



ANALYSIS OF RESIDENTIAL COPPER WATER PIPES

ATS JOB # D280682

PURCHASE ORDER # 17-04201

Prepared for

COLE BLACKWELL
COBB COUNTY-MARIETTA WATER AUTHORITY
1170 ATLANTA INDUSTRIAL DRIVE
MARIETTA, GA 30066

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Purchase Order # 17-04201

Cole Blackwell
Cobb County-Marietta Water Authority
1170 Atlanta Industrial Drive
Marietta, GA 30066

Subject

Analysis of Residential Copper Water Pipes

Material

Copper

Objective and Background

The purpose of this evaluation was to determine the cause of pinhole leaks of several copper pipe sections from different residences per ATS Procedure 931 Rev. 2. Similar leaks were observed in around 200 houses within a 7 mile radius from a drinking water plant. The customer reported that the affected houses were built between 1973 and 1985. The leaks mainly occurred in the cold water lines. The customer reported that the water pH was recently determined to be 8.0-8.2 and a calcium hydroxide slurry is regularly used as water treatment.

Test Procedure and Results

The pipes were documented in the as-received condition (Figures 1 through 4). All of the pipes exhibited similar leak areas at the outer diameter (OD). The rest of the OD surfaces were relatively clean and did not exhibit any corrosion products. The pipes were sectioned open and examined visually. Yellowish deposit was observed along the entire inner diameter (ID) surface of all of the pipes (Figures 5 and 6). Pitting through the pipes were observed initiating from the IDs along with some tubercles.

The ID deposits and pitting areas were chemically analyzed per ASTM E1508-12, *Standard Guide for Quantitative Analysis by Energy-Dispersive Spectroscopy*. The corrosion products within the pits consisted of copper oxide with significant concentrations of sulfur and silicon. The yellowish ID deposits exhibited elevated concentrations of silicon and aluminum. See Figures 7 and 8 for the EDS spectra and the SEM images.

Pipe sections were metallurgically prepared transversely per ASTM E 3-11(17), *Standard Guide for Preparation of Metallographic Specimens*. The samples exhibited localized pitting corrosion on the ID (Figures 9 through 12). No microstructural abnormalities that could contribute to corrosion were observed.



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Discussion and Conclusions

The pipes exhibited localized pitting initiating on the ID surface that corroded through the pipe wall to form pin hole leaks. Pitting corrosion is the non-uniform localized attack of the copper pipe wall which initiated on the interior/waterside surface in the domestic water distribution system.

The corrosion mechanism was most likely under-deposit corrosion. Under deposit corrosion occurs when regions on a metal surface have varying degrees of access to oxygen and other ions due to the presence of deposits. Cathodic reactions within the fluid being transported ($O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$) occur at the exposed surfaces, while anodic reactions that dissolve the base metal ($4Cu + 2H_2O \rightarrow 2Cu_2O + 4H^+ + 4e^-$) occur beneath deposits. The excess H^+ ions beneath the deposit also attract chlorine and sulfur ions if present in the fluid that can create acidic conditions under the deposit and further accelerate corrosion. Corrosion can occur even when large distances separate the exposed and “under-deposit” surfaces, provided they are in electrical contact.

The ID deposits exhibited significant concentrations of silicon and aluminum. The customer reported that no silicate based corrosion inhibitors were used in the system. Silica/sand is another possibility and usually seen in well waters or may be coming from a deteriorating concrete water main. The cause of this silicon rich deposit should be investigated.

No pipe material abnormalities that could contribute to the corrosion was observed.



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Figure 1: Photograph of an as-received pipe showing leak location (encircled)



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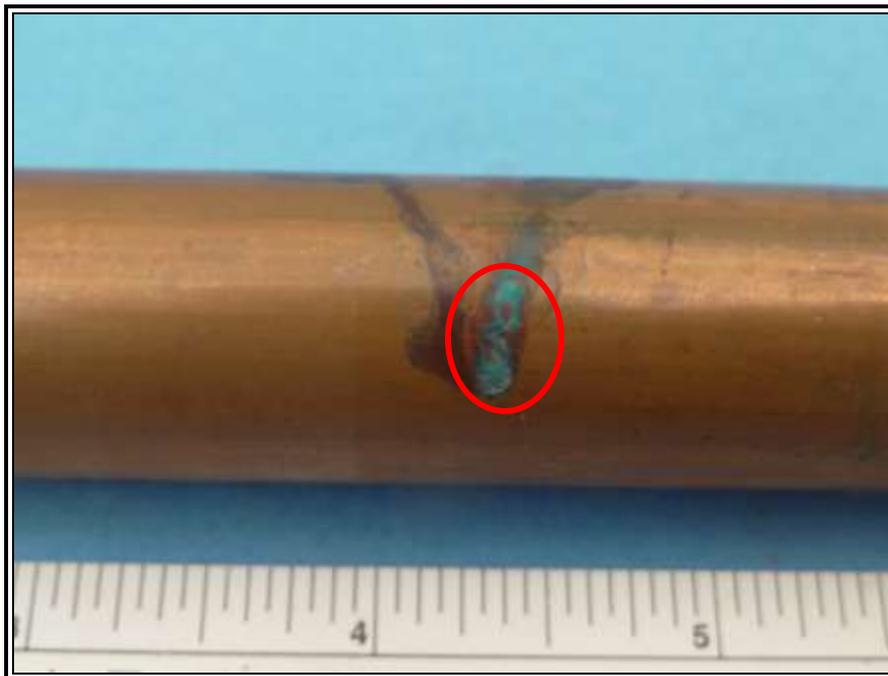


Figure 2: Photograph of an as-received pipe showing leak location (encircled)



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Figure 3: Photograph of an as-received pipe showing leak location (encircled)



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Figure 4: Photograph of an as-received pipe showing leak location (encircled)



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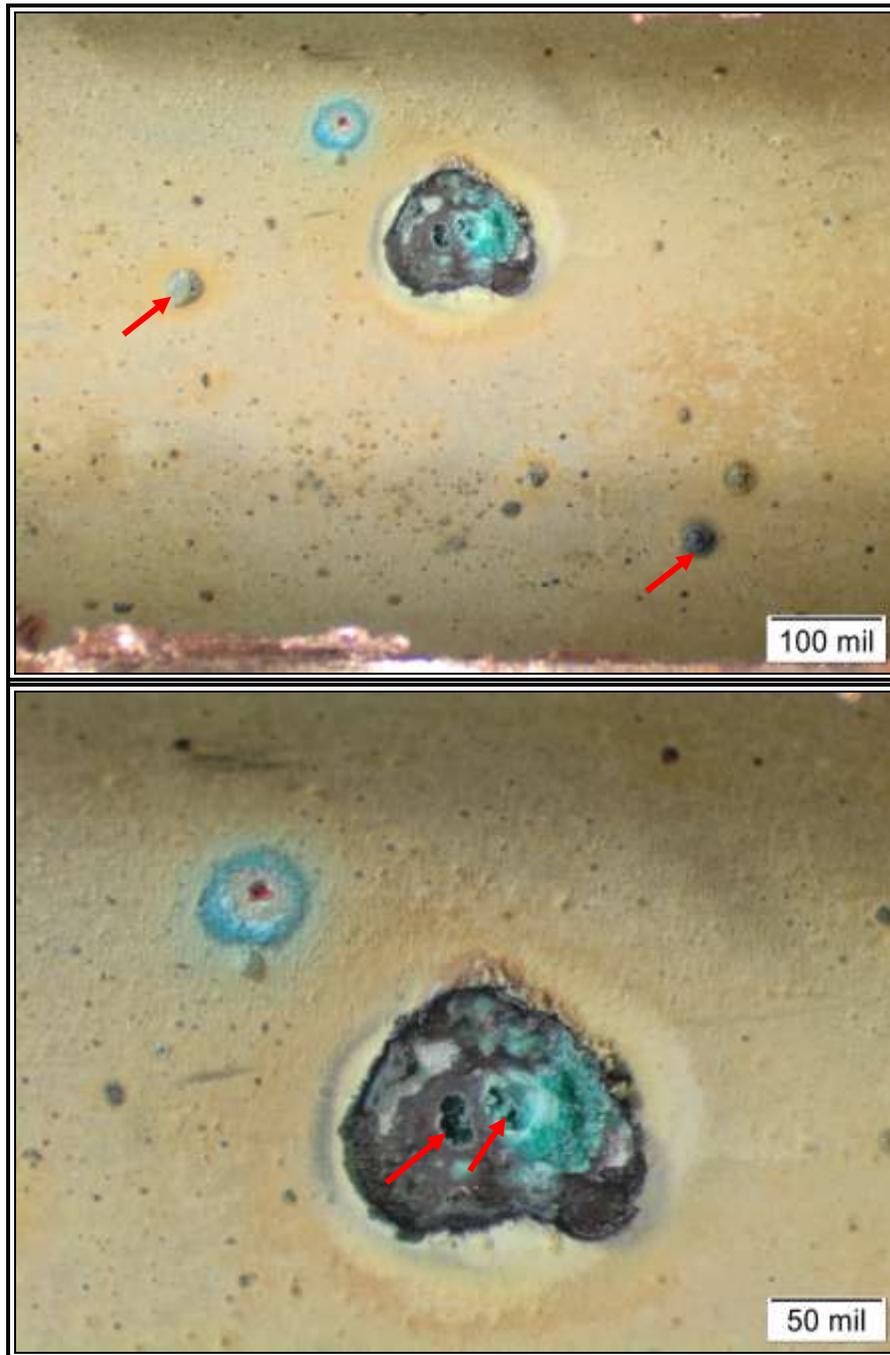


Figure 5: Photomicrographs showing the ID of a pipe exhibiting tubercles (top, arrows) and the pitting (bottom, arrows)

Note the yellowish deposit at the ID surfaces.



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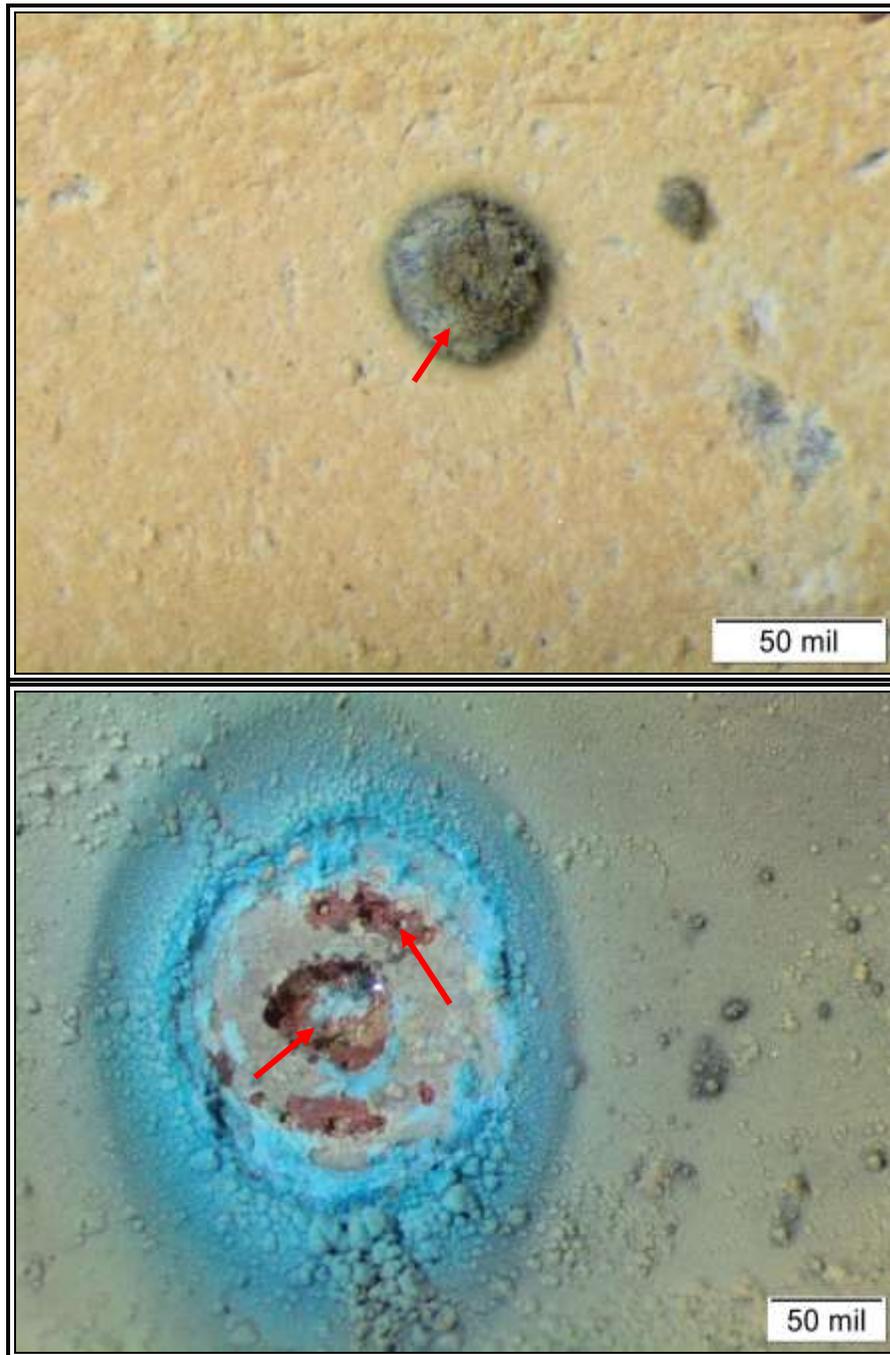


Figure 6: Photomicrographs showing the ID of a pipe exhibiting a tubercle (top, arrows) and the pitting (bottom, arrows)

Note the yellowish deposit at the ID surfaces.



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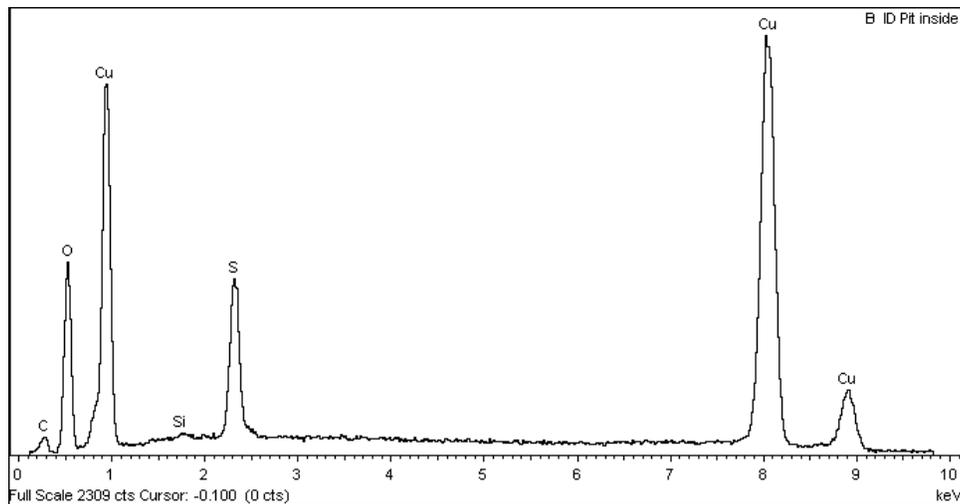


Figure 7: Back-scattered electron image (top) and EDS spectrum (bottom) of a corrosion pit (bottom)

Carbon (C), oxygen (O), copper (Cu), silicon (Si), and sulfur (S) were detected



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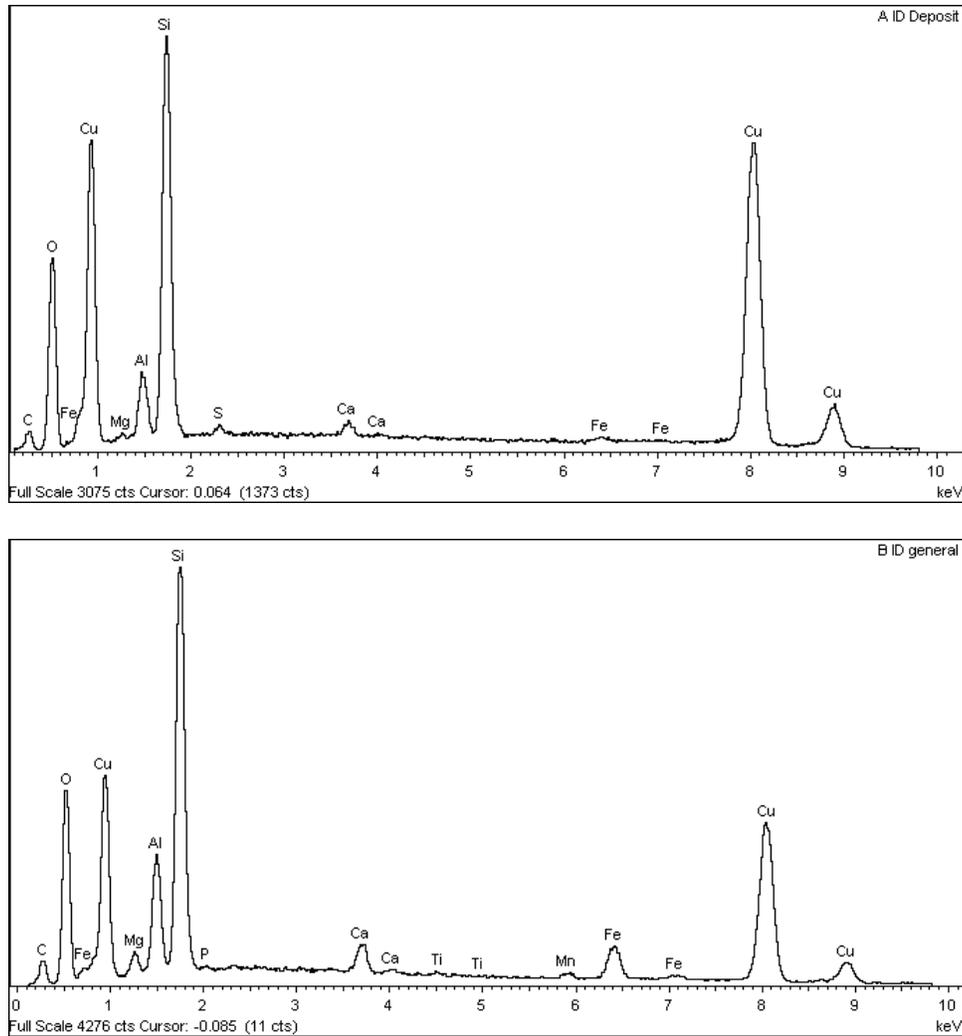


Figure 8: EDS spectra of the ID deposits from different pipes

Carbon (C), oxygen (O), iron (Fe), copper (Cu), magnesium (Mg), aluminum (Al), silicon (Si), phosphorus (P), sulfur (S), calcium (Ca), titanium (Ti), and manganese (Mn) were detected.



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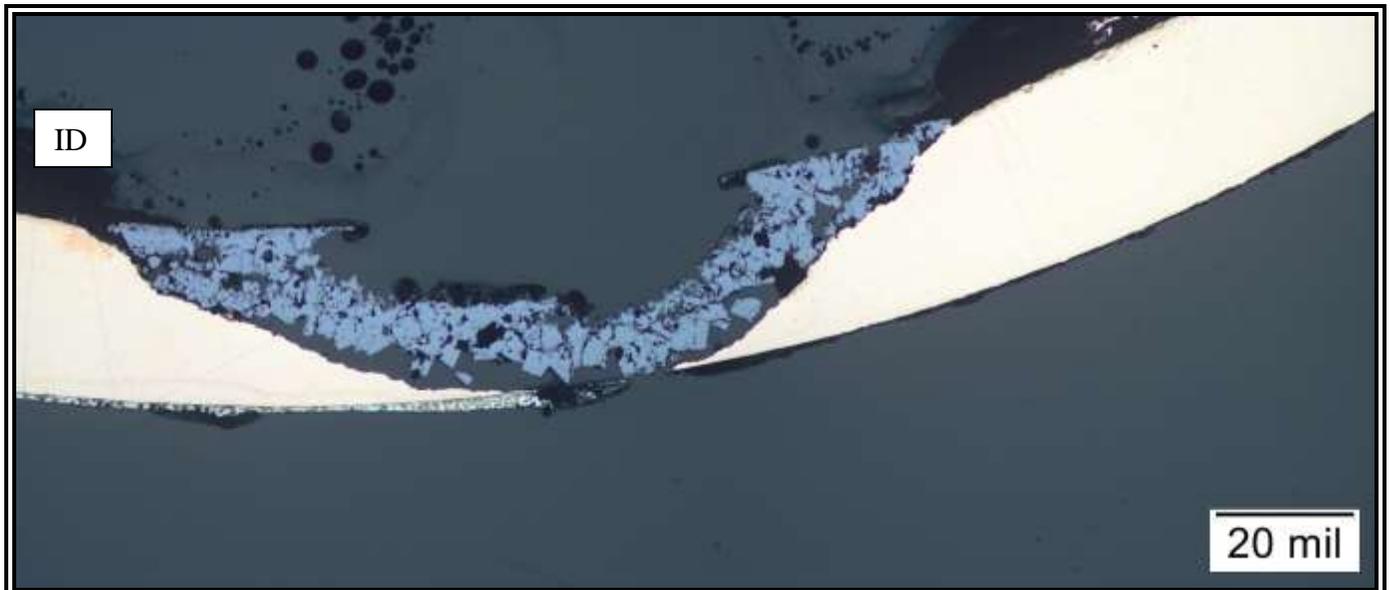
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As Polished



As Polished

Figure 9: Photomicrographs of the samples exhibiting localized pitting corrosion of the ID and propagating through to the OD



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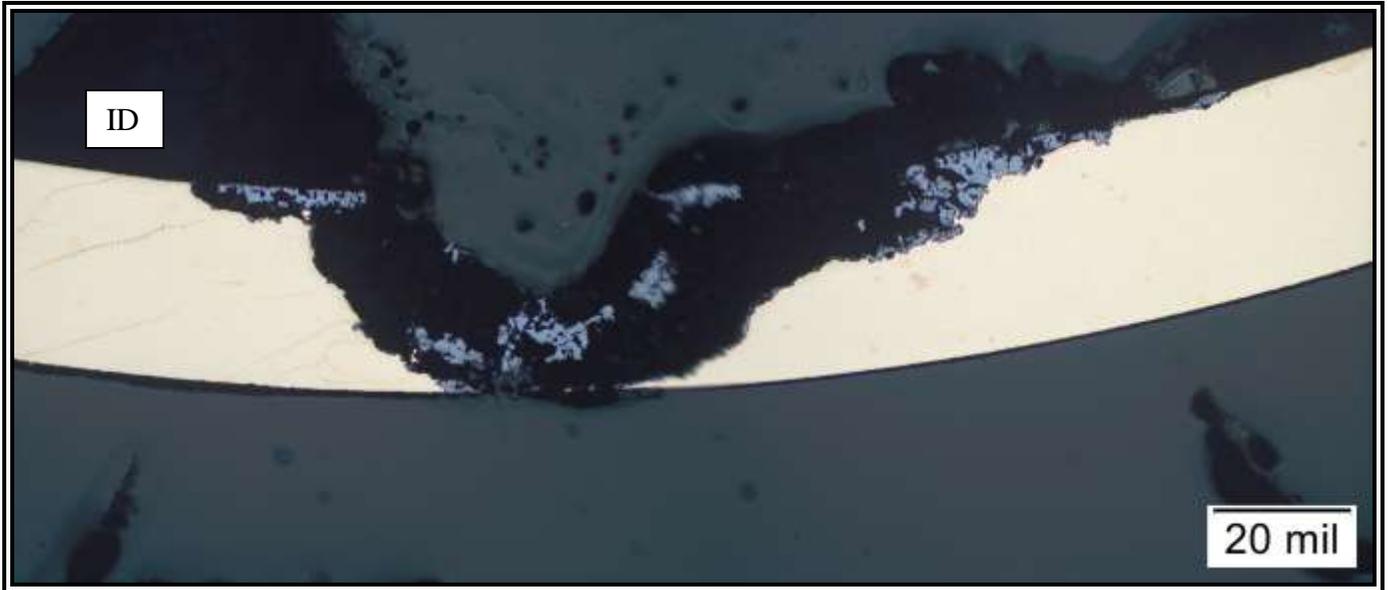
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As Polished

Figure 10: Photomicrograph of a pipe sample exhibiting localized pitting corrosion of the ID and propagating through to the OD



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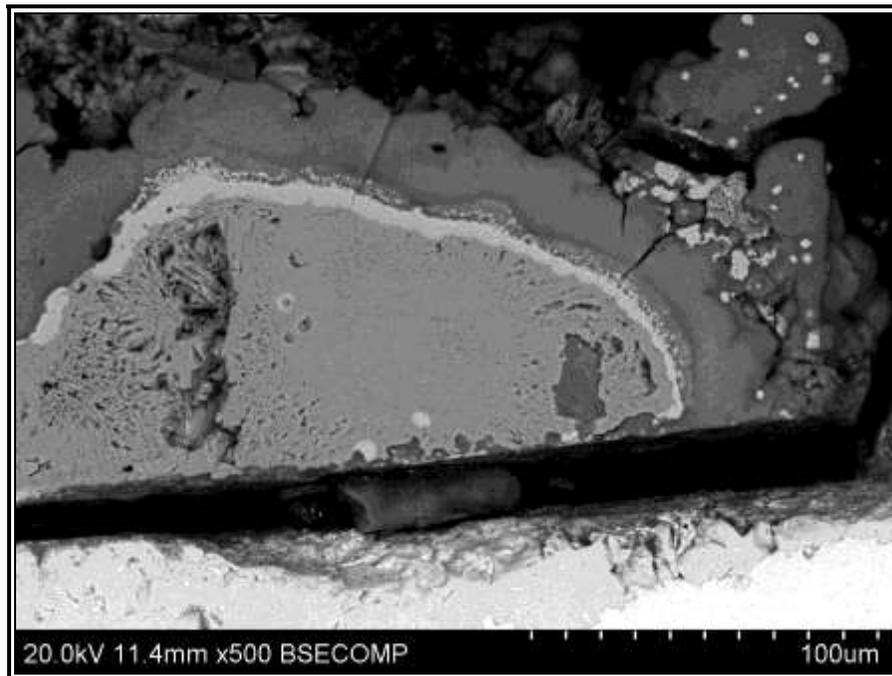
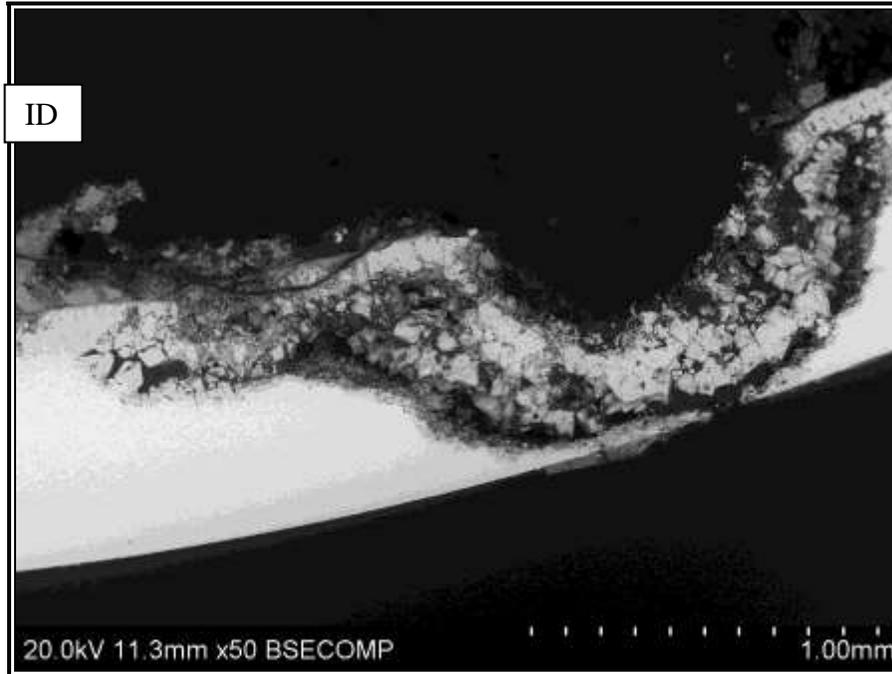


Figure 11: Back-scattered electron image of a pipe sample exhibiting localized pitting corrosion (top), and the OD deposit (bottom)



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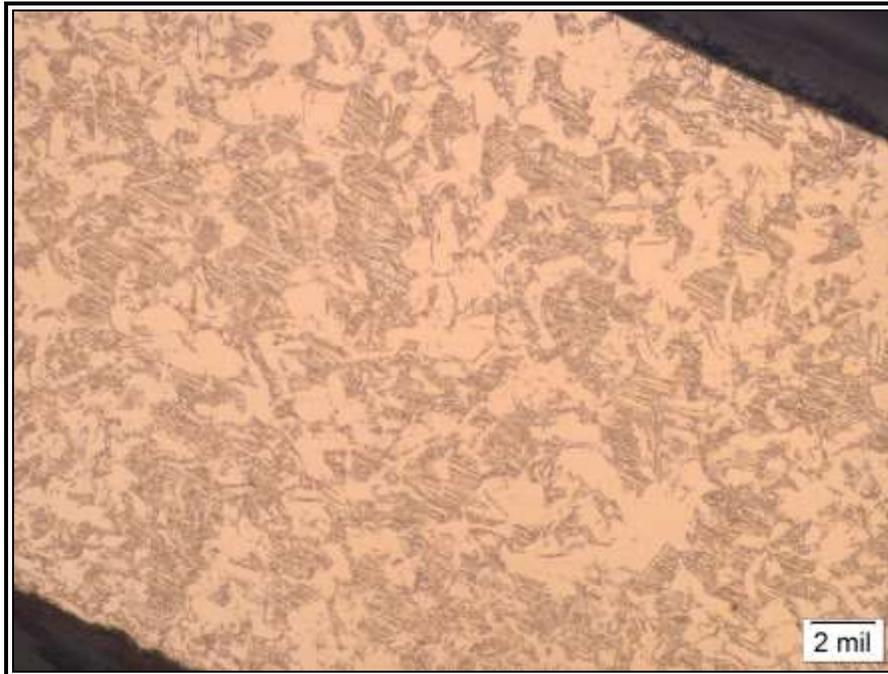
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Ammonium Hydroxide Etch



Ammonium Hydroxide Etch

Figure 12: Photomicrographs of the pipe sections showing the typical microstructure