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AVR DECOMMISSIONING, ACHIEVEMENTS AND FUTURE PROGRAMME

P. POHL
Arbeitsgemeinschaft Versuchsreaktor AVR GmbH,
Düsseldorf, Germany

Abstract

Safestore decommissioning of the AVR 15 MWe experimental nuclear power plant with pebble bed high-temperature gas-cooled reactor (HTGR) began in March 1994 with defuelling (phase 1). Beginning of Aug. 1997, defuelling was to 81 % completed. Other achievements: The dismantling in the turbine hall and outside the buildings is nearly terminated, the cooling towers are demolished, and the helium bottle-battery storage and helium compressors were removed from the ring buildings in Dec. 1996. The latter was the first dismantling inside the reactor building and belonged to projects that had been advanced from the 2nd into the 1st phase of Safestore decommissioning because of the delay in defuelling. Furthermore, the licence for a first supplement to Safestore decommissioning was granted in March 1997.

Inside the containment, the removal of shielding material and of insulation material from the secondary circuit components is either already or will shortly be terminated. This will give access for cutting and sealing the 120 steam generator pipe penetrations above the outer reactor vessel.

The scope of Safestore decommissioning, as licensed in March 1994, will be extended by three supplements, comprising mainly the dismantling of (1) the fuel handling system, coolant circulators, and interspace convection pipe, (2) the coolant purification system, and condensation coolers, and (3) the shutdown rod system. The goal is to clear the containment from all auxiliary systems and to seal the outer reactor vessel until the end of 2001.

The final goal of Continued dismantling is the restoration of the green field until 2011. The term indicates the direct transition from the present Safestore decommissioning and a stepwise procedure that can be interrupted after each step and be transferred into a Safestore mode. The decision for Continued dismantling is expected in 1998; a contract for the design and licence planning will be awarded soon.

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1. Introduction

The 15 MWe AVR experimental nuclear power plant is one of Germany's oldest nuclear installations; construction began in 1959. Its reactor belongs to the first generation of high temperature gas-cooled reactors (HTGRs) and was among these with its 21 years of operation certainly the most successful. For design and achievements, former publications like /1/ should be referred to. In this report on decommissioning only some key items shall shortly be recalled:

- Core of about 100,000 ball shaped fuel elements (pebble bed) cycled during reactor operation,
- Highest ever reached coolant temperature of 950 °C,
- Indispensable mass test facility for HTGR fuel development,
- First-ever-done experimental simulation of a loss-of-coolant accident /2/.

An overview of the reactor design and the site structure is given in Figures 1 and 2.

The plant was finally shut down end of 1988. A licence for Safestore decommissioning, first applied for in 1986, was granted in March 1994. Since a pebble bed reactor is never defuelled during reactor operation, defuelling is the major concern in Safestore decommissioning, and the whole task was separated in a first phase with defuelling and dismantling outside of the reactor building and a second phase with dismantling and preparations for the later dormancy period inside the reactor building.

The paper looks at the achievements obtained in now three and a half years of decommissioning activities, the future programme of Safestore decommissioning , and gives an outlook on the possible continuation of decommissioning towards the green field. The latter is presented in more detail in an own presentation within this TCM.

2. Overall Progress, Achievements, Highlights

Although defuelling is still not terminated, and the second phase of Safestore decommissioning with major dismantling in the containment could not yet start, the project has not been lacking considerable progress, summarised in the following.

- Since all obstacles and limitations concerning the transfer of the low-enriched part of the AVR fuel to the neighbouring Jülich Research Center could be finally lifted in July 1996 a major progress in defuelling has been achieved. Beginning of August 1997, only 19 % of the fuel was still left in the reactor.

- The dismantling in the turbine hall is nearly and that outside of the buildings is fully terminated.

- The cooling towers are demolished.

- The helium bottle-battery storage and helium compressors were removed from the ring buildings in Dec. 1996. This was the first dismantling inside the reactor building and belonged to the projects that AVR was allowed to advance from the second into the first (defuelling) phase of Safestore decommissioning because of the delays in defuelling.

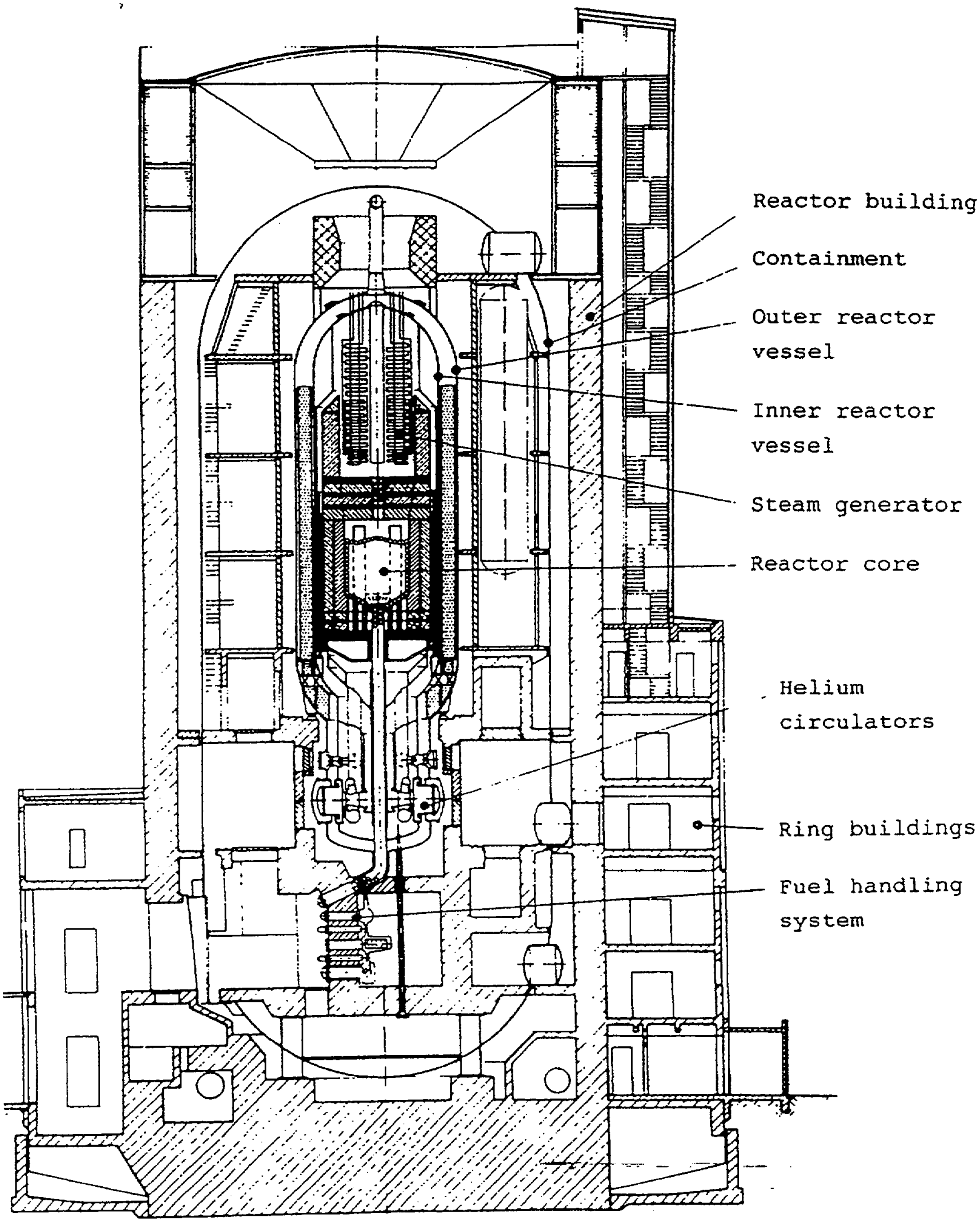

Fig. 1 AVR reactor building

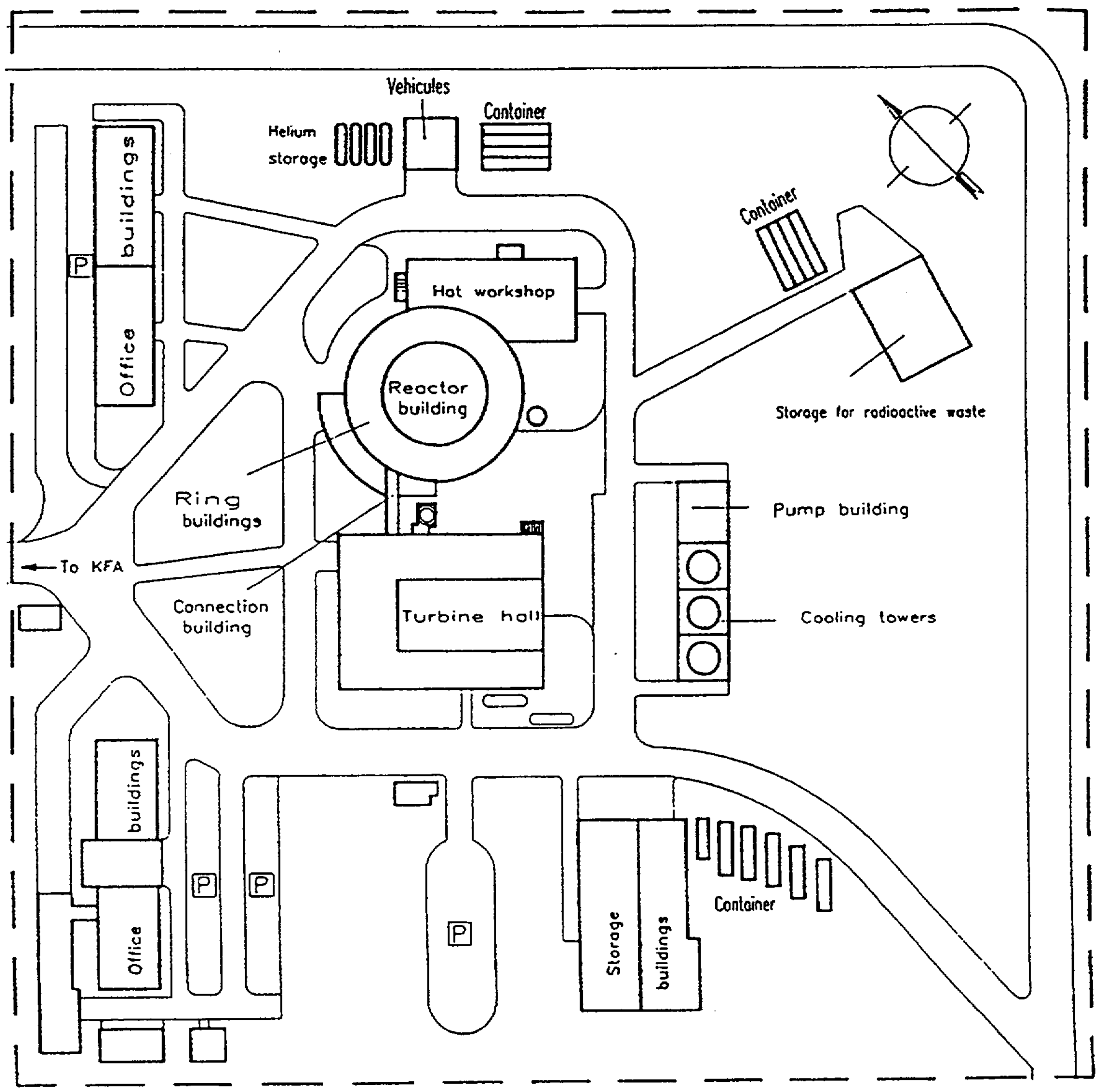

Fig. 2 Plan of AVR site

- Large amounts of shielding material (bricks and lead) with which the top floor of the containment was covered were removed only recently. The removal of all insulation from the secondary circuit components in the containment has begun and is well in progress. These tasks, too, belong to the before mentioned advanced projects.

- A first supplement to Safestore decommissioning was licensed in March 1997 (details below).

- The strategy for a possible continued dismantling (towards green field) has been finally agreed upon between AVR and the Research Center.

3. Progress in Technical Areas

3.1 The defuelling story thus far

In defuelling the about 112,000 pebbles of the AVR two major concerns had to be taken into consideration:

(i) Since the reference fuel of the AVR had always been HEU fuel but the AVR core consisted in the end to about 50 % of LEU fuel, the Research Center needed an extra licence to transfer that fuel through the water basin of their Hot Cells facility on the way to its storage in CASTOR casks.

(ii) Displacement processes of pebbles in the core during defuelling would lead to an increase in the fuel concentration in the core center so that an intermediate increase of reactivity during defuelling could not be ruled out.

To deal with the reactivity concern it was fixed that the course of subcriticality during defuelling had to be closely followed by regular critical measurements so that, if any necessity arose, countermeasures could be taken in time.

The above mentioned licence not obtained in time defuelling started in April 1994 with HEU fuel only. The LEU fuel was charged back to the reactor. The distinction was made by gammaspectrometrical measurement of each pebble, measuring U 232 which is practically only present in the Thorium-containing HEU fuel /3/. The selection quality had to be tested and verified in Nov. 1994, leading to an interruption in defuelling of about 2 months. Within June, July, and August 1995 the share of HEU elements in the discharged pebbles fell from about 50 % to a mere 17 %, and the selective HEU defuelling was stopped after about 35,000 pebbles had been discharged.

After the licence for Hot Cells was obtained, defuelling - and this time HEU and LEU - restarted in March 1996, though at first still under some limitations. Limit values for heavy metals, and Pu 239 was critical here, had to be observed in the Waste Cells of the waste management facilities of the Research Center where the CASTOR casks are loaded. To use up the permitted quantities in a best manner, selective defuelling was continued, with about 10 % of the pebbles (mostly HEU) returned to the reactor. In July 1996, then, the Research Center obtained permission to regard considerably higher limit values in the Waste Cells, and unselective defuelling could finally begin.

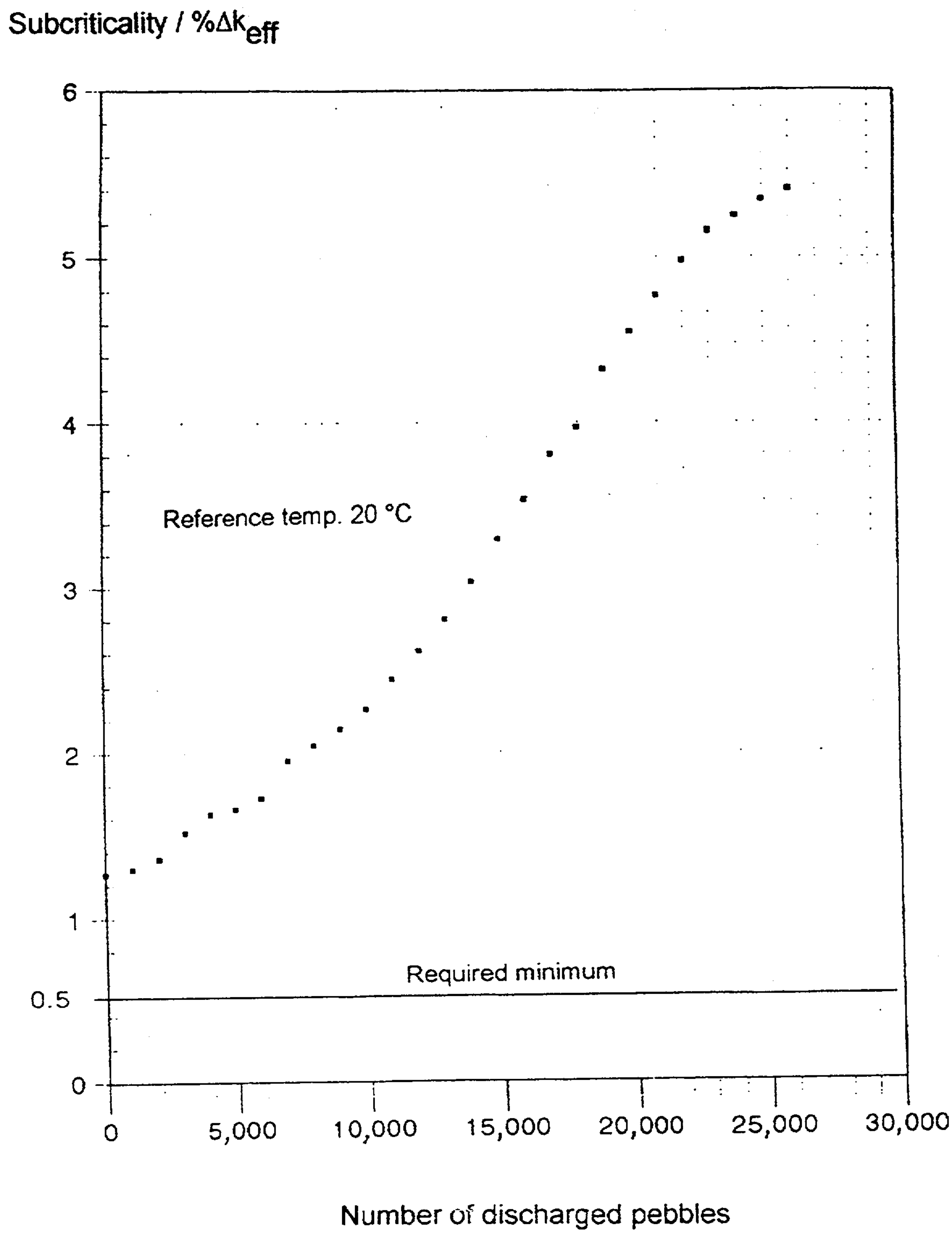

Fig. 3 Measurement of subcriticality during AVR defuelling

Thus, defuelling was no straight path, and neither it was in regard of concern (ii), though that concern, other then (i), fortunately did not cause any delay. Fig. 3 shows the results of the regular subcriticality measurements (details in /4/) up to a defuelling of 26,000 pebbles. Because of the massive return of pebbles to the reactor, the mentioned displacement processes could not take place, and so the steep rise in subcriticality came as no surprise. The return of the LEU elements, however, also led to a certain increase in the fuel density of the inner core, to which the decrease in subcriticality gain in the upper part of the curve in Fig. 3 can be attributed. Beyond the defuelling of 26,000 critical measurements were no longer possible. Regular measurement trials by full withdrawal of the rod bank were, nevertheless, continued, proving that the reactor remained higher subcritical in amount than the full rod bank worth.

When the complete, unselective defuelling started, the displacement processes were initiated in full scale for the remaining 63,000 pebbles still in the reactor. It was argued then, that the measurement trials were of little use to detect a rapid decrease in subcriticality if a rapid decrease in the rod worth was assumed. A different method to determine subcriticality in a very approximate way similar to the critical experiment in loading fresh reactors was turned down since the remaining zero level of the neutron flux instrumentation was regarded as insufficient. The way out was a theoretical study taking into account all experimental data gathered so far during defuelling, and also data of the AVR's own critical experiment. The result was that regardless of the procedure in further defuelling the reactor would always remain strongly subcritical. As a consequence, all measurement requirements were abolished, the neutron flux instrumentation was permanently taken out of service, and the shut-down rods have remained inserted.

When defuelling went at its best, 36 fuel cans, or 1800 pebbles, per week could be transported to the Research Center. Necessary repairs in parts on the fuel handling system led to several interruptions in defuelling between Feb. and May 1997, summing up to about 8 weeks. A major setback then, with only 24,000 pebbles left in the reactor, was the break down of the ring channel machinery in June 1997. The ring channel is used as a buffer for empty and filled fuel cans and allows to disconnect can filling and can transportation. This advantage gone, defuelling continued at a much smaller pace, can filling and transportation can by can. The repair of the ring channel machinery will take longer; 31 filled fuel cans have to be retrieved first by remote techniques. Ways to accelerate defuelling without the ring channel are in examination.

3.2 Cutting experience

The cutting of pipes and vessels of the secondary and cooling water circuits in the turbine hall and outside of the buildings was exclusively carried out by sawing. This proved to be effective and not too time consuming. Since there is no controlled ventilation system in the turbine hall, it is obligatory not to release any radioactive substances at all. By sawing inside ventilated plastic sheet housings this could easily be achieved. For smaller pipes a reciprocating saw with automatic feed was used that is directly fixed on the pipe. Some larger pipes and vessels were cut with a self-advancing machine that uses a circular-saw-blade-like milling tool. The machine is held and guided by a chain that surrounds the work piece. Most cuts, however, were carried out with hand-held motor-driven backsaws. With these, it was possible, e. g., to cut through the condensate collecting tank with a diameter of 1.8 m and a wall thickness of 7 mm circumferentially in 5.5 hours.

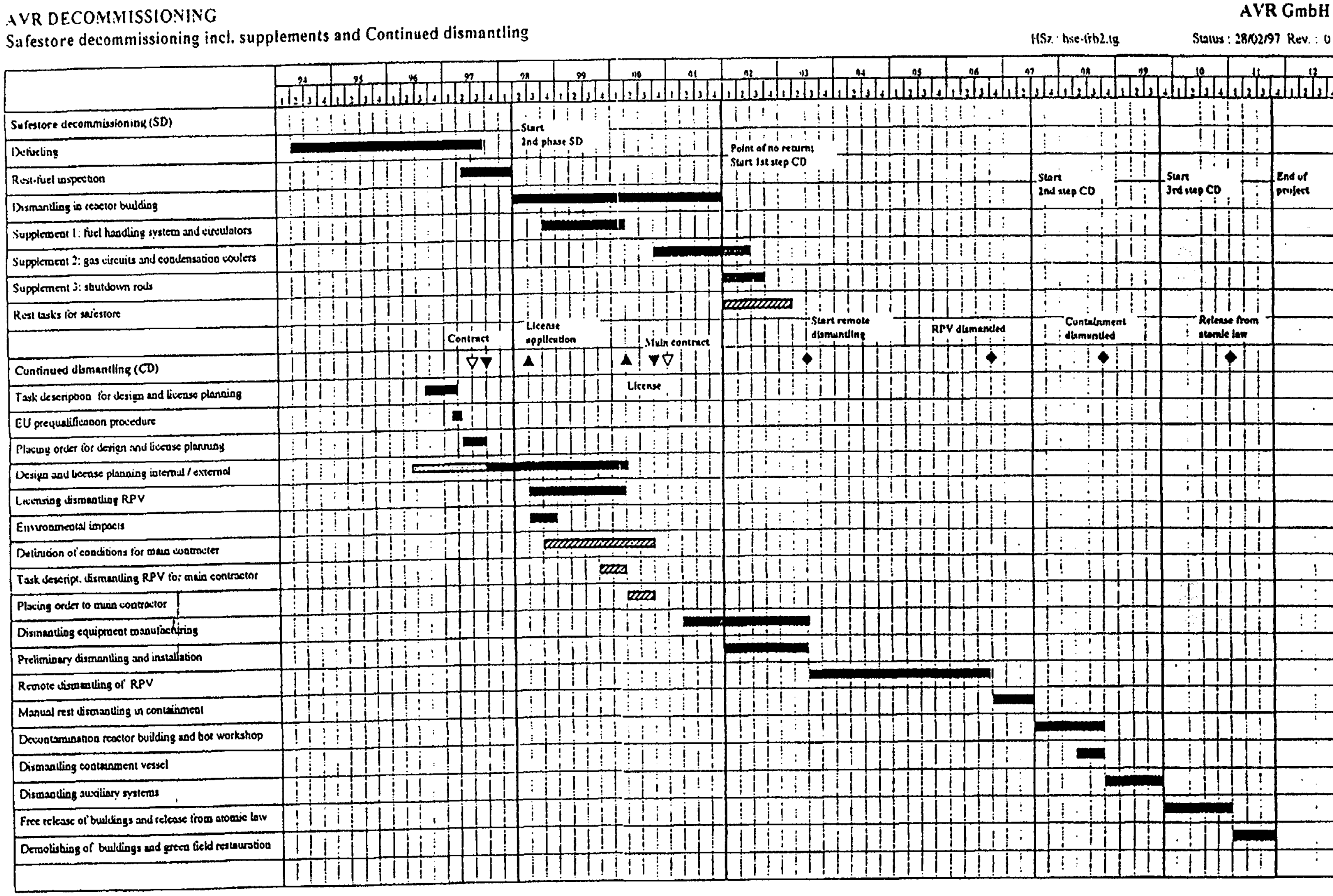

Fig. 4 Project schedule

4. Future Programme

4.1 Near future

The near future - rest of 1997, beginning of 1998 -will see the continuation of Safestore decommissioning. Most important is of course defuelling which despite the above mentioned break down of the ring channel for buffering fuel cans ought to be terminated within 1997. In direct continuation the core cavern will be inspected for rest fuel through a radial borehole drilled at core mid-height and later also all components of the fuel handling system. The boring and inspection equipment has been enabled to take out graphite and carbon brick samples.

Parallel to defuelling the decommissioning activities concentrate on the following tasks:

- Finishing the removal of insulation from the secondary circuit components in the containment.
- Removal of a shielding wall in the top part of the containment.
- Having created the necessary access by the above mentioned removal of insulation and shielding material, cutting of the 120 steam generator tube penetrations through both reactor vessels above the outer vessel and closing the tube ends by welding. The task - referred to as 'hedgehog' - is due to be completed still within 1997.

The remaining task in the turbine hall, the dismantling of turbine and condenser, has got low priority and will be addressed later when suitable from both budget and personnel availability.

4.2 Overall programme Safestore decommissioning

Scope and schedule of Safestore decommissioning, as finally defined in 1996, is represented in Fig. 4. It is characterised by three supplements to the original licence of March 1994. The scope of dismantling inside the containment covered by the original licence is fairly limited, as has repeatedly been reported in the past /5/. The planned supplements, however, will bring about the clearance of the containment from all auxiliary systems and will eventually leave the sealed outer reactor vessel as the only radioactivity containing area. The inclusion of these supplements into Safestore decommissioning, i. e., not deferring the related tasks, is of vital importance for the whole AVR decommissioning project in terms of profiting from own personnel's knowledge and experience and thus reducing dose uptake and costs. It is appropriate, therefore, to regard these supplements in somewhat closer detail in the following.

The supplements concern systems that contained helium and are therefore, no matter if filled with primary coolant or barrier gas helium, extensively contaminated with Sr 90 bound to very volatile graphite dust which is, as has often been reported before, the major point of concern in AVR decommissioning.

4.2.1 First supplement

The first supplement to Safestore decommissioning, licensed in March 1997, comprises the dismantling of the

- fuel handling system,
- coolant circulators, and
- interspace convection pipe.

The **fuel handling system** can be divided into 4 main sections:

- First-components' wall: It contains vertical-in-line all the components below the fuel discharge pipe, from the reducer-wheel that closes that pipe down to the scrap collection bottle.

- Pebble distribution wall: It contains the switch wheel as well as pebble valves in all incoming and off-going pebble pipes. The 5 feeding pipes to the core will be cut and sealed below their penetration through the outer reactor vessel.

- Fresh fuel feed system: It comprises components in- and outside of the containment.

- Spent fuel discharge system: It also comprises components in - and outside of the containment, including the installations in the ring channel for buffering empty and filled fuel cans.

The **coolant circulators**, integrated into the bottom part of the 2 reactor vessels, will be dismantled including their oil lubrication system. The circulators will be removed using existing equipment for removal, shielding and transportation.

The **interspace convection pipe** with the in-built water-operated inter-space cooler enabled the natural convection and cooling of the helium in the interspace between the reactor vessels at power operation. The pipe extends from the top of the outer reactor vessel, all the way down the containment wall, spreading up at the bottom, and entering the 4 shut-down rod casings at their lower ends.

4.2.2 Second supplement

The second supplement to Safestore decommissioning is in an advanced planning stadium and the licensing process is about to start. It will address the dismantling of the helium purification system and the condensation coolers.

The term **'helium purification system'** is to understand here in a wider sense since the central part of the system, the adsorption-material-containing vessels (partly deep temperature adsorption), are already covered by the original licence under the task item: removal of operational material. The wider sense comprises here all of the helium systems inside which, in a way, the purification system is central, comprising all pipework, valves (including their control systems), various compressors, a vacuum pump, vessels and filter units. The multitude of valves and many of the smaller components are grouped in a number of steel racks on nearly all floors in the containment. The goal is to remove these racks as whole or in larger units and further dismantle them at a more appropriate location in order to reduce dose uptake. Since most of the racks contain not only components of one single system it will be a precondition for their dismantling that all the concerned systems are shut-down, switched free (as is usual), and that for those systems that are still needed, like the pressurised air supply, new off-rack installations will have been provided to the necessary extend.

The 3 **condensation coolers** are huge, thick-walled (16 mm) tanks extending over several floors, designed to mitigate accident situations with a rupture of the steam generator at reactor operation by taking up the high-pressure mixture of helium and steam and condensing steam on water then present at the bottom part of the vessels. Since that sort of accident never occurred, the coolers are, in comparison to other vessels, only little contaminated. Besides the coolers, the dismantling comprises their safety valves as well as those of the two reactor vessels.

4.2.3 Third supplement

The third supplement to Safestore decommissioning considers only the removal of the **shut-down rods** including their driving units. There is a whole maintenance procedure with special devices and tools for exchanging rods making use of the Hot Cells' facilities of the Research Center. However, since that procedure is lengthy and has never been fully practised, a new-to-develop, more direct, dismantling-oriented way is supposed to be favourable. Studies are being done.

Anyway, the dismantling of the shut-down rods, as well as that of the condensation coolers, will be taken over into Continued dismantling (next chapter) if that option is chosen.

4.3 Continued dismantling

Strategy

The final goal of 'Continued dismantling' is the restoration of the green field. The term has been chosen to indicate the direct transition from the present Safestore decommissioning and a procedure that can be interrupted after each of a number of dis-mantling steps and be terminated with and transferred into a new Safestore mode should any obstacle arise, in both financial or organisational terms, to the continuation of the project. According to schedule (Fig. 4), that transition to Continued dismantling, if envisaged, would take place in the beginning of 2002. That date would be the start of the first step of Continued dismantling, addressing remotely controlled the two reactor vessels and their internals. The second step, beginning in 2007, would comprise the decontamination of the reactor building (incl. Hot workshop) and the dismantling of the containment vessel. The third step, starting in late 2009, would concern the free release of the buildings, the release of the site from atomic law, and the demolition of the buildings including the field restoration of the site until late 2011.

Reference Concept

For the remote reactor dismantling the 'in situ' concept has been chosen in which the containment vessel remains intact and the steam generator has to be cut in situ. The concept was given preference to the competing 'extension concept' in which the containment vessel would be opened at the top and largely extended to a veritable dismantling house offering enough space to pull out the steam generator as a whole unit. The key advantage of the in situ concept is that it relies on an existing and accepted boundary which should facilitate and shorten the licensing procedure to a large extend.

The in situ concept has been further detailed and fixed to a reference concept considering on top of the reactor vessels a ventilation tight dismantling area that tightens at its bottom on the cylindrical part of the outer reactor vessel. Furthermore, it has to be designed in a way that it can be moved down on the cylindrical part of the outer vessel according to the dismantling progress. Thus, a certain pre-determination of the overall method to be employed has already been made, and any detailed solution has to be based on this concept.

Design and Licence Planning

A first important step towards Continued dismantling was the decision in 1996 to award a contract for the design and licence planning. The budget for this task has been secured (about 8 mill. DEM). An EU prequalification for bidding was evaluated in July 1997 and the actual bidding process is in an advanced stage. The task list for the contractor has been divided into the following items:

(1) Planning of Continued dismantling
(2) Accompaniment of the licensing process
(3) Execution of Continued dismantling
(4) Execution of a distinguished task from Safestore decommissioning (dismantling the fuel handling system)
(5) Maintenance of the remaining plant

Items (4) and (5) are bound to a transition of AVR personnel to the contractor.

5. Costs

At present, the costs situation of the AVR decommissioning project for both Safestore decommissioning and Continued dismantling can be summarised as follows:

Spent for waiting period 1989 till 1993	c. 120 mill. DEM
Spent for decommissioning from the beginning in March 1994 till the end of 1996	c. 105 mill. DEM
Estimated total for Safestore decommissioning (incl. supplements)	c. 270 mill. DEM
Estimated costs for Continued dismantling	c. 230 mill. DEM
Public funding for AVR project, as of 31 Dec. 1996	c. 670 mill. DEM

6. Conclusions

Although it may not seem so at a first glance, AVR decommissioning is well in progress. Sure, a number of delays caused the defuelling to be a lengthy procedure but it is well advanced and the end is in sight. The task of AVR decommissioning is like the task of writing a text. The full text has not been written yet, but the subject is clear, the text has been structured, and a list of contents been drafted. The way how to proceed is clear. The costs have been estimated without the costs for waste disposal which are still too uncertain to predict. Budget and time requirement for the complete dismantling of the plant will not be exceptional in comparison to other decommissioning projects. The 3 supplements will put Safestore decommissioning on a sounder basis and make use of the own personnel's experience and knowledge in a best manner. And finally, the advantages of a transition from Safestore decommissioning to Continued dismantling are well recognised, and it is quite likely that this path will be followed.

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