Commissioner Briefing

NRC Delegation Visit to Germany on the Safety Aspects of HTGR Technology

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The NRC Delegation

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Location of Meetings

Two days at GRS in Cologne

Two days at the Julich Research Center

German representatives came from around the country for meetings

Most representatives participated for multiple days

HTR Fuel Design, Development, Testing and Experience

- TRISO fuel particle is primary fission product retention boundary
- TRISO particle and pebble fuel element design and manufacture evolved over 30 years to a reference standard for use in German HTGRs
- Defective TRISO particles from manufacture dominates fission product release mechanisms during normal and off-normal reactor conditions
- Pebble Fuel element manufacturing process development achieved TRISO fuel particle defect rate specification of 6×10^{-5}
- Irradiation testing of reference fuel for german reactor design conditions showed no additional particle failures & low releases
- Irradiated Pebble fuel accident simulation (heatup) tests demonstrated low fission product release for predicted accident conditions
- Mechanistic Release model used for fission product source term
- Fuel for PBMR & GT-MHR will need to demonstrate equivalent performance

Pebble Bed Reactor Core Heat Transfer and Fluid Flow

- Fuel maximum steady-state temperature and peak accident temperature must stay within design limits to assure fuel integrity basis
- Experiments and analytical model and methods development were conducted to predict heat transfer and temperature distributions in pebble bed cores (e.g., in coated particles, pebbles, pebble-to-coolant, between pebbles)
- HTR-Modul predicted accident temperatures showed passive reactor shutdown, and effective passive decay heat removal with fuel, vessel wall and reactor support structures within the design envelope.
- Pebble Melt-wire tests conducted at AVR for normal operation indicated that calculated maximum local core temperatures were non-conservative.
- Large scale model tests have been conducted to validate the analytical models and methods that are used to calculate radial and axial core temperature distributions in modular HTRs due to decay heat transfer during accidents.

AVR Operation, Testing, Lessons Learned (Continued)

AVR Testing Program Highlights

Melt-Wire Experiments Showed Unpredicted Core Hot Spots at Power:

- Ongoing Re-Analysis by Jülich Research Center:
  - Implications for code validation/correction in predicting maximum fuel operating temperatures
  - Implications for similar measurements needed in future reactors

Demonstration of Modular HTR Safety Principles:

- Simulation of Pressurized & Depressurized Loss of Forced Cooling Without Scram

AVR Provided Large-Scale Irradiation Testing of Pebble Fuels, including the HTR-Modul TRISO Fuel Design

THTR - Safety Assessment

1971 THTR Construction Started - Technical Rules and Guidelines did not Exist for THTR Concept

1977 Safety Criteria Went Into Effect for all Reactor Types - HTR Specific Characteristics were not Considered

1978 Reactor Specific Interpretation of Safety Criteria was Developed ("THTR-Planning Basis")

1980 HTR Safety Criteria Developed Which Provided More Precise Technical Requirements

- External Impact (Aircraft, Pressure Wave, Earthquake, Etc.)
- Internal Impact (Pipe Whip, Etc.)
- Radiation Protection

"Backfits" Were Required During THTR Construction to Address Evolving Requirements

1985 Commercial Power Generation

Licensing Process was Much Longer than Anticipated (>14 Years)

HTR Nuclear Materials Safety

Alex Murray, NMSS

Know-How Transfer From Germany to ESKOM

and

Overall Conclusions

Stuart Rubin, RES

Conclusions from the Trip to Germany

- The German nuclear power industry believes they have demonstrated that HTRs can be successfully designed, constructed and licensed, and operated with acceptable safety performance.

- German safety and regulatory authorities believe that the HTR-Modul design (a modular pebble bed reactor similar tp the PBMR) would be able to meet the safety criteria for licensing in Germany.

- German HTGR operating experience shows that startup problems with new HTGR plant designs can be expected.

- German experiments, plant operations and tests show that important HTGR design, technology and safety analysis issues exist and will need to be investigated and resolved before licensing an HTGR in the US.

- German HTGR information, expertise and experience will be valuable in supporting NRC HTGR infrastructure development for HTGR safety reviews.