HTGR Technology Course for the Nuclear Regulatory Commission

May 24 – 27, 2010

Module 10c

Helium Inventory and Purification System
• HTGR Helium Purification System (HPS) design
  – Functions
  – Requirements
  – Design approach
  – Design description

• Helium Transfer and Storage System (HT&SS) design
  – Functions
  – Design description

• Operating experience
  – Lessons learned for HTGR design
HPS Functions

• Removes chemical and radionuclide impurities from helium coolant
• Pressurizes, depressurizes, and controls the primary helium coolant inventory (in conjunction with Helium Transfer and Storage System)
• Provides purified helium for purges and buffers
• Maintains primary coolant system slightly subatmospheric during refueling/maintenance
• Purifies helium pumped to storage
• Remove H$_2$O from primary circuit following water ingress event
Summary of HPS Requirements

- Each reactor module shall have an independent helium purification system
- Shall remove H₂O, CO, CO₂, H₂, N₂, O₂, H₂S, CH₄, and higher molecular weight hydrocarbons
- Shall allow depressurization of the Reactor Module (and/or adjacent module) within 24 hours after shutdown
- Shall include one regeneration train for two HPSs
- Shall be sized to process a slipstream of the primary coolant, typically on the order of 1% of the primary loop volume flow rate
HPS Design Approach

- Passive components (filters, packed beds, etc.) with redundancy
  - High reliability
  - High availability

- Modularized components
  - Reduces construction time/cost
  - Allows easier maintenance

- High temperature filter/adsorber module performs adsorption/chemisorption on activated charcoal
  - High temperature filters remove particulates
  - Removes condensable metallic fission products
HPS Design Approach - Continued

- **Oxidizer-cooler module oxidizes impurities**
  - Converts CO and H₂ to CO₂ and H₂O
  - HT and T₂ oxidized and removed as HTO and T₂O
  - Condenses water vapor for water ingress event

- **Dryer module removes impurities with molecular sieve adsorber**
  - Removes CO₂ and H₂O coming from oxidizer-cooler module

- **Low-temperature adsorber module includes a low-temperature heat exchanger and a low temperature adsorber section**
  - Removes CH₄, Kr, Xe, N₂, and Ar
  - Removes small quantities of CO, CO₂, and N₂ for air ingress event during refueling/maintenance of primary circuit components
HPS Design Approach - Continued

- Purified helium compressor module includes compressor, filter, pulsation bottles, and an aftercooler
  - Boosts helium pressure for return to primary system
  - Provides cool pure helium for purges
  - Dampens out surges in helium flow

- Regeneration train includes oxidizer, compressor, and dryer modules
  - Operates only when needed for regeneration
  - Regenerates dryers and low temperature adsorbers
Helium Purification Train

Contaminants Removed

- **Red Section:** Condensable Radionuclides & Particulates
- **Green Section:** $\text{H}_2\text{O}$, including tritiated $\text{H}_2\text{O}$ & $\text{CO}_2$
- **Blue Section:** $\text{Kr, Xe, N}_2$
Fort St. Vrain HPS Flow Diagram
OUTLINE

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• Operating experience
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Helium Transfer and Storage System Functions

- Provides storage capacity for helium during inventory changes
  - Load changes for GT designs
  - Depressurizations for prismatic refueling, off-line maintenance
- Supplies primary coolant system makeup helium during normal plant operation
- Provides source of high pressure helium for specific plant uses
- Transfers/distributes helium among various plant users
- Works in conjunction with HPS to pressurize, depressurize, and control the primary coolant inventory
Helium Transfer and Storage System
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• **Operating experience**
  – Lessons learned for HTGR design
Operating Experience/Lessons Learned

• HPS and HT&SS performed well in seven steam-cycle HTGRs

• Specific lessons from FSV
  – HPS overwhelmed by large H₂O ingresses; long times required for dry out of primary coolant circuit
  – Single transfer compressor required taking plant offline for compressor maintenance

• Components performed well except for Ti Getter Beds in FSV
  – FSV used Ti getter beds instead CuO oxidizers/driers for the removal of hydrogen and tritium
  – Ti beds were frequently deactivated by N₂
  – No operational consequences because H₂ and H-3 sorbed on core graphite

• Design recommendations for future HTGRs:
  – Provide suitable drains for removal of standing water
  – Provide backup He transfer compressor
  – Use CuO oxidizer beds/driers for H2 and H-3 removal
Pebble Bed-Specific Operating Experience/Lessons Learned

- AVR and THTR experience with HPS indicated good performance and reliability.
- Care must be taken in the design to minimize leaks from large number of equipment and piping items; this has an adverse impact on economics.
- PBMR is making use of a scaled down version of an HPS and HT&SS in the Helium Test Facility in South Africa.
• HPS technology well established and demonstrated in operating HTGRs and in-pile loops
• Primary purpose of HPS in an HTGR is to control chemical impurities in the primary coolant
• HPS removes longer-lived noble gases, but little effect on condensable radionuclides (plateout controlling)
• HPS and HT&SS have performed well in seven steam-cycle HTGRs
  – Ti getters in FSV performed poorly: use CuO oxidizer beds instead
  – Provide backup He transfer compressor for good plant availability
• HPS effectively removes tritium from primary coolant, but core graphite more important sink for tritium removal
• No technology development needed for HPS
Suggested Reading

- “Fort St. Vrain Nuclear Generating Station, Final Safety Analysis Report” (updated), USNRC Docket No. 50-267