IAEA REGULATIONS TS-R-1 AND PACKAGES FOR UF_6

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ABSTRACT

The new IAEA regulations TS-R-1 (ST-1 Revised, 1996) include specific requirements for packages which are used to transport uranium hexafluoride (UF_6) such as a drop test and a thermal test. Under auspices of the World Nuclear Transport Institute (WNTI), an industry working group was formed at the end of 1999. This HEX Transport (HEXT) working group has since its formation been evaluating the new requirements against the current practice of transports, and the packages used for the transport of non-fissile UF_6.

The working group has initially concentrated its efforts on the issue of compliance with the drop test requirement in TS-R-1 and a special project on this subject was started. During this project, a new valve protection for 48 inch cylinders was developed and its positive performance successfully demonstrated by finite element calculation and by actual tests. Early March 2001 an application for H(M) approval for loaded 48 inch cylinders was sent to the competent authority.

Work on the thermal test requirement is another important issue. Also UF_6 Cylinder Standard issues, i.e. compliance with ISO 7195 and ANSI N14.1 are dealt with in the HEXT working group.

This paper describes the valve protection device and its testing; the application for approval of 48 inch cylinders fully loaded and with heels; and the status of work concerning the thermal protection.

INTRODUCTION

Millions of tonnes of uranium hexafluoride (UF_6) have been transported throughout the world for decades with no significant transport incidents that resulted in serious consequences from either the radiological or the chemical nature of UF_6; an excellent safety record.

In 1984 a ship, the Mont-Louis, carrying 30 large cylinders of UF_6, sank before the coast of Belgium. All cylinders were recovered, with no release of contents. Although the cylinders were deformed, they demonstrated an exceptional capability of withstanding the rough conditions inside the hull of the ship during the period that recovery had to be delayed because of rough weather.

In 1986 a cylinder was ruptured at Gore, Oklahoma, USA, as a result of an operational failure. This resulted in a large part of the UF_6 content being released to atmosphere. The cloud of reaction products, especially the hydrogen fluoride (HF), spread over the plant area causing the death of one person.

The Mont-Louis accident supported the excellent safety record of UF_6 transport. The Gore accident, which led to a casualty, had in fact nothing to do with transport operations.

Nevertheless, public and political attention was attracted by both accidents and the International Atomic Energy Agency (IAEA) felt it necessary to develop early guidance on UF_6 for the dangerous goods transport community. During 1986 consultant services and technical committee meetings took place, resulting in recommendations that were published in 1987 as IAEA-TECDOC-423 [1].

TECDOC-423 recommended, amongst others, to develop improved analytical models for evaluation of thermal behaviour of UF_6 cylinders, and stated that it is important that the results of such safety evaluations are consistent amongst Member States. This recommendation led to a Co-ordinated Research Programme (CRP) initiated by the IAEA. This CRP was contributed to by scientific investigators from Argentina, Germany, France, Japan, United Kingdom and USA.

TECDOC-423 was followed by TECDOC-608 [2] in 1991 and the special attention for UF_6 was brought into the revision process of IAEA Safety Series No. 6 “Recommendations for the Safe Transport of Radioactive Materials”, 1985 (as amended 1990) [3]. This revision process formed the basis for the issue of IAEA ST-1 “Regulations for the Safe Transport of Radioactive Materials”, 1996. In 2000 a re-issue of ST-1 took place as TS-R-1 “Regulations for the Safe Transport of Radioactive Materials” (ST-1 Revised, 1996) [4].

SAFETY SERIES NO. 6 / TS-R-1 AND UF_6

Safety Series No. 6 (SS6) does not address UF_6 as a special category of radioactive material and no specific requirements are listed. UF_6 is a radioactive material, but is also chemically reactive when in contact with water (e.g. moisture in air). In that case uranyl fluoride (UO_2F_2) is formed, and, more important, also HF gas. These chemical properties constitute the subsidiary risk of UF_6 and for that reason §407 of SS6 has to be complied with. In Safety Series No. 7 “Explanatory Material to SS6” [5], no further information on UF_6 is found. In Safety Series No. 37 “Advisory Material to SS6” [6], references to packaging of UF_6 are found in § 407.6. In this document the cylinder standards ANSI N14.1 [7] and ISO/DIS 7195 [8] are mentioned, as well as TECDOC-423 and -608.

TS-R-1 incorporates specific requirements for UF_6 packages in § 629-632. The most important requirements are the hydraulic test, the drop test and the thermal test. Furthermore, package approvals for UF_6 are introduced: Type H packages, both as multilateral and unilateral approval, i.e. H(M) and H(U) respectively. As far as cylinder standards are concerned, TS-R-1 only makes reference to the international standard ISO 7195.

For the transport of enriched UF_6 with more than 1% U-235, the new regulations TS-R-1 practically do not impose any change in comparison to SS6. A 9 meter drop test as well as a thermal test were already applicable because of the fissile properties of the material. For UF_6 with a maximum U-235 content of 1%, i.e. mainly natural and depleted material, the drop test and the thermal test are new elements that have to be complied with.

THE WORLD NUCLEAR TRANSPORT INSTITUTE

The World Nuclear Transport Institute (WNTI) was founded in April 1998.
During 1999 WNTI members concluded that the new regulations, at that time still known as ST-1, required a co-ordinated effort of study and evaluation and for that purpose two industry working

groups were formed. The so-called ST-1 Working Group would deal with ST-1 in general, except those regulations regarding UF_6, which were to be dealt with by the HEXT Working Group.

Since its formation, the HEXT Working Group has been working, under the auspices of WNTI, on the requirements for transport of UF_6 under TS-R-1, striving to find practical, effective and efficient solutions not entailing excessive cost.
WNTI maintains close relations with other international organisations like the Nuclear Energy Institute (NEI), the World Nuclear Association (WNA) and Foratom with regard to TS-R-1 issues.

THE SPECIFIC REQUIREMENTS IN TS-R-1

There is a widespread use throughout the industry of 30 inch cylinders (30B) and 48 inch cylinders (48Y and 48X) for the packaging of UF_6. The design, manufacture and testing of these cylinders is covered by the standards ANSI N 14.1 and ISO 7195. ANSI N 14.1 is the American national standard and has been in use throughout the world for many years, while ISO 7195 is the international equivalent of ANSI N 14.1. Cylinders based on either standard are equal in terms of technical performance quality.

Comparing these standard cylinders to the specific requirements in TS-R-1 leads to the following conclusions with regard to the hydraulic test, the drop test and the thermal test.

The hydraulic test requirement for the 30 inch and the 48 inch cylinders in § 718 of TS-R-1 is met, both by the requirements in ANSI N14.1 and in ISO 7195.

The drop test requirement for 30 inch cylinders with overpacks (for fissile material) is stated in § 727 of TS-R-1. This requirement, a 9 meter drop and a 1 meter puncture test, is identical to SS6 and the existing certified overpacks satisfy this requirement.
For 48 inch cylinders (for natural and depleted material) the drop test requirement in § 630 (c) requires a 0.6 meter drop for a full cylinder, in such an orientation that maximum damage is suffered. Back in the 1960s and 1970s, 48 inch cylinder drop tests were performed from larger heights (up to 9 meters), but no conclusions could be drawn from these experiences to satisfy the TS-R-1 requirement. The HEXT Working Group therefore concluded that further work was necessary.

The thermal test requirement for 30 inch cylinders with overpacks (again for fissile material) is found in § 728 . Like the requirement for the drop test, here also is the TS-R-1 requirement identical to SS6 and in short it consists of a 30 minute stay in an 800^{o}C, fully engulfed hydro carbon fire. The requirement is met by the existing certified overpack.

The thermal test requirement for 48 inch cylinders (for natural and depleted uranium) is given in § 630 (c). This requirement is new and is a consequence of the attention requested for the issue of thermal behaviour of UF_6 packages in TECDOC-423, 1987. Based on this request the IAEA CRP was established in 1992 with the aim of providing more insight in this subject. The programme however did not result in general conclusions with respect to survival of a large cylinder in a fire, nor could consensus be reached on a general computer model / calculation method. The latest draft of the CRP report is dated April 1999 [9]; the final report had not yet been issued at the time this paper was written. The CRP was undertaken to assist in making the decision whether a fire test requirement for UF_6 packages was justified. The thermal test requirement, however, has been included in the 1996 edition of the regulations, before the CRP effort was completed. The HEXT Working Group concluded further work to be necessary also with regard to this issue.

The further work required focuses especially on 48 inch cylinders, both for the drop test requirement and for the thermal test requirement. These issues are explored further in the sections below.

COMPLIANCE OF 48 INCH CYLINDERS WITH TS-R-1

A package design for UF_6 that qualifies for both the drop test requirement and the thermal test requirement (as well as other requirements, not mentioned here), will receive H(U) approval from the Competent Authority (CA). In the context of this paper this is called the "one step approach".
TS-R-1 requires H(U) approval ultimately as from 31 December 2003 (§ 805 (a)) for packages meeting all the requirements of § 629-631. Before 31 December 2003 and starting 31 December 2000, packages that meet the requirements of § 632 (c) must have H(M) approval. This paragraph excludes the thermal test requirement for packages containing more than 9,000 kg of UF_6.
The HEXT Working Group has chosen to concentrate its work initially on H(M) approval for 48 inch cylinders and at a later stage on the thermal issue. This is the so-called "two step approach".
The above is depicted in Figure 1 below.

Figure 1	Drop test	Thermal test
Two step approach	Valve protection + CRP result (end 2001)	Valve protection + Thermal protection, either through use of end caps or full covers (end 2003)
One step approach	Overpack-like designs including both valve protection and thermal protection (end 2003)	

The drop test requirement was the first aspect in the two step approach to be evaluated. A project was initiated to investigate how a standard 48 inch cylinder might meet the drop test requirement, and ultimately to conduct a drop test on a specimen cylinder.

THE DROP TEST PROJECT

This project was funded jointly by a consortium of UF_6 users. The work was carried out in Canada. Finite Element models of the 48Y cylinder were subjected to computer simulated tests. The fully loaded cylinder was suspended at an angle of approximately 23^o to the vertical with the valve facing downwards and then dropped from a height of 0.6 m. The computer simulations showed that the current design of the valve guard in ANSI N 14.1 and ISO 7195 could not prevent the skirt from deforming inwards and damaging the valve, both for the 48Y and the 48X cylinder. Further computer modelling was used to design a structure that would prevent the skirt from deforming inwards and damaging the valve. An initial design made of steel was discarded because it weighed approximately 35 kg. This is too large a weight to be handled by a single operator and could lead to unsafe working conditions during routine cylinder handing. A re-design manufactured from welded high-strength aluminium plate resulted in a much more acceptable weight of 11 kg. This design was named Valve Protector Assembly (VPA) and was bolted through three holes drilled in the skirt of the cylinder. Photographs of the prototype VPA are shown in Figure 2 and 3.

Figure 2: VPA – front view

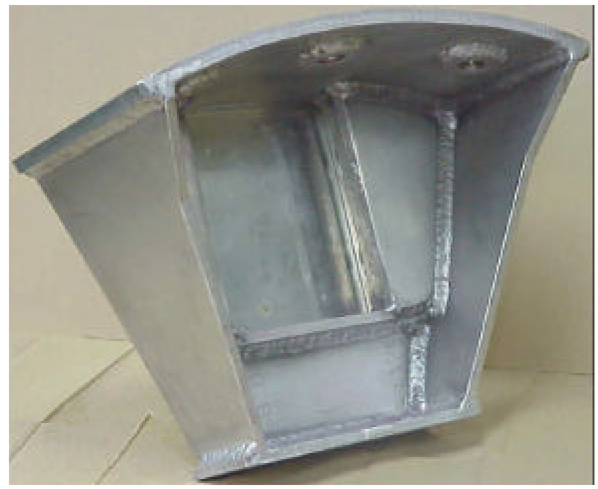

Figure 3: VPA – back view

While computer modelling showed that the loaded 48Y cylinder with VPA would pass the TS-R-1 drop test requirement, it was recognised that an actual drop test should be carried out in order to confirm the computer calculations. Accordingly a test specimen package was made from a 48Y cylinder filled with steel balls to simulate the maximum UF_6 fill, and fitted with a prototype VPA. The drop test was carried out at the Cameco Rabbit Lake mine site in September 2000, in the presence of a Canadian CA representative.
Although the skirt showed some deformation, it was insufficient to let the skirt make contact with the valve. The cylinder valve was not damaged by the drop and it successfully passed the required leak test at 690 kPa (100 psig).

After the drop test of the loaded cylinder, an empty 48Y cylinder with a simulated maximum heel weight was dropped from a height of 1.2 m with no valve protection in place. This cylinder also survived the drop without inflicting damage to the valve, thus again confirming the computer modelling study that had been performed before.

Following these successes, the consortium partners continued their efforts, with the support of the HEXT Working Group and agreed to the format and content of a Safety Analysis Report (SAR) which would accompany the application for an H(M) approval certificate for 48Y and 48X cylinders.

On 6 March 2001, the application plus SAR were submitted by Cameco Corporation to the US Department of Transport (US-DOT). Simultaneously, requests for validation of this H(M), as soon as approved, were submitted to relevant CA's in North America and Europe by other partners of the drop test consortium.

Furthermore, a request was made for incorporation of the new VPA design in ANSI N 14.1 in order to render recognition for and acceptance of the design. Following this request, an addendum to the 2000-edition of the standard was drawn up in which the VPA was incorporated as an alternative valve guard. This addendum was passed through the necessary voting rounds and is currently in the process of publication.

Also incorporation of the use of alternative valve guards into ISO 7195 has been discussed and accepted during the annual ISO meetings in April 2001.

At the time this paper was written, US-DOT has prepared a draft H(M) certificate covering full 48Y and 48X cylinders as well as "heeled" cylinders. Transport of full cylinders requires the use of VPA's; empty cylinders, up to the maximum heel weight, may be transported without VPA, but must have the standard ANSI/ISO valve guard.

THE THERMAL TEST REQUIREMENT

The CRP did not provide clear insight in the thermal behaviour of the large cylinders, nor was consensus reached on a general calculation model. The calculated survival times for a bare cylinder range from 26 to 35 minutes. Many experts in the UF_6 industry think it improbable that a large cylinder filled with UF_6 will not last longer than 30 minutes in the thermal test. A live test to demonstrate the actual behaviour of a large cylinder in a fire is not easy to perform.

As long as no actual and accurate information is available, there are two options for the future beyond 31 December 2003. The first is continued use of the H(M) approval. The second option involves the application of some form of thermal protection.

The HEXT working group is currently evaluating solutions for thermal protection covers which allow continued use of all existing transport equipment, such as cradles and tie-down systems. Such to avoid the necessity of excessive investments for adaptation of such equipment. It has already become clear however that any form of thermal protection will require substantial investments and will result in higher operations cost.

SUMMARY

The new IAEA Transport Regulations TS-R-1 impose additional requirements to the transport of non-fissile and non-fissile excepted UF_6. Through co-ordinated initiatives by the industry, under auspices of WNTI, these new requirements have been evaluated. As a consequence, a new VPA for 48 inch cylinders has been developed and successfully tested against the drop test requirements in TS-R-1. The use of the VPA has been incorporated in the relevant cylinder standards. Work on compliance with the thermal test requirement for 48 inch cylinders is ongoing.

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