

Drop Tests of Type-B Packaging Under -40°C Conditions

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INTRODUCTION

The 1985 edition of the IAEA regulations (IAEA 1985) for the safe transport of radioactive material has invalidated the previously approved fresh fuel packages that were designed as Type-AF. As a result of the invalidation of these packagings, a new JRF-90Y-950K packaging was designed as Type-B(U)F and two packagings of the new design were fabricated by Mitsubishi Heavy Industries, Ltd.

As a part of the package design process, two full-scale tests were performed to obtain data on the response of the full-scale system, and to verify the validation of the safety analysis. In the first drop tests, one test packaging cooled down to -40°C was tested, hereafter referred to as 'the cold tests', to give the maximum impact loads. Another purpose of the cold tests was to confirm the integrity of components (seal, closure bolts, welds) that cannot be evaluated completely by analyses.

In the second drop tests, the other one was tested under accident conditions that gave maximum damage to the package as an initial condition for the thermal analysis. All test results were fully satisfied.

After the package design was authorized by the Japanese Government, 18 packagings were fabricated. The transportation of fresh fuel elements from overseas fuel manufacturers to the Japan Materials Testing Reactor (JMTR) has, up to now, been undertaken using the new packaging.

This paper describes detailed information on the cold tests and their results.

PACKAGE DESIGN

The new package is shown in figure 1. The package has a cylindrical shape, 1.8m in height and 0.84 m in diameter. The maximum design weight of the package is 950 kg with 10 fresh fuel elements loaded. The packaging consists of the main body, the outer lid, the inner lid, and the fuel basket. The main body and the outer lid consist of the outer shell and the inner shell made of stainless steel. A combination of balsa and hard polyurethane foam is installed between the inner and outer shells to protect the containment system and contents against the impact and thermal loads under either normal transportation or accidental environments. The inner lid is made of stainless steel with a pair of elastomeric O-rings (silicone), and attached to the inner shell flange by 24 closure bolts. Two kinds of fuel baskets made of stainless steel were fabricated. One is capable of containing ten fuel elements of the rectangular type, and another 7 fuel elements of the cylindrical type.

The test packaging, loaded with 7 dummy fuel elements made of aluminum alloy, which weighed approximately 860 kg, was subjected to the cold tests.

PACKAGING TESTING

The cold tests were performed at the testing field of Mitsubishi Heavy Industries, Ltd. The test facility consists of the drop test target, separating system, crane, and cooling system as shown in figure 2. The drop test target consists of a reinforced concrete pad with an armor plate. The concrete pad and the armor plate weigh approximately 100 tons. A mild steel bar for a puncture test was rigidly mounted on the armor plate with bolts. The cooling system consists of a temperature conditioning enclosure and a liquid nitrogen feeder unit with spraying nozzles.

The test packaging was equipped with two accelerometers to measure decelerations, four mono-axial and seven bi-axial strain gauges to measure impact force, and nine thermocouples to measure temperatures placed in selected locations as shown in figure 3. The mild steel bar was equipped with two strain gauges. The signals from these sensors were sent to a data recording system.

A vertical orientation was chosen for the cold tests because the maximum deceleration was yielded for this orientation according to preliminary analyses. Figure 4 shows the cold tests flow. The test packaging was cooled down to -40°C by spraying liquid nitrogen in the temperature conditioning enclosure for about 10 hours, and the test packaging was subjected to 9-m drop test followed by 1-m puncture test. Leakage tests were carried out before and after each drop test to confirm the leaktightness at low temperature.

TEST RESULTS

Figures 5 and 6 show the moment of start and crush at the 9-m drop test and the 1-m puncture test, respectively.

Time history data measured by the accelerometers and strain gauges were stored in the data recording system. The high frequency components of deceleration and strain were removed from these time histories by a low pass filter. Five of 18 signals from the strain gauges failed because the corresponding cables were broken during the 9-m drop.

Table 1 shows the test results compared with respective analysis. The deformation and deceleration obtained by the cold tests were less than the calculation results in the safety analysis.

Neither crack nor deformation was observed on the outer surface of the test packaging except on the outer lid. The deformation of the internal structure and contents were only observed on the upper flange of the basket and one of the seven dummy fuel elements. The upper flange slightly deformed at connection points mounted on the boss of the inner shell by bolts. Only a handle welded to top-section of the dummy fuel element deformed, and the fuel plates remained intact.

Preliminary leakage tests were performed on the closure seal prior to the cold tests to provide guidance at the lowest allowable temperature for the leaktightness, and the temperature at the start of the drop test was controlled in the narrow temperature range of -40 to -45°C at the closure seal. Table 2 shows leakage test results. No appreciable leakage was detected, and it was confirmed that the leaktightness at low temperature was maintained before and after each drop test.

CONCLUSION

The test packaging proved to have enough integrity under the cold tests as well as a series of the drop tests at room temperature, followed by a fire test. It was confirmed throughout all the test results that the validation of safety analysis was verified, and the JRF-90Y-950K package retained its integrity under normal transportation and accidental environments.

REFERENCE

International Atomic Energy Agency, Regulations for The Safe Transport of Radioactive Material, 1985 Edition, Safety Series No.6.

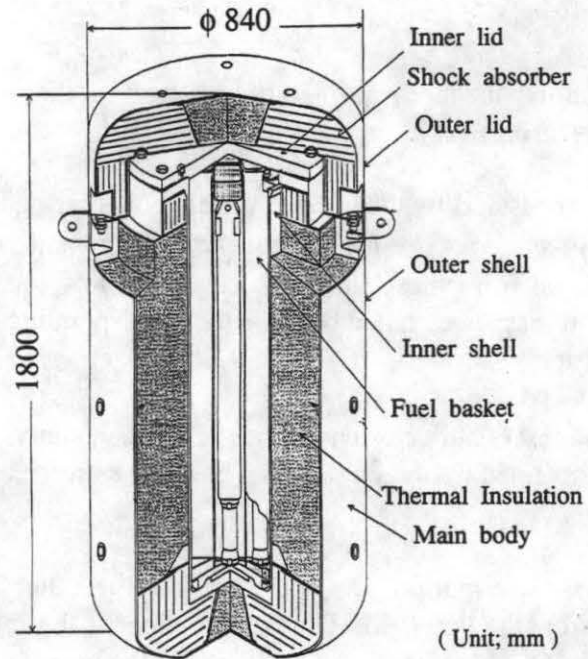


Figure 1 The JRF-90Y-950K package

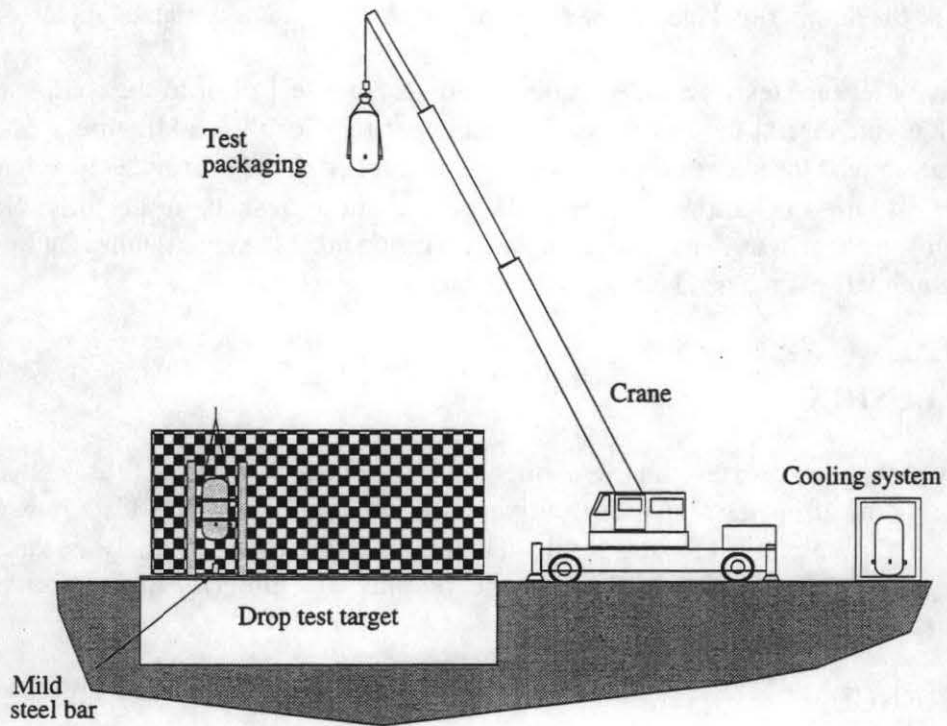
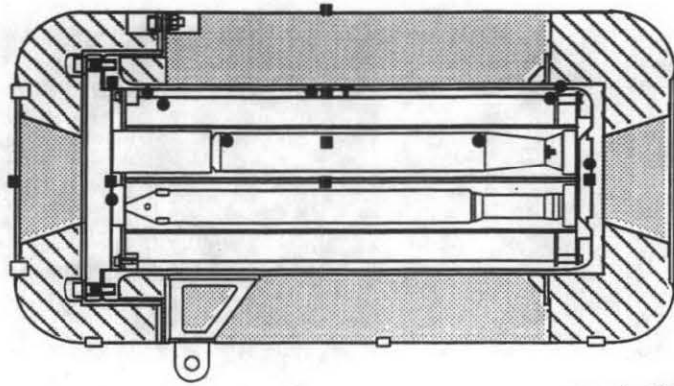


Figure 2 Schematic view of drop test



- ▲ Accelerometer (2)
- Strain gauge (11)
- Thermocouple (9)

Figure 3 Instrumentation locations

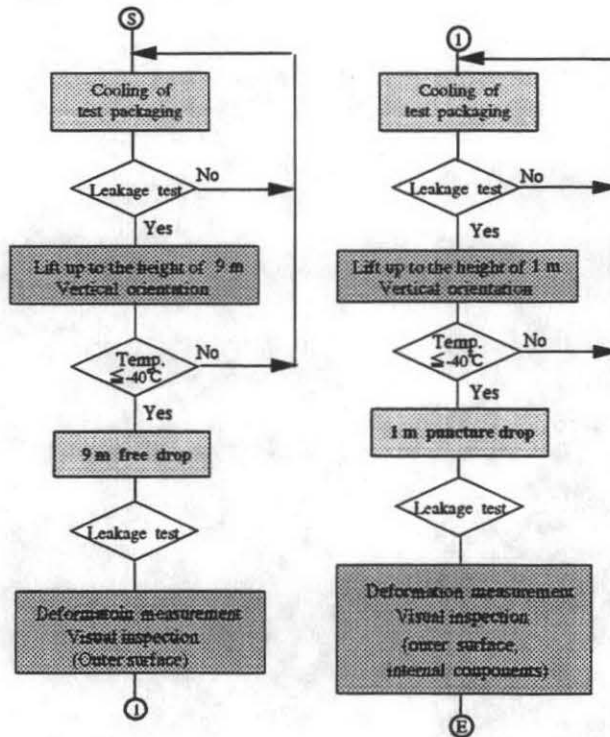


Figure 4 Cold tests flow

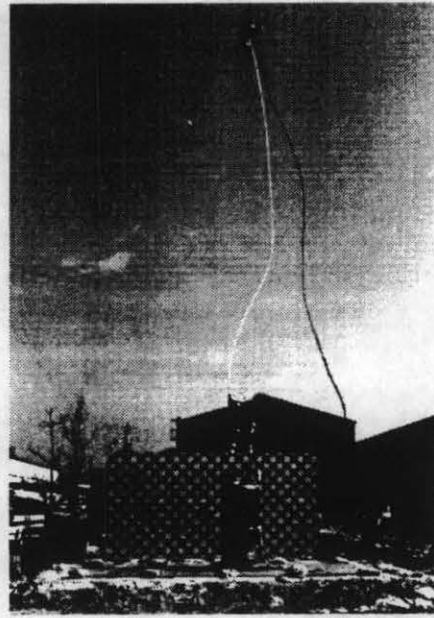


Figure 5 9 m drop test

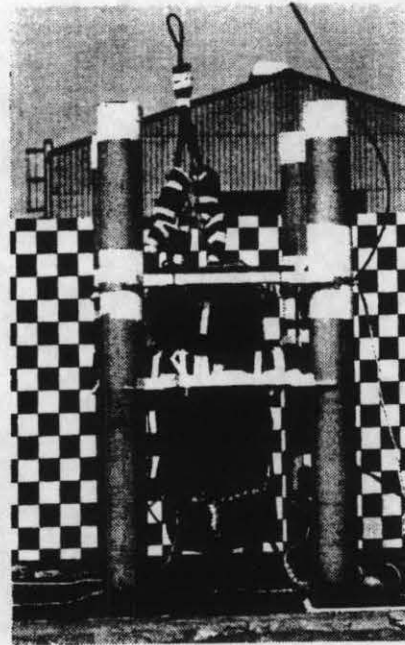
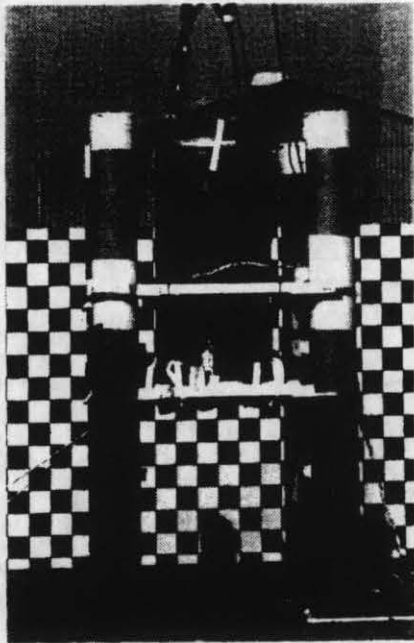


Figure 6 1 m puncture test

Table 1 Comparison between analytical and test results

| | | Test | Analysis |
|---|--------------------|------------------------|----------|
| 9 m Drop test Deformation (mm) | Outer lid | 28 | 127 |
| | Inner shell center | 539 | 682* |
| Deceleration (g) | Dummy fuel element | 21 | — |
| | Inner shell center | -3.95×10^{-4} | — |
| Strain (-) | Dummy fuel element | -1.15×10^{-4} | — |
| | Closure bolt | 9.94×10^{-4} | — |
| | Fuel basket | -1.16×10^{-3} | — |
| | | | |
| 1 m Puncture test Deformation (mm) ** | Outer lid | 55 | 133 |
| | Inner shell center | 5 | 164 |

* Value corresponding to -40 °C

** Cumulative deformation subjected to 9m drop and 1m puncture

Table 2 Leakage test results

| | | Leak rate at low temperature (atm cc/sec) |
|--------------------------|--------|--|
| 9 m Drop test | Before | 2.22×10^{-3} |
| | After | 5.56×10^{-3} |
| 1 m Puncture test | Before | 4.89×10^{-2} |
| | After | 1.04×10^{-2} |
| Allowable limit | | 1.1×10^{-1} |