ISA-S12.16.01-1998 (IEC 79-7 Mod)

Approved November 30, 1997

Standard

Electrical Apparatus for Use in Class I, Zone 1 Hazardous (Classified) Locations Type of Protection — *Increased Safety "e"*

Certain provisions of this document differ from analogous provisions of ANSI/UL 2279. ISA and UL are actively working to harmonize these provisions and anticipate jointly publishing a single set of American National Standards when these differences are resolved.

ISA-12.16.01 (IEC 79-7 Mod), Electrical Equipment for Use in Class I, Zone 1 Hazardous (Classified) Locations Type of Protection- *Increased Safety "e"*

ISBN 1-55617-647-3

Copyright © 1998 by the Instrument Society of America. All rights reserved. Printed in the United States of America. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means (electronic, mechanical, photocopying, recording, or otherwise), without the prior written permission of the Publisher.

ISA
67 Alexander Drive
P. O. Box 12277
Research Triangle Park, North Carolina 27709

Preface

This ISA Standard is based on IEC Publication 79-7. It is the intention of the ISA SP12 Committee to develop an ANSI Standard that is harmonized with IEC 79-7 to the fullest extent possible.

This preface, as well as all footnotes and annexes, is included for informational purposes only and is not part of ISA-S12.16.01 (IEC 79-7 Mod).

This standard has been prepared as part of the service of ISA, the international society for measurement and control, toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static, but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms, and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; 67 Alexander Drive; P. O. Box 12277; Research Triangle Park, NC 27709; Telephone (919) 990-9227; Fax (919) 549-8288; E-mail: standards.info@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards, recommended practices, and technical reports. The Department is further aware of the benefits to USA users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavor to introduce SI-acceptable metric units in all new and revised standards to the greatest extent possible. *Standard for Use of the International System of Units (SI): The Modern Metric System*, published by the American Society for Testing & Materials as IEEE/ASTM SI 10-97, and future revisions, will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

It is the policy of ISA to encourage and welcome the participation of all concerned individuals and interests in the development of ISA standards. Participation in the ISA standards-making process by an individual in no way constitutes endorsement by the employer of that individual, of the ISA, or of any of the standards, recommended practices, and technical reports that ISA develops.

CAUTION—THE USE OF THIS STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT MAY INVOLVE HAZARDOUS MATERIALS, OPERATIONS OR EQUIPMENT. THE STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT CANNOT ANTICIPATE ALL POSSIBLE APPLICATIONS OR ADDRESS ALL POSSIBLE SAFETY ISSUES ASSOCIATED WITH USE IN HAZARDOUS CONDITIONS.

THE USER OF THIS STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT MUST EXERCISE SOUND PROFESSIONAL JUDGMENT CONCERNING ITS USE AND APPLICABILITY UNDER THE USER'S PARTICULAR CIRCUMSTANCES. THE USER MUST ALSO CONSIDER THE APPLICABILITY OF ANY GOVERNMENTAL REGULATORY LIMITATIONS AND ESTABLISHED SAFETY

AND HEALTH PRACTICES BEFORE IMPLEMENTING THIS STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT.

ADDITIONALLY, IMPLEMENTATION OF THE STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT MAY REQUIRE USE OF TECHNIQUES, PROCESSES, OR MATERIALS COVERED BY PATENT RIGHTS. ISA TAKES NO POSITION ON THE EXISTENCE OR VALIDITY OF ANY PATENT RIGHTS WHICH MAY BE INVOLVED IN IMPLEMENTING THE STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT. ISA WILL NOT BE RESPONSIBLE FOR IDENTIFYING ALL PATENTS THAT MAY REQUIRE A LICENSE BEFORE IMPLEMENTATION OF THE STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT OR FOR INVESTIGATING THE VALIDITY OR SCOPE OF ANY PATENTS BROUGHT TO ITS ATTENTION. THE USER SHOULD CAREFULLY INVESTIGATE RELEVANT PATENTS BEFORE USING THE STANDARD, RECOMMENDED PRACTICE, OR TECHNICAL REPORT FOR THE USER'S INTENDED APPLICATION.

The following people served as members of ISA Subcommittee SP12.16:

NAME	**COMPANY**
J. Kuczka, Chairman	Killark
*D. Bishop	Chevron USA Production Company
N. Abbatiello	Eastman Kodak Company
A. Ballard	Crouse-Hinds
H. Bockle	Killark-Stahl, Inc.
K. Boegli	Phoenix Contact, Inc.
J. Bossert	Hazloc, Inc.
R. Brodin	Fisher Controls International, Inc.
W. Brown	ISD Corp.
C. Casso	Schlumberger Services
I. Cleare	Electrical Equipment Certification
P. Dobler	Weidmuller Inc.
R. Doughty	DuPont Engineering
J. Eidelberg	Consultant
T. Feindel	R. Stahl, Inc.
W. Fiske	Intertek Testing Services
R. Frease	Fanuc Robotics
G. Garcha	PCS Engineering
E. Geissler	U.S. Corp.
*P. Hamer	Chevron Research & Tech. Company
C. Hendrickson	Northern Illinois Gas Company
E. Henning	Bailey-Fischer & Porter
M. Herzog	Rittal Corp.
D. Jagger	Hawke America
B. Johnson	Thermon Manufacturing Company
D. Kaplan	Phoenix Mecano
*P. Kelly	Underwriters Laboratories, Inc.
J. Kline, Sr.	Emerson Motor Tech. Center
L. Kramer	Drexelbook Engineering Company

*S. Kushman	Raychem Corp.
M. Lane	WAGO Corp.
*W. Lawrence	Factory Mutual Research Corp.
W. Leber	Appleton Electric
*D. Li	Canadian Standards Association
I. Mazza	Transferimento di Tecnologie
*F. McGowan	Factory Mutual Research Corp.
R. McNeal	Hawke America
J. Miller	Detector Electronics Corp.
*A. Mobley	3M Company
W. Mostia, Jr.	Amoco Company
M. Oakes	WAGO Corp.
*E. Olson	3M Company
B. Piquette	INERIS
M. Popp	TUV
*S. Prisby	Underwriters Laboratories, Inc.
V. Rowe	Shell Canada, Ltd.
*C. Sandberg	Raychem Corp.
P. Schimmoeller	Weidmuller Inc.
T. Schnaare	Rosemount Inc.
*W. Shao	Canadian Standards Association
*D. Styrcula	Underwriters Lab Inc.

* One vote per company

The following people served as members of ISA Committee SP12:

NAME	COMPANY
*F. McGowan, Chairman	Factory Mutual Research Corp.
*D. Bishop, Managing Director	Chevron USA Production Company
*N. Abbatiello	Eastman Kodak Company
B. Apel	MSA Instrument
S. Arnold	Drexelbrook Engineering Company
*P. Babiarz	Crouse-Hinds Company
*A. Ballard	Crouse-Hinds Company
G. Bentinck	Dupont Engineering
*R. Berthold	Compression Systems Inc.
H. Bockle	Killark/Stahl Inc.
K. Boegli	Phoenix Contact Inc.
J. Bossert	Hazloc, Inc.
R. Brodin	Fisher Controls International, Inc.
M. Buettner	Ralston Purina Company
R. Buschart	PC & E, Inc.
*W. Calder III	Calder Enterprises.
R. Cardinal	Bently Nevada Corp.
C. Casso	Schlumberger Oil Field Services
R. Castillo	Industrias Venoco CA
J. Cawley	US Dept of the Interior
H. Conner	Congorhar Inc.
M. Coppler	Ametek Inc.

J. Cospolich	Waldemar S. Nelson & Company, Inc.
J. Costello	Henkel Corp.
*E. Cranch	Drexelbrook Engineering Company
A. Czyz	INERIS
W. Dill	DMT
P. Dobler	Weidmuller Inc.
T. Dubaniewicz Jr.	Pittsburgh Research Laboratory
U. Dugar	Mobil Chemical Company
R. Ellis	Servomex Co.
A. Engler	Appleton Electric
T. Feindel	R. Stahl, Inc.
W. Fiske	Intertek Testing Services
S. Florence	Motorola Inc.
G. Garcha	PCS Engineering
E. Geissler	US Corp.
B. Gibson	ABB Kent-Taylor Inc.
J. Greenwald	Huntsman Corp.
L. Hamman	U. S. Coast Guard
E. Henning	Bailey Fischer & Porter
D. Hohenstein	Pepperl + Fuchs
C. Hoy	O-Z/Gedney
D. Jagger	Hawke America
X. Jianping	Shanghai Institute of Process Automation Instr.
D. Kaplan	Phoenix Mecano
*P. Kelly	Underwriters Laboratories, Inc.
F. Kent	Honeywell Inc.
G. Kozinski	Symbol Technologies Inc.
J. Kuczka	Killark
B. Larson	Turck Inc.
*W. Lawrence	Factory Mutual Research Corporation
W. Leber	Appleton Electric
T. Lewis Jr.	Applied Automation Inc.
N. Ludlam	Factory Mutual Research Corp
V. Maggioli	Feltronics Corp.
*E. Magison	Consultant
*F. Maltby	Drexelbrook Engineering Company
R. Masek	Bailey Controls Company
D. McDermott	Dexion House
I. McMurchie	Petromarine of Texas
R. McNeal	Hawke America
J. Miller	Detector Electronics Corp.
*A. Mobley	3M Company
M. Morrow	Data Instruments
W. Mueller	Pepperl + Fuchs Inc.
E. Nesvig	ERDCO Engineering Corp.
M. Oakes	WAGO Corp.
*E. Olson	3M Company
C. Oudar	ExLoc Corp.
A. Page III	MSHA Certification Center
R. Pellizze	Intertek Testing Services
J. Propst	Shell Development Company
C. Sandberg	Raychem Corp.

C. Sawyer	MI Cable Co Inc.
J. Shaffer	Endress+Hauser Co.
T. Schnaare	Rosemount, Inc.
W. Shao	Canadian Standards Association
A. Stafford	Foxboro Company
D. Stevens	Chevron USA Inc.
*D. Styrcula	Underwriters Laboratories Inc.
J. Thomason	Omni Industrial Systems Inc.
P. Thurnherr	Thuba Ltd.
L. Truscott	Motorola Inc.
P. Turner	3M Company
T. Vu	Milltronics Ltd.
D. Wechsler	Union Carbide Corp.
R. Weinzler	Consultant

* One vote per company

This standard was approved for publication by the ISA Standards and Practices Board on November 30, 1997.

NAME	COMPANY
R. Webb, Vice President	Pacific Gas & Electric Company
H. Baumann	H. D. Baumann & Associates, Ltd.
D. Bishop	Chevron USA Production Company
P. Brett	Honeywell, Inc.
W. Calder III	Calder Enterprises
M. Cohen	Flexonics, Inc.
H. Dammeyer	Ohio State University
R. Dieck	Pratt & Whitney
W. Holland	Southern Company Services, Inc.
H. Hopkins	Consultant
A. Iverson	Ivy Optiks
K. Lindner	Endress + Hauser GmbH
V. Maggioli	Feltronics Corp.
T. McAvinew	Instrumentation & Control Engineering Services
A. McCauley, Jr.	Chagrin Valley Controls, Inc.
G. McFarland	Honeywell Inc.
E. Montgomery	Fluor Daniel, Inc.
D. Rapley	Rapley Engineering Services
R. Reimer	Rockwell Automation
J. Rennie	Factory Mutual Research Corporation
W. Weidman	Parsons Energy and Chemical Group
J. Weiss	Electric Power Research Institute
J. Whetstone	National Institute of Standards & Technology
M. Widmeyer,	Carnegie-Mellon University
H.R. Wiegle	Canus Corp.
C. Williams	Eastman Kodak Company
G. Wood	Graeme Wood Consulting
M. Zielinski	Fisher•Rosemount Systems, Inc.

Contents

Foreword

All text of IEC 79-7 (with Amendments 1 and 2 incorporated) is included. U.S. National Deviations are shown by ~~strikeout~~ through text deleted and underline under text added. All added tables are numbered by a table number corresponding to the applicable subclause and for improved clarity are NOT underlined. A note appears in the table title showing the table as added material. There are nine annexes in this Standard. Annexes D, F, G, H and I are Informative and are not considered part of this Standard. Annexes A, B, C and E are Normative and are considered part of this Standard.

1 Scope

~~This part of IEC 79~~ ISA-S12.16.01 (IEC 79-7 Mod) prescribes the specific requirements for the design, construction, testing, and marking of electrical apparatus with type of protection "e" for use in Class I, Zone 1,* Groups IIA, IIB, and IIC hazardous (classified) locations with a rated value of supply voltage not exceeding 11 kV r.m.s. a.c. or d.c., ~~with type of protection "e"~~ that does not produce arcs, sparks, or dangerous temperatures in normal operation or under specified abnormal conditions.

NOTES

1) Requirements for rotating machinery further limit the supply voltage to 5.5 kVrms ac or dc.

*2) Class I, Zone 1, and Gas Groups IIA, IIB, & IIC are further described in ISA-S12.0.01 (IEC 79-0 Mod). For additional comparisons between "Divisions" and "Zones," also refer to ISA-S12.1.01.

3) Internationally, the groups are not divided into subgroups IIA, IIB, & IIC for type of protection "e". However, as the 1996 edition of ANSI/NFPA 70 requires the use of the subgroup, the subgroups have been included here.

These specific requirements are additional to the general requirements in ~~IEC 79-0~~ ISA- S12.0.01 (IEC 79-0 Mod) ~~which~~ that apply to type of protection "e" unless specifically excluded.

2 ~~Normative~~ References

The following standards may contain provisions which, through reference in this text, constitute provisions of this standard ~~part of IEC 79~~. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard ~~part of IEC 79~~ are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards. ANSI maintains registers of currently valid U.S. National Standards.

IEC 34-1*: 1983	Rotating electrical machines, Part 1: Rating and performance.
IEC 34-5: 1981	Rotating electrical machines, Part 5: Classification of degrees of protection provided by enclosures for rotating machines.
IEC 34-6: 1969	Rotating electrical machines, Part 6: Methods of cooling rotating machinery.
IEC 50(426): 1990	International Electrotechnical Vocabulary (IEV), Chapter 426: Electrical apparatus for explosive atmospheres.
IEC 61-1:1996	Lamp caps and holders together with gauges for the control of interchangeability and safety, Part 1: Lamp caps. (Consolidated edition.)
IEC 61-2:1996	Lamp caps and holders together with gauges for the control of interchangeability and safety, Part 2: Lampholders. (Consolidated edition.)
IEC 64*: 1987	Tungsten filament lamps for domestic and similar general lighting purposes. Performance requirements.
IEC 68-2-27:1987	Basic environmental testing procedures, Part 2: Tests – Test and guidance: Shock.
IEC 68-2-42:1987	Basic environmental testing procedures, Part 2 :Tests —and guidance: Sulphur dioxide test for contacts and connections.
IEC 68-2-6:1987	Basic environmental testing procedures, Part 2: Tests — Test and guidance: Vibration (sinusoidal).
~~IEC 79-0 (1983)~~	~~Electrical apparatus for explosive atmospheres, Part 0: General requirements.~~
ISA-S12.0.01 (IEC 79-0 MOD)	Electrical apparatus for use in Class I, Zones 0 & 1, Hazardous (Classified) Locations - *General Requirements*.
IEC 79-1*: 1971	Electrical apparatus for explosive gas atmospheres, Part 1: Construction and test of flameproof enclosures of electrical apparatus.
IEC 79-2: (1983)	Electrical Apparatus - Type of Protection "p"

IEC 79-4: 1975	Electrical apparatus for explosive gas atmospheres, Part 4: Method of test for ignition temperature.
IEC 85: 1984	Thermal evaluation and classification of electrical insulation.
IEC 112: 1979	Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions.
IEC 185: 1987	Current transformers.
IEC 238: 1987	Edison screw lampholders.
IEC 317-3: 1970	Specifications for particular types of winding wires, Part 3: Enameled round copper wires with a temperature index of 155.
IEC 317-7: 1988	Specifications for particular types of winding wires, Part 7: Polyamide enameled round copper wire, class 220.
IEC 317-8: 1988	Specifications for particular types of winding wires, Part 8: Polyesterimide enameled round copper winding wire, class 180.
IEC 364-3: 1977	Electrical installations of buildings, Part 3: Assessment of general characteristics.
~~IEC 364-5-523: 1983,~~	~~Electrical installations of buildings, Part 5: Selection and erection of electrical equipment. Chapter 52: Wiring systems. Section 523: Current-carrying capacities.~~
IEC 400:1996	Lampholders for tubular fluorescent lamps and starterholders
IEC 432*: 1984	Safety requirements for tungsten filament lamps for domestic and similar general lighting purposes.
IEC 529: 1989	Classification of degrees of protection provided by enclosures.
IEC 664: 1980	Insulation coordination within low-voltage systems including clearances and creepage distances for equipment.
IEC 664A: 1981	First supplement.
IEC 707:1992	Methods of Test for the Determination of the Flammability of Solid Electrical Insulating Materials When Exposed to an Igniting Source
IEC 755: 1983	General requirements for residual current-operated protective devices.

IEC 947-1:1996	Low-voltage switchgear and controlgear – Part 1: General Rules
IEC 947-7-1:1989	Low voltage switchgear and controlgear. Part 7: ancillary equipment section 1 terminal blocks for copper conductors
IEC 1195: 1993	Double-capped fluorescent lamps - Safety Specifications
IEC/ISO Guide 2: 1986	General terms and their definitions concerning standardization and related activities.
ANSI C78.1:1991	Fluorescent Lamps – RapidStart Types - Dimensional and Electrical Characteristics
ANSI C81.61:1990	Electric Lamp Bases
ANSI C81.62:1995	Lampholders for Electric Lamps
ANSI/IEEE 515: 1989	IEEE Recommended Practice for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications.
ANSI/IEEE 841: 1994	IEEE Standard for Petroleum and Chemical Industry - Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors - Up to and including 500 hp.
ANSI/NFPA 70:1996	*National Electrical Code* ®
ANSI/NFPA 497:1997	Classification of Flammable Liquids, Gases or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas**.**
ANSI/:199	Enclosures for Electrical Equipment
ANSI/NEMA MW 1000: 1994	Magnet Wire
ANSI/UL 94: 1995	Tests for Flammability of Plastics Materials
ANSI/UL 486E:1995	Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors
ANSI/UL 508:1988	Industrial Control Equipment
ANSI/UL 746A:1995	Standard for Polymeric Materials ShortTerm Property Evaluations
ANSI/UL 746C:1989	Standard for Polymeric Materials Use in Electrical Equipment Evaluations

ANSI/UL 840:1995	Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment
ANSI/UL 1059:1993	Terminal Blocks

* Including the amendments in force at the date of publication of this standard.

3 Definitions

For the purpose of this standard, the definitions and some terms used in ~~IEC 79-7~~ ISA- S12.0.01 (IEC 79-0 Mod) apply and also the following terms and definitions. For the definitions of any other terms, particularly those of a more general nature, reference should be made to Chapter 426 (in course of printing) or other appropriate chapters of the International Electrotechnical Vocabulary (IEV).

NOTE – Where a word, for example "battery", is shown in parentheses in a term, it may be omitted when there is no risk of confusion or misunderstanding.

3.1 increased safety "e": Type of protection applied to electrical apparatus that does not produce arcs or sparks in normal service and under specified abnormal conditions, in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks.

NOTES

1) This type of protection is denoted by "e".

2) Apparatus producing arcs or sparks in normal service is excluded by this definition of increased safety.

3.2 limiting temperature: Maximum permissible temperature for apparatus or parts of apparatus equal to the lower of the two temperatures determined by:

a) the danger of ignition of the explosive gas atmosphere

b) the thermal stability of the materials used.

NOTE – This temperature may be the maximum surface temperature (see 2.7 and clause 4 of ~~IEC 79- 7~~ ISA-S12.0.01 [IEC 79-0 Mod]) or a lower value (see 4.7).

3.3 initial starting current I_A: Highest r.m.s. value of current absorbed by an ac motor when at rest or by an ac magnet with its armature clamped in the position of maximum air gap when supplied at rated voltage and rated frequency.

NOTE – Transient phenomena are ignored.

3.4 starting current ratio I_A/I_N: Ratio between initial starting current I_A and rated current I_N.

3.5 time t_E: Time taken for an ac rotor or stator winding, when carrying the initial starting current I_A, to be heated up to the limiting temperature from the temperature reached in rated service at the maximum ambient temperature (see Figure B.1).

3.6 rated short-time thermal current I_{th}: R.M.S. value of the current required to heat up the conductor within one second from the temperature reached in rated service at the maximum ambient temperature to a temperature not exceeding the limiting temperature.

3.7 rated dynamic current I_{dyn}: Peak value of the current, the dynamic effect of which the electrical apparatus can sustain without damage.

3.8 short-circuit current I_{sc}: Maximum r.m.s. value of the short-circuit current to which the apparatus may be subjected in service.

NOTE – This maximum value ~~will be~~ is recorded in the documentation according to 22.2 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod).

3.9 creepage distance: Shortest distance along the surface of an electrical insulating material between two conductive parts.

3.10 clearance: Shortest distance in air between two conductive parts.

3.11 working voltage ~~(identical with 3.7 of IEC 664)~~: Highest r.m.s. value of the ac or dc voltage across any particular ~~which may occur (locally) across any~~ insulation that can occur when the equipment is supplied at rated ~~supply~~ voltage, ~~transients being disregarded, in open circuit conditions or under normal operating conditions~~.

NOTE 1—Transients are disregarded.

NOTE 2—Both open circuit conditions and normal operating conditions are taken into account.

3.12 (electrochemical) cell or battery: Electrochemical system capable of storing in chemical form the electric energy received and which can give it back by reconversion.

NOTE – The terms and definition in 3.12 are based on those in the draft IEV Chapter 486 "Storage batteries." Chapter 486 has been issued, and these definitions will be updated in the next edition of IEC 79-7 (ISA S12.16.01 [IEC 79-7 Mod]).

3.12.1 (secondary) cell: Assembly of electrodes and electrolyte which constitutes the basic unit of a battery.

NOTES

1) A cell consists substantially of positive and negative plates and separators, ~~of the~~ items needed for assembling and connecting (plate lugs, group bars, terminal posts), of the cell container, and of the electrolyte.

2) A sketch illustrating the various parts of a cell is given in Figure 1. This sketch is included for descriptive purposes only and is not intended to imply any requirement or preference for a particular form of construction.

3.12.2 battery: Two or more cells electrically connected and used as a source of energy.

3.12.3 (cell) container: Container for the plate pack and electrolyte of a cell made of a material impervious to attack by the electrolyte.

3.12.4 (battery) container: Enclosure to contain the battery.

NOTE – The cover is a part of the battery container.

3.12.5 (battery) capacity: Quantity of electricity (electric charge), usually expressed in ampere-hours (Ah), which a fully charged battery can deliver under specified conditions.

3.12.6 plate pack: Assembly of the positive and negative groups with separators.

3.12.7 partition wall: Integral part of a battery container dividing it into individual sections and increasing its mechanical strength.

3.12.8 insulating barrier: Electrical insulating material between groups of cells subdividing the battery.

3.12.9 intercell connector: Electrical conductor used for carrying current between cells.

3.13 resistance heating devices

NOTE – Where the word "resistance" is shown in parentheses at the beginning of the term, it may be omitted when there is no risk of confusion with heating devices and units outside the scope of this standard.

3.13.1 resistance heating device: Part of a resistance heating unit , comprising one or more heating resistors, typically composed of metallic conductors or an electrically conductive compound suitably insulated and protected.

3.13.2 resistance heating unit: Apparatus comprising an assembly of one or more resistance heating devices, associated with any devices necessary to ensure that the limiting temperature is not exceeded.

NOTE – It is not intended that the devices necessary to ensure that the limiting temperature is not exceeded should have type of protection "e", or any type of protection when they are located outside the hazardous area.

3.13.3 workpiece: Object to which a resistance heating device or unit is applied.

3.13.4 self-limiting property: Property such that the thermal output of a resistance heating device ~~element~~ at its rated voltage decreases as the temperature of its surroundings increases until the device ~~element~~ reaches a temperature at which its thermal output is reduced to a value at which there is no further rise in temperature.

~~**NOTE** – The temperature of the surface of the element is then effectively that of its surroundings.~~

3.13.5 stabilized design: Concept where the temperature of the resistance heating device or unit will, by design and use, stabilize below the limiting temperature, under the most unfavorable conditions, without the need for a protective system to limit the temperature.

3.14 connections, external: Terminations intended for connection in the field.

3.15 connections, internal: Terminations intended for connection in the factory under controlled conditions.

3.16 normal service, motors: Normal service for motors includes continuous operation at nameplate ratings including starting conditions.

3.17 rated cross section: The rated cross section of a terminal is a value of connectable conductor cross-section, stated by the manufacturer, and to which certain thermal, mechanical and electrical requirements are referred.

3.18 rated connecting capacity, terminal: The rated connecting capacity of a terminal is the range or number of rated cross-sections for which the terminal is designed.

3.19 Resistance heat tracing system

3.19.1 heat tracing cable: Part of a resistance heating system, comprising one or more heating elements, suitably insulated and protected, usually used to heat pipes and other equipment.

3.19.1.1 parallel heating cable: Heating elements that are electrically connected in parallel, either continuously or in zones, so that watt density per unit length is essentially maintained irrespective of any change in length for the continuous type or for any number of discrete zones.

3.19.1.2 series heating cable: Heating elements that are electrically connected in series with a single current path and have a specific resistance at a given temperature for a given length.

3.19.1.3 trace heater unit (set): A series heating cable, parallel heating cable, or heating panel suitably terminated in compliance with manufacturer's instructions.

3.19.2 heating panel: A surface heater with defined watts per unit area output and comprised of series or parallel connected elements having sufficient flexibility to conform to the area to be heated.

3.19.3 resistance heat tracing system: Equipment comprising an assembly of one or more resistance heat tracing cables, units, and/or panels, together with any fastening, electrical connecting, power distribution, thermal insulating, weather protecting, control and monitoring devices.

3.19.4 heated equipment: Equipment on which resistance heat tracing units are installed.

4 Constructional requirements for all electrical apparatus

The requirements of this clause apply, unless otherwise stated in clause 5, to all electrical apparatus with type of protection "e". They are additional to the general requirements of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) (see clause 1) and are themselves supplemented for certain electrical apparatus by the supplementary requirements in clause 5.

4.1 Terminals for external (field) connections

Terminals for connections to external circuits shall be generously dimensioned to permit the effective connection of copper conductors of cross-section equal to at least that corresponding to the rated current of the electrical apparatus.

The number and sizes of copper conductors that can be safely connected to terminals shall be specified in the ~~descriptive documents~~ manufacturer's instructions according to 22.2 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) and shall be designed to accommodate wires sized in AWG / kcmil.

NOTES

1) A table comparing AWG / kcmil and metric (mm^2) wire sizes is located in Annex H.

2) Service conditions may require the provision of larger terminals and the conductor size corresponding to the rated current may depend upon the application. Attention is drawn to ANSI/NFPA 70 ~~IEC 364-5-523~~.

Terminals shall be subjected to the type tests of sub-clause 6.10.

A terminal that complies with the construction requirements of Clause 4 and the test requirements of ANSI/UL 1059 and ANSI/UL 486E (for industrial applications) need only be additionally evaluated against sub-clause 6.10.5.

These terminals shall:

a) be fixed to their mountings without possibility of self-loosening;

b) be constructed in such a way that the conductors cannot slip out from their intended location;

c) be such that proper contact is assured without damage to the conductors that would impair the ability of the conductors to fulfill their function, even if multi-stranded conductors are used in terminals intended for direct clamping of a conductor. A wiring terminal intended for use with stranded conductors shall be constructed such that all strands of the conductors are confined within the terminal. The clamping movement alone shall adapt the terminal for use with a stated range of wire sizes without permanent removal or addition of parts, if such use is intended;

d) allow the conductors to be connected by means that ensure reliable mechanical and electrical connection. The construction of the terminal shall not allow the conductors attached to the terminals, the terminals themselves, or the terminal assemblies to be displaced in a manner detrimental to the insulation. Likewise, under the above conditions, the construction shall not allow a reduction of clearance or creepage distance, or both. The terminal shall be able to withstand the forces that can be applied through the connected conductors under the condition of 6.10.3.

NOTE – The use of "crimped" cable terminations is allowed provided that the requirements in a), b) ~~and~~ c), and d) are fulfilled.

In particular, terminals shall not:

- have sharp edges which would damage the conductors;
- be able to turn, twist or be permanently deformed during normal tightening which shall be defined by the manufacturer of the apparatus;
- be constructed of aluminum.

Terminals shall be such that the contact they assure is not appreciably impaired by temperature changes occurring in normal service. The contact pressure shall not be transmitted through insulating material.

Screw terminals intended for clamping stranded conductors shall include a resilient intermediate part. ~~Terminals for connecting conductors of cross-sections not exceeding 4 mm² shall also be suitable for the effective connection of conductors having a smaller cross-section.~~

Terminals employing copper alloys containing less than 85 percent copper shall be subjected to the stress corrosion cracking test of sub-clause 6.10.6.

NOTES

1) Special precautions against vibration and mechanical shock may be required.

~~2) Special precautions against electrolytic corrosion should be considered where aluminum is used.~~

3) Special precautions against corrosion should be considered where ferrous material is used.

4.2 Internal (factory-installed) connections

Within electrical apparatus, connections shall not be subject to undue mechanical stress. Only the following means for the connection of conductors are permitted:

a) screwed fasteners with means of locking;

b) crimping;

c) soldering, provided that the conductors are not supported by the soldered connection;

d) brazing;

e) welding; and

f) any means of connection complying with the requirements of 4.1.

If aluminum conductors or terminals are ~~is~~ used, special precautions against electrolytic corrosion are required.

Terminals employing copper alloys containing less than 85 percent copper shall be subjected to the stress corrosion cracking test of sub-clause 6.10.6.

Terminals shall be subjected to the type tests of sub-clause 6.10.

A terminal that complies with the construction requirements of Clause 4 and the test requirements of ANSI/UL 1059 and ANSI/UL 486E (for industrial applications) need only be additionally evaluated against sub-clause 6.10.5.

4.3 Clearances

Clearances between bare conductive parts at different potentials shall be as given in Table 1 with a minimum value for external connections of 3 mm. Spacings at wiring terminals shall be measured with the conductor size that produces the minimum clearance.

NOTE – For the requirements for lamps with screw caps see A.2.

Clearances shall be determined as a function of the working voltage (definition 3.11) specified by the manufacturer of the apparatus. Where the apparatus is intended for more than one rated voltage or for a range of rated voltage, the value of working voltage to be used shall be based on the highest value of rated voltage. In determining the clearances, examples 1 to 11 inclusive in Figure 2 illustrate the features to be taken into account and the appropriate clearances.

NOTE – These examples are identical with those given in IEC 664A.

Table 1 – Creepage distances and clearances

Working Voltage U	Minimum Creepage Distance Material Group			Minimum Clearance
	I	II	IIIa	
V		mm		mm
U ≤ 15	1.6	1.6	1.6	1.6
15 < U ≤ 30	1.8	1.8	1.8	1.8
30 < U ≤ 60	2.1	2.6	3.4	2.1
60 < U ≤ 110	2.5	3.2	4	2.5
110 < U ≤ 175	3.2	4	5	3.2
175 < U ≤ 275	5	6.3	8	5
275 < U ≤ 420	8	10	12.5	6
420 < U ≤ 550	10	12.5	16	8
550 < U ≤ 750	12	16	20	10
750 < U ≤ 1,100	20	25	32	14
1,100 < U ≤ 2,200	32	36	40	30
2,200 < U ≤ 3,300	40	45	50	36
3,300 < U ≤ 4,200	50	56	63	44
4,200 < U ≤ 5,500	63	71	80	50
5,500 < U ≤ 6,600	80	90	100	60
6,600 < U ≤ 8,300	100	110	125	80
8,300 < U ≤ 11,000	125	140	160	100

NOTE – This Table 1 combines the information of the earlier Table 1 and Table 3.

4.4 Creepage distances

4.4.1 The required values of creepage distance are dependent on the working voltage, the resistance to tracking of the electrical insulating material and its surface profile.

Table 2 gives the grouping of electrical insulating materials according to the Comparative Tracking Index (CTI) determined in accordance with IEC 112 or ANSI/UL746A. Inorganic insulating materials, for example glass and ceramics, do not track and need not therefore be subjected to the determination of the CTI. They are conventionally classified in material group I.

NOTES

1) The material groups are identical with those given in IEC ~~664A~~ 664-1 or UL 840.

2) Transient over voltages are ignored as they will not normally influence tracking phenomena. However, temporary and functional over voltages may have to be considered, depending upon the duration and frequency of occurrence (see IEC ~~664A~~ 664-1 for additional information).

Table 2 – Tracking resistance of insulating materials

Material group	Comparative tracking index (CTI)
I	600 ≤ CTI
II	400 ≤ CTI < 600
IIIa	175 ≤ CTI < 400

4.4.2 Creepage distances between bare conductive parts at different potentials shall be as given in Table 1, with a minimum value for external connections of 3 mm, and shall be determined as a function of the working voltage specified by the manufacturer of the apparatus.

NOTE – For the requirements for lamps with screw caps see A.2.

4.4.3 In determining the creepage distance, examples 1 to 11 (see Figure 2) inclusive illustrate the features to be taken into account and the appropriate creepage distance. The value of dimension X is 2.5 mm.

NOTE – Cemented parts should be seen as solid parts.

The effects of ribs and grooves may be taken into account provided that

a) ribs on the surface are at least 2.5 mm high and of a thickness appropriate to the mechanical strength of the material with a minimum value of 1.0 mm; and

b) grooves on the surface are at least 2.5 mm deep and at least 2.5 mm wide.

NOTE – Projections above or depressions below the surface are considered as being either ribs or grooves irrespective of their geometric form.

4.5 Solid electrical insulating materials

NOTE – This term describes the form in which the materials are used and not necessarily that in which they are supplied; for example, insulating varnishes when cured are considered as being solid electrical insulating materials.

4.5.1 The mechanical characteristics of the materials that affect their functional behavior, such as strength and rigidity, shall be satisfactory either:

a) at a temperature up to at least 20 K above the maximum temperature attained in rated service, and at least 80 °C; or

b) for insulated windings (see 4.7.3 and Table 4), for internal wiring (see 4.8) and for cables permanently connected to electrical apparatus (see 14.1 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) up to the maximum temperature attained in rated service.

~~**4.5.2** Insulating parts made of plastics or laminates, where the original surface is removed during manufacture or is damaged, shall be coated with an insulating varnish having at least the same grading according to CTI as the original surface. This requirement does not apply to materials when these actions have not affected the grading according to CTI or when the specified creepage distance is provided by other parts not subjected to these actions.~~

4.6 Windings

4.6.1 Insulated conductors shall comply with the requirements of either 4.6.1.1 or 4.6.1.2.

4.6.1.1 The conductors shall be covered with at least two layers of insulation, for example, conductors with two layers of enamel such as Class MW 35 conductors per ANSI/NEMA MW 1000.

4.6.1.2 Enameled round winding wires shall be in accordance with either

a) Grade 1 of IEC 317-3, 317-7 or 317-8 provided that:

- when tested in accordance with clause 13 of IEC 317-3, 317-7 or 317-8 there shall be no failure with the minimum values of breakdown voltage listed for Grade 2 and that;

- when tested in accordance with clause 14 of IEC 317-3, 317-7 or 317-8 there shall be not more than six faults per 30 m of wire irrespective of diameter; or

b) Grade 2 of IEC 317-3, 317-7 or 317-8;

4.6.2 Windings shall be dried after having been fastened or wrapped and shall subsequently be impregnated with a suitable impregnating substance by dipping, trickling or vacuum impregnation. Coating by painting or spraying is not recognized as impregnation.

The impregnation shall be carried out according to the specific instructions of the manufacturer of the impregnating substance used and in such a way that the spaces between the conductors are filled as completely as possible and that good cohesion between the conductors is achieved.

This does not apply to fully insulated coils and conductors of high voltage (over 1,100 V) windings if, prior to their fitting into the electrical apparatus, the slot portions and end windings of these coils and conductors have been impregnated, provided with filling material, or otherwise insulated in an equivalent manner, and if, after assembly, they are no longer accessible for the stated insulating procedures.

If impregnating substances containing solvents are used, the impregnation and drying processes shall be carried out at least twice.

4.6.3 The nominal conductor diameter of round wires used for windings shall be at least 0.25 mm (30 AWG), except for the sensors of resistance ~~thermometers~~ temperature detectors (RTDs) embedded in the slot of an electrical machine and impregnated or sealed together with the machine windings.

Windings made with round wires having a nominal diameter less than 0.25 mm (30 AWG) shall be protected by another of the standard types of protection listed in ~~IEC 79- 0~~ ISA-S12.0.01 (IEC 79-0 Mod).

4.6.4 Insulating parts made of plastics or laminates, where the original surface is removed during manufacture or is damaged, shall be coated with an insulating varnish having at least the same grading according to CTI as the original surface. This requirement does not apply to materials when these actions have not affected the grading according to CTI or when the specified creepage distance is provided by other parts not subjected to these actions.

4.7 Limiting temperature

4.7.1 No part of an electrical apparatus shall reach:

a) a higher surface temperature than the maximum surface temperature prescribed in clause 4 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod); or

b) if lower, the temperature, determined according to 4.7.2, 4.7.3 and 5.1.4, dependent on the thermal stability of the materials used; or

c) for lamps in luminaires, a higher temperature than that determined according to ~~5.2.4~~, 5.2.5 and 5.2.6.

4.7.2 The permissible temperature of conductors and other metal parts is further limited by:

a) reduction of mechanical strength;

b) unacceptable mechanical stress due to thermal expansion;

c) damage to neighboring electrical insulating parts.

In determining the temperature of the conductors, both the self-heating of the conductors and the effect of heating by neighboring parts shall be taken into account.

4.7.3 The limiting temperature of insulated windings shall not exceed the values given in Table 4, which take account of the thermal endurance of electrical insulating materials, provided that the electrical apparatus still complies with the requirements of 4.7.1.

Table 4 – Limiting temperatures for insulated windings

	Method of temperature measurement (see note 1)	Thermal class of insulating material according to IEC 85 (see note 2)				
		A	E	B	F	H
1 Limiting temperature in rated service a) insulated single layer winding	Resistance or thermometer	°C 95	°C 110	°C 120	°C 130	°C 155
b) other insulated windings	Resistance	90	105	110	130	155
	Thermometer	80	95	100	115	135
2 Limiting temperature at end of time t_E (see note 3)	Resistance	160	175	185	210	235

NOTES

1) Measurement by thermometer is permissible only when measurement by change of resistance is not possible. In this context "thermometer" has the same meaning as in IEC 34-1. (i.e., a bulb thermometer, or a non-imbedded thermocouple or resistance temperature detector (RTD) applied to the points accessible to the usual bulb thermometer)

2) As an interim measure until values have been prescribed, the higher thermal classes of insulating material denoted by Figures in IEC 85 are considered as subject to the limiting temperatures given for class H.

3) These values result from the ambient temperature, the temperature rise of the winding in rated service and the increase of temperature during time t_E .

4.7.4 Windings shall be protected by suitable devices to ensure that the limiting temperature (see 4.7.1, 4.7.2 and 4.7.3) cannot be exceeded in service. Such devices are not required if the temperature of the windings does not exceed the limiting temperature given for rated service in 4.7.3, even when the windings are subjected to continuous overload (for example as occurs in the case of a stalled motor) or if the windings cannot be subjected to overload.

NOTES

1) The protective device (sensor) may be inside and/or outside the electrical apparatus.

2) Electrical faults in insulated windings are excluded as a service condition.

4.8 Internal wiring

Wiring which might come into contact with a conductive part shall be either mechanically protected, secured, or routed ~~or fixed~~ to avoid ~~any~~ insulation damage.

4.9 Degrees of protection provided by enclosures

The degrees of protection as defined in IEC 34-5 and 529 shall be as prescribed in a) or b) ~~unless otherwise specified in clause 5.~~

a) Enclosures containing bare conductive parts shall provide at least degree of protection IP54. (Enclosure Types 3, 3S, 4, 4X, 6, and 6P as defined in ANSI/ are acceptable.)

b) Enclosures containing only insulated conductive parts per 4.5 shall provide at least degree of protection IP44. (Enclosure Types 3, 3S, 4, 4X, 6, and 6P as defined in ANSI/ are acceptable.)

If the enclosure is provided with drain holes or ventilation openings to prevent the accumulation of condensation, the presence of the drain holes or ventilation openings shall not reduce the degree of protection provided by the enclosure below IP44 in a) or IP24 in b). The details of the drain holes or openings (position and dimensions) shall be stated by the manufacturer and included in the documentation.

Where the presence of drain holes or ventilation openings to prevent the accumulation of condensation reduces the degree of protection below that in a) or b), the marking of apparatus shall include the markings ~~sign "X"~~ in accordance with 9) of 25.2 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) and the degree(s) of protection provided by enclosure.

~~4.10 Fasteners~~

~~For Group I electrical apparatus containing bare live parts, special fasteners according to 8.2 of IEC 79-0 shall be used.~~

5 Supplementary requirements for specific electrical apparatus

These requirements supplement those of clause 4 of this standard which are applicable also, unless otherwise stated, to the specific electrical apparatus considered in 5.1 to 5.7 and also to the other electrical apparatus considered in 5.8.

5.1 Rotating electrical machines

The requirements of 5.1 are applicable to motors with supply value not exceeding 5.5 kVrms ac or dc.

5.1.1 Degrees of protection provided by enclosures for rotating machines

The degree of protection for rotating machines shall be in accordance with sub-clause 4.9 (a) or (b).

> **NOTE** – The IP54 or IP44 required by sub-clause 4.9 is considered to provide suitable minimum ingress protection against contaminants to reduce the potential for ignition of a flammable atmosphere . This is consistent with current IEEE - 841.

~~As an exception to the requirements given in 4.9 for protection against the ingress of solid foreign bodies and water, the following degrees of protection suffice in the cases stated for the enclosures of rotating electrical machines (except for terminal boxes and bare conductive parts).~~

a) ~~In the case of enclosed ventilated machines with pipe connection for cooling air inlet and outlet (cooling method IC3X in accordance with IEC 34-6):~~

- ~~IP20~~

> ~~**NOTE** – The application of these requirements will result in the enclosure of the apparatus, when installed with suitable ducting, providing degree of protection IP44.~~

~~The marking of rotating electrical machines designed for use only with pipe connections for cooling air inlet and outlet shall include the sign "X" in accordance with 9) of 25.2 of IEC 79-0.~~

b) ~~In the case of rotating electrical machines designed for use only in clean environments and regularly supervised by trained personnel:~~

- ~~IP23 for Group I,~~
- ~~IP20 for Group II.~~

~~Solid foreign bodies shall be prevented from falling vertically through the ventilating openings into the enclosures of machines.~~

~~The marking of rotating electrical machines designed for use only in clean environments shall include the sign "X", in accordance with 9) of 25.2 of IEC 79-0 and the degree of protection provided by enclosure.~~

5.1.2 Internal fans

Internal fans shall comply with the requirements for clearances and materials specified for external fans in 16.3 and 16.4 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod).

5.1.3 Minimum radial air gap

The minimum radial air gap between the stator and the rotor (in mm in the active core area), when the rotating electrical machine is at rest, shall be not less than the value given by the following formula:

where *Minimum radial air gap (mm)* = $$\left[0.15 + \frac{D - 50}{780}\left(0.25 + \frac{0.75n}{1000}\right)\right] rb$$

D is the rotor diameter in millimeters, which in the formula for the minimum radial air gap is subject to a minimum value of 75 and a maximum value of 750; and

n is the maximum rated speed in rev/min and is subject to a minimum value of 1,000; and

r has the value given by the following formula and is subject to a minimum value of 1.0; and

$$r = \frac{core\ length\ (mm)}{1.75\ x\ rotor\ diameter,\ D\ (mm)};$$

b has the value of 1.0 for machines with rolling bearings or 1.5 for machines with plain bearings.

NOTE – The formula is not directly dependent on the supply frequency or number of poles as can be seen from the example of a 2-pole or 4-pole motor with rolling bearings designed for a 50 Hz / 60 Hz supply and having a rotor with a diameter of 60 mm and a core length of 80 mm.

D is then taken as 75, the minimum value; n as 3,600, the maximum value; b as 1.0;
r = 80/(1.75 x 60), that is 0.76 approximately and therefore taken as 1.0; when the minimum radial air gap becomes:

$$\left[0.15 + \frac{75 - 50}{780}\left(0.25 + \frac{0.75 \text{ x } 3{,}600}{1{,}000}\right)\right] 1.0 \text{ x } 1.0$$

or approximately 0.25 mm.

5.1.4 Machines with cage rotors

In addition to the requirements of 5.1.1, 5.1.2 and 5.1.3, the requirements of this sub-clause apply to machines with cage rotors, including synchronous machines with "cage rotor" starting or damping windings.

5.1.4.1 The bars of cage rotors shall be brazed or welded to the short-circuiting rings, unless the bars and rings of the cages are manufactured as a single unit.

The bars shall fit tightly in the slots in order to prevent sparking between bars and rotor cores during starting.

Except for rotor bars of cast-in-place construction, regardless of voltage or power rating, the non-sparking performance shall be verified by the test of 6.2.3.

To minimize air-gap sparking, machines rated greater than 200 kW per pole shall not have skewed slot construction in the rotor or stator.

> **NOTE** – Tight fit in the slots ~~This~~ may be achieved, for example, by casting aluminum under pressure, by supplementary lining in slots containing single bars, by wedging the bars or by keying the bars.

5.1.4.2 The limiting temperature of the rotor shall not be exceeded even during starting. The limiting temperature is the lesser of 300 °C or the value specified in 4.7.

> **NOTE** – Parts in the leakage flux path may need to be non-magnetic or insulated; otherwise, their temperatures may exceed those of the rotor bars under stall conditions. Examples of such parts may include retaining rings, balance disks, centering rings, fans, or air shrouds.

5.1.4.3 The starting current ratio I_A/I_N and the time t_E shall be determined and marked in order to provide for the selection of a suitable current-dependent device to protect against the occurrence of non-permissible temperatures.

The length of time t_E shall be such that, when the motor is stalled, it can be disconnected by a current-dependent protective device before time t_E has elapsed. In general, this is possible if the minimum values for t_E given in Figure 3 as a function of the starting current ratio I_A/I_N are exceeded. Values of time t_E below the values in Figure 3 are permissible only if a suitable overload protective device is used for the machine and it is shown to be effective by test. This device shall be identified by marking on the machine.

In no case shall

- the value of time t_E be less than 5 s when using a current-dependent protective device;
- the ratio I_A/I_N exceed 10.

5.1.4.4 Guidance on the thermal protection by overload protective devices of cage motors in service is given in Annex D. Thermal protective devices (excluding their sensors) shall be external to the motor.

Motors supplied at varying frequency and voltage by a converter shall be tested for this duty together with the converter specified in the ~~descriptive documents~~ manufacturer's instructions according to 22.2 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) and in association with the protective device provided.

As an alternative to requiring a specific converter, at least the following parameters shall be specified in the supplied installation instructions:

Speed range
Load speed-torque characteristic
Carrier frequency (PWM)
Base speed (frequency)
Any overload current device settings
Supplemental thermal protection devices and settings
Any overspeed trip devices

NOTE – Where motors are connected to converters for variable speed applications, proper selection of the motor is required to avoid winding failures due to repetitive high-amplitude voltage spikes created by the converter and can be further aggravated by the length and characteristics of the cable feeder between the converter and the motor.

Winding temperature sensors associated with protective devices shall be considered adequate for the thermal protection of the machine if the requirements of 4.7.4 are satisfied, even when the machine is stalled. The associated protective devices shall be identified by marking on the machine.

5.1.4.5 For motors rated at more than 500 kW per pole, radial cooling ducts shall not be used on the rotor.

5.1.5 Winding requirements

For polyphase windings rated 200 through 750 volts, supplemental phase insulation (in addition to varnish) shall be provided between the phases of random windings.

For windings rated over 750 volts, coils shall be form-wound and vacuum pressure impregnated (VPI).

5.1.6 Equipotential bonding jumpers for large (> 400 kW) rotating machines

Rotating machines with multisection enclosures shall have equipotential bonding jumpers fitted across enclosure joints, symmetrically placed with respect to the axis of the shaft.

5.1.6.1 According to the design and rating of the machine, the manufacturer shall specify the cross-sectional area and construction of the bonds.

5.1.6.2 The bonds shall be protected against corrosion and loosening in accordance with clause 13.6 of ISA-S12.0.01 (IEC 79-0 Mod).

5.1.6.3 Bonds shall be such that they will only conduct through their designed connection points and not through any insulated joints at time of motor starting. Particular care shall be taken with bare flexible conductors in close proximity to the bonded parts.

5.1.7 Shaft seals

Shaft seals shall be of non-sparking material.

5.1.8 Stator winding terminals

Stator winding terminals shall meet the requirements of sub-clause 6.10.4.2 with starting current I_A applied for a time period of t_{eE}.

5.2 Line-connected luminaires ~~designed for mains supply~~

5.2.1 The light source shall be one of the following:

~~a) fluorescent lamps of the cold starting type with single-pin caps (Fa6) in accordance with IEC 61-1;~~

Tubular fluorescent bi-pin lamps with lamp caps according to ANSI C78.1. Lampholders and sockets shall comply with 5.2.7.

b) tungsten filament lamps for general lighting service in accordance with ~~IEC 64 and 432~~ ANSI C81.61;

~~c) blended (MBTF) lamps;~~

d) other lamps for which there is no danger that parts of the light source may attain for a period longer than 10 s a higher temperature than the limiting temperature following breakage of the bulb. Lamps containing free metallic sodium are not permissible.

5.2.2 For fluorescent tubes, the distance between the lamp and a protective cover shall be not less than 5 mm unless the protective cover is an outer tube, in which case the minimum distance is 2 mm.

For other lamps, the distance between the lamp and the protective cover shall be not less than the value given in Table 5, according to the lamp wattage.

Table 5 – Minimum distance between lamp and protective cover

Lamp wattage, P W	Minimum distance mm
$P \leq 60$	3
$60 < P \leq 100$	5
$100 < P \leq 200$	10
$200 < P \leq 500$	20
$500 < P \leq$	30

5.2.3 Lampholders shall comply with the requirements given in Annex A.

5.2.4 The maximum surface temperature prescribed by clause 4 of ISA S12.0.01 (IEC 79-0 Mod) ~~IEC 79-0~~ may be exceeded when the highest surface temperature of the lamp inside the luminaire is at least 50 K below the lowest temperature of ignition inside the luminaire of the potentially explosive atmosphere for which the luminaire's intended, as determined by tests made under the most unfavorable conditions of use. This dispensation is only valid for the gas atmospheres indicated in the specific installation instructions or reference to a specific installation document ~~certificate~~, these being those for which the tests have given satisfactory results.

> **NOTE** – Measurements on existing luminaires have established that the temperatures at which ignition will occur inside the luminaires are considerably higher than the ignition temperatures published in ANSI/NFPA 497 ~~measured in accordance with IEC 79-4~~.

5.2.5 The temperature at the rim of the lamp cap and at the soldering point of the lamp cap shall not exceed the limiting temperature. The limiting temperature is the lesser of 195 °C or the value specified in 4.7.

5.2.6 The limiting temperature of ballasts for bi-pin tubular fluorescent lamps shall not be exceeded even in the case of aging lamps (rectifying effect). The type test is given in 6.3.2.

5.2.7 Luminaires for tubular fluorescent bi-pin lamps shall additionally comply with the following requirements.

5.2.7.1 The two pins on each side of the lamp shall be connected in parallel inside each lampholder. Therefore, the filament of the lamp is not heated and the lamp is of the cold-cathode type using an electronic ballast. The current carrying capacity of each connection between a lamp pin and lampholder socket shall be rated for the whole current of the lamp to achieve redundancy.

5.2.7.2 The creepage distances and clearances (to ground) shall be based upon the maximum igniting (striking) r.m.s. voltage of the lamp/ballast. The metal ring of the lamp tube shall be assumed to be at the same electrical potential as the pins.

5.2.7.3 The maximum values for torque or force occurring when installing or removing the lamp in the luminaire shall be not more than 50 percent of the limit values that may be applied to the pins of the new lamp specified in Table 1 of IEC 1195.

5.2.7.4 The electrical contact between each pin of the lamp and the lampholder must be reliable even under corrosion and vibration conditions. The type tests are given in 6.3.3 and 6.3.4.

5.2.7.5 An isolation switch shall be provided to disconnect all current carrying conductors of the supply and shall operate automatically when the protective cover of the luminaire is removed. The switch shall comply with the following:

➔ The switch must be one of the following: 1) an isolator IEC 664-1, IEC 947-1 Category III, 2) a manual disconnect switch per ANSI/UL 508 rated Category III per ANSI/UL 840, or 3) a switch with the contact clearance of each pole at least 1.25 mm and rated for a maximum nominal supply voltage of 300 V (dc or r.m.s.)

➔ The contacts shall open upon removal of the protective cover of the luminaire.

➔ The switch and its operation shall not be capable of manual defeating. One solution may be IP 2X protection according to IEC 529 of the operating part of the switch. Another solution may be that the switch can only be closed (after operating) by means of a tool.

➔ The switch shall be protected using one of the Class I, Zone 1, types of protection.

5.2.7.6 The insulating material of the lampholder shall comply with clause 6 of ISA-S12.0.01 (IEC 79-0 Mod).

NOTE — To limit heating of a neutral conductor, third-order harmonics should be limited to 30 percent of the fundamental frequency current.

5.3 Cap lamps ~~(except for Group I)~~ and hand lamps with their own source of supply

The lamp shall be protected against mechanical damage by a protective cover. The distance between the protective cover and the lamp when the latter is securely inserted shall be at least 1 mm. If the lamp is inserted in a spring-loaded lampholder and is in contact with the protective cover, the spring travel shall be at least 3 mm. The protective cover shall be:

a) protected by a guard, or

b) if not exceeding 50 cm^2 in area, protected by a protruding rim with a minimum height of 10 mm, or

c) if exceeding 50 cm^2 in area, able to withstand the mechanical test requirements specified for guards and fan hoods in 22.4.3.1 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod).

Switching devices in the lamp circuit which produce sparks or arcs in normal service, including devices such as reed switches where the sparks or arcs are produced in hermetic enclosures, shall either be mechanically or electrically interlocked to prevent contact separation within the hazardous area or they shall be protected by one of the standard types of protection listed in ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod).

5.4 Measuring instruments and instrument transformers

5.4.1 Measuring instruments and instrument transformers shall be able to withstand continuously 1.2 times their rated current and/or their rated voltage, as appropriate, without exceeding the limiting temperatures according to 4.7.

5.4.2 Current transformers and the current-carrying parts of measuring instruments (excluding voltage circuits) shall be able to withstand thermal and dynamic stresses resulting from currents equal to at least the values stated in Table 6 for the periods as indicated in 6.4 with no reduction in their level of security against explosions.

Table 6 – Resistance to the effect of short-circuit currents

Current	Current transformer and current-carrying parts of measuring instruments
I_{th}	$\geq$ 1.1 x I_{sc} (see 3.8 and note 2)
I_{dyn}	$\geq$ 1.25 x 2.5 I_{sc} (see notes 1 and 2)

NOTES

1) 2.5 I_{sc} is the maximum peak value of the short-circuit current.

2) The factors 1.1 and 1.25 are safety factors. It follows that the r.m.s. value of the permissible short-circuit current in service may not exceed I_{th}/1.1 and its peak value may not exceed I_{dyn}/1.25.

5.4.3 The temperature attained during the passage of a current equal to the rated short-time thermal current I_{th} shall not exceed the limiting temperature specified in 4.7, and in no case shall it exceed 200 °C.

5.4.4 Where the current-carrying parts of measuring instruments are supplied by current transformers, the values of I_{th} and I_{dyn} need only equal the current flowing in the short-circuited secondary windings of the current transformer with its primary windings carrying the currents I_{th} and I_{dyn} applicable to them.

5.4.5 Measuring instruments with moving coils are not permitted.

5.5 Transformers other than instrument transformers

Transformers, other than instrument transformers for which the requirements are given in 5.4, shall be tested in accordance with 6.5.

5.6 Secondary batteries

Secondary batteries shall be of the lead-acid, nickel-iron or nickel-cadmium type and shall comply with the requirements of this standard.

For secondary batteries with a capacity greater than 25 Ah at the 5 h rate, the following additional requirements apply. The test methods are in sub-clause 6.6.

NOTE – Compliance with these requirements does not ensure safety during charging. The latter should therefore take place outside the hazardous area unless other safety measures are applied.

5.6.1 Battery containers

5.6.1.1 ~~Battery containers (including partition walls and covers) shall be of steel. However, for batteries for Group II, alternative materials are permissible.~~ All internal surfaces of the battery containers and of the covers, when of metallic material, shall be completely lined with a bonded insulating layer; for covers a suitable paint can be sufficient. Internal surfaces shall not be adversely affected by the action of the electrolyte.

5.6.1.2 Battery containers, including covers, shall be designed so as to withstand the mechanical stresses in use, including those due to transportation and handling. In order to achieve this, it may be necessary to incorporate partition walls in the containers.

5.6.1.3 If necessary, battery containers shall be provided with insulating barriers. Partition walls can be accepted as insulating barriers, if suitably constructed. Insulating barriers shall be positioned to prevent the development of a nominal voltage exceeding 40 V in any section. The insulating barriers shall be constructed in such a manner that the required creepage distance in service will not be reduced in an inadmissible way. The height of insulating barriers shall be at least two-thirds of the height of the cells. The method indicated in Figure 2 ~~b)~~ example 2 shall not be used in the calculations of these creepage distances.

The creepage distance between the poles of adjacent cells and between these poles and the battery container shall be at least 35 mm. Where nominal voltages between adjacent cells of the battery exceed 24 V, these creepage distances shall be increased by at least 1 mm for each 2 V in excess of 24 V.

5.6.1.4 The covers of battery containers shall be fixed in such a way that any inadvertent opening or displacement whilst in service is avoided.

~~Each cover shall be provided with a fastener complying with clause 8 of IEC 79-0.~~

5.6.1.5 The cells shall be built into the battery containers in such a way that there is no significant displacement in service. The materials of terminal mountings and other built-in items (for example, packing and insulating barriers) shall be insulating, non-porous, resistant to the action of the electrolyte and not easily ignitable.

5.6.1.6 The extraction of liquid which may have entered battery containers without drain holes shall be possible without the removal of the cells.

5.6.1.7 Battery containers shall be provided with sufficient ventilation openings. Contrary to 4.9, degree of protection IP23 according to IEC 529 is sufficient for battery containers.

The ventilation openings shall provide ~~adequate~~ sufficient ventilation such that~~. This is the case when~~ the hydrogen concentration in the battery container during the type test (6.6.3) does not exceed 2 percent by volume.

5.6.1.8 Plugs and sockets shall comply with the requirements of clause 19 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod). This does not apply to plugs and sockets which can only be separated with the use of a tool and which bear a warning label

CAUTION - SEPARATE ONLY IN A NON-HAZARDOUS AREA.

Positive and negative plugs of single-pole plugs and sockets shall be non-interchangeable.

5.6.1.9 The polarity of the battery and of plugs and sockets shall be marked in a durable and unambiguous manner.

5.6.1.10 Any other electrical apparatus affixed to or incorporated in the battery container shall comply with the requirements for one of the standard types of protection listed in ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod).

5.6.2 Cells

5.6.2.1 The cell lids shall be sealed to the cell containers so as to prevent detachment of the cell lid and leakage of the electrolyte. Readily ignitable materials shall not be used.

5.6.2.2 The positive and negative plates shall be supported effectively.

5.6.2.3 Each cell requiring maintenance of the electrolyte level shall be provided with a means of indicating that the electrolyte level lies between the minimum and maximum permissible levels. Precautions shall be taken to avoid excessive corrosion of the plate lugs and the busbars when the electrolyte is at the minimum level.

5.6.2.4 In each cell sufficient space shall be provided to prevent the cell overflowing due to expansion of the electrolyte and also for deposition of slurry. These spaces shall be related in volume to the anticipated life of the battery.

5.6.2.5 Filling and vent plugs shall be designed to prevent any ejection of the electrolyte under normal conditions of use. They shall be located in such a manner that they are easily accessible for maintenance.

5.6.2.6 A seal shall be provided between each terminal pole and the lid of the cell to prevent leakage of the electrolyte.

5.6.2.7 New batteries, fully charged and ready for service, shall have an insulation resistance of at least 1 MΩ between the live parts and the battery container.

NOTE – Batteries in service should have an insulation resistance of at least 50Ω per volt of nominal voltage with a minimum value of 1,000Ω.

5.6.3 Connections

5.6.3.1 The intercell connectors between adjacent cells which can move relative to one another shall be non-rigid. When non-rigid intercell connections are used, each end of the connection shall be:

a) welded or soldered into the terminal post, or

b) crimped into a copper sleeve cast into the terminal post, or

c) crimped into a copper termination screwed by a threaded fastener to a copper insert cast into the cell terminal post.

In cases b) and c) the intercell connector shall be copper.

5.6.3.2 In 5.6.3.1 c), screwed joints shall be prevented from loosening.

The effective contact area between the termination and the cell terminal post shall be equal to at least the intercell connector cross-section. Screwed joints shall pass the temperature test of 22.4.6.1 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) when the termination is carrying a current equal to the continuous rated current of the connector, which shall be specified in documents submitted by the manufacturer.

In calculating the effective contact area, no account shall be taken of the area of male and female threads in contact.

5.6.3.3 The connectors shall be able to carry the current required for the duty without giving rise to inadmissible temperatures (see 4.5.1, 4.7.1 and 4.7.2). Where the duty cannot be defined, the battery shall be assessed at the discharge rate used by the battery manufacturer to determine the battery capacity. Where double connectors are used, each single connector shall be capable of carrying the total current without producing inadmissible temperatures.

5.6.3.4 All connectors exposed to attack by the electrolyte shall be suitably protected; for example, for lead-acid batteries, non-insulated connectors of metals other than lead shall be lead-coated. This does not apply to screw threads.

5.6.3.5 ~~In Group I batteries, each live part shall have an insulating covering to avoid tracking currents and any accidental contact.~~

~~In Group II batteries~~ Live parts shall have insulating protection to avoid any accidental contact.

5.7 General-purpose connection and junction boxes

General-purpose connection and junction boxes shall be allocated a permissible maximum dissipated power determined by the method in 6.7 to ensure that the limiting temperatures of 4.7 are not exceeded in service.

~~The general purpose connection or junction box may be fitted with any number of the recognized terminals up to the maximum permitted by the physical constraints of the enclosure and within the permissible maximum dissipated power determined in accordance with 6.7.~~

~~For each terminal, the dissipated power is calculated using the 20 °C resistance value for that terminal and its associated conductor, which is assumed to have a length equal to the maximum internal linear dimension of the enclosure, and the maximum current for which that terminal is to be used. The sum of these dissipated powers represents the total dissipated power for that configuration and circuit condition.~~

The rating (see Annex F) shall be expressed as either:

a) the rated maximum dissipated power; or

b) the set of values comprising, for each terminal size, the permissible number and size of conductor and the maximum current.

Information on the use of the rating in determining safe combinations of terminals and conductor for particular values of current is given in Annex F.

5.8 Resistance heaters (other than heat tracing)

This sub-clause specifies supplementary requirements for the resistance heating devices and resistance heating units (other than heat tracing) defined in 3.13.1 and 3.13.2 respectively. It does not apply to induction heating, skin effect heating, dielectric heating or to any other heating system which involves passing current through a liquid, an enclosure or pipework.

5.8.1 For the purpose of this standard:

- heating resistors are not considered to be windings and 4.6 of this standard does not apply;
- clause 6 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) does not apply to the insulating materials of heating resistors and to the sheath of heating cables and tapes.

5.8.2 The heating resistor shall have a positive temperature coefficient. The manufacturer shall specify the value of the resistance at 20 °Cand its tolerance.

5.8.3 The manufacturer shall declare the maximum operating temperature T_p in °C. The materials used in the resistance heating device shall withstand a temperature of (T_p + 20) °C, when tested in accordance with 6.8.3.

5.8.4 The cold-start current of the resistance heating device when tested in accordance with 6.8.5 shall not exceed the manufacturer's declared value by more than 10 percent at any time after the first 10 seconds of energization.

5.8.5 The resistance heating device shall be constructed for use with an electrical protective device, as described in Annex E, unless the resistance heating device, for example an anti-condensation heater in an electric motor, is intended to be protected by the manner in which it is incorporated in an electrical apparatus.

5.8.6 When an electrically conductive covering ensures the function of the protective device foreseen in 5.8.5, it shall extend over the whole of the surface of the insulating sheath and consist of an evenly distributed conductive layer with a coverage of at least 70 percent of the insulating surface.

The electrical resistance of the conductive covering shall be less than that of the heating resistor, for the same length of the resistance heating device, unless it can be shown that excessive temperature under fault conditions is prevented by the protective device foreseen in 5.8.5 or, in the case of a heating resistor with self-limiting property, the resistance of the conductive covering shall be not less than that of one bus conductor.

5.8.7 The electrical insulation shall ensure that the heating resistors cannot be in contact with the potentially explosive atmosphere.

NOTE – Beaded insulation, for instance, would not satisfy this requirement.

5.8.8 The cross-section of the conductors for connections to the resistance heating device shall be at least 1 mm^2 for mechanical reasons.

5.8.9 For the determination of the temperature class of a resistance heating device, thermal insulation shall not normally be considered as excluding access of the potentially explosive atmosphere.

5.8.10 The resistance heating device or unit shall be prevented from exceeding the limiting temperature when energized.

This shall be ensured by one of the following means

a) a stabilized design (under specified conditions of use);

b) a self-limiting property of the resistance heating device;

c) an electrical protective system according to 5.8.11 which, at a predetermined surface temperature, isolates all live parts of the resistance heating device or unit. This protective system shall be entirely independent of any control system provided for the purpose of regulating the functional temperature of the resistance heating device or unit under normal conditions.

The temperature of a resistance heating device being dependent on the relationships between various parameters:

- its heat output;
- the temperature of its surroundings: gas, liquid, workpiece;
- the heat transfer characteristics between the resistance heating device and its surroundings.

The necessary data regarding these relationships shall be provided by the manufacturer in the ~~descriptive documents~~ manufacturer's instructions foreseen by 22.2 of ISA S12.22.01 (IEC 79-0 Mod) ~~IEC 79-0~~.

5.8.11 The protection by a protective system shall be achieved

- by sensing the temperature of the resistance heating device or, if appropriate, of its immediate surroundings;
- or by sensing the surrounding temperature and one or more other parameters;

- or by sensing two or more parameters other than the temperature.

  NOTE – Examples of the parameters include the following: level, flow, current, leakage current, power consumption.

Where special conditions for safe use are necessary, appropriate instructions shall be given (see also ~~IEC 79-0~~ ISA-S12.0.01 [IEC 79-0 Mod], 25.2[9]). For example, when the resistance heating unit is supplied with an incomplete protective system, all the data for handling the signal (such as the compatibility between the transmitter and the receiver, etc.) shall be indicated in the ~~descriptive documents~~ manufacturer's instructions.

The protective system shall de-energize the resistance heating ~~device or unit~~ either directly or indirectly. It shall be of a type that has to be manually replaced or manually re-armed to re-energize the heating device or unit after it has returned to its normal operating condition, except when the information from the protective system is continuously monitored. In the event of failure of the sensor, the heating device shall be de-energized before the limiting temperature is reached. Resetting or replacement of a manually re-armed protective system shall be possible only with the aid of a tool.

The adjustment of the protective devices shall be locked and sealed and shall not be capable of being subsequently altered when in service.

NOTE – Thermal fuses should be replaced only by parts specified by the manufacturer.

The protective system shall operate under abnormal conditions and shall be additional to and functionally independent of any regulating device which may be necessary for operational reasons under the normal conditions.

5.8.12 Resistance heating devices and units shall comply with the requirements for type verifications and tests in 6.8 and for routine verifications and tests in clause 7.

5.9 Resistance heat tracing systems

This sub-clause specifies supplementary requirements for resistance heat tracing systems defined in 3.19. It does not apply to induction heating, skin-effect heating, dielectric heating or to any other heating system which involves passing current through a liquid, an enclosure or pipework.

5.9.1 For the purpose of this standard:

- resistance heat tracing cables and panels are not considered to be windings and 4.6 of this standard does not apply;

- clause 6 of ISA-S12.0.01 (IEC 79-0 Mod) does not apply to the insulating materials of heating units or panels and to the sheath of heating cables.

- all resistance heating cables shall have a grounded metal covering (braid).

5.9.2 The manufacturer shall specify power output at a specified temperature and its tolerance by one of the following three methods: 1) conductance, 2) resistance, or 3) thermal as outlined in ANSI/IEEE 515.

5.9.3 The manufacturer shall declare the maximum exposure temperature (energized and deenergized) in °C. The materials of construction shall be suitable for this temperature.

5.9.4 The manufacturer shall declare the start-up current of the resistance heating unit or panel at various temperatures. This shall be verified by tests as outlined in ANSI/IEEE 515.

5.9.5 The resistance heat tracing system shall be constructed for use with a ground fault protection device, as described in Annex E.

5.9.6 A metallic braid or sheath, covering at least 80 percent of the surface, is required in heating cable construction. For surface heating devices (panels), an integral screen grid or covering on the exposed surface opposite the surface to be heated shall be incorporated into the construction.

5.9.7 For the determination of the temperature class of a resistance heating system, thermal insulation shall not be considered as excluding access of the potentially explosive atmosphere.

5.9.8 The resistance heating unit shall be prevented from exceeding the limiting temperature when energized.

This shall be ensured by one of the following means and verified by methods specified in ANSI/IEEE 515:

a) A product classification approach, in which maximum sheath temperatures are generated in an artificial environment, simulating worst-case condition. (T rating based solely on the heating unit.)

b) A systems approach in which the product is subjected to a test condition where the manufacturer demonstrates the ability to design and predict sheath temperatures by conducting a test on specific installation. (T rating based on evaluation of a complete system exclusive of limit devices as shown in c);

c) A controlled design system which will ensure the limiting temperature is not exceeded. These applications require the use of a temperature control device to limit the maximum pipe or temperature of the surface to be heated. When using a temperature controller, without failure annunciation, a separate high temperature limit controller shall be included in the design with either a manual reset or annunciation. Alternatively a single temperature controller with failure annunciation may be used.

5.9.9 The protection by a protective system shall be achieved

- by sensing the temperature of the resistance heat tracing system;
- or by sensing the surrounding temperature and one or more other parameters;
- or by sensing two or more parameters other than the temperature.

NOTE – Examples of the parameters include the following: level, flow, current, leakage current and power consumption.

5.9.10 Resistance heat tracing cables, units, panels, and systems shall comply with the requirements for type and routine tests as outlined in 6.9.

~~5.9~~ 5.10 Other electrical apparatus

Electrical apparatus that is not specifically mentioned in 5.1 to ~~5.8~~ 5.9 shall comply with the constructional requirements in clause 4 and in spirit with any supplementary requirements in clause 5 that may apply.

6 Type verifications and type tests

These requirements supplement those of clause 22 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) which are applicable also, unless otherwise stated, to type of protection "e".

6.1 Dielectric strength

The dielectric strength shall be verified by a test:

a) either as given in a specific product standard ~~(as defined in IEC/ISO Guide 2)~~ for the individual items of electrical apparatus;

b) or, if there is no test requirement, made at 500 V r.m.s. with a tolerance of + 5 percent, - 0 percent for electrical apparatus for supply voltages not exceeding 90 V peak or, for higher voltages, at (1,000 + twice rated voltage ~~2 U~~) V r.m.s. or 1,500 V r.m.s., whichever is the greater, with a tolerance of + 5 percent, - 0 percent; except that for resistance heating devices and resistance heating units to which the additional requirements of 5.8 apply, the test voltage to be applied is (1,000 V + twice rated voltage ~~2 U~~), with a tolerance of + 5 percent, - 0 percent~~, where U is the rated voltage of the apparatus~~.

The test voltage shall be applied for 1 min + 5 percent, - 0 percent.

DC test voltages are permitted as an alternative to the specified ac test voltage and shall be 170 percent of the specified ac r.m.s. test voltage for insulated windings, or 140 percent of the specified ac r.m.s. test voltage for situations where air or creepage distance is the insulating medium.

6.2 Rotating electrical machines

6.2.1 Machines with cage rotors shall be subjected to tests with their rotors locked in order to determine the starting current ratio I_A/I_N and the time t_E.

For machines rated at more than 160 kW, the temperature rise in rated service and time t_E may alternatively be calculated.

~~Where it is not possible to make tests on a machine of which the rating exceeds 75 kW, either in the manufacturer's works or in the testing station, the manufacturer and the testing station may agree to accept calculated figures.~~

The methods of test and of calculation are given in Annex B.

> **NOTE** – It is preferred that the calculation method be used only to supplement the test method. See Annex G for references concerning the calculation of locked-rotor temperature.

6.2.2 Provided that the test conditions are equivalent to the service conditions, rotating electrical machines may be tested with the axis only in the horizontal position, even if they are intended for use with it in other positions.

6.2.3 Rotor sparking tests for rotating machines

6.2.3.1 Rotor sparking tests shall be carried out using a motor which has a stator and rotor which are representative of a finished motor in terms of stator core and windings, and the rotor and cage. This shall include cooling ducts, centering rings, rings under the endrings and balance discs, where applicable.

6.2.3.2 Before the gas ignition tests, the rotor cage shall be subjected to an aging process comprising a minimum of 5 locked rotor tests. The maximum temperature of the cage shall cycle between the maximum design temperature and less than 70 °C. The applied voltage shall not be less than 50 percent of the rated voltage.

6.2.3.3 The test motor shall be filled with 21 percent (± 2 percent) hydrogen, by volume, in air. The rotor shall be subjected to 10 direct-on-line uncoupled starts or locked rotor tests. These tests shall have a duration of at least one second. The terminal voltage shall not fall below 90 percent of the rated voltage. No ignition of the internal atmosphere shall occur during any of the tests. The concentration of hydrogen shall be confirmed after each test.

6.3 Line-connected luminaires ~~designed for mains supply~~

6.3.1 Mechanical tests for screwed (Edison base) lampholders

~~Except in the case of the E10 lamp cap, to which this test does not apply,~~ A test lamp cap in accordance with the dimensions specified in ~~IEC 238~~ (ANSI C81.61) shall be fully inserted into the lampholder, applying an insertion torque as prescribed in Table 7.

The test lamp cap shall then be partly withdrawn by rotating through 15 degrees, and the torque then required to remove the cap shall be not less than the minimum removal torque prescribed in Table 7.

Table 7 – Insertion torque and minimum removal torque

Lamp cap size	Insertion torque (N-m)	Minimum removal torque (N-m)
~~E 14~~	~~1.0 ± 0.1~~	~~0.3~~
~~E 27~~ E26 (Medium)	1.5 ± 0.1	0.5
~~E 40~~ E39 (Mogul)	3.0 ± 0.1	1.0

6.3.2 Thermal test for luminaires with tubular fluorescent lamps

A diode is connected in series with the lamp, and the luminaire is supplied at a voltage of 110 percent of its rated voltage. At the end of the test, the temperature shall not have exceeded that given in ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) for the temperature class.
With the diode in circuit, the luminaire is then supplied at rated voltage and the limiting temperature given in 1 b) of Table 4 shall not be exceeded.

6.3.3 Sulfur dioxide test for the connection of bi-pin lamp caps to lampholders

The connections shall be tested according to IEC 68-2-42 "Sulfur dioxide test for contacts and connections" with the following conditions applying:

- State of the contacts during the test: fully assembled
- Duration of the test: 21 days
- After the test the contact resistance shall not have increased by more than 50 percent of the initial value.

6.3.4 Vibration test for luminaires with bi-pin lamps

The luminaires shall be submitted to a vibration endurance test according to IEC 68-2-6.

A complete sample of the luminaire is mounted by its normal fixings to a rigid test fixture, and exposed to frequencies between 1 Hz and 100 Hz.

Between 1 and 9 Hz the amplitude shall be 1.5 mm; between 9 and 100 Hz the test unit shall be subjected to an acceleration of 0.5 g.

The frequency sweep rate shall be 1 octave per minute with an endurance exposure of 20 cycles in each of the orthogonal planes.

After the exposure, there shall be no visible mechanical damage on all parts of the luminaire. Furthermore, during the test the luminaire shall be operated and the current from the lampholder to the lamp shall be monitored. Only one pin shall be connected electrically at each side of the lamp. The test is satisfactory if during the exposure to vibration no significant change in the current flow occurs. In the case that it is difficult to detect interruptions of the lamp current at the rated frequency, a test with a direct current of similar value than the rated lamp current (r.m.s value) may be conducted. In this case the test arrangement in Fig. 6 shall be used.

Alternatively, the test may be conducted with hydrogen/air mixture of (21 ± 2 percent hydrogen in air) inside the luminaire. The test is passed if no ignition occurs during the exposure.

6.4 Measuring instruments and instrument transformers

6.4.1 The temperature rise of current transformers with their secondary windings short-circuited and of the current-carrying parts of measuring instruments when the current I_{th} flows for 1 s may be established by calculation or test. In making these calculations, the temperature coefficient of resistance shall be taken into account, but heat losses shall be ignored.

6.4.2 The dynamic strength of current-carrying parts shall be verified by testing. Current transformers shall be subjected to the test with their secondary windings short-circuited. The duration of the dynamic test shall be at least 0.01 s with a primary current peak value not less than I_{dyn} for at least one peak.

The duration of the thermal test shall be at least 1 s with an r.m.s. value of primary current not less than I_{th}.

The dynamic test may be combined with the thermal test provided that:

- the first major peak current of the test is not less than the dynamic current (I_{dyn}); and

- the test is made at a current I for a time t such that (I^2_t) is not numerically less than $(I_{th})^2$ and provided t has a value between 0.5 s and 5 s.

6.4.3 An interturn overvoltage test shall be carried out on current transformers by the method given in IEC 185 but with an r.m.s. value of primary current equal to 1.2 times the rated value of primary current.

6.5 Transformers other than instrument transformers

The temperature rise of transformers shall be determined by test when connected to the specified load. Any integral or fully-specified protective device shall be in circuit.

Additionally, if the specified load does not form part of the apparatus for which compliance with this standard is claimed, the transformer shall be tested under the most adverse load conditions, including short circuit of secondary windings. Any integral or fully-specified protective device shall be in circuit.

6.6 Secondary batteries

These type tests are applied to batteries to which the additional requirements of 5.6 apply.

6.6.1 Insulation resistance

6.6.1.1 The test conditions are:

a) the measuring voltage of the ohmmeter shall be at least 100 V;

b) all connections between the battery and the external circuits and, where fitted, the battery container shall be disconnected; the cells shall be filled with electrolyte up to the maximum permissible level.

6.6.1.2 The insulation resistance is considered satisfactory if the measured value is equal to at least the value specified in 5.6.2.7.

6.6.2 Shock test

Batteries which are subject to mechanical shocks in normal service shall be submitted to this test. Other batteries are not to be submitted to this test but their marking shall then include the markings ~~sign "X"~~ according to 9) of 25.2 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod).

The test shall be carried out only on samples of cells and their connections. Where cells of similar construction are foreseen in a range of capacities, it is not necessary to test every capacity but only a sufficient number of them to allow assessment of the behavior of the complete range.

6.6.2.1 Test conditions

A test shall be carried out on each sample, comprising at least 2 x 2 new and fully-charged cells complete with intercell connectors, installed in a suitable container. Each sample shall be in ready-for-use condition.

Each sample shall be mounted in its normal operating attitude and by its normal means of attachment, either directly or by means of a rigid fixture, to the mounting surface of the shock machine. The mounting shall satisfy the requirements of 4.3 of IEC 68-2-27.

The shock machine shall generate a half-sine pulse as shown in Figure 3 of IEC 68-2-27. The velocity change tolerance, transverse motion, and measuring system shall satisfy the requirements of 4.1.2, 4.1.3 and 4.2 respectively of IEC 68-2-27. The peak acceleration value shall be 5 g_n as defined in Table 1 in clause 5 of that publication.

6.6.2.2 Test procedure

The test procedure for each sample shall be as follows:

a) the capacity of each sample is determined;

b) a constant 5 h discharge current flows during the test;

c) 15 independent shocks are applied to each sample as follows:

- 3 successive shocks in the vertically upwards direction,
- 3 successive shocks in each direction along two perpendicular axes in the horizontal plane. These axes are chosen so as to reveal possible weaknesses;

d) after recharging, the capacity is again determined.

6.6.2.3 Acceptance criteria

The following three conditions shall be satisfied for each sample:

a) no abrupt change in voltage during the test;

b) no visible damage or deformation;

c) no reduction in capacity of more than 5 percent.

6.6.3 Test for ~~adequate~~ ventilation of battery container

The purpose of the test is the determination of the maximum hydrogen concentration within the battery container and the adequate dimensioning of its ventilation openings. For this, hydrogen is released within the battery container.

6.6.3.1 The flow-rate ~~volume~~ of hydrogen to be released in the battery container shall be determined by the formula:

$$\text{Hydrogen } (m^3/h) = \text{number of cells} \times \text{capacity (Ah)} \times 5 \times 10^{-6}$$

NOTE – The formula is valid when pure hydrogen is used. When impure hydrogen is used, the flow rate should be sufficiently increased to compensate for the impurity of the hydrogen.

6.6.3.2 Either of the following methods may be used.

a) **Method 1.** That part of the battery container which is normally occupied by the cells shall be fitted with closed boxes. The lids of the boxes shall be provided with filler and vent plugs identical in form, number and location with those on the cells. The location of the boxes shall be such that the natural ventilation normally existing between the cells is unchanged.

Into the space above the boxes, hydrogen shall be fed through the filler and vent plugs with a constant flow corresponding to the type of construction of the cells and to their capacity. The volume of hydrogen required shall be determined from the formula given in 6.6.3.1.

The hydrogen shall be distributed equally amongst all the filler and vent plugs.

b) **Method 2.** The battery container shall be equipped with a battery made up of cells of the number, type and capacity it is intended to contain in service.

The cells shall be new, fully-charged and connected in series.

An overcharging current shall be passed through the battery to produce hydrogen at a constant flow corresponding to the number, size, type of construction and capacity of the cells in the battery.

The volume of hydrogen to be released shall be determined by the formula given in 6.6.3.1. The overcharging current is determined by the following formula:

$$\text{Overcharging current (A)} = \frac{hydrogen(m^3 \ / h)}{number\ of\ cells\ x\ 0.44\ x\ 10^{-3}}$$

6.6.3.3 For the duration of the test, the ambient temperature, the temperature of the battery container and the temperature of the cells or of the boxes simulating the cells shall not differ from each other by more than 4 K. These temperatures shall be between 15 °C and 25 °C.

The test shall be carried out at the barometric pressure at the testing station and in an area free from appreciable draughts.

6.6.3.4 The test shall be continued until four consecutive measurements have shown that the increase in the hydrogen concentration does not exceed by more than 5 percent of the mean of the four measurements.

The time interval between consecutive measurements shall be not less than 30 minutes.

The measurements shall be made at a distance from the filler and vent plugs ensuring that the concentration measured is that of the hydrogen within the battery container and not that of the hydrogen released from the filler and vent plugs.

6.6.3.5 The test shall be carried out at least twice.

6.6.3.6 The test is satisfactory if the hydrogen concentration thus determined does not exceed 2 percent.

6.7 General purpose connection and junction boxes

~~The general purpose connection or junction box is fitted with a number of the "worst case" terminals which are wired in series using conductors of the maximum size specified for that particular terminal. The length of wiring per terminal is equal to the maximum internal linear dimension of the enclosure. The conductors are arranged in groups of six within the box.~~

The general purpose connection or junction box is fitted with a number of the "worst case" terminals that are wired using conductors of the maximum size specified for that particular terminal. The length of conductor connected to each terminal and contained within the enclosure is equal to the maximum internal linear dimension of the enclosure. The wiring is arranged such that the test current is passed through each terminal and its wiring in series. In order to represent the thermal effects of bunching of conductors in typical installation, the conductors within the box are arranged in groups of six.

A current equal to the rated current ascribed to the terminal for the application is passed through the series circuit. The temperature of the hottest part is measured when steady state conditions have been reached.

If the limiting value of the maximum dissipated power is to be determined for a particular temperature class, then it is necessary to vary the number of terminals and repeat the test until the limiting temperature is approached. The rated maximum dissipated power (see 5.7 (a) and Annex F) is calculated using the circuit resistance at 20 °C and the rated current applied in the test.

NOTES

1) The "worst-case" terminal is that which has been found to exhibit the highest temperature rise.

2) The rated maximum dissipated power is calculated using the 20 °C resistance value to facilitate the calculation of permissible combinations of terminals, wiring and currents (see Annex F).

6.8 Resistance heating devices and resistance heating units

These type tests apply to resistance heating devices and resistance heating units to which the additional requirements of 5.8 apply. Unless specifically referenced, these tests do not apply to resistance heat tracing cables, units, panels, or systems as described by 5.9.

6.8.1 The tests shall be carried out on a prototype of a resistance heating device. ~~In the case of a heating cable or tape, this shall be a sample or prototype of not less than 3 m in length and including constructional discontinuities to ensure that these are tested.~~ Unless otherwise specified, the tests shall be carried out at a temperature between 10 °C and 25 °C.

6.8.2 The verification of the electrical insulation of a sample or prototype shall be by immersion of the relevant part in tap water for 30 minutes and then subjecting the sample or prototype to the test in a) followed by that in b):

a) Apply an r.m.s. voltage of (500 V + twice rated voltage ~~2U~~) V (+5% / -0%)~~, where U is the rated voltage of the apparatus~~, for 1 minute, with the conductive covering foreseen in 5.8.6 entirely exposed to the water. The voltage is applied between the heating conductor and the conductive covering or, where there is no conductive covering, the water.

When there are two or more conductors electrically insulated from each other, the voltage is applied between each pair of conductors and then between each conductor and the conductive covering or the water. Connections between conductors shall be broken if necessary.

b) Measure the insulation resistance with a dc source voltage (nominal) of 500 V. The prototype or sample shall have an insulation resistance of at least 20 MΩ. However, for resistance devices comprising cable or tape, having a possible installed length greater than 75 meters, the insulation shall have a resistivity not less than 1.5 MΩ.-km (for example, 500 MΩ for a 3 m sample).

6.8.3 The thermal stability of the insulating materials of the resistance heating device shall be verified on a sample or prototype after it has been stored in air at a temperature of (T_p + 20) °C, but not less than 80 °C, for at least 4 weeks and also at a temperature between -25 °C and -30 °C for at least 24 hours. Compliance of the sample or prototype shall be verified by submitting it to the insulation integrity test of 6.8.2 a) and b).

6.8.4 The test for resistance to impact shall be carried out on two new samples or prototypes with an apparatus similar to that shown in Figure A.1 Annex A of ISA-S12.0.01 (IEC 79-0 Mod) ~~IEC 79-0~~ using a hemispherical hardened steel impact head with an impact energy of 7 J or 4 J according to the degree of mechanical risk as prescribed in 22.4.3.1 of ISA-S12.0.01 (IEC 79-0 Mod) ~~IEC 79-0~~, unless the resistance heating device or unit is protected by an enclosure complying with the requirements for enclosures in 22.4.3.1 of ISA S12.0.01 (IEC 79-0 Mod) ~~IEC 79-0~~.

~~In the case of cable or tape, the hemispherical impact head shall be replaced by a steel cylinder of 25 mm diameter, with an adequate length to cover the total width of the cable or tape and oriented for the impact test at right-angles to the axis of the sample or prototype. Compliance shall be verified by submitting the impacted area to the test insulation integrity test in 6.8.2 a) and b).~~

6.8.5 The test for the coldstart current shall be carried out on three samples or prototypes of resistance heating device attached either to a thermal mass or to a heat sink in a cold chamber stabilized at the manufacturer's declared coldstart temperature ± 2 °C.

The operating voltage shall be applied to the samples without removing them from the cold environment and a continuous record of the current flow obtained during the first minute of energization.

6.8.6 Tests for specific forms of resistance heating devices or units shall be carried out in accordance with Annex C.

6.9 Resistance tracing systems

Resistance heat tracing cables, units, panels, and systems shall comply with the requirements for type and routine tests as outlined in ANSI/IEEE 515.

6.10 Terminals

6.10.1 Voltage Drop Test

Two terminal assemblies shall be used. The voltage drop shall be measured at the points indicated in Figure 4. The test is made with DC equal to 0.1 times the value of the test current corresponding to the cross section of the conductor, as specified in Table 6.10.1. Once the terminals are tightened to the torque specified by the manufacturer, there shall be no readjustment or retightening of the terminals during the sequence of tests 6.10.1 through 6.10.3.

The voltage drop measured shall not exceed 3.2 millivolts dc.

Table 6.10.1 – Test currents corresponding to cross section of conductor
This table is added material.

Rated Cross Section AWG/kcmil	(mm^2)	Test Currents Amperes Copper Conductor
24 AWG	(0.2)	2
22 AWG	(0.33)	3
20 AWG	(0.52)	5
18 AWG	(0.82)	7
16 AWG	(1.3)	10
14 AWG	(2.1)	20.0
12 AWG	(3.31)	25.0
10 AWG	(5.26)	35.0
8 AWG	(8.37)	50.0
6 AWG	(13.3)	65.0
4 AWG	(21.1)	85.0
2 AWG	(33.6)	115
1 AWG	(42.4)	130
1/0 AWG	(53.5)	150
2/0 AWG	(67.4)	175
3/0 AWG	(85.0)	200
4/0 AWG	(107)	230
250 kcmil	(127)	255
300 kcmil	(152)	285
350 kcmil	(177)	310
400 kcmil	(203)	335
500 kcmil	(253)	380
600 kcmil	(304)	420
700 kcmil	(355)	460
750 kcmil	(380)	475
800 kcmil	(405)	490
900 kcmil	(456)	520
1000 kcmil	(507)	545
1250 kcmil	(634)	590
1500 kcmil	(760)	625
1750 kcmil	(887)	650
2000 kcmil	(1014)	665

NOTE – This table is based on NEMA ICS 4 Table 8-4.

6.10.2 Secureness test

The samples used for the test of 6.10.1 shall be used. For a terminal rated to accept a range of single conductors, the maximum rated cross section conductor shall be tested in one of the terminal assemblies, and the minimum cross section conductor shall be tested in the second terminal assembly. A length of conductor of a rated cross section at least 75 mm longer than the height specified in Table 6.10.2 shall be connected to one terminal assembly and a suitable length to the other side of the same terminal assembly. The terminal shall be tightened to the torque specified by the manufacturer. For screwless-type terminals the conductor shall be attached as specified by the manufacturer. Leads for the measurement of voltage drop shall be attached as shown in Figure 4. The terminal block shall be secured as shown in Figure 5. The end of the length of conductor specified above shall be passed through an appropriate size bushing positioned at a height below the terminal block as given in Table 6.10.2. The bushing is to be positioned in a horizontal plane concentric with the conductor. The bushing is to be moved so that its center describes a circle of 75 mm diameter about its center line in the horizontal plane at a rate of approximately 9 rpm. The distance between the mouth of the clamping unit and the upper surface of the bushing shall be within 13 mm of the distance "height" in Table 6.10.2. The bushings are to be lubricated to prevent binding, twisting, or rotation of the insulated conductor. A weight as specified in Table 6.10.2 is to be suspended from the end of the conductor. The duration of the test shall be 15 minutes.

The conductor shall not pull out of the clamping unit and the terminal assembly shall not separate from the terminal insulator.

Table 6.10.2 – Values for secureness and pullout tests
This table is added material.

Size of Conductor AWG	Bushing Hole Diameter mm	Height to Bushing mm†	Secureness Weight Kg	Pullout Force N
24	6.5	260	0.3	10
22	6.5	260	0.3	20
20	6.5	260	0.3	30
18	6.5	260	.45	30
16	6.5	260	.45	40
14	9.5	279	.68	50
12	9.5	279	.9	60
10	9.5	279	1.4	80
8	9.5	279	2	90
6	13	296	3	94
4	13	296	4.5	133
3	14	317	5.9	156
2	14	317	6.8	187
1	16	343	8.6	236
1/0	16	343	9.5	285
2/0	19	368	10.4	285
3/0	19	368	14	351
4/0	19	368	14	427
250 kcmil	22	406	14	427
300 kcmil	22	406	15	441
350 kcmil	25	432	17	503
400 kcmil	25	432	17	503
500 kcmil	29	464	20	578
600 kcmil	29	464	23	578
700 kcmil	32	495	23	645
750 kcmil	32	495	23	690
800 kcmil	35	540	25	690
900 kcmil	35	540	25	703
1000 kcmil	38	572	25	779
1250 kcmil	45	640	34	966
1500 kcmil	51	711	41	1175
1750 kcmil	54	762	45	1348
2000 kcmil	54	762	54	1522

NOTE – This table is similar to NEMA ICS 4 - Table 8.5.

If the bushing with the hole diameter specified is not adequate to accommodate the conductor, a bushing having the next larger hole may be used.

†The tolerance on height is ± 13 mm.

6.10.3 Pullout test

The terminal assemblies used for 6.10.2 shall be used. A pulling force corresponding to the conductor size given in Table 6.10.2 shall be applied gradually to the conductor and maintained at that value for one minute.

The conductor shall not pull out of the clamping unit and the terminal assembly shall not separate from the terminal insulator. The voltage drop measured per 6.10.1 (Voltage Drop Test) shall not exceed 4.8 millivolts. The maximum change from the initial value measured in 6.10.1 to the final voltage drop measured after this test shall not be greater than 50 percent.

6.10.4 Temperature rise test

6.10.4.1 A terminal sample is required. The sample need not be one of the samples tested in 6.10.1 through 6.10.3. If not one of the samples previously tested, the voltage drop across the terminal must be measured in accordance with 6.10.1. On products with multiple terminals, a sample consisting of at least three terminal assemblies shall be connected in series, as shown in Figure 4, using conductors of the rated cross section to maximize the effects of mutual heating. The length of each of the conductors shall be 1 m for cross sections up to and including 8 AWG (10 mm^2) and 2 m for larger cross sections. Voltage drop measuring leads shall also be attached to one of the terminal assemblies as shown in Figure 4. The terminals shall be tightened to the torque specified by the manufacturer. The currents for the temperature rise test shall be in accordance with the values stated in Table 6.10.1. The test sample is considered to have attained a stable temperature when the rate of rise of temperature does not exceed 2K per hour.

6.10.4.2 The measured temperature rise of the terminal shall not exceed 45K. The voltage drop measured per 6.10.1 (Voltage Drop Test) shall not exceed 4.8 millivolts. The maximum change from the initial value measured to the final voltage drop measured after this test shall not be greater than 50 percent.

6.10.5 Dielectric strength

This test shall be conducted on the samples used for the tests of 6.10.4. The test sample is mounted as in normal use. Any jumpers installed for the temperature rise test shall be removed. The voltage specified in Table 6.10.5 shall be applied for one minute, first between the adjacent terminal assemblies and then between all the terminal assemblies connected together and the mounting means.

There shall be no dielectric breakdown during any of the tests.

Table 6.10.5 – Dielectric test voltage
This table is added material.

Rated Insulation Voltage V_I volts	Dielectric Test Voltage (AC) (r.m.s.)
$V_I \leq 60$	1000
$60 < V_I \leq 300$	2000
$300 < V_I \leq 660$	2500
$660 < V_I \leq 800$	3000
$800 < V_I \leq 1000$	3500
$1000 < V_I \leq 1500$*	4000

* For dc only

NOTE – Extracted from IEC 947-7-1 - Table IV

6.10.6 Stress corrosion cracking test

This test is to be conducted on copper alloy parts containing less than 85 percent copper. Copper alloys containing not less than 85 percent copper are known to be resistant to corrosion cracking. Three test samples are to be subjected to the physical stresses normally imposed on or within a part as a result of the wire termination. Such stresses are to be applied to the samples prior to and maintained during the test. Samples shall be assembled to a 150 mm length of the maximum rated size conductor and tightened to the torque specified by the manufacturer. For screwless-type terminals, the conductor shall be attached as specified by the manufacturer. The samples are to be degreased and then continuously exposed in a set position for ten days to a moist ammonia-air mixture maintained in a glass chamber approximately 305 x 305 x 305 mm having a glass cover. Approximately 600 ml of aqueous ammonia having a specific gravity of 0.94 is to be maintained at the bottom of the glass chamber above the samples. The samples are to be positioned 38 mm above the aqueous ammonia solution and supported by an inert tray. The moist ammonia-air mixture in the chamber is to be maintained at atmospheric pressure and a temperature of 34 °C ± 2 °C.

After being subjected to the above conditions, there shall be no evidence of cracking when examined using 25X magnification.

6.10.7 Thermoplastic insulator stress relief test

This test shall be performed on one sample of each insulating part made from thermoplastic. This test is not required for rigid or low-pressure formed thermosetting molded parts. The test sample shall be one terminal with the maximum number of terminal assemblies. The terminal shall be placed in a full-draft circulating oven for 7 hours. The oven is to be maintained at a temperature that is 10K above the manufacturer's stated maximum operating temperature for the insulating material in the terminal.

There shall be no softening of the insulator material, and immediately after removal from the oven, while being handled, there shall be no distortion or bending under its own weight. After allowing the terminal to cool down to room ambient temperature, the insulator shall again be examined. There shall be no shrinkage, warping or other distortion resulting in the reduction of clearances or creepage distances below the specified values.

7 Routine verifications and routine tests

These requirements supplement the requirements of clause 23 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod), which are applicable also to type of protection "e".

7.1 A~~n~~ dielectric strength test shall be carried out in accordance with 6.1. Alternatively, at 1.2 times the test voltage, but with a duration of between 3s and 5s.

7.2 Contrary to 7.1, the dielectric strength test for batteries shall be carried out in accordance with 6.6.1.

The insulation resistance of a battery is considered satisfactory when the value required by 5.6.2.7 is obtained.

8 Marking

These requirements supplement the requirements of clause 25 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) which are applicable also to type of protection "e". Electrical apparatus shall be additionally marked with the following:

a) rated voltage and rated current;

b) for rotating electrical machines and a.c. magnets, the starting current ratio I_A/I_N and time t_E;

c) for measuring instruments and instrument transformers, the rated short-time thermal current I_{th} and rated dynamic current I_{dyn};

d) for luminaires, the technical data of the lamps to be used, for example, electrical rating and, if necessary, the dimensions;

e) ~~for general purpose connection and junction boxes, the permissible maximum dissipated power~~ for general purpose connection or junction boxes, the rating expressed as either:

- the rated maximum dissipated power; or

- the set of values comprising for each terminal size, the permissible number and size of conductor and the maximum current;

f) restrictions in use, for example, use in clean environments only;

g) the characteristics of special protective devices where required, for example, for temperature control or for arduous starting conditions, and special supply conditions, for example, for converters;

h) for batteries in accordance with 5.6,

➔ type of construction of cells,

➔ number of cells and nominal voltage,

➔ rated capacity with the corresponding duration of discharge.

If no safety measures as foreseen in the note to 5.6 are applied, then the battery container shall carry the following warning plate

CAUTION – DO NOT CHARGE IN A HAZARDOUS AREA.

~~**NOTE –**~~ Instructions for use (instructions for maintenance), for display in the battery charging station, shall ~~should~~ be supplied with each battery. These shall ~~should~~ include all instructions necessary for the charging, use and maintenance.

The instructions for use shall ~~should~~ include at least the following information:

➔ the name of the manufacturer or supplier or his registered trade mark,

➔ the manufacturer's type identification,

➔ the number of cells and the nominal voltage of the battery,

➔ the rated capacity with the corresponding duration of discharge,

➔ the charging instructions,

➔ any other conditions concerning the safe operation of the battery, for example restrictions on the lifting of the cover during charging, the minimum time before closing the cover because of the release of gas after termination of charging, the checking of the electrolyte level, the specifications for the electrolyte and water for topping up the mounting position.

i) for resistance heating devices and resistance heating units to which the additional requirements of 5.8 apply, the temperature T_p.

j) for terminals

the conductor range in AWG / kcmil (where space is limited, this information may appear in the instructions)

Installation instructions shall include at least the following information:

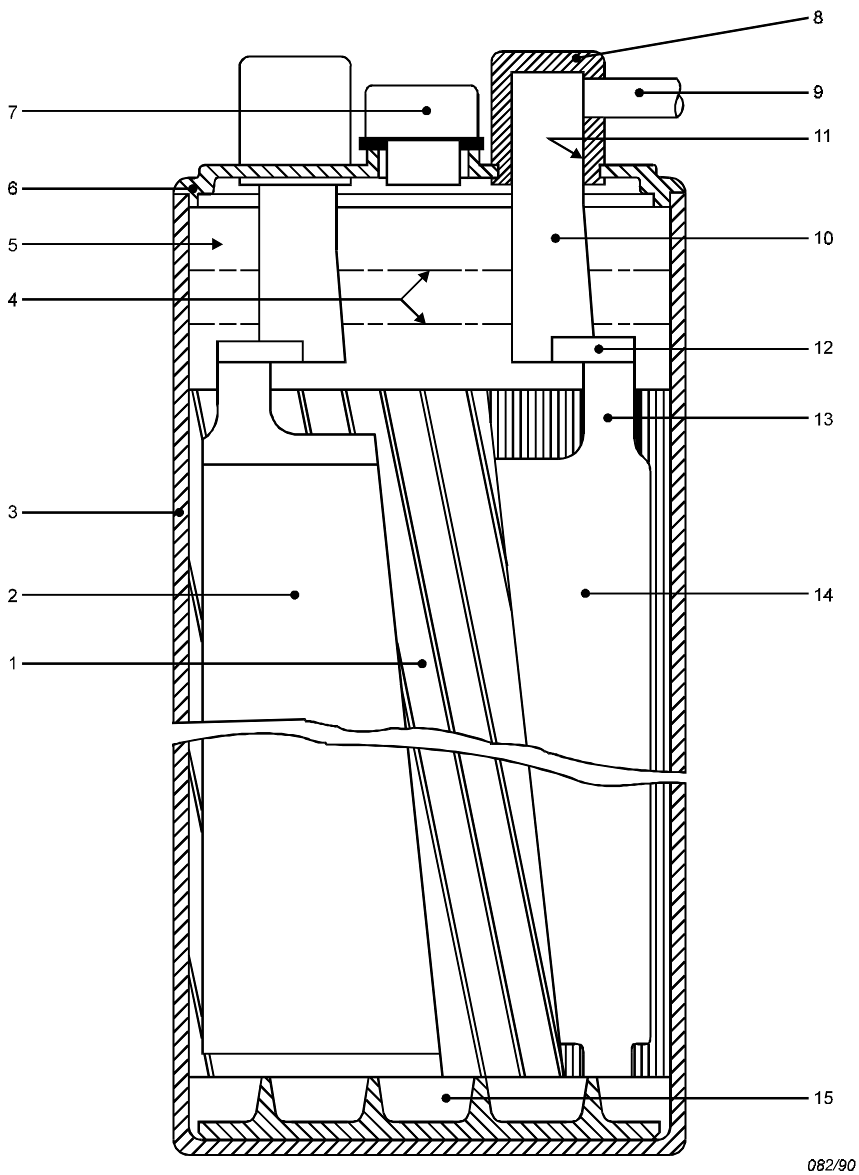
The assigned torque values if the manufacturer assigns a value of tightening torque.

Suitable markings or other instructions to indicate clearly any rearrangement or adjustment that is necessary to adapt to various sizes of conductors if the rearrangement or adjustment is not obvious.

Instructions for proper installation of the conductor for terminal constructions where the wiring method is not obvious., e.g., the use of only copper conductors with field wiring terminals.

The conductor insulation stripping requirements.

* * * * *

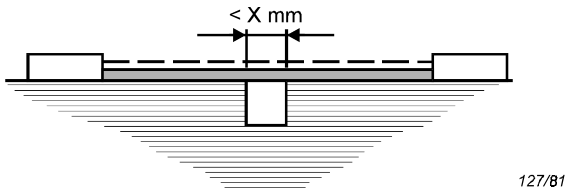


Note - this sketch is included for descriptive purposes only and is not intended to imply any requirement or preference for a particular form of construction.

1 Separator
2 Positive plate
3 Cell container
4 Electrolyte level (max./min.)
5 Headspace
6 Electrolyte-tight lid seal
7 Filler and vent plug
8 Encapsulated post
9 Intercell connector
10 Terminal post
11 Electrolyte-tight terminal post seal
12 Group bar
13 Plate lug
14 Negative plate
15 Mud space

Figure 1 — Parts of a Cell

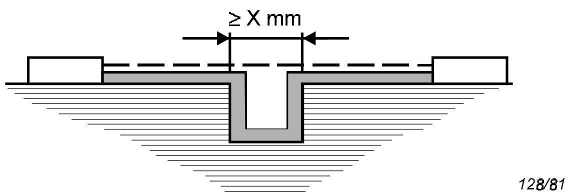
Example 1



Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

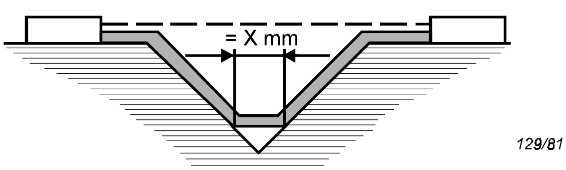
Example 2



Condition: Path under consideration includes a parallel-sided groove of any depth and equal to or more than X mm.

Rule: Clearance is "line-of-sight" distance. Creepage path follows the contour of the groove.

Example 3



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line-of-sight" distance. Creepage path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

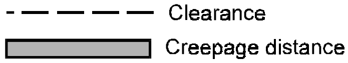
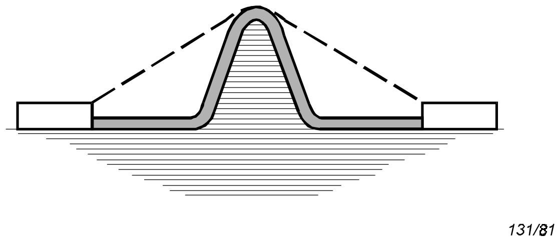


Figure 2 - Determination of Creepage Distances and Clearances

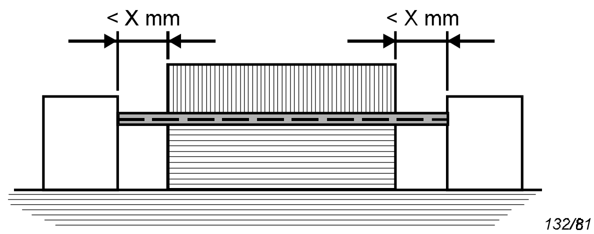
Example 4



Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top the rib. Creepage path follows the contour of the rib.

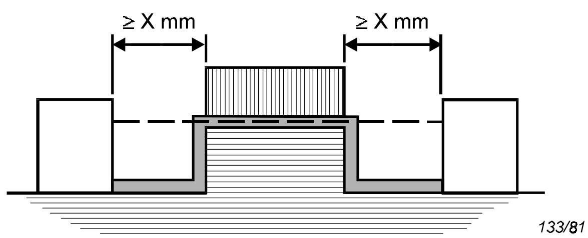
Example 5



Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage and clearance path is the "line-of-sight" distance shown.

Example 6



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

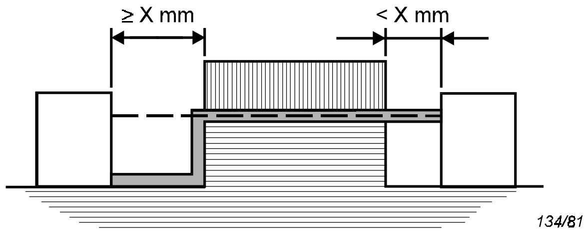
Rule: Clearance is the "line-of-sight" distance. Creepage path follows the contour of the grooves.

- – – – – Clearance

▭ Creepage distance

Figure 2 - Determination of Creepage Distances and Clearances (Continued)

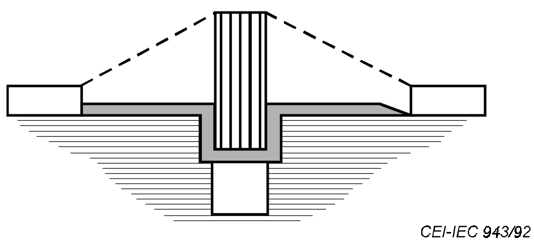
Example 7



Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

Example 8



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

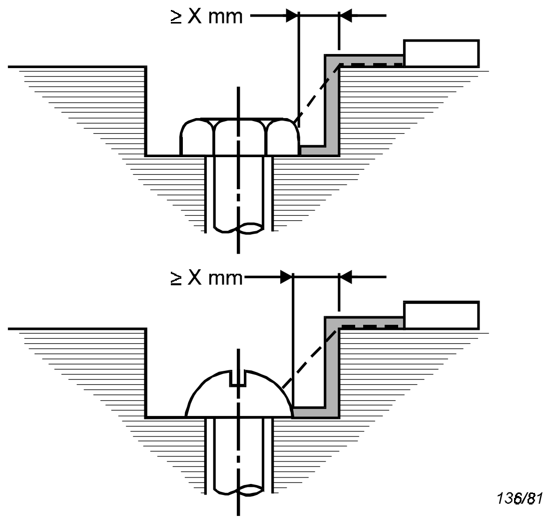
Rule: Clearance is the shortest direct air path over the top of the barrier.

- — — — Clearance

Creepage distance

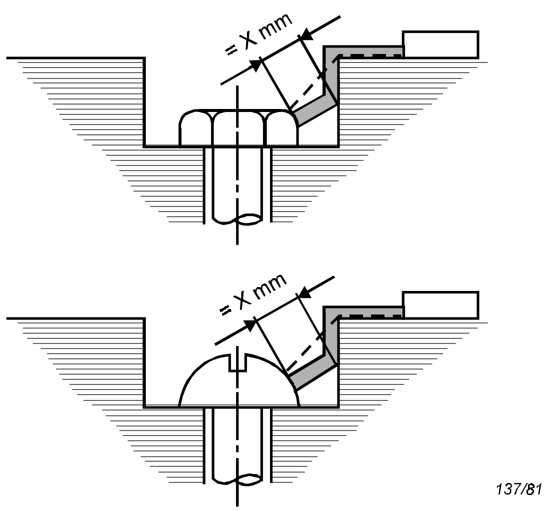
Figure 2 - Determination of Creepage Distances and Clearances (Continued)

Example 9



Gap between head of screw and wall of recess wide
enough to be taken into account.

Example 10



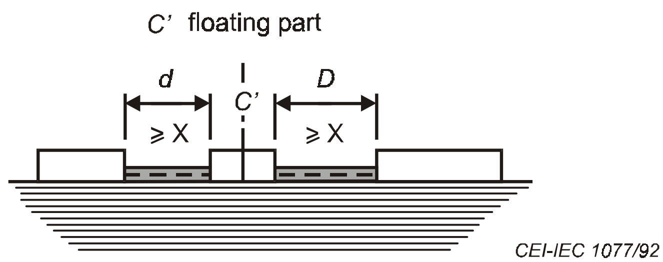
Gap between head of screw and wall of recess too
narrow to be taken into account.

Measurement of creepage distance is from screw to
wall when the distance is equal to X mm.

Clearance
Creepage distance

Figure 2 - Determination of Creepage Distances and Clearances (Continued)

Example 11



Clearance is the distance = $d + D$
Creepage distance is also = $d + D$

- - - - - - - Clearance

▬ Creepage distance

Figure 2 - Determination of Creepage Distances and Clearances (Continued)

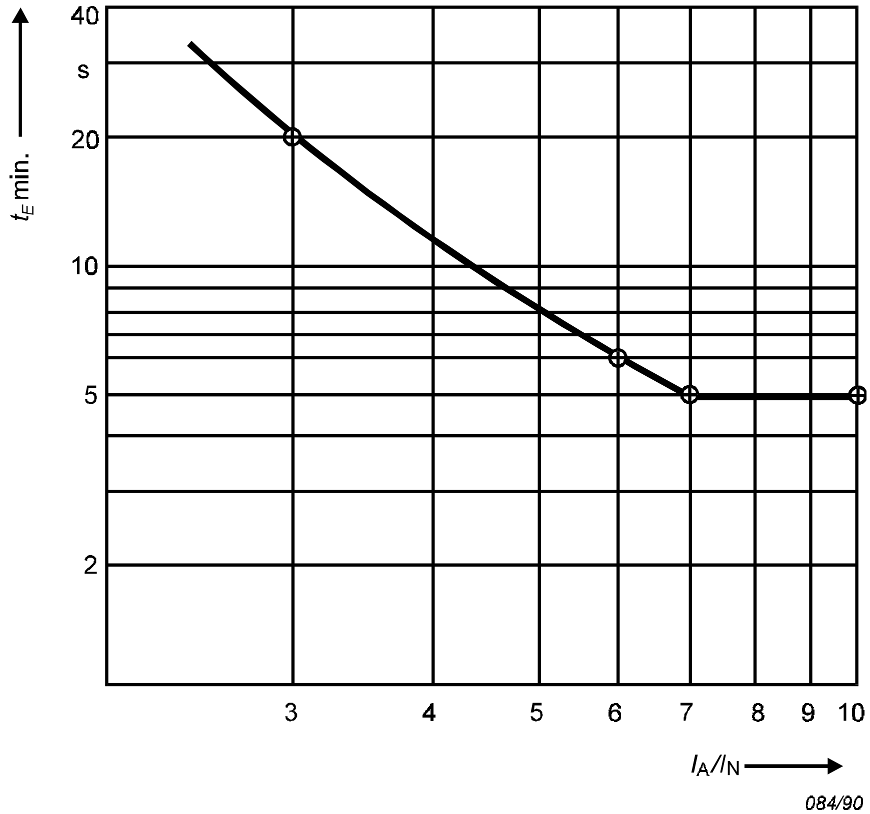


Figure 3 - Minimum Values of the Time t_E of Motors in Relation to the Starting Current Ratio I_A / I_N

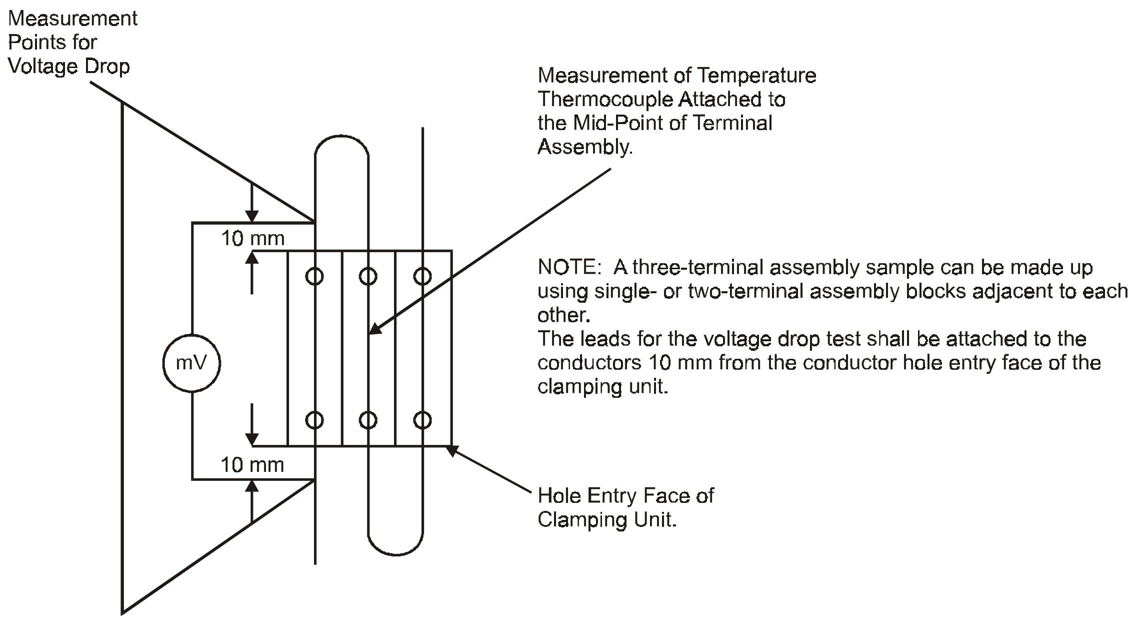


Figure 4 - Arrangement for Voltage Drop and Temperature Rise Measurement Tests

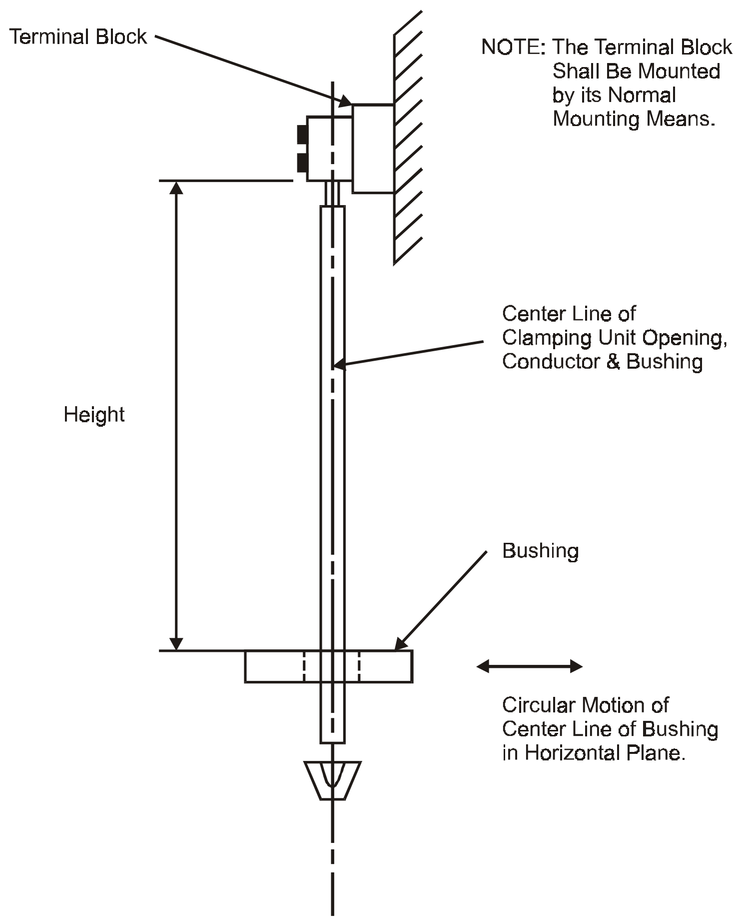


Figure 5 - Arrangement for the Verification of Conductor Attachment

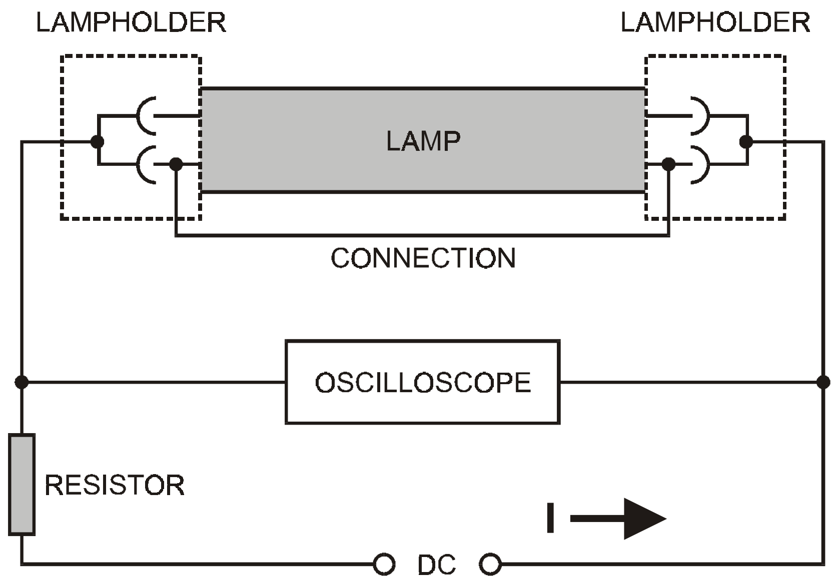


Figure 6 - Arrangement for the Luminaire Vibration Test

ANNEX A (normative) — Lampholders and lamp caps for line connected luminaires ~~designed for mains supply~~

~~**A.1** Lampholders with the appropriate lamp cap fitted shall comply with the test requirements for non-transmission of an internal ignition of IEC 79-1 for Group I or Group IIC.~~

A.2 Screw lampholders (Edison base) with the appropriate lamp caps fitted shall ~~either comply with A.1 or the lampholder shall~~ be fitted with a quick-acting switch with an enclosure complying with the construction and test requirement for non-transmission of an internal ignition laid down in ISA-S12.22.01 (IEC 79-1 Mod) ~~IEC 79-1~~ for ~~Group I or~~ Group IIC.

Precautions shall be taken to prevent self-loosening of the lamp in the lampholder.

Screw lampholders with the appropriate lamp cap fitted shall additionally comply with the test requirements in 6.3 relating to insertion and removal torques. As an exception to the requirements of 4.3 and 4.4, lamps with screw caps used in the luminaires are required to use Material Group I insulation (see Table 2) and to comply with the minimum requirements in Table A.1 for creepage distances and clearances.

Table A.1. – Creepage distance and clearance for screw lampholders and caps

Voltage	Creepage distance and clearance (mm)
$U \leq 60$	2
$60 < U \leq 250$	3

A.3 Lampholders for bi-pin tubular fluorescent lamps shall comply with the dimensional requirements for G 13 or G 5 of IEC 400 or ANSI C81.62 ~~of data sheet Fa6 of IEC 61-2~~.

~~**A.4** For lampholders other than those prescribed in A.2 and A.3, the length of the path through the joint between the lampholder and the cap or the pin, at the moment of contact separation, shall be at least 10 mm.~~

ANNEX B (normative) — Cage motors – Methods of test and of calculation

The temperature rises of the stator and rotor which are attained during rated service and the temperature rise occurring in the stalled motor shall be determined.

For motors with an output exceeding 160 kW ~~(or 75 kW if the third paragraph of 6.2.1 applies),~~ the values of temperature rise referring to rated service and stalled condition may be determined by calculation instead of by test. As far as possible, comparative measurements on similar motors and investigations on models shall be used to check the accuracy of the calculations.

B.1 The temperature rise of the stator and rotor windings in rated service shall be determined by the method described in 15.4.1 and 15.4.2 of IEC 34-1, except that the table in 15.4.1 of IEC 34-1 is replaced by Table B.1.

Table B.1. – Time after switch-off for the determination of the temperature rise in rated service

Rated Output, P kW/(kVA)	Time After Switch Off s
$P \leq 50$	30
$50 < P \leq 200$	90
$200 < P$	120

B.2 The temperature rise in stalled motors shall be determined experimentally as follows.

B.2.1 With the stalled motor initially at ambient temperature, rated voltage and rated frequency shall be applied.

B.2.2 The stator current measured 5 s after switching on shall be considered to be the starting current I_A.

B.2.3 The temperature rises in the rotor cage (bars and rings) shall be measured by thermocouples and measuring instruments having time constant that are small compared with the rate of rise of temperature, or by temperature detectors or other means. The highest of the temperatures obtained during these measurements is the one to be considered.

B.2.4 The average temperature rise of the stator, determined from resistance measurements, is taken as the temperature rise of the winding.

B.2.5 When the stalled motor test is made with a voltage less than the rated voltage, the measured values shall be increased in proportion to the ratio of those voltages, directly for the starting current (see B.2.2) and according to the square of the temperature rise. Saturation effects, if any, shall be taken into account.

B.3 The temperature rises in stalled motors shall be calculated as follows.

B.3.1 When calculating the temperature of the short-circuited rotor, the temperature rise shall be calculated from the joule heating effect, taking account of the heat generated in the bars and rings as well as of the thermal capacity of the cage. The influence of skin effect on the heat distribution in the bars shall be considered. Allowance may be made for the heat transfer to the iron.

B.3.2 The rate of temperature rise with time, $\Delta\theta/t$, of the stator windings in the stalled motor shall be calculated as follows:

$$\frac{\Delta\theta}{t} = a \cdot j^2 \cdot b$$

Where:

j is the starting current density, in A/mm2

a is the coefficient in

$$\frac{K}{(A/mm^2)^2 s}$$

(for copper, a = 0.0065)

b = 0.85 (a reduction factor which takes into account the heat dissipation from impregnated windings).

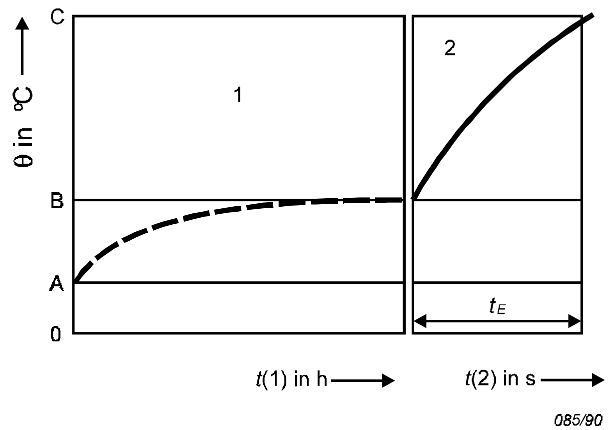
B.4 The time t_E shall be determined as follows (see Figure B.1).

From the limiting temperature OC, the maximum ambient temperature OA (normally 40 °C) and the temperature rise in rated service AB are subtracted. From this difference BC and the rate of temperature rise in the stalled motor test (obtained by measurement or calculation), the time t_E is determined.

Separate calculations are made for the rotor and for the stator. The smaller of the two values is taken as the time t_E for the motor for the appropriate temperature class.

B.5 Motors designed for arduous starting conditions or provided with special protective devices (for example, devices monitoring the temperature of the windings) shall be tested in conjunction with those protective devices.

B.6 Motors forming units with converters and the associated protective devices shall be tested to determine that the relevant limiting temperatures are not exceeded over the range of operating conditions given by the combination of motor and converter.



A = Highest permissible ambient temperature
B = Temperature in rated service
C = Limiting temperature (4.7)
t = Time
θ = Temperature
1 = Temperature rise in rated service
2 = Temperature rise during stalled rotor test

Figure B.1 - Diagram illustrating the determination of time t_E

* * * * *

ANNEX C (normative) — Type tests for specific forms of resistance heating devices or resistance heating units

~~C.1Resistance heating devices subjected to mechanical stresses~~

~~Resistance heating devices, such as heating cables and tapes, not protected by an enclosure complying with the requirements for enclosures in 22.4.3.1 of IEC 79-0, shall be submitted to the crushing and low temperature bend tests in C.1.1 and C.1.2.~~

~~C.1.1 Crushing test~~

~~A sample is placed on a rigid flat steel support. A crushing force of 1 500 N is then applied to the sample for 30 s, without shock, by means of a 6 mm diameter steel rod with hemispherical ends and a total length of 25 mm. For the test, the rod is laid flat on the sample and in the case of a cable or tape it is placed across the sample at right- angles.~~

~~Compliance is then verified by the insulation integrity test in 6.8.2 a) and b).~~

~~C.1.2 Low temperature bend test~~

~~The test apparatus used for the bend test is shown in Figure C.1. The test apparatus, with a sample in position, is maintained for a period of 4 hours at a temperature of -10 °C or at the lowest temperature declared by the manufacturer with a tolerance of ±3 °C. Immediately afterwards, the sample is bent through 90° around one of the mandrels, then bent through 180° in the opposite direction over the second mandrel and then straightened to its original position. This bending cycle is carried out twice with one cycle in about 5 s.~~

~~Compliance is then verified by the insulation integrity test in 6.8.2 a) and b).~~

> ~~**NOTE** – The manufacturer should state all constraints and precautions to be taken and at least the minimum permissible values of the bending radius and of the temperature at which the resistance heating device may be formed.~~

C.2 Resistance heating devices or units intended for immersion

A sample or part of the sample intended for immersion is immersed under 50 mm + 5 mm, 0 mm of tap water, for 14 days. Compliance is then verified by the insulation integrity test in 6.8.2 a) and b).

> **NOTE** – This test is not intended to verify the suitability of resistance heating devices or units for operation immersed in liquids other than water or at pressures of more than 500 Pa.

C.3 Resistance heating devices or units having hygroscopic insulating material

The parts which ensure vapor tightness are subjected to a temperature of (80 ± 2) °C for 4 weeks at not less than 90 percent R.H. After being wiped dry, compliance of the sample is verified by the insulation integrity test in 6.8.2 a) and b) but omitting the water immersion.

The ~~descriptive documents~~ manufacturer's instructions according to 22.2 of ~~IEC 79-0~~ ISA-S12.0.01 (IEC 79-0 Mod) shall specify the process and the materials to be used to complete the sealing of the resistance heating device or unit.

C.4 Verification of limiting temperature of resistance heating devices (other than heat tracing cables, units, panels, and systems)

The test shall be carried out according to the procedure of C.4.1, C.4.2 or C.4.3.

C.4.1 Resistance heating unit protected by a protective system in accordance to 5.8.11

The test shall be carried out at the power output of the apparatus corresponding to 10 percent over-voltage with any declared minus tolerance on the ohmic resistance.

> **NOTE –** Heating units protected by a protective system according to 5.8.11, but tested without the protective system, may be certified as apparatus only if the operating conditions are simulated during the test. Otherwise, the heating unit can only be regarded as an Ex component and will require additional certification of any electrical apparatus with which it is used.

C.4.1.1 Protective system sensing the temperature

The maximum temperature permitted by the protective system shall be determined with any additional regulating devices rendered inoperable. Thermal ~~inertia~~ time constants to ensure stable temperatures shall be taken into account.

C.4.1.2 Protective system sensing the temperature and at least one other parameter

The maximum temperature shall be determined as in C.4.1.1 taking into account the most adverse conditions permitted by the device(s) sensing the other parameter(s).

C.4.1.3 Protective system sensing a parameter other than the temperature

The maximum temperature shall be determined taking into account the most adverse conditions permitted by the devices sensing the other parameter(s).

C.4.2 Resistance heating unit of stabilized design

The sample shall be tested in the worst installation conditions specified by its manufacturer and recognized as such by the testing authority. These test conditions shall include, where relevant, zero fluid flow or an empty pipe or vessel. The test is carried out at the power output determined as in C.4.1.

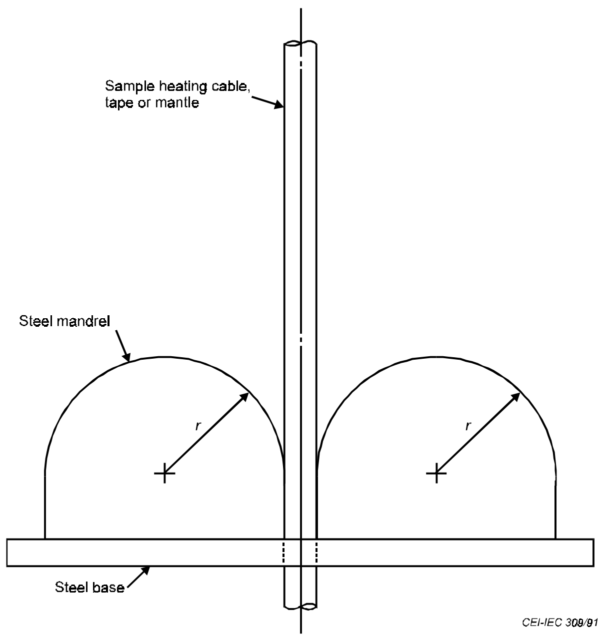
Simulated operating conditions may be agreed between the testing authority and the manufacturer.

C.4.3 Heating device with self-limiting characteristic

In the case of a cable or tape, a sample between 3 m and 4 m in length shall be close-coiled inside a close-fitting box of thermally insulating material capable of withstanding the temperature produced. The box shall be effectively adiabatic. Thermocouples shall be attached to the sample to measure its maximum surface temperature. The sample shall then be energized at its rated voltage + 10 percent at an initial temperature of (-20 ± 3) °C until thermal equilibrium is reached.

The maximum temperature shall be determined.

Other resistance heating devices with a self-limited property shall be similarly tested in a suitable effectively adiabatic enclosure.



NOTE - r = Bending radius (minimum value provided for by the manufacturer).

Figure C.1 - Low Temperature Bend Test Apparatus

ANNEX D (informative) — Cage motors – Thermal protection in service

This annex gives additional information for the user as guidance for the selection of protective devices with particular reference to those installation matters that are different from, or supplementary to, practice in normal industrial installations.

D.1 To satisfy the requirements of 4.7.4 in service, an inverse-time delay overload protective device (for example, a direct-on-line starter with thermal overload relay or release) is acceptable provided that it satisfies the recommendations of D.2.

D.2 Inverse-time delay overload protective devices shall be such that not only is the motor current monitored but also that the stalled motor will be disconnected within the time t_E. The current-time characteristic curves giving the delay time of the overload relay or release as a function of the starting current ratio IA/IN should be in the possession of the user.

The curve shall indicate the value of delay time from the cold state related to an ambient temperature of 20 °C and for a range of starting current ratios of at least 3 to 8. The tripping time of the protective devices should be equal to these values of delay time ± 20 percent.

D.3 In general, motors for continuous service, involving easy and infrequent starts which do not produce appreciable additional heating, are acceptable with inverse-time delay overload protection. Motors for arduous starting conditions or to be started frequently are acceptable only when suitable protective devices, which ensure that the limiting temperature is not exceeded, are used.

Arduous starting conditions are considered to exist if an inverse-time delay overload protective device, correctly selected according to D.2, disconnects the motor before it reaches its rated speed. Generally, this will happen if the total starting time exceeds 1.7 times t_E.

* * * * *

ANNEX E (~~informative~~)(normative) — Resistance heat~~ing~~ tracing cables and panels ~~units~~ – additional electrical protection

E.1 Objective

The function of the protection, which is additional to the overcurrent protection, is to limit the heating effect and possible arcing due to abnormal ~~earth~~ ground fault and ~~earth~~ ground leakage currents.

E.2 Method of protection

Grounded systems are required to enable ground fault equipment protection to function properly.

~~This will depend on the type of system earthing (see IEC Publication 364-3, Chapter 31 for definitions).~~

E.2.1 TT and TN systems (Line-Line and Line-Neutral systems)

Ground fault equipment protection shall be provided for branch circuits supplying electrical resistance heating cables.

Exception: In industrial process establishments where conditions of surveillance, maintenance, and supervision assure that only qualified persons will service the installed system and continuous circuit operation is necessary for safe operation of equipment or processes, an alarm indication of ground fault shall be provided.

> **NOTE** – Typically this system will disconnect all non-grounded phases at a trip level of 30 mA or higher.

~~A residual current operated protective device with a rated residual operating current not exceeding 300 mA should be used.~~

~~Preference should be given to protective devices with a rated residual operating current of 30 mA. This protective device should have a maximum break time not exceeding 5 s at the rated residual operating current and not exceeding 0.15 s at 5 times the rated residual operating current.~~

> ~~**NOTE** – Additional information on residual current protective devices is given in IEC Report 755.~~

~~E.2.2 IT system~~

~~An insulation monitoring device should be installed to disconnect the supply whenever the insulation resistance is not greater than 50 Ω/V of rated voltage.~~

ANNEX F (informative) — Combinations of terminals and conductors for general purpose connection and junction boxes

This annex gives additional information relevant to the two methods of expressing the rating of general purpose connection and junction boxes.

F.1 General

In most types of electrical apparatus, the source of heat is a well-defined part of that apparatus. However, for general-purpose connection and junction boxes containing only an array of terminals, the principal source of heat is more likely to be the cables connected to those terminals than the terminals themselves, and it is therefore critically dependent on the actual installation. This fact needs to be recognized in any system of allocating to such general-purpose connection and junction boxes rating for the purpose of allocating a temperature class.

The maximum temperature rise within the enclosure of such a box depends on two factors: the overall population of terminals and wiring within the enclosure, leading to an increased local temperature within the enclosure; and the temperature rise of individual terminals and wiring above their own local temperature. The "worst-case" terminal referred to in 6.7 is chosen from all terminals permitted for use in the enclosure but exhibiting, in conjunction with its maximum rated conductor, the highest temperature rise above the local temperature.

F.2 Maximum dissipated power method

The rated maximum dissipated power is determined in accordance with 6.7 using the "worst-case" terminal. For an allocated temperature class, the enclosure may be fitted with any number of the recognized terminals, which may or may not include the "worst-case" terminal, up to the maximum number permitted by the physical constraints of the enclosure, provided that the rated maximum dissipated power is not exceeded.

For each terminal, the dissipated power is calculated using the maximum current for that terminal and the value of resistance at 20 °C for the terminal and its associated conductor(s). Each conductor is assumed to have a length from the cable entry device to the terminal equal to 0,5 times the maximum internal linear dimension of the enclosure, that is, the length of the conductor from the cable entry device to the terminal is assumed to be one half the length of the terminal-to-terminal conductor used in 6.7. The sum of these dissipated powers represents the total dissipated power for the configuration and circuit condition. It should not exceed the rated maximum dissipated power.

> **NOTE** – To assist in the calculations for an installation, the manufacturer should have available a table of resistance values at 20 °C for all terminals and cables that may be used with the enclosure.

ANNEX G (informative)

Refer to the following papers for discussions of locked-rotor temperature calculations.

J. H. Dymond, "Stall Time, Acceleration Time, Frequency of Starting: The Myths and the Facts," *IEEE Transactions Industrial Applications*, IA-29, no. 1, pp. 42-51, January/February 1993.

J. Bredthauer, N. Struck, "Starting of Large Medium Voltage Motors – Design, Protection, and Safety Aspects," in *Conf Rec 1994 41st Annual Meeting IEEE Ind. Applications Society Petroleum and Chemical Industries Conference*, IA-31, pp. 141-151, September/October 1995.

ANNEX H (informative) — Standard cross-sections of copper conductors

This table is added material.
Information in table extracted from IEC 947-7-1 and NEMA ICS-4

Metric Size ISO (mm^2)	Comparison between AWG/kcmil and metric sizes	
	Size AWG/kcmil	Equivalent metric area (mm^2)
0.2	24	0.205
-	22	0.324
0.5	20	0.519
0.75	18	0.82
1	-	-
1.5	16	1.3
2.5	14	2.1
4	12	3.3
6	10	5.3
10	8	8.4
16	6	13.3
25	4	21.2
35	2	33.6
50	0	53.5
70	00	67.4
95	000	85
-	0000	107.2
120	250 kcmil	127
150	300 kcmil	152
185	350 kcmil	177
240	500 kcmil	253
300	600 kcmil	304
350	700 kcmil	355
380	750 kcmil	380
400	800 kcmil	405
450	900 kcmil	456
500	1000 kcmil	507
630	1250 kcmil	634
750	1500 kcmil	760
890	1750 kcmil	887
1000	2000 kcmil	1014

ANNEX I (informative) — United States Major Deviations

General. Group I is excluded from the scope of this document and all associated text has been deleted.

General Marking. The word "CAUTION" has been added as a prefix to required cautionary markings.

1. This standard applies to Groups IIA, IIB, and IIC.

   The 1996 National Electrical Code® (NEC) includes only Groups IIA, IIB, and IIC, and not Group II. IEC 79-7, as written, does not recognize Type of Protection "e" as being dependent upon the Group and is applicable to Group II, which is not defined by the NEC.

2 Additional NFPA, IEC, NEMA, and UL Standards have been added to the list of reference standards as they have been referred to in the added US text.

3 Definitions for external connections, internal connections, normal service, rated cross section, rated connecting capacity, heat tracing cable, parallel heating cable, series heating cable, trace heater unit, heating panel, resistance heat racing system, and heated equipment have been added to help promote a uniform understanding of the terms.

4.1 "External" connections have been further defined as "field" connections to use the customary U.S. term to designate connections intended to be made upon installation.

Connection of field wiring conductors has been limited to copper.

Due to the U.S. experience with other-than-copper conductors, the importance of a reliable connection, and the need to use anti-oxidant materials that could compromise spacings, other conductor materials for field connections were prohibited.

Requirement has been added that permitted wire sizes shall be specified in the instructions in AWG / kcmil.

The NEC only addresses wire sizes in AWG / kcmil.

Performance tests have been added to quantify what were considered to be vague requirements. With the exception of the vibration test, tests are consistent with ANSI/UL 1059 and/or ANSI/UL 486E.

It was felt that the requirements in 4.1 and 4.2 were too general in nature and insufficiently descriptive and needed to be quantified to permit uniform application of this standard.

Requirement has been added for terminals intended for use with stranded conductors to require that all strands be confined within the terminal.

Added to preclude inadvertent reduction of critical spacings.

Aluminum has been excluded as a construction material for external terminals.

Due to the U.S. experience with other than copper-to-copper connections, the importance of a reliable connection and the need to use anti-oxidant materials that could compromise spacings, aluminum was prohibited as a terminal material.

Stress corrosion cracking test has been added for copper alloy terminal with less than 85 percent copper.

Those alloys are subject to cracking failure over time and could lead to an unreliable connection.

4.2 "Internal" connections have been further defined as "factory-installed" connections to use the customary U.S. term to designate connections intended to be made in the factory under controlled conditions.

Aluminum conductors or terminals are not prohibited.

Aluminum terminals and conductors have not been excluded from internal connections as the concerns for reliable connection and application of anti-oxidant can be better controlled at the factory.

Performance tests have been added to quantify what were considered to be vague requirements. With the exception of the vibration test, tests are consistent with ANSI/UL 1059 and/or ANSI/UL 486E.

It was felt that the requirements in 4.1 and 4.2 were too general in nature and insufficiently descriptive and needed to be quantified to permit uniform application of this standard.

Stress corrosion cracking test has been added for copper alloy terminal with less than 85 percent copper.

Those alloys are subject to cracking failure over time and could lead to an unreliable connection.

4.5.2 / 4.6.4 Text of 4.5.2 on modified or damaged insulation has been relocated to 4.6.4 and now applies only to windings.

Coating described not considered reliable means of maintaining the quality of the insulation in other than winding applications.

4.9 *Appropriate Type designations have been added as alternates to IP54 and IP44. To permit use of U.S. rated enclosures.*

5.1 Maximum voltage for rotating machines has been limited to 5.5 kVrms ac or dc.

Motors above 5.5 kV were considered to present an unacceptable risk of ignition due to end-winding discharges on contaminated windings. This limit is based on the work of CENELEC

Working Group WG31-013 "Electrical discharging mechanisms in high voltage rotating electrical machines."

5.1.1 Exception for lesser degree of protection of motors has been deleted so requirement defaults back to IP54 / IP44.

The IP54 or IP44 required by sub-clause 4.9 is considered to provide suitable minimum ingress protection against contaminants to reduce the potential for ignition of a flammable atmosphere. This is consistent with current IEEE - 841 for Petroleum and Chemical Industry Motors.

5.1.4.1 Construction of rotor has been further limited to avoid risk of ignition from rotor sparking or high temperatures.

This is based on CENELEC Working Group WG31-013 for "Electrical discharging mechanisms in high voltage rotating electrical machines."

5.1.4.4 Requirement has been clarified to show that the thermal protection devices, with the exception of the sensor, shall be located outside the motor. Specific requirements have been added to allow use of a converter for variable speed applications.

5.1.4.5 Radial cooling ducts on motors rated at more than 500 kW per pole have been excluded.

This is based on CENELEC Working Group WG31-013 for "Electrical discharging mechanisms in high voltage rotating electrical machines."

5.1.5 Requirements for supplemental phase insulation to reduce the risk of ignition from phase-to-phase faults have been added. Requirements of form-wound coils and vacuum pressure impregnated windings have been added due to the improved integrity of this type of winding and of other types of winding and insulation.

5.1.6 Requirement for equipotential bonding jumpers of large machines to reduce the risk of ignition has been added.

This is based on CENELEC Working Group WG31-013 for "Electrical discharging mechanisms in high voltage rotating electrical machines."

5.1.7 Requirement that shaft seal material be non-sparking has been added.

5.1.8 Requirement to evaluate potential loosening of terminal during starting conditions has been added.

5.2.1 Lamp types of a) and c) have been excluded as they are no longer readily available. Bi-pin fluorescent lamps have been added in accordance with proposed changes to CENELEC standard.

5.2.7 Text for bi-pin fluorescent lamps has been added and is consistent with proposed changes to CENELEC standard.

Text developed by CENELEC WG10 of SC31-4.

5.7 Text has been rewritten (Annex F) based on text of EN 50.019 2nd Edition.

Original text did not adequately address product being designed and sold today.

5.8 Heat tracing has been excluded as it is now in new sub-clause 5.9.

5.9 Sub-clause has been added to specifically address heat tracing consistent with ANSI/IEEE 515.

6.1 dc has been added as an alternative to ac dielectric testing.

Reflects common industry practice for large capacitive loads that would otherwise require large ac supplies.

6.2.1 Text has been revised to indicate that testing is always the preferred method, although the calculation methods have not been prohibited.

Test facilities for all but the largest motors are available at the manufacturers' facilities.

6.2.3 Rotor Sparking Test has been added for large rotating machines.

This is based on CENELEC Working Group WG31-013 for "Electrical discharging mechanisms in high voltage rotating electrical machines."

6.3.3 Corrosion test has been added for bi-pin fluorescent lamps.

Text developed by CENELEC WG10 of SC31-4.

6.3.4 Vibration test has been added for bi-pin fluorescent lamps.

Text developed by CENELEC WG10 of SC31-4.

6.7 Text has been rewritten (Annex F) based on text of EN 50.019 2nd Edition.

Original text did not adequately address product being designed and sold today.

6.8 Test specifically addressing heat tracing has been deleted and is now addressed in 6.9 / Annex F.

6.9 Tests have been added for heat tracing (ANSI/IEEE 515).

6.10.1 Voltage drop test for terminals has been added.

Test added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC tests for terminals.

6.10.2 Secureness test for terminals has been added.

Test added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC tests for terminals.

6.10.3 Pullout test for terminals has been added.

Test added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC tests for terminals.

6.10.4 Temperature rise test for terminals has been added.

Test added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC tests for terminals.

6.10.5 Dielectric strength test for terminals has been added.

Test added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC tests for terminals.

6.10.6 Stress corrosion cracking test has been added for terminals.

Test added to evaluate those alloys that are subject to cracking failure over time and could lead to an unreliable connection.

6.10.7 Thermoplastic insulator stress relief test has been added for terminals.

Test added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC tests for terminals.

7.1 Reduced time / increased voltage dielectric test has been added.

Test is consistent with other national and international standards.

8 e) Marking has been added for junction boxes consistent with the revised text of 5.7 and 6.7.

8 j) Specific Marking / Instruction information has been required for terminals.

Text added to cover terminals not within scope of ANSI/UL 1059 or ANSI/UL 486E and is consistent with current CSA/NEMA/UL/IEC marking for terminals.

A.3 U.S. lamp references have been added.

Annex C. Tests specific to heat tracing have been deleted.

Heat tracing tests addressed in Annex E

Annex E. Text based on Annex C has been added to specifically address heat tracing.

The NEC and the revision of IEEE 515 require both grounded metallic covering and ground fault protection of equipment for all electrical heat tracing circuits. This changes the types of protection from that recommended in IEC 79-7. Typically the ground fault protection setpoint is 30 mA but this rating is left to the designer and the availability of compatible quipment.

Developing and promulgating technically sound consensus standards, recommended practices, and technical reports is one of ISA's primary goals. To achieve this goal the Standards and Practices Department relies on the technical expertise and efforts of volunteer committee members, chairmen, and reviewers.

ISA is an American National Standards Institute (ANSI) accredited organization. ISA administers United States Technical Advisory Groups (USTAGs) and provides secretariat support for International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) committees that develop process measurement and control standards. To obtain additional information on the Society's standards program, please write:

ISA
Attn: Standards Department
67 Alexander Drive
P.O. Box 12277
Research Triangle Park, NC 27709

ISBN: 1-55617-647-3