

American National Standard

general requirements for
liquid-immersed distribution, power,
and regulating transformers

ANSI/IEEE C57.12.00-1987



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An American National Standard

IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

1. Scope

This standard is a basis for the establishment of performance, limited electrical and mechanical interchangeability, and safety requirements of equipment described; and for assistance in the proper selection of such equipment.

This standard describes electrical, mechanical, and safety requirements of liquid immersed distribution and power transformers, and autotransformers and regulating transformers; single and polyphase, with voltage 601 V or higher in the highest voltage winding.

This standard applies to all liquid-immersed distribution, power, and regulating transformers except as indicated below:

- (1) Instrument transformers
- (2) Step-voltage and induction voltage regulators
- (3) Arc furnace transformers
- (4) Rectifier transformers
- (5) Specialty transformers
- (6) Grounding transformers
- (7) Mobile transformers
- (8) Mine transformers

When this standard is used on a mandatory basis, the words *shall* and *must* indicate mandatory requirements; and the words *should* and *may* refer to matters that are recommended or permissive, but not mandatory.

NOTE: The Foreword of this voluntary consensus standard describes the circumstances under which the standard may be used on a mandatory basis.

2. Terminology

Standard transformer terminology available in ANSI/IEEE C57.12.80-1978 (R 1986) [24]¹ shall apply.

Other electrical terms are defined in ANSI/IEEE Std 100-1984 [40].

¹ The numbers in brackets correspond to those of the references in Section 3.

3. References

This standard shall be used in conjunction with the following publications:

- [1] ANSI B1.1-1982, American National Standard Unified Inch Screw Threads (UN and UNR Thread Form).²
- [2] ANSI C57.12.10-1977, American National Standard Requirements for Transformers 230 000 Volts and Below, 833/958 through 8333/10 417 kVA Single-Phase, and 750/862 through 60 000/80 000/100 000 kVA Three Phase.
- [3] ANSI C57.12.10a-1978, (Supplement to ANSI C57.12.10-1977).
- [4] ANSI C57.12.20-1981, American National Standard Requirements for Overhead-Type Distribution Transformers, 67 000 Volts and Below; 500 kVA and Smaller.
- [5] ANSI C57.12.21-1980, American National Standard Requirements for Pad-Mounted Compartmental-Type Self-Cooled Single-Phase Distribution Transformers with High-Voltage Bushings (High Voltage, 34 500 GrdY/19 920 Volts and Below; Low-Voltage 240/120 Volts; 167 kVA and Smaller).
- [6] ANSI C57.12.22-1980, American National Standard Requirements for Pad-Mounted Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers with High-Voltage Bushings (High Voltage, 34 500 GrdY/19 920 Volts and Below; 2500 kVA and Smaller).
- [7] ANSI C57.12.23-1985, American National Standard Requirements for Underground-Type Single-Phase Distribution Transformers, with Separable Insulated High-Voltage Connectors (High Voltage 24 940 GrdY/14 400 Volts and Be-

² ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

low; Low-Voltage 240/120; 100 kVA and Smaller).

[8] ANSI C57.12.24-1982, American National Standard Requirements for Underground-Type Three-Phase Distribution Transformers, 2500 kVA and Smaller (High Voltage 24 940 GrdY/14 400 Volts and Below; Low Voltage 480 Volts and Below).

[9] ANSI C57.12.25-1981, American National Standard Requirements for Pad-Mounted Compartmental-Type Self-Cooled Single-Phase Distribution Transformers with Separable Insulated High-Voltage Connectors (High Voltage 34 500 GrdY/19 920 Volts and Below; Low Voltage 240/120; 167 kVA and Smaller).

[10] ANSI C57.12.26-1986, 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 24 940 GrdY/14 400 Volts and Below; 2500 kVA and Smaller).

[11] ANSI C57.12.27-1982, American National Standard for Liquid-Filled Distribution Transformers Used in Pad-Mounted Installations Including Unit Substations.

[12] ANSI C57.12.30-1977, American National Standard Requirements for Load Tap Changing Transformers 230 000 Volts and Below, 3750/4687 through 60 000/80 000/100 000 kVA Three Phase).

[13] ANSI C57.12.40-1982, American National Standard Requirements for Secondary Network Transformers, Subway and Vault Types (Liquid-Immersed).

[14] ANSI C57.12.70-1978, American National Standard Terminal Markings and Connections for Distribution and Power Transformers.

[15] ANSI C62.2-1981, American National Standard Guide for Application of Valve-Type Surge Arresters for Alternating-Current Systems.

[16] ANSI C84.1-1982, American National Standard Voltage Ratings for Electric Power Systems and Equipment (60 Hz).

[17] ANSI C92.1-1982, American National Standard Insulation Coordination.

[18] ANSI C92.2-1981, American National Standard Preferred Voltage Ratings for Alternating-

Current Electrical Systems and Equipment Operating at Voltages above 230 kV Nominal.

[19] ANSI/ASME B1.1a-1984, Unified Inch Screw Threads (UN and UNR Thread Form) Supplement to ANSI B1.1-1982.³

[20] ANSI/ASME Boiler and Pressure Vessel Code (BPV), 1984 Edition.

[21] ANSI/CGA-V-I-1977, Compressed Gas Cylinder Valve Outlet and Inlet Connections.⁴

[22] ANSI/IEEE C57.12.11-1980, IEEE Guide for Installation of Oil-Immersed Transformers (10 MVA and Larger, 69 kV to 287 kV Rating).⁵

[23] ANSI/IEEE C57.12.12-1980, IEEE Guide for Installation of Oil-Immersed Extra-High-Voltage Transformers 345 kV and Above.

[24] ANSI/IEEE C57.12.80-1978 (R 1986), IEEE Standard Terminology for Power and Distribution Transformers.

[25] ANSI/IEEE C57.12.90-1987, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers, and Guide for Short-Circuit Testing of Distribution and Power Transformers.

[26] ANSI/IEEE C57.13-1978, IEEE Standard Requirements for Instrument Transformers.

[27] ANSI/IEEE C57.13.1-1981, IEEE Guide for Field Testing of Relaying Current Transformers.

[28] ANSI/IEEE C57.13.2-1986, IEEE Standard Conformance Test Procedures for Instrument Transformers.

[29] ANSI/IEEE C57.91-1981, IEEE Guide for Loading Mineral-Oil-Immersed Overhead and Pad-Mounted Distribution Transformers Rated 500 kVA and Less with 55 °C or 65 °C Average Winding Rise.

³ ANSI/ASME publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from The American Society of Mechanical Engineers, 345 East 47 Street, New York, NY 10017.

⁴ ANSI/CGA publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Compressed Gas Association, Inc, Crystal Gateway 1, Suite 501, 1235 Jefferson Davis Highway, Arlington, VA 22202.

⁵ ANSI/IEEE publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.

- [30] ANSI/IEEE C57.92-1981, IEEE Guide for Loading Mineral-Oil-Immersed Power Transformers (up to and including 100 MVA with 55 °C or 65 °C Winding Rise).
- [31] ANSI/IEEE C57.98-1986, IEEE Guide for Transformer Impulse Tests.
- [32] ANSI/IEEE C57.104-1978, IEEE Guide for the Detection and Determination of Generated Gases in Oil-Immersed Transformers and Their Relation to the Serviceability of the Equipment.
- [33] ANSI/IEEE C57.105-1978, IEEE Guide for Application of Transformer Connections in Three-Phase Distribution Systems.
- [34] ANSI/IEEE C57.106-1977, IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment.
- [35] ANSI/IEEE C57.109-1985, IEEE Guide for Transformer Through-Fault-Current Duration.
- [36] ANSI/IEEE C62.1-1984, IEEE Standard Surge Arresters for AC Power Circuits.
- [37] ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.
- [38] ANSI/IEEE Std 21-1976, IEEE Standard General Requirements and Test Procedures for Outdoor Apparatus Bushings.
- [39] ANSI/IEEE Std 24-1984, IEEE Standard Electrical, Dimensional, and Related Requirements for Outdoor Apparatus Bushings.
- [40] ANSI/IEEE Std 32-1972, (R 1984), IEEE Standard Requirements, Terminology, and Test Procedure for Neutral Grounding Devices.
- [41] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.
- [42] ANSI/IEEE Std 315-1975, IEEE Standard Graphic Symbols for Electrical and Electronics Diagrams.
- [43] ANSI/IEEE Std 315A-1986, IEEE Standard—Supplement to Graphic Symbols for Electrical and Electronics Diagrams.
- [44] ANSI/IEEE Std 799-1987, IEEE Guide for Handling and Disposal of Transformer Grade Insulating Liquids Containing Polychlorinated Biphenyls.
- [45] ASTM D117-1987, Standard Methods of Testing and Specifications for Electrical Insulating Oils of Petroleum Origin.⁶

- [46] ASTM D1933-1964 (R 1979), Specifications for Nitrogen Gas as an Electrical Insulating Material.
- [47] ASTM D3487-1981, Specifications for Mineral Insulating Oil Used in Electrical Apparatus.
- [48] IEEE Std 76-1974, IEEE Guide for Acceptance and Maintenance of Transformer Askarel in Equipment.
- [49] IEEE Std 469-1977, IEEE Recommended Practice for Voice Frequency Electrical-Noise Tests of Distribution Transformers.

4. Service Conditions

4.1 Usual Service Conditions

4.1.1 General. Transformers conforming to this standard shall be suitable for operation at rated kilovoltamperes under the following usual service conditions.

4.1.2 Temperature

4.1.2.1 When air cooled, the temperature of the cooling air (ambient temperature) shall not exceed 40 °C and the average temperature of the cooling air for any 24 h period shall not exceed 30 °C.

4.1.2.2 The top liquid temperature of the transformer (when operating) shall not be lower than -20 °C. Starting temperatures below -20 °C are not considered as usual service conditions.

4.1.2.3 When water cooled, the temperature of the cooling water (ambient temperature) shall not exceed 30 °C and the average temperature of the cooling water for any 24 h period shall not exceed 25 °C. Minimum water temperature shall not be lower than 1 °C, unless the cooling water includes antifreeze suitable for -20 °C operation.

4.1.3 Altitude. The altitude shall not exceed 3300 ft (1000 m).

4.1.4 Supply Voltage. The supply-voltage wave shape shall be approximately sinusoidal, and the phase voltages supplying a polyphase transformer shall be approximately equal in magnitude and time displacement.

⁶ ASTM publications are available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

4.1.5 Load Current. The load current shall be approximately sinusoidal. The harmonic factor shall not exceed 0.05 per unit.

NOTE: **harmonic factor** is defined in ANSI/IEEE C57.12.80-1978 (R 1986) [24].

4.1.6 Operation Above Rated Voltage or Below Related Frequency

4.1.6.1 Transformers shall be capable of

(1) Operating continuously above rated voltage or below rated frequency, at maximum rated kilovoltamperes for any tap, without exceeding limits of observable temperature rise in accordance with 5.11.1 when all of the following conditions prevail:

(a) Secondary voltage and volts per hertz do not exceed 105% of rated values

(b) Load power factor is 80% or higher

(c) Frequency is at least 95% of rated value

(2) Operating continuously above rated voltage or below rated frequency on any tap at no load, without exceeding limits of observable temperature rise in accordance with 5.11.1 when neither the voltage nor volts per hertz exceed 110% of rated values.

NOTE: In the case of multiwinding transformers or autotransformers, 4.1.6.1 applies only to the specific loading conditions used as the basis of design. These loading conditions involve simultaneous coordination of kilovoltampere input and output, load power factors, and winding voltage combinations [see 4.3.3 (10)]. Differences in loading and voltage regulation for various output windings may prevent simultaneous achievement of 105% voltage on all output terminals. In no case shall the kilovoltampere outputs specified for any loading condition require continuous loading of any input winding in excess of its rating.

4.1.6.2 The maximum continuous transformer operating voltage should not exceed the levels specified in ANSI C84.1-1982 [16].

NOTE: System conditions may require voltage transformation ratios involving tap voltages higher than the *maximum system voltage* for regulation purposes. However, the appropriate maximum system voltage should be observed under operating conditions (ANSI C92.2-1981 [18]).

4.1.7 Outdoor Operation. Unless otherwise specified, transformers shall be suitable for outdoor operation.

4.1.8 Step-Down Operation. Unless otherwise specified, transformers shall be for step-down operation.

4.1.8.1 Transformers identified as generator step-up transformers shall be designed for step-up operation.

4.1.8.2 Transformers identified as system tie autotransformers (or transformers) shall be designed for either step-down operation, or step-up operation, or both, as specified by the user.

4.1.9 Tank or Enclosure Finish. Temperature limits and tests shall be based on the use of a nonmetallic pigment surface paint finish.

NOTE: Metallic flake paints, such as aluminum and zinc, have properties that increase the temperature rise of transformers except in direct sunlight.

4.2 Loading at Other Than Rated Conditions. ANSI/IEEE C57.91-1981 [29] and ANSI/IEEE C57.92-1981 [30] provide guidance for loading at other than rated conditions including

(1) Ambient temperatures higher or lower than the basis of rating

(2) Short-time loading in excess of nameplate kilovoltamperes with normal life expectancy

(3) Loading that results in reduced life expectancy.

NOTE: The guides are not standards. They provide the best known general information for loading of transformers under various conditions based on typical winding insulation systems, and are based upon the best engineering information available at the time of preparation. The guides discuss *limitations* of ancillary components other than windings that may limit the capability of transformers. When specified, ancillary components and other construction features (cables, bushings, tap changers, oil expansion space, etc) shall be supplied so that they in themselves will not limit the loading to less than the capability of the windings.

4.3 Unusual Service Conditions. Conditions other than those described in 4.1 are considered unusual service and when prevalent should be brought to the attention of those responsible for the design and application of the apparatus. Examples of some of these conditions are listed in 4.3.1.

4.3.1 Unusual Temperature and Altitude Conditions. Transformers may be used at higher or lower ambient temperatures or at higher altitudes than those specified in 4.1.3 but special consideration must be given to these applications. ANSI/IEEE C57.91-1981 [29] and ANSI/IEEE C57.92-1981 [30], provide information on recommended practices.

4.3.2 Insulation at High Altitude. The dielectric strength of transformers, which depend in whole or in part upon air for insulation, decreases as the altitude increases due to the effect of decreased air density. When specified, transformers shall be designed with larger air spacings using the correction factors of Table 1 to obtain adequate air dielectric strength at altitudes above 3300 ft (1000 m).

4.3.2.1 The insulation level at 3300 ft (1000 m) multiplied by the correction factor from

Table 1
Dielectric-Strength Correction-Factors for
Altitudes Greater than 3300 ft (1000 m)

Altitude		Altitude Correction Factor for Dielectric Strength
(ft)	(m)	
3300	1000	1.00
4000	1200	0.98
5000	1500	0.95
6000	1800	0.92
7000	2100	0.89
8000	2400	0.86
9000	2700	0.83
10 000	3000	0.80
12 000	3600	0.75
14 000	4200	0.70
15 000	4500	0.67

NOTE: An altitude of 15 000 ft (4500 m) is considered a maximum for transformers conforming to this standard.

Table 1 must be not less than the required insulation level at the required altitude.

4.3.2.2 Bushings with additional length or creep distance shall be furnished when necessary for operation above 3300 ft (1000 m).

4.3.3 Other Unusual Service Conditions

(1) Damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture, or dripping water, etc

(2) Abnormal vibration, tilting, shock, or seismic conditions

(3) Ambient temperatures outside of normal range

(4) Unusual transportation or storage conditions

(5) Unusual space limitations

(6) Unusual maintenance problems

(7) Unusual duty or frequency of operation, impact loading

(8) Unbalanced alternating-current voltages, or departure of alternating-current system voltages from a substantially sinusoidal wave form

(9) Loads involving abnormal harmonic currents such as those that may result where appreciable load currents are controlled by solid-state or similar devices. Such harmonic currents may cause excessive losses and abnormal heating

(10) Specified loading conditions (kilovoltampere outputs, winding load power factors, and winding voltages) associated with multiwinding transformers or autotransformers

(11) Excitation exceeding either 110% rated voltage or 110% rated volts per hertz

(12) Planned short circuits as a part of regular operating or relaying practice

(13) Unusual short-circuit application conditions differing from those described in Section 7 as *usual*

(14) Unusual voltage conditions including transient overvoltages, resonance, switching surges, etc, which may require special consideration in insulation design

(15) Unusually strong magnetic fields

NOTE: Solar magnetic disturbances may result in the flow of telluric currents in transformer neutrals.

(16) Large transformers with high-current isolated phase bus ducts.

NOTE: High-current isolated-phase bus ducts with accompanying strong magnetic fields may cause unanticipated circulating currents in transformer tanks and covers, and in the bus ducts. The losses resulting from these unanticipated currents may result in excessive temperatures when corrective measures are not included in the design.

(17) Unusually high nuclear radiation

(18) Parallel operation

NOTE: While parallel operation is not unusual, it is desirable that users advise the manufacturer when paralleling with other transformers is planned, and the identification of the transformers so involved.

5. Rating Data

5.1 Cooling Classes of Transformers

5.1.1 Liquid-Immersed Air-Cooled

(1) Liquid-immersed, self-cooled: class OA

(2) Liquid-immersed, self-cooled/forced air-cooled: class OA/FA

(3) Liquid-immersed, self-cooled/forced air-cooled/forced air-cooled: class QA/FA/FA

5.1.2 Liquid-Immersed Air-Cooled/Forced Liquid-Cooled

(1) Liquid-immersed, self-cooled/forced air-cooled/forced liquid-cooled: class OA/FA/FOA

(2) Liquid-immersed, self-cooled/forced air-forced liquid-cooled/forced air-forced liquid-cooled: class OA/FOA/FOA

5.1.3 Liquid-Immersed Water-Cooled

(1) Liquid-immersed, water-cooled: class OW

(2) Liquid-immersed, water-cooled/self-cooled: class OW/A

5.1.4 Liquid-Immersed Forced Liquid-Cooled

(1) Liquid-immersed, forced liquid-cooled with forced air-cooler: class FOA

(2) Liquid-immersed, forced liquid-cooled, water-cooled: class FOW

5.2 Frequency. Unless otherwise specified, transformers shall be designed for operation at a frequency of 60 Hz.

5.3 Phases

5.3.1 General. Transformers described in this standard are either single phase or three phase. Standard ratings are included in the product standards for particular types of transformers. When specified, other phase arrangements may be provided.

5.3.2 Scott- or T-Connected Transformers

5.3.2.1 These may be provided to accomplish three-phase or two-phase transformation, or vice versa; or to accomplish three-phase to three-phase transformation. Several arrangements commonly utilized to accomplish such transformations are described here.

5.3.2.2 Two single-phase transformers are assembled in an enclosure, permanently interconnected, with the following characteristics:

(1) Performance characteristics shall be based on bank operation of three-phase to two-phase transformation or vice versa.

(2) The single-phase transformers may not be identical or interchangeable.

5.3.2.3 An assembly utilizing a three-legged core with main and teaser coil assemblies located on the two outer legs, and with a center leg that has no coil assembly and provides a common magnetic circuit for the two outer legs.

5.3.2.4 When specified, two identical single-phase transformers shall be furnished.

(1) The kilovoltampere rating of each transformer shall be half the bank output required, and the rating of the individual units shall agree with the ratings established for single-phase transformers.

(2) Performance characteristics, except heating, shall be based on single-phase operation.

(3) The temperature rise shall be based on delivering the required bank capacity when transforming from three-phase to two-phase or from two-phase to three-phase, as specified.

(4) Transformers shall be interchangeable as main and teaser.

(5) Regulating taps are not usually supplied on transformers for three-phase to two-phase or from two-phase to three-phase service. When taps are required, the teaser tap shall be 86.6% of the mean regulating taps (*Mean*, as used here, refers to the midpoint of the range of regulating taps).

Table 2

Preferred Continuous Kilovoltampere Ratings

Single-Phase Transformers	Three-Phase Transformers
5	15
10	30
15	45
25	75
37.5	112.5
50	150
75	225
100	300
167	500
250	750
333	1000
500	1500
	2000
833	2500
1250	3750
1667	5000
2500	7500
3333	10 000
	12 000
5000	15 000
6667	20 000
8333	25 000
10 000	30 000
12 500	37 500
16 667	50 000
20 000	60 000
25 000	75 000
33 333	100 000

5.4 Rated Kilovoltamperes

5.4.1 General. The rated kilovoltamperes of a transformer shall be the output that can be delivered for the time specified at rated secondary voltage and rated frequency without exceeding the specified temperature-rise limitations under prescribed conditions of test, and within the limitations of established standards.

5.4.2 Preferred Continuous Kilovoltampere Ratings. Preferred continuous kilovoltampere ratings of single-phase and three-phase distribution and power transformers are based on an average winding rise by resistance of 65 °C in accordance with 5.11.1.1 and are listed in Table 2.

5.5 Voltage Ratings and Taps

5.5.1 General. Standard *nominal system voltages* and *maximum system voltages* are included in ANSI C84.1-1982 [16] and are listed in Table 3.

5.5.2 Voltage Ratings. The voltage ratings shall be at no load and based on the turn ratio.

5.5.3 Ratings of Transformer Taps. Whenever a transformer is provided with taps from a winding they shall be full capacity taps. When specified, other than full capacity taps may be

Table 3
Relationships of Nominal System Voltage to Maximum System
Voltage and Basic Lightning Impulse Insulation Levels (BIL)
for Systems 765 kV and Below

Application	Nominal System Voltage (kV rms)	Maximum System Voltage (from ANSI C84.1-1982 [16] and ANSI C92.2-1981 [18]) (kV rms)	Basic Lightning Impulse Insulation Levels (BIL) in Common Use (kV crest)		
Distribution	1.2		30		
	2.5		45		
	5.0		60		
	8.7		75		
	15.0		95		
	25.0		150	125	
	34.5		200	150	125
	46.0	48.3	250	200	
Power	69.0	72.5	350	250	
	1.2		45	30	
	2.5		60	45	
	5.0		75	60	
	8.7		95	75	
	15.0		110	95	
	25.0		150		
	34.5		200		
	46.0	48.3	250	200	
	69.0	72.5	350	250	
	115.0	121.0	550	450	350
	138.0	145.0	650	550	450
	161.0	169.0	750	650	550
	230.0	242.0	900	825	750 650
	345.0	362.0	1175	1050	900
	500.0	550.0	1675	1550	1425 1300
	765.0	800.0	2050	1925	1800

NOTES: (1) BIL values in bold type-face are listed as standard in one or more of ANSI C57.12.10-1977 [2], ANSI C57.12.20-1981 [4], ANSI C57.12.21-1980 [5], ANSI C57.12.22-1980 [6], ANSI C57.12.23-1985 [7], ANSI C57.12.24-1982 [8], ANSI C57.12.25-1981 [9], and ANSI C57.12.26-1986 [10].

(2) Single-phase distribution and power transformers and regulating transformers for voltage ratings between terminals of 8.7 kV and below are designed for both Y and Δ connection and are insulated for the test voltages corresponding to the Y connection, so that a single line of transformers serves for the Y and Δ applications. The test voltages for such transformers when operated Δ connected are, therefore, higher than needed for their voltage rating.

(3) For series windings in transformers, such as regulating transformers, the test values to ground shall be determined by the BIL of the series windings rather than by the rated voltage between terminals.

(4) Values listed as *nominal system voltage* in some cases (particularly voltages 34.5 kV and below) are applicable to other lesser voltages of approximately the same value. For example, 15 kV encompasses nominal system voltages of 14 440, 13 800, 13 200, 13 090, 12 600, 12 470, 12 000, 11 950, etc.

provided, and this shall be stated on the name-plate.

NOTE: Transformers with load tap-changing equipment commonly have reduced capacity taps for taps below rated winding voltage.

5.6 Connections. Standard connection arrangements are included in the standards for particular types of transformers, and in ANSI C57.12.70-1978 [14].

5.7 Polarity, Angular Displacement, and Terminal Markings

5.7.1 Polarity of Single-Phase Transformers. Single-phase transformers in sizes

200 kVA and below having high-voltage ratings 8660 V and below (winding voltage) shall have additive polarity. All other single-phase transformers shall have subtractive polarity.

5.7.2 Angular Displacement (Nominal) Between Voltages of Windings for Three-Phase Transformers. The angular displacement between high-voltage and low-voltage phase voltages of three-phase transformers with Δ — Δ or Y—Y connections shall be zero degrees.

The angular displacement between high-voltage and low-voltage phase voltages of three-phase transformers with Y— Δ or Δ —Y connections shall be 30°, with the low voltage lagging

the high voltage as shown in Fig 1. The angular displacement of a polyphase transformer is the time angle expressed in degrees between the line-to-neutral voltage of the reference identified high-voltage terminal H_1 and the line-to-neutral voltage of the corresponding identified low-voltage terminal X_1 .

NOTE: Additional phasor diagrams are described in ANSI C57.12.70-1978 [14].

5.7.3 Terminal Markings. Terminal markings shall be in accordance with ANSI C57.12.70-1978 [14].

5.8 Impedance. The impedance shall be referred to a temperature equal to the sum of the rated average winding temperature rise by resistance, plus 20 °C. Preferred standard values of impedance are included in the product standards for particular types of transformers.

5.9 Total Losses. The total losses of a transformer shall be the sum of the no-load losses and the load losses.

Power required for cooling fans, oil pumps, space heaters, and other ancillary equipment is not included in the total loss. When specified, loss data on such ancillary equipment shall be furnished.

The standard reference temperature for the load loss of power and distribution transformers shall be 85 °C.

5.10 Insulation Levels. Transformers shall be designed to provide coordinated low-frequency and impulse insulation levels on line terminals, and low-frequency insulation levels on neutral terminals. The primary identity of a set of coordinated levels shall be its basic lightning impulse insulation level (BIL).

The system voltage and the type of transformer may also influence insulation levels and test procedures. In this regard, power transformers are separated into two different classes as follows:

(1) Class I power transformers shall include power transformers with high-voltage windings of 69 kV and below.

(2) Class II power transformers shall include power transformers with high-voltage windings from 115 kV through 765 kV.

Table 3 lists BIL levels in current use at various system voltages; however, the use of any given BIL choice requires careful attention to proper insulation coordination and to accurate

assessment of the coefficient of grounding as outlined in 5.10.3.

Table 4 outlines coordinated insulation levels for distribution transformers and for Class I power transformers.

Table 5 outlines coordinated insulation levels for Class II power transformers.

Table 6 outlines minimum phase-to-phase insulation test levels for distribution transformers and for Class I power transformers.

Table 7 outlines minimum insulation levels for neutral terminals.

For test procedures, see ANSI/IEEE C57.12.90-1987 [25].

5.10.1 Line Terminals

5.10.1.1 Each line terminal of a winding shall be assigned a basic lightning impulse insulation level (BIL) from Table 3. The associated insulation levels shall be provided regardless of whether tests are or can be performed.

5.10.1.2 Windings, for system voltages 115 kV and above, shall be designed for the switching impulse insulation levels (BSL) associated with the assigned BIL. In addition, low-voltage windings shall be designed to withstand stresses resulting from switching impulse tests on the high-voltage winding regardless of whether or not such tests are specified.

5.10.1.3 Front-of-wave insulation levels and tests, when desired, must be specified; otherwise withstand insulation capability is not required.

5.10.1.4 Each wye-winding line terminal shall be specified as suitable or unsuitable for ungrounded neutral operation.

5.10.1.5 Windings that have no terminals brought out shall be capable of withstanding voltages resulting from the various tests that may be applied to other terminals corresponding to their respective BIL.

5.10.2 Neutral Terminals

5.10.2.1 A transformer winding designed for wye connection only and with the neutral end accessible external to the tank shall be assigned a low-frequency test level for the neutral terminal. This assigned low-frequency test level may be lower than that for the line terminal.

5.10.2.2 The assigned low-frequency test level, for neutral terminals that are solidly grounded directly or through a current transformer, shall be not less than that specified in Table 7, Column 2.

The assigned low-frequency test level for other cases shall be coordinated with voltages that can occur between the neutral and ground during