ANSI/IEEE C57.12.80-1978
(Reaffirmed 1986)
(Revision of C57.12.80-1958)

An American National Standard

IEEE Standard Terminology for Power and Distribution Transformers

Sponsor
Transformers Committee of the IEEE Power Engineering Society

Approved June 3, 1976
Reaffirmed June 19, 1986
Reaffirmed May 1, 1992
IEEE Standards Board

Secretariat

National Electric Manufacturers Association
Edison Electric Institute
Institute of Electrical and Electronics Engineers

Approved April 7, 1977
Reaffirmed December 2, 1992
American National Standards Institute

Published by
The Institute of Electrical and Electronics Engineers, Inc
345 East 47th Street, New York, NY 10017

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtained the latest editions.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Foreword

(This Foreword is not a part of ANSI/IEEE C57.12.80-1978, American National Standard Terminology for Power and Distribution Transformers.)

This revision of ANSI C57.12.80 incorporates a substantial number of changes since the last major revision occurred in 1958. In addition to providing many new terms, some of the more significant changes which have been introduced include:

1) Change in organization structure, as shown in the table of contents
2) Addition of reference standards
3) A section of Transformer Definitions considering general and specialized types and classified by size, insulation, and location. These are cross-referenced to other sections where appropriate.
4) Grouping of terms relating to rating data in a separate section
5) A new section relating to insulation terms. This includes numerous terms concerning the new insulation temperature class ratings, including identification by temperature index, and new insulation coordination terms.
6) A new section on Testing
7) Expansion of terms concerning construction and location in a separate section
8) Addition of a section of Terminology for Specialized Types of Transformers
9) Addition of a number of system terms applicable to transformers.

One of the significant goals in this new revision was to also provide input for revision of IEEE Std 100-1972 (ANSI C42.100-1972), IEEE Standard Dictionary of Electrical and Electronics Terms. An effort has been made to use common terms whenever possible.

The IEEE Transformers Committee of the IEEE Power Engineering Society provided many very helpful questions and comments, and the IEEE Standards Board was particularly helpful in furnishing a broad perspective and many constructive inputs.

Suggestions for improvement of this standard will be welcome. They should be sent to the

American National Standards Institute
1430 Broadway
New York, NY 10018

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

H. D. Lewis, *Chair*
C. R. Wilmore, *Secretary*

Organization Represented	*Name of Representative*
Bonneville Power Administration	George W. Iliff
Electric Light and Power Group	R. P. Bast
	I. O. Berkhan
	I. H. Koponen
	J. P. Markey *(Alt)*
	P. H. Philippidis
	B. F. Smith
Furnace Equipment Manufacturers Association	
Institute of Electrical and Electronics Engineers	S. Bennon
	W. P. Burt
	J. C. Dutton
	D. C. Johnson *(Alt)*
	L. W. Long

	D. E. Massey
Naval Facilities Engineering Command	Leonard W. Johnson
National Electrical Manufacturers Association	L. C. Aicher
	W. R. Courtade
	J. D. Douglass
	W. C. Kendall
	H. D. Lewis
	G. W. MayaIl *(Alt)*
	W. J. McNutt
	Norman M. Neagle *(Alt)*
	R. L. Schwab
	R. E. Uptegraff, Jr
	G. C. Wilburn
Rural Electrification Administration	J. C. Arnold, Jr
Tennessee Valley Authority	L. R. Smith
Underwriters Laboratories	W. A. Farquhar *(Alt)*
	E. J. Huber
U.S. Bureau of Reclamation	R. H. Richardson

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

J. C. Dutton, *Chair*
C. C. Honey

The Transformers Committee of the IEEE Power Engineering Society of 1976 reviewed and approved this standard.

When this standard was approved June 3, 1976, the IEEE Standards Board had the following membership:

CLAUSE PAGE

An American National Standard

IEEE Standard Terminology for Power and Distribution Transformers

1. Scope and Reference Standards

1.1 Scope

This standard is a compilation of terminology and definitions primarily related to electrical transformers and associated apparatus included within the scope of ANSI Committee C57, Transformers, Regulators, and Reactors. It also includes similar data relating to power systems and insulation which is commonly involved in transformer technology.

1.2 Reference Standards

[1] ANSI/IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms.

[2] Glossary of ASTM Definitions, 1986.

[3] ASTM D17111-1983, Standard Definitions of Terms Relating to Electrical Insulation.

[4] ASTM D2864-1984, Standard Definitions of Terms Relating to Electrical Insulating Liquids and Gases.[1]

2. Transformer Definitions

2.1 General

2.1.1 Transformer

A static electric device consisting of a winding, or two or more coupled windings, with or without a magnetic core, for introducing mutual coupling between electric circuits.

NOTE — Transformers are extensively used in electric power systems to transfer power by electromagnetic induction between circuits at the same frequency, usually with changed values of voltage and current.

[1]ASTM documents are available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa., 19103.

2.1.2 Step-Down Transformer

A transformer in which the power transfer is from a higher voltage source circuit to a lower voltage circuit.

2.1.3 Step-Up Transformer

A transformer in which the power transfer is from a lower voltage source circuit to a higher voltage circuit.

2.1.4 Autotransformer

A transformer in which at least two windings have a common section.

2.1.5 Constant-Voltage Transformer

A transformer that maintains an approximately constant voltage ratio over the range from zero to rated output.

2.1.6 Constant-Current Transformer

A transformer that automatically maintains an approximately constant current in its secondary circuit under varying conditions of load impedance when supplied from an approximately constant-voltage source.

NOTE — Additional related terms defined in 7.5.

2.2 Transformers — Specialized Types

2.2.1 Load-Tap-Changing Transformer

A transformer used to vary the voltage, or the phase angle, or both, of a regulated circuit in steps by means of a device that connects different taps of tapped winding(s) without interrupting the load.

2.2.2 Regulating Transformer

A transformer used to vary the voltage, or the phase angle, or both, of an output circuit (referred to as the "regulated circuit") controlling the output within specified limits, and compensating for fluctuations of load and input voltage (and phase angle, when involved) within specified limits.

2.2.3 Phase-Shifting Transformer

A transformer that advances or retards the voltage phase-angle relationship of one circuit with respect to another.

NOTES:

1 — The terms "advance" and "retard" describe the electrical angular position of the load voltage with respect to the source voltage.

2 — If the load voltage reaches its positive maximum sooner than the source voltage, this is an "advance" position.

3 — Conversely, if the load voltage reaches its positive maximum later than the source voltage, this is a "retard" position.

4 — Additional related terms defined in 7.2.

2.2.4 Furnace Transformer

A transformer that is designed to be connected to an electric arc furnace.

2.2.5 Rectifier Transformer

A transformer that operates at the fundamental frequency of an alternating-current system and designated to have one or more output windings conductively connected to the main electrodes of a rectifier.

NOTE — Additional related terms defined in 7.6.

2.2.6 Scott or T-Connected Transformer

An assembly used to transfer energy from a three-phase circuit to a two-phase circuit, or vice versa; or from a three-phase circuit to another three-phase circuit. The assembly consists of a main transformer with a tap at its midpoint connected directly between two of the phase wires of a three-phase circuit, and of a teaser transformer connected between the mid-tap of the main transformer and a third phase wire of the three-phase circuit. The other windings of the transformers may be connected to provide either a two-phase or a three-phase output. Alternatively, this may be accomplished with an assembly utilizing a three-legged core with main and teaser coil assemblies located on the two outer legs, and with a center leg which has no coil assembly and provides a common magnetic circuit for the two outer legs.

NOTE — Additional related terms defined in 7.3.

2.2.7 Grounding Transformer

A transformer intended primarily to provide a neutral point for grounding purposes.

NOTES:

1 — It may be provided with a Δ winding in which resistors or reactors are connected. See also 6.3.5 concerning "stabilizing windings."

2 — Additional related terms defined in 7.4.

2.2.8 Instrument Transformer

A transformer which is intended to reproduce in its secondary circuit, in a definite and known proportion, the current or voltage of its primary circuit, with the phase relations and waveform substantially preserved.

NOTE — Additional related terms defined in 7.8.

2.2.9 Specialty Transformer

A transformer generally intended to supply electric power for control, machine tool, Class 2, signaling, ignition, luminous-tube, cold-cathode lighting, series street-lighting, low-voltage general purpose, and similar applications.

NOTE — Additional related terms defined in 7.9.

2.2.10 Other Electromagnetic Inductive Apparatus

2.2.10.1 Step-Voltage Regulator.

A regulating transformer in which the voltage of the regulated circuit is controlled in steps by means of taps and without interrupting the load.

NOTE — Such units are generally 833 kVA (output) and below, single-phase; or 2500 kVA (output) and below, three-phase.

2.2.10.2 Induction Voltage Regulator.

A regulating transformer having a primary winding in shunt and a secondary winding in series with a circuit, for gradually adjusting the voltage or the phase relation, or both, of the circuit by changing the relative magnetic coupling of the exciting (primary) and series (secondary) windings.

2.2.10.3 Variable-Voltage Transformer.

An autotransformer in which the output voltage can be changed (essentially from turn to turn) by means of a movable contact device sliding on the shunt winding turns.

2.3 Transformers — Classified by Size, Insulation, and Location

2.3.1 Size

2.3.1.1 Distribution Transformer.

A transformer for transferring electrical energy from a primary distribution circuit to a secondary distribution circuit or consumer's service circuit.

NOTE — Distribution transformers are usually rated in the order of 5—500 kVA.

2.3.1.2 Power Transformer.

A transformer which transfers electric energy in any part of the circuit between the generator and the distribution primary circuits.

2.3.2 Insulation

2.3.2.1 Liquid-Immersed Transformer.

A transformer in which the core and coils are immersed in an insulating liquid.

2.3.2.2 Dry-Type Transformer.

A transformer in which the core and coils are in a gaseous or dry compound insulating medium.

NOTE — Additional related terms defined in 7.10.

2.3.3 Location

2.3.3.1 Indoor Transformer.

A transformer which, because of its construction, must be protected from the weather.

2.3.3.2 Outdoor Transformer.

A transformer of weather-resistant construction suitable for service without additional protection from the weather.

2.3.3.3 Pole-Type Transformer.

A transformer which is suitable for mounting on a pole or similar structure.

2.3.3.4 Station-Type Transformer.

A transformer designed for installation in a station or substation.

2.3.3.5 Unit-Substation Transformer.

A transformer which is mechanically and electrically connected to, and coordinated in design with, one or more switchgear or motor-control assemblies, or combinations thereof.

NOTE — Additional related terms defined in 7.1.

2.3.3.6 Submersible Transformer.

A transformer so constructed as to be successfully operable when submerged in water under predetermined conditions of pressure and time.

2.3.3.7 Subway Transformer.

A submersible-type distribution transformer suitable for installation in an underground vault.

2.3.3.8 Vault-Type Transformer.

A transformer that is so constructed as to be suitable for occasional submerged operation in water under specified conditions of time and external pressure.

2.3.3.9 Network Transformer.

A transformer designed for use in a vault to feed a variable capacity system of interconnected secondaries.

NOTE — A network transformer may be of the submersible or of the vault type. It usually, but not always, has provision for attaching a network protector.

2.3.3.10 Sub-Surface Transformer.

A transformer utilized as part of an underground distribution system, connected below ground to high-voltage and low-voltage cables, and located below the surface of the ground.

2.3.3.11 Pad-Mounted Transformer.

An outdoor transformer utilized as part of an underground distribution system, with enclosed compartment(s) for high-voltage and low-voltage cables entering from below, and mounted on a foundation pad.

2.3.3.12 Direct-Buried Transformer.

A transformer designed to be buried in the earth with connecting cables.

3. Rating Data

3.1 Performance Characteristics

Those characteristics (such as impedance, losses, dielectric test levels, temperature rise, sound level, etc) which describe the performance of the equipment under specified conditions of operation.

3.2 Duty

A requirement of service that defines the degree of regularity of the load.

3.2.1 Continuous Duty

A duty that demands operation at a substantially constant load for an indefinitely long time.

3.2.2 Short-Time Duty

A duty that demands operation at a substantially constant load for a short and definitely specified time.

3.2.3 Intermittent Duty

A requirement of service that demands operation for alternate periods of (a) load and no load; or (b) load and rest; or (c) load, no load, and rest; such alternate intervals being definitely specified.

3.2.4 Periodic Duty

A type of intermittent duty in which the load conditions are regularly recurrent.

3.2.5 Varying Duty

A requirement of service that demands operation at loads, and for periods of time, both of which may be subject to wide variation.

3.3 Rating

3.3.1 Rating of a Transformer

The rating of a transformer consists of a volt—ampere output together with any other characteristics, such as voltage, current, frequency, power factor, and temperature rise, assigned to it by the manufacturer. It is regarded as a rating associated with an output which can be taken from the transformer under prescribed conditions and limitations of established standards.

3.3.2 Continuous Rating

The maximum constant load that can be carried continuously without exceeding established temperature-rise limitations under prescribed conditions.

3.3.3 Short-Time Rating

Defines the maximum constant load that can be carried for a specified short time without exceeding established temperature-rise limitations, under prescribed conditions.

3.4 kVA Rating

3.4.1 Rated kVA of a Transformer

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.

3.4.2 Rated kVA Tap (in a Transformer)

A tap through which the transformer can deliver its rated kVA output without exceeding the specified temperature rise.

3.4.3 Reduced kVA Tap (in a Transformer)

A tap through which the transformer can deliver only an output less than rated kVA without exceeding the specified temperature rise. The current is usually that of the rated kVA tap.

3.4.4 Equivalent Two-Winding kVA Rating

The equivalent two-winding rating of multi-winding transformers or autotransformers is one-half the sum of the kVA ratings of all windings.

NOTE — It is customary to base this equivalent two winding kVA rating on the self-cooled rating of the transformer.

3.4.5 Load (Output)

The apparent power in megavolt-amperes, kilovolt-amperes, or volt-amperes that may be transferred by the transformer.

3.5 Voltage and Current Rating

3.5.1 Rated Voltage of a Winding

The voltage to which operating and performance characteristics are referred.

3.5.2 Rated Primary Voltage (Constant-Voltage Transformer)

The voltage calculated from the rated secondary voltage by turn ratio.

NOTES:

1 — See turn ratio of a transformer and its note, for the definition of the turn ratio to be used.

2 — In the case of a multiwinding transformer, the rated voltage of any other winding is obtained in a similar manner.

3.5.3 Rated Secondary Voltage (Constant Voltage Transformer)

The voltage at which the transformer is designed to deliver rated kVA and to which operating and performance characteristics are referred.

3.5.4 Rated Secondary Current (Constant Voltage Transformer)

The secondary current obtained by dividing the rated kVA by the rated secondary voltage, in kV.

NOTE — The relationship above applies directly for single-phase transformers, but requires additional consideration of the connections involved in three-phase transformers.

3.6 Polarity, Angular Displacement, and Phase Sequence

3.6.1 Lead Polarity

A designation of the relative instantaneous direction of the currents in the leads of a transformer. Primary and secondary leads are said to have the same polarity when, at a given instant, the current enters the primary lead in question and leaves the secondary lead in question in the same direction as though the two leads formed a continuous circuit.

The lead polarity of a single-phase distribution or power transformer may be either additive or subtractive. If adjacent leads from each of the two windings in question are connected together and voltage applied to one of the windings: (1) the lead polarity is additive if the voltage across the other two leads of the windings in question is greater than that of the higher voltage winding alone; (2) the lead polarity is subtractive if the voltage across the other two leads of the windings in question is less than that of the higher voltage winding alone.

The polarity of a polyphase transformer is fixed by the internal connections between phases; it is usually designated by means of a phasor diagram showing the angular displacements of the voltages in the windings and a sketch showing the marking of the leads. The phasors of the phasor diagrams represent induced voltages. The standard rotation of phasors is counterclockwise.

3.6.2 Angular Displacement of a Polyphase Transformer

The phase angle expressed in degrees between the line-to-neutral voltage of the reference identified high-voltage terminal and the line-to-neutral voltage of the corresponding identified low-voltage terminal.

NOTE — The preferred connection and arrangement of terminal markings for polyphase transformers are those which have the smallest possible phase-angle displacements and are measured in a clockwise direction from the line-to-neutral voltage of the reference identified high-voltage terminal. Thus standard three-phase transformers have angular displacements of either zero or 30 degrees.

3.6.3 Definition of Phase Sequence

The order in which the voltages successively reach their positive maximum values.

3.6.4 Direction of Rotation of Phasors

Phasor diagrams should be drawn so that an advance in phase of one phasor with respect to another is in the counterclockwise direction. In the following figure, phasor 1 is 120 degrees in advance of phasor 2, and the phase sequence is 1, 2, 3.

3.7 Losses, Excitation Current, and Impedance Voltage

3.7.1 Efficiency

The ratio of the useful power output to the total power input.

3.7.2 Losses

3.7.2.1 Total Losses (transformer or regulator)

The sum of the no-load and load losses, excluding losses due to accessories.

3.7.2.2 No-Load (Excitation) Losses.

Those losses which are incident to the excitation of the transformer. No-load (excitation) losses include core loss, dielectric loss, conductor loss in the winding due to exciting current, and conductor loss due to circulating current in parallel windings. These losses change with the excitation voltage.

3.7.2.3 Load Losses.

Those losses which are incident to the carrying of a specified load. Load losses include I^2R loss in the windings due to load and eddy currents; stray loss due to leakage fluxes in the windings, core clamps, and other parts, and the loss due to circulating currents (if any) in parallel windings, or in parallel winding strands.

3.7.2.4 Core Loss.

The power dissipated in a magnetic core subjected to a time-varying magnetizing force. Core loss includes hysteresis and eddy-current losses of the core.

3.7.3 Excitation Current (No-Load Current)

The current which flows in any winding used to excite the transformer when all other windings are open-circuited. It is usually expressed in percent of the rated current of the winding in which it is measured.

3.7.4 Impedance

3.7.4.1 Impedance Voltage of a Transformer.

The voltage required to circulate rated current through one of two specified windings of a transformer when the other winding is short-circuited, with the windings connected as for rated voltage operation.

NOTE — It is usually expressed in per unit, or percent, of the rated voltage of the winding in which the voltage is measured.

3.7.4.2 Resistance Drop.

The component of the impedance voltage drop in phase with the current.

3.7.4.3 Reactance Drop.

The component of the impedance voltage drop in quadrature with the current.

3.7.4.4 Impedance Drop.

The phasor sum of the resistance voltage drop and the reactance voltage drop.

NOTE — For transformers, the resistance drop, the reactance drop, and the impedance drop are, respectively, the sum of the primary and secondary drops reduced to the same terms. They are determined from the load-loss measurements and are usually expressed in per unit, or in percent.

3.7.4.5 Impedance kVA (Rated).

The kVA measured in the excited winding with the other winding short-circuited and with sufficient voltage applied to the excited winding to cause rated current to flow in the winding.

3.7.4.6 Zero-Sequence Impedance.

An impedance voltage measured between a set of primary terminals and one or more sets of secondary terminals when a single-phase voltage source is applied between the three primary terminals connected together and the primary neutral, with the secondary line terminals shorted together and connected to their neutral (if one exists).

NOTES:

1 — For two-winding transformers, the other winding is short-circuited. For multiwinding transformers, several tests are required, and the zero-sequence impedance characteristics are represented by an impedance network.

2 — In some transformers, the test must be made at a voltage lower than that required to circulate rated current in order to avoid magnetic core saturation or to avoid excessive current in other windings.

3 — Zero-sequence impedances are usually expressed in per unit or percent on a suitable voltage and kVA base.

3.7.4.7 Interlacing Impedance of Scott-Connected Transformer.

See 7.3.4.

3.8 Ratio and Regulation

3.8.1 Turn Ratio of a Transformer

The ratio of the number of turns in a higher voltage winding to that in a lower voltage winding.

NOTE — In the case of a constant-voltage transformer having taps for changing its voltage ratio, the nominal turn ratio is based on the number of turns corresponding to the normal rated voltage of the respective windings, to which operating and performance characteristics are referred.

3.8.2 Voltage Ratio of a Transformer

The ratio of the rms terminal voltage of a higher voltage winding to the rms terminal voltage of a lower voltage winding, under specified conditions of the load.

3.8.3 Voltage Regulation of a Constant-Voltage Transformer

The change in output (secondary) voltage which occurs when the load (at a specified power factor) is reduced from rated value to zero, with the primary impressed terminal voltage maintained constant.

NOTE — In case of multiwinding transformers, the loads on all windings, at specified power factors, are to be reduced from rated kVA to zero simultaneously.

The regulation may be expressed in per unit, or percent, on the base of the rated output (secondary) voltage at full load.

4. Insulation

4.1 Major Insulation

4.1.1 Liquid-Immersed Transformer

See 2.3.2.1.

4.1.2 Dry-Type Transformer

See 2.3.2.2.

4.2 Liquid Insulation

4.2.1 Oil

The term “oil” includes the following insulating and cooling liquids: Type I Mineral Oil (uninhibited oil), Type II Mineral Oil (inhibited oil), and Askarel.

4.2.1.1 Uninhibited Oil.

Mineral transformer oil to which no synthetic oxidation inhibitor has been added.

4.2.1.2 Inhibited Oil.

Mineral transformer oil to which a synthetic oxidation inhibitor has been added.

4.2.1.3 Askarel.

A generic term for a group of synthetic, fire-resistant, chlorinated, aromatic hydrocarbons used as electrical insulating liquids. They have a property under arcing conditions such that any gases produced will consist predominantly of noncombustible hydrogen chloride with lesser amounts of combustible gases.

4.3 Insulation Coordination Terms

4.3.1 Coordination of Insulation (Insulation Coordination.)

The process of correlating the insulation strengths of electrical equipment with expected overvoltages and with the characteristics of surge protective devices.

4.3.2 Withstand Voltage

The voltage that electric equipment is capable of withstanding without failure or disruptive discharge when tested under specified conditions.

4.3.3 Insulation Level

An insulation strength expressed in terms of a withstand voltage.

4.3.4 Transient Insulation Level (TIL)

An insulation level expressed in kilovolts of the crest value of the withstand voltage for a specified transient wave shape; that is, lightning or switching impulse.

4.3.5 Lightning Impulse Insulation Level

An insulation level expressed in kilovolts of the crest value of a lightning impulse withstand voltage.

4.3.6 Switching Impulse Insulation Level

An insulation level expressed in kilovolts of the crest value of a switching impulse withstand voltage.

4.3.7 Basic Lightning Impulse Insulation Level (BIL)

A specific insulation level expressed in kilovolts of the crest value of a standard lightning impulse.

4.3.8 Basic Switching Impulse Insulation Level (BSL)

A specific insulation level expressed in kilovolts of the crest value of a standard switching impulse.

4.3.9 Standard Lightning Impulse

An impulse that rises to crest value of voltage in 1.2 μs (virtual time) and drops to 0.5 crest value of voltage in 50 μs (virtual time), both times being measured from the same origin and in accordance with established standards of impulse testing techniques. It is described as a 1.2/50 μs impulse. (See ANSI/IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing.)

NOTE — The virtual value for the duration of the wavefront is 1.67 times the time taken by the voltage to increase from 30 percent to 90 percent of its crest value. The origin from which time is measured is the intersection with the zero axis of a straight line drawn through points on the front of the voltage wave at 30 percent and 90 percent crest value.

4.3.10 Standard Switching Impulse

A full impulse having a front time of 250 μs and a time to half value of 2500 μs. It is described as a 250/2500 impulse.

NOTES:

It is recognized that some apparatus standards may have to use a modified wave shape where practical test considerations or particular dielectric strength characteristics make some modification imperative. Transformers, for example, use a modified switching impulse wave with the following characteristics:

1- Time to crest greater than 100 μs.

2- Exceeds 90 percent of crest value for at least 200 μs.

3- Time to first voltage zero on tail not less than 1000 μs, except where core saturation causes the tail to become shorter.

(See 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.)

4.3.11 Lightning Impulse Protection Level (of a Protective Device)

The maximum lightning impulse voltage expected at the terminals of a surge protective device under specified conditions of operation.

4.3.12 Switching Impulse Protection Level (of a Protective Device)

The maximum switching impulse expected at the terminals of a surge protective device under specified conditions of operation.

4.3.13 Internal Insulation

The insulation that is not directly exposed to atmospheric conditions.

4.3.14 External Insulation

The external insulating surfaces and the surrounding air.

NOTE — The dielectric strength of external insulation is dependent on atmospheric conditions.

4.3.15 Self-Restoring Insulation

Insulation which completely recovers its insulating properties after a disruptive discharge caused by the application of a test voltage; insulation of this kind is generally, but not necessarily, external insulation.

4.3.16 Non-Self-Restoring Insulation

An insulation which loses its insulating properties or does not recover them completely, after a disruptive discharge caused by the application of a test voltage; insulation of this kind is generally, but not necessarily, internal insulation.

4.3.17 Insulation Class (non-preferred term).

See Insulation Level.

4.4 Insulation — Temperature Classes and Related Terms

4.4.1 Temperatures

4.4.1.1 Ambient Temperature.

The temperature of the medium such as air, water, or earth into which the heat of the equipment is dissipated.

NOTES:

1 — For self-ventilated equipment, the ambient temperature is the average temperature of the air in the immediate neighborhood of the equipment.

2 — For air- or gas-cooled equipment with forced ventilation or secondary water cooling, the ambient temperature is taken as that of the ingoing air or cooling gas.

3 — For self-ventilated enclosed (including oil-immersed) equipment considered as a complete unit, the ambient temperature is the average temperature of the air outside of the enclosure in the immediate neighborhood of the equipment.

4.4.1.2 Winding Hottest Spot Temperature.

The highest temperature inside the transformer winding. It is greater than the measured average temperature (using the resistance change method) of the coil conductors.

4.4.1.3 Inside Top Air Temperature.

The temperature of the air inside a dry-type transformer enclosure, measured in the space above the core and coils.

4.4.1.4 Limiting Temperature.

The maximum temperature at which a component or material may be operated continuously with no sacrifice in normal life expectancy.

4.4.1.5 Limiting Insulation System Temperature (limiting hottest-spot temperature).

The maximum temperature selected for correlation with a specified test condition of the equipment with the object of attaining a desired service life of the insulation system.

4.4.2 Temperature Index

An index that allows relative comparisons of the temperature capability of insulating materials or insulation systems based on specified controlled test conditions. Preferred values of temperature index numbers are:

Number Range	Preferred Temperature Index
90–104	90
105–129	105
130–154	130
155–179	155
180–199	180
200–219	200
220 and above	no preferred indices established.

NOTE — See ANSI/IEEE Std 1-1986 , IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.

4.4.3 Insulation System

An assembly of insulating materials in a particular type, and sometimes size, of equipment.

4.4.4 Insulation, Temperature Class Ratings

These temperatures are and have been, in most cases over a long period of time, benchmarks descriptive of the various classes of insulating materials, and various accepted test procedures have been or are being developed for use in their identification. They should not be confused with the actual temperatures at which these same classes of insulating materials may be used in the various specific types of equipment, nor with the temperatures on which specified temperature rises in equipment standards are based. (1) In the following definitions the words “accepted tests” are intended to refer to recognized test procedures established for the 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 may be 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. Likewise, some insulating materials when operated in dielectric liquids will have lower or higher thermal endurance than in air. (2) It is important to recognize that other characteristics, in addition to thermal endurance, such as mechanical strength, moisture resistance, and partial discharge (corona) endurance, are required in varying degrees in different applications for the successful use of insulating materials.

4.4.4.1 Class 105 Insulation System.

Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid.

NOTE — Other materials or combinations may be included in this class if by experience or accepted tests the insulation system can be shown to have comparable thermal life at 105°C.

4.4.4.2 Class 120 Insulation System.

Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated or coated or when immersed in a dielectric liquid; and which possess a degree of thermal stability which allows them to be operated at a temperature 15°C higher than temperature index 105 materials.

NOTE — Other materials or combinations may be included in this class if by experience or accepted tests the insulation system can be shown to have comparable thermal life at 120°C.

4.4.4.3 Class 150 Insulation System.

Materials or combinations of materials such as mica, glass fiber, asbestos, etc, with suitable bonding substances.

NOTE — Other materials or combinations of materials may be included in this class if by epxerience or accepted tests the insulation system can be shown to have comparable thermal life at 150°C.

4.4.4.4 Class 185 Insulation System.

Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc, with suitable bonding substances such as appropriate silicone resins.

NOTE — Other materials or combinations of materials may be included in this class if by experience or accepted tests the insulation system can be shown to have comparable thermal life at 220°C.

4.4.4.5 Class 220 Insulation System.

Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc, with suitable bonding substances such as appropriate silicone resins.

NOTE — Other materials or combinations of materials may be included in this class if by experience or accepted tests, the insulation system can be shown to have comparable thermal life at 220°C.

4.4.4.6 Class Over-220 Insulation System.

Materials consisting entirely of mica, porcelain, glass quartz, and similar inorganic materials.

NOTE — Other materials or combinations of materials may be included in this class if by experience or accepted tests the insulation system can be shown to have the required thermal life at temperatures over 220°C.

4.4.4.7 Class 0 Insulation (non-preferred term).

4.4.4.8 Class A Insulation (non-preferred term).

4.4.4.9 Class B Insulation (non-preferred term).

4.4.4.10 Class C Insulation (non-preferred term).

4.4.4.11 Class F Insulation (non-preferred term).

4.4.4.12 Class H Insulation (non-preferred term).

4.5 Miscellaneous Insulation Terms

4.5.1 Partial Discharge (PD)

An electric discharge which only partially bridges the insulation between conductors, and which may or may not occur adjacent to a conductor.

NOTES:

1 — Partial discharges occur when the local electricfield intensity exceeds the dielectric strength of the dielectric involved, resulting in local ionization and breakdown. Depending on intensity, partial discharges are often accompanied by emission of light, heat, sound, and radio influence voltage (with a wide frequency range).

2 — The relative intensity of partial discharge can be observed at the transformer terminals by measurement of the apparent charge (coulombs). However, the apparent charge (terminal charge) should not be confused with the actual charge transferred across the discharging element in the dielectric which in most cases cannot be ascertained.

Partial discharge tests using the radio influence voltage techniques which are responsive to the apparent terminal charges are generally used for measurement of relative discharge intensity.

3 — Partial discharges can also be detected and located using sonic techniques.

4 — “Corona” has also been used to describe partial discharges. This is a non-preferred term since it has other unrelated meanings.

4.5.1.1 Corona (non-preferred term).

See “partial discharge.”

4.5.2 Radio Influence Voltage (RIV)

A radio frequency voltage generally produced by partial discharge and measured at the equipment terminals for the purpose of determining the electromagnetic interference effect of the discharges.

NOTES:

1 — “RIV” can be measured with a coupled radio interference :measuring instrument and is commonly measured at approximately 1 MHz, although a wide frequency range is involved.

2 — “RIV” values are often used as an “index” of “partial discharge” intensity.

3 — The RIV of equipment was historically measured to determine the influence of energized equipment on radio broadcasting, hence — RIV.

4.5.3 Insulation Power Factor

The ratio of the power dissipated in the insulation, in watts, to the product of the effective voltage and current in volt—amperes, when tested under a sinusoidal voltage and prescribed conditions.

NOTE — If the current is also sinusoidal, the insulation power factor is equal to the cosine of the phase angle between the applied voltage and the resulting current.

4.5.4 Nominal Rate of Rise (Impulse)

The slope of the line that determines the virtual zero.

NOTE — It is usually expressed in volts or amperes per microsecond.

4.5.5 Distance (Insulation)

4.5.5.1 Creepage Distance.

The shortest distance between two conducting parts measured along the surface or joints of the insulating material between them.

4.5.5.2 Striking Distance.

The shortest unobstructed distance measured through a dielectric medium such as liquid, gas, or vacuum; between parts of different electric potential.

4.5.6 Parts

4.5.6.1 Dead-Metal Part.

A part, accessible or inaccessible, which is conductively connected to the grounded circuit under conditions of normal use of the equipment.

4.5.6.2 Live-Metal Part.

A part consisting of electrically conductive material which can be energized under conditions of normal use of the equipment.

4.5.7 Telephone Influence Factor (TIF)

Of a voltage or current wave in an electric supply circuit, the ratio of the square root of the sum of the squares of the weighted root-mean-square values of all the sine-wave components (including in alternating-current waves both fundamental and harmonics) to the root-mean-square value (unweighted) of the entire wave.

NOTE — This factor was formerly known as telephone interference factor, which term is still used occasionally when referring to values based on the original (1919) weighting curve.

5. Testing

5.1 Test Classifications

5.1.1 Routine Tests

Tests made for quality control by the manufacturer on every device or representative samples, or on parts or materials as required, to verify during production that the product meets the design specifications.

5.1.2 Design Tests

Those tests made to determine the adequacy of the design of a particular type, style, or model of equipment or its component parts to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions if specified; and to demonstrate compliance with appropriate standards of the industry.

NOTE — Design tests are made only on representative apparatus to substantiate the ratings assigned to all other apparatus of basically the same design. These tests are not intended to be used as a part of normal production. The applicable portion of these design teats may also be used to evaluate modifications of a previous design and 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, the tests need not be repeated unless the design is changed so as to modify performance.

5.1.3 Other Tests

Tests so identified in individual product standards which may be specified by the purchaser in addition to routine tests. (Examples: impulse, insulation power factor, audible sound.)

NOTE — Transformer "General Requirements" Standards (such as ANSI/IEEE C57.12.00-1987, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers) classify various tests as "routine," "design," or "other" depending on the size, voltage, and type of transformer involved.

5.1.4 Conformance Tests

Tests that are specifically made to demonstrate conformity with applicable standards.

5.2 Temperature Rise Tests

5.2.1 Temperature Rise

The difference between the temperature of the part under consideration (commonly the "average winding rise" or the "hottest spot winding rise") and the ambient temperature.

5.2.2 Methods of Temperature Determination

5.2.2.1 Thermometer Method of Temperature Determination.

The determination of the temperature by mercury, alcohol, resistance, or thermocouple thermometer, any of these instruments being applied to the hottest accessible part of the device.

5.2.2.2 Resistance Method of Temperature Determination.

The determination of the temperature by comparison of the resistance of a winding at the temperature to be determined, with the resistance at a known temperature.

5.3 Dielectric Tests

5.3.1 Dielectric Withstand-Voltage Tests

Tests made to determine the ability of insulating materials and spacings to withstand specified overvoltages for a specified time without flashover or puncture.

NOTE — The purpose of the tests is to determine the adequacy against breakdown of insulating materials and spacings under normal or transient conditions.

5.3.2 Applied Voltage Tests

Dielectric tests in which the test voltages are low-frequency alternating voltages from an external source applied between conducting parts and ground without exciting the core of the transformer being tested.

5.3.3 Induced Voltage Tests

Induced voltage tests are dielectric tests on transformer windings in which the appropriate test voltages are developed in the windings by magnetic induction.

NOTE — Power for induced voltage tests is usually supplied at higher-than-rated frequency to avoid core saturation and excessive excitation current.

5.3.4 Impulse Test

An insulation test in which the voltage applied is an impulse voltage of specified wave shape.

5.3.4.1 Lightning Impulse Test (Transformer).

Application of the following sequence of impulse waves:

1) one reduced full wave
2) two chopped waves
3) one full wave.

5.3.4.2 Full-Wave Lightning Impulse Test.

Application of the “standard lightning impulse” wave, a full wave having a front time of 1.2 μs and a time to half value of 50 μs, described as a 1.2/50 μs impulse.

5.3.4.3 Reduced Full-Wave Test.

A wave similar in shape and duration to that involved in a “full-wave lightning impulse test,” but reduced in magnitude.

NOTE — The reduced full wave normally has a crest value between 50 and 70 percent of the full-wave value involved, and is used for comparison of oscillograms in failure detection.

5.3.4.4 Chopped-Wave Lightning Impulse Test.

A voltage impulse that is terminated intentionally by sparkover of a gap, which occurs subsequent to the maximum crest of the impulse wave voltage, with a specified minimum crest voltage, and a specified minimum time to flashover.

5.3.4.5 Front-of-Wave Lightning Impulse Test.

A voltage impulse, with a specified rate-of-rise, that is terminated intentionally by sparkover of a gap which occurs on the rising front of the voltage wave with a specified time to sparkover, and a specified minimum crest voltage.

Complete front-of-wave tests (transformer) involve application of the following sequence of impulse waves:

1) one reduced full wave
2) two front-of-waves
3) two chopped waves
4) one full wave.

5.3.5 Switching Impulse Test

Application of the “standard switching impulse,” a full wave having a front time of 250 μs and a time to half value of 2500 μs, described as a 250/2500 impulse.

NOTE — It is recognized that some apparatus standards may have to use a modified wave shape where practical test considerations or particular dielectric strength characteristics make some modification imperative. Transformers, for example, use a modified switching impulse wave with the following characteristics:

1) Time to crest greater than 100 μs.
2) Exceeds 90 percent of crest value for at least 200 μs.
3) Time to first voltage zero on tail not less than 1000 μs, except where core saturation causes the tail to become shorter.

6. Construction

6.1 Methods of Cooling

6.1.1 Dry-Type

6.1.1.1 Dry-Type Self-Cooled Transformer (Class AA).

A dry-type transformer which is cooled by the natural circulation of air.

6.1.1.2 Dry-Type Self-Cooled/ Forced-Air-Cooled Transformer (Class AA/FA).

A dry-type transformer which has a self-cooled rating with cooling obtained by the natural circulation of air and a forced-air-cooled rating with cooling obtained by the forced circulation of air.

6.1.1.3 Dry-Type Forced-Air-Cooled Transformer (Class AFA).

A dry-type transformer which derives its cooling by the forced circulation of air.

6.1.1.4 Dry-Type Nonventilated Self-Cooled Transformer (Class ANV).

A dry-type self-cooled transformer which is so constructed as to provide no intentional circulation of external air through the transformer, and operating at zero gauge pressure.

6.1.1.5 Sealed Dry-Type Transformer, Self-Cooled (Class GA).

A dry-type self-cooled transformer with a hermetically sealed tank.

NOTE — The insulating gas may be air, nitrogen, or other gases (such as fluorocarbons) with high dielectric strength.

6.1.2 Oil-Immersed Air-Cooled

6.1.2.1 Oil-Immersed Self-Cooled Transformer (Class OA).

A transformer having its core and coils immersed in oil, the cooling being effected by the natural circulation of air over the cooling surface.

6.1.2.2 Oil-Immersed Self-Cooled/Forced-Air-Cooled Transformer (Class OA/FA).

A transformer having its core and coils immersed in oil and having a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface, and a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface.

6.1.2.3 Oil-Immersed Self-Cooled/Forced-Air-Cooled/Forced-Air-Cooled Transformer (Class OA/FA/FA).

A transformer having its core and coils immersed in oil and having a self-cooled rating obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating obtained by the forced circulation of air over a portion of the cooling surface, and an increased forced-air-cooled rating obtained by the increased forced circulation of air over a portion of the cooling surface.

6.1.2.4 Oil-Immersed Self-Cooled/Forced-Air-Cooled/Forced-Oil-Cooled Transformer (Class OA/FA/FOA).

A transformer having its core and coils immersed in oil and having a selfcooled rating with cooling obtained by the natural circulation of air over the cooling surface, a forced-air-cooled rating with cooling obtained by the forced circulation of air over this same cooling surface, and a forced-oil-cooled rating with cooling obtained by the forced circulation of oil over the core and coils and adjacent to this same cooling surface over which the air is being forced circulated.

6.1.2.5 Oil-Immersed Self-Cooled/Forced-Air, Forced-Oil-Cooled/Forced-Air, Forced-Oil-Cooled Transformer (Class OA/FOA/FOA).

A transformer similar to class OA/FA/FOA transformer except that its auxiliary cooling controls are arranged to start a portion of the oil pumps and a portion of the fans for the first auxiliary rating and the remainder of the pumps and fans for the second auxiliary rating.

6.1.2.6 Oil-Immersed Forced-Oil-Cooled Transformer with Forced-Air Cooler (Class FOA).

A transformer having its core and coils immersed in oil and cooled by the forced circulation of this oil through external oil-to-air heat-exchanger equipment utilizing forced circulation of air over its cooling surface.

6.1.3 Oil-Immersed Water-Cooled

6.1.3.1 Oil-Immersed Water-Cooled Transformer (Class OW).

A transformer having its core and coils immersed in oil, the cooling being effected by the natural circulation of oil over the water-cooled surface.

6.1.3.2 Oil-Immersed Water-Cooled/ Self-Cooled Transformer (Class OW/A).

A transformer having its core and coils immersed in oil and having a water-cooled rating with cooling obtained by the natural circulation of oil over the water-cooled surface, and a self-cooled rating with cooling obtained by the natural circulation of air over the cooling surface.

6.1.3.3 Oil-Immersed Forced-Oil-Cooled Transformer with Forced-Water Cooler (Class FOW).

A transformer having its core and coils immersed in oil and cooled by the forced circulation of this oil through external oil-to-water heat-exchanger equipment utilizing forced circulation of water over its cooling surface.

6.2 Form (or Type)

6.2.1 Core-Form Transformer

A transformer in which those parts of the magnetic circuit surrounded by the windings have the form of legs with two common yokes.

6.2.2 Shell-Form Transformer

A transformer in which the laminations constituting the iron core surround the windings and usually enclose the greater part of them.

6.3 Windings

6.3.1 High-Voltage and Low-Voltage Windings

The terms high voltage and low voltage are used to distinguish the winding having the greater from that having the lesser voltage rating.

6.3.2 Primary Winding

The winding on the energy input side.

6.3.3 Secondary Winding

The winding on the energy output side.

6.3.4 Tertiary Winding

An additional winding in a transformer which can be connected to a synchronous condenser, a reactor, an auxiliary circuit, etc. For transformers with Y-connected primary and secondary windings, it may also help:

a) to stabilize voltages to the neutral, when delta connected
b) to reduce the magnitude of third harmonics when delta connected
c) to control the value of the zero-sequence impedance
d) to serve load.

6.3.5 Stabilizing Winding

A delta connected auxiliary winding used particularly in Y-connected three-phase transformers for such purposes as the following:

1) To stabilize the neutral point of the fundamental frequency voltages
2) To minimize third-harmonic voltage and the resultant effects on the system
3) To mitigate telephone influence due to third-harmonic currents and voltages
4) To minimize the residual direct-current magnetomotive force on the core
5) To decrease the zero-sequence impedance of transformers with Y-connected windings.

NOTE — A winding is regarded as a stabilizing winding if its terminals are not brought out for connection to an external circuit. However, one or two points of the winding which are intended to form the same corner point of the delta may be brought out for grounding, or grounded internally to the tank. For a three-phase transformer, if other points of the winding are brought out, the winding should be regarded as a normal winding as otherwise defined.

6.3.6 Control-Power Winding (or Transformer)

The winding (or transformer) which supplies power to motors, relays, and other devices used for control purposes.

6.3.7 Common Winding (Autotransformer)

That part of the autotransformer winding which is common to both the primary and the secondary circuits.

6.3.8 Series Winding (Autotransformer)

That portion of the autotransformer winding which is not common to both the primary and the secondary circuits, but is connected in series between the input and output circuits.

6.3.9 Concentric Windings (of a Transformer)

An arrangement of transformer windings where the primary and secondary windings, and the tertiary winding, if any, are located in radial progression about a common core.

6.3.10 Interleaved Windings (of a Transformer)

An arrangement of transformer windings where the primary and secondary windings, and the tertiary windings, if any, are subdivided into disks (or pancakes) or layers and interleaved on the same core.

6.4 Taps

6.4.1 Tap (in a Transformer)

A connection brought out of a winding at some point between its extremities, to permit changing the voltage, or current, ratio.

6.5 Methods of Oil Preservation

6.5.1 Sealed-Tank System

A method of oil preservation in which the interior of the tank is sealed from the atmosphere and in which the gas plus the oil volume remains constant over the temperature range.

6.5.2 Gas—Oil Sealed System

A system in which the interior of the tank is sealed from the atmosphere, over the temperature range specified, by means of an auxiliary tank or tank to form a gas—oil seal operating on the manometer principle.

6.5.3 Inert Gas-Pressure System

A system in which the interior of the tank is sealed from the atmosphere, over the temperature range specified, by means of a positive pressure of inert gas maintained from a separate inert gas source and reducing valve system.

6.5.4 Conservator (Expansion Tank System)

A system in which the oil in the main tank is sealed from the atmosphere, over the temperature range specified, by means of an auxiliary tank partly filled with oil and connected to the completely filled main tank.

6.5.5 Conservator/Diaphragm System

A system in which the oil in the main tank is completely sealed from the outside atmosphere, and is connected to an elastic diaphragm tank contained inside a tank mounted at the top of the transformer. As oil expands and contracts within a specified temperature range the system remains completely sealed with an approximately constant pressure.

6.6 Enclosures

6.6.1 Accessible

Admitting close approach because not guarded by locked doors, elevation, or other effecitve means.

6.6.1.1 Readily Accessible.

Capable of being reached quickly, for operation, renewal, or inspection, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

6.6.2 Conduit Knockout

See “Knockout.”

6.6.3 Corrosion-Resistant

So constructed, protected, or treated that corrosion will not exceed specified limits under specified test conditions.

6.6.4 Dripproof Enclosure

An enclosure, usually for indoor application, so constructed or protected that falling drops of liquid or solid particles which strike the enclosure at any angle within a specified variation from the vertical shall not interfere with the successful operation of the enclosed equipment.

6.6.5 Driptight Enclosure

An enclosure so constructed that falling drops of liquid or solid particles striking the enclosure at any angle within a specified variation from the vertical cannot enter the enclosure either directly or by striking and running along a horizontal or inwardly inclined surface.

6.6.6 Dusttight Enclosure

An enclosure so constructed that dust will not enter the enclosing case under specified conditions.

6.6.7 Enclosure

A surrounding case or housing used to protect the contained equipment and prevent personnel from accidentally contacting live parts.

6.6.8 Flush-Mounted Device

A device in which the body projects only a small specified distance in front of the mounting surface.

6.6.9 Indoor (prefix)

Not suitable for exposure to the weather.

NOTE — For example, indoor equipment designed for indoor service or for use in a weather-proof housing.

6.6.10 Knockout

A portion of the wall of a box or cabinet so fashioned that it may be readily removed by a hammer, screwdriver, and pliers at the time of installation in order to provide a hole for the attachment of a raceway cable or fitting.

6.6.11 Nonventilated

So constructed as to provide no intentional circulation of external air through the enclosure.

6.6.12 Oil-Resistant Gaskets

Those made of material which is resistant to oil or oil fumes.

6.6.13 Oiltight

So constructed as to exclude oils, coolants, and similar liquids under specified test conditions.

6.6.14 Outdoor

Suitable for installation where exposed to the weather.

6.6.15 Proof (suffix)

Apparatus is designed as splash-proof, dust-proof, etc, when so constructed, protected, or treated that its successful operation is not interfered with when subjected to the specified material or condition.

6.6.16 Rainproof

So constructed, protected, or treated as to prevent rain under specified test conditions from interfering with successful operation of the apparatus.

6.6.17 Raintight

So constructed or protected as to exclude rain under specified test conditions.

6.6.18 Resistant (used as a suffix)

So constructed, protected, or treated that the apparatus will not be damaged when subjected to the specified material or conditions for a specified time.

6.6.19 Sealed

So constructed that the enclosure will remain hermetically sealed within specified limits of temperature and pressure.

6.6.20 Sleetproof

So constructed or protected that the accumulation of sleet (ice) under specified test conditions will not interfere with the successful operation of the apparatus.

6.6.21 Submersible

So constructed as to be successfully operable when submerged in water under specified conditions of pressure and time.

6.6.22 Tight (suffix)

Apparatus is designed as watertight, dusttight, etc, when so constructed that the enclosing case will exclude the specified material under specified conditions.

6.6.23 Ventilated

Provided with a means to permit circulation of the air sufficiently to remove an excess of heat, fumes, or vapors.

6.6.24 Watertight

So constructed that water will not enter the enclosing case under specified conditions.

NOTE — A common form of specification for watertight is: "So constructed that there shall be no leakage of water into the enclosure when subjected to a stream from a hose with a 1 in nozzle and delivering at least 65 gal/min, with the water directed at the enclosure from a distance of not less than 10 ft for a period of 5 min, during which period the water may be directed in one or more directions as desired."

6.7 Miscellaneous

6.7.1 Apparatus

A general designation for large electrical equipment such as generators, motors, transformers, circuit breakers, etc.

6.7.2 Equipment

A general term including material, fittings, devices, appliances, fixtures, apparatus, and the like, as a part of, or in connection with, an electrical installation.

6.7.3 Accessories

Devices that perform a secondary or minor duty as an adjunct or refinement to the primary or major duty of a unit of equipment.

6.7.4 Combustible Materials

Materials which are external to the apparatus and made of or surfaced with wood, compressed paper, plant fibers, or other materials that will ignite and support flame.

6.7.5 Contactor

A device for repeatedly establishing and interrupting an electric power circuit.

6.7.6 Core

An element made of magnetic material, serving as part of a path for magnetic flux.

6.7.7 Interlock

A device actuated by the operation of some other device with which it is directly associated, to govern succeeding operations of the same or allied devices.

NOTE — Interlocks may be either electric or mechanical.

6.7.8 Terminal

a) A conducting element of an equipment or a circuit intended for connection to an external conductor.
b) A device attached to a conductor to facilitate connection with another conductor.

6.7.8.1 Terminal Connector.

A connector for attaching a conductor to a lead, terminal block, or stud of electric apparatus.

6.7.8.2 Terminal Board.

A plate of insulating material that is used to support terminations of winding leads.

NOTES:

1 — The terminations, which may be mounted studs or blade connectors, are used for making connections to the supply line, the load, other external circuits, or among the windings of the machine.

2 — Small terminal boards may also be termed terminal blocks, or terminal strips.

6.7.9 Lead

A conductor that connects a winding to its termination (that is, terminal, bushing, terminal board, or connection to another winding).

6.7.10 Overcurrent Protection

A form of protection that operates when current exceeds a predetermined value.

6.7.11 Shield

A conductive protective member placed in relationship to apparatus or test components to control the shape of magnitude, or both, of electric or magnetic fields, thereby improving performance of apparatus or test equipment by reducing losses, voltage gradients, or interference.

6.7.12 Network Protector

An assembly comprising a circuit breaker and its complete control equipment for automatically disconnecting a transformer from a secondary network in response to predetermined electric conditions on the primary feeder or transformer, and for connecting a transformer to a secondary network either through manual control or automatic control responsive to predetermined electrical conditions on the feeder and the secondary network.

NOTE — The network protector is usually arranged to connect automatically its associated transformer to the network when conditions are such that the transformer, when connected, will supply power to the network and to automatically disconnect the transformer from the network when power flows from the network to the transformer.

6.7.13 Tap Changers

6.7.13.1 Tap-Changer, for De-Energized Operation.

A selector switch device used to change transformer taps with the transformer de-energized.

6.7.13.2 Load-Tap-Changer (LTC).

A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load.

6.7.14 Bushing

An insulating structure including a central conductor, or providing a central passage for a conductor, with provision for mounting on a barrier, conducting or otherwise, for the purpose of insulating the conductor from the barrier and conducting current from one side of the barrier to the other.

6.7.15 Separable Insulated Connector

A system for terminating and electrically connecting an insulated power cable to electrical apparatus, other power cables, or both, so designed that the electrical connection can be readily established or broken by engaging or separating mating parts of the connector at the operating interface.

6.7.15.1 Dead-Break Connector.

A separable insulated connector designed to be separated and engaged on de-energized circuits only.

6.7.15.2 Load-Break Connector.

A separable insulated connector designed to close and interrupt current on energized circuits.

6.7.16 Exposure.

6.7.16.1 Live-Front.

So constructed that there are exposed live parts on the front of the assembly.

6.7.16.2 Dead-Front.

So constructed that there are no exposed live parts on the front of the assembly.

7. Terminology for Specialized Types of Transformers

7.1 Unit Substation Transformers

See 2.3.3.5.

7.1.1 Unit Substation

A substation consisting primarily of one or more transformers which are mechanically and electrically connected to and coordinated in design with one or more switchgear or motor control assemblies, or combinations thereof.

7.1.2 Primary Unit Substation

A substation in which the low-voltage section is rated above 1000 V.

7.1.3 Secondary Unit Substation

A substation in which the low-voltage section is rated 1000 V and below.

7.1.4 Integral Unit Substation

A unit substation in which the incoming, transforming, and outgoing sections are manufactured as a single compact unit.

7.1.5 Articulated Unit Substation

A unit substation in which the incoming, transforming, and outgoing sections are manufactured as one or more subassemblies intended for connection in the field.

7.1.5.1 Radial Type.

A unit substation which has a single stepdown transformer and which has an outgoing section for the connection of one or more outgoing radial (stub-end) feeders.

7.1.5.2 Distributed-Network Type.

A unit substation which has a single stepdown transformer having its outgoing side connected to a bus through a circuit breaker equipped with relays which are arranged to trip the circuit breaker on reverse power flow to the transformer and to reclose the circuit breaker upon the restoration of the correct voltage, phase angle, and phase sequence at the transformer secondary. The bus has one or more outgoing radial (stub-end) feeders and one or more tie connections to a similar unit substation.

7.1.5.3 Spot-Network Type.

A unit substation which has two stepdown transformers, each connected to an incoming high-voltage circuit. The outgoing side of each transformer is connected to a common bus through circuit breakers equipped with relays which are arranged to trip the circuit breaker on reverse power flow to the transformer and to reclose the circuit breaker upon the restoration of the correct voltage, phase angle, and phase sequence at the transformer secondary. The bus has one or more outgoing radial (stub-end) feeders.

7.1.5.4 Secondary-Selective Type (Low-Voltage-Selective Type).

A unit substation which has two stepdown transformers each connected to an incoming high-voltage circuit. The outgoing side of each transformer is connected to a separate bus through a suitable switching and protective device. The two sections of bus are connected by a normally open switching and protective device. Each bus has one or more outgoing radial (stub-end) feeders.

7.1.5.5 Duplex Type (Breaker-and-a-Half Arrangement).

A unit substation which has two stepdown transformers, each connected to an incoming high-voltage circuit. The outgoing side of each transformer is connected to a radial (stub-end) feeder. These feeders are joined on the feeder side of the power circuit breakers by a normally open-tie circuit breaker.

7.2 Regulating and Load-Tap-Changing Transformers

7.2.1 Regulating Transformer

See 2.2.2.

7.2.2 Load-Tap-Changing Transformer

See 2.2.1.

7.2.3 Phase-Shifting Transformer

See 2.2.3.

7.2.4 Circuits

7.2.4.1 Primary Circuits.

The circuit on the input side at the regulator.

7.2.4.2 Regulated Circuit.

The circuit on the output side of the regulator, and in which it is desired to control the voltage, or the phase relation, or both.

NOTE — The voltage may be held constant at any selected point on the regulated circuit.

7.2.5 Preventative Autotransformer

An autotransformer (or center-tapped reactor) used in load-tap-changing and regulating transformers, or step-voltage regulators to limit the circulating current when operating on a position in which two adjacent taps are bridged, or during the change of taps between adjacent positions.

7.2.6 Series Transformer

A transformer with a “series” winding and an “exciting” winding, in which the “series” winding is placed in a series relationship in a circuit to change voltage or phase, or both, in that circuit as a result of input received from the “exciting” winding.

NOTES:

Applications of series transformers include:

1- Use in a transformer such as a load-tap-changing or regulating transformer to change the voltage or current duty of the load-tap-changing mechanism.

2- Inclusion in a circuit for power factor correction to indirectly insert series capacitance in a circuit by connecting capacitors to the exciting winding.

7.2.7 Series and Main Units of a Two-Core Regulating Transformer

7.2.7.1 Series Unit.

The core and coil unit which has one winding connected in series in the line circuit.

7.2.7.2 Main Unit.

The core and coil unit which furnishes excitation to the series unit.

7.2.8 Windings of a Two-Core Regulating Transformer

7.2.8.1 Series Winding.

The winding of the series unit which is connected in series in the line circuit.

NOTE — If the main unit of a two-core transformer is an autotransformer, both units will have a series winding. In such cases, one is referred to as the series winding of the autotransformer and the other, the series winding of the series unit.

7.2.8.2 Excited Winding.

The winding of the series unit which is excited from the regulating winding of the main unit.

7.2.8.3 Regulating Winding.

The winding of the main unit in which taps are changed to control the voltage or phase angle of the regulated circuit through the series unit.

7.2.8.4 Excitation Winding.

The winding of the main unit which draws power from the system to operate the two-core transformer.

7.2.8.5 Excitation-Regulating Winding.

In some designs, the main unit will have one winding operating as an autotransformer which performs both functions listed under excitation and regulating windings. Such a winding is called the excitation-regulating winding.

7.2.9 Controls

7.2.9.1 Voltage-Regulating Relay.

A voltage-sensitive device that is used on an automatically operated voltage regulator to control the voltage of the regulated circuit.

7.2.9.2 Line-Drop Compensator.

A device which causes the voltage-regulating relay to increase the output voltage by an amount that compensates for the impedance drop in the circuit between the regulator and a predetermined location on the circuit (sometimes referred to as the load center).

7.2.9.3 Voltage Winding (or Transformer) for Regulating Equipment.

The winding (or transformer) which supplies voltage within close limits of accuracy to instruments, such as contact-making voltmeters.

7.3 Scott-Connected Transformers

7.3.1 Scott-Connected Transformer

See 2.2.6.

7.3.2 Main Transformer

The term "main transformer" as applied to two single-phase Scott-connected units for three-phase to two-phase or two-phase to three-phase operation, designates the transformer that is connected directly between two of the phase wires of the three-phase lines.

NOTE — A tap is provided at the midpoint for tconnecion to the teaser transformer.

7.3.3 Teaser Transformer

The term "teaser transformer," as applied to two single-phase Scott-connected units for three-phase to two-phase or two-phase to three-phase operation, designates the transformer that is connected between the midpoint of the main transformer and the third-phase wire of the three-phase system.

7.3.4 Interlacing Impedance Voltage of a Scott-Connected Transformer

The interlacing impedance voltage of Scott-connected transformers is the single-phase voltage applied from the midtap of the main transformer winding to both ends, connected together, which is sufficient to circulate in the supply lines a current equal to the rated three-phase line current. The current in each half of the winding is 50 percent of this value.

7.3.4.1

The per-unit or percent interlacing resistance is the measured watts expressed on the base of the rated kVA of the teaser winding.

7.3.4.2

The per-unit or percent interlacing impedance is the measured voltage expressed on the base of the teaser voltage.

7.4 Grounding Transformers

7.4.1 Grounding Transformer

See 2.2.7.

7.4.2 Voltage Rating of a Grounding Transformer

The maximum "line-to-line" voltage at which it is designed to operate continuously from line to ground without damage to the grounding transformer.

7.4.3 Rated kVA of a Grounding Transformer

The short-time kilovolt-ampere rating is the product of the rated line-to-neutral voltage at rated frequency, and the maximum constant current that can flow in the neutral for the specified time without causing specified temperature-rise limitations to be exceeded, and within the limitations of established standards for such equipment.

7.5 Constant-Current Transformers

7.5.1 Constant-Current Transformer

See 2.1.6.

7.5.2 Rated Secondary Current of a Constant-Current Transformer

The secondary current for which the transformer is designed and to which operation and performance characteristics are referred.

7.5.3 Impedance Voltage of a Constant-Current Transformer

The measured primary voltage required to circulate rated secondary current through the short-circuited secondary coil for a particular coil separation.

NOTE — It is usually expressed in per-unit or percent of the rated primary voltage.

7.5.4 Current Regulation of a Constant-Current Transformer

The maximum departure of the secondary current from its rated value, with rated primary voltage at rated frequency applied, and at rated secondary power factor, and with the current variation taken between the limits of a short circuit and rated load.

NOTE — This regulation may be expressed in per-unit, or percent, on the basis of the rated secondary current.

7.5.5 Rated Kilowatts of a Constant-Current Transformer

The kilowatt output at the secondary terminals with rated primary voltage and frequency, and with rated secondary current and power factor, and within the limitations of established standards.

7.5.6 Rated Primary Voltage of a Constant-Current Transformer

The primary voltage for which the transformer is designed, and to which operation and performance characteristics are referred.

7.6 Rectifier Transformers

7.6.1 Rectifier Transformer

See 2.2.5.

7.6.2 Power Rectifier Transformer

A rectifier transformer connected to mercury-arc or semiconductor rectifiers for electrochemical service, steel processing applications, electric furnace applications, mining applications, transportation applications, and direct-current transmissions.

7.6.3 Alternating-Current Winding of a Rectifier Transformer

The primary winding that is connected to the alternating-current circuit and usually has no conductive connection with the main electrodes of the rectifier.

7.6.4 Direct-Current Winding of Rectifier Transformer

The secondary winding that is conductively connected to the main electrodes of the rectifier, and that conducts the direct current of the rectifier.

7.6.5 Rating of Rectifier Transformer

The kilovolt—ampere output, voltage, current, frequency, and number of phases at the terminals of the alternating-current winding; the voltage (based on turn ratio of the transformer), root-mean-square current, and number of phases at the terminals of the direct-current winding, to correspond to the rated load of the rectifier unit.

NOTES:

1 — Because of the current wave shapes in the alternating- and direct-current windings of the rectifier transformer, these windings may have individual ratings different from each other and from those of power transformers in other types of service. The ratings are regarded as test ratings that define the output that can be taken from the transformer under prescribed conditions of test without exceeding any of the limitations of the standards.

2 — For rectifier transformers covered by established standards, the root-mean-square current ratings and kilovolt-ampere ratings of the windings are based on values derived from rectangular rectifier circuit element currents without overlap.

7.6.6 Interphase Transformer

An autotransformer, or a set of mutually coupled reactors, used to obtain parallel operation between two or more simple rectifiers that have ripple voltages that are out of phase.

7.6.7 Rating of Interphase Transformer.

The root-mean-square current, root-mean-square voltage, and frequency at the terminals of each winding, when the rectifier unit is operating at rated load and with a designated amount of phase control.

7.6.8 Anode Paralleling Reactor

See 7.7.12.1.

7.6.9 Commutating Reactor

See 7.7.12.2.

7.7 Reactors

7.7.1 Reactor

An electromagnetic device, the primary purpose of which is to introduce inductive reactance into a circuit.

7.7.2 Alternating-Current Saturable Reactor

A reactor whose impedance varies cyclically with the alternating current (or voltage).

7.7.3 Filter Reactor

A reactor used to reduce harmonic voltage in alternating-current or direct-current circuits.

7.7.4 Shunt Reactor

A reactor intended for connection in shunt to an electric system for the purpose of drawing inductive current.

NOTE — The normal use for shunt reactors is to compensate for capacitive currents from transmission lines, cable, or shunt capacitors. The need for shunt reactors is most apparent at light load.

7.7.5 Current-Limiting Reactor

A reactor intended for limiting the current that can flow in a circuit under short-circuit conditions, or under other operating conditions such as starting, synchronizing, etc.

7.7.6 Bus Reactor

A current-limiting reactor for connection between two different buses or two sections of the same bus for the purpose of limiting and localizing the disturbance due to a fault in either bus.

7.7.7 Feeder Reactor

A current-limiting reactor for connection in series with an alternating-current feeder circuit for the purpose of limiting and localizing the disturbance due to faults on the feeder.

7.7.8 Neutral Grounding Reactor

A current-limiting inductive reactor for connection in the neutral for the purpose of limiting and neutralizing disturbances due to ground faults.

7.7.9 Starting Reactor

A current-limiting reactor for decreasing the starting current of a machine or device.

7.7.10 Synchronizing Reactor

A current-limiting reactor for connecting momentarily across the open contacts of a circuit-interrupting device for synchronizing purposes.

7.7.11 Paralleling Reactor

A current-limiting reactor for correcting the division of load between parallel-connected transformers which have unequal impedance voltages.

7.7.12 Reactors for Use with Rectifiers

7.7.12.1 Anode Paralleling Reactor.

A reactor with a set of mutually coupled windings connected to anodes operating in parallel from the same transformer terminal.

7.7.12.2 Commutating Reactor.

A reactor used primarily to modify the rate of current transfer between rectifying elements.

7.8 Instrument Transformers

7.8.1 Instrument Transformers

See 2.2.8.

7.8.2 General Terms

7.8.2.1 Continuous-Thermal-Current Rating Factor (RF).

The specified factor by which the rated primary current of a current transformer can be multiplied to obtain the maximum primary current that can be carried continuously without exceeding the limiting temperature rise from 30° C ambient air temperature. (When current transformers are incorporated internally as parts of larger transformers or power circuit breakers, they shall meet allowable average winding and hot-spot temperatures under the specific conditions and requirements of the larger apparatus.)

7.8.2.2 Transformer Correction Factor (TCF).

The ratio of true watts or watthours to the measured watts or watthours, divided by the marked ratio.

NOTE — The transformer correction factor for a current or voltage transformer is the ratio correction factor multiplied by the phase-angle correction factor for a specified primary circuit power factor.

The true primary watts or watthours are equal to the watts or watthours measured, multiplied by the transformer correction factor and the marked ratio.

The true primary watts or watthours, when measured using both current and voltage transformers, are equal to the current transformer correction factor times the voltage transformer correction factor multiplied by the product of the marked ratios of the current and voltage transformers multiplied by the observed watts or watthours.

7.8.2.3 True Ratio.

The ratio of the root-mean-square (rms) primary value to the rms secondary value under specified conditions.

7.8.2.4 Marked Ratio.

The ratio of the rated primary value to the rated secondary value as stated on the nameplate.

7.8.2.5 Ratio Correction Factor (RCF).

The ratio of the true ratio to the marked ratio. The primary current or voltage is equal to the secondary current or voltage multiplied by the marked ratio times the ratio correction factor.

7.8.2.6 Percent Ratio.

The true ratio expressed in percent of the marked ratio.

7.8.2.7 Percent Ratio Correction of an Instrument Transformer.

The difference between the ratio correction factor and unity expressed in percent.

NOTE — The percent ratio correction is positive if the ratio correction factor is greater than unity. If the percent ratio correction is positive, the measured secondary current or voltage will be less than the primary value divided by the marked ratio.

7.8.2.8 Phase Angle of an Instrument Transformer.

The phase displacement, in minutes, between the primary and secondary values.

NOTE — The phase angle of a current transformer is designated by the Greek letter beta (β) and is positive when the current leaving the identified secondary terminal leads the current entering the identified primary terminal.

The phase angle of a voltage transformer is designated by the Greek letter gamma (γ) and is positive when the secondary voltage from the identified to the unidentified terminal leads the corresponding primary voltage.

7.8.2.9 Phase-Angle Correction Factor.

The ratio of the true power factor to the measured power factor. It is a function of both the phase angles of the instrument transformer and the power factor of the primary circuit being measured.

NOTE — The phase-angle correction factor is the factor which corrects for the phase displacement of the secondary current or voltage, or both, due to the instrument transformer phase angles.

The measured watts or watthours in the secondary circuits of instrument transformers must be multiplied by the phase-angle correction factor and the true ratio to obtain the true primary watts or watthours.

7.8.2.10 Polarity.

The designation of the relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle.

NOTE — Primary and secondary terminals are mid to have the same polarity, when, at a given instant during most of each half cycle, the current enters the identified, similarly marked primary lead and leaves the identified, similarly marked secondary terminal in the same direction as though the two terminals formed a continuous circuit.

7.8.2.11 Secondary Winding of an Instrument Transformer.

The winding that is intended to be connected to the measuring or control devices.

7.8.2.12 Excitation Losses for an Instrument Transformer.

The watts required to supply the energy necessary to excite the transformer which includes the dielectric watts, the core watts, and the watts in the excited winding due to the excitation current.

7.8.3 Voltage Transformers

7.8.3.1 Voltage Transformer.

An instrument transformer intended to have its primary winding connected in shunt with a power supply circuit, the voltage of which is to be measured or controlled.

7.8.3.2 Cascade-Type Voltage Transformer.

An insulated-neutral terminal type voltage transformer with the primary winding distributed on several cores with the cores electromagnetically coupled by coupling windings. The secondary winding is on the core at the neutral end of the high-voltage winding. Each core of this type of transformer is insulated from the other cores and is maintained at a fixed voltage with respect to ground and the line to ground voltage.

7.8.3.3 Insulated-Neutral Terminal Type Voltage Transformer.

A voltage transformer which has the neutral end of the high-voltage winding insulated from the case or base and connected to a terminal which provides insulation for a lower voltage than required for the line terminal.

7.8.3.4 Double-Secondary Voltage Transformer.

One which has two secondary windings on the same magnetic circuit insulated from each other and the primary.

7.8.3.5 Fused-Type Voltage Transformer.

One which is provided with the means for mounting a fuse, or fuses, as an integral part of the transformer in series with the primary winding.

7.8.3.6 Turn Ratio of a Voltage Transformer.

The ratio of the primary winding tums to the secondary winding turns.

7.8.3.7 Thermal Burden Rating of a Voltage Transformer.

The volt-ampere output that the transformer will supply continuously at rated secondary voltage without causing the spoiled temperature limitations to be exceeded.

7.8.3.8 Rated Voltage of a Voltage Transformer.

The primary voltage selected for the basis of performance specifications of a voltage transformer.

7.8.3.9 Rated Secondary Voltage.

The voltage divided by the marked ratio.

7.8.4 Current Transformers

7.8.4.1 Current Transformer.

An instrument transformer intended to have its primary winding connected in series with the conductor carrying the current to be measured or controlled. (In window type current transformers, the primary winding is provided by the line conductor and is not an integral part of the transformer.)

7.8.4.2 Bushing-Type Current Transformer.

One which has an annular core and a secondary winding insulated from and permanently assembled on the core but has no primary winding nor insulation for a primary winding. This type of current transformer is for use with a fully insulated conductor as the primary winding. A bushing-type current transformer usually is used in equipment where the primary conductor is a component part of other apparatus.

7.8.4.3 Double-Secondary Current Transformer.

One which has two secondary coils each on a separate magnetic circuit with both magnetic circuits excited by the same primary winding.

7.8.4.4 Multiple-Secondary Current Transformer.

One which has three or more secondary coils each on a separate magnetic circuit with all magnetic circuits excited by the same primary winding.

7.8.4.5 Multi-Ratio Current Transformer.

One from which more than one ratio can be obtained by the use of taps on the secondary winding.

7.8.4.6 Window-Type Current Transformer.

One which has a secondary winding insulated from and permanently assembled on the core, but has no primary winding as an integral part of the structure. Complete insulation is provided for a primary winding in the window through which one turn of the line conductor can be passed to provide the primary winding.

7.8.4.7 Wound-Type Current Transformer.

One which has a primary winding consisting of one or more turns mechanically encircling the core or cores. The primary and secondary windings are insulated from each other and from the core(s) and are assembled as an integral structure.

7.8.4.8 Three-Wire Type Current Transformer.

One which has two primary windings each completely insulated for the rated insulation level of the transformer. This type of current transformer is for use on a three-wire single-phase service.

NOTE — The primary windings and secondary windings are permanently assembled on the core as an integral structure. The secondary current is proportional to the phasor sum of the primary currents.

7.8.4.9 Rated Current.

The primary current selected for the basis of performance specifications of a current transformer.

7.8.4.10 Rated Secondary Current.

The rated current divided by the marked ratio.

7.8.4.11 Turn Ratio of a Current Transformer.

The ratio of the secondary winding turns to the primary winding turns.

7.8.5 Potential Transformer

See 7.8.3.

7.9 Specialty Transformers

7.9.1 Specialty Transformer

See 2.2.9.

7.9.2 Individual-Lamp Autotransformer

A series autotransformer that transforms the primary current to a higher or lower current as required for the operation of an individual street light.

7.9.3 Series Street-Lighting Transformer

A series transformer that receives energy from a current-regulating series circuit and that transforms the energy to another winding at the same or different current from that in the primary.

7.9.4 Energy-Limiting Transformer

A transformer that is intended for use on an approximately constant-voltage supply circuit and that has sufficient inherent impedance to limit the output current to a thermally safe maximum value.

7.9.5 High-Reactance Transformer

An energy-limiting transformer that has sufficient inherent reactance to limit the output current to a maximum value.

7.9.6 Non-Energy-Limiting Transformer

A constant-potential transformer that does not have sufficient inherent impedance to limit the output to a thermally safe maximum value.

7.9.7 High Power Factor Transformer

A high-reactance transformer that has a power-factor-correcting device, such as a capacitor, so that the input current is at a power factor of not less than 90 percent when the transformer delivers rated current to its intended load device.

7.9.8 Low Power Factor Transformer

A high-reactance transformer that does not have means for power-factor correction.

7.9.9 Insulating Transformer

A transformer used to insulate one circuit from another.

7.9.10 Individual-Lamp Insulating Transformer

An insulating transformer used to protect the secondary circuit, casing, lamp, and associated luminaire of an individual street light from the high-voltage hazard of the primary circuit.

7.9.11 Group-Series Loop Insulating Transformer

An insulating transformer whose secondary is arranged to operate a group of series lamps or a series group of individual-lamp transformers.

7.9.12 Luminous-Tube Transformers

Transformers, autotransformers, or reactors (having a secondary open-circuit rms of 1000 V or more) for operation of cold-cathode and hot-cathode luminous tubing generally used for signs, illumination, and decoration purposes.

7.9.13 Ignition Transformer

Set-up transformer generally used for electrically igniting oil, gas, or gasoline in domestic, commercial, or industrial heating equipment.

7.9.14 Series Circuit Lighting Transformer

Dry-type individual lamp insulating transformer, autotransformer, and group series loop transformers for operation of incandescent or mercury lamps on series lighting circuits such as for street and airport lighting.

7.9.15 Signaling and Doorbell Transformers

Step-down transformers (having a secondary of 30 V or less), generally used for the operation of signals, chimes, and doorbells.

7.9.16 Control Transformers

Step-down transformers generally used in circuits which are characterized by low power levels and which contribute to a control function, such as in heating and air conditioning, printing, and general industrial controls.

7.9.17 Machine-Tool Control Transformers

Step-down transformers which may be equipped with fuse or other overcurrent protection device, generally used for the operation of solenoids, contactors, relays, portable tools, and localized lighting.

7.9.18 General-Purpose Transformers

Step-up or step-down transformers or autotransformers generally used in secondary distribution circuits of 600 V or less in connection with power and lighting service.

7.9.19 Mercury Vapor Lamp Transformers (Multiple-Supply Type)

Transformers, autotransformers, or reactors for operating mercury or metallic iodide vapor lamps for all types of lighting applications, including indoor, outdoor area, roadway, uviarc, and other process and specialized lighting.

7.9.20 Sodium Vapor Lamp Transformers (Multiple-Supply Type)

Transformers, autotransformers, or reactors for operating sodium vapor lamps for all types of lighting applications, including indoor, outdoor area, roadway, and other process and specialized lighting.

7.9.21 Saturable Reactor (Saturable-Core Reactor)

(1) a magnetic-core reactor whose reactance is controlled by changing the saturation of the core through variation of a super-imposed unidirectional flux.

(2) A magnetic-core reactor operating in the region of saturation without independent control means.

NOTE — Thus a reactor whose impedance varies cyclically with the alternating current (or voltage).

7.9.22 Electronic Transformer

Any transformer intended for use in a circuit or system utilizing electron or solid-state devices.

NOTE — Mercury-arc rectifier transformers and luminous-tube transformers are normally excluded from this classification.

7.9.23 Series Transformer Rating

The lumen rating of the series lamp, or the wattage rating of the multiple lamps, that the transformer is designed to operate.

7.9.24 Primary Voltage Rating of a General-Purpose Specialty Transformer

The input circuit voltage for which the primary winding is designed, and to which operating and performance characteristics are referred.

7.9.25 Secondary Voltage Rating

The load circuit voltage for which the secondary winding is designed.

7.9.26 IR-Drop Compensation Transformer

A provision in the transformer by which the voltage drop due to transformer load current and internal transformer resistance is partially or completely neutralized. Such transformers are suitable only for one-way transformation, that is, not interchangeable for step-up and step-down transformations.

7.9.27 kVA or Volt-Ampere Short-Circuit Input Rating of a High-Reactance Transformer

One that designates the input kVA or volt-amperes at rated primary voltage with the secondary terminals short-circuited.

7.9.28 Secondary Short-Circuit Current Rating of a High-Reactance Transformer

One that designates the current in the secondary winding when the primary winding is connected to a circuit of rated primary voltage and frequency and when the secondary terminals are short-circuited.

7.9.29 “Class 2” Transformer

A step-down transformer of the low-secondary-voltage type, suitable for use in Class 2 remote-control low-energy circuits. It shall be of the energy-limiting type, or of a non-energy-limiting type equipped with an overcurrent device.

NOTE — “Low-secondary-voltage,” as used here, has a value of approximately 24 V.

7.10 Dry-Type Transformers

7.10.1 Dry-Type Transformer

See 2.3.2.2.

7.10.2 Ventilated Dry-Type Transformer

A dry-type transformer which is so constructed that the ambient air may circulate through its enclosure to cool the transformer core and windings.

7.10.3 Nonventilated Dry-Type Transformer

A dry-type transformer which is so constructed as to provide no intentional circulation of external air through the transformer, and operating at zero gauge pressure.

7.10.4 Sealed Transformer

A dry-type transformer with a hermetically sealed tank.

7.10.5 Gas-Filled Transformer

A sealed transformer, except that the windings are immersed in a dry gas which is other than air or nitrogen.

7.10.6 Compound-Filled Transformer

A transformer in which the windings are enclosed with an insulating fluid which becomes solid, or remains slightly plastic, at normal operating temperatures.

NOTE — The shape of the compound-filled transformer is determined in large measure by the shape of the container or mold used to contain the fluid before solidification.

8. System Terminology

8.1 System Voltage Terms

8.1.1 System Voltage

A root-mean-square (rms) phase-to-phase power frequency voltage on a three-phase alternating-current electrical system.

8.1.2 Nominal System Voltage

The system voltage by which the system is designated and to which certain operating characteristics of the system are related. (The nominal voltage of a system is near the voltage level at which the system normally operates and provides a per-unit base voltage for system study purposes. To allow for operating contingencies, systems generally operate at voltage levels about 5 to 10 percent below the maximum system voltage for which system components are designed.)

8.1.3 Maximum Voltages

8.1.3.1 Maximum System Voltage.

The highest rms phase-to-phase voltage which occurs on the system under normal operating conditions, and the highest rms phase-to-phase voltage for which equipment and other system components are designed for satisfactory continuous operation without derating of any kind. (This voltage excludes voltage transients and temporary overvoltages caused by abnormal system conditions such as faults, load rejection, etc.)

8.1.3.2 Maximum Design Voltage.

The highest rms phase-to-phase voltage that equipment components are designed to withstand continuously, and to operate in a satisfactory manner without derating of any kind.

8.1.4 Overvoltage

Abnormal voltage between two points of a system that is greater than the highest value appearing between the same two points under normal service conditions. Overvoltages may be low frequency, temporary, and transient — meaning a lightning or switching surge overvoltage.

8.1.4.1 Temporary Overvoltage.

An oscillatory phase-to-ground or phase-to-phase overvoltage at a given location of relatively long duration and which is undamped or only weakly damped. Temporary overvoltages usually originate from switching operations or faults (for example, load rejection, single-phase faults) or from nonlinearities (ferro-resonance effects, harmonics), or both. They may be characterized by their amplitude, their oscillation frequencies, their total duration, or their decrement.

8.1.4.2 Phase-to-Ground Per Unit Overvoltage.

The ratio of a phase-to-ground overvoltage to the phase-to-ground voltage corresponding to the maximum system voltage.

8.1.4.3 Phase-to-Phase Per Unit OverVoltage.

The ratio of a phase-to-phase overvoltage to the phase-to-phase voltage corresponding to the maximum system voltage.

8.1.5 Rated Voltage

The voltage to which operating and performance characteristics of apparatus and equipment are referred.

NOTE — Deviation from rated voltage may not impair operation of equipment, but specified performance characteristics are based on operation under rated conditions. However, in many cases apparatus standards specify a range of voltage within which successful performance may be expected.

8.1.6 Neutral Point

(1) The common point of a Y-connection in a polyphase system.

(2) The point of a symmetrical system which is normally at zero voltage.

8.2 Grounding

8.2.1 Grounded

Connected to earth or to some extended conducting body that serves instead of the earth, whether the connection is intentional or accidental.

8.2.2 Grounded System

A system of conductors in which at least one conductor or point (usually the middle wire or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a current-limiting device.

8.2.3 Ungrounded

A system, circuit, or apparatus without an intentional connection to ground except through potential-indicating or measuring devices or other very-high-impedance devices.

8.2.4 Neutral Ground

An intentional ground applied to the neutral conductor or neutral point of a circuit, transformer, machine, apparatus, or system.

8.2.5 Solidly Grounded

Grounded through an adequate ground connection in which no impedance has been inserted intentionally.

NOTE — Adequate as used herein means suitable for the purpose intended.

8.2.6 Impedance Grounded

Grounded through impedance.

NOTE — The component of the impedance need not be at the same location as the device to be grounded.

8.2.7 Resistance Grounded

Grounded through impedance, the principal element of which is resistance.

NOTE — The resistance may be inserted either directly, in the connection to the ground, or indirectly, as for example, in the secondary of a transformer, the primary of which is connected between neutral and ground, or in series with the delta-connected secondary of a wye-delta grounding transformer.

8.2.8 Reactance Grounded

Grounded through impedance, the principal element of which is reactance.

NOTE — The reactance may be inserted either directly, in the connection to ground, or indirectly, by increasing the reactance of the ground return circuit. The latter may be done by intentionally increasing the zero-sequence reactance of apparatus connected to ground, or by omitting some of the possible connections from apparatus neutrals to ground.

8.2.9 Ground-Fault Neutralizer Grounded (Resonant Grounded)

Reactance grounded through such values of reactance that, during a fault between one of the conductors and earth, the rated-frequency current flowing in the grounding reactances and the rated-frequency capacitance current flowing between the unfaulted conductors and earth shall be substantially equal.

NOTES:

1 — In the fault these two components of current will be substantially 180 degrees out of phase.

2 — When a system is ground-fault neutralizer grounded, it is expected that the quadrature component of the rated-frequency single-phase-to-ground fault current will be so small that an arc fault in air will be self-extinguishing.

8.2.10 Voltage to Ground

The voltage between any live conductor of a circuit and the earth.

NOTE — Where safety considerations are involved, the voltage to ground which may occur in an ungrounded circuit is usually the highest voltage normally existing between the conductors of the circuit, but in special circumstances, higher voltages may occur.

8.2.11 Multigrounded Neutral System

A distribution system of the four-wire type where all transformer neutrals are grounded, and neutral conductors are directly grounded at frequent points along the circuit.

8.2.12 Effectively Grounded

An expression that means grounded through a grounding connection of sufficiently low impedance (inherent or intentionally added, or both) that fault grounds that may occur cannot build up voltages in excess of limits established for apparatus, circuits, or systems so grounded.

NOTE — An alternating-current system or portion thereof may be said to be effectively grounded when, for all points on the system or specified portion thereof, the ratio of zero-sequence reactante to positive-sequence reactance is less than three and the ratio of zero-sequence resistance to positive-sequence reactance is less than one for any condition of operation and for any amount of connected generator capacity.

8.2.13 Coefficient of Grounding (Surge Arrester)

The ratio ($E_{L\,G}/E_{L\,L}$) expressed as a percentage, of the highest root-mean-square line-to-ground power-frequency voltage ($E_{L\,G}$) on a sound phase, at a selected location, during a fault to earth affecting one or more phases to the line-to-line power-frequency voltage ($E_{L\,L}$) that would be obtained, at the selected location, with the fault removed.

NOTES:

1 — Coefficients of grounding for three-phase systems are calculated from the phase-sequence impedance components as viewed from the selected location. For machines use the subtransient reactance.

2 — The coefficient of grounding is useful in the determination of an arrester rating for a selected location.

3 — A value not exceeding 80 percent is obtained approximately when for all system conditions the ratio of zero-sequence reactance to positive-sequence reactance is positive and less than three and the ratio of zero-sequence resistance to positive-sequence reactance is positive and less than one.

8.3 Connections

8.3.1 Delta Connection

So connected that the windings of a three-phase transformer (or the windings for the same rated voltage of single-phase transformers associated in a three-phase bank) are connected in series to form a closed circuit.

8.3.2 Open-Delta Connection

A connection similar to a delta—delta connection utilizing three single-phase transformers, but with one single-phase transformer removed.

NOTE — The two remaining transformers of an open-delta bank will carry 57.7 percent of the load carried by the bank using three identical transformers connected delta—delta.

8.3.3 Interconnected Delta Connection

A three-phase connection using six windings (two per phase) connected in a six-sided circuit with six bushings to provide a fixed phase-shift between two three-phase circuits without change in voltage magnitude.

NOTE — The interconnected delta connection is sometimes described as a “hexagon autotransformer,” or a “squashed delta.”

8.3.4 Extended Delta Connection

A connection similar to a delta, but with a winding extension at each corner of the delta, each of which is 120 degrees apart in phase relationship.

NOTE — The connection may be used as an autotransformer to obtain a voltage change or a phase shift, or a combination of both.

8.3.5 Y (or Wye) Connection

So connected that one end of each of the windings of a polyphase transformer (or of each of the windings for the same rated voltage of single-phase transformers associated in a polyphase bank) is connected to a common point (the neutral point) and the other end to its appropriate line terminal.

8.3.6 Zigzag Connection

A polyphase transformer with Y-connected windings, each one of which is made up of parts in which phase displaced voltages are induced.

8.3.7 Hoeppner Connection

A three-phase transformer connection involving transformation from a wye winding to the combination of a delta winding and a zigzag winding which are connected permanently in parallel.

NOTE — This connection is used when a wye—delta connection is needed, with ground connections on both primary and secondary windings.

8.3.8 Star Connection (non-preferred term)

See Y-connection.

8.3.9 T-Connected (or Tee-Connected) Transformer

A three-phase to three-phase transformer, similar to a Scott-connected transformer. (See 2.2.6.)

8.4 Miscellaneous

8.4.1 Alternating Current

A periodic current the average value of which over a period is zero.

NOTE — Unless distinctly specified otherwise, the term alternating current refers to a current that reverses at regularly recurring intervals of time and that has alternately positive and negative values.

8.4.2 Ampacity

Current-carrying capacity expressed in amperes, of a wire or cable under stated thermal conditions.

8.4.3 Circuits

8.4.3.1 Single-Phase Circuit.

An alternating-current circuit consisting of two or three intentionally interrelated conductors that enter (or leave) a delimited region at two or three terminals of entry. If the circuit consists of two conductors, it is intended to be so energized that, in the steady state, the voltage between the two terminals of entry is an alternating voltage. If the circuit consists of three conductors, it is intended to be so energized that, in steady state, the alternating voltages between any two terminals of entry have the same period and are in phase or in phase opposition.

8.4.3.2 Two-Phase Circuit.

A polyphase circuit of three, four, or five distinct conductors intended to be so energized that in the steady state the alternating voltages between two selected pairs of terminals of entry, other than the neutral terminal when one exists, have the same periods, are equal in amplitude, and have a phase difference of 90 degrees. When the circuit consists of five conductors, but not otherwise, one of them is a neutral conductor.

NOTE — A two-phase circuit as defined here does not conform to the general pattern of polyphase circuits. Actually a two-phase, four-wire, or five-wire circuit could more properly be called a four-phase circuit, but the term two-phase is in common usage. A two- phase three-wire circuit is essentially a special case, as it does not conform to the general pattern of other polyphase circuits.

8.4.3.3 Three-Phase Circuit.

A three-phase circuit is a combination of circuits energized by alternating electromotive forces which differ in phase by one third of a cycle, that is, 120 degrees.

NOTE — In practice, the phases may vary several degrees from the specified angle.

8.4.3.4 Six-Phase Circuit.

A combination of circuits energized by alternating electromotive forces which differ in phase by one-sixth of a cycle, that is, 60 degrees.

NOTE — In practice, the phases may vary several degrees from the specified angle.

8.4.4 Crest Value (Peak Value)

The maximum absolute value of a function when such a maximum exists.

8.4.5 Crest Factor (of a Periodic Function)

The ratio of its crest (peak, maximum) value to its root-mean-square (rms) value.

8.4.6 Eddy Currents

The currents that are induced in the body of a conducting mass by the time variation of magnetic flux.

8.4.6.1 Eddy Current Loss.

The energy loss resulting from the flow of eddy currents in a metallic material.

8.4.7 Hysteresis Loss (Magnetic)

The energy loss in magnetic material which results from an alternating magnetic field as the elementary magnets within the material seek to align themselves with the reversing magnetic field.

8.4.8 Cycle

The complete series of values of a periodic quantity that occurs during a period.

NOTE — It is one complete set of positive and negative values of an alternating current.

8.4.9 Frequency

The number of periods occurring per unit time.

8.4.10 Hertz

The unit of frequency (cycles per second).

8.4.11 Ferroresonance

A phenomenon usually characterized by overvoltages and very irregular wave shapes and associated with the excitation of one or more saturable inductors through capacitance in series with the inductor.

8.4.12 Overload (General)

Output of current power, or torque, by a device, in excess of the rated output of the device on a specified rating basis.

8.4.13 Harmonic Factor

The ratio of the effective value of all the harmonics to the effective value of the fundamental.

$$\text{Harmonic Factor (for voltage)} = \frac{\sqrt{E_3^{\,2} + E_5^{\,2} + E_7^{\,2} \ldots}}{E_1}$$

$$\text{Harmonic Factor (for current)} = \frac{\sqrt{I_3^{\,2} + I_5^{\,2} + I_7^{\,2} \ldots}}{I_1}$$