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# Characterization of Corrosion Probe Coupons Exposed in Tank 241-AN-107

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

**CH2MHILL**
*Hanford Group, Inc.*
**Richland, Washington**

Contractor for the U.S. Department of Energy
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# CHARACTERIZATION OF CORROSION PROBE COUPONS EXPOSED IN TANK 241-AN-107

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## ABSTRACT

C-Ring and Pin electrodes from Corrosion Probe retrieved from Tank 241-AN-107 were examined visually and by weight loss measurements. The weight loss measurements were carried out according to ASTM(1) Method G-1 90. Corrosion rates estimated from the weight loss measurements indicated extremely limited corrosion with no visually observable pitting or cracking. The extremely low corrosion rates are in agreement with the results of ultrasonic examination of the primary tank wall.

Keywords: corrosion probe coupons, tank 241-AN-107, steel, weight loss, corrosion rate, pitting, cracking

## INTRODUCTION

Hanford Site in South Eastern Washington State has a series of single-shell and double-shell tanks (DSTs) storing nuclear waste. A fully operational eight-channel electrochemical noise corrosion (EN) probe was installed in DST 241-AN-107 on September 24, 1997. The EN probe system was designed to detect the onset of localized corrosion phenomena if tank conditions should change to allow these phenomena to occur. The system was also intended to monitor the effectiveness of upcoming sodium hydroxide corrosion inhibitor additions. However, the probe never provided realistic data due to interference and noise picked up by the probe leads, which could not be completely corrected. After approximately 4 years of exposure to waste in tank 241-AN-107, the EN probe was replaced by a new, more improved, EN probe system on August 9, 2001. Waste in tank 241-AN-107 had been out of compliance with the DST waste specifications[1] for several years and corrosion inhibiting hydroxide additions were planned for the tank to bring the waste into compliance with the waste specifications. In spite of the non-compliance of the waste with the waste specifications, ultrasonic (UT) examination conducted on the tank in 1998 revealed no significant corrosion of the tank wall. Based on the foregoing, it was determined to analyze the coupons from the corrosion probe retrieved from tank 241-AN-107 by weight loss and visual examinations to assess the corrosion status of the tank wall. In addition, another objective of this analysis is to compare these results with the UT examination results, which indicated insignificant corrosion.

## CONFIGURATION OF CORROSION PROBE ASSEMBLY

The corrosion probe had four two-channel electrode arrays. Arrays were positioned at 6.0 m, 10.3 m, 12.8 m, and 15.5 m from the top of the riser. The eight total channels allowed corrosion monitoring in the vapor space, supernatant and the sludge phase of the tank. The top array of electrodes (Detector 1) was located in the vapor space, while the array

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(1) American Society for Testing and Materials Standard G-190

immediately below (Detector 2) was situated just above the waste surface in the vapor space. The third array of electrodes (Detector 3) was in the supernatant region, while the bottom array (Detector 4) was in the sludge region. Each channel on the probe utilized three nominally identical electrodes of either a C-Ring (ASTM G-38) or pin type geometry constructed of archived ASTM A537-Class 1 tank steel (leftover from the 241-AP farm construction). The surface areas of each C-Ring electrode and each Pin type electrode exposed to the waste were approximately 45 $cm^2$ and 5 $cm^2$ respectively[2]. One electrode of each C-Ring array was pre-cracked by cyclic fatigue and strained beyond the proportional limit just prior to immersion in the waste to assist in monitoring stress corrosion cracking (SCC) should it occur. Pre-cracks were approximately 0.5 mm in depth. The other electrodes were not strained. In addition to the corrosion monitoring electrodes employed by the EN system, each electrode array also contained three long-term exposure coupons (5 $cm^2$ archived ASTM A537-Class 1 pins) not connected to the EN equipment. The Detector configuration is shown in Figure 1.

## WEIGHT LOSS DATA AND VISUAL EXAMINATION

Weight loss and visual examination evaluations were performed at the 222-S laboratory. For details on these evaluations, the reader is referred to Duncan and Anantatmula (2001). The evaluations were performed only on one C-Ring and one Pin from Detector 1 (Top level), two C-Rings and one Pin from Detector 2 (Second level), one C-Ring and one Pin from Detector 3 (Third level) and two C-Rings and one Pin from Detector 4 (Fourth level). The weight loss evaluation was performed after digestion with dibasic ammonium citrate using ASTM standard method G1-90[3]. The coupons were cleaned (soaked) in the dibasic ammonium citrate solution and were weighed after each 10-minute soak. The weight data were plotted against soak number to determine the inflection point that indicates the corrosion product removal per the ASTM standard method G1-90[3]. The evaluation by Reference 1 only addressed weight losses. An attempt is made in this paper to calculate conservative general corrosion rates based on the weight measurements after each soak and the weight loss vs. soak number plots.

The weight loss vs. soak number plots for the coupons from Duncan and Anantatmula (2001) are reproduced as cumulative weight loss vs. soak time plots in Figures 2-11 per the ASTM standard method G1-90. It should be noted that these plots are based on pre-soak weight as the starting weight. The corrosion rates in mils per year (mpy) were calculated using the following formula[4]:

$$\text{Corrosion Rate} = (3.45 \times 10^6 \times W) / (A \times T \times D)$$

where W = Weight loss in grams, A = Exposed surface area in $cm^2$ (45 for C-Ring and 5 for Pin) T = Exposure time in hours (33,960) and D = Density in grams/ $cm^3$ (7.86 for carbon steel).

Table 1 gives the initial, pre-soak and final weights of the coupons, and general corrosion rates. The ASTM method works very well with metals that experience moderate to high corrosion rates. Because of the extremely low weight losses experienced by the corrosion probe coupons submerged in the waste, it was difficult to clearly identify the inflection point that separates the corrosion product removal and base metal removal. A small amount of error was introduced in the weight measurement for the control coupons by retention of moisture in the threaded hole due to the wicking action. However, this problem was corrected for all the weight loss coupons. Therefore, the inflection points were picked conservatively in most cases from figures 2-11 in order to arrive at conservative general corrosion rates. The soak number at which the inflection point was picked and final weight obtained is indicated in the table for each coupon.

The weight loss and corrosion rate for each coupon were estimated from the initial (not pre-soak) and final weights. The initial weight (weight prior to installation in tank 241-AN-107) for all coupons was more than the presoak weight (weight after removal from the tank and before soaking in the dibasic ammonium citrate solution). It also became apparent from the data that the difference between the initial weight and presoak weight was more than the weight loss measured after each soak time for all the coupons. This suggests that some or all of the loose corrosion product might have been washed away by the fairly thorough rinsing of the coupons inside the tank by warm water prior to retrieval from the tank.

Based on the data in Table 1 and results of the visual examination, the corrosion probe coupons, in general, showed extremely limited amount of corrosion after approximately 4 years of exposure in the tank, with maximum corrosion seen in coupons exposed to the vapor space. Localized small rusty regions were visible[2] on the vapor space coupons with probable shallow pitting, although no pits were visible to the naked eye. The extent of corrosion on coupons submerged in the waste appeared extremely limited with no localized areas of rusting and no observable pitting or stress corrosion cracking (SCC). No cracking was noted visually on the pre-stressed and pre-cracked C-Ring coupons (coupons B and H). Optical metallography of these C-Ring specimens and the coupons exposed to the vapor space confirmed the absence of pitting and SCC.

## ASSESSMENT OF TANK WALL CORROSION

The tank wall was fabricated from low carbon steel ASTM A537, Class 1. The corrosion probe coupons installed in the tank were fabricated from the same steel left over from the construction of the AP Farm tanks (ASTM G-38) or low carbon steel with similar composition and mechanical properties. Therefore, the corrosion behavior of the tank wall is expected to be similar to that of the corrosion probe coupons. On this basis, the tank wall contacting the waste is expected to be corroding at a very low general corrosion rate with no observable pitting or SCC similar to the corrosion probe coupons. This is also supported by the results of the 1998 UT examination, which indicated little or no general corrosion of the tank wall exposed to the waste with no pitting or cracking. The present results also indicate that the steel corrosion rates in the vapor space are higher than in the waste. According to recent evaluation[5], the ventilation rates in the primary tank dome space for the AN Farm are lower than in other Tank Farms leading to higher probability for condensation of moisture in the dome space. Localized corrosion in the form of pitting could become the prime contributor that could lead to earlier failure in this region of the tank unless the ventilation rates are increased to prevent condensation. Furthermore, corrosion rates for the tank wall could be higher in the vapor space compared to the corrosion probe coupons because a larger quantity of moisture is expected to condense on the tank wall due to exposure to cold air in the annulus during the winter season.

## CONCLUSIONS

The results of the tank 241-AN-107 corrosion probe coupon analysis indicated very low general corrosion rates with no observable pitting or SCC for coupons immersed in the waste. The corrosion rates for the coupons in the waste appear to decrease with increasing depth in the waste. These results are supported by the results of the 1998 UT examination, which indicated little or no general corrosion of the tank wall exposed to the waste with no pitting or cracking. Maximum corrosion rates (although fairly low) were seen in the vapor space due to higher availability of oxygen combined with the presence of high humidity.

## REFERENCES


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2. J. B. Duncan, R. P. Anantatmula, RPP-8920, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, 2001.

3. ASTM, "Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens", Designation: G 1 – 90 (Re-approved 1999), American Society for Testing and Materials, 2000.

4. Metals Handbook, Ninth Edition, Corrosion, Volume 13, ASM International, Metals Park, Ohio, 1987.

5. D. M. Ogden, M. J. Thurgood, R. P. Anantatmula, G. P. Duncan, D. H. Shuford, RPP-12422, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington, 2003.

TABLE 1
WEIGHT LOSS AND CORROSION RATE ESTIMATES*

| Coupon Type (Detector #) | Tank Location | Initial Weight (grams) | Pre-soak Weight (grams) | Final Weight (grams) | Weight Loss (grams) | Corrosion Rate (mpy) |
|---|---|---|---|---|---|---|
| C-Ring X (Detector 1) | Vapor Space | 74.3170 | 74.3058 | 73.9995 (Wt. After soak 1) | 0.3175 | 0.091 |
| Pin Y (Detector 1) | Vapor Space | 4.9734 | 4.9327 | 4.9022 (Wt. After soak 2) | 0.0712 | 0.184 |
| C-Ring R (Detector 2) | Vapor Space | 72.9774 | 72.9451 | 72.8825 (Wt. After soak 2) | 0.0949 | 0.027 |
| C-Ring N (Detector 2) | Vapor Space | 74.3109 | 74.2255 | 74.1880 (Wt. After soak 1) | 0.1229 | 0.035 |
| Pin T1 (Detector 2) | Vapor Space | 5.1834 | 5.1767 | 5.1517 (Wt. After soak 2) | 0.0317 | 0.082 |
| C-Ring H (Detector 3) | Supernatant | 71.9258 | 71.9047 | 71.8361 (Wt. After soak 2) | 0.0897 | 0.026 |
| Pin M1 (Detector 3) | Supernatant | 5.2468 | 5.2402 | 5.2349 (Wt. After soak 1) | 0.0119 | 0.031 |
| C-Ring B (Detector 4) | Sludge | 72.6529 | 72.6363 | 72.5910 (Wt. After soak 2) | 0.0619 | 0.018 |
| C-Ring C (Detector 4) | Sludge | 73.4843 | 73.4756 | 73.4375 (Wt. After soak 1) | 0.0468 | 0.013 |
| Pin E (Detector 4) | Sludge | 5.3126 | 5.3121 | 5.2942 (Wt. After soak 1) | 0.0184 | 0.048 |

*The corrosion rates from the pins are expected to be less accurate than those from the C-Ring coupons because of the much smaller surface area of the pins.

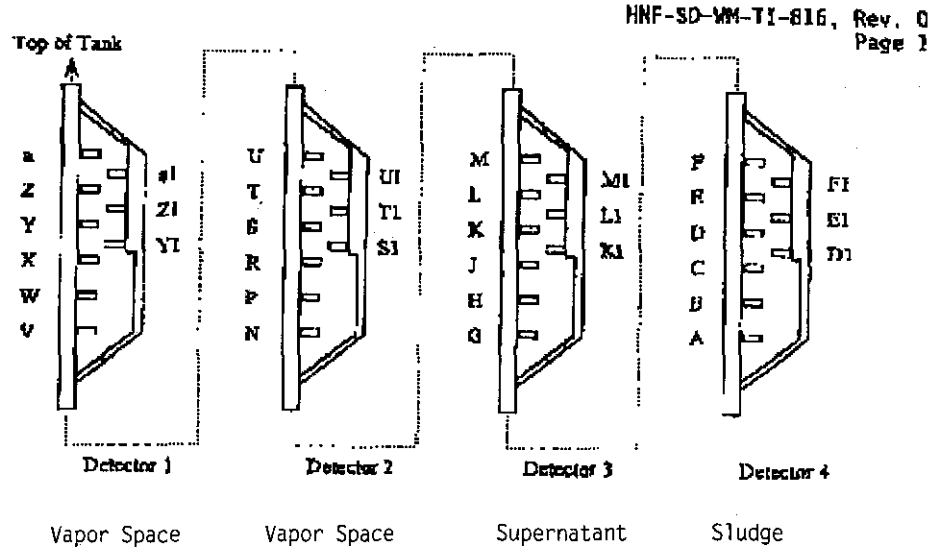


FIGURE 1 – Detector configuration

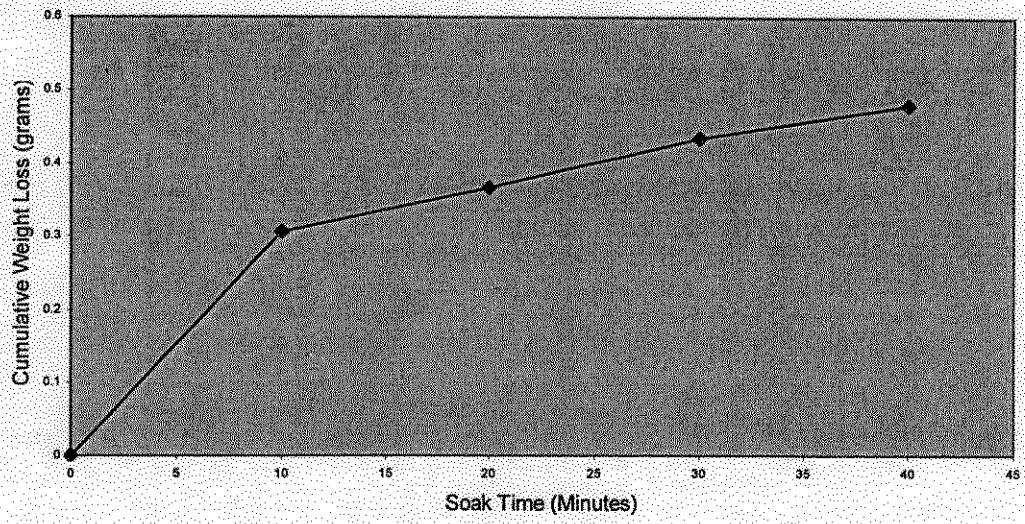


FIGURE 2 - Weight loss vs. soak time for C-Ring X, Detector 1

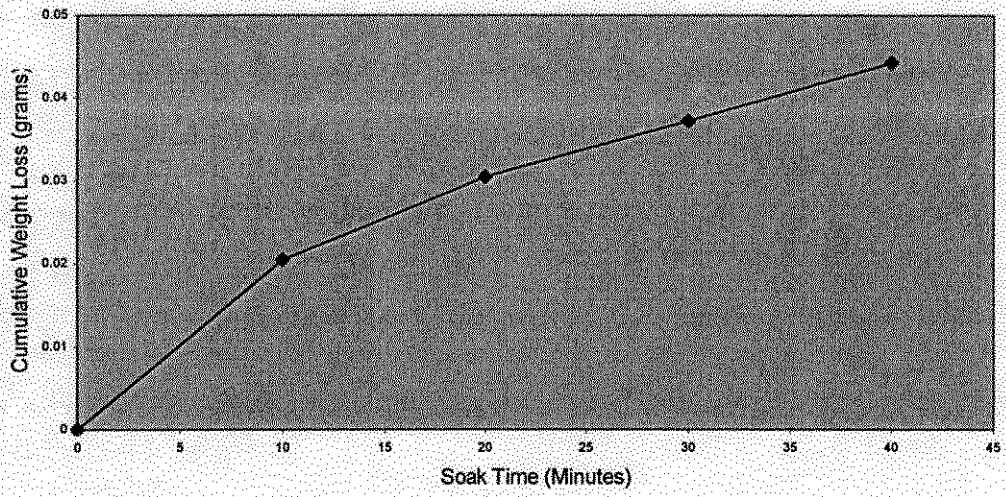


FIGURE 3 - Weight loss vs. soak time for Pin Y, Detector 1

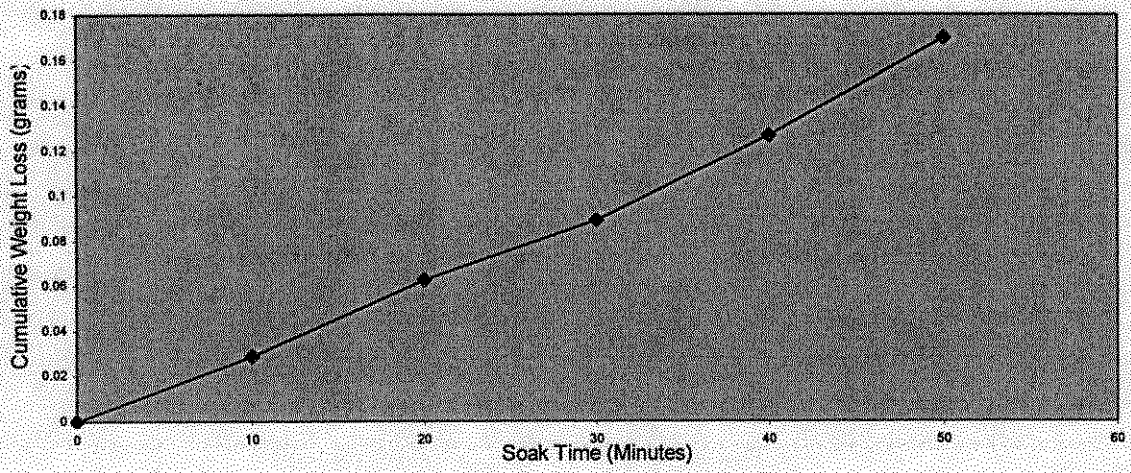


FIGURE 4 - Weight loss vs. soak time for C-Ring R, Detector 2

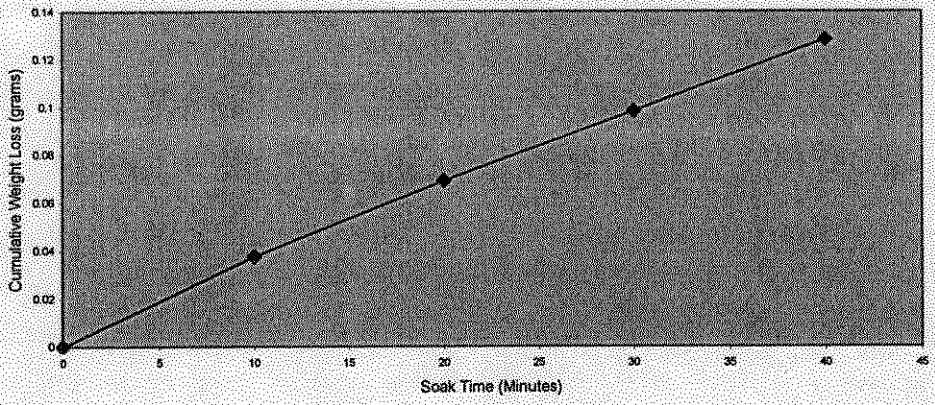


FIGURE 5 - Weight loss vs. soak time for C-Ring N, Detector 2

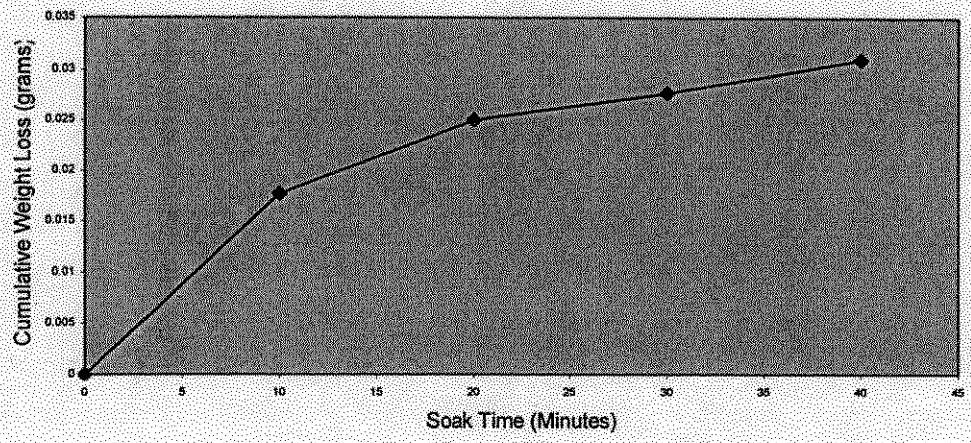


FIGURE 6 - Weight loss vs. soak time for Pin T1, Detector 2

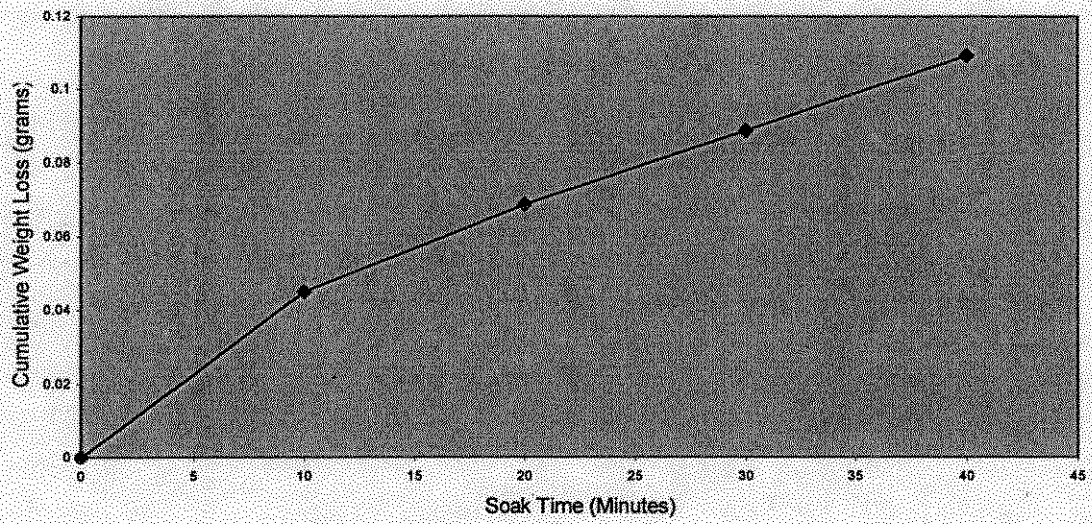


FIGURE 7 - Weight loss vs. soak time for C-Ring H, Detector 3

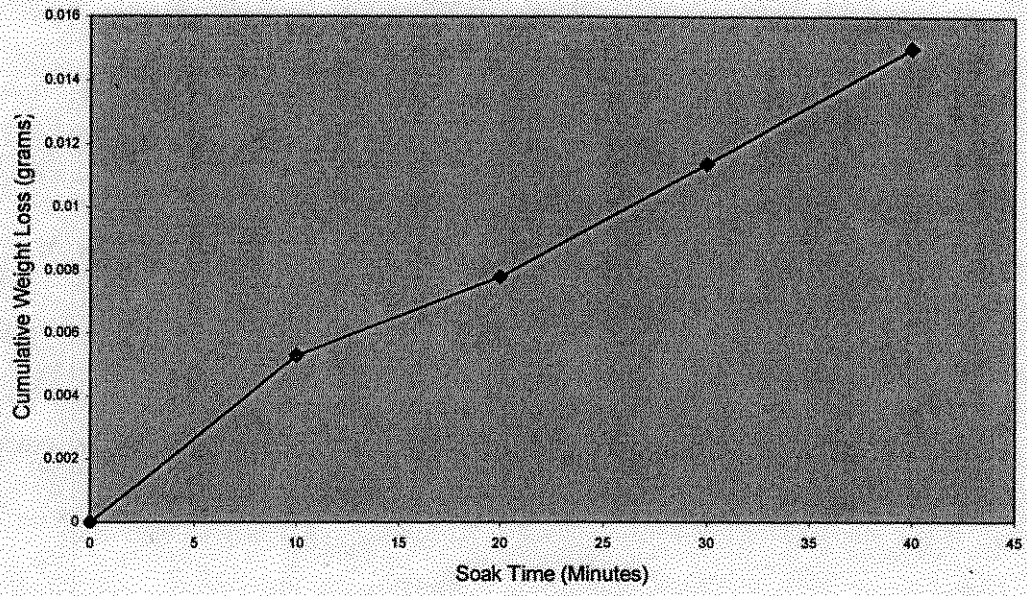


FIGURE 8 - Weight loss vs. soak time for Pin M1, Detector 3

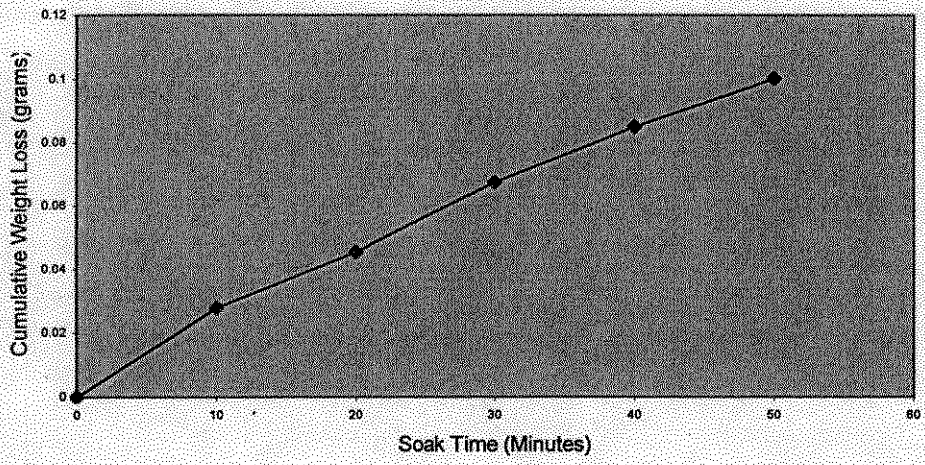


FIGURE 9 - Weight loss vs. soak time for C-Ring B, Detector 4

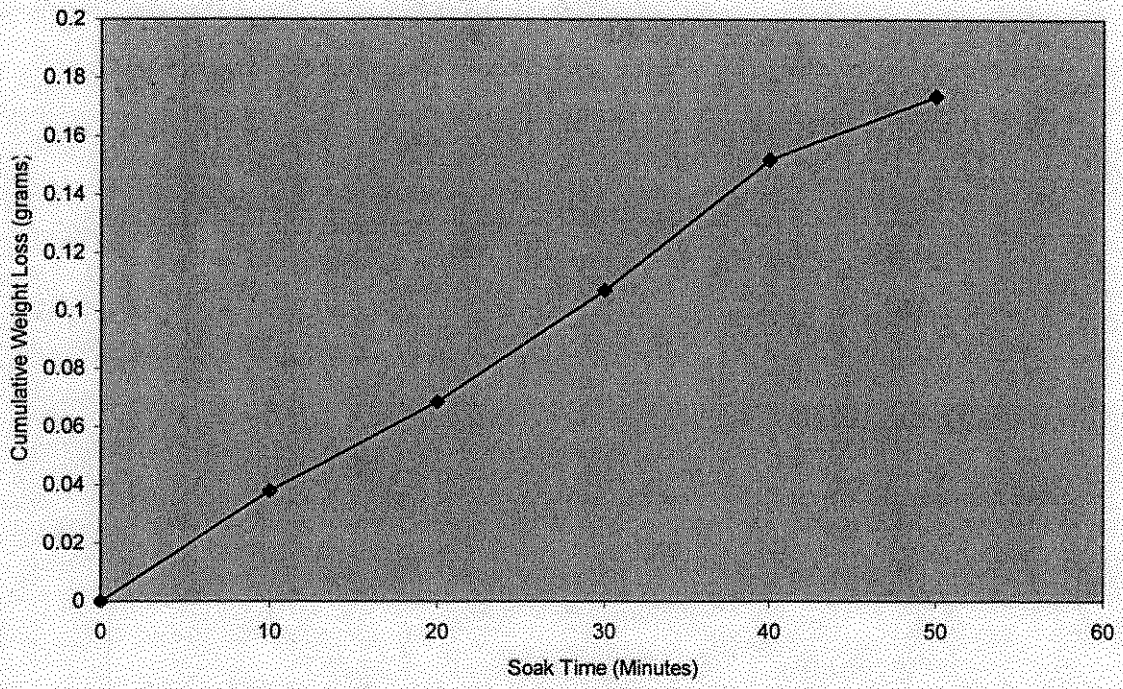


FIGURE 10 - Weight loss vs. soak time for C-Ring C, Detector 4

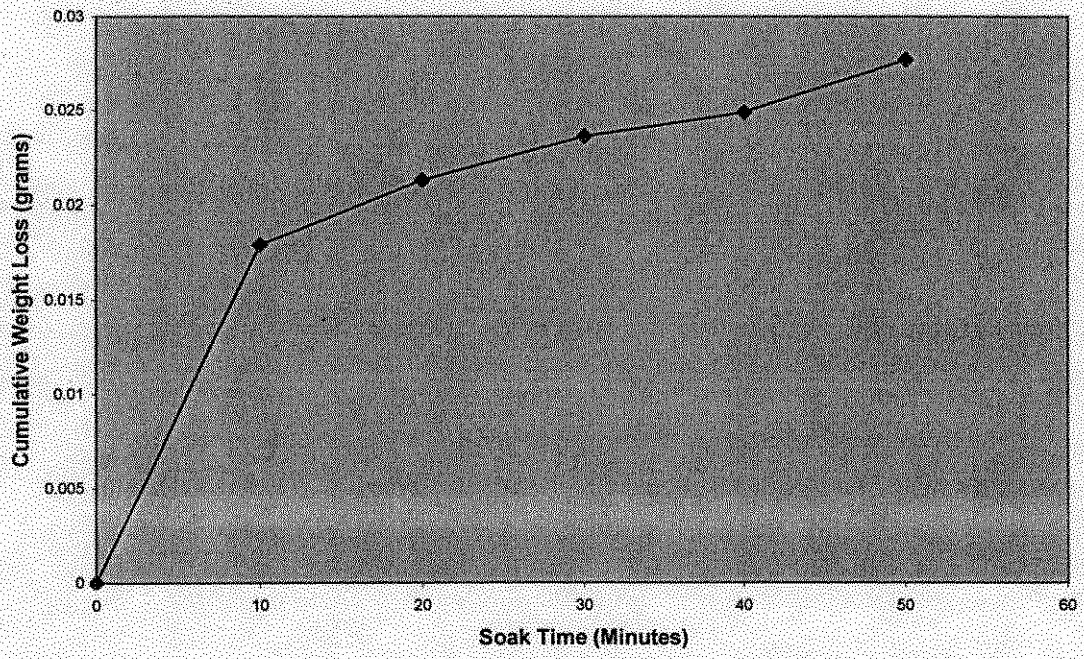


FIGURE 11. Weight Loss vs. Soak Time for Pin E, Detector 4