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Hafnium Absorber Latching Mechanism Redesign

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Changing the World's Energy Future

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Background:

The ATR safety rods are the primary system for immediate reactor shutdown, where the safety rods rapidly insert hafnium into the core. Hafnium is a neutron absorber, which terminates the nuclear reaction. The role of each Hafnium Absorber Latching Mechanism (HALM) is to latch a quarter-circle piece of hafnium to the safety rod. The HALMs employ a complex internal ratcheting mechanism to tighten and lock each HALM in place. ATR's core consists of six safety rods, each requiring four HALMs to create a cylindrical shell of hafnium. During the previous fabrication process and recent core changeout (CIC), several design deficiencies were observed. Procurement of the next batch of HALMs will begin in the coming years, which provides the opportunity to revise the design.

Design Deficiencies:

Galling occurs when two pieces of metal are moved against each other. This generates heat, which can lead to the metals fusing. During installation, galling has been observed between the threads of the locking pin and internal nut. Once galled, the locking pin can no longer be tightened. If further tightening was attempted, the dowel pin would shear and break. Failure of the dowel pin allowed for free rotation of the locking pin. Both issues would lead to the HALM being removed from service.

Installation Issues:

HALMs must be capable of being installed onto the safety rod from a distance while in the reactor. When the locking pin was fully lowered, its foot couldn't rotate into the proper position. Flux wire insertion is often improperly aligned with the adjacent hole. The operators requested changes to both design features.

Expensive Welding:

The original design called for Electron Beam Welding (EBW) in four locations. EBW was chosen for its ability to join dissimilar metals. The issue is that very few companies have EBW capabilities, leading to a large procurement cost for the HALM.

Figure 3: Inventor assembly view of visibly changed parts.

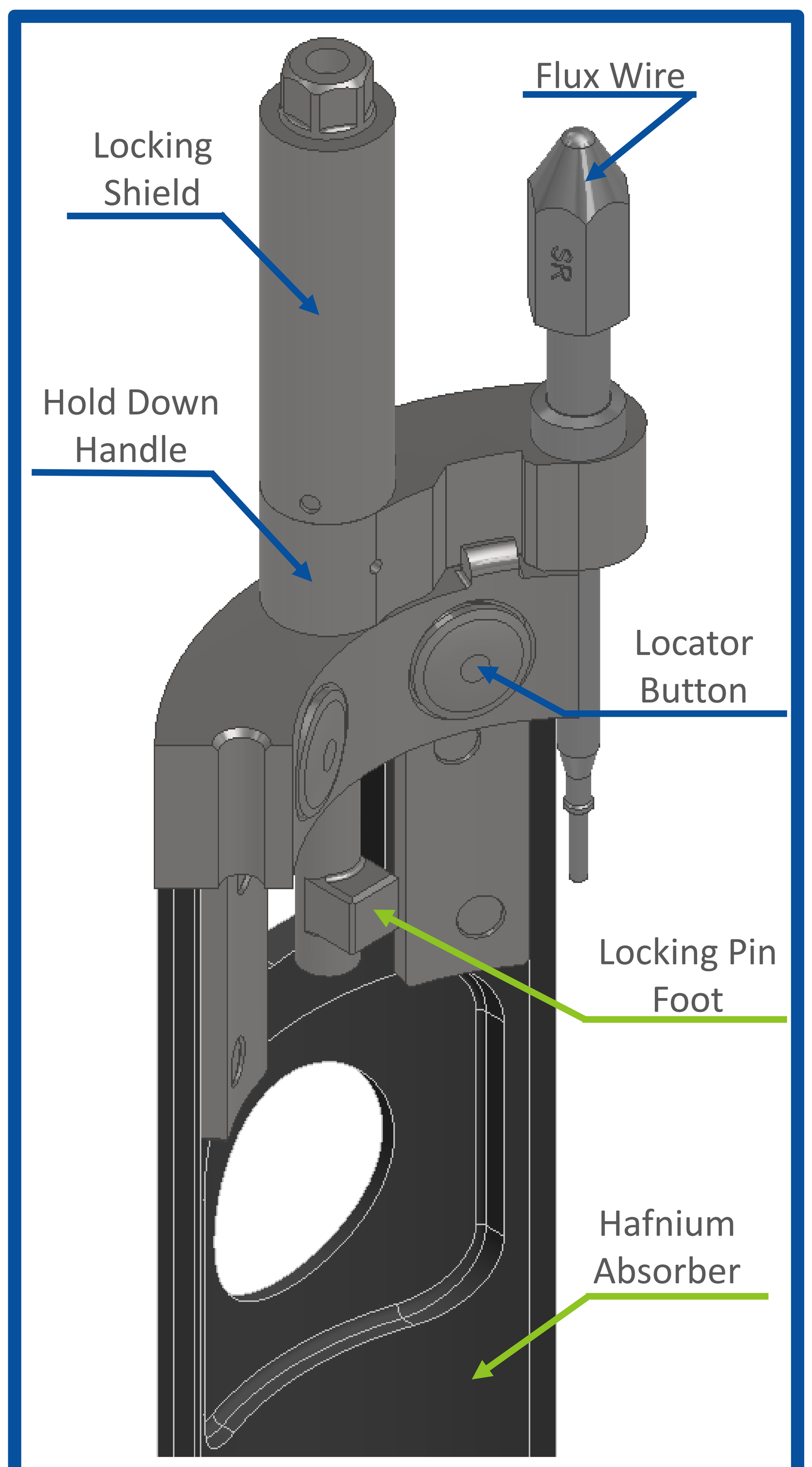

Figure 1: Inventor assembly view of updated hafnium absorber latching mechanism with hafnium shielding attached.

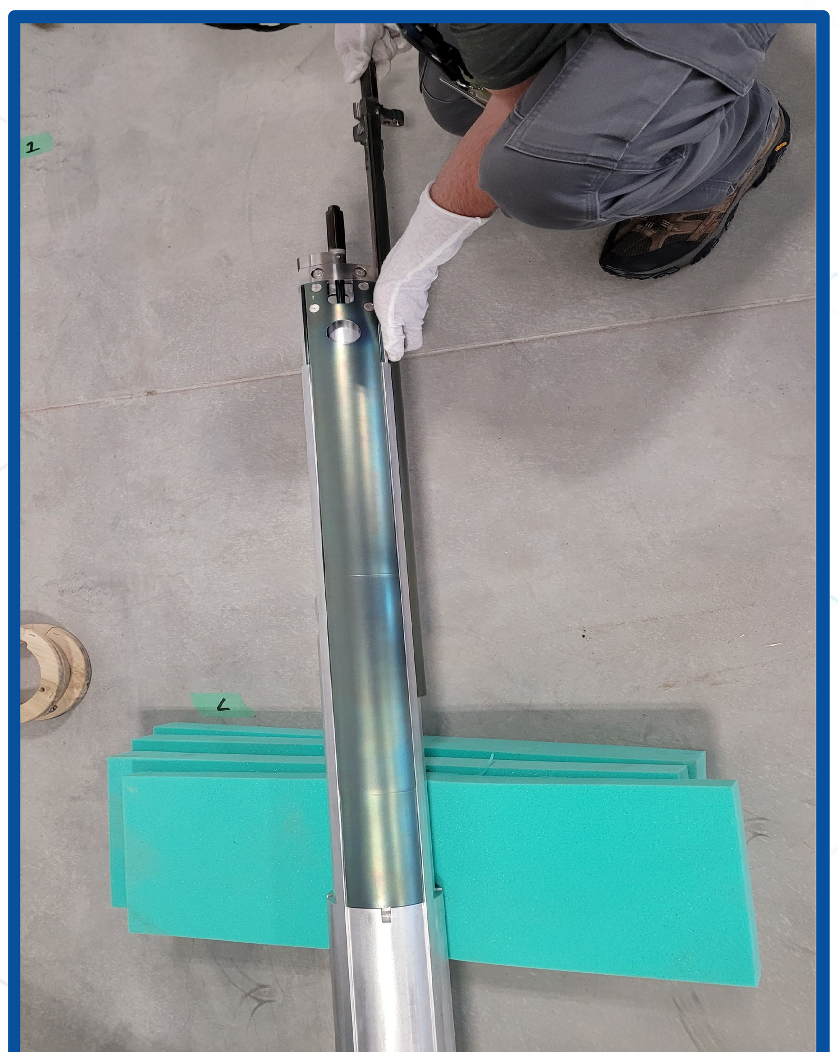

Figure 4: Picture from the recent CIC of HALM being installed onto the guide tube.

Internal Galling Prevention:

To prevent galling, the internal parts were changed from 304L SST and Inconel X750 to Nitronic 60 and 17-4 SST. These stainless steels were chosen because Nitronic 60 performs exceptionally well in galling threshold testing between itself and other stainless steels. This material change practically eliminates the chance of galling during installation.

Pin Shearing Prevention:

To address the pin shearing issues, the pin's material was swapped from 303 SST to 17-4 SST. When heat treated to H900 conditions, 17-4 SST increased the tensile strength by 95 ksi. This mitigates the chance of pin shearing during installation by strengthening the pin.

Installation Ergonomics:

To avoid the locking pin foot catching when latching, the bottom of the foot was shortened. This required a shear stress analysis for the locking pin to ensure the foot still met the necessary strength requirements. To address the flux wire insertion, the middle hole was removed after concluding its original purpose had been phased out, and a bevel was added to the flux wire hole. These changes ease the installation process for operators.

Updated Welding Methods:

All welding procedures on the HALM were switched to Gas Tungsten Arc Welding (GTAW). To facilitate GTAW, the material between two welded pieces was set to compatible materials. The locking shield and hold down handle were changed to a threaded connection, allowing for a small tac weld to be used. Plug welds were also added to the locking shield to prevent rotation of the updated torque bushing.

Figure 2: Picture from the recent CIC showing a fully assembled safety rod.

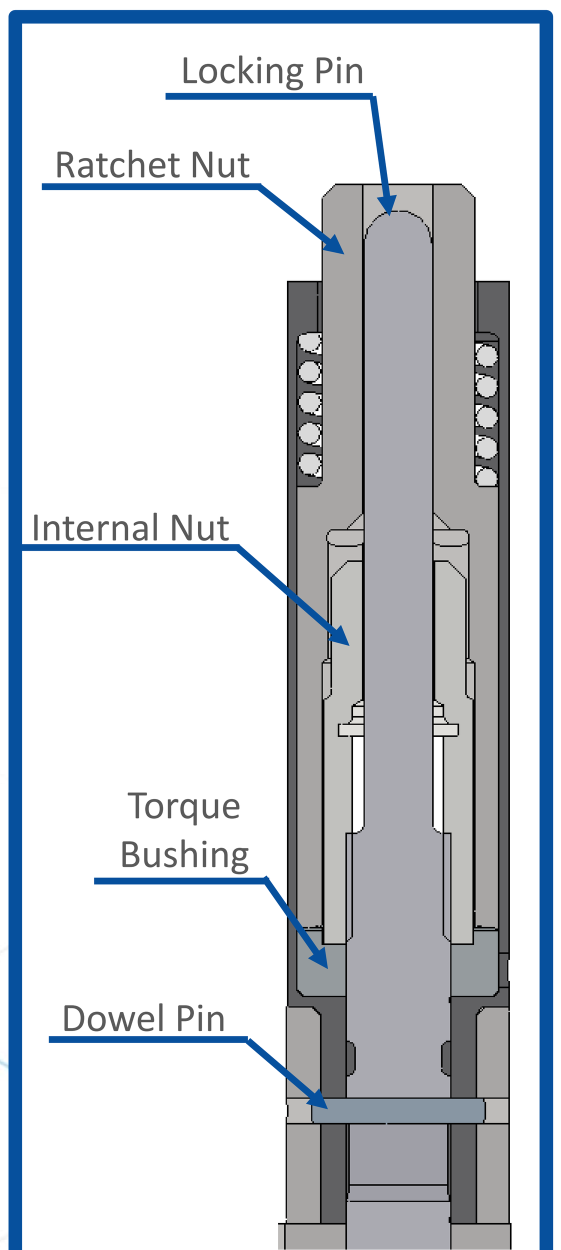

Figure 5: Inventor half-section view of the HALM internal ratchet mechanism.

Conclusion:

The changes in the updated design will protect the internal mechanisms from the reoccurring issues previously addressed. Additional adjustments have been made to lower the HALM's production cost while improving the installation process for operators. The final step is to complete the engineering change process by submitting an ECAR, a drawing, and an USQ. Once completed, procurement can begin to prepare for the next CIC.

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