

LOW-LEVEL RADWASTE TRANSPORTATION IN TAIWAN

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INTRODUCTION

Currently there are three nuclear power plants in operation in Taiwan, including six nuclear power units; the total power output amounts to 5,144 MWe. 95% of low-level waste in Taiwan is generated by nuclear power plants, 5% are generated by medicine, agriculture, industry, and academic organizations. For the interim storage of low-level waste, the Atomic Energy Council (AEC) constructed a storage facility on Lan-Yu (Orchid Island), and started operation in 1982, to receive wastes from nuclear power plants and the Institute of Nuclear Energy Research (INER). Sea transportation is the major part of low-level waste transportation and land transportation is the minor part. The transport ship parks at the northern end of Taiwan, the southern end of Taiwan, and Lan-Yu. The waste in transport includes packaged waste to be sent to Lan-Yu and waste from the Third Nuclear Power Plant to be incinerated or compacted at the Volume Reduction Center (VRC) of Taiwan Power Company (Taipower). Since 1982, 79,476 drums of low-level waste have been sent to Lan-Yu; in each shipment 288 drums of waste are carried by 6 containers. At present, Taipower has constructed a new ship named "Tien-Kuang No.1" to join the transport operation. This paper describes the history of low-level waste transport in Taiwan, relevant regulatory regulations, marine incidents encountered in the past, and the status of transportation.

HISTORY OF RADWASTE TRANSPORTATION

When Taipower was drawing the plan to build the first nuclear power plant, the Taiwan government had considered a well-organized process to manage the low-level radwaste produced by nuclear power plants. A managing process storing all radwaste together is safe not only to a human's living environment but also to ecology. However, it was hard to find a suitable radwaste storage site on highly populated Taiwan Island. After several years' investigation and evaluation,

Lan-Yu, an islet in the southeast of Taiwan, was selected for establishing an interim storage site to hold the low-level radwaste from nuclear power plants of Taipower.

The storage facility was finished in 1982 and the first shipment of 288 drums (55 gallons per drum) of solidified radwaste was shipped to Lan-Yu from the First Nuclear Power Plant in May of 1982. There were not much local or international reference data for such a shipment. It was full of difficulties and resistance then. Nevertheless, all authorities contribute their best to completing the maiden voyage without any trouble. Consequently, the low-level radwaste produced by the Second Nuclear Power Plant and the Third Nuclear Power Plant and INER were transported to Lan-Yu storage site. Till May of 1992, there were 273 voyages with 79,476 drums of solidified radwaste shipped to and stored in Lan-Yu storage facility.

In the initial stage, a vessel named "Ta Ya No.2" was chosen as the shipping vehicle. After several alternatives, Tien Kuang No.1 belonging to Taipower is the present specific vessel to ship low-level radwaste now. Keelung Wharf was the first wharf for the transportation. Then Chung Jiao was chosen as the second wharf. At present, Mingkuang Wharf and the wharf in the Third Nuclear Power Plant are departure wharves and Lan-Yu Wharf is the destination wharf.

REGULATIONS

Because radwaste contains radioactivity, its transportation shall never have any delinquency. Any events may cause the public's panic and an impact to the environment. Besides the regulations issued by ordinary land and marine transport administrative agencies, voyage administration, and harbor management agencies, the transportation of radwaste is also controlled by the main regulations as follows:

(1) Safe Transportation Rule of Radioactive Materials

It sets the requirements for protective measures and safety distance between radwaste and wheelhouse, working chamber, and personnel in order to keep personnel, goods and other properties away from damage by the ionizing radiation and radiation contamination.

(2) Radwaste Management Regulation

It requires the transportation applicant to submit a radwaste transport plan and emergency response plan in accordance with the above mentioned regulation. It also asks for the identity of drums, warning signs, and personnel with radiation protection training.

(3) Regulation on the Safe Transport of Low-level Radwaste by Ships

It sets rules for recoverability of vessel, configuration of containers, double-layer of vessel shell, facilities and equipment of vessels such as: container-fixing equipment, radioactivity measuring equipment, contaminated water collecting system, extinguishing facility, locking device of chambers, lighting of working area, electricity system, navigation facility, age limit and so on, to ensure voyage safety and personnel protection.

(4) Radwaste Transportation Plan and Emergency Response Plan

It sets requirements for vehicles, operation teams, operation procedure, radiation protection, environmental evaluation, and accident mode analysis, treatments, handling procedure of events to prevent events and enlargement of events.

(5) Navigation Rule of Low-Level Radwaste Marine Transport

It requires controlling water depth of wharf, meteorology, tides, harbor incoming and outgoing operating procedure, communication, and location of vessel.

TRANSPORTATION PROCEDURES

The radwaste transportation procedures with pre-transportation preparation includes: application for storage, inspection of storage drums, drums loading to containers, inland transportation, marine transportation, and receipt in Lan-Yu. Herewith we would introduce only inland transportation and marine transportation.

1. Inland Transportation

After the drums packed with radwaste are loaded in containers, the applicant shall check the forecast data announced by Central Weather Bureau. When average wind force of northern, eastern and southeastern sea waters of Taiwan is not over Grade 7 and the strongest gust is not over Grade 8 for the next three days, the applicant shall prepare for transporting the containers and notify the Radwaste Administration. All vehicles, operators, and various equipment are mobilized to operation area. The containers are lifted by hoist to container carrier and fixed firmly. The dose rates of surface of container and two meters away from the surface of container shall be measured. (Criteria: Surface-less than 200mR/hr; 2-meter away from surface-less than 10mR/hr). Ensuring the dose rates in safe range, a label showing "radioactive substance" shall be attached to the containers. The transportation index shall be filled out. And the goods are ready for shipment.

Basically, inland transportation is held in nights when passengers and vehicles are rare. The fleet is led by police cars. On the way, there is traffic control. Maintenance car is in the fleet to deal with any possible incidents. The fleet runs at a speed of 30 kilometer per hour. Right now, the fleet leaves First and Second Nuclear Power Plants at 2:00 a.m. The

transfer wharf is located in the Third Nuclear Power Plant so all transportation procedures are taken in daytime. The inland transportation distance from INER is longer; therefore, the fleet leaves INER at 11:00 p.m. As soon as the fleet arrives at Mingkuang Wharf, a controlled area is set up. All persons and vehicles are under control and cannot move in or out without permission. The next stage of marine transportation starts from then on.

2. Transportation Procedures in Wharf and Marine Transport

First of all, the radiation background value of the vessel shall be measured and the machinery of the vessel shall go through a complete inspection before transportation. The containers whose dose rates are higher are put in the ends of the hold. This arrangement intends to minimize any possible radiation dose on the operators during shipment. When the containers are put in right place, the vessel shall sail at best time according to tides. Nowadays, the vessel cannot leave the harbor until the tide is high. First Nuclear Power Plant and Second Nuclear Power Plant and INER take Mingkuang Wharf to transport radwaste to Lan-Yu. The distance between Mingkuang Wharf and Lan-Yu is 220 nautical miles and takes 20 hours to finish the voyage. The Third Nuclear Power Plant uses its specific wharf in the plant which is 40 nautical miles away from Lan-Yu and its voyage takes four hours. As soon as the vessel reaches Lan-Yu, the entire transportation is completed.

MANAGEMENT OF MARINE INCIDENTS IN THE PAST

Though there are many safety regulations for sea freight, changeable weather and mechanical defects of vessel cannot not be totally controlled by the human. Besides, operators' delinquency also is one of the factors causing voyage incidents. Based on statistics, up to May 1992, ten events out of total 273 voyages for the transportation of low-level radwaste occurred in the past ten years. Table 1 shows the date, type and treatment of these incidents.

- (1) It was 4 p.m. on June 3, 1983 when the six containers packed with low-level radwaste from the First Nuclear Power plant were unloaded to the specific wharf in Lan-Yu. The vessel of the 39th voyage was going to return to Taiwan. Suddenly, a strong southwest wind attacked the harbor. Surges brought the vessel to collide with the protective pier of the wharf that damaged broadside. The damaged vessel returned to Mingkuang Wharf for repairs on June 7, 1983.
- (2) At 2:30 a.m. June 27, 1984, the vessel of 53rd voyage from the First Nuclear Power Plant was passing Yehliu sea waters on its course from Mingkuang Wharf to Lan-Yu, there were three fishing ships in operation in the sea. After warning by light the third one made an abrupt yield and collided with the left broadside of the vessel. After ensuring no casualty, the vessel went

- on to Lan-Yu directly. Investigation proved that the event was caused by the delinquency of the fishing ship. After negotiation, both sides reached a mutual understanding. The collision did not affect the transport at all.
- (3) The weather changed suddenly at 6:40 August 12, 1984, when the 81st voyage of the First Nuclear Power Plant headed toward Lan-Yu. The vessel returned to Chengkung Wharf of Taitung County to shelter from strong wind and embarked to Lan-Yu on August 22.
 - (4) At 6:15 November 13 of 1984, the 8th voyage of INER departed Mingkuang Wharf for Lan-Yu. It was at ebb tide and surges appeared. The captain of the vessel did not pay enough attention to the situation so that the vessel got stranded in the voyage course. Then the master engine broke due to sucking-in sands. After discussion, a salvage service was called on to rescue the vessel. However, the weather was so bad that the containers packed with radwaste were moved to land by hoist. After that, the vessel was towed away from aground site. In reviewing the incident, it was suggested the main reasons of the incident were bad weather and the captain's improper operation. After the incident happened, both the shipping company and INER sent their professionals to handle the incident.
 - (5) When the 90th voyage of the First Nuclear Power Plant was sailing to Lan-Yu on August 21 of 1986, Typhoon Wynne made a sudden change in her direction. The vessel shipping radwaste returned to the closest Hwalien Harbor for shelter. Then on September 9 when the weather complied with requirements, the shipment was carried on.
 - (6) On June 21 of 1987, the 107th voyage transporting radwaste of the First Nuclear Power Plant from Mingkuang Wharf to Lan-Yu got stuck at 43 kilometers south of Hwalien because of breakdown of the master engine. In emergency inspection, the pulley of blast machine was found broken. In that case, the ship returned at low speed to Hwalien Harbor to fix. Then it sailed out from Hwalien on June 23 to carry on its mission.
 - (7) The 53rd voyage shipped radwaste of the Second Nuclear Power Plant to Lan-Yu. At 15:55 March 18 of 1988, while in Su Au sea waters, the steering gear of the vessel was found broken. It returned immediately to Su Au Harbor for repairs. Then it sailed out for Lan-Yu to finish its mission on March 22 after fixture.
 - (8) The empty vessel berthing on Keelung Port moved to Mingkuang Wharf on November 4 of 1988. At the moment when it was ebb tide, the bottom plate of afterpeak touched the sea bed. The examination proved the incident affected neither its propellant power nor its voyageability; therefore, it performed its assignment without disturbance. To keep its best condition and safety, the vessel was checked and fixed in Keelung after the assignment.
 - (9) It was the 120th voyage shipping radwaste of the First Nuclear Power Plant on June 11 of 1989. When the vessel arrived at Lan-Yu specific wharf and was ready for hoist operation, the weather became worse suddenly with strong wind

and surges. The vessel oscillated violently and collided with the wharf, breaking 16 towlines and deforming several ribs of left broadside. Fortunately, the vessel did not lose its power. As soon as it turned to good weather, the unloading operation was going on. After that, the vessel returned to Keelung for repairs.

- (10) The 97th voyage shipped radwaste of the Second Nuclear Power Plant from Mingkuang Wharf to Lan-Yu on February 21 of 1990. While the vessel was passing Bitou Cape, it was suspected that the master engine was out of order. The examination suggested that most of the power was lost because of breakdown of the pulley of blast machine and partially broken belt. Telegrams were sent to Military Rescue Center asking for assistance of salvage ship. In the meantime, the repairmen in the vessel were working to fix it. With primary repairs, the vessel returned to Mingkuang Wharf at low speed. After the radwaste had been moved to the pier, the vessel was repaired.

The causes for the incidents are summed up as follows: (1) mechanical failure--three out of ten, (2) silt-up of course and improper operation--two out of ten, (3) weather--four out of ten, and (4) collision--one out of ten. From the statistics, 90% of incidents were caused by weather factors, mechanical failure and silt up of course and improper operation. These reasons shall be paid more attention to for safe transportation in the future.

CONCLUSIONS

In the past ten years, 273 voyages have been made to ship radwaste produced by nuclear power plants and INER. It more or less lowers the problem of insufficient storage space in Taiwan. Although all organizations followed various regulations to operate the transportation, ten events occurred in marine transport. However, they were ordinary incidents and neither released any radiation to contaminate the environment nor caused any casualty.

According to the statistics, all the incidents fell into the types which are mentioned in the "Emergency Response Plan." Those are : (1) inevitable surges, (2) collision, (3) being stranded, (4) mechanical failure, and (5) special sea perils. In these events, the employees working in the vessels as well as controlling agencies responded effectively and efficiently by following the Emergency Response Plan to eliminate enlargement of incidents. It bears out that the Emergency Response Plan can effectively deal with incidents in marine transportation.

Table 1 Statistics of Marine Incidents During Radwaste Transportation

	Date	Site	Consignee	Type of Incident	Cause	Remarks
1	1983 Jun 03	Lan-Yu Wharf	First Nuclear Power Plant	Collision of vessel Against wharf	Sudden change of weather & surges	Empty vessel
2	1984 Jun 27	Yehliu sea waters	First Nuclear Power Plant	Collision with a fishing ship	The fishing ship didn't follow signal to yield	
3	1984 Aug 12	Chengkung sea waters	First Nuclear Power Plant	Return to harbor for shelter from wind	Sudden change of weather	
4	1984 Nov 13	Mingkuang Wharf	INER	Ship got stranded	Improper operation	
5	1986 Aug 21	Hwalien Chengkung sea waters	First Nuclear Power Plant	Return to Hwalien to shelter from wind	Sudden change of weather	
6	1987 Jun 21	Hwalien sea waters	First Nuclear Power Plant	Ship lost power	Breakdown of master engine	
7	1988 Mar 18	Su Au sea waters	Second Nuclear Power Plant	Uneasy operation Return to harbor for check & repair	Breakdown of wheels	
8	1988 Nov 04	Mingkung Wharf	---	Loss of bottom plate of afterpeak Repair in dry dock	Silt-up of harbor	Empty-vessel
9	1989 Jun 11	Lan Yu Wharf	First Nuclear Power Plant	Breakdown of towline Collision to wharf Return for repair	Sudden change of weather	
10	1990 Feb 21	Bitou Cap sea waters	Second Nuclear Power Plant	Partial loss of power Return for repair	Breakdown of master engine	

PACKAGING SYSTEMS

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