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SAFETY DURING WHOLE LIFE TIME – AN IMPORTANT ASPECT IN SAFETY ASSESSMENT OF SEALED RADIOACTIVE SOURCES

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ABSTRACT

Many sealed sources with long half-life isotopes commonly used in industry or medicine have a long working life, up to several decades. Source integrity must be guaranteed in transport and use at any time. On the one hand, safety during the working life has to be ensured by the source design. Its strain has to be tested. On the other hand, source durability depends on the specific operating conditions. BAM has to assess the suitability of a source design for safe transport and use also for a longer service life in different domains:

BAM is the competent authority for approvals for special form radioactive material (in regulations for transport) and for type testing of devices with inserted radioactive material (in the German Radiation Protection Ordinance). Furthermore, BAM has to give an expert opinion if applicants want to extend the period of the required yearly leak test for high activity radioactive sources.

In all these domains BAM has to assess if design and additional arrangements are qualified and guaranteed to prevent a release of radioactive content under the mechanical, chemical and physical operating conditions of the specified working life. As a result, limits for the duration of validity of the special form status of a source or a type approval of a device are specified and, in many cases, special additional responsibilities for users, like periodical control and test measurements, have to be specified as binding conditions.

This paper will present BAM's experiences and show which aspects should be considered in assessment of a lifetime limit of sealed sources.

INTRODUCTION

The ageing performance of a sealed radioactive source with long half-life isotopes depends on capsule design, content and service conditions during use or storage. BAM as the competent authority in Germany has to assess if source designs satisfy the required safety standards for a specified life span for:

- sources approved as special form radioactive material (according to transport regulations /1/)
- sources in approved devices for licence free use (Radiation Protection Ordinance, Para 25 /2/)
- sources with an extended leak test period (Radiation Protection Ordinance, Para 66 /2/)

Ageing influences during use and storage can produce changes in source design properties, after years the design might not satisfy the required safety standards anymore. A limit for a safe life span has to be specified.

TYPICAL SOURCES WITH LONG LIVING NUCLIDES

Co-60, Sr-90, Cs-137, Pu-234, Ni-63, and Am-241 are typical nuclides with a long half-life, commonly used in industry, research and medicine, as level, thickness or density gauges, in detectors or for therapy. Different fields of application imply a wide range of environmental conditions, from a clean-room atmosphere in medicine or research to highly aggressive industrial conditions on oil platforms, in cement production or on mining or milling sites, with different temperatures and mechanical loads like vibration or impacts. Source manufacturers have to consider this wide range of use in source designs. The standard ISO 2919 /3/ provides the manufacturers with a series of tests to evaluate the safety of the source for a variety of source applications but does not cover all conditions of use. Radioactive material is mostly enclosed into a stainless steel capsule with a welded lid. Figure 1 shows typical designs.

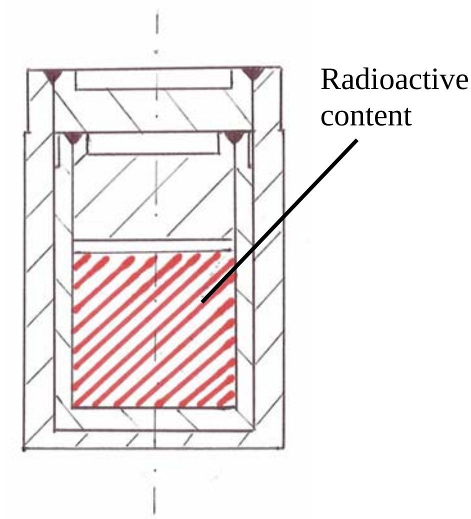


Figure 1. Typical designs of stainless steel capsuled sealed radioactive sources, Manufacturer QSA Global GmbH, Braunschweig, Germany

Often, especially in case of Cs-137 or high active sources, double encapsulation is used. Capsule materials like titanium, zircon or tantalum are used more rarely.

FACTORS INFLUENCING AGEING PERFORMANCE

Factors influencing ageing performance of a sealed radioactive source basically are

- capsule design, construction and manufacture quality (material, wall thickness, welding quality)
- radioactive content (pressure build-up by alpha emitting isotopes, radiation effects on capsule material)
- environmental conditions of use (temperature, mechanical load, corrosive atmosphere)

The assessment of these factors is not always easy. There are good calculable factors like pressure build-up or load alternation, but also difficult quantifiable and complex interacting influences like corrosion. Additionally improper operations has to be assumed.

Corrosion

Most commonly used types of stainless steels for the capsule have a chromium content over 12 %, which prevents steady corrosion. Not all of them contain molybdenum to reduce the pitting sensitivity, or titanium to prevent chromium depletion in the grains. Only one sort of stainless steel used contains both titanium and molybdenum.

An example of the relevance of suitable stainless steel: on the territory of the former GDR highly active Co-60 sources were used in well facilities for drinking water to protect filters against iron ochre. The type of steel specified was molybdenum containing X8CrNiMoTi18.11.2. Due to an unavailability or mistakes in some cases, molybdenum-free stainless steel X8CrNiTi18.10 was used. Pitting corrosion was detected on some of these Mo-free source capsules, and some were even untight because of pitting near the weld seam. /4/

Pitting corrosion can occur rapidly if stainless steel is in contact with chloride. For example: an Am-241 source in a stainless steel capsule for measuring the silicon content in brown coal was protected by a plastic polyvinylchloride foil. After a very short time first pitting was seen. The source had to be changed and protected by an aluminium foil. /5/

Moreover, corrosion starting from the inner side of the capsule has to be considered. A very special example: a stainless steel capsuled Cs-137 source was stored in a bunker when huge water penetration occured. When it was removed 3 months later the source fell and broke into many pieces. There was a very serious caesium contamination. The reason was corrosion caused by caesium chloride due to water penetration in the capsule through a small undetected leak. /5/

Corrosion is a very complex system and has to be analysed in detail whenever a sealed source is exposed directly to corrosive atmospheres or materials.

Radiation effects

In the past the influence of gamma radiation on steel-embrittlement was considered negligible, but in the last few years some experimental findings have suggested a deteriorating effect. We contacted experts from the Research Centre Dresden Rossendorf who did calculations for some typical source designs with activities up to 100 TBq and a life time of 30 years. The result is, that the calculated number of displacements per atom (DPA) cannot cause embrittlement for such sources in this time./6/ A practical validation of this result is desirable.

Alpha radiation can cause spallation effects resulting for example in a disintegration of the inactive top layer of an Am-241 foil source. To ensure no release of radioactive material , such foils should not be used longer than 5 to 10 years.

Pressure build- up by helium resulting from alpha emitting isotopes or radiolysis has to be calculated and considered in safety assessment.

SAFE LIFE LIMITS FOR SPECIAL FORM RADIOACTICE MATERIAL

Applicants for an approval of a special form radioactive material have to specify a limit of a safe life span for their source design. It is not always easy for them. Users – for both technical and economical reasons – prefer, of course, to employ sources with the longest possible working life, and there is commercial pressure on manufacturers. On the other hand, ageing performance of source designs is less easily predictable, especially when manufacturers are only in contact with distributors and not informed in detail about the conditions of use. In many cases manufacturers specify the recommended working life (RWL) as the safe life limit and the RWL is usually not longer than 10 years, which seems to be a manageable time.
BAM expects in addition to design specification detailed information about:

- conditions of use
- instructions for use and maintenance
- pre- shipment measures
- arrangements for getting feedback about ageing performance of source designs

The more details BAM knows about service conditions, the more exact the assessment can be. If applicants do not know the conditions of use in detail, they very often formulate requirements for the user- for instance: “use this source only in a non- corrosive atmosphere”. However we fear that users are often not aware of their responsibility or are overburdened with decisions about what is corrosive for the source design and what not. Remaining uncertainties can be partly absorbed by suitable pre-shipment measures, which are usually a visual inspection as far as possible and a leakage test. In general BAM requires leakage tests before transport dated back no longer than 6 month.
Experience resulting from a good feedback management system is very important. Manufacturers producing sealed radioactive sources for 20 or 30 years normally have taken back thousands of old spent sources, and if they have a good data base their safe life limit specifications are well founded.
BAM includes the safe life limit as well as the pre-shipment measures in the approval certificate. Competent authorities from other countries often do not include these or refer only to quality assurance measures . In general, we find form and content of approval certificates vary greatly in different countries, and we think harmonization could be helpful for users and authorities.

Extension or revival of the special form status

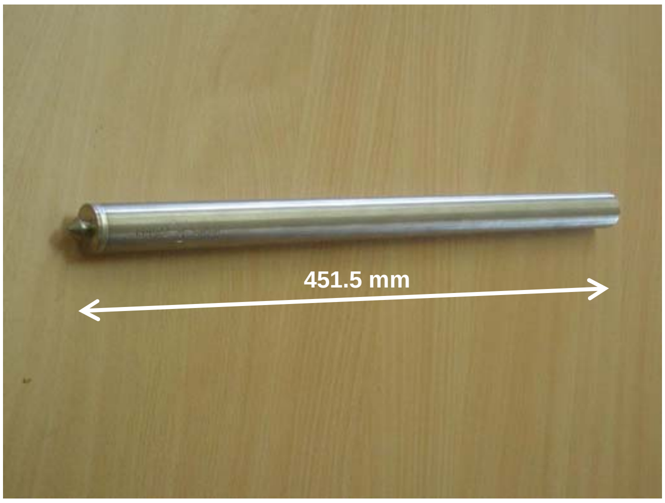
With growing experience applicants sometimes request an extension of the approved special form status limit. As an example: recently an applicant requested such an extension from 10 to 15 years for two designs of Co-60 and Cs-137 sources with a maximum activity of 55 GBq. As a justification he submitted an additional risk analysis focused mainly on inner and outer corrosion and ageing of capsule material. The most important part of this analysis was

- the evaluation of users` experience, and
- results of examinating retrieved sources (several hundreds).

On this well justified basis BAM extended the life limit in a revised approval.

There is currently an increasing request by users and manufacturers for a revival of an expired special form status of a source for a final transport for end-of-life-disposal. This mostly concerns 20 – 30 years old sources which should, or can only be, transported in Type A packages. However, BAM has so far never reactivated a special form status of such an old source because of missing documentation.

We recognise the risk that high transport costs or unavailable transport packages can prevent safe disposal. Therefore, we understand manufacturers` interests in a general solution and it is certainly worth considering together a suitable concept.
Sometimes it is very essential to have a special form certificate as in the current case of a 30 years old Pu/Be –source, which should be transported from Germany to the United States for disposal. One possibility is to give the source a new jacket. A German manufacturer has had a suitable welding procedure in a hot box qualified. Approval for the new covering capsule design has been applied for.
Putting old sources with an expired special form status but sufficient residual activity in a new capsule is in general a reasonable alternative in order to get an approval. Figure 2 shows an example for an approved design with Co-60 sources used for product sterilization.



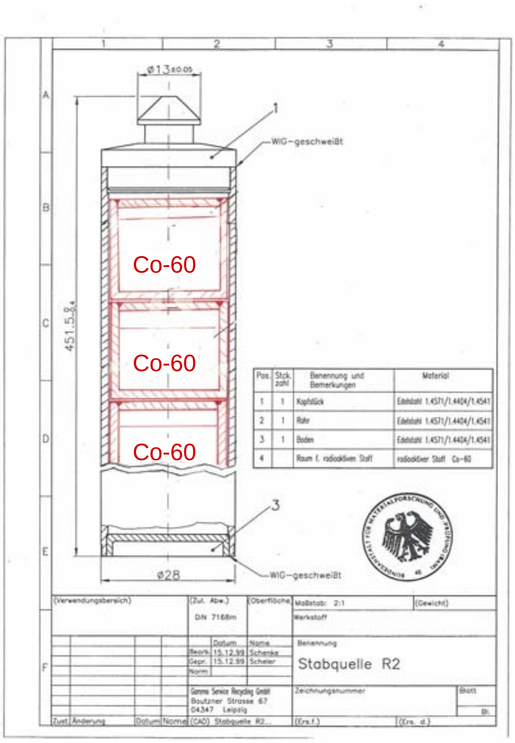


Figure 2: Source R2 for product sterilization, Manufacturer Gamma Service Recycling GmbH, Leipzig, Germany

LIFE LIMITS FOR SOURCES IN APPROVED DEVICES

In Germany devices with inserted radioactive material can get a type approval for licence free use on the basis of type testing done by BAM. BAM has to assess whether the source is sufficiently protected against chemical and physical attacks and confirm that there is no release of radioactive content during service life of the device.
For assessment BAM expects the specification of

- fields of application and environmental conditions of use,
- permitted limits for mechanical, thermal and corrosive load,
- modes of transport, and
- experience in use.

In cases where the sealed source is additionally protected against atmosphere, dust and moisture by a sealed housing, BAM has to assess corrosive resistance or the ageing performance of this housing. /7/

EXTENSION OF PERIODICAL LEAK TEST PERIODS

In Germany periodical leak tests are required for sealed sources. A one year interval is usual. For a permission of an extension of or an exemption to this test period, applicants need an expert opinion by BAM. Reasons for such applications are mostly economic, i.e. to reduce costs and prevent longer down times, but the prevention of radiation exposure for service staff is also a motive. Otherwise, periodical testing is an essential instrument for early stage identification of source damage after unexpected influences or incorrect use. Therefore, the advantage and risk of longer test periods have to be evaluated carefully and German regulations give a clear limit. The test period must not exceed 10 years. /4/
Applicants for an extension have to submit

- specification of source design and device,
- classification according to ISO 2919 /3/,
- service conditions,
- service life for source and device, and
- quality assurance programme.

BAM requires manufacturers to have a feedback management system and also seeks to gain practical experience itself. In Germany we have a good reporting system for periodical leak test results of sealed radioactive sources. Data is published in a yearly report, and whenever any noticeable accumulation is recognised, we ask for details. In preparation for this paper we interviewed experts with more than 20 years experience in source leak testing, who had tested 20 – 50,000 sources. On average they found only 1 or 2 % of them damaged or untight, which we think is a very good result. Moreover, we got a lot of interesting information about source behaviour in special applications and special problems in testing. As a result we plan to organise such an exchange of experience in regular meetings.

CONCLUSIONS

Source age performance influencing factors are in most cases well- known but by their nature less easily predictable and quantifiable. The remaining uncertainty makes it difficult for regulators to assess and decide safe life limits for sources in different applications. A suitable assessment concept should include in every case an interpretation of experience. Competent authorities or those responsible for decisions about safe life limits should be well informed about all scientific results concerning long time material behaviour.
Furthermore, it is important that every involved party (manufacturer, distributor, user, carrier, leak-test-expert) gets the necessary information and knows his/her responsibilities. It also has to be clear which information should be included in which document. Our experience in Germany shows that there are only a few incidents with untight sealed radioactive sources which have been used for a longer time. This demonstrates that our approach is appropriate. May be we are too restrictive in some cases but applicants should feel free to convince us of the admissibility of longer running safe life limits.

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