WORLD NUCLEAR TRANSPORT INSTITUTE

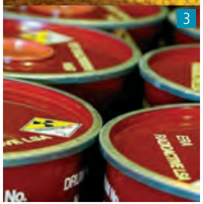
FACT SHEET

Nuclear Fuel Cycle Transport

Front End Materials

Dedicated to the safe, efficient and reliable transport of radioactive materials

Nuclear Fuel Cycle Transport – Front End Materials



Introduction

Nuclear power currently supplies around 14% of the world's demand for electricity making clean, carbon-free, affordable energy available to people the world over. The majority of these reactors are either pressurised water reactors or boiling water reactors and in both cases the primary fuel is enriched uranium oxide. The fuel core for these light water reactors typically contains many fuel assemblies consisting of sealed fuel rods each filled with uranium dioxide pellets.

To sustain this important source of energy it is essential that nuclear fuel cycle materials continue to be transported internationally both safely and efficiently. The transport of nuclear materials is strictly regulated and has an outstanding safety record spanning several decades.

Nuclear fuel cycle transports are commonly designated as either front end or back end. The front end covers all the operations from the mining of uranium to the manufacture of new fuel assemblies for loading into the reactors, i.e. the transport of uranium ore concentrates to uranium hexafluoride conversion facilities, from conversion facilities to enrichment plants, from enrichment plants to fuel fabricators and from fuel fabricators to the various nuclear power plants. The back end covers all the operations concerned with the spent fuel which leaves the reactors, i.e. the shipment of spent fuel elements 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 interim storage facilities pending its final disposal.

Mining to produce uranium ore concentrate

The raw material to make nuclear fuel is uranium ore, the main sources of which are found in North America, Australia, Southern Africa and Central Asia. The ore typically contains about 1.5% uranium but some deposits are much richer. The ore is first ground and purified using chemical and physical processes to yield a dry powder of natural uranium oxide known as uranium ore concentrate, or UOC. The historical name for UOC was "yellowcake" because the early concentrates were typically yellow in colour.

UOC is a low specific activity material and the radiological hazard is very low. It is normally transported in sealed 210 litre drums (an Industrial Package) in standard sea (ISO) freight containers. These can be transported by road, rail or sea, and in many cases a combination of modes of transport is used. The UOC is transported to conversion plants for conversion into uranium hexafluoride (Hex).

Conversion of uranium ore concentrate to uranium hexafluoride

UOC is transported worldwide from the mining areas to conversion plants located in North America, Europe and Russia. It is first chemically purified and then converted by a series of chemical processes into natural Hex, which is the form required for the following enrichment stage. The natural Hex produced from the conversion of UOC is a very important intermediate in the manufacture of new reactor fuel. There is a very large commercial trading in it that involves international transport.

In the production process, large cylindrical steel transport cylinders some 1.25m (48") in diameter, each holding up to 12.5 tonnes of materials are filled directly with Hex which can be liquid or gaseous depending on the manufacturing process. The Hex then solidifies inside the cylinder on cooling to room temperature. In storage and during transport the Hex material inside the cylinders is in a solid form. Natural Hex is also stored in these cylinders prior to being transported to an enrichment plant. Hex is routinely transported by road, rail or sea, or more commonly, by a combination of modes.

Although Hex is a low specific activity material, there would be a chemical hazard in the unlikely event of a release because it produces toxic by-products on reaction with moist air.

Enrichment of uranium hexafluoride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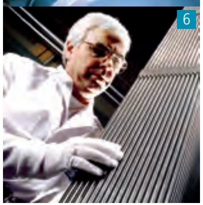
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The valuable isotope of uranium that splits (fissions) in a nuclear reactor is U-235, but only around 0.7% of naturally occurring uranium is U-235. This is increased to the level required, about 3-5% for light water reactors, either by a gaseous diffusion process or in gas centrifuges.

Commercial enrichment plants are in operation in the USA, Western Europe and Russia, which gives rise to international transport of Hex between conversion and enrichment plants.

Enriched Hex is transported in smaller universal cylinders. These cylinders are some 76cm (30”) in diameter and are loaded in overpacks so that the packaging is resistant to crashes, fires, immersion and prevents chain reactions. The loaded overpacks are generally transported using ISO flat rack containers for transport to fuel fabrication plants.

Depleted Hex, the residual product from the enrichment process, has the same physical and chemical properties as natural Hex and is transported using the same type of cylinders.

Fuel fabrication

Uranium dioxide powder derived from Hex of less than 5% enrichment is also a low specific activity material. The enriched Hex is first converted into uranium dioxide powder which is then processed into pellets by pressing and sintering. The 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. Fuel fabrication plants are located in many countries across the world.

The fuel assemblies are typically about 4m (12’) long. They are transported in specially designed robust steel packages. The design and configuration of packages during transport is arranged so that a nuclear chain reaction does not occur.


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Regulations for nuclear fuel cycle transport

The International Atomic Energy Agency (IAEA) Regulations for the Safe Transport of Radioactive Material set the basis for nuclear fuel cycle material transport. The basic concept is that safety is vested principally in the package that has to provide shielding to protect people, property and the environment against the effects of radiation, to prevent chain reactions and also to provide protection against dispersion of the contents. In addition, it is important to reduce radiation doses to workers and the public as far as reasonably achievable by adopting the best practices at the operating level.

The Regulations provide for five different primary packages; designated as Excepted, Industrial, Type A, Type B and Type C, and criteria are set for design based on the nature of the radioactive materials they are to contain. The Regulations prescribe additional criteria for packages containing fissile material, i.e. material that can support a nuclear chain reaction. The Regulations also prescribe the appropriate test procedures. This graded approach to packaging whereby the package integrity is related to the potential hazard - the more hazardous the material the tougher the package - is important for safe and efficient commercial nuclear fuel cycle transport operations. Road, rail and sea are all commonly used for nuclear fuel cycle materials.

IAEA tests for front end packages

UOC is a benign material and the potential hazard is low. Packages for UOC are required to maintain their integrity during normal transport conditions and are designed to withstand a series of tests simulating these conditions, e.g. a water spray, a free drop, a stacking test and a puncture test to reproduce the kind of treatment packages may be subjected to during normal transport.

Hex is different in so far as it is a solid which can give off a toxic vapour. The steel cylinders used as packages for natural and depleted Hex are internationally standardised and are subjected to a pressure test which they must withstand without leakage and unacceptable stress. In addition, they have to be evaluated against a thermal test requirement.

Enriched front end materials, i.e. enriched Hex, uranium dioxide powder and new fuel assemblies are fissile. The potential hazard associated with these materials is an unwanted chain reaction. For this reason the packages are subjected to tests to guarantee that criticality could not occur under all accident conditions which could be realistically envisaged in transport, including crashes, fires and submergence.

Experience in nuclear materials transport

The IAEA Regulations for the Safe Transport of Radioactive Material have provided a sound basis for the design of equipment and procedures for the safe and efficient transport of radioactive material. No sector of the transport industry is more highly regulated and incidentally, no sector of the transport industry has a better safety record. In over half a century there has never been a single incident which has resulted in significant radiological damage to mankind 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.

Photographs

1 Uranium ore
2 Uranium ore processed and turned into powder – "yellowcake"
3 Drums of uranium ore concentrate
4 48" Hex cylinders
5 30" Hex cylinders with overpacks
6 Uranium fuel assembly
7 Preparing drums of uranium ore concentrate for transport
8 Tie-down for fresh fuel transport
9 Road transport of front end materials

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