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ARTICLE

Test of Type FCo70-YQ Transport Container for Medical Radioactive Source in CIRP

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Radioactive material transport is an important part of radioactive material management. In this paper, regulations on radioactive material transport in China are introduced, test facilities and data acquiring instruments for radioactive material packages in CIRP are presented, which are used in drop test and thermal test. According to the requirements of *Regulations for the Safe Transport of Radioactive Material(GB 11806--2004)* of China and IAEA *Regulations for the Safe Transport of Radioactive Material(TS-R-1)*, certification tests of type FCo70-YQ container (type B) used for medical ^{60}Co and ^{137}Cs sealed sources transport have been conducted in CIRP, and the results are discussed.

KEYWORDS: radioactive source, transport, container, test

Ⅰ Introduction

Research on transport safety for radioactive material has been doing since 80's of last century in China Institute for Radiation Protection(CIRP). In the field of radioactive material transport, the transport mainly complies with *Regulations for the Safe Transport of Radioactive Material (GB 11806--2004)*[1] in China. Tests on transport package for radioactive material are conducted in accordance with *Regulations for the Safe Transport of Radioactive Material(GB 11806--2004),* referring to IAEA *Regulations for the Safe Transport of Radioactive Material (TS-R-1)* [2]at the same time .

Type FCo70-YQ container is specially designed for the transport and transfer of medical ^{60}Co sealed radioactive sources which is used for remote control Cobalt-therapy equipment and blood Cobalt-radiation equipment. The container also can been used in transport and transfer ^{137}Cs radioactive sources after replacing drawers. The maximum activity of ^{60}Co and ^{137}Cs is less than 444 TBq and 296 TBq, respectively.

Tests for demonstrating ability to withstand accident conditions of transport are introduced in this paper, including mechanical test, thermal test and water immersion test. The acceptance criteria after each test are: (1) to retain sufficient shielding to ensure that radiation level at 1 m from the surface of package would not exceed 10 mSv/h with the maximum radioactive contents (444 TBq for ^{60}Co and 296 TBq for ^{137}Cs) which the package is designed to contain; (2) restrict the accumulated loss of radioactive contents in one week to not more than A2, for ^{60}Co and ^{137}Cs i.e. 4×10^{-1} TBq and 6×10^{-1} TBq, respectively.

Ⅱ Container design

Type FCo70-YQ container mainly include two parts, i.e. a main body and a shield, weighing about 4200 kg. The overall external dimensions are 1300 mm width by 1150 mm depth and 1451 mm height. The main body is a column, with steel--lead--steel structure. The inner shell is made of 0Cr18Ni9 stainless steel, with 8 mm thick. The outer shell is made of 16Mn steel, with 16 mm thick. Lead is filled between inner shell and outer shell, with 280 mm thick. There are two drawers in main body, the upper drawer is used for storing source and the bellow one is a dummy. The main body is, in turn, inserted in a cuboid shield, made of 60 mm Fiberfrax insulated and covered by 30 mm Q235A steel at top and bottom, by 10 mm Q235A steel at side. The schematic diagram of container structure is showed in **Fig.1.**

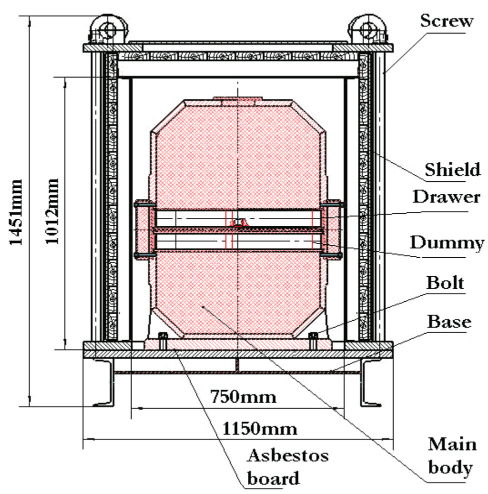

Fig.1 Schematic diagram of the container structure

Ⅲ Test facility

1. Drop test facility

Drop test facility mainly includes a target, crane, automatic release device, screen, puncture bar, etc.

The target was designed and manufactured according to the requirements of *GB11806* and *TS-R-1*, which has total mass of 130 t and can be used to test a package with weight less than 13 t. The target includes a reinforced concrete block with dimensions of 3800 mm length by 3550 mm width by

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3500 mm depth, covered by a steel plate with dimensions of 3500 mm length by 3250 mm width by 100 mm thick, and a group of steel bar with length of 1700 mm welded under the steel plate, which makes the steel plate tightly link with the concrete block. **Figure 2** is the target under construction.

Fig.2 Target under construction

The release device is driven by electrical-gas equipment, the puncture bars were made according to the requirements of *GB11806-2004*. The free drop test, penetration test, puncture test and crush test can be conducted using this facility.

Data from strain gauge and accelerometer can be provided during test, the image can also be provided during the course of the test. Instruments measuring strain and acceleration have maximum continuous sampling frequency of 20 kHz and instantaneous sampling frequency of 3 MHz, providing maximum 24 channels data, respectively. High speed camera has a speed of 11527 frame per second at 512 by 512 image elements, and can get more high frame rate when reducing the resolving power.

2. Thermal test facility

The thermal test facility mainly includes a furnace, coal gas source, instruments for temperature control, trolley, temperature-measuring instruments, etc.. The furnace has a inner cavity with 4000 mm width by 7000 mm depth by 2800 mm height, and 8 fuel nozzles. The fuel is coal gas. The maximum temperature which the furnace can be achieved is 1100 ℃. The maximum mass of package to be tested is 80 t. The outer side temperature of the container tested can be measured by thermocouple and digital instruments, ranges from 0 ℃ to 1200 ℃. 48 channels date can be provided during test. The temperature in inner drawers can be measured by temperature-indicating strips, ranges from 30 ℃ to 290 ℃.

Ⅳ Container test

1. Free drop test Ⅰ

Type FCo70-YQ container shall be subjected to the free drop test Ⅰ under hypothetical accident conditions according to *GB11806-2004*, the height of drop from the lowest of the container to the upper surface of the target is 9 m. In order to find out a orientation resulting in the greatest damage for a specimen, Simulation calculation has performed using ANSYS/LS-DYNA code. The calculated stress distribution on container is showed in **Fig.3** after drop test in bottom corner drop orientation, the container after test is showed in **Fig.4**. The impact corner part was bended up about 20 cm, four bolts was ruptured connecting the shield and soleplate, a gap appeared between shield and soleplate ranging from 0 cm to 2 cm width. No significant damage on main body was observed after test. The measured maximum strain data is 1348 με on main body.

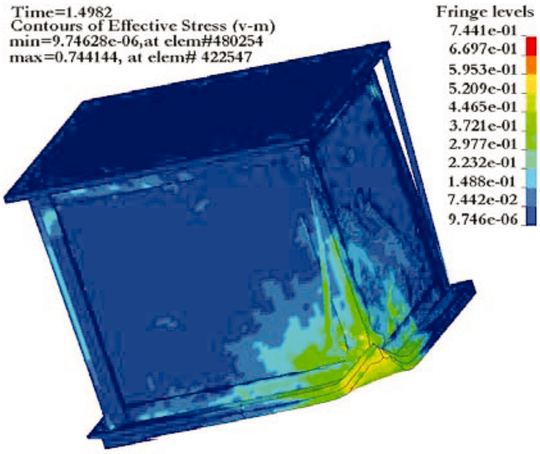

Fig.3 Calculated Stress distribution on container after simulated bottom corner drop test

Fig.4 Container after test

2. Free drop test Ⅱ

For free drop test Ⅱ, the container shall drop so as to suffer the maximum damage onto a bar rigidly mounted perpendicularly on the target. The bar is made of solid mild steel of circular section, (15.0±0.5) cm in diameter and 20 cm long. The upper end of the bar is flat and horizontal with its edges rounded off to a radius of not more than 6 mm. The height of the drop from the intended point of impact of the container to the upper surface of the bar is 1 m. ANSYS/

LS-DYNA code was used in simulated calculation to obtain the drop orientation causing the maximum damage during test. A oblique drop test was conducted according to calculated results, with an angle of 25º between side of container and upper surface of bar. **Figure 5** shows the stress distribution on container using simulated calculation, and **Fig.6** shows the container in preparation for the free drop test Ⅱ. Test caused a reentering hole at impact point on the shield, about 20 cm in diameter and 2.5 cm in depth. No evidence damage was found on the main body of the container after test.

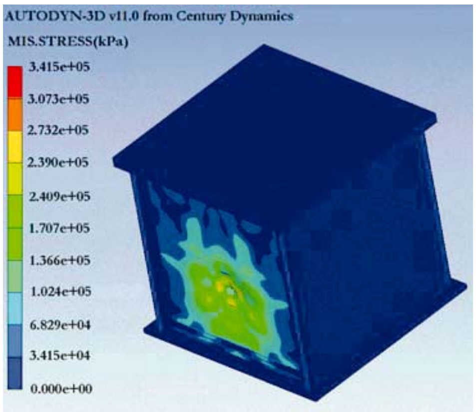

Fig.5 Diagram of stress distribution on the container

Fig.6 The container subjected to the free drop test Ⅱ

3. Thermal test

Thermal test requires that the container shall be exposed to a thermal environment which give a minimum average flame emissivity coefficient of 0.9 and an average temperature of at least 800℃ for a period of 30 minutes, fully engulfing the specimen. The code of ANSYS DesignSimulation was used to simulate temperature distribution of the container, and the simulated temperature distribution on main body surface is showed in **Fig.7**. **Figure 8** shows the container during performance of thermal test. The measured and calculated temperature of main body surface are under 200 ℃, less than melting point temperature of lead (327.3 ℃). The fact shows that the shield ability of lead is completely kept after thermal test.

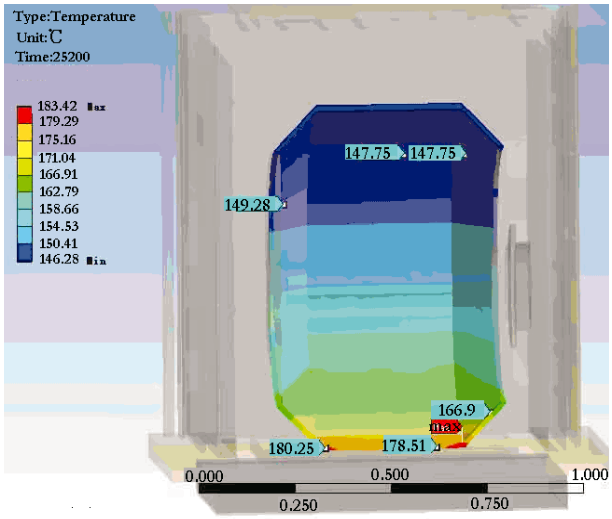

Fig.7 Temperature distribution on main body surface obtained from simulated calculation

Fig.8 Thermal test

4. Water immersion test

Water immersion test require that the specimen shall be immersed under a head of water of at least 15 m for a period of not less than 8 h in the attitude which will lead to maximum damage. The ANSYS DesignSimulation Code was used in water immersion test. The calculated cell are SOLID90 and SOLID186. There are 57481 elements and 177898 nodes in the model. **Figure 9** shows the stress distribution on the shield for fifteen-meter water immersion test, the maximum stress to which the container suffered is 112 MPa.

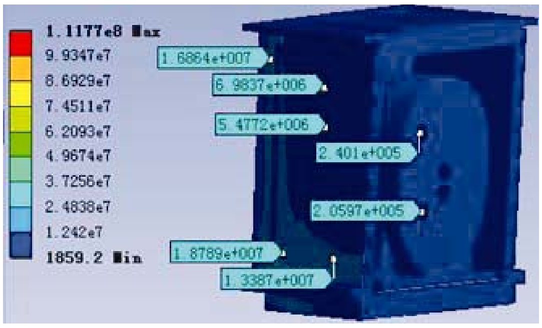

Fig.9 Stress distribution on the shield

Ⅴ Conclusion

According to *GB11806－2004*, type FCo70－YQ container had subjected to tests for demonstrating ability to withstand normal conditions of transport before tests for demonstrating ability to withstand accident conditions of transport, including the water spray test, the free drop test, the stacking test and the penetration test. There are not significant damage to container after test for demonstrating ability to withstand normal conditions of transport. Shielding ability and containment ability are analyzed after each test. Results from simulated calculation and test have proven that type FCo70－YQ container design complies with the requirements of *GB11086－2004*.

References

1) Regulations of peoples republic of china, Regulations for the Safe Transport of Radioactive Material, China press for standardization publishing, Beijing,49(2004).
2) IAEA. Regulations for the safe transport of radioactive material,2005 edition,IAEA,Vienna,104(2005).