European Experience in the Transport of Irradiated Light-Water Reactor Fuel

by H.W. Curtis

The service for transporting irradiated fuel relieves the reactor operator of a number of problems. These include the provision of flasks (approved in accordance with international and national regulations), technical assistance in preparing for the handling of flasks and during their subsequent handling operations and loading, provision of insurance and compliance with nuclear indemnity requirements, full documentation and customs clearance and transport of full and empty flasks between the reactor and the reprocessing plant in accordance with agreed programmes. In this article, various aspects of this transport service are described.

DESIGNS OF FLASK

In any discussion of flask design, arguments can be put forward in favour of flasks in which the internal heat transfer medium is air at or slightly below atmospheric pressure (dry flasks) or water (wet flasks), in favour of light flasks designed for transport by road, or heavy flasks for transport mainly by rail or sea with short stretches of road transport when the reactor or reprocessing plant does not have a rail connection. When considering heavy flasks, the choice lies between flasks of around 75 tonnes and "Jumbo"-sized flasks up to 100 tonnes. During the past eleven years of experience in the transport of irradiated light-water reactor fuel, no single one of these alternatives has emerged as the perfect answer in all situations. The existing European flask pool includes all these variations.

TRANSPORT METHODS TO WINDSCALE

Irradiated fuel has been transported by road, rail and sea. The choice of transport method is dictated largely by the geographical location of the reprocessing plant and the reactor. Flasks depart to Windscale from reactor sites by a number of different methods: by direct loading to a charter ship at the site, by road transport to the nearest port for loading to a charter ship, by loading onto a rail wagon, which is routed direct through to Windscale, or by loading onto a road trailer which also is routed direct to Windscale. There are considerable technical and economic advantages in minimizing the number of the changes in mode of transport. The transfer from road to rail or sea transport requires the use of an expensive heavy-lift crane and careful surveillance of the tie-down after the transfer. For shipments from continental Europe to Windscale, single-mode transport can only be used for heavy flasks when the reactor has a rail connection, or by the use of trailer-mounted light

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flasks. For road transport operations, use is made, as far as possible, of local contractors to provide the tractor to haul the semi-trailer. To the end of 1978, the distribution of transport methods has been:

Flask movements by charter ship:	53
Flask movements by rail ferry:	36
Roll-on, Roll-off ferry movements:	60

Most transport to Windscale has been performed in heavy flasks (Figure 1). Of the total quantity of 267 tonnes of European fuel transported to Windscale by the end of 1978, 209 tonnes were transported in flasks weighing about 65 tonnes; of the total number of 149 movements, 60 were in light flasks of less than 40 tonnes. All future movements to Windscale will be by rail between the arrival port and the site.

TRANSPORT METHODS TO LA HAGUE

For the medium term, all flasks must be delivered to La Hague by road for at least the terminal part of the journey. Of 350 LWR flasks delivered to La Hague, 312 transports were entirely by road using light flasks (Figure 2).

The trend in irradiated fuel transport is towards heavy flasks moving by rail. Light flasks with road transport over the entire route will be reserved for those cases where geographical conditions indicate a substantial advantage for this transport mode. If a reactor is not connected to the rail system, however, major problems will be encountered in transferring heavy flasks by road to a nearby rail siding where a special crane must be hired or constructed. In most cases, the costs of bringing a heavy, mobile hire crane from the nearest depot which may be located at a considerable distance from the reactor, will justify the construction of a fixed crane. Other solutions such as rail wagons on which the rail bogeys can be converted to road bogeys are technically possible, but the minimum length of 21 metres for a rail wagon results in an extremely unwieldy road vehicle which may be unable to negotiate the approach roads to the reactor. Moreover, a wagon designed for rail operation at 100 km per hour is a more sensitive item of equipment than the cumbersome vehicles normally encountered in such rail/road movements. It is regrettable that many reactors are still being constructed without provision for rail transport of irradiated fuel.

SOME PROBLEMS IN IRRADIATED FUEL TRANSPORT

Irradiated fuel transport is an activity which is largely taken for granted by the European nuclear industry. Perhaps the reason for this outlook is that the service has worked successfully. However, it is sometimes wrongly assumed that the service works successfully because there are no problems. It is true that many of the early problems of nuclear indemnity, insurance, customs clearance, MB10 availability, regulatory approvals from many different authorities (more than twenty per campaign in some cases), disappear provided the experience and know-how is available. Numerous problems still exist however and new ones appear as old ones are solved. Some of the more frequent problems are discussed below.

Crud

Flask designs have been based on the assumption that Zircaloy-clad uranium oxide fuel would be discharged from the reactor with a reasonably clean surface. In practice, the surface of the fuel from almost all BWRs and some PWRs is heavily encrusted with crud which detaches from the fuel during loading and transport and during unloading at the reprocessing plant. The crud builds up between the two walls of flasks of a composite wall design, and in and around the flask orifices, increasing the radiation dosage of personnel engaged in flask handling operations. The solution to this problem adopted at Windscale has been the encapsulation of the fuel in "bottles" within the flask; these can be flushed in the pond to remove the crud before the lid of the "bottle" is removed to unload the fuel from the flask. The use of "bottles" does however reduce flask capacity by up to 30%. At La Hague, less use has been made of composite wall flasks and the fuel delivered has been predominantly PWR. In consequence, intensive flushing before unloading has so far been accepted. Water activity after loading of the flask is measured and approved before despatch to ensure that the fuel is in acceptable condition for reception at La Hague.

Failed Fuel

Reprocessing plants will not normally accept failed fuel. Where such fuel has been accepted in the past, it has been transported in sealed capsules which do not need to be opened before storage in the reprocessing plant pond. The increased cross-section of such a capsule usually necessitates a new internal flask basket and flask capacity can be reduced by as much as 40%.

Criticality Criteria

The IAEA Regulations for the Safe Transport of Radioactive Materials provide the basis for the criticality clearance of irradiated fuel flasks for transport. Because of the large quantity and variety of flasks and fuels received by a reprocessing plant, a trend towards more stringent criteria has appeared. These reprocessing plant criteria require that no allowance be made for the irradiated condition of the fuel, whilst the K_{eff} must not exceed 0.95 to three standard deviations. In some cases, this trend will limit the capacity of a flask to less than the quantity of fuel which the flask can physically accommodate.

Flask Contamination

External contamination of flasks has caused problems due to the "sweating out" of contamination from both painted and stainless steel surfaces many hours after the surfaces have been decontaminated and passed as clean. Whilst the problem can be resolved by cleaning the flask initially to one-tenth of the permissible limit so that subsequent "sweating out" still lies below the limit, the better solution is to protect the surface of the flask from contact with contaminated pond water by the use of plastic or metal skirts or removable adhesive coatings. A rigid metal skirt covering all the finned area of the flask has been developed and is in use at the La Hague reprocessing plant and some reactors.

Reactor Access

Reference has been made to the difficulties of transport access to the reactor site but equally grave problems can be encountered within the reactor building. Little consideration was given during the design of first generation reactors to the problems of irradiated fuel transport and the path to be followed by the flask through the building. These reactors place insuperable limitations on such vital factors as flask length and flask weight. The route from the transport vehicle is tortuous and sometimes not beneath the crane operating area, necessitating horizontal dragging of the flask. Examples can be quoted today of new reactors

Figure 1. 75 tonne NTL 11 flask mounted on a road transporter.

Figure 2. 36 tonne NTL 8 flask on a road trailer.

where the minimum possible length of rail wagon capable of transporting a heavy flask can not be accepted within the air-lock, even though a rail connection has been provided. Elsewhere, the wagon can enter the air-lock but cannot be positioned so that the crane lifing beam can be attached to tilt the flask from the horizontal to the vertical.

Vehicle Maintenance

With conditions such that a halt by the roadside to change a punctured tyre is apt to be publicized by the media as a "nuclear incident", it is essential that vehicles be maintained to as high a standard as possible to prevent breakdowns. Whilst no more than good transport practice is called for, it is essential that the standards are maintained on all vehicles and ancillary equipment.

Operational Control

Apart from operational and technical problems, the international nature of irradiated fuel transport creates organizational problems. The service is provided by an international company (Nuclear Transport Limited) which happens to be registered in England where its headquarters are located. The company could not however fulfil its functions from a UK base without the support of personnel located in Paris and Hanau. In conjunction with the UK headquarters, these offices maintain close contacts with those reactors for which they have project responsibility, obtain approvals and manage the day-to-day control of transport operations. Technical assistance can also be readily provided from one of the three centres.

The transporter acts as the bridge between the reprocessing plant and the reactor and must endeavour to meet the requirements of both parties. Indeed, it would not be practical to envisage the successful performance of irradiated fuel transport without the closest collaboration on technical, operational and programming matters between the reprocessor and the transporter. For this reason, reprocessing and transport have been marketed as a joint service and it would be imprudent to separate the two activities.

The programming of transport campaigns for twenty-one reactors also gives rise to considerable problems. Flask requirements are estimated at least two years in advance and determine the available transport capacity. Transport campaigns are formulated in accordance with reactor requirements to remove each discharge of fuel before the following shut-down. A surplus flask capacity of approximately 40% is allowed to cover maintenance, clashes between the programmes of reactors using the same flasks and other contingencies The system works satisfactorily as long as no major disruption occurs, such as the complete unavailability of the reprocessing plant unloading facility for technical or other reasons. When the problem is removed, it is clear that insufficient flask capacity is available until the backlog has been cleared and a return to equilibrium achieved. During these difficult periods, it appears that the available flask pool is too small.

Figure 3. Special rail wagon developed for the transport of irradiated fuel flasks. ▶


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SAFETY

The transport of irradiated fuel is performed in accordance with the IAEA Regulations for the Safe Transport of Radioactive Materials, which are discussed elsewhere in this issue. The safety record of irradiated fuel transport can be quickly described because no accidents have occurred and the IAEA regulations must be given considerable credit for this fact. The 1973 edition of the regulations has reduced the permissible radioactivity release rates to the fringe of what is technically demonstrable, causing a further tightening up of procedures and increasing the safety factors.

FUTURE TRENDS

Of 350 transports of oxide fuel to La Hague, 312 have been made in light flasks travelling throughout by road with a payload of approximately 1.2 tonnes of uranium. This system provides efficient and economic transport. However, the position is changing rapidly as a result of pressure from reprocessors and reactor operators to reduce the number of flask handlings per discharge to a minimum. This pressure has been answered by the provision of heavy flasks in the range of 75 to 100 tonnes, with a capacity from 1.2 to 5 tonnes of uranium (Figure 4). These heavy flasks can be transported only by rail or sea and the limiting factor becomes the dimensions and shape of the railway profile or gabarit. The introduction of heavy flasks has also required the development of a special eight-axle rail wagon able to transport these loads at the speeds of normal freight trains (Figure 3).

It is frequently asked why the European flask pool contains so many variants and why flask standardization has not been achieved. The transporter would be pleased to be able to operate only one type of flask but this is technically impossible even if one considers the most modern reactors. A flask optimized to suit the five German Kraftwerk Union PWRs would be unacceptably long and heavy for the German BWRs. A flask optimized for other PWRs and BWRs could not be handled at any of the earlier reactors such as Gundremmingen, Obrigheim, Sena, Zorita, Garigliano and Trino.

Nevertheless, the trend is now towards one type of heavy flask for each reprocessing plant, supported by a small quantity of light flasks for special cases. The old flasks or similar replacements will still be needed, however, to service many of the existing reactors.

The early days of irradiated fuel transport necessitated a small pool of very versatile flasks which could be switched rapidly from one reactor to another. However, the allocation of single flasks or pairs of flasks to specific reactors would have resulted in highly uneconomic transport and a total flask pool much larger than was required. The trend towards flask standardization will now be accompanied by a move towards the allocation of identified flasks to serve specific countries and ultimately to serve specific utilities or reactors. This trend is a natural consequence of the fact that the annual discharge from a modern reactor is up to five times greater than the tonnage from a small first generation reactor and it will become possible to justify the allocation of one or two flasks to one reactor. As the size of the flask pool increases, the spare capacity of 40% represents a much greater resource than was the case when the pool consisted of fewer flasks and will provide a greater ability to cope with disturbances in the planning schedule

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◀ **Figure 4. 100 tonne NTL 12 flask being tilted on a rail wagon.**

Subject to the availability of the unloading facilities at the reprocessing plants, the international transport of European irradiated oxide fuel has been performed successfully over the past eleven years. The scale of operations will increase in the future as more reactors are commissioned. The consequent increase in the size of the flask pool and its spare capacity and the trend towards larger flasks and standardization will help to improve the flexibility and efficiency of the service.