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An American National Standard

IEEE Guide for Loading Dry-Type Distribution and Power Transformers

Sponsor
**Transformers Committee
of the
IEEE Power Engineering Society**

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Foreword

(This Foreword is not a part of ANSI/IEEE C57.96-1989, IEEE Guide for Loading Dry-Type Distribution and Power Transformers.)

This guide for loading dry-type distribution and power transformers with 80 °C, 115 °C, and 150 °C average winding rises has been developed to cover modern transformers through 10 000 kVA.

The 150 °C, 185 °C, and 220 °C insulation systems meet the thermal evaluation criteria established by ANSI/IEEE C57.12.56-1986, IEEE Standard Test Procedure for Thermal Evaluation of Insulation Systems for Ventilated Dry-Type Power and Distribution Transformers.

Work completed by the IEEE Insulation Subcommittee, comprising life test on transformer models is the basis for the insulation life versus temperature relationship, designated as minimum life expectancy in ANSI/IEEE C57.12.56-1986, which in turn is based on the Arrhenius reaction rate theory. To avoid ambiguity, this guide will use the term normal life expectancy to indicate the life to be expected at a given temperature. The normal life expectancy at 140 °C, 175 °C, and 210 °C hottest-spot temperature in a 30 °C ambient for 80 °C, 115 °C, and 150 °C rise transformers respectively is 20 years.

The load profile used in the preparation of the loading tables in this guide was chosen as a representative daily cycle. Loss of life was determined by computer computation of the actual hottest-spot profile for the lead cycle and ambient conditions.

This new method of calculation is more accurate than previous methods. Hand calculation methods are illustrated in Section 6.

The assumed characteristics were obtained by a consensus of users and manufacturers as being the best typical characteristics for modern transformers.

At present, this guide is not intended to be applied to transformers with solid-cast or resin-encapsulated windings. It is expected that this type of transformer will be included in the next revision of the guide when adequate data are available.

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1. General

1.1 Scope

1.1.1

This guide covers general recommendations for the loading of dry-type distribution and power transformers that have 80 °C, 115 °C, and 150 °C average winding rises and insulation systems limited to 150 °C, 185 °C, and 220 °C maximum hottest-spot operating temperatures respectively. The guide includes recommendations for ventilated, nonventilated, and sealed dry-type transformers having impregnated insulation systems.

1.1.2

If the user desires more specific recommendations for a particular transformer, the manufacturer of that transformer should be consulted.

1.2 Limitations

1.2.1

It must be recognized that the recommendations given in this guide are based solely on the thermal characteristics of dry-type transformers. Loads above rating, based on this guide, may be applied only after a thorough study has been made of all the other various limitations that may be involved. Among these limitations are gas expansion and pressure in sealed dry-type units and, in both ventilated and sealed transformers, the bushings, leads, connections, tap changers, and the thermal capability of associated equipment, such as cables, reactors, circuit breakers, disconnecting switches, and current transformers. Also, limitations may be imposed by voltage regulation necessary for satisfactory operation of connected apparatus and by the increased operating costs due to the higher losses accompanying loads above rating. These may constitute the practical limit on load-carrying ability and should be considered before applying loads in excess of rating.

1.2.2

It is intended that dry-type transformers be installed based on the recommendations given in ANSI/IEEE C57.94-1982 [2].¹ If dry-type transformers are installed in subsurface vaults or enclosures of minimum size where the natural ventilation is insufficient to prevent marked changes in the ambient temperature with changes in transformer losses, then the increase in effective ambient temperature for expected increased transformer losses must be determined before loading limitations can be estimated.

1.2.3

Dry-type transformers are generally designed to permit loading in line with these guides, but if there are any questions as to the capability of a particular transformer to carry the desired load, the manufacturer should be asked for specific recommendations.

1.3 Transformer Life Expectancy

1.3.1

Recommendations in this guide are based on life expectancy of transformer insulation as affected by operating temperature and time.

1.3.2

Transformer life expectancy at various operating temperatures is not accurately known, but the information given regarding loss of life of insulation is considered to be conservative and the best that can be produced from present knowledge of the subject. (The effects of temperature on insulation life are being investigated continuously, and new findings may affect future revisions of the guide. The word "conservative" is used in the sense that the expected loss of insulation life for recommended load will not be greater than the amount stated.)

1.4 Transformer Rated Output

1.4.1

The rated kilovolt-ampere output of a transformer is that load that it can deliver continuously at rated secondary voltage and rated frequency without exceeding the specified temperature rise under usual service conditions, as described in Section 4 of ANSI/IEEE C57.12.01-1979 [2]. The term "rated output" or "rated load" used in these guides refers to nameplate rating of continuously rated transformers. For transformers that do not have a continuous rating, the manufacturer should be consulted for additional information when such information is not indicated on the nameplate.

1.4.2

The temperature rise on which the rating is based takes into consideration the experience of the industry regarding the following:

- 1) Insulation life as affected by operating temperature; and
- 2) The ambient temperature assumed to exist throughout the life of the transformer.

¹The numbers in brackets correspond to those of the references listed in Section 2.

1.4.3

The actual output that a transformer can deliver at any time in service without undue deterioration of the insulation may be more or less than the rated output, depending upon the ambient temperature, altitude, and other attendant operating conditions.

1.5 Aging of Insulation

1.5.1

Aging or deterioration of insulation is a function of time and temperature. Since, in most apparatus, the temperature is not uniform, that part that is operating at the highest temperature will ordinarily undergo the greatest deterioration. Therefore, aging studies consider the aging effects produced by the highest temperature.

1.5.2

Practically all of the data in reference to the aging of insulation at different temperatures have been obtained in laboratory tests in which the changes in mechanical or electrical properties, or both, have been measured. The relation between the life expectancy of insulation as indicated by laboratory tests and the actual life of a transformer is largely theoretical; thus loading based on such information should be tempered by sound judgment based on experience.

1.5.3

Because the cumulative effects of temperature and time in causing deterioration of transformer insulation are not thoroughly established, it is not possible to predict to a great degree of accuracy the length of life of a transformer even under constant or closely controlled conditions, much less under widely varying service conditions.

1.5.4

The change in rate of deterioration with change in temperature has received much study, but the amount of change in actual transformer life with a change in operating temperature remains debatable. However, there is agreement that, in all of the methods of calculating the effect of operating temperature on insulation life, higher than normal operating temperatures, whether they are due to loads above rating or to high ambients, result in some reduction in transformer life expectancy.

1.5.5

The many variables mentioned and particularly the many varying conditions of load and ambient to which a transformer can be subjected in service, make it impossible to give precise rules for the loading of transformers. However, it is possible to give suggested loadings under specified conditions to assist the user in making loading decisions.

1.6 Ambient Temperature

1.6.1

Ambient temperature is an important factor in determining the load capability of a transformer, since the temperature rise for any load must be added to the ambient to determine the operating temperature. Whenever the actual ambient temperature can be determined from readings taken at the time of the load being considered, such temperatures should be used to determine the winding hottest-spot temperature and the load capability of the transformer.

1.6.2

It is often necessary to predict the load that a transformer can carry with no sacrifice of life expectancy at some future time when the actual ambient temperature is unknown. For dry-type transformers used in indoor installations, the ambient temperature can be approximated from heating or air conditioning records of the installation. For transformers used outdoors, the ambient temperature for the month in which the expected load is anticipated can be obtained from reports gathered by the Environmental Data and Information Service, National Oceanic and Atmospheric Administration. These reports are available for various sections of the United States.²

1.6.3

These ambients should be used as follows:

- 1) For loads with normal life expectancy, use the average temperature over a period of years for the month involved.
- 2) For short-time loads above rating with moderate sacrifice of life expectancy, use the average of the daily maximum temperatures for the month involved, averaged with similar values for the same month over a period of years.

Table 1— Self-Cooled Continuous Loading on Basis of Average Ambient Temperature

Type of Unit	Maximum Rated Hottest-Spot Temperature °C	Hottest-Spot Temperature 30 °C Ambient	Percent of Rated kVA/°C
			Increase for Average Ambient Less than 30 °C or Decrease for Average Ambient Greater Than 30 °C
Ventilated	150	140	(0.57)
Self-Cooled	185	175	(0.43)
	220	210	(0.35)
Sealed	150	140	(0.65)
Self-Cooled	185	175	(0.49)
	220	210	(0.40)

1.7 Influence of Ambient Temperature

1.7.1

The average ambient temperature should cover periods of time not exceeding 24 hours with the maximum temperature not more than 10 °C greater than the average temperature. For each degree C that the average temperature of the cooling air is above or below 30 °C, a transformer may be loaded below or above its nameplate kilovolt-ampere rating for any period of time as specified in Table 1.

1.7.2

Loading on the basis of ambient temperature with the loads permitted by Table 1 will give approximately the same life expectancy as if the transformers had been operated at nameplate rating and standard ambient temperatures over the same period.

²This information can be obtained by writing to the National Climatic Data Center, Federal Bldg, Asheville, NC 28801, or by calling (704) 259-0682.

1.7.3

The operation of transformers in cooling air above 50 °C, or below 0 °C, is not covered by Table 1 and should be checked with the manufacturer.

1.7.4

Since the ambient temperature is an important factor in determining the load capability of a transformer, it should be controlled for indoor installations by adequate ventilation, and it should always be considered in outdoor installations.

1.8 Influence of Altitude on Loading

1.8.1

The effect of the decreased air density due to high altitude is to increase the temperature rise of transformers since they are dependent upon air for dissipation of heat loss.

1.8.2

Transformers may be operated at rated kilovolt-amperes at altitudes greater than 3300 ft (1000 m) without exceeding temperature limits, provided the average temperature of the cooling air does not exceed the values of Table 2 for the respective altitudes. The data included in Table 2 apply to ventilated dry-type transformers only, and are not applicable to sealed and nonventilated dry-type transformers. Data for sealed and nonventilated dry-type transformers will be included in a later revision of this guide.

1.8.3

Transformers may be operated in a 30 °C ambient at altitudes greater than 3300 ft (1000 m) without exceeding temperature limits, provided the load to be carried is reduced below rating by the percentages given in Table 3 for each 330 ft (100 m) that the altitude is above 3300 ft (1000 m).

**Table 2— Unusual Temperature and Altitude Conditions
(Maximum Allowable 24-Hour Average Temperature of Cooling Air,
in Degrees Celsius for Operation at Rated kVA)**

Type of Apparatus	Altitude			
	3300 ft (1000 m)	6600 ft (2000 m)	9900 ft (3000 m)	13200 ft (4000 m)
Class AA				
80 °C Rise	30	26	22	18
115 °C Rise	30	24	18	12
150 °C Rise	30	22	15	7
Class AA/FA and AFA				
80 °C Rise	30	22	14	6
115 °C Rise	30	18	7	-5
150 °C Rise	30	15	0	-15