TEMPERATURES IN THE AVR: THE UNDERSTOOD SURPRISE

As is well known, the melt-wire experiment in the AVR of 1986 revealed unusually high temperatures in that reactor. Although they came as a surprise, it was soon clear why they occurred. As will be shown here, they were special to the AVR design and operation, and any allusions that temperatures in pebble bed reactors in general were uncertain are without a basis.

The first reason for the high AVR temperatures is connected to the reactor's two-zone core with a higher fuel concentration in the outer core compared to that in the inner one. The difference in the fuel concentrations was exaggerated during the continuous fuelling due to an insufficient cooperation between the theoretical and practical reactor physics staff. This could easily have been avoided.

The second, more important, reason is the helium bypass flow through the 4 shut-down-rod guiding boreholes in the graphite roses drawing away coolant from passing the pebble bed. The significance of this bypass, intended to cool the rods, has been underestimated by the AVR designer and been more or less forgotten about by the operator. This latter was furthered by the tricky circumstance with AVR that the bypass helium was mixed to the coolant before this reached the various thermocouples in the core ceiling structure. Of these, the most important were the replaceable ones in the radially oriented temp. measuring lances at the upper edge of the core ceiling structure, at 2 different core angles. Each of these lances contained 18 to 20 thermocouples in an area-weighted arrangement. The effect of the bypass manifests clearly when comparing radial temp. profiles as indicated by both lances on one side and by the melt-wire pebbles on the other. Starting from the core axis, the melt-wire pebbles indicate a strong temp. rise (reflecting the enhanced fuel concentration of the outer core) before the temperatures drop towards the side reflector. The thermocouples in the lances do not show this rise but a pointed drop to the sides. The temp. indications of the innermost thermocouples are about the same as those of the innermost melt-wire pebbles. Further out, the thermocouples show much lower temperatures than the melt wires.
There can be no doubt that, if the bypass helium had been guided further upward and been let out, e.g., in the void below the steam generator, the thermocouples would have indicated values much closer to the real core coolant outlet temp. and in the temp. rise of 1974 the real "950°C" been achieved at a fairly higher coolant flow.

The thermocouple lances, in the same experimental tubes that also housed the Vampyr experiments, were posthumously installed, makeshift solutions after the thermocouples in the core ceiling structure had failed. AVR never had a reliable measurement for the average hot coolant temperature. This is why it was later determined thermodynamically by inputting the steam generator power, the coolant inlet temp., the helium pressure and the circulator speed. But the circulators also fed into the bypass, so it is clear that the result could not be correct until the bypass had joined in again.

Modern pebble bed designs will use an array of lances with replaceable thermocouples pointing into the hot coolant collection chamber which will allow a perfect measurement of the temperature. And on the basis of the coolant temp. it is very simple and straightforward to calculate fuel temperatures, a great advantage of the pebble bed.

The 2-dimensional computer model of the AVR, AVR-80, predicted in principal a similar temp. profile as shown by the melt wires, only at lower temperatures. The model did not consider the bypass. Here again, an insufficient computer modelling of the AVR cannot be attributed to the pebble bed system as such.

And, finally, allusions that the high temperatures in the AVR could have been the result of random hot spots in the pebble bed are pure speculations. The melt-wire experiment showed a regular temperature pattern in azimuthal direction. Pebbles with all wires molten were obtained from all 4 inter-nose sections of the outer core.

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