IEEE Std C57.12.23™-2002
(Revision of
IEEE Std C57.12.23-1992)

IEEE Standard for Underground Type, Self-Cooled, Single-Phase, Distribution Transformers with Separable Insulated High-Voltage Connectors; High Voltage 25 000 V and Below; Low Voltage 600 V and Below; 167 kVA and Smaller

Sponsor

Transformers Committee
of the
IEEE Power Engineering Society

Approved 13 June 2002

IEEE-SA Standards Board

Abstract: Electrical, dimensional, and mechanical characteristics and certain safety features of single-phase, 60 Hz, mineral-oil-immersed, self-cooled, distribution transformers with separable insulated high-voltage connectors are covered. Ratings, testing, and construction are discussed.
Keywords: distribution transformer, mineral-oil-immersed, self-cooled, single-phase, submersible, subsurface, transformer, underground

---

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-3307-8 SH95006
PDF: ISBN 0-7381-3308-6 SS95006

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied "**AS IS**."

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. Furthermore, 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 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.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

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 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 societies and Standards Coordinating 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 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. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

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

Introduction

(This introduction is not part of IEEE Std C57.12.23-2002, IEEE Standard for Underground Type, Self-Cooled, Single-Phase, Distribution Transformers with Separable Insulated High-Voltage Connectors; High Voltage 25 000 V and Below; Low Voltage 600 V and Below; 167 kVA and Smaller.)

This standard covers certain electrical, dimensional, and mechanical characteristics and takes into consideration certain safety features of single-phase, 60 Hz, mineral-oil-immersed, self-cooled, underground distribution transformers with separable insulated high-voltage connectors. These transformers are generally used for step-down purposes from an underground primary cable supply and are suitable for occasional submerged operation. This standard is intended for use as a basis for determining performance, interchangeability, and safety of the equipment covered, and to assist in the proper selection of such equipment.

The 1986 revision to the standard expanded the scope to include 167 kVA. In addition, the dielectric test levels were updated and maximum test levels introduced to be consistent with other transformer standards.

The 1992 revision to the standard added the clause on storage and installation with particular emphasis on the position when stored and consideration of the angle of tilt when installed. This revision was reaffirmed in 1999.

The 2002 revision further expands the scope to include all high-voltage ratings 25 000 volts and below, including transformers designed for phase-to-phase connection. Previous revisions only included transformers designed for phase-to-ground connection. Also, the scope was expanded to include low-voltage ratings 600 volts and below. Previous revisions only covered a 240/120 volt rating.

The 2002 revision is the first standard in the C57.12.2X series to use the SI units of measure exclusively. The intent of this revision is to simply convert the in-lb units of the 1992 revision to SI units. Users of this standard should use judgement when converting from SI units back to the in-lb equivalent.

Participants

At the time this standard was completed, the working group had the following membership:

Roger J. Lee, *Co-Chair*
Alan R. Traut, *Co-Chair*

Donald Duckett	Thomas Holifield	Daniel H. Mulkey
Ken Hanus	Gael R. Kennedy	Edward Smith
Mike Hardin	Samuel E. Michael	Ronald J. Stahara

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

Samuel Aguirre
David Aho
Paul Ahrens
Glenn Andersen
Martin Baur
John Borst
Donald Chu
Tommy Cooper
Jerry Corkran
Stephen Dare
Alan Darwin
Ronald Daubert
Randall Dotson
Horgan Edward
Gary Engmann
Jorge Fernandez
Eduardo Garcia
Manuel Gonzalez
Randall Groves
Robert Grunert
Wayne Hansen
Ken Hanus
Michael Hardin
Thomas Holifield
James D. Huddleston, III
Vladimir Khalin
Brian Klaponski
William Larzelere
Roger J. Lee
Donald Lowe
Gregory Luri
William Maguire
J. Dennis Marlow
Tito Massouda
John Matthews
Thomas McCaffrey
Nigel McQuin
Samuel E. Michael
Gary Michel
Daniel H. Mulkey
Kyaw Myint
Krste Najdenkoski
Larry Nunnery
Gerald Paiva
Paulette Payne
Thomas Pekarek
Linden Pierce
Madan Rana
Arlise Robinson
John Rossetti
James Ruggieri
Hyeong Sim
Tarkeshwar Singh
David Singleton
Edward Smith
Brian Sparling
Ronald J. Stahara
John Sullivan
John Teixeira
Alan R. Traut
Shelby Walters
James Wilson
William Wimmer

When the IEEE-SA Standards Board approved this standard on 13 June 2002, it had the following membership:

James T. Carlo, *Chair*
James H. Gurney, *Vice Chair*
Judith Gorman, *Secretary*

Sid Bennett
H. Stephen Berger
Clyde R. Camp
Richard DeBlasio
Harold E. Epstein
Julian Forster*
Howard M. Frazier
Toshio Fukuda
Arnold M. Greenspan
Raymond Hapeman
Donald M. Heirman
Richard H. Hulett
Lowell G. Johnson
Joseph L. Koepfinger*
Peter H. Lips
Nader Mehravari
Daleep C. Mohla
William J. Moylan
Malcolm V. Thaden
Geoffrey O. Thompson
Howard L. Wolfman
Don Wright

*Member Emeritus

Also included is the following nonvoting IEEE-SA Standards Board liaison:

Alan Cookson, *NIST Representative*
Satish K. Aggarwal, *NRC Representative*

Catherine Berger
IEEE Standards Project Editor

Contents

This page is intentionally blank.

IEEE Standard for Underground Type, Self-Cooled, Single-Phase, Distribution Transformers with Separable Insulated High-Voltage Connectors; High Voltage 25 000 V and Below; Low Voltage 600 V and Below; 167 kVA and Smaller

1. Overview

1.1 Scope

This standard covers certain electrical, dimensional, and mechanical characteristics and takes into consideration certain safety features of single-phase, 60 Hz, mineral-oil-immersed, self-cooled, distribution transformers with separable insulated high-voltage connectors. These transformers are rated 167 kVA and smaller, with high voltages of 25 000 V and below and with low voltages of 600 V and below. These transformers are generally used for step-down purposes from an underground primary cable supply and are suitable for occasional submerged operation.

This standard does not cover the electrical and mechanical requirements of any accessory devices that may be supplied with the transformer.

1.2 Purpose

This standard is intended for use as a basis for determining performance, interchangeability, and safety of the equipment covered, and to assist in the proper selection of such equipment.

2. References

This standard shall be used in conjunction with the following publications. When these publications are superseded by an approved revision, the revision shall apply:

ANSI C57.12.20-1997, American National Standard for Overhead-Type Distribution Transformers, 500 kVA and Smaller: High voltage, 34 500 Volts and Below; Low Voltage, 7970/13 800 Y Volts and Below.[1]

[1]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

ANSI C57.12.70-1978 (Reaff 1987), American National Standard Terminal Markings and Connections for Distribution and Power Transformers.

ICEA S-66-524/NEMA WC7-1991, Standard for Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.[2]

IEEE Std C57.12.00™-2000, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.[3]

IEEE Std C57.12.80™-1978 (Reaff 1992), IEEE Standard Terminology for Power and Distribution Transformers.

IEEE Std C57.12.90™-1999, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE Std C57.91™-1995, IEEE Guide for Loading Mineral-Oil-Immersed Transformers.

IEEE Std 386™-1995, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V.

NEMA C57.12.32-1994, Submersible Equipment—Enclosure Integrity.[4]

NOTE—The IEEE standards referred to in this clause are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

3. Ratings

3.1 Kilovoltampere ratings

Kilovoltampere ratings shall be continuous and based on, but not exceeding, an average winding temperature rise of 55 ˚C and a hottest-spot temperature rise of 70 ˚C. The temperature rise of the insulating oil shall be measured near the top of the tank and shall not exceed 55 ˚C. The transformers shall have a temperature-rise insulation system of 65 ˚C.

Kilovoltampere ratings shall be as follows: 25, 37.5, 50, 75, 100, 167

The kilovoltampere ratings for transformers conforming to this standard shall be suitable for continuous operation at the rated kilovoltamperes, provided that the temperature of the cooling air (enclosure ambient temperature) does not exceed 50 ˚C and the average temperature of the cooling air does not exceed 40 ˚C for any 24-hour period.

[2]This standard has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

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

3.2 Voltage ratings

Voltage ratings shall be in accordance with Table 1 and Table 2.

No taps shall be provided.

4. Basic lightning impulse insulation levels and dielectric test levels

Basic lightning impulse insulation levels (BILs) shall be in accordance with Table 1 and Table 2.

Dielectric test levels shall be in accordance with the distribution levels in IEEE Std C57.12.00-2000 and IEEE Std C57.12.90-1999.

Table 1—Transformer and connector requirements —High voltage

Transformers		High-voltage connectors[a]		
High-voltage rating (V)	**BIL (kV)**	**High-voltage rating Phase-to-Ground/ Phase-to-Phase (kV)**	**BIL (kV)**	**1 min withstand 60 Hz, Dry (kV)**
4160 Grd Y/2400	60	8.3/14.4	95	34
8320 Grd Y/4800	75	8.3/14.4	95	34
12 000 Grd Y/6930	95	8.3/14.4	95	34
12 470 Grd Y/7200	95	8.3/14.4	95	34
13 200 Grd Y/7620	95	8.3/14.4	95	34
13 800 Grd Y/7970	95	8.3/14.4	95	34
16 340 Grd Y/9430	95 or 125	8.3/14.4 or 15.2/26.3[b]	95 or 125[b]	34 or 40[b]
12000	95 or 125	8.3/14.4	95 or 125[b]	34 or 40[b]
16340	95 or 125	8.3/14.4 or 15.2/26.3[b]	95 or 125[b]	34 or 40[b]
17200	95 or 125	8.3/14.4 or 15.2/26.3[b]	95 or 125[b]	34 or 40[b]
20780	125	15.2/26.3	125	40
22 860 GrdY/13 200	125	15.2/26.3	125	40
23 900 GrdY/13 800	125	15.2/26.3	125	40
24 940 GrdY/14 400	125	15.2/26.3	125	40

[a]For complete connector rating, see IEEE Std 386-1995.
[b]The required connector rating is to be specified.

Table 2—Transformer and terminal requirements—Low voltage

Low-voltage ratings (V)	BIL (kV)	Nominal system voltage (kV)	1 min withstand 60 Hz, Dry (kV)	Number of terminals
120/240	30	1.2	10	4
240/480	30	1.2	10	4
240/120	30	1.2	10	3
120, 240, 277, 480	30	1.2	10	2

5. Tests

5.1 General

Except as specified in 5.2, tests shall be performed as specified in IEEE Std C57.12.00-2000 and IEEE Std C57.12.90-1999.

5.2 Dielectric tests

No applied-potential test is required on high-voltage windings of units designed for use phase-to-ground. Phase-to-phase units will require an applied-potential test, as described in IEEE Std C57.12.00-2000.

Induced-potential tests shall be performed by applying between the terminals of one winding a voltage that will develop between the high-voltage terminals and ground a voltage of 1000 V plus 3.46 times the rated high voltage. However, in no case shall the line-to-ground voltage developed exceed 34 kV for 60 kV, 75 kV, or 95 kV BIL transformers or 40 kV for 125 kV BIL transformers. For this test, the neutral terminal (if any) shall be grounded.

6. Construction

6.1 General

The transformers covered in this standard shall include high-voltage bushings and low-voltage terminals as described in 6.2.

When specified, devices such as switch handles, tap changers, separable connectors, and replaceable fuses, which are designed for operation after the transformer is in place, shall be located on the transformer so that they can be operated from above with hot-line tools.

Construction of the units shall be such that they can be lifted and lowered into place in a suitably designed and constructed enclosure having a minimum diameter of 910 mm. To allow for cabling space and proper air flow for cooling, the transformers covered by this standard shall not have overall diameters in excess of 760 mm for sizes 100 kVA and smaller, or overall diameters in excess of 840 mm for 167 kVA.

The transformer tank, cover, and all external appurtenances shall be of corrosion-resistant material, unless they are otherwise rendered corrosion-resistant.

Corrosion-resistant base bars or other suitable means shall be provided on the transformer tank to protect the bottom of the tank while in transit and when installed in the underground enclosure. Minimum bar height is 25 mm.

For the purpose of locating terminations and operating devices, the plan view of the transformer is divided into four segments with the segments numbered in a clockwise direction. See Figure 1.

The lifting provisions shall be permanently attached and arranged on the tank to provide a distributed balanced lift in a vertical direction for the completely assembled transformer; they shall be designed to provide a safety factor of 5. This safety factor of 5 is the ratio of the ultimate stress of the material used to the working stress. The working stress is the maximum combined stress developed in the lifting provisions by the static load of the completely assembled transformer.

6.2 Connectors and terminals

The electrical characteristics of the completely assembled high-voltage connectors shall be as shown in Table 1. The electrical characteristics of the completely assembled low-voltage terminals shall be as shown in Table 2.

Separable insulated high-voltage connectors shall be provided for connection to the distribution system. The high-voltage connectors shall consist of either bushing wells, bushing wells with bushing inserts, or integral bushings, as specified. One cable accessory parking stand shall be provided for each phase of supplied high-voltage. For specific details concerning high-voltage separable connectors and cable accessory parking stands, refer to IEEE Std 386-1995.

Separable insulated high-voltage connectors that are designed for operation after the transformer is in place shall be located so that they can be operated with hot-line tools.

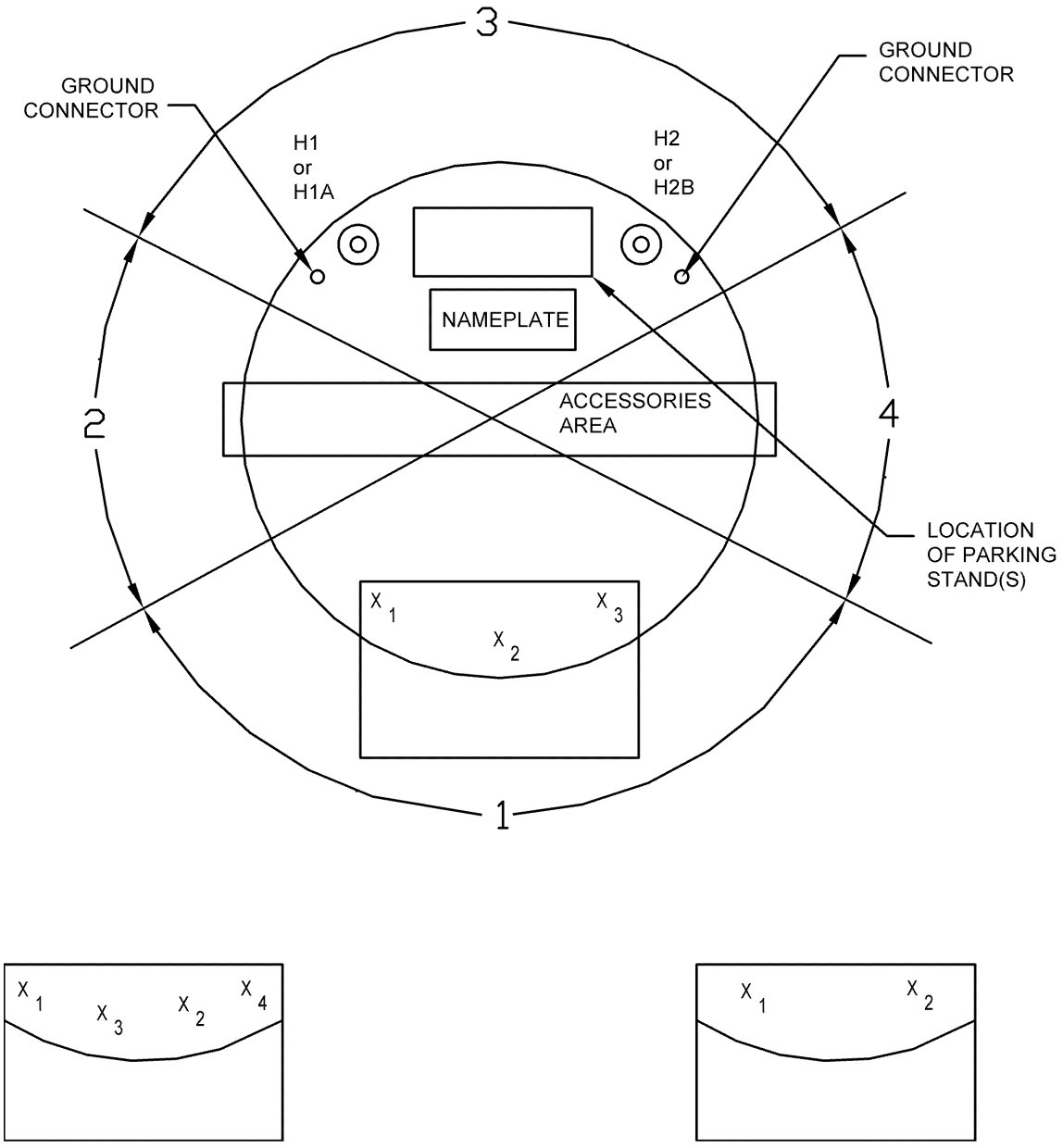
On phase-to-ground transformers, the H_2 end of the high-voltage winding shall be connected to the tank internally. This connection shall be independent of all other electrical connections.

Low-voltage cable leads extending 350 mm above the top of the cover shall be provided and arranged for vertical takeoff. Cable insulation shall be in accordance with ICEA S-66-524/NEMA WC7 or functional equivalent for continuous operation at a minimum of 90 ˚C and 600 V. Cable flexibility shall be such that bending it into an arc having a radius of 300 mm can be accomplished without overstressing the low-voltage bushing. Cable sizes shall be as shown in Table 3.

Table 3—Low-voltage cable leads

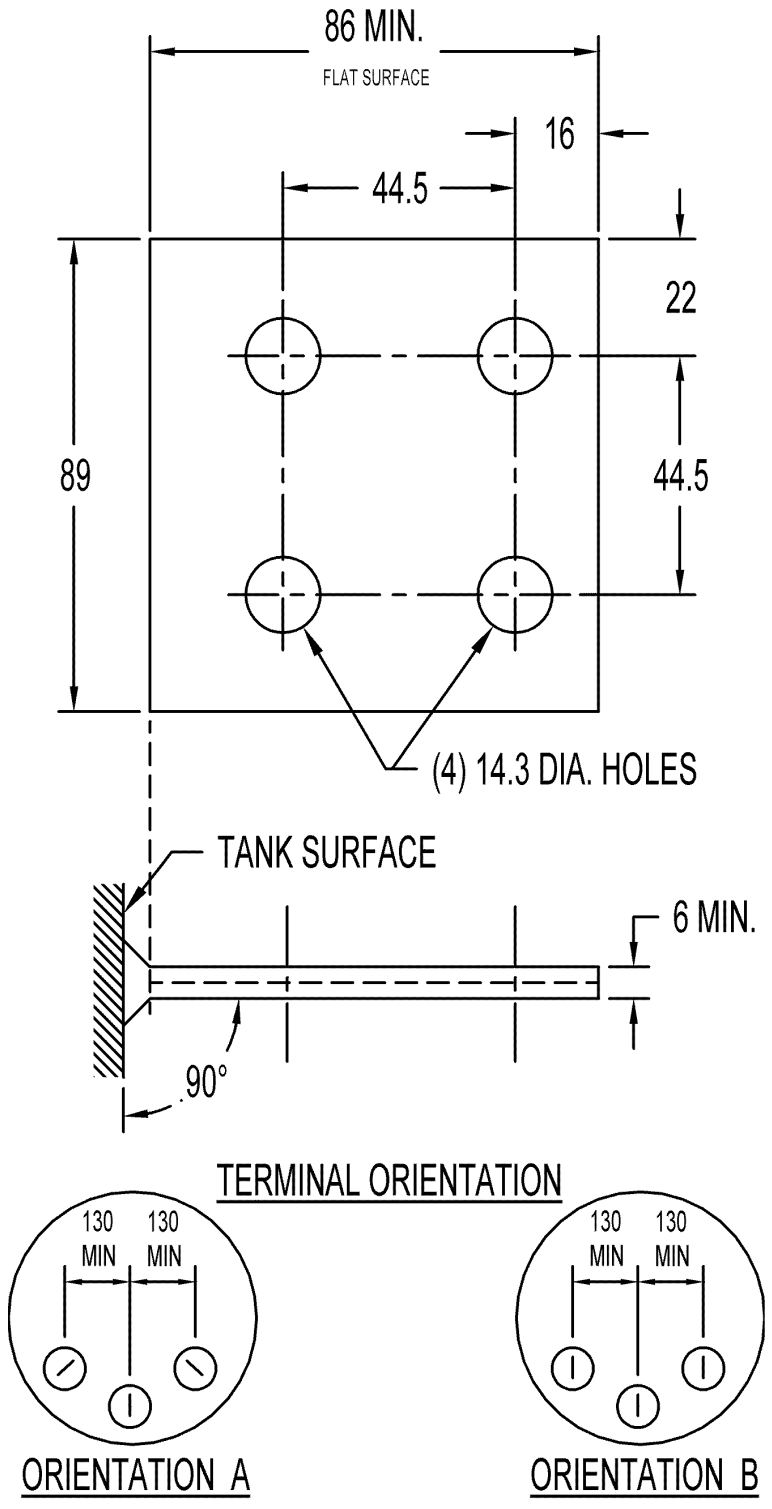
kVA rating	Copper cable size
25	2/0 AWG
37.5, 50	4/0 AWG
75, 100	500 kcmil or spade terminal
167	500 kcmil (2/terminal) or spade terminal

When spade terminals are specified (one per terminal), they shall be in accordance with Figure 2.



NOTES
1—Low-voltage terminals shown for subtractive polarity transformers. Locations are reversed for additive polarity. For more information, refer to ANSI C57.12.20-1997.
2—The preferred location for the externally replaceable fuse is in Segment 2 or 4.
3—To maintain adequate mechanical and electrical clearances in Segment 3, it is permissible to encroach upon adjacent segments.
4—Dashed boxes indicate either side wall or cover location.
5—Omit H1B and adjacent ground connector on non-loop-feed phase-to-ground units.

Figure 1—Location of high-voltage and low-voltage connectors and terminals



NOTES
1—All dimensions are in millimeters and are nominal unless otherwise specified.
2—Greater thickness may be required to provide adequate conductivity.
3—Corners and edges may be rounded.

Figure 2—Spade terminals

On three-secondary-bushing (240/120V) units only, the low-voltage neutral (X_2) connection of the winding shall be made to the tank or cover but not to the core clamp. When a fully insulated terminal is used for this low-voltage neutral connection, it shall be externally identified as being internally connected to the tank or cover.

All neutral connections shall be suitably sized for the short-circuit rating of the transformer as defined in IEEE Std C57.12.00-2000.

Connector and terminal designations shall be as defined in ANSI C57.12.70-1978. The high-voltage connector and low-voltage terminal designations and locations are shown in Figure 1. The identification of the connector and terminal connections shall be shown on the instruction nameplate.

The tank grounding connector, as shown in Figure 1, shall be solderless-type connectors that will accommodate AWG conductor size No. 8 solid to No. 2 stranded.

6.3 Instruction nameplate

The instruction nameplate shall be located on the transformer cover in Segment 3.

The nameplate shall conform to the requirements of nameplate "A," as described in IEEE Std C57.12.00-2000, but shall also include

— The total weight of the transformer.
— The volume of the contained oil.

The nameplate shall be made of corrosion-resistant material and secured with non-corrosive hardware.

6.4 Oil preservation

The transformer shall be of sealed-tank construction. Sealed-tank construction is construction that seals the interior of the tank from the atmosphere, and in which the gas plus the oil volume remains constant. The transformer shall remain effectively sealed for a top oil temperature range of –5 ˚C to +105 ˚C continuous under operating conditions as described in IEEE Std C57.91-1995. An oil-level sight gauge shall be provided.

6.5 Tanks

The tank shall be of sufficient strength to withstand a static internal pressure of 50 kPa gauge without permanent distortion and 140 kPa gauge without rupturing.[5] A 1/2 inch or larger NPT fitting sized for specified minimum flow rate shall be provided for the installation of a pressure-relief device.

The cover shall be welded in place.

If a handhole is required, it shall be located on the cover, be adequately sized, and be suitably located to permit access to internal components.

The completely assembled transformer enclosure shall be capable of passing the fault current tests as defined in ANSI C57.12.20-1997.

[5] 50 kPa = 7 lbf/in^2 ; 140 kPA = 20 lbf/in^2.

Tank grounding provisions shall consist of stainless steel or non-corrosive pads with a 1/2-inch-13-NC tapped hole, 11 mm deep, located in Segment 3, as shown in Figure 1.

6.6 Components for primary cable system

The minimum current-carrying capabilities of components for primary cable systems shall be 200 A (continuous) and 10 000 A rms symmetrical for 0.17 s (short-time current rating) for transformers with or without high-voltage switching.

7. Storage and installation

7.1 Storage

The transformer shall be stored in a vertical position and shall remain essentially in that position at all times including transport to the site and during installation.

7.2 Installation

Equipment manufactured to this standard may be installed in areas where environmental and climatic conditions make operation at varying angles of tilt from the horizontal an important consideration. Under these circumstances, the user may wish to make a particular maximum “angle of tilt” part of their specification.