MOX FUEL TRANSPORT
FROM EUROPE TO JAPAN

INFORMATION FILE
[ 2009 EDITION ]
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EXECUTIVE SUMMARY

In 1999, the first transport of MOX fuel from Europe to Japan started the process of shipping recycled nuclear fuel back to Japan. This complements the transport of spent nuclear fuel from Japan to Europe and the vitrified residues return from Europe to Japan (which has involved approximately one shipment per year for just over a decade). Similar MOX fuel and vitrified residues transports will continue to be performed on a regular basis for some years to come.

Background

In February 1997, the Japanese government stated that, in line with the country’s long-term commitment to nuclear energy, it was necessary for Japan to start using MOX fuel in its commercial nuclear reactors. Following this announcement, the Japanese electric power companies unveiled their plans to use MOX fuel in 16 to 18 reactors. Since then, several MOX fabrication contracts have started this process.

MOX fuel is manufactured in Europe with plutonium recovered at French and British recycling facilities under long-standing commercial contracts between AREVA (France), NDA (United Kingdom) and Japanese electric power companies. The AREVA and NDA facilities have an extensive track record in safely manufacturing and transporting MOX fuel to various electric power companies in Europe.

Basic schedule

- MOX fuel is fabricated in dedicated facilities in Europe owned by AREVA or NDA.
- The MOX fuel assemblies to be used in Japanese nuclear power plants are then loaded into special transport casks.
- The sea transport of the casks from Europe to Japan takes place on dedicated ships which are specially built for transporting nuclear materials.
- On arrival in the Japanese ports, the casks are transported by road to the reactor sites where the MOX assemblies are loaded in the reactor cores.
AREVA
In France, recycling facilities belong to AREVA (former COGEMA). AREVA is the world leader in spent fuel recycling notably with La Hague plant for used fuel treatment and MELOX for MOX fuel fabrication. AREVA is also the reference for nuclear fuel transport services worldwide through its subsidiary TN International.

NDA, INS
In the United Kingdom, the reprocessing and MOX facilities at Sellafield are owned by the Nuclear Decommissioning Authority (NDA). Operation of the facilities is however carried out by Sellafield Ltd under contract to the NDA. NDA’s wholly owned subsidiary International Nuclear Services (INS) manages all reprocessing, MOX and transport contracts on NDA’s behalf. INS also undertakes all the associated international transport operations including the management of Pacific Nuclear Transport Ltd (PNTL). These organisations together perform the role of the former BNFL for MOX fabrication and transport.

ORC
In Japan, there are 10 electric power companies which operate nuclear power plants. Japan’s 10 electric power companies signed spent fuels reprocessing contracts with AREVA and NDA. The Overseas Reprocessing Committee (ORC) is an organisation, belonging to the Federation of Electric Power Companies (FEPC), which manages and implements the reprocessing contracts and the transport contracts of nuclear materials on the behalf of the 10 electric power companies. These companies are the major owners of the Rokkasho reprocessing plant.

Learning more?
Have a look on the Companies profiles page 46 or on the web sites:
AREVA
www.areva.com
INS
www.innuserv.com
PNTL
www.pntl.co.uk
1. WHAT IS THE NUCLEAR POWER POSITION IN THE WORLD ENERGY MIX?

Energy issues are now getting more crucial than ever: within the current century, and whichever current scenario is envisaged, the world will face both the shortage of some traditional fossil fuels and the developing global warming. Since the first oil shock, energy policies carried out by developed countries have aimed to secure and diversify their energy sources. Countries such as Japan, which do not benefit from domestic fossil resources, have built a nuclear energy policy to meet their energy demand and protect climate. The current new energy context makes those historic choices particularly accurate. The renewal of nuclear power confirms Japan’s willingness to develop the entire nuclear fuel cycle. The use of MOX fuel is to be envisaged in this light.

1.1 A growing demand in energy

Economic growth and energy consumption are closely related: the graphic below represents the increase of energy demand. It clearly states the increased share related to developing economies: Over 70% of the increased energy demand until 2030 will be coming from emerging countries led by China and India.

World Primary Energy Demand by region (Reference scenario)

Source: IEA WEO 2008
Indeed, no matter which economic growth scenario is taken (graph below), energy demand will continue its sharp increase. This is due to a growing population (from 6.7 billions in 2008 to 8.3 billions by 2030 according to the United-Nations), and increasing standards of living for many people in developing countries, which results in higher energy consumption per capita.

**Projected Energy Demand to 2100**

![Projected Energy Demand to 2100](image)

Source: OECD/NEA (2003), Nuclear Energy Today.

World energy consumption increases, electricity demand typically grows at twice the overall rate. It is predicted to almost double from today to 2030. Currently, some two billion people have no access to electricity (Source WNA 2008). It is a high priority to address this lack.

### 1.2 The share of nuclear energy

Nuclear energy is an established part of the world's electricity mix and represents today 16% of the world electricity generation. It can be compared to the whole hydro-electricity production in the world.

At the end of 2007, according to the IAEA, 439 nuclear power plants were in operation worldwide for a total net generating capacity of 371,898 MW(e). Two-thirds of the world population is living in nations where nuclear power plants contribute to electricity production and industrial infrastructures. More than 15 countries rely on nuclear power for at least 25% of their electricity, the share being around 30% in Europe and Japan, and of 20% in the United States.
1.3 The competitive advantages of the nuclear energy explain its revival

Electricity is the main sector for CO$_2$ emissions in the world before transportation. After years of stabilisation, the nuclear energy benefits from renewed approaches in many countries. The key factors for this increased interest are the following:

- climate change has become a key issue. There is a consensus on the link between greenhouse gas emissions and global warming.

### Projections of Future Changes in Climate

![Graph showing projections of future changes in climate](image)

Source: IPCC, 4th assessment report

### CO$_2$ emissions intensity by source in Japan

![Graph showing CO$_2$ emissions intensity by source in Japan](image)

Source: Central Research Institute of Electric Power Industry Report etc.

**Note:**
1. CO$_2$ emissions intensity is calculated from all energy consumed in mining, plant construction, fuel transport, refining, plant operations and maintenance, etc. as well as burning of fuel.
2. Data for nuclear power includes reprocessing of spent fuel in Japan (now under construction). MOX fuel use in thermal reactors (assuming recycling once) and disposal of high level radioactive waste.
- This situation clearly pleads for no greenhouse gas emissions energies, which is at the advantage of the nuclear one. The OECD clearly demonstrated the low level of emission related to nuclear energy, whereas fossil fuels cannot prevent those greenhouse gas emissions. Substantial emissions of carbon dioxide have been avoided by the development of nuclear power since 1970. Worldwide, nuclear power contributes today to saving more than 2 billion tonnes of CO₂ a year. In Europe alone, it currently saved around 700 million tonnes of CO₂ every year.
- Half of the uranium comes from OECD countries (Australia, Canada) strengthening the security of supply.
- Lastly, the price of the electricity according to the energy resource is also in favour of the nuclear energy. If one compares the cost structure of nuclear, gas and coal, there are key differences, the main ones being the low level of the fuel in the cost of the nuclear electricity (between 5 and 10%) and the absence of potential tax carbon.

- oil and gas reserves are much debated. However, beside the peak oil question, the current oil and gas resources' availability does not exceed the century. As far as oil is concerned, the estimated reserves were of 60 years at the consumption level of 2005 (source Total, planete-energies.com). As a comparison, the natural uranium resources are estimated between 85 and 200 years, beside the recycling perspectives.

OECD clearly stated the economic competitiveness of the nuclear industry for the electric production. In the recent years, the instability of raw materials' prices furthermore valued the low share of uranium prices in the cost of nuclear electricity.

The comparative advantages of the nuclear energy explain why several governments throughout the world reconsider their position on nuclear energy, for example, China, India, and the United States of America.
2. WHAT IS THE SITUATION OF NUCLEAR ENERGY IN JAPAN?

Japan is one of the developed countries which have promoted the nuclear energy with high constancy. Given its lack of domestic resources, the choice of nuclear energy was never revised. Since more than 50 years, Japan has successfully maintained a proactive policy on equipping and controlling nuclear technologies in every field: enrichment, fuel fabrication and used fuel treatment plants, development of fast breeder reactors.

2.1 Japan’s energy policy

Japan has decided in the 50s to develop its nuclear industry to provide electricity to its fast growing economy. It has always been seen as an answer to limit its high dependence to oil imports: Japan is the second country in the world for oil imports, the Middle East representing 90% of them.

JAPAN

Total primary energy supply by source in 2007.

Total : 530.5 Mtoe (tonne oil equivalent)

Energy Mix: 83% of primary energy supply comes from fossil fuels (oil, coal, gas)

Given its energetic situation, Japan is committed to promoting a sustainable and secure energy pathway, which includes helping expand energy efficiency and, as a result, increasing energy security and reducing greenhouse gas emissions. According to the International Energy Agency (report on Japan, 2007) “The country is also steadfast in its commitment to nuclear energy as a major component of its energy mix, extracting the significant benefits of this greenhouse gas-free generation source. Its nuclear industry is also prominent globally, supplying the international market with state-of-the-art technologies”.

Source: BP Statistical review of World Energy June 2007
This commitment to nuclear energy is a continuous trend. Nuclear electric production started in 1963 and Japan now holds 55 nuclear plants located on 17 sites.

Map of nuclear power plants in Japan end 2007

In 2002, the Japanese government confirmed the role of nuclear energy to limit Japan’s dependence and help meeting the Kyoto objectives. De facto, Japan has never stopped building Nuclear Power Plants: four were in construction in 2001, at a time where most OECD countries had stopped their construction programmes, and there are now three reactors in construction.

As a result of this continuous policy, Japan nuclear production represents one of the highest rates of electric production in the world: the 55 nuclear power plants now produce almost 30% of the Japanese electricity.
2.2 Japan’s nuclear energy situation

Japan has decided to develop domestic facilities, including the Rokkasho reprocessing plant, throughout the entire nuclear cycle, located in five different sites. Nuclear power is fueled by uranium, which is mined and then processed in various ways before being used in nuclear reactors. After use, the spent nuclear fuels still contain elements that can be recycled as fuel. According to this recycling fuel policy, Japan Nuclear Fuel Limited (JNFL) has started the construction of the Rokkasho reprocessing plant in Aomori prefecture since 1993. In 2008, it is on the final stage of test operation. In addition to the above facilities, the Japan Atomic Energy Agency (JAEA) has developed the prototype Fast Breeder Reactor (FBR) called Monju. Japanese Government sets FBR a core technology of nuclear fuel recycling policy, because it can produce more resources than it is consumed.

This choice of using nuclear recycled fuel to produce electricity is consistent with the constant Japanese policy in favour of the nuclear energy. To establish a commercial FBR, it still needs some time. So, for the time being, nuclear recycled fuel is used in light water reactors, as uranium and plutonium Mixed Oxide Fuel (MOX). In fact, MOX can be seen as a domestic resource which saves natural uranium, free of greenhouse gas emissions.
One MOX assembly provides enough electricity for a 68,000 people city for a whole year. (French Utility EDF design)
1. WHAT INTEREST TO CLOSE THE FUEL CYCLE?

1.1 Nuclear fuel cycle and back-end management

- Nuclear fuel cycle
The nuclear fuel cycle is the series of industrial processes which enable the production of electricity from uranium in nuclear power reactors.

The two main parts of the fuel cycle are:
- the “front end” of the cycle including the stages before electricity is produced in the reactor (uranium mining, conversion, enrichment, UO$_2$ fuel fabrication)
- the “back end” of the cycle including the stages after power generation.

The difference between closed cycle and the open or “once-through” cycle refers to used fuel management approaches. There are currently two different approaches to manage used fuel in the world:

- in the once-through cycle, used fuel is considered as waste. This is the option chosen for the time being by countries such as Sweden and Finland.
- in the closed cycle, used fuel, still containing valuable materials, is thus not considered as waste. Uranium and plutonium are recyclable into new nuclear fuels: MOX fuel and ERU fuel (Enriched Reprocessed Uranium). The ultimate radioactive waste (materials of the used fuel that cannot be recycled) is safely conditioned by vitrification and stored pending ultimate disposal.

Countries such as France, Japan, the United Kingdom, Russia and India have developed recycling industrial facilities. Other countries, including the USA and China, have launched initiatives to implement indigenous recycling capabilities.

In Europe, France, Germany, Switzerland and Belgium have used MOX fuel for more than 35 years. Japan will follow the same procedure for its own reactors. Several countries, including the USA, China and India, are thinking of recycling used nuclear fuel as energy resources become scarce and geopolitical tensions threaten the security of oil supply.

- Spent fuel
In the reactor, fuel assemblies release energy through the fission of atomic nuclei. Overtime, the proportion of fissile atoms decreases and the quantity of fission products increases. Some of these fission products are neutron absorbers meaning that they absorb neutrons useful in fission. The loss of fissile atoms is only partially offset by the appearance of plutonium, also a fissile element. It can thus be seen that fuel becomes less and less reactive until it finally stops producing energy. The used fuel must then be replaced with fresh fuel.
What does used fuel contain?
The components of the used fuel depend on its time in the reactor, hence the energy produced (measured by the discharge burn-up).

Used fuel removed from the core of the reactor after 3 to 4 years of electricity production, still contains roughly:
- 94 to 96% uranium, although it is much less enriched than it was initially and contains non-fissile isotope, with U-235 still making up about 0.8% of it.
- approximately 1% plutonium
- 3 to 5% fission products and minor actinides. They constitute the non-reusable part of the fuel. They are the ultimate residues.

**Recycling**

After a few years of cooling down in the electric power utility reactor ponds, used fuel is shipped to recycling facilities. Recycling involves a series of mechanical and chemical operations:

- The separated uranium, called reprocessed uranium (RepU), is first stored as a stable liquid (uranyl nitrate) and then converted into solid state such as \( \text{U}_3\text{O}_8 \) or \( \text{UO}_3 \) prior to re-enrichment and recycling.
- The plutonium is converted into plutonium oxide powder (\( \text{PuO}_2 \)) before shipment in sealed canisters to a MOX fuel fabrication plant.
- The fission products and minor actinides constitute radioactive residues and are packaged after being incorporated into a highly stable glass matrix. The vitrified residues are then shipped to an interim storage facility, before final disposal.

So, the current back-end strategy relies on many different processes, one of them being using plutonium for making new MOX fuel. For nuclear power utilities, the recycling strategy offers a possibility of an optimized management of their used fuel.

### 1.2 Interests in recycling fuel

Recycling is essential, for used nuclear fuel like for other materials in many industries. Like other recycling processes, uranium and plutonium recycling offers the two-fold advantage of limiting both resource consumption and waste production. Responsible solution, used fuel recycling reduces the environmental footprint of nuclear energy.

**Saving natural resources and securing energy supply**

The possibility of reusing a raw material is a comparative plus of nuclear energy in confronting global energy requirements.
MOX recycling allows taking advantage of the huge energy potential of plutonium and saves natural uranium consumption. 1 g of plutonium or 100 g of recycled uranium produce the same amount of electricity as the combustion of 1 to 2 tonnes of oil. Each tonne of MOX fuel replaces one tonne of UO$_2$ fuel, which would have needed around seven tonnes of natural uranium to be mined, together with the corresponding enrichment services. Recycling both uranium and plutonium recovered through recycling will save around 25 % of natural uranium needs even in the case of light water reactors.

- **Reducing the impact on health and environment**
  Once the recyclable material is extracted from the used fuel, the amount of waste remaining is greatly diminished. The high-level radioactive waste is concentrated and vitrified. The standardized conditioning facilitates storage and final disposal. The recycling strategy is the optimum method of used fuel management in terms of reduction of both the volume and the radio-toxicity of the waste to be finally disposed of.

- **Contributing to non-proliferation**
  Using MOX fuel in commercial light water reactors bring consistent answers to the non-proliferation issue because it reduces plutonium inventory. As it is the case with all other commercial nuclear activities, British and French MOX fabrication plants are under the control of the appropriate national and international Authorities in particular EURATOM and the IAEA. This statement is also valid for reactors utilization as well as for all associated logistics steps. Once arrived in Japan, MOX fuel is monitored under full-scope enhanced safeguards by IAEA.
2. MOX FUELS

2.1 MOX fabrication

MOX fuel is a conventional nuclear fuel used in standard commercial nuclear reactors in different countries. It is the second most common fuel for commercial nuclear plants. The only difference with the basic nuclear fuel, made only of enriched uranium and known as UO$_2$ fuel, is that MOX fuel contains a small proportion of plutonium (high energy production element recovered from used fuel) mixed with depleted uranium (MOX stands for Mixed uranium and plutonium OXides). The plutonium ratio varies according to the design of MOX fuel. Typically, the plutonium content ranges from 5 to 10%.

Europe has a lengthy experience in handling, designing, fabricating and using MOX fuel in reactors. The first MOX fuel element was loaded in Belgium in 1963. Since then, more than 2000 tonnes of MOX have been loaded into reactors worldwide, mostly in Europe.

The operational and safety record of MOX fuel is excellent and comparable to uranium fuel (UO$_2$ fuel). No or only minor modifications are required to load a commercial nuclear reactor with MOX fuel.

In fact, burning plutonium in commercial nuclear reactors is a well-known and well-assessed process with over 40 years of experience.

• AREVA MOX plant and process

The AREVA recycling process involves separating the final waste from the reusable materials, which is done at the AREVA La Hague site and then converting those materials into fuel in the MELOX plant.

The France-based AREVA MELOX facility is a seven hectares site located on the Rhône river side in the south of France. MELOX plant started operations in 1995. It is the first large-scale, highly automated MOX fabrication plant in the world. With over 1,300 tonnes of MOX produced since the beginning at the end of 2007, it has acquired a solid know-how and experience.

MELOX is safely manufacturing MOX fuel for Utilities across the world (i.e. Japanese Utilities).

MELOX process

The process in use at AREVA MOX fabrication plant is known as MELOX process. The MELOX process is the high throughput development of the first generation MOX plants process: AREVA Cadarache in France and Belgonucléaire Dessel in Belgium now both under decommissioning. The MELOX process is a robust process ensuring high quality MOX manufacturing, proven for more than 35 years.
MELOX receives the plutonium oxide from the AREVA La Hague plant. The MELOX process involves first “micronizing” the plutonium oxide powder with a part of the uranium oxide powder to form a primary blend, or “master blend”, containing up to 30% of plutonium. The master blend is then mechanically diluted and homogenized with a free flowing uranium oxide powder to obtain the final blend at the specified plutonium content.

The second step consists in pressing powder to obtain cylindrical pellets. MELOX capacity is about 100,000 pellets per day. The pellets are then sintered in furnaces at around 1,700°C giving the pellets a hardened, ceramic-like, highly resistant and highly stable composition. The operating parameters of the furnace are tuned in order to obtain pellets fitting the specifications in terms of density, porosity, impurities, and solubility...

The third step is very similar to those in use for the manufacturing of UO$_2$ fuels. (The rods and fuel assemblies design and geometry is exactly the same as for the UO$_2$ fuel: only the pellets inside rods are specific.) The pellets are then ground and inserted into empty tubes made of zirconium alloy. Each rod is around four meters long and is made up of around 300 pellets depending on the customer’s specifications. The rods are closed by welding. The rods are carefully cleaned and inspected. Then they are assembled together to form a MOX fuel assembly.

The last stage consists in assembling the rods to constitute the MOX fuel assembly for delivery to the customer. The MOX fuel assemblies are then stored prior to their shipment.

At each step of the MELOX process, numerous stringent quality controls are made in order to guaranty the fuel quality and to respect the customers specifications. More than one hundred specification values are carefully checked. The MELOX fabricated fuel guarantees to its customers the full safety both during the transport and the use into their reactors.
• **NDA MOX plant and process**

The United-Kingdom-based MOX Facility “Sellafield MOX plant” or SMP was commissioned in the 2000’s. Several hundred people are employed in the plant, which has performed its first MOX fuel deliveries to a Swiss customer.

The MOX Demonstration Facility (MDF), commissioned in 1993, is now being decommissioned. The purpose of constructing the MDF was to produce PWR MOX fuel using NDA’s Short Binderless Route (SBR) process to obtain experience of the manufacture and in-reactor performance of SBR MOX fuel. This experience was then used to support the future operation of SMP, as SMP also uses the SBR process.

Prior to MDF, Fast Reactor MOX fuel was manufactured in the period 1970 to 1988. This experience was directly relevant to the production of thermal reactor MOX fuel and so was used in MOX fuel fabrication in the MDF (MOX Demonstration Facility). The need to comply with the specific requirements of Fast Reactor Fuel resulted in extensive development work in the early 1980’s to identify a new fabrication process.

This work resulted in the use of a high energy attritor mill to blend the uranium oxide and plutonium oxide powders. It was recognised that this same technology could be applied to thermal reactor MOX production and consequently the SBR process was developed.

The SBR process uses a high energy attritor mill to blend the uranium oxide and plutonium oxide feed powders and a spheroidiser to condition the powder before it is fed to the pelleting press. The process produces homogeneous press feed in only a fraction of the time required to produce similar quality material using a conventional ball mill and eliminates the need for a precompaction stage for the production of suitable press feed.

Other technologies incorporated into SMP include:
- the use of dry grinding of pellets to control pellet diameter and surface finish.
- the use of automatic pellet diameter measurement techniques to measure the diameter of each pellet at multiple positions along the pellet length and assess pellet shape.
- the use of highly automated rod fabrication and inspection lines.

The process in use at NDA/Sellafield Ltd facility is known as SBR (Short Binderless Route).
2.2 MOX experience and perspectives

MOX experience has been developed by many countries all around the world since the 1950s in United Kingdom (Sellafield), Germany (Hanau), Japan (Tokai Mura) and France (AREVA Cadarache) for MOX fuel fabrication for PWR, BWR and Fast Breeder Reactors.

MOX is the second most common fuel for commercial nuclear power plants, just after uranium fuel. The first MOX fuel elements were manufactured in the late 1950s in Belgium. Countries such as France, Germany, and Switzerland have been using MOX fuel in commercial nuclear power plants. 35 commercial nuclear power reactors are currently loaded with MOX fuel in Europe: 20 in France, 10 in Germany, 3 in Switzerland, and 2 in Belgium. Numerous reactors worldwide are scheduled to be using this fuel in the next decade including Japan and the United States.

MOX fuel has been safely generating electricity in commercial reactors over the world since the 1970s without a single incident. The first one was in Germany in 1972. Numerous countries have loaded nuclear reactors with MOX fuel and there will be more in the years to come. Overall, more than 5000 MOX fuel assemblies have been loaded into nuclear reactors.

Among these 35 commercial nuclear reactors, France is the biggest MOX user in the world with 20 reactors loaded with a limited in-core MOX ratio of 30%. In fact, 22 reactors are today licensed for using MOX. A French reactor was first loaded with MOX fuel in 1987. The French MOX experience, shows that there is no operational differences between UO$_2$ and MOX fuels regarding fuel performance and safety. Loading MOX fuel into French reactors has only needed minor and easy-to-made adaptations.

Safe and efficient use of MOX fuel in Japanese commercial reactors was successfully demonstrated by two testing campaigns performed in the late 1980s. The Tsuruga 1 unit was loaded with 2 MOX fuel assemblies between 1986 and 1990, and the Mihama 1 unit was loaded with 4 MOX fuel assemblies between 1988 and 1991. Like France, Japan would start using its commercial nuclear reactors with a in-core MOX ratio of around 30%.

Research and development programmes are underway in Europe and Japan to increase the percentage of MOX fuel assemblies to be loaded in a reactor. For instance, the EPR™ reactor is under construction in Finland, France and China. The EPR™ reactor is designed for recycling with a ratio of MOX in the core answering the need of the Utilities (up to 100% MOX).

In Japan, the Advanced Boiling Water Reactor (ABWR) that can load MOX fuel in the whole core, started construction in 2008 in Ohma (1,383 MW capacity).

ATMEA 1, jointly developed by AREVA and Misubishi Heavy Industries will also develop, market, license and sell a 1100 MWe PWR reactor combining innovative and proven nuclear technologies. This design will include the capacity to use MOX fuel.
TRANSports to Japan
1. WHY IS MOX FUEL TRANSPORTED FROM EUROPE TO JAPAN?

Japan has large energy needs and scarce natural resources. Japan is therefore engaged in a comprehensive long-term programme for the development of its nuclear energy industry, producing secure supplies of electricity. This strategy includes a complete closed fuel cycle with the final stage being the construction of the domestic light water reactor reprocessing plant and the commercial introduction of fast breeder reactors in the future.

Before the domestic reprocessing plant being operational, Japanese Utility companies contracted with AREVA in France and NDA in the United Kingdom for overseas reprocessing services in order to manage such reprocessing programme. Germany, Switzerland, Belgium, the Netherlands and Italy have signed the similar contracts. Under these contracts, spent fuel has been safely transported from Japan to Europe until 2001, then reprocessed by AREVA and NDA. Part of the recovered plutonium has been returned to Japan and used as FBR fuel. Main part has remained in Europe and will be fabricated into MOX fuel for light water reactors usage in Japan.

MOX fuel is transported from Europe to Japan with the full approval of British, French, and Japanese Authorities. The USA have approved the transfer of MOX fuel from Europe to Japan according to the US-Japan and US-EURATOM Agreements for Co-operation concerning Peaceful Uses of Nuclear Energy. As part of the USA co-operation and assistance, the USA Executive Branches review the transportation plan and its adequacy to the physical protection criteria, prior to each shipment.

Dedicated casks and ships are used for the transport of MOX fuel from Europe to Japan.

Learning more?

Established in 1998, the World Nuclear Transport Institute (WNTI) has grown to 45 member companies drawn from all sectors of the transport industry. WNTI is the only body dedicated to presenting the industry point of view on radioactive materials transport matters from an international perspective. www.wnti.co.uk
2. HOW MOX FUEL IS TRANSPORTED TO JAPAN?

■ 2.1 Dedicated casks

Casks are designed to protect people and the environment from radiation risks during the transportation of nuclear materials. If an accident occurs, packages must ensure the safe confinement of the contents and the protection of the public and operators.

MOX fuel is transported in specific casks such as TN 12/2 for the maritime shipment. These casks have been fully licensed for the transport of MOX fuel by the competent Authorities in France, Japan, and the UK, according to the materials transported. They comply with very stringent Type B tests imposed by the International Atomic Energy Agency (IAEA).

The preliminary operations before maritime shipment consist in transporting the MOX fuel into these dedicated casks from the MOX fabrication plants to the respective departure ports. Adequate land transport systems and facilities used for these transfers and dedicated gantry cranes used for the loading onto the ship ensure a very high reliability and operation safety level. Once the ship is loaded with the casks, the voyage to Japan really begins. For nearly 40 years, used nuclear fuel have been shipped from Japan to Europe using such types of casks without any incident involving the release of radioactivity until its completion in 2001.
Outline of TN™ 12/2:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of package</td>
<td>TN 12/2</td>
</tr>
<tr>
<td>Weight of empty transport cask</td>
<td>98 tonnes</td>
</tr>
<tr>
<td>Total weight (with payload)</td>
<td>110 tonnes</td>
</tr>
<tr>
<td>Dimensions</td>
<td>$\phi$ 2.5 m x 6.150 m</td>
</tr>
<tr>
<td>Maximum payload</td>
<td>12 BWR or 8 PWR MOX fuel assemblies</td>
</tr>
<tr>
<td>Thermal output</td>
<td>3.6 kW/cask</td>
</tr>
</tbody>
</table>

Main materials of transport cask:

- **Body** - Carbon steel, resin, wood, etc.
- **Lid** - Stainless steel, resin, etc.
- **Basket** - Aluminium alloy, stainless steel.
- **Bottom shock absorbing cover** - Stainless steel, wood, etc.
2.2 Dedicated ships for maritime transport

PNL ships are used to transport MOX fuel assemblies to Japan. PNL is owned by INS (62.5%), Japanese utilities (25%) and AREVA through its subsidiary TN International (12.5%).

PNL uses dedicated vessels, which have regularly transported spent fuel from Japan to France and the United Kingdom. Since 1995, PNL vessels have routinely shipped vitrified residues from Europe to Japan as well as MOX fuels. These ships are over 100 metres long and more than 16 metres wide and each ship carries sufficient amounts of diesel fuel to complete a journey, without any port-call. They meet the international standards and requirements of the International Maritime Organization (IMO), and comply with the requirements of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) as well as the British and French competent Authorities.

PNL ships, with more than 5 million miles covered without a single incident resulting in the release of radioactivity, have a safety record second to none. With almost 40 years experience, PNL has transported more than 2,000 casks in over 170 shipments.

Two ships, sailing together for mutual support and protection, are used to transport MOX fuel from Europe to Japan. This system is part of the physical protection measures required by the 1988 US-Japan Agreement for Co-operation Concerning Peaceful Uses of Nuclear Energy. The ships are also armed with guns and are protected by a specially trained force from the British Civil Nuclear Constabulary (CNC). All these measures meet or exceed the International Atomic Energy Agency requirements.

Technical description of the INF 3 PNL vessel “Pacific Heron”:
Type of vessel: Pacific class vessel

Main dimensions
- *length 104 metres
- *width 17 metres
- Deadweight tonnage 4,500 tonnes
- Displacement tonnage 9,500 tonnes

Main engine
- Diesel engine 2 x 2,500 kW
*(Approx.)
3. WHAT IS THE REGULATORY FRAMEWORK FOR MOX TRANSPORT?

3.1 International regulatory framework

All the countries (France, Japan and the United Kingdom) involved in the production, use and transportation of this MOX fuel abide with the international regulatory framework guaranteeing the peaceful use of nuclear materials. The main constituting elements of this framework are:

- **The Treaty of Non-proliferation of Nuclear Weapons (NPT)**
  In adhering to the NPT, non-nuclear weapons states (NNWS) pledge not to acquire nuclear weapons in exchange for a pledge by the nuclear weapons states not to assist the development of nuclear weapons in any NNWS. The NPT entered into force in March 1970. In 2007, there were 190 parties to the NPT, including France, Japan and the UK.

- **The Convention on the Physical Protection of Nuclear Material**
  The Convention sets levels of physical Protection to be applied in international transport of nuclear materials. It outlines security requirements for the protection of nuclear materials against the intentional commission of malevolent acts relating to the transboundary carriage of nuclear materials and provides for the prosecution and punishment of such offences. The Convention entered into force in February 1987 and has been amended on July 8, 2005 by 89 countries, involving fundamental changes that substantially strengthen it.

The basic guidelines for physical protection systems have been developed by the IAEA (INFCIRC/225/Rev. 4, Recommendations for the Physical Protection of Nuclear Material). First published in 1972, the guidelines have been revised several times since then. They cover physical protection for nuclear material in use, storage, and transport, both domestically and internationally. They have proven to be of significant importance in the development of international agreements and national requirements. For nuclear material in international transport, the responsibility for implementing effective physical protection systems rests with the shipping and receiving States.

INFCIRC/225/Rev.4 sets an objective for States to establish conditions which would minimise the possibilities for unauthorised removal of nuclear material or for sabotage and requires that appropriate measures, consistent with national requirements, should be taken to protect the confidentiality of information relating to transport operations, including detailed information on the schedule and route.

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**The International Atomic Energy Agency (IAEA)**

The IAEA, a United Nations-affiliated international organisation, performs a dual mission: acting as the primary verification mechanism for NPT through numerous safeguards, and providing peaceful nuclear technology assistance to developing nations. The IAEA was created in July 1957. In 2007, the Vienna-based Agency had 145 members, including France, Japan and the UK.

**The European Atomic Energy Community (EURATOM)**

EURATOM is in charge of safeguarding all nuclear material in EURATOM NNWS (Non Nuclear Weapon States) and all civil-use nuclear material in EURATOM NWS (Nuclear Weapon States). EURATOM was created in March 1957. The 27 Member States of the European Union are members of EURATOM.

The 2005 convention amendment has been considered by IAEA as "an important step towards greater nuclear security".
The Convention on the Physical Protection of Nuclear Material (INFCIRC/274/rev.2) also requires States Parties to implement specific protection measures for nuclear material in the course of international carriage and establishes a framework for international co-operation in the field of physical protection.

The PNTL vessels, being United Kingdom flagged, meet the requirements of the UK Nuclear Industry Security Regulations 2003. These regulations incorporate into UK law the UK's obligations under INFCIRC/225/Rev4 and the Convention. Regulatory responsibility for security of the transport operations rests with the UK Government's Office of Civil Nuclear Security. The whole transportation system thereby ensures the appropriate measures are in place to counter the threat of theft, sabotage or other unlawful removal of the nuclear material.

• US-Japan / US-EURATOM Agreements
In the frame of the agreements of cooperation for Peaceful Uses of Nuclear Energy between US and Japan as well as between US and EURATOM, the USA through the US Atomic Energy Act have endorsed the retransfer to Japan of plutonium that had been previously separated in Europe (under the form of plutonium powder or product such as MOX fuel manufactured with this plutonium) so long as the transfer takes place under conditions designed to ensure adequate protection against theft or diversion during transit.

In addition, a fundamental principle of Japan’s recycling programme is that Japan will not possess separated plutonium stocks under its national control beyond the amount required to implement its energy programme. This policy is known as the “no surplus plutonium” principle.

• INF Codes
These MOX transports between Europe and Japan will be carried out within the prescriptions of the INF 3 class.

Background
In 1965, the International Maritime Organization (IMO) issued the IMDG code (International Maritime Dangerous Goods) ruling the transport of dangerous goods by sea.

Japan's nuclear policy framework
Japan’s Atomic Energy Basic Law sets forth a national commitment that the development and utilisation of nuclear energy shall be dictated solely for peaceful purposes. Japan is therefore an active supporter of the international non-proliferation regime. This principle provides an additional level of transparency with regard to plutonium use in Japan.
In 1993 and in addition to already existing IAEA regulations, IMO proposed an international regulation with more particular constraints for vessels carrying the most sensitive radioactive material.

In 1999, the INF code is the international code for the safe carriage of packaged Irradiated Nuclear Fuel, plutonium, and high-level radioactive waste on board ships. It was adopted and became mandatory in 2001, defining three classes of ships, depending on the total radioactivity of cargo which is carried on board, and regulations vary according to the Class:

1: Class INF 1 ship - Ships which are certified to carry INF cargo with an aggregate activity less than $4 \times 10^{3}$ TBq (Terabecquerel = measurement of radioactivity).

2: Class INF 2 ship - Ships which are certified to carry irradiated nuclear fuel or high-level radioactive wastes with an aggregate activity less than $2 \times 10^{6}$ TBq and ships which are certified to carry plutonium with an aggregate activity less than $2 \times 10^{5}$ TBq.

3: Class INF 3 ship - Ships which are certified to carry irradiated nuclear fuel or high-level radioactive wastes and ships which are certified to carry plutonium with no restriction of the maximum aggregate activity of the materials.

• ISPS

The International Ship and Port Facility Security (ISPS) Code is an amendment to the Safety Of Life At Sea (SOLAS) Convention (1974/1988) on minimum security arrangements for ships, ports and government agencies. Having come into force in 2004, it prescribes responsibilities to governments, shipping companies, shipboard personnel, and port/facility personnel to "detect security threats and take preventative measures against security incidents affecting ships or port facilities used in international trade."

The main objectives of the ISPS Code are:
- to detect security threats and implement security measures
- to establish roles and responsibilities concerning maritime security for governments, local administrations, ship and port industries at the national and international level
- to collate and promulgate security-related information
- to provide a methodology for security assessments so as to have in place plans and procedures to react to changing security levels.
### 3.2 Regulations for multimodal transportation

Dangerous goods transportation is regulated by various rules depending on the modes of transport (road, rail and sea) and the countries involved. In Europe, the current regulations for land transport are based on the following European Union Directives:
- the order relative to the carriage of dangerous goods by road based on the European Agreement concerning the international carriage of Dangerous goods by Road (or ADR),
- the order relative to the carriage of dangerous goods by rail based on the international Regulations concerning the carriage of dangerous goods by rail (or RID).

Sea transportation complies with the rules of the IMDG Code, adopted by the IMO. This Code offers guidance to persons involved in handling and transport of radioactive materials in ports and on ships (provisions on identification of the packages, marking, labelling and placarding, stowage, documentation and marine pollution aspects).

### 3.3 Regulations for packages

The regulations are enforced by each country’s Authority and rely basically on the integrity of the transportation package to ensure safety during transport. Indeed, the safety of all transportation operations lies primarily in the package.

The packages must therefore fulfill extremely stringent requirements. This is particularly important as most nuclear transport operations will involve different modes of transport. The protection provided by the packaging is therefore conceived to respond to the potential hazard of the nuclear material being transported and has led to the development of various types of packaging. The regulations define three packaging categories, as well as excepted and industrial packages, and the corresponding design criteria takes account of the physical and chemical nature of the particular material, together with its radioactivity and radiotoxicity:
- Type A packages for shipment of small amounts of radioactive materials.
- Type B packages, required for the transport of MOX fuel, vitrified residues, used fuel and other high activity material,
- Type C packages remain the conceptual design for significant quantities of nuclear materials which could be transported by air.
3.4 National regulatory bodies in charge of implementing the regulations

In France, the Nuclear Safety Authority (ASN) is in charge of the safety regulations of the transport. The French Nuclear Radioprotection and Safety Institute (IRSN) provides technical expertise for the evaluation of safety to the ASN.

In the United Kingdom, the Department for Transport (DfT) is responsible for regulations governing transport. The Maritime and Coastguard Agency (MCA), an executive agency of the DfT, implements the regulations which cover all types of ships and cargoes. Also, the Radioactive Materials Transport Division of the same Department implements regulations, which cover the transport of radioactive materials by any mode of transport.

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the Ministry of Economy, Trade and Industry (METI) are responsible for the implementation of transport regulations.
4. WHAT ARE THE PHYSICAL PROTECTION MEASURES?

4.1 In compliance with International regulations and agreements

The potential risk of possible use of nuclear material for non-peaceful purposes underlines the need for its special protection. Effective systems are therefore required to protect nuclear material and facilities from theft, sabotage or unauthorised removal. The responsibility clearly rests with governments for ensuring that such systems are properly established and operated.

The international competent Authorities controlling these issues are the International Atomic Energy Agency (IAEA) and its Member States and in the European Union, EURATOM.

IAEA is fully dedicated to guarantee the safe, secure and peaceful use of the nuclear technologies in the world whereas EURATOM has developed a complete European legislation in terms of nuclear security.

The physical protection regulations distinguish three different categories of nuclear materials associated with specific measures from the most stringent ones to the less demanding.

Because of its nuclear characteristics (it contains significant amount of fissile materials), MOX fuel is classified in the category requiring stringent measures. Extensive physical measures are incorporated in the transportation plan for shipping MOX fuel from Europe to Japan to ensure that the ships and their cargo are protected against threats, theft or sabotage.

The elaborated measures to be taken to defend the PNTL ships and their cargo of MOX fuel against potential threats meet or exceed the standards provided for in:
- the Convention on the Physical Protection of Nuclear Material (International Atomic Energy Agency - IAEA - publication INFCIRC 274),
- the Recommendations on the Physical Protection of Nuclear Material published by the IAEA (INFCIRC 225),
- the 1988 US-Japan Agreement for Co-operation Concerning Peaceful Uses of Nuclear Energy. That agreement elaborates in detail extensive physical protection measures to be employed for the transportation of plutonium oxide or MOX fuel by sea.

Following are excerpts of letters sent by the USA government to several high-ranking members of the USA Congress and House of Representatives and to the Japanese government stating the adequacy of the physical protection measures to be employed for the transport of MOX from Europe to Japan:

"As required by the Agreement, Japan has prepared a transportation plan for the upcoming MOX shipment in close consultation with the United States. [...] USA experts have carefully scrutinised successive drafts of the plan over a period of
several years. [...] In addition the responsible USA Executive Branch agencies have formally reviewed the final plan. They have concluded that it fully satisfies all requirements of the 1988 US-Japan Agreement, including the requirements of adequate physical protection”.

“It is the judgement of USA experts that the final transportation plan fully satisfies the provision of Annex 5 of the Implementing Agreement and thus constitutes a sound basis for the Government of Japan to undertake its responsibilities pursuant to the Agreement for Co-operation in connection with the planned initial retransfer of MOX fuel from Europe to Japan”.

### 4.2 Physical protection measures for maritime shipments

The security measures for MOX shipments fully satisfy the requirements of the US-Japan Agreement as detailed:
- use of a dedicated transport ship.
- careful selection of the route to be used.
- no scheduled port call en route.
- use of armed escorts aboard the transport ship that are independent of the crew.
- an armed escort vessel to accompany the transport ship from departure to arrival.
- measures to impede the removal of the cargo at sea.
- use of multiple and secure communications system.
- monitoring of the transport ship location and cargo status by an operation centre.
- preparation of a contingency plan.

To satisfy these requirements, the proposed physical protection system for the MOX transport includes two armed escort vessels, as part of a comprehensive physical protection system. The ships sail together each providing an armed escort service for the other. The ships have a broad range of protection systems to deal with any potential threats including naval guns.

Specially trained and armed officers of the British Civil Nuclear Constabulary (CNC) protect both ships. The CNC has extensive experience in protecting nuclear materials and nuclear facilities in the UK and has received special training for the shipments.

The choice of the route also includes consideration of all issues relating to physical protection. For instance, the ship avoids areas of civil disorder.

Prior to each shipment, a transportation plan is prepared documenting the specific arrangements to be implemented for the shipment to assure, among other things, adequate physical protection of the MOX fuel elements to be transported. The plan is established through co-ordination among the industry parties concerned and the governments of Japan, the UK, France and the USA.
5. WHAT ARE THE TRANSPORT SAFETY MEASURES?

5.1 Safety in depth

A series of barriers are used in order to protect nuclear cargo during every phase of the transport process: this system of protection is called “safety in depth”.

The first barrier is the MOX fuel pellets themselves under ceramic form. The MOX pellets are highly stable materials which are insoluble in water.

The second barrier is made up of the zirconium alloy MOX fuel rods containing the pellets.

The third barrier is the forged steel transport casks. Weighing up to 110 tonnes, the casks are built to standards set by international experts representing the member countries of the IAEA. Their collision, fire, and submersion performance has been demonstrated by a series of stringent tests.

The fourth barrier is the ship. PNTL ships have been designed and built specifically to carry nuclear materials: spent fuel, MOX fuel, vitrified waste... They employ numerous safety features such as a reinforced double hull. The transport casks are locked in the hold of the ship.

Together these barriers make implausible a scenario of the nuclear material contained in the MOX pellets somehow becoming directly exposed to the seawater.

Even in the highly unlikely event of the successive ruptures of the hold, the cask and the fuel rods, leading the solid MOX pellets themselves to be exposed, it would take thousands and thousands of years for the pellets to dissolve.

In addition, a study by the Central Research Institute of Electric Power Industry (CRIEPI) in Japan shows that even in the highly unlikely circumstances that the ship, the cask containment and the fuel rods breach in coastal waters, the impact on those living near the accident would amount to one millionth of natural background radiation. If such an accident happened in deep waters, the impact would be equivalent to ten millionth of background radiation.

All the equipment used for the transportation of MOX fuel is designed in accordance with relevant regulations in order to prevent any risk of accident. However, possible accidental situations have been analysed, applying the safety in depth principle, to ensure the safety of the transport.
5.2 Ship: regulatory requirements and safety features

- **Sea regulatory requirements**

  The PNTL vessel design meets all the requirements of the United Kingdom Regulations which are derived from the International Maritime Organization (IMO) Conventions and Codes. These regulations are applied to all types of ships and collectively they cover just about every aspect of ship design and operation. PNTL vessels also comply with the requirements of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the British and French competent Authorities.

  The International Convention for the Safety of Life at Sea (SOLAS) regulations set standards for the safe operation of vessels, encompassing a vessel’s subdivision, stability, machinery, electrical installation, fire protection, fire detection, fire extinction, life saving, radio communication, safety of navigation and carriage of dangerous goods for all vessels.

  The International Convention for the Prevention of Pollution from Ships (MARPOL) protects the marine environment from pollution by vessels. MARPOL regulations require that a report is made to the nearest coastal state of any incident involving the loss or likely loss overboard of any dangerous or polluting goods. Any serious threat to a vessel’s safety would also have to be reported under these regulations.

  The IMO consults expert organisations when it requires specialist advice in drafting its instruments: the IAEA gives expert advice on radioactive materials. The IAEA regulations were adopted by the IMO to form those parts of the International Maritime Dangerous Goods (IMDG) Code applicable to radioactive materials.

  PNTL also complies with the requirements of the IMO’s International Safety Management Code (ISM Code) and International Ship and Port Facility Security Code (ISPS Code). The ISM Code establishes safety management objectives which are to provide for safe practices in ship operation and a safe working environment, to establish safeguards against all identified risks, to continuously improve safety management skills of personnel. The ISPS Code is a comprehensive set of measures to enhance the security of ships and port facilities, developed in response to the perceived threats to ships and port facilities in the wake of the 9/11 attacks in the United States. In essence, the Code takes the approach that ensuring the security of ships and port facilities is a risk management activity and that, to determine what security measures are appropriate, an assessment of the risks must be made in each particular case.
The United Nations Convention on the Law of the Sea (UNCLOS) recognises the principles of the right of innocent passage through territorial seas and the freedom of navigation beyond. Article 23 of the same Convention also lays down that inter alia vessels carrying nuclear substances must carry documents and observe special precautionary measures when exercising the right of innocent passage through territorial seas. PNTL adheres strictly to the requirements of the UNCLOS.

**Transport vessel safety features**

In the 1970’s, BNFL decided to develop a design for purpose-built vessels for nuclear transport which provided enhanced protection for the ships and crews, so increasing the safety and reliability of transportation operations... Following wide consultation with Lloyds of London, the Salvage Association and leading salvage companies and as a result of Japanese standards developed at the same time, today’s PNTL fleet was constructed.

Since this time extra equipment has been added in line with technological developments and operating experience to maintain high standards of operational safety.

The present PNTL fleet consists of 3 vessels, Pacific Sandpiper (1985), Pacific Pintail (1987) and Pacific Heron (2008). They are all registered in the UK. Two additional vessels have been ordered to be built at a Japanese shipyard in order to renew the fleet.

The basic design of the PNTL ships is a double hull configuration with impact resistant structures between the hulls and with duplication and separation of all the essential systems to provide high reliability and accident survivability. This means that if any important system fails during a voyage, either due to mechanical failure or as a result of an accident, there is always a back-up system ready to be brought into operation.
PNLT’s vessels have a number of advanced safety features. These include:

- **Double hull to withstand damage and remain afloat**
  These are designed to withstand a severe collision with a much larger vessel without penetrating the inner hull. The double hull structure extends over two-fifths of the width of the vessel, effectively making it “a ship within a ship” and the area between the hulls is reinforced for the length of the hold area with 20 mm thick horizontal steel plates. The inner shell embracing the cargo space is formed by watertight longitudinal and transverse bulkheads.

- **Enhanced buoyancy**
  The vessel is subdivided into numerous watertight compartments as a result of which a number of the holds and machinery spaces could be completely flooded with the vessel remaining afloat in a stable attitude. The sub-division of the hull is preserved by the use of watertight doors.

- **Duplicated navigation, communication, electrical and cooling systems**
  These are designed so that in the event of damage or mechanical failure in any part of the ship all essential systems will be able to continue functioning. This includes the duplicated routing of power supply cables for all these systems along both sides of the ship to prevent damage in one area severing supplies and considerable redundancy in power supplies.
  In addition to the main alternators situated aft, there are two additional alternators situated forward which are capable of supplying all the ship’s main power. There is also an emergency alternator, which starts automatically in the event of a main power failure, capable of supplying all essential functions, such as navigational equipment, lights, steering equipment, fire fighting systems, etc.

- **Satellite Navigation and Tracking**
  The ships are fitted with five multiple navigation systems including satellite navigation. Position, heading and speed reports are transmitted by each ship every two hours without intervention by the PNLT crew. These are monitored in the UK and during MOX voyages are transmitted over secure communications systems.

- **Additional Fire Detection and Fire Fighting Systems**
  The ships are fitted with extensive fire detection and fire fighting systems, including fixed suppressant gas or water mist systems in the machinery spaces and the ability to flood the cargo holds with water. The ship’s fire detection system covers every space on the ship and the pumps which supply fire fighting and spray systems are also duplicated, being located in both the main engine room and the forward machinery space. The ship would remain afloat, stable and able to function if all of the cargo holds were flooded at the same time.

- **Twin Propellers and Engines**
  Conventional ships of this size are normally single engine, single rudder configurations but for the purpose of reliability all the ships have twin propellers and engines which operate entirely independently. In practice, one engine can be stopped and declutched while the ship maintains progress at about 10 knots on the other engine.
- **Bow thruster**
  All the ships are fitted with bow thrusters to provide greater manoeuvrability at slow speeds.

- **Radiation Monitoring Systems**
  All the ships are fitted with fixed radiation monitors which are linked to a monitoring point outside the holds and to an alarm system on the bridge. In parallel, routine manual radiation monitoring are carried out.

- **PNTL experienced crew**
  PNTL’s ships typically carry a crew which is substantially larger than that found on chemical tankers of a similar size. All navigating and engineering officers hold certificates of competence for a higher rank than the one they serve. For example, the Chief Officer must hold a Master’s Certificate. All personnel are actively encouraged to enhance their skills and qualifications and to take relevant training courses.

  All members of the ship’s crew wear film badges to monitor individual radiation doses whenever radioactive packages are on board. The statutory maximum dose for transport workers involved in the movement of radioactive materials, in the Ionising Radiations Regulations (IRR 1999), is 20 mSv/yr and records show that the effective annual dose to ships crew over the last 20 years is well below the 1 mSv/yr limit set for “other persons” (i.e. general public) in the IRR 1999. It should be noted that world natural occurring average background radiation is 2.4 mSv/yr (3.0 mSv/yr in the USA and 1.7 mSv/yr in Japan).

  During voyages, routine checks are made by the crew of the hold cooling systems and radiation levels. Cask securing arrangements are additionally checked in heavy weather conditions. The cargo space is segregated from the rest of the ship by dense radiation shielding material which is also extended forward from the accommodation under the deck and beneath the hatch covers.

A PNTL team in Panama in 2002.
5.3 Casks: regulatory requirements and safety features

The Type B packages are required for the transport of MOX fuel, vitrified residues, spent fuel and other high activity material. In order to be licensed, they must undergo stringent tests as recommended by IAEA and prescribed by British, French and Japanese regulations.

Throughout its operating life, each cask is subject to a series of regulatory controls and inspections:
- after the completion of the design, the cask receives a certificate of approval from the regulatory bodies,
- each cask manufactured is registered,
- before each shipment, the transport casks are inspected.
- a programme of periodic inspections associated with a maintenance plan is set up.

It includes: checks each time fuel is loaded, before use of each cask, yearly maintenance, basic maintenance... every 3 years and major maintenance every 6 years to cover both normal operations and extreme situations.

Under international regulation, a list of very stringent tests must be performed to check the resistance and safety of the casks. The IAEA accident conditions tests include two kinds of drop tests: a 9 metres drop onto a totally unyielding surface and a one metre drop onto a steel spike. The cask, with any damage sustained in the drop tests, is then subjected to an engulfing fire test for 30 minutes at 800 degrees Celsius, followed by an immersion test of 200 metres. After these tests the cask must still be leak tight and retain enough of its shielding to ensure radiation doses are within internationally agreed limits.

A thorough safety evaluation of these casks has been performed showing that the safety criteria related to structural integrity, thermal performance, containment level, shielding capability and maintenance of sub-criticality are all satisfied. This ensures the safety of the transportation casks under normal and extreme situations.

In fact, it has been confirmed that the casks would maintain their integrity in greater depths of water than the regulatory one. Even in the extreme case of water penetration into the cask, the ultimate barrier to the dispersion of the radioactivity would be the ceramic-like MOX fuel pellet itself.
6. WHAT ARE THE EMERGENCY RESPONSE ARRANGEMENTS AND EXERCISES?

PNTL vessel Pacific Heron

A significant record of used fuel and high level waste transportation between Japan and Europe (more than 170 shipments) have been accumulated during nearly 40 years of operation on the same class of ships without any incident.

The safety of these radioactive material transports is based on 3 principles:
- the transport system
- the application of the regulations
- the emergency response organisation
6.1. Dedicated equipments

- The strength and integrity of the cask coupled with the protection provided by the ship are the first guarantees of the shipment safety.

- The ship is equipped with modern radars and anti-collision system which drastically reduces the probability of a collision or grounding. If a collision were somehow to occur, the consequences would be limited by the double-hull and anti-collision structure of the ship.

- In the unlikely event a PNTL vessel was lost at sea, it could be located initially using the satellite tracking system. In addition, the emergency response team is equipped with a sonar search system capable of locating a sunken vessel at depths in excess of 6,000 m and has a range of up to 20 km.

All the PNTL vessels are fitted with this sonar location and telemetry system. This consists of four acoustic transponders wired to a number of onboard detectors. It can relay back to the surface:
- the depth and inclination of the vessel,
- whether the vessel remains intact,
- whether the hatch covers remain in place,
- the radiation level in each hold,
- the temperature.

The equipment is self-powered by high-grade lithium batteries with a working life of over seven years after the loss of ships power.

- All PNTL vessels operate an Automatic Voyage Monitoring System which reports the vessel’s latitude and longitude, speed and heading to the constantly manned Report Centre at Barrow. If a message is not received this would automatically activate the Emergency Response System. This system is supported by secondary systems such as telex over radio, radio telephone and company ship relay. On a MOX voyage this reporting is carried out over secure communications to a secure communications centre.

- The protection against the risks of internal fire is provided by the separation (by a steel wall) of the holds from the energy and propulsion equipment (engine room, fuel tank, shaft), and the installation of prevention and fire-fighting systems. The cargo itself is fireproof.

The fire fighting systems (detection equipment, hold flooding system, sprinkler...) provide the means to quickly detect and put out any fire on board the vessel. Moreover, the fire resistance of the cask is demonstrated by regulatory tests.
6.2 Trained teams

- In the unlikely event of a ship getting into difficulty, a fully trained and equipped team of marine and nuclear experts is available on a 24-hour emergency standby system, in line with IAEA requirements.
- Any emergency during the transport would involve the call out of suitably trained and qualified personnel (health physics and engineering), their transport to the incident scene, and this team would direct and manage all remedial operations.

6.3 A dedicated emergency organisation

Emergency response exercises are a requirement of international radioactive materials transport regulations and form an essential part of any contingency planning system. Several emergency training exercises are held each year: they test the communication systems, the expertise of the team members and the ship’s crews as well as the performance of the emergency equipment.

PNTL believes that regular exercises are an important part of emergency response planning. The annual exercise programme includes 2 United Kingdom based ship exercises (1 in port and 1 at sea), 2 Japan ship exercises, 4 fire exercises, and 1 desk top communications exercise (UK and Japan).

The Emergency Control Centre at Barrow is fully equipped with charts for sea routes, ship and cask drawings, multiple communications systems including several telephone lines, a ship stability computer and an emergency power supply.

Immediate arrangements can be put in hand to salvage the ship or cargo where required in the event of a vessel sinking. Since 1981, PNTL has had contractual arrangements with Smit Salvage, which has world-wide salvage capabilities along for all routes.
7. WHAT ARE THE LIABILITY ASPECTS?

The stringent safety arrangements - the high integrity of the MOX fuel itself, the special transport casks, the specially designed and constructed ships, and the extensive emergency and salvage plans - provide substantial protection against risk of accidents.

In the highly unlikely case of an accident having any nuclear consequences, the Paris and Brussels Convention would enable a person who suffered injury or damage from the nuclear characteristics of the cargo to recover compensation without having to prove that anyone was at fault. The conventions cover damage suffered on the high seas and liability is backed up by insurance.

For the countries that are not covered by these conventions a nuclear accident affecting their territory or territorial waters would be dealt with under relevant civil law.

In the case of an accident not having any nuclear consequences, the relevant civil law would apply.
1. PROFILES

AREVA

With manufacturing facilities in 43 countries and a sales network in more than 100, AREVA offers customers reliable technological solutions for CO$_2$-free power generation and electricity transmission and distribution. AREVA is the world leader in nuclear power and the only company to cover all industrial activities in this field. Its 71,000 employees are committed to continuous improvement on a daily basis, making sustainable development the focal point of the group’s industrial strategy.

AREVA’S INTEGRATED OFFER

AREVA is the world leader in the used fuel treatment and recycling market, with more than 30 years of experience in the back end of the nuclear fuel cycle corresponding to:
- more than 23,600 tonnes of Heavy Metal (tHM) at La Hague plant
- more than 1,300 tHM of MOX fuel fabricated on the MELOX plant at the end of 2007.
AREVA also runs engineering and industrial services businesses and operates nuclear fuel transport services worldwide through its subsidiary TN International. AREVA’s activities contribute to the optimisation of the use of energy resources and the minimisation of ultimate waste volume and toxicity in line with the objectives defined at the 1992 Earth Summit regarding sustainable development. They also contribute to the reduction of the greenhouse effect and global warming in line with the objectives defined at the 1997 International Conference on Climate Change held in Kyoto. AREVA’s businesses help meet the 21st century’s greatest challenges: making energy available to all, protecting the planet, and acting responsibly towards future generations.

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INTERNATIONAL NUCLEAR SERVICES LIMITED

International Nuclear Services (INS) manages the contracts and logistics for nuclear fuel recycling products and services for UK and overseas customers. Formerly the spent fuel services business of Sellafield, INS is a limited company now 100% owned by the Nuclear Decommissioning Authority. The main focus for INS, as the customer interface to over 20 utility customers for reprocessing and MOX fuel supply contracts and the associated transport of these products, is to endeavour to meet customers’ needs to exacting standards of quality and safety. In over 40 years of transporting nuclear cargoes, not once has there been a single release of radioactivity.

INS consists of 140 professionals based at offices and facilities in the UK, France, Germany and Japan. The team has in-depth experience, with quality and safety being paramount.

Products & Services
INS works in partnership with the Sellafield Ltd plant operation teams to ensure delivery of customer requirements.

INS’ portfolio of products and services include:
- The reprocessing of irradiated oxide fuel in the Thermal Oxide Reprocessing Plant (Thorp) to reclaim reusable uranium and plutonium
- The manufacture of Mixed Oxide Fuel (MOX) from the plutonium reclaimed from Thorp
- The safe treatment and storage of the different categories of waste arising from reprocessing operations via a range of waste management facilities
- Worldwide transport of nuclear materials through our logistics subsidiary company Pacific Nuclear Transport Ltd (PNTL), which includes a dedicated fleet of ships, marine terminals at Barrow-in-Furness and Dunkirk and a range of transport casks for shipping used nuclear fuel, new MOX fuel and high-level wastes from Sellafield back to the customer’s country of origin
- Cask maintenance in a bespoke facility on the Sellafield site

In addition, INS offers consultancy services, as, with over 40 years experience of delivering used nuclear fuel services, INS has the expertise, resources and capabilities to provide utilities and government agencies with specialist knowledge covering a range of topics associated with used fuel and waste management and the transport of nuclear materials.
These services include:
• Regulatory compliance
• Technology transfer
• Technical and licensing consultancy
• Optioneering studies
• Peer Reviews

INS has overseas customers in Japan, China, Germany, Switzerland, Netherlands, Spain, Sweden and Italy. With the current resurgence in interest in nuclear energy, INS believes their expertise can benefit utilities and government agencies around the world.

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OVERSEAS REPROCESSING COMMITTEE

The Overseas Reprocessing Committee was founded in October 1977 by members of the Federation of Electric Power Companies (FEPC) of Japan (9 companies, excluding one company without nuclear plant) and Japan Atomic Power Company. Its main purpose is to support and coordinate implementation of the reprocessing contracts between these ten electric power companies and NDA and AREVA regarding radioactive material shipment.

- Each of Japan’s ten electric power companies is charged with task of supplying its service area with electric power and is responsible for all local operations from power generation to final distribution. The companies are independent, and tailor their activities to the distinctive characteristics, demand traits and other features that exist in the regions they serve.

- As of March 2008, 55 commercial nuclear power reactors operate in Japan, providing a total supply of 49,467 MGW, and accounting for approximately 30 percent of Japan’s total electric power output.

As of March 2008 the total generating capacity of Japan’s 10 electric power companies: 201,549 MGW.

Responsibilities of the Committee:
1) Representing the Japanese Electric Power Companies for Reprocessing Service Agreements with NDA and AREVA
   - Review of business plans with respect to reprocessing projects,
   - Correspondence with competent Authorities concerning specifications of waste to be returned.

2) Representing the Japanese Electric Power Companies for Transport Service Agreements with NDA and AREVA (spent nuclear fuel, vitrified residues)
   - Review of transport business plans and co-ordination of transport schedule,
   - Development of proposals for procurement of transport assets (vessels and transport packages) and co-ordination between related companies.

3) Public Acceptance activities and management of shipments of spent nuclear fuel, vitrified residues and MOX fuel
   - Co-ordination of procedures for shipments of spent fuel, vitrified residues and MOX fuel, public acceptance work overseas and preparation of information materials.
4) Others
- Documentation of applications to competent Authorities for various licenses and approvals with respect to the reprocessing and transport contracts,
- Advisory work on procedures required by international conventions with respect to the reprocessing and transport contracts and co-ordination between related companies,
- Technical review and collection of information concerning transport, reprocessing and waste.

**Overseas Reprocessing Committee**
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Japan
2. GLOSSARY

ADR
European agreement for the international carriage of dangerous goods by road.

Assembly, fuel assemblies
A fuel assembly is made of fuel rods containing uranium oxide pellets — the fissile material — held together in a metal frame, or “skeleton”, usually made of zirconium alloy.

ASN
Autorité de Sûreté nucléaire (French Safety Authority).

BWR
Boiling Water Reactor.

CLI
Commission locale d’information. A French local information commission is located nearby every nuclear site.

CNC
United Kingdom Civil Nuclear Constabulary.

CO₂
Carbon dioxide, a greenhouse gas produced primarily by burning fossil fuels as coal, oil, natural gas etc.

Core
Area in a nuclear fission reactor comprising the nuclear fuel and arranged to foster the fission chain reaction.

Control of nuclear materials
There are two sides to nuclear materials control:
- measures taken by the operators to ensure the safety of the materials in their possession (monitoring, accountability, containment, surveillance, physical security of materials and facilities, transportation safety),
- national or international monitoring by organisations such as the IAEA or EURATOM to verify the effectiveness and reliability of these measures.
In both cases, the objective of controls is to prevent the diversion of nuclear material and subversive activities.

EDF
Electricité de France (French Electric company).

EURATOM
European Atomic Energy Community.
EPR
Evolutionary Power Reactor.

IAEA
The International Atomic Energy Agency.

IEA
The International Energy Agency (IEA) is a forum for co-ordinating the energy policies of 28 industrialised countries. The IEA addresses all types of energy sources. The Nuclear Energy Agency (NEA) specialises in nuclear-related issues and brings together 28 OECD Member countries.

IMO
International Maritime Organization.

IMDG
International Maritime Dangerous Goods.

INES
International Nuclear Event Scale.

INF

ISPS
The International Ship and Port facility Security Code is an amendment to the Safety Of Life At Sea (SOLAS) convention on minimum security arrangements for ships, ports and government agencies.

FEPC
The Federation of Electric Power Companies was established in 1952 by the major electric power companies of Japan to promote the smooth and efficient development of Japan’s electric power industry.

Kyoto Protocol
The Earth Summit held in Rio in 1992 signaled global awareness of the risks of climate change. In 1997, the Kyoto Protocol set limits for signatory countries and penalties for polluting countries that emit greenhouse gases.

MARPOL
International convention for prevention of pollutions from ships.
MOX ("Mixed OXide")
A mixture of uranium and plutonium oxides ("mixed oxides") used to fabricate certain types of nuclear fuel.

NEA
Nuclear Energy Agency; specialised agency within OECD.

NPT
Non Proliferation Treaty of nuclear weapons launched in 1970 signed by several countries including France, United-Kingdom and Japan.

NNWS
Non Nuclear Weapons States.

NWS
Nuclear Weapons States.

OECD
Established in 1961 the Organisation for Economic Co-operation and Development brings together the governments of countries committed to democracy and the market economy from around the world to support sustainable economic growth, boost employment...
OECD also shares expertise and exchanges views with more than 100 other countries and economies, from Brazil, China, and Russia to the least developed countries in Africa.

PNTL
Pacific Nuclear Transport Limited, established in 1975, is the world’s most experienced shipper of nuclear cargoes with 170 shipments completed over the last 30 years. PNTL is owned by NDA, Japanese nuclear companies and AREVA.

PWR
Pressurized Water Reactor.

RID
European agreement for the international carriage of dangerous good by rail.

SOLAS
Convention on Safety Of Life At Sea.

WNA
World Nuclear Association.

WNTI
World Nuclear Transport Institute.
Energy is our future, don’t waste it!

NOTES:
The MOX fuel transport from Europe to Japan file is based on the information available at the time of writing: December 2008.

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