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Report in Part

Pebble Flow Experimental Results Review

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Visit of the NRC-Delegation to Germany
Mo 23. to Th. 26. July 2001

January 2001

Topic:
Safety Aspects of HTR Technology

Report Number: FZJ–ISR–RC–5025/2001
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1 Flow behaviour dependence on relevant parameters

1.1 Preliminary Remarks

1.2 Filling Height of the Core

Fig.4 gives a survey of many experimental investigations, which show the transition times of first and last (99%) test balls vs. H/D - ratio (5). In this figure only experiments were considered, where the core models had a bottom with simulated cooling gas holes like THTR. This bottom roughness affects the flow behaviour, as explained in detail in chapter 1.4. The former investigations, reported in (1) to (4), were performed mainly in models with a bottom with smooth surface; this explains the differences between the results in Fig.4 and the earlier investigations just below H/D = 1.

The values in Fig.4 at H/D - ratios >2 were taken from model experiments with 3,4 or 6 outlets in the bottom, and the H/D - ratio was calculated in regard of the region of one outlet by multiplying the filling height H of the model with the number of outlets. This is a simplification, so these values in Fig.4 should be considered as an estimation of the influence of H/D on the flow behaviour.

The results of an INTERATOM experiment with a 1:6 model of the HTR - Modul (H/D = 3.1, see Fig.4) show a more even pebble bed flow than the values calculated from the multiple outlet experiments. If the Modul model had a smooth bottom without any roughness caused by cooling gas holes, the difference can be easily explained, as pointed out above. Otherwise the calculation of H/D from the multiple outlet experiments may be to pessimistic.

The H/D - ratio of the PO - core is marked in Fig.4.

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2 Mixing of Pebbles between Inner and Outer Zone

2.1 Mixing of Pebbles of the Inner and Outer Zone due to Loading Process

2.2 Mixing of Pebbles of the Inner and Outer Zone by Interchange during Flow

Early experiments, performed in 1970 with the glass pebble model, are shown in Fig. 13 and 14. The glass pebble model was filled with glass pebbles in an immersion liquid, which had an index of refraction like glass. So the model became transparent, and the the flow lines of aluminum test balls give a visual impression of mixing during flow (10).

Fig. 15 gives the result of an experiment in a 1:6 model of the THTR, filled with graphite pebbles. Colored test balls were introduced into the pebble bed surface at 11 positions after every step of 2.5 % circulated core volume (Vc). After circulation so long, that the entire core contained test balls, the core pebbles were removed layer by layer using a vacuum cleaner and the test ball postions were recorded (11).

2.3 Conclusions from the Review of Pebble Mixing

Looking to the experimental results reported in chapter 2.1 and 2.2, the amount of mixing during loading predominates the mixing during flow.

This must not be so at the PO - reactor, because the outer and inner loading cones have the same height and therefore the possibility of the transition of fuel elements from one to the other zone will be reduced, compared to THTR (Fig.17).

The mixing area will depend also on the number of loading tubes in the outer zone, as shown in Fig.17. The lower the number of outer charging tubes is, the more the circle between inner and outer zone degenerates to a serpentine, increasing the mixing. Fig.17 shows the situation in the PO - reactor with 6 and 9 loading tubes outside.

3 Angle of Inclination of the Loading Cones in Dependence on relevant Parameters (Friction Coefficient, Pebble Density, Dropping Speed)

The first measurements of the cone inclination dependence on the density of the pebble material were reported in (1). The cone inclination varied from 29 ° (Graphite, $\gamma = 1.6$ g/cm) to 20.5 ° (Steel, $\gamma = 7.8$ g/cm).

Because these experiments were performed with a dropping speed near zero, the results are not representative for reactor conditions, where the dropping speed will be much higher, according to a height of fall of about 1m.

Further model experiments with more realistic loading conditions, regarding the dropping speed, are reported in (5) and shown in Fig.18. These experiments concerned mainly the influence of the friction coefficient, the material density varied only by a factor of 2. Looking to these experimental results, a loading cone inclination angle of 25° - 26° can be expected.

4 Flow Lines

Fig.15 shows also the flow lines of the THTR. In this figure is marked the vertical part of the flow lines, 40 pebble diameters.

From this measure in Fig.15 the curved part of flow lines near the core bottom can be calculated to about 35 pebble diameters or 2.10 m.

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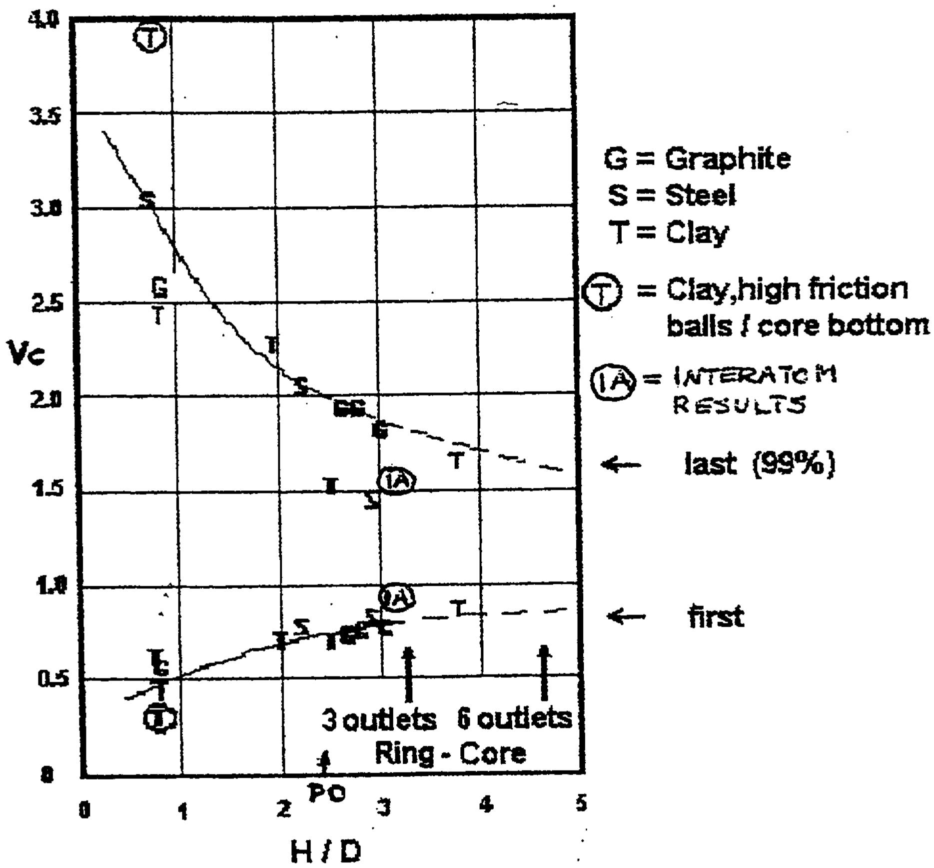

Fig.4 Transition Times of Pebbles through the Core vs. H / D

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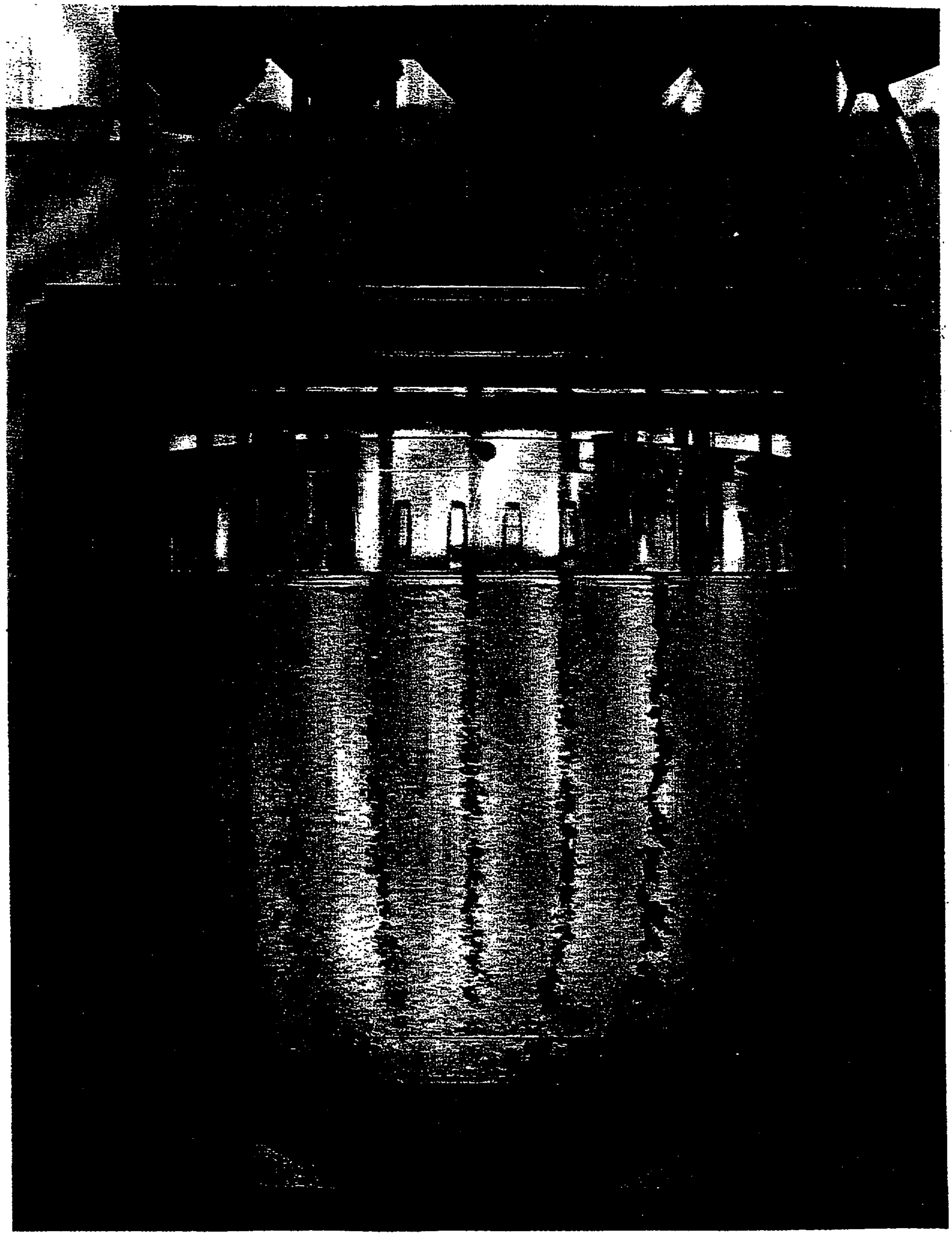
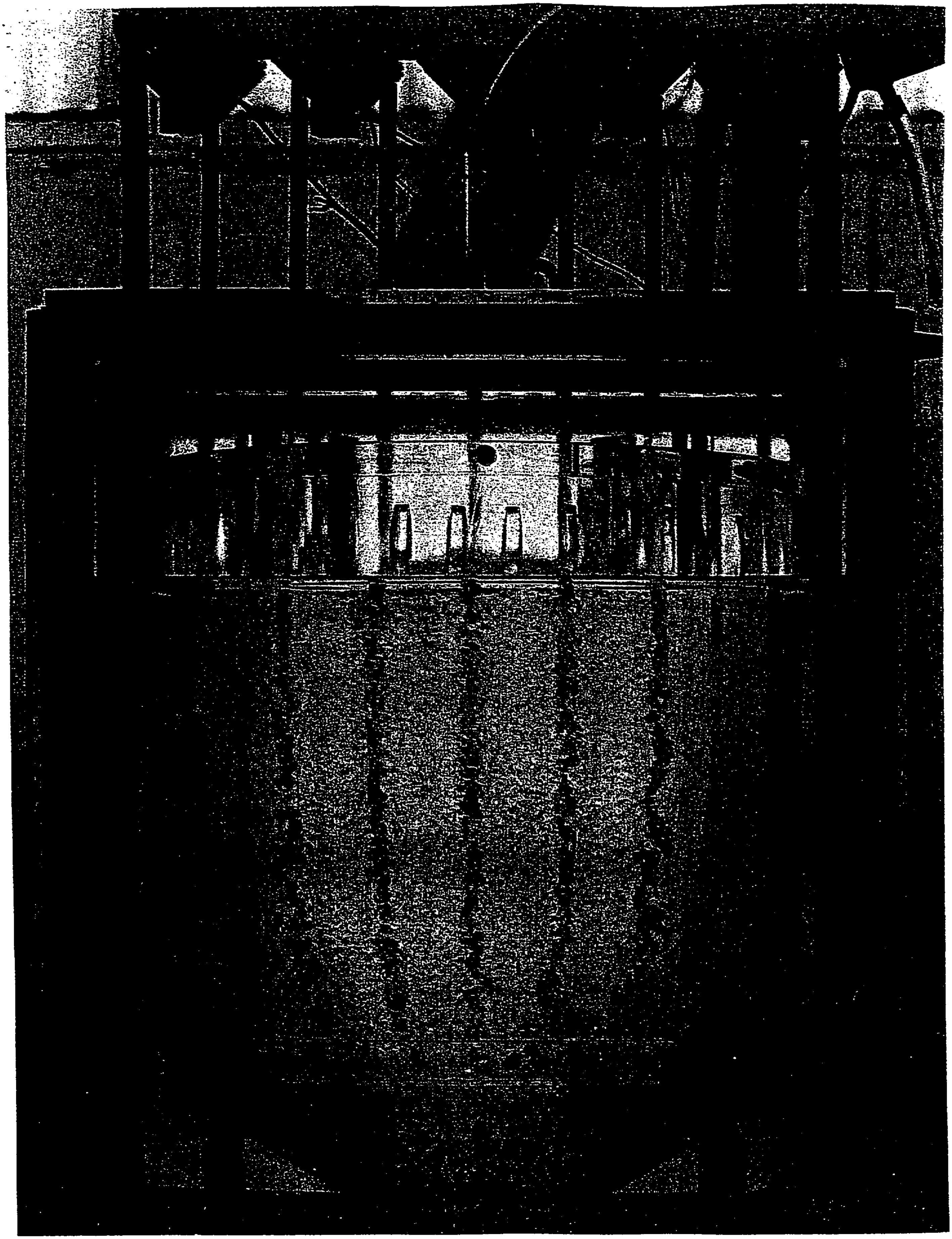
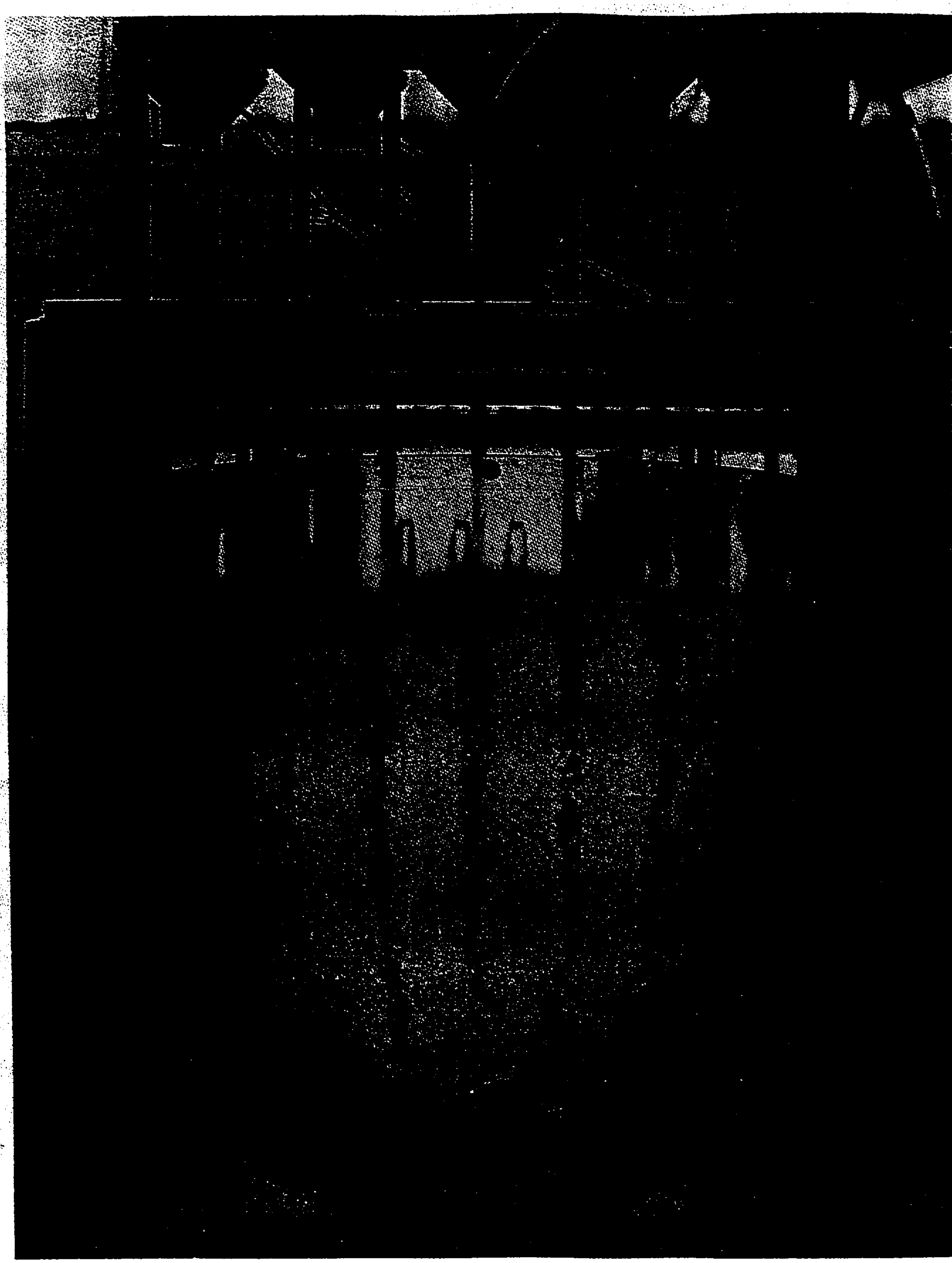


Fig.14 Flow lines of Test Balls in the Glass Pebble Model of AVR



Flow lines of Test Balls in the Glass Pebble Model of AVR



Flow lines of Test Balls in the Glass Pebble Model of AVR

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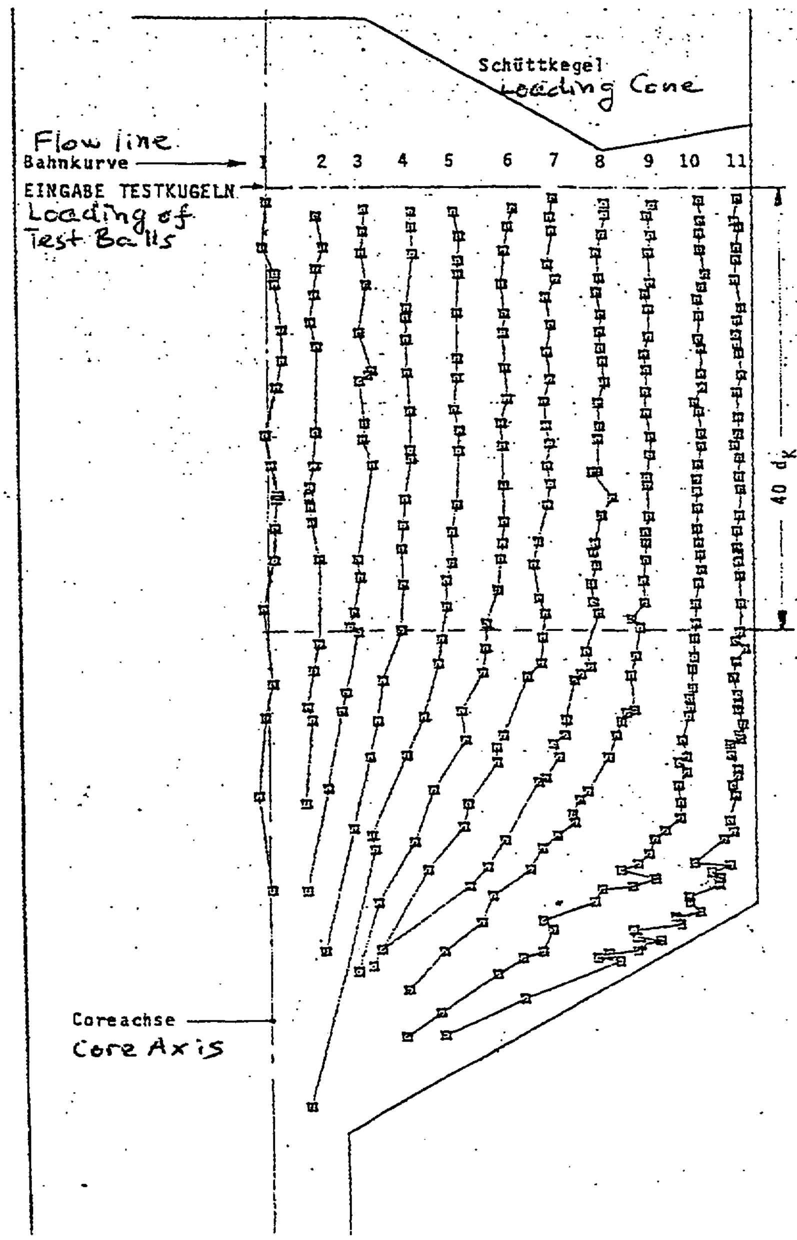

Fig.15 Flow Lines of Test Balls in 1:6 Model of THTR

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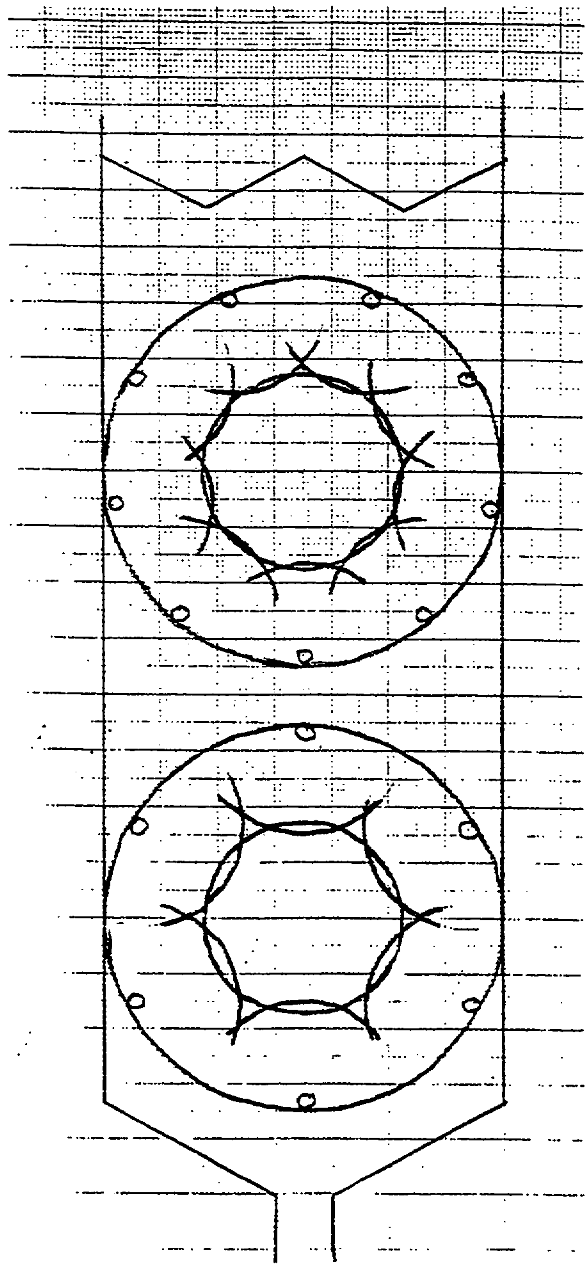

Fig.17 Geometry of PO - Core with Two Arrangements of Loading Tubes