Total Safety Assessment for Transportation of Radioactive Wastes

N. Watabe, S. Ozaki and C. Itoh
Central Research Institute of Electric Power Industry, Abiko Chiba, Japan

K. Noguchi, Y. Kinehara and H. Suzuki
Mitsubishi Research Institute Inc, Otemachi Tokyo, Japan

K. Satoh
Central Research Service co.,LTD, Kanda Tukasa-cho Tokyo, Japan

Background

In Japan, safety assessments for transportation of nuclear fuels and radioactive wastes have been ever done individually about necessary items. The nuclear fuel cycle facilities is being constructed in Japan, to which various packages, e.g. Natural UF6, Spent Fuel, Low Level Waste and Returnable High Level Waste will be transported. Then CRIEPI has begun to assess the safety of transporting these packages by road or sea and in normal or accident condition (see Table-1).

This paper will discuss the concept, process and some of the results of the total safety assessment in accident conditions.

Table-1 Package and Transportation Routes

Package	Packaging	Transportation Route
Spent Fuel	Cask	Road : Loading Port ~ JNFS et. al. Sea : Each Power Stastion ~ Unloading Port
Returnable High Level Waste	Cask	Road : Each Power Stastion ~ JNFS Sea : Oversea ~ Unloading Port
Low Level Waste	Container	Road : Oversea ~ JNFI et. al. Sea : Each Power Station ~ Unloading Port
Natural UF6	48-Cylinder	Road : Each Power Station ~ JNFI Sea : Oversea ~ Unloading Port

The Concept of Total Safety Assessment in Accident Conditions

Each package is designed, manufactured and tested in accordance with the safety standards set by IAEA and Japanese government. The safety standards are meant to guarantee the safety of packages, but they seem not to be exactly sufficient to explain simply the safety of transportation. For example, the safety standards are not obviously related to actual accident conditions and only type B packages are subjected to tests to withstand accident conditions.

We recommend that the total safety assessment process should be carried out as follows. Fig.-1 shows the process of this assessment.

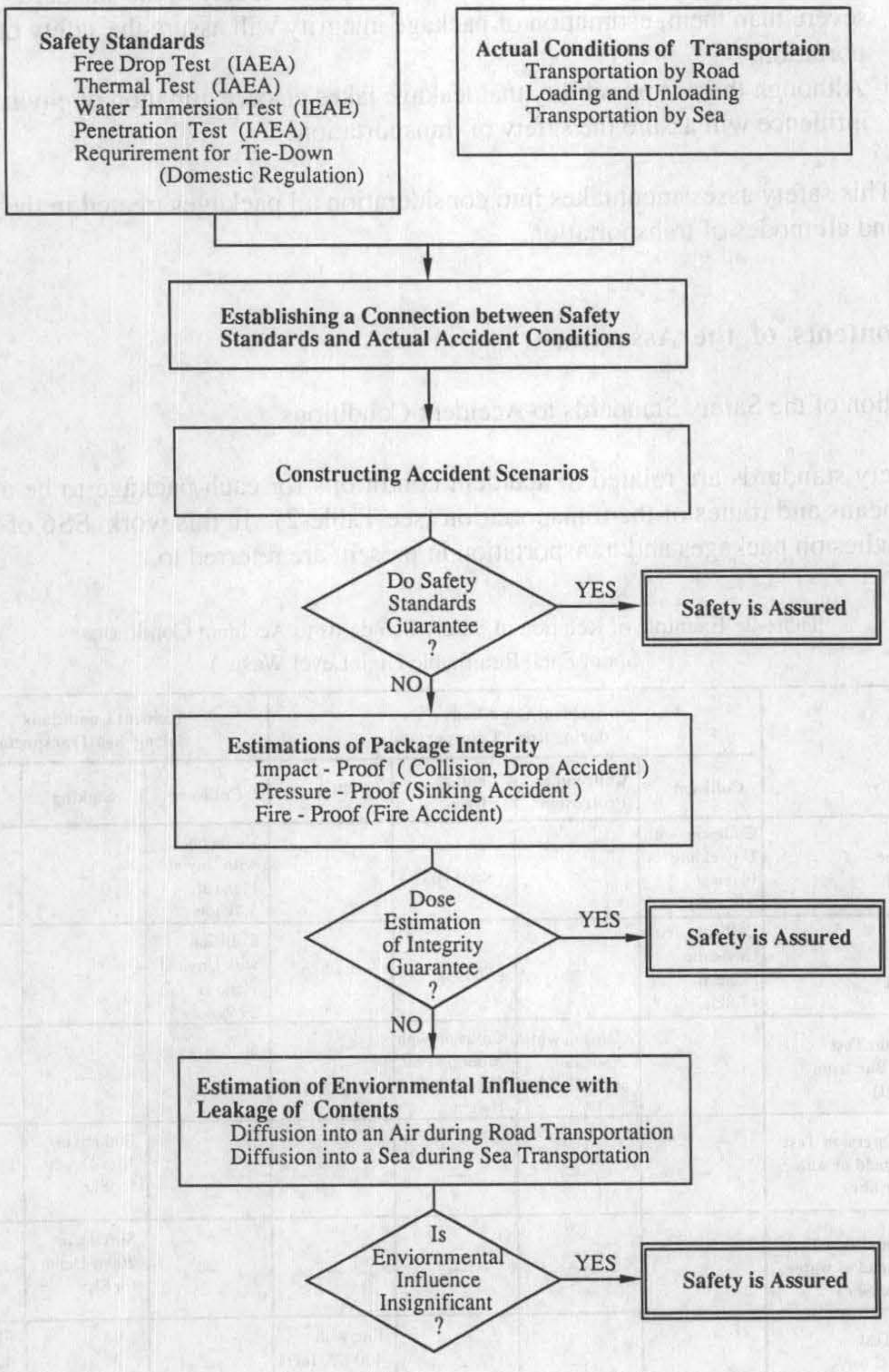

Fig. -1 Process of Total Safety Assessment

(1) This safety assessment is based on assumptions of realistic accident conditions.

(2) This safety assessment consists of synthetic examination in three stages as follows.
   i- The safety standards guarantee the safety of the transportation, as the accident condition is obviously easier than items of the standards.
   ii- Although the accident condition is not related obviously to the standards or more severe than them, estimation of package integrity will assure the safety of transportation.
   iii- Although there is possibility that leakage takes place, estimation of environmental influence will assure the safety of transportation.

(3) This safety assessment takes into consideration all packages treated in the facilities and all modes of transportation.

The Contents of the Assessment

1. Relation of the Safety Standards to Accident Conditions

The safety standards are related to accident conditions for each package to be assumed in actual means and routes of the transportation (see Table-2). In this work, SS6 of IAEA and some studies on packages and transportation in present are referred to.

Table-2 Example of Relation of Safety Standards to Accident Conditions
(Spent Fuel, Returnable High Level Waste)

IAEA Safety Standards	Accident Conditions during Road Transportation				Accident Conditions during Sea Transportation		
	Collision	Collision to Protrusion	Fall & Drop	Fire	Collision	Sinking	Fire
0.3 m Free DropTest	Collision with Unyielding Plane at 8.7km/hr	—	(See Fig. -3)	—	Collision with Unyield Plane at 5.4knots	—	—
9 m Free Drop Test	Collision with Unyielding Plane at 47.8km/hr	—	(See Fig. -3)	—	Collision with Unyield Plane at 29.9knots	—	—
Penetration Test (Fall to a Bar from 1m-Height)	—	Collison with Protrusion at 15.9 km/hr	Collision with Mooring Post from 1.0m-Height	—	—	—	—
Water Immersion Test (under a head of water of 15m for 8hr)	—	—	—	—	—	Sinking in 15m-Depth for 8hr	—
Water Immersion Test (under a head of water of 200m for 8hr)	—	—	—	—	—	Sinking in 200m-Depth for 8hr	—
Thermal Test (with 800°C for 30min)	—	—	—	Fire with 400-800 liters of Gasoline	—	—	Fire with 400-800 liters of Gasoline

2. Estimation of Package Integrity

Estimation of package integrity is made for accident conditions that are not obviously easier than the standards.

(1) Fall accident during road transportation and drop accident during loading-unloading
This estimation takes into consideration the difference of target plane between the drop test and the actual fall or drop accidents. Fig.-2 shows the relation of target plane to the impact force of a package calculated by a numerical method. This graph establishes a relationship between transportation accident and the drop test to unyielding plane.

(2) Collision accident during road transportation.
The force of impact package in a collision is compared with the force of impact in a drop test and with the force of impact specified as intensity of tie down. A numerical simulation model for a collision using the mass-spring method is shown in Fig.-3.

3. Estimation of Environmental Influence

Estimation of environmental influence is made for accident conditions that any leakage from a package is presumed due to the estimation of package integrity. Further for some of accident conditions guaranteed by package integrity, estimation of environmental influence is made from a viewpoint of multiple safety checks.

The environmental influence is estimated according to the following scenarios.

(1) The case of a road accident where content is diffused into the atmosphere.
Concentration in the air and ground surface is calculated by using a numerical simulation for three dimensional diffusion which considers the topography and wind of the accident location.

(2) The case of a road accident where leakage into a river takes place.
Concentration in the water is calculated while considering water flow of the river.

(3) The case of a sinking accident at sea where leakage takes place.
Concentration in the water is calculated by using an analytical solution of three dimensional diffusion equation which considers current flows. Individual equivalent dose of internal exposure by ingestion of sea food and external exposure by contact with coastal sand is evaluated according to ICRP Pub. 30.

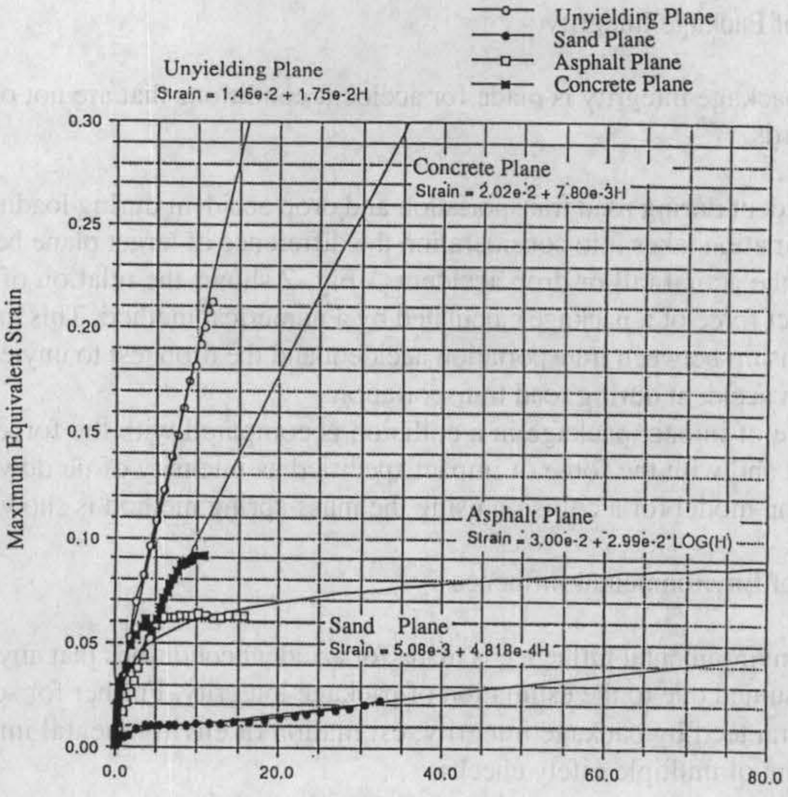

Fig. -2 Relation of Dropping Plane and Generated Strain (48y-Cylinder of Natural UF_6)

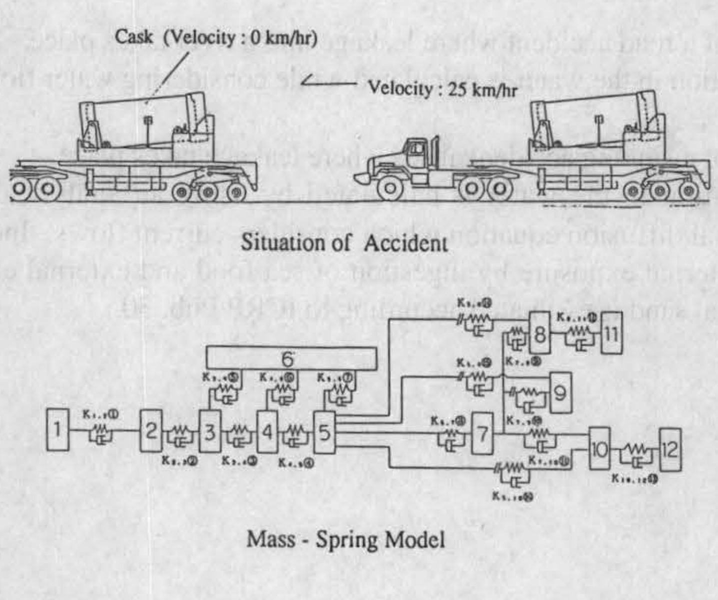

Fig. -3 Model for Collision Accident by Mass - Spring Method

Sample of Results

Sample of the results to date is presented in Table-3.

For Spent Fuel and Returnable High Level Waste, it was confirmed that the safety standards assure the integrity of package in most accident conditions.

For Natural UF6, the normal tests of the standards cover some accident conditions, but the special test as type B package assures the safety of transportation in most of accident conditions. 48Y cylinder, which is a package for Natural UF6, has been confirmed to pass the special tests.

The safety standards for Low Level Waste, which are subject to only the normal tests, does not guarantee the integrity of package in many accident conditions. Estimation of environmental influence will assure the safety.

Table-3 Sample of the Results of Assessment

Package	Means of Transpor-tation	Accident Scenario	Decision	Results
Spent Fuel **Returnable High Level Waste**	Road	Trailer Collision	○	Force of impact is less than the requirement for tie-down . [due to simulation]
		Trailer Fall	◎	There is no location on the route that exceeds conditions of the free drop test (9 m).
		Trailer Fire	◎	There are no combustibles that exceed conditions of the thermal test (800 ℃ - 30 min.).
	Sea	Vessel Collision	○	Force of impact is less than the requirement for tie-down of trailer. [due to inquiry of instances]
		Sinking of Vessel in Shallow Sea	◎	The integrity is assured in shallow sea that does not exceed conditions of the water immersion test (200 m - depth).
Natural UF6	Road	Trailer Collision	○	Force of impact is less than conditions of the free drop test (9 m). [due to simulation]
		Trailer Fall	○	There is no location on the route that exceeds conditions of the free drop test (9 m).
		Trailer Fire	○	The possibility of fire accident that exceeds conditions of the thermal test (800 ℃ - 30 min.) is extremely small.
	Sea	Vessel Collision	○	Force of impact is less than the requirement for tie-down of trailer. [due to inquiry instances]
		Sinking of Vessel in Shallow Sea	○	Package retains its integrity in shallow sea. [due to simulation]
Low Level Waste	Road	Trailer Collision	○	Force of impact is less than conditions of the free drop test (1.2 m) . [due to simulation]
	Sea	Vessel Collision	○	Force of impact is less than the requirement for tie-down of trailer. [due to inquiry instances]

◎ = Accident scenario guaranteed by safety standards
○ = Accident scenario guaranteed by estimation of package integrity

Postscript

When this total safety assessment is completed, the safety of transportation will be assured. Because this assessment is based on realistic assumptions about accident conditions, it is expected to be useful both as a tool for public relations and as a blueprint for the development of an emergency response plan.

Reference

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