EXPERIENCE WITH CONTAMINATION PROTECTION OF SPENT FUEL TRANSPORT PACKAGES IN GERMANY SINCE 2000/2001

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INTRODUCTION

On April 30, 1998 just a few days before the PATRAM 1998 conference at Paris, the French Nuclear Installations Safety Directorate (DSIN now DGSNR) published a press release, that during the year before some 35 % of the spent fuel transports to the reprocessing plant of COGEMA at La Hague have had non-fixed surface contamination in excess of the regulatory standard [1]. A few days in advance DSIN informed the French Ministries and the competent foreign authorities of the customer countries of COGEMA. The consequences of this publication were multi-fold and perceived by the public as an act of negligence of the nuclear industry. Because of concerns about additional radiation exposure to the railway workers by the unions the French Railway company SNCF suspended all transports by May 6, 1998 until implementation of corrective measures. This decision of SNCF interrupted also the spent fuel transports from continental Europe to the reprocessing plant of BNFL at Sellafield all performed across France to the port of Dunkirk. Furthermore on May 25, 1998 the German Federal Ministry of Environment, Nature Protection and Nuclear Safety (BMU) imposed a transport ban for shipment of spent fuel from commercial power plants and for high active waste returned from La Hague to the Gorleben site. The conditions for resumption of these transports were outlined by BMU in a 10-point programme.

In response to these publications on contamination findings competent German State and Federal Authorities commissioned investigations by independent experts dealing with the identification of the causes, the proposal of counter measures, the investigation of shortcomings in the transport system in general and recommendations for rectification of it. Over the period September to December 1998 three reports were issued by expert organizations (GRS, Öko-Institut and TÜV Süddeutschland) on the contamination issue. Based on the independent expert reports, the BMU compiled two guideline documents for the resumption of spent fuel transports to the reprocessing plants abroad. In a common effort of the industry engaged in the spent fuel transport cycle in Germany, France and UK a concept for clean transports was developed, substantiated and discussed with the competent authorities in the period July 1998 to June 1999. Because of priority setting by authorities the expert report on spent fuel transports to reprocessing plants was issued on November 22, 1999 and as the last one of a row starting with a report on domestic spent fuel shipments and continuing then with one for vitrified residue transports from La Hague to Gorleben. All recommendations and all remarks set-out in this report have been treated by the industry with confirmation of fulfillment by GRS/Öko-Institut on April 17, 2000 [2]. Details of the authorities' requirements and the corresponding response by the industry are provided in the next chapter. The implementation of all measures for "clean" transports finally led in October 2000 to the first loading of a flask in a German power plant and after clearance of some political issues between France and Germany in April 2001 to first transports with special cargo trains to La Hague and Sellafield. Compared to other countries concerned by the contamination crisis of May 1998 the German transport moratorium was by far the longest and lasted nearly 3 years (Figure 1). Over this period about 250 spent fuel transports equivalent to the shipment of appr. 1000 t Heavy Metal of fuel were lost and fuel ponds running full in some power plants getting close to the risk of plant shut down because of blockage of spent fuel evacuation routes. Some plants were in such desperate fuel pond conditions that only special core management measures like stretch out operations or reduction of power generation enabled the survival of plant operation.

MAY 1998 CONTAMINATION INCIDENT / MORATORIUM PERIODS FOR SPENT FUEL TRANSPORTS

Number of Nuclear Power Plants		1998			1999				2000				2001			
		II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Great Britain	35	0														
Japan	53	0														
France	58	2														
Belgium	7		6										1st transport			
Switzerland	5			16												
Germany	19					35 Months										

Figure 1: Moratorium periods for spent fuel transports - an international review

1. AUTHORITY REQUIREMENTS AND NUCLEAR INDUSTRY RESPONSE FOR "CLEAN" SPENT FUEL TRANSPORTS

All recommendations and measures elaborated in the expert reports were collected and bundled by BMU in two documents called "Criteria for transport of empty transport flasks, of flasks loaded with irradiated fuel assemblies from power plants and of flasks containing vitrified fission products" and "Catalogue of measures for resumption of transports of spent fuel and of vitrified residues". The main requirements of BMU for performance of "clean" transports are listed in Figure 2.

ISSUE OF GUIDELINES OF FEDERAL MINISTER OF ENVIRONMENT FOR RESUMPTION OF TRANSPORTS (JUNE 7, 1999)

Main requirements contained therein were:

- Optimization of technical measures to achieve one tenth of regulatory standards for non-fixed contamination on packages and vehicles
- Resumption of transports in a three phase concept
- Enhanced scope of non-contamination controls based on a commonly agreed monitoring programme
- Improvement of decontamination techniques and specification of key process parameters
- Improvement of organisational structures and exchange of experience
- Implementation of extended documentation files covering the entire transport cycle

Figure 2

The system developed for prevention of contamination by the nuclear industry in response to the authority requirements consisted of improvements in essentially three areas:

- Implementation of additional technical and monitoring measures for prevention of surface contamination including the "closed transport cycle" concept (Figures 3 to 6),
- Introduction of additional administrative measures (Figure 7),
- Supplementary organisational measures (Figure 8).

A transport cycle is hereby defined as the shipment of the empty and of the loaded package including all necessary operations at the power plant and at the reprocessing plant. Closed cycle means that packages are in exclusive use for German plants only (members of a dedicated pool of flasks with specified entry conditions). In Figure 3 and 4 the additional technical measures implemented at the power plants and at the reprocessing plants are summarised. Photos of the two designs for skirts in use at German plants and protecting the total outside surface of the flask from contact with radioactive water during immersion of flasks in fuel pond are shown in Figure 5 and 6.

ADDITIONAL TECHNICAL MEASURES FOR PREVENTION OF SURFACE CONTAMINATION APPLIED AT NUCLEAR POWER PLANTS

- Decontamination of loaded packages and of transport vehicles to less than 0.4 Bq/cm² (β, γ) resp. 0.04 Bq/cm² (α); 10 % of regulatory standards
- Installation of “non-contaminated” and “contaminated”
  - ⇨ working areas
  - ⇨ tools
  - ⇨ handling equipment

  during flask handling and loading for prevention of “cross-contamination”
- Optimization of Contamination Protection Skirts for flasks immersed in fuel ponds for loading

  Aim: Exclusion of pond water contact with total outside surface of flasks

  Design options: Plastic skirt
Three part metal skirt
- Application of large-area (A) smear test (1000 cm² < A < 1 m²) for pre-check of non-contamination of flask surfaces (called “screening” test)
- Application of “screening test” or of direct measurement for pre-check of non-contamination of vehicles
- Filtration of demineralized water drained from interspace between skirt and flask for monitoring of absence of CRUD particles
- Threefold number of smear tests on package surface compared to period before transport ban of May 1998

Figure 3

ADDITIONAL TECHNICAL MEASURES FOR PREVENTION OF SURFACE CONTAMINATION - AT REPROCESSING PLANTS

- Selection and special treatment of flasks for German Pool and approval by Authority (closed transport cycle concept)
- Decontamination of empty flasks to less than 2 Bq/cm² (β, γ) resp. 0.2 Bq/cm² (α)
- Provision of key process parameters affecting flask surface contamination and witnessing of processes by Independent German Experts
- Priority of “dry” unloading and use of plastic contamination protection skirt for “wet” unloading at La Hague
- Extra purification of the inlet pond water and warm water wash of loaded flask before immersion for unloading of multi-element bottle at Sellafield
- Periodic check of working areas for flasks and of handling tools / equipment for non-contamination to prevent cross-contamination.

Figure 4

The additional administrative and the supplementary organisational measures introduced for the management of these transports are listed in Figure 7 and 8.

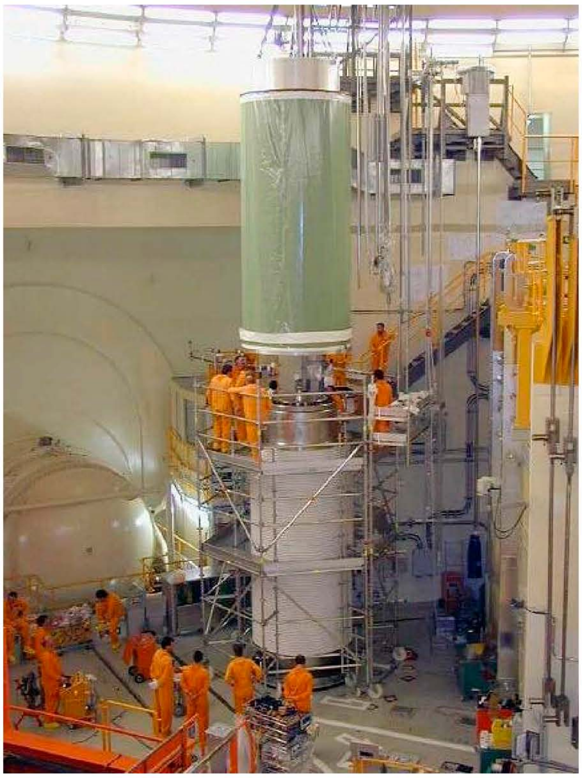

Figure 5 Plastic skirt prepared for fitting to transport flask

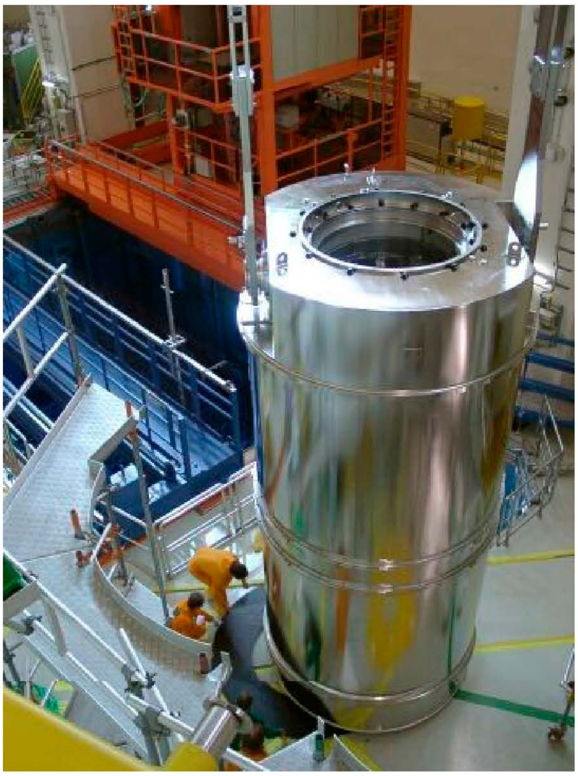

Figure 6 Transport flask fully encapsulated by three part metal skirt

ADDITIONAL ADMINISTRATIVE MEASURES FOR SPENT FUEL TRANSPORTS

- Creation of a Utilities' Working Group "Technology and Radiology" in charge of
  - ⇨ development of an improved contamination protection regime
  - ⇨ conclusion of it with reprocessors
  - ⇨ discussion with Authority and their Experts
- Preparation of Generic Documents dealing with contamination protection for handling and for non-contamination controls of spent fuel flasks applicable to all German Nuclear Power Plants
- Implementation of 3 Phase-concept for spent fuel transport composed of
  - Phase I (inactive test) — demonstration of efficiency of technical contamination protection measures at operational conditions
  - Phase II — transports with supplementary non-contamination monitoring for verification of "clean" transports
  - Phase III — routine transports (after performance of 3 to 5 flask transport cycles in Phase II conditions and approval by competent authority)
- Supplemental Agreement between nuclear power plants and reprocessors for binding implementation of additional measures

Figure 7

SUPPLEMENTARY ORGANISATIONAL MEASURES FOR SPENT FUEL TRANSPORTS

- Restructuring of responsibilities of companies engaged in transport activities
- Introduction of project management structure at power plants for flask loading operations
- Creation of specialized flask loading teams at power plants with stable staff composition
- Installation of Nuclear Transport Adviser (NTB) function in power plant management
- Enhanced communication for exchange of experience and selection of best practices
  - ⇨ amongst power plant operators
  - ⇨ between plant operators and reprocessors

Figure 8

2. EXPERIENCE GAINED WITH TECHNICAL MEASURES AGAINST POTENTIAL SOURCES OF CONTAMINATION

No.	SOURCE OF CONTAMINATION	COUNTER MEASURE	EXPERIENCE
1	Fuel pond water activity / CRUD particle sedimentation	Isolation of flask surface from pond water during immersion by plastic skirt or three part metal skirt Non-contamination controls on flask and skirt surfaces after use for re-check of proper skirt function	Efficiency of contamination protection verified by inactive tests and demonstrated for 249 flask loadings at German power plants
2	Cross-contamination of packages and of transport vehicles due to flask handling operations	Strict separation of contaminated / non-contaminated tools and equipment Installation of contaminated / non-contaminated work areas with rigorous radiation controls Periodic non-contamination controls on flask handling and lifting equipment	No cross-contamination above regulatory standards Very few monitoring results above 0.4 Bq/cm² for 498 flask movements
3	"Weeping" phenomenon	Protection of flask surfaces against contact with pond water by ° plastic or metal skirts ° covering of unprotected surfaces with self-adhesive films	No weeping effect found Insignificance confirmed by repetition of non-contamination controls 1,3 and 5 days after loading (measurements implemented by Authority as precondition for clearance of transports)
4	Fixation of contamination on stainless steel or coated flask surfaces by adsorption of radionuclides contained in fuel pond water (Ag 110m, Cs 134, Cs 137, Co 60)	Thorough decontamination of flask surfaces Covering of trunnion surface with self-adhesive films	Some observations with contamination below 4 Bq/cm² Mobilization of isotopes by seaside climatic conditions found for storage period of about 6 months
5	Release of aqueous contamination from small gaps on package surfaces (due to atmospheric conditions, flask heating, transport loads)	Closure of gaps by silicone sealant or self-adhesive films with verification by visual controls or tightness tests	498 movements of flasks confirmed effectiveness of this measure

Table 1 Sources of contamination, technical counter measures and experience since April 2001 (Status: August 2004)

The investigation of the contamination issue by industry, authorities and independent experts led to a common understanding about the potential sources of non-fixed and fixed contamination on accessible surfaces of packages and of transport vehicles. Counter measures were developed for each source of contamination and their efficiency verified at each plant and for each type of package in inactive tests (Phase I) defined as precondition for clearance of flask loading and transport (Phase II) by the competent authority.

The experience gained since April 2001 until end of August 2004 with the particular measures implemented for "clean" transports is summarised in Table 1. All technical measures implemented for protection of accessible surfaces on loaded packages demonstrated their effectiveness on all German power plants and all types of flasks, whether of COGEMA LOGISTICS or of BNFL origin.

Key for this success is the isolation of the total outside flask surface from pond water by the skirts, the reassurance of the skirt function by non-contamination controls on flask and on skirt surfaces especially on interface areas, the strict separation of non-contaminated and of contaminated tools, handling equipment and work areas with rigorous radiation monitoring as well as the closure of small gaps on the flask surface by silicone sealants or self adhesive films. A very helpful tool for verification of the effectiveness of these contamination protection measures was the large area smear test, called screening test, providing a qualitative information of the contamination status of nearly 100 % of the accessible flask surface.

The "Weeping" phenomenon, of very much concern as source of contamination at the onset of the contamination crisis, turned out to be insignificant for the periods representative for empty or full flasks transports in Europe (2 to 10 days on average for regular traffic conditions). This fact is confirmed by the repetition of non-contamination controls 1, 3 and 5 days after transfer of the loaded package onto the transport vehicle requested by the competent authority as precondition for clearance of transports in Phase II. This experience is further supported by the non-contamination controls performed at the consignees shops during incoming inspections on packages for European transport conditions.

Mobilisation of fixed isotopes on stainless steel surfaces was observed once on an empty flask, when after inactive tests (Phase I) a flask was put on stock for about 6 months in seaside air atmosphere before the flask loading commenced. Smear tests on this flask revealed contamination values in the range of 0.6 to 2.2 Bq/cm². This flask was in service since more than 15 years and formation of fixed contamination by radionuclides of the fuel pond water in earlier days was obvious.

3. ACHIEVEMENTS WITH SPENT FUEL TRANSPORTS SINCE RESUMPTION

Since April 2001 up to end of August, 2004 in total 249 packages loaded with spent fuel from nuclear power plants left Germany with 39 special cargo trains. 173 packages arrived safely at COGEMA, La Hague and the other 76 packages at BNFL, Sellafield. All transports were in full compliance with regulatory requirements for class 7 shipments. The performance of these transports demonstrated the effectiveness of all measures implemented at the plants of the transport cycle and at intermodal transfer stations. The goal of "clean" transports set-out for the resumption of spent fuel transports has been met with impressive results as illustrated in Table 2.

NUMBER OF TRANSPORT CYCLES FOR SPENT FUEL SHIPMENTS AND RESULTS OF NON-CONTAMINATION CONTROLS

PERIOD: April 10, 2001 to August 31, 2004 GOAL: Non-fixed surface contamination of packages and vehicles 10 % of regulatory standards

Destination	Transport mode of packages in Germany	Number of smear tests per transport cycle (package and vehicles)	Number of transport cycles	Total number of smear tests	Results of non-contamination measurements Number of smear tests		
					> 4 Bq/cm²	< 4 Bq/cm²	≤ 0,4 Bq/cm²
COGEMA La Hague	Rail Road/Rail	1 558 1 947	148 25	230 584 48 675	0	9	279 240 (99.997 %)
BNFL Sellafield	Rail Road/Rail	1 393 1 981	41 35	56 908 69 335	0	210 [1)]	126 033 (99.833 %)
			249	**405 502**	**0**	**219**	**405 273**

[1)] Different instrument calibration at power plants and at Sellafield is the main reason for this observation.

Table 2

Only very few regulatory smear tests were above 0.4 Bq/cm² (β/γ) corresponding to 10 % of the international standard for non-fixed surface contamination. 99.95 % of 405 500 smear tests were below or equal to 0.4 Bq/cm². This excellent performance, never expected in the aftermath of the May 1998 contamination crisis, results from the improvements implemented into the transport system and because of the engagement and the professionalism of the workforce acting in the plants of the transport cycle. An important contribution to this success must be allocated to the encapsulation of the flask for isolation from pond water and to the closed transport cycle concept with allocation of selected and specially cleaned flasks to a pool for exclusive use at German power plants. Membership to this pool was subject of approval by competent authority.

The performance of large area (A) smear tests (1000 cm² < A < 1 m²) for a pre-check of non-contamination provided a reliable information of the radiological cleanliness of the packages prior to the regulatory smear tests. For this test the intervention limit for initiation of decontamination procedures was set to 40 Bq. Filtration of the demineralized water drained from the interspace between protection skirt and flask for detection of presence of CRUD particles either caused by improper cleaning of the cooling spike area (TN flasks) or by malfunction of the contamination protection skirt did not reveal any result above the detection level set to 1000 Bq.

The transition with the transports to Phase III, called routine transports and highlighted by a reduced scope of non-contamination controls, based on Phase II experience, became a heavy process with many interactions between the industry and the German Authorities. With approval by competent authority COGEMA at end of 2003 went with its facilities at Valognes and La Hague to Phase III transport conditions. End of June 2004 also one German power plant moved to Phase III.

This impressive performance of transports for export of spent fuel from Germany has also its price, not to speak about monetary consequences. This price is characterised by the following facts:

1. The workforce engaged at power plants during flask loading campaigns increased in number by about 30 to 50 %.

2. The total man-hours of staff presence in radiation field of flask respective of power plant increased by a factor of 2 to 3.

3. The collective dose uptake ranges from 2.5 to 7 mSv per loading and is approximately 30 to 45 % higher than before the May 1998 transport ban.

Whether this price is justifiable can be disputed. Studies performed by reputable organisations like DSIN (now DGSNR) of France, NRPB of UK, PSI of Switzerland, GRS of Germany came even for the worst case contamination scenarios to the conclusion, that radiological consequences towards the public, the workers and the environment were negligible.

4. CONCLUSIONS

From the experience with the spent fuel transports to the reprocessing plants performed after lifting of the transport ban in the period from April 2001 to August 2004 it is concluded that

1. The additional technical measures implemented in all nuclear facilities of the transport cycle demonstrated impressively their effectiveness
   - ° no non-fixed contamination on flask and vehicle surfaces in excess of regulatory standards for 249 empty and 249 loaded flask transports
   - ° 405 500 smear test results recorded in the transport documentation files of which 99.95 % were less than or equal to 0.4 Bq/cm² (β/γ)

2. Imposed administrative and organisational measures supported improvement of operational performance, exchange of experience amongst operators of nuclear facilities in transport cycle and stipulated identification of best practices.

3. Recruitment of specialized, well trained teams together with strict attention to clearly defined and structured procedures formed the base for the performance of “clean” transports.

4. Dose uptake by the flask loading teams at German power plants is increased by approximately 30 to 45 % compared to period before the transport ban and is in the range of 2.5 to 7.0 mSv ($n+\gamma$) per flask loading and dispatch.

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