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Expertise

on radiation resistance of the sealing system

"DualProof"

for use as external seal to an underground concrete structure

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<u>Client:</u>

BPA GmbH, Behringstrasse 12, 71083 Herrenberg-Gültstein

The opinion comprises a total of 8 pages.

1. Occasion and objective

For using the DualProof sealing system supplied by the company BPA GmbH as a sealing material on the outside of tunnels and buildings that are still exposed, despite considerable wall thicknesses, to a considerable radiation field, an evaluation of the working life of the materials used is necessary before any installation is carried out.

For this reason, Kiwa GmbH TBU was commissioned to formulate an opinion on the basis of existing test results on polymers, conclusions on the working lives of the sealing system in a radiation environment, and the suitability of the materials used.

2. DualProof sealing system

The DualProof sealing system is a one-sided fleece-laminated sheet composed of polyvinyl chloride containing a plasticizer (PVC-P). The thickness of the uniform polymer layer is either 1.2 mm or 2.0 mm depending on the product type.

The fleece-lamination of the DualProof sealing system is based on a mechanically strengthened polypropylene-fibre mixture that can be enriched with special super-absorbent polypropylene fibres for special sealing applications - a sealing system with a self-healing function.

3. Data basis

The CERN report "Compilation of radiation damage test data - Part I, 1st and 2nd edition" [1,2] provides data that allow conclusions to be drawn about lifetimes in a radiation environment and on the suitability of the materials described. The CERN data contain numerical values, with each concerning the maximum ingestible radiation dose of polymers before radiation damage of varying severity occurs, where such polymers are used as insulating materials for electric cables. It can be deduced from the resulting scales how resistant a particular material will be to radiation, or how long it takes for its functionality to be changed or decreased due to the radiation damage. The investigations were carried out on different product materials from different manufacturers.

The stated effects of the radiation on different materials and the resulting damage which occurs are qualified as follows:

Table 1: Qualification of radiation damage

Damage	Elongation tensile test in (%) at the beginning value	Usability
starting - slight (mild)	75 – 100	almost always usable
Transition area	25 – 75	often satisfactory
moderate - strong	< 25	not recommended

4. Transferability to its application as a sealant

The use of DualProof as a sealing system in a radiation environment requires that the system when exposed to a permanent defined level of radiation will ensure complete integrity over the entire lifetime of the structure. Narrow cracks in the material can lead to a restriction of permitted use or a failure of the seal.

The same applies to the use of materials as insulation for electrical cables. In this case, any fine cracks can lead to functional failure. Therefore, the results of the CERN investigations can be used to assess the working life of DualProof components as sealing elements. It should also be noted that this can only be a general assessment, since influences from the environment such as temperature, humidity and radiation intensity as well as the type and amount of additives added can influence the resistance behaviour of the materials to radiation differently.

Using the CERN test results (Fig. 1), the radiation exposure limits listed in Table 2 for the DualProof polymers can be obtained.

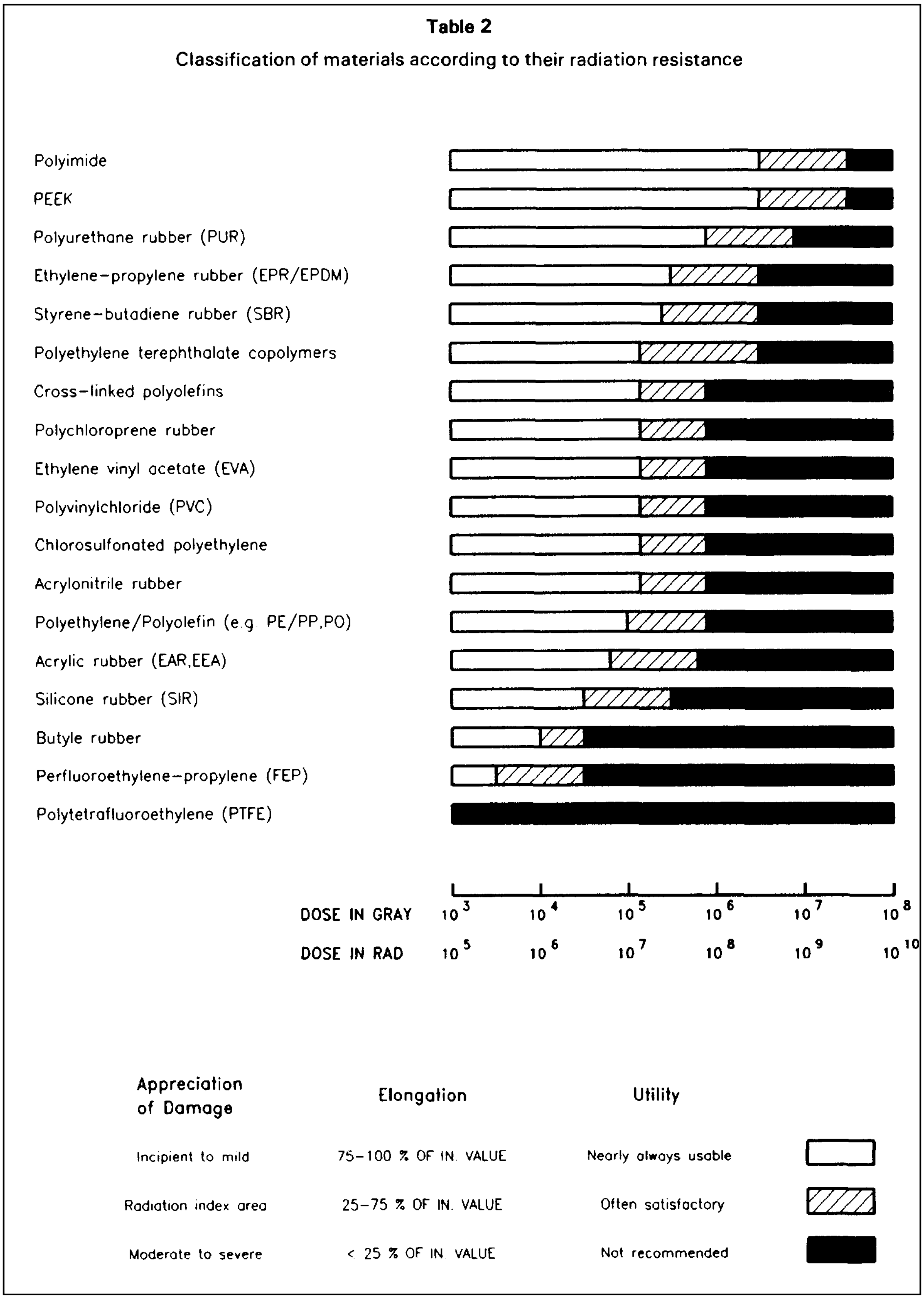

Figure 1: Radiation damage of polymers depending on radiation stress (excerpt from CERN report [2])

Table 2: Radiation exposure limits of DualProof polymers

Polymer	Radiation exposure limit for damage extending to mild [Gy]	Radiation exposure limit for damage extending to moderate [Gy]
Polyvinyl chloride (PVC-P)	2.0E+05	1.0E+06
Polypropylene	1.0E+05	1.0E+06

5. Assessment with regard to radiation fields in the FAIR project

According to [5], the FAIR project identified the regions external to the concrete shield having the strongest radiation fields. The extraction area of SIS100 in T110 and the beam dump of SIS 18 in G004 (see Figures 2 and 3) are considered as providing ample coverage for the actually occurring radiation fields. For the extraction area the dose rate on the outside of the concrete shield is approx. 3E+5 µSv/h, while at the rear area of the SIS18 beam dump it is approx. 5E+5 µSv/h. The dose rate in the extraction area is therefore somewhat lower, but here one might expect longer operational times and as such a higher total dose.

The radiation weighting factor ω_R for the conversion of Sieverts (Sv) into Grays (Gy) was determined in calculations at the GSI for the radiation fields occurring as $\omega_r = 10$, provided that the energy dose caused by neutron radiation is comparable in its effect with gamma radiation for the materials in question [5]. The calculated annual dose on the outside is therefore 262 Gy/year for the extraction area and 438 Gy/year behind the SIS18 beam dump, whereby a continuous bombardment of the beam dump is not planned.

Based on these values, a life expectancy for polyvinyl chloride and polypropylene of approximately 2,300 years can be calculated in the area behind the SIS18 beam dump with the highest expected dose rate under continuous operation, before moderate damage should be expected. Lower threshold values for polyvinyl chloride of approximately 460 years and polypropylene of about 230 years can be calculated before mild damage can be expected.

Regarding the extraction area of the SIS100, a life expectancy of polyvinyl chloride and polypropylene of about 3800 can be calculated before moderate damage should be expected. These figures are about 760 years for polyvinyl chloride and 380 years for polypropylene before mild damage can be expected.

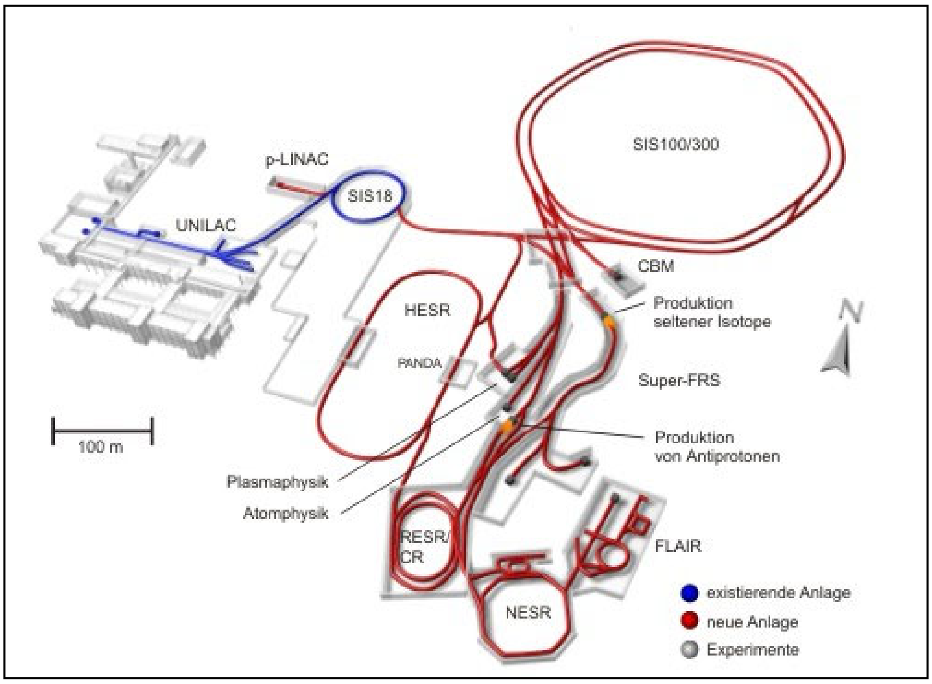

Figure 2: Location of SIS18 and SIS 100 (Source: www.faircenter.de)

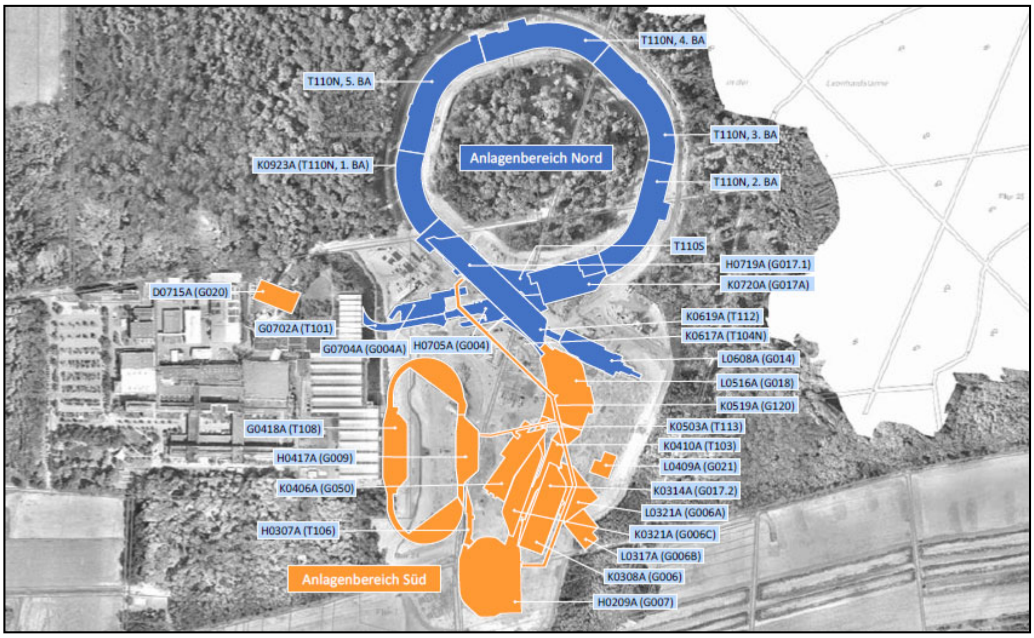

Figure 3: Project FAIR at a glance with location of areas T110 and G004 [4

6. Summary

The DualProof sealing system from the company BPA-GmbH is intended to be used as an external sealing system for underground structures that are exposed to a permanent radiation load. It is therefore necessary to assess the extent to which radiation causes damage to the system. For this purpose, the individual components of the system must be assessed as a function of the radiation dose. Studies by CERN containing data on the total radiation dose that can be endured before damage to different polymers occurs was used for the data. This observation makes it possible to calculate an estimation of the working life of the DualProof polymers regarding the radiation dose in the FAIR project. It should also be noted that external influences and the composition of the polymers can lead to deviations in the calculated working lives.

The result shows that the materials, taking into account the maximum radiation dose determined in the FAIR project and the applied radiation weighting factor ω_R = 10 have a working life which exceeds the normal useful life of such a system (see Table 3).

Table 3: Overview of the life expectancy of DualProof components

Material	Radiation exposure limit for mild to moderate damage [Gy]	Life expectancy at radiation dose of 3E+5 µSv/h in [a]	Life expectancy at radiation dose of 5E+5 µSv/h in [a]
Polyvinyl chloride (PVC-P)	2.0E+05 - 1.0E+06	**760** - 3800	**460** – 2300
Polypropylene	1.0E+05 - 1.0E+06	**380** - 3800	**230** – 2300

References

[1] H. Schonbacher; A. Stolarz-Ifycka: COMPILATION OF RADIATION DAMAGE TEST DATA: PART I – Cable insulating materials, CERN 79-04 (Geneva, 1979)

[2] H. Schonbacher; M. Tavlet: COMPILATION OF RADIATION DAMAGE TEST DATA, PART I, 2nd edition – Halogen free cable-insulating materials, CERN 89-12 (Geneva, 1989)

[3] P. Beynel; P. Maier; H. Schonbacher: COMPILATION OF RADIATION DAMAGE TEST DATA, PART III – Materials used around high energy accelerators, CERN 82-10 (Geneva, 1982)

[4] Announcement Project FAIR: Construction description of construction logistics service provider. Current as of 12/05/2017

[5] Report SSBv: Radiation resistance of polymers and bitumen - Sealing material in concrete shielding bodies at FAIR. Version 5, 22/11/2016

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