Notes from a Side Meeting at Petten, NL, on
Potential NRC Cooperation with the European Commission's HTR-N Project

Don Carlson, RES

On Thursday, April 25, Don Carlson (RES) met with Dominique Hittner (Framatome ANP) and Werner von Lensa of Forschungszentrum Jülich (FZJ) for a 4-hour discussion focusing primarily on the European Commission's (EC's) HTR-N project: Reactor Physics and Fuel Cycle Studies. Dr. Hittner chairs the overall HTR-TN (high temperature reactor - technology network) program and Dr. von Lensa leads the HTR-N project within HTR-TN. The stated objectives of HTR-N are "to validate codes for calculating HTR core physics, to assess the feasibility of different types of core and fuel cycle concepts, and to assess the potential of HTR for solving the main waste issues." Dr. von Lensa provided a one-page diagram of the HTR-N activities that is included in the other attachments to the Petten trip report. Additional information on HTR-N is available in the attachments to the NRC staff's summary of the April 19, 2002, meeting with Dominique Hittner and Georges van Goethem at NRC headquarters. Significant HTR-N activities to-date include the coordination and reporting of European participation in the HTTR and HTR-10 neutronics benchmarks through the International Atomic Energy Agency's Fifth Cooperative Research Project on HTGRs (CRP-5).

Much of the 4-hour meeting at Petten focused on the thirteen HTGR nuclear analysis issues described in three sections of the NRC's Advanced Reactors Research Plan. A 4-page summary of those issues was given to Dr. Hittner on April 19 and to Dr. von Lensa during the April 25 meeting and is included among the other attachments to the Petten trip report. To those thirteen NRC issues, Dr. Carlson added two more issues related to HTGR nuclear analysis: (i) an evaluation of how fuel performance is affected by fission product decay and other changes during the time intervals been irradiation and out-of-pile accident testing of TRISO fuels, and (ii) a thorough analysis of the claim that, while the shipped volume of spent fuel elements from HTGRs may be more than ten times that from LWRs, the total decay heat and, hence, the required volume in a geologic repository is less for HTGR fuel than for LWR fuel used to generate the same amount of electrical energy.

Following are selected highlights from the meeting discussions:

1. Drs. Hittner and von Lensa expressed particular interest in having HTR-N address, with NRC, a series of scoping calculations on the time evolution of postulated reactivity and power transients as well as a basis for defining credible design basis and beyond design basis power transients in selected modular HTGR designs. It was noted that any definition of design basis and beyond design basis power transient events should be pursued in close coordination with the new HTR-L activities on licensing safety analysis.

2. Dr. Hittner reiterated his request for NRC assistance in obtaining operating data, event reports, and waste data from the Fort Saint Vrain (FSV) reactor, a request he first made the previous week during a visit to NRC headquarters. NRC/RES has since initiated a project with Oak Ridge National Laboratory to help the staff gather the FSV data of interest.

3. Dr. von Lensa identified Heinz Werner of FZJ as being able to provide comprehensive information about Germany's past work on several NRC nuclear analysis issues concerning pebble bed reactors. Such issues include (a) the analytical evaluation and treatment of pebble-to-pebble variations of fission power and decay power density; (b) the existing database of radiochemical assays of fission product and actinide inventories in irradiated low-enriched HTGR fuels, as would be needed for code validation in the analysis of core neutronics, decay heat sources, and burnup credit for spent fuel criticality safety; (c) the past analyses of bounding and licensing-basis reactivity and power transients for the German HTR-Modul design; and (d) the evaluation of radionuclide decay during the time intervals between irradiation and out-of-pile accident testing of TRISO fuels. Werner Schenk of FZJ was also identified as a source of information on the last issue.

4. Dr. von Lensa expressed interest in expanding the scope of HTR-N to include NRC-identified nuclear analysis issues in the areas of waste management and material safeguards and security. He noted that this type of activity, which would address such issues as material control and accounting, burnup credit analysis for spent fuel criticality safety evaluations, and decay heat analysis for geologic disposal of spent fuel, would likely find more political acceptance in Germany than any HTR-N activities toward the development or licensing of new reactors.

5. There was mutual interest in conducting a cooperative analysis of the claim that, while the shipped volume of spent fuel may be more than ten times that from LWRs, the total decay heat, and, hence, the required volume in a repository is less for HTGR fuel than for LWR fuel used to generate the same usable energy. It was noted that studies on decay heat and associated transport and repository volume requirements should address several different HTGR fuel design types and disposal scenarios. These would include (a) the Japanese fuel-pin-in-block design, in which spent fuel pins can be readily removed from the graphite block; (b) the U.S. fuel-compacts-in-block design, where special measures may be taken to remove the spent compacts from the graphite block; (c) the U.S. design, where spent compacts are assumed to remain in the graphite block; and (d) the German-developed fuel pebble design, for which the separation of spent fuel particles from the pebble's matrix graphite is not considered feasible. The question of whether factors other than decay heat may affect the spacing requirements of spent fuel packages in a geologic repository should be addressed by the respective national experts on repository design analysis.

6. Dr. Hittner made a note to add to the planned HTR-M activities the theoretical and experimental evaluation of heat sources from the annealing of high-energy neutron-induced damage in graphite during reactor heatup accidents. The HTR-M project has already included plans for thermal conductivity measurements on irradiated graphites before and during high-temperature annealing. It was noted that calorimetric difficulties may significantly limit the accurate measurement of internal heat sources that arise in the annealing of heated graphite. JAERI has expressed particular interest in this area. Calculations of reactor heatup events in earlier modular HTGR designs (e.g., the DOE MHTGR) have shown the heat liberated by graphite annealing to be a much smaller than the decay heat from the fuel and that the predicted recovery of thermal conductivity in irradiated graphite during the heatup accident can significantly reduce the calculated maximum fuel temperatures in the core.

7. In discussing the motivations for performing radiochemical assays on LEU TRISO fuels irradiated in the HFR and other test reactors, it was noted that the value of such assays for validating HTGR depletion codes may be limited by the nonprototypicality of the neutron flux spectra and accelerated burnup rates in the test reactors. On the other hand, the usefulness of radiochemical assays on fuel pebbles irradiated in the AVR, HTR-10, or other HTGRs may be limited by the uncertain temperature histories of the individual fuel pebbles. Parametric depletion calculations can provide a basis for assessing the sensitivity of computed radionuclide inventories to temperature uncertainties during irradiation and to the neutronic differences between test reactors and HTGRs (e.g., differing burnup rates, fast neutron fluences, plutonium production rates, and plutonium fission fractions). A question was raised on how the accident performance of TRISO fuels irradiated in test reactors might differ from the performance of the same fuels irradiated in HTGRs.

8. Previously planned HTR-N activities on waste degradation include leaching experiments on TRISO fuel particles. Preliminary results on unirradiated particles are not considered representative of irradiated fuel. Proposed tests include leaching experiments on irradiated TRISO fuel in the form of bare fuel kernels, defective or failed coated particles, and intact coated particles. China (Professor Xu) has indicated that they cannot make anything but intact particles.

9. Dr. Hittner briefly reviewed key points from various other side meetings, including the following:
   - HTR-TN projects may now pursue a pre-test analysis of the HTR-10 melt-wire experiments that are proposed to start in mid 2003. China's HTR-10 safety test program is still not well established. E.C. and U.S. will interact with INET and NNSA on developing test plans. The U.S. may offer assistance on quality assurance. HTR-10 is considering experiments on fission product transport and plateout.
   - JAERI's draft HTTR test plan is being provided to the E.C. The U.S. and HTR-TN participants will have a chance to comment on the test plan and offer cooperation on test equipment and analysis.
   - In the HTR-F meetings, Dr. Shiozawa reported that JAERI is negotiating with PBMR on performing fuel pebble irradiations in HTTR. This would provide a more prototypic neutron flux spectrum than that provided by HFR, ATR, and other test reactors used for fuel irradiations. HTTR may have to install special thermoelements for this purpose. The HFR fuel irradiations will all be at 1100 C (helium at 850 C) to burnups >15% FIMA, whereas ATR irradiations will be at different temperatures and burnups. Fuel heatup testing in corrosive environments is under consideration.
   - The HTR-M meetings included discussions of hot corrosion testing on various graphites. It was noted that FZJ tests have shown the higher oxidation rates of pebble matrix graphite to be mainly at low temperatures. Graphite irradiations will start in June 2002 at Oak Ridge and by December 2002 at HFR. HFR irradiations will have 130 samples of 5 graphite grades, all at one temperature, whereas the Oak Ridge irradiations will have just one grade and ten temperature zones between 400 and 1500 C.

Dr. von Lensa indicated that all of the NRC's nuclear analysis issues will be discussed, along with upcoming proposals for the EC's 6^{th} Framework activities, at the next HTR-N coordination meeting, which he revealed will be held May 27-28, 2002, in Pisa, Italy. NRC staff will not be able to participate in the meeting in Pisa due to a scheduling conflict with the NRC's publicly announced May 28-29 meetings on phenomena identification and ranking tables for TRISO fuel performance in modular HTGRs. However, Dr. Carlson did agree to e-mail more detailed talking points for the Pisa meeting. Dr. Hittner also reiterated his intention to again visit NRC headquarters either before or after the June 10-13, 2002, American Nuclear Society meeting in Florida. His visit will provide an opportunity to review the outcome of the Pisa meeting on HTR-N coordination.