REPORT ON REGULATORY DROP TESTS

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SUMMARY

This appendix to the Chapter describes the report of the drop tests conducted on a ½ scale mockup of the TN-MTR packaging.

The drop mockup includes the packaging body and its lid and shock absorbing cover. The content of the mockup is made as a ½ scale mockup of the MTR-68 basket, loaded with pins to simulate the fuel assemblies. Appendix 5 to chapter 1 describes the drop test mockup.

This document summarises the drops that were made, demonstrating that they are representative of the drop cases that cause the most damage, and then describes each drop specifying the results of dimensional readings, accelerations and leak tests.

This appendix describes the calculation of the natural frequency of the basket containing the assemblies and determines the filter frequency of acceleration curves.

- The natural frequency of the full scale basket at 20°C is:

  f_p = 283 Hz;

- The filter frequency determined taking account of the scale ratio and a safety factor is:

  f_{filter} = 1000 Hz;

These drops demonstrated:

- That the packaging remains leak-tight during the tests, particularly after the sequence of five 9-metre drops and 2 bardrops on a bar.

- Accelerations to be used for design of the packaging:

  ◊ Acceleration along the longitudinal axis of the 1/2 scale packaging = [redacted] g

  ◊ Acceleration along a radial axis of the 1/2 scale packaging = [redacted] g

1. INTRODUCTION

The TN-MTR packaging is a packaging for the transport of research reactor fuels.

This document presents the report on regulatory drop tests defined in section 4.

The purpose of these drop tests is to demonstrate conformity of the TN-MTR packaging on which tests are carried out as defined by regulation <1> for type B fissile packages, with the assumptions made in this file for the thermal and the dose equivalent rate calculations and for analysis of the release of activity and nuclear safety of the package.

2. DROP TEST FACILITY

All equipment used complies with the requirements of section 618 in <1>.

The drop test facility is shown in figure -6.59.

The composition of the target used for the 9 m drop tests is as follows (from top to bottom):

– a 7 x 3 m horizontal steel plate fixed on a concrete foundation (total mass of target: 150 tonnes).

– the target is supported on the soft limestone subsoil through a 0.20 m layer of compacted sand.

The target used for the regulatory tests concerning the 1 m drop onto a bar consists of a solid mild-steel bar with a circular section and a diameter of 75 ± 2.5 mm (representative of the 150 mm diameter bar used for full scale). This bar is welded vertically on a horizontal steel plate that is itself fixed to the steel plate of the target described above.

The height of the bar above the steel plate is greater than the length necessary to penetrate into the body cavity.

Release is performed by a mechanical load release that is opened remotely by cable.

3. MOCKUP FOR DROP TESTS

The drop test mockup is designed to be representative of the strength and dynamic behaviour of the mockup.

The mockup and its content are shown in Appendix 5 in Chapter 1.

The masses of the as-built mockup are shown in Table 1-6.2.

The real properties of the materials for manufacturing the mockup are shown in table 1-6.4.

The screw numbering system used in table 1-6.5 is shown on figure 1-6.60.

The mockup and its drop contents are shown on the drawings in Appendix 4 in chapter 1.

4. DROP TEST PROGRAMMEME

Table -6.1 details the drop test programme in the order of the tests. All drops are shown in figure 1-6.1.

This test programme includes five 9-metre drops and two 1-metre drops on a bar.

Figure 1-6.1 presents all drops made.

The tests will be carried out in the following order:

- **Sequence No. 1**

  - **Drop No. 1**: 9 m lateral drop flat on the line of impact, perpendicular to the axis of the trunnions, with shock absorbing cover No. 1, packaging axis tilted towards the shock absorbing cover end by 5° from the horizontal (the angle between the packaging axis and the horizontal is justified later in this section).

  - **Drop No. 2**: 1 m vertical drop on a bar with corner on the outer shell and shock absorbing cover No. 1, packaging axis tilted towards the bottom end of the packaging by 30° from the horizontal.

- **Sequence No. 2**

  - **Drop No. 3:** 9 m lateral drop flat on the line of impact, along the axis of the trunnions with shock absorbing cover No. 2, packaging axis tilted towards the bottom end of the packaging by 5° from the horizontal (the angle between the packaging axis and the horizontal is justified later in this section).

- **Sequence No. 3**

  - **Drop No. 4**: 9 m vertical drop on the corner of shock absorbing cover No. 2, centre of gravity of the mockup on the same vertical line as the point of impact.

- **Sequence No. 4**

  - **Drop No. 5**: 9 m vertical bottom-down drop with shock absorbing cover No. 1, packaging axis vertical.

- **Sequence No. 5**

  - **Drop No. 6**: 1 m drop on a bar, on shock absorbing cover No. 3, oriented such that the bar, orifice B and the centre of gravity are all on the same vertical line.

  - **Drop No. 7**: 9 m axial drop, flat on shock absorbing cover.

- **0.3-metre drops**

  Two 0.3 metre bottom-down drops of the packaging were added to drop programme <1> to determine accelerations in the case of a drop under normal transport conditions.

  - **Drop No. 8**: 0.3 m vertical bottom-down drop with shock absorbing cover No. 1, packaging axis vertical.

  - **Drop No. 9**: 0.3 m vertical bottom-down drop on corner with shock absorbing cover No. 1, centre of gravity aligned with the impact point.

The drop configurations to be found are the most severe configurations for each case shown above. The following presents the analysis that was used to determine these configurations for the drops made.

There are no alternatives for axial bottom-down and lid drops, corner drop cases are more severe when the centre of gravity is in line with the impact point and drops on a bar are more severe when the centre of gravity is in line with the vertical of the bar.

Therefore the cases to be studied are lateral drops corresponding to drops 1 and 3 in the programme.

The analysis given below specifies the angle of inclination of the axis of the TN-MTR drop mockup from the horizontal for the 2 lateral drop cases:

- Lateral drop at an angle offset from the axis of the trunnions
- Lateral drop along the axis of the trunnions

4.1. Angle of the packaging axis for a 9 m lateral drop offset from the axis of the trunnions

4.1.1. Calculation assumptions

This angle is defined from <4>. The geometric model used for the calculation is shown in Figure 1-6.64.

The packaging mesh is composed of shell elements containing infinitely rigid materials. The shock absorbing cover is deemed to be integral with the body of the packaging.

The mass of the shock absorbing cover used for the calculation is 210 kg, the mass of the body is 2695 kg.

The centre of gravity is positioned at 428 mm from the bottom of the packaging.

All nodes in the model are subjected to a vertical acceleration due to gravity and an initial velocity of about 13.29 m/s resulting from a 9-metre drop.

The drop mockup is modelled by two non-linear shock absorbers that only work in compression and only along the vertical axis.

The spring stiffness follows the curves given in figures 1-6.62 and 1-6.63 determined as a function of the surface area in compression multiplied by the compression stress.

The shock absorbing cover compression curves shown in figure 1-6.62 are based on compression stresses of oak, equal to 60 MPa. This stress is an average compression stress for oak to take account of the acceleration (higher when the compression stress increases) and also the compression (lower when the compression stress increases).

Due to the lack of data for the bottom compression stress, and particularly the set of steel, lead and resin layers, the bottom compression curves are given for a variable stress between 20 MPa and 100 MPa.

The ground is modelled by shell elements containing an infinitely rigid material.

Calculation angles are chosen with a pitch of 5°, from -5° to 13.92° corresponding to simultaneous impact of the shock absorbing cover and the bottom.

4.1.2. Calculation results

The purpose of the calculation is to define the drop configuration that gives the maximum radial acceleration. This may be obtained either during the impact on the shock absorbing cover, or during the impact on the bottom. Therefore accelerations were calculated for the impact of the shock absorbing cover (section 4.1.2.1), and then for the impact on the bottom of the mockup (section 4.1.2.2).

4.1.2.1 Accelerations for the impact on the shock absorbing cover

The following table presents calculated accelerations on the bottom of the mockup for the first mockup impact (on the shock absorbing cover) as a function of the compression stresses on the bottom. These accelerations were calculated in <4>.

Impact on shock absorbing cover	$\sigma_{bottom\ compression}$ = 20 MPa	$\sigma_{bottom\ compression}$ = 40 MPa	$\sigma_{bottom\ compression}$ = 100 MPa
-5	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
0	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
5	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
10	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
13.92	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²

Accelerations projected into the plane of the bottom of the mockup were calculated from the above table by multiplying the values by $\cos(\alpha)$, where α is the initial drop angle that in this case also corresponds to the angle at the time that the acceleration is calculated.

The following table is deduced:

Impact of shock absorbing cover	$\sigma_{bottom\ compression}$ = 20 MPa	$\sigma_{bottom\ compression}$ = 40 MPa	$\sigma_{bottom\ compression}$ = 100 MPa
-5	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
0	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
5	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
10	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
13.92	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²

This table can be presented in graphic form:

PROPRIETARY

This analysis clearly shows that the angle between the packaging axis and the horizontal that gives the maximum lateral acceleration on the basket is [redacted], which occurs when the shock absorbing cover and the bottom of the mockup impact simultaneously.

These results are consistent, because at the time of the drop, the bottom has not impacted (except for the [redacted] case) and accelerations are variable depending on the angle of impact but are the same for the different compression stresses, which is clearly shown on the above curve. The shock absorbing cover and the bottom impact simultaneously when the angle of impact is [redacted], therefore it is normal that a higher acceleration is obtained for a higher compression stress.

4.1.2.2 Accelerations for the impact on the bottom of the packaging

The following table presents calculated accelerations on the bottom of the mockup for the second mockup impact (on the bottom of the packaging) as a function of the compression stresses on the bottom (curves shown in figure 1-6.63). These accelerations were calculated in <4>.

Impact on the bottom	$\sigma_{bottom\ compression}$ = 20 MPa	$\sigma_{bottom\ compression}$ = 40 MPa	$\sigma_{bottom\ compression}$ = 100 MPa
-5	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
0	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
5	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
10	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²
13.92	[redacted] mm/ms²	[redacted] mm/ms²	[redacted] mm/ms²

Accelerations on the bottom occur with a constant angle (shock absorbing cover and bottom simultaneously in contact with the ground), the difference being due to the difference in compression of the shock absorbing cover. Therefore the acceleration projection calculation is not useful for determining the worst case.

The accelerations table can be presented in graphic form:

PROPRIETARY

This graph shows that the angle leading to maximum accelerations is either [redacted] or [redacted], depending on the compression stress considered.

4.1.2.3 Choice of the drop angle

The analysis of the acceleration curves calculated for impacts on the shock absorbing cover or on the bottom shows that:

- The maximum acceleration during the impact on the shock absorbing cover occurs for the case in which the shock absorbing cover and the bottom impact simultaneously
- If the shock absorbing cover and the bottom impact simultaneously, the calculated acceleration for each of these elements is identical (which was to be expected).

- Accelerations during the bottom impact at -5° and 13.92° calculated with compression curve SIG 4.2 (bottom compression stress = 40 MPa) are similar, and the acceleration for an angle of -5° calculated with compression curves SIG 4.1 (bottom compression stress = 20 MPa) and SIG 4.3 (bottom compression stress = 100 MPa) is higher than the acceleration calculated for the angle of 13.92°.

The chosen drop angle is -5°.

The worst case will have been tested if the real compression stress curve is close to SIG 4.1 or SIG 4.3, and if the compression stress is close to curve SIG 4.2, the tested case will be very close to the worst case.

In conclusion, the angle chosen for the 9-metre lateral drop with the axis offset from the axis of the trunnions (drop 1) is equal to -5° from the horizontal, which means that the packaging axis is lower on the side of the shock absorbing cover. The drop position is shown in Figure 1.6-2.

4.2. Angle of the packaging axis for a 9 m lateral drop along the axis of the trunnions

This angle is determined using two different methods, firstly the calculation <4> results are analysed, and secondly compression is calculated using the compression relation for a cylinder dropping on an edge.

4.2.1. Calculation results

The following table presents compression values of the shock absorbing cover calculated in <4> for drop case 3:

Compression of the shock absorbing cover	$\sigma_{bottom\ compression}$ = 100 MPa
-5	[redacted]
0	[redacted]
5	[redacted]
10	[redacted]
13.92	[redacted]

The compression curve as a function of the initial angle is shown below in graphic form:

PROPRIETARY

It is deduced that the angle between the packaging axis and the horizontal that gives the maximum compression of the shock absorbing cover is 5°.

4.3. Conclusion on the calculation of angles between the packaging axis and the horizontal for lateral drop cases

The angle chosen for the 9-metre lateral drop, with the axis offset from the axis of the trunnions (drop 1) is -5° from the horizontal, which means that the packaging axis is lower on the side of the shock absorbing cover. The drop position is shown in Figure 1-6.2.

The angle chosen for the 9-metre lateral drop, with the drop axis along the axis of the trunnions (drop 3) is +5° from the horizontal, which means that the packaging axis is lower on the side of the bottom of the mockup. The drop position is shown in Figure 1-6.24.

5. EXECUTION OF THE TESTS

5.1. Test preparation

Reception of the mockup on 25/03/97.

Check of the leak-tightness of mockup seals (see values in table 1.6-3).

Assembly of the shock absorbing cover on the body of the packaging

5.2 Drop No. 1: lateral drop, axis perpendicular to the trunnions

5.2.1 Preparation for drop

See test preparation

- The 0° orientation of the shock absorbing cover is facing the 0°orientation of the mockup.
- The spacer in the cavity is placed on the lid side of the mockup.
- Installation of the instrumentation on the mockup body.
- The angle between the packaging axis and the horizontal, measured for drop 1 is 5°, tilted towards the shock absorbing cover.
- The line of impact of the mockup is at 180° and that of the basket is at 270°.
- The measured height under the lowest point of the packaging is 9.0 m

Photo 1-6.1 shows the position of the mockup before the drop.

5.2.2 Description of the drop

The first impact takes place on the shock absorbing cover, which is compressed until impact of the bottom of the mockup (see figure 1-6.2). The mockup then bounces and drops again on the bottom and comes to rest in the normal transport position.

The position of the mockup after the drop is shown in Photograph 1-6.2.

5.2.3 Damage caused by the drop

Damage caused by the drop is shown in Photographs 1-6.3 to 1-6.5.

- Crushing of the shock absorbing cover over the entire height of the line of impact (180°) during the first shock.
- Slight deformation of the 2 trunnion recesses (the recess measurement varies from 120 to 125 mm (nominal dimension 125 mm)).
- Deformation of the sleeve of screw 4 (impact side): the sleeve is partially closed off by ovalling of the tube.
- During the second impact, crushing of the bottom of the outer shell and the truncated cone of the packaging on the 180° line.
- Convex deformation of the bottom at the location of the impact.

5.2.4 Comments

- Tie-down lug on line of impact, intact
- The 6 shock absorbing cover attachment screws are intact.
- The 36 lid attachment screws are intact (observed after drop No. 2).
- The 4 orifice B plug attachment screws are intact (observed after drop No. 2).
- The lid centring pin is intact (observed after drop No. 2).
- The shock absorbing cover centring pin is intact (observed after drop No. 2).

5.2.5 Measurements

- Dimensional survey: see figures 1-6.3 and 1-6.4
- Leak test on the lid inner seal after this drop (see table 1-6.3). The test is made without touching the shock absorbing cover.

- Duration of impact

  ◊ Duration of impact on shock absorbing cover: 7.5 ms
  measured from the curve of the accelerometer placed on the packaging shell.

  ◊ Time between impact on the shock absorbing cover and impact on the bottom: 7.5 ms
  measured from the curve of the accelerometer placed on the shell and on the bottom of the packaging.

  ◊ Duration of the impact on the bottom of the packaging 9 ms
  measured from the curve of the accelerometer placed on the bottom of the packaging.

- Acceleration on the mockup body.

  The accelerations shown below are measured on the ½ scale mockup of the packaging, along the y axis shown in figure 1-6.2.

  ◊ The filter frequency of acceleration / time curves is defined as follows:

  The natural frequency of the full scale basket full of fuel is calculated in chapter 1A, and gives a value of f_1 = 215 Hz for the cores of baskets filled with fuel.

  The natural frequency at full scale can also be estimated by the relation:

  $$f_2 = \frac{1}{2\pi}\sqrt{\frac{g}{x}}$$

  f_2: first natural frequency in Hz

  g: acceleration due to gravity = 9.81 m/s²

  x: displacement of the basket under the force generated by the basket self-weight plus its load, in metres.

  This value is taken to be the average of three points located on the central core of the basket, as defined in figure 1-6.61.

  $x = (4.26 + 3.39 + 1.65) / 3 \times 10^{-6} = 3.1 \times 10^{-6}$ m

This formula is created from the standard formulae for springs:

$$\omega = \sqrt{\frac{K}{m}} = 2\,\pi\,f$$

and

$K \times x = m\,g$

where K: spring stiffness in N/m

m: mass in kg

therefore

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{g}{x}} = \frac{1}{2\pi}\sqrt{\frac{9{,}81}{3{,}1.10^{-6}}} = 283 \text{ Hz}$$

Frequencies of the full scale basket evaluated using these two methods give the same order of magnitude of results, and the highest of these frequencies is used, namely:

$f_3 = \max\{ f_1 ; f_2 \} = 283$ Hz

The natural frequency of the basket is proportional to the scale ratio, thus:

$f_{p\ basket\ mockup} = \eta \times f_3 = 2 \times 283 = 566$ Hz

The filter frequency for the basket is conservatively fixed at:

$f_{filter} = 1000$ Hz (that corresponds to a coefficient of 1.76).

This filter frequency is kept for the packaging body because the basket does not "see" higher frequencies (natural frequency of the full scale basket of the order of 300 Hz).

The curves are filtered at 1000 Hz, and are shown in Figures 1-6.7 and 1-6.8.

◊ The following table gives the accelerations used for this drop case:

	Accelerations on the half scale mockup, filtered at 1000 Hz	
	Accelerometer on the mockup shell. 1Ax	Accelerometer on the mockup bottom. 1Dx
Axis of the measured acceleration	[redacted]	[redacted]
Shock on the shock absorbing cover	[redacted]	[redacted]
Shock on the bottom of the packaging	[redacted]	[redacted]

Response spectra for these two accelerometers are shown in figures 1-6.7 and 1-6.8.

- Stresses in the basket

Stresses are measured in the basket, positioned on the instrumented compartment close to the line of impact, as shown in figure 1-6.2 (series 3).

The curves are filtered at 3200 Hz, and are shown in Figures 1-6.9 to 1-6.11.

Since the validity range of strain gauges is limited to the elastic strain range, stresses are only calculated if the yield stress has not been reached. When the yield stress has been exceeded, the gauge does not indicate a reliable value of the stress, simply that plastic strain has occurred.

	Stresses in the half scale basket mockup, filtered at 3200 Hz			
	Disk on lid side (3)		Disk on bottom side (7)	
	Gauge on core parallel to the drop axis	Gauge on core perpendicular to the drop axis	Gauge on core parallel to the drop axis	Gauge on core perpendicular to the drop axis
	J1	J2	J3	J4
Shock on the shock absorbing cover	Compression: 530 MPa	HS	Compression and tension: 200 MPa	Compression: 220 MPa
Shock on the bottom of the packaging	Compression: 472 MPa	HS	Tension: plastic strain. Compression 532 MPa	Tension: plastic strain Compression: 440 MPa

- Accelerations on the basket:

  Measured accelerations on the basket are unusable because cables were either cut or stretched.

  Curves for accelerometers for which cables were stretched or cut at the beginning of impact are not shown.

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.3 Drop No. 2: lateral drop, bar on shell

5.3.1 Preparation for drop

- No modifications were made to the mockup between drops 1 & 2.
- Installation of the instrumentation on the mockup body.
- The line of impact of the mockup is at 180° and that of the basket is at 270°.
- The 0° orientation of the shock absorbing cover is facing the 0°orientation of the mockup.
- The angle between the centreline of the packaging and the horizontal, measured for drop 2 is 31°, inclined towards the bottom of the packaging.
- The drop height measured from the point of impact is 1 m.

Photo 1-6.6 shows the position of the mockup before the drop.

5.3.2 Description of the drop

The packaging bounces on the bar after the first impact, drops back onto the bar a second time, then sustains a series of small shocks on the ground before the packaging comes to rest on its bottom in the normal transport position (see figure 1-6.12).

The position of the mockup after the drop is shown in Photograph 1-6.7.

5.3.3 Damage caused by the drop

Damage caused by the drop is shown in Photograph 1-6.8.

- Puncturing (without breaking the plate) of the outer shell at the first impact on the 180° line.
- Denting of the outer shell at the second impact on the 180° line.

5.3.4 Damage caused by the combination of the first two drops

The steps in opening the packaging are shown on photographs 1-6.10 and 1-6.7. Photographs1-6.9 and 1-6.14 show the basket after extraction from the cavity.

The damage listed below is found on the cavity of the packaging and on the basket the first time it is opened after drop No. 2.

Since the packaging was not opened between drops No. 1 and No. 2, a priori it is unknown which drop caused the damage.

- Cavity

  The cavity is deformed at the location of the impact on the bar, also corresponding to the top end of the deformation on the outer shell of the packaging due to the first drop (see photo 1-6.12).

- Basket (see Figures 1-6.15 to 1-6.16).

  ◊ Traces of shocks, with the ends of the pins simulating the assemblies, can be seen on the lower side of the upper disk (disk No. 2 see photo 1-6.15).

  ◊ The two cores of a basket compartment (left empty for the instrumentation) of disk 7, located facing the deformation of the cavity, perpendicular to the impact surface, are deformed (see photos 1-6.16 to 1-6.18).

  ◊ The central core of disk 6, which is the compartment closest to the impact point, is slightly deformed (see photo 1-6.19).

  ◊ The lower disk (disk 8) of the basket is warped on the side of the cavity deformation.

5.3.5 Comments

- The 6 shock absorbing cover attachment screws are intact.
- The 36 lid attachment screws are intact.
- The 4 orifice B plug attachment screws are intact.
- The lid centring pin is intact.
- The shock absorbing cover centring pin is intact.

- The lid is taken off to open the packaging without problem.
- The spacer placed above the basket is removed without problem.
- The basket is removed with some difficulty due to deformation of the cavity.
- The outer surface of the basket has some traces of banging at the cavity deformation.

5.3.6 Measurements

- Dimensional survey: see figures 1-6.13 to1-6.14

	Cavity inside diameter			
	0°-180° (mm)	**45°-225°** (mm)	**90°-270°** (mm)	**135°-315°** (mm)
Nominal dimension	$480^{+2\ -0}$			
Bottom of cavity	[redacted]	[redacted]	[redacted]	[redacted]
Level of cavity deformation	[redacted]	[redacted]	[redacted]	[redacted]
280 mm above the bottom of the cavity.	[redacted]	[redacted]	[redacted]	[redacted]
top of cavity	[redacted]	[redacted]	[redacted]	[redacted]

	Basket outside diameter:			
	0°-180°	**45°-225°**	**90°-270°**	**135°-315°**
	(mm)	(mm)	(mm)	(mm)
Nominal dimension	$477.5^{\pm 0.25}$			
Disk No. 2 (top of basket)	[redacted]	[redacted]	[redacted]	[redacted]
Disk No. 3 (instrumented)	[redacted]	[redacted]	[redacted]	[redacted]
Disk No. 4	[redacted]	[redacted]	[redacted]	[redacted]
Disk No. 5	[redacted]	[redacted]	[redacted]	[redacted]
Disk No. 6	[redacted]	[redacted]	[redacted]	[redacted]
Disk No. 7 (instrumented, level of deformation in the cavity)	[redacted]	[redacted]	[redacted]	[redacted]
Disk No. 8 (bottom of basket)	[redacted]	[redacted]	[redacted]	[redacted]

Table 1-6.7 presents the survey of the inside dimensions of the compartments, table 1-6.8 presents the thicknesses of the cores of basket disks.

- Table 1-6.5 presents the loosening torques of the lid and plug screws.
- Complete leak test after this drop (see table 1-6.3).
- Duration of impact
  - ◊ Duration of impact: 17 ms
    measured from the curve of the accelerometer placed on the packaging shell.

- Acceleration on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.18 to 1-6.20.

	Accelerations on the half scale mockup, filtered at 1000 Hz		
	Accelerometer on the shell close to the lid.	**Accelerometer on shell close to the centre of gravity**	
	2Ax	2Bx	2By
Axis of the measured acceleration	[redacted]	[redacted]	[redacted]
Impact on bar	[redacted]	[redacted]	[redacted]

  The response spectrum of the 2Bx accelerometer is shown in figure 1-6.65.

- Accelerations on the basket:

  Accelerations are filtered at 1000 Hz, and are shown in Figure 1-6.17.

	accelerations in the half scale basket mockup, filtered at 1000 Hz Instrumented compartment close to the drop line			
	Disk on lid side (3)		**Disk on bottom side (7)**	
	Accelerometer on core parallel to the drop axis	Accelerometer on core perpendicular to the drop axis	Accelerometer on core parallel to the drop axis	Accelerometer on core perpendicular to the drop axis
	Lu: drop axis (x) Lv: ⊥ drop axis (z)	Ku: drop axis (x) Kv : ⊥ drop axis (z)	Du: drop axis (x) Dv: ⊥ drop axis (z)	Cu: drop axis (x) Cv: ⊥ drop axis (z)
Shock on the body of the packaging	Lu: 104g Lv: cut	Ku: cut Kv: stretched	Du: cut Dv: cut	Cu: stretched Cv: stretched

	Accelerations in the ½ scale basket mockup, filtered at 1000 Hz Instrumented compartment opposite the drop line			
	Disk on lid side (3)		Disk on bottom side (7)	
	Accelerometer on core parallel to the drop axis	Accelerometer on core perpendicular to the drop axis	Accelerometer on core parallel to the drop axis	Accelerometer on core perpendicular to the drop axis
	Nu: drop axis (x) Nv: ⊥ drop axis	Mu: drop axis Mv: ⊥ drop axis	Fu: drop axis Fv: ⊥ drop axis	Eu: drop axis Ev: ⊥ drop axis
Shock on the body of the packaging	Nu: stretched Nv: cut	Mu: cut Mv: cut	Fu: cut Fv: cut	Eu: cut Ev: cut

- Stresses in the basket

  Measured stresses are stresses in the basket, positioned on the instrumented compartment close to the line of impact, as shown in figure 1-6.2.

  The curves are filtered at 3200 Hz, and are shown in Figures 1-6.21 to 1-6.23.

  Since the validity range of strain gauges is limited to the elastic strain range, stresses are only calculated if the yield stress has not been reached. When the yield stress has been exceeded, the gauge does not indicate a reliable value of the stress, simply that plastic strain has occurred.

  Due to the plastic strains measured during the first drop and since it is impossible to recalibrate the gauges (the packaging must not be opened between the first two drops), some strain gauge measurements may be disturbed during the second drop.

	Stresses in the ½ scale basket mockup			
	Disk on lid side (3)		Disk on bottom side (7)	
	Gauge on core parallel to the drop 1 axis	Gauge on core perpendicular to the drop 1 axis	Gauge on core parallel to the drop 1 axis	Gauge on core perpendicular to the drop 1 axis
	J1	J2	J3	J4
Impact on bar	Tension: 90 MPa	HS	Tension: 82 MPa	Tension: 90 MPa

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.4 Drop No. 3: lateral drop, axis parallel to the trunnions

5.4.1 Preparation for drop

- Straightening of the basket lower disk(8).
- Assembly of the basket (the basket was disassembled for the dimensional check made after drop No. 2). The order and the arrangement of disks in the basket were unchanged.
- Positioning of the spacer at the bottom of the packaging, the basket on the lid side, and pins in the basket (see photo 1-6.20).
- The groove of the seal on the original plug is not conforming with drawing 4466-11 index B, therefore the plug is replaced by a new plug. This plug is positioned on orifice A due to a tool mark present on the bearing surface of orifice B .
- Replacement of the 2 seals of the orifice B plug, close the orifice and torque the screws.
- Replacement of the lid outer seal
- Leak testing of the lid inner and outer seals and the orifice A plug after closing the mockup (see table 1-6.3).

- Installation of shock absorbing cover No. 2 on the packaging. The 0° orientation of the shock absorbing cover is facing the 180°orientation of the mockup (due to the change in the test orifice).

- Installation of the instrumentation on the mockup body.

- The line of impact of the mockup is at 270° and that of the basket is at 180°.

- The angle between the packaging axis and the horizontal, measured for drop 3 is 4.9°.

- The measured height under the lowest point of the packaging is 9.15 m

Photo 1-6.21 shows the position of the mockup before the drop.

5.4.2 Description of the drop

The mockup firstly impacts on the shock absorbing cover and then on the bottom. It then bounces twice on the 270° line, slides and then comes to rest (see figure 1-6.24).

The mockup orientation (270°) is kept the same throughout the drop.

The position of the mockup after the drop is shown in Photograph 1-6.22.

5.4.3 Damage caused by the drop

Damage caused by the drop is shown in Photographs 1-6.23 to 1-6.26.

- Shock absorbing cover at the point of impact. The welds of the metal casing of the shock absorbing cover are torn in the recess of the shock absorbing cover in the impact zone.

  The shock absorbing cover deformed to partially fill the empty recess.

- The sleeves of screws 2 and 3 (around the line of impact) are slightly ovalled. This deformation is not enough to prevent access to the screws.

- The shell and the truncated cone are flattened on the 270° line, at the point of impact on the bottom of the mockup. Deformations of the truncated cone and the shell are in the same plane.

- Convex-shaped deformation of the bottom at the location of the impact.

5.4.4 Comments

- The shock absorbing cover attachment screws had to be loosened so that the test tool could be put into place on orifice B.
- The trunnion located on the side of the impact is not deformed and shows no traces of shock.
- The 6 shock absorbing cover attachment screws were intact.
- The 36 lid attachment screws are intact (observed after the shock absorbing cover was removed after drop No. 4).
- The 4 orifice B plug attachment screws are intact (observed after the shock absorbing cover was removed after drop No. 4).
- The lid centring pin is intact (observed after the shock absorbing cover was removed after drop No. 4).

5.4.5 Measurements

- Dimensional survey: see figures 1-6.25 and 1-6.26
- Leak testing of welds, lid inner and outer seals after this drop (see table 1-6.3).
- Duration of impact

  Duration of impact: 17 ms
  measured from the curve of the accelerometer placed on the packaging shell close to the shock absorbing cover.

- Accelerations on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.27 to 1-6.32.

	Accelerations on the ½ scale mockup, filtered at 1000 Hz					
	Accelerometer on the shell close to the lid.		Accelerometer on the shell close to the centre of gravity.		Accelerometer on the bottom close to the centre line of the mockup	Accelerometer on the bottom on the impact side
	3Ax	3Ay	3Bx	3By	3Cx	3Dx
Axis of the measured acceleration	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Impact on shock absorbing cover	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Impact on bottom	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.5 Drop No. 4: drop on corner of shock absorbing cover, axis parallel to the trunnions

5.5.1 Preparation for drop

- The shock absorbing cover is retightened after the leak test made after drop No. 3.
- Installation of the instrumentation on the mockup body.
- The line of impact of the mockup is at 90° and that of the basket is at 0°.
- The 0° orientation of the shock absorbing cover is facing the 180°orientation of the mockup.
- The centre of gravity of the mockup is in line with the impact point, the angle measured between the packaging axis and the horizontal is 50°.
- The measured height under the lowest point of the package is 9.25 m

Photo 1-6.27 shows the position of the mockup before the drop.

5.5.2 Description of the drop

The corner of the shock absorbing cover of the packaging mockup is compressed and the mockup then bounces, overturns and impacts on the bottom of the packaging (see figure 1-6.33). The packaging mockup comes to rest in the normal transport position.

The position of the mockup after the drop is shown in Photograph 1-6.28.

5.5.3 Damage caused by the drop

Damage caused by the drop is shown in Photographs 1-6.29 to 1-6.31.

- Compression of the corner of the shock absorbing cover at the point of impact.

- The two sleeves of screws 5 and 6 are completely closed off by deformation of the cover.

- The welds of the metal casing of the recess of the shock absorbing cover are torn in the impact zone.

- The anti-shear shell (704) is warped at the point of impact.

- The top surface of the flange is marked under the tightening area of the shock absorbing cover attachment screws by slipping of the cover relative to this flange. These marks are limited to the area around the threaded holes for the shock absorbing cover attachment screws.

  These marks are measured and indicate a slip of about 6 mm.

5.5.4 Comments

- The trunnion located on the side of the impact shows traces of shock. The impact side edge is very slightly deformed. This deformation appears to be due to deformation of the plates rather than a shock on the target.

- The 6 shock absorbing cover attachment screws are intact (observed after cutting out the compressed part of the shock absorbing cover).

- The 36 lid attachment screws are intact.

- The 4 orifice B plug attachment screws are intact.

- The top edge of the mockup on the 90° line (impact line) shows no sign of deformation nor trace of impact
- The lid is disassembled without problems (see photo 1-6.33).
- The basket and the spacer are removed without problems.
- There is no deformation in the basket in addition to the deformation found during the examination made after drop No. 2 (see photographs 1-6.32 and 1-6.34).
- Screw number 9 located on the same side as the impact has a high loosening torque (14 kg.m) and remains hard to unscrew for the first 1 to 2 turns.

5.5.5 Measurements

Dimensional survey: see figure 1-6.34.

Flange outside diameter (105)			
0°-180°	**45°-225°**	**90°-270°**	**135°-315°**
Nominal dimension: remachined to 737 mm			
[redacted]	[redacted]	[redacted]	[redacted]

Clearance between the lid and the flange,			
0°	**90°**	**180°**	**270°**
[redacted]	[redacted]	[redacted]	[redacted]

	Cavity inside diameter			
	0°-180°	45°-225°	90°-270°	135°-315°
	(mm)	(mm)	(mm)	(mm)
Nominal dimension	$480^{+2\ -0}$			
Bottom of cavity	[redacted]	[redacted]	[redacted]	[redacted]
Level of cavity deformation	[redacted]	[redacted]	[redacted]	[redacted]
280 mm above the bottom of the cavity.	[redacted]	[redacted]	[redacted]	[redacted]
top of cavity	[redacted]	[redacted]	[redacted]	[redacted]

	Basket outside diameter:			
	0°-180°	45°-225°	90°-270°	135°-315°
Nominal dimension	$477.5^{\pm 0.25}$			
Disk No. 2 (top of basket)	[redacted]	[redacted]	[redacted]	[redacted]

Height between the top surface of the mockup and the bottom of the cavity				
0°	90°	180°	270°	centre
Nominal dimension: 670 mm				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

- Complete leak test after this drop (see table 1-6.3).
- Table 1-6.5 presents the loosening torques of lid screws.

- Duration of impact.

  Duration of impact: 24 ms
  measured from the curve of the accelerometer placed on the packaging shell close to the shock absorbing cover.

- Accelerations on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.35 to 1-6.39.

	Accelerations on the ½ scale mockup, filtered at 1000 Hz				
	Accelerometer on the shell close to the lid.		Accelerometer on the mockup bottom, impact side.		Accelero meter at the lifting point
	4Ax	4Ay	4Bx	4By	4Cw
Axis of the measured acceleration	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Impact on shock absorbing cover	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.6 Drop 5: axial drop on bottom of packaging

5.6.1 Preparation for drop

- Local grinding and cutting of the basket so that the basket can be inserted into the bottom of the cavity.

- The basket is placed in the bottom of the cavity, the 0° orientation of the basket facing the 90° orientation of the packaging. The spacer is placed above the basket.

- Installation of shock absorbing cover 1 on the mockup, fixed by five screws (the screw located on the 180° line impacted by the first two drops cannot be turned). The 0° orientation of the shock absorbing cover is placed on the 0°orientation of the mockup.

- Installation of the instrumentation on the mockup body.

- The mockup is lifted by the two tie-down lugs welded onto the shell, the angle between the axis of the mockup and the horizontal measured just before the drop in the vertical plane passing through the lifting points is 89.9°.

- The measured height under the lowest point of the package is 9.30 m

Photo 1-6.35 shows the position of the mockup before the drop.

5.6.2 Description of the drop

The mockup impacts the bottom surface, bounces and turns over during the bounce. It impacts the periphery of the bottom a second time and tilts over onto its side. The mockup slides, bearing on the shock absorbing cover and on the bottom, before coming to rest (see figure 1-6.40).

The position of the mockup after the drop is shown in Photograph 1-6.36.

5.6.3 Damage caused by the drop

Damage caused by the drop is shown in Photographs 1-6.37 to 1-6.39.

- The bottom of the mockup is straightened without any obvious damage, the truncated cone is deformed on the 180° and 270° lines on which the impact occurred during lateral drops 1 and 3 (see photo 1-6.37).

- The shock absorbing cover is slightly deformed by the shock when the mockup was lying on its side.

- The bottom of the cavity is convex.

- The basket bottom disk has the same convexity as the bottom of the cavity.

- The threaded rod at 225°relative to the basket (315° relative to the packaging for this drop) is twisted at the nut.

5.6.4 Comments

- The 5 shock absorbing cover attachment screws are intact (screw No. 4 was not installed because the sleeve for this screw in shock absorbing cover No. 1 used for the drop was deformed so that the screw could not be tightened).

- The 36 lid mounting screws are intact.

- The 4 orifice B plug attachment screws are intact.

- The lid was removed without problem.

- The spacer and the basket are removed without problem.

- The three intact basket tightening nuts are untightened.

- The lid is marked by the spacer
  The basket top disk is marked by the outside diameter of the spacer (see photo 1-6.38)
  The bottom of the cavity is marked by the basket bottom disk and by the pins (see photo 1-6.39).

- During the drop, the cavity height was reduced (see table below) and the lid applied pressure on the basket and the spacer. After the mockup was opened, the basket and the spacer that were in compression due to the body and the lid were released, and returned to a total height more than the height of the cavity.

5.6.5 Measurements

- Dimensional survey:

	Cavity inside diameter			
	0°-180° (mm)	**45°-225°** (mm)	**90°-270°** (mm)	**135°-315°** (mm)
Nominal dimension	$480^{+2\ -0}$			
Bottom of cavity	[redacted]	[redacted]	[redacted]	[redacted]
Level of cavity deformation	[redacted]	[redacted]	[redacted]	[redacted]
280 mm above the bottom of the cavity.	[redacted]	[redacted]	[redacted]	[redacted]
top of cavity	[redacted]	[redacted]	[redacted]	[redacted]

Height between the top surface of the mockup and the bottom of the cavity				
0°	**90°**	**180°**	**270°**	**centre**
Nominal dimension: 670 mm				
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Height between the top surface and the bottom of the mockup				
[redacted]				

- Complete leak test after this drop (see table 1-6.3).
- Table 1-6.5 presents the loosening torques of the lid and plug screws.

- Duration of impact.

  Duration of impact: 6.6 ms
  measured from curves from accelerometers placed on the packaging shell close to the shock absorbing cover.

- Acceleration on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.41 and 1-6.42.

	Accelerations on the half scale mockup, filtered at 1000 Hz	
	Accelerometer on the shell close to the lid. orientation 90° 5Ay	**Accelerometer on the shell close to the lid. orientation 270° 5By**
Axis of the measured acceleration	[redacted]	[redacted]
Impact on the bottom of the mockup.	[redacted]	[redacted]

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.7 Drop No. 6: drop on bar, on shock absorbing cover

5.7.1 Preparation for drop

- The 0° orientation of the basket faces the 90° orientation of the packaging. The spacer is placed at the bottom of the cavity, with the basket at the lid end.

- When the spacer and the basket are put into place and after compression of the basket and the spacer by the body and the lid during drop 5 (see section 5.6.4), the height of these two elements is greater than the height of the cavity. The stainless steel disk (3) of the basket is removed so that the lid can be closed.

The basket assembly rods are sawn off so that they do not project beyond the stack of disks (which would create a stacking problem with the spacer).

- Installation of shock absorbing cover No. 3. The 0° orientation of the shock absorbing cover is aligned with the 180° orientation of the mockup so that the lid seals can be leak-tested between drops 6 and 7.

- Installation of the instrumentation on the mockup body.

- The angle between the centreline of the packaging and the horizontal, measured for drop 6 is 27.7°.

- The drop height between the first impact point and the bar is 1.3 m (regulatory height 1 m plus 0.25 m to take account of compression of the shock absorbing cover plus 0.05 for the difference between the mass of the mockup and the maximum mass).

Photo 1-6.40 shows the position of the mockup before the drop.

5.7.2 Description of the drop

The mockup drops on the bar, the bar pierces the outer plate of the shock absorbing cover and the balsa layer, and compresses the oak layer. The mockup bounces on the bar, remaining along the drop line. It falls on the bar again and then tips over (see figures 1-6.43 and 1-6.44).

The position of the mockup after the drop is shown in Photograph 1-6.41.

5.7.3 Damage caused by the drop

Damage caused by the drop is shown in photo 1-6.42.

- The shock absorbing cover is punctured at the point of bar impact. The bar left an oval indentation due to the tilt of the mockup onto the bar; this indentation is 75 mm wide, and 140 mm deep (thickness of the projecting part of the shock absorbing cover 200 mm).

  The outer plate is pierced

  The balsa layer is pierced.

The plate (725) between the oak and balsa is partly sheared.

- The edge of the shock absorbing cover impacted during the shock of the mockup on the floor after tipping is slightly deformed.

5.7.4 Comments

- The 6 shock absorbing cover attachment screws are intact; the screw sleeves (730) are not deformed.

5.7.5 Measurements

- Dimensional survey: see figures 1-6.45 and 1-6.46.

- Check leak-tightness of lid inner and outer seals after this drop (see table 1-6.3). The check is made without touching the shock absorbing cover.

- Duration of impact.

  Duration of impact: 56 ms
  measured from curves from accelerometers placed on the packaging shell close to the shock absorbing cover.

- Acceleration on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.47 and 1-6.50.

	Accelerations on the ½ scale mockup, filtered at 1000 Hz			
	Accelerometer on the shell - side opposite the 150°impact line		**Accelerometer on the shell - impact side 330° line**	
	6Ax	6Ay	6Bx	6By
Axis of the measured acceleration	[redacted]	[redacted]	[redacted]	[redacted]
Impact on shock absorbing cover	[redacted]	[redacted]	[redacted]	[redacted]

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.8 Drop No. 7: axial drop on shock absorbing cover

5.8.1 Preparation for drop

- No modifications are made to the mockup between drops 6 & 7. The 0° orientation of the basket faces the 90° orientation of the packaging. The spacer is placed at the bottom of the cavity, with the basket at the lid end.

- Shock absorbing cover No. 3 is used. The 0° orientation of the shock absorbing cover is placed on the 0°orientation of the mockup.

- Installation of the instrumentation on the mockup body.

- The angle between the centreline of the packaging and the horizontal, measured for drop 7 is 89.6°.

- The drop height between the first point of impact and the target is 9.3 m.

Photo 1-6.43 shows the position of the mockup before the drop.

5.8.2 Description of the drop

The mockup drops flat on the shock absorbing cover and crushes it. The mockup then bounces and comes to rest on the shock absorbing cover after this bounce (see figure 1-6.51).

The position of the mockup after the drop is shown in photos 1-6.44 and 1-6.45.

5.8.3 Damage caused by the drop

The damage caused by the drop is shown in photographs 1-6.46 and 1-6.47.

- The shock absorbing cover is crushed over the entire impact area.

- The top parts of the screw sleeves are crushed.

5.8.4 Comments

- The six shock absorbing cover attachment screws are intact.
- The 36 lid attachment screws are intact.
- The 4 orifice B plug attachment screws are intact.
- The lid is removed without problem.
- The spacer and the basket are removed without problem.

5.8.5 Measurements

- Dimensional survey:

Flange outside diameter (105)			
0°-180°	**45°-225°**	**90°-270°**	**135°-315°**
[redacted]	[redacted]	[redacted]	[redacted]

	Crushing of the shock absorbing cover	
	Dimension between top surfaces (724) and (726)	**Dimension between top surfaces (722) and (726)**
Theoretical dimension before the drop	[redacted]	[redacted]
centreline of screw No. 1	[redacted]	[redacted]
centreline of screw No. 2	[redacted]	[redacted]
centreline of screw No. 3	[redacted]	[redacted]
centreline of screw No. 4	[redacted]	[redacted]
centreline of screw No. 5	[redacted]	[redacted]
centreline of screw No. 6	[redacted]	[redacted]
Average	[redacted]	[redacted]
Average compression	[redacted]	[redacted]
	[redacted]	

	Cavity inside diameter			
	0°-180° (mm)	45°-225° (mm)	90°-270° (mm)	135°-315° (mm)
Nominal dimension	$480^{+2\ -0}$			
Bottom of cavity	[redacted]	[redacted]	[redacted]	[redacted]
Level of cavity deformation	[redacted]	[redacted]	[redacted]	[redacted]
280 mm above the bottom of the cavity.	[redacted]	[redacted]	[redacted]	[redacted]
top of cavity	[redacted]	[redacted]	[redacted]	[redacted]

Height between the top surface of the mockup and the bottom of the cavity				
0°	90°	180°	270°	centre
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Height between the top surface and the bottom of the mockup				
[redacted]				

- Complete leak test after this drop (see table 1-6.3).
- Table 1-6.5 presents the loosening torques of the lid and plug screws.
- Duration of the impact and accelerations on the mockup body: accelerometer measurements are not correct because the accelerometer cables were stretched.

  Estimated acceleration of the ½ scale mockup based on measurements:

  $\gamma = E / (m\ g\ e)$

  where γ: acceleration in g

m: mass of the dropped mockup,

E: energy absorbed during the impact. The calculation will be slightly conservative because the bounce is ignored.

E = m g h

h: height of drop = 9.3 m.

e: compression of the shock absorbing cover. The measurement gives the residual compression after the shock and not the maximum compression during the impact. Therefore the measured value of e is less than the maximum compression, and the calculated acceleration is conservative.

therefore: $\gamma = m\ g\ h / (m\ g\ e) = h / e$

e = [redacted]

γ = [redacted]

- Mockup bounce height after the first impact: [redacted] (estimate based on the video recording).

5.9. Drop No. 8: axial drop on bottom of packaging (0.3 m)

5.9.1 Preparation for drop

- The 0° orientation of the basket faces the 90° orientation of the mockup. The spacer is placed at the lid end, and the basket at the bottom.

- Shock absorbing cover No. 1 is used, fixed by five screws (the screw located on the 180° line impacted by the first two drops cannot be turned). The 0° orientation of the shock absorbing cover is placed on the 0°orientation of the mockup.

- Installation of the instrumentation on the mockup body.

- The angle between the centreline of the packaging and the horizontal, measured for drop 8 is 89.6°.

- The drop height between the first point of impact and the target is 0.3 m.

Photo 1-6.48 shows the position of the mockup before the drop.

5.9.2 Description of the drop

The mockup drops on the bottom, bounces (bounce height about [redacted]) and comes to rest in the normal transport position (see figure 1-6.52).

5.9.3 Measurements

- Accelerations on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.53 and 1-6.54.

	Accelerations on the ½ scale mockup, filtered at 1000 Hz	
	Accelerometer on the shell close to the lid. orientation 90° 8Ay	Accelerometer on the shell close to the lid. orientation 270° 8By
Axis of the measured acceleration	[redacted]	[redacted]
Impact on the bottom of the mockup.	[redacted]	[redacted]

5.10 Drop No. 9: Drop on corner, at the bottom (0.3 m)

5.10.1 Preparation for drop

- The 0° orientation of the basket faces the 90° orientation of the mockup. The spacer is placed at the lid end, and the basket at the bottom.

- Shock absorbing cover No. 1 is used, fixed by five screws (the screw located on the 180° line impacted by the first two drops cannot be turned). The 0° orientation of the shock absorbing cover is facing the 0°orientation of the mockup.

- Installation of the instrumentation on the mockup body.

- The angle between the centreline of the packaging and the horizontal measured for drop 9 is 47° when the centre of gravity is in line with the point of impact.

- The drop height between the first point of impact and the target is 0.3 m.
- The impact of the mockup takes place on the 0° line.

Photo 1-6.49 shows the position of the mockup before the drop.

5.10.2 Description of drop

The mockup drops on the truncated cone, bounces (bounce height about [redacted]), drops again and comes to rest in equilibrium on the truncated cone (see figure 1-6.55).

The position of the mockup after the drop is shown in Photograph 1-6.50.

5.10.3 Measurements

- Accelerations on the mockup body.

  The curves are filtered at 1000 Hz, and are shown in Figures 1-6.56 to 1-6.58.

	Accelerations on the ½ scale mockup		
	Accelerometer on the shell close to the lid. orientation 0° 9Ax	Accelerometer on the shell close to the lid. orientation 90° 9By	Accelerometer on the shell close to the lid. orientation 270° 9Cy
Axis of the measured acceleration	[redacted]	[redacted]	[redacted]
Impact on the bottom of the mockup.	[redacted]	[redacted]	[redacted]

6. CONCLUSION

The drop tests were made on a ½ scale mockup representative of the full scale TN-MTR packaging (described in Appendix 5 of chapter 1) containing a basket and pins to simulate the fuel assemblies.

The tests included 5 9-meter drops, 2 drops on a bar and 2 0.3-meter drops.

They demonstrated that the TN-MTR complies with assumptions made for the thermal and the dose equivalent rate calculations and for the analysis of the activity release and nuclear safety of the package, when subjected to the drop sequences performed on the TN-MTR as defined by the IAEA regulation <1>.

7. REFERENCES

<1> IAEA Safety Collection No. 6 – Rules for the Transportation of Radioactive Materials – 1985 Edition (Amended 1990)

<2> VALOREL manufacturer's file, TN-MTR 1/2 scale mockup, 602 - 3393, date 24/03/97.

<3> AMG manufacturer's file, Mockup of the MTR-68 basket for the TN-MTR 1/2 scale mockup, 666 - 6257, March 1997.

<4> Study of the TN-MTR packaging drop - DYNALIS - Fax date 24/03/97

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TABLE 1-6.1: DROP TEST PROGRAMME

TN-MTR 1/2 Scale MOCKUP - REGULATORY DROPS							
drop / line of impact	execution order	Definition	Orientation	Tested equipment zone	Cover No.	Cover 0° orientation	Position of the basket spacer
9 m / 180°	1	lateral drop, axis perpendicular to the trunnions	packaging axis tilted by 5° at shock absorbing cover end, impact at angle 180° on the mockup and angle 270° on the basket.	cover, lid and basket	1	0°	lid end
1 m on bar / 180°	2	lateral drop on bar on shell	axis 30° from the horizontal, cover at top, impact at angle 180° on the mockup and angle 270° on the basket.	packaging shells	1	0°	lid end
9.15 m / 270°	3	lateral drop, axis parallel to the trunnions	axis horizontal, impact at angle 270° on the mockup and angle 180° on the basket.	No. and lid	2	180°	bottom end
9.25 m / 90°	4	drop on corner of shock absorbing cover, axis parallel to the trunnions	impact point vertically in line with the centre of gravity, impact at angle 90° on the mockup and angle 0° on the basket.	cover. and lid	2	180°	bottom end
9.3 m	5	axial drop on bottom of the packaging	axis vertical	cover and lid	1	0°	lid end
1.3 m on bar	6	drop on bar, on shock absorbing cover:	impact point, orifice and centre of gravity of the packaging all in line on the same vertical	shock absorbing cover, lid, orifices	3	180°	bottom end
9.3 m	7	axial drop on shock absorbing cover	axis vertical	cover and lid	3	180°	bottom end
0.3 m	8	axial drop on bottom of the packaging	axis vertical	acceleration under normal conditions of transport	1	0°	lid end
0.3 m / 0°	9	Drop on corner, bottom end	Centre of gravity in line with the impact point	acceleration under normal conditions of transport	1	0°	lid end

TABLE 1-6.2
MASSES OF THE AS-BUILT TN-MTR MOCKUP

	Masses calculated with maximum densities	**Masses of the mockup fabricated for the drop tests**
Mass of body	**2,000 kg**	**1,920 kg <2>**
Mass of lid	**336 kg**	**320 kg <2>**
Mass of basket	40 kg	41 kg <3>
Mass of pins simulating the assemblies	190 kg	191 kg
Basket spacer in the packaging	100 kg	127 kg
Mass of contents	**330 kg**	**359 kg**
Mass of shock absorbing cover	**210 kg**	**180 kg <2>**
Total mass,(drops 1 to 5)	**2,875 kg**	**2 780 kg**
Difference (%) drops 1 to 5		**- 3.4 %**

	Masses calculated with maximum densities	**Masses of the mockup fabricated for the drop tests**
Mass of the basket after the disk (3) has been removed (mass of disk: 3.1 kg)		**37.9 kg**
Total mass, drops 6 and 7)	**2,875 kg**	**2,777 kg**
Difference (%) drops 1 to 5		**- 3.4 %**

TABLE 1-6.3

LEAK TESTS AFTER EACH DROP

	Internal lid seal helium leaktest using the global vacuum method)	Lid outer seal (pressurization test)	Containment welds (helium leak test using the global vacuum method)	Orifice B plug inner seal helium leak test using the global vacuum method)	Orifice B plug outer seal (pressurization test)
	Pa m^3 / s	Pa m^3 / s	Pa m^3 / s	Pa m^3 / s	Pa m^3 / s
Before drops	$\leq 4.2 \times 10^{-11}$ PV 4466-01	6.1×10^{-5} PV 4466-02	Not done	1.1×10^{-10} PV 4466-03	$< 2.0 \times 10^{-5}$ PV 4466-04
After drop 1	6.4×10^{-11} PV 4466-05	Not done	Not done	Not done	Not done
After drop 2	$\leq 4.5 \times 10^{-11}$ PV 4466-06	4.1×10^{-5} PV 4466-07	2.2×10^{-10} PV 4466-08	8.6×10^{-08} PV 4466-09	5.6×10^{-6} PV 4466-10
Before drop 3	$\leq 8.6 \times 10^{-11}$ PV 4466-11	1.3×10^{-5} PV 4466-12	Not done	$\leq 7.9 \times 10^{-11}$ PV 4466-13	4.1×10^{-5} PV 4466-14
After drop 3	$\leq 5.5 \times 10^{-11}$ PV 4466-15	Not done	$\leq 1.0 \times 10^{-10}$ PV 4466-16	Not done	Not done
After drop 4	$\leq 8.6 \times 10^{-11}$ PV 4466-17	$\leq 2.0 \times 10^{-5}$ PV 4466-18	$\leq 1.2 \times 10^{-10}$ PV 4466-19	$\leq 1.1 \times 10^{-10}$ PV 4466-20	2.0×10^{-5} PV 4466-21
Before drop 5	8.6×10^{-11} PV 4466-22	1.1×10^{-5} PV 4466-23	Not done	Not done	Not done
After drop 5	$\leq 2.3 \times 10^{-10}$ PV 4466-24	$\leq 2.0 \times 10^{-5}$ PV 4466-25	$\leq 3.2 \times 10^{-10}$ PV 4466-26	$\leq 2.0 \times 10^{-10}$ PV 4466-27	$\leq 2.0 \times 10^{-5}$ PV 4466-28
Before drop 6	$\leq 9.5 \times 10^{-11}$ PV 4466-29	Not done	Not done	Not done	Not done
After drop 6	$\leq 1.2 \times 10^{-10}$ PV 4466-30	$\leq 2.0 \times 10^{-5}$ PV 4466-31	Not done	Not done	Not done
After drop 7	$\leq 2.2 \times 10^{-10}$ PV 4466-32	$\leq 2.0 \times 10^{-5}$ PV 4466-33	$\leq 2.3 \times 10^{-10}$ PV 4466-34	$\leq 1.9 \times 10^{-10}$ PV 4466-35	$\leq 2.0 \times 10^{-5}$ PV 4466-36
After drop 8	Not done	Not done	Not done	Not done	Not done
After drop 9	Not done	Not done	Not done	Not done	Not done
Maximum value	2.3×10^{-10}	6.1×10^{-5}	3.2×10^{-10}	8.6×10^{-08}	4.1×10^{-5}

Note: the ≤ sign before the value of the leak shows that the sensitivity limit has been reached.

TABLE 1-6.4

CHARACTERISTICS OF THE MATERIALS USED IN THE PACKAGING THE MOCKUP AND THE SPACER

		Drop mockup	Required characteristics for the tests
Body and bottom	Inner containment shell (101)	Z3 CN 18-10	σ_e = 200 MPa σ_r = 520 MPa A% = 45% E = 200 000 MPa
	Inner containment bottom (201)	Z3 CND 22 05 Az	σ_e = 470 MPa σ_r = 660 MPa A% = 25% E = 200 000 MPa
	Shielding containment (102, 202)	Lead	
	Insulation containment (103, 203, 251)	Type F resin	
	Outer containment (104, 204, 252)	Z3 CN 18-10	σ_e = 200 MPa σ_r = 520 MPa A% = 45% E = 200 000 MPa
	Trunnions	Z3 CN 18-10	σ_e = 200 MPa σ_r = 520 MPa A% = 45% E = 200 000 MPa
	Flange (105)	Z3 CN 18-10	σ_e = 200 MPa σ_r = 520 MPa A% = 45% E = 200 000 MPa

TABLE 1-6.4-1.1 (continued)
CHARACTERISTICS OF THE MATERIALS USED IN THE PACKAGING
THE MOCKUP AND THE SPACER

		Drop mockup	Required characteristics for the tests
Lid	Lid inner disk (301)	Z3 CND 22 05 Az	σ_e = 470 MPa σ_r = 660 MPa A% = 25% E = 200 000 MPa
	Shielding containment (302, 303)	Lead	
	Reinforcing shell for the lid (305)	Z3 CND 22 05 Az	σ_e = 470 MPa σ_r = 660 MPa A% = 25% E = 200 000 MPa
	Lid outer shell (306)	Z3 CND 22 05 Az	σ_e = 470 MPa σ_r = 660 MPa A% = 25% E = 200 000 MPa
	Lid flange (307)	Z3 CND 22 05 Az	σ_e = 470 MPa σ_r = 660 MPa A% = 25% E = 200 000 MPa
Seals		VITON hardness: $70^{\pm 5}$ Shores	
Content	Upper basket structural disk (2)	Z3 CND 22 05 Az	σ_e = 538 MPa σ_r = 726 MPa A% = 33% E = 200 000 MPa
	Intermediate and lower structural disks (3 to 8)	Z3 CND 22 05 Az	σ_e = 552 MPa σ_r = 754 MPa A% = 35% E = 200 000 MPa
	Basket poison disks	Aluminium 6082	
	Assemblies Basket spacer in the mockup	Stainless steel Stainless steel	

TABLE 1-6.5
SCREW LOOSENING TORQUES AFTER THE DROPS

	Screw number	After drop 1	After drop 2	After drop 3	After drop 4	After drop 5	After drop 6	After drop 7
		kg.m	kg.m	kg.m	kg.m	kg.m	kg.m	kg.m
Lid screw	1		5		8	7		7
	2		7		10	6		8
	3		7		10	6		8
	4		7		12	7		12
	5		10		12	6		8
	6		9		11	6		9
	7		9		12	7		9
	8		9		10	8		15
	9		9		14	6		9
	10		8		11	7		14
	11		9		12	6		10
Initial tightening	12		9		12	6		11
torque: 7 kg.m	13		8		12	8		9
	14	Screws	8	Screws	12	7	Screws	14
	15	not	8	not	12	7	not	10
	16	remove	8	remove	7	6	remove	9
	17	d	11	d	7	7	d	9
	18		9		7	5		9
	19		10		7	7		8
	20		9		7	6		8
	21		10		8	7		7
	22		8		7	6		9
	23		7		7	6		6
	24		9		7	6		7
	25		9		7	6		5
	26		8		7	5		9
	27		8		8	5		6
	28		7		9	7		8
	29		8		10	7		7
	30		9		9	5		6
	31		9		7	6		7
	32		9		6	6		9
	33		10		9	7		7
	34		9		7	8		7
	35		10		8	8		7
	36		9		9	7		9
Representative	1	Screws	≤ 1 (1)	Screws	Screws	≤ 1 (1)	Screws	≤ 1 (1)
orifice plug screw	2	not	≤ 1 (1)	not	not	≤ 1 (1)	not	≤ 1 (1)
(Initial tightening	3	remove	≤ 1 (1)	remove	remove	≤ 1 (1)	remove	≤ 1 (1)
torque: 0.7 kg.m)	4	d	≤ 1 (1)	d	d	≤ 1 (1!	d	≤ 1 (1)

(1) Minimum precision of torque wrench.

TABLE 1-6.6

MAXIMUM ACCELERATIONS MEASURED DURING THE DROPS

	x axis of mockup (radial axis)				y axis of mockup (longitudinal axis)			
	Shell close to lid	**Shell close to centre of gravity**	**Impact bottom end**	**Bottom close to the mockup axis**	**Shell close to lid**	**Shell close to centre of gravity**	**Impact bottom end**	**Bottom close to the mockup axis**
After drop No. 1	[redacted]			[redacted]				
After drop No. 2	[redacted]	[redacted]				[redacted]		
After drop No. 3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
After drop No. 4	[redacted]		[redacted]		[redacted]		[redacted]	
After drop No. 5					[redacted]			
After drop No. 6	[redacted]				[redacted]			
After drop No. 7					[redacted]			
After drop No. 8					[redacted]			
After drop No. 9	[redacted]				[redacted]			
Maximum on mock-up	[redacted]				[redacted]			

TABLE 1-6.7
BASKET DIMENSIONS AFTER DROP No. 2
COMPARTMENT INSIDE DIMENSIONS

	90°-270° axis measurements							0°-180° axis measurements						
Disk No. / Compartment No.	8	7	6	5	4	3	2	8	7	6	5	4	3	2
Nominal dimension: 43.6 mm														
2	[redacted]													
3	[redacted]													
5	[redacted]													
6	[redacted]													
7	[redacted]													
8	[redacted]													
9	[redacted]													
10	[redacted]													
11	[redacted]													
14	[redacted]													
15	[redacted]													
17	[redacted]													
18	[redacted]													
20	[redacted]													
23	[redacted]													
24	[redacted]													
26	[redacted]													
29	[redacted]													
31	[redacted]													
33	[redacted]													
34	[redacted]													
39	[redacted]													
41	[redacted]													
43	[redacted]													
44	[redacted]													
53	[redacted]													
54	[redacted]													
59	[redacted]													
60	[redacted]													
61	[redacted]													
62	[redacted]													
63	[redacted]													
67	[redacted]													
68	[redacted]													
69	[redacted]													
70	[redacted]													
74	[redacted]													
75	[redacted]													

Disk and compartment numbers are shown in Figure 1-6.15.

TABLE 1-6.8
BASKET DIMENSIONS AFTER DROP No. 2
BASKET CORE THICKNESSES

	90°-270° axis measurements measurement of the core to the right of the marked compartment							0°-180° axis measurements measurement of the core above the marked compartment						
Disk No. / Compartment No.	8	7	6	5	4	3	2	8	7	6	5	4	3	2
Nominal dimension: 3 mm														
2														
3														
5														
6														
7														
8														
9														
10														
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61														
62														
63														
67														
68														
69														
70														
74														
75														
minimum														
maximum														
average														

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FIGURE 1-6.6: DROP 1 - ACCELERATION READINGS ON THE BASKET: C_v (see figure 1-6.2 continued 2)

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FIGURE 1-6.22: DROP 2 - ACCELERATION READINGS ON THE BASKET

FIGURE 1-6.17: DROP 2 - ACCELERATION READINGS ON THE BASKET

FIGURE 1-6.24: DROP 2 - ACCELERATION READINGS ON THE BASKET

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FIGURE 1-6.19: DROP 2 - ACCELERATION READINGS ON THE MOCKUP

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FIGURE 1-6.21: DROP 2 - STRESS READINGS DURING THE DROP

FIGURE 1-6.22: DROP 2 - STRESS READINGS DURING THE DROP

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FIGURE 1-6.29: DROP 3 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.30: DROP 3 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.31: DROP 3 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.32: DROP 3 - ACCELERATION READINGS ON THE MOCKUP

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FIGURE 1-6.36: DROP 4 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.37: DROP 4 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.38: DROP 4 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.39: DROP 4 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.40: DROP 5 - 9-METER AXIAL DROP ON THE BOTTOM OF THE PACKAGING

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FIGURE 1-6.47: DROP 6 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.48: DROP 6 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.49: DROP 6 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.50: DROP 6 - ACCELERATION READINGS ON THE MOCKUP

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FIGURE 1-6.57: DROP 9 - ACCELERATION READINGS ON THE MOCKUP

FIGURE 1-6.58: DROP 9 - ACCELERATION READINGS ON THE MOCKUP

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FIGURE 1-6.64: GEOMETRIC CALCULATION MODEL

FIGURE 1-6.65: DROP 2 - ACCELEROMETER 2Bx RESPONSE SPECTRUM (see figure 1-6.12)

FIGURE 1-6.1
SET OF DROPS

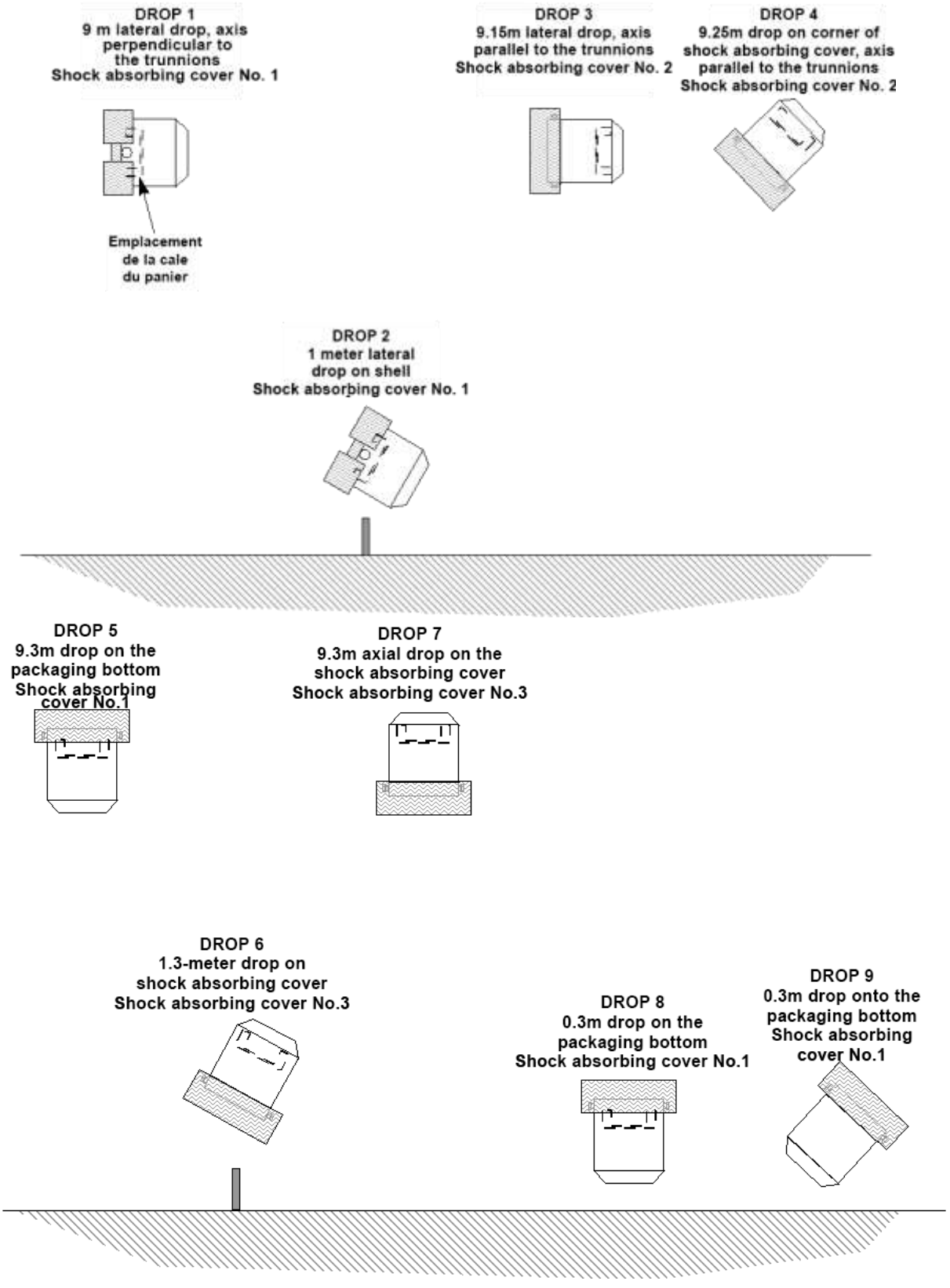


FIGURE 1-6.2

DROP 1

9-METER LATERAL DROP, PERPENDICULAR

TO THE TRUNNION AXIS

Drop with shock absorbing cover No. 1, basket spacer at lid end.

Basket axis providing minimum resistance, in the vertical direction.

PROPRIETARY

FIGURE 1-6.2 (continued 1)

DROP 1

9-METER LATERAL DROP, PERPENDICULAR

TO THE TRUNNION AXIS

BASKET ORIENTATION IN THE PACKAGING

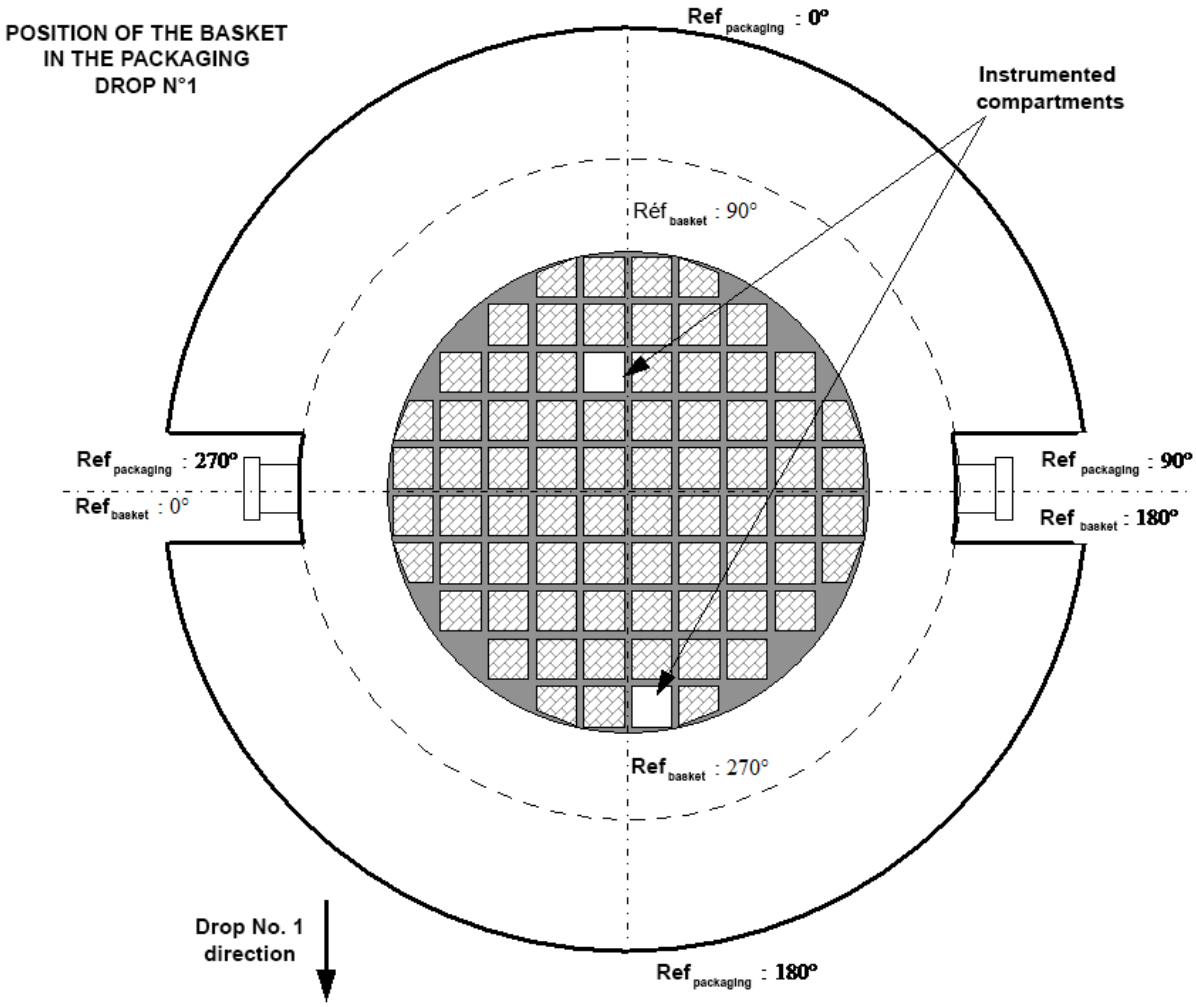


FIGURE 1-6.2 (continued 2)

DROP 1

9-METER LATERAL DROP, PERPENDICULAR

TO THE TRUNNION AXIS

POSITION OF ACCELEROMETERS ON THE BASKET

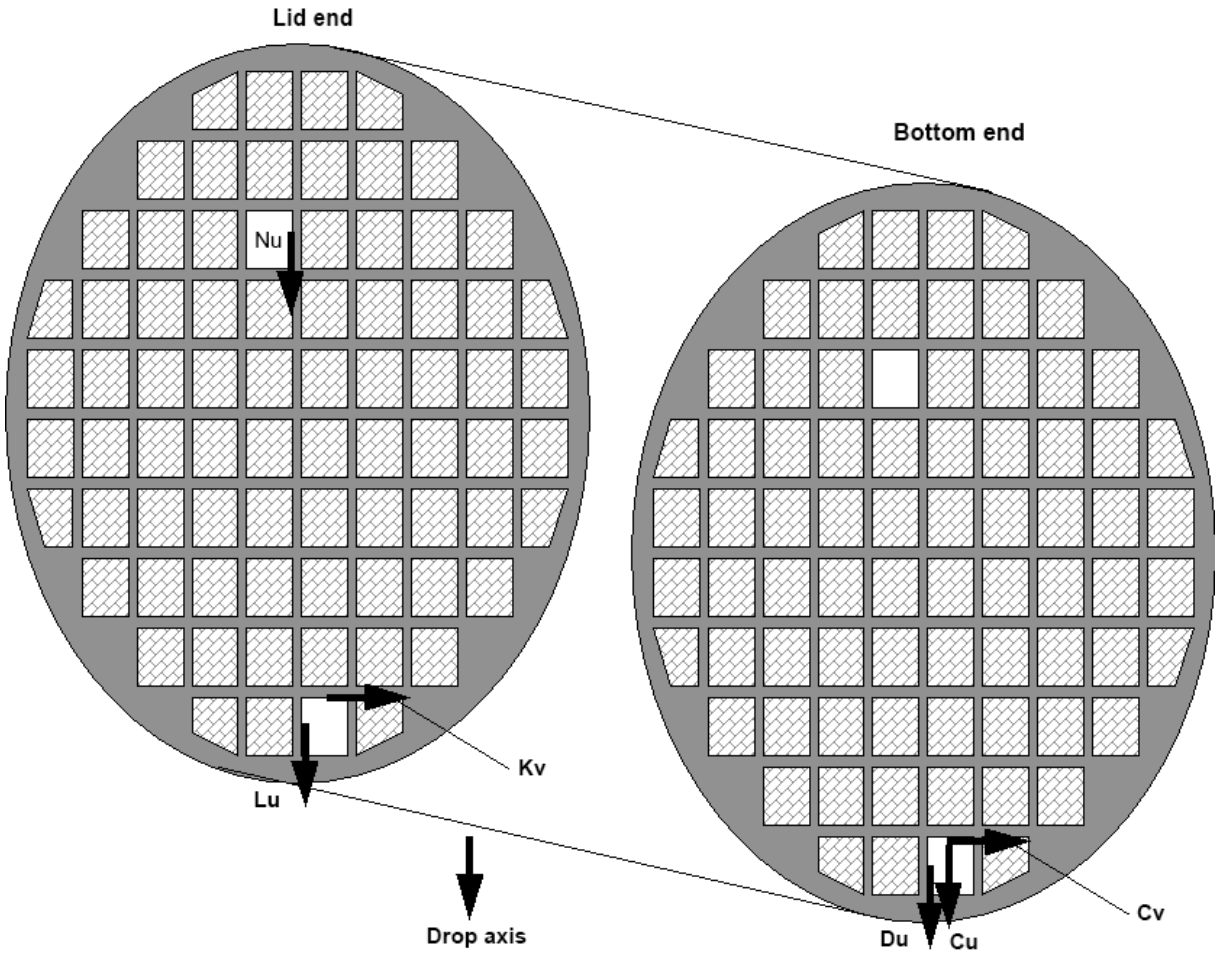


FIGURE 1-6.2 (continued 3)

DROP 1

9-METER LATERAL DROP, PERPENDICULAR

TO THE TRUNNION AXIS

POSITION OF DEFORMATION GAUGES ON THE BASKET

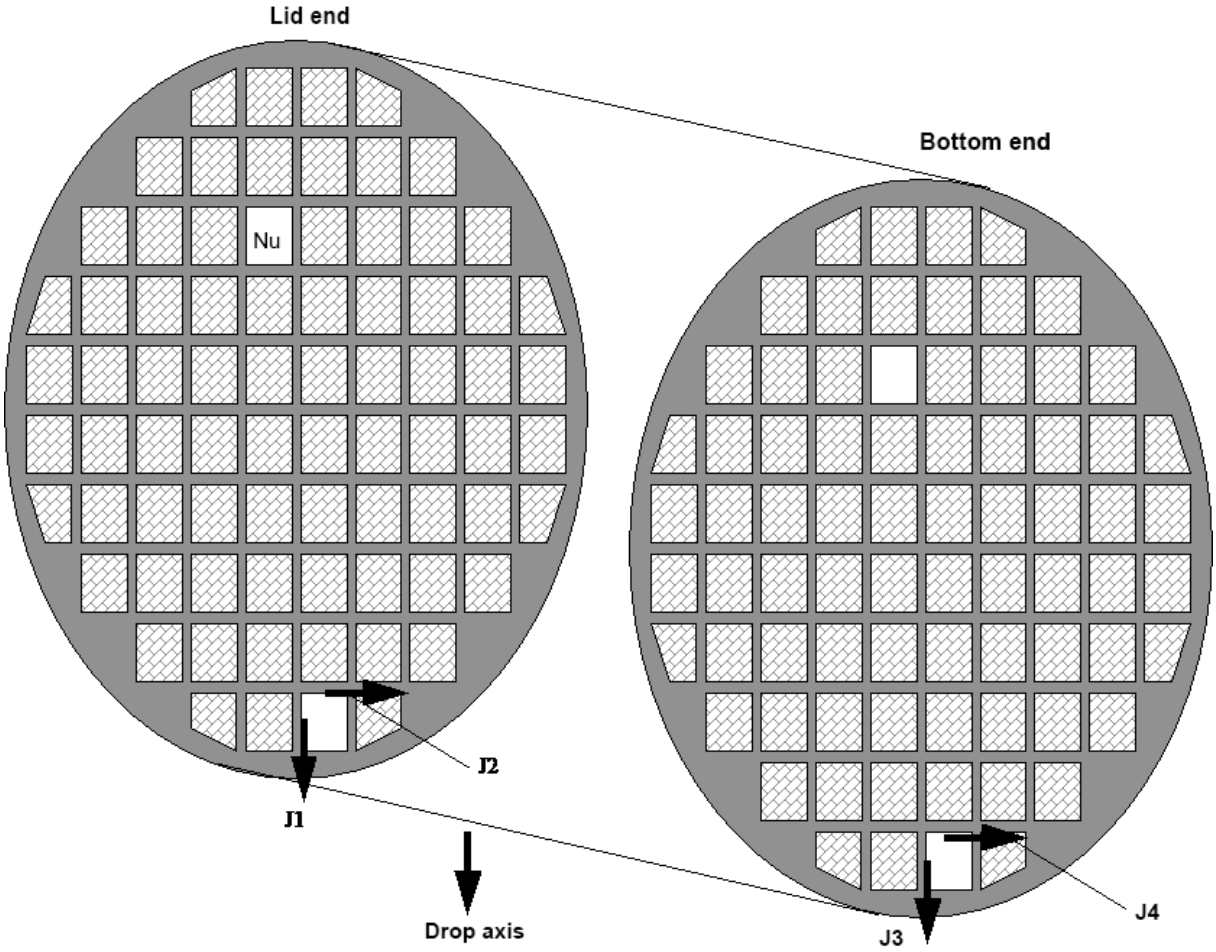


FIGURE 1-6.3

DEFORMATIONS AFTER

DROP No. 1

DEFORMATION OF SHOCK ABSORBING COVER

180° LINE

PROPRIETARY

FIGURE 1-6.4

DEFORMATIONS AFTER

DROP No. 1

DEFORMATION OF PACKAGING BOTTOM

180° LINE

PROPRIETARY

FIGURE 1-6.5
DROP 1
ACCELEROMETER 1Ax RESPONSE SPECTRUM (see figure 1-6.2)

PROPRIETARY

FIGURE 1-6.6
DROP 1
ACCELEROMETER 1Dx RESPONSE SPECTRUM (see figure 1-6.2)

PROPRIETARY

FIGURE 1-6.7

DROP 1

ACCELERATION READINGS ON THE MOCKUP - 1Ax (see figure 1-6.2)

PROPRIETARY

FIGURE 1-6.8

DROP 1

ACCELERATION READINGS ON THE MOCKUP - 1Dx (see figure 1-6.2)

PROPRIETARY

FIGURE 1-6.9

DROP 1

STRESSES MEASURED DURING THE DROP

PROPRIETARY

FIGURE 1-6.10

DROP 1

STRESSES MEASURED DURING THE DROP

PROPRIETARY

FIGURE 1-6.11

DROP 1

STRESSES MEASURED DURING THE DROP

PROPRIETARY

FIGURE 1-6.12

DROP 2

1 METER LATERAL DROP ON SHELLS

Drop with shock absorbing cover No. 1, basket spacer at lid end.

Basket orientation identical to drop 1.

PROPRIETARY

FIGURE 1-6.13

**SHELL DEFORMATION
AFTER DROP No. 2**

PROPRIETARY

FIGURE 1-6.14

SHELL DEFORMATION

MEASURED WITH JIG

AFTER DROP No. 2

PROPRIETARY

FIGURE 1-6.15

DEFORMATION OF DISK 6

OBSERVED WHEN OPENING AFTER

DROP No. 2

PROPRIETARY

FIGURE 1-6.16

DEFORMATION OF DISK 7

OBSERVED WHEN OPENING AFTER

DROP No. 2

PROPRIETARY

FIGURE 1-6.17

DROP 2

ACCELERATION READINGS ON BASKET L_u (see figure 1-6.12)

PROPRIETARY

FIGURE 1-6.18

DROP 2

ACCELERATION READINGS ON THE MOCKUP - 2Ax

PROPRIETARY

FIGURE 1-6.19

DROP 2

ACCELERATION READINGS ON THE MOCKUP - 2Bx

PROPRIETARY

FIGURE 1-6.20

DROP 2

ACCELERATION READINGS ON THE MOCKUP - 2By

PROPRIETARY

FIGURE 1-6.21

DROP 2

STRESS READINGS DURING THE DROP

PROPRIETARY

FIGURE 1-6.22

DROP 2

STRESS READINGS DURING THE DROP

PROPRIETARY

FIGURE 1-6.23

DROP 2

STRESS READINGS DURING THE DROP

PROPRIETARY

FIGURE 1-6.24

DROP 3

9-METER LATERAL DROP, PARALLEL

TO THE TRUNNION AXIS

Drop with shock absorbing cover No. 2, basket spacer at bottom end.

PROPRIETARY

FIGURE 1-6.25

DEFORMATION OF THE

SHOCK ABSORBING COVER AFTER

DROP No. 3

PROPRIETARY

FIGURE 1-6.26

DEFORMATION OF THE SHELL AND

THE TRUNCATED CONE AFTER

DROP No. 3

PROPRIETARY

FIGURE 1-6.27

DROP 3

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.28

DROP 3

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.29

DROP 3

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.30

DROP 3

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.31

DROP 3

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.32

DROP 3

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.33

DROP 4

9-METER DROP ON EDGE OF SHOCK ABSORBING COVER

Drop with shock absorbing cover No. 2, basket spacer at bottom end of packaging.

PROPRIETARY

FIGURE 1-6.34

DEFORMATION OF SHOCK ABSORBING COVER

AFTER DROP No. 4

PROPRIETARY

FIGURE 1-6.35

DROP 4

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.36

DROP 4

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.37

DROP 4

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.38

DROP 4

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.39

DROP 4

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.40

DROP 5

9-METER AXIAL DROP ON THE BOTTOM OF THE PACKAGING

Drop with shock absorbing cover No. 1, basket spacer at lid end.

PROPRIETARY

FIGURE 1-6.41

DROP 5

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.42

DROP 5

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.43

DROP 6

1-METER DROP ON SHOCK ABSORBING COVER

Drop with shock absorbing cover No. 3, basket spacer at bottom end of packaging.

PROPRIETARY

FIGURE 1-6.44

DROP 6

1-METER DROP ON SHOCK ABSORBING COVER

OUTLINE

The following elements are in line on the same vertical:

- Centre of gravity
- Centre of the orifice B plug
- A longitudinal line on the bar

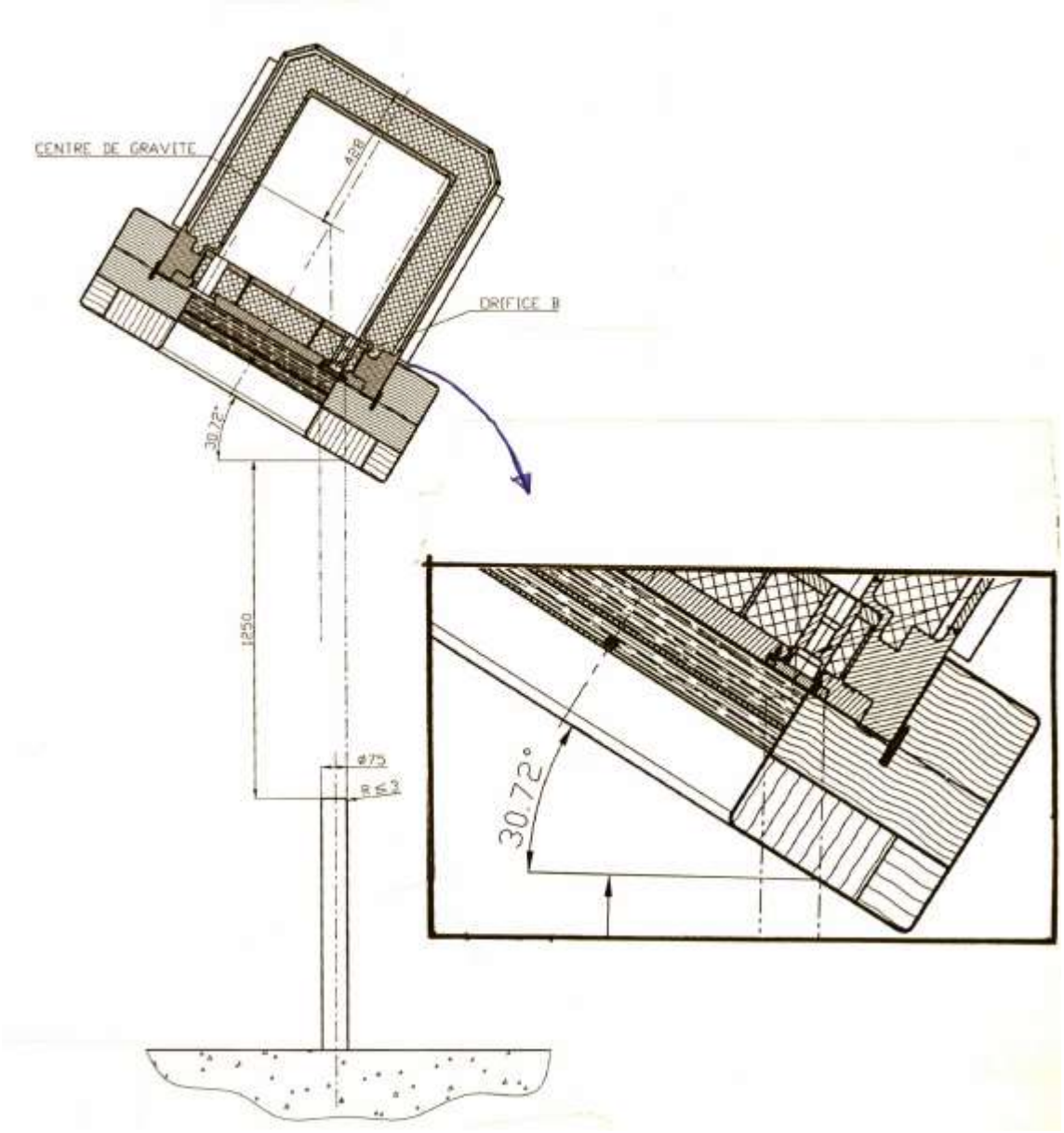


FIGURE 1-6.45

DROP 6

1-METER DROP ON SHOCK ABSORBING COVER

DERORMATION OF SHOCK ABSORBING COVER

TOP VIEW

PROPRIETARY

FIGURE 1-6.46

DROP 6

1-METER DROP ON SHOCK ABSORBING COVER

DEFORMATION OF SHOCK ABSORBING COVER

CROSS-SECTION

PROPRIETARY

FIGURE 1-6.47

DROP 6

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.48

DROP 6

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.49

DROP 6

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.50

DROP 6

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.51

DROP 7

9-METER AXIAL DROP ON SHOCK ABSORBING COVER

Drop with shock absorbing cover No. 3, basket spacer at bottom end of packaging.

PROPRIETARY

FIGURE 1-6.52

DROP 8

0.3-METER AXIAL DROP ON THE BOTTOM OF THE MOCKUP

Drop with shock absorbing cover No. 1, basket spacer at packaging lid end.

PROPRIETARY

FIGURE 1-6.53

DROP 8

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.54

DROP 8

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.55

DROP 9

0.3-METER AXIAL DROP ON THE BOTTOM CORNER

PROPRIETARY

FIGURE 1-6.56

DROP 9

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.57

DROP 9

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.58

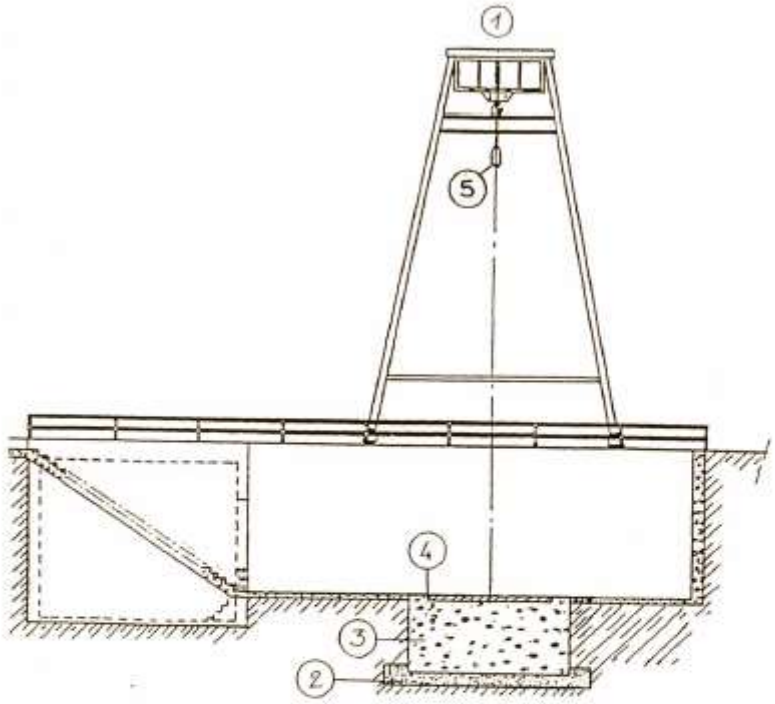
DROP 9

ACCELERATION READINGS ON THE MOCKUP

PROPRIETARY

FIGURE 1-6.59

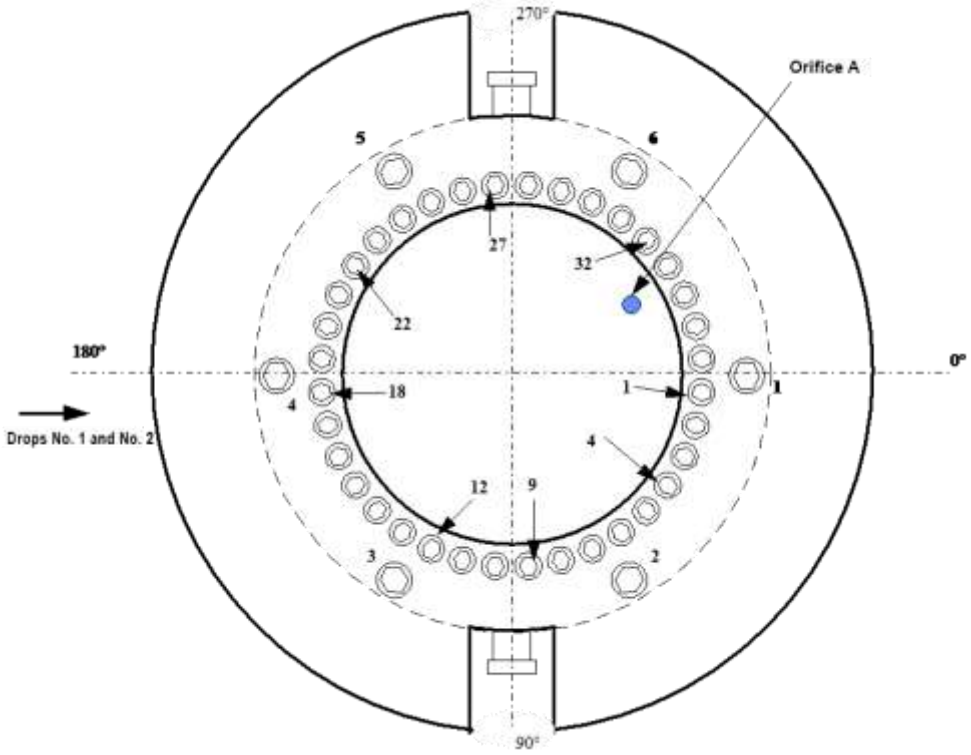
DROP TEST FACILITY



1 PONT ROULANT
2 SABLE
3 MASSIF DE BETON
4 PLAQUE D'ACIER 7M X 3M X 0,15M
5 DISPOSITIF DE LARGAGE

FIGURE 1-6.60: NUMBERING OF SCREWS

DURING DROPS 1, 2 and 5



DURING DROPS 3, 4, 6 AND 7

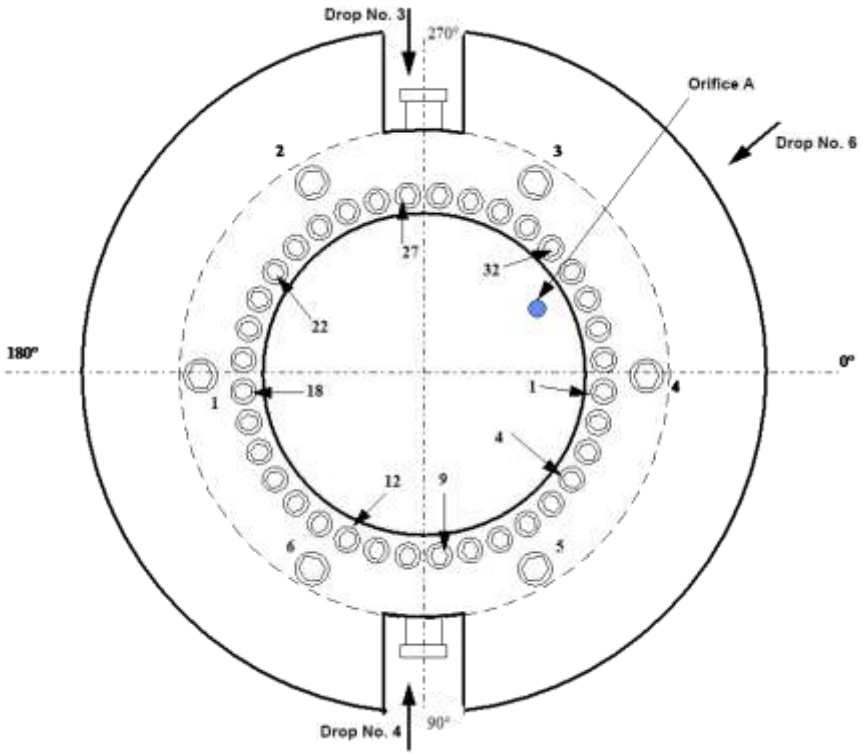


FIGURE 1-6.61

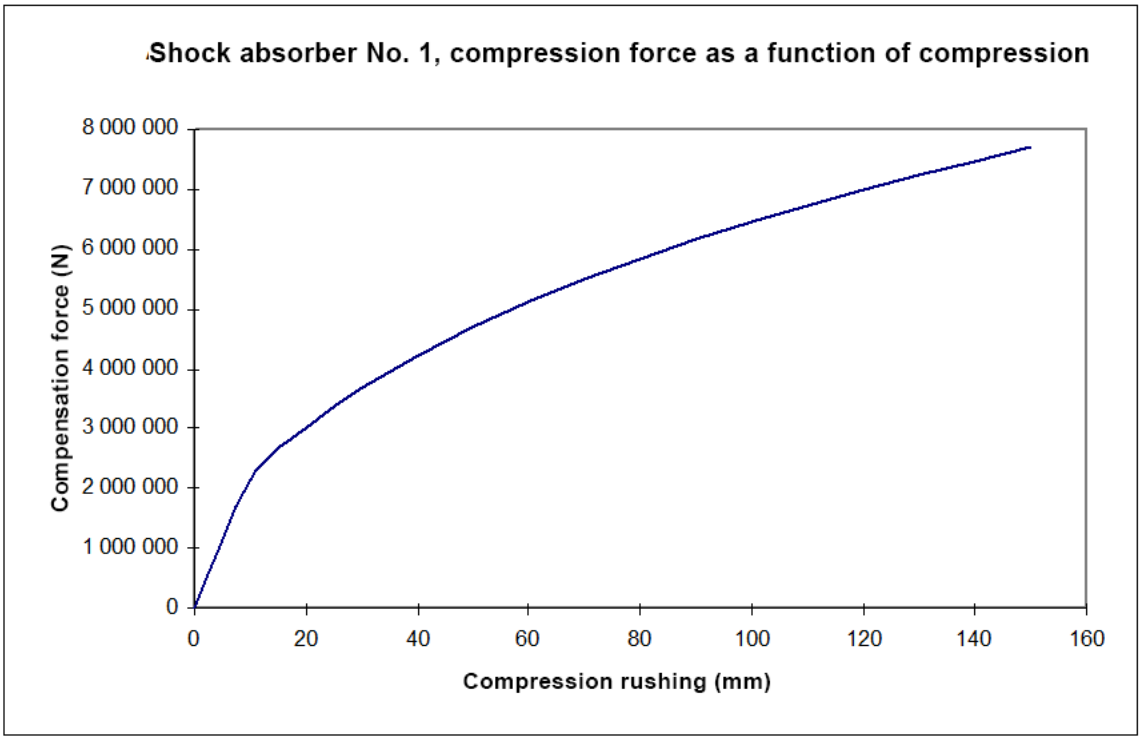
DISPLACEMENT OF THE MTR-68 BASKET UNDER A LOAD OF 1 G

PROPRIETARY

FIGURE 1-6.62

MODEL OF THE SHOCK ABSORBING COVER

Case 3.1: line of drop offset from the axis of the trunnions



Case 3.2: line of drop along the axis of the trunnions

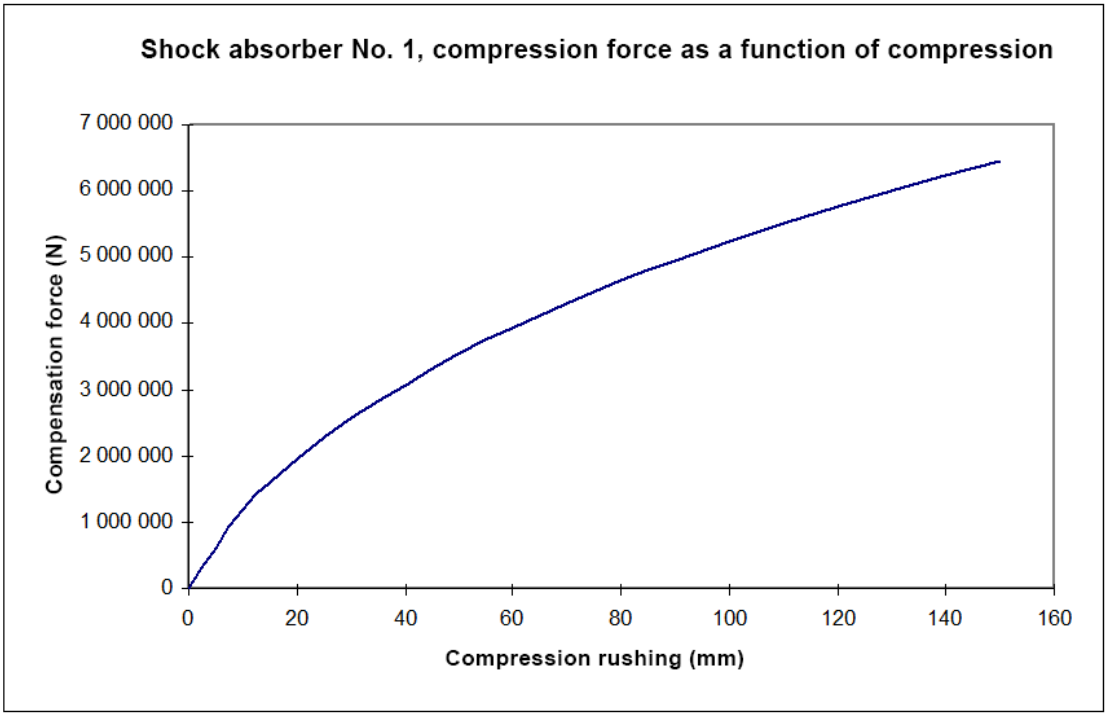
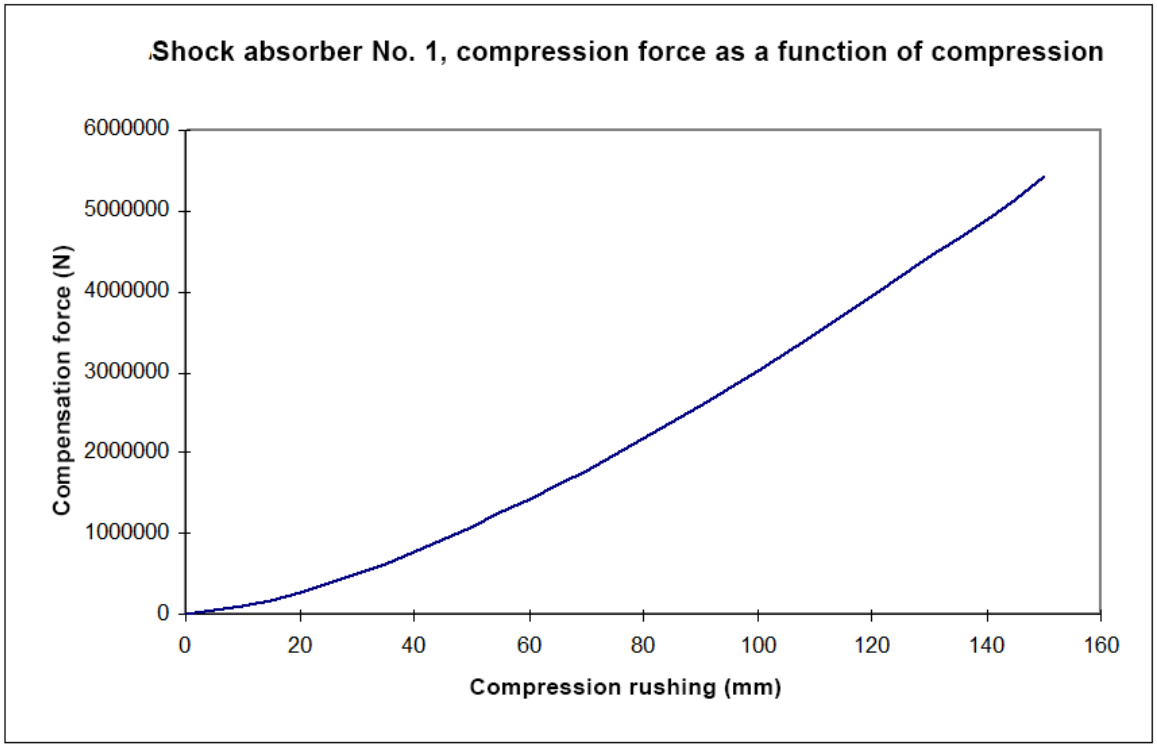


FIGURE 1-6.63

MODEL OF THE PACKAGING BOTTOM SHOCK ABSORBER

Curve SIG 4.1: Bottom equivalent compression stress =20 MPa.



Curve SIG 4.2: Bottom equivalent compression stress =40 MPa.

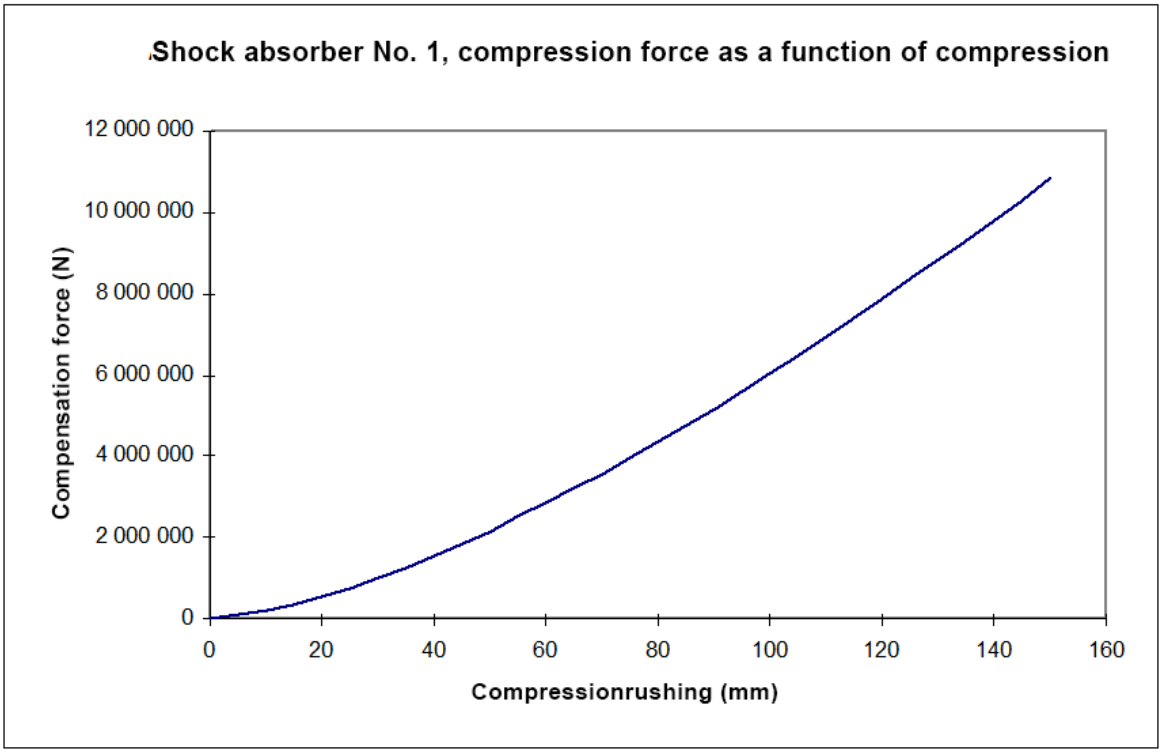


FIGURE 1-6.63 (continued and end)

MODEL OF THE PACKAGING BOTTOM SHOCK ABSORBER

Curve SIG 4.3: Bottom equivalent compression stress =100 MPa.

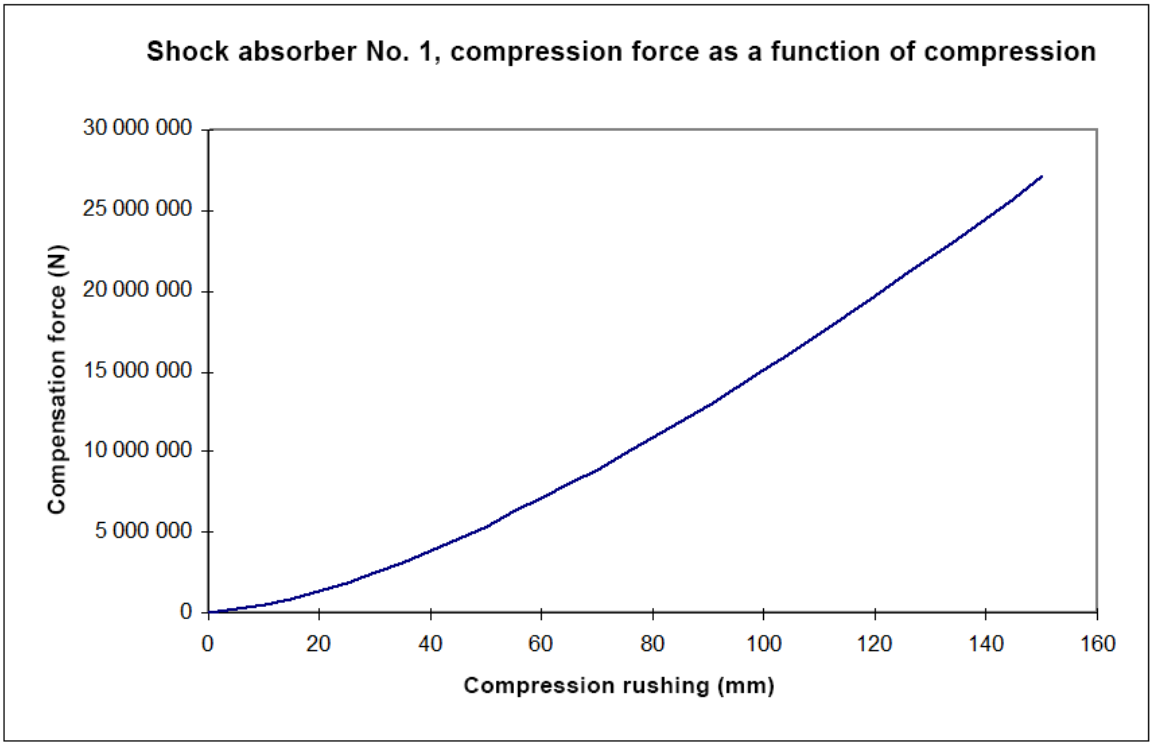
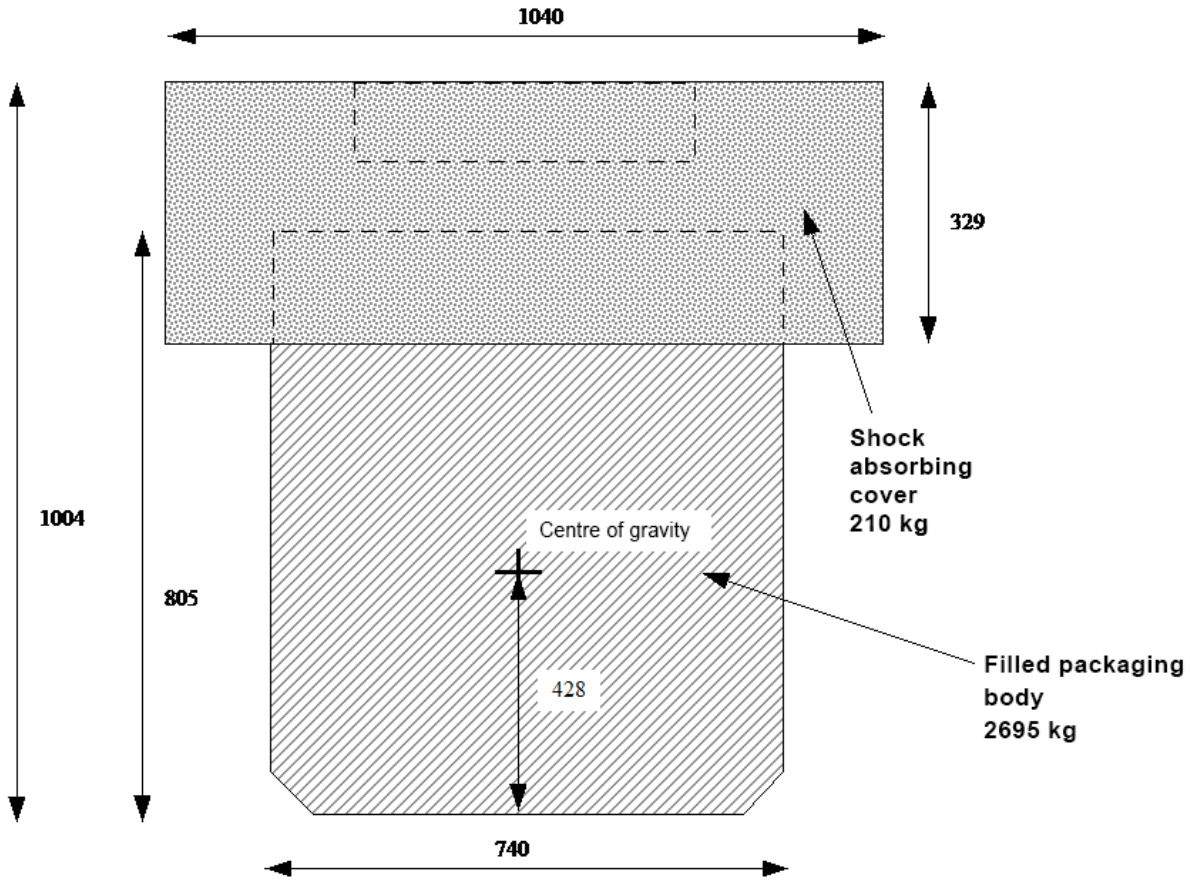


FIGURE 1-6.64

GEOMETRIC CALCULATION MODEL



Total mass of the drop mockup: 2905 kg

FIGURE 1-6.65

ACCELEROMETER 2Bx RESPONSE SPECTRUM (see figure 1-6.12)

PROPRIETARY

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PHOTO 1-6.12: AFTER DROP 2 - OPENING THE MOCKUP - BASKET REMOVED - DETAIL OF THE CAVITY DEFORMATION

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PHOTO 1-6.14: AFTER DROP 2 - OPENING THE MOCKUP - BASKET BOTTOM VIEW

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PHOTO 1-6.17: AFTER DROP 2 - OPENING THE MOCKUP - BASKET - DETAIL OF DEFORMATION OF BASKET DISK 7 (continued)

PHOTO 1-6.18: AFTER DROP 2 - OPENING THE MOCKUP - BASKET - DETAIL OF DEFORMATION OF BASKET DISK 7 (continued)

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PHOTO 1-6.34: AFTER DROP 4 - OPENING THE MOCKUP - BASKET TOP VIEW

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PHOTO 1-6.36: DROP 5 - MOCKUP POSITION AFTER DROP

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PHOTO 1-6.42: DROP 6 - DAMAGE CAUSED BY THE DROP - FRONT VIEW

PHOTO 1-6.43: DROP 7 - MOCKUP DROP POSITION

PHOTO 1-6.44: DROP 7 - MOCKUP POSITION AFTER DROP - FRONT VIEW

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PHOTO 1-6.49: DROP 9 - MOCKUP DROP POSITION

PHOTO 1-6.50: DROP 9: MOCKUP POSITION AFTER DROP

PHOTO 1-6.1

DROP 1

MOCKUP DROP POSITION

PHOTO 1-6.2

DROP 1

MOCKUP POSITION AFTER DROP

PHOTO 1-6.3

DROP 1

DAMAGE CAUSED BY THE DROP - FRONT VIEW

PHOTO 1-6.4

DROP 1

DAMAGE CAUSED BY THE DROP - SIDE VIEW

PHOTO 1-6.5

DROP 1

DAMAGE CAUSED BY THE DROP - DETAIL AT BOTTOM END OF MOCKUP

PHOTO 1-6.6

DROP 2

MOCKUP DROP POSITION

PHOTO 1-6.7

DROP 2

MOCKUP POSITION AFTER DROP

PHOTO 1-6.8

DROP 2

DAMAGE CAUSED BY THE DROP - FRONT VIEW

PHOTO 1-6.9

AFTER DROP 2

OPENING THE MOCKUP - SPACER IN POSITION

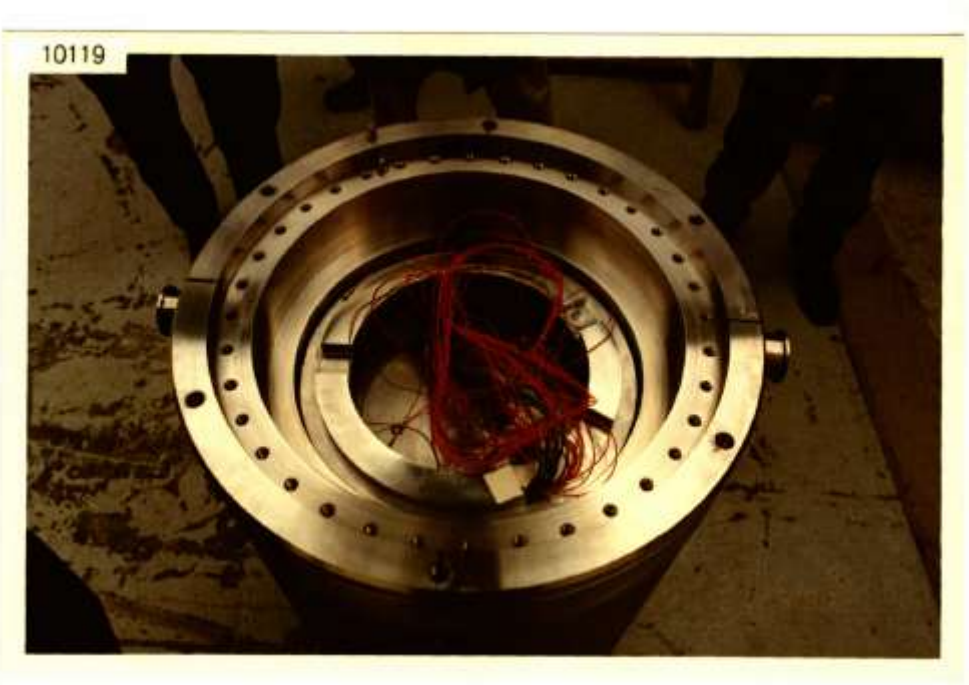

PHOTO 1-6.10

AFTER DROP 2

OPENING THE MOCKUP - SPACER REMOVED - BASKET IN POSITION

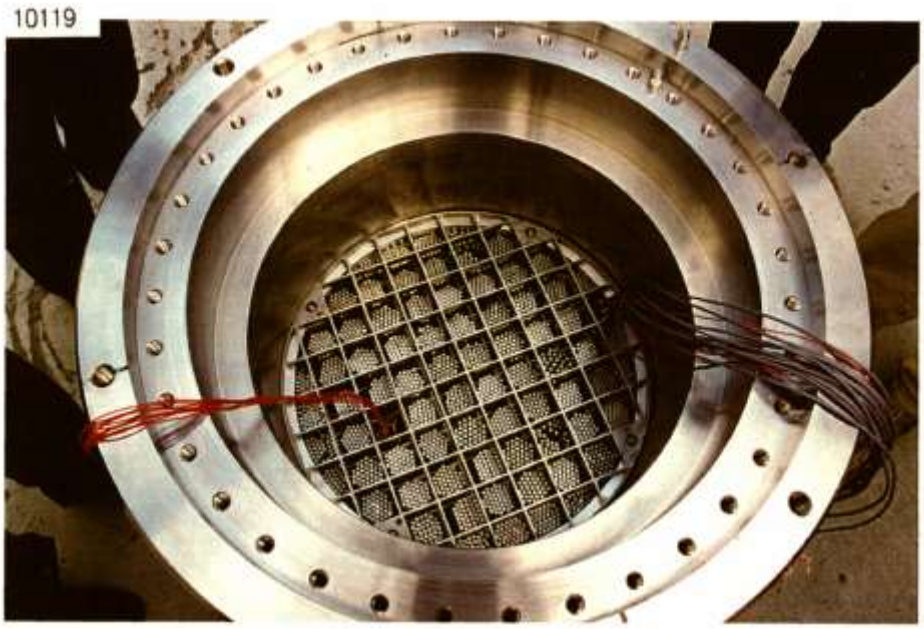

PHOTO 1-6.11

AFTER DROP 2

OPENING THE MOCKUP - BASKET REMOVED

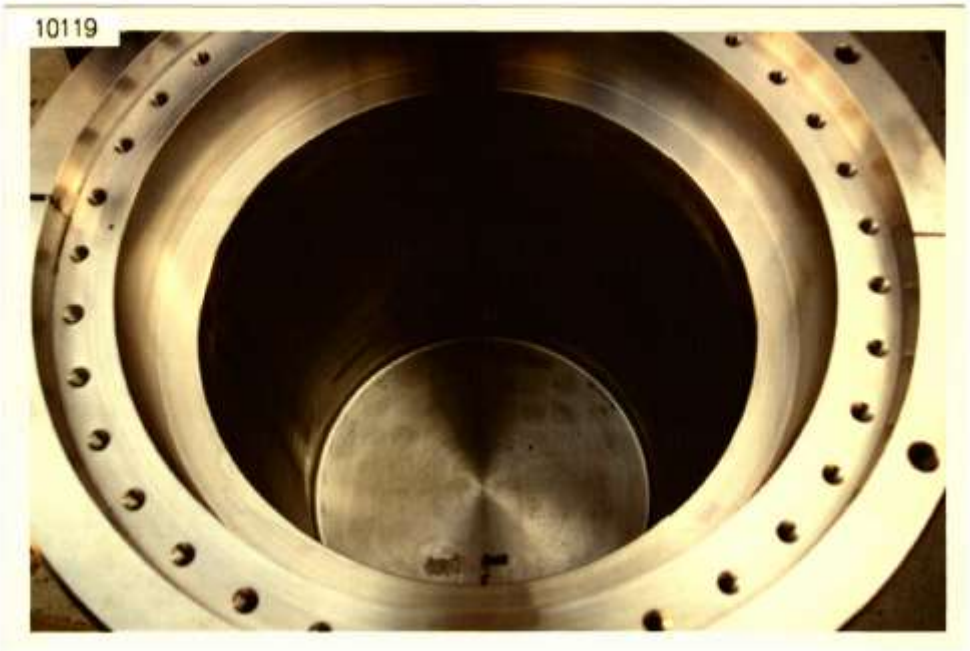

PHOTO 1-6.12

AFTER DROP 2

OPENING THE MOCKUP - BASKET REMOVED

DETAIL OF CAVITY DEFORMATION

PHOTO 1-6.13

AFTER DROP 2

OPENING THE MOCKUP - BASKET FRONT VIEW

PHOTO 1-6.14

AFTER DROP 2

OPENING THE MOCKUP - BASKET BOTTOM VIEW

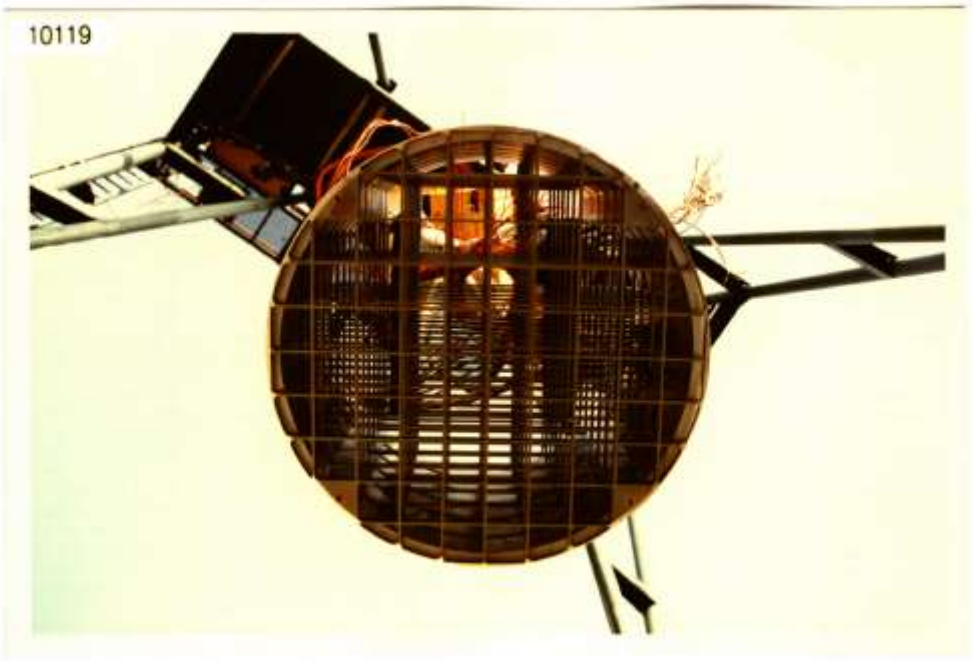

PHOTO 1-6.15

AFTER DROP 2

OPENING THE MOCKUP

BASKET - DETAIL DISK 2

PHOTO 1-6.16

AFTER DROP 2

OPENING THE MOCKUP

BASKET - DETAIL OF THE DEFORMATION OF BASKET DISK 7

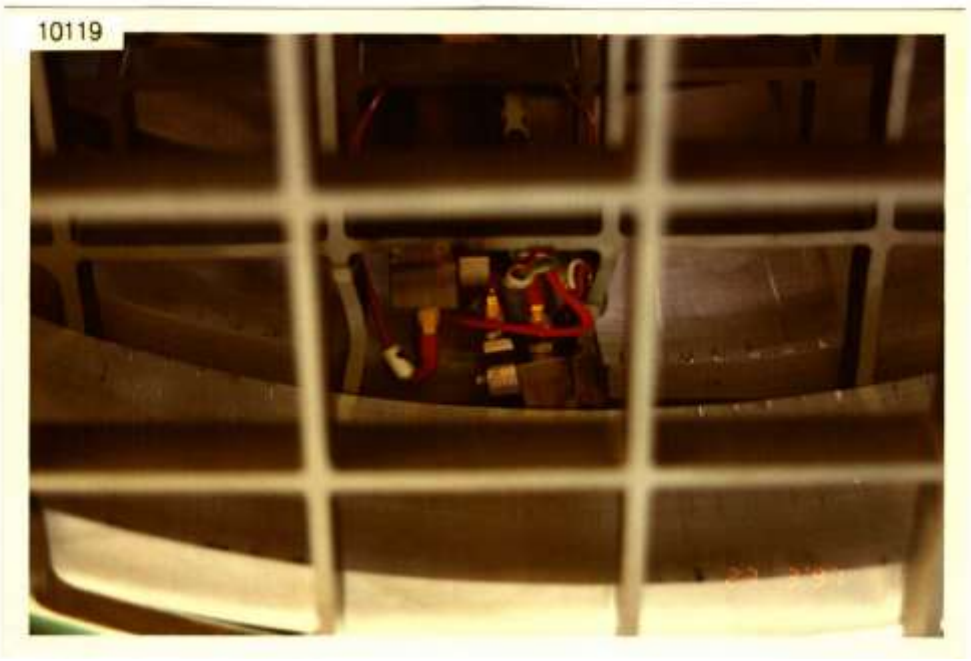

PHOTO 1-6.17

AFTER DROP 2

OPENING THE MOCKUP

BASKET - DETAIL OF THE DEFORMATION OF BASKET DISK 7 (continued)

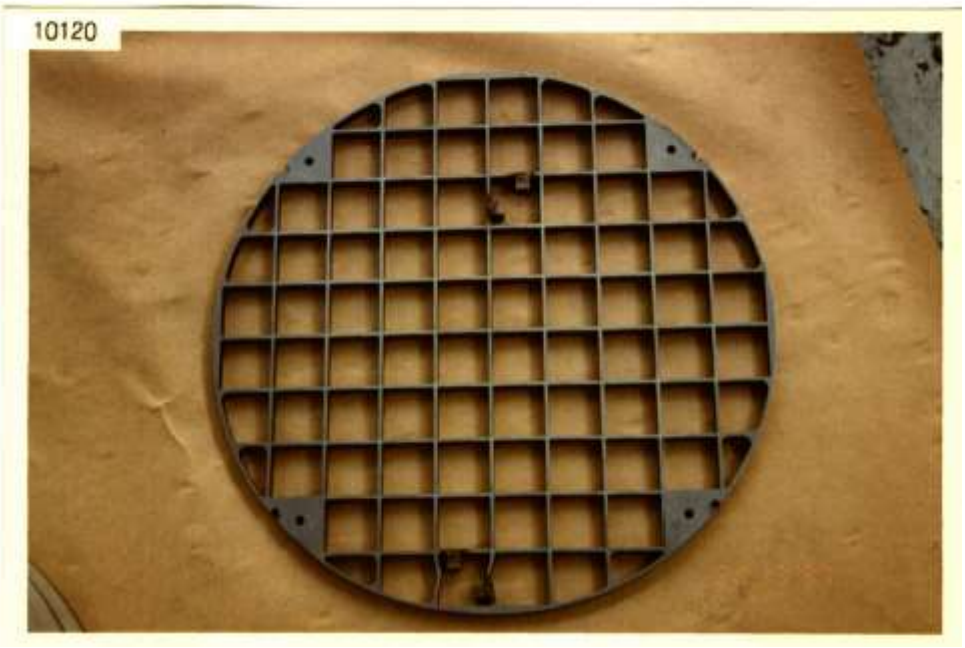

PHOTO 1-6.18

AFTER DROP 2

OPENING THE MOCKUP

BASKET - DETAIL OF THE DEFORMATION OF BASKET DISK 7 (continued)

PHOTO 1-6.19

AFTER DROP 2

OPENING THE MOCKUP

BASKET - DETAIL OF THE DEFORMATION OF BASKET DISK 8

PHOTO 1-6.20

BEFORE DROP 3

INSTALLATION OF BASKET AND PINS IN THE MOCKUP

PHOTO 1-6.21

DROP 3

MOCKUP DROP POSITION

PHOTO 1-6. 22

DROP 3

MOCKUP POSITION AFTER DROP

PHOTO 1-6. 23

DROP 3

DAMAGE CAUSED BY THE DROP - FRONT VIEW

PHOTO 1-6. 24

DROP 3

DAMAGE CAUSED BY THE DROP - SIDE VIEW

PHOTO 1-6. 25

DROP 3

DAMAGE CAUSED BY THE DROP

DETAIL OF DEFORMATION BOTTOM END OF MOCKUP

PHOTO 1-6. 26

DROP 3

DAMAGE CAUSED BY THE DROP

DETAIL OF DEFORMATION AROUND THE TRUNNION

PHOTO 1-6. 27

DROP 4

MOCKUP DROP POSITION

PHOTO 1-6. 28

DROP 4

MOCKUP POSITION AFTER DROP

PHOTO 1-6. 29

DROP 4

DAMAGE CAUSED BY THE DROP - FRONT VIEW

PHOTO 1-6. 30

DROP 4

DAMAGE CAUSED BY THE DROP - SIDE VIEW

PHOTO 1-6. 31

DROP 4

DAMAGE CAUSED BY THE DROP

DETAIL OF DEFORMATION AROUND THE TRUNNION

PHOTO 1-6. 32

AFTER DROP 4

OPENING THE MOCKUP - BASKET IN POSITION

PHOTO 1-6. 33

AFTER DROP 4

OPENING THE MOCKUP - DETAIL OF LID

PHOTO 1-6. 34

AFTER DROP 4

OPENING THE MOCKUP - BASKET TOP VIEW

PHOTO 1-6. 35

DROP 5

MOCKUP DROP POSITION

PHOTO 1-6. 36

DROP 5

MOCKUP POSITION AFTER DROP

PHOTO 1-6. 37

DROP 5

DAMAGE CAUSED BY THE DROP - SIDE VIEW

DETAIL OF STRAIGHTENING THE BOTTOM AFTER THE DROP

PHOTO 1-6. 38

AFTER DROP 5

OPENING THE MOCKUP - DETAIL OF BASKET

DEFORMATION OF DISK 2

PHOTO 1-6. 39

AFTER DROP 5

OPENING THE MOCKUP

MARKING ON THE CAVITY BOTTOM

PHOTO 1-6. 40

DROP 6

MOCKUP DROP POSITION

PHOTO 1-6. 41

DROP 6

MOCKUP POSITION AFTER DROP

PHOTO 1-6. 42

DROP 6

DAMAGE CAUSED BY THE DROP - FRONT VIEW

PHOTO 1-6. 43

DROP 7

MOCKUP DROP POSITION

PHOTO 1-6. 44

DROP 7

MOCKUP POSITION AFTER DROP - FRONT VIEW

PHOTO 1-6. 45

DROP 7

MOCKUP POSITION AFTER DROP - SIDE VIEW

PHOTO 1-6. 46

DROP 7

DAMAGE CAUSED BY THE DROP

DETAIL OF DEFORMATIONS AROUND THE TRUNNION

PHOTO 1-6. 47

DROP 7

DAMAGE CAUSED BY THE DROP - BOTTOM VIEW

PHOTO 1-6. 48

DROP 8

MOCKUP DROP POSITION

PHOTO 1-6. 49

DROP 8

MOCKUP DROP POSITION

PHOTO 1-6. 50

DROP 8

MOCKUP POSITION AFTER DROP