UC BERKELEY NUCLEAR ENGINEERING
Thermal Hydraulics Laboratory

Tritium and Chemistry Management for the Mark-1 PB-FHR

Workshop on Tritium Control and Capture in Salt-Cooled Fission and Fusion Reactors: Experiments, Models, and Benchmarking

Salt Lake City

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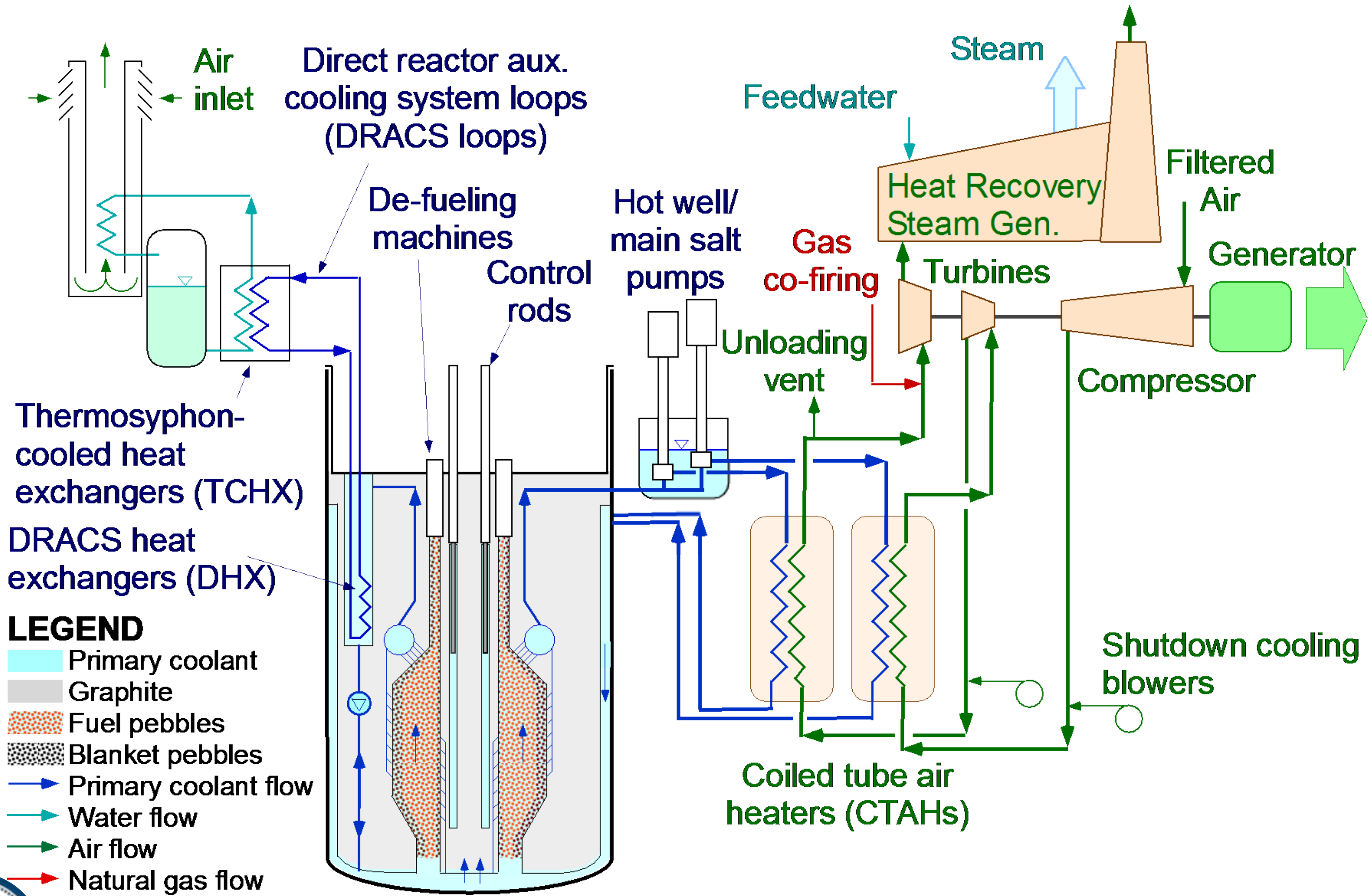
U.C. Berkeley

FHR
Fluoride Salt Cooled High Temperature Reactor

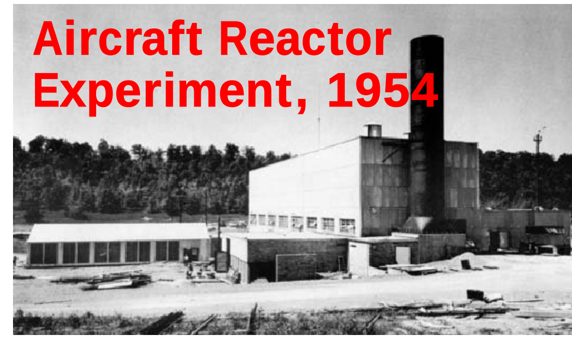
NEUP Nuclear Energy University Programs
U.S. Department of Energy

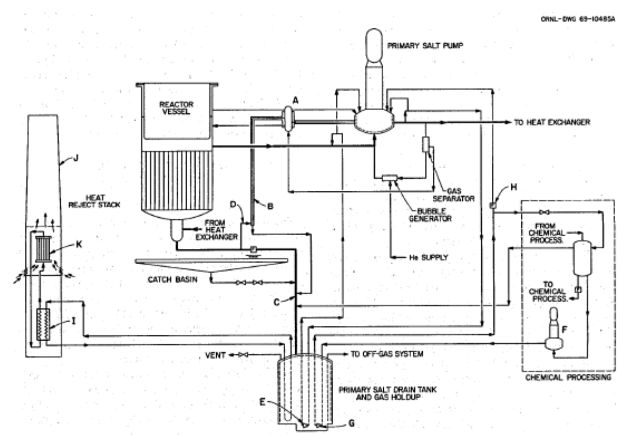
Mk1 PB-FHR flow schematic



The recent UC Berkeley Mk1 PB-FHR design effort had 4 goals

- **Demonstrate a plausible, self-consistent Nuclear Air Combined Cycle (NACC) system design**
  - **Believable predictions for base-load and peaking power levels using an industry-standard design code (Thermoflex)**
    - **2 archival articles now published in the *ASME Journal of Engineering for Gas Turbines and Power***
  - **Self-consistent approach to heat air directly with primary coolant**
- **Provide detailed design for decay heat management systems**
  - **Provide basis for establishing CIET experiment test matrix**
  - **Enable TH code validation and benchmarking exercises**

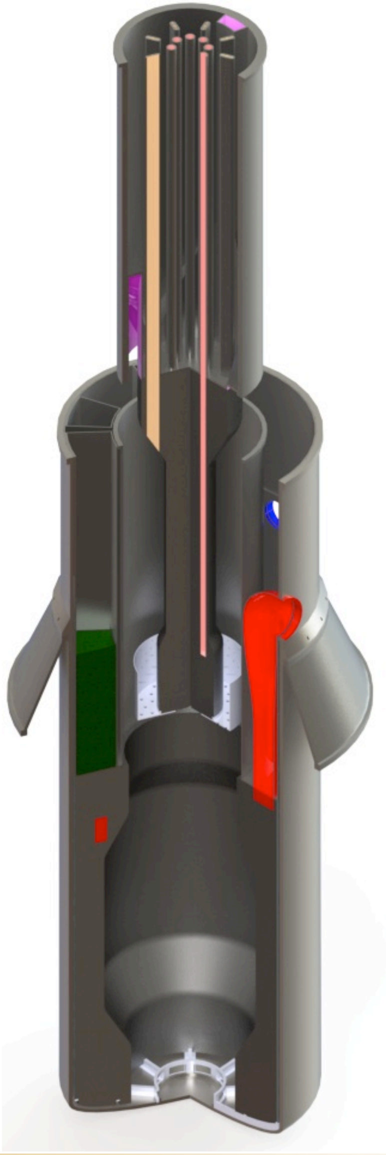




MSBR drain tank cooling system

The Mk1 PB-FHR design had 4 goals (con't)

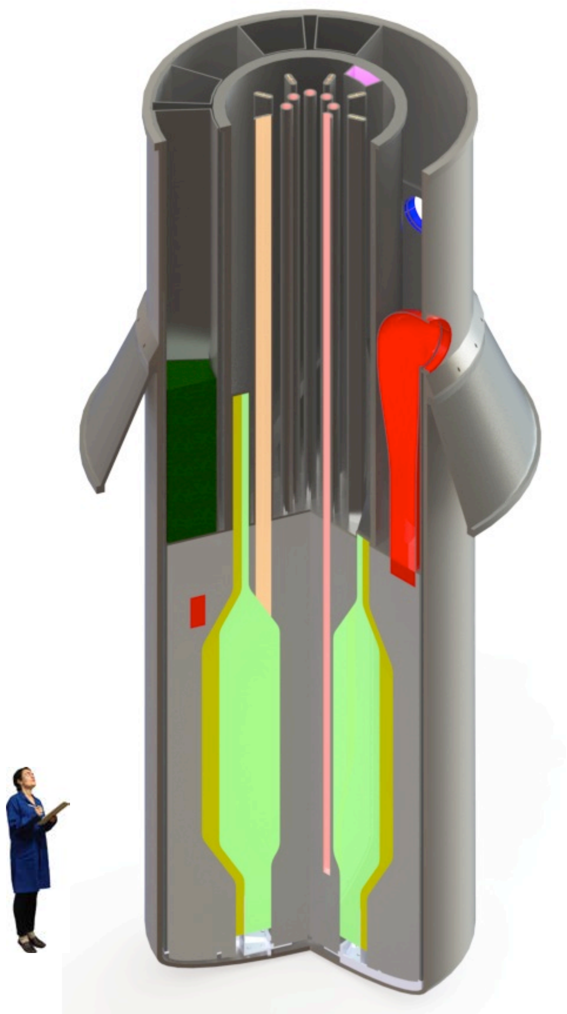
- **Develop a credible, detailed annular FHR pebble core design**
  - **Inner and outer graphite reflector including assembly method**
  - **Pebble injection and defueling**
  - **Coolant flow distribution and pressure loss calculations**
  - **Provide basis for future FHR code benchmarking**
  - **Neutronics/depletion/control-rod worth calculations are documented in A.T. Cisneros doctoral dissertation**
- **Identify additional systems and develop notional reactor building arrangement**
  - **"Black-box" level of design for many of these systems**
  - **Includes beryllium and tritium management, and chemistry control strategies**



Nominal Mk1 PB-FHR Design Parameters

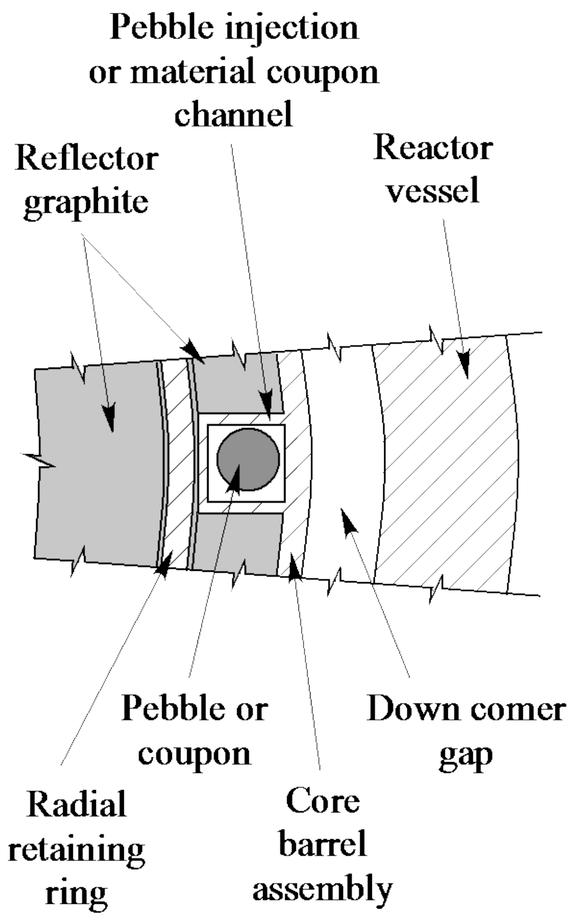
- **Annular pebble bed core with center reflector (600/700° C Core Inlet/Outlet)**
- **Reactor vessel 3.5-m OD, 12.0-m high**
- **Power level: 236 MWth, 100 MWe (base load), 242 MWe (peak w/ gas co-fire)**
- **Power conversion: GE 7FB gas turbine w/ 3-pressure HRSG**
- **Air heaters: Two 3.5-m OD, 10.0-m high CTAHs, direct heating**
- **Tritium control and recovery**
  - **Recovery: Absorption in fuel and blanket pebbles and additional graphite media**
  - **Control: Diffusion barrier coating on air side of CTAHs**

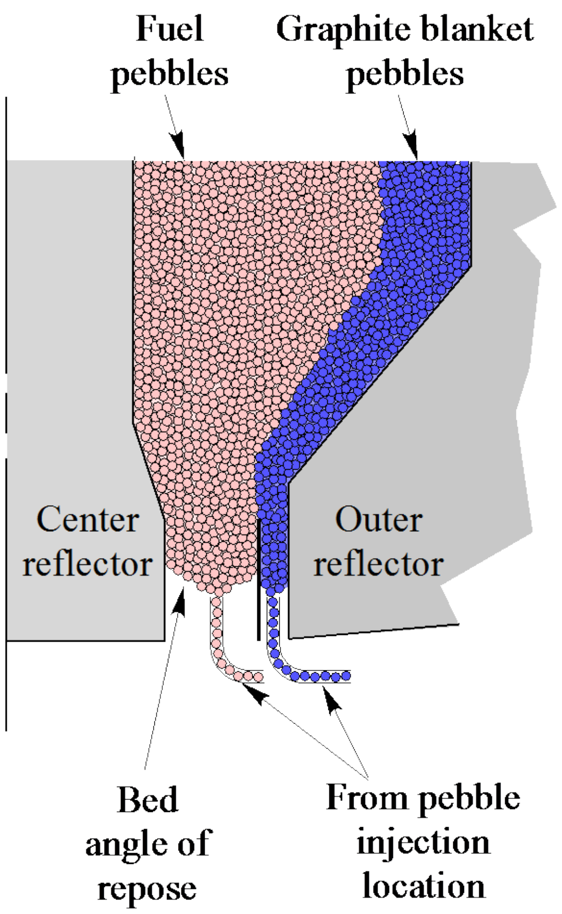
Equilibrium Tritium Production
~0.07 g (670 Ci) per EFPD
99.9% Target Recovery Rate



PB-FHR cross section

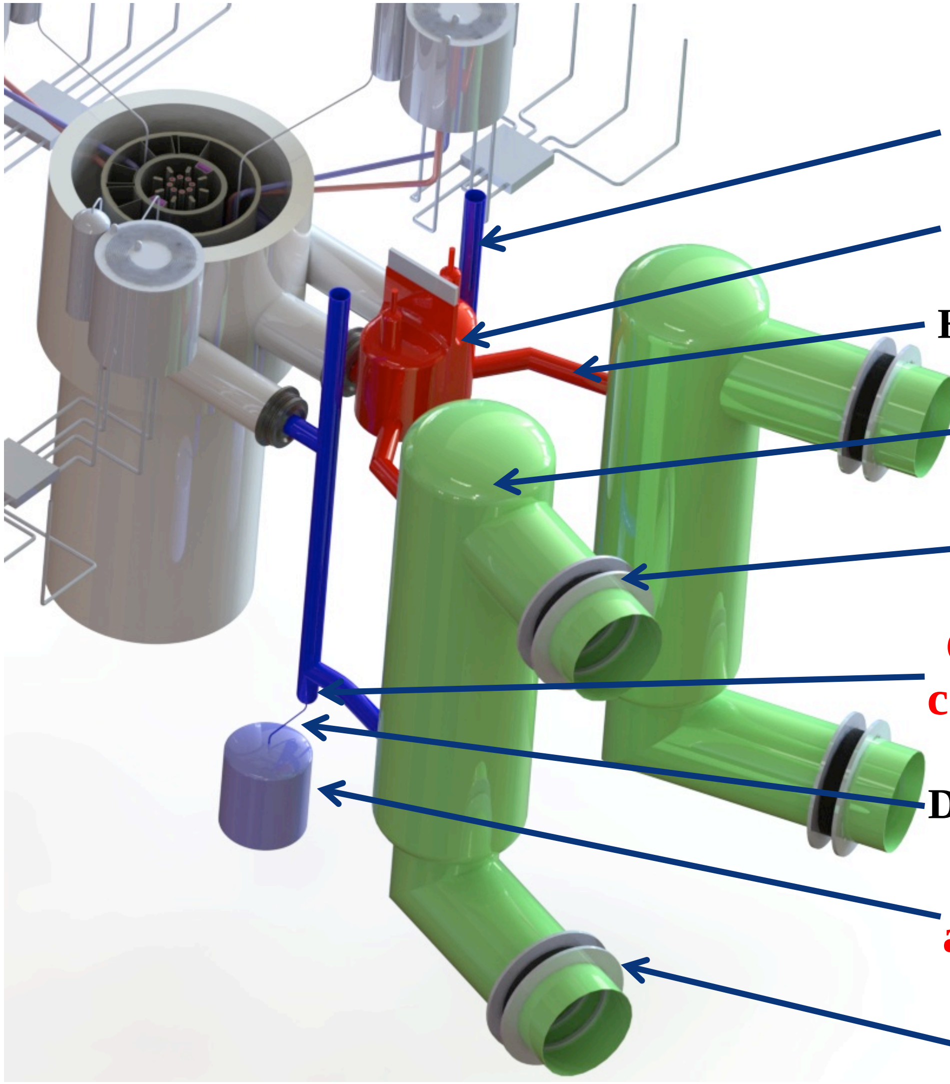
Mk1 pebble injection feeds pebbles to the bottom of the core at a controlled rate





Mk1 blanket and fuel pebbles are expected to provide an important sink for tritium

The Mk1 heat transport system delivers heated salt to the two CTAHs



Cold leg stand pipes

Hot well with main salt pumps

Hot salt crossover legs

CTAHs with internal tritium filter cartridges

Hot air ducts and expansion bellows

Cold traps with redox control and filter media

Drain tank freeze valve

Drain tanks for loop and bulk salt clean-up

Warm air ducts and expansion bellows

Mk1 CTAHs have 36 annular sub-bundles

Baffle plate

Tube spacer bars w/ tie rod holes

Hot salt manifold

Electric heater electrode

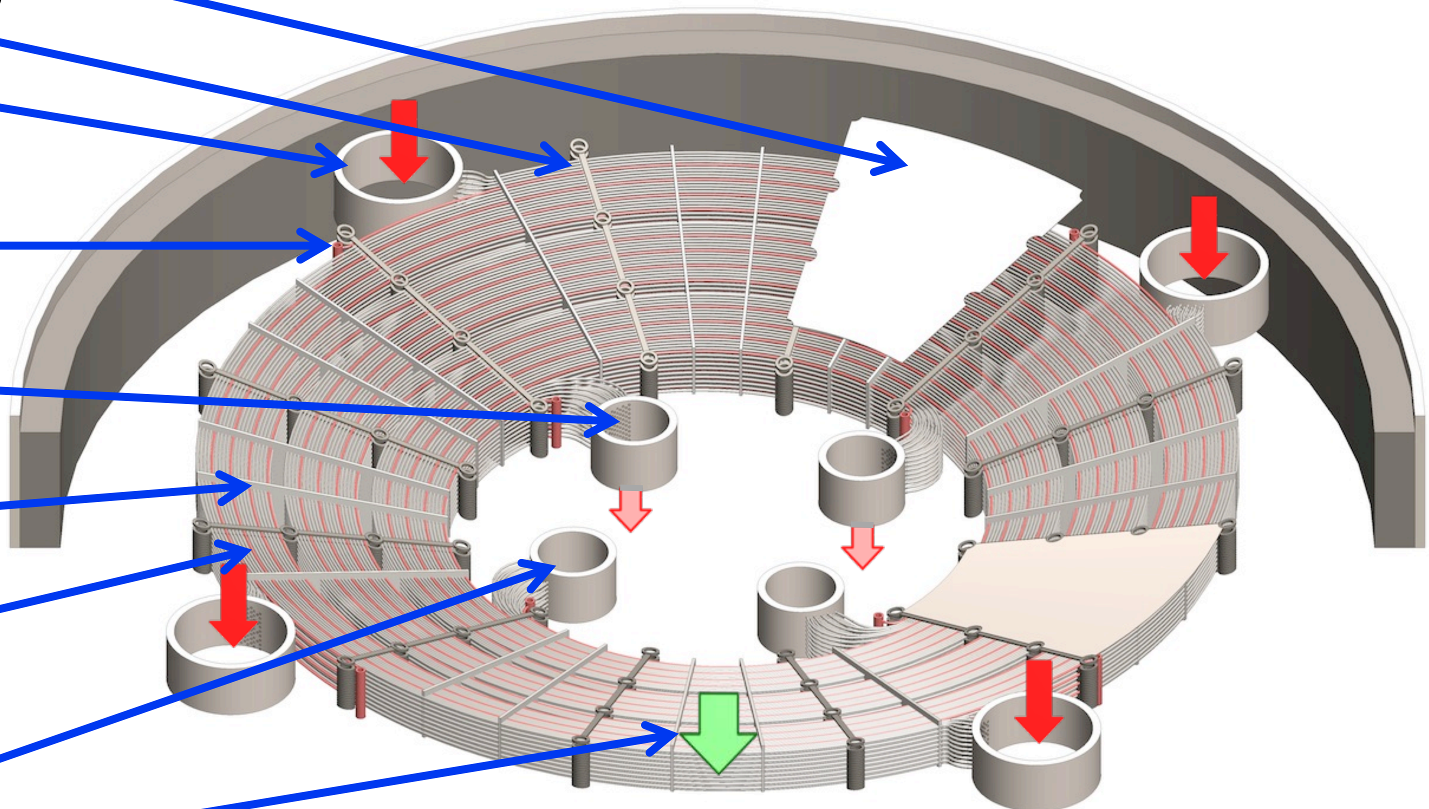
Tube to tube-sheet joints

Anti-vibration supports

Tube lanes (5x4= 20 tubes across)

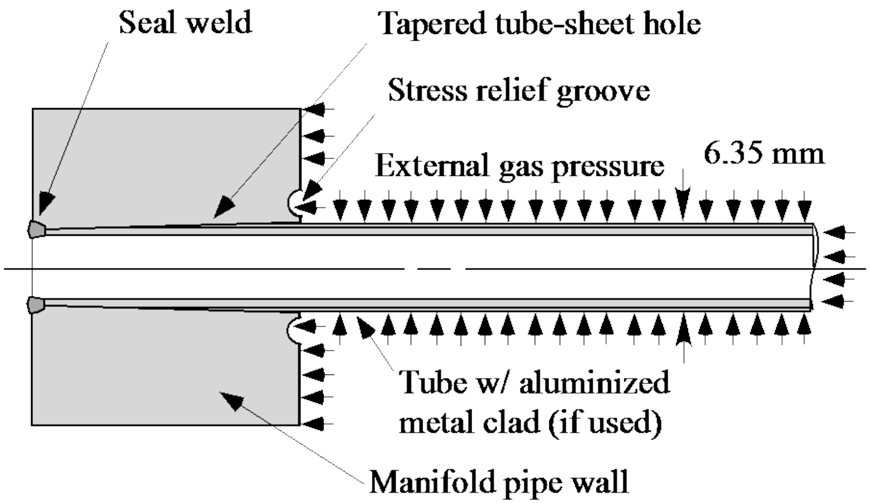
Cool salt manifold

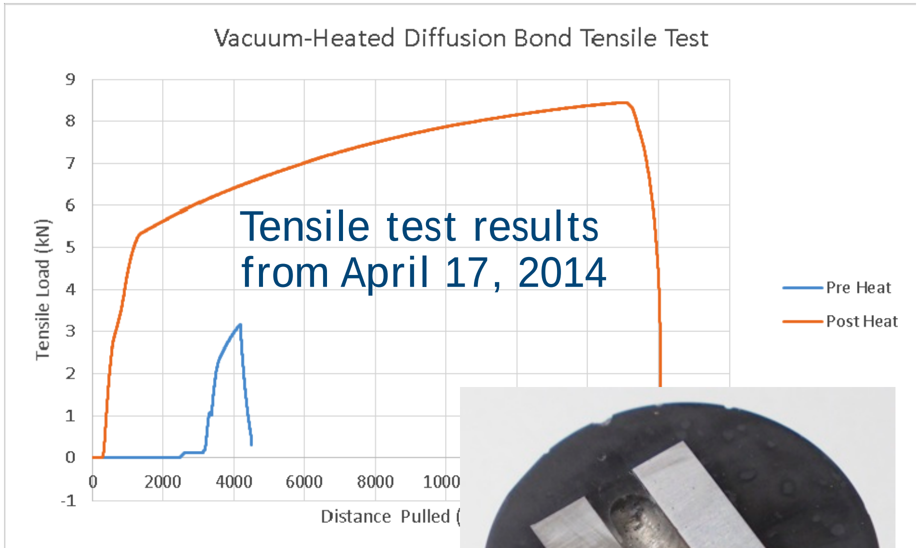
Air flow direction

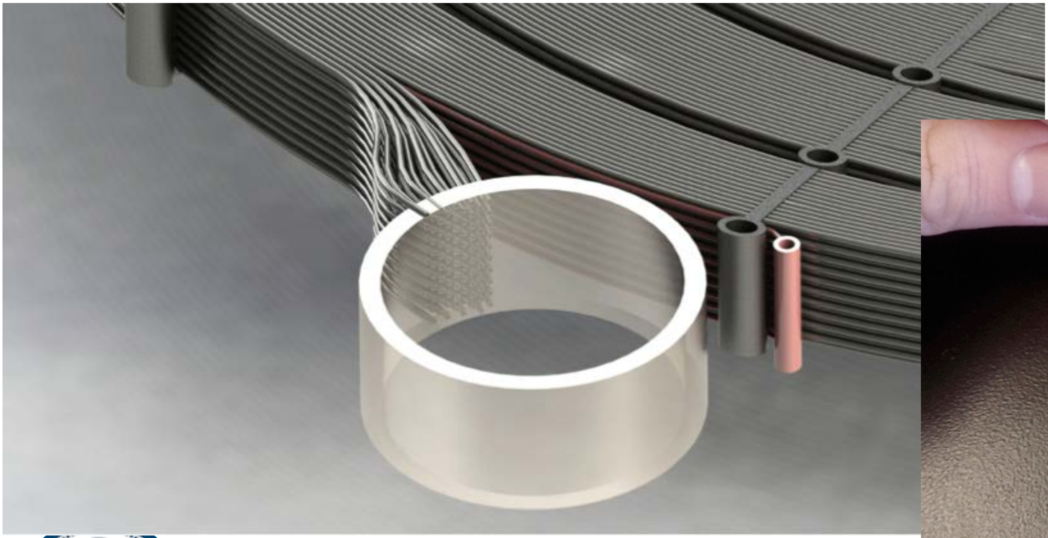


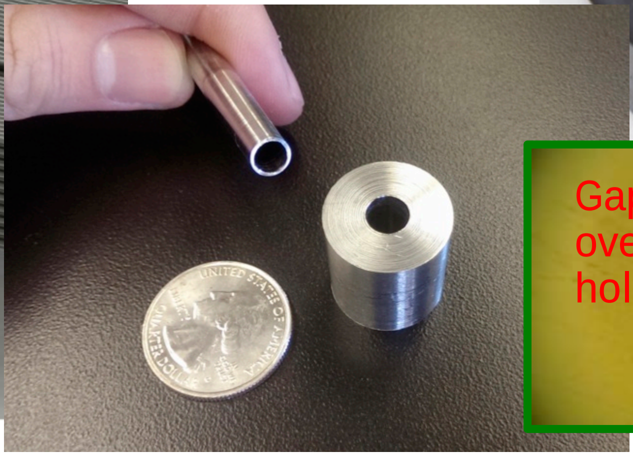
Mk1 CTAH Tube Sub-bundle Model

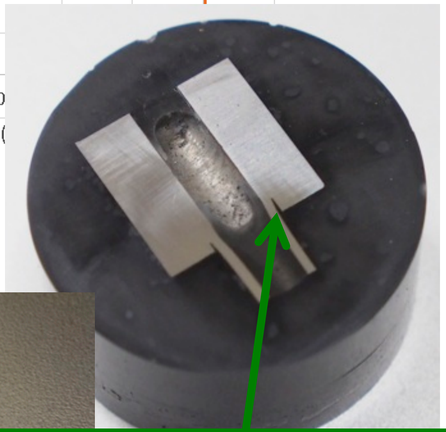
Tapered Mk1 CTAH tube to tube-sheet joints allow use of alumina-forming coating

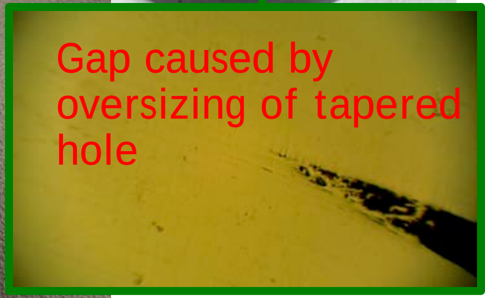






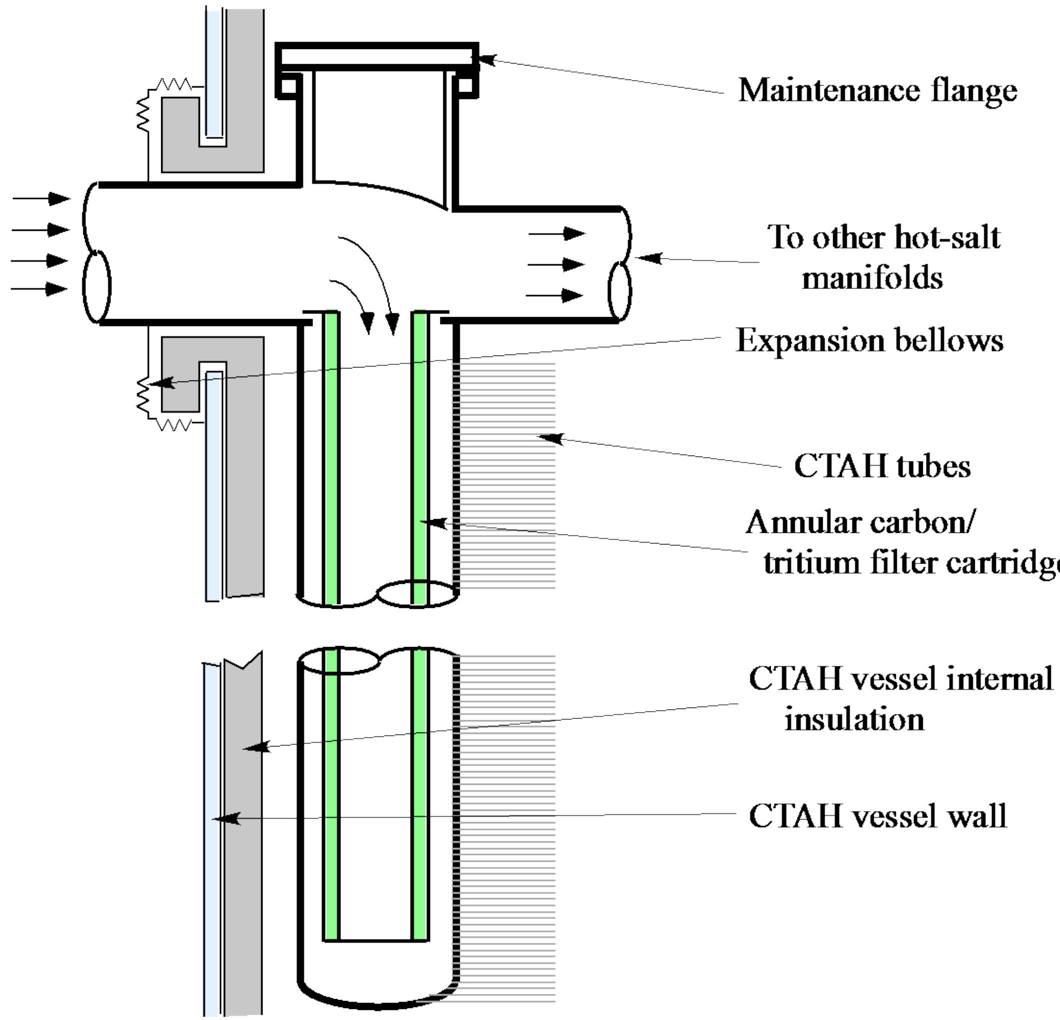






Mk1 CTAH hot leg stand pipes allow the use of an annular filter cartridge.

- **100% of hot salt flow can be treated before it enters the CTAH tubes**
- **Solid filter media can be used to remove tritium if absorption in fuel and blanket pebbles is not sufficient**



Cold spray coating provides a scalable method to apply tritium diffusion barriers to tubes

- **Cold spray coating uses a supersonic jet to deposit particles onto surfaces**
  - **Process performed at ambient pressure, so can be used for mass production of coated tubes and other primary coolant boundary external surfaces**
  - **Alumina forming compounds can be applied as well as other diffusion barriers**
- **Many possible alumina forming compounds are possible**
  - **Ti_2AlC ceramic has been demonstrated by UW Madison**
  - **Many ductile coating materials are also candidates**
    - » **Kanthal (Al_2O_3 forming alloy)**
    - » **316SS or Alloy N alloyed with a few percent aluminum**
    - » **Many others**

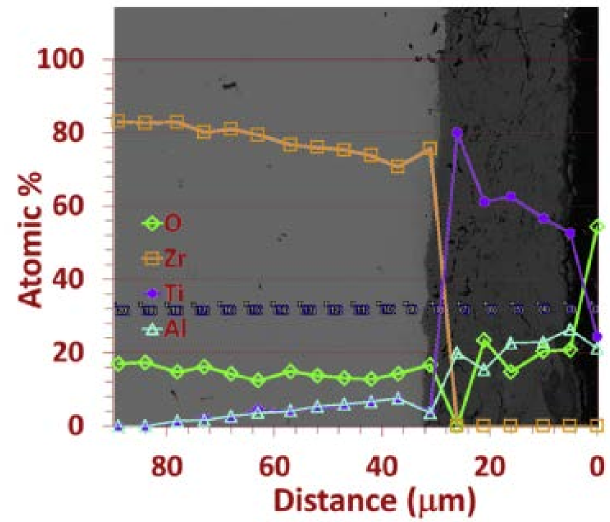
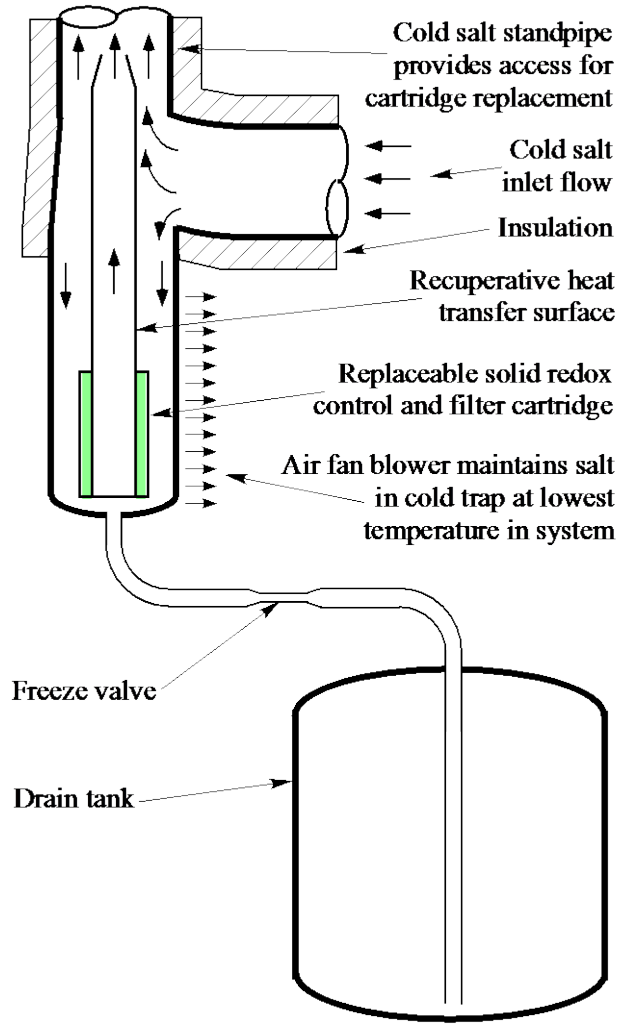


Fig. 11. Cross-sectional SEM image of Ti_2AlC MAX phase coated Zry-4 after simulated LOCA testing at 1005 °C for 20 min in an Ar/steam environment followed by quenching in boiling water. The EDS line scan is also overlaid on the SEM image.

UW Madison has demonstrated cold spray coating of Ti_2AlC on zirconium cladding

Mk1 Cold Traps and Drain Tanks aid coolant chemistry control

- **Cold trap filters oxides and other contaminants that precipitate at low temperature**
- **Cold trap also provides location to continuously contact salt with reducing agent (if used)**
- **Drain tank allows CTAHs to be drained for inspection/maintenance**
- **Drain tank provides volume to perform bulk salt clean up (e.g., HF/H_2 sparging) if needed during shutdown and maintenance.**



Questions?