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Edition 3

IEC 60079-18:2009
Edition 3

SOUTH AFRICAN NATIONAL STANDARD

Explosive atmospheres

Part 18: Equipment protection by encapsulation "m"

This national standard is the identical implementation of IEC 60079-18:2009 and is adopted with the permission of the International Electrotechnical Commission.

WARNING — Can only be used in conjunction with SANS 60079-0

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Table of changes

Change No.	Date	Scope

National foreword

This South African standard was approved by National Committee SABS TC 65, *Explosion prevention*, in accordance with procedures of the SABS Standards Division, in compliance with annex 3 of the WTO/TBT agreement.

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Atmosphères explosives – Partie 18: Protection du matériel par encapsulage «m»

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EXPLOSIVE ATMOSPHERES –

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FOREWORD

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International Standard IEC 60079-18 has been prepared by IEC technical committee 31: Equipment for explosive atmospheres.

This third edition cancels and replaces the second edition of IEC 60079-18 (2004) and IEC 61241-18 (2004), and constitutes a technical revision.

The significant technical changes with respect to the previous edition are as follows:

– Incorporation of level of protection "mc"
– Equipment protection levels (EPL Ma, Ga, Da, Mb, Gb, Db, Gc, Dc)
– Incorporation of the dust requirements
– Incorporation of switching contacts for level of protection "ma"

The text of this standard is based on the following documents:

FDIS	Report on voting
31/784/FDIS	31/801/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This standard is to be read in conjunction with IEC 60079-0:2007, *Explosive atmospheres – Part 0: Equipment – General requirements.*

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all parts of IEC 60079 series, under the general title *Explosive atmospheres*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

EXPLOSIVE ATMOSPHERES –

Part 18: Equipment protection by encapsulation "m"

1 Scope

This part of IEC 60079 gives the specific requirements for the construction, testing and marking of electrical equipment, parts of electrical equipment and Ex components with the type of protection encapsulation "m" intended for use in explosive gas atmospheres or explosive dust atmospheres.

This part applies only for encapsulated electrical equipment, encapsulated parts of electrical equipment and encapsulated Ex components (hereinafter always referred to as "m" equipment) where the rated voltage does not exceed 11 kV.

The application of electrical equipment in atmospheres, which may contain explosive gas as well as combustible dust simultaneously may require additional protective measures.

This standard does not apply to dusts of explosives, which do not require atmospheric oxygen for combustion, or to pyrophoric substances

This standard does not take account of any risk due to an emission of flammable or toxic gas from the dust.

This standard supplements and modifies the general requirements of IEC 60079-0. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirement of this standard shall take precedence.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

IEC 60079-7, *Explosive atmospheres – Part 7: Equipment protection by increased safety "e"*

IEC 60079-11, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-15, *Explosive atmospheres – Part 15: Equipment protection by type of protection "n"*

IEC 60079-26, *Explosive atmospheres – Part 26: Equipment with equipment protection level (EPL) Ga*

IEC 60079-31, *Explosive atmospheres – Part 31: Equipment dust ignition protection by enclosures "t"*

IEC 60127 (all parts), *Miniature fuses*

IEC 60243-1, *Electrical strength of insulating material – Test methods – Part 1: Tests at power frequencies*

IEC 60691, *Thermal-links – Requirements and application guide*

IEC 60730-2-9, *Automatic electrical controls for household and similar use – Part 2-9: Particular requirements for temperature sensing controls*

IEC 60738-1, *Thermistors – Directly heated positive temperature coefficient – Part 1: Generic specification*

IEC 61241-11, *Electrical apparatus for use in the presence of combustible dust – Part 11: Protection by intrinsic safety 'iD'*

IEC 61558-2-6, *Safety of power transformers, power supply units and similar – Part 2: Particular requirements for safety isolating transformers for general use*

IEC 62326-4-1, *Printed boards – Part 4: Rigid multilayer printed boards with interlayer connections – Sectional specification – Section 1: Capability detail specification – Performance levels A, B and C*

ISO 62, *Plastics – Determination of water absorption*

ANSI/UL 248-1, *Standard for low-voltage fuses – Part 1: General requirements*

ANSI/UL 746B, *Standard for polymeric materials – Long term property evaluations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60079-0 and the following definitions specific to encapsulation "m" apply.

NOTE Additional definitions applicable to explosive atmospheres can be found in IEC 60050-426.

3.1
encapsulation "m"
type of protection whereby parts that are capable of igniting an explosive atmosphere by either sparking or heating are enclosed in a compound in such a way as to avoid ignition of a dust layer or explosive atmosphere under operating or installation conditions

3.2
compounds
any thermosetting, thermoplastic, epoxy resin or elastomeric materials with or without fillers and/or additives, in their solid state

3.3
temperature range of the compound
range of temperatures within which, the properties of the compound, in either operation or storage, permit compliance with the requirements of this standard

3.4
continuous operating temperature (COT) of the compound
temperature range within which, according to the details given by the manufacturer, the properties of the compound, during operation, satisfy the requirements of this standard on a permanent basis during the foreseen lifetime of the equipment

3.5
encapsulation
process of applying the compound to enclose any electrical device(s) by suitable means

3.6
free surface
compound surface exposed to the explosive atmospheres and/or dust layers

3.7
normal operation
operation of equipment conforming electrically and mechanically with its design specification and used within the limits specified by the manufacturer

NOTE 1 The limits specified by the manufacturer may include persistent operational conditions, for example operation of a motor on a duty cycle.

NOTE 2 Variation of the supply specifications within stated limits and any other operational tolerance is part of normal operation.

3.8
void
unintentional space created as a consequence of the encapsulation process

3.9
free space
intentionally created space surrounding components or space inside components

3.10
switching contact
mechanical contact, which makes and breaks an electrical circuit

3.11
adhesion
moisture, gas and dust tight permanent bonding of a compound to a surface

3.12
countable fault
fault, which occurs in parts of electrical equipment conforming to the constructional requirements

3.13
infallible separation or insulation
separation or insulation between electrically conductive parts that is considered as not subject to short circuits as specified in IEC 60079-18. The probability of such fault modes occurring in service or storage is considered to be so low that they are not to be taken into account

3.14
non-countable fault
fault, which occurs in parts of electrical equipment not conforming to the constructional requirements of IEC 60079-18

3.15
solid insulation
insulation material, which is extruded or moulded, but not poured

NOTE Insulators fabricated from two or more pieces of electrical insulating material, which are solidly bonded together may be considered as solid. Varnish and similar coatings are not considered to be solid insulation.

4 General

4.1 Level of protection (Equipment protection level (EPL))

Electrical equipment with encapsulation "m" shall be either

a) level of protection "ma" (EPL "Ma, Ga, Da"),

b) level of protection "mb" (EPL "Mb, Gb, Db") or in

c) level of protection "mc" (EPL "Gc, Dc").

The requirements of this standard shall apply to all levels of protection "m" (EPL`s) unless otherwise stated.

4.2 Additional requirements for level of protection "ma"

The working voltage at any point in the circuit shall not exceed 1 kV.

Components without additional protection shall be used only if they cannot damage the encapsulation mechanically or thermally in the case of any specified fault.

Alternatively, where a fault of an internal component may lead to failure of the encapsulation "m" due to increasing temperature, the requirements of 7.9 shall apply.

4.3 Rated voltage and prospective short circuit current

The rated voltage and the prospective short circuit current shall be specified such that the limiting temperature is not exceeded for the relevant level of protection "ma", "mb" or "mc".

5 Requirements for compounds

5.1 General

The documentation shall specify the compound(s) used and the processing method(s).

As a minimum, those properties of the compound(s) on which the encapsulation "m" depends shall be provided.

NOTE Due consideration should be given in the selection of compounds to allow for the expansion of components during operation and in the event of allowable faults.

5.2 Specification

The specification for the compound shall include the following:

a) the name and address of the manufacturer of the compound,

b) the exact and complete reference of the compound and if relevant, percentage of fillers and any other additives, the mixture ratios and the type designation,

c) if applicable, any treatment of the surface of the compound(s), for example varnishing,

d) if applicable, to obtain correct adhesion of the compound to a component, any requirement for pre-treating of the component for example cleaning, etching,

e) the dielectric strength in accordance with IEC 60243-1 at the maximum temperature of the equipment determined according to 8.2.2 if available. If not available, the requirements of 5.3.2 shall be applied,

f) temperature range of the compound(s) (continuous operating temperature),

g) in the case of "m" equipment where the compound is part of the external enclosure, the temperature index TI value as defined by IEC 60079-0. As an alternative to the TI, the

relative thermal index (RTI-mechanical impact) may be determined in accordance with ANSI/UL 746B,

h) the colour of the compound used for the test samples, where the compound specification will be influenced by changing the colour.

NOTE It is not a requirement of this standard that conformity to the manufacturer's specification of the compound needs to be verified.

5.3 Properties of the compound

5.3.1 Water absorption

If the equipment is to be exposed to dampness, the compound shall be tested in accordance with 8.1.1. If this test is not performed, the equipment shall be marked "X" in accordance with the marking requirements of IEC 60079-0 and the restriction of use to dry environments clarified in the instructions.

5.3.2 Dielectric strength

Where the dielectric strength according to IEC 60243-1 is not available at the maximum temperature of the equipment as defined according to 8.2.2, see 5.2 e), a test shall be performed in accordance with 8.1.2.

6 Temperatures

6.1 General

The maximum value of the continuous operating temperature of the compound shall not be exceeded under normal operation. The maximum surface temperature, determined in accordance with IEC 60079-0 shall not be exceeded under normal operation and under fault conditions as defined in 7.2.1. The "m" equipment shall be protected in such a way that the encapsulation "m" is not adversely affected under these fault conditions.

NOTE Normal operation includes operation at the extremes of voltage tolerances of the supply normally 90 % to 110 % if not otherwise specified.

6.2 Determination of the limiting temperature

6.2.1 Maximum surface temperature

The maximum surface temperature shall be determined using the test method given in 8.2.2 in accordance with the supply conditions specified in 4.3. This temperature shall be used to determine the temperature class for explosive gas atmosphere or the maximum surface temperature in degrees Celsius for explosive dust atmosphere of the equipment.

6.2.2 Temperature of the compound

The hottest component(s) shall be determined. The maximum temperature in the compound, adjacent to the hottest component(s), shall be determined using the test method given in 8.2.2 for normal operation.

As an alternative the determination of the temperature of the hottest component may be done by calculation, manufacturer's specification or by a practical test prior to encapsulating the components.

6.3 Temperature limitation

Where the equipment may be subject to fault in accordance with 7.2.1, or where there is the possibility of an increased temperature, for example by an unfavourable input voltage in accordance with 7.2.1 or an unfavourable load, this shall be taken into account in determining the limiting temperatures.

When a protective device is required to limit temperatures for safety reasons, it shall be an internal or external, electrical or thermal device, as defined in 7.9.

7 Constructional requirements

7.1 General

Where the compound forms part of the external enclosure it shall comply with the requirements of IEC 60079-0 for non metallic enclosures and parts of non metallic enclosures.

If the surface of the compound is totally or partly surrounded by an enclosure and the enclosure is part of the protection, the enclosure or parts of the enclosure shall comply with the enclosure requirements of IEC 60079-0

If additional protective measures are required to be provided by the user in order to satisfy the requirements of this standard, for example, additional mechanical protection, to indicate this specific condition of use the equipment shall be in accordance with the "specific conditions of use" marking requirements of IEC 60079-0.

Appropriate action shall be taken to accommodate the expansion of components during normal operation and in the event of faults according to 7.2.

In 7.2 to 7.9 the requirements differ according to whether the compound adheres to the enclosure. Where adhesion is specified, the aim is to prevent the ingress of explosive atmospheres and moisture at the boundary surfaces (for example enclosure-compound, compound-parts that are not completely embedded in the compound, such as printed wiring boards, connection terminals, etc.). Where adhesion is required to maintain the type of protection, it shall be maintained after completion of all the prescribed tests.

NOTE The choice of the compound(s) to be used for a specific application is dependent on the task each compound has to perform. In general, testing a compound once is not sufficient for universal use for encapsulation "m".

7.2 Determination of faults

7.2.1 Fault examination

The encapsulation "m" shall not be invalidated even under the most adverse input rating, but between 90 % and 110 % of the rating and most adverse output load and up to two internal countable faults for level of protection "ma", and up to one internal countable fault for level of protection "mb.

No faults are taken into account for level of protection "mc".

NOTE Examples of faults are: a short circuit in any component; the failure of any component and a fault in the printed wiring board.

Components meeting the requirements of 7.2.2 are not considered to fail and infallible separation distances shall only be considered to fail in accordance with 7.2.4.

The failure of some components may result in an unstable condition, for example, alternating between high and low resistance. In those cases, the most onerous condition shall be considered.

If a fault leads to one or more subsequent faults, for example, due to the overload of a component, the primary and subsequent fault(s) shall be considered to be a single fault.

7.2.2 Components considered as not subject to fail

For levels of protection "ma" and "mb" the following components shall be considered as not to fail if they are encapsulated according to the requirements of this standard, if they are suitable for the service temperature and if they are not operated at more than 2/3 of their rated voltage, rated current or rated power specified by the manufacturer of the respective component:

– resistors, if they comply with the current limiting resistors of IEC 60079-11,
– single-layer, spirally wound coils,
– plastic foil capacitors,
– paper capacitors,
– ceramic capacitors,
– shunt semiconductors, if they are used in accordance with the shunt safety assemblies of IEC 60079-11,
– series semiconductor devices used to limit current:
  – a single device is adequate for level of protection "mb"
  – two devices shall be used for level of protection "ma".

For levels of protection "ma" and "mb" coils, motor windings and transformers that comply with IEC 60079-7, including also those that have wire diameters of less than 0,25 mm shall be considered as not subject to failure if they are encapsulated according to the requirements of this standard.

7.2.3 Isolating components

The following components for the segregation of different circuits shall be considered to provide isolation and are not considered to fail across the segregation:

- optocouplers and relays, if the rated insulation voltage conforms to $2U$ + 1 000 V r.m.s. $^{+5}_{0}$ % or 1 500 V r.m.s. whichever is greater (U is the sum of the rated r.m.s. voltages of both circuits);
- transformers, complying with IEC 61558-2-6 or IEC 60079-11.

7.2.4 Infallible separation distances

It is not necessary to consider the possibility of a fault occurring as described in 7.2.1 in respect of voltage breakdown, if the distances between bare current-carrying parts

– of the same circuit, or
– of a circuit and earthed metal parts, or
– of two separate circuits (sum of the working voltages shall be taken as the voltage for Table 1; where one of the working voltages is less than 20 % of the other, it shall be ignored),

comply with the requirements of 7.2.4.1 and if applicable 7.2.4.2.

7.2.4.1 Distances through the compound

Distances through compound shall be considered to be infallible against short circuit for level of protection "ma" and level of protection "mb" if they comply with the values in Table 1, provided that the distances in the compound are fixed or secured mechanically before encapsulation.

Distances between the minimum distances given for level of protection "mc" and the infallible distances given for level of protection "ma" and "mb" are not considered infallible and shall be

assessed as a "countable fault". Distances less than those given for level of protection "mc" are considered as short-circuits if this impairs the type of protection "m".

For level of protection "mc" the values of Table 1 are the constructional requirements and may be achieved by mechanically fixing before encapsulation.

Table 1 – Distances through the compound

Voltage *U* r.m.s. or d.c. (see note) V	**Minimum distance** mm		
	"ma"	"mb "	"mc "
≤32	0,5	0,5	0,2
≤63	0,5	0,5	0,3
≤400	1	1	0,6
≤500	1,5	1,5	0,8
≤630	2	2	0,9
≤1 000	2,5	2,5	1,7
≤1 600	-	4	4
≤3 200	-	7	7
≤6 300	-	12	12
≤10 000	-	20	20
NOTE Voltages shown are derived from IEC 60664-1. For all voltages, the actual voltage may exceed the value given in the table by up to 10 %. This is based on the rationalisation of supply voltages given in Table F.3b of IEC 60664-1.			

7.2.4.2 Distances through solid insulation

The distance through solid insulation, on which the type of protection "m" depends, shall be at least 0,1 mm and shall comply with the dielectric strength test of 8.2.4.

7.3 Free space in the encapsulation

7.3.1 Group III "m" equipment

The compound shall be free of voids.

The sum of the free spaces is not limited, but the volume of each individual free space is limited to 100 000 mm^3. The thickness of the compound surrounding such free spaces shall meet the requirements of Table 2.

Table 2 – Minimum thickness of compound adjacent to free space for Group III "m" equipment

Level of protection	**Minimum thickness of compound adjacent to free space to:**	**Free space ≤ 1 mm^3**	**Free space > 1 cm^3 ≤ 100 mm^3**
"ma"	Free space or free surface	3 mm	3 mm
	Non-metallic or metal enclosure with adhesion	3 mm (enclosure + compound)[a]	3 mm (enclosure + compound)[a]
	Non-metallic or metal enclosure without adhesion	3 mm	3 mm

Level of protection	Minimum thickness of compound adjacent to free space to:	Free space ≤ 1 mm³	Free space > 1 cm³ ≤ 100 mm³
"mb"	Free space or free surface	1 mm	3 mm
	Non-metallic or metal enclosure with adhesion	1 mm (enclosure + compound)	3 mm (enclosure + compound)[a]
	Non-metallic or metal enclosure without adhesion	1 mm	3 mm
"mc"	Free space or free surface	1 mm	1 mm
	Non-metallic or metal enclosure with adhesion	1 mm (enclosure + compound)	1 mm (enclosure + compound)
	Non-metallic or metal enclosure without adhesion	1 mm	1 mm
[a] Wall thickness of the enclosure ≥ 1 mm.			
NOTE The thickness of the materials quoted in this table does not imply compliance with other mechanical tests required by IEC 60079-0.			

7.3.2 Group I and Group II "m" equipment

The compound shall be free of voids.

The sum of the free spaces shall not exceed

- 100 000 mm³ for level of protection "mb" and "mc";
- 10 000 mm³ for level of protection "ma".

The minimum thickness of the compound surrounding such free spaces shall comply with Table 3.

Table 3 – Minimum thickness of compound adjacent to free space for Group I and Group II "m" equipment

Level of protection	Minimum thickness of compound adjacent to free space to:	Free space ≤ 1 cm³	Free space > 1 mm³ ≤ 10 mm³	Free space > 10 mm³ ≤ 100 mm³
"ma"	Free space or free surface	3 mm	3 mm (pressure test in accordance with 8.2.6)	Not permitted
	Non-metallic or metal enclosure with adhesion	3 mm (enclosure + compound)[a]	3 mm (enclosure + compound)[a] (pressure test in accordance with 8.2.6)	Not permitted
	Non-metallic or metal enclosure without adhesion	3 mm	3 mm (pressure test in accordance with 8.2.6)	Not permitted
"mb"	Free space or free surface	1 mm	3 mm	3 mm (pressure test in accordance with 8.2.6)

Level of protection	Minimum thickness of compound adjacent to free space to:	Free space ≤ 1 cm^3	Free space > 1 mm^3 ≤ 10 mm^3	Free space > 10 mm^3 ≤ 100 mm^3
	Non-metallic or metal enclosure with adhesion	1 mm (enclosure + compound)	3 mm (enclosure + compound) [a]	3 mm (enclosure + compound) [a] (pressure test in accordance with 8.2.6)
	Non-metallic or metal enclosure without adhesion	1 mm	3 mm	3 mm (pressure test in accordance with 8.2.6)
"mc "	Free space or free surface	1 mm	1 mm	3 mm
	Non-metallic or metal enclosure with adhesion	1 mm (enclosure + compound)	1 mm (enclosure + compound)	3 mm (enclosure + compound) See note
	Non-metallic or metal enclosure without adhesion	1 mm	1 mm	3 mm
[a] Wall thickness of the enclosure ≥ 1 mm.				
NOTE The thickness of the materials quoted in this table does not imply compliance with other mechanical tests required by IEC 60079-0.				

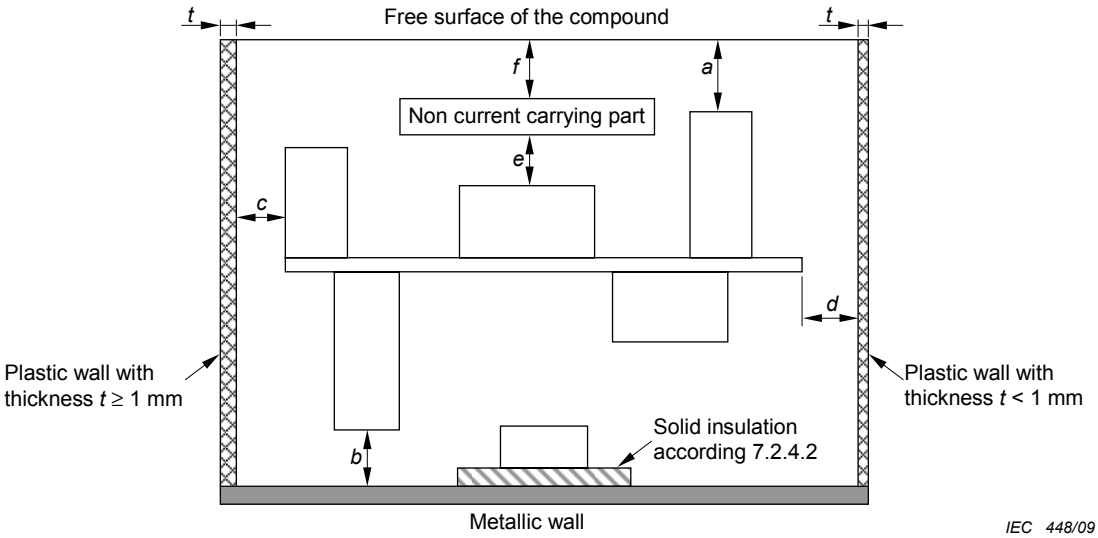
7.4 Thickness of the compound

7.4.1 "m" equipment

The minimum thickness of compound surrounding the electrical components and circuit shall be in accordance with Table 4 and Figure 1.

If solid insulation according to 7.2.4.2 is used in an enclosure with metallic walls as shown in Figure 1, the compound shall adhere to the wall.

NOTE Figure 1 does not necessarily represent a practical construction, but is intended to assist in understanding Table 4 by showing an encapsulated circuit with all of: a free surface; a metallic enclosure; a plastic enclosure with different wall thicknesses.



Key

a distance to free surface

b distance to metallic enclosure

c distance to plastic enclosure with wall thickness $t \geq 1$ mm

d distance to plastic enclosure with wall thickness $t < 1$ mm

e distance to non current carrying part within the compound

f distance from non current carrying part to free surface

Figure 1 – Dimensional key for thickness through the compound

In all cases the compound shall be subjected to the dielectric strength test of 8.2.4.

Table 4 – Thickness of the compound

	Level of protection "ma"	Level of protection "mb" or "mc"
Free surface ≤ 2 cm^2	$a \geq 3$ mm	$a \geq$ distance according to Table 1 but not less than 1 mm
Free surface > 2 cm^2	$a \geq 3$ mm	$a \geq$ distance according to Table 1 but not less than 3 mm
Plastic housing with adhesion (wall thickness $t < 1$ mm)	$d \geq 3$ mm	$d \geq$ distance according to Table 1 but not less than 1 mm
Plastic housing with adhesion (wall thickness $t \geq 1$ mm)	$c \geq (3\text{ mm} - t)$ [a]	$c \geq$ (distance according to Table 1 $- t$)[a]
Plastic housing without adhesion	$c = d \geq 3$ mm	$c = d \geq$ distance according to Table 1 but not less than 1 mm
Metal housing	$b \geq 3$ mm	$b \geq$ distance according to Table 1 but not less than 1 mm
Non current carrying part	$e \geq 3$ mm	$e \geq$ distance according to Table 1 but not less than 1 mm
Non current carrying part – free surface	$f + e \geq a$	$f + e \geq a$

[a] In the case of plastic housing with adhesion and wall thickness ≥ 1mm if the application of the formula allows $c = 0$ the component may be against the wall.

7.4.2 Windings for electrical machines

For electrical machines with windings in slots, the solid slot insulation shall have:

a) for level of protection "ma" only, a minimum thickness of 0,1 mm and shall be extended by at least 5 mm beyond the end of the slot;

b) for levels of protection "ma" and "mb", the end of the slot and the end-winding shall be protected by the minimum thickness of compound in accordance with 7.4.1. A dielectric strength test in accordance with 8.2.4, shall be passed with a test voltage $U = 2U +$ 1 000 V r.m.s. $^{+5}_{0}$ % with a minimum of 1 500 V a.c. at 48 Hz to 62 Hz.

7.4.3 Rigid, multi-layer printed wiring boards with through connections

7.4.3.1 General

Multi-layer printed wiring boards complying with the requirements of IEC 62326-4-1, performance level C, operated at voltages less than or equal to 500 V, shall be considered to be encapsulated providing they meet 7.4.3.2

7.4.3.2 Minimum distances

The insulation thickness of both, the copper-clad laminates and the adhesive films shall comply with the requirements of 7.2.4.2.

The minimum distance between the printed circuit conductors and the edge of the multi-layer printed wiring board or any hole in it shall be at least distance b of Table 5. If the edges or holes are protected with metal or insulating material extending at least 1 mm along the surface of the board from the edges or holes, the distance between the printed wiring conductors and the metal or insulating material may be reduced to distance c of Table 5. Metal coating shall have a minimum thickness of 35 μm, see also Figure 2 and Table 5.

Table 5 – Minimum distances for multi-layer printed wiring boards

Distance	Level of protection "ma"	Level of protection "mb"	Level of protection "mc"
a	3 mm	0,5 mm	0,25 mm
b	3 mm	3 mm	1mm
c	3 mm	1 mm	0,5 mm
d	0,1 mm, see 7.2.3.2	0,1 mm, see 7.2.3.2	0,1 mm, see 7.2.3.2
e	In accordance with Table 1	In accordance with Table 1	In accordance with Table 1

where

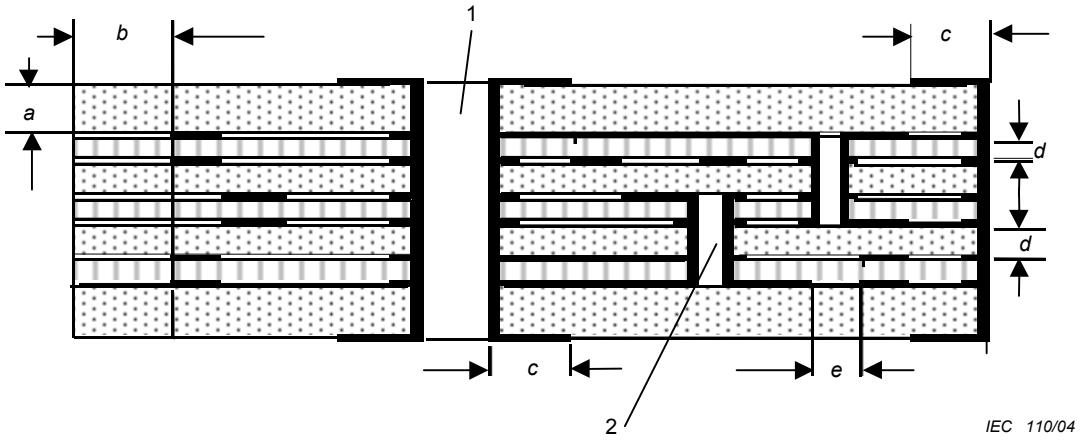
a is the distance between the current carrying part and the outside surface through the cover layer;

b is the distance between the current carrying part and the outside surface along the cover layer;

c is the length of metal or insulation extending along the surface of the board from the edge or the hole;

d is the thickness of the adhesive film or the core where segregation is required;

e is the distance between two circuits inside the multilayer where segregation is required.



Key

core and cover layer

adhesive filmcopper

copper

1 Through contact for termination

2 Through contact to connect the printed conductors to the layers

Figure 2 – Minimum distances for multi-layer printed wiring boards

7.5 Switching contacts

NOTE Compound should not enter the enclosure of the switching contacts during the encaspulation process

7.5.1 Level of protection "ma"

Switching contacts shall be provided with an additional enclosure in accordance with the requirements for hermetically-sealed devices as defined in IEC 60079-15 before encapsulation.

NOTE This additional enclosure should withstand all stresses during potting and all stresses expected during lifetime of the equipment.

The rating of the switching contact shall be less or equal 60 V and 6 A. The additional enclosure shall be made of inorganic material if the switched current exceeds 2/3 of the rated current specified by the manufacturer of the component.

7.5.2 Level of protection "mb"

Switching contacts shall be provided with an additional enclosure before encapsulation. This additional enclosure shall be made of inorganic material if the switched current exceeds 2/3 of the rated current specified by the manufacturer of the component or if the current exceeds 6 A.

7.5.3 Level of protection "mc"

Switching contacts shall be provided with an additional enclosure before encapsulation. This additional enclosure shall be made of inorganic material if the switched current exceeds 6 A.

7.6 External connections

7.6.1 General

The entry of all electric conductors, including cables, into the compound shall be designed in such a way that the ingress of an explosive atmosphere into the "m" equipment under normal operating conditions and fault conditions in 7.2 is prevented.

NOTE This may be achieved by a bare conductor path in the compound that is at least 5 mm long.

When compounds are used to secure a permanently connected cable, the cable shall be suitably protected against damage from flexing and the pull test shall be carried out according to 8.2.5

7.6.2 Additional requirements for "ma" equipment

External connections shall meet the following requirements:

- for EPL Ma, level of protection "ia" ;
- for EPL Ga, the "Ga" requirements of IEC 60079-26 ;
- for EPL Da, the "Da" requirements of IEC 60079-31 or IEC 61241-11, level of protection "iaD".

NOTE IEC 61241-11 specifies "category" "iaD" and "ibD" and refers to Clause 5 of IEC 60079-11 where "ia" and "ib" are identified as "levels of protection". For the purposes of IEC 60079-18, the terms "category" and "level of protection" should be considered to be synonymous.

7.7 Protection of bare live parts

Depending on the required EPL bare live parts that pass through the surface of the compound shall be protected by another type of protection as listed in IEC 60079-0 for the required EPL.

NOTE This implies that the equipment be marked as combined types of protection in accordance with IEC 60079-0

7.8 Cells and batteries

7.8.1 General

When evaluating battery control arrangements with respect to the potential release of gas, the full range of operating temperatures, internal resistance and voltage capability shall be considered. It shall be assumed that batteries can become unbalanced, but cells with negligible resistance or voltage capability need not be taken into account.

Subclause 7.8 applies to all levels of protection, unless specifically excluded.

For level of protection "ma" cells and batteries shall additionally comply with the cell and battery requirements of IEC 60079-11 except for the relaxation for parallel cells, which are not permitted in equipment solely protected by encapsulation.

7.8.2 Prevention of gassing

Electrochemical systems that can release gas during normal operation are not permitted. If for levels of protection "ma" and "mb" the release of gas in the event of a fault cannot be precluded, the gassing shall be minimised by a control device in accordance with 7.8.8. With secondary cells, the control device shall be effective not only during charging, but also during discharging. This also applies for charging outside the hazardous area.

In particular,

a) vented cells shall not be used,

b) sealed valve regulated cells shall not be used,

c) sealed gas-tight cells that, within the range of the ambient temperature of the electric equipment, do not release gas under any operating or fault conditions may be used without a control device in accordance with 7.8.8.

Gas-tight cells that do not fulfil the requirements of 7.8.2 c) shall have a control device in accordance with 7.8.8.

7.8.3 Protection against inadmissible temperatures and damage to the cells

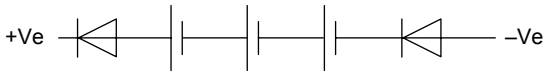
Cells or batteries under worst case load shall comply with either a) or b):

a) in normal service, the surface temperature of the cells shall not exceed either the temperature specified by the manufacturer of the cells or batteries, or 80 °C if not specified by the manufacturer, at the maximum ambient temperature of the equipment, and the maximum charging and discharging current shall not exceed the safe value specified by the manufacturer, or

b) cells or batteries shall be provided with one or more control devices as described in 7.8.5 or 7.8.8, to prevent unacceptable overheating or gassing inside the compound.

7.8.4 Reverse current

For level of protection "ma" and "mb" where there is another voltage source in the same enclosure, the encapsulated cell or battery and its associated circuits shall be protected against charging by circuits other than those specifically designed for charging. For example, by separating the cell or battery and its associated circuits from all other voltage source(s) inside the enclosure, using the distances specified in Table 1 for the highest voltage capable of causing the reverse current. Alternatively, the cell or battery only may be separated, from the other voltage source(s) using the distances specified in Table 1, but with one blocking diode for level of protection "mb", or two blocking diodes for level of protection "ma", fitted as shown in Figure 3 below, and so arranged as to reduce the risk of a single fault causing both diodes to be short-circuited.



IEC 449/09

NOTE Figure shows arrangement for level of protection "ma".

Figure 3 – Fitting of blocking diodes

7.8.5 Current limitation

The maximum surface temperature shall be determined using the highest discharge current permitted by the maximum load specified by the equipment manufacturer, or by the protective device, see 7.9, for example 1,7 x rating of the fuse, or at short circuit if neither a load nor a protective device is specified.

A resistor, a current limiting device or a fuse according to IEC 60127 or an equivalent standard may be used to ensure the maximum discharge current specified by the manufacturer of the cells or battery is not exceeded. If replaceable fuses are used the equipment shall be marked to show their rating and function.

7.8.6 Protection against the polarity inversion and deep discharge of the cells

For level of protection "ma" and "mb" when more than 3 cells are used in series, the cell voltage shall be monitored. During discharging, if the voltage falls below the limit value for the cell voltage specified by the manufacturer of the cells or battery, the control device shall disconnect the cells or battery. For level of protection "mc", if more than three cells are

connected in series, precautions shall be taken to prevent reverse polarity charging of the cell.

NOTE 1 If several cells are connected in series, cells can change polarity during discharge due to the various capacities of the cells in a battery. These "reversed pole“ cells can enter an inadmissible gassing range.

Where a deep discharge protection circuit is used to prevent reverse polarity charging of cells during discharge, the minimum cut-off voltage shall be that specified by the cell or battery manufacturer. After disconnecting the load, the current shall be no more than the discharge capacity at the 1 000 h rate.

NOTE 2 If too many cells are connected in series, there may be no safe protection due to the tolerances of the individual cell voltages and the deep discharge protection circuit. Generally no more than six cells (in series) should be protected by one deep discharge protection circuit.

7.8.7 Charging of cells or batteries

7.8.7.1 Level of protection “ma” and “mb”

The charging circuits shall be fully specified as part of the equipment. The charging system shall be such that either:

a) with one fault condition of the charging system, the charging voltage and current shall not exceed the limits specified by the manufacturer;

   or

b) if, during charging, it is possible for the limit values specified by the manufacturer of the cells or battery for the cell voltage or the charging current to be exceeded, a separate protective device in accordance with 7.9 shall be provided to minimize the possibility of a release of gas and also exceeding the manufacturer’s maximum rated cell temperature during charging.

7.8.7.2 Level of protection “mc”

The charging system shall be such that in normal operation the charge voltage and current do not exceed the limits specified by the manufacturer based on the specified temperature range of the equipment. If cells and batteries, which are an integral part of the electrical equipment are to be charged in the hazardous area, the charger shall be fully specified as part of the equipment design. If cells or batteries, which are an integral part of the electrical equipment or can be separated from the equipment are charged outside of the hazardous area, the charging shall be within the limits specified by the manufacturer of the equipment.

7.8.8 Requirements for control safety devices for cells or batteries

Where required, the control devices shall form safety related parts of a control system. It shall be the responsibility of the manufacturer to provide the information necessary to maintain the integrity of the system.

NOTE Safety related parts meeting the requirements of PL c of ISO 13849-1 “Safety of machinery – Safety related parts of control systems – Part 1: General principles for design” would satisfy this subclause.

7.9 Protective devices

7.9.1 General

Where the “m” equipment is not able to withstand a single fault for level of protection “mb” or two faults for level of protection “ma” without exceeding the COT of the compound, or the temperature class for explosive gas atmosphere or the maximum surface temperature in degree Celsius for explosive dust atmosphere, a protective device shall be provided either external to the equipment or directly integrated into the equipment. Protective devices for level of protection “ma” shall be non resettable. Thermal protective devices for level of protection “mb” may be resettable.

NOTE 1 For level of protection "mc" the equipment operating under normal conditions should not exceed the COT of the compound or the temperature class for explosive gas atmospheres or the maximum surface temperature in degree Celsius for explosive dust atmosphere.

The protective device shall be capable of interrupting the maximum fault current of the circuit in which it is installed. The rated voltage of the protective device shall at least correspond to the working voltage of the circuit in which it is installed.

Where the "m" equipment contains a cell or battery and a control device is provided to prevent excessive overheating (see 7.8.5), the control device can also be considered as a protective device, providing it also protects all other components inside the same compound from exceeding the COT or temperature class for explosive gas atmospheres or the maximum surface temperature in degree Celsius for explosive dust atmospheres .

NOTE 2 The use of protective devices is to protect against faults and unforeseen overloads which overheat and/or permanently damage or compromise the operational life of the equipment. Where resettable devices are used, instructions should be provided to guide the user in the desirability of re-setting the devices. These instructions should consider external operational conditions under which they might be reset and also any subsequent monitoring that might be desirable.

NOTE 3 Both self-resetting and manually resettable devices are considered to be resettable devices for the purpose of this standard.

For level of protection "ma", if the non resettable protective device complies with IEC 60127 series or IEC 60691 or ANSI/UL 248-1, only one device is necessary.

7.9.2 Electrical protective devices

7.9.2.1 General

Fuses shall have a voltage rating not less than that of the circuit in which they are installed and shall have a breaking capacity not less than the fault current of the circuit. Unless otherwise specified, a fuse shall be assumed to be capable of passing 1,7 x rated current continuously. The time-current characteristic of the fuse, as stated by the manufacturer of the fuse, shall ensure that the COT of the compound and the temperature class for explosive gas atmospheres or the maximum surface temperature in degree Celsius for explosive dust atmospheres are not exceeded.

For electrical protective devices two devices are required for level of protection "ma" and one device is required for level of protection "mb".

An electrical protective device is not required for level of protection "mc".

NOTE In the case of electrical supply networks where the rated voltage does not exceed 250 V, the prospective short-circuit fault current is usually 1 500 A.

7.9.2.2 Protective devices that are connected to the "m" equipment

If the protective device is external to the "m" equipment it shall be seen as equipment required for the safety of the "m" equipment, in accordance with 7.9.2. This specific condition of use shall appear on the certificate and the equipment shall be marked in accordance with the "specific conditions of use" marking requirements of IEC 60079-0.

The use of an external protective device and its connection to "m" equipment requires the device to have a suitable type of Ex protection compatible with "ma", "mb", or "mc" as appropriate.

NOTE Failure to use such a device in the intended manner will lead to loss of level of protection. Where an external protective device is used to control the correct application of voltage, current and power to equipment with level of protection "ma", the performance of the external protective device or protective circuit should be safe with one countable fault. The permitted levels of voltage, current and power should be determined by the thermal characteristics of the "m" equipment.

7.9.3 Thermal protective devices

Thermal protective devices shall be used to protect the compound from damage caused by local heating, for example, by faulty components or from exceeding the maximum surface temperature (temperature class for explosive gas atmospheres, or the maximum surface temperature in degree Celsius for explosive dust atmospheres).

Non-resettable devices have no provision for being reset and open a circuit permanently after being exposed to a temperature higher than their operating temperature for a given maximum period. Adequate thermal coupling shall be achieved between the monitored component and the thermal protective device. The switching capability of the device shall be defined and shall be not less than the maximum possible load of the circuit.

NOTE Additional resettable devices may be used for functional reasons. If these devices are used, they should operate at temperatures lower than the operating temperature of the thermal protective device.

If resettable thermal protective devices are used, two devices in series are required for type of protection “mb” and one device is required for type of protection “mc”.

Resettable thermal protective devices with switching contacts shall not be operated at more than 2/3 of their rated current and voltage specified by the manufacturer of the device.

Resettable thermal protective devices with switching contacts shall either comply with IEC 60730-2-9, or shall be tested according to 8.2.7.1

Resettable thermal protective devices without switching contacts shall either comply with IEC 60738-1, or shall be tested according to 8.2.7.2

7.9.4 Built-in protective devices

Protective devices integral with the “m” equipment shall be of the enclosed type such that no compound can enter during the encapsulation process.

The suitability of the protective device for encapsulation shall be confirmed either by:

a) a documentation from the manufacturer of the device ;

or

b) testing of samples according 8.2.8

NOTE Devices in glass, plastic, ceramic or otherwise sealed are regarded as enclosed types.

8 Type tests

8.1 Tests on the compound

8.1.1 Water absorption test

The test shall be carried out only on samples of the compound(s) used in “m” equipment, which are intended to be used in a moist environment during operation of the “m” equipment.

Three dry samples, see ISO 62, of the compound(s) shall be tested. The samples shall be circular with a diameter of 50 mm ± 1 mm and a thickness of 3 mm ± 0,2 mm. The samples shall be weighed then immersed for at least 24 h in water, at a temperature of 23 °C $^{+2}_{0}$ K. They shall then be taken out of the water, wiped dry and weighed again. The increase in mass shall not exceed 1 %.

NOTE It is not required to use distilled water for this test.

8.1.2 Dielectric strength test

The sample shall be circular with a diameter of 50 mm ± 1 mm and a thickness of 3 mm ± 0,2 mm. The sample shall be symmetrically placed between electrodes 30 mm ± 1 mm in diameter, within a temperature controlled oven, set to achieve the highest temperature defined in 3.3.

A voltage of 4 kV r.m.s. $^{+5}_{0}$ % and with frequency between 48 Hz and 62 Hz shall be applied for not less than 5 min. No flashover or breakdown shall occur during the test.

8.2 Tests on the apparatus

8.2.1 Test sequence

The test sequence and number of samples are given in Annex B.

8.2.2 Maximum temperature

A sample of "m" equipment shall be subjected to a type test to ensure that:

a) the temperature limits specified in 6.1 are not exceeded in normal operation;

b) for level of protection "ma" and "mb" the maximum surface temperature is not exceeded under fault conditions as defined in 7.2.1.

For "m" equipment without an external load, the test shall be carried out in accordance with the temperature measurements of IEC 60079-0 taking into account the supply conditions given in 4.3.

For "m" equipment with an external load, the test shall be carried out for level of protection "ma" and "mb" by adjusting the current to the highest value, which does not cause the protective device to operate, and for level of protection "mc" at the specified load parameters in normal operation and in the case of regular expected occurrences.

NOTE For equipment with characteristics such as non linear external loads, input power control or difficult to define failure modes, testing, simulation and analysis may be necessary in order to achieve safety under malfunction conditions.

8.2.3 Thermal endurance test

8.2.3.1 Thermal endurance to heat

8.2.3.1.1 Level of protection "ma" and "mb"

The test shall be carried out in accordance with IEC 60079-0. The temperature to be used as the reference service temperature for the test shall be the higher of the following:

a) the maximum surface temperature of the test sample taking into account fault conditions, see 8.2.2;

or

b) the maximum temperature at the component surface in the compound under normal operation, see 6.2.2.

8.2.3.1.2 Level of protection "mc"

The test shall be carried out in accordance with IEC 60079-0.

The temperature to be used shall be the maximum surface temperature under normal operation, see 6.2.1, of the test sample plus at least 20 K.

8.2.3.2 Thermal endurance to cold

The test shall be carried out in accordance with IEC 60079-0.

8.2.3.3 Acceptance criteria

After each test the sample shall be subjected to a visual inspection. No visible damage to the compound that could impair the type of protection shall be evident, for example cracks in the compound, exposure of encapsulated parts, failure of adhesion, inadmissible shrinkage, discoloration, swelling, decomposition or softening. A discoloration on the surface of the compound is permissible (for example oxidation in the case of epoxy resin).

In addition, any electrical protective device on which safety depends, other than thermal fuses, shall be verified as remaining functional.

8.2.4 Dielectric strength test

8.2.4.1 Test procedure

The test shall be carried out on the following arrangements of circuits as applicable:

a) between galvanically isolated circuits;

b) between each circuit and all earthed parts;

c) between each circuit and the surface of the compound or the non-metallic enclosure that, if necessary, can be clad with a conductive foil.

For arrangement a), the voltage *U* to be used shall be the sum of the rated voltages of the two circuits being tested and for arrangements b) and c), the voltage *U* to be used shall be the rated voltage of the circuit being tested.

For equipment where the voltage *U* does not exceed 90 V peak, the test voltage shall be 500 V r.m.s. ($^{+5}_{0}$ %) at 48 Hz to 62 Hz.

For equipment where the voltage *U* exceeds 90 V peak, the test voltage shall be 2*U* + 1 000 V r.m.s. ($^{+5}_{0}$ %), with a minimum of 1 500 V r.m.s. at 48 Hz to 62 Hz. Alternatively, the test voltage shall be 2*U* + 1400 V d.c. ($^{+5}_{0}$ %) with a minimum of 2100 V d.c.

The test voltage shall be increased steadily within a period of not less than 10 s until it reaches the prescribed value, and it shall then be maintained for at least 60 s.

NOTE 1 In the case of equipment that, for electro-magnetic compatibility reasons, contain components connected to the enclosure for the suppression of interference pulses and which could be damaged during the tests, a partial discharge test may be considered.

NOTE 2 If the circuit under test is not accessible from the exterior it may be necessary to prepare a specific test sample with additional connections

8.2.4.2 Acceptance criteria

The test shall be deemed as passed if no breakdown or arcing occurs during testing.

8.2.5 Cable pull test

8.2.5.1 Test procedure

The test shall be carried out on one sample, previously unstressed and at 21 °C ± 2 °C

A further test sample shall be subjected to the cable pull test after conditioning according to 8.2.3.1 at the maximum temperature at the cable entry point.

The tensile force (in Newton) applied shall either be 20 times the value in millimetres of the diameter of the cable or 50 times the mass (in kilograms) of the "m" equipment, whichever is the lower value. This value can be reduced to 25 % of the required value in the case of permanent installations. The minimum tensile force shall be 1 N and the minimum duration shall be 1 h. The force shall be applied in the least favourable direction.

This test shall not be performed on "Ex" components.

8.2.5.2 Acceptance criteria

After testing, the sample shall be subjected to a visual inspection. Visible displacement of the cable, which affects the type of protection, shall not be evident. No damage to the compound or cable that could impair the type of protection shall be evident, for example, cracks in the compound, exposure of the encapsulated components or failure of adhesion.

8.2.6 Pressure test for Group I and Group II electrical equipment

8.2.6.1 Test procedure

For level of protection "ma" with any individual free spaces between 1 cm^3 and 10 cm^3 and level of protection "mb" with any individual free spaces between 10 cm^3 and 100 cm^3, test samples shall be prepared with a pressure connection. Where there is more than one free space of a size requiring testing, the pressure test shall be carried out simultaneously in all those free spaces.

The pressure test shall be carried out on samples that have already been submitted to the thermal endurance tests see 8.2.3.

The test shall be carried out with a pressure as shown in Table 6 applied for at least 10 s.

Table 6 – Test pressure

Minimum ambient temperature °C	**Test pressure** kPa
≥ –20 (see note)	1 000
≥ –30	1 370
≥ –40	1 450
≥ –50	1 530
≥ –60	1 620
NOTE This covers equipment designed for the standard ambient temperature range specified in IEC 60079-0.	

8.2.6.2 Acceptance criteria

After testing, the samples shall be visually inspected. No compound damage (such as cracks in the compound, exposure of the encapsulated components or failure of adhesion) that could impair the type of protection shall be evident.

8.2.7 Test for resettable thermal protective device

8.2.7.1 Resettable thermal protective devices with switching contacts

8.2.7.1.1 Test procedure

The function of the protective device shall be verified. This test shall be performed after the thermal endurance test. The device must be capable switching its rated current ≥ 5 000 times.

8.2.7.1.2 Acceptance criteria

The test shall be deemed as passed if the protective device acts correctly after the test in the range specified in its datasheet

8.2.7.2 Resettable thermal protective devices without switching contacts

8.2.7.2.1 Test procedure

The function of the protective device shall be verified. This test shall be performed after the thermal endurance test. The device shall be capable of acting (direct or indirect limiting the temperature rise) ≥ 500 times.

8.2.7.2.2 Acceptance criteria

The test shall be deemed as passed if the protective device acts correctly after the test in the range specified in its datasheet

8.2.8 Sealing test for build-in protective devices

With the test samples at an initial temperature of (25 ± 2) °C, they are suddenly immersed in water at a temperature of (65 ± 2) °C to a depth of 25 mm for 1 min. If no bubbles emerge from the samples during this test, they are considered to be "sealed" for the purposes of this standard.

9 Routine verifications and tests

9.1 Visual inspections

Each piece of “m” equipment shall be subjected to a visual inspection. No damage shall be evident, such as cracks in the compound, exposure of the encapsulated parts, flaking, inadmissible shrinkage, swelling, decomposition, failure of adhesion or softening.

9.2 Dielectric strength test

For circuits, which are accessible from the exterior the dielectric strength test shall be used to test the isolation of circuits from each other and from their environment. The test shall be carried out on these circuits in accordance with 8.2.4.

The test voltage shall be applied for at least 1 s.

Alternatively, 1,2 × test voltage may be applied and maintained for at least 100 ms.

NOTE In some cases, the actual test period could be significantly longer than 100 ms as a sample with a large distributed capacitance may take some additional time to reach the actual test voltage.

The test shall be deemed as passed if no breakdown or arcing occurs during testing.

Contrary to the above, the dielectric strength test for cells or batteries shall be carried out in accordance with the routine dielectric test requirements of IEC 60079-7.

10 Marking

In addition to the requirements of IEC 60079-0, the marking shall include:

a) the rated voltage,

b) the rated current,

c) the prospective short-circuit current of the external electric supply source if less than 1 500 A, for example “Permitted supply short-circuit current: 500 A”.

d) optionally, the permitted prospective short-circuit current of the external electrical supply if the equipment is designed for a short-circuit current of 1 500 A or more, for example “Permitted supply short-circuit current: 3 500 A”.

e) other information necessary for safe operation of the particular equipment.

Annex A
(informative)

Basic requirements for compounds for "m" equipment

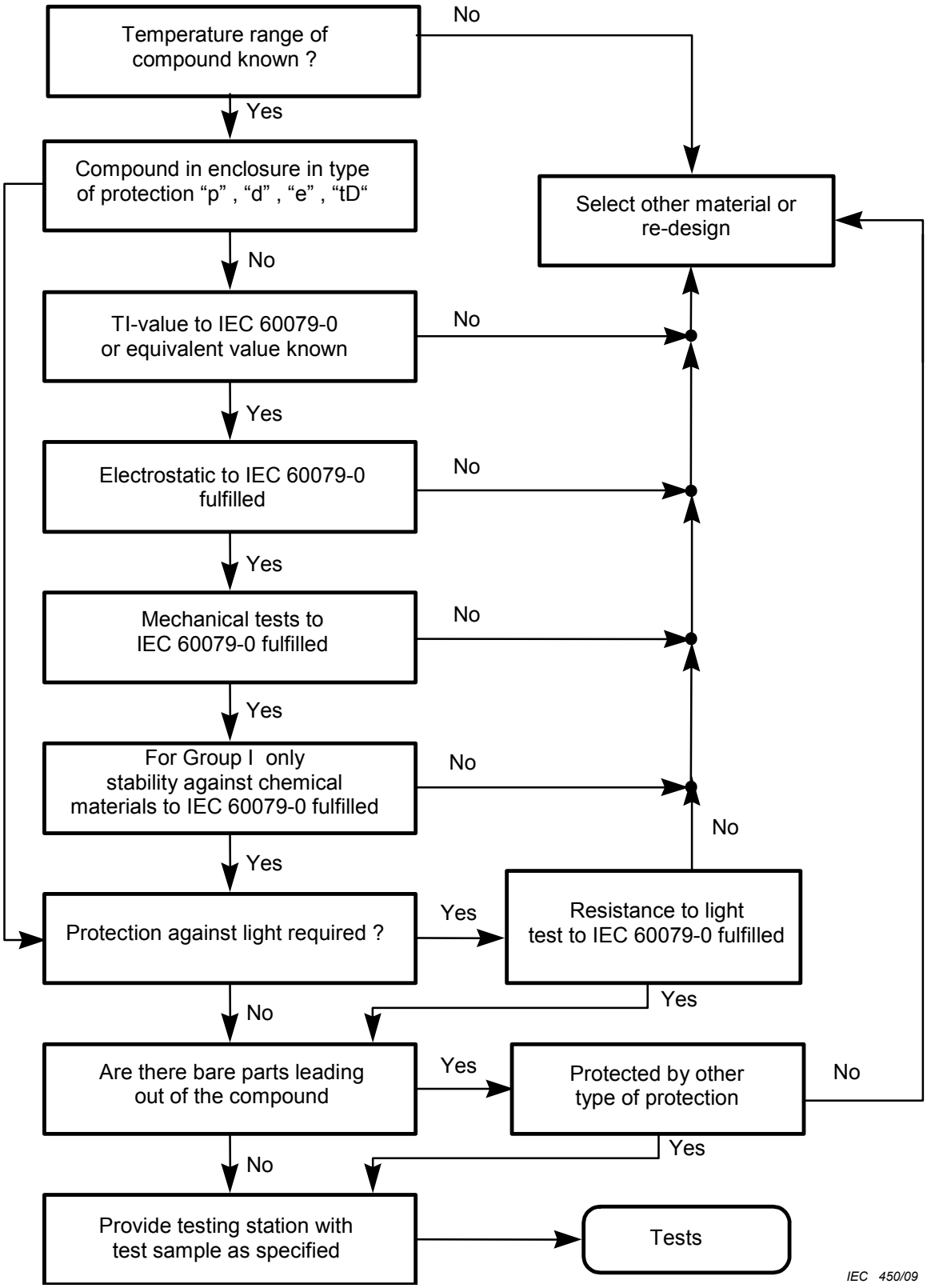


Figure A.1 – Basic requirements for compounds for "m" equipment

Annex B
(normative)

Allocation of test samples

Table B.1 – Allocation of test samples

Standard tests		Additional tests	
Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Determination of limiting temperature in accordance with 6.3			
		Cable pull test in accordance with 8.2.5	Thermal endurance test based on the service temperature determined at the point where the cable enters the compound in accordance with 8.2.3.1
Thermal endurance to heat in accordance with 8.2.3.1	Thermal endurance to heat in accordance with 8.2.3.1		
Thermal endurance to cold in accordance with 8.2.3.2	Thermal endurance to cold in accordance with 8.2.3.2		
Resettable thermal protective device test in accordance with 8.2.7	Resettable thermal protective device test in accordance with 8.2.7		Cable pull test in accordance with 8.2.5
Dielectric strength test in accordance with 8.2.4	Dielectric strength test in accordance with 8.2.4		
Pressure test in accordance with 8.2.6 (if required)	Pressure test in accordance with 8.2.6 (if required)		
Mechanical tests in accordance with IEC 60079-0 (if required)	Mechanical tests in accordance with IEC 60079-0 (if required)		
Note: The tests are carried out in the order they appear in each column.			

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