TRANSPORTATION OF SPENT FUEL FROM LIGHT WATER REACTORS

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INTRODUCTION

Because it is such a vital link between the reactor site and the reprocessing plant, COGEMA, as a leading reprocessor, takes a deep interest in the transportation of spent nuclear fuel, and established a transportation network to provide its reprocessing clients with safe and reliable transportation services. This paper gives an overview of COGEMA's experience in the transportation of spent fuel from light water reactors (LWR), including the industrial, technical, system, safety, maintenance and economic aspects.

1. INDUSTRIAL ASPECTS

Were a spent fuel transportation accident to occur, even a minor one with no nuclear consequences, the resulting public outcry could lead to an indefinite ban on this activity, jeopardizing not only reprocessing operations but also power plant operations for utilities that have elected to reprocess their spent fuel. Well aware of this possibility, COGEMA has chosen to become closely involved in spent fuel transportation to ensure that it is performed according to the highest standards of transportation safety.

All spent fuel transportation to the La Hague and Marcoule reprocessing plants is performed under COGEMA oversight. Fuel from French power stations is transported in COGEMA–owned equipment by Transnucléaire, a COGEMA affiliate, which also provides technical assistance and inspection during fuel loading operations at the reactor site. Fuel transportation from other European power plants is subcontracted to Nuclear Transport, Ltd. (NTL), a Transnucléaire affiliate, which uses both COGEMA equipment and its own fleet of casks and rail cars. Fuel is transported from Japan to La Hague and to the BNFL plant at Sellafield by Pacific Nuclear Transport, Ltd. (PNTL), which contracts directly with the Japanese utilities. COGEMA is a part–owner of PNTL. This transportation network offers several advantages :

. the right organization for the specific task,
. a high degree of industrial and nuclear safety, and
. a reliable service.

2. TECHNICAL ASPECTS

2.1. **Spent Fuel Acceptance**

After discharge from the reactor core, spent fuel is cooled in the reactor pool for at least six months. Prior to transportation, the fuel must undergo acceptance qualification to minimize the risks to the transporter during transit and to the reprocessing plant operator during cask unloading. COGEMA has established a number of qualification procedures, depending on whether it is PWR or BWR fuel, and depending on whether in–core sipping or out–of–core sipping equipment is used at the reactor.

The sipping test determines the degree of fuel integrity and detects cladding failures that could result in fuel leaching during wet unloading and pool storage. COGEMA inspects the sipping equipment and audits its use. Fuel qualification also involves an assessment of structural strength, surface crud, deformation and other parameters.

The compliance of the fuel assemblies with transportation requirements is verified by a third party, which also records the identification numbers of individual assemblies and their precise location in the transportation cask.

2.2. **Cask Design**

In the early eighties, COGEMA made a decision to use only large–payload transportation casks for shipments to the La Hague plants. This decision was based on its operating experience with gas cooled reactor fuel (GCR) transportation in the mid–sixties and with LWR fuel in the mid–seventies, which showed that high payload casks reduce the number of operators required for cask handling, hence occupational exposure, and that the corresponding unloading facilities require less space. Substantial cost savings could be realized as a result, both at the reprocessing plant and for transportation operations. Moreover, large payload casks are moderately priced, are highly reliable because their design draws on extensive operating experience, and their fabrication, operation and maintenance is standardized. These factors contribute to a higher level of safety during cask transportation and handling operations.

The rising numbers of spent fuel shipments to La Hague and the potential for widely diverging cask designs prompted COGEMA to develop acceptance criteria for the casks, taking into consideration the relative standardization of reactor and fuel designs. An important criterion was compatibility with remote and, if feasible, automatic cask handling systems at the reprocessing plant. To ensure this, certain design features were specified, allowing for variations in size due to differing capacities and weights.

	Small diameter	Large diameter
Normal length (PWR 900)	TN 17	TN 12
Long length (PWR 1300)		TN 13

General cask design criteria developed by COGEMA include the following:

. absence of water in the cask cavity during transportation;

. feasibility of both dry unloading and pool unloading;

. compatibility with standard protective skirts;

. minimum thickness of stainless steel shell;

. feasibility of automated internal and external decontamination; and

. compatibility with standard unloading procedures.

Detailed design criteria were also established for cask shape, trunnion materials, orifices, covers and lids, screws and bolts, and all cask dimensions of interest for operations. Since developing its the cask design criteria nine years ago, COGEMA has certified four cask designs, as shown on the table below.

Type	Loaded Weight (metric tons)	Capacity	
		BWR	PWR
TN* 17/2	76	17	7
TN 12/2	102	32	12
LK** 100	103		12
TN 13/2	110		12

* TN: Transnucléaire ** LK: Lemer

More than 80 of these large-payload casks are in operation today. The TN12 high-payload cask developed by Transnucléaire has been in operation for more than ten years.

2.3. **Future Cask Developments**

In the years to come, cask design will be influenced by changes in fuel characteristics and by the use of dual–purpose casks.

Fuel Characteristics

As fuel burn–up is gradually increased and plutonium is recycled into MOX fuel, casks will be required to have greater shielding and heat dissipation capability. These requirements may be partially offset by longer fuel cooling times at the reactor before transportation.

Dual–Purpose Casks

Dual–purpose cask designs use proven technologies but double the capacity of the largest existing casks for even greater transportation efficiency. Transnucléaire recently developed its TN24 dual–purpose cask for the transportation and storage of 24 PWR fuel assemblies cooled for five years. The TN24 cask is currently being used in the United States to store 48 consolidated PWR fuel assemblies. New dual–purpose cask designs are being developed for 28 and 32 PWR fuel assemblies, depending on overall weight limitations.

COGEMA is developing detailed acceptance criteria for dual–purpose casks for spent fuel that has been out of the reactor for more than five years to ensure their compatibility with the unloading facilities of the La Hague reprocessing plant.

3. TRANSPORTATION SYSTEM AND EQUIPMENT

Spent fuel is transported to the La Hague reprocessing plant by rail, by road and by sea. Transportation from continental European locations is provided by rail in specially–designed 25 meter long rail cars weighing 160 tons; these cars are allowed into normal railway traffic without speed restrictions. For very short distances between certain power plants and the rail terminal in their vicinity, or between COGEMA's Valognes rail terminal and the La Hague plant, spent fuel is transported over public roads on special tractor–trailers with adjustable cradles that accommodate different cask lengths. In France, the trailers have 8 to 10 axles, for a total of 64 wheels, and weigh approximately 130 tons. Fuel is shipped from Japan in rather small, specially–designed ships weighing in at 3,000 tons. Ships used to transport fuel between European countries weigh 2,000 tons. The equipment on these ships is unique in many respects, including redundant engines, double hull, radiation shielding and advanced redundant communications systems.

4. INDUSTRIAL AND NUCLEAR SAFETY

Spent fuel transporters must comply with many different regulations: French regulations for the transportation of radioactive materials within France; ADR, RID and IMCO regulations for international road, rail and sea transportation; and any other pertinent regulation in the country concerned. For example, spent fuel transportation in France must comply with pressure vessel regulations, insofar as the transportation cask may be pressurized during the unloading process at La Hague.

Although numerous, these regulations are very similar in their basic content, having been drawn from the recommendations of the IAEA with very few alterations other than to their form. The universality and relative stability of stringent transportation regulations, and especially those relating to cask design, contributes to the overall safety of spent fuel transportation and facilitates cask certification. A cask certified in one country is normally accepted automatically in other countries.

Operating experience and analysis have shown that spent fuel transportation casks have a large margin of safety with respect to regulatory requirements and actual operating conditions. The 9 meter drop test onto an unyielding surface, required by IAEA regulations, corresponds to a speed of 50 km/hr. The equivalent speed in highway or rail crashes, in which the probability of encountering unyielding surfaces is low, is well in excess of 100 km/hr. Even more demanding tests have been devised to demonstrate the ability of the current generation of casks to withstand crash conditions that are more severe than those specified in the regulations.

5. MAINTENANCE ASPECTS

IAEA transportation regulations issued in 1985 set forth requirements for cask maintenance and the associated quality assurance program. To meet these requirements, the three companies involved in spent fuel transportation -- COGEMA, PNTL and NTL -- developed a joint cask maintenance policy which calls for :

. routine maintenance after 15 shipments or every 3 years ;

. in-depth maintenance after 60 shipments or every 6 years.

Cask maintenance has been performed on some 650 casks at the AMEC facility at La Hague since 1984, and a total of 950 casks have been received at La Hague for various operations, including repair, change-out of internal equipment and refurbishing of components. All cask functions and components are checked or inspected in accordance with procedures approved by the regulatory authorities and by the clients, and casks are repaired and refurbished at the facility as necessary prior to turn-around. The major operations involved in cask maintenance are :

. detailed inspection of the cask body, lid, basket, orifices, threaded components and protective covers ;

. replacement of screws, O-rings and other components ;

. integrity test of the cask cavity and other sealed components, including the drums and impact limiters ;

. detailed ultrasonic and visual inspections and load-bearing tests of the trunnions ;

. criticality safety check of the baskets ;

. shielding integrity check by gamma and neutron scanning ; and

. heat transfer efficiency check by temperature measurements.

6. ECONOMIC ASPECTS

6.1. Transportation Figures

Large-scale transportation of spent fuel began in France in 1966 with the start-up of commercial gas-cooled reactor fuel reprocessing operations. Today, two ocean ships, a dozen rail cars and two trucks transport casks loaded with spent fuel to La Hague through various countries on any given day. Over the next 10 years, approximately 13,000 tons of LWR fuel from some 110 reactors, half of which are in France, will be sent to La Hague in some 3,000 cask shipments.

6.2. Manpower Requirements

The work force involved in spent fuel transportation to La Hague is very small : fewer than 100 personnel participate in the design, procurement, operation, maintenance, supervision and inspection of spent fuel transportation casks at COGEMA, NTL and Transnucléaire. Obviously, there are others involved in transportation activities, including railroad personnel, ship crews, port staffs and truck drivers. However, compared to other areas of the fuel cycle, transportation manpower requirements are relatively low.

6.3. **Transportation Equipment and Facilities**

At first sight, spent fuel transportation has nothing spectacular about it: no big facilities, no extraordinary equipment, only relatively small and widely scattered resources on highways, railroads and in the middle of the ocean. Nonetheless, the equipment involved in spent fuel transportation is extensive and represents major investments. For LWR spent fuel alone, there are :

. 90 large payload casks owned by COGEMA, NTL and PNTL ;

. 30 rail cars owned by COGEMA and NTL ;

. 5 ships owned by PNTL operating between Japan and Sellafield or La Hague ; and

. several specially-designed trucks owned by COGEMA.

The facilities involved in spent fuel transportation include :

. a private rail terminal near Cherbourg owned by COGEMA, including maintenance facilities for rail cars and trucks ;

. a port terminal at Cherbourg ;

. a facility for cask maintenance and reinspection at La Hague ;

. a cask receiving facility at La Hague, where casks are transferred from trucks to one of the 60 lorries available for interim storage prior to unloading ;

. the NPH wet unloading facility at La Hague, with its two unloading lines ; and

. the T0 dry unloading facility at La Hague.

The latter facility, in particular, offers several advantages for spent fuel cask handling :

. extensive automation ;

. faster unloading and cask turn-around ;

. no contamination of the external surface of the cask, making decontamination unnecessary while reducing liquid effluent volumes and cask turn-around times ; and

. lower occupational exposure.

7. CONCLUSION

Radioactive materials transportation is the only activity in the nuclear fuel cycle to take place outside a nuclear facility -- on public roads, on railways, or on the open sea. Were an accident to occur, even a minor one, the environment wouldn't be the only thing to be affected: it could spur public reactions that would have potentially negative consequences for the entire nuclear industry. An exceedingly high level of safety is therefore an absolute requirement for all transportation operations, as it is for all areas of the nuclear industry. That this imperative has been respected is evidenced by a few statistics: in over 350 shipments to La Hague per year and 19,000 tons of spent fuel transported in 5,500 cask shipments to date, there has never been any personal injury or property damage as the result of a spent fuel transportation accident.