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Corrosion Evaluation of Tank 40 Leak Detection Box

by

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Introduction and Summary

Leak detection from the transfer lines in the tank farm has been a concern for many years because of the need to minimize exposure of personnel and contamination of the environment [1]. The leak detection box (LDB) is one line of defense, which must be maintained to meet this objective. The evaluation of a failed LDB was one item from an action plan aimed at minimizing the degradation of LDBs [2]. The Tank 40 LDB, which failed in service, was dug up and shipped to SRTC for evaluation. During a video inspection while in service, this LDB was found to have black tubercles on the interior, which suggested possible microbial involvement. The failure point, however, was believed to have occurred in the drain line from the transfer line jacket. Visual, metallurgical, and biological analyses were performed on the LDB. The analysis results showed that there was not any adverse microbiological growth or significant localized corrosion. The corrosion of the LDB was caused by exposure to aqueous environments and was typical of carbon steel pipes in soil environments.

Background

The LDB contains a conductivity probe which alarms when water or waste collects [3]. A typical LDB is shown in Figure 1. The LDB is connected to drain lines from the jackets of various transfer lines. As shown in the figure, the LDB has a discharge drain line to the sump and an overflow line, which are typically plugged or capped. Additionally, three capped dip tubes are available for instrumentation. The LDB is constructed of 8" diameter carbon steel pipe that was been welded closed at both ends. The discharge and drain lines are made of 1.5" carbon steel pipe, while the dip tubes are made of 0.5" carbon steel pipe. When the LDB was placed into service, a backfill, Gilsulate 500™, was used around it. The Tank 40 LDB had been in service for approximately 18 years.

SRTC Evaluation

The Tank 40 LDB was shipped from the tank farm to SRTC for evaluation. This evaluation included a visual examination, metallurgical and corrosion analysis, and microbial characterization.

Visual Examination

The exterior surface of the LBD is shown in Figures 2 and 3. Figure 2 shows the LDB and lower sections of the dip tubes and other lines. The surface morphology is variable. The area marked 'A' had a residual layer of the backfill material, which is Gilsulate 500™, adhering to the steel. The steel surface itself had regions of either a uniform black oxide, which is marked 'B', or non uniform general corrosion with the formation of reddish brown oxides, which is marked 'C'. The general corrosion probably resulted from the excursion of water through the backfill to the steel surface. The upper pipe sections shown in Figure 3 passed through the concrete pad and into the atmosphere. The section through the concrete, which is marked 'A', has a black oxide film with minimal surface corrosion. The above ground sections were painted. The visual assessment did not reveal any significant area of corrosion where the LDB integrity was impaired.

The LDB was sectioned so that the interior surface could be evaluated. Figure 4 shows the sectioning of the LDB. The two end caps and the pipes that extended to the surface were cut off the 8" pipe (cuts 1 and 2 in Figure 4, respectively). The interior surface was examined prior to further sectioning. The individual welds were then sectioned (cut 3 in Figure 4).

The interior surface had a variable morphology, indicating different environmental exposures. However, aggressive or severe degradation was not observed. Figure 5 shows a picture from the conductivity probe end of the pipe. Figure 6 is a picture of a weld region after sectioning. The arrow in the figure indicates the weld. Three regions were identified based on the morphology of the corrosion products and are shown schematically in Figure 7. These three regions had well defined lines of demarcation. Region 1 had a light flaky corrosion product which was a light reddish brown in color. Region 2 had a heavy crusty layer of black/brown corrosion products. Region 3 had a thin adherent layer of rust and surface oxide. If the lines of demarcation are taken as previous water lines, their orientation indicated that the LDB was not vertically in place, but slightly skewed.

Region 3 is typical of a normal atmospheric exposure of carbon steel. The light layer of surface rust probably formed due to atmospheric moisture at points where the mill oxide was either thin or damaged. Regions 1 and 2 had more exposure to water. Region 1 was probably were stagnant water collected in the LDB. The surface appeared as if a sediment layer remained intact. Region 2 may have had a condensate or a water film resulting from run down out of the drain lines. The coloring of the corrosion products indicated a higher oxygen concentration than found in Region 1. Chemical analysis of the surface was not performed to verify corrosion products and oxides or surface contaminants.

Metallurgical Analysis

Representative samples were removed from Regions 1 and 2 for metallurgical evaluation of the weld. These two regions showed the greatest degradation, although there were no indications of pitting or microbiological corrosion. Samples were mounted in an epoxy resin so the weld microstructure could be viewed both longitudinally along and transversely through the weld. Figure 8 shows a photomicrograph of the weld from Region 1. The thick corrosion product layer can be seen on the surface. The metallographic analysis did not reveal any subsurface pitting or tunneling indicative of microbiological involvement. The weld, heat-affected zone, and base metal appeared typical for carbon steel. These areas are indicated in the figure.

Microbiological Characterization

The characterization of the microbes involved several analysis procedures: direct bacterial counts, microbial characterization using MicKits®, and surface distributions of microbes in the biofilm. For the direct counts and the MicKit®, scrapings were taken using a sterile cotton swab soaked in sterile homogenizing buffer. This buffer has a small amount of detergent to facilitate removal of biological and non-biological material from the surface. A sample was taken from a one-inch area and the swab was placed in 10 ml of buffer and then vortexed for three minutes. Swabs were taken at representative sites along the interior and exterior surfaces. The exterior swabs were from three areas on the dip tubes and overflow lines: above ground, in the concrete, and in the soil/Gilsulate. The interior surfaces were swabbed near the weld in the three regions identified above.

For direct counts, 50 μL of the buffer solution was placed into separate wells on glass toxoplasmosis slides and observed under an epi-fluorescent microscope. Individual microbes were counted at a 1500X magnification across the well. These counts were used to calculate an approximate density. For the MicKit®, a drop of buffer solution was placed into vials containing nutrients specific for the growth of aerobic, acid producing, anaerobic and sulfate reducing microorganisms. The technique provides a measure of the number of organisms present. For observing the biofilm on the LDB surface, sections of the weld were stained with DAPI (4',6-diamidino-2-phenylindole*2HCl), which binds to DNA in the microorganism. Weld sections were viewed under an epi-fluorescent microscope at 600X.

The results of the direct count and MicKits® are shown in Table 1.

Table 1. Microbial Densities* On LDB Made From Direct Counts And MicKits®

LBD Section	Location	Direct Count	MicKits® **			
			SRB	APB	Anaerobes	Viable Aerobes
Overflow Line	Above ground	1.67E+04	N/A	N/A	N/A	N/A
	In cement	7.29E+03	N/A	N/A	N/A	N/A
	Near 8" section	9.34E+03	1-5	N/D	N/D	30-300
Dip Tube	Above ground	1.79E+04	N/D	N/D	1-5	200-2000
	In cement	1.95E+04	N/D	N/D	N/D	ND
	Near 8" section	1.61E+04	N/D	N/D	N/D	200-2000
Weld	Region 2	1.26E+05	N/D	N/D	N/D	N/A
	Region 1	1.02E+04	>20	N/D	N/D	N/A
	Region 3	2.23E+04	N/D	>20	N/D	N/A
End Cap	Region 2	3.26E+04	N/A	N/A	N/A	N/A

* Unit for density measurement - #microbes/cm^2

** SRB – sulfate reducing bacteria, APB – acid producing bacteria

For the direct counts, these results are near the detection limit of the technique, which indicates that there were a limited number of microbes on the surface of the LDB. The results from the MicKits® showed that the bacteria commonly associated with microbial corrosion in carbon steel, especially sulfate reducing bacteria, were not present in significant number. Generally, a developed biofilm has microbial densities between $10^8 - 10^{11}$ cells/cm^2.

The observation of the carbon steel surface under the epi-fluorescent microscope showed that the distribution of microbes was variable. The formation of a continuous biofilm was not observed. The microbes that were present were among the corrosion products as well as on top. Figure 9 shows a picture of the surface with heavy activity from Region 1 as viewed under the microscope. A small strip of the corrosion products was scrapped from the samples. The scrapped section was re-stained with DAPI. The purpose of this step was to observe if a high concentration of microbes was closer to the surface, realizing that the scrapping process would remove some organisms. The steel surface had even a smaller concentration of microbes than at the surface of the corrosion products.

The results of the microbial characterization showed that that there was not an extensive microbial environment near or within the LDB. A continuous biofilm was not observed and the typical bacteria associated with microbial corrosion in carbon steel (sulfate-reducing bacteria) were not present. These results are in agreement with the results of the visual evaluation and the metallurgical analysis which showed that the LDB only had experienced mild general corrosion typical for carbon steels exposed to soils and non-aggressive aqueous environments [4]. There was no observed tunneling or pitting that are commonly associated with microbial influenced corrosion.

Conclusion

The Tank 40 LDB, which failed in service, was characterized for the degradation process(es). This task was done as part of a planned assessment of LDBs so as to optimize their performance for leak detection and environmental protection. The analysis included visual evaluation, metallurgical analysis, and microbial characterization. The LDB was found to have experienced only mild general corrosion which is typical for carbon steel corrosion in soils and mild aqueous environments. The microbial characterization showed that an adverse microbial environment, which would lead to microbial influenced corrosion, was not present. These results are in agreement with the failure point of this LDB being located in the drain line from the transfer line jacket, which was not analyzed during this task.

References

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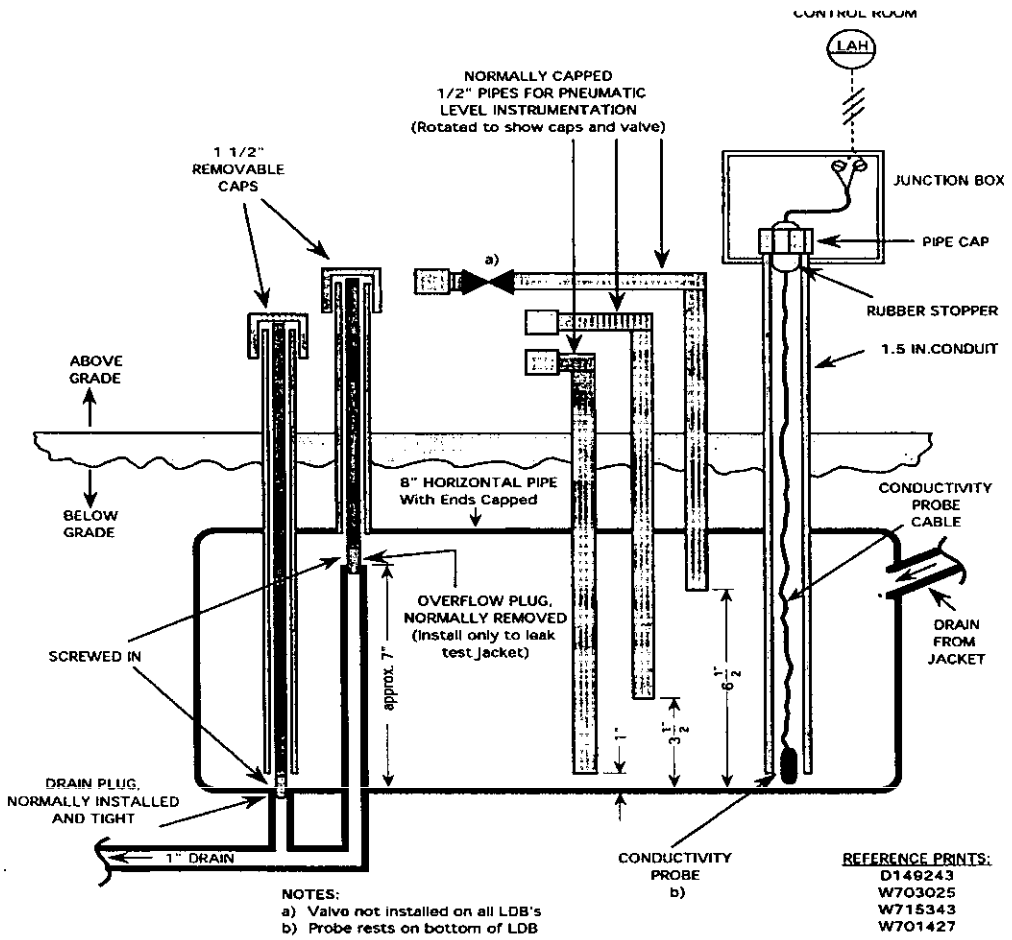

Figure 1. Drawing of a typical LDB

Figure 2. View of Tank 40 LDB and support piping

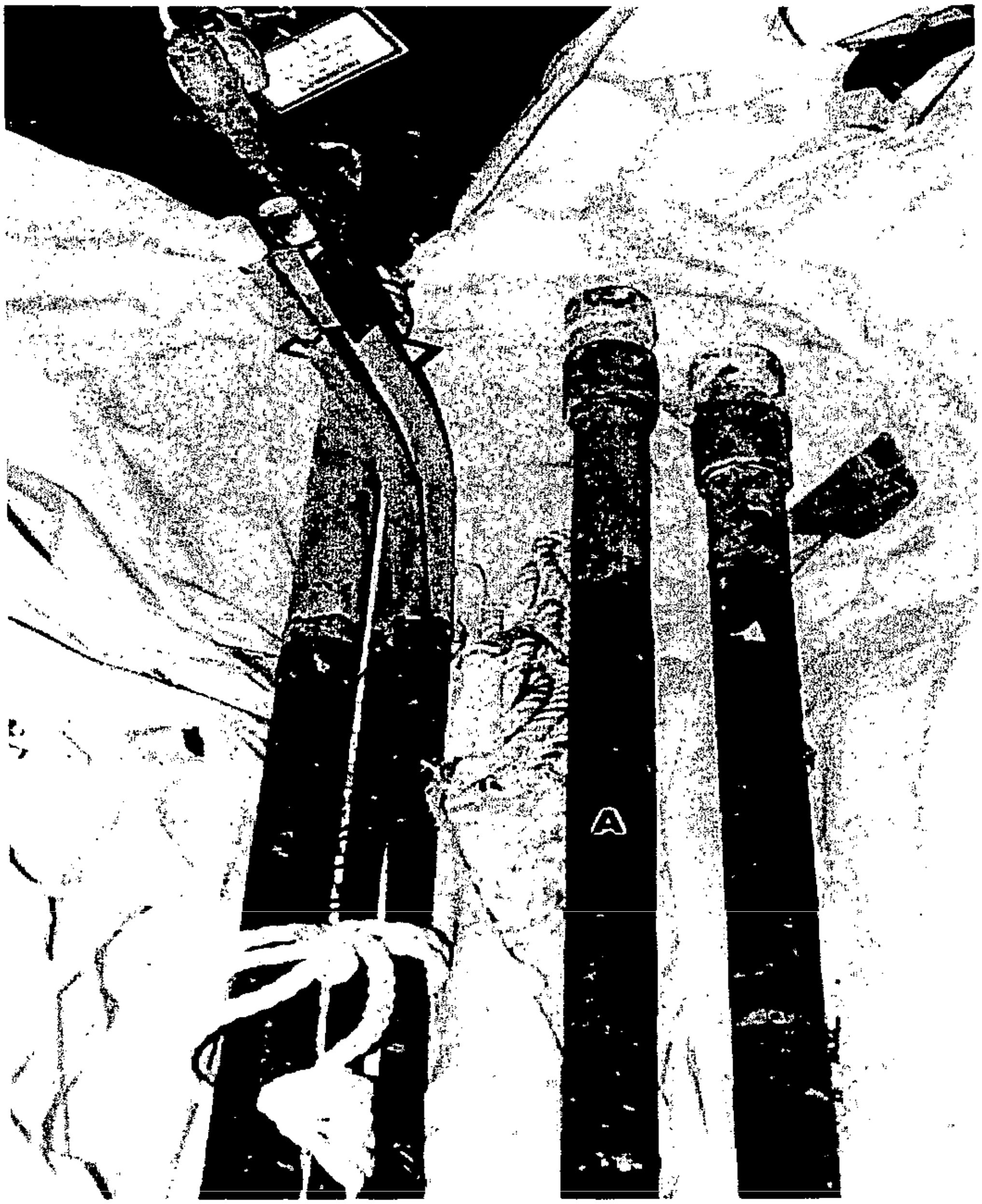

Figure 3. View of upper section of dip tubes and other piping for Tank 40 LDB

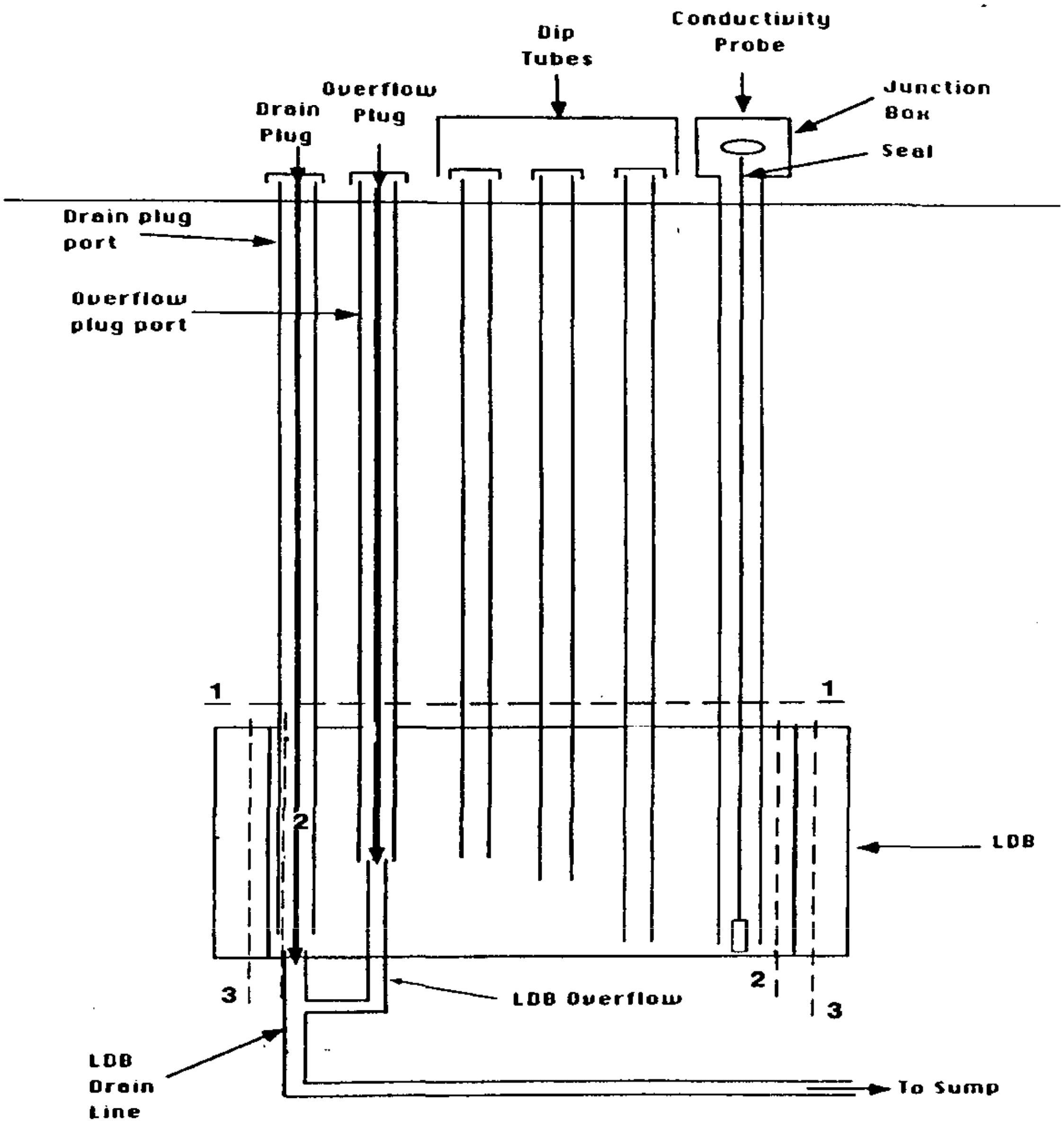

Figure 4. Schematic drawing of weld section cuts made in Tank 40 LDB

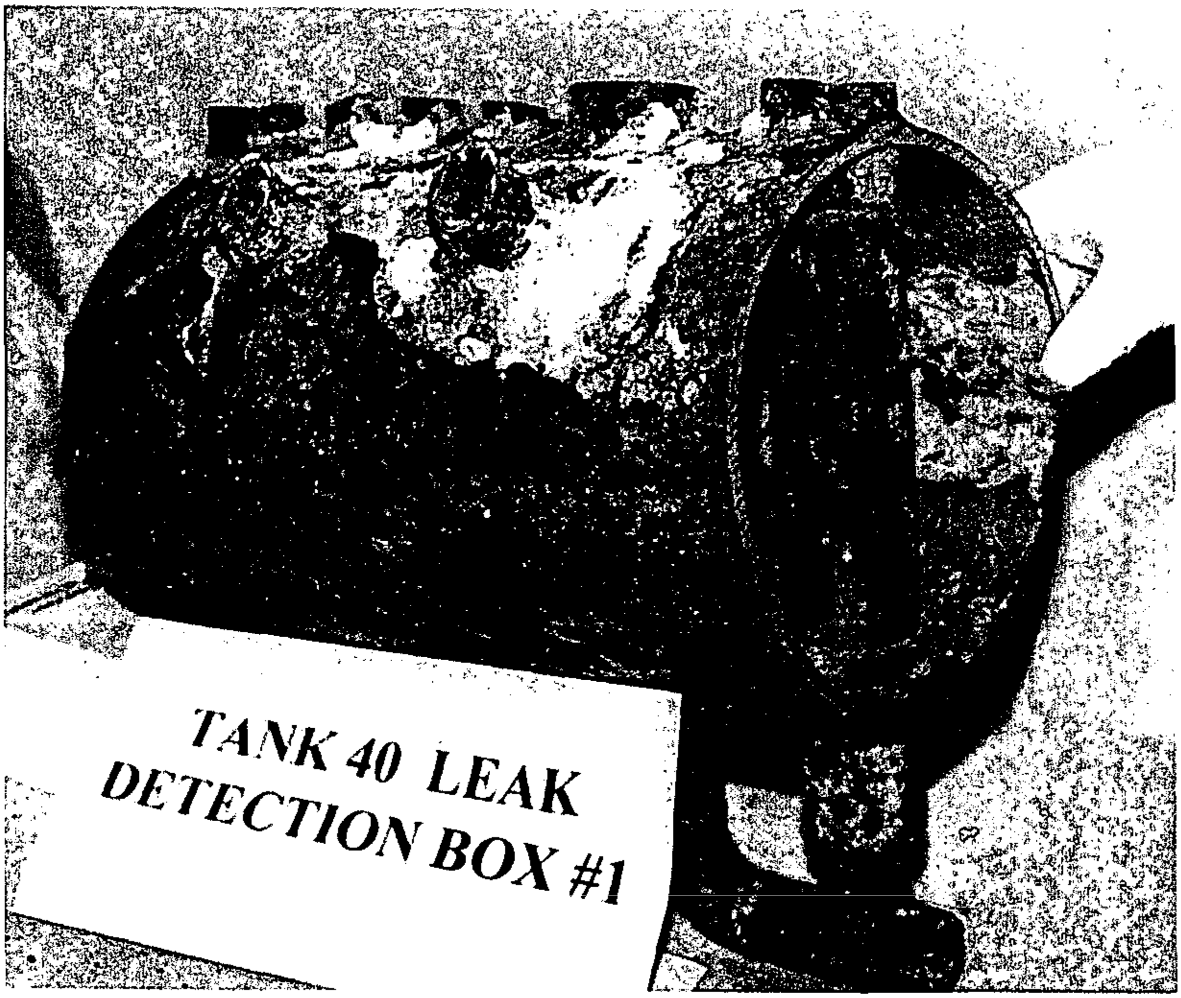

Figure 5. View of Tank 40 LDB with end caps removed

Figure 6. View of sectioned weld from Tank 40 LDB

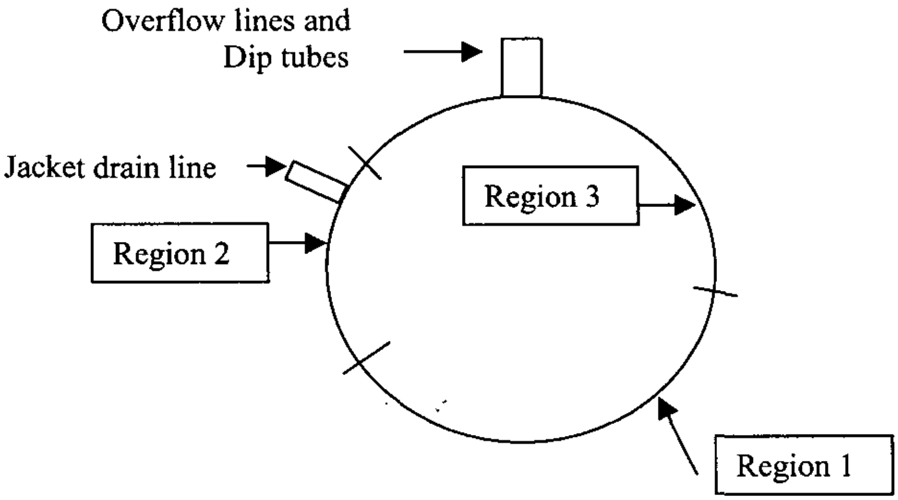

Figure 7. Schematic drawing of regions of different corrosion morphology

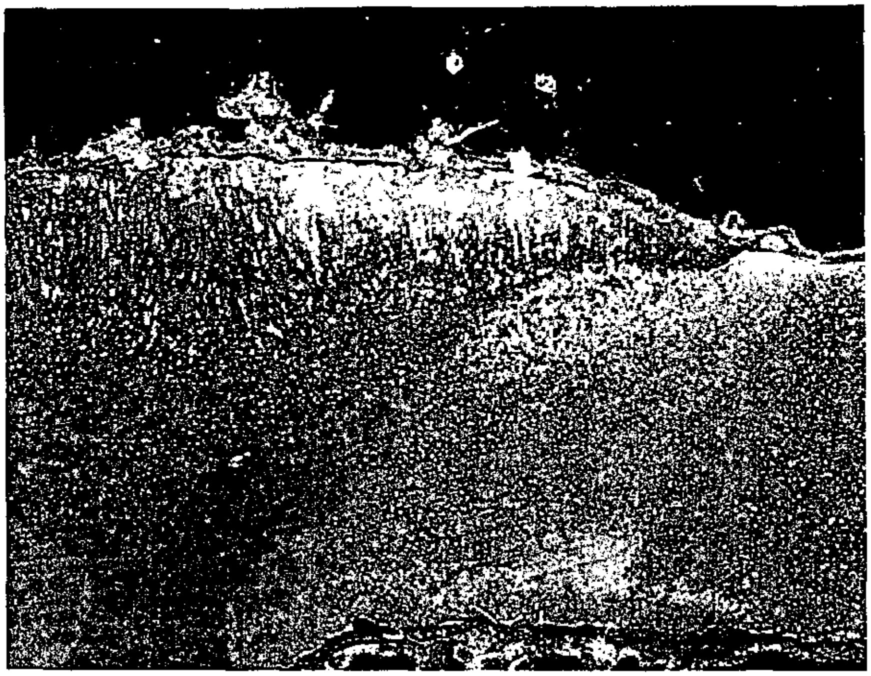

Figure 8. Photomicrograph of weld region from LDB

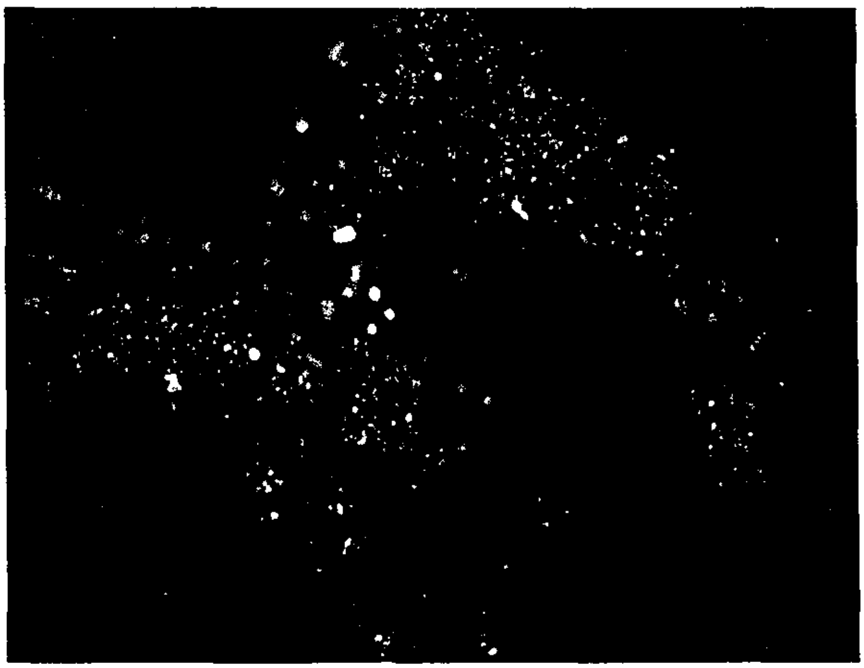

Figure 9. Picture of microbial activity from Region 2

Distribution

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