ENHANCING THE SAFETY AND RELIABILITY OF PLASTIC GAS DISTRIBUTION PIPELINES: DEFECT REMEDIATION,REPAIR AND MITIGATION

> **Presented at**
> **Government/Industry Pipeline R&D Forum**
> **New Orleans, LA**
> **February 7,2007**

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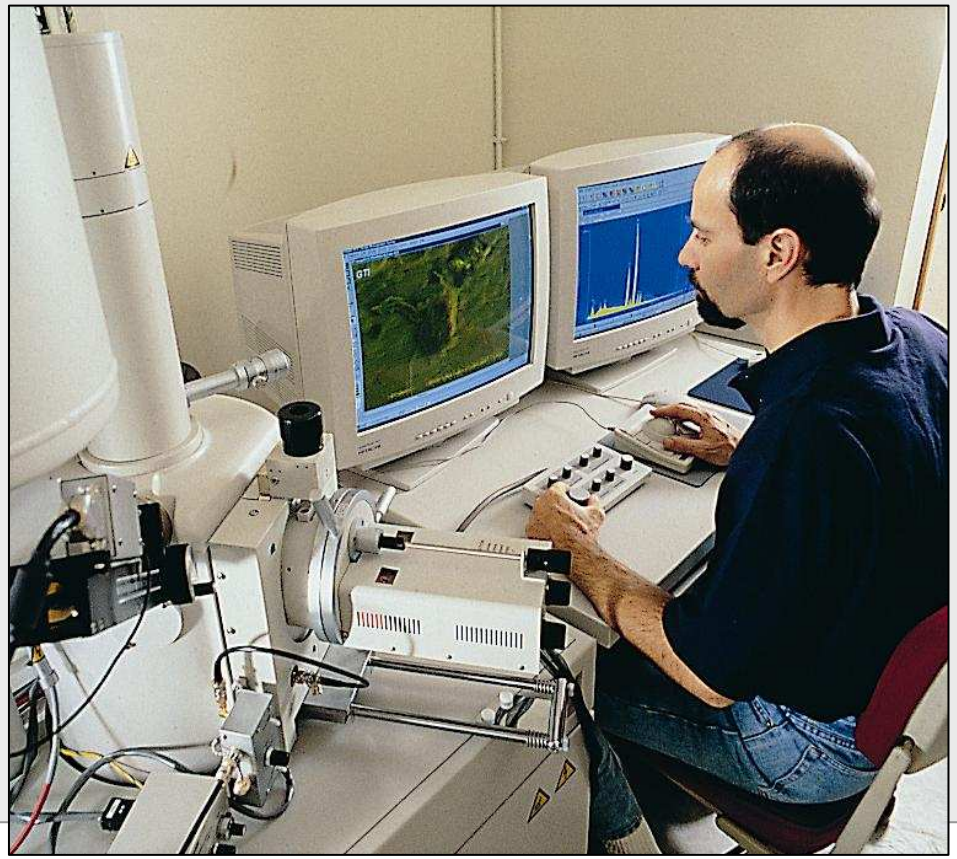
GTI Technology Development, Testing and Evaluation

- **Development and Testing of pipes, materials, fittings, tools and equipment**
  - Plastic and metal piping systems
  - Pipe and leak location sensors and equipment
  - Pipe installation and maintenance tools
  - Trenchless technologies- Directional Boring Equipment

GTI State-of-the Art Laboratory for Plastic and Metal failure analysis

- **Optical and Microscopic Examinations**

Scanning Electron Microscopy (SEM) for material examinations up to 200,000X



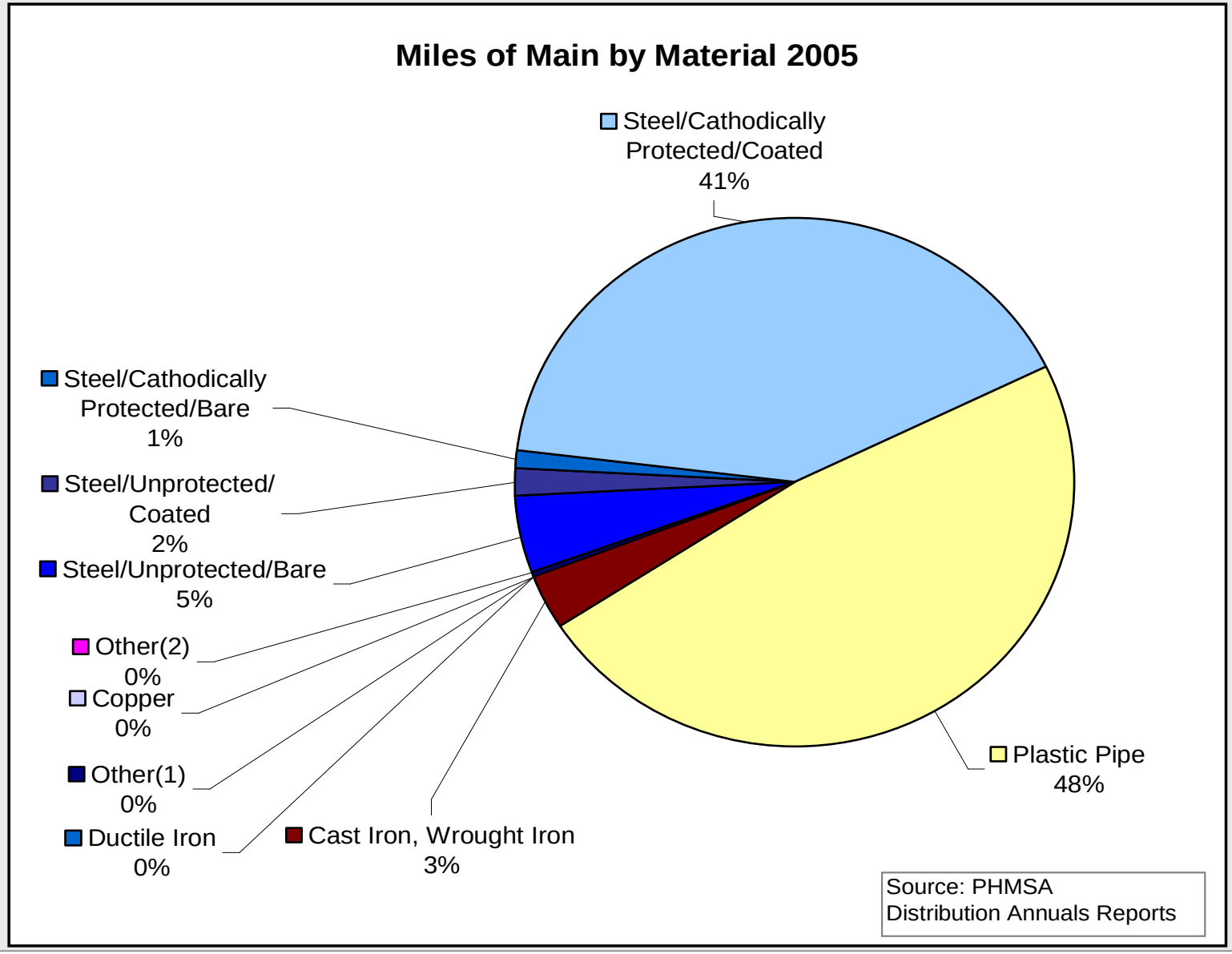
GTI Machine Shops and Field Test Facility

- **Large-scale and field test facility**
  - Accelerated testing of long-term performance
  - Full size components / fitness-for-purpose/ Prototype manufacturing
  - Corrosion testing and mitigation

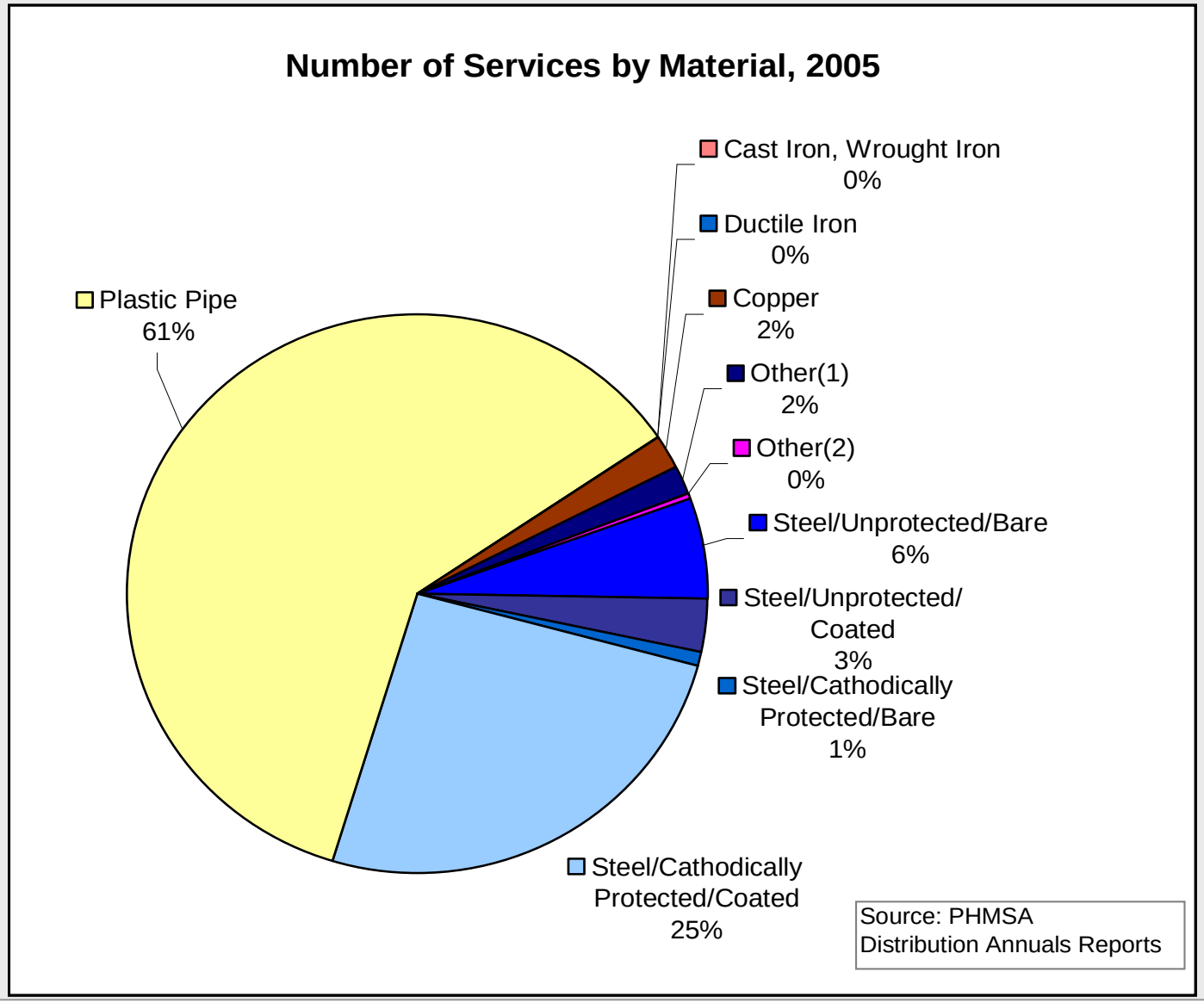
Make-Up of the U.S. Gas Distribution Pipeline Network

- In 2006, the U.S. Gas Distribution Pipeline Network Consisted of About
  - 1,450,000 Miles of Mains
    - 900,000 miles of steel, CI, etc. mains
    - 550,000 miles of plastic mains
  - 750,000 Miles of Services (About 60,000,000 Services)
    - 40,000,000 plastic services
    - 20,000,000 services other materials

Distribution Miles of Main by Material



Number of Services by Material



U.S. Gas Distribution Pipeline Construction Activity

- **In 2006, the U.S. Gas Distribution Industry Installed**
  - 28,500 Miles of Mains
    - 13,500 miles of new mains
    - 15,000 miles of replacement mains
  - 30,000 Miles of Services (70-ft service length)
    - 12,500 miles of new services
    - 17,500 miles of replacement services

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U.S. Gas Distribution Pipeline Construction Activity

- **Currently, About 95% of All NEW and Replacement Mains & Services Installed are Plastic Polyethylene (PE) Pipe Materials**

» U.S. gas distribution industry began using plastic pipes for services and mains in the late 1960's

U.S. Gas Distribution Industry Expenditures in 2006

- **In 2006, the U.S. Gas Distribution Industry Expenditures consisted of About:**
  - **$4 Billion for New Construction to Extend Mains & Services to New Customers**
  - **$5 Billion for Operations and Maintenance Including Pipe Rehabilitation, Repair and Replacement of Existing Distribution Systems**

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In-Service Normalized Failure/Leak Rates in Non-Plastic (Steel, CI, etc) VS Plastic Distribution Pipelines Excluding Third-Party Damage**

- **376,000 Approximate Total Number of Leaks In Non-Plastic Mains (coated and bare steel, CI, etc.)**
  - **Non-plastic main leaks 8 times > plastic**
- **172,000 Approximate Total Number of Leaks In Non-Plastic Services**
  - **Non-plastic service leaks 4 times >plastic**

	Coated Steel Mains	Total Non-Plastic Mains	Plastic
Leaks /Mile of Main /Yr	0.1748	0.4177	0.0564
Leaks /Service/ Yr	0.0034	0.0086	0.0025

In-Service Failures in Plastic Distribution Pipelines Including Third-Party Damage

- According to Surveys and Reports
  - 290,000 Total Number of Plastic Pipe Main & Service Leaks Per Year Including Third- Party damage
    - 70,000 Plastic Mains Leaks/Yr (includes third-party)
    - 220,000 Plastic Services Leaks/Yr (includes third-party)
      - 0.12563 leaks/ mile / year Plastic Main Leak Index -- Includes Third-Party Damage
      - 0.005505 leaks/service/year Plastic Service Leak Index --Includes Third-Party Damage.

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Third-Party Plastic Pipe Failures

- **55% of All Plastic Pipe Field Failures/Leaks Are Caused by Third-Party Damage, i.e.**
  - **160,000 Total Third-Party Plastic Pipe Main and Service Leaks/Yr**
    - **38,000 Third-Party Plastic Main Leaks/yr**
    - **122,000 Third-Party Plastic Services Leaks/yr**

Plastic Distribution Pipelines In-Service Failures –cont'd

- **45% Other Plastic Pipe Failures**
  - **130,000 Other Plastic Pipe Main and Service Leaks/Yr**
    - 31,000 Plastic Main Leaks/yr
    - 99,000 Plastic Services Leaks/yr
  - **Due to Fusion Joining, Squeeze-Off, Rock Impingement, Pipe Bending, Earth Loading and Settlement, Pipe Defects/ Manufacturing, etc**

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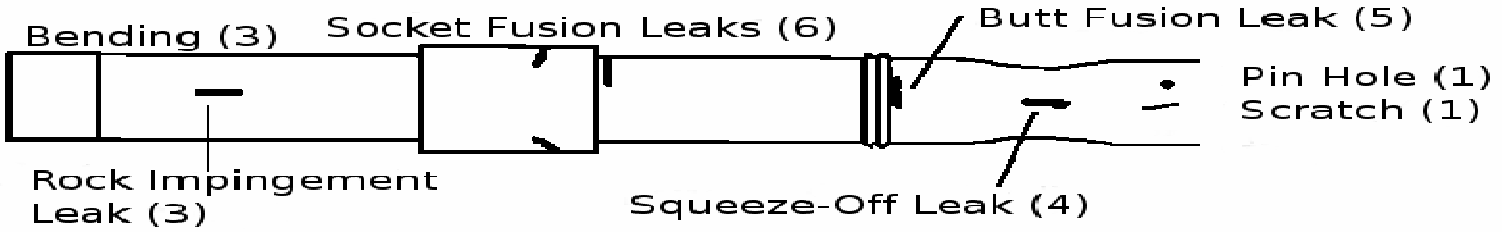
Type & Relative Frequency of Plastic Gas Pipe Failures

Type of Failure	Frequency of Failure	Relative Rank /Risk Index by Failure Type
Saddle Fusion Joints	**119**	10
Socket Fusion Joints	**69**	9
Butt Fusion Joints	**23**	8
Tees and Ells Joints	**20**	7
Material: Quality Control, Inclusions, and Other Defects (pin holes)	**15 (>100)**	6 (10)
End Caps and Tapping Tee Caps	**11**	5
Rock Impingement	**6**	4
Bending and Earth Settlement	**6**	4
Squeeze-off	**5**	3
Plow-in, Insert Renewal, installation-related	**2**	2
Internal Pressure	**1**	1

Schematic Illustration Depicting Type and Approximate Relative Ranking of Plastic Pipe Field Failures/Leaks



Leaking Cap (2)

Leaks Associated with Saddles (7) and Tees (5)

Heat Fused Lateral Joint Failure

Electro-fusion Saddle Joint Failure

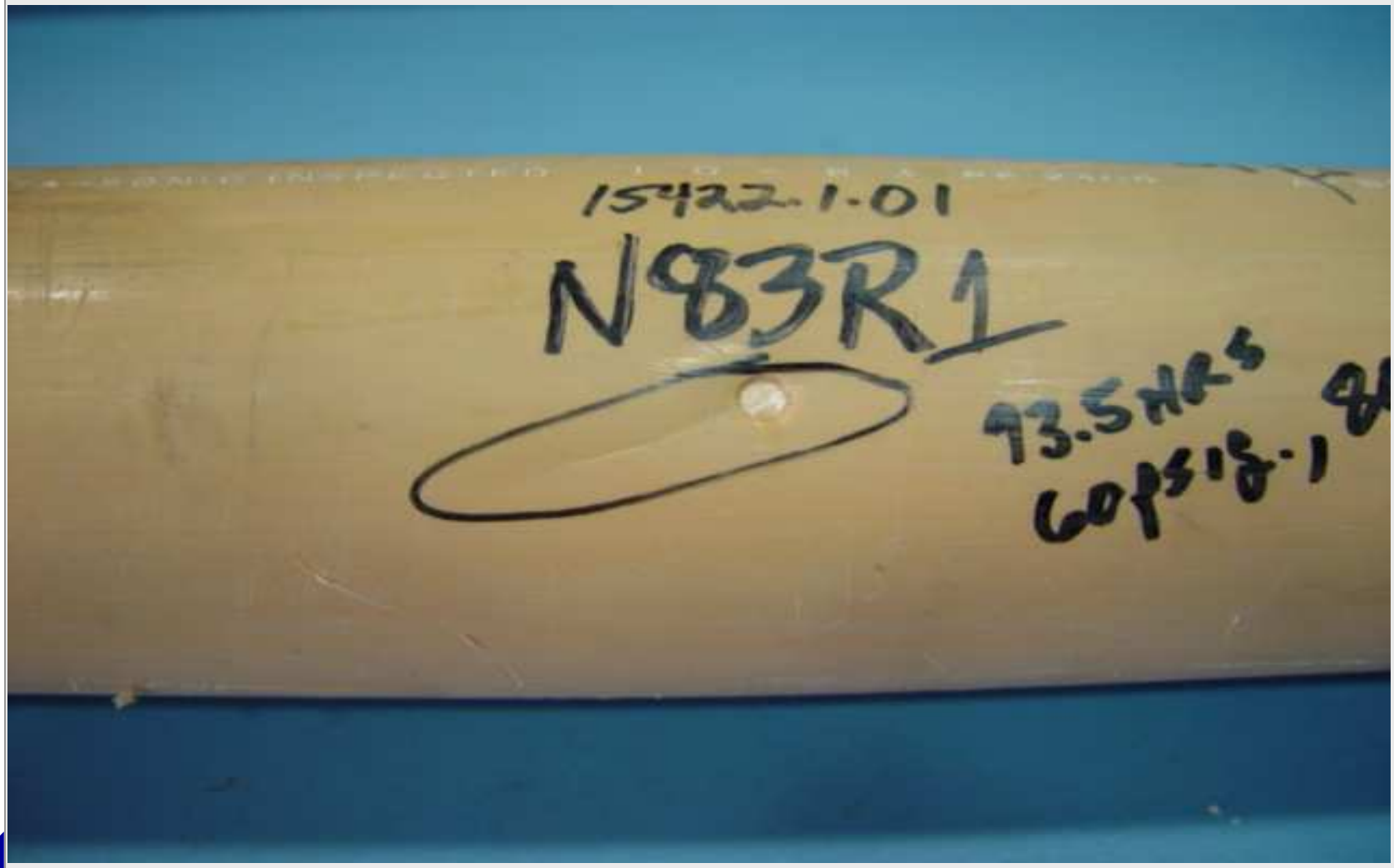
Electrofusion Lateral Joint Failure

Squeeze-off Failure

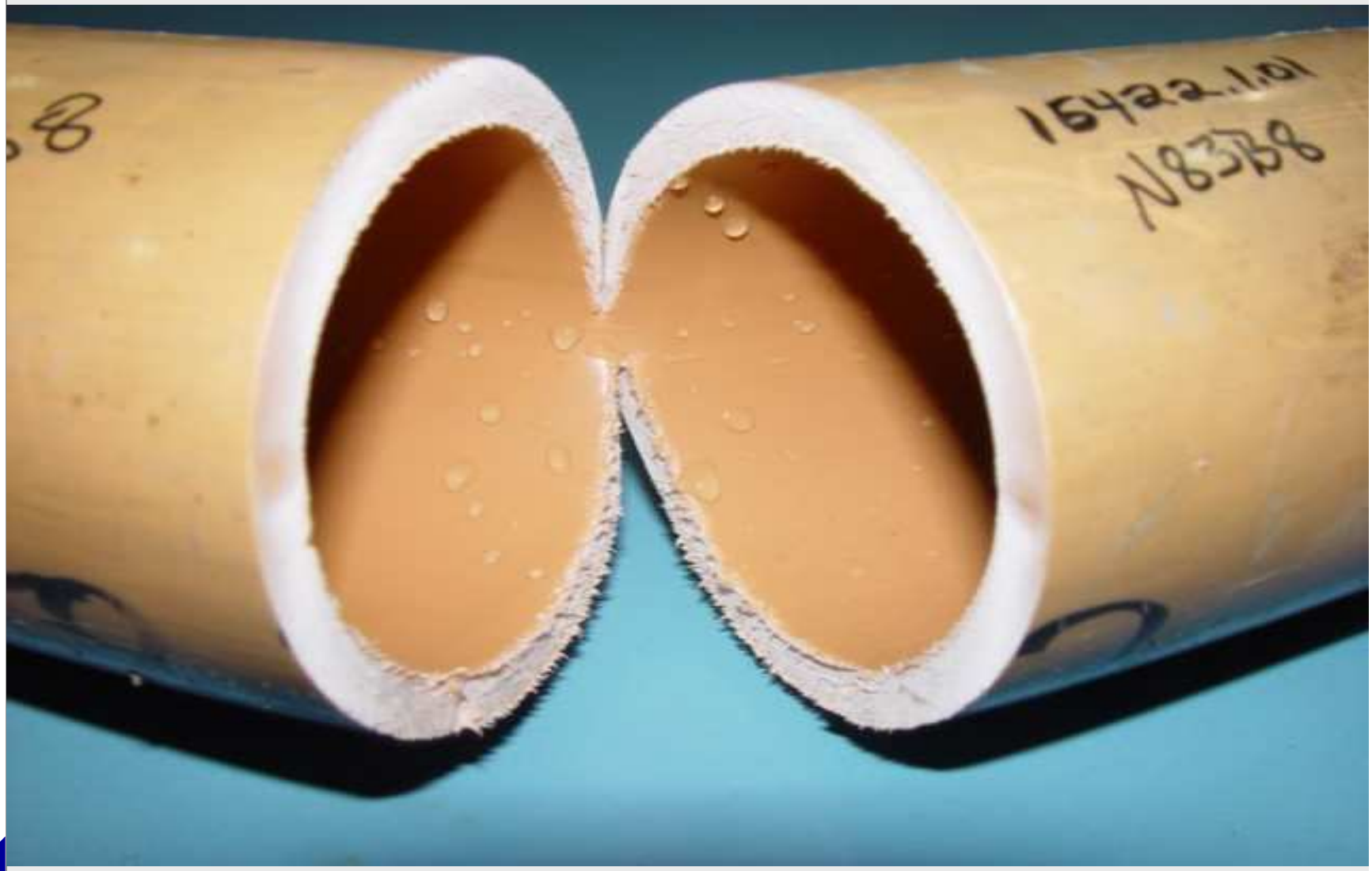
Slit failure In Pipe Due to an Inclusion

Rock Impingement Failure

Rock Impingement Failure



Pipe Bending Circumferential Slit Failure



Probable Cause of Plastic Pipe Failures

Type of Failure	Probable Root Cause
Saddle/Lateral Fusion Joints	Inadequate fusion--lack of bond or penetration, Contaminants, Inclusions, Stress Concentrations
Socket Fusion Joints	Inadequate fusion--lack of bond or penetration, Contaminants, Extrusion lines,
Butt Fusion Joints	Inadequate fusion--lack of bond or penetration, Wall-to-wall mismatch, Contaminants, Inclusions,
Material: Quality Control (Pin Holes)	Defects, Inclusions, Cavities, Extrusion Lines, Non-Homogenous Melting (High % of Re-Grind)
Rock Impingement	High Localized Stress Concentration Combined with Defects, Inclusions,
Bending and Earth Settlement	High Bending Stresses
Squeeze-off	High Localized Stresses Due to High % Squeeze

Cost of Repairing Plastic Gas Pipes

- **$2,000 Average cost to find/locate and repair a leaky or damaged PE gas main**
- **$750 Average cost to find/locate and repair a leaky or damaged PE service**

Method of Repairing Plastic Gas Pipes

- **Currently, Repair of a Leaky/Damaged PE Gas Pipe Involves**
  - Pipe Squeeze-off at Three Locations to Stop Gas Flow
    - Squeeze at damaged/leaky site, and
    - Squeeze up-and down-stream from leak
  - Cutting out the Damaged/Leaky Section,
  - Replacing Damaged Section with a Short Pipe Section, and
  - Joining Short Pipe Section to Host Pipeline Using
    - Electro-fusion couplings,
    - Butt-fusion Joining, or
    - Mechanical Repair Coupling

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Mitigating Plastic Pipe Failures

- **Need to Identify, Address and Eliminate Root Causes**
  - Improve Fusion Procedures and Field Training
  - Enhance Design of Saddle / Lateral Fusion Joints
  - Improve Pipe Quality Control
  - Develop Inspection Sensors to identify root-cause defects
  - Improve Pipe Installation and Operational Procedures for Squeeze-Off, Pipe Bending, Bedding and Back-fill Materials
  - Develop innovative non-intrusive gas shut-off techniques
  - Develop Enhanced Electrostatic discharge techniques
  - Develop Accurate Pipe Locating and Tracing Techniques
  - **Develop Sensors to Detect in Real-Time Impact loads**
- Develop Inexpensive Pipe Repair Methods
- Assess/Rank Plastic Pipe Failures, Risks, and Threats

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