$157 * 10^6$ MWH (ELECTRIC) WITH 6217 FUEL ELEMENTS - INTACT, LEAKY, DAMAGED AND EXPERIMENTAL. AND NOW ? THE FUEL MANAGEMENT IN THE SWITCHED OFF NPP NORTH (GERMANY)

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ABSTRACT

Between start of operation in 1966 of the NPP Rheinsberg (KKR), the shut down of the last unit in NPP Greifswald (KGR) and today, several interesting events conserning the nuclear fuel took place.

After the reunification of Germany, all units changed into a post-operation phase. To reach a higher safety level and prepare dismantling, several important decisions were required.
The removal of the fuel cores became highest priority. A new storage strategy was needed. Dry transport/storage casks in connection with a long term interim storage seemed the best option.

To make decisions is one thing, execution another. So it was necessary to resolve several issues. The major ones will be explained below. Safe drying of defect spent fuel and a method to keep the fuel dry during long term storage was designed. The cost saving storage of very different parts of spent fuel in only one cask will also be reported.

INTRODUCTION

During the time of the reunification in Germany, out of order situated units remained switched of and in operation situated units were switched of. All units changed into a post-operation phase. Until this time, 157 E6 MWh el had been produced. Based on a treaty, 2448 spent fuel elements were returned to the former Soviet Union until the end of the eighties, 504 from the Rheinsberg site and 1944 from Greifswald (Fig. 1). At the time of reunification in 1990, 6217 fuel elements remained on the site.

Fig. 1: View KGR NPP

Six units with altogether 2270 MW_{el} installed power were in operation. One of them was in test operation (unit 5 at the Greifswald site). 3 other units were short before completion or still in construction and thus, without nuclear fuel.

Table I: Operation time

unit	First criticality	permanent operation	shutdown	produced output [10^3 MWh]
KKR	11.03.66	30.05.66	01.06.90	9.036
1	03.12.73	12.07.74	18.12.90	41.321
2	02.12.74	16.04.75	15.02.90	40.040
3	06.10.77	06.05.78	28.02.90	36.028
4	22.07.79	30.10.79	01.06.90	32077
5	26.03.89	24.04.89 *)	29.11.90	240
6	no	--	--	
7	not ready	--	--	
8	not ready	--	--	

*) electric switch on

All units were equipped with pressurized water reactors /1/. The temperature of water at reactor exit was not more than 295 °C. The thermal nominal power was 1375 MW (unit 1 to 5 and planned for unit 6 to 8), and the Rheinsberg reactor had 265 MW.

The enrichment of fuel reached 3,6 % U-235 or less, the average burn-up 16,4 (Rheinsberg) up to 33 MWd/kg (Greifswald) and max. 42 MWd/kg.

Due to manufacturing and operation history (Tab. II) in connection with some incidents fuel elements had leaks and damages.

Incidents in 1974 to 1975 at unit 1 and 2 in Greifswald were of special concern. Activity in primary cooling loops had a major increase /2/. Following investigations showed the reason to be fretting corrosion.

Table II: Disturbance response

unit	**shut down (reactor)**	**shut down (power 50 - 100 %)**
KKR	82	
1	41	9
2	54	9
3	41	9
4	30	3
5	1	1

- figures without planned processes

After shutdown a new storage strategy was created. The main way is storage of fuel in special casks - the main issues to be resolved are the guaranteed fuel dryness and time consuming procedures. Storage of very different fuel in only one cask shows the know-how at this time. Conclusion is increasing safety.

CHOSEN WAY

After shut down (Tab. I), the removal of the fuel of reactors and spent fuel ponds became a priority task. At the end of the eighties the return of spent fuel to the Soviet Union through Poland was stopped. Spent fuel ponds became filled. A wet storage for 4680 fuel elements was constructed on site. The fuel number reached 6217 (Tab. III) at the time of shutdown. The licence of the wet storage is limited to 2005.

Thus, an expansion of the storage capacity for longer time was required. A safe on-site interim storage was chosen, until suitable technologies for treatment and economical disposal will be available. A wet storage seemed too susceptible for the chosen interim storage life of

40 years. A dry storage in special hermetic supervised casks (Tab. IV) within a new storage building /3/ was chosen.

Table III: Fuel inventory

	in 1990	**today**
number of spent fuel		
KGR [a]	5037	4298 *
KKR [b]	246	0 *
sales	--	(235)
in casks [c]	--	750
total	5283	5048
fresh fuel		
KGR	860	0
KKR	74	0
sales	--	(934)
total	934	0
* not in casks	6217	5048

Thus, larger interventions in old licensed units were avoidable with this strategy. The new status of engineering was applicable and a rapid dismantling of the old plants would be possible. The casks should be suitable for the intact and leaky, damaged and experimental spent fuel (Table V).
Spent fuel conditioning facilities should be helpful at KKR site, also available dry and wet (at KGR site) reloading stations.

SOLVE QUESTIONS

Humidity in the cask mainly can cause difficulties during storage over 40 years. To remain hermetically sealed no more than 4,8 g/m³ or all 21 g water is allowed per cask. One fuel rod can contain 13 g if leaky or damaged. Therefore a detection of the defect rate (Tab. V) was required /2/. 24 defect rods or 314 g water was theoretical the maximum in a CASTOR-cask, still 310 g to much.

With 2 kg adsorption agent (ZEOLITE [d]) about 400 g water can be collected in the cask. Thus, the humidity will not cause problems.
To be sure that the basic humidity is not too high, a time consuming measurement procedure is applied (Fig. 2). Dry seals at the primary lid of the cask required a special clearance procedure after an under water loading, protection against contamination too.

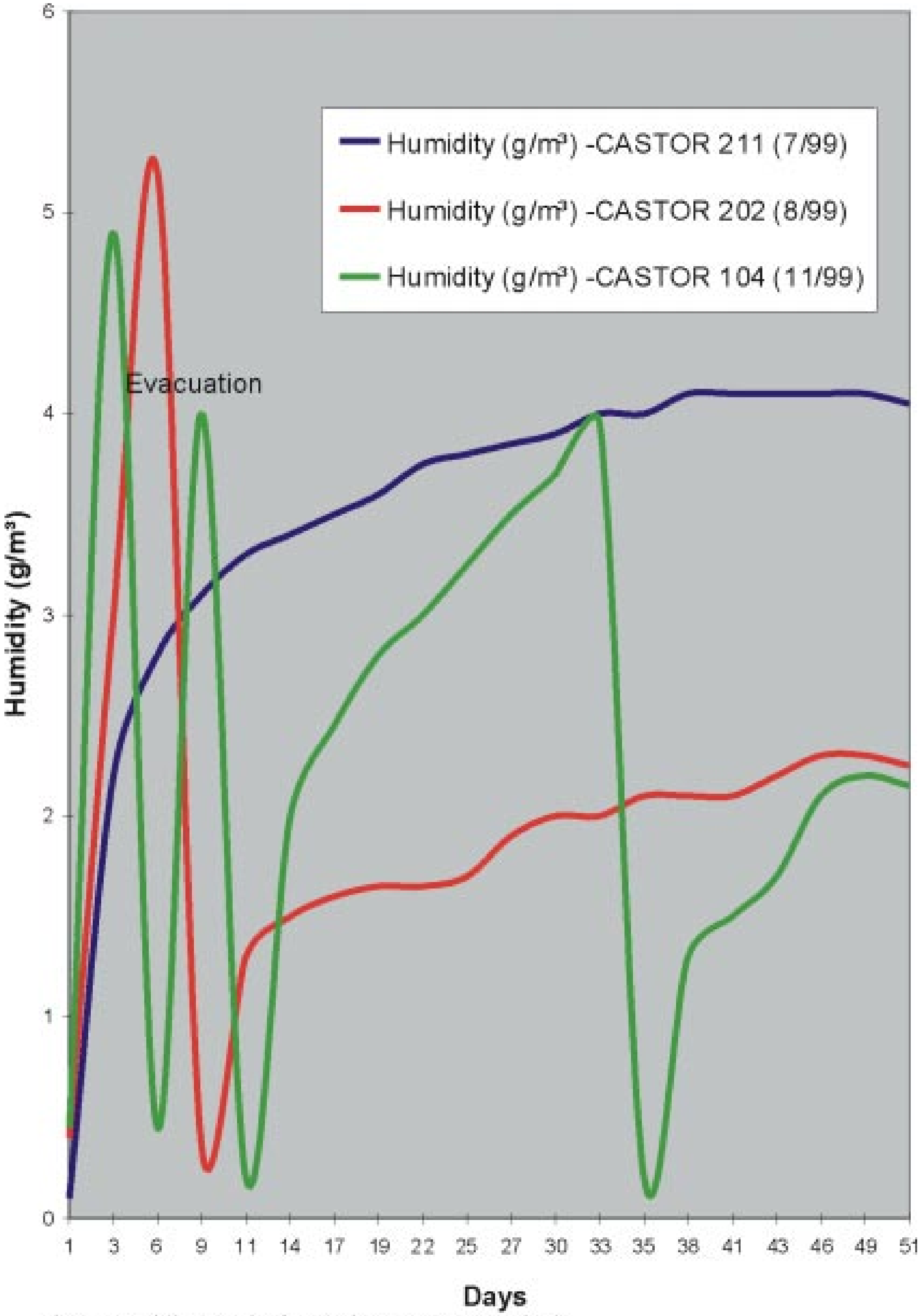

Fig 2: Humidity watch after drying (curves smoothed)

Table IV: Licensed parameters /4/

Interim storage:	
heavy metal:	< 585 Mg
total activity:	< 7.5 E+18 Bq
decay heat power:	< 600 kW
casks:	80 CASTOR-cask
Cask inventory (each):	
enrichment:	< 3.7 % U 235
decay heat power:	< 12.5 kW
total activity:	< 2.7 E+17 Bq
max. burn-up:	42 MWd/kg
decay time:	>= 78 months

Table V: Fuel condition

method	**checked elements**	**defect elements**
Sipping	276	4
integral (per 30)	720	0
single	1436	88
	2432	92

Without fuel elements in NPP KKR and 3 damaged (fretting corrosion)
Detection methods /2/:
Sipping: Indication I-131, Cs 137, ...
Integral: Rising water activity
Single: Cs 137 at the top of the selfheated fuel element

A SPECIAL PROBLEM

In KKR, 26 special fuel elements with destroyed geometry remained, elements with artificial defects in fuel rods and research fuel with divergent constructions. Another remaining group were some fresh fuel pellets and neutron sources and finally control rod drives and other activated components of the core. In total 52 very different parts of mainly spent fuel to be taken care of.

The chosen cask was a CASTOR cask type with adapted basket (Fig. 3). This basket contains 14 intermediate bottoms with support plates and holes to carry the inventory with and without tubes.

One storage position was reserved for 25 kg ZEOLITE to collect water during loading and storage. To load all parts into the cask, difficult operations in an already existing hot cell were performed (Table VI).

Table VI: Hot cell works

part	**conditioning**
defect fuel elements	putting into sleeves
storage tubes	putting into sleeve, drying new seals
neutron sources	putting into double sleeve
Different	assemble loadsuppporting devices at the top, shortening
control rod drive	separate of parts lower radiation

The conditioning of the parts was executed with qualified in plant staff. Complicated work steps were thoroughly trained in the front-end under control of the authorised experts (Fig. 4).

Monitoring of each step with a new TV system was not only helpful but also essential. The previous storage of the parts was a wet storage in the spend fuel pond, all following operation were performed dry.

Fig. 3: Special basket for special fuel

Transportation was made with a precision of ± 5 mm of the refuelling machine and ± 10 mm of the coordinate-controlled crane with special grab tools for different parts. The crane cabin is radiation protected and equipped with remote observation devices.

During load in (the cask was opened 45 once) a radiation protection lid was helpful (Table VII). A self designed suction cleaner for the cask flange

Table VII: Cask radiation

Dose rate: [mS/h]		
at the top *)	neutron	gamma
min	0.0274	0.0027
max	0.0438	0.0117
body half high)		
min	0.0278	0.0027
max	0.0438	0.0117

*) still equipped with screening lid

guaranteed save tightness of the primary lid after this. All steps were in accordance with regulatory procedures and based on different licenses (Table VIII).

Table VIII: Licensing needs

Authority	**license**
Local	handling fuel & cask
Country	cask transport interim storage for 40 years
storage land	interim storage for 40 years

Fig. 4: Calibration tube for Zeolite

CONCLUSIONS

The new Interim Storage North, chosen casks, knowledge of fuel condition, qualified dry - and clearance technology, use of ZEOLITE and trained personal are suitable to dismantle all NPP facilities and to increase the storage safety of fuel. At NPP KKR site, solely removal of 4 cask is needed. Thus main requirements for dismantling have been fulfilled.

The way is OK. That's one of present situation. Another conclusion is needing a realistic feeling for time consuming procedures, licences, paperwork and so on.

The selected procedure has worked out very well and long term safe storage can be guaranteed.

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FOOTNOTES/ABBREVIATIONS

[a] KGR: NPP at the Greifswald site
[b] KKR: NPP at the Rheinsberg site (1 unit)
[c] type CASTOR
[d] ZEOLITE: An Alumino-silicate