DECOMMISSIONING OF THE THORIUM HIGH TEMPERATURE REACTOR (THTR 300)

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Abstract

The prototype Thorium-High-Temperature-Reactor (THTR 300) was decommissioned using the option of safe enclosure. Decision was made in 1989 and safe enclosure was reached in February 1997, followed by up to thirty years of operation of the safe enclosed plant.

I. Introduction

The pebble bed high temperature reactor THTR 300 was shutdown on 01.09.89 after more than 16,000 h in operation. The THTR 300 is a prototype reactor project that is jointly sponsored by the Federal Republic of Germany, the state North Rhine Westphalia and the operator Hochtemperatur-Kernkraftwerk GmbH (HKG). The public financiers of this prototype reactor and the operator could not solve the financial problems for continued operation of this technically intact plant. The decommissioning decision had not been expected at the time by the operator. This is why safe enclosure the German term for SAFSTOR turned out to be the only technical solution for quick decommissioning of the plant, apart from financial reasons and the non availability of a final repository . The plant is intended to be dismantled after about thirty years of safe enclosure, provided respective funds are available. The decommissioning was done in three steps that were mostly scheduled one after the other (FIG. 1), /1/.

II. Description of the Work

A. SHUTDOWN OPERATION

Step 1 has included the conversion of plant operation from the power mode to the shutdown regime to keep the operating costs of the plant low until the license required under the Atomic Energy Act for the core unloading has been granted.

In shutdown operation, the shutdown rods were fully inserted and locked to prevent withdrawal. Recriticality of the reactor core was thus precluded.

Owing to the long outage period, which started when the reactor was shut down for the scheduled maintenance on September 29, 1988, forced residual heat removal by operating systems was not longer required. These systems have been taken out of service by depressurization, removal of operation media, cutting off the energy supply and by blockage. These measures also apply to the prestressed-concrete reactor vessel (PCRV) with the primary system in which the helium was replaced by air/nitrogen.

This lead to a reduction in the number of yearly inservice inspections from about 4,000 to 2,000. Moreover, savings have been achieved in terms of insurance, plant security, maintenance and through labor reduction, so that the monthly operating costs of about 9 million DM in power operation could be decreased to 5 million DM in shutdown operation.

B. CORE UNLOADING

Step 2 was the core unloading, according to Section 7 (3) of the Atomic Energy Act a prerequisite for the establishment of the safe enclosure /2, 3/. For the THTR 300 this meant that about 580,000 irradiated fuel elements, which still were in the reactor core, had to be unloaded. This could only be done by the complete unloading of the core, including the absorber and graphite elements that remained there, too. A worldwide first of its kind activity to a pebble bed reactor (*FIG. 2*).

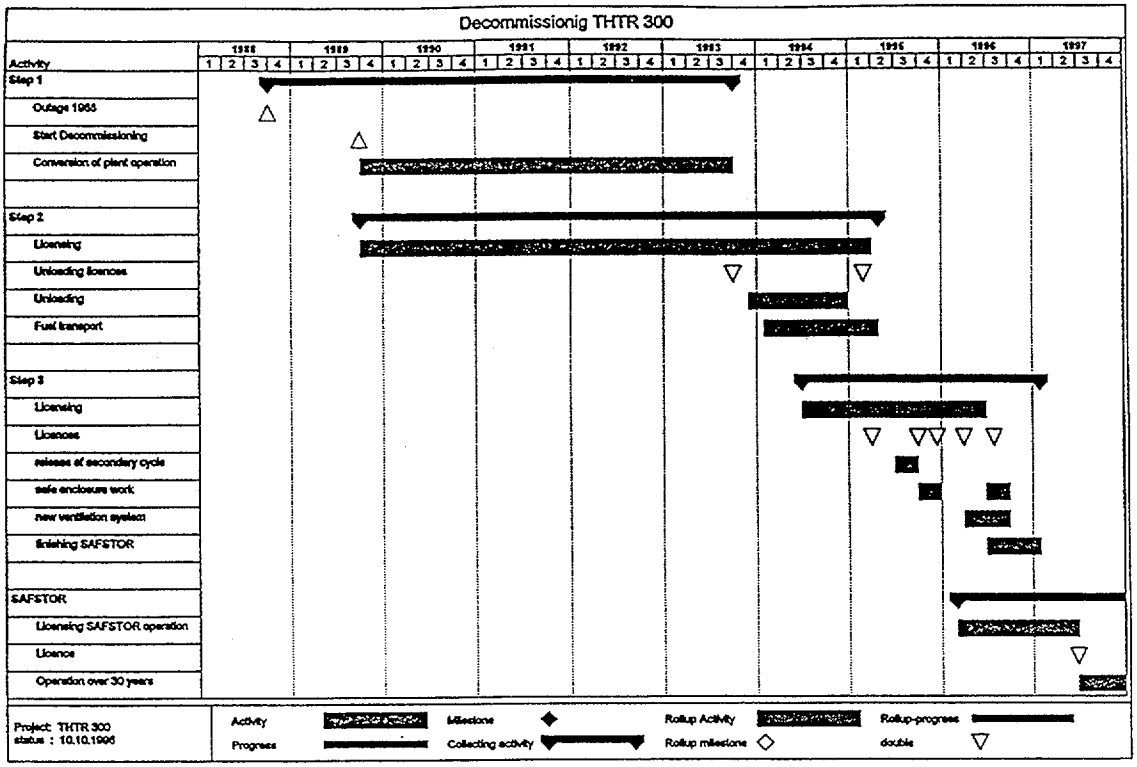


FIG. 1 *Time schedule, Decommissioning THTR*

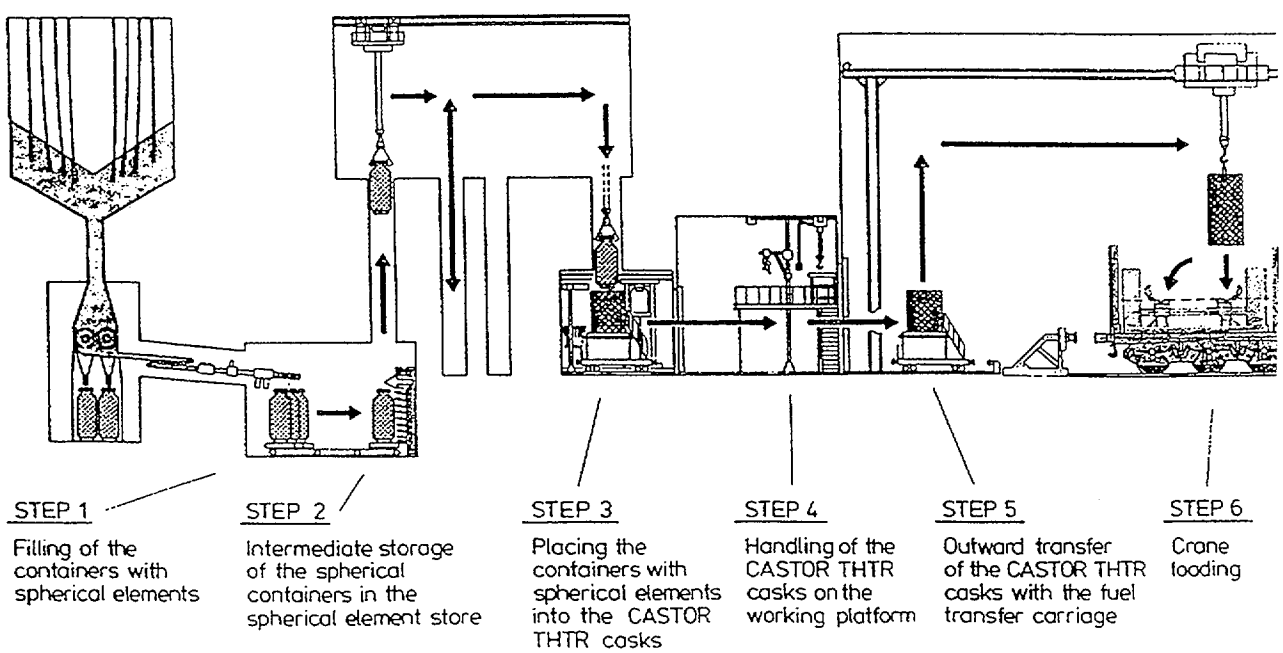


FIG. 2 *Core unloading, Management of the spherical elements*

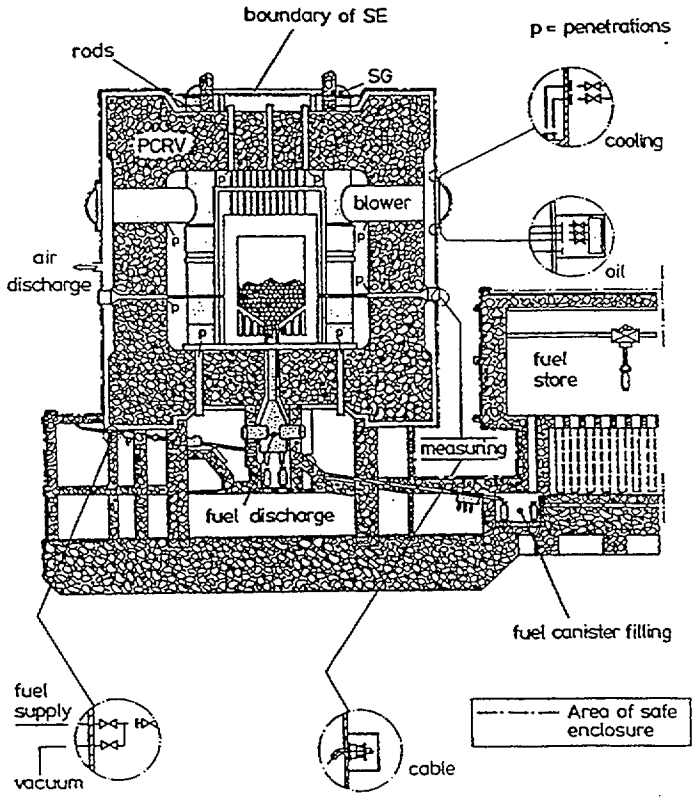


FIG. 3 *Closing scheme of penetrations through the safe enclosure*

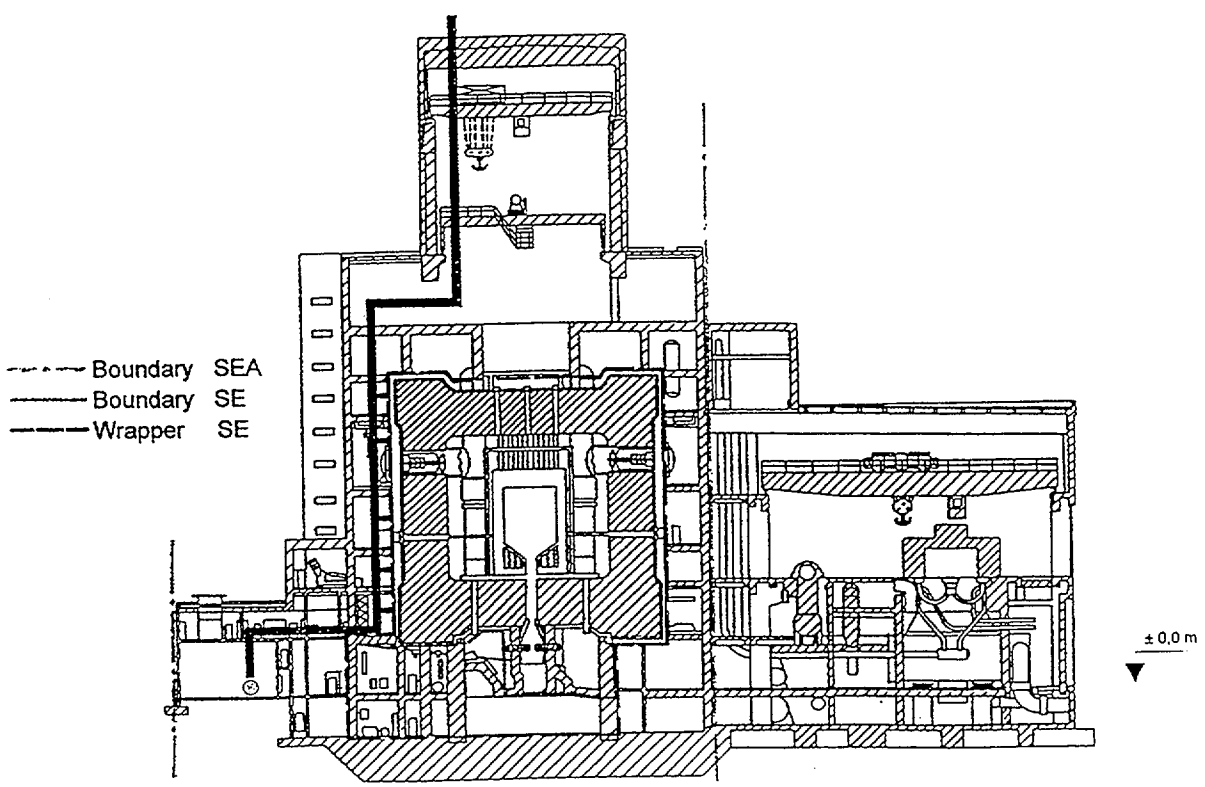
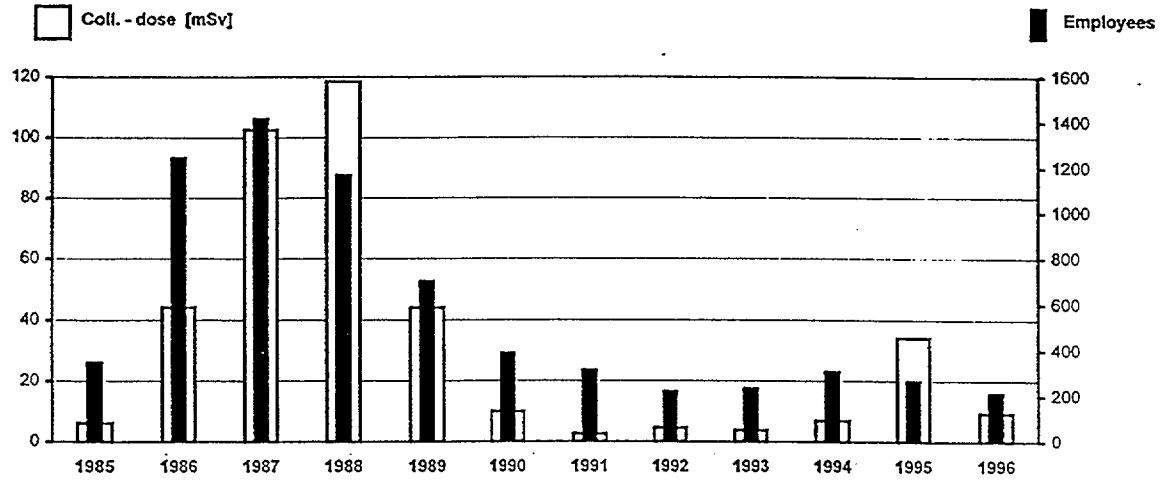


FIG. 4 *Safe enclosure concept (Reaktor building sectional drawing)*



1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	
6,1	44,1	102,5	118,46	43,98	9,89	2,54	4,5	3,71	6,89	34,19	9,38	Coll. - dose [mSv]
352	1249	1418	1172	705	392	317	224	237	311	270	217	Employees

FIG. 5 *Collective dose from 1985 - 1996, Decommissioning during 1990 - 1996*

The respective license was granted after a four years long lasting licensing procedure in October 1993 (*TAB. I*) The unloading itself was executed in a one year period from Dec. 1993 till Dec. 1994 accompanied and followed by regularly (weekly) fuel transport campaigns with CASTOR casks to the Ahaus fuel interim storage facility (in total fifty-seven transports without any rumors as unfortunately on Gorleben-CASTOR transports).

Also the nearly hands-on decommissioning of the small burn-up measuring reactor, used for distinguishing fuel absorber and graphite elements and monitoring the burn-up of fuel elements containing 3.6 kg U^{235} in form of high enriched U-Al-fuel, took place just after finishing of core unloading in early 1995.

C. ESTABLISHING THE SAFE ENCLOSURE

Step 3, the establishment of safe enclosure, was started also in 1995 after applying for in 1994/95 and granting of attachments to the core unloading license in 1995 (*TAB. I*). The main steps undertaken and finished by a general contractor even in 1995 /4/ were

- enclosing the prestressed-concrete reactor vessel by cutting and sealing all approx. 2,000 penetrations (*FIG. 3*)
- sealing all primary circuit system components
- establishing of an additional enclosure for those sealed components by using the existing vented containment as a type of air flow guidance envelope
- release of the water-steam-cycle with turbine and generator and the four emergency diesel generators from the restrictions of the Atomic Energy Act
- preparation work for the establishment of a new ventilation system tailored to the requirement for the safe enclosure operation.

In April 1996 the first part of the next license (safe enclosure establishment and pre operational tests) was granted (see also *TAB. I*) concerning mainly the erection of the new ventilation and the exhaust air measuring system. That work was finished on schedule in September 1996.

TABLE I. LICENSING, DECOMMISSIONING THTR 300

step	application	license
Core unloading	19.12.89	22.10.93
Sorting of some operating elements	14.01.94	09.02.95
Closure of PCRV, steam cycle	13.07.94	23.05.95
Closure of wrapper SE	29.06.95	02.10.95
Dismantling the He-purification	04.09.95	27.10.95
Erection of new ventilation	28.06.94/ 06.12.95	26.04.96
Establishment of SE	28.0694/ 01.02.96	15.07.96
Operation of safe enclosed plant	14.05.96	21.05.97

TABLE II. OVERALL COST, DECOMMISSIONING THTR FROM 1990-2009

	Mio. DM
Waste	253.0
Experts	55.0
Contractors	112.0
Operation 1990 - 2/1997	288.5
Operation 3/1997 - 2009	35.0
Financing	30.0
Total	773.5

TABLE III. SOLD EQUIPMENT OF THTR 300

	Mio. DM
Secondary cycle - steamturbine - generator - auxiliaries	15.0
Transformer	4.1
4 emergency diesel generator sets	3.0
Spare parts, tools etc.	1.3
Electrical-, communication-, radiation monitoring equipment	1.2
Total	24.6

The second but more important part of this license was granted in July 1996, containing the main steps for the establishment of safe enclosure and allowing to:

- dismantle the liquid waste store and evaporation system, decontamination shop and the like
- adapt the power supply
- dismantle contaminated equipment outside safe enclosure that doesn't fulfill the requirements of this area later concerning contamination limits
- adapt the drainage of the building
- decommission all other systems that are not needed for operation of safe enclosure
- install new control equipment fitting with the new operation tasks
- release all buildings of the site (except the three buildings of the safe enclosed plant: reactor hall, reactor operating and auxiliary building) from the restrictions of the Atomic Energy Act.

One important issue of this phase was the conversion of the major part ($\approx$ 80%) of the controlled area inside the safe enclosed plant into an "operational supervised" area with a dose level less than 2μSv, which can be entered for maintenance purposes without health physics monitoring. This area is the area outside the "envelope of safe enclosure" but inside the safe enclosed plant (*FIG. 4*), /4/.

This last but one part of step 3 took approximately eight months for execution and ended with the THTR 300 in safe enclosure (*FIG. 4*), comparable with the US-SAFSTOR or the IAEA passive SAFE STORAGE option at end of February 1997.

The last part of Step 3 was given on the way for licensing in May 1996. The applying documents like final safety analysis report, operating manual for thirty year operations of the safe enclosed plant and the like were checked by the experts. The license was granted on May 21, 1997.

Results

Work executed since 1990, even core unloading, resulted in yearly collective doses of personnel less than those in the years of operation (*FIG. 5*). The highest value during decommissioning occurred in 1995 due to the hands-on decommissioning of the small burn-up measuring reactor and the enclosing of the PCRV-penetrations.

Operating personnel could be reduced during step 1 + 2 only from 10 to a 8 men shift. Starting step 3 a further reduction to 5 men was allowed and at the end of second part of step 3 (safe enclosure established) only one control panel has to be checked by the site guard (24 hours a day). The personnel will then consist of the operator's plant manager plus one engineer and four additional standby service engineers on a call and contract basis. Necessary inspections will be done by specialized and certified companies on contract basis.

Then the yearly operating costs are reduced from more than 50 million DM per year during step 1, step 2 and first and second part of step 3, to 1.5 million DM per year. The overall costs of the decommissioning (1990 - 2009) sum up to 773.5 million DM and include costs of fuel transport and storage and also other waste handling and mandatory financing of final storage and financing of the project during 1990 - 2009 (*TAB. II*). The design of the THTR 300 that has for the secondary cycle a similar layout as fossil fueled power plants enabled the operator to sell many of the used components and spare parts to make financing of the decommissioning easier (*TAB. III*).

Starting into decommissioning of a nuclear power plant without chances of preplanning causes two to three years additional project execution time, equivalent to approximately 250 million's DM in the case THTR. This is why latest schedules for decommissioning up to green field include preplanning phases of up to four years.

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