Update of French experience shipping irradiated fuel

by B. Lenail

Transport of irradiated fuel is an industrial activity that already has a long history in France. In fact, in 1966 the first shipments of irradiated fuel from the first nuclear power plants (graphite-gas reactors) of Electricité de France (EDF) were made from Chinon to La Hague.

Less than 10 years later, in 1973, shipments of fuel from light-water reactors (LWRs) began. At that time, material transported to La Hague was irradiated fuel from nuclear power plants in Belgium, the Federal Republic of Germany, and Switzerland, and from the Franco-Belgian station at Chooz.

Experience acquired has been considerable for both reactor types: In all, about 10 000 tonnes of irradiated uranium have been shipped to the two reprocessing plants at La Hague (in the northwestern part of France) and Marcoule (in the southeast). Fuel from the fast reactors, Rapsodie and Phénix, also has been taken there, but the quantities shipped from these reactors have been naturally relatively small.

COGEMA, of course, has not worked alone in this field and has always had the active support of various groups that specialize in various types of transport and/or are responsible for particular geographical regions.

Irradiated fuel shipments: amounts

Irradiated fuel shipments to La Hague and Marcoule by COGEMA reflect accumulated experience that can be matched only by fuel transports to the British plant at Sellafield.

Natural uranium-graphite-gas reactors

At the outset – beginning in 1966 with the shipment of natural uranium fuel from EDF's graphite-gas reactors, as well as fuel irradiated in Spain's Vandellos reactor operated by Hifrensa – all the fuel was sent to La Hague. However, for some years now part of it has been sent to Marcoule to relieve the La Hague plant and allow greater capacity for reprocessing fuel from water reactors. It is expected that from 1986 onwards, all the gas-graphite reactor fuel will go to Marcoule.

This activity today represents a volume of 100 or so packages, or shipments containing 500 to 600 tonnes of uranium per year. It is expected to go on for another 10 to 15 years.

As of 1 January 1985, the cumulative total of transported fuel has reached 6865 tonnes. A year-by-year breakdown is provided in the accompanying table.

Light-water reactors fuelled with enriched uranium

Shipments of oxide fuel to La Hague began in 1973 but remained fairly small (about 100 tonnes per year) until 1981 when they increased by a factor of three over the previous year. Since then, growth has continued and it is expected that in the course of the next decade the flow will stabilize at about 1200 to 1500 tonnes per year, or about 250 shipments annually.

The cumulative total as of 1 January 1985 was 3370 tonnes, as the table shows.

Irradiated fuel shipments in France by year

Tonnes of uranium fuel shipped from graphite-gas reactor plants:

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
La Hague	53	150	166	235	197	101	291	430	555	532
Marcoule	–	–	–	–	–	–	–	–	–	52

	1976	1977	1978	1979	1980	1981	1982	1983	1984	*Totals*
La Hague	326	333	388	238	160	185	111	144	81	4676
Marcoule	174	62	201	308	365	222	190	199	416	2189

Tonnes of light-water reactor fuel shipped to La Hague:

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	*Total*
9	25	95	53	106	94	121	140	441	665	810	811	3370

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The Marcoule industrial centre. (Credit: COGEMA)

Fast reactors

Although fast reactors have been developed to a relatively advanced stage in France, so far they have not yielded a large volume of fuel for shipment. At present, COGEMA has shipped 12 tonnes of uranium and plutonium.

There are three reasons for this: First, the number of reactors is small. The only two that have provided fuel for reprocessing so far are Rapsodie, which operated for about 10 years at Cadarache, and Phénix, the first demonstration plant (250 MWe) located at Marcoule. Second, fast reactor fuels are taken to very high burn-ups compared with other types, and amounts released for shipment are inversely proportional to the degree of irradiation. Third, only part of the Phénix fuel has to be shipped by public highways from Marcoule to La Hague, with the rest reprocessed at Marcoule itself and therefore not requiring any transport as such.

Transport packages: regulatory aspects

French regulations for the transport of radioactive materials are based on recommendations established by the IAEA. They are brought up-to-date regularly after each revision of the Agency's recommendations.

The national regulations, like the Agency's recommendations, stipulate that safety must be based on the package itself and not on the mode or special procedures followed in the course of transport.

The regulations are based on the principle that the degree of safety provided by the package must be adapted to the potential risks of the material it contains and transports.

In the case of those types of irradiated fuel presenting the greatest risk, the packages must satisfy the most stringent criteria. These packages must naturally be resistant and fulfil all their functions of shielding and containment in both normal operating conditions and in anticipated accident conditions. They must also resist, without serious damage, severe accidents, such as a free fall from nine metres onto an unyielding concrete target and a hydrocarbon fire lasting half-an-hour at 800°C.

Principle characteristics of certain standard packages

Packages	Loaded weight (tonnes uranium)	Capacity (No. of fuel assemblies) BWR	PWR
TN 17/2	72	17	6
TN 12/2 and LK 100	102/105	32	12
TN 13/2	110	–	11 or 12

TN = Transnucléaire BWR = Boiling water reactor
LK = Lemer PWR = Pressurized-water reactor

These tests are extremely stringent, as various experiments have shown, and indeed more severe than anything the package is likely to be submitted to in real life.

Moreover, tests carried out on existing packages have shown them to be more resistant than the regulations require. In fact, accidents that have occurred during the transport of irradiated fuel in France, as elsewhere, have never resulted in rupture or violation of a package's containment function.

COGEMA requirements. Criteria specified in the regulations were established more in light of risks to the general public and the environment than in light of risks confronting workers. COGEMA's experience soon showed that the integrated doses received by personnel engaged in loading and unloading operations were likely to be significant if precautions were not taken.

This problem worried COGEMA precisely because unloading packages at a reprocessing plant, in contrast to a reactor plant, is an almost daily operation (250 packages per year at La Hague). For this reason, COGEMA felt obliged to define:

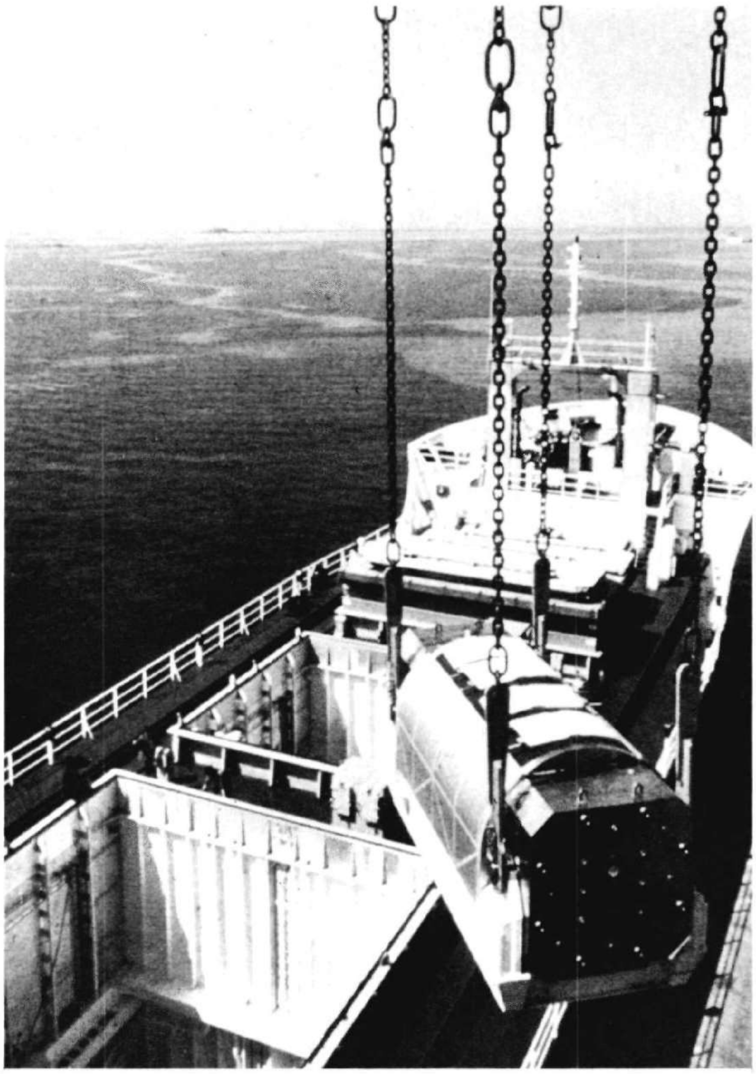
- *Standard package criteria.* These include size, dimensions, positions of gudgeons and apertures, surface state, and so on, which make it impossible to use any packages other than those allowing the use of standard procedures and automation techniques.
- *Useful transport loads.* These are defined as large as possible, in order to reduce the number of shipments, the integrated doses received by unloading personnel, and the cost of transport.
- *Concepts for dry transport.* This refers to transport after complete drainage of water from the internal cavity. COGEMA has always been concerned by the possibility that – despite containment properties of the package designed to hold even in accidental conditions – some accident might occur during the life of a package (through violation of handling procedures or joints in bad condition) that would result in an escape of radioactive liquid onto a public road.

Together, these latter two requirements (large shipment capacities, dry shipment) obviously mean that difficult technological solutions have to be found because of the heat released from the fuel and the need to prevent overheating. However, COGEMA believes that, all things considered, the options that have been selected are good.

Packages for natural uranium/graphite-gas fuels

Packages used by COGEMA for shipping natural uranium fuels all take the form of a cube measuring about 2.3 metres on the side and weighing between 50 and 55 tonnes loaded. Shielding consists of lead between two stainless steel liners (internal and external).

The capacity of these packages varies considerably – from 2.2 to 5 tonnes of uranium, depending on the internal arrangement. It is 2.2 tonnes when the fuel is transported in a container with its graphite jacket, and 5 tonnes when the bare fuel is transported in a basket.



Contained inside a forged steel cask called a TN-12 package, irradiated fuel is lowered to fit into into a specially-designed compartment for safe sea shipment. (Credit: Transnucléaire)

Packages for light-water fuel

Ten years ago, before COGEMA introduced the standards indicated above, these shipments were made in packages of very different types and sizes. Some were dry, some not, and some were suitable for transport by road, while others were not.

Introduction of the standards reduced to three the types of packages that could be used. These are of large capacity, shipped by rail or by sea, and capable of satisfying all possible requirements (for pressurized-water and boiling-water reactor plants, no matter what their electrical output). Except over very short distances, however, they cannot be shipped by road.

The design of the packages includes a thick steel wall lined on the inside by stainless steel and on the outside by various heat removal systems. Today, 70 of these standard packages are in service.

Types of transport

As previously noted, the selection of a transport mode is not dictated by safety imperatives because safety is considered to reside exclusively in the package design. The choice of mode follows directly from operational requirements. Obviously, given the great weight of the packages, preference is given to rail transport for overland journeys; otherwise, to transport by sea. Road transport is reserved for each end of a shipment – that is, between a rail junction and the installation (reactor or reprocessing plant) when these are not linked directly with the railway network.

Ship vessels and railway cars used for fuel transport are specialized equipment with definite characteristics. The railway cars, for example, have an aggregate loaded weight of about 150 tonnes, which makes them the heaviest cars routinely drawn by ordinary trains without particular limitations on speed. This remarkable result was obtained through a particular design: the 100- to 110-tonne packages rest on a low frame linking double bogies at each end.

The ships also have unusual characteristics: The five ships that ply between Japan and Europe with fuel, for example, are specially equipped for the transport of these packages (15 to 20 per ship), and are specially designed to ensure good stability at sea and great buoyancy (through compartmentalization). They are also equipped with special shielding, ventilation, and monitoring equipment that allows consistent protection of the vessel, and are fitted with the latest navigation aids.