IEEE Std C37.37-1996
(Revision of
IEEE Std C37.37-1979)

IEEE Loading Guide for AC High-Voltage Air Switches (in Excess of 1000 V)

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IEEE Loading Guide for AC High-Voltage Air Switches (in Excess of 1000 V)

Sponsor

IEEE Switchgear Committee of the IEEE Power Engineering Society

Approved 20 June 1996

IEEE Standards Board

Abstract: An aid to users to determine (1) the allowable continuous current class (ACCC), (2) the continuous load current capabilities of air switches under various conditions of ambient temperature, and (3) the emergency load current capabilities of air switches under various conditions of ambient temperature, is provided. This guide does not apply to switches used in enclosures covered by IEEE Std C37.20.2-1993, IEEE Std C37.20.3-1996, IEEE Std C37.23-1987, IEEE Std C37.71-1984, and ANSI C37.72-1987.
Keywords: ACCC, allowable continuous current class, current capabilities, emergency loading, high-voltage air switches, outdoor switches

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Introduction

[This introduction is not part of IEEE Std C37.37-1996, IEEE Loading Guide for AC High-Voltage Air Switches (in Excess of 1000 V).]

IEEE Std C37.37-1996 is a loading guide that designates the continuous and emergency load current capabilities of air switches over a range of ambient temperatures. This is accomplished through a family of loadability factor curves.

The Standards Committee on Power Switchgear, C37, which reviewed and approved this standard, had the following personnel at the time of approval:

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IEEE Loading Guide for AC High-Voltage Air Switches (in Excess of 1000 V)

1. Overview

1.1 Scope

This loading guide applies to ac high-voltage air switches in excess of 1000 V rated in accordance with IEEE Std C37.30-1992.[1] This standard does not apply to switches used in enclosures covered by IEEE Std C37.20.2-1993, IEEE Std C37.20.3-1996, IEEE Std C37.23-1987, IEEE Std C37.71-1984, and ANSI C37.72-1987. Moreover, interrupter switches covered by IEEE PC37.39 are excluded from the scope of this standard. If an air switch is equipped with a load-break device or interrupter, it may not successfully interrupt currents above the nameplate rating.

1.2 Purpose

The purpose of this guide is to aid users and manufacturers in the determination of:

a) The allowable continuous current class (ACCC) designations.
b) The continuous load current capabilities of air switches under various conditions of ambient temperature.
c) The emergency load current capabilities of air switches under various conditions of ambient temperature.

2. References

This recommended practice shall be used in conjunction with the following publications:

Accredited Standards Committee C2-1997, National Electrical Safety Code® (NESC®) (ANSI).[2]

ANSI C29.1-1988, Test Methods for Electrical Power Insulators.[3]

ANSI C29.8-1985 (R1995) Wet-Process Porcelain Insulators (Apparatus, Cap and Pin Type).

ANSI C29.9-1983, Wet-Process Porcelain Insulators (Apparatus, Post Type).

[1]Information on references can be found in clause 2.

[2]The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[3]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

ANSI C37.32-1990, American National Standard for Switchgear—High-Voltage Air Switches, Bus Supports, and Switch Accessories—Schedule of Preferred Ratings, Manufacturing Specifications, and Application Guide.

ANSI C37.72-1987 American National Standard for Manually-Operated Dead-Front, Padmounted Switchgear with Load-Interrupting Switches and Separable Connectors for Alternating Current Systems.

ASA C37.30-1962, American Standard Definitions and Requirements for High-Voltage Air Switches, Insulators, and Bus Supports.[4]

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing (ANSI).[5]

IEEE Std 119-1974, Recommended Practice for General Principles for Temperature Measurements as Applied to Electrical Apparatus (ANSI).[6]

IEEE Std C37.010-1979 (R1988), IEEE Application Guide for Alternating Current High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C37.20.2-1993, IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear (ANSI).

IEEE Std C37.20.3-1996, IEEE Standard for Metal-Enclosed Interrupter Switchgear (ANSI).

IEEE C37.23-1987 (R1991) IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus (ANSI).

IEEE Std C37.30-1992, IEEE Standard Requirements for High-Voltage Air Switches (ANSI).

IEEE PC37.39 (P1247) (D12-9/9/96), Draft Standard for Interrupter Switches for Alternating Current, Rated Above 1000 V.[7]

IEEE Std C37.71-1984 (R1990), IEEE Standard for Three-Phase, Manually Operated Subsurface Load Interrupting Switches for Alternating Current Systems (ANSI).

IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear (ANSI).

3. Definitions

The definitions of terms contained in this document, or in other standards referred to in this document, are not intended to embrace all legitimate meanings of the terms. They are applicable only to the subject treated in this standard. For additional definitions, see IEEE Std C37.100-1992. An asterisk (*) following the definition indicates that, at the time this standard was approved, there was no corresponding definition in IEEE Std C37.100-1992.

3.1 allowable continuous current class (ACCC) designation (of an air switch): A code that identifies the composite curve relating the loadability factor (LF) of the switch to the ambient temperature θ_A as determined by the limiting switch part class designations.*

3.2 loadability: The allowable continuous current capability of an air switch at a given ambient temperature.*

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[4]ASA, the American Standards Association, is a former name of the American National Standards Institute. This publication is available from the ANSI archives.

[5]IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[6]IEEE Std 119-1974 has been withdrawn; however, copies can be obtained from the IEEE Standards Department, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[7]This authorized standards project was not approved by the IEEE Standards Board at the time this went to press. It is available from the IEEE.

3.3 loadability factor (of an air switch): The ratio of allowable continuous current at a given ambient temperature to rated current.*

3.4 switch part class designation: A code that identifies the curve that relates the loadability factor (LF) of a switch part material and function to the ambient temperature θ_A.*

4. General application conditions

Air switches are designed for normal application in accordance with IEEE Std C37.30-1992 where the sustained load current does not exceed the rated continuous current, the altitude above sea level is 3300 ft (1000 m) or less, and the ambient temperature does not exceed 40 °C. The rated continuous current is based on the limits of observable temperature rise at rated continuous current from table 3 of IEEE Std C37.30-1992, reprinted herein as table 1.

Table 1—Temperature limitations for air switches

Switch parts	Nonenclosed indoor and outdoor switches			Enclosed indoor and outdoor switches	
	Allowable maximum temperature θ_{max} (°C)	Limit of observable temperature rise and rated current, θ_r (°C) (see NOTE 1)	Switch part class designation	Limit of observable temperature rise at rated current, θ_r (°C)	Switch part class designation
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
1. Contacts in air (see NOTE 2)					
a. Copper or copper alloy	75	33	BO2	20	$QO_3$3
b. Copper or copper alloy to silver or silver alloy, or equivalent	90	43	DO_4	33	RO4
c. Silver, silver alloy, or equivalent	105	53	FO6	43	TO6
d. Other (see NOTE 3)	—	—	—	—	—
2. Conducting mechanical joints					
a. Copper or aluminum	90	43	DO4	33	RO4
b. Silver, silver alloy, or equivalent	105	53	FO6	43	TO6
c. Other (see NOTE 3)	—	—	—	—	—
3. Switch terminals with bolted connections	90	43	DO4	33	RO4
4. Welded or brazed joints or equivalent	105	53	FO6	43	TO6
5. Other current-carrying parts					
a. Copper or copper alloy castings	105	53	FO6	43	TO6
b. Hard-drawn copper parts (see NOTE 4)	80	37	CO3	25	$PO_2$2
c. Heat-treated aluminium alloy parts	105	53	FO6	43	TO6

Table 1—Temperature limitations for air switches (*Continued*)

Switch parts	Nonenclosed indoor and outdoor switches			Enclosed indoor and outdoor switches	
	Allowable maximum temperature θ_{max} (°C)	Limit of observable temperature rise and rated current, θ_r (°C) (see NOTE 1)	Switch part class designation	Limit of observable temperature rise at rated current, θ_r (°C)	Switch part class designation
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
d. Woven wire flexible connectors	75	33	BO2	20	$QO_3 3$
e. Other materials (see NOTE 3)	—	—	—	—	—
6. Insulator caps and pins and bushing caps	110	57	GO7	47	UO7
7. Current–carrying parts in contact with insulating materials (see NOTE 5)					
a. Insulation class 90 °C	80	37	CO3	25	$PO_2 2$
b. Insulation class 105 °C	95	47	EO5	37	SO5
c. Insulation class 130 °C	120	63	HO8	53	VO8
d. Insulation class 155 °C	145	80	IO9	70	WO9
e. Insulation class 180 °C	170	97	JO10	87	XO10
f. Insulation class 220 °C	210	123	KO11	113	YO11
g. Oil (see NOTE 6)	90	43	DO4	33	RO4
8. Nonenergizable parts subjected to contact by personnel					
a. Handled by operator (see NOTE 7)	50	10	—	10	—
b. Accessible to operator (see NOTE 7)	70	30	—	30	—
c. Not accessible to operator (see NOTE 8)	—	—	—	—	—
9. Entire switch in accordance with ASA C37.30-1962					
a. Outdoor	70	30	AO1	—	—
b. Indoor	85	—	—	30	NO1

NOTES

1—The limit of observable temperature rise listed in this column is suitable for use in rating switches for application in enclosures of IEEE Std C37.20.1-1993, IEEE Std C37.20.2-1993, and IEEE Std C37.20.3-1996, if corresponding allowable maximum temperature listed in column 1 is not exceeded when in the enclosure.

2—Contacts as used here include: a) stationary and moving contacts that engage and disengage, and b) contacts that have relative movement but remain engaged.

3—Other materials may become available for contacts and conducting mechanical joints and other current-carrying parts that have a different allowable maximum temperature, θ_{max}. Their limit of observable temperature rise at rated continuous current, θ_r, shall be related to their θ_{max} in accordance with 3.1.2 of IEEE Std C37.30-1992.

Table notes continued from table 1:

4—If annealing will not impair switch operation or reduce ability to meet any of the ratings, 105 °C may be used for θ_{max} and corresponding increase in θ_r as determined in 3.1.2 of IEEE Std C37.30-1992.

5—The temperature of materials used on the switch to insulate current-conducting parts from phase-to-ground, from phase-to-phase, or from terminal-to-terminal of an open switch shall be limited to the values listed. It is recognized that these limits are generally less than those associated with the insulating class in IEEE Std 1-1986, since such insulation may be subject to severe mechanical as well as dielectric stress when used on high-voltage switches. Although all insulation temperature classes are included for completeness, and to allow possible future use of higher temperature current-carrying material, the maximum temperatures of current-carrying materials listed in table 1 of IEEE Std 1-1986 shall not be exceeded.

6—The top oil (upper layer) temperature shall not exceed 80 °C total. The 90 °C value refers to the hottest-spot temperature of parts where they contact the oil.

7—It is assumed that any parts handled by or accessible to an operator will be in ambient air not to exceed 40 °C.

8—The maximum temperature of any nonenergizable part not accessible to the operator shall not exceed a temperature that will necessitate maintenance or replacement of parts during the life of the switch.

5. Application considerations for continuous load current capability

5.1 Allowable continuous current

The allowable continuous current of an air switch is a function of the maximum allowable total temperature of the switch parts and the ambient temperature. The loadability of each switch part class at various ambient temperatures may be determined by utilizing the formula in 3.4.1 in IEEE Std C37.30-1992, and table 1 in this guide.

5.2 Switch part class designation

An air switch is made up of a number of different switch parts. For purposes of this guide, these parts are classified and grouped in accordance with their material and function into switch part classes, each of which is given a switch part class designation. (See IEEE Std C37.30-1992, 3.4.3.) The loadability factors of each switch part class, as a function of ambient temperature, are represented by a curve, such as AO1 of figure 1. (Figures begin on page 9 of this guide.) The point 1 is the loadability factor at –30 °C ambient. All curves intersect at letter O (1.22 loadability factor at 25 °C ambient).

5.3 Allowable continuous current class (ACCC) designation

The ACCC designation of an air switch is a code that identifies a composite curve made up from the limiting switch part classes. (See IEEE Std C37.30-1992, 3.4.4.) For example, a nonenclosed air switch, when combining switch part classes DO4 and FO6, has an ACCC designation of DO6 (see figure 1—use curve DO between 60 °C and 25 °C, then use curve O6 between 25 °C and –30 °C.). It is not the intention of this guide to imply or require a multiplicity of switch designs in accordance with IEEE Std C37.30-1992. From a practical standpoint, there may be available switches with only a few ACCC designations.

5.3.1 Allowable continuous current capability

The allowable continuous current capability of an air switch at a given ambient temperature is equal to the loadability factor at the given ambient temperature multiplied by the rated continuous current of the switch. For example, a 1200 A nonenclosed switch with ACCC designation DO6 has a loadability factor, LF = 1.47 at –10 °C. Therefore, it has an allowable continuous current capability of 1764 A (see figure 1) at –10 °C.

5.3.2 Allowable continuous current class designation for ANSI C37.30-1962 switches

Air switches designed in accordance with ANSI C37.30-1962 and earlier standards may not have an ACCC designation on the nameplate. Such nonenclosed switches having a 30 °C limit of observable temperature rise in a maximum ambient of 40 °C (indicative of an allowable maximum temperature of 70 °C) are assigned an ACCC designation of AO1 on figure 1 and table 1. In like manner, such enclosed switches having a 30 °C limit of observable temperature rise in a maximum ambient of 55 °C (indicative of an allowable maximum temperature of 85 °C) are assigned an ACCC designation of NO1 on figure 2 and table 1.

5.4 Exceptions to temperature limitations

Although the temperature limitation and switch part class designation for insulator cap and pin and bushing caps are included in this guide, it should be noted that under normal conditions, these switch parts do not reach their limit of observable temperature rise with rated continuous current applied, and hence, are not a limiting factor in determining the allowable continuous current of an air switch.

Nonenergized switch parts subject to contact by personnel (item 8, table 1) have not been given switch part class designations in this guide because

a) Temperatures reached by these parts are a function of individual switch construction and cannot generally be predicted.

b) The parts involved are non-current carrying and, therefore, do not limit switch capability.

5.5 Precautions

When the air switch ACCC designation is applied, the user should consider the following precautions:

a) Loadability factors greater than unity should be applied only to new switches and switches that have been properly maintained in order that they can carry rated continuous current without exceeding their limit of observable temperature rise.

b) It is recommended that a loadability factor be limited to 2.0 regardless of the ambient temperature. See figure 2 and table 1, switch part class designation $QO_3$3.

c) Air switches designed in accordance with ASA C37.30-1962 or earlier have –10 °C as the low end of the ambient temperature range for usual service conditions. These switches have been assigned ACCC designations of:

   1) AO1 of figure 1 for nonenclosed switches

   2) NO1 of figure 2 for enclosed switches

   Before utilizing the loadability factors at ambients below –10 °C, the manufacturer should be consulted.

d) Operating companies using a class loading procedure in which each piece of similar equipment is assigned the same loadability factor may find it necessary to specify a 1.22 loadability factor at 25 °C ambient to coordinate existing and future equipment.

e) This guide does not imply a relationship between the allowable continuous current or emergency current capabilities of the interrupter switch and its interrupting capabilities. For interrupting capabilities of interrupter switches at higher than rating, or at ambients other than the range specified for the interrupter switch, the manufacturer should be consulted.

6. Application considerations for emergency load current capability

6.1 Considerations

During emergency periods, operation may be required at higher load currents than permitted by the ambient compensation procedures outlined in clause 3. Under these conditions, all the general considerations for ambient compensation are applicable to emergency loading, with additional considerations and limitations as outlined in this subclause.

NOTE—The limits of total temperature for the switch will be exceeded under the specified emergency load currents, and these higher temperatures may cause a reduction in the operating life of the switch. Therefore, it is recommended that the user inspect the switch after it has been subjected to a severe emergency overload or to cumulative hours of lesser overloads. Normal maintenance should be performed in accordance with IEEE Std C37.35-1995 and the manufacturer's recommendations. If, during the inspection and maintenance, deterioration is noted in any of the switch parts, the parts should be replaced or the manufacturer should be consulted before returning the switch to service.

6.2 Capabilities

The switch emergency time durations and maximum temperatures are as follows:

Time periods	Maximum total temperatures
Less than 24 h	20 °C greater than temperature θ_{max} listed in table 1
More than 24 h	10 °C greater than temperature θ_{max} listed in table 1

For the most common switch manufactured and supplied in accordance with IEEE Std C37.30-1992, the emergency load current ratings for the time period listed above are plotted in figures 3 through 6 for the ACCC designations.

NOTES

1—The curves have been plotted for a 24 h time period and can be safely used for shorter time periods. However, because higher emergency load currents are allowable for shorter time periods, similar curves may be constructed using the formula (L_{E1}) given in this guide.

2—The formula and curves shown in this guide are satisfactory to use, provided the allowable maximum temperatures of the switch parts were not exceeded during the 2 h prior to an emergency.

3—The maximum emergency load current shall not exceed 200% of the continuous current of the switch.

4—Figures 3 through 6 are illustrative of the procedure required to ascertain the current capability of the switch under emergency conditions. The user of this guide is encouraged to contact the switch manufacturer for information concerning the ACCC designation of the switch if it is not known. Knowledge of the ACCC designation and the temperature limitations are required to construct realistic graphs of the current capability of the switch under emergency conditions.

The formulas for emergency loadability factor are as follows:

$$L_{E1} = \left[\frac{\theta_{max} + \Delta\theta_{E1} - \theta_r(e^{-dIT}) - \theta_A}{\theta_r(1 - e^{-dIT})}\right]^{0.5} \leq 2.0 \text{ for a duration less than 24 h.} \quad (1)$$

$$L_{E2} = \left[\frac{\theta_{max} + \Delta\theta_{E2} - \theta_A}{\theta_r}\right]^{0.5} \leq 2.0 \text{ for a duration more than 24 h} \qquad (2)$$

where

L_{E1} is the ratio of emergency load current capability to rated continuous current for a duration of less than 24 h.

L_{E2} is the ratio of emergency load current capability to rated continuous current for a duration more than 24 h.

θ_{max} is the allowable maximum temperature (°C) when carrying rated continuous current, according to IEEE Std C37.30-1992.

$\Delta\theta_{E1}$ is the additional temperature, 20 °C, allowed during emergency conditions for durations less than 24 h.

$\Delta\theta_{E2}$ is the additional temperature, 10 °C, allowed during emergency conditions for durations more than 24 h.

θ_r is the limit of observable temperature rise (°C) at rated continuous current (actual temperature rise data may be used).

θ_A is the ambient temperature (°C) for nonenclosed switches or external ambient temperature for enclosed switches. For enclosed switches only, add 15 °C to the external ambient temperature in each of the above formulas to realistically represent the cooling air temperature inside the enclosure.

T is the thermal time constant in minutes (generally 30 min for switches).

d is the duration of emergency in minutes.

e is 2.718.

Annex A

(informative)

Bibliography

Smithsonian Institute Meteorological tables, 6th ed., Washington, D.C.

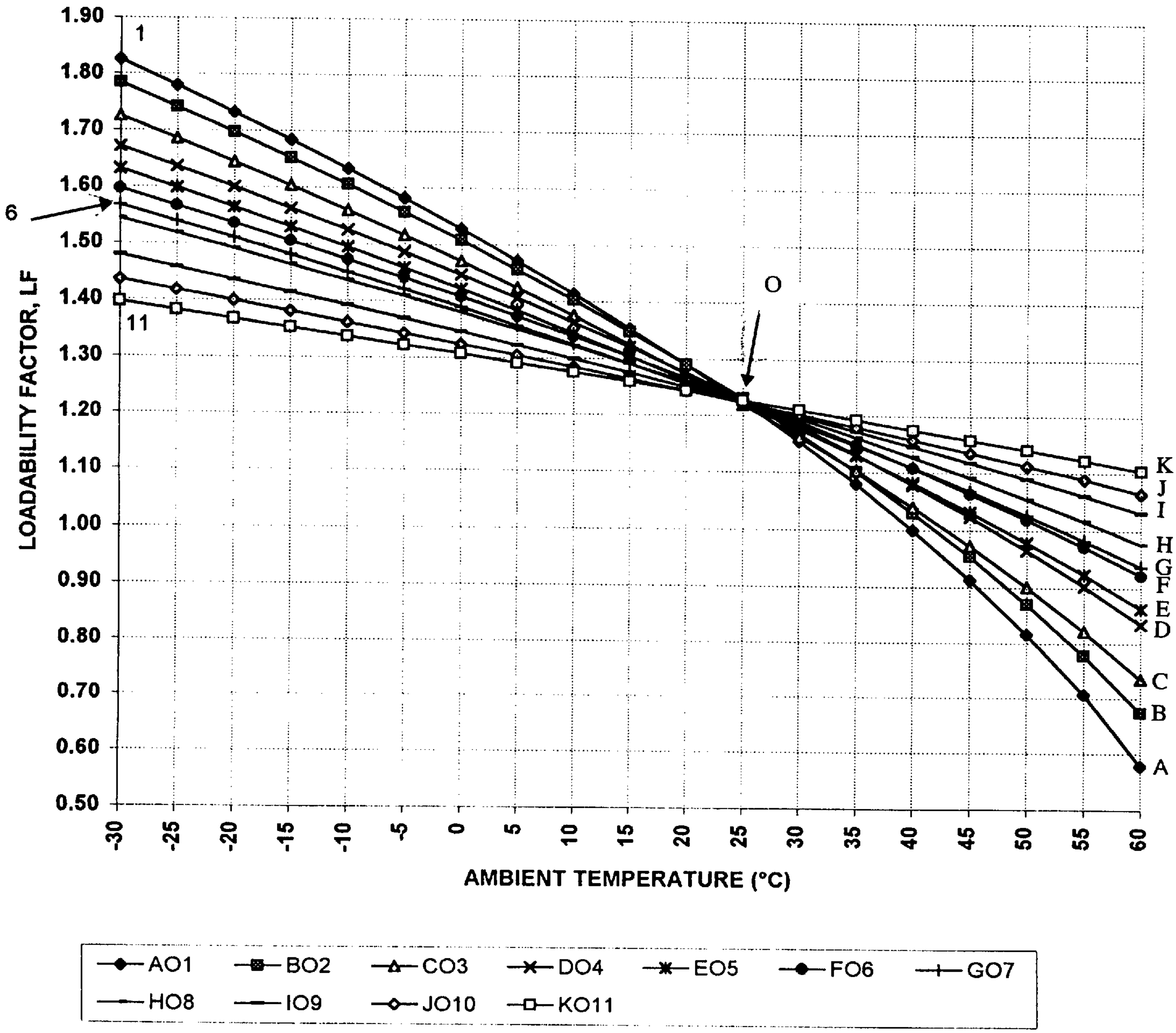

Figure 1—Nonenclosed indoor and outdoor switches Loadability factor vs. ambient temperature

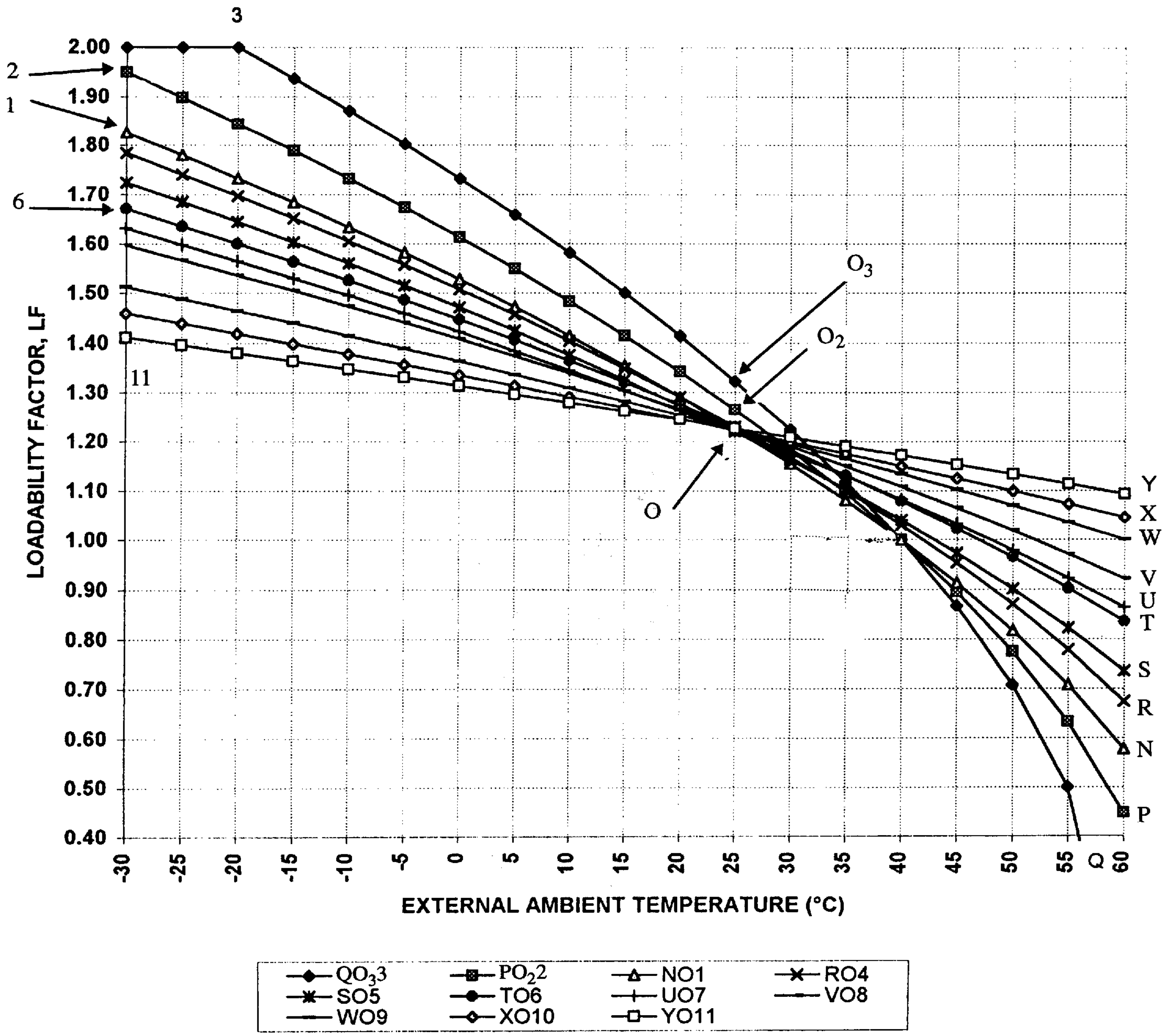

Figure 2—Enclosed indoor and outdoor switches Loadability factor vs. external ambient temperature

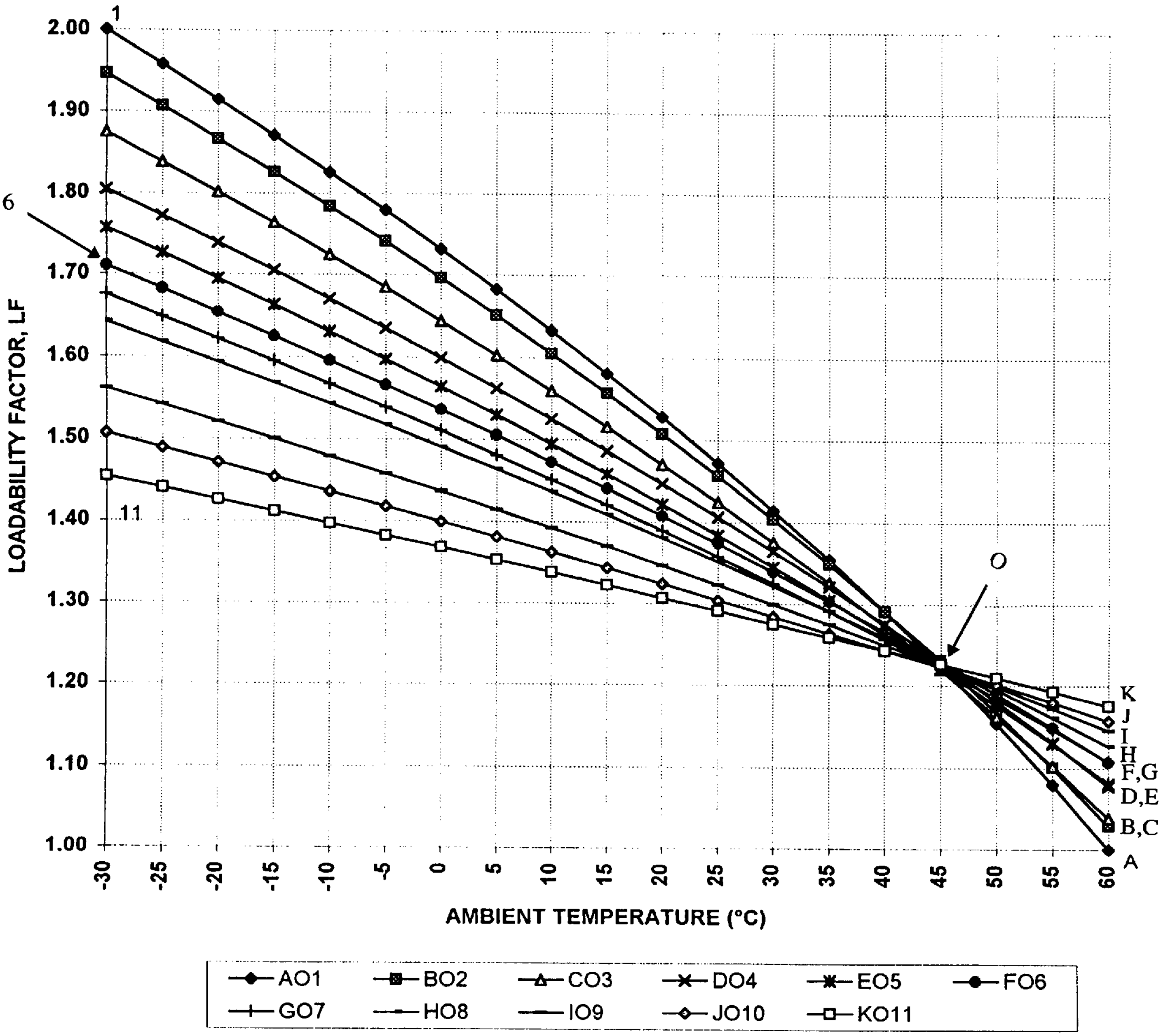

Figure 3—Nonenclosed indoor and outdoor switches
Emergency loadability for less than 24 h
Loadability factor vs. ambient temperature

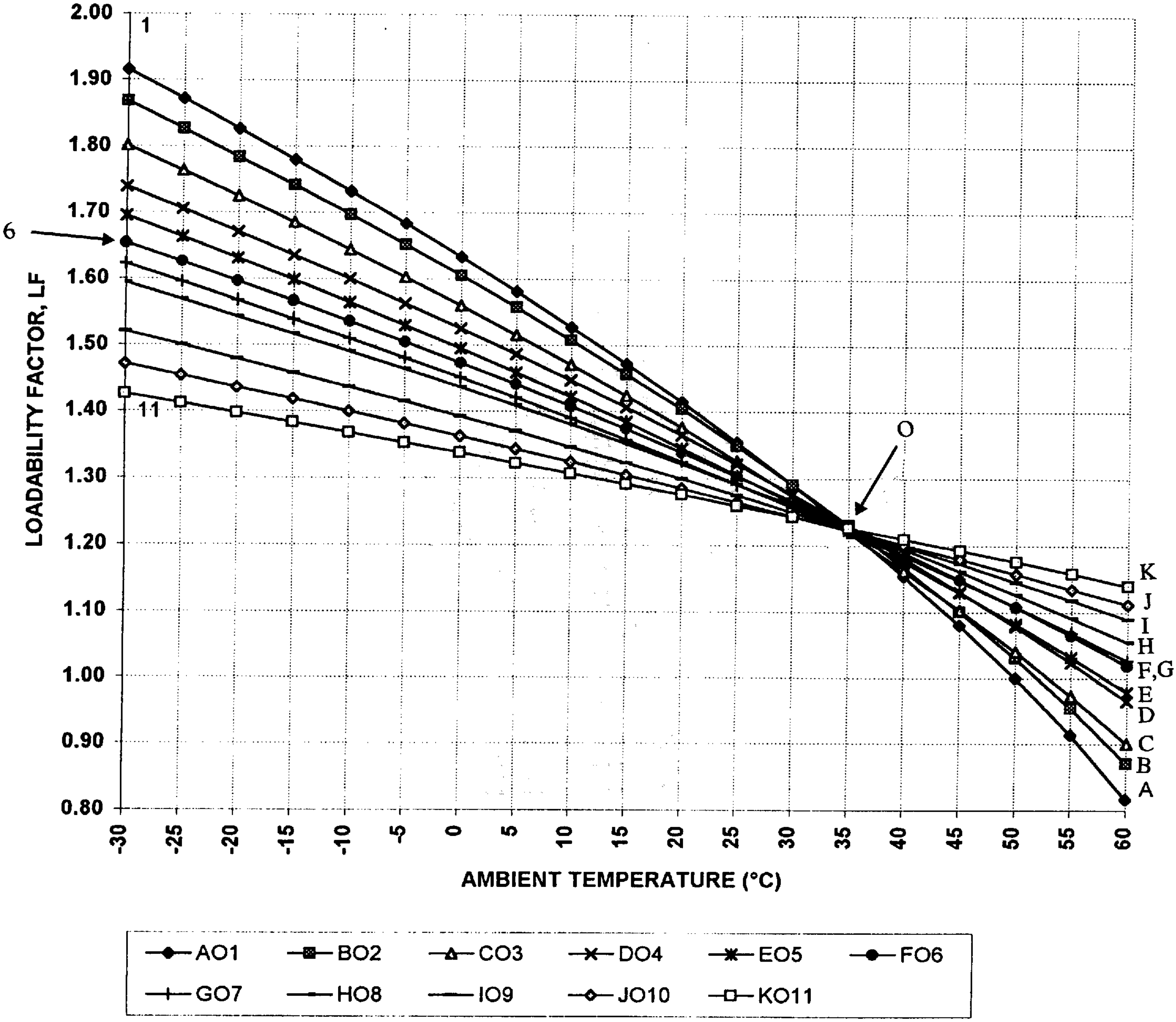

Figure 4—Nonenclosed indoor and outdoor switches Emergency loadability for more than 24 h Loadability factor vs. ambient temperature

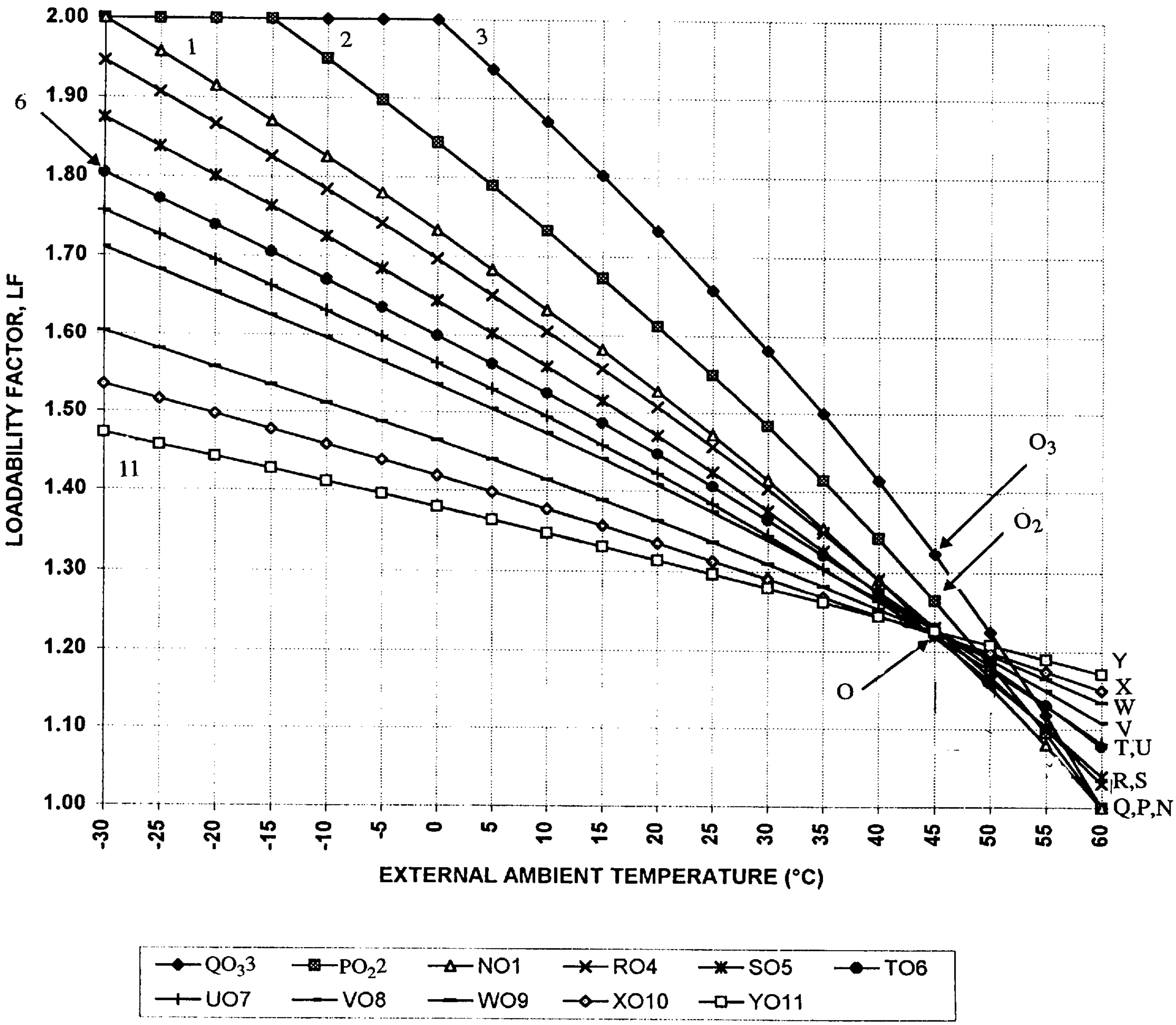

Figure 5—Enclosed indoor and outdoor switches
Emergency loadability for less than 24 h
Loadability factor vs. external ambient temperature

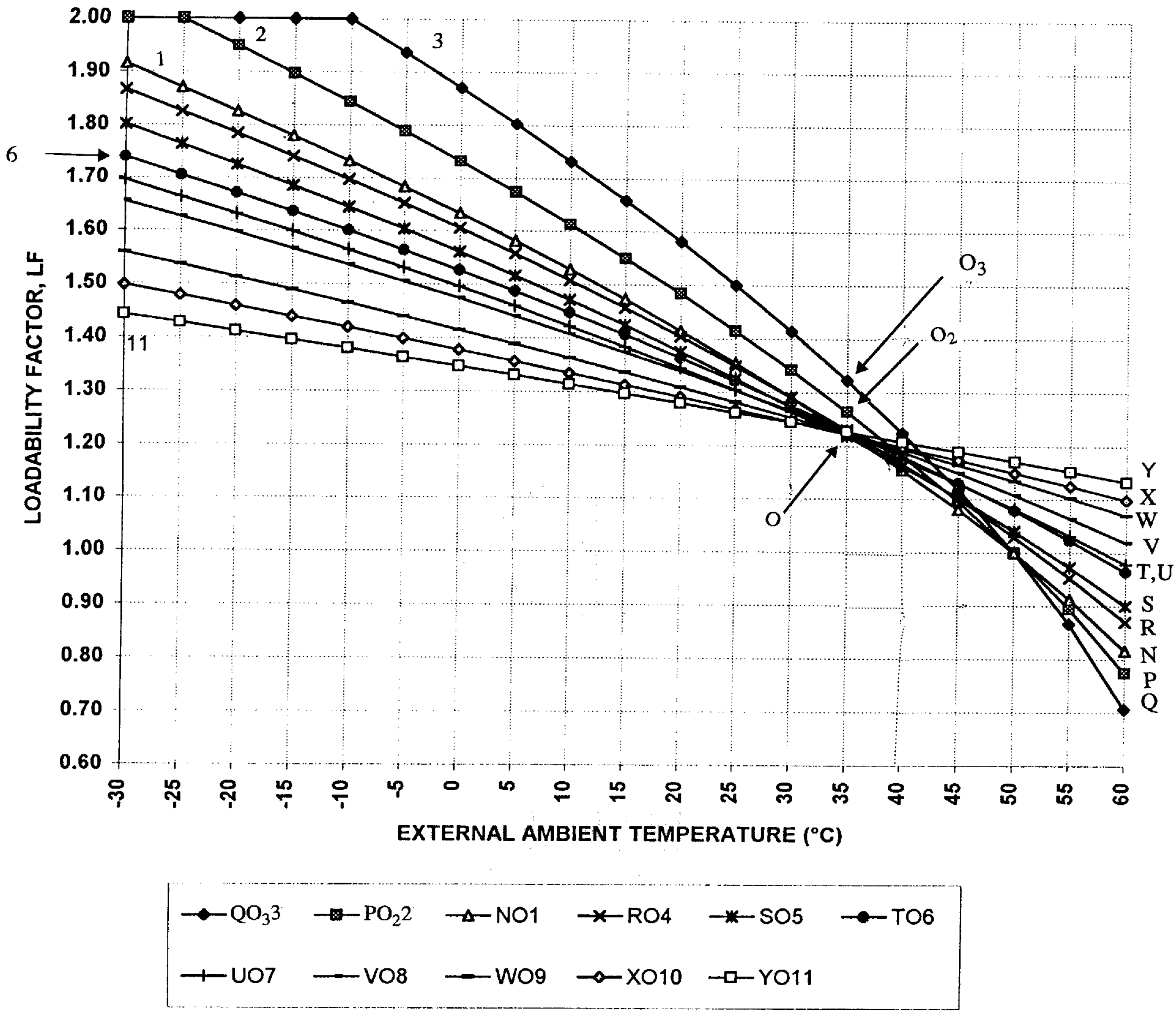

Figure 6—Enclosed indoor and outdoor switches Emergency loadability for more than 24 h Loadability factor vs. external ambient temperature

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