

IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Enhancing nuclear safety

ASSESSMENT OF SAFETY DEMONSTRATIONS RELATIVE TO PACKAGES CONTAINING UF₆

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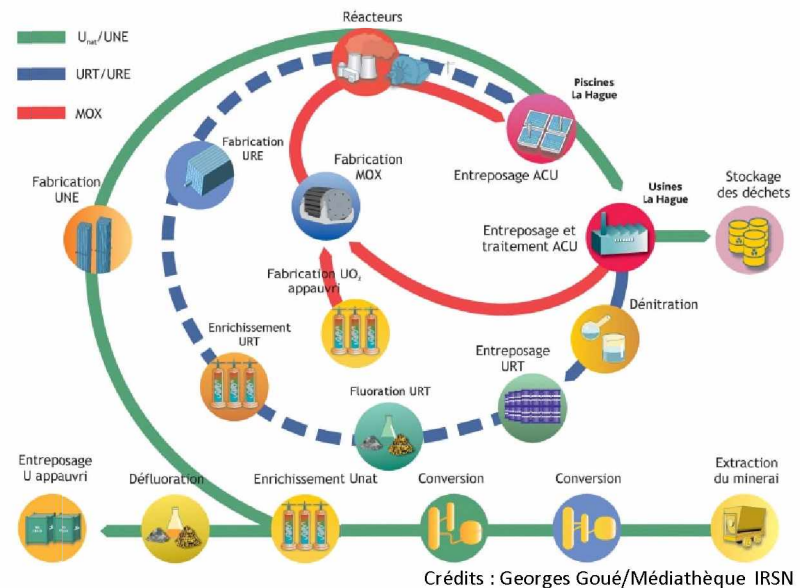
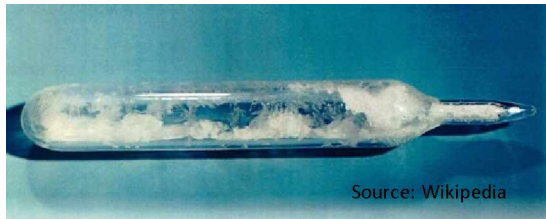
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Summary

1. Isotopic composition of the UF₆
2. Leak-tightness of the valve and the plug of cylinders after regulatory drop tests
3. Thermal behaviour of the package designs in accident conditions of transport
4. Use and maintenance
5. Conclusion

Introduction



- Package designs containing enriched UF_6 shall fulfill IAEA requirements.
- Main objective = package remains leak tight and the dose rate measured remains below the regulatory criteria
- Assessment of the safety demonstration transmitted by applicants in support to their approval request put in the light that a specific attention should be paid on several topics.

Isotopic composition of the UF₆

- Isotopic composition of the UF₆ loaded within the cylinder have to be considered :
 - in containment and shielding demonstrations,
 - for package classification.

- The composition of UF₆ (full cylinder/heels) should be evaluated considering :
 - the filling history of the cylinder (filling/emptying cycles, possible washes, storage time of the material in the cylinder),
 - and the UF₆ origin, i.e. natural or reprocessed.

- In general composition of the UF₆ presented in the safety analysis reports are based on ASTM C996 standard.

- ASTM C996 standard specifies limits applicable for some isotopes (²³²U, ²³⁴U, ²³⁶U, ⁹⁹Tc) present in initial production of UF₆ enriched from natural or reprocessed uranium.

Isotopic composition of the UF₆

■ UF₆ from natural uranium

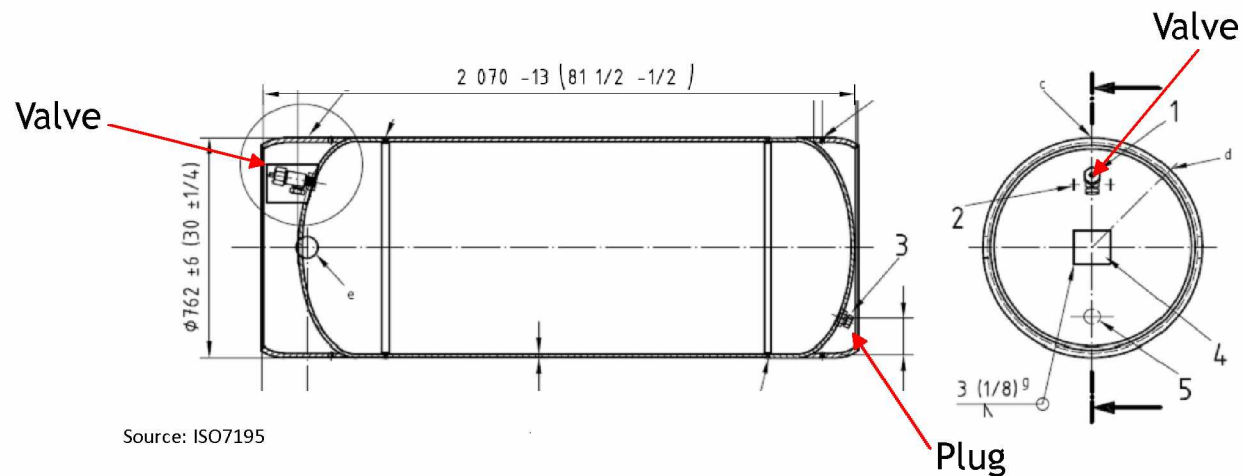
- In 2010, measurements performed after cylinders washing operations showed that the composition given in ASTM C996 standard covers enriched UF₆ from natural uranium.
- If the isotopic composition of the UF₆ exceeds the limits specified in ASTM C996 standard -> additional justifications should be provided, to demonstrate that the limits considered in the safety demonstrations covered the maximum UF₆ isotopic composition.

■ UF₆ from reprocessed uranium

- Measurements should be performed to confirm that the limits considered in ASTM C996 standard are penalizing.
- Or systematic washing of the cylinder is necessary.

Leak-Tightness of the valve and the plug after regulatory drop tests

- Containment of UF_6 is ensured by the cylinder, including its valve and plug, which could be loaded (30B) into an overpack (mechanical and thermal protection).
- Leak rates measured on the valve and the plug shall not exceed $10^{-4} \text{ Pa m}^3 \text{ s}^{-1}$ (SLR) as specified in ISO 7195 / ANSI N14.1 in all conditions of transport.

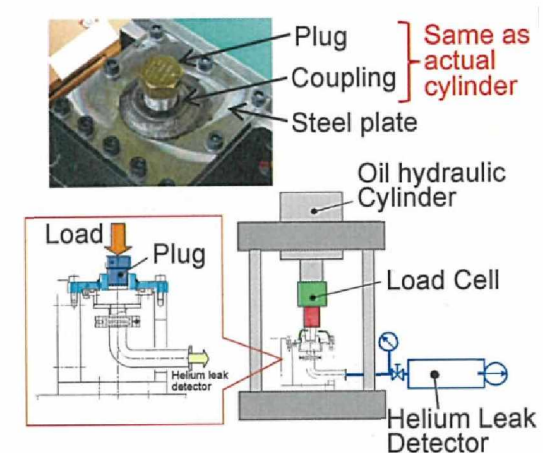


Source: ISO7195



Leak-Tightness of the valve and the plug after regulatory drop tests

- To justify the cylinder leak-tightness after ACT tests, drop tests and numerical calculations are performed.
- Objective = to guarantee the absence of contact between the valve (or the plug) and the internal surface of the overpack in all conditions of transport (*).
- Numerical calculations: to take into account parameters not simulated during drop tests.
- If an impact of the plug occurs :
 - the maximum loading acting on the plug should be evaluated;
 - then the leak-tightness of the cylinder should be confirmed on the basis of dedicated tests.



(*) According to the IAEA SSR-6, prevention of contact between valve (plug) and any other component ensures the integrity of the package containment

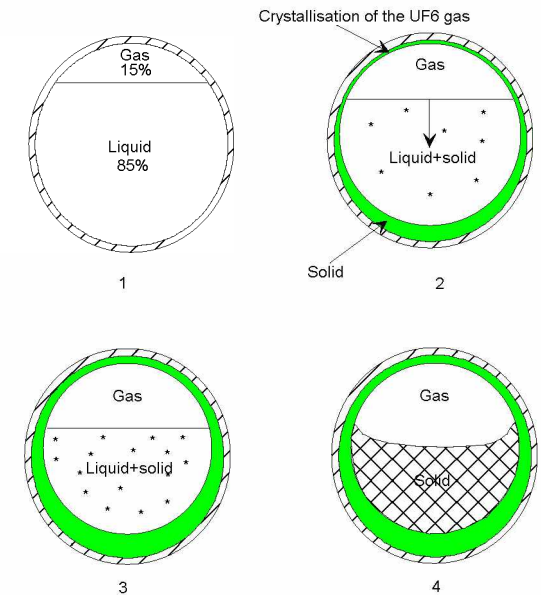
Proceedings of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials, PATRAM 2016, "Integrity of 30B cylinder plug for physical contact", Hiroshi Takahashi and al.

Representativeness of the ballast used to simulate UF₆ in drop tests

- Ballast used during drop tests: balls, shots (steel, iron, lead), sometimes embedded in paraffin.
- Lack of information regarding the mechanical behaviour of UF₆
- Justification of representativeness of ballast usually based on :
 - mass,
 - bulk density,
 - cylinder filling rate.

Representativeness of the ballast used to simulate UF₆ in drop tests

- Other parameters influencing representativeness has to be considered :
 - Diameter of the shots,
 - Energy absorption capacity by the ballast (paraffin, lead, ...)
 - Filling configuration : representativeness of the UF₆ crust behavior (200 to 400 kg of fragments)



Source : IRSN

- Recent drop test campaigns were performed using a ballast made of:
Mixture of cement and steel grit to form a main block and additional debris of this mixture simulating UF₆ crust damages.

Thermal behaviour of the cylinders in accident conditions of transport

- IAEA thermal test : fire of 800° C during 30min.



Source : ENSTTI / IRSN

- Leak-tightness of the connection between the valve/plug and the cylinder is assured by the tinning of the thread of the valve/plug.
- ISO 9453 and ASTM B32 standards specify that the softening (and then melting) temperature of this tinning starts at 183° C.



Tinning of the valve

Maximum temperature of tinning of valve/plug should be lower than 183° C to guarantee the leak-tightness of the connection between the valve or plug and the cylinder, even if the leak tightness of the tested cylinder is checked.

Use and maintenance

■ Leak-tightness tests

- Periodic inspection and tests performed on cylinders at intervals not exceeding 5 years (ISO 7195 and ANSI N14.1)

- Discussions during the latest revision process of the ISO 7195 :
 - Possibility to demonstrate leak-tightness by a simple contamination check when no valve or plug change has occurred

- **Regulatory bodies position** : Pneumatic leak tests should be performed at each five-years inspection of empty (washed) cylinders even if no valve or plug has been changed. Contamination check is not accepted as a replacement of the pneumatic test.

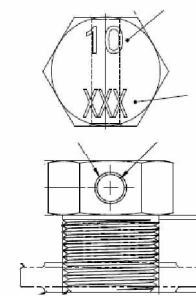
- Latest draft : For cylinders which contain UF₆ (including heeled cylinders), the leak test shall be performed on the valve seat only. After the next emptying, the cylinder shall be cleaned and washed out, and a complete leak test (not only the valve seat) should be performed.

Use and maintenance

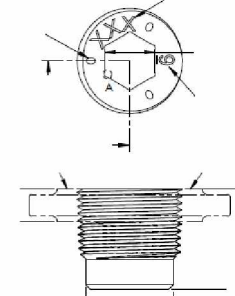
■ Cylinder's plug designs

■ Cylinder's initial concept of plug = hex head plug

- Problem: exposed to direct mechanical shocks in case of drops, leading to a risk of leak-tightness loss.



Hex head plug



Socket head plug

Source: ANSI N14.1

■ Alternative concept of plug : socket head plug (non-protuberant)

- New plug design reducing the risk of a direct impact due to its dimensions and the reduced height.
- Difficulties reported by many users during the assembling and disassembling operations of these plugs (leading sometimes to cracking of plugs).
- Guidance presenting best practices to facilitate the use of socket head plugs was elaborated (for instance, removing tinning from the first two threads to facilitate the insertion of plugs).
- A complementary testing program has been requested by the French Nuclear Authority to evaluate the behaviour of this plug considering the number of assembling and disassembling operations and also the pressure and temperature effects taking into account the filling and emptying operations of the cylinders.

Conclusion

- Several technical issues raised up during recent assessments of shipment of cylinders containing UF₆.
- A specific attention should be paid on the ballast used to simulate UF₆ during the regulatory drop tests.
 - Presence of debris within the cylinder cavity resulting from the upper crust damage should be considered.
- Temperature of the valve, including the tinned joint, should not exceed the softening temperature of the tinning (183 °C) during the regulatory fire test.
- Difficulties reported during the assembling and disassembling operations of the socket head plugs put in the light the necessity to evaluate the torque specifications mentioned in the standards and to evaluate the stress resulting from the cylinders filling and emptying operations.

Thank you for your attention

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