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CONTENTS

INTRODUCTION

In order to be in phase with the progress reports of the R & D division of KEMA (in Dutch language) it was decided to change over from quarterly reports on the suspension reactor project to semiannual reports on this subject too.
The present report covers the period April 1 through September 30, 1976.
In this period the energy production of the KSTR was rather small, due to problems with the inventory determinations and an unaccountable decrease of the critical temperature at power operation.
Several hypotheses have been put forward to explain the phenomena observed, but not anyone has been proven yet.

I KSTR OPERATION

I.1 *Results of experiments with the KSTR*

The energy production in this period was rather small. The total energy produced increased from 83.3 to 100.6 MWh. This was effectuated during two runs, in June and August respectively. The reason for this small increase is the continuing problem with the fuel inventory. At the start of critical operation of the KSTR there was 29.3 kg Th-U-oxide available in the storage vessel. This was reduced to 28.4 kg at the beginning of this period. Since this is hardly tolerable for safety reasons, an extensive search programme for the missing fuel was started:
the weighing device of the storage vessel was tested, system pipes were X-rayed and scanned with a γ-spectrometer. No sediments of fuel could be traced by anyone of these methods, only in the homogenizer GJ-20 of the sampling bypass a few fuel knobs were detected again. However, two parts of the main system were difficult to control, viz. the components situated inside the pressure vessel and the main suspension pump.
In Mai permission was obtained for a critical run under moderate condition: outlet temperature max. 235°C (normal 255°C), a relatively high pressure and a maximum power of 500 kW. Special attention had to be paid on the core vessel wall temperatures in order to detect eventual hot spots in time.
Critical operation started on the 3rd of June. On the first day the power was maintained at about 50 kW, then the power was raised to 150 kW.

This phase also lasted one day, after which the power was increased to 450 kW. During the 50 kW and the 150 kW stage the critical temperature decreased slowly (1.3°C and 2.8°C, respectively). This could partly be explained by Xe-135 poisoning. Then the temperature decrease was compensated by increasing the suspension concentration.
During the 450 kW period (3hrs) the critical temperature decreased faster (total decrease 11°C), and the flow in the sampling bypass was blocked, causing an additional drop in the critical temperature of 10°C. After shut down and after rinsing the sampling loop, the amount of fuel weighed in the storage vessel was 27.7 kg.
During the critical periods there was no indication of hot spots on the core vessel wall.
In July it appeared from fuel samples that the density of the fuel was decreased to 9.0 g/cm^3. Freshly prepared fuel has a density of 10.3 g/cm^3. This means that the amount of water displaced in the storage vessel by 28 kg of fuel has been increased with 0.4 kg. Therefore, the actual amount of fuel in the storage vessel was not 27.7 but 28.1 kg.
Now critical operation was permitted again, with the same conditions as in the previous run.
The aim of the next run was to investigate the origin of the temperature decrease at critical operation. The sampling by pass was closed by freeze plugs, so that settling of fuel in that part of the system was impossible. In order to detect a possible change of the "hold-up" of fuel in the core, due to a change in the setting velocity of the suspension particles, every three hours the flow rate in the main loop was increased by 15% during half an hour, while measuring the critical temperature.
The decrease of the critical temperature is a measure for the hold-up. This decrease has to be compared with the results of previous measurements.

The history of this run resembled the one in June. So there was little or no decrease of the critical temperature at 50 kW, a decrease of 4°C during the 150 kW period (one day) and a faster decrease at 320 kW (9°C total).
After 5.5 hours at 320 kW the power was reduced to 60 kW and lower. During the two following days there was no significant increase in critical temperature, which would be normal due to the decay of Xe-135. On the contrary, there was a steady decrease of about 8°C. Also in this run no hot spots were detected on the core vessel wall, and no significant change in the hold-up was measured. The amount of fuel weighed in the storage vessel just after this run was 26.4 kg. The decrease in weight was in fair agreement with the temperature decrease.
After the run a water sample was taken to analize the amount of the isotope I-132. This isotope is formed as a daughter of the fission product Te-132. Because the soluble isotope I-132 ($t_{\frac{1}{2}}$ = 2.3 h) has a much shorter halflife than the insoluble isotope Te-132 ($t_{\frac{1}{2}}$ = 78 h), it is possible to use I-132 as a tracer for active fuel, that remains in the main system after the collection of fuel in the storage vessel. It was found that an amount of 700 grams possibly remains in the main system.
The most probable explanation for the phenomena mentioned above seems to be that the fuel tends to settle somewhere inside the pressure vessel (most probably at the gas inlet on top of the reactor core). Other possible explanations are: a failure of the weighing device, a decrease in the density of the fuel causing a decrease in the hold-up of fuel in the core, or an adherence of gas bubbles onto the fuel particles.

I.2 Instrumental performance

I.2.1 Modifications of electric instruments and additional reactor instruments

In the ventilation systems of the reactor hall and the hot lab modifications were carried out to prevent that the underpressure might become too large in case the gas supply for the pneumatic control valves should fail. Especially when the reactor is out of operation and the staff is not on duty, this too large underpressure could led to damage of the building. Now a pressure control switch and additive micro switches for valve position indication turn off the ventilation system when the gas supply fails.

A new safety alarm has been introduced for too large temperature differences on the wall of the reactor vessel. If this alarm is tripped ($\Delta T = 30^{\circ}C$) the reactor has to be shut down.

As a consequence of troubles with the communication system between the rooms of the KSTR building the old intercom system was replaced by a new one.

I.2.2 Maintenance and repairs

Again some solenoid valves in the Y-compartiment had to be repaired due to gas leakage in that compartment.

The phase angle meter in the electric power supply lines of the main suspension pump, which forms part of the emergency stop, has been recalibrated as a function of the frequency.

Because there was no change with respect to the calibrations made before, it might be concluded that there was no extravagant erosion in the pump house or fan.

In the main compartment a coil of the safety rod mechanism had to be repaired. It appeared that a clable was pinched off in the proximity of the driving gear. The reparation could be done on spot because the radiation level was relatively low, and the reparation took only 10 minutes.

During the hollidays when the reactor was out of operation the lead accumulator for emergency power supply was tested and checked on capacity. All the 100 cell's appeared to be in good condition.

In the primary cooling system an orific plate was installed to check the turbine flow meter for the main flow during operation.

To get more indications for the fuel inventory some radiation detectors were mounted near the main suspension loop during the reactor stop.
As usually the normal routine maintenance and reparation of small disturbances were carried out.

I.2.3 Mechanical performance

No remarkable work has been done during this period.

I.2.4 Remaining construction and modifications

Tools to remove the gas injection section have been designed. Also the script for such an operation has been made. It appeared that no insuparable problems have to be expected.

II PHYSICS

A study will be carried out by the IAEA in Vienna on the status and prospects of thermal breeders. A part of the study will be done by the IIASA in the last quarter of this year. It will be a strategy study with the purpose to check the need of thermal breeder reactors in the future. At this point the reactor physics department of KEMA will assist the IIASA.

In the framework of this study some calculations were made in addition to the work already done for the 250 MWe design report.
First the computer programmes were adapted. The existing programmes FUELPART and POISPART were joined together to one programme SUSVER, so that now an alternate use of the fuel and poisoning part is possible, instead of running one part for a certain time with a constant influence of the other part, and reversed.
However, the original programmes can be run separately by keeping the input concentrations from the other part constant.
Test calculations showed a good agreement with the calculations for the design report.

Calculations made for 400 g/l and 800 g/l suspensions showed a saturation of the conversion ratio at a value of 1.04.
The calculations were performed for a suspension temperature of 300°C, a core to total volume ratio of 1:5, a constant Th concentration, and a contineous fission products purification of 1/300 of the inventory per day.

The cross-sections (input for SUSVER) were re-evaluated with the programmes GAM and SATAN. Some resonance integrals and 2200 m/s cross-sections were updated from BNL-325 (1973 issue, vol. 1).
A report of these calculations is in preparation.

III CHEMISTRY

III.1 Fuel irradiation

A. Irradation at high temperature

Also during this period no post-irradation work of the LISA-3 and LISA-4 capsules could be performed, because much work had to be done with respect to the KSTR.

B. Hotlab

1. Investigation of the KSTR-samples

Seven samples have been taken. Some of the results are mentioned in the following table.

Table I

Sample	conc. (gM/1) at 225°C	pH	electr. conductance (μS)	Settling velocity (mm/sec)	Remarks
L118	< 2	8.2	25.5		Water sample to determine the quantity of fines
L119	165	8.5	15.4	1.2^{5}	These samples have about the same circulation time.
L120	222				
L121	< 2				Water sample, to determine the quantity of fines
L122	142	8.3	16.6	1.3	
L123					No measurements have been carried yet
L124					Water sample for γ-spectrometry determinations

The quantities of solid material, determined in the water samples L118 and L121 showed, that the amount of fines in the water of the KSTR is negligible.
The quantities of uranium and thorium, dissolved during the usual etching procedure are given in table II.

Table II

Sample	L114	L115	L116	L120	
% uranium dissolved	4.0	25.9	3.3	23.3	(with respect to the amount of uranium and thorium in the fuel particles)
% thorium dissolved	4.2	25.6	3.3	21.8	

Remarkable are the high values of samples L115 and L120.
The quantities of erosion/corrosion products, adsorbed onto the surface of the fuel of sample L115 were small (see quarterly report of the first quarter of 1976).
In this case the etchants can react more easily with uranium and thorium of the fuel spheres. This may explain the high values of dissolved uranium and thorium.
The quantities of erosion/corrosion products adsorbed onto the fuel particles of the L120 sample are not known yet.
Pictures made by means of the scanning electron microscope showed, that the greater part of the fuel particles became angular.

2. Examination of the knobs, isolated from GJ-20.
By means of out of pile autoclave experiments, it was tried to find the conditions necessary to form knobs or depositions with channels, formed during boiling.

These experiments have been performed in an autoclave with a heated spiral in the suspension. This spiral has a high heat flux. The autoclave contains an aqueous suspension of fuel particles and hydroxides of uranium, thorium, iron, chromium and nickel at 250°C (with different pH values). Some thin depositions with small gaps were formed on the spiral. It is not clear, whether these gaps were formed by boiling of the water in the proximity of the spiral.

3. Density determinations of the KSTR-fuel.
Some determinations by means of a pyknometer have been performed.

Sample	L 77	L 89	L110	L119	L122
Density (gr/cm^3)	9.65	9.54	9.27	9.00	9.00

It appeares, that the density decreases and this decrease is lineareIy proportinal to the number of circulation hours of the suspension in the KSTR.

III.2 General services

III.2.1 The analytical group S.B.A. carried out a number of analyses of samples taken for various studies related to the suspension reactor project.
Though the number of samples gradually decreases, their handling becomes increasingly complicated. This is due to the increasing radioactivity, associated with the higher fuel burn up.

Consequently, the following number of analyses give an underestimation with respect to the amount of labour involved. The number of analyses performed during the present period are:

	2nd quarter	3rd quarter	sum
Operation KSTR	26	58	84
Fuel research	18	13	31
Sol-gel research	12	5	17
Supporting	22	21	43
	78	97	175

III.2.2 Electron microscopy

A number of heating wires were examined. The wires were used in the investigation on how the formation of the knobs in the homogenizer GL-20 of the KSTR sampling loop takes place.

In this period only four samples of KSTR fuel (13 specimen) were investigated with the Transmission Electron Microscope (TEM) and the Scanning Electron Microscope (SEM). The examinations with SEM give only little information in addition to the investigations by TEM.

IV TECHNOLOGY

In this period no work on the suspension reactor project has been reported by the Technological department.

V SAFETY

V.1 Summary

Only during two short periods, in the course of June and August, experiments at power took place. The main problems from safety view point were the uncertainty in the fuel balance and the indications from the performance of the reactor, that fuel was segregating from the suspension circulation.
Each time the risk had to be considered that the fuel should return uncontrolled in the main loop. Though additional evidence was found to explain deficiences in the balance to a certain extent, no final argument could be found to exclude the possibility of local deposition of fuel particles somewhere in the system. Therefore, the possibility was considered to open the main system of the reactor in order to locate the stagnant fuel and to gain more insight into the phenomena through which deposition takes place.

V.2 Safety of KSTR operation

V.2.1 Experiments and procedures

In the present period the safety related work on the KSTR mainly was concentrated in attempts to locate and to retrieve the fuel, that seemed to have segregated from the main circulation system. Both from the fall in operating temperature at power and because of the lower indication of the weight measurement of the collecting vessel, after the extraction of the fuel into that vessel, it was concluded that some 1000 grams of fuel did not partake anymore in the reactor process, neither could be extracted from the system after shut down.

As this amount of fuel could not have escaped from the completely closed system, it had to be accepted that the fuel was immobilised somewhere inside this system.
Many attemps were undertaken to cause remobilisation of the stagnant fuel.
Moreover, the possible consequences of a sudden re-introduction of fuel for temperature, pressure and power had been calculated before (see Safety Report of the KSTR). The results were within all safety limits.

The weak points, however, were that practically no fuel had been detected in any of the parts of the system that were checked, and that the process of segragation from the main stream was not known. Probably, there might be a connection with the detectable occurence of radiolysis and with the formation of the fuel modules of 1 - 3 mm diameter, that again and again blocked the sampling line.
It must also be remarked that not all parts of the main system could be checked on depositions of fuel, and that especially in the pressure vessel fuel could have settled inside the system without possibilities to detect it there.

As mentioned before, the reactor was brought to power again after the normal procedures for the restoration of containment - leaktightness and for the check of safety functions.
The operation at power up to 450 kW was completely regular.
However, once at sub-critical operation a reactivity addition of about 200 pcm has occurred during about 10 seconds, after which an additional amount of fuel of 350 grams was weighed in the storage vessel at the end of the run.

During the rise of reactivity (flux level) no deviations of temperature and pressure occurred.

After the first run (June) a routine check was performed on the radioactivity content of the gases in the compartments. In the M-compartment the amount of ^{131}I proved to have increased to a significant higher level (the gas sample contained about 1 - 2 mCi/m^3 of this isotope).

The cause of this activity probably was the leakage of some of the flanges in the main system, during one of the attempts to remobilize the stagnant fuel by short pressure- and temperature-pulses. The suspected flanges were checked later on after the opening of the compartment; the bolts of these flanges were tightened. The leakage did not occur again, but it was considered safe to increase the frequency of the sampling of the compartment contents.

As a result of the measurements on the density of the fuel in the suspension samples that were taken regularly, it was discovered that this density had diminished from 10.3 (measured value at the start) to about 9.0 gcm^{-3}. This could account for about 400 g in the fuel balance, as weighed in the collecting vessel.

The run in August again presented the characteristics mentioned before, which resulted in the termination of the run.
The newly discovered effect of the changing density may account for part of the measured deficiency in fuel, but the introduction of this effect without quantitive information during the operation of the reactor, adds another factor of uncertainty to the fuel inventory.

During subcritical operation at low multiplication (M= 130) a scram occurred when suddenly the reactivity increased and criticality occurred (peak: 500 kW, integrated power: 0.15 MWsec). This phenomenon followed immediately after the opening of a secondary valve in the main system, and did not prove to be reproducible. No safety limits were surpassed; all safeguards did operate satisfactorily. A report is in preparation.

V.2.2 Quality of systems

After a period of operation the M-compartment was opened again for the reasons given below.
The following points are worthwhile to be mentioned with respect to quality.

a. inside the M-compartment

The first reason for opening of the M-compartment was an abnormal behaviour of the signal of one safety rod. Inspection revealed that an electric cable for the lifting coil was slightly damaged by rubbing during movement due to the small available space.
Correction of the cable movement was carried out by the instrument section.

The second reason for opening was a small increase of the compartment activity, presumably due to leaking water or gas through one of the flanges. Inspection by tissue activity measurement revealed that the flange of the gas separator must have been leaking for short periods during operational temperature transients. These transients were willingly carried out during the search for non circulating fuel.

As a normal procedure the compartment closures were tested on leaktightness after closing. The leak rates were within the accepted values.

b. <u>outside the compartment</u>

The HK-17 blower which circulates compartment gas for O_2-inleak measurements was improved to better leak rate values. This was necessary as the acceptable limits for leaktightness against the active compartment gas were decreased.
As the leak rate increases slightly during operation a second unit has been ordered with selected fabrication quality for the parts in order to achieve a more constant and acceptable leak rate.

V.2.3 Radiological safety

The normal routine controls on surface and air contaminations in the laboratories and the reactor building were carried out. No unexpected high contaminations were found.
Examination of the gas samples taken from the compartment at the end of the run in June, showed that the activity of iodine 131 was higher than normal. It was assumed that thermoshocks could be the cause of the leakage of some flanges.
It was agreed that during following runs thermoshocks should be avoided, and gas samples should be taken from the compartments during power operation.

The analyses of the samples during the run in August showed normal concentrations of noble gas and iodine. At the end of the run the KSTR was cooled down slowly and the gas samples showed no higher concentrations than normal.

The total radiation dose to the personnel of the nuclear laboratory was 21.3 manrem. A classification of the doses is given in the following table.

Radiation dose to the personnel of the nuclear laboratory, second quarter and July and August 1976 (including assistance at power plants)	
Dose (mrem)	Number of persons
0 - 100	163
101 - 300	25
301 - 500	11
501 - 1000	5
1001 - 1500	4
> 1500	0

V.2.4 Radioactivity discharges

The total activity released to the Rhine river in the second quarter and July and August 1976 was less than 27.4 mCi β-equivalent. The discharge limit given in the license is 20 mCi per month. Radioactivity released to the atmosphere via the ventilation stack amounted to less than 22.7 Ci noble gases, 0.2 mCi I-131,

0.5 mCi other halogens and 2.9 μCi particulate material.
The release limits given in the license are 1000 Ci, 20 mCi, 80 mCi and 80 mCi per year, respectively.

V.2.5 External contacts

On the 24th of May a meeting was held with some members of the governmental "Begeleidings Commissie" to discuss the results of the experiments in January and February and the attempts to recover the amount of fuel, that since then was missing from the fuel inventory. The Commission agreed to resume operation at power under the condition, that special attention should be paid to the temperatures of the wall of the reactor vessel. This was motivated by the consideration that the missing fuel could be stagnant on the inner surface of the vessel, and during power operation could cause unacceptable heating of the vessel wall.
During the runs in June and August special attention was paid to these temperature measurements, but no abnormal behaviour was found.

VI WORKING PROGRAMME SUSPENSION REACTOR PROJECT

From the working programme activities the following points are going on:

- KSTR activities for the finalising of the normal programme. At the moment the not understood reduction of the weight of fuel still disturbes the programme. Further details on this point are given in other chapters of this report.
- the strategy studies in coöperation with the IIASA have been started.
- the importance of the total programme for the near future has been subject of an internal discussion. Final discussions on this point are pending.

LIST OF REPORTS

B 115/76	A. Stortelers Inventarisatie Materialen in MS en GPS
B 116/76	J. Matteman Mechanisch onderhoud in M en G tijdens splijtstof zoeken
B 117/76	A. Stortelers Inventarisatie Materialen in FDSS en WPS
B 118/76	D. Peters Mechanisch onderhoud Y-compartiment KSTR-stop febr.-apr. 1976
B 119/76	G. Selleger Behandeling van het MS water met fosforzuur en verwerking van het water d.m.v. het WPS
Ch 179/76	G.J. Zondervan Onderzoek natuurlijk mengoxyde (UO_2/ThO_2= 25/75)
Ch 180/76	J. Kanij; F. Janssen Mogelijkheden van ESCA (Electron Spectroscopy for Chemical Analysis) en Gc-MS (Gaschromatography - Mass Spectrometry) t.b.v. onderzoek binnen de divisie
Ch 181/76	J. Kanij Experimenten met de geautomatiseerde oveninstallatie
Ch 182/76	J. Kanij; F. Janssen Onderzoek aan sol-gel processen
RCG 88/76	J.H.C. v.d. Veer Groepsverslag splijtstof zoeken M-comp.
RCG 89/76	A. Thus Veegproefmonsters uit M-compartiment
RCG 90/76	W. v.d. Broeke Resultaten van run 23, na het splijtstof overbrengen

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RCG 91/76	W. v.d. Broeke Resultaten van de subkritieke metingen in run 24
RCG 92/76	J.H.C. v.d. Veer Groepsverslag splijtstof zoeken M-compartiment
RCG 93/76	J.H.C. v.d. Veer Analyse van de fluctuaties in de reactorvat temperaturen; Het stromingsmodel van de KSTR
RCG 94/76	W. v.d. Broeke Resultaten van de experimenten in run 25
RCG 95/76	J.J. Veerman (examenopdracht - praktikant) Het ijken en werken met een (Ge(Li)) gamma-straling spectrometer
T 252/76	A. Thus Nieuwe referentie per 76-05-06 voor de weeginrichting van MV-10 (dit memo vervangt B 97/76)
T 253/76	C. Rietman Lekmeting met N_2 overdruk in de compartimenten van de KSTR
T 256/76	A. Spruyt Andere mogelijkheden voor kringloop met lage buitensysteemconcentratie
T 258/76	A. Spruyt Nadere analyse van de mogelijke oorzaken van het "verdwijnen" van splijtstof
T 262/76	C. Rietman Lekmetingen met N_2-overdruk in het M-compartiment

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