# HTGR Technology Course for the Nuclear Regulatory Commission

**May 24 – 27, 2010**

**Module 10c**

**Helium Inventory and Purification System**

# OUTLINE

- **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 $H_2O$ from primary circuit following water ingress event

# Summary of HPS Requirements

- **Each reactor module shall have an independent helium purification system**
- **Shall remove $H_2O$, $CO$, $CO_2$, $H_2$, $N_2$, $O_2$, $H_2S$, $CH_4$, 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

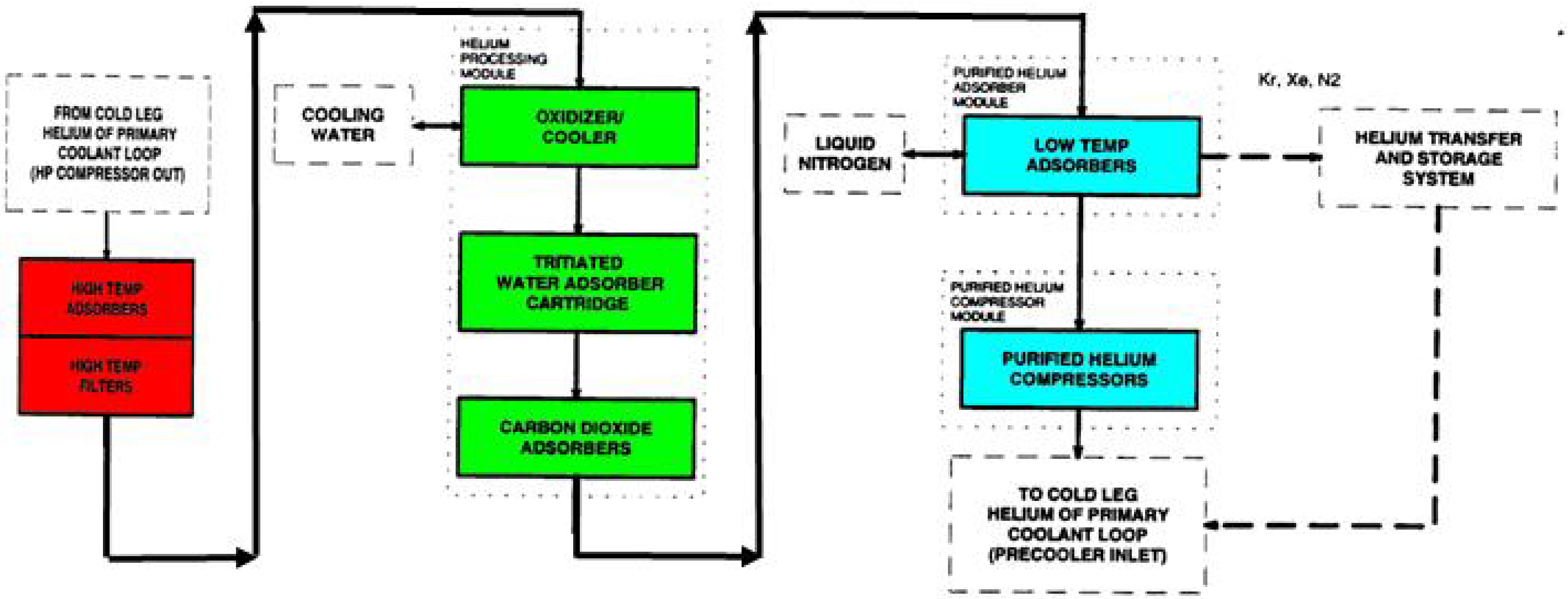
# HPS Design Approach - Continued

- **Oxidizer-cooler module oxidizes impurities**
  - Converts CO and $H_2$ to $CO_2$ and $H_2O$
  - HT and $T_2$ oxidized and removed as HTO and $T_2O$
  - Condenses water vapor for water ingress event
- **Dryer module removes impurities with molecular sieve adsorber**
  - Removes $CO_2$ and $H_2O$ coming from oxidizer-cooler module
- **Low-temperature adsorber module includes a low-temperature heat exchanger and a low temperature adsorber section**
  - Removes $CH_4$, Kr, Xe, $N_2$, and Ar
  - Removes small quantities of CO, $CO_2$, and $N_2$ for air ingress event during refueling/maintenance of primary circuit components

# HPS Design Approach - Continued

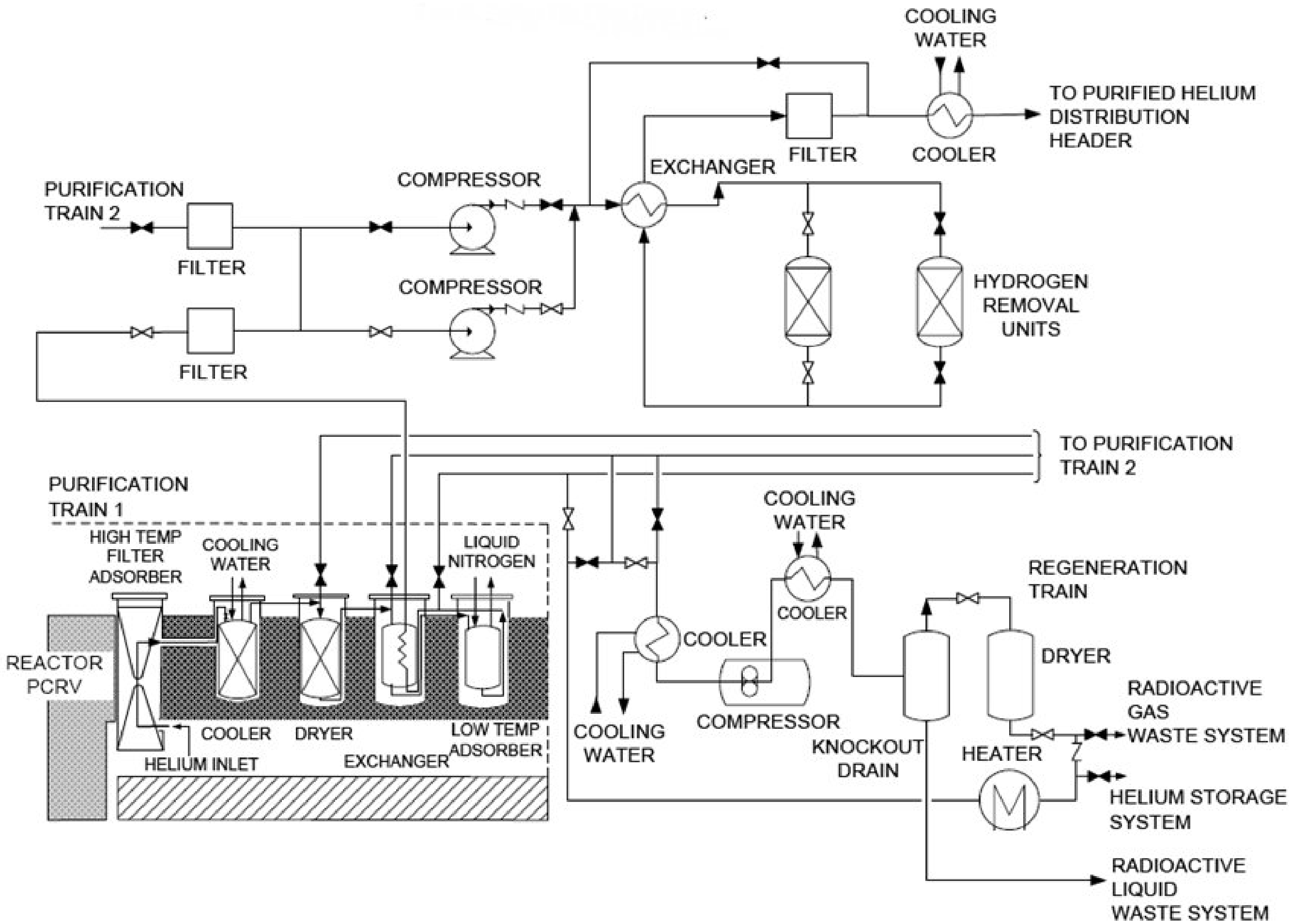
- **Purified helium compressor module includes compressor, filter, pulsation bottles, and an aftercooler**
  - Boosts helium pressure for return to primary system
  - Provides cool pure helium for purges
  - Dampens out surges in helium flow
- **Regeneration train includes oxidizer, compressor, and dryer modules**
  - Operates only when needed for regeneration
  - Regenerates dryers and low temperature adsorbers

# Helium Purification Train




| Contaminants Removed | Red Section: | Green Section: | Blue Section: |
|---|---|---|---|
| | Condensable Radionuclides & Particulates | $H_2O$, including tritiated $H_TO$ & $CO_2$ | Kr, Xe, $N_2$ |

# Fort St. Vrain HPS Flow Diagram



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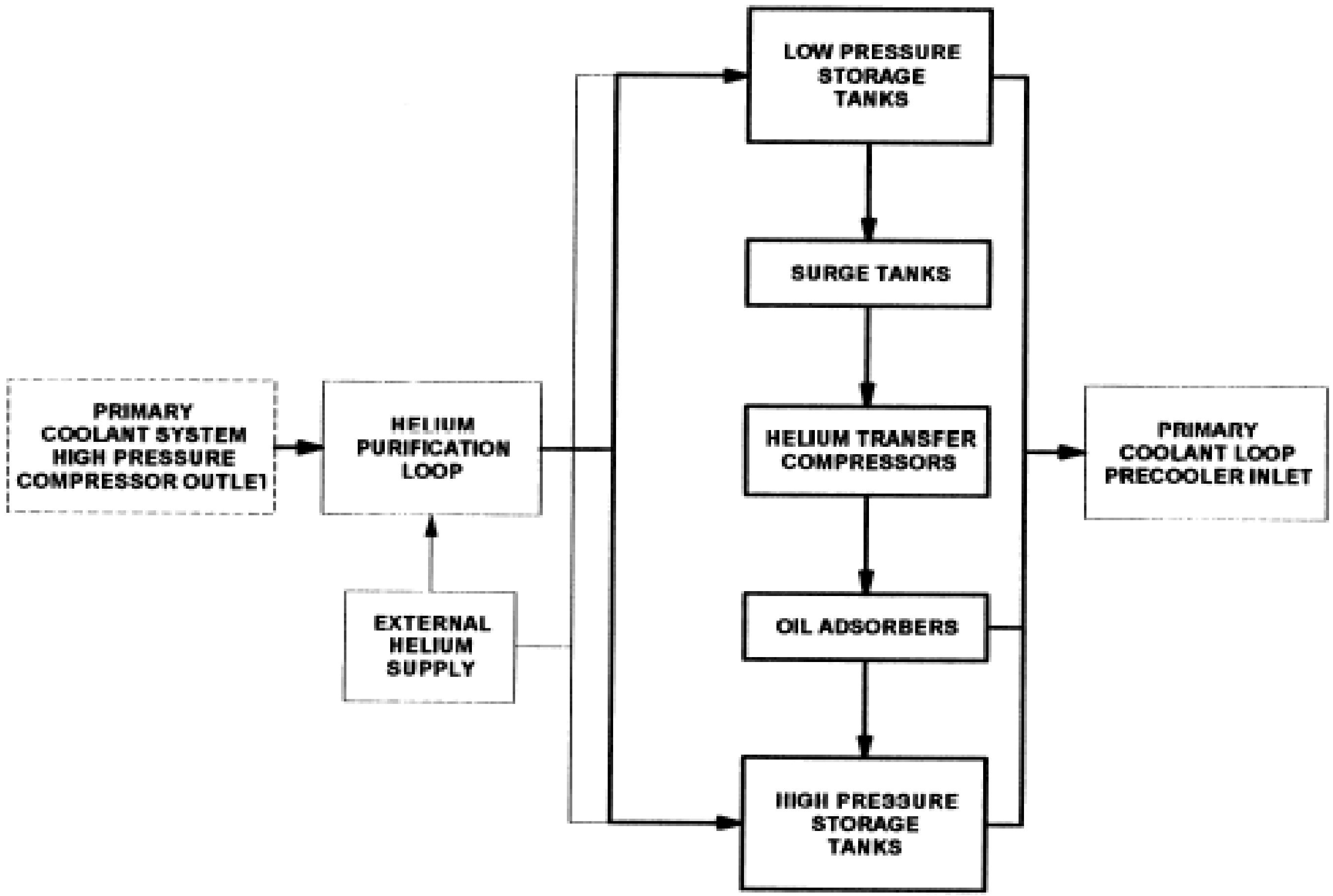
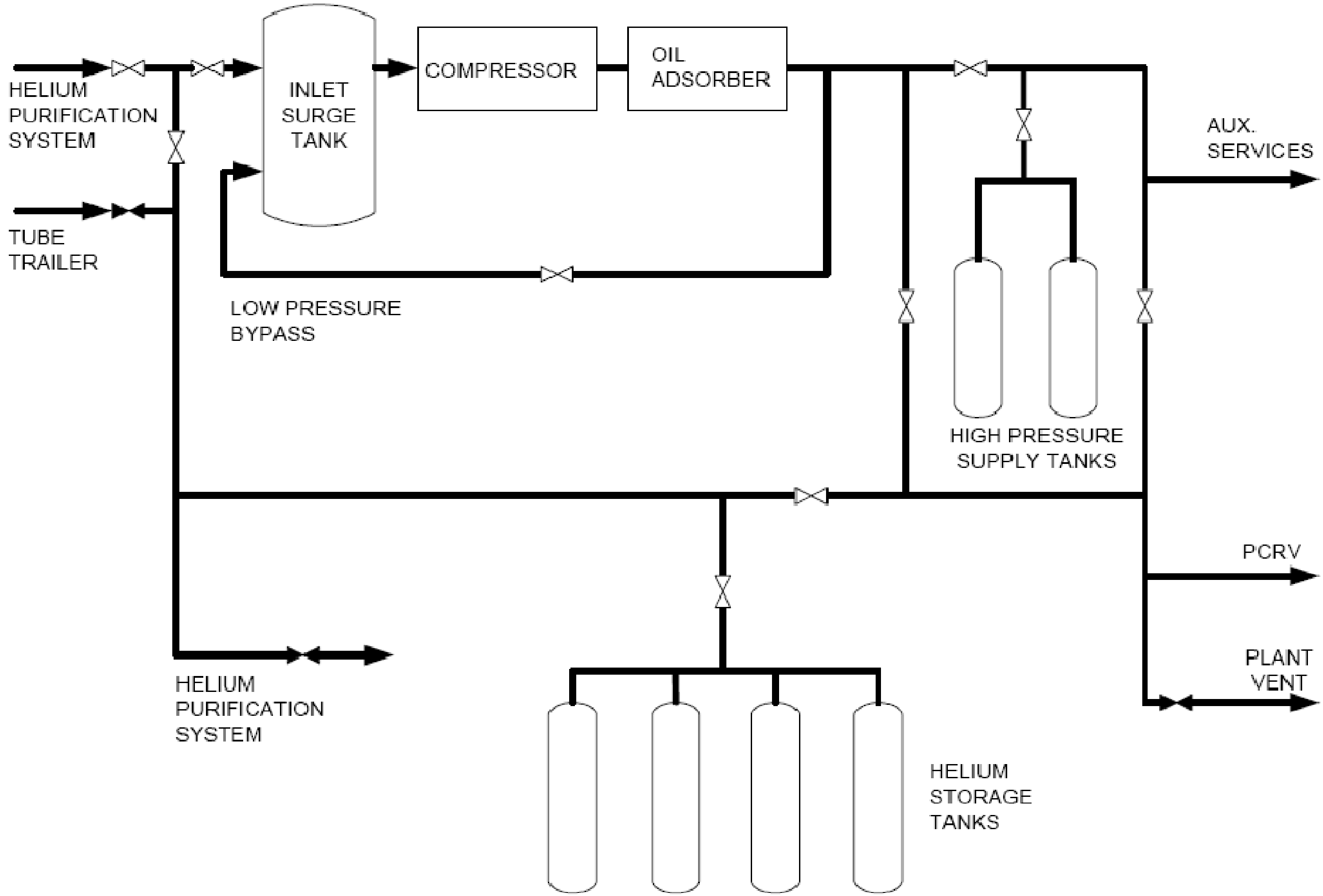
# Helium Transfer and Storage System Functions

- **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



# Fort St. Vrain Helium Storage System



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# Operating Experience/Lessons Learned

- **HPS and HT&SS performed well in seven steam-cycle HTGRs**
- **Specific lessons from FSV**
  - HPS overwhelmed by large $H_2O$ 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 $N_2$
  - No operational consequences because $H_2$ 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**




# Summary

- **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

- "Preliminary Safety Information Document for the Standard MHTGR," HTGR-86024, Rev. 13, Stone & Webster Engineering Corp., September 1992
- "Fort St. Vrain Nuclear Generating Station, Final Safety Analysis Report" (updated), USNRC Docket No. 50-267
- "Fort Saint Vrain Gas Cooled Reactor Operational Experience," NUREG/CR-6839 (ORNL/TM-2003/223), Oak Ridge National Laboratory, January 2004
- "Primary Coolant Chemistry of the Peach Bottom and Fort St. Vrain High Temperature Gas-Cooled Reactors," IAEA Conference Proceedings IGGGCRI2, December 1980