

DEVELOPMENT OF PACKAGING FOR ENRICHED URANIUM HEXAFLUORIDE

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INTRODUCTION

Revised IAEA Regulations of the Safe Transport of Radioactive Materials (IAEA, 1996) adds some new requirements for the transport of uranium hexafluoride (UF_6). Especially for the criticality safety of UF_6 , new requirements prescribed in para. 667(b) are added as follows;

For packagings containing uranium hexafluoride only:

- (i) packagings where, following the tests prescribed in para. 682 (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; and
(ii) a high degree of quality control in the manufacture, maintenance and repair of packagings coupled with tests to demonstrate closure of each package before each shipment.

A new package of Type F for enriched UF_6 has been developed to satisfy both the previously mentioned new requirements and the present transport system. This new packaging also satisfies the Type B requirements.

BACKGROUND

The USDOT specified 21PF-1 series overpacks have been used for transport enriched UF_6 worldwide as well as Japan. For the original DOT-21PF-1 overpacks, some reformed overpacks named DOT-21PF-1A, DOT-21PF-1B, GE-21PF-1 and W-21PF-1 have been actively used without any problem. But the quality control trouble of the phenolic foam and the subsequent test which revealed itself being unprepared made the US competent authority issue a certificate with a special arrangement on Nov. 8th 1995. The unpreparedness showed that the valve of the cylinder was damaged under the accident conditions in transport. After the issuance of the special arrangement, the United State Enrichment Corporation organized an international consortium to develop the valve protection device (VPD) in fall of 1996 to deal with the valve damage problem. Although the transportation using the overpack with the VPD has been approved in Japan, the hard-to-handle VPD began to request the transporters, fuel fabricators and so on to develop a newly designed overpack which required no VPD. This situation made Mitsubishi Materials Corporation develop the new overpack with no VPD.

PACKAGING DESCRIPTION

Major Specification

Content	UF ₆ with Max. Enriched to 5.0%	Dimension (nominal)	Length Width Height	2,420 mm 1,340 mm 1,360 mm
Type	IF/AF/B(M)F package	Weight (max.)	30B Cylinder	665 kg
			UF ₆ Overpack	2,277 kg
			Package	1,308 kg
				4,250 kg

Main Features

- No valve protection device.
- A special ring to prevent the valve from contacting the innerplate of the overpack.
- A valve pocket to make more margin to avoid the valve contact with the overpack.
- A cylinder-rotation stopper to keep the valve position stable in the overpack.

The valve pocket functions effectively with the combination of this device.

- Synthetic materials instead of natural wood to mitigate the possible mechanical shock.

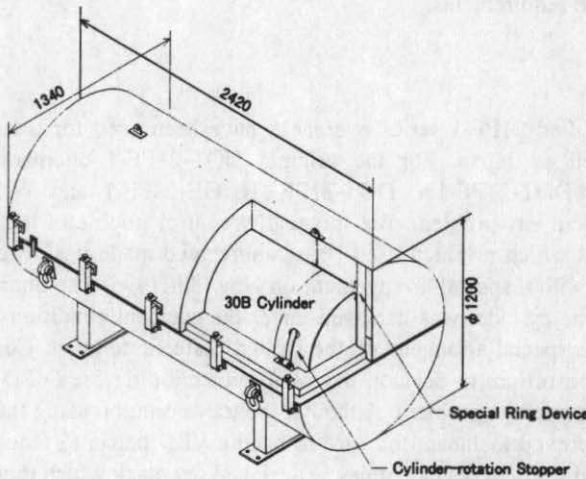
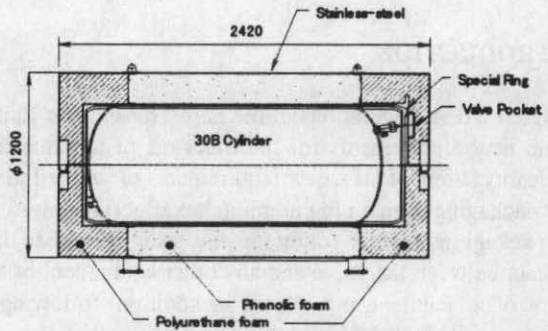


Fig.2 Bird's Eye View of Package

CONCEPTUAL DESIGN

The preliminary analysis using DYNA-3D (Hallquist and Whirley, 1989), the three-dimensional finite element code for nonlinear dynamic analysis was performed to optimize the new PSP (Protective Shipping Package) design in the process of the conceptual design. Furthermore, drop tests using partially modeled packagings were carried out to verify the integrity of the conceptual design.

Preliminary Analysis

The dynamic analysis was performed with DYNA-3D for the preliminary analysis using an axi-symmetric geometry and 180° symmetric models in order to optimize forms and dimensions of components such as shock absorbers, thermal insulators, the special ring, and the valve pocket. Examples of the analysis model and a result of deformation mode of the structure are shown in Fig.3.

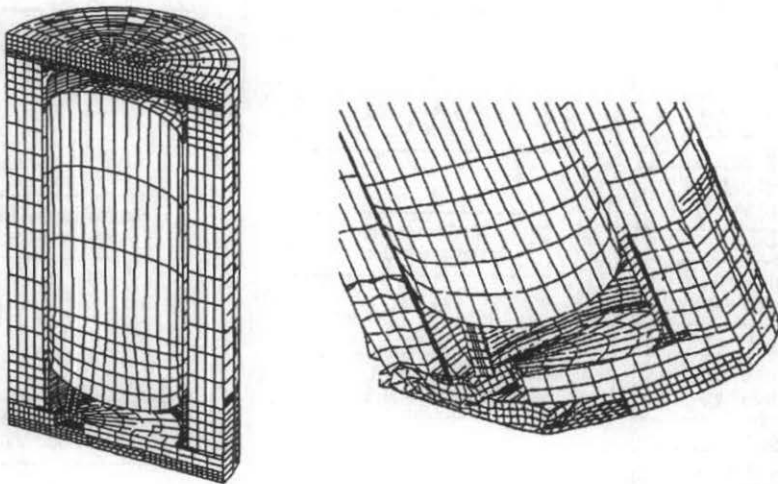


Fig.3 Examples of Analysis Model and Result of Deformation Mode

Preliminary Drop Tests

In order to verify the integrity of the conceptual design, a 15° slanting 9m-drop test followed by a 1m-puncture test, and a 9m-corner drop test (27°) followed by a 1m-puncture test using two partially modeled packagings were carried out. As a result, we found out that the latter case (corner drop series) was more severe than the former one (15° slanting drop series) with regard to the deformation toward the valve. Therefore, the corner drop series were chosen to be carried out in the coming compliance tests. It was confirmed that deformations of the inside and outside of the packagings were sufficiently similar to the predicted values from the numerical analysis mentioned above. It was also confirmed that valve of the 30B cylinder didn't contact the aluminum honeycomb (contact indicator) installed in the valve pocket in both cases. The leaktightness of cylinders was also verified by the helium gas leak test before and after the drop tests.

COMPLIANCE TESTS

Based upon the results of the preliminary tests, some improvements were introduced and three prototype packagings were fabricated. Using the prototype packagings, three series of compliance tests were carried out. The test procedures were determined according to the IAEA regulations. The test sequence flow is shown in Fig.4.

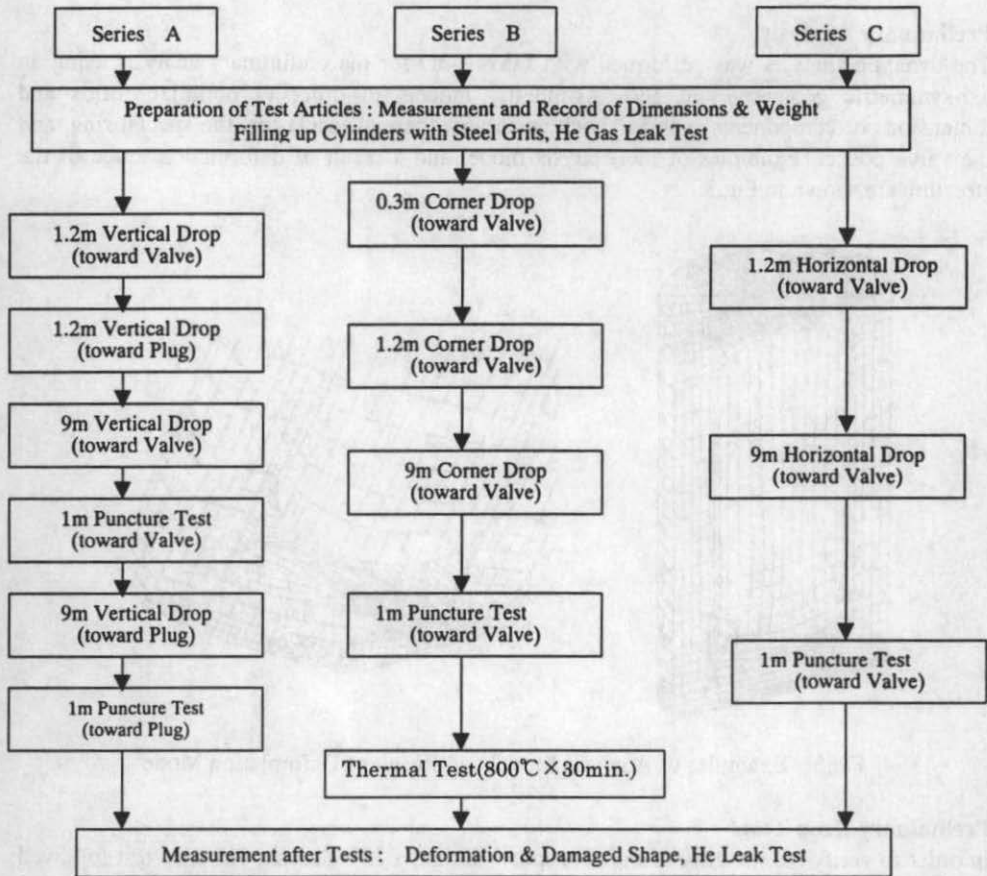


Fig.4 Test Sequence Flow

Drop Tests

Measurements of acceleration, dynamic strain and static strain were made during the 9m-drop and 1m-puncture tests in the compliance tests. The deforming behaviors of test articles during impact were recorded by a high-speed video camera. On the other hand, normal video cameras were used to record the overall drop sequence and rebounding behavior. Deformed shapes were sketched and recorded by cameras, and also detailed dimensions were measured. The aluminum honeycomb was installed in the valve pocket as a contact-indicator.

A summary of these results is as follows:

Series A (Vertical Drop Test: 1.2m + 9m + 1m Puncture)

In the 9m-vertical drop test, the prototype packaging was dropped almost perpendicularly to the ground with the drop orientation of the valve or the plug downward. It landed on the target steel plate without falling over. The impact area was almost flatly compressed. Though some folds were produced on the cylindrical surface of the outerplate, there was neither crack nor tear anywhere. In the 1m-puncture test, a slight dent on the surface was produced by $\phi 150\text{mm}$ puncture bar. There was neither crack nor tear anywhere. The subjected test article overturned, but the secondary impact didn't cause further deformation. The valve didn't reach the aluminum honeycomb installed in the valve pocket.

Series B (Corner Drop Test: 0.3m + 1.2m + 9m + 1m Puncture)

In the 9m-corner drop test, the prototype packaging was dropped at the inclination of 27° from vertical with the impact onto the valve location. The displacement of the impact area was similar to the predicted value calculated at the preliminary analysis. Though deformation occurred, there was neither crack nor tear. When dropped onto the target steel plate, the test article overturned with a slight rebound. But the secondary impact didn't result in further deformation. In the 1m-puncture test, a dent with some depth on the surface was produced by $\phi 150\text{mm}$ puncture bar, but there was neither tear nor crack anywhere. In spite of the deformation, the valve didn't reach the aluminum honeycomb installed in the valve pocket. The secondary impact by overturn didn't cause further deformation either.

Series C (Horizontal Drop Test: 1.2m + 9m + 1m Puncture)

In the 9m-horizontal drop test, the prototype packaging was dropped almost horizontally onto the target steel plate with the drop orientation of valve downward. The packaging had a slight rebound. Though the impact area was flatly deformed and folds was produced on the endplates, there was neither crack nor tear observed. In the 1m-puncture test, a large dent in the thermal insulator of phenolic foam was produced by $\phi 150\text{mm}$ puncture bar. Its deformation reached the 30B cylinder and caused a slight dent on the cylinder's surface. But there was neither tear nor crack observed.

Thermal Test

The thermal test at an average flame temperature of at least 800°C for a period of 30 minutes was carried out in a furnace.

The maximum temperature of the cylinder was about 60°C throughout this test.

Temperature curves are shown in Fig.5.

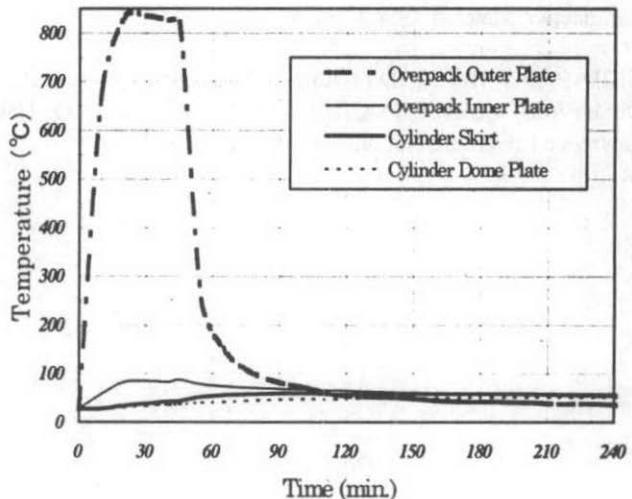


Fig.5 Temperature Curves at Thermal Test

Helium Gas Leak Tests

The water leaktightness under a head of water at least 0.9m or 15m for a period of not less than eight hours is required for this fissile package. The experiments which determine the gas leak rate (std·cc/s) of the leakage path which doesn't permit water leakage was carried out separately.

Though this research has not been completed yet, the data obtained so far shows that the gas leak rate corresponding to the threshold of water leaktightness in the above condition (under a head of water at 15m for eight hours) seems to be more than the order of 10^{-4} std·cc/s. Leak rates for the cylinders after the series of the drop and/or thermal tests were measured with the helium leak detector. The maximum leak rate was 2.2×10^{-7} std·cc/s. The water leaktightness of this package was demonstrated by this result.

SUMMARY

The new PSP developed by Mitsubishi Materials Corporation has been confirmed to meet the Type F and/or B(M) requirements prescribed in the revised IAEA Regulations for the Safe Transport of Radioactive Materials (1996 Edition).

The combination of the valve pocket and the cylinder-rotation stopper worked well to protect the valve of the cylinder. Since we found out through the test that the cylinder can easily rotate within the overpack by the shock of the drop tests, the "cylinder-rotation stopper" was essential to make the valve pocket work properly. In addition, the special ring also worked well to minimize the deformation of the cylinder skirt. Polyurethane foam showed itself to be a good mechanical shock absorber and a thermal insulator through the tests.

Furthermore the PSP demonstrated good handling performance and good quality assurance by eliminating wooden materials. Currently, an approval for the design from the Japanese competent authority is being examined. After obtaining Japanese approval, a multilateral approval will be applied successively.

REFERENCES

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UCID-19592, Rev.5 "DYNA3D (Nonlinear Dynamic Analysis of Structures in Three Dimensions) USER'S MANUAL Revision 5", John O. Hallquist and Robert G. Whirley, Lawrence Livermore National Laboratory, May 1989