

From: Amy Cabbage
To: Shoop, Undine > NRD
Date: Wed, Aug 1, 2001 11:41 PM
Subject: slides

Well these are not prettied up at all and the AVR experience slide is really weak (I had very little info/notes on AVR), but I quit for tonight. I'm getting cross-eyed! I'll see you in the morning. We can always make the slides prettier after we talk to Jerry.

B-25

Briefing on the visit of the NRC Delegation to Germany

Safety Aspects of HTR Technology
July 23-26, 2001

Undine Shoop and Amy Cabbage
August 2, 2001

Participants of the NRC Delegation

Howard Faulkner - OIP
Undine Shoop - Reactor Systems Branch, NRR
Amy Cabbage - New Reactor Licensing Project Office, NRR
Stuart Rubin - Advanced Reactor Group, RES
Donald Carlson - Advanced Reactor Group, RES
Alex Murray - Special Projects Branch, NMSS
Vanice Perin - Special Projects Branch, NMSS (Observer)

Agenda

July 23 - GRS office in Cologne

- Overview of HTR program in Germany (Westinghouse)
- Overview of Safety Assessment of HTR-Module (TUV Hannover)

July 24 - FZJ, Research Center in Julich

- Overview of Research and Development at FZJ (FZJ)
- Fuel Element Irradiation and Post-Irradiation Examination for Establishing the 1600 °C Fission Product Retention Limit (FZJ)
- Fuel Element Research & Development and Production (NUKEM)

July 25 - FZJ, Research Center in Julich

- Nuclear Graphite Research and Development and Production (FZJ)
- Heat Transfer and Fluid Flow (FZJ)
- AVR Operational Experience (FZJ)
- THTR Operational Experience (FZJ)
- Core Physics and Pebble Flow (BFS)
- Tour of Intermediate Storage Facility
- Short Visit to AVR

July 26 - GRS office in Cologne

- Safety Assessment of HTR-module (TUV Hanover)
- Safety Assessment of THTR (TUV Essen)
- Safety Issues during Licensing of THTR (Ministry for Economy)
- Rules and Standards (BFS)
- Know-How Transfer to ESKOM (Westinghouse, FZJ)
- Waste Management (FZJ)

HTR Development and Experience in Germany

AVR

15 MWe Research/Test Reactor

Test Bed for Pebble Fuel Designs

Design included Containment (Designed Prior to Development of TRISO Fuel Particles)

Operated from 1967-1989

Shut down for political reasons

THTR

300 MWe Prototype Reactor

Operated from 1985-1989

Shut down for Financial and Political Reasons

HTR-Module Design

200 MWe Modular Reactor Design

Two Modules per Facility

Co-Generation - Electricity and Process Steam

Application for Concept License Withdrawn for Political Reasons

AVR Operational Experience and Lessons Learned

The AVR ran for 22 years with Excellent Results

Issues:

- Fuel Handling System Maintenance
- Graphite Dust Accumulated due to Abrasion of Pebbles
- Water Ingress Event Occured
- Several Pebbles Became Stuck in Lower Core Region (burnup is unknown)

Safety Assessment of the THTR

When Beginning Construction in 1971, Technical Rules and Guidelines did not exist for the THTR concept

Necessary Rules and Guidelines had to be Developed

BMI Safety Criteria (Valid for all Reactor Types) Went into Effect in 1977

These Safety Criteria did not Consider the Specific Characteristics of an HTR

In 1978 the "THTR-Planning Basis" (a Reactor Specific Interpretation of the BMI Safety Criteria) was Established

In 1980 Safety Criteria for HTR were Developed which made the Technical Requirements More Precise

- External Impact (Aircraft, Pressure Wave, Earthquake, Etc.)

- Internal Impact (Pipe Whip, Etc.)

- New Radiation Protection Requirements for Personnel

Technical Requirements Resulted in Design Changes and Construction Delays

- Redundancy in Decay Heat Removal

- Siesmic Design

- Aircraft Impact

- Internal Impact from Pressure Vessel Damage

- Etc.

Operational Experience and Lessons Learned from THTR

Reliability and Availability typical for prototype. Operational problems were not viewed as serious technical or safety issues. These included:

- Broken Pebble Fuel Elements (~17,000 pebbles) due to In-Core Control Rod Insertion
 - Caused Reliability Problems with Fuel Handling System
 - Did not Result in Failure of TRISO particles

- Initially, the Fuel Handling System did not work above 40% power
 - Fuel Handling was Restricted to Weekends when Power was Reduced

- Predicted Pebble Flow Profile was Significantly Underestimated Requiring Adjustment of Fuel Loading Pattern
 - THTR Core width to height ratio of 1:1
 - PBMR Ratio is 1:3

Core Helium coolant bypass flow was found to be 18% vs. the predicted 7%. Resulted in higher core outlet temperature, but fuel element temperatures remained below the design values.

Inspection revealed a significant number of damaged bolts in the thermal insulation in the hot gas ducts. The cause was determined to be an Elevated Temperature Gradient at the core exit which led to thermal overstress.

Inadequate Filters to collect Graphite dust generated in the core led to an offsite Release (There was no Safety Consequence)

Plant was prematurely shutdown for political reasons and financial risk issues

Safety Assessments of HTR-Module

4/87 Design was Submitted for Concept License by Siemens/Interatom (HTR GmbH)

4/89 Application was Withdrawn due to Unfavorable Political Climate

7/89 Draft Review Report (Prepared by TUV under contract to the Federal Ministry for Research and Technology)

12/89 Completion of Final Review Report (900 pages)

Safety Assessment took 2 ½ years to complete and a level of effort of 25 man-years

No Technical Rules and Guidelines for HTR-Module were available for Design and Safety Assessment. Rules were very Specific to Siemens LWR Design.

Existing LWR Rules and Guidelines screened for applicability (Applicable, Partially Applicable, Not Applicable)
Consideration of concept specific requirements
Result: Comprehensive and Consistent set of Design and Evaluation Criteria applicable to HTR-Module

Conclusion of Safety Assessment: With Respect to Safety a License Could Have Been Granted

Chinese HTR-10 reactor is based on HTR-Module Design (Scaled down)

The PBMR Design is similar to the HTR-Module concept but there are Several Differences

Know-How Transfer

Eskom has agreements with HTR GmbH, Julich, TUV Hannover, and NUKEM for access to technical documentation and support

TUV Hannover - New Contract Signed Last Week to Review the PBMR SAR for Eskom Prior to Submittal to NNR

NUKEM - Recently Completed 6 Month Contract with Eskom for Fuel Fabrication Facility Design
German Fuel Fabrication Facility was sold to China.

Exelon is not Included in the Above Agreements. These agreements are Exclusive to Eskom.

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