NEVADA SITE OFFICE

Coal Tar Flaking in Fire Protection Water Supply

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Coal Tar Flaking in Fire Protection Water Supply

Background:

- **Underground steel lead-in piping was installed between a material storage building and the building's water supply source that include a water tank and looped system feeding the lead-in lines.**

- **Interior surface of underground steel lead-in pipes were treated with a factory-applied, corrosion resistant, coal-tar epoxy coating.**

- **Coal tar lined lead-in pipes were incorrectly installed (early 1990s).**

Coal Tar Flaking in Fire Protection Water Supply

Background (cont'd):

- **Instead of mechanical fittings, the installing contractor "field welded" pipe sections together.**
- **As a result of heat applied during the welding process, the coal-tar epoxy coating was damaged at the joints.**
- **Coal tar epoxy coating lost its adhesion at the pipe joints and began to flake off.**

Coal Tar Flaking in Fire Protection Water Supply

In FY-07 significant increase in coal tar collected during flush (one strainer/one flush)

Coal Tar Flaking in Fire Protection Water Supply

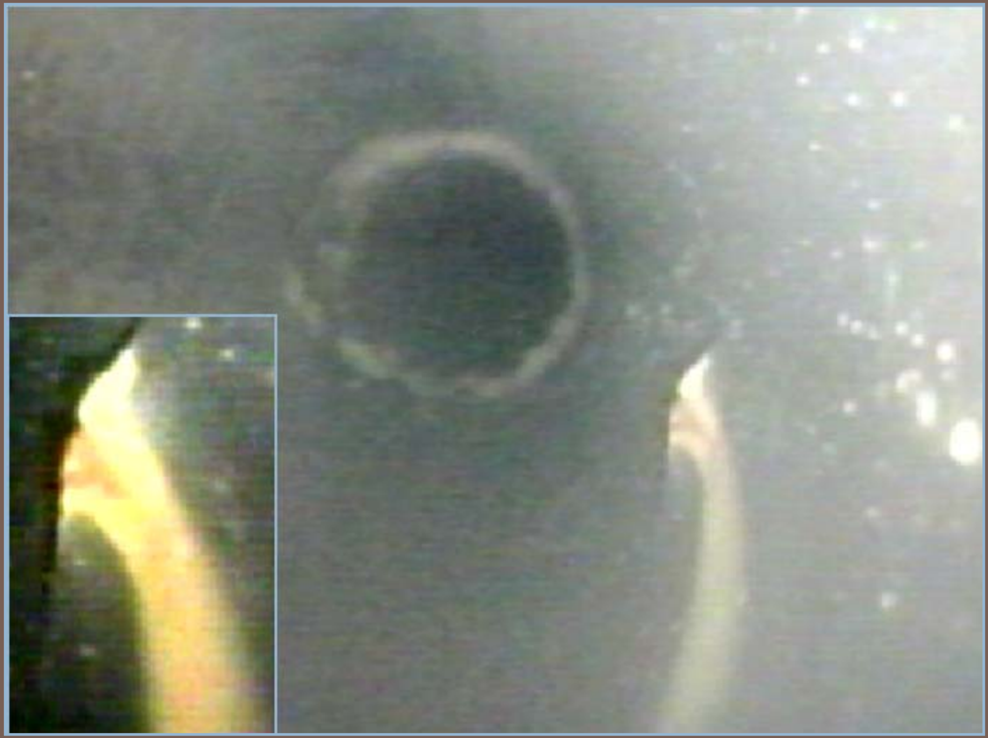
In FY-07 significant increase in coal tar collected during flush Cont'd

Coal Tar Flaking in Fire Protection Water Supply

FY 08 and 09 Funded Actions (examples):

- **Perform Reliability Analysis**
- **Strainer Replacement Project**
- **Coal Tar Study**
- **Flow Testing**
- **Gather Results and Determine Needed Approach**

Coal Tar Flaking and Corrosion in the Device Assembly Facility Fire Suppression System



2009 DOE/Contractor Fire Safety Workshop

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Introduction

- Device Assembly Facility (DAF) fire suppression system:
  - Main 10-in. diameter, mortar-lined, ductile iron header loop.
  - 29 ASTM A106 Sch 40 carbon steel pipes (4-in. or 6-in. diameter) lead-in lines.
- Lead-in lines lined with CTE per ANSI/AWWA C203.
- Particles and flakes of CTE in flush water since startup.
- DNFSB expressed concerns about continuing degradation of the underground lead-in lines.
- ARES Corporation contracted by NSTec to determine:
  - Determine why CTE lining continues to delaminate,
  - Assess corrosion implications of the loss of the lining, and
  - Identify possible solutions for mitigating these issues.

Technical Approach

- Six lines proposed for evaluation:
  - Five 6-in. diameter lines plus Line 712, a 4 in. diameter line.
- Techniques:
  - CTE particle analysis,
  - Lead-in line water analyses,
  - Borescopic videos, and
  - Remote Field Tool (RFT) – remote field eddy current.
- Could not fully investigate all the lines as planned.
  - Unexpected joints and elbows in pipes below DAF floor.
- Collected as much field data as possible.

Inspections

Line	Diameter	RFT Inspection	Borescopic Inspection?	CTE Analysis?	Water Testing?
370-1E	6 in.	Yes	Yes	Yes	Yes
370-1W	6 in.	Yes	Yes	Yes	Yes
712	4 in.	No	Yes	Yes	Yes
494	4 in.	No	Yes	Yes	Yes
492	4 in.	No	Yes	Yes	Yes
711	4 in.	No	Yes	Yes	Yes
491	4 in.	No	Yes	Yes	Yes
301	6 in.	No	No	Yes	Yes
303	6 in.	No	No	Yes	Yes
354	6 in.	No	No	Yes	Yes
352	6 in.	No	No	Yes	Yes
Feed Tank		No	No	N/A	Yes

CTE Particle Analysis

- Analysis of 831 CTE samples collected in 2000 – 2008:
  - Weighed and categorized by line,
  - Visual and microscopic inspections,
  - Lining thickness measurements,
  - Temperature at application, and
  - Comparison with borescopic videos of line interiors.

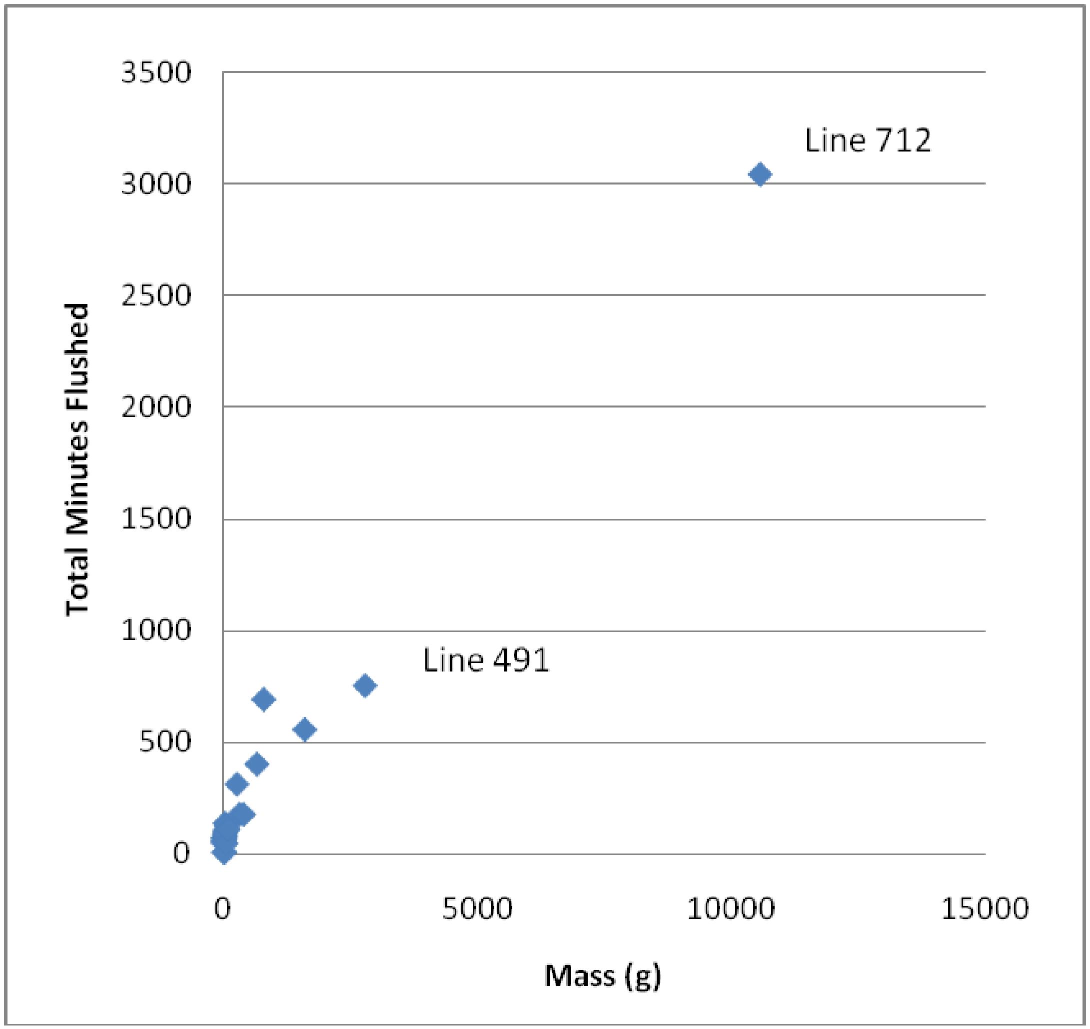
CTE Particle Analysis (Cont'd)

- Surface profile: ~0.5 mils.
  - AWWA C203: 1.5 to 3.5 mils.
  - No sharp, angular profile on the backs of the samples.
- Piping improperly prepared for application of CTE.
  - Proper surface preparation is critical to adhesion.
- Random chip sampling, 40 to 60 mils in thickness.
  - AWWA C203 recommends 62 to 125 mils.
- Does not meet minimum thickness requirements.
- Lack of corrosion product on the back of many samples.
  - Mechanical stripping, likely due to high flow rates.

CTE Particle Analysis (Cont'd)

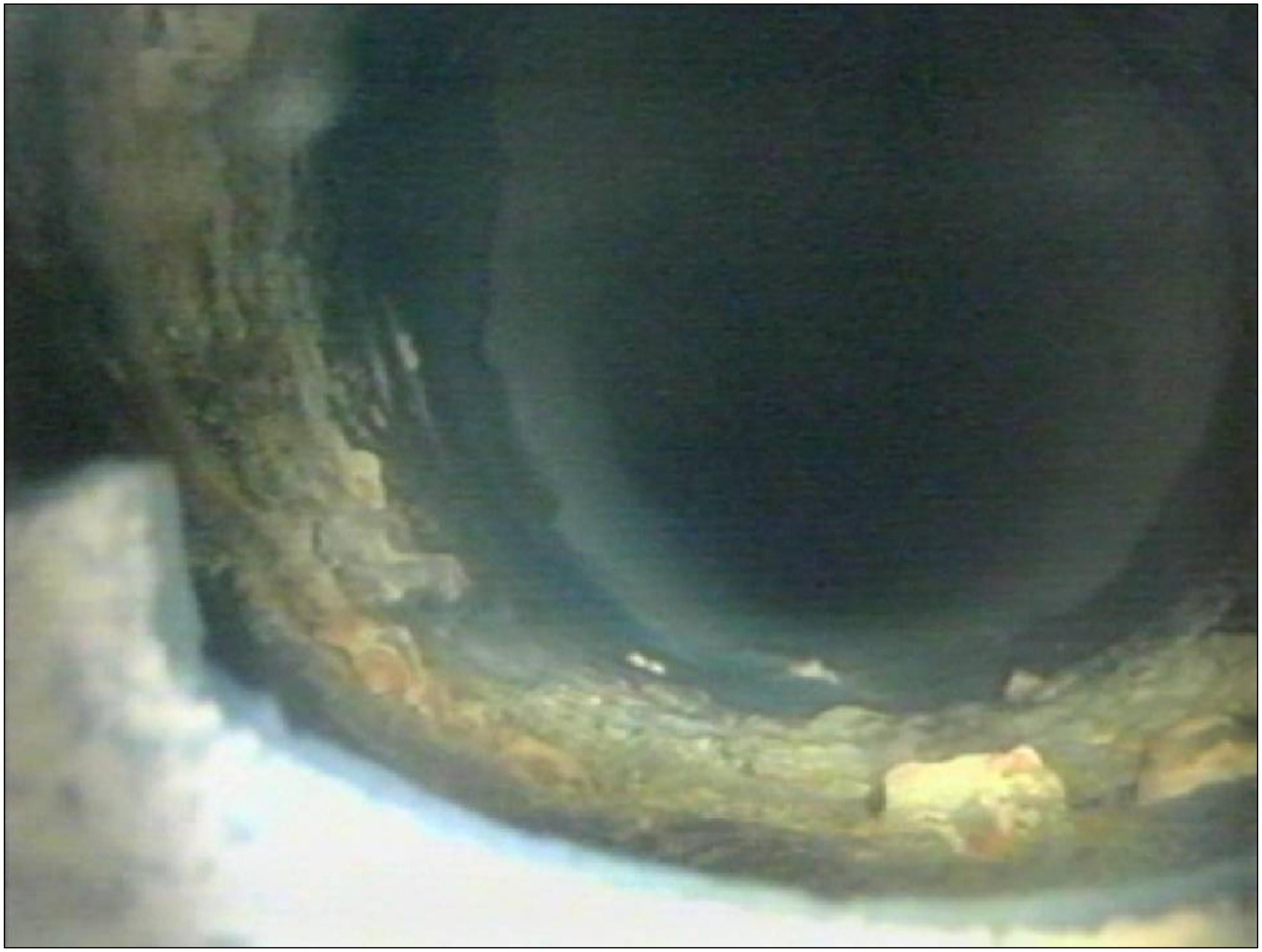
- Pipes welded, not flange-fitted.
- Welding damage provides initiation points for delamination.
- Pits/blisters provide new initiation points.
- Lining continues to delaminate once initiated.
  - Poor adhesion + turbulence + viscous forces + corrosion.
- Supported by video: CTE lining loss well away from joints.
- Supported by flow rate data: flushes (<15 ft/sec).
  - Good CTE should withstand ~45 ft/sec.
- Current flushing protocol likely exacerbates delamination.
  - Oxygen for corrosion and high flow rates to strip CTE.

CTE Mass Loss vs. Flush Time

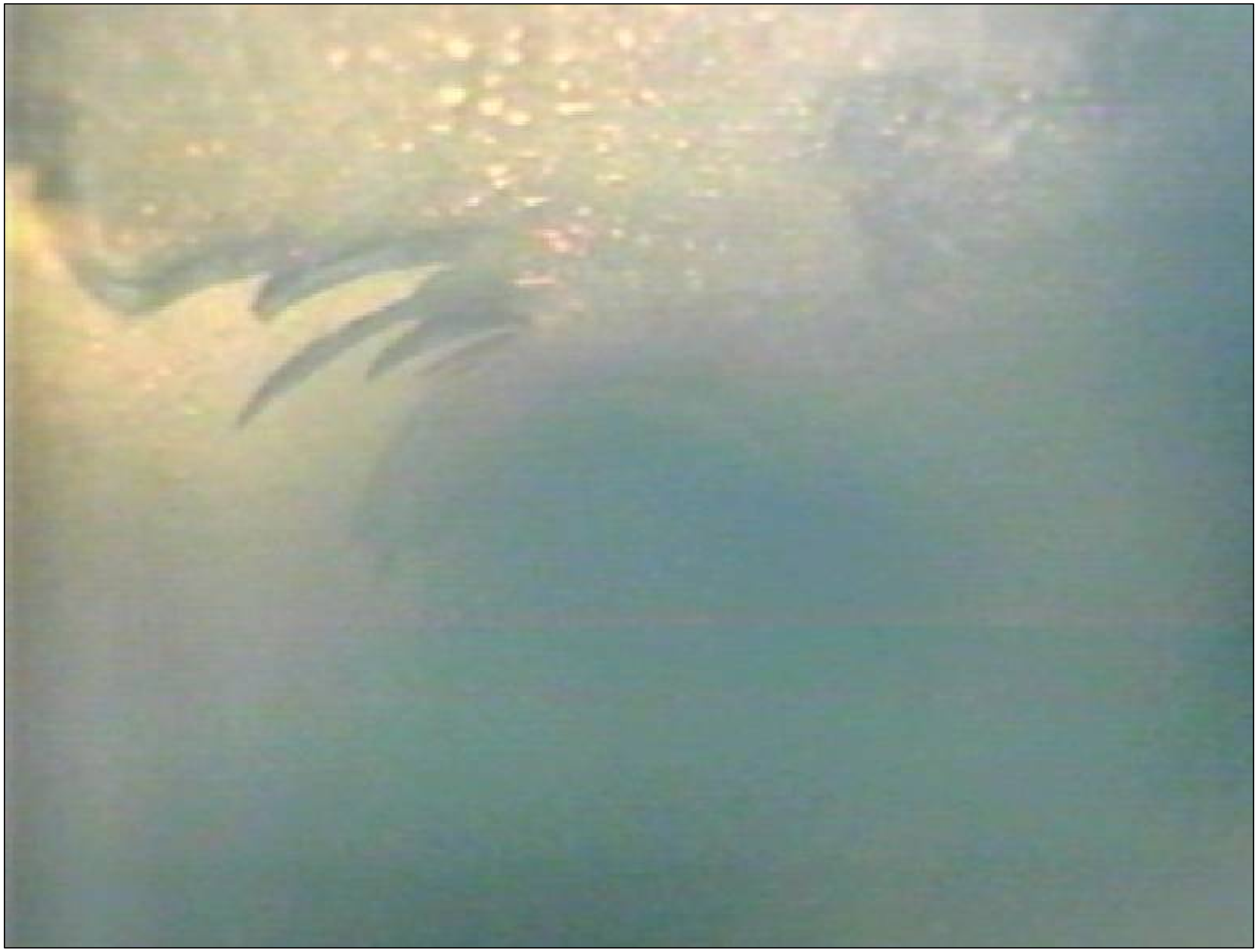


- Mass loss by line varies over four orders of magnitude.
- Generally linear relationship between flush time and mass loss.

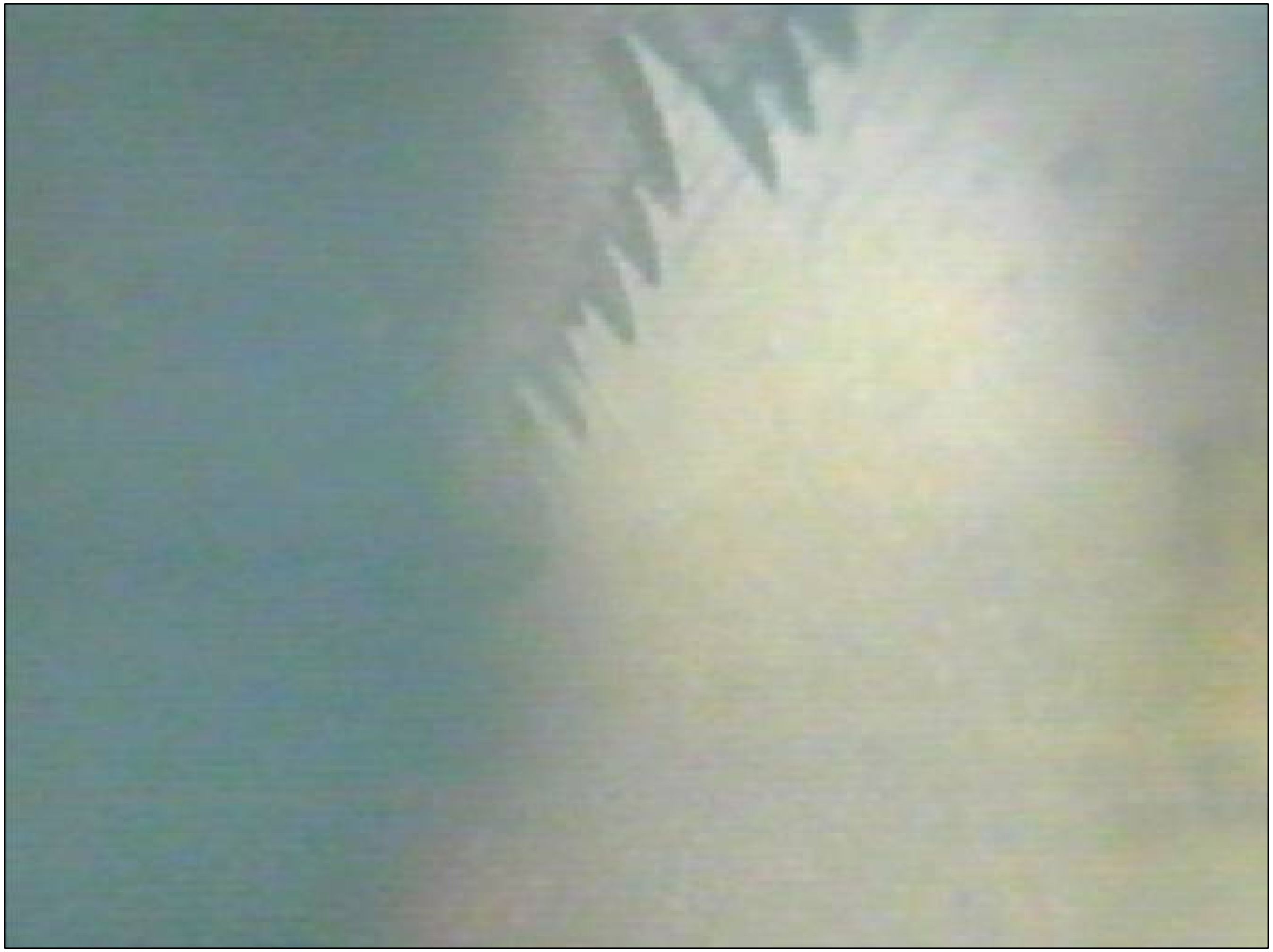
Liner Damage at Welds: Line 370-1W, Third Joint (87 ft.)



Delamination:
Line 712 (Between DIP & Joint 1)



Delamination:
Line 712 (Between Joints 2 & 3)



Delamination:
Line 491 (Between Joints 5 & 6)

Microbiologically Induced Corrosion

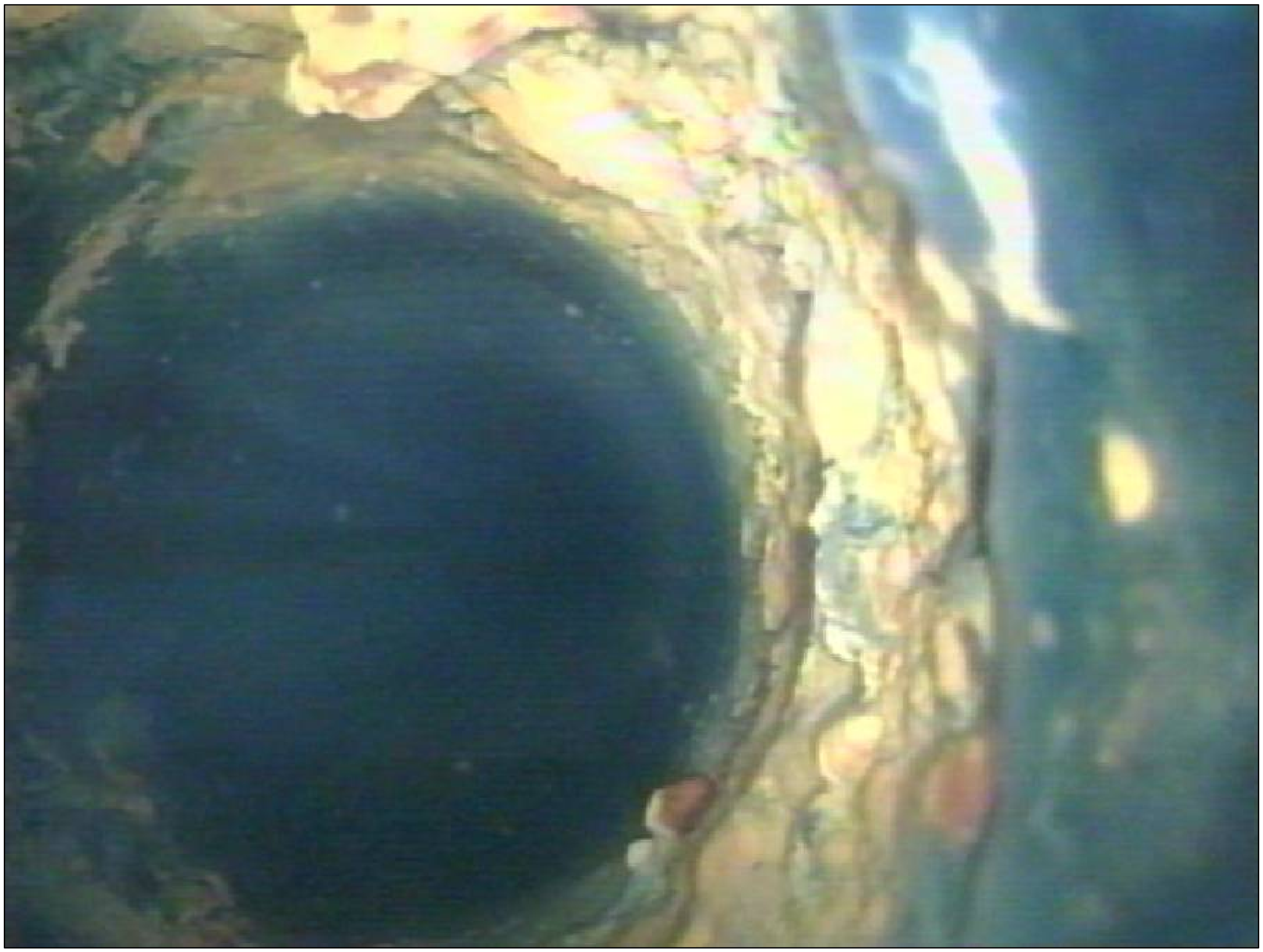
- MIC is simply corrosion accelerated due to microbial activity.
- MIC common in FPS with extended periods of wet or dry lay-up.
- Produces slime (bio-mass) and tubercles…
  - lumpy growths of corrosion products, living/dead cells, and accumulated sediment.
- Tubercles isolate metal surface underneath from bulk solution.
  - Pitting often under tubercles due to isolation.
  - Localized corrosion and rates of metal loss can be high.
- Treatment of the underlying microbes with a biocide difficult.
  - Most treatment relies on contact of the chemicals with living cells.

Water Testing for MIC

- Water tested in each line opened for chlorine and MIC-producing bacteria common to fire suppression systems.
  - Aerobic bacteria
  - Acid-producing bacteria
  - Sulfate-reducing bacteria
  - Iron-related bacteria
  - Low nutrient bacteria
- All lead-in line water samples tested positive for some.
- Tubercles consistent with MIC observed with borescope.
- Residual chlorine levels essentially zero in most lines.

MIC Tubercles:
Line 370-1E, Second Joint (77 ft.)

MIC Tubercles:
Line 711, Sixth Joint (114 ft.)



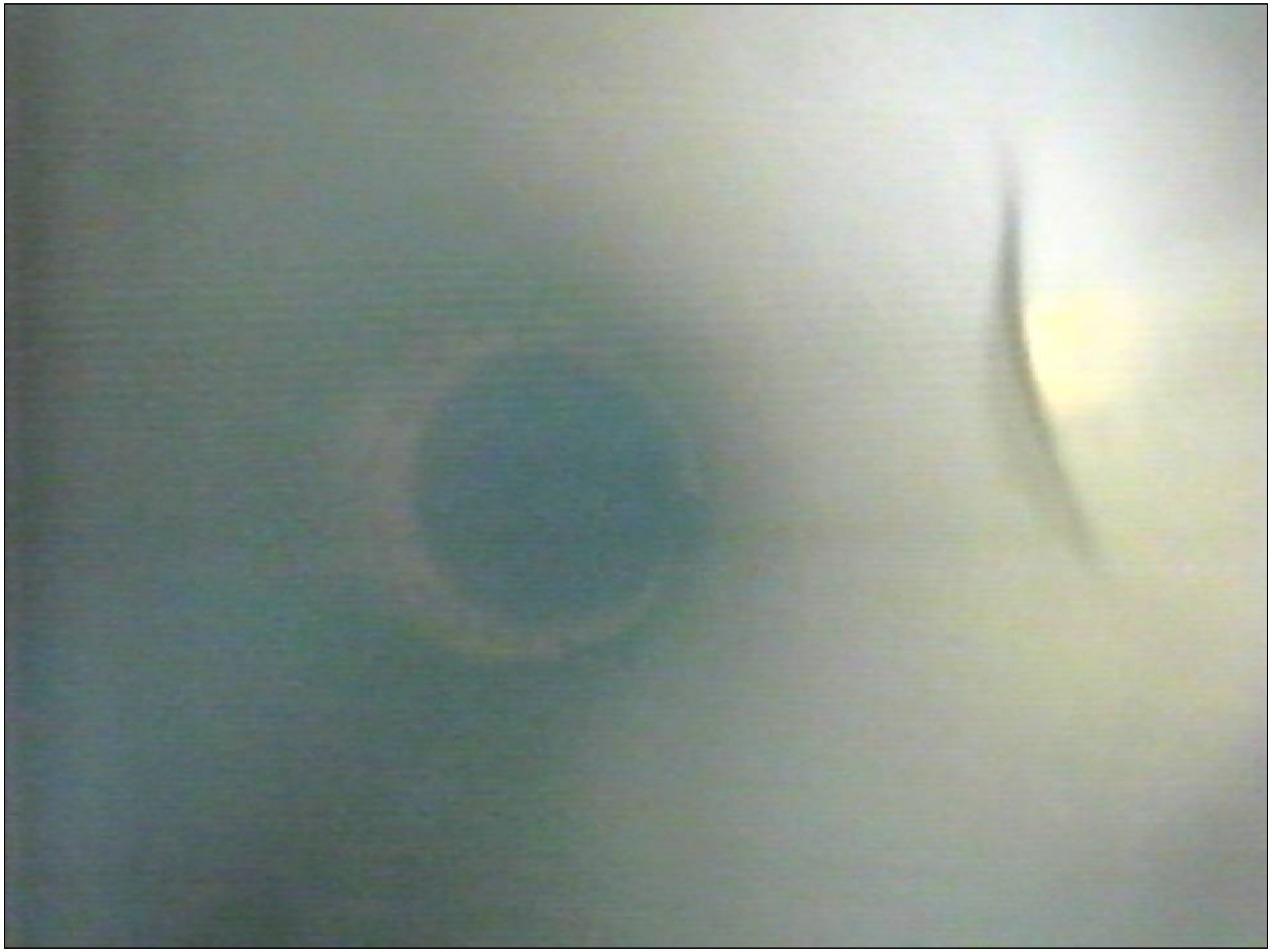
MIC Tubercles:
Line 711, Seventh Joint (131 ft.)

Morphology of MIC

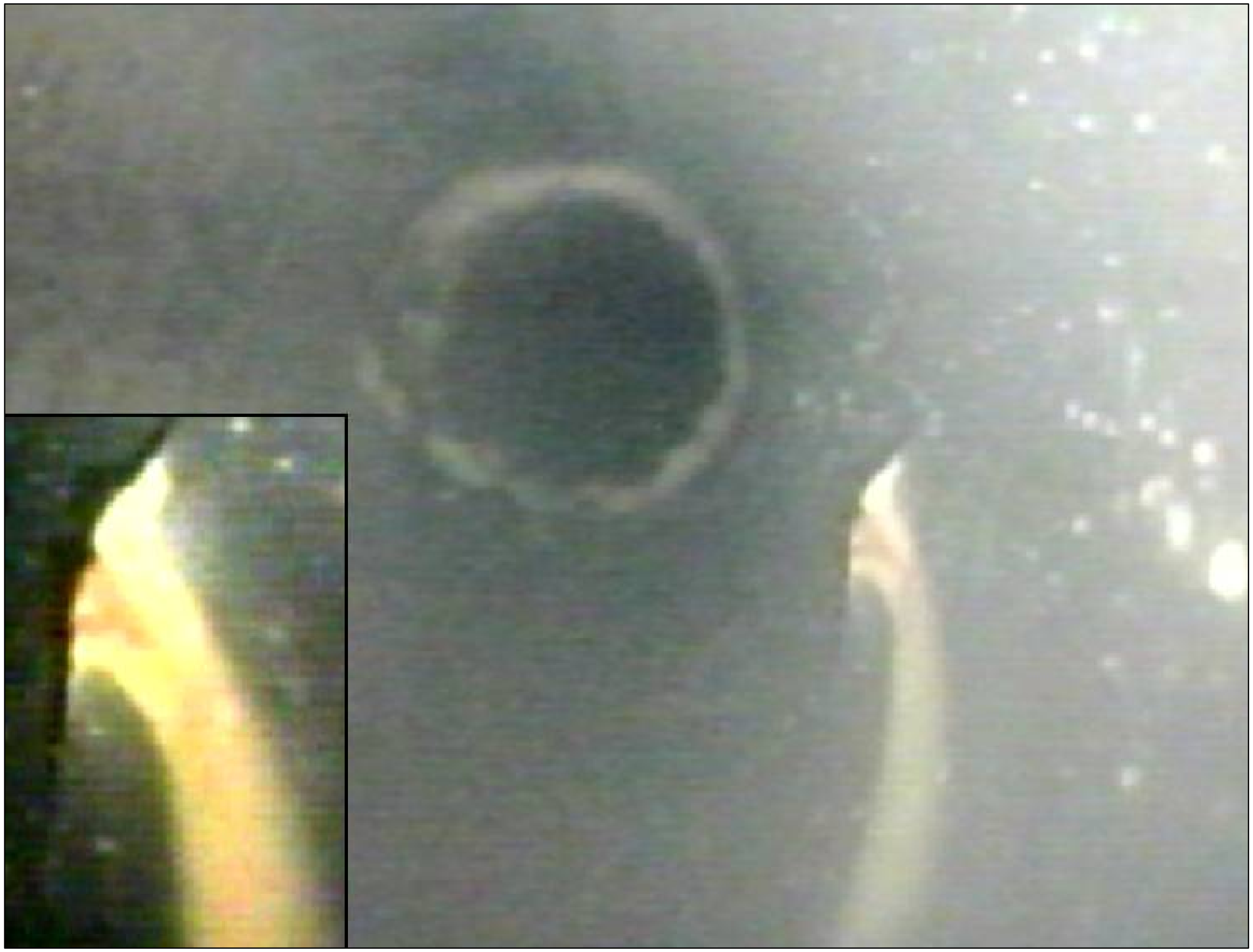
Blistering & Pitting Corrosion

- Blistering of liner due to corrosion.
  - Pits Initiate at holidays/defects in lining.
- Local area caps, fills with corrosion product
  - Differential aeration cell forms to accelerate corrosion
  - Can acidify over time further accelerating corrosion.
- Metal dissolution concentrated in small areas.
- Corrosion can become autocatalytic under cap.
  - Increasingly rapid rates of corrosion.
  - Unresponsive to changes in the bulk water chemistry.

Blistering & Pitting:
Line 494 (Downstream of Joint 6)



Blistering & Pitting:
Line 711 (Between Joints 3 & 4)



Blistering & Pitting:
Line 711 (Between Joints 4 & 5)

Galvanic Corrosion

- Brass Pressure Isolation Valves (PIVs) not electrically isolated from the carbon steel lead-in lines.
- Substantial corrosion noted at the brass/steel intersection.
- Damage confined to steel exposed under the edge of the lining adjacent to the PIV.
- Corrosion in this small area is accelerated by galvanic couple.
- Typically prevented with flange insulation kits.
- No insulating kits were specified or observed.

Galvanic Corrosion:
Line 494 PIV/Pipe Intersection

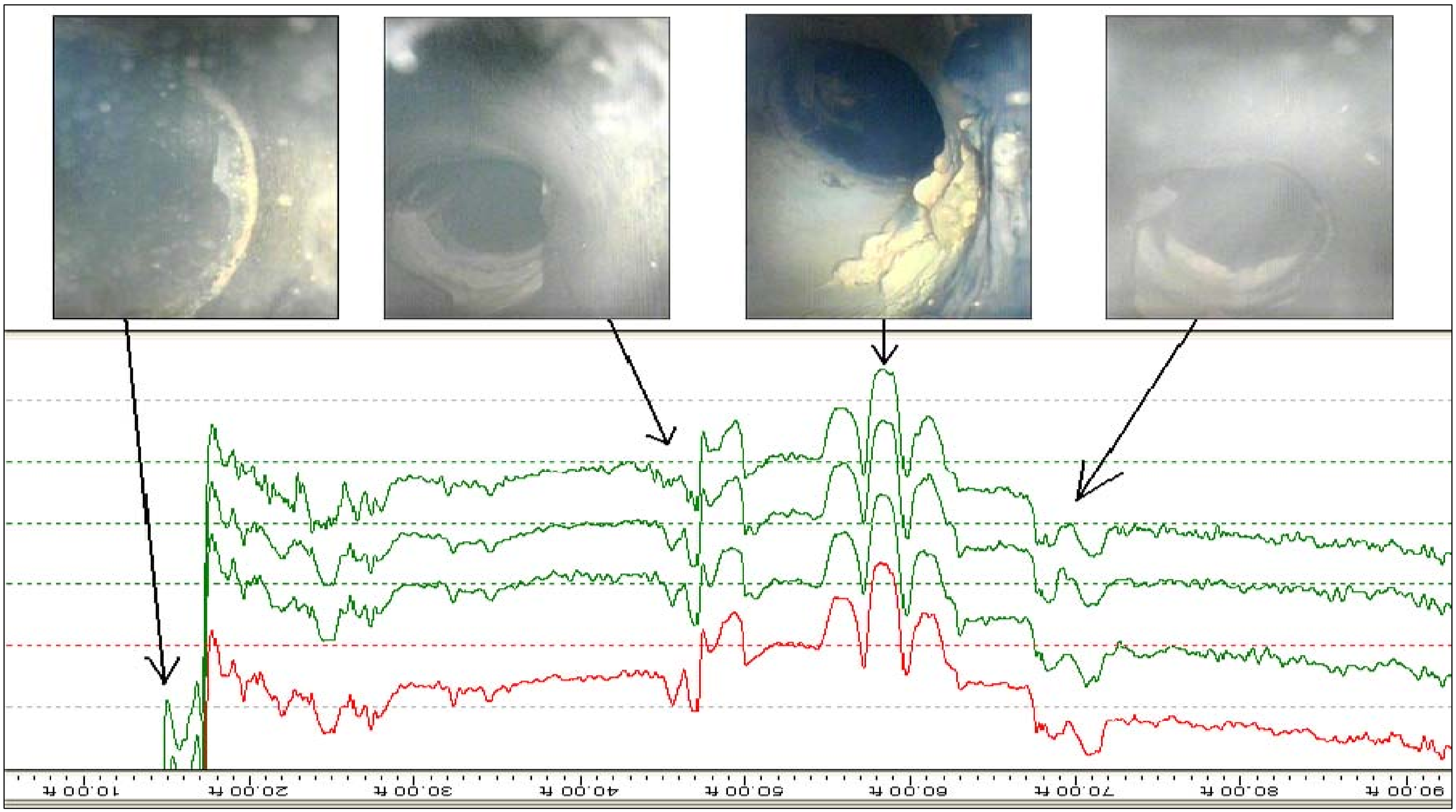
Galvanic Corrosion: Line 370-1W PIV/Pipe Intersection

Wall Thickness: RFT Technique

- RFT: is modification of traditional eddy-current techniques.
- Creates complete map of corrosion damage in pipe wall.
- Inline, water-propelled tool + wireline winch.
- Exciter coil and a circumferential array of detector coils.
- Two coupling paths between the exciter and the detector coils:
  - Eddy currents induced at exciter, pass through wall, along outside wall, then back to detectors…measure “flight time”.
- Anomalies in indirect path change received signal.
- Changes in signal indicate wall thinning/corrosion damage.
- Characterizes both the interior and exterior line surfaces.

RFT Equipment

Example RFT Data: Line 370-1E



RFT Results: Lines 370-1E & 370-1W

370-1E Feature	Max. Wall T Loss (% Nom)
Ductile Iron-to-Steel Flanged Joint	Not Recorded
First Welded Steel Joint	30%
Second Welded Steel Joint	20%
Third Welded Steel Joint	20%
Fourth Welded Steel Joint, End Inspection	Not Recorded

370-1W Feature	Max. Wall T Loss (% Nom)
Ductile Iron-to-Steel Flanged Joint	Not Recorded
First Welded Steel Joint	20%
Second Welded Steel Joint	20%
Third Welded Steel Joint	80%
PIV, End of Inspection	Not Recorded

Other Issues: Cathodic Protection

- There are no CP systems on the DAF lead-in lines.
- Lines coated in CTE and wrapped in Kraft paper prior to burial.
- CP necessary to minimize soil-side corrosion at breaks in coating.
  - Even the best coatings contain holidays from factory.
  - Coatings almost always damaged by handling/backfilling.
  - Shear stresses damage coating as the soil settles.
- Sheer stresses are of particular concern at the DAF.
- Corrosion can be very rapid without the application of CP.
  - High soil resistivities-yes, but gradients in aeration, chloride content, porosity, etc. set up anodes and cathodes on pipe exterior…

Electrical Continuity

- All lead-in lines electrically continuous with DAF:
  - Building ground system
  - Concrete-encased rebar and other concrete-encased steel.
- Not an uncommon problem with fire suppression piping.
- Creates galvanic corrosion cell between the lead-in lines and the copper and/or concrete-encased steel.
- Galvanic cell accelerates corrosion at breaks in coating
  - Both on interior and exterior surfaces.
- Typically prevented with flange insulation kits
- No insulating kits were specified or observed.

Ignored Electrical Continuity

Summary of Inspection Findings

- DAF lead-in lines do not appear to have been properly prepared for CTE lining.
- Delamination is partly mechanical, partly corrosion related.
  - Problem exacerbated by flushing.
- General, MIC, pitting, crevice, and galvanic corrosion are active.
- MIC and pitting present substantial threats to line integrity.
  - Wall thickness loss of 20% and 80% at welded joints.
- Galvanic corrosion at uninsulated PIV/pipe interface.
- No CP.
- Fire piping grounded to building ground systems.

Life Extension

- Reduce line flush rate/periodicity (preserve remaining CTE),
- Pig for deposits (minimize new pitting/crevice corrosion),
- Apply water treatment and corrosion monitoring program,
- Install insulating flange kits (eliminate galvanic cells),
- Install a CP system (minimize external corrosion),
- Inspect balance of system (header loop, internal lines),
- Periodic analysis of biological activity & water chemistry,
- Periodic internal inspection, and
- Eternal vigilance.

Rehabilitation

- Clean/Repair and Treat:
  - Clean/reline and water treat.
  - “Trenchless”, “Repair-in-place” liners, coatings, etc.
    - Becoming more popular...
- Re-plumb/Replace and Treat:
  - Depends on owner’s perspective and risk aversion.
- Run to Failure:
  - Simple, but risky.
  - Most often applied…

Conclusions

- Lining delamination related to:
  - Improper application of liner + corrosion + flushing.
- Lining delamination can be reduced by reducing flushing.
- Corrosion mechanisms are multifaceted; damage is significant.
  - General, MIC, pitting, crevice, and galvanic corrosion are active internally.
  - Lack of CP and building ground issues affecting external degradation.
- Good news: Multiple paths forward…
  - Immediate changes/upgrades can be made to minimize rate of degradation.
  - Longer term rehabilitation options: clean & treat, or repair/replace.

Nevada Site Office
Fire Suppression System Actions

- FY'09 with Carry Over into FY'10:

- Strainer Replacement and FSS Reconfiguration
- Tank Refurbishment
- Stand Alone Units
- Leak Detection

- Long term:

- Replace Water Tank and Lead-in Lines (Line Items)