Spectra Tech Inc.

Engineering, Environmental & Nuclear Services

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SUBJECT: Contract DE-EM0003976 NRC Licensed Facilities –Transmittal of Engineering Design File FSV Hydrogen Sampling (EDF-STI-17-01) Revision 1

Mr. Nebeker,

Attached is EDF-STI-17-01, Engineering Design File - FSV Hydrogen Sampling Rev 1 with comments incorporated, as requested. This EDF addresses Fuel Storage Container (FSC) hydrogen gas sampling issues and provides a recommended a path forward.

If you have any questions, comments or need clarification, please feel free to contact me at 623-693-1128.

Regards,

David Bland
Program Manager

Attachment:
EDF-STI-17-01, Engineering Design File - FSV Hydrogen Sampling Rev 1

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Engineering Design File

FSV Hydrogen Sampling

EDF-STI-17-01, Rev. 1

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Purpose

On May 23 and 24, 2017, Fuel Storage Container (FSC) hydrogen gas sampling operations were performed as required by FSV SAR Chapter 9, Conduct of Operations, Section 9.8, Aging Management Program (AMP). The AMP requires six FSCs be sampled. Four of the six FSCs were sampled but the remaining two were not because the FSC seal plugs could not be removed due to a misalignment of the shield plug and FSC. This deficiency was entered into the Corrective Action Tracking System (CATS) as Deficiency Report DR-2017-013. The purpose of this EDF is to document DR-2017-013 Corrective Actions and recommend a path forward.

Evaluation

The dual lid seals of the four FSCs sampled in May of 2017 were also leak tested in September of 2016 as required by Surveillance Requirement (SR) 3.3.1.1 to leak test one FSC from each vault. All FSCs met the Limited Condition for Operability (LCO) 3.3.1 requirement that the leakage rate not exceed 1×10^{-3} standard cc/sec. This establishes a high confidence that the gas samples taken from the four FSCs sampled are representative of the conditions of FSCs that have been sealed since they were placed into storage.

DR-2017-013: Corrective Action (CA) Summary

CA #1 shows that the shield plugs and FSCs are misaligned. Specifically the gas sample port FSC seal plugs were found to be misaligned and the leak test FSC seal plugs were found to be aligned. Photographs were taken using an optical scope to document the condition.

CA #2 evaluates the misalignment by reviewing facility drawings and construction records and concludes, based on component tolerances and construction photos showing the FSC support stools being placed using a plumb line, that it is possible for the gas sample port FSC seal plug to be misaligned while the leak test FSC seal plug is aligned.

CA #3 evaluates tooling options to remove the misaligned gas sample port FSC seal plug and perform H2 sampling and concludes, based on component dimensions, that modification of both the seal plug removal tool and gas sample probe would be required to accomplish gas sampling of the FSCs. Both pose unique challenges because of the limited 2 inch high vertical space between the bottom of the shield plug and the top of the FSC (needed to allow the seal plug to be rotated into position for removal thru the shield plug) and the internal plunger inside the hydrogen probe.

CA #4 evaluates whether 4 samples versus 6 samples provide adequate data. The four samples taken were determined to provide adequate data because the measured H2 gas concentrations (0.01 to 0.11 percent) and the 96 percent Confidence Level (CL) H2 gas concentration (less than 0.30%) are small relative to the steady state hydrogen gas concentration (3.6 percent) associated with acceptable FSC corrosion rates and because the change in error from 4 versus 6 samples was estimated to be only 9 percent.

FSV SAR Chapter 9, Conduct of Operations, Section 9.8, Aging Management Program (AMP) states that "The gas inside one FSC in each of the six vault modules will be sampled for hydrogen in order to validate the conclusions reached in SAR Section 4.2.3.2.3, Fuel Storage Containers; specifically, the very low probability of conditions conducive to a galvanic cell reaction resulting in the production of hydrogen gas inside an FSC".

SAR Section 4.2.3.2.3, Fuel Storage Containers, states that "if no significant hydrogen concentration is detected in the first six storage containers whose internal atmospheres are tested, then it will be assumed the theoretical galvanic reaction is not occurring at a significant rate in the FSCs, and additional FSCs will not be tested".

The measured hydrogen concentration (0.01 to 0.11 percent) is not significant when compared to the steady state hydrogen gas concentrations (3.6 percent) (EDF-9166) and therefore validate the SAR conclusion.

Conclusion

Based on consideration of the following:

- The established high confidence that the gas samples taken from the four FSCs sampled are representative of the conditions of the FSCs that have been sealed since they were placed into storage.
- Modification of tooling to remove misaligned gas sample port FSC seal plugs is not feasible due to the limited space between the bottom of the shield plug and the top of the FSC.
- The four samples taken were determined to provide adequate data.
- The theoretical galvanic reaction discussed in SAR Section 4.2.3.2.3 is not occurring at a significant rate.
- FSC handling procedures are in place to preclude the handling of a loaded FSC, or removal of the lid bolts, until the gas space inside the FSC has been analyzed and determined not to have a combustible gas mixture as required by SAR Section 4.2.3.2.3, Fuel Storage Containers.

The recommended path forward is:

- Revise the SAR Section 9.8, Aging Management Program to allow sampling hydrogen gas concentrations from "four FSCs from different vault modules" instead of "one FSC in each of the six vault modules" to address the theoretical galvanic cell reaction issue.

DR-2017-013 Corrective Actions

CA No. 1 Verify misalignment using video inspection and or feeler gauge

The following photographs (figures 1 to 4) were taken on June 21, 2017 using an optical scope thru a half inch inside diameter PVC pipe inserted thru the shield plug access port to center the optical tip over the centerline of the access port. As can be seen the leak test port plugs are centered and the gas sample port plugs are not. This is confirmation at t[illegible] misalignment of the as-found condition of the FSCs.

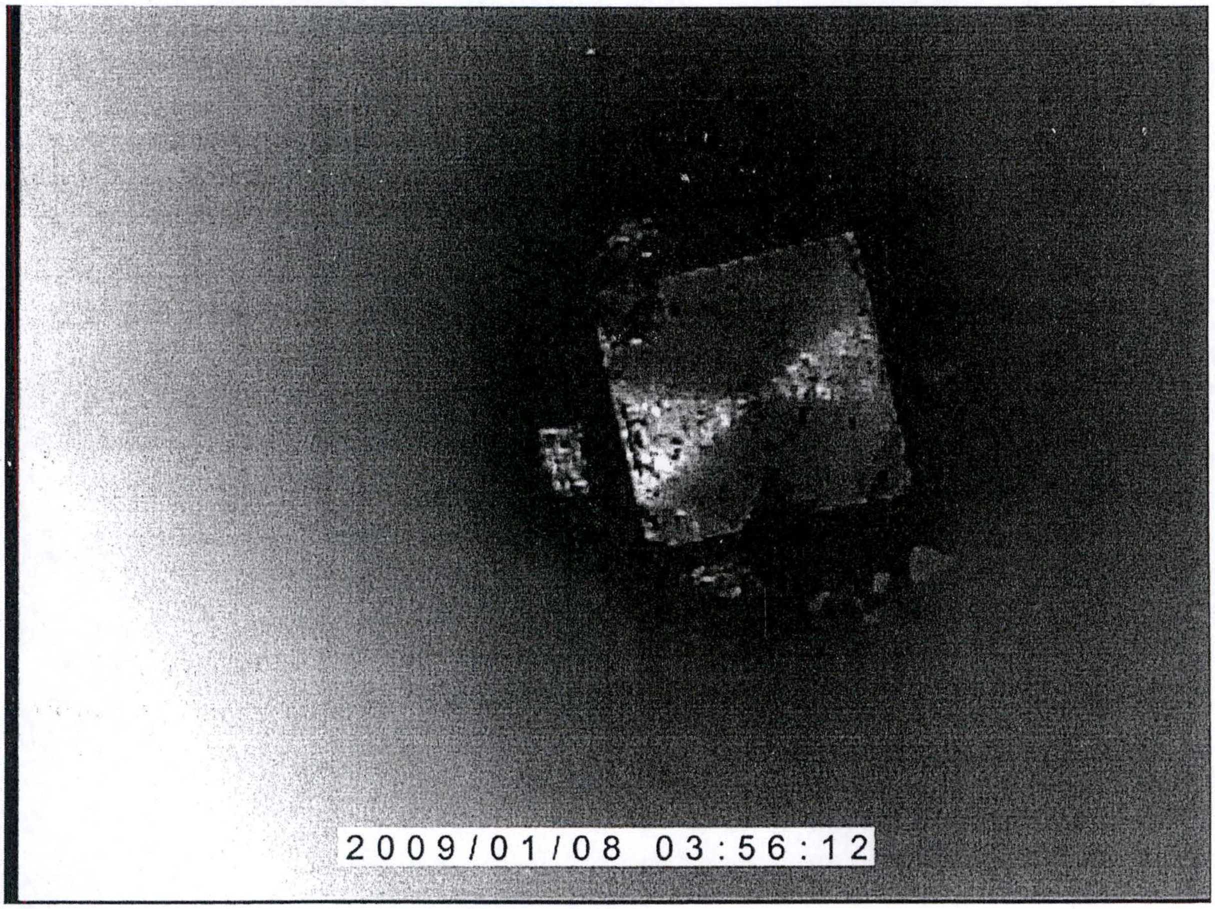


Figure 1– Vault E – Leak Test Port – (June 21, 2017)

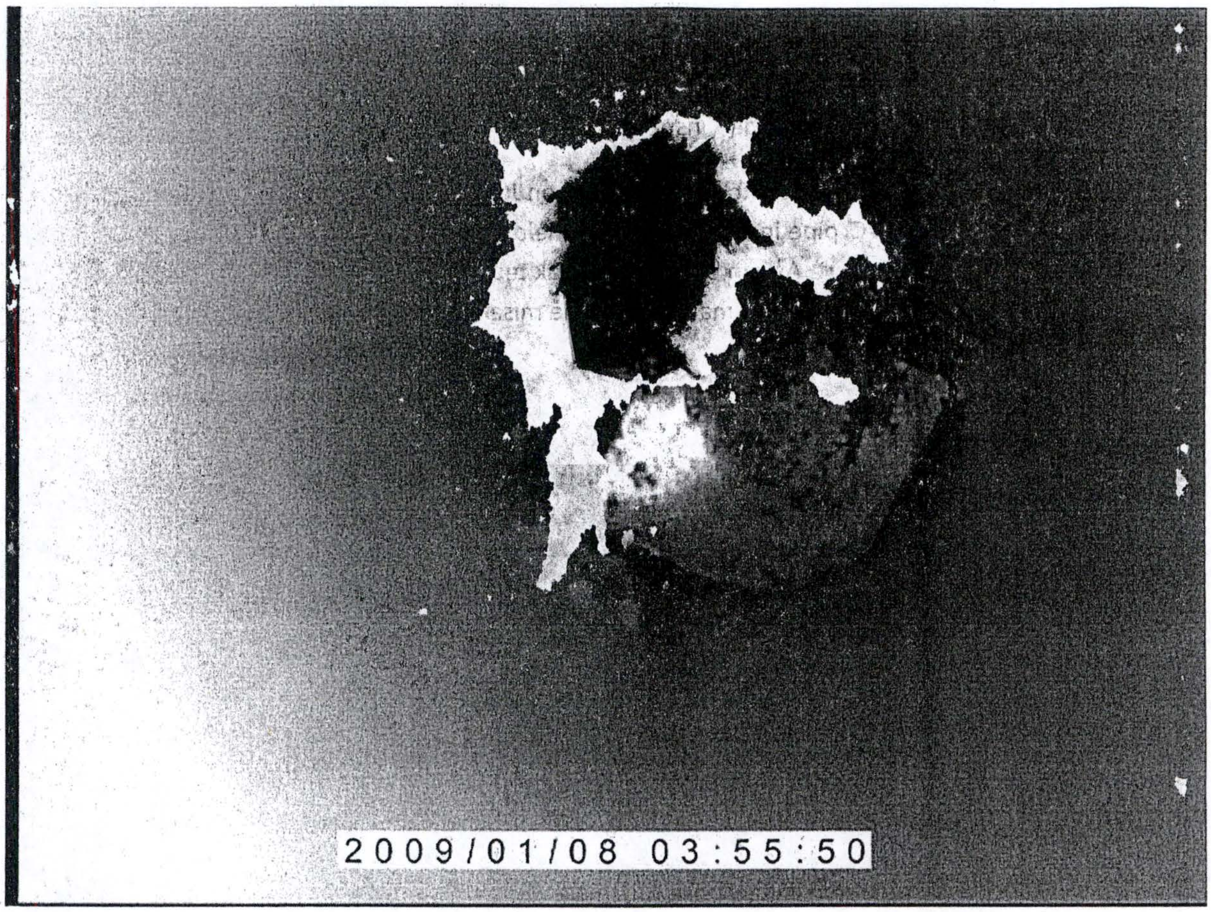


Figure 2 – Vault E - Gas Sample Port – (June 21, 2017)

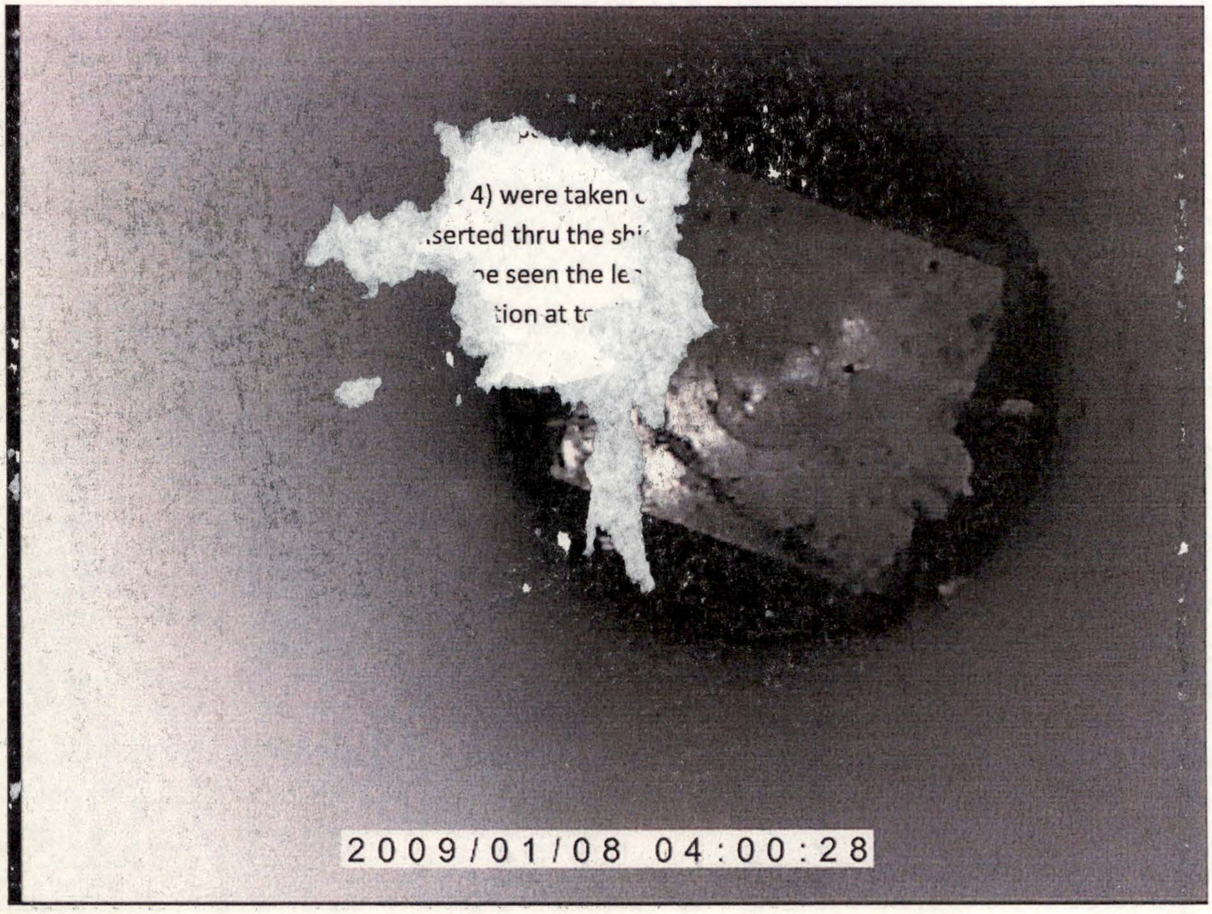


Figure 3 - Vault F - Leak Test Port – (June 21, 2017)

Figure 4 - Vault F - Gas Sample Port – (June 21, 2017)

CA No. 2: Evaluate "As Found" Condition.

The "as-found" condition documented in CA No. 1 shows a significant misalignment between the fuel storage container (FSC) seal plugs and the shield plug access holes for two FSCs located in vaults E and F. This CA reviews the facility design records (drawings and construction records) to determine how a misalignment can exist at the gas sample port location while the adjacent leak test port is perfectly aligned. This evaluation is needed to support determination of any realignment efforts.

Drawing Review (drawings available in EDMS)

The charge face structure (CFS) and FSC assembly are shown on drawing 362A0251. This drawing depicts the CFS, FSC, Shield Plug, and Support Stool.

The seal plug removal tool, seal plug, shield plug and FSC are shown in View A on drawing 362A0029.

The nominal diameter of the access holes in the shield plug used to insert the seal plug removal tool thru to access the FSC lid seal plug s is 0.812 inches (drawing 362A0063).

The nominal diameter of the seal plug removal tool is 0.75 inches (362A0029). The nominal diameter of both the leak test and gas sample probes are also 0.75 inches.

The inside diameter of the CFS liner tube is a minimum of 20.55 inches (drawing 362A0065). Both the FSC lid and FSC flange diameters are a maximum of 20.45 inches (drawings 362A0067 and 362A0068).

Construction Record Review

The positions of the support stools on the vault floor were established using a plumb line centered on the CFS liner tubes as observed in construction photographs (see figures 5 and 6).

Evaluation

Assume a "true horizontal alignment" to be the common alignment of the vertical centerlines of the shield plug, CFS liner tube, FSC assembly, and support stool.

Also assume a "true rotational alignment" to be the common alignment of the vertical centerlines of the access holes in the shield plug to the vertical centerlines of the FSC lid seal plugs. These features are both 9.75 inches from the shield plug and FSC assembly centerlines and 90 degrees apart. One access hole is for leak testing and the other for gas sampling.

All tooling (seal plug removal tool, leak test probe, gas sample probe) that use the 0.812 inches diameter access holes in the shield plug are 0.75 inches in diameter. This means that the actual positions of the shield plug access holes and the FSC lid seal plugs must be within 0.03125 inches of "true horizontal alignment" and "true rotational alignment" for the tooling to be able to properly engage the seal plugs (or the seal plug threaded holes that the probes thread into).

$(0.8125 - 0.75) / 2 = 0.03125$

The accuracy at which the support stools were placed using a plumb line as depicted in figures 1 and 2 is unknown. However assuming that the shield plug is on "true horizontal alignment" with the CFS liner tube and comparing the minimum inside diameter of the CFS liner tube (20.55 inches) to the maximum FSC lid/ flange diameter (20.45 inches) suggests that the FSC could be off of true center as much as 0.050 inches depending on the accuracy in which the support stools were placed.

(20.55 – 20.45) / 2 = 0.050

Conclusion

This evaluation shows that any combination of horizontal and rotational misalignment of more than 0.03125 inches would result in a tooling misalignment to the seal plugs/seal plug threaded holes. Because the potential misalignment between the shield plug and the FSC alone is 0.050 inches (exceeds 0.03125 inches) and because this evaluation does not consider all worst case tolerances/conditions it is reasonable to conclude that being able to remove and install a seal plug thru one of the shield plug access ports does not mean the other access port is aligned such that the corresponding seal plug can be removed and installed.

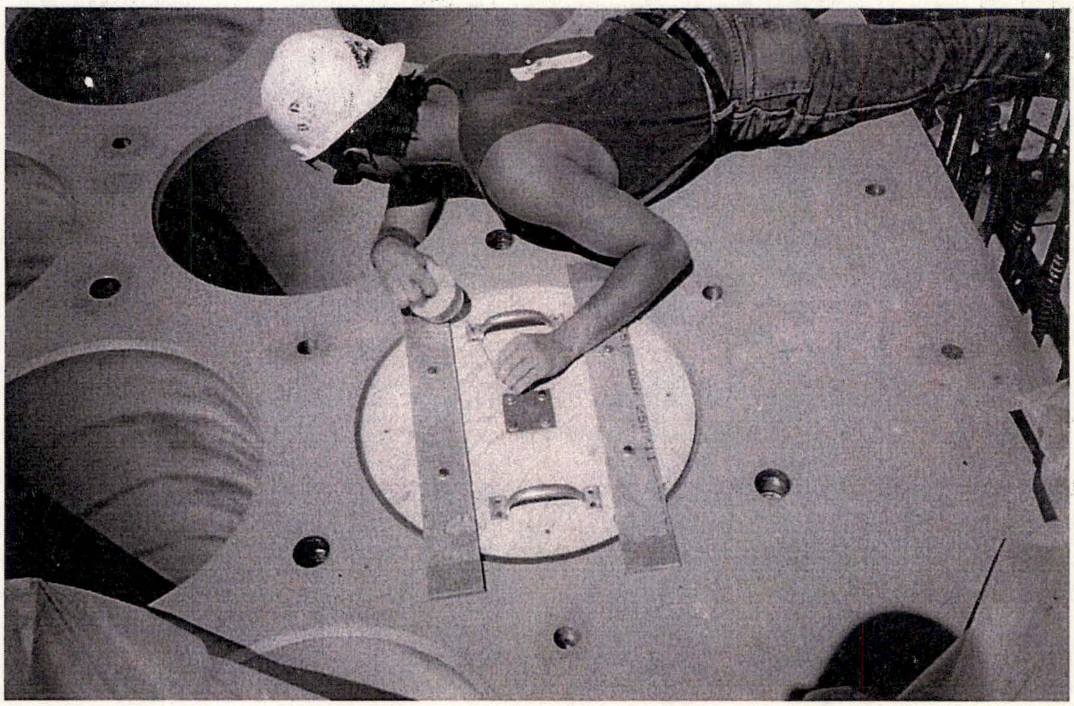


Figure 5 – CFS Plumb Line Centering Jig

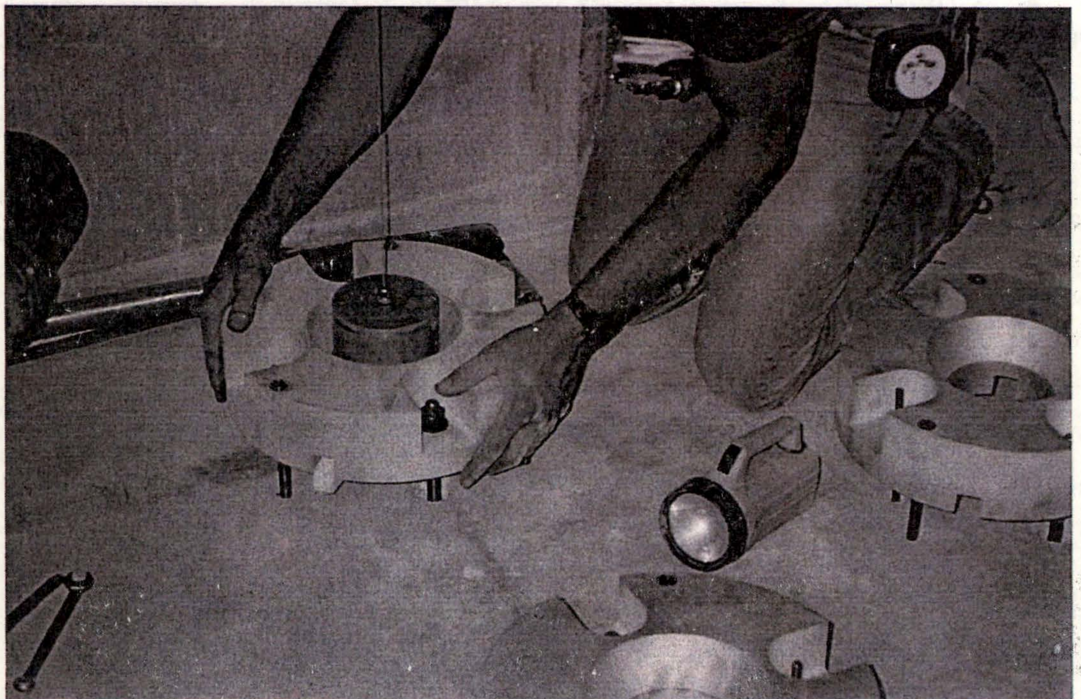


Figure 6 – Plumb Line Weight and Support Stool on Vault Floor

References

GEC Alsthom Engineering Drawing 362A0029, FSV F.S.C. Leak test Equipment, Rev B (EDMS Drawing 512595)

GEC Alsthom Engineering Drawing 362A0063, 352A0063, Rev B, NSW/SSW Shield Plug, Rev B (EDMS Drawing 512640)

GEC Alsthom Engineering Drawing 362A0065, Charge Face Structure Fab, Rev D (EDMS Drawing 512643)

GEC Alsthom Engineering Drawing 362A0067, Fuel Storage Container Fab, Rev H (EDMS Drawing 512668)

GEC Alsthom Engineering Drawing 362A0068, Fuel Storage Container Lid Fab, Rev F (EDMS Drawing 512670)

GEC Alsthom Engineering Drawing 362A0251, C.F.S. & F.S.C. Assembly, Rev D (EDMS Drawing 512834)

CA No. 3: Based on results of CA's 1 and 2, evaluate tooling options to remove seal plug and perform H2 sampling.

The nominal height or clearance between the bottom of the shield and the top of the FSC is 2.0 inches (drawing 362A0029). How much this dimension varies from 2.0 inches is unknown and would depend upon the elevation differences between the top of the CFS and the support stool. The height of the FSC seal plug is 1.5 inches long with a head diameter of 0.75 inches (drawing 362L0069). Revised tooling to remove the seal plug would need to pass thru the 37 inch long, 0.812 inch diameter shield plug access hole, be smaller in diameter than the existing 0.75 inch diameter tool to allow engagement of the off center seal plug, capable of vertically extracting the 1.5 inches long seal plug in a nominal 2.0 inches vertical space before translating the 0.75 inch diameter seal plug horizontally to align it to the center of the 0.812 inch diameter shield plug access hole for retrieval (See Figure 7 for seal plug removal detail)

Assuming that revised tooling can be manufactured to remove and reinstall the seal plug, because the nominal diameter of the gas sample probe is also 0.75 inches it would also need modification to a smaller diameter to allow engagement of the off center threaded hole in the FSC lid. The gas sample probe has an internal plunger (see Figure 8 item 5) that is vertically actuated to open the valve in the FSC lid after the tool is threaded into the lid.

Based on the above evaluation, modification of both the seal plug removal tool and gas sample probe would be required to accomplish gas sampling of the FSCs. Both pose unique problems because of the limited 2 inch high vertical space between the bottom of the shield plug and the top of the FSC and the internal plunger inside the hydrogen probe. Because of these problems modification of tooling to remove the misaligned gas sample port FSC seal plugs is not feasible.

References

GEC Alsthom Engineering Drawing 362A0029, FSV F.S.C. Leak test Equipment, Rev B (EDMS Drawing 512595)

GEC Alsthom Engineering Drawing 362L0069, Special Blanking Plug, Rev C (EDMS Drawing 512671)

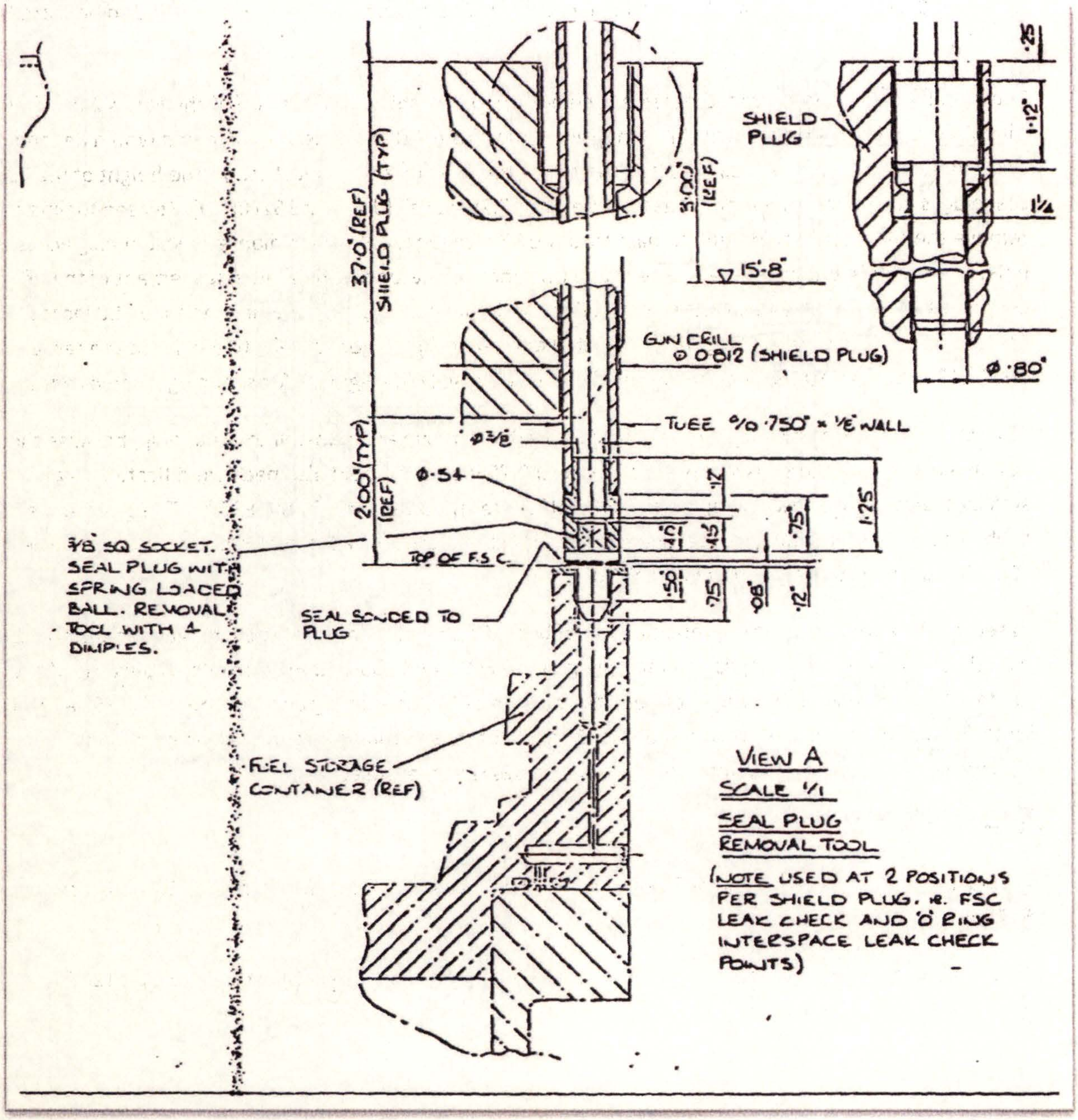
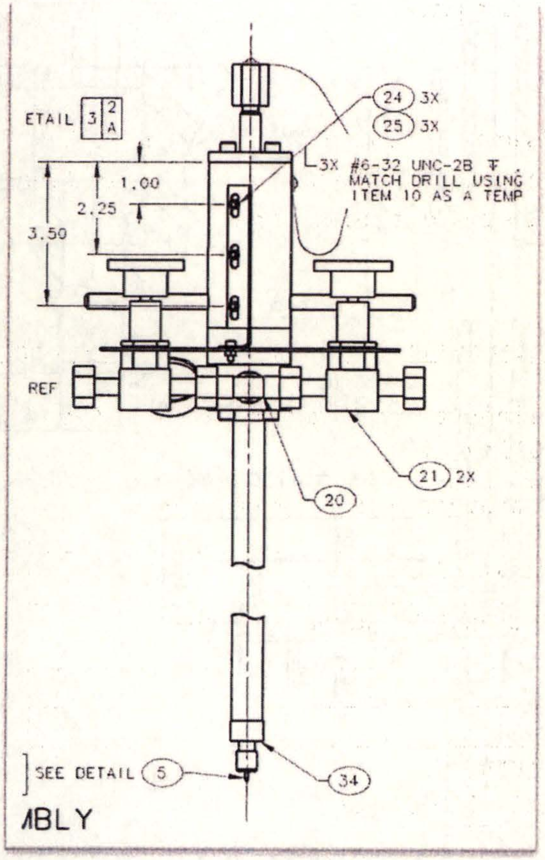


Figure 7 – Seal Plug Removal Detail



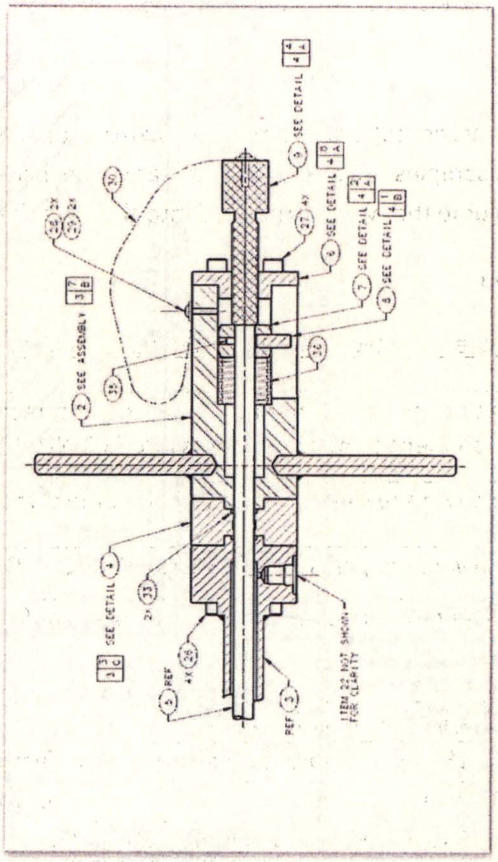


Figure 8 – Hydrogen Probe

CA No. 4: Determine whether 4 versus 6 samples provide adequate data

Purpose

Perform a statistical evaluation of the existing data and sampling criteria to determine whether four versus six samples provide adequate data. Also include adjustment of the sample readings based upon the air volume that was introduced into the FSCs that were below atmospheric pressure.

Evaluation

Calculate the adjusted hydrogen readings (Xi adj) to compensate for the diluted FSC internal atmosphere

Xi: hydrogen concentration (percent by volume) recorded after air was introduced into the FSC to bring it to ambient atmospheric pressure (STI-NLF-OPS-015 step 4.4.4)						
Xi values shown are the upper end of instrument range bands. Instrument readings were "< Xi".						
Pvac: initial vacuum pressure of FSC (STI-NLF-OPS-015 step 4.2.10)						
Xi adj: adjusted hydrogen reading to compensate for the diluted FSC internal atmosphere.						
Based on Boyles Law P1/P2 = V1/V2						
Let P2 = 12.182 psia (ambient pressure at 5000 feet elevation)						
Let P1 = P2 -Pvac			1 inch H2O = 0.036127 psi			
Let V1 = 14740 in3 (FSC void volume - EDF 9166 R2)						
Let V2 = Volume of air in FSC after air is introduced to bring FSC to ambient pressure						
Xi adj = Xi*(V2/V1)						
Vault	**Xi (%H2)**	**Pvac (in H2O)**	**Pvac (psi)**	**P1 (psi)**	**V2 (in3)**	**Xi adj (%H2)**
A	0.1	0	0.000	12.182	14740	0.1000
B	0.1	39	1.409	10.773	16668	0.1131
C	0.1	39	1.409	10.773	16668	0.1131
D	0.01	52	1.879	10.303	17428	0.0118
Let n = number of samples						
Let Xmean be the average of the Xi adj values					Xmean =	0.0845
Let S be the standard deviation of Xi adj					S =	0.0423

Determine the Upper Range of the adjusted hydrogen readings (Xi adj) for a 96% confidence level (CL)

Based on Tchebysheff's Theorem, for random samples a fraction of at least $1-(1/k^2)$ of the observations lie within k standard deviations of the mean (Marks' Handbook). This theorem can be applied to completely arbitrary distributions (Wikipedia).

For a 96% confidence level (CL) (k = 5) (interval including (+/-) 5 S from the mean) the upper range of the H2 readings would be:

Xmean + 5S = 0.0845 + (5)0.0423 = 0.296% H2

Estimate the change in error associated with for 4 versus 6 samples.
Reference (STAT 414/415)

The error (e) for a proportion (p) of a small population is

$e = z\ ((p(1-p)/n)(N-n/N-1))^{0.5}$

where:
e = error
N = population size =244 FSCs in Storage (SAR CH1)
n = sample size (4 or 6)
z value = 1.96 for a 95% confidence level
p = population proportion
note: p(1-p) = 0.25, its maximum when p = 0.5

The change in error (delta e) using 4 versus 6 samples would be:

$\text{Delta } e = z\ ((p(1-p)/n)(N-n/N-1))^{0.5}{}_{(\text{for } n=4)} - z\ ((p(1-p)/n)(N-n/N-1))^{0.5}{}_{(\text{for } n=6)}$

$= 1.96\ ((0.25/4)(244-4/244-1))^{0.5} - 1.96\ ((0.25/6)(244-6/244-1))^{0.5} = 0.09$

Conclusion

Four samples provide adequate sampling data because:

- The four FSCs sampled contained insignificant concentrations of H2 gas (0.01 to 0.11 percent) relative to the maximum calculated steady state hydrogen concentration of 3.6 percent (see Note 1).
- Statistical evaluation of the four samples indicate that for a CL of 96 percent the upper range of the H2 gas concentration is less than 0.30 percent and insignificant relative to the maximum calculated steady state hydrogen concentration of 3.6 percent (see Note 1).
- The change in error (Delta e) from taking 4 instead of 6 samples is estimated to be 9 percent

Note 1 Steady state hydrogen gas concentration of 3.6 percent is based on conservative assumptions of absorbed water and conclude that the associated corrosion rates are still acceptable for continued use of the FSCs though 2031 (EDF-9166).

References

(EDF-9166) Engineering Design File (EDF) 9166, FSV ISFSI MVDS Fuel Storage Container and Support Stool Corrosion Analysis, Revision 2

(Marks' Handbook) Marks' Standard Handbook for Mechanical Engineers, Tenth edition, Section 17.3

(SAR CH1) FSV ISFSI SAR Chapter 1 - Introduction and General Description of Installation

(STAT 414/415) PennState Eberly College of Science STAT 414/415, Probability Theory and Mathematical Statistics

(Wikipedia) https://en.wikipedia.org/wiki/Chebyshev%27s_inequality