ANALYSIS OF THE DOSES ASSOCIATED WITH THE SPENT FUEL SHIPMENTS FROM THE FRENCH NPPs: ARE THEY ALARA?

Jean-Pierre Degrange*, C. Benhamou*, L. d'Ascenzo*

A. Leroy**, E. Vrigneau**

*cepn, ** EDF

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INTRODUCTION

- **Spent fuel shipments from French NPPs to La Hague**
  - Require significant efforts to prevent/eliminate non-fixed contamination on flask surface during their preparation (loading, drying and cleaning),
  - Workers involved receive individual annual doses that may be significantly higher than average,
  - Reinforced procedure of contamination monitoring introduced since 1988.
- **French utility Electricité de France (EDF) initiated several studies with CEPN**
  - A statistical study (1999-2000)
    Analysed the dosimetric results of the survey of 100 shipments to La Hague
  - Two extensive measurement campaigns (1999-2000)
    Evaluated the duration and dose-rates associated with each elementary operation involved in the preparation and monitoring of a cask before shipment

OBJECTIVES OF THESE STUDIES

- **To gain a better knowledge on:**
  - the distribution of gamma and neutron collective doses received during the cask preparation and contamination monitoring operations,
  - the influence on these doses of the reactor model (900/1300MWe), fuel type (UO_2/MOX) and thermal residual power of the assemblies.
- **To determine the relative contributions to the collective dose of the main operations, irradiation sources and workplaces:**
  - with a specific focus on operations associated with the prevention, elimination and monitoring of the contamination
- **To identify a set of radiological protection options and past experience analysis**
  - in order to reduce ALARA the collective dose associated with the preparation and monitoring of spent fuel casks before shipment from NPPs

DOSIMETRIC STAKES OF THE SPENT FUEL SHIPMENTS (1)
Collective dose

- **Annual expected collective dose (200 shipments per year)**

		Collective dose (man.Sv/y)
Preparation	gamma	0.8
	neutron	0.2
	Total	**1.0**
Monitoring	gamma	0.1
	neutron	0.2
	Total	**0.3**
Total		**1.3**

- **Not negligible for it corresponds broadly to:**
  - the annual collective dose (operation and maintenance) of one average French reactor,
  - a little less than 2% of the collective dose (operation and maintenance) of all French reactors

DOSIMETRIC STAKES OF THE SPENT FUEL SHIPMENTS (2)
Individual dose

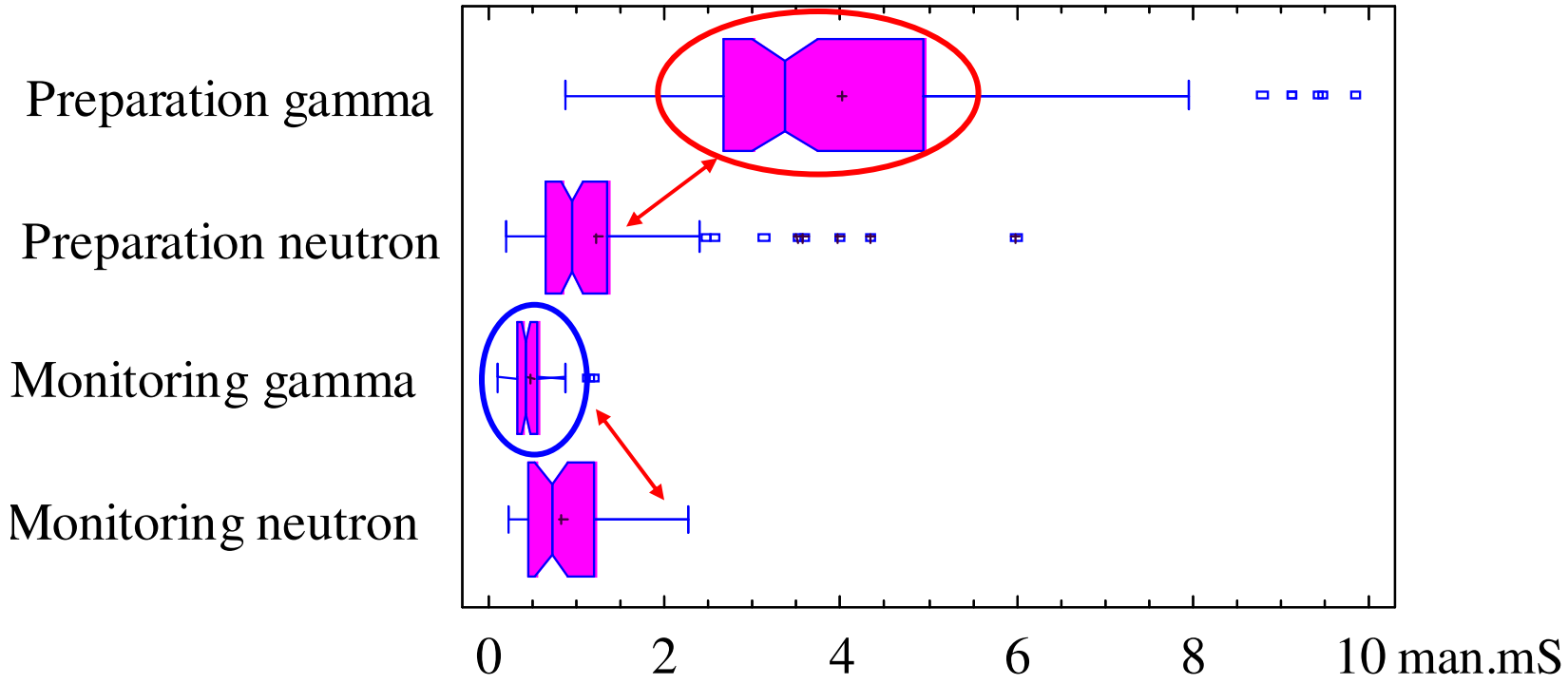
- **Contribution of the spent fuel shipments to the annual individual dose of Chinon B operators**

  - **Preparation**
    almost the half part (2.5 mSv/y out of 5.7 mSv/y, i.e. 44%) of the General Services operators* annual individual dose that are the highest exposed group

  - **Monitoring**
    only a small fraction (0.5 mSv/y out of 3 mSv/y, i.e. 16%) of the Radiation Protection Department operators** annual individual dose

* operators involved at least one in a year in the preparation of a spent fuel shipment
** operators involved at least one in a year in the monitoring of a spent fuel shipment

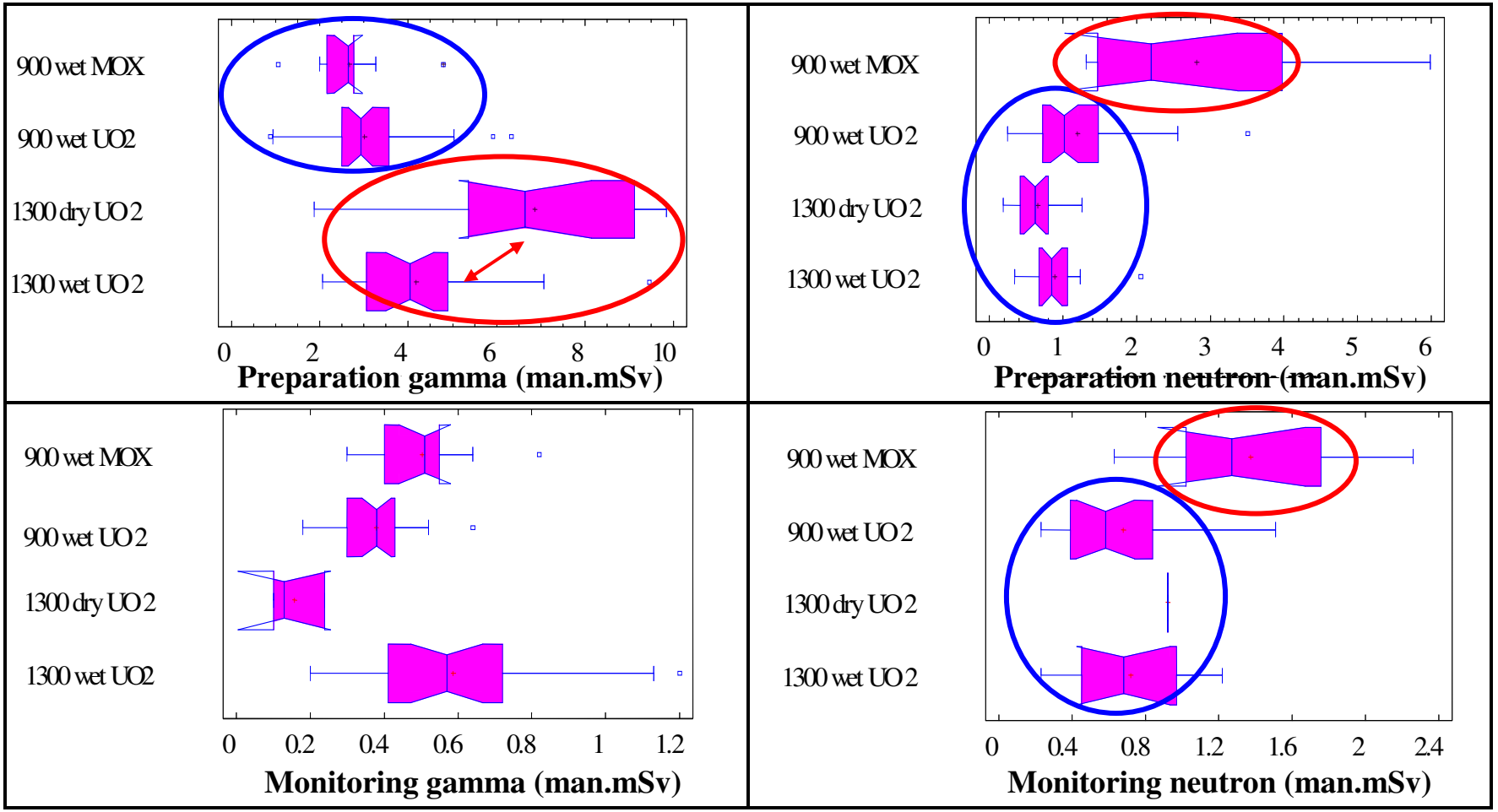
DISTRIBUTION OF THE COLLECTIVE DOSE PER SHIPMENT (1)



- **Important variability of the collective dosimetry associated with preparation and monitoring operations → to be explained**

DISTRIBUTION OF THE COLLECTIVE DOSE PER SHIPMENT (2)

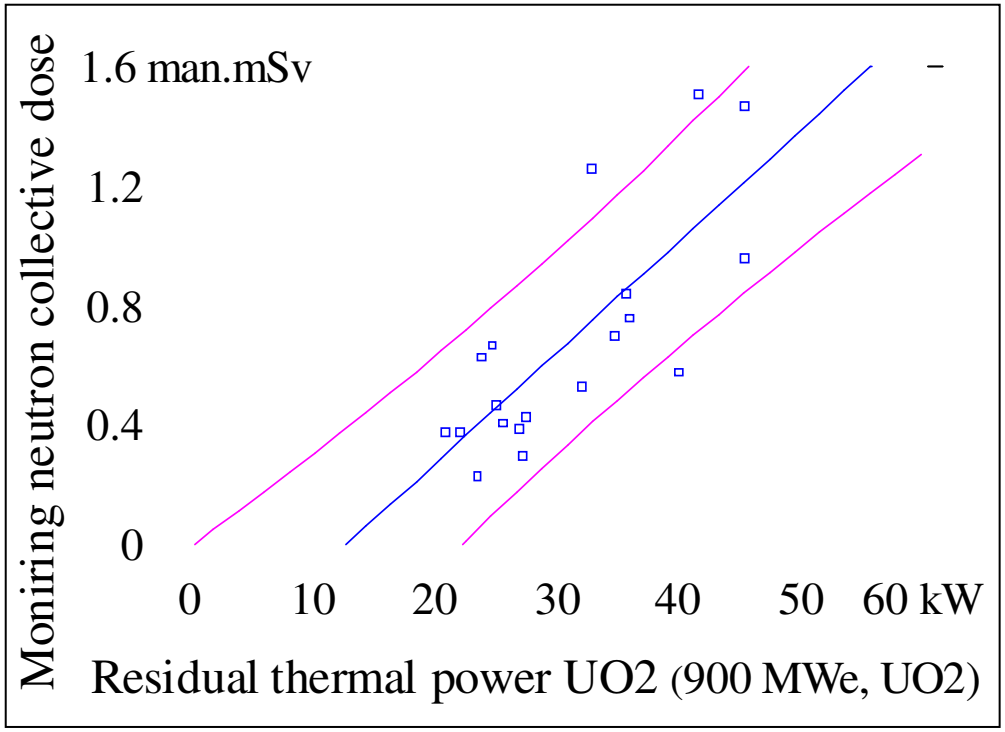
- **Significant influence of the shipment characteristics: reactor model (900/1300 MWe), loading type (dry/wet), fuel type (UO_2/MOX)**



"UO_2" shipment: 12 UO_2 assemblies ; "MOX" shipment: 4 MOX assemblies surrounded by 8 UO2 assemblies

DISTRIBUTION OF THE COLLECTIVE DOSE PER SHIPMENT (3)

- **Significant influence of residual thermal power on collective dose:**



- **Most often for neutron (6 out of 8) than for gamma radiation (2 out of 8)**
  → Influence of gamma radiation external to the cask

- **Limited influence ($R^2 < 0.53$)**
  → Influence of other sources of variability: site effect, mishaps occurrence…

FINAL RESULTS OF THE STATISTICAL STUDY (1)

- **Expected values of the collective dose by shipment type** (reactor model 900/1300 MWe, loading type (dry/wet), fuel type (UO_2/MOX), thermal residual power range)

=> Derivation of dosimetric objectives depending on the shipment characteristics

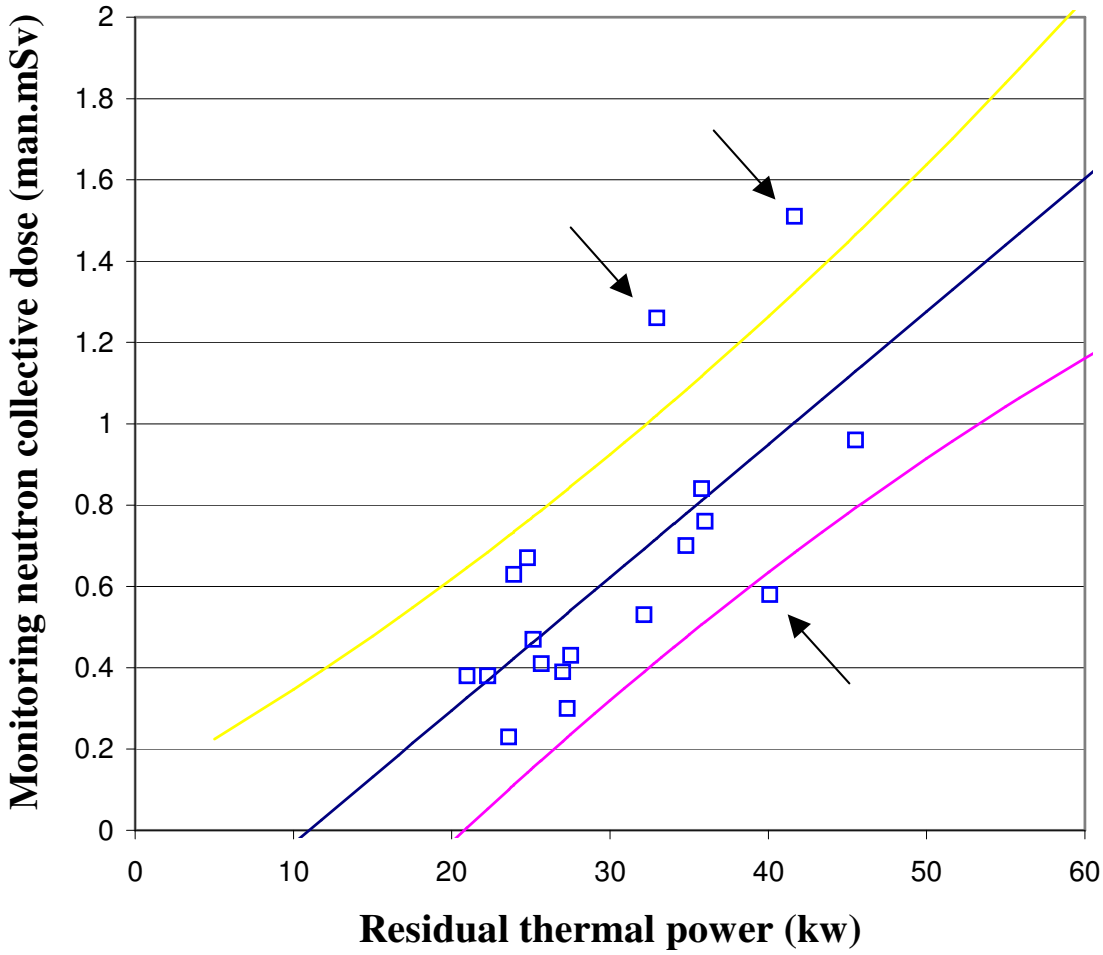
- **Limits of the 60% statistical "tolerance intervals" for the collective dose by shipment type** (expected to contain 60% of the collective dose values)

=> Identification and study of shipments that present dosimetric results significantly distant from other shipments of the same type and look for:

- **good practices** within the most efficient shipments from the dosimetric point of view
- **operation mishaps** within the least efficient shipments

FINAL RESULTS OF THE STATISTICAL STUDY (2)

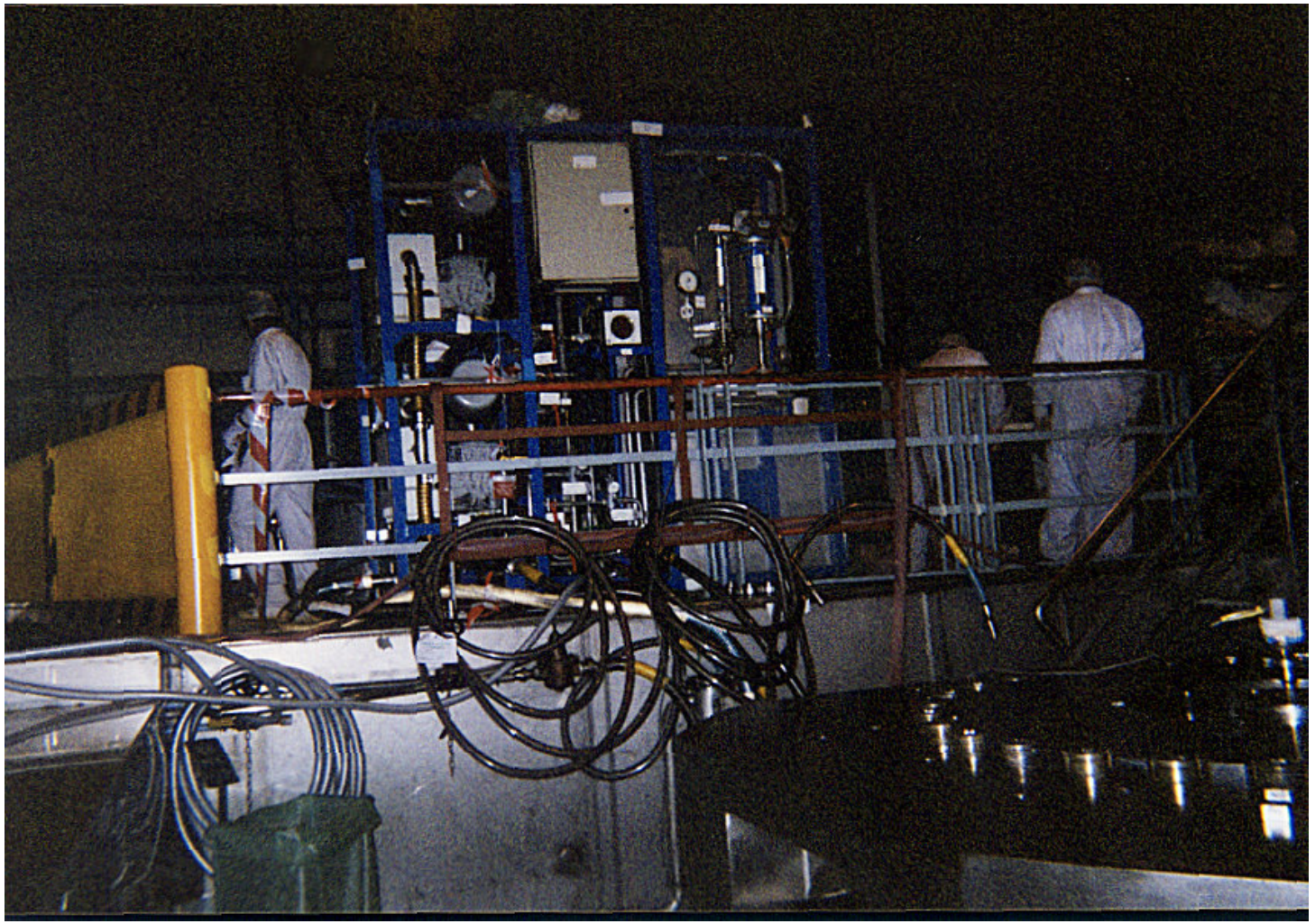
- **Limits of the 60% statistical "tolerance intervals" for the neutron collective dose per shipment (900 MWe reactor, UO_2 fuel, monitoring)**



SHIPMENT PREPARATION (900 MWe, General Services): Main steps

- **Tools transfer**
  Transfer/decontamination of control module, hoses, tools
- **Package reception**
  Monitoring against contamination, Package preparation
  Adhesives and cover fitting
- **Loading**
  Loading, monitoring
- **Preparation before shipment**
  Cover and adhesives unfitting
  Emptying, draining, drying
  Tightness monitoring
  Decontamination
- **Monitoring at railway terminal**

TOOLS TRANSFER



Control module, hoses, tools

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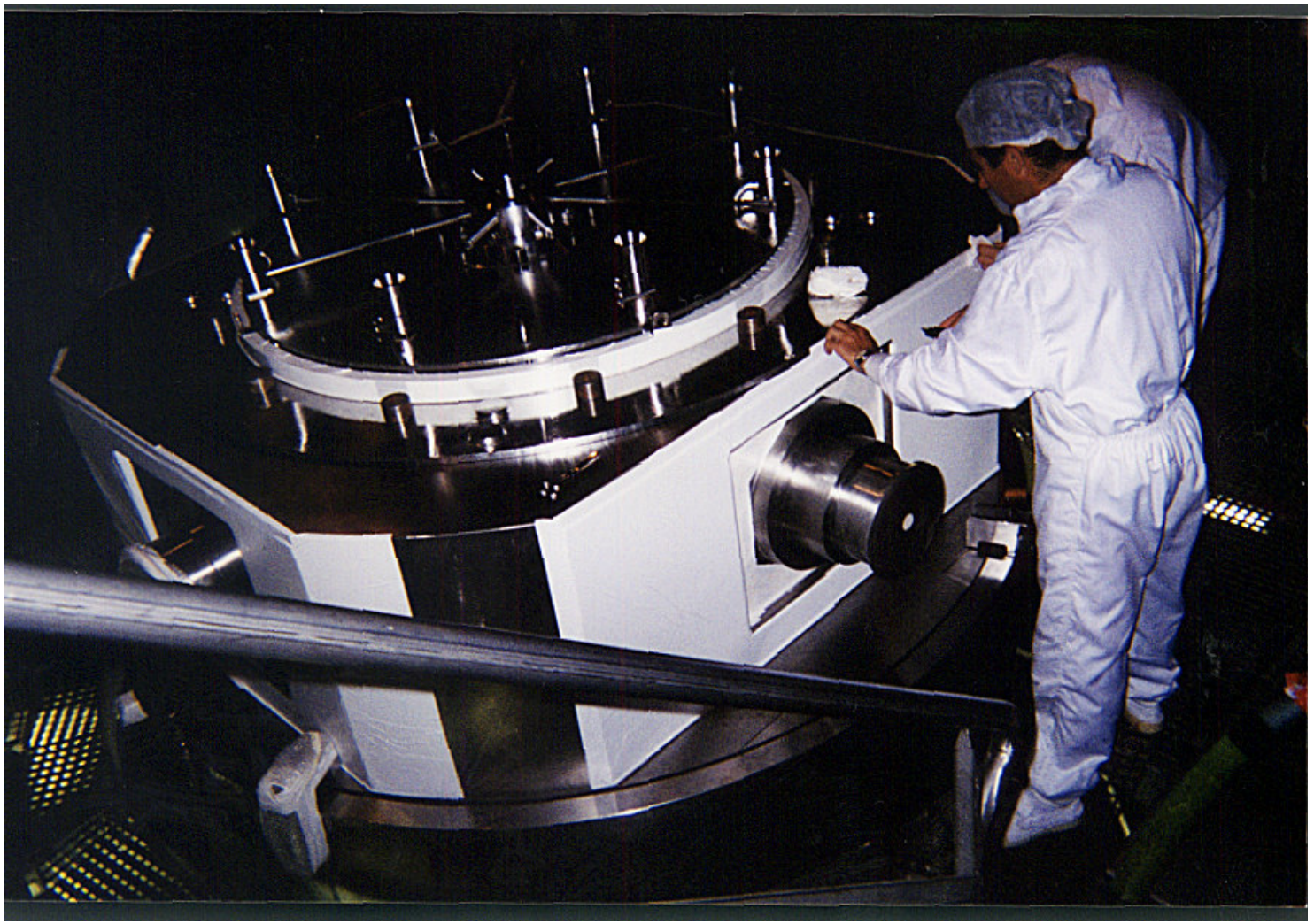
PACKAGE RECEPTION (1)



Adhesives fitting (before loading)

PACKAGE RECEPTION (2)

Cover fitting (before loading)

SHIPMENT PREPARATION (900 MWe, General Services): Main steps

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  Transfer/decontamination of control module, hoses, tools
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  Adhesives and cover fitting
- **Loading**
  Loading, monitoring
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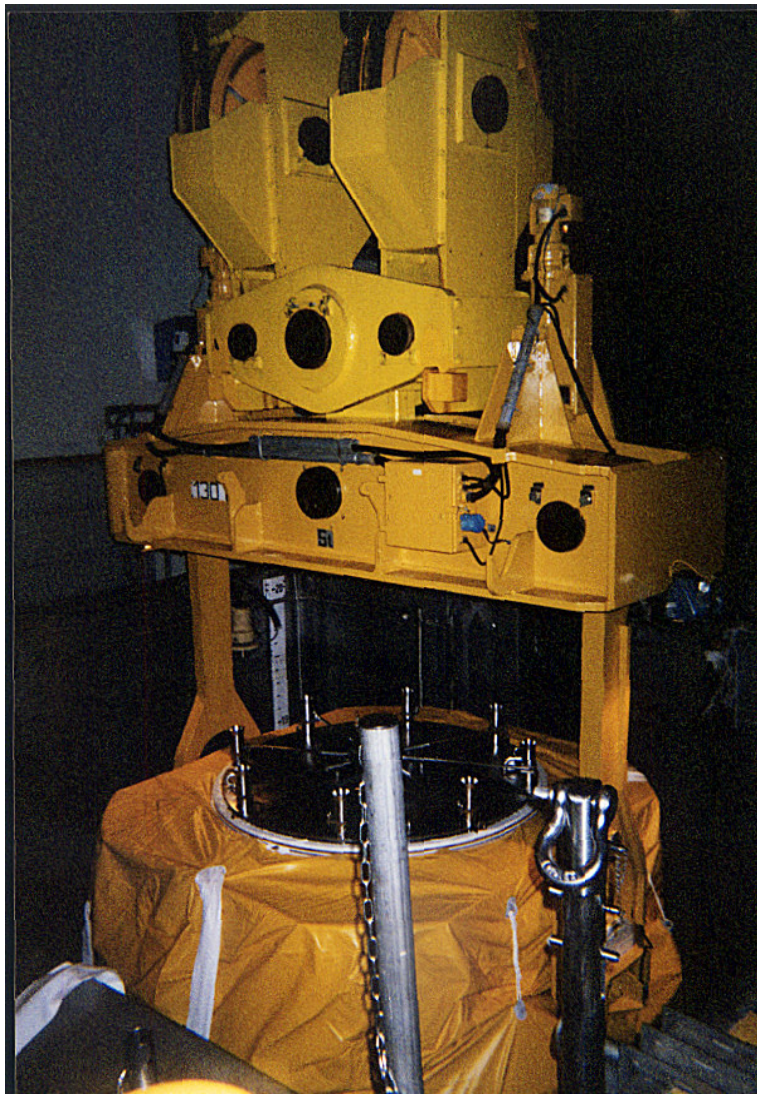
- **Monitoring at railway terminal**

PACKAGE LOADING



Handling

SHIPMENT PREPARATION (900 MWe, General Services): Main steps

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  Transfer/decontamination of control module, hoses, tools
- **Package reception**
  Monitoring against contamination, Package preparation
  Adhesives and cover fitting
- **Loading**
  Loading, monitoring
- **Preparation before shipment**
  Cover and adhesives unfitting
  Emptying, draining, drying
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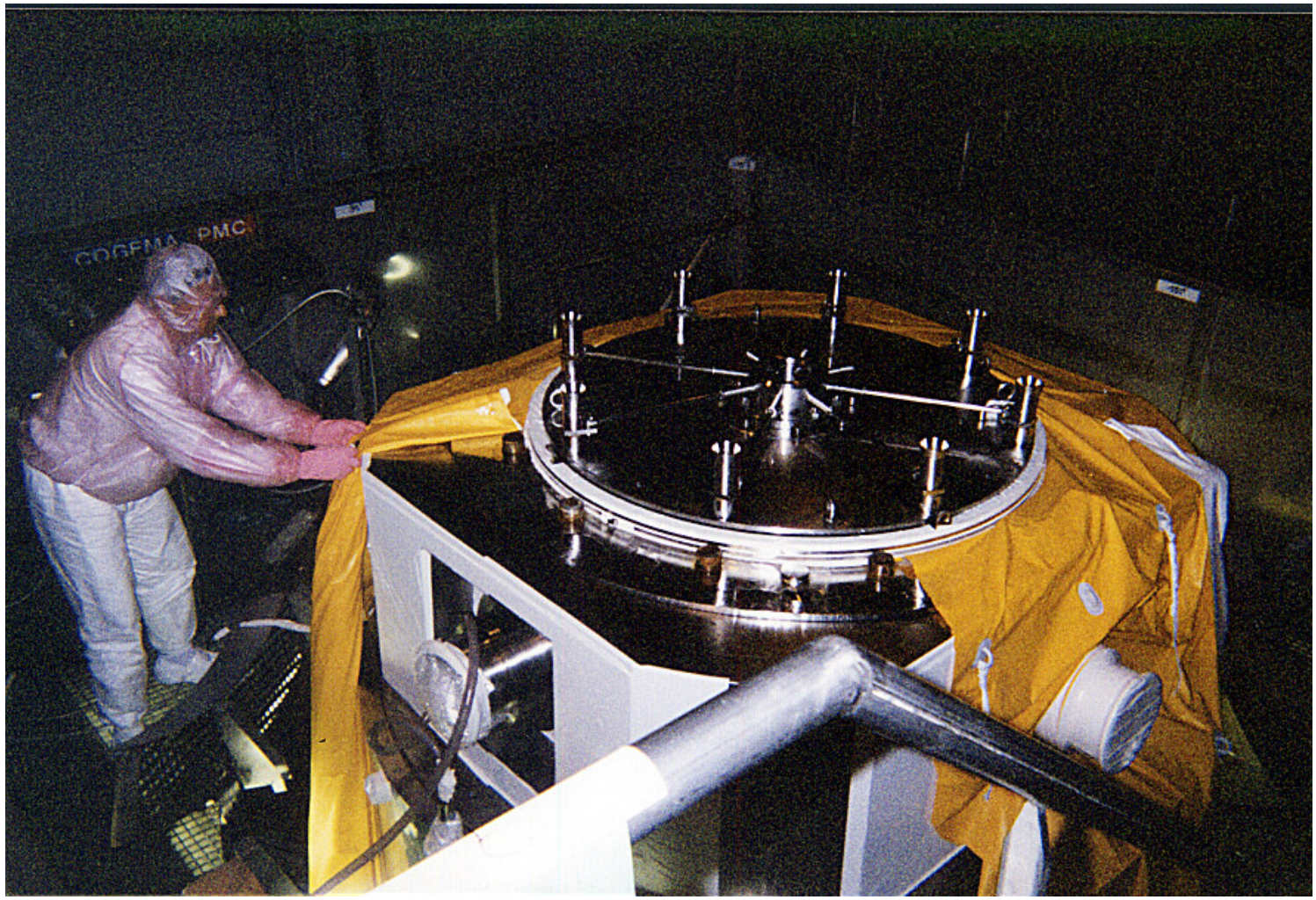
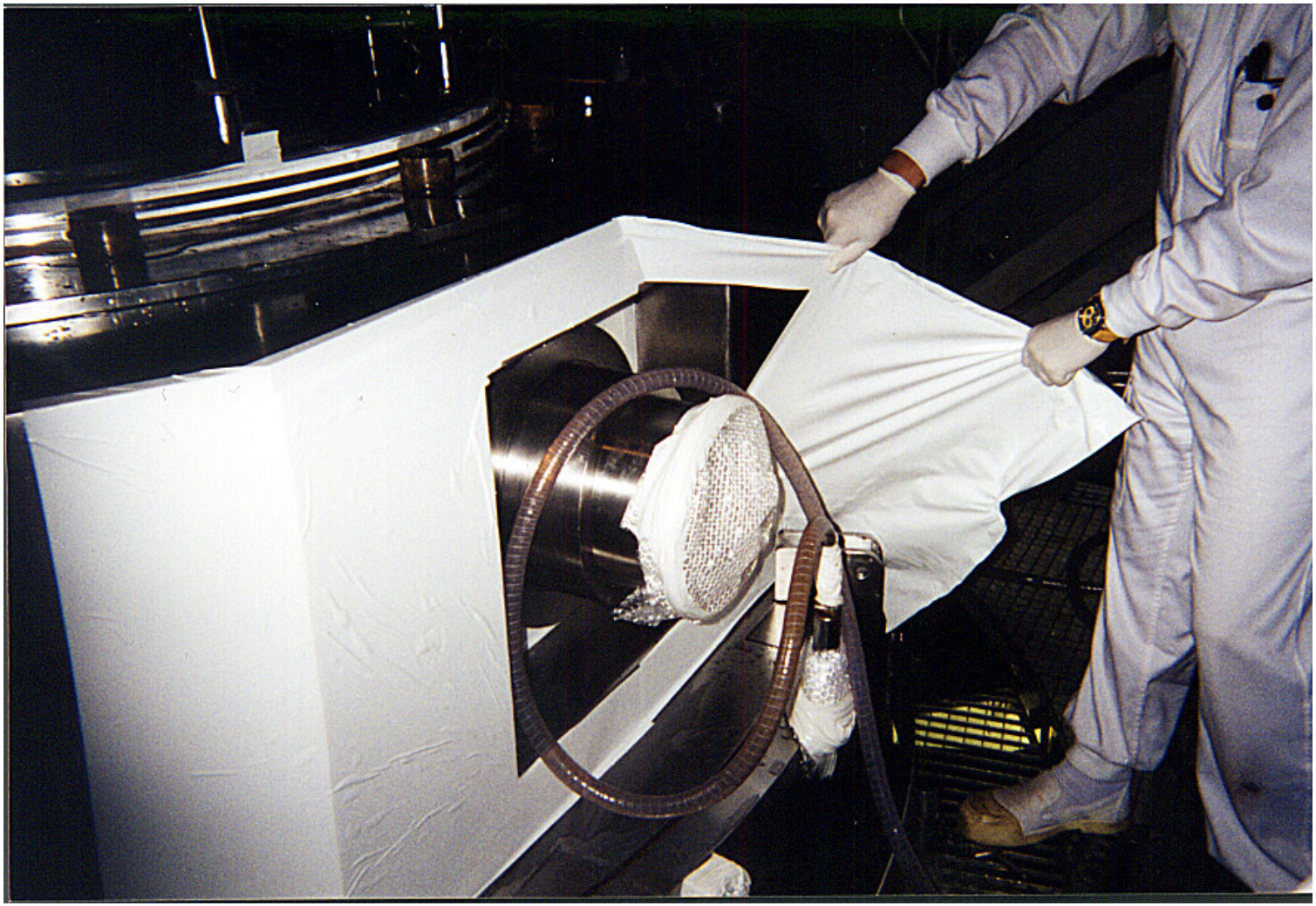
  Decontamination
- **Monitoring at railway terminal**

PREPARATION BEFORE SHIPMENT (1)



Cover unfitting (after loading)

PREPARATION BEFORE SHIPMENT (2)

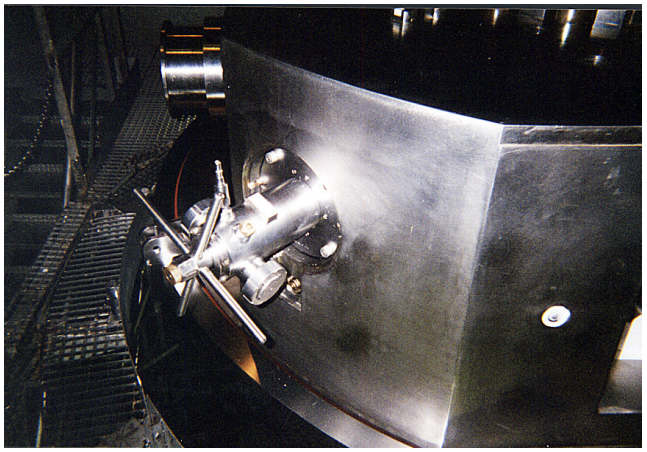


Adhesives unfitting (after loading)

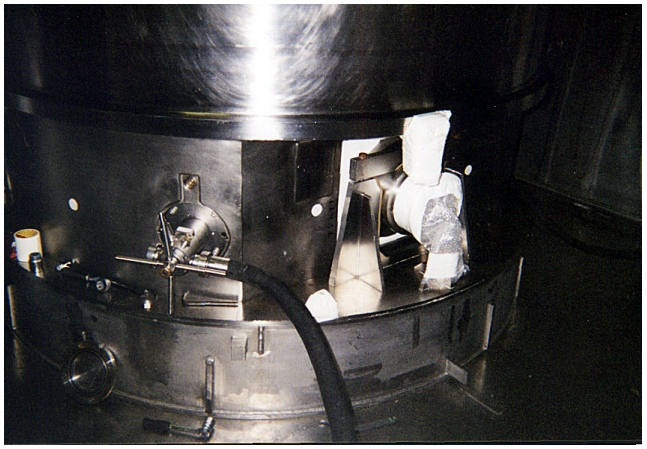
PREPARATION BEFORE SHIPMENT (3)

Adhesives fitting (before transport)

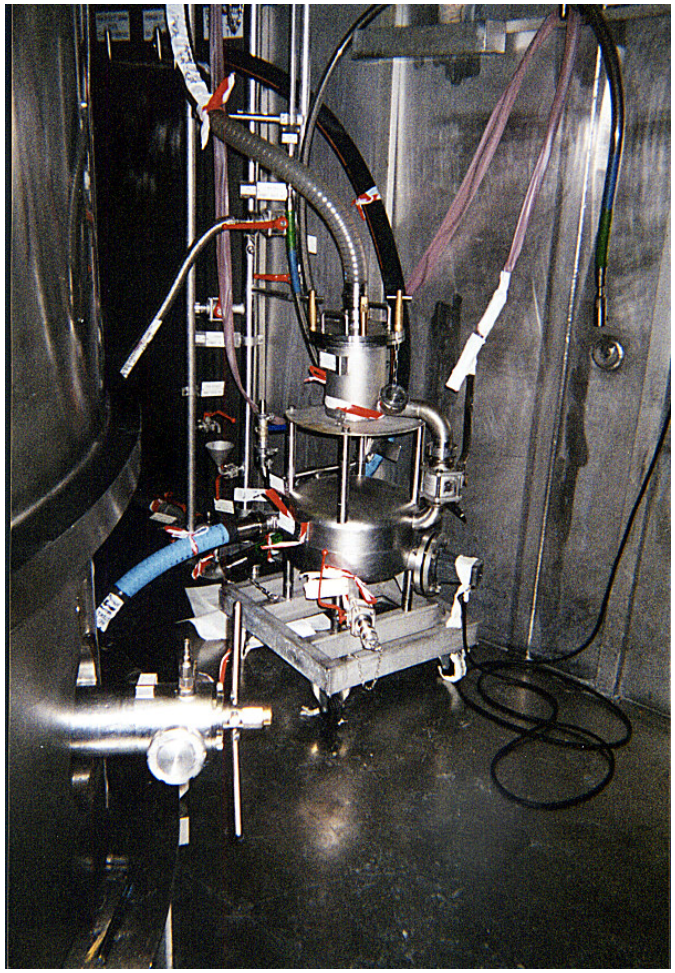
PREPARATION BEFORE SHIPMENT (4)



Tool A



Tool B



Tool B, liquid/vapour separator

Emptying, draining, drying

PREPARATION BEFORE SHIPMENT (5)

Tightness monitoring

SHIPMENT PREPARATION (900 MWe, General Services): Main steps

- **Tools transfer**
  Transfer/decontamination of control module, hoses, tools
- **Package reception**
  Monitoring against contamination, Package preparation
  Adhesives and cover fitting
- **Loading**
  Loading, monitoring
- **Preparation before shipment**
  Cover and adhesives unfitting
  Emptying, draining, drying
  Tightness monitoring
  Decontamination
- **Monitoring at railway terminal**

DECONTAMINATION

Front part

Rear part

Decontamination

SHIPMENT PREPARATION (900 MWe, General Services): Main steps

- **Tools transfer**
  Transfer/decontamination of control module, hoses, tools
- **Package reception**
  Monitoring against contamination, Package preparation
  Adhesives and cover fitting
- **Loading**
  Loading, monitoring
- **Preparation before shipment**
  Cover and adhesives unfitting
  Emptying, draining, drying
  Tightness monitoring
  Decontamination
- **Monitoring at railway terminal**

TOOLS TRANSFER

Handling

SHIPMENT PREPARATION (900 MWe, General Services): Contribution of steps to collective dose

Operation	Duration		Dose %	Average dose rate (µSv/h)		
	(h)	%	Gamma + Neutrons	Gamma	Neutron	Gamma + Neutrons
Tools transfer	*25.0*	*16%*	*2%*	*2*	*0*	*2*
Package reception	*30.9*	*20%*	*6%*	*7*	*0*	*7*
Loading	*26.9*	*17%*	*7%*	*8*	*0*	*8*
Preparation before shipment - Cover and adhesives unfitting - Emptying, draining, drying, - Leak tightness monitoring	68.6	**44%**	**74%**	*19*	*15*	**34**
Decontamination	4.5	3%	**11%**	34	44	**78**
Monitoring at railway terminal	*0.2*	*0.1%*	*0.0%*	*0*	*0*	*0*
Others	*0.4*	*0.2%*	*0.1%*	*3*	*2*	*5*
Total	**156.4**	**100%**	**100%**	**12**	**8**	**20**

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SHIPMENT PREPARATION (900 MWe, UO_2, General Services)
Contribution to collective dose of main operations

Operation	Duration		Dose	Average dose rate (µSv/h)			Main sub-operations / sources
	(h)	%	%				
			Gamma + neutrons	Gamma	Neutron	Gamma + neutrons	
Prevention & elimination of contamination							
Decontamination	4.5	3%	**11%**	**34**	**44**	**78**	After cavity emptying (90%)
Adhesives fitting/unfitting	2.3	1%	**10%**	55	**80**	**135**	Transport adhesives fitting (90%)
Cover fitting, rinsing, unfitting	9.2	6%	**8%**	16	10	26	Cover unfitting (80%)
Total	**16.0**	**10%**	**29%**	**27**	**29**	**56**	
Package preparation							
Leak tightness monitoring	10.0	6%	**14%**	27	18	45	Draining tool (33%)
Skirt emptying/removal	1.7	1%	**8%**	**79**	**62**	**141**	Separator (43%)
Cavity draining/drying	1.9	1%	**6%**	**70**	26	**96**	Separator/draining tool (73%)
Waiting/forms filling	31.2	**20%**	**6%**	3	3	6	Desk (82%)
Total	**44.8**	**29%**	**34%**	**14**	**10**	**24**	
Total	**60.8**	**39%**	**63%**	**17**	**15**	**32**	

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SHIPMENT PREPARATION (900 MWe, UO_2, General Services)
Proposed protection actions

Protection action	Dosimetric saving collective dose %
Liquid/vapour separator shielding	**< 11%**
Elimination of special adhesives (before/after transport)	**10%**
Decontamination operations with full cavity	**< 7%**
Desk protected from radiation	**5%**
Remote display devices in protected desk	**2%**
Well suited special adhesives (before transport)	5%*
Removal of the liquid/vapour separator from the draining orifice	**4%**
Forms filling outside the fuel building	3%*
Early exit of operators at the end of operation	2.5%*
Remote monitoring/emptying of the liquid/vapour separator	1%*
Systematic decontamination of the immersion tool	< 0.5%
Total	**< 39.5%**

* Actions not considered in the sum

MONITORING AGAINST CONTAMINATION
(900 MWe, UO2#, Radiation Protection Department)
Contribution of monitoring steps to collective dose

- **Total of 221 screening tests + 221 300 cm^2 smear tests**
- **Plus double monitoring by an independent organisation**

Monitoring step	Duration		Dose %	Average dose rate (µSv/h)		
	(h)	%	Gamma + Neutrons	Gamma	Neutron	Gamma + Neutrons
Fuel building	12	**58%**	**53%**	17	34	50
Lorry*	5	25%	25%	13	45	58
Railway wagon	4	17%	22%	20	42	62
Total	**21**	**100%**	**100%**	**17**	**38**	**55**

* NPP not directly connected to the railway network

10 UO2 / 2 MOX

MONITORING AGAINST CONTAMINATION
(900 MWe, UO2#, Radiation Protection Department)
Contribution to collective dose of operations

Operation	Duration		Dose %	Average dose rate (µSv/h)		
	(h)	%	Gamma + Neutrons	Gamma	Neutron	Gamma + Neutrons
Monitoring against contamination						
- Rear part	1.89	9%	**30%**	39	**140**	**179**
- Front part	2.55	12%	**29%**	24	**105**	**129**
- Waiting/circulation	13.12	**63%**	**21%**	9	9	18
- Fins zone	0.70	3%	**7%**	51	63	**114**
- Lorry and wagon	*0.95*	*5%*	*4%*	*21*	*24*	*45*
- Smear test handling	*0.61*	*3%*	*0%*		*3*	*3*
Total	**19.9**	**96%**	**90%**	**16**	**36**	**52**
Other operations						
Regulatory dose rate measurements	0.55	3%	**7%**	40	**96**	**136**
Seals affixing	*0.33*	*2%*	*3%*	*18*	*84*	*106*
Total	**0.88**	**4%**	**10%**	**32**	**92**	**125**
Total	**20.7**	**100%**	**100%**	**17**	**38**	**55**

10 UO2 / 2 MOX

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MONITORING AGAINST CONTAMINATION
(900 MWe, UO2#, Radiation Protection Department)
Relation monitoring-dose / detected-contamination by monitoring zone

Monitoring zone		Gamma + Neutron Dose % A	Relative probability of residual contamination (Valognes, 1997) B	Monitoring interest index B /A
Trunnions + trunnion bases	Front	7%	27%	3.9
Vertical and oblique parts	Front	11%	26%	2.4
Trunnions + trunnion bases	Rear	4%	8%	2.0
Skirt side and seal face	Front	15%	19%	1.3
Total		**36%**	**80%**	**2.2**
Vertical and oblique parts	Rear	23%	16%	0.7
Skirt side and seal face	Rear	11%	4%	0.4
Shock absorber	Front	2%	0,5%	0.3
Total		**36%**	**20%**	**0.6**
Horizontal part	Rear	4%	-	-
Shock absorber	Rear	5%	0%	-
Horizontal part	Front	8%	-	-
Fins zone		11%	-	-
Total		**28%**	**0%**	**0**

10 UO2 / 2 MOX

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MONITORING AGAINST CONTAMINATION
(900 MWe, UO2#, Radiation Protection Department)
Proposed protection actions

Protection action	Dosimetric saving Collective dose %
Reduction of waiting time/removal from cask	**10.5%**
Discontinuation of double monitoring for zones with no detected contamination in 1997	
- Fins zone	5.5%
- Horizontal parts	4%
- Shock absorbers	1%
Total	**10.5%**
Total	**21%**

10 UO2 / 2 MOX

CONCLUSIONS (1)

- **Significant collective and individual doses associated with preparation and monitoring of spent fuel shipments from French NPPs to La Hague:**
  - **1.3 men.Sv/y** (annual operation & maintenance collective dose of one reactor)
  - Preparation of the casks represents **almost the half part of the annual individual dose (6 mSv/y) of General services workers**
- **Important influence on the collective dose of the shipment characteristics**
  - Reactor model (900/1300 MWe), loading type (dry/wet), fuel type (UO2/MOX), residual thermal power
- **Significant contribution to the collective dose of operations associated with the prevention, elimination and monitoring of contamination**
  - **29% of preparation dose, 90% of monitoring dose, i.e. 42% of total dose**

CONCLUSIONS (2)

- **Significant but limited potential dosimetric savings of identified protection actions:**

- **40%** of **preparation** dose, **21%** of **monitoring** dose
  (**31%** of total dose) + (**4%** of total dose) = **35% of total dose**

- **Other protection actions could be envisaged:**
  - Choice of best protection method to protect cask surface against pond water,
  - Minimisation of operation mishaps and contamination events during preparation,
  - Optimisation of monitoring procedure in terms of number & location of smear tests (minimum collective dose for the same level of residual contamination risk)

- **The implementation of such actions would require the organisation of a suitable past experience collection and analysis**

CONCLUSIONS (3)

- **The above-described studies have demonstrated the feasibility and the interest of:**
  - **Extensive analytical studies of dosimetry**
    (on a task per task basis)
    → **to identify he most potentially effective protection actions**
  - **Detailed statistical analysis of dosimetry**
    → **for the definition of dosimetric objectives**
    (on the basis of average expected values)

    → **for the optimisation of the past experience collection**
    (with the help of statistical "tolerance intervals")
    to identify good practices and operation mishaps
- **The results of these studies are expected to help keeping as low as reasonably achievable (ALARA) the doses associated with the spent fuel shipments from the French NPPs**