WHITE PAPER

Thermal endurance of RF cables

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Scope

The operating temperature of RF cables is defined by the materials used in a certain cable construction. In fact, there is a relationship between lifetime and exposure temperature. The higher the temperature the shorter the lifetime due to oxidative polymer degradation or diffuse. This relationship is analysed and presented for several jacket materials used in HUBER+SUHNER's RF cables portfolio. RADOX® is the best halogen-free compound in terms of lifetime and admissible temperature from the selection of tested materials.

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1 Theoretical background

1.1 RF cable

RF cables often have a coaxial structure with centre conductor, dielectric (insulation between conductors), outer conductor and jacket (insulation towards air), see Figure 1.

Figure 1: Typical construction of RF cable

1.2 Materials

An overview of materials for dielectric and jacket used by HUBER+SUHNER for RF cables is given in [1]. Certain materials can be used for both components, others for dielectric or jacket only. All materials were tested without colour batches.

1.3 Thermal limitations

The continuous service temperatures of the components of a coaxial cable vary considerably. All metallic parts resist to temperatures ranging from the very low extreme up to several hundred degrees Celsius. Obviously, the thermal limitation of a coaxial cable is given by its polymeric constituents. An important property of polymers is the so called glass transition temperature, T_g. At this reversible transition the polymers pass from the glassy to the rubbery state. On a molecular level, this transition can be explained by a strong variation of the mobility of the polymer chains within the amorphous phase what has a large impact on the mechanical properties. Considering T_g when talking about service temperatures of polymers is crucial. Depending on the application and the type of polymer it can be used below or above the T_g. The service temperature of the polymers used in coaxial cables is generally defined to be between T_g and the melt temperature, T_m. The melt temperature is the temperature at which a polymer melts or crystallizes. It is relevant only for polymer types which can build a crystalline phase. In the molten phase, most polymers have a very low viscosity but the softening starts already a few degrees below T_m. Thermal degradation of polymers can be observed at even lower temperatures. Thus, the maximum continuous service temperature is generally set to a temperature far below T_m.

This White Paper focusses on degradation of jackets due to exposure to high temperatures below melting temperature. The aim is to explain how the maximum continuous service temperature of the polymeric parts is found.

1.4 Methods

The elongation at rupture (ε^r) was selected as failure criterion. Tensile tests were carried out on a ZwickRoell according to ISO 527 (7 samples). The samples were prepared acc. to DIN 53504:2009-10 – tensile bar of the type S2. For each tested material, the initial values of ε^r were determined. Subsequently, the tensile bars were heat aged in air at a minimum of 4 different temperatures between 75 and 120°C. ε^r was measured again after 7, 14, 28, 56, 112 and 224 days. The data were used to draw the Arrhenius curves acc. to IEC 60216-8 [2]. Values beyond 224 days were extrapolated.

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1.5 Failure criterion

50% of the initial elongation at break has been set as ageing condition for evaluating the admissible lifetime of a certain material. 20’000 hours has been defined as the minimum lifetime which is a common standard in polymer industry. In case of coaxial cables, other criteria could also be defined, e.g. 20% or 80% of the initial elongation at break. Even at less than 20% the functionality of a jacket material might still be ok. 50% is a rather conservative value for cable jacket materials.
The electrical attenuation (tan δ) or insertion loss change could be taken as the boundary condition for dielectric materials.

2 Results

Figure 2 illustrates the extrapolated Arrhenius curves of some heat aged polymers which are used in coaxial cables. According to the technical data sheet of certain manufacturers, the continuous service temperature of FEP is at 205°C. As this is far above the other values and no raw data is available, FEP is not illustrated in Figure 2.

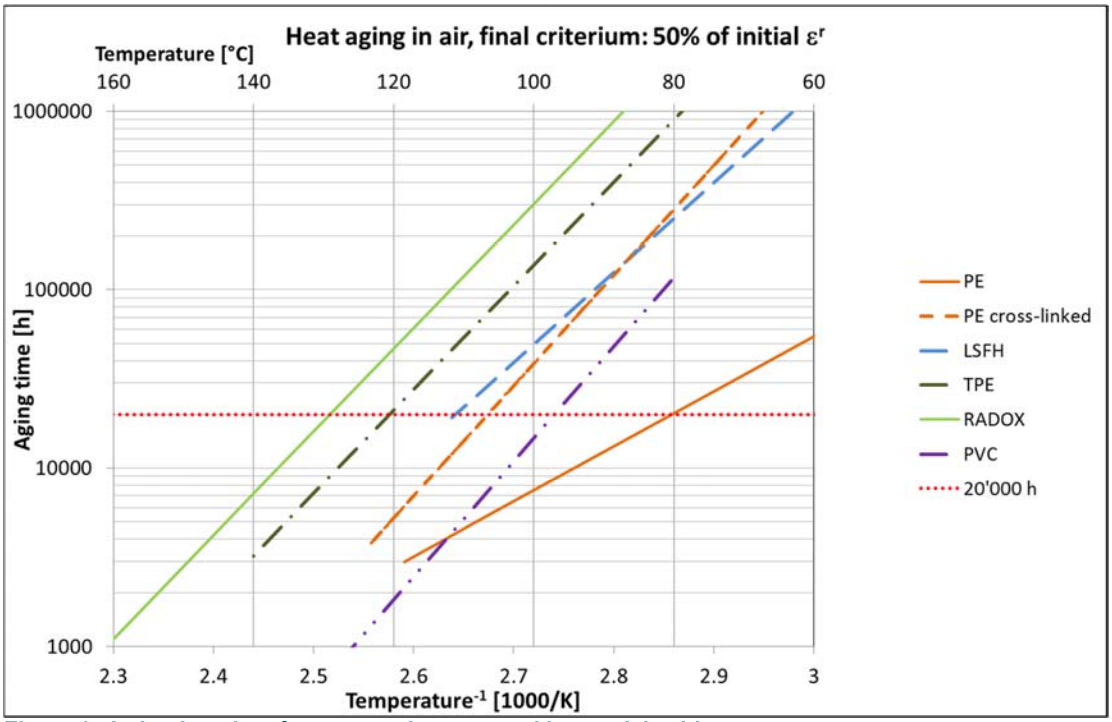

Figure 2: Arrhenius plots for some polymers used in coaxial cables.

3 Interpretation

RADOX® has the best performance from the selection of tested materials: It has the longest lifetime over the given temperature range.

The results have shown that depending on the application it is possible to use RF cables outside of the defined operating temperature range as it is defined in datasheets and catalogues. For example a cable with cross-linked PE dielectric (105°C according to [1]) and LSFH jacket (85°C according to [1]) can also be used at 105°C when limited to 40'000 hours lifetime.

An important note is that the thermal resistivity of the polymeric constituents is only one aspect of the resistivity of a coaxial cable. It should not be forgotten that different thermal expansion coefficients between metals and polymers can lead to internal stresses which may have undesirable effects on the cable design and its electrical properties.

4 References

[1] http://literature.hubersuhner.com/Technologies/Radiofrequency/RFCablesEN/
[2] IEC 60216-8:2013-03