Co-Generation of Electricity and Desalinated Seawater by Uranium, Thorium and Solar High Temperature Energy

Dr.-Ing. Urban Cleve
Ex-CTO of BBC/Krupp Reaktorbau GmbH

Desalination Powered by Nuclear Energy

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1. Using TVHTR Technology to generate High Temperature Energy without any nuclear risks

THTR – 300 MW Kernkraftwerk
Hamm-Uentrop

Kurzbeschreibung

The goal is to develop a nuclear technology with exceptional safety considerations:

- There cannot be any nuclear risk
- No nuclear or design rest-risc
- Safety considerations are deemed to be more important than economical considerations

These goals can be attained by:

- Extensive nuclear physics calcultions
- The development of extremely safe fuel elements
- The overall safe design of the entire nuclear plant and all components

The most important component of every nuclear powerstation are the fuel elements:

- New pebble elements must be treated and stored inside and outside the reactor system by hand
- The nuclear materiel must be enclosed within a gastight layer
- Each pebble has a diameter of 60 mm and about 15,000 coated nuclear particles with a diameter of 0.5 mm enclosed within

The most important component of every nuclear powerstation are the fuel elements:

- Each particle has three gastight layers that are able to prevent the emission of dangerous fissile products into the primary helium gas and after burn down to the environment
- A total loss of all primary cooling helium gas into the environment must not lead to unacceptably high pollution
- The fuel particles of Thorium 232,Uranium 233/235/238, and Plutonium 238 – 243 can be used

The most important component of every nuclear powerstation are the fuel elements:

- All fission products are safely stored within the interior of the coating after extraction of the core during transport and storage to prevent any danger to personnel or the environment

These goals can be achieved through large international cooperation to develop fuel elements with Triso coating. This fuel can only be operated in graphite moderated high temperature power stations.

2. Operational Experiences of the HTR-KKW AVR Jülich and THTR-300 Hamm Germany

Operational experiences with the AVR Jülich:

- The AVR was placed into operation in 1967 and shut down due to governmental order in 1989.

- At this time it reached an average opertional time of 66.4 %.

- The maximum operational time was 92 % and was comparable to other nucler power stations that had been in service for a longer time. The AVR set a world record for a new power station design.

- No release of radioactive material occured and neither the personnel or the environment had been polluted.

Operational experiences with the AVR Jülich:

- The graphite construction was a first in the world and and 22 years of operation it showed not the slightest indication of damage or movement.

- The fuel charging unit for the pebbles operated without any problems and 2,400,000 pebbles had been moved. Only 220 crushed pebbles had been taken out of the circuit resulting in 99.999 % efficiency.

- According to the INES scale only one incident occured with “1” and all the other events had an INES level of “zero” during 23 years of operation.

Operational experiences with the AVR Jülich:

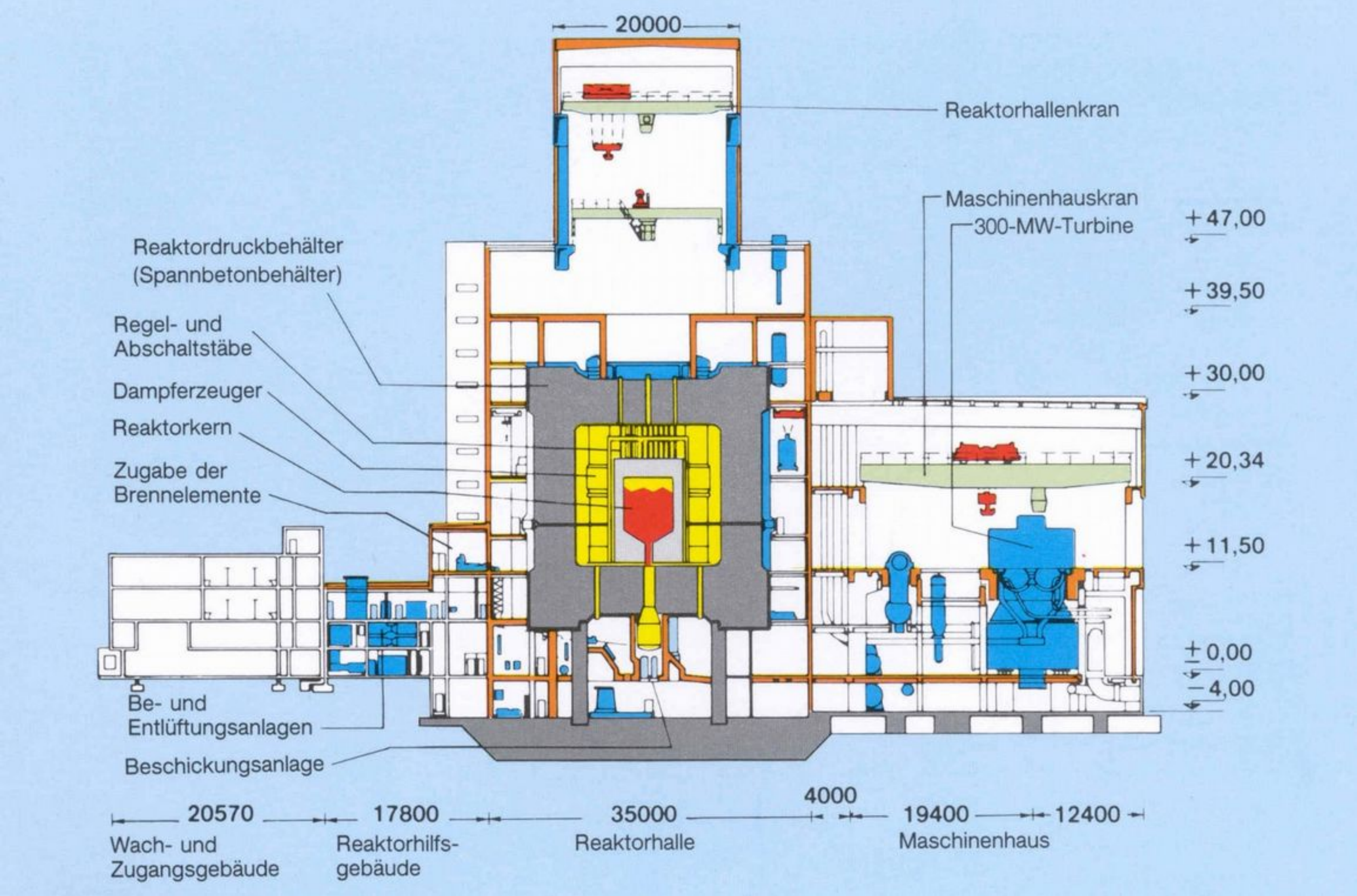
- A exceptional and symmetrical flow of the helium cooling gas was reached in the pebble bed and the steam generator.

- New fuel pebbles could be handeld and stored by hand without any danger of pollution.

- Nearly all newly developed components worked without additional problems.

Operational experiences with the THTR-300

The design of the THTR-300:



Operational experiences with the THTR-300
The design of the THTR-300:

- The newly developed pre-stressed concrete pressure vessel showed to be a key design choice for HTR-Reactors due to safety reasons:

- Safe against airplane crashes
- Safe aigainst political reasons
- Safe against air ingress
- Safe against every type of potential rupture and loss of primaray helium gas
- Safe againt the highest magnitude of earthquake
- Safe against possibility of cracks

The design of the THTR-300:

- The steam generators worked without the slightest of problems.

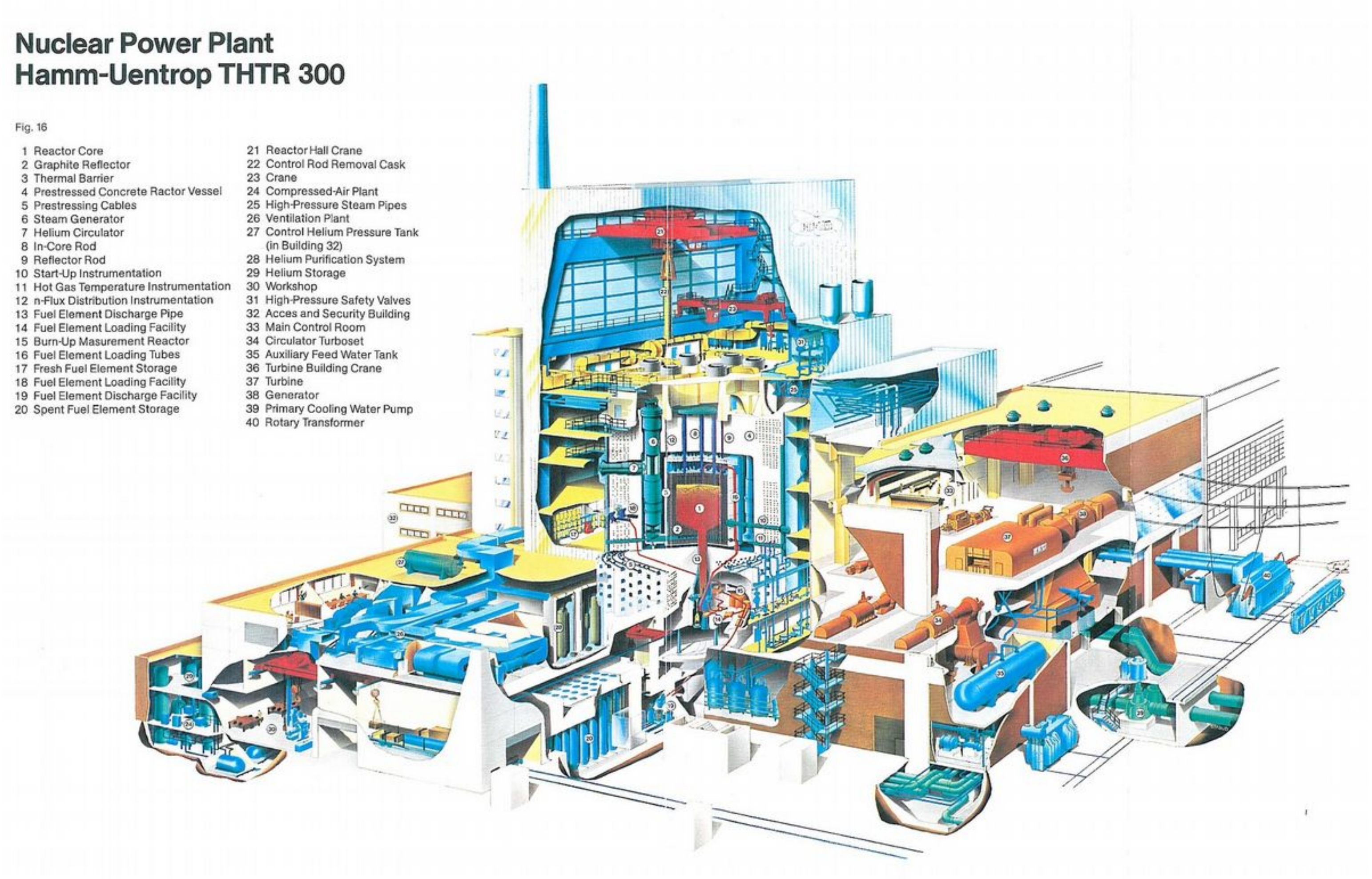
- The oil lubricated Helium gas blowers demonstrated no risks at all.

- The reactor proved to have stable regultation possibilities from low power up to full and was able to maontain the regultion of net-frequency.

The design of the THTR-300:

- The helium cooling gas flow from bottom upwards as in the AVR proved better than the downward flow.
- The graphite wall design of the AVR was much better then that of the THTR-300.
- The newly designed extraction device for the fuel pebbles performed more poorly than the AVR.

The design of the THTR-300:



Nuclear Power Plant
Hamm-Uentrop THTR 300

Fig. 16

1 Reactor Core
2 Graphite Reflector
3 Thermal Barrier
4 Prestressed Concrete Ractor Vessel
5 Prestressing Cables
6 Steam Generator
7 Helium Circulator
8 In-Core Rod
9 Reflector Rod
10 Start-Up Instrumentation
11 Hot Gas Temperature Instrumentation
12 n-Flux Distribution Instrumentation
13 Fuel Element Discharge Pipe
14 Fuel Element Loading Facility
15 Burn-Up Masurement Reactor
16 Fuel Element Loading Tubes
17 Fresh Fuel Element Storage
18 Fuel Element Loading Facility
19 Fuel Element Discharge Facility
20 Spent Fuel Element Storage
21 Reactor Hall Crane
22 Control Rod Removal Cask
23 Crane
24 Compressed-Air Plant
25 High-Pressure Steam Pipes
26 Ventilation Plant
27 Control Helium Pressure Tank (in Building 32)
28 Helium Purification System
29 Helium Storage
30 Workshop
31 High-Pressure Safety Valves
32 Acces and Security Building
33 Main Control Room
34 Circulator Turboset
35 Auxiliary Feed Water Tank
36 Turbine Building Crane
37 Turbine
38 Generator
39 Primary Cooling Water Pump
40 Rotary Transformer

3. Development and functional tests of main components

Prestressed concrete pressure vessel:

Extensive pressure tests were performed in a laboratory using a 1:20 scale model pf a pre-stressed concrete pressure vesssel. The vessel was pressurized to nearly 200 bars with warm water. The results are:

- No cables had been damaged
- Small cracks were noticed under high pressure and after repressurizing the concrete was tight
- The results of the pressure tests enabled the development of calculations to used when testing a larger PCPV. The pressure tests of the PCPV of the HTR-300 indicated the caculations were very precise

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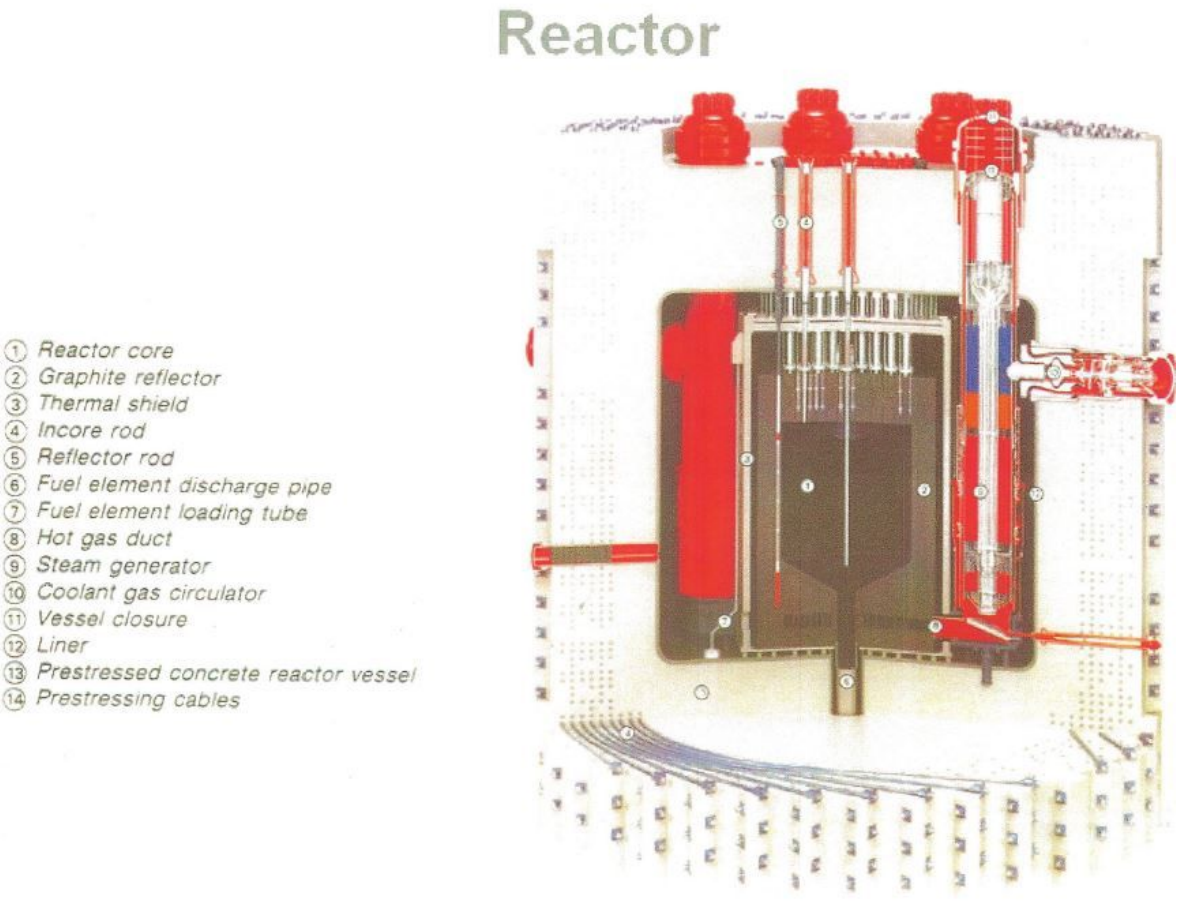

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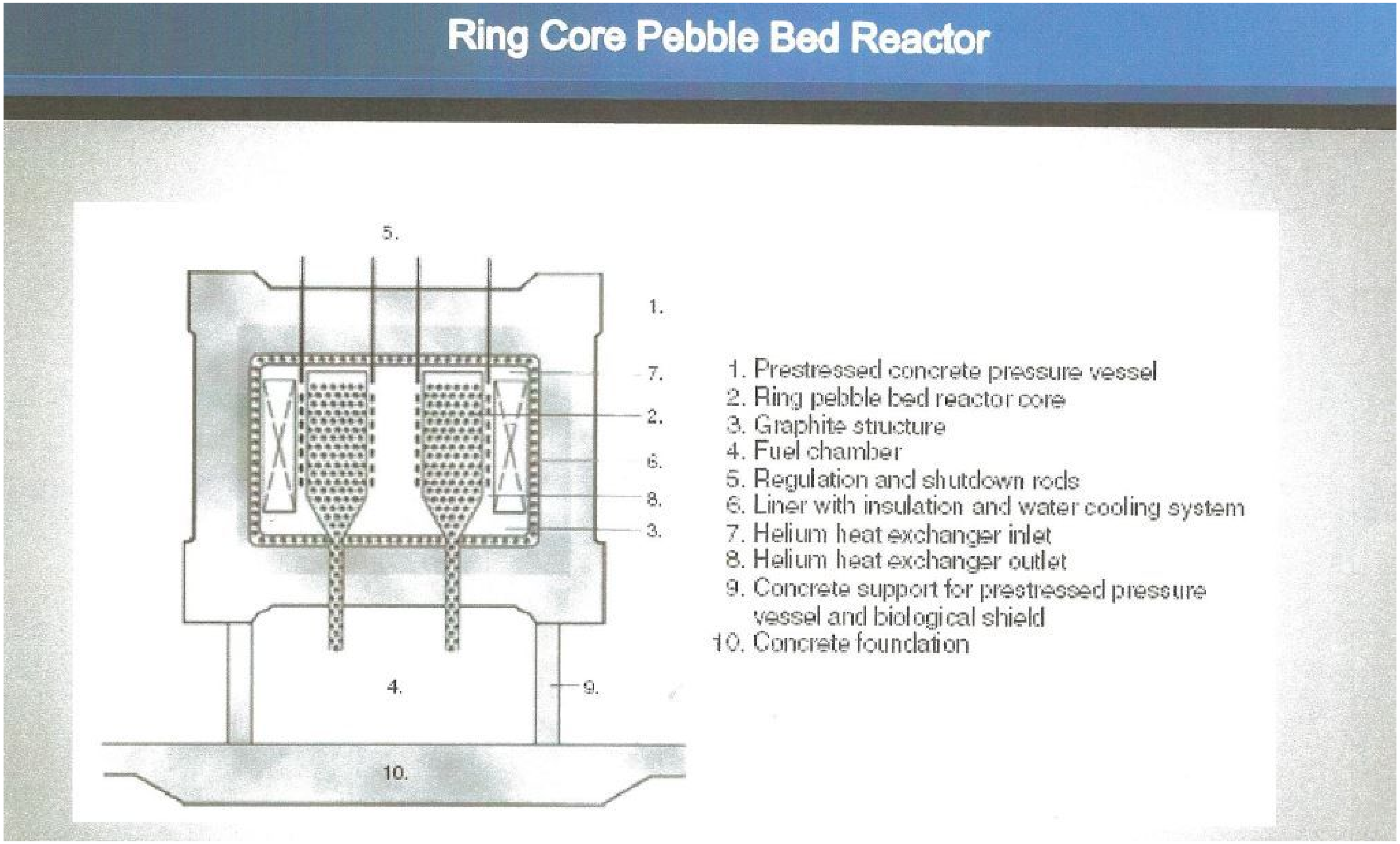


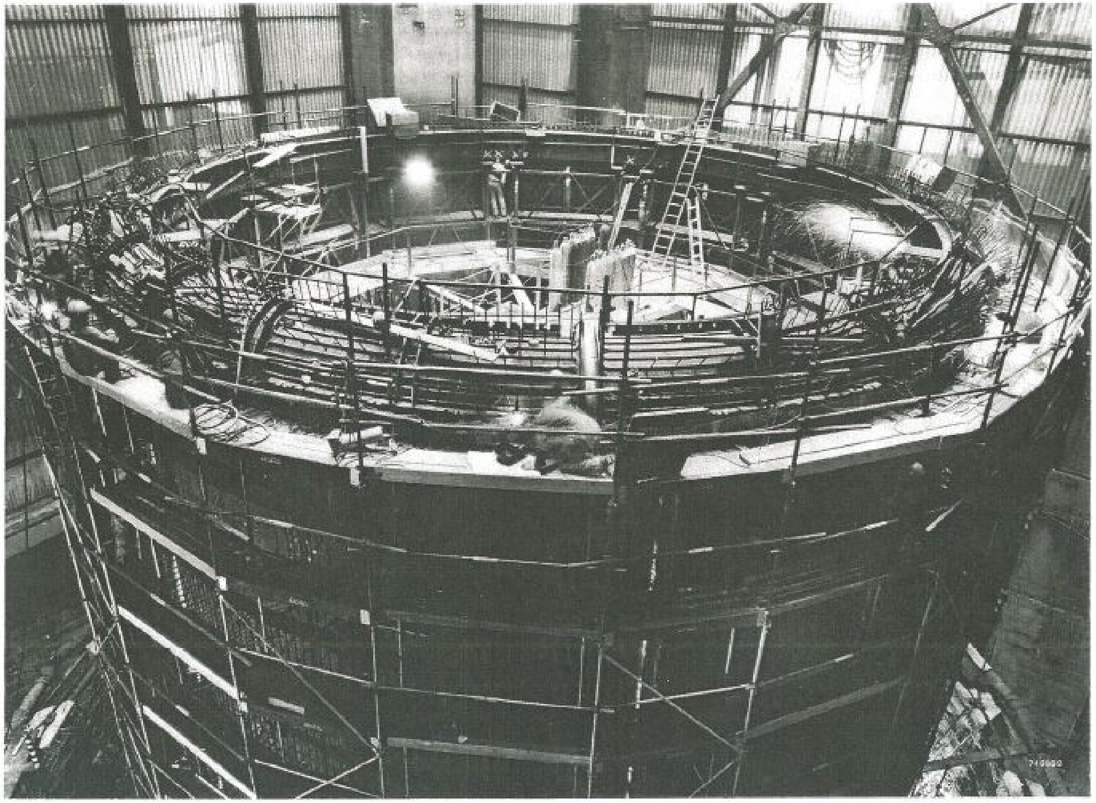
Ring Core Pebble Bed Reactor

1. Prestressed concrete pressure vessel
2. Ring pebble bed reactor core
3. Graphite structure
4. Fuel chamber
5. Regulation and shutdown rods
6. Liner with insulation and water cooling system
7. Helium heat exchanger inlet
8. Helium heat exchanger outlet
9. Concrete support for prestressed pressure vessel and biological shield
10. Concrete foundation

Prestressed concrete pressure vessel:

Baustelle des Spannbetondruckbehälters nach der Montage des Linerzylinders

Construction Site of Prestressed Concrete Pressure Vessel after Assembly of Liner Cylinder



Cooling Gas blowers:

The oil lubricated blowers, two in the AVR and six in the THTR-300, functioned without any problems.

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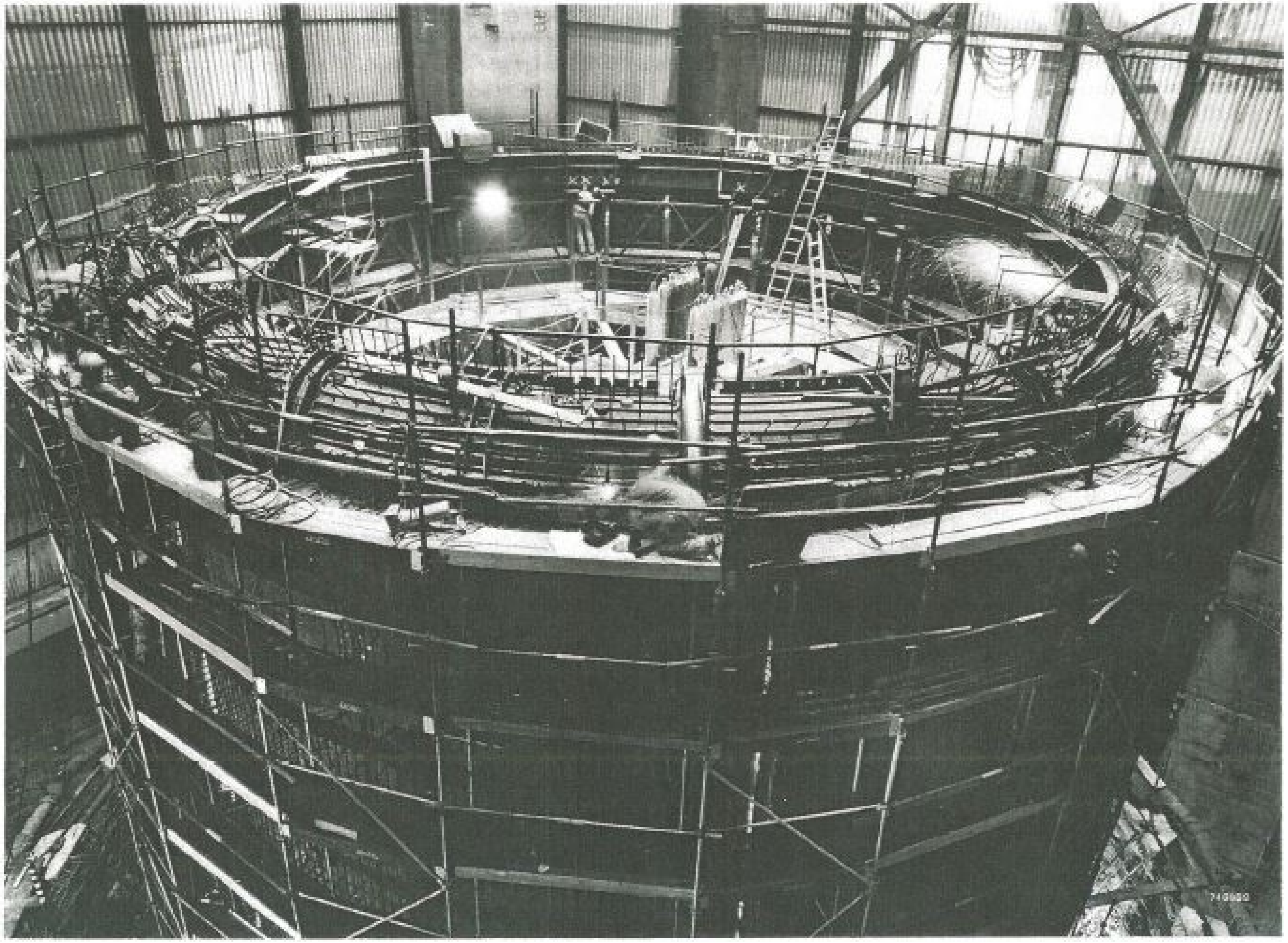

Shut down and regulation rods:

- The shut down rods of the AVR had been tested for years in the labratory of BBC/Krupp, no problems occured. After installimg into the reactor and tested under helium conditions they failed completedly. They were redesigned and worked without any problems.
- The insertion of the shut down rods into the pebble bed of the THTR discovered late was a mistake. About 0.6 % of the pebbles ruptured, which was substantually higher when compared to the results of the AVR at 0.0092 %.

Shut down and regulation rods:

- The regulation rods were installed and guided into the graphite reflector and worked without any problems. This design can be installed in future ring core designs as regulation and shut down rods similar to the AVR design.

Helium Valves:

All valves of the helium circuits were tested under normal conditions and were delivered by experienced suppliers. Under helium conditions they failed completedly and had to be newly desinged by BBC/Krupp engineers. Upon testing in a helium atmosphere they worked very well. The valves were a special design for the nuclear power plants without assistance of normal suppliers.

Steam Generators:

During manufacturing of the steam generators for the AVR it was necessary to develop new test instruments and new documents for the tube material. The generators were manufactured on the job site. Pressure and tightness tests were successfully performed with helium. They were designd with an interlocking system. It was a very difficult solutionand it was decided to design the steam generator as a tube-winding design which proved to be a good decision. Both designs of the steam generator worked very well with no problems. Capacity, steam pressure, temperature, and the intermediate steam datas were successfully achieved.

4. Safety requirements for High-Temperature Nuclear Power Stations

The German Ministry for Nuclear Safety, BMFT, was invited to a fundamental discussion concerning the safety of nuclear power stations held at KIT Technical University of Karlsruhe. The following basic requirements, fixed by Prof. Dr. K. Kugeler, former member of the German RSK, was discussed:

- Safe against cracking of the pressure vessel. /LWR+HTR-PM (-)
- Independent reduction of decay heat. / LWR (-)
- Safe against earthquakes and tsunamis of the highest magnitude. /LWR+HTR-PM (-)
- Zero emission under all circumstances, such as cyber attacks or political disturbances. /LWR+HTR-PM (-)

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It was decided that these demands can only be realized with fuel elements having Triso-coated fuel particles together with a pre-stressed concrete pressure vessel.

5. Combination of TVHTR-KKW with solar plants to desalinate sea/waste water

The production of drinking water with the following step:

- Seawater intake by pumps and pre-cleaning
- First warm up stage in the turbine condenser
- Second warmup stage by solar energy in the heat exchanger
- Final warm up by low pressure steam from the power turbine

The production of drinking water with the following step:

- The condensed water is returned to the steam generator turbine thermodynamic circuit
- The brine will be dried and can be sold
- The desalinated water will be stored in water tanks to ensure a continual production process for electricity and water is possible

Technical and economical criteria:

- The seawater is in the first warm up stage and is used as cooling water for the exhaust steam of the turbine. No cooling tower or a smaller tower may be necessary. The temperature rise may be 15 to 30 C and is only an economical question. The lower the temperature rise, the higher the efficiency of the themodynamic circuit.
- The heat production of the solar plant varies between daily and seasonal changes. In times of less heat production the quantity of exhaust low pressure steam of the turbine varies in the same degree. The unused exhaust steam will be extended into the condensor.

Technical and economical criteria:

- It is able to produce electrical energy indirectly.
- The turbine generator set is able to take part in net regulation.
- The brine, partly of high value will be dried and sold.
- The capacity range for electricity and drinking water production can be modified.

Technical and economical criteria:

- The possible capacities of the TVHTR reactors may start with 40MWth up to 100 MWth with the AVR concept. If very large capacities are required, the range of a pre-stressed concrete pressure vessel is up to greater than 3,000 MWth.
- It is possible to design power stations up to 1,200 MWel/h and more than 2,000,000 m3 drinkingwater /day using digital CAD programs.
- This combination makes it possible to operate the desalination plant continuously without interruption.

6. Summary and state of development

Compared with well known nuclear power stations, the PWR/BWR, LWR, and the TVHTR have numerous advantages:

- To substitute the fossil fuel primary energy sources, oil and gas
- All pebbles can be circulated in the reactor continiously with out interruption of operation

6. Summary and state of development

- They can be recirculated to reach maximum burn down
- The production of the pebbles can be completed at a central plant to serve many different power stations in several countries
- New fuel pebbles will only be delivered against exchange of the burned down pebbles
- Reprocessing can be done in the same facility
- The transportation from production facility to the power stations is without any nuclear risk

6. Summary and state of development

- The NPT agreement can be kept under all circumstances
- The thermodynamic circuit is much better due to the potential higher steam temperature and pressure
- A combination with solar heat is easily possible
- It is possible to convert useless Thorium to breed fissile Uranium
- This design is a thermal breeding power station with very high efficiency

Thank you for your attention!