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Corrosion Control Treatment:
Lessons Learned from the Field

Milt Larsen,
Kennedy/Jenks

Lessons

- Source changes require re-evaluation of corrosion treatment
- Changes in treatment can affect lead & copper corrosion
- Just because the system is “optimized” does not mean there are no corrosion issues
- All plumbers are not created equal
- Pay attention to the NaOH injection point design

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Lesson 1: Changing Sources Require Re-evaluation of Corrosion Control Treatment

- Central Arizona Project
- South Tahoe PUD, CA
- Lake Stevens, WA
- Longview, WA
- Manteca, CA
- Flint, MI

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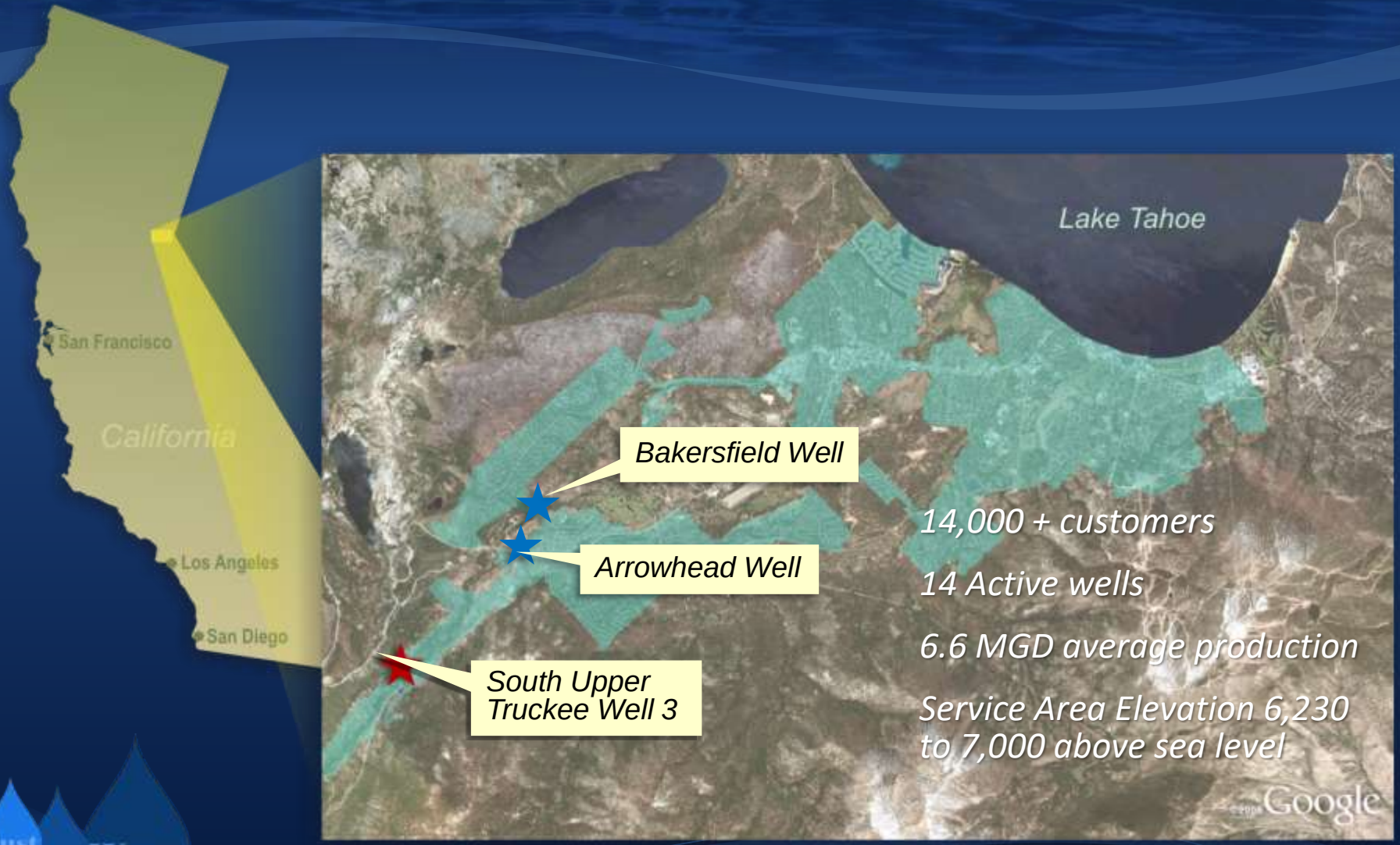
Central Arizona Project

- Tucson
  - Historically used groundwater
  - Imported surface water from CAP
- Destabilized scale on the pipe wall
- Vote to not allow CAP water into system
- Substantial $ spent on corrosion control evaluations and treatment
- CAP water used for ASR

S Tahoe PUD Location Map



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Arsenic Compliance Plan

- Arrowhead & Bakersfield Wells
  - Reduce their production
  - Provide arsenic treatment
- S Upper Truckee Wellfield
  - Increase production
  - Treat to reduce water's corrosivity

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Corrosion Concerns
Christmas Valley Pressure Zone

- Lead & Copper Rule Monitoring (system wide)
  - 90th percentile lead – 6.4 µg/l
  - 90th percentile copper – 0.48 mg/l
- 4 of 7 first draw tap samples exceeded 1.3 mg/l copper when the South Upper Truckee wells were in service
- Premature corrosion failures
  - Hot water heaters
  - Sand separator

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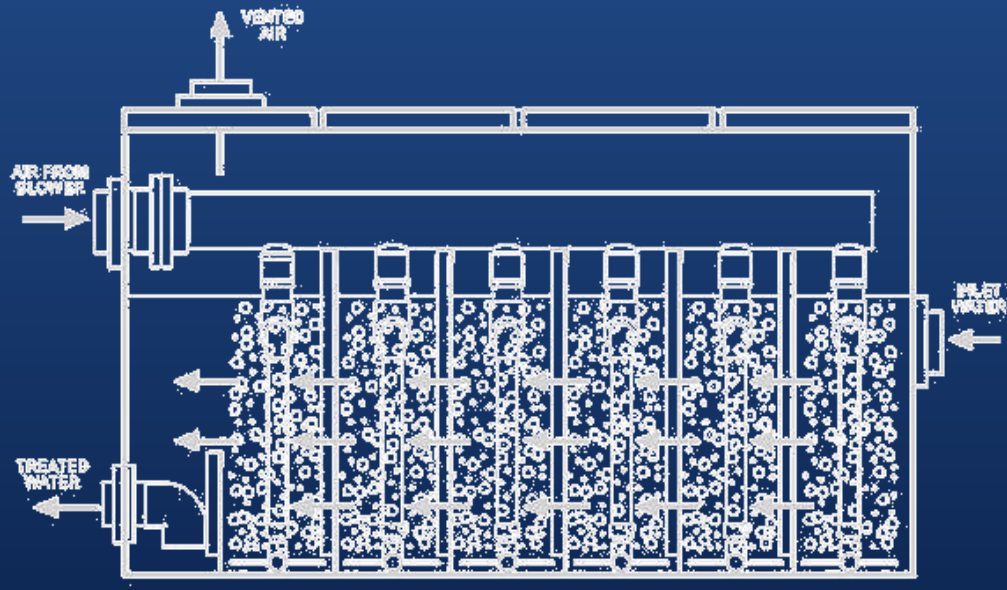
Aeration Alternatives for pH Adjustment

- Low Profile Aeration
  - DeepBubble Mult-Stage Aeration
  - Shallow Tray Aeration
- Packed Tower Aeration
- Venturi Eductor CO_2 Stripping
- Multiple Tray Aeration
- Rotating Packed Bed Stripping



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Pilot Testing

- Goals
  - Raise pH ≥ 7.5
  - CO_2 ≤ 5 mg/l
  - Rn-222 ≤ 300 pCi/l
- Evaluate
  - Copper - corrosion & leaching
  - Lead-tin solder - corrosion & leaching
  - Mild steel - corrosion & scale release
  - Galvanized steel – corrosion & scale release

Pilot Aeration Unit

- Lowered Rn-222
  - Well water 462 pCi/l (median)
  - Aerated water 18 pCi/l (median)
- Stripped carbon dioxide to less than 5 mg/l
- Increased pH from 6.2-6.3 to 7.6
- Moderate increase in dissolved oxygen from 7.4 to 9.5 mg/l

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Linear Polarization Probes & Copper Tubing

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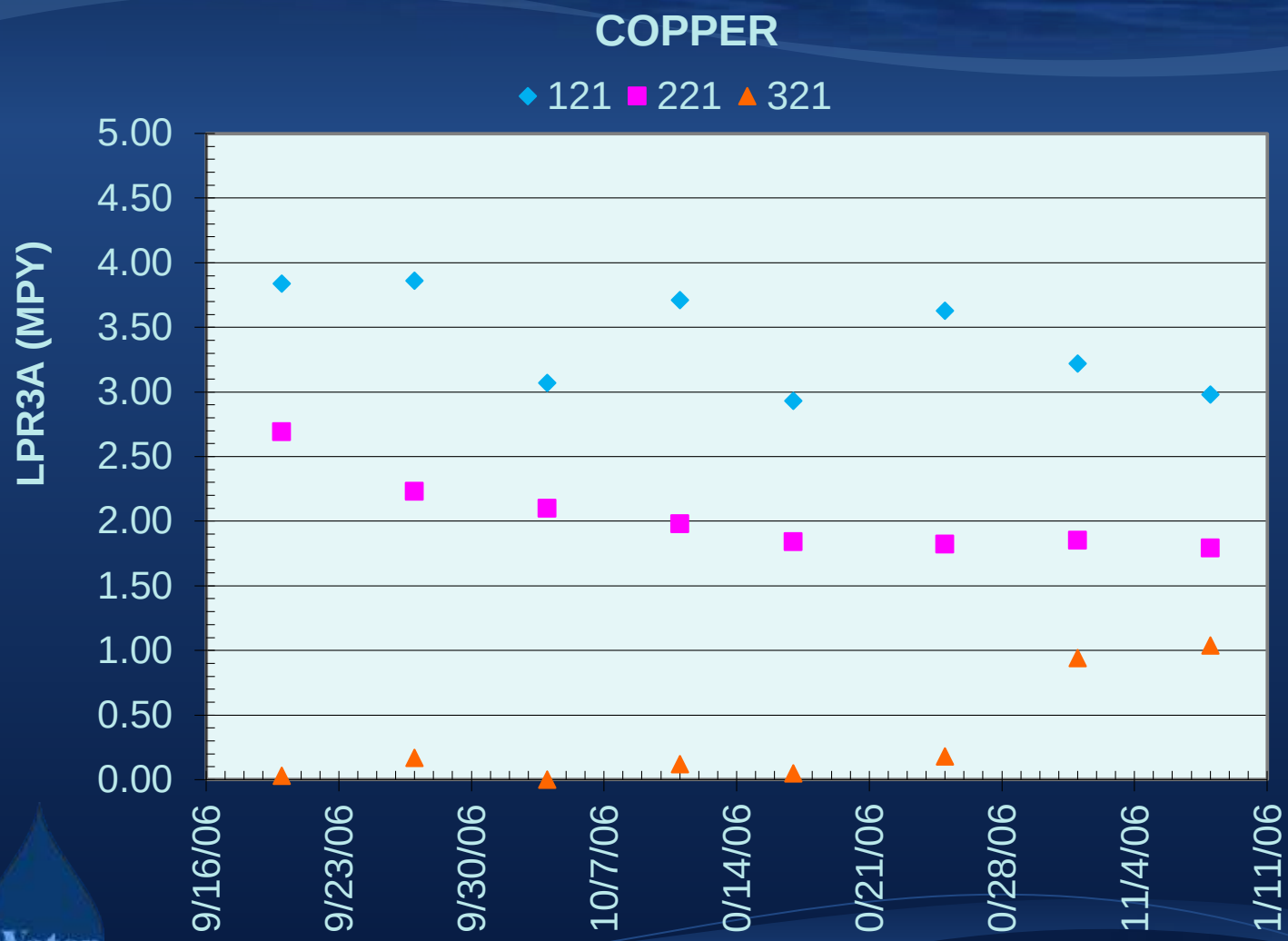
Linear Polarization Measurements: Copper



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Findings: Copper Corrosion

- Aeration
  - Reduced copper corrosion 34%
  - Reduced first draw copper 30%
- Aeration plus sodium silicate
  - Reduced corrosion 83%
  - Reduced first draw copper 58%
  - Silicate addition was beneficial
- Uniform corrosion
- No pitting corrosion observed

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Findings: Lead-Tin Solder Corrosion

- Aeration
  - Reduced lead-tin corrosion 90%
  - Reduced first draw lead >77%
  - Uniform corrosion with very slight pitting
- Aeration plus sodium silicate
  - Reduced lead-tin corrosion 52%
  - Reduced first draw lead >77%
  - Uniform corrosion with very slight pitting
  - Silicate addition not beneficial

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Treatment Recommendations

- Provide low profile aeration for South Upper Truckee Well No. 3
- Provide room for 3 mg/l NaOH feed or sodium silicate
- Collect lead & copper tap samples after the facility has been on line 4-6 months

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South Upper Truckee Well 3 Aeration Facility

- 2 DeepBubble Multi-Stage Aeration Units
- Results
  - Raised pH from 6.35 to 7.75
  - Reduced CO_2 from 30 mg/l to <2 mg/l
  - Reduced Rn from 589 pCi/l to 44 pCi/l
  - Christmas Valley tap samples (90th percentile)
    - Pb <2.5 µg/l
    - Cu 0.03 mg/l
  - Supplemental sodium hydroxide is not necessary

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South Upper Truckee Well 3 Aeration Facility

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Lake Stevens

- Everett water
  - Elevated DO: 11.0 mg/l
  - High ORP: 600
  - Soft, low alkalinity, low TDS water
- Lake Stevens well
  - Low DO: 0.5 mg/l
  - Low ORP: 350
  - Moderately hard, iron, manganese, H_2S, ammonia
- Groundwater introduced into area previously receiving surface water
  - Destabilized iron scale on galvanized steel and steel pipe
  - Leaks in unlined steel
  - PUD discontinued use of well as a result

Manteca, CA

- Originally 100% groundwater supply
- 2005 – Sierra surface water supply added
- Red water complaints
  - Manteca– pre 1970 galvanized services & plumbing
- No red water complaints
  - Tracy – Zn barrier coat
  - Lathrop – new community
- 90th percentile Pb & Cu
  - Virtually unchanged

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Manteca, CA Surface Water

- Surface water: low TDS, high DO
- Ryzner Index: 9.3
  - >8 increasingly corrosive of iron & steel
  - >8.5 typical of red water conditions
- Cl^-/SO_4^{-2} mass ratio: 2.8
  - >0.58 increased galvanic corrosion
- Cl_2 residual: 1.2 mg/l at turnouts
  - > 0.8 mg/l increasing corrosive to steel

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Manteca, CA

- Florist shop
  - Galvanized service
  - Received groundwater in morning
  - Received surface water in afternoon
  - pH varied 7.4 to 8.2
  - TDS varied 82 to 260 mg/l

Manteca Corrective Action

- Modify operation of S San Joaquin Irrigation District WTP
  - Initially operating at pH 8.0 & 40 mg/l alkalinity (lime & CO_2 addition)
  - Reduced CO_2 addition
  - Raised pH near 8.5
- Orthophosphate addition at turnouts
  - Not implemented

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Lesson 2: Changes in treatment can effect lead & copper corrosion

- Washington, DC

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Washington, DC

- Potomac River source of supply
- Conventional treatment with free Cl_2 residual
- 1992 – June 1994 initial LCR sampling exceeded Lead Action Level
- 1993-1996 TCR violations
- 1994 increased Cl_2 residual to 4 mg/l
  - ORP increased
  - Pb (II) scale oxidized to Pb (IV)
  - PbO_2 scales low solubility over wide pH range
- June 1997 optimum corrosion control LSI > 0

Washington, DC

- 1992-2004 seasonal pH fluctuation 7.0 to 8.9
- Feb 2000 optimum corrosion control pH
  - 7.7 ± 0.3 points of entry
  - 7.7 ± 0.3 distribution samples
- May 2002 optimum corrosion control pH
  - 7.4 to 7.8 points of entry
  - 7.0 distribution samples
  - Retroactive to July 2000
- Feb 2000 reduced tap monitoring

Washington, DC

- Nov 2000 converted to chloramine
  - Lower ORP from >650 mV to 450-500 mV
  - Pb (IV) scale reverted to Pb (II)
  - Pb (II) influenced by low and varying pH
- Exceeded Lead Action Level 2000 – 2004
  - 90th percentile 36 to 75 µg/l
  - 17 to 68% samples exceeded 15 µg/l
- Aug 2004
  - Orthophosphate addition
  - pH 7.7 ± 0.1 goal (± 0.3 enforceable)

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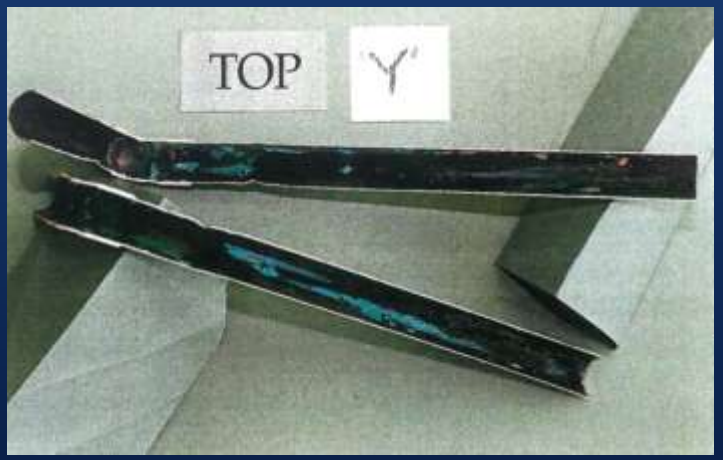
Lesson 3: Just because the system is "optimized" does not mean that there are no corrosion issues

- Horizon House, Seattle – fire sprinkler & recirculation hot water system leaks
- Spokane VA Hospital – fire sprinkler leaks
- San Ramon, EBMUD – blue water
- Manteca, CA – red water
- Hollister Country Rose – blue water



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Horizon House - Seattle

- Three Buildings Housing 450 Elderly Assisted Living Housing
- Buildings – 5 to 20 Years Old.
- Water Supply: LCR Optimized
  - pH – 8.0 - 8.2,
  - Alkalinity > 20 mg/l $CaCO_3$
- Problems:
  - Recirculating Hot Water Copper Pipe Pitting Failures
    - 10 - 15 years
  - Fire Sprinkler Water Supply Steel Pipe Pitting Failures
    - 15-20 years

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Horizon House

- Sink Sampling for Copper
  - Hot Water – 0.5 mg/L + 0.2 mg/l
  - Cold Water – 0.2 mg/l + 0.1 mg/l
- Corrective Measures:
  - Smaller hot water circulating pumps to lower velocity from 7 to 3 ½ FPS
  - Use Type L copper rather than Type M (increased wall thickness)
  - Phosphate corrosion pot feeders for fire sprinkler supply
  - Reduce frequency of fire sprinkler pipe flushing from weekly to monthly

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EBMUD: San Ramon

- EBMUD optimized for corrosion control
- Source: S Bay Aqueduct
- Extended transmission main with new reservoir to serve developing area
- Water age
  - Lost chlorine residual
- ≈ 5,000 residences
- 40 - 50% blue water complaints

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EBMUD: San Ramon

- Poorly adherent malachite scale
- Rechlorination station installed after the reservoir
- Building moratorium
- Developers sued EBMUD
- EBMUD sued insurance company
  - Battling experts
    - MIC
    - ORP
  - >$10 million award

Conclusions:

- Changing treatment and water quality can destabilize corrosion scale
- Corrosion problems occur even when system has “optimized” per LCR
- Water quality and purveyor are often blamed
- Water purveyors need to carefully assess situation or liability can be substantial

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Lesson 4: All Plumbers Are Not Created Equal

- Duplex in Pierce County served by a groundwater
- The Hamilton, Palo Alto

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Pierce County Duplex

- First draw copper > 6 mg/l
- Concerned resident
- Attorneys got involved
- Plumbing samples collected
- Acidic flux runs

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The Hamilton Apartments: Palo Alto

- 3-Year-old building housing
- 35 luxury residences for elderly
- Kitchen and dining room
- All copper piping
- Black greasy scum in tubs and sinks
- Particulate matter clogging faucets in a week
- Discoloration of kitchen cartridge filters in a week
- Plumber/contractor responsible under warranty

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Excess Flux and Dirt Deposits in Luxury Apartment Residence – Palo Alto, CA

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The Hamilton Water Quality Testing

Before – Chlorine Disinfection of Apartment Complex Plumbing

	Cold Water	Hot Water
HPC	91 – 3700	3700 – 57,000
Coliform	1 Positive/4	0 Positive/3
Iron	1.35 mg/l	1.5 – 3.2 mg/l
Copper	1.6 mg/l	1.5 – 6.5 mg/l

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The Hamilton – Water Quality Testing

After Chlorine Disinfection (200 mg/l for 3 hrs)

	Cold Water		Hot Water	
HPC	0 – 4	0 – 14	0 – 2	0 – 52
Coliform	0/14	1/14	0/14	0/4
Iron (mg/l)	< 0.05	0.10	< 0.05	0.15
Copper (mg/l)	0.01	0.05	0.07	0.10
pH	8.45	-	7.98	-

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*The Hamilton – 3 Months After Chlorine Disinfection**

- Tub Film Testing
  - Petroleum hydrocarbons - 5. 9%
  - Copper - 2.3 mg/l
  - Iron - 0.06 mg/l

**200 mg/l for 3 hours*

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Corps of Engineers Hot Water Flushing Technique to Dissolve Excessive Flux

- Temperature: 160 – 180ºF
- Velocity: > 7 FPS
- Time: 4 Hours
- Facilities Engineering Application Program
  - FEAP - TR – FM – 94109 – June 1994
- “Demonstration of a field rehabilitation technique for removing corrosive solder flux in cold water copper piping systems.”

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Lesson 5: Pay attention to the NaOH Injection Point Design

- Pipeline immediately downstream of NaOH can have a pH significantly higher that the downstream distribution system
- Do not feed NaOH near a control valve
- Have a positive NaOH shutoff at the injector

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Do Not Feed NaOH in Front of a Control Valve

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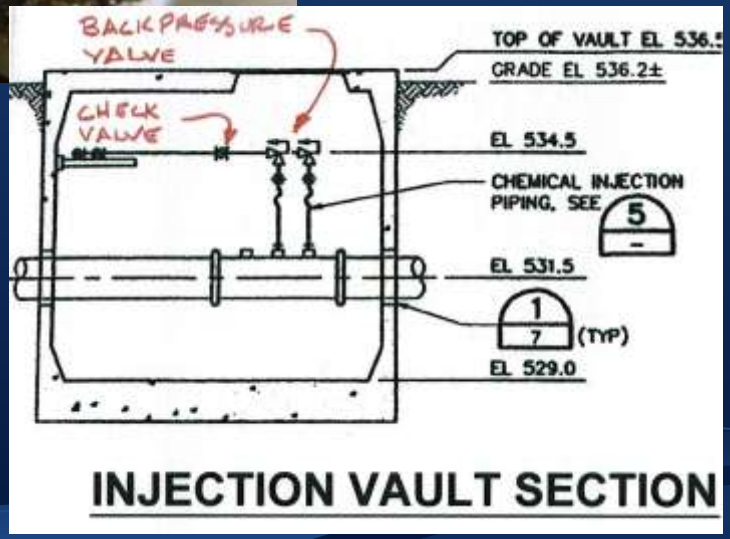
NaOH Injected Above the Pipe

- NaOH may leak into water main when the well shuts down
- $CaCO_3$ precipitate will form in the pipe



INJECTION VAULT SECTION

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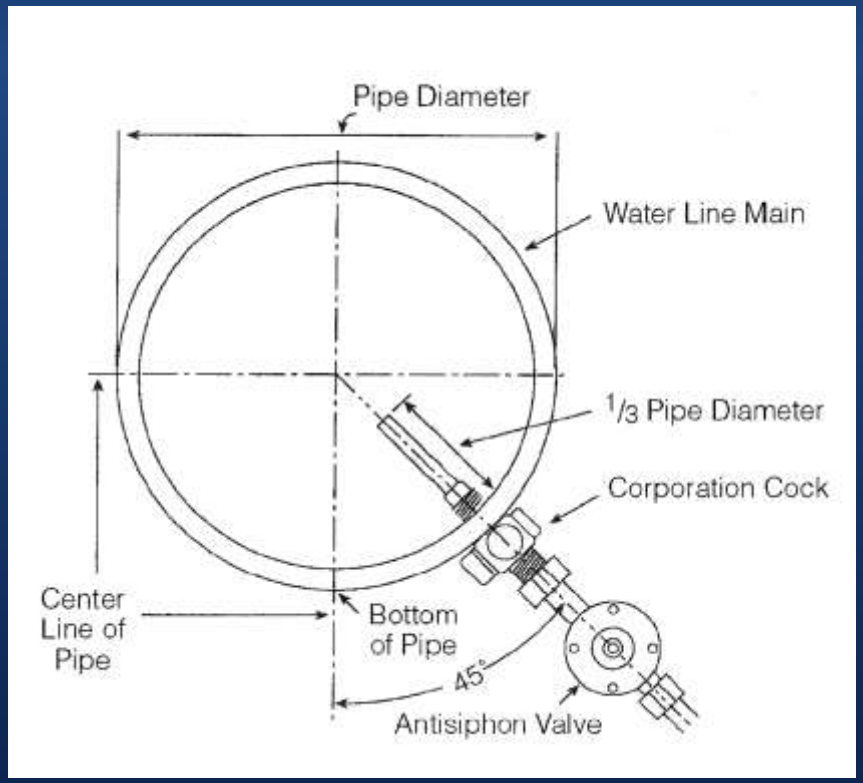
Improved NaOH Injection



- Install the injector & NaOH piping below horizontal centerline
- Consider installing an electrically actuated ball valve near the injector interlocked with the well pump starter

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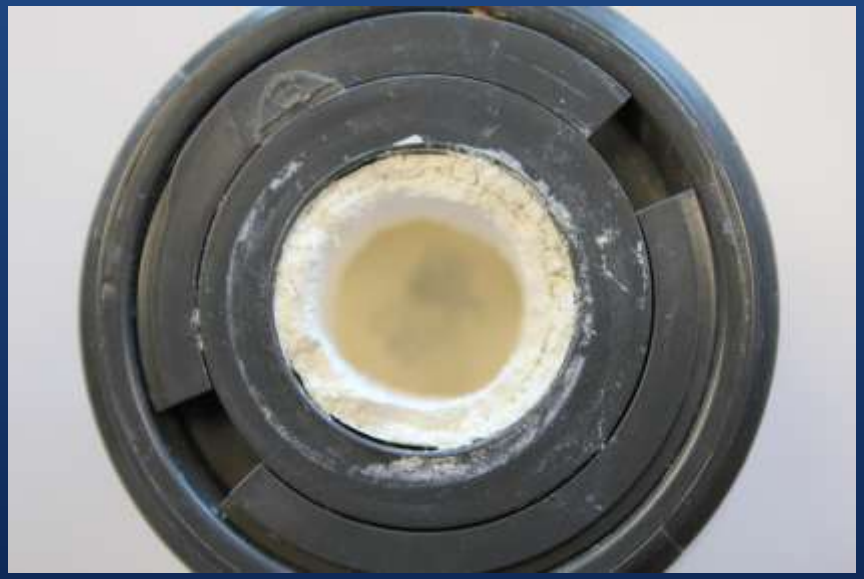
Soften Carrier Water if Used



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Questions