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Freeze-Out Purifier for Helium Refrigeration System Applications

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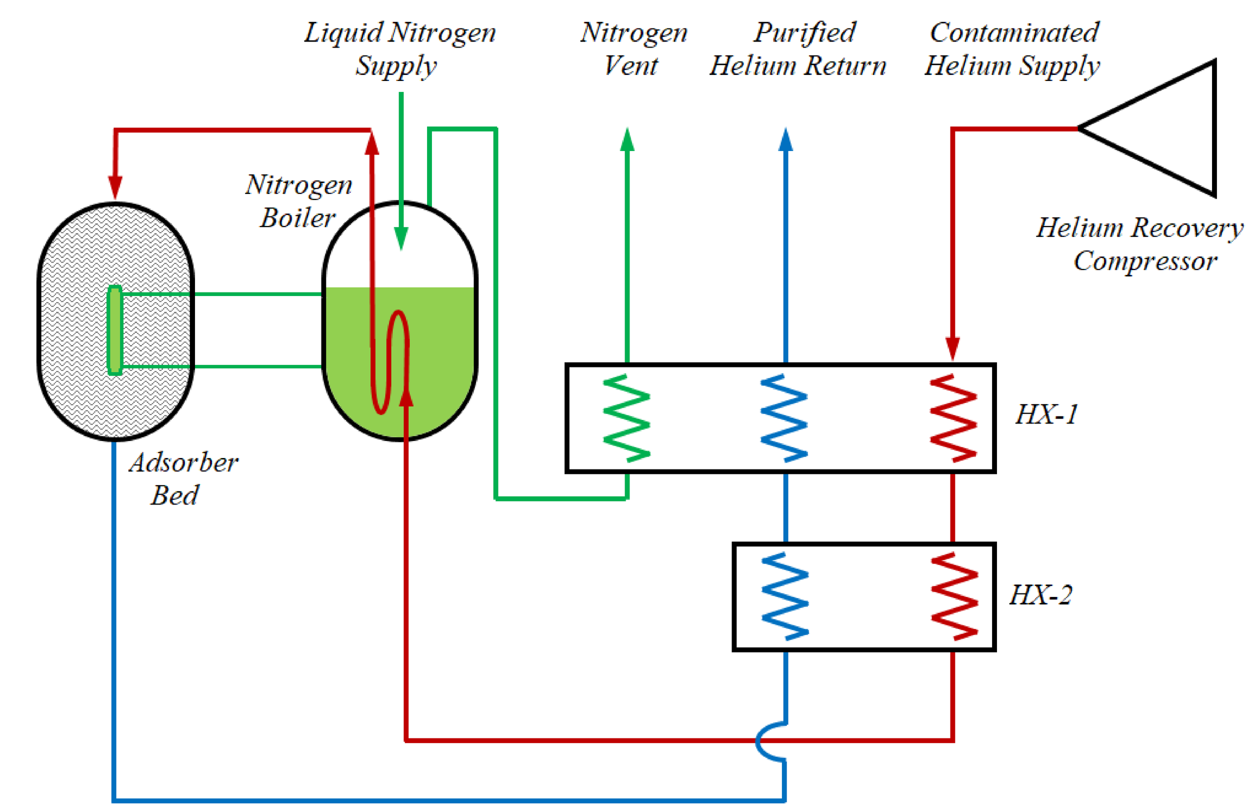
Background and Motivation

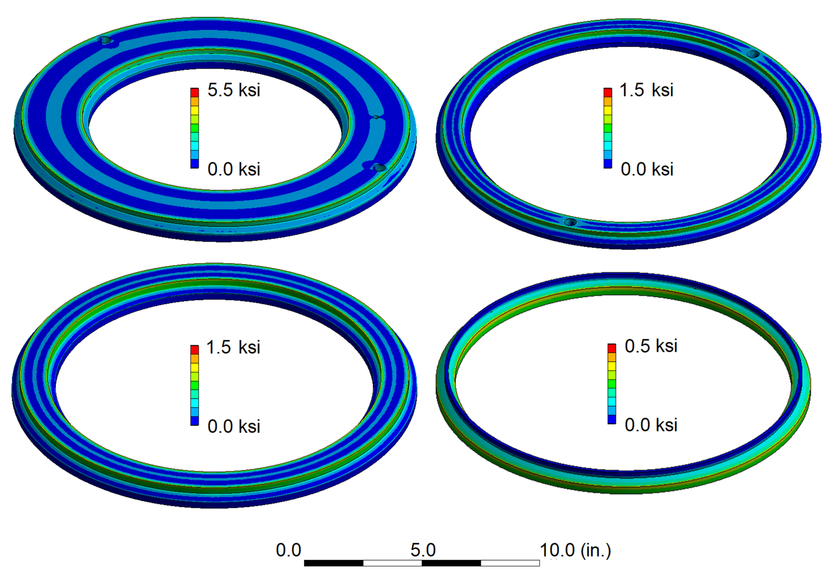
- Helium cryogenic refrigerators are necessary for systems using superconducting devices, such as magnetic resonance imaging and particle accelerators. They operate at 4.5 K, or lower (2 K at FRIB).
- Presence of any other substances (contaminants) except helium will result in solidification leading to damage.
- Traditional helium purification systems used for large-scale cryogenic refrigerator applications use molecular sieve for moisture removal. Molecular sieve is unable to remove low level moisture sufficiently, despite reasonable regeneration practices.



- Freeze-out purification is a very effective method for removing low level moisture contamination.
- Requires a heat exchanger design that is well suited for contaminate solidification distribution and minimal impact on flow distribution.

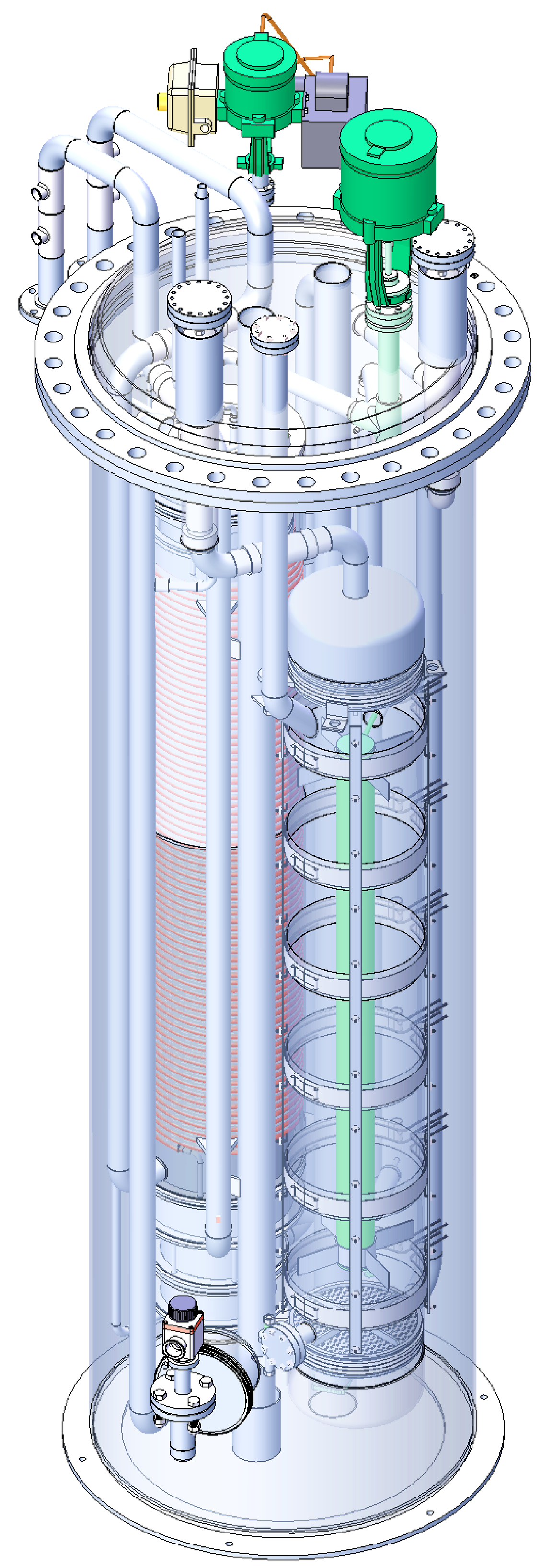
Mechanical Design

- Design of pressure vessels, end plates, and rings are done following ASME BPV Code Sec. VIII, Div 1 and 2.
- Design and analysis of the process piping is done following ASME B31.3 Process Piping Code.
- Ansys Workbench FEA used for design of machined parts, non-standard components.

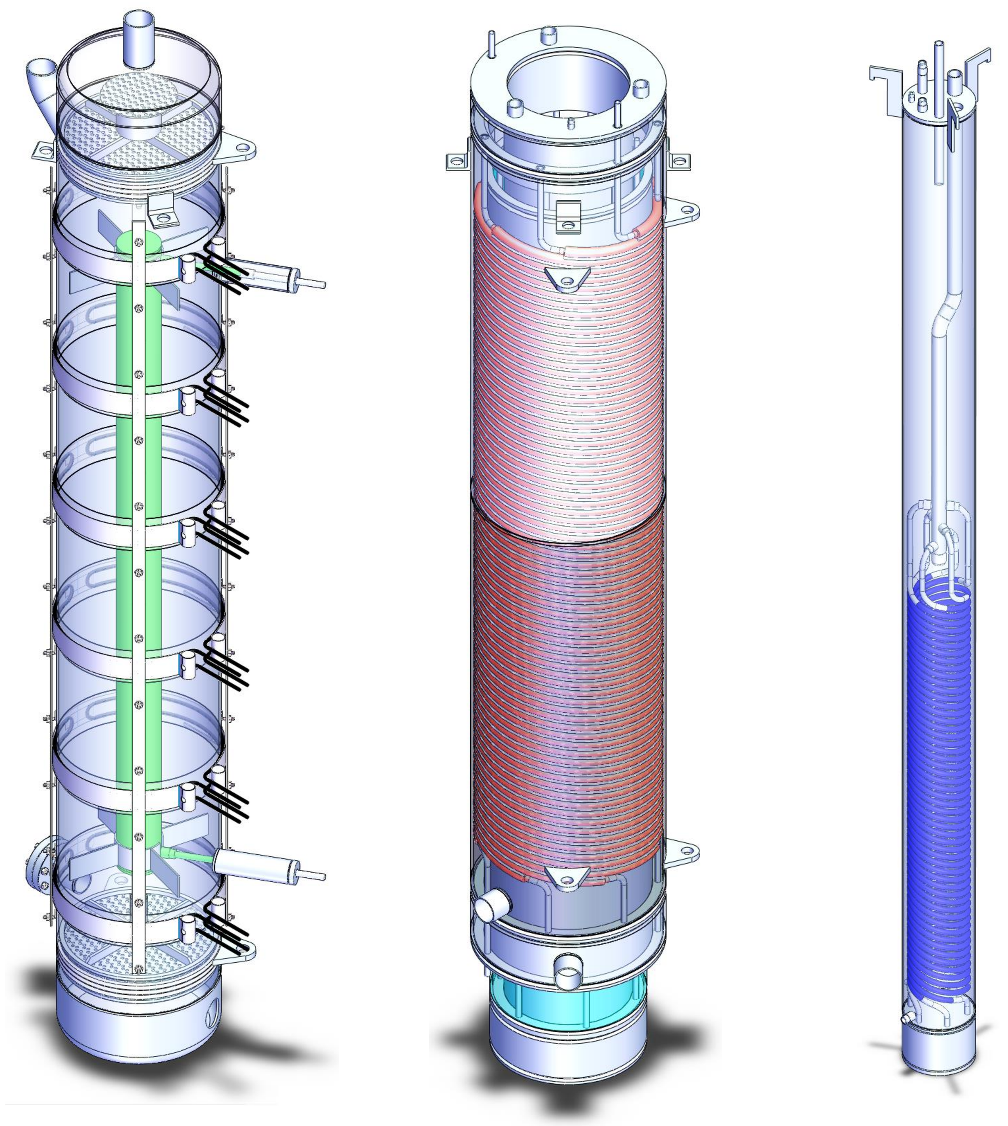


Stress distribution of end plates/rings used in the design

Major Components

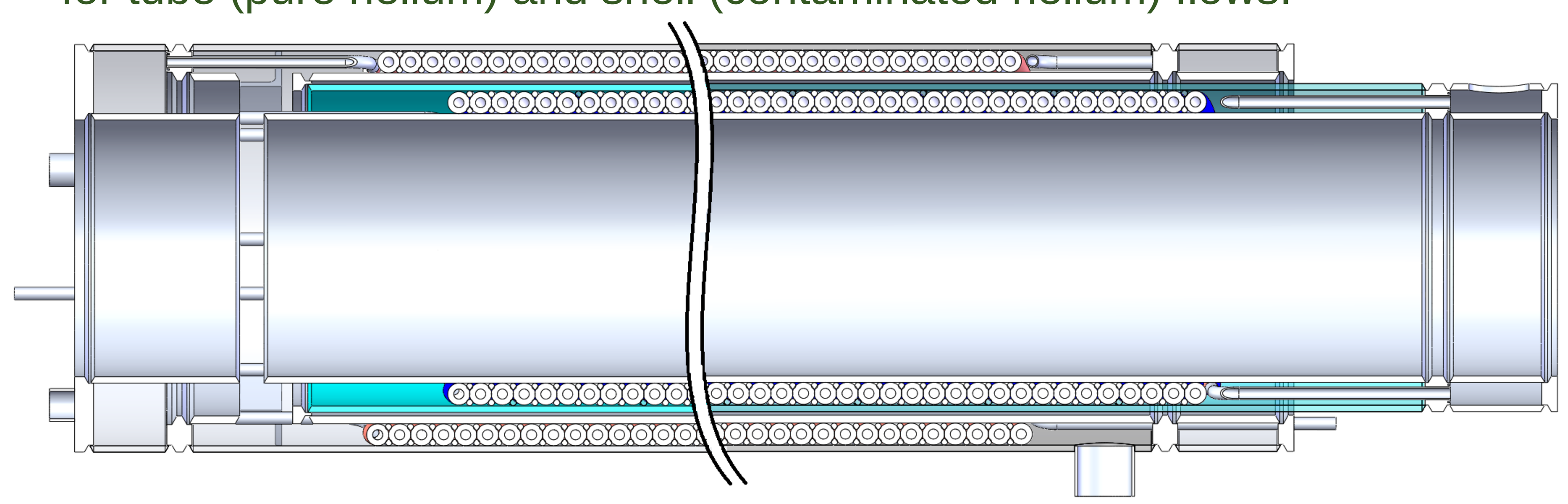


- ***Carbon (adsorber) bed*** is comprised of two pressure vessels. Outer vessel holds the adsorbent (activated carbon) in a fixed bed and inner vessel filled with liquid nitrogen (LN) is used to keep the fixed bed cooled.
- ***Nitrogen boiler*** consists of six parallel passes of stainless-steel tubing coiled inside a vessel.



Sketches showing (left to right) complete purifier assembly, carbon (absorber) bed, freeze-out heat exchanger (without outermost shell) and nitrogen boiler.

- ***Freeze-out HX***s consist of copper finned-tubes coiled around a mandrel and are enclosed by a shell creating an annular vessel. The two HXs are concentrically nested inside one another.
- Annular flat heads at the ends of both heat exchangers serve as headers for tube (pure helium) and shell (contaminated helium) flows.

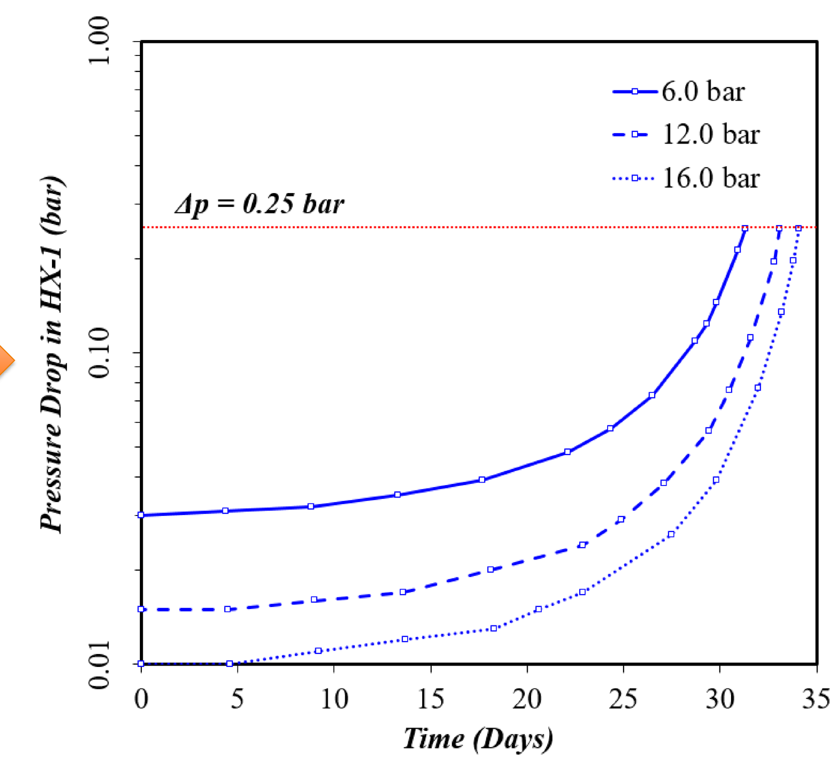


Longitudinal section view of the freeze-out heat exchanger

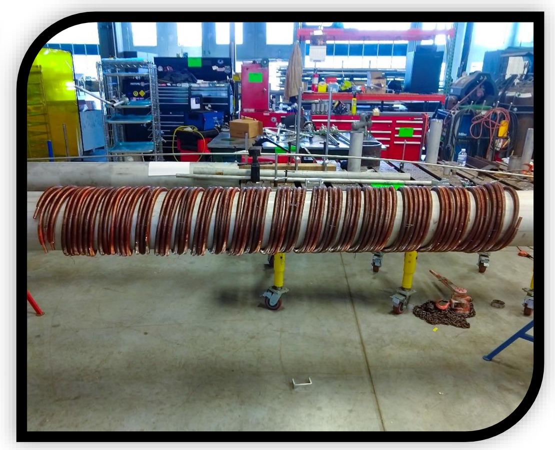
Process Requirements

Max. Mass flow rate (helium)	30 g/s
Operating pressure	6.0 to 16.0 bar (helium)
Design max. pressure drop	0.25 bar (tube side / shell side)
Design. max. contamination	30 ppm_v (H_2O), 30 ppm_v (N_2)
Minimum time between regenerations	14 days
Design LN usage	0.05 m^3/hr.

Effect of stream operating pressure on purifier operating period at max. design contamination (moisture)



Fabrication & Installation



- A detailed and extensive fabrication plan has been developed and a prototype is being fabricated.
- Challenging steps such as, installation of the fin-tube coil, shell will be re-evaluated based on prototype fabrication and installation and mechanical design will be revised as required.

Summary

- Detailed analysis of the purification system demonstrates an effective and efficient design for supporting 30 g/s helium flow at 6-16 bar operation and an LN consumption of approx. 0.05 m^3/hr.
- Designed freeze-out purifier is expected to serve as the primary helium purification system for MSU-FRIB cryogenic refrigerator and superconducting magnet test facility.

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