



# Technical Guideline

Number

01

B

## Material Selection and Radiation

Status

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### 1. Scope

- I. This document is regarded as a guideline for selecting basic materials and components used for building the accelerators of the FAIR project at places where significant ionising radiation occurs. It is essential that all materials which could be subject to radiation damage are carefully selected.

The rules given in this document can however only be applied to components outside the vacuum chamber and not to parts which are directly hit by the primary beam. For these parts dedicated documents have to be applied.

- II. The supplier company is encouraged to contact FAIR/GSI for technical information and regarding the interpretation of this specification before an offer is made. If there is any doubt regarding the radiation hardness of materials not referenced in this specification the supplier has to consult FAIR/GSI.

### 2. Definitions

- I. The radiation dose is defined as the amount of energy deposited in a mass unit of a medium by ionizing radiation. The resulting unit J/kg is given the name Gray (Gy).
- II. A rough estimation points out, that during 30 years of operation there could be a radiation dose of 2 MGy accumulated for components installed close to the beam pipe in the SIS100 tunnel.

### 3. General Restrictions

- I. Risky chemical isotopes with respect to radioactive activation

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Because of their risk of activation and their radioactive lifetimes the following chemical elements cannot be installed close to the beam pipe.

- Eu - Europium
- Ir - Iridium
- Sc - Scandium
- Ta - Tantal
- Co - Cobalt
- Cs - Caesium
- Cr - Cromium
- Tl - Tellurium

The use of these elements may be considered only in agreement with FAIR/GSI.

## 4. Materials Qualified by Application

### 4.1. Vacuum Parts

There are no restrictions for metallic materials generally used for vacuum vessels. Materials shall be selected carefully with respect to neutron activation and atomic transmutation probability. The final quality check of the selected materials will be done by FAIR/GSI department with respect to vacuum requirements.

Recommended materials:

- Stainless steel (also with Chromium as alloying component included)
- Polyimide (Vespel® / Kapton®)
- Al<sub>2</sub>O<sub>3</sub>, SiO, Marcor (glass ceramics)
- Metal sealing
- NBR sealing (Acrylnitril-Butadien Rubber, Nitril)

Not usable materials:

- Polytetrafluoroethylene (Teflon®)
- Viton® (organic sealing)
- in general all weak plastics

### 4.2. Conductors, Ferrites and Magnetic Alloys

Concerning the risk of activation chemical elements listed in section 3 should be avoided whenever possible.

### 4.3. Thermoplastic Materials

Recommended (the best materials are listed first):

- Polystyrene
- Acrylonitrile-butadiene-styrene (ABS)
- Polyethylene (dose <10<sup>6</sup>Gy)

Not usable materials:

- Polytetrafluoroethylene (Teflon®)

### 4.4. Thermostatic Materials

Recommended (the best materials are listed first):

- Phenolic, glass laminate
- Epoxy, glass laminate
- Glass-fibre reinforced epoxy resin
- Phenolic, mineral filled

- Polyurethane (PUR) (dose <math>10^7</math>Gy)
- Polyester, glass filled
- Polyester, mineral filled
- Silicone, glass filled
- Silicone, mineral filled

Not usable materials (to be used only in agreement with FAIR/GSI):

- general unfilled resin
- Polyester unfilled

#### 4.5. Elastomer

In general elastomers do not fulfil the specification (IEC 544) made for radiation doses up to  $10^6$  Gy. But in some applications they are essential.

Recommended (the best materials are listed first):

- Polyurethane rubber (PUR)
- Ethylene-propylene rubber (EPR)
- Styrene-butadiene rubber (SBR)
- Polychloroprene rubber (Neoprene®)
- Chlorosulfonated polyethylene (Hypalon®)
- Acrylonitrile rubber

#### 4.6. Cable Insulating

Cables must be conform to the CERN Safety Instructions for cables (fire and radiation) IS23, (CERN Official Documents CD-ROM <http://lhc-proj-qawg.web.cern.ch/lhc-proj-qawg/CD-ROM/>).

- Retention of functional capabilities up to an integrated radiation dose of  $10^6$ Gy.
- Connections from the cable trench to the component close to the beam pipe have to be easily exchangeable or of special radiation-resistant material (up to  $10^8$ Gy).

The following list of recommended materials for cable insulation can only serve as a guideline (the best materials are listed first) because environmental conditions like temperature and dose rate are not taken into consideration:

- Polyimide (Kapton®)
- Polyurethane rubber (PUR)
- Ethylene-propylene rubber (EPR/EPDM)
- Polyethylene/Polyolefin (e.g. PE/PP, XLPE)
- Chlorosulfonated polyethylene (Hypalon®)
- Ethylene-chlorotrifluoroethylene (Halar)
- Ethylene-propylene rubber (EPDM) flame- retardant (Pyrofil)
- Ethylene-tetrafluoroethylene copolymer (Tefzel)

- Polychloroprene rubber (Neoprene®)
- Ethylene vinyl acetate (EVA)
- Polyethylene terephthalate copolymer (Hytrel)
- Polyolefin, flame-retardant (Flametrol. Radox)
- Polyvinylchloride (PVC)

Unsuitable materials:

- Polytetrafluoroethylene (Teflon®)

#### 4.7. Water and Air Hoses

The following can only serve as a guideline (the best materials are listed first) because environmental conditions like temperature, pressure and dose rate are not taken into account:

- special EDPM rubber
- Polyphenylene oxide (PPO)
- Polyolefins, glass reinforcement
- Polyethylene, synthetic reinforcement (PE) + SR
- Water hoses on EPR base, reinforced with glass tape or Kevlar (dose <math><10^7\text{Gy}</math>)
- Polyethylene (PE) (dose <math><10^6\text{Gy}</math>)
- Combination PE-PVC (dose <math><10^6\text{Gy}</math>)
- Ethylene Propylene Rubber (EPR) (dose <math><10^6\text{Gy}</math>)

Elastomers:

- Ethylene-propylene rubber, glass reinforcement
- Acrylonitrile-butadiene rubber (Perbunan), synthetic reinforcement

#### 4.8. Oil, Fluids and Gases

Recommended fluids:

- Aromatic alkyl
- Ethers
- Mineral oils
- Water
- Helium
- Nitrogen
- Argon
- Methane, Ethane

Fluids not allowed:

- Chlorofluorocarbons
- Fluorinated compounds

#### 4.9. Paint

Recommended:

- Epoxy resins
- Phenolics
- Melamine-formaldehyde
- Polyurethanes
- Polyesters

Materials not allowed:

- Polymethyl methacrylate
- Cellulose esters

#### 4.10. Textile

Recommended:

- Aromatic polyamide (Nomex®)
- Polyesters (Dacron®)
- Polyacryl (Orlon®)

Not recommended:

- all natural fibres
- Polyamide (Nylon®)

#### 4.11. Fiber Optics

Common optical fibre cables are very sensitive to radiation; it is recommended not to use them in radiation areas. Special radiation resistant optical fibres with radiation-induced attenuation of less than 20dB/km at 10<sup>4</sup>Gy are available on the market. In general mono-mode cables are better than multi mode ones.

Test results at a dose of 80Gy:

- The multi-mode fibres showed an attenuation of some 50db per km
- The mono-mode fibres only a loss of 8dB per km at a dose of 80Gy.

**Note:** Radiation-induced luminescence (RIL) effects are expected mainly at wavelength between 400nm and 800nm wavelength.

CERN Selects Fujikura's Multi Mode Radiation Resistant Fibre up to 1.4MGy(Si) working at 850nm

#### 4.12. Optical Couplers

Optical couplers can be used up to doses <20Gy. For laser diodes and optical couplers in general, up to the 1 MeV equivalent neutron flux exceeding 10<sup>11</sup> per cm<sup>2</sup> no significant component degradation from displacement damage should be observed.

## 5. Material Classification by given Dose Range

Classification of materials and components according to the dose range up to which they may typically be used

Materials	Upper dose limit in Gy = 100 rad	Materials	Upper dose limit in Gy = 100 rad
Acrylic scintillator	$10^2 - 10^4$	Araldite B (epoxy resin) Araldite F (epoxy resin) Epikote (epoxy resin) Epoxy Novolac Epoxy resin, aromatic hardener Glass-fibre reinforced EPR-hoses Mineral oil Paints based on epoxy or polyurethane resins Polyimide resin Special radiation resistant lubricants Special radiation resistant motors	$1-2 \times 10^7$
Butyl rubber	$5 \times 10^4$		
Electronics components (active)	$10^2 - 10^3$		
Optical fibre	$10 - 10^2$		
Perfluoro ethylene-propylene (FEP)	$5 \times 10^4$		
Phenolic resin, unfilled	$10^4$		
Polyacryl (Plexiglas)	$10^5$		
Polyamide (Nylon)	$1 \times 10^5$		
Polyester resin, unfilled	$5 \times 10^4$		
Silicone oil	$5 \times 10^5$		
Silicone rubber	$5 \times 10^5$		
Teflon (PTFE)	$10^3$		
Viton	$1-2 \times 10^5$		
Araldite D (epoxy resin, cured at ambient temperature)	$1-2 \times 10^6$	Cerium-doped glass Ryton (PPS) Inorganic filled resins: - Epoxy, aromatic hardener - Phenolic - Polyester - Polyimide - Polyurethane - Silicone	$1 \times 10^8$
Chlorosulfonated PE (Hypalon, CSP)			
Cross-linked PE (XLPE)			
Ethylene-acrylate rubber (EAR)			
Ethylene-propylene rubber (EPR)			
Ethylene vinyl acetate (EVA)			
Flamtrol (polyolefin)			
Halar (CTFE)			
Hytrel (PETP copolymer)			
Lupolen (PE)			
Polychloroprene (Neoprene)			
Polyolefin			
Polyvinyl chloride (PVC)			
		Aluminium oxide Magnesium oxide Magnetic materials Metals Mica Glass fibre Quartz	$> 10^8$

\* Use of these materials in radiation areas is not recommended, or must be used with precaution.

Previous compilation is taken from A. Fasso, H. Schönbacher et.al. "Radiation Problems in the Design of LEP", CERN Yellowrep 84-02, <http://cdsweb.cern.ch/record/150653>