Eleventh International Conference on the HTGR

Dimitrovgrad, 19 - 20 June 1989

THTR Commissioning and Operating Experience

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1. Introduction

The Thorium-High-Temperature Reactor THTR 300 is the prototype power plant for a medium-sized pebble bed reactor. The commissioning period up to handover of the plant to the user was marked by the following milestones which characterize the extensive and time-consuming commissioning program:

Sept 13, 1983	first criticality
Nov 16, 1985	first synchronization to power grid
Sept 23, 1986	first 100 % power operation
Juni 1, 1987	completion of nuclear trial operation and handover of the plant to the user company HKG

Until today the plant was in operation 16 410 h and has generated 2 891 068 MWh. The time availibilty has been 61 % in 1987 and 52 % in 1988.

The diagram of the previous operating history is a spike curve which is characterized by frequent power changes and several prolonged plant downtimes.

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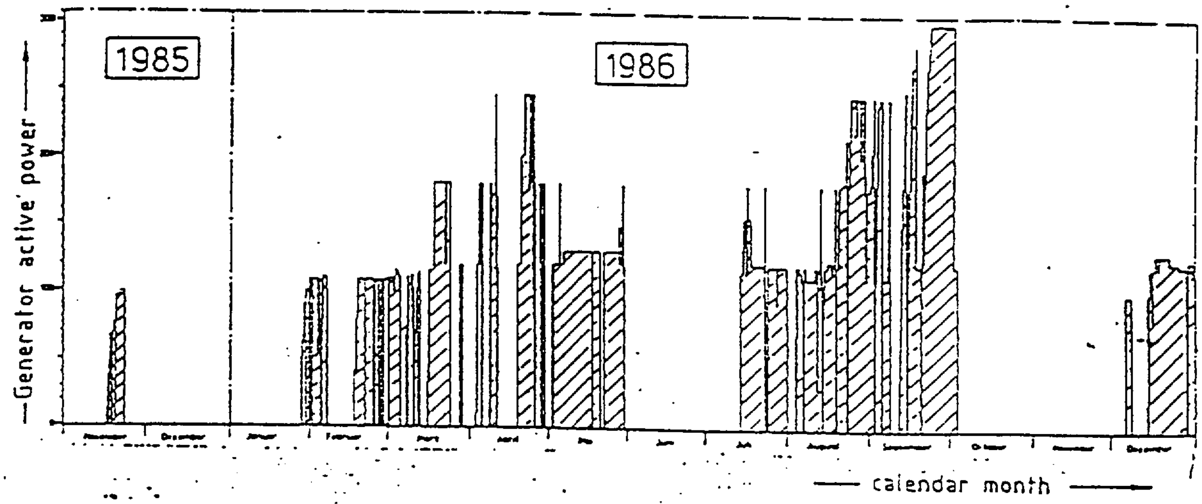
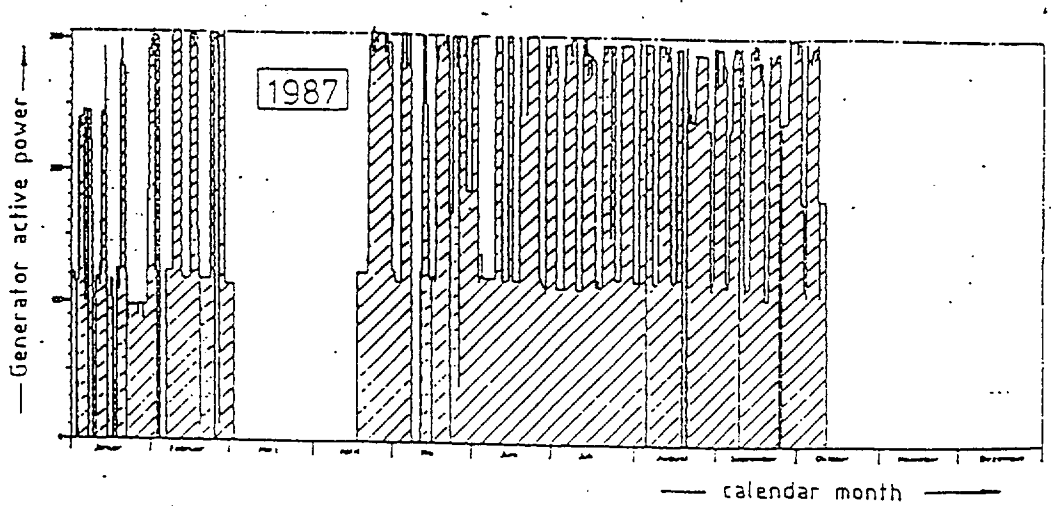
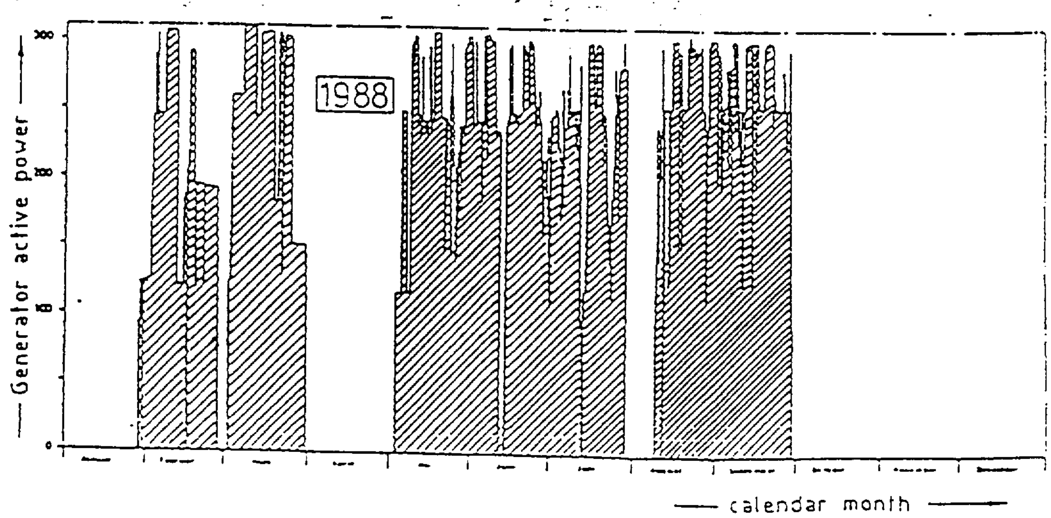
HKG THTR 300	Electric power output diagram during operating phase between Nov. 16, 1985 and Dec. 31, 1988





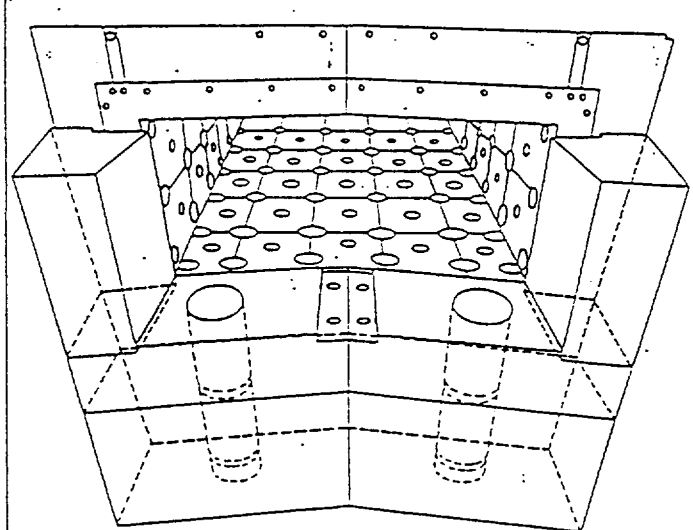


The power changes were initially caused by difficulties arising in the withdrawal of spherical elements from the reactor. In the beginning of the plant operation spheres could be withdrawn only at reduced plant power, since only with a reduced helium mass flow which is partly passed in countercurrent to the fuel element flow direction for cooling the fuel element discharge pipe, withdrawal of the spherical elements was possible. This defect was eliminated during the 1987/88 plant inspection. Further downtimes resulted from jamming of spheres in the singulizer disk of a helical damaged-spheres separator in the refuelling system and from the necessity to exchange the casks which collect the damaged spherical elements. Finally power reduction was repeatedly required in summer 1988 to keep the exhaust air temperature in those parts of the reactor hall within the permissible limits, which accommodate the components of the steam/feedwater circuit, e.g. the steam generator ring rooms. On September 29, 1988 the power plant was shut down for the scheduled 1988 inspection.

On the occasion of a routine inspection, we inspected - as a precautionary measure - a hot gas duct, the duct through which the hot helium passes from the reactor core to the steam generator. The figure shows an internal view of a hot gas duct with its rectangular passage through the graphite side reflector. The lower graphite blocks of the hot gas duct are each fixed to the respective carbon block by a graphite dowel. In the outer wall of the side reflector these dowels are positioned in bore holes penetrating the blocks. The figure shows the front part of the metallic section of the hot gas duct showing the inner insulation which consists of metal foil blankets, covered by 30 cm x 30 cm cover plates which are each held down and fixed by 4 corner bolts and 1 central bolt. After the inspection of the first duct had revealed damage on some attachment fixtures (central bolts), we decided to inspect all the 6 ducts, and it was detected that out of the approx. 2600 bolts 35 bolts heads had come off. In addition it was detected that several graphite dowels installed for holding in position the lower outer blocks of the hot gas duct had been displaced.

The damage has been thorougly analysed and the following causes have been determined: The bolt heads failed due to stresses which had concentrated in the range of the bolt head as a result of differential thermal expansion of the materials of the metal foil insulation consisting of 18 layers and the structure of the attachment fixture bolts. In addition a reduction in the material ductility as a result of thermal neutron irradiation in the temperature range above 500 °C was observed.

HKG THTR 300 | Front part of the hot gas duct



After thorough analyses we and the plant supplier have jointly come to the result that further operation of the THTR 300 is justified in spite of the existing damage.

Since the damage is essentially concentrated on the central bolts, the thermal insulation in the metal part of the hot gas duct is held down by the corner bolts as before. Thus the functional capability of the thermal insulation is safely ensured also in the present situation. In case that parts of the insulation were detached afterall, this would be detected by the operational monitoring of the process parameters mass flow and pressure loss. We have, however, the intention to observe the situation in future by inspecting the hot gas ducts in shorter intervals.

During the overall operation until shutdown of the power plant on September 29, 1988 for the 1988 inspection the plant has generated 2 891 068 MWh. For generating this electrical gross output the plant had to be operated for 423 full power days including the commissioning period.

In the following the main results of the plant operation are presented.

HKG THTR 300 — THTR-Operating experience

Safety-relevant conclusions

Operation

Normal operation	Shutdowns Plant outages	Inspections
Design	Shutdowns / Decay heat removal	Radiological protection data
Core dynamics	Shutdown rods	Graphite dust
Temperature distribution	Penetration isolation valves	Activity
Refueling / spheres damage	Emergency power supply	Inspection manual
Coolant gas activity		
Non-active impurities in the coolant gas		
Thermodynamics		
Measuring methods		

The evaluation of the operating data can be subdivided into three sections:

power operation,
plant downtimes including shutdown procedures, and
inspections.

From all three sections important information has been obtained which will be discussed in the paragraphs below.

2. Evaluation of Operating Experience

2.1 Design Data and Power Operation

HKG THTR 300	Comparison of measured and calculated operating data at 100 % power output on February 9, 1988		
	Unit	Measured valve	Calculated valve
Thermal power of core and internals	MW	756	755
Circulator speed	min⁻¹	5407	5380
Helium flow rate	kg/s	48,26	49,12
Feedwater flow rate	t/h	151,6	151,7
Mass flow through reheater	t/h	144,7	144,1
Hot gas temperature at SG inlet	°C	750,3	750
Cold gas temperature at SG outlet	°C	246,8	246,3
Main steam temperature	°C	534,2	535
Main steam pressure	bar (abs)	186,9	186,7
Reheat steam temperature	°C	530,6	527
Reheat steam pressure	bar (abs)	48,5	48,4
Generator active power	MW	304,3	304,3
Cooling water temperature	°C	26,7	26,5

The design data which had been specified for the THTR power operation have been confirmed by measurements during operation. This fact is not evident for a prototype plant. It shows that the theoretical bases for the design of hightemperature reactors are available. From the point of view of safety engineering the following aspects are interesting in this context:

2.1.1 Core Dynamics, Control Behaviour, Power Distribution

The core power output can be controlled at all power levels and under all core conditions without any problems. Power changes are possible in the range between 40 % and 100 % power output in any steps desired. Power changes are performed by ramps of 8 % per minute within the main operation range.

The previous operation has, on the one hand, confirmed the design values for the core and the operational and safety procedures and, on the other hand, it has verified the functional capability of the control equipment and the components of the primary and secondary system.

During power changes the electrical unit output, the main steam pressure, the main steam temperature and the cold gas temperature are controlled. The control variables for this purpose are the helium mass flow, the position of the reflector rods and the feed water quantity.

The control concept especially controls also upset operating conditions, such as the automatic power reduction to about 70 % in the event of failure of one circulator turboset, load rejection to plant auxiliary power, or turbine scram. Instabilities of the core behaviour never occur during such control porcedures, nor fluctuations of the power distributions (e.g. xenon fluctuations). The temperature coefficient of the THTR is negative in all power ranges. It is between Γ = - 12 mN/K and - 4 mN/K. For demonstrating the negative feed-back, the power and temperature curves were recorded at a thermal power of several per cent in the course of a controlled intentional "return to criticality" of the reactor. The curves showed the expected slow changes of power and temperature thus confirming the design calculations. The inherent safety of the THTR and its "good-natured" control behaviour has thus been verified experimentally.

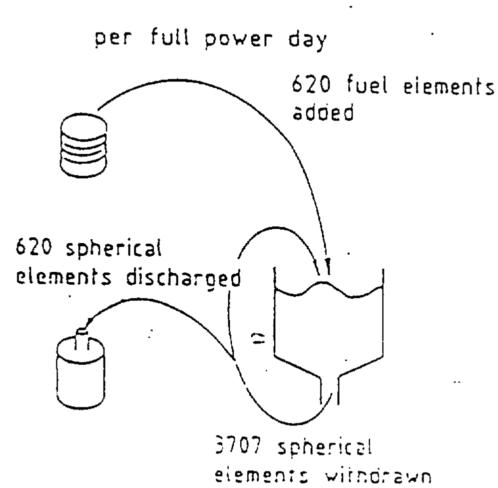
2.1.2 Temperature Distribution in the Core

The requirements for the temperature distribution in the core result from the maximum permissible temperature of the fuel elements as well as from the maximum permissible insertion depth of the incore rods, which, in turn, results from the rod temperature which must not exceed the specified design values.

The permissible fuel element temperatures can be observed without any difficulties by manoevering the incore rods and the reflector rods so as to prevent power concentration in the lower core region. Another possibility of indirect control of the permissible temperatures is obtained by monitoring the hot gas temperature in the bottom reflector. Observance of the maximum incore rod tip temperatures is more difficult. For this purpose it is necessary to perform design calculations on the temperature and power distribution in the core in parallel with the operation. During the running-in phase these distributions continously change. Due to potential uncertainties in the calculated maximum rod tip temperatures in practice conservative safety margins for the permissible insertion depth are required. This sets a limit to the possibility of using the incore rods. Due to high excess reactivities, which occur for example after prolonged plant downtimes, relatively deep insertion of the incore rods is required also during power operation. This may result in power restrictions for a limited period (approx. 2 weeks) to ensure that the maximum incore rod tip temperatures are not exceeded.

2.1.3 Refueling and Damage of Spherical Elements

HKG THTR 300 — Fuel circulating system



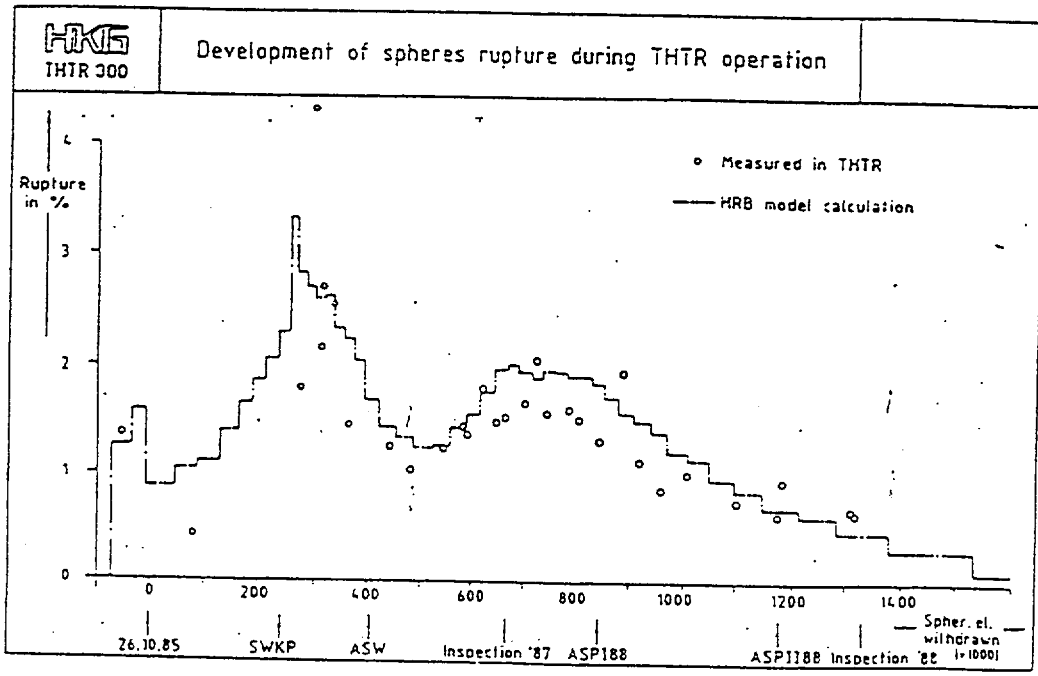
Since the beginning of refueling as a function of burn-up on October 26, 1985

248 055 Fuel elements have been added
5 200 Absorber elements have been added
1327 493 Spherical elements have been withdrawn
250 690 Spherical elements have been discharged

A special characteristic of the THTR is continuous refueling. 3707 spherical elements are withdrawn from the reactor core per full power day. 620 spherical elements are discharged from the circuit, the rest is returned into the reactor core. The 620 spherical elements withdrawn are replaced by 620 fresh fuel elements.

Up to 29.09.1988 a total of 1,3 million spherical elements from the core have been drawn off, from this figure 235 000 spherical elements taken away and replaced by a correspondant number of fresh spherical elements. Essential for the safety of reactor operation is the correct, i.e. refueling of the reactor core according to design. The spherical elements are added to the core according to a refueling strategy calculated in advance. This procedure has proven to be successful in previous refueling practice. The subsequent calculations will, however, require new reference data for calculations to actual measured values. In this aspect the calculation model can certainly be further improved, e.g. by using measured values on the flow behaviour of the spherical elements and the measured burn-up spectrum of the fuel elements discharged. The observance of the safety-relevant design data such as excess reactivity, power distribution and temperature distribution and, thus, the guaranty of the rod worths does not pose any problems. These data are continously verified experimentally and are thus ensured at any time independent of the calculations.

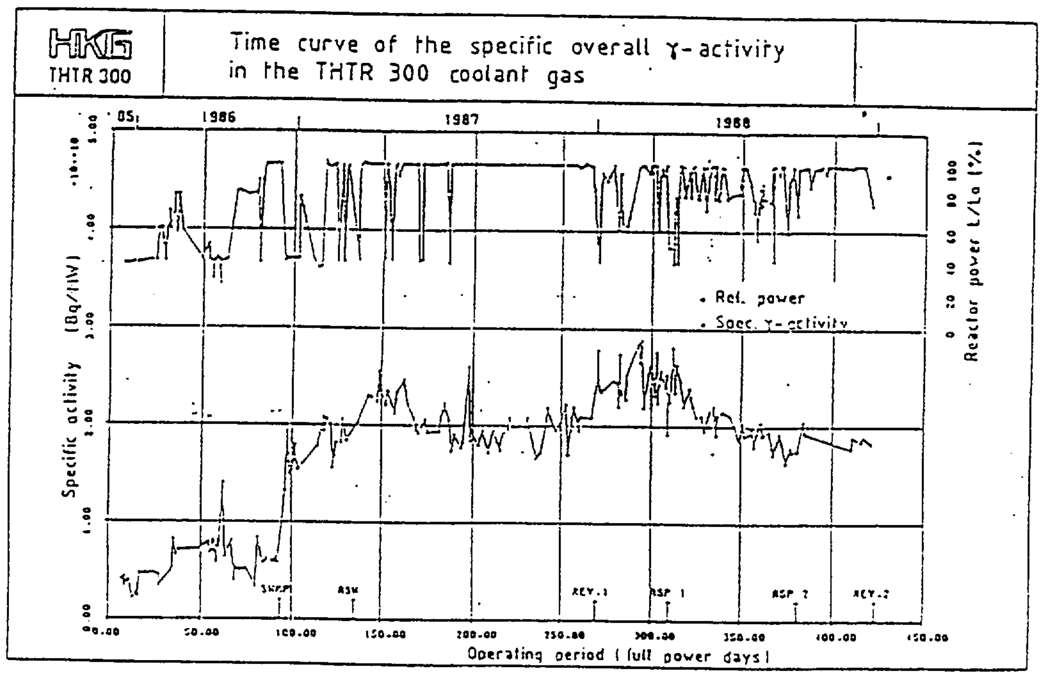
The practical performance of the refueling procedure met with some difficulties. They had no safety relevance and were eliminated as was described earlier. This applies as well to the unexpected high number of damaged sherical elements, which were sorted out by the helical scrap separator during withdrawal of the spherical elements from the reactor core. Up to the present time 10 casks have been filled with approx. 17.000 damaged spherical elements. The share of damaged spherical elements in the total amout of spherical elements withdrawn was about 1.5 % in the beginning of the refueling operation and is continously drecreasing. Recently the rate reached 0.6 %.



A model calculation was performed based on the assumption that the damage was mainly caused by frequent and deep insertion of the incore rods during the THTR commissioning phase. This assumption has been confirmed by the agreement with the experimental data. Since the damage in most cases only concerns the graphite shell in which the fuel is embedded, i.e. the coated fuel particles in the damaged fuel elements are intact in their greatest part, retention of the fission products is ensured as before. The flow behaviour of the spherical elements in the reactor core and the insertion of the incore rods is not impaired by the damaged spherical elements. Therefore the damage of spheres has no safety relevance.

Elimination of the disturbances of the process described above requires, however, a great effort, e.g. the exchange of casks for damaged spherical elements requires complete depressurization of the prestressed concrete reactor vessel. Therefore it is intended - in particular also for economic reasons - to change the mode of manoevering the incore rods so that damage of further spherical elements is reduced to a minimum, R + E work is carried out for an evaluation of the mode of spheres rupture and the mechanical behaviour of the pebble bed in order to obtain an exact analysis of all the effects occurring.

2.1.4 Coolant Gas Activity in the Primary Circuit



The coolant gas activity of the THTR does not exceed the expected values. The overall development of the coolant gas activity is shown in the figure. As had been expected, the coolant gas activity increased during the commissioning phase with increasing reactor power reaching almost constant values at continuous full power operation. It remains clearly and constantly below the design values. As for the AVR, the fission product retention capability of the fuel elements has thus been confirmed also for the THTR in power operation.

2.1.5 Non-Radioactive Impurities in the Coolant Gas

The impurities contained in the coolant gas, H_2O, CO_2, H_2 and in some rare cases also traces of O_2, which have an oxidizing effect on graphite, have removed 65 kg of carbon from the spherical elements and the graphite internals up to the present time.

This carbon quantity has to be considered in relation to the overall carbon inventory of the core which is 728 tons. The helium purification system of the THTR has been able to cope with all concentrations of impurities without any problems. The primary circuit with its auxiliary systems does not pose any problems with regard to chemical and radiochemical parameters.

HKG THTR 300 — Impurities in the THTR 300 Coolant Gas

		undisturbed	after injection of ammonia
H_2O	µbar/vpm	≤ 0,5/< 0,01	< 2/< 0,05
H_2	µbar/vpm	30 / 0,8	up to 4000/ up to 100
CH_4	µbar/vpm	4 / 0,1	up to 200/ up to 5
CO_2	µbar/vpm	8 / 0,2	
CO	µbar/vpm	16 / 0,4	
N_2	µbar/vpm	<4 /<0,1	up to 2000/ up to 50
O_2	µbar/vpm	n.n.	
Ar	µbar/vpm	n.n.	
Kr, Xe	Bq/m^3 i.N.	3×10^4	
^3H	Bq/m^3 i.N.	$5-20 \times 10^5$	
^{14}C	Bq/m^3 i.N.	100 - 300	
Aerosole	Bq/m^3 i.N.	< 100	
NH_3	µbar/vpm	n.n.	up to 3800/ up to 100

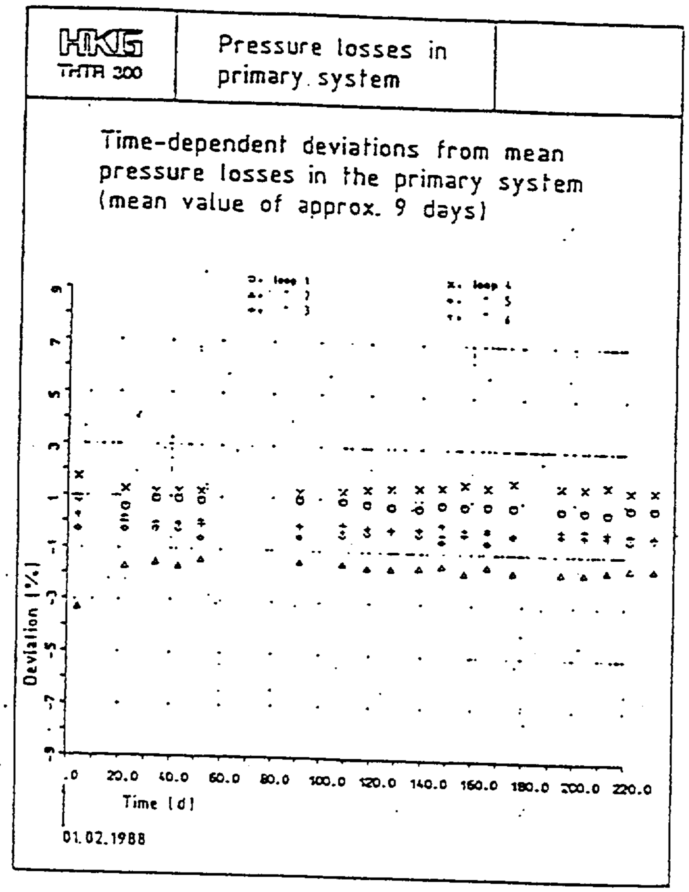
In general the impurities in the coolant gas (H_2O, H_2, CH_4, CO_2, Co und N_2) are low. During steady-state operation they sum up to a maximum of 80 µbar (= 2vpm). Only during start-up the contents of hydrogen and nitrogen may rise by NH_3 decay up to the level of a few mbar. During shutdown of the reactor ammonia is fed into the core to reduce the friction factor of the incore rods in the pebble bed core.

2.1.6 Thermodynamic Parameters of the Primary System

In addition to the operational data quoted at the beginning of this chapter, which are directly included into the power calculation, a number of additional data are measured to describe the primary system. This has shown that the bypass of the helium mass flow is higher than expected. It is defined to be being 18 % instead of 7 %, which had been expected. The core outlet temperature which has therefore to be higher by about ten per cent is below the design values for fuel elements and graphite internals even at full power operation, thus it does not pose any problems. In connection with the damage of the attachment fixtures of the hot gas duct insulation reference should briefly be made to another group of thermodynamic data of the primary system. Apart from the temperatures, these are the helium mass flows and the pressure losses of the 6 steam generator/circulator units. These data are continuously recorded and evaluated in the THTR. In addition, derived values such as e.g. the pressure loss coefficients are continuously determined.

These values are observed, on the one hand as mean values of all the six steam generator/circulator units for detecting uniform changes in all the 6 hot gas ducts and, on the other hand, they are evaluated as relative deviations from the mean value for determining irregular changes in individual hot gas ducts.

Evaluations performed during the latest year of operation have shown that changes of the above-mentioned data in the primary system are detectable with an accuracy of 1 %.



These statements show that in addition to the measured values for the reactor core itself also the thermodynamic data of the primary system are stable and reproduceable. Therefore safety-relevant changes which may occur can be detected safely and early enough. Thus it is demonstrated that the design has been confirmed and that the components such as e.g. the helium circulator and the steam generator have proven their functional capability.

2.1.7 Measuring Methods

Another condition for safe plant operation is the correct acquisition and reliable processing of all the measured values required for plant safety and plant operation. The instrumentation concept of the THTR - including the elimination of incore instrumentation - and the practical application of the measuring facilities have proved to be efficient. This applies also to the special measuring facilities necessary for a prototype plant, such as neutron flux instrumentation, temperature measurements of the metal and ceramic internals, instrumentation for measurements in the helium circulators and steam generators, spheres counting equipment and burn-up measurement facility. The information on the plant required for safety reasons has been available at any time.

2.2 Conclusions from Shutdown Procedures and Plant Downtimes

2.2.1 Shutdown Procedures, Decay Heat Removal Systems

As shown earlier in the operational diagram, the THTR has been shut down relatively frequently during the commissioning phase and the power operation. Part of the shutdown procedures were scheduled and maintenance and repair measures, especially in-service inspections. In addition, especially during the trial operation, the excitation of the two automatic shutdown procedures was repeatedly triggered by the Plant Protection System: reactor scram (11 x, 4 of them as tests during the commissioning phase) or Decay Heat Removal 45 procedure (20 x). The causes were a too narrow adjustment of the limiting values, (this was eliminated during the comissioning phase), defective instruments, errors in detail planning of release logics and operator errors. The greatest part of the releases were not required for safety reasons. In all the shutdown procedures heat removal from the core and from the internals was effected according to the design principles. Minor irregularities in the procedures were never of safety relevance and were eliminated in the course of the commissioning phase. Experience has shown up to now that the decay heat removal systems which are partly identical with operational systems have a sufficient availability, an appropriate process design, and have proven their fuctional capability in practice. In the course of the overall operating period including the shutdown procedures several hundred measuring data are being recorded and evaluated in sections by the continuously operating long-term recording program of the process computer system. The "service life consumption" of the steam generators and the associated piping amounts only a few percent. Only some solid parts which could be exchanged, have reached a life time consumption of about 10 % up to now. Assuming a "normal" further power operation, there are no restrictions or safety-relevant problems to be expected from today's point of view for a further long-term operation.

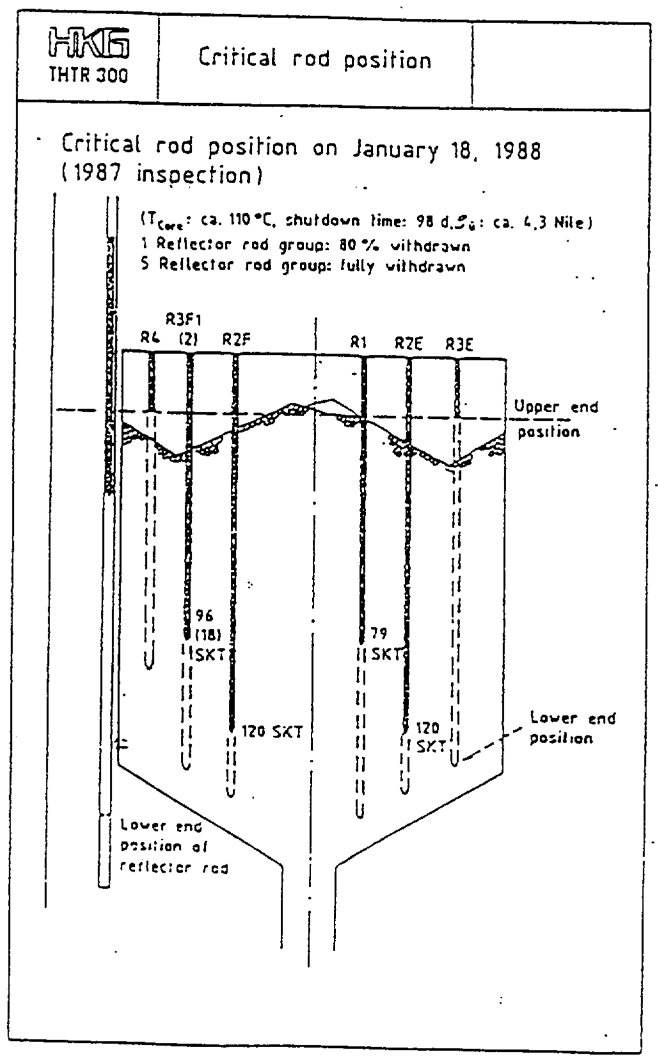
The cooldown procedure "Heat Removal 5" designed to come into action in the event of major disturbances, or the measures for resumption of heat removal after a prolonged interruption of decay heat removal (LUNWA) have not come into action up to now. Therefore it can be stated that the previous operating experience does not give rise to any new safety requirements with regard to detection of disturbances and release and sequence of cooldown procedures. It is currently being investigated, whether there is a possibility of simplifying the excitation logics of the Plant Protection System and improving the sequence of the cooldown procedures. The use of the absorber rods could be reduced, as will be demonstrated in the section below.

2.2.2 Shutdown Systems

The THTR ist equipped with two independent shutdown systems, the reflector rods (6 groups of 6 rods each) and the incore rods (7 groups of 6 rods each). Four reflector rod groups represent the shutdown system, the incore rods are inserted for long-term shutdown. In order to ensure sufficient subcriticality, it was claimed that during the running-in phase in the event of reactor scram in addition to the reflector rods a group of incore rods (group R3E) should be automatically inserted by the long-stroke pistion drive.

This claim has proven to be unnecessary at an early date, since it has been demonstrated during the commissioning phase on the occasion of scram tests from power operation that the reactor is still subcritical after 30 minutes by insertion of the reflector rod shutdown groups alone without additional insertion of the incore rod group and that the reactor remaine subcritical over the period of xenon build-up. This situation is maintained even under the most adverse conditions by definition (start-up after prolonged standstill, no xenon, low helium temperature). The claim for automatic insertion of an incore rod group in the event of reactor scram can therefore be eliminated.

For automatic long-term shutdown it was envisaged to insert all the 42 incore rods to their lower end position. Also for these conditions it has been repeatedly demonstrated that the measures for long-term shutdown of the reactor need not be applied to the extent originally envisaged. Even with the boundary conditions of maximum excess reactivity, low helium temperature, long-term subcriticality after prolonged operation, i.e. with full protactinium conversion, it is sufficient to insert 4 incore rod groups to a depth about 1 m above the lower end position. The figure below shows as an example the critical rod position after the 1987 Inspection.



The long-term shutdown system was designed too conservatively so that it is overdimensioned. For this reason the incore rods are only inserted in that number and depth which is required for safety reasons to ensure sufficient subcriticality during prolonged plant downtimes. Since the incore rods have to be considered to be the cause of the increased rate of damaged spherical elements, it is expected that this measure will result in a marked reduction of spheres damage.

From a process design aspect the incore rods and the reflector rods have proven to be efficient safety systems. The dropping times of the reflector rods corresponded to the design values, the insertion times and insertion depths of the incore rods when automatically inserted by the long-stroke pistons have ensured subcriticality of the reactor at any time.

2.2.3 Penetration Isolation System

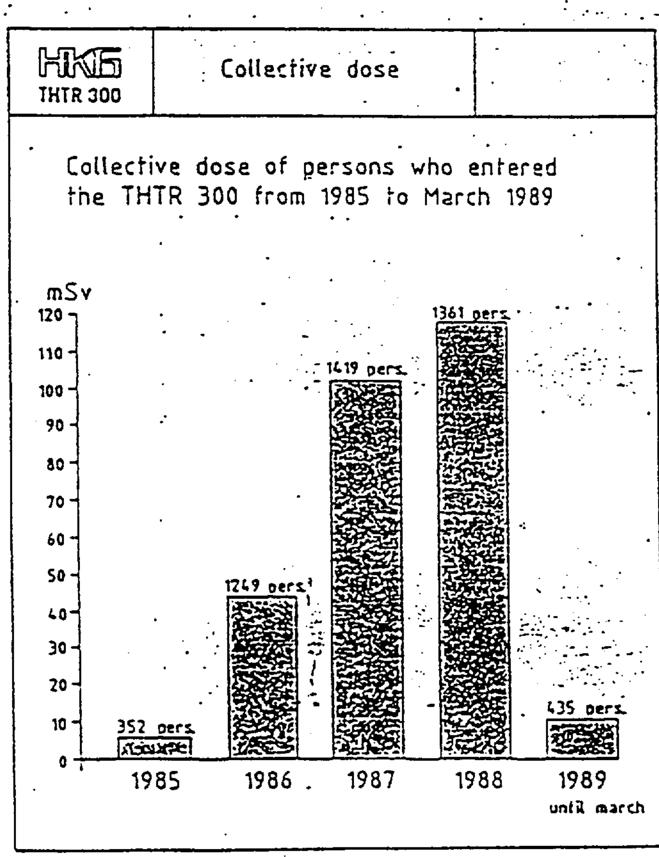
The penetration isolation system consists of shut-off valves equipped with diverse drive systems. Each pipe penetrating the PCRV and carrying primary gas is shut off by these valves to ensure activity confinement. Each line is equipped with two valves which close in case of demand upon excitation by the Plant Protection System. In the course of the THTR operation no disturbances have occurred up to now which would have required an activation of the penetration isolation system. Modifications or backfitting of these active engineered safety systems has not become necessary as a result of the previous operation.

2.2.4 Emergency Power Supply

The only case of emergency power supply occurred in the beginning of the commissioning phase. It was initiated by the attempt to switch over the electrical feed water pump form a supply line to a redundant line within approximately 1 second. This resulted in shutdown of the supplying transformer. This distrubance gave rise to several modifications of details, optimizations and definitions of process design. In principle, however, the concept for detection and activation of the emergency power supply system has been confirmed.

2.3 Inspections

2.3.1 Radiological Protection Data Referring to Plant Personnel



Radiation exposure of the THTR plan personnel is very low. The radiation exposure values for the previous operating period are indicated in the figure. The data demonstrate that the plant concept with a prestressen concrete reactor vessel has proven to be successful.

This fact applies also to the conditions prevailing in the event of maintenance or repair work on components of the primary. By using special disassembly facilities and tools and observance of the sequences of work planned in detail, these activities can be carried out with a low collective as well as single dose. When in April 1988 repair work on one of the helical damaged-spheres separators of the fuel circulating system had to be performed, the overall collective dose was 2.71 mSv and the maximum single doses were less than 0.2 mSv. We assume that such favorable values can be maintained also in future.

2.3.2 Graphite Dust

It has been detected on piping carrying primary gas and on components disassembled from the primary system that surfaces of components which are part of the helium circuits and the fuel circulation system are contaminated by radioactive graphite dust (mass deposition about 1 mg/cm^2). The specific activity of the dust was determined to be 2×10^8 Bq/g at a maximum. It is mainly caused by the radionuclides Co-60, Nb/Zr-95, Hf-181 und Pa 233. The overall quantitiy of graphite dust detected corresponds to the expected weigth loss of the spherical elements during circulation by abrasion. Under the aspect of radiological protection it does not pose any problems for disassembly work. The only effects of the graphite dust on the operation of systems were noticed in the beginning of the commissioning phase, when individual moisture sensors in the moisture monitoring system of the steam generators failed. This source of failure was eliminated by installing simple dust filters upstream the sensors. It can thus be stated that the graphite dust does not pose any problems, neither with regard to operation nor to safety.

Measurements on piping carrying primary gas have shown that also in the event of a depressurization accident the graphite dust does not cause an increased release of activity.

2.3.3 Activity Release with Vent Air

HKG THTR 300 — Activity release

Activity release with exhaust air 1988

	Release in Bq	Licensed annual limit value in Bq	Release in % of annual limit value
Inert gases	2,504 E11	6,66 E14	6,037 %
Aerosols	8,968 E07	3,7 E08	24,2 %
Jodine	1,086 E07	3,7 E08	2,9 %
H3-Control area	3,471 E12	8,14 E12	42,8 %
C 14	2,682 E10	7,4 E12	0,36 %

The activity release with vent air measured in 1988 is presented in the figure. It was no problem during power operation to remain below the low limiting values specified in the THTR license, because at that time only minor repair work was performed on components of the helium circuit.

To reduce the release of radioactive aerosols to the environment, i.e. the release of activity carried by graphite dust, it has proved necessary in the course of the commissioning phase to provide all exhaust paths with filters. This has been done and has proved to be a successful solution.

Contrary to normal operating conditions, during inspections the PCRV is often depressurized and open to perform some work on integrated components. To maintain a specified flow direction, the PCRV is kept under a slightly negative pressure during the performance of the above-mentioned repair work. For this purpose a small partial quantity of the helium inventory is withdrawn from the PCRV and released to the atmosphere with the vent air. Since the graphite internals still contain tritium after depressurization, which in case of moisture enters the gas phase via exchange reactions, the gas mixture withdrawn form the PCRV has to be passed through catalysers and a molecular sieve before it is released to the atmosphere. By this measure it is ensured that even in the event of complete ventilation of the PCRV no safety problems will arise.

3. Experience Expected form Further Operation of the THTR-300

A further operation of the THTR-300 is expected to furnish essential know-how in addition to the present operating experience and would thus allow to come to a valuable completion of the research contract. It is especially expected by us that it will be possible to extend and confirm by experiments the know-how on core design, spheres damage rate, and the activity release from the spheres.

Another objective is the verification of the long-term performance of the prototype components. The hot gas duct is an example which is significant at the present moment, but also the long-term behaviour of other prototype components such as shutdown rods, PCRV and graphite internals is of great interest.

A further task which could be persued during a further operation of the THTR is the development of disassembly and repair equipment for the components installed within the PCRV. The previous operation has demonstrated that the problem of accessiblity is of utmost importance to the operating company and that the development of disassembly equipment is urgently required. In our opinion it is another task of a prototype to verify the easy repairability of High-Temperature Reactors.

For initiating these tasks it is, however, necessary to obtain a new definition of the financial basis for the THTR-300 project.

4. The Risk Participation Contract and Covering of Financial Risks

As early as in 1971 the partners cooperating in the THTR-300 project had realized that because of the prototype character of the THTR-300 and the research objectives pursued with this reactor it would not be possible to achieve a commercial operation of the plant from the very beginning. For this reason a risk participation contract was negotiated and concluded already at the beginnig of the project earmarking a liability sum of DM 450 million to cover the economic risks of the plant operation and the decommissioning risks of the plant operation and the decommissioning costs. Two thirds of this sum was furnished by the Federal Government and one third by the Federal State Government of North Rhine Westphalia. DM 270 million are reserved for compensating losses from plant operation, and DM 180 million are presently envisaged for decommissioning of the plant.

It is further stipulated in the contract that during the first 3 years 10 % of the operating deficit is covered by the HKG partners and 90 % is furnished form the sum guarranteed in the risk participation contract.

After three years the share assumend by the HKG partners increases to 30 %. Since the latest up-dating of the risk participation contract in 1983 the costs of decommissioning (dismantlement) of the plan have increased compared to the costs earmarked in the risk participation contract. Based on an expert opinion the costs of dismantlement of the plant, quoted at DM 180 million in the existing risk participation contract, have now increased to about DM 450 million.

As a result of new risks affecting the THTR-300 project from external sources, which might result in plant outages, the HKG partners are of the opinion that the guaranteed sum of DM 450 million is not sufficient. All these new risks came up in concrete form late in 1988.

In the following they will be briefly characterized:

Risk of Standstill due to Fuel Element Supply Problems

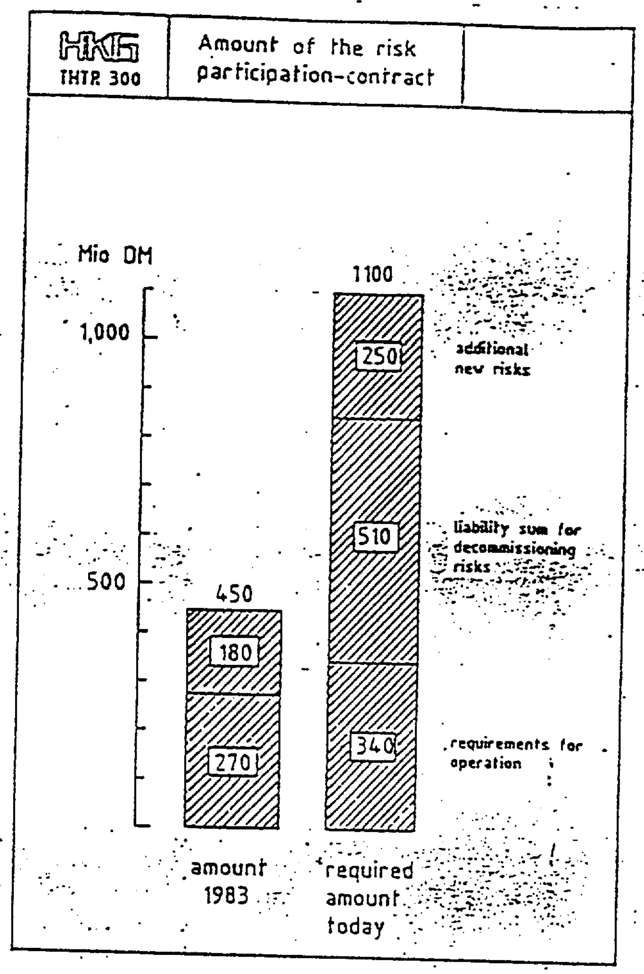
The fuel elements for the THTR-300 fabricated by NUKEM up to the present time are sufficient for an operating period until end 1991. On December 31, 1988 NUKEM terminated the fabrication of the spherical fuel elements. Continuation of the fuel element fabrication in due time is currently not ensured.

Risk of Standstill due to Fuel Element Disposal Problems

It is claimed in the operating license for the THTR-300 that it has to be given evidence at the end of 600 full power days, this would be some time early in 1990, that external intermediate storage facilities for the spent fuel elements are available and that the license has been obtained for the transport preparation hall for storing low-activity waste on the THTR plant site. Both conditions have not yet been met at the present time.

Risk of Standstill due to Problems Regarding the Permanent Operating License

The present operating license for the THTR-300 covers 1100 full power days, i.e. it will expire in mid 1992. The subsequent permanent operating license requires another licensing procedure. At the moment it cannot be predicted which will be the requirements and criteria of this licensing procedure. In any case there is a high probability that the competent nuclear licensing authority will perform a detailed safety investigation before granting a license for further plant operation. In view of this situation the HKG partners have asked the partners of the risk participation contract to increase the contractual amount guaranteed to DM 1.1 billion. In evaluating the increase of the sum guaranteed it has to be emphasized that it is intended to cover a financial risk which must not occur with certainty. If for example a further operation of the THTR-300 at an availability of 70.4 % was possible within a long-term program, the sum guaranteed would be claimed only to a maximum of DM 340 million.



The figure shows the individual items of the risk participation contract and the increase considered necessary by the HKG partners.

5. Summary

The evaluation of the operating experience gained from the THTR up to now comes to an absolutely positive result. The principal design data have been confirmed.

The THTR-300 represents the successful connection link between the 15 MW_{el} AVR experimental reactor and a future commercial plant. On the basis of the present know-how obtained from the THTR operation another optimized high-temperature reactor can be designed and constructed thus representing a further step towards commercialization of advanced reactors.

It is evident that the necessity to increase the risk participation contract does not arise from safety considerations but exclusively from economic factors affecting the THTR from outside.