

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

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2001 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 21 March 2001. Printed in the United States of America.

Print: ISBN 0-7381-2810-4 SH94913
PDF: ISBN 0-7381-2811-2 SS94913

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS.**”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

IEEE is the sole entity that may authorize the use of certification marks, trademarks, or other designations to indicate compliance with the materials set forth herein.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

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

At the time this standard was completed, the working group had the following membership:

William Larzelere Jr., *Chair*

Kevin Loving, *Secretary*

Jeffrey Britton
Larry Coffeen
Ross Daharsh
Dana Dufield
Gerald Fitzpatrick
Ernst Hanique
Jeff Hildreth
John Kise
Rudi Kremer

John Kuffel
Jim McBride
Terry McComb
Nigel McQuin
Arthur Molden
Randy Newnam
Gary Schneider
Herman Schneider
Daniel Schweickart

Stephen Sebo
H. Melvin Smith
Eddy So
David Train
Subhash Tuli
Loren Wagenaar
Barry Ward
Yixin Zhang
Hugh Zhu

The following members of the balloting committee voted on this standard:

William J. Buckley
Jorge Fernandez-Daher
George Gela
Randall C. Groves

Daleep C. Mohla
Arthur Molden
George R. Nourse

T. W. Olsen
Madan Rana
Gerald Sakats
H. Melvin Smith

When the IEEE-SA Standards Board approved this standard on 17 March 2001, it had the following membership:

Donald N. Heirman, *Chair*
Judith Gorman, *Secretary*

Mark D. Bowman
Chuck Adams
Clyde R. Camp
James T. Carlo
Richard DeBlasio
Harold E. Epstein
H. Landis Floyd
Jay Forster*

Howard M. Frazier
James H. Gurney
Raymond Hapeman
Richard J. Holleman
Richard H. Hulett
Lowell G. Johnson
Joseph L. Koepfinger*
Peter H. Lips

Paul J. Menchini
Daleep C. Mohla
Robert F. Munzner
Ronald C. Petersen
Malcolm V. Thaden
Geoffrey O. Thompson
Akio Tojo
Howard L. Wolfman

*Member Emeritus

Also included is the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Alan H. Cookson, *NIST Representative*
Donald R. Volzka, *TAB Representative*

Catherine Berger
IEEE Standards Project Editor

Contents

1. Overview.....	1
1.1 Scope	1
1.2 Purpose	1
1.3.5 Atmospheric conditions.....	2

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 ~~striketrough~~ (to remove old material) and underscore (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/m³. 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.

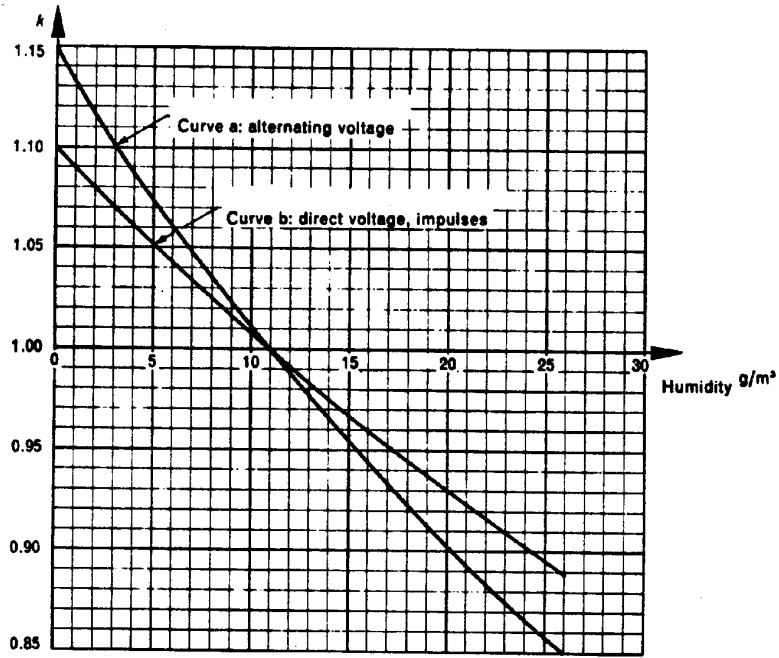


Figure 1.3—Humidity correction factor k as a function of absolute humidity
(For applicability, see 1.3.4.3 and Table 1.3)

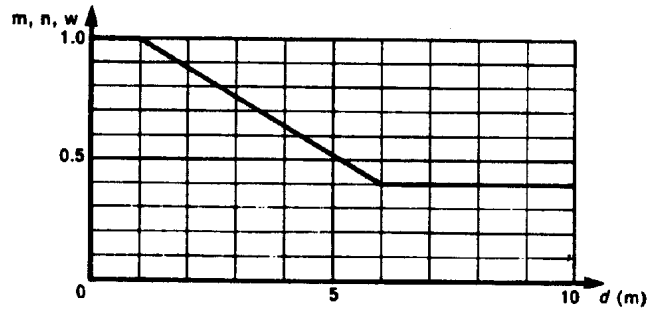


Figure 1.4—Values of the exponents m and n for air density correction and w for humidity corrections, as a function of sparkover distance, in meters
(See 1.3.4.3 and Table 1.3)

Table 1.3—Application of atmospheric correction factors













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

^aNo guidance or correction given.