

American National Standard

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



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Foreword

(This foreword is not a part of ANSI/IEEE C57.12.00-1980, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.)

This revision of ANSI C57.12.00 includes several significant changes including general re-organization and rearrangement, incorporation of previous ANSI supplements concerning short-circuit requirements and temperature testing, incorporation of new technical information from the IEEE Transformers Committee, and removal of data relating to dry-type transformers. Dry-type transformer data is being placed in a new series of proposed American National Standards C57.12.01, C57.12.50, C57.12.51, C57.12.52, and C57.12.91.

The re-organization and other changes in C57.12.00-1980 are intended to update various transformer terminology words and phrases, reduce and simplify tabular data, and arrange the contents to improve the ease and efficiency of use. Metric equivalents have been added in accordance with ANSI policy.

This standard and ANSI C57.12.10-1976 recognize that the distinction between “power” and “distribution” transformers is no longer a fixed line at 500 kVA since many small power transformers are being built with distribution transformer construction features. While the line at 500 kVA still appears useful and necessary in determining certain standard requirements for tests, accessories, etc, both C57.12.00 and C57.12.10 provide the flexibility needed to allow users to obtain small power transformers with distribution transformer construction features.

Certain data from ANSI C57.12.00-1973 which related to loading at altitudes above 3300 feet (1000 meters) is felt to belong in loading guides, and is being temporarily placed in an appendix.

This American National Standards Institute document is a voluntary consensus standard. Its use may become mandatory only when required by a duly constituted legal authority, or when specified in a contractual relationship. To meet specialized needs and to allow innovation, specific changes are permissible when mutually determined by the user and the producer, provided such changes do not violate existing laws, and are considered technically adequate for the function intended.

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

This standard was prepared by a special task force of the Transformers Committee of the Institute of Electrical and Electronic Engineers, and following which, was approved by the IEEE Transformers Committee, the IEEE Standards Board and the ANSI C57 Committee for Distribution and Power Transformers and Regulators. The applicable rules and procedures of IEEE and ANSI for the preparation and approval of voluntary consensus standards were followed. These specify procedures for voting, review, and attempted reconciliation of dissenting viewpoints, a 60-day public review period, and final review and approval by the ANSI Board of Standards Review.

Suggestions for improvement gained in the use of this standard will be welcomed. They should be sent to the American National Standards Institute, Inc, 1430 Broadway, New York, NY 10018.

At the time it approved this standard, C57 had the following membership:

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The Transformers Committee of the IEEE Power Engineering Society of 1978 reviewed and approved this standard.

The Working Group which developed this standard had the following membership:

J. C. Dutton, *Chairman*

When this standard was approved December 14, 1978, the IEEE Standards Board had the following membership:

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Contents

SECTION	PAGE
1. Scope	7
2. Terminology	7
3. References	7
4. Service Conditions	9
4.1 Usual Service Conditions	9
4.2 Loading at Other Than Rated Conditions	10
4.3 Unusual Service Conditions	10
5. Rating Data	11
5.1 Cooling Classes of Transformers	11
5.2 Frequency	11
5.3 Phases	11
5.4 Rated kVA	12
5.5 Voltage Ratings and Taps	12
5.6 Connections	12
5.7 Polarity, Angular Displacement, and Terminal Markings	12
5.8 Impedance	13
5.9 Total Losses	13
5.10 Insulation Levels	13
5.11 Temperature Rise and Loading Conditions	19
5.12 Nameplates	19
6. Construction	24
6.1 Bushings	24
6.2 Transformer Accessories	24
6.3 Bushing Current Transformers	24
6.4 Thermometer Wells	24
6.5 Tank Pressure Requirements	24
6.6 Liquid Insulation System	24
6.7 Grounding	25
7. Short Circuit Characteristics	25
7.1 Short Circuit Requirements	25
7.2 Components	28
7.3 Base kVA	28
7.4 Calculation of Winding Temperature During a Short Circuit	29
8. Testing and Calculations	31
8.1 General	31
8.2 Routine, Design, and Other Tests for Transformers	31
8.3 Additional Routine Tests on Transformers with Load-Tap-Changing, or Regulating Transformers	31
8.4 Calculations	31
9. Tolerances	31
9.1 Tolerances for Ratio	32
9.2 Tolerances for Impedance	32
9.3 Tolerances for Losses	32
10. Connection of Transformers for Shipment	32

FIGURES	PAGE
Fig 1 Phase Relation of Terminal Designations for Three-Phase Transformers	13
Fig 2 Designation of Voltage Ratings of Three-Phase Windings (Schematic Representation) ...	20
Fig 3 Dimensions of Thermometer Well	24

TABLES

Table 1 Dielectric-Strength Correction-Factors for Altitudes Greater than 3300 ft (1000 m)	10
Table 2 Preferred Continuous kVA Ratings	12
Table 3 Relationships of Nominal System Voltage to Maximum System Voltage and Basic Lightning Impulse Insulation Levels (BILs) for Systems 1100 kV and Below	14
Table 4 Interrelationships of Dielectric Insulation Levels for Transformers Used on Systems with BILs 2425 kV and Below	15
Table 5 Minimum Insulation Levels at Neutral	16
Table 6 Minimum Phase-to-Phase Insulation Levels for Three-Phase Power Transformers	19
Table 7 Nameplate Information	22
Table 8 Electrical Characteristics of Transformer Bushings	23
Table 9 Distribution Transformer Short-Circuit Withstand Capability	26
Table 10 Values of K	27
Table 11 Short-Circuit Apparent Power of the System to be Used Unless Otherwise Specified	27
Table 12 Subtransient Reactance of Three Phase Synchronous Machine	28
Table 13 Base Current Calculation Factors	30
Table 14 Routine, Design, and Other Tests for Liquid-Immersed Transformers	30
Table 15 Additional Tests	31
Table 16 Tolerances for Single-Phase and Three-Phase Transformer Losses	32

APPENDIXES

Appendix A Unusual Temperature and Altitude Conditions	33
Appendix A1 Unusual Temperatures and Altitude Service Conditions	33
Appendix A2 Effect of Altitude on Temperature Rise	33
Appendix A3 Operation at Rated kVA	33
Appendix A4 Operation at Less than Rated kVA	33
Appendix B Specification Forms	34

APPENDIX TABLES

Table A1 Maximum Allowable Average Temperature of Cooling Air for Carrying Rated kVA	33
Table A2 Rated kVA Correction Factors for Altitudes Greater than 3300 ft (1000 m)	33

An American National Standard

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

1. Scope

1.1 This standard is intended as 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.

1.2 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.

1.3 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

1.4 When this standard is used on a mandatory basis, the words *shall* and *must* indicates mandatory requirements; and the words *should* and *may* refer to matters which 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 shall apply.

Other electrical terms are defined in ANSI/IEEE Std 100-1977, Dictionary of Electrical and Electronics Terms.

3. References

3.1 **Standards References.** When the following ANSI standards and guides referred to in this standard are superseded by a revision approved by the American National Standards Institute, the latest revision shall apply.

ANSI B1.1-1974, Unified Inch Screw Threads¹

ANSI B2.1-1968, Pipe Threads (except Dryseal)

ANSI C57.12.10-1977, 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

ANSI C57.12.10a-1978, (supplement to ANSI C57.12.10-1977)

ANSI C57.12.20-1974, Requirements for Overhead-type Distribution Transformers, 67 000 Volts and Below; 500 kVA and Smaller

ANSI C57.12.20a-1978 (supplement to ANSI C57.12.20-1974)

ANSI C57.12.21-1980, 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; 168 kVA and Smaller.

¹ ANSI documents are available from The American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

ANSI C57.12.22-1980, 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

ANSI C57.12.23-1978, Requirements for Underground-Type Single-Phase Distribution Transformers, with Separable Insulated High-Voltage Connectors, High-Voltage 24 940 GrdY/14 400 Volts and Below, Low-Voltage 240/120; 100 kVA and Smaller

ANSI C57.12.24-1978, 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

ANSI C57.12.25-1975, Requirements for Pad-Mounted Compartmental-Type Single-Phase Distribution Transformers with Separable Insulated High-Voltage Connectors; High-Voltage 24 940 GrdY/14 400 Volts and Below; Low-Voltage 240/120; 167 kVA and Smaller

ANSI C57.12.26-1975, 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

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

ANSI C57.12.40-1975, Requirements for Secondary Network Transformers, Subway and Vault Types, (liquid-immersed)

ANSI C57.12.70-1978, Terminal Markings and Connections for Distribution and Power Transformers

ANSI C57.91-1974, Guide for Loading Mineral Oil-Immersed Overhead-Type Distribution Transformers with 55°C or 65°C Average Winding Rise

ANSI C57.92-1962, Guide for Loading Oil-Immersed Distribution and Power Transformers (appendix to ANSI C57.12 Standards)

ANSI C62.2-1969, Guide for Application of Valve-Type Lightning Arresters for Alternating-Current Systems

ANSI C84.1-1977, Voltage Ratings for Electric Power Systems and Equipment (60 Hz)

ANSI C92.1-1971, (R1978), Voltage Values for Preferred Transient Insulation Levels

ANSI C92.2-1978, Preferred Voltage Ratings for Alternating-Current Electrical Systems and Equipment Operating at Voltages above 230 kV Nominal

ANSI/ASME Boiler and Pressure Vessel Code (BPV), 1977 Edition

ANSI/ASTM D117-1978, Standard Methods of Testing Electrical Insulating Oils

ANSI/ASTM D1933-1964 (R1974), Specifications for Nitrogen Gas as an Electrical Insulating Material

ANSI/ASTM D3487-1979, Specifications for Mineral Insulating Oil Used in Electrical Apparatus

ANSI/CGA-VI-1977, Compressed Gas Cylinder Valve Outlet and Inlet Connections

ANSI/IEEE C57.12.11-1980, Guide for Installation of Oil-Immersed Transformers, 10 MVA and Larger, 69 kV to 287 kV

ANSI/IEEE C57.12.12-1980, Guide for Installation and Maintenance of Extra-High-Voltage Power Transformers (Appendix)

ANSI/IEEE C57.12.80-1978, Terminology for Power and Distribution Transformers

ANSI/IEEE C57.12.90-1980, Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and Guide for Short-Circuit Testing of Distribution and Power Transformers.

ANSI/IEEE C57.13-1978, Requirements for Instrument Transformers

ANSI/IEEE C57.98-1968, Guide for Transformer Impulse Tests (Appendix to C57.12.90-1968)

ANSI/IEEE C57.104, Guide for the Detection and Determination of Generated Gases in Oil-Immersed Transformers and their Relation to the Serviceability of the Equipment

ANSI/IEEE C57.105-1978, Guide for Application of Transformer Connections in Three-Phase Distribution Systems

ANSI/IEEE C57.106-1977, Guide for Acceptance and Maintenance of Insulating Oil in Equipment

ANSI/IEEE Std 100-1977, Dictionary of Electrical and Electronics Terms

ANSI/IEEE Std 28-1974, Standard Surge Arresters for AC Power Circuits

IEEE Std 4-1978, Standard Techniques for High-Voltage Testing

ANSI/IEEE Std 21-1976, General Requirements and Test Procedures for Outdoor Apparatus Bushings

ANSI/IEEE Std 24-1977, Standard Electrical, Dimensional and Related Requirements for Outdoor Apparatus Bushings

ANSI/IEEE Std 315-1975, Graphic Symbols for Electrical and Electronics Diagrams

IEEE Std 32-1972, (R1978), Requirements, Terminology, and Test Procedure for Neutral Grounding Devices

IEEE Std 76-1974, Guide for Acceptance and Maintenance of Transformer Askarel in Equipment

IEEE Std 262B-1977, Trial-Use Standard Test Requirements for Dielectric, Power Transformers for Operation on Effectively Grounded Systems, 345 kV and Above

3.2 Applicable Document in Preparation²

4. Service Conditions

4.1 Usual Service Conditions

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

4.1.2 Temperature

4.1.2.1 If 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.

²When the following documents are completed, approved, and published, they will become part of this listing.

(1) Guidelines for Handling and Disposal of Capacitor and Transformer-Grade Askarels Containing Polychlorinated Biphenyls.

(2) Transformer Through Fault Current Duration Guide.

(3) Techniques for Switching Impulse Testing (ANSI C68.1).

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 If 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 f (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.

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.

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 kVA 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.

4.1.6.2 The maximum continuous transformer operating voltage should not exceed the levels specified in ANSI C84.1-1977.

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 C92.2-1978)

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 non-metallic pigment surface paint finish.

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

4.2 Loading at Other Than Rated Conditions. ANSI C57.91-1974 and ANSI C57.92-1962 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 kVA 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 which 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 such 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 below.

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 C57.91-1974, ANSI C57.92-1962

and Appendix A 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 f (1000 m).

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

Altitude (feet)	Altitude (meters)	Altitude Correction Factor for Dielectric Strength
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.

4.3.2.1 The insulation level at 3300 f (1000 m) multiplied by the correction factor from 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 f (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 systems voltages from a substantially sinusoidal wave form

(9) Loads involving abnormal harmonic currents such as those which 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 (kVA outputs and power factors) associated with multi-winding 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 as *usual* in Section 7

(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 if 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 if 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 OA/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-cooled/forced-liquid-cooled/forced-air-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 kVA rating of each transformer shall be one 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.)

5.4 Rated kVA

5.4.1 General. The rated kVA 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 kVA Ratings. Preferred continuous kVA 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 C84.1-1977, 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 provided, and this shall be stated on the nameplate.

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.

5.7 Polarity, Angular Displacement, and Terminal Markings

Table 2
Preferred Continuous kVA 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

5.7.1 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.