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Laboratory Test Report
Technical and Ecological Services
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SUBJECT: LEAK IN GAS LINE DFM-3, BETWEEN SANTA CRUZ AND DAVENPORT

BACKGROUND

In June of 1996 a leak was discovered during a walk-down of the DFM-3 gas line, between Santa Cruz and Davenport (installation year 1957). The leak was located in a section of pipe where the line had been field bent to transit down an embarkment (Figure 1). After excavation, the TES Welding and Inspection Services Unit performed visual, wall thickness and x-ray inspection of an eight foot section. No evidence of pitting or other wall loss due to corrosion was found. Wet fluorescent magnetic particle examination found a linear indication that ran longitudinally along the pipe and encompassed all six leak sites (Figures 2 and 3). It was recommended to remove the entire spool piece. The section that had been inspected was sent to the TES Metallurgy Lab for evaluation.

This work was completed and reported by e-mail at the end of July, 1996. This report formally summarized the results of the investigation.

METALLOGRAPHIC INSPECTION

Three cross-section were taken through the linear indication in order to characterize the leak. It was discovered that the leaks are associated with the longitudinal weld of the pipe. The pipe was formed by forge welding, a method were a sheet is formed into a pipe and the longitudinal edges, each with a single bevel, are forge-welded together. The pipe is then usually cold or hot expanded to its final diameter and the weld is not evident anymore. Although no through-wall leak was seen in the cross-sections, several areas with lack of bonding were noted along the forge weld (Figures 4 and 5). It is likely that these are scale or oxide inclusions that were not expelled from the weld during manufacturing.

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TENSILE TESTING

Four tensile tests were conducted, two across the weld and two in the base metal 180° opposite the weld. Tests were performed per API 5L and are reported in Table 1. The pipe meets API 5L Grade X42 specifications for the base metal. The No. 2 weld coupon had a 8% lower tensile strength than minimum. This coupon failed in the weld metal, with less ductility than the No. 1 weld coupon. A weld defect (incomplete bonding) was noted on the No. 2 weld coupon.

Table 1
Tensile Test Data

	Parent Metal Coupons (180° from Weld)		Weld Metal Coupons		API 5L Grade X42
	1	2	1	2	(minimum)
Tensile Strength (psi)	63,200	65,000	59,8000	55,300	60,000
Yield Strength (psi)	44,400	47,500	48,200	45,600	42,000
Elongation (%)	38	35	30	14.5	35
Fracture Location	Parent Metal	Parent Metal	Parent Metal	Parent Metal/ Forge Weld	
Fracture Characteristics	Ductile	Ductile	Ductile	Ductile	

CHEMICAL ANALYSIS

Chemical analysis showed the pipe to consist of low carbon steel. It meets the requirements for API Grade X42.

Table 2
Chemical Analysis of Pipe Steel (Weight %)

Carbon	Chromium	Manganese	Molybdenum	Nickel	Phosphorus	Silicon	Sulfur
0.05	<0.005	0.38	0.005	0.007	0.05	<0.005	0.010

CONCLUSION

- The pipe meets the tensile specifications for API 5L Grade X42.
- It was forge welded (not seamless).
- The leaks occurred along the weld. Metallographic cross-sections showed that there were areas of disbonding due to scale or oxide inclusions. This is a common defect in forge welds.
- Because no evidence of corrosion was found, it is possible that the leaks were created when the pipe was field bent.

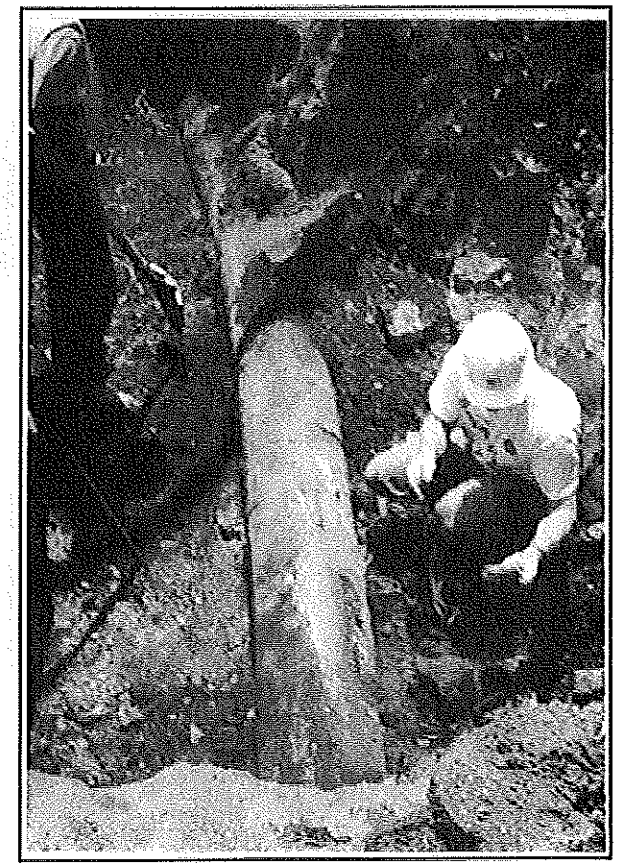

Figure 1 (left). DFM-3 pipe while being excavated. Note bend in pipe necessary to transit down embarkment.

Figure 2 (bottom). Pipe during inspection. White round circles indicate leaks. Note their linear arrangement along the longitudinal axis of the pipe.

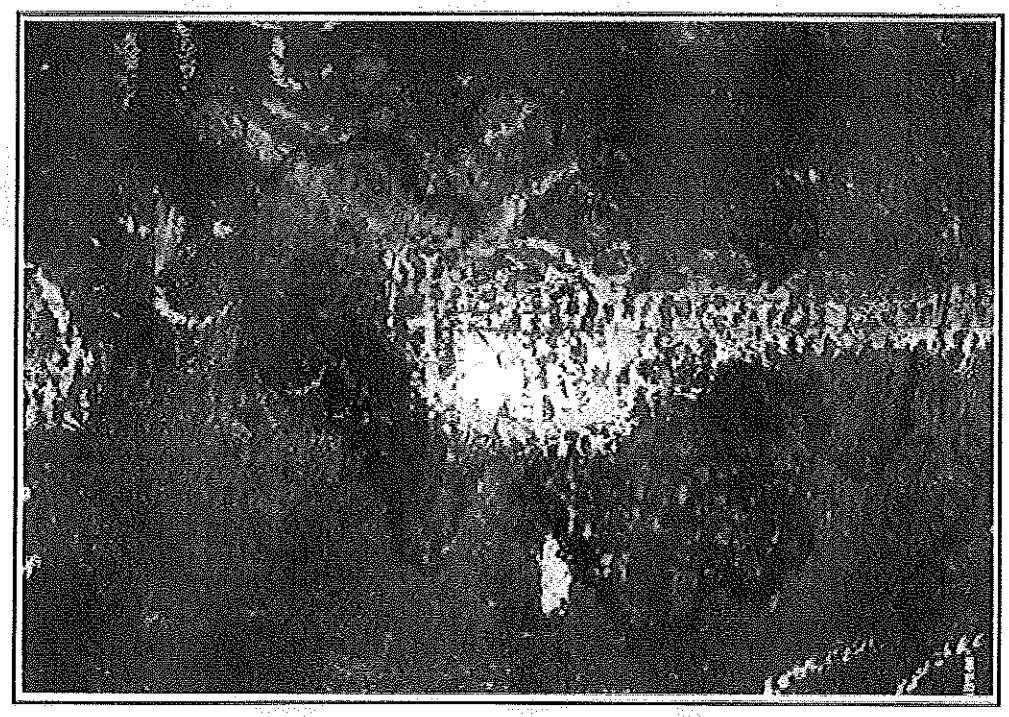

Figure 3. Close-up of linear indication. It runs left to right, about midway through the picture.

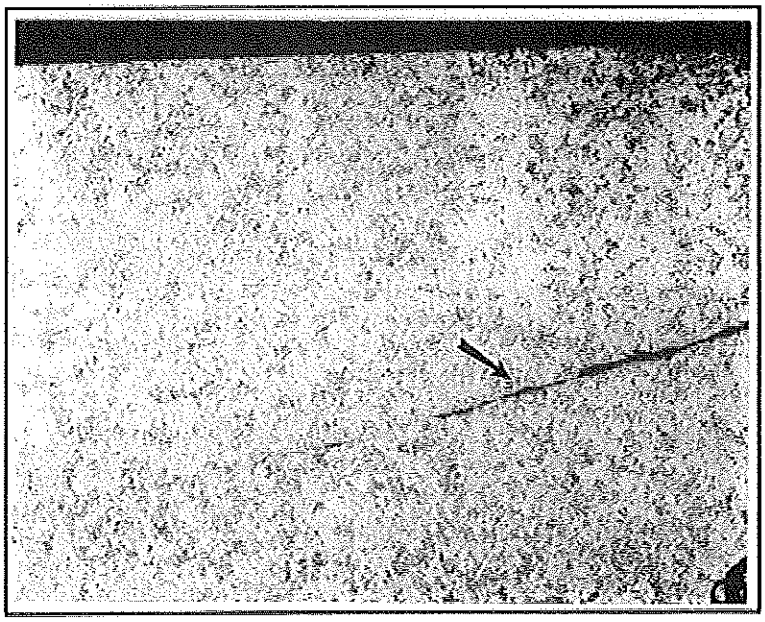

Figure 4. Metallographic cross-section through defect area. Arrow points towards linear defect along forge weld. This delamination is most likely due to scale on the bevel surface.

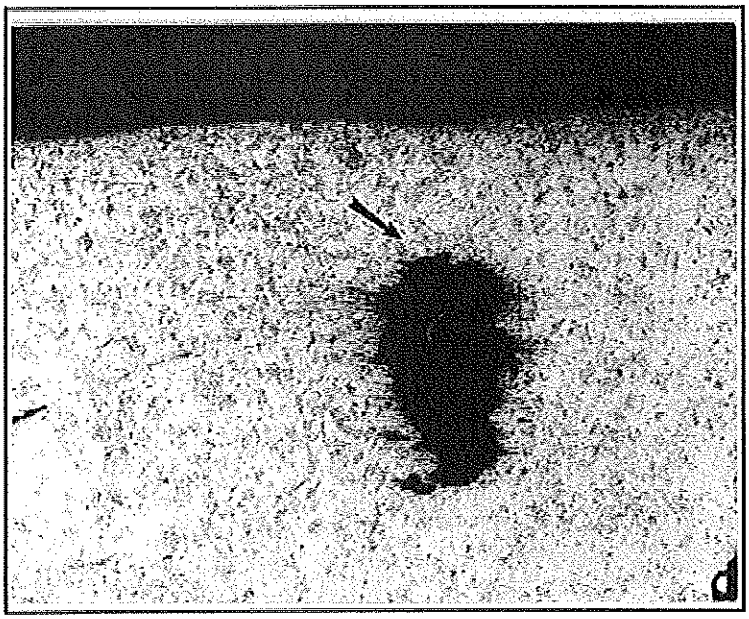

Figure 5. Another defect seen on the forge weld. this is most likely due to a slag inclusion. Index marks on the outside of the picture indicate location of forge weld (both pictures 15X, nital etch).