

SEG/TRJ/PR0-030

Trojan Proof of Principle Test Summary

(TRJ-PRD-1-05)

Filter Media Processing System
Trojan Nuclear Plant
Spent Fuel Pool Debris Project

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1.0 EXECUTIVE SUMMARY

This test report consists of four main sections;

- Section 1.0: An executive summary of the Proof-of-Principle Testing
- Section 2.0: Operational results from the testing conducted on the full-scale steam-reformer using a prototype can feed evaporator (CFE)
- Section 3.0: Results from residue testing completed at a commercial laboratory
- Section 4.0: Conclusions and recommendations for conducting the Integrated Test

1.1 Background

The purpose of the Trojan project is to clean up contaminated canisters located in the fuel pool rack, and produce a concentrated residue with a low hydrogen (H_2) content so that formation of radiolytic hydrogen in long-term storage casks is below 5 volume percent (vol %) of the container void space. This is a very restrictive limitation and translates to about 250 milligrams H_2 in a treated process can capsule.

The fuel pool canisters contain deteriorated cylindrical sock and cartridge filters loaded with clay sediment, metallic electro-dielectric machining material, and other organics contaminated with failed fuel element fines and fuel pellets. The operation involves remote handling procedures for the recovery of this waste and the loading of steam-reforming process cans that will be inserted into the CFE. The waste will be thermally processed in the CFE, organic off-gases are further processed into syn-gas in the steam-reformer (Galloway, 1996).

There are three major phases in this project:

- The Proof-of-Principle (POP) Test was completed at SEG's Bear Creek Facility in Oak Ridge, TN, in the commercial steam-reformer. The objective of this test was to verify the ability of steam reforming to achieve the requisite low hydrogen content in the final residue.
- The Integrated Test will be conducted at the Washington Public Power Supply System (WPPSS) Nuclear Plant #1. During this test the can feeder/steam-reformer system will be integrated and demonstrated with full remote handling equipment.
- The actual processing of the Trojan Nuclear Power Plant debris.

1.2 Description of Testing

The POP Test runs were conducted in accordance with the Trojan Proof of Principle Test Plan (SEG/TRJ/R-001), the Trojan Proof of Principle Test Procedure (SEG/TRJ/PRO-005), and the Residue Hydrogen Analysis Protocol (SEG/TRJ/PRO-006).

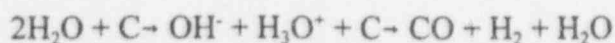
In the POP Test three runs were conducted, surrogate waste was processed at increasing increments in residence time and temperature. The median residence time and temperature proved to be optimum treatment conditions, resulting in a hydrogen content analysis for the residue of 25 milligrams in the process can. Based on these findings, the residue and five process cans could be placed into the final process can capsule and still be less than the specified hydrogen limit.

The residue handling procedures used during the POP Test were designed to minimize any potential contamination by room moisture, a component in the formation of radiolytic hydrogen. For example, when operators removed the residue samples from the can feed evaporator, they had to unload the process can within an inerted tent while wearing self-contained breathing apparatus. To quantify the residual moisture picked up during residue removal operation, trip blank samples were used.

1.3 Residue Hydrogen Analysis

The residue H₂ analysis performed at a commercial analytical laboratory (hereafter referred to as "the lab") provided a unique challenge of maintaining very low H₂ and H₂O background levels in the glove box, analytical instrumentation, sample bags, etc.

The gas chromatograph (GC) in use could not provide quantitative moisture analysis for the residue samples. It could reliably provide an indication that moisture was present above 100 ppm or that it was not present. Therefore, the protocol described in SEG/TRJ/PRO-006 was modified to include a plug of dry, activated carbon in the quartz furnace down stream from the sample. Each sample remained in the quartz furnace at 1100°C for approximately 5 hours as shown in Figure 1. With the low argon flow rate through the furnace, moisture passing through the activated carbon plug had a residence time of at least 30 seconds. At the elevated temperature of the furnace, the activated carbon decomposes at least 99% of the moisture into hydrogen and carbon monoxide. The chemical balance of the carbon and moisture reaction is represented as follows:



Each sample was analyzed for moisture and the GC detected none. It is assumed, therefore, that the hydrogen content detected by the GC fully accounted for all of the hydrogen and moisture present in the residue samples.

A graphical display of the test results is shown in Figure 1. The top curve labeled "Blank Spike" involved the addition of a known hydrogen content in the process can. Thus, this top curve reflects the maximum acceptable hydrogen content.

Figure 1 also shows the residue hydrogen content of the waste stream after steam-reforming for Runs #1, #2, and #3. Run #1 had the shortest residence time and the lowest temperature, and Run #3 the highest residence time and the highest temperature.

The almost horizontal curve, the "Trip Blank Sample" with chemisorbed and adsorbed water, verifies handling procedures were successful in minimizing H_2 contamination of the test samples. The amount of moisture in the Trip Blank was 20 parts per million (ppm) H_2 averaged over a gas evolution time of 50 minutes, equivalent to 1.6 micro-g-moles of H_2 .

The residue was found to contain a few small particles of unreacted carbon mixed into the metal dross. To conservatively account for all of the residual hydrogen, one sample of each run was biased to contain all of the carbon particles. Run #1, Run #3, and Run #2 Replicate samples contained the carbon particles. Calculations conservatively assumed that these biased samples were representative of the entire residue. Run #2 Sample did not contain carbon particles biasing.

1.4 Control of Integrated Test

Gas measured during Run #3 showed H_2 production from the surrogate waste dropped from 15,000 ppm to 1000 ppm. Based on this information our process procedures provide an excellent opportunity for determining the appropriate end of each run. It is recommended that this sampling approach be used for the integrated test. In addition, the temperature conditions used in Run #2 are recommended for the Integrated Test.

2.0 PROOF-OF-PRINCIPLE TESTING AT BEAR CREEK

The POP Test was conducted in accordance with the *Trojan Proof of Principle Test Plan* (SEG/TRJ/R-001). This section discusses the overall test objectives and results, the residual hydrogen and gas sample results for each run, and provides comments on achieving the data quality objectives.

2.1 Test Objectives and Results

There were four objectives for the POP Test. Each of the objectives and comments achievement are listed below:

- 2.1.1 Prove that the steam reformer can reduce organic filters and dross to less than 0.050 gram-moles (g-moles) elemental hydrogen per process can.

Results: All three test runs successfully met established hydrogen limits therefore, the steam reformer can reduce organic filters and dross to less than 0.050 g-moles elemental hydrogen per process can.

- 2.1.2 Evaluate the effectiveness of the seal between the bottom of the process can and the inlet of the CFE.

Results: Throughout the testing, the flow rate of steam to the process can remained relatively steady. This indicates that the bottom process can seal successfully channeled the steam flow without excessive bypassing.

- 2.1.3 Determine if the filters in the process can are subject to plugging, evaluate the ability of flow sensors to detect process can filter plugging, and determine the ability to recover if filter plugging occurs.

Results: During each test, the flow rate of steam to the process can remained relatively constant, indicating that the process can filters were not subject to plugging. In all three runs, process can steam flow rates declined less than 7% over the first 12 hrs of processing. During Run #3, process can steam flow was reduced 33%, as the dross in the residue fused into a solid mass, partially blocking the process can bottom filter. An attempt to back flush resulted in an additional flow loss of 22%. Apparently, back flushing forces the waste against the process can bottom filter.

- 2.1.4 Determine the optimum process control limits for steam reformer operation to ensure each process batch meets the hydrogen specification:

- a. Determine the time, process temperature, and flow rate required to successfully reform a process can full of organic filters and dross.

Results: Using the times and temperatures in Runs #1, #2, and #3 and considering steam flow control problems, this tests objective could not be adequately determined. However, based on the data collected, the operating parameters in Run #2 will be used as a starting point for the Integrated Test.

- b. Determine the maximum steam flow rate through the process can that does not cause plugging of the upper filter.

Results: Process can steam flow rates reached a sustained maximum of 4.8 scfm with peaks as high as 5.4 scfm, no evidence of plugging of the upper filter occurred.

- c. Determine how the presence of carbon monoxide (CO) in the steam reformer vent relates to hydrogen concentration.

Results: The on-line gas analyzers were non-functional during most of the testing. Tedlar bag samples indicated CO below detectable levels. However, H₂ and carbon dioxide (CO₂) were directly correlated. Since oxygen (O₂) levels generally were above 6%, it is probable that the CO was converted to CO₂.

2.2 Run #1 Gas Analysis

Run #1 had the lowest temperature and the shortest processing time. The gas evolution was monitored carefully by gas chromatograph (GC) to detect any H₂ evolution as temperature increased. The resulting data suggest that the dips in O₂ correspond with the production of CO₂ and H₂, providing validation of the reaction mechanism. The increased temperature resulted in added H₂ production from the reduction of carbon.

2.3 Run #2 Gas Analysis

Run #2 was designed to be of moderate intensity in terms of temperature and processing time. The gas composition, analyzed by the GC, revealed additional H₂ evolution as the temperature increased. O₂ measured by the GC steadily dropped during the course of the run. CO₂ production resulted from the reaction of leaked oxygen with CO that was co-produced with the H₂ during steam-reforming. The data suggest that the dips in O₂ correspond with the production of CO₂ and H₂, again validating the reaction mechanism.

The higher temperature provided evidence that an increased temperature produced more H₂ and CO, even after steam-reforming of most organic hydrogen had been completed. At the higher temperature, the steam reacts with the remaining carbon char to form H₂ and CO.

The computed quantity of H₂ produced, was 2.5 g-moles H₂. This is an order of magnitude greater than the volume of H₂ generated from the waste, after the initial H₂ peak. Thus, the H₂ levels generated from the waste, capable of indicating process completion, could not be detected.

2.4 Run #3 Gas Analysis

Run #3 was designed to be of maximum intensity in terms of temperature and processing time. Because of the high temperatures used in this run, the metal dross in the surrogate waste fused together, creating a solid mass. This blockage inhibited steam movement and reaction with the organics. As a result, the reaction rates were much slower than Run #1 or #2. Also the H₂ peaked at a lower level as compared with the peak in Run #2, indicating lower rate.

The curves of O₂, H₂, and CO₂ sampled correlate well for the last 30 hours of the run, suggesting that the steam-carbon reaction was producing H₂ from the steam supply. At the end of the run when the steam flow was stopped and the cooling was initiated, additional gas samples were taken to check for additional H₂ evolution, none was detected.

2.5 Data Quality Objectives

The data quality objectives, as listed in the Test Plan (SEG/TRJ/R-001), are provided below with comments on the success achieved during testing:

- 2.5.1 Measure the weight of the process can upper filter assembly before and after processing to determine how much, if any, of the residue has been captured in the filter.

Results: The mass of residue captured in the filter varied between <1 grams (g) and 7 g.

- 2.5.2 Measure the weight of the surrogate waste filters, sufficient filter material should be selected and used to obtain a weight of 0.96 kilograms (kg) \pm 57 g.

Results: For each run, seven filters were used as surrogate waste, filling the process can to capacity. The total mass of the filters in each run ranged between 1007.6 and 1010.6 g.

- 2.5.3 Measure the weight of the surrogate waste dross load, sufficient dross will be used to obtain a weight of 3.71 kg \pm 85 g.

Results: Actual surrogate dross load in each run ranged between 3.635 and 3.704 kg.

- 2.5.4 The weight of the residue remaining after each test run is anticipated to consist of the dross, plus a few ounces of processed filter residue.

Results: Actual residue weights ranged between 3.685 and 3.778 kg.

- 2.5.5 Steam temperature entering the lower inlet of the process can should meet previously determined specifications.

Results: Throughout Runs #1, #2, and the first 29 hours of Run #3, steam temperatures were not able to reach specified criteria. Lack of sufficient heat tracing, two orifices in series, and two piping transitions caused excessive heat loss. As steam flow into the process can slowed the temperature decreased. This was especially evident during the latter stages of Run #3.

- 2.5.6 Steam temperature in the CFE chamber should reach previously determined specifications.

Results: The highest steam chamber temperature achieved during Run #1, Run #2, Run #3 was not able to reach specified limits. Additional insulation was added to the can feed evaporator prior to Run #2, and hot syn-gas was introduced into the drum feed evaporator (DFE) during Run #3 to apply additional heat to the can feed evaporator. Each modification increased the steam chamber temperature.

- 2.5.7 Syn-gas temperature, exiting the process can, should reach previously determined specifications.

Results: Due to excessive heat loss and improper placement of the thermocouple, exit temperatures were not able to reach specified limits.

- 2.5.8 Steam pressure entering the bottom of the process can should meet previous specified criteria during operation.

Results: Steam pressure entering the process can exceeded planned values; pressure in the CFE was raised above atmosphere pressure in an effort to minimize oxygen leakage into DFE.

- 2.5.9 Steam pressure in the CFE chamber should be maintained within previously specified limits when steam is applied, and must remain negative at all times during processing.

Results: Pressure in the steam chamber exceeded specified pressure, dependent on flow rate and downstream pressures. A one inch restriction in the piping plus several tight radius elbows, between the detector and the steam chamber, caused a significant pressure change. In addition, the CFE was operated at a slight positive pressures to reduce oxygen leakage into the DFE.

- 2.5.10 Exit chamber pressure in the CFE should range between -7 and -12 inches water column (in. w.c.), and must remain negative during processing.

Results: Because of excessive oxygen leakage into the CFE, when attempting to operate the system at a negative pressure, the system ran at a positive pressure most of the time. When leakage was minimized, it was possible to obtain a negative pressure.

- 2.5.11 Steam flow rate entering the bottom of the process can should range between previously specified limits. Steam flow less than the specified limits indicates a plugged process can upper filter.

Results: During Run #1 process can steam flow slightly exceeded specified limits. Although 7 g of residue were imbedded in the process can upper filter after the run, flow was not restricted. During Run #2 process can steam flow was just above specified limits, with less than 1 g of residue imbedded in the process can upper filter after the run. During Run #3 process can steam flow was above specified limits, with less than 1 g of residue imbedded in the process can upper filter after the run. These results indicate that the upper filter is not plugging even after extended operation. Reduced flow in Run #3 was presumed to be caused by blockage of the bottom filter.

- 2.5.12 Temperature of the superheater outlet should be within specified limits.

Results: With preheated steam entering the superheater, temperatures exceeding specified limits were achieved at the outlet. The superheater was operated at an increased temperature to make up for excessive heat loss in the down stream piping.

- 2.5.13 Steam pressure at the superheater outlet should be within specified limits.

Results: During Runs #1 and #2, superheater outlet pressure, was maintained within specified limits. In order to achieve higher processing temperatures during Run #3, steam flow was increased by raising superheater outlet pressure above specified limits.

- 2.5.14 CO should range from zero at the start of processing to a peak value during processing, and back to zero at the end of processing. The curve should correlate with the measured H₂ curve.

Results: During the POP Test, the gas analyzers system was not functional, preventing CO readings. The gas chromatograph analysis measured CO below minimum detection levels (MDL) throughout testing. Excessive oxygen present in the DFE converted CO to CO₂, which correlated with the H₂ content.

- 2.5.15 O₂ at the SSR vent should be within a specified range, and should always remain below the upper limit of the range.

Results: Tedlar bag samples from the CFE outlet were measured above the specified range. The DFE had excessive oxygen leaks.

- 2.5.16 Syn-gas, sampled at the CFE outlet, will be analyzed for H_2 , CO, CO_2 by GC. Concentrations should range from zero at the start of processing to a peak value and back to zero at the end of processing in parallel curves. H_2 should have the largest peak value with CO and CO_2 peak values below that of H_2 .

Results: The Tedlar bag sampling results did not indicate peak and tailing off curves as expected. Most likely the peak occurred early in the processing and passed too rapidly to be sampled. The Integrated Tests will include additional sampling to determine the best way to sample and measure gas levels.

- 2.5.17 Syn-gas analysis for O_2 sampled at DFE outlet should be within specified limits.

Results: DFE outlet samples for O_2 were measured in excess of the specified limits. Filter inlet samples indicated O_2 levels within specified limits due to the dilution caused by the carrier gas.

- 2.5.18 Residual elemental hydrogen in process can residue must be <0.05 g-mole or <0.05 g total hydrogen content.

Results: Residual hydrogen content analysis results for all three runs met the criteria.

Run 1	0.0376 g-moles H
Run 2	0.0121 g-moles H
Run 2	0.0267 g-moles H (replicate sample)
Run 3	0.0237 g-moles H

3.0 RESIDUE TESTING AT A COMMERCIAL ANALYTICAL LABORATORY

Residue testing at the lab involved three test runs plus several blank and duplicate tests for quality assurance. The following sections describe each of the runs and results. More detailed descriptions are provided in the labs *Final Work Plan and Quality Assurance Project Plan*.

3.1 Analytical Apparatus

The analytical H_2 apparatus was contained inside an inerted glove box. The sample handling and treatment was established in SEG/TRJ/R-002.

3.2 Calibration H_2

A five point calibration of the apparatus was performed in accordance with the *Final Work Plan and Quality Assurance Plan*. Just prior to and following every run, a single point verification was performed.

3.3 Sample Blank

Just prior to processing the sample blank a background curve was obtained for H_2 . The data scatter was less than ± 1.5 ppm.

The background curve for H_2 provides the best estimate of the background that must be subtracted from each sample. The experimental uncertainty in establishing this curve was estimated as ± 0.014 millimoles H_1 with a 90% certainty.

The background curve should be subtracted from the H_2 profile for each residue sample. Thus, a more conservative approach was adopted resulting in the highest possible H_2 content being used.

3.4 Trip Blank

At the lab, the trip blank was loaded into the H_2 apparatus. Just before the sample processing began, a background curve was obtained for H_2 . A decay rate and data scatter of ± 1.5 ppm was observed.

Once the background curve was determined the H_2 apparatus was opened and the sample inserted. As the trip blank processed, the H_2O , H_2 , and other gas evolutions increased. The tail end of the curve leveled out 20% higher than the original background, indicating a background shift.

The gas sample bag, collecting gases produced from the analytical H_2 apparatus, was thoroughly mixed, and the contents sampled every 15 minute to determine an average H_2 concentration. Using these values the H_2 concentration was determined to be 0.0099 g-mole H_1 in the trip blank.

3.5 Hydrogen Quantitation Via Spiked Sample

This section verifies the H_2 apparatus can quantitatively simulate the total hydrogen production expected from the long-term radiolysis in the repository.

A spike, was selected to simulate the residue remaining after steam-reforming based on it's availability as a certified analytical reagent, known hydrogen content, and the material similarity to partially steam-reformed substances. The quantity used was calculated so the H_2 evolved would be at the critical level of 0.05 g-moles H_1 .

The concentration of H_2 generated from the first run of the spike was measured at 510 ppm, with a background level of 150 ppm, 72% of the hydrogen in the spike was recovered.

The concentration of H_2 generated from the duplicate run of the spike was measured at 654 ppm, 146% of the hydrogen in the spike was recovered (without moisture correction) and 107% after moisture correction, with no blank/trip correction.

For both runs the curve for H_2 evolution was comparable to the actual residue sample; thus, it is concluded that the spike is a good surrogate for validating and quantifying H_2 recovery.

3.6 Hydrogen Quantitation Via Matrix Spike

The matrix spike run was performed to ensure that the presence of waste matrix did not adversely affect the H_2 recovery. The method involved placing a spike under a sample of actual residue from Run #2, so the gases evolved from the spike had to diffuse through the residue. If there were any diffusion, hydrate formation, or readsorption this test would identify them.

The results for the spike in the matrix compares almost exactly to the spike alone. The matrix spike curve should have been the sum of the spike samples and the Run #2 sample. The actual recovery was only 74.6% of the expected results.

The 72% recovery of the blank spike and the 74.6% recovery of the matrix spike indicate that measured H_1 values should be corrected for a 28% loss rate.

3.7 Run #1 Residue Sample

Approximately 16 grams of residue was taken from vial #1 from. After 300 min, the H_2 level was at a relatively steady value of 228 ppm, the run was stopped. The gas sample bag measured 389 ppm, subtracting the background 91 ppm, the result is 298 ppm, or 0.0376 g-mole H_1 . In addition, the correction factor of 0.0099 g-moles H_1 for sample handling should be subtracted.

3.8 Run #2 Residue Sample

Approximately 16 grams of residue was taken from vial #2 from Run #2. After 193 min, the H_2 level was below the background and the run stopped. The gas sample bag measured 334 ppm, subtracting the background of 160 ppm, the result is 174 ppm, or 0.0121 g-mole H_1 . As determined in Section 3.4, the correction value for sample handling is 0.0099 g-moles H_1 .

3.9 Run #2 Residue Replicate Sample

The residue was taken from vial #1 from Run #2, approximately 15g was analyzed. After 216 min the H_2 level was changing at a rate of <0.2 ppm per minute and the run was stopped. The gas sample bag measured 388 ppm. Subtracting the background at an average value of 67 ppm, the results were 321 ppm, or 0.0267 g-mole H_1 . As determined in Section 3.4, the correction value for sample handling is 0.0099 g-moles H_1 . The results of the Run #2 Sample and the Run #2 replicate showed reasonably good repeatability. The replicate run was biasly sampled to contain more organic char, and therefore, produced a higher H_2 content.

3.10 Run #3 Residue Sample

The residue was taken from vial #1 from Run #3, approximately 13g was analyzed. After 521 min, the H_2 level was at 161.5 ppm, and changing about 0.2 ppm/min so the run was stopped. The gas sample bag measured 294.1 ppm. Subtracting the background at an average value of 131 ppm, the results were 163.1 ppm, or 0.0237 g-mole H_1 . As determined in Section 3.4, the correction value for sample handling is 0.0099 g-moles H_1 .

3.11 Residue Hydrogen Content Computation

The H_2 concentration remaining in the residue after the waste sample was steam-reformed was calculated from the mass of the residue taken out of the process can, the measured H_2 level collected in the gas bag, the volume of gas mixture in the gas bag, the density of the gas in the sample bag, the mass of the residue sample placed into the H_2 apparatus, and the molecular weight of atomic hydrogen, H_1 . The equation used for calculation purposes is as follows:

$$\text{g-moles } H_1 \text{ in residue} = \frac{2 \cdot (\text{g residue}_{\text{cfe}}) \cdot (H_2 \text{ in bag, ppm} - L_{H_2}/L_{\text{bag}}) \cdot (\text{Bag Vol. } L_{\text{bag}}) \cdot (\rho \cdot g_{H_2}/L_{H_2})}{1 \times 10^6 \cdot (2.01594 \text{ g}_{H_2}/\text{g-mole } H_2) \cdot (\text{g sample})}$$

where: L = liters of gas, and

ρ = gas density calculated by: $\rho = P \cdot Mw/R \cdot T$ (typically around $0.083 \text{ g}_{H_2}/L_{H_2}$)

where: P = 1 atmosphere (with small correction for 1100 ft altitude)

Mw = molecular weight of H_2 = 2.01594

R = Universal Gas Constant = $0.08205 \text{ L} \cdot \text{atmos}/\text{g-mole} \cdot ^\circ\text{K}$

T = Gas Bag Absolute Temperature $^\circ\text{K}$. (approximately 294.82°K)

NOTE: Normally g-moles of hydrogen are reported in g-moles H_2 ; however, NRC requires that it be reported in g-moles H_1 . Accordingly, there are two g-moles of H_1 in one g-mole of H_2 .

$$\text{g-moles } H_1 = 2 \text{ g-moles } H_2.$$

A summary of the calculated elemental hydrogen, H_1 , results for each run is presented in Table 1.

TABLE 1 RESIDUE HYDROGEN, H_1 , CONTENT					
RUN #	Sample Mass (g)	Residue stuck in CFE (% estimate)	Residue in CFE (g)	Uncorrected H_1 Content (g-moles)	Corrected H_1 Content (g-moles)
1	3680.85	0.10	3684.53	0.0376	0.0382
2	3703.14	1.00	3740.17	0.0121	0.0056
2 rep.	3703.14	1.00	3740.17	0.0267	0.0243
3	3565.19	5.96	3777.68	0.0237	0.0204
trip blank	6.821	--	---	0.0099*	---
Spike correction				+28%	---

* This content was calculated from the measured content of 0.84 g-moles H_2 then normalized to a typical total residue sample size of 3600 g.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This section analyzes the Bear Creek "Proof-of-Principle" test runs as well as the residue hydrogen content determinations and makes suggestions for improving the performance of the integrated test.

4.1 Operational and Design Recommendations

Throughout all test runs, the process can upper filter assembly showed no signs of plugging. One attempt at back flushing during Run #3 actually reduced flow by compacting the metal dross against the lower filter. Therefore, the design of the Trojan CFE was simplified by removing the back flush piping and valves.

The process can/CFE bottom seal performed adequately ensuring that steam flow directed to the process can interior did not bypass around the process can through the steam chamber. The design of the CFE and associated piping and access gates has been reviewed to minimize oxygen leaks. To provide a more direct reading of hydrogen content in the syn-gas, a hydrogen gas analyzer has replaced the CO_2 analyzer.

Difficulties in obtaining expected operating temperatures and pressures during the POP Test dictated that the Trojan CFE be designed with shorter pipe runs and fewer restrictions to minimize pressure loss and a maximum of insulation and heat tracing to minimize heat loss. Plans have been made to install the steam superheater directly on

the outside of the CFE shielding and to add heat tracing to the CFE shell. In addition, the CFE exit thermocouple will be moved to a higher location.

4.2 Residual Hydrogen and End of Run Determinations

The test results are best summarized by concluding that Run #1 was barely long enough in residence time and high enough in temperature to reach the required H₂ content with an adequate margin of safety. Run #2 was acceptable in temperature, but probably could have been shorter, since the H₂ production from the steam-carbon reaction confused the end-of-run criterion. Run #3 was too hot and too long, causing the stainless steel cross filings in the surrogate waste to fuse together, slowing the reaction and blocking flow.

Gas samples measured during the end portion of Run #3 showed no detectable H₂.

H₂ production from the surrogate waste could have been monitored during processing.

5.0 ACRONYMS

CFE	Can Feed Evaporator
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
DFE	drum feed evaporator
g	gram(s)
g-mole	gram mole
GC	gas chromatograph
H ₂	Hydrogen in its normal state
in. w.c.	inches water column
kg	kilogram(s)
MDL	minimum detection level
O ₂	Oxygen
ppm	parts per million
POP	Proof-of-Principle
vol %	volume percent
WPPSS	Washington Public Power Supply System

6.0 REFERENCES

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- 6.3 SEG Procedure *Trojan Proof of Principle Test Procedure*, SEG/TRJ/PRO-005, Rev 1, Sep X, 1996.
- 6.4 SEG Procedure *Residue Hydrogen Analysis Protocol*, SEG/TRJ/PRO-006, Rev 0, Sep 3, 1996.

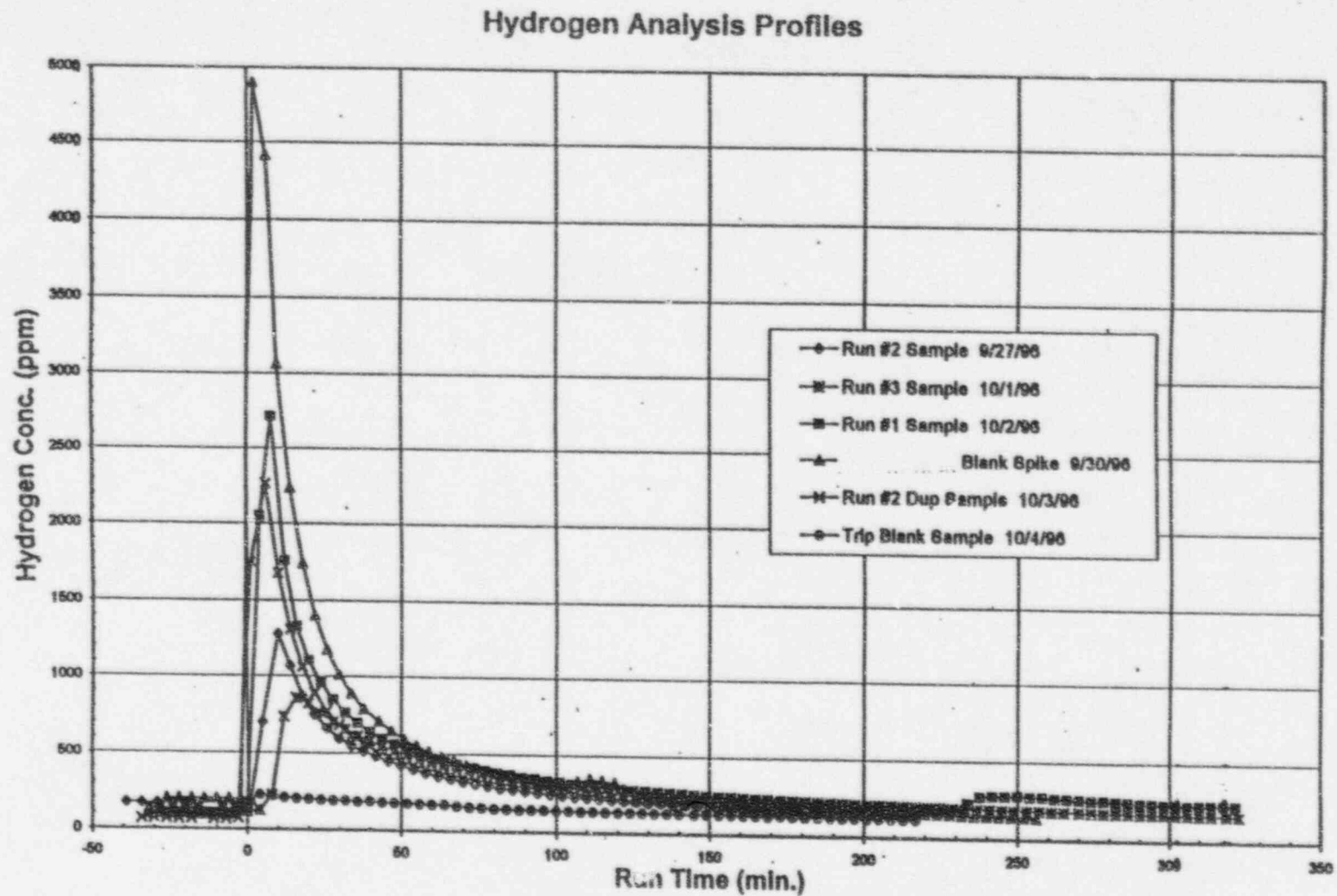


FIGURE 1: TEST RESULTS