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NEW METALLIC GASKETS QUALIFICATION: RESISTANCE TO ACCIDENT CONDITIONS OF TRANSPORT IN TN INTERNATIONAL CASKS

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ABSTRACT

For dual purpose “transport/storage” casks (like the TN24 casks family or casks for vitrified wastes), the confinement by way of metallic gaskets has long been the chosen solution. Their metallic nature leading to a good behaviour in long-term and high temperature conditions, they still have to satisfy the transport regulations requirements, which are not a given. In order to secure the supplying of such strategic parts of a cask and, above all, to keep developing efficient sealing solutions, TN International has found and qualified new metallic gaskets.

For this qualification, a series of tests complying with the accident conditions of transports have been designed and performed on these new metallic gaskets. Indeed, the gaskets have to withstand three major types of “accident” conditions: 1/ parallel sliding of the lid and the body, resulting in a lateral displacement of the contact surfaces, 2/ separation of the lid and the body, resulting in a decompression of the gasket, 3/ 30 minutes-800°C fire on the cask, resulting in a peak temperature of the gasket. Tests assemblies and procedures have been developed, in accordance with TN International cask design, and after that lateral quasi-static displacement tests up to 3-mm, lateral dynamic displacement tests up to 3-mm, multiple decompression and recompression tests, and over-400°C peak temperature tests were carried out.
The dimensional, visual and leaktightness results of these conservative and highly severe tests were fully satisfactory and allow to establish the safety and efficiency of these new metallic gaskets.

1. ISSUE

The use of spring-energized metallic gaskets for dual purpose casks sealing is a well-known and well-tried solution.

Such metallic gaskets have been chosen because of their natural good behaviour in long term and high temperature conditions. Indeed, they are the logical substitutes to elastomeric gaskets for storage applications.

Being such a strategic part of a cask, TN International has decided to secure the supplying and find new efficient solutions for these seals by qualifying new metallic gaskets.

Even if standard metallic gasket design (an helicoïdal internal spring creating an internal sealing stress, an intermediary jacket regularly distributing the spring force, and an external coating in ductile material absorbing the flange roughness) is especially thought to make them resilient to all kinds of harsh conditions, there is still a need to make satisfactory justifications showing they comply with the regulation and safety standards <1>. Simply put, we still need to demonstrate they can guarantee leaktightness in the most harmful accident conditions (related to the 10^{-6} A2/hours regulatory criterion <1>).

This paper presents the tests performed by TN International to assess the good behaviour of new metallic gaskets regarding the following accident conditions:

Accident conditions	
CASK ⇨	LID (AND METALLIC GASKET)
Horizontal drop	Sliding
Axial drop	Decompression
Fire (800°C)	Peak temperature

Table 1 : three main accident conditions and consequences

2. DETERMINATION OF TEST CONDITIONS

Accident conditions for every dual-purpose TN International casks (for spent fuel, standard waste canister…) can be traduced into gasket stresses.

Indeed, for the three types of accident conditions, every dual-purpose cask and design has been investigated in order to assess the worst configuration, and thus the input parameters for the test specification.

The following stresses came out :

	CASK ⇨	LID (AND GASKET) ⇨	CONSERVATIVE VALUE
Accident conditions	Horizontal drop	Sliding	for large torus diameters : < 1,5 mm in most cases (< 2,5 mm in 3 special cases)
	Axial drop	Decompression	[no value]
	Fire (800°C)	Peak temperature	without impact limiters : temperature profile (+ margins) for the orifice cover gasket = peak at 380°C with a 45 min-period over 300°C

Table 2 : TN casks accident conditions

We had then to define, design and perform tests according these specifications.

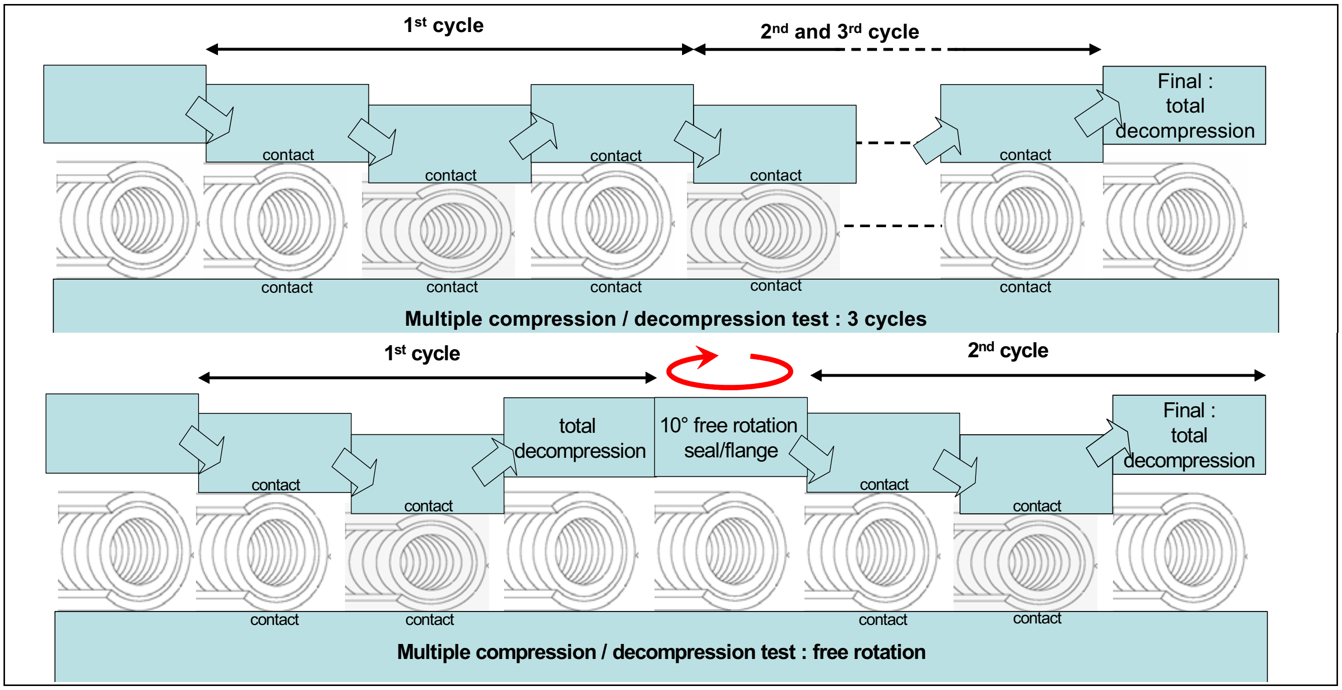
3. TESTS DESCRIPTION

3.1 Multiple compression/decompression tests

Context: To assess the resistance of the metallic gaskets to some potential upheaval of the lid, highly conservative multiple compression/decompression tests were performed.

They consisted of 2 types of tests (see figure 1):

- 3 consecutive compression / decompression cycles, without losing the seal/flanges contact between two consecutive cycles.
- 2 consecutive compression / decompression cycles, with a total loss of contact between the 2 cycles and a 10° free-rotation of the flange relative to the gasket.



<u>Figure 1</u> : 2 types of multiple compression / decompression tests

Such stress conditions, as the ones reproduced in the 3-cycle test, are very conservative and severe compared to the stress conditions for actual metallic gaskets fitted in transportation/storage casks. In normal conditions of transport, these gaskets are used for one compression only. In accident conditions of transport / storage, there is no rebound of the cask that would lead to 3 consecutive significant lid or lid bolts deformations, during the regulated 9-m drop test. Nonetheless these tests allow us to appreciate the resistance of metallic seals to extreme recurrent mechanical conditions.

Total decompression/recompression tests, with a free rotation in between, is a conservative reproduction of a potential upheaval of the lid during the 9m drop test. Indeed, the free relative 10° rotation makes sure the gasket will not be recompressed “exactly” as it has been in the first place.

<u>Test assembly</u>:

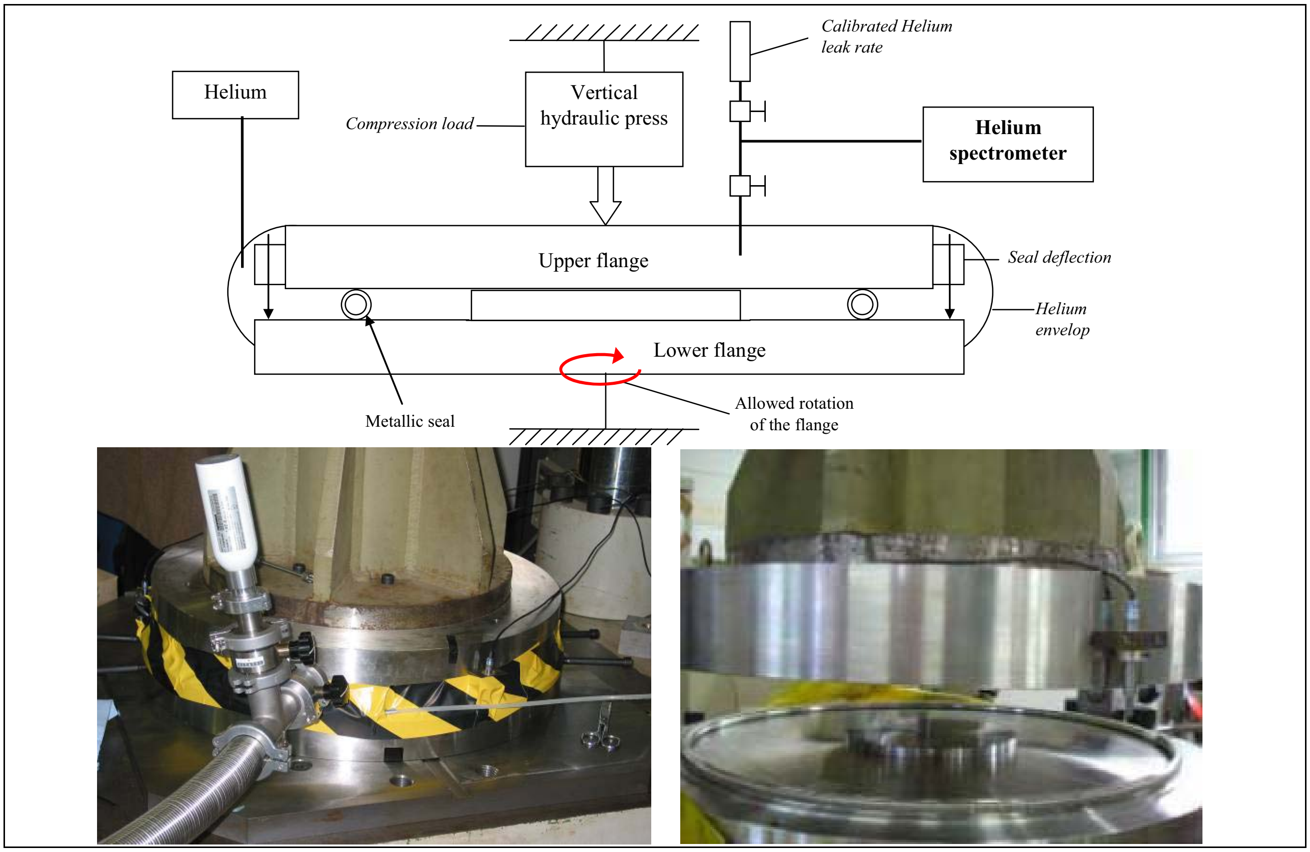


Figure 2: Sketch and photos of the multiple compression / decompression test assembly

3.2 Sliding (scraping) tests

Context: To assess the resistance of the metallic gaskets to some potential sliding of the lid during a horizontal 9m drop test, conservative scraping tests were performed.

They consisted of 2 types of tests:

- Up to 3 mm quasi-static scraping tests on full size gaskets (i.e. Ø11,8mm torus diameter),
- Up to 3 mm dynamic scraping tests on small-size gaskets (i.e. Ø5,6mm torus diameter).

Detailed description:
The quasi-static lateral displacement is obtained by shifting the lower flange of the test assembly, which contains the groove and the gasket, thanks to a screw (see figure 3). Meanwhile, the upper flange is kept in place by a reaction point fixed on the base. A 1,5mm lateral displacement is first performed. After waiting a few minutes, the lateral displacement is continued up to 3mm.

The dynamic lateral displacement is obtained by dropping a sledge hammer on a 3-flanges sandwich, which middle flange is protuberating of exactly the wished sliding distance (see figure 4). 2 tests were performed : one with a step-by-step incremented scraping distance, from 0,75mm to 3mm, and the other one with a one-blow scraping distance of 1,5mm.

Remarks:

- On full-size casks, such lateral displacement, limited by the gap between the centering diameter of the lid and the internal diameter of the cask body is usually <1,5mm for TN International casks, and can reach <2,5 mm in rare special cases.
- The dynamic scraping tests were launched as an alternative way to demonstrate the metallic gaskets good behaviour in case of lid-sliding. Indeed, the first quasi-static campaign was greatly sufficient to demonstrate such a good behaviour (in light of the results presented below). Nonetheless, in the end, the dynamic tests were rather used to try and find the performance limit in terms of scraping resistance, as the gaskets were tested further.

Test assemblies:
Both test assemblies are described in figure 3 and 4.

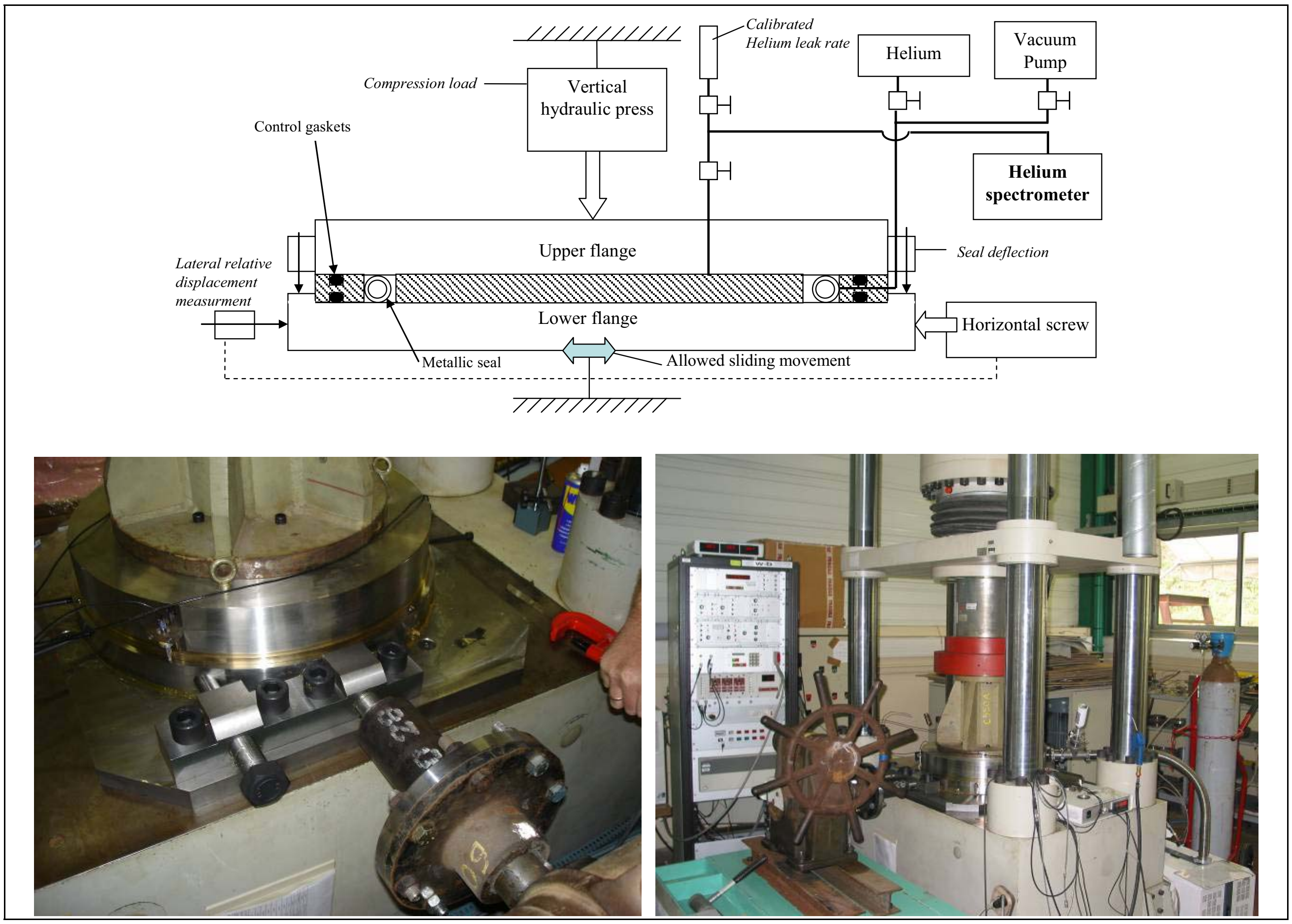


Figure 3: Sketch and photos of the quasi-static scraping test assembly

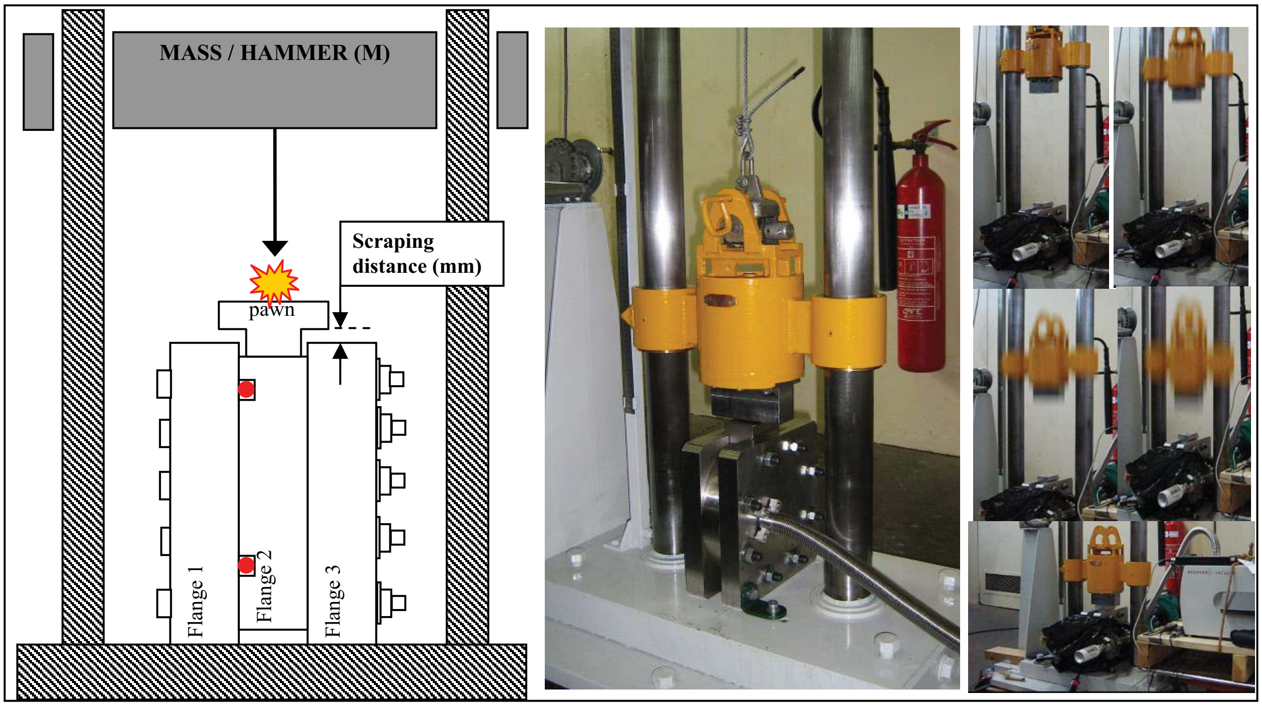


Figure 4: Dynamic scraping test assembly

3.2 High temperature tests

Context: To assess the resistance of the metallic gaskets to some potential accident fire conditions (regulated 800°C fire for 30min, but without the impact limiters), conservative high temperature resistance tests were performed.

- They consisted of a heating of the gaskets for at least one hour at a temperature above 300°C, with a peak temperature of 400°C (minimum). This temperature profile is deliberately higher than the already conservative profile describe in §2, in order to simplify the whole specification. To see the impact of such accident conditions on the gaskets, the leak rates were measured before and after each high temperature test.

Remark:
On a general basis, the accident conditions of fire for transport are defined as a 800°C fire surrounding the cask for 30 minutes. In this case the cask is in its transport configuration, which means it has both impact limiters on. These impact limiters serve as thermal barriers and thus prevent the gaskets to be submitted to high temperatures such as the ones used for this test. Regarding storage regulations, most involve accident conditions of fire as 600°C for 1 hour, which are less harmful for the gaskets, or 800°C for ½ hour without impact limiters, which is the worst-case scenario regarding gaskets temperature, and therefore has been chosen as our test specification basis.

Test assembly:

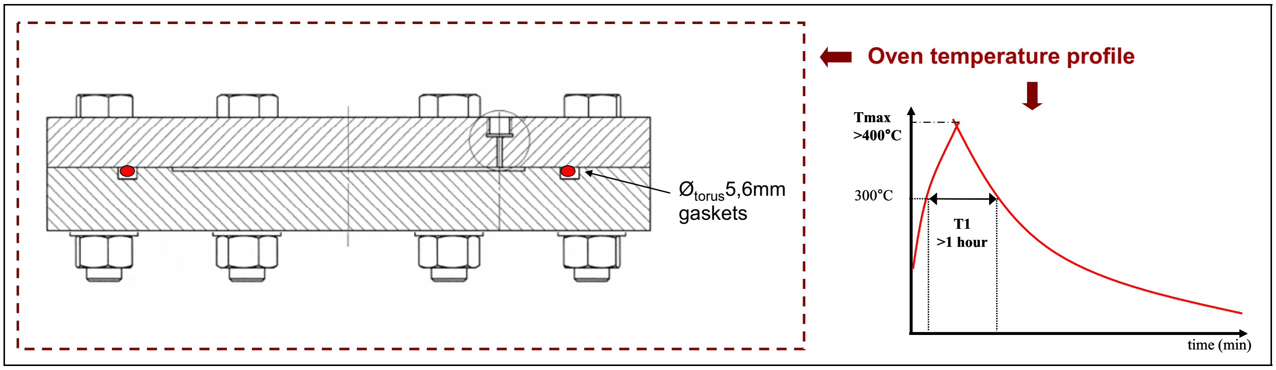


Figure 5: Sketch of the high temperature test assembly

4. TESTS RESULTS

4.1 Multiple compression/decompression tests

For the multiple compression and decompression tests, six identical full-size gaskets (i.e. Ø11,8mm torus diameter) have been tested.

The maximum leak rate measured after the third (and final) compression is $1{,}3.10^{-8}$ Pa.m^3/s, while the initial leak rate, at the first compression, were below 2.10^{-10} Pa.m^3/s. The useful springback after the third consecutive compression is, for 4 out of 5 gaskets, over 0,32mm and is 0,22mm for the fifth (the sixth gasket useful springback was not measured).

For the total decompression/recompression (+rotation) tests, four identical full-size gaskets (i.e. Ø11,8mm torus diameter) have been tested.

The maximum leak rate at the working point, after the total decompression and rotation, is $1{,}3.10^{-8}$ Pa.m^3/s (instantly after), and $9{,}6.10^{-9}$ Pa.m^3/s (after 2 hours), while the initial leak rate, at the first compression, were $\approx 2.10^{-10}$ Pa.m^3/s.

All of these results show the very good behavior of these metallic gaskets under accident multiple compression conditions, as the measured leak rates are far below the accident criterion, and rather near the normal conditions criterion, which rather tend to prove that they could be used more than once.

4.2 Sliding (scraping) tests

During the quasi-static tests, five identical full-size gaskets (regarding the torus diameter) have been tested.

The results show that :

- during the lateral displacement the instantaneous leak rate has increased from the initial leak rate to a leak rate lower than $1.2\ 10^{-7}$ Pa m^3/s,
- 10 minutes after 1.5 mm and 3 mm lateral displacement, for each of the 5 seals tested, the leak rate was below 10^{-8} Pa.m^3/s. The most important result is that 10 minutes after the 3mm lateral displacement, the leak rates were almost identical (variation less than half a decade up) to the initial leak rates.

During the dynamic tests, two identical small-size gaskets have been tested.

The results show that :

- during the "step-by-step incremented" displacement (up to 3mm), the leak rate stood below 3.6 10^{-11} Pa m^3/s, and was mostly below the sensitivity limit of the leaktightness tests,
- before and after the "one blow" displacement (1,25 mm), the leak rate stood below the sensitivity limit of each leaktightness tests ($\leq \sim 2.10^{-12}$ Pa.m^3/s).

These results show the excellent scraping resistance of these seals, even for great scraping distance.

4.3 High temperature tests

Three identical $Ø_{torus}$5,6mm gaskets have been submitted to the thermal profile described in §3.2.

The actual temperatures undergone by the gaskets are detailed in the table 1. For the three gaskets, the leak rate measured before and after the thermal cycle did not evolve, and stood around 10^{-10} Pa.m^3/s.

Seal n°	Tmax (°C)	T1 (test duration above 300°C, min)
1	407	116
2	412	124
3	410	108

Table 3 : High temperature tests results

These results confirm the resistance of these new metallic gaskets to the most severe accident conditions of fire.

5. CONCLUSION

Large scale tests were designed and perform to assess the behaviour of new metallic gaskets, in case of accident conditions on TN International dual-purpose casks.

Quasi-static and dynamic lateral displacement tests, multiple compression/decompression and free rotation tests, and high temperature tests were performed according highly conservative specifications.

The results of these tests showed that these new metallic gaskets can guarantee the leaktightness even after a 3-mm lateral displacement, or after 3 successive compression/decompression cycles, or after a total decompression with a 10° free rotation followed by a new compression cycle, or even after a 400°C peak temperature cycle.

The final and thorough reports for these tests have already been transmitted to several competent authorities, and successfully analysed (in detail), assessing the good behaviour of the gaskets, and thus the cask leaktightness, during accident conditions of transport.

This characterization of metallic gaskets in case of accident conditions, will allow us to make the most of their abilities in casks designing, and safety demonstrations, while securing the supply of such important parts and thus simplifying the manufacturing of TN International dual-purpose casks.

6. REFERENCES

<1> IAEA Safety Requirements N° TS-R-1 – Regulations for the safe transport of radioactive material 2005 Ed.