Transport experience of uranium solution after JCO criticality accident

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ABSTRACT

The criticality accident occurred on September 30, 1999 at JCO's (formerly Japan Nuclear Fuel Conversion Co., Ltd.) uranium processing plant in Tokai-mura of Japan. The accident occurred in the operation which produce uranium nitrate solution as a product after the purification of uranium powder of less than 18.8% of U-235 enrichment. The detailed report on this incident was made available to the public by the Nuclear Safety Commission of Japan. [1]

This paper details the steps taken by Japan Nuclear Cycle Development Institute (JNC) to transport the uranium nitrate solution including the fission products after the criticality accident (JCO's Uranium Solution) from the JCO's plant to the Tokai reprocessing plant of JNC. This report includes an explanation of the preparation of the packaging that would enclose the JCO's Uranium Solution and its conformity to safety regulations, the transportation of the Uranium Solution, and disclosure of transport information

In the preparation of the packaging, JNC would normally rely on packaging which could enclose the normal nitrate solution, but in this instance, JCO's Uranium Solution needed a higher level of shielding than the normal nitrate uranium solution without fission products. Given this situation, and the challenges of handling the material at the facility, JNC decided to modify the existing packaging to increase its shielding properties. The design of the modification, and quality assurance plan for the fabrication of additional shielding was approved by the competent authority.

Security concerns dictate that information concerning transportation of nuclear materials must be kept confidential. However, the weight of nuclear materials per transportation at once time was less than weight specified which would warrant additional protection measures. This weight-based assessment is the basis of national regulations for physical protection of nuclear materials. With these circumstances in mind, JNC decided on a limited disclosure of information on transport except for physical protection after consulting with concerned organizations. Also, JNC explained the safety of the transportation in the public hearing held by SAT and local governments.

1. INTRODUCTION

After the criticality accident, a special committee in the Nuclear Safety Commission of Japan initiated an investigation as to the causes, while ensuring that JCO's Uranium Solution would be immediately and safely transported to another facility. STA, which was competent authority for safety of the JCO's plant and JCO asked JNC to transport and treat JCO's Uranium Solution.

JNC did not possess the packaging to be able to enclose the JCO's Uranium Solution. After considering the challenges with regard to the handling of this material after a period for preparation, JNC decided to modify the packaging called "UOX/D" for nitric uranium acid solution which is to be used for material of fuel for "JOYO" which is the fast breeder experimental reactor of JNC. As the Tokai reprocessing plant has already received a license to treat spent fuel of light water reactors, JNC made an application to treat JCO's Uranium Solution in the same process as that of light water reactors after dilution of concentration of U-235 and adjustment of concentration of uranium.

This paper delivers a brief summary of the criticality accident and the design of the packaging for transport of JCO's Uranium Solution, as well as the modification that was made to augment that ability of the

packaging material to shield gamma rays. Additionally, this paper details the inspection process with respect to the modification, and measures taken concerning the actual transport and disclosure of transport information.

After these preparations were completed, the transports were carried out between March 23rd and April 14th in 2000. In the Tokai Reprocessing Plant, Uranium-235 enrichment of the solution was diluted from 18.8% to less than 4%, and Uranium solution concentration was adjusted to less than 240g-U per liter, and then the solution was treated in the same way as spent fuel of light water reactors between November and December in 2000.

2. SUMMARY OF CRITICALITY ACCIDENT [1]

September 29th: Start of operation to make concentration of nitrate uranium solution with 18.8% U-235 enrichment adjusted to less than 380g-U per liter as fuel material for fast breeder experimental reactor "JOYO".

Four buckets (about 9.6kgU) of the solution were poured into the precipitator that should have held only one bucket (2.4kgU).

September 30th: Additional three buckets of the solution (about 7.3kgU) were poured into the precipitator.

Around 10:35AM: The uranium nitrate solution in the precipitator reached criticality. A major power excursion occurred instantaneously at the point of criticality and after that a low-level nuclear fission lasted about 20 hours

October 1st around 2:30 AM: The beginning of drawing cooling water from the jacket around the perimeter of the precipitator.

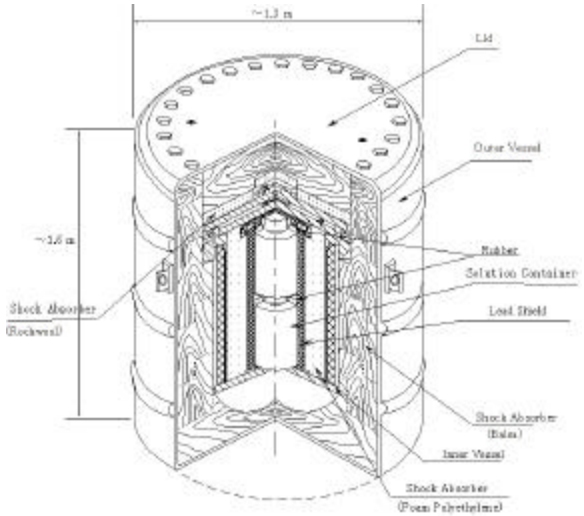
Around 6:15AM: Criticality was terminated.

Boric acid was poured into the precipitator.

8:50 AM: The end of criticality was confirmed.

3. DESIGN OF THE PACKAG

JNC possesses two packagings called "UOX/D" for nitric uranium acid solution. The packaging is composed of steel inner vessel made for containment, a steel outer vessel and wood shock absorber in between. (See Fig.1, 2)



The packaging "UOX/D" for nitrate uranium solution

Fig.1

FIg.2 Outward appearance of UOX/D

[Method of enclosure of nitric uranium acid solution before modification]

Nitric uranium acid solution as product is put into the bottle made of stainless steel with a capacity of 4 liters.

Ten bottles with the solution are settled in a holder made of stainless steel which has no special ability of shield

The holder is enclosed into the inner vessel of a UOX/D packaging

JNC has already obtained the approval of STA for the design as type BM package for normal nitric uranium acid solution.

3.1 The main issue of the design of the modification

To keep the weight and outer dimension of the new holder with the content as same as the former holder with the content.

To keep standards on dose rate at the surface and 1m from the surface of the package with JCO's Uranium Solution.

3.2 The main procedure

[Establishment of the source]

The comparison of the result of analysis of the sample of the JCO's Uranium Solution by JAERI with the result of burn-up calculation by ORIGEN.

Examination of effect of the library of ORIGEN and the neutron spectrum

Establishment of the library

Evaluation of the calculation result on dose rate by ANISN

Establishment of the source

[The design and fabrication of the package]

Temporary safety analysis of the package based on the specification of JCO's Uranium Solution

Establishment of the design specification of the package

Detailed safety analysis of the package

Establishment of the fabrication specification of the new holder with shielding

Application to STA on the safety of the package with the description of the safety analysis and the fabrication

Reflection of the discussion at the Technical Advisory Committee for the packaging safety

Inspection in the fabrication of the new holder by JNC and STA

Completion of the packaging

3.3 The specification of content of the JCO's Uranium solution per a package

The determined specification of the content of the package is as follows;

Item		Specification
Name		Irradiated uranium solution $UO_2(NO_3)_2$ B Na Ag Gd
Weight	Irradiated uranium solution	Less than 13.4kg
	Uranium	Less than 2.7kgU
	Uranium-235	Less than 540g
Strength of the source		Less than 8.04GBq
Property		Liquid
Uranium concentration		Less than 20wt%
Burn up		60kWd/t
Heat generation		Less than 0.0017w
Cooling time		More than 120days

3.4 The main nuclides and activity of the designed content of JCO's Uranium Solution

The calculated activity(*)of the main nuclide the content of the package is as follows

Nuclide	Activity Bq	Nuclide	Activity Bq
Sr-89	6.60E+08	Ce-141	4.89E+08
Sr-90	1.92E+07	Ce-144	4.98E+08
Y-90	1.92E+07	Pr-143	3.59E+07
Y-91	8.49E+08	Pr-144	4.98E+08
Zr-95	1.06E+09	Pr-144m	5.98E+06
Nb-95	1.55E+09	Nd-147	4.33E+06
Nb-95m	7.88E+06	Pm-147	8.78E+07
Ru-103	3.38E+08	Sm-151	4.49E+05
Ru-106	3.26E+07	Eu-155	6.79E+05
Rh-103m	3.05E+08	Th-231	4.32E+07
Rh-106	3.26E+07	Th-234	2.60E+07
Sn-123	8.40E+05	Pa-234m	2.60E+07
Sb-125	1.43E+06	-	-
Te-125m	2.52E+05	U-232	8.53E+05
Te-127	3.48E+06	U-234	1.25E+09
Te-127m	3.55E+06	U-235	4.32E+07
Te-129	6.01E+06	U-236	6.46E+06
Te-129m	9.23E+06	U-238	2.69E+07
Cs-137	2.01E+07	-	-
Ba-137m	1.90E+07	Kr-85	2.43E+06
Ba-140	2.50E+07	I-131	4.00E+05
La-140	2.88E+07	Xe-131m	2.56E+05
Total			8.04E+09
Heat generation			0.0017w

*CODE:ORIGEN2

Calculation condition:

Weight of uranium : 2.7kgU Including impure nuclides of ECGU specification
Weight of uranium 540g
Burn up 60 kWd t
Burning time 20 hours
Cooling Time 120 days

4. The fabrication of the new holder with shielding(See Fig.3,4)

In an original design the packaging held up to ten bottles (capacity of 4 liter) of uranium solution. Gamma rays from the fission products in the JCO's Uranium Solution were so strong that the number of bottles had to be reduced from ten to two. Furthermore, additional shielding capacity was required by installing a lead shield. For that purpose, while maintaining the outer diameter and weight, the older holder was replaced by a new one with a lead shield of 15mm thickness.

In the fabrication of the new holder with lead shield, a control-based quality assurance program was applied to fabrication process with the cooperation of an experienced packaging producer. The main items of in-

spections were the material, dimensions, welding, appearance, weight and handling. An emphasis was placed on shielding ability, which was strictly examined through inspections of filling-up rate of lead, specific gravity of lead, chemical composition and also shield-testing with gamma ray exposure. All specifications were proven to be satisfactory.

Fig3

Fig.4

Fig.5

Fig.3: Insert of the holder with lead shield to outer shell of the holder
Fig.4: Outward appearance of top and outer shell of the holder
Fig.5: The former holder with ten bottles

5. Transportation

There were about eighty liters of JCO's Uranium Solution stored at JCO plant and the solution was contained in twenty bottles with about four liters. On the other hand, with a total of only two UOX/D packagings available and each holding only two bottles of the solution, one shipment could transport four bottles at once and five shipments were needed to transport all twenty bottles.

The basic pattern of the transport process was as follows; (See Table-1, Fig.6,7,8,9,10,11)

First day: packing, pre-shipment inspection by JNC

Second day: pre-shipment inspection by STA

The pre-shipment inspection included appearance, lifting, weight, surface contamination and dose rates at the surface and 1m point from the surface, content, subcriticality and leaktightness.

Third day: loading onto a vehicle, loading inspection by MOT

The inspection included contamination and dose rate of the vehicle loaded with the packages, equipment carried with the convoy and so on.

Actual transport, unloading at INC reprocessing plant, unpacking of the packages (or unpacking was on forth day.)

Forth day: return of the empty packaging to JCO

Transport was arranged in a convoy, with supporting vehicles in front of and behind the vehicle carrying the two UOX/D packages. Transportation headquarters were set up at JNC's Tokai works in order to be able to quickly respond to an emergency.

After the above arrangements were completed, and with the cooperation of concerned organizations, five trips were performed from March 23rd to April 14th, 2000.

Fig.6 Fig.7

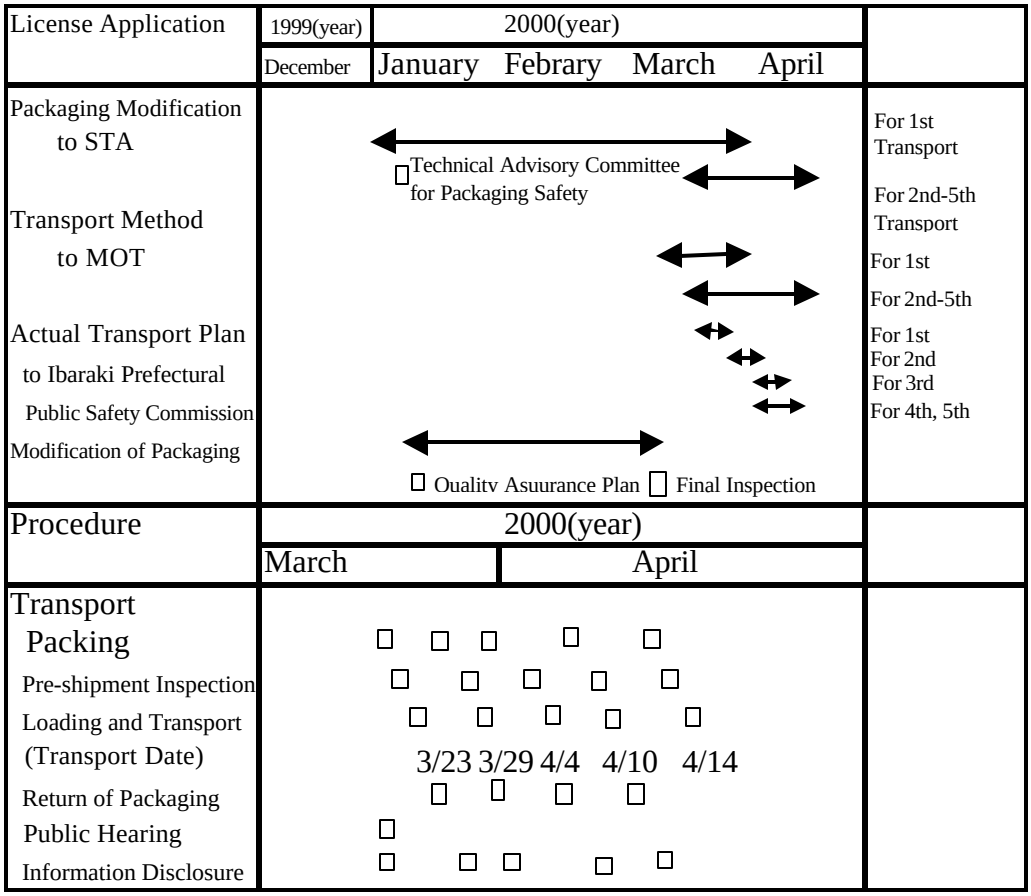
Fig.6: Insert bottle with JCO Uranium Solution to the holder

Fig.7: Measurement of neutron at 1m from surface of the packaging

Fig.8 Loading Fig.9 Convoy

Fig.10 Transfer to the facility Fig.11 Unpacking

Table1 Process for JCO Uranium Solution



6.Disclosure of transport information

Due to a concern for the security of nuclear material, information regarding transport routes and times of transport is restricted. The weight of nuclear materials per transport was 500-900g in U-235 metal (See Table -2). The fuel material and its weight are measured in order to ensure adequate measures for protection in Japan (See Table-3). In this case, the weight of U-235 per transport was less than the weight (1,000g in U-235) needed to take additional measures for physical protection. The transport drew some concern from the public and media. Taking into account public concerns, JNC decided to disclose transport information regarding the date, route, shipper's and receiver's facility and etc. by taking additional measures such as reinforcement of self-guard following publication. The disclosure was done a few days before transportation and the information was available in web site.

JNC also explained the safety of the transport in the public hearing held by SAT and local governments .

Table 2 Transport of JCO Uranium Solution

No	Date	Uranium Solution Weight	Uranium Metal Weight	U-235 Metal Weight
1	2000.03.23	16.5kg	4.2kg	764g
2	2000.03.29	21.6kg	4.6kg	842g
3	2000.04.04	21.7kg	4.6kg	842g
4	2000.04.10	18.1kg	3.1kg	579g
5	2000.04.14	19.1kg	2.8kg	509g

Table 3 Specified Nuclear Material to be protected

Category	Classification	Weight
Irradiated(1Gy/h At the surface)	Pu	More than 15g
	20% U-235	More than 15g
	10% U-235 20%	More than 1000g
	Natural U-235 10%	More than 1000g
	U-233	More than 15g

[1]:http://nsc.jst.gojp/anzen/sonota/jco/uran_eng