Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2019
August 4-9, 2019, New Orleans, LA, USA

Design and Aging – a New Challenge for License Holders and Users

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ABSTRACT

Rev. 1 of the Regulations contains a new para. 613A which comprises a simple sentence:

"The design of the package shall take into account ageing mechanisms."

However, it can be anticipated that this simple sentence will have a considerable impact on the existing fleet of packagings. Para. 613A will certainly affect relicensing of packagings regularly used for transport as well as packages in interim storage.

This paper will concentrate on transport packagings regularly loaded and unloaded and not used for long term interim storage. It will discuss possible consequences for relicensing of "old" packages in use for decades, medium aged packages where already some aspects of aging were considered in the design phase, and new packages which were just licensed taking into account the new para. 613A to come into force in the next few years. It will show solutions to satisfy the requirements if a large number of rather inexpensive packagings is available and discuss the possible problems if only a small number of expensive packagings exists.

For the first case study – old package design, large number of inexpensive packagings available – the BU-D package is used. The paper will present possible solutions to overcome the problem that the package had been designed before para. 613A was born.

For the second case study – medium old package design, small number of expensive packagings available – the NCS 45 package is used. Here, a showcase gap analysis is presented to evaluate strong and weak points of the design with respect to para. 613A.

Finally, for the third case study – new package design anticipating para. 613A – the DN30 package is used. Here, the design steps to assure compliance with para. 613A are explained and presented.

INTRODUCTION

Packagings for radioactive material designed and used for long term operations have to undergo regular recertifications. These recertifications must be carried out every three to five years depending on the design and the country of origin. In these recertifications the design features relevant for safety are checked and it is ensured that the packaging complies with the requirements of the certificate of package approval. Some examples of the extent of these recertifications are overload tests, leak tests or liquid penetrant testing of important welding seams. The checks, acceptable and inacceptable results and corrective actions are specified in the safety analysis report or in separate procedures pertaining to the safety analysis report.

With this approach aging was taken into account in a somewhat indirect way. The safety analysis report defined properties of the different parts of the package and the recertifications verified that these properties were still present. If not, corrective actions were taken and the part either repaired or replaced. It is obvious that this approach works only for accessible parts, either parts directly accessible from the outside or parts accessible after other parts had been removed. Parts which are not accessible, or which could not be made accessible, could not be reasonably recertified, such as

- shielding encapsulated in a steel casing,
- shock absorbing structures in a steel casing,
- contact areas of inner surfaces of different materials which are compatible in the short run but might not be compatible in the long run under certain ambient conditions.

The first bullet point, shielding, might be more relevant for dual purpose casks as they are experiencing long term elevated temperatures leading to a loss of shielding efficiency due to degradation of the neutron shielding. However, this kind of packaging is not the topic of this paper.

One example of the second bullet point is the protective structural package design 21-PF-1 for the transport of UF_6 which is out of service since a long time. Water ingress into the phenolic foam used as shock absorbing structure and a subsequent drying process lead to its complete deterioration to some kind of powdery substance in some of the packagings.

One example of the last bullet point is another design of a protective structural packaging for 30B cylinders for the transport of UF_6. The steel casing was made of austenitic stainless steel, the shock absorbing and thermal protecting structure was made of phenolic foam. Unfortunately, the chloride content of the foam was not controlled, and the steel casing was not water tight. So, life took its chance, water leaked into the foam and caused a chemical reaction to result in hydrochloric acid. This acid caused pitting corrosion from the inside (invisible) with an indication on the visible surface only after about five years. A rather big number of these PSPs, foreseen for a lifetime of some 20-30 years, had to be scrapped then after about five years of service.

The new para. 613A of the Regulations “The design of the package shall take into account ageing mechanisms” might help to avoid such issues. The emphasis of the Regulations is shifting from a

- “check that the properties are still compliant (wherever possible)”
  to a
- “assure by design that the properties will be compliant in the long run (for all materials).”

As mentioned above, the paper will concentrate on transport packagings regularly loaded and unloaded and not used for long term interim storage.

GENERAL CONSIDERATIONS

For the following discussion, packagings are subdivided into three categories:

1. “old” package designs in use for decades

2. “medium aged” package designs where already some aspects of aging were considered in the design phase, and
3. “new” package designs which are just licensed or will be licensed soon, taking into account the new para. 613A which will be in force in most modal regulations by 2021.

Many old package designs, if still in use, have been designed in a conservative way. Computers were not commonly available (if at all) and today’s state-of-technique tools like FE analysis were used by only few experts. In 1988/89, the year the BU-D package received its first license, the PC had just reached commercial application and workstations for everyone seemed like a Star-Trek story. At that time, designers were forced to stick to known materials and large safety factors, just because they could not prove safety to the competent authority for sophisticated materials or approaches.

With the advent of computing technologies and new materials in the next decades, designs of packages for radioactive materials became more and more sophisticated. Safety factors used for the design got smaller and new materials were introduced. This was certainly a positive development from a designer’s standpoint as it lead to better or even optimal use of resources, reduced waste of material and enabled new design approaches. On the other hand, with the reduction of safety factors the allowance for deterioration was reduced as well and with the use of new, unproven materials uncertainties concerning aging and long-term behaviour are the price to be paid.

Rather new designs have the chance to take into account the new para. 613A. Proven materials can be used for the structural parts, precautions can be taken for inaccessible parts and the long-term behaviour of the different materials in the packaging together with its content can be assessed in the safety analysis report.

“OLD” PACKAGE DESIGNS

In general, packages designed to comply with earlier revisions of the 1996 Regulations are not in use any more unless their certificate of package approval has been upgraded to comply with the 1996 Regulations. One of these package designs is the BU-D package.

The BU-D package (see Fig. 1) consists of an outer 200 l drum and an inner 120 l drum, both made from mild steel. The space between inner and outer drum is filled with lightweight concrete (a mixture of Perlite and concrete). The outer drum is closed by a lid with clamping ring and EPDM gasket, the inner drum is closed by a bolted lid and also an EPDM gasket. The outer and inner surfaces are painted with a two component Epoxy painting. The allowed content is enriched solid Uranium compounds with no other dangerous properties.

During design, care had been taken to fulfil para. 614 of the Regulation which requires that all used materials are physically and chemically compatible with each other and with the content. As the first series of 2000 units of these packagings had been manufactured and put in operation in 1988/1989, considerable long-term experience is available through six recertifications (a recertification is required every five years).

Fig. 1: The BU-D package

To fulfil para. 613A of the new Regulations, the aging of the materials used for the BU-D has to be evaluated and assessed.

- Mild steel can be considered not to be affected by aging unless there is high stress and/or corrosion. During routine conditions of transport there is no stress in the mild steel components of the BU-D. The outer and inner surfaces are protected against corrosion by the paint layer, the surfaces in contact with the concrete by its high ph-value. Measurement of the sheet thickness of the inner and outer drum during each recertification (over a period of 30 years) prove that there is no corrosion in any of the packagings.
- The lightweight concrete might be affected by aging and loose some of its mechanical or thermal properties.
- The gaskets are replaced during each recertification, so aging is not an issue here.
- The bolts, which experience stress during routine conditions of transport, are replaced during each recertification.
- The same applies to the paint which is repaired or renewed at least during each recertification.

Concerning the lightweight concrete, a rather straightforward approach can be used if deemed necessary by the competent authority. One of the BU-D packagings must die!
I. e., one of the many BU-D packagings has to be put out of operation and used to produce samples of the lightweight concrete. With a proper sampling planning, the material from this

sample BU-D can be used to monitor the aging behaviour of the lightweight concrete until the end of the lifetime of the BU-D which, hopefully, is still a long time to go.

"MEDIUM OLD" PACKAGE DESIGNS

Medium old packages, like the NCS 45 package which received its first license in 2008, are designed to comply with the 1996 Regulations. At that time the new Regulations were not yet on the horizon. Aging was certainly already a topic but mostly connected with long term interim storage of waste and fuel.

The NCS 45 packaging (see Fig. 2) consists of an inner and outer shell made of stainless steel which enclose the shielding made of lead. Between outer shell and lead there is a thermal insulation layer of concrete. The openings of the packaging are closed by bolted lids with EPDM O-rings. During transport, the two ends of the package are protected by shock absorbers consisting of wood in a stainless-steel casing.

The assessment of aging is facilitated by the fact that only few and long term proven materials are used for the design.

- As there is no tensile stress on any components during routine conditions of transport, aging is not a topic for the austenitic stainless-steel components (unless of course the stainless steel is in contact with corrosion inducing materials which is not the case for the NCS 45).
- Aging of the lead shielding is as well not a topic; this shielding is enclosed in a stainless-steel casing and not exposed to the environment.
- The concrete layer between lead and outer shell is as well not exposed to the environment; as its function is only to reduce the thermal input into the cask during accident conditions of transport, aging (which could be in this case development of cracks) does not affect its ability to meet its purpose.
- The EPDM gaskets are either replaced before each transport or, for some of the lids not used during loading and unloading, every three years before recertification, hence aging is not an issue for these parts.
- For the wood in the shock absorbers it is well known that there is no effect of aging on the properties if the wood was sufficiently aged when the shock absorber was assembled and there is no ingress of water or humidity during its lifetime. This leak tightness condition is recertified every three years and in the three recertifications carried out until now the leak tightness of the shock absorber housing was proven.

As a somewhat special feature the NCS 45 is equipped with bolts made of NITRONIC 50HS, a nitrogen alloyed steel with high galling resistance. Before the first certificate for the package design was issued long term tests were carried out to investigate and prove its resistance against creep under stress.

Fig. 2: The NCS 45 package

"NEW" PACKAGE DESIGNS

New packages are still licensed according to the 2012 Edition of Rev. 0 of SSR-6 as the new Rev. 1 is not yet in force. In ADR countries this is going to happen in January 2021. Formally, the proof regarding para. 613A is therefore not yet part of the safety analysis report. However, it is certainly prudent for the designer of new packages to assess the new design with respect to para. 613A as he may wish to upgrade the certification basis of the package design to Rev. 1 of SSR-6 in the period between 2021 and 2025 (para. 820 of SSR-6 requires multilateral approval of SSR-6 Rev. 0 approvals after the end of the transitional period in 2025).

The development of the DN30 started a little over 10 years ago. At that time the 2005 Edition of the Regulations (TS-R-1) based on the 1996 edition of the Regulation was in force. During the development phase the 2009 Edition of TS-R-1 came into force and in 2012 the Regulations were renamed to SSR-6 (by the way the old name they had some decades ago). So, even a new design has seen several revisions of the Regulations coming and going.

The DN30 packaging (see Fig. 3) consists of the DN30 Protective Structural Packaging (PSP) and a standard 30B cylinder specified in ANSI N14.1 and ISO 7195. Any of the existing 30B cylinders can be loaded in a DN30 PSP, there is no allocation of a specific 30B cylinder to a PSP.

The 30B cylinder has been used for transport, handling and storage of UF_6 for decades. The parts relevant for safety during transport consist of steel and other metallic components (the PTFE parts of the valve have no safety function during transport). Furthermore, the cylinders are recertified every 5 years. During transport, the pressure inside the 30B cylinder is required to be below atmospheric pressure. So, from a transport standpoint, aging of the 30B cylinders should not be a topic. However, during filling and emptying, the pressure in a 30B cylinder can be as high as the maximum normal operating pressure (MNOP) defined in ANSI N14.1 and ISO 7195. Hence, aging might be a topic for site operations. This issue will not be discussed in the present paper.

The DN30 PSP consists of an inner and outer shell of austenitic stainless steel enclosing a shock absorbing structure made of a kind of polisocyanurate foam and a thermal protection made of inorganic materials. Care has been taken in the design phase to use materials with a long usage history.

- There is no tensile stress during routine conditions of transport except handling in any of the metallic parts of the DN30 PSP, hence for the austenitic stainless-steel aging is not a topic. Fatigue analysis of all parts used during handling and tie-down is part of the safety analysis report.
- Interaction of the austenitic stainless steel with the shock absorbing material and the thermal protection materials has been thoroughly investigated. It was concluded that due to the properties of the shock absorbing material (closed cell structure, free of acids and halogens) and of the thermal protection materials (inorganic materials, free of acids and halogens) no negative effects are to be considered.
- Aging of the shock absorbing material could affect the safety of the package and has to be taken into account, see below.
- The inorganic materials used as thermal protection do not show any deterioration of their thermal properties during long term use. Aging is for these materials not a topic.

To address the aging of the foam used as shock absorbing material, the following measures were taken:

- Aging of the material after foaming to reach stable material properties before assembling with the steel structure.
- Preparation of reference samples of each manufacturing batch of the foam.
- Stockage of the reference samples in specified ambient conditions comparable to the conditions the PSP is going to encounter during normal use.
- Verification of the shock absorbing properties as required by the competent authority after some years of continuous operation of the DN30 PSP fleet.

CONCLUSIONS

The present paper shows the impact of the new para. 613A on design and licensing of packages. Three designs are presented and the impact of this new para. is discussed.

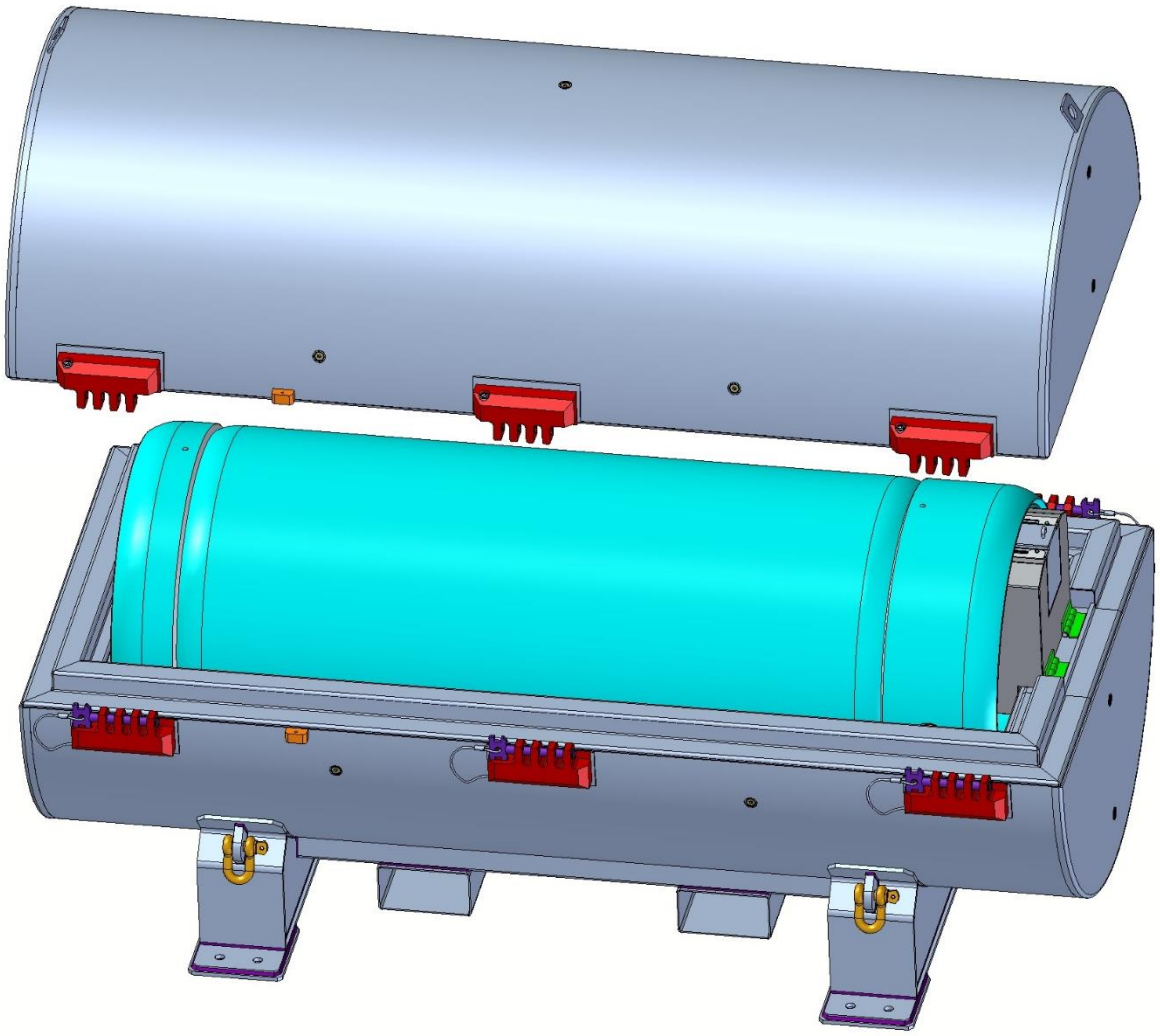

Fig. 3: The DN30 package

For the BU-D, a rather old design, several successful recertifications show that the appearance of the packaging has not changed over the long usage period. Parts which might deteriorate due to aging are replaced regularly, such as gaskets and bolts. In case there are some doubts about the properties of inaccessible parts, i. e. the shock absorbing structure consisting of light weight concrete, one of the numerous BU-Ds could be used to produced samples for evaluating the properties of this material.

The conservative design approach applied for the medium aged NCS 45 package by using well known materials helps considerably in the assessment of the design regarding para. 613A. There is no tensile stress on most parts during routine operations and all materials are physically and chemically compatible with each other. Parts which are stressed during routine operations are replaced on a regular scheme.

For the DN30 package, a very new design, the impact of the new para. 613A has been taken into account. Proven materials are used throughout the design and for inaccessible parts reference samples are stored for further testing in the years to come.