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TRANSPORT AS A PART OF NUCLEAR FUEL CYCLE IN JAPAN

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ABSTRACT

Japan, as a nation with scarce energy resources, makes it a basic national energy policy to establish nuclear fuel cycle. Construction of nuclear fuel cycle facilities of Japan Nuclear Fuel Limited (JNFL) in Rokkasho-mura, Aomori Prefecture has made steady progress with a uranium enrichment plant, a low level radioactive waste (LLW) disposal center, a high level radioactive waste (HLW) storage center and a spent fuel (SF) storage facility already in operation. A spent fuel reprocessing plant has been almost completed and final test is being carried out. Nuclear Fuel Transport Co., Ltd. (NFT), as the only company in Japan that specializes in the transport of nuclear fuel materials, has engaged in transport business, since its establishment in 1973. NFT is mainly responsible for transporting SF and LLW generated from the nuclear power plants to the nuclear fuel cycle facilities. These transports have been securely carried out following rigorous national transport regulations based on IAEA safety transport regulations with outstanding safety records. At the last meeting, NFT representative, Mr. Kitamura reported the role of NFT in detail. In this paper, I updated the previous report considering the last 2 years performance, and briefly mentioned some new topics.

Keywords: *Transport, Nuclear Fuel Cycle, Spent fuel (SF), Low level radioactive waste (LLW)*

1. Introduction

Japan has been making a steady progress to establish the nuclear fuel cycle for the nation's long-term energy security. An essential component of the fuel cycle is reprocessing of spent fuel (SF) which extracts the remaining uranium and plutonium for recycling. Japan Atomic Energy Agency (JAEA) has been operating a reprocessing plant in Tokai-mura, Ibaraki Prefecture since 1977. However, as the capacity of the plant is insufficient, electric power companies had concluded reprocessing contracts with overseas companies and sent spent fuel to their overseas reprocessing plants until 1998. After that, spent fuel has been sent to a spent fuel storage facility started operation in 1999 which is a part of the JNFL reprocessing plant being currently under construction in Rokkasho, Aomori Prefecture toward commercial operation scheduled in the near future.

Nuclear Fuel Transport Co., Ltd. (NFT), as the only company in Japan that specializes in the transport of nuclear fuel materials, has engaged in transport business over 30 years, since its establishment in 1973. NFT is mainly responsible for transporting SF by sea from the nuclear power plants to the JAEA Reprocessing Plant in Tokai and the JNFL Reprocessing Plant in Rokkasho and LLW generated from the nuclear power plants to the LLW Disposal Center in Rokkasho. In addition, NFT transports on land high-level radioactive waste (HLW) and natural uranium hexafluoride (natural UF6), transported from overseas to the Mutsu-Ogawara Port in Rokkasho.

Transport is a vital part of the nuclear fuel cycle. In considering a new introduction of nuclear power plant, it is of vital importance to take into account transport factors, e.g. access road, port facilities, to meet the future transport requirements of fresh fuel, SF and LLW, etc.

This paper describes the nuclear fuel cycle in Japan, discusses transport as part of the nuclear fuel cycle and outlines NFT's transport operations of SF and LLW, the regulatory framework and the transport performance.

2. Nuclear Fuel Cycle in Japan

As a nation with scarce energy resources, Japan struggles with the critical issue of securing a long-term stable supply of energy, perhaps more than any other country in the world. The establishment of a nuclear fuel cycle is vital to the energy security of Japan's future. Fig.1 shows Japanese Nuclear Fuel Cycle and the essential transports which NFT now engages. The main cycle starts with the imported natural uranium hexafluoride transport to the uranium enrichment plant, and goes to the fuel fabrication plant, nuclear power plant, reprocessing plant, MOX fuel fabrication plant and nuclear power plant again. In this cycle, NFT now carries out the transports of natural uranium hexafluoride to uranium enrichment plant, spent fuel from nuclear power plant to reprocessing plant, low-level radioactive waste from nuclear power plant to LLW disposal center, vitrified residue from reprocessing plant to vitrified waste storage center.

NFT has accumulated a lot of experiences and expertise in the transport business and achieved a flawless safety record with no accident since our foundation. In this way, NFT has been and will be contributing to the establishment of the nuclear fuel cycle in Japan by gaining the public confidence with full commitment to safe and secure transport of nuclear fuel materials.

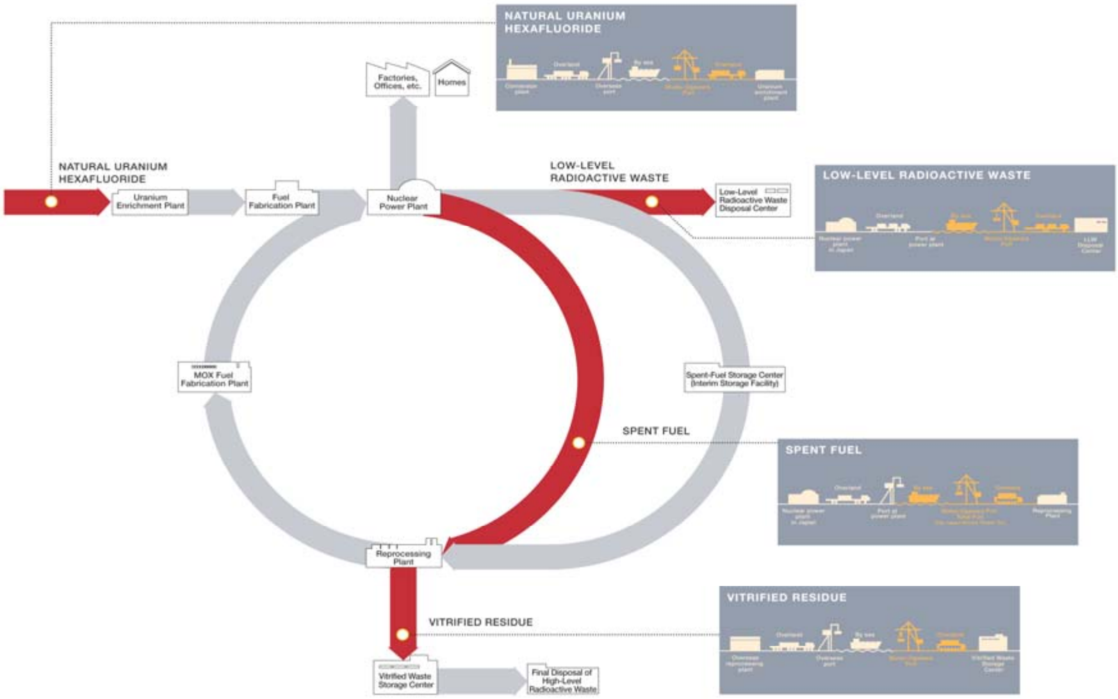


Fig. 1. The Nuclear Fuel Cycle

In Japan, fifty-five (55) nuclear power plants are currently in operation. The total nuclear power generation capacity is approximately fifty (50) gigawatts, and supplying about 30 percent of the total electricity demand in Japan.

It is a basic national policy of Japan to reprocess spent fuel and to recycle the remaining uranium and plutonium. Following this policy, JAEA has been operating a reprocessing plant in Tokai-mura since 1977. However, since the capacity of the plant is insufficient, electric power companies consigned reprocessing to the overseas reprocessing plants until 1998. After that, spent fuel has been to a spent fuel storage facility started operation in 1999 which is a part of the JNFL reprocessing plant currently under construction in Rokkasho-mura. As regards other nuclear fuel cycle facilities in Rokkasho-Mura, a uranium enrichment plant and a LLW disposal center already started operation in 1992 and a high level radioactive waste (HLW) storage center in 1995. And Rokkasho reprocessing plant will start commercial operation in few months.

This Nuclear Fuel Cycle will be completed with some new projects. The first project is the use of MOX fuel in Light Water Reactor. It will start with the transportation of MOX fuel from abroad. And JNFL already started the plan of construction of the MOX fuel fabrication plant in Japan. The second project is the construction of Spent-Fuel Storage Center for interim storage. Rokkasho reprocessing plant is not sufficient to reprocess the whole production of SF. The third project is decommissioning of nuclear power plant. Two nuclear power plants, Tokai nuclear power station and Fugen nuclear power station, were shut down, and the decommissioning already started. Every project creates the new demand for transportation.

In Japan, all of nuclear power stations and nuclear fuel cycle facilities are located alongside the coast (see Fig. 2 below) and have their own private port or a public port nearby. These geographical locations facilitate transport by sea of SF to Tokai and Rokkasho and LLW to Rokkasho from nuclear power stations by specially designed dedicated ships.

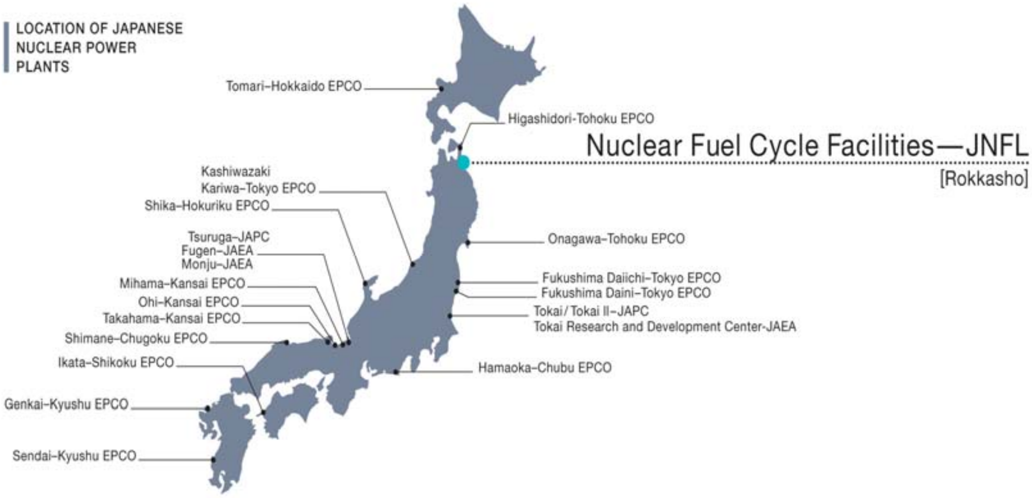


Fig.2 Locations of Nuclear Power Stations and Nuclear Fuel Cycle Facilities in Japan

3. Regulatory Framework

3.1 Regulations and Competent Authorities

Transport of nuclear fuel materials in Japan is governed and regulated by the competent authorities, mainly based on the two national laws; one is the Law of the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors and the other is the Ship Safety Law. The former is based on the safety transport regulations of International Atomic Energy Agency (IAEA), the latter is SOLAS Convention of International Maritime Organization (IMO).

Ministry of Economy, Trade and Industry (METI), Ministry of Education, Culture, Sports, Science and Technology (MEXT), and Ministry of Land, Infrastructure and Transport (MLIT), Japan Coast Guard (JCG) and prefectural public safety commissions (PSC) are respectively responsible for regulating nuclear fuel materials transport outside/inside the nuclear power plants and fuel cycle facilities. The basic regulatory framework for nuclear fuel materials transport in Japan is shown in Fig.3.

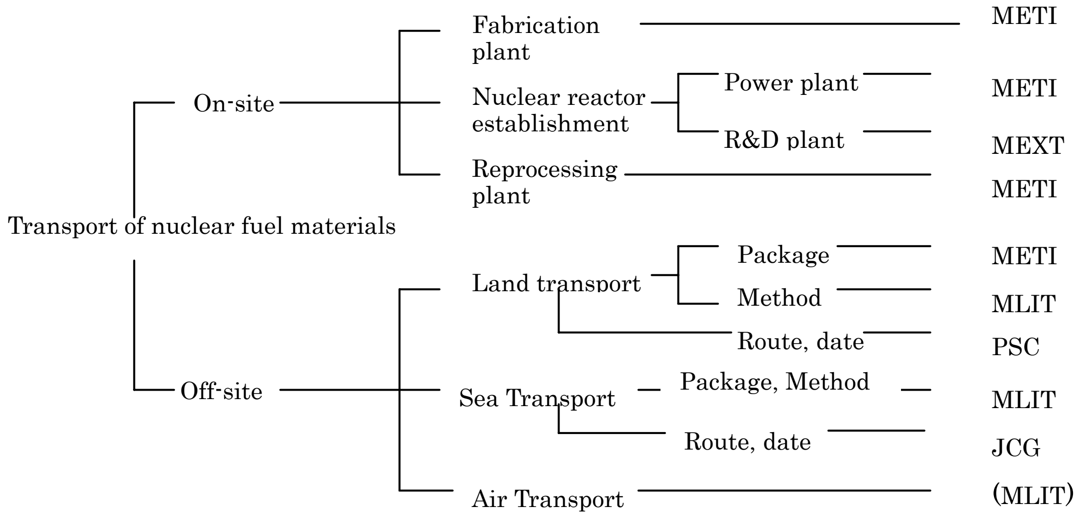


Fig..3. The Basic Regulatory Framework for Transport of Nuclear Fuel Materials in Japan

3.2 Approval Procedures

Confirmation of safety for the packages containing nuclear materials and the transport methods is implemented by the competent authorities following the three phases;

1) Approval of package design:
The competent authorities confirm whether a package design meets the technical requirements, by performing safety analysis in terms of package structure, heat, containment, shielding and criticality.

2) Approval of packaging:
The competent authorities confirm whether a transport packaging is manufactured in accordance with the approved package design.

3) Pre-shipment confirmation for package and method of transport:
Prior to shipment, a package is inspected for such items as surface dose rate, sealing performance, etc. Method of fastening the package to the conveyance, and method of radiation exposure control are also verified.

4. Transportation System

4.1 Transport Operations

To achieve the transport securely, the role and duty at each transport process are clearly defined among the contracting parties. Prescribed procedures should be taken surely by the responsible person.

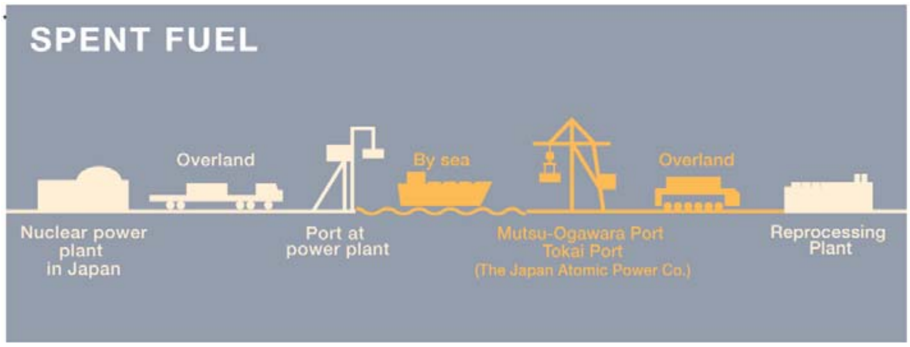
4.1.1 SF Transport Operations

In January 1978, NFT commenced to transport spent fuel (SF) from the domestic nuclear power plants to Tokai Reprocessing Plant of JAEA. NFT also started in September 1998 to transport SF to Rokkasho Reprocessing Facility of JNFL.

The transport operations of SF are as follows and shown in Fig.4;

- At the nuclear power plant, the transport casks are filled with spent fuel and inspected by METI for transport.
- After the filled casks were confirmed to comply with the regulatory requirements, they are transferred to the private port within the site or the public port nearby.
- After the inspection for loading by MLIT at the port, the casks are loaded on board the dedicated transport ship by using a wharf crane.
- The ship carries the casks to Tokai port of Japan Atomic Power Company (JAPC) located in Tokai-mura or to Mutsu-Ogawara port (MO port) in Rokkasho.
- During the voyage, the radiation control engineer monitors the radiation in the ship.
- At the port, the casks are unloaded from the ship by a wharf crane and loaded onto the transport truck-trailer. After safety inspection and radiation measurement of the casks by MLIT, they are transported in a fleet to the Reprocessing Plant.

Fig. 4 Transport Operations of Spent Fuel



4.1.2 Transport Operations of LLW

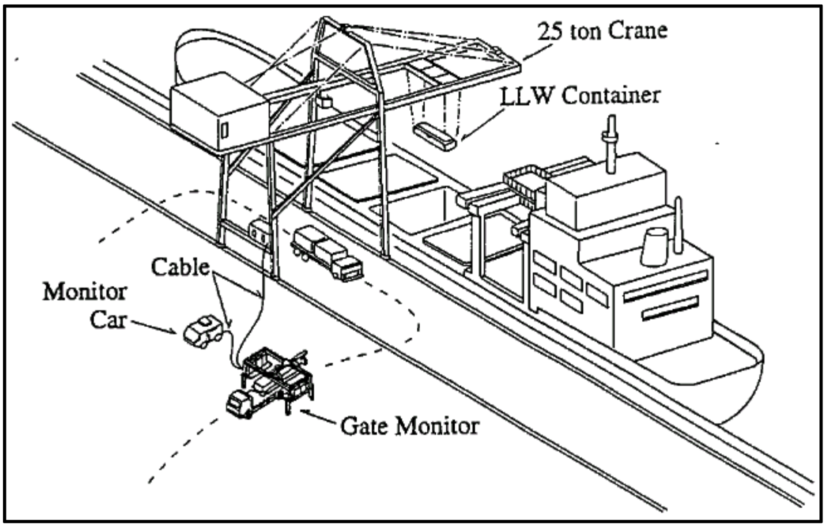
NFT started to transport LLW in December 1992 from the nuclear power plants to the LLW Disposal Center of JNFL in Rokkasho. The transport operations of LLW are as follows;

- At the nuclear power plant, LLW drums are confirmed to comply with the disposal requirements and packaged in the dedicated containers, eight drums for each, and then transported to the private port within the site or the public port nearby.
- The LLW containers are loaded into the dedicated LLW transport ship by using an on-board crane.
- The ship carries the containers to MO port in Rokkasho.
- At the MO port, the containers are unloaded from the ship by a 25-ton wharf crane and loaded onto LLW transport trucks, two for each, and then radiation level around the vehicle is checked by automatic radiation measurement equipment.

- The containers are transported on land approximately nine kilometers via the private road to the LLW Disposal Center.
- The drums are taken out from the containers, confirmed again to meet the disposal requirements and buried in a concrete pit.

The unloading operations of LLW containers are illustrated in Fig.5.

Fig.5 Unloading Operation of LLW Containers



4.2 Transport Packages

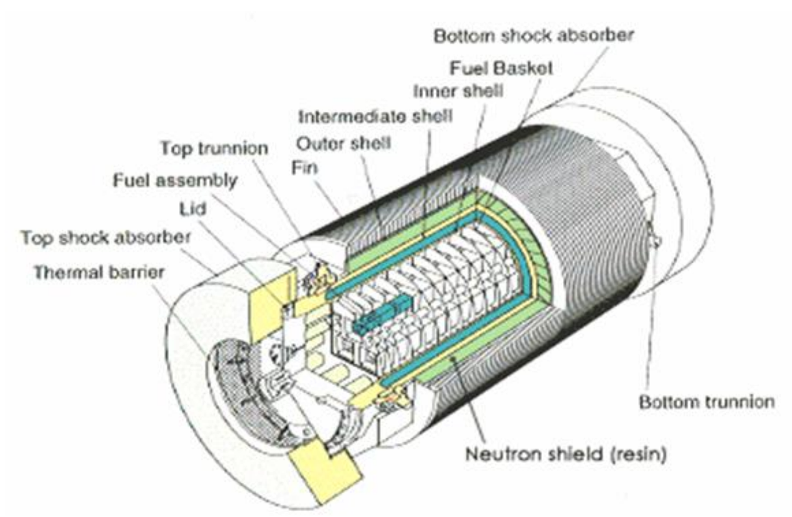
Designing the suitable packaging is important to carry out transport smoothly and efficiently. The packaging must conform to the IAEA transport regulation and the conformity shall be approved by the competent authorities.

4.2.1 SF Transport Packages

NFT has six different types of NFT-type casks for Rokkasho (two for PWR and four for BWR) and three types of HZ-type casks for Tokai to transport spent fuels. They were designed and manufactured to meet the requirements for cask handling at the nuclear power plants (i.e. crane lifting capacity, space to handle casks, etc.). The dimensions and weight of the largest NFT-type cask is 2.6 meters in diameter, 6.4 meters in length, and 118 tons in weight.

An overview of a typical NFT-type cask is shown in Fig.6.

Fig. 6 Overview of a Typical NFT-Type Cask



4.2.2 LLW Transport Packages

In developing the LLW transport packaging, NFT mainly took into consideration for safety and easiness in handling. The packaging has the following special features as compared to the ordinary freight containers.

1) The LLW transport container as shown in Fig. 7 is smaller in size than ordinary transport containers of 6 or 12 meters in length. As the same materials are used for its frames, steel plates and brackets, the LLW container is of stronger structure. The total weight of the LLW transport package is about 7.5 tons (including about 1 ton for the container itself).
2) The packaging lid is securely fastened down with four bolts, not to be easily opened like an ordinary container.
3) To ensure that the drums do not move during transport, they are secured firmly by rubber packing on the lid and brackets on the floor.
4) The loading/unloading operations of the packages can be performed remotely by crane. The opening/closing operations of the hatch-covers are also carried out by remote control.
5) Identification numbers of the packages can be automatically read by the device (Data Carrier).

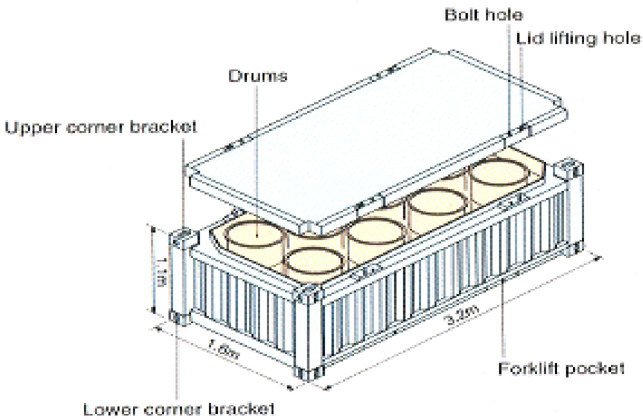


Fig.7 LLW Packaging and Drums

4.3 Transport Ships

Sea transport is major part of transport in Japan. While the ship can carry a large quantity of package, the ship is designed for exclusive use due to the radiation shielding, the special shape of package and the special technical standards.

The dedicated ships for SF and LLW transport were designed and constructed with the following special features.

4.3.1 SF Transport Ships

NFT operates the two dedicated ships for transport of SF. One is Rokuei-Maru for Rokkasho Reprocessing Plant, the other is new ship Kaiei-Maru for Tokai Reprocessing Plant. The followings are the special features of SF transport ships, and Fig.8 shows the overview of Kaiei-Maru.

1) Design requirements

The ship was constructed to conform to the "Special Criteria for Irradiated Nuclear Transport Ships" which is based on the INF code of IMO.

2) Special features

The ship is equipped with the following features:

a) Double-hulled structure

The double-hulled structure ensures the safety of the cargo by preventing the ship from sinking due to flooding of seawater in the event of a collision or stranding.

b) Refrigeration system and emergency flooding system

The refrigeration system keeps the ambient temperature around the casks at 38℃ or less and the surface temperature of the casks at 85℃ or less. In addition, an emergency system for flooding the holds with water can be operated from the bridge. These systems are redundant.

c) Tie-down device for securing casks

Tie-down device prevents the casks from moving and overturning in the hold. A fixed guide and rotating cleat system secure the casks. These can be remotely controlled.

d) Radiation shielding

The ship holds are encased in thick steel plates and concrete to provide a full shielding against radiation.

3) Main specifications of Rokuei-Maru and Kaiei-Maru

Length : approx. 100 m

Breadth : approx. 16.5 m

Dead weight : approx. 3,000 metric tons
Gross tonnage : approx. 5,000 tons
Loading capacity : 20 SF casks (Rokuei)
: 12 SF casks (Kaiei)

Fig.8 SF Transport Ship, Kaiei-Maru

4.3.2 LLW Transport Ship

A dedicated ship, Seiei-Maru, is used to transport LLW from the nuclear power plants to Mutsu-Ogawara port nearby the LLW Disposal Center in Rokkasho. The ship was constructed to conform to the criteria for LLW transport ship, which is less restrictive than SF transport ship, but requires double-hulled and double-bottom structure.

Size of the ship is as follows;

Length : approx. 100 m
Breadth : approx. 16 m
Dead weight : approx. 3,000 metric tons
Gross tonnage : approx. 4,000 tons
Loading capacity : 384 LLW packages

Fig.9 LLW Transport Ship, Seiei-Maru

4.4 Loading and Unloading Operation

Loading and unloading operation is carried out only in the daytime. The performance of the crane is an important factor of the cargo works at the port. At the power station port, loading or unloading is carried out by using a wharf crane in the case of SF, and by using an on-board crane in case of LLW.

At Mutsu-Ogawara port, loading and unloading operations are carried out by using the two types of wharf crane; 150-ton crane for SF (shown in Fig.10) and 25-ton crane for LLW. These cranes have the latest technologies and systems as follows;

1) Inverter Control System
The inverter-control system offers a wide range of speeds and provides smooth acceleration and deceleration to ensure ease in operation.
2) Collision/Overload Prevention System
Each crane is equipped with sensors that prevent collisions by detecting the proximity of the other crane. The cranes are also fitted with devices that halt operations in the event that the load is overweight.
3) Backup Motors/Power Supplies
In the unlikely event that the primary

motor breaks down, the back-up motor can raise or lower the suspended cargo, or move it laterally. In addition, an emergency power supply can safely lower a suspended load in the event of a power failure.

4) Drop-Prevention System
Accidental dropping of cargo is prevented by double winding cables and a motor brake is activated in the event of a power loss.

5) Curved Track System
In order to use the quay efficiently, when the cranes are not in use, they can be moved to the port apron along a curved track laid to rotate 90° as they travel. Their ability to travel on a curve in this way makes them quite unique.

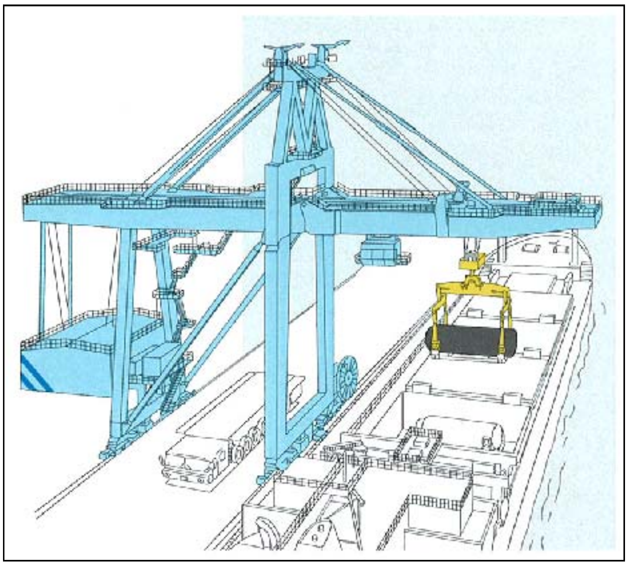


Fig.10 150-ton Wharf Crane Installed at Mutsu-Ogawara Port

4.5 Overland Transport Carrier

NFT carries out overland transport at Tokai port and Mutsu-Ogawara port. Transport at Mutsu-Ogawara port is as follows.

4.5.1. Overland Transport Carrier for SF

The packages containing SF, unloaded from the ship at the Mutsu-Ogawara port are placed onto specially designed overland transport carriers shown in Fig.11. Then, they are carried approximately 7 km through a private road to the SF storage facilities. The carrier is self-powered with no inter-vehicle links. They have 48 wheels to minimize the danger of skidding during snowy winters. In addition to ordinary braking systems, they have safety brakes to stop the vehicle stably in emergencies. They also have rear obstruction detectors and rear-viewing TV cameras to allow the operator to check the vehicle's rear status when reversing.

4.5.2 Overland Transport Carrier for LLW

Unloaded from the ship at Mutsu-Ogawara port, the LLW packages are placed onto specially designed 15-ton trucks with two containers each and then carried through a private road to the LLW Disposal Center, some 9 kilometers away. The trucks are equipped with an anti-lock braking system, anti-spin regulators and other safety equipment designed with winter travel in mind.

Fig.11 Overland Transport Carrier for SF

4.6 Radiation inspection

While transporting nuclear fuel materials, radiation inspection is carried out several times; at the power station port, while the voyage and at the unloading port. Radiation inspection at the Mutsu-Ogawara port is as follows.

After unloaded from the ship and prior to the overland transport to the nuclear cycle facilities in Rokkasho, the radiation levels at the surface of transport packages are inspected to confirm if the level meet the regulatory requirements. The inspections for the SF transport casks were implemented manually. On the other hand, the LLW transport containers are automatically measured by Gate Monitor System shown in Fig.12, introduced by NFT due to the high frequency of transports and large numbers of containers. This system is movable by an ordinary truck and is operated remotely and atomically, and can detect even extremely low levels of radiation quickly and accurately. The Gate Monitor System plays an important role in safe and efficient surveillance and measurement of radiation levels around the LLW packages as loaded on trucks.

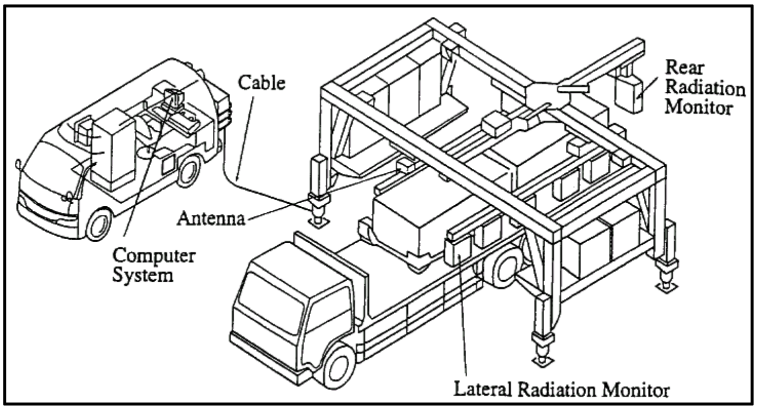


Fig.12 Gate Monitor System

5. Transport performance

5.1 SF Transport

As of the end of march 2007, the total quantity of spent fuel transported to Tokai Reprocessing Plant since the start of transport in 1978, is approximately 992 MTU (439 casks), 231 voyages by Hinoura-Maru (prvious ship) and Kaiei-Maru (new ship), and the total quantity transported to Rokkasho Reprocessing Plant since 1998, is approximately 2,269 MTU (396casks), 59 voyages by Rokuei-Maru. Fig.13 shows the annual and cumulative quantities of SF, transported by NFT.

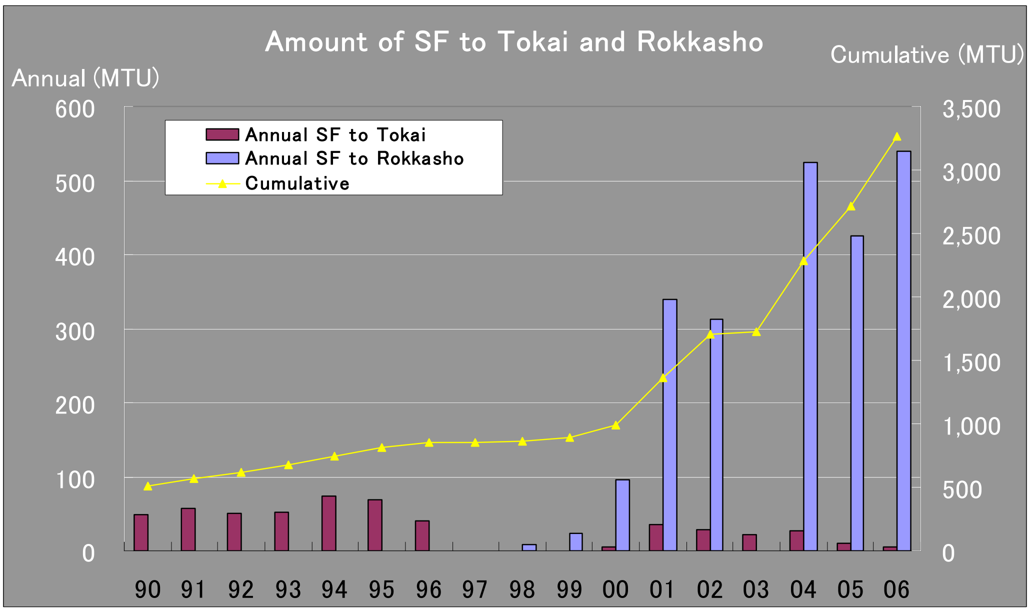


Fig.13 Quantity of SF Transported

5.2 LLW Transport

As shown in Fig. 14, the total quantity of LLW transported to the LLW Disposal Center in Rokkasho by Seiei-Maru since 1992 is 194,347 drums (24,294 containers) as of the end of March 2007.

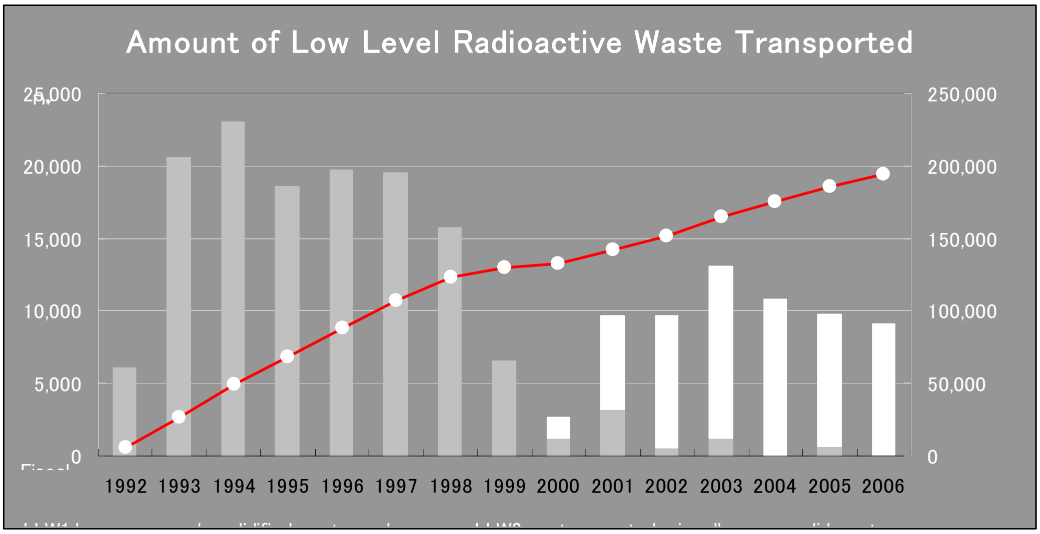


Fig.14 Quantity of LLW Transported

5.3 HLW Transport

High Level Vitrified Waste (HLW) has been returned from overseas reprocessing since 1995. NFT transports HLW from Mutsu-Ogawara port to the HLW Storage Center in Rokkasho, the total quantity transported as of the end of March 2007 is 1,310 canisters (55 casks) of HLW. (See FIG.15 below.)

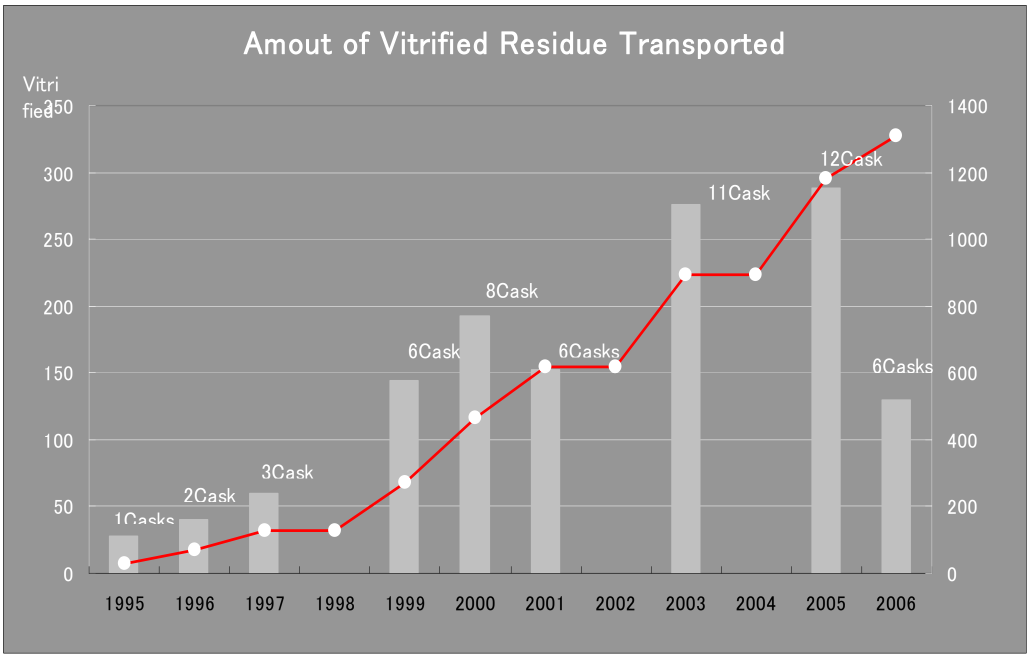


Fig.15 Quantity of HLW Transported

5.4 Transport of Natural UF6

Natural uranium hexafluoride (UF6) has been imported from overseas suppliers as a feed material for uranium enrichment. NFT transports Natural UF6 from Mutsu-Ogawara port to the Uranium Enrichment Plant in Rokkasho. The total quantity transported as of the end of March 2007 is 845 cylinders (10,550 tons) of UF6. (See FIG.16 below.)

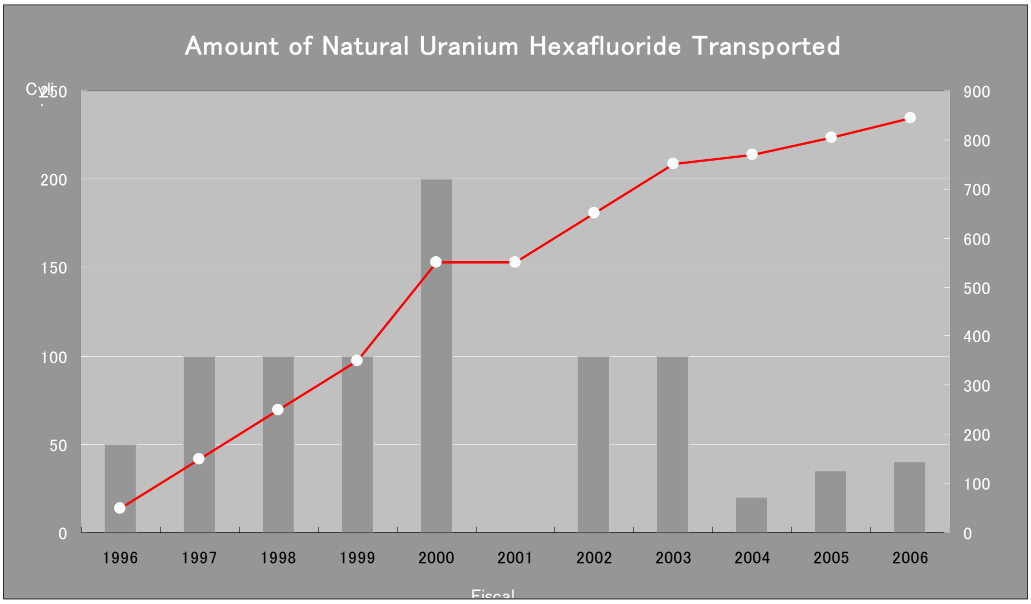


Fig.16 Quantity of Natural UF6 Transported

6. Conclusion

Transport is a vital part of the nuclear fuel cycle, it is intrinsic to it. As one of the key players in the nuclear fuel cycle, it is important to demonstrate to the general public that these transports have been securely carried out. In Japan, NFT has safely conducted transport of nuclear fuel materials in large volume and number over 30 years since its establishment in 1973 following rigorous national transport regulations based on IAEA safety transport regulations with no single accident and no workers' radiation exposure exceeding the regulation limits. These distinguished transport performance and safety records have been undoubtedly contributing to the establishment of nuclear fuel cycle in Japan.

Japan's nuclear fuel cycle needs further more kinds of transportation. In this new area, NFT will also take on the responsibility based on our safety performance.

In considering a new introduction of nuclear power plant, it is absolutely necessary to take full consideration of transport factors at the early stage of designing the plant for all phases of its construction, operation/maintenance and even future decommissioning/dismantling.

Such consideration should range from infrastructures to the transport-related facilities like an access road, port facilities, ships, casks, cranes, cask handling and maintenance facilities, etc. to meet all the future transport requirements.

Even a full-fledged or perfect nuclear power generating plant cannot be kept in good operating order if these transports to and from the plant are not smooth.