Section-(II)-B Thermal Analysis

(II)-B Thermal Analysis

In this chapter, it is clarified that the package satisfies the criteria under the normal and accident conditions of transport defined in the transport regulation and maintaing integrity of the package.

B.1 Analysis condition

The thermal analysis conditions are shown in Table(II)-B.1.

Where, the 55℃ of ambient temperature is the additional condition for the package transported by air.

Table(II)-B.1 Thermal analysis conditions

Item \ Conditions		Normal conditions of transport				Accident conditions of transport		
						Before the fire accident	During the fire accident	After the fire accident
Heat generated		25 W	0 W	25 W	25 W	25 W	25 W	25 W
Environmental conditions	Ambient temperature	38℃	−40℃	38℃	55℃	38℃	30 minutes 800℃	38℃
	Solar heat [a]	none	none	existing	none	none	none	exisiting
	Ambient emissivity rate	1.0	1.0	1.0	1.0	1.0	0.9	1.0
Container surface emissivity rate		0.2	0.2	0.2	0.2	0.2 [b]	0.8 [c]	0.55 [d]

(a) curved surface : 400 W/m^2 flat surface : 800 W/m^2

(b) 0.2 : Surface emissivity of stainless steel before exposed to the fire

(c) 0.8 : Surface emissivity of stainless steel being exposed to the fire

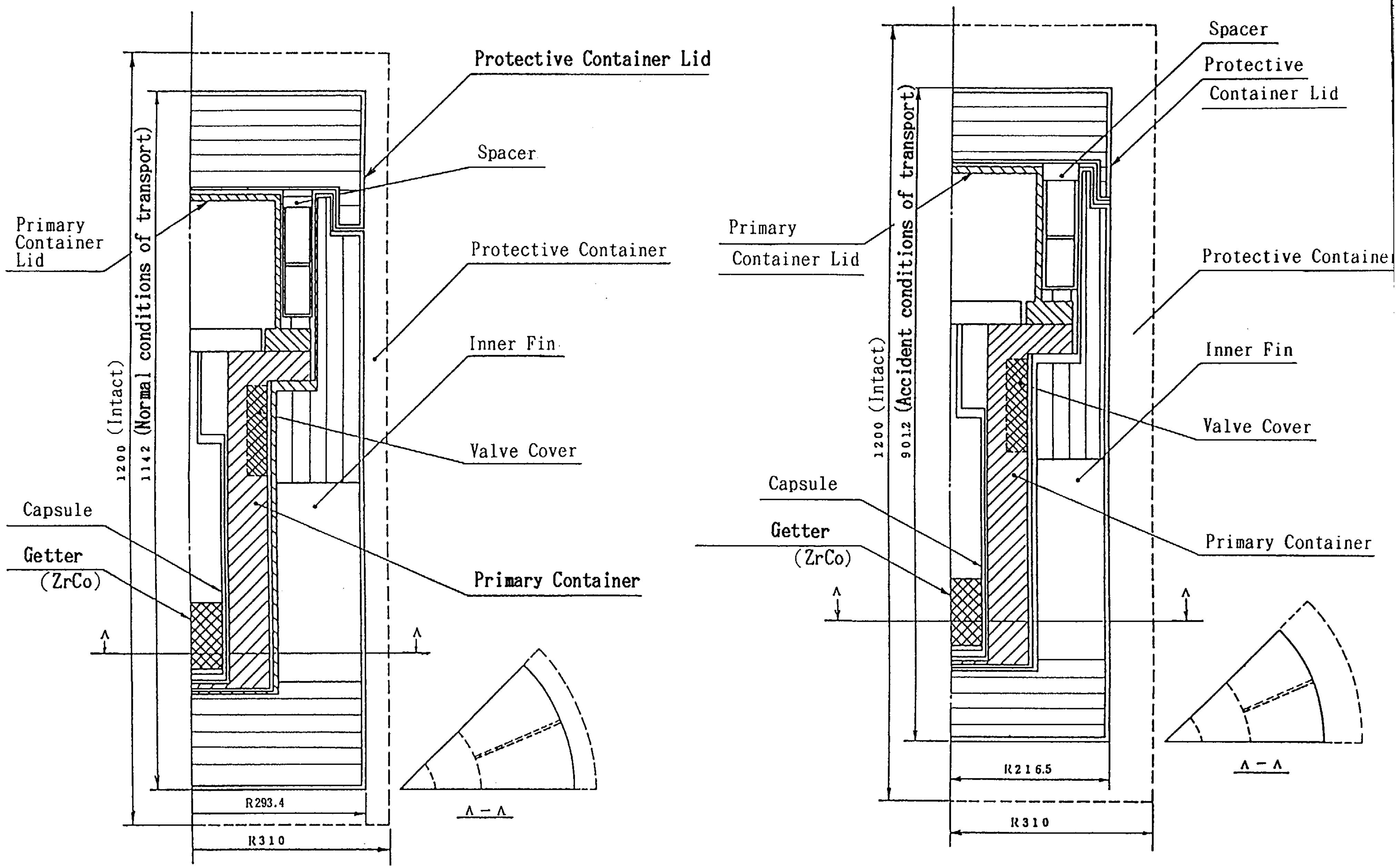
(d) 0.55 : Surface emissivity of stainless steel after exposed to the fire

B.2 Analysis model and method

Fig.(II)-B.1 shows the analysis model which comprises 3 dimensional 1/8 divided sector type model.

The above models are considerd vertical and horizontal drop deformations in the 1.2 m drop under the normal conditions of transport and deformations for each of the cases of 9 m drop and 1 m puncture drop evaluations under the accident conditions of transport.

The evaluation has been carried out by "TRUMP", 3-dimensional unsteady state temperature distribution computation code.



(Normal conditons of transport)

(Accident conditions of transport)

Fig.(II)-B.1 Analysis model

B.3 Results of analysis

The temperatures at each of the locations under the normal and accident conditions of transport are follows :

Table(II)-B.2 Thermal analysis results

Item / Location	Normal conditions of transport				Accident condition of transport	
	Ambient Temperature 38℃ Without Solar heat	Ambient Temperature -40℃ Without Solar heat	Ambient Temperature 38℃ With Solar heat	Ambient Temperature 55℃ Without Solar heat	Maximum temperature	Time required for reaching the maximum temperature from the fire accident taking place
getter	96℃	-40℃	110℃	110℃	158℃	approx. 4.5hr
Capsule surface	61℃	-40℃	77℃	77℃	133℃	approx. 4.0hr
Primary container internal surface	58℃	-40℃	73℃	74℃	131℃	approx. 3.5hr
Primary container external surface	56℃	-40℃	72℃	72℃	129℃	approx. 3.5hr
Protective container body internal surface	50℃	-40℃	65℃	66℃	258℃	approx. 0.7hr
Protective container body external surface	44℃	-40℃	59℃	61℃	794℃	approx. 0.5hr
Primary container lid O-ring part	48℃	-40℃	64℃	64℃	129℃	approx. 1.7hr
Valve cover O-ring part	50℃	-40℃	66℃	67℃	123℃	approx. 4.0hr
Primary container lid side surface	47℃	-40℃	63℃	63℃	194℃	approx. 0.7hr

The internal pressure of the primary container under the normal and accident conditions of transport are as follows : -

Table(II)-B.3 Analysis results of the internal pressure

Condition / Location	The maximum pressure under the normal conditions of transport (MPa・G)	The maximum pressure under the accident conditions of transport (MPa・G)
Primary container inside	0.056	0.109

From the analysis, the following results have been obtained and it has been confirmed that the package's intergity is maintained and the package complies with the requirements of the regulations.

① The surface temperature of the package under the normal conditions of transport is approx. 44℃, which is obviously lower not only than the criteria (85℃) in case of exclusive use but also than the criteria (50℃) in case of non-exclusive use

② The temperature at each part under the normal conditions of transport is lower than the design temperature(100℃).

③ As mentionend in the structural analysis, as for the materials employed in the package, the lowest service temperatures and the brittleness transition temperatures of them are all lower than -40℃ therefore, no failure or crack occurs in the package under condition of -40℃ ambient temperature.

④ The temperatures both on the primary container and capsule are all lower than the design temperature(200℃) under the accident conditions of transport and also the temperature on the O-ring part is lower than the maximum service temperature(250℃).

⑤ Under either of the normal and accident conditions of transport the maximum internal pressure of the primary container are lower than the design pressures.

Section (II)-C Containment Analysis

(II)-C Containment Analysis

C.1 Outline

This article describes the containment property of the packaging under both normal and accident conditions of transport.

The portion of the packaging dedicated to maintaining the containment property is referred to as the containment system - in this case, the primary container.

The primary container consists of the primary container body, primary container lid and valve cover. Between the primary container body and primary container lid as well as between the primary container body and valve cover are metal O-rings on each of the contacting surfaces. Their purpose is to maintain the containment property.

The radioactive material to be stored in this packaging is tritium. Consequently, not only "leakage" from the O-ring part (sealing part) due to pressure differential between the inside of the primary container and the atmosphere are to be taken into account, but also "permeation" via absorption, dissolution and diffusion through the primary container construction materials. These evaluations are executed according to the procedures defined in the "Tritium Packaging Investigation Committee Report[1]."

The containment system undergoes containment leakage test, etc., during the manufacturing process, or at the time of maintenance and inspection to ensure that the leak rate conforms with the accepted criteria.

The O-ring parts on the primary container lid and valve cover shall undergo containment leakage tests before shipping to ensure that the leak rate satisfies the criteria.

The results of the drop tests and thermal tests as stipulated for a prototype of the packaging confirms that the primary container and capsule did not sustain any damage and that the integrity of the packaging was maintained.

C.2 Containment System

C.2.1 Containment System

(1) Structure

The containment system of this packaging consists of the primary container body, primary container lid and valve cover as shown in Fig. (II)-C.1.

(2) Material

The primary container body, primary container lid and valve cover which compose the containment system are all made of stainless steel. Metal O-rings are used for the seal part of the primary container lid and valve cover.

(3) Design pressure and design temperature

Evaluation of the leak rate is executed according to the design pressure and design temperature shown in Table (II)-C.1.

Table (II)-C.1 Design Pressure and Design Temperature of Containment System

Condition	Item	Containment system
Normal conditions of transport	Design pressure	71 kPa·G
	Design temperature	100°C
Accident conditions of transport	Design pressure	121 kPa·G
	Design temperature	200°C

(4) Sealing

Since the primary container is enclosed inside the protective container, it shall never be exposed to careless opening through loosening or falling off of the tie-down bolt of the primary container lid. Moreover, the protective container lid is fixed on the protective container body by the tie-down bolts, sealed and locked.

(5) Manufacturing and inspection

The manufacturing and inspection of the construction parts of the containment system are performed in the appropriate method to secure and maintain the containment property, the details of which are described in Section (III).

C.2.2 Penetration Portion of the Containment System

As shown in Fig. (II)-C.1, the hull part of the primary container is provided with a penetration portion and a valve is provided to allow replacement of gases contained inside the primary container. This valve is covered with a valve cover during transport. Since the valve cover composes the containment boundary, it is equipped with double O-ring so that leaktightness test is facilitated through a test-hole provided between the two O-rings.

C.2.3 Containment System Gasket and Welded Part

(1) Containment system gasket

A metal O-ring is used for the containment system gasket. The O-ring material does not cause any chemical or galvanic reaction, as shown in (II)-A.3.1. It is designed to assure sufficient containment property against the pressure and temperature under both normal and accident conditions of transport.

(2) Welded parts

The welded part of the containment system comprises the primary container lid cap, flange and plug, as shown in Fig. (II)-C.1. Welding is performed in the method described in (III)-A. The welded parts are subjected to non-destructive inspection during manufacturing using the method described in (III)-B, to ensure their integrity. Pressure test is also performed to ensure that they are free of any leaks.

C.2.4 Lid

In the two grooves in the seal area of the primary container lid and valve cover, as shown in Fig. (II)-C.1, a metal O-ring is fitted into the inside groove to make sure the primary container does not leak, while a silicon elastomer O-ring is fitted into the outside groove for leaktightness testing. The primary container lid and valve cover are also constructed to ensure strength sufficient enough to withstand shock and maintain containment property both under normal and accident conditions of transport.

To assure the primary container lid and valve cover maintain the containment property of the container, they are tied down using the tie-down bolts and the appropriate fastening torque, as indicated in Table (II)-C.2.

Table (II)-C.2 Tie-down Bolts for Each Lid

[PROPRIETARY]

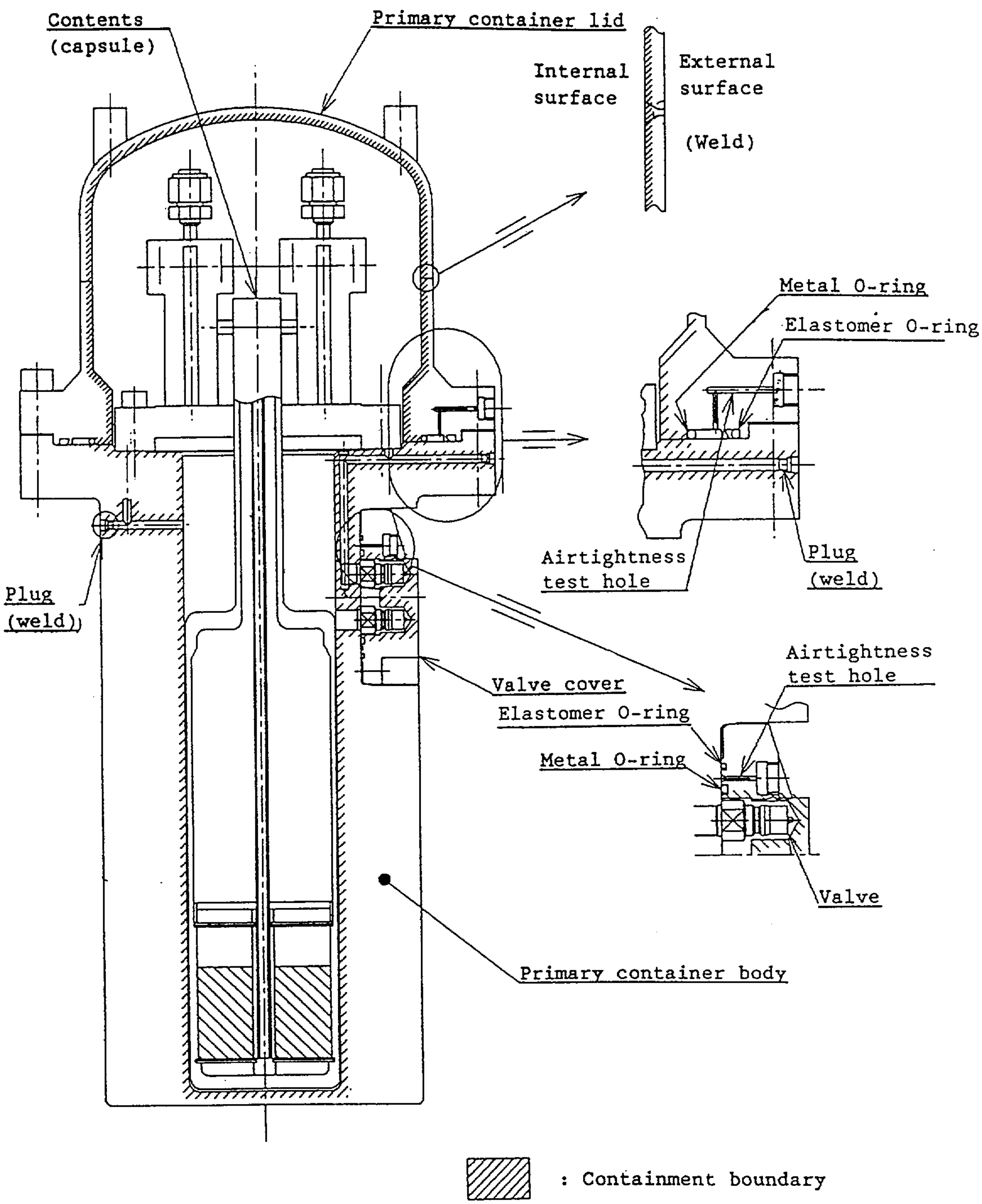


Fig. (II)-C.1 Containment boundary of the packaging

C.3 Normal Conditions of Transport

From the results of the structural analysis, described in (II)-A, it has been proved that the package containment system's integrity is maintained under normal conditions of transport, as is required of a BU-type package. Thermal analysis, described in (II)-B, verified that the integrity is not compromised by any temperature or pressure under normal conditions of transport.

The containment system is then evaluated for tritium leakage from the sealing part due to differential pressure. An evaluation is made using the criteria of the leak-tightness test for the O-ring parts of the primary container and valve cover, which is to be performed prior to shipment of the package. An evaluation for permeability of tritium is also executed using the design temperature stipulated on the basis of the results of the thermal analysis. The sum of these results is compared with the criteria stipulated by the regulation to ensure that it does not exceed the prescribed value.

C.3.1 Leaks of Radioactive Material

C.3.1.1 Tritium Leaks from the Seal Part of the Primary Container Due To Pressure Differential

An evaluation for leakage from the seal part due to differential between the external and internal pressure of the primary container is conducted on the basis of the acceptance criteria of the primary container O-ring part leaktightness test.

(1) Acceptance criteria at leaktightness test

The acceptance criteria (L_c) for the leak rate at leaktightness test is the following value:

$L_c = 1.014 \times 10^{-5}$ [Pa•m^3/sec]

(1.0 x 10^{-4} [atm•mℓ/sec])

where, L_c is the sum of the rates of leakage of the primary container lid seal part and valve cover seal part which compose the seal part of the containment boundary.

(2) Gas leak rate from the primary container

The gas leak rate under normal conditions of transport is obtained with the assumption that there is a leakage as described in the acceptance criteria to be applied to leaktightness test by correcting the temperature and pressure against its leak rate.

The gas leak rate under normal conditions of transport is calculated using the following formula[4] under normal conditions of transport:

$$L = L_c \frac{\eta_y \cdot (P_{ux}^2 - P_{dx}^2)}{\eta_x \cdot (P_{uy}^2 - P_{dy}^2)} \qquad \text{(C.3-1)}$$

where

L ; Gas leak rate under normal conditions of transport [Pa•m^3/sec]

L_c ; Gas leak rate acceptance criteria at leaktightness test [Pa•m^3/sec]

η_x ; Gas viscosity factor under normal conditions of transport [kg/m•sec]

η_y ; Gas viscosity factor at leaktightness test [kg/m•sec]

P_{ux} ; Primary container internal pressure under normal conditions of transport [kPa•A]

P_{dx} ; Atmospheric pressure under normal conditions of transport [kPa•A]

P_{uy} ; Upstream side pressure of leaktightness test [kPa•A]

P_{dy} ; Downstream side pressure of leaktightness test [kPa•A]

where,

L_c ; 1.014×10^{-5} [Pa•m³/sec]

η_x ; 19.93×10^{-6} (at 20°C*) [kg•m/sec]

η_y ; 19.93×10^{-6} (at 20°C) [kg•m/sec]

P_{ux} ; 71 [kPa•G] = 172 [kPa•A]

P_{dx} ; 25 [kPa•A]

P_{uy} ; 30 [kPa•G] = 132 (initial filling pressure; at 20°C) [kPa•A]

P_{dy} ; 0 [kPa•A]

* Since the viscosity of the gas increases as the temperature rises, a conservative evaluation is made by using the value of normal temperature, which is lower than the design temperature under the normal conditions of transport.

From the above, the gas leak rate from the primary container is calculated as follows;

$$L = 1.014 \times 10^{-5} \times \frac{19.93 \times 10^{-6}}{19.93 \times 10^{-6}} \times \frac{172^2 - 25^2}{132^2 - 0}$$

$= 1.69 \times 10^{-5}$ [Pa•m^3/sec]

$= 6.09 \times 10^{-2}$ [Pa•m^3/h]

(3) Leak rate of radioactive material (tritium)

In order to be conservative, assumption as mentioned below is made in evaluating leakage of the radioactive material (tritium).

(a) Results of the structural analysis of the contents (capsule) indicate that the integrity of package is maintained. However, a margin is provided by assuming that the capsule does not have the containment property.

(b) The tritium inside the primary container (inside the capsule) in a gaseous state is assumed to be the radioactive material concerned with leakage. Here, as for (b), from the results of thermal analysis ((II)-B-5), although the maximum temperature of ZrCo comes to 110°C, it is taken as 120°C taking into account the margin. The partial pressure in equilibrium at this time is obtained using the method given below.

(1) Obtain the atomic ratio for ZrCo (750 g) vs. the absorption of tritium (25 g)

(2) Obtain the equilibrium partial pressure for the hydrogen isotope (at 120°C) from the following relationship: tritium equilibrium partial pressure vs. hydrogen isotope atomic weight/ZrCo atomic weight ratio.

where,

X_{Zr} ; Atomic weight of Z_r $X_{Zr} = 91.22$ [g]

X_{Co} ; Atomic weight of C_o $X_{Co} = 58.93$ [g]

The atomic weight of ZrCo, X_{ZrCo}, is calculated as follows:

$$X_{ZrCo} = 91.22 + 58.93$$

$$= 150.15 \quad [g]$$

The atomic weight, X_T, of the tritium is:

$$X_T = 3 \quad [g]$$

The atomic ratio of ZrCo vs. tritium is calculated as follows:

Number of mole in ZrCo:

$$n_{ZrCo} = \frac{750}{150.15} = 5.00 \quad [mol]$$

Number of mole in tritium is calculated as follows:

$$n_T = 25/6 = 4.167 \quad [mol]$$

Consequently, the atomic ratio;

$$n_T/n_{ZrCo} = \frac{4.167 \times 2}{5.00} = 1.667 \simeq 1.7$$

The relationship between the equilibrium partial pressure of tritium and temperature and the T vs. ZrCo (atomic ratio) is as shown in Fig. (II)-C.2.

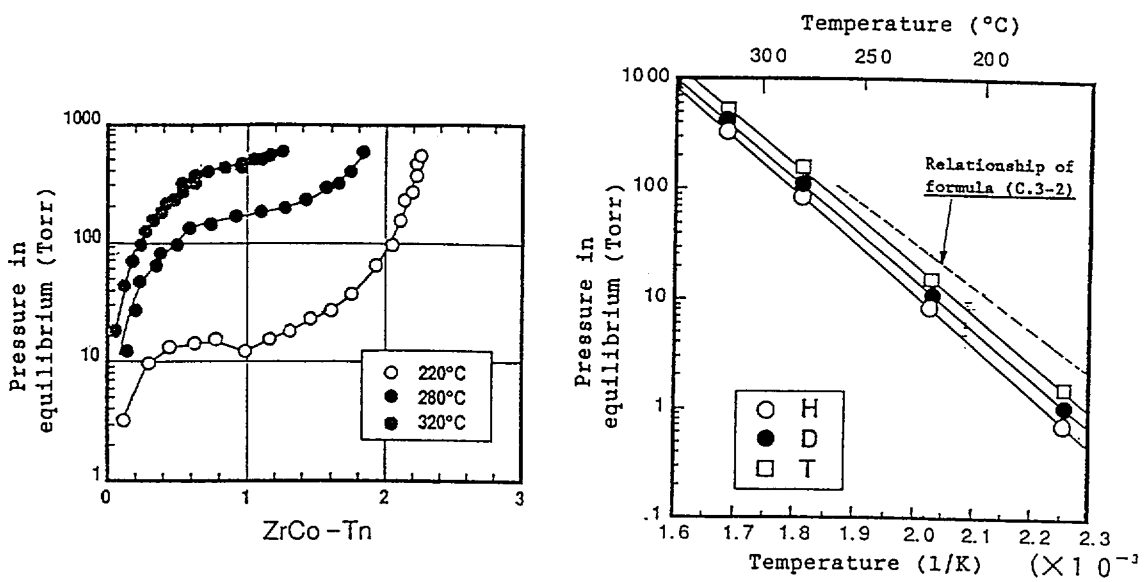


Fig. (II)-C.2 Equilibrium partial pressure of tritium[6]

The relationship between equilibrium partial pressure of hydrogen isotope vs. temperature is calculated using the following formula[2] when ZrCo: T (H) is 1:1.7. As shown in Fig. (II)-C.2, the formula provides an estimated value with a good margin, in the range lower than 250°C.

$$\log (P_T) = -4042/T + 11.75 \quad \text{(C.3-2)}$$

where, replacing T = 393K (120°C) ultimately

P_T = 29.5 [Pa]

Allowing a margin, the evaluation is conducted using a value of P_a = 50. Thus, D_{T2}, the ratio of the number of tritium molecules to the number of helium molecules in the primary container is determined as follows:

$$D_{T2} = \frac{P_T}{P_{ux}} \quad \text{(C.3-3)}$$

P_T ; Tritium partial pressure $P_H = 50$ [Pa]

P_{ux} ; Primary container internal pressure

1.72×10^5 [Pa•A]

$$D_{T2} = \frac{50}{1.72 \times 10^5} = 2.91 \times 10^{-4}$$

Since L = 6.09×10^{-2} [Pa•m³/h] the leak rate of tritium gas in mole quantity from the seal part is expressed as follows:

$$L_{T2} = D_{T2} \cdot L \cdot \frac{1}{R \cdot T} \quad \text{(C.3-4)}$$

L_{T2} ; Tritium gas leak rate in mole quantity

[mol/h]

D_{T2} ; 2.91×10^{-4}

$L = 6.09 \times 10^{-2}$ [$Pa \cdot m^3/sec$]

R ; Gas constant $R = 8.31$ [$\frac{Pa \cdot m^3}{mol \cdot K}$]

T ; Seal-part temperature $T = 293$ [K]

(The temperature of the seal part is considered to be somewhat lower, for giving adequate margin.)

$$L_{T2} = 2.91 \times 10^{-4} \times 6.09 \times 10^{-2} \times \frac{1}{8.31 \times 293}$$

$= 7.28 \times 10^{-9}$ [mol/h]

Thus, tritium leak rate, L_T [TBq/h] from the seal part due to pressure differential is calculated as follows:

$$L_T = L_{T2} \cdot X \cdot Y \qquad (C.3\text{-}5)$$

X ; Molecular weight of tritium $X = 6$[g/mol]

Y ; Specific radioactivity of tritium

$Y = 3.7 \times 10^2$ [TBq/g]

$$L_T = 7.28 \times 10^{-9} \times 6 \times 3.7 \times 10^2$$

$= 1.62 \times 10^{-5}$ [TBq/h]

C.3.1.2 Tritium Permeation from the Primary Container Body

Since tritium is a hydrogen isotope, the permeation of hydrogen isotope must be evaluated. The tritium permeation rate from the primary container body is evaluated as follows. To provide an adequate margin, the following assumption, that is similar to the leakage from the seal part of the primary container due to pressure difference is made.

(a) Although integrity of the content (capsule) is verified by the structural analysis to be conservative, an assumption that the capsule possesses no containment property is made.

(b) The radioactive material subject to permeation is assumed to be gaseous tritium inside the primary container (inside the capsule) equivalent to a component pressure in equilibrium of 50 Pa.

(c) The concentration distribution of tritium formed inside the primary container construction material through diffusion takes sometime to be the steady state. However, here it is assumed that ample time has passed and that it is already steady. The tritium concentration distribution in the cylinder and plane surface as shown in Fig. (II)-C.3, can be expressed using the following formula;

$$\frac{\partial C(r,t)}{\partial t} = D \left\{ \frac{\partial^2 C(r,t)}{\partial r^2} + \frac{1}{r} \frac{\partial C(r,t)}{\partial r} \right\} \quad \text{(C.3-6)}$$

(Cylinder)

$$\frac{\partial C(x,t)}{\partial t} = D \frac{\partial^2 C(x,t)}{\partial x^2} \quad \text{(Flat plate) (C.3-7)}$$

where,

C (r,t) ; Concentration of tritium in the container wall [STP-T_2/cm^3]

D	;	Diffusion factor	[cm^2/sec]
t	;	Time	[sec]
r	;	Location in radial direction ($r_1 \le r \le r_2$)	[cm]
x	;	Location in direction of plate thickness ($0 \le x \le \ell$)	[cm]
r_1	;	Internal radius of container	[cm]
r_2	;	External radius of container	[cm]
ℓ	;	Plate thickness of container	[cm]

where, since a steady state is considered to have been reached:

$$\frac{\partial C}{\partial t} = 0$$

Subsequently,

$$\frac{d^2C}{dr^2} + \frac{1}{r}\frac{dC}{dr} = 0 \qquad (C.3\text{-}8)$$

$$\frac{d^2C}{dx^2} = 0 \qquad (C.3\text{-}9)$$

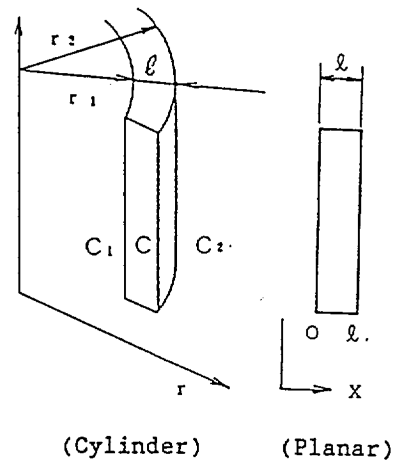


Fig. (II)-C.3 Evaluation model for quantity of permeation

Thus, the tritium permeation rate Q is calculated using the following formula;

(Cylinder)

$$Q = \frac{-Y \times 6}{22.4 \times 10^3} \times A \cdot D \left.\frac{dC}{dr}\right|_{r = r_2}$$

$$Q = -9.91 \times 10^{-2} A \cdot D \left.\frac{dC}{dr}\right|_{r = r_2} \qquad (C.3\text{-}10)$$

(Flat plate)

$$Q = \frac{-Y \times 6}{22.4 \times 10^3} \times A \cdot D \frac{dC}{dx}\Big|_{x = \ell}$$

$$Q = -9.91 \times 10^{-2} \times A \cdot D \frac{dC}{dx}\Big|_{x = \ell} \qquad \text{(C.3-11)}$$

where,

Q ; Quantity of tritium permeated [TBq/sec]

Y ; Specific radioactivity of tritium $Y = 3.7 \times 10^2$ [TBq/g]

A ; Tritium permeation area of packaging [cm^2]

The followings are applied as the boundary conditions.

$$C\ (r_1) = SP^{1/2} \qquad \text{(C.3-12)}$$

$$C\ (r_2) = 0 \qquad \text{(C.3-13)}$$

where,

S ; Solubility of tritium in packaging wall [$STPcm^{3-}T_2/cm^3 \cdot torr^{1/2}$]

P ; Pressure of tritium gas inside container [torr]

From the above, the values, Q, are determined as follows:

$$Q = 9.91 \times 10^{-2} A \cdot D \cdot S \cdot P^{1/2} \times \frac{1}{\ell n\ (r_2/r_1)} \times \frac{1}{r_2} \times 3600$$

[TBq/h]

(Cylinder) (C.3-14)

$$Q = 9.91 \times 10^{-2} A \cdot D \cdot S \cdot P^{1/2} \times \frac{1}{\ell} \times 3600 \qquad \text{[TBq/h]}$$

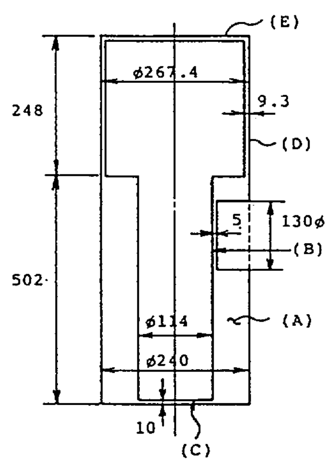
(Flat plate) (C.3-15)

The D and S of stainless steel, which is the construction material of primary container, are determined as follows.[1][2]

Table (II)-C.3 Effective Diffusion Factor of Tritium (D) and Solubility (S) of Tritium into Container Wall

Temperature	Effective diffusion factor of tritium [D] [cm^2/sec]	Solubility of tritium into packaging wall [S] [$STP\text{-}cm^3/cm^3 \cdot Torr^{1/2}$]
80	1.90×10^{-10}	3.04×10^{-3}
100	4.32×10^{-10}	3.60×10^{-3}
120	9.14×10^{-10}	4.18×10^{-3}
140	1.82×10^{-9}	4.79×10^{-3}
160	3.42×10^{-9}	5.41×10^{-3}
180	6.12×10^{-9}	6.05×10^{-3}
200	1.05×10^{-8}	6.70×10^{-3}

The model used for the primary container is as shown in Fig. (II)-C.4. The flange part for the primary container lid and primary container body is neglected in order to provided a good margin. The valve cover part is assumed to be a flat plate having a minimum thickness of (5 mm).



	Location	Plate thickness [cm]	Surface area [cm^2]	Shape
(A)	Primary container body side surface	6.3	3.65×10^3	Cylinder
(B)	Valve cover	0.5	1.33×10^2	Planar plate
(C)	Primary container bottom part	1.0	1.02×10^2	ditto
(D)	Primary container lid side surface	0.93	2.08×10^3	Cylinder
(E)	Primary container lid upper surface	0.93	5.61×10^2	Planar plate

Fig. (II)-C.4 Evaluation model for quantity of permeation from the primary container

The tritium pressure is considered to be 50 Pa (= 0.38 torr), as stipulated in article C.3.1.1.

Using formulas (C.3-14) and (C.3-15), the permeation rate of each part is calculated and the following values are obtained;

(Part A)

$$9.91 \times 10^{-2} \times 3.65 \times 10^{3} \times 4.32 \times 10^{-10} \times 3.60 \times 10^{-3} \times (0.38)^{1/2} \times \frac{3600}{12 \times \ell n\,(12/5.7)} = 1.40 \times 10^{-7} \quad [\mathrm{TBq/h}]$$

(Part B)

$$9.91 \times 10^{-2} \times 1.33 \times 10^{2} \times 4.32 \times 10^{-10} \times 3.60 \times 10^{-3} \times (0.38)^{1/2} \times \frac{3600}{0.5} = 9.10 \times 10^{-8} \quad [\mathrm{TBq/h}]$$

(Part C)

$$9.91 \times 10^{-2} \times 1.02 \times 10^{2} \times 4.32 \times 10^{-10} \times 3.60 \times 10^{-3} \times (0.38)^{1/2} \times \frac{3600}{1} = 3.49 \times 10^{-8} \quad [\mathrm{TBq/h}]$$

(Part D)

$$9.91 \times 10^{-2} \times 2.08 \times 10^{3} \times 4.32 \times 10^{-10} \times 3.60 \times 10^{-3} \times (0.38)^{1/2} \times \frac{3600}{13.37 \times \ell n\,(13.37/12.44)} = 7.38 \times 10^{-7} \quad [\mathrm{TBq/h}]$$

(Part E)

$$9.91 \times 10^{-2} \times 5.61 \times 10^{2} \times 4.32 \times 10^{-10} \times 3.60 \times 10^{-3} \times (0.38)^{1/2} \times \frac{3600}{0.93} = 2.06 \times 10^{-7} \quad [\mathrm{TBq/h}]$$

From the above, the permeation rate from the primary container under normal conditions of transport is determined as follows:

$Q = 1.21 \times 10^{-6}$ [TBq/h]

C.3.1.3 Evaluation of Leak Rate from the Primary Container under Normal Conditions of Transport

The leak rate from the primary container, which is the containment boundary of the package, can be obtained by adding the leak rate of tritium through the seal part depending on the pressure differential and tritium permeation rate, that is:

$$Q_{Total} = L_T + Q \quad (C.3\text{-}17)$$

where,

Q_{Total} ; Leak rate from the primary container [TBq/h]]

L_T ; Tritium leak rate from seal part due to pressure difference [TBq/h]

(Quoted from article C.3.11.)

Q ; Tritium permeation rate

(Quoted from article C.3.1.2.) [TBq/h]

$Q_{Total} = 1.62 \times 10^{-5} + 1.21 \times 10^{-6}$

$= 1.74 \times 10^{-5}$ [TBq/h]

The allowable leak rate of tritium is, $A_2 \times 10^{-6} = 40 \times 10^{-6}$ [TBq/h].

$$\frac{Q_{Total}}{A_2 \times 10^{-6}} = \frac{1.74 \times 10^{-5}}{40 \times 10^{-6}} = 0.435$$

Thus, the above value satisfies the criteria.

C.3.2 Pressurization of Containment System

This package is to be transported in a dry environment filled with He gas. The inside of the package is pressurized by the thermal expansion of the He gas in the primary container as the temperature rises. The internal pressure built up inside the container is as described in Table (II)-B.3. The pressure strength analysis of the containment system is executed on the basis of the design pressure, as shown in Table (II)-A.4, allowing a margin of safety beyond the internal pressure given in Table (II)-B.3.

He gas is generated by the decay of tritium. However, the internal pressure imposed by He generation is lower than the primary container internal pressure even if the transport period of 1 year is taken into consideration. Thus, no probable effect on the pressure inside the primary container are foreseen.

C.3.3 Coolant Contamination

As no coolant is used in the packaging, this article is not considered in the investigation.

C.3.4 Coolant Loss

This article is not considered for the same reason indicated above.

C.4 Accident Conditions of Transport

The results of the structural analysis given in (II)-A verified that the containment device of this package maintains its integrity with the loading conditions under the accident conditions of transport, which is a prerequisite for BU-type packaging. The results of the thermal analysis given in (II)-B also revealed that the integrity of this package is not compromised by the temperature and pressure likely to be incurred under accident conditions of transport.

Consequently, for the purpose of this analysis, leakage of tritium from the seal part related to pressure differential is evaluated on the basis of the acceptance criteria applied in the leaktightness test of O-ring parts of the primary container and valve cover which is to be executed prior to shipment of the package. The evaluation for the permeation of tritium is executed using the design temperature specified on the basis of the results of the thermal analysis. It should be verified that sum of these values does not exceed the criteria value stipulated by the regulation.

C.4.1 Fission Gases

The content is not fissile material, thus this article is not applicable.

C.4.2 Leaks of Radioactive Material

C.4.2.1 Leakage of Tritium from the Seal Part of Primary Container Due to Pressure Differential

(1) Rate of gas leakage from the primary container

The leak rate of gas from the primary container under accident conditions of transport is determined using compensation for temperature and pressure against the leak rate criteria assuming there is some leakage which is within the acceptance criteria of the preshipment leaktightness test for the primary container lid and valve cover O-ring parts.

The following formula is used to calculate the leak rate of gas under accident conditions of transport:

$$L = L_c \frac{\eta_y \cdot (P_{ux}^2 - P_{dx}^2)}{\eta_x \cdot (P_{uy}^2 - P_{dy}^2)} \qquad (C.3\text{-}1)$$

where,

L ; Leak rate of gas under accident conditions of transport [Pa•m^3/sec]

L_c ; Gas leakage acceptance criteria at leaktightness test [Pa•m^3/sec]

η_x ; Gas viscosity factor under accident conditions of transport [kg/m•sec]

η_y ; Gas viscosity factor of leaktightness test [kg/m•sec]

P_{ux} ; Primary container internal pressure under accident conditions of transport [kPa•A]

P_{dx} ; Atmospheric pressure under accident conditions of transport [kPa•A]

P_{uy} ; Upstream side pressure at leaktightness test [kPa•A]

P_{dy} ; Downstream side pressure of leaktightness test [kPa•A]

where,

L_c ; $2 \times 5.06 \times 10^{-6}$ [Pa•m^3/sec]

η_x ; 19.93×10^{-6} (at 20°C)*1 [Pa•m/sec]

η_y ; 19.93×10^{-6} (at 20°C) [Pa•m/sec]

P_{ux} ; 121 [kPa•G] = 223 [kPa•A]

P_{dx} ; 25 [kPa•A]

P_{uy} ; 30 [kPa•G] = 132 (initial filling pressure at 20°C) [kPa•A]

P_{dy} ; 0 [kPa•A]

*1 : Since the viscosity of the gas increases as the temperature rises, a margin of safety is provided by employing a normal temperature that is less than the design temperature under accident conditions of transport

From the above, the quantity of gas leakage from the primary container under accident conditions of transport is calculated as follows;

$$L = 1.012 \times 10^{-5} \times \frac{19.93 \times 10^{-6}}{19.93 \times 10^{-6}} \times \frac{223^2 - 25^2}{132^2 - 0}$$

$= 2.86 \times 10^{-5}$ [Pa•m³/sec]

$= 1.73 \times 10^{1}$ [Pa•m³/week]

(2) Quantity of leakage of radioactive material (tritium)

For the evaluation of leakage of radioactive material (tritium) under accident conditions of transport, the following assumptions, that are identical to those stated for the test under normal conditions of transport are made for reasons of safety.

(a) Results of the structural analysis of the content (capsule) indicate that the integrity of package is maintained. However, a margin of safety is provided by assuming that the capsule does not have the containment property.

(b) The tritium gas inside the primary container (inside the capsule) is assumed to be the radioactive material concerned with leakage. In this case, 180°C is used for the temperature of ZrCo for the margin although the maximum temperature according to the results of thermal analysis is 158°C. The partial pressure in equilibrium at this time is obtained using the method given below, similar to article C.3.1.1.

$$\log (P_T) = -4042/T + 11.75 \qquad (C.3-2)$$

where, replacing T = 453K (180°C) ultimately

$\log (P_T) = 2.83$

$P_T = 671$ [Pa]

Adding a margin for safety to the above value, evaluation is conducted using $P_T = 700$ [P_a].

Consequently, the ratio of the number of molecules of helium vs. tritium is determined to be as follows:

$$D_{T2} = \frac{P_T}{P_{ux}} \qquad (C.3-3)$$

P_T ; Tritium partial pressure $P_T = 700$ [Pa]

P_{ux} ; Primary container internal pressure

$P_{ux} = 2.23 \times 10^5$ [Pa•A]

$$D_{T2} = \frac{700}{2.23 \times 10^5} = 3.14 \times 10^{-3}$$

And $L = 1.73 \times 10^1$ [Pa•m^3/week]. Thus the tritium gas mole leakage from the seal-part is calculated using the following formula:

$$L_{T2} = D_{T2} \cdot L \cdot \frac{1}{R \cdot T} \qquad (C.3-4)$$

L_{T2} ; Tritium gas leakage in mole [mol/week]

D_{T2} ; 3.14×10^{-3}

$L = 1.73 \times 10^1$ [Pa•m^3/week]

R ; Gas constant R = 8.31 $\left[\frac{Pa \cdot m^3}{mol \cdot K}\right]$

T ; Seal-part temperature T = 293 [K]

(In order to allow an adequate margin of safety, the temperature in the seal part is considered to be lower than the actual temperature.)

$$L_{T2} = 3.14 \times 10^{-3} \times 1.73 \times 10^{1} \times \frac{1}{8.31 \times 293}$$

$$= 2.23 \times 10^{-5} \quad [\text{mol/week}]$$

From the above, the tritium leak rate L_T [TBq/week] from the seal part due to pressure differential is calculated as follows:

$$L_T = L_{T2} \cdot X \cdot Y \tag{C.3-5}$$

X ; Molecular weight of tritium gas X = 6 [g/mol]

Y ; Specific radioactivity of tritium

$Y = 3.7 \times 10^{2}$ [TBq/g]

$$L_T = 4.95 \times 10^{-2} \quad [\text{TBq/week}]$$

C.4.2.2 Permeation of Tritium from Primary Container Body

Evaluation is conducted to determine tritium leak rate by permeating from the primary container body under accident conditions of transport based on the same assumptions as those for normal conditions of transport for reasons of safety (refer to article C.3.1.2).

That is to say;

(a) It is that no containment property is available, despite the fact that the construction analysis verified that the integrity of the capsule is not be impaired.

(b) The radioactive material in danger of permeation is assumed to be tritium existing in a gaseous state inside the primary container (inside the capsule) corresponding to a 700-Pa equilibrium partial pressure in equilibrium.

(c) The concentration distribution of the tritium inside the primary container construction material is assumed to be stabilized in a steady state;

The quantity of tritium permeation in each of the cylindrical wall and flat plate wall is thus calculated as follows:

$$Q = 9.91 \times 10^{-2} A \cdot D \cdot S \cdot P^{1/2} \times \frac{1}{\ell n (r_2/r_1)\ r_2} \times 3600 \times 24 \times 7 \quad \text{[TBq/week]}$$

(Cylinder) (C.3-14)

$$Q = 9.91 \times 10^{-2} A \cdot D \cdot S \cdot P^{1/2} \times \frac{1}{\ell} \times 3600 \times 24 \times 7$$

(Flat plate) (C.3-15)

where,

Q	; Permeation of T_2	[TBq/week]
A	; Area of permeation	[cm^2]
D	; Effective diffusion factor	[cm^2/sec]

S ; Solubility of tritium into container wall [$STPcm^{3}$-$T_2/cm^3 \cdot torr^{1/2}$]

P ; Partial pressure of tritium [torr]

r_2 ; Outer radius of cylinder wall [cm]

r_1 ; Inner radius of cylinder wall [cm]

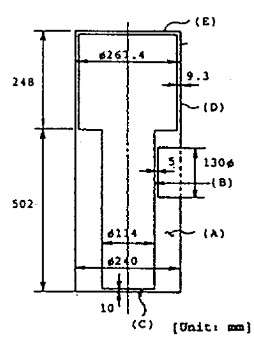
ℓ ; Plate thickness [cm]

The design temperature of the primary container under accident conditions of transport is 200°C, where the diffusion factor, D, and solubility of tritium into the container wall, S, are as given below, according to Table (II)-C.3.

$D = 1.05 \times 10^{-8}$ [cm^2/sec]

$S = 6.70 \times 10^{-3}$ [$STPcm^3$-$T_2/cm^3 \cdot torr^{1/2}$]

In addition to the above, a model of the primary container such as that used for normal conditions of transport is employed (Fig. (II)-C.4). In this model, the tritium pressure under accident conditions of transport is considered to be P_T = 700 Pa (= 5.25 torr), as determined in article C.4.2.1.



	Location	Plate thickness [cm]	Surface area [cm^2]	Shape
(A)	Primary container body side surface	6.3	3.65×10^3	Cylinder
(B)	Valve cover	0.5	1.33×10^2	Planar plate
(C)	Primary container bottom part	1.0	1.02×10^2	ditto
(D)	Primary container lid side surface	0.93	2.08×10^3	Cylinder
(E)	Primary container lid upper surface	0.93	5.61×10^2	Planar plate

Fig. (II)-C.4 Evaluation model for quantity of permeation from the primary container

The permeation of tritium through each part of the primary container at various locations is evaluated using formulae (C.3-14) and (C.3-15) as follows.

(Part A)

$$9.91 \times 10^{-2} \times 3.65 \times 10^{3} \times 1.05 \times 10^{-8} \times 6.70 \times 10^{-3}$$

$$\times (5.25)^{1/2} \times \frac{24 \times 7 \times 3600}{\ell n\,(12/5.7)} \times \frac{1}{12} = 3.95 \times 10^{-3} \quad [\mathrm{TBq/week}]$$

(Part B)

$$9.91 \times 10^{-2} \times 1.33 \times 10^{2} \times 1.05 \times 10^{-8} \times 6.70 \times 10^{-3}$$

$$\times (5.25)^{1/2} \times \frac{24 \times 7 \times 3600}{0.5} = 2.57 \times 10^{-3} \quad [\mathrm{TBq/week}]$$

(Part C)

$$9.91 \times 10^{-2} \times 1.02 \times 10^{2} \times 1.05 \times 10^{-8} \times 6.70 \times 10^{-3}$$

$$\times (5.25)^{1/2} \times \frac{24 \times 7 \times 3600}{1} = 9.85 \times 10^{-4} \quad [\mathrm{TBq/week}]$$

(Part D)

$$9.91 \times 10^{-2} \times 2.08 \times 10^{3} \times 1.05 \times 10^{-8} \times 6.70 \times 10^{-3}$$

$$\times (5.25)^{1/2} \times \frac{24 \times 7 \times 3600}{13.37 \times \ell n\,(13.37/12.44)} = 2.08 \times 10^{-2}$$

[TBq/week]

(Part E)

$$9.91 \times 10^{-2} \times 5.61 \times 10^{2} \times 1.05 \times 10^{-8} \times 6.70 \times 10^{-3}$$

$$\times 5.25^{1/2} \times \frac{24 \times 7 \times 3600}{0.93} = 5.83 \times 10^{-3} \quad [\mathrm{TBq/week}]$$

From the above, the permeation of tritium from the primary container under accident conditions of transport is determined to be as follows:

$Q = 3.41 \times 10^{-2}$ [TBq/h]

C.4.2.3 Evaluation of Leakage from the Primary Container under Accident Conditions of Transport

The leakage from the primary container, which is the containment boundary of the package, can be obtained by adding the quantities of tritium leakage and tritium permeation through the seal part depending on the pressure differential, that is:

$$Q_{Total} = L_T + Q \qquad (C.3\text{-}17)$$

where,

Q_{Total} ; Leakage from primary container [TBq/week]

L_T ; Tritium leakage from seal-part due to pressure differential(Quoted from article C.4.2.1.) [TBq/week]

Q ; Tritium permeation (Quoted from article C.4.2.2.) [TBq/week]

$Q_{Total} = 4.95 \times 10^{-2} + 3.41 \times 10^{-2}$

$= 8.36 + 10^{-2}$ [TBq/week]

The leak rate allowable is $A_2 = 40.$ [TBq/week]

$$\frac{Q_{Total}}{A_2} = \frac{8.36 \times 10^{-2}}{40} = 2.09 \times 10^{-3}$$

Thus, criteria are satisfied.

C.5 Summary and Evaluation of Results

Radioactive material (tritium) leakage from the primary container is evaluated. The evaluation took into account tritium leakage from the seal part of the primary container due to pressure differential, tritium permeation via absorption into the primary container construction materials, dissolution and diffusion.

As concerns leakage of radioactive material from the primary container, the quantity is evaluated as 0.435 times the value of criteria $A_2 \times 10^{-6}$ [TBq/h] under normal conditions of transport, and 2.09×10^{-3} times A_2 [TBq/week] under accident conditions of transport. Thus the criteria value is satisfied in both cases.

C.6 Attached Documents

C.6.1 Reference Literatures

(1) Tritium Packaging Investigation Committee Report, Nuclear Safety Bureau, Science and Technology Agency, (June, 1986).

(2) "Equilibrium Hydrogen Pressure of ZrCo-H, etc., as materials for tritium getter," Masao Nagasaki, Tetsuyuki Konishi; Hiroyuki Katsuda and Yuji Naruse. Japan Atomic Power Association Subcommittee, Transactions 1985 (held Oct. 2-5, 1985: Tohoku University).

(3) WFPS-TME-004 "Tritium Properties and Related Quantities used in the TFTR Conceptual Design" (1975)

(4) ANSI-N14.5

"American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials" (1977)

(5) Heat Transmission Technology Information, Rev. 4, Japan Mechanical Engineers Association (1986).

(6) Internal Data, Japan Atomic Energy Research Institute.

(II)-D Shielding Analysis

(II)-D Shielding Analysis

This package contains Tritium as a form of hydride of getter(ZrCo) in a capsule which is the material to be stored. Tritium releases only soft β-ray(energy 18.6 keV in max. and 5.6 keV in average) and the maximum range is much shorter than the wall thickness of packaging therefore it is possible that the dose rate at the surface of package is ignored.

(II)-E Criticality Analysis

(II)-E Criticality Analysis

This package dose not contains fissile material therefore, it is not necessary to carry out criticality analysis.

Section (III) Manufacturing of Packaging

Section (III) Manufacturing of Packaging

Each of the processes required to manufacture the packaging - procurement of materials, cutting, forming, shearing, welding, adjustment, testing and inspection shall be undertaken so as to comply with ordinance and notification issued by the Japanese competent authorities.

This packaging is manufactured according to the "manufacturing method of packaging" cited in article A, so as to satisfy the dimension and structure requirements stipulated by each analysis of the structure, thermal, and containment described in Section II "Safety Analysis of Radioactive Package." Compliance with each of the design conditions is ensured by means of the testing and inspection described in article B "Testing, Inspection Method, etc." To maintain consistency in the design, manufacture, testing and inspection, the "quality control" defined in article D is applied.

Section (III)-A Manufacturing Method of Packaging

(III)-A Manufacturing Method of Packaging

A.1 Outline

The major components of this packaging are as listed below:

(1) Primary container body:

Primary container body, valve cover, valve cover tie-down bolts, capsule flange fixing bolts, metal O-ring, elastomer O-ring and valves.

(2) Primary container lid:

Primary container lid, primary container lid tie-down bolts, metal O-ring, elastomer O-ring and eyebolt fixing boss.

(3) Protective container body:

External plate, internal plate, flange, external base plate, inner fins, internal base plate, shock absorber, fusible plug, and packing.

(4) Protective container lid:

External plate, internal plate, flange, shock absorber, fusible plug, protective container lid tie-down bolts, eyebolt mounting seats and key.

(5) Spacer:

Spacer body and rubber cushioning

The manufacturing of the packaging shall be implemented according to the comprehensive packaging manufacturing schedules and detailed drawings descriptions of which are to follow, so as to satisfy the requirements of the "Safety Analysis of Radioactive Package" cited in Section (II) for each of the component parts listed above.

A.1.1 Comprehensive Manufacturing Schedule and Detailed Drawings of Packaging

The outline and composition of the comprehensive manufacturing procedure and detailed drawings of the packaging are found in Table (III)-A.1

Table (III)-A.1 List of Detailed Drawings

No.	Drawing name	Description
Fig. (III)-A.1	Comprehensive manufacturing procedure of packaging	Outline of manufacturing procedures and method of packaging in the whole are shown.
Fig. (III)-A.2	Packaging overall assembly diagram	Assembled status of Figs. (III)-A.3 to (III)-A.8 are shown.
Fig. (III)-A.3	Primary container assembly diagram	Assembled status of Fig. (III)-A.4 and Fig. (III)-A.5 are shown.
Fig. (III)-A.4	Primary container body detailed drawing	Shape and dimensions are indicated.
Fig. (III)-A.5	Primary container lid detailed drawing	
Fig. (III)-A.6	Protective container body detailed drawing	
Fig. (III)-A.7	Protective container lid detailed drawing	
Fig. (III)-A.8	Spacer detailed drawing	

A.1.2 Outline of Manufacturing Method and Manufacturing Procedures

This packaging is manufactured according to the procedures indicated in Fig. (III)-A.1.

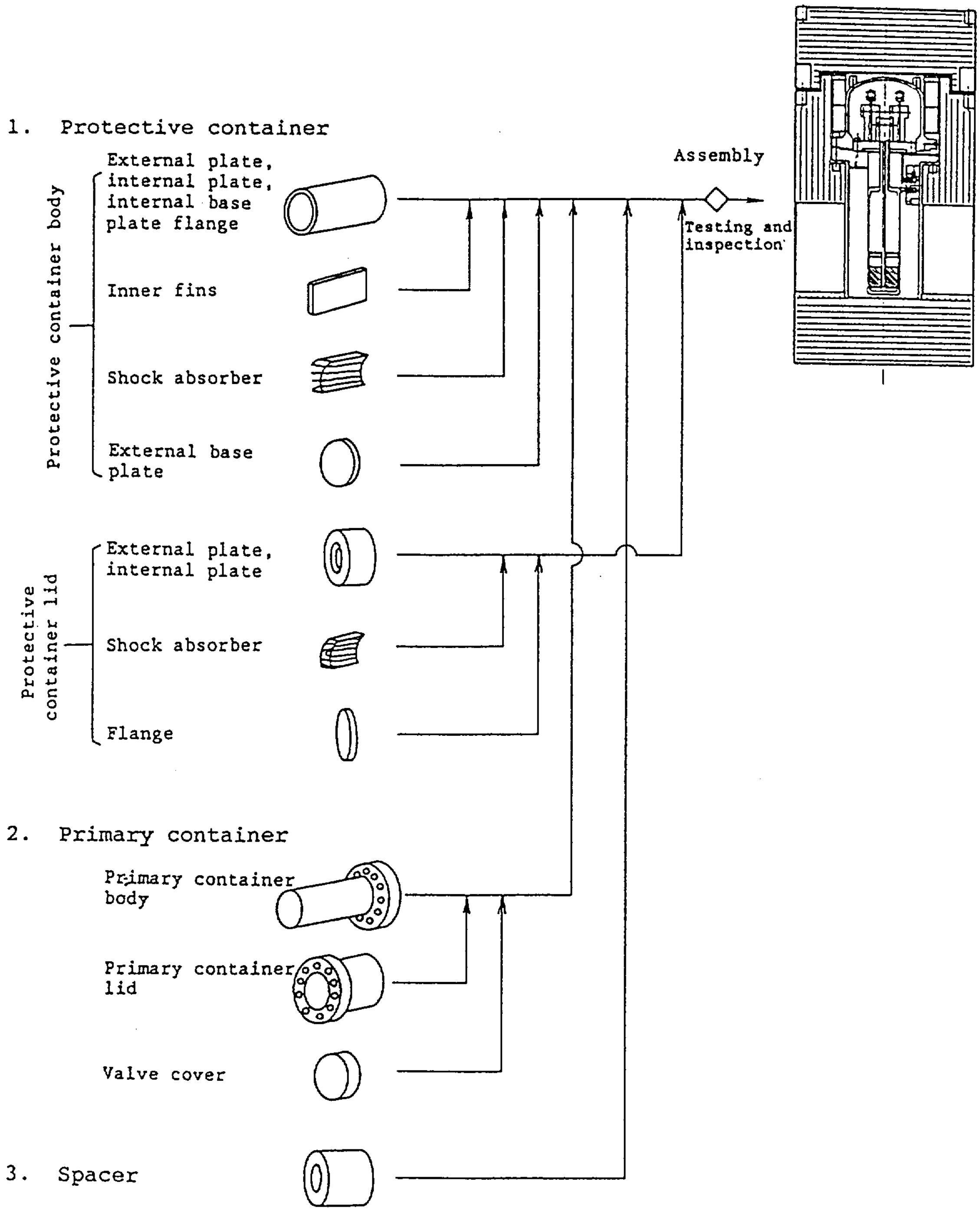


Fig. (III)-A.1 Overall procedures for manufacturing the packaging

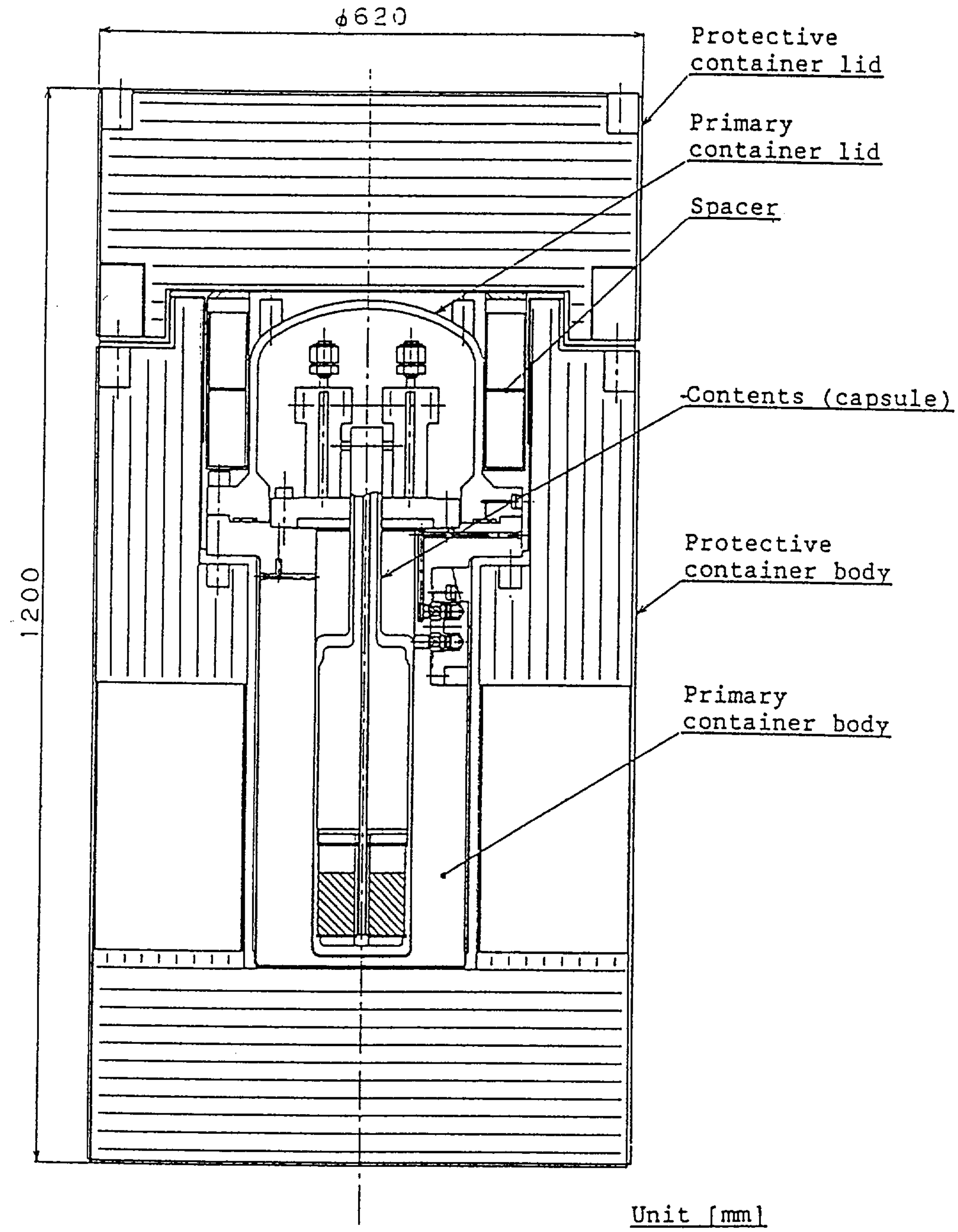


Fig. (III)-A.2 General assembly diagram of the packing

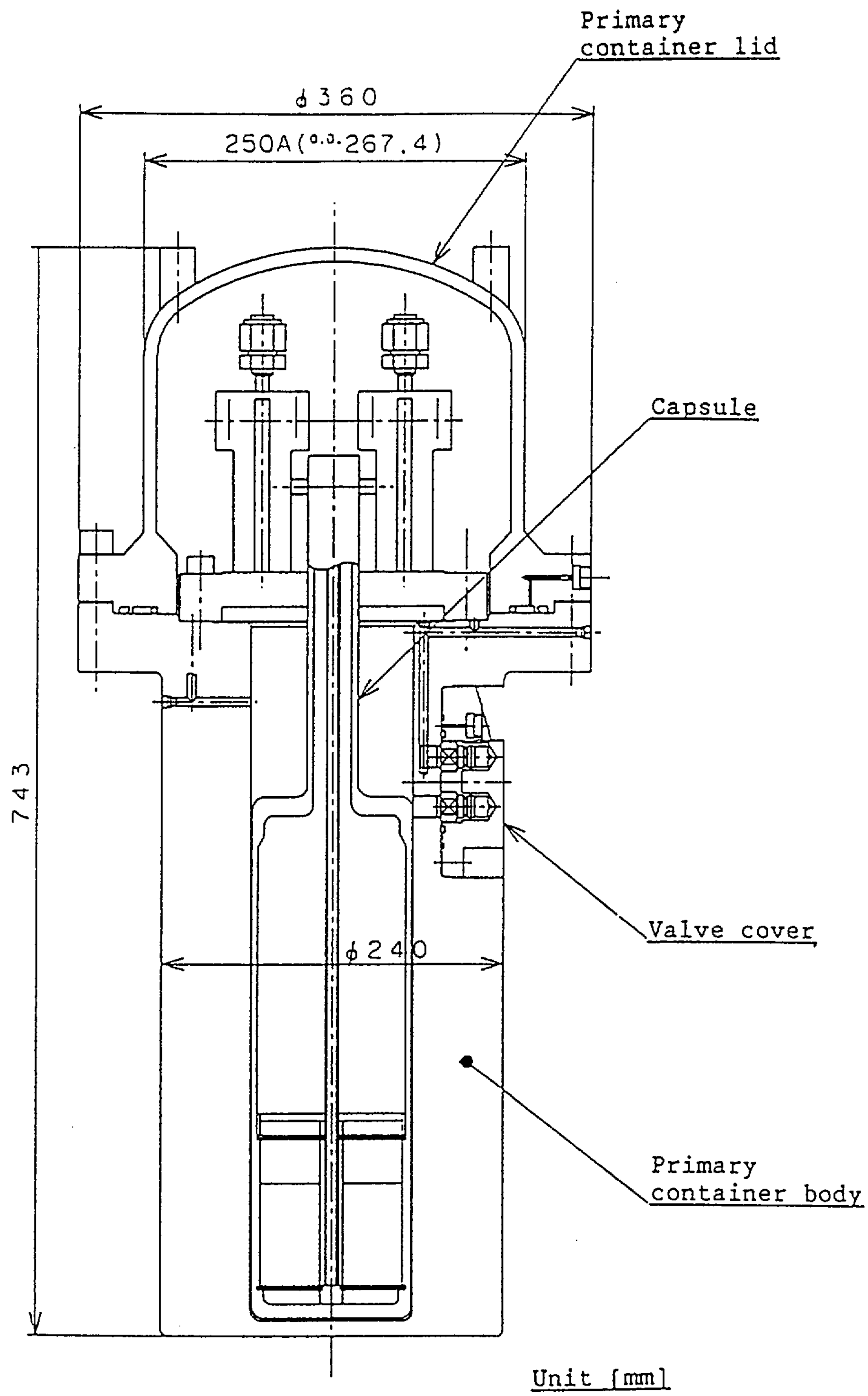


Fig. (III)-A.3 Assembly drawing of the primary container

PROPRIETARY

Fig. (III)-A.4 Detailed drawing of the primary container body

PROPRIETARY

Fig. (III)-A.5 Detailed drawing of the primary container lid

PROPRIETARY

Fig. (III)-A.6 Detailed drawing of the protective container body

PROPRIETARY

Fig. (III)-A.7 Detailed drawing of the protective container lid

PROPRIETARY

Fig. (III)-A.8 Detailed drawing of the spacer

A.2 Materials

A.2.1 Sheet Materials

The sheet materials to be used in the manufacture of this packaging are listed in Table (III)-A.2.

Table (III)-A.2 Sheet Materials to be Used for Manufacture of Packaging

Material	Specification
Hot rolled Stainless steel plate	JIS G 4304 (1987) SUS304-HP
Cold rolled Stainless steel	JIS G 4305 (1987) SUS304-CP

A.2.2 Piping Materials

The piping materials used for manufacture of the packaging are shown in Table (III)-A.3.

Table (III)-A.3 Piping Materials Used for Manufacture of the Packaging

Material	Specification
Stainless steel pipes for piping	JIS G 3456 (1988) SUS304-TP

A.2.3 Forgings, Bolts, Nuts, etc.

The forgings, bolts and nuts to be used in manufacturing the packaging, are listed in Table (III)-A.4.

Table (III)-A.4 Forgings, Bolts and Nuts, etc. Used in Manufacturing the Packaging

Material	Specification
Stainless steel forging	JIS G 3214 (1988) SUSF-304
Stainless steel bar	JIS G 4303 (1988) SUS304-B
	JIS G 4303 (1988) SUS630-H1150

A.2.4 Electrode for Welding, Covered Electrode and Wires

The covered electrode to be used in manufacturing the packaging must be selected from among those stipulated by the JIS (Japanese Industrial Standard) Standard.

A.2.5 Special Materials

Special materials to be used in manufacturing the packaging are those listed in Table (III)-A.5.

Table (III)-A.5 Special Materials

Application	Material		Specification
Shock absorber	Balsa wood		Density: 0.16±0.02 [g/cm^3] Moisture content: Less than 10%
Metal O-ring	External plate	Aluminum	JIS H 4000 (1988)
	Internal plate	Inconel	JIS G 4902 (1991)
	Spring	Inconel	JIS G 4901 (1988)
Elastomer O-ring	Silicon rubber		Manufacturer's Standard
Inner fin	Copper		JIS H 3100 (1986)
Fusible plug	Solder		JIS Z 3282 (1986)
Packing	E.P.D.M.		Manufacturer's Standard
Spacer	Aluminum		JIS H 4000 (1988)

A.2.6 Mill Sheet

The contents of descriptions to be given on the mill sheets of materials to be used in manufacturing the packaging are as indicated in Table (III)-A.6. Information required includes the name of the manufacturer, manufacturing lot number, specification or applicable standard, description of material or abbreviated symbol, etc.

Table (III)-A.6 Contents of Mill Sheet Description

Material	Specification
Plate material	Chemical components, mechanical properties, dimensions and weight
Pipe material	ditto
Bar material	ditto
Nuts and bolts	Chemical components, mechanical properties, dimensions
Special materials	Type, type number, grade, etc.

A.3 Welding

A.3.1 Quality Assurance Plan for Welding, etc.

The welding of the packaging is performed using the welding method stipulated by the JIS (Japanese Industrial Standard), etc. and by the welder qualified by the official organizations like JIS, etc., using well maintained welding machine and covered electrode. Weld joint numbers, the method of welding, contents of work and the name of the welder are recorded to control welding operation.

After completion of the welding, a welding inspection is executed to ensure intact of the welded part.

A.4 Shielding Manufacturing Method

Since no particular radiation shielding body is incorporated in this package, this article does not apply.

A.5 Manufacturing Method for Ancillary Parts Such as Valves, etc.

The valves used in the packaging must be those listed in the manufacturer's standards. The valves are mounted on the primary container body through the elastomer O-ring.

A.6 Assembly Procedure

Assembly portions by means of bolt fastening in this package are the primary container lid, valve cover, protective container lid, etc. The method of assembling is shown as follows:

(1) The O-ring is mounted on the valve cover and fastened with bolts to the primary container body by tool.

(2) The content is loaded into the primary container body, and are fixed by bolts using a tool.

(3) The O-ring is mounted on the primary container body lid and fastened onto the primary container body by tool.

(4) After mounting the packing onto the protective container body, the protective container lid is fastened onto the protective container body by bolts using a tool.

Section (III)-B Testing • Inspection Method, etc.

B. Testing • Inspection Method, etc.

During and after completion of manufacturing of the packaging, testing and inspection are performed to ensure that the product meets the values of analysis and the requirements described in Section (II). Table (III)-B.1 summarizes the inspection procedure to be used during and after completion of manufacturing.

Descriptions of each testing and inspection methods follow.

Table (III)-B.1 Inspection Procedure Applicable during and after Completion of Manufacturing of the Package

No.	Inspection item	Inspection method	Acceptance criteria
1	Material inspection	Materials used in the packaging are checked by referring to the mill sheet, etc.	According to article (III)-B.1.
2	Dimension inspection	Major dimensions are checked using measuring instruments.	According to article (III)-B.2.
3	Welding inspection	1) Outlook, 2) groove dimension, 3) liquid penetrant examination, 4) radiographic testing, etc. are used to inspect the integrity of weld portions.	According to article (III)-B.3.
4	Outlook test	The outlook of the packaging is checked by visual inspection.	The product must be free of flaws, cracks, etc. The shape must be free of abnormal defects.
5	Pressure test	Pressurize the primary container body using a gaseous medium, and check outlook by visual inspection.	According to article (III)-B.5.
6	Leaktightness test	A test to determine the rate of leakage of the seal part of the primary container lid and valve cover is conducted using the helium leakage method or vacuum leakage method.	According to article (III)-B.6.
7	Shielding property test	Not applicable.	-
8	Thermal test	The maximum surface temperature of the packaging is inspected by applying a heat source equivalent to the heat generated by the contents.	According to article (III)-B.9.
9	Lifting load test	Load placed on packaging, and verify absence of abnormalies	The packaging shall be capable of enduring a load equivalent to twice its lifting weight.
10	Weight test	Measure the total weight of the completed packaging	According to article (III)-B.10.
11	Subcriticality test	Not applicable.	-
12	Operation confirmation test	Operate the valves on the primary container body by means of exclusive use socket.	It must operate in order.
13	Handling test	Load simulated content into the packaging and perform a series of handling.	According to article (III)-B.14.

B.1 Material Inspection

The materials to be used in the packaging must be verified at the time of purchase that the required properties meet the standard specified in mill sheet, etc.

B.2 Dimension Check

The dimensions of each part of the packaging are checked and measured by using calipers, etc.

The dimensions of major parts of the packaging must fall within the range of tolerances indicated in Figs. (III)-A.2 through (III)-A.8.

When there is no indication in the drawing, judgement is made according to Table (III)-B.2, tolerance table for parts without symbol, described as follows:

Table (III)-B.2 Tolerance Table for Parts without Symbol

Welded construction without symbol tolerance*1 [Unit: mm]	
Preliminary dimensions	Tolerance
Greater than 1, less than 120	±1.5
Greater than 120, less than 315	±2.0
Greater than 315, less than 1000	±3.0
Greater than 1000, less than 2000	±5.0
Greater than 2000, less than 4000	±7.0
Greater than 4000, less than 8000	±10.0
Greater than 8000, less than 16000	±15.0

Cutting without symbol tolerance*2 [Unit:mm]	
Preliminary dimensions	Tolerance
Greater than 0.5, less than 6	±0.2
Greater than 6, less than 30	±0.5
Greater than 30, less than 120	±0.8
Greater than 120, less than 315	±1.2
Greater than 315, less than 1000	±2.0
Greater than 1000, less than 2000	±3.0
Greater than 2000, less than 4000	±4.0
Greater than 4000, less than 8000	±5.0

*1 : Refer to class 16 of the attached Table 1, Japanese Industrial Standards (JIS) B 0404 (1977).

*2 : Refer to class 16 of the attached Table 1, Japanese Industrial Standards (JIS) B 0405 (1977).

B.3 Welding Inspection

To ensure the integrity of welded parts during manufacture of the packaging, welding inspection is executed on major parts of the packaging as shown below.

(1) Temporary fitting test

(a) It is confirmed that the shape of the groove is machined as indicated in the relevant drawing, and that no paint, fats, oils, rust, etc. contaminate the groove or its vicinity.

(b) Tolerance for groove dimensions (during temporary fitting)

(i) Groove angle: ±5°

(ii) Root gap : ±1 mm

(iii) Offset between plates: Must be within the tolerance shown in Table (III)-B.3. (by Ordinance No. 74 issued by the Prime Minister's Office)

Table (III)-B.3 Allowable Offset between Plates of Weld Joints

Longitudinal joint		Peripheral joint	
Plate thickness	Gap	Plate thickness	Gap
Less than 20 mm	Less than 1 mm	Less than 15 mm	Less than 1.5 mm
20 - 120 mm	Less than 5% of plate thickness	15 - 120 mm	Less than 10% of plate thickness
Greater than 120 mm	Less than 6 mm	Less than 120 mm	Less than 12 mm

(2) Welding outlook inspection

After completion of welding, the work is visually inspected to ensure that the product is free of any cracks, undercut, overlap, or other hazardous defects:

(a) Cracks : Should not be present.

(b) Under cut: Less than 0.5 mm in depth

(c) Overlap : Less than 0.5 mm in length

(3) Liquid penetrant examination

The testing method complies with ordinance No. 74 issued by the Prime Minister's Office. The acceptance criteria are as follows:

(a) There should not be any linear defect indicating pattern

(b) Circular defect indicating patterns must be of the second class stipulated by JIS (Japanese Industrial Standards) Z 2343; "8.3 Classification of defect indicating patterns."

(c) There must not be more than 10 circular defect indications within a rectangular area of 3,750 mm^2 (length of the shorter sides being longer than 25 mm). If circular defect indicating pattern is 1.5 mm or less in length, counting is not necessary.

(4) Radiation penetration testing

The testing method is performed in accordance with the ordinance No. 74 issued by the Prime Minister's Office. The acceptance criteria are as follows:

(a) The test results must be of class 1 stipulated by "3. Classification method for grading the transmitted pictures" of JIS (Japanese Industrial Standard) Z 3104 (1968) "Method of radiation penetration testing for steel welded parts and classification method for grading the transmitted pictures" of Japanese Industrial Standard. In this case, number of defective blow holes is obtained by enlarging the test field of vision by 3 times, counting defective points and taking 1/3 of the values as defective points.

(b) When blow holes are found, their diameter must not exceed 0.2 times the plate thickness when the distance between the blow hole in question and an adjacent blow hole is less than 25 mm (when exceeding 3.2 mm, the distance is 3.2 mm). Nor must it exceed 0.3 times the plate thickness when the distance between the blow hole in question and an adjacent blow hole is more than 25 mm (when exceeding 6.4 mm, the distance is 6.4 mm).

(c) Within a range of 12 times the plate thickness, the distance between adjacent slug entanglements must be less than 6 times the length of the longer slug entanglement and when they are lined up continuously along a straight line, the total sum of these length must not exceeds thickness of the plate.

The marginal height of welded part to undergo radiographic testing must be as indicated in Table (III)-B.4.

Table (III)-B.4 Marginal Height of Welded Part to Undergo Radiographic Testing

Division of base material thickness	Marginal height
Less than 12 mm	Less than 1.5 mm
More than 12 mm and less than 25 mm	Less than 2.5 mm
More than 25 mm and less than 50 mm	Less than 3 mm
Over 50 mm	Less than 4 mm

B.4 Outlook Inspection

Visual inspection must ensure that all parts of the packaging are free of any hazardous flaws, cracks, etc.; gaskets, bolts, nuts, etc. are all installed correctly; the design is as specified in the appropriate drawing; that fats and oils etc. have all been completely removed; and that corrosion, rust etc. is not present.

B.5 Pressure Inspection

During manufacture of the packaging, pressure inspection must be performed for the primary container body to ensure that its ability to withstand pressure as required.

The pressure inspection is implemented, using a pressure equivalent to 1.5 times the design pressure.

(1) Inspection pressure: 182 kPa•G

(2) Inspection method and acceptance criteria

Continuous pressurization to 182 kPa•G using nitrogen or argon is performed, and this pressure held for at least 30 minutes.

When pressurization is imposed, no pressure drop must be observed, and visual inspection must observe no irregularities in outlook.

B.6 Leaktightness Test

After completion of package manufacturing, an leaktightness test must be performed on the seal parts of both the primary container lid and valve cover using the helium or vacuum leakage method to confirm that the package is leaktight.

(1) Acceptance criteria: 1.01×10^{-5} [Pa•m^3/s]* (1.0×10^{-4} [atm•mℓ/s]) must not be exceeded.

*; Total values for the two test locations i.e., the seal parts of the primary container lid and valve cover).

B.7 Shielding Property Test

Not applicable.

B.8 Thermal Test

After the completion of package manufacturing, an electric heater capable of generating more than 25 W of heat is inserted into the packaging in the attitude to transport conditions, and when surface temperature is measured, it must satisfy the standard values.

(1) Objective location of test

Packaging surface

(2) Acceptance criteria

The temperature converted using the results of a measurement which assumed an atmospheric temperature of 38°C must never exceed 50°C for any packaging surface which is easily accessible.

B.9 Lifting Load Test

After completion of package manufacturing, a visual observation must reveal that no deformations, cracks, etc. appear in the eyebolt boss or external plate as a result of loading twice the total weight of the package on the lifting device.

B.10 Weight Test

After completion of package manufacturing, the total weight of whole body is measured to confirm that it is less than 427 kg.

B.11 Subcriticality Test

Not applicable.

B.12 Operation Confirmation Inspection

The two valve units attached to the hull part of the primary container body are operated using the exclusive use socket to confirm correct performance.

B.13 Handling Test

Using simulated contents, etc. a series of operations such as loading and unloading into the packaging, etc. are performed to verify that there are no anomalies.

The outline of the operation procedure is as follows:

(1) Prepare empty packaging, simulated content, etc.

(2) Insert the simulated content etc., into the empty packaging (primary container body), and fix them.

(3) Mount the O-ring onto the primary container lid, and fasten the lid.

(4) Mount the O-ring on the valve cover, and fasten the lid.

(5) Insert the primary container into protective container and mount the spacer.

(6) Mount the packing onto the protective container, and fasten the protective container lid.

(7) Lift the package by means of a lifting device.

(8) The above operations shall then be conducted in the reverse sequence and the simulated content, etc. removed.

Section (III)-C Manufacturing Schedule for Packaging

C. Manufacturing Schedule for Packaging

Table (III)-C.1 gives the manufacturing schedule for the packaging.

Table (III)-C.1 Packaging Manufacturing Schedule

No.	Item \ Term of work (month)	1	2	3	4	5	6	7	8	9
1	Primary container	Materials procurement		Cutting and machining					Assembly test	
2	Primary container lid	Materials procurement		Cutting, welding and machining						
3	Protective container body	Materials procurement		Cutting, bending and welding			Balsa wood cutting and insertion	Welding and machining		
4	Protective container lid	Materials procurement		Cutting, bending and welding			Balsa wood cutting and insertion	Welding and machining		
5	Spacer	Materials procurement		Cutting, bending welding, machining						

Section (III)-D Quality Control

D. Quality Control

All of the activities throughout the design, production preparation, manufacturing, inspection, quality control and others for the packaging are implemented according to the quality assurance program described in the following.

D.1 System Organization

The system organization for the manufacture of TPL-92Y-450K type packaging is as shown in Fig. (III)-D.1.

The applicant must be responsible for command and control over a range of activities of designers and manufacturer; namely, design manufacture, quality control, and process control, in order to ensure the safety of packaging which is the subject of this application. The responsibility of each division for designing and manufacturing concerning the manufacture of TPL-92Y-450K type packaging are shown as follows:

(1) Design Division

The design division is responsible for providing necessary instructions from view point of designing as to determining the design specifications, compilation of manufacturing drawings, and compiling of manufacturing and inspection procedures, etc.

(2) Purchase Division

The purchase division is responsible for procurement works to purchase the materials conforming to the purchase and order specifications by the time when are required.

(3) Manufacturing Division

The manufacturing division is responsible for preparing manufacturing plan and manufacturing procedures to meet the design specifications and design requirements and also manufacturing products of appropriate quality through actual application of the procedures.

(4) Quality control division

The quality control division has an overall authority in carrying out the quality control plan, and is responsible for ensuring that the products meet the design specifications and design requirements.

(5) Process (daily process) control division

The division is responsible for maintaining the manufacturing process (daily process) for the products.

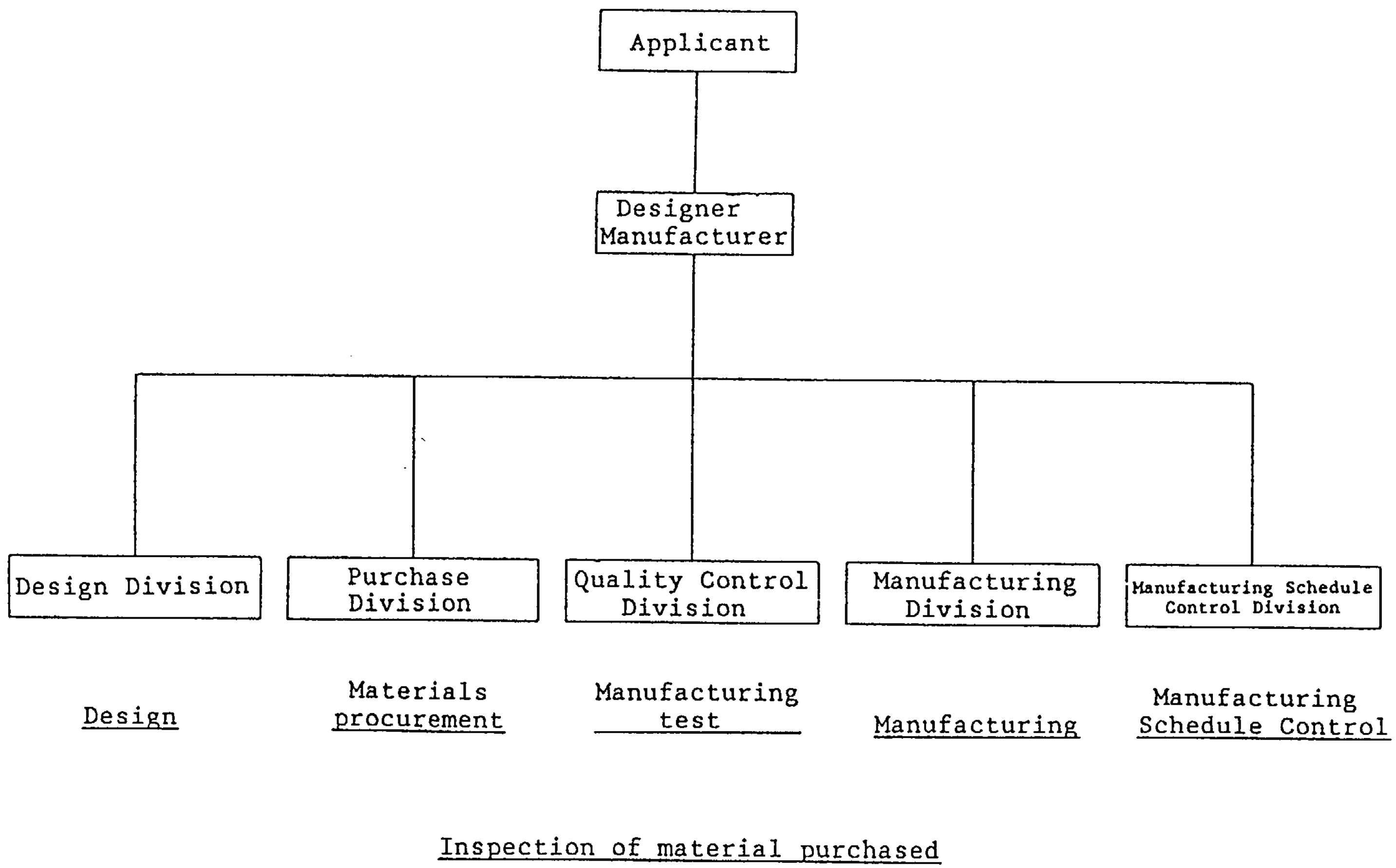


Fig. (III)-D.1 Manufacturing and quality control system organization

D.2 Quality Assurance Plan

The contents for each item of the quality assurance plan are as follows:

(1) Functional obstacle or trouble of the machinery

Parts of the packaging likely to cause functional obstacle are the O-rings. However, during the stages of manufacturing, stringent dimension control is provided and an airtightness test is executed on the O-ring part prior to shipment of each package to ensure its containment property. Consequently, the probability of the packaging having any functional obstacle is minimal.

(2) Relationship between designing and manufacturing

The design division of the designer and manufacturer is requested to describe the requirements of design into documents such as the drawing, specifications, procedures, etc., related to manufacturing and on the basis of these documents, provides the manufacturing division with instructions for manufacturing. The quality control division will execute various tests and inspections during the course of manufacturing, as described in articles (III)-B.1 through B.13, to ensure all requirements of the design are fulfilled.

(3) Control and supervision of the processes and devices

Associated with manufacture of packaging, the process control division of the designer/manufacturer controls processes related to manufacturing, inspection, etc. based on a detailed manufacturing inspection flow sheet compiled beforehand. The quality control division will also execute periodic inspection of measuring instruments, nondestructive test equipment, etc. to ensure that they operate correctly and accurately.

(4) Functional fidelity to be verified by testing and inspection

The methods of testing and inspection to be executed during manufacture of the packaging by the quality control division of the designer/manufacturer's are those well acknowledged as industrial testing and examination method. In performing the tests and inspections, described in articles (III)-B.1 through B.13, they will ensure that the function of this packaging satisfies the design requirements, having all the handling capabilities described in Section (IV).

(5) Grade of criteria, grade of quality history and standardization

Manufacture of the packaging shall be undertaken according to ordinance issued by the Prime Minister's Office, the JIS Standards, etc. The results of tests and inspections executed by the quality control division during manufacturing must all be preserved as quality control records to ensure that the quality history of the packaging during its manufacture is both easily understood and traceable. All tests and inspections executed by the designer/manufacturer are implemented on the basis of guidelines compiled by the quality control division.

D.3 Design Control

Design control shall be executed adequately. The reviews of the manufacturing and Quality Control Division will execute reviews of the design specifications, manufacturing drawings, instruction manuals, etc. compiled by the design division. These reviews are to be executed at the manufacturing design stage on the basis of the design specifications and conceptual drawing. The requirements of the design and quality standards described in the safety analysis package are to be clearly stated in these documents.

D.4 Instructions and Other Method

All operations (materials purchasing, manufacturing, testing, inspection etc.) which affect the quality during manufacturing, application and maintenance of the packaging are instructed by written documents, etc. The method, etc. of these instructions are be as follows;

(1) Manufacturing

The design department of the designer/manufacturer provide all necessary instructions for the design requirements regarding the manufacturing to the manufacturing Division. The manufacturing division will compile an instruction manual that satisfies the design requirements. This manual is used to carry out all manufacturing procedures. The quality control division will undertake testing and inspection during manufacturing on the basis of the written testing and inspection procedures manual.

(2) Application and maintenance

All part products, etc. shall be handled throughout the period from acceptance by designers/manufacturers to shipment in accordance with the instruction manual to prevent any possible degradation of quality of the products and parts.

D.5 Document Control

Documents such as instructions relating to quality, manual, drawings, etc. shall be controlled on the basis of the quality control system of the designer/manufacturer. The compilation, review, approval, distribution, etc. of documents concerning the design, manufacturing and testing compiled by the designer/manufacturer shall be controlled on the basis of the regulations stipulated by the designer/manufacturer. Revisions of these documents shall be conducted using the same procedure as that indicated above to ensure that the most current versions of these documents are always available and history of the revision number are also controlled.

All documents related to the quality of the product shall be kept in safekeeping for a period stipulated by the designer/manufacturer after completion of the packaging.

D.6 Material, Equipment and Service Procurement

The materials, equipment, etc. associated with the manufacturing of this packaging shall be procured by the materials division according to the purchasing specification compiled by the design division of the designer/ manufacturer. When the materials are delivered, the quality control division accept them and conduct acceptance inspection. Acknowledgement of material selection, confirmation of the number of units and an outlook inspection shall be undertaken with reference to the mill sheets to ensure compatibility with the requirements of the purchase specification.

D.7 Control Regarding Confirmation of Materials, Parts and Equipments

Out of materials and parts of the packaging, steel materials are to be clearly marked by the material's manufacturer with the manufacturing number (including the heat treatment number) to facilitate easy identification or collation with the mill sheet.

In the event that transfer of this mark becomes necessary during manufacturing, an inspection of the remarking in the presence of a witness shall be performed by the quality control division according to the stipulated procedure. Other parts, equipments, etc. shall be identified and controlled by the method such as marking according to the specified procedures by the quality control division on completion of acceptance inspection by the same division.

D.8 Control of Special Process Steps

The following criteria shall apply to the control of special process such as welding, nondestructive testing, etc.

(1) Welding

Weld of the packaging is implemented according to JIS (Japanese Industrial Standard) Standards, etc. Actual welding operation is performed by the welders who have successfully passed the qualifying test conducted by the official organizations such as JIS, etc.

The integrity of welded part is confirmed during the welding process when the current and voltage etc. are controlled and assured as required. Welded parts are inspected by a qualified inspector of the quality control division after completion of welding.

(2) Nondestructive inspection

The nondestructive inspection of the packaging shall be executed by licensed employees qualified by the Quality Control Division. The test shall be undertaken according to the non-destructive test manual compiled by the Quality Control Division.

(3) Shock absorber insertion

The contractor will present a shock absorber insertion procedure manual and quality control manual prior to start of filling. The procedure shall be executed in the sequence and manner approved by the designer/manufacturer.

D.9 Inspection Control

The data sheet regarding the quality and the inspection method shall be controlled as indicated below:

(1) Data sheet

The inspection results for each step in the manufacturing process shall be recorded and controlled by the quality control division according to the specified procedure manual.

(2) Inspection method

For inspections to be executed to the items cited in application sheet (III)-B, the inspection manual shall be compiled by the designer/manufacturer. The non-destructive test, dimension inspection, pressure testing, airtightness test, etc. shall all be executed on the basis of these documents.

(3) Qualifications of the inspector

The inspector to conduct the nondestructive test shall be a licensed person qualified by the quality control division on the basis of the non-destructive inspection qualification acknowledgement manual compiled by the said division.

(4) Inspection control regarding repairs, modifications and replacement

When irregularities are found during inspection, the manufacturing division shall compile an irregularity handling procedure manual. The quality control division will confer with the design division to determine the said procedure manual, provide instructions on how to deal with the irregularity, and also execute inspection again after the procedure has been performed.

D.10 Measuring Instrument and Testing Equipment Control

Measuring instruments, testing equipment, etc., used in the manufacturing processes shall be subject to periodic official approval and proofreading by the quality control division. These procedures will be performed using the testing equipment adjustment manual compiled by the same division on the basis of the standards of the instrumentation laws, etc. Performance of these checks and the effective period shall be clearly identified by a label affixed to the equipment. Measurements and testing related to quality control shall use the appropriate equipments and devices within the official effective period.

D.11 Handling and Safekeeping

The quality control division shall check the materials, parts, etc., of the packaging using the mill sheets. They will also execute the acceptance inspection, confirming numbers of units received, performing the outlook test, etc., and providing identifying adhesive labels or markings for those accepted. Accepted materials, parts, etc. shall be stored by the manufacturing division at specified storage locations for safekeeping.

D.12 Control of Inspection and Manufacturing Progress

The progress of the inspection and manufacturing shall be controlled referring to the process (daily process) compiled by the control division.

The inspection and manufacturing for each of the process shall be controlled according to the manufacturing inspection flow sheet in which necessary inspection and items of manufacturing are entered in the sequence of the process.

D.13 Corrective Control

When irregularities deviating from the requirements of the design drawings, specifications, etc. are found, the quality control division shall provide indications clearly showing the irregularities or unacceptable marking in question. A sheet for processing unacceptable item shall also be issued simultaneously. The manufacturing division will then investigate appropriate remedies, conferring with the design and quality control divisions. If repair is found to be appropriate, the manufacturing division will take necessary measures. The results of the process will be checked using by an appropriate method by the quality control division.

D.14 Quality Control Records

After completion of the packaging, the records are summarized by each of the design, quality control and manufacturing divisions and stored for a specified period in order to avoid damage or loss.

The quality control records include the following;

- Packaging approval application
- Design specification
- Manufacturing drawings
- Manufacturing procedures manual and inspection procedures manual
- Material certificate and test records
- List of materials used

D.15 Quality Control Audit

In order to confirm the proper operation of the quality assurance plan, the designer/manufacturer organize an audit team to supervise the divisions concerned with the quality assurance plan.

The audit team is divided into two; an "internal audit" and an "external consignee's audit."

(1) Internal audit

The audit team periodically checks the offices and operating shops of each of the divisions of the company concerned with the quality assurance plan, and submit a summary report of the results of the inspection to the person responsible for quality control, for each of the areas concerned to ensure that appropriate corrective action is taken, if the same is required.

(2) External consignee's audit

An audit team inspects the actual status of execution of the quality control procedures in the facilities and workshops of the consignee prior to placing purchase order for materials, equipment and/or machining. If the results of the inspection prove acceptable, the purchase order shall be placed with the dealer who passed the auditing.

Section (IV) Handling Method and Maintenance Condition of the Package

Section (IV)-A Handling Method of the Package

A. Handling Method of the Package

A.1 Loading Method

A.2 Pre-shipment Inspection of the Package

A.3 Method of Removing Content

A.4 Preparation of Empty Packaging

Table (IV)-A.1 Package Pre-shipment Test Procedures Manual

Test item	Test procedure	Acceptance criteria
Outlook test	The primary container body, primary container lid, protective container body and protective container lid shall all be visually inspected.	The parts must all be free of any hazardous flaws, cracks, etc. No anomalies or defects in shape should be seen.
Lifting test	Appearance test shall be performed on the package while it is suspended.	The portion of eyebolt installation must be free of hazardous defect such as any cracks, anomalies, deformations, etc.
Weight test	Check the total weight of package.	The weight must be less than 450 kg.
Surface contamination density test	Execute a surface density test on the package using the Smear method.	The surface density shall be less than 4 Bq/cm^2.
Content test	(1) The appearance, dimensions, and weight of the contents shall be checked. (2) The results of calculations of the quantities of radio-activity, and heat generated by the contents shall be checked. Records of measurements of the quantity of radioactive isotope (tritium) contained in the capsule shall be used for this purpose.	(1) a. No anomalies in appearance b. The weight of the capsule after the tritium is sealed in must not exceed 23 kg. c. Height; 700 mm Hull part outer diameter; ⌀115 mm Flange part outer diameter; ⌀220 mm (2) a. The quantity of radioactive isotope shall never exceed 25 g. b. The intensity of radioactivity shall not exceed 9.25 PBq. c. The quantity of heat generated shall not exceed 25 W.
Leaktightness test	Measurement inspection for the rate of leakage using the helium leakage method or vacuum leakage method shall be executed on the O-ring part of each of the primary container lid and valve cover.	Total rate of leakage for each shall not exceed 1.01×10^{-5} $Pa \cdot m^3/s$.
Temperature measurement test	The surface temperature of package is to be measured prior to shipment.	The surface temperature after compensating for an atmospheric temperature of 38°C shall be less than 50°C.
Pressure measurement test	The initial pressure of gas filled inside the primary container is to be measured.	The conditions of initial seal-in pressure setting, as described in the application sheet, must be satisfied.
Dose rate test	The dose rate of package is to be measured by survey meter, etc.	Acceptance criteria of surface dose rate: 2 mSv/hr must not be exceeded. Acceptance criteria of 1 meter dose rate: 0.1 mSv/hr must not be exceeded.

B. Maintenance Condition

The packaging shall be stored indoors. Voluntary testing shall be implemented according to the method indicated below. The frequency of this testing shall be more than once a year (more than once every ten uses for those used more than 10 times per year).

B.1 Outlook Inspection and Pressure Test

B.1.1 Visual Inspection

Visual inspection shall confirm that there are no hazardous deformations, flaws, cracks, etc. on the external and internal surfaces of the primary container body and lid, protective container body and lid and spacer.

B.1.2 Pressure Test

Visual inspection during the pressure test shall indicate that there are no hazardous deformations, flaws, cracks, etc. after pressurization is imposed. Should any repair, etc. which could have an effect on the pressure endurance capability of the container be performed, pressurization shall be imposed using gaseous pressure and pressure test executed immediately thereafter.

B.2 Leaktightness Test

To verify the containment property of the packaging body, a leak test shall be executed on the primary container lid and valve cover seal part according to the descriptions in (C)-B.6. This test must confirm that the rate of leak is less than the value of criteria.

B.3 Maintenance of Auxiliary System

This packaging has no auxiliary system provided, thus this article does not apply.

B.4 Maintenance of Valves, Gaskets, etc. of Containment Device

No irregular deformations, cracks, etc. in the primary container lid or valve cover O-rings should be observed. If any such anomaly is found, the O-ring in question is to be replaced.

B.5 Shield Test

Not applicable.

B.6 Subcritical Test

Not applicable.

B.7 Thermal Test

The outlook of the primary container body and lid, and the protective container body and lid shall be checked by visual inspection so as to confirm that there are no irregular defects in their appearances.

B.8 Other Tests

None.