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HYDRODYNAMIC TESTING OF ZIRCALOY TO STEEL HUB COUPLINGS FOR USE IN ADVANCED TEST REACTOR I-LOOP TUBE

August 2024

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Idaho National Laboratory

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Sadie Schenk, Southern Utah University. Kendell R. Horman, INL Experiment Design.

Introduction & Background

Advanced Test Reactor (ATR) I-positions experience a lower flux due to their location outside the flux trap region of the reactor core. Because of this isolation from the flux trap region, a loop facility in an I-position could create test conditions representative of commercial light water reactors.

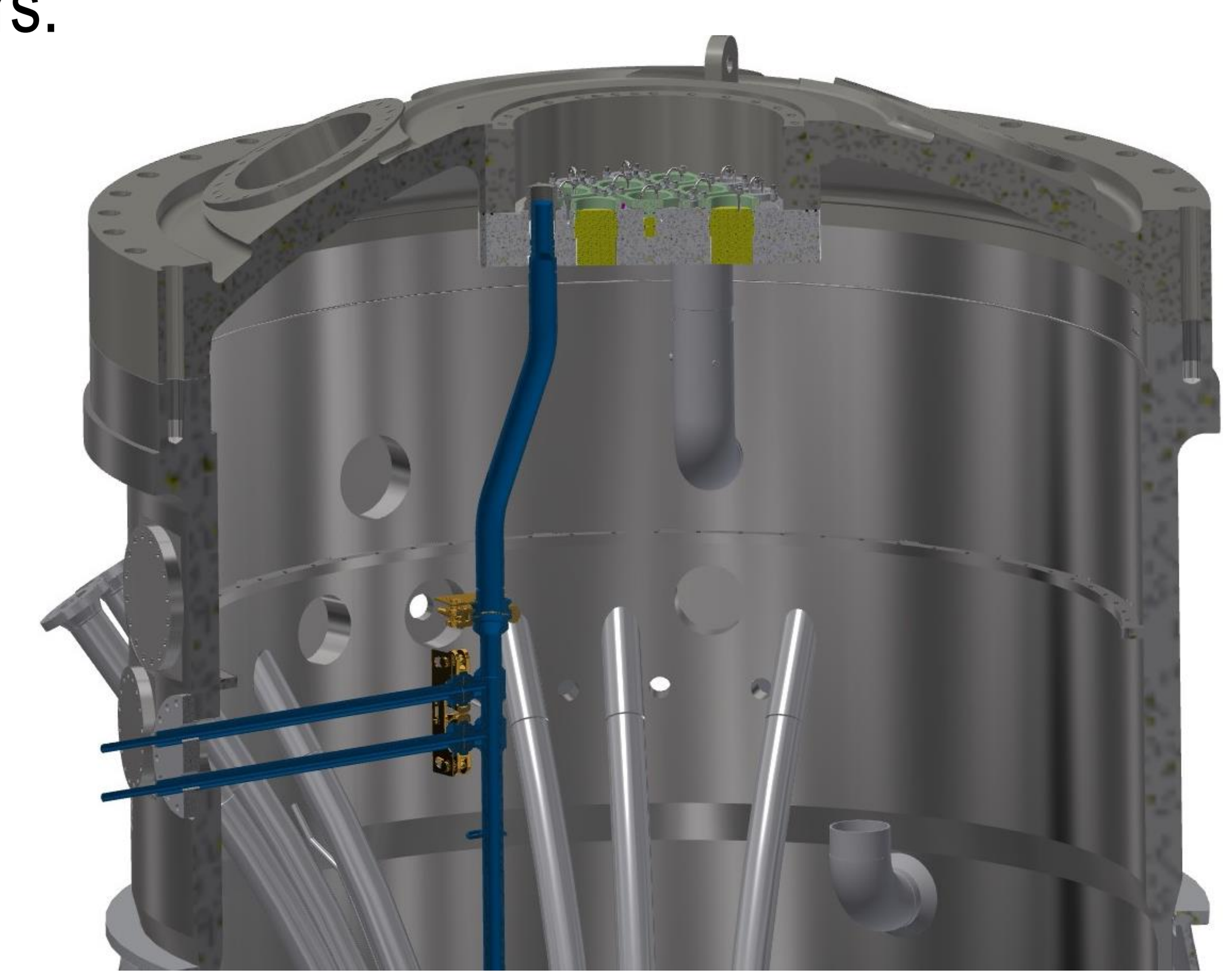

Figure 1: Representation of I-loop facility installation into ATR

Because components installed in ATR undergo many irradiation cycles in a working lifetime, great thermal stresses are experienced. Therefore, such a facility requires piping couplings and joints that withstand high thermal stresses and a high-pressure environment. Also, couplings will act as transition points between stainless steel piping and zircaloy piping inside the reactor vessel.

Grayloc hub couplings are commonly used in extreme environments, yet these couplings have not been sufficiently tested for leakage where there is a transition between materials.

Objective

Thermal and pressure cycling and hydrodynamic testing will be conducted to verify seal integrity of the steel to zircaloy hub coupling when subjected to ATR conditions.

Design Considerations

Properties of stainless steel and zircaloy are compared in Table 1 below.

Table 1: Physical properties of 316 Stainless Steel and Zircaloy

	Stainless Steel	Zircaloy
Max Tensile Strength (ksi)	89.9	74.6
Thermal Expansion (10^{-6} in/(in °F))	8.9	3.1
Neutron Cross Section (barns)	3.1	0.185

Transitioning from steel to zircaloy piping inside the reactor vessel allows the neutronic properties of zircaloy to be leveraged for components in the reactor vessel while using cost-effective stainless steel outside of the core.

A challenge is posed because the thermal expansion coefficients differ. Seal integrity between the two components may be greatly affected by thermal expansion at the connection. Thus, the effect of thermal cycling must be assessed.

Final Design

The design includes the following features to accommodate accurate testing conditions.

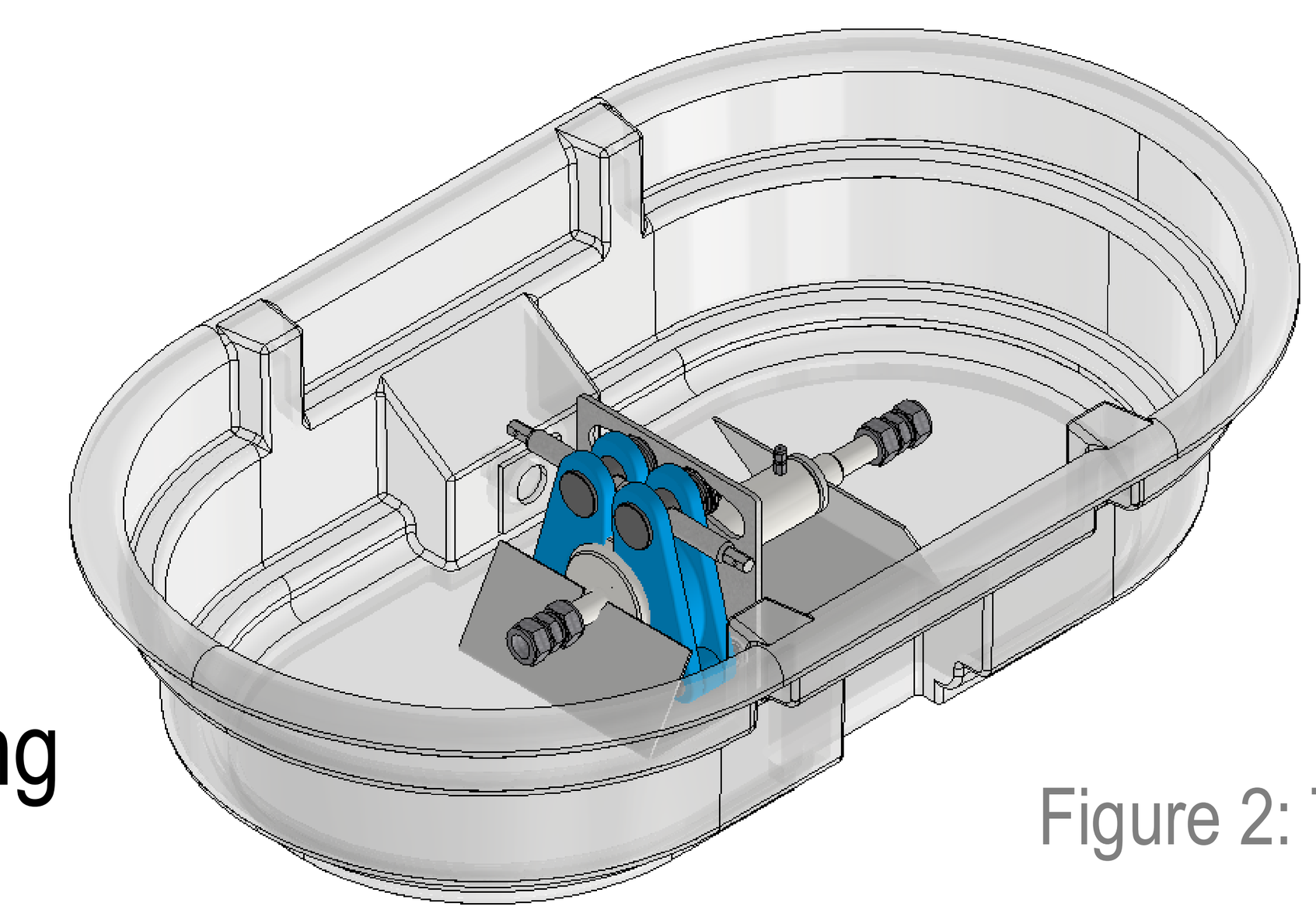

Figure 2: Test fixture

- Basin allows primary cooling system temperature to be simulated
- 650 F water to be pumped through hubs
- Helium jacket provides insulation as it will be configured in ATR

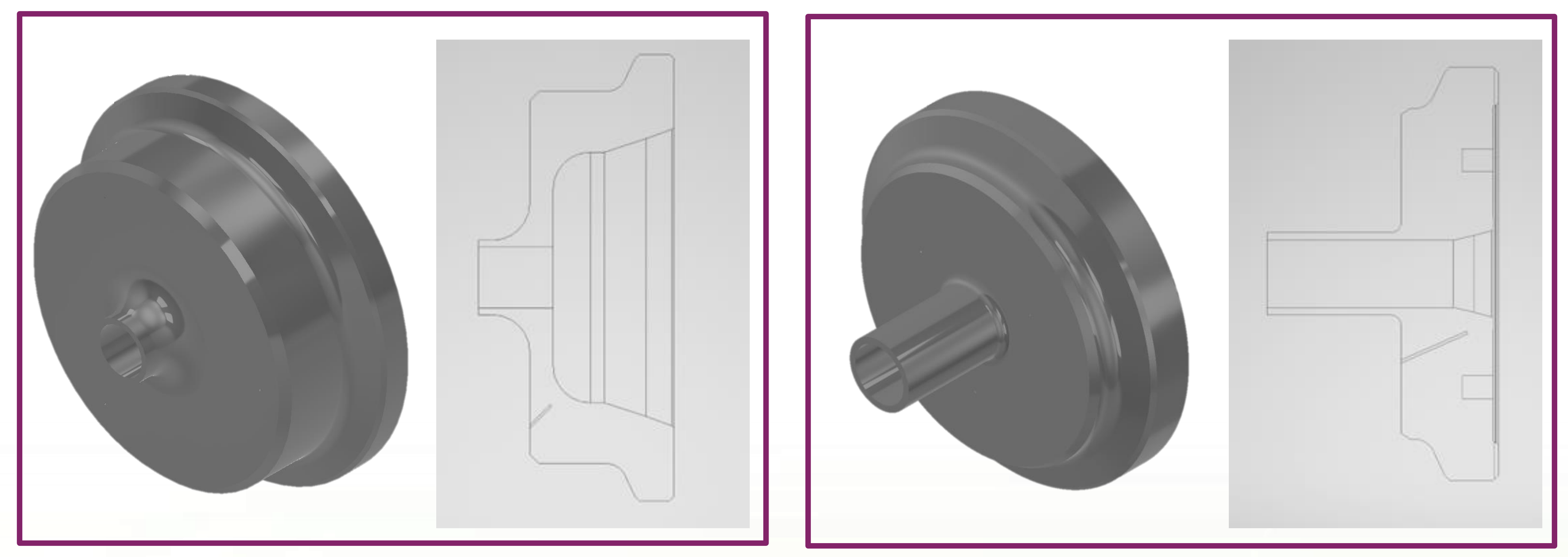

Figure 3: Large hub and small hub for use with helium jacket, respectively

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