Fact Sheet

Quick Facts on the Transport in the Nuclear Fuel Cycle

Contents

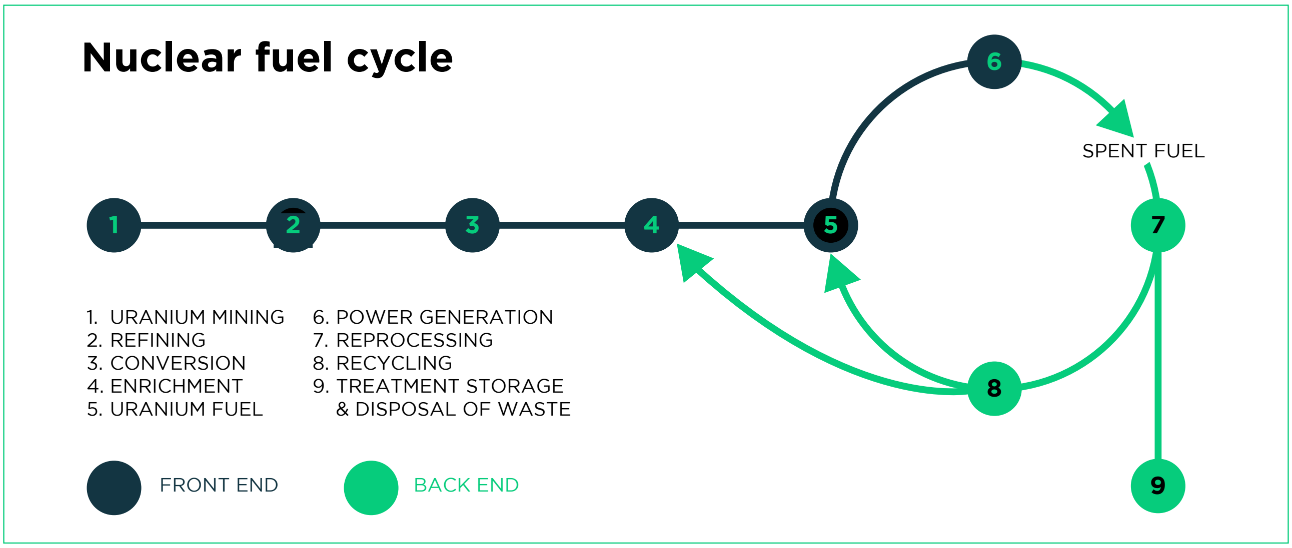
01

The nuclear fuel cycle

Today, nuclear power provides around 14% of global electricity, making affordable, clean, carbon-free energy available to people the world over. To sustain this important source of energy, it is essential that radioactive materials continue to be transported both safely and efficiently.

The transport of radioactive materials is strictly regulated and has an outstanding safety record spanning several decades.

The fuel cycle can be broken down into what is generally known as the front end and back end operations.



02

Front end operations

The front end of the nuclear fuel cycle encompasses the following operations:

- Mining of uranium ore;
- Conversion to uranium hexafluoride;
- Enrichment;
- Fuel fabrication;
- Enriched uranium pressed into pellets;
- Pellets assembled into fuel rods.

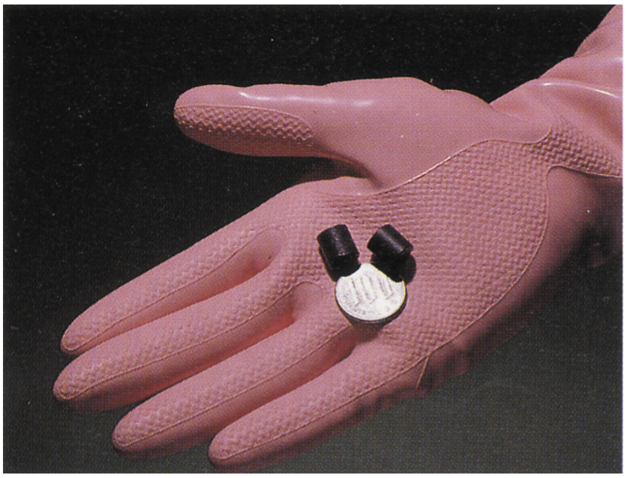
03

Fuel fabrication

A fuel pellet for typical light water reactors weighs about 10 grams and produces the equivalent energy of around 30 tonnes of coal or 20,000 litres of oil. The fuel pellets are stacked into zirconium alloy tubes that are then made up into fuel assemblies for transport from the fabrication plant to the reactor site. They are transported in specially designed fissile packages. The design and configuration of packages during transport ensures that a nuclear chain reaction cannot occur. However, the other types of packages are also used to the commensurate contents.

2 Uranium ore processed and turned into powder – 'yellowcake'

1 Uranium ore – raw material



3 Fuel pellets

04

Back end operations

The back end of the nuclear fuel cycle covers all the operations concerned with the spent fuel that leaves the reactors, including the shipment of spent fuel assemblies from nuclear power plants to reprocessing facilities for recycling, and the subsequent transport of the products of reprocessing. Alternatively, if the once-through option is chosen, the spent fuel is transported to temporary storage facilities pending its final disposal.

05

Reprocessing

Fuel used in a nuclear power plant generates electricity for about five years. After this time, it becomes less efficient and needs to be replaced. The spent fuel is highly radioactive; it still contains 96% of the original uranium, but also about 3% of waste products, and 1% of plutonium. At this stage, spent fuel can either be sent for storage pending final disposal, or reprocessed to recover the uranium and plutonium.

The residual uranium can be recycled. The plutonium which is produced in the reactor is fissile, i.e. it can support a nuclear chain reaction. It can be combined with uranium to produce Mixed Oxide (MOX) fuel. The 3% of high-level waste products are transformed into a solid, insoluble glass form by a process called vitrification and returned to the country of origin for disposal.

The solid nature of back end materials – spent fuel, MOX fuel, and vitrified high-level waste – is one of the most important safety factors. The materials are characterised by long term stability and low solubility in water and would stay in a solid form after any accident.

06

Transport packagings for back end materials

Back end materials are transported in specially designed transport packagings, known as casks or flasks. Casks containing nuclear materials have been safely transported internationally for over half a century. They are designed for the particular radioactive material they contain. They provide protection to people, property and the environment against radiation and are designed to withstand severe accidents. The casks are built to standards established by the International Atomic Energy Agency (IAEA). The philosophy of the regulations is that safety is ensured primarily by the special packagings no matter what mode of transport is used. The regulations cover both normal and accident conditions of transport. Under these regulations the cask design has to successfully meet a series of rigorous fire, impact and immersion tests.

- Prior to the transport cask receiving approval it must be proven that the design meets the IAEA test requirements which include:

  a minimum of two drop tests – a 9 metre drop onto an unyielding surface and a 1 metre drop onto a steel punch bar; a subsequent fire test in which the package is subjected to a fully engulfing fire of 800°C for 30 minutes; an immersion test where the cask is then subjected to conditions equivalent to 15 metre submersion for 8 hours. For casks designed for the more highly radioactive materials, there is an enhanced immersion test of 200 metres for 1 hour.

After these tests the containment, shielding and criticality control must remain efficient. Once the cask design has been approved, it can be used for surface transport by truck, rail or ship.

Regulations have also been introduced for the transport of back end radioactive materials by air. The requirements for this type of packaging include additional tests to ensure that it can maintain its integrity under air accident conditions.

Sea transport: purpose-built vessels

In 1993, the International Maritime Organization (IMO) introduced the voluntary Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes in Flasks on Board Ships (INF Code), complementing the IAEA Regulations. These complementary provisions mainly cover ship design, construction and equipment. The INF Code was adopted in 1999 and made mandatory in January 2001. It introduced advanced safety features for ships carrying spent fuel, MOX fuel and vitrified high-level waste.

INF3 is the highest IMO safety rating for ships carrying irradiated nuclear fuel, plutonium and high level radioactive wastes cargoes. The safety features of these ships include:

- double hull construction around the cargo areas with impact resistant structures between hulls;
- at least two sets of safety-related equipment such as navigation, communication, cargo monitoring, electrical and cooling systems so the ship can use the second system if a fault develops;
- satellite navigation and satellite tracking;
- extra fire detection and fire fighting equipment including a hold flooding system. All the holds could be completely flooded with the vessel remaining in a stable attitude.

For more than 40 years, purpose-built vessels have been used to transport back end materials between Europe and Japan. The ships are owned by Pacific Nuclear Transport Limited (PNTL, UK), a subsidiary company owned by Nuclear Transport Solutions (NTS, UK), Orano (France) and a consortium of Japanese nuclear companies.

The ships typically carry a crew approximately two to three times larger than that found on chemical tankers of a similar size. Navigating and engineering officers hold certificates of competence for a higher rank than the one they serve.

All PNTL ships meet the international standards and requirements of the IMO, and comply with the requirements of the relevant competent authorities.

Emergency response

Transport operations are carried out according to applicable international regulations. A full worldwide emergency response system is operated.

In the event of a serious incident, notification and communication to the relevant organizations shall be taken. In addition, some emergency responses shall be taken such as ensuring the safety of the packages, restriction of access to the incident site, evacuation warnings to prevent radiation hazards, prevention of the spread of contamination, decontamination, and rescue of injured persons. In case of fire, fire extinguishing and fire spread prevention shall be taken. In order to ensure the implementation of these emergency responses, business operators regularly conduct various types of education and training.

Emergency response exercises form an essential part of any contingency planning system. Regular exercises are carried out to test the communication systems, the expertise of team members and ships' crews as well as the performance of the emergency equipment. These exercises involve the call out of trained and qualified personnel (e.g. health physics and engineering), their transport to the incident scene and the necessary remedial actions to resolve a simulated radiological cask incident.

Security

For transports of irradiated nuclear fuel, plutonium and high-level radioactive wastes, security is a top priority. Shipments must comply with State requirements, as well as the physical protection measures developed by the IAEA, and the security requirements of the IMO. The overarching Convention relating to international transport (and in some respects, domestic transport) is the Convention on the Physical Protection of Nuclear Material (CPPNM).

The CPPNM was the first legally binding international instrument relating to physical protection of nuclear material. The obligations of States Parties, those countries that have signed the convention, include the protection of nuclear material during international transport.

In 2016, an amendment to the CPPNM entered into force. The amendment expanded the obligations of States Parties to the CPPNM who ratified the amendment. These expanded obligations include the requirement to ensure physical protection of nuclear material in domestic transport and protection against the sabotage of nuclear material in transport.

Another international instrument that is very important but not legally binding is the IAEA Nuclear Security Series No. 13 (INFCIRC/225/Rev 5). This document provides recommendations to States on how to establish, maintain, and sustain an effective physical protection regime for nuclear facilities and for nuclear material, including during the transport of nuclear material. It also has important guidance for countries that are not State Parties to the CPPNM but either are responsible as consignors, consignees, or carriers of nuclear material or are a country through which nuclear material may transit and want to demonstrate an appropriate level of protection.

The obligations of States Parties to the CPPNM as well as the recommendations and guidance in the IAEA Nuclear Security Series is used by States as a basis for their national legislation and regulations. These documents provide support to regulators, operators and carriers in relation to the secure transport of nuclear material. In particular IAEA Nuclear Security Series No. 26-G (Security of Nuclear Material in Transport) provides additional guidance on how to implement in practice the recommendations on the physical protection of nuclear material contained in INFCIRC/225/Rev 5.

Environmental

The transport system for irradiated nuclear fuel, plutonium and high-level radioactive wastes shipments involves a series of independent barriers – solid cargoes, casks, ships - between the material and the environment ensuring a high level of safety.

Several well-supported studies have concluded that even in the event of a cask being damaged in a maritime accident, the level of effect to the public or the environment would be insignificant compared to natural background radiation.

Industry experience

The international transport of nuclear fuel cycle materials has played an essential role in bringing the benefits of nuclear power to people the world over. These transports have supported all stages of the nuclear fuel cycle. Globally, about 15 million packages of radioactive material are transported around the world each year.* The safety record for the transport of radioactive materials is impressive; in over half a century there has never been a transport incident which has caused significant radiological damage to people or the environment. This is due in part to the strict regulatory regime, but credit is due also to the professionalism of those entities performing packaging and transport activities.

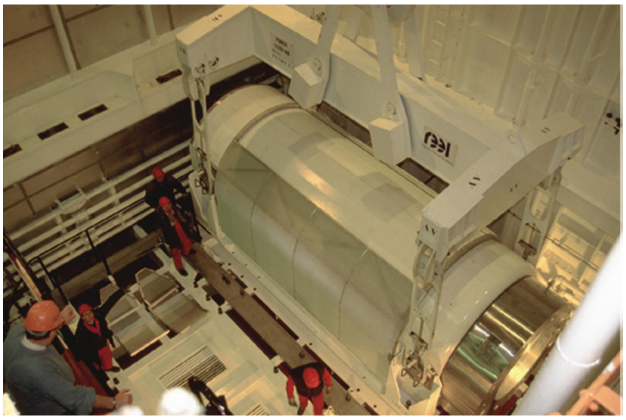
* World Nuclear Association, Transport of Radioactive Material, https://world-nuclear.org/information-library/nuclear-fuel-cycle/transport-of-nuclear-materials/transport-of-radioactive-materials.aspx, (Updated January 2022)

4 Purpose-built vessel

5 Spent fuel cask

7 MOX fuel cask

8 Purpose-built vessel, Barrow Port, UK



6 Sea transport of vitrified high-level waste

9 Unloading operations

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The information presented is valid as per September 2022.

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