text{RATED MAXIMUM VOLTAGE}}{\sqrt{3} \times \text{RATED SWITCHING CURRENT}}$$

$$\frac{X_s}{R_s} = 5 \text{ TO } 7$$

POWER FACTOR = 80% OR LESS LAGGING

Figure 2— Load Switching Test Circuits

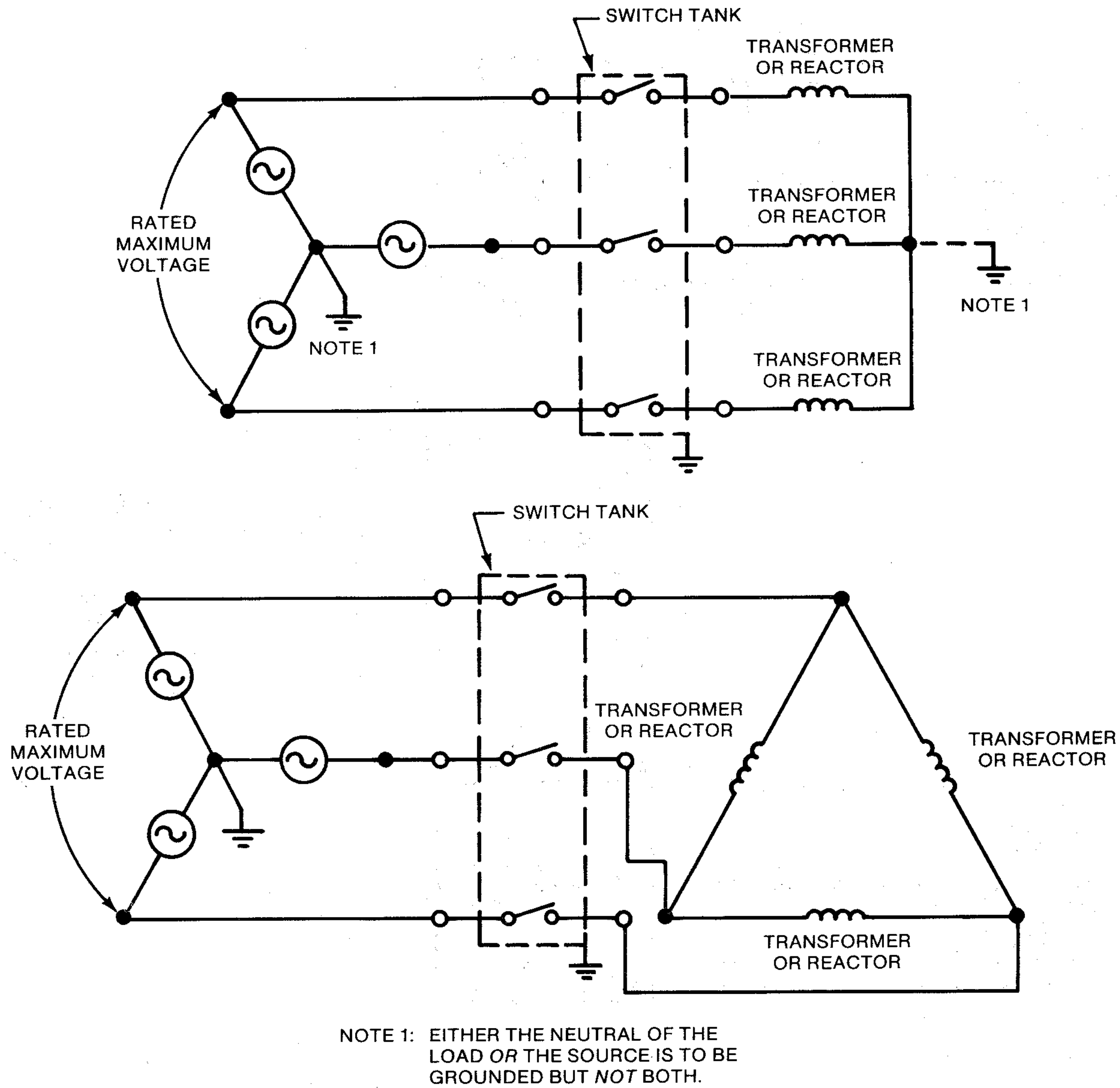


Figure 3— Magnetizing Current Test Circuits

This test shall be made at rated maximum voltage of the switch. Three-phase switches shall be tested on a three-phase circuit (see Fig 5).

5.3.2.2 Test Procedure

The test shall consist of three closing operations at the symmetrical short-time current value listed in Table 3. At least one of the closing operations shall have the rms value of the first major current loop equal to the asymmetrical value specified.

The magnitude shall be measured in accordance with ANSI/IEEE C37.09-1979 [6]. The minimum duration of current for each operation shall be 10 cycles. Sufficient time may be allowed between operations for the contacts to cool.

5.3.3 One Second Current Test

5.3.3.1 Test Conditions

The switch should not have been previously subjected to any interrupting tests. Bushings may be changed for this test to accommodate conductors of sufficient thermal capacity. This test may be made at any voltage up to rated voltage of the switch.

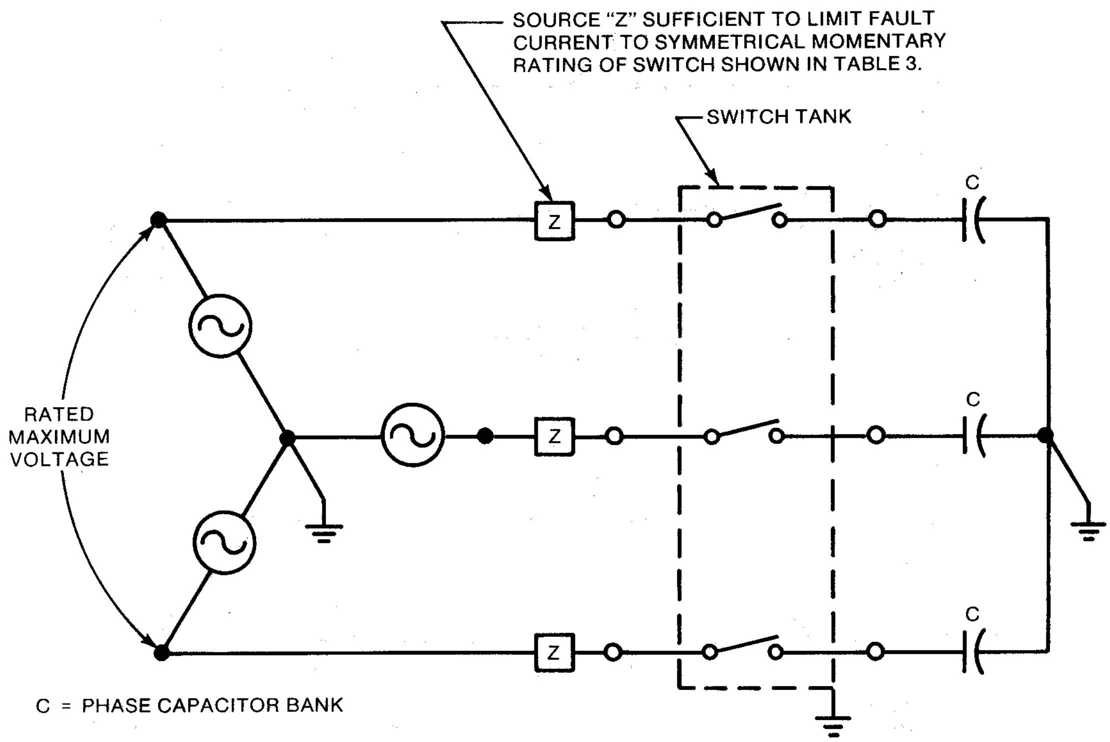


Figure 4— Cable Charging Current Test Circuit

Three-phase switches may be tested on a three-phase circuit (see Fig 5), or may be tested single phase by tying two adjacent phases together in series.

5.3.3.2 Test Procedure

The switch shall be subjected to a single current carrying test of 1 s minimum duration at the symmetrical short-time current value shown in Table 3. For practical purposes, this current shall be taken as the integrated heating equivalent of the 1 s rating; the maximum application period shall not exceed 2 s.

5.3.3.3 Condition of Switch After Test

There shall be no visible damage to the device after the tests have been completed. However, the tests may result in some visual evidence of the device having passed current, such as slight contact markings.

When slight contact marking occurs, *or when visual inspection is not feasible,* rating shall be considered met when the device will withstand repeated mechanical operations without cumulative damage, and is capable of carrying its rated continuous current without exceeding the temperature limits specified for the device being tested.

5.4 Insulation (Dielectric) Tests

Dielectric tests are made to determine the ability of the insulating materials and spacing to withstand specified overvoltages for a specified time without flashover or puncture.

5.4.1 Points of Application of Test Voltage

The test voltage shall be applied:

1) Across open contacts
2) From terminals to ground(switch [es] open and closed)
3) Between phases (switch[es] open and closed)

During the tests, the tank case and all unenergized terminals shall be grounded.

5.4.2 Temperature

Dielectric tests shall be made at the temperature prevailing in the test area.

5.4.3 Dielectric Test Procedures and Voltage Measurements

The dielectric test procedures and the methods of voltage measurements shall be in accordance with ANSI/IEEE Std 4-1978 [3].

If terminations (see 8.8) capable of meeting the specified dielectric test voltages are not available, other terminations (bushings and connectors or both) may be substituted for the purpose of performing this test.

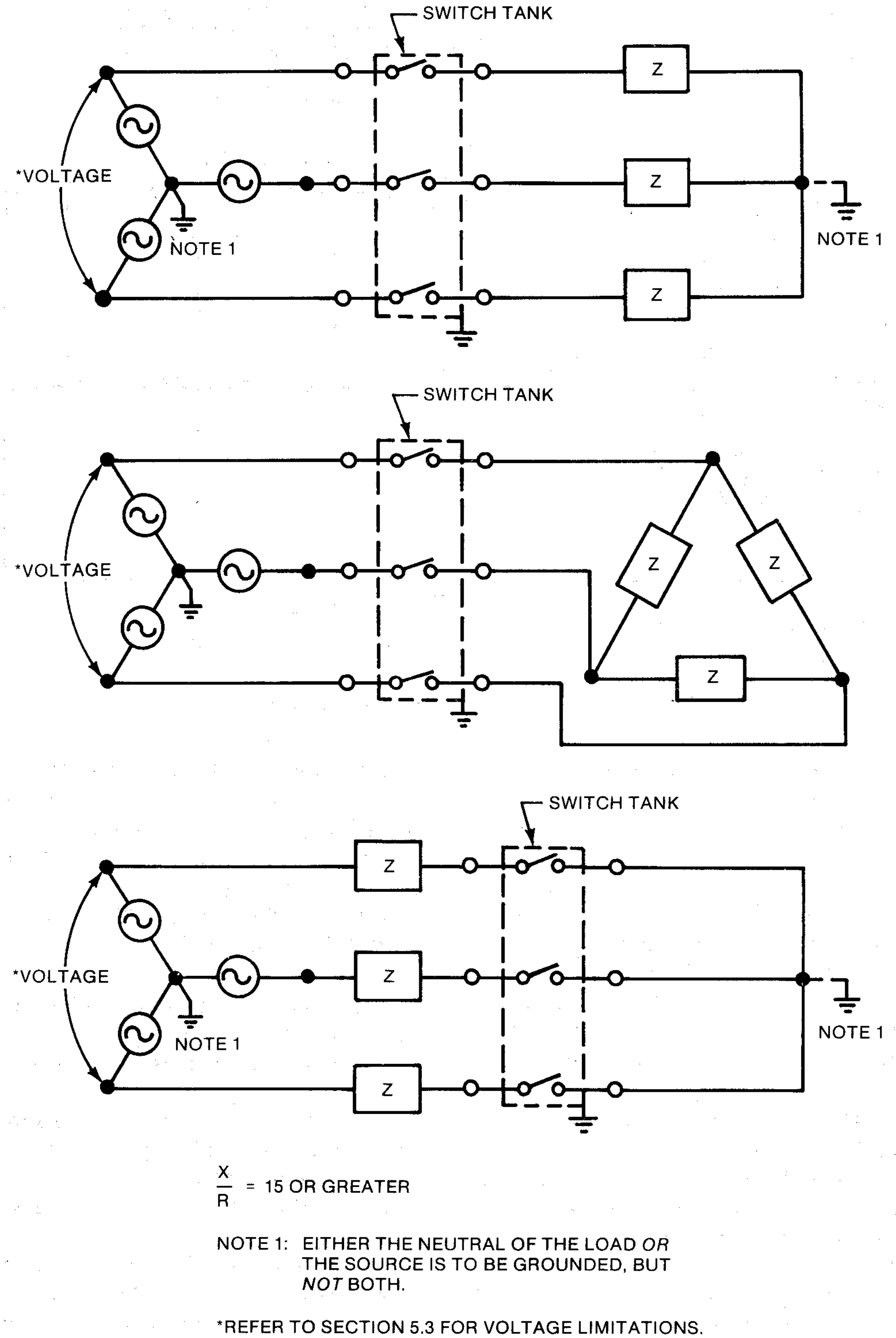


Figure 5— Short-Time Current Test Circuits

5.4.4 Impulse Withstand Tests

Switches shall withstand a full wave 1.2×50 µs voltage impulse with crest values as given in Table 2, column (2), with a virtual front time based on the rated full-wave impulse voltage (≤ 1.2 µs) with a crest voltage equal to or exceeding the rated impulse withstand voltage, and with a time to the 50% value of the crest voltage ≥ 50 µs. At least three positive and three negative impulses shall be applied to the test specimen. If a flashover occurs on only one test during any group of three consecutive tests, three more tests shall be made. If the switch withstands all three of the second group of tests, the flashover in the first group shall be considered a random flashover, and the switch shall be considered as having passed the test. If an additional flashover occurs, the switch shall be considered to have failed the test.

5.4.5 60 Hz Withstand Tests

5.4.5.1 Test Procedure

Low frequency withstand test voltages shall be applied having a crest value equal to 1.414 times the rated low frequency withstand test shown in Table 2, columns (3) and (4). The wave shape shall be as close to a sine wave as practicable. The test voltage shall be raised to the specified value within 30 s. The switch shall withstand the specified voltage for 1 min with no disruptive discharge.

5.4.5.2 Test for Rated 60 Hz Withstand

Rated 60 Hz withstand tests (5.1.6) shall be performed at the value from Table 2, column (3). Failure of a bushing will not invalidate this test if the bushing can be replaced and the test passed. The test can also be performed with enhanced insulation on bushings, since the intent is to prove insulation of switch internal parts rather than to demonstrate the bushings can meet the switch rating.[3]

5.4.5.3 Test for 60 Hz Withstand Following Making Current Test

Following the making current test (5.3.2), the switch shall be subjected to a 60 Hz withstand test (5.1.5) at the value from Table 2, column (4). This is the same value as used for production tests.

5.5 Continuous Current Test

The switch shall meet the conditions of continuous current rating and limits of observable temperature rise as specified in 4.3.1 and 4.3.2, respectively, when tested as outlined in 5.1 and as follows:

5.5.1 Test Conditions

The switch shall be installed in a closed room, substantially free from air currents other than those generated by heat from the switch being tested.

5.5.2 Connections

The switch shall have terminations in accordance with ANSI/IEEE 386-1977 [4], and have conductors at least 4 ft long (1.2 m). The conductors shall be 1000 kcmil aluminum, or equivalent, for 600 A terminations; and AWG #4/0 aluminum, or equivalent, for 200 A terminations.

[3]At the time of writing this standard, separable connectors were not available with ratings corresponding to the desired switch ratings.

5.5.3 Test Procedure

The rated continuous current of a switch at rated frequency shall be applied continuously to all three phases until the temperature becomes stable. The temperature shall be considered stable with three consecutive values of temperature rise taken at 30 min intervals at all points where readings are being taken show a maximum variation of one degree. All temperature determinations shall be made as follows:

5.5.3.1 Method of Temperature Determination

This method consists of the determination of temperature by thermocouples, or by mercury, spirit, or resistance thermometers.

5.5.3.2 Value of the Ambient Temperature

The value of the ambient temperature during these tests shall be taken as that of surrounding air and shall not be less than 10 °C nor more than 40 °C.

5.5.4 Determination of the Ambient Temperature

5.5.4.1 Placing of Thermocouples (Thermometers)

The ambient temperature shall be determined by means of a thermocouple placed 12 in (30 cm) above and 12 in (30 cm) to one side of the switch.

5.5.4.2 Use of Oil Cup

In order to avoid errors due to the time lag between the temperature of apparatus and the variations in the ambient temperature, all reasonable precautions must be taken to reduce these variations and the errors arising from them. Thus, when the ambient temperature is subject to such variations that error in taking the temperature rise might result, the thermocouple for determining the ambient temperature should be immersed in a suitable liquid (such as oil), in a suitable, heavy cup. A convenient form for such an oil cup consists of a metal cylinder with a hole drilled partially through it. This hole is filled with oil and the thermocouple is placed therein with its bulb immersed. The response of the thermocouple to various rates of temperature change will depend largely upon the size, kind of material, and mass of the containing cup, and may be further regulated by adjusting the amount of oil in the cup. The larger the apparatus under test, the larger should be the metal cylinder employed as an oil cup in the determination of the cooling air temperature. The smallest size of oil cup employed in any case shall consist of a metal cylinder 1 in (25 mm) in diameter and 2 in (50 mm) high.

5.5.5 Thermal Runaway Test

The purpose of this test is to verify that the switch, after being subjected to Tests 1 through 4 of 5.1.5, will operate at a stable temperature while carrying rated continuous current.

Test conditions and procedures shall be the same as for the Continuous Current Test (5.5). The switch shall have passed this test if the temperature stabilizes as indicated by three consecutive readings at 30 min intervals. The limits of observable temperature rises may be exceeded.

NOTE — The thermal runaway test requires that thermocouples and leads be installed at various points on the switch blades, contacts, bus bars, and similar points. It maybe necessary to untank, partially disassemble and reassemble, drill holes for thermocouples, and perform other procedures, before or after the thermal runaway test. It shall be understood that such work does not constitute “maintenance.”

5.6 Mechanical Operation Test

The purpose of this test is to verify that the switch can complete a specified number of opening and closing operations without maintenance or replacement of any parts or components, and is to be run following the Thermal Runaway Test, 5.5.5.

5.6.1 Test Procedure

The mechanical operation test shall consist of 200 no-load opening and closing operations.

5.6.2 Condition After Test

The switch shall be mechanically operable and capable of carrying the rated continuous current without thermal runaway, and passing the 60 Hz withstand voltage test; see Table 2, column (4).

NOTE — The means of showing ability to carry current is optional. For example, it may be accomplished by means of a dc resistance test. It is not necessary to repeat the Thermal Runaway test.

5.7 Partial Discharge (Corona) Level Test

The purpose of this test is to verify that the partial discharge extinction voltage of the switch and its associated terminals is not less than the values shown in Table 2, column (6).

5.7.1 Detection and Measurement

The detection and measurement of partial discharge shall be performed in accordance with ANSI/IEEE Std 454-1973 [5].

5.7.2 Test Conditions

The test voltage shall be applied in accordance with 5.4.1.

5.7.3 Test Procedure

The voltage shall be applied and raised to at least one half the rated 60 Hz withstand test voltage—see Table 2, column (3) —until partial discharge starts or for 1 min, and shall then be reduced to the specified partial discharge extinction voltage and held at this voltage for not less than 2 min.

At the end of the 2 minute period, if discharge is evident only in the form of spurious or random spikes spaced at least 2 s apart, then for the purposes of this test the partial discharge will be considered as having ceased.

5.7.4 Acceptance

(This paragraph is being studied by committee and will be published when completed.)

5.8 DC Withstand Test

The purpose of this test is to verify that the switch is capable of withstanding the dc test voltages that may be applied to installed cable systems.

5.8.1 Test Procedure

The rated dc 15 min withstand voltage of negative polarity shall be applied to the switches. Points of application of voltage shall be as specified in 5.4.1. The voltage shall be raised gradually to the specified test voltage, as shown in Table 2, column (5), and maintained at that voltage for 15 min.

NOTE — Field tests of switches or associated cables shall be performed only when all ways of the switch and cables are completely isolated from all system voltages.

5.9 Pressure Tests

The purpose of these tests is to demonstrate that the switch will withstand pressure and remain operable when subjected to a positive pressure resulting from the operation of the switch (for example, temperature rise, load interrupting, and fault closing), and negative pressure resulting from flooding of vaults and enclosures where they may be installed.

5.9.1 External Pressure Test

For this test the internal pressure shall be reduced 5 psig below the minimum operating pressure of the switch. Tanks shall not deform sufficiently to impair operation of the switch. Five psig corresponds to approximately a 10 ft head of water above the switch top.

5.9.2 Internal Pressure Test

For this test the switch shall be pressurized to the maximum operating pressure conditions expected during maximum temperature, altitude, etc, as specified herein. The tank shall not deform sufficiently to impair operation of the switch.

6. Production Tests

Production tests are those tests made to check the quality and uniformity of the workmanship and materials used in the manufacture of subsurface switches. Switches shall meet the production tests described in 6.1 through 6.4 inclusive (6.5 if required). Production tests shall be performed on every completely assembled and sealed switch.

6.1 Circuit Resistance Test

The purpose of this test is to verify that all switch contacts have been properly aligned and current transfer points have been properly assembled.

6.1.1 Test Procedure

The dc resistance of the current carrying circuit from terminal to terminal of each pole unit in the closed position shall be measured with current of at least 10 A flowing. The resistance shall not exceed a limit for each rating of the switch specified by the manufacturer.

6.2 60 Hz Withstand Test

The tests shall be performed in accordance with 5.4. The test value shall be from Table 2, column (4).

6.3 Leak Test

The leak test is intended to verify that a leak does not exist that will impair the dielectric integrity of the assembly during its contemplated service life.

Each assembled switch shall be tested to verify that it does not leak by pressurizing it to 7 psig or its maximum operating pressure, whichever is greater, for at least 24 hrs without any detectable leaks. Time may be reduced by use of any equivalent test, such as pressurizing the switch to the appropriate value and applying a soap solution, alcohol, and chalk, or pressurizing the switch with freon or similar gas and using a halogen leak detector.

6.4 Operating Assurance Tests

Each switch shall be operated and tested to verify:

1) That the switch position indicators and contacts are in correct position for both open and closed position.
2) That the insulating medium quantity indicator (if provided) is functioning properly.
3) That the switch circuit configuration is shown correctly.

6.5 Partial Discharge (Corona) Level Test

This test applies only to switches containing insulating material that may be subject to deterioration from partial discharge. The test shall be performed in accordance with 5.7.

This test need not be performed on the completed switch if those components utilizing such insulating material have been previously tested satisfactorily.

7. Conformance Tests

If conformance tests are required by the purchaser, they shall be made in accordance with this standard.

7.1 Temperature Measurements

When temperature measurements are required for conformance tests, it is sufficient to measure accessible parts and compare with like points on the design tests.

7.2 Impulse Withstand Tests

When impulse tests are required for conformance tests, switches shall be capable of passing a 1.2×50 µs full-wave impulse voltage test series with values as specified by the purchaser in accordance with the following: virtual front time, based on the rated full-wave impulse voltage ≥ 1.2 µs with a crest voltage not exceeding the rated full-wave impulse withstand voltage, and with a time to 50% value of the crest voltage not exceeding 50 µs. The test procedure used shall be in accordance with 5.4.4.

7.3 Loop Current Requirement

The application of the switch may require it to interrupt the current in a loop circuit. However, the resulting voltage across each switch contact should not exceed 10% of the rated maximum voltage.

If tests are necessary to demonstrate this capability, the switch shall interrupt the current value shown in Table 3, columns (2) or (3), at not less than 10% of the rated maximum voltage. The test circuit shown in Fig 6 shall be used.

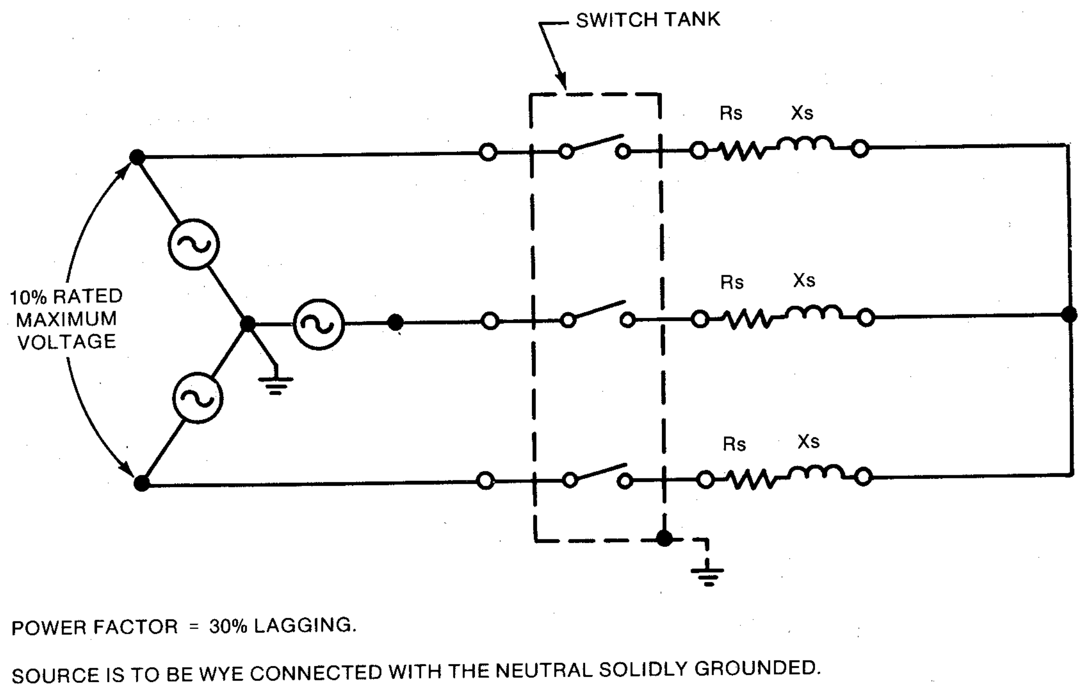


Figure 6— Loop Current Interruption Test Circuit

8. Construction Requirements

8.1 Grounding Provision

Unless otherwise specified, one stainless steel grounding pad with a $^1/_2$ in 13 NC hole, $\frac{7}{16}$ in (11.1 mm) deep, shall be provided for each way and shall be located near the center bushing of each way.

8.2 Manual Operating Provisions

Manual operating handles shall turn clockwise to close, counterclockwise to open; or *in* to close and *out* to open. The direction of operation shall be apparent.

Manual operating handles shall be located where they can be operated from the surface with standard live-line tools or lanyard, or both. The force required to operate the handle shall be such that one man in a standing position can readily operate it without standing directly over the switch.

The switch mechanism shall be designed so that operation does not require any special skills, and the closing and opening speeds of the contacts are independent of the speed at which the operating handle is operated.

Manual operating handles shall be capable of being padlocked in both the open and closed positions.

8.3 Position Indicators

Switches shall be provided with position indicators or other suitable means that clearly and positively indicate the open and closed positions of the contacts. The indicators shall be visible from the surface with the enclosure open. If colors are used to indicate an open and closed position, red shall signify closed and green shall signify open, with the words *Open* and *Closed* in contrasting colors. Corrosion-resistant and legible lettering (raised or engraved) shall be used.

8.4 Insulating Medium Quantity Indicators

Where liquid or gas is used as the insulating medium, provision shall be made for personnel to readily determine the insulating liquid level or insulating gas pressure with the switch energized. Indicator markings shall show the safe operating levels or pressures over the temperature range specified in 3.1. Procedures or devices that require exposing the insulating medium to the outside environment shall not be used.

8.5 Drain and Replacement Provisions

Where liquid or gas is used as the insulating medium, provision shall be made to facilitate replacement of the insulating medium with the switch energized. This provision shall be made on the top of the tank.

8.6 Sampling and Addition Provisions

When a liquid is used as the insulating medium, provisions shall be made to obtain a bottom sample through the top of the tank with the switch energized.

Provisions shall be made for adding the insulating medium, liquid or gas, through the top of the tank with the switch energized.

8.7 Tank Construction

8.7.1

The tank and all appurtenances shall be made of corrosion-resistant material, or provided with an impact- and corrosion-resistant finish. In addition, the switching assembly shall be suitable for storage in uncovered areas.

8.7.2

No external portion of the tank or accessories shall trap water.

8.7.3

Switch tanks shall be equipped with mounting provisions (such as feet or support rails) that shall include provision for anchoring the tank to the mounting surface.

8.7.4

Lifting lugs shall be provided and positioned so that the switch will remain level when being lifted. The lugs shall be designed and located to avoid interference between lifting slings and any attachments (bushings, switch handles, etc), and to avoid scratching or marring the tank finish during handling.

8.7.5

Parking stands shall be provided as specified. (For parking stand dimensions see ANSI C57.12.26-1975, Fig 5 [2].

8.8 Terminations

The switch bushings shall accommodate cable terminations in accordance with ANSI/IEEE Std 386-1977 [3].

8.9 Bushing Designation

The switch bushings shall be identified and legibly marked adjacent to each bushing with the appropriate phase designation, using a nameplate of stainless steel, or other corrosion-resistant material.

8.10 Nameplate

A nameplate of stainless steel or other corrosion-resistant material shall be provided. The nameplate shall be securely attached to the top of the tank by means of stainless steel screws, rivets, or other corrosion-resistant fasteners. All letters, schematics and numbers shall be stamped, embossed or engraved on the nameplate. The nameplate shall contain at least the following information:

1) The word *Switch*
2) Name of manufacturer
3) Date of manufacture (month and year, for example, 1–80)
4) Serial number
5) Model number or style number (if any)
6) Rated maximum voltage
7) Rated impulse withstand voltage
8) Rated continuous current
9) Rated load interrupting current
10) Rated momentary current
11) Rated making current
12) A three-line, bushing-oriented schematic diagram, using standard symbols (this may be put on a separate nameplate)
13) Total weight (including insulating medium)
14) Type and quantity of insulating medium

8.11 User Identification Plate

Space and provisions for attaching a user identification (switch number) plate shall be provided adjacent to each switch handle, when specified. Dimensions of this plate are shown in Fig 7.

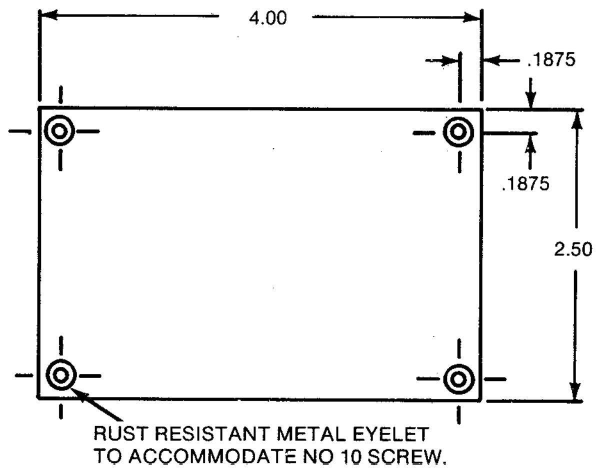


Figure 7— Outline for User Identification Plate

9. Shipping Requirements

9.1

The switch shall be completely assembled and, unless otherwise specified, include the correct amount of insulating medium considering the temperature of the medium.

9.2

Internal positive pressure shall be applied to prevent entrance of moisture.

9.3

Plugs shall be provided for threaded holes, and caps shall be provided for threaded studs and bushings.

9.4

Instructions and checklists for the inspection, installation and maintenance of the switch shall be provided.

9.5

Switches shall be properly packaged and braced to prevent damage during shipment.