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

I. Title of USI Evaluation:

USI Evaluation for Addition of Diagnostic Instrumentation into Target Interstitial

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

It is proposed to install diagnostic sensors (optical strain sensors and continuous high rad test fiber (without polymeric coating)) within the interstitial region of the SNS Target Module for the purpose of making measurements of module parameters to support target life extension research.

The sensors will be installed in the interstitial space between the mercury vessel and the water shroud. As described in FSAD-NF Section 3.3.1 *Target and Mercury Process Systems*, the interstitial region is helium filled and is equipped with two different types of instruments (conductivity probe and RTD) to detect leaks.

The fibers will be mounted on the mercury vessel surface (see Figure 1 showing sensor locations and mounting of sensors on the module). The fiber optic leads of the strain sensors will be fed through a ½ inch OD stainless steel tube mounted with a Swagelok fitting in a penetration hole drilled into the rear target flange. The penetration will be sealed with epoxy with the fiber optic leads in place.

The fiber optic strain sensors are commercial sensors. They have fiberglass sheathing. A loop of fiber of a more radiation resistant fiber will also be installed. This fiber has no sheathing.

Fibers will be attached to the target module using Stycast 2850FT epoxy using Catalyst 11 (See Figure 1). 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. The inside of the tube is sealed using the same Stycast 2850FT using Catalyst 11. The fiberglass 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.

Materials added to the interstitial region consists of the fibers, the fiberglass sheathing, and Stycast 2850FT using Catalyst 11. It should be noted that these materials already exists within the interstitial region. Existing RTD materials use a glass (passivation) coating and Stycast 2850 FT epoxy is used to seal the conductivity probes.

Potential malfunctions and failures introduced by the installation of the interstitial sensors include 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 materials (fiber optics and/or epoxy) become dislodged, it is possible that a fiber or epoxy could fall across the target interstitial conductivity probes. A conductive material could cause a false indication of a leak. The resistivity of the fiber optic (glass) is 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 existing interstitial leak detector conductivity sensors. This seal effectively "shorts" the two conductivity sensors as can be seen in Figure 3. Therefore, a false leak

indication would not be expected if the conductivity sensors were "shorted" by a fiber optic or epoxy. A table of resistivities is provided below. It should be noted that the second installed target interstitial leak detector using a heated RTD would be unaffected by a "short" from a fiber optic sensor or stycast epoxy.

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

Concerns were raised during the initial sensor design that perhaps polymers used for sheathing of some fiber optics might have the potential to somehow vaporize and redeposit on the conductivity sensors. It was postulated that perhaps such a deposit could coat and insulate all of the exposed conductivity sensor wires rendering them incapable of detecting a leak. Although the credibility of such a scenario has not been established, it was decided to avoid the use of polymers and sensors using fiberglass sheathing were selected.

Potential Impacts of Failed Feed-thru Seal

The penetration feed thru at the rear of the target flange consists of a ½ inch OD stainless steel tube. The fiber optic leads pass through the feed thru into the Service Bay side of the flange (Figure 2). 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 exists multiple 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 between the interstitial and Service Bay through the inside of the sheathing. Figure 3 is a photograph of post-irradiation Target 10 after the bolt on shroud was removed. The target underwent ~600 MW-hr irradiation at ~ 1 MW power. The epoxy seen in Figure 3 shows no sign of degradation or disintegration. Target 10 failed prematurely, SNS targets have lasted up to 7 times longer[1]. The epoxy feed thru seal is located at the back of the target module and would be exposed to significantly less radiation damage than that of the epoxy directly adhered to the mercury vessel as shown in Figure 3. Although the visual evidence showing the epoxy condition in Target 10 does not provide assurance of how well the seal will perform, it does provide an indication that the epoxy can be expected to remain intact and not significantly disintegrate over the expected lifetime of an SNS target.

Since air has a lower thermal conductivity than helium, a thermo-hydraulic analysis was performed by the target engineers that showed no overheating concerns associated with continued operations with air in the interstitial [1]. 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 [2, 3] 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

[1] The longest-lived target run at SNS to date was Target 9 which lasted 4195 MW-hrs.

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 less susceptible to corrosion impacting performance. Further analysis would be required to more realistically determine if such corrosion could credibly affect the performance of the interstitial leak sensors.

The FSAD-NF evaluates postulated events that assume an undetected leak (no credit taken for the 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 or prevent potential leakage into the Service Bay.

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 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 briefly 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 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. Potential malfunctions associated with the proposed diagnostic instrumentation within the interstitial include i) degradation or failure of 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. Potential malfunctions associated with the proposed diagnostic instrumentation within the interstitial include i) degradation or failure of 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 or prevent potential leakage into the Service Bay. 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.

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 interstitial instrumentation does 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) degradation or failure of 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.

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) degradation or failure of 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.

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]	March 20, 2015
Qualified Preparer, David Freeman, SNS Accelerator Safety Specialist	Date
[signature]	3/23/2015
Reviewer, Mark Wendel, Target Systems Engineering Lead	Date
[signature]	3/23/2015
Reviewer, Steven Trotter, SNS Environmental Engineer	Date
[signature]	3/20/2015
Qualified Reviewer, Mike Harrington, Accelerator Safety Consultant	Date

Approvals:

[signature]	03.23.2015
Signature of SNS Operations Manager or Designee	Date

REFERENECES

[1] Wendel, et. al., *Instrumentation of SNS Target Module*, PowerPoint presentation (slide 36) presented to the SNS Configuration Control Committee, February 13, 2015.

[2] SNS-NFDD-ENG-TD-0003-R00SNS, *Fusion Materials Irradiation Test Station (FMITS) Design Study*, December 30, 2011.

[3] SNS-102030102-ES0074, R00, Preliminary Safety Assessment for FMITS Feasibility Study, June 2014.

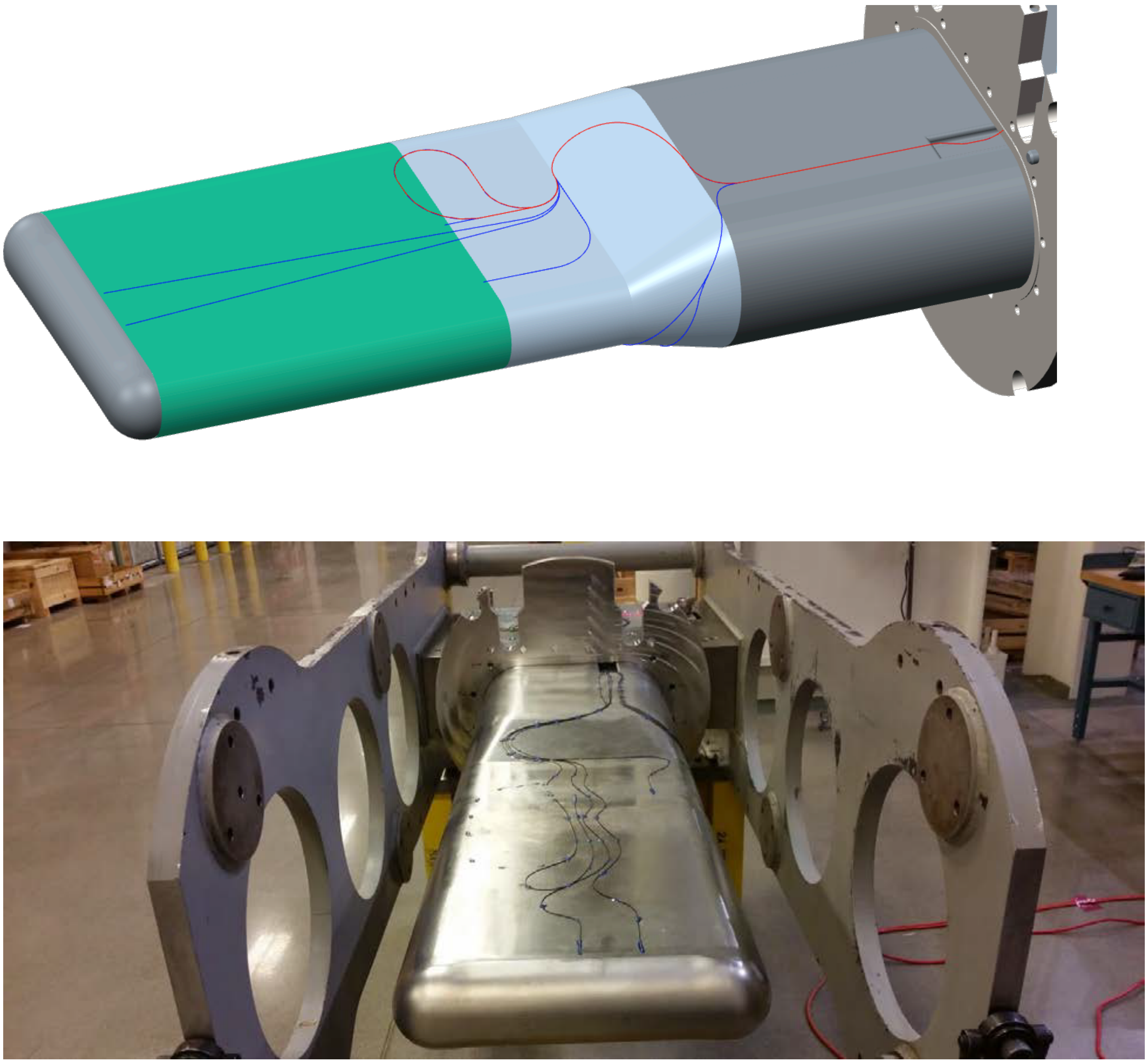

Figure 1. Strain Sensors Mounting to Target Module. Note that the Water Shroud is removed.

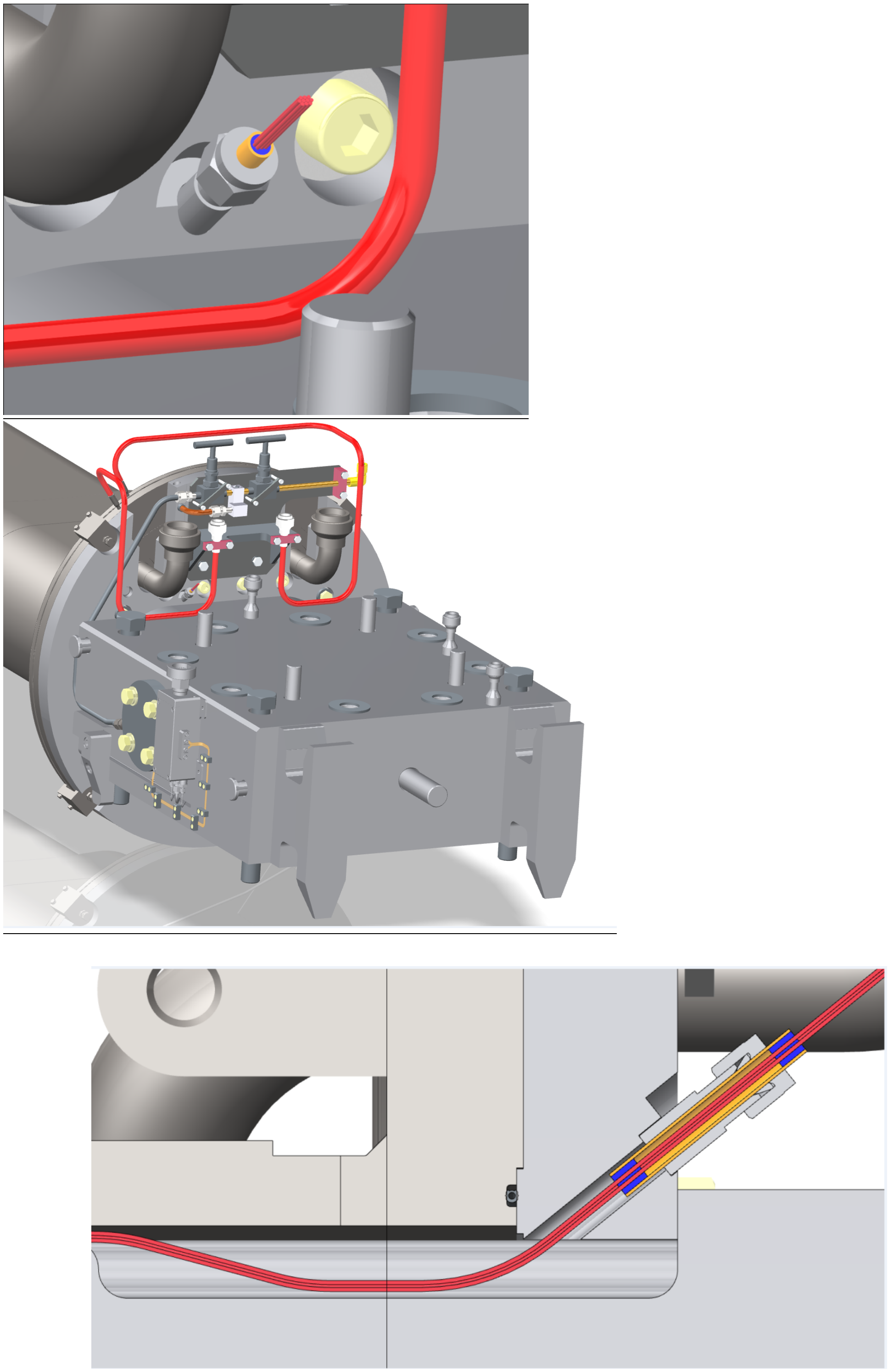

Figure 2. Depiction of the Feed Through Penetration. (Note that the feed through will be sealed with epoxy.)

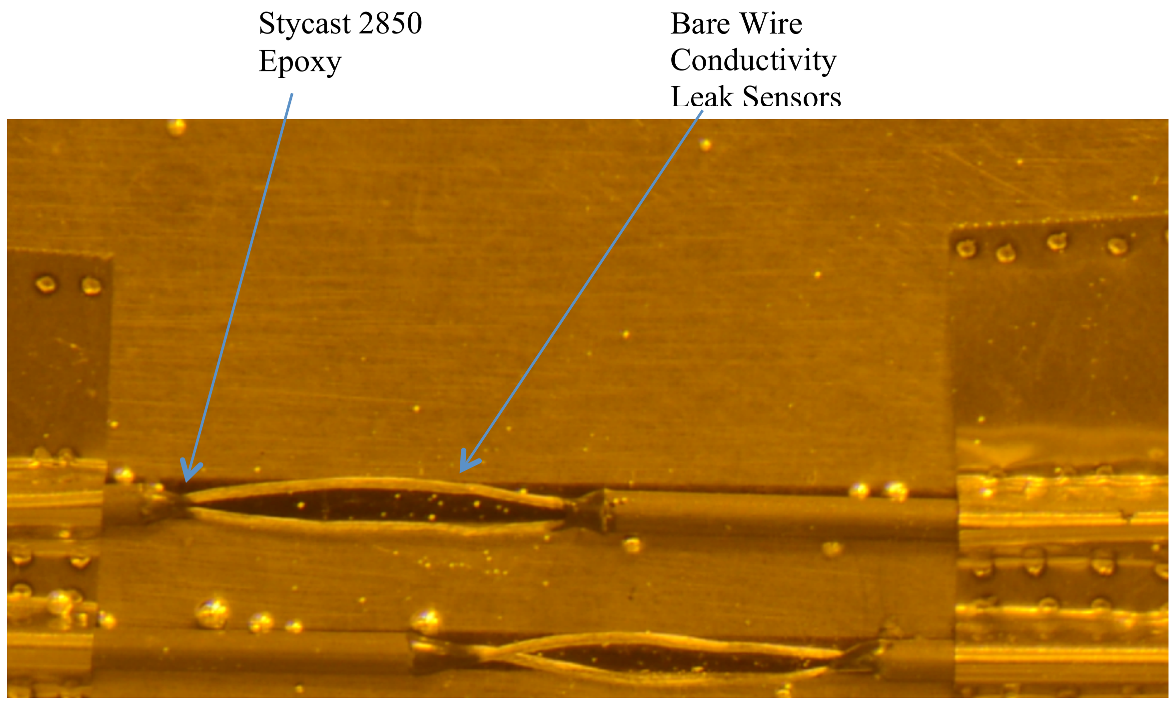

Figure 3. Stycast Epoxy Seals of Interstitial Conductivity Leak Sensors of TGT 10 after irradiation. Note the mercury beads.