Radiation safety in sea transport of radioactive material in Japan

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ABSTRACT

Radiation safety for sea transport of radioactive material in Japan has been discussed based on records of the exposed dose of sea transport workers and measured data of dose rate equivalents distribution inboard exclusive radioactive material shipping vessels. Recent surveyed records of the exposed doses of workers who engaged in sea transport operation indicate that exposed doses of transport workers are significantly low. Measured distribution of the exposed dose equivalents inboard those vessels indicates that dose rate equivalents inside those vessels are lower than levels regulated by the transport regulations of Japan. These facts clarify that radiation safety of inboard environment and handling of transport casks in sea transport of radioactive material in Japan are assured.

1. INTRODUCTION

Most of nuclear fuel materials used at nuclear power plants are transported by general cargo ships from abroad while spent fuels are transported to nuclear fuel reprocessing plants in Japan and abroad by shipping vessels in exclusive use. Although the spent fuel (SF) have been transported to a reprocessing plant at Tokai-mura and reprocessing plants in UK and France from each nuclear power station by exclusive shipping vessels, sea transport of spent fuels to domestic reprocessing plants from each nuclear power station would take lead from now on because receipt of spent fuel at a storage facility in the reprocessing plant of Japan Nuclear Fuel Ltd. (JNFL) located at Rokkasyo-mura has been started since 1998. The low level radioactive wastes (LLW) has been transported to the LLW burial site of JNFL located at Rokkasyo-mura. As described above sea transport of radioactive material has played an important role in the nuclear fuel cycle in Japan. Due to recent increase of transported radioactive material and diversification of transport form with enlargement of nuclear research, development, and utilization, safety securement for sea transport of radioactive material is one of important subjects in the nuclear fuel cycle.

To discuss the radiation protection for sea transport of radioactive material, the target consignment was set to the SF and LLW package transported to the facilities at Rokkasyo-mura from each nuclear power station by exclusive shipping vessels considering amount of radioactivity and transport track record of radioactive material to be conveyed. This paper verifies safety of sea transport of radioactive material in recent years from a viewpoint of radiation protection based on the surveyed records of the exposed dose of workers engaged in sea transport operation and measured data of distribution of dose rate equivalents inboard environment of the exclusive shipping vessels.

2. RADIATION PROTECTION REGULATIONS FOR SEA TRANSPORT OF RADIOACTIVE MATERIAL IN JAPAN

In Japan legislative system between regulations in nuclear facilities that the radiation protection is managed by preparation of radiation control area and transport regulations applied outside an establishment differ. Sea transport of radioactive material is treated as shipment outside an establishment and is regulated by safety standards concerning nuclear fuel packages and methods of transportation including methods of loading onto the ship in the order of Ministry of Land, Infrastructure and Transport, “Rules concerning Maritime Transportation and Storage of Hazardous Materials” under Ship Safety Law. Nuclear entrepreneurs, however, may participate in shipment outside an establishment. Observance duty of regulations for package, packaging, marking, labelling, and placarding is applied to consignor, namely, nuclear entrepreneurs, while observance duty for requirements such as methods of loading onto a ship is applied to a captain or ship’s owner. In case that consignor is nuclear entrepreneur, because general radiation control for workers, engaged in transport operation, as employees of nuclear facilities inside an establishment is managed by Reactor Regulation Law, no special prescription is carried out under the transport regulations and the transport regulations prescribed to inboard residence such as crew of a shipping vessel. Thus, the exposed dose limit prescribed in the transport regulation is 1 mSv/year that is same level as the dose limit for general public and the level of the dose limit is regulated as sufficiently safe level. In case that Minister of Land, Infrastructure and Transport especially approved under specific circumstances that it is impossible to obey the regulations and required radiation control measures are taken, the regulation allows to exceed the dose limit.

However, It is not allowed to exceed 50 mSv/year in any cases.

3. RECORDS OF EXPOSED DOSE OF SEA TRANSPORT WORKERS

Survey of records of exposed dose of sea transport workers engaged in handling of packages at Mutsu Ogawara port and crew of the exclusive radioactive material shipping vessel was conducted. The packages concerned are the LLW and SF and the exclusive shipping vessels concerned are Seiei Maru and Rokuei Maru. Records from 1997 to 2001 were surveyed for the LLW transport while records from 1998 to 2001 were surveyed for the SF transport. The recent records of the exposed dose of workers were statistically processed and used for discussions hereafter.

Workers engaged in handling of packages include cargo operation workers, personnel for the radiation control and transportation firm personnel. For control of the exposed dose of workers engaged in handling of packages, both the glass batch and the pocket personal dosimeter are used. Measurement of the exposed dose for radiation control for crew of the exclusive shipping vessels is carried out by either the film batch or the glass batch. In case that personnel of electric power companies and cargo operation firms, and inspectors are temporarily required to enter inboard restricted area, measurement of the individual exposed dose is carried out by using the photo-diode type pocket dosimeter.

Results of survey of exposed dose records of the workers are shown in Table I and Table II. From a viewpoint of the individual exposed dose, the exposed dose of the workers, engaged in handling of the packages, such as personnel of transport firms, cargo operation workers, and radiation control workers at the Mutsu Ogawara port are shown in Table I. Packages considered for preparation of the Table I are the SF, LLW, vitrified wastes and UF_6. Results arranging the exposed dose records by type of package are shown in Table II. In the Table II, attention was paid to shipment of the SF and LLW, and records of the exposed dose during handling of each package are shown. Crew and personnel temporarily entered the vessels are also included in the workers in the Table II addition to workers engaged in handling of packages.

For workers, engaged in handling of the packages, such as transport firm personnel, cargo operation workers, radiation control workers, measured result of the glass batch was less than the detection limit of the dosimeter, 100 μSv. Because the workers also have put on pocket dosimeter whose detection limit is 1 μSv, small amount of the exposed dose was possible to measure. Average individual exposed dose for each year was 1.2 to 7.7 μSv and maximum exposed dose equivalent for one time transport operation for the workers is approximately 10 μSv. There was no worker whose annual exposed dose exceeded 30 μSv. The survey results indicate that recent records of the exposed dose for the workers are significantly small level compared with the exposed dose limit of the transport regulation.

The exposed doses for crew of the exclusive shipping vessels, Seiei Maru and Rokuei Maru, were less than detection limit of the dosimeter, 100 μSv, and the exposed doses for personnel temporarily entered the vessels were also less than the detection limit of the pocket dosimeter, 10 μSv, except for the LLW transport in 1997. These facts indicate that the exposed dose records inboard the vessel are significantly low level.

Table 1. Exposed dose of sea transport workers

Year	Number of workers	Total dose (man·μSv)	Average dose (μSv)	Annual individual dose distribution				
				< 1μSv	1−9μSv	10−19μSv	20−29μSv	> 30μSv
1996	65	136	2.1	30	34	1	0	0
1997	60	200	3.3	19	35	6	0	0
1998	62	76	1.2	41	21	0	0	0
1999	69	285	4.1	19	38	12	0	0
2000	69	534	7.7	19	28	9	13	0
2001	76	460	6.1	27	30	12	7	0

Table 2. Exposed dose and collective dose of sea transport workers engaged in transport of SF and LLW

Type of transport		Total number of workers	Total dose (man·μSv)	Average dose (μSv)	Maximum dose [a] (μSv)	Total TI handled	Collective dose per TI (μSv/TI)
LLW	1997	301	119	4.0×10^{-1}	20	16320.61	7.3×10^{-3}
	1998	333	42	1.3×10^{-1}	5	9275.85	4.5×10^{-3}
	1999	252	6	2.4×10^{-2}	1	3167.1	1.9×10^{-3}
	2000	152	10	6.6×10^{-2}	2	910.44	1.1×10^{-2}
	2001	229	25	1.1×10^{-1}	8	599.59	4.2×10^{-2}
SF	1998	165	4	2.4×10^{-2}	1	2.0	2.0×10^{0}
	1999	271	4	1.5×10^{-2}	1	1.0	4.0×10^{0}
	2000	480	39	8.1×10^{-2}	2	5.42	7.2×10^{0}
	2001	870	116	1.3×10^{-1}	9	19.81	5.9×10^{0}

[a] Maximum dose received in one time transport operation.

To compare the present survey result regarding sea transport workers with data of other mode of transport in abroad, the collective dose per the transport index (TI) was derived from the annual total dose and total transport index of packages transported in each year. The results are also shown in the Table II. Crew, personnel temporarily entered the vessel, transport firm personnel, cargo operation workers, and radiation control workers are included in the sea transport workers. The transport indexes used in the present study were determined from the measured doses of packages before dispatch. The collective doses per TI for transport of the SF are the order of 1 μSv/TI. The collective doses per TI for transport of the LLW are lower than those of the SF transport 2 to 3 orders of magnitude. The values for the SF transport are consistent with surveyed data in Ref. [1], the collective dose per TI during transport by road and air in UK and USA. It can be considered that a reason that the collective doses per TI for the LLW are lower than those for the SF is that complete remote handling of the LLW packages made possible by adoption of remote and automatic crane operation as much as possible and adoption of the gate monitor [2] to measure the dose equivalent rate of a track loading with packages automatically.

4. DOSE DISTRIBUTION INBOARD EXCLUSIVE SHIPPING VESSELS

National Maritime Research Institute (NMRI) has been conducted measurement of dose distribution inboard the exclusive shipping vessels during transport of the SF and LLW to verify radiation safety of sea transport of radioactive material. NMRI conducted onboard measurement for exclusive shipping vessels and transport casks shown in Table 3. In this paper measurement carried out in recent 10 years are presented.

Table 3. Measurement of dose rate distribution inboard the exclusive shipping vessels for SF and LLW by National Maritime Research Institute. This list includes experiment carried out by former Ship Research Institute.

Shipping Vessel	Packages loaded	Remarks	Reference
Hinoura maru	2 HZ-75 casks and 1 NH-25 cask	BWR, 19.7 GWD/MTU	[3]
Pacific Swan	8 TN-12A casks	PWR, 15 GWD/MTU	[4]
Seiei Maru	336 LLW container	Cement solidified LLW	[5]
Rokuei Maru	6 NFT-14P casks	PWR, 40 GWD/MTU	[6]

(1) LLW SHIPPING VESSEL SEIEI MARU

Measurement of distribution of dose rate equivalents inboard the exclusive LLW shipping vessel, Seiei Maru, was carried out in October 1993 [5]. The Seiei Maru has 7 cargo holds and 336 containers were loaded in No.2 to No.7 cargo hold for shipment. Eight LLW drums are contained in one container. Principle radiation sources from the LLW container are ^{137}Cs and ^{60}Co. For measurement of distribution of dose rate equivalents, the NaI(Tl) scintillation survey meter was used. Measured points inboard the vessel are shown in Fig. 1 with dotted circle. Measured dose rates inboard the vessel are shown in Table 4. Measured maximum dose rate equivalent in an accommodation area was 0.05 μSv/h and was sufficiently low level compared with a criterion for the accommodation area, 1.8 μSv/h.

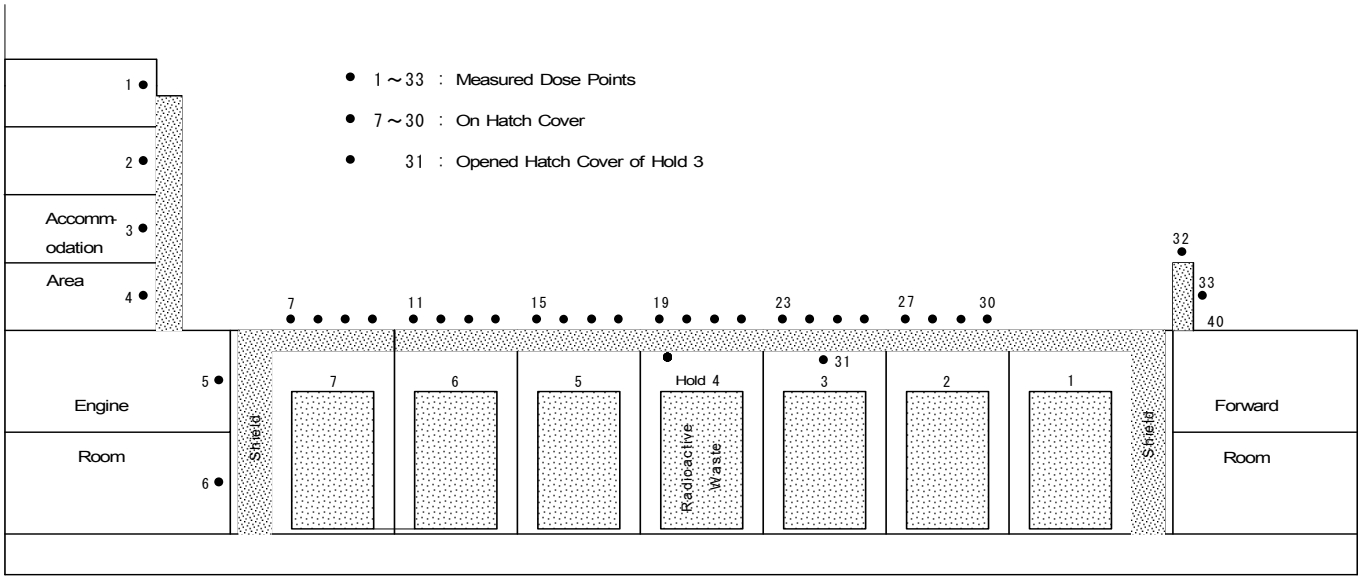

Fig.1. Schematic view of points where dose rate was measured in the LLW shipping vessel.

Table 4. Measure dose rate equivalent

Measured point	Measured dose rate equivalent (μSv/h)	Measured point	Measured dose rate equivalent (μSv/h)
1	0.05 ± 0.0075	18	0.92 ± 0.138
2	0.045 ± 0.00675	19	0.63 ± 0.0945
3	0.045 ± 0.00675	20	0.96 ± 0.144
4	0.025 ± 0.00375	21	0.78 ± 0.117
5	0.025 ± 0.00375	22	0.66 ± 0.099
6	0.02 ± 0.003	23	0.40 ± 0.06
7	0.50 ± 0.075	24	0.57 ± 0.085
8	0.82 ± 0.123	25	1.00 ± 0.15
9	0.77 ± 0.1155	26	0.91 ± 0.1365
10	0.63 ± 0.0945	27	0.39 ± 0.0585
11	0.59 ± 0.0885	28	0.58 ± 0.087
12	1.09 ± 0.1635	29	0.83 ± 0.1245
13	0.81 ± 0.1215	30	0.75 ± 0.1125
14	0.58 ± 0.087	31	19.7 ± 2.955
15	0.58 ± 0.087	32	0.04 ± 0.006
16	1.10 ± 0.165	33	0.01 ± 0.0015
17	1.17 ± 0.1755		

Measured maximum dose rate equivalent above the hatch cover was 1.2 μSv/h and was sufficiently low level compared with a criterion for above the hatch cover, 2000 μSv/h.

(2) SF SHIPPING VESSEL ROKUEI MARU

Measurement of distribution of dose rate equivalents inboard the exclusive SF shipping vessel, Rokuei Maru, was carried out in November 2001 [6]. The Rokuei Maru has 5 cargo holds and three NFT-14P casks were loaded in No.2 and No.3 cargo hold, respectively, as shown in Fig. 2. Average burn-up of the SF enclosed in six NFT-14P casks was 40,000 MWD/MTU and cooling time varies between 694 and 2188 days. In the experiment, dose rate

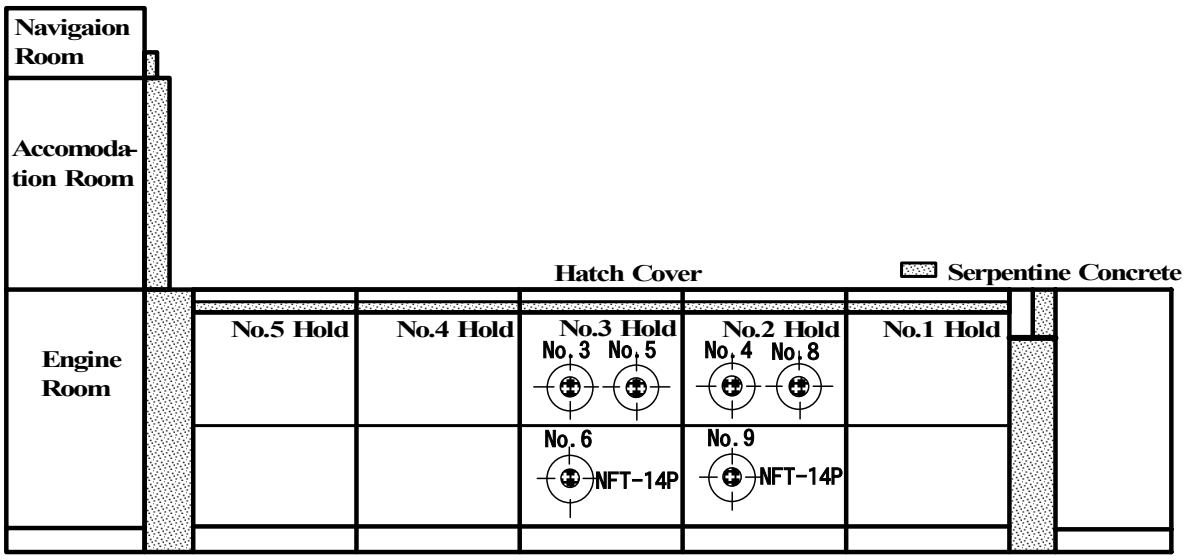

Fig.2 Schematic view of SF shipping vessel Rokuei Maru.

Table 4. Measure dose rate distribution above hatch cover of the No.3 hold of SF shipping vessel Rokuei Maru.

Measure point	Dose equivalent rate (μSv/h)		
	Gamma ray	Neutron	Total
1 Stern	0.077	0.037	0.11
2	0.090	0.045	0.14
3	0.090	0.050	0.14
4	0.10	0.050	0.15
5	0.063	0.040	0.10
6	0.087	0.030	0.12
7	0.087	0.037	0.13
8	0.073	0.030	0.10
9 Bow	0.063	0.030	0.093

measurements at surface of the casks and at 1 m from surface of the casks were also carried out. Maximum dose rate equivalent, summation of neutron and gamma ray dose rate equivalent, at surface of the casks was 29 μSv/h and maximum dose rate equivalent at 1 m from surface of the cask was 6.8 μSv/h. These values were sufficiently lower than criteria prescribed in the transport regulations; dose rate equivalent at surface of the package is less than 2000 μSv/h and dose rate equivalent at 1m from surface of the package is less than 100 μSv/h. Maximum dose rate equivalent at surface of the shipping vessel was observed above the hatch cover of the No.3 cargo hold and was 0.15 μSv/h. Measured dose rate distribution above hatch cover of the No.3 hold are shown in Table 4. The measured dose rate equivalent is sufficiently lower than criteria of the transport regulations; criteria at surface of the shipping vessel is less than 2000 μSv/h and criteria at 2m from surface of the vessel is less than 100 μSv/h. Although dose rate equivalents were also measured in the accommodation area, those were back ground level.

As described above, radiation level inboard the shipping vessels was significantly lower than the criteria prescribed in the transport regulations. This fact proves that the exposed dose record of crew of the shipping vessels is significantly low.

5. SUMMARY

Result of survey of recent records of the exposed dose for workers engaged in sea transport operation of radioactive material indicates that the annual exposed dose of the workers is lower than the dose limit prescribed in the transport regulation. Measurement of distribution of dose rate equivalents inboard the exclusive shipping vessels for transport of the spent fuel and the low level radioactive wastes indicates that dose rate equivalents in the accommodation area and above the hatch cover are significantly lower than the criteria of the transport regulations. Thus, it is clear that radiation safety in handling of the transport casks and inboard the shipping vessel during sea transport of radioactive material is sufficiently secured in Japan.

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