From: Donald Carlson
To: Chatterton, Margaret; Shoop, Undine; Ulses, Anthony
Date: Thu, Jun 28, 2001 5:49 PM
Subject: Pebble Bed Issues

Undine, Muffet, Tony, et al,

I really look forward to discussing some PBMR issues with you. The attached e-mails provide a preview.

In particular, I suspect you will be interested in the issues of (a) no in-core instrumentation and (b) in-core thermal hot spots and the gross non-uniformity of the radial coolant outlet temperature distribution. The first issue happens to relate fairly directly to the work I did a long time ago in Germany and the second would seem to bode serious trouble in terms of the resulting engineering and materials issues, if not so much safety per se.

In the attachments, I allude to the AVR test data that showed the existence of coolant hot spots >1280 C with a nominal average outlet temperature of 950 C. My bottom line is that I am very skeptical about both the familiar "reflector nose" explanation of the AVR test results and the South African design team's claim that the maximum PBMR fuel operating temperature is only 1060 C with a nominal average outlet temperature of 900 C. I suspect the actual maximum fuel temperatures under normal PBMR operating conditions may be as high as 1300 or even 1400 C.

[Fortunately, initial hot spots will have little effect on the maximum temperatures reached in the bounding depressurized loss-of-forced-cooling conduction cooldown events, because it takes a few days for the hottest fuel temperatures reach maximum (<1600 C, or so they claim) during which time any fine structure in the initial fuel temperature distributions is largely smeared away. So the real safety-related issues would have more to do with the slightly degraded fuel particle performance over time at higher operating temperatures and greater release of the silver from the fuel pebbles, a fission product that tends to diffuse through intact particle coatings at operating temperatures and ultimately plate out in the gas turbine, fuel handling system, etc.]

Anyway, it gets worse: What I think may really exacerbate the operating-temperature problems beyond what was apparently shown in the AVR tests, or perhaps dominate them, is the PBMR's tall annular core with its central region of graphite moderator/reflector pebbles (which look exactly like fuel pebbles). Note that (1) the viscosity of helium increases with temperature and (2) the design uses downward helium flow. Especially helium viscosity but also thermal buoyancy will tend to make the central reflector region the coolant flow path of least resistance. This will presumably result in outlet temperatures from the central "reflector" region being much lower than those from the annular core region, which the AVR results suggest are themselves far from uniform. So what we may really have here is nothing at all like a uniform 900 C outlet temperature, but rather an outlet flow with very large radial and azimuthal temperature variations, perhaps on the order of plus or minus 200 C or more.

This would then give rise to questions about thermal-expansion-fatigue-related materials problems and about flow mixing in the lower plenum and the potential for propagation of hotter/colder flow strata or streamlets thru the cross duct and into the helium turbine. But here we are getting into technical disciplines that are a bit foreign to a neutronics type like me...

By the way, it occurs to me that a possible design solution might be to have two sizes of graphite pebbles in the central reflector region - say 2-cm-diameter pebbles in addition to the standard ones (6 cm). The smaller ones would tend to fill the interstices and thus reduce bed porosity and increase flow resistance in the central region. But then maybe the smaller graphite pebbles would tend to mix into the annular core region more than the bigger ones; who knows? Anyway, I haven't seen any mention of this or any other design fixes in what little conceptual design information we have been able to find about the South African PBMR or the MIT-INEEL MPBR.

I think it might be very useful if we could briefly put our heads together on these and other potential issues

before Undine, Amy, Stu, and I go talk with the experts in Germany next month. What do you think? Who else on the NRC staff do you think we should include in these kinds of discussions?

Sorry for rambling. I look forward to talking with you.

Don
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CC: Boyd, Christopher; Caruso, Ralph; Cubbage, Amy; Flack, John; Jackson, Diane; King, Thomas; Rosenthal, Jack; Rubin, Stuart; Wilson, Jerry