INSTRUCTION DE SÉCURITÉ
SAFETY INSTRUCTION

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Criteria and Standard Test Methods for the Selection of Electric Cables and Wires with Respect to Fire Safety and Radiation Resistance

This Safety Instruction is published by the Safety Commission as defined by the CERN Safety Policy document SAPOCO/42 and under the provisions of the CERN Safety Codes. It is based on:

- The CERN Fire Code E
- Standards and publications of the IEC and other internationally recognized bodies
- The CERN Electrical Safety Code C1
- Recommendations of the Materials and Cable Working Group on fire and radiation resistant cables.

This Instruction is intended to ensure a very high level of safety and must be applied to all new cable installations at CERN, including the addition of cables to existing installations. CERN attaches an increased importance to the hazards associated with smoke, toxicity and corrosivity from burning plastics.

In particular, IS23 must be fully taken into account in the specifications for all cable purchases. It is also applicable to the CERN infrastructure such as cranes, lifts, ventilation plants, etc.

EDMS 335745

Contents

1 Introduction and Scope

This instruction prescribes standard test methods for selecting suitable materials for the insulation and sheathing of power, control and signal cables and wires with respect to their resistance to fire and ionizing radiation. It summarizes the required properties for the different materials and cable types, giving criteria for their specification, selection and testing. It is applicable to all kinds of cables and wires to be used in CERN installations, including equipment for prototypes, tests and experiments (power, control, signal, high and low voltage, high and low frequency, fiber optics, etc.). The use of other insulated parts associated to electrical installations is covered in IS41.

2 Required Properties of Cable Insulating Materials

The requirements for all types of cables are the following:

- Electrical, mechanical, thermal and environmental endurance properties conforming to the appropriate standards
- Flame retardant characteristics satisfying the relevant standards
- Halogen and sulphur free
- Low smoke density
- Low toxicity of gases from fires
- Low corrosivity of gases from fires
- Retention of functional capabilities up to the specified Radiation Index (up to an integrated radiation dose of 5×10^5 Gy for general purpose cables and 10^7 Gy for special radiation resistant cables).

Note: The requirements of low smoke density, low toxicity and corrosivity of gases from fires exclude some very commonly available materials such as polyvinyl chloride (PVC), chlorosulphonated polyethylene (Hypalon®), polychloroprene (Neoprene®), fluorocarbons (e.g. Teflon®) and other halogenated or sulphur containing compounds.

3 Criteria for Specification and Selection of Cable Insulating Materials

3.1 Applicable standards

The required properties are described in this section and summarized together with the standards in Table 1 and Appendix 3. Independent laboratories capable of carrying out fire, smoke and toxicity tests are listed in Appendix 2.

3.2 Flame propagation and fire resistance

A distinction is made between the fire properties of materials and those for cables. Using flame retardant materials is a pre-requisite but does not guarantee that the finished cable will have the required fire properties.

Electric cables and wires can be classified in four categories with increasing fire resistance:

i) Small, single-core, insulated wires with conductors smaller than 0.8 mm diameter (0.5 mm^2) shall be tested according to IEC 60332-2.

ii) Single-core insulated wires with conductors greater than 0.5 mm^2 and all multiconductor cables, round or flat of any dimension, shall pass IEC 60332-1. For flat cables the flame shall be applied to one edge of the flat cable with the axis of the burner tube in the same plane as the major axis of the cables.

iii) All types of finished cables having an outer diameter exceeding 10 mm. and all those to be used in bunches, must be tested under bunched configuration and pass the IEC 60332-3 test, Category 24.

iv) Fire resistant cables are those which must continue to function for a defined time during and after a fire. They are mainly used for safety installations. They have to comply with IEC 60331 standard.

3.3 Smoke density

Samples of finished cables and wires shall be tested according to ASTM E 662, or ISO 5659-2. The required value of the specific optical density, Ds, is less than 250 in both the flaming and non-flaming modes.

For all major CERN cable contracts the cables must in addition pass the more extensive tests IEC 61034, Part 1 and Part 2.

3.4 Toxicity of gases from fires

The IEC 60695-7 part 50 and 51 shall be applied to finished cable. The principle of this method is to calculate the fractional effective dose of toxic products accumulated by exposure to the effluent from a fire.

All the results must be analyzed with the Gas and Chemistry Section of the CERN Safety Commission.

3.5 Corrosivity of gases from fires

All constituent materials of cables, including tapes and fillers, must be halogen and sulphur free. The materials must pass the IEC 60754-2 test with pH greater than 4.3 and conductivity less than 100 μS/cm.

3.6 Radiation resistance

The specification requirements below apply to all installation of cables in areas of CERN where the life dose is expected to exceed 100 Gy.

A distinction is made between general purpose cables and special cables used in high-radiation areas.

Common optical fiber cables are very sensitive to radiation. It is recommended not to use them in radiation areas.

3.6.1 General purpose cables

For cables with common elastomeric or thermoplastic insulation and sheath materials the radiation resistance and Radiation Index (RI) are assessed according to IEC 60544-4.

This Standard recommends as critical property the elongation at break of insulating material measured according to ISO R37 (elastomer) or ISO R527 (plastic).

The radiation index is defined as the logarithm (log 10) of the absorbed dose in gray (Gy), rounded off to two significant figures, above which the value of the appropriate critical property has reached the end-point criterion under the specified conditions. For example, a material which satisfies the end-point at 5×10^5 Gy, has a radiation index of 5.7 (i.e. log 5×10^5 = 5.699).

The elongation as end point criterion may be expressed as an absolute value e.g. 100% or as a percentage of the initial value, e.g. 50%.

The value of RI will be specified in relation to the application. It is however strongly recommended to specify for cables of multi purpose applications e.g. those in the CERN Stores, a RI of 5.7 which corresponds to an integrated dose of 5×10^5 Gy.

Note: The recommendation is based on long experience which has shown that this specification requirement can be fulfilled for a large number of cable materials available on the market from many different manufacturers.

The Radiation Protection Group of CERN can arrange for the radiation tests to be carried out. Irradiations for qualification are usually performed at a high dose rate (> 1 Gy/s).

Note: In polymeric materials the damage may be up to a factor of 10 times more severe when the irradiation is carried out at lower or at service dose rate. This has to be taken into consideration when specifying the RI.

3.6.2 Special radiation resistant cables

For control and signal cables, polyimide tapes (e.g. Kapton®) or a polyetherether ketone thermoplast (e.g. PEEK) is recommended as insulation. The radiation resistance achieved is about 5×10^7 Gy. For higher doses and power cables inorganic materials have to be used e.g. mica tape, magnesium-oxide or aluminium-oxide.

3.7 Existing materials satisfying the specified criteria

3.7.1 Power cables

The specification of an ethylene propylene rubber polymer (EPR or EPDM) should be used for both the insulation and the outer sheath of power cables.

Ethylene vinyl-acetate (EVA) or a copolymer of polyolefin may be accepted as an alternative if the properties are equivalent to those of EPR. In view of the fact that these materials show more severe degradation after long-term irradiation than EPR, this option is not recommended for use of power cables in radiation areas.

A polyethylene insulation may be used for high voltage cables where its electrical properties represent a distinct advantage.

3.7.2 Control and signal cables

The preferred dielectric and/or insulation material is polyethylene (PE). For the outer sheath a flame retardant material such as ethylene vinylacetate (EVA) or a polyolefin copolymer should be used.

3.7.3 Miniature wires and cables for electronics

Miniature wires are used in electronics circuits where there are often severe space limitations and functional requirements. For these cables and wires it is recommended that the insulation and/or sheath be based on polyimide (e.g. Kapton®), polyetherimide (e.g. Ultem®), polyetherether ketone (PEEK), polyphenylene oxides (Noryl®) or similar materials.

4 Insulating Materials Used in Electrical and Electronic Equipment

For obvious reasons, the same rules should also be applied when considering associated equipment. Recommendations for the use of plastic and synthetic materials in areas where the products of combustion in a fire may cause material damage or threaten the health or life of affected persons are given in CERN Safety Instruction 41: ‘The use of plastics and other non metallic materials at CERN with respect to fire safety and radiation resistance’.

5 Procurement of Cables

Large quantities of power, control and signal cables have been purchased by CERN in the Member States in conformity with the criteria specified in the present document and the preceding editions.

All cables and wires in the CERN stores have been replaced by halogen free types.

In order to facilitate the ordering of cables conforming to the specified criteria, the relevant specialists in FI/LS Group (i.e. purchasing, stock management group) and the CERN’s Safety Commission can be consulted by CERN users. Clear specifications for all enquiries and orders are essential to ensure that the cables delivered have the required properties.

Exceptions can only be authorized by the Leader of the Safety Commission. In such cases, compensatory measures will be required. A complete record of the installation of all cables not conforming to IS23 must be kept by the Group Leader or GLIMOS responsible for the installation. This list will be communicated to SC which will also keep a record.

Table 1
Required properties for the selection of electric cables and wires with respect to fire safety and radiation resistance

Property	**Standard***	**Requirements**	**Remarks**
Flame and fire propagation	CEI 60332-2	Pass	Applies to all single wires.
	CEI 60332-1	Pass	Applies to all cables and to all single wires > 0.5 mm^2.
	CEI 60332-3 Category 24	Pass	Applies to all cables with outer diam. > 10 mm,
Fire resistance	CEI 60331	Pass	For cables with special safety functions (eg. emergency lighting, alarms, lifts, etc.)
Smoke density	ASTM E 662 or ISO 5659	D_s < 250 in the flaming and non-flaming modes	For all cables.
	CEI 61034-1 and 2	Pass	For all major CERN cable contracts.
Toxicity of fire gases	CEI 60695-7 50 and 51	Calculation of the Fractional Effective Dose	The conditions of the test have to be agreed with SC, and the results must be acceptable to all parties.
Corrosivity of fire gases	CEI 60754-2	pH > 4.3 conductivity < 100 mS/cm	Cables shall be halogen and sulphur free.
UV Resistance	CEI 60068-2-5	No discoloration No stickiness	Procedure C, 10 days, 40°C
Radiation resistance	CEI 60544-2 and 4 and ISO R527	Radiation Index in relation to application recommended RI > 5.7	Elongation at break (ISO 37) 50% of initial value or 100 % absolute value at specified absorbed dose. Test at high-dose rates (> 1 Gy/s).

* *See Appendix 3.*
NB: Alternative ISO, IEC and other International Standards or National Standards may be considered in agreement with CERN(Safety Commission) , and should preferably be selected from survey of test methods listed in IEC 60695-3-1 section 5 and Appendix A, or IEC safety Handbook. All the standards quoted above are available for consultation, via CERN's safety commission.

Appendix 1

Summary of Required Properties for the Selection of Electric Cables, and Wires with Respect to Fire Safety and Radiation Resistance

A All Cables and Wires

a) Flame retardant characteristics satisfying the appropriate standards

b) Halogen and sulphur free

c) Low smoke density

d) Low toxicity of fire gases

e) Low corrosivity of fire gases

f) Retention of functional capabilities up to the specified integrated radiation dose. A dose of 5×10^5 Gy is recommended for cables of multipurpose applications at CERN eg Stores.

The supplier must provide test results or certificates to prove that the cable satisfies the test requirements defined in Table 1.

Note on b), c), d) and e): These requirements exclude some very commonly used materials such as PVC, Hypalon®, Neoprene®, fluorocarbons and other halogenated or sulphur containing compounds (e.g. Teflon®).

Note on f): This requirement applies to all installations of cables in areas where the life dose is expected to exceed 100 Gy. The radiation index[1)] at a specified integrate dose is assessed according to IEC 60544. The supplier must either prove this radiation resistance or supply test samples in order to carry out radiation tests by CERN.

B Power Cables

Both the insulation and outer sheath material should preferably be made of EPR or EPDM. Suppliers may propose alternative materials for insulation and outer sheaths (e.g. EVA or polyolefin). They must, however, prove that all specification requirements are fulfilled.

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1 *RI = log10 of the absorbed dose in gray above which the appropriate critical property value has reached the end-point criterion.*

C Control and Signal Cables and Wires

The recommended material for insulation is PE and for the outer sheaths a flame retardant material such as EVA or a polyolefin copolymer.

D Electrical and Electronic Equipment

Internal wiring of electrical and electronic equipment should follow the same rules as applied for power, control and signal cables. The same applies for all other kinds of organic materials used in this equipment such as connectors, conduits, terminal boards, frames, covers, spacers, etc. (see IS41).

Appendix 2

A Selection of Independent Laboratories Capable of Carrying out Fire, Smoke or Toxicity Tests, and Capabilities of Independent Laboratories

1. FRS, BRE
Garston
Watford
WD 259 XX
UK
Tel: +44 (0) 1923 664982
Fax: +44 (0) 1923 664910
Web: www.bre.co.uk

2. Warrington Fire Research Centre
Holmesfield Road
Warrington
Cheshire
WA1 2DS
Tel: +44 (0)1925 655 116
Fax: +44 (0)1925 655 419
Web: www.wfrc.co.uk

3. Laboratoire National d'Essai
LNE TRAPPES-ELANCOURT
ZA de Trappes-Élancourt
29, avenue Roger Hennequin
78197 TRAPPES Cedex
Tel: 01 30 69 10 00
Fax: 01 30 69 12 34
Web: www.lne.fr

4. Laboratoire Cental des Industries Electriques
33, avenue du General Leclerc
F-92260 Fontenay-Aux-Roses
France
Tel: +33 1 40 95 60 60
Fax: +33 1 40 95 60 95
Web: www.lcie.fr

5. ISSEP

200 rue du Chera
B- 4000 Liege
Belgique
Tel: + 32 41 229 83 11
Fax: + 32 41 252 46 65
Web: www.issep.be

6. Kema

Utrechtseweg 310 , 6812 AR Arnhem
P.O.Box: 9035, 6800 ET Arnhem
The Netherlands
Tel: +1 7036316912
Fax: +1 7036314119
Web: www.kema.nl

7. VDE

Testing and certification institute
Merianstrasse 28
63069 Offenbach
Allemagne
Tel: + 49 69 83 06 0
Fax: + 49 69 83 08 555
Web: www.vde-institute.com

8. Danish Institute of Fire and Security Technology

Jernholmen 12
DK-2650 Hvidovre
Danemark
Tel: +45 36349000
Fax: +45 36349001
Web: www.dift.dk

Capabilities of Independent Laboratories

Standards	Laboratories						
	Warrington	LCIE	ISSEP	Kema	VDE	FRS	Danish institute
CEI 60332-2		X	X	X	X	X	
CEI 60332-1	X	X	X	X	X	X	X
CEI 60332-3	X		X		X	X	
CEI 60331	X		X	X	X	X	
ASTM E 662 or ISO 5659	X		X	X		X	X
CEI 61034	X		X	X	X	X	
CEI 60795-7 50 and 51						X	
CEI 60754-2	X	X	X	X	X	X	

Appendix 3

Quoted Standards[2)]
(the most recent version will apply)

ASTM E 662	Standard Test Method for Specific Optical Density of smoke generated by Solid Materials.
IEC 60068-2-5	Simulated solar radiation at ground level
IEC 60331	Fire-resisting characteristics of electric cables
IEC 60332	Tests on electric cables under fire conditions: 332-1 Part 1: Test on a single vertical insulated wire or cable 332-2 Part 2: Test on single small vertical insulated copper wire or cable 332-3 Part 24: Tests on bunched wires or cables
IEC 60544	Guide for determining the effects of ionizing radiation on insulating materials 544-1 Part 1: Radiation interaction 544-2 Part 2: Procedures for irradiation and test 544-4 Part 4: Classification system for service in radiation environments
IEC 60695– 7	Fire hazard testing Parts 50 and 51 Part 50: toxicity of fire effluent, estimation of toxic potency, test method Part 51: toxicity of fire effluent, estimation of toxic potency, calculation and interpretation of test results.
IEC 60754-2	Test on gases evolved during combustion of electric cables
IEC 61034	Test for the measurement of smoke density of electric cables burning under defined conditions Parts 1 and 2
ISO 5659 -2	smoke generation, determination of optical density by a single-chamber test.
ISO R37	Rubber, vulcanized. Determination of tensile stress-strain properties.
ISO R527	Plastics, determination of tensile properties

[2] *ASTM = American Society for Testing and Materials*
IEC = International Electrotechnical Commission
ISO = International Standardization Organization