NSUF GAIN Nuclear Thermal-Hydraulics Workshop

# UM Thermal Hydraulics Laboratory: Overview and Capabilities (HTGR and MSR)

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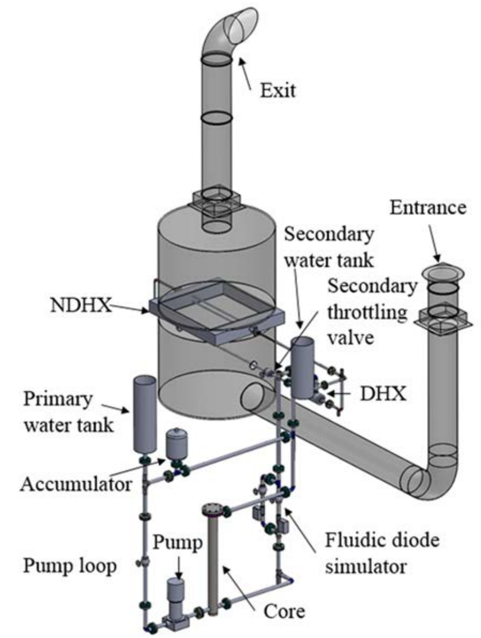
# Thermal Hydraulics Lab Capabilities

Molten Salt Reactor (MSR)

# Low-Temperature DRACS Test Facility (LTDF)

- Objectives
  - Examine the couplings among the natural circulation/convection loops
  - Provide us with experience beneficial to construction and operation of the high-temperature fluoride salt test facility
- Previous Work
  - DRACS startup tests
  - DRACS steady-state tests
  - Pump trip test without IHX
  - Pump trip test with IHX




| | Primary Water (10 bar) | Secondary Water (1 bar) | Air |
|---|---|---|---|
| $T_{hot}$ (°C) | 76.5 | 65.2 | 40 |
| $T_{cold}$ (°C) | 63.7 | 34.8 | 20 |
| $\Delta T$ (°C) | 12.8 | 30.4 | 20 |
| $\dot{m}$ (kg/s) | 0.038 | 0.016 | 0.102 |
| Loop Height (m) | 1.71 | 0.42 | 2.1 |
| Pipe ID (cm) | 3.7 | 2.0 | 35.6 |

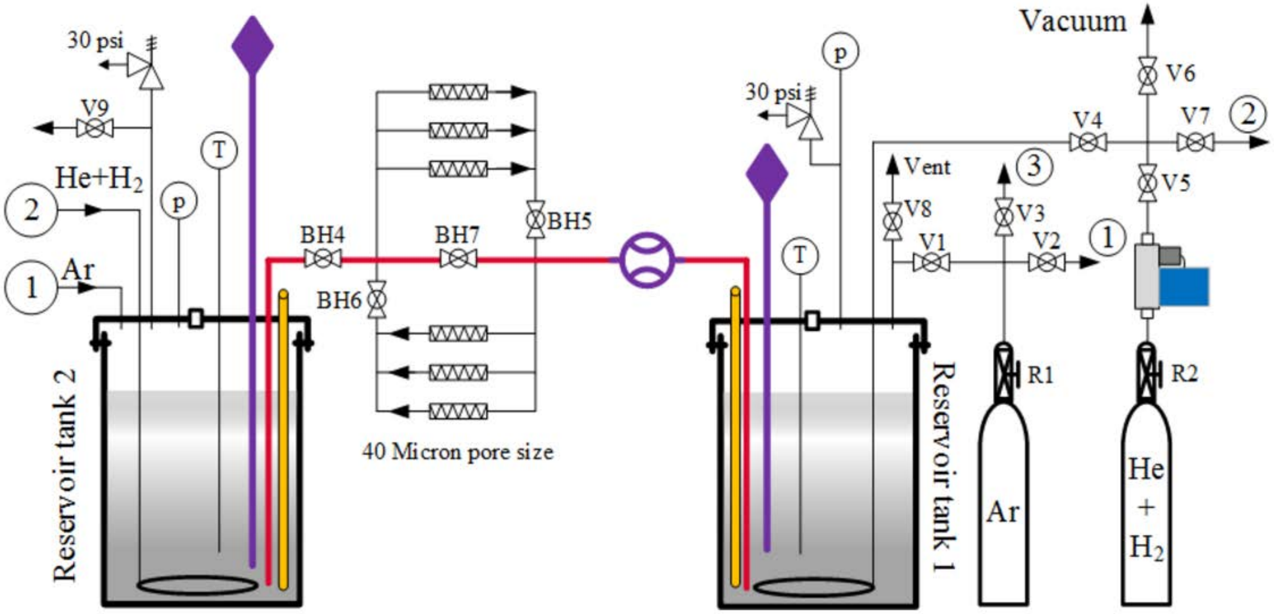
# High-Temperature Fluoride Salt Test Facility (HT-FSTF)

- Objectives
  - Examine the couplings among the natural circulation/convection loops using fluoride salts
- Capabilities
  - Current capabilities
    - Coupled natural circulation loops
    - Salt heat transfer and pressure drop
  - Potential capabilities
    - Component testing (valve, fluidic diode)
    - Salt corrosion testing

| | Primary Fluid (FLiNaK) | Secondary Fluid (KF and $ZrF_4$) | Air |
|---|---|---|---|
| $T_{hot}$ (°C) | 722 | 666 | 110 |
| $T_{cold}$ (°C) | 678 | 590 | 40 |
| $\dot{m}$ (kg/s) | 0.120 | 0.127 | 0.142 |
| Loop Height (m) | 1.14 | 1.08 | 3.43 |

# HT-FSTF (Cont'd)

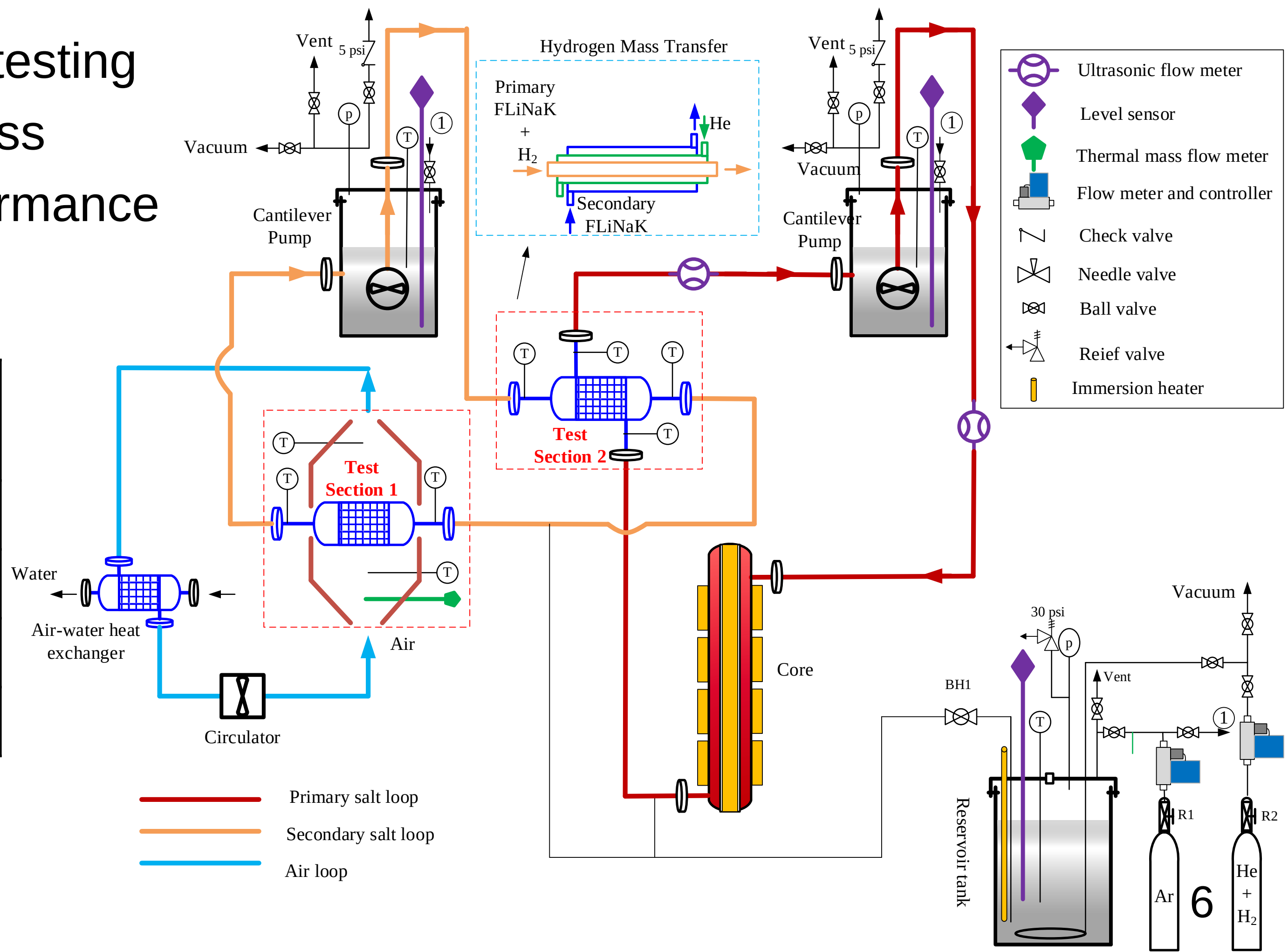
- Salt Purification and Components Testing
  - Test valves and filters
  - Test ultrasonic flow meter at high-temperature liquid salt conditions (Salt flows from one tank to anther)
  - Test and calibrate level sensors
  - Test differential pressure measurement method in liquid salt conditions



# Liquid Fluoride Salt Test Facility

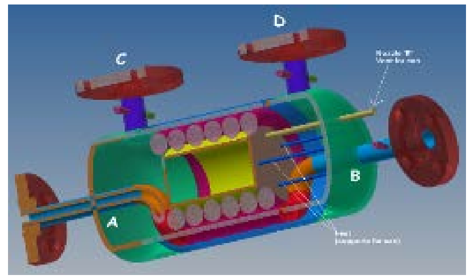
- Objectives: Heat Exchanger Testing
  - Heat transfer performance testing
  - Hydrogen mass transfer performance testing

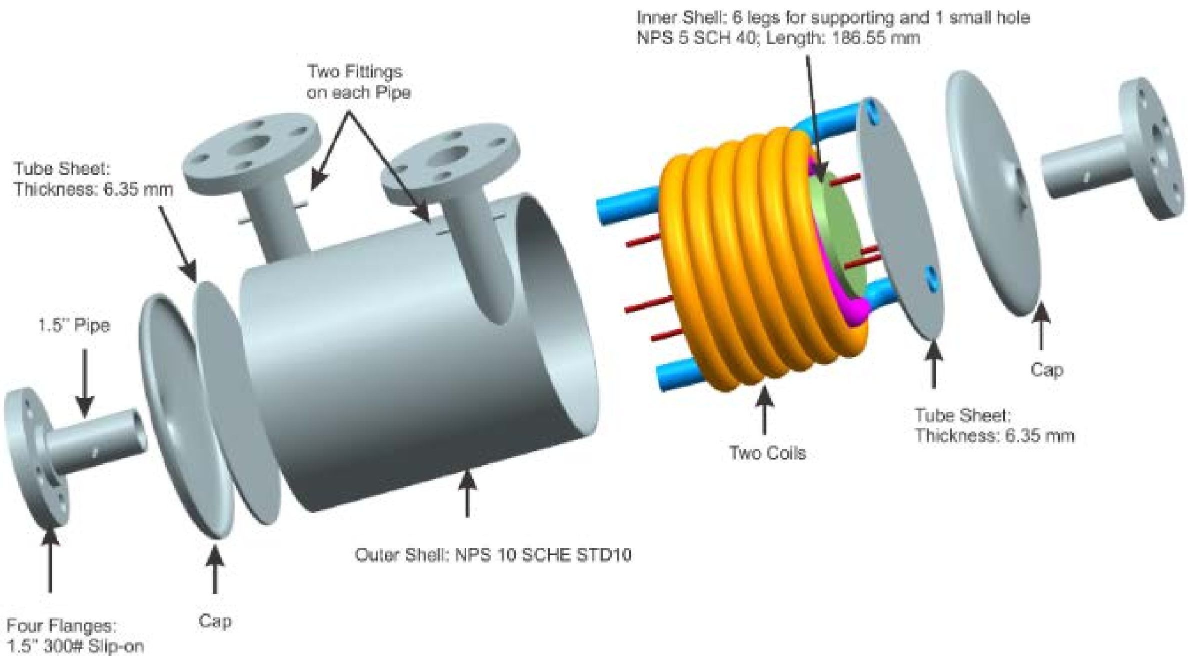
| | | |
|---|---|---|
| Core power (kW) | | 40 |
| Primary FLiNaK | $T_{hot}$ (°C) | 700 |
| | $T_{cold}$ (°C) | 676 |
| Secondary FLiNaK | $T_{hot}$ (°C) | 570 |
| | $T_{cold}$ (°C) | 550 |

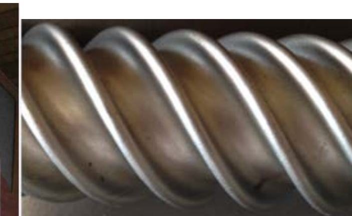


# Heat Exchangers for FHRs/MSRs

- Helically-Coiled Fluted Tube Heat Exchangers



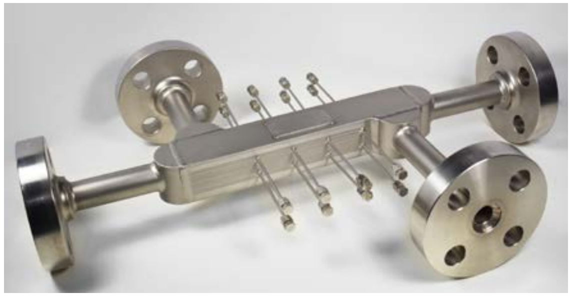



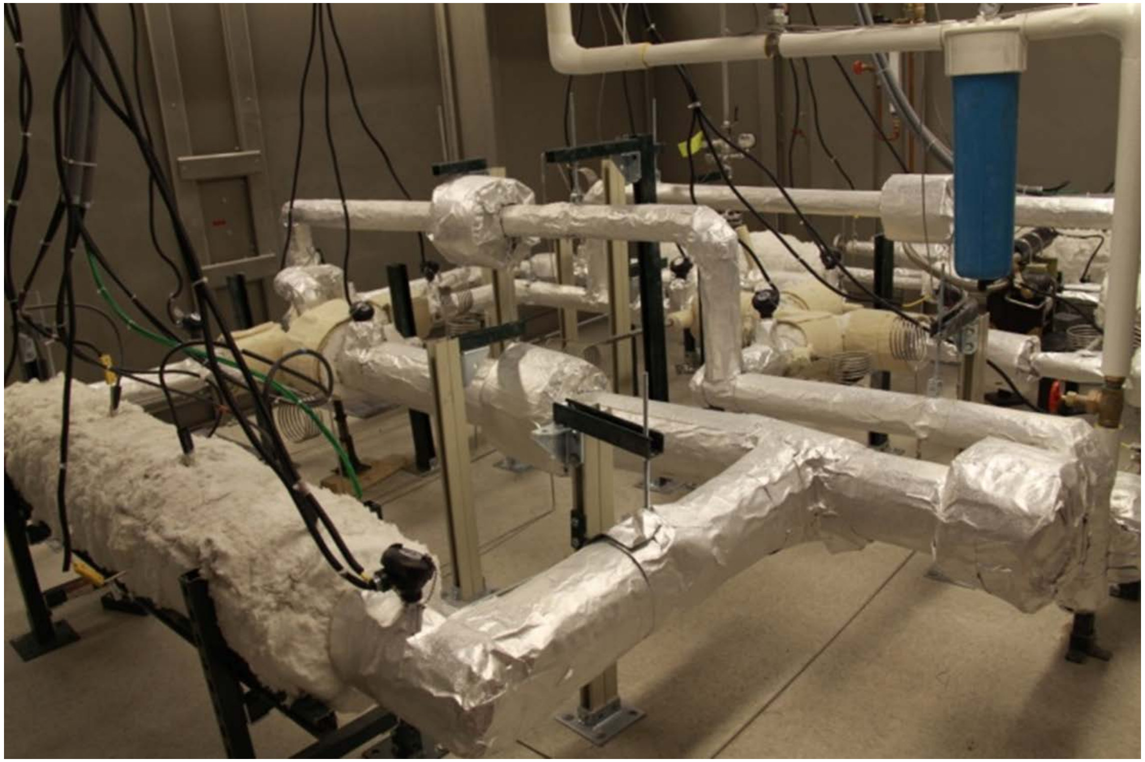
# Thermal Hydraulics Lab Capabilities

High-Temperature Gas-Cooled Reactor (HTGR)

# High-Temperature Helium Test Facility

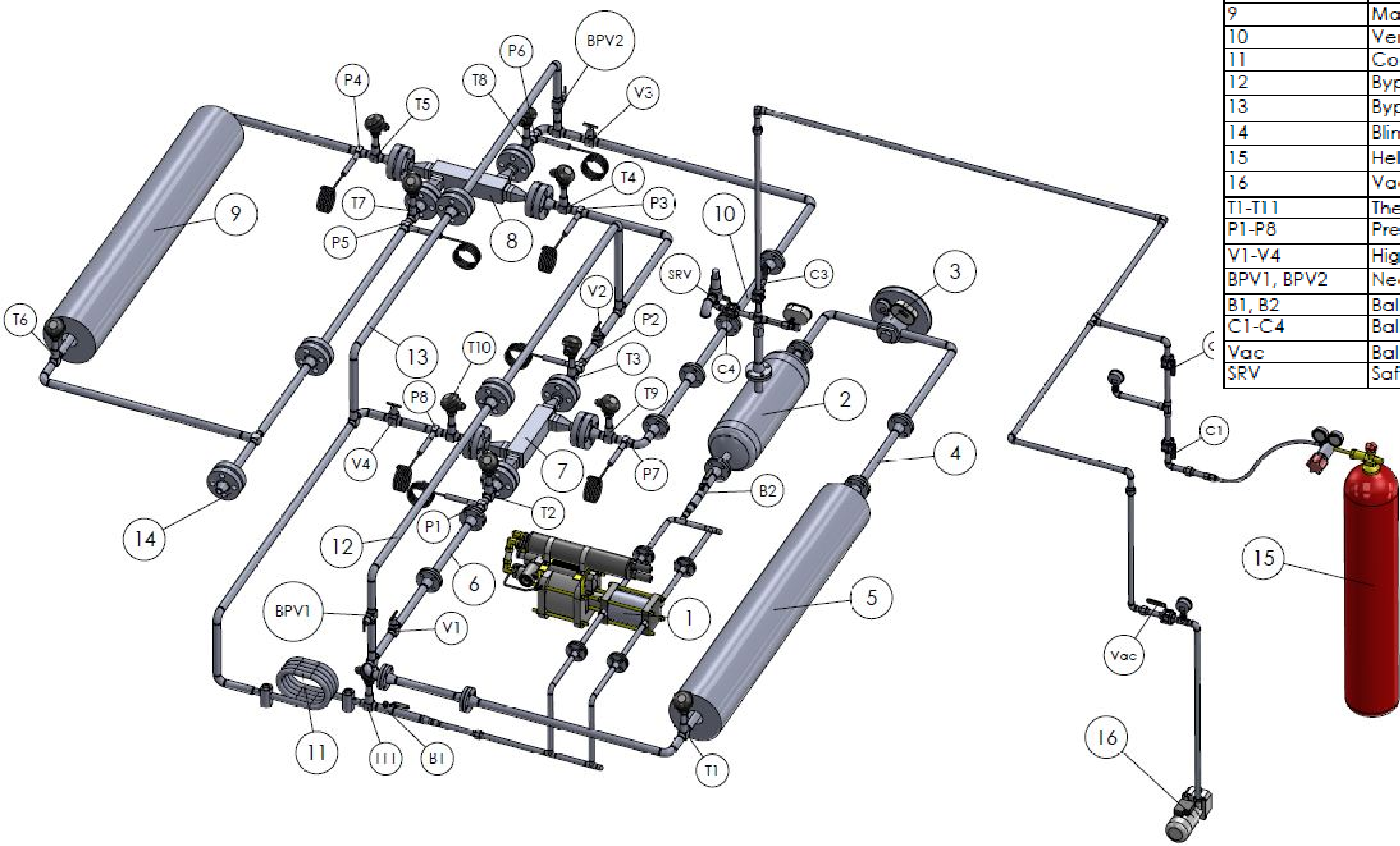
- HTHF Design Temperature & Pressure: 850$^{o}$C and 3 MPa
- Electric heating power: 46 kW
- Two PCHEs made of Alloy 617 plates installed and tested
- HTHF can be used for testing of heat exchangers, valves, and instrumentation





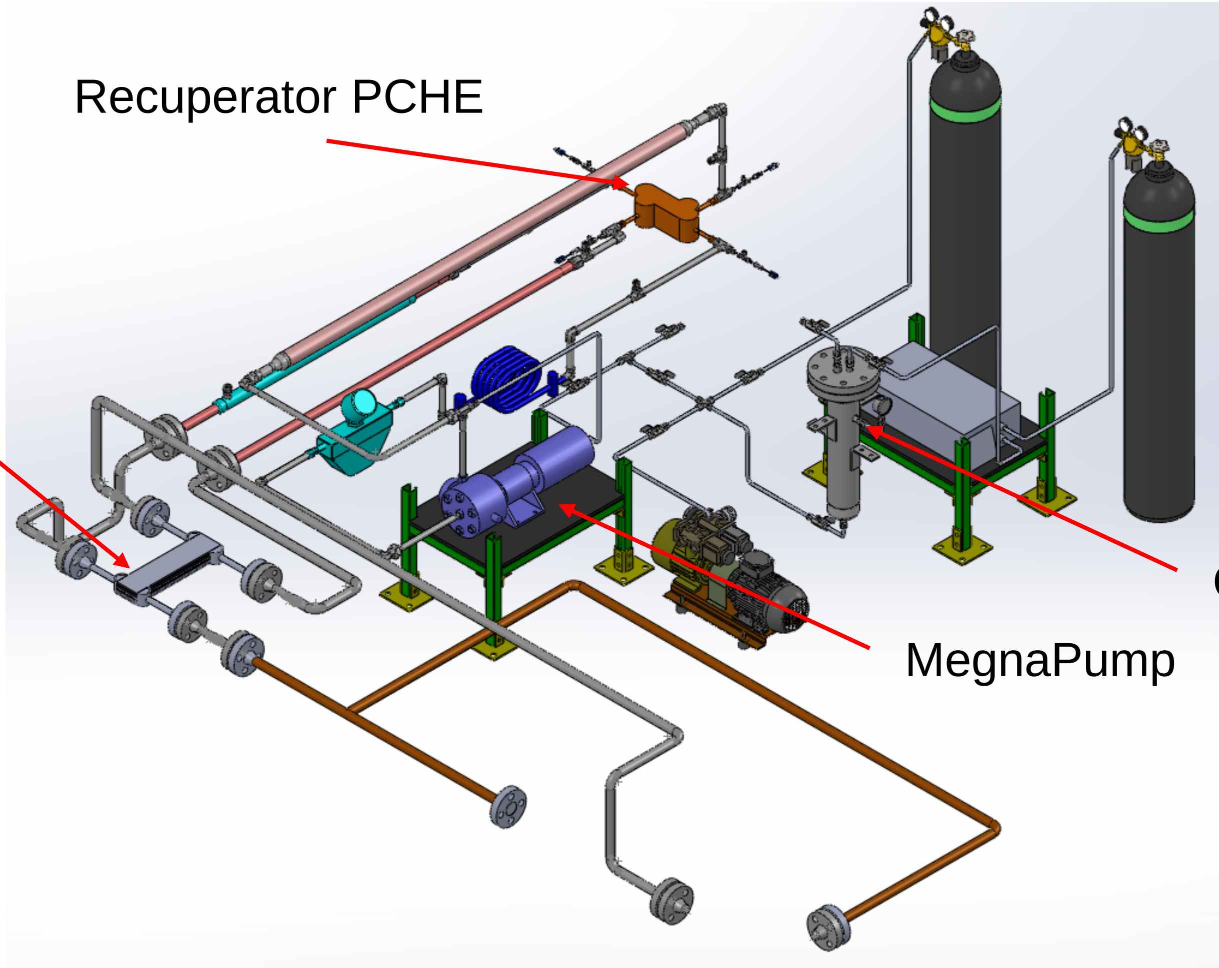
# High-Temperature Helium Test Facility (Cont'd)

| Balloon No. | Name |
|---|---|
| 1 | Gas Booster |
| 2 | Surge Volume Tank |
| 3 | Pressure Reducing Valve |
| 4 | Venturi Flow Meter 1 |
| 5 | Pre Heater |
| 6 | Venturi Flow Meter 2 |
| 7 | PCHE 1 |
| 8 | PCHE 2 |
| 9 | Main Heater |
| 10 | Venturi Flow Meter 3 |
| 11 | Cooler |
| 12 | Bypass 1 |
| 13 | Bypass 2 |
| 14 | Blind Flange |
| 15 | Helium Gas Cylinder |
| 16 | Vacuum Pump |
| T1-T11 | Thermowells |
| P1-P8 | Pressure Taps |
| V1-V4 | High Temperature Needle Valves |
| BPV1, BPV2 | Needle Valve in Bypass Lines |
| B1, B2 | Ball Valves at Booster Inlet and Exit |
| C1-C4 | Ball Valves in the Charging Line |
| Vac | Ball Valve in Vacuum Line |
| SRV | Safety Relief Valve |



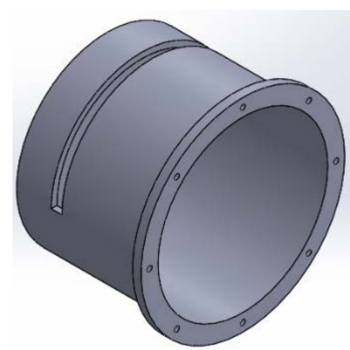
# S-$CO_2$ Test Loop (STL)

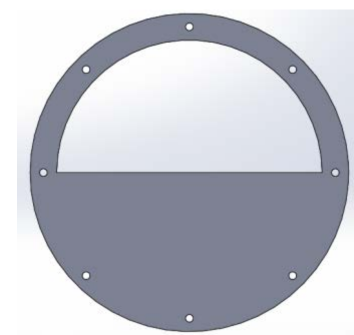
- Temperature and pressure up to 630ºC and 16 MPa

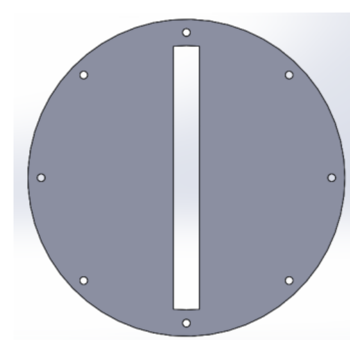


# Air-ingress Test Facility

- Research Objectives
  - Understand air ingress phenomenon into hot exit plenum following cross vessel break – directly affects graphite oxidation
  - Understand how break geometry affects air ingress phenomenology – molecular diffusion vs. density-driven countercurrent flow

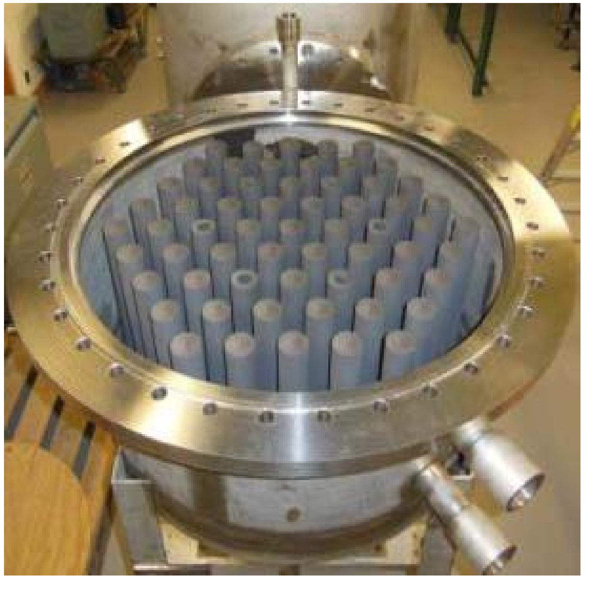






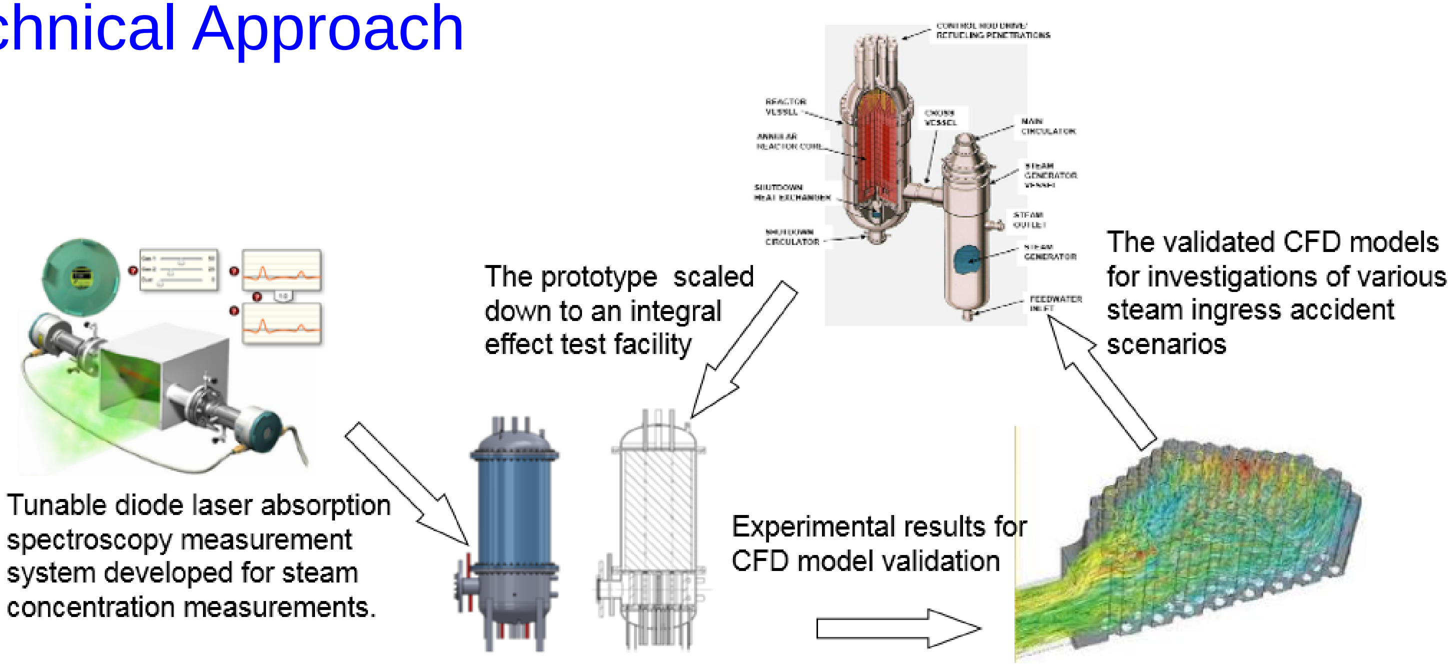
# Air-ingress Test Facility (Cont'd)

- Main Test Vessel
  - Simulates hot exit plenum and hot duct of cross vessel
  - SS 316 vessel rated up to 0.35 MPa at 540$^{o}$C
  - Contains 59 IG-110 graphite rods arranged hexagonally
  - Instrumented with 36 TCs, 10 PTs, 5 $O_2$ Sensors
- Containment Vessel
  - SS 304 vessel rated up to 0.17 MPa at 100$^{o}$C
  - Break Initiation (Air piston and break cap)
  - 5 TCs, 1 $O_2$ Sensor



# Steam Ingress Accidents in HTGRs

- Research Objectives
  - Experimentally investigate steam ingress accidents, focusing on both thermal-hydraulic behavior and graphite oxidation
  - Develop and validate predictive Computational Fluid Dynamics (CFD) models for the steam ingress phenomena
- Technical Approach

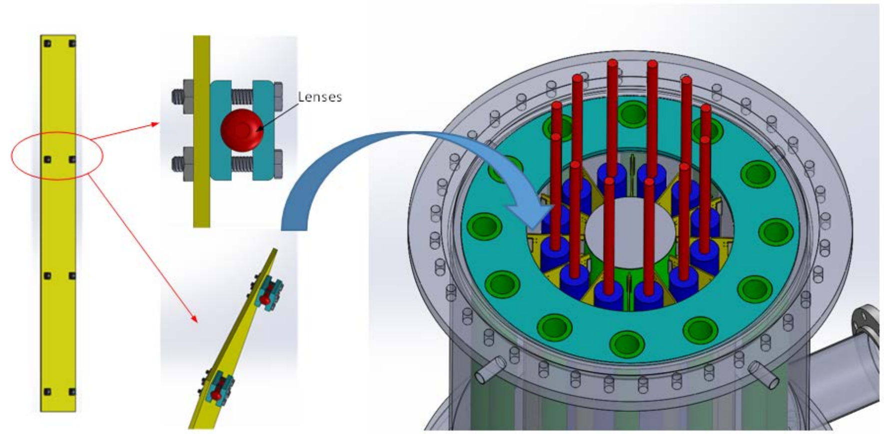


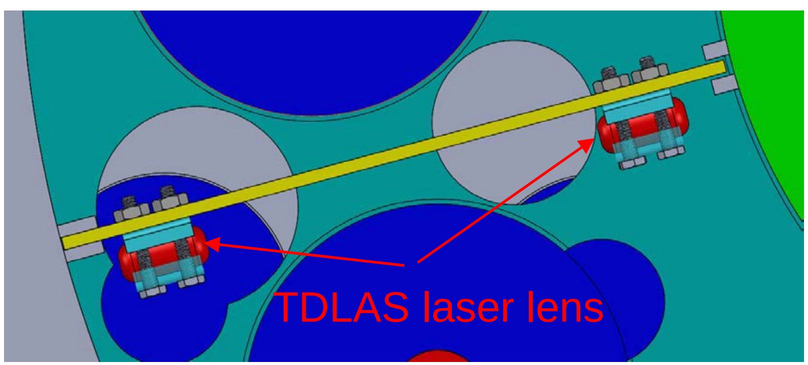

Technical approach for steam ingress project

# Steam Ingress Accidents in HTGRs (Cont'd)

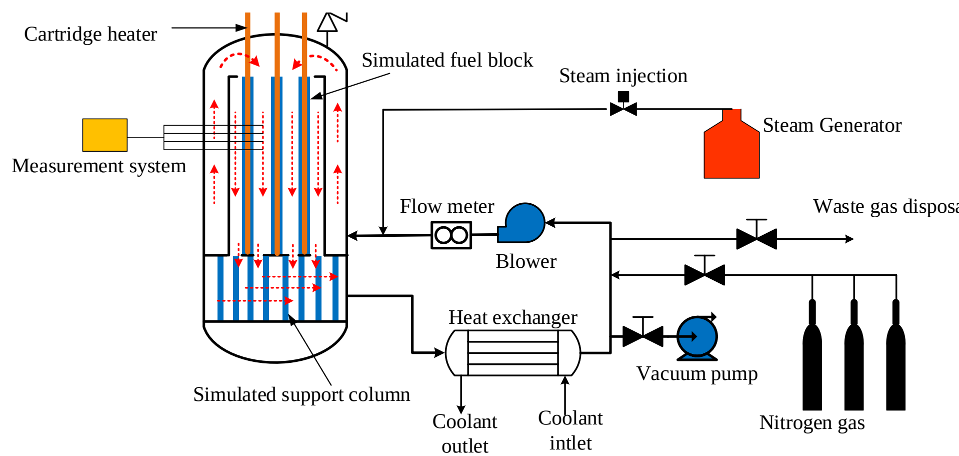
- Integral Effect Test Facility Design


TDLAS lens




Installation of TDLAS in core region




Schematic of the integral effect test facility