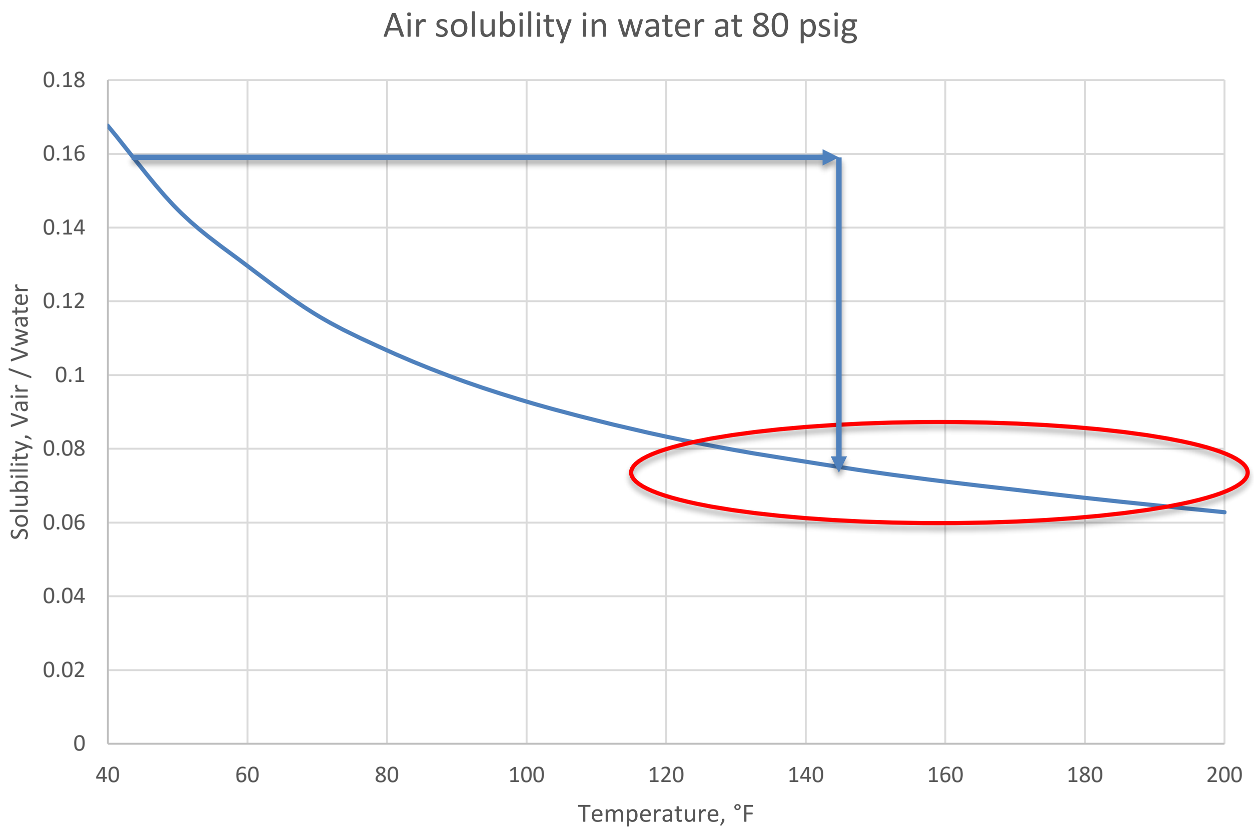
CAVITATION DAMAGE TO POLYPROPYLENE PIPING IN HIGH-RISE DHWR APPLICATIONS

JAMES R. PASCHAL, P.E.

Topics

- Temperature
  - Air/oxygen, Total Dissolved Gas (TDG) content
  - Boiler conditions
  - Saturation, source water
- Pressure
  - Air/oxygen, Total Dissolved Gas (TDG) content
  - Strength vs. temperature relationship
  - Water hammer, pressure surge and low pressure, transient
  - Cavitation
- Flow
  - Hydraulic balancing
  - Flow restriction
  - Velocity changes, water hammer
- Water Chemistry
  - Oxidation, pH, ORP
  - Sources of oxidizing chemicals
  - Accelerating effects of temperature, catalysts
- Cavitation damage examples
  - Domestic hot water recirculating systems
  - Mechanical damage, crack initiation
  - Stabilizer depletion, crack propagation

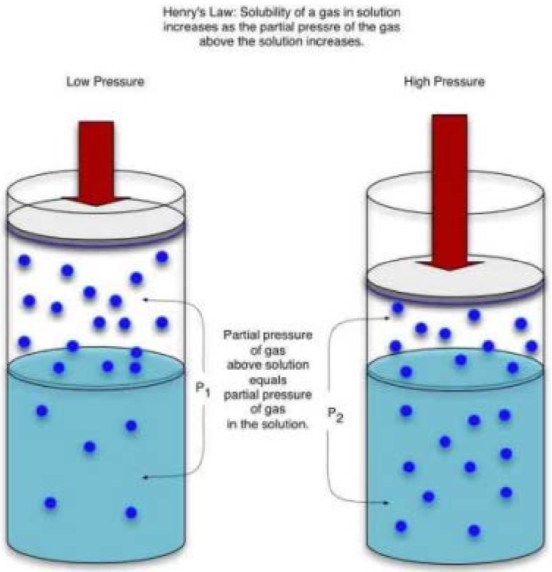
Temperature



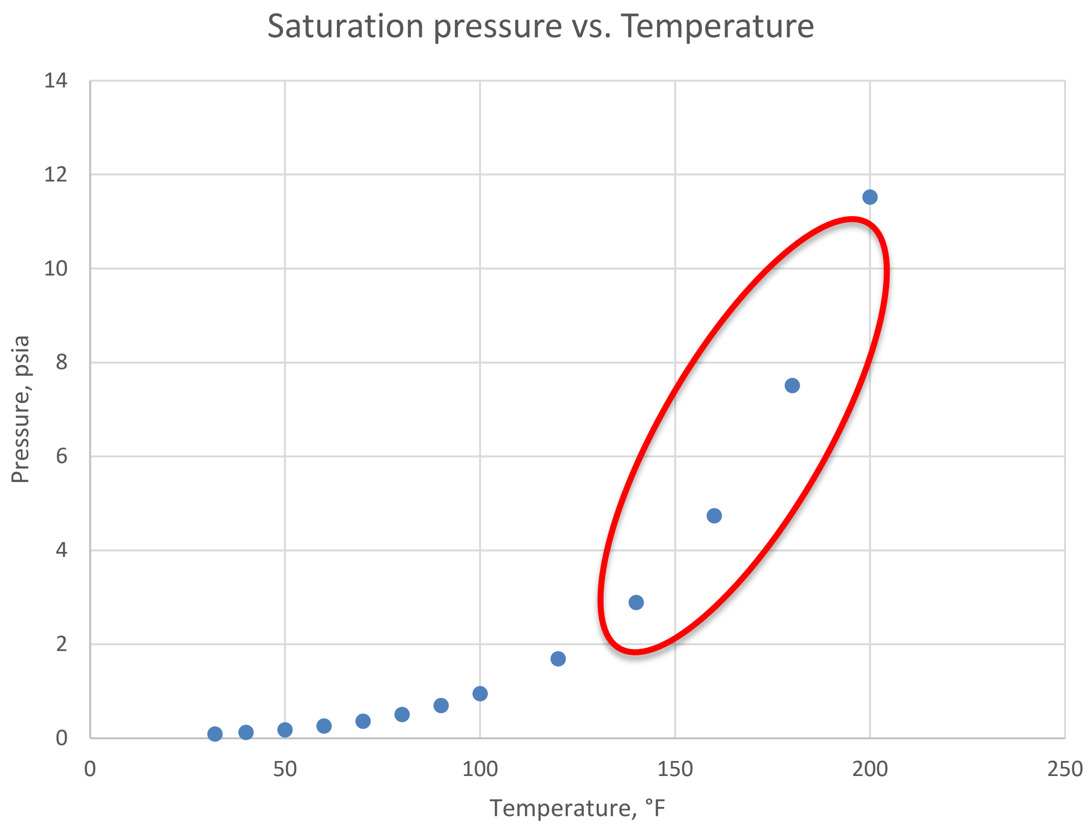
- As temperature increases, dissolved air comes out of solution
- For plumbing systems, incoming cold water is normally close to saturation

Temperature

- Gaseous cavitation
- Pressure falls below saturation pressure of fluid
- As temperature increases, saturation pressure decreases
- Release of gas, less dissolved gas in fluid, higher gas concentration out of solution



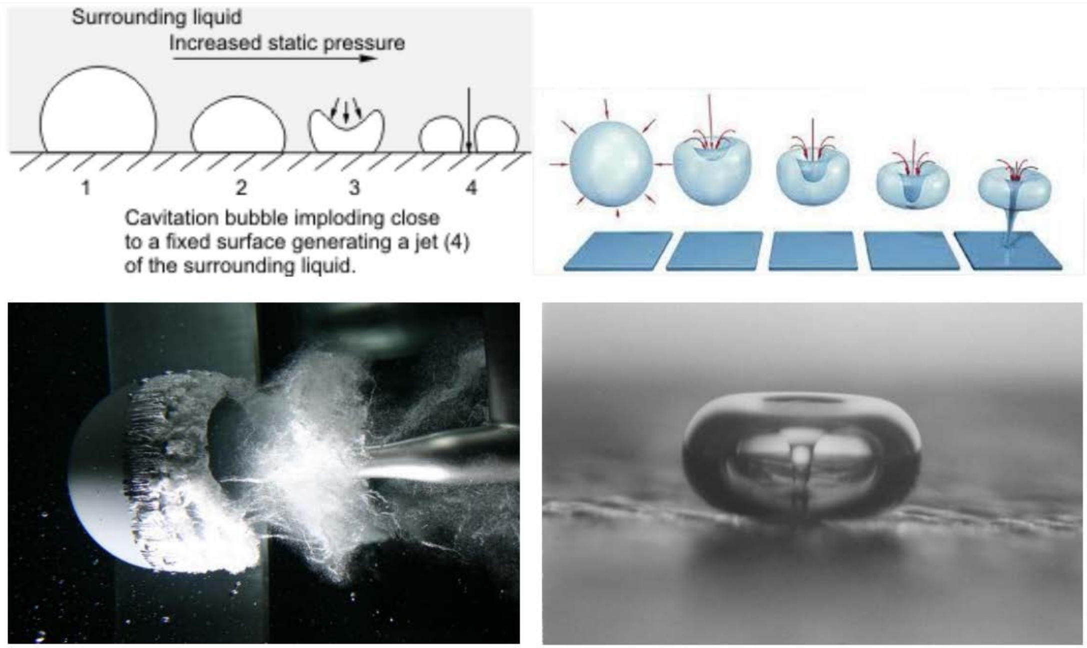
Temperature



- As temperature increases, vapor pressure increases
- Increases likelihood of vapor bubbles forming in low pressure region

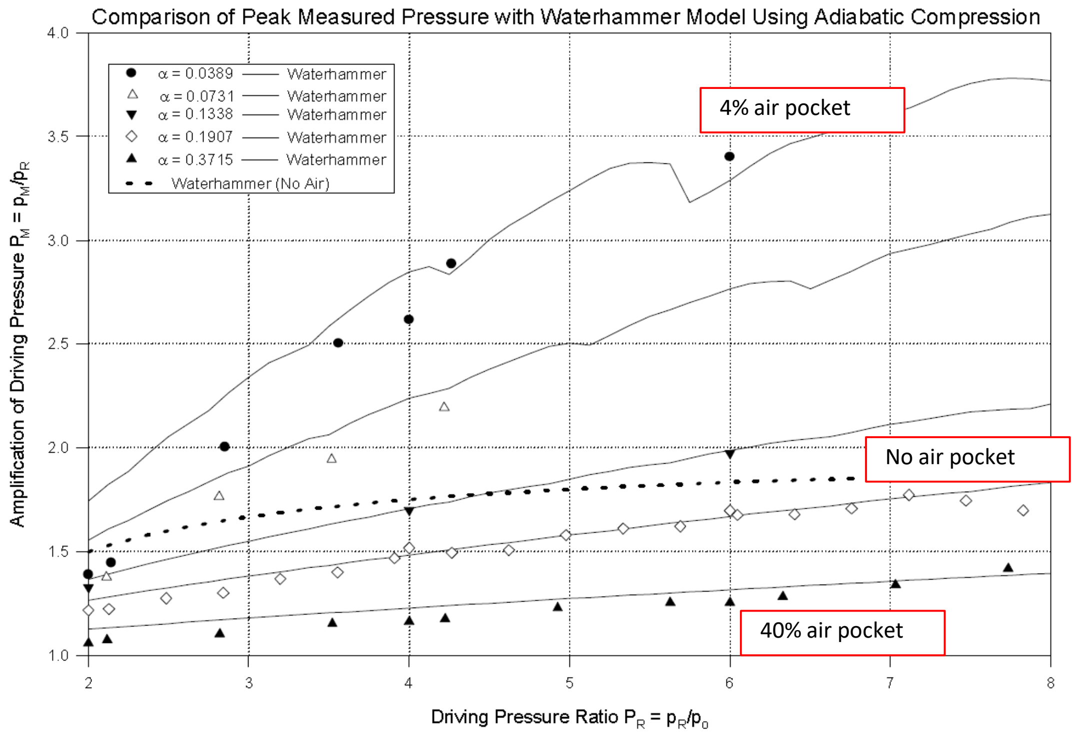
Temperature

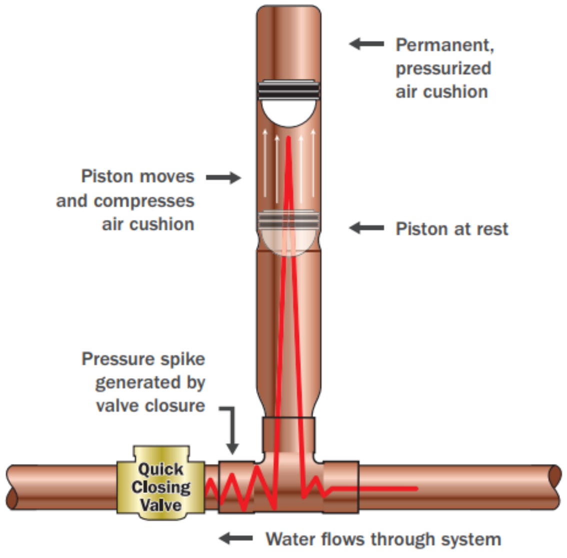
- Vaporous cavitation
- Pressure falls below vapor pressure of fluid
- As temperature increases, vapor pressure increases
- Locally low static pressure will promote the production of vapor bubble



Pressure

- Pressure surge, water hammer
- If air in pipelines can substantially magnify the pressure surge effects, why do water hammer arresters work?

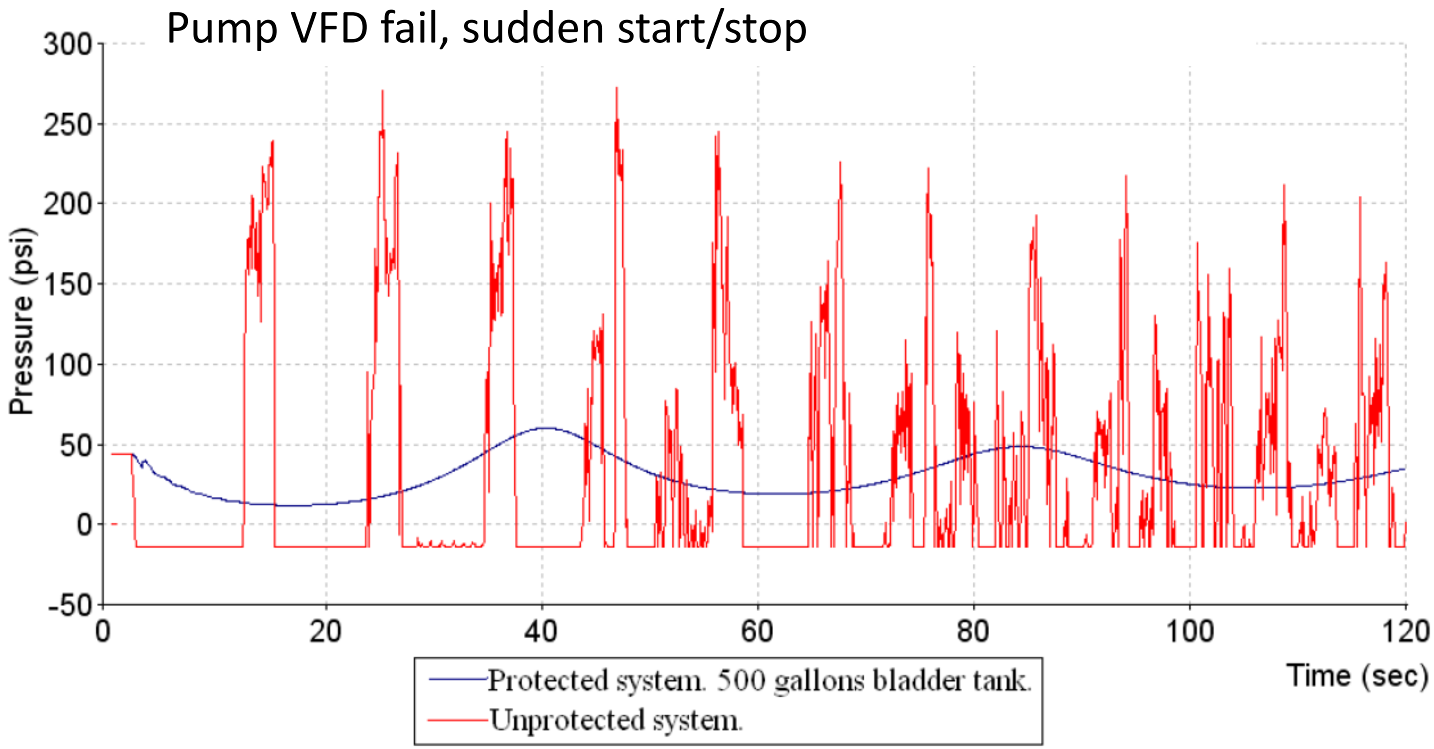




Experimental and Analytical Investigation of entrapped air in a horizontal pipe
3rd ASME/JSME Joint Fluids Engineering Conference, N. Lee, S. Martin

Pressure

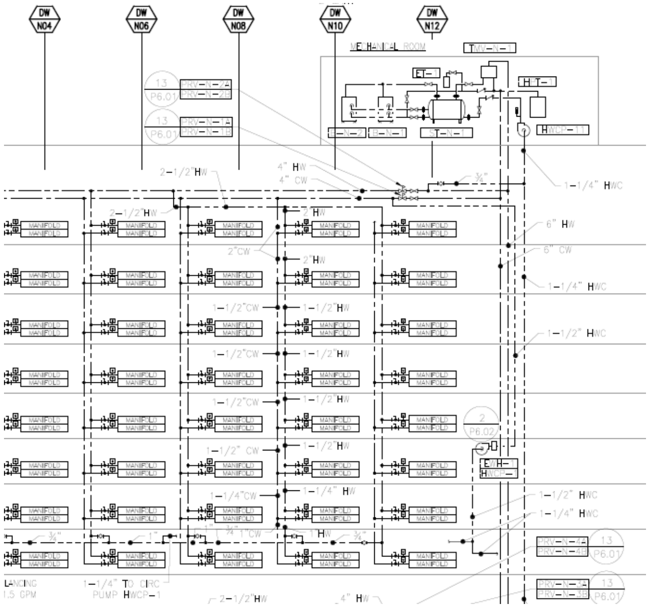
- Conversely, transient pressure surges, water hammer will also cause low pressure events
- Cavitation (low pressure)



Flow

- Balanced flow is critical for:
  - Maintaining proper temperatures,
  - System operation at best efficiency point (energy savings), and
  - Reducing or eliminating damage to piping.
- Common in hydronic heating/cooling systems, information and data readily available
- Much less common in plumbing hot water circulating systems
- Balancing valves

  - Flow restrictors (flow balancing)
  - Temperature maintenance (thermal balancing, flow modulation)



- Oversized circulating pumps, or flow imbalance
  - High velocity in some legs, low or no flow in others
  - High velocity areas can erode/corrode piping, introduce copper into water

- Copper erosion/corrosion, pinhole leaks
  - Often initiated by cavitation, then susceptible to erosion/corrosion

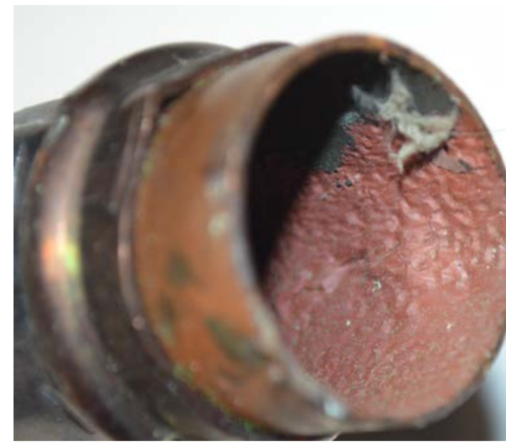


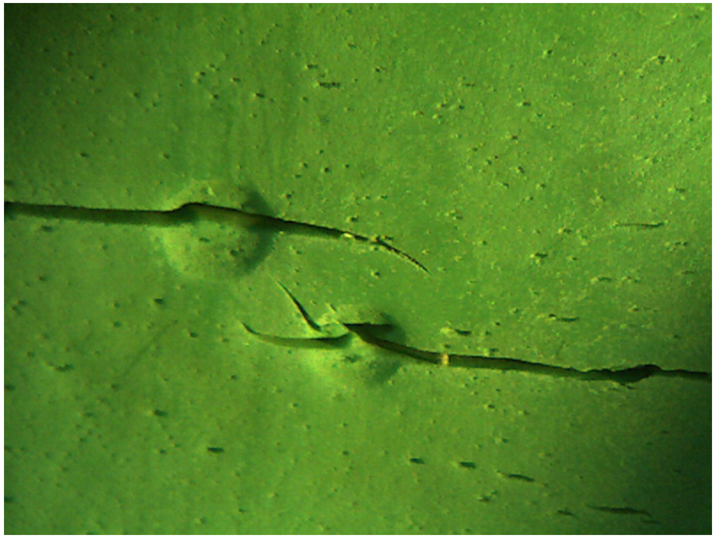
Figure 2: Pinhole leak at bend, viewed from outside of pipe

Identification

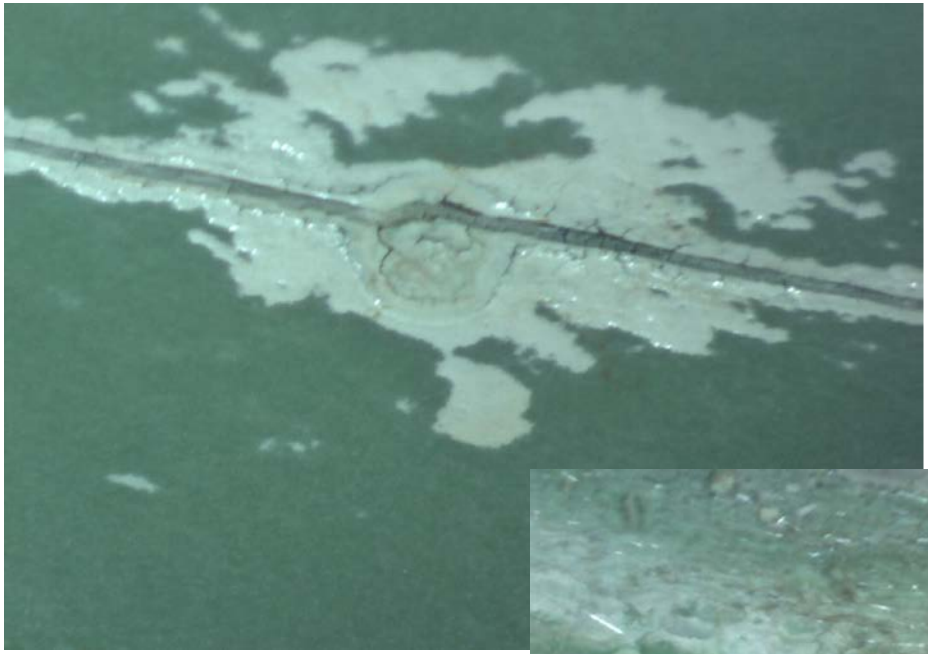
- Mechanical stress under elevated temperature, over-tightened clamp
- Cracks, degradation at clamp location
- Thermal oxidation, excessive temperature,

Identification

- Cavitation-initiated cracks, degradation
- Cavitation “divot” at crack origin
- Localized excessive stress, stabilizer depletion susceptible to crack propagation and oxidative degradation



Identification

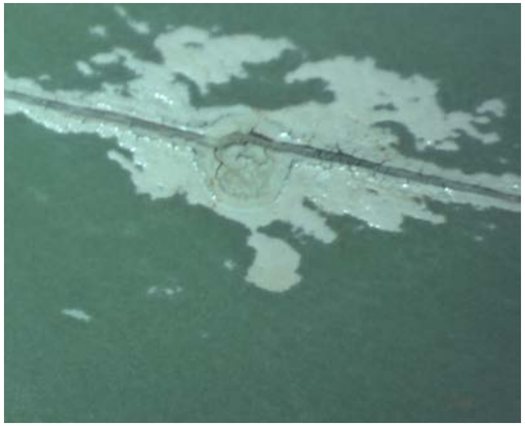


Divot with localized oxidative degradation

Cross-section, crack arrest lines

Identification

Sample	Wall depth	OIT, minutes
At divot location	ID (1 mm)	0.3
	Mid-wall	21.6
	OD (1 mm)	34.8
Undamaged area	ID (1 mm)	16.0
	Mid-wall	19.1
	OD (1 mm)	40.7

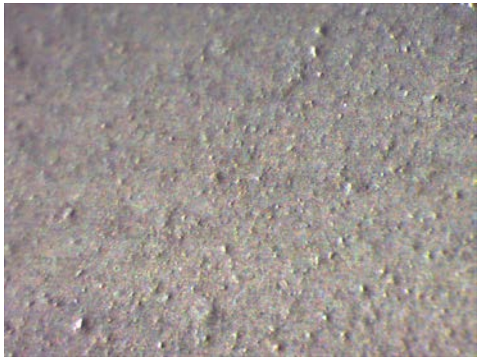


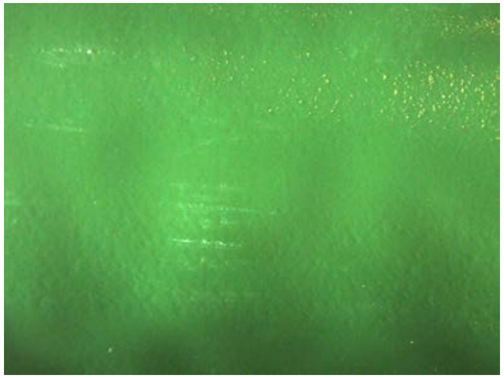
Testing

- Standard cavitation test stand, valving to reduce pressure on suction side of pump
- Aluminum pipe for comparison

Testing

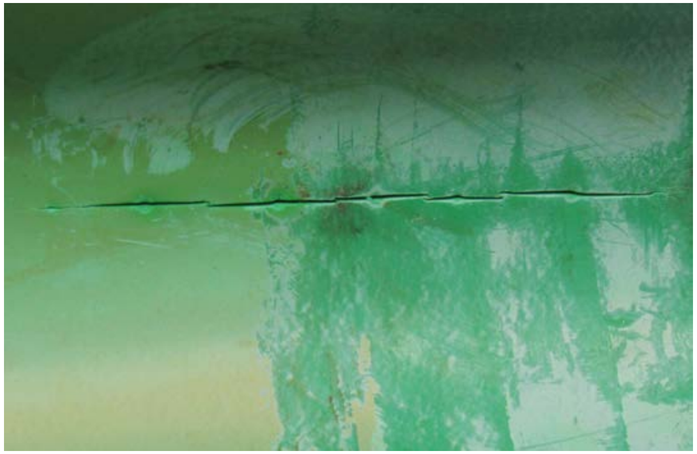
- Aluminum pipe cavitation damage
- No apparent damage to PP-R pipe





Testing

- Next Steps
  - No apparent damage to PP-R pipe
  - Damaged pipe in field
  - Differences in flow restriction vs. surge for cause of low pressure
  - Heat aging, oxidation, evaluation of surface embrittlement
- Operation and Maintenance
  - Air release
  - Pump operation, water hammer
  - Temperature monitoring
  - Copper corrosion, levels in water



QUESTIONS?