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INDUSTRY EXPERIENCE WITH THERMAL PROTECTORS ON 48 INCH UF_6 CYLINDERS

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ABSTRACT
The International Atomic Energy Agency (IAEA) Transport Safety Regulations (TS-R-1) require packages filled with non-fissile and fissile excepted uranium hexafluoride (further indicated as natural and depleted UF_6) to pass the thermal test. The thermal behaviour of cylinders filled with UF_6 has been studied extensively and also an IAEA Co-ordinated Research Programme was allocated to this subject

The studies show that the standard 48-inch UF_6 cylinders have a large thermal mass and some conclude that they would meet the thermal test requirement. A continued unilateral approval, however, was not supported by all parties involved.

In order to be able to continue international operations under H(U) approval, an industry consortium developed thermal protection units (BTP's and CTP's) to be added to the standard cylinders. Actual use of the newly developed thermal protectors started in January 2005.

This paper reviews the UF_6 specific regulatory developments, research and analysis activities to assist the regulatory development and to verify compliance with the new requirements and describes the industry experience with these. The paper describes experience with the use of thermal protectors. Also, the paper looks forward to new activities with regard to demonstration of compliance with the thermal test.

INTRODUCTION
The paper briefly describes and discusses the important events and occurrences, connected with the introduction of the UF_6 specific requirements in the regulations. The focus thereby is especially on the new thermal requirement for natural and depleted UF_6, but also other aspects of the new 1996 requirements are reviewed. Earlier papers on transport of UF_6 and TS-R-1 [10, 11, 12] contain the more detailed information.

In the paper, the industry experience with the development of the regulations, with the implementation and interpretation of the regulations and with the application of the regulations is reflected.

HISTORY OF THE UF_6 SPECIFIC REGULATORY REQUIREMENTS

This historic overview starts with the observation that millions of tonnes of UF_6 have been transported throughout the world **for decades** with no significant transport incidents that have resulted in serious consequences from either the radiological or the chemical nature of UF_6.

In 1984 a ship, the Mont Louis, carrying 30 large 48 inch cylinders with UF_6, sank near the coast of Belgium. This transport accident attracted worldwide intensive press coverage during the weeks of the recovery operation that had to be delayed because of bad weather conditions. However, all cylinders were recovered, with no release of contents, thus sustaining the excellent safety record of UF_6 transport.

In 1986 an overfilled cylinder with UF_6 ruptured in the conversion plant at Gore, Oklahoma, USA, as a result of an uncontrolled heating operation. Both the overfilling and the uncontrolled heating were the result of operational failures. The combination of the two caused the cylinder to rupture, followed by a release of a large part of the content to the atmosphere. The cloud of reaction products, especially the hydrogen fluoride (HF), did spread over the plant area, causing the death of one person. This tragic accident also received a great deal of press coverage, but the accident had nothing to do with transport operations.

As a result of the public and political attention attracted by both accidents, the IAEA started to develop guidance for UF_6 transport and organised consultant services and technical meetings **during 1986**.

This resulted in the publication of IAEA-TECDOC-423 [5] **in 1987**. The document contained a recommendation to develop improved analytical models for evaluation of the thermal behaviour of UF_6 cylinders and to achieve consistency amongst Member States. This led to a Co-ordinated Research Programme (CRP), established by the IAEA, which started in 1992.

Following TECDOC-423, further technical meetings were held by the IAEA. These meetings led to the publication of IAEA-TECDOC-608 [6] **in 1991**. In this period also the revision of IAEA Safety Series No. 6 “Recommendations for the Safe Transport of Radioactive Materials”, 1985 (as amended 1990) was being prepared.

After a preparation and planning period of about two years, a contract between CEA-IPSN, France and CRIEPI, Japan was signed **in 1991** for the so-called TENERIFE programme. The programme did “Research on Behaviour of UF_6 Containers Exposed to Fire”. The programme ran till about the **end of 1996** and the final report was issued in **April 1997** [7]. The TENERIFE programme used a shortened 48 inch model cylinder. The programme concluded to expect that a bare full size 48 inch cylinder would not survive the fire conditions stipulated by the IAEA.

In 1992, the IAEA established a CRP “Assessment of Safety of UF_6 Transport Packages in Fires”. The IAEA initiated this CRP, because the IAEA, its Member States, and associated international bodies were, in the early 1990s, considering the addition to the International Transport Regulations of a thermal test requirement for packages designed to transport UF_6.

The designated Chief Scientific Investigators (CSI's) from Argentina, France, Germany, Japan, United Kingdom and the United States of America exchanged information on their research in this area and tried to come to common conclusions. The six CSI's, however, could not reach consensus as to whether a 48Y cylinder would rupture in the regulatory fire test and, if it did rupture, they could not fully agree on either what time in the fire exposure the rupture would occur, or what would be the mode and rate of release. The survival times calculated ranged from less than 26 minutes to as high as 35 minutes. The work of the CSI's ended in **May 1998** and summary report was written by the IAEA in **April 1999** as a preliminary draft TECDOC- UF_6 [8].

The CRP was undertaken to assist in making the decision whether a fire test requirement for UF_6 packages was justified. However, before the CRP effort could be completed, a decision was taken by the regulatory revision panel to include a thermal test requirement for UF_6 packages in the 1996 edition of the regulations.

In advance of the regulatory revision panel meeting in the second half of 1996, the IAEA convened a Consultants Services Meeting (CSM) in **May 1996**. This CSM, with participants from industry, advised not to include the thermal test requirement at this stage and to further investigate the issue. The CSM also considered the 48 inch UF_6 cylinders to be able to survive the thermal test, because of the large thermal mass.
The advice of the CSM not to incorporate the thermal test requirement was not honoured. The large thermal mass of the 48 inch cylinders, however, was addressed in paragraph 632 (c) of the regulation, with the option for an H(M) approval.

IAEA ST-1 "Regulations for the Safe Transport of Radioactive Materials", now TS-R-1, was accepted, approved and published in **1996** [1].

In 1998 the World Nuclear Transport Institute (WNTI) was founded.

Due to the interest by WNTI members in dealing with the implications of the changes to the new regulations, the WNTI HEXT Industry working Group (HEXT = uranium HEXafluoride Transport) was formed in **November 1999**. The HEXT WG was composed of all of the commercial converters, enrichers and transporters of UF_6 in North America and Europe and they worked extensively to evaluate the new requirements for UF_6. The objective of this work was to find practical, effective and efficient solutions to address the changes in the regulations and to share best practices.

This work became more focussed **during 2000** with the formation of an Industry Consortium, derived from the HEXT WG. The consortium, consisting of Cameco, BNFL, Cogema, Urenco, USEC, EDF and Honeywell, started with a drop test project. This project resulted in the development of a Valve Protector Assembly (VPA) for the 48 inch cylinders, to replace the existing standard valve cover.

With the results of the drop test project, an application for an H(M) approval was submitted to US-DOT in **March 2001**. The certificate was issued on 31 **August 2001** as USA/0592?H(M)-96, Revision 0, expiring on September 1, 2006. Initial and subsequent validations followed in other jurisdictions. The H(M) validations in Europe (from the CA's of Belgium, France, Germany, Netherlands, Spain and UK, which co-operated in this matter) finally terminated by the end of

2004, leaving no other options for compliance with the regulations in Europe than an H(U) approval.

The industry consortium continued their co-operation and transformed the droptest project into a thermal project in **early 2002**. The aim of this project was to find solutions for compliance with the thermal requirement that allowed for continued use of existing transport equipment. This was a different approach as had been chosen in Japan, where a completely new transport system had been developed, the Dedicated Transport Container (DTC). At PATRAM 1998 in Paris, France, a paper on this DTC was presented [9]. An H(U) validation for the DTC was issued in Japan during **April 2002**.

The industry consortium, facing the fact that a long term use of an H(M) approval was not possible in Europe, did decide to develop an insulation system that would provide confidence to regulators in surviving the thermal test conditions. The IAEA CRP was thereby taken as a starting point, i.e. the insulation system should reduce the CRP heat transfer by about a factor of 50 %, roughly doubling the survival times to a range from 50 to 70 minutes. This large margin was taken at the time to exclude discussions on accuracy of modeling and calculation.

Two designs of thermal protection were developed on this basis, both in the form of a removable “cladding”. One design is called the Blanket Thermal Protector (BTP), the other design is called the Composite Thermal Protector (CTP). An H(U) approval was applied for with UK-DfT in **late 2003** and certificates were issued in **May 2004** as GB/3570/H(U)-96 for the BTP and GB/3571/H(U)-96 for the CTP. Another certificate was issued for the transport of a bare 48 inch cylinder with small quantities of UF_6 (heels) as GB/3572/(H(U)-96. The UK certificates have received endorsement or validations in USA and Russia and were accepted in Canada. The Russian validation RU/320/H(M)-96-T covers the use of the BTP and the CTP based on the UK certificates, but also allows transport of bare cylinders inside Russia.
More details on the thermal protector development project were presented during the UF_6 Seminar 2007 [14].

The new thermal protectors (BTP’s and CTP’s) have been in use for international transports since **January 2005**, using the H(U) certificates issued in the UK or their validations. The UK certificates were re-issued **in 2007**.

In parallel to the work on the thermal case, the industry consortium started to evaluate a drop of a cylinder on the plug side in 2003. This resulted in the development of an alternative plug design, the countersunk plug. The latest design of the countersunk plug has been forwarded to ANSI N14.1 **in 2006**, for incorporation into the revision of this cylinder standard.
More details on the development work for the countersunk plug were presented at the UF_6 Seminar 2007 [15].

The certificate USA/0592/H(M)-96 was re-issued **in 2006**. International transports between Canada and USA use this certificate.

INDUSTRY EXPERIENCE – REGULATORY DEVELOPMENTS

The major development in this context is the incorporation of specific requirements for UF_6 packages, which has had large consequences for the transport of natural and depleted UF_6 in 48 inch cylinders. These worldwide standardized cylinders had been in use for decades successfully, for the purpose of transport, as well as for use in process plants.

Nevertheless the safety of UF_6 transport came subject of discussion during the mid 1980's, as a result of the Mont Louis accident and the Gore accident.

The question remains till today whether these two events did warrant such a specific change of the regulations, as happened. There was no shortcoming of the transport regulations involved with the Mont Louis accident and these regulations were not at all in play with the Gore accident.

Industry participation in the meetings and work that led to publication of the IAEA-TECDOC's -423 and -608 was limited. The same applies to the drafting of the revision of Safety Series No. 6. The CSM in May 1996 saw relative more participants from industry, but the advice from the meeting, with respect to the thermal test requirement, was not honoured.

Although the industry participants worked well together during the meetings, there was no structured industry co-operation in the regulatory area at the time.

INDUSTRY EXPERIENCE – IMPLEMENTATION AND INTERPRETATION OF REGULATIONS

The revision of Safety Series No. 6 was published as IAEA ST-1 in 1996 facing industry with UF_6 specific sections and paragraphs. In 2000, ST-1 was changed into TS-R-1.

It happened to be that in 1998 the World Nuclear Transport Institute (WNTI) was founded, to address fuel cycle transport issues. WNTI's scope later expanded to cover also other sectors of radioactive material transport.

The new issue of the transport regulations became a subject for joint study of the WNTI-members and working groups were formed for this purpose. The WNTI HEXT Industry Working started in 1999, to evaluate the standard UF_6 cylinders in use against the new UF_6 requirements.

The most important requirements to address were: the hydraulic test, the drop test and the thermal test.

The hydraulic test was easily complied with by 48 inch cylinders conforming to ANSI N14.1 [3] and ISO 7195 [4].
The available information on drop testing, although some of the testing was much more severe, appeared not to be in line with the present regulatory requirement. This conclusion resulted in the drop test project, for which an industry consortium was formed.

Satisfactory evidence in complying with the hydraulic test and drop test requirement were important to be able to obtain an H(M)-approval for the 48 inch cylinders based on paragraph 632 (c) of TS-R-1. This paragraph, important for the thermal requirement, has been included following the outcome of the CSM in May 1996.

The drop test project resulted in the development of the VPA and with that an application for H(M)-approval has been filed with US-DOT, resulting in USA/0592/H(M)-96 on 31 August

2001. This H(M)-approval has been validated in other countries, but in some cases with a shortened validity period.

Although paragraph 632 has no time limitation, Competent Authorities (CA's) in Europe made clear that they would require H(U)-approvals beyond 2003.

Facing the fact, the industry consortium started a thermal project and decided to develop an insulation system that would provide confidence to regulators in surviving the thermal test conditions. This resulted in the development of the BTP and the CTP, for which H(U)-approval was requested with UK-DfT. GB/3570/H(U)-96 for the BTP and GB/3571/H(U)-96 for the CTP were issued in May 2004. Another certificate was issued for the transport of a bare 48 inch cylinder with small quantities of UF6 (heels) as GB/3572/(H(U)-96. Endorsement and validation followed in Canada, USA and Russia.

From 1 January 2005 onward, 48 inch cylinders with natural and depleted UF_6 are transported in, into and from Europe using thermal protectors under H(U)-approval.

In the USA, Canada and Russia and between Canada and USA 48 inch cylinders are transported bare under H(M)-approval.

INDUSTRY EXPERIENCE– APPLYING THE REGULATIONS

The new requirements have resulted in increased cost to the industry, especially the use of thermal protectors.

Development cost and investment cost may be a one time matter, but operational costs did also rise substantially, due to increased handling and additional logistics, such as separate return transport of thermal protection equipment.

Furthermore, risk and dose to workers have increased; the results of a study in this area was presented earlier in a paper at PATRAM 2004 in Berlin [13].

Industry is currently working on a re-evaluation of the thermal data to present a solid safety case for a bare full 48 inch cylinder without thermal protection.

CONCLUSIONS

Looking at the historic overview, the regulatory situation with respect to the transport of natural and depleted UF_6 can be divided in a pre and post 1996 period.

The turning point hereby is the publication of the IAEA ST-1 (now TS-R-1).

This new issue of the regulations, for the first time, included substance specific requirements, but for UF_6 only.

The development and now routine use of the VPA is considered as a positive result of the new requirements. The thermal test requirement, however, has resulted in a high burden to industry so far.

Another turning point in time can be observed, which is the establishment of WNTI in 1998 and, for UF_6, the start of the HEXT Industry Working Group in 1999.

Before WNTI, there was (UF_6) industry co-operation with regard to the cylinder standards ANSI N14.1 and ISO 7195 and, specifically, the UF_6 converters held their annual Safety Meeting. Also USEC-651 [2] acted as an important reference document in the UF6 industry. Furthermore, in 1988, 1991 and 1995, the UF_6 Conferences were organised in the USA.

Under the auspices of WNTI, industry co-operation developed to become more intensive and structured and allowing for a closer contact with regulators and the regulatory developments.

From 2000 onward, industry has been in frequent contact with the regulators at IAEA meetings and other occasions to exchange information on the progress in the compliance projects.

Industry will continue to keep the regulators informed on new developments with regard to a new safety case, as it remains committed to safe, efficient and reliable transport of UF_6.

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