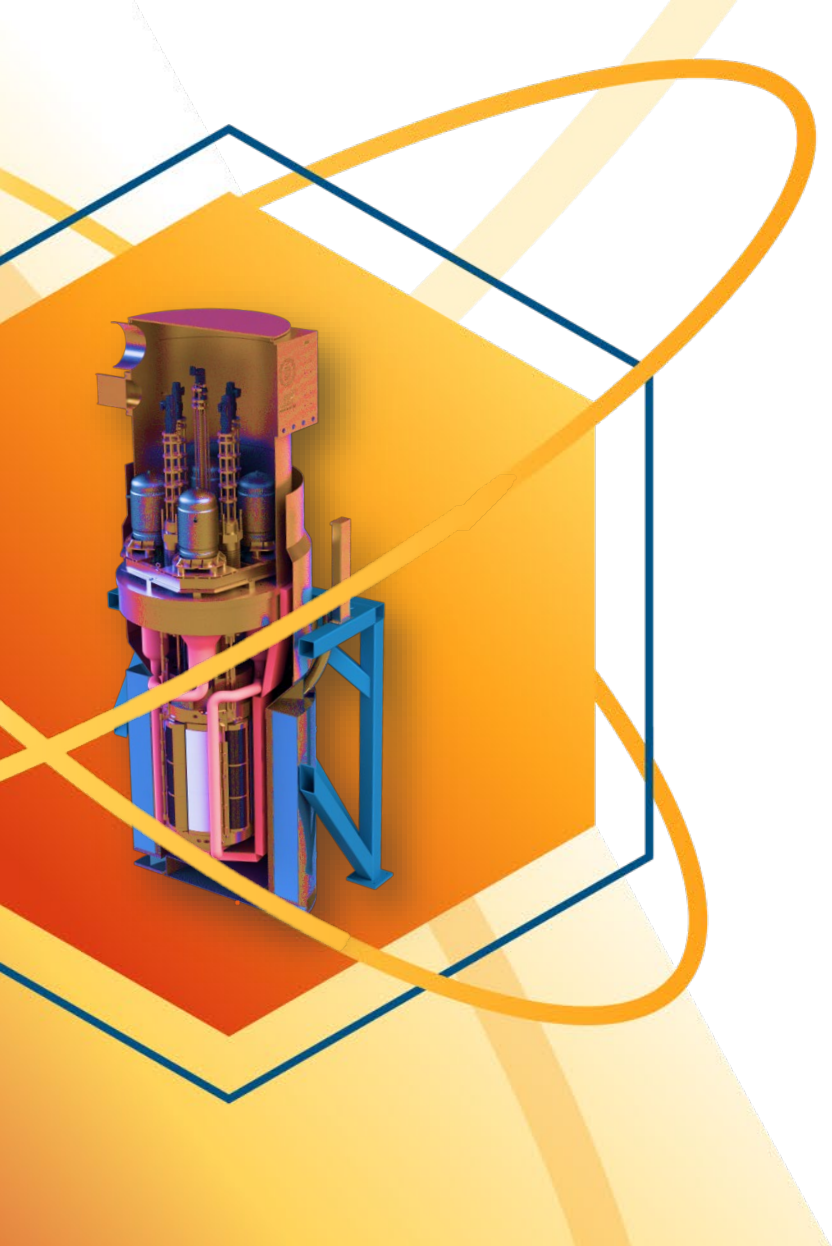


(Microreactor Applications Research, Validation & Evaluation),

HEAT EXTRACTION SYSTEM (HES)

March 2026

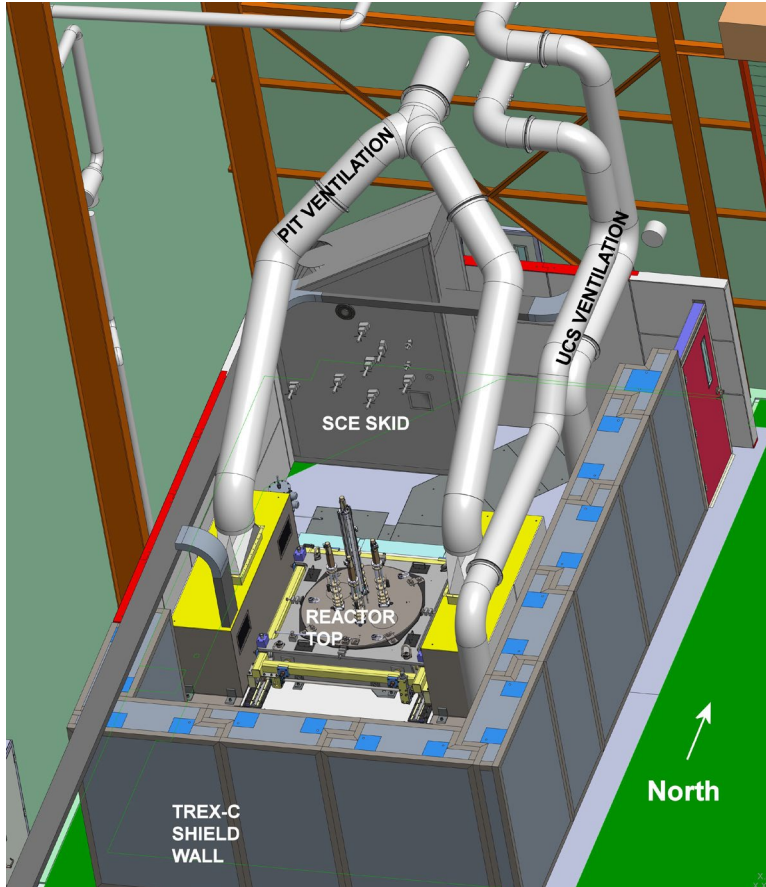
C. Baily



Heat Extraction System (HES)

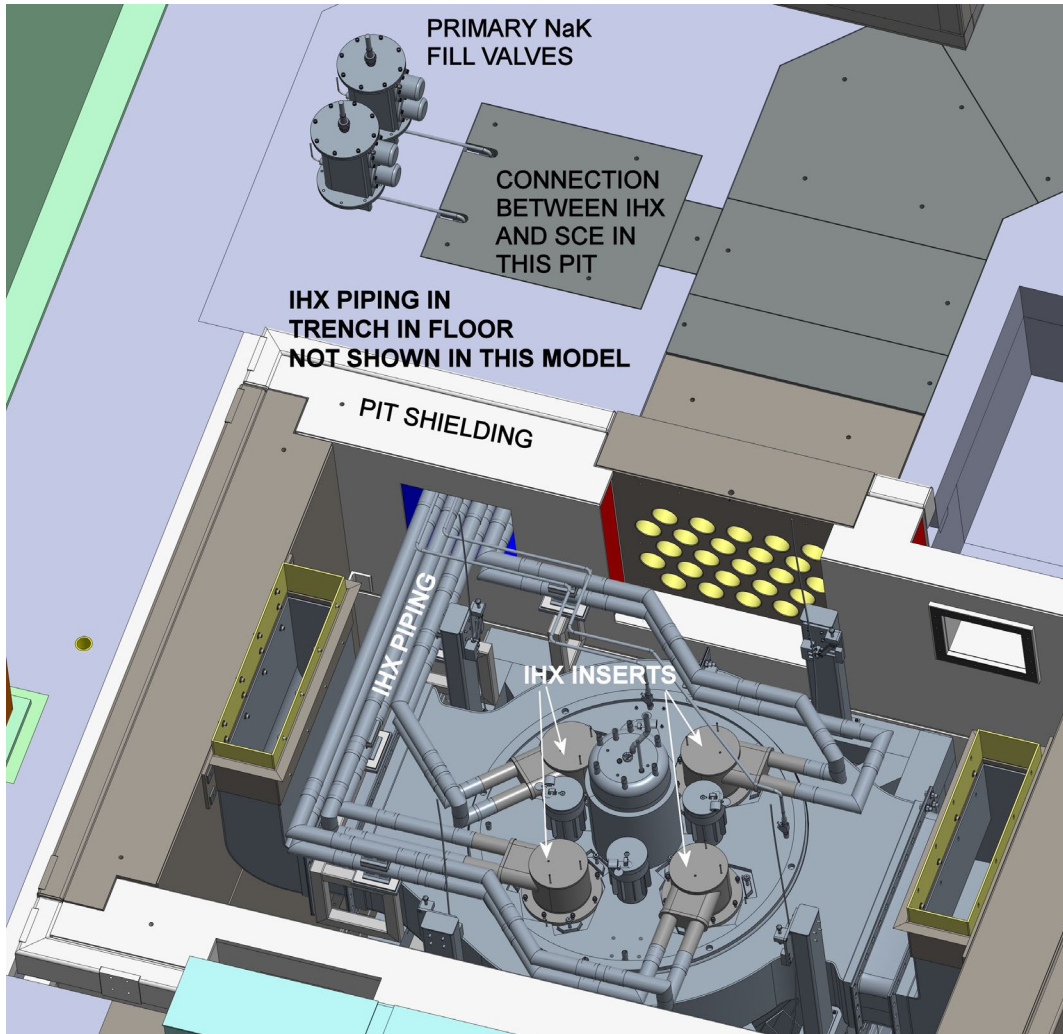
- The Heat extraction system replaces the original Stirling engines. It extracts heat from the reactor for use by end user systems. It uses pumped eutectic sodium-potassium alloy (NaK) to transfer heat from the reactor.
- A NaK-Air heat exchanger gives the ability to dissipate this heat directly to the environment for startup and testing of the reactor.
- The system consists of two sub-systems
 - The Secondary Coolant Equipment (SCE) subsystem is a skid containing the pump, heat exchanger and equipment to control flow in the secondary system
 - The Intermediate Heat Exchanger (IHX) system includes heat exchange inserts which fit into the Primary Coolant System IHX wells to transfer heat, and the piping inside the tREX-C pit which connects to the SCE.

System Arrangement in TREAT



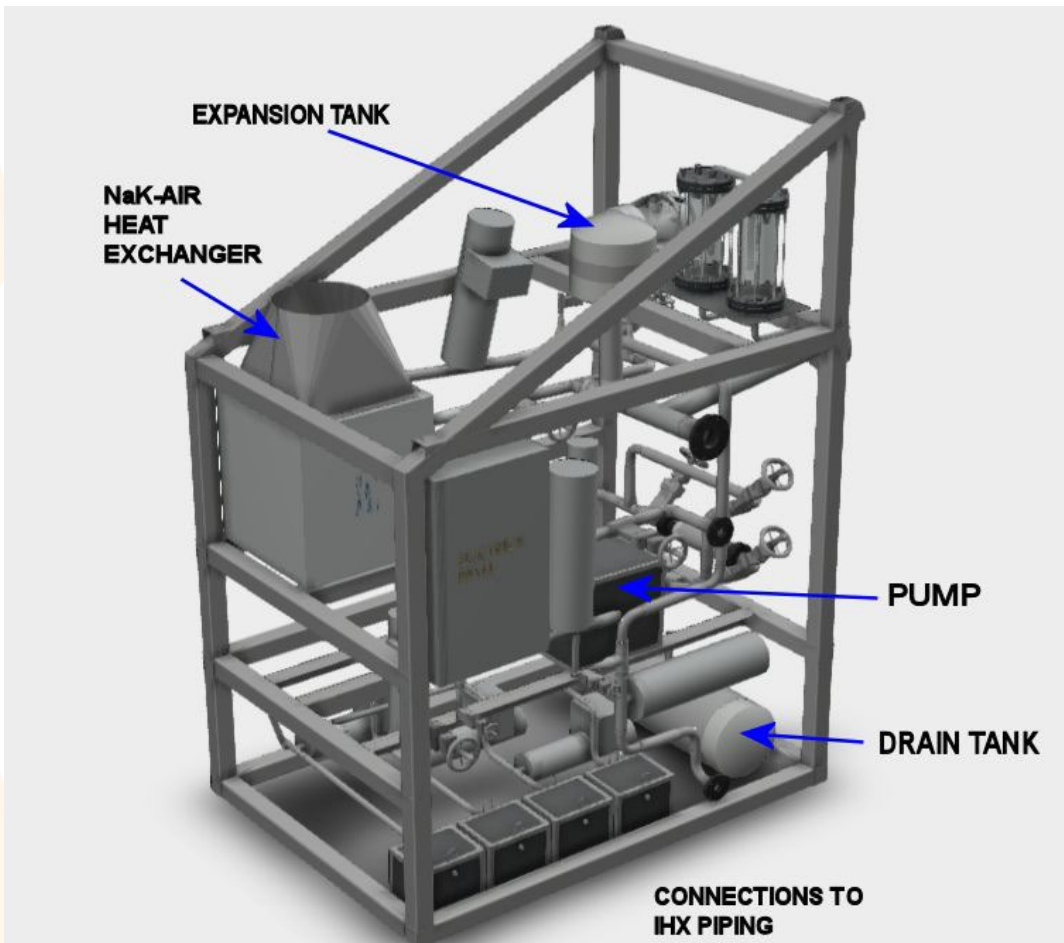
- The reactor is located in the tREX-c pit in the TREAT facility floor, near the North wall.
- The model here shows the most recent fully modeled configuration. Some changes to this configuration are under consideration.
 - Removal of the Upper Confinement Subsystem (UCS) has been proposed, and evaluation/analysis of this option is currently underway. Initial evaluation appears positive.
 - Removal of all or a portion of the tREX-c shield wall has been proposed. Initial radiological dose calculations show that design requirements for the tREX-c facility should still be met without this shield wall. The south wall may be retained.

IHX AND IHX PIPING IN PIT



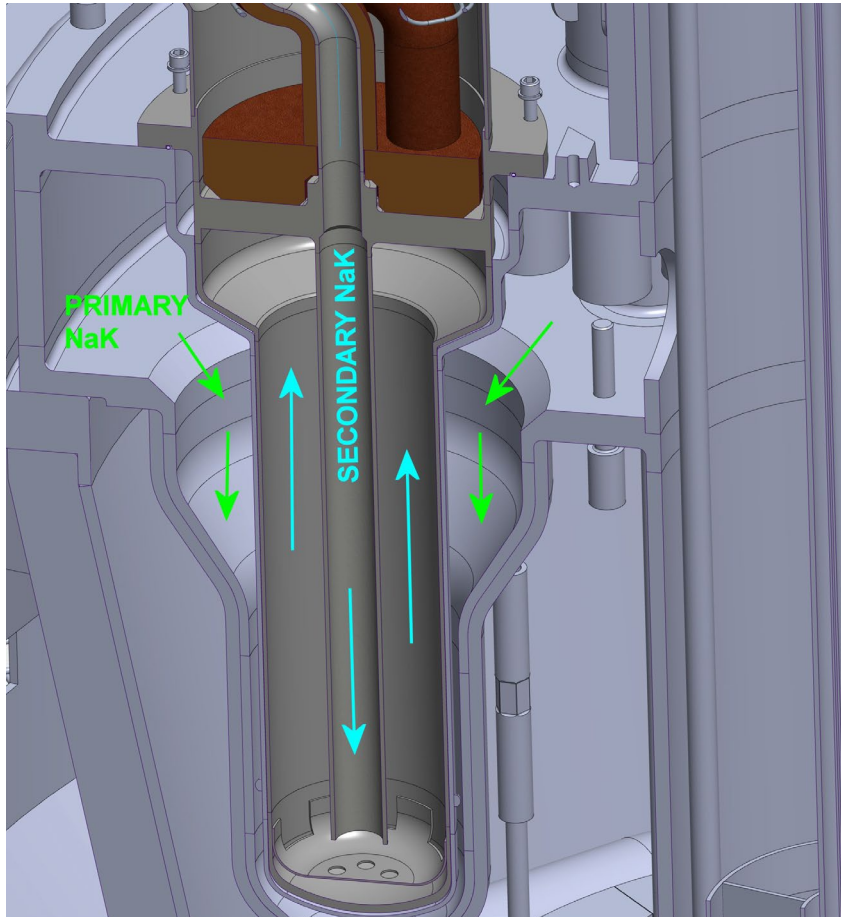
- Four IHX inserts are installed into primary coolant system (PCS) IHX wells
- Piping is run to a trench (not shown) through the pit shielding and TREAT floor to a pit, where connections will be made to the SCE system.
- The trench and pit will be sealed with a SST or steel liner to act as a spill confinement for NaK leakage.

SCE System



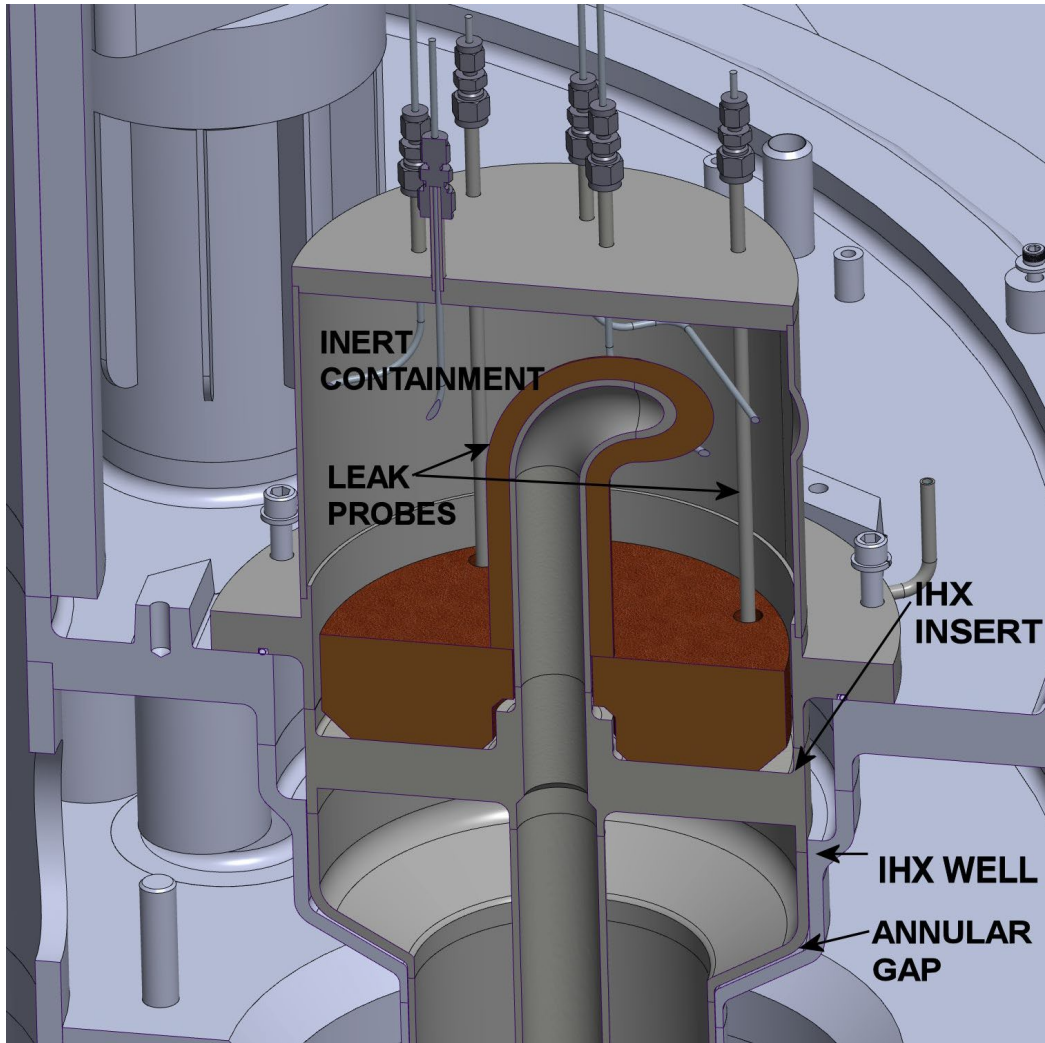
- Controls NaK inventory and flow in HES system
- Four 1-inch lines provide flow to the IHXs. Each has control valve and flowmeter.
- One 2-inch line for return from IHXs. Return lines (1inch) from IHXs will be manifolded into single 2-inch line.
- NaK-air heat exchanger includes controllable fan for removal of heat from system.
- System can be remotely drained to drain tank shown.
- System in integral skid, will be fitted with open confinement pan for NaK leakage.

IHX Insert



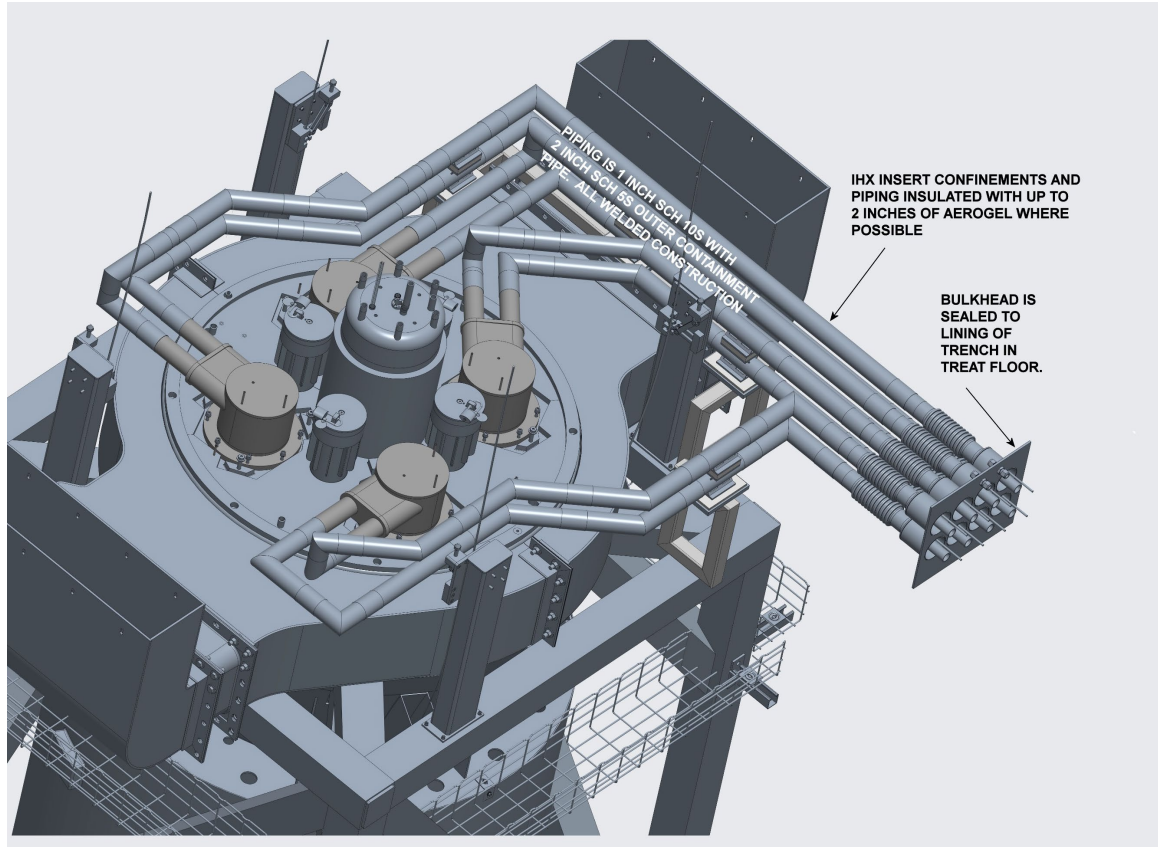
- Insert is designed to install into the PCS using the same configuration as for the liners which were to be used with the Stirling engines.
- Secondary NaK is pumped into the center tube of each liner, and flows upward around the outside
- Heat is transferred through the insert wall and PCS IHX Well wall. Thermal Paste is applied in the annular space to maximize heat transfer.
- Computational Fluid Dynamics (CFD) analysis is currently underway to fully characterize heat transfer

Detailed IHX Installation showing Annular Gap



- Annular gap will be filled with heat transfer compound to maximize heat transfer.
- Simplified physical mockups of the IHX insert and IHX well are being fabricated to allow development process for thermal paste application and curing.
- In addition, mockups will allow experimentation with paste formulations to determine the optimal parameters. Boron-nitride paste is currently baseline, but other types of paste may provide superior application characteristics.

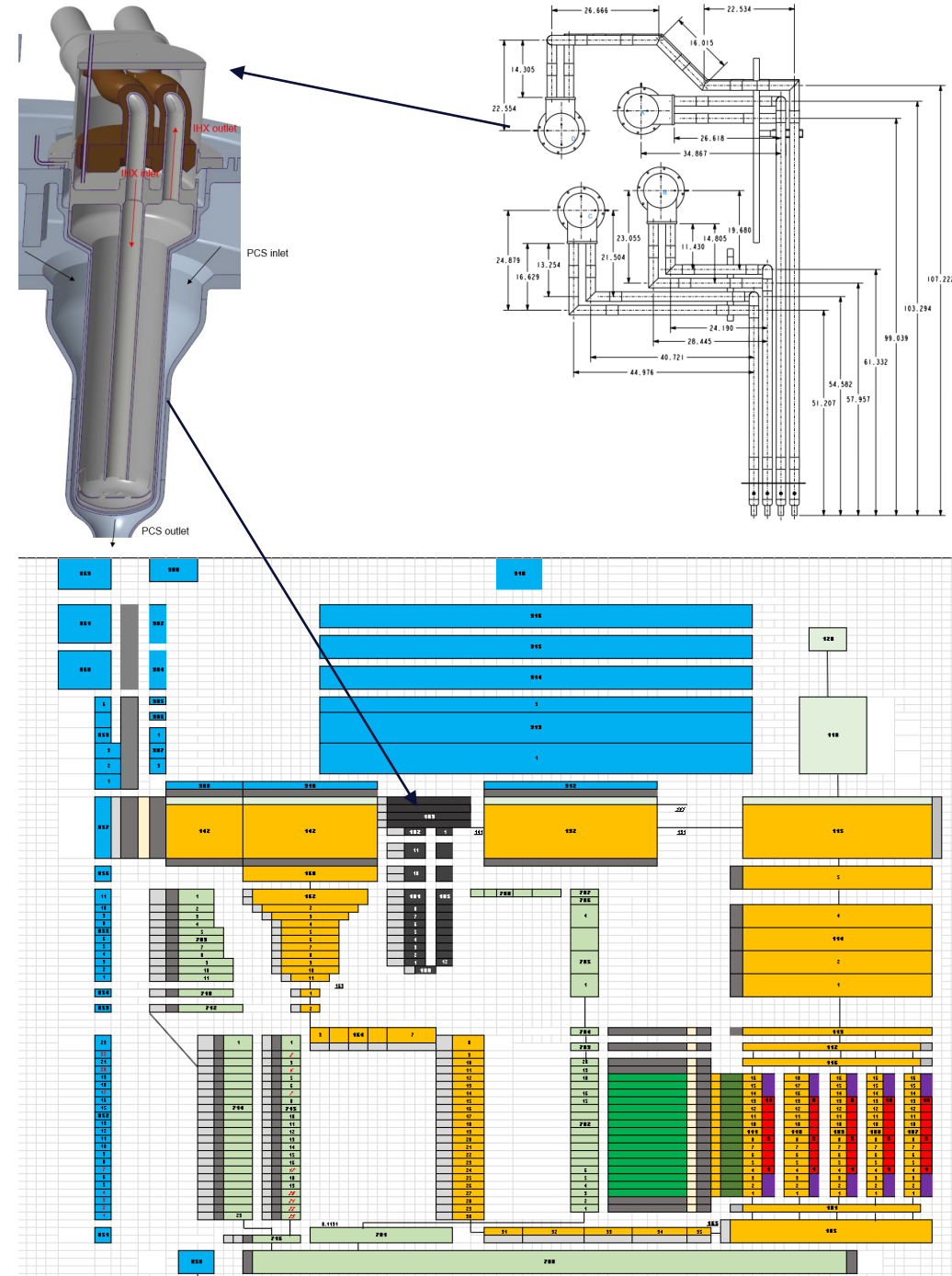
IHX Piping



- Piping layouts have been developed and initial ASME B31.3 analysis has been performed.
- To provide sufficient flexibility over full temperature range of system, rather complex routing was required.
- IHX analysis of inserts was also performed per ASME BPV Section VIII
- Initial analyses look acceptable for normal and some accident conditions.
- Additional analysis will be needed for DBE reactor accidents which are outside capability of ASME software. These are one-time events and only survival of piping is required to be demonstrated. .

Thermal Hydraulic Analysis

- This is a reperformance of the previous RELAP5 thermal-hydraulic analysis of MARVEL.
- Currently, the RELAP analysis and the CFD analysis of the IHXs are being adjusted to bring them into agreement. Solutions appear to be converging.
- The HES system does introduce some new behaviors (with respect to the Stirling engine characteristics) which are being incorporated
- The HES system introduces the potential for an “overcooling” event since it can draw more heat than the Stirling engines. Based on initial analyses, the consequences of this event are bounded by the Unprotected overpower transient (UTOP) previously analyzed.



Current Status

- Design of SCE is in progress at Creative Engineers Inc (CEI). Design is nearing completion
- Design drawings for the IHX/piping systems are being prepared by Walsh engineering for INL. Final piping drawings will need to wait until the final SCE drawings/models are available to detail interconnections.
- I&C design at INL will be performed once the I&C design at CEI is available.
- Initial analyses are complete; work is starting on final analyses. Some additional accident analyses will be needed.
- The HES design does impact a number of MARVEL analyses. For instance, the thermal environment at the top of the reactor is different due to removal of the Stirling engines, and radiation dose analyses for the reactor top area will be different due to removal of the Stirling's GaInSn secondary coolant. These analyses will need to be revised.