AUTORITÉ
DE SÛRETÉ
NUCLÉAIRE

DEPARTMENT OF TRANSPORT AND SOURCES

APPROVAL CERTIFICATE
FOR A PACKAGE DESIGN

The French Governing Authority,

Pursuant to the request submitted by the Atomic Energy and Alternative Energies Commission (CEA) by letter CEA MR/DPSN/SSN/2012/177 dated 24 November 2012,

and in light of the safety analysis report CEA DSN/STMR/LEPE/TNBGC1 DSEM 0600 Ed. 02 dated 11 October 2012,

hereby certifies that the package design comprising the **TN-BGC 1** packaging described hereafter in appendix 0 index bb and

- loaded with:
  - uranium oxide powder, as described in appendix 2 index bb; or with
  - uranium metal ingots, as described in appendix 4 index bb; or with
  - uranium oxide fuel rods or fuel rod sections or pellets, as described in appendix 7 index bb; or with
  - solid uranium-bearing materials as described in appendix 11 index bb; or with
  - TRIGA fuel as described in appendix 26 index bb; or with
  - an aqueous solution of uranyl nitrate, as described in appendix 40 index bb; or with
  - U-Zr alloy fuel plates, as described in appendix 41 index bb; or with
  - uranium-bearing materials of diverse forms, as described in appendix 42 index bb;

is compliant, as a type B(U) package loaded with fissile materials, with the requirements of the regulations, agreements or recommendations listed below:

- International Atomic Energy Agency (IAEA) regulations for the safe transport of radioactive material, IAEA Safety Standards series, No. TS-R-1 2009 edition;
- European Agreement on the International Carriage of Dangerous Goods by Road (ADR);
- Technical Instructions for safe air transport of dangerous materials (ICAO-TI);
- Administrative decision of 29 May 2009 amended, on the carriage of dangerous goods by terrestrial routes (TMD decision);
- Instruction of 26 June 2008 pertaining to the technical rules and administrative procedures applicable to commercial air transport and regulation EC 859/2008 dated 20 August 2008 (EU OPS1).

Nonetheless, only contents no. 11 and no. 26 are authorised for air transport.

This certificate does not dispense the consignor from respecting the requirements established by the authorities of the countries across which or to which the package will be transported.

This certificate is valid until: **30th June 2013**

Record number: **CODEP-DTS-2013-054429**

Montrouge, 10th October 2013

SUMMARY OF CERTIFICATE REVISIONS

Produced	Expired	Type of revision and modifications	Authority	Certificate Ref. No.	Revision index							
					Body	t	0	1	2	3	4	5
		Reserved	DSND		Haj							
25/08/08	15/11/10	Prolongation: contents 2, 4, 7, 11 and 26	ASN	F/313/B(U)F-96	Iak	-	ak	-	ak	-	ak	-
25/08/08	31/08/13	Prolongation: contents 5, 6 and 15	ASN	F/313/B(M)F-96 T	Ial	al	al	-	-	-	-	al
	31/08/13	Reserved	DSND		Iam							
	31/08/13	Reserved	DSND		Ian							
12/02/09	31/08/13	Extension: inclusion of contents 1 and 3	ASN	F/313/B(M)F-96 T	Iao	ao	ao	ao	-	ao	-	-
10/04/09	31/08/13	Extension: modification of contents 1 and 3	ASN	F/313/B(M)F-96 T	Iap	ao	ao	ap	-	ap	-	-
04/11/09	31/08/13	Extension: modification of contents 1, 3, 5, 6 and 15; inclusion of contents 8, 9, 10, 18, 19, 20 and 23	ASN	F/313/B(M)F-96 T	Iaq	aq	aq	aq	-	aq	-	aq
	31/08/13	Reserved	DSND		Iar							
28/04/10	31/08/13	Extension: inclusion of content 39	ASN	F/313/B(M)F-96 T	Ias	as	as	-	-	-	-	-
04/06/10	31/08/13	Extension: cancels and replaces certificate F/313/B(U)F-96 (Iak)	ASN	F/313/B(U)F-96	Iat	-	at	-	at	-	at	-
	31/08/13	Reserved	DSND		Iau							
04/08/10	31/08/13	Extension: inclusion of content 42	ASN	F/313/B(U)F-96	Iav	-	av	-	-	-	-	-
	31/08/13	Reserved	DSND		Iaw							
10/11/10	31/08/13	Extension: inclusion of content 40	ASN	F/313/B(U)F-96	Iax	-	ax	-	-	-	-	-
10/05/11	31/08/13	Extension: modification of content 40	ASN	F/313/B(U)F-96	Iay	-	ay	-	-	-	-	-
17/08/11	31/08/13	Extension: inclusion of CH_2	ASN	F/313/B(U)F-96	Iaz	-	az	-	az	-	az	-
20/04/12	31/08/13	Extension: inclusion of content 46	ASN	F/313/B(M)F-96 T	Iba	ba	ba	-	-	-	-	-
		Prolongation: contents 2, 4, 7, 11, 26, 40, 41 and 42	ASN	F/313/B(U)F-96	Jbb	-	bb	-	bb		bb	-
10/10/13	30/06/18	Prolongation : contents 2, 4, 7, 11, 26, 40, 41 et 42	ASN	F/313/B(U)F-96	Jbb	-	bb	-	bb		bb	-
		Reserved	DSND		Jea							

Revision index																																						
Body	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	46
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Iaz	-	az	-	-	-	az	-	-	-	-	-	-	-	-	-	-	-	-	-	-	az	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	ba
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ANNEXE 0

TN-BGC 1 PACKAGING

1. PACKAGING DEFINITION

The packaging is designed, manufactured, inspected, tested, maintained and used in compliance with Safety Analysis Report CEA DSN/STMR/LEPE/TNBGC1 DSEM 0600 Rev. 02 dated 11 October 2012.

The packaging consists of a parallelepiped cage inside which a generally cylindrical body equipped with a closure system and a shock absorber cover is fixed. The packaging is presented in figure 0.1.

The packaging design drawings are as follows:

– concept drawing - overall	:	TN 9990-65 (C);
– cage	:	TN 9990-118 (B);
– fitted plug	:	TN 9990-117 (B);
– shock absorber cover	:	EMB TNBGC PBC PDC CA 010001 A.

The main dimensions of the packaging are as follows:

– cage cross-section	:	600 x 600 mm^2;
– overall height of cage	:	1 821 mm;
– diameter of body in centre section	:	295 mm;
– diameter of cover	:	466 mm;
– overall body length with cover fitted	:	1 808 mm.

The maximum admissible mass of the loaded packaging for transport is 396 kg; its mass when empty is 280 kg.

In light of the tolerances on the dimensions and densities of the balsa and poplar wood in the packaging (shock absorber cover and base of body), the total mass of water in these elements is below 1670 grammes.

The packaging comprises the principal sub-assemblies described below.

1.1 Cage

The cage is a structure made of 30 x 30 mm, 2 mm thick aluminium tubes.

Reinforced passages are built in at two heights to enable introduction of the forks of a forklift truck, in order to handle the packaging.

Frames are provided inside the cage to connect the cage to the body. They are welded to the vertical struts of the cage and drilled to allow the passage of the body mounting bolts.

1.2 Body

The cavity has a useful diameter of 178 mm and useful length of 1,475 mm. It is formed from a 6 mm stainless steel shell (that provides most of the radial gamma shielding) and an 8 mm base also made of stainless steel.

A second 1.5 mm stainless steel shell with an internal diameter of 292 mm cooperates with the first shell to delimit a space filled with resin (minimum thickness 48 mm), which acts as a neutron absorber and an active thermal insulation.

From the inside of the packaging towards the outside, the base also features a 25 mm thick steel diffuser plate made of high-strength steel, a 24 mm layer of resin, a false bottom, a wooden shock-absorbing disk and a stainless steel plate.

In the upper part, a stainless steel machined flange is welded to the two shells to receive the closure system described below.

1.3 Closure system

The body cavity is closed using a system composed of 3 main parts: a plug, a compression ring and a bayonet ring.

The plug is held against the body by the compression ring. This component is screwed into the bayonet ring, which itself is compressed against the body flange.

In the centre of the plug, a hole fitted with a quick-connect coupling allows the package to be de-pressurised before dispatch and re-pressurised to atmospheric pressure upon arrival before unloading. This hole is closed with a cap.

The leaktight seal between the plug and body and the quick-connect cap is formed by two pairs of O-ring seals. The spaces between the seals both communicate with the same inspection port used to verify the leaktight properties of closure system.

The two O-ring seals defining the limit of the containment system are made of THT silicone, with a hardness rating of shore 65. These seals are numbered 11 and 13 on the TN 9990-65 (C) plan. The other two seals (12 and 14) are Viton seals.

1.4 Shock absorption system

A leaktight shock absorber cover is placed over the top of the body and the closure system.

It is composed of two steel plate compartments, that closer to the body is filled with resin, the other is filled with wood.

The cover is attached to the body using two bent rods that fit into the lugs on the body, and with two clamping pins, the ends of which are bolted onto the cover and welded to the packaging body.

1.5 Handling and tie-down components

The cage is used to handle and secure the packaging.

The packaging can be handled either in a horizontal or a vertical position.

The packaging is transported in horizontal or vertical position, according to the principles set out in the instructions for use of the package model and in the safety file of the package model:

- in horizontal position: the packaging is stowed on the floor and tied down around the cage by strapping. Only one stacking level is allowed. Wooden structures can be used between two packagings and around the cages.

- in vertical position: the packagings are grouped in batches and held by straps which are arranged above the cage and at mid-height. The leg is stowed. Stowing devices (for example corner beams) are added in the upper section. The packagings can be grouped in rows of 2.

Stowing and tie-down must be performed on the basis of a pre-set procedure checked according to the provisions of the quality management system.

1.6 Safety functions and elements important for safety

The main safety functions and elements important to safety are:

- the **containment** function offered by the packaging containment system, represented by the inner shell, the base of the body and their circumferential welds, the plug and the quick-connect cap, which are fitted with silicone internal seals;
- **radiological protection**, mainly provided by:
  - lateral shielding represented by the stainless steel of the inner shell and the outer shell for the main part of the shielding against gamma radiation, and by the resin (48 mm minimum) for the shielding against neutron radiation;
  - base shielding represented by the stainless steel of the base of the cavity and the two closure plates as well as the carbon steel in the distribution baffle for the main part of the shielding against gamma radiation, and by the resin (24 mm minimum) and wood for the shielding against neutron radiation;
  - top shielding represented by the stainless steel of the plug and the sheet metal cover for the gamma protection, and by the resin (min. 24 mm) and wood contained in the cover for the neutron protection;
- **criticality safety** provided by the confinement system which comprises the elements described in the content appendix and:
  - the packaging: geometry (maximum diameter of the packaging to favour interactions, cage), the materials used, the composition and thickness of the neutron-absorbing resin (hydrogen and boron content, thickness of burnt resin);
  - the internal fittings: geometry of shims, constituent materials of shims (aluminium), geometry (diameter, thickness) of container, material used for container;

  For the internal fittings, the parameters important to safety are indicated in the table below.

Internal fitting	Internal diameter (mm)	Thickness (mm)	Material
TN90	≤ 120	≥ 2	Z2 CN 18-10
AA-41 - AA203 - AA204	≤ 115	≥ 2	Z2 CN 18-10
TN90 type 2	≤ 130	4 ≤ e ≤ 5	Z2 CN 18-10
E7	≤ 60	≥ 2	UA4G

- the **dissipation of internal thermal power** via radiation between the radioactive materials and the inner shell within the body, by conduction in the body and heat exchange between the body and the ambient air;
- **impact protection**, provided by the shock absorber cover and the cage;
- **fire protection**, provided by the radiological protection and the cover. The body and the cover are fitted with fuse plugs that prevent the risk of overpressure due to the accumulation of steam.

2. MEASURES TO BE TAKEN BY THE CONSIGNOR PRIOR TO SHIPPING THE PACKAGE

The packaging must be used according to procedures that comply with the instructions for use in chapter 10 of the safety analysis report CEA DSN/STMR/EMBAL/LEPE/DSEM 0610 Rev. 02 dated 11 October 2012.
Furthermore, for the leakage test of the closure system via the inspection port, the leakage rate must remain below 6.65 x 10^{-4} Pa.m^3.s^{-1} SLR.

3. MAINTENANCE PROGRAMME

The packaging must be used according to procedures that comply with the instructions for use in chapter 10 of the safety analysis report CEA DSN/STMR/EMBAL/LEPE/DSEM 0610 Rev. 02 dated 11 October 2012.

4. NOTIFICATION AND REGISTRATION OF SERIAL NUMBERS

The applicable authorities must be kept informed of any packaging that is taken out of service or transferred to another owner. With this in mind, it is the ceding owner who is responsible for providing the name of the acquiring owner.

5. QUALITY ASSURANCE

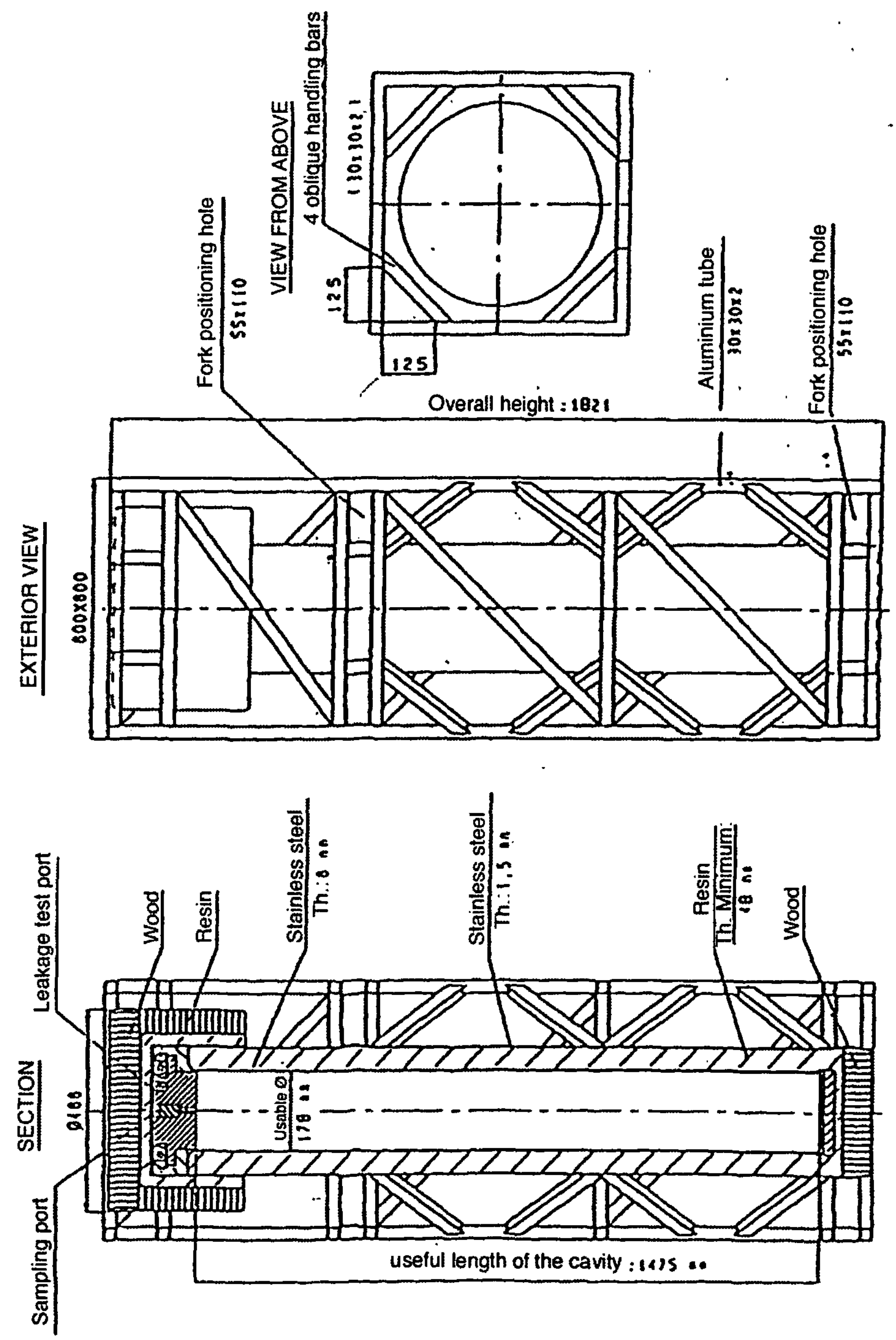
The quality assurance principles applied during the design, manufacturing, inspection, testing, maintenance and use of the package must comply with those described in chapter 11 of the safety analysis report CEA DSN/STMR/EMBAL/LEPE/DSEM 0611 Rev. 01 dated 17 July 2012.

6. ADDITIONAL REQUIREMENTS IN THE EVENT OF CONFINED TRANSPORT

If packages are shipped inside a type CB9 transport crate, the heat dissipation conditions may be modified. The thermal power must therefore be below 4W per package and 48W for all packages transported.

FIGURE 0.1

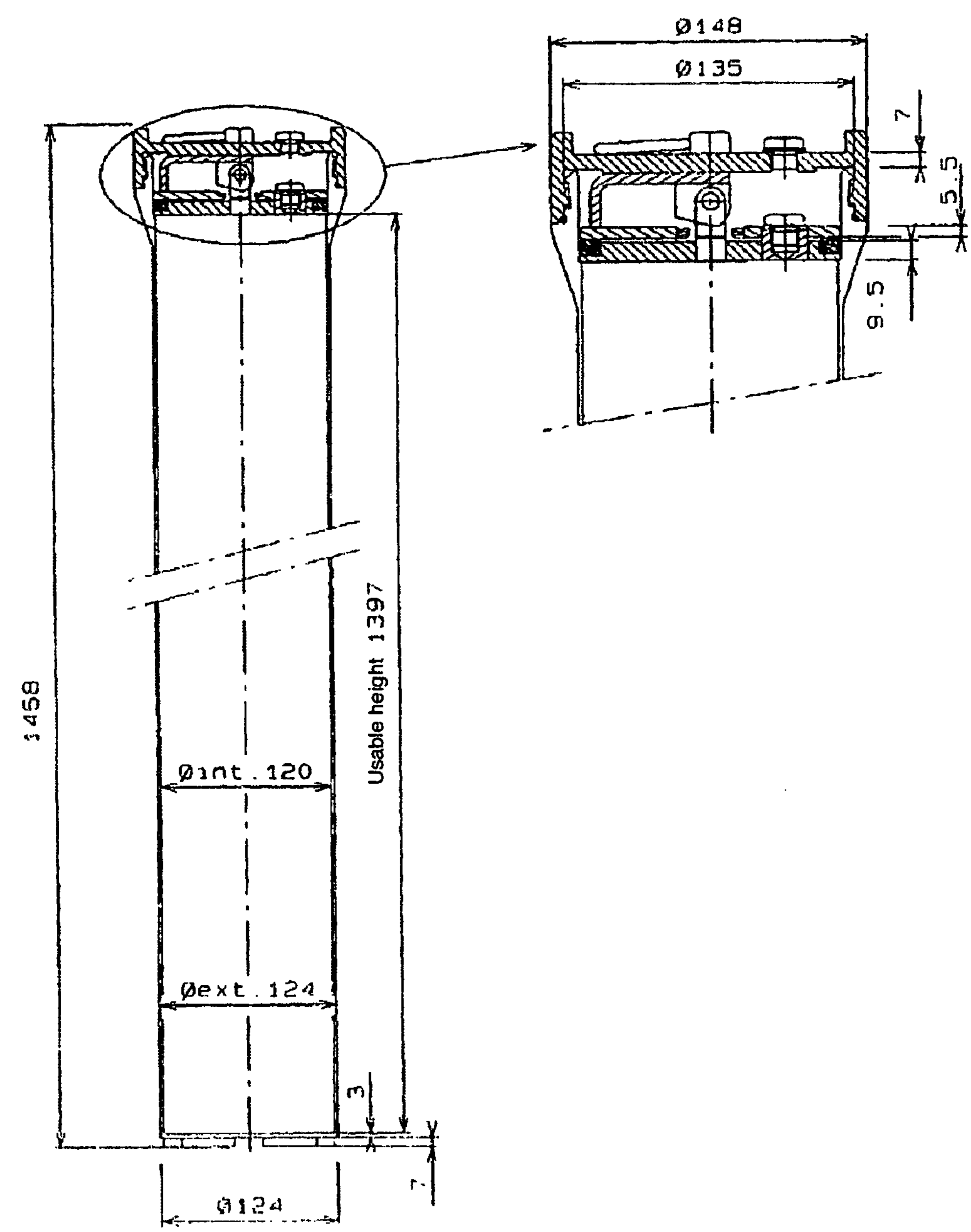
SCHEMATIC VIEW OF PACKAGING



Note: dimensions are in millimetres.

FIGURE 0.2

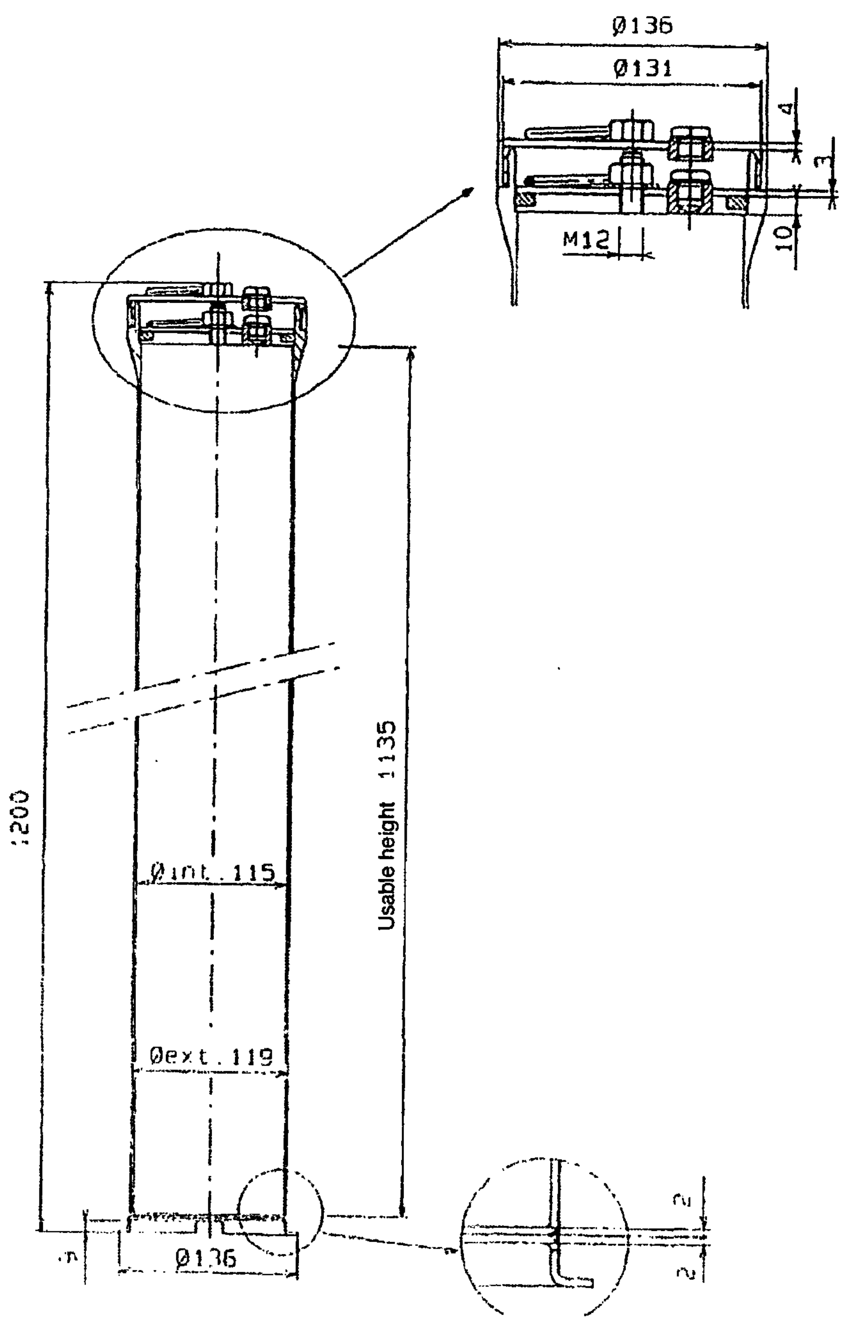
SCHEMATIC VIEW OF TN 90 CONTAINER



Note: dimensions are in millimetres.

FIGURE 0.3

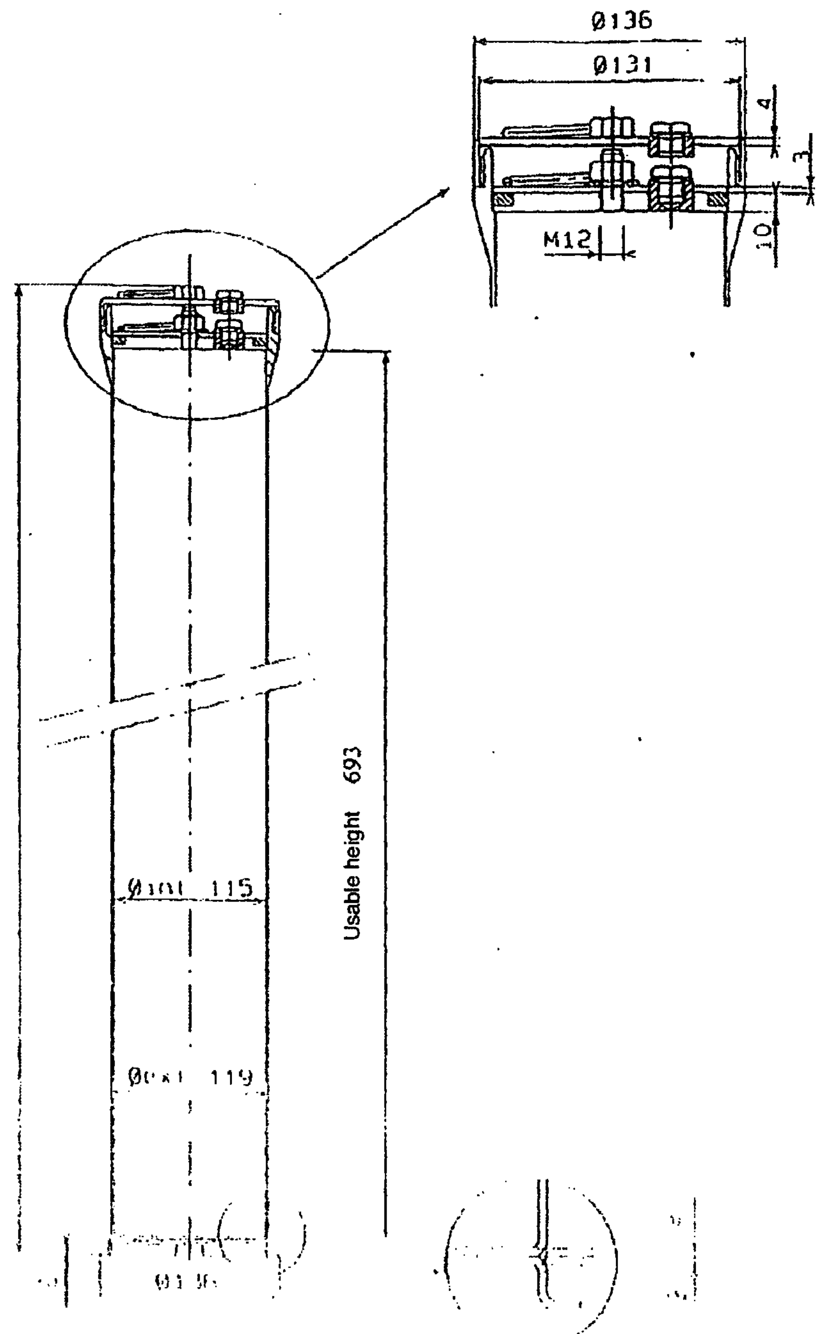
SCHEMATIC VIEW OF AA 204 CONTAINER



Note: dimensions are in millimetres.

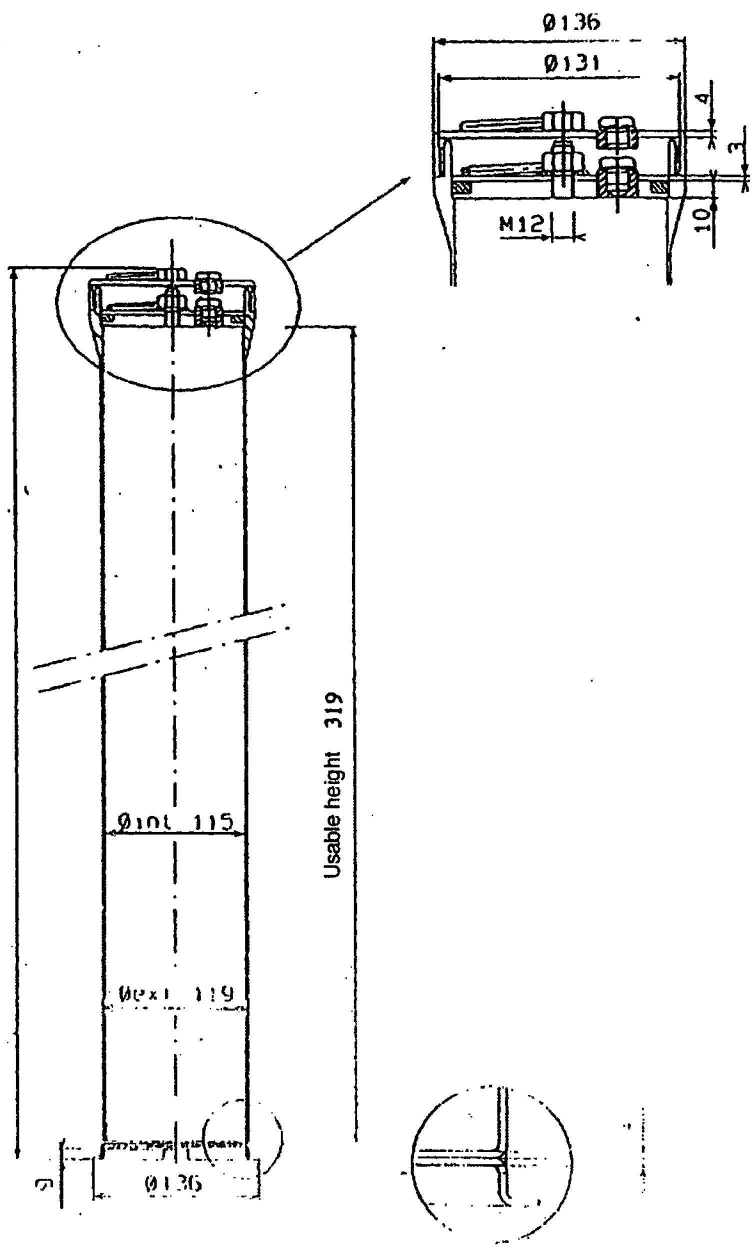
FIGURE 0.4

SCHEMATIC VIEW OF AA 203 CONTAINER



Note: dimensions are in millimetres.

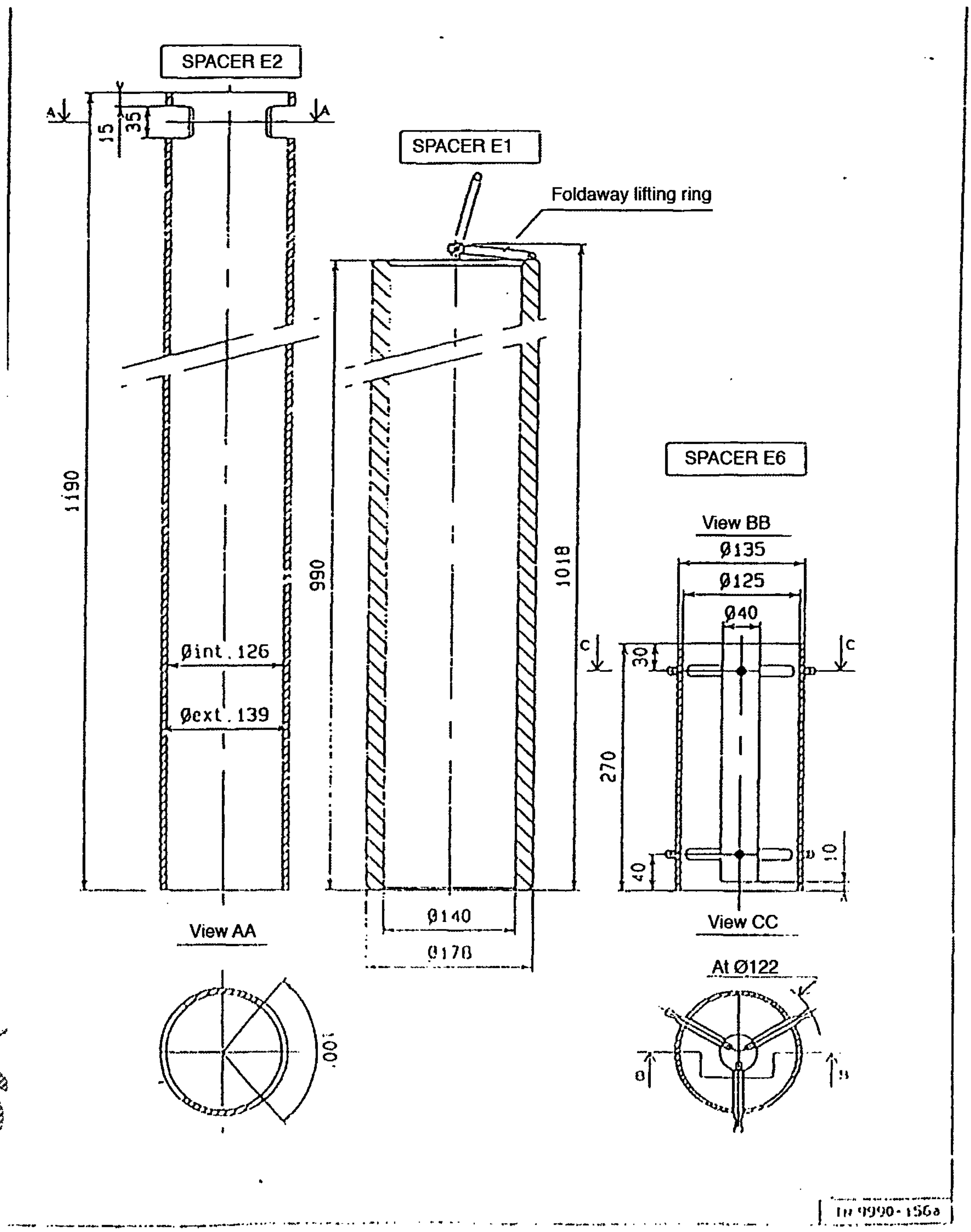
FIGURE 0.5
SCHEMATIC VIEW OF AA 41 CONTAINER



Note: dimensions are in millimetres.

FIGURE 0.6

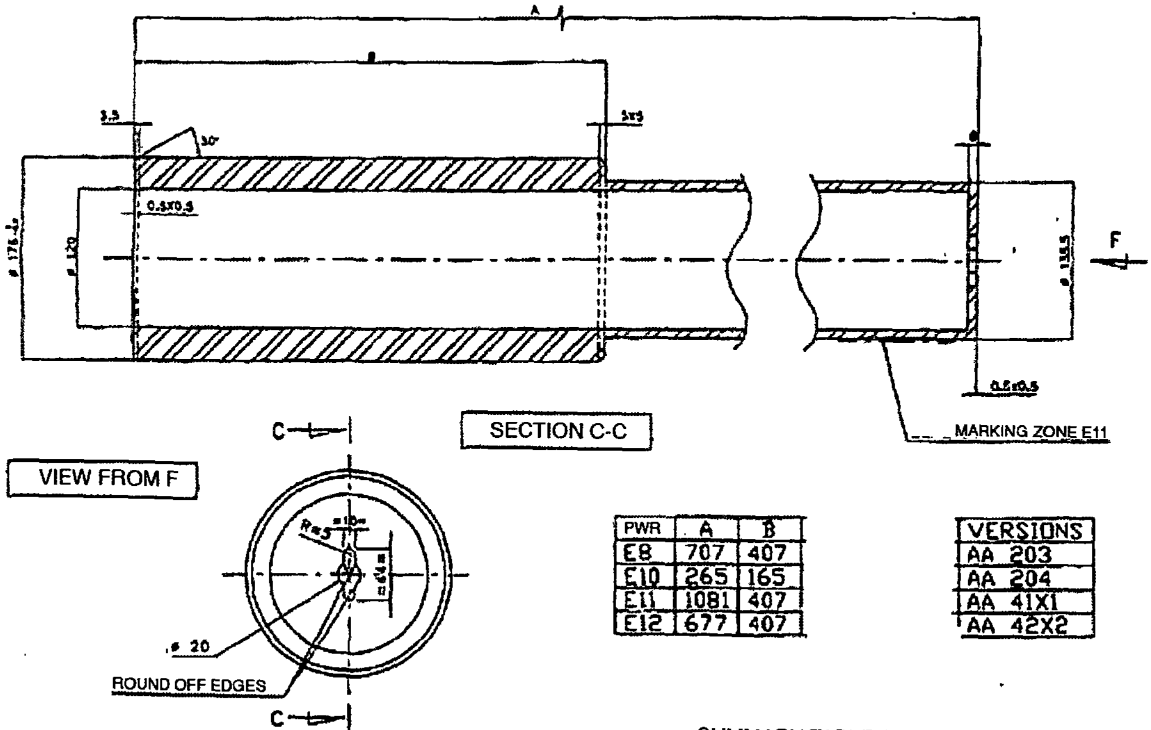
SCHEMATIC VIEW OF SPACERS E1, E2, E6



Note: dimensions are in millimetres.

FIGURE 0.7

SCHEMATIC VIEW OF SPACERS E8, E10, E11, E12



PWR	A	B
E8	707	407
E10	265	165
E11	1081	407
E12	677	407

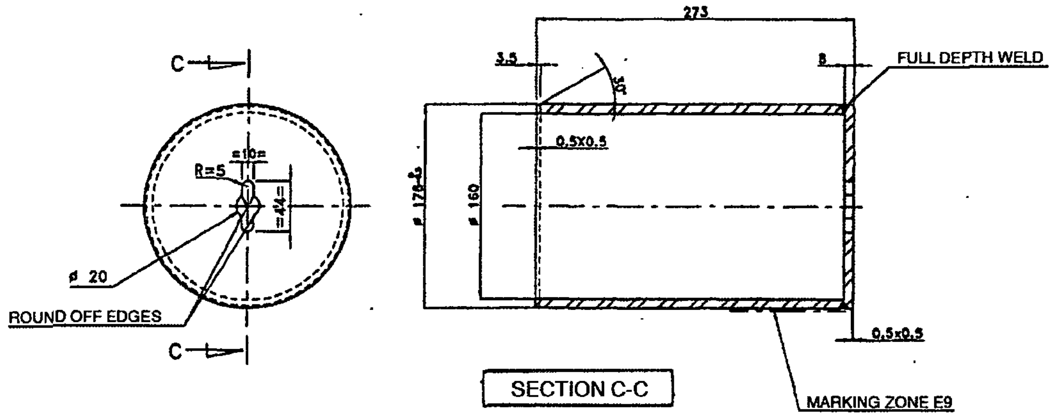
VERSIONS
AA 203
AA 204
AA 41X1
AA 42X2

SUMMARY TABLE SHOWING SHIMS

Note: dimensions are in millimetres.

FIGURE 0.8

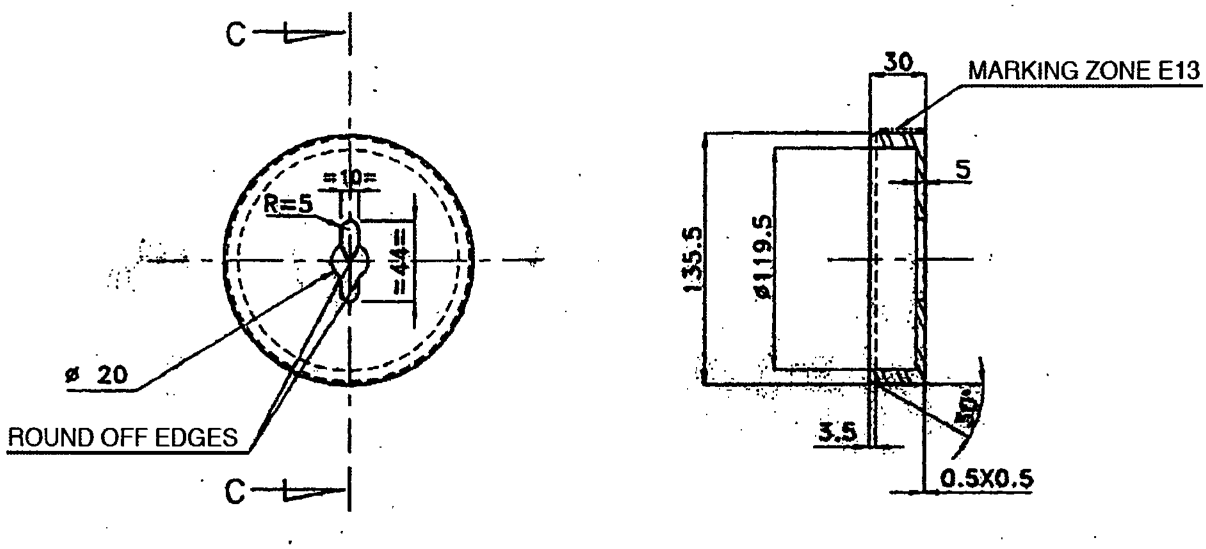
SCHEMATIC VIEW OF SPACER E9



Note: dimensions are in millimetres.

FIGURE 0.9

SCHEMATIC VIEW OF E13 SPACER FOR AA 41



Note: dimensions are in millimetres.

ANNEXE 2

CONTENT NO. 2

NON-IRRADIATED URANIUM OXIDE POWDER

1. DEFINITION OF AUTHORISED CONTENT

This content comprises powdered uranium in the form of UO_2 or U_3O_8.

The powder may be a result of reprocessing but must not have been irradiated after this reprocessing.

The presence of other materials than those defined in this appendix (content and internal fittings) is excluded.

Isotropic composition and maximum admissible mass

The authorised masses are given in the table below:

Content No.	Guaranteed containment diameter (mm)	Presence of hydrogen-bearing materials with higher hydrogen content than water authorised	Enrichment in ^{235}U	Mass Maximum of U	Number of packages
2a	≤ 120 mm	Yes	any	2,2 kg	4
2b			any	2,4 kg	3
2c	≤ 115 mm		< 30 %	40 kg	25
2d	≤ 120 mm	No	any	20 kg	25

The hydrogen-bearing materials authorised for transport are polyethylene, polyurethane and PVC. The presence of polyethylene in content 2d is not permitted. In other contents, its maximum mass is limited to 500g.

Physical characteristics

Maximum powder density: any

Chemical form

Oxide

Special form

The material is not in a special form.

Specific

The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2. INTERNAL FITTINGS AND CONTAINERS

The content is placed in primary containers, which may be metal boxes, plastic flasks or double-skin plastic casings. These boxes are positioned in a secondary container with a maximum internal diameter of 120 mm or 115 mm (content 2c) and thickness of 2mm: types TN 90, AA 204, AA 203 or AA 41 (see figures 0.2 to 0.5).

The following spacers should be used to position and secure the secondary container in the packaging cavity:

- for the TN 90: Spacers E1 and E2,
- for the AA 204: Spacers E1 and E10 or E6,
- for the AA 203: Spacers E1 and E8,
- for 1 x AA 41: Spacers E1 and E11,
- for 2 x AA 41: Spacers E1, E12 and E13,
- for 3 x AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the loaded internal fittings (AA41, AA203, AA204 and TN90 (materials + primary container) must not exceed 60 kg.

The maximum admissible mass of the whole load within the cavity of the TN-BGC 1 package (material transported, primary/secondary containers & shims) is 116 kg.

<u>**Special provisions**</u>
If the primary container has been in storage for over a month, the crown must be renewed before loading into the secondary container then into the packaging.

The time between the closure of the secondary containment in the dispatching plant and the arrival of the package at the destination must be less than one year.

3. CRITICALITY STUDY

This is covered by attachments 1, 10 and 12 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1 DSEM 0608 Rev. 01 dated 17 July 2012.

For contents 2a, 2b and 2c, it permits the presence of **hydrogenated materials with a hydrogen concentration greater than that of water** and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

For content 2d, it permits the presence of **hydrogenated materials with a hydrogen concentration less than or equal to that of water** and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

<u>**Criticality Safety Index:**</u>
For content 2a: CSI = 12.5 (number "N" : 4).
For content 2b: CSI = 16.7 (number "N" : 3).
For contents 2c and 2d: CSI = 2 (number "N" : 25).

ANNEXE 4

CONTENT NO.4

NON-IRRADIATED URANIUM METAL INGOTS

1. DEFINITION OF AUTHORISED CONTENT

This content comprises uranium metal ingots. The uranium does not come from reprocessing.

The presence of other materials than those defined in this appendix (content and internal fittings) is excluded.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

The hydrogen-bearing materials authorised for transport are polyurethane and PVC.

The content must be free of all traces of humidity.

Isotopic composition and masses

The isotopic composition of the uranium is unimportant.

The maximum admissible mass corresponds to 9 ingots of non-irradiated uranium metal each weighing 5 kg (i.e. a maximum total mass of 45 kg of uranium metal loaded into the packaging).

Physical characteristics

Any density

Chemical form

Metal

Special form

The material is not in a special form.

Specific

The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory lim for dose-rates around the package are not exceeded.

Special provisions

Particular attention should be paid to the surface condition of the content when loading into their packaging. The surface of the content should be free of scoring or hydrides.

2. INTERNAL FITTINGS AND CONTAINERS

The secondary container must be type TN 90 (see figure 0.2).

A full E4 type spacer must be placed between each ingot under normal and accident conditions of transport, with a minimum edge-to-edge distance of 90 mm between the ingots (see figures 4.1 and 4.2 below).
In addition, all spacers to be used for a maximum load must be stacked within the container cavity, even if the number of ingots actually loaded into the container has not reached the admissible maximum.

Spacers E1 & E2 should be used to position and secure the TN 90 internal fitting in the packaging cavity:

The total mass of the whole load including internal fitting TN 90 is restricted to 60 kg.

The maximum admissible mass of the whole load within the cavity of the package (spacers + TN 90 container + shims) is 116 kg.

Special provisions
The time between the closure of the secondary containment in the dispatching plant and the arrival of the package at the destination must be less than one year.

3. CRITICALITY STUDY

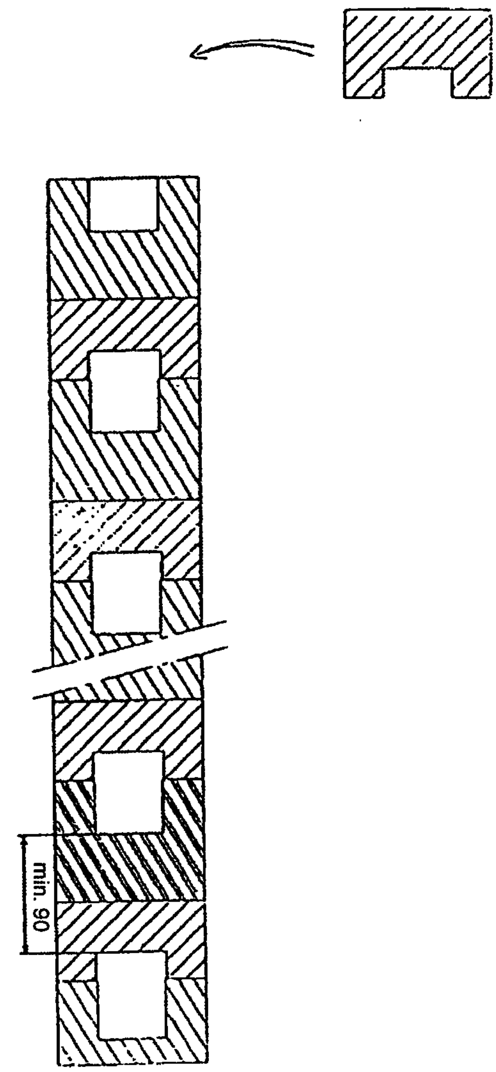
This is covered in note EMB TNBGC PBC DJS CA 0000357 A provided in appendix 4 of chapter 9 of the safety analysis report EMB TNBGC PBC DS- CA 000001 B dated 20 August 2003.

It permits the presence of hydrogenated materials with a hydrogen concentration less than that of water and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

Criticality Safety Index: CSI = 1 (number "N" : 50).

FIGURE 4.1

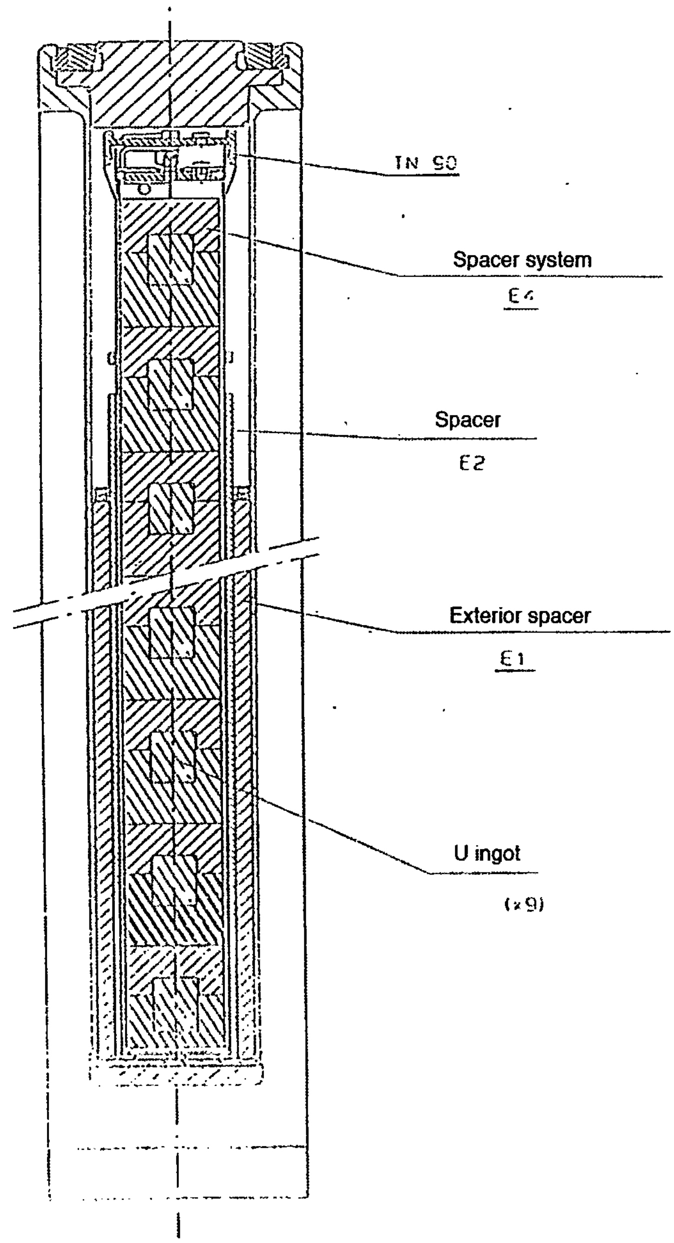
SCHEMATIC VIEW OF E4 SPACER



Note: dimensions are in millimetres.

FIGURE 4.2

EXAMPLE OF INGOT LAYOUT IN TN 90 CONTAINER



ANNEXE 7

CONTENT NO.7

NON-IRRADIATED URANIUM OXIDE FUEL RODS OR SECTIONS OR PELLETS

1. DEFINITION OF AUTHORISED CONTENT

This content comprises uranium oxide (UO_2 only), which can be in the form of pellets, fuel rod sections or complete fuel rods. The uranium is non-irradiated.

In the event that the uranium is reprocessed, the material should not have been irradiated at any moment post-reprocessing.

The presence of other materials than those defined in this appendix (content and internal fittings) is excluded.

The content must be free of all traces of humidity.

<u>Masses & isotopic composition</u>

The authorised masses are given in the table below:

content No.	Guaranteed containment diameter (mm)	Presence of hydrogen-bearing materials with higher hydrogen quantity than water authorised	Enrichment in ^{235}U	Total mass of U	Number of packages
7a	≤ 120 mm	Yes	any	2,2 kg	4
7b			any	2,4 kg	3
7c	≤ 115 mm		< 30 %	40 kg	25
7d	≤ 120 mm	No	any	20 kg	25

The hydrogen-bearing materials authorised for transport are polyethylene, polyurethane and PVC. The presence of polyethylene in content 7d is not permitted. In other contents, its maximum mass is limited to 500 g.

<u>Physical characteristics</u>

The density of the pellets is, as a maximum, equal to 100 % of the maximum theoretical density (d=10.96).

The maximum internal pressure of the rods is 3 bar (abs) at 20°C.

The pellets may be damaged and therefore potentially in the form of debris.

<u>Chemical form</u>

Oxide

<u>Special form</u>

The material is not in a special form.

Specific
The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2. INTERNAL FITTINGS AND CONTAINERS

The uranium oxide pellets are placed in a primary containment, which may be metal boxes, plastic flasks or double plastic envelopes. The whole assembly is then placed within a container representing the secondary containment.

Sections of rod may be inserted into sleeving tubes. The rods or sleeving tubes can then be placed in a rack. The tubes, sleeves and racks are made of metal and represent the first container.

The secondary containers that may be used must have a maximum internal diameter of 120 mm or 115 mm (content 7c) and a thickness of 2mm. They may be TN 90, AA 204, AA 203 or AA 41 containers (see figures 0.2 to 0.5).

The following spacers (figures 0.6 to 0.9) should be used to position and secure the secondary container in the packaging cavity:

- for the TN 90: Spacers E1 and E2,
- for the AA 204: Spacers E1 and E10 or E6,
- for the AA 203: Spacers E1 and E8,
- for 1 x AA 41: Spacers E1 and E11,
- for 2 x AA 41: Spacers E1, E12 and E13,
- for 3 x AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the secondary container load (material + primary container) must not exceed 60 kg.

The maximum admissible mass of the whole load within the cavity of the TN-BGC 1 package (material transported, primary/secondary containments & shims) is 116 kg.

Special provisions
The time between the closure of the secondary containment in the dispatching plant and the arrival of the package at the destination must be less than one year.

3. CRITICALITY STUDY

This is covered by attachments 1, 10 and 12 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1 DSEM 0608 Rev. 01 dated 17 July 2012.

For contents 7a, 7b and 7c, it permits the presence of **hydrogenated materials with a hydrogen concentration greater than that of water** and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

For content 7d, it permits the presence of **hydrogenated materials with a hydrogen concentration less than or equal to that of water** and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

<u>**Criticality Safety Index:**</u>
For content 7a: CSI = 12.5 (number "N" : 4)
For content 7b: CSI = 16.7 (number "N" : 3)
For contents 7c and 7d: CSI = 2 (number "N" : 25).

ANNEXE 11

CONTENT NO.11

NON-IRRADIATED SOLID URANIUM-BEARING MATERIAL

1. DEFINITION OF AUTHORISED CONTENT

This content comprises uranium-based solids. The presence of traces of plutonium, in the order of grammes, is permitted.

The uranium is non-irradiated. In the event that the uranium is reprocessed, the material should not have been irradiated at any moment post-reprocessing.

The presence of other materials than those defined in this appendix (content and internal fittings) is excluded.

<u>**Isotopic composition and masses**</u>

The Uranium 235 enrichment level is unimportant, but authorisation is granted for a single type of uranium material per package (single isotopic composition).

For transport by air: the maximum quantity of uranium 235 transported in a TN-BGC 1 package is 7 kg. In this case a quantity of 400 g of materials with a greater hydrogen content than water is authorised.

For transport other than by air: the maximum admissible masses are specified in the following table:

Content No.	Presence of hydrogen-bearing materials with higher hydrogen content than water authorised	Guaranteed containment diameter (mm)	Enrichment in ^{235}U	Maximum mass of U (kg)	Number of packages
11a	Yes	$\varnothing \leq 120$	any	2	10
11b		$\varnothing \leq 100$	any	19,5	5
11c		$\varnothing \leq 120$	$\leq 20\ \%$	40	10
11d	No	$100 < \varnothing \leq 120$	any	7	50
11e		$60 < \varnothing \leq 100$	any	15	16
11f		$\varnothing \leq 60$	any	40	50
11g		$\varnothing \leq 120$	$\leq 20\ \%$	40	50
11h		$\varnothing \leq 115$	$\leq 30\ \%$	40	25

The hydrogen-bearing materials authorised for transport are polyethylene, polyurethane and PVC. The presence of polyethylene in sub-contents 11d, 11e, 11f, 11g and 11h is not permitted. In other sub-contents, its maximum mass is limited to 500g.

In the event it proves impossible to guarantee a single isotopic composition per package, the mass limitations are as follows:

- If the uranium is enriched to more than 20 %, the maximum transportable mass of uranium is 7 kg in the absence of materials with a higher hydrogen content than water and 2 kg in the presence of such materials;

- If the various uranium products are enriched to less than or equal to 20 % the maximum transportable mass of uranium is 40 kg in the absence or presence of materials with a higher hydrogen content than water.

Physical characteristics

Any density

Chemical form

The material is exclusively in one of the following chemical forms (or in the form of a mixture of these forms):

- Metallic Uranium,
- Uranium oxides: UO_2, UO_3, U_3O_8,
- Uranium tetrafluoride: UF_4
- Uranium nitrides: UN, U_2N_3, UN_2,
- Uranium carbides: UC, UC_2 and U_2C_3,
- Uranium alloyed with the following metals: aluminium (Al), Molybdenum (Mo), Silicon (Si), Zirconium (Zr).

Special form

The material is not in a special form.

Specific

The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2. INTERNAL FITTINGS AND CONTAINERS

The metallic uranium powder is placed in a primary container, which may be metal boxes, flasks or polymer casings. The whole assembly is then placed within a container representing the secondary containment.

The secondary containers must have a maximum internal diameter of 120 mm and a thickness of 2 mm. They may be TN 90, AA 204, AA 203 or AA 41 containers (see figures 0.2 to 0.5).

In the event that the required internal diameter is less than 120 mm, the secondary container used must be a TN 90 type; the positioning and radial securing inside the TN 90 container must feature E7 type spacers.

The following spacers (figures 0.6 to 0.9) should be used to position and secure the secondary container in the packaging cavity:

- for the TN 90: Spacers E1 and E2,
- for the AA 204: Spacers E1 and E10 or E6,
- for the AA 203: Spacers E1 and E8,
- for 1 x AA 41: Spacers E1 and E11,
- for 2 x AA 41: Spacers E1, E12 and E13,
- for 3 x AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the loaded internal fittings (AA41, AA203, AA204 and TN90 (materials + primary containment) must not exceed 60 kg.

The maximum admissible mass of the whole load within the cavity of the TN-BGC 1 package (material transported, primary/secondary containments & shims) is 116 kg.

Special provisions

When the content is in powder form and if the primary container has been in storage for over a month, the crown must be renewed before loading into the secondary container then into the packaging.

The time between the closure of the secondary containment in the dispatching plant and the arrival of the package at the destination must be less than one year.

3. CRITICALITY STUDY

This is covered by attachments 1, 10 and 12 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1/DSEM 0608 Rev. 01 dated 17 July 2012 and note CEA/SEC/T n°89-18 dated 20 January 1989.

Their sub-criticality related characteristics are listed below:

For contents 11a, 11b and 11c, it permits the presence of **hydrogenated materials with a hydrogen concentration greater than that of water** and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

For contents 11d, 11e, 11f and 11g, it permits the presence of **hydrogenated materials with a hydrogen concentration less than or equal to that of water** and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

Criticality Safety Index:

For contents 11a and 11c: CSI = 5 (number "N" : 10).
For content 11b: CSI = 10 (number "N" : 5).
For content 11e: CSI = 3.125 (number "N" : 16).
For contents 11d, 11f and 11g: CSI = 1 (number "N" : 50).
For content 11h : CSI = 2 (number "N" : 25)

4. SPECIAL PROVISIONS

When the material is in a metallic form, particular attention should be paid to the surface condition of the content when loading into their packaging. The surface of the content should be free of scoring or hydrides.

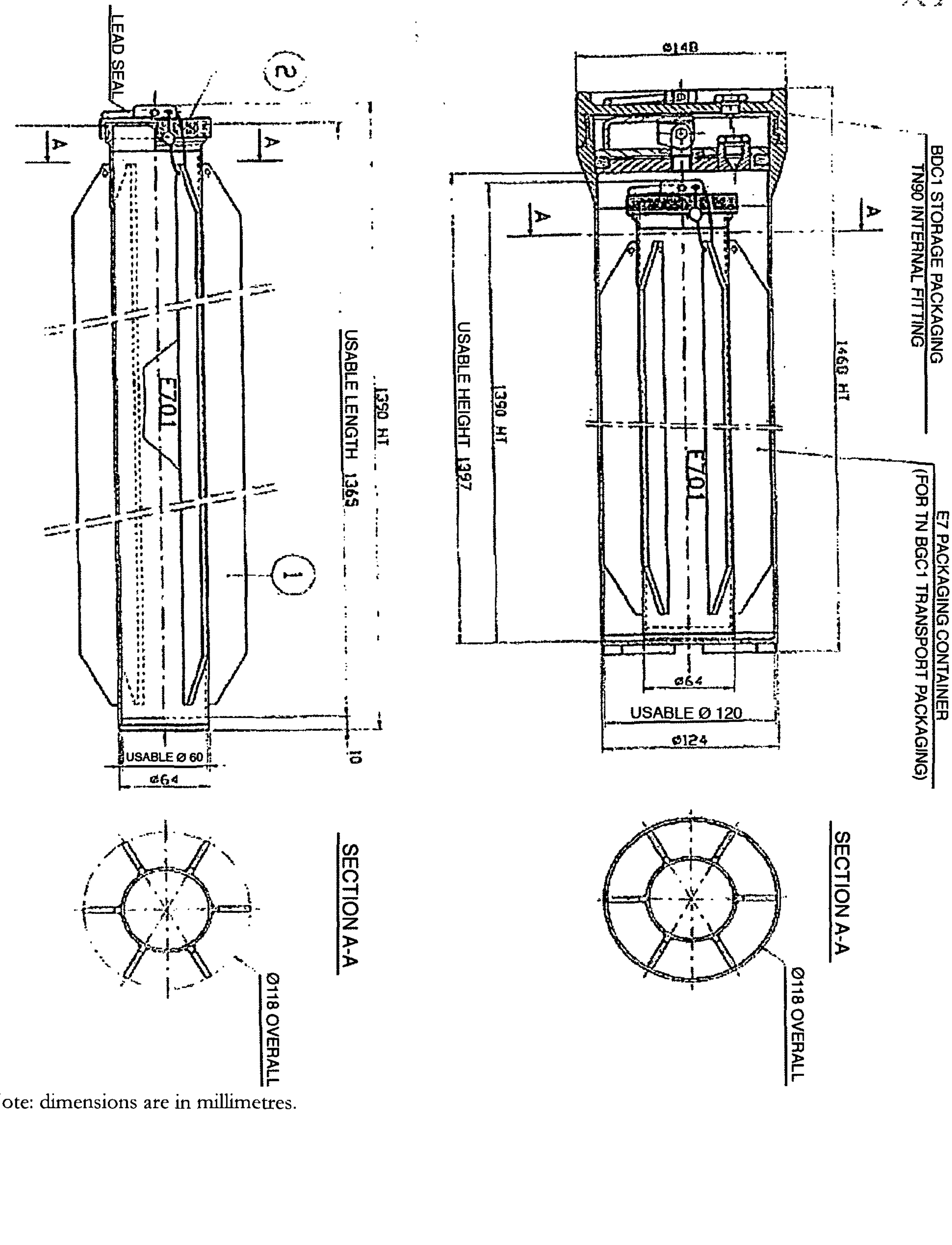
In the event that metallic powders are transported, the containers, the secondary containment and the TN-BGC1 cavity itself must all be inerted at ambient pressure, and a leak test must be carried out on the secondary container (leakage rate below 1.33×10^{-5} Pa.m^3.s^{-1}).

FIGURE 11.1

SCHEMATIC VIEW OF E7 TYPE CONTAINER

AND

PACKING OF URANIUM-BEARING MATERIALS



Note: dimensions are in millimetres.

ANNEXE 26

CONTENT NO. 26

TRIGA FUEL

1. DEFINITION OF AUTHORISED CONTENT

This content comprises non-irradiated bars of TRIGA fuel elements.

These bars are based upon U ZrH_x (where x is between 0 and 2); they are in cylindrical form and are of one of two types- standard or thin, with the following geometric characteristics:

- Standard: diameter = 3.63 cm; length = 12.7 cm,
- Thin: diameter = 1.29 cm; length = 18.6 cm.

The uranium does not come from reprocessing.

The standard bars are drilled, hydrogenated by the centre, the diameter of the hole is 6.35 mm.

The schematic view of standard and thin TRIGA fuel elements is presented in figure 26.1.

The hydrogen-bearing materials authorised for transport are polyethylene and polyurethane. The presence of hydrogen-bearing materials with a hydrogen concentration greater than that of water is not permitted.

The content must be free of all traces of humidity.

The presence of materials other than those defined in the approval certificate is excluded.

Isotopic composition and masses

The maximum 235U enrichment level is 20%. The mass content of U varies between 8 and 47% depending on the type of element:

TYPE	U (% by mass)	ZrH_x (% by mass)	U-Zr (g/cm^3)	U-ZrH_2 (g/cm^3)
Composition of standard TRIGA fuel elements				
103	8	92	6,9	6,04
105	12	88	7,1	6,22
107	12	88	7,1	6,22
117	21	79	7,4	6,64
119	31	69	8,1	7,24
Composition of thin TRIGA fuel elements				
424	47	53	9,3	8,40

Maximum transportable quantities

The maximum transportable quantities are given in the tables below.

- For **transport by air**: the maximum mass of uranium transportable in a TN-BGC 1 package is dependent on the type of fuel element as shown by the table below:

TYPE	Total mass of U (kg)
103	1,1
105	1,7
107	1,7
117	3,3
119	5,3
424	6,6

- For **other modes of transport**: the maximum mass of uranium transportable in a TN-BGC 1 package is dependent on the type of fuel element as shown by the table below, however, the maximum masses defined in Paragraph 2 for the loads applicable to internal fittings and packagings must be respected:

TYPE	Total mass of U (kg)
103	9
105	14
107	14
117	27
119	43
424	76

Special form

The material is not in a special form.

Specific

The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

Special provisions

For transport by air, the mass of water present with the fissile materials, independently of the hydrogen-bearing materials of the package, is less than 1,200 g, or 1,950 g, depending on whether they are standard or thin fuel elements.

The time between the closure of the secondary containment in the dispatching plant and the arrival of the package at the destination must be less than one year.

2. INTERNAL FITTINGS AND CONTAINERS

The TRIGA bars are placed inside cardboard protective tubes, which in turn are placed in a secondary container.

The secondary containers that may be used must have a maximum internal diameter of 120 mm and a thickness of 2 mm. They may be TN 90, AA 204, AA 203 or AA 41 containers (see figures 0.2 to 0.5).

A primary container (Type E7) (see figure 26.2) can be used with the TN 90 for uranium-bearing materials.

The following spacers (figures 0.6 to 0.9) should be used to position and secure the container in the packaging cavity:

- for the TN 90 : Spacers E1 and E2;
- for the AA 203 : Spacers E1 and E8;
- for the AA 204 : Spacers E1 and E10;
- for 1 x AA 41 : Spacers E1 and E11;
- for 2 x AA 41 : Spacers E1, E12 and E13;
- for 3 x AA 41 : Spacers E1, E9 and 2 x E13.

The total mass of the loaded internal fittings (AA41, AA203, AA204 and TN90 (materials + primary containment) must not exceed 60 kg.

The maximum admissible mass of the whole load within the cavity of the TN-BGC 1 package (material transported, primary/secondary containments & shims) is 116 kg.

3. CRITICALITY STUDY

This is covered by attachments 9 and 11 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1 DSEM 0608 Rev. 01 dated 17 July 2012.

It permits the presence of hydrogenated materials with a hydrogen concentration less than or equal to that of water and/or water penetration in all the unoccupied space in the packaging, including in the containment system.

<u>**Criticality Safety Index**: CSI = 0 ("N" : infinity).</u>

FIGURE 26.1

SCHEMATIC VIEW OF TRIGA ELEMENTS

TRIGA FUEL ELEMENT DIMENSIONS

–STANDARD
–*( ) THIN

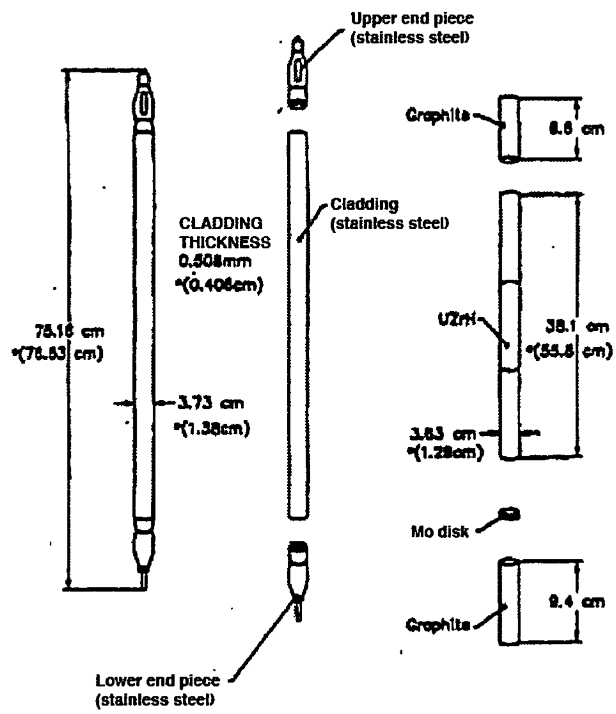
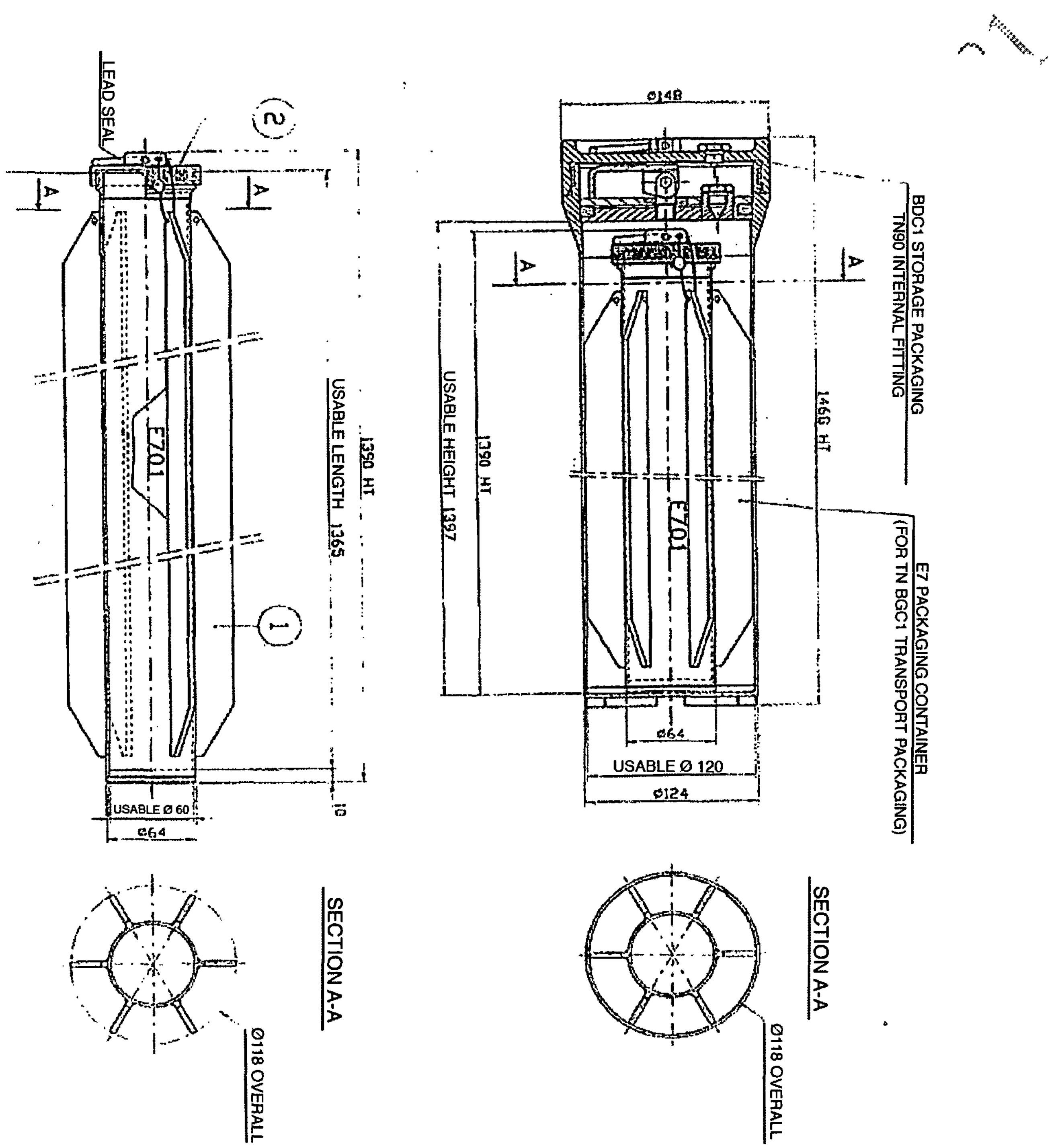


FIGURE 26.2

SCHEMATIC VIEW OF E7 TYPE CONTAINER



Note: dimensions are in millimetres.

ANNEXE 40

CONTENT NO. 40
URANYL NITRATE SOLUTIONS

1. DEFINITION OF AUTHORISED CONTENT

The content is an aqueous solution of uranyl nitrate.

The aqueous solution has not been irradiated.

In order to avoid the production of excess hydrogen within the packaging and its internal fittings, the uranyl nitrate solutions must not have been stored for more than 35 years in an AA 203 or TN 90 container prior to transport.

The presence of hydrogen-bearing materials (other than the flask containing the solution) with a hydrogen content greater than that of water is not permitted.

Isotopic composition

The enrichment in ^{235}U (by mass) is less than or equal to 95%

The presence of the following impurities:
- Pu (*) limited to 0.010 g,
- ^{237}Np limited to 0.015 g,

is permitted.

A quantity of 900 g of ^{232}Th is permitted.

(*) *The quantity of ^{238}Pu must be below 150 µg.*

Maximum quantities

The maximum content quantity authorised for transport is 5 litres of aqueous solution (uranyl nitrate) for a total mass of uranium of less than or equal to 1,800 g.

Specific Activity

The specific activity of the solution is less than or equal to 64 A_2/m^3.

Thermal power

The thermal power of the content is less than or equal to 2.0×10^{-3} W.

2. INTERNAL FITTINGS AND CONTAINERS

The flasks containing the uranyl nitrate solution must be packaged inside cylindrical internal fittings with a maximum diameter of 120 mm and a minimum thickness of 2 mm. The packaging principals are as follows:
- The uranyl nitrate solution must be placed within a flask (primary container) in polyethylene, with a mass of less than or equal to 900 g, then, it may be packaged in a double-skinned polymer cover with a lower hydrogen content than water (PVC or polyurethane). The maximum weight of these covers is 350 g.

- The primary container must be placed in an AA 203 (figure 0.4) or TN90 (figure 0.2) internal fitting (secondary container), where the lid is bolted and fitted with silicone leaktight seals;
- The E3 (figure 40.1) and E3-203 (figure 40.2) metal insulating spacers must respectively be used to position the TN 90 and AA 203 secondary containers in the packaging cavity.

Prior to transport, it must be verified that when polyurethane is used for the double-skin cover, it contains less hydrogen than water.

Note: The primary containment flask may be inserted into a metal basket.

The total mass of the whole load including internal fitting is restricted to 60 kg. The maximum permissible mas of the whole load within the cavity of the TN-BGC 1 package (shims + containers + cargo transported) is 116 kg.

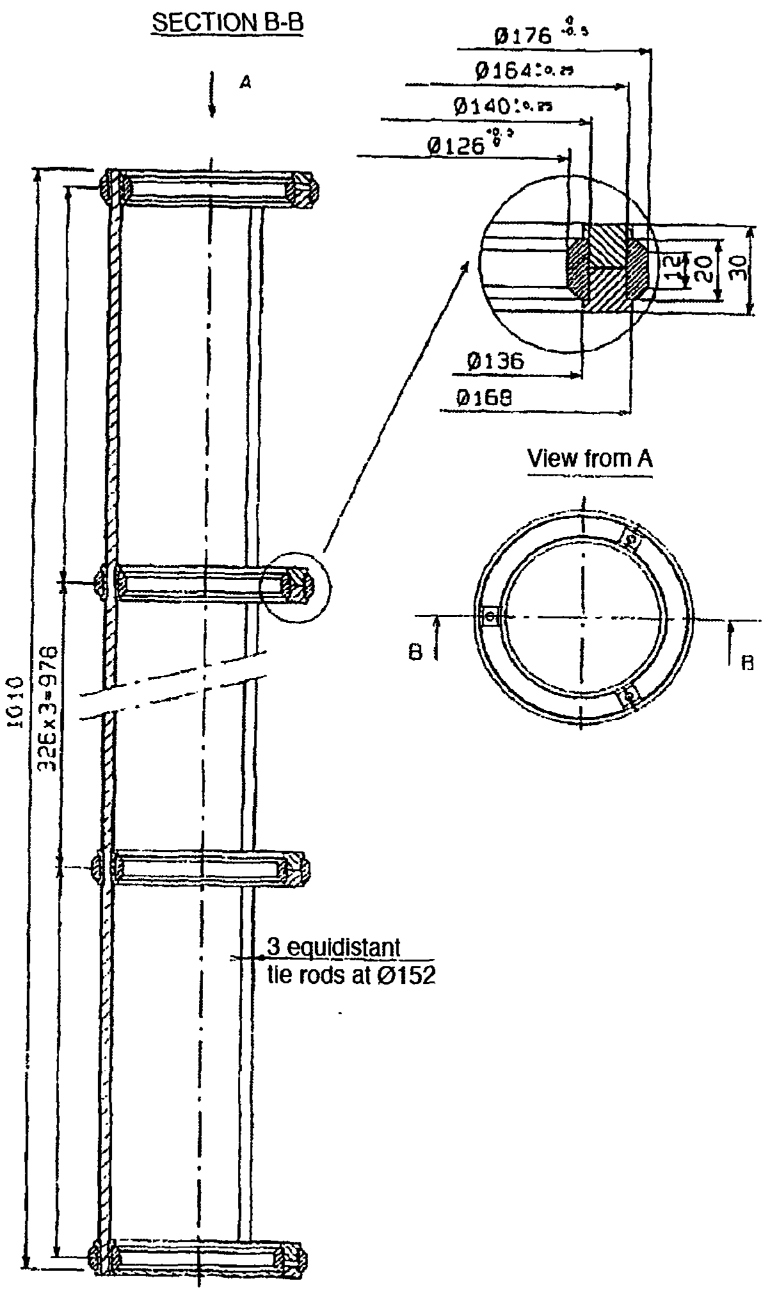
3. CRITICALITY STUDY

This is covered by attachment 7 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1-DSEM 0608 Rev. 01 dated 17 July 2012.

Criticality Safety Index: CSI = 10 ("N" = 5). The presence of hydrogen-bearing materials with a hydrogen content greater than that of water must be less than or equal to 900 g.

FIGURE 40.1

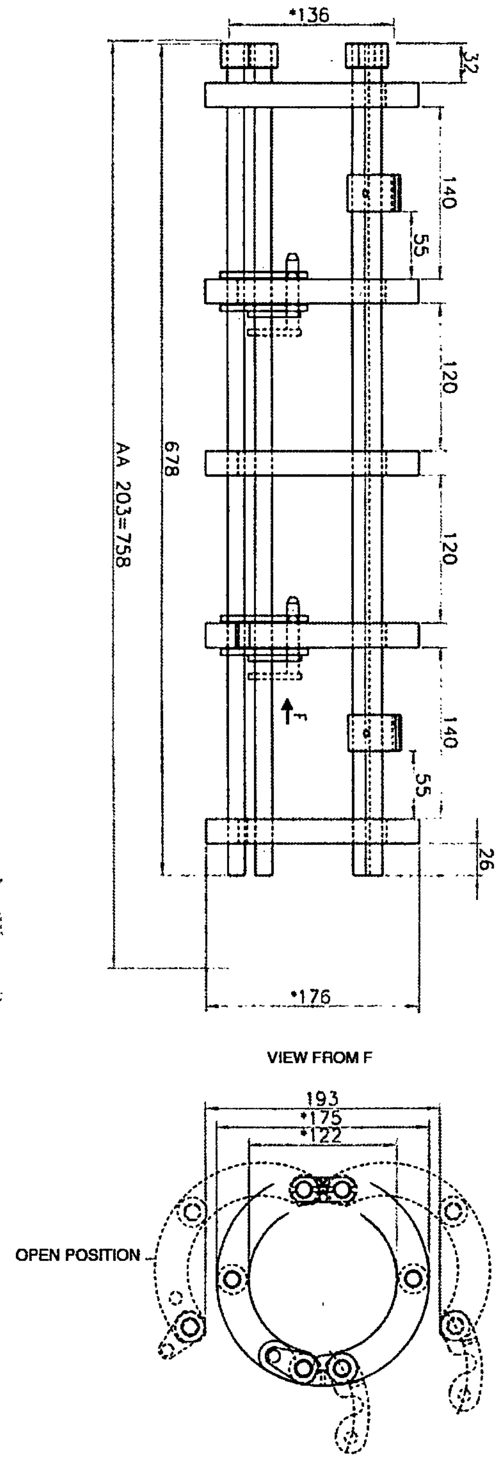
SCHEMATIC VIEW OF SPACER E3 FOR TN90 CONTAINER



Note: Dimensions are given in mm

FIGURE 40.2

SCHEMATIC VIEW OF SPACER E3-203 FOR AA 203 CONTAINER



Note: Dimensions are given in mm

ANNEXE 41

CONTENT NO. 41
U-ZR FUEL PLATES

1. DEFINITION OF AUTHORISED CONTENT

The plates are metallic fuel plates made of an U-Zr alloy, whose principal characteristics given in the table below:

Principal characteristics	
Form	U-Zr metal alloy
Max. uranium content by mass (U/(U+Zr))	8 %
Max. ^{235}U enrichment	91 %

The total mass of uranium in content 41 is 1680 g.
The presence of materials other than those defined in the approval certificate is excluded.

Thermal power

The thermal power of the content is less than or equal to 10^{-3} W.

Hydrogen-bearing materials

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

1.1 content 41a

This content features a maximum of 60 U-Zr metal allot fuel plates called "short AZUR plates", packed as specified in paragraph 2. These plates have been subjected to low level irradiation. For information, the activity is in the order of 10^7 Bq per plate.

The dimensions of each short AZUR plate are: 74 x 1.5 x 500 mm and its total mass is 330 ± 10 g.

1.2 Content 41b

This content features 1 U-Zr alloy plate with any dimensions. Its total mass is limited to 60 kg.

2. INTERNAL FITTINGS AND CONTAINERS

For content 41a, the plates are packed in a stainless steel sleeve. The maximum number of plates per sleeve is 30. One or two sleeves are inserted in a TN 90 internal fitting (see figure 0.2), itself secured inside the TN-BGC 1 cavity using spacers E1 and E2 (figure 0.6).

For content 41b, the plate is packed directly in the TN90 internal fitting (see figure 0.2), itself secured inside the TN-BGC 1 cavity using spacers E1 and E2 (figure 0.6).

The total mass of the whole load of the TN 90 container (material transported + primary container) is limited to 60 kg. The maximum admissible mass of the whole load within the cavity of the TN-BGC 1 packaging (material transported + internal fittings + spacers) is 116 kg.

3. CRITICALITY STUDY

This is covered by attachment 1 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1 DSEM 0608 Rev. 01 dated 17 July 2012.

Criticality Safety Index: CSI = 2.5 ("N" = 20).

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

ANNEXE 42

CONTENT NO. 42

MIXTURE OF URANIUM-BASED MATERIALS IN VARIOUS FORMS

1. DEFINITION OF AUTHORISED CONTENT

This content comprises a mixture of uranium-bearing materials in various forms. The uranium may be from reprocessing but must not have been irradiated after this reprocessing.

The presence of materials other than those included in the appendix (content and internal fittings) is not authorised, specifically the presence of powdered metallic thorium.

The hydrogen-bearing materials authorised for transport are polyethylene, polyurethane and PVC. The presence of polyethylene in content 42b-6 is not permitted. In other contents, its maximum mass is limited to 500 g.

Several cases are possible, depending on the physical and chemical nature of the content:

1.1 Content 42a

Chemical form

The material may be present in the following forms:

- Uranium oxide UO_2, U_3O_8;
- UO_2F_2
- Ammonium diuranate (ADU)
- mixture of various chemical forms.

The presence of thorium, in metal or oxide form, alloyed or mixed closely with the uranium, is authorised in all quantities. The thorium is mainly in the form of isotope 232.

Isotopic composition, masses, packaging and number of packages permitted.

Content No.	Guaranteed containment diameter (mm)	Thickness of internal fittings guaranteeing containment	Max. uranium enrichment level	Maximum weight of uranium (kg)	Number of packages
42a1	Ø ≤ 120	2 mm	Any	2,4	4
42a2	Ø ≤ 115	2 mm	94 %	3,066	Infinite
42a3	Ø ≤ 127	2 mm	87 %	2,801	1
42a4	Ø ≤ 115	2 mm	85 %	4,082	Infinite
42a5	Ø ≤ 120	2 mm	60 %	13,285	4
42a6	Ø ≤ 115	2 mm	27 %	11	Infinite
42a7	Ø ≤ 120	2 mm	20 %	60*	4
42a8	Ø ≤ 120	2 mm	70 %	3,327	10

* without prejudicing the maximum load mass for internal fittings - also limited to 60 kg (See Section 2).

Physical characteristics

The maximum density of the fissile materials is 10.96.

Special form
The material is not in a special form.

Specific
The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

1.2 Content 42b

Chemical form
The material may be present in the following forms:
- Metallic Uranium;
- Alloys of uranium and aluminium;
- Mixtures of metallic uranium and oxides.

The presence of thorium, in metal or oxide form, alloyed or mixed closely with the uranium, is authorised in all quantities. The thorium is mainly in the form of isotope 232.

Isotopic composition, masses, packaging and number of packages permitted.

Content No.	Guaranteed containment diameter (mm)	Thickness of internal fittings guaranteeing containment	Max. uranium enrichment level	Maximum weight of uranium (kg)	Number of packages
42b1	∅ ≤ 120	2 mm	Any	2	4
42b2	∅ ≤ 115	2 mm	94%	2,906	Infinite
42b3	∅ ≤ 120	2 mm	93 %	2,5	4
42b4	∅ ≤ 115	2 mm	35 %	6,811	Infinite
42b5	∅ ≤ 120	2 mm	20 %	60*	4
42b6	∅ ≤ 130	4 ≤ e ≤ 5	94 %	Disks with a diameter of 130 mm and a thickness of 51 mm (max. mass of U = 12970 g).	2

Note: Mixtures of different 42b contents are not permitted.

* without prejudicing the maximum load mass for internal fittings - also limited to 60 kg (See Section 2).

Physical characteristics
Any density

Special form
The material is not in a special form.

Specific
The activity of the content must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2. INTERNAL FITTINGS AND CONTAINERS

The content is placed in a primary container, which may be metal boxes or polymer flasks. The packing of sub-content 42b-6 in flasks or casings with a higher hydrogen content than water is forbidden.

Primary containers may be placed inside secondary containers comprising a metal box or metal sleeve. The resulting assembly [radioactive material + primary container + secondary container] must then by placed inside a stainless steel internal fitting comprising an enclosed tube fitted with sealed covers (checkable or not).

Five tertiary containers may be used. The cylindrical containers are types AA 41; AA 203; AA 204; TN 90 or TN 90 Type 2. They are represented on figures 0.2 to 0.5 and 42.1. Their safety-related characteristics are listed below:

AI	Internal diameter (mm)	E (mm)
AA-41 - AA203 - AA204	≤ 115	2
TN90	≤ 120	2
TN90 type 2	≤ 130	4 ≤ e ≤ 5

The following spacers (figures 0.6 to 0.9) should be used to position and secure the tertiary container in the packaging cavity:

- for the TN 90 : spacers E1 and E2;
- for the AA 204 : spacers E1 and E10 or E6;
- for the AA 203 : spacers E1 and E8;
- for 1 x AA 41 : spacers E1 and E11;
- for 2 x AA 41 : spacers E1, E12 and E13;
- for 3 x AA 41 : spacers E1, E9 and 2 x E13;
- for the TN90 type 2 : spacer E1.

The total mass of the whole load of internal fittings (AA41, AA203, AA204, TN90 and TN90 - Type 2 (materials + primary & secondary containers) must not exceed 60 kg.

The maximum admissible mass of the whole load within the cavity of the TN-BGC 1 packaging (material transported, primary/secondary/tertiary containers & shims) is 116 kg.

Special provisions

When the content is in powder form and if the primary container has been in storage for over a month, the crown must be renewed before loading into the secondary and tertiary containers then into the packaging.

The time between the closure of the secondary containment in the dispatching plant and the arrival of the package at the destination must be less than one year.

3. CRITICALITY STUDY

This is covered by attachments 10 and 14 in chapter 8 reference CEA DSN/STMR/LEPE/TNBGC1 DSEM 0608 Rev. 01 dated 17 July 2012.

Criticality Safety Index = 0 for contents 42a-2, 42a-4, 42a-6, 42b-2 and 42b-4 ("N" = infinity).
Criticality Safety Index = 12.5 for contents 42a-2, 42a-4, 42a-6, 42b-2 and 42b-4 ("N"= 4).
Criticality Safety Index = 25 for content 42b-6 ("N" = 2).
Criticality Safety Index = 50 for content 42a-3 ("N" = 1).

4. SPECIAL PROVISIONS

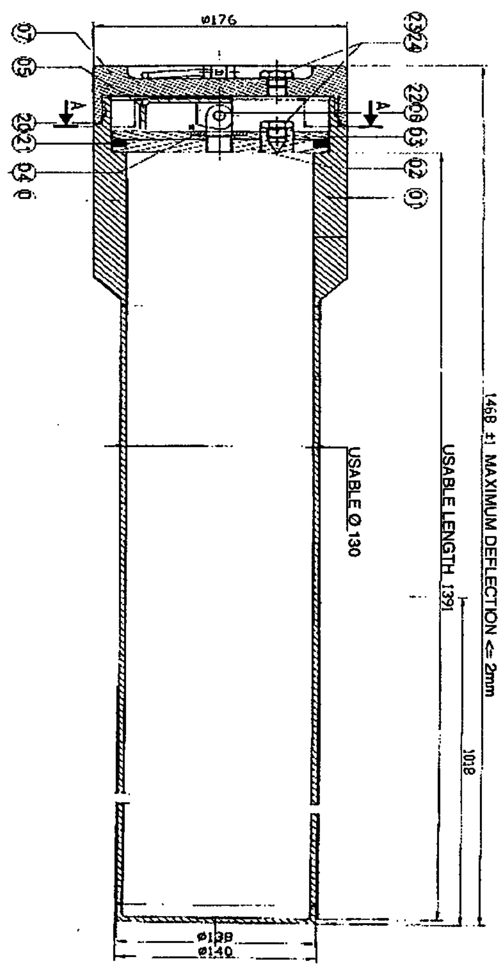
In the event that metallic powders are transported, the containers, the secondary and tertiary containers and the TN-BGC1 cavity itself must all be inerted at ambient pressure, and a leakage test must be carried out on the tertiary container (leakage rate below $1.33x10^{-5}$ $Pa.m^3s^{-1}$).

FIGURE 42.1

SCHEMATIC VIEW OF TN90 TYPE 2 CONTAINER

GENERAL CHARACTERISTICS:

Overall dimensions	Ø(mm)	h(mm)	H(mm)	Unitary mass (Kg)	Handling
TN-90	176	1391	1468	Max 45	



Note: dimensions are in millimetres.

TN International	COMPARISON OF F/313/B(U)F-96 (IAT) AND F/313/B(U)F-96 (JBB)				AREVA
TN-BGC1			Names	Signatures	Dates
		Prepared by	G.GALLAIS	[signature]	18/10/2013
		Verified by	O. DOUAUD	[signature]	18/10/13
Réf. NTC-13-00090486	Rév 00	Approved by	J.F. MALHAIRE	[signature]	25/10/2013

TABLE OF CONTENT

REVISION STATES

Revision	Date	Modifications	Prepared by / Verified by
0	10/2013	First issue	G.GALLAIS / O. DOUAUD

1. INTRODUCTION

The TN-BGC1 package certificate reference F/313/B(U)F-96 (Iat) expired on August 31, 2013 <1>.

This certificate was approved by the US Department of Transportation on February 22, 2013 <2>.

The renewal of the certificate of the TN-BGC1 package under the reference F/313/B(U)F-96 (Jbb) has been signed by the French Competent Authorities (ASN) <3>. It will expire on June 30, 2018.

To answer the need for transportation of radioactive material between America and Europe, in particular the transport of material used for the production of 99-Mo, this certificate has to be revalidated by the US Department of Transportation and by the Canadian Competent Authorities.

This document aims at a description of the main differences between the former certificate F/313/B(U)F-96 (Iat) and the latest F/313/B(U)F-96 (Jbb).

Since only content No. 11 and content No. 26 have been approved in <2>, this document only treats these ones.

2. REFERENCES

<1> TN-BGC1 French Certificate of Approval No. F/313/B(U)F-96 (Iat)

<2> TN-BGC1 USA Certificate of Approval No. USA/0492/B(U)F-96 Rev. 15

<3> TN-BGC1 French Certificate of Approval No. F/313/B(U)F-96 (Jbb)

<4> Safety Analysis Report 160 EMBAL PFM DET 0800157 A of February 26, 2008

<5> Safety Analysis Report CEA DSN/STMR/LEPE/TNBGC1 DSEM 0600 Rev. 02 of October 11, 2012

3. COMPARISON OF THE BODY OF THE CERTIFICATES

To ease the identification of the differences, the comparison of the certificates follows the order of paragraphs.

3.1 Description of the packaging

The renewal of the certificate <3> is based on the safety analysis report <5> whereas the former certificate <1> was based on <4>. The demonstration is based on the same elements. A cross referencing of these two safety analysis reports is available in Appendix 1.

The main difference on the description of the packaging is the modification of the shock absorber: Improvement of the leak-tightness by replacement of the rivets near the handles by welds;

Compared to the initial French certificate <1>, the net mass was added in USA validation <2>. The net mass is taken from <4> and remains unchanged.

3.1.1 Cage

No difference.

3.1.2 Body

No difference.

3.1.3 Closure system

No difference

3.1.4 Cover

The connection of the two clips (11) on the body is detailed. The connection remains unchanged compared to the former certificate.

3.1.5 Elements of handling and stowage

The description of the requirements on handling is reduced. However, the handling procedure remains unchanged compared to the former certificate.

The description of stowage requirements is detailed. However, the stowage procedure remains unchanged between Safety Analysis Reports <4> and <5>.

3.1.6 Safety Functions

The circumferential welds of the bottom of the body of the packaging and of the internal shell are added in the containment system description.

The important parameters for safety are reminded for each type of known internal fitting. A table helps to clarify the main characteristics of internal fittings.

Since it has been made leak-tight (see §3.1 of this document), the shock absorbing cover is equipped with pressure relief devices. This helps to ensure the protection against fire.

3.2 Measures to be made by the consignor before shipment

The numbering of the chapter of the safety analysis report dedicated to the instructions for use is updated.

Plus, in accordance to chapter 10 of <5>, the leak rate measured on the test port of the closure system should be less than $6{,}65.10^{-4}$ $Pa.m^3.s^{-1}$ SLR. This value is unchanged compared to the value used in the previous safety analysis report <4>.

3.3 Maintenance program

The numbering of the chapter of the safety analysis report dedicated to the maintenance programme is updated.

3.4 Notification and recording of the serial numbers

No differences

3.5 Quality Assurance

The numbering of the chapter of the safety analysis report dedicated to the quality assurance is updated.

A paragraph is added regarding the check of consistency between the safety analysis report and the relevant applicable documents.

3.6 Complementary prescription in case of a confined transportation

The following condition on the thermal power transported is added:

- transport in a CB9 type caisson may modify heat dissipation. The maximum power per package must be less than 4 W, and the maximum total thermal power released by all the packages must be below 48 W.

3.7 Figures

In the certificate <1>, figure 0.2 to figure 0.7 have been removed to clarify the document.

4. COMPARISON OF CONTENTS NO. 11

The comparison of the content No. 11 of the certificates <1> and <3> follows the order of the paragraphs.

It has to be stressed that the content No. 11 allowed in USA validation <2> is still included in the content No. 11 allowed in certificate renewal <3>.

The changes between the two certificates concerning the content No. 11 are mainly due to the addition of allowed contents.

4.1 Description

The presence of plutonium traces is allowed if mass of plutonium remains under 1g. This was not allowed in the former certificate <2>.

Reprocessed uranium is allowed provided that it has not been irradiated after reprocessing. This was not allowed in the former certificate <2>.

A restrictive list of hydrogenated material is allowed: polyurethane, polyethylene and PVC. In the former certificate <2>, this precision was not given.

4.1.1 Maximum quantity and composition

For Air transportation: The allowance of the presence of materials in which the hydrogen rate is greater than in water is added. The mass is limited to 400g. This was not allowed in the former certificate <2>.

For any transport, other than by air: Additional contents are allowed to take into account the allowance of hydrogenated materials or a specific enrichment of ^{235}U.

In the former certificate <2>, the enrichment of ^{235}U was indifferent.

A table is given to clarify the maximum quantities which can be transported according to the enrichment of ^{235}U, the confinement diameter and the presence or absence of materials with hydrogen rate greater than in water.

Description of the table:

Contents in which materials with hydrogen rate greater than in water are allowed are labeled No. 11a to No. 11c.

Contents in which materials with hydrogen rate greater than in water are not allowed are labeled No. 11d to No. 11h. The contents which were allowed in the former certificate <2> are labeled content No. 11d, No. 11e and No. 11f.

Changes on the maximum transported quantity and composition

The maximum mass of content No. 11e is set to 40 kg. In the former certificate <2>, the mass of ^{235}U in this content was indifferent.

The presence of polyethylene is not allowed in content No. 11d, No. 11e, No. 11f, No. 11g, No. 11h.

Additional provisions are given on the mass limit in the paragraph regarding the case in which the presence of only one isotopic composition can not be guaranteed:

- The mass limits remain unchanged with respect to the former certificate <2>. A limit of mass of 2kg is added for an enrichment of uranium greater than 20% with presence of materials with hydrogen rate greater than in water.

- For an enrichment of uranium of each type of uranium-bearing less than or equal to 20%, the limit of mass (40 kg) does not depend on the presence of materials with hydrogen rate greater than in water.

4.1.2 Physical form

No change

4.1.3 Chemical form

The list of chemical forms allowed is extended. Alloys of uranium containing Zirconium (Zr) are allowed.

Plus, the mix of the allowed chemical forms is permitted. This was not allowed in the former certificate <2>.

4.1.4 Special form

No change

4.1.5 Activity

No change

4.2 Internal arrangements

A more detailed description of the primary packaging is given. Uranium powders can not only be placed inside metallic boxes but also in plastic flasks or plastic coverings.

Regarding the secondary conditioning containers, a precision on the required dimensions is given. The internal arrangements allowed remain the same.

The paragraph regarding the case in which the required diameter is strictly less than 120mm is rephrased.

The limit on the total mass of the loading of all the secondary conditioning containers is set to 60kg. In the former certificate <2>, only the TN90 was indicated.

The total maximal mass of the loading inside the packaging cavity of the TN-BGC1 is unchanged.

The following special instructions are added:

- When the content is in powder form and if the primary conditioning container was stored more than one month before its loading in the secondary conditioning container and in the packaging, the internal gaz of the primary conditioning container must be renewed;
- The time between the closure of the secondary conditioning container in the sending installation and the arrival of the package in the receiving installation has to be inferior to one year.

4.3 Safety analysis report

This paragraph is deleted. The references of the safety report are reported in paragraph 1 of the body of the certificate.

4.4 Criticality study

To justify the addition of contents, the criticality study is completed by two attached documents: Attachment No 10 and No 12 of chapter 8 of the safety report <5>.

A literal description of the table given in paragraph 1 of content No. 11 is done.

Criticality safety index

The criticality safety index for contents No. 11a to No. 11h are given.

The CSI of content No. 11e is 3,125 instead of 3,1 in the former certificate <2>. This has no impact since the maximum number of packaging "N" remains unchanged.

4.5 Special instructions to be followed for use of the packaging

The paragraph is rephrased: the inertage pressure is set from "1 bar absolute" to "atmospheric pressure".

5. COMPARISON OF CONTENTS NO. 26

The comparison of the content No. 26 of the certificates <1> and <3> follows the order of the paragraphs.

The title of the appendix is corrected to TRIGA Fuel Elements.

It has to be stressed that the content No. 26 allowed in USA validation <2> is still included in the content No. 26 allowed in certificate renewal <3>.

5.1 Description

A restrictive list of hydrogenated material is allowed: polyurethane and polyethylene. Materials with hydrogen rate greater than in water are still not allowed.

No other material than the one described in this certificate is allowed.

The content is not allowed to contain traces of moisture. In the former certificate <2>, this restraint was not specified.

5.1.1 Maximum quantity and composition

No change

5.1.2 Maximum transportable quantities

No change

5.1.3 Special form

No change

5.1.4 Activity

No change

5.1.5 Special dispositions

Addition of the following disposition:

- The time between the closure of the secondary conditioning container in the sending installation and the arrival of the package in the receiving installation has to be inferior to one year.

5.2 Internal arrangements

Regarding the secondary conditioning containers, a precision on the required dimensions is given. The internal arrangements allowed remain the same.

The limit on the total mass of the loading of all the secondary conditioning containers is set to 60kg. In the former certificate <2>, only the TN90 was indicated.

The total maximal mass of the loading inside the packaging cavity of the TN-BGC1 is unchanged.

5.3 Safety Analysis Report

This paragraph is deleted.

5.4 Criticality study

The reference of the safety report is updated.

The documents referenced to justify the criticality study remain the same as the documents referenced in the former certificate <2>.

5.5 Figures

The drawing of the TRIGA fuel rod for 16-rod cluster is removed.

Appendix 1
Cross referencing of safety analysis reports <4> and <5>
1/6

Title	Reference of former safety analysis report <4>	Reference of new safety analysis report <5>
Introduction – table of contents	Chapter 0 160 EMBAL PFM DET 08000157 A	Chapter 0 **DSN/STMR/LEPE/TNBGC1/DSEM 0600 Rev.02**
Description of the contents	Chapter 1 160 EMBAL PFM DET 08000158 A	Chapter 1 **DSN/STMR/LEPE/TNBGC1/DSEM 0601 Rev.02**
	Appendix 1-1 160 EMBAL PFM DET 08000159 A	
Description of the package	Chapter 2 160 EMBAL PFM DET 08000160 A	Chapter 2 **DSN/STMR/LEPE/TNBGC1/DSEM 0602 Rev.01**
Conceptual drawings of TN-BGC 1 package	Appendix 2-1 Plan 9990-65 indice C - Ensemble Plan 9990-118 indice B – cage Plan 9990-117 indice B – bouchon assemblé	Attachment 1 Drawing 9990-65 rev C - Assembly Drawing 9990-118 rev B – cage Drawing 9990-11rev B – assembled plug
Drawing of the leak-tight modified cover -	-	Attachment 2 **EMB TNBGC PBC PDC CA 01 0001 A**
Mechanical analysis of a TN-BGC 1 package	Chapter 3.1 160 EMBAL PFM DET 08000161 A	Chapter 3 **DSN/STMR/LEPE/TNBGC1/DSEM 0603 Rev.01**
Drop tests TN-BGC 1 – summing-up of the tests	Appendix 3.1-1 EMB TNBGC PBC NTT CA000524 A	Attachment 1 EMB TNBGC PBC NTT CA000524 A
Report on the drop tests on prototypes of TN-BGC 1 package	Appendix 3.1-2 EMB TNBGC PBC DJS CA 000333 A	Attachment 2 EMB TNBGC PBC DJS CA 000333 A

Appendix 1
Cross referencing of safety analysis reports <4> and <5>
2/6

Title	Reference of former safety analysis report <4>	Reference of new safety analysis report <5>
Report on the additional drop tests on TN-BGC 1 package	Appendix 3.1-3 EMB TNBGC PBC DJS CA 000334 A	Attachment 3 EMB TNBGC PBC DJS CA 000334 A
Mechanical study of a 9 m vertical drop of TN-BGC 1 package with the cover downwards	Appendix 3.1-4 2CE3E100 rév. 2	Attachment 4 2CE3E100 rev. 2
Study on the maintenance of tightness performance of TN-BGC 1 package during a 9 m drop in oblique position	Appendix 3.1-5 G03CAL022A Rev. 2.0	Attachment 5 G03CAL022A rev. 2.0
Mechanical strength of the enclosure during immersion	Appendix 3.1-6 160 EMBAL PFM DET 08000162 A	Attachment 6 160 EMBAL PFM DET 08000162 A
Strength of the handling devices	Appendix 3.1-7 160 EMBAL PFM DET 08000163 A	Attachment 7 160 EMBAL PFM DET 08000163 A
Mechanical lashing studies on TN-BGC 1 package – Combined accelerations	Appendix 3.1-8 299E05W03	Attachment 8 299E05W03
Mechanical performance of TN-BGC1 package during an explosion	Appendix 3.1-9 2BP6E042	Attachment 9 2BP6E042
Modal analysis of TN-BGC 1 package	Appendix 3.1-10 159A3W03 Rev. B	Attachment 10 159A3W03 Rev. B
Mechanical analysis of the contents of TN-BGC 1 package	Chapter 3.2 160 EMBAL PFM DET 08000164 A	Chapter 4 **DSN/STMR/LEPE/TNBGC1/DSEM 0604 Rev.01**
Resistance to internal pressure of packages AA204, TN90, AA226, AA227, AA236 and AA303	Appendix 3.2-1 EMB TNBGC PBC DJS CA 000339 A	Attachment 1 EMB TNBGC PBC DJS CA 000339 A

Appendix 1
Cross referencing of safety analysis reports <4> and <5>
3/6

Title	Reference of former safety analysis report <4>	Reference of new safety analysis report <5>
TN-BGC 1 package – Consequences of hydrogen combustion in the TN90 internals	Appendix 3.2-2 195H03W01 Rev. A	Attachment 2 195H03W01 Rev. A
Mechanical analysis of the TN998	Attachment 3.2-3 NTC-07-00101341-002 Rév. 0	-
Thermal analysis of TN-BGC 1 package model	Chapter 3.3 160 EMBAL PFM DET 08000165 A	Chapter 5 **DSN/STMR/LEPE/TNBGC1/DSEM 0605 Rev.02**
Temperatures in TN-BGC 1 package model in normal and accident conditions of transport	Attachment 3.3-1 EMB TNBGC PBC DJS CA 000345 A	Attachment 1 EMB TNBGC PBC DJS CA 000345 A
Thermal analysis of TN-BGC 1 package in HAC	Attachment 3.3-2 477314C050263 Rev. B	Attachment 2 477314C050263 Rev. B
Thermal analysis of TN-BGC 1 package	Attachment 3.3-3 472891C030118 Rev. B	Attachment 3 472891C030118 Rev. B
Further calculations	Attachment 3.3-4 EMB TNBGC PBC DJS CA 000388 A	Attachment 4 EMB TNBGC PBC DJS CA 000388 A
Thermal analysis of fuel rods (content No8) in TN-BGC 1 package	Attachment 3.3-5 EMB TNBGC PBC DJS CA 000348 A	Attachment 5 EMB TNBGC PBC DJS CA 000348 A
Thermal analysis of TN-BGC 1 package – Model of an explosion in the internals	Attachment 3.3-6 472891C040024 Rev. A	Attachment 6 472891C040024 Rev. A
Thermal analysis of TN-BGC 1 package	Attachment 3.3-7 CAL-07-00090487-002 Rév. 0	-

Appendix 1
Cross referencing of safety analysis reports <4> and <5>
4/6

Title	Reference of former safety analysis report <4>	Reference of new safety analysis report <5>
Thermal calculation note for TN-BGC 1 package loaded with 238Pu sources	-	Attachment 7 **1063-02/SIM/NOT/001 Rev. A**
Calculation note on the thermal tests of TN-BGC 1 package	-	Attachment 8 **1063-15/SIM/NOT/001 Rev. A**
Containment analysis of TN-BGC 1 package model	Chapter 3.4 160 EMBAL PFM DET 08000166 A	Chapter 6 **DSN/STMR/LEPE/TNBGC1/DSEM 0606 Rev.01**
Test report for the dilatometer tests on the STACEM seals	Attachment 3.4-1 LNE report – File D031080 – document CM1/1	Attachment 1 LNE report – file D031080 – document CM1/1
Containment analysis of package model TN-BGC 1	Attachment 3.4-2 NTC-07-00101341-006 Rév. 0	-
Radiation protection analysis of TN-BGC 1 package model	Chapter 3.5 160 EMBAL PFM DET 08000167 A	Chapter 7 **DSN/STMR/LEPE/TNBGC1/DSEM 0607 Rev.01**
Calculation of photon and neutron flow rates around a TN-BGC 1 package containing americium	Attachment 3.5-1 CEA DCE-S-UGSP-SPR-SRI-T-99-1172	Attachment 1 CEA DCE-S-UGSP-SPR-SRI-T-99-1172
Shielding analysis of TN-BGC 1 package model	Attachment 3.5-2 CAL-07-00091006-002 Rév. 2	-
Radiation protection study of TN-BGC 1 package model loaded with mixed oxide or plutonium oxide	-	Attachment 2 **DSN/STMR/LEPE TNBGC NOT0050 Rev. 01**
Radiation protection study of TN-BGC 1 package model loaded with 17 kg of plutonium oxide	-	Attachment 3 **160 EMBAL PFM NTE 09000062 A**

Appendix 1
Cross referencing of safety analysis reports <4> and <5>
5/6

Title	Reference of former safety analysis report <4>	Reference of new safety analysis report <5>
Criticality safety analysis of TN-BGC 1 package model	Chapter 3.6 160 EMBAL PFM DET 08000168 A	Chapter 8 **DSN/STMR/LEPE/TNBGC1/DSEM 0608 Rev.01**
Further criticality calculations	Attachment 3.6-1 EMB TNBGC PBC DJS CA 000481 A	Attachment 1 EMB TNBGC PBC DJS CA 000481 A
Criticality safety of TN-BGC 1 package – Permissible mass determination – content 8	Attachment 3.6-2 Note SGN NT.12862.00.008. Rév. A	Attachment 2 Note SGN NT.12862.00.008. Rev. A
Criticality safety of TN-BGC 1 package – Determination of the permissible number of packages – content 8	Attachment 3.6-3 Note SGN NT.12862.00.009. Rév. A	Attachment 3 Note SGN NT.12862.00.009. Rev. A
Criticality calculations for TN-BGC 1 package	Attachment 3.6-4 Fax CEA/DEN/CAD/DTAP/SET DO 247	Attachment 4 Fax CEA/DEN/CAD/DTAP/SET DO 247
Criticality study of TN-BGC 1 package loaded with plutonium oxide powder	Attachment 3.6-5 160 EMBAL PFM NOT 06001678 A	Attachment 5 160 EMBAL PFM NOT 06001678 A
Criticality study of TN-BGC 1 package loaded with various contents: influence of the type of spacers	Attachment 3.6-6 160 EMBAL PFM NOT 06001677 A	Attachment 6 160 EMBAL PFM NOT 06001677 A
Criticality study of TN-BGC 1 package loaded with content 6 : uranyl nitrate solution	Attachment 3.6-7 160 EMBAL PFM NOT 06001679 A	Attachment 7 160 EMBAL PFM NOT 06001679 A
Criticality study of TN-BGC 1 package loaded with content 11 : medium metallic U at 100 % 235U	Attachment 3.6-8 160 EMBAL PFM NOT 06001680 A	Attachment 8 160 EMBAL PFM NOT 06001680 A
Criticality study of TN-BGC 1 package loaded with content 26 : medium U-ZrH2	Attachment 3.6-9 160 EMBAL PFM NOT 06001518 A	Attachment 9 160 EMBAL PFM NOT 06001518 A

Appendix 1
Cross referencing of safety analysis reports <4> and <5>
6/6

Title	Reference of former safety analysis report <4>	Reference of new safety analysis report <5>
Criticality study of TN-BGC 1 package	Attachment 3.6-12 CAL-07-00090811-002 Rév. 00	-
Criticality study of TN-BGC 1 package model loaded with various contents	-	Attachment 10 **U-8061-NT-01 Rev. 1**
Criticality study of TN-BGC 1 package model loaded with content No26 : TRIGA fuel	Attachment 3.6-11 EMB TNBGC PBC DJS CA 000386 A	Attachment 11 EMB TNBGC PBC DJS CA 000386 A
Criticality study of TN-BGC 1 package loaded with metallic uranium or uranium oxide 30% enriched in ^{235}U	-	Attachment 12 DSN/STMR/EMBAL/LEPE NOT0020 Rev. 01
Criticality study of TN-BGC 1 package loaded with various MCMF contents in normal and accident conditions of transport	Attachment 3.6-10 160 EMBAL PFM NOT 06001310 C	Attachment 13 160 EMBAL PFM NOT 06001310 C
Criticality study of TN-BGC 1 package model loaded with various contents	-	Attachment 14 **U-8122-NT-01 Rev. 2**
Subsidiary risk analysis	Chapter 3.7 160 EMBAL PFM DET 08000169 A	Chapter 9 **DSN/STMR/LEPE/TNBGC1/DSEM 0609 Rev.01**
Analysis of the risks of gaseous releases	Attachment 3.7-1 NTC-07-00101341-007 Rev. 1	-
Instructions for use of the package – test, receiving and maintenance programs	Chapter 4 160 EMBAL PFM DET 08000170 A	Chapter 10 **DSN/STMR/LEPE/TNBGC1/DSEM 0610 Rev.02**
Quality assurance applicable to the package model	Chapter 5 160 EMBAL PFM DET 08000171 A	Chapter 11 **DSN/STMR/LEPE/TNBGC1/DSEM 0611 Rev.01**

Nuclear Energy Division
Nuclear Services Department
Radioactive Materials Transportation Service
Packaging Operations Laboratory

Safety Analysis Report

TN-BGC 1 package

Chapter 0 – table of contents, summary and applicable regulations

This document supersedes document 160 EMBAL PFM DET 0800157 A dated 26/02/08

Clt: 7.1.1.3.

Classification: DO

	AUTHORED BY	CHECKED BY	APPROVED BY
Name	V. PAUTROT	S. CHAIX	S. CLAVERIE-FORGUES
Sign-off			**Date:**

TABLE OF REVISIONS

REV	DATE	AUTHOR	REASON FOR REVISION	NB PAGES
01	17/07/12	V. PAUTROT	First issue	19
02	10/10/12	V. PAUTROT	Inclusion of CSMN remarks	19

TABLE OF CONTENTS

1. REFERENCE DOCUMENTS

- [DR01] IAEA Radioactive Materials Transport Regulation –Safety standards collection, N° TS-R-1 – 2005 edition
- [DR02] Applicant's guide to the applications for shipment approval and licensing of package models or radioactive materials for peaceful purposes transported on the public highway

2. CONTEXT

TN-BGC 1 package is used both nationally and internationally for the transport of fissile uranium-bearing and plutonium-bearing radioactive materials.

Packages TN-BGC 1 may be transported by road, rail, river or sea or by plane for some contents.

Package model TN-BGC 1 is approved up to August 31st 2013. This file was prepared as part of an application for approval extension.

3. SIMPLIFIED DESCRIPTION OF THE PACKAGE MODEL

3.1. TN-BGC 1 PACKAGE

TN-BGC 1 package is made up of:

- a cage whose structure is formed of welded aluminum tubes,
- a body consisting of a shell and a bottom head, surrounded by a resin-based mixture providing neutronic and thermal shielding, and featuring a wooden shock-absorber at its base; the body is joined to the cage by brackets welded to the body and bolted to the cage,
- a system for closing the body cavity, mainly featuring a plug, a bronze clamping ring and a bayonet ring,
- a shock-absorbing cover protecting the package in case of a drop on the plug side.

The body and its closure system bound the enclosure.

The main dimensions are as follows:

- overall dimensions of the cage :
  - length: 600 mm
  - width: 600 mm
  - height: 1 821 mm
- overall dimensions of the body equipped with its cover:
  - diameter of continuous section: 295 mm
  - diameter at the cover: 466 mm
  - height: 1 808 mm

- cavity effective dimensions:
  - length: 1 475 mm
  - diameter: 178 mm

Weights are as follows:

- total tare weight of the package: 280 kg
- maximum total weight of the loaded package: 396 kg

TN-BGC 1 package may be one of the following types:

- B(M)F when the two O-rings bounding the enclosure are of Viton type,
- B(U)F when the two O-rings bounding the enclosure are of silicon THT type.

3.2. CONTENTS

TN-BGC 1 package meets the regulatory requirements applicable to:

- packages type B(U)F for fissile radioactive materials, for the transport of:
  - uranium oxide powder (content No 2),
  - metallic uranium ingots (content No4),
  - uranium oxide rods or rod sections or pellets (content No7),
  - solid uranium-bearing materials (content No11),
  - TRIGA fuel (content No26),
  - Uranyl nitrate (content No40),
  - Azure plates (content No 41),
  - Blend of uranium-bearing materials in various forms (content No42),
- packages type B(M)F for fissile radioactive materials, for the transport of:
  - plutonium oxide powder (content No1),
  - mixed uranium-plutonium powder (content No3),
  - compact stacks of ZEBRA type plates (content No5),
  - mixed uranium-plutonium oxide rods or rod sections or pellets (content No8),
  - heterogeneous plutonium oxide blend (content No9),
  - heterogeneous mixed uranium-plutonium blend (content No10),
  - plutonium tetrafluoride (content No18),
  - mixed uranium-plutonium nitride (content No19),
  - plutonium in metallic form (content No20),
  - plutonium, uranium, neptunium or americium oxide powder or a blend of these powders (content No23),
  - plutonium sources (content No46),

in agreement with:

- the recommendations of the International Atomic Energy Agency [DR01] together with the national regulations, agreements and codes referred to,
- the Applicant's guide [DR02],
- the safety rules and regulations applicable to the loading and unloading operations, particularly the regulations governing the lifting rigs of the country where the packages are built,
- the Quality Assurance rules of the safety standard section of the IAEA n°50-C-QA.

When the package is of type B(M), the requirements on the packages type B(U) to which the package does not comply are those:

- of articles 637 and 664 of [DR01] : the package seals are elastomer FKM (Viton) and consequently the minimum required ambient temperature is over -40°C. The limit service temperature of the package seals is -27°C,
- of article 662 [DR01] : for reasons of gas releases into the cavity, the maximum normal service pressure as defined in article 228 cannot be guaranteed under 7 bars.

4. FEATURES IMPORTANT FOR SAFETY

The package safety functions, together with the parameters to be guaranteed, are tabulated below:

Safety Functions	Features important for safety	Parameters to be guaranteed
Control of radioactive material confinement	Internal O-ring seals Enclosure	Performance of the O-ring characteristics (double O-ring at the plug and quick disconnect cap location ; O-ring material) Sound internal cavity (stainless steel shell and bottom head assembled by continuous welds; steel plug)
Limitation of external exposure	Lateral shielding: External shell steel thickness Internal shell steel thickness Resin thickness Axial shielding (bottom head) : Stainless steel of the bottom head Stainless steel of the two closure plates Carbon steel of the distribution plate Resin Axial shielding (top head): Stainless steel of the plug Resin	 1.5 mm 6 mm 48 mm minimum 8 mm 2 x 1.5 mm 25 mm 24 mm minimum 59 mm 24 mm

Safety Functions	Features important for safety	Parameters to be guaranteed
Criticality safety control	<u>Cage</u> Cage width <u>Radial part of the package body</u>: Effective diameter of the internal cavity Thickness of the stainless steel inner shell Borated resin Thickness of the stainless steel outer shell <u>Plug</u> : Stainless steel <u>Bottom head (from inside to outside)</u> : Stainless steel shell and carbon steel distribution plate Resin Stainless steel shell Effective diameter and thickness of the AI Presence of materials more hydrogenated than water Fissile material	 60 cm x 60 cm (in NCT) (*) 178 mm (181 mm max) 6 mm In NCT, thickness of 48 mm + composition ; In ACT, thickness of 33 mm + composition 1.5 mm Thickness of 92 mm thickness 33 mm thickness 24 mm+ composition thickness 1,5 mm See chapter 1 Forbidden or not (*) Physical-chemical form, mass and composition (*)
Residual heat removal	Resin thickness Inner shell thickness Outer shell thickness	48 mm (radial) 6 mm 1.5 mm

(*) Only for some contents (see the definition of the isolation system specific to each content)

5. TABLE OF CONTENTS

This file was drawn up to demonstrate that the package model formed by package TN-BGC 1 loaded with one of the contents described in **chapter 1**, is compliant as fissile type B package model with the requirements of the applicable regulations, agreements or recommendations.

Chapter 2 sets out the main characteristics of package TN-BGC1, which is designed to transport uranium-bearing or plutonium-bearing radioactive materials which may take a large variety of forms.

The safety analyses and justifications which demonstrate that the package model is compliant with the regulations are set out in the following **chapters**:

- **chapter 3** : mechanical analysis of package TN-BGC1,
- **chapter 4** : mechanical analysis of the contents of package TN-BGC1,
- **chapter 5** : thermal analysis of package model TN-BGC1,
- **chapter 6** : confinement analysis of package model TN-BGC1,
- **chapter 7** : radiation protection analysis of package model TN-BGC1,
- **chapter 8** : criticality safety analysis of package model TN-BGC1,
- **chapter 9** : analysis of subsidiary risks.

Chapter 10 sets out the instructions to be followed for the proper use of package TN-BGC 1 and defines the test, acceptance and startup programs planned at end of manufacturing of the packages type TN BGC1, together with the maintenance program applied during the lifetime of the packages.

Lastly, **chapter 11** recalls the quality assurance provisions applicable to package model TN-BGC1.

The detailed table of contents of this safety file is shown in Table 1 below.

6. APPLICABLE REGULATIONS

This file is drawn up in accordance with the Applicant's Guide [DR02].

It brings answers to the requests for further information by the Safety Authority in the following letters:

- ASN/DIT/0632/2009 dated November 13 2009,
- CODEP-DTS-2011-02880 dated May 17 2011
- CODEP-DTS-2011-046417 dated September 12 2011.

Table 3 shows these requests and, for those which are processed, the part of the file which meets these requirements.

TN-BGC 1 package may be used for international transports, so this safety file is drawn up with reference primarily to the IAEA regulation [DR01].

Other regulations are met by package model TN-BGC 1; the list of these regulations is as follows:

- European Agreement on the International Transport of Dangerous Goods by Road (ADR) ;

- Regulation on the International Transport of Dangerous Goods by Rail (RID) ;
- International Maritime Code of Dangerous Goods (OMI's IMDG code) ;
- Technical instructions for the safety of air transport of dangerous goods (IT of the OACI) ;
- *Government Order of May 29 2009 on the Overland Transport of Dangerous Goods (Government Order TMD »)* ;
- Government Order of November 23 1987, as amended, governing the safety of ships, division 411 of the appended regulation (Government Order RSN) ;
- Instruction dated June 26 2008 governing the technical rules and administrative procedures applicable to commercial transport by airplane and EU regulation N°859/2008 dated August 20 2008 (EU OPS1).

The correspondence between the different parts of the Safety File and the sections of [DR01] is indicated in Table 2.

TABLE 1 : SAFETY FILE CONTENTS

Reference	Title	Date
Chapter 0 DSN/STMR/LEPE/TNBGC1/DSEM 0600 rev.02	Introduction – table of contents	11/10/2012
Chapter 1 DSN/STMR/LEPE/TNBGC1/DSEM 0601 rev.02	Description of the contents	11/10/2012
Chapter 2 DSN/STMR/LEPE/TNBGC1/DSEM 0602 rev.01	Description of the package	17/07/2012
Attachment 1 Drawing 9990-65 rev C - Assembly Drawing 9990-118 rev B – cage Drawing 9990-11rev B – assembled plug	Conceptual drawings of TN-BGC 1 package	04/09/1991
Attachment 2 EMB TNBGC PBC PDC CA 01 0001 A	Drawing of the leak-tight modified cover -	02/06/2009
Chapter 3 DSN/STMR/LEPE/TNBGC1/DSEM 0603 rev.01	Mechanical analysis of a TN-BGC 1 package	17/07/2012
Attachment 1 EMB TNBGC PBC NTT CA000524 A	Drop tests TN-BGC 1 – summing-up of the tests	20/02/2004
Attachment 2 EMB TNBGC PBC DJS CA 000333 A	Report on the drop tests on prototypes of package TN-BGC 1	07/08/2003
Attachment 3 EMB TNBGC PBC DJS CA 000334 A	Report on the additional drop tests on package TN-BGC 1	07/08/2003
Attachment 4 2CE3E100 rev. 2	Mechanical study of a 9 m vertical drop of package TN-BGC 1 with the cover downwards	16/02/2004
Attachment 5 G03CAL022A rev. 2.0	Study on the maintenance of tightness performance of package TN-BGC 1 during a 9 m drop in oblique position	30/05/2007
Attachment 6 160 EMBAL PFM DET 08000162 A	Mechanical strength of the enclosure during immersion	26/02/2008
Attachment 7 160 EMBAL PFM DET 08000163 A	Strength of the handling devices	26/02/2008
Attachment 8 299E05W03	Mechanical lashing studies on package TN-BGC 1 – Combined accelerations	17/08/2005

Attachment 9 2BP6E042	Mechanical performance of package TN-BGC1 during an explosion	02/05/2006
Reference	**Title**	**Date**
Attachment 10 159A3W03 Rev. B	Modal analysis of package TN-BGC 1	23/01/2003
Chapter 4 DSN/STMR/LEPE/TNBGC1/DSEM 0604 Rev.01	Mechanical analysis of the contents of package TN-BGC 1	17/07/2012
Attachment 1 EMB TNBGC PBC DJS CA 000339 A	Resistance to internal pressure of packages AA204, TN90, AA226, AA227, AA236 and AA303	07/08/03
Attachment 2 195H03W01 Rev. A	Package TN-BGC 1 – Consequences of hydrogen combustion in the TN90 internals	12/08/03
Chapter 5 DSN/STMR/LEPE/TNBGC1/DSEM 0605 Rev.02	Thermal analysis of package model TN-BGC 1	11/10/2012
Attachment 1 EMB TNBGC PBC DJS CA 000345 A	Temperatures in package model TN-BGC 1 in normal and accident conditions of transport	07/08/03
Attachment 2 477314C050263 Rev. B	Thermal analysis of package TN-BGC1 in ACT	29/06/06
Attachment 3 472891C030118 Rev. B	Thermal analysis of package TN-BGC 1	26/01/04
Attachment 4 EMB TNBGC PBC DJS CA 000388 A	Further calculations	07/08/03
Attachment 5 EMB TNBGC PBC DJS CA 000348 A	Thermal analysis of fuel rods (content No8) in package TN-BGC 1	07/08/03
Attachment 6 472891C040024 Rev. A	– Thermal analysis of package TN-BGC 1 – Model of an explosion in the internals	26/03/04
Attachment 7 1063-02/SIM/NOT/001 Rev. A	Thermal calculation note for package TN-BGC1 loaded with ^{238}Pu sources	05/11/10
Attachment 8 1063-15/SIM/NOT/001 Rev. A	Calculation note on the thermal tests of package TN-BGC 1	28/09/12

Reference	Title	Date
Chapter 6 DSN/STMR/LEPE/TNBGC1/DSEM 0606 Rev.01	Confinement analysis of package model TN-BGC1	17/07/2012
Attachment 1 LNE report – file D031080 – document CM1/1	Test report for the dilatometer tests on the STACEM seals	19/09/2003
Chapter 7 DSN/STMR/LEPE/TNBGC1/DSEM 0607 Rev.01	Radiation protection analysis of package model TN-BGC1	17/07/2012
Attachment 1 CEA DCE-S-UGSP-SPR-SRI-T-99-1172	Calculation of photon and neutron flowrates around a package TN-BGC 1 containing americium	21/10/1999
Attachment 2 DSN/STMR/LEPE TNBGC NOT0050 Rev. 01	Radiation protection study of package model TN-BGC 1 loaded with mixed oxide or plutonium oxide	10/02/2012
Attachment 3 160 EMBAL PFM NTE 09000062 A	Radiation protection study of package model TN-BGC 1 loaded with 17 kg of plutonium oxide	27/01/2009
Chapter 8 DSN/STMR/LEPE/TNBGC1/DSEM 0608 Rev.01	Criticality safety analysis of package model TN-BGC1	17/07/2012
Attachment 1 EMB TNBGC PBC DJS CA 000481 A	Further criticality calculations	05/01/2004
Attachment 2 Note SGN NT.12862.00.008. Rev. A	Criticality safety of package TN-BGC 1 – Permissible mass determination – content 8	19/11/2004
Attachment 3 Note SGN NT.12862.00.009. Rev. A	Criticality safety of package TN-BGC 1 – Determination of the permissible number of packages – content 8	19/11/2004
Attachment 4 Fax CEA/DEN/CAD/DTAP/SET DO 247	Criticality calculations for package TN-BGC 1	14/05/2004
Attachment 5 160 EMBAL PFM NOT 06001678 A	Criticality study of package TN-BGC 1 loaded with plutonium oxide powder	07/11/2006

Reference	Title	Date
Attachment 6 160 EMBAL PFM NOT 06001677 A	Criticality study of package TN-BGC 1 loaded with various contents: influence of the type of chocks	07/11/2006
Attachment 7 160 EMBAL PFM NOT 06001679 A	Criticality study of package TNGBC 1 loaded with content 6 : uranyl nitrate solution	07/11/2006
Attachment 8 160 EMBAL PFM NOT 06001680 A	Criticality study of package TN-BGC 1 loaded with content 11 : medium metallic U at 100 % ^{235}U	07/11/2006
Attachment 9 160 EMBAL PFM NOT 06001518 A	Criticality study of package TN-BGC 1 loaded with content 26 : medium U-ZrH_2	06/10/2006
Attachment 10 U-8061-NT-01 Rev. 1	Criticality study of package model TN-BGC 1 loaded with various contents	14/12/2009
Attachment 11 EMB TNBGC PBC DJS CA 000386 A	Criticality study of package model TN-BGC 1 loaded with content No26 : TRIGA fuel	07/08/2003
Attachment 12 DSN/STMR/EMBAL/LEPE NOT0020 Rev. 01	Criticality study of package TN-BGC 1 loaded with metallic uranium or uranium oxide enriched 30% in ^{235}U	05/10/2010
Attachment 13 160 EMBAL PFM NOT 06001310 C	Criticality study of package TN-BGC 1 loaded with various MCMF contents in normal and accident conditions of transport	24/07/2007
Attachment 14 U-8122-NT-01 Rev. 2	Criticality study of package model TN-BGC 1 loaded with various contents	23/07/2010
Chapter 9 DSN/STMR/LEPE/TNBGC1/DSEM 0609 Rev.01	Subsidiary risk analysis	17/07/2012
Chapter 10 DSN/STMR/LEPE/TNBGC1/DSEM 0610 Rev.02	Instructions for use of the package – test, receiving and maintenance programs	11/10/2012
Chapter 11 DSN/STMR/LEPE/TNBGC1/DSEM 0611 Rev.01	Quality assurance applicable to the package model	17/07/2012

TABLE 2 : CORRESPONDENCE BETWEEN THE ARTICLES OF THE APPLICABLE REGULATION AND THE PARAGRAPHS OF THE SAFETY FILE

Paragraphs of IAEA 96 (2005 edition)	Applicable paragraphs of the Safety File
306	Chapter 11
508	Chapter 10
539	Chapter 2
540	Chapter 2
569	Chapter 8
570	Chapter 8
573	Chapter 8
501 a	Chapter 10
501 b	Chapter 10
501 c	Chapter 10
502 a	Chapter 10
502 b, c, d	Chapter 10
606	Chapter 10
607	Chapter 10
608	Chapter 10
609	Chapter 2
610	Chapter 2
612	Chapters 3 and 6
613	Chapter 1 and 2
615	Chapters 2, 3, 4 and 5
616	Chapter 9
634	Chapter 2
635	Chapter 2
636	Chapter 3
637	Chapters 2 and 3
638	Chapters 0, 2, 10 and 11
639	Chapters 2, 3 and 10
642	Chapters 2, 3 and 9
643	Chapters 3 and 6
646	Chapters 3, 4, 6 and 7
651	Chapters 3, 4, 5 and 6
652	Chapter 5
653	Chapter 5
654	Chapter 5
655	Chapter 5
656	Chapters 10 and 11
657	Chapters 6 and 7
658	Chapter 3
659	Chapters 2 and 6
660	Chapters 2 and 6
661	Not respected
662	Chapters 3 and 6

Paragraphs of IAEA 96 (2005 edition)	Applicable paragraphs of the Safety File
664	Chapters 1 and 3
671	Chapter 8
675	Chapter 8
677	Chapter 8
678	Chapter 8
679	Chapter 8
680	Chapter 8
681	Chapter 8
682	Chapter 8
676	Chapters 1 and 3
719 - 724	Chapter 3
726 - 729	Chapter 3
730	Chapter 3
731- 733	Chapter 3
807 a	Chapter 1
807 b	Chapters 1 and 2
807 c	Chapters 3 and 5
807 d	Chapter 10
807 e	Chapter 3
807 f	Chapter 4
807 g	Chapter 10
807 h	Chapter 2
807 i	Chapter 11

TABLE 3: TABLE OF ACTIONS TAKEN FOLLOWING THE SAFETY AUTHORITY RECOMMENDATIONS

Subject	Requests	Responses
CODEP-DTS-2011-046417 dated 12/09/11	Request 1 : Update the relevant criticality safety notes, considering the package array: N = 10, for sub-contents n°2a and 7a; N = 8, for sub-contents n°2b and 7b; N = 5, for sub-contents n°11b.	See chapter 8 - § 4.3 and 4.11
	Request 2 : Include in the file a study of the radiolysis and thermolysis risks.	See chapter 9 - § 3.1.1and 3.1.2
	Request 3 : 1/ Supplement the production of inflammable gases in the package by radiolysis and thermolysis to take into account in particular the introduction of polyethylene (the gas formation rates and the thermal decomposition thresholds considered for the polyethylene thermal degradation phenomenon shall be justified); 2/ update the definition of the contents: for sub-contents n° 3c-2, 3c-3, 10b-2 and 10b-3, limitation of the maximum mass of uranium-plutonium to 20kg; for sub-contents n° 3a-5, 8a-5, 10a-5 : when the plutonium mass concentration is between 15% and 30%, limitation of the fissile material mass to 4 kg and of the number of packages to 10; when the plutonium mass concentration is less than 15%, limitation of the fissile material mass to 2.4 kg and of the number of packages to 8; for the sub-contents n°10a-1 and 10a-2, limitation of the permissible mass to respectively 14.2kg and 9.6 kg; Revise the criticality safety study of the sub-contents n°3a-5, 3a-6, 8a-5, 8a-6, 10a-5 and 10a-6 to include the fact that the maximum plutonium content does not lead to the worst case configuration.	1/ CH2 is not allowed for these contents. 2/ these contents are not re-applied in this file
ASN-DIT-0632-2009 dated 13/11/09	1.1 Study the representativeness of the test specimens with respect to the package model (container and contents), taking into account: - the tolerances (seal grooves, welds, enclosure components, torques and preloads, etc), - the actual properties of the materials of these specimens with respect to the minimum properties of the package model properties, - the temperature ranges, - the ageing of the materials (aluminum and resin in particular), - the grade of the seals and their residual compression.	The CEA no longer wishes to revisit the 4 test campaigns conducted from 1998 to 2003 and whose results were deemed satisfactory to the extent that the required approvals were obtained.
	1.2 Analyze the damage that could be caused by a drop of a 500kg plate when the center of gravity of the plate is aligned with that of the container plug.	
	1;3 Conduct a study on the fatigue behavior of the lashing devices for all the transport modes considered for TNBGC1, taking into account: - the cumulative acceleration cycles in the various directions, - the preload exerted in the materials, - the surface condition, notch factor and scale factor of the lashing devices.	See chapter 3 - § 5.4 Partial response as the lashing devices are checked before transport and during maintenance, which removes the need to take into account the surface condition and notch factors
	2.1 Analyze the temperature deviations between the thermal simulation results and the benchmarking with fire tests.	The CEA no longer wishes to refer to the fire tests. Solely calculation-based approach.
	2.2 Identify in the numeric studies the authorized transport configurations and the related package temperatures.	See chapter 6 – appendix 1

Subject	Requests	Responses
ASN-DIT-0632-2009 dated 13/11/09	3.1 For contents n°1a(iii), 1c(ii), 3d, 8c and 9, justify the conservatism of the model adopted for the chocks, taking into account the qualification of the computer codes, particularly in the case where they are modeled in aluminum.	Content 9 is not covered by this request. The other contents are not re-applied in this file
	3.2 For contents n°3 and 8, include a calculation bias to take into account the current lack of qualification of the criticality computer codes for the low-moderation fissile materials.	See chapter 8, § 4.4 and 4.8 (notes SGN in atts 2 and 3)
	3.3 For content No1b, justify the conservatism of the package stack adopted for the array configurations, particularly with respect to a plane array.	This content is not reapplied in this file
	3.4 For content No10, analyze the heterogeneous modeling of the fissile material for loadings whose uranium enrichment in 235U is 100%.	See chapter 8, § 4.10 (notes SGN in atts 2 and 3)
	3.5 For content No26, supplement the justification of the modeling of the aluminum spacers, taking into account the most reactive configuration (fissile material in homogeneous form).	See chapter 8, § 4.16 (note in att. 9)
	3.6 Regarding contents for which model n°1 was adopted, take into account either model n°2, or a model sufficiently representative of the container condition following the ACT tests.	Analysis on-going.
	3.7 Revise the study justifying the subcriticality of TNBGC1 loaded with content No3a, taking into account a model sufficiently bounding of the container following the tests representative of the ACT.	See chapter 8, § 4.4 (notes SGN in atts 2 and 3)
	4.1 Justify the compliance with the requirement in 573(b) of the IAEA 2005 regulation in the case where the dose equivalents exceed 2mSv/h on contact with the package.	See chapter 5 - § 2
	4.2 Update chapter 4 of the Safety File, specifying the characteristic points to be checked and the inclusion of the measurement uncertainties.	See chapter 10 - § 1.2.5 The uncertainties are not included (See letter COR ARV SHS DIR 07-42 dated 16/07/07)
	5.1 Revise the radiolysis and thermolysis studies of the contents in solid form, taking into account: - the uncertainties on the evaluation of the PuO2 moisture radiolysis, - 7 days of accident conditions (incl. 30mn of fire), - duration of contingencies versus the transports to be performed (national, European, transcontinental).	See chapter 9 - § 3.1
	5.2 Revise the uranyl nitrate radiolysis study, taking into account: - the radiolysis and thermolysis of polyethylene, - 7 days of accident conditions (incl. 30mn of fire), - duration of contingencies versus the transports to be performed (national, European, transcontinental) – the effects of temperature on hydrogen production, - the volume of the flasks in the calculation of free volume, - the tightness or non-tightness of the flasks transporting uranyl nitrate.	See chapter 9 - § 3.3
	5.3 Submit a procedure describing the set of inspection processes of the TNBGC1 loaded with radiolyzable contents to avoid any risk during unloading in case of the excessive presence of hydrogen or of an explosion occurrence during transport. At all events, this risk should be addressed in the package unloading facilities.	See chapter 10 - § 1.4

Subject	Requests	Responses
ASN-DIT-0632-2009 dated 13/11/09	6.1 update the Safety File to include the periodic inspection of the fusible plugs of the covers and the modifications of the covers.	See chapter 10 - § 2.2 and chapter 2 - § 4.4
	6.2 Justify the effectiveness of the modifications of the covers aiming to guarantee their tightness.	See chapter 2 - § 4.4
	7.1 Define actions for checking the compliance between the Safety File (definition of the package model and safety demonstration) and the relevant applicable documents (specifications and manufacturing process outline, "manufacturer packages", results of tests and calculations, user's manual, maintenance program, user procedures and process outlines...), including for the documents issued by companies separate from that of the designer.	See chapter 11 - § 6
	7.2 Define the responsibilities regarding the checks to be made, in particular the compliance of the documents issued by companies separate from that of the designer.	See chapter 11 - § 6
CODEP-DTS-2011-028880 dated 17/05/11	Revise the radiolysis calculations by: - including the radiolysis and thermolysis of the polyethylene flasks; -considering the cavity of container DV27; - considering bounding hypotheses, in particular regarding: - the permeation coefficients minimizing the leak rates and representative of hydrogen; - the maximum interim storage time.	See chapter 9 - § 3.3 Infinite medium considered around the stored container
	Demonstrate that the polymer materials used for the protective covers of the uranyl nitrate flasks are less hydrogenated than water. Failing this, conduct a thorough inspection before transport on the basis of cover supplier data or update the criticality safety study by considering the presence of 1250g of polyethylene.	See chapter 1 - § 2.16.1

Nuclear Energy Division
Nuclear Services Department
Radioactive Materials Transportation Service
Packaging Operations Laboratory

Safety Analysis Report
TN-BGC 1 package
Chapter 1 - Description of Authorised Contents

Clt : 7.1.1.3.

Classification: DO

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MODIFICATIONS

VERSI ON	DATE	AUTHOR	TYPE OF MODIFICATION	NO. OF PAGES
01	17/07/12	V. PAUTROT	Initial issue	83
02	10/10/12	V. PAUTROT	Integration of remarks by CSMN	83

CONTENTS

1. INTRODUCTION

This chapter details the contents likely to be transported within the TN-BGC1 package, and specifies, for each:

- Physical and chemical characteristics
- The isotopic characteristics of the radioactive materials being transported
- Maximum quantities transported
- Thermal characteristics
- Fissile material composition (uranium & plutonium content)
- Any specific measures
- Usable internal fittings.

2. DESCRIPTION OF THE CONTENTS

The following contents may be transported in the TN-BGC 1 package:

- Plutonium oxide powder (Contents 1)
- Uranium oxide powder (Contents 2)
- Uranium-Plutonium mixed oxide (MOX) powder (Contents 3)
- Uranium metal ingots (Contents 4)
- Compact stacks of ZEBRA plates (Contents 5)
- Uranium oxide pellets, rod sections or fuel rods (Contents 7)
- Uranium-Plutonium MOX pellets, rod sections or fuel rods (Contents 8)
- Homogeneous mixture of plutonium oxides (Contents 9)
- Homogeneous mixture of uranium & plutonium oxides (Contents 10)
- Solid uranium solids (Contents 11)
- Plutonium fluoride (Contents 18)
- Uranium-plutonium nitride mixture (Contents 19)
- Plutonium in metallic form (Contents 20)
- Powdered oxides of plutonium, uranium, neptunium, americium or a mixture of the above powders (Contents 23)
- TRIGA fuel (Contents 26)
- Uranyl nitrate (Contents 40)
- Azur plates (Contents 41)
- Mixture of uranium-based materials in various forms (Contents 42)
- Plutonium sources (Contents 46)

Note: A description of the internal fittings is given in Section 3.

2.1. CONTENT 1: POWDERED PLUTONIUM OXIDE

2.1.1. Description

The powder may be from reprocessing but must not have been irradiated after this reprocessing.

Impurities may be present in trace quantities.

2.1.1.1. Isotopic composition and masses

Several cases are possible, dependant on the isotopic characteristics of the plutonium:

Contents	Isotopic composition	Φ of internal fittings	Thickness of internal fittings	Permissible mass of Pu (kg)	Permissible number of packages
1a	$^{240}Pu \geq 5\%$	≤ 120 mm	2 mm	13.5	25
1d	$^{240}Pu \geq 5\%$			17	16
1c	100% ^{239}Pu			7	25

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.1.1.2. Physical characteristics

Max. powder density: 3.5.

2.1.1.3. Chemical form

Oxide

2.1.1.4. Special form

The material is not in a special form.

2.1.1.5. Specific

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 6% (by mass) of Americium 241 is permitted.

2.1.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the PuO_2 powder is dependent on the internal fittings used:

- If the powder is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the powder is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - 20 W if using type AA41 internal fittings,
  - 71.4 W/m length of the secondary container if the internal fittings are types AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.1.1.7. Special provisions

If the water content is below 0.5% no particular measures are needed. When transporting powders with moisture levels of between 0.5 and 3.0% and/or powders packaged with vinyl covers, the particular measures detailed in Chapter 9 are applicable, limiting the time of transport with relation to the quantities of material and type of packaging used.

2.1.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the water content,
- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Water content of less than 0.5% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 87**
$1,33.10^{-4}$	**≤ 175**
$6,65.10^{-5}$	**≤ 352**
$1,33.10^{-5}$	**≤ 1799**

Water content of between 0.5 and 3% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 13**
$1,33.10^{-4}$	**≤ 27**
$6,65.10^{-5}$	**≤ 54**
$1,33.10^{-5}$	**≤ 286**

Water content of less than 0.5% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 78**
$1,33.10^{-4}$	**≤ 158**
$6,65.10^{-5}$	**≤ 318**
$1,33.10^{-5}$	**≤ 1811**

Water content of between 0.5 and 3% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 12**
$1,33.10^{-4}$	**≤ 24**
$6,65.10^{-5}$	**≤ 49**
$1,33.10^{-5}$	**≤ 256**

2.1.2. Internal fittings

The powder must be packaged in internal fittings with a maximum diameter of 120 mm and a minimum thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The powder **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [powder + possible primary packaging + possible secondary packaging] **must** then by placed inside an internal fitting made up of an enclosed tube fitted with sealed covers. Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.

- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 et 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.2. CONTENT 2: POWDERED PLUTONIUM OXIDE

These contents comprise powdered uranium in the form of UO_2 or U_3O_8

2.2.1. Description

The powder may be from reprocessing but must not have been irradiated after this reprocessing.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is authorised for certain sub-contents - within the limit of 500 g.

2.2.1.1. Isotopic composition and masses

The authorized masses are tabulated below:

Contents No.	Presence of hydrogen-bearing materials with higher hydrogen quantity than water authorised	^{235}U enrichment level	Total mass of U	Permissible number of packages
2a		≥ 20 %	2,2 kg	10
2b	Yes	≥ 20 %	2,4 kg	8
2c		< 30 %	40 kg	25
2d	No	≥ 20 %	20 kg	25

2.2.1.2. Physical characteristics

Max. powder density: any

2.2.1.3. Chemical form

Oxide

2.2.1.4. Special form

The material is not in a special form.

2.2.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded. For information, the regulatory dose limits are respected for the transportation of reprocessed uranium when the total equivalent activity from the residual fission products remains below 2.52 GBq (68 mCi).

2.2.1.6. Specific activity

If the uranium is from reprocessing sources, the specific activity of the contents must be below 46 A_2/g.

2.2.2. Internal fittings

The oxide powder is placed within primary packaging, which may be metal boxes, flasks or double-skinned polymer casings.

The primary packaging is placed within internal fittings of type TN90, AA204, AA203 or AA41.

The following spacers are used to position and secure the tertiary packing container in the packaging cavity:

- With the TN 90: Spacers E1 & E2,
- With the AA 204: Spacers E1 & E10 or E6,
- With the AA 203: Spacers E1 & E8,
- With 1 x AA 41: Spacers E1 & E11,
- With 2 x AA 41: Spacers E1, E12 & E13,
- With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.3. CONTENT 3: POWDERED PLUTONIUM-URANIUM MIXED OXIDE (MOX)

2.3.1. Description

The powder may be from reprocessing but must not have been irradiated after this reprocessing.

Impurities may be present in trace quantities.

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.3.1.1. Isotopic composition and masses

Several cases may occur, depending on the plutonium content and the isotopic characteristics of the plutonium and uranium:

Contents No.	Pu/U+Pu	^{235}U enrichment level	Isotopic composition of plutonium (by mass)	Maximum weight of uranium-plutonium (kg)	Number of packages
3a	≤ 30 %	Any	5 % ≤ ^{240}Pu	15,6	25
3f	≤ 30 %	Any	5 % ≤ ^{240}Pu	20	7
3c	≤ 30 %	≤ 0,71 %	5 % ≤ ^{240}Pu	20	25
3g	≤ 30 %	Any	100% ^{239}Pu	1,5	10
3e	≤ 30 %	≤ 0,71 %	100% ^{239}Pu	20	10

2.3.1.2. Physical characteristics

The powder may have any density.

2.3.1.3. Chemical form

Oxide

2.3.1.4. Special form

The material is not in a special form.

2.3.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 3.4 % (by mass) of Americium 241 is permitted. If the mass of the materials exceeds 17 kg the authorised percentage of 241Am is 4.1% by mass.

2.3.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the (U,Pu)O2 powder is dependent on the internal fittings used:

- If the powder is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the powder is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per internal fitting unit limited to:
  - 20 W if using type AA41 internal fittings,
  - 71.4 W/m length of the secondary container if the internal fittings are types AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.3.1.7. Special provisions

If the water content is below 0.5% no particular measures are needed. When transporting powders with moisture levels of between 0.5 and 3.0% and/or powders packaged with vinyl covers, the particular measures detailed in Chapter 9 are applicable, limiting the time of transport with relation to the quantities of material and type of packaging used.

2.3.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the water content,
- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Water content of less than 0.5% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2{,}66.10^{-4}$	**≤ 87**
$1{,}33.10^{-4}$	**≤ 175**
$6{,}65.10^{-5}$	**≤ 352**
$1{,}33.10^{-5}$	**≤ 1799**

Water content of between 0.5 and 3% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2{,}66.10^{-4}$	**≤ 13**
$1{,}33.10^{-4}$	**≤ 27**
$6{,}65.10^{-5}$	**≤ 54**
$1{,}33.10^{-5}$	**≤ 286**

Water content of less than 0.5% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2{,}66.10^{-4}$	**≤ 78**
$1{,}33.10^{-4}$	**≤ 158**
$6{,}65.10^{-5}$	**≤ 318**
$1{,}33.10^{-5}$	**≤ 1811**

Water content of between 0.5 and 3% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2{,}66.10^{-4}$	**≤ 12**
$1{,}33.10^{-4}$	**≤ 24**
$6{,}65.10^{-5}$	**≤ 49**
$1{,}33.10^{-5}$	**≤ 256**

2.3.2. Internal fittings

The powder must be packaged in internal fittings with a maximum diameter of 120 mm and a minimum thickness of 2 mm (TN 90, AA 204, AA 203, AA 41).

The packaging principle is as follows:

- The powder **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [powder + possible primary packaging + possible secondary packaging] **must** then by placed inside a stainless steel internal fitting made up of an enclosed tube fitted with sealed covers (checkable or not). Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.

- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.4. CONTENT NO. 4: INGOTS OF METALLIC URANIUM

2.4.1. Description

These contents comprise ingots of metallic uranium.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.4.1.1. Isotopic composition and masses

The isotopic composition of the uranium is variable

The maximum permissible mass corresponds to 9 ingots of un-irradiated uranium metal each of 5 kg (giving a total maximum mass loaded into the package of 45 kg or metallic uranium).

2.4.1.2. Physical characteristics

The ingots may have any density.

2.4.1.3. Chemical form

Metal

2.4.1.4. Special form

The material is not in a special form.

2.4.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2.4.1.6. Special provisions

Particular attention should be paid to the surface condition of the contents when loading into their packaging. The surface of the contents should be free of scoring or hydrides.

2.4.1.7. Specific activity

If the uranium is from reprocessing sources, the specific activity of the contents must be below 46 A_2/g.

2.4.2. Internal fittings

The secondary packaging container must be type TN 90.

A solid, type E4 spacer is used to assure that during NCT & ACT, a minimum edge-to-edge distance of 90 mm is maintained between each ingot.

In addition, all spacers to be used for a maximum load must be stacked within the container cavity, even if the number of ingots actually loaded into the container is not at its maximum permissible figure.

Spacers E1 & E2 should be used to position and secure the TN 90 packing container in the packaging cavity:

The total mass of the whole load including internal fitting TN 90 is restricted to 60 kg. The maximum permissible mass of the whole load within the cavity of the package (spacers + container + cargo transported) is 116 kg.

2.5. CONTENT NO. 5: COMPACT STACKS OF ZEBRA-TYPE PLATES

2.5.1. Description

These contents comprise a number of sub-assemblies made up of a compact stack of metallic plutonium plates surrounded by cladding in stainless steel with a height of less than or equal to 100 mm.

The plutonium may be from reprocessing but must not have been irradiated at any stage after this reprocessing.

The geometry of the square plates is the following:

- Total thickness: $e \leq 3{,}17$ mm,
- Length of one side: $a \leq 50{,}7$ mm,
- Stainless steel cladding thickness : $e_{cladding} \langle 0{,}40$ mm.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.5.1.1. Masses & isotopic composition

The isotopic composition of the plutonium is such that:

$$\frac{^{240}Pu}{Pu_{total}} \geq 0{,}15 \text{ (en masse)}$$

The maximum mass of Pu per plate is 83 g. The maximum quantity transported per TN-BGC 1 package is 7 sub-assemblies (7 stacks of plates), for a total maximum mass of 18.011 kg of Pu.

2.5.1.2. Physical characteristics

The maximum density of the metallic plutonium is less than or equal to 19.6.

2.5.1.3. Chemical form

Metal

2.5.1.4. Special form

The material is not in a special form.

2.5.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2.5.1.6. Maximum thermal power of the contents

The maximum thermal power released by the contents of a package must be below 150 W.

2.5.1.7. Specific activity

The specific activity of the contents is limited with relation to the leak rate checked prior to shipping.

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	**Specific activity in A2/g**
$2,66.10^{-4}$	**≤ 87**
$1,33.10^{-4}$	**≤ 175**
$6,65.10^{-5}$	**≤ 352**
$1,33.10^{-5}$	**≤ 1799**

2.5.2. <u>Internal fittings</u>

The role of the internal fittings is to assure the longitudinal and radial positioning of the plate stacks under NCT & ACT. The stacks must be packaged inside internal fittings with a maximum diameter of 120 mm and a minimum thickness of 2 mm. The packaging principals are as follows:

- Each stack of plates is contained within a box to assure the stack remains compact.
- The boxes **must** be separated by solid **spacers/Spacers** (Type E5) to assure a minimum spacing between stacks of 90 mm. All E5 spacers must be loaded into the container even if the number of stacks actually loaded is not the maximum permissible figure.
- All these elements are then placed within an internal fitting (Type TN 90 only) which assures the radial positioning of the plate stacks.
- **Spacers** E1 & E2 should be used to hold the internal fittings in place within the package cavity.

The total mass of the whole load including intemal fitting TN 90 is restricted to 60 kg. The maximum permissible mass of the whole load within the cavity of the package (spacers + container + cargo transported) is 116 kg.

2.6. CONTENT NO. 7: URANIUM OXIDE PELLETS, ROD SECTIONS OR FUEL RODS

These contents comprise uranium oxide (UO_2 only), which can be in the form of pellets, fuel rod sections or complete fuel rods.

2.6.1. Description

The uranium is non-irradiated. In the event that the uranium is reprocessed, the material should not have been irradiated at any moment post-reprocessing.

The presence of hydrogen-bearing materials with a hydrogen content of greater than that of water is authorised for certain sub-contents - within the limit of 500 g.

2.6.1.1. Isotopic composition and masses

The authorised masses are given in the table below:

Contents No.	Presence of hydrogen-bearing materials with higher hydrogen quantity than water authorised	235U enrichment level	Total mass of U	Permissible number of packages
7a	Yes	≥ 20 %	2,2 kg	10
7b		≥ 20 %	2,4 kg	8
7c		< 30 %	40 kg	25
7d	No	≥ 20 %	20 kg	25

2.6.1.2. Physical characteristics

The density of the pellets is, as a maximum, equal to 100% of the maximum theoretical density (d=10.96).

The maximum internal pressure of the rods is 3 bar (abs) at 20°C.

The pellets may be damaged and therefore potentially in the form of debris.

2.6.1.3. Chemical form

Oxide

2.6.1.4. Special form

The material is not in a special form.

2.6.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2.6.1.6. Specific activity

If the uranium is from reprocessing sources, the specific activity of the contents must be below 22 A_2/g.

2.6.2. Internal fittings

The uranium oxide pellets can be placed within primary packaging, which may be metal boxes, flasks or double-skinned polymer casings. The whole assembly is then placed within a container making up the internal fittings.

Sections of rod may be inserted into sleeving tubes. The rods or sleeving tubes can then be placed in a rack.

Those internal fittings which can be used are TN 90, AA 204, AA 203 or AA 41.

The following spacers should be used to hold the internal fittings in place within the package cavity:

- With the TN 90: Spacers E1 & E2,
- With the AA 204: Spacers E1 & E10 or E6,
- With the AA 203: Spacers E1 & E8,
- With 1 x AA 41: Spacers E1 & E11,
- With 2 x AA 41: Spacers E1, E12 & E13,
- With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.7. CONTENT NO. 8: URANIUM-PLUTONIUM MIXED OXIDE PELLETS, ROD SECTIONS OR FUEL RODS

2.7.1. Description of the Contents

These contents comprise a mixture of uranium and plutonium oxides (UO_2 PuO_2), which can be in the form of pellets, fuel rod sections or complete fuel rods with metallic cladding surrounding the pellets.

The pellets, either alone or incorporated into fuel rods, may be from reprocessing but must not have been irradiated after this reprocessing. They should only contain trace quantities of carbon.

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.7.1.1. Isotopic composition and masses

Several cases may occur, depending on the plutonium content and the isotopic characteristics of the plutonium and uranium:

Contents No.	Pu/U+Pu	^{235}U enrichment level	Isotopic composition of plutonium (by mass)	Maximum weight of uranium-plutonium (kg)	Number of packages
8a	≤ 30 %	Any	5 % ≤ ^{240}Pu	15,6	25
8f	≤ 30 %	Any	5 % ≤ ^{240}Pu	20	7
8b	≤ 30 %	≤ 0,71 %	5 % ≤ ^{240}Pu	40	25
8d	≤ 30 %	Any	100% ^{239}Pu	1,5	10
8e	≤ 30 %	≤ 0,71 %	100% ^{239}Pu	20	10

2.7.1.2. Physical characteristics

The density of the pellets is, as a maximum, equal to 100% of the maximum theoretical density (d=11.46).

The maximum internal pressure of the rods is 2 bar (abs) at 20°C.

The pellets may be damaged and therefore potentially in the form of debris.

2.7.1.3. Chemical form

Oxide

2.7.1.4. Special form

The material is not in a special form.

2.7.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 3.4% (by mass) of Americium 241 is permitted. If the mass of the materials is limited to 17 kg the authorised percentage of ^{241}Am is 4.1% by mass.

2.7.1.6. Maximum thermal power of the contents

The total maximum thermal power output by these contents is dependent on the internal fittings used:

- If the contents are packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the contents are packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
    - 20 W if using type AA41 tertiary packaging containers.
    - 71.4 W/m length of the secondary container if the tertiary packaging container is of type AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.7.1.7. Specific activity

In the absence of covers and if the rods are depressurised, the specific activity of the contents is limited with regard to the leakage rate checked prior to shipping as detailed in the table below:

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 47**
$1,33.10^{-4}$	**≤ 94**
$6,65.10^{-5}$	**≤ 191**
$1,33.10^{-5}$	**≤ 987**

In the presence of covers and when transporting pellets and/or debris from rods, the specific activity of the contents is limited with regard to the leakage rate checked prior to shipping as detailed in the table below:

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity en A2/g
$2{,}66.10^{-4}$	**≤ 78**
$1{,}33.10^{-4}$	**≤ 158**
$6{,}65.10^{-5}$	**≤ 318**
$1{,}33.10^{-5}$	**≤ 1635**

2.7.1.8. Special provisions

If the materials are packaged using vinyl covers, the specific measures stated in Chapter 9 to limit transport times with respect to the quantities of material and type of packaging are applied.

2.7.2. Internal fittings

Pellets of mixed oxides (uranium-plutonium) (or sections or full rods) should be packaged in cylindrical internal fittings. The packaging principle is as follows:

- **Primary packaging:**
  - The pellets **may** be placed in boxes,
  - Sections of rods are placed inside sleeving tubes, these tubes **may** then be placed in racks.
  - The rods or sleeving tubes **may** be placed in a rack.

  The primary packaging boxes may be encased in one or more heat-sealed plastic covers (PVC or Polyurethane).
- **Secondary packaging**: the boxes (or sets of boxes) **may** be placed inside additional boxes,
- The resulting assembly [pellets/rod sections/rods + possible primary packaging + possible secondary packaging] must then by placed inside a stainless steel internal fitting made up of an enclosed tube fitted with sealed covers (checkable or not). Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.
- The following spacers must be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - with 3 AA 41: Spacers E1, E12 and 2 × E13,

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.8. CONTENT 9: HETEROGENEOUS MIXTURE OF PLUTONIUM OXIDE

2.8.1. Description

These contents are made up of plutonium oxide in the form of powder, pellets, pieces of pellet, rod sections or a heterogeneous mixture of the above.

The material may be from reprocessing but must not have been irradiated after this reprocessing. It should only contain trace quantities of carbon.

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.8.2. Isotopic composition and masses

Several cases are possible, dependant on the isotopic characteristics of the plutonium:

Contents	Isotopic composition of plutonium (by mass)	Maximum mass of Pu (kg)	Number of packages
9a	Any	4	1
9b	5 % $\leq$ ^{240}Pu	9	10

2.8.3. Physical characteristics

The density of the pellets is, as a maximum, equal to 100% of the maximum theoretical density (d=11.46).

2.8.4. Chemical form

Oxide

2.8.5. Special form

The material is not in a special form.

2.8.6. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.
The presence of 50 g or 6% (by mass) of Americium 241 is permitted.

2.8.7. Maximum thermal power of the contents

The total maximum thermal power output by this mixture is dependent on the internal fittings used:

- If the material is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the material is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.

- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - 20 W if using type AA41 tertiary packaging containers.
  - 71.4 W/m length of the secondary container if the tertiary packaging container is of type AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.8.8. Special provisions

If the water content is below 0.5% no particular measures are needed. When transporting materials with moisture levels of between 0.5 and 3.0% and/or materials packaged with vinyl covers, the particular measures detailed in Chapter 9 are applicable, limiting the time of transport with relation to the quantities of material and type of packaging used.

2.8.9. Specific activity

The specific activity of the contents is limited with relation to:

- the water content,
- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Water content of less than 0.5% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 87**
$1,33.10^{-4}$	**≤ 175**
$6,65.10^{-5}$	**≤ 352**
$1,33.10^{-5}$	**≤ 1799**

Water content of between 0.5 and 3% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 13**
$1,33.10^{-4}$	**≤ 27**
$6,65.10^{-5}$	**≤ 54**
$1,33.10^{-5}$	**≤ 286**

Water content of less than 0.5% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 78**
$1,33.10^{-4}$	**≤ 158**
$6,65.10^{-5}$	**≤ 318**
$1,33.10^{-5}$	**≤ 1811**

Water content of between 0.5 and 3% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 12**
$1,33.10^{-4}$	**≤ 24**
$6,65.10^{-5}$	**≤ 49**
$1,33.10^{-5}$	**≤ 256**

2.8.10. Internal fittings

The material must be packaged into appropriate internal fittings with a maximum diameter of 120 mm and a thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The materials **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [materials + possible primary packaging + possible secondary packaging] **must** then by placed inside an internal fitting made up of an enclosed tube fitted with sealed covers. Four types of internal fitting are available, depending on isotopic compositions: These containers are types TN 90, AA 204, AA 203 & AA 41.
- The following **spacers** should be used to hold the internal fittings in place within the package

cavity:

- With the TN 90: Spacers E1 & E2,
- With the AA 204: Spacers E1 & E10 or E6,
- With the AA 203: Spacers E1 & E8,
- With 1 x AA 41: Spacers E1 & E11,
- With 2 x AA 41: Spacers E1, E12 & E13,
- With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.9. CONTENT NO. 10: HOMOGENEOUS MIXTURE OF URANIUM & PLUTONIUM OXIDES

2.9.1. Description

These contents comprise a mixture of uranium and plutonium oxides in the form of a heterogeneous mixture of powder, pellets, pieces of pellet and sections of rods.

The mixture may be from reprocessing but must not have been irradiated after this reprocessing.

It should only contain trace quantities of carbon.

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.9.1.1. Isotopic composition and masses

Several cases may occur, depending on the plutonium content and the isotopic characteristics of the plutonium and uranium:

Contents No.	Pu/U+Pu	^{235}U enrichment level	Isotopic composition of plutonium (by mass)	Maximum weight of uranium-plutonium (kg)	Number of packages
10a	≤ 30 %	Any	5 % ≤ ^{240}Pu	14,2	25
10f	≤ 30 %	Any	5 % ≤ ^{240}Pu	20	7
10b	≤ 30 %	≤ 0,71 %	5 % ≤ ^{240}Pu	20	25
10d	≤ 30 %	Any	100% ^{239}Pu	1,5	10
10e	≤ 30 %	≤ 0,71 %	100% ^{239}Pu	20	10

2.9.1.2. Physical characteristics

The mixture may have any density.

2.9.1.3. Chemical form

Oxide

2.9.1.4. Special form

The material is not in a special form.

2.9.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 3.4% (by mass) of Americium 241 is permitted. If the mass of the materials is limited

to 17 kg the authorised percentage of ^{241}Am is 4.1% by mass.

2.9.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the mixture of (U,Pu)O2 is dependent on the internal fittings used:

- If the powder is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the powder is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - ➢ 20 W if using type AA41 tertiary packaging containers.
  - ➢ 71.4 W/m length of the secondary container if the tertiary packaging container is of type AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.9.1.7. Special provisions

If the water content is below 0.5% no particular measures are needed. When transporting materials with moisture levels of between 0.5 and 3.0% and/or materials packaged with vinyl covers, the particular measures detailed in Chapter 9 are applicable, limiting the time of transport with relation to the quantities of material and type of packaging used.

2.9.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the water content,
- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Water content of less than 0.5% - no covers

Inspection prior to transport (SLR) in Pa.m^3.s^{-1}	Specific activity in A2/g
2,66.10^{-4}	≤ 87
1,33.10^{-4}	≤ 175
6,65.10^{-5}	≤ 352
1,33.10^{-5}	≤ 1799

Water content of between 0.5 and 3% - no covers

Inspection prior to transport (SLR) in Pa.m^3.s^{-1}	Specific activity in A2/g
2,66.10^{-4}	≤ 13
1,33.10^{-4}	≤ 27
6,65.10^{-5}	≤ 54
1,33.10^{-5}	≤ 286

Water content of less than 0.5% - with covers

Inspection prior to transport (SLR) in Pa.m^3.s^{-1}	Specific activity in A2/g
2,66.10^{-4}	≤ 78
1,33.10^{-4}	≤ 158
6,65.10^{-5}	≤ 318
1,33.10^{-5}	≤ 1811

Water content of between 0.5 and 3% - with covers

Inspection prior to transport (SLR) in Pa.m^3.s^{-1}	Specific activity in A2/g
2,66.10^{-4}	≤ 12
1,33.10^{-4}	≤ 24
6,65.10^{-5}	≤ 49
1,33.10^{-5}	≤ 256

2.9.2. Internal fittings

The material must be packaged in internal fittings with a maximum diameter of 120 mm and a thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The materials **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [materials + possible primary packaging + possible secondary packaging] **must** then by placed inside an internal fitting made up of an enclosed tube fitted with sealed covers. Four types of internal fitting are available, depending on isotopic compositions: These containers are types TN 90, AA 204, AA 203 & AA 41.
- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.10. CONTENT NO. 11: SOLID URANIUM MATERIALS

These contents comprise uranium-based solids. The presence of traces of plutonium, in the order of grammes, is permitted.

2.10.1. Description

The uranium is non-irradiated and not from reprocessing sources.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is permitted.

2.10.1.1. Isotopic composition and masses

Any uranium 235 enrichment level can be used, but authorisation is granted for a single type of uranium material per package (single isotopic composition).

For transport by air: the maximum quantity of uranium 235 transported in a TN-BGC 1 package is 7 kg. In this case a quantity of 400 g of materials with a greater hydrogen content than water is authorised.

For all other modes of transport: the maximum quantity transported in a TN-BGC 1 package is dependent on the guaranteed containment diameter, which is summarised by the table below:

Contents No.	Presence of hydrogen-bearing materials with higher hydrogen quantity than water authorised*	Guaranteed containment diameter (mm)	^{235}U enrichment level	Maximum mass of ^{235}U (kg)	Number of packages
11a	Yes	$\varnothing \leq 120$	> 20 %	2	10
11b		$\varnothing \leq 100$	> 20 %	19,5	5
11c		$\varnothing \leq 120$	≤ 20 %	40	10
11d	No	$100 < \varnothing \leq 120$	> 20 %	7	50
11e		$60 < \varnothing \leq 100$	> 20 %	15	16
11f		$\varnothing \leq 60$	> 20 %	40	50
11g		$\varnothing \leq 120$	≤ 20 %	40	50
11h		$\varnothing \leq 115$	≤ 30 %	40	25

The hydrogen-bearing materials authorised for transport are polyethylene, polyurethane and PVC. The maximum mass of polyethylene is limited to 500 g.

In the event it proves impossible to guarantee a single isotopic composition per package, the mass limitations are as follows:

- If the uranium is enriched to more than 20%, the maximum transportable mass of uranium is 7 kg in the absence of materials with a higher hydrogen content than water and 2 kg in the presence of such materials;
- If the various uranium products are enriched to less than or equal to 20% the maximum transportable mass of uranium is 40 kg in the absence or presence of materials with a higher hydrogen content than water.

2.10.1.2. Physical characteristics

The material may have any density.

2.10.1.3. Chemical form

The material must be in one of the following chemical forms:

- Metallic Uranium,
- Uranium oxides: UO_2, UO_3, U_3O_8,
- Uranium tetrafluoride: UF4 ;
- Uranium nitrides: UN, U_2N_3, UN_2,
- Uranium carbides: UC, UC_2 and U_2C_3,
- Uranium, alloyed with the following metals: aluminium (Al), Molybdenum (Mo), Silicon (Si), Zirconium (Zr).

2.10.1.4. Special form

The material is not in a special form.

2.10.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2.10.1.6. Special provisions

When the material is in a metallic form, particular attention should be paid to the surface condition of the contents when loading into their packaging. The surface of the contents should be free of scoring or hydrides.

In the event that metallic powders are being transported, the powder packaging containers, the secondary containment and the TN-BGC1 cavity itself must all be 'inerted' at 1 bar absolute pressure, and a leak test must be carried out on the secondary containment package (leak rate below 1.33×10^{-5} Pam^3s^{-1}).

2.10.1.7. Specific activity

If the uranium is from reprocessing sources, the specific activity of the contents must be below 46 A_2/g.

2.10.2. Internal fittings

The metallic uranium powder is placed within primary packaging, which may be metal boxes, flasks or double-skinned polymer casings. These primary containment packages are placed inside the internal fittings.

Those internal fittings which can be used are TN 90, AA 204, AA 203 or AA 41.

In the event that the diameter required is less than 115 mm, the positioning and radial securing inside the TN 90 container is to be assured by E7 type spacers.

The following spacers should be used to hold the internal fittings in place within the package cavity:

- With the TN 90: Spacers E1 & E2,
- With the AA 204: Spacers E1 & E10 or E6,
- With the AA 203: Spacers E1 & E8,
- With 1 x AA 41: Spacers E1 & E11,
- With 2 x AA 41: Spacers E1, E12 & E13,
- With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fitting TN 90 is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.11. CONTENT 18: PLUTONIUM FLUORIDE

These contents comprise plutonium tetrafluoride powder, oxides of plutonium fluoride or a mixture of the two.

2.11.1. Description

The powder may be from reprocessing but must not have been irradiated after this reprocessing.

It should only contain trace quantities of carbon.

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.11.1.1. Isotopic composition and masses

Several cases are possible, depending on the isotopic characteristics of the plutonium:

- content 18a: the isotopic composition of the plutonium is such that 5 % ≤ ^{240}Pu (by weight). The maximum transportable quantity of plutonium oxide is 9 kg.
- Content 18b: the plutonium may have any isotopic composition. The maximum transportable quantity of plutonium oxide powder is 7 kg.

2.11.1.2. Physical characteristics of the powder

Max. powder density: 3,5.

2.11.1.3. Chemical form

The material is in the form of oxyfluorides and fluorides.

2.11.1.4. Special form

The material is not in a special form.

2.11.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 6% (by mass) of Americium 241 is permitted.

2.11.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the powder is dependent on the internal fittings used:

- If the powder is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the powder is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - 20 W if using type AA41 tertiary packaging containers.
  - 71.4 W/m length of the secondary container if the tertiary packaging container is of type

AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.11.1.7. Special provisions

If the water content is below 0.5% no particular measures are needed. When transporting powders with moisture levels of between 0.5 and 3.0% and/or powders packaged with vinyl covers, the particular measures detailed in Chapter 9 are applicable, limiting the time of transport with relation to the quantities of material and type of packaging used.

2.11.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the water content,
- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Water content of less than 0.5% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	**Specific activity in A2/g**
$2,66.10^{-4}$	**≤ 87**
$1,33.10^{-4}$	**≤ 175**
$6,65.10^{-5}$	**≤ 352**
$1,33.10^{-5}$	**≤ 1799**

Water content of between 0.5 and 3% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 13**
$1,33.10^{-4}$	**≤ 27**
$6,65.10^{-5}$	**≤ 54**
$1,33.10^{-5}$	**≤ 286**

Water content of less than 0.5% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 78**
$1,33.10^{-4}$	**≤ 158**
$6,65.10^{-5}$	**≤ 318**
$1,33.10^{-5}$	**≤ 1811**

Water content of between 0.5 and 3% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 12**
$1,33.10^{-4}$	**≤ 24**
$6,65.10^{-5}$	**≤ 49**
$1,33.10^{-5}$	**≤ 256**

2.11.2. Internal fittings

The powder must be packaged in internal fittings with a maximum diameter of 120 mm and a minimum thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The powder **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [powder + possible primary packaging + possible secondary packaging] **must** then by placed inside an internal fitting made up of an enclosed tube fitted with sealed covers (verifiable or otherwise). Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.

- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.12. CONTENT NO. 19: MIXED URANIUM-PLUTONIUM NITRIDES

2.12.1. Description

These contents comprise mixed uranium and plutonium nitrides in solid form (powders, pellets (possibly damaged), debris, etc. . .).

It should only contain trace quantities of carbon.

The total mass of the polymers (PVC or PE) in the package must be less than 372 g. The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.12.1.1. Isotopic composition and masses

The plutonium may have any isotopic composition and ^{235}U enrichment level.

The mixture may have any plutonium content.

The maximum acceptable weight is 4 kg.

2.12.1.2. Physical characteristics of the material

The maximum density of the pellets is equal to 100% of the maximum theoretical density (d=14).

2.12.1.3. Chemical form

The material is in the form of nitrides.

2.12.1.4. Special form

The material is not in a special form.

2.12.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 6% (by mass) of Americium 241 is permitted.

2.12.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the contents is dependent on the internal fittings used:

- If the material is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the material is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - ➢ 20 W if using type AA41 tertiary packaging containers.
  - ➢ 71.4 W/m length of the secondary container if the tertiary packaging container is of type

AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.12.1.7. Special provisions

If the materials are packaged using vinyl covers, the specific measures stated in Chapter 9 to limit transport times with respect to the quantities of material and type of packaging are applied.

The transportation of material in a finely divided particulate form (powders or shavings) is authorised as long as the package cavity is filled with an inert gas prior to transport.

2.12.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Absence of covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 87**
$1,33.10^{-4}$	**≤ 175**
$6,65.10^{-5}$	**≤ 352**
$1,33.10^{-5}$	**≤ 1799**

Covers present

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	**≤ 78**
$1,33.10^{-4}$	**≤ 158**
$6,65.10^{-5}$	**≤ 318**
$1,33.10^{-5}$	**≤ 1811**

2.12.2. Internal fittings

The material must be packaged in internal fittings with a maximum diameter of 120 mm and a thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The materials **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [powder + possible primary packaging + possible secondary packaging] **must** then by placed inside a stainless steel internal fitting made up of an enclosed tube fitted with sealed covers (checkable or not). Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.
- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 et 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.13. CONTENT NO. 20: METALLIC PLUTONIUM

The contents comprise plutonium in its metal state.

2.13.1. Description

The plutonium may be from reprocessing but must not have been irradiated after this reprocessing.

It should only contain trace quantities of carbon.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

The mass of polymers (PVC or polyurethane) within the package must be less than 372 g.

2.13.1.1. Isotopic composition and masses

The plutonium may have any isotopic composition. The maximum weight of the plutonium is 4 kg.

2.13.1.2. Physical characteristics

The contents are in a solid form.

2.13.1.3. Chemical form

Metal

2.13.1.4. Special form

The material is not in a special form.

2.13.1.5. Specific

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of 50 g or 6% (by mass) of Americium 241 is permitted.

2.13.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the material is dependent on the internal fittings used:

- If the material is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the material is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - 20 W if using type AA41 tertiary packaging containers.
  - 71.4 W/m length of the secondary container if the tertiary packaging container is of type

AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.13.1.7. Special provisions

If the materials are packaged using vinyl covers, the specific measures stated in Chapter 9 to limit transport times with respect to the quantities of material and type of packaging are applied.

The transportation of material in a finely divided particulate form (powders or shavings) is authorised as long as the package cavity is filled with an inert gas prior to transport.

2.13.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Absence of covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2{,}66.10^{-4}$	**≤ 87**
$1{,}33.10^{-4}$	**≤ 175**
$6{,}65.10^{-5}$	**≤ 352**
$1{,}33.10^{-5}$	**≤ 1799**

Covers present

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2{,}66.10^{-4}$	**≤ 78**
$1{,}33.10^{-4}$	**≤ 158**
$6{,}65.10^{-5}$	**≤ 318**
$1{,}33.10^{-5}$	**≤ 1811**

2.13.2. Internal fittings

The material must be packaged in internal fittings with a maximum diameter of 120 mm and a thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The materials **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [powder + possible primary packaging + possible secondary packaging] **must** then by placed inside a stainless steel internal fitting made up of an enclosed tube fitted with sealed covers (checkable or not). Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.
- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.14. CONTENT NO. 23: POWDERED OXIDES OF PLUTONIUM, URANIUM, NEPTUNIUM, AMERICIUM OR A MIXTURE OF THE ABOVE POWDERS

The contents comprise powdered oxides of plutonium, uranium, neptunium or americium (or a mixture of the above).

2.14.1. Description

These powders may be from reprocessing but must not have been irradiated after this reprocessing.

They should only contain trace quantities of carbon.

The americium must be from either irradiated fuel processing operations, with the exclusion of any other isotopic separation operation, or, from a process to remove americium from plutonium.

The neptunium should be from the processing of irradiated fuels and should not have been subjected to other isotopic separation operations.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

The mass of polymers (PVC or polyurethane) within the package must be less than 372 g.

2.14.1.1. Isotopic composition and masses

The uranium and plutonium may have any isotopic composition.

Mass limitations are in the following proportions:

- Mass of uranium - less than 200 g
- Mass of plutonium - less than 200 g
- Mass of (neptunium + americium) - less than 50g

2.14.1.2. Physical characteristics

Max. powder density: 3.5.

2.14.1.3. Chemical form

Oxide

2.14.1.4. Special form

The material is not in a special form.

2.14.1.5. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2.14.1.6. Maximum thermal power of the contents

The total maximum thermal power output by the powder is dependent on the internal fittings used:

- If the powder is packaged using Type TN 90 packages, the maximum total thermal power output is 340 W.
- If the powder is packaged using Type AA-41, AA 203 or AA 204 packages, the maximum total thermal power output is 170 W.
- If covers are used, the maximum total thermal power output of the contents is reduced to 80 W with a thermal power output per secondary container limited to:
  - 20 W if using type AA41 tertiary packaging containers.
  - 71.4 W/m length of the secondary container if the tertiary packaging container is of type AA203, AA204 or TN90.

The maximum thermal power density is 20 W/kg.

2.14.1.7. Special provisions

If the water content is below 0.5% no particular measures are needed. When transporting powders with moisture levels of between 0.5 and 3.0% and/or powders packaged with vinyl covers, the particular measures detailed in Chapter 9 are applicable, limiting the time of transport with relation to the quantities of material and type of packaging used.

2.14.1.8. Specific activity

The specific activity of the contents is limited with relation to:

- the water content,
- the presence or absence of covers,
- The leak rate (verified prior to shipping).

Limits are given in the tables below.

Water content of less than 0.5% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	≤ 87
$1,33.10^{-4}$	≤ 175
$6,65.10^{-5}$	≤ 352
$1,33.10^{-5}$	≤ 1799

Water content of between 0.5 and 3% - no covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	≤ 13
$1,33.10^{-4}$	≤ 27
$6,65.10^{-5}$	≤ 54
$1,33.10^{-5}$	≤ 286

Water content of less than 0.5% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	≤ 78
$1,33.10^{-4}$	≤ 158
$6,65.10^{-5}$	≤ 318
$1,33.10^{-5}$	≤ 1811

Water content of between 0.5 and 3% - with covers

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Specific activity in A2/g
$2,66.10^{-4}$	≤ 12
$1,33.10^{-4}$	≤ 24
$6,65.10^{-5}$	≤ 49
$1,33.10^{-5}$	≤ 256

2.14.2. Internal fittings

The material must be packaged in internal fittings with a maximum diameter of 120 mm and a thickness of 2 mm (TN 90, AA 204, AA 203, AA 41). The packaging principle is as follows:

- The materials **may** be placed inside sealed aluminium or stainless steel boxes (**primary packaging**). The primary packaging boxes may be enveloped in one or more heat-sealed plastic covers (PVC or Polyurethane). The number of covers is restricted to two per primary packaging box.
- These boxes **may** then be placed within **secondary packaging** made up of a box or tube (in stainless steel) with a press-fit, screw-fit or welded cover.
- The resulting assembly [powder + possible primary packaging + possible secondary packaging] **must** then by placed inside a stainless steel internal fitting made up of an enclosed tube fitted with sealed covers (checkable or not). Four internal fittings can be used. These containers are types TN 90, AA 204, AA 203 & AA 41.
- The following **spacers** should be used to hold the internal fittings in place within the package cavity:
  - With the TN 90: Spacers E1 & E2,
  - With the AA 204: Spacers E1 & E10 or E6,
  - With the AA 203: Spacers E1 & E8,
  - With 1 x AA 41: Spacers E1 & E11,
  - With 2 x AA 41: Spacers E1, E12 & E13,
  - With 3 AA 41: Spacers E1, E9 and 2 × E13.

The total mass of the whole load including internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.15. CONTENT NO. 26: TRIGA FUELS

These contents comprise non-irradiated bars of TRIGA fuel

2.15.1. Description

These bars are based upon U ZrHx (where x is between 0 and 2); they are in cylindrical form and are of one of two types - standard or thin, with the following geometric characteristics:

- Standard: Diameter 3.63 cm; length 12.7 cm,
- Thin: Diameter 1.29 cm; length 18.6 cm.

The uranium does not come from reprocessing.

The standard bars are holed, hydrogenated by the centre, the diameter of the hole is 6.35 mm.

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.15.1.1. Isotopic composition and masses

The maximum 235U enrichment level is 20%.

The mass content of the U_{total} varies between 8 and 47% depending on the type of element:

TYPE	U (% by mass)	ZrH_X (% by mass)	U-Zr (g/cm^3)	U-ZrH_2 (g/cm^3)
Composition of standard TRIGA fuel elements				
103	8	92	6,9	6,04
105	12	88	7,1	6,22
107	12	88	7,1	6,22
117	21	79	7,4	6,64
119	31	69	8,1	7,24
Composition of thin TRIGA fuel elements				
424	47	53	9,3	8,40

The maximum transportable quantities are given in the tables below.

- For **transport by air**: the maximum mass of uranium transportable in a TN-BGC 1 package is dependent on the type of fuel element as shown by the table below:

TYPE	Total mass of U (kg)
103	1,1
105	1,7
107	1,7
117	3,3
119	5,3
424	6,6

- For **other modes of transport**: the maximum mass of uranium transportable in a TN-BGC 1 package is dependent on the type of fuel element as shown by the table below, however, the maximum masses defined in Paragraph 2.15.2 for the loads applicable to internal fittings & packages must be respected:

TYPE	Total mass of U (kg)
103	9
105	14
107	14
117	27
119	43
424	76

2.15.1.2. Chemical form

Metal

2.15.1.3. Special form

The material is not in a special form.

2.15.1.4. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

2.15.1.5. Special provisions

For transport by air, the mass of water present with the fissile materials, independently of the hydrogen-bearing materials of the package, is less than 1200 g, or 1950 g, depending on whether they are 'standard' or 'thin' fuel elements.

2.15.2. Internal fittings

The TRIGA bars are placed inside cardboard protective tubes, which, in turn, are placed into the internal fittings.

Those internal fittings which can be used are TN 90, AA 204, AA 203 or AA 41. A primary packaging container (Type E7) can be used with the TN 90 when packaging uranium materials.

The following spacers should be used to hold the internal fittings in place within the package cavity:

- with the TN 90 : Spacers E1 + Spacer E2;
- with the AA 203 : Spacers E1 + Spacer E8;
- with the AA 204 : Spacers E1 + Spacer E10;
- with one AA 41 : Spacers E1 + Spacer E11;
- With two AA 41 : Spacers E1, + Spacer E12 + Spacer E13;
- With three AA 41 : Spacers E1, + Spacer E9 + 2 x Spacers E13;

The total mass of the whole load of internal fittings is restricted to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + internal fittings + cargo transported) is 116 kg.

2.16. CONTENT NO. 40: URANYL NITRATE

2.16.1. Definition of authorised radioactive contents

The contents are an aqueous solution of uranyl nitrate.

The aqueous solution has not been irradiated. The uranium can only be sourced from the reprocessing of UNGG type fuel (Uranium Natural Graphite-Gas).

In order to avoid the production of excess hydrogen within the package and its internal fittings, the uranyl nitrate solutions must not have been stored for more than 35 years in an AA 203 or TN 90 container prior to transport.

The presence of hydrogen-bearing materials (other than the flask containing the solution) with a hydrogen content greater than that of water is not permitted. For information, the PVC & polyurethane covers have lower hydrogen content than water (respectively 3.99×10^{22} & 4.74×10^{22} atm/cm^3 as opposed to 6.69×10^{22} atm/cm^3 for water).

2.16.1.1. Isotopic composition

The enrichment in ^{235}U (by mass) is less than or equal to 95%

The presence of the following impurities:

- Pu (*) limited to 0.010 g,
- 237Np limited to 0.015 g,

is permitted.

A quantity of 900 g de ^{232}Th is also permitted.

(*) *The quantity of ^{238}Pu must be below 150 µg.*

2.16.1.2. Maximum quantities

The maximum content quantity authorised for transport is 5 litres of aqueous solution (uranyl nitrate) for a total mass of uranium of less than or equal to 2000 g.

2.16.1.3. Specific Activity

The specific activity of the solution is less than or equal to 64 A_2/m^3.

2.16.1.4. Thermal power

The thermal power of the content is no more than 2.10^{-3} W.

2.16.2. Internal fittings

The flasks containing the uranyl nitrate solution must be packaged inside cylindrical internal fittings with a maximum diameter of 120 mm and a minimum thickness of 2 mm. The packaging principles are as follows:

- The uranyl nitrate solution must be placed within a flask (primary container) in polyethylene, with a mass of less than or equal to 900 g, then, it may be packaged in a double-skinned polymer casing with a lower hydrogen content than water (PVC or polyurethane). The maximum weight of these covers is 350 g.
- The primary container must be placed within Type AA 203 or TN 90 internal fittings, the cover on which is screwed down and fitted with silicon seals.
- The isolating metallic spacers (E3 & E3-203) must be used to position the internal fittings (TN90 & AA203) respectively within the package cavity.

Note: The primary containment flask may be inserted into a metallic basket.

The total mass of the whole load including internal fitting is restricted to 60 kg. The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + containers + cargo transported) is 116 kg.

2.17. CONTENTS NO. 41: AZUR PLATES

The contents comprise one or two tubes, each one containing a maximum of 30 plates. The two tubes are placed inside a TN90 internal fitting before being inserted into the TN-BGC1.

2.17.1. Definition of authorised radioactive contents

The AZUR plates are metallic fuel plates made of an U-Zr alloy, with its principal characteristics given in the table below:

Principal characteristics of an AZUR plate	
Form	Metal in U-Zr alloy
Irradiation	Low level irradiation
Dimensions	74 x 1.5 x 500 mm
Max. uranium mass	28 g
Total plate weight	330 g (± 10 g)
Max. uranium content (U/(U+Z))	8 %
Max. ^{235}U enrichment	91 %

The presence of hydrogen-bearing materials with a hydrogen content greater than that of water is not permitted.

2.17.2. Activity

The AZUR plates may have been subjected to low level irradiation. Activity readings from three plates were taken and are used to evaluate neutron and gamma DeR as well as the activity of the major isotopes. This data is listed below.

AZUR plate	Activity: ^{235}U (GBq)	Activity: ^{137}Cs (GBq)	DER gamma (µSv/h)	DER neutron (µSv/h)
Plate 506-10B	$1,68.10^{-3}$	$2,15.10^{-2}$	1400	120
Plate 506-18B	$1,65.10^{-3}$	$7,55.10^{-3}$	500	8
Plate 502-04A	$1,67.10^{-3}$	$1,67.10^{-2}$	1300	8

The specific activity of the contents is below 46 A_2/g.

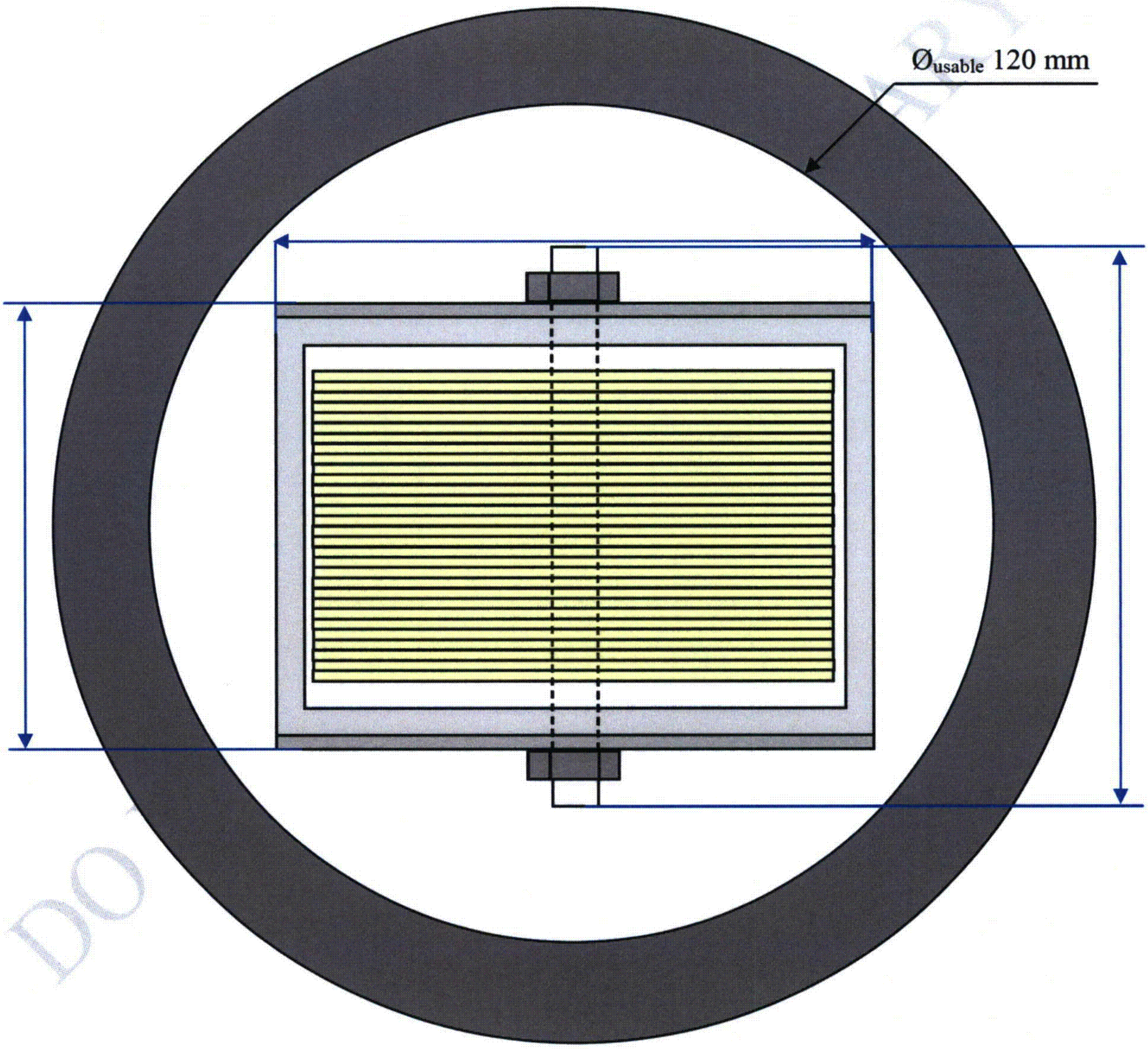
2.17.3. Thermal power

The thermal power of the contents is less than or equal to 10^{-3} W.

2.17.4. Internal fittings

The AZUR plates are packaged in 30s, in a stainless steel 304 L tube, 4 mm thick.

The tube is sealed using a plug, held in place by two bolts. The usable cross section of the tubes is 52x77 mm; the overall cross section is 80x85 mm (including plug bolts). The tubes have a maximum overall length of 535 mm. The assembly is shown in radial section on the diagram below.



The packaging tubes are inserted in pairs into a TN90 internal fitting, which, in turn is held in place within the TN-BGC1 cavity by E1 & E2 spacers.

The total mass of the whole load including internal fitting is restricted to 60 kg. The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (Spacers + containers + cargo transported) is 116 kg.

2.18. CONTENT NO. 42: MIXTURE OF URANIUM-BASED MATERIALS IN VARIOUS FORMS

2.18.1. Description

These contents comprise a mixture of uranium based materials in various forms. The uranium may be from reprocessing but must not have been irradiated after this reprocessing.

The presence of materials other than those included in the appendix (contents and internal fittings) is not authorised, specifically the presence of powdered metallic thorium.

Several cases are possible, depending on the physico-chemical nature of the contents.

2.18.1.1. Contents 42a

Chemical form

The material may be present in the following forms:

- Uranium oxides - UO2, U3O8;
- UO2F2;
- Ammonium diuranate (ADU)
- mixture of various chemical forms.

The presence of thorium, in metal or oxide form, alloyed or mixed closely with the uranium, is authorised in all quantities. The thorium is mainly in the form of isotope 232.

Isotopic composition, masses, packaging and number of packages permitted.

Contents No.	Guaranteed containment diameter (mm)	Thickness of IA guaranteeing containment	Max. uranium enrichment level	Maximum weight of uranium (kg)	Number of packages
42a1	∅ ≤ 120	2 mm	Any	2,4	8
42a2	∅ ≤ 115	2 mm	94%	3,066	Infinite
42a3	∅ ≤ 127	2 mm	87 %	2,801	1
42a4	∅ ≤ 115	2 mm	85%	4,082	Infinite
42a5	∅ ≤ 120	2 mm	60%	13,285	10
42a6	∅ ≤ 115	2 mm	27%	11	Infinite
42a7	∅ ≤ 120	2 mm	20%	60*	10
42a8	∅ ≤ 120	2 mm	70%	3,327	10

* without prejudicing the maximum load mass for internal fittings - also limited to 60 kg (See Section 2).

Physical characteristics

The maximum density of the fissile materials is 10.96.

Special form

The material is not in a special form.

Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

Specific activity

In the event the uranium is reprocessed, the specific activity of the contents must be below 46 A_2/g.

2.18.1.2. Contents 42b

Chemical form

The material may be present in the following forms:

- Metallic Uranium;
- Alloys of uranium and aluminium;
- Mixtures of metallic uranium and oxides.

The presence of thorium, in metal or oxide form, alloyed or mixed closely with the uranium, is authorised in all quantities. The thorium is mainly in the form of isotope 232.

Isotopic composition, masses, packaging and number of packages permitted.

Contents No.	Guaranteed containment diameter (mm)	Thickness of IA guaranteeing containment	Max. uranium enrichment level	Maximum weight of uranium (kg)	Number of package s
42b1	∅ ≤ 120	2 mm	Any	2	10
42b2	∅ ≤ 115	2 mm	94%	2,906	Infinite
42b3	∅ ≤ 120	2 mm	93 %	2,5	10
42b4	∅ ≤ 115	2 mm	35%	6,811	Infinite
42b5	∅ ≤ 120	2 mm	20%	60*	10
42b6	∅ ≤ 130	6 mm	94%	Disks with a diameter of 130 mm and a thickness of 51 mm (max. mass of U = 12970 g).	5

Note: Mixtures of different 42b contents are not permitted.

* without prejudicing the maximum load mass for internal fittings - also limited to 60 kg (See Section 2).

Physical characteristics

Any density

Special form

The material is not in a special form.

Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

Specific activity

In the event the uranium is reprocessed, the specific activity of the contents must be below 44 A_2/g.

2.18.2. Internal arrangements

The contents are placed within primary packaging, which may be metal boxes, flasks or polymer casings. The packaging of sub-contents 42b6 in flasks or casings with a higher hydrogen content than water is forbidden.

Primary packaging may be placed inside secondary packaging comprising a box or metallic tube. The resulting assembly [radioactive material + primary packaging + secondary packaging] must then by placed inside a stainless steel internal fitting made up of an enclosed tube fitted with sealed covers (checkable or not).

Five different internal fittings can be used. The cylindrical containers are types AA 41; AA 203; AA 204; TN 90 or TN 90 Type 2. Their safety-related characteristics are listed below:

AI	Int. diameter (mm)	E (mm)
AA-41 - AA203 - AA204	115	2
TN90	120	2
TN90 type 2	130	6

The following spacers should be used to position and secure the tertiary packing container in the packaging cavity:

- with the TN 90 : Spacers E1 & E2;
- with the AA 204 : Spacers E1 & E10 or E6;
- with the AA 203 : Spacers E1 & E8;
- with 1 x AA 41 : Spacers E1 & E11;
- with 2 x AA 41 : Spacers E1, E12 & E13;
- with 3 x AA 41 : spacers E1, E9 and 2 × E13 ;
- with the TN90 type 2 : Spacer E1.

The total mass of the assembly of the internal fittings (AA41, AA203, AA204, TN90 and TN90 - Type 2

(materials + primary & secondary packaging) must be, at the most, equal to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (material being transported, primary/secondary/tertiary packaging & Spacers) is 116 kg.

2.19. CONTENT NO. 46: PLUTONIUM SOURCES

2.19.1. Description

Content No. 46 comprises plutonium sources. The plutonium may be in the form of:

- Metallic alloys - PuSc,
- PuO_2,
- or a mixture of these varied forms.

2.19.1.1. Isotopic composition, masses and number of packages permitted.

The characteristics of the contents are given in the table below:

Isotopic composition of plutonium (by mass)	Maximum mass of Plutonium (g)
$88\% \leq {}^{238}Pu/Pu\ tot \leq 94\%$ ${}^{239}Pu \leq 12\%$	180

2.19.1.2. Physical characteristics

The maximum density of the fissile materials is 19.86.

2.19.1.3. Activity

The activity of the contents must be such that, given the nature and energy of the radiation emitted, the regulatory limits for dose-rates around the package are not exceeded.

The presence of Americium 241 is permitted.

2.19.1.4. Specific activity

The specific activity is limited with relation to the leak rate checked prior to shipping.

Inspection prior to transport (SLR) in $Pa.m^3.s^{-1}$	Maximum specific activity in A2/g
$2,66.10^{-4}$	**87**
$1,33.10^{-4}$	**175**
$6,65.10^{-5}$	**352**
$1,33.10^{-5}$	**1799**

2.19.1.5. Thermal power

The total thermal power is limited to 100 W.

This is limited to 34 W per tertiary packaging container.

The specific thermal power of the contents is less than 556 W/kg.

2.19.2. Internal fittings

The contents may be packaged inside capsules made up of 2 or 3 metallic envelopes (tantalum, platinum-iridium, etc.) placed inside a primary package comprising boxes, pots or metallic tubes. The contents and any eventual primary packaging may be placed inside a secondary container - Type AA99.

The resulting assembly (radioactive materials + primary packaging + secondary packaging) is then placed inside the stainless steel internal fittings.

Their safety-related characteristics are listed below:

Int. diameter (mm)	E (mm)	Material
115	2	Z2 CN 18-10

The following spacers should be used to position and secure the tertiary packing container in the packaging cavity:

- with the TN 90 : Spacers E1 & E2;
- with the AA 204 : Spacers E1 & E10 or E6;
- with the AA 203 : Spacers E1 & E8;
- with 1 x AA 41 : Spacers E1 & E11;
- with 2 x AA 41 : Spacers E1, E12 & E13;
- with 3 x AA 41 : Spacers E1, E9 and 2 × E13.

The total mass of the whole internal fitting load (material + primary & secondary packaging) must be, at the most, equal to 60 kg.

The maximum permissible mass of the whole load within the cavity of the TN-BGC 1 package (material being transported, primary/secondary/tertiary packaging & Spacers) is 116 kg.

3. DESCRIPTION OF THE INTERNAL FITTINGS

Each of the contents is packaged inside one or more internal fittings, held in place by a system of spacers.

The currently known internal fittings and their chock systems are detailed below.

Note: This list is not exhaustive. Any internal fittings with designs similar to those described may be used.

They must:

- be in stainless steel (Z2 CN 18.10 or Z6 CN 18.09), with the minimum mechanical characteristics detailed below (See Table 1)
- have an internal diameter less than or equal to 115 mm (120 mm for the TN90)
- have a shell 2 mm thick
- be fitted to a sealing assembly identical to that of the TN90, AA204, AA203 or AA41.

In addition, it must be held in position radially by suitable spacers in AG3 or AU4G, assuring:

- centring within the package cavity
- no offset impacts of the internal fittings against the plug of the package when dropped.

The currently known secondary containment packaging which is compatible for use with the TN-BGC 1 is presented in Figures 1 & 2.

The various currently known internal fittings for use with the TN-BGC 1 are presented in Figures 3 & 4.

The spacers and chocks used to hold the internal fittings in place (axially & radially) within the cavity are presented in Figures 5 to 15.

The minimum mechanical and thermal properties of the principal component materials are given in Table 1.

Table 2 details the volumes of the TN-BGC 1 cavity and the various internal fittings in use. Table 3 gives their weights.

TABLE 1: MECHANICAL AND THERMAL CHARACTERISTICS OF THE PRINCIPAL MATERIALS USED IN THE INTERNAL FITTINGS

	Temperature (°C)	Yield strength (MPa)	Rupture limit (MPa)	Stretch at break (%)	Thermal conductivity (W/m.K)	Specific Heat Capacity (J/kg.K)	Emissivity figure for cavity walls
Stainless steel	40°	≥ 172	≥ 448				
Z2 CN 18.10	200°	-	≥ 404				
(or equivalent)	240°	≥ 115	≥ 400	≥ 20	≥ 15	≥ 502	0,5
	250°	≥ 108	≥ 400				
	300°	≥ 100	≥ 395				
	340°	-	≥ 390				
Stainless steel	150°	>142	>420				
Z6 CN 18.09	200°	>127	≥ 400				
Aluminium AG3 /	40°	≥ 250	≥ 390				
AU4G	140°	≥ 125	≥ 110	-	≥ 134	≥ 962	≥ 0,55
(or equivalent)	190°	≥ 90	≥ 60				
	260°	≥ 50					

TABLE 2: VOLUMES OF INTERNAL FITTINGS AND SPACERS

Internal fittings	Volume (l)
Cavity TN-BGC 1	37,6
Spacer E1	9,4
Spacer E2	3,2
Spacer E6	0,9
Spacer E10	2,5
Spacer E8	2,1
Spacer E11	2,8
Spacer E12	1,9
Spacer E13	0,15
Spacer E9	1,3
Exterior - TN 90	17,9
Interior - TN 90	15,8
Exterior - AA 204	12,9
Interior - AA 204	11,6
Exterior - AA 203	8
Interior - AA 203	7
Exterior - AA 41	3,8
Interior - AA 41	3,2
AA 99	2

Note: by 'exterior volume' we mean the 'overall volume' of the container, thus the sum of its internal volume and the volume of the walls.

TABLE 3: MASSES OF INTERNAL FITTINGS AND SPACERS

INTERNAL FITTINGS	WEIGHT (KG)
Spacer E1	24
Spacer E2	8,5
Spacer E6	3
Spacers E3 & $E3_{-203}$	3,5
Spacer E7	11,5
Spacer E10	6,8
Spacer E8	15,5
Spacer E11	20,1
Spacer E12	16,5
Spacer E13	0,26
Spacer E9	2,75
TN 90	13,5
AA 204	9,8
AA 203	7,2
AA 41	4,9
AA 99	0,4
AA 213	5,3

These results are given for information purposes only.

FIGURE 1: DIAGRAM SHOWING AA99 CONTAINER

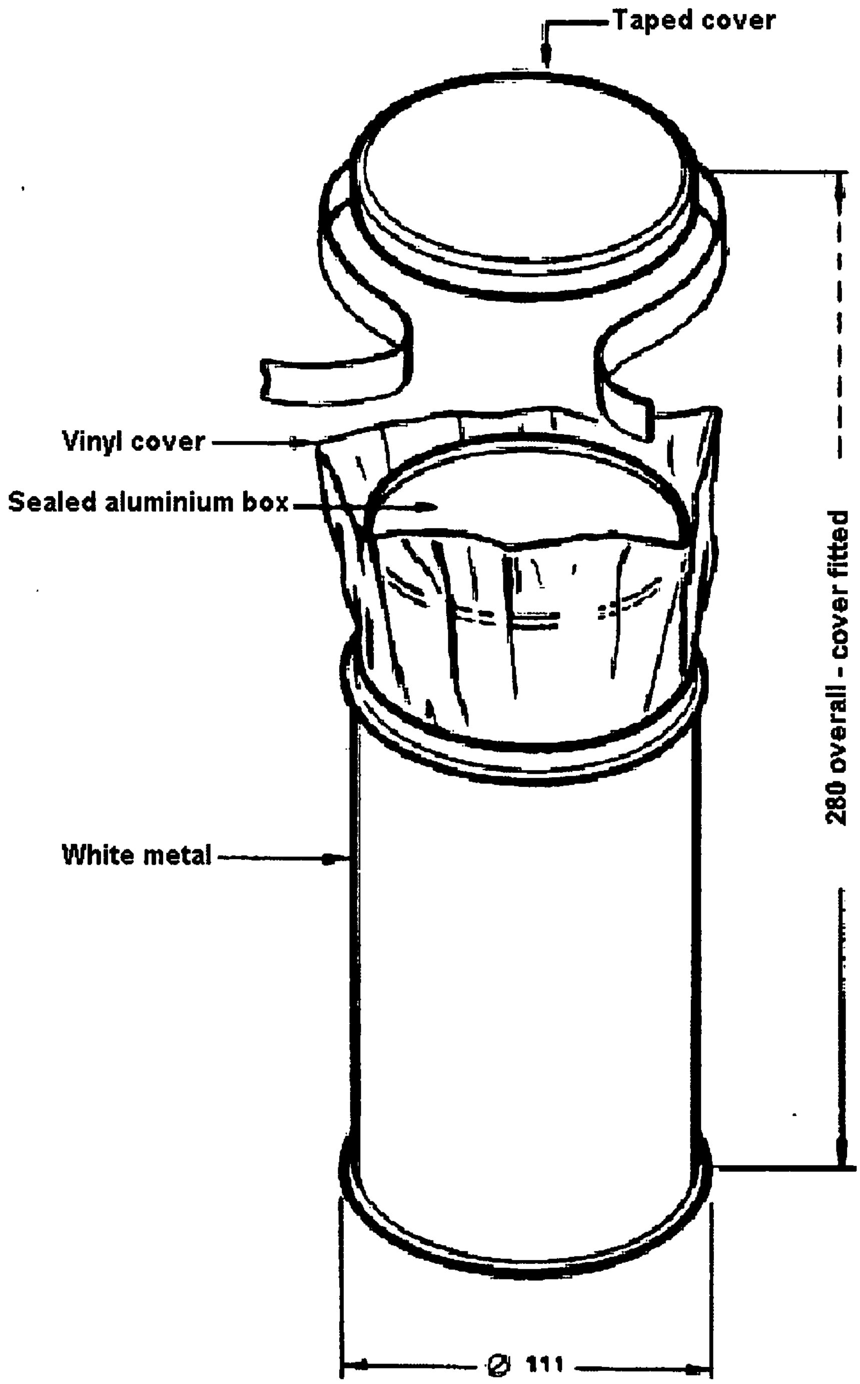


FIGURE 2: DIAGRAM OF THE AA 213

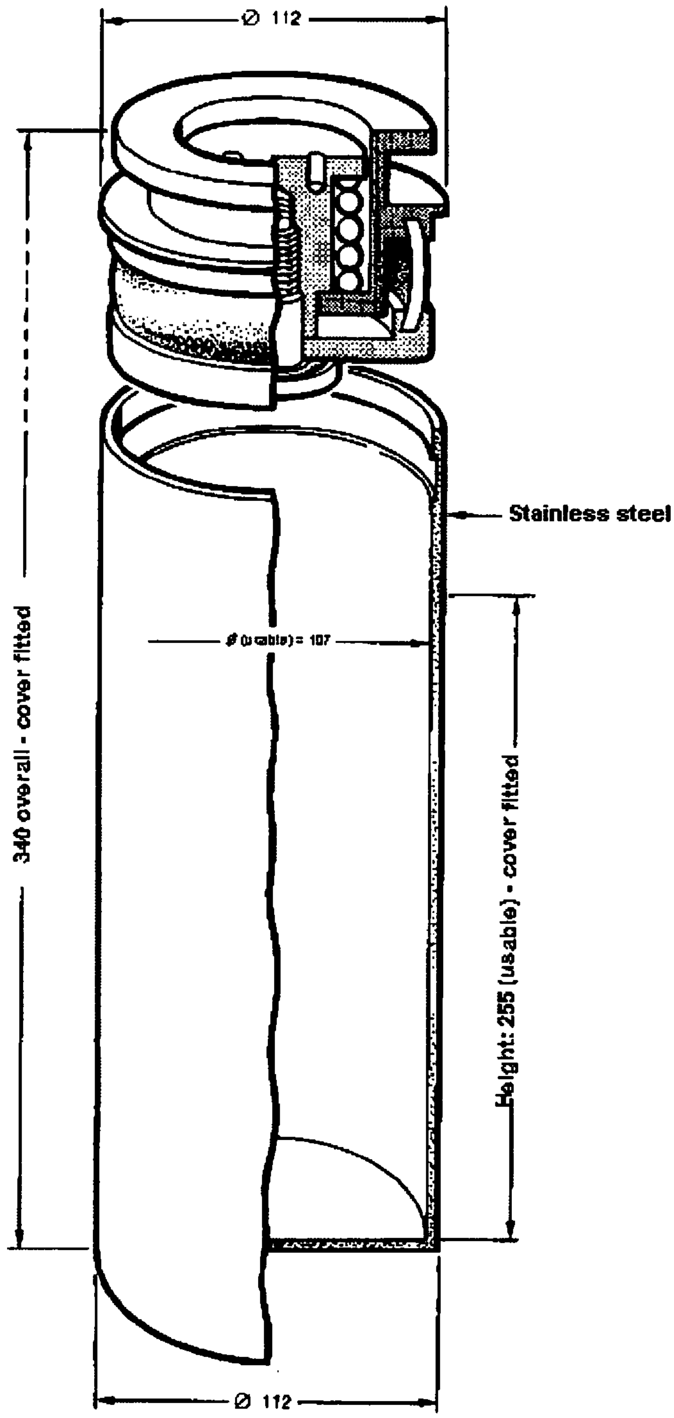


FIGURE 3: DIAGRAM OF THE TN 90

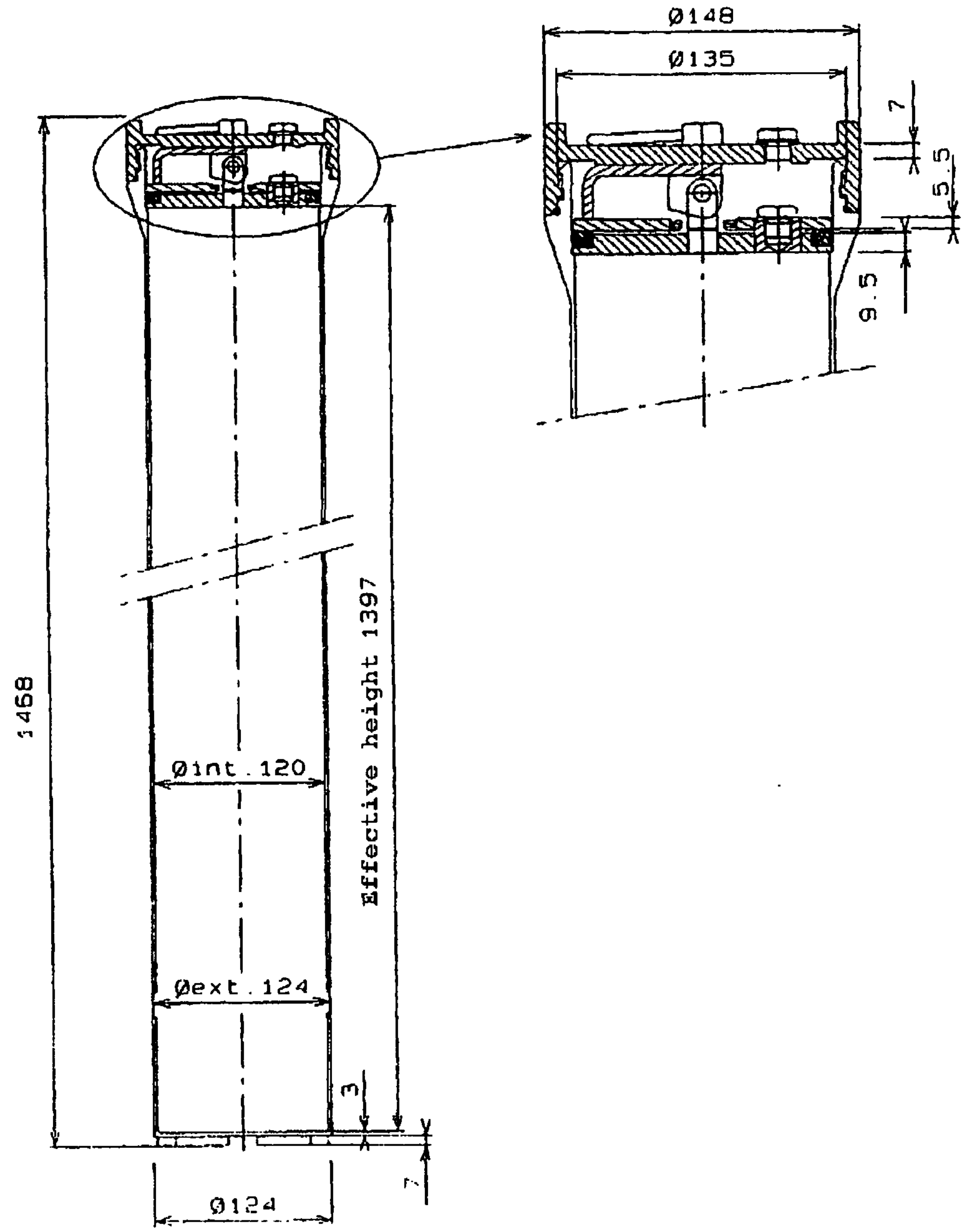
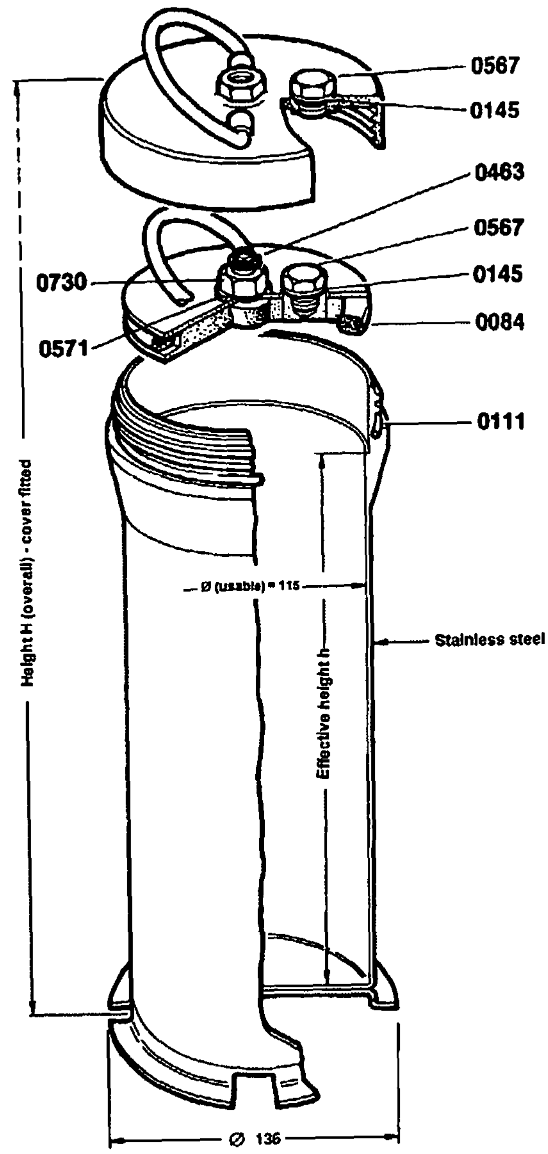


FIGURE 4: DIAGRAMS OF THE AA41 – AA203 & AA204



SPARE PARTS

0084 Inner cover seal
0111 Outer cover seal
0145 Plug seal
0463 Retaining ring
0567 Plug
0571 Washer
0730 Nut

ACCESSORIES

0304 1 Leaktightness test connector
0321 1 Additional connector (0304)

GENERAL CHARACTERISTICS

TYPE	h mm	H mm	MASS kg	USED in
AA-41	319	384	4,9	FS-51.55
AA-203	693	758	7,2	
AA-204	1 135	1 200	9,8	FS-52

FIGURE 5: DIAGRAM OF SPACER E1

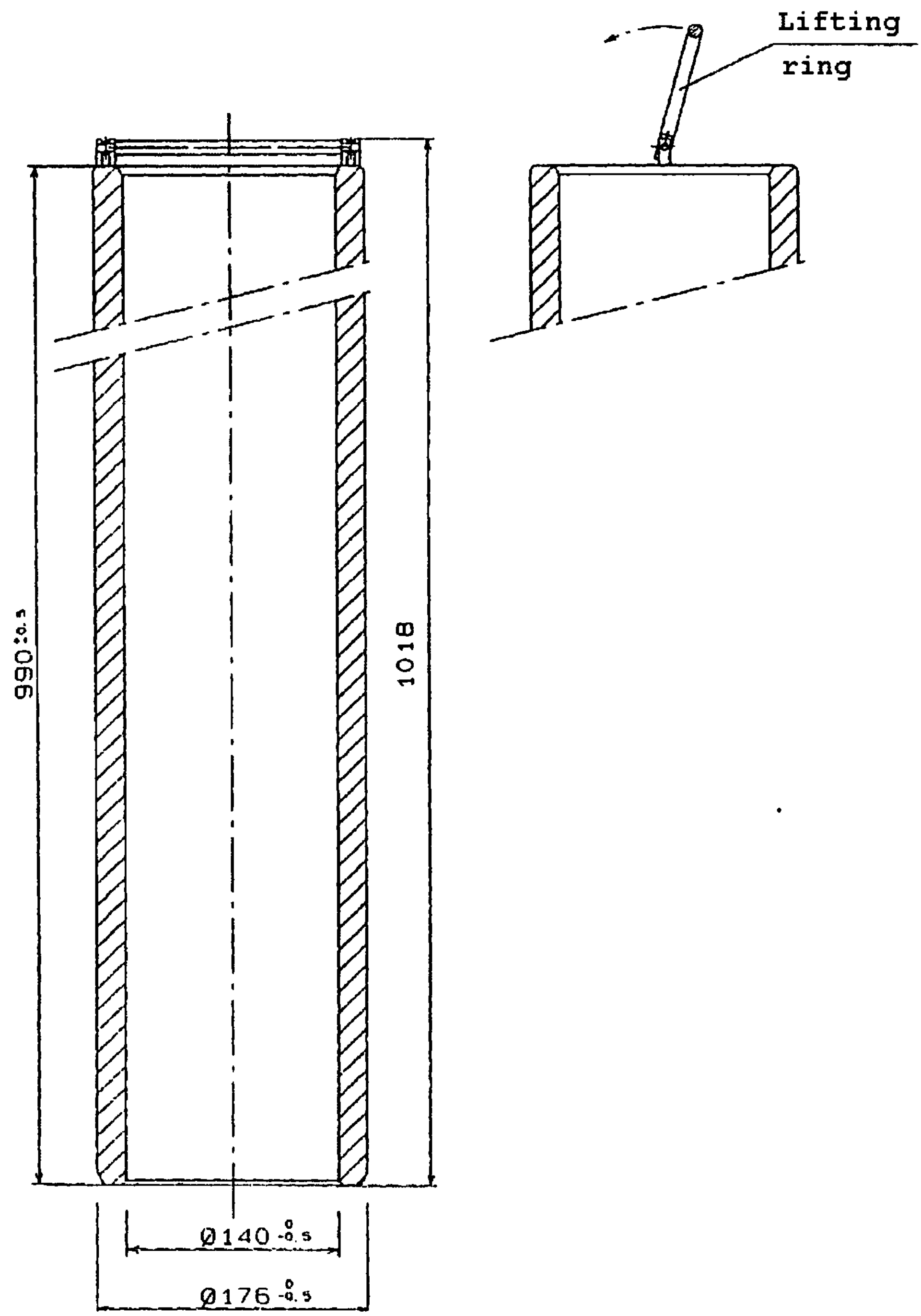


FIGURE 6: DIAGRAM OF SPACER E2

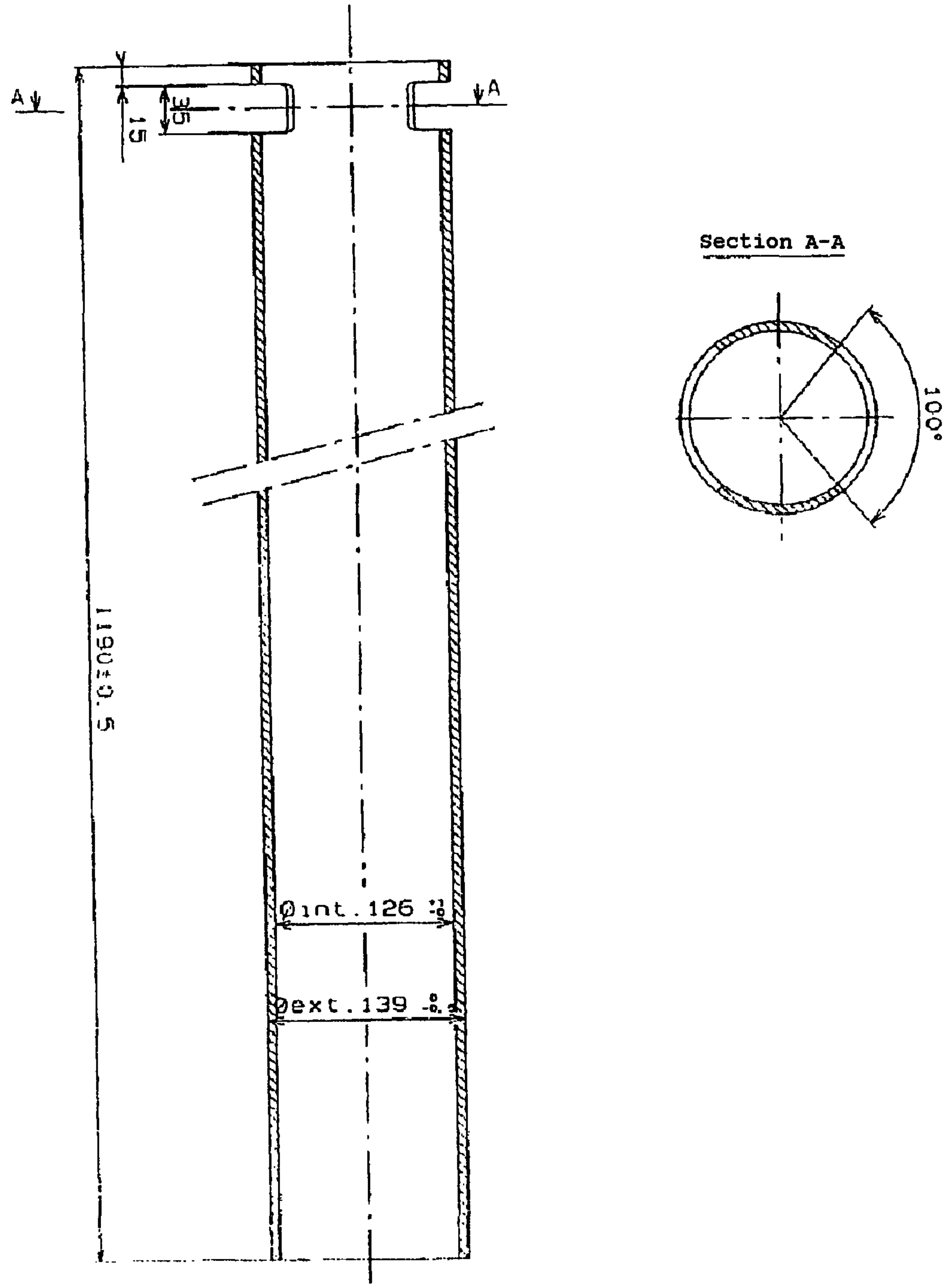


FIGURE 7: DIAGRAM OF SPACER E3 FOR TN90

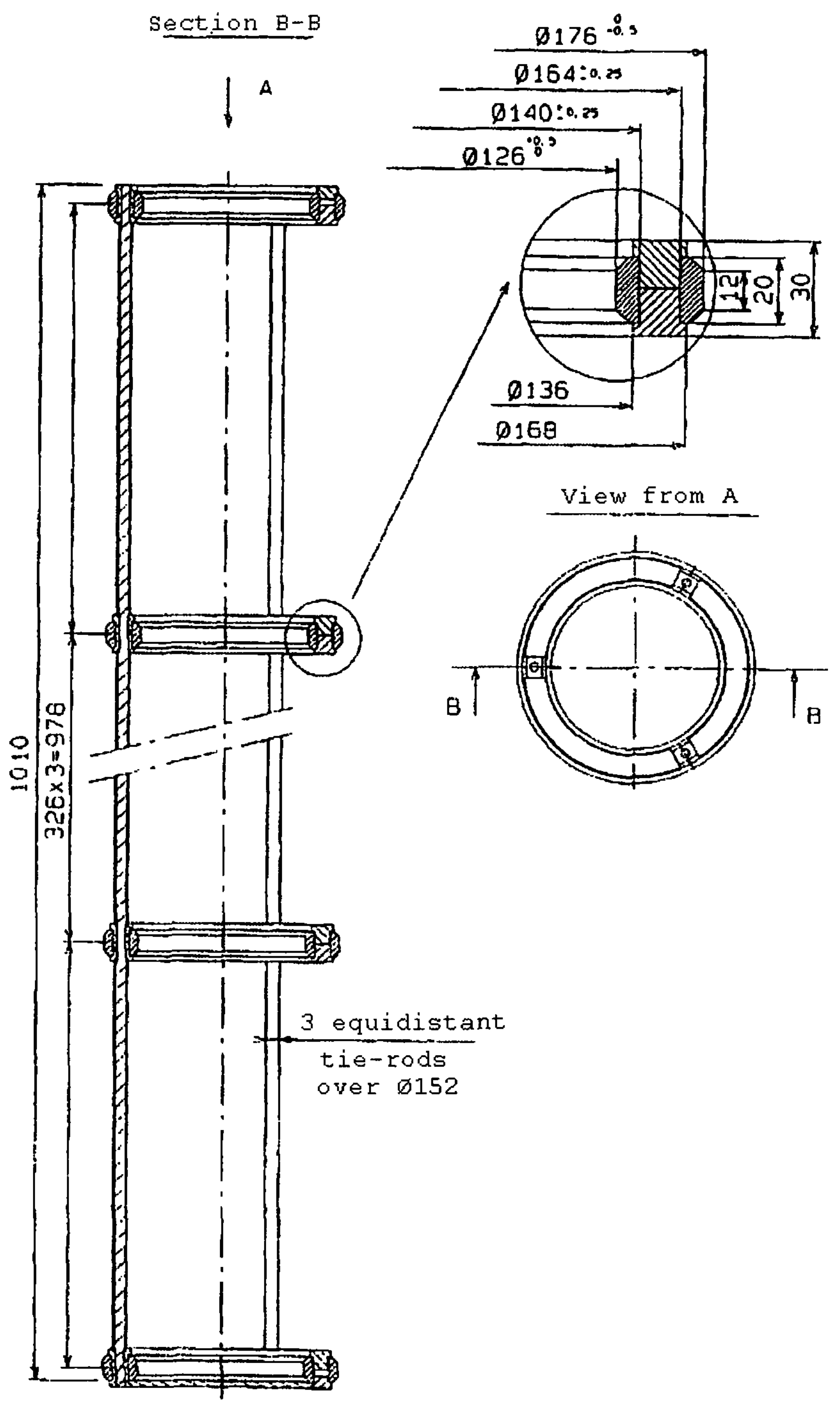


FIGURE 8: DIAGRAM OF SPACER E3-203 FOR AA203

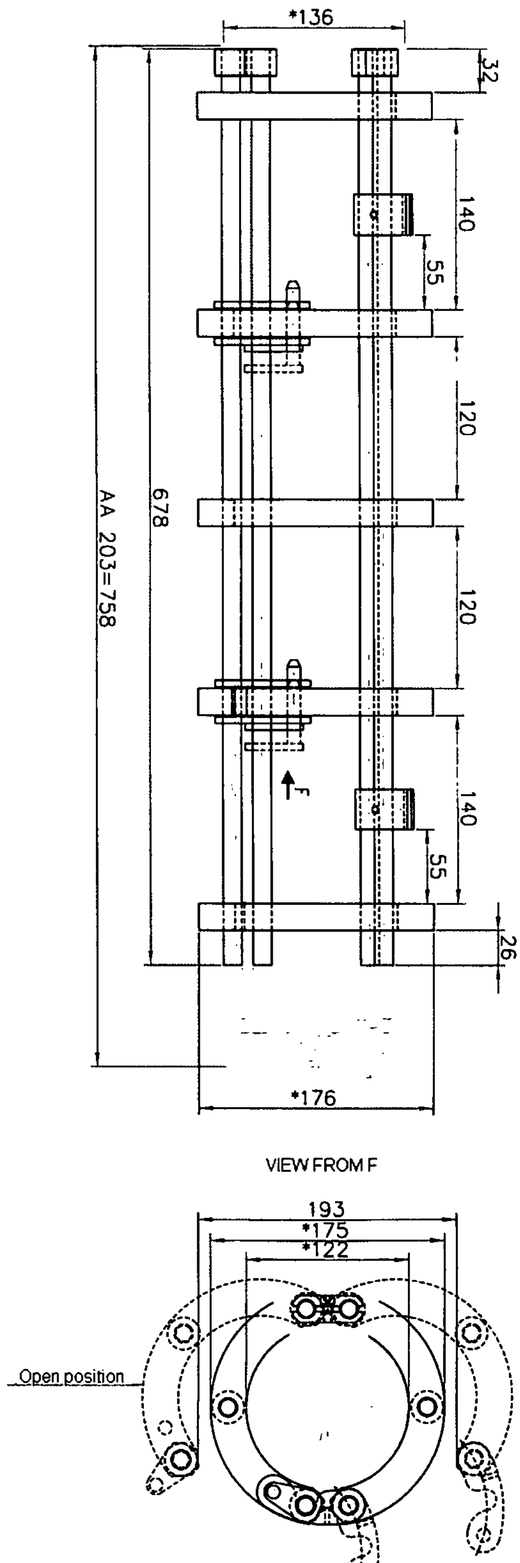


FIGURE 9: DIAGRAM OF SPACER E4

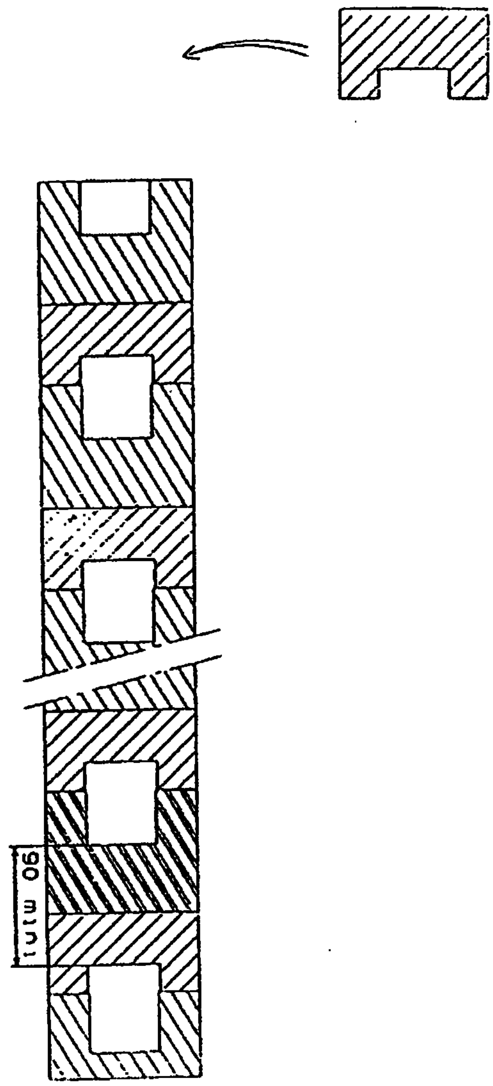


FIGURE 10: DIAGRAM OF SPACER E5

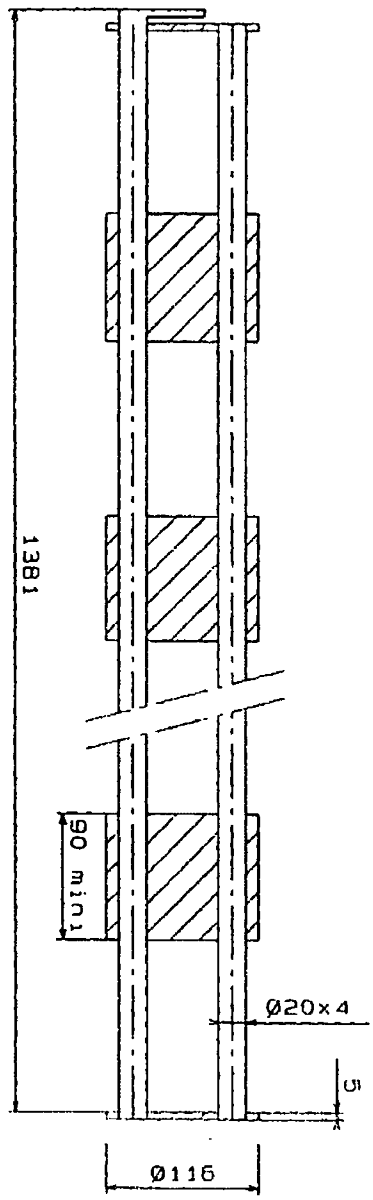


FIGURE 11: DIAGRAM OF SPACER E6

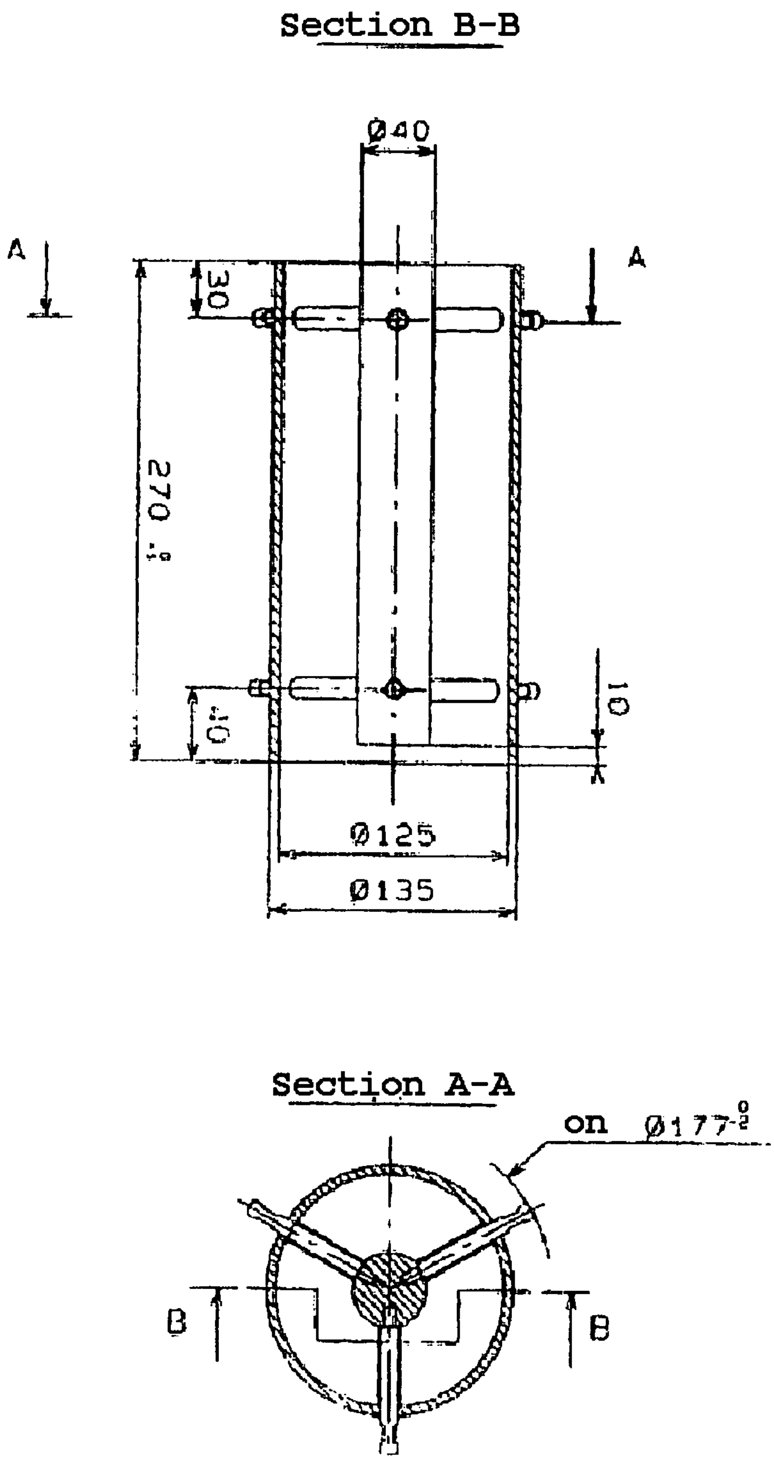


FIGURE 12: DIAGRAM OF SPACER E7

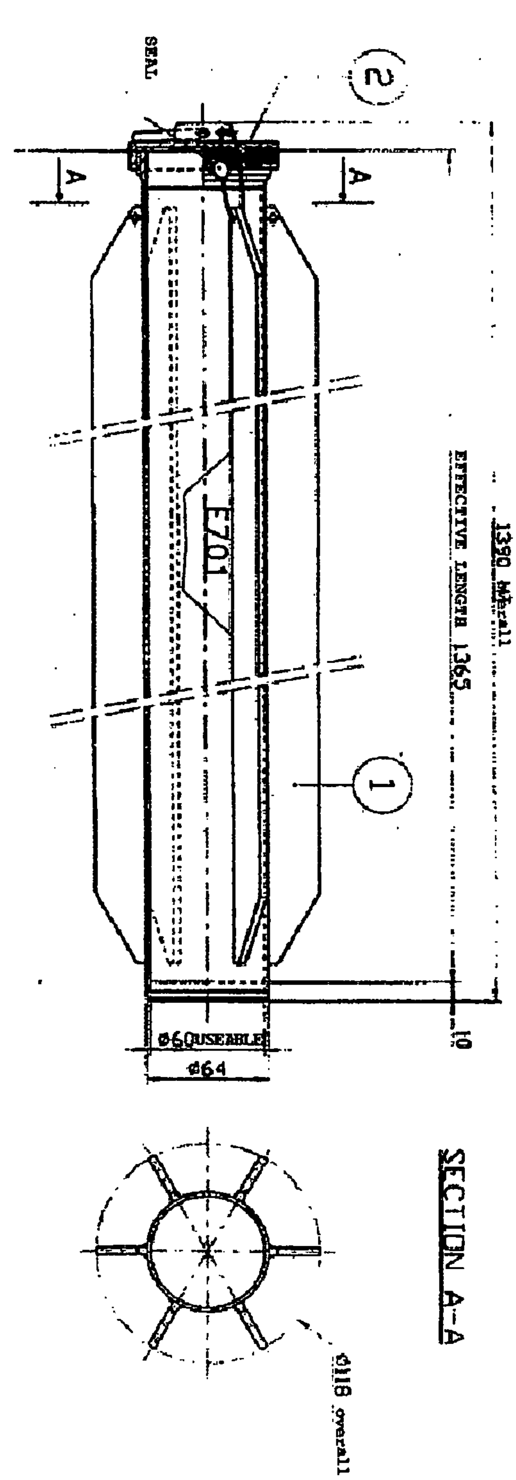
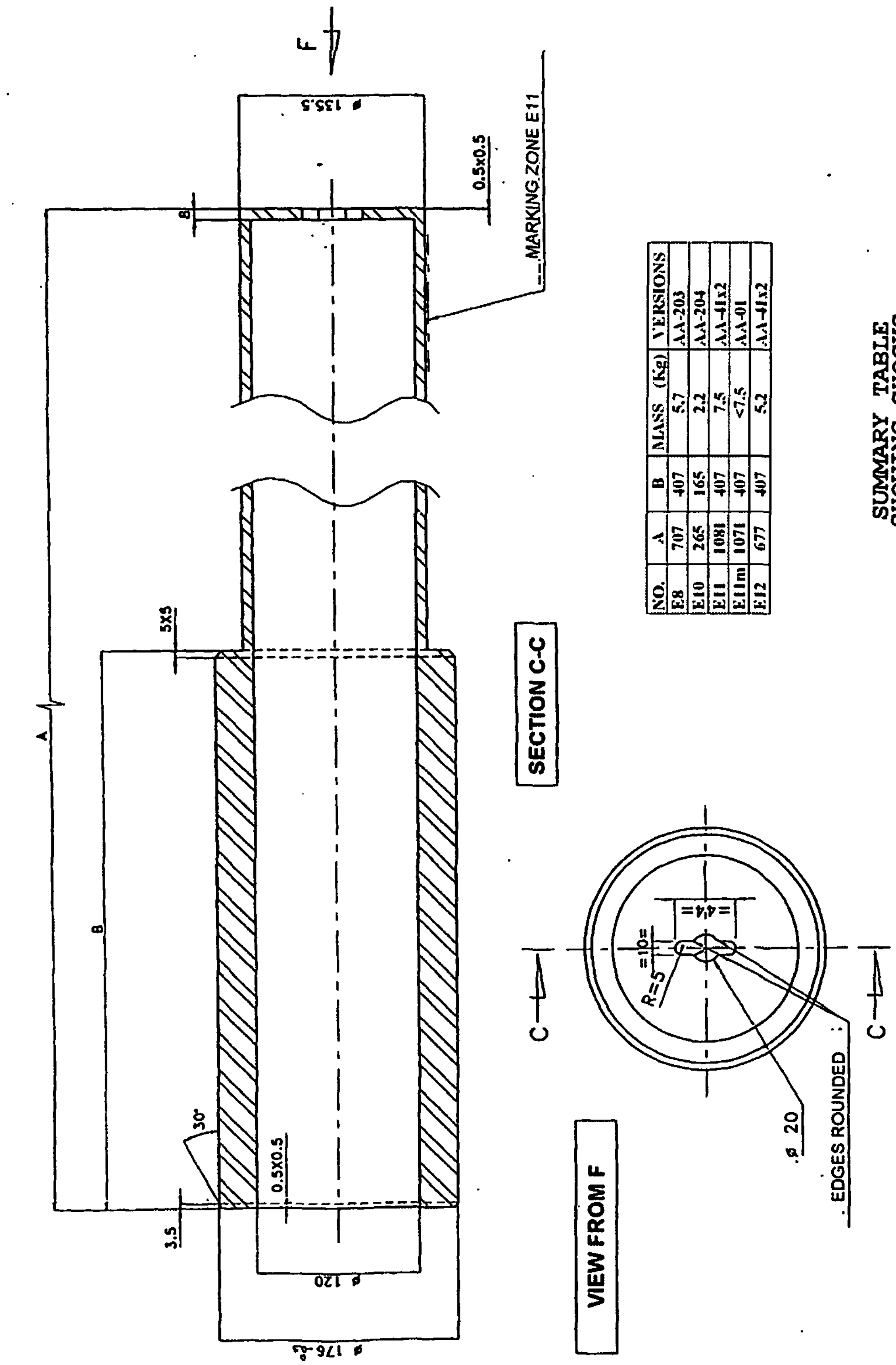


FIGURE 13: DIAGRAM OF SPACERS E8 - E10 - E11 - E12



NO.	A	B	MASS (Kg)	VERSIONS
E8	707	407	5.7	AA-203
E10	265	165	2.2	AA-204
E11	1081	407	7.5	AA-41x2
E11m	1071	407	<7.5	AA-01
E12	677	407	5.2	AA-41x2

SUMMARY TABLE
SHOWING CHOCKS

FIGURE 14: DIAGRAM OF SPACER E9

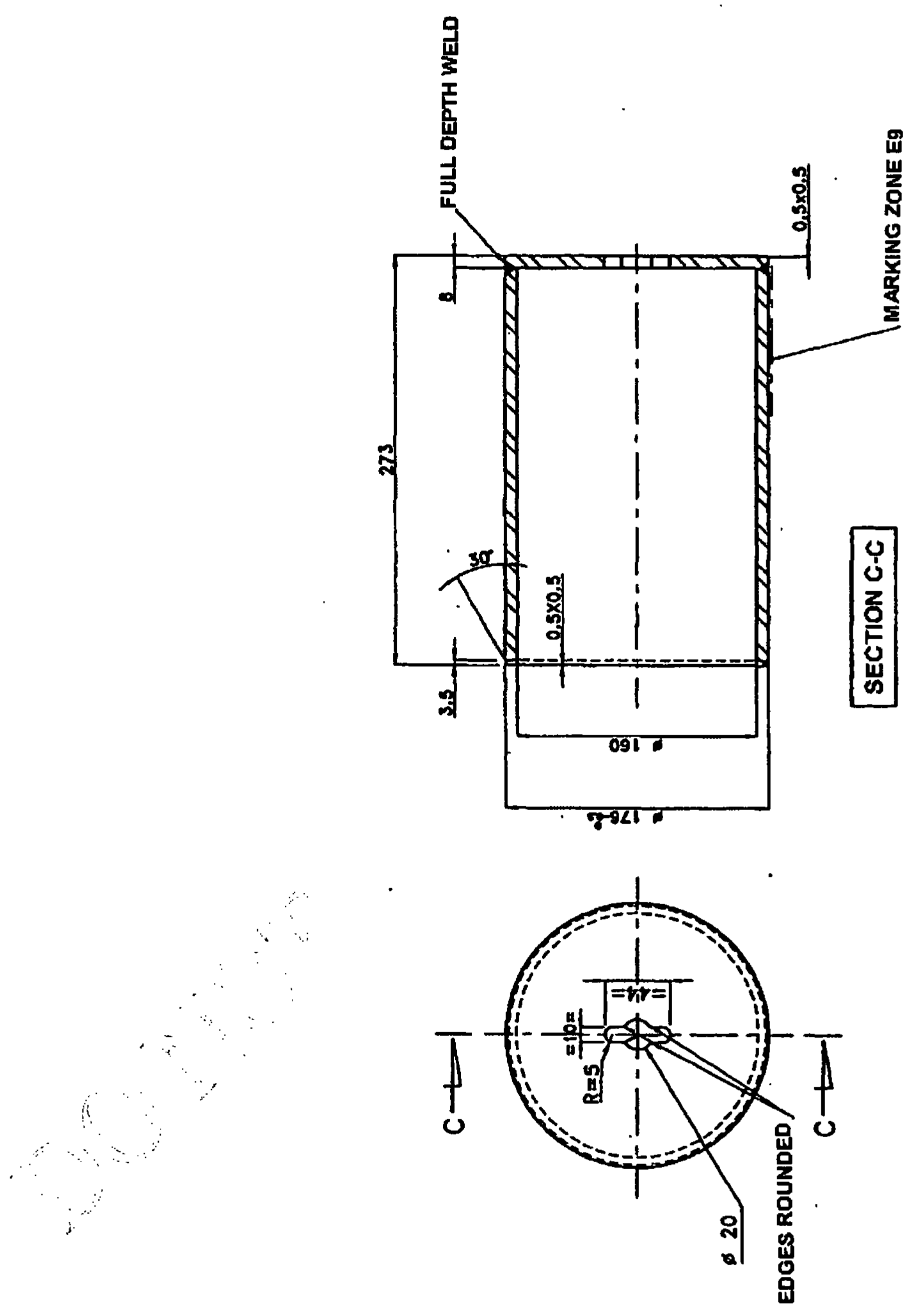
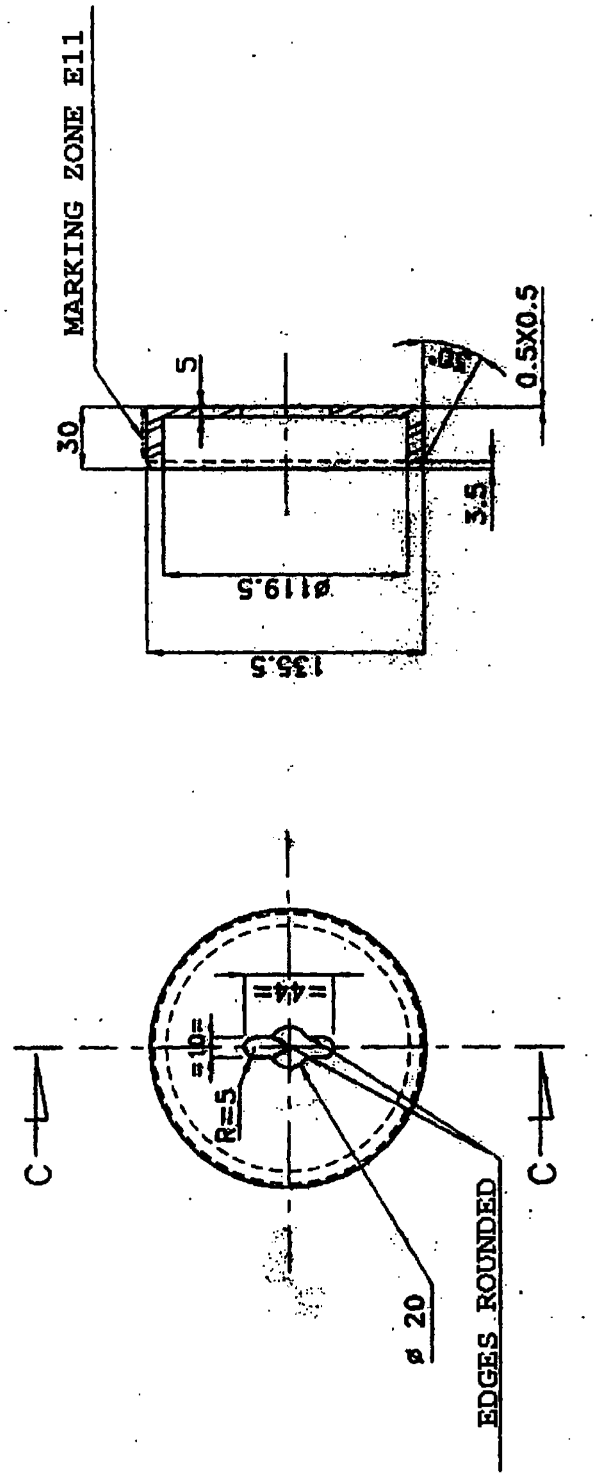


FIGURE 15: DIAGRAM OF SPACER E13



Nuclear Energy Division
Nuclear Services Department
Radioactive Materials Transportation Service
Packaging Operations Laboratory

Safety Analysis Report
TN-BGC 1 package
Chapter 2 – description of the package

Clt: 7.1.1.3.

Classification: DO

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SIGN.			Date:

TABLE OF CHANGES

VERSION	DATE	AUTHOR	TYPE OF CHANGE	NB PAGES
01	17/07/12	V. PAUTROT	Initial issue	20

LIST OF ATTACHED DOCUMENTS

(independent pagination, identification and formalism)

No.	TITLE	NB PAGES
1	Plan 9990-65 version C - overall Plan 9990-118 version B – cage Plan 9990-117 version B – assembled plug	3
2	Plan EMB TNBGC PBC PDC CA 01,0001 A dated 02/06/09	1

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1. INTRODUCTION

The TN-BGC 1 package is provided for the transport and storage of fissile material in very varied forms such as ingots of plutonium or metallic uranium, powders consisting of plutonium oxide or highly enriched uranium, and liquids such as uranyl nitrate. The fissile material is always contained in packaging (see chapter 1) that is placed in the cavity of the TN-BGC 1 package.

This chapter supplies a brief description of the package and all the characteristics (dimensions, materials,...) that are relevant to the safety evidence provided in the rest of the report.

2. CONCEPT DRAWINGS FOR THE PACKAGING

The TN-BGC 1 package is represented in the concept drawings supplied in attachment n° 1. These drawings specify:

- the dimensions and tolerances related to the use of the packaging and the safety analysis contained in this report,
- the identification references for the various components. These references will be used in the rest of this report.

3. GENERAL DESCRIPTION

The TN-BGC 1 package model is composed of:

- a **cage** for which the structure is formed of tubes made of welded aluminium,
- a **body** receiving, in its cavity, one of the internal fittings described in chapter 1; this body is composed of a shell and a base, surrounded by a mixture based on resin providing neutron and thermal protection, and includes, in its base, a wooden shock-absorber; the body is connected to the cage by fixing lugs welded to the body and screwed on to the cage,
- a **closure system** for the cavity of the body, composed essentially of a plug, a bronze tightening ring and a bayonet ring,
- a shock-absorbing **cover** protecting the package in case of a drop on the plug side.

The main dimensions are as follows (see figure 1):

- overall dimensions of the cage:
  - length: 600 mm,
  - width: 600 mm,
  - height: 1821 mm,
- overall dimensions of the body fitted with its cover:
  - diameter of the body in the part remote from discontinuities or openings: 295 mm,
  - diameter at the level of the cover: 466 mm,
  - height: 1808 mm,
- usable dimensions of the cavity:

- length: 1475 mm,
- diameter: 178 mm.

The masses are as follows:

- total mass of the package under vacuum: 280 kg
- maximum total mass of the loaded package: 396 kg

The maximum load on the floor provided by the package is:

- in the vertical position: 1.1 t/m²
- in the horizontal position: 0.4 t/m²

4. DESCRIPTION OF THE MAIN COMPONENTS

The references given in this paragraph are those specified on the plans shown in the attached document 1.

4.1. CAGE (3)

Two types of cages are defined. They differ only by minor changes. (See attached document 1).

The cage is a structure of dimensions 600 x 600 x 1821 mm^3 formed of tubes welded to each other. The tubes are laminated, made of aluminium, of square section 30 x 30 mm² and 2 mm thick. It is formed is essentially of vertical risers and horizontal bars defining three levels. Tubes laid out along the diagonals provide transversal rigidity to this structure.

Passages, strengthened by angle bars 40 x 40 x 4 mm^3 (and angle bars 60 x 40 x 4 for option 2), also made of aluminium, are provided in the lower part and at approximately two-thirds of the height to allow the free passage of the forks of a fork-lift truck for the package to be handled.

In the upper part, on one of the sides, an opening of 200 x 125 mm² has been made to allow the internal fitting to be extracted, while reducing the height under the hook that is necessary if the package is handled by an overhead crane.

In the case of option 2, the other 3 sides are modified as follows:

- a square aluminium horizontal tube (30 x 30 x 2) is added at 95 mm under the upper square tube (at the same level as the square horizontal tube on the front side). Two square vertical tubes, per side, are placed between the horizontal tubes,
- the transverse squares of the three upper lateral sides are therefore modified, as well as the protective sheet metal.

The vertical risers are closed at their upper end by an end-fitting (3e) made of plastic or aluminium to avoid the penetration of water, and at their lower end by an aluminium foot (3g) that strengthens the tube in this zone, thus preventing it from being crushed in the case of impacts that may occur during handling; they are drilled to avoid water accumulating in the risers.

Inside the cage, frames have been provided to connect the cage to the body:

- they are offset by 45° in relation to the cage and drilled to allow the passage of the body's mounting bolts (1u),
- inclined tubes are welded between the frames and the rest of the structure to ensure the good transmission of mechanical force from the body to the cage; the non-welded part of the extremity on the frames is closed by rectangular end-fittings made of plastic (3i).

When the package is in the vertical position, the cages can be handled using an appropriate lifting beam or by using straps or slings passed around the tubes that strengthen the corners of the cage in the upper part. When the package is in the horizontal position, it may be handled using straps passed around the cage.

The TN-BGC 1 package is designed to be transported in a shielded transport caisson that ensures the physical security of the content. In the transport caisson, the packages are in the vertical position only. The securing of the packages in this caisson is detailed and justified in chapter 3.

Between the aluminium tubes that compose the structure of the cage, a device is placed to prevent parts of the human body coming into contact with the body of the package and thus to delimit the external surface of the package. This device may be composed of a set of perforated aluminium plates or any other means intended to fulfil this function. This device is such that the additional stiffness that it provides to the structure of the cage is negligible and so that the external surface of the cage consists of 40% empty space.

4.2. BODY (1)

The cavity of the body is formed of a shell (rolled and welded sheet metal) made of stainless steel at least 6 mm thick and of 178 mm in usable interior diameter and with a base at least 8 mm thick, also made of stainless steel, joined by a circular weld.

A second shell made of stainless steel 1.5 mm thick and 292 mm in internal diameter delimits, together with the first shell, a space that is filled with loaded resin, which plays the role of a neutron absorber and active thermal insulator.

A distribution baffle (1d) of 25 mm, made of carbon steel, is fixed to the base (using 4 studs (1j) welded onto it) to strengthen it in case of a drop on the base of the package.

A caisson (1h) composed of a disc of poplar in the central part and a ring of balsa on the outside plays the role of a shock absorber in the lower part of the body.

In the upper part, a machined flange made of stainless steel is welded onto the two shells to receive the closure system described below and ensure a correct support surface for its seals.

This flange also includes 4 x 50° impressions to allow the introduction and axial locking of the bayonet ring on the plug tightening system. They are drilled with 4 threaded holes to take the tool for closing the package. They also include a 6 mm hole to visually check the quality of the support of the plug on the flat surface of the flange.

To fix the cover on (see paragraph 4.4), the external shell includes two clips (1l) that are screwed or welded ((1w) + (1x)) on the external shell, together with two attachment lugs (1t) to receive two bent rods (4h) that are joined on to the cover.

The connection with the cage is provided by fixing lugs (1m), made of folded stainless steel, welded on one side on the external shell and screwed on the other side on the cage, each using a screw HM6-50 (1u) and a self-locking nut H6 (1v) that cannot be unscrewed. The support on the cage is provided by neoprene pads (1p) to compensate for the play between the cage and the body.

Two identification plates (1n) and one manufacturer's plaque (1o), made of stainless steel and engraved in accordance with the regulations, are fixed on the body using rivets.

Discs made of sintered stainless steel (1s), gas-permeable, are fixed to the external walls of the body (using supports (1q) welded onto the external shell) to de-gas, during initial use, the solvents trapped in the resin.

Fuse plugs (1r) made of plastic evacuate burnt gases in the case of fire, thus avoiding over-pressure.

4.3. CLOSURE SYSTEM

The cavity of the body is closed using a system composed of 3 main parts: a plug (2), a tightening ring (6) and a bayonet ring (5).

The plug is machined into a stainless-steel disc 92 mm thick.

At its edge, it has a 20 mm thick shoulder that is supported by the flange of the body.

A handling button is provided on the upper side for handling by an automatic tool.

A polyethylene ring placed inside the plug completes the package's axial neutron shielding.

In the centre of the plug, a hole fitted with a quick-connect coupling (10) (fitted with an O-ring joint (16)) allows the package to be depressurised before dispatch and re-pressurised to atmospheric pressure upon arrival before unloading.

The plug on the body and the orifice that is fitted with the quick-connect coupling are kept leak tight respectively by two O-ring seals (11) and (12) fitted in two concentric trapezoidal grooves machined in the shoulder of the plug, and by a cap on the quick-connect coupling (7) with two O-ring seals ((13) and (14)). The spaces between the seals (11)/(12) and (13)/(14) both communicate with a common inspection orifice that is blanked by the bronze inspection plug (9) M20 (fitted with a cleanliness seal (15)) accessible on the upper side of the plug.

The cap (7) on the quick-connect coupling is machined from stainless steel and includes a semi-circular groove to allow it to be handled by an automatic bearing tool.

It is maintained in position by a tightening nut (8) M72 x 2 made of bronze (to avoid any risk of seizing with the plug (2) made of stainless steel) that is tightened by a tool that is positioned in the four holes of diameter 6 mm laid out at regular intervals on the diameter of 56 mm and drilled on its upper side.

This plug is maintained in place by a tightening ring made of bronze (6) that screws in the bayonet ring (5) made of stainless steel. This ring (6) (provided in bronze to avoid any risk of seizing during its movements in the bayonet ring (5) made of stainless steel) has 4 threaded holes M10 to allow the connection screws to be fixed with the tool that is used to handle and tighten it.

The bayonet ring (5) includes an internal thread M 230 x 4 that is 26 mm high and 12 mm wide, and on the

outside, it has four male extrusions of 40° that are 15 mm thick and 6 mm wide that fit in the corresponding marks on the flange on the package's body. Its rotation is locked by a stop pin (5a) that is pressed into the flange.

4.4. SHOCK-ABSORBING COVER (4)

A leak-tight shock-absorbing cover is fitted on the head of the body and the closure system (see attached document n° 2).

It is composed of two caissons made of sheet stainless steel that is generally 1.5 mm thick, except for the flat intermediate sheet metal, where the thickness is brought to 4 mm to make sure that force is correctly transmitted and distributed. The caisson that is closest to the body is filled at 25 mm (minimum 24 mm) in the upper part and 23.5 mm (minimum 22 mm) in the lower part by a resin identical to that surrounding the body, to thermally protect the closure system. The second contains wood: poplar, for which the fibres are laid out radially in the lateral part (thickness: 55 mm), and balsa in the upper part, for which the fibres are laid out longitudinally on the external ring and transversely in the middle (thickness: 70 mm).

Two folding handles (4f) fixed at the top of the cover allow handling.

The cover is connected to the body as follows (also see paragraph 4.2):

- two clips (11), screwed and welded on the body, attach to the lugs welded on threaded rods (4h) that are screwed and locked (by the nut (4i)) in the bosses (4g) welded on the cover (security seals may be put in place between the clip handles and the body),
- two bent rods, partially threaded and fixed to the cover in the same way as previously, penetrate the attachment lugs (1t) welded onto the body.

<u>Note</u>: the shock-absorbing covers are defined on the plan supplied in the attached document n° 2. They have been made more leak-tight compared to the initial design by eliminating the rivets near the handles. The covers are now entirely welded and their overall leak-tightness (welds and fuse plugs) is checked at the end of the modification, by liquid penetrant tests and during periodic maintenance, in accordance with the specifications in chapter 4.

5. CONFINEMENT ENVELOPE

The confinement envelope for the TN-BGC1 package is constituted by the internal shell and the base of the body, the plug and the cap for the quick-connect coupling (figure 2).

The confinement envelope is made leak-tight by O-ring joints marked (11) for the plug and (13) for the cap on the quick-connect coupling. They are made of silicone for packages of type B(U) and Viton for packages of type B(M). These O-ring seals are always doubled (click respectively (12) and (14)), and are always made of Viton, to create a space that can be inspected (an inspection orifice is present that is common to two spaces between seals).

The internal shell of the body and its base are made of stainless steel, as is the plug and the cap for the quick-connect coupling.

The plug is maintained on the body (1) using the tightening ring (6) that screws into the bayonet ring (5) that is supported by the flange on the body. The cap (7) on the quick-connect coupling is fixed on the plug using a tightening nut (8) that screws into the plug.

The interior volume of the empty confinement envelope is 37.6 litres.

6. COMPOSITION OF THE SHIELDING

6.1. LATERAL SHIELDING

This is composed of the stainless steel of the internal shell (6 mm) and the external shell (1.5 mm) for the main part of the shielding against gamma radiation, and by the resin (48 mm) for the shielding against neutron radiation.

6.2. BASE SHIELDING

This is composed of the stainless steel of the base of the cavity (8 mm) and the two cover plates (2 x 1.5 mm) as well as the carbon steel in the distribution baffle (24 mm minimum) for the main part of the shielding against gamma radiation, and by the resin (25 mm) and wood (65 mm) for the shielding against neutron radiation.

6.3. HEAD SHIELDING

This is composed of the stainless steel of the plug (59 mm) and the sheet metal cover (2 x 1.5 mm) for the gamma protection, and by the resin (24 mm) and wood (70 mm) contained in the cover for the neutron protection.

7. HANDLING AND SECURING POINTS

In the vertical position, the package may be handled in two ways:

- by a fork-lift truck, for which the forks penetrate into the passages provided for this purpose (two levels possible), as described in paragraph 4.1,
- by straps or slings fitted on in the middle of the tubes that strengthen the corners of the cage in the upper part.

In the horizontal position, the package can be handled by passing two straps around the cage.

When the package is transported in the vertical position, it can be secured in two ways:

- by wedging at the foot and maintenance at mid-height using straps,
- by wedging using cross-pieces at two different levels.

When the package is transported in the horizontal position, securing is provided by wedging on the floor around the cage and by strapping above the cage.

The package is designed so that at no point do the stresses exceed the elastic limit when the package is subjected to statutory accelerations.

The precise description specifying the means of handling and wedging, and justifying the stresses, is given in chapter 3.

8. CHARACTERISTICS OF THE MATERIALS USED FOR THE PACKAGE

The materials used for manufacturing the package are as follows:

- steels,
- aluminium,
- bronze,
- welding material,
- resin,
- wood,
- elastomer,
- plastic materials.

All of these materials have the mechanical and thermal characteristics that are respectively specified in tables 2 and 3.

Materials equivalent to those specified in the safety analysis report may be used providing that these differences are explained and justified.

8.1. STEELS

8.1.1. Stainless steel

All of the shells, base and sheet-metal, are of type Z2 CN 18.10 (standard NFA 35-575) or Z6 CN 18.09 (or equivalent).

Bolts/screws and rivets, clips, fixing lugs and statutory plaques are made of stainless steel of one of the previous types.

8.1.2. Carbon Steel

The distribution baffle is made of carbon steel of type 39 CD 4 (or equivalent).

8.2. BRONZE

The tightening nut (8) on the cap for the quick-connect coupling is made of CuSn12 (or equivalent) known as bronze B.

The tightening ring (6) for the plug is made of Cu Al9 Ni5 Fe5 Y20 (or equivalent) known as bronze A.

8.3. ALUMINIUM

8.3.1. Structure of the cage

The aluminium of the cage structure is of grade 6082. It is delivered hardened and tempered. The tubes are extruded so as to retain all of the properties of the metal.

8.3.2. Flat parts, angle bars and feet

Grade and state: grade 6060 (or equivalent).

8.4. WELDING MATERIALS

They are compliant with the requirements of CODAP or the ASME code for fabricated constructions made of stainless steel or aluminium. For example, for stainless steel, it is the standard AFNOR NF A 81-329E (or equivalent) and for aluminium, it is the standard AFNOR NF A 81-331 (or equivalent).

8.5. RESIN

Its characteristics are as follows:

- minimum density: 1.6,
- range of use: -40°C / +160°C in continuous operation,
- composition: see table 7,
- implementation: the resin is prepared according to the composition specified above; it then forms a viscous liquid, which is poured between the walls of the body and the walls of the cover. Polymerisation takes place once the resin is in place between the walls of the body. Preparation and pouring are performed according to the procedure TRANSNUCLEAIRE 9990-P-19,
- check: a check on the effectiveness of the resin is provided for through a measurement, outside the body, of the attenuation of the radiation of a source placed inside. It is performed according to the TRANSNUCLEAIRE 9990-P-6 and 9990-P-12 procedures,

8.6. WOOD

The woods used in the cover and at the base of the package are, depending on the zones, poplar and balsa. They have the characteristics specified in table 4.

8.7. SEALS OR GASKETS

They are made of fluorocarbon elastomer of type "Viton" (or equivalent) for the packages of type B(M) or silicone for the packages of type B(U). Their properties are given in table 5.

8.8. SMALL COMPONENTS

8.8.1. Fuse plugs

They are made of polyethylene or any other material for which the melting temperature is below 150°C.

8.8.2. Pads

They are made of neoprene or any other elastomer material for which the Shore hardness is between 30 and

70.

8.8.3. Plastic end-fittings

They are intended to prevent the penetration of water inside the cage.

8.8.4. Polyethylene disc

It is included in the plug and supplements the axial shielding of the package.

9. TRANSPORT IN A CAISSON

In the case of the transport of fissile material covered by the requirements of physical protection, the package may be enclosed in a shielded caisson. This configuration concerns only transport in the vertical position. Table 6 summarises the thermal characteristics of the caisson.

10. MANUFACTURING THE PACKAGE

The packages were manufactured according to the general specification drawn up by TRANSNUCLEAIRE 9990-A-1, which defines the general principles that should apply to the production of packages and their components. In particular, this specification imposes the following checks:

- visual check on all welds for the cage,
- liquid penetrant tests by sampling welds on the cover and accessories,
- 100% liquid penetrant tests on the welds accessible in the internal and external shells and the plug,
- leak tightness of the welds in the containment chamber,
- effectiveness of the resin,
- functional tests,
- leak-tightness test using helium in each package at the end of manufacture.

Each element of the package (cage, body, resin, wood, small components,...) has been the subject of special manufacturing specifications and installation procedures.

TABLE 1: LIST OF THE MAIN COMPONENTS OF THE PACKAGE

Comment: Not all of the versions are used. This is because this numbering is extracted from other documents that use the entire list of identifiers.

Identification n°	Description	Material (as an example)
	ASSEMBLY	
1	BODY	
	Flange, shells, bases, cover plate	Z6 CN 18.09 or Z2 CN 18.10
1d	Distribution baffle	39 CD 4
1g	Resin filler	Resin
1h1	Wood filler	POPLAR
1h2	Wood filler	Balsa
1j	Shaft M8	Z6 CN 18.09 or Z2 CN 18.10
1k	M8 nut	Z6 CN 18.09 or Z2 CN 18.10
1l	Clip	Z6 CN 18.09 or Z2 CN 18.10
1m	Fixing lug	Z6 CN 18.09 or Z2 CN 18.10
1n	Identification plaque	Z6 CN 18.09 or Z2 CN 18.10
1o	Regulatory plaque	Z6 CN 18.09 or Z2 CN 18.10
1p	Rubber pad	Neoprene 40sh
1q	Disc holder	Z6 CN 18.09 or Z2 CN 18.10
1r	Plastic plug 0 9	Polyethylene
1s	Poral disc	Sintered stainless steel
1t	Cover stop	Z6 CN 18.09 or Z2 CN 18.10
1u	Screw HM6 - 50	Z6 CN 18.09 or Z2 CN 18.10
1v	Screw H6 self-locking	Z6 CN 18.09 or Z2 CN 18.10
1w	Self-tapping screw	Z6 CN 18.09 or Z2 CN 18.10
1x	Washer	Z6 CN 18.09 or Z2 CN 18.10
2	PLUG	
2a	Plug	Z6 CN 18.09 or Z2 CN 18.10
2b	Polyethylene disc	HD 100
2c	Cover plate	Z6 CN 18.09 or Z2 CN 18.10

Identification n°	Description	Material (as an example)
3	CAGE	
	Structure	6082
3e	Square end-fittings	Polyethylene or aluminium
3f	Flat	6060
3g	Bottom	6060
3h	Angle bar	6060
3i	Rectangular plastic end-fittings	Polyethylene
3j	Perforated plaques	Aluminium
4	SHOCK ABSORBER COVER	
	Bases and shells	*Z6 CN 18.09 or Z2 CN 18.10*
4e1	Wood filler	POPLAR
4e2	Wood filler	Balsa
4f	Folding handle	Stainless steel 304
4g	Boss for clip and stop	Z6 CN 18.09 or Z2 CN 18.10
4h	Threaded rod	Z6 CN 18.09 or Z2 CN 18.10
4i	Stop nut	Z6 CN 18.09 or Z2 CN 18.10
4j	Resin filler	Resin
5	BAYONET RING	Z6 CN 18.09 or Z2 CN 18.10
5a	Stop pin	Z6 CN 18.09 or Z2 CN 18.10
6	TIGHTENING RING	Cu Al9 Ni5 Fe5 Y20
7	STAUBLI PLUG	Z6 CN 18.09 or Z2 CN 18.10
8	TIGHTENING NUT	CuSn12
9	TEST PLUG	Bronze ASTM BI 51
10	CONNECTOR, STAUBLI	Stainless steel 304
11	O-ring joint $\varnothing_{int}$ 196.25	Viton (low-temperature) or silicone
12	O-ring joint $\varnothing_{int}$ 228	Viton
13	O-ring joint $\varnothing_{int}$ 32.915	Viton (low-temperature) or silicone
14	O-ring joint $\varnothing_{int}$ 53.57	Viton

TABLE 2: MECHANICAL PROPERTIES OF THE MATERIALS USED IN THE PACKAGE

Material	Temperature (°C)	Yield strength (MPa)	Young's modulus (MPa)	Poisson coefficient	Expansion coefficient (°C^{-1})
Aluminium 6082 (or equivalent)	20° - 70°	260 (cold worked state) 110 (annealed state)	> 69500	0.33	-
Stainless steel Z2 CN 18.10 (or equivalent)	20° - 160° 240 250°	> 220 ≥ 115 ≥ 108	200000 - -	0.33 - -	< 16 x 10-6 - -
Steel 39 CD 4 (or equivalent)	20° - 150°	> 500	180000	0.33	-
Bronze A	20° - 160°	> 250	115000	-	-
Bronze B	20° - 150°	> 60	-	-	-

TABLE 3: THERMAL PROPERTIES OF THE MATERIALS USED IN THE PACKAGE

Material	Conductivity thermal (W/m.K)	Specific heat (J/kg)	Surface emissivity	Solar heat absorption coefficient
Stainless steel	≥ 15	≥ 500	0.5	0.3
Aluminium	134	950	0.55	
Resin	≥ 0.66* (intact)			
	From 0.47 to 0.09 during the fire test	≥ 1250	-	-

*: *Only this value for the conductivity of resin will be considered as an essential parameter.*

TABLE 4: PROPERTIES OF SPECIES OF WOOD

(values obtained on a number of samples representative of manufacturing)

Properties	Balsa	Poplar
Density	0.11 ± 0.03	0.36 ± 0.03
Maximum humidity rate before installation (%)	12	12
Average crushing stress (MPa)	7 ± 2	23 ± 2
Minimum crushing stress (%)	60	45

TABLE 5: PROPERTIES OF SEALS

Properties	Value
<u>Properties common to all seals</u>	
Hardness "shore" "A"	70 ± 5
Range of use of <u>seals delimiting the containment chamber</u>	
<u>Case 1: Viton</u>	-25°C / +250°C
Case 2: Silicone	-45°C / +315°C
Expansion coefficient	
Case 1: Viton	227.10-6 m.K-1
Case 2: Silicone	274.10-6 m.K-1

TABLE 6: PARAMETERS RELATIVE TO THE USE OF A CAISSON

(the exterior geometry of the caisson must be the same as that of a caisson of the ISO type 20 feet)

External emissivity of the caisson		0.9
Internal emissivity of the caisson		0.2
Solar absorbance		0.3
Conductivity ($W/m^2.K$)	Roof and lateral walls	0.13
	Doors	0.22

TABLE 7: CHARACTERISTICS OF THE RESIN

Nominal composition	
Products	(%) by weight (at +/- 5%)
Norsodyne M 0070C resin from CDF Chimie	35
Styrene monomer C_8H_8	5
Zinc borate 4ZnO, $6B_2O_3$, $7H_2O$	15
Aluminium hydrate $A1_2O_3$, $3H_2O$	44.8
Cut glass fibre	0.2
Accelerator	
Catalyst	
Minimal values of the finished product	
density	1.6
number of atoms of hydrogen per cm^3	4.06.1022
number of atoms of boron per cm^3	9.45.1020

The resin mentioned may be replaced by an equivalent resin.

FIGURE 1: OUTLINE DIMENSIONS

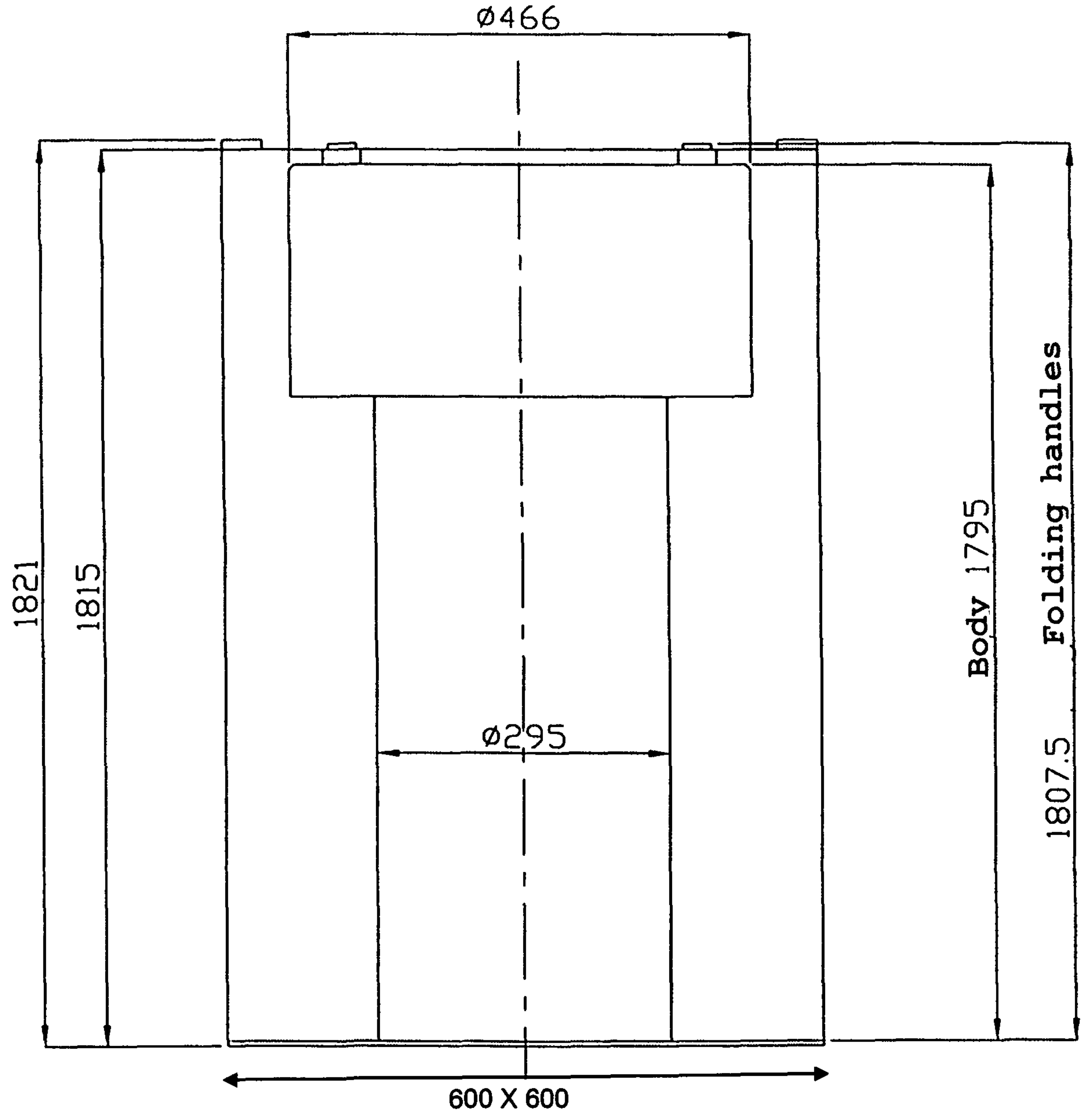
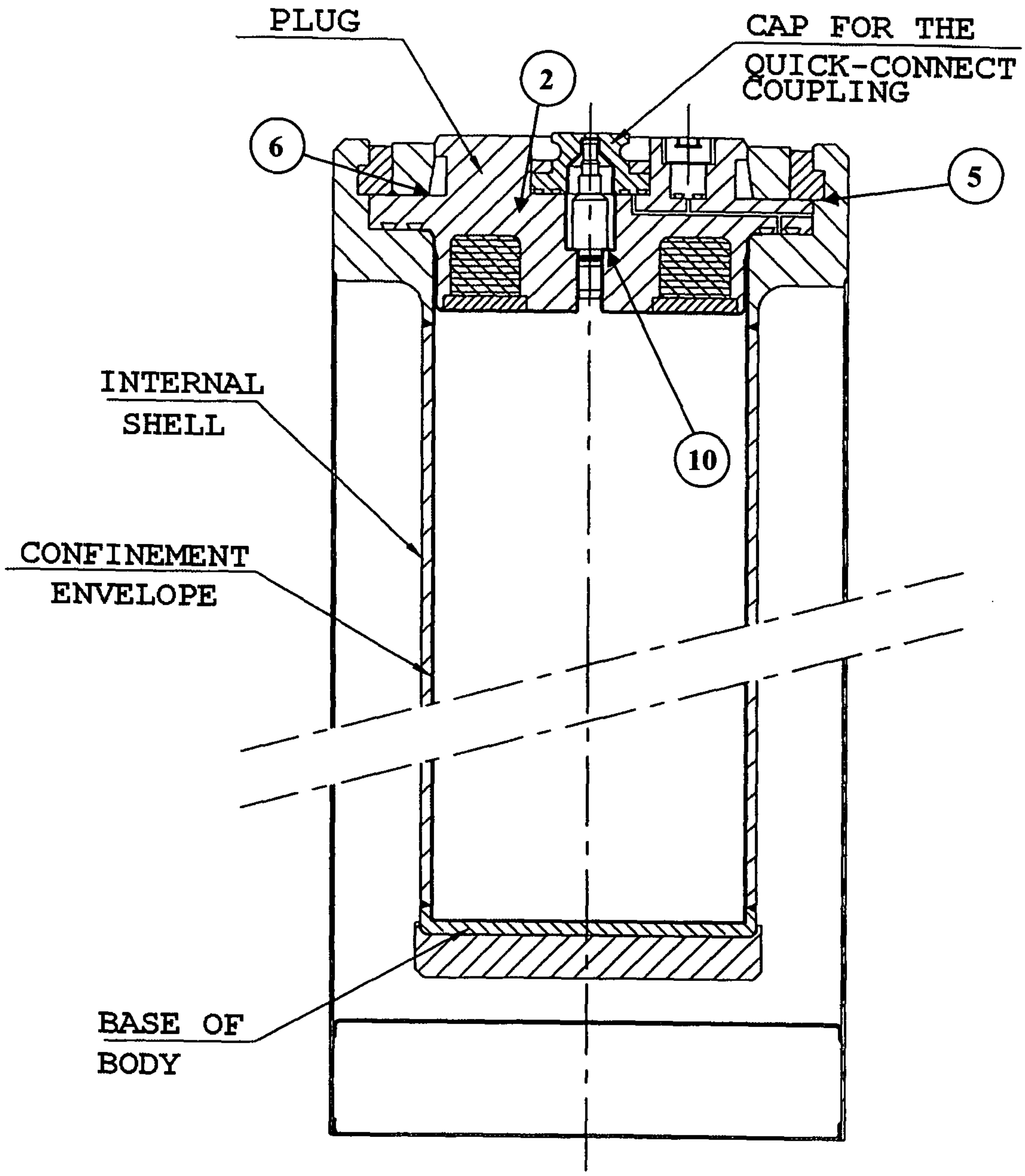


FIGURE 2: CONFINEMENT ENVELOPE



LEGEND	
Chanfrein	Bevel
Coupe C-C	Cross-section C-C
DETAIL B	CLOSE-UP B
DETAIL A	CLOSE-UP A
Ind. B suivant DMAM 6434-H3 Rév. 0	Op. B in accordance with DMAM 6434-H3 Rev. 0
D'après plan Transnucléaire 9990-67A	According to Transnucléaire plan 9990-67A
Ind.	Op.
Dess	Designed by
Vérif	Checked by
Appr	Approved by
Ech	Scale
Format	Format
AFFAIRE	Project
EMBALLAGE TN-BGC1	TN-BGC1 PACKAGING
BOUCHON ASSEMBLE	ASSEMBLED PLUG
Ce plan est la propriété de TRANSNUCLEAIRE et ne peut être reproduit ou communiqué sans son autorisation	This plan belongs to TRANSNUCLEAIRE and cannot be copied or transmitted without their authorisation

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Figure Withheld Under 10 CFR 2.390

TRANSNUCLEAIRE

AFFAIRE 9990

EMBALLAGE TN-BGC1
BOUCHON ASSEMBLE

9990-117

Security-Related Information
Figure Withheld Under 10 CFR 2.390

TRANSNUCLEAIRE

AFFAIRE 9990

EMBALLAGE TN-BGC1
CAGE ③

9990-118

VUE J – VUE G	VIEW J – VIEW G
½ VUE I	½ VIEW I
½ VUE H	½ VIEW H
OPTION 1	OPTION 1
Fixation par rivets pop	Attachment via pop rivets
Vue suivant F	View in line with F
Epaisseur de la tôle	Sheet metal thickness
Diamètre des trous tels que	Diameter of the holes as shown
Surface Trous et vides	Surface area Holes and cavities
Surface total extérieur de la cage	Surface area total cage exterior
Embouts carrés	Square end-pieces
OPTION 2	OPTION 2
ECH	SCALE
Section B-B et C-C	Cross-section B-B and C-C
Section F-F	Cross-section F-F
Section A-A	Cross-section A-A
OPTION 2	OPTION 2
Section E-E	Cross-section E-E
Section D-D	Cross-section D-D
4 PIEDS 26 x 26 EP 10 SOUDES	4 26 X 26 WELDED FEET 10 THICK
Embouts plastique rectangulaire	Rectangular plastic end-pieces
LES AUTRES COTES DE POSITIONNEMENT SONT TOLERANCEES ± 20	OTHER POSITIONING DIMENSIONS ARE TOLERANCED ± 20
LES TOLERANCES SUR DIMENSIONS DES TUBES ET PROFILES ± 1	TOLERANCES FOR TUBE AND EXTRUDED SECTION DIMENSIONS ± 1
LES TOLERANCES SUR EPAISSEURS DES TUBES ET PROFILES ± 0,5	TOLERANCES FOR TUBE AND EXTRUDED SECTION THICKNESSES ± 0.5
Ind B suivant DMAM 6434-H3-Rév 0	Op. B in accordance with DMAM 6434-H3 Rev. 0
D'après plan TRANSNUCLEAIRE 9990-66A	According to Transnucléaire plan 9990-66A
Ind.	Op.
Dess	Designed by
Vérif	Checked by
Appr	Approved by
Ech	Scale
Format	Format
AFFAIRE	Project
EMBALLAGE TN-BGC1	TN-BGC1 PACKAGING
CAGE	CAGE
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Figure Withheld Under 10 CFR 2.390

TRANSNUCLEAIRE

A : 0

9990

EMBALLAGE TN-BGC1
PLAN DE CONCEPT-ENSEMBLE

9990-85

mini	min.
VOIR DETAIL D	SEE CLOSE-UP D
4 vis à 90°	4 screws at 90°
DETAIL D	CLOSE-UP D
Ech 3	Scale 3
Détail de montage des pastilles frittées	Close-up of the sintered pellet assembly
Ech 2	Scale 2
Soudure par pointage à l'intérieur	Tack welding on the inside
VOIR DETAIL B	SEE CLOSE-UP B
Détail de montage	Assembly close-up
Détail B	Close-up B
Ech 1	Scale 1
COUPE A-A	CROSS-SECTION A-A
Remplissage résine	Resin filling
VOIR DETAIL C	SEE CLOSE-UP C
Pour vis H M6x50	For H M6x50 screw
+ écrou H M6 indesserable	+ H M6 loosening-proof nut
DETAIL C	CLOSE-UP C
VUE ISO	ISO VIEW
4x4 pattes de fixation à 45°, 135°, 225°, 315°	4x4 retaining lugs at 45°, 135°, 225°, 315°
2 Grenouillères à 90° et 270°	2 domed locking devices at 90° and 270°
2 Pattes d'accrochage à 0° et 180°	2 locking flaps at 0° and 180°
2 bouchons fusibles Ø 9 à 45°, 135°, 225°, 315°	2 x Ø 9 fuse plugs at 45°, 135°, 225°, 315°
4 bouchons fusibles id + 1 poral Ø 23 à 0°	4 identical fuse plugs + 1 x Ø 23 Poral at 0°
4 bouchons fusibles id + 1 poral Ø 23 à 180°	4 identical fuse plugs + 1 x Ø 23 Poral at 180°
4 bossage à 90°, 180°, 270° et 0°	4 nozzles at 90°, 180°, 270° and 0°
VOIR DETAIL A	SEE CLOSE-UP A
DETAIL DU BOSSAGE	CLOSE-UP OF THE NOZZLE
Détail A	Close-up A
Ech 1	Scale 1
Peuplier	Poplar
4 + 4 bouchons plastiques Ø 9 à 45°, 135°, 225°, 315°	4 + 4 Ø 9 plastic plugs at 45°, 135°, 225°, 315°
Tige filetée soudée sur patte d'accrochage des grenouillères	Threaded rod welded to the locking flaps on the domed locking devices
TOLERANCES GENERALES	GENERAL TOLERANCES
Résine	Resin
Balsa	Balsa
2 poignées fixées par 2 rivets pop en inox 5x15	2 handles attached by 2x5x15 stainless steel pop rivets
2 pattes d'accrochage des capots	2 cover locking flaps
Ind B, modifs suivant DMAM 9990-H-20 rév 0	Op. B, modifs. in accordance with DMAM 9990-H-20 rev. 0
Ind. C, modifs suivant DMAM 6434-H-3 rév. 0	Op. C, modifs. in accordance with DMAM 6434-H-3 rev. 0
Ind.	Op.
Dess	Designed by

Vérif	Checked by
Appr	Approved by
Ech	Scale
Format	Format
AFFAIRE	Project
EMBALLAGE TN-BGC1	TN-BGC1 PACKAGING
PLAN DE CONCEPT-ENSEMBLE	GENERAL DESIGN PLAN
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CENTRE DE CADARACHE

TOLERANCES GENERALES / GENERAL ALLOWANCES
ISO 2768-MK
ISO 13920-BF

N° PLAN / REFERENCE DRAWING

PRODUCER : DEN/DPIE/SET

PACKAGE TN-BGC 1
SHOCK ABSORBER COVER

Folio 1/1

EMB TNBGC PBC PDC CA 01 0001 A

NOTE: The plan in the computer-aided drawing software can only be modified in this software

Nuclear Energy Division
Nuclear Services Department
Radioactive Materials Transportation Service
Packaging Operations Laboratory

Safety Analysis Report

TN-BGC 1 package

Chapter 3 - Mechanical performance of TN-BGC 1 package

Clt : 7.1.1.3

Classification: DO

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MODIFICATIONS

VERSION	DATE	AUTHOR	TYPE OF MODIFICATION	NO. OF PAGES
01	17/07/2012	V. PAUTROT	Initial issue	19

LIST OF ATTACHMENTS

(formalism, identification and independent pagination)

N°	TITLE	NO. OF PAGES
1	Drop tests on TN-BGC 1 - summary of tests conducted ref. EMB TNBGC PBC NTT CA000524 A of 20 February 2004	8
2	Drop test report on prototypes of TN-BGC 1 packaging ref. EMB TNBGC PBC DJS CA 000333 A of 07 August 2003	40
3	Supplementary drop test report on prototypes of TN-BGC 1 packaging ref. EMB TNBGC PBC DJS CA 000334 A of 07 August 2003	153
4	Mechanical analysis of vertical 9m drop of TN-GBC 1 package with top facing down ref. 2CE3E100 rev. 2 of 165 February 2004	58
5	Analysis of sustained leaktight performance of TN-BGC 1 packaging in inclined drop from 9 metres ref. G03CAL022A Ed. 2.0 dated 30 May 2007	56
6	Mechanical performance of containment system during immersion ref. 160 EMBAL PFM DET 08000162 A of 26 February 2008	8
7	Resistance of handling devices ref. 160 EMBAL PFM DET 08000163 A of 26 February 2008	19
8	Mechanical analysis of tie-down devices on TN-BGC 1 packaging - combined acceleration ref. 299E05W03 of 17 August 2005	57
9	Mechanical performance of TN-BGC 1 packaging during explosion ref. 2BP6E042 of 02 May 2006	40
10	Modal analysis ref. 159A3W03 Ed. B of 17 January 2003	20

TABLE OF CONTENTS

1. INTRODUCTION

The aim of this chapter is to analyse the mechanical strength of the TN BGC 1 packaging and to show that it meets the regulatory requirements concerning type B packages loaded with fissile materials.

The condition of the packaging following the regulatory drop tests under NCT and ACT is deduced from the mechanical performance.

The mechanical performance of the TN-BGC 1 packaging is analysed according to the following points:

- forces and stresses generated by the various types of content it may transport:
  - thermal gradients,
  - internal pressure caused by a temperature rise in the cavity, by the generation of gasses in the containment system,
  - internal over-pressure resulting from an explosion caused by hydrogen release into the cavity via radiolysis,
- customary handling & transport operations,

taking into account the ambient temperature and pressure conditions defined by applicable regulations.

The compliance of the TB-BGC 1 packaging is also analysed concerning the regulatory tests specified by applicable regulations, i.e. the following:

- **under normal conditions of transport**:
  - water spray test (paragraph 721 of [1])
  - free fall drop test from a height of 1.2 m (paragraph 722 a) of [1])
  - stacking test (paragraph 723 of [1])
  - penetration test (paragraph 724 of [1])
- **under accident conditions of transport**:
  - 9-metre free fall drop test onto an unyielding surface (paragraph 727 a) of [1], applicable in this safety analysis report for all contents containing less than 1000 A_2,
  - 9-metre dynamic crush test using a 500 kg mass (paragraph 727 c) of [1], applicable in this safety analysis report for all contents containing more than 1000 A_2,
  - free fall drop test from a height of 1 m onto a bar (paragraph 727 b) of [1])
  - immersion test under a 15-metre head of water for 8 hours (paragraph 729 of [1])
  - the advanced immersion test under a head of water 200 m deep for 1 hour, which is applicable here for certain contents with activity in excess of 10^5 A_2 (paragraph 730 of [1]).

Note: for air transport, the package must resist PNUM + 95 kPa. Air transport is only applicable to contents that present no risk of gaseous discharge, so this requirement is covered by the analysis of resistance to internal pressure.

2. REFERENCES

[1]: International Atomic Energy Agency (IAEA) regulations for the safe transport of radioactive material, IAEA Safety Standards series, No. TS-R-1 1996 edition (Amended 2005).

[2]: Roark's formulas for stress and strain – Warren C.YOUNG – 7th edition.

[3]: "Compression test on wood according to temperature" reference 160 EMBAL PFM NOT 04001858 A of 29 November 2004

3. RESISTANCE TO INTERNAL PRESSURE

3.1. CALCULATION CONDITIONS

The description of the containment system is given in chapter 2.

The calculations below are done taking into account a pressure of 10 bars relative. This pressure is a conservative estimate of the maximum pressure encountered by the package under normal and accident conditions of transport.

3.2. MATERIALS

The mechanical properties of the materials, defined in chapter 2 are indicated below;

- Z2 CN 18 10 steel: elastic limit: 130 MPa at 160°C (conservative temperature of components of containment system under NCT) and 100 MPa at 300°C (conservative temperature of components of containment system under ACT),
- Bronze A: elastic limit: 150 MPa at 160 °C and 290 °C

3.3. RESISTANCE OF INTERNAL SHELL

The formulae used in [2] (table 13.5) are used to determine the maximum circumferential stress (σ2) exerted on the walls of the internal shell and shearing (τ) by:

$$\sigma_2 = p.\frac{D_e^2 + D_i^2}{D_e^2 - D_i^2}$$

$$\tau = p\frac{D_e^{\,2}}{D_e^{\,2} - D_i^{\,2}}$$

Where:
p : Internal pressure, p = 1 MPa.
D_i : Internal diameter D_i = 180 mm (conservative value),
D_e : External diameter D_e = 192 mm.

Therefore: $\sigma_2 = 1.\frac{192^2 + 180^2}{192^2 - 180^2} = 15.52\,MPa$ and $\tau = 1\frac{192^2}{192^2 - 180^2} = 8.26\ MPa$

The maximum radial stress is equal to σ_3 = - p = - 1 MPa.

The Von-Mises equivalent stress is then equal to:

$$\sigma: \sqrt{(\sigma_2 - \sigma_3)^2 + 3\tau^2} = 21.9\ MPa$$

This stress is below the elastic limit of stainless steel, namely 175 MPa. Re = 130 MPa at 160°C and R'e = 100 MPa at 300°C.

3.4. RESISTANCE OF SHELL BASE

We can consider that the base is embedded in the shell.

The formulae given in column 10b of table 11.2 in [2] are used to determine the stresses.

The unitary flexion moment values are:

On embedding $$Me = \frac{p.D_i^2}{32} = \frac{1x180^2}{32} = 1012.5\,mm.N$$

In centre $$Mc = \frac{p.D_i^2\,(1+\nu)}{64}$$ where the coefficient of Poisson $\nu = 0.3$

$$Mc = \frac{1\ x180^2\ (1+0.3)}{64} = 658.2\,mm.N$$

The maximum flexion stress is therefore applied to the embedded part and is equal to:

$$\sigma_f = \frac{6.Me}{e^2}$$ where the thickness of the base e = 8 mm.

$$\sigma_f = \frac{6\ x\ 1012.5}{8^2} = 94.9\ MPa$$

The shearing stress on the embedded part is equal to:

$$\tau = \frac{p.D_i}{4.e}\ or\ \tau = 5.6\ MPa$$

The Von-Mises equivalent stress is therefore equal to:

$$\sigma: \sqrt{\sigma_f^2 + 3\tau^2} = 95.4\ MPa$$

This stress is below the elastic limit of Z2 CN 18.10 stainless steel: Re = 130 MPa at 160°C and R'e = 100 MPa at 300°C.

3.5. RESISTANCE OF PLUG

We can consider that the plug is embedded in the shell. Given that the diameter of application of pressure (180 mm) is identical to that on the base (cf. 2.4) and that the minimum thickness of the lid (13 mm) is greater than that of the base (8 mm), the Von Mises stress on the plug is lower than on the base and is therefore below the elastic limit of Z2 CN 18.10 stainless steel in NCT and ACT.

3.6. RESISTANCE OF BAYONET RING AND ITS MOUNTING ON THE PACKAGING

The bayonet ring features a cylindrical washer with an internal thread and on the outside, four flat parts making a clover-form impression.

The upper flange of the packaging body features a collar with this same impression. The bayonet ring is mounted on the packaging flange using these parts.

The ring is tightened using a bronze ring with an external thread, screwed on to the bayonet ring and pushing on the plug.

The closure system is subject to a maximum force due to pressure, of:

$$F_p = p \frac{\pi \cdot D_m^2}{4}$$

With an average diameter of the internal seal groove on the plug: Dm = 203.5 mm

$$F_p = 1 \frac{\pi \ x \ 203.5^2}{4} = 32525 \ N$$

The force used to tighten the seals is equal to:

$$F_S = s.L_d$$

Where:

Unitary tightening force s = 12 N/mm,

Developed length of lid seals Ld = 1380 mm,

Fs = 12 x 1380 = 16,560 N.

The total force (seal tightening & pressure) is equal to:

Fsp = Fs + Fp = 16560 + 32525 = 49085 N

3.6.1. Forces in the impressions

Flexion

Each impression has a thickness h = 15 mm and a length L = 86 mm (corresponding to a 40° angle on a ∅ 254).

The force is applied over an average diameter (Øm 260.5 mm) at a distance d = 3 mm from the external diameter of the cylindrical washer (Øi 254.5 mm) on the bayonet ring.

Each of the four impressions is assumed to be embedded on the ring collar.

The unitary load on the contact points is equal to:

$$q = \frac{F_{sp}}{4\,.\,L} = \frac{49085}{4\,.\,86} = 142.7\,N$$

The unitary flexion moment is equal to:

Mu =q . d =142,7 x 3 = 428.1 mm.N

The flexion force is equal to:

$$\sigma_f = \frac{M_u}{I_u / v}$$

with a unitary inertia module

$$\frac{I_u}{v} = \frac{1\,.\,h^2}{6} = \frac{1\,.\,15^2}{6} = 37.5\,mm^3$$

$$\sigma_f = \frac{428.1}{37.5} = 11.4\,MPa$$

<u>Shearing</u>

The shearing stress on each impression is equal to:

$$\tau = \frac{F_{sp}}{4\,.\,S} = \frac{49085}{4\,.\,86\,.\,15} = 9.5\ MPa$$

<u>The Von-Mises equivalent stress is therefore equal to:</u>

$$\sigma:\ \sqrt{\sigma_f^2 + 3\tau^2} = 20\ MPa$$

This stress is below the elastic limit of Z2 CN 18.10 stainless steel: Re = 130 MPa at 160°C (NCT) and R'e = 100 MPa at 300°C (ACT).

3.6.2. <u>Shearing of threads</u>

The threads on the bayonet ring and the compression ring are ISO type M230 (as per NF E 03-001) with a thread height P = 4 mm, flank diameter df = 227.4 mm. The threaded length is L = 26 mm.

The minimum length of thread contact is equivalent to:

lp = L – P = 26 – 4 = 22 mm

The shearing cross section for the threads is equal to:

$$S_f = \frac{\pi\,.d_f\,.1_p}{2} = \frac{\pi\,.\,227.4\,.\,22}{2} = 7858\,mm^2$$

The shearing stress is equal to:

$$\tau = \frac{F_{sp}}{S_f} = \frac{49085}{7\ 858} = 6.3\,MPa$$

The stress intensity is equal to:

I = 2τ = 12.6 MPa.

This stress is below the elastic limit of bronze: Re = 150 MPa at 160°C (NCT) and 290°C (ACT).

3.7. RESISTANCE OF COMPRESSION RING ON QUICK-FIT CONNECTION CAP

The quick-fit connection cap and its compression ring are subjected to a force due to pressure p, equal to:

$$F'_p = p\frac{\pi d_m^2}{4} = 1\ \frac{\pi\ .\ 57^2}{4} = 2551.8\,N$$

The seal tightening force is equal to:

$F'_S = s' \times l'_d$

Where:

Unitary tightening force s = 6 N/mm,

Developed length of cap seals l'd = 294 mm,

F's = 6 x 294 = 1764 N.

The total force (seal tightening & pressure) is equal to:

F'sp = F's + F'p = 1764 + 2552 = 4316 N

Shearing

The compression ring has an M72 thread (ISO type) with a thread height P' = 2mm, a flank diameter d'f = 70.7 mm and a length of thread L' = 12 mm.

The length of thread contact is equivalent to:

l'p = L' - P' = 12 - 2 = 10 mm

The shearing cross section for the threads is equal to:

$$S'_f = \frac{\pi . d'_f . l'_p}{2} = \frac{\pi .70.7 x 10}{2} = 1111\,mm^2$$

The shearing stress is equal to:

$$\tau = \frac{F'_{sp}}{S'_f} = \frac{4316}{1111} = 3.9\ MPa$$

The stress intensity is equal to:

I = 2τ = 7.8 MPa

This stress is below the elastic limit of bronze A: Re = 150 MPa at 160°C (NCT) and 290°C (ACT).

3.8. MECHANICAL PERFORMANCE OF PACKAGING DURING EXPLOSION DUE TO HYDROGEN

In attachment 9, we proceeded to analyse the resistance of the containment vessel to a pressure of 88(*) bars for a period of 100 ms, which is a conservative estimate of the maximum duration of overpressure due to an explosion of hydrogen in the cavity. Most of all, the materials were assumed to be at their maximum temperature reached after the fire test. This attachment therefore highlights that:

- during the explosion, the maximum gap between the plug and the flange is 1.34 mm (for about 1 ms), which causes the seal to be compressed by 10% (30% in normal conditions),
- at the end of the explosion, a residual gap of 0.29 mm remains, caused by a slight matting of the flange and the bayonet ring. This corresponds to a seal compression rate of 25%.
- The levels of stress in all parts during the explosion are low. In most cases, the elastic limit (yield stress) of the materials is not reached. Deformations are localised in the closure system: the body flange, the bayonet ring and the plug are slightly matted in their respective support areas, which causes slight plastic deformations in the order of 0.7%. As these plastic deformations are below 1%, they are not significant to the leaktight performance of the packaging during or after the explosion.

Therefore, the containment vessel of the TN-BGC 1 packaging demonstrates satisfactory resistance to pressure during an internal explosion caused by an accumulation of hydrogen generating a peak pressure of 88 bars.

(*) 88 bars corresponds to an initial pressure of 10 bars relative since it is accepted that the initial pressure in the packaging cavity is multiplied by a factor of 8.8 during an explosion.

3.9. CONCLUSION

The resistance of the containment vessel to a relative pressure of 10 bars is demonstrated even in the event of an explosion of a gaseous mixture that may form.

4. EFFECT OF THERMAL GRADIENTS

The highest thermal gradient existing between the inner and outer shells remains on average below 41 K under normal conditions of transport (see chapter 5).

The length of the inner shell is L1 = 1515 mm and that of the outer shell L2 = 1573 mm.

The differential dilation is equal to:

$\Delta l = a\, L2\, (t1 - t2)$ where $a = 16.10^{-6}\ K^{-1}$ the thermal dilation coefficient

$\Delta l = 16.10^{-6} \times 1\,573 \times 41 = 1.04$ mm

4.1. TRACTION IN OUTER SHELL

The unitary extension is equal to:

$$\varepsilon = \frac{\Delta l}{L2} = \frac{1{,}04}{1573} = 65.10^{-5}$$

The traction stress is equal to:

$a = E \times \varepsilon = 1.8 \times 10^{5} \times 65 \times 10^{-5} = 118.1$ MPa

4.2. COMPRESSION IN INNER SHELL

The unitary reduction in length is equal to:

$$\varepsilon = \frac{\Delta l}{L1} = \frac{1{,}04}{1515} = 68.10^{-5}$$

The compression stress is:

$\sigma = E \times \varepsilon = 1.8 \times 10^{5} \times 68 \times 10^{-5} = 122.6$ MPa

4.3. CONCLUSION

The stresses observed remain below the elastic limit (yield stress) of Z2 CN 18.10 steel which is Re = 130 MPa at 160°C.

5. RESISTANCE OF PACKAGING DURING HANDLING AND ROUTINE CONDITIONS OF TRANSPORT

The package is designed to be handled and transported in either a vertical or horizontal position.

5.1. HANDLING

When the package is in a vertical position, handling can be done:

- either using a four-strap sling set, with an angle below or equal to 45° from the vertical,
- or using a forklift truck lifting the cage; the cage can be gripped at two different levels.

When the package is in a horizontal position, it can be handled using straps passed around the cage.

5.2. TIE-DOWNS

When the package is in a vertical position, it can be secured for transport either by:

- placing shims at two levels using cross-members when the package is transported in a container, or by
- placing shims at the base and attaching straps at mid-height.

When the package is in a horizontal position, it can be secured by placing shims on the floor around the case and attaching straps above the cage.

5.3. RESULTS

5.3.1. Handling

Attachment 7 demonstrates that in the various possible handling configurations the stresses applied to the body or to the cage remain below or equal to the yield stress (elastic limit) of the material.

5.3.2. Tie-downs

Attachment 8 analyses the resistance of tie-down devices on the TN-BGC 1 package to combined regulatory accelerations in different transport configurations. The summary table below highlights the configurations that are acceptable or not in terms of integrity of the cage and the package body.

	Acceptance criteria satisfied				
Configuration N°	Road Haulage	Rail transport	Maritime transport	Air transport with net	Air transport without net
N°1: 1 vertical package	Yes	No	No		
N°2: 2 vertical packages	Yes	No	Yes		
N°3: 4 vertical packages	No	No	No		
N°4: 3 horizontal packages				Yes	No
N°5: 1 horizontal package	Yes	Yes	Yes	Yes	Yes

5.4. RESISTANCE TO FATIGUE

Three components of the packaging are subject to fatigue. They are:

- the 6080 T6 grade aluminium cage,
- the standard 304 L grade stainless steel body of the package,
- the A5-80 grade bolts that attach the cage to the body.

The cage and body are subject to traction stress and the bolts are subject to shearing forces.

The yield stress of the 3 materials above is respectively:

- 6080 T6 aluminium: Rm = 310 Mpa at 50°C
- 304 L stainless steel: Rm = 450 Mpa at 100°C
- A5-80 bolts: Rm = 700 Mpa at 100°C

The tie-down performance note in attachment 8 demonstrates that the maximum stresses undergone by these three components for permitted configurations (or for air transport as this mode does not subject the tie-down devices to fatigue), are respectively 161 MPa for the bolts, 114 Mpa for the steel and 144 Mpa for the aluminium.

The fatigue calculation is carried out in accordance with the method specified in CETIM 4th edition. For a yield stress below 800 MPa and for a percentage of non-rupture of 97.7%, the formula is as follows:

σD (97.7 %) = Rm (0.55 - 1.6 10^{-4} Rm)

This formula is to be weighted with a coefficient to take into account the mode causing the stress, such as planar flexion or traction/compression.

This coefficient is considered as 0.9 when the component subjected to traction/compression stress and as 0.6 when subjected to shearing stress.

The application of this formula to the package model is possible as the state of the surface and the absence of fissures likely to negatively affect resistance to fatigue on the tie-down devices are inspected during periodical maintenance on packages.

So for the stainless steel of the outer shell of the TN-BGC 1 at 100°C, the endurance limit is:

σD (97.7 %) = 0.9 x 450 (0.55 - 1.6x10^{-4} x 450) or 193 MPa.

For the A5-80 bolts at 100°C, the endurance limit is:

σD (97.7 %) = 0.6 x 700 (0.55 - 1.6x10^{-4} x 700) or 184 MPa.

For the 6080 T6 aluminium at 50°C, the endurance limit is:

σD (97.7 %) = 0.9 x 310 (0.55 - 1.6x10^{-4} x 310) or 140 MPa.

Therefore the endurance limit for the three elements is 140 MPa for the 6080 T6 aluminium, 193 MPa for the 304L stainless steel and 194 MPa for the bolts.

In light of the maximum stresses generated in these components (as a reminder, 144 MPa for the 6080 T6 aluminium, 114 MPa for the 304L stainless steel and 161 MPa for the bolts), and taking into account highly penalising hypotheses in the resistance analysis provided in attachment 8, resistance to fatigue is shown to be satisfactory.

The resistance of tie-down devices to fatigue is therefore demonstrated.

6. COMPLIANCE OF PACKAGE UNDER REGULATORY TEST CONDITIONS

An analysis is conducted on the compliance with specifications when the package model is subjected to regulatory test conditions.

6.1. TESTS RELATING TO NORMAL CONDITIONS OF TRANSPORT

These tests are:

- water spray test
- free fall drop test from a height of 1.2 m
- stacking test
- penetration test

6.1.1. Water spray test

The plug and its orifice are made leaktight using Viton or silicone seals.

All outer walls of the packaging and those of the shock absorber covers are made of stainless steel with leaktight welds.

In light of the evidence and taking into account the leaktight seals created, the water spray test has no effect on the behaviour of the packaging during the following tests.

6.1.2. Free fall from 1.2 m

The drop test series on prototypes of the TN-BGC 1 packaging, summarised in attachment 1 and analysed in attachments 2 and 3 demonstrate that the package satisfactorily completes this test without alteration of its safety functions.

6.1.3. Stacking test

When the package supports a load equal to five times its mass (5g), this force is absorbed fully by the four cage uprights when the package is in a vertical position and by eight uprights when it is a horizontal position. The analysis of the package in a vertical position therefore covers the case where the package is in a horizontal position.

The total force exerted is equal to:

F = 400 x 9.81 x 5 = 19620 N

The compression force in each upright is:

$$\sigma = \frac{19\,620}{4\,x\,224} = 21.9\,MPa$$

The uprights are supported locally by intermediate frame cross-members.

The longest free length is equal to 550 mm and the minimum inertia is 35 998 mm^4.

Euler's critical load is equal to:

$$\sigma_c = \frac{\pi^2 EI}{L^2} = \frac{\pi^2\ x\ 69\,500\ x\ 35\,998}{550^2} = 81\,627\,MPa$$

In this case the safety coefficient is greater than 3727 and the risk of buckling is non-existent.

The packaging body suspended inside the cage does not support a load during this test as all forces are fully absorbed by the cage.

In light of the evidence, this test has no effect on the packaging body and consequently no influence on the content containment function.

6.1.4. <u>Penetration test</u>

The series of drop tests on a prototype package, reported in attachment 2, demonstrates that this test causes no significant damage to the outer surface of the packaging shell, whatever the point of impact.

6.2. TESTS RELATING TO ACCIDENT CONDITIONS OF TRANSPORT

These tests are:

- 9-metre free fall drop test onto an unyielding surface, applicable for all contents containing less than 1000 A_2,
- 9-metre dynamic crush test using a 500 kg mass, applicable for all contents containing more than 1000 A_2,
- free fall drop test from a height of 1 m onto a bar,
- immersion test under a 15-metre head of water for 8 hours,
- the advanced immersion test under a head of water 200 m deep for 1 hour, which is applicable for certain contents with activity in excess of 10^5 A_2.

6.2.1. <u>Drop tests</u>

The series of drop tests summarised in attachment 1 and analysed in attachments 2 and 3 demonstrate that the packaging resists the regulatory mechanical tests (1-metre drop onto a bar and 9-m free fall drop).

The additional tests conducted during a vertical 9-metre drop onto the shock absorber cover (attachment 4) and an inclined drop (attachment 5) confirm the satisfactory behaviour of the package model after the drop tests representing accident conditions of transport. In particular, the containment vessel retains its geometry

and its leakage rate remains acceptable.

Integration of temperature of -40°C

Two components are active in absorbing impacts, the aluminium cage and the shock absorber covers.

The mechanical properties of the aluminium cage increase at low temperature (yield stress, shearing load). At -40°C, the mechanical properties of the aluminium are therefore slightly improved in relation to ambient temperature. Nonetheless, the mechanical performance of the cage is sufficiently weak that its contribution to the deceleration undergone by the closure system is insignificant.

The mechanical properties of the wood in the shock absorber covers at 20°C are increased by 40% to take into account the hardening of the wood at -40°C (cf. [3]).

The notes presented in attachment 4 (where the drop test configuration analysed is the most sensitive to the hardening of the shock absorbing wood) and attachment 5, indicate that the behaviour of the package model during an axial and inclined drop at -40°C is satisfactory.

Therefore, the mechanical performance of the TN-BGC 1 package is confirmed under accident conditions of transport.

Justification of choice of cut-off frequency:

This justification is given in attachment 10. It demonstrates that the natural frequencies of the package likely to be solicited during an axial drop are below 432 Hz.

6.2.2. Immersion test

The package immersed under 15 metres of water is subjected to a relative external pressure of 1.5 bars, and 20 bars under 200 m of water. The latter pressure is used in this paragraph.

In attachment 6 it is demonstrated that the containment system resists a pressure of 20 bars relative without the materials of its constituent components being subjected to forces beyond their elastic limit.

Consequently, the package remains leaktight after the immersion tests.

6.2.3. Water immersion test

There is no rupture of the containment system but for criticality, in light of the leakage flow under air, a certain volume of water may penetrate the packaging cavity.

The criticality-safety studies conducted in this safety file use a worst case scenario of water penetration in the packaging cavity. So in accordance with paragraph 731 of [DR01], the TN-BGC1 package is exempted from this test.

7. CONCLUSION

This chapter demonstrates that the TN-BGC 1 package satisfies the applicable requirements, in particular in terms of sustaining the leakage rate and the retention of the geometry (shape) of the containment vessel.

The modelling hypotheses resulting from the regulatory mechanical tests and used in the thermal analysis (chapter 5), activity release (chapter 6), radiation protection (chapter 7) and criticality (chapter 8) are recalled below.

Thermal

Under normal conditions of transport, an intact packaging without specific damage is considered. Under accident conditions of transport the following hypotheses are applied:

- the shock absorber cover is impacted by 42 mm on its longitudinal axis (the balsa wood is assumed to be compressed by approximately 60%) following an axial drop on the shock absorber cover,
- the shock absorber cover is impacted by 33 mm on its radius due to a drop on the generatrix,
- a part of the outer body shell is dented following the impact of a bar,
- the shock absorber part of the body is impacted by 39 mm along the longitudinal axis following an axial drop on the body base.

Activity release

Sustainment of the leakage rate after being subjected to normal and accident conditions of transport is considered. In effect:

- the compression rings ensuring that seals are leaktight are not subjected to stresses in excess of their elastic limit.
- Therefore the leaktight seal on the containment vessel is guaranteed.
- Major deformations only occur on ancillary organs (e.g. shock absorber covers) and certain parts of the packaging that do not contribute to maintaining the integrity of the containment system (cage).

Radiation protection

Under normal conditions of transport, no significant local reductions in the thickness of the shield are considered. Under accident conditions of transport the following hypotheses are applied:

- the resin of the package body is not considered (to take into account its denting by the bar but also to take into account the results of the thermal test - cf. chapter 5).
- The balsa wood and resin in the shock absorber covers are not considered.

Criticality

In order not to respect the requirements of the water immersion test under normal and accident conditions of transport, for the package lattice a worst case scenario of water penetration in all free spaces of the packaging is considered. The shape of the cavity is sustained and the shock absorbers are ignored in normal and accident conditions of transport.

Under accident conditions, for single package like for a lattice, the thickness of the resin in the packaging body is assumed to be reduced by 15 mm (to take into account its denting by the bar but also to take into account the results of the thermal test - cf. chapter 5).

For package lattice configurations under accident conditions of transport the cage is not taken into consideration.

PROGRAMME: RENEWAL OF STOCK OF CEA PACKAGES

TITLE:

DROP TESTS ON TN-BGC 1

SUMMARY OF TESTS CONDUCTED

Summary:
This document summarises all drop tests conducted on the TN-BGC 1. It demonstrates the satisfactory behaviour of the package under accident conditions of transport (ACT).

Signoff			
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LIST OF CHANGES			
EDITION	DATE	Nature of modification	Pages modified
A	20/02/2004	Document creation	

Contents

I. PURPOSE

In order to verify the exhaustive character of the drop test configurations to which the TN-BGC 1 has been subjected, this document summarises all drop tests that represent the ACT tests conducted on the TN-BGC 1.

The purpose of this document is not to provide a detailed recap of the consequences for the packaging of each drop, but to provide an evaluation of the drop test configurations used and to very their character, which if not exhaustive should be extremely conservative and cover the most penalising worst-case scenarios.

II. REFERENCE DOCUMENTATION

The documents providing details of the drop test configurations or analyses of the test results are as follows:

- Note EMB TNBGC PBC DJS CA000333A, of 07 August 2003 ([2]),
- Note EMB TNBGC PBC STE CA000001A of 17 October 2000 ([1]),
- Note EMB TNBGC PBC CRX CA000018A, of 09 February 2001,
- Note EMB TNBGC PBC NTT CA000149C, of 30 September 2002,
- Note EMB TNBGC PBC CRX CA000304A, of 03 June 2003.

III. DETAILS OF DROP TESTS CONDUCTED

Four series of tests were conducted on the TN-BGC1, i.e.

- one series in February 1988
- a second series in March 1988
- a third series in December 2000
- a fourth series in January 2003.

The tables below summarise the drop test configurations that represent accident conditions of transport. The greyed-out boxes correspond to the first series of tests, which produced deformations on the closure flange and therefore a loss of leaktight seal on the closure system. The containment system (internal shell and welds) remained perfectly intact. The deformations produced are not prohibitive and were taken into account in the supplementary safety analysis alongside the tests. Subsequent to theses drop tests the closure system was modified to produce that described in the current design and tested in the second, third and fourth series of tests. Therefore the conclusions of the first series of tests are not all positive. However, we have included them in the table as they have enabled us to validate the drop test configurations used for the following series (drop tests mainly generated stress on the closure systems).

Drop test configurations representative of ACT are:

- 9-metre free fall drop of 500 kg plate,
- 1-metre drop onto a bar,
- 1-metre free fall drop,

1° <u>9-metre free fall drop of 500 kg plate</u>

	Drop type	Date	A I	Cumulative total	Sanctions	Comments
[redacted]	[redacted]	February 1988	TN 90	After drop tests representative of NCT	General crushing of the structure Protective barrier intact	
[redacted]	[redacted]	February 1988	TN 90	After previous drop test	Shearing of cage by plate and crushing of shock absorber cover	As this drop did not affect the closure system, it was not repeated in March 1988
3	Package vertical	March 1988	TN 90	None	Same as drop test 1 and sustained leaktight seal on packaging	Same drop configuration as drop test 1
4	Package inclined by 15° from vertical	December 2000	TN 90	None	Denting of shock absorber cover, base and deformation of cage Leaktight seal on packaging maintained, radiation protection barrier intact.	*OK*
5	Package horizontal	January 2003	TN90	After NCT drop of 1 m 20	Crushing of cage and shock absorber cover. Leaktight seal on packaging and PAI maintained, radiation protection barrier intact.	

In conclusion, all worst-case scenarios were tested (package in vertical, inclined and horizontal position). The determination of the drop angle for drop test 4 was defined in agreement with PIRSN (cf. [1]). Certain drop tests were not preceded by drops representative of NCT, which is without consequence as they are not of a nature to cause deformation of the shock absorbing components of the package (cf. [2]).

2° 1-metre drop onto a bar

Drop type		Date	AI	Cumulative total	Sanctions	Comments
		February 1988 (2 drops of this type)	TN 90 and AA227	After plate drops (TN90) or 9-metre free fall drops (AA227)	Small dents on shock absorber cover	
2	Drop onto base	February 1988	TN90	After plate drops	Very small dent in base	
		February 1988 (2 drops of this type)	TN 90 and AA227	After plate drops (TN90) or 9-metre free fall drops (AA227)	No visible consequences	
		February 1988	AA227	After free fall from 9 metres	Small dents on shock absorber cover	Results compar[illegible] to drops 1
5	Drop onto cover, package vertical, in centre of cover	March 1988	AA227	After free fall from 9 metres	Small dents on shock absorber cover Leaktight seal on packaging and internal fitting intact	Same as drop 1 Of drops 1, 2, 3, 4, this caused the most stress on the closure system
6	Drop onto bar, package vertical, cover side, inclination of 14° to the vertical	January 2003	TN90	After free fall from 9 metres	Limited denting on cover No perforation of cover Good leaktight seal on packaging and internal fitting	
7	Drop on to generatrix, angle of drop 21° to the horizontal	January 2003	TN90	After plate drop	Slight dent in resin Good leaktight seal on packaging and internal fitting	
8	Drop onto generatrix, inclination of 35° to the horizontal	January 2003	TN90	After plate drop	More marked dents on the resin and localised baring	

This table shows that the bar applied forces on the most vulnerable parts of the packaging (cover, base, body), whether an inclination was applied or not. What is more, these drops were systematically accumulated with others representative of ACT in accordance with the regulations. Using a conservative approach, the drops onto a bar were always conducted after a free fall or a plate drop. All these drop tests serve therefore to reasonably cover the most penalising drop test configurations that may be encountered during transport.

3° <u>9-metre free fall drop</u>

	Drop type	Date	AI	Cumulative total	Sanctions	Comments
[redacted]		February 1988	AA227	None	Shortening of cage - Dents in cover	
		01 February 1988	AA227	After drop n° 1	Shearing of the majority of body-cage bolts	
		08 February 1988	AA227	None	Dents in base and buckling of cage upright suffering the impact	
		February 1988	AA227	After drop n° 3	Crushed cover and cage	
5	Vertical drop on cover	March 1988	AA227	None	Cover crushed and flexion of an upright Leaktight seal on packaging and PAI	Re-execution of drop 1
6	Inclined drop on shock absorber cover	March 1988	AA227	None	Crushed shock absorber cover Leaktight seal on packaging and internal fitting	Re-execution of drop 4
7	Vertical drop on cover	January 2003	TN90	None	Deformation of cage and dents in shock absorber cover. Leaktight seal on packaging and internal fitting	Re-execution of drop 1

8	Horizontal drop with whiplash (10° angle)	January 2003	TN90	After a 9-metre free fall drop and drop onto a bar	Shearing of cage-body bolts and displacement of packaging body Leaktight seal on packaging and internal fitting	Re-execution of drop 2

The selected configurations therefore enable us to either maximise the deceleration on the closure system (drops with whiplash and vertical drops), or to maximise the deformation of shock-absorbing components (inclined drops). Certain drops were reproduced to check that the closure system on the packaging and the internal fitting behaved correctly. The two main types of internal fittings used in the package were tested (TN 90 representing internal fittings with thin walls and AA227 representing internal fittings with thick walls).

IV. CONCLUSION

This summary shows that the consequences of the drop tests conducted demonstrate the satisfactory behaviour of the package under accident conditions of transport.

As a whole the package conserves a satisfactory leaktight seal and its radiation protection is not altered (layers of steel and resin).

The deformations observed on the cage were taken into account in criticality studies.

PROGRAMME: RENEWAL OF STOCK OF CEA PACKAGES

TITLE: SAFETY ANALYSIS REPORT FOR THE TN-BGC1 PACKAGING

CHAPTER 4 APPENDIX 1

DROP TEST REPORT ON PROTOTYPES OF THE TN-BGC 1 PACKAGING

COPY

Summary:
This note is an integral part of the TN-BGC 1 safety analysis report. It presents the results of the regulatory drop tests conducted on prototypes of the TN-BGC 1 packaging during the months of February and March 1988.

Signoff			
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E M B T N B G C P B C D J S C A 0 0 0 3 3 3 A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

LIST OF CHANGES

EDITION	DATE	Nature of modification	Pages modified
A	07/08/03	Document creation	

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1 INTRODUCTION

This appendix presents the results of the regulatory drop tests conducted on prototypes of the TN-BGC 1 packaging during the months of February and March 1988 at the test facility belonging to the Department of Mechanical and Thermal Studies Department of the Atomic Energy Commission (CEA- DEMT) in SACLAY, France.

After a reminder of the purpose of these tests, we will describe the prototypes and the test facility, each of the tests carried out and its consequences, then provide the results of the inspections conducted during and after the tests.

The tests were carried out according to programmes <1> and <2> respectively for the first and second series, and according to specification <3>.

2 PURPOSE OF THE TESTS

The tests conducted correspond to the drop tests envisaged by the French Regulations on the transport of radioactive materials dated 15 April 1945 (administrative order of 24 June 1974) and in the IAEA recommendations (1985 Edition - Vienna).

Their purpose is to show that the prototypes of the TN-BGC 1 package model successfully complete the regulatory drop tests in such a way that it will then be possible to demonstrate that the package model itself satisfies the provisions concerning Fissile Class II Type B(U) packages.

3 DESCRIPTION OF PROTOTYPES

3.1 General information

The prototype packagings used for these tests are 1:1 scale replicas of the TN-BGC 1 serial-produced packagings (photo no. 1). Two prototype models were used for the two series of tests (see plans <5> to <7>).

3.2 Contents

The content of the prototypes was either a type AA227 internal fitting loaded with scrap metal, or a TN 90 type internal fitting. In the latter case, the prototype was loaded with two bottles of the same type as those used to transport uranyl nitrate, containing water (to obtain a boiling point as close as possible to that of uranyl nitrate) and sand (to achieve the same mass).

3.3 Reference plans

The reference plans used to manufacture and assembly the prototypes are appended to the end of this appendix.

3.4 Manufacture

The prototypes were manufactured using identical procedures to those envisaged for the packagings themselves, in particular concerning welds and inspections.

3.5 Differences between prototypes and serial packages

The differences between the prototype packagings and the serial-produced packagings are due to the alterations adopted after the tests were completed, in order to improve the performance of the serial-produced packagings.

3.5.1 Differences between the second prototype and serial packages

3.5.1.1 Cages

The device delimiting the outer surface of the package was built on the prototype using flat aluminium sections attached to the tubes of the cage structure. In the series packagings these flat sections may be replaced by fixed perforated plates or any other equivalent device.

As the mechanical resistance of this device is insignificant, these fittings have not effect on the behaviour of the packaging.

The height of the different levels was modified for the serial packagings; all stages have the same height (535 mm) yet on the prototypes they had the following heights: 520 mm for the two lower stages and 565 mm for the upper stage.

The modification was so minor that it did not alter the behaviour of the cage: the vertical and horizontal uprights were identical and the variation in the angle of the diagonals was less than 3°.

Aluminium feet were added to stiffen the base of the uprights against any slight knocks occurring during handling. It is clear that this can only improve the behaviour of the cage.

In the case of option 2 (see chapter 3), the following additional modifications were made:

- Certain 40x40x4 cornices were replaced with 60x60x4 cornices flared at their ends to facilitate the passage of forks. For this reason, the distance between the small vertical tubes onto which the 60x60x4 cornices were mounted was shortened for 200 mm.
- In the upper part, the three faces other than the front side were modified by adding a 30x30x2 square tube at 95 mm below the top square tube, at the same height as that of the front side.

  Two square vertical tubes were placed on each side between the horizontal tubes.

  The transverse squares of the three upper side faces and the protective sheeting were therefore altered.

  Of these two changes, only the latter is likely to significantly alter the behaviour of the cage during drop tests, by altering the rigidity of the upper part of the cage, in particular in the drop onto a shock absorber.

  In effect a static crush test <4> on the two upper parts of the cage (options1 and 2) showed that the behaviour of the two stages was identical. For the representative sample of option 1 of the cage design, the ruin was observed for a load of 19500 daN and crushing of 9.6 mm. For option 2 the load was 22500 daN and the crushing amounted to 11.8 mm.

  The difference of 15 ô observed between the crush forces applied to the two types of cage was not significant, as it lay within the same order of size as the difference that could be observed for example between two cages built according to the same specifications. Moreover, this difference corresponds to 3000 daN, or an acceleration below 10 g. This difference is also insignificant in relation to the acceleration of 510 g measured during the drop (see paragraph 5.4.2), in light of the total lack of damage observed on the closure system.

3.5.1.2 *Body*

The identification and regulatory plates were welded to the serial packagings. These plates have no role in the mechanical performance of the packaging and therefore do not alter its behaviour.

The attachment of the cage to the body was modified: elimination of one of the two bolts, alteration of the size of the attachment tabs. The bolts play no role during drop tests, vertically the connection is provided by the pressure applied by the tabs on the cage and horizontally by the body pressing directly on the cage. So the elimination of one of the bolts did not alter its behaviour. Concerning the new tab, in light of the role explained above and the type of operation described in chapter 3, the thicker version (3 mm instead of 2) and the smaller size offer better performance.

3.5.1.3 *Plug*

All helicoids were eliminated from the serial packaging, which can only improve the resistance of the closure system.

On the serial-produced packagings, the inspection port was used to inspect two inter-seal spaces. On the prototypes, two inspection ports were built in to test the double seals independently. Eliminating one port can only improve the performance of the plug.

On the serial packaging, the polyethylene ring was 4 mm thinner than on the prototypes, this thickness being absorbed by the closure sheet. The quantity of steel was therefore higher, which can only improve the performance on the plug.

3.5.1.4 *End covers*

The holes drilled in the sheets to enable pouring of the resin are not located in the same position. As these holes were re-plugged after pouring the resin with a welded patch, their position has no effect on the resistance of the end cover.

3.5.1.5 *TN 90*

The three bosses on the TN90 plug were replaced by a collar around the plug. This improves the distribution of forces on the plug and therefore increases its resistance.

The inspection ports were modified to facilitate operations. This has no influence on the plug's resistance capacity.

3.6 Differences between the two prototype models

The first prototype is the initial version of the packaging and shows more differences with the serial production packaging than the second prototype.

The differences between the two prototypes are visible on the plans appended to this chapter and concern the closure systems on the body and on the shock absorber cover.

3.6.1 Closure system

The differences concern how the plug is held in position on the body. The principle is the same in both cases: the plug is applied to the flange using a bronze ring, which is screwed into a bayonet ring resting on the body flange. However, although the plug is the same, the bronze ring, the bayonet ring and the body flange have been modified. The choice of the second design was justified by the test results.

3.6.2 Shock absorber cover

The differences between the two designs concern:

- the internal form, which must be compatible with the closure system,
- the nature and orientation of the wood used in the upper part: in the first prototype the upper part featured poplar wood, with the fibres oriented along the same axis as the shock absorber cover. In the second design, to reduce the stiffness, poplar wood was replaced with balsa, and in the central part, the fibres were perpendicular to the axis of the shock absorber cover;
- the attachment of the shock absorber cover to the body: in the first design this was done using four clamping pins; in the second design two pins are used along with two bent rods that are embedded in two attachment tabs. The second system is not subject to the risk of release of the clamping pins and is therefore an improvement.

The choice of the second cover design was also justified by the test results.

3.6.3 Masses

For the first prototype model, the mass of the packaging loaded with the TN 90 internal fitting was 310 kg, when loaded with the AA227 version it weighed 372 kg. For the second prototype model, the masses are respectively 320 and 384 kg. The new masses are equivalent to those of a serial produced packaging.

4 TEST FACILITY

4.1 Target

The target surface for the drop tests, with a total weight of 182 tonnes, was made up of the four following elements:

- four reinforced concrete piles with a diameter of 0.80 m and a depth of 14 m, seated in a layer of sand;
- two reinforced concrete beds measuring 3.5 x 1.2 x 1.0 m linking the pile heads two by two;
- a reinforced concrete table anchored to the two beds, measuring 7.7 x 3.0 m, with a thickness of 1.0 m at its ends and 1.70 m in the centre, on a surface area of 3.0 x 3.0 m;
- two distribution plates measuring 3.0 x 3.0 x 0.05 m each, the first fixed using tie-rods in the table and the second drilled with a large volume of threaded holes to enable the attachment of other components if necessary.

In particular, the bar used for the regulatory no. 2 drop tests was vertically inserted and bolted into an intermediate plate, itself bolted into the second distribution plate. The height of the bar above the plate was always greater than the length of its penetration into the prototypes.

4.2 Plate

The assembly used for the 500 kg plate drops featured an 850 x 1000 x 70 mm plate topped with a structure to enable the handling and orientation of the assembly.

For the plate drop test the plate is guided using two tensioned cables, each passing either side of the plate and through two holes in the structure above the plate. To keep friction to a minimum, each hole is lined with a Teflon coating.

Note: The dimensions of the plate are smaller than those envisaged by the IAEA 1985 recommendations. As the plate is larger than the packaging, the consequences of this difference in dimensions are highly limited. Moreover, this can only have a penalising effect by increasing the load concentration.

4.3 Lifting and release

The plate and package were raised using a hoist with a lifting height of 19 m.

The release was actuated using hook with a pyrotechnical opening system. The system was controlled remotely using an electric cable.

4.4 Instrumentation and measurement systems

For the 9-metre drop tests the packaging was equipped with two acceleration meters. The signals were recorded on magnetic tape. The recording was done raw, but also features post-recording treatments to filter the high frequencies; as the filter level could be adapted to each case, it is indicated on the acceleration curves attached to the end of this chapter.

What is more, in certain drop tests films were made using fast-action cameras. This may enable additional analysis.

Lastly, leakage tests were conducted on the packaging body and on the internal fitting. For the body, in relation to the level required, a helium vacuum method was used. The vacuum was created in the two inter-seal spaces (the plug itself and the quick-fit connection cap), and in the cavity, then the cavity was filled with pressurised helium. Lastly the helium penetrating the inter-seal spaces was measured. However for the AA927 and TN 90 internal fittings, as the required level was lower, a simple pressure rise measurement was sufficient.

5 FIRST SERIES OF TESTS

The first series of drop tests took place between 29 January 1988 and 17 February 1988. It was carried out in respect of programme <1>, which also justifies the choice of the drop tests executed.

5.1 Tests representative of normal conditions of transport

<u>Packaging used:</u> Cage: 1

Body: 1

Shock absorber cover: 1

Internal fitting: TN 90

Cage 1 presents clearly inferior mechanical properties than those of cage in its definitive design, insofar that the welds between the tubes were milled.

5.1.1 30 cm drops (drop tests no. 1 to 8)

Description:

A series of 8 drops from 30 cm onto each corner.

Damage:

For these drop tests, the packaging was systematically tilted into a vertical position except for drop no. 3 (drop onto a lower corner).

In general we observed the appearance of numerous fissures in the welds between the tubes (photo no. 2) and the shearing of certain bolts attaching the body to the overpack.

For the drops onto lower corners, we observed local crushing in the order of 15 mm to the impacted corner and a flexion of the whole horizontal tube up to the level of the vertical upright stopping at the fork passage (photo no. 2).

For the drops onto upper corners, the local crushing has the same order of value as previously. We also observed a greater global deformation (in parallelogram) near to the upper fork passage opening.

5.1.2 1.20 m drops (drop test no. 9)

Description:

The packaging falls onto its base in a vertical position.

Damage:

Essentially we noted an elephant foot deformation of the bottom of the packaging body on a portion of the perimeter (increased radius by 5 mm, height by 5 mm, angle 135°) - these deformations are comparable to those observed in photo no. 8. We also observed the shearing of a body support tube near the passage of an anchoring bolt. Lastly, the fissures appearing during the 30 cm drop opened slightly more.

5.1.3 Drop of 6 kg bar (drop no. 19)

Description:

The bar was dropped onto a generatrix on the packaging body in the horizontal position.

Damage:

Damage was non-existent, the paint was hardly scratched (photo no. 4).

5.1.4 Conclusion

All these tests representing normal conditions of transport essentially caused the appearance of damage on the cage. They are therefore not of a nature to alter the different functions concerning the containment of radioactive materials, evacuation and thermal protection, shielding against radiation and sub-criticality.

What is more the weld fissures appearing in the 320 cm and 1.20 m drops should not appear on a serial-produced package as the 9-metre drops (much more severe than these) executed with cages on which the welds were not milled, demonstrated the almost non-existence of damage in these areas.

5.2 500 kg plate drops

Packaging used: Cage: 1b

Body: 1

Cover: 1

Internal fitting: TN 90

Cage 1b is the same as cage 1 but its welds were redone to avoid being overly penalising and to ensure compliance with the definitive version of the design.

5.2.1 Vertical packaging (drop no. 10)

Damage:

After this drop, the main observations of apparent damage are as follows:

- deformation of the wood protection at the base of the body in an elephant foot form, with the maximum diameter extending to 315 mm (for an initial value of 295 mm) and the deformations are visible over a height of 20 mm (visible on photo no. 8);
- reduced height of cage, from 1815 mm (nominal value) to a value between 1770 and 1780 mm (photo no. 5);
- the length of the body is shortened to 1780 mm for an initial value of 1795 mm.

We also observed the following points:

- a handle on the shock absorber cover was torn off
- certain rivets anchoring the plates (ensuring no passage with dimensions greater than 10 cm) to the cage were ejected
- some fuse plugs were torn from their housing
- the fissure in an attachment tube observed after the 1.2 m drop (paragraph 5.1.2) was wider.

5.2.2 Horizontal packaging (drop no. 11 - photo no. 5)

Description:

For this test the packaging in a condition after the previous drop test is placed in a horizontal position on a cage ridge. The packaging is held steady using thin expanded polystyrene plates that provide no significant additional resistance.

Damage:

- Shearing of the cage by the plate (photo no. 6)
- crushing of shock absorber cover reducing its diameter to 440 mm (initially 466 mm) (photo no. 7)
- crushing of cage modifying the large diagonal to 990 mm and the small diagonal to 500 mm (initial values: 850 mm) (photo no. 7)

5.3 Drops onto bar

Packaging used:

Identical to that undergoing the two plate drops described in the previous paragraph.

5.3.1 Drop on shock absorber cover (drop no. 12)

Damage:

We observed denting with a depth of 3 to 5 mm on the cover (deformations visible on photo no. 9) and the opening of a clamping pin.

5.3.2 Drop on base (drop no. 12)

Damage:

The depth of the denting in the base of the packaging is less than the previous test and remains below 3 mm (photo no. 8).

5.3.3 Drop on body generatrix

(drop no. 14 - photo no. 9)

Damage:

We observed no perceptible deformation, the paint was hardly scratched.

5.4 9-metre drop tests

Packaging used: Cage: 2

Body: 2

Cover: 2

Internal fitting: AA 227

5.4.1 Vertical drop on shock absorber cover (drop no. 15)

Damage:

- shortening of the cage, with the height varying between 1795 and 1799 mm after a drop,
- crushing of cover with appearance of slight elephant foot deformation and flexion of parts not resting against the body,
- local buckling (blistering) of cage tubes near to the fork passages (photo no. 10).

Accelerations

The packaging was equipped with two accelerometers fixed to the bottom of the packaging. As these devices became unstuck from the support, the measurements were deemed unusable.

5.4.2 Horizontal inclined drop

(drop no. 16 - photo no. 11)

Packaging used:

Packaging in condition after previous drop test.

Description:

The angle of inclination measured for the drop was 10°, the rear of the packaging impacting the target surface first.

Damage:

- Opening of a clamping pin fixing the shock absorber cover to the body,
- the majority of the anchoring bolts between the body and the cage were shorn and the support tubes shorn in certain places by the bolts,
- a diagonal and an upright were shorn.

Accelerations

The packaging was fitted with two accelerometers anchored to the body using small supports to ensure they remained in a vertical position. One of the two signals was usable (accelerogram no. 1) and gave a first result with a maximum value of 180 g. After 15 ms, there were significant variations in accelerations with positive and negative values, the first rising to 405 g for positive values and 51g in negative values. We can consider that this corresponds to the impact of the shock absorber cover, although in light of the initial drop angle this should have occurred later.

5.4.3 Inclined drop on base (drop no. 17)

Packaging used: Cage: 3

Body: 2

Cover: 2

Internal fitting: AA 227

Damage:

- denting of bottom casing to a maximum of 80 mm with deformations over more than half of the base (170 mm for a diameter of 300 mm) (photo no. 12),
- crushing of cage by approximately 150 mm at the angle of impact and 10 mm at the two adjacent corners, the edge not impacted directly not suffering deformation (photo no. 13),
- shearing of 3 zones of the lower support frame (photo no. 13),
- buckling of upright suffering the impact (photo no. 13).

Accelerations (Accelerogram no. 2)

One accelerometer was attached to the shock absorber cover and another to the body. The accelerometer on the body produced a maximum value of 180 g. However that on the shock absorber cover produced a signal that was difficult to interpret: the signal started at 0, then rose to 550 g and fell back to 250 g, not 0. Aside the fact that the signal did not return to 0 (which generates serious reserves concerning this measurement), we accept that the accelerometer was attached to the shock absorber casing, and therefore subject to extensive vibrations during the impact, which amplified the accelerations artificially. The usable value is therefore that measured on the body, i.e. 180 g.

5.4.4 Inclined drop on shock absorber cover (drop no. 18)

Packaging used:

Packaging in condition after previous drop test.

Damage:

- the cover was crushed to a maximum of 30 mm, the deformations were significant over a width of 170 mm (for a nominal diameter of 466 mm) (photo no. 14),
- crushing of approximately 80 mm on the corner of the cage subjected to the impact (photo no. 15),
- buckling of the diagonal arriving at the angle subjected to the impact (photo no. 15),
- flexion of a lower upright due to the impact on the corner of the slab when tilting over.

Accelerations:

The packaging was fitted with 2 accelerometers: one on the base and the other on the body. The meter located on the body provided a maximum acceleration value of 265 g and did not return completely to 0 (residue of approximately 40 g) and that on the base registered a maximum of 330 g. The general aspect of the two accelerometers is nonetheless almost identical (Accelerogram no. 3).

5.5 Drops on bar

Packaging used:

Packaging that was subjected to the two previous 9-metre drops: the body and the shock absorber cover were therefore subjected to four drop tests while the cage was only subjected to drops 17 and 18.

Description:

A series of 3 drops comparable to those described in paragraph 5.3 was conducted: drop on body generatrix (drop no. 20), drop on base (drop no. 21), drop on shock absorber cover (drop no. 22).

However in relation to the previous series, for the drop onto the shock absorber cover, the point of impact on the bar was not located in the centre of the cover but was offset, if possible in order to highlight the cover being shorn from the body.

Damage:

The possible tearing phenomenon of the cover did absolutely not occur and the overall results for these three drops are comparable to those observed after the previous series (paragraph 5.3) (photos no. 16 for the drop on the generatrix, no. 17 for the drop on the base and no. 18 for the drop onto the shock absorber cover).

5.6 Final observations, analysis and conclusion

After these tests, the shock absorber covers were removed from each packaging. It was then revealed that the leaktight seal was no longer present on the plug. In effect, the deformations of the bronze ring were such that the plug no longer correctly fitted the body and therefore the seals no longer performed their function. However, the helium tests conducted showed that the containment vessel itself remained perfectly leaktight. Furthermore, we observed totally insignificant deformations on the body.

We can therefore conclude that the packagings subjected to this series of tests were satisfactory in terms of the body and cage design. There remained nonetheless a problem concerning the plug. To resolve this problem, we decided to modify the design of the closure system (bronze compression ring + bayonet ring + body flange) so as to produce a system that tended to compress the plug into the body during a vertical impact. Furthermore, to reduce the acceleration and therefore the forces exerted on the components, the upper part of the shock absorber cover was modified to make it more supple, but the side part was not changed.

Concerning the internal fittings, the AA227 remained perfectly leaktight. The TN 90 however was no longer leaktight, due to the major deformations of its lid. In effect, due to the high accelerations, the TN 90 violently impacted the packaging plug via the nut located in the centre of the lid. The lid therefore buckled due to the extensive force exerted in its centre. To remedy this, on one hand the closure system was modified to improve the contact between the seals and on the other hand pins were added to the lid so that the pressure on the packaging plug would be applied on the outside.

Consequently, it was necessary to execute new tests for those affecting the plug and closure system directly. This concerned the 500 kg plate drop on the package in vertical position, the drop on the shock absorber cover with the packaging in vertical position, the inclined drop on the shock absorber cover and the 1-metre drop onto a bar.

6 SECOND SERIES OF TESTS

This series of tests was carried out from 24 March to 29 March 1988, in respect of the programme defined in document <2>.

6.1 Plate drop test (drop no. 23)

Packaging used: Cage: 4

Body: 3

Cover: 3

Internal fitting: TN 90

Apparent damage:

- Shortening of the cage, with the height varying between 1755 and 1763 mm after impact,
- Elephant feet deformation on the base with a diameter after impact of 303 mm,
- Crushing of the shock absorber cover corresponding to a 25 mm compression of the balsa in the cover (initial balsa thickness 70 mm),
- Local buckling (blistering) of the uprights near the fork passages (photos no. 19 and 20).

6.2 9-metre drop - vertical packaging (drop no. 24)

Packaging used: Cage: 4

Body: 3

Cover: 4

Internal fitting: AA 227

Description of drop:

The packaging falls onto a shock absorber cover in a vertical position.

Apparent damage:

- Crushing of the shock absorber cover corresponding to a 25 mm compression of the balsa in the cover (initial balsa thickness 70 mm),
- Significant flexion of one of the uprights.

Accelerometers : (Accelerogram no. 4)

The two accelerometers fixed to the base of the packaging produced comparable signals and maximum values of 540 g and 510 g. However we observed residual signals in both cases, of 50 and 90g respectively, which leads us to believe that the maximum values indicated previously are undoubtedly overvalued.

6.3 9-metre drop onto corner - shock absorber cover side (drop no. 25).

Packaging used: Cage: 4

Body: 3

Cover: 5

Internal fitting: AA 227

Deformations observed:

- Crushing of shock absorber cover with visible deformations on half of the surface (photo no. 21). The exact value of the deformations of the wood is difficult to evaluate as the casing that encloses it also presents major deformations that are different to those on the wood (in particular the casing becoming detached from the wood). After the fire test (see chapter 2.4) the cover was cut open and we observed that the thickness of wood in the impact corner was reduced by 10 mm by the fall.

Accelerations:

The form of the two signals corresponding to the two accelerometers (on the base and on the body) is comparable. The levels are somewhat different nonetheless. The accelerometer on the base (therefore subject to amplified and parasite vibrations) gave a maximum value of 330 g while that on the body only produced a reading of 240 g (accelerogram no. 5).

6.4 Drops onto bar (drops no. 26 and 27).

Description of drop:

The packaging was dropped onto the bar in the centre of the shock absorber cover, a zone where the fibres of the balsa wood are aligned crossways and therefore where the resistance is least. The previous tests (paragraph 5.5) showed that an offset drop did not cause more significant damage to the packaging.

Packaging used: Cage: 4

Body: 3

Covers: 4 and 5

Internal fitting: AA 227

Damage:

Denting of shock absorber cover at point of bar impact (photo no. 22). For the same reasons as before, the exact crushing value is difficult to evaluate precisely. After cutting the cover open, we measured a thickness of compacted wood reaching values between 30 and 35 mm.

6.5 Tests

After the drop tests, the helium tests conducted on the packaging demonstrated that the leakage rate was below $6x10^{-7}$ $atm.cm^{3/s}$ or $0.5x10^{-3}$ lusec (for a helium pressure of 1.2 bars).

For the TN 90 and AA227 internal fittings, the leakage rate reached less than $6x10^{-4}$ $atm.cm^3/s$.

7 CONCLUSION

A series of tests was carried out on two prototype models of the TN-BGC 1 packaging, the first model featuring a closure system and upper part of the shock absorber cover that differed from the final design.

The tests representing normal conditions of transport were conducted on a prototype of the first model. In light of the limited character of the damage observed, it is perfectly representative of what would have been observed on the design for which this safety analysis report is applicable (in particular neither the body nor the shock absorber cover were affected).

The 500 kg plate drop test on a vertical packaging was conducted on the second prototype model, which represented a serial-production packaging.

The 500 kg plate drop test on a horizontal packaging was conducted on the first prototype model, but the result showed that the closure system of the packaging was in no way affected by this type of impact. The result of this test can therefore be transposed to the second prototype model and to the serial production packagings.

Therefore the TN-BGC 1 packaging is resistant to a 500 kg plate drop.

Four 9-metre drops were carried out:

- The drop onto the base does not depend on the design of the packaging closure system and the shock absorber cover, it only concerns the lower part of the packaging.
- The horizontal packaging drop only affects the behaviour of the side part of the shock absorber cover and the cage (identical for both prototype versions).

  These two tests demonstrated that the cavity of the tested packaging remained leaktight. As it is the only area affected by these drops, and although the packaging was the first prototype model, any packaging using the final design would remain leaktight after these two drop tests.
- The two last drops on the shock absorber cover were conducted using the prototype with the upper part compliant with the configuration used for serial production as in option 1.

  The test report enclosed in the official report <4> validates these drops for the serial-production packaging with a cage built according to option 2.

It is therefore proven that the TN-BGC 1 packaging model remains leaktight after the 9-metre drop tests.

Lastly, the drops onto a bar were conducted on the base of the body, a generatrix of the body or shock absorber cover. Each time for the zones in question, they were carried out on packagings representing serial-production packagings and after either the 500 kg plate drops or the 9-metre drops. The packagings remained perfectly leaktight after these tests.

Concerning the masses, the 9-metre drops were conducted with the heaviest packagings. However between the first and the second series the mass was increased and the maximum mass may reach 396 kg (chapter 2). An increase in mass, all other things equal, results in 1) a reduction in the acceleration (therefore a beneficial effect, especially for internal fittings) and 2) increased deformation in the same proportion as the increase in mass. Between the first series packaging (372 kg) and the heaviest serial-production model (396 kg) the increase in mass is below 7%. The margin available on the crushing of wood was largely superior to this value, the fall of a 396 kg packaging will not cause damage significantly greater than those observed.

As no notable loosening of the closure system was observed during the drops onto the shock absorber cover, we can therefore affirm that the missile effect of the contents during a fall is not likely to cause damage to this type of closure system (there is no notable difference between the masses of the contents used for the drop tests and those of the contents used in the serial-production packagings).

In conclusion, after completing drop tests representing normal and accident conditions of transport, the TN-BGC 1 packaging model remained leaktight with a leakage rate below $6x10^{-7}$ atm.cm^3/s. The TN 90 and AA 227 internal fittings presented a leakage rate below $6x10^{-4}$ atm.cm^3/s for the TN 90 and $6x10^{-5}$ atm.cm^3/s for the AA 227.

Furthermore the maximum acceleration reached 510 g in a horizontal drop, 180 g for a drop onto a bottom corner, 540 g in a vertical drop onto the shock absorber cover and 330 g in a drop onto a cover corner.

Lastly the damage observed is sufficiently insignificant to not impair the thermal analysis, the sub-criticality calculations and the evaluation of dose rates.

8 REFERENCES

<1> Note TRANSNUCLEAIRE 9990-B-1 Rev. 1 Programme of application of tests imposed by transport regulations.

<2> Note TRANSNUCLEAIRE 9990-B 2 Rev. 0 Supplementary test programme

<3> Specification TRANSNUCLEAIRE 9990-A-10 Rev. 1 Specifications for regulatory tests

<4> CEBTP report - official test report no. 1 - Document 2342-6-545 of 24 January 1991.

PLANS OF PROTOTYPE PACKAGINGS (attached to this appendix)

<5> Second TN-BGC1 prototype - Layout - Plan 9990-70 A.

<6> First TN-BGC1 prototype - Plug fitted - Plan 9990-71 A.

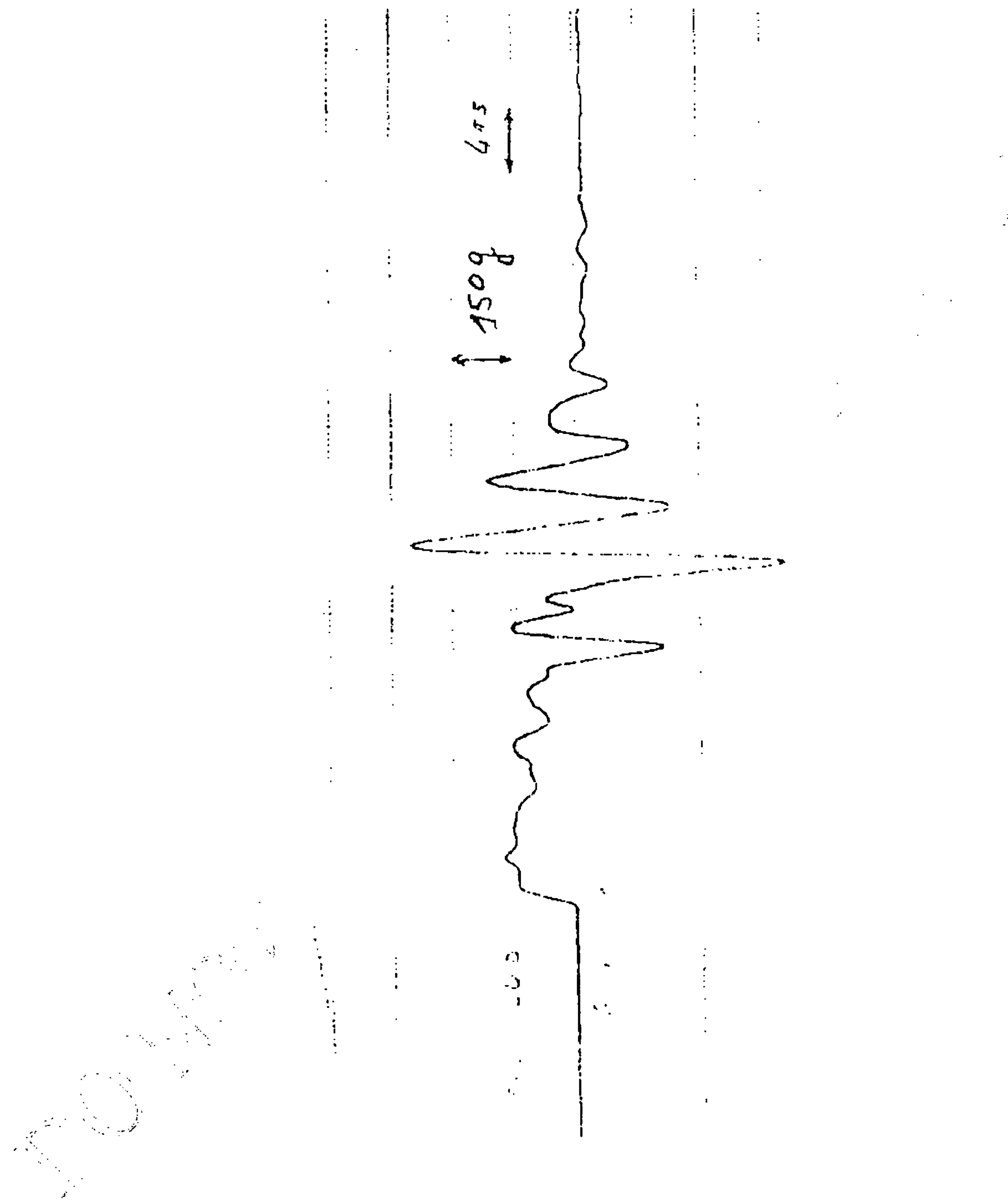
<7> Second TN-BGC1 prototype - Plug fitted - Plan 9990-72 A.

LIST OF ACCELEROGRAMS

LIST OF PHOTOGRAPHS

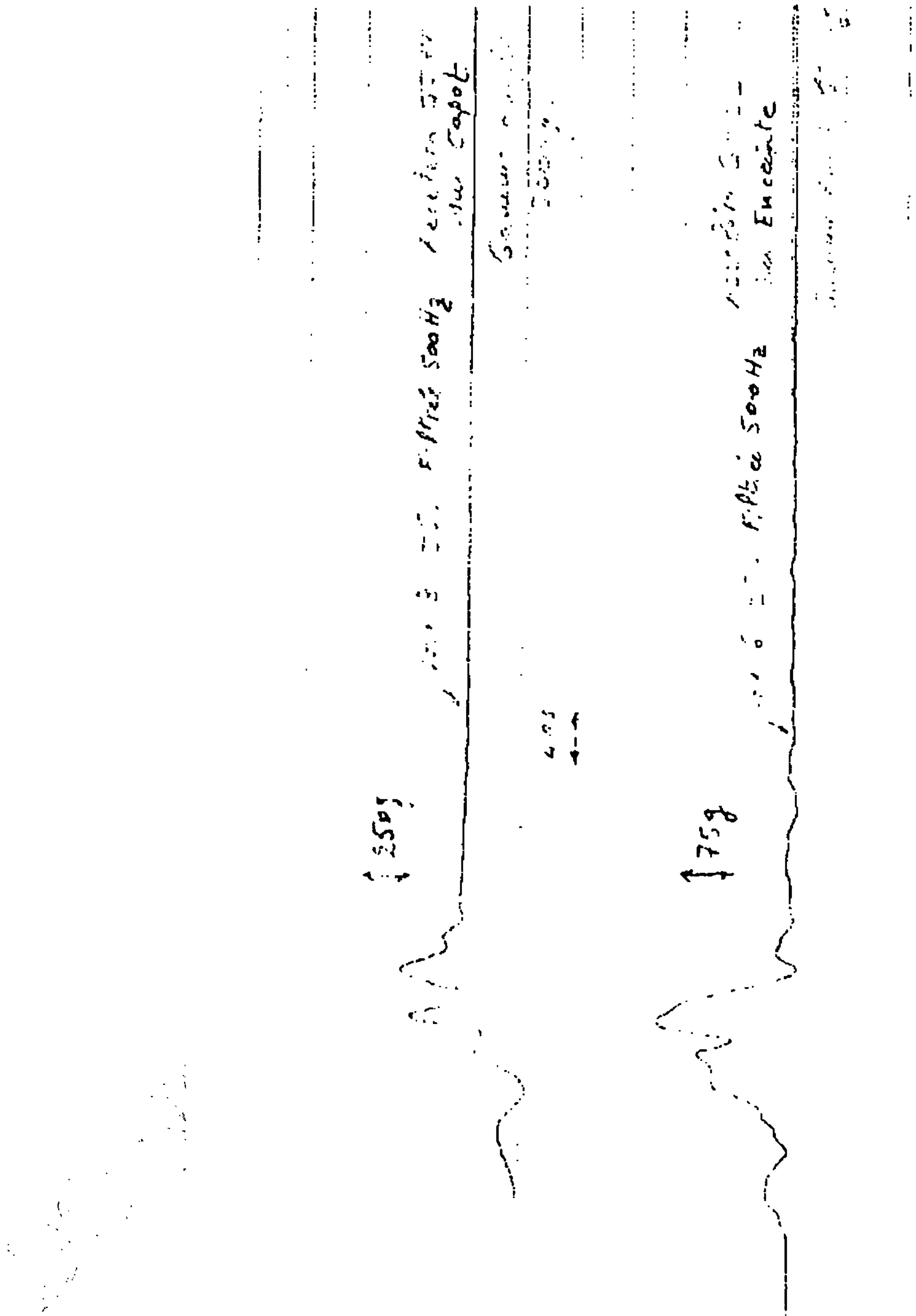
Accelerogram 1

Drop no. 16 - Horizontal



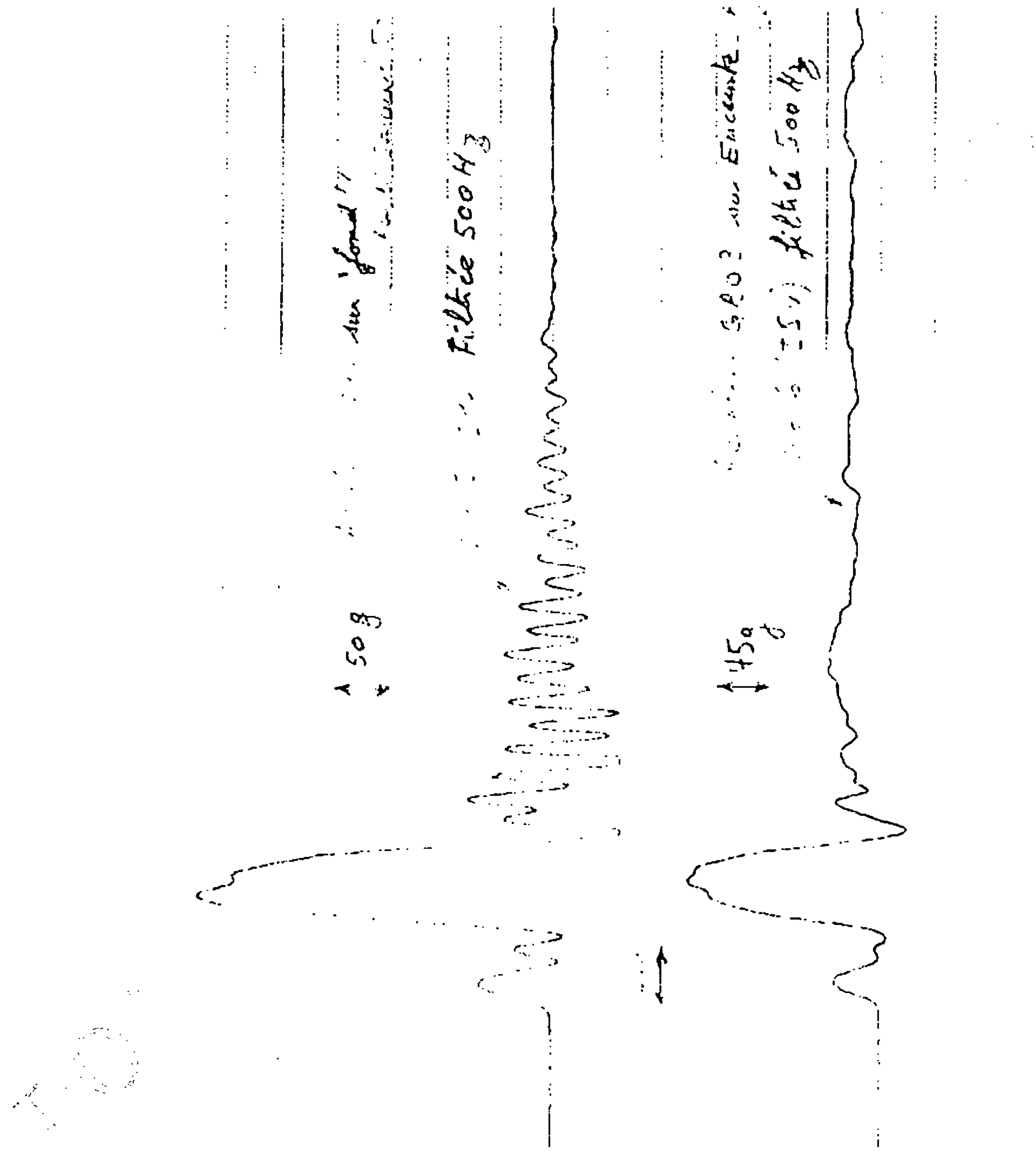
Accelerogram 2

Drop no. 17 - Inclined drop onto base



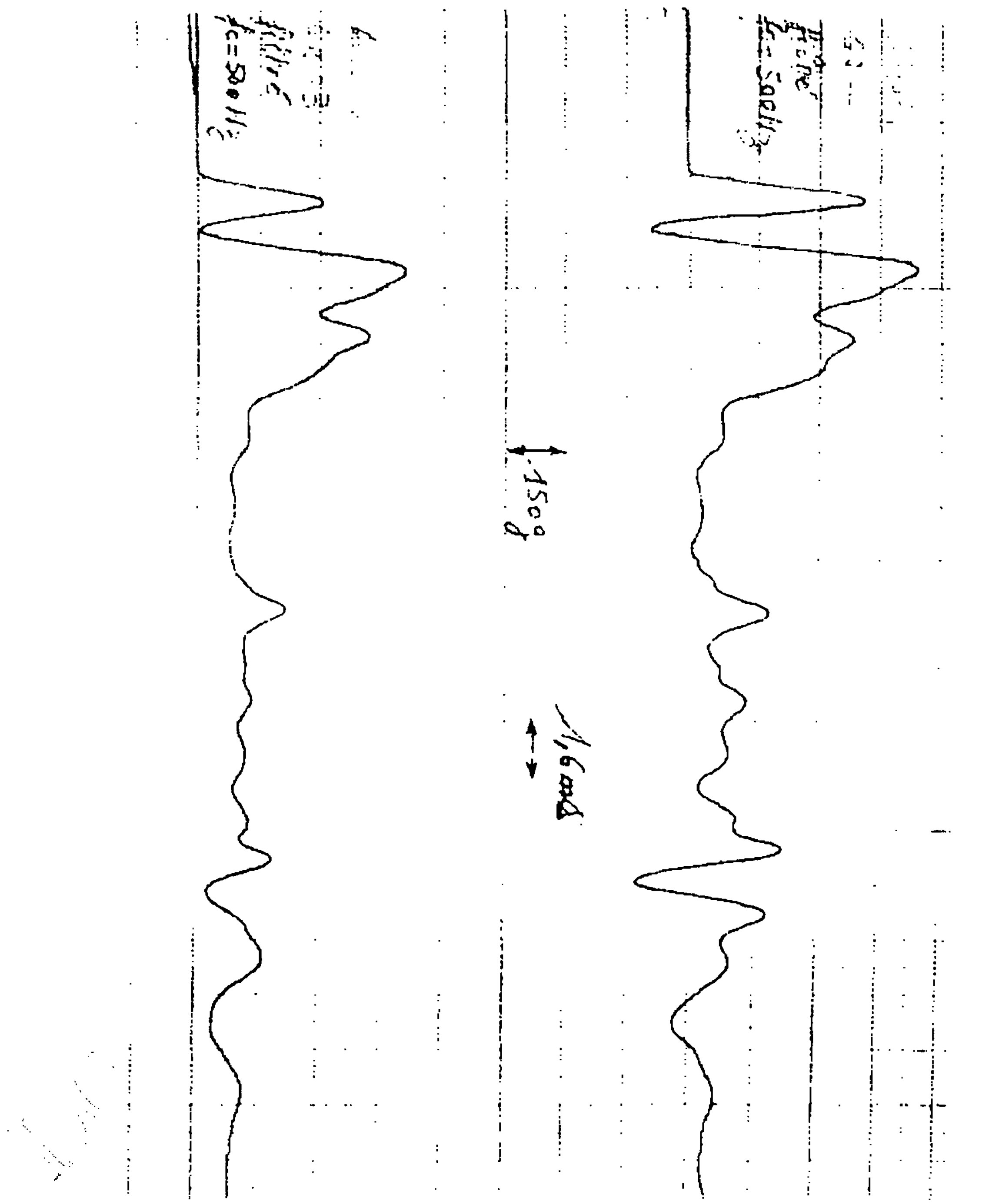
Accelerogram 3

Drop no. 18 - Inclined drop onto cover



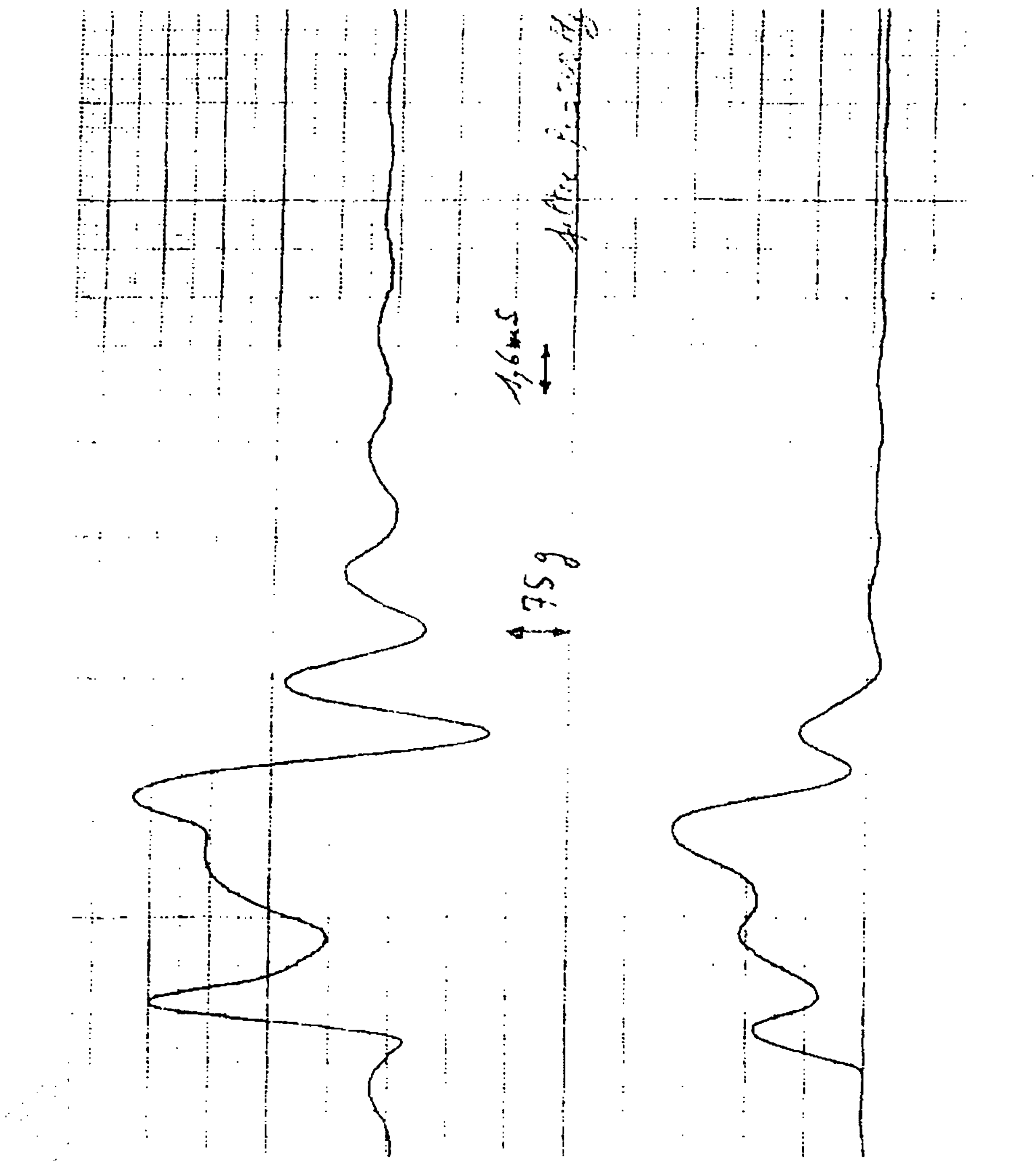
Accelerogram 4

Drop no. 24 - Vertical



Accelerogram 5

Drop no. 25 - Inclined drop onto cover



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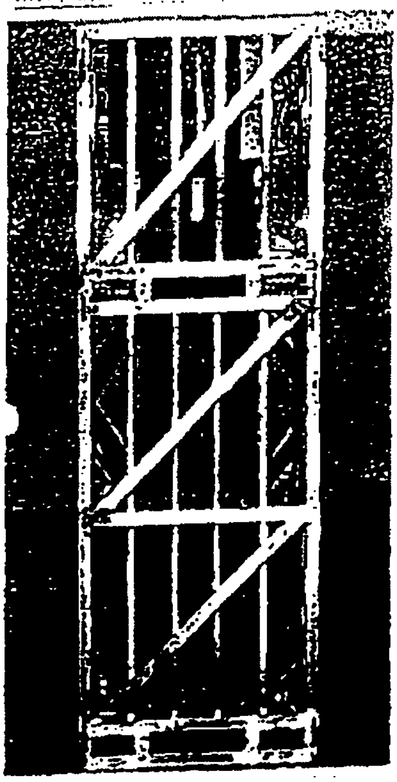

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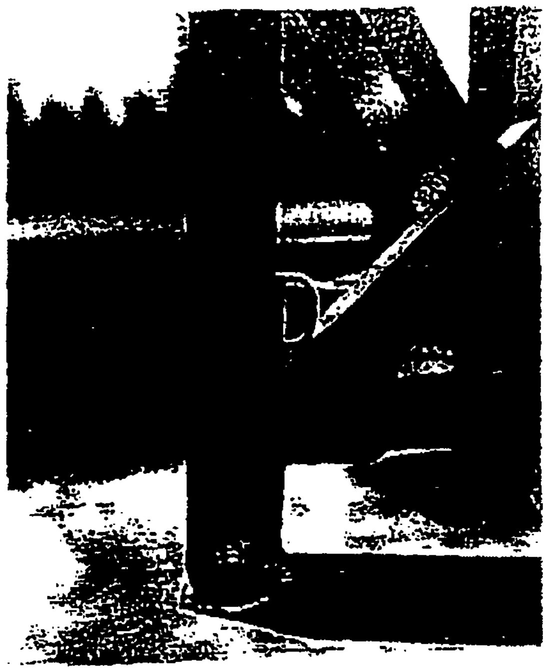
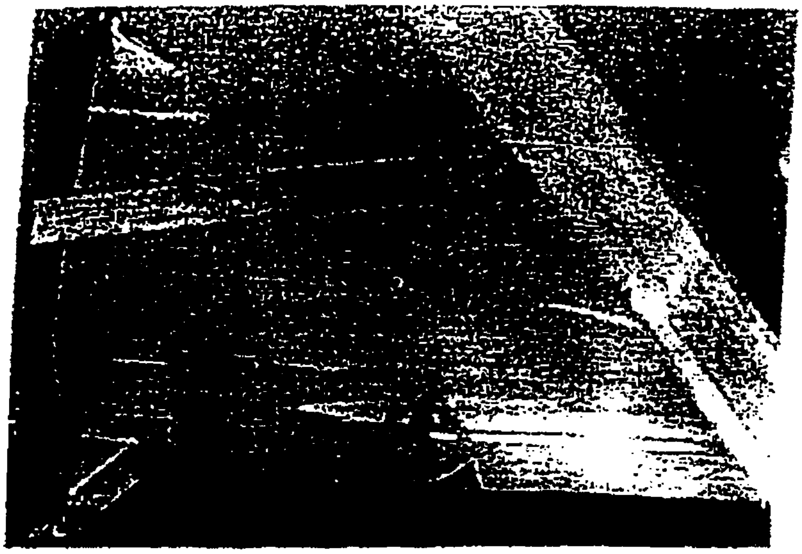
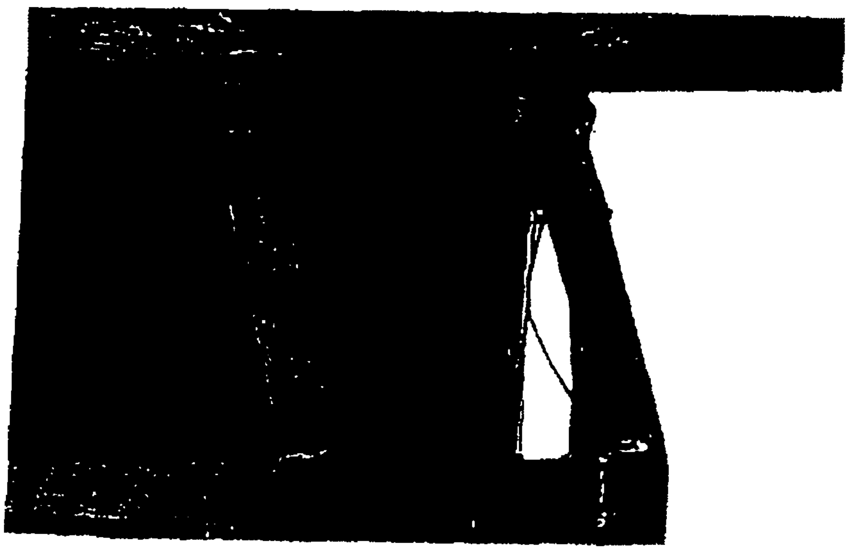


[illegible] dommages [illegible] ouverture

[illegible]



Photographie [illegible]
Chute de la plaque de [illegible] kg
Emballage vertical
(Chute [illegible])



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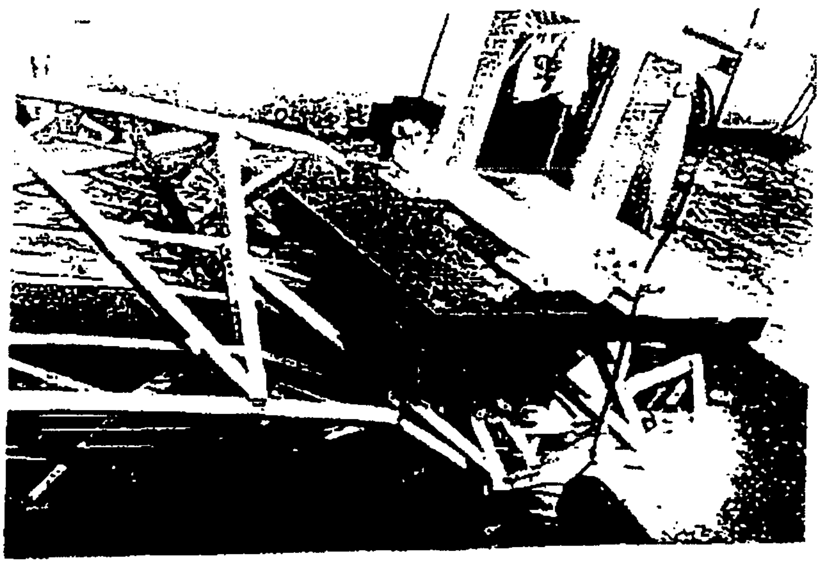
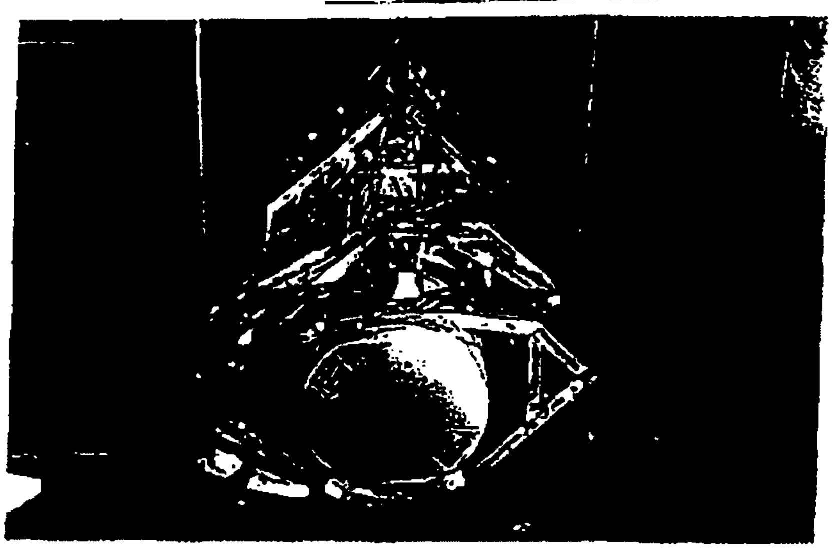
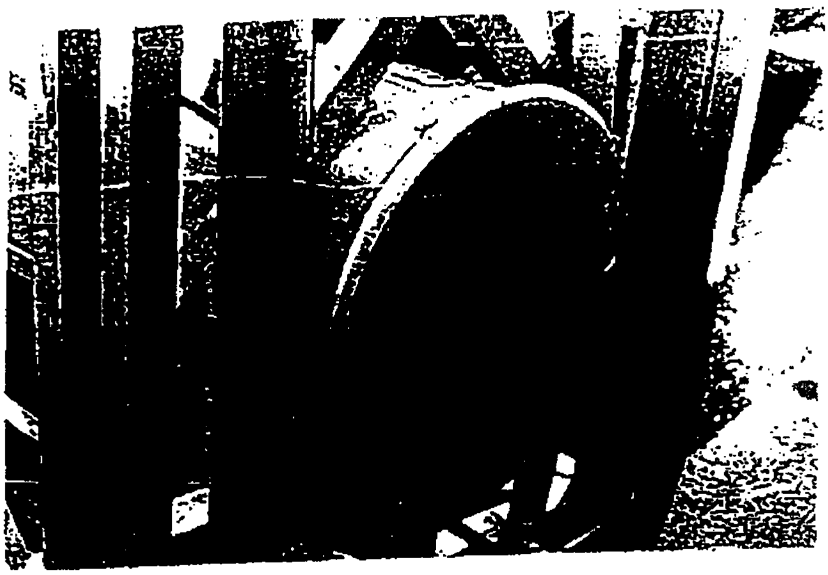
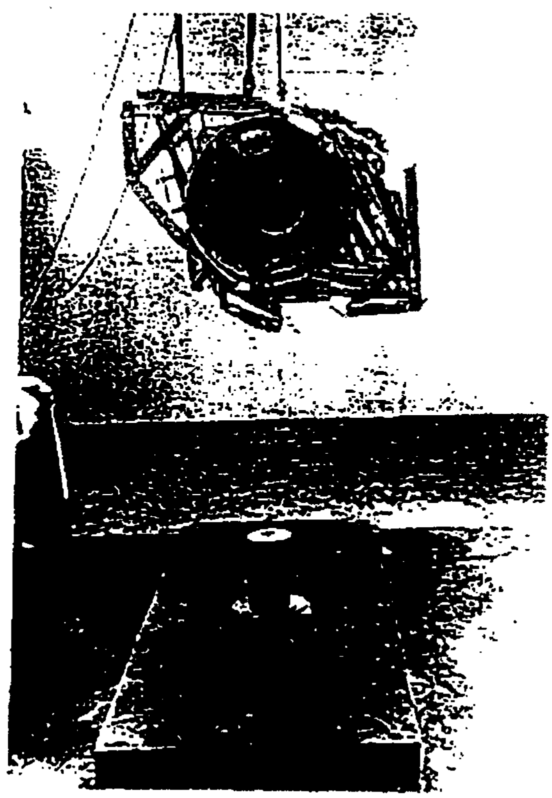
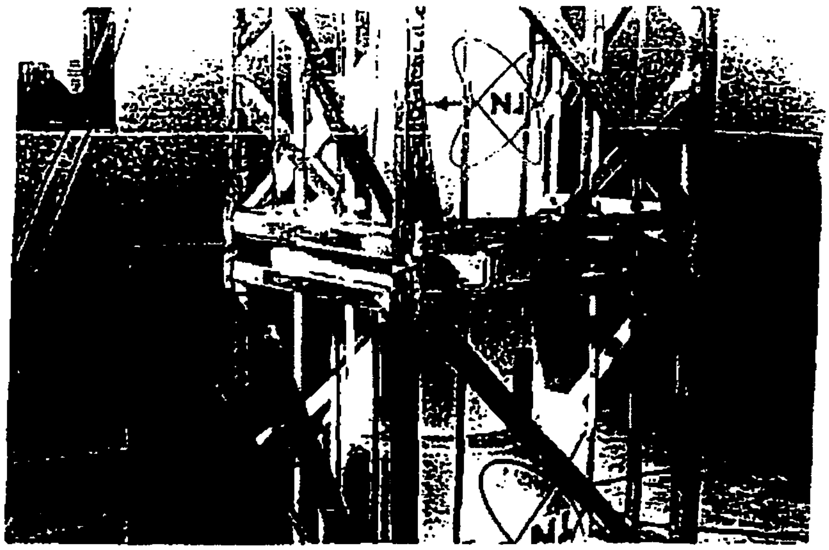


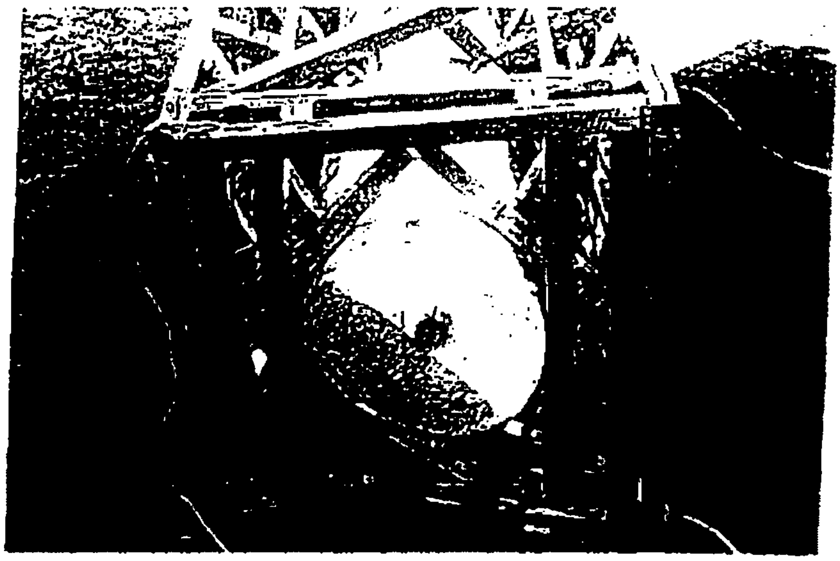
Photographie
Chute de la plaque de
500 kg - Emballage
horizontal (chute n° [illegible])

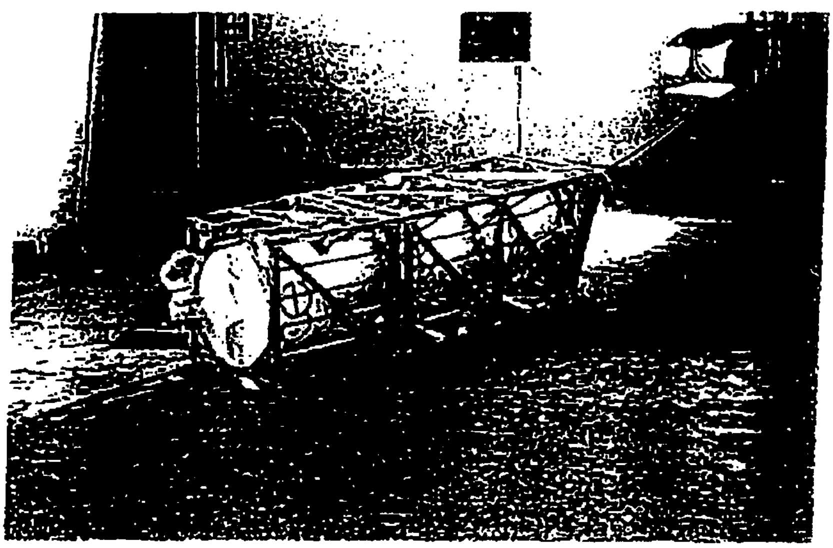


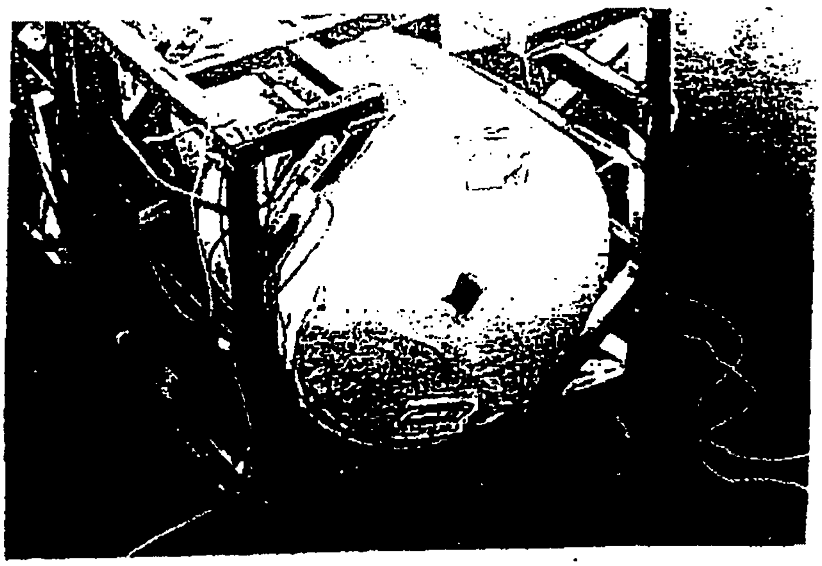




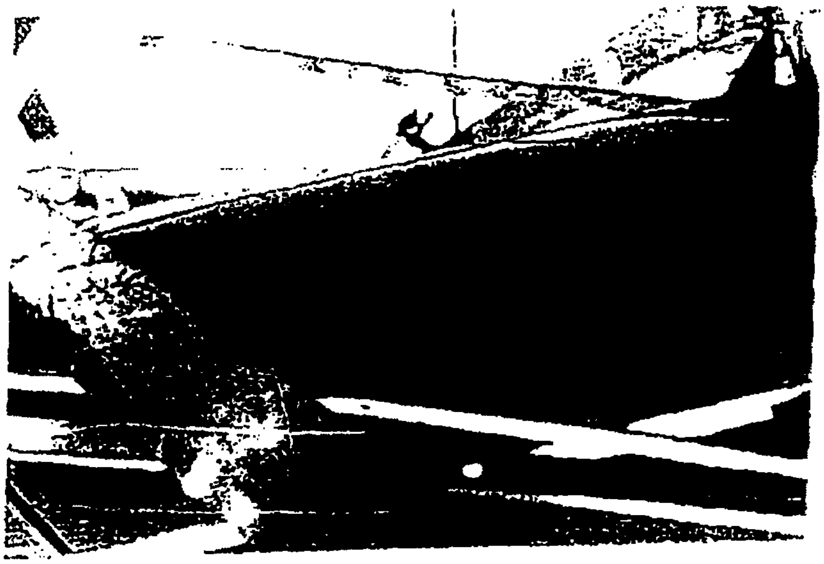




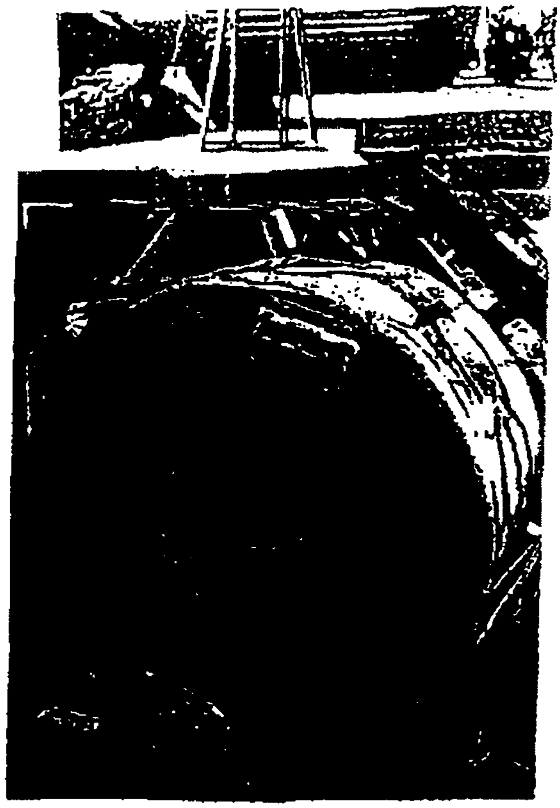




Photographie 1[illegible]
Chute de 9 m [illegible]
[illegible] Chute n° [illegible]

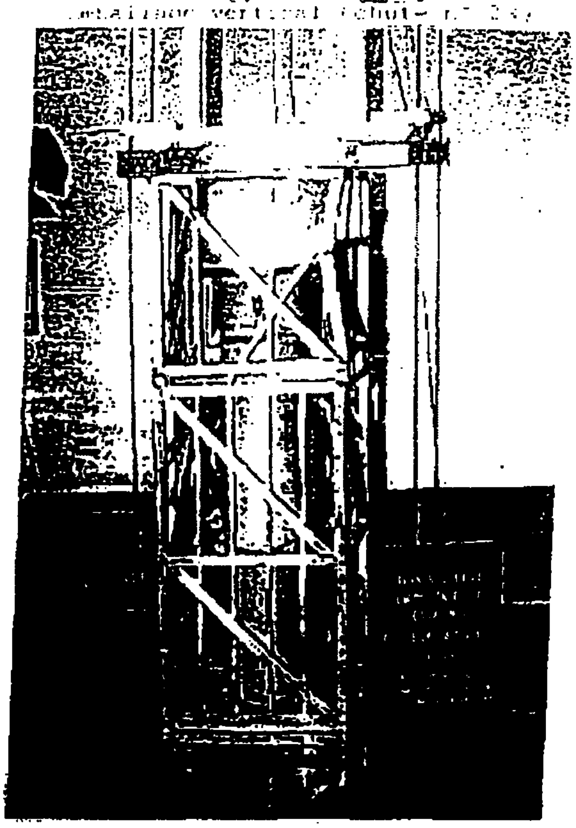


Photographie [illegible]
Chute [illegible]
[illegible] capot (Chute n° [illegible]

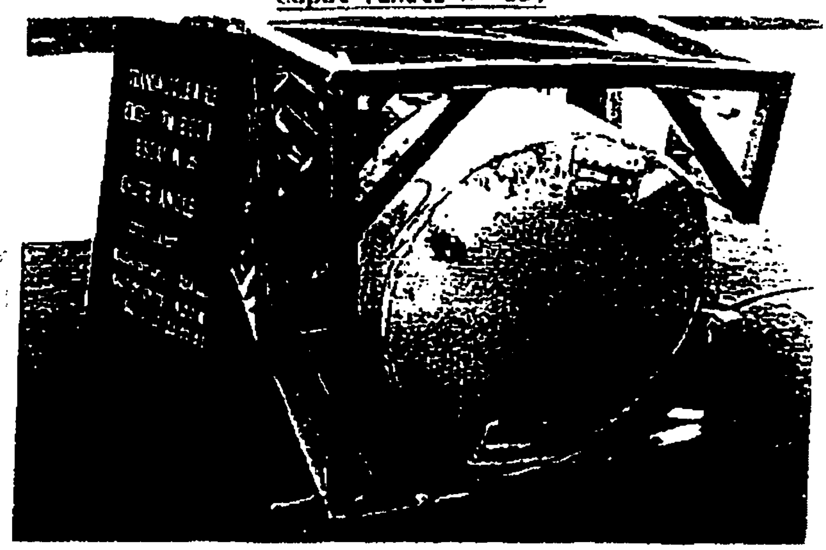


Photographie 19 :
Chute de plaques de 500 kg
Emballage vertical (Chute n° 23)

Photographie [illegible]
Chute de plaque de [illegible] kg
[illegible] vertical (chute n° [illegible])



Photographie 21 :
Chute de 9 m - Coin côté capot (chute n° 25)



Photographie 22
Chute sur poinçon - côté capot (chute n° 26)

ORIGINAL

PROGRAMME: RENEWAL OF STOCK OF CEA PACKAGES

TITLE: SAFETY ANALYSIS REPORT FOR THE TN BGC1 PACKAGING

CHAPTER 4 APPENDIX 2
REPORT OF SUPPLEMENTARY DROP TESTS ON TN BGC 1 PACKAGING

Summary:
This note is an integral part of the TN-BGC 1 safety analysis report. It presents the results of the supplementary regulatory drop tests conducted on the TN-BGC1 packaging between 2001 and 2003. It also presents the procedure on which the tests conducted in 2003 were based. This procedure demonstrates the exhaustiveness of the drop tests conducted on the packaging model.

Signoff			
Date	18/07/2003	04/08/2003	07/08/2003
Name	C. MATHON	T. CUVILLIER	D. LALLEMAND
Unit	ATR Ingénierie	DENT/DTAP/SPI/GET	DENT/DTAP/SPI/GET
Function	Engineer	Project manager	GET manager
	Author	Reviewer	Approver

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

LIST OF CHANGES			
EDITION	DATE	Nature of modification	Pages modified
A	07/08/03	Document creation	

This appendix comprises the following drop test reports:

- ☐ CEA technical note reference DEN/DTAP/SPI/GET EMB TNBGC PBC CRX CA 000018A of 09 February 2001. Drop test report
- ☐ CEA technical note reference DEN/DTAP/SPI/GET EMB TNBGC PBC NU CA 000149C of 30 September 2002. TN-BGC 1 packaging Supplementary test programme.
- ☐ CEA technical note reference DEN/DTAP/SPI/GET EMB TNBGC PBC CRX CA 000304A of 03 June 2003 Drop test report - January 2003

ORIGINAL

PROGRAMME: RENEWAL OF STOCK OF CEA PACKAGES

TITLE:

SUPPLEMENTARY DROP TEST REPORT - PLATE DROP ONTO TN-BGC 1 PACKAGING

Summary
This document summarises the plate drop test onto the inclined TN-BGC 1 packaging, requested in addition to the formal restructuring of the TN-BGC 1 safety analysis report. It provides details of the test conditions determined in agreement with the technical support of the Safety Authority, and demonstrates that the shielding and containment functions of the packaging are not altered by this drop.

[redacted]			
	09/02/01	09/02/01	09/02/01
	T. CUVILLIER	V. MARTIN	D. LALLEMAND
	DTAP / SPI / GET	DTAP / SPI / GET	DTAP / SPI / GET
	Engineer	Engineer	Unit manager
	Author	Reviewer	Approver

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

LIST OF CHANGES			
EDITION	DATE	Nature of modification	Pages modified
A	09/02/01	Document creation	[redacted]

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	M. CUVILLIER	1																	
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	TOTAL	8																	

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

CONTENTS

1/ PURPOSE

The TN-BGC 1 is a CEA design packaging rated for the transport of non-irradiated fissile materials. A formal reorganisation of its safety analysis report was transmitted to the Nuclear Safety Authority for expert assessment in November 2000. In addition to this reorganisation, via the letter DSIN/FAR/SD1/ no.10945/00, the Safety Authority requested CEA to provide justification of the package's performance for the drop of a 500 kg plate from 9 metres onto the inclined package.

This life-size test was conducted on 19 December 2000 in the SOPEMA test facility in Vélizy-Villacoublay.

2/ TEST

The test procedure was first defined by the test specification EMB TNBGC PBC STE CA00000IA of 17 October 2000, amended by faxes STMR no. 435 of 22 November 2000, DCS/SHSP/2000-1251 of 01 December 2000 and DCS/SHSP/2000-1269 of 08 December 2000. A test procedure referenced EMB TNBGC PBC PRE CA000015A dated 13 December 2000, reproducing the elements of the specification and the modifications requested by the SSTR, was used as a basis for conducting the test.

The test specimen was a conventional TN-BGC 1 packaging fitted with a suitably secured TN 90 internal fitting. It only differed from other packages currently in use by the addition of a leakage rate measurement device on the body. An inlet was made on the lower third of the packaging body to be able to take the leakage measurements (vacuum, injection of helium in the cavity) during the test.

Prior to the test, the packaging and the plate were weighed. The packaging weighed 334 kg and the steel plate along with its lifting ring weighed 506.6 kg. A helium leakage test (conducted by ETC) was also conducted. It showed that the packaging presented a leakage rate below the sensitivity threshold of the measuring device (Cf. appendix 2).

The configuration was as follows: the packaging, initially vertical, was inclined by 15° on a 9-tonne steel slab and secured in place using polyurethane plates, which contributed no significant amount of additional resistance to the packaging. Two accelerometers were attached to the packaging body (to measure the acceleration in three dimensions) and one on the plate.

The plate was hoisted to nine metres above the highest point of the TN-BGC 1, with the centre of the plate vertically above the planned point of impact on the shock absorber cover. When released, the plate fell flat onto the upper edge of the packaging. Two recordings were made with normal-speed and high-speed cameras. The photos of the drop test are provided in appendix 1.

After the drop, the following deformations were observed (see photos in the appendix)

- slight denting of the shock absorber cover at the point of impact
- localised denting of packaging base at its point of contact with the ground
- deformation of outer cage, with certain struts being broken.

A visual inspection showed that the shock absorber cover closure system (clamping pins) remained intact; the lid was not deformed and opened normally. The shock absorber cover was easily removed from the packaging.

The shells were not affected by the drop and the radiological protection was not altered. The leakage test conducted after the drop test demonstrated that the containment vessel remained intact. **The packaging is leaktight to the sensitivity threshold (leakage rate below $2.5x10^{-8}$ $Pa.m^3/s$).**

In conclusion, **the packaging did not present any damage likely to impair its security** (radiological protection intact, containment intact, absence of deformation on TN 90 internal fitting).

3/ REFERENCES

The full report for this drop test is SOPEMEA test report LV 30378 "Plate drop test on transport packaging". It provides photos of the packaging before and after the drop test, along with accelerometer readings.

The official report of the helium leakage test is ETC report no. 157-09 / AVCHT.

4/ APPENDIX 1: PHOTOGRAPHS OF THE TESTS

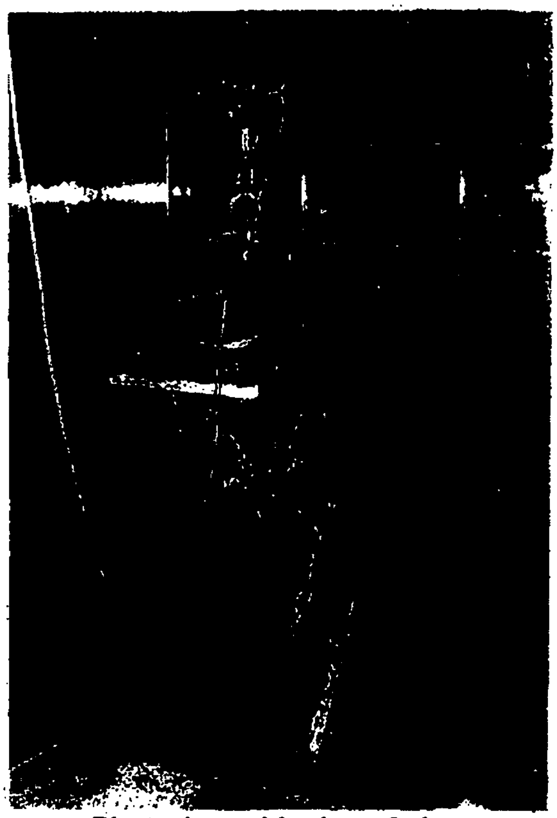

Photo 1: positioning of plate

Photo 2: securing system, 15° inclination

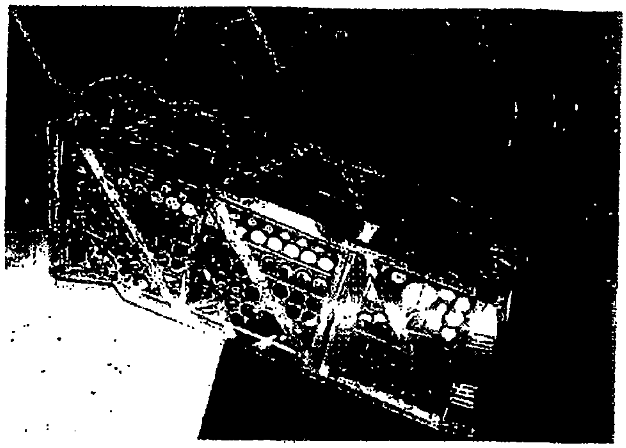
Photo 3: general view of packaging after the drop test


Photo 4: damage to shock absorber cover


Photo 5: damage to base

Photo 6: damage to lower part of cage

Photo 7: general view of shock absorber cover

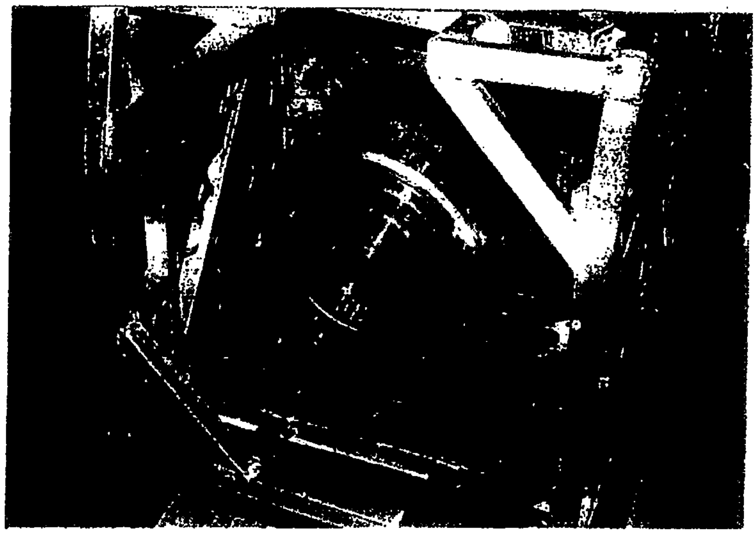

Photo 8: closure system

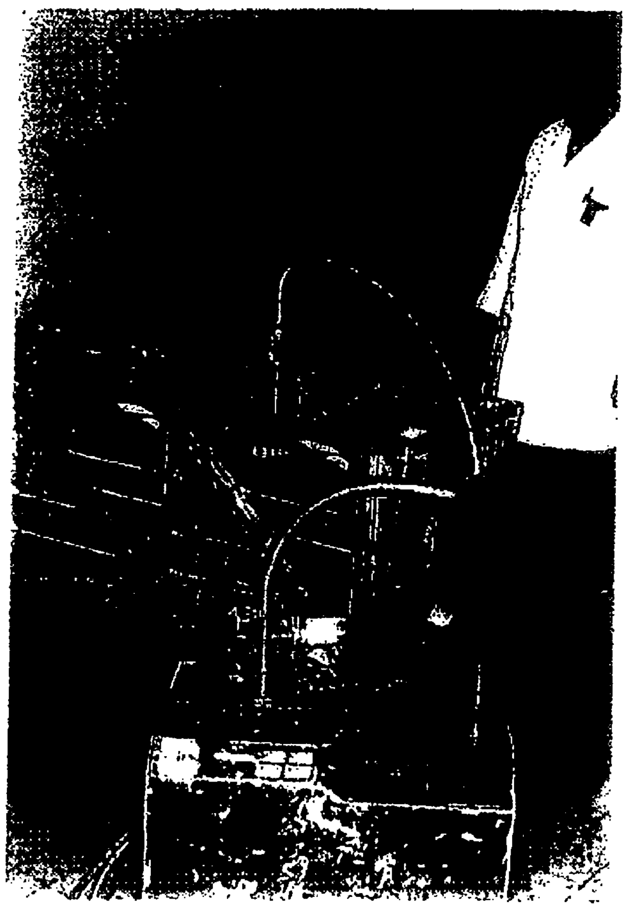

Photo 9: leakage test

5/ APPENDIX 2: HELIUM LEAKAGE TEST REPORT (2 pages)

	HELIUM LEAKAGE TEST REPORT VACUUM METHOD (NF A 09 492)

CUSTOMER:	CEA-STMR Cadarache	FIELD SERVICE No.	00-157-09
ADDRESS:	Building 220	ORDER NO.	R000 0A512180
	St Paul lez Durance	REPORT NO.	157-09/ AVCHT
DATE:	18 and 19 December 2000	PROCEDURE NO.	LTP-434a

SUBJECT:	TN-BGC 1 mock-up drop test programme
SITE:	SOPEMEA in VELIZY-VILLACOUBLAY
DEVICE:	no. 203 before drop
SUB-ASSEMBLY:	Inter-seal spaces on lid and Staubli cap

TEST EQUIPMENT	Reference	Type	Number
Detector	ALCATEL	180T	LT54
Reference leak	ALCATEL	Fe24	LT51
Calibrated leak	ALCATEL	FC10635	LT57
Pump generator	Detector		
Leak pre-evacuation pump	ALCATEL	2004A	LT35
Vacuum measurement gauge	Detector	TN121	LT14

DETECTOR CALIBRATION:			
Reference leak value:	Q1=	1,1 e-08	$Pa.m^3.s^{-1}$
Signal generated	Sf=	1,0 e-07	
Minimum legible signal	Sm=	2,0 e-10	
Residual signal	R=	2,0 e-10	
Detector sensitivity:	$Qs = \frac{Qf * Sm}{Sf - R} =$	2,20 e-11	$Pa.m^3.s^{-1}$

TEST CALIBRATION:			
Calibrated leak value:	Qfe =	6,1 e-07	$Pa.m^3.s^{-1}$
Signal generated	Sfe =	6,0 e-06	
Minimum legible signal	Sm =	5,0 e-09	
Residual signal	Sr =	3,7 e-08	
Helium concentration	C% =	100%	
Vessel pressure	P =	1,0 e+01	Pa
Cell pressure	P =	1,0 e-03	Pa
Appearance time	Ta =	immediate	seconds
Response time 9/10	Tr =	6,0 e+02	seconds
Sensitivity test:	$Qst = \frac{Qfe * Sm}{Sfe - Sr} * \frac{100}{C\%} =$	5,0 e-09	$Pa.m^3.s^{-1}$
	TOLERANCE:	N/A	$Pa.m^3.s^{-1}$

OBSERVATIONS:	Test conducted before drop Residual signal measured before helium injection 3.0 e-7 Signal measured after a hold time of 15 minutes: 3.0 e-7 Leaktight to test sensitivity threshold.

TECHNICIAN	DATE: 19 DEC 2000	MANAGER	DATE: 04 JAN 2001
J. JALABERT	SIGNATURE :	R. WADOUX	SIGNOFF:

HELIUM LEAKAGE TEST REPORT VACUUM METHOD (NF A 09 492)

CUSTOMER:	CEA-STMR Cadarache	FIELD SERVICE No.	00-157-09
ADDRESS:	Building 220 St Paul lez Durance	ORDER NO. REPORT NO.	R000 0A513180 157-09/ APCHT
DATE:	18 and 19 December 2000	PROCEDURE NO.	LTP-434a

SUBJECT:	TN-BGC 1 mock-up drop test programme
SITE:	SOPEMEA in VELIZY-VILLACOUBLAY
DEVICE:	no. 203 before drop
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TEST EQUIPMENT	Reference	Type	Number
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Pump generator	Detector		
Leak pre-evacuation pump	ALCATEL	2004A	LT35
Vacuum measurement gauge	Detector	TN121	LT14

DETECTOR CALIBRATION:

Reference leak value:	Q1=	1,1 e-08	$Pa.m^3.s^{-1}$
Signal generated	Sf=	1,0 e-07	
Minimum legible signal	Sm=	2,0 e-10	
Residual signal	R=	2,0 e-10	

Detector sensitivity: $Qs = \frac{Qf * Sm}{Sf - R} =$ 2,20 e-11 $Pa.m^3.s^{-1}$

TEST CALIBRATION:

Calibrated leak value:	Qfe =	6,1 e-07	$Pa.m^3.s^{-1}$
Signal generated	Sfe =	6,0 e-06	
Minimum legible signal	Sm =	5,0 e-09	
Residual signal	Sr =	3,7 e-08	
Helium concentration	C% =	100%	
Vessel pressure	P =	1,0 e+01	Pa
Cell pressure	P =	1,0 e-03	Pa
Appearance time	Ta =	immediate	seconds
Response time 9/10	Tr =	6,0 e+02	seconds

Sensitivity test: $Qst = \frac{Qfe * Sm}{Sfe - Sr} * \frac{100}{C\%} =$ 5,0 e-09 $Pa.m^3.s^{-1}$

TOLERANCE: N/A $Pa.m^3.s^{-1}$

OBSERVATIONS:

Test conducted before drop
Residual signal measured before helium injection 5.0 e-7
Signal measured after a hold time of 15 minutes: 2.5 e-8
Leaktight to test sensitivity threshold.

TECHNICIAN	DATE: 19 DEC 2000	MANAGER	DATE: 04 JAN 2001
J. JALABERT	SIGNATURE :	R. WADOUX	SIGNOFF:

ORIGINAL

PROGRAMME: RENEWAL OF STOCK OF CEA PACKAGES

TITLE:

TN-BGC1 PACKAGING
SUPPLEMENTARY TEST PROGRAMME

Summary
This document provides as summary of the drop tests conducted to qualify the TN-BGC 1 package model and in light of the latest remarks of the Safety Authority, proposes a supplementary test programme.

[redacted]

27/09/02	27/09/02	30/09/2002
T. CUVILLIER	A. BONNEVILLE	D. LALLEMAND
DEN/DTAP/SPI/GET	DEN/DTAP/SPI/GET	DEN/DTAP/SPI/GET
Engineer	External package manager	GET manager

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

LIST OF CHANGES			
EDITION	DATE	Nature of modification	Pages modified
A	October 2001.	Document creation	[redacted]
B	April 2002	Supplement subsequent to IRSN remarks	5 to 17
C	September 2002	Transition to edition C following express request of IRSN, integrating the latest modifications sent to IRSN by fax, for which approval was given.	11 and following

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	A.BONNEVILLE	1	1	1															
	A.RICHARD	1	1	1															
	TOTAL	8																	

CONTENTS

I. REFERENCES

[1] DSIN letter of 28 June 2001 DSIN/FARSDI/N°10670/0 I
[2] Appendix A4.1 of safety analysis report EMB TNBGC PBC DS C.A00001A of 3 October 2000
[3] Test application programme imposed by transport regulation 9990-B-1 Rev I of 13 November 1987 (appended to this report)
[4] Supplementary test programme 9990-B-2 Rev 0 of 4 March 1988 (appended to this report)
[5] Regulations for the Safe Transport of Radioactive Material no. ST-1
[6] Plate drop test report EMB TNBGC PBC CRX CA000018A of 09 February 2001

II. INTRODUCTION

The TN-BGC 1 packaging holds two qualifications valid until 31 December 2003 (type B(U) and type B(M)). Nonetheless, the DSIN letter [1] requests that the CEA provides additional justifications for certain points of the safety analysis report [2] with a view to a future extension of the qualification. The purpose of this document is to provide a response to the elements concerning the drop tests.

The main observations of the appendix to the DSIN letter [1] can be resumed as follows:

- The drop tests conducted were not described accurately.
- The choice of drop configurations was not fully justified.
- Systematic analysis to demonstrate that the drop test programmes are sufficient to fully satisfy the regulatory requirements was not done.

These points are covered in paragraph III of this document, which completes the drop test specification provided in paragraph V.

- The choice of cut-off frequency for the accelerations recorded during the drop tests was not justified in the safety analysis report.
- The behaviour of the balsa and poplar wood at low temperature (-40°C) is to be taken into consideration.
- No leakage measurement was taken on the TN 90 internal fitting after the drop test performed on it. The drop configuration used was not justified. It was not demonstrated that the tertiary containers remained leaktight after a drop.

These points are covered in paragraph IV of this document.

We therefore reviewed the tests described in the TN-BGC 1 safety analysis report in order to provide a detailed assessment and to propose a supplementary drop test programme.

III. ANALYSIS OF EXISTING TEST REPORT

This test report appears in appendix A4.1 of the last version of the safety analysis report for the TN-BGC 1 packaging.

Prior to any detailed analysis, note that this drop test report on the prototypes of the TN-BGC 3 prototype [2] indicates on page 8 that:

"[This series] was carried out in respect of programme <1>, which also justifies the choice of the drop tests executed. "

and for the second test series:

"This series of tests was carried out from 24 March to 29 March 1988, in respect of the programme defined in document <2>."

In the appendix we provide the full versions of these two programmes (ref [3] and [4]). They duly justify the drop configurations used for the drop tests and highlight their compliance with MEA regulations. The descriptions and explanations given below are taken from these programmes.

Below is an assessment of all tests conducted on the TN-BGC 1.

In accordance with regulation MEA 85 amended 90, the following tests were performed:

- tests representative of normal conditions of transport, in particular the most damaging (free fall). In accordance with regulations, the package was dropped from a height of 1.20 m, preceded by eight other drops on each corner of the packaging and from a height of 30 cm. The 1.2 m drop was conducted with a packaging in the vertical position, which corresponds to the most likely drop during handling.

Note that the choice of another configuration would not have altered the results to any significant amount. The 9-metre drops conducted under multiple configurations did not negatively impact the packaging (which conserved the integrity of all welds). Furthermore, as the leaktight seal on the packaging and its internal fittings remained intact after the 9-metre drops, we can assume that it also remains intact after drops from 1.2 m.

- tests representative of accident conditions of transport; these drop tests were subjected to detailed analysis. Two series of tests were conducted for the qualification of the TN-BGC 1.

Below we provide a summary of the test sequences executed. For further details, please refer to the test report [2]. As a reminder several examples of the cage, shock absorber cover and body were available for the tests. Two different cage models were tested, yet they only feature minor differences that have a limited effect on their mechanical behaviour.

1. First series of tests

To conduct the tests, several specimens of the body, cage, shock absorber cover and internal fittings were available.

First set tested:
Cage 1b
Body 1
Cover 1
TN 90 internal fitting

Drop tests executed (on same set, cumulative)

Plate drop onto vertical package
Plate drop onto horizontal package laying on a ridge (impact on side part of shock absorber cover)
Drop onto bar, cover end, package vertical, in centre of cover
Drop onto bar, bottom end, package vertical, in centre of base
Drop onto bar: impact on body generatrix, package horizontal

Second set tested:
Cage 2
Body 2
Cover 2
AA 227 internal fitting

Drop tests executed:

9-metre drop on to shock absorber cover, package vertical
Horizontal 9-metre drop with slap-down (10° inclination)

Third set tested:
Cage 3
Body 2
Cover 2
AA 227 internal fitting

Drop tests executed:

9-metre inclined drop on base (alignment of CoG and lower corner with vertical)
9-metre inclined drop on shock absorber cover (alignment of CoG and lower corner with vertical)
Drop onto a bar on shock absorber cover (with offset to highlight possible shearing of cover)
Drop onto a bar on the base
Drop onto bar: impact on body generatrix

Major conclusions of this first test sequence: the containment system is no longer intact on the lid of the TN 90 and the lid of the packaging. However the cage and packaging body present deteriorations that do not impair the robustness of their design.

Moreover, the configurations used (except for drops onto a bar) seem exhaustive. In general, the 9-

metre drops executed maximised the accelerations, and the plate drop tests maximised the deformations likely to be observed on the TN-BGC 1. The alignment of the centre of gravity and the point of impact along the same vertical line means that no drop energy is dissipated in rotation. The accumulation of forces (cumulation on the same set for several regulatory drop tests) is sufficient to not impair the penalising character of the selected sequences.

For the 9-metre drops, the horizontal drop without slap-down was not selected, as for a package of this size, the acceleration is potentially higher with slap-down than for a direct flat drop where the whole cage will play a role of shock absorber. For the drop with slap-down, the choice of the angle of inclination was made through comparison with studies carried out on another packaging (the TN 12), which showed that the impact was more damaging for an angle of 4° but less sensitive to the value of the angle when this is low (10° or less).

No horizontal drop onto a ridge was carried out as the cage would have been more flexible in this position and the accelerations less powerful. It was replaced by a plate drop test on the ridge of the horizontal packaging, which is more penalising than a 9-metre drop in terms of deformations.

The vertical drop onto the base was not conducted either as it was considered less damaging than onto the shock absorber cover (notably in terms of the consequences on the internal fitting).

We should also remember that a supplementary plate drop test onto the upper ridge of the packaging at an angle of 15° was conducted in December 2000 and its report transmitted to the Security Authority for expert assessment in February 2001 (ref. [6]). This test was deemed satisfactory and generated no specific remarks during the expert assessment of the safety analysis report.

For the drop onto a bar, all drop tests are exhaustive (impacts on the body, the shock absorber cover and the base) with the exception of the inclined drops that had not been taken into account.

A second drop test sequence was then conducted. Subsequent to the first series, the closure systems on the packaging lid and on that of the internal fitting were modified. The shock absorber cover was also modified in its centre section (replacement of poplar by balsa wood with modification of fibre directions in order to reduce the acceleration). For this reason, certain drop tests were repeated. The repeated tests concerned the upper part of the packaging (only part where modifications were made). The drop tests on the side or base were not repeated. The modifications slightly altered the mass of the package/cage/cover assembly, but the change was sufficiently insignificant to impair the tests. All these elements are fully justified in [2].

2. Second series of tests

First set tested:
Cage 4
Body 3
Cover 3
TN 90 internal fitting

Drop tests executed: Plate drop onto vertical package

Second set tested:
Cage 4
Body 3
Cover 4
AA 227 internal fitting

Drop tests executed: 9-metre drop on to shock absorber cover, package vertical

Third set tested:
Cage 4
Body 3
Cover 5
AA 227 internal fitting

Drop tests executed: 9-metre drop onto corner, shock absorber cover end (alignment of centre of gravity and point of impact with the same vertical)

Fourth set tested:
Cage 4
Body 3
Covers 4 and 5
AA 227 internal fitting

Drop tests executed: Drop onto bar on cover side (in the centre, where the wood fibres are the most vulnerable).

Important conclusions concerning the second sequence of tests: the leaktight seal is intact on both the packagings and the internal fittings. The impacts of the drops do not impair the hypotheses used in the criticality, thermal and radiation protection calculations. In particular, no perforation was observed. The modifications made to the design are therefore fully satisfactory.

Consequently, this assessment highlights that the level of testing required is fully satisfied by the tests conducted, except for the absence of execution of inclined drops on a bar.

IV. PROPOSAL FOR A SUPPLEMENTARY TEST PROGRAMME - JUSTIFYING ELEMENTS

As part of the revision of the TN BGC1 safety analysis report, we based our findings on the reference MEA 96 now in force [5]. Consequently:

a) to qualify as a package to transport fissile material, the TN BGC 1 must be subjected to the plate drop test (whatever the type of radioactivity transported). The containment of active materials inside the internal fitting must be demonstrated as this component is an integral part of the containment system.

b) As a type B(U) package, according to the contents transported, it must be subjected to either a plate drop test or a 9-metre free fall drop test. In both cases the packaging must remain leaktight (containment system). The TN BGC 1 will be used to transport all categories of contents and must therefore be subjected to both these tests.

For this reason the supplementary tests that the TN BGC 1 package model must undergo must satisfy these requirements.

Point a): The plate drop is penalising in terms of deformations on the package, as it risks deforming the containment vessel and impairing the criticality calculations. The previous analysis (chapters II and III) shows that many drop tests were carried out (on a vertical packaging, on a packaging with a 15° incline and on the packaging laid horizontally on a ridge). The principal conclusion of these drops is that the deformations are covered by the criticality studies. However no drop test on onto a packaging laid on its side face was carried out. It is taken into account in part V.

Point b): The plate drops executed in previous sequences (on a vertical packaging and a 15°-inclined packaging) showed that the closure system on the packaging remained intact. The most penalising 9-metre drops in terms of forces exerted on the packaging closure system (maximum decelerations) were carried out again in the second series of tests (Cf. previous paragraph) and demonstrated that the lid remained leaktight.

In summary, it appears that the lack of justifications concerns the inclined drop onto a bar.

An inclined drop onto a bar impacting the base does not bear much significance (or in light of the dimensions of the packaging, an inclination of just a few degrees would be necessary, but is difficult to implement and would have consequences barely different from the flat drop). However an inclined drop onto a bar impacting the shock absorber cover end, may cause more damage than the drop test that was actually conducted. It will therefore be taken into account.

Lastly, the inclined drop onto the package body may also increase the risk of perforation, in relation to a drop without an inclination.

Consequently, we propose the following test sequences:

Package 1

<u>Inclined drop onto a bar</u> impacting the body. This test risks being more penalising than the sequence presented in the safety analysis report (increased risk of perforation). Two inclinations are used to

cover all possible configurations as efficiently as possible. The regulatory test sequence for packages transporting fissile material requires the accumulation of tests representing normal and accident conditions of transport. This drop will therefore be preceded by a free fall drop from 1.20 m and a plate drop onto the packaging body (described below).

Package 2

In previous tests, the cut-off frequency used was 500 Hz. But this value is not justified in the safety analysis report. It is possible that this frequency is slightly too low in light of the mass of the TN-BGC 1.

For this reason, we intend to conduct a 9-metre drop with the TN-BGC 1 in a vertical position. The acceleration values will be measured using accelerometers placed at strategic locations on the body. The accelerogram will firstly be raw data (for future use) with filters being used in the range of 800 Hz to 1000 Hz, suited to small packages of this type. This drop test is used due to the high acceleration observed in the drop test sequences described in the safety analysis report. It produced a maximum observed acceleration value of 540 g.

The choice of the cut-off frequency will be duly justified in the next edition of the safety analysis report.

This drop test will precede the packaging drop, vertical with a slight incline, on to a bar impacting the shock absorber cover end. The accumulative effect of the two drops is penalising. The two sequences will be carried out on a serial-production packaging containing a type AA204 or TN 90 type internal fitting.

We also add in a 9-metre inclined drop in order to more rigorously justify using leakage tests, that this drop already conducted in previous sequences does not impair the leaktight seal on the packaging.

Remarks

- the drop test involving just the TN 90 internal fitting in a cylinder, secured using an E3 spacer also raised questions indicated in paragraph II. It should be noted that this drop test had only one purpose: to assess the level of deformation observed on the internal fitting with this insulating padding. The drop is highly penalising (as strictly no shock absorbing elements are involved) and it was never intended to test the efficiency of the internal fitting closure system (since the internal fitting remained intact in the on-site drop tests). Due to the choice of conducting a drop test in a cylinder without shock absorbing elements, we can affirm without further calculations that the deformations are forcibly conservative compared to what would be observed on a TN-BGC 1 packaging whatever the drop configuration used. The deformation observed on the internal fitting body does not impair its leaktight seal and was taken into consideration in all safety-criticality studies.

- in response to the question on the leaktight seal on internal fittings, we must take into account the fact that the leakage tests were carried out on the fittings after the second series of tests; these tests showed that the internal fittings remained intact. All this information is fully presented in the safety analysis report [2]. Furthermore, under the IAEA 96 regulations, only the leak tightness of the internal fitting after the plate drop must be demonstrated.

- Influence of an excursion at -40°C on the shock absorber elements of the packaging: the influence of the temperature on the acceleration values measured may be done firstly by taking into account a multiplication factor of 1.3 on the acceleration values. Tests on the mechanical properties of the balsa and poplar wood are also planned in order to extrapolate the results of these tests to transport conditions at -40°C.

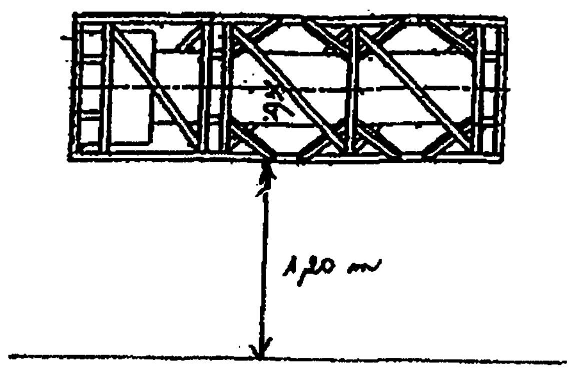
V. DETAILED PROGRAMME

The two sequences are executed on a TN-BGC 1 packaging that is intact and ballasted with the maximum admissible load (total mass of package: 396 kg). It is equipped with a type AA 204 or TN 90 internal fitting, customarily used in the packaging. A different TN BGC1 will be used for each sequence.

Sequence 1:

a) drop from 1.20 m, packaging horizontal.

The consequences of this drop test will not be subject to any specific inspection. It is performed to respect the regulatory sequence (paragraph 682a, ref [5]). The other tests representing normal conditions of transport should have no negative effect on the package. The test results will only be examined at the end of the whole sequence. The choice of placing the packaging in a horizontal position is motivated by the fact that a drop from 1.20 m for a vertical package has already been performed in earlier sequences. Furthermore, in light of the configuration of the following drop and in order to generate maximum damage, this drop will even weaken the cage elements that will be impacted by the plated drop.



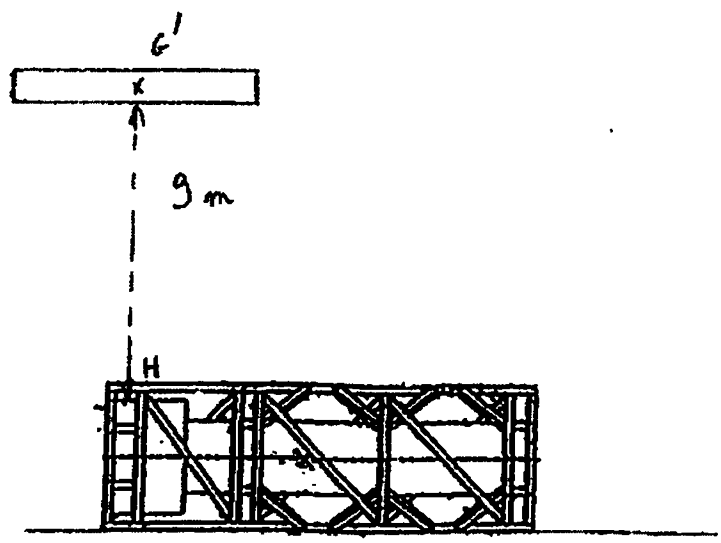
b) 9-metre plate drop onto horizontal packaging

In accordance with regulatory requirements concerning mass and dimension, the plate will be located 9 metres above the point of impact on the cage. The packaging will be laid horizontally, without needing to be secured. This configuration was chosen for two reasons:

- firstly a plate drop onto the packaging laid horizontally on a ridge has already been performed in earlier sequences.
- Secondly the package is self-stabilising on the slab, which ensures that all the compression energy is absorbed by the packaging itself.

The centre of gravity G' of the plate will be aligned with the vertical of point H indicated on the following diagram. In other words the centre of gravity of the plate will be vertically above the packaging closure flange. This configuration will firstly enable the packaging closure system to be subjected to stress, and secondly it will weaken the cage prior to the drops onto a bar that will follow, in line with the regulations that stipulate that the drop tests are executed in the most penalising order. This risks damaging the cage, therefore favouring the impact of the bar; inversely, performing the drop tests onto a bar prior to the plate drop would be less penalising as the drop onto a bar is intended to cause a possible perforation of the packaging body, and would not damage the structures in any way that would make the accelerations stronger during the plate drop.

The plate drop test, identical to this one and which took place in an earlier sequence, showed that the plate severely damaged the cage (appendix A4-1 of safety analysis report EMB TNBGC PBC DS-CA000001A).



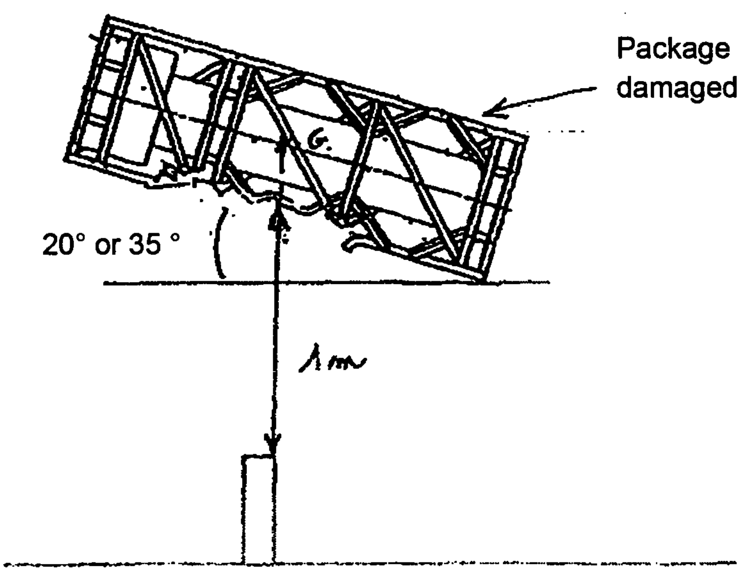
c) Drop onto a bar (with two successive drop angles)

For this drop test, the packaging is inclined by 20° and 35°. The centre of gravity of the packaging and the impact ridge of the bar will be aligned vertically so as to ensure that no drop energy is lost due to rotation. The distance of 1 m will be measured between the top of the bar and the lowest point of the packaging vertically above the bar (see diagram). No accelerometer measurements are foreseen for this sequence. One drop test will be conducted on the side directly impacted by the plate, the other on the side that was lying on the ground. Insofar as it is possible, CEA would like to favour the direct impact of the bar on the body (alignment of bar with the centre of gravity), yet avoiding that the bar impacts a cage member first, which could cause the trajectory of the packaging to be deviated.

The choice of the degrees of inclination is justified as follows:

Test feedback on similar packages shows that the most damaging angles lie in general between 15° and 40°. Our decision to perform two drop tests covers the most damaging configurations. Smaller angles do not significantly increase the risk of perforation in relation to a flat drop and wider angles could cause a loss of impact energy due to the body sliding on the bar.

The properties of the bar will be those specified by the regulations [5]. In particular, the length of the bar will be approximately 70 cm in order to cause maximum damage.



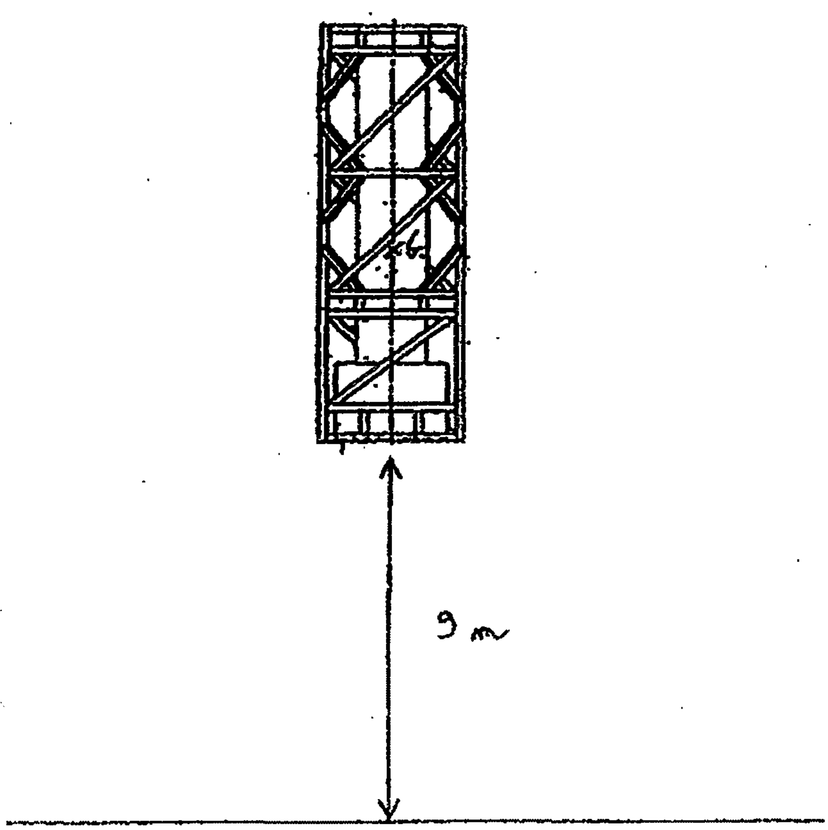
Note:

It is important to note that the configuration of the test may change slightly according to the results of the previous drop test (plate drop). In effect, we may decide not to align the bar and the centre of gravity of the packaging precisely if it is revealed that the plate drop generated serious damage on other parts of the body.

Sequence 2:

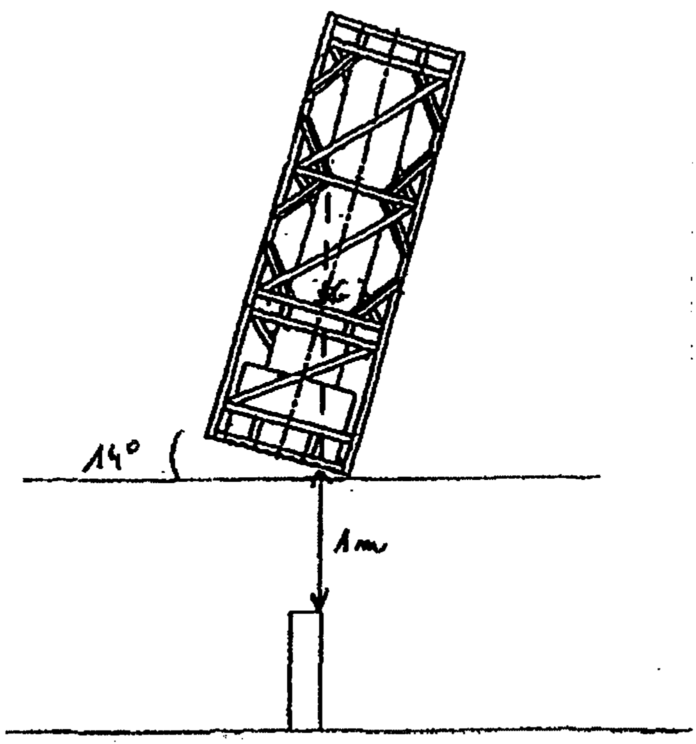
a) 9-metre drop, packaging vertical, shock absorber cover facing down

The packaging will be loaded with an AA 204 or TN 90 internal fitting that is suitably secured and ballasted with the maximum admissible load. The 3-dimensional accelerations will be measured using accelerometers placed on the body.



b) Drop onto bar

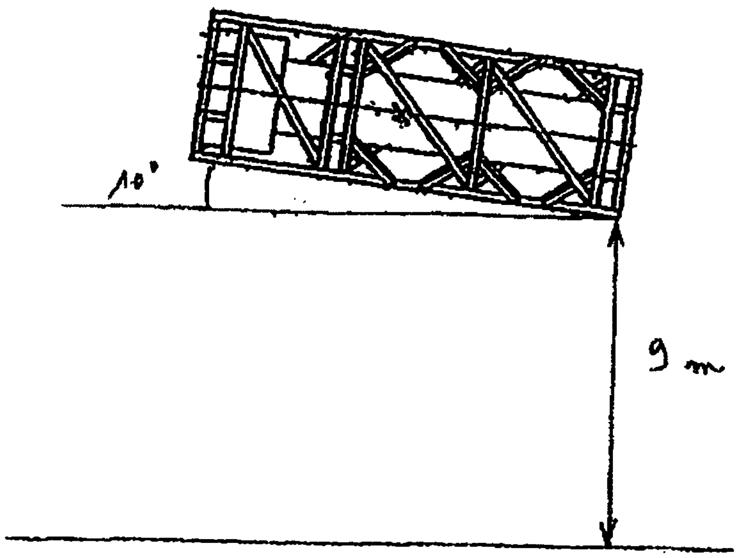
For this drop test the centre of gravity and the ridge of impact on the bar will be aligned vertically. The angle of inclination will be 14° in order to maximise the angle (impact at a few centimetres from the edge of the shock absorber cover) so that it can be sufficiently distinguished from a flat drop and highlight any perforation of the shock absorber cover. This angle would also enable the bar to reach the shock absorber closure system if the cover was severely perforated. The shock absorber cover handling lugs will not be targeted.



c) 9-metre free fall drop

The angle of inclination from the horizontal will be 10%; the first impact will occur on the lower part of the packaging so that the decelerations are the strongest near the closure system during the second impact. This drop test is intended to prove that the packaging remains leaktight after a drop causing strong decelerations on the closure system.

This drop was already carried out in earlier sequences. Nonetheless we intend to rerun it to ensure that the leaktight seal on the packaging remains suitably intact after the test.



For all these drop tests, we will:

a. film the drop with standard and/or fast-action cameras;
b. perform visual inspections and measure the main deformations caused by the two sequences;
c. a photo report.

Leakage tests will be carried out as follows:

After the two drop test sequences, leakage tests will be done on the packaging closure system.

After the first sequence, we will also test the leaktight seal on the internal fitting. As the internal fitting has a safety-criticality role, it must offer a sufficient leaktight barrier to the dispersion of fissile material in the cavity after any sequence featuring a plate drop.

A leakage test will also be done after the second drop in sequence 2, as the 9-metre drop after the drop onto a bar represents a regulatory sequence.

The tests will be conducted by a company specialising in this type of service. A Quality Assurance plan specific to this assignment will be requested from them.

All these drops will be covered in a drop test report presenting the main results produced. It will be referred to in the next version of the safety analysis report.

VI. CONCLUSION

In conclusion, this analysis highlights the following points:

Firstly the drop tests performed on the TN-BGC 1 are valid, but merit additional tests intended to demonstrate its performance under accident conditions of transport, which is the topic of this document. Secondly these tests provide a response to the questions raised by the Safety Authority concerning the leaktight qualities of the internal fittings. Special provisions will also be made to provide a response to the question concerning the resistance of the wood at -40°C, a generic question touching most transport packages. Lastly, internal fittings other than those actually tests may be used in the packaging; their use will be justified using suitable calculations.

APPENDICES

- Test programme imposed by transport regulation 9990 B-1 rev 1 (21 pages)
- Supplementary test programme 9990-B-2 rev 0 (9 pages)

1. INTRODUCTION

The purpose of this programme is to present the regulatory drop tests representative of normal and accident conditions of transport to be conducted on the TN-BGC 1 packaging.

2. DESCRIPTION

A general view of the packaging is presented in figure 1.

The packaging comprises a cage, a body (supported by the cage), an internal fitting (loaded inside the body) and a shock absorber cover that protects the body plug).

The mockups used for these regulatory tests are 1:1 scale.

The serial-production packagings will be identical to these mockups. Any differences will be presented and justified in the safety analysis report.

The content of the mockups will comprise either an internal fitting intended to transport plutonium oxide powder (type AA226 or AA227 fitting), or an internal fitting intended to receive containers of uranyl nitrate. The plutonium oxide will be replaced by a mixture of aluminium hydrate and lead balls, the uranyl nitrate will be replaced by water.

To carry out the tests we will use three cages (numbered 1 to 3), two sets of packaging body + internal fittings (labelled P for powder, L for liquid) and 3 or 4 shock absorber covers (numbered 1 to 4).

3. MECHANICAL TESTS

3.1 Normal conditions

French regulations <1> and IAEA regulations <2> stipulate that the packaging must first undergo a drop test from 30 cm on each of its corners (figure 2).

Then as its mass is less than 5000 kg, it must be subjected to a drop from a height of 1.20 m. We selected the drop test that represents the most likely handling accident; this drop test will cause the packaging to be dropped on its base, with the longitudinal axis of the packaging vertical.

Lastly, the packaging shall be subjected to a bar measuring 3.2 cm and with a mass of 6 kg, dropping onto the packaging from a height of 1 m. It is clear that for this type of impact, the weak point of the packaging is the thin outer shell. This test will therefore be carried out with the package in a horizontal position (figure 4).

This whole programme will be carried out on one packaging set: cage 1, internal fitting L, shock absorber cover 1.

3.2 Accident conditions

3.2.1 9-metre drops

The first drop test will be one where the packaging is in a vertical position, falling on the plug end (figure 5). This drop test will be conducted using the packaging comprising cage 2, body P (heavier than L) and shock absorber cover 2.

The drop on the base will not be carried out. It appears to be less damaging than the drop onto the cover and a suitable analysis could be made using the results of the 1.20 m drop.

Using the same set as for the drop onto the cover, we will then perform an almost horizontal drop onto one side of the packaging. A slight inclination will be used to take into account the slap-down effect (figure 6). This effect has two aspects: first, the acceleration of the content and second the occurrence of a second impact on the top end (which may be more violent than the first impact on the bottom end). On this first point, the equations used in <3> show that for narrow angles, the speed of rotation (and therefore the centrifugal force that causes the content to accelerate) is not particularly sensitive to the angle of impact. Indeed, for an elastic impact of a rigid bar, and all other things being equal, it is proportional.

$$u = \frac{003\,\theta}{1+3\cos^2\theta}$$ (formula 2.91 of <3>)

Between 0 and 10° the difference is less than 1%. For the second aspect, the study carried out on the TN 12 packaging (Cf. <4>) shows that for this packaging the maximum effect was obtained for an initial angle of 4° but that up to 10° it varied little. In the present case, the structure is considered to be more flexible. The slap-down should therefore be less and occur at a wider angle. We will use an angle of 10°.

This drop test will not be carried out with the packaging in a horizontal position and onto a ridge. In this type of drop test, the cage will be more flexible and the acceleration on the body less. Furthermore, for this position we will conduct a 500 kg plate drop test (see paragraph 3.2.2).

Using the same system (cage 2 internal fitting P, shock absorber cover 2), we will conduct a drop test on the corner of the packaging base (figure 7). We will select one of the corners that was not impacted in the previous test.

Lastly, using cage 1 after any repairs that may be necessary after the tests representing normal conditions of transport, we will perform a drop onto a corner, on the top end.

3.2.2 500 kg plate drop tests

The IAEA 1985 rules <2> foresee that this type of packaging (weighing less than 500 kg, with a density less than 1000 kg/m² and for which the content exceeds 1000 A_2, which is not in a special form - paragraph 548 of <2>), must be subjected to a 9-metre plate drop test, using a 1 m x 1 m soft steel plate with a mass of 500 kg.

If the packaging is placed flat on the target surface, the 500 kg plate drop is less damaging than the drop of the packaging itself. Indeed, when the packaging falls, it is mainly deformed in its lower half (that impacted by landing on the unyielding target surface). However, if the packaging is impacted by a plate, it may suffer deformation both on the side in contact with the ground and the side impacted (see figure 9). There is therefore twice as much material likely to absorb the energy. As elsewhere, in the present case the energies to absorb are comparable (packaging of approximately 400 kg falling from 9 metres or 500 kg plate falling from the same height), the packaging drop is much more penalising for the body.

Nonetheless, a test will be conducted with the packaging horizontal, yet resting on a ridge (figure 11). This will be done with cage 3, internal fitting L and shock absorber cover 3. It is also clear that this test is more severe than that indicated earlier.

Lastly, we will conduct a test where the packaging is in a vertical position (figure 10). We will not perform tests where the packaging rests on a corner; this test is effectively covered by the impact on a corner in the previous paragraph. Moreover, the position of the packaging is too unstable and would lead to the body tipping over immediately.

3.2.3 Drop on bar

The purpose of this test is to damage the packaging body as much as possible. To this end, for each of the two bodies, we will perform a test with a drop on the top end (figure 14), on the base (figure 12) and on the outer shell (figure 13). The first drop test with the bar impacting the top end will be done asymmetrically (figure 14b) in order to reveal a possible detachment from the shock absorber cover and the body. If this is the case, the second test will be carried out in the same way. Otherwise, the packaging will be centred.

Summary

A description of all drop tests and the packaging used for each is summarised in table 1.

4. FIRE TEST

The vessel to use is 4 m long and 3 m wide. The two bodies used will be placed inside this vessel, with their respective internal fittings. They will be placed top-to-tail so that the space between, the two bodies be as wide as possible everywhere and to ensure that at least one of the covers be subjected to the maximum effect of the flames, even in the event of strong winds. The plan view layout is shown in figure 15.

5. TESTS TO BE PERFORMED

A leakage test on the containment systems and internal fittings of each of the mockups used will be carried out:

□ At the end of the tests representing normal conditions of transport:

Criterion
- Containment system: 5×10^{-6} atm.cm^3 / S
- Internal fitting: 10^{-4} atm.cm^3 / S

□ At the end of the tests representing accident conditions of transport:

Criterion
- Containment system: 5×10^{-5} atm.cm^3 / S
- Internal fitting: 10^{-4} atm.cm^3 / S

□ At the end of the fire test:

Criterion
- Containment system: 5×10^{-5} atm.cm^3 / S
- Internal fitting: 10^{-4} atm.cm^3 / S

Acceleration measurements will be taken on the packaging body for the 9-metre drops.

The temperatures of the packaging body will be recorded at various locations during the fire test.

A detailed description of the tests and measurements to perform after each series of drop tests, along with the applicable criteria, are given in the specification <5>.

6. REFERENCES

<1> Extract of regulation of 15 April 1981 - Transport and handling of hazardous materials: transport of radioactive materials (class IV b) - text enacted on 31 December 1981 - Special edition no. 74-68b.

<2> Regulation for the safe transport of radioactive material - IAEA -1985 Edition

<3> Impact: the theory and physical behaviour of colliding solid – Goldsmith Edward Apollo Publisher – London.

<4> PATRAM – New Orleans 1983 – D.J. NOLAN – C. FERNANDEZ – C. MILLER – Analysis method for the design of transport packaging shock absorbing end covers.

<5> TRANSNUCLEAIRE specification 9990-A-JOA Regulatory test specifications

Table 1

	Drop type	Figure	cage	Body + Internal fitting	Shock absorber cover
Normal Conditions	30 cm drop on each of 8 corners	2	1	L	1
	1.20 m drop on base	3	1	L	1
	6 kg bar drop from 1 m	4	1	L	1
Accident conditions 9-metre drops	Plug	5	2	P	2
	Horizontal	6	2	P	2
	Base corner	7	2	P	1
	Top corner	8	1	P	1
Accident conditions 500 kg plate drop	Vertical	10	3	L	3
	Horizontal	11	To be determined	L	3 or 4

	Drop type	Figure	cage	Body + Internal fitting	Shock absorber cover
Drop onto bar	Base	12	2	P	2
			3	L	3
	Shell	13	2	P	2
			3	L	3
	Plug	14	2	P	2
			3	L	3

Figure 1: General view of packaging

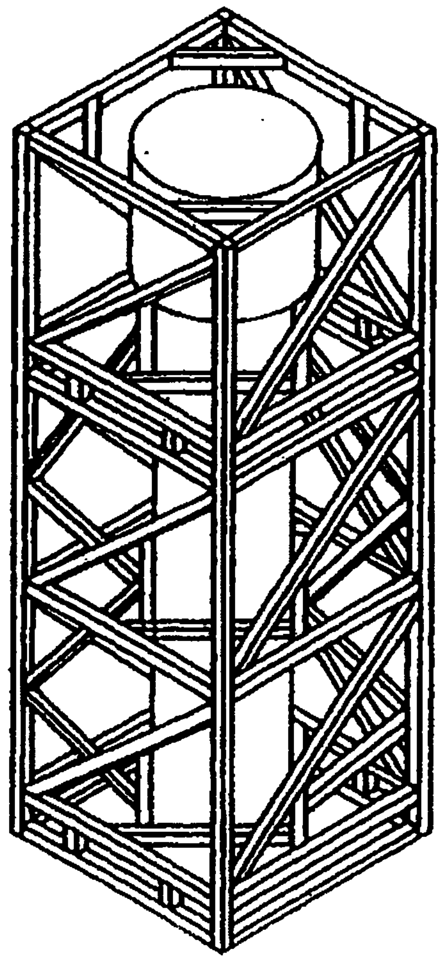


Figure 2: 30 cm drop on corner

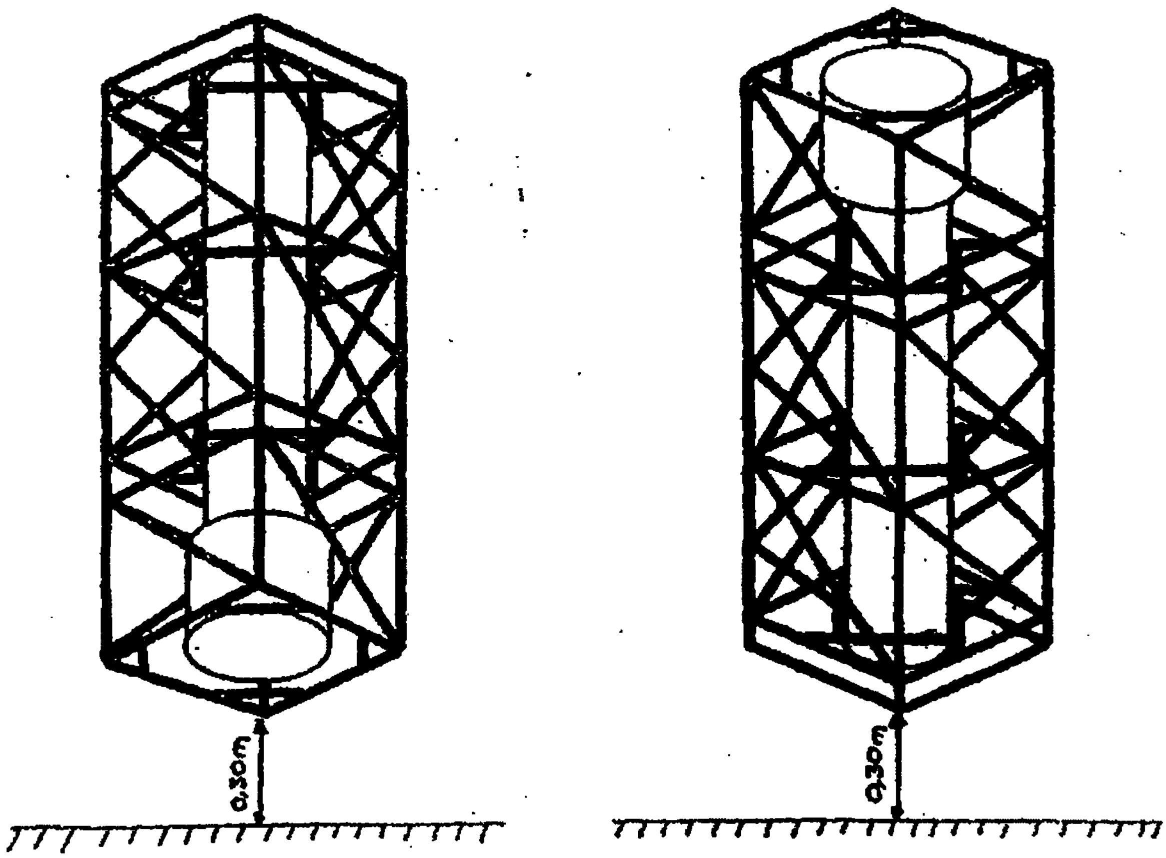


Figure 3: 1.20 m drop on base

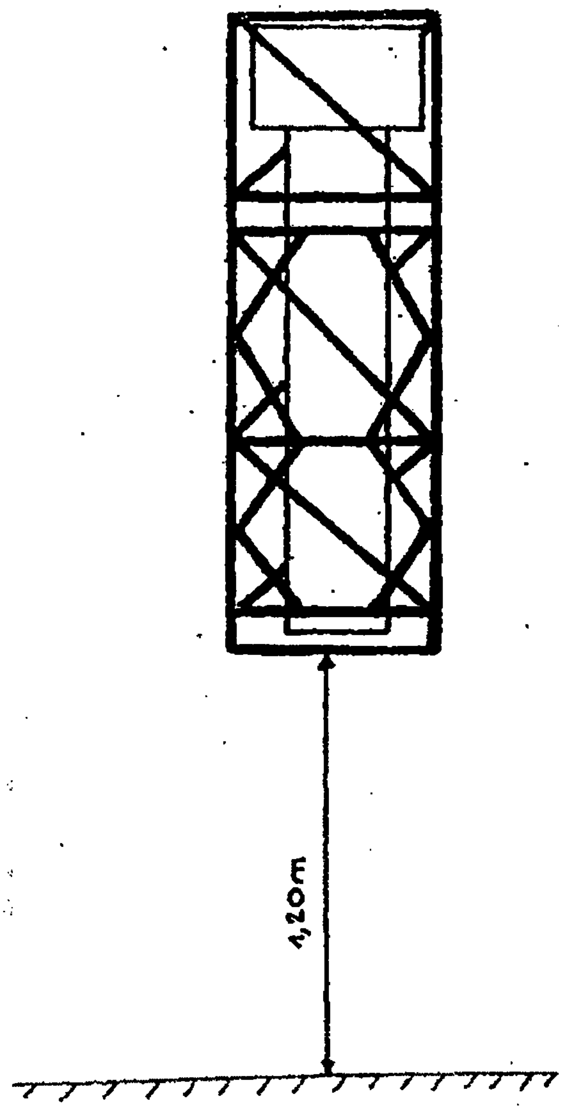


Figure 4: 6 kg bar drop from 1 m

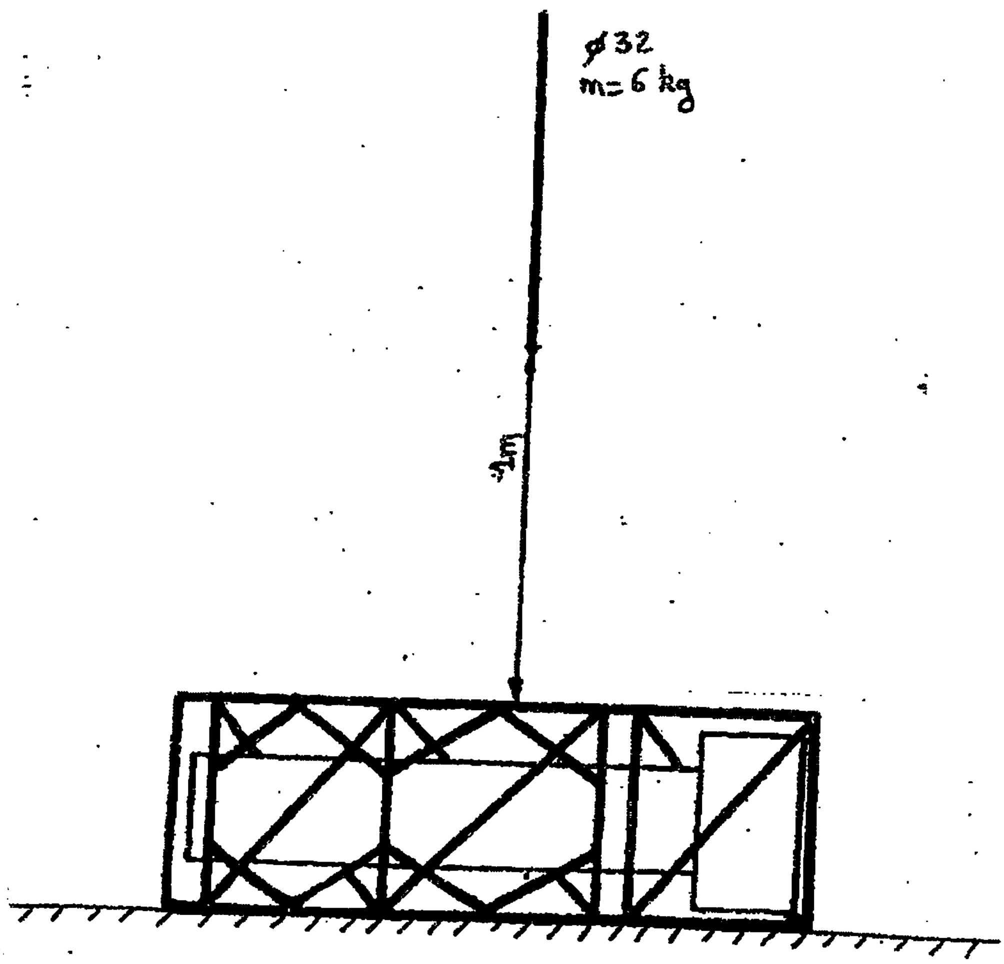


Figure 5: 9-metre drop on top end

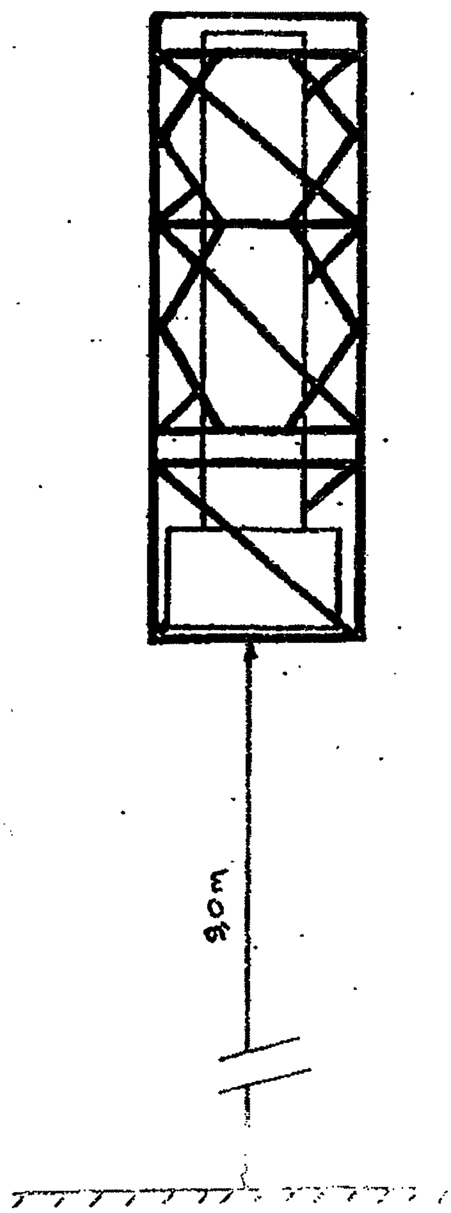


Figure 6: 9.0 m drop horizontal

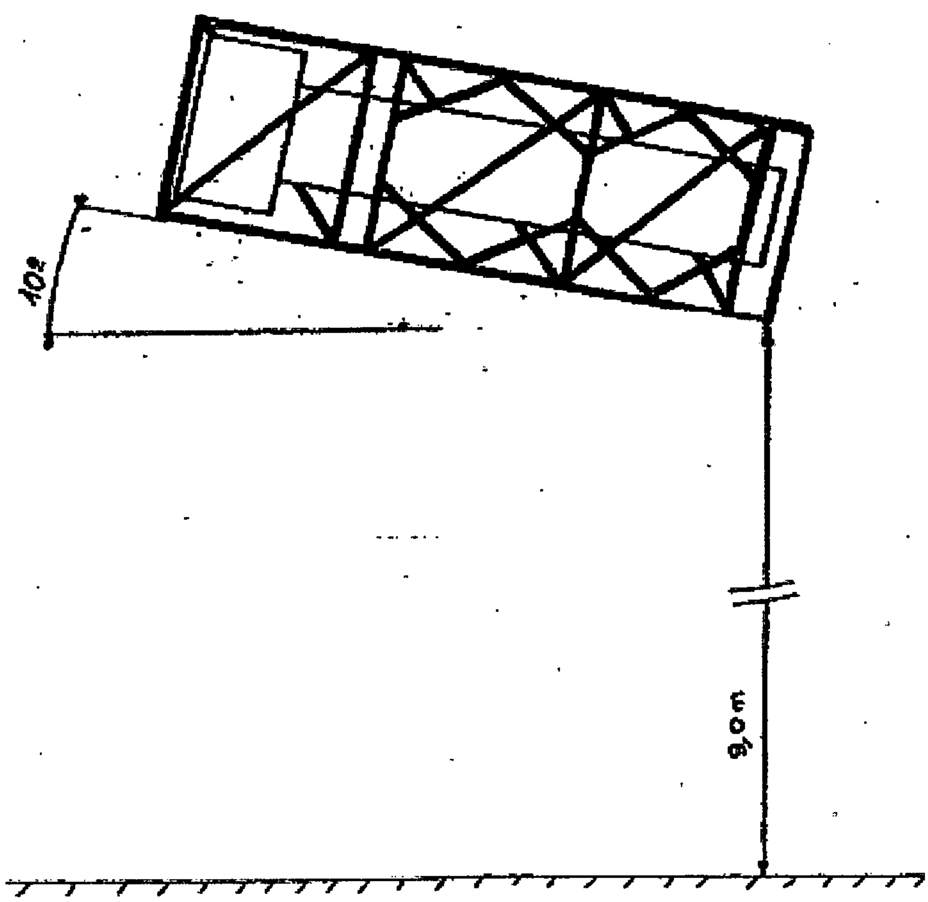


Figure 7: 9.0 m drop on base corner

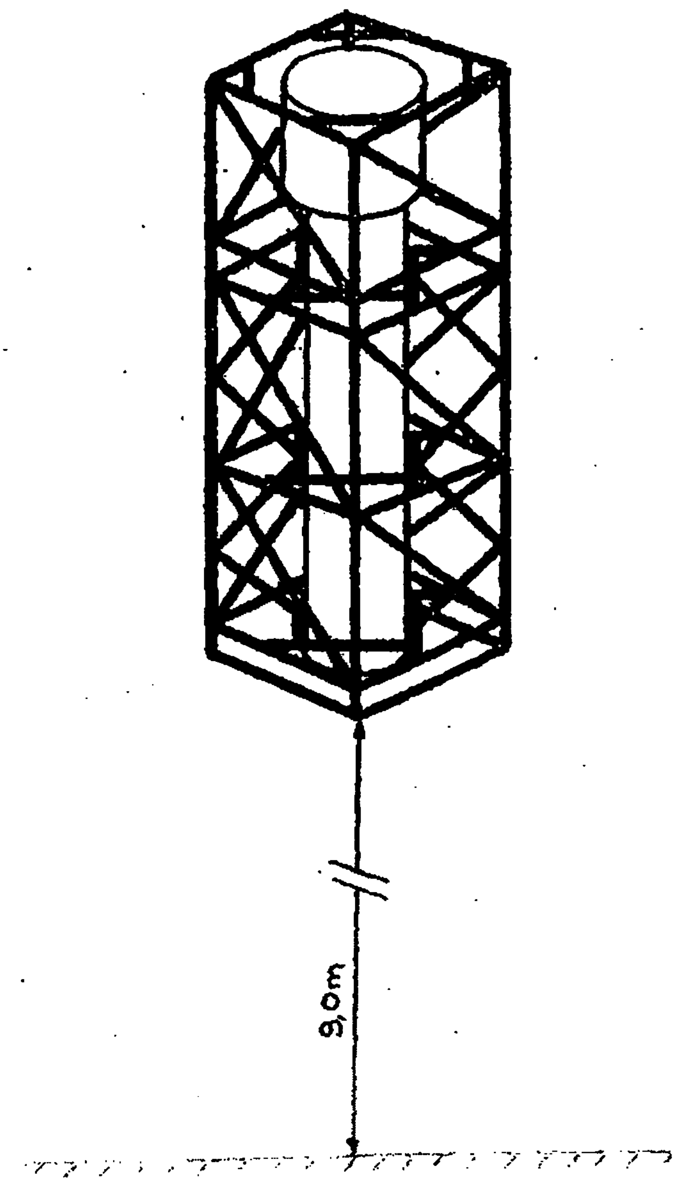


Figure 8: 9.0 m drop on top corner

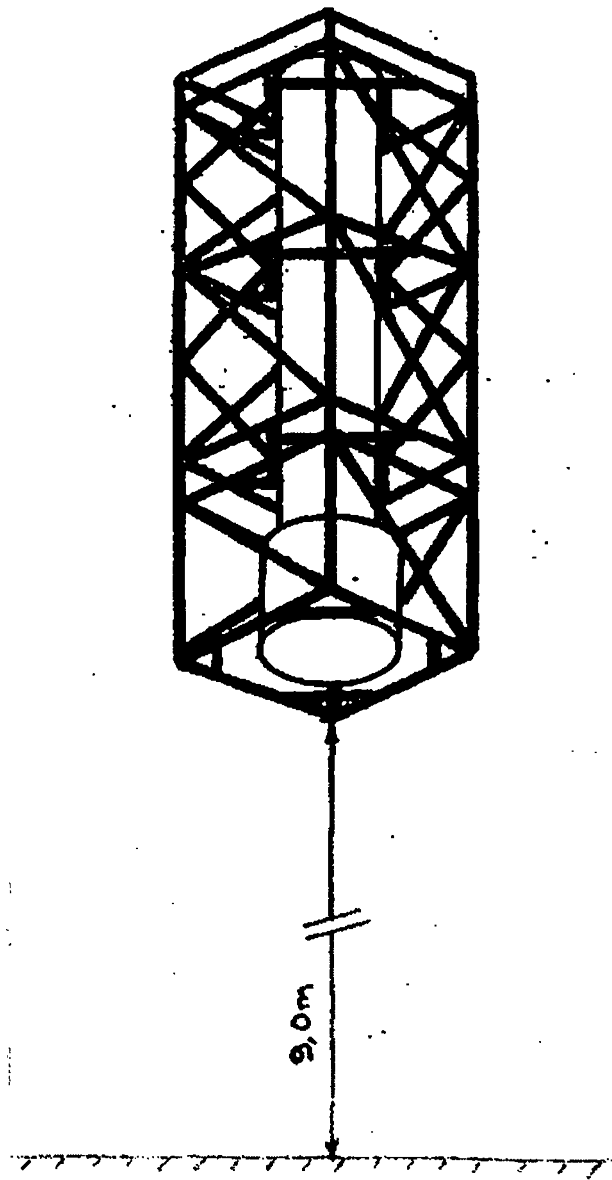


Figure 9: Deformations after various tests

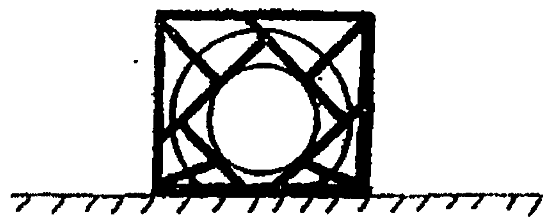


Figure 9a: Packaging drop

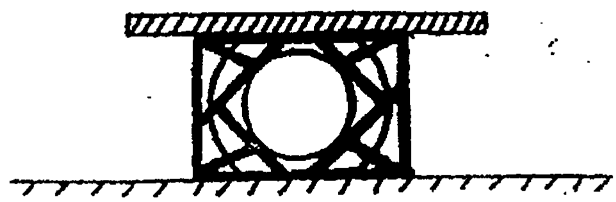


Figure 10: 500 kg plate drop from 9.0 m
packaging vertical

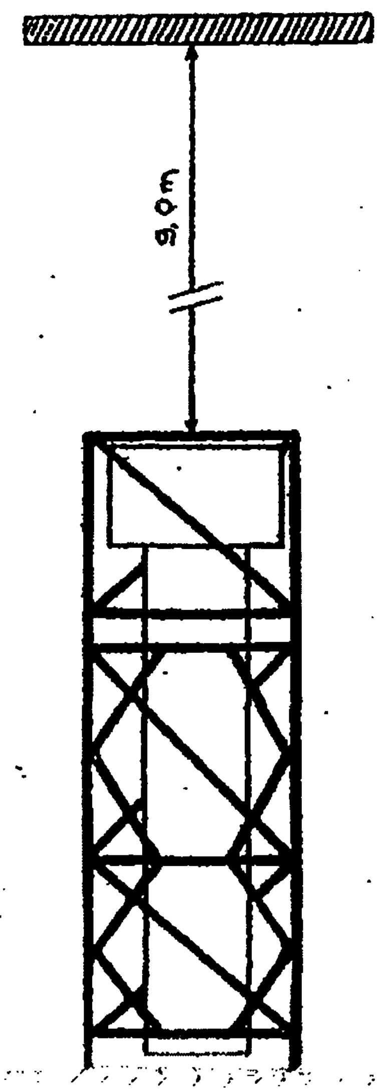


Figure 11: 500 kg plate drop from 9.0 m
packaging horizontal

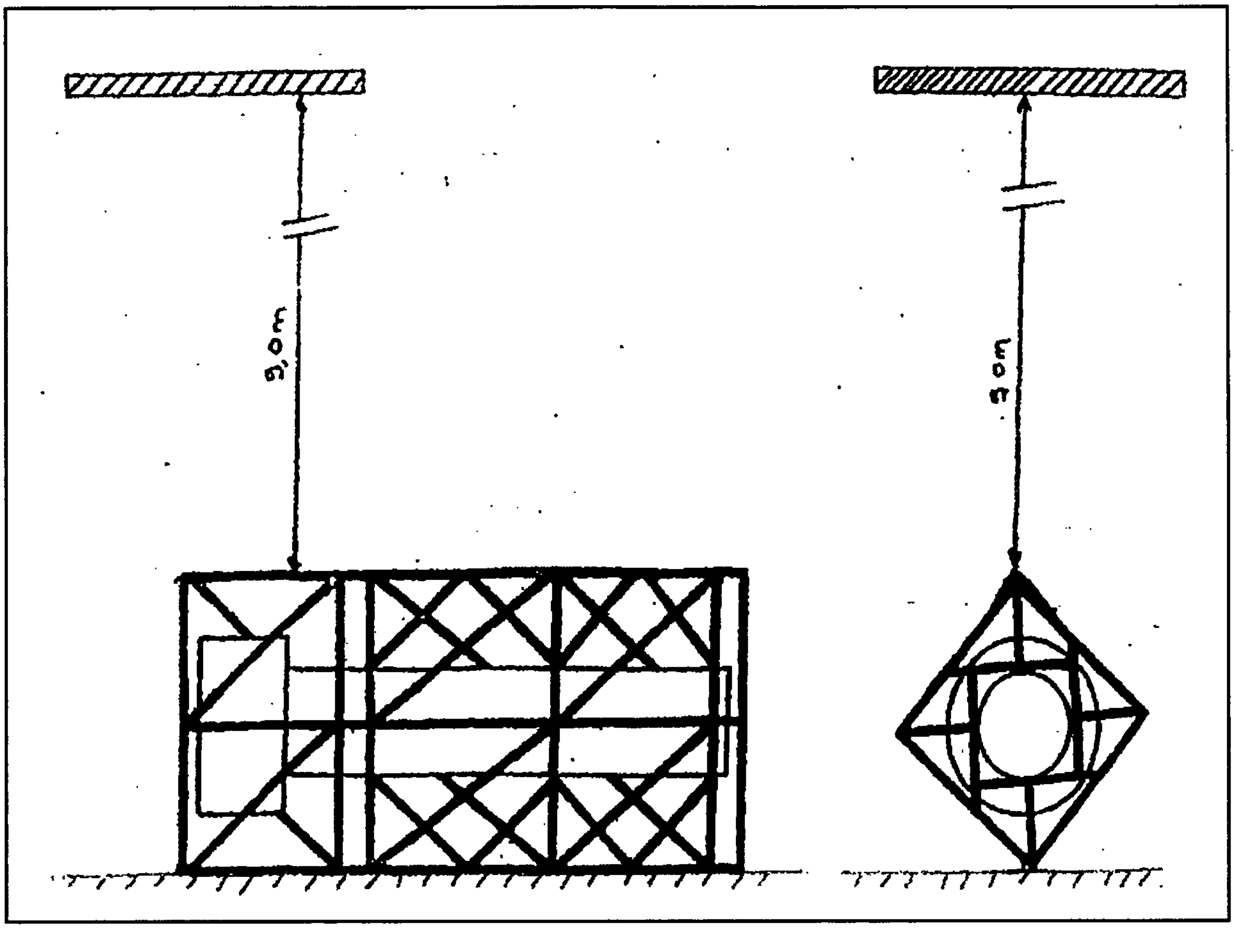


Figure 12: 1.0 m drop onto bar - impact on base

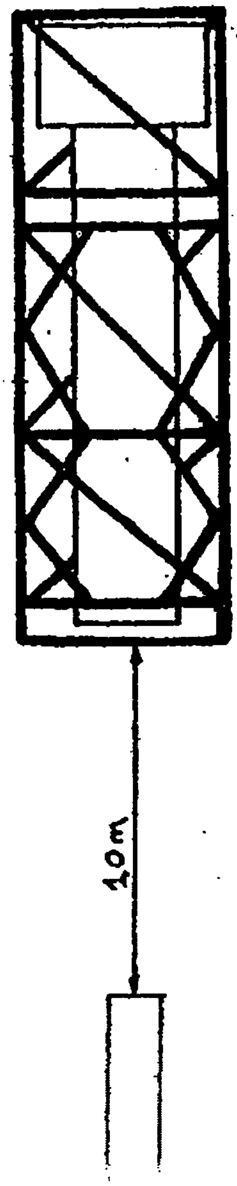


Figure 13: 1.0 m drop onto bar - impact on shell

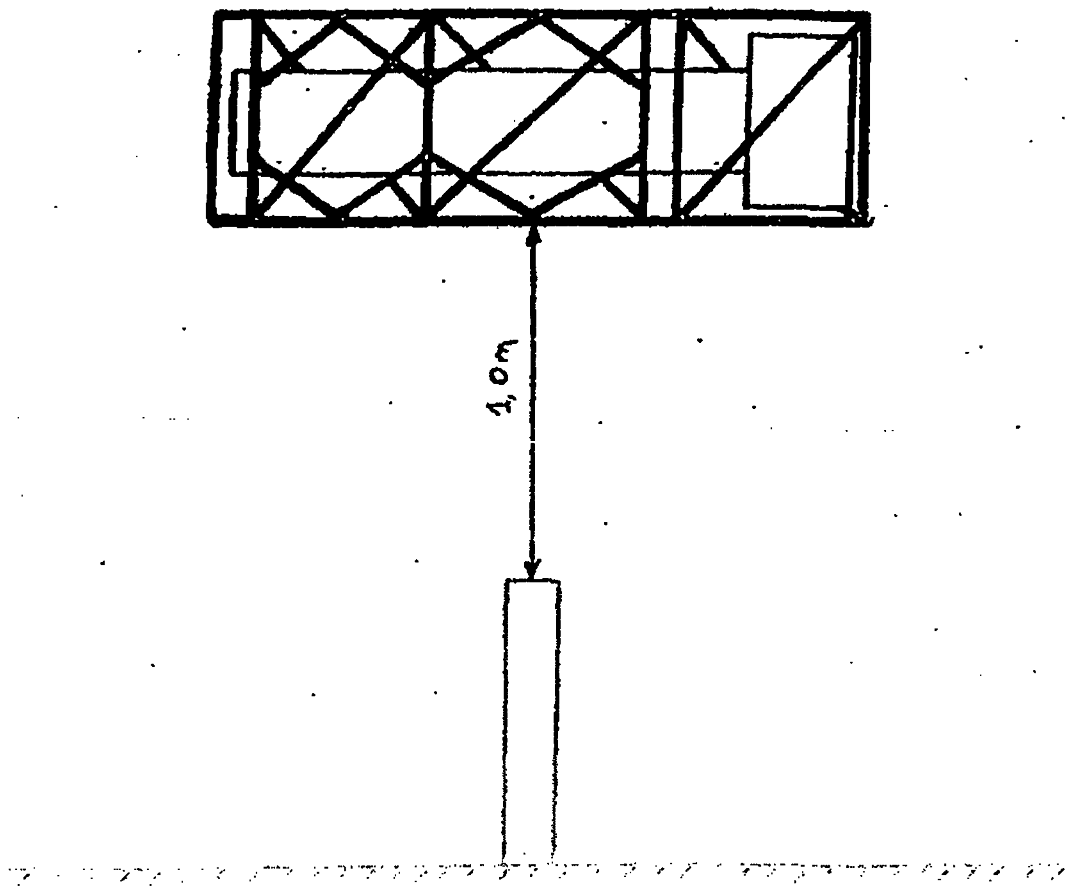


Figure 14: 1.0 m drop onto bar - impact on top end

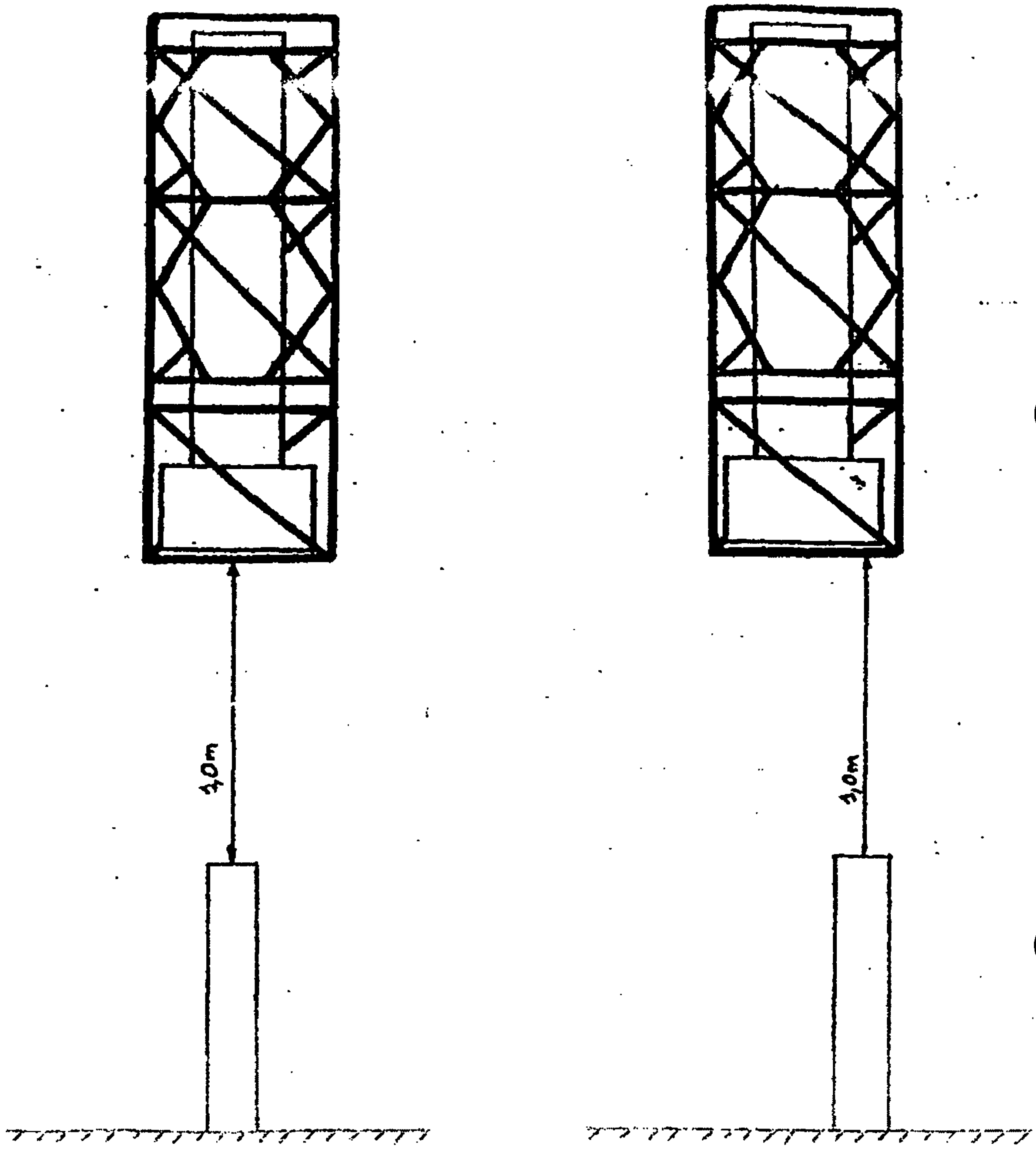
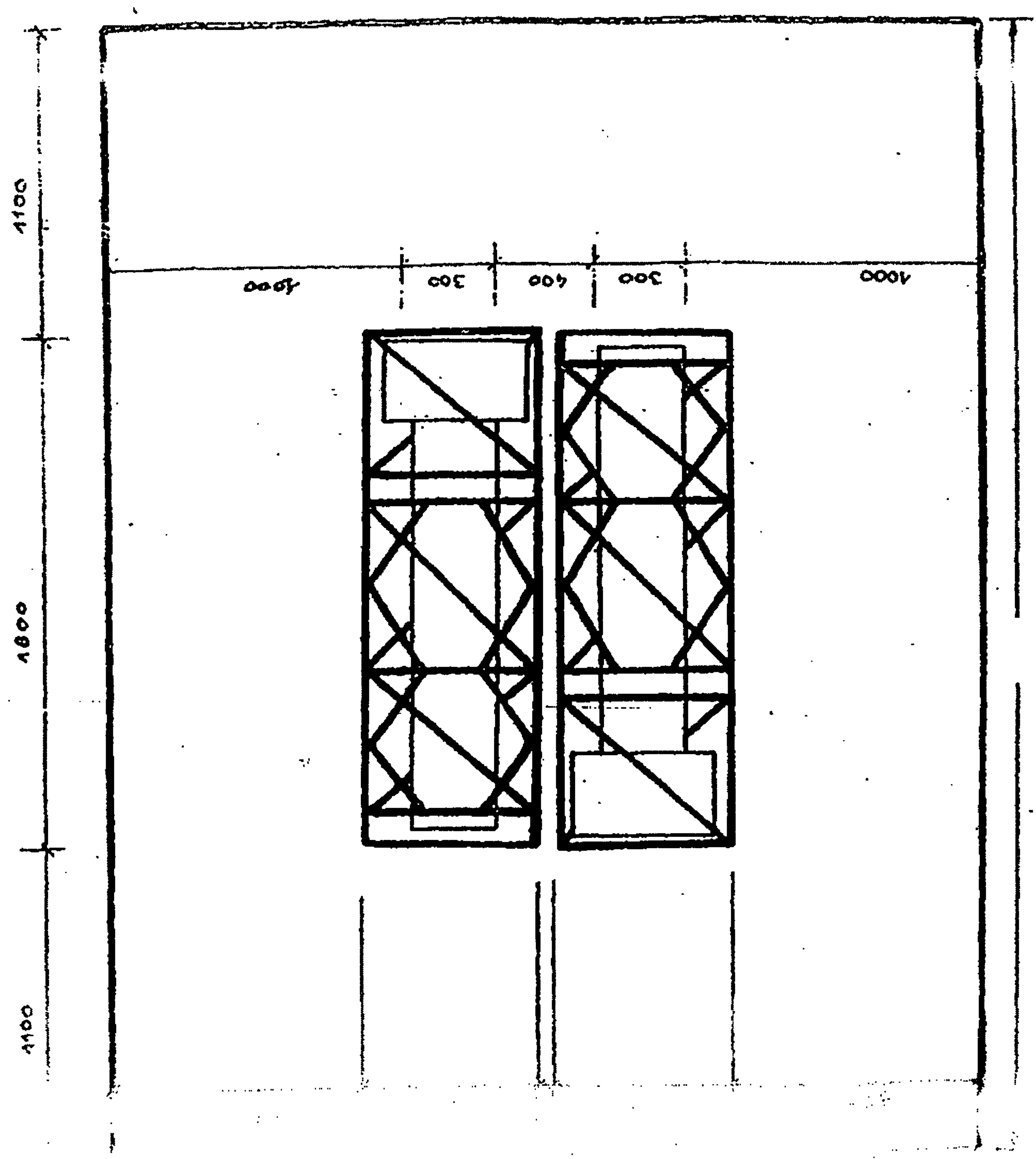


Figure 15: Packaging layout for fire test
(plan view)



TRANSNUCLEAIRE		SUPPLEMENTARY TEST PROGRAMME			Page 1 of 9
TN-BGC1 PACKAGING			Name	Signature	Date
9990-B-2	Rev 0	Prepared by Verified by	P. MALESYS Y. BRACHET		04/03/1988 04/03/1988

D542d14

1. INTRODUCTION

As the first series of regulatory tests representing normal and accident conditions of transport conducted on the TN BGC 1 packaging was not deemed fully satisfactory, a supplementary set of tests must be carried out. The purpose of this note is to present the range of tests that we plan to perform.

2. MAIN RESULTS OF FIRST SERIES

The first series of tests was carried out according to the programme described in <1>.

Two bodies were used, one with an internal fitting containing two bottles of liquid (representing uranyl nitrate), the other an internal fitting containing a solid (representing the mass of plutonium oxide powder).

The first body was subjected to the tests representing normal conditions (drops from 30 cm, drop from 1.20 m), the two 500 kg plate drops and the 3 drops onto a bar.

The second body was used for a series of four 9-metre drops and 3 drops onto a bar.

The following deformations were observed:

- packaging with liquid - plate drops
  - vertical packaging: base crushed to approx. 20 mm and cover dented by a few mm.
  - horizontal packaging: shearing of cage struts along with serious deformation of cage, slight denting of cover
- packaging with solid content - 9-metre drops
  - drop on top end: slight denting of shock absorber cover (approx. 10 mm)
  - horizontal drop: deformations of cage and detachment of body from cage
  - Drop on base corner: denting over approximately half the base to a maximum of approx. 20 mm.
  - Drop on top corner: local deformation of shock absorber cover to a maximum of 30 mm.

The drops onto a bar provided the following observations:

- Impact on base and on top end: slight denting at point of bar impact with higher value on base
- Impact on body: no apparent deformation

For both bodies we observed after the test sequences a loss of leaktight seal on the plug. Our initial analysis was this loss was related to the major deformation of a part on the closure system (bronze ring), which itself was due to over-stiffness of the shock absorber cover and that the bronze material was too soft. However, the packaging cavity remained perfectly leaktight.

For the packaging containing bottles of liquid, we also observed a loss of leaktight seal on the TN 90 internal fitting, with serious deformation of the lid and bursting of the upper bottle in the collar area. We suppose that this is due to the excessive accelerations resulting from the drop onto a bar (top end) and the lack of protection of the TN 90 closure system, which directly impacted the plug.

The overall results of the drops on the package base (9-metre drops and drops onto a bar) or horizontal drop (plate drop, 9-metre drop, drop onto bar), indicate that the behaviour of the packaging was satisfactory.

The modifications to make to the packaging only concern the cover (upper part) and the closure system - they do not modify its behaviour during the tests indicated previously.

The closure system of the TN 90 internal fitting will also be modified slightly to protect the centre section and a shock absorbing material placed between the bottles.

3. SUPPLEMENTARY DROP TESTS

3.1 Packaging used

The packaging used will be that used for the plate drops but after repairs are made to the base and the upper part. It will therefore be comparable to a packaging that has not been dropped.

3.2 Plate drop

In light of the major modifications to the upper part of the cover and the closure system, we need to repeat a test where the packaging is vertical and subjected to a 9-metre drop of the 500 kg plate (figure 1).

This test will be performed with the TN 90 internal fitting loaded with two bottles of liquid in order to observe the consequences of a possible contraction of the body.

However, the plate drop with a horizontal packaging will not be repeated as the side part of the cover is impacted in this drop and it has not been modified. Furthermore, no radial deformation on the body and closure system was observed previously.

3.3 9-metre drops

For the same reasons as previously, we need to repeat the two drops on the cover (top end) - vertically (figure 2) and on a corner (figure 3) - but we do not need to repeat the drops on to the base (corner) and with the packaging horizontal.

The drop tests will be performed using the same packaging as before, after replacement of the shock absorber cover.

In terms of internal fittings, the drop test with a vertical packaging will be done with the TN 90 (to test its behaviour) and the drop onto a corner with the AA 227 internal fitting (which has a higher mass and releases the most energy).

The shock absorber cover will be replaced in between the two drops if the damage suffered justifies this.

3.4 Drops onto bar

These drop tests are accumulated with a plate drop or a 9-metre drop. Once again, only the drops onto the top end (shock absorber cover) need to be repeated.

These tests will be performed i) using the packaging with the TN 90 internal fitting and the cover used for the plate drop and ii) using the packaging with the AA 227 internal fitting and the cover suffering the most damage after the 9- metre drops (this is most likely to be the cover used in the vertical drop).

The packaging will be dropped onto the centre of the cover (figure 4) where the balsa wood is positioned crossways and presents the least resistance. The previous tests demonstrated that offsetting the point of impact from the centre did not cause additional damage that could be envisaged (tearing of cover).

3.5 Conclusion

All these drop tests are indicated in table 1.

4. FIRE TEST

Two packages will be arranged in the fire. One will be the packaging subjected to the previous tests with the TN 90 internal fitting and the cover subjected to the plate drop test and a drop onto a bar. This packaging will therefore be perfectly representative of a packaging that has undergone a plate drop and a drop onto a bar.

Furthermore, we will also use the body that was subjected to the first series of tests with the AA227 internal fitting and fitted with cover 2 or 3 that was subjected to the drop onto a bar (see table 1).

It will therefore be representative of a packaging that has undergone a series of 9-metre drop tests both on its base and its top end. Only the closure system will be different (as it will be the defective version but which has been repaired to ensure a leaktight seal), but its behaviour which essentially depends on the temperature of seals will be similar, as the fire protection offered by the cover is the same.

REFERENCES

<1>Note TRANSNUCLEAIRE 9990-B-1 Rev. 1: Test programme imposed by transport regulation

TABLE 1

	DROP TYPE	FIGURE	COVER	INTERNAL FITTINGS
1	500 kg plate Package vertical	1	1	TN 90
2	Bar Centre of cover	4	1	TN 90
3	9 metre drop on cover Package vertical	2	2	TN 90
4	9 metre drop on cover Drop onto corner	3	2	AA 227
5	Bar Centre of cover	4	2 or 3	AA 227

Figure 1: 500 kg plate drop from 9 m - packaging vertical

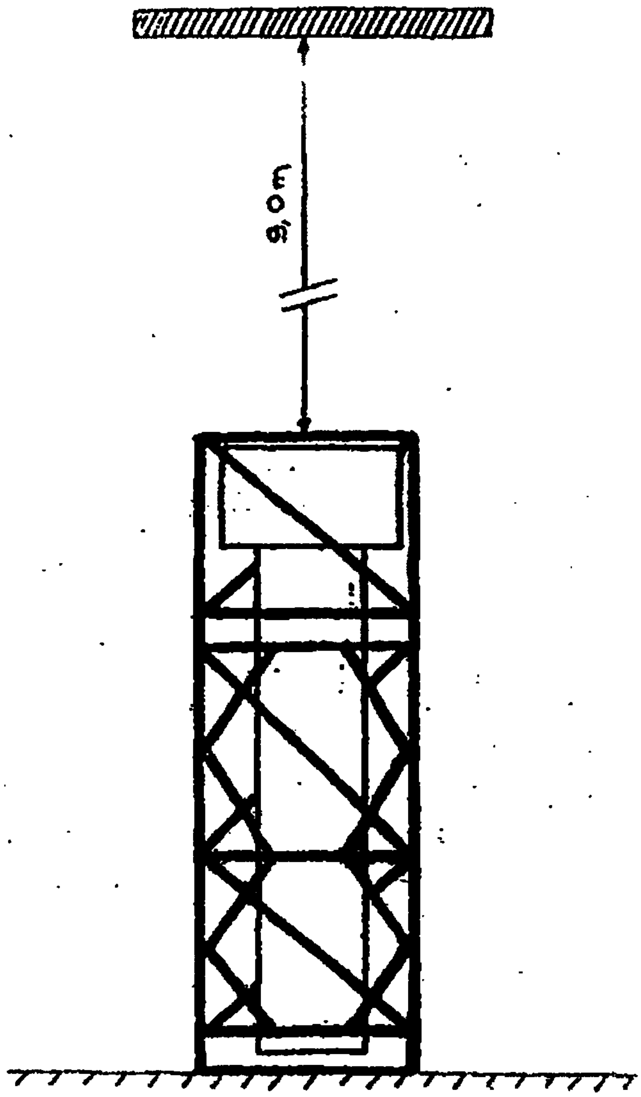


Figure 2: 9-metre drop on top end

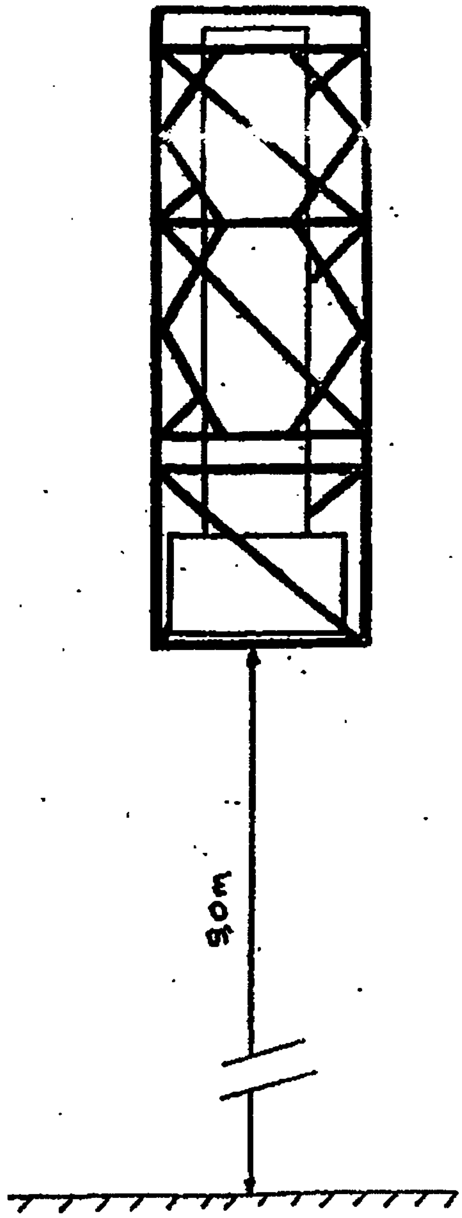


Figure 3: 9 m drop on corner - top end

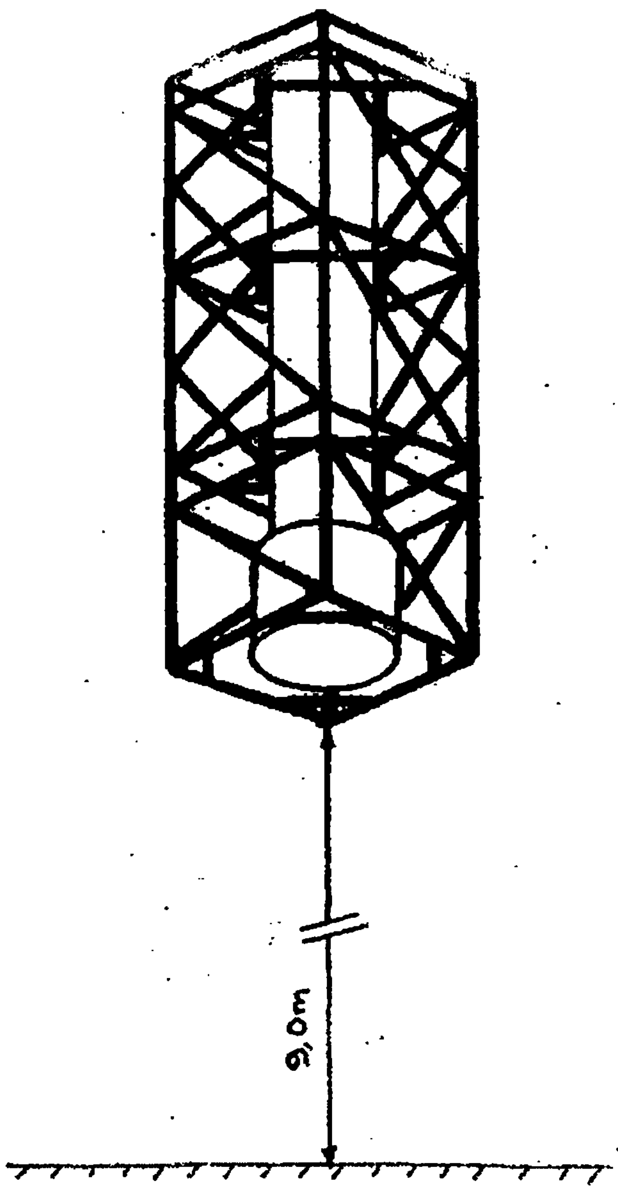
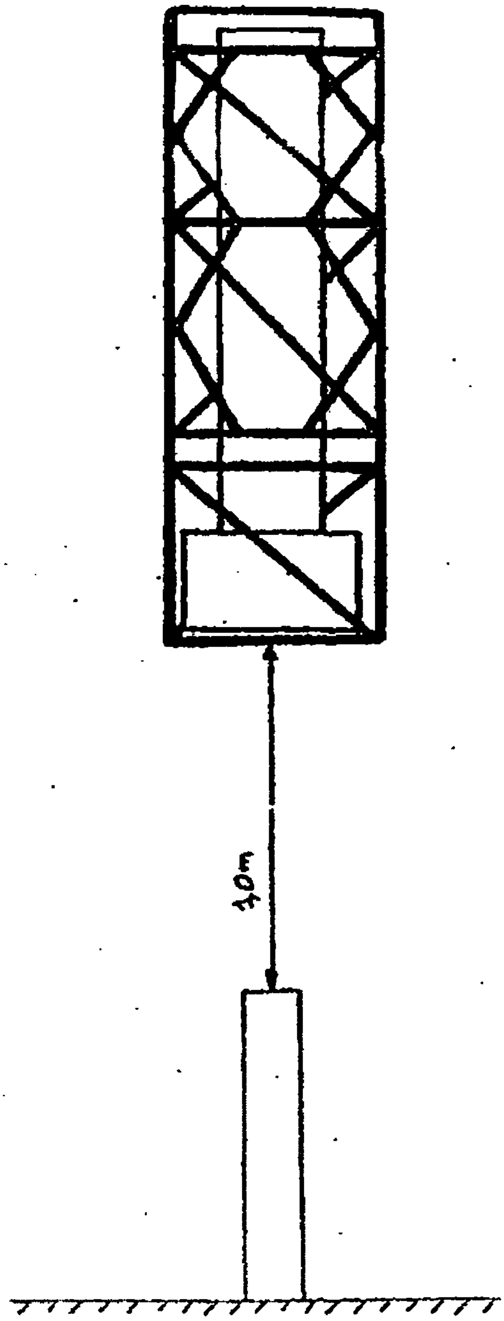


Figure 4: 1 m drop onto bar - top end



PROGRAMME: RENEWAL OF STOCK OF CEA PACKAGES

TITLE:

TN BGC 1
Drop test report
January 2003

ORIGINAL

Summary:
- This document summarises the results of the drop test series performed in January 2003 using the TN BGC packaging.

Signoff			
Date	02/06/03	03/06/03	03/06/03
Name	T. CUVILLIER	S. CLAVERIE-FORGUES	D. LALLEMAND
Unit	DEN/DTAP/SPI/GET	DEN/DTAP/SPI/GET	DEN/DTAP/SPI/GET
Function	Engineer	Engineer	GET manager

E M B (1 2 3) T N B G C (4 5 6 7 8) P B C (9 10 11) C R X (12 13 14) C A 0 0 0 3 0 4 A (15 16 17 18 19 20 21 22 23)

	Author	Reviewer	Approver

LIST OF CHANGES

EDITION	DATE	Nature of modification	Pages modified
A		Document creation	[redacted]

CONTENTS

I PURPOSE

This note provides a summary of the drop tests performed in January 2003 according to the reference drop test programme [1]. The test programme received prior approval from the Nuclear Safety Authority through letter [2].

The tests took place on the premises of Robatel, in Genas, in accordance with the test programme (except for a modification explained in paragraph II).

After each test sequence, leakage tests were performed to demonstrate:

- the leaktight seal on the containment vessel
- the leaktight seal on the TN 90 internal fitting.

II PRESENTATION

Three sequences of different drops were carried out. They supplement the two drop test sequences performed in 1998 to qualify the package model.

The detailed analysis of the drop tests carried out and the justification of our last test configuration choices are given in document [1].

The sequences are as follows:

1° first packaging:

- 9-metre drop, packaging vertical, shock absorber cover facing down (drop no. 1) followed by
- 1-metre drop onto a bar, impact on cover, packaging inclined by 14° from the vertical (drop no. 2)

2° using the same packaging:

- 9-metre drop with slap-down (packaging inclined by 10° to the horizontal) (drop no. 3)

3° second packaging:

- 1.20 m drop, horizontal position (drop no. 4) followed by
- 500 kg plate drop from 9 metres, the packaging laid horizontally on the unyielding surface (drop no. 5) followed by

- drop onto a bar impacting the body, with the packaging inclined by 21° in relation to the horizontal (drop no. 6) followed by
- drop onto a bar impacting the body, with the packaging inclined by 35° in relation to the horizontal (drop no. 7).

Prior to each sequence, in accordance with the instructions for use of the packaging, we apply a pre-stress force of 30 kN to the packaging lid, a tightening torque of 50 N.m for the Staubli cap and 20 N.m for the TN 90 internal fitting lid.

In relation to the planned test programme, there is only one notable difference: after the first drop onto a bar with impact on the body, it was decided to remove the perforated metal sheet so that the bar was allowed to impact the body directly. This choice is highly penalising yet enables a better aim and to ensure that the bar does not hit a cage strut before hitting the body.

The detailed report of these tests along with the damage report after each test and a photographic account, is provided in appendix L 11a, Robatel reference 102221 RES01.

An extract from the end of intervention report for the leakage tests before and after each sequence is provided in appendix 2. It demonstrates that the seals on the containment system of the packaging and on the internal fitting remain sufficiently intact and leaktight after the drop test sequences.

Lastly, we provide several additional photos in appendix 3.

III ANALYSIS OF TESTS

Using these tests, we were able to demonstrate that:

- the packaging remains leaktight after each drop sequence (global leakage rate in the order of 10^{-7} $Pa.m^3.s^{-1}$). No deformation of the closure system was observed. The Staubli connector cap was not loosened after a drop (50 N.m).
- The TN 90 internal fitting is not as leaktight after a drop compared to before. In all cases the leakage rate remains below 3.10^{-3} $Pa.m^3.s^{-1}$ after each sequence (order of value prior to drop: 10^{-5} $Pa.m^3.s^{-1}$), which is satisfactory. This is explained by the consequences of the 9-metre drops. The steel ballast (60 kg) pushed the internal lid, which in turn exerted pressure on the outer lid. The displacement caused differences in the conditions of seal compression. These modifications are reversible, as after opening and closing the internal fitting, the leaktight closure returns to its pre-drop leakage value.

- The shape of the internal cavity of the TN BGC 1 and the TN 90 were not modified;
- The cover perforation test did not provoke tearing of the cover casing.
- One of the body perforation tests (35°) caused denting and a local perforation of the outer shell.
- In all cases, whether after NCT or ACT drop tests, the shock absorber cover remained connected to the packaging,
- The drop test representing NCT highlighted a shearing of certain bolts connecting the cage to the body but without impairing the link between them (subsequent to this drop, a 9-metre drop test and two drops onto a bar were carried out using the same packaging, without causing the cage to disconnect from the body).

IV CONCLUSION

This supplementary drop test sequence demonstrated that:

- after the NCT tests the packaging retains the integrity of its biological protection and remains leaktight (leakage flow in the order of 10^{-7}Pa.m^3.s^{-1}). The compliance of the package with applicable regulations is therefore ensured.
- after the ACT drop tests, the leakage rate measured on the packaging is in the order of 10^{-7}Pa.m^3.s^{-1}, the biological protection is not affected, the shape of the internal fittings is not modified and they remain leaktight. These data are used for additional safety assessments (radiation protection, heat insulation, criticality).

V REFERENCES

[1] Note EMB TNBGC NTT CA000149 C of 30 September 2002
[2] Letter DGSNR/SD1/0971/2002 of 26 November 2002

Appendix 1 Drop test report

Reference Robatel 102221 RES01

Sequences 0, 1 and 2

Pages 7 + 44 + 7

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CEA DEN/DTAP/SPI GET	**TN BGC1 PACKAGING** **Drop tests**	Cust. order: 4000046416Q/P5H33

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Associated Documents

Photographic account 102221 RES 01-1
Acceleration measurements 102221 RES 01-2

2				
1				
0	F. LABERGRI	H. RUBY	C. BOCHARD	

1. REFERENCE DOCUMENTATION

• Drop test specifications	EMB TNBGC CDC PBC CA 000123A
• Fax	FAX/GET/2002/F385
• Completed drop test sheets	102221 FES 00 rev.1
• Quality Assurance programme	102221 FES 001 rev.1
• Photographic account	102221 RES 01-1
• Acceleration measurements	102221 RES 01-2
• Fast-action video	102221 VID 01
• CD-Rom containing photos, normal-speed video, acceleration measurements	102221 CD 01

2. INTRODUCTION

The drop tests are carried out by ROBATEL on the Genas site.

SOGEDEC personnel will perform the opening/closing operations on the packaging.

CTE Nordtest is responsible for the leakage tests.

ROBATEL also performs the acceleration measurements, the normal and fast-action videos, photographic accounts and observations of mechanical damage.

Seven drop tests were carried out between 27 and 29 January 2003.

Persons present:

M. RUBY	ROBATEL
M. LABERGRI	"
M. BOCHARD	"
M. CUVILLIER	CEA
M. TIPHAINE	CEA
M. DEBAYE	SOGEDEC
M. CAST	CTE NORDTEST
M. FIESKI	IRSN (drops 3.1 and 3.2 only)
M. MATHON	ATR Ingénierie (drops 3.3 and 3.4 only)

3. DROP no. 1.1: 9.02 m vertical package

3.1. Preparation (see photo 1)

Date: 27 January 2003

- mass of packaging: 400 kg
- 2 accelerometers in the drop axis near to the shock absorber cover
- cover (top end) pointing downwards
- packaging aligned vertically

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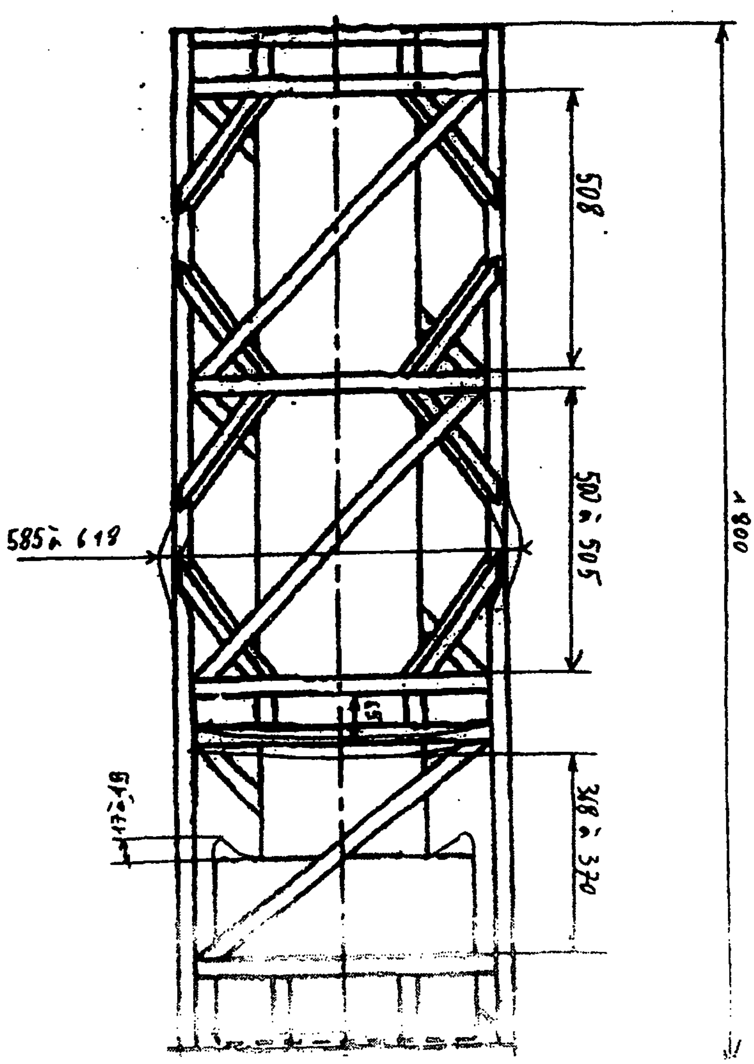
3.2. Drop

- rebound of approximately 20 cm
- the acceleration measurement did not work for reasons unknown.

3.3. Post-drop observations (see photos 2 to 13 and side diagram)

- The cover was dented by 17 to 19 mm (photos 4 to 6);
- The cage was compressed by around 15 mm, mainly due to the buckling of the four main side struts in the centre section (photos 7 and 8);
- The cover remained in place, the latches were closed;
- Three weld ruptures near to the front body mountings (photos 9 and 10);
- The mounting profiles in the centre of the body were locally flattened (photo 11);
- the rear mounting nuts perforated a side of the profiles (photos 12 and 13).

Drop 1.1: 9.02 m, packaging vertical, cover end downwards



4. DROP no. 1.2: 1.02 m onto a bar at 14° incline and near to a lug on the cover

4.1. Preparation (see photos 14 and 15)

Date: 28 January 2003

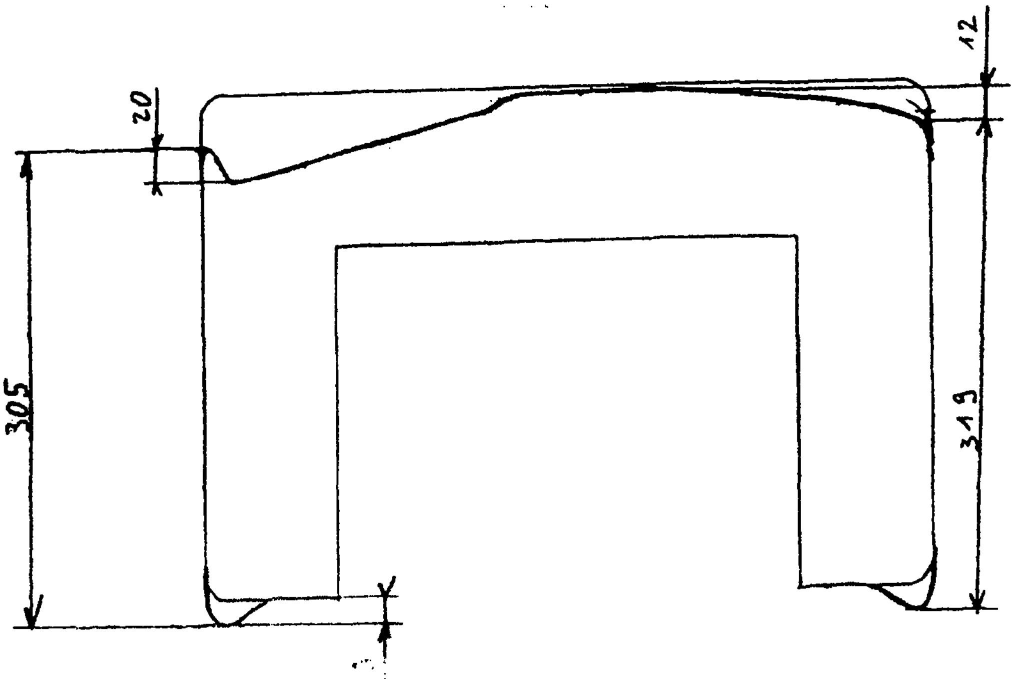
- The packaging is used in the condition subsequent to drop 1.1.
- inclination of the package relative to vertical: 14.4°
- the point of impact is close to a lug where the shock absorber cover is already slightly deformed.

4.2. Drop

- After a very shallow rebound (just a few centimetres), the packaging fell back on the steel slab at an angle, shearing 2 cage struts (photo 19).

4.3. Findings

- The cover is dented locally by approximately 50 mm in relation to its new condition (see diagram of side and photos 16 to 18).
- Two longitudinal struts were broken in the centre section due to the angular rebound on the slab (photo 19).
- After dismantling, we observed the mark of the handle of the internal fitting on the lid (photo 24).



5. DROP no. 2: 9.02 m with slap-down, 10° incline, base facing downward 5.1.

5.1. Preparation (see photos 25 and 26)

Date: 28 January 2003

- Four accelerometers (see photos 33 and 34)
  - accelerometer 0 and 1 close to the cover in the drop axis
  - accelerometer 2 near the base in the drop axis
  - accelerometer 3 close to the cover in the axis of the packaging
- the face of impact is where the longitudinal cage struts are not broken
- the packaging is that used in drop no. 2 after opening and closing.

5.2. Drop

- Shallow rebound

5.3. Findings

- All the mountings attaching the body to the cage and the internal reinforcements of the cage were broken. The body touched the ground on the cover end and the base end (photos 27 to 32).
- The acceleration measurements (filtered at 1000 Hz, 500 Hz and 250 Hz) are presented in document 102221 RES 01-2. In summary, the maximum absolute accelerations are given in the following table:

			1000 Hz	500 Hz	250 Hz
(a_0)	near cover	vertical	765	731	682
(a_1)	near cover	vertical	814	710	631
(3_2)	at base	vertical	1070	956	366
(a_3)	near cover	horizontal	170	76	65

We can also deduce that

T = 0 ➔ first impact on base end
t = 22.2 ms ➔ second impact on top end
t = 26.3 ms ➔ end of second impact
t = 440 ms ➔ end of rebound

6. DROP no. 3.1: 1.22 m horizontal package

6.1. Preparation (see photo 36)

Date: 29 January 2003

- We used a fully intact packaging.
- Mass of packaging: 402 kg
- The face of impact is such that the cover mounting latches are in the median plane.

6.2. Drop

- Flat drop
- rebound of a few centimetres

6.3. Observations (photos 37 to 44)

- four bolts shorn on top mountings (photo 39)
- three bolts shorn on centre mountings
- bolt not shorn at base
- two fissures in top end mounting reinforcements (photos 40 and 41)
- at the top end, the body is de-centred by 22 mm in relation to the frame (photo 38) the cover impacted the cage frame (marks)
- one cover closure latch opened. The mounting stud seems to extrude from the cover by 5 mm (photos 42 to 44).

7. DROP no. 3.2: 9.02 m, 512 kg plate

7.1. Preparation (see photos 45 and 46)

Date: 29 January 2003

- Mockup used as is after drop 3.1
- mass of plate: 512 kg
- the point of impact of the centre of gravity of the plate is 170 mm from the top edge of the packaging.
- The packaging is laid flat on the slab.

7.2. Drop

- The plate was projected 2 m along the packaging axis.

7.3. Observations (photos 47 to 53)

- The shock absorber cover remained in place (one latch remained closed)
- several welds close to the impact zone were broken
- at the top end the cage height ranged from 450 mm to 480 mm, with compression amounting to approximately 130 mm (photo 49).

8. DROP no. 3.3: 1.02 m onto a bar at 20°

8.1. Preparation (photos 54 and 55)

Date: 29 January 2003

- Mockup used as is after drop 3.2
- *The bar passed in between two cage struts towards the body, close to the centre of gravity.*
- The axis of the packaging was 21° from the horizontal.
- The shock absorber cover was facing upwards.

8.2. Drop

- The bar did not touch the struts
- High rebound

8.3. Findings

- The cover turned by 16 mm (measured by mountings) - see photos 59 and 60.
- The perforated casing impacted by the bar remained attached on one side (photo 56)
- the imprint of the bar on the body left a perforation of 5 to 6 mm (photos 59 and 60).

9. DROP no. 3.4: 1.02 m onto a bar at 35°

9.1. Preparation (photos 63 and 66)

Date: 30 January 2003

- Mockup used as is after drop 3.3
- Angular repositioning of cover; only one closure latch is engaged
- the perforated casing in the axis of the bar was shorn
- the bar passed in between two cage struts towards the body, close to the centre of gravity.
- the axis of the packaging was 35° from the horizontal.
- the shock absorber cover was facing upwards.

9.2. Drop

- Major rebound (between 10 and 20 cm)

9.3. Findings

- The cover closure latches were open (photos 69 and 70)
- the cover turned (photos 71 and 72)
- the bar tore the outer shell of the body, behind the point of impact (photos 73 to 76)

the dimensions of the imprint are:

- depth: 9.3 mm
- length: 72 mm
- width: 30 mm

the dimensions of the fissure are:

- length: 38 mm
- gap: 6 mm

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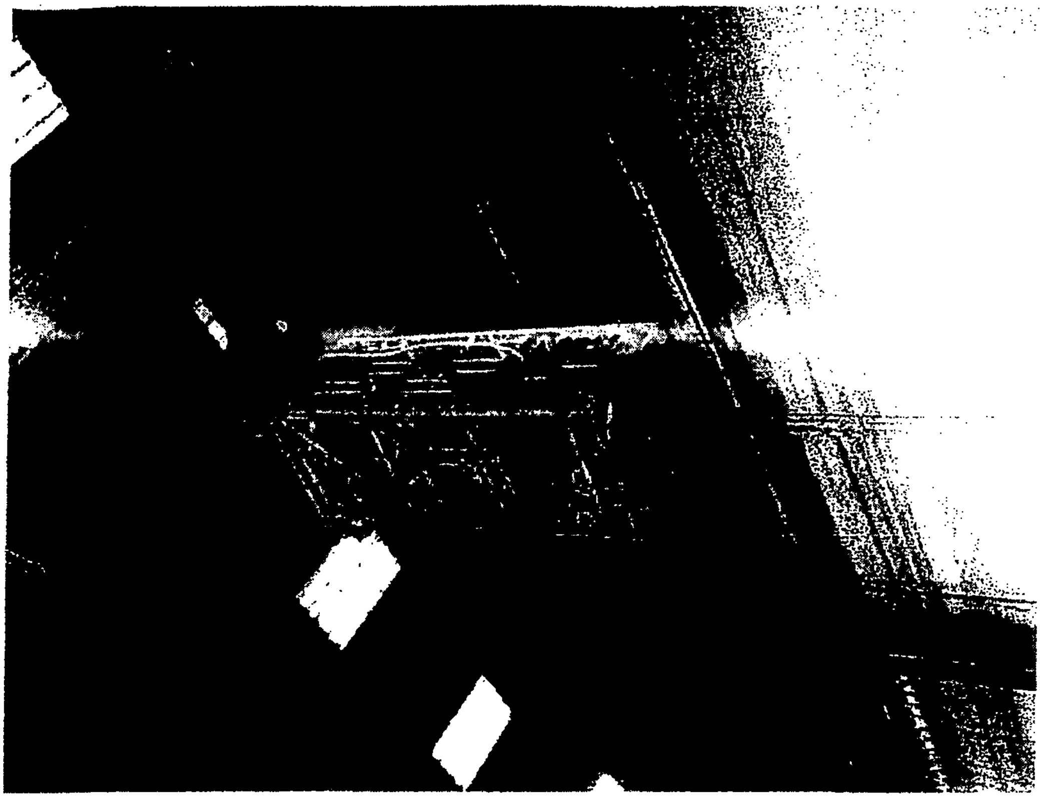

Photo 1; before drop no. 1.1 (9.02 m)

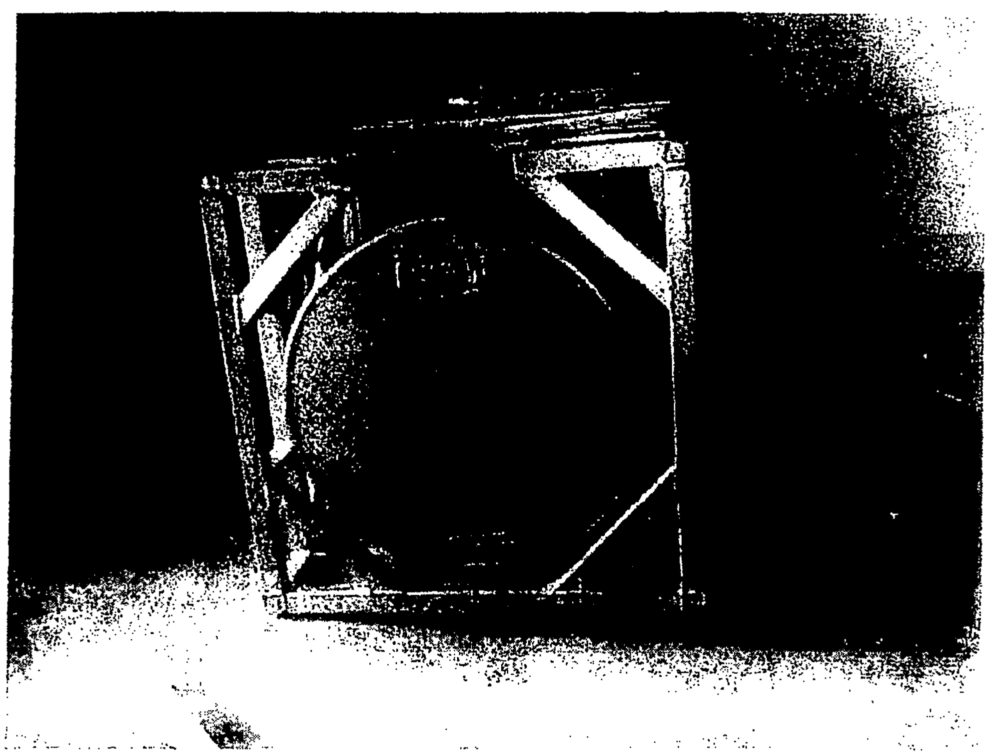

Photo 2; after drop no. 1.1

Photo 3; after drop no. 1.1 (general view)

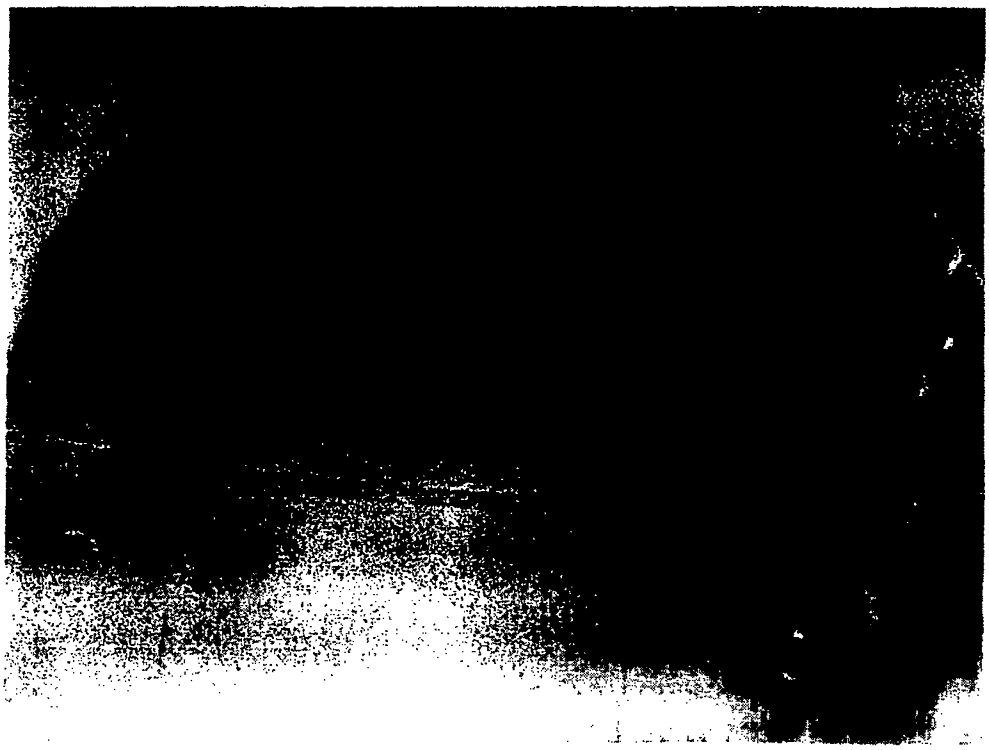

Photo 4; after drop no. 1.1 (deformation of cover)

Photo 5; after drop no. 1.1 (cover mountings)

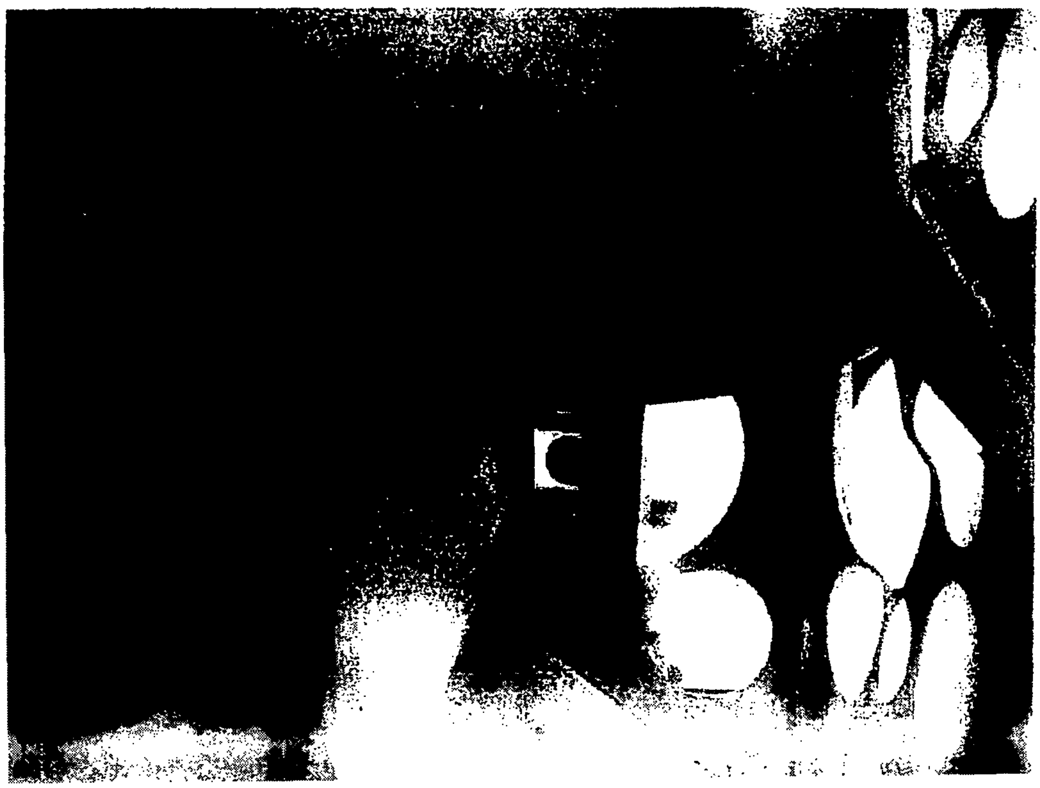

Photo 6; after drop no. 1.1 (cover mountings)

Photo 7; after drop no. 1.1 (deformation of struts)

Photo 8; after drop no. 1.1 (deformation of struts)

Photo 9; after drop no. 1.1 (shearing of top end mounting welds)

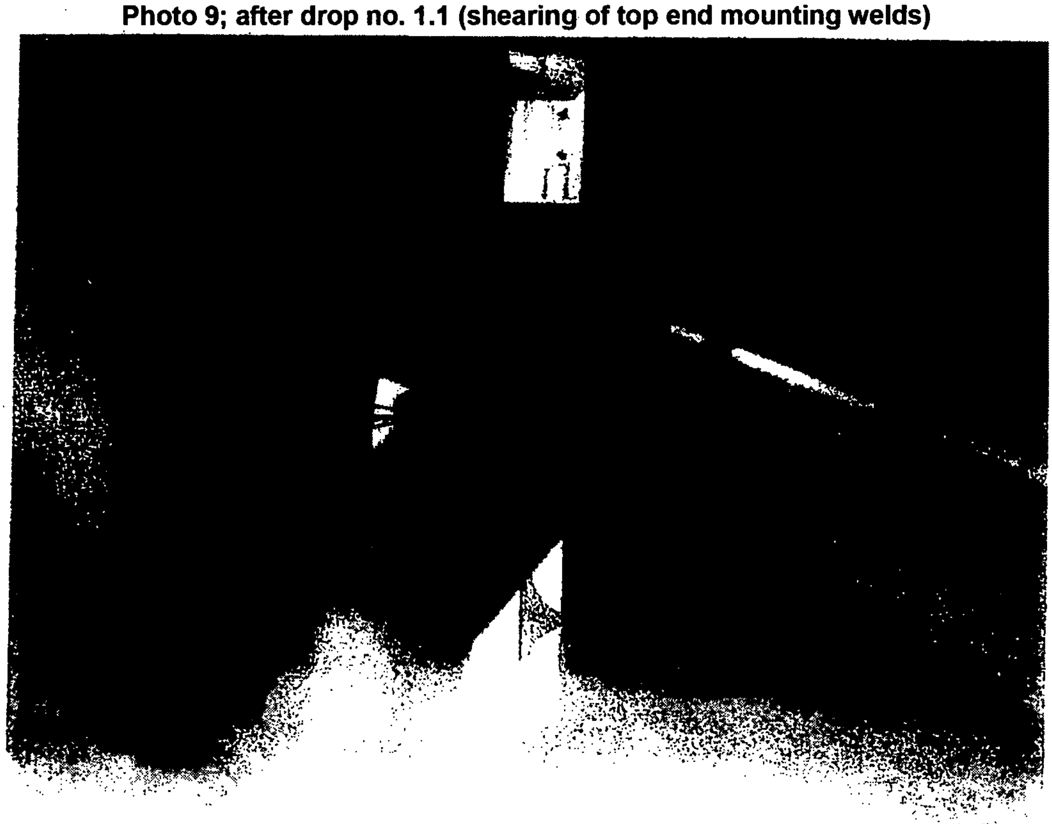

Photo 10; after drop no. 1.1 (shearing of top end mounting welds)

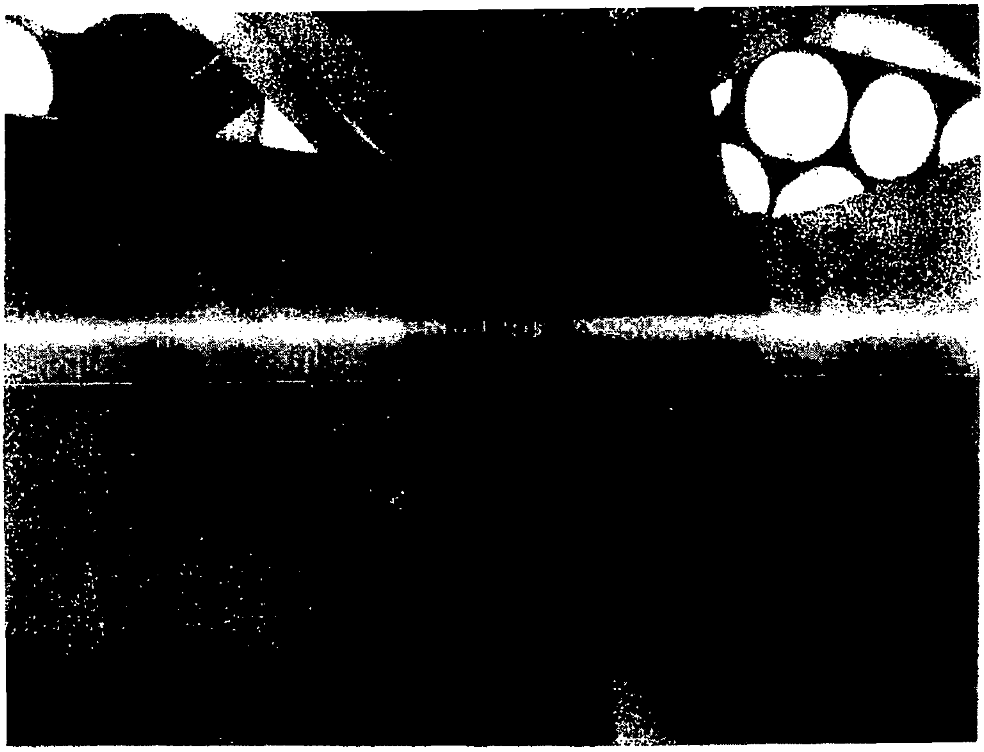

Photo 11; after drop no. 1.1 (flattening of bolted profiles, centre mountings

Photo 12; after drop no. 1.1 (nut traversing rear mounting profiles)

Photo 13; after drop no. 1.1 (nut traversing rear mounting profiles)

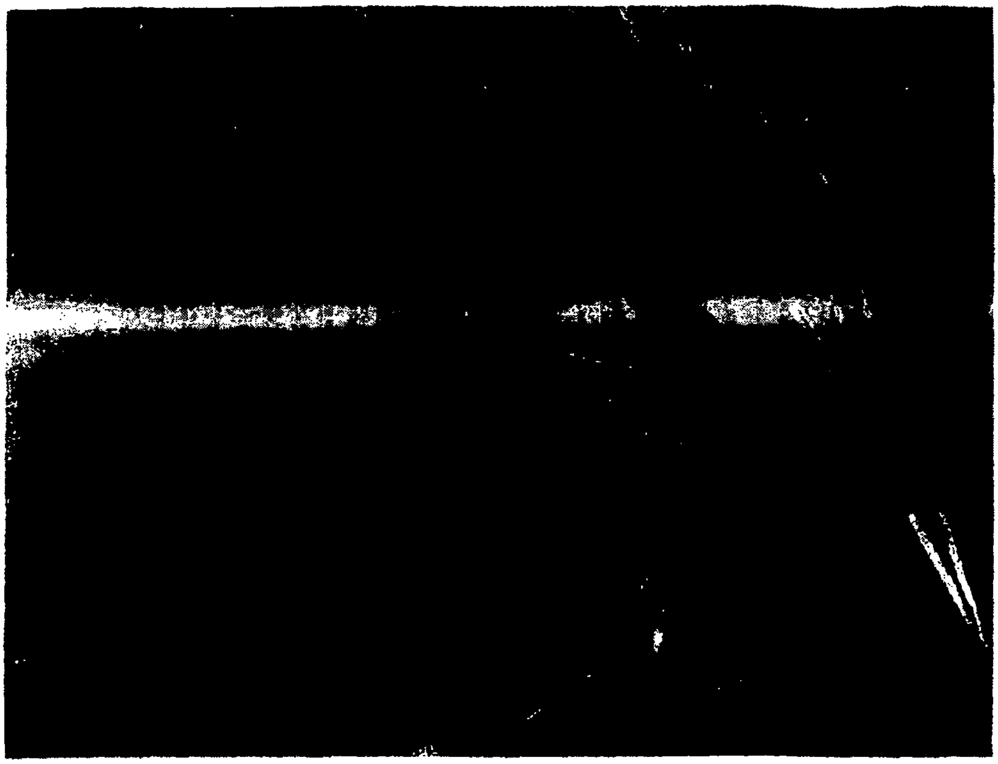

Photo 14; before drop no. 1.2 (point of impact)

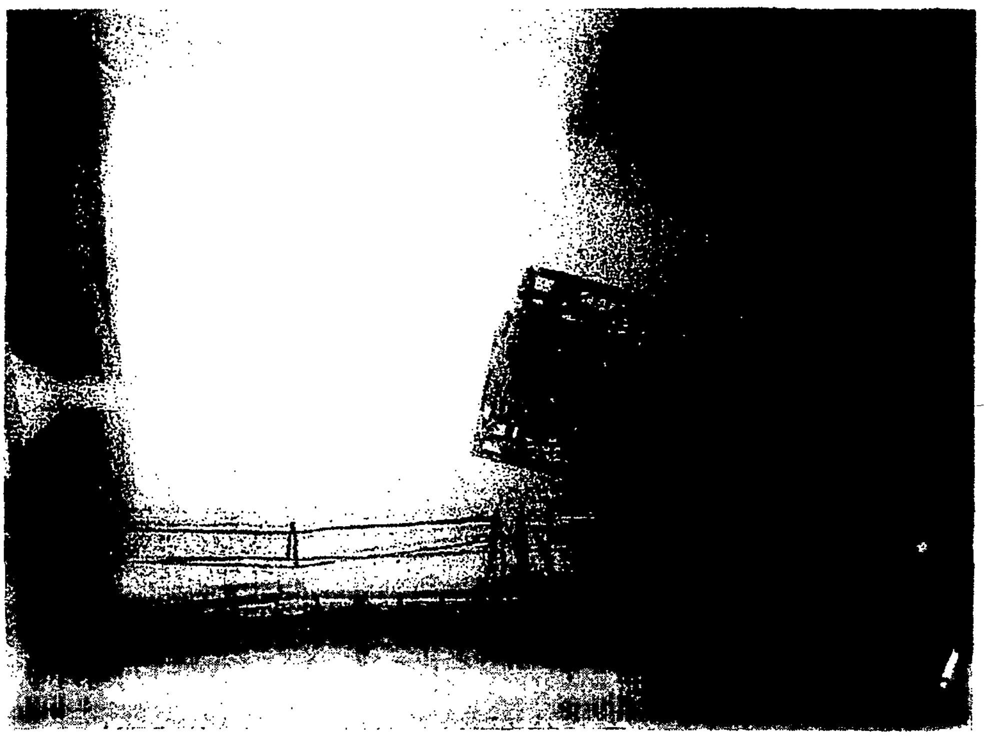

Photo 15; before drop no. 1.2 (1.02 m onto bar)

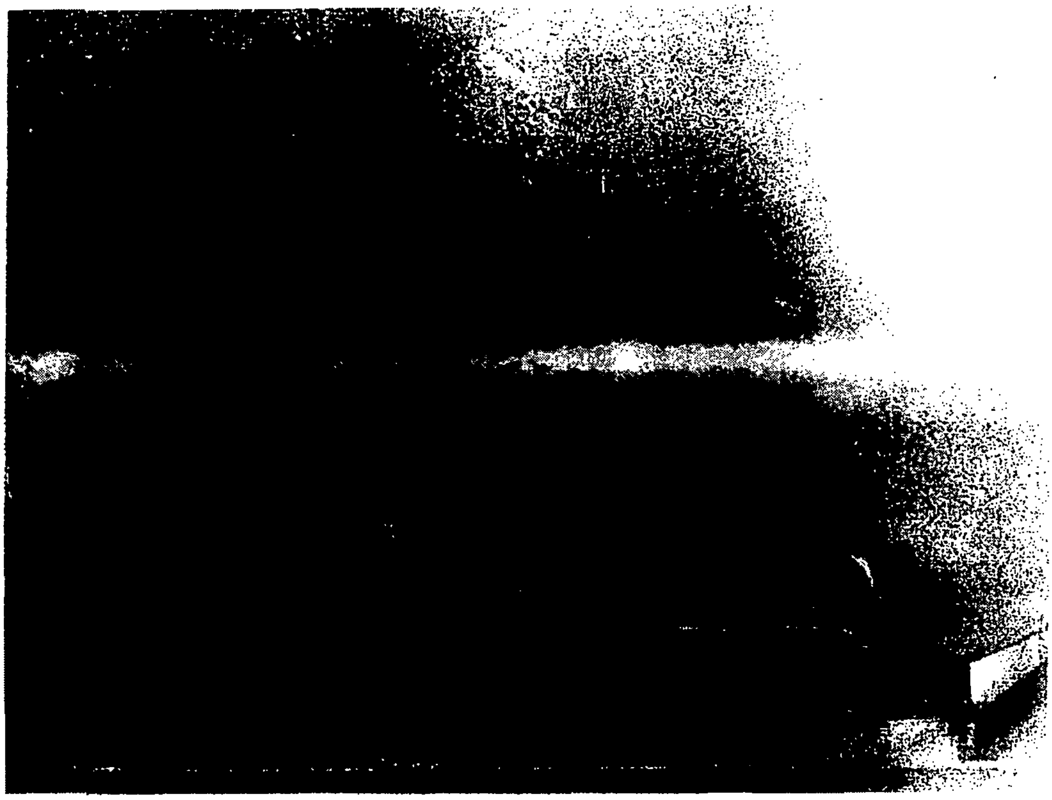

Photo 16; after drop no. 1.2 (impact of bar)

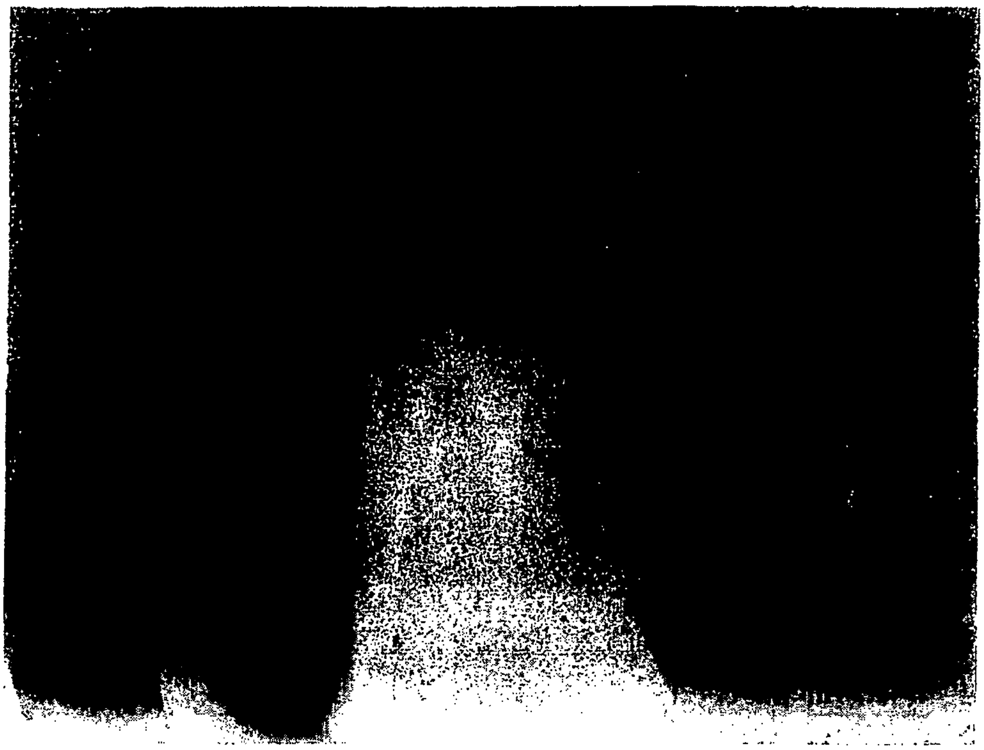

Photo 17; after drop no. 1.2 (impact of bar)

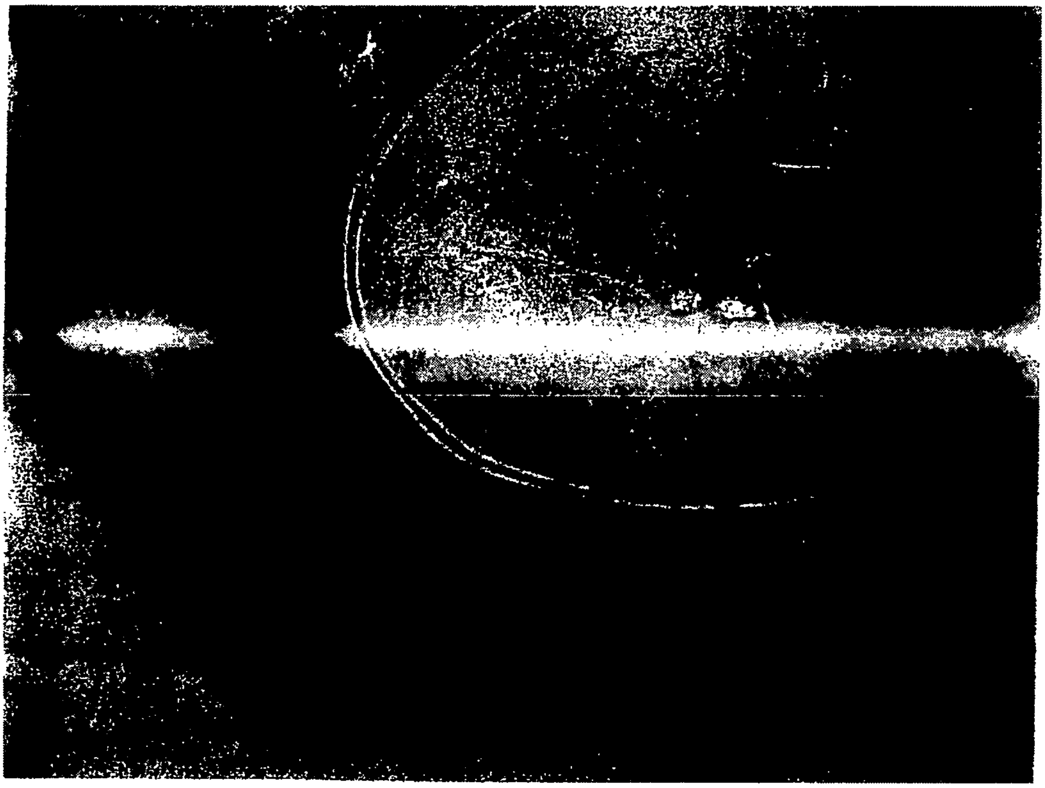

Photo 18; after drop no. 1.2 (impact of bar)

Photo 19; after drop no. 1.2 (shearing of 2 struts)

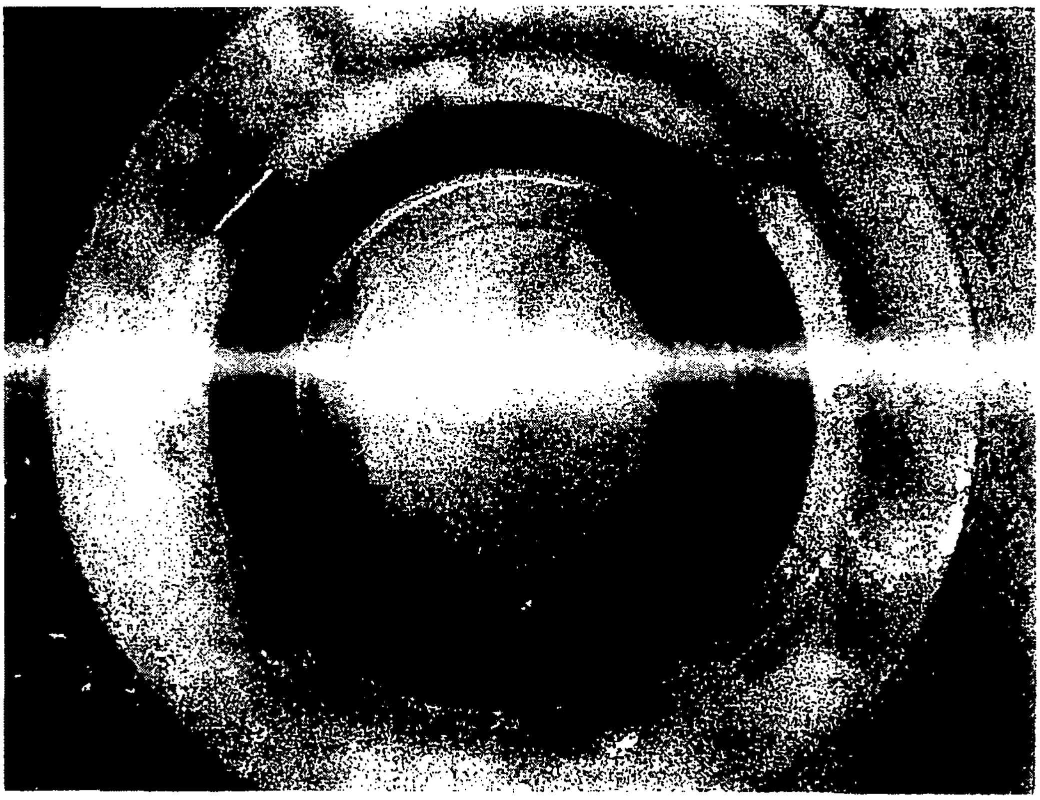

Photo 20; after drop no. 1.2 (inside cover)

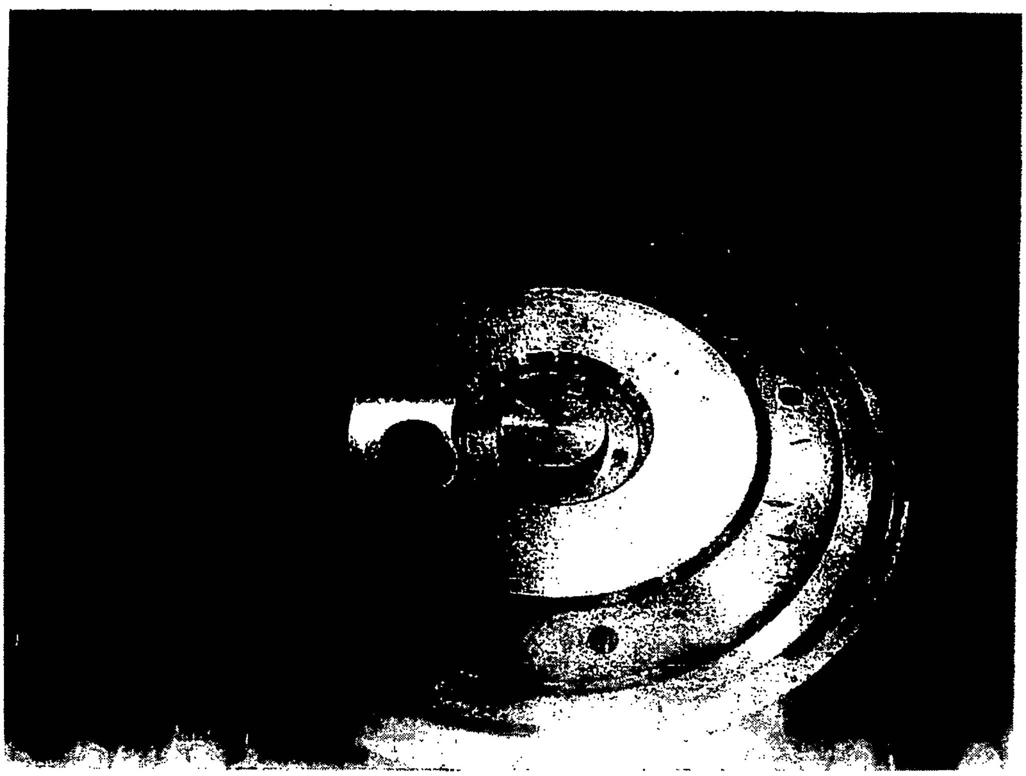

Photo 21; after drop no. 1.2

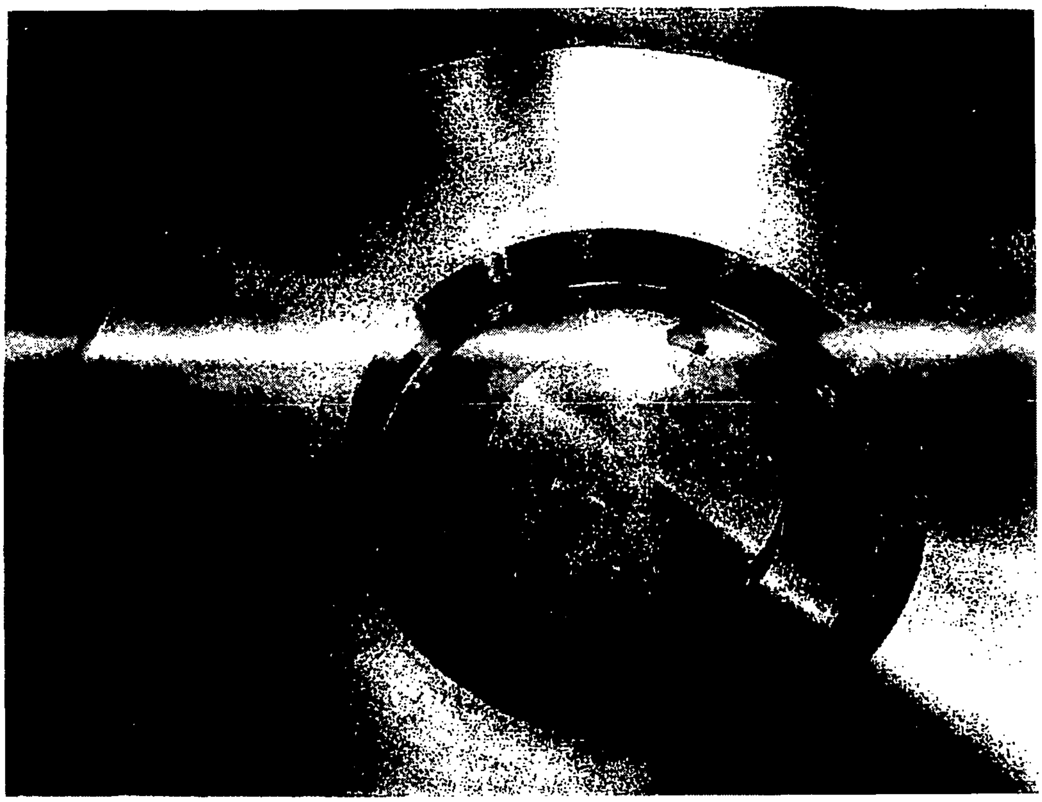

Photo 22; after drop no. 1.2

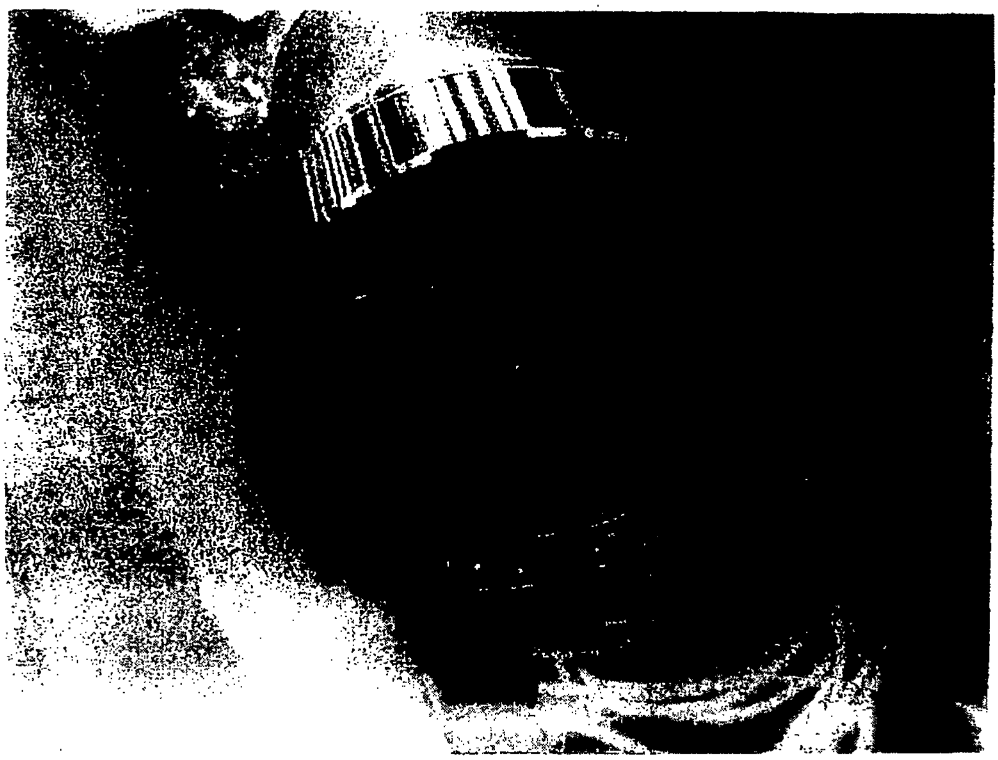

Photo 23; after drop no. 1.2

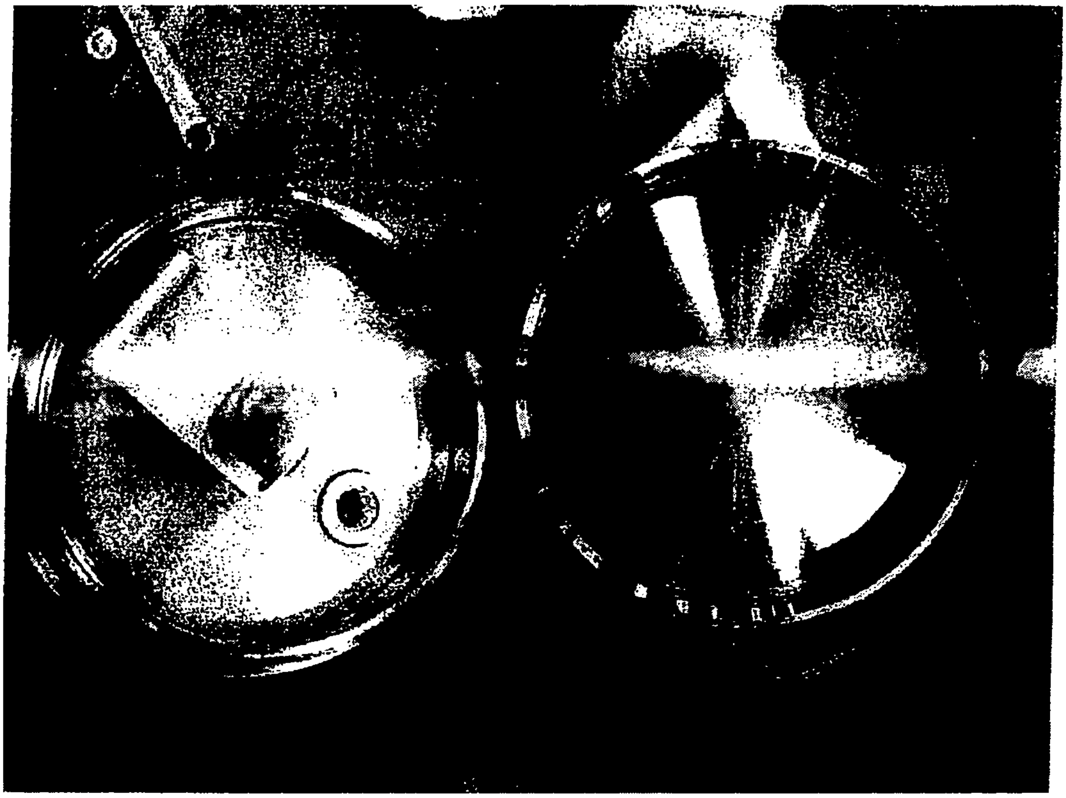

Photo 24; after drop no. 1.2 (imprint of handle on lid)

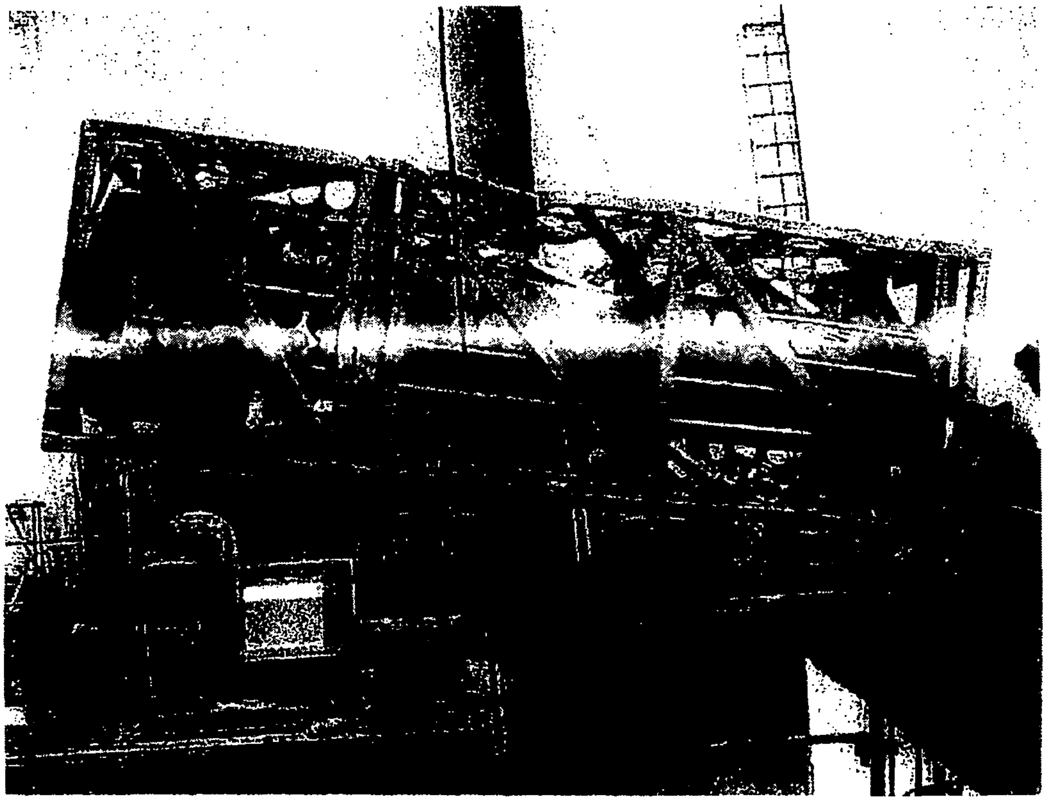

Photo 25: preparation of drop no. 2

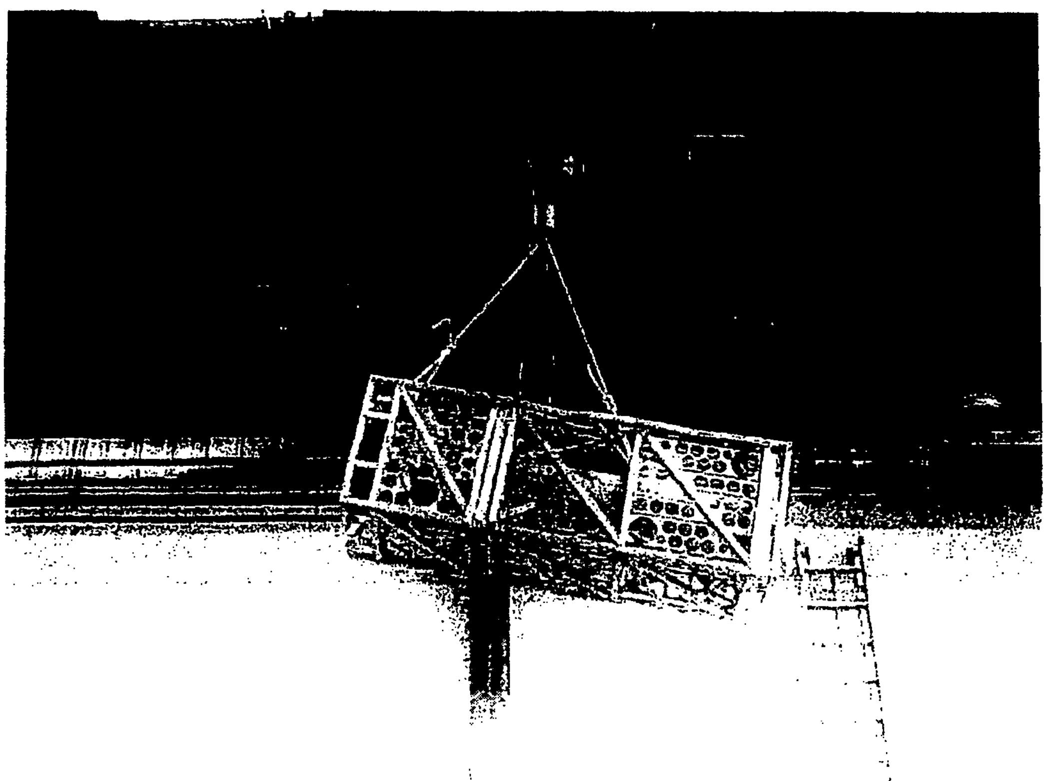

Photo 26; before drop no. 2 (9.02 m slap-down)

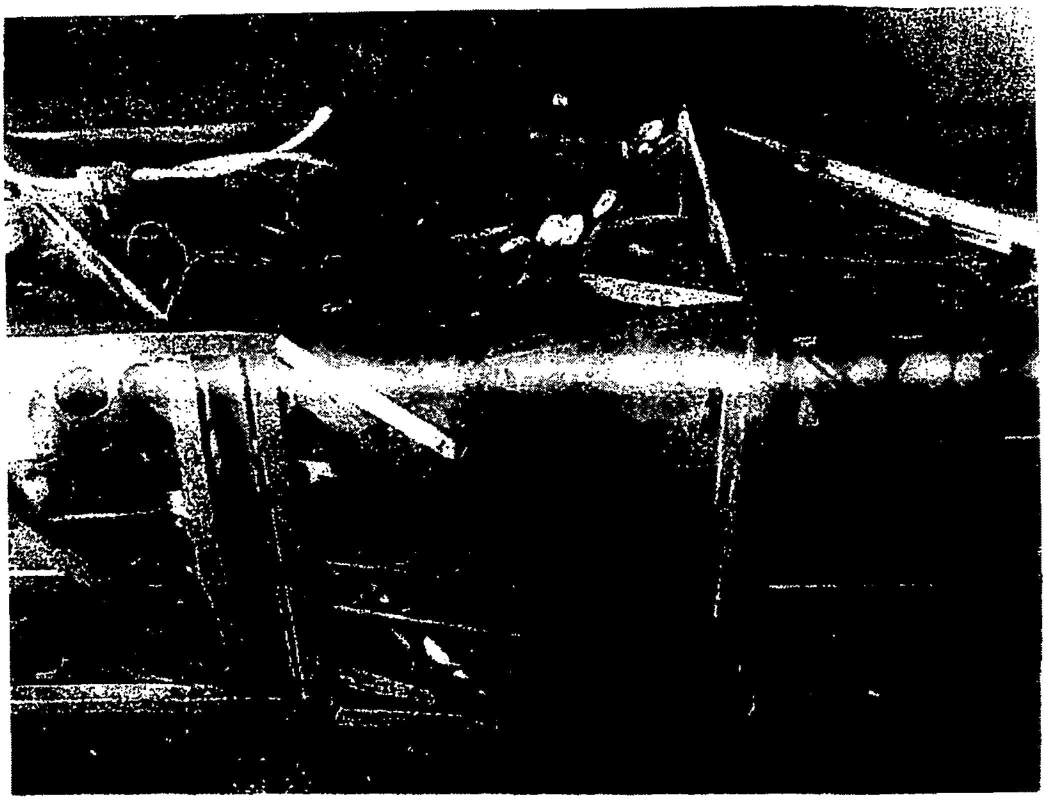

Photo 27; after drop no. 2

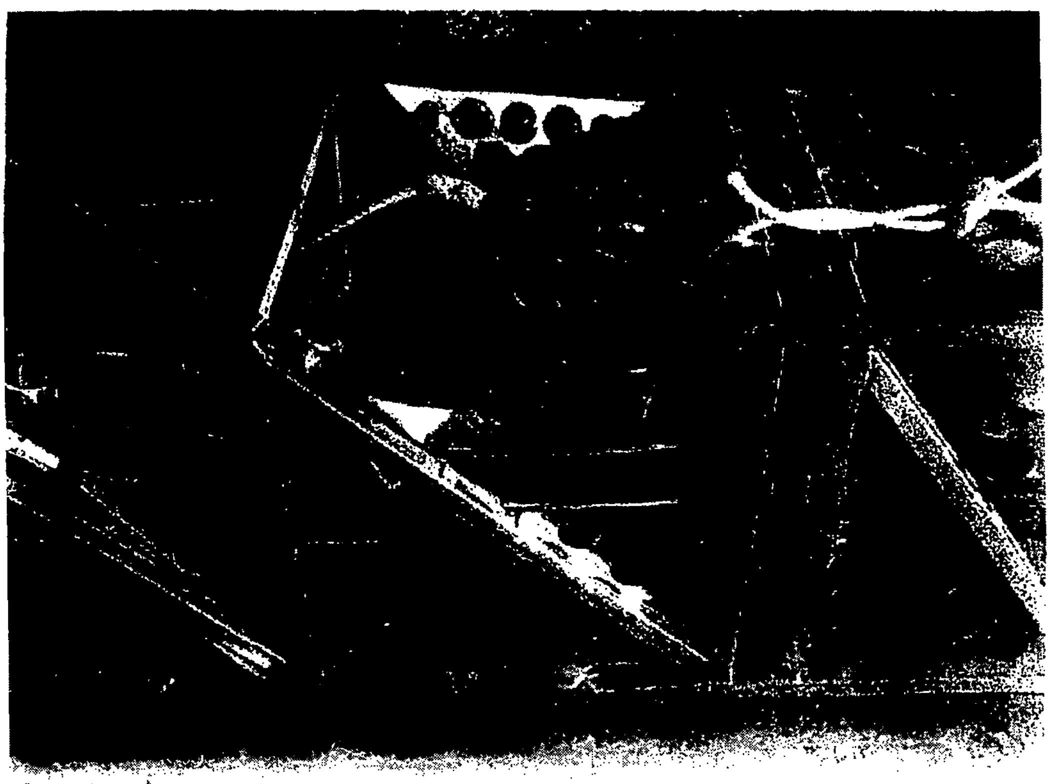

Photo 28; after drop no. 2

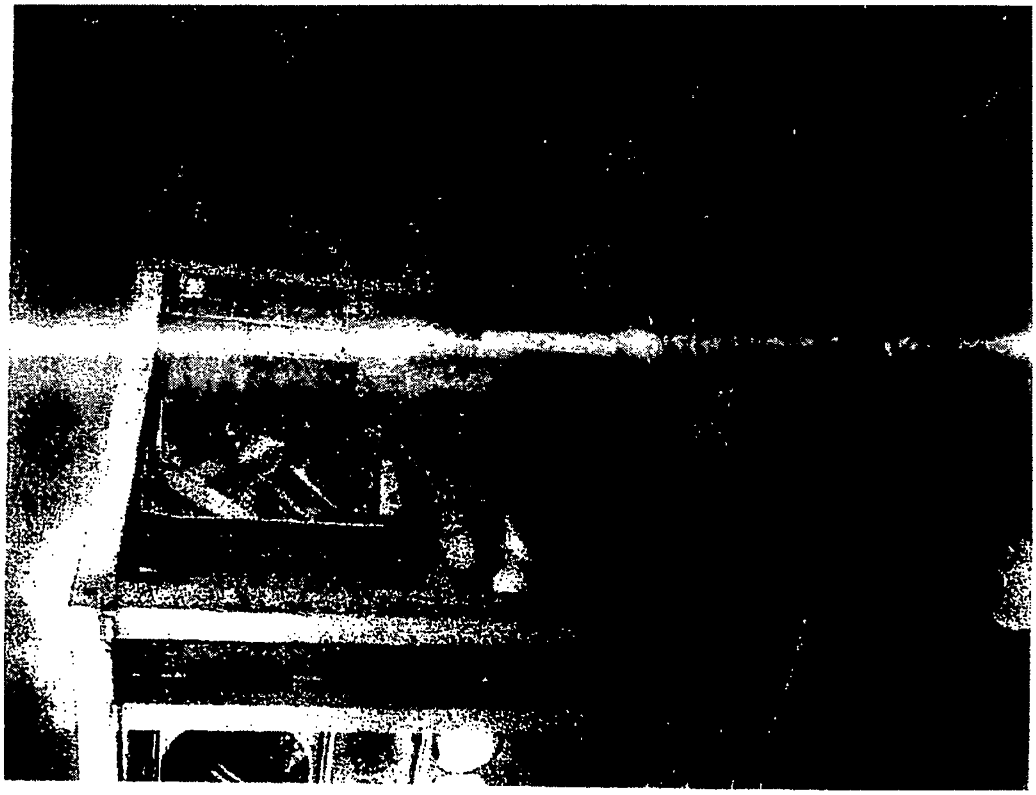

Photo 29; after drop no. 2 (body no longer centred in cage)

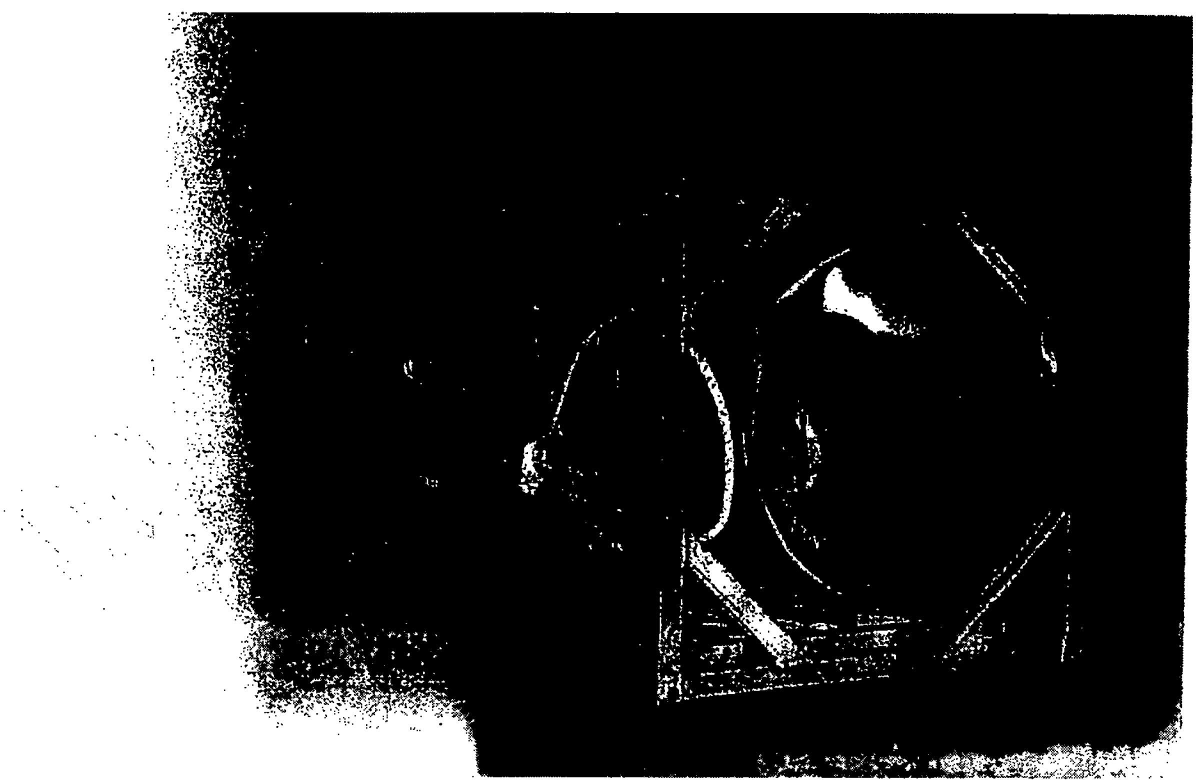

Photo 30; after drop no. 2 (body no longer centred in cage)

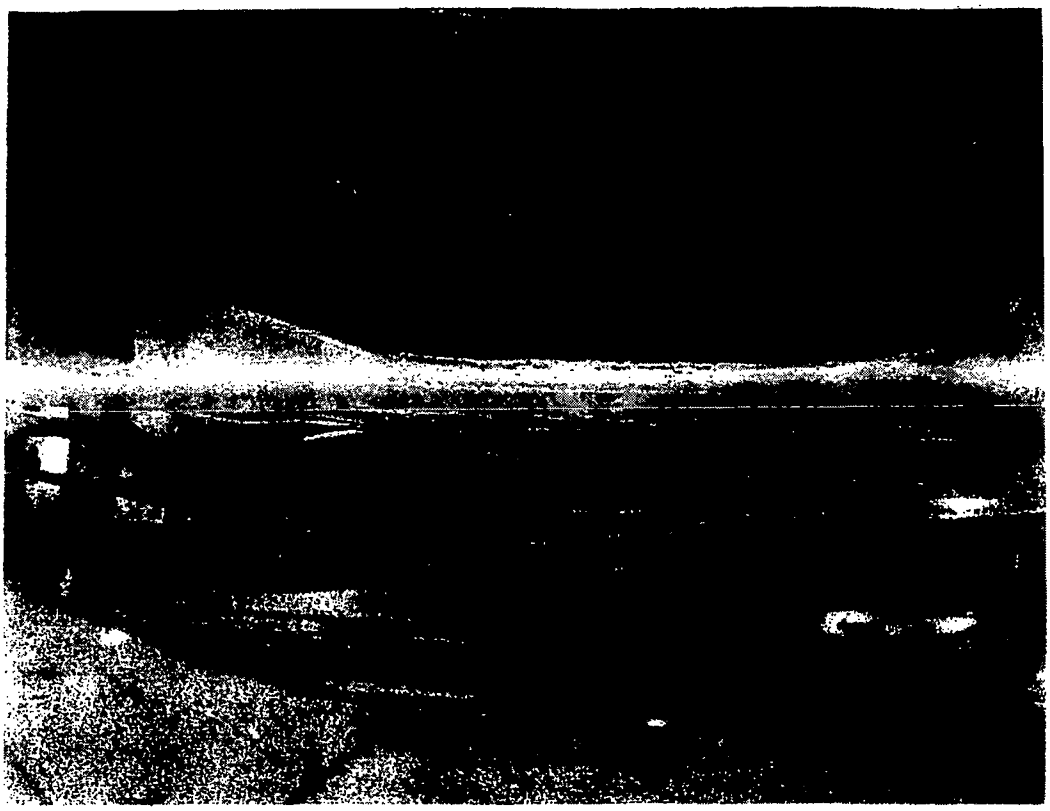

Photo 31; after drop no. 2 (cover crushed profiles)

Photo 32; after drop no. 2 (cover crushed profiles)

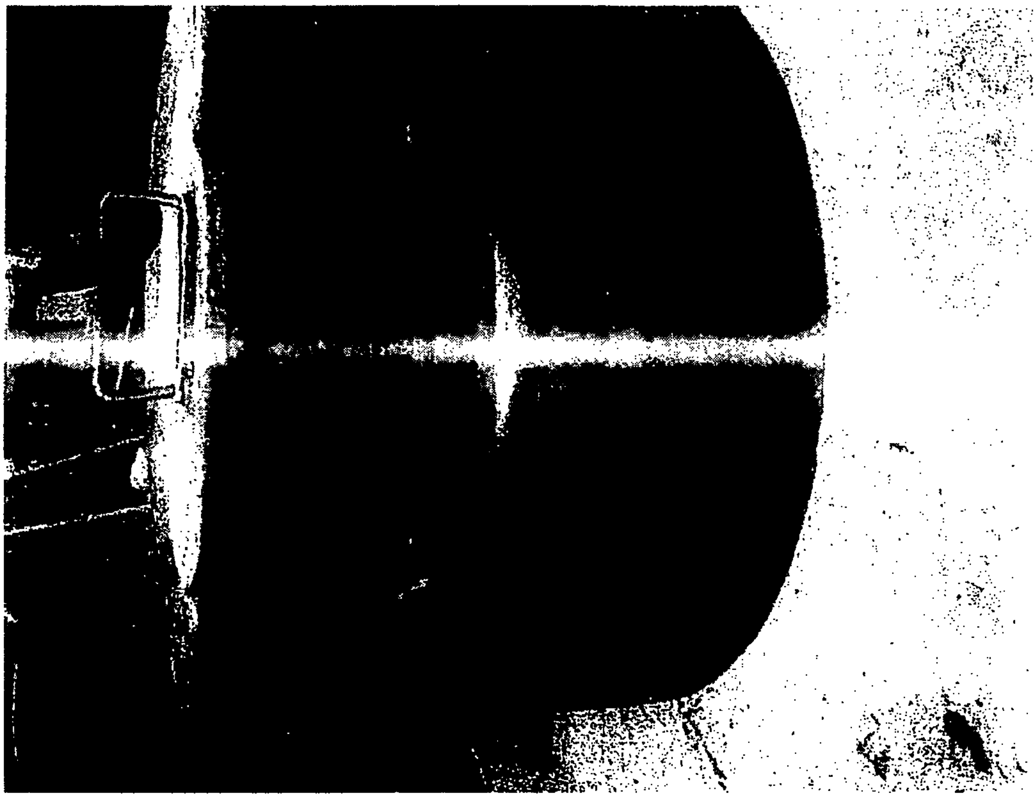

Photo 33; after drop no. 2 (marks of cage on cover)

Photo 34; after drop no. 2 (accelerometer A0, A1 and A3 supports)

Photo 35; after drop no. 2 (accelerometer A support)

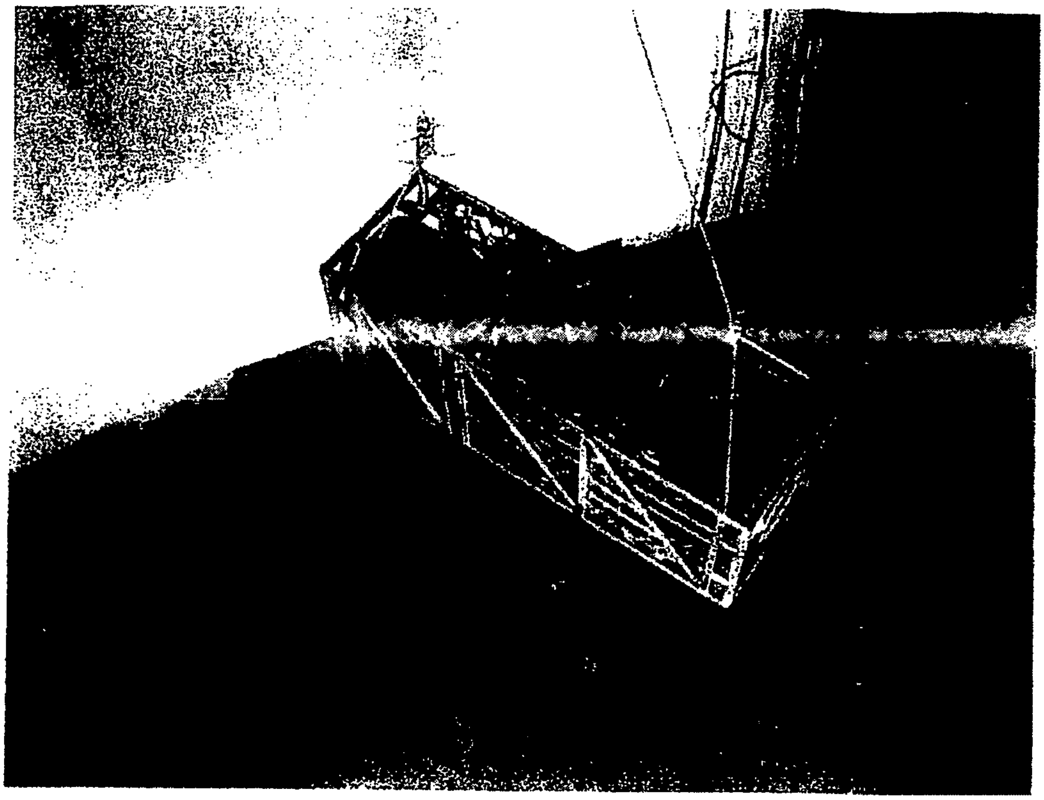

Photo 36; before drop no. 3.1 (1.22 m flat)

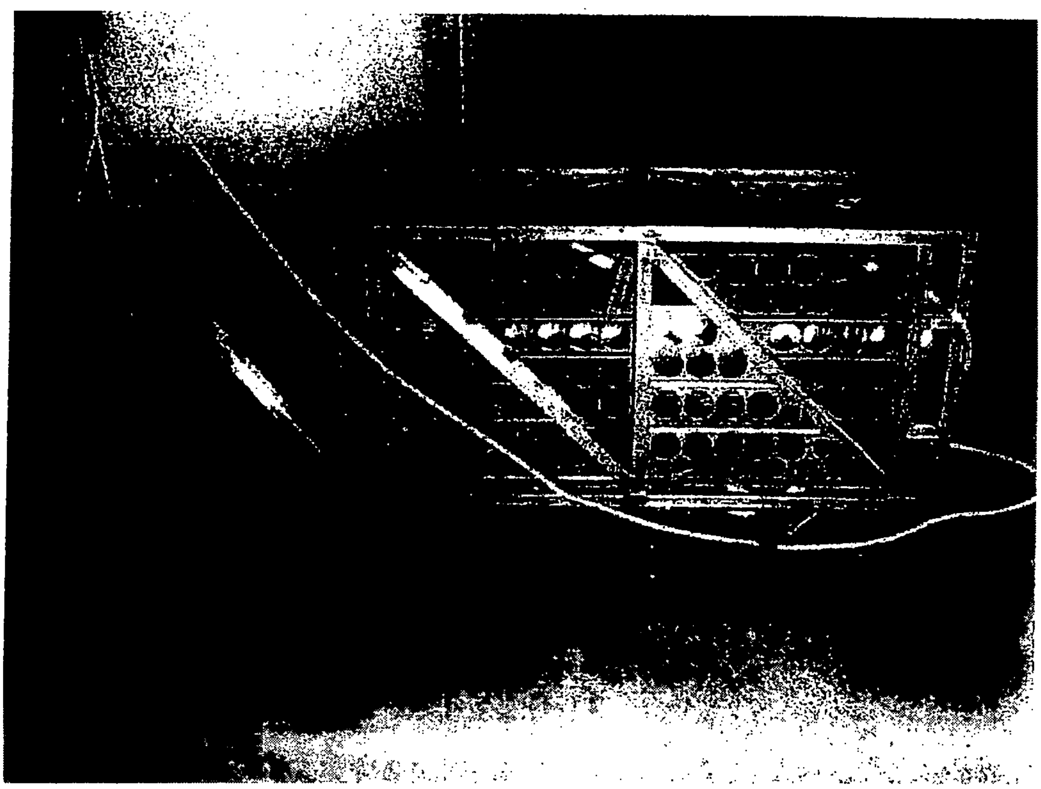

Photo 37; after drop no. 3.1

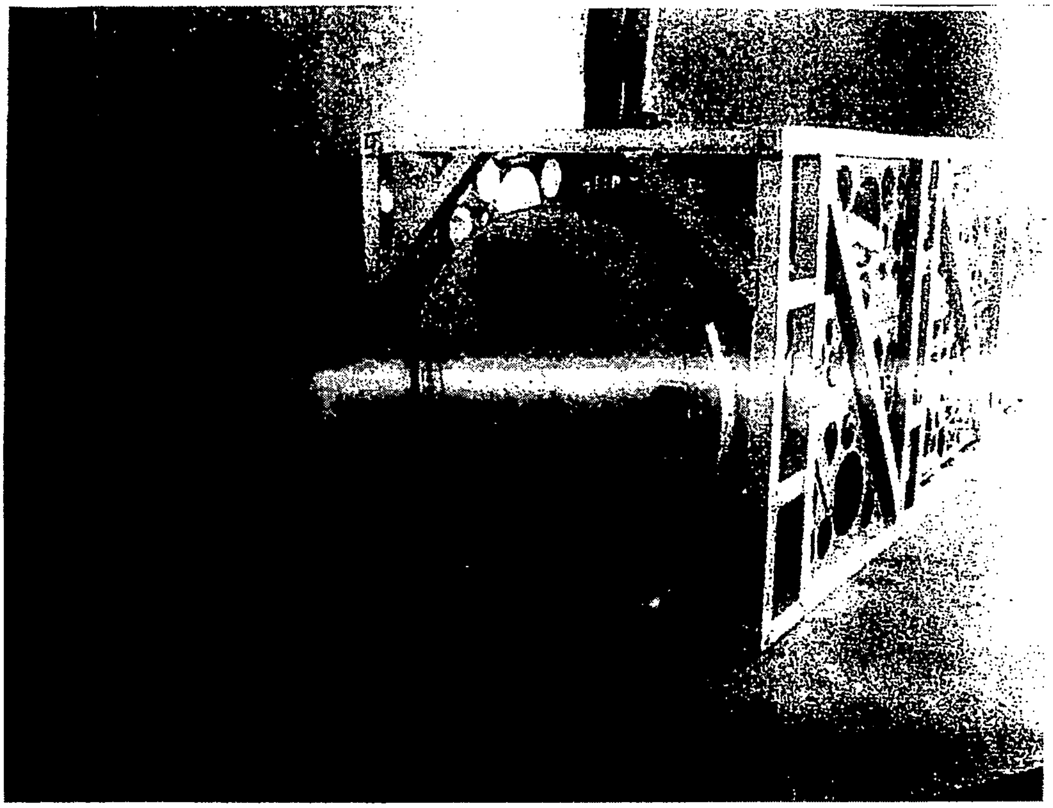

Photo 38; after drop no. 3.1 (body de-centred towards base)

Photo 39; after drop no. 3.1 (7 bolts shorn)

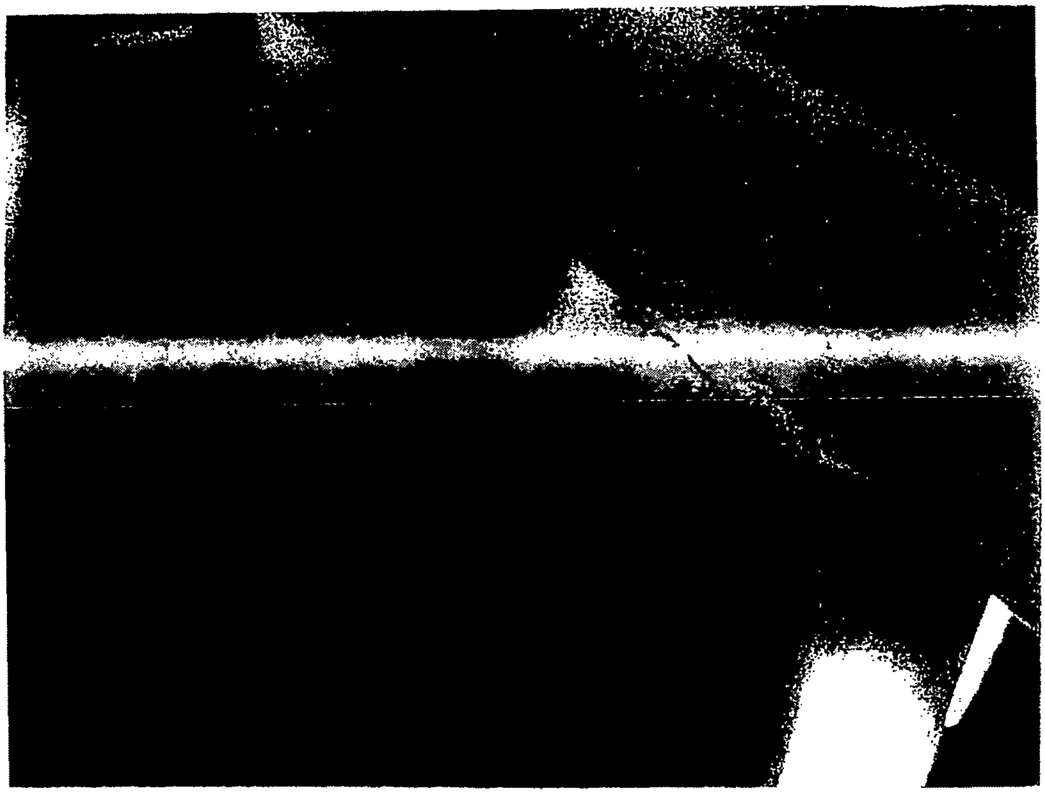

Photo 40; after drop no. 3.1 (fissures in 2 welds)

Photo 41; after drop no. 3.1 (fissures in 2 welds)

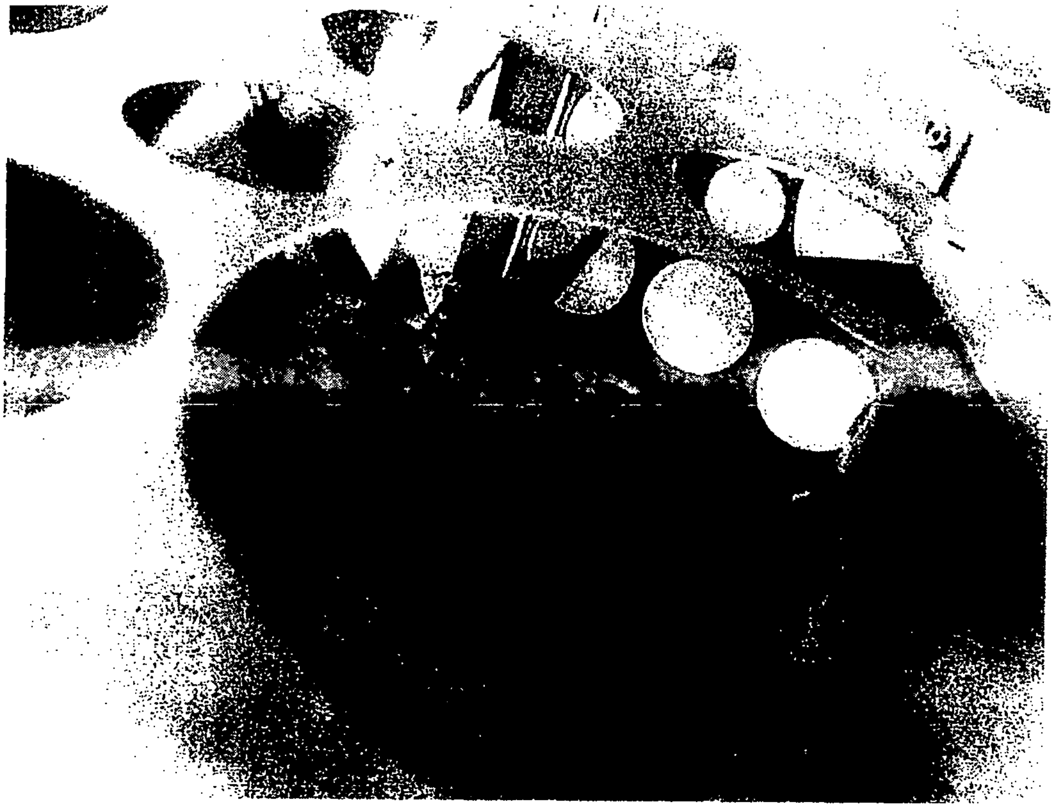

Photo 42; after drop no. 3.1 (1 latch open)

Photo 43; after drop no. 3.1 (1 latch open)

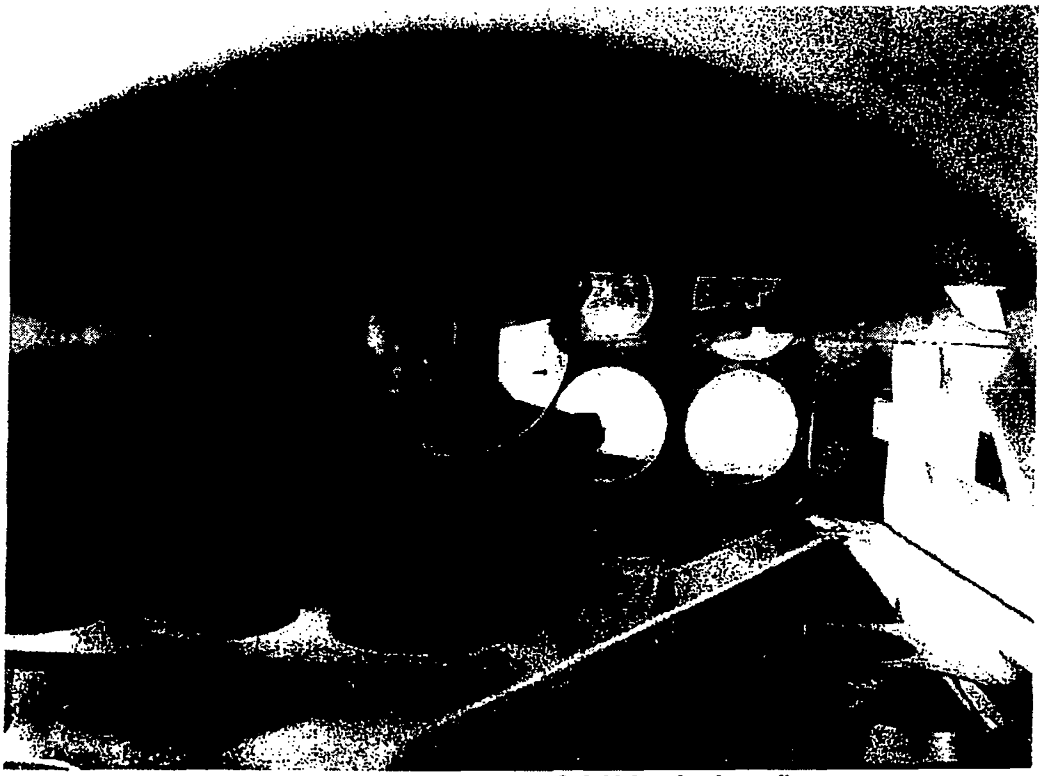

Photo 44; after drop no. 3.1 (1 latch closed)

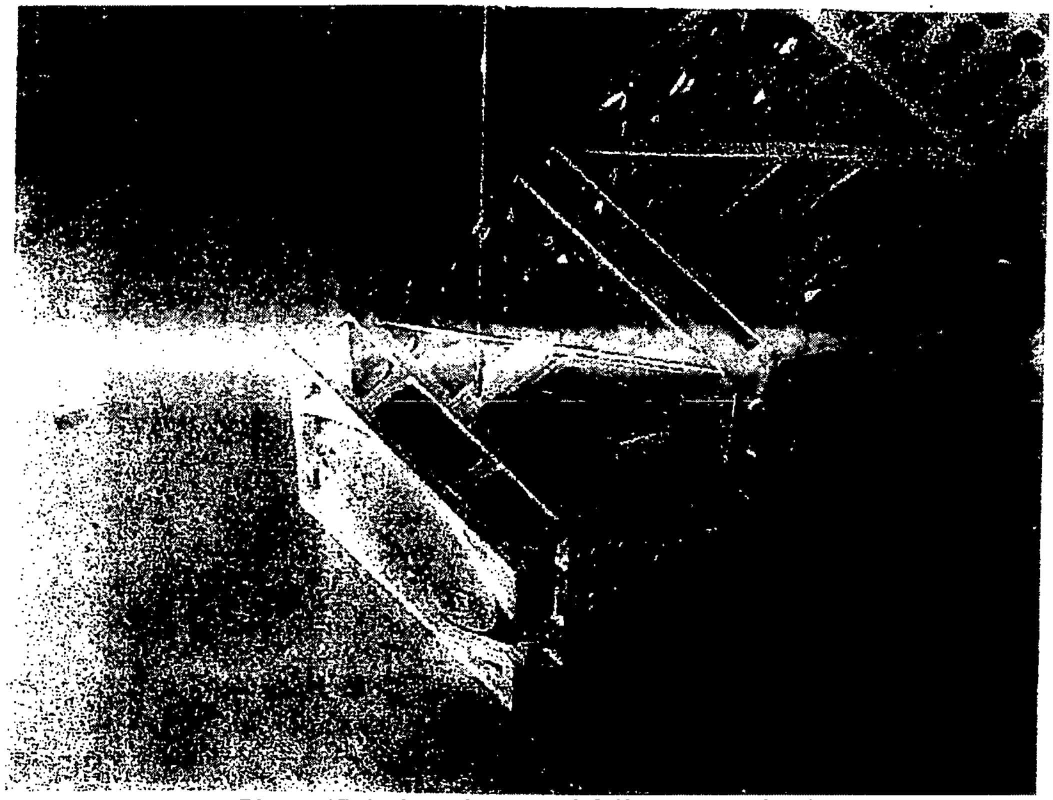

Photo 45; before drop no. 3.2 (9-metres, plate)

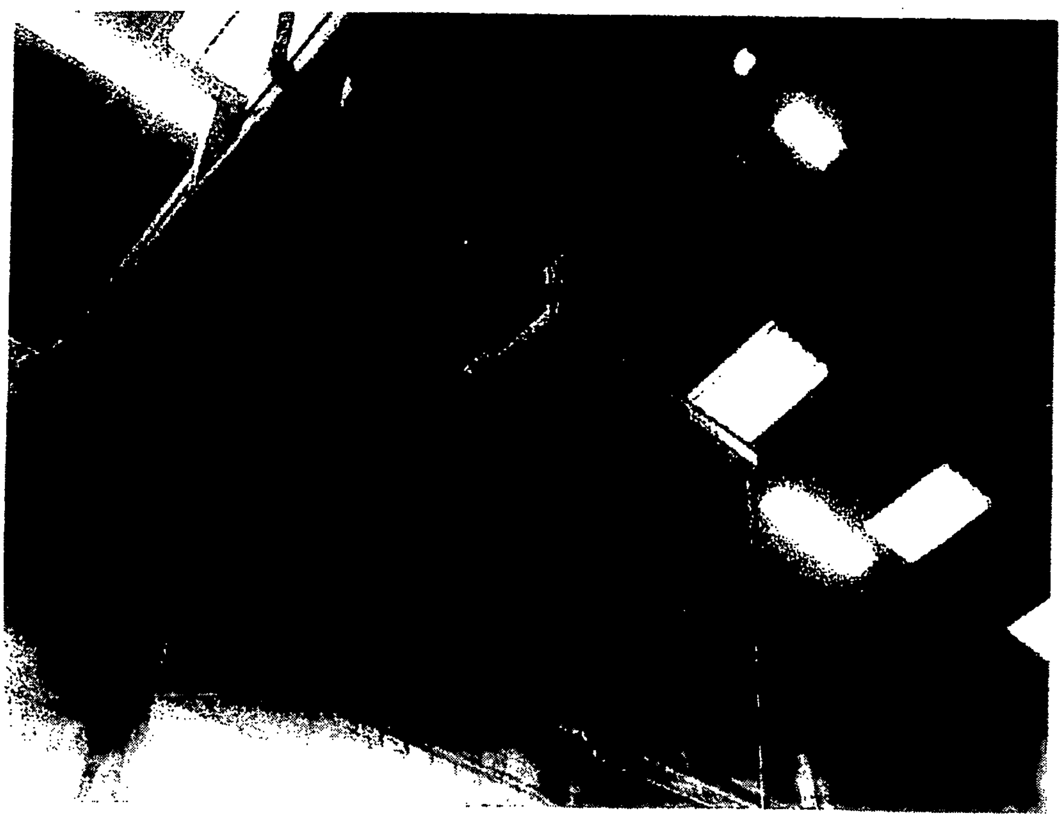

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Photo 46; before drop no. 3.2 (9-metres, plate)

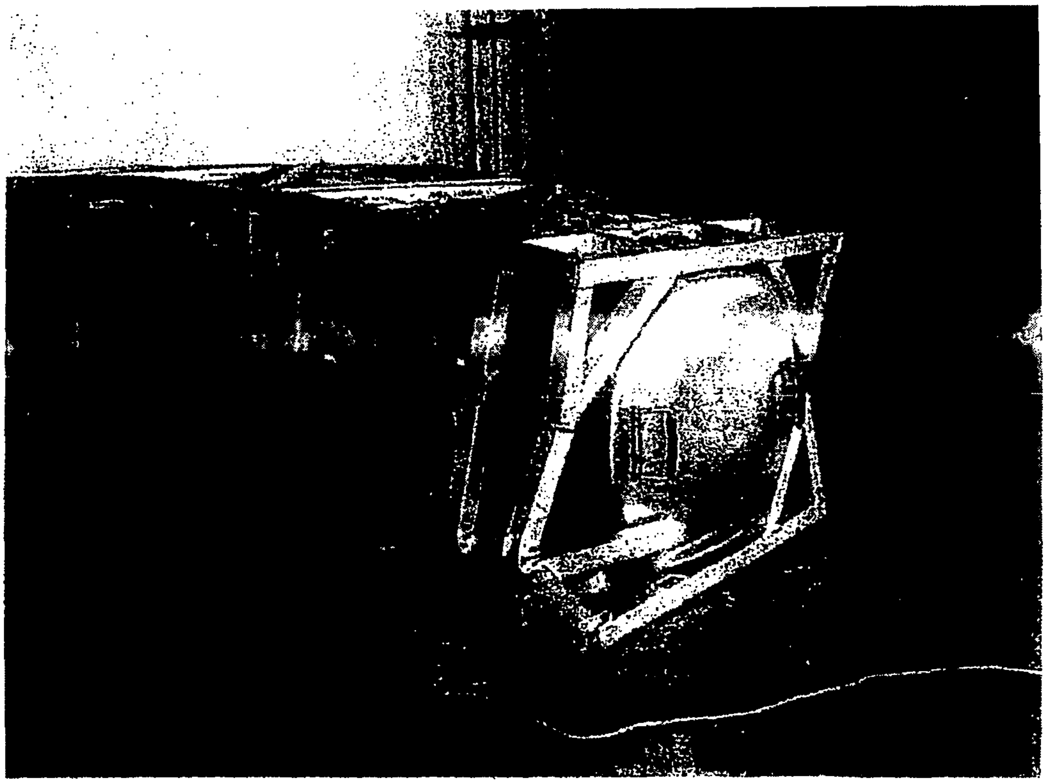


Photo 47; after drop no. 3.2 (frame crushed at top end)

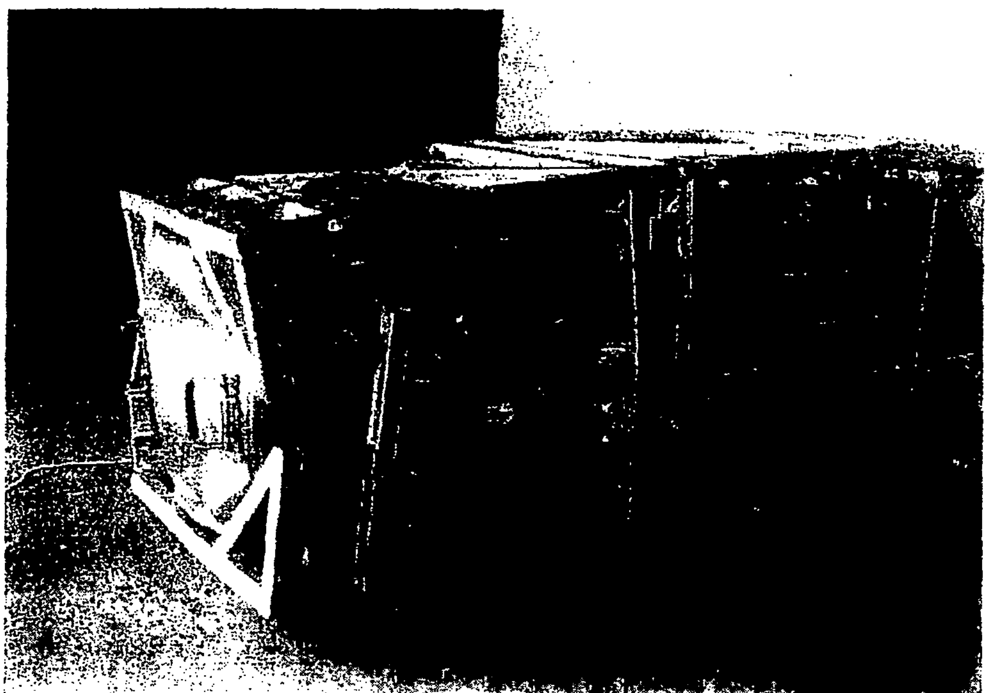


Photo 48; after drop no. 3.2 (frame crushed at top end)

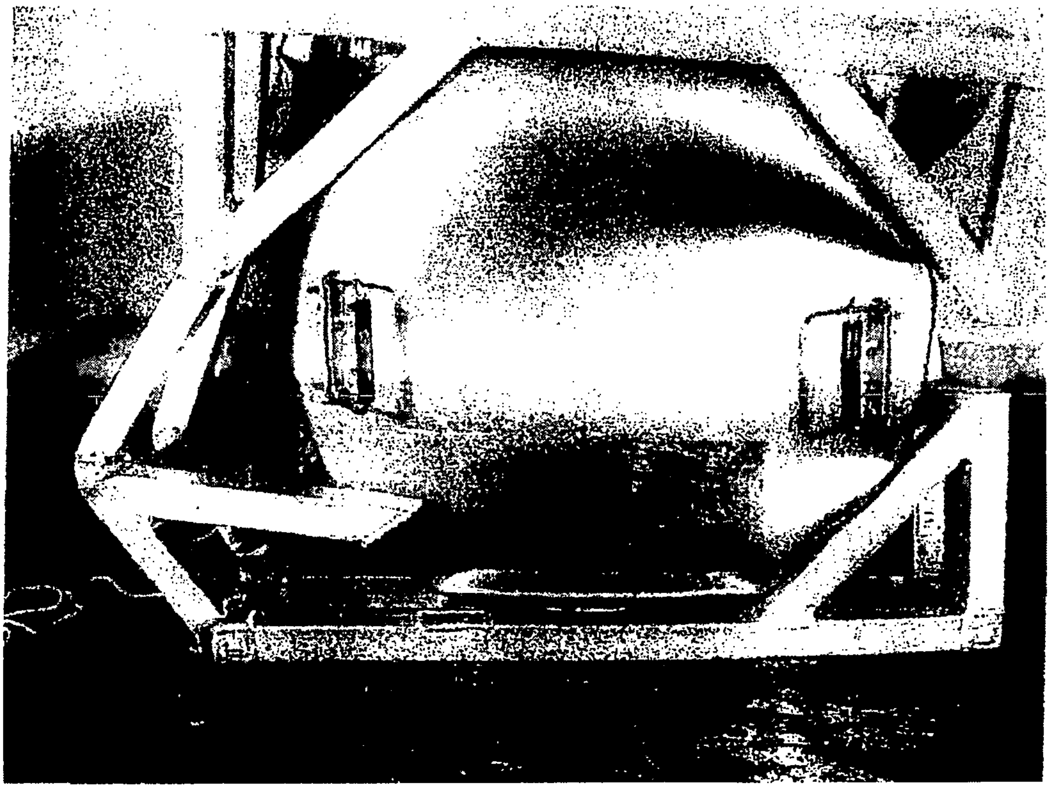


Photo 49; after drop no. 3.2 (frame crushed at top end)

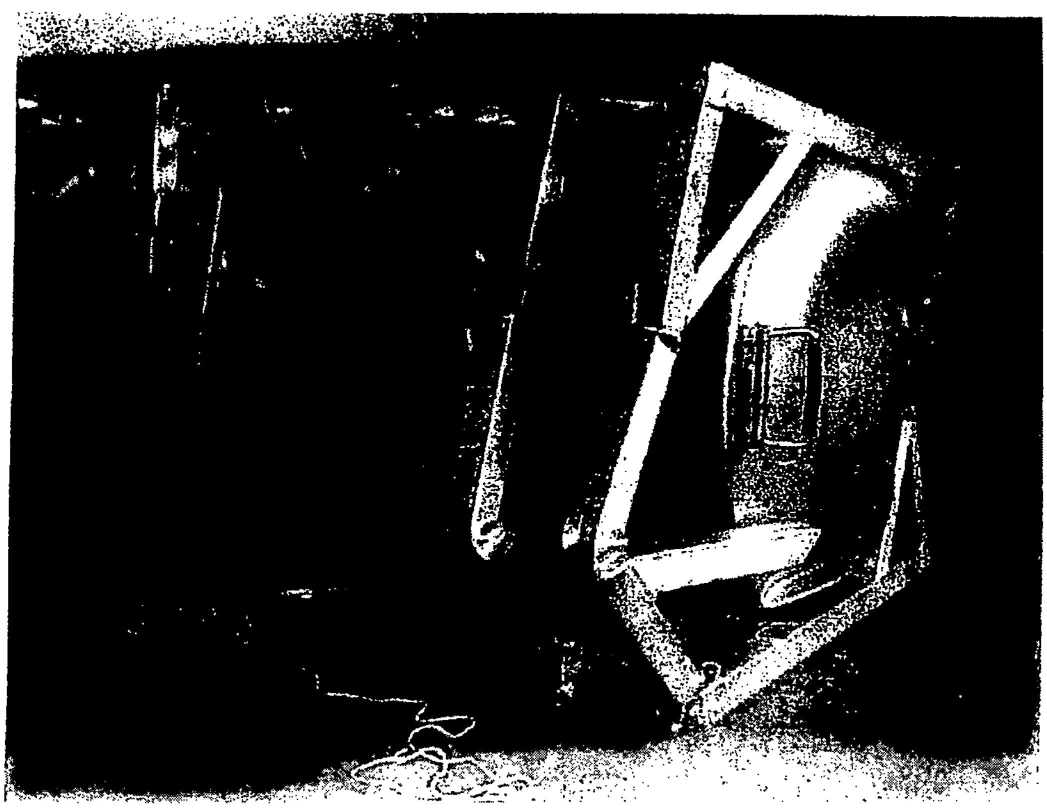


Photo 50; after drop no. 3.2 (frame crushed at top end)

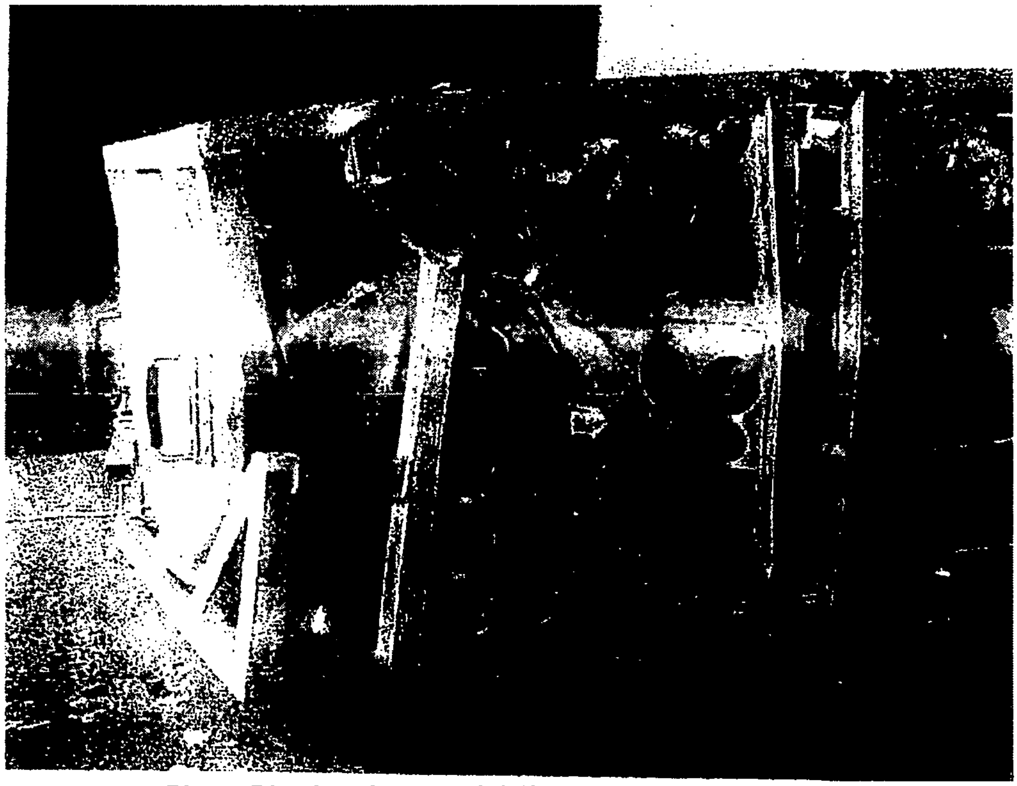


Photo 51; after drop no. 3.2 (frame crushed at top end)

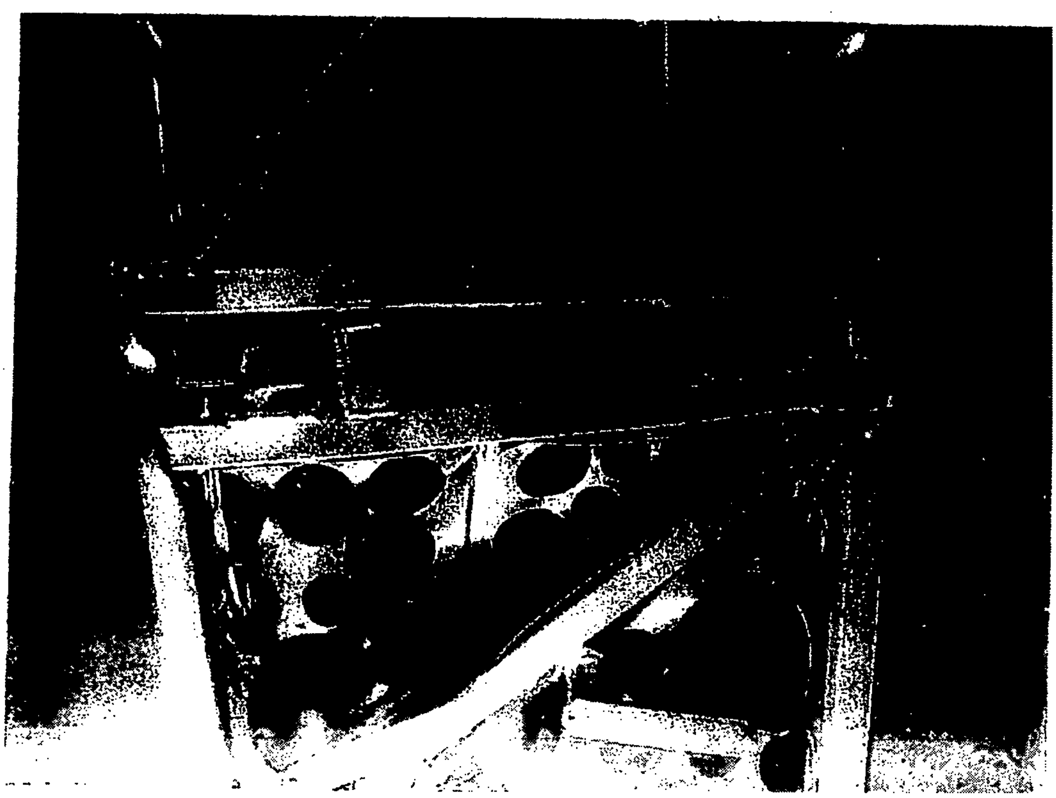


Photo 52; after drop no. 3.2 (shearing of strut)

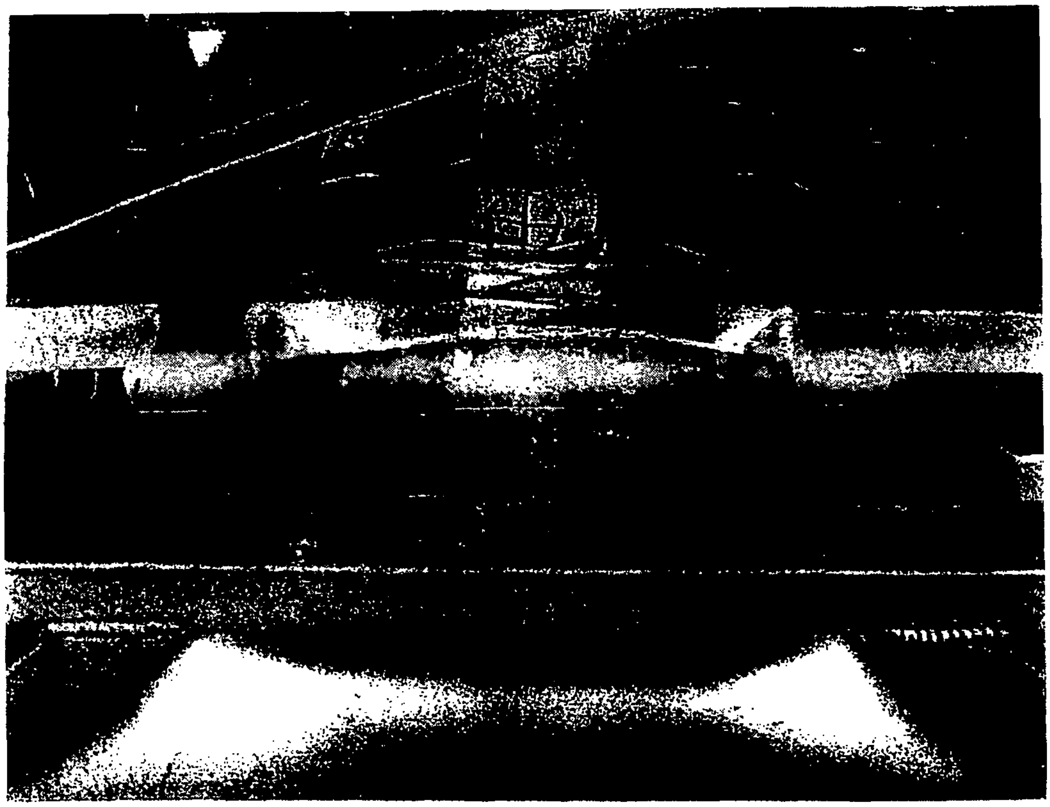


Photo 53; after drop no. 3.2 (point of impact)

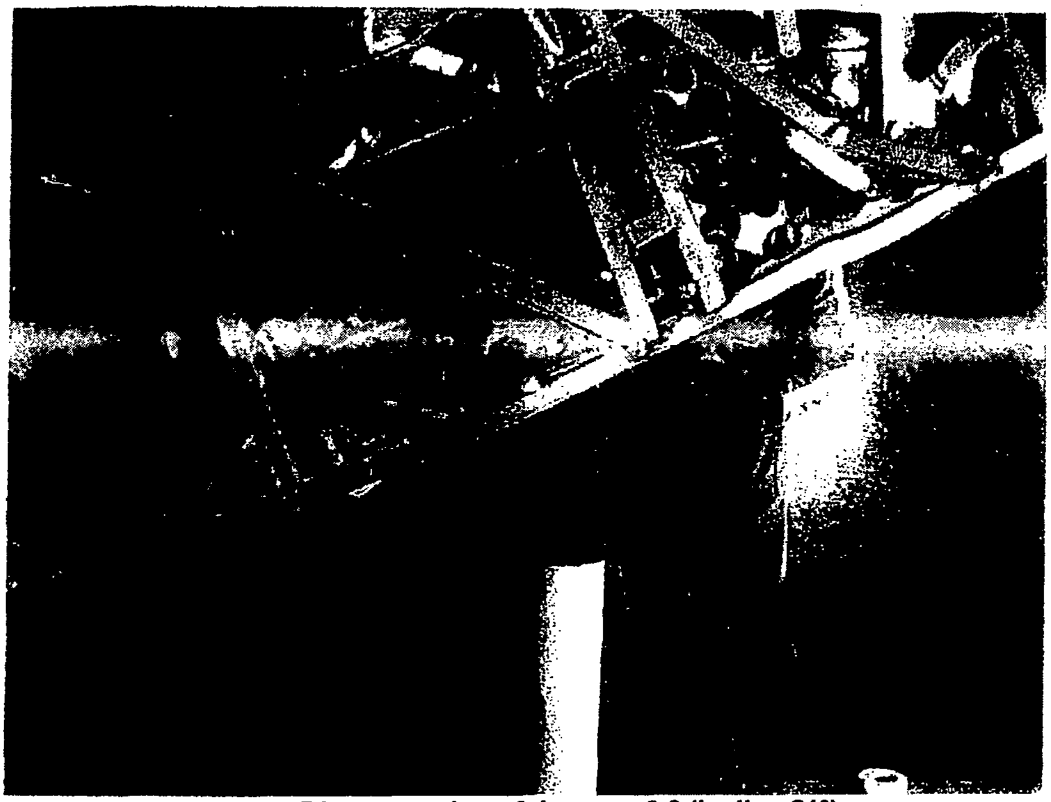


Photo 54; preparation of drop no. 3.3 (incline 21°)

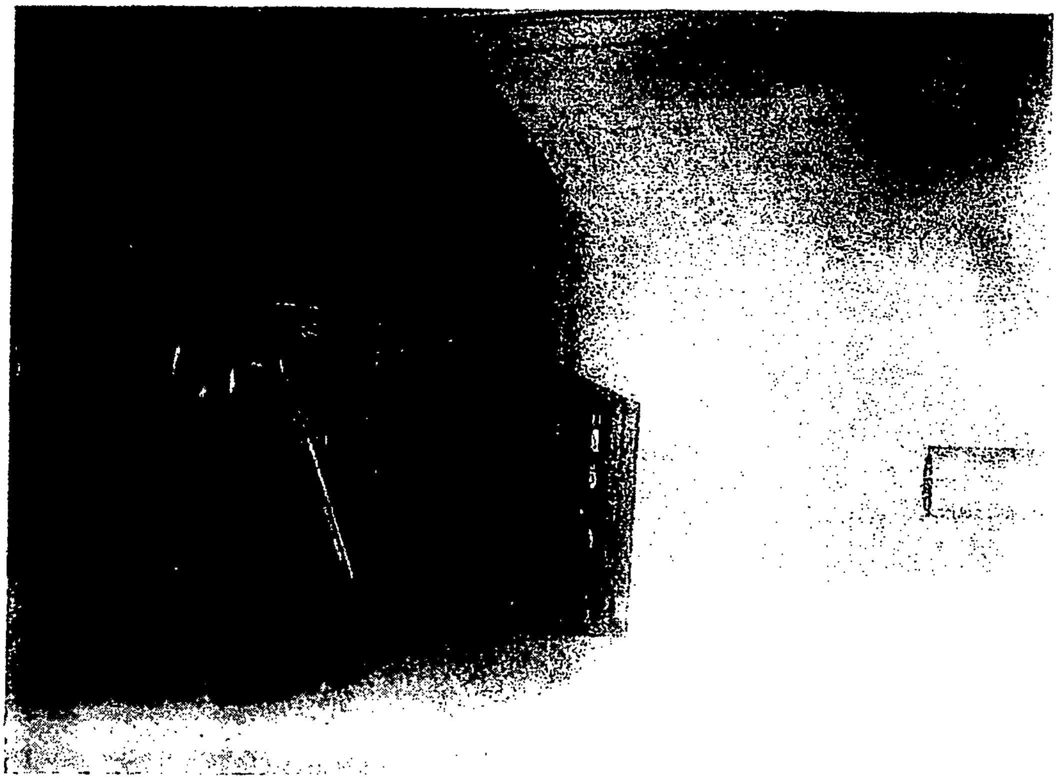


Photo 55; before drop no. 3.3 (1.02 m onto bar, incline 21°)

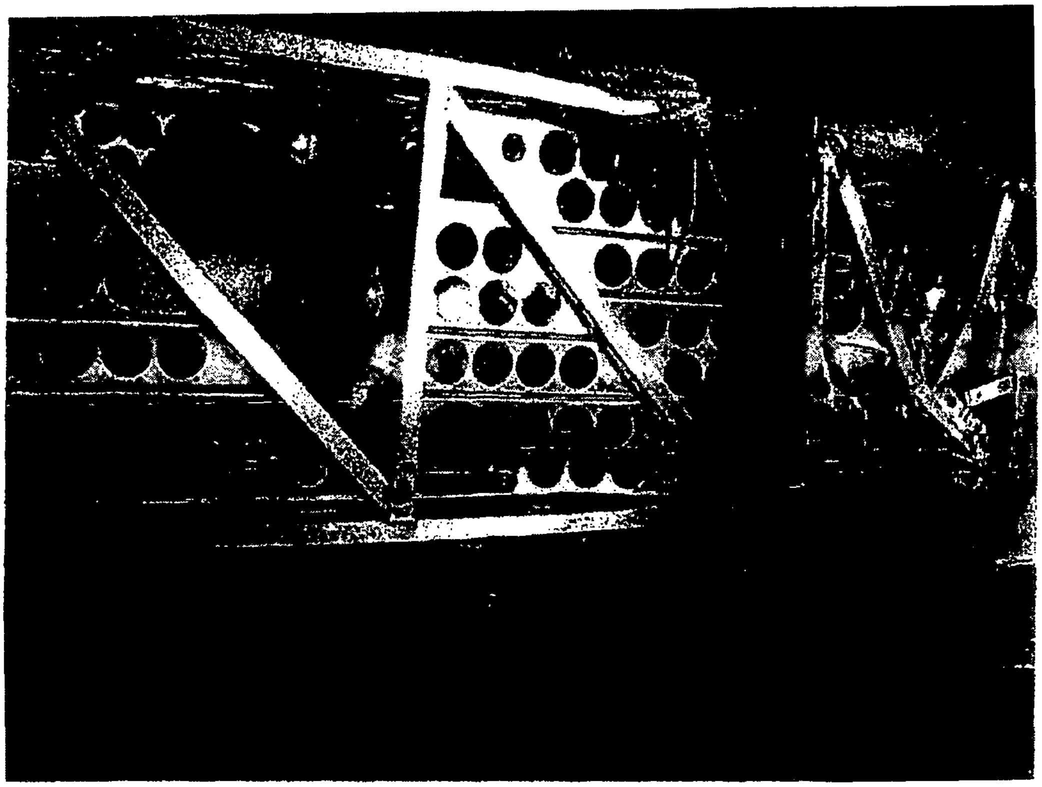


Photo 56; after drop no. 3.3

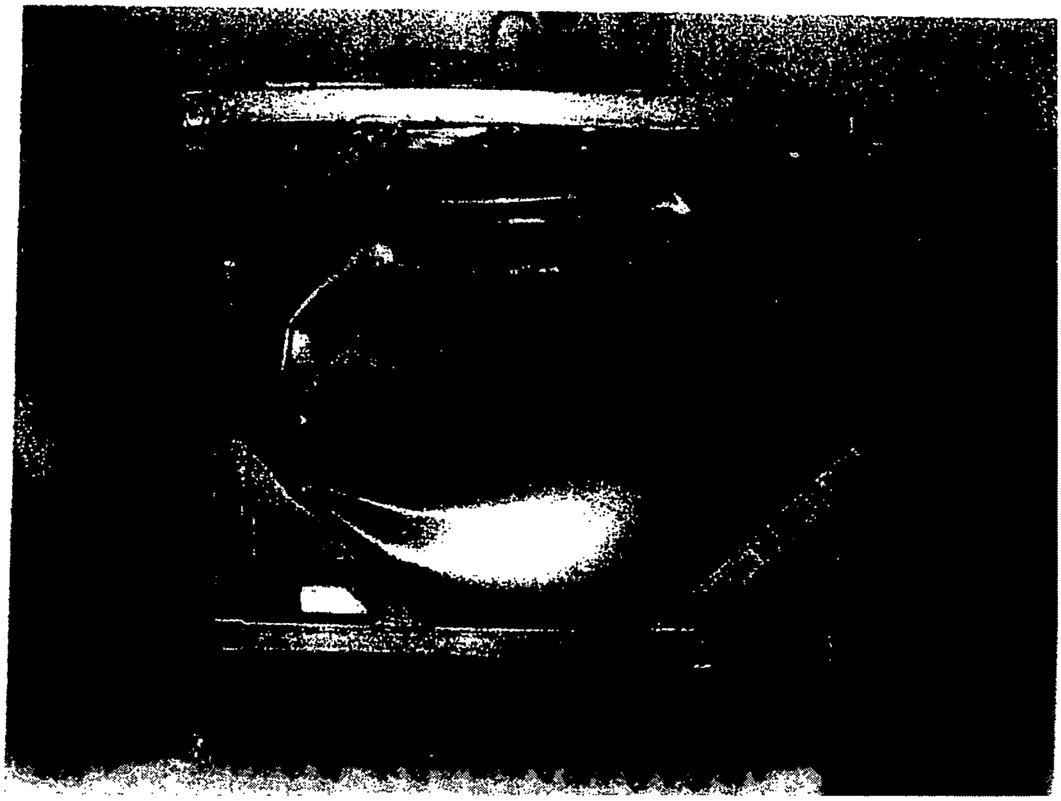


Photo 57; after drop no. 3.3

Photo 58; after drop no. 3.3 (zone of impact)

Photo 59; after drop no. 3.3 (rotation of cover)

Photo 60; after drop no. 3.3 (rotation of cover)

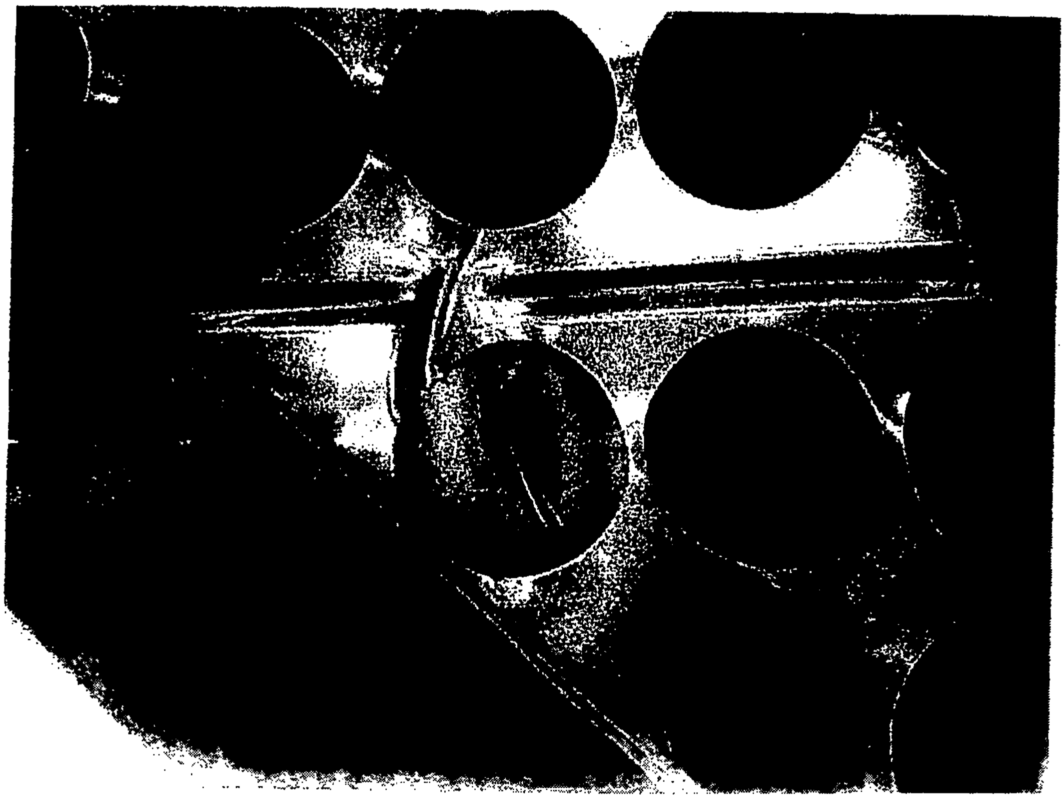


Photo 61; after drop no. 3.3 (imprint of bar)

Photo 62; after drop no. 3.3 (imprint of bar, frame removed)

Photo 63; preparation of drop no. 3.4 (one latch open, cover repositioned)

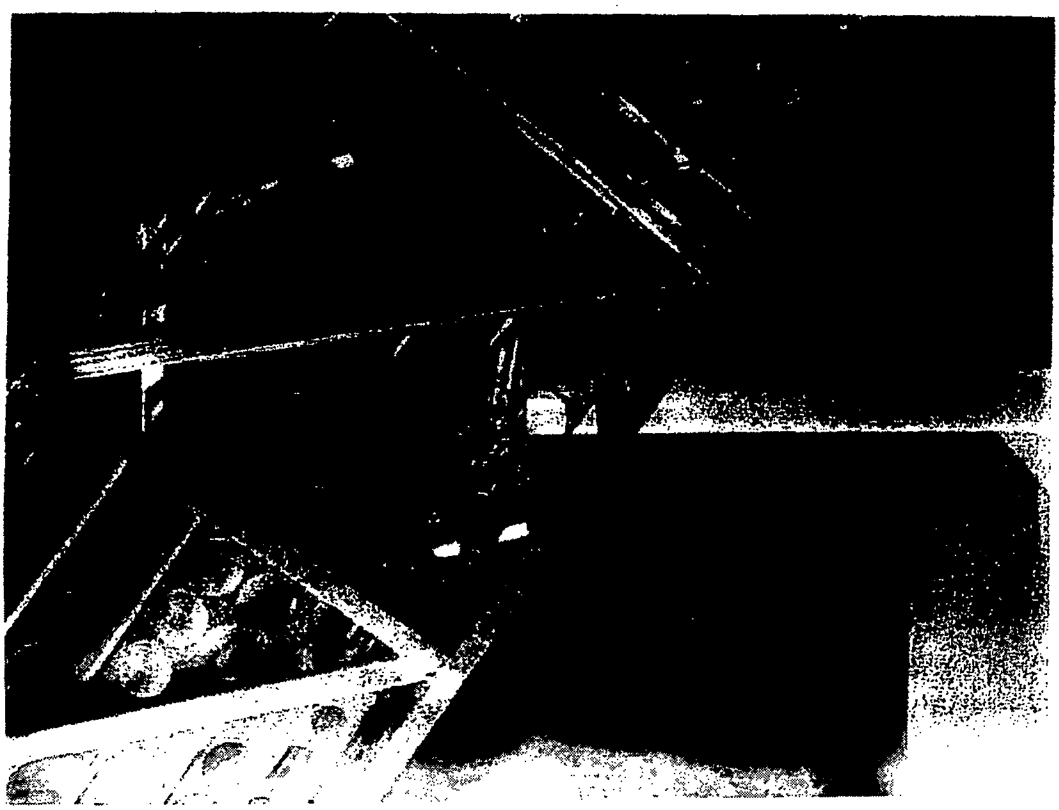


Photo 64; preparation of drop no. 3.4 (incline 35°)

Photo 65; preparation of drop no. 3.4 (incline 35°)

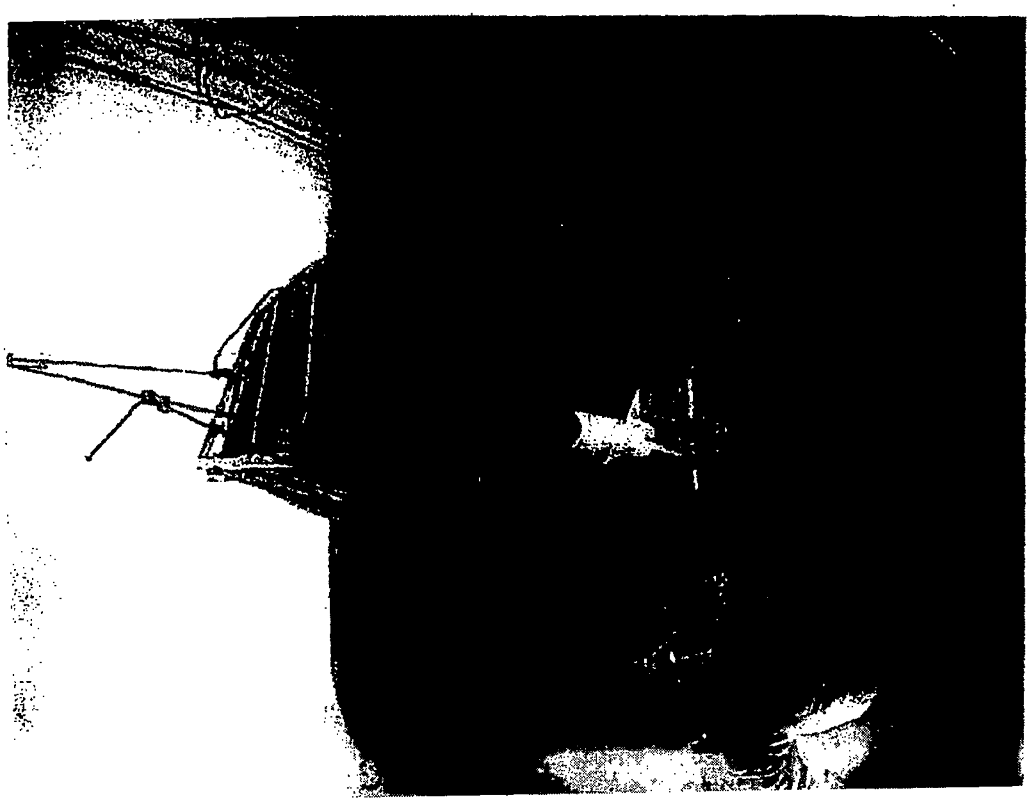


Photo 66; preparation of drop no. 3.4 (incline 35°)

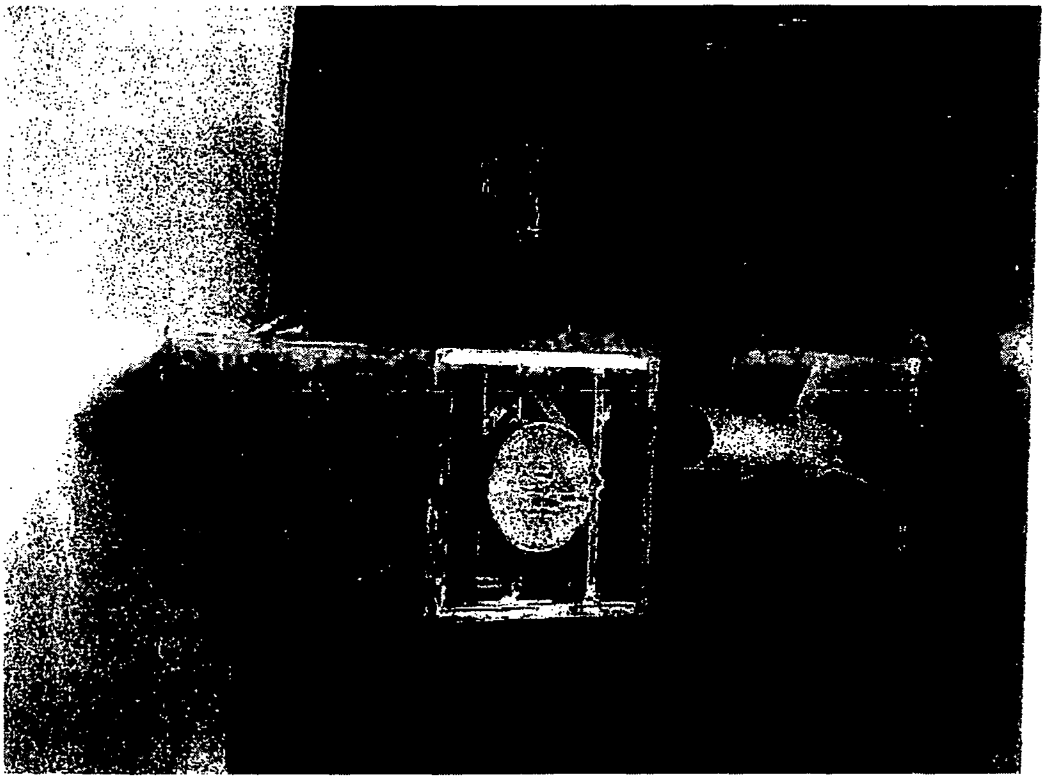


Photo 67; after drop no. 3.4

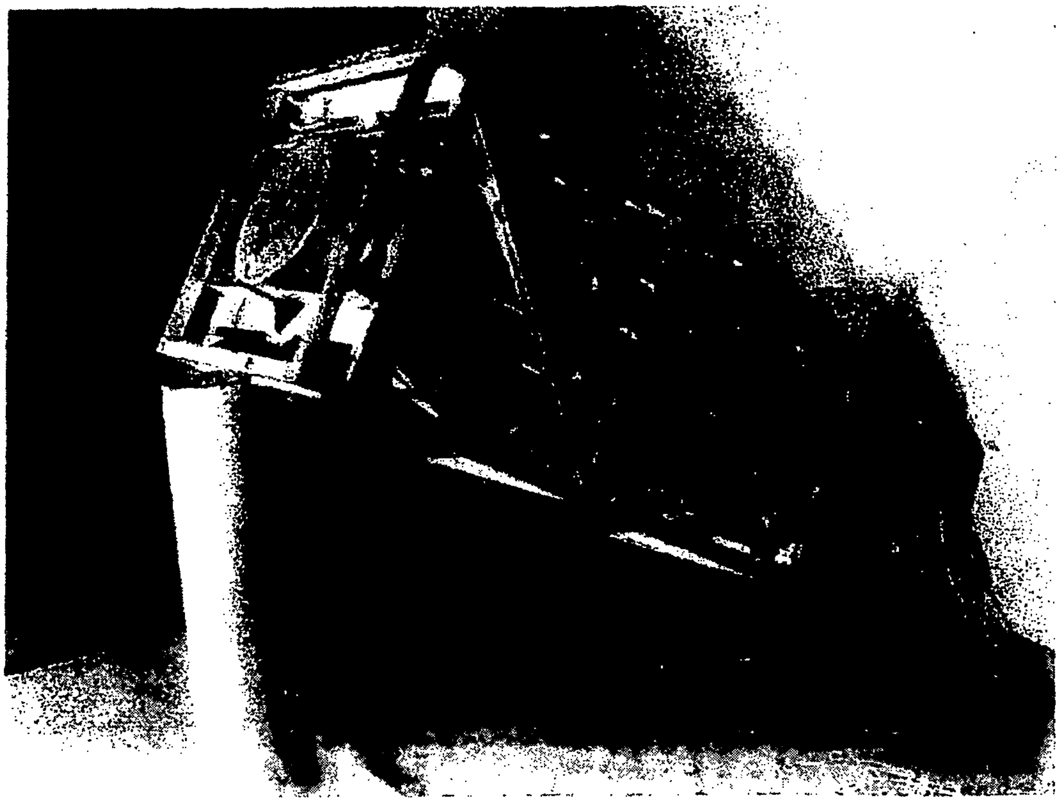


Photo 68; after drop no. 3.4

Photo 69; after drop no. 3.4 (2 latches open, rotation of cover)

Photo 70; after drop no. 3.4 (2 latches open)

Photo 71; after drop no. 3.4 (rotation of cover)

Photo 72; after drop no. 3.4 (rotation of cover)

Photo 73; after drop no. 3.4 (imprint of bar)

Photo 74; after drop no. 3.4 (imprint of bar)

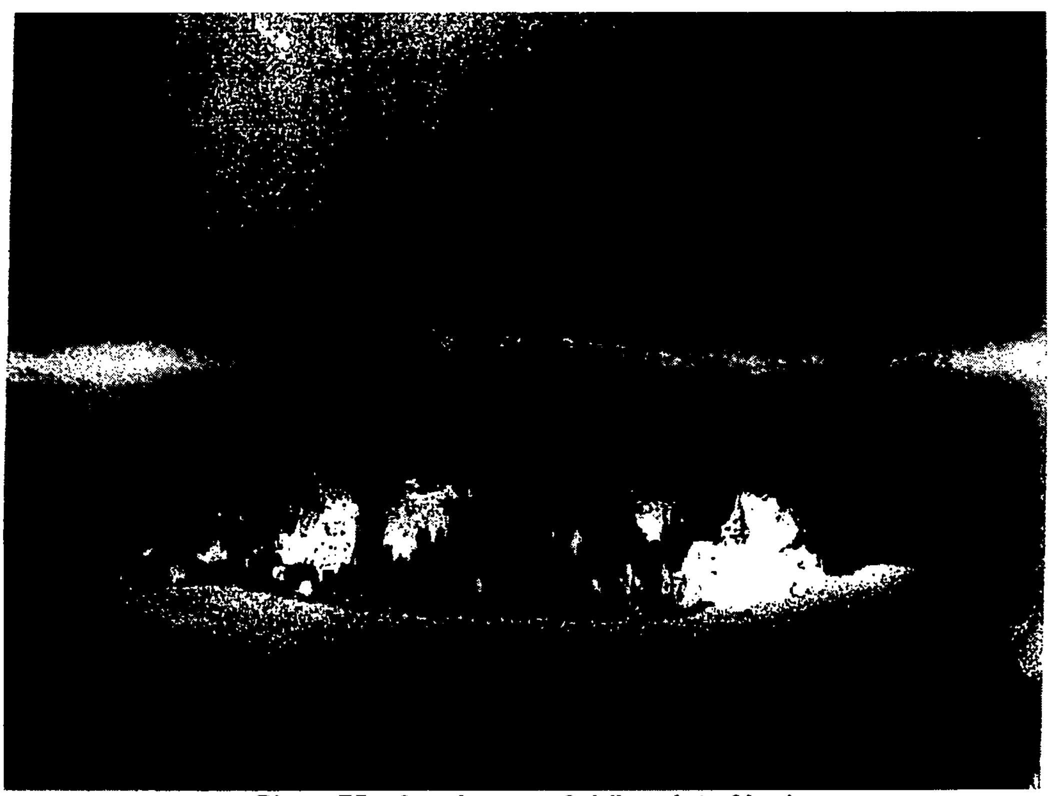


Photo 75; after drop no. 3.4 (imprint of bar)

Photo 76; after drop no. 3.4 (imprint of bar)

Photo 77; after drop no. 3.4

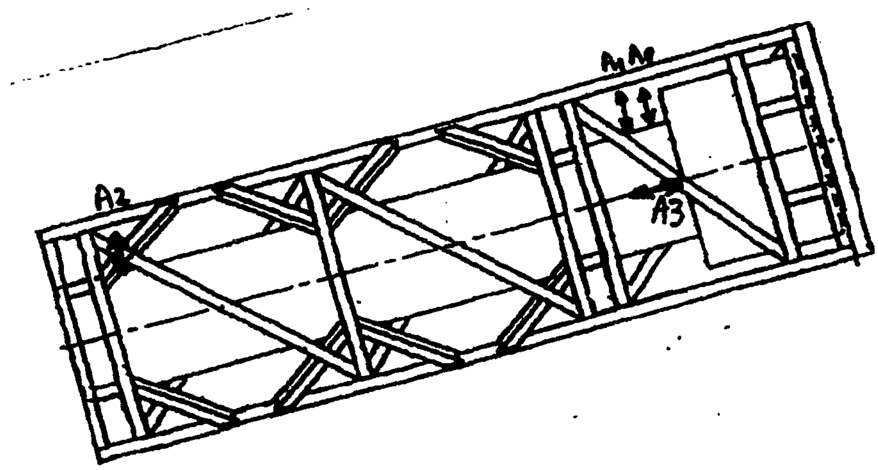
1. PURPOSE:

This document presents the results of the acceleration measurements carried out during drop no. 2 (with slap-down) described in document 102221 RES 01-0.

2. DESCRIPTION:

Four accelerometers were attached to the packaging (see photos 34 and 35).

- Two of these accelerometers were placed near the cover end to measure vertical acceleration: a0 and a1
- One accelerometer was positioned at the base to measure vertical acceleration: a2
- One accelerometer was positioned near the cover to measure axial acceleration: a3



The sensors used are PCB impact sensors model M350B03 (serial numbers: 7711, 7712, 8251, 6853). Last inspection report date (R 11 7711 2A): 07 January 2003.

The sampling frequency of the acquisition system is 100 kHz.

High frequencies are filtered during post-treatment above 1000 Hz, 500 Hz and 250 Hz. The filtered accelerations are recorded in the following pages (time in ms, acceleration in g).

2				
1				
0	F. LABERGRI	C. BOCHARD	H. RUBY	19/02/03
Rev	Author	Verified by	Approved by	Date

The final accelerations (absolute value) are indicated in the following table according to the filter level.

	1000 Hz	500 Hz	250 Hz
a0 vertical top end	765	731	682
a1 vertical top end	814	710	631
a2 vertical bottom end	1070	956	366
a3 axial top end	170	76	65

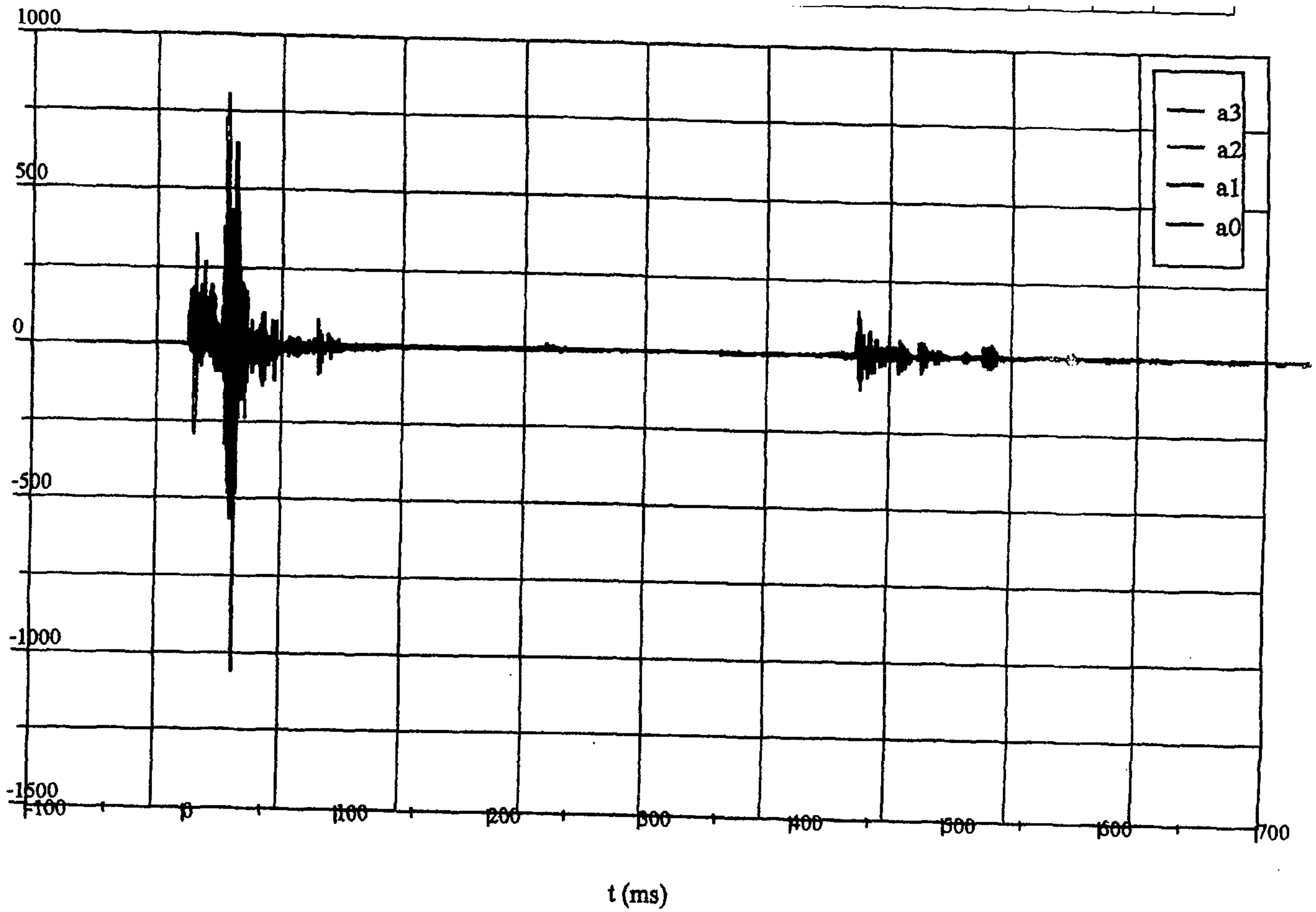


Figure 1: accelerations filtered at 1000Hz

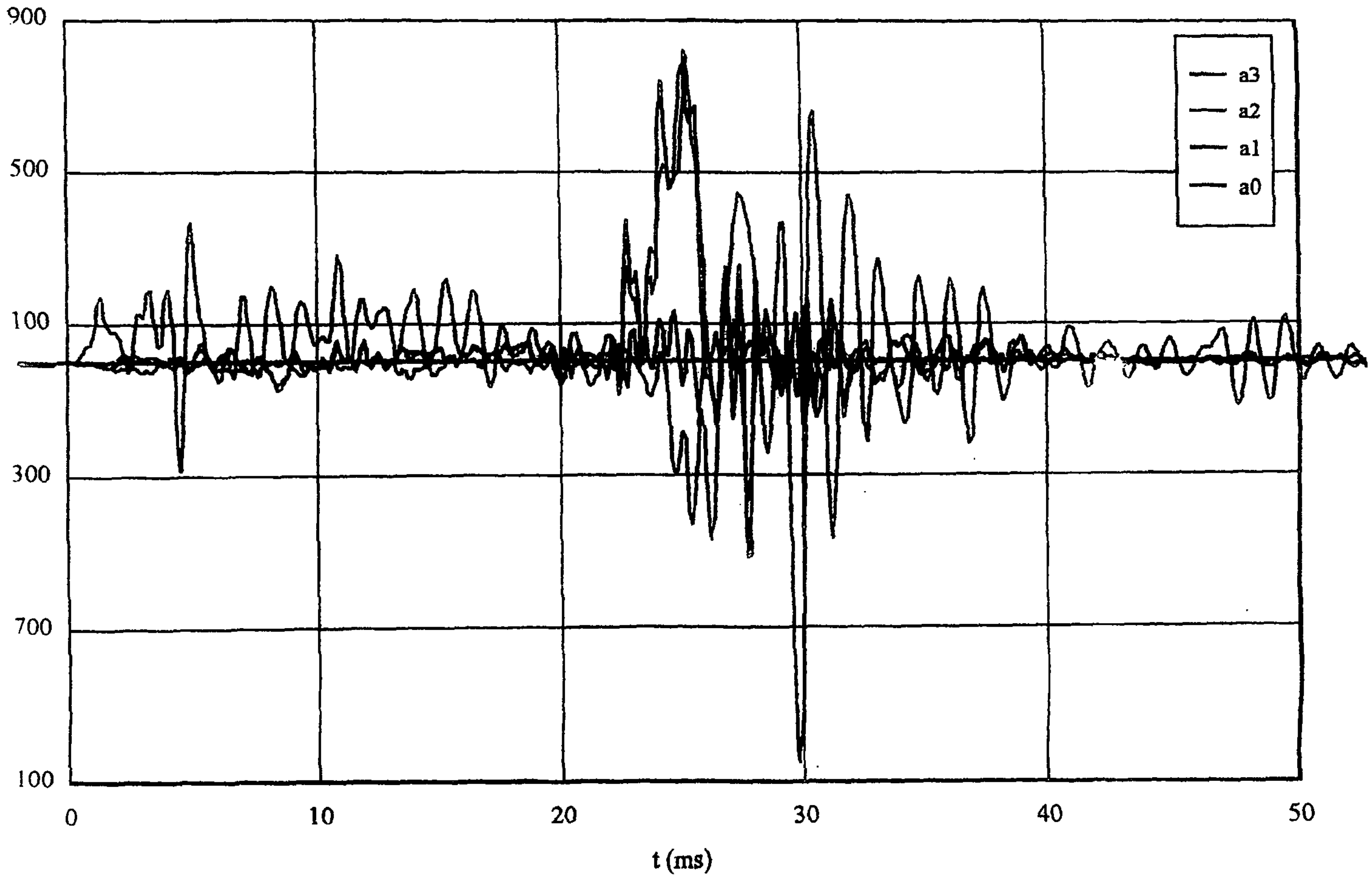


Figure 2: accelerations filtered at 1000Hz

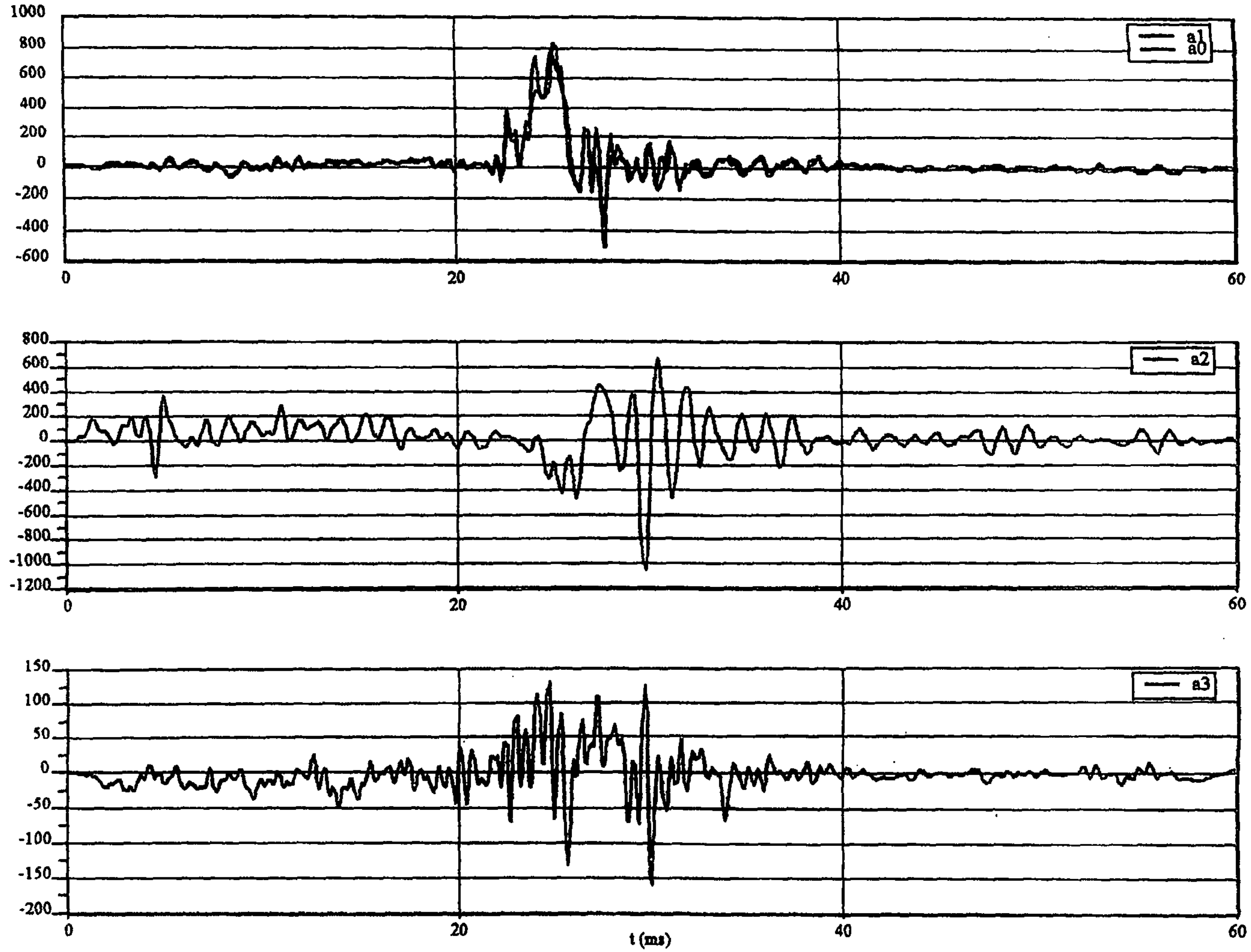


Figure 3: accelerations filtered at 1000Hz

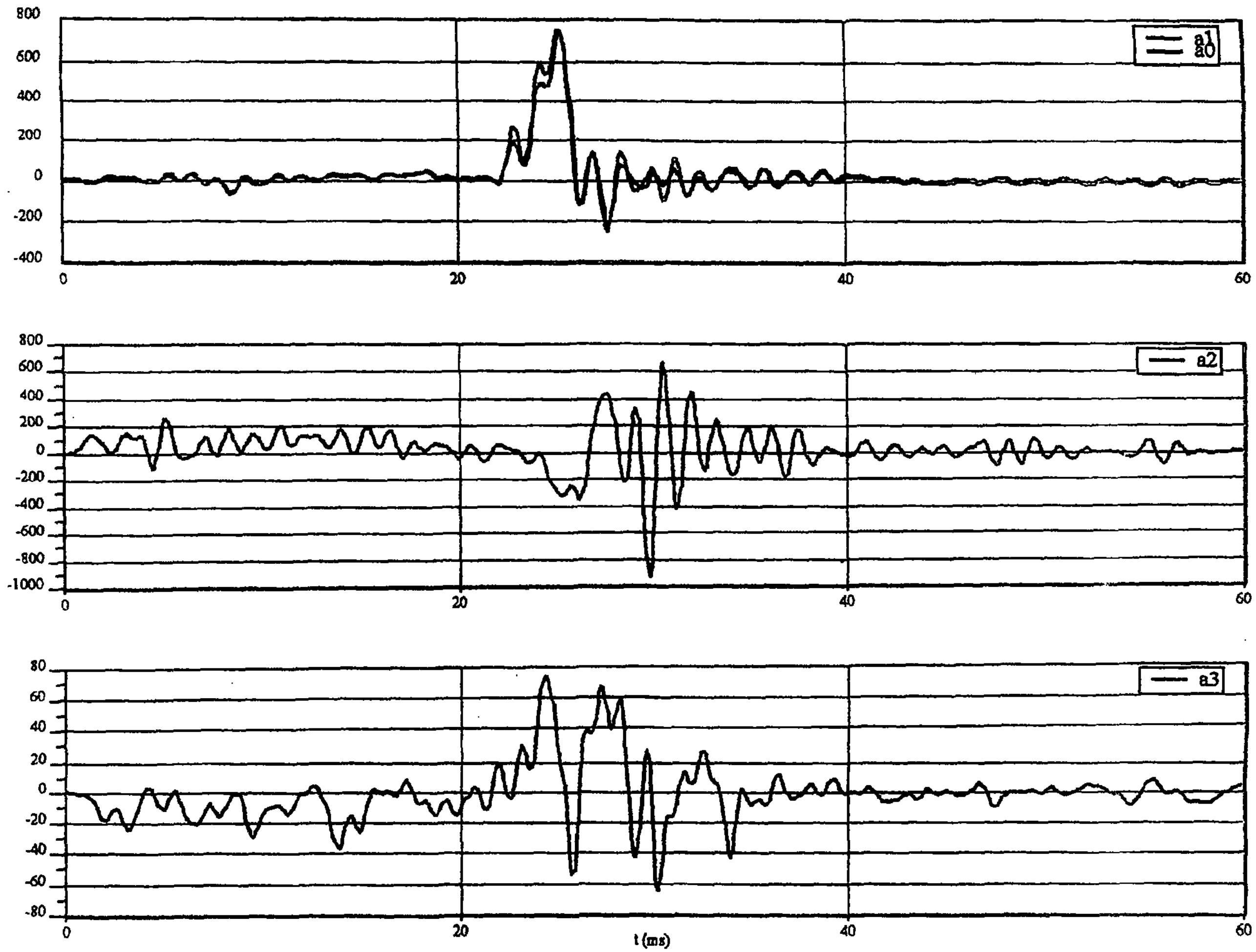


Figure 4: accelerations filtered at 500Hz

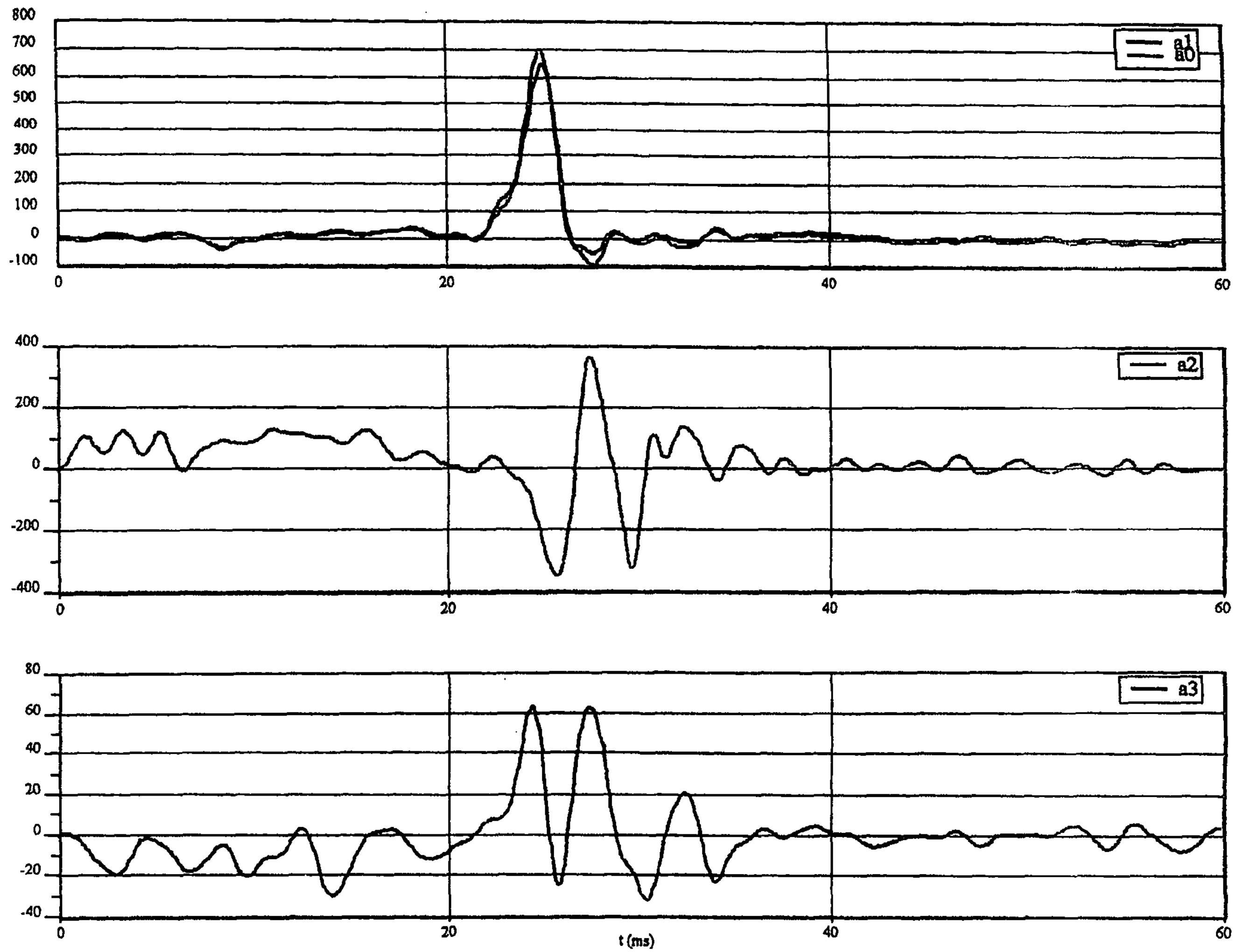


Figure 5: accelerations filtered at 250Hz

Appendix 2: Leakage test report
References 140266/1 and 140266/2
Number of pages: 4

FRAMATOME ANP

OFFICIAL REPORT ON LEAKAGE TEST

Report N° 140266/1 1/2

CTE NORDTEST

Client : CEA
Customer : CADARACHE
Affaire : ____________
Business :

N° CTE NDT : 140266

Fabricant :
Manufacturer :
N° de cde 4000045496
Order number :
Lieu d'intervention: GENAS
Operation place :

Elément contrôlé : EMBALLAGE
Examined object:TN BGC 1 N°144
TN 90 N°4

Specification: IS2 LT 707 Rév1

Test method: HELIUM VACUUM LEAKAGE TEST

Areas tested: seals and whole apparatus	Time of tests: before and after drop tests

Equipment used	Type	Number	Value at 20°C
Sensor:	BALZERS HLT 260	ET 4000087931	
Pump generator:	ALCATEL 20-12	ET 1463	
Reference leak	ALCATEL FE 24	ET 00086	1.1.10 —7Pam3.s-1

Test parameter readings	
Pressure in device:	1 Pa
Pressure of trace gas applied:	Atmospheric pressure
Concentration of trace gas:	100%
Response time:	/
Ambient temperature:	17°C
Residual signal:	Appendix
Test sensitivity:	Appendix

Acceptance criterion: TN BGC 1: 1.10^{-7} Pa.m3.s-1 & TN90: 1.10^{-5} Pa.m3.s-1

RESULTS AND OBSERVATIONS:

NO LEAKAGE IN EXCESS OF CRITERION APPLICABLE TO PACKAGING TN BGC 1 No.144
LEAK IN EXCESS OF CRITERION ON TN 90 CONTAINER No. 4 AFTER DROP TESTS

☐ Compliant with specification ■ Not compliant with specification ■ Appended sheet

	CONTROLLER niveau 2/ level 2	CONTROLLER niveau 2/ level 2	CLIENT/CUSTOMER
NAME	R. CAST		
DATE	03 FEBRUARY 2003		
SIGN.			

CTE NORDTEST BP 13 13115 St Paul Les Durance Tel : +33 (0)4 42 17 36 60 Fax: +33 (0)4 42 17 36 61

FRAMATOME ANP

OFFICIAL REPORT ON LEAKAGE TEST

Report N° 140266/1 2/2

CTE NORDTEST

Client : CEA CADARACHE
Customer :
Affaire : ____________
Business :

N° CTE NDT : 140266

Fabricant :
Manufacturer :
N° de cde 4000045496
Order number :
Lieu d'intervention: GENAS
Operation place :

Elément contrôlé : TN BGC 1 N°144
Examined object : TN 90 N°4

Specification: IS2 LT 707 Rév 1

Leak flux (SLR in Pa.m3.s-1)			
TIMING OF TEST	**TN BGC1 No. 144**	**TN 90 No. 4**	
		Inner seal	Outer seal
Before drop			
Residual signal	3.10-8	4.10-8	2.10-8
Sensitivity	1.10-8	1.10-8	1.10-8
Leak flux	**< $1x10^{-8}$**	**4.10-6**	**1.10-5**
After 9-metre drop packaging vertical and from 1 m onto bar incline 14°			
Residual signal	2.10-8	1.10-6	2.10-6
Sensitivity	1.10-8	1.10-6	1.10-6
Leak flux	**< $1x10^{-8}$**	**3.10-3**	**4.10-4**
After reassembly			
Residual signal	7.10-8	2.10-8	1.10-8
Sensitivity	1.10-8	1.10-8	1.10-8
Leak flux	**< $1x10^{-8}$**	**1.10-7**	**2.10-6**
After 9-metre drop, horizontal, incline 14°			
Residual signal	1.10-8	2.10-9	6.10-9
Sensitivity	1.10-8	1.10-9	1.10-8
Leak flux	**< $1x10^{-8}$**	**4.10-6**	**3.10-6**
TN 90 at end of test	**Whole apparatus (except seals)**		
Residual signal	3.10-8		
Sensitivity	1.10-8		
Leak flux	**< $1x10^{-8}$**		
TN BGC 1 at end of test	**Whole apparatus**		
Residual signal	1.10-9		
Sensitivity	1.10-9		
Leak flux	**< $1x10^{-9}$**		

CTE NORDTEST BP 13 13115 St Paul Les Durance Tel : +33 (0)4 42 17 36 60 Fax: 04 42 17 36 61

FRAMATOME ANP

OFFICIAL REPORT ON LEAKAGE TEST

Report N° 140266/1 1/2

CTE NORDTEST
Client : CEA
Customer : CADARACHE
Affaire : ____________
Business :

N° CTE NDT : 140266

Fabricant :
Manufacturer :
N° de cde 4000045496
Order number :
Lieu d'intervention: GENAS
Operation place :

Elément contrôlé : EMBALLAGE
Examined object :TN BGC 1 N°144
TN 90 N°3

Specification : IS2 LT 707 Rév1

Test method: HELIUM VACUUM LEAKAGE TEST

Areas tested: seals and whole apparatus	Time of tests: before and after drop tests

Equipment used	Type	Number	Value at 20°C
Sensor:	BALZERS HLT 260	ET 4000087931	
Pump generator:	ALCATEL 20-12	ET 1463	
Reference leak	ALCATEL FE 24	ET 00086	1.1.10 —7Pam3.s-1

Test parameter readings	
Pressure in device:	1 Pa
Pressure of trace gas applied:	Atmospheric pressure
Concentration of trace gas:	100%
Response time:	/
ambient temperature:	17°C
Residual signal:	Appendix
Test sensitivity:	Appendix

Acceptance criterion: TN BGC 1: 1.10^{-7} Pa.m3.s-1 & TN90: 1.10^{-5} Pa.m3.s-1

RESULTS AND OBSERVATIONS:

NO LEAKAGE IN EXCESS OF CRITERION APPLICABLE TO PACKAGING TN BGC 1 No.164
LEAK IN EXCESS OF CRITERION ON TN 90 CONTAINER No. 4 AFTER DROP TESTS

☐ Compliant with specification ■ Not compliant with specification ■ Appended sheet

	CONTROLLER niveau 2/ level 2	CONTROLLER niveau 2/ level 2	CLIENT/CUSTOMER
NAME	R. CAST		
DATE	03 FEBRUARY 2003		
SIGN.			

Report N° 140266/1 2/2

FRAMATOME ANP

OFFICIAL REPORT ON LEAKAGE TEST

CTE NORDTEST

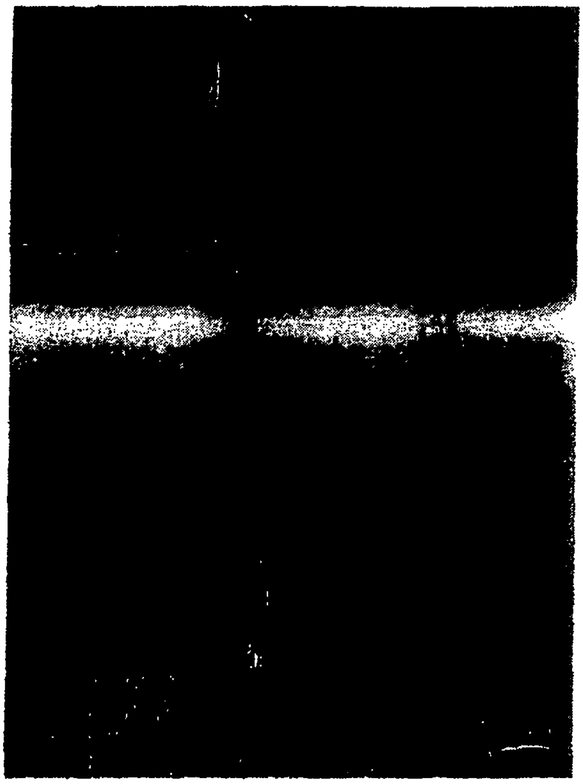
Client : CEA CADARACHE	Fabricant :	Elément contrôlé : TN BGC 1 N°144
Customer :	Manufacturer :	Examined object : TN 90 N°4
Affaire : ____________	N° de cde 4000045496	
Business :	Order number :	
	Lieu d'intervention: GENAS	
N° CTE NDT : 140266	Operation place :	Specification : IS2 LT 707 Rév 1

Leak flux (SLR in Pa.m3.s-1)

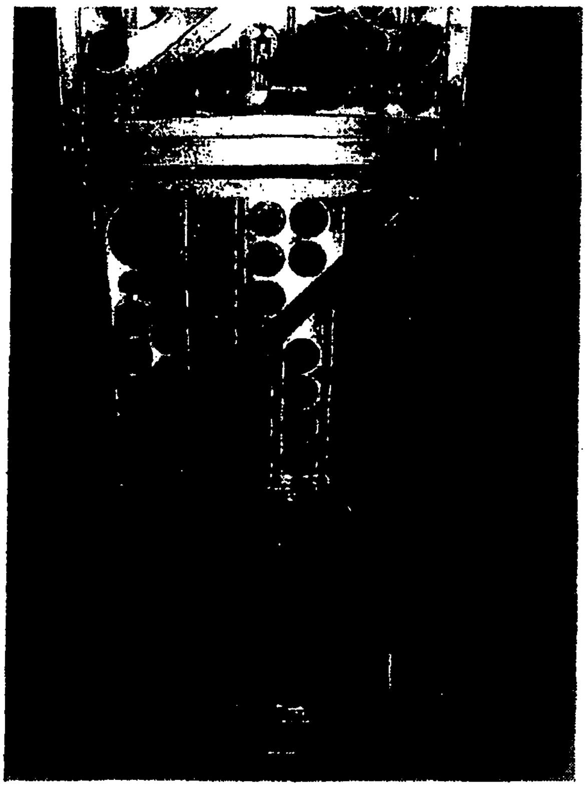
TIMING OF TEST	**TN BGC1 No. 144**	**TN 90 No. 4**	
		Inner seal	Outer seal
Before drop			
Residual signal	2.10-8	6.10-8	8.10-8
Sensitivity	1.10-8	1.10-8	1.10-8
Leak flux	**$< 1x10^{-8}$**	**3.10-6**	**7.10-6**
After 1.22 m drop, horizontal package, 500 kg plate drop and drops onto bar with 20° and 35° inclines			
Residual signal	2.10-8	1.10-6	6.10-7
Sensitivity	1.10-8	1.10-6	1.10-7
Leak flux	**$< 1x10^{-8}$**	**2.10-5**	**2.10-4**
After reassembly			
Residual signal	1.10-8	2.10-8	2.10-7
Sensitivity	1.10-8	1.10-8	1.10-7
Leak flux	**$< 1x10^{-8}$**	**4.10-6**	**3.10-6**
TN 90 at end of test	**Whole apparatus (except seals)**		
Residual signal	3.10-8		
Sensitivity	1.10-8		
Leak flux	**$< 1x10^{-8}$**		
TN BGC 1 at end of test	**Whole apparatus**		
Residual signal	1.10-7		
Sensitivity	1.10-7		
Leak flux	**$< 1x10^{-7}$**		

CTE NORDTEST BP 13 13115 St Paul Les Durance Tel : +33 (0)4 42 17 36 60 Fax: +33 (0)4 42 17 36 61

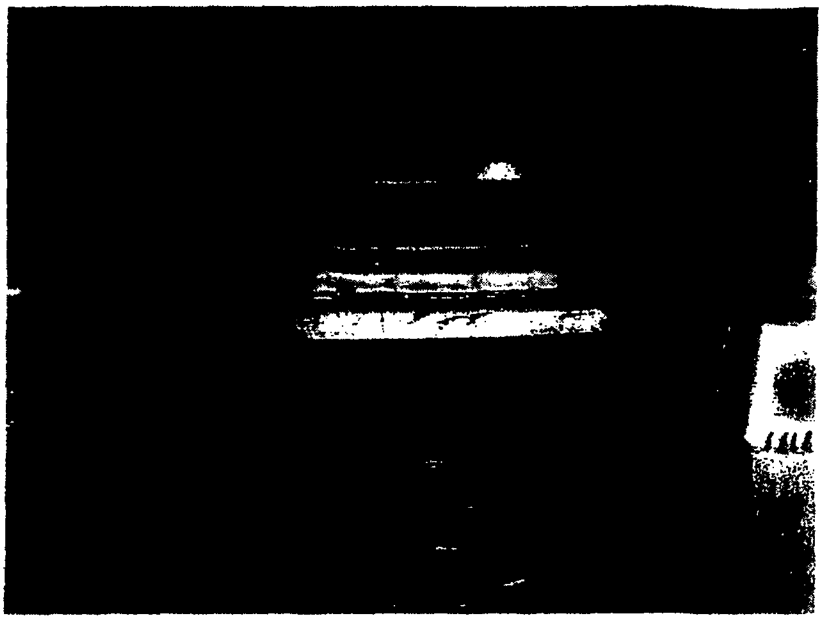
Appendix 3: additional photos



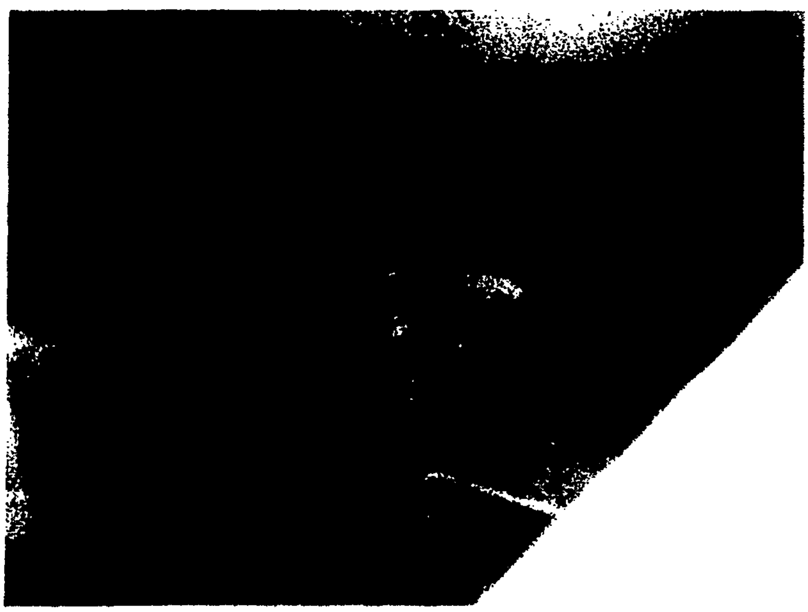
Drop No.1: 9 metres, positioning



Drop no. 1: damage to cage



Drop no. 1: denting on cover



Drop no. 1: deformation of cage-body mounting bolt

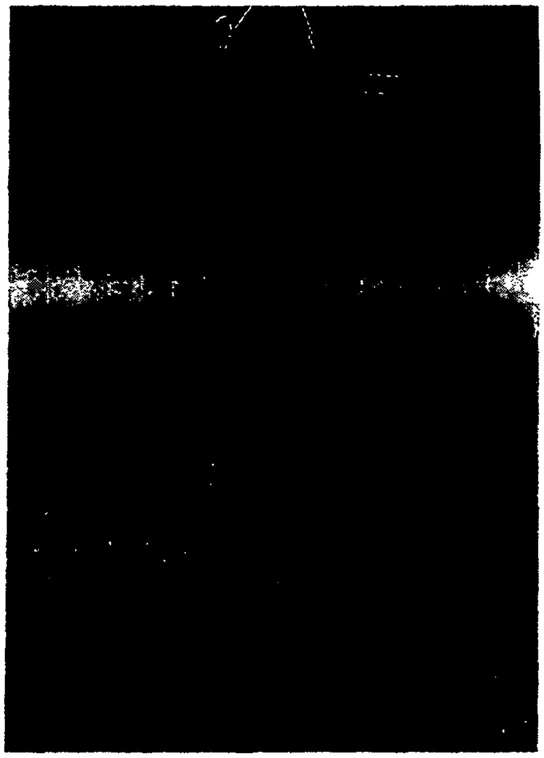
Drop no. 2: 1 m onto bar, positioning

Drop no. 2: denting on cover

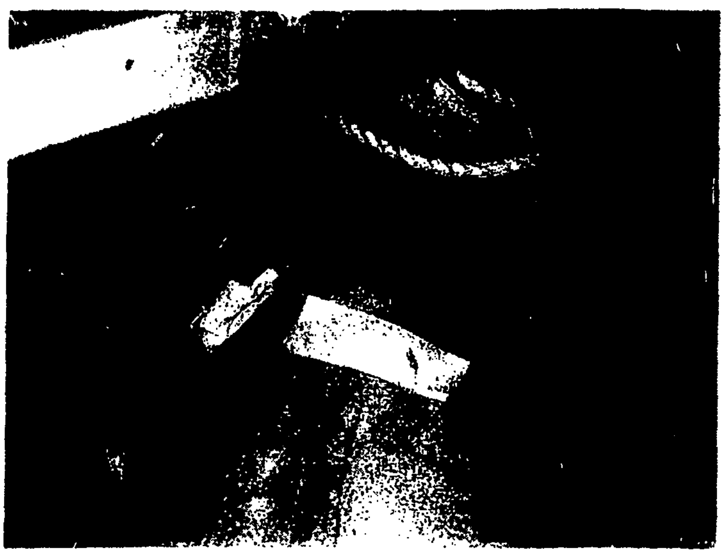
Drop no. 2: denting on cover

Drop no. 2: view of impacts (second mark occurred after impact)

Drop no. 2: shearing of two cage struts after rebound on edge of test surface



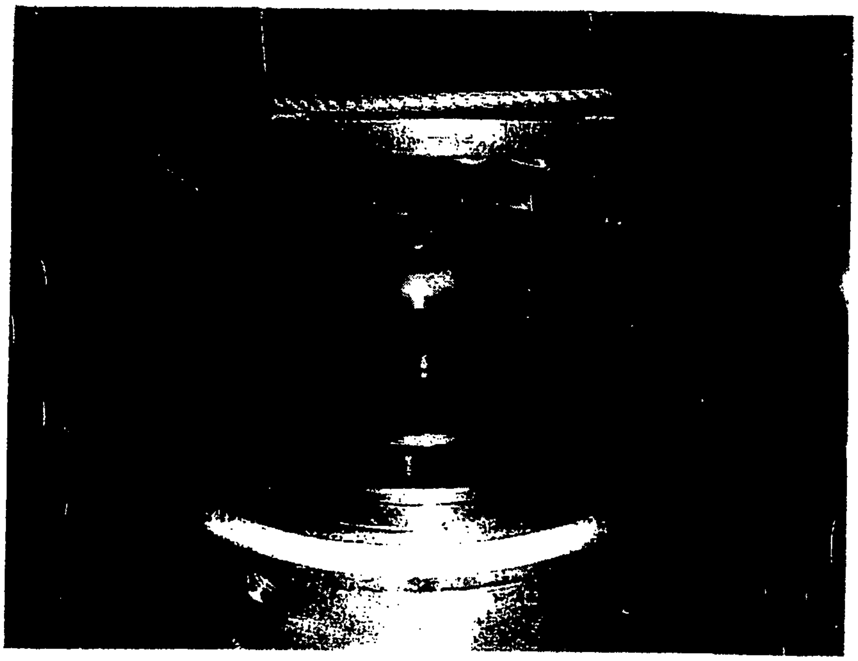
Drop no. 3: 9 metres, positioning



Drop no. 3: disconnection of body

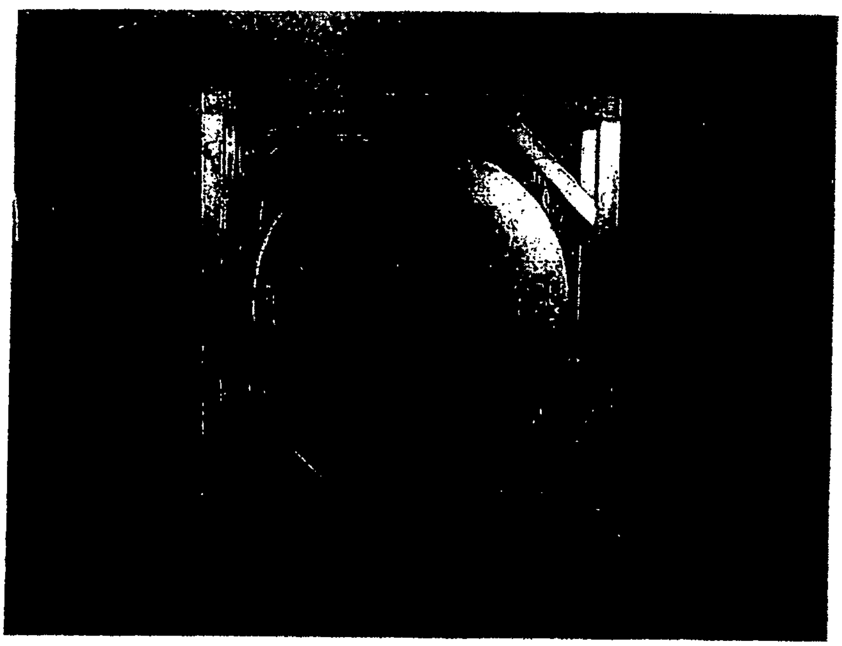
Drop no. 3: deformation of cover

Drop no. 3: de-centring of body in rear section

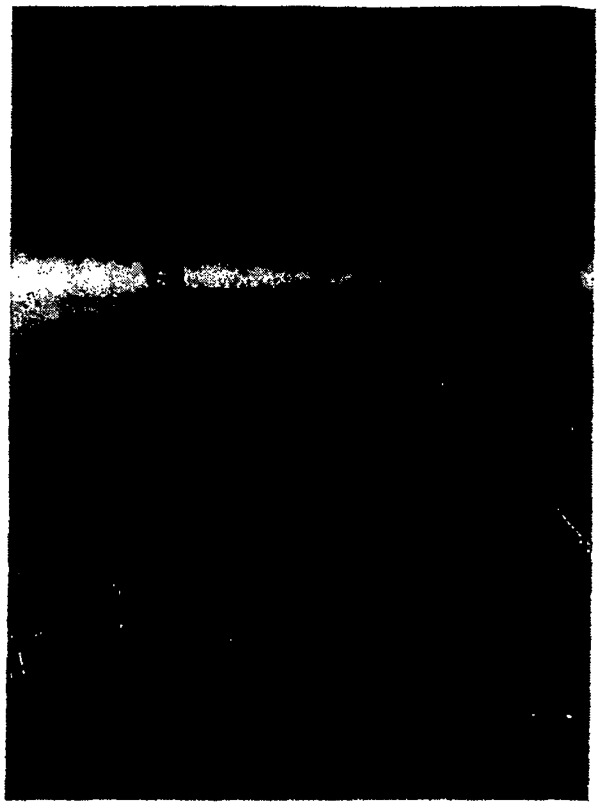


Drop no. 3: integrity of closure system

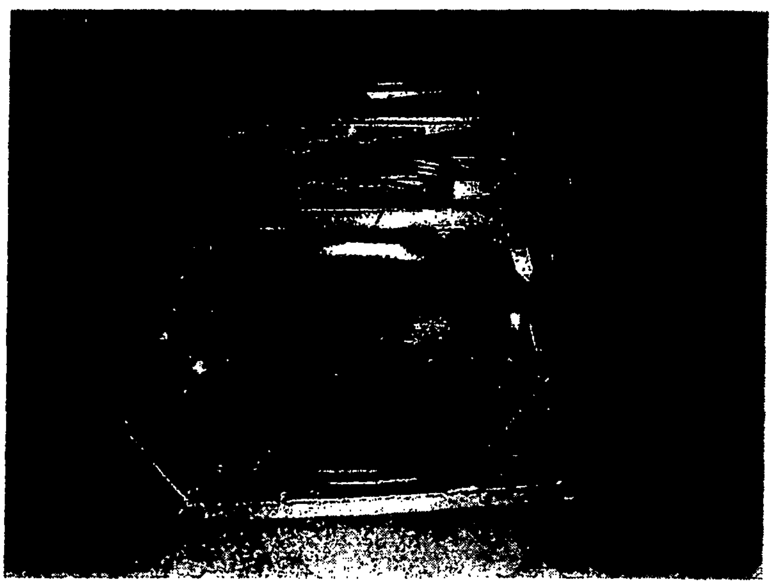
Drop no. 4: 1.20 m, positioning



Drop no. 4: no de-centring on cover end



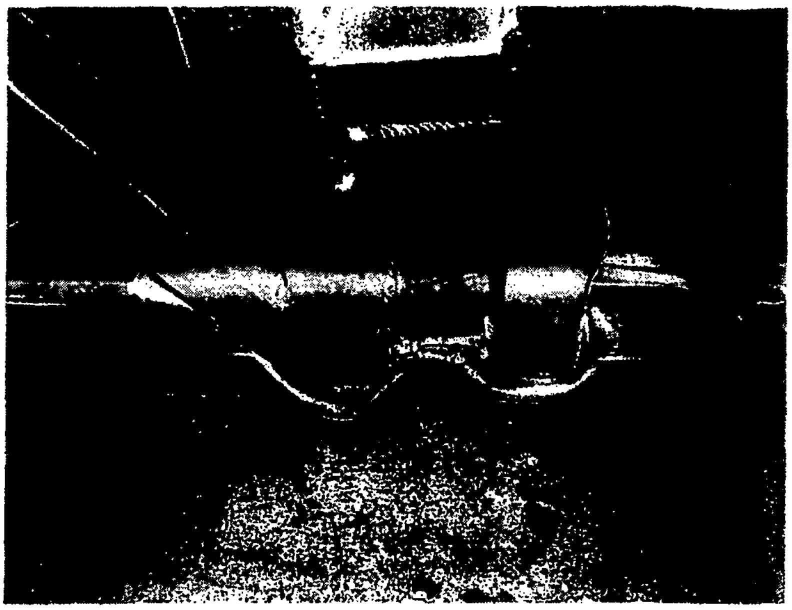
Drop no. 5: plate drop from 9 metres, positioning



Drop no. 5: damage to cage and cover

Drop no. 5: deformation of cage

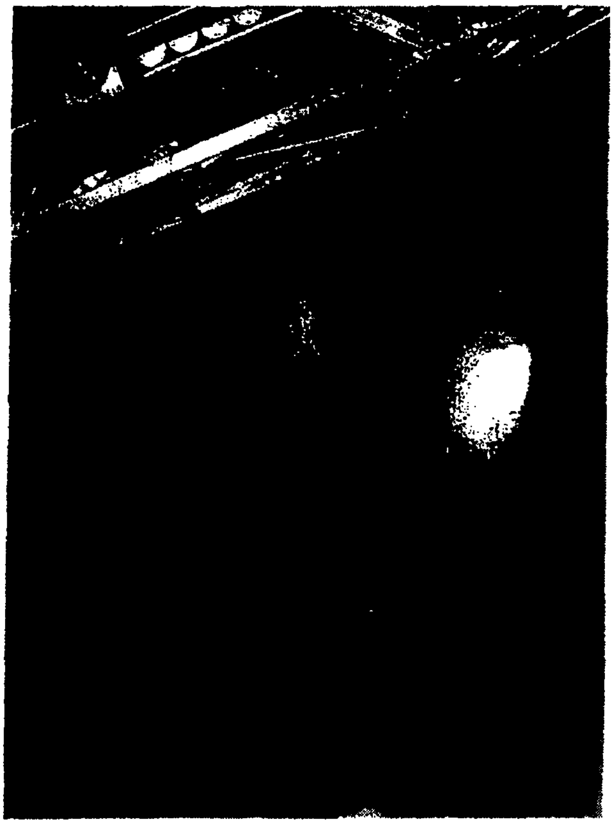
Drop no. 5: deformation of cage



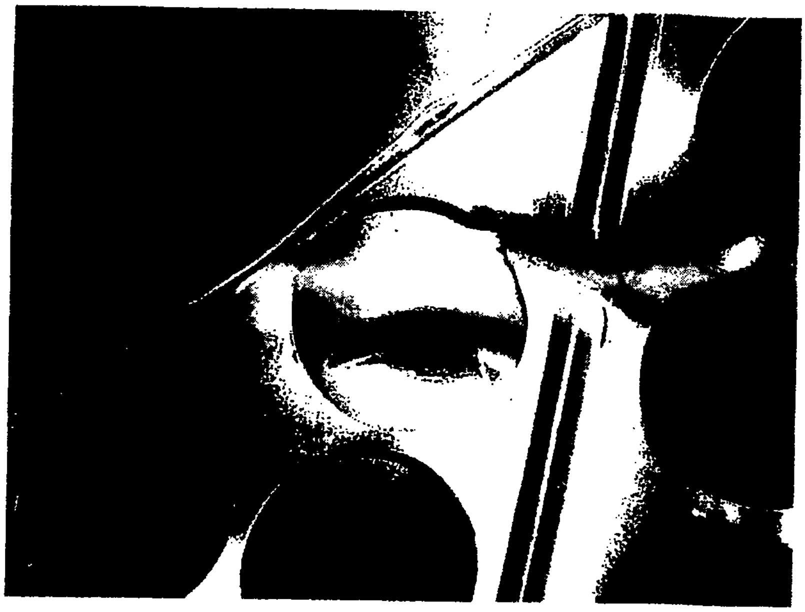
Drop no. 5: compression of cage strut

Drop no. 5: centring of body/cage

Drop no. 6: 20° incline, positioning

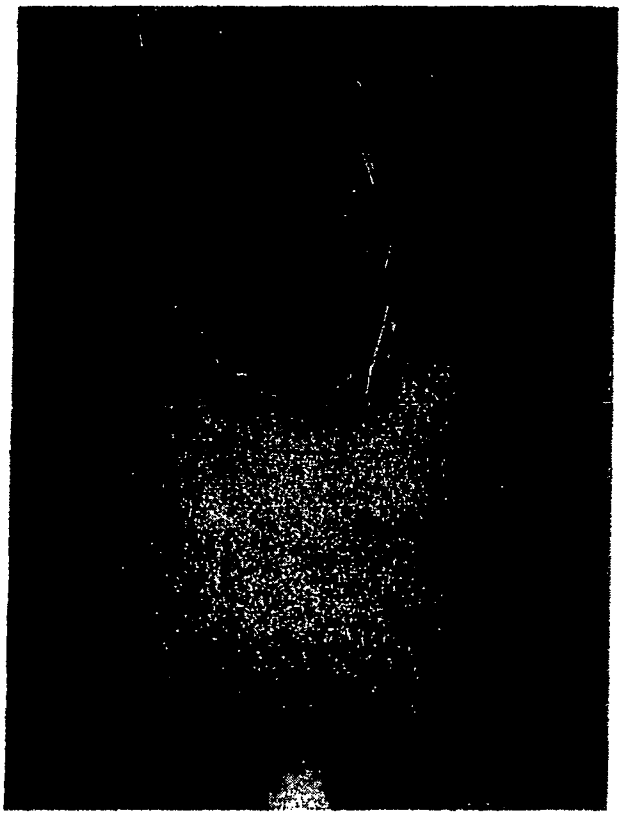


Drop no. 6: 20° incline, positioning

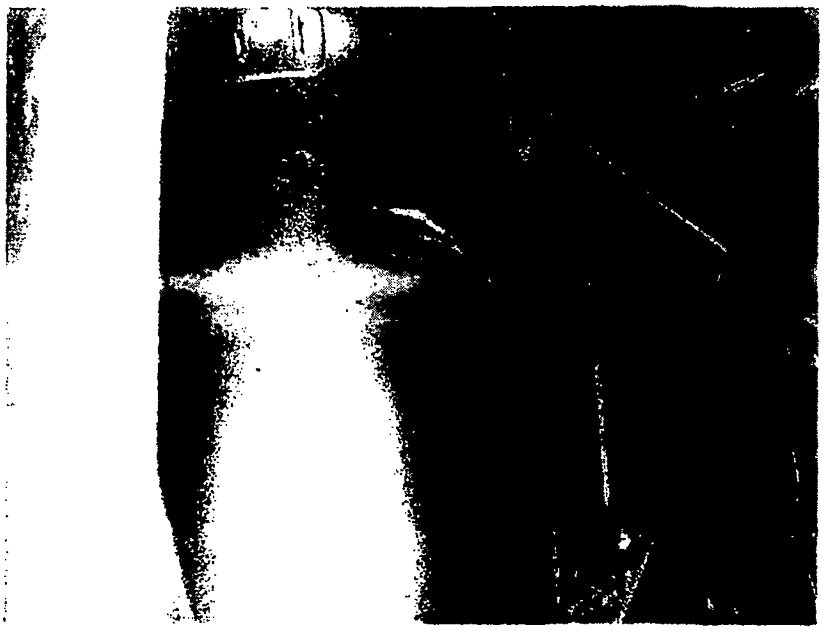


Drop no. 6: denting on outer body shell

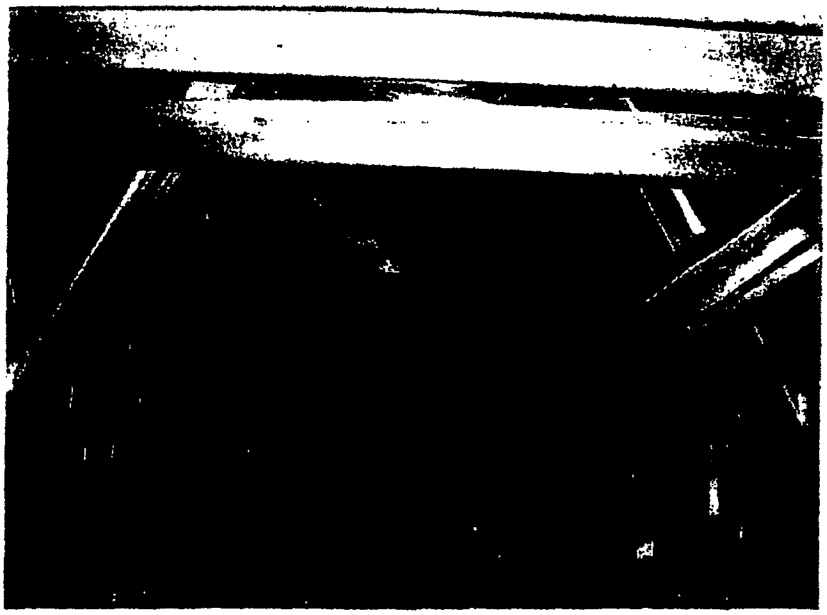
Drop no. 7: 35° incline, positioning



Drop no. 7: 35° incline, positioning



Drop no. 7: tearing of outer shell



Drop no. 7: tearing of outer shell