HTGR Technology Course for the Nuclear Regulatory Commission

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Module 10e

Intermediate Heat Exchanger

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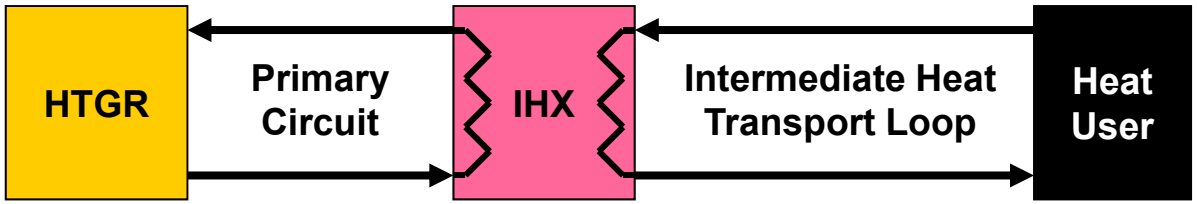
AREVA

Outline

- Introduction
- IHX functions and requirements
- IHX configurations
- IHX design considerations
- Applicable IHX experience

Introduction

- Future HTGR concepts have been envisioned to meet a variety of long-term energy needs
- Direct high temperature process heat applications will require an IHX (> 500°C)
- Several IHX concepts have been developed for HTGR plant designs with core outlet temperature up to 950°C
- The present reference HTGR steam cycle designs do not require an IHX
- IHX technology is available for next generation HTGRs



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Typical IHX Functions and Requirements

- **Transfer heat from primary coolant to secondary heat transport fluid**
- **Maintain separation of primary and secondary coolant streams**
- **Support primary coolant pressure boundary**
- **Control radionuclide releases**
  - Circulating activity
  - Role in tritium control
- **Specific requirements depend on application**
  - Operating temperature
  - Heat transfer effectiveness

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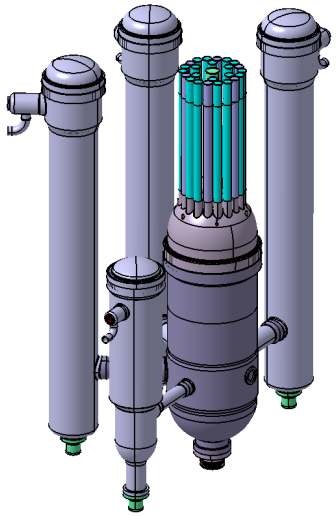
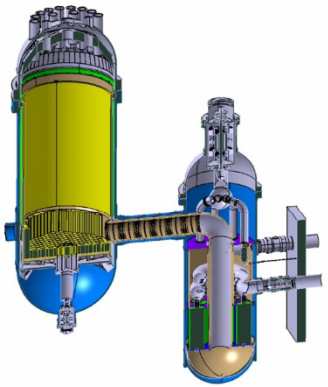
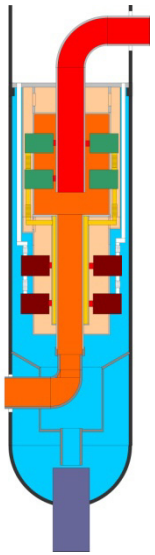
Three Basic Types of HTGR IHXs

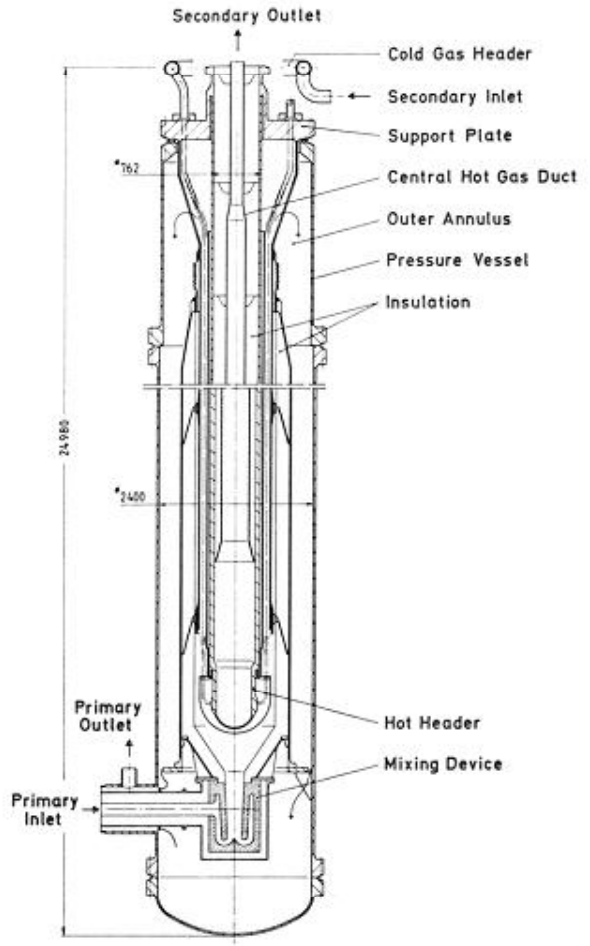
- **Tubular heat exchangers**
  - More established technology
  - Low heat transfer density
  - Large size
  - Thick pressure boundary sections
- **Compact heat exchangers**
  - More advanced technology
  - High heat transfer density
  - Small size
  - Thin pressure boundary sections
- **Hybrid (or 2-stage) heat exchangers**
  - Separate sections
  - Different configurations
  - Different materials
  - Different lifetimes





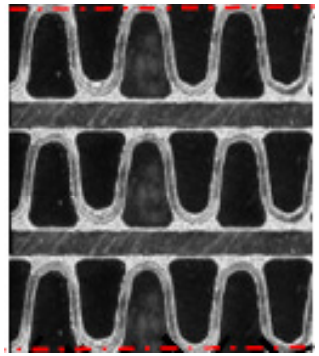


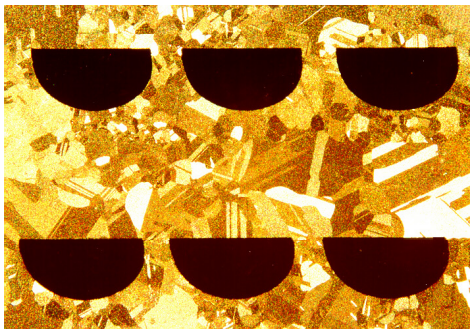
Tubular IHX Technology

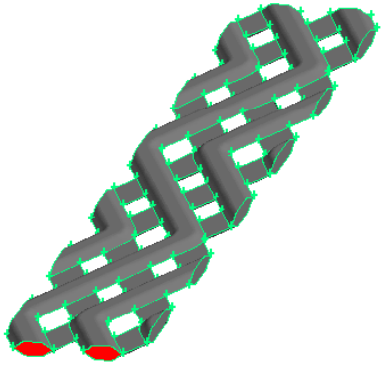


- **Based on conventional shell and tube construction**
- **Large physical size**
- **Thick walls**
  - Robust
  - Greater corrosion resistance
- **Greater initial cost**
  - Heat exchanger
  - Vessels
  - Buildings
- **Longer component lifetime**
- **Fabrication-conventional**
- **Maintenance**
  - Tube inspection
  - Tube leaks can be identified and plugged

Compact IHX Technology







- **Multiple compact HX concepts**
  - Plate fin HX
  - Printed circuit/plate machined HX
  - Plate stamped HX
- **Small physical size**
- **Thin walls**
  - Corrosion can be a concern
- **Multiple modules (~1-5 MW each)**
- **Lower initial cost**
- **Potentially shorter component lifetime**
- **Fabrication**
  - Diffusion bonding
  - Brazing
  - Peripheral welding
- **Maintenance**
  - Inspection of modules
  - Replacement of defective modules

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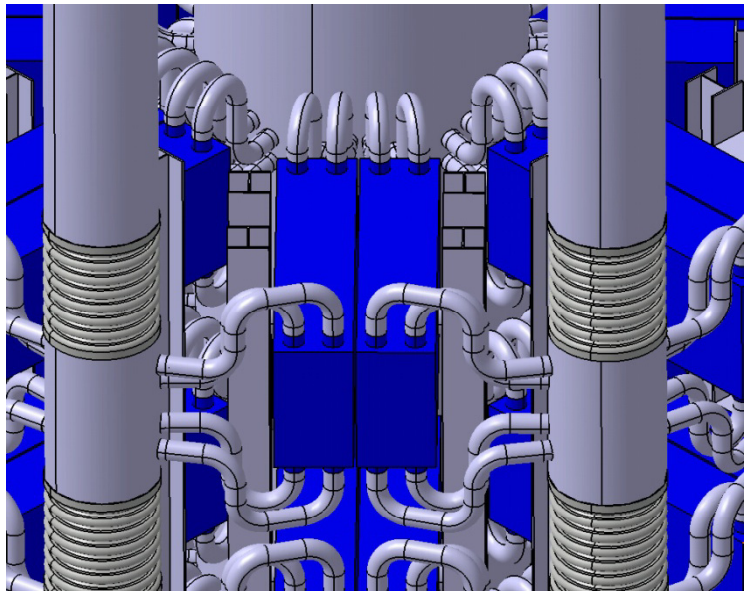
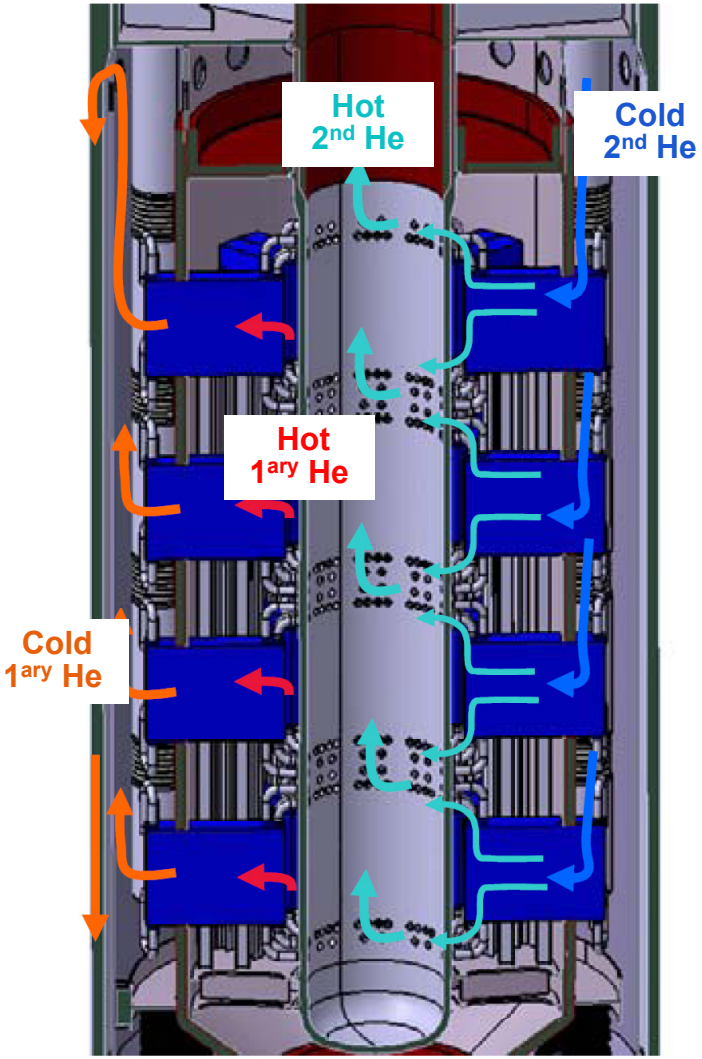
Integration of Compact IHX Modules in the Pressure Vessel

- Multiple IHX modules required for necessary capacity
- Primary and secondary ducting must connect to each module
- Flow must be balanced for all modules





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Key IHX Design Considerations

- **Performance**
- **Size**
  - HX size
  - Headers
  - Vessel size
  - Building
- **Pressure balance (primary-to-secondary)**
- **Fabrication**
- **Corrosion**
- **Integrity**
- **Lifetime**

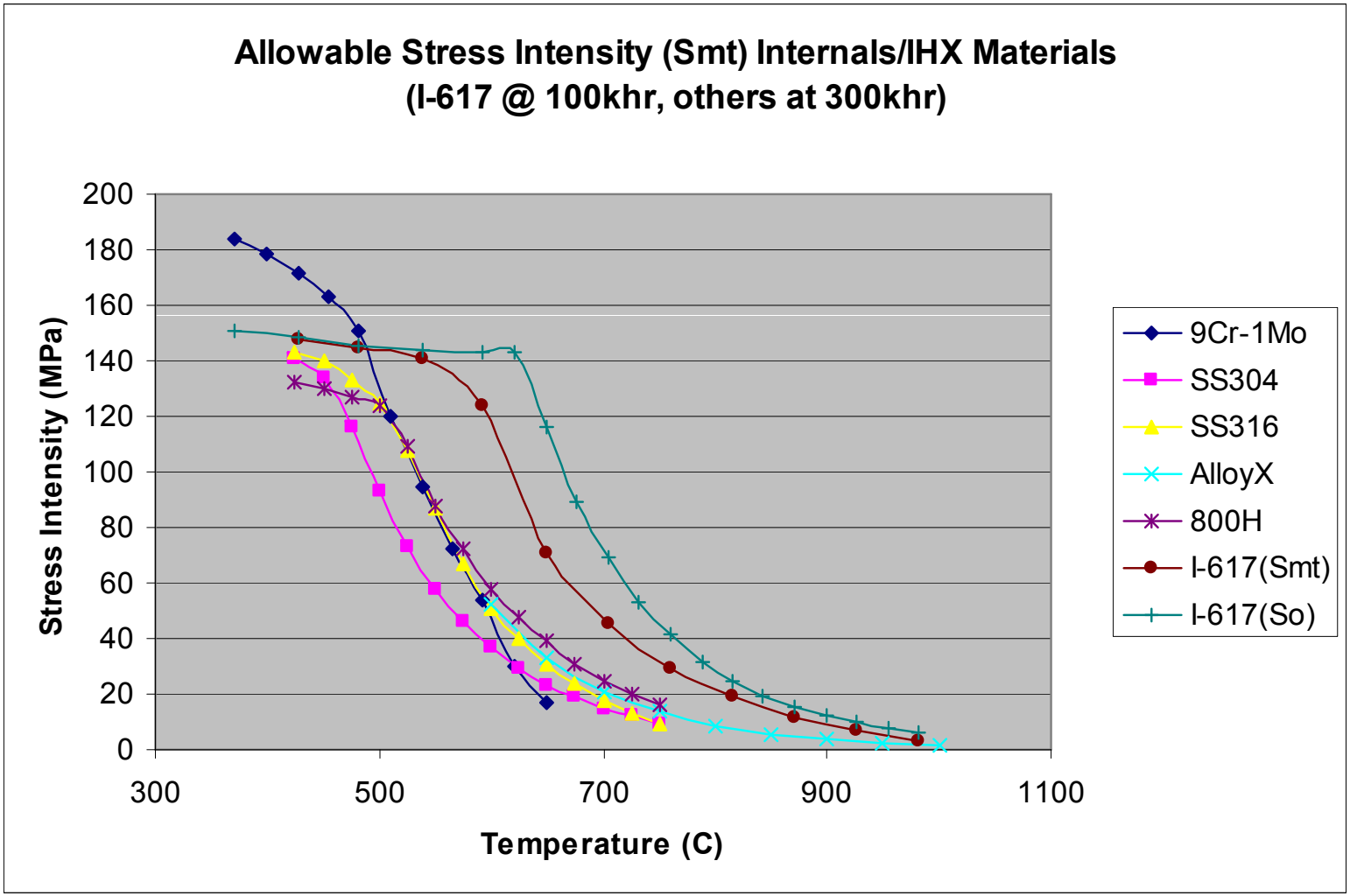
IHX Performance Considerations

- **Heat exchanger effectiveness**
  - Minimize approach temperature between primary and secondary
  - Maximize process heat delivery temperature for application performance
  - Minimize required reactor outlet temperature for given process temperature
- **Effectiveness considerations**
  - Cutting approach temperature by 2 requires doubling heat transfer area
  - Compact IHX might achieve 90-95%
  - Tubular IHX might achieve 80-90%
- **Pressure drop**
  - Primary
  - Secondary
- **Transient performance**
  - Impact on system performance
  - Response of IHX

IHX Material Candidates

- **High temperature alloys**
  - Inconel 617
  - Alloy 230
  - Hastelloy X/XR
  - Alloy 800H (lower temperature)
- **Advanced metallics**
  - Oxide dispersion strengthened (ODS) alloys
- **Ceramics**
  - Carbon-carbon composites
  - Silicon carbide

IHX Near Limit of Metallic Capabilities



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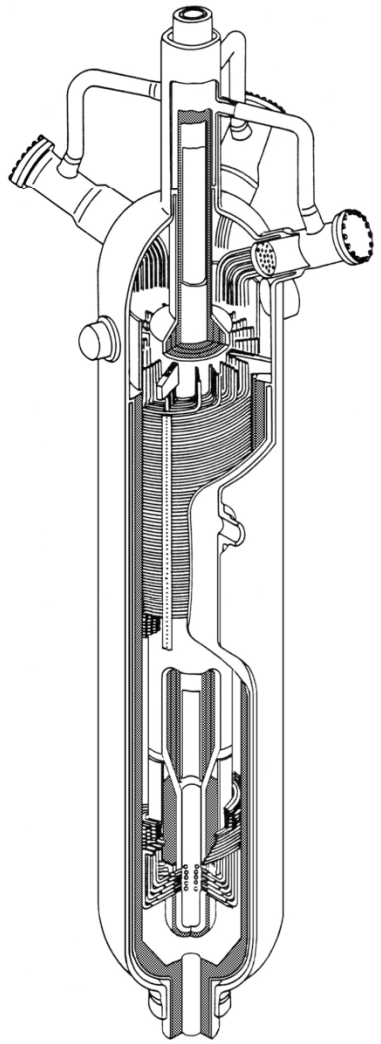
Overall IHX Experience

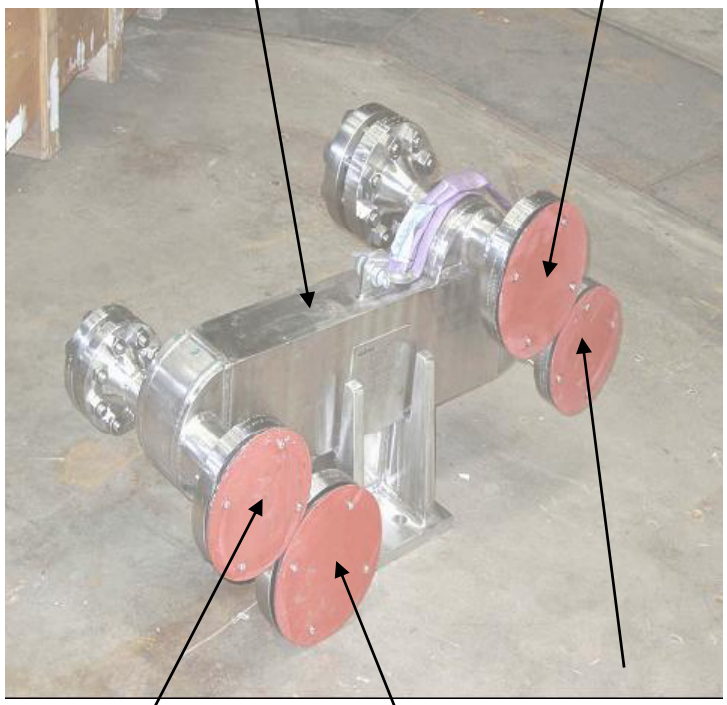
- **Laboratory experience**
  - Materials and corrosion
  - Environmental testing
  - HX mockups
- **Large scale IHX experience**
  - Gas turbine recuperators (compact)
  - HTGR engineering test modules (tubular)
- **Reactor operating experience**
  - HTTR (tubular)



HTTR IHX

Compact IHX Experience

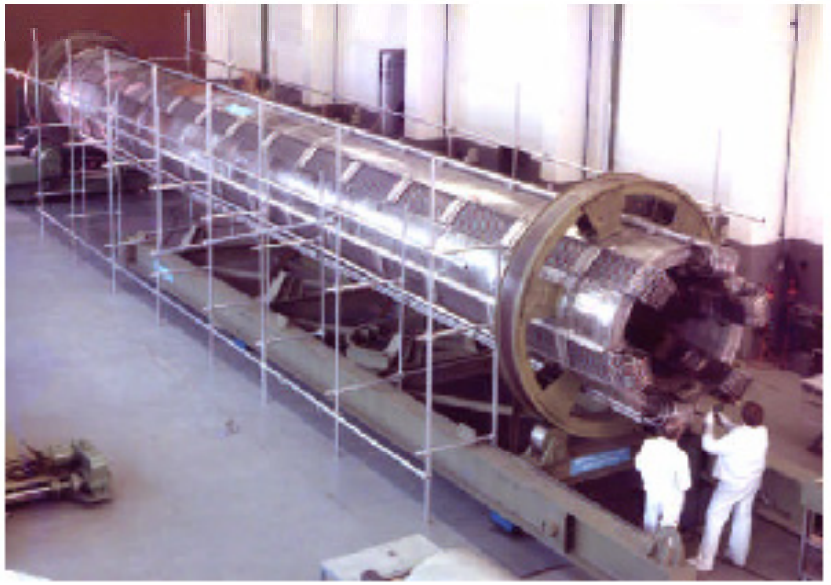
- **Several design studies**
  - Thermal performance
  - Stress analysis
  - Fabrication
  - Header concepts
- **Gas turbine recuperators**
  - Lower temperature
  - Higher differential pressure
- **Corrosion testing for HTGR IHX conditions**
- **Scale mockup testing**



Compact IHX Mockup with Headers Attached

Tubular IHX Experience

- **Basic configuration similar to helical coil steam generator**
- **PNP program (Germany)**
  - Technology demonstrated for 950°C (KVK test loop)
  - Helical and U-tube
  - 10MWt (engineering prototype)
- **HTTR (Japan)**
  - Operated up to 950°C
  - Helical tubular IHX
  - 10MWt



He-He intermediate heat exchanger before installation

Summary

- **IHX required to transfer heat to high temperature direct heat process applications**
- **Tubular IHX technology demonstrated at engineering scale to 950°C**
- **Compact IHX technology offers size and performance advantages**
  - Significant design challenges remain to be addressed for very high temperatures (>850°C)
- **Design challenges very dependent on service temperature**