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1013 Advanced Safety Features of the DN30 Package for the Transport of UF6

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Abstract

The DN30 package was developed by DAHER NUCLEAR TECHNOLOGIES GmbH (DAHER NT) for the transport of enriched commercial grade and reprocessed UF_6 up to an enrichment of 5 %. It consists of a standard 30B cylinder and the DN30 Protective Structural Packaging (PSP) and shall be licensed as type AF, IF and B(U)F package. The basic design was already presented at PATRAM 2010 [3] and 2013 [4].

The design of the DN30 PSP has new and advanced safety features to comply not only with the current edition of the IAEA regulations but also the next edition to be published soon. The presentation will concentrate on these advanced safety features:

1. **The valve protecting device**
   The valve protecting device prevents contact of the valve with any part of the DN30 PSP or the 30B cylinder other than its original point of attachment during normal (NCT) and accident conditions of transport (ACT).
2. **The plug protecting device**
   The plug protecting device prevents contact of the plug with any part of the DN30 PSP or the 30B cylinder other than its original point of contact during NCT and ACT. This plug protecting device can be used with the standard hex head plug; installation of a socket head plug is not required.
3. **The rotation preventing devices**
   The rotation prevention devices prevent a rotation of the cylinder around its longitudinal axis relative to the DN30 PSP, especially when dropped onto the side of the package. Without this devices the UF_6 content concentrated in the lower half of the 30B cylinder would cause a rotation of the cylinder and render safety features depending on relative position of PSP and

cylinder inoperable.

4. **The closure system**
   The two halves of the DN 30 PSP are connected by a closure system consisting of 6 robust mortise-and-tenon like systems, three at each side. The design of the mortise-and-tenon systems is such that neither the connecting pin nor the securing bolt are exposed to mechanical impacts but protected by the massive body of the system. The closure system ensures that the top and bottom half remain tightly connected during routine conditions of transport (RCT), NCT and ACT. The design of the closure system assures that it cannot be opened unintentionally.

5. **The intumescent thermal protection**
   In order to reduce the impact of the thermal test on the 30B cylinder to ensure containment the DN30 PSP has an intumescent thermal protection. This protection as well as the results of tests are presented in another paper of PATRAM 2016 [5].

6. **The P10 tube receptacles**
   The DN30 PSP is equipped with receptacles allowing the transport of P10 sample tubes containing samples of the content of the 30B cylinder together with the respective cylinder.

Introduction

Enriched uranium hexafluoride (UF_6) is transported worldwide since decades in 30B cylinders using an additional PSP for mechanical and thermal protection under normal and accident conditions of transport. There are several PSP designs in use today; however some time ago it became apparent that a new state-of-technique design was required to answer the evolving requirements of the Regulations. DAHER NT presented the new PSP design and its safety analysis at PATRAM 2010 [3] and first results of the extensive drop test program at PATRAM 2013 [4]. Further papers are presented during this PATRAM of thermal testing [5] and drop testing [6].

The package DN30 is going to be licensed in France as Type AF, IF and B(U)F for commercial grade and enriched reprocessed uranium up to an enrichment of 5 wt.%.

The following presentation contains a description of the safety features of the DN30 PSP.

Overview about the design of the DN30 package

The DN30 package consists of the 30B cylinder according to [1] and [2] and the DN30 PSP. The DN30 PSP accommodates the 30B cylinder and provides the mechanical and thermal protection for the 30B cylinder during RCT, NCT and ACT. The DN30 PSP consists of a top and bottom half which are connected by a closure system consisting of 6 individual closure devices, 3 at each side of the PSP. A gasket is fitted on the step-joint part between both halves to prevent water inleakage.

The halves consist of an inner and outer stainless steel shell and energy-absorbing and insulating closed-cell PIR foam (fire retardant PU foam) of different densities filling the space between the shells. Lifting and tie-down interfaces permit the safe handling and stowing of the DN30 package and its parts. The tie-down interfaces are compatible with the existing PSP designs and allow the transport of 4 DN30 packages on a flatrack (industry standard).

A sketch of the 30B cylinder is shown in Figure 1 and the DN30 PSP is shown in Figure 2 and .Figure 3.

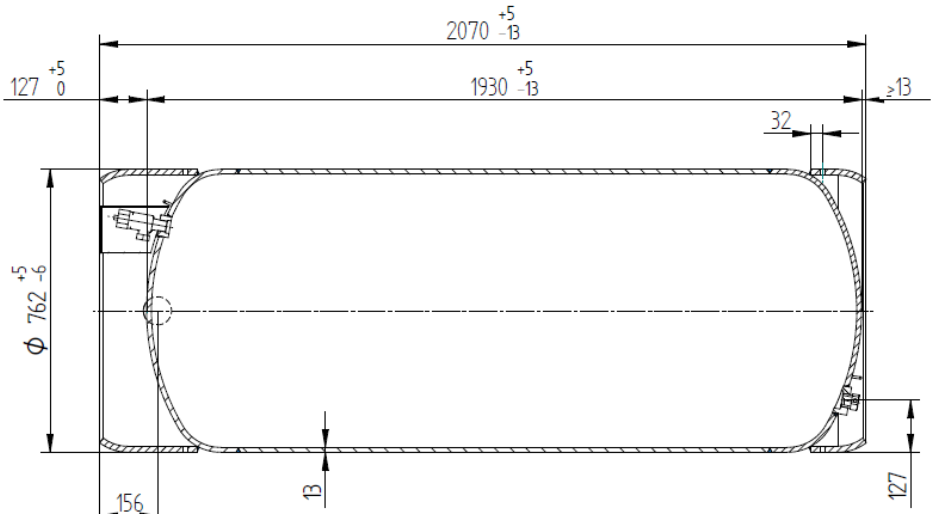

Figure 1: 30B cylinder according to [1] and [2]

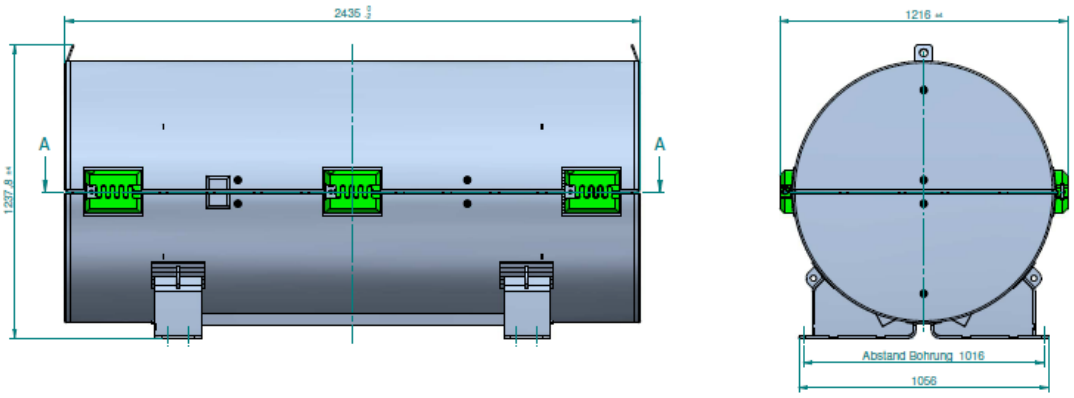

Figure 2: Outer view of the DN30 PSP

Figure 3: Prototype of the DN30 PSP

The main characteristics of the DN30 overpack design are summarized in Table 1.

Table 1: Main data of the DN30 package

Mass approx.:	
DN30 PSP (without 30B cylinder)	960 kg
Max. gross weight DN30 package (loaded with UF_6)	3900 kg
Dimensions:	
Length	2435 mm
Width	1216 mm
Height	1238 mm

Advanced safety features of the DN30 PSP

The valve protecting device

The valve is part of the containment and confinement system. It is fitted to the 30B cylinder with a NPT thread and sealed against the cylinder by a layer of tin-lead solder between the valve thread and the thread in the cylinder. Mechanical forces acting at the valve might affect the sealing.

The Regulations address the leaktightness of the valve of the 30B cylinder in a special para.:

> *680. For a package in isolation, it shall be assumed that water can leak into or out of all void spaces of the package, including those within the containment system.*
> *However, if the design incorporates special features to prevent such leakage of water into or out of certain void spaces, even as a result of error, absence of leakage may be assumed in respect of those void spaces. Special features shall include either of the following:*
> *(a) ...*
> *(b) For packages containing uranium hexafluoride only, with a maximum uranium enrichment of 5 mass per cent uranium-235:*
>
> > *(i) Packages where, following the tests prescribed in para. 685(b), there is no physical contact between the valve and any other component of the packaging other than at its original point of attachment and where, in addition, following the test prescribed in para. 728, the valves remain leaktight;*
> > *(ii) ...*

The valve protecting device prevents contact of the valve with any other component of the 30B cylinder and the DN30 PSP during NCT and ACT by providing a safe space around the valve which is preserved during NCT and ACT.

The valve protecting device consists of a stainless steel housing filled with PIR foam. The device is shaped like a U and encloses the valve of the 30B cylinder during transport. It is connected to the lower half of the DN30 PSP by two hinges. In open condition it is turned to horizontal position to allow loading and unloading of the DN30 PSP with the 30B cylinder. When the filled cylinder is loaded into the PSP the device is turned by 90° to vertical orientation so that it is in contact with the cylinder head. The valve protecting device is patented (EP 2 335 251 B1).

The valve protecting device is shown in Figure 4 in “transport” position. Figure 5 shows the results of the analysis of the 1.2 m free drop test simulating NCT and the 9 m drop test and 1 m drop test onto the bar simulating ACT.

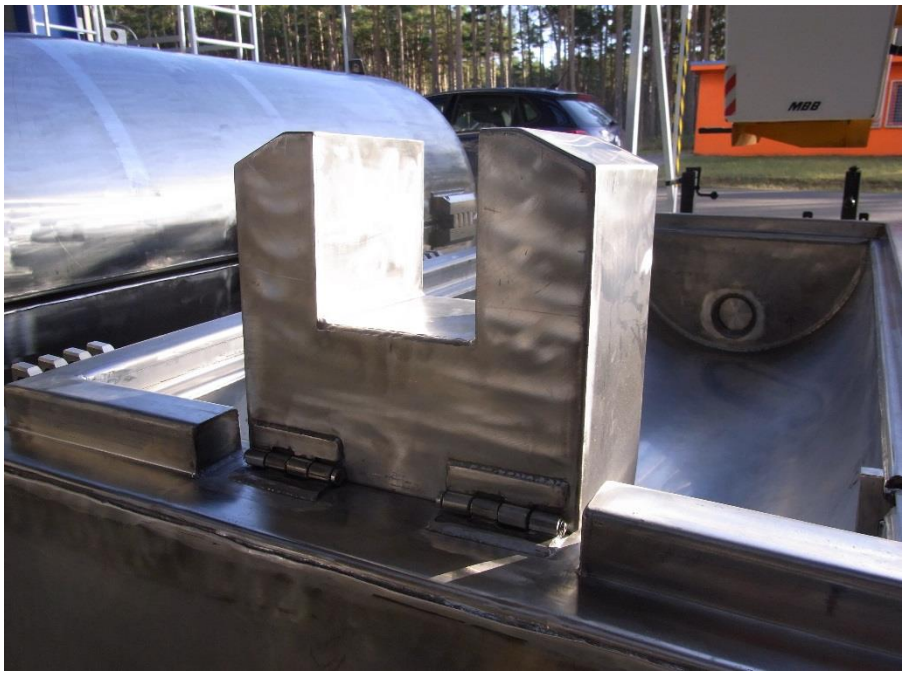

Figure 4: The valve protecting device

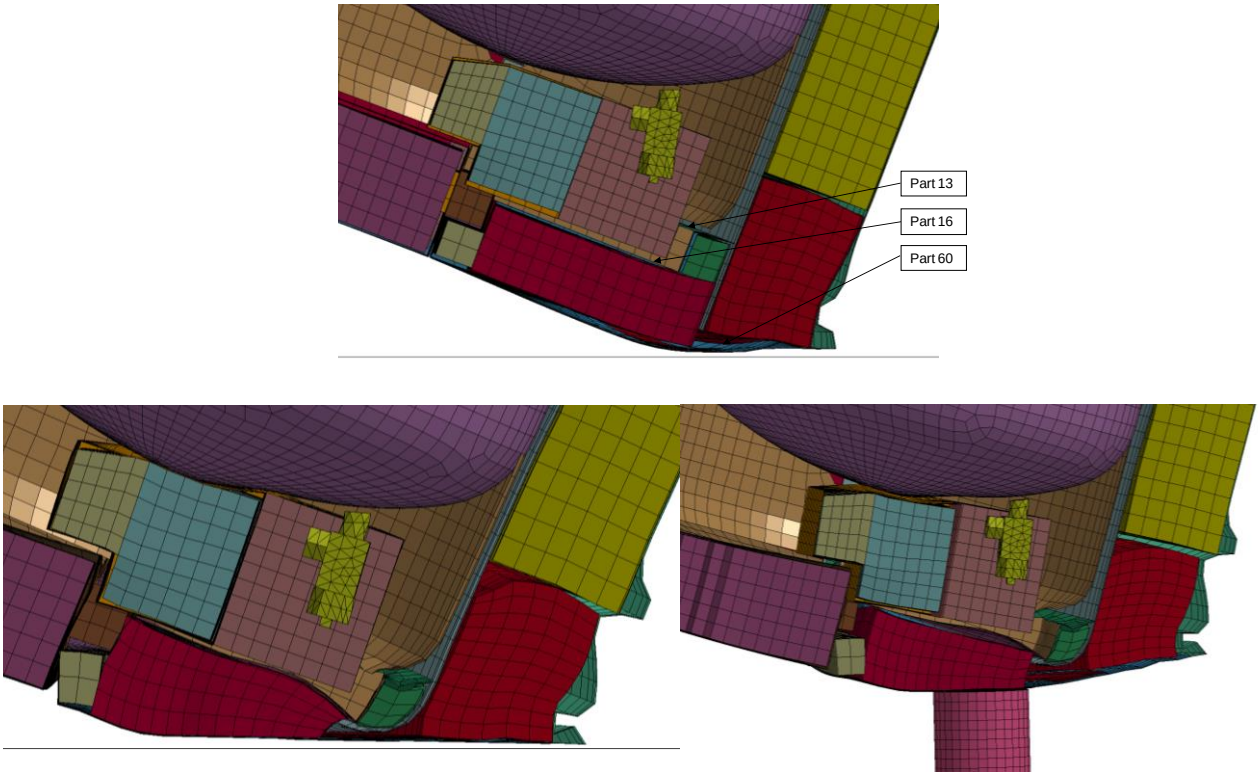

Figure 5: Distance between valve and inner shell after the drop tests simulating NCT (top) and ACT (bottom)

Five drop test sequences simulating NCT and ACT have been carried out with prototypes of the DN30 PSP. Before the drop tests the valve was covered with pressure sensitive tape to ensure the “no contact” condition. The successful drop test campaign proved the excellent function of the valve protecting device. There was no contact between the valve and the 30B cylinder or the DN30 PSP in all cases. Furthermore, in all cases the leaktightness criterion was met.

The plug protecting device

The plug is part of the containment and confinement system. It is fitted to the 30B cylinder with a NPT thread and sealed against the cylinder by a layer of tin-lead solder between the plug thread and the thread in the cylinder. Mechanical forces acting at the plug might affect the sealing.

The current valid Regulations do not address the leaktightness of the plug of the 30B cylinder. However, some competent authorities request already today that the plug fulfills the same requirements as the valve. Furthermore, para. 680 of the Regulations will be extended in future editions also to the plug.

The plug protecting device consists of a pot made of stainless steel welded to the inner shell of the lower half of the PSP. This device allows the plug to move in axial and radial direction without making contact with any part of the 30B cylinder or the DN30 PSP except its original point of attachment under NCT and ACT.

The plug protecting device is shown in Figure 6

Figure 6: Plug protecting device

The plug protecting device is applicable for the two different types of plugs defined in [1] and [2] for the 30B cylinder, the socket head plug and the hex head plug.

Five drop test sequences simulating NCT and ACT have been carried out with prototypes of the DN30 PSP. Before the drop tests the plug was covered with pressure sensitive tape to ensure the "no contact" condition. The successful drop test campaign proved the excellent function of the plug protecting device. There was no contact between the plug and the 30B cylinder or the DN30 PSP in all cases. Furthermore, in all cases the leaktightness criterion was met.

The rotation-prevention devices

When changing its state from solid to liquid the volume of UF_6 increases considerably. Thus, in order to avoid a rupture of the 30B cylinder during filling and emptying, the cylinder is filled only by about 60% when presented for transport. The mass of UF_6 is eccentrically concentrated in the lower half of the 30B cylinder. During an impact this eccentric load might cause a rotation of the cylinder and render safety features depending on relative position of PSP and cylinder inoperable. Hence, the rotation of the 30B cylinder during NCT and ACT must be prevented.

The rotation prevention devices consists of two identical devices installed at the sides of the inner flange of the lower half of the DN30 PSP. The device consists of a stainless steel pin accommodated in a housing which is welded to the flange. A handlebar is welded onto the steel pin to allow turning and lateral movements. In open condition the steel pin is withdrawn into the flange so that the cylinder can be loaded into the DN30 PSP and unloaded from it. In this condition the top half of the PSP cannot be fit onto the bottom half as the position of the handlebar prevents the proper positioning of the upper flange onto the lower flange. Top and bottom half of the DN30 PSP will only fit when the rotation protection devices are properly engaged.

The rotation preventing device is shown in Figure 7.

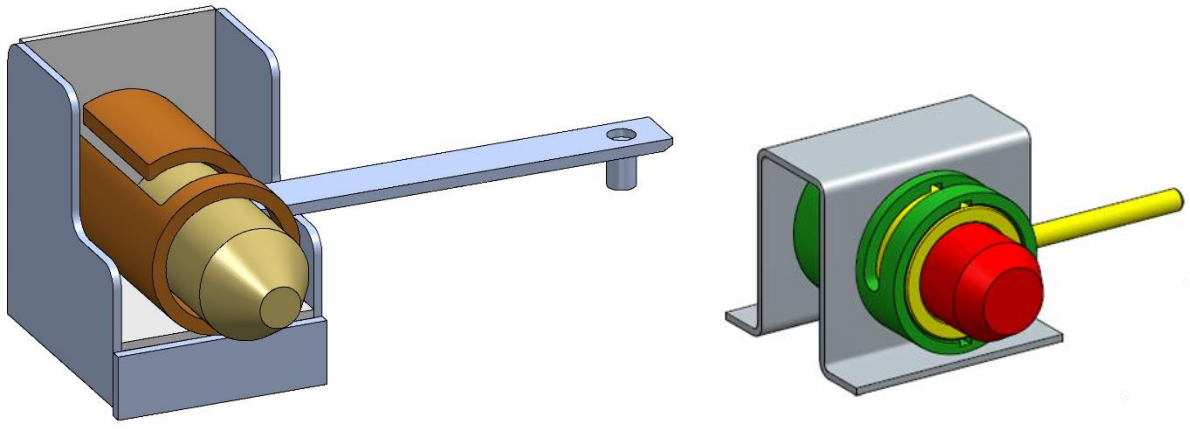

Figure 7: Rotation preventing device (left: prototype – right: serial)

The five drop test sequences carried out with prototypes of the DN30 PSP showed the excellent function of the rotation preventing devices. The devices were still engaged after the tests and prevented

any rotation of the cylinder.

The closure system

The DN30 PSP must be securely closed during RCT, NCT and ACT as it provides the mechanical and thermal protection for the 30B cylinder and its content. During RCT following principle requirements apply:

- Operation of the closure system must be easy under ambient conditions routinely expected for transport
- It must remain securely fastened under all condition experienced under RCT like vibration, transport related acceleration, thermal influences, etc.
- It must prevent unintentional opening

During NCT and ACT it must ensure that the top and bottom half of the DN30 PSP remain securely connected; the closure system must not break during the drop tests simulating NCT and ACT.

The closure system consists of 6 robust mortise-and-tenon like devices. The two parts of each mortise-and–tenon device have four fingers each with a hole in the center. When closed, the two halves are connected by a pin inserted into these holes. This pin is secured by a bolt. The bolt is secured by a pair of special washers which prevent that the bolt becomes loose by vibrations. The design of the mortise-and-tenon device is such that neither the connecting pin nor the securing bolt are exposed to mechanical impacts but protected by the massive body of the device. The closure system is patented (DE 10 2012 101 300 B3).

Figure 8 shows a sketch of the closure device. Figure 9 shows the closure device of the prototype before the drop tests and Figure 10 the closure device after the drop test sequence onto the side of the DN30 PSP with the final impact of the bar directly onto the device. The figures show that the closure device is securely fastened after all tests.

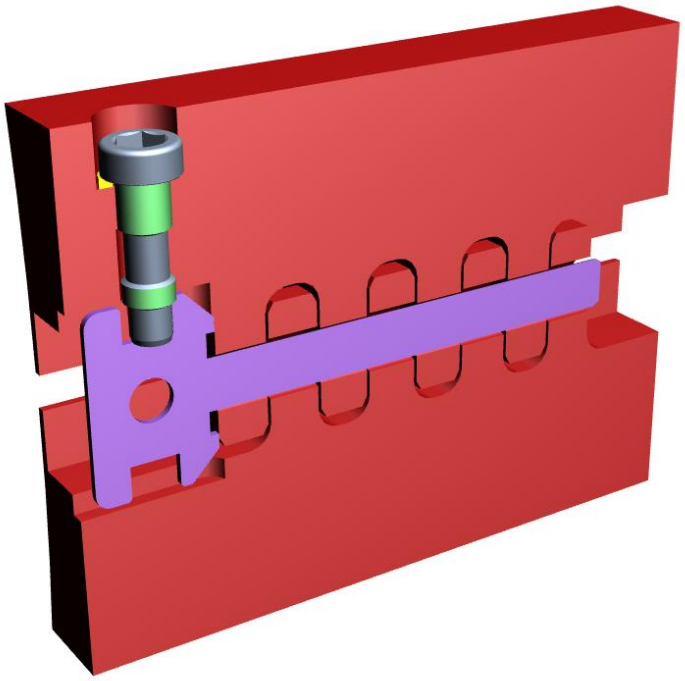

Figure 8: Closure device

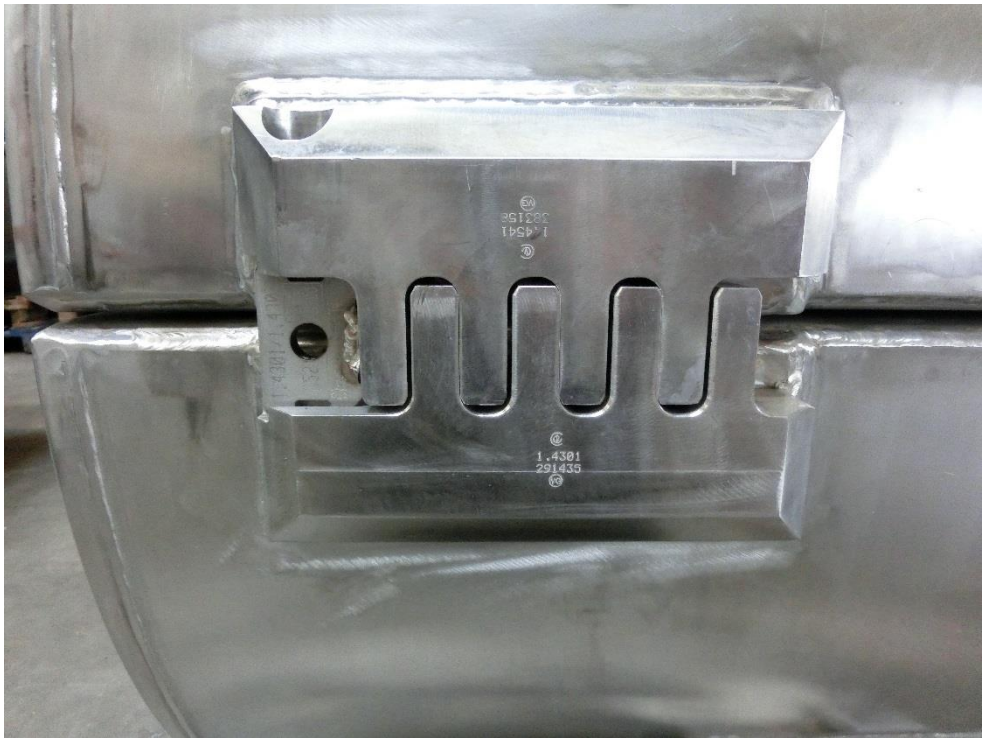

Figure 9: Prototype closure device before the drop tests

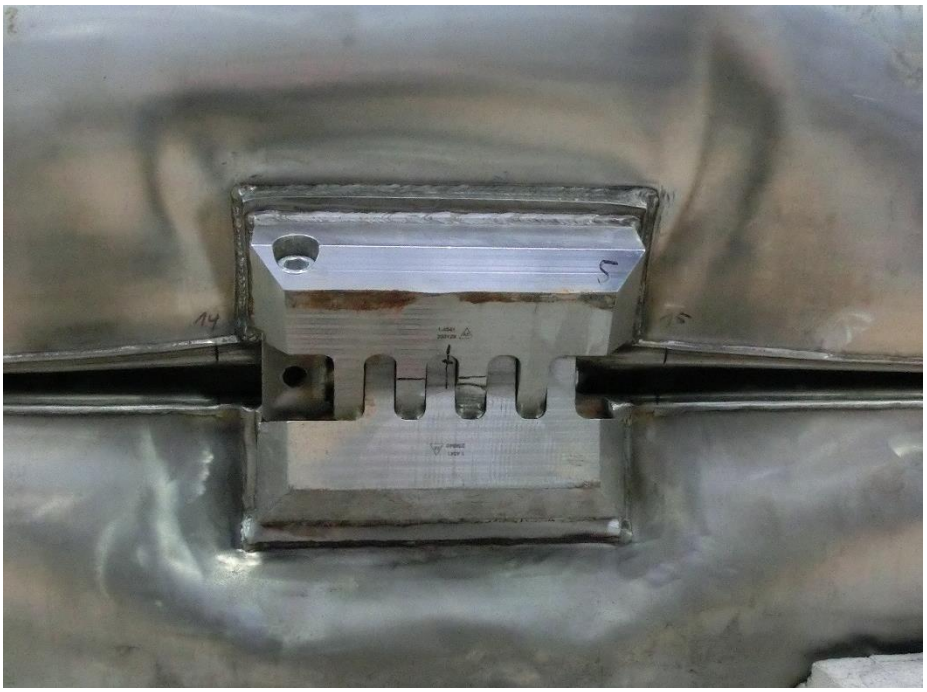

Figure 10: Closure device after the drop test sequence onto the side of the PSP with final impact of the bar onto the closure device

The intumescent thermal protection

The thermal test to simulate ACT must be carried out in sequence to the drop tests simulating NCT and ACT. During the drop test campaign with the DN30 prototypes local cracks in the inner shell of the PSP were recorded. Thermal tests showed that the pyrolysis products of the heated PIC foam were driven also through this cracks into the inner space of the PSP. Depending on the location of the cracks and possible gas flow paths this additional heat input could affect the sealing of the valve and plug against the cylinder if the solidus temperature of the tin-lead solder is exceeded.

The DN30 PSP is covered on the inside of top and bottom half with a layer of intumescent material. This material expands when a certain temperature is reached and closes the gaps between 30B cylinder and DN30 PSP, such preventing gas flow around the cylinder. Valve and plug protecting device carry as well such a layer of intumescent material which encloses valve and plug when a certain temperature well below the admissible temperature is reached during the thermal test. Details of the thermal tests and the intumescent thermal protection are presented in paper [5].

The P10 tubes receptacle

In many cases UF_6 samples filled in P10 tubes are required by the user of the enriched product. Today, the P10 tubes are shipped separately as fissile excepted. To facilitate the transport of these P10 tubes together with the 30B cylinder a P10 tube receptacle for up to three P10 tubes was developed. This receptacle is positioned on the valve protecting device.

Figure 11 shows a sketch of the receptacle and Figure 12 shows its point of attachment to the valve protecting device. DAHER NT will include this receptacle in the application for the certificate of package approval.

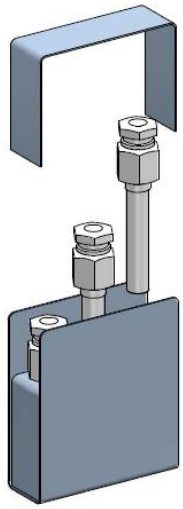

Figure 11: P10 tube receptacle

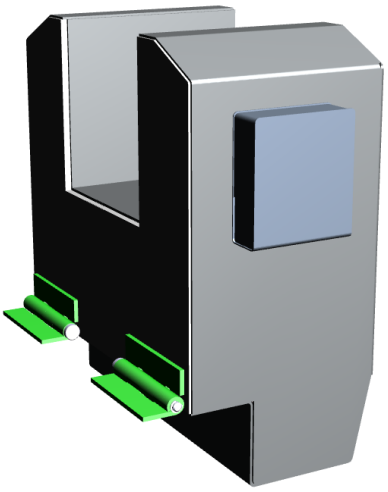

Figure 12: P10 tube receptacle on the valve protecting device

Conclusions

The new DN30 package fulfils all the requirements toward a type AF, IF and B(U)F package design for the transport of commercial grade and enriched reprocessed uranium up to an enrichment of 5 wt.%. Advanced and innovative safety features had to be introduced to provide a state-of-technique package design. After several years of development and testing the design is now mature for commercial applications. With the anticipation of future evolutions of the Regulations the design is a long term solution for the demand of the UF_6 industry. Last but not least, the introduction of new ideas with respect to the transport of UF_6 samples the overall number of transports in this area might be reduced.

References

[1] ISO 7195, Nuclear Energy – Packaging of uranium hexafluoride (UF6) for transport

[2] ANSI N14.1 Uranium Hexafluoride – Packaging for Transport

[3] F. Hilbert, W. Bergmann, F. Noyon: The DN30 Overpack – A new Solution for 30B cylinders, PATRAM 2010

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