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REPORT FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT

on the conditions under which the decommissioning of the High-Flux Reactor (HFR) at Petten should be envisaged

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On 27 June 1996, the Council adopted the Supplementary Research Programme to be implemented by the Joint Research Centre for the European Atomic Energy Community (1996-99), in accordance with Article 7 of the Euratom Treaty.

During its adoption, the following statement was entered in the Council minutes:

> "The Council notes that the Commission will make provision for decommissioning, as it did in previous years, when fixing the tariffs for irradiation services. Such provision will be added to that already settled and be used at the appropriate time.
>
> In addition, the Commission will examine the question of the decommissioning of the HFR and make a report to the Council on this matter before the end of 1996."

The Commission hereby requests the Council and Parliament to take note of the enclosed report.

REPORT FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT

on the conditions under which the decommissioning of the High-Flux Reactor (HFR) at Petten should be envisaged

Intoductory remarks

Decommisioning is not an acute practical issue for the HFR. The reactor is in a very good technical condition. This has been achieved through constant upgradings and in-time renewal of its main components. The residual life time of the present reactor vessel - which was exchanged in 1984/85 and has a total design life time of 30 years - will allow HFR operation until 2015 and even longer, the all-three-years performed in-service inspections are aimed at confirming this. Moreover, another fully licenced reactor vessel - identical to the present HFR vessel - is in stock and could be employed in another vessel replacement operation.

Therefore around the year 2015, the Commission will have the choice between three options:
- to stop the operation of the HFR and propose its decommissioning;
- to evaluate the exact situation of the vessel and to decide on a prolongation of the life of the reactor with its present vessel;
- following the evaluation of the situation of the vessel, to decide to replace it.

Long term HFR operational schedules corresponding to the first and the third options are given in Tables 1 & 2

The choice between these options will necessitate an in-depth concertation with the Dutch licencing authorities, the Member States which will support the HFR at that time, and the customers. The decision will be taken in particular on the basis of an economic assessment of the viability of the reactor at that time.

Therefore, the question whether the HFR will be decommissioned should be relevant only after 2015 and might not arise before the middle of the next century. Nevertheless, independently of the time of the decision, the characteristics of the HFR allow for a description of the decommissioning process and an evaluation of its cost.

This document addresses this question and has been subject to expert review [i.e. DETEC, Germany] which confirmed the feasibility of this proposal and the estimates on waste volumes as originally assumed by. (DETEC is a recognised and experienced company in the field of decommissioning and a joint daughter company of SIEMENS and NUKEM).

The comments of the experts have been included in the Commission report. Nevertheless, it seemed worthwhile to attach to it the DETEC report.

I. Scope

This preliminary study defines the main stages of decommissioning the HFR at Petten site, based on International Atomic Energy Agency (IAEA) Safety Series no. 74 "Safety in Decommissioning of Research Reactors", Safety Guide, 1986. It also gives the contemplated steps for dismantling and decommissioning the HFR, and the rough estimate of associated waste quantities and cost.

II. Stages in decommissioning

The process of decommissioning is considered to begin with the final shutdown of the HFR reactor and to end with the release of the reactor site for unrestricted use.

Three stages are specified within this process :

Stage 1 - Storage with surveillance

During and subsequent to this stage, continuing surveillance of the reactor is necessary.
The main activities include :
- the removal of fuel.
- the removal of coolants and other readily removable activated or slightly radioactive material. It is easily possible with existent on-site facilities at reasonable low cost.

Stage 2 - Restricted site use

As a consequence of the decommissioning activities, on completion of this stage, parts of the site may be released for use with constraints and remaining parts of the reactor and site will be subject to a storage with surveillance.

The main activities include :
- decontamination of all areas which are readily decontaminated
- physically sealing of the remaining areas containing radioactivity.

This would comprise removal of the vessel and all activated or highly contaminated components around the vessel, in the pool (beam tubes), of the primary circuit, and removal of activated or contaminated parts of the pool liner and the concrete walls, as well as sealing all the parts which may still contain activity.

All necessary actions can be executed with in-house (including Energy Centrum Nederland - ECN) manpower and expertise. The waste would go to the Dutch disposal facility COVRA (Centrale Organisatie Voor Radioactief Afval), even if a small amount would have to be stored temporarely in the medium active waste facility of ECN prior to shipment to the COVRA facility.

Stage 3 - Unrestricted site use

At this stage, decommissioning of the reactor is completed. All radioactive materials, equipment and structures are either decontaminated or removed to the Dutch disposal facility COVRA. A final radiation survey is then conducted to ensure that no residual radioactivity remains on site. The site is then released for unrestricted use and no further surveillance inspections or tests are required. The buildings and site is released from the obligations of the nuclear laws.

After release from the nuclear laws, employment of the site and buildings for any other purpose may be considered and give rise to income, if not, the cost arisen from stage 3 will be linked to the normal management of ordinary buildings.

It is proposed to proceed with the execution of stage 3 directly after completion of the stage 2. Following expert advice, the advantages from a continuoued decommissioning operation until completion of stage 3 are substantial in comparision to a scenario where stage 3 is performed after a waiting period.

Decommissioning Costs :

- preparation and contacts to licensing authorities :	2 MECU
- Preparation and execution of the actual work (needs to retain the capacity under the present ECN operation contract for roughly 1.5 years) :	14 MECU
- Waste disposal to COVRA	9 MECU
- Total (rough estimate)	25 MECU

III. Sequencing of decommissioning activities

The HFR decommissioning activities are based on the experiences gained during the vessel replacement in 1984/85. At that time, the total operation was carried out with the normal operation and maintenance crew, with additional help of the HFR users and site workshop.

Based on the amounts of waste handled during vessel replacement in 1984, the general step-by-step approach is the following :

0. *Removal of fuel elements*
   The fuel elements are stored safely elsewhere or shipped to a reprocessing facility.

1. *Removal of all auxiliary equipment and mechanisms from inside and around the vessel*
   Same amount of waste is anticipated from very similar auxiliary equipment.

2. *Destructive removal of beam tubes and other "fixed" connections to the vessel (viz. restraint structures, etc.)*

Equal amounts will originate from the beam tubes and other "fixed" structures with some more middle active parts due to increased use of stainless steel bolts and rings. The amount of stainless steel material is very low due to the absence of bellows. However more material is now present with a thickness exceeding 3 cm requiring special handling as waste.

3. *Vessel removal*

Amounts of material from the vessel itself will be less, however of an increased thickness.

4. *Removal of active parts of beam tubes 11 and 12 and parts of the pool liner with radioactive spots*

The amount of waste from beam tubes 11 and 12 is reduced due to a simplified construction; pool liner material is set at 10 % of total.

5. *Activated concrete of the pool walls around the beam tube openings to be removed*

For the activated concrete around the beam tube openings the assumption is made that the "penetration depth" is average some 30 cm around the openings.

6. *Contaminated concrete under the pool bottom liner to be removed*

For the contaminated concrete under the pool bottom liner due to the existing leakage also a thickness of 30 cm is assumed. For the vertical walls only the concrete in the neighbourhood of the pool gates is suspected.

7. *Extensive decontamination of all system piping of the primary and pool cooling systems*

Decontamination of the primary and pool system piping will result in radioactive decontamination fluids only. The material itself is not activated. The same is valid for auxiliary systems like hot and warm drain systems.

8. *Removal of activated and or contaminated auxiliary equipment (resins of ion exchangers, tools, etc.) and standard experimental facilities*

The amounts of ion exchanger resins are well known, after thorough regeneration the resins can be handled as low active waste. Tools, storage racks, etc. will offer only minor amounts of slightly activated material after decontamination. For the removal of standard experimental facilities estimates are based on the 1991 situation.

9. *General radiological control of remaining system parts*

The final radiological control of the plant is expected to result in minor amounts of low level waste only.

10. *Standard demolition to the required levels for further plant use*

Non-activated material is concerned by this operation.

Table 3 gives the estimated amounts of waste subdivided per category. The high and medium active waste can be temporarily stored in the ECN Waste facility. In case of transport to and storage at COVRA Borsele, Table 3 can be translated into Table 4.

On the whole, it is anticipated to get high-medium-level waste of 5 m^3 and 370 TBq (1000 Ci), and low-level waste of 120 m^3 and 5,9 TBq (16 Ci).

Tab. 1 : Longterm HFR Operational Schedule (1rst OPTION)

Period : 1996 to 2030

Year : 19.. oe 20..	96 to 09	10	11	12	13	14	15	16	17	18 to 30
Lease contract CEC / NL	Remaining time of present CEC / NL lease agreement on the HFR and Petten Site									
Life time HFR vessel	Remaining anticipated life time of the HFR pressure vessel nb. 2									
HFR decommissioning										
Preparation		Preparation								
Stage 1 and 2										
Stage 3										Unrestricted site use

Period : 2031 to 2065

Year : 20..	31 to 61	62	63	64	65
Lease contract CEC / NL	Continuation of remaining time of present CEC / NL lease agreement on the HFR and Petten Site				
HFR decommissioning					
Stage 3	Unrestricted site use continued				

Tab. 2: Longterm HFR Operational Schedule (3rd OPTION)

Period : 1996 to 2030

Year : 19.. or 20..	96 to 09	10	11	12	13	14	15	16	17 to 30
Lease contract CEC / NL	Remaining time of present CEC / NL lease agreement on the HFR and Petten Site								
Life time HFR vessel	Remaining anticipated life time of the HFR pressure vessel nb. 2								Anticipated life time of the HFR pressure vessel nb. 3 [existent]
HFR vessel replacement									
Preparation		Preparation							
Replacement									

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Period : 2031 to 2065

Year : 20..	31 to 43	44	45	46	47	48	49	50	51 to 61	62	63	64	65
Lease contract CEC / NL	Continuation of remaining time of present CEC / NL lease agreement on the HFR and Petten Site												
Life time HFR vessel	Anticipated life time of the HFR pressure vessel nb. 3 continued												
HFR decommissioning													
Preparation			Preparation										
Stage 1 and 2													
Stage 3								Unrestricted site use					

Table 3 : Estimated amounts of waste subdivided per category and or destination

Waste category	High/medium-level waste			Low level waste		
	Standard waste boxes (25 l) containing			Drums of		
	Aluminium	Stainless Steel	kCi	200 l	600 l	Ci
Vessel and auxiliary equipment around the vessel	180	20	1,0	200	20	12
Activated concrete	-	-	-	220	-	2
Contaminated auxiliary equipment	-	-	-	130	-	2
TOTAL	180	20	1,0	550	20	16

Table 4 : *Estimated amounts of waste to be stored at COVRA*

	Number of concrete containers			
Container volume	200 l		600 l	
Dose equivalent/h	< .2 mSv/h	> .2 mSv/h <2.0 mSv/h	< .2 mSv/h	> .2 mSv/h <2.0 mSv/h
Vessel and auxiliary equipment around the vessel	200	-	100	100
Activated concrete	150	-	-	-
Contaminated auxiliary equipment	150	-	-	-
TOTAL	500	-	100	100

DETEC	Bericht	Empfänger siehe Verteiler

Titel: **Expert Review of the Draft JRC Petten Document on Decommissioning of HFR Petten**
(Summarizing Report)

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Abstract

The intention of the expert review is to check the feasibility of the technical concept and the plausibility of the estimated costs.

A comparison of HFR with 3 German research reactors actually in the state of decommissioning leads to the result that the calculated amounts of waste and costs seem to be in a reasonable order of magnitude if one takes into account:

- the comparatively low residual radioactivity of the HFR
- the comparatively low estimated waste arisings
- low estimated decommissioning and temporary supervision costs.

The results obtained by a plausibility check were subsequently confirmed by an independent detailed calculation. Total costs for decommissioning to free release (directly following stage 2) should therefore not exceed 25 MECU.

Weighing the pros and cons for decommissioning as planned, it becomes apparent that there are hardly any pros left for a long time phase of supervision following stage 2.

Radioactive decay, the argument often used in favour of deferring stage 3, is of no significant importance. A dormancy period of several decades will not improve the contamination situation substantially and will therefore not lighten the dismantling work decisively.

Conversely, the advantages of immediate decommissioning to unrestricted release of the controlled areas are obvious:

- Auxiliary systems that will be needed for decommissioning are either still in operating condition or can be kept operational. Deferred dismantling would require new installations with all implications (such as licensing).

- Costs for sampling and waste management (decontamination, waste conditioning) can be kept low as long as neighbouring JRC still has appropriate facilities at its disposal. This might not be the case several decades after decommissioning to stage 2.

- The availability of experienced HFR staff and of personnel with specific HFR knowledge at authorities and in industry. That knowledge is about to disappear gradually.

1 Scope

The Institute for Advanced Materials, HFR Unit, at Petten has prepared a preliminary study about the decommissioning of the High Flux Reactor (HFR) at Petten.

The study is based on IAEA Safety Series no. 74 „Safety in Decommissioning of Research Reactors", Safety Guide, 1986. It estimates expected costs for reactor dismantling including amounts of waste and costs of waste disposal.

It is the intention of the expert review to check the feasibility of the technical concept and the plausibility of the estimated costs.

2 Assumptions

The expert review is based upon the following assumptions:

- decommissioning of HFR will be performed in accordance with IAEA Safety Series no. 74.
- after decontamination and dismantling of contaminated and activated areas and components the buildings will be returned to the former owner for unrestricted site use.
- most dismantling work will be performed by the HFR operating staff.
- all costs are calculated on 1996 price level.

3 Review of technical concept

The IAEA Safety Series no. 74 recommends decommissioning by three stages:

stage 1 includes the removal of fuel and all other removable contaminated and activated material like for example cooling water.

stage 2 comprises decontamination and disassembly of such areas and components which can be quite easily treated and removed like the reactor vessel.

In stage 2 it is intended to remove the main part of activity and to achieve unrestricted release conditions for large building areas. Those areas which cannot easily be cleaned from activity will be sealed and will remain as restricted use areas for perhaps a long period of time.

stage 3 finally will consist in removing all the remaining contamination and activation and will terminate the decommissioning by unrestricted release of the complete facility.

The HFR preliminary study strictly follows these recommendations.

It must be mentioned that the IAEA Safety Series no. 74 is no binding regulation but a guide which explicitely admits departures from the recommended strategy.

By the experience of decommissioning German research reactors (e.g. AVR, FR-2 and MZFR) a 3-stage strategy guided by the grade of technical complexity and by the radiological demands is a very reasonable approach to decommissioning. But we do not follow the idea to keep the facility within stage 2 for perhaps some ten years, an idea which at least is implicitely included in this concept.

By nearly all actual decommissioning projects it can be learned that direct and immediate dismantling is the most effective way.

This can be supported by mainly two arguments:
- until completion of stage 3 at least some auxiliary systems like ventilation and off-gas systems must be kept working. This will cause costs.
- practical experience demonstrates the need for operating staff availability during all stages of decommissioning. Several decades after shut down it cannot be expected that experienced operating personnel from the facility will still be at hand. This situation will then also give rise to additional costs.

Taking into account the development of waste disposal costs it must be an additional argument to complete the work as soon as possible - once the decision for final shut down has been taken.

We therefore strongly recommend to perform the decommissioning stage-wise but without long interruptions between different stages.

The decommissioning sequence described in chapter III of the HFR preliminary study seems to be reasonable but with one exception: decontamination of the primary system and pool cooling system (item 7) should be performed right at the beginning of the decommissioning work. To be precise: decontamination should be foreseen directly after item 1.

Decontamination of the primary and pool coolant loop system should be performed with Full System Chemical Decontamination (FSD). Highly efficient closed loop processes of this kind also for aluminum are available. Such a process will decontaminate large system areas fairly down below the limit values for material free release.

Appropriate processes are available which are strongly waste minimizing. Ion exchange resins which contain the total amount of activity and of kations will be the only secondary waste resulting from such processes. Decontamination chemicals are completely decomposed within the process and will not contribute to the waste volume.

FSD will not only help to save dose rate during system dismantling but will also help to save costs because the complete system will be decontaminated in one single working operation and most of the material can afterwards be reused unrestrictedly.

The application of FSD presupposes an intact system to be decontaminated which is an additional demand for performing this process at an early stage of decommissioning.

After FSD of primary system and pool cooling loops the pool itself should be decontaminated by standard chemical spraying. We have based our cost review on a decontamination strategy just outlined above.

4 Review of costs

4.1 Plausibility check

The preliminary study gives a rough estimate for HFR waste arisings and decommissioning costs. For an overall plausibility check it is helpful to compare data of HFR with corresponding data of other research reactors. For this comparison German research reactors of different types were chosen. Their electric power is of the same order of magnitude like HFR and actually they are in the state of decommissioning. For these comparative reactors the decomissioning will also be terminated by unrestricted release of the controlled areas. Details are shown in the following Tables 1 and 2. The cost data of the reactors (status: January 1995) are based upon a BMBF publication.

In our opinion the data of waste amount and costs given in the Tables for HFR fit together with the 3 other projects in a reasonable manner if one takes into account:

- the comparatively low residual radioactivity of the HFR, which is due to
  the very compact design of the high flux reactor and
  the material aluminum (already experienced during the reactor vessel dismantling campaign in 1984),
- the comparatively low estimated waste arising with decommissioning of HFR,
  which is a direct consequence of
  the low residual radioactivity,
- the low estimated decommissioning costs,
  which are directly depending upon
  the low waste arisings,
- the assumed availability of the operating staff and again the low residual radioactivity which both contribute to low temporary supervision costs.

Table 1: Drawing up of relevant data of research reactors
(DM/ECU = 1.85)

name/site/country: electric power (at operation): residual radioactivity: (after removal of nuclear fuel) estimated waste arisings for disposal: estimated decommissioning costs to stage 3: estimated temporary supervision costs in stage 1:	AVR Jülich (Germany) 15 MWe 2.6 E15 Bq 668 Mg steel 2000 Mg concrete 1015 Mg other materials 193 MECU 11 MECU/year
name/site/country: electric power (at operation): residual radioactivity: (after removal of nuclear fuel) estimated waste arisings for disposal (without thermal column): estimated decommissioning costs to stage 3: estimated temporary supervision costs in stage 2:	FR-2 Karlsruhe (Germany) 44 MWe 6.5 E15 Bq 1200 Mg total 132 MECU 2.4 MECU/year

Table 2: Drawing up of relevant data of research reactors (DM/ECU = 1.85)

name/site/country: electric power (at operation): residual radioactivity: (after removal of nuclear fuel) estimated waste arisings for disposal: estimated decommissioning costs to stage 3: estimated temporary supervision costs in stage 2:	MZFR Karlsruhe (Germany) 58 MWe 1 E17 Bq 1580 Mg steel 1080 Mg concrete 100 Mg other materials 237 MECU 4.2 MECU/year
name/site/country: electric power (at operation): residual radioactivity: (after removal of nuclear fuel) estimated waste arisings for disposal (without thermal column): estimated decommissioning costs to stage 3 (without demolition of the buildings and other conventional systems): estimated temporary supervision costs in stage 2:	HFR Petten (The Netherlands) 45 MWe 3.7 E13 Bq 4 Mg MAW 121 Mg LAW 22 MECU (according 4.2) 0.5 MECU/year

Therefore on this basis of direct comparison with other decommissioning projects the costs for HFR decommissioning given in the preliminary study seem to be quite plausible.

4.2 Detailed evaluation

Beside checking the costs by plausibility and comparison with other decommissioning projects costs can be proved by an independent and more direct approach. This must include the consideration of:

- extent of dismantling work
- duration of work
- amount of masses to be dismantled
- amount of waste arising
- material and mass specific dismantling costs
- planning and licensing
- extent of and techniques for decontamination
- handling and disposal of waste
- plant supervision, auxiliary systems standby, amount of personnel and operating staff.

All these aspects were taken into consideration and were evaluated. Corresponding costs were then calculated on basis of existing knowledge and experience.

Costs for the following activities are not considered here:

- Removal of fuel from the reactor site
- Removal of contaminated coolants and other readily removable contaminated and activated materials.

As already pointed out above we assume that extensive use will be made of chemical system decontamination and that such components which are not decontaminated during system decontamination will be treated after dismantling. In our opinion a consequent decontamination strategy can reduce the amount of waste expected in the preliminary study.

In addition we presuppose that stage 3 will immediately follow stage 2 so that within a period of 5 years the reactor building will completely be cleared from all components and structures with residual radioactivity above authorized limits. At the end of this time the building will be released from atomic law.

The costs thus derived are presented in Table 3.

Table 3: Breakdown of costs (status: 01.01.1996)

Activities	MECU
System and single component decontamination	2.0
Decontamination and release measurements of buildings	1.6
Dismantling of medium activated/contaminated components and systems	1.4
Dismantling of low-contaminated components and systems	3.9
Operational costs and management	4.1
Planning and licensing	2.0
Disposal of waste	7.0
Total	22.0

Costs for planning and licensing were calculated on the basis of German conditions. With respect to HFR this assumption could therefore be a conservative one.

We tried to recalculate the amount of waste, and we concluded that about 300 m³ of waste must be expected. Included in these 300 m³ are 1 - 2% of high/medium level waste, mostly arising from activated material. The 300 m³ of low level waste were evaluated on the basis of enhanced decontamination work applying advanced decontamination technologies.

Assuming that the complete waste volume will finally be disposed off at COVRA about 3.5 MECU must be set aside for a direct disposal of waste.

Based upon information we received from HFR most likely the medium/high level waste will need preconditioning prior to be sent to COVRA. Preconditioning costs seem to be somewhat uncertain and not well established for the time being. We expect to be on the safe side by assuming once again 3.5 MECU for preconditioning and intermediate storage.

In sum 7.0 MECU should therefore be sufficient to cover the waste disposal costs.

Up to the end of extended stage 2 (as defined above) overall costs of 22.0 MECU must therefore be expected.

Following our recommendation no temporary supervision costs will arise during stage 3.

The assumptions of the preliminary study therefore seem to be formulated on a sound and solid basis.

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