Testing, Failure Analysis, and Life Prediction of Fused Polyethylene Pipe

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State of the Art

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Best Way.

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State of the Art - Testing

PE Piping Materials

- Slow Crack Growth (SCG) of PE by ASTM F1473 (“PENT”) - 1997
- Long-term resistance to brittle failure by Rate-Process Method (RPM) Validation by ASTM D2837 - 1988
- Long-term resistance to creep failure (Hydrostatic Design Basis) by ASTM D2837 - 1969

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State of the Art - Testing

Plastic Pipe Fusion Welds

- Tensile Impact to evaluate butt-fused joints - ASTM F17.40 WK4683 (2006)
- Qualification of PE Saddle-Fusion Joints to CFR Title 49 Part 192.283 by ASTM F905 (1984)
- PPI TR-33 - Generic Butt Fusion evaluation by tensile impact, tensile, quick-burst, 80C sustained pressure, ultrasonic inspection.

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State of the Art - Failure Analysis

- **Careful excavation, documentation, and preservation of failures**
- **Visual examination, optical microscopy, scanning electron microscopy**
- **EDS (SEM) for inorganic contamination**
- **FTIR, GC/MS, for organic contamination (ie: foreign polymer, solvent exposure)**
- **DSC for stabilizer functionality**
- **Instruments evolve; techniques unchanged for 30 years**

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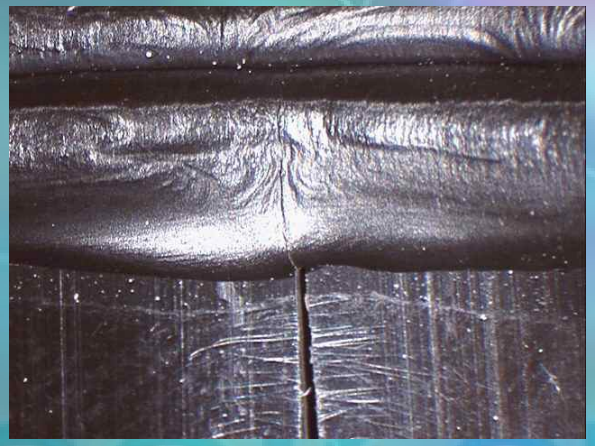
Failure Analysis - Fusion Welds



- Leak near weld as seen from outside - no visible propagation to / from weld
- From inside, propagation into fused area is apparent

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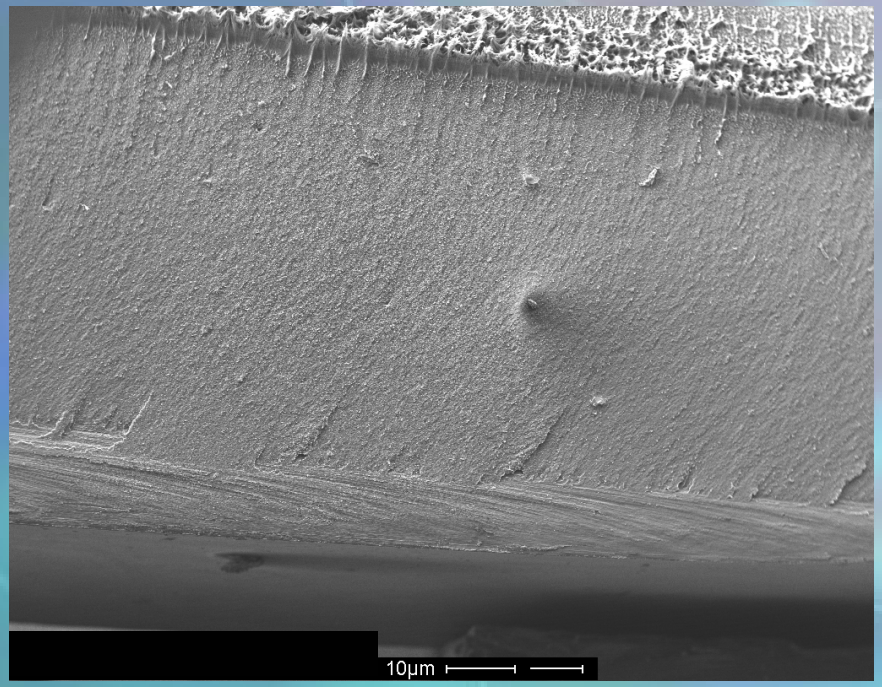
Failure Analysis - Fusion Welds



- SEM examination reveals atypical fracture with initiation at relatively brittle inner surface feature. Feature determined to be process-related.

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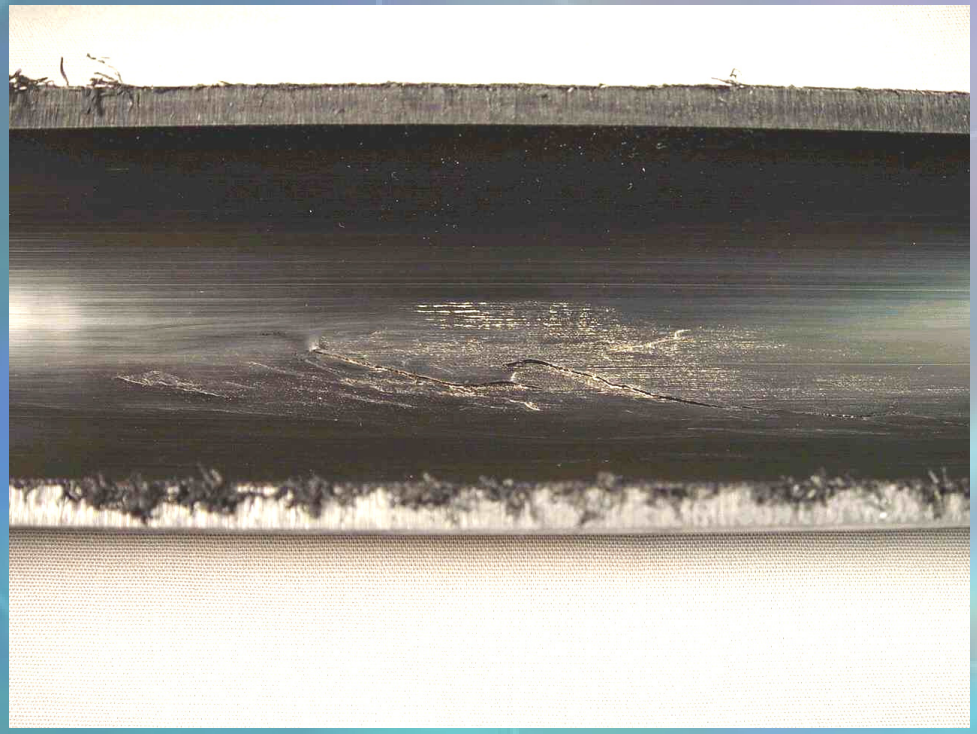
Failure Analysis - Contamination



- Field failure (leak) location seen from inside view

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Failure Analysis - Contamination

- Optical microscopy reveals visible foreign matter in fracture surface

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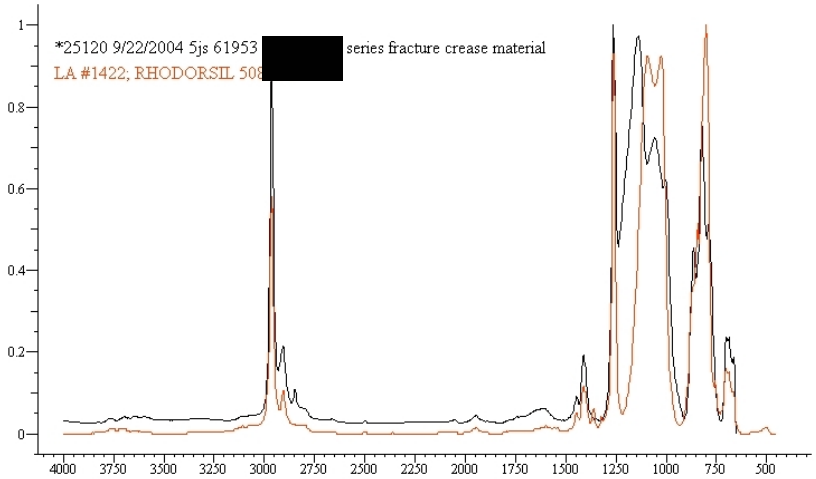
Failure Analysis - Contamination

Source of Sample	RHONE-POULENC SA	
Technique	FTIRSpectrometer= DigiLab FTS-40	
Comments	Description= ORGANOSILICONE (SILICONE) PRODUCT	
Use	RELEASE AGENT	



- FTIR spectrum matches silicone lubricant

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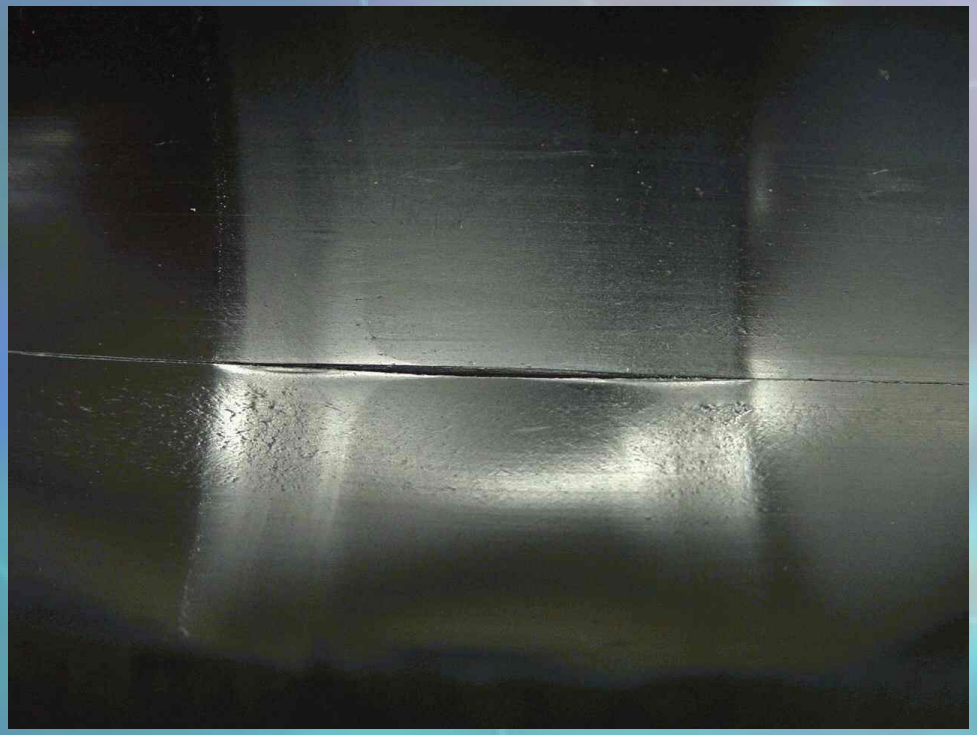
Failure Analysis - mechanical stress effects



- Field failure (leak) at squeeze-off location, inside view. PE pipe is ordinarily resistant to squeeze-off effects.

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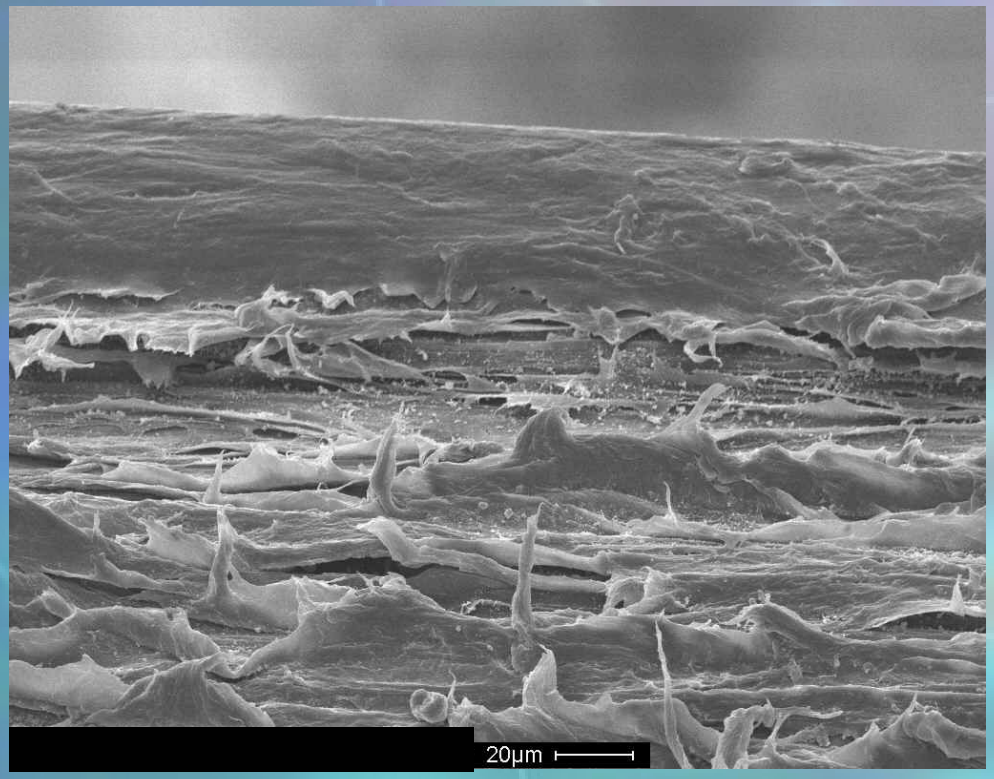
Failure Analysis - mechanical stress effects



- SEM examination shows brittle crack initiation at inner wall due to manufacturing process problem.

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State of the Art -
Failure Prediction, Life Estimation

- **Why do it:**
  - Evaluate suspect lines, areas, days, crews, products, or techniques
  - Evaluate clusters of failures
  - Estimate remaining service life
  - Valuation of buried assets
  - Risk assessment
- **How to do it:**
  - RPM or single-condition elevated-temperature stress-rupture pressure testing

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Summary

- State-of-the art in plastic materials testing emphasizes SCG reistance and avoidance of brittle failure modes
- State-of-the art in failure analysis of plastic pipelines has not changed -- analyst skill and experience are critical
- Sustained pressure testing at elevated temperature (RPM or single-point) best for failure prediction and life estimation

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