



IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers

STANDARDS

IEEE Power and Energy Society

Developed by the
Transformers Committee

IEEE Std C57.12.01™-2020
(Revision of IEEE Std C57.12.01-2015)



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of the
IEEE Power and Energy Society

Approved 24 September 2020

IEEE SA Standards Board

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Abstract: Electrical, mechanical, and safety requirements of ventilated, non-ventilated, and sealed dry-type distribution and power transformers or autotransformers (single and polyphase, with a voltage of 601 V or higher in the highest voltage winding) are described in this standard.

Keywords: autotransformer, dry-type distribution, IEEE C57.12.01, power transformer, voltage winding

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Introduction

This introduction is not part of IEEE Std C57.12.01–2020, IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers.

This standard is the result of an effort encompassing the interests of users, manufacturers, and others dedicated to producing voluntary consensus standards for dry-type transformers.

This standard was first published in 1979, and was revised and updated in 1989, 1998, 2005, and 2015. In the current version of the standard the cooling ratings were revised to correlate with those found in IEC and IEEE Std C57.12.00 and the description for Scott T connected transformers was enhanced. Additionally, the maximum system voltages were added to complement the nominal system voltages in Table 3 and the 0.25 kV and 0.6 kV voltage classes were removed as they are out of scope. The partial discharge (PD) test method and protocol was moved to IEEE Std C57.12.91 and an alternate short circuit thermal calculation was added from IEC.

The dielectric tests discussed in this standard consist of low-frequency and high-frequency testing. Low-frequency tests include induced voltages up to two times rated volts, which are intended to verify the integrity of turn-to-turn and layer-to-layer insulation systems. Applied potential tests verify the integrity of major insulation systems to ground and between separate windings. High-frequency tests include a $1.2 \times 50 \mu\text{s}$ wave and a chopped wave to verify the integrity of electrical windings to withstand lightning and certain switching transients.

It is important to reference NEMA ST 20 [B10]¹ and the National Electrical Code® (NEC®) (NFPA 70)^{2,3} [B11] as these standards refer to this standard.⁴ NEMA ST 20 is a standard for dry-type transformers with primary windings connected to secondary distribution circuits with voltages of 600 V and below usually installed and used in accordance with the National Electric Code. NEMA ST 20 is referenced in this introduction for information on voltages 600 V and below applications only.

This revision was developed by the General Requirements for Dry-Type Distribution and Power Transformers Working Group of the Dry-Type Transformers Subcommittee of the IEEE Transformers Committee of the IEEE Power and Energy Society.

¹NEMA publications are available from the National Electrical Manufacturers Association (<https://www.nema.org/>).

²NFPA publications are published by the National Fire Protection Association (<https://www.nfpa.org/>).

³The NEC is published by the National Fire Protection Association (<http://www.nfpa.org/>). Copies are also available from the Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

⁴The numbers in brackets correspond to those of the bibliography in Annex A.

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1. Overview

1.1 Scope

This standard describes electrical and mechanical requirements of single and polyphase ventilated, non-ventilated, and sealed dry-type distribution and power transformers or autotransformers, with a voltage of 601 V or higher in the highest voltage winding. This standard applies to all dry-type transformers, including those with solid-cast and/or resin encapsulated windings except as follows:

- a) Instrument transformers
- b) Step- and induction-voltage regulators
- c) Arc-furnace transformers
- d) Rectifier transformers
- e) Specialty and general-purpose transformers
- f) Mine transformers

g) Testing transformers

h) Welding transformers

NOTE—Where IEEE standards do not exist for the transformers mentioned above or for other special transformers, this standard may be applicable as a whole or in parts subject to agreement between the parties responsible for the application and for the design of the transformer.^{5 4}

1.2 Purpose

This standard is intended to serve as a basis for the establishment of performance⁴—and interchangeability requirements of equipment described, and for assistance in the proper selection of such equipment.

1.3 Word usage

~~When this standard is used on a mandatory basis,~~ The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).^{6, 7}; ~~the words *should* and *may* refer to matters that are recommended or permissive but not mandatory.~~

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

^{5 4}Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements. *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

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

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C57.12.55, American National Standard for Dry-Type Transformers—Used in Unit Installations, Including Unit Substations—Conformance Standard.^{8 2}

ANSI C84.1, American National Standard for Electric Power Systems and Equipment—Voltage Ratings (60 Hz ~~Hertz~~).

IEEE Std C57.12.52™, IEEE Standard for Sealed Dry-Type Power Transformers, 501 kVA and Higher, Three-Phase, with High-Voltage 601 to 34500 Volts, Low-Voltage 208Y/120 to 4160 Volts, General Requirements.^{9,10}

IEEE Std C57.12.60™, IEEE Standard ~~Guide for Test Procedures~~ for Thermal Evaluation of Insulation Systems for Dry-Type ~~Solid-Cast and Resin-Encapsulated~~ Power and Distribution Transformers.³

^{8 2}—ANSI publications are available from the ~~Sales Department~~, American National Standards Institute, ~~25 West 43rd Street, 4th Floor, New York, NY 10036, USA~~ (~~https~~ http://www.ansi.org/).

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^{10 3}—IEEE publications are available from The Institute of Electrical and Electronics Engineers, ~~445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA~~ (~~https~~ http://www.standards.ieee.org/).

IEEE Std C57.12.70™, IEEE Standard for [Standard](#) Terminal Markings and Connections for Distribution and Power Transformers.

IEEE Std C57.12.80™, IEEE Standard Terminology for Power and Distribution Transformers.

IEEE Std C57.12.91™, IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.

IEEE Std C57.96™, IEEE Guide for Loading Dry-Type Distribution and Power Transformers.

[IEEE Std C57.110™, IEEE Recommended Practice for Establishing Liquid-Immersed and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents.](#)

IEEE Std C57.124™, IEEE Recommended Practice for the Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers.

IEEE Std C57.142™, IEEE Guide to Describe the Occurrence and Mitigation of Switching Transients Induced by Transformers, Switching Device, and System Interaction.

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.^{11 4} Standard transformer terminology, which is available in IEEE Std C57.12.80™⁵,¹² shall [also](#) apply.

reference temperature: Unless otherwise stated, the reference temperature shall be defined as 20 °C plus the rated average winding rise. For multiple winding transformers that have more than one base rated average winding rise, the highest average winding rise shall be used to determine the reference temperature.

^{11 4} *IEEE Standards Dictionary Online* ~~subscription~~ is available at: [http://dictionary www.ieee.org](http://dictionary.ieee.org). [An IEEE Account is required for access to the dictionary, and one can be created at no charge on the /portal/innovate/products/standard/standards_dictionary sign-in page.html.](#)

^{12 5} Information on references can be found in Clause 2.

reference temperature for no-load losses: The no-load losses of power and distribution transformers shall be determined based on a reference temperature ~~at of~~ 20 °C.^{13 6}

4. Service conditions

4.1 Usual service conditions

4.1.1 General

Transformers conforming to this standard shall be suitable for operation at rated ~~kVA power~~ under the usual service conditions in 4.1.2 through 4.1.9. For unusual service conditions see Unusual service conditions in 4.2.

4.1.2 Temperature

4.1.2.1 Cooling air temperature limit

The temperature of the cooling air (ambient temperature) shall not exceed 40 °C, and the average temperature of the cooling air for any 24-~~h hour~~ period shall not exceed 30 °C.

The minimum ambient temperature shall not be lower than –30 °C.

~~For special ambient temperatures below –30 °C, see 4.2.1 and 4.2.6.~~

4.1.2.2 Cooling water temperature limit

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

^{13 6}~~Correction of~~ No-Load Losses will be required to be measured when the ~~top yoke~~ temperature of the top yoke of the core is less ~~greater~~ than 40 °C.

4.1.3 Altitude

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

4.1.4 Supply voltage

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

4.1.5 Load current

The load current shall be approximately sinusoidal. The harmonic factor shall not exceed 0.05 per unit. ~~NOTE~~—Harmonic factor is defined in IEEE Std C57.12.80. [Refer to IEEE Std C57.110 for information on establishing transformer capability when supplying nonsinusoidal load currents.](#)

4.1.6 Operation above rated voltage [or below rated frequency](#)

Transformers shall be capable of

- a) Operating continuously above rated voltage or below rated frequency, at maximum rated kilovolt-amperes for any tap, without exceeding limits of observable temperature rise when secondary voltage and volts per hertz does not exceed 105% of rated values, load power factor is 80% or higher, and frequency is at least 95% of rated value.
- b) Operating continuously above rated voltage or below rated frequency on any tap at no load, without exceeding limits of observable temperature rise when neither the voltage nor volts per hertz exceed 110% of rated values.

The maximum continuous transformer operating voltage should not exceed the levels specified in ANSI [C844](#) ~~C84~~.1.

NOTE—System conditions may require voltage transformation ratios involving tap voltages higher than the maximum system voltage for regulation purposes. However, the appropriate maximum system voltage should be observed under operating conditions.

4.1.7 Location

Sealed and non-ventilated transformers shall be suitable for indoors, outdoors, or indoor and outdoor operation as specified.

Unless otherwise specified, ventilated transformers shall be suitable for indoor operation or outdoor operation as specified. When used outdoors, the transformer shall be provided with a suitable weather-resistant enclosure that complies with the requirements contained in ANSI C57.12.55 for outdoor enclosures.

4.1.8 Step-down operation

Unless otherwise specified, dry-type transformers shall be designed for step-down operation.^{14 7}

4.1.9 Tank or enclosure finish

Temperature limits and tests shall be based on the use of a non-metallic pigment-coating finish.

4.2 Unusual service conditions

4.2.1 General

Conditions, other than those described in 4.1, are considered unusual service conditions and, when present, shall ~~should~~ be brought to the attention of those responsible for the design and application of the apparatus.

4.2.2 Ancillary components

When specified, construction features (cables, leads, tap changers, etc.) shall be supplied so that the ancillary components will not, in themselves, limit the short-time loading to less than that which will result in no loss in normal life expectancy of the winding insulation system.

^{14 7} See Footnote i of Table 10 12.

4.2.3 Unusual loading

IEEE Std C57.96 provides guidance for loading under unusual conditions, including [the following](#):

- a) Ambient temperatures higher or lower than the basis of rating
- b) Short-time loading in excess of nameplate [kVA](#) ~~rated power~~ with normal life expectancy
- c) Loading that results in reduced life expectancy
- d) High-altitude service conditions

NOTE—IEEE Std C57.96 is a guide. It provides the best known general information for the loading of transformers under various conditions based on typical winding insulation systems, and it is based on the best engineering information available at the time of preparation. The guide discusses limitations of ancillary components other than windings that may limit the capability of transformers to meet the guide.

4.2.4 Unusual altitude conditions

[4.2.4.1 Thermal performance at high altitude](#)

Information regarding the operation of transformers above 1000 m (3300 ft) is presented in IEEE Std C57.96. The [guide](#) ~~standard~~ provides information that includes the effects of altitude on temperature rise, operation at rated [kVA](#) ~~power~~ and reduced ambient temperature, and operation at less than rated [kVA](#) ~~power~~. An altitude of 4500 m (15 000 ft) is considered a maximum for transformers conforming to this standard.

4.2.4.2 Insulation at high altitude

The dielectric strength of transformers that depend in whole or in part on air for insulation, decreases as the altitude increases due to the effect of decreased air density. Standard dielectric insulation test levels are found in Table [3](#) ~~5~~.

When specified for installation and/or testing above 1000 m (3300 ft), transformers shall be designed with [an](#) appropriate insulation system to meet the required dielectric insulation test level. To [define](#) ~~determine~~ this insulation test level, use the altitude correction factor found in Table 1.

4.2.4.2.1 Insulation test levels

When performing dielectric insulation tests, multiply the standard dielectric insulation test level found in Table [3](#), [5](#) by the Test Correction Factor, T_{CF} .

$$T_{CF} = \frac{\text{correction factor at tested altitude}}{\text{correction factor at installed altitude}}$$

For altitudes not listed, the correction factor can be defined by interpolation of the data in Table 1.

NOTE—If the transformer is tested at the same altitude as it is to be installed, there is no correction to the dielectric insulation ~~test~~ levels.

Table 1—Dielectric insulation level correction factors, [T_{CF}](#)

Altitude		Altitude correction factor for dielectric strength, T_{CF}
Meters (m)	Feet (ft)	
≤ 1 000	≤ 3 300	1.00
1 200	4 000	0.98
1 500	5 000	0.95
1 800	6 000	0.92
2 100	7 000	0.89
2 400	8 000	0.86
2 700	9 000	0.83
3 000	10 000	0.80
3 600	12 000	0.75
4 200	14 000	0.70
4 500	15 000	0.67

[\(New\)](#)

Altitude		Altitude correction factor for dielectric strength
Meters (m)	Feet (ft)	
≤ 1000	≤ 3300	1.00
1200	4000	0.98
1500	5000	0.95
1800	6000	0.92
2100	7000	0.89
2400	8000	0.86
2700	9000	0.83
3000	10 000	0.80
3600	12 000	0.75
4200	14 000	0.70
4500	15 000	0.67

(Deleted)

An altitude of 4500 ~~m meters~~ (15000 ft) is considered a maximum for transformers conforming to this standard.

Examples in Annex B illustrate how to determine the test correction factor, T_{CF} .

4.2.5 Other unusual service conditions

Other unusual service conditions include [the following](#):

- a) Damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, and excessive moisture or dripping water constitute service conditions for which some dry-type transformers are not intended and, therefore, may have detrimental effects on transformer life.

NOTE—The seriousness of the effects of the unusual conditions listed in item a) varies widely, depending on the design of ~~the~~ dry-type transformer involved. Although such conditions may have little or no effect on sealed or non-ventilated dry-type transformers, they may have serious effects on ventilated dry-type transformers. Contact the manufacturer to determine potential impacts, if any, on ventilated dry-type transformers.

- b) Abnormal vibrations, tilting, shock, or seismic conditions.

- c) Ambient temperatures outside the normal range.
- d) Unusual transportation or storage conditions.
- e) Unusual space limitations.
- f) Unusual maintenance problems.
- g) Unusual duty or frequency of operation, impact loading.
- h) Unbalanced ac voltages, or departure of ac system voltages from a substantially non- sinusoidal wave form.
- i) Loads involving abnormal harmonic currents, such as those that may result where solid-state or similar devices control appreciable load currents. Harmonic currents may cause excessive losses and abnormal heating. Refer to IEEE Std C57.110 ~~Limits for usual service conditions are identified in 4.1.5.~~
- j) Multi-winding transformers with a specified combination of kVA ~~power~~ outputs and power factors for each winding.
- k) Unusually high, low, or unbalanced ac system impedance.
- l) ~~Over~~-Excitation exceeding either 110% rated voltage or 110% rated volts per hertz ~~V/Hz~~.
- m) Planned short circuits as part of a regular operating or relaying practice.
- n) Short-circuit application conditions requiring special consideration as described in 7.5.
- o) Special insulation requirements or unusual transient voltages present on the ac power supply, including resonant or switching-related disturbances, refer to ~~(IEEE Std C57.142TM {B2})~~.
- p) Unusually strong magnetic radiation.
- q) Unusually high nuclear fields.

- r) Parallel operation. It should be noted that while ~~NOTE—Although~~ parallel operation is not unusual, it is desirable that users advise manufacturers if paralleling with other transformers is planned and identify the transformers involved. Users should consider the matching of unit voltages and impedances in specifying transformers for parallel operation for appropriate load sharing.

5. Rating data

5.1 Cooling classes of transformers

Transformers shall be identified according to the cooling method employed. For dry-type transformers, this identification is expressed by a four letter code, described as follows.

NOTE 1—These designations are consistent with IEEE Std C57.12.00 [B7].

First letter: Internal cooling medium in contact with the windings

A Air

G Dry air or nitrogen (sealed)

W Water

Second letter: Circulation mechanism for internal cooling medium

N Natural convection flow through windings

F Forced circulation through windings (fans or pumps)

Third letter (optional): External cooling medium

A Air

W Water

Fourth letter (optional): Circulation mechanism for external cooling medium

N Natural convection

F Forced circulation (fans or pumps)

NOTE 2—The third and fourth letters are only optional if the external cooling medium is Air.

A transformer may be specified with more than one kVA rating. The transformer nameplate shall list the rated kVA and cooling class designation for each rating. The ratings shall be listed in order of increasing kVA and separated with a “/”. The cooling class designations shall be listed in the order corresponding with the kVA and a diagonal slash separating each one.

Examples:

AN/AF. The base kVA rating of the transformer is by normal convection of air. The elevated kVA rating is produced by forced air flow.

GNAN. The transformer is a sealed dry-type per IEEE Std C57.12.52 with dry air inside and cooled by the natural convection of air outside.

AFWF. The transformer is inside a non-ventilated enclosure with forced air using a pumped water heat exchanger.

ANAN. The transformer is inside an enclosure that provides no intentional circulation of external air through the transformer, and that operates at zero gauge pressure.

ANAF. The transformer is inside an enclosure that provides no intentional circulation of external air through the transformer, and that operates at zero gauge pressure but includes means to circulate the air inside the enclosure.

~~Transformer cooling classes are listed in Table 2.~~