Optimization of Spent-Fuel Cask Operations During More Than 20 Years

R. Bach
NTL Nukleare Transportleistungen GmbH

INTRODUCTION

Since 1973 NTL have been responsible for the carriage of PWR and BWR spent fuel elements mainly from Western European reactor sites to the reprocessing plants of COGEMA at La Hague and BNFL at Sellafield. In total, NTL has safely performed more than 3,000 transports of spent nuclear fuel.

NTL operate a wide range of dry and wet-type transport casks for the transport of spent fuel elements:

- NTL casks (dry and wet types) designed for all sizes of BWR and PWR reactor sites,
- COGEMA casks (dry type) designed for larger sized BWR and PWR reactor sites, and
- BNFL casks (wet type) designed for larger sized BWR and PWR reactor sites.

The tasks and responsibilities of NTL are briefly described as follows:

- Organization and management of the transports using combined services of the offices at Risley (UK), Paris, La Hague, Dunkirk (France), and Hanau (Germany),
- Provision of optimized loading plans for Uranium (U) and Mixed Oxide (MOX) fuel element cask-loading,
- Acting as reprocessor representative during cask-loading at reactor site,
- Provision of technical assistance during cask-handling and loading at reactor site,

- Performance of consignor duties at the laden cask departure,
- Provision of casks, transport equipment, and associated cask-handling equipment,
- Provision of transport and fuel feasibility studies, and
- Provision of technical analysis for criticality, shielding, thermal and stress using internationally recognized computer software.

To fulfill these tasks properly NTL has established a Quality Management System which has been independently certified by officially acknowledged auditing companies in each country.

This paper briefly describes the development in the different areas of spent fuel transports as well as the improvements in cask-handling and loading at reactor sites over a period of more than 20 years and will give an outlook for future development.

REQUIREMENTS FOR SAFE CASK OPERATIONS AT REACTOR SITES

In 1973, when NTL commenced working in the field of the safe carriage of spent fuel from reactor sites to reprocessing plants, there was only a very limited number of fuel types to be considered for transport. The initial enrichment of U-235 did not exceed 3.30 % and the final average burnup of the spent fuel elements to be transported was in the range of 30 to 35,000 MWd/tHM. For most of the small reactors it was and in some cases it is still essential to perform the transports of the spent fuel elements prior to their next shut-down, which means commencing the transport campaign after 6 months cooling time.

During the last decade the improvements in fuel element performance have been considerable. NTL is now loading U and MOX spent fuel elements into the transport casks with initial enrichment of U-235 / Pu content up to 4% and final burnups after four to five irradiation cycles in the range of 50,000 MWd/tHM.

In the early years, the casks used for spent fuel transports were quite small. Their weight did not exceed 50 tonnes, therefore these transports were usually performed by road. This resulted in a large number of transports as the capacity of those small casks was limited to three to seven fuel elements. As previously mentioned, the fuel parameters have greatly increased, and thus the main considerations in designing new cask types focused on higher fuel element capacity and to improvements on decay heat dissipation and gamma/neutron shielding.

Compared to the old casks, the new casks are considerably more sophisticated in design. The cask-handling equipment has been designed to cope with cask-handling weights over the fuel element loading pond up to 120 tonnes. In the same manner the operating equipment around the flask has been considerably extended.

The development in cask-handling at reactor sites can be summarized as follows:

- With the introduction of 1,300 MW reactor plants as standard reactor types (PWR and BWR) the availability of a large number of spent fuel elements from these reactor sites has strongly forced development of new cask designs of bigger capacity and better performance with respect to decay heat transfer and dissipation and gamma and neutron shielding.

  The standard transport casks presently in operation are capable of accepting 12 PWR or 32 BWR spent fuel elements with an initial enrichment of U-235 of up to 4%, total decay heat capacity up to 85 kW and cooling times of 12 months or even less.

- It is obvious that to meet the regulatory requirements for the leak tightness criteria, cavity dryness acceptance limits (for dry type transport casks), and to minimize the dose uptake rates of the operating staff, specially designed operating equipment has been required and has been provided by NTL.

  Typical examples of such are special valve equipment for remote orifice plug handling, metallic skirt for protection of the cask cooling fins, orifice leak-testing equipment, cavity-drying equipment etc.,

- NTL has continuously reviewed the practices of cask operations such as preparation for loading, loading with spent fuel, testing after loading, and preparation for despatch are more comprehensive at present as it was in the past. All testing results have to be recorded on a special set of transport documents and have to be assessed against the specified permitted values prior to release.

- As cask-loading and testing operations are comprehensive and observation of regulatory and specified limits is mandatory, it is essential to have professional working and skilled operating and witnessing staff at reactor sites. NTL's staff is permanently present for the performance of all the activities of witnessing cask-handling and loading operations, such as fuel identification and loading, verification of testing results, and finally acting as consignor at the despatch of the shipment.

To enable NTL to safely perform cask-handling and loading, NTL has developed and continuously reviews its system of cask and equipment operating procedures.

The **operating procedures** can be separated into their areas of application:

a) Cask-related operations

- **Handling and Loading Working Sequence Plan** with reference to all relevant handling procedures and loading instructions applicable for the type and the reactor site. This document is treated as a live document on the spot.

- **Handling and Loading Operating Manual** providing detailed information about each handling and loading working sequence.

In this document there are references made to all relevant handling procedures and loading instructions for the relevant type and the reactor site. This manual contains information about components and replacement parts as well as for testing and operating criteria. It is based on the Design Safety Analysis Report of the relevant type.

Similar documents have been developed for cask-unloading operations.

b) Equipment-related operations

- **Operating Procedures** for safe operating of cask-handling equipment such as lifting beams, transport trolley, lid lifting equipment, etc.

- **Handling Procedures** for safe handling of ancillary equipment such as testing and measuring equipment, orifice equipment, cavity-drying equipment, etc.

c) Safety and special process-related operations

- **NTL Group Procedures** have been developed for the performance of essential/ verification operations and are common to all companies of NTL, such as fuel element identification, preparation of cask-loading plans, turnaround inspection, etc.

- **Testing Procedures** for performing the required tests on the spent fuel and on the such as verification of fuel element status prior to loading and and equipment status prior to and after loading. These testing procedures concern further examinations such as leak testing of orifices, dryness testing of cavity, burnup verification on spent fuel elements (qualitative or/and quantitative), etc.

It is essential in NTL's working field that all parties concerned are providing reliable services. To meet this target NTL has set up an efficient, working Quality Management System giving full assurance to customers and competent authorities that loading and handling is performed in full accordance with regulatory requirements and approved procedures.

NTL is in the position to confirm that only accepted fuel elements are loaded and that final testing on the laden s is carried out in full compliance with the requirements of the Design Safety Analysis Report, licences, permits, and with the standards and regulations for transport of radioactive goods set up by international and national authorities.

OPTIMIZATION OF OPERATIONS AT REACTOR SITES

As explained above the process of fuel element development during the past has effected further improvements on the design and fuel verification equipment such as:

- Design and provision of high-performance fuel element baskets to meet high-enriched U and MOX fuel elements up to 4% U-235 / Pu content;

- Provision of fuel element baskets with special compartments in the basket for carrying bottled failed fuel elements;

- Increase of neutron shielding capabilities to be able to transport high burnup fuel after short cooling periods (12 months or even less); and

- Design and provision of burnup verification equipment to take advantage of burnup credit for high-enriched U fuel elements.

All these measures have been performed to comply with the reactor operators requirements for high-performance fuel elements.

NTL has made considerable efforts to **optimize loading and testing processes** in the light of **minimizing operating times** at reactor sites and **dose uptake** of operators and NTL technical assistance staff.

The **training activities** of the operation teams have been strengthened and are showing remarkable results in respect to decreasing dose uptake and minimization of mishandling operations.

Based on dose uptake records combined with dose predictions, NTL has performed a study about the dose uptake of staff during future loadings in a 1,300 MW nuclear power plant.

The results are presented in Figure 1. The **total dose uptake** of the personnel in charge of the loading amounts to **1.68 mSv**, including **0.63 mSv** for **neutron** and **1.05 mSv** for **gamma radiation.**

About 10 years ago the collective dose uptake of operating staff was up to 2 to 3 times higher. To achieve the current dose uptake level for the operating staff, the following measures have been performed on a regular basis:

- Performance of cold trials of each new type at reactor site to verify and optimize the handling and loading working sequence plan;

- Training of reactor operating staff on handling and ancillary equipment operation at other reactor sites where the same type is used to avoid time- consuming working sequences during operations (preparation, loading, testing, etc.), which are not required;

- Providing information to the health physics staff at the site to perform dose rate measurements on the spot at special working sequences;

- Provision of an optimized loading plan for each individual loading with particular consideration on dose rate minimization;

- Periodic inspection and maintenance of s in accordance with commonly agreed procedures at defined intervals. Prior to the performance of periodic inspection the is internally and externally cleaned; and

- Availability of properly designed and maintained handling equipment at reactor sites. Presently most of the reactor sites are ordering maintenance services from NTL prior to the relevant transport campaigns.

DEVELOPMENT OF DOSE UPTAKE OF NTL SERVICE STAFF

In addition to predicting dose rates for loadings NTL have been permanently following the dose uptake of their service staff. In this context NTL have worked out the dose uptake figures on their staff giving technical assistance at reactor sites.

The results are presented in Figure 2. From the NTL service teams four technicians who have been permanently working with NTL have been chosen for demonstration (T1 to T4). The survey shows that the values of dose uptake have been constantly decreasing from a maximum level of **11.4 mSv in 1983** up to a maximum level of **6.6 mSv in 1994**. The peak of the column T2 in 1986 (14.2 mSv) can be explained because this technician attended a certain number of loadings of small type flasks with the first spent MOX fuel elements for reprocessing and interim storage.

The average individual dose uptake, as shown in Figure 3, has been steadily decreasing from **9.4 mSv in 1983** to **3.8 mSv in 1994.** The evaluation was performed taking into account the variation of the number of shipments per year, frequency of individual services and difference of types.

Another comparison of interest is presented in Figure 4. In this figure the average dose uptake of the NTL service staff during the operation is shown. From an average dose uptake value per loading operation of **0.62 mSv in 1983** to a value of **0.3 mSv in 1994** the factor of reduction is more than 2.

It can be noted that the columns for the years 1990 to 1992 are higher compared to the preceding years. The reason is that from 1990 onwards more and more high burnup and MOX fuel elements have been loaded for transport to the reprocessing plants. To cope with this development a time lag of about 2 years need to be met.

It can be summarized that despite a constant increasing of the fuel element burnup in the past a considerable reduction of dose uptake of the servicing staff has been reached at present and NTL's efforts are going on for further optimization.

OUTLOOK FOR FUTURE DEVELOPMENT

Especially in Germany, a discussion is going on about the neutron qualification factor in connection with spent-fuel transports. The International Commission on Radiological Protection (ICRP) has published recommendations about radiation protection in 1990 (known as ICRP 60), suggesting for neutron efficiency the factor of 20 in comparison to the efficiency of photons be considered. Those recommendations will be taken into consideration in the new IAEA Safety Series No. 6, to be issued in 1996.

In most of the cases the impact on transports may be very limited, but it must be considered that these recommendations will have to be seriously analyzed to ensure accurate application, taking care on radiation physics (energy levels, ratio per energy level, etc.).

In respect to future transports of spent fuel elements they can be separated into:

- *Transports to reprocessing plants in specially designed transport s (wet and dry type)*
- *Transports to long term storage facilities in specially designed transport* ***and*** *storage for storage over decades in dry conditions.*

The characteristics of spent fuel elements will reach the following targets in the near future:

- *Initial enrichment of U-235 / Pu content up to 4.5%;*
- *Irradiation cycles of fuel elements up to 6 or in some cases up to 7;*
- *Average burnup of fuel elements up to 60,000 MWd/tHM with peak burnups of up to 65,000 MWd/tHM.*

The majority of s presently used for carriage of spent fuel can cope with these spent fuel element characteristics, but it seems necessary to go for longer cooling periods. In addition the option to take advantage of burn-up credit for PWR **and** BWR fuel elements will need to be used to a greater extent.

The progress in fuel element development during the past two decades has been considerable and has required strong efforts on design and improvements and optimizations for safe fuel element loading at reactor sites. The types and the associated handling equipment have reached a high level of development. But to cope with the long-term future spent fuel element characteristics, further efforts and improvements may be required. Some types for transport only or for transport and storage may require improvements on shielding capabilities especially in respect to neutron radiation.

It can be stated that the safe carriage of spent fuel elements has become a well-established operation in the nuclear field. NTL is very confident to meet the future demands and to fulfil a vital part of the nuclear fuel cycle.

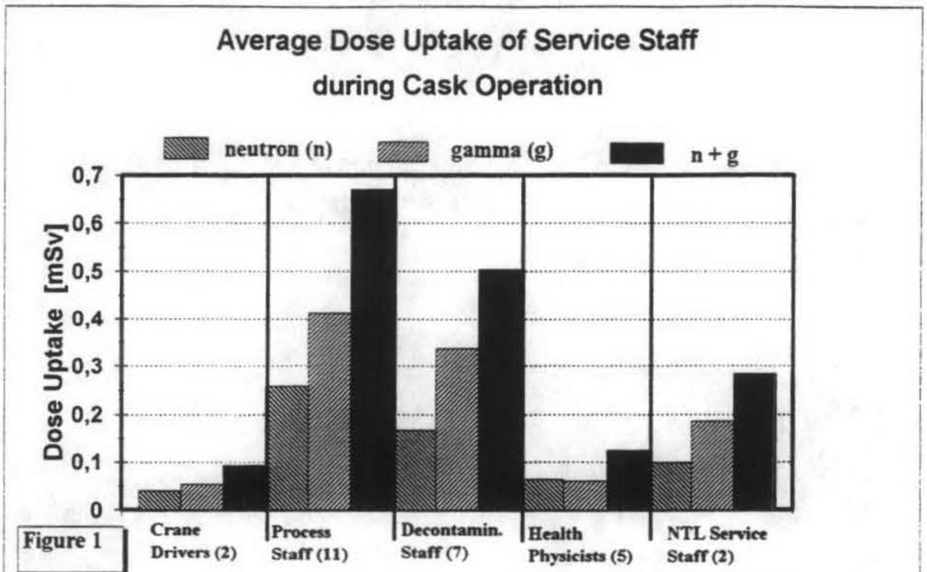


Figure 1

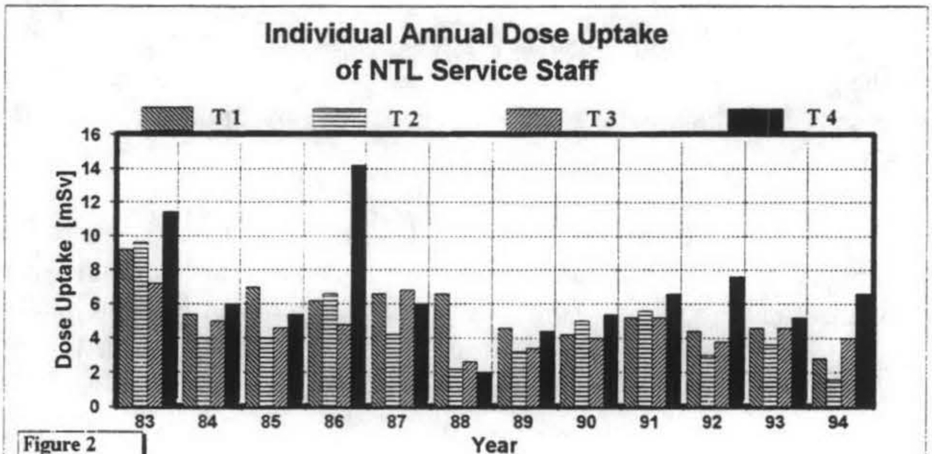
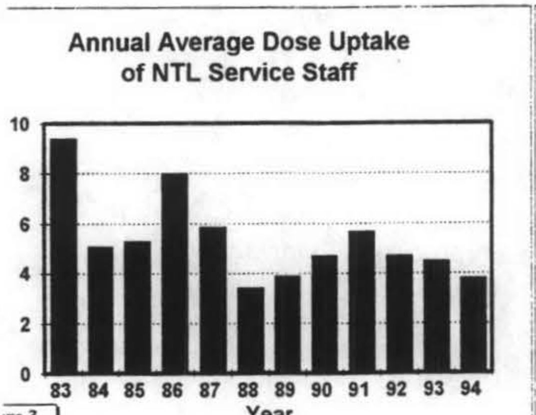


Figure 2



ıre 3

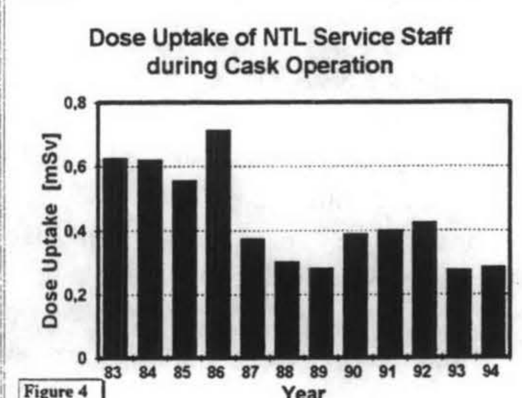


Figure 4