HEBER
GEOTHERMAL COUPON
ANALYTICAL REPORT

Contract No: DE-AC03-85SF15490

DCN: 86-212-044-04

Date Received: 9 July 1986

Report Date: 20 October 1986

Lot No.: 2

Analyst: Peter F. Ellis II

Coupons Received

DOE/SF/15490--T1

DE89 009101

Coupon No.	88	104	65	86
Alloy	A53B	A53B	1018	1018
Station	6.2	E-01A Outlet	6.2	E-01A Outlet
Environment				
- brine	X	X	X	X
- hydrocarbon				
- cooling water				
Date Installed	3/5/86	3/5/86	3/5/86	3/5/86
Date Removed	5/20/86	7/1/86	5/20/86	7/1/86
Days Exposure				
- Total	76	118	76	118
- Bring flow	76	118	76	118
- Stagnant Brine	0	0	0	0
- N ₂ Blanket	0	0	0	0
Max. Temp (°F)	150	150	150	150
Min. Temp (°F)	150	150	150	150
Avg. Temp. (°F)	150	150	150	150
Station Opened to Atm	No	No	No	No
Wt-loss Corrosion of Companion Coupons (mpy)	*	*	*	*

REPRODUCED FROM BEST
AVAILABLE COPY

MASTER

*Wt-loss corrosion measurements are not significant when conspicuous amounts of localized corrosion have occurred.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

RESULTS

OBJECTIVES

1. To determine the cause of accelerated metal loss from the loading edges (as relates to brine flow) of carbon steel coupons in the low temperature portion of the Heber brine loop.
2. To clarify the reason for the distinctly different morphology of attack on the A53B pipe steel compared to the sheet 1018 steel.

FINDINGS

As-received

Four coupons, two of 1018 carbon steel and two of A53B carbon steel were received by Radian. These coupons are shown as received in Figures 1 and 2, respectively.

The difference in the morphology of attack on the two alloys is evident from these figures. The attack on the 1018 steel extended a considerable distance around the circumference to each side of the leading (most upstream) point on the coupons. The attack had the appearance of multiple "nibbles" on the edge of a cookie. The attack on the A53B coupons took the form of a single deep "bite".

Imaging

Stereomicroscopic examination of the as received coupons verified that the morphology of attack on the two 1018 coupons was quite similar, as was the attack on the two A53B coupons. Coupon 65 (1018 steel) and coupon 88 (A53B steel) were then subjected to detailed analysis.

These two coupons were cleared of all deposits by ultrasonic means coupled with a strongly inhibited acid solution which Radian has determined to be suitable for fractographic preparation. The two coupons were then examined by scanning electron microscope (SEM).

Figure 3 compares the "eroded" edges of the two coupons at low magnification, while Figure 4 provides more detail of the surface of the 1018 coupon. This surface shows a "horseshoe" pattern of metal loss indicative of erosion corrosion, while the small-scale morphology clearly indicates that electrochemical (corrosive) effects predominated. The indicated directions of fluid flow in this figure are based on the position of the area imaged relative to the center of the eroded zones.

The imaging of the A53B coupon was more complex. Visible in Figure 3 are fine parallel ridges which run parallel to the flat face of the coupon outside of the eroded "bite". The scale of these features is much too large to be microstructural in origin, and Radian surmises that these ridges are artifacts from the machining of the A53B coupon from pipe stock.

These machining marks extend across the floor of the eroded bite as is visible in Figure 3, and in more detail in Figure 5. The preservation of these machining marks across the eroded zone indicates that corrosive, rather than abrasive, processes predominated the metal loss.

However, some evidence of abrasive damage, most likely from impingement of fine sand particles, was found. Figure 6 shows a high magnification image from the eroded zone of coupon 88. The large arrow indicates a micro-scratch or gouge which has sliced through carbide structures. This is interpreted as an impingement track by a fine hard particle. Etch pits, typical of erosion corrosion, are also evident in this figure.

Microstructure and Hardness

Figure 7 shows the microstructure of coupon 65 (1018 steel). The microstructure consists of spheroidized carbides in a ferrite matrix. The

typical microstructure of 1018 steel is pearlite in a ferrite matrix. However, a spherodized microstructure is intentional in some instances where deep drawing or heavy cold work is to be done. This may have been the case of for the 1018 coupons, which were stamped from 0.125 inch sheet.

Figure 8 shows the microstructure of coupon 88 which was reportedly manufactured from A53B grade pipe stock. The microstructure consists of tempered bainite in a ferrite matrix. This microstructure is consistent with the heat treatments required by the A53B specification.

Multiple Vickers diamond pyramid microhardness measurements were made on the two coupon materials. Such measurements are not very reliable on spherodized microstructures and there was considerable variation in the values obtained from the 1018 material. It is probable that the mean hardness thus obtained for the 1018 is higher than would have been determined if a macrohardness test had been possible. Even with the probable over estimate of the 1018 and hardness, the A53B steel was still on the order of 10 Rockwell E units harder than the 1018 steel. This hardness difference is consistent with the microstructures of the two alloys.

CONCLUSIONS

- It is concluded that the leading edge attack on both the 1018 carbon steel and the A53B carbon steel resulted from erosion corrosion with electrochemical metal dissolution, rather than abrasion, predominating. This means that the accelerated attack results primarily from increased mass transport of corrosive species and corrosion products to and from the metal surface at the coupon leading edge where a sudden acceleration of the brined occurs.
- Some evidence of abrasion, probably by entrained fine sand particles, was found. This appears to have been a minor contributor to the erosion corrosion process.

- The difference in morphology between the attack on the 1018 and A53B steels can be explained by the microstructural and hardness differences between these alloys.
- The flow conditions around the coupons are much different and more severe than along the pipe walls. On the basis of this examination Radian can not determine whether the results from these coupons indicate a significant erosion corrosion problem for the brine piping. However, it appears likely that corrosion rates calculated from these coupons are misleadingly high.

RECOMMENDATIONS

- Radian recommends that the brine production and return lines be opened for inspection during the next major inspection outage if this can be arranged.
- Some method of protecting the assemblies of coupons from direct impingement of brine should be considered. One option would be partial insertion of the sample holder so that the distal end of the coupon mounting rod is "flush" with the pipe wall.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Figure 1. Coupons 65 from station 6.2 (Top) and 86 from the E-01A outlet (Bottom) as received. The fairly widespread "nibbling" of the leading (upstream) edges of these 1018 steel coupons is evident.

Figure 2. Coupons 88 from station 6.2 (Top) and 104 from the E-01A outlet (Bottom) as received. The characteristic "single bite" on the leading edges of these A53B steel coupons is distinctive.

Mag: 100X
Etchant: Nital

Mag: 800X
Etchant: Nital

Figure 7. Typical microstructure of coupon 65 (1018), consisting of spheroidized carbides in a ferrite matrix.

Mag: 100X
Etchant: Nital

Mag: 800X
Etchant: Nital

Figure 8. Typical microstructure of coupon 88 (A53B), consisting of tempered bainite in a ferrite matrix.

PART I - THE SCHEDULE

SECTION C - DESCRIPTION/SPECIFICATIONS/STATEMENT OF WORK

STATEMENT OF WORK

The contractor shall provide the necessary personnel, facilities, equipment, materials, supplies, and documentation to perform the following tasks:

1. Familiarization with the operation, maintenance and material corrosion monitoring plans and procedures of the Heber plant.

Includes the physical layout of the plant, plant operation, and the existing corrosion monitoring features incorporated into the plant. Includes coordination with SDG&E and Battelle, Pacific Northwest Laboratory. Includes the preparation of procedures to be followed for conducting the analysis.

2. Analysis of material coupons for indication of problems.

Contractor shall conduct analysis of a total of approximately 50 coupons divided into separate groupings of between 5 to 15 coupons each, as determined by SDG&E. SDG&E will determine and report the weight loss of each coupon. Additional coupons, beyond the 50, may be included for analysis as an extra cost option. The objective of the analysis is to determine,

- a. Probable reason for unexpected rate of degradation.
- b. Recommendation for altering existing operation, maintenance, repair or replacement procedures, and changes in the materials used in the plant, if appropriate.

3. Analysis of failed or rapidly deteriorating components on an as required basis.
4. Prepare a letter type report on each set of material coupons analyzed and all other investigations.
5. Prepare a final report that summarizes the findings and conclusions of the material analysis contract.

Reporting Requirements

The type, frequency, and distribution of all reports are as outlined in the Reporting Requirements Checklist.

Figure 5. Scanning electron micrograph of the floor of the "single bite" zone of coupon 88 (A53B). The parallel situations are continuations of fine machining marks evident on the unattacked edges of the coupon. The perpetuation of these situations in the eroded zone indicate that electrochemical dissolution, rather than abrasion, is the primary metal removal mechanism (Mag: 100X).

Figure 6. High magnification (3500X) scanning electron micrograph of the eroded surface of coupon 88 (A53B). The large arrow indicates a micro-scratch or gouge which slices through carbide structures. The small pointers highlight carbide structures which were sliced apart by the impinging particle.

Figure 3. Scanning electron micrograph comparing the eroded edges of coupon 65 (1018) above and 88 (A53B) below. The white arrows indicate the direction of circumferential brine flow at the imaged locations. The dotted lines indicate the bounds of the "single bite" on the edge of the A53B coupon (Mag: 15X).

Figure 4. Scanning electron micrograph of the eroded edge of coupon 65 (1018), displaying the "horseshoe" pattern typical of erosion corrosion as well as strong evidence of generalized electrochemical attack (Mag: 100X).