SNS-OPM-ATT 2.B-10.a.
Unreviewed Safety Issue (USI) Evaluation Form

I. Title of USI Evaluation:

Addition of Generation II Diagnostic Instrumentation into the Target Interstitial and Addition of Materials Test Specimen Holder Assembly

II. Description of Proposed Activity (or discovered condition) (use attachments if necessary):

A second generation of target module instrumentation is proposed. As with the first generation which was installed on MTX-009 [1], it is proposed to install sensors on a mercury vessel inside the interstitial region of the SNS MTX-010 target module and future target modules to measure the physical parameters that will support target life extension research. In addition to second generation instrumentation, a materials test specimen holder to be installed on the target block is proposed. The discovery of information from these sensors and tests should improve target reliability by measurement of target response to the beam loads and by providing a basis for using more reliable diagnostics on future targets.

The second generation diagnostic instrumentation is very similar to the first generation instrumentation which was evaluated in USI Evaluation 10030102-0078 [1]. The second generation target module instrumentation suite will consist of the following:

- Interstitial sensors
  - 8 Radiation resistant (high OH content) optical strain sensors will be used that include a Kapton (polyimide) coating instead of a fiberglass coating
  - 2 sample single-mode sensors
  - 2 metal thermocouples with a stainless steel sheath spot welded onto the mercury vessel inside interstitial
  - 2 metallic (Constantan) foil strain gages spot welded onto the mercury vessel inside the interstitial
- Accelerometers (identical to those installed as part of first generation instrumentation) on the target block and mercury piping
- Materials irradiation sample holders mounted on the rear of target module.

The primary changes from the first generation configuration are:

- Use of Kapton® in lieu of fiberglass as an insulating material,
- The addition of two single mode sensors,
- The addition of 2 Type K thermocouples,
- The addition of 2 metallic Constantan foil strain gages, and
- The addition of materials test specimen holder.

The strain sensors and thermocouples will be installed in the interstitial space between the mercury vessel and the water shroud but will have insufficient length to reach and potentially short the leak detector conducting wire should they become dislodged.

The fibers will be mounted on the mercury vessel surface. Figure 1 shows planned locations of second generation sensors. The thermocouples will be mounted in a similar manner as was done for first generation instrumentation on MTX-009 (see Figure 2).

The fiber optic strain sensors are commercial sensors that have a Kapton coating, unlike the first set of sensors installed on MTX-009 which had a fiberglass sheathing. Because of its excellent radiation resistance, Kapton is frequently used in high radiation environments where flexible insulating material is required [2].

Two single-mode (higher radiation resistant) fiber optic sensors will also be installed. This fiber has no sheathing.

As with the first generation instrumentation, fibers will be attached to the target module using Stycast 2850FT epoxy using Catalyst 11 (See Figure 2). The same epoxy has been used to seal the conductor/sheathing interface of the existing interstitial leak detector conductivity sensors. As described above, the fiber optic leads feed through a ½ inch OD stainless steel tube at the rear of the target flange. The outside of the tube is sealed using a Swagelok fitting. As with the first generation instrumentation, the inside of the tube is sealed using the same Stycast 2850FT using Catalyst 11. The Kapton sheathing around the strain sensors is separated inside the tubing. The resulting seal from this method was tested and found to hold 45 psig pressure with an acceptable leak rate.

Potential malfunctions and failures introduced by the installation of the interstitial sensors are the same as those identified for the first generation instrumentation; 1) failure of sensors, 2) materials becoming dislodged or disintegrating (e.g. failure of epoxy mounting) within the interstitial and 3) failure of the seal at the penetration feed through. Failure of the sensors has no safety implications and is expected after minimal beam time due to radiation damage.

Potential Impacts of Materials Becoming Dislodged or Disintegrating in Interstitial
Should material installed into the interstitial become dislodged or disintegrate, the possibility that the material could somehow fall across the target interstitial conductivity probes is evaluated. A conductive material could cause a false indication of a leak.

If the metallic strain sensors and thermocouples are made of conductive material and could cause false positive leak indication if they were to somehow fall across the conductivity probes. This interference is prevented by by the design requirement that the length of the metallic strain sensors and thermocouples inside of the interstitial are limited to 12.6 inches in length. A minimum length of 14.3 inches would be required for a sensor to reach one of the conductivity probes.

The other materials to be added to the interstitial are the fiberglass strain sensors with Kapton sheathing, the single mode sensors and the stycast epoxy mounting material. The resistivity of the fiber optic (glass) and Kapton is at least seven orders of magnitude higher than water or mercury and is on the same order of magnitude as the Stycast epoxy already used to seal the conductor/sheathing interface of the first generation interstitial leak detector conductivity sensors. This seal effectively "shorts" the two conductivity sensors as can be seen in Figure 4. Therefore, a false leak indication would not be generated if the conductivity sensors were "shorted" by a fiber optic, Kapton or epoxy. A table of resistivities is provided below.

Material	Resistivity (Ohm-m)
Mercury	10^{-7}
Water	$10^{0} – 10^{3}$
Stycast Epoxy	10^{13}
Glass	$10^{10} – 10^{14}$
Kapton	10^{15}
Air	10^{16}

The Kapton material is widely used in nuclear applications and space applications because it has high radiation resistance and low off-gassing properties [2]. For this reason, it is expected to be inert toward the leak detector function throughout the target lifetime.

It should be noted that the other target interstitial leak detectors; one using a heated RTD and the other using an instrumented low pressure burst disk would be unaffected by a "short" from a fiber optic sensor or stycast epoxy.

Potential Impacts of Failed Feed-thru Seal

As with the first generation instrumentation, the penetration feed thru at the rear of the target flange consists of a ½ inch OD stainless steel tube that will be sealed with Stycast epoxy. The potential impacts of a failed feed-thru seal described below are unchanged from the first generation instrumentation as documented in the USI Evaluation [1].

The fiber optic leads pass through the feed thru into the Service Bay side of the flange. Should the Stycast epoxy seal fail, the helium filled interstitial region of target module could communicate with the Service Bay air. It should be noted that there already exist several penetration seals that could fail, such that the addition of a feed thru penetration does not create the potential for a new type of failure. Although none of the other flange penetrations use an epoxy seal, Stycast epoxy is used to seal the conductivity probe wire/sheathing interface (see Figure 3) which seals the leak path into the Service Bay through the inside of the sheathing.

Since air has a lower thermal conductivity than helium, a thermal analysis was performed by the target engineers that showed no overheating concerns associated with continued operations with air in the interstitial. Air within the interstitial would lead creation of gaseous activation products (e.g. Ar-41) which could diffuse through a failed seal into the Service Bay. The Service Bay is designed for such contaminated atmospheres. Gaseous activation products potentially released into the Service Bay can be considered to be similar to releases calculated for the FMITS project [1 and 2] where argon gas was assumed to flow through the tubes in front of the target module and then discharge into the Service Bay. Analysis showed no significant radiological concerns associated with the FMITS gas discharge.

Additionally, air within the interstitial region would lead to the production of nitric acid, which could cause some corrosion within the module. Such corrosion could conceivably impact the performance of the conductivity probes by altering the electrical properties of the bare probe wires. The heated RTD leak detector relies on thermal properties rather than electrical and would be much less susceptible to corrosion impacting performance. Further analysis would be required to more realistically determine if corrosion could credibly affect the performance of one or both of interstitial leak sensors.

The FSAD-NF evaluates postulated events that assume an undetected leak (no credit taken for the two interstitial leak detector systems) into the interstitial region leads to the failure of the target module that releases cooling water and mercury into the Core Vessel. Isolation features of the Core Vessel are credited with safely mitigating such an event.

If it were postulated that the feed thru seal fails concurrently with a leak of mercury and/or Loop 2 water into the interstitial, the failed seal would provide a pathway for mercury and/or Loop 2 water to travel into the Service Bay. Mercury and Loop 2 water leaks in the Service Bay are anticipated and the Service Bay is designed to safety confine such spills. It should be noted that the interstitial leak detectors would normally promptly detect such a condition and non-credited automatic corrective actions (e.g. draining of the mercury loop) and operator alarms would minimize potential leakage.

Potential Impacts of Installing Materials Test Specimen Holder

The holder assembly itself posses no hazards as it made of stainless steel and is located on top of the target block outside of the core vessel (Figure 5). The types of material specimens envision to be placed in holder include polymer O-rings, plastic fiber optic connectors, cured epoxy, and radiographic film dosimetry. The purpose for the material irradiation tests would be to assess impacts of relatively high gamma and neutron fields on the durability of engineering components that could be used in the future to improve reliability within the target systems. Because of its location, materials can only be replaced/removed with the target cart in the withdrawn position.

Explosive materials will be prohibited in the Materials Test Specimen Holder. The amount of combustible materials potentially placed in the holder will be limited by the relatively small size of the holder and would be controlled under the provisions of the credited SNS Combustible Material Control Program as implemented in OPM 2.J-3 [6]. Other inherent or induced hazards potentially introduced by placement of material specimens (e.g. induced activation, high pressure within sample holders, highly corrosive materials, toxicity, etc.) will be screened and managed in accordance with an approved SNS procedure [5] to insure no new significant hazards are introduced.

III. Does the proposed activity or discovered condition affect information presented in the FSAD-NF or FSAD-PF, e.g. regarding equipment, administrative controls, or safety analyses. If so specify the applicable FSAD and relevant sections.

No. The proposed addition of instrumentation into the target interstitial region and the materials test specimen holder assembly does not affect information presented in the FSAD-NF. No changes to the FSAD-NF are required to address the proposed change. The FSAD-NF addresses the target interstitial region in Section 3.3.1 *Target and Mercury Process Systems.* This section describes the interstitial as being He filled and containing two different types of leak detectors. The proposed installation of the interstitial strain sensors will not affect information presented in Section 3.3.1. The FSAD-NF also acknowledges the presence of interstitial leak detectors but takes no credit for their functionality in Section 4.3.1 *Target System Event Scenario Summary*. The proposed installation of the interstitial strain sensors will not affect information presented in Section 4.3.1.

IV. Does the proposed activity or discovered condition affect any of the requirements of the ASE. If so, list the affected sections

No. The proposed addition of instrumentation into the target interstitial region and the materials test specimen holder assembly does not affect any of the requirements presented in the ASE.

V. USI Evaluation Criteria:

1. Could the change significantly increase the probability of occurrence of an accident previously evaluated in the FSADs? Yes __ No_x_
   Justification: (use attachment if necessary)

   No. The presence and use of the materials test specimen holder assembly has no affect on the probability of occurrence of any accident evaluated in the FSADs. Fire is a chief concern in the mercury process region. Explosive materials are prohibited and the small size of the holder limits potential combustibles to an insignificant amount. Additionally, all combustibles introduced into the Service Bay are limited by SNS Combustible Material Control Program. All materials specimens are screened by approved SNS procedure to ensure that no potential significant hazards are introduced.

Potential malfunctions associated with the proposed diagnostic instrumentation include i) degrading the interstitial leak detector performance and ii) failure of the diagnostic instrumentation feed thru seal at the rear of the target module.

The interstitial leak detectors are not credited in the FSAD-NF accident analysis, failure of the leak detector systems does not significantly increase the probability of occurrence for any accident evaluated in the FSAD-NF.

Failure of the feed thru seal could potentially create a leak pathway out of the rear of the target module into the Service Bay. In order for leakage to occur into the Service Bay, a significant interstitial boundary leak (water and/or Hg) would have to occur concurrently with a failure of the instrumentation feed through seal. Accident analysis in the FSAD-NF assumes Hg and Loop 2 water leaks within the Service Bay to be anticipated events (TS3-7, CW3-1 thru -16). The probability of occurrence is not significantly increased by the proposed addition of interstitial instrumentation.

2. Could the change significantly increase the consequences of an accident previously evaluated in the FSADs? Yes__ No _x_
Justification: (use attachment if necessary)

No. The presence and use of the materials test specimen holder assembly has no significant impact on the consequences of any accident evaluated in the FSADs. Fire is a chief concern in the mercury process region. Explosive materials are prohibited and the small size of the holder limits potential combustibles to an insignificant amount. Additionally, all combustibles introduced into the Service Bay are limited by SNS Combustible Material Control Program. All materials specimens are screened by approved SNS procedure to ensure that no potential significant hazards are introduced.

Potential malfunctions associated with the proposed diagnostic instrumentation within the interstitial include i) degrading the interstitial leak detector performance and ii) failure of the diagnostic instrumentation feed thru seal at the rear of the target module.

The interstitial leak detectors are not credited in the FSAD-NF accident analysis, failure of the leak detector systems does not significantly increase the consequences for any accident evaluated in the FSAD-NF. Consequences of undetected leak into the interstitial followed by a complete failure of the target module and subsequent release of Hg and Loop 2 water into the core vessel is an FSAD-NF analyzed event (TS 3-4 and TS 3-6) and appropriate mitigating Credited Controls (Confinement function of the Core Vessel) are in place. The consequences of this type of accident are unaffected by the proposed interstitial instrumentation.

Failure of the feed thru seal could potentially create a leak pathway out of the rear of the target module into the Service Bay. In order for leakage to occur into the Service Bay, a significant boundary leak (water and/or Hg) would have to occur concurrently with a failure of the instrumentation feed through seal. The non-credited interstitial leak detectors would normally promptly detect such a condition and non-credited automatic corrective actions (e.g. draining of the mercury loop) and operator alarms would minimize potential leakage. Accident analysis in the FSAD-NF assumes Hg and Loop 2 water leaks within the Service Bay to be anticipated events (TS3-7, CW3-1 thru -16). The consequences of a Hg and/or Loop 2 water leak into the interstitial potentially leading to a release into the Service Bay are analyzed in the FSAD-NF and appropriate mitigating Credited Controls (e.g. confinement function of the Service Bay) are in place. The consequences of this type of accident are unaffected by the proposed interstitial instrumentation.

3. Could the change significantly increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the FSADs?

   Yes__ No _x_
   Justification: (use attachment if necessary)

   The probability of a malfunction of Credited Engineered Controls (CECs) is not affected by the proposed addition of the interstitial instrumentation. The interstitial leak detector is not credited in the FSAD-NF accident analysis. Related CECs include the Core Vessel and Service Bay confinement functions. The proposed interstitial instrumentation does not have the potential to affect the probability of occurrence of malfunctions of these systems.

   The presence and use of the materials test specimen holder assembly does not have the potential to affect the probability of a malfunction of CECs. CECs in the same general area of the holder include the Core Vessel and Service Bay confinement function and the massive steel shielding that covers the mercury process loop. The location and limited size of the specimen holder combined with the specimen hazard screening procedure ensure that there is no potential to negatively impact any CEC.

4. Could the change significantly increase the consequences of a malfunction of equipment important to safety previously evaluated in the FSADs?

   Yes__ No _x_
   Justification: (use attachment if necessary)

   No, the consequences of a malfunction of CECs are not affected. Related CECs include the Core Vessel and Service Bay confinement functions. The proposed specimen trays, specimens and interstitial instrumentation do not have the potential to affect the consequences of malfunctions of these systems.

5. Could the change create the possibility of a different type of accident than any previously evaluated in the FSADs that would have potentially significant safety consequences? Yes__
   No _x_
   Justification: (use attachment if necessary)

   The proposed interstitial instrumentation does not have the potential to create any new types of accidents. Potential malfunctions associated with the proposed diagnostic instrumentation within the interstitial include i) degrading the interstitial leak detector performance and ii) failure of the diagnostic instrumentation feed thru seal at the rear of the target module. Neither of these malfunctions has the potential for creating any new types of accidents beyond those already addressed in the FSAD-NF.

   The presence and use of the materials test specimen holder assembly does not have the potential to create a new accident with significant safety consequences. Explosive materials are prohibited and the small size of the holder limits potential combustibles to an insignificant amount. Additionally, all combustibles introduced into the Service Bay are limited by SNS Combustible Material Control Program. All materials specimens are screened by approved SNS procedure to ensure that no potential significant hazards are introduced.

6. Could the change increase the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the FSADs?

   Yes__ No _x_
   Justification: (use attachment if necessary)

   The proposed interstitial instrumentation does not have the potential to increase the possibility of a different type of malfunction of Credited Engineered Controls. Potential malfunctions associated with the proposed diagnostic instrumentation within the interstitial include i) degrading the interstitial leak detector performance and ii) failure of the diagnostic instrumentation feed thru seal at the rear of the target module. Related CECs include the Core Vessel and Service Bay confinement functions. The proposed interstitial instrumentation does not have the potential to increase the possibility of a different type malfunction of these systems.

   The presence and use of the materials test specimen holder assembly does not have the potential to create a different type of malfunction of CECs. CECs in the same general area of the holder include the Core Vessel and Service Bay confinement function and the massive steel shielding that covers the mercury process loop. The location and limited size of the specimen holder combined with the specimen hazard screening procedure ensure that there is no potential to negatively impact any CEC.

VI. USI Determination: A USI is determined to exist if the answer to any of the 6 questions above (Section V) is "Yes." If the answer to all 6 questions is "No", then no USI exists.

a. Does the proposed activity (or discovered condition) constitute a USI?

__ Yes – DOE approval required prior to implementing

_x_ No – Proposed activity may be implemented with appropriate internal review.

[signature] Nov 23, 2015

Qualified Preparer, David Freeman, SNS Accelerator Safety Specialist — Date

[signature] Nov 23, 2015

Reviewer, Mark Wendel, SNS Target Systems Engineering Lead — Date

[signature] 11/23/2015

Qualified Reviewer, Steve Trotter, SNS Environmental Engineer — Date

[signature] 11/23/15

Signature of NScD Operations Manager — Date

Approvals:

[signature] 2015/11/23

Signature of SNS Operations Manager or Designee — Date

References

[1] *USI Evaluation for Addition of Diagnostic Instrumentation into Target Interstitial,* SNS 102030102-ES0078, March 23, 2015.
[2] Baumgartner, M. J., *Independent Review of Proposal to Modify Target Module Sensors*, August 18, 2015.
[3] SNS-NFDD-ENG-TD-0003-R00SNS, *Fusion Materials Irradiation Test Station (FMITS) Design Study*, December 30, 2011.
[4] SNS-102030102-ES0074, R00, *Preliminary Safety Assessment for FMITS Feasibility Study*, June 2014.
[5] Wendel, M. W., *Procedure for Selection and Approval of Samples to be Irradiated on SNS Target Modules*, SNS Internal Procedure, Approved November, 2015.
[6] SNS OPM 2.J-3, *Target Building Combustible Controls*, March 14, 2007.

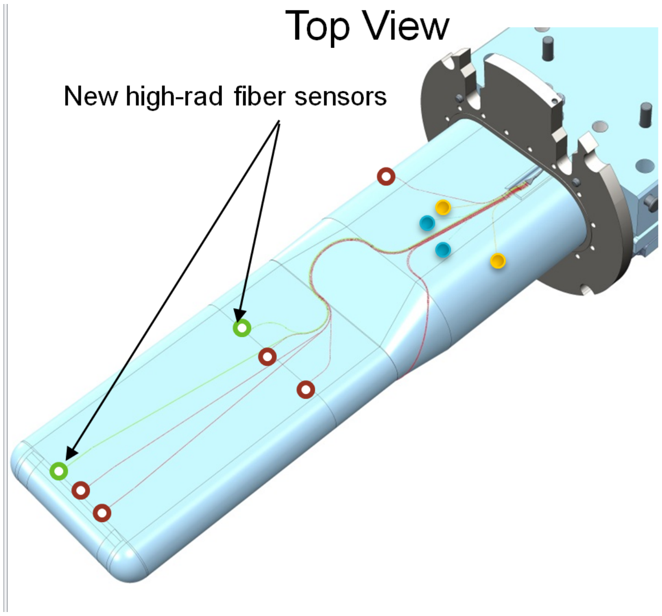

Figure 1. Planned Locations of Second Generation Interstitial Sensors.

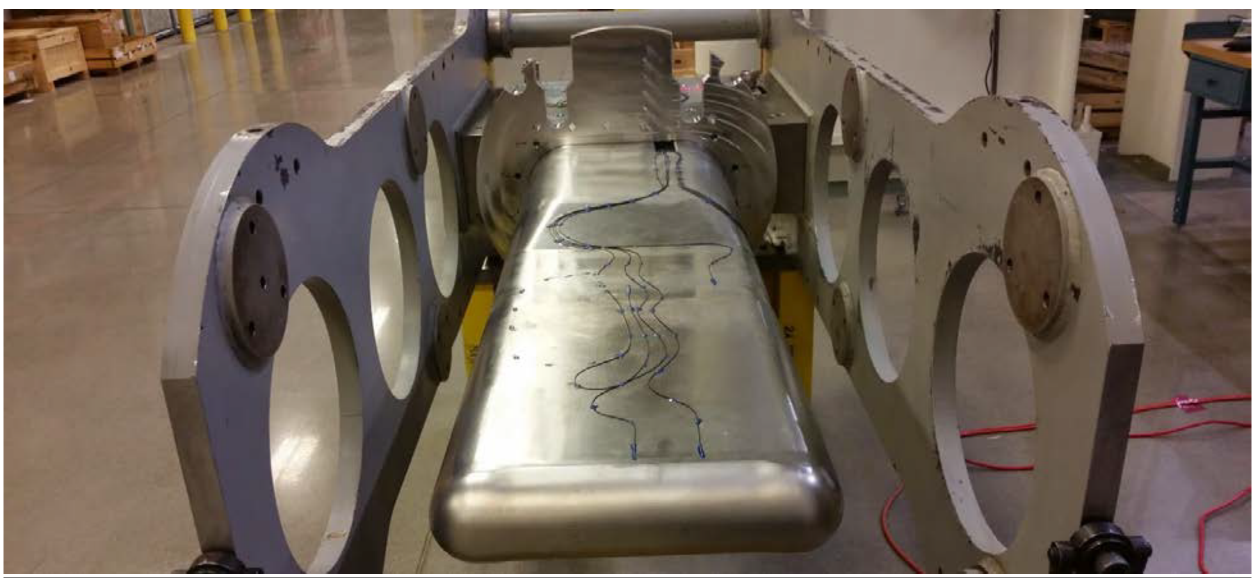

Figure 2. Strain Sensors (first generation) Mounting to MTX-009 Target Module. Note that the Water Shroud is removed.

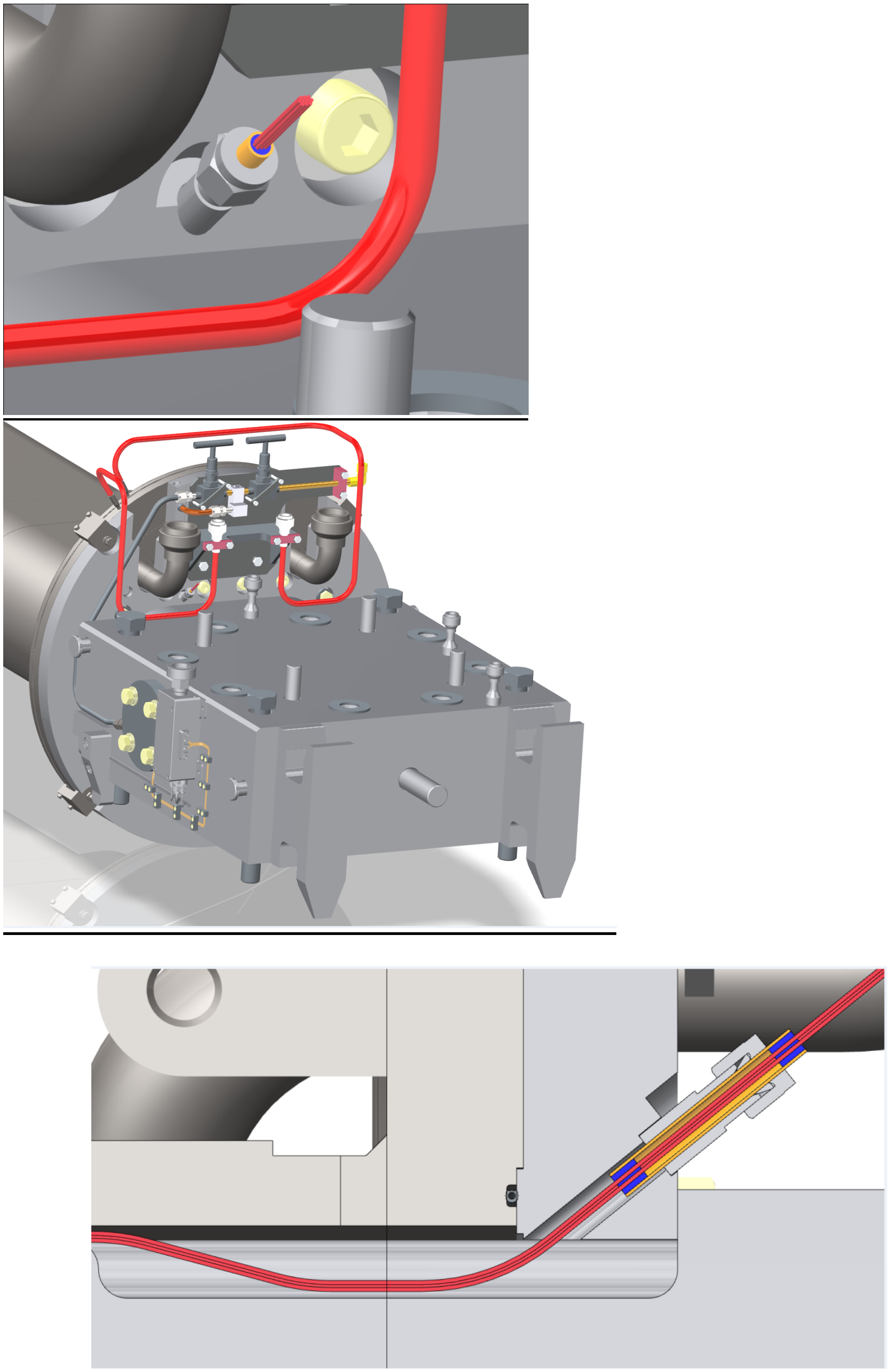

Figure 3. Depiction of the Feed Through Penetration. (Note that the feed through will be sealed with epoxy.)

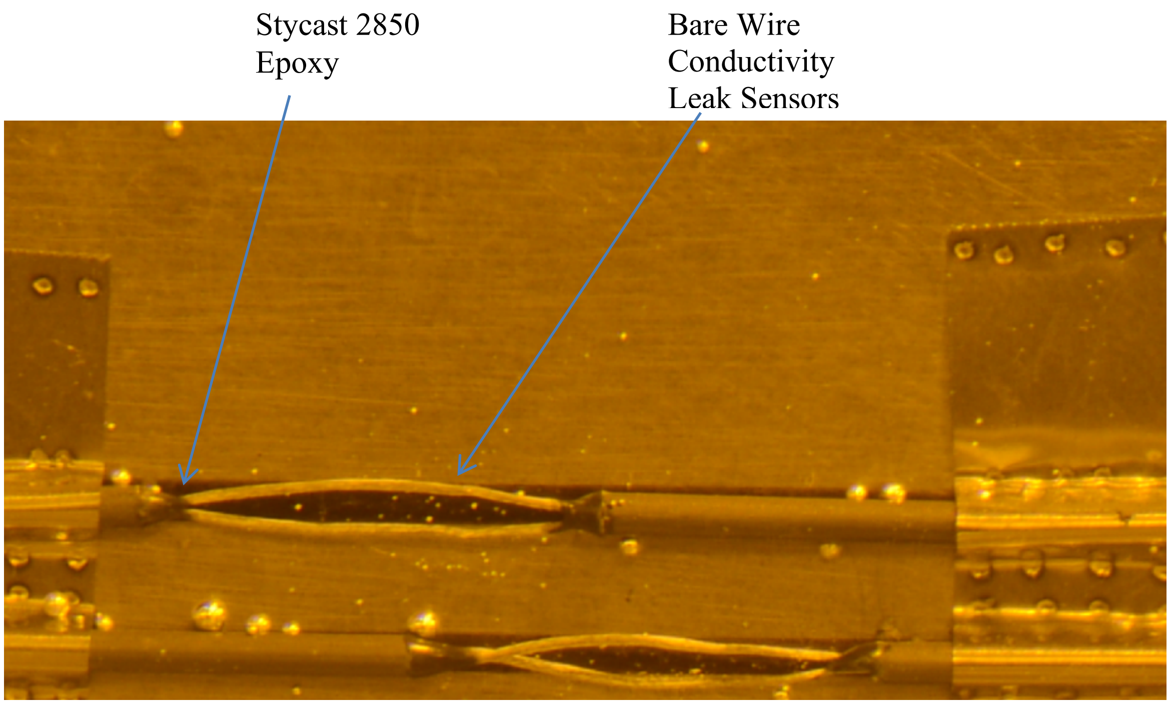

Figure 4. Stycast Epoxy Seals of Interstitial Conductivity Leak Sensors of TGT 10 after irradiation with detected leak of mercury. Note the mercury beads. A short between the bare wires or short between either bare wire and ground (target module) provides a leak indication signal.

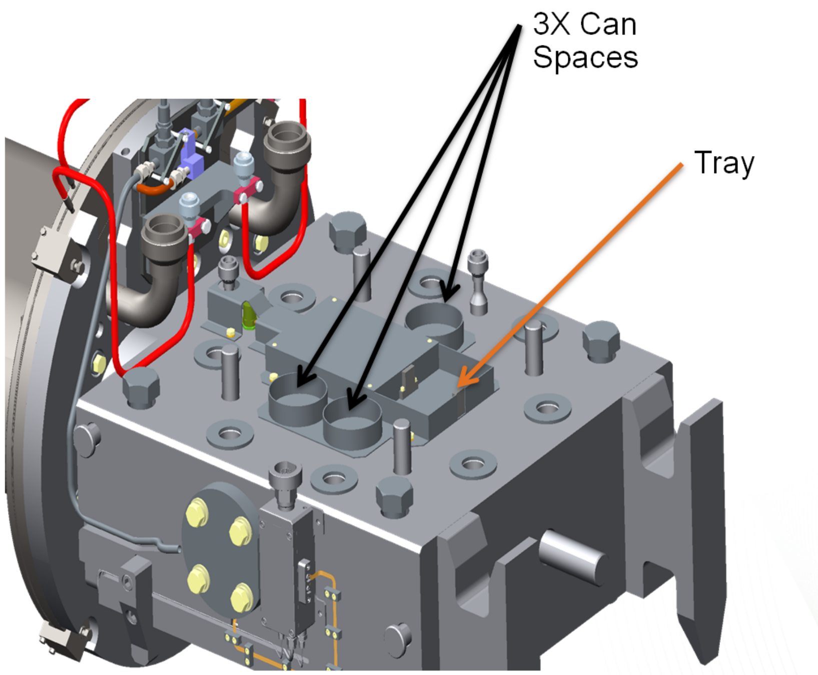

Figure 5. Irradiation specimen holder on back of target module (graphic generated by ProEngineer solid model).