IEEE Std 4a-2001
(Amendment to
IEEE Std 4-1995)

Amendment to IEEE Standard Techniques for High-Voltage Testing

Sponsor

Power Systems Instrumentation and Measurement Committee
of the
IEEE Power Engineering Society

Approved 17 March 2001

IEEE-SA Standards Board

Abstract: This amendment sets forth a number of clarifications and corrections to IEEE Standard Techniques for High-Voltage Testing.
Keywords: atmospheric correction factors, high-voltage testing, testing

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Introduction

(This introduction is not part of IEEE Std 4a-2001, Amendment to IEEE Standard Techniques for High-Voltage Testing.)

Shortly after IEEE Std 4-1995 was published, test laboratories and manufacturers of certain types of switchgear equipment observed that the Air Density and Humidity Correction Factors were substantially different for the smaller air gaps. Subsequent to this, a paper "Humidity Correction Procedures and Their Effects on AC Sparkover Voltage Characteristics of Small Air Gaps" by Christopher M. Pawlak, Daniel S. Oswiecinski, Weiguo Que, and Stephen A. Sebo from Ohio State University was presented at the October 1998 North American Power Conference in Cleveland Ohio. This paper substantiates that for air gaps less than 0.3 meter in length there is a measurable difference between the density and humidity correction factors as obtained from the 1978 and the 1995 versions of IEEE Std 4.

The purpose of this amendment is to reinstate and permit the use of the rod-gap data and the air density and humidity correction factors as given in IEEE Std 4-1978 when the electrical clearance is 1 meter or less in length. A partial list of standards covering known equipment affected is given below.

1) ANSI C37.54-1996, American National Standard for Switchgear—Indoor Alternating-Current Medium-Voltage Circuit Breakers Applied as Removable Elements in Metal-Enclosed Switchgear—Conformance Test Procedures
2) ANSI C37.55-1989, American National Standard for Switchgear—Metal-Clad Switchgear Assemblies—Conformance Test Procedures
3) ANSI C37.57-1990, American National Standard for Switchgear—Metal-Enclosed Interrupter Switchgear Assemblies—Conformance Test Procedures
4) ANSI C37.58-1990, American National Standard for Switchgear—Indoor AC Medium-Voltage Switches for Use in Metal-Enclosed Switchgear—Conformance Test Procedures
5) IEEE C37.04-1999, IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
6) IEEE C37.09-1999, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
7) IEEE C37.20.2-1999, IEEE Standard for Metal-Clad Switchgear
8) IEEE C37.20.3-1987 (Reaff 1992), IEEE Standard for Metal-Enclosed Interrupter Switchgear
9) IEEE C37.20.4-1996, IEEE Trial-Use Standard for Indoor AC Medium-Voltage Switches for Use in Metal Enclosed Switchgear
10) IEEE C37.30 series where applicable for High-Voltage Air Switches, Insulators, and Bus Supports
11) IEEE C57.19.00-1991 (Reaff 1997), IEEE Standard General Requirements and Test Procedures for Outdoor Apparatus Bushings

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Contents

Amendment to IEEE Standard Techniques for High-Voltage Testing

NOTE—The editing instructions contained in this amendment define how to merge the material contained herein into the existing base standard and its amendments to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make small corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strikethrough~~ (to remove old material) and <u>underscore</u> (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make large changes in existing text, subclauses, tables, or figures by removing existing material and replacing it with new material. Editorial notes will not be carried over into future editions because the changes will be incorporated into the base standard.

1. Overview

1.1 Scope

This amendment is applicable to dielectric tests with alternating voltages and impulse voltages, when testing an apparatus with air gaps up to 1 meter in length. It specifies correction factors for air density and humidity, which may be applied when the specific apparatus standard allows. This amendment is to be applied in conjunction with IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing. The paragraph numbering beginning at 1.3.5, equations, and figure numbers are as they were in IEEE Std 4-1978. Thus a reference to this amendment for a specific clause, etc., will be the same as in the original standard.

1.2 Purpose

This amendment adds the air density and humidity correction factors of the 1978 version of IEEE Std 4 to be used with the standardized rod-gap data when testing apparatus with air gaps up to 1 meter in length.

Dielectric test voltage atmospheric correction factors

The atmospheric correction factors listed in 1.3.5 may be applied for gap spacing up to 1 meter in length to the standardized rod-rod gap sparkover data for impulse test voltages found in 17.7, Table 11 of IEEE Std 4-1995.

1.3.5 Atmospheric conditions

1.3.5.3 Atmospheric correction factors

The disruptive discharge voltage of external insulation depends upon the prevailing atmospheric conditions. Usually, the flashover voltage for a given path in air is raised by an increase in either air density or humidity. However, when the relative humidity exceeds about 80 percent, the flashover voltage becomes irregular, especially when the flashover occurs across an insulating surface.

By applying correction factors, a measured flashover voltage may be converted to the value that would have been obtained under the reference atmospheric conditions. Conversely, a test voltage specified for the reference conditions can be converted into the equivalent value under the prevailing test conditions.

There are two correction factors. They are as follows:

a) The air density correction factor k_d (see 1.3.5.3)
b) The humidity correction factor k_h (see 1.3.5.3)

The disruptive discharge voltage is proportional k_d/k_h.

If not otherwise specified by the appropriate apparatus standard, the voltage to be applied during a withstand test on external insulation is determined by multiplying the specified withstand voltage by k_d/k_h. Similarly, measured disruptive discharge voltages are corrected to those applicable for a standard reference atmosphere by dividing by k_d/k_h.

It is left to the appropriate apparatus standard to specify whether or not corrections have to be applied to the voltage values in those cases where both external and internal insulations are involved. The test report should always contain the actual atmospheric conditions during the test and it shall be indicated whether corrections have been applied or not.

1.3.5.2 Standard reference atmosphere

The standard reference atmosphere is as follows:

Temperature t_o = 20 °C

Pressure p_o = 101.3 kPa (760 mm Hg)

Humidity h_o = 11 g water vapor per cubic meter

NOTES

1—A pressure of 101.3 kPa corresponds to a height of 760 mm in a mercury barometer at 0 °C. If the height of the barometer is H millimeters of mercury and the temperature is *t* degrees Celsius, the atmospheric pressure in Pascals is as follows:

$$p = \frac{1.013 \times 10^5 H}{760}(1 - 1.8 \times 10^{-4} \times t)$$

Correction for temperature is negligible under normal temperature conditions.

2—In previous issues of this standard the reference temperature was 25 °C and the reference humidity was 15g/m^3. The change in temperature has the effect of increasing corrections to standard conditions by 1.8 percent for air density and decreasing those for humidity by approximately 5 percent for alternating voltage and 4 percent for lightning impulse.

1.3.5.3 Air density and humidity correction factors

The air density correction factor, k_d, is given by the following:

$$k_d = \left(\frac{p}{p_o}\right)^m \times \left(\frac{273 + t_o}{273 + t}\right)$$

where

p	is the atmospheric pressure under test conditions
t	is the temperature (in °C) under test conditions

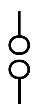
Similarly, the humidity correction factor is as follows:

$$k_h = (k)^w$$

The constant k is given in Figure 1.3 as a function of absolute humidity, curve a or b being applicable according to the type of voltage. The exponents m, n, and w depend on the type and polarity of the voltage and on the flashover distance d as given in Table 1.3 and Figure 1.4. Lacking more precise information, m and n are assumed to be equal.

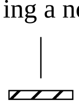
The symbols of Table 1.3 are as follows:

Gaps giving an essentially uniform field.



Rod–rod gaps and test objects with electrodes giving a nonuniform field, but with essentially symmetrical voltage distribution.

Rod-plane gaps and test objects with similar characteristics such as support insulators; that is, electrodes giving a nonuniform field with a pronounced asymmetrical voltage distribution.



For any electrode arrangement not falling into one of the preceding classes, only the air density correction factor, using exponents $m = n = 1$, and no humidity correction, should be applied.

For wet tests, the air density correction factor should be applied but not the humidity correction factor. For artificial contamination tests, neither correction factor should be used.

NOTE—In Table 1.3, Figure 1.3, and Figure 1.4, a simplification of the existing information is given. The available experimental data from different sources always show large dispersions and are often conflicting; moreover, relevant information for direct voltages, and for switching impulses is scarce. The correctness of using equal exponents m and n, and of their numerical values as given, is therefore uncertain.

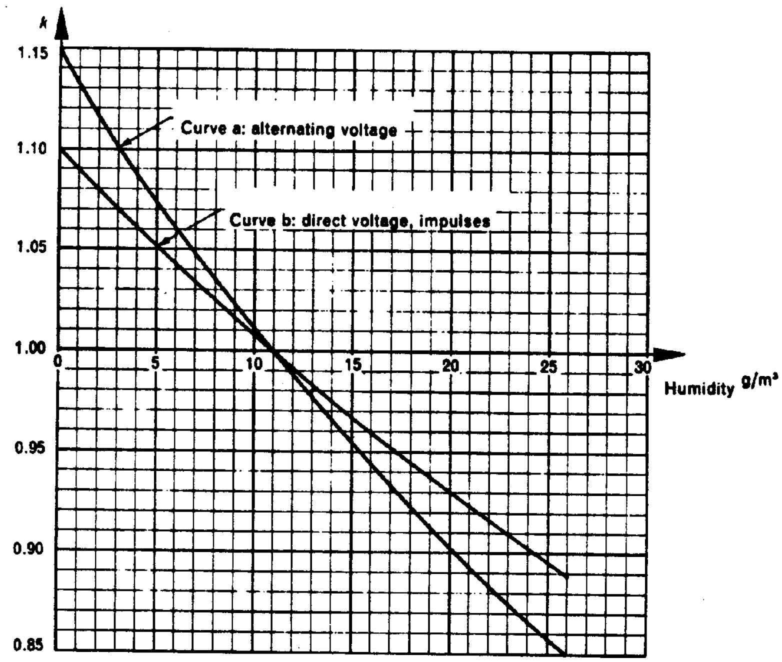


Figure 1.3—Humidity correction factor *k* as a function of absolute humidity
(For applicability, see 1.3.4.3 and Table 1.3)

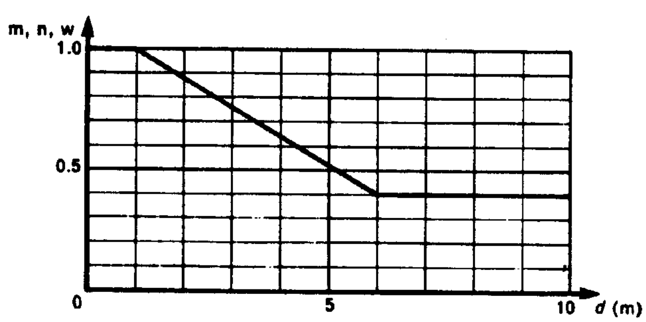


Figure 1.4—Values of the exponents *m* and *n* for air density correction and *w* for humidity corrections, as a function of sparkover distance, in meters
(See 1.3.4.3 and Table 1.3)

Table 1.3—Application of atmospheric correction factors

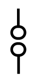
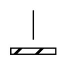
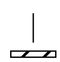
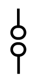
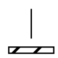
Type of test voltage	Electrode form	Polarity	Air density correction Exponents *m* and *n* (see note in 1.3.5.3)	Humidity correction Factor *k*	 Exponent *w*
Direct voltage		+ –	1.0	See Figure 1.3, (curve *b*)	0 0
		+ –			1.0 1.0
		+ –			1.0 0
Alternating Voltage		~	1.0	See Figure 1.3 (curve *a*)	0
		~	See Figure 1.4		See Figure 1.4
		~	See Figure 1.4		See Figure 1.4
Lightning impulse voltage		+ –	1.0	See Figure 1.3 (curve *b*)	0 0
		+ –			1.0 0.8
		+ –			1.0 0

Table 1.3—Application of atmospheric correction factors *(continued)*

Type of test voltage	Electrode form	Polarity	Air density correction: Exponents *m* and *n* (see note in 1.3.5.3)	Humidity correction: Factor *k*	Humidity correction: Exponent *w*
Switching impulse voltage		+ –	1.0 1.0	See Figure 1.3 (curve *b*)	0 0
		+ –	See Figure 1.4 0[a]		See Figure 1.4 0[a]
		+ –	See Figure 1.4 0[a]		See Figure 1.4 0[a]

[a]No guidance or correction given.