IER 555: Status of Godiva-IV Benchmark (HEU-MET-FAST-086) Revision

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Godiva-IV

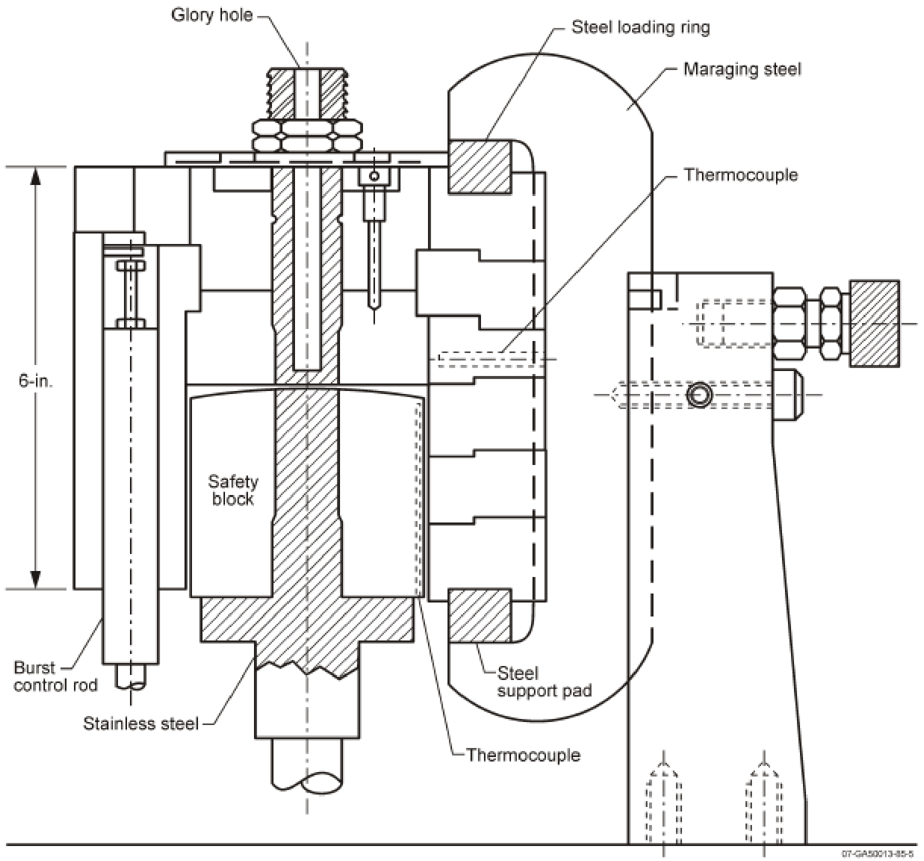


Figure 1. Cutaway View of the Godiva-IV Core and its Restraints.

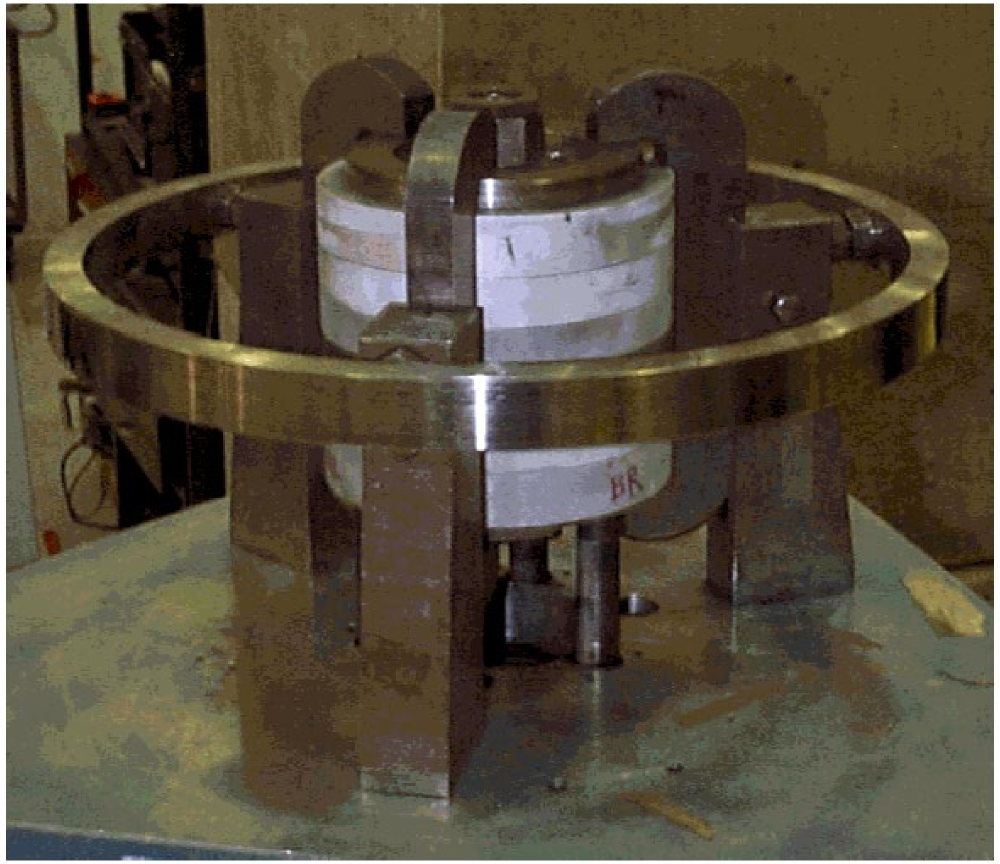
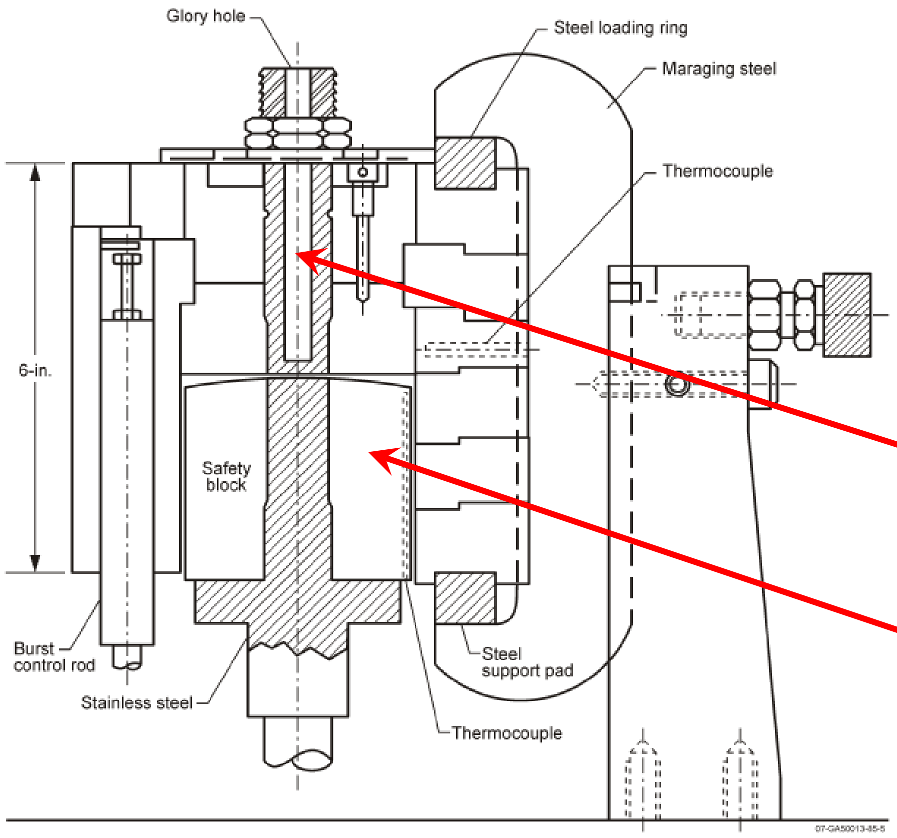


Figure 2. Side View of the Godiva-IV Assembly on Top of Its Mounting Plate.

- Pictures are from HEU-MET-FAST-086, “Godiva-IV Delayed-Critical Experiments and Description of an Associated Prompt-Burst Experiment,” 2012.

- The uncertainty of the benchmark (Case 4) is ±220 pcm.

Updates Needed



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GODIVA-IV DELAYED-CRITICAL EXPERIMENTS AND DESCRIPTION OF AN ASSOCIATED PROMPT-BURST EXPERIMENT

DISCLAIMER:

When the Godiva IV critical assembly was refueled in 2012, additional details relevant to this benchmark became apparent. There are two revisions necessary for this evaluation to be correct:

First, the original drawing of the spindle was obsolete, which had a smaller glory hole than what is currently used in the assembly. The effect of the larger glory hole on system reactivity is negative due to the increased neutron leakage.

Second, there is a shim plate located under the safety block that alters the assumed height (and thus density) of the safety block. The presence of the shim has an important impact on the system. The density in the high importance region is currently underestimated and any neutron reflection from the shim piece is not accounted for. The corresponding correction of adding the shim and increasing the density of the safety block would have a positive effect on system reactivity.

The current evaluation is still available for use until the revised evaluation becomes available.

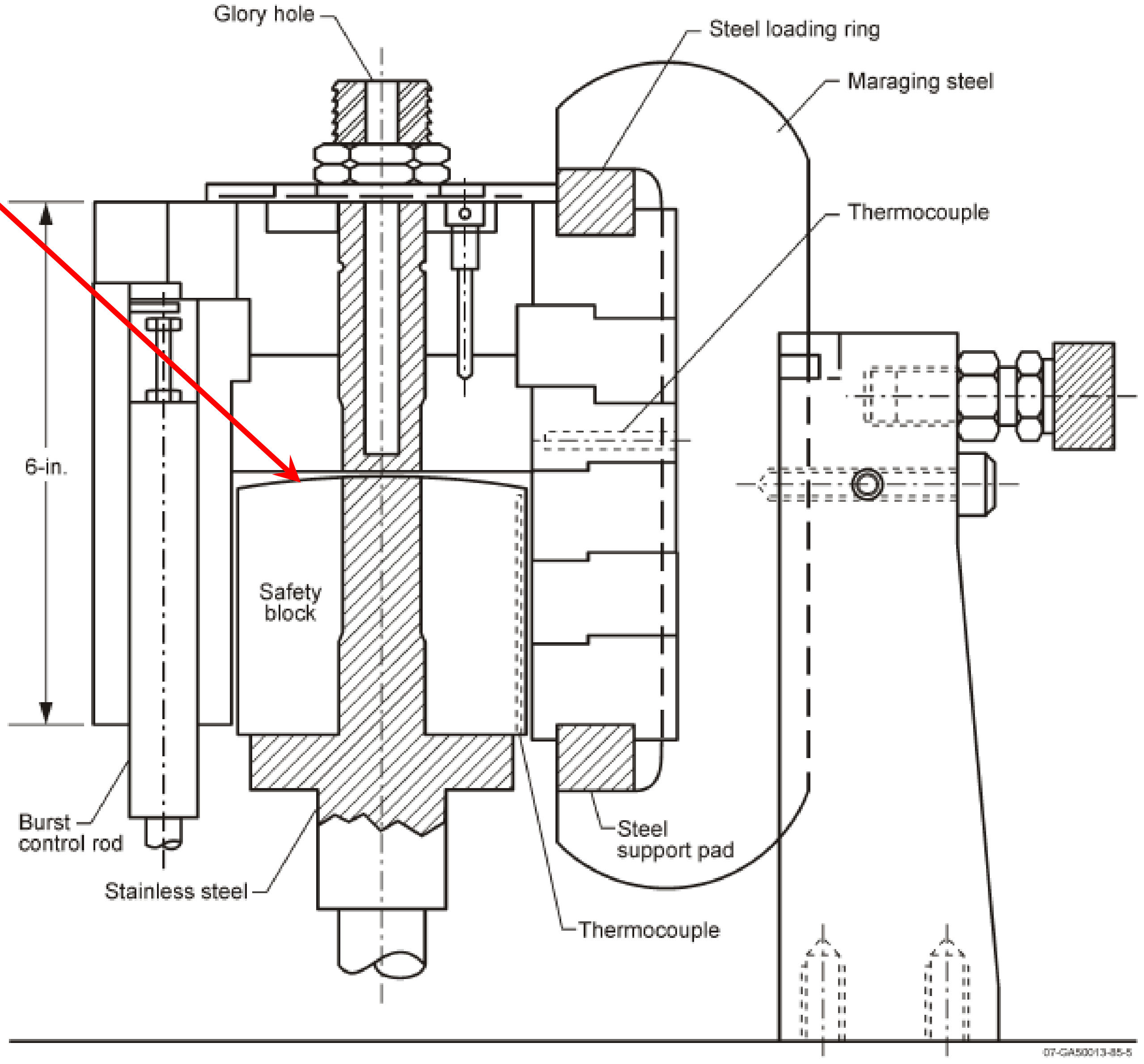
Additional information is provided below regarding the necessary revisions:

(Highlights added.)

Third…

- Third, the safety block at its full-in position was closer to the inner subassembly plate than was modeled in the benchmark.

  + In the benchmark, the separation distance is 0.100 in.
  + In 2012, it was measured as 0.0145 to 0.0175 in. (minus an assumed 0.010-in. recess)
  + In 2023, it was measured as 0.0197 in. (minus an estimated 0.010-in. recess)



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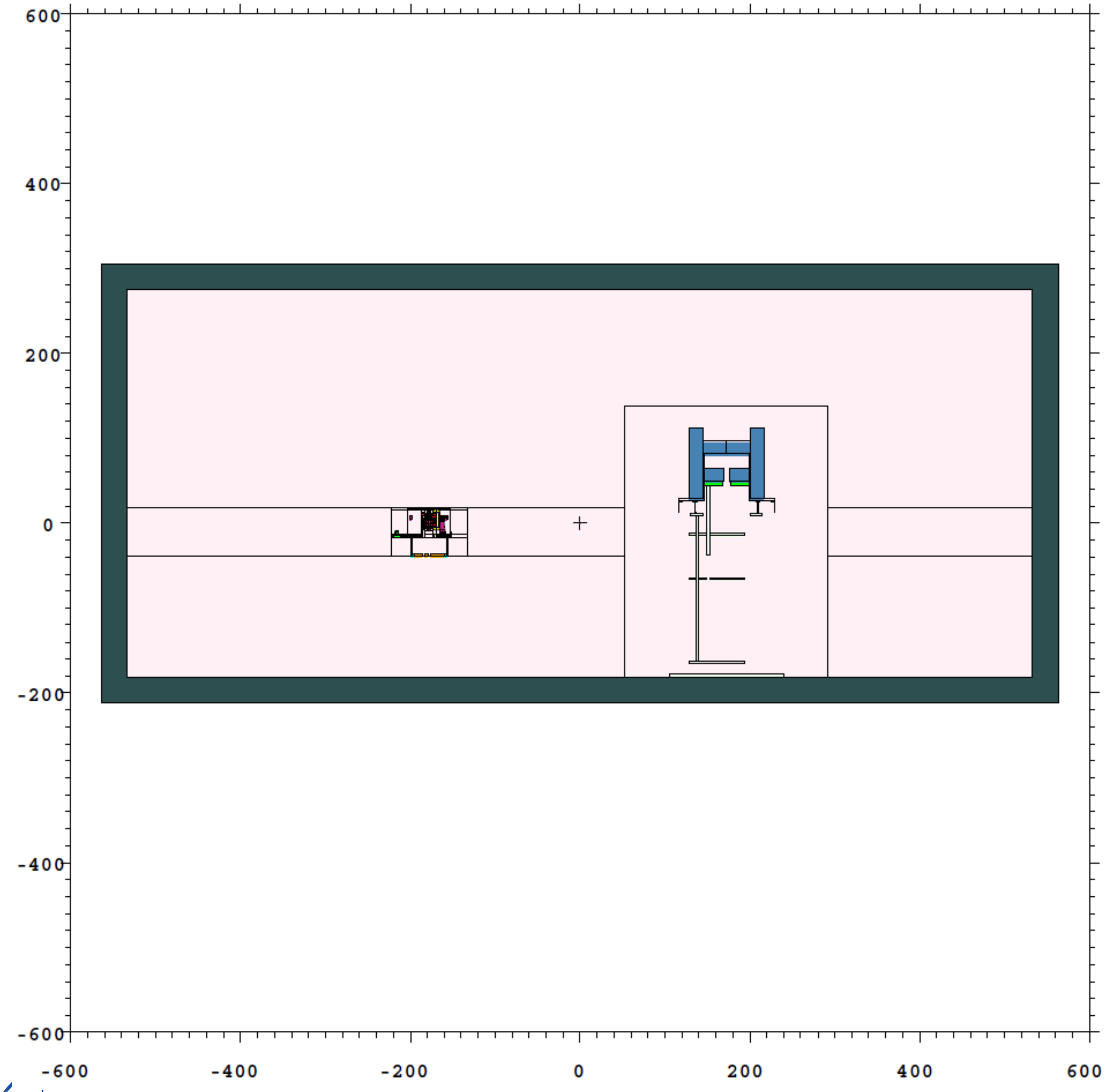
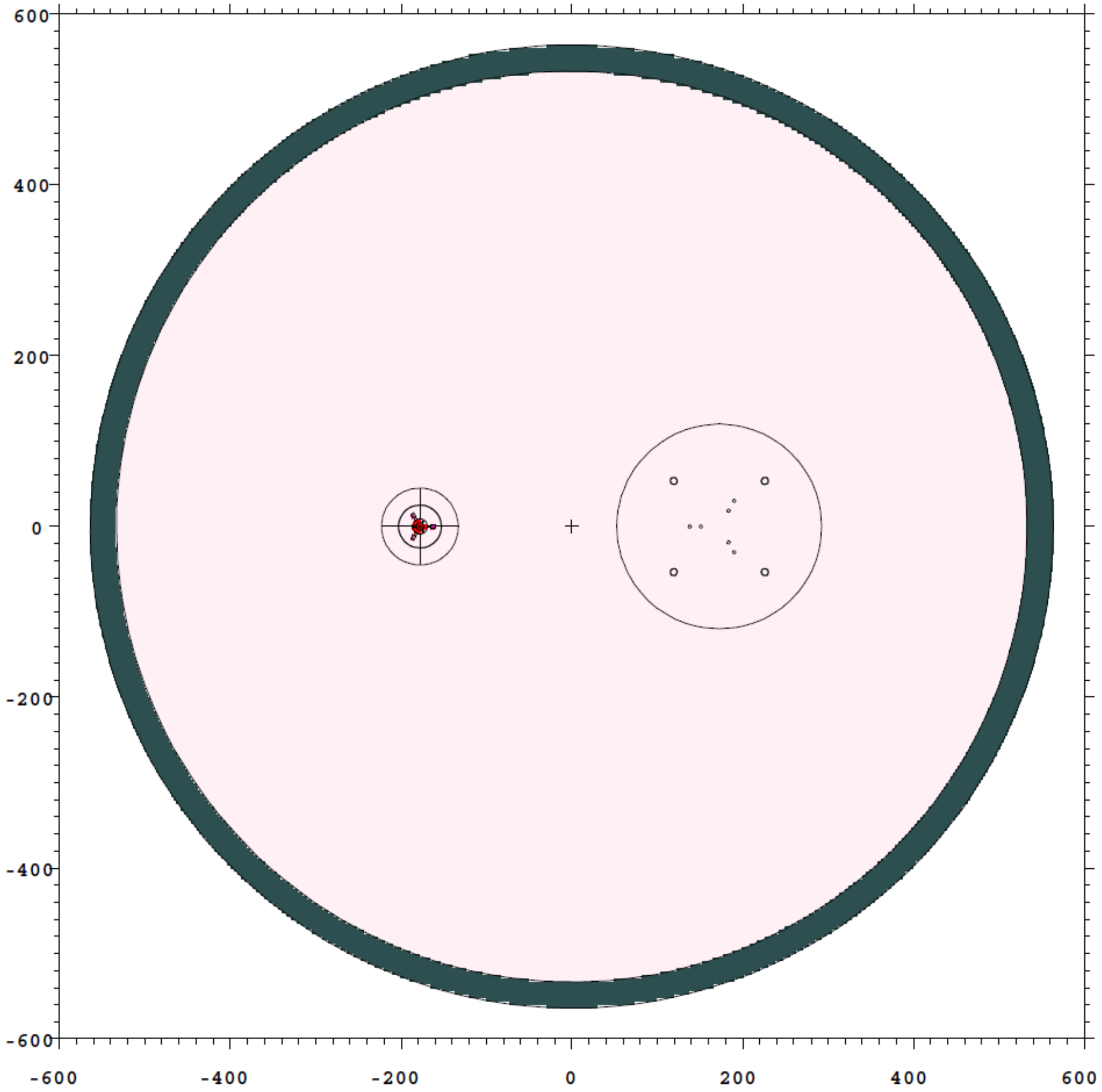
Fourth…

- Godiva-IV is now at NCERC in the DAF with Comet.





Our Plan for the Benchmark

- HEU-MET-FAST-086 presents a fairly detailed but simplified benchmark model.
  - + Mosteller documented the full detailed model in Appendix B.
- The revision will include a very detailed benchmark model and a simplified benchmark model for the present (DAF) configuration (4 cases).
- The TA-18 benchmark model (5 cases) will be corrected and retained.
  - + Most current dimensions will be assumed to have existed at TA-18.
  - + The main differences will be Top Hat dimensions; control rod positions; safety block position; and presence of the building.

Current benchmark model

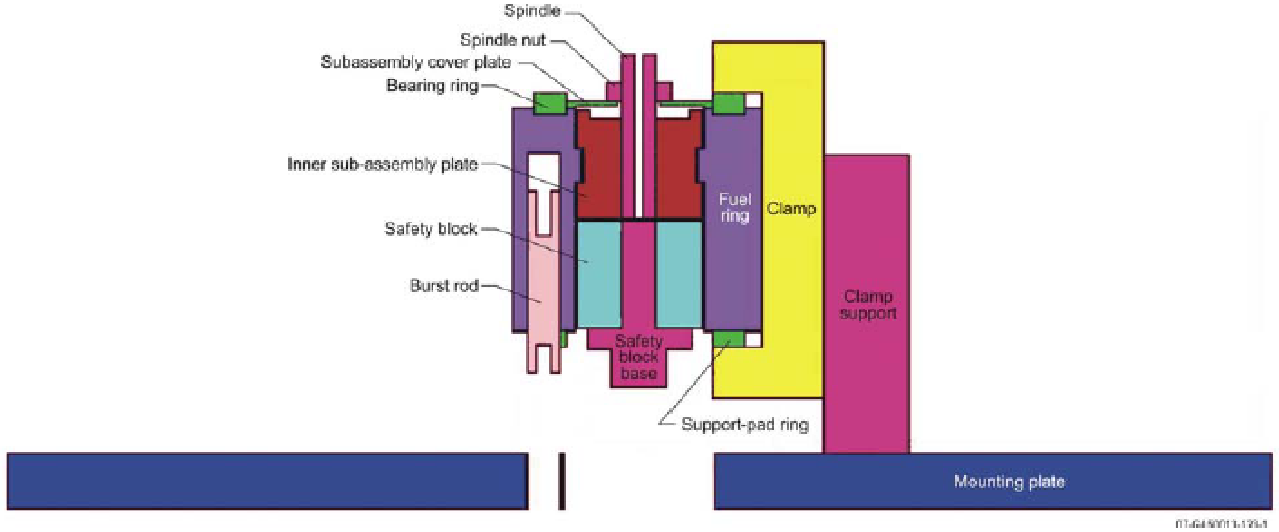


Figure 28. Vertical Slice through the Benchmark Model for Case 2.

Appendix B

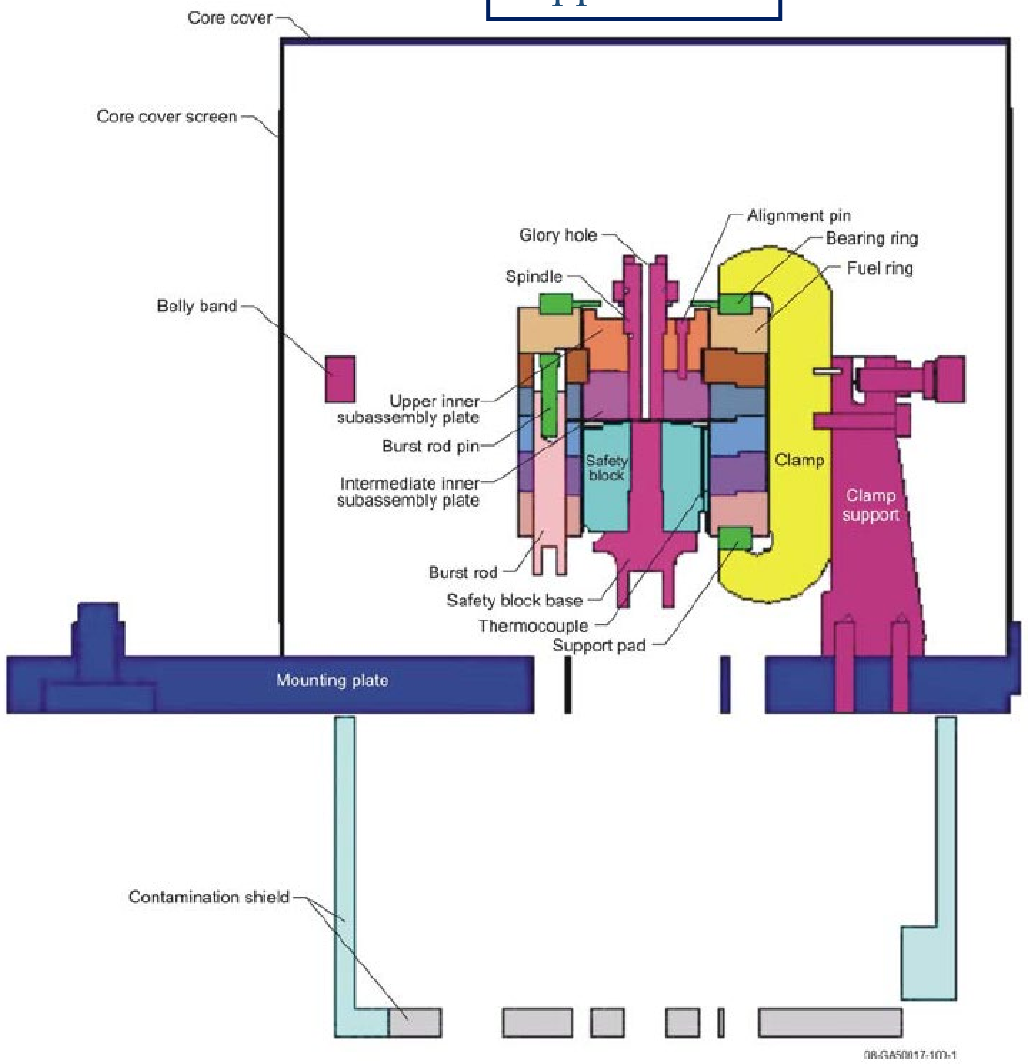
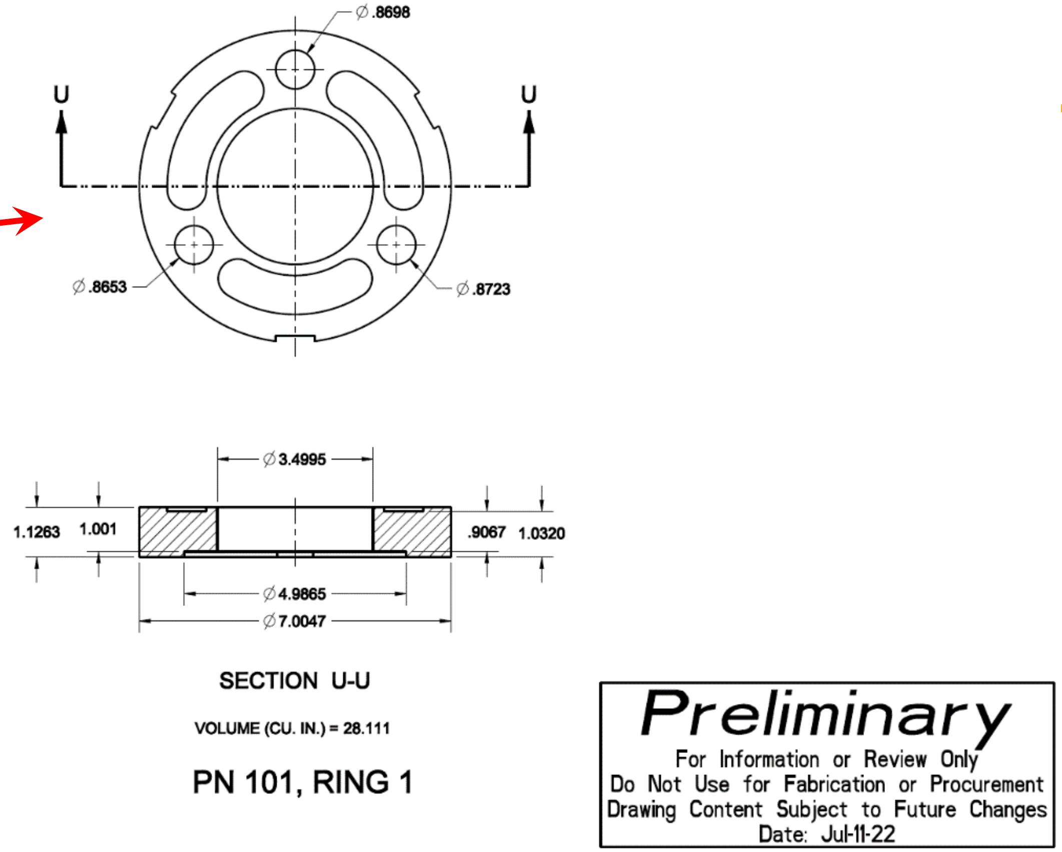


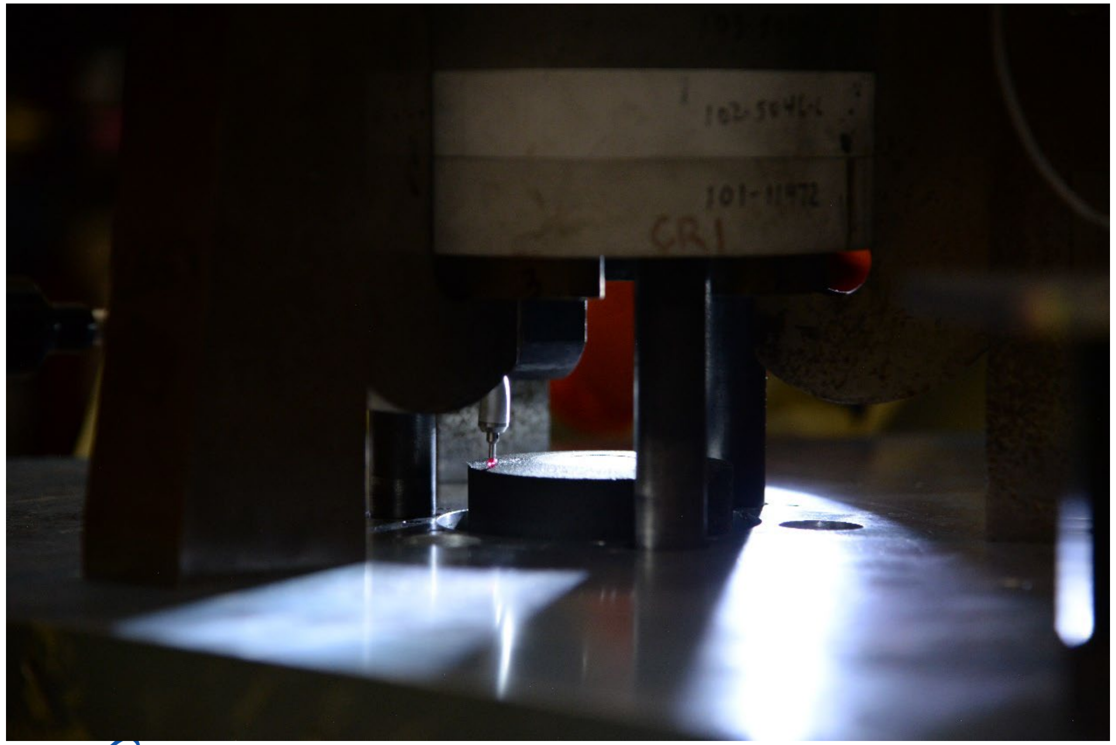
Figure B-1. Vertical Slice through the Center of the Detailed Model for Case 2.

Physical Measurements

- In February 2012,
  - + the fuel part dimensions were measured with calipers; and
  - + the fuel parts were weighed.

- In March and June 2023, the assembly was measured with a coordinate measurement machine (CMM) and calipers.
  - + Could not reach inner dimensions.





Incorporating the Physical Measurements

- The 2012 and 2023 measurements are not always consistent.

- Precedence:
  1. CMM measurements
  2. Caliper measurements from 2023
  3. Caliper measurements from 2012 but only lengths/heights (not diameters)

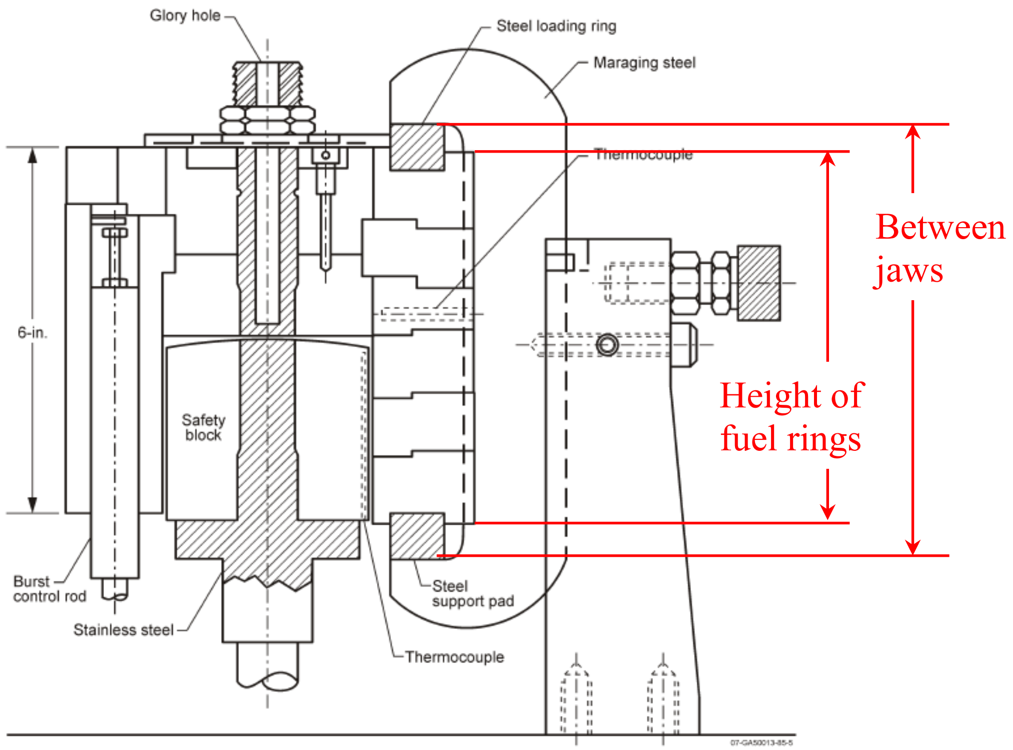
- Some dimensions (in.)

	CMM (2024)	Calipers (2012)	Drawings
Height of fuel rings	6.049	6.059	6.059
Dist. between jaws	7.100	–	7.047 or 7.000
Avg. OD of fuel rings	6.995	7.004	7.000

- All fuel ring heights were reduced by 0.0017 in. → Match total height of fuel rings

- Mosteller had assumed a 0.062-in. depression at the top of Ring 6. It was not observed in 2012. Remove it → Match distance between jaws

- All fuel rings use average CMM OD → Match average OD



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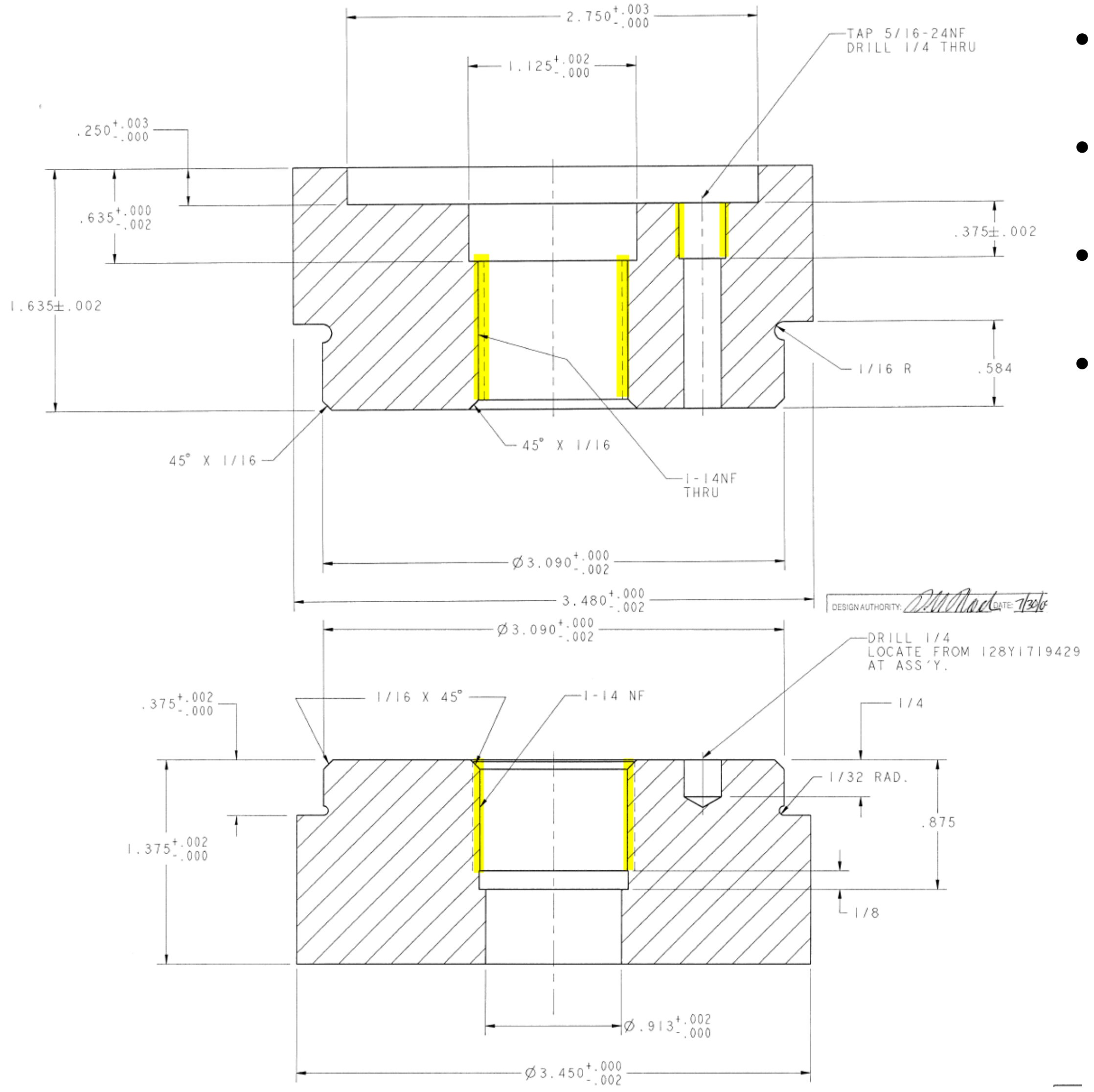
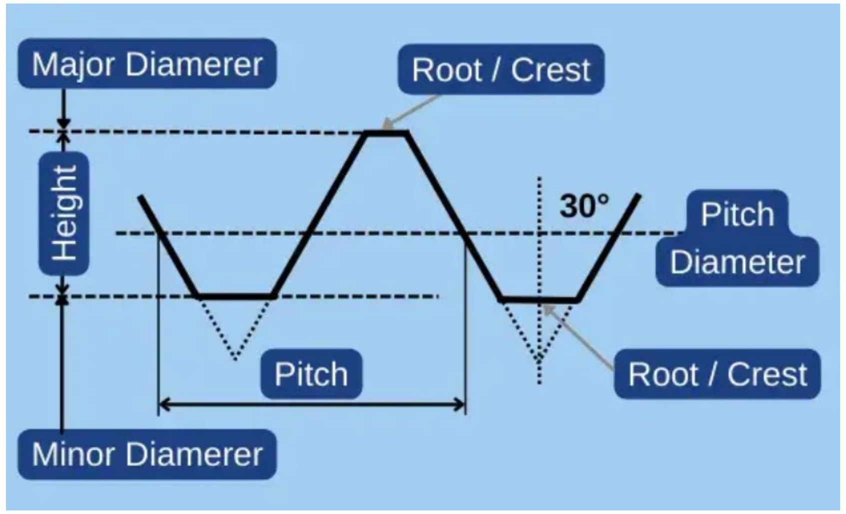
When Large SNM Parts Have Large Threaded Areas, It Matters a Lot!



- The diameter on a drawing (e.g. “1-14NF”) is the Major or Nominal Diameter.
- Using that diameter in the model adds material in the crests.
- I use Diam. = (Nominal Diam. + Minor Diam.)/2
- The effect on density is 0.32 %, 0.52 %, and 0.70 % for three Godiva parts!



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Basic Thre

Property	Inch	mm
Nominal Diameter	1	25.4
Pitch (TPI)	12	
Pitch (Distance)	0.0833	2.116
Pitch Diameter	0.9459	24.026
Minor Diameter	0.9008	22.88

https://www.machiningdoctor.com/charts/unified-inch-threads-charts/#unified-inch-threads-dimensions-charts

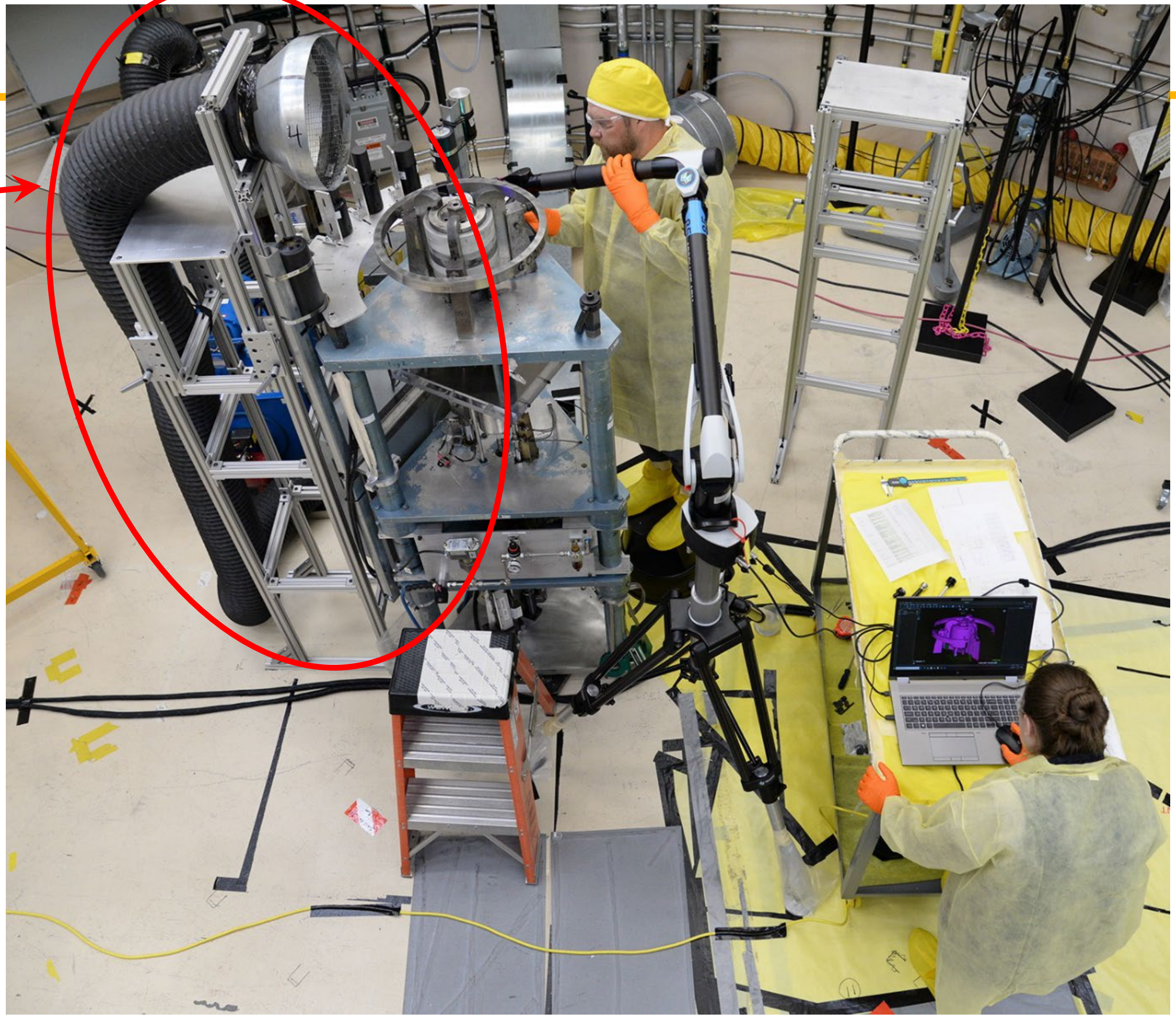
Results so Far

- Current updated model for Case 4 has k_{eff} = 1.00112.
  - Put it in the building; k_{eff} = 1.00152
  - Reactivity worth of peripherals was measured as 32.79 ¢ = 0.00214 Δk_{eff} so model has k_{eff} = 1.00366

- The current Top Hat reactivity worth was measured to be 30 ¢.
  - But it is calculated to be worth 21 ¢.

- Current updated TA-18 model for Case 4 has k_{eff} = 0.99947.
  - Appendix B model (not updated) calculates k_{eff} = 0.99268 (ENDF/B-VIII).
  - Changing spindle, decreasing height of safety block, and raising safety block added Δk_{eff} = 0.00453 (NCSD 2022); $k_{eff} \approx$ 0.99721.
  - Presumably the remaining Δk_{eff} = 0.00226 comes from improved dimensions.

- In summary, the current DAF model overpredicts by 366 pcm; the current TA-18 model underpredicts by 53 pcm.

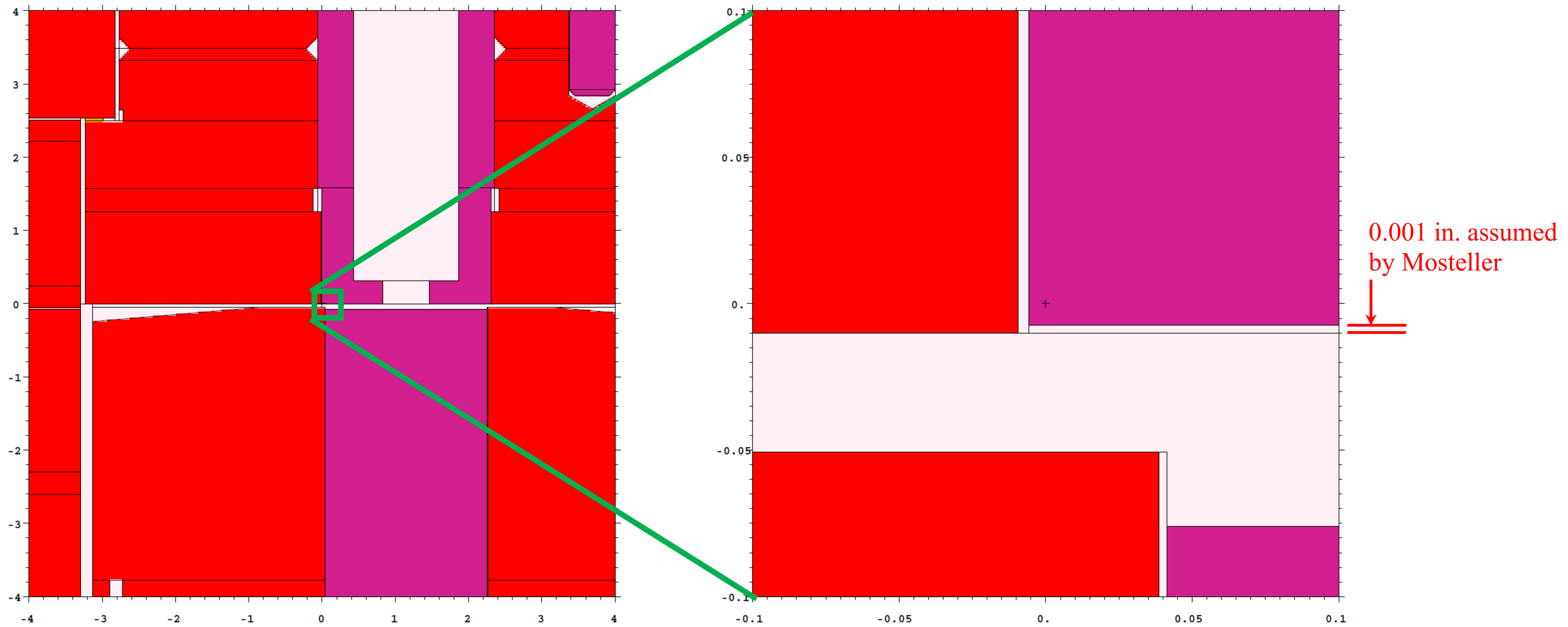


- Other (calculated) numbers to remember:
  - Reactivity worth of the building: 40 pcm = 6 ¢
  - Reactivity worth of Comet: 0 pcm = 0 ¢

Issues that We Are Investigating

- There is a mismatch of 1/16 to 1/8 in. between physical measurements of control rod travel and HMI (controller) readings.
  + The resulting uncertainty in k_{eff} is ≈ 20 pcm (if these are considered bounding uncertainties for control rod location).

- We don't quite know where the spindle is relative to other axial surfaces.
  + Does not affect k_{eff} (raising to 0.100 in. has no effect) but could affect foil irradiation inferences.



Summary and Conclusions

- The Godiva-IV benchmark reevaluation progresses.
- There will be a detailed and a simplified model.
- There will be a legacy TA-18 version and a new DAF version → 9 cases.
  - \+ My system for modeling makes it very little extra work to have all these versions.
  - \+ Control rod, burst rod, and safety block motion is all done with translations.
- The current DAF model overpredicts by 366 pcm; the current TA-18 model underpredicts by 53 pcm.
- I have not started the uncertainty analysis yet and won't speculate on what the result will be!
  - \+ I don't believe that all perturbation calculations are needed for all cases.
- Nothing that I have presented has been formally reviewed.
- I welcome your comments and suggestions.
- Acknowledgment:

This work was supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.