June 25, 2001

MEMORANDUM TO: Ashok C. Thadani, Director
Office of Nuclear Regulatory Research

FROM: Thomas L. King, Director /RA/
Division of Risk Analysis & Applications

SUBJECT: SUMMARY OF JUNE 8, 2001, MEETING WITH NII ON UK EXPERIENCE WITH HIGH TEMPERATURE GAS REACTORS

At my request, Dr. Peter Storey (NII) arranged or a one day meeting with NII staff to discuss experience in the UK with high temperature gas reactors. A list of attendees is in Attachment 1. The meeting was intended to gather information which may be of relevance to our preapplication review of the PBMR, as discussed in the PBMR preapplication review plan (SECY-01-0070). The meeting was held in Manchester, UK, on June 8, 2001, following the CSNI PRG meeting in Paris on June 5-6, 2001.

The meeting focused on experience and lessons learned from the operation of 14 Advanced Gas Reactors (AGRs) in the UK. Although the AGRs do not use coated fuel particles (they use conventional fuel pins with stainless steel clad), they are graphite moderated, CO_2 cooled, with core inlet and outlet temperatures of approximately 330°c and 650°c, respectively. They have steel lined concrete RPVs and no containment building. Key points from the meeting are summarized below. The NII representatives also offered to make their experts available for followup discussions, if we so desire.

- Graphite Behavior:

  – There is no standard for graphite manufacture that assures uniform properties. Properties (e.g., density, thermal conductivity, strength, etc.) and impurities can vary depending on the feed material and fabrication process used. The NII noted that the IAEA is compiling a graphite data base document and strongly suggested a standard for nuclear grade graphite be considered. A copy of a paper summarizing basic graphite manufacture processes, properties, variances and suggested elements for a standard was handed out at the meeting (Attachment 2).

  – As a followup to the meeting, Mark Bassett committed to provide us with information on graphite properties (e.g., thermal conductivity, thermal expansion, dimensional changes under irradiation, etc.) This will be in the form of an instruction manual used in the UK for a course on graphite. I should receive the material by July 6, 2001, and will distribute copies.

- Graphite, under irradiation, initially shrinks radially (as carbon atoms are displaced into voids in the graphite structure by neutron collisions). Axially there is an incubation period, then the graphite begins to grow. Since the graphite blocks have a flux gradient across them, the growth is uneven causing the blocks to take a bowed shape. The growth is also temperature dependent. The bowing can cause distortions in holes designed for control rod insertion, cause gaps to open up between blocks (which redistributes gas flow in the core and reflector) and can also cause stress which lead to graphite cracking (a potential structural integrity concern).

- At a point called "turnaround", the initial radial shrinkage will stop and radial expansion will start. At this point graphite is expanding radially and axially and starts to lose strength and becomes very susceptible to wear due to rubbing (e.g., pebbles against the reflector blocks). This point is a good "rule of thumb" for the end of life of graphite. In the UK, samples of graphite are required to be taken, roughly every 3 years, and a plant specific evaluation of the graphite condition assessed.

- <u>Safety Considerations</u>:

  - Air ingress accidents were highlighted as an area of concern that should receive careful attention. Such accidents could arise from vessel failure or pipe/penetration failure allowing air to enter. Graphite will start to oxidize at approximately 400°c and the rate of reaction is affected by impurities in the graphite and its porosity, as well as the temperature and amount of air present. The time at which air ingress occurs is also important. If air is present after the graphite heats up (from decay heat following a depressurization accident) the graphite oxidation will become self sustaining at approximately 550^{C}c (called runaway oxidation) and continue as long as there is a source of air, regardless of cooling. AGRs prevent air ingress in the design with a system to bleed CO_2 into the RPV to keep air out upon a depressurization accident (i.e., largest RPV penetration failure) .

  - There will be coolant leaks from the primary system. At the places where the leaks occur, the structural material will see the full coolant temperature. Therefore the design should account for this potential.

  - Graphite dust will circulate with the coolant and collect in stagnent areas. Depending on its activation, which is dependent upon its impurities, it could cause maintenance and personnel dose problems.

The meeting was very useful as an overview of potential issues and is an example of good cooperation with our foreign counterparts, illustrating the benefit of keeping current our international contacts through participation in activities such as CSNI.

Attachments: 1. List of Attendees
2. Paper on Graphite

cc: R. Zimmerman
R. Barrett

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ATTACHMENT 1

NII Staff in Attendance on June 8, 2001

Peter Storey, Director Nuclear Safety Research

William W. Ascroft-Hutton, HM Superitendent Inspector of Nuclear Installations

J. L. Summers, HM Principal Inspector Nuclear Installations

Mark Bassett, HM Principal Inspector of Nuclear Installations

Dr. M. El-Shanawany

L. P.Harrop, Principal Inspector

James Murray