Radiation Leaks from Nuclear Power Ship “Mutsu”

September 1, 1974 on the Pacific Ocean near Aomori (800 km east of the Cape Shiriya)

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When the first Japanese nuclear power ship “Mutsu” was in its experimental voyage in 1974. At 800 km east of the cape Shiriya in Aomori, it began leaking radiation when its crew brought the reactor power up to 1.4% of full capacity. The alarm went off as it detected radiation leaks; fast neutrons made their ways out of the reactor shielding (streaming). This incident made national headlines. Concerned about the dangers posed by the ship to the community and the fishing industry, the locals at Ohminato harbor, where Mutsu was built, refused to let the ship return to the harbor.

1. Event

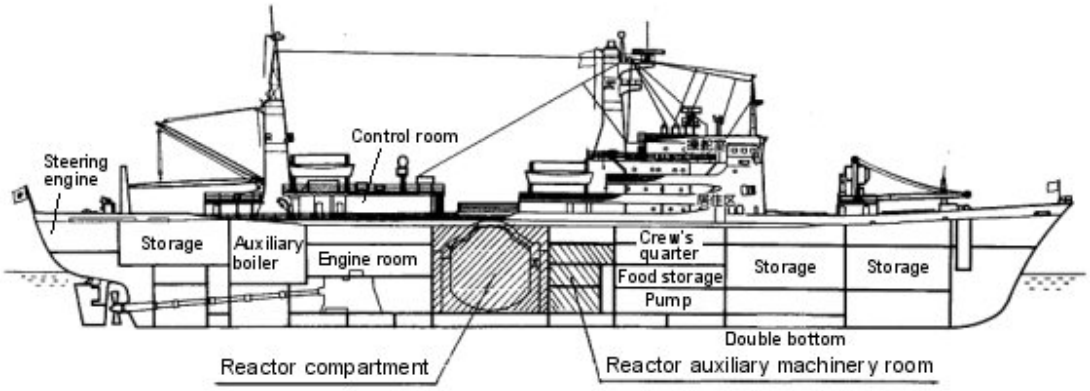
The first Japanese nuclear powered merchant ship “Mutsu” was put to sea for the first experimental voyage in 1974. At 800 km east of cape Shiriya in Aomori, the alarm went off as it detected radiation leak when its crew brought the pressurized-water reactor up to 1.4% of full capacity. This incident made national headlines. Concerned about the dangers posed by the ship to the community and the fishing industry, the locals at Ohminato harbor, where Mutsu was built, refused to let the ship return to the harbor.

2. Course

Based on the “Basic plan on the studies necessary for the research and development of nuclear powered ship by Japan Atomic Energy Research Institute” stipulated by the government, the nuclear powered ship “Mutsu” was built as a prototype commercial ship for transporting special cargos and training crew.

Authorities expected the leading 7 shipbuilding companies to enter the bid for constructing the ship, but the bids fell short of the expectation due to the low budget. They evaluated outsourcing to an overseas company such as Babcock & Wilcox Co. (U.S.A.), however, that would have made no difference in the construction costs, and they decided to commission Japanese companies to build the reactor. Through the Shipbuilders’ Association of Japan, the hull was commissioned to Ishikawajima-Harima Heavy Industries Co., Ltd. and the reactor to Mitsubishi Atomic Power Industries, Inc.

Figure 1 illustrates the nuclear powered ship “Mutsu”.



Purpose: Prototype	Gross tonnage: 8240 t	Reactor: Pressurized water reactor
Length overall: 130 m	Output of main engine: 10000 horsepower	Thermal output: 36 MW
Molded breadth: 19 m	Maximum speed: 32 km/h	Nuclear power: 145000
Molded depth: 13.2 m	Normal speed: 30 km/h	Cruising distance: NM (Under contemplation)
Draft: 6.9 m	Auxiliary power: 18 km/h	Crew capacity: 80

Figure 1. Nuclear Powered Ship “Mutsu” [4]

Ishikawajima-Harima Heavy Industries started construction of the hull at its Second Tokyo Factory on November 17, 1968. The hull of “Mutsu” was launched on June 12, and delivered to the registered port of Ohminato at Mutsu Bay on July 13, 1970.

The reactor was completed on August 25, 1972, and the nuclear fuel was loaded on September 4. The officials announced the test run of the ship where the reactor was to be operated at low output. The local fishermen and inhabitants protested against this experiment, unexpectedly to the officials, and the test run at the mooring facility and offshore within the bay was postponed. After several negotiations, the government, the Japan Nuclear Ship Development Agency and the local community agreed to test the ship away in the outer sea.

On August 26, 1974, while there were some protest activities, the ship left the port of Ohminato. On August 28, the ship’s reactor attained criticality for the first time in the testing area 800 km east of cape Shiriya in Aomori.

At around 17:00 on September 1, the alarm went off as it detected an increase in radiation when its crew brought the reactor up to 1.4% of full capacity. The mass media reported this incident saying, “Nuclear powered ship Mutsu leaked radioactivity”. Concerned about the dangers posed by the ship to the community and the fishing industry, the community (the town Mutsu and Aomori Prefecture) and the fishing industry, refused to allow the ship to return to the harbor, although they once had accepted the reactor test.

On October 14, a compromise was reached and the government, the local government of Aomori, the town of Mutsu and the Aomori Prefectural Fishery Cooperation signed an agreement on Mutsu’s entrance into its home harbor and withdrawal from its current home harbor. The ship returned to the port of Ohminato on

October 15.

3. Cause

(1) Cause of the radiation leak

Radiation leaked from the shielding ring. The alarm went off as it detected fast neutrons leaking out of the reactor shielding (streaming). The faulty design of the reactor shield was due to lack of experience. Only few models of reactor shields had been designed in Japan at that time, and there were few experienced reactor shield designers. The engineers made poor judgments about the capacity shielding with hard to calculate complex shapes. Although Westinghouse Electric Company (U.S.A.) had reviewed the design of the reactor shield as requested and had warned about the possibility of "streaming", the designer made no correction to the original design.

(2) Lack of comprehensive examination on radiation shielding efficiency

Because the ship and its reactor were commissioned to different independent companies, radiation shielding was not designed in a cohesive and integrated way. The efficiency of the shielding was not examined comprehensively.

(3) Report of "radiation" leak as "radioactivity" leak

The mass media reported radioactivity leak, instead of radiation leak. This made the community and the whole Japan fear radiation contamination of seafood (scallop) and produced an image of Mutsu to be "the nuke-leaking ship". Officials and investigators inherited this terminology "radioactivity", fueling bitter protests and general public distrust. It caused a significant delay in the project while the government tried to persuade harbor authorities to allow the ship to berth.

4. Immediate Action

The government created the Mutsu Radiation Leak Investigation Commission to investigate the details on the accident, and the Commission submitted a report on May 13, 1975. While reporting issues on the project, organization, technology and contract, the Commission evaluated positively that Mutsu satisfied the relatively high standards in the technological aspect. It then concluded that Mutsu would accomplish its objectives with appropriate repairs and modifications, and recommended 6 improvements in its development plan.

On March 18, the Atomic Energy Commission established the Nuclear Powered Vessels Council to discuss the future development of nuclear powered ships, as well as to review the Mutsu's development plan and the role of the Japan Nuclear Ship Research and Development Agency. On June 10, the Atomic Energy Commission publicly stated its disappointment in the government agency's inadequate judgment and inefficiency that invited the public's distrust, granted that the reactor was shut down before contamination became serious. It supported the Investigation Commission's recommendations and promised to implement them in the development plan as swiftly as possible. It also expressed support for the continuation of the nuclear powered ship program, the efforts in elevating the level of technology of Japan Nuclear Ship

Research and Development Agency, and a thorough review and overhaul by a governmental agency.

On September 11, the Nuclear Powered Vessels Council submitted a report supporting Mutsu's completion based on the original schedule. It emphasized Mutsu's contribution to the advancement of the industry's technology through domestic commissioning of its construction, experimental voyages for studies on its safety and adaptability, benchmark experiments for building the nuclear ship database and design improvements. It also recommended fundamental research and development of reactor equipment for ships while developing Mutsu.

On September 23, in response to the above report, the Atomic Energy Commission supported the development of Mutsu to benefit shipbuilding and shipping, as well as a part of the energy policy for nuclear power's future adaptations to vessels. It agreed to update the existing "Basic plan on the studies necessary for the research and development of nuclear powered ship" in accordance with the research and development leading to the ship's commercial use. It also agreed to extend the period of the Japan Nuclear Ship Research and Development Agency Law, which was originally set to end on March 31, 1976.

The Science and Technology Agency and the Ministry of Transport of Japan jointly established the Overhaul and Repair Technology Committee comprised of specialists from related fields (established on August 12, 1975). The Committee, which was delegated responsibility in reviewing the overhaul and repair plan of the Japan Nuclear Ship Research and Development Agency, submitted its first report acknowledging the validity of the plan and assuring the environmental safety.

On December 12, the government decided on the continuation of Mutsu's development at the Ministerial Conference on Nuclear Powered Vessels.

5. Countermeasure

Mutsu underwent lengthy repairs since 1978 until 1982 at the port of Sasebo.

The reactor shield had the following repairs and modifications (Figure 2).

(1) The new primary shield at the top is made of neutron-absorbing serpentinite concrete.
(2) The new auxiliary shield is made of heavy concrete, which was previously made from lead and polyethylene.
(3) Neutron-absorbing chrysotile heat insulator was installed to the flange joint of the reactor pressure vessel.
(4) Neutron-absorbing zirconium hydride was added to the cap of the reactor pressure vessel.
(5) Layers of polyethylene shield were added to the surface of the double bottom of the reactor containment (exterior).
(6) A shield made of serpentinite concrete and silicon was added to the bottom of the reactor containment.

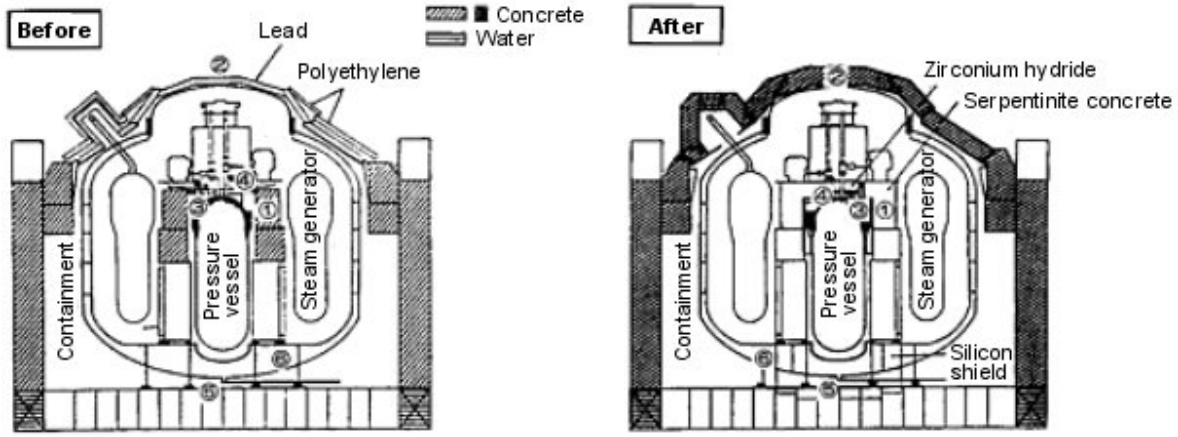


Figure 2. Reactor Shielding Improvements [5], [6]

6. Summary

The faulty design of the reactor shield caused radiation leak during the first power output experiment of Mutsu. While the engineers shut down the reactor before contamination became serious, the mass media's wording of "radioactivity" leak undermined the image of Mutsu. This undesirable image impacted the development. Radiation has various types such as alpha radiation composed of the nuclei of helium-4 atoms, beta radiation consisting of energetic electrons or positrons, and gamma radiation that are high-energy electromagnetic waves. Radioactivity refers to the particles that are emitted from nuclei as a result of nuclear instability and they emanate some form of radiation. Radioactivity leak describes, for an exaggerated example, leak of uranium or primary coolant water. The first Japanese nuclear powered ship "Mutsu" was completed in February 1991 after number of experiments and through overhaul in the Sekinehama Mooring Port, its mother port since 1983. It was designed to travel 82,000 km (circles the earth twice) with the reactor using 42.g of uranium-235 as fuel (5000t if petroleum). After accomplishing its objective, Mutsu was decommissioned in 1992. By that time in the world, Otto Hahn of West Germany and Savanna of the U.S.A had already completed their experiments and research voyages. There is no plan to develop nuclear powered commercial ships, because construction of nuclear powered ships are economically inefficient unless the ships' size is larger than 100000t. People may wonder what significance the lengthy project had, spending more than 120 billion yen in 25 years. At least, it generated investigation reports on radiation leak, which determined the direct cause, and offered a paradigm for an ambitious development project.

7. Knowledge

(1) Factually accurate report on an accident is required to take an appropriate action.

The officials originally reported the Mutsu accident to be "radiation leak". However, it ended up being reported as "radioactivity leak", which neither legal entity nor governmental agency corrected.

(2) It is always difficult to recover from negative publicity. The mass media has great influence on general public. A good example is the "Sayama dioxin report" broadcasted in 1999, in which the network's false report on a serious dioxin contamination in vegetables led to a collapse in vegetable prices (actual contamination was found in tea leaves).

(3) Commissioning a project to more than one company by dividing the tasks increases the likelihood of failure in the resulting product. (The hull and the reactor of Mutsu were commissioned to different independent companies.)

8. Background

The trend in the shipbuilding and the shipping industries at that time was increases in size and speed to accommodate the growing trade volume. It was found economically inefficient to infinitely increase output with the existing propulsion engine. The problems of oil prices and supply spurred discussion on nuclear powered vessels on a global scale.

In order to operate nuclear powered vessels for commercial purposes, nuclear powered vessels must have a competitive strength against the existing vessels. They must also be proven safe and reliable. Technological development and global safety standard, as well as navigational regulations were required to put such vessels into practical use.

Considering the strength of the shipbuilding industry and the future nuclear power era, Japanese government emphasized the research and development of nuclear powered vessels. It also emphasized active participation in the standardizing safety of nuclear powered vessels to enable early realization of their commercial applications.

The government started development of Mutsu based on the "Basic plan on the studies necessary for the research and development of nuclear powered ship", along with the establishment of the Japan Nuclear Ship Research and Development Agency in August 1963.

Looking back the history, the development of Mutsu was understandable considering the global trend at that time, the government acted too slowly to drop the nuclear powered ship program. Some may even say that Japan has a tendency to take no action even when it is necessary and we have no words to talk back to such criticism.

References

[1] Mutsu Radioactivity Leak Investigation Commission (1975) "Mutsu Radioactivity Leak Investigation Report", *Atomic Energy Commission Monthly Report*, *May 1975*, *Vol. 20*, *No. 5*, Atomic Energy Commission.

[2] Development of the First Nuclear Powered Ship "Mutsu", http://aec.jst.go.jp/NC/about/hakusyo/wp1976/sb20601.htm

[3] Genshiryoku Hyakka Jiten (Nuclear Energy Encyclopedia), http://mext-atm.jst.go.jp/atomica/

[4] "Development (Seika) of Nuclear Powered Ship MUTSU" (1992) Japan Atomic Energy Agency.

[5] "Profile (Gaiyoo) of Nuclear Powered Ship MUTSU" (1990) Japan Atomic Energy Agency.

[6] Japan Atomic Energy Agency (Editor), Nuclear Powered Ship Directorate (1992) "Trajectory (Kiseki) of Nuclear Powered Ship MUTSU – Current and Future R&D", *Genshiryoku Koogyoo (Nuclear Science and Engineering)*, *Vol. 1*, *No. 4*, 25.