IEEE Standards

IEEE Std C37.24™-2003
(Revision of
IEEE Std C37.24-1986)

C37.24™

IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

IEEE Power Engineering Society

Sponsored by the
Switchgear Committee

IEEE

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

26 February 2004

Print: SH95149
PDF: SS95149

Recognized as an
American National Standard (ANSI)

IEEE Std C37.24™-2003
(Revision of
IEEE Std C37.24-1986)

IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

Sponsor

Switchgear Committee
of the
IEEE Power Engineering Society

Approved 12 June 2003

IEEE-SA Standards Board

Approved 9 October 2003

American National Standards Institute

Abstract: This guide provides information to assist in evaluating the effect of solar radiation on outdoor metal-enclosed switchgear including metal-enclosed bus and control switchboards. Specific data are given in the form of a continuous current capability factor for specific maximum monthly normal temperatures at the installation location, to adjust the continuous current capability of outdoor metal-enclosed switchgear to the solar radiation condition required. Tables of maximum monthly normal temperatures at various locations in the US and Canada are provided.
Keywords: absorption coefficient, finish, guide, metal-enclosed switchgear, outdoor, solar constant, solar radiation, temperature

---

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

Copyright © 2004 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 26 February 2004. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

Print: ISBN 0-7381-3730-8 SH95149
PDF: ISBN 0-7381-3731-6 SS95149

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.

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; +1 978 750 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 C37.24-2003, IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear.)

This guide is an outgrowth of a technical paper presented at the AIEE winter general meeting in New York, NY, January 18–22, 1954. In October 1955, the paper was issued by the AIEE Standards Committee as Publication 955. In 1962, 3000 A ratings were added and the temperature data from the National Oceanic and Atmospheric Administration were updated. Subsequently, it was revised and published as an IEEE guide in 1971. A new section was added in the 1986 guide discussing color and finish of the metal-enclosed switchgear and their impact on temperature due to solar radiation.

This guide is a revision of IEEE Std C37.24-1986. Standards references have been updated and the latest temperature data (for 1961–1990) for the US and Canada has been included. This revision also includes metrification of English units and the additional bibliographical entries to cover broad geographic locations.

Participants

This guide was prepared by a working group operating under the Switchgear Assemblies Subcommittee of the IEEE Switchgear Committee. At the time this guide was completed, the working group had the following membership:

S. S. Gohil, *Chair*

D. J. Edwards
A. F. Morgan
P. J. Notarian
G. R. Nourse
E. O'Donnell
T. W. Olsen
S. H. Telander
M. Wactor

The Switchgear Assemblies Subcommittee of the IEEE Switchgear Committee, which reviewed and approved this guide, had the following membership:

D. J. Lemmerman, *Chair*

C. J. Ball
T. A. Burse
E. R. Byron
J. J. Dravis
D. J. Edwards
S. S. Gohil
R. K. Iyer
J. M. Jerabek
W. E. Laubach
W. C. McKay
A. F. Morgan
P. J. Notarian
G. R. Nourse
T. W. Olsen
G. O. Perkins
E. A. Peters
R. J. Puckett
G. Sakats
S. H. Telander
M. Wactor

Copyright © 2004 IEEE. All rights reserved.

This guide was processed and approved for submittal to ANSI by the Accredited Standards Committee on Power Switchgear C37. Committee approval of the guide does not necessarily imply that all committee members voted for its approval. At the time of its approval, the C37 Committee had the following members:

T. W. Olsen, *Temporary Chair*
A.K. McCabe, *Executive Vice Chair, HV Standards*
J. Scott, *Executive Vice Chair, LV Standards*
D.L. Swindler, *Executive Vice Chair, IEC Activities*
J. Collins, *Secretary*

Organization Represented	*Name of Representative*
Electric Light and Power Group	D. E. Galicia
Institute of Electrical and Electronics Engineers, Inc.	Joseph L. Koepfinger
	G. J. Martuscello
	Y. Musa
	E. Worland
	A. Dixon
	J. M. Jerabek
	D. Sigmon
	D. J. Lemmerman *(Alt.)*
	T. E. Royster
	R. W. Long *(Alt.)*
	J. G. Wood *(Alt.)*
National Electrical Manufacturers Association	G. Jones
	W. Long
	T. W. Olsen
	G. Sakats
	D. Stone
International Electrical Testing Association	A. Petersen
National Electrical Contractors Association	D. Harwood
Testing Laboratory Group	P. J. Notarian
	E. Roseen
Tennessee Valley Authority	J. Nelson
US Dept. of Agriculture	H. L. Bowles
US Dept. of the Army—Office of the Chief of Engineers	J. A. Gibson
US Dept. of the Navy—Naval Construction Battalion Center	D. L. Mills
Technical Liaison	W. E. Lauback
	C. Wagner

Copyright © 2004 IEEE. All rights reserved.

The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

Chris Ambrose
Stan J. Arnot
Anne Bosma
Dave Burns
Ted Burse
Tommy Cooper
Guru Dutt Dhingra
Alexander Dixon
Denis Dufournet
Doug Edwards
Marcel Fortin
David Gilmer
S. (Dave) Gohil
Randall Groves
Erik Guillot
Bob Hughes
William Hurst
Richard Jackson
Jerry Jerabek
Stephen R. Lambert
Thomas Larose
Ward Laubach
R. W. Long
Gregory Luri
John Martin
Kenneth Mcclenahan
John Merando
Gary Michel
Daleep Mohla
Georges Montillet
Anne Morgan
Frank Muench
Paul Notarian
George Nourse
Edward O'Donnell
T. W. Olsen
Miklos Orosz
Edward Peters
James Ruggieri
Gerald Sakats
Jordan Shikoski
Shaun Slattery
H. Melvin Smith
David Stone
Alan Storms
Stanton Telander
Shanmugan Thamilarasan
Gerald Vaughn
Charles Wagner
James Wilson

When the IEEE-SA Standards Board approved this standard on 12 June 2003, it had the following membership:

Don Wright, *Chair*
Howard M. Frazier, *Vice Chair*
Judith Gorman, *Secretary*

H. Stephen Berger
Joe Bruder
Bob Davis
Richard DeBlasio
Julian Forster*
Toshio Fukuda
Arnold M. Greenspan
Raymond Hapeman
Donald M. Heirman
Laura Hitchcock
Richard H. Hulett
Anant Jain
Lowell G. Johnson
Joseph L. Koepfinger*
Tom McGean
Steve Mills
Daleep C. Mohla
William J. Moylan
Paul Nikolich
Gary Robinson
Malcolm V. Thaden
Geoffrey O. Thompson
Doug Topping
Howard L. Wolfman

*Member Emeritus

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

Alan Cookson, *NIST Representative*
Satish K. Aggarwal, *NRC Representative*

Noelle D. Humenick
IEEE Standards Project Editor

Copyright © 2004 IEEE. All rights reserved.

Contents

1. Overview ... 1

1.1 Introduction ... 1
1.2 Scope ... 1
1.3 Purpose ... 2

2. References ... 2

3. Operating limitations ... 2

4. External influences on internal operating temperatures ... 3

4.1 Ambient temperatures ... 3
4.2 Solar radiation ... 4
4.3 Wind influence ... 5

5. Ventilation and condensation control ... 5

6. Enclosure color and finish considerations ... 5

7. Current-carrying capabilities of switchgear ... 6

7.1 Metal-clad switchgear ... 6
7.2 Metal-enclosed low-voltage power circuit breaker switchgear ... 7
7.3 Metal-enclosed interrupter switchgear ... 7
7.4 Control switchboards ... 7
7.5 Metal-enclosed bus ... 8

8. Suggested modifications of standard designs ... 8

9. Conclusion ... 8

Annex A (informative) Figures ... 9

Annex B (informative) Tables ... 11

Annex C (informative) Conversion tables ... 27

Annex D (informative) Bibliography ... 30

Copyright © 2004 IEEE. All rights reserved.

IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

1. Overview

1.1 Introduction

Outdoor metal-enclosed low-voltage power circuit breaker switchgear, outdoor metal-clad switchgear, and outdoor metal-enclosed interrupter switchgear have reached a position of widespread application comparable to that of indoor switchgear. Outdoor switchgear has had a satisfactory operating record for many years in cold, temperate, and hot climates that has contributed to this increased usage. However, there are conditions affecting the application of outdoor switchgear that are different from those for indoor switchgear and warrant special consideration.

Realizing this situation, a study for metal-enclosed switchgear was undertaken by the Switchgear Assemblies Subcommittee. It was soon established that temperature data were not available on fully loaded units in the field. Outdoor laboratory and field testing was then tried, and it became evident that, due to uncontrollable conditions, accurate and complete data suitable for establishing the current-carrying capability of outdoor metal-enclosed switchgear could not be obtained. Metal-enclosed switchgear was then tested indoors with outdoor conditions simulated. While valuable data were accumulated, no reliable relationship between results obtained indoors and conditions existing outdoors was found. However, based on these investigations, sufficient data were accumulated for the preparation of a guide for application of outdoor metal-enclosed switchgear in various climates.

1.2 Scope

The general information in this guide is intended to assist in evaluating the effect of solar radiation on outdoor metal-enclosed switchgear and is applicable to outdoor metal-enclosed power switchgear, control switchboards, and metal-enclosed bus. Specific data are given in current-temperature relationship and tabulation form for outdoor metal-enclosed low-voltage power circuit breaker switchgear, outdoor metal-clad switchgear, and outdoor metal-enclosed interrupter switchgear.

Copyright © 2004 IEEE. All rights reserved.

1.3 Purpose

Switchgear will perform satisfactorily and have a reasonable life when operated within the temperature limits established in IEEE Std C37.20.1™-2002, IEEE Std C37.20.2™-1999, IEEE Std C37.20.3™-2001, IEEE Std C37.21™-1985, and IEEE Std C37.23™-1987. These standards specify the temperature rise limits above a standard (maximum) ambient temperature of 40 °C. This is satisfactory for indoor applications where the temperature rise is due entirely to heat release (internal losses). In outdoor applications, the limiting temperatures result from the net effect of internal losses and external influences, principally the sun, wind, and local ambient temperatures. All of these must be considered in determining the current-carrying capacity of outdoor metal-enclosed switchgear.

The magnitude of these factors will vary geographically and from season to season. The time relationship of maximum circuit loads with respect to maximum ambient temperature is important. It is not practical to design switchgear on the basis that all adverse factors reach their maxima coincident with maximum loads. If this does not occur, full current ratings may be realized. Recommendations will be made to point out the cumulative effect of these various influences.

2. References

This guide shall be used in conjunction with the following publications. When these standards are superseded by an approved revision, the revision shall apply.

IEEE Std C37.20.1-2002, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.[1, 2]

IEEE Std C37.20.2-1999, IEEE Standard for Metal-Clad Switchgear.

IEEE Std C37.20.3-2001, IEEE Standard for Metal-Enclosed Interrupter Switchgear.

IEEE Std C37.21-1985, IEEE Standard for Control Switchboards.

IEEE Std C37.23-1987, IEEE Guide for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus.

IEEE/ASTM SI 10™-2002, American National Standard for Use of the International Systems of Units (SI): The Modern Metric System.

3. Operating limitations

Temperature limitations for metal-enclosed switchgear are established to ensure a satisfactory life span of the insulation. Operation at higher temperatures than permitted by the appropriate standard will result in shortened life, but if the temperature of the insulation goes above normal for only a few hours during just a few days of the year, the effect on total life is hardly measurable. This is very different from the establishment of higher short-duration ratings that might be repetitive on a day-to-day basis. The hazard of immediate breakdown is not increased unless extreme temperatures are reached.

To exclude wind-blown dust and dirt, outdoor metal-enclosed switchgear is usually designed with more restricted ventilation than indoor switchgear. Because of this design difference, outdoor switchgear has a

[1]The IEEE standards or products referred to in Clause 2 are trademarks of the Institute of Electrical and Electronics Engineers, Incorporated.

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

 Copyright © 2004 IEEE. All rights reserved.

somewhat increased internal temperature even when there is an equivalent number of circuit breakers and buses. These conditions have been recognized in designs. With this restricted ventilation, the effect of solar radiation on an enclosure will cause the air immediately under the roof to be relatively warm. Electrical parts located near the roof will operate in air considerably warmer than that surrounding equipment in the center or lower portion of the switchgear units. Some types of cable insulation may not be rated for the higher air temperature found immediately under the roof. If cables are located in the upper part of housings, insulation with appropriate thermal characteristics should be selected. IEEE Std C37.20.1-2002, IEEE Std C37.20.2-1999, and IEEE Std C37.20.3-2001 state, in effect, that the temperature of the air surrounding insulated cables within any compartment shall not exceed 65 ºC when the assembly is in an ambient air temperature of 40 °C. This temperature is based on the use of 90 ºC insulated power cables. Use of lower temperature rated cables requires special consideration. In many cases the effect of solar radiation alone will raise the inside temperature above that permitted by the appropriate standard. The insulation and size of conductors in this location should be carefully considered by both manufacturers and users.

End units, particularly those exposed to the sun during periods of heavy load, should be considered on a different basis from the others in determining loading, conductor sizes, and cable insulation.

In addition to the effect on insulation, high internal air temperatures will increase the total temperature of the conducting parts. If circuit breakers are properly maintained, no adverse effects will result if their temperatures exceed allowable limits by a few degrees for short intervals during a few days of the year. All primary connections in metal-enclosed switchgear are usually silver surfaced or equivalent, and no trouble should be experienced with them if rated temperatures are exceeded under similar conditions. Here again, it is important to realize the difference between increased temperatures due to outside influences that occur infrequently as compared to higher short-duration temperatures that might be repetitive on a daily basis.

Caution must be used, however, in the application of temperature sensitive devices, such as devices with electronic components in outdoor metal-enclosed switchgear. Accelerated component aging and device failure can result from increased temperatures that occur infrequently. Maximum temperature limitations for temperature-sensitive devices should be determined, and those temperature limitations should be considered during equipment design.

It is noted that the use of electronic devices has become widespread in outdoor metal-enclosed switchgear. Common electronic devices employed include protective relays, power metering devices, transducers, supervisory control and data acquisition (SCADA) systems, remote terminal units (RTUs), programmable logic controllers (PLCs), as well as many other devices. These devices are generally designed in accordance with specific component standards and may be subject to temperature limitations more restrictive than those applicable to the switchgear equipment.

4. External influences on internal operating temperatures

4.1 Ambient temperatures

The ambient temperature surrounding switchgear is the base to which the temperature rise of insulation and electric parts is added. At rated current, the conducting parts have an established temperature rise above the outside air. If the ambient temperature of outside air is lower, the total temperature of the electric parts will be correspondingly reduced. In all test work, measurements are made with the ambient temperature determined by the method established in IEEE Std C37.20.1-2002, IEEE Std C37.20.2-1999, IEEE Std C37.20.3-2001, or IEEE Std C37.23-1987, and the thermal performance of the equipment is based on the temperature rise above this ambient temperature. Outdoor ambient temperatures vary widely in most localities over a 24-hour period and provide a varying influence on the internal temperatures of switchgear. Under the more stable conditions affecting indoor applications, it is possible to establish a reasonably accurate relationship between ambient temperature and the temperature rise of electrical equipment.

Copyright © 2004 IEEE. All rights reserved.

However, with the changing conditions that exist outdoors, it was found that it was impossible to get test data sufficiently accurate and consistent for use in establishing the current-carrying capability of switchgear. The establishment of ambient temperatures over a period of time, as would be necessary to fix a value to be used for determining the loading of switchgear, is a rather lengthy procedure. Readings of ambient temperature should be taken in standard US Weather Bureau enclosures. The construction of these can be obtained from any US Weather Bureau station. The housing for the thermometer should be located in a position that will expose it to air of about the same temperature as that around the switchgear. In outdoor locations there is no significant variation with respect to the top, middle, or bottom of the structure. However, the thermometer should not be affected by heat reflection from the ground.

A publication from the National Climatic Data Center (formerly US Weather Bureau) [B3] covers data taken or adjusted to a standard time period of 30 years of 1961–1990. These data were obtained from Weather Bureau stations in the US, Puerto Rico, and Pacific Islands and are believed to be the best information available for determining reference temperatures for the purpose of this guide (see Table B.3). The monthly normal maximum temperatures are given for each month of the year. The monthly normal maximum temperature for the month of July, for example, is computed by adding the maximum temperature for each day in July in a particular year and dividing the sum by the number of days. This provides the monthly normal maximum temperature for July of that year. The yearly temperatures for that month are averaged to provide the figure shown in the tabulation. It is recognized that an average obtained in this way may be lower than an average based on some particular shorter period of time. Table B.4 provides monthly normal maximum temperatures for Canada. The effect of reflected solar radiation, whether from surrounding objects or other conditions at the site, should be considered.

The absolute maximum temperature for a particular month (available in other US Weather Bureau records) is the maximum temperature that has ever been reached in a particular locality. Ordinarily, such extremes of temperature would occur for only a few hours on one day over a period of several years. It does not seem feasible to design and apply switchgear on this basis, and therefore, the monthly normal maximum temperatures are recommended for determining the continuous current-carrying capacity of outdoor metal-enclosed switchgear in the locality where it is to be installed and operated. An examination of this tabulation will show that in the hot months of the year, the 40 ºC standard ambient temperature was exceeded only in Arizona, California, and Nevada. In most localities the monthly normal maximum temperature is considerably below 40 ºC, leaving a margin that should help to offset some of the adverse factors caused by higher temperature and that should provide longer than normal insulation life.

There are many Weather Bureau stations where long-time records of monthly normal maximum temperatures are available in addition to those listed in this guide. Where such additional local Weather Bureau data can be obtained, a check should be made to be sure that the temperature data used for determining current-carrying capacity are representative of the conditions where the outdoor metal-enclosed switchgear will be installed and operated.

4.2 Solar radiation

The most important source of heat in outdoor metal-enclosed switchgear, aside from electrical losses within the equipment itself, is the effect of solar radiation. The intensity (flux density) of solar radiation on a surface normal to the sun's rays, beyond the earth's atmosphere, and at the mean earth-sun distance is termed the solar constant. Its value approximates 1335 W/m^2 (see IEEE/ASTM SI 10-2002 for conversion factors for units of the SI). In passing through the earth's atmosphere, the sun's radiation is scattered and absorbed by dust, gas molecules, ozone, and water vapor. The extent of this depletion at any given time depends upon the composition of the atmosphere and the length of the path through the atmosphere that the sun's rays must travel. Thus, the irradiance at a given point on the earth's surface depends on this depletion as well as on the deviation from the mean earth-sun distance, the declination of the earth's axis, the time of year, the time of day, and the latitude of the given point.

 Copyright © 2004 IEEE. All rights reserved.

For example, records at Santa Fe, New Mexico, and Mt. Whitney, California, representative of high and dry locations where depletion should be minimal, show magnitudes of 1141 and 1195 W/m^2, respectively. Tests made during the last two weeks of June at State College, Pennsylvania, and at Columbus, Ohio, indicate that a maximum of approximately 1044 W/m^2 is reached at these two locations. The value varies from zero at sunrise approximately sinusoidally to a maximum at noon (solar time), and diminishes to zero at sunset. Figure A.1 shows the measured maximum irradiation at these two locations. It also shows a curve indicating what this irradiation would be if the increase and decrease during the day were exactly sinusoidal. At both locations, the average maximum irradiation over several days was considerably below the maximum values shown in Figure A.1. However, in other localities, particularly in the West, full values of irradiation may be an almost daily occurrence in the summer.

A value of 1044 W/m^2 was chosen as a practical value representative of areas in which the majority of outdoor metal-enclosed switchgear will be installed. Indoor tests were made with this value of irradiation simulated by banks of infrared lamps. These lamps were selected from a practical standpoint, but they are not entirely satisfactory since their emission does not contain the entire spectrum of solar radiation. The indoor tests did take into account the additional horizontal component of irradiation on a southern exposed vertical surface, approximately 312 W/m^2 at 40º-north latitude at the time of the field measurements.

On the basis of field measurements, indoor tests, and calculated data that were accumulated during this study on outdoor metal-enclosed switchgear, it was established that the maximum temperature rise of the conducting parts is about 15 °C due to solar radiation alone.

4.3 Wind influence

It is estimated that 16 km/h wind would totally offset the heating effect of the noonday sun. However, switchgear structures vary so much in shape and relative amount of exposed surface that no accurate figure can be given. The effect of air movement as low as 5 km/h would be significant, and the values in this range are recognized as having a cooling effect on transmission line conductors. However, since there may be localities where the wind velocity is very low and no accurate data are available, it is recommended that no consideration be given to the effect of wind in cooling switchgear.

5. Ventilation and condensation control

Ventilation of outdoor switchgear is usually more restricted than that for indoor switchgear because it is desirable to provide filters to exclude airborne dust and dirt. It is not desirable to seal switchgear units tightly because moisture condensation may occur on the electrical parts and insulation. Some form of heat is also necessary to keep the internal air above the dew point. When appreciable loads are being carried on the circuits, electrical losses would usually be adequate, but the automatic means required to recognize this source of heat and turn off the heaters have not been used consistently. A large percentage of outdoor switchgear units are equipped with heaters under manual control. However, thermostats, humidistats, and differential thermostats have all been used. Theoretically, the use of the latter is one of the better approaches to the problem, but differential thermostats operating on the small heat differential provided by the usual heater installation may not be entirely satisfactory or reliable. If heaters are used in the hotter parts of the country in the months when maximum temperatures are reached and the application requires that switchgear be operated very near to full load, it may be desirable to use current-responsive relays to turn them off. This would result in a 2 °C–3 ºC decrease in internal air temperature.

6. Enclosure color and finish considerations

The exterior color and finish of outdoor switchgear enclosures can have a significant impact on the heating effect of solar radiation. Since light-colored paints absorb and radiate heat from low temperature sources

Copyright © 2004 IEEE. All rights reserved.

(below 200 °C) as well as do dark-colored paints, the interior and exterior enclosure color has little impact on the thermal performance of the enclosure for heat generated by the electrical equipment within. Light-colored paints will radiate heat generated from internal equipment loading as effectively as will dark-colored paints. However, since light-colored paints should absorb heat from high temperature sources (above 1500 °C, which includes solar radiation) at a lower rate than dark-colored paints, the exterior enclosure color has a significant impact on interior temperature rise due to solar radiation. Light-colored paints will absorb less solar radiation than dark-colored paints, resulting in a reduced maximum internal temperature rise due to solar radiation.

Metallic and reflecting paints and finishes absorb and radiate heat generated from both low-temperature and high-temperature sources at a low rate. They will usually not materially reduce internal temperatures because, while they keep radiated energy out, they also keep heat from internal losses in. These effects largely cancel each other out when the switchgear is fully loaded.

Table B.1 lists several representative colors and their approximate solar radiation absorption coefficients. Since the heating effect due to solar radiation for different colors varies directly as the ratio of their solar radiation absorption coefficients, the maximum temperature rise of conducting parts due to solar radiation alone also varies directly as a ratio of their coefficients [see Equation (1)]. Black and dark colors have the highest absorption coefficients. Enclosures painted those colors exhibit the maximum temperature rise of 15 ºC. With the coefficient for black of 0.97, and the coefficient for white of 0.14, the corresponding maximum temperature rise for a white-painted enclosure would be:

$$\frac{0.14}{0.97} \times 15\ °\text{C} = 2.2\ °\text{C} \tag{1}$$

The associated derating temperature threshold (rated ambient temperature less expected temperature rise of conducting parts due to solar radiation) for a white-painted enclosure would be as shown in Equation (2):

$$40\ °\text{C} - 2.2\ °\text{C} = 37.8\ °\text{C} \tag{2}$$

compared to 25 ºC for a black or dark-painted enclosure.

Paint color, however, is not the only factor to consider when establishing a temperature rise due to solar radiation. An accurate solar radiation coefficient must be determined for the paint color used because there can be a wide variation in coefficients, even when the colors appear visually identical. Table B.1 lists approximate values only. Paint color durability and paint adherence must be considered. For certain applications, surface accumulation of dust and soot may be as important a factor in the resulting temperature rise as enclosure color. The solar radiation absorption coefficient for acetylene soot is 0.99 and sufficient regular accumulations would negate any advantage gained from the application of light colored paint. It is recommended that consideration be given to the effect of exterior color in reducing the 15 °C maximum temperature rise due to solar radiation only if all the above factors are addressed throughout the service life of the equipment.

7. Current-carrying capabilities of switchgear

7.1 Metal-clad switchgear

The continuous current rating of metal-clad switchgear is based on a temperature rise above a 40 ºC ambient temperature. The sum of the temperature rise and the 40 ºC ambient temperature must not exceed the maximum total temperature limits as established by IEEE Std C37.20.2-1999. When the ambient temperature exceeds 40 ºC, it is necessary to decrease the continuous current loading in order to stay within the established maximum total temperature limits. Since the test and calculated data previously mentioned

 Copyright © 2004 IEEE. All rights reserved.

has established that solar radiation contributes a maximum temperature rise of 15 ºC to the conducting parts, a correction factor for the continuous current capability is required whenever the ambient temperature exceeds 25 ºC. The curve in Fig A.2 takes this into account. The values given on the horizontal scale are not temperatures that can be measured at any particular time, but are the 30-year monthly normal maximum temperatures. The values given on the vertical scale provide the continuous current capacity factor that should be multiplied by the rated continuous current for the metal-clad switchgear equipment to derive the allowable current-carrying capacity of the equipment.

For example, a 1200 A metal-clad switchgear equipment, operating outdoors in a 40 ºC monthly normal maximum temperature and exposed to the effect of a typical solar cycle of 1044 W/m^2 maximum amplitude, should not be loaded continuously above 1200 A × 0.84 = 1008 A. Likewise under the same conditions, a 2000 A metal-clad switchgear equipment should not be loaded above 2000 A × 0.84 = 1680 A, and a 3000 A equipment should not be loaded above 3000 A × 0.84 = 2520 A. However, at 25 ºC ambient all of this equipment can be loaded to their continuous current ratings. This is further illustrated in the examples in Table B.2, which shows monthly normal maximum temperatures of 25 ºC and 40 ºC as approximately the midsummer conditions encountered at Duluth, Minnesota, and Phoenix, Arizona, respectively.

Based on the National Climatic Data Center data, there are only a few localities where the monthly normal maximum temperature is above 32 ºC, and a reference to the curve in Fig A.2 indicates a relatively small reduction in the current-carrying capacity of the switchgear.

7.2 Metal-enclosed low-voltage power circuit breaker switchgear

Outdoor enclosures for metal-enclosed low-voltage power circuit breaker switchgear are similar in size, shape, etc., to metal-clad switchgear. Therefore, the effects of solar radiation will, on an average basis, be similar. Figure A.2 is based on a maximum temperature rise of 15 ºC of the conducting parts due to solar radiation alone. The continuous current capacity factor from Figure A.2 should be multiplied times the allowable cumulative loads for indoor equipment. The preferred values for allowable cumulative loads are stated in Table 15, Circuit-Breaker Loads, of IEEE Std C37.20.1-2002. For example, with a maximum monthly normal temperature of 40 ºC, the allowable cumulative loading for four 1600 A circuit breakers in a vertical section is 4500 A × 0.84 = 3780 A.

7.3 Metal-enclosed interrupter switchgear

Outdoor enclosures for metal-enclosed interrupter switchgear have many similarities to metal-clad switchgear, such as size and shape. Therefore, the effects of solar radiation will be similar on an average basis. The continuous current capacity factor from Figure A.2 should be multiplied by the rated continuous current of the metal-enclosed interrupter switchgear equipment to derive the allowable current-carrying capability of the switchgear equipment. For example, with a maximum monthly normal temperature of 40 ºC, the allowable cumulative loading a 1200 A metal-enclosed switchgear equipment would be 1200 A × 0.84 = 1008 A.

7.4 Control switchboards

Control switchboards, as defined in IEEE Std C37.21-1985, do not have continuous current ratings. However, the heating effect of solar radiation on control and secondary wiring requires the same consideration as metal-enclosed switchgear.

Copyright © 2004 IEEE. All rights reserved.

7.5 Metal-enclosed bus

Metal-enclosed bus, as defined in IEEE Std C37.23-1987, is used with metal-enclosed switchgear and requires the same consideration regarding the heating effect of solar radiation.

8. Suggested modifications of standard designs

Where the full current rating must be realized on outdoor metal-enclosed switchgear units, various methods can be used to reduce internal temperatures. Modifications that can be made vary with the designs of different manufacturers and therefore should be discussed with them.

Properly applied shading can be reasonably effective in reducing the air temperature in the top of the enclosure. The need for such construction is influenced by the relative location of the conductors. It should be realized that standard designs with conductors, particularly those near the roof, can be affected by these temperature conditions.

Shading the sides of units with southern exposures, such as the use of double walls with free air circulation between the sheets will be helpful in controlling the internal temperatures. Shading should be considered only under the most adverse combination of high current and external heat. An increase of approximately 5% in current-carrying capability can be expected from this arrangement. This, of course, will vary with different designs of housings and should be checked with manufacturers. Various types of thermal insulation are rather ineffective for the reason that they keep heat in as well as out.

Forced ventilation may also be used to keep the electrical parts within the allowable temperature limits of IEEE Std C37.20.1-2002, IEEE Std C37.20.2-1999, IEEE Std C37.20.3-2001, IEEE Std C37.21-1985, and IEEE Std C37.23-1987.

However, if a ventilation duct system is required, the installation of a suitable one may be expensive. Isolation between compartments should not be sacrificed. The ventilating equipment will require maintenance. Forced ventilation can also be helpful in unusual conditions where the standard breaker ratings may be less than the actual load current. Circulation of air within a cubicle may be effective in reducing the temperature near the top in some switchgear designs.

Specifying load and service conditions are the responsibilities of the user/specifier, with agreement between the two parties on the final equipment installation arrangement to ensure proper application throughout the service life of the equipment.

9. Conclusion

A maximum temperature rise of about 15 ºC may be expected on the conducting parts in metal-enclosed switchgear due to solar radiation alone. Furthermore, as shown in Figure A.2, where the switchgear is operated in a monthly normal maximum temperature above 25 ºC, its full rating may not be realized.

However, where full current ratings at maximum temperature are expected, remedial measures are suggested. The various problems associated with high temperatures and high currents have been pointed out. Satisfactory performance of outdoor metal-enclosed switchgear should be realized if it is applied and used as recommended in this guide.

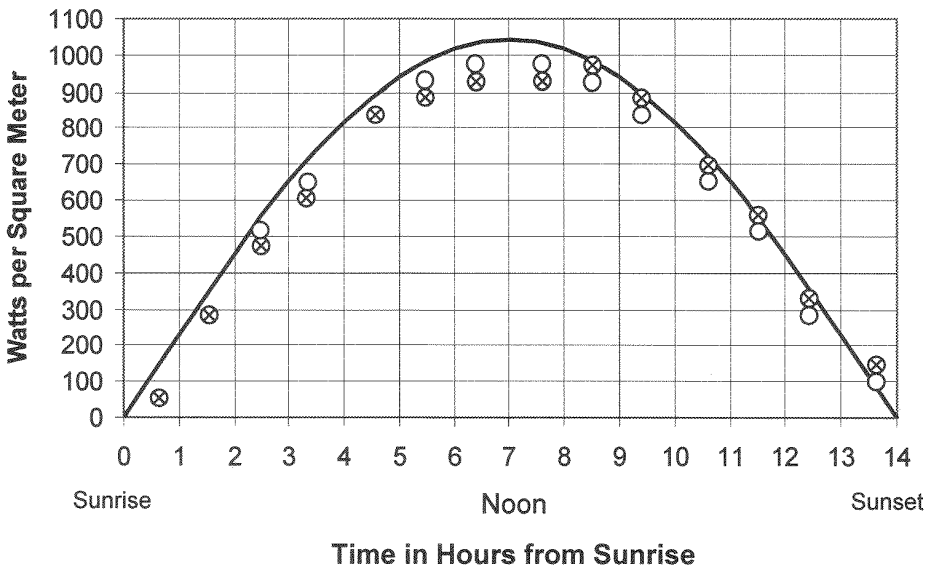
 Copyright © 2004 IEEE. All rights reserved.

Annex A

(informative)

Figures

A.1 Figure A.1



NOTES

1-Curve is a Sine Function
2-Data points are hourly maximum irradiation on horizontal plane (local solar time) recorded by U.S. Weather Bureau at:
○ State College, PA
⊗ Columbus, OH
3-Vertical axis indicates average irradiation for each hour

Figure A.1—Relation between recorded data for solar irradiation on a horizontal surface and a sine function curve

Copyright © 2004 IEEE. All rights reserved.

A.2 Figure A.2

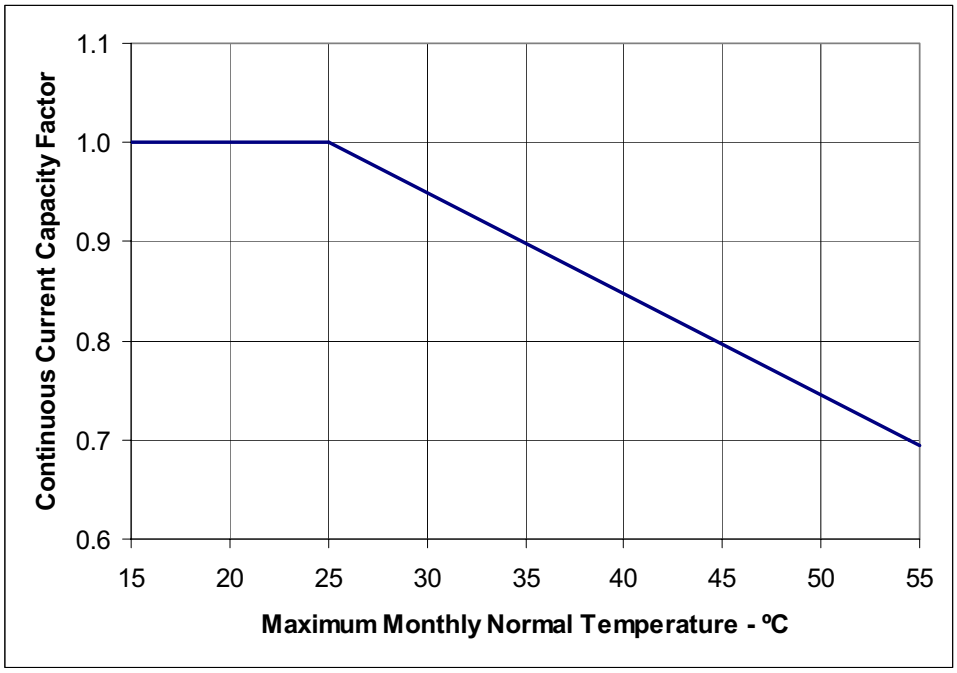


Figure A.2—Current-temperature relationship for outdoor metal-enclosed switchgear (including the effect on a typical solar cycle of 1044 W/m^2 maximum amplitude, as shown in Figure A.1 on standard switchgear units)

 Copyright © 2004 IEEE. All rights reserved.

Annex B

(informative)

Tables

B.1 Table B.1

Table B.1—Approximate solar radiation absorption coefficients (according to paint color)

Paint color	Approximate solar radiation absorption coefficient
White	0.14
Cream	0.25
Yellow	0.30
Light grey, blue, green	0.50
Medium grey, blue, green	0.75
Dark grey, blue, green	0.95
Black	0.97

Copyright © 2004 IEEE. All rights reserved.

B.2 Table B.2

Table B.2—Sample calculations

	Duluth (°C)	Phoenix (°C)
Maximum limit of observed temperature (IEEE Std C37.20.2-1999)	105.0	105.0
Less the monthly normal maximum temperature	25.1	41.1
Less the temperature rise due to solar radiation	15.0	15.0
Allowable temperature rise of buses and connections due to switchgear losses	64.9	48.9
	Amperes	
Continuous current capacity of metal-clad switchgear under above conditions	1200	1008
	2000	1680
	3000	2520
Continuous current capability factor (from Figure A.2)	1.00	0.84

B.3 Table B.3

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Alabama												
Birmingham	10.9	13.8	18.9	23.7	27.2	30.8	32.2	31.7	28.8	23.7	18.1	13.2
Huntsville	9.0	11.9	17.1	22.5	26.3	30.3	31.7	31.6	28.2	22.8	16.9	11.4
Mobile	15.4	17.6	21.6	25.8	29.2	32.2	32.9	32.5	30.5	26.4	21.3	17.2
Montgomery	13.5	16.0	20.3	24.7	28.3	31.9	32.8	32.4	30.6	25.7	20.4	15.7
Alaska												
Anchorage	–5.9	–3.4	0.6	6.0	12.4	16.4	18.4	17.2	12.9	4.7	–2.7	–5.3
Annette	3.8	5.5	7.1	9.7	13.2	16.0	18.1	18.3	15.7	11.0	6.6	4.4
Barrow	–21.9	–24.3	–22.8	–15.2	–4.3	3.5	7.2	5.7	1.0	–7.7	–15.8	–20.7
Bethel	–10.6	–10.7	–6.1	–0.4	9.0	14.9	16.8	15.3	11.1	1.7	–5.2	–9.6
Bettles	–20.5	–17.6	–9.8	–0.3	11.6	19.7	20.9	17.1	9.4	–3.9	–14.9	–18.8
Big Delta	–16.1	–11.9	–4.2	4.6	13.7	19.1	20.9	18.2	11.8	–0.4	–10.7	–14.8
Cold Bay	0.6	0.0	1.6	3.3	6.9	10.2	12.8	13.3	11.2	6.8	3.8	1.8
Fairbanks	–18.7	–13.8	–4.6	5.0	15.2	21.2	22.4	19.1	12.7	0.0	–11.7	–16.8

 Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Gulkana	–16.4	–10.2	–2.2	5.3	12.7	17.9	20.2	18.2	12.3	1.8	–10.7	–15.2
Homer	–1.9	–0.4	2.2	5.7	10.0	13.5	15.8	15.8	12.6	6.6	1.4	–1.1
Juneau	–1.4	1.2	3.7	8.4	12.8	16.1	17.7	17.1	13.3	8.4	2.6	–0.2
King Salmon	–5.5	–5.1	–0.7	3.9	10.5	14.8	17.2	16.3	12.6	4.3	–1.3	–4.8
Kodiak	1.7	2.3	3.8	6.5	9.7	13.1	15.8	16.6	13.7	8.4	4.4	2.4
Kotzebue	–14.7	–16.5	–12.9	–6.5	3.3	9.8	15.1	13.9	8.3	–2.4	–10.5	–14.7
McGrath	–17.6	–12.8	–4.8	2.8	12.5	18.6	20.2	17.5	11.6	–0.4	–10.9	–16.3
Nome	–9.6	–11.0	–8.1	–3.6	5.6	11.6	14.3	13.4	9.3	0.9	–5.3	–9.4
St. Paul Island	–0.7	–2.8	–1.7	0.4	4.1	7.7	9.8	10.6	9.3	5.6	2.8	0.7
Talkeetna	–7.1	–3.7	0.8	6.3	13.3	18	19.8	18	13.1	4	–3.8	–6.8
Unalakleet	–11.7	–11.7	–7.3	–1.4	7.6	12.3	16.2	15.5	10.8	0.6	–7.0	–11.0
Valdez	–3.4	–1.1	2.2	6.8	11.4	15.1	16.8	16.0	12.3	6.3	0.2	–2.3
Yakutat	–0.3	1.7	3.4	6.4	10.0	13.1	15.2	15.4	12.9	8.4	2.9	0.6
Arizona												
Flagstaff	5.7	7.4	9.6	14.3	19.7	25.7	27.7	26.3	22.9	17.4	10.6	6.3
Phoenix	18.8	21.5	24.2	29.2	34.2	39.7	41.1	39.8	36.8	31.2	23.8	19.0
Tucson	17.7	19.9	22.7	27.3	32.2	37.6	37.4	36.0	34.1	29	22.6	17.9
Winslow	7.1	11.9	16.1	21.1	26.4	32.5	34.2	32.4	28.7	22.3	14.7	7.8
Yuma	20.4	23.6	26.1	30.2	34.6	39.6	39.8	40.7	38.1	32.4	25.2	20.3
Arkansas												
Fort Smith	9.1	11.9	17.8	23.4	26.9	31.1	33.9	33.6	29.6	24.3	17.1	10.7
Little Rock	9.4	12.2	17.8	23.0	27.4	31.8	33.6	33.0	29.2	23.9	17.1	11.4
North Little Rock	8.7	11.5	17.1	22.7	26.4	30.8	33.1	32.2	28.3	22.8	16.2	10.4
California												
Bakersfield	13.8	17.7	20.5	24.4	29.2	33.6	36.9	35.9	32.3	27.1	19.3	13.6
Bishop	11.9	14.7	17.4	21.7	27.0	32.5	36.2	34.9	30.4	24.6	16.9	12.1
Blythe	19.8	23.0	25.9	30.3	34.9	40.0	42.6	41.4	39.0	32.6	24.7	19.9
Eureka	12.4	13.1	13.0	13.3	14.4	15.7	16.6	17.0	17.2	16.0	14.5	12.7
Fresno	12.3	16.5	19.2	23.9	29.0	33.7	37.0	35.9	32.3	26.5	18.2	12.1
Long Beach	19.3	19.8	20.0	21.9	22.9	25.0	28.2	28.9	27.8	25.8	22.3	19.4
Los Angeles AP	18.7	18.8	18.6	19.7	20.6	22.2	24.1	24.8	24.8	23.6	21.3	18.8

Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Los Angeles CO	19.8	20.8	20.8	22.4	23.3	25.7	29.2	28.2	28.2	26.1	22.4	19.9
Redding	12.9	16.3	16.9	21.1	26.9	32.4	36.8	35.4	31.8	25.3	16.7	12.6
Sacramento	11.5	15.6	17.8	21.7	26.8	31.0	34.0	33.4	30.7	25.5	17.3	11.5
San Diego	18.8	19.2	19.1	20.2	20.6	22.0	24.6	25.4	25.1	23.7	21.1	18.9
San Francisco AP	13.1	15.2	16.0	17.7	19.2	21.3	22.0	22.4	23.1	21.2	16.9	13.4
San Francisco CO	13.5	15.6	16.0	16.7	17.1	17.8	18.1	18.7	20.4	20.4	17.1	13.6
Santa Barbara	17.6	18.1	18.5	19.7	20.3	21.8	23.3	24.1	24.0	22.8	20.3	18.0
Santa Maria	17.7	18.2	17.9	19.4	19.9	21.7	22.9	23.4	23.8	23.3	20.4	17.9
Stockton	11.7	15.9	18.6	22.7	27.6	31.7	34.7	33.8	31.1	25.7	17.4	11.6
Colorado												
Alamosa	0.7	4.4	9.3	14.8	20.0	25.4	27.8	26.2	22.6	16.9	8.6	1.9
Colorado Springs	5.2	7.0	10.0	15.4	20.4	26.1	29.1	27.4	23.1	17.5	10.4	5.7
Denver	6.2	8.1	11.2	16.6	21.6	27.4	31.2	29.9	24.9	19.1	11.4	6.9
Grand Junction	1.9	7.4	13.1	18.8	24.4	30.9	34.2	32.5	27.3	19.8	10.8	3.7
Pueblo	7.4	10.4	14.0	19.9	24.7	30.9	33.9	32.1	27.4	21.4	13.8	8.2
Connecticut												
Bridgeport	2.2	3.1	7.9	13.7	19.3	24.4	27.6	27.2	23.4	17.8	11.7	5.0
Hartford	0.7	2.4	8.2	15.5	22.0	26.7	29.4	28.2	23.8	17.6	10.6	3.1
Delaware												
Wilmington	3.7	5.5	11.2	17.0	22.7	27.4	29.8	28.9	25.4	19.2	13.1	6.6
District of Columbia												
Washington Dulles AP	4.5	6.6	12.6	18.4	23.5	28.2	30.6	29.7	26.1	19.8	13.7	7.2
Washington Reagan Nat'l AP	5.7	7.7	13.6	19.3	24.6	29.3	31.4	30.5	26.7	20.6	14.6	8.3
Florida												
Apalachicola	15.9	17.2	20.3	24.2	27.8	30.7	31.3	31.3	29.9	26.1	21.4	17.7
Daytona Beach	20.0	20.8	23.8	26.7	29.2	31.1	32.1	31.7	30.4	27.5	24.2	21.3

 Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Fort Meyers	23.5	24.1	26.5	29.0	31.5	32.4	32.8	32.9	32.1	29.9	27.1	24.4
Gainesville	18.7	20.1	23.8	27.1	30.1	31.9	32.6	32.3	30.7	27.2	23.5	20.1
Jacksonville	17.9	19.4	22.8	26.2	29.3	31.8	33.0	32.6	30.7	26.8	23.1	19.3
Key West	23.8	24.1	25.9	27.6	29.5	30.9	31.7	31.8	31.1	29.1	26.7	24.5
Miami	24.0	24.7	26.2	28.0	29.6	30.9	31.7	31.7	31.0	29.2	26.9	24.8
Orlando	21.6	22.6	25.6	28.3	31.0	32.5	33.1	33.1	32.1	29.2	25.8	22.7
Pensacola	15.4	17.2	20.8	24.8	28.4	31.5	32.2	31.8	30.2	26.2	21.2	17.2
Tallahassee	17.2	19.1	23.1	26.9	30.2	32.7	32.9	32.8	31.4	27.5	22.8	18.8
Tampa	21.0	21.9	24.8	27.6	30.7	31.9	32.3	32.3	31.7	29.1	25.4	22.3
Vero Beach	22.5	23.1	25.3	27.5	29.6	31.2	32.3	32.2	31.3	28.9	25.9	23.4
West Palm Beach	23.6	24.4	26.0	27.8	29.8	31.2	32.2	32.2	31.4	29.4	26.7	24.4
Georgia												
Athens	10.9	13.5	18.4	23.0	26.9	30.6	32.0	31.2	28.2	23.1	18.0	12.8
Atlanta	10.2	12.8	17.9	22.6	26.4	29.9	31.1	30.6	27.7	22.6	17.4	12.2
Augusta	13.2	15.6	20.4	24.8	28.7	31.8	33.2	32.4	29.8	25.1	20.2	15.3
Columbus	13.4	16.1	20.6	25.2	28.7	32.4	33.2	32.9	30.1	25.3	20.1	15.0
Macon	13.7	16.0	20.8	25.4	29.2	32.3	33.3	32.8	30.2	25.5	20.4	15.7
Savannah	15.4	16.9	21.2	25.3	28.9	31.6	32.8	32.1	29.6	25.3	21.1	16.8
Hawaii												
Hilo	26.6	26.6	26.4	26.6	27.3	28.2	28.3	28.7	28.8	28.4	27.4	26.7
Honolulu	26.7	26.9	27.6	28.2	29.3	30.3	30.8	31.5	31.4	30.5	28.9	27.3
Kahului	26.6	26.7	27.3	27.9	29.0	29.9	30.4	30.9	30.9	30.2	28.7	27.3
Lihue	25.5	25.6	25.8	26.4	27.3	28.4	28.9	29.3	29.3	28.4	27.1	25.9
Idaho												
Boise	2.4	6.8	11.6	16.3	21.7	27.2	32.3	31.2	25.0	18.1	9.3	3.2
Lewiston	4.2	8.1	11.9	16.4	21.2	26.6	31.7	31.3	25.1	17.3	8.9	4.6
Pocatello	0.1	3.6	8.2	14.2	19.7	25.6	31.2	30.2	23.9	16.9	7.3	0.9
Illinois												
Chicago	–1.7	0.8	7.7	14.8	21.2	26.6	28.7	27.7	23.8	17.4	9.1	1.1
Moline	–2.0	0.9	8.2	16.3	22.7	28.1	29.9	28.6	24.4	17.9	9.1	0.8
Peoria	–1.2	1.6	8.9	16.7	22.7	27.9	29.8	28.4	24.9	18.2	9.9	1.4

Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Rockford	–3.0	-0.2	6.6	14.7	21.6	26.8	28.8	27.4	23.4	16.8	7.9	–0.1
Springfield	0.3	2.9	10.0	17.7	23.7	28.8	30.5	29.0	25.9	19.3	10.9	2.9
Indiana												
Evansville	3.8	6.5	13.3	19.7	24.9	30.1	31.7	30.7	27.1	20.9	13.3	6.4
Fort Wayne	–0.9	1.1	7.9	15.4	21.8	27.2	29.2	27.9	24.2	17.3	9.5	1.9
Indianapolis	0.9	3.5	10.5	17.4	23.2	28.2	29.7	28.7	25.3	18.8	11.1	3.6
South Bend	–0.9	1.2	7.6	14.8	21.1	26.4	28.3	27.1	23.4	16.8	9.2	1.9
Iowa												
Des Moines	–2.2	0.9	8.3	16.6	22.8	27.9	30.4	29.0	24.2	17.9	8.9	0.3
Dubuque	–4.5	-1.3	5.8	14.3	20.7	25.8	28.0	26.6	22.1	15.8	7.0	–1.6
Sioux City	–2.4	0.7	7.7	16.8	22.9	27.8	30.3	28.6	23.8	17.8	8.0	–0.6
Waterloo	–4.6	–1.4	6.3	15.2	22.0	26.9	28.8	27.5	23.2	16.6	7.3	–1.7
Kansas												
Concordia	2.2	5.4	11.4	18.0	23.2	29.4	32.9	31.3	26.1	20.1	11.2	4.1
Dodge City	5.3	8.5	13.7	20.0	24.6	30.6	33.9	32.6	27.4	21.5	12.9	6.6
Goodland	5.3	7.4	11.5	17.6	22.4	28.6	32.1	30.7	25.6	19.2	10.9	5.6
Topeka	2.8	5.9	12.8	19.4	24.3	29.0	31.8	30.8	26.5	20.6	12.2	4.7
Wichita	4.3	7.7	14.0	20.2	24.9	30.4	33.8	32.6	27.4	21.4	12.9	6.1
Kentucky												
Greater Cincinnati AP	2.6	4.9	11.7	17.9	23.3	27.8	29.7	28.9	25.5	18.9	11.8	5.3
Jackson	5.2	7.5	14.0	19.5	23.6	27.3	28.8	28.4	25.1	19.6	13.6	7.8
Lexington	3.9	6.4	12.9	18.6	23.5	28.2	29.9	29.4	25.7	19.6	12.7	6.8
Louisville	4.6	7.1	13.5	19.6	24.4	28.6	30.6	29.8	26.8	20.7	13.8	7.3
Paducah	5.3	7.9	14.2	20.3	25.2	29.9	31.7	30.8	27.2	21.4	14.2	7.8
Louisiana												
Baton Rouge	15.4	17.6	22.4	26.6	29.8	32.5	33.0	32.8	30.8	26.7	21.6	17.4
Lake Charles	15.4	17.4	21.5	25.5	28.9	31.7	32.7	32.7	30.4	26.8	21.6	17.4
New Orleans	16.0	17.8	22.0	25.8	29.1	31.8	32.6	32.3	30.3	26.3	21.7	17.9
Shreveport	13.0	15.9	20.7	25.1	28.4	32.1	33.9	33.9	30.7	25.9	20.0	14.7
Maine												
Caribou	–7.0	–5.0	1.3	8.2	16.5	22.2	24.7	23.1	17.8	11.1	3.1	–4.4

 Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Portland	–0.9	0.6	5.2	11.3	17.3	22.6	26.0	25.2	20.7	14.8	8.3	1.7
Maryland												
Baltimore	4.6	6.5	12.2	17.9	23.4	28.4	30.7	29.7	25.8	19.6	13.6	7.3
Massachusetts												
Blue Hill	0.6	1.8	6.7	12.9	19.2	23.9	27.0	25.8	21.5	15.9	9.6	3.0
Boston	2.1	3.1	7.7	13.3	19.2	24.6	27.7	26.6	22.7	17.1	11.2	4.7
Worcester	–0.7	0.6	5.8	12.2	18.8	23.6	26.3	25.2	20.9	15.3	8.6	1.5
Michigan												
Alpena	–3.1	–2.1	3.3	10.9	18.2	23.6	26.8	24.9	20.2	13.8	6.1	–0.6
Detroit	–0.9	0.7	6.9	14.3	20.9	26.1	28.5	27.4	23.3	16.4	8.9	1.8
Flint	–1.8	–0.4	5.7	13.3	20.0	24.9	27.5	26.2	22.0	15.4	8.1	1.0
Grand Rapids	–1.7	–0.2	6.0	13.7	20.7	25.9	28.2	26.9	22.2	15.4	7.7	0.8
Houghton Lake	–3.7	–2.2	3.4	11.5	18.9	23.8	26.4	24.7	19.9	13.2	5.6	–1.4
Lansing	–1.9	–0.2	5.9	13.7	20.6	25.7	28.1	26.9	22.2	15.2	7.7	0.8
Marquette	–6.4	–4.5	0.8	8.6	16.6	21.6	24.8	22.9	17.7	11.3	2.7	–4.1
Muskegon	–1.8	–0.7	5.1	12.5	19.2	24.2	26.8	25.6	21.6	15.0	7.8	0.9
Sault Ste. Marie	–6.1	–4.9	0.4	8.9	17.0	21.4	24.6	23.2	18.8	12.4	4.4	–3.2
Minnesota												
Duluth	–8.8	–5.7	0.5	9.0	16.6	21.7	25.1	23.3	17.7	11.3	1.8	–6.3
International Falls	–11.2	–7.1	0.4	10.1	18.1	23.0	26.0	24.2	17.9	11.0	0.4	–8.6
Minneapolis/ St. Paul	–6.3	–3.0	4.0	13.6	20.8	26.0	28.9	27.1	21.5	14.9	5.0	–3.6
Rochester	–6.6	–3.3	3.4	12.9	20.1	25.4	27.7	26.0	21.0	14.6	4.9	–3.9
Saint Cloud	–7.5	–4.0	3.1	12.8	20.2	25.2	28.1	26.3	20.6	14.1	3.9	–4.9
Mississippi												
Jackson	13.1	15.6	20.7	25.2	28.9	32.6	33.6	33.3	31.1	26.2	20.7	15.3
Meridian	13.6	16.2	20.9	25.2	28.7	32.2	33.4	33.2	30.5	25.4	20.3	15.6
Tupelo	9.3	12.5	17.9	23.3	27.2	31.0	32.6	32.2	29.3	23.8	17.5	11.6
Missouri												
Columbia	2.6	5.2	11.8	18.7	23.4	28.2	31.4	30.4	26.0	19.8	12.0	4.6
Kansas City	1.5	4.8	11.6	18.4	23.5	28.5	31.5	30.2	25.6	19.7	11.4	3.8

Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
St. Louis	3.2	5.9	12.6	19.4	24.5	29.6	31.8	30.7	26.6	20.3	12.6	5.4
Springfield	5.4	7.9	14.1	19.9	24.4	29.1	32.0	31.4	26.8	21.0	13.7	7.4
Montana												
Billings	–0.1	3.7	7.7	13.9	19.3	25.3	30.4	29.3	22.0	15.9	6.9	1.3
Glasgow	–6.7	–-2.7	4.3	13.6	19.6	25.3	29.3	28.6	21.3	14.8	4.2	–3.9
Great Falls	–0.8	3.1	6.5	12.9	18.4	23.7	28.5	27.6	20.9	15.2	6.4	0.6
Helena	–1.3	2.7	7.1	13.4	18.6	24.3	29.4	28.4	21.0	14.7	5.8	–0.4
Kalispell	–2.1	1.7	6.3	12.9	17.9	21.9	26.7	26.3	19.8	12.4	3.5	–1.2
Missoula	-1.1	3.0	8.1	14.2	18.7	23.3	28.6	27.9	21.6	13.9	4.8	-1.0
Nebraska												
Grand Island	0.3	3.4	9.6	17.5	22.9	28.7	31.4	29.9	24.6	18.6	9.3	2.1
Lincoln	0.2	3.3	10.2	18.0	23.4	29.3	32.2	30.4	25.1	19.3	10.1	2.1
Norfolk	–1.3	1.5	7.9	16.4	22.6	27.8	30.4	28.8	23.9	17.8	8.3	0.4
North Platte	1.4	4.9	9.9	16.9	22.1	27.6	31.0	30.0	24.8	18.7	9.7	2.9
Omaha Eppley AP	–0.4	2.8	9.7	17.7	23.3	28.7	31.1	29.6	24.7	18.7	9.6	1.4
Omaha (North)	–1.3	1.7	8.7	16.9	22.7	28.0	30.3	28.9	23.8	17.8	8.7	0.5
Scottsbluff	3.3	6.4	10.2	16.3	21.6	27.8	32.1	30.7	25.1	18.6	10.1	4.2
Valentine	0.3	3.2	8.1	15.6	21.7	27.7	31.6	30.3	24.5	17.8	8.5	1.8
Nevada												
Elko	2.6	6.1	10.1	15.1	20.8	26.8	32.8	31.4	25.7	18.8	9.5	3.0
Ely	4.3	6.4	9.1	13.9	19.6	25.7	30.6	29.1	24.0	17.5	9.6	4.8
Las Vegas	14.1	17.4	20.4	25.3	31.0	37.9	41.1	39.6	34.8	27.8	19.7	14.2
Reno	7.3	10.9	13.5	17.6	22.7	28.4	33.3	32.0	26.4	20.3	12.1	7.5
Winnemucca	5.6	9.4	12.8	17.2	22.8	28.4	33.9	32.6	26.7	20.1	11.3	5.9
New Hampshire												
Concord	–1.2	0.6	6.0	13.5	20.5	25.2	28.0	26.6	22.0	15.9	8.4	1.2
Mt. Washington	–10.9	–10.5	–6.6	–1.8	5.0	9.7	12.0	11.0	7.7	2.4	–2.6	–8.3
New Jersey												
Atlantic City AP	4.7	5.8	10.9	15.9	21.8	26.7	29.2	28.5	24.8	18.9	13.2	7.4
Atlantic City CO	4.2	5.3	9.3	14.1	18.7	23.6	26.7	26.6	23.2	17.9	12.7	7.5

 Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Newark	3.2	4.7	10.4	16.6	22.4	27.9	30.6	29.7	25.3	19.3	13.0	6.1
New Mexico												
Albuquerque	8.2	11.9	16.3	21.6	26.5	32.2	33.6	31.7	27.7	21.7	14.1	8.6
Clayton	8.5	10.1	14.0	19.1	23.4	28.6	30.9	29.4	25.3	20.4	13.6	8.8
Roswell	12.4	15.5	19.9	24.8	29.3	34.2	34.8	33.3	30.0	25.2	18.9	13.3
New York												
Albany	–1.0	0.7	6.7	14.2	20.9	26.1	28.9	27.4	22.9	16.6	9.3	1.6
Binghamton	–2.3	–1.1	4.7	11.9	18.6	23.2	25.9	24.7	20.3	14.1	7.2	0.4
Buffalo	–1.0	–0.2	5.4	12.3	18.9	24.1	26.8	25.5	21.6	15.2	8.4	1.8
Islip	2.2	3.2	7.7	13.9	19.6	24.1	27.1	27.1	22.7	17.4	11.2	5.5
New York Central Park	3.1	4.6	10.0	16.2	22.1	26.7	29.6	28.7	24.6	18.5	12.2	5.8
New York (JFK AP)	3.1	4.2	8.9	14.6	19.8	25.0	28.2	27.7	23.9	18.2	12.1	5.9
New York (LaGuardia AP)	2.8	4.1	9.1	15.1	21.0	26.1	28.8	27.9	23.9	17.8	11.8	5.6
Rochester	–0.6	0.3	5.9	13.3	19.9	24.3	27.1	25.6	22.1	15.8	8.8	2.1
Syracuse	–0.8	0.3	5.9	13.3	20.2	24.8	27.6	26.1	22.0	15.7	8.9	1.9
North Carolina												
Asheville	8.1	10.0	15.1	19.9	23.9	26.9	28.3	27.8	24.9	20.2	15.2	10.2
Cape Hatteras	11.3	11.9	15.3	19.4	23.6	27.1	29.2	29.3	27.1	22.4	18.2	13.8
Charlotte	9.4	11.7	16.8	21.8	25.7	29.9	31.6	30.9	27.7	22.2	17.0	11.3
Greensboro/ Winston-Salem	8.2	10.4	15.7	20.9	25.0	28.7	30.5	29.7	26.6	21.1	15.8	10.3
Raleigh	9.4	11.4	16.7	22.1	25.9	29.4	31.1	30.4	27.3	22.0	17.0	11.5
Wilmington	12.9	14.5	18.7	23.3	27.1	29.7	31.4	30.9	29.6	24.9	20.6	15.2
North Dakota												
Bismarck	–6.6	–3.1	3.6	12.7	19.9	25.1	29.1	28.2	21.6	14.8	4.1	–4.2
Fargo	–9.2	–6.1	1.4	12.1	20.3	25.2	28.6	27.4	20.8	13.7	2.7	–6.6
Williston	–6.9	–2.9	4.1	13.2	20.2	25.6	29.3	28.5	21.2	14.5	3.3	–4.7
Ohio												
Akron	0.3	2.2	8.5	15.1	20.9	25.8	27.9	26.9	23.2	16.7	9.8	3.2

Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Cleveland	–0.1	1.7	7.9	14.4	20.3	25.7	28.0	26.9	23.1	16.7	10.0	3.0
Columbus	1.2	3.3	10.3	16.7	22.4	26.9	28.7	27.8	24.6	18.1	10.8	4.0
Dayton	1.2	3.3	10.0	16.6	22.5	27.6	29.4	28.3	24.7	18.1	10.7	3.9
Mansfield	0.1	1.7	8.1	14.8	20.7	25.7	27.8	26.7	23.2	16.8	9.6	2.7
Toledo	–1.0	0.8	7.5	14.9	21.4	26.6	28.6	27.4	23.6	16.9	9.2	1.8
Youngstown	–0.7	1.1	7.4	14.3	20.4	25.2	27.4	26.4	22.6	16.1	9.1	2.2
Oklahoma												
Oklahoma City	8.2	11.2	16.7	22.2	26.2	30.7	34.1	33.6	28.8	23.1	15.8	9.9
Tulsa	7.4	10.6	16.7	22.8	26.5	30.9	34.3	33.6	28.7	23.2	15.7	9.3
Oregon												
Astoria	8.8	10.6	11.8	13.3	15.6	17.8	19.7	20.4	19.9	16.2	11.9	9.0
Burns	0.9	4.2	8.7	13.6	18.7	23.6	29.5	28.5	23.1	16.6	7.3	1.8
Eugene	8.0	10.8	13.3	15.8	19.5	23.4	27.6	27.7	24.6	18.1	11.3	7.9
Medford	7.6	11.8	14.7	18.1	22.7	27.8	32.5	32.2	28.2	20.8	11.4	6.8
Pendleton	4.3	8.3	12.3	16.3	21.1	26.4	31.0	30.1	24.6	17.6	9.4	4.7
Portland	7.4	10.6	13.3	15.9	19.5	23.3	26.6	26.8	23.7	17.8	11.4	7.6
Salem	8.0	10.8	13.2	15.8	19.4	23.6	27.6	27.8	24.4	17.9	11.3	8.0
Pacific Islands												
Guam	28.7	28.6	29.2	29.9	30.4	30.5	30.2	29.9	30.1	29.9	29.6	29.0
Koror	30.6	30.6	30.9	31.3	31.4	31.0	30.6	30.7	30.9	31.1	31.4	31.1
Kwajalein, Marshall Island	29.9	30.3	30.6	30.4	30.4	30.4	30.4	30.6	30.6	30.6	30.4	30.1
Majuro, Marshall Island	29.4	29.7	29.8	29.8	29.9	29.9	29.8	30.1	30.2	30.2	30.0	29.6
Pago Pago, Am. Samoa	30.2	30.3	30.4	30.2	29.5	29.0	28.4	28.5	29.1	29.3	29.6	30.0
Pohnpei, Caroline Island	29.8	30.4	30.7	30.8	30.9	30.9	31.0	31.2	31.2	31.2	31.2	30.7
Chuuk, E. Caroline Island	29.9	29.9	30.2	30.4	30.7	30.7	30.6	30.7	30.7	30.7	30.7	30.2
Wake Island	27.9	27.8	28.4	28.8	29.8	30.9	31.2	31.2	31.2	30.8	29.7	28.6

 Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Yap, W. Caroline Island	29.9	30.1	30.5	30.9	31.0	30.7	30.4	30.4	30.6	30.7	30.7	30.3
Pennsylvania												
Allentown	1.3	3.2	9.3	15.8	21.8	26.7	29.2	27.9	23.9	17.7	11.0	4.0
Erie	0.3	0.9	6.4	12.5	18.8	24.1	26.6	25.8	22.3	16.1	9.7	3.2
Middletown/ Harrisburg AP	2.2	4.0	10.2	16.7	22.5	27.3	29.9	28.8	24.6	18.2	11.4	4.8
Philadelphia	3.3	5.0	10.9	17.0	22.8	27.6	30.1	29.2	25.3	19.1	12.8	6.3
Pittsburgh	0.9	2.7	9.4	15.7	21.4	26.1	28.1	27.1	23.5	16.9	10.2	3.7
Avoca	–0.1	1.4	7.5	14.3	20.7	25.3	27.7	26.5	22.4	16.1	9.3	2.6
Williamsport	0.7	2.6	8.7	15.6	21.7	26.1	28.4	27.3	23.2	16.9	9.9	3.3
Rhode Island												
Providence	2.6	3.5	7.8	13.9	19.6	24.9	27.8	27.1	23.5	17.8	11.7	5.1
South Carolina												
Charleston AP	14.3	16.1	20.3	24.3	28.2	30.9	32.3	31.7	29.4	25.1	20.8	16.4
Charleston CO	13.3	14.9	18.6	22.8	26.4	29.5	31.2	30.6	28.2	23.9	19.6	15.4
Columbia	12.9	15.2	20.1	24.7	28.6	31.6	33.1	32.3	29.5	24.6	19.9	14.9
Greenville/ Spartanburg AP	10.1	12.4	17.5	22.2	26.3	29.7	31.2	30.4	27.3	22.2	16.9	11.8
South Dakota												
Aberdeen	–6.2	–2.8	4.3	14.1	20.9	26.0	29.9	29.1	22.7	15.8	4.7	–3.7
Huron	–4.4	–1.3	5.6	14.8	21.3	26.8	30.6	29.3	23.4	16.4	6.1	–2.1
Rapid City	1.0	3.4	7.7	14.4	20.1	25.4	30.1	29.5	23.6	16.9	8.2	2.0
Sioux Falls	–4.3	–1.3	5.7	15.0	21.5	26.9	30.2	28.5	22.8	16.2	6.3	–2.2
Tennessee												
Bristol/ Johnson City/ Kingsport	6.5	8.9	14.9	19.7	24.0	27.9	29.2	28.9	26.2	20.6	14.6	8.9
Chattanooga	8.2	11.3	16.6	21.9	25.8	30.2	31.7	31.2	27.8	22.2	16.2	10.4
Knoxville	7.7	10.5	16.3	21.3	25.3	29.2	30.6	30.4	27.3	21.4	15.5	10.1
Memphis	9.2	11.9	17.3	22.9	27.2	31.8	33.5	32.7	28.8	23.5	16.8	11.4
Nashville	7.7	10.4	16.2	21.6	26.0	30.3	31.9	31.3	28.1	22.5	15.8	10.1

Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Oak Ridge	7.1	9.9	15.6	21.1	25.2	29.0	30.4	30.0	26.7	21.1	14.7	9.1
Texas												
Abilene	12.7	15.4	20.5	25.4	29.1	33.0	35.1	34.7	30.4	25.5	19.1	13.9
Amarillo	9.4	11.6	16.4	21.9	26.2	30.9	33.2	31.7	27.7	22.5	15.4	10.1
Austin	14.9	17.4	22.2	26.3	29.3	32.8	35.0	35.3	32.5	27.8	22.1	16.7
Brownsville	20.5	22.3	25.8	28.9	31.0	32.8	34.1	34.2	32.4	29.6	25.7	22.1
Corpus Christi	18.3	20.6	24.3	27.6	30.1	32.4	34.1	34.1	32.1	28.8	24.3	20.2
Dallas-Fort Worth	12.3	14.9	19.9	24.6	28.3	33.3	35.8	35.7	31.0	25.8	19.3	14.2
Del Rio	16.6	19.5	24.3	28.6	31.2	34.2	35.7	35.6	32.4	27.6	22.1	17.5
El Paso	13.4	16.8	21.1	25.9	30.6	35.8	35.6	34.2	30.6	25.8	19.1	14.2
Houston	16.1	18.5	21.7	25.8	29.2	32.3	33.7	33.6	31.3	27.6	22.4	18.2
Lubbock	11.6	14.2	18.9	24.1	28.4	32.2	33.3	32.0	28.3	23.7	17.3	12.3
Midland-Odessa	13.6	16.4	21.8	26.6	30.8	34.1	35.2	34.5	29.7	25.2	19.0	14.7
Port Arthur	15.7	17.9	21.9	25.7	28.9	31.9	33.3	33.2	30.7	26.8	21.8	17.9
San Angelo	13.8	16.7	22.6	27.3	30.8	33.7	35.7	35.2	30.4	26.0	20.1	15.0
San Antonio	16.0	18.7	23.1	26.8	29.6	33.2	35.0	35.2	31.8	27.6	22.2	17.5
Victoria	17.1	19.3	23.2	26.8	29.6	32.6	34.2	34.4	31.6	28.0	23.0	18.9
Waco	13.4	16.0	20.9	25.6	29.1	33.3	36.0	36.2	32.0	26.8	20.4	15.2
Wichita Falls	11.1	14.0	19.1	24.3	28.5	33.1	36.2	35.5	30.4	24.9	17.9	12.7
Utah												
Salt Lake City	2.4	6.4	11.2	16.3	22.2	28.2	33.4	31.9	26.2	18.9	10.4	3.2
Vermont												
Burlington	–3.8	–2.5	4.1	12.0	19.6	24.3	27.3	25.5	20.6	13.9	6.7	–0.9
Virginia												
Lynchburg	6.4	8.4	14.1	19.8	24.2	28.1	30.0	29.4	25.8	20.2	14.5	8.7
Norfolk	8.5	9.8	14.4	19.4	24.1	28.3	30.2	29.5	26.4	20.8	16.2	11.2
Richmond	7.6	9.6	15.3	21.1	25.4	29.5	31.3	30.6	27.2	21.5	16.3	10.1
Roanoke	6.6	8.5	14.3	19.6	24.3	28.3	30.2	29.6	25.8	20.1	14.4	8.7
Wallops Island	6.3	7.3	11.7	16.7	21.4	26.2	28.6	28.3	25.3	18.2	14.4	9.2

 Copyright © 2004 IEEE. All rights reserved.

Table B.3—30-year monthly normal maximum temperature in degrees celsius, US *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Washington												
Olympia	6.9	9.7	12.2	14.9	18.5	21.6	24.7	25.1	21.7	15.8	10.0	6.8
Quillayute	7.8	9.5	10.8	12.8	15.5	17.9	20.1	20.6	19.4	15.2	10.5	7.9
Seattle CO	7.8	10.3	12.1	14.5	17.9	20.9	23.4	23.4	20.4	15.6	10.8	7.9
Seattle Sea-Tac AP	7.2	9.7	11.5	14.0	17.7	21.1	24.0	24.0	20.7	15.4	10.3	7.3
Spokane	0.7	4.8	8.7	13.9	18.8	23.7	28.4	28.1	22.2	14.8	5.2	1.0
Yakima	3.1	8.0	12.9	17.3	22.0	26.6	30.4	29.8	24.9	18.0	9.1	3.1
Puerto Rico												
San Juan	28.4	28.7	29.1	29.9	30.7	31.4	31.4	31.5	31.6	31.3	29.9	28.8
West Virginia												
Beckley	3.3	5.1	11.0	16.6	21.2	24.7	26.2	25.8	22.4	17.0	11.3	5.8
Charleston	5.1	7.4	13.7	19.3	24.2	28.4	29.8	29.1	26.0	20.1	14.1	7.8
Elkins	3.3	5.2	11.2	16.4	21.6	25.3	26.9	26.3	23.1	17.6	11.6	5.9
Huntington	4.8	6.8	13.6	19.3	24.0	27.4	29.1	28.4	25.6	19.6	13.3	7.4
Wisconsin												
Green Bay	–5.1	–2.7	3.6	12.2	19.6	24.2	26.9	25.3	20.6	14.1	5.6	–2.4
La Crosse	–4.7	–1.3	5.6	14.7	21.6	26.6	29.2	27.6	22.4	15.7	6.3	–2.2
Madison	–4.0	–1.1	5.3	13.7	20.5	25.7	28.0	26.4	21.9	15.5	6.7	–1.2
Milwaukee	–3.3	–1.1	4.7	11.6	17.9	23.8	26.6	25.4	21.4	14.8	7.1	–0.4
Wyoming												
Casper	0.4	2.8	7.3	13.4	19.2	25.9	30.9	29.8	23.2	15.8	6.8	1.1
Cheyenne	3.2	4.7	7.2	12.6	18.1	23.6	27.9	26.7	21.7	15.6	8.2	3.8
Lander	–0.4	2.8	7.6	13.2	18.9	25.2	30.1	28.8	22.4	15.4	5.8	0.1
Sheridan	0.6	3.5	7.9	13.9	19.1	24.9	30.1	29.6	22.7	16.5	7.4	1.7

NOTE—CO refers to city office, A or AP refers to airport, and CDA refers to city district airport.

Copyright © 2004 IEEE. All rights reserved.

B.4 Table B.4

Table B.4—30-year monthly normal maximum temperature in degrees Celsius, Canada

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
British Columbia												
Dawson Creek A	–9.1	–5.6	0.6	9.8	16.4	19.8	21.8	20.7	15.4	9.6	–1.9	–7.6
Kamloops A	–1.3	3.4	10.2	16.2	21.1	25.4	28.3	27.8	21.7	14.0	5.3	0.0
Prince George A	–5.8	–0.7	4.6	10.8	16.0	19.7	22.1	21.4	16.0	9.8	0.6	–4.5
Prince Rupert A	4.1	5.9	7.2	9.4	12.0	14.1	15.9	16.5	15.0	11.3	7.0	4.8
Vancouver Int'l A	5.7	8.0	9.9	12.7	16.3	19.3	21.7	21.7	18.4	13.5	9.0	6.1
Victoria Int'l A	6.5	8.4	10.2	12.9	16.3	19.3	21.8	21.8	19.1	14.1	9.4	6.8
Yukon Territory												
White Horse A	–14.4	–8.2	–1.5	5.7	12.7	18.1	20.3	18.3	12.3	4.3	–6.4	–11.7
Burwash A	–15.9	–10.4	–2.7	4.7	11.8	17.2	19.0	17.2	11.3	2.2	–8.5	–13.9
Mayo A	–21.7	–13.1	–3.3	6.1	14.3	20.4	22.4	19.5	12.3	1.7	–12.3	–18.5
Northwest Territories												
Yellowknife A	–23.9	–19.7	–12.5	–0.5	10.1	18.0	20.8	18.1	10.0	1.3	–10.8	–20.1
Alberta												
Calgary Int'l A	–3.6	–0.5	3.3	10.6	16.4	20.6	23.2	22.7	17.4	12.6	2.9	–2.3
Edmonton Int'l A	–8.7	–5.1	0.1	19.9	17.4	20.9	22.5	21.8	16.6	11.3	–0.4	–6.9
Fort McMurray A	–14.5	–8.6	–1.1	9.3	17.1	21.5	23.2	21.8	15.1	8.4	–4.5	–12.6
Grande Prairie A	–10.0	–6.1	–0.3	9.3	16.6	20.3	22.2	21.4	16.0	10.1	–2.1	–8.3
Lethbridge A	–2.6	1.1	5.3	12.2	18.0	22.6	25.9	25.3	19.6	14.3	4.6	–0.9
Medicine Hat A	–5.1	–1.1	4.7	13.0	19.3	24.0	27.3	26.8	20.3	14.4	3.8	–3.0
Saskatchewan												
Prince Albert A	–13.7	–9.3	–2.4	9.0	17.8	22.1	24.2	23.1	16.5	9.8	–2.8	–11.4
Regina A	–11.0	–7.4	–0.6	10.5	18.5	23.4	26.3	25.6	18.6	11.9	0.2	–8.4

 Copyright © 2004 IEEE. All rights reserved.

Table B.4—30-year monthly normal maximum temperature in degrees Celsius, Canada *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Saskatoon A	–12.3	–8.6	–1.8	10.0	18.4	23.0	25.4	24.5	17.7	11.1	–1.3	–9.8
Swift Current A	–7.9	–4.6	1.1	10.4	17.4	22.3	25.4	24.9	18.0	11.8	1.1	–5.9
Manitoba												
Brandon A	–12.9	–9.2	–1.8	9.4	18.2	23.2	25.8	24.9	18.3	11.5	–0.6	–9.9
Brandon CDA	–12.4	–8.7	–1.3	10.1	18.7	23.8	26.5	25.4	18.8	11.9	–0.2	–9.5
Churchill A	–22.9	–21.2	–15.3	-5.2	2.7	10.9	16.9	15.6	8.8	1.4	–8.8	–18.8
Flin Flon A	–16.8	–11.5	–3.5	6.9	15.2	20.3	23.2	21.7	13.7	6.2	–5.1	–14.5
Grand Rap-ids HYDRO	–15.1	–11.5	–3.6	5.8	14.0	20.1	23.7	22.4	15.5	7.7	–3.5	–12.4
Thompson A	–19.5	–14.4	–5.6	4.6	13.2	19.3	22.6	20.7	12.6	4.2	–7.2	–17.1
Winnipeg Int'l A	–13.2	–9.7	–1.8	9.8	18.6	23.4	26.1	24.9	18.6	11.3	–0.4	–9.9
Ontario												
Kapuskasing A	–12.3	–9.2	–1.9	6.8	15.5	20.8	23.7	21.7	15.5	8.8	–0.5	–9.6
Kenora A	–13.1	–9.0	–1.1	8.5	16.8	21.6	24.7	22.9	16.3	9.3	–1.2	–10.2
London A	–2.8	–2.0	3.8	11.7	18.7	23.8	26.4	25.2	20.9	14.2	7.1	0.1
Ottawa Int'l A	–6.3	–4.6	1.8	10.8	18.6	23.6	26.4	24.6	19.6	12.8	4.7	–3.7
Ottawa CDA	–6.4	–4.5	1.8	10.8	18.6	23.6	26.4	24.7	19.7	12.8	4.8	–3.6
Sault Ste. Marie A	–5.5	–4.9	0.6	8.5	16.1	20.8	24.3	22.8	18.0	11.8	4.3	–2.6
Sudbury A	–8.5	–6.7	–0.5	8.2	16.7	21.6	24.8	22.8	17.3	10.4	2.2	–5.6
Thunder Bay A	–8.9	–6.2	0.2	8.7	15.7	20.5	24.4	22.9	17.3	10.8	2.0	–6.0
Toronto	–1.3	–0.6	4.4	11.5	18.2	23.5	26.5	25.3	20.9	14.2	7.7	1.4
Windsor A	–1.3	–0.1	6.0	13.4	20.2	25.3	27.7	26.5	22.5	15.8	8.5	1.5
Quebec												
Baie Comeau A	–8.5	–6.9	–1.5	4.1	11.5	17.8	21.0	19.5	14.4	8.3	1.7	–5.6
Montreal/ Dorval Int'l A	–5.8	–4.2	2.0	10.7	18.5	23.4	26.2	24.6	19.8	13.0	5.2	–2.9
Quebec A	–7.7	–6.0	0.1	7.9	16.7	22.2	24.9	23.1	17.9	11.0	2.9	–4.9
Sept-Iles A	–9.3	–7.4	–1.8	3.9	10.3	16.4	19.6	18.7	13.6	7.5	1.1	–6.3

Copyright © 2004 IEEE. All rights reserved.

Table B.4—30-year monthly normal maximum temperature in degrees Celsius, Canada *(continued)*

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
New Brunswick												
Fredericton A	–4.0	–2.5	2.9	9.4	17.2	22.8	25.6	24.5	19.3	13.1	5.7	–1.5
Moncton A	–3.7	–3.0	1.7	7.7	15.6	21.2	24.4	23.6	18.7	12.7	5.9	–1.0
Saint John A	–2.8	–2.3	2.1	7.9	14.4	19.2	22.1	21.8	17.6	12.1	6.0	–0.2
Nova Scotia												
Halifax Int'l A	–1.5	–1.5	2.6	8.0	14.7	20.1	23.4	23.0	18.7	13.0	7.0	1.2
Sydney A	–1.3	–2.1	1.2	5.9	12.6	18.7	22.9	22.7	18.2	12.6	7.1	1.6
Prince Edward Island												
Charlotte-town A	–3.4	–3.6	0.6	6.3	13.8	19.4	23.1	22.5	17.8	12.1	5.9	–0.3
Summerside A	–3.6	–3.4	0.9	6.3	13.7	19.6	23.3	22.7	18.0	5.8	5.8	–0.5
Newfoundland												
Churchill Falls A	–15.9	–13.4	-6.8	0.6	8.1	15.0	19.0	17.2	10.4	2.9	–4.2	–13.5
Goose A	–12.3	–9.9	–3.5	3.1	10.3	16.6	21.1	19.4	13.7	6.4	–0.4	–9.1
St John's A	–0.7	–1.4	1.0	4.8	10.3	15.8	20.2	19.5	15.6	10.6	6.2	1.5
Stephenville A	–2.3	–3.1	0.5	5.6	11.3	16.1	20.0	20.0	15.8	10.4	5.6	0.3

NOTE—CO refers to city office, A or AP refers to airport, and CDA refers to city district airport.

 Copyright © 2004 IEEE. All rights reserved.

Annex C

(informative)

Conversion tables

C.1 Table C.1

Table C.1—Wind speed

Meters per second	Kilometers per hour	Miles per hour
1	3.6	2.2
2	7.2	4.5
3	10.8	6.7
4	14.4	8.9
5	18.0	11.2
6	21.6	13.4
7	25.2	15.7
8	28.8	17.9
9	32.4	20.1
10	36.0	22.4
15	54.0	33.6
20	72.0	44.7
25	90.0	55.9
30	108.0	67.1
35	126.0	78.3
40	144.0	89.5
45	162.0	100.7

NOTES
1—Kilometers per hour (km/h) = meters per second (m/s) × 3.6.
2—Miles per hour (mi/h) = meters per second (m/s) × 2.237.

Copyright © 2004 IEEE. All rights reserved.

C.2 Table C.2

Table C.2—Temperature

Temperature degree Fahrenheit (°F) = (°C × 1.8) + 32	
Degree Celsius (°C)	**Degree Fahrenheit (°F)**
–40	–40
–35	–31
–30	–22
–25	–13
–20	–4
–15	5
–10	14
–5	23
0	32
5	41
10	50
15	59
20	68
25	77
30	86
35	95
40	104
45	113
50	122
55	131

 Copyright © 2004 IEEE. All rights reserved.

Table C.2—Temperature *(continued)*

Temperature degree Fahrenheit (°F) = (°C × 1.8) + 32	
Degree Celsius (°C)	**Degree Fahrenheit (°F)**
60	140
65	149
70	158
75	167
80	176
85	185
90	194
95	203
100	212
105	221

Copyright © 2004 IEEE. All rights reserved.

Annex D

(informative)

Bibliography

Approved standards are listed in Clause 2. There are many other publications that provide additional information. Some of these are listed below.

[B1] Benfor, F., "Duration and intensity of sunshine," *Illum. Eng.* (New York), July 1948.

[B2] "Canadian Climate Normals, Volume 2, Temperature, 1961–1990," Atmospheric Environment Service, Downsview, Ont., Climatological Service Division.

[B3] "Climatography of U.S. No. 81, 1961–1990," National Climatic Data Center.

[B4] Cottony and Dill, "Solar Heating of Various Surfaces," US Weather Bureau Abstract, July 1940.

[B5] Freese, E., "Pathways of the sun," *Amer. Architect*, Nov. 1934.

[B6] Fritz and MacDonald, "Average solar radiation in the United States," US Weather Bureau, *Heating and Ventilating*, July 1949.

[B7] Fritz, S., "Solar radiation during cloudless days," US Weather Bureau, *Heating and Ventilating*, Jan. 1949.

[B8] "Global Climate Normals, 1961–1990," National Climatic Data Center, Jan. 1999 (CD-ROM).

[B9] Hall, J. D., *Industrial Applications of Infrared*, New York: McGraw-Hill, 1947.

[B10] IEC 60068-2-5 (1975-01), Environmental testing, Part 2: Tests—Simulated solar radiation at ground level.

[B11] IEC 60068-2-9 (1989), Environmental testing, Part 2: Tests—Guidance for solar radiation testing.

[B12] IEC 60721-2-4 (1987), Classification of environmental conditions, Part 2: Environmental conditions appearing in nature—Solar radiation and temperature.

[B13] IEEE Std C37.100™-1992, IEEE Standard Definitions for Power Switchgear.[3]

[B14] King, W. J., "Free convection" and "Radiation," *Mech. Eng.*, Vol. 54, 1932.

[B15] Lee, R. H., "The Effect of color on temperature of electrical enclosures subject to solar radiation," Sumpwr Abstract C73-388-6, T-PAS73 Nov./Dec. 1806–1807 (1B08).

[B16] "Local Climatological Data—Annual Summary with Comparative Data," National Climatic Data Center.

[B17] McAdams, W. H., *Heat Transmission*, 3rd ed., New York: McGraw-Hill, 1954.

[3]The IEEE standard referred to in Annex D is a trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

 Copyright © 2004 IEEE. All rights reserved.

[B18] National Climatic Data Center, Asheville, NC (http://www.ncdc.noaa.gov).

[B19] National Oceanic and Atmospheric Administration, US Department of Commerce, Washington, DC (http://www.noaa.gov).

[B20] Penney, G.W., "Temperature rise of electrical apparatus as affected by radiation," *AIEE Trans.*, Vol. 59, June 1940, pp. 338–344.

[B21] "Report No. 12," Astrophysical Lab, Smithsonian Inst., Washington, DC.

[B22] Surig and Frick, "Heating and current-carrying capacity of bare conductors for outdoor service," *Gen. Elec. Rev.*, Mar. 1930.

[B23] "Temperature and precipitation tables (1961–1990)," Meteorological Branch, Dept. Transport, Toronto, Ont., Canada.

[B24] "U.S. Divisional and Station Climatic Data and Normals," National Climatic Data Center, Dec. 1994.

[B25] "Weekly mean values of daily total solar and sky radiation," US Weather Bureau, Tech. Paper 11, 1949.

[B26] Wetherill and Montsinger, "Effect of color of tank on temperature of self-cooled transformers under service conditions," AIEE, Sept. 1929.

[B27] World Meteorological Organization (http://www.wmo.ch).

Copyright © 2004 IEEE. All rights reserved.

Copyright © 2004 IEEE. All rights reserved.