Root Cause Analysis of Plastics Failures

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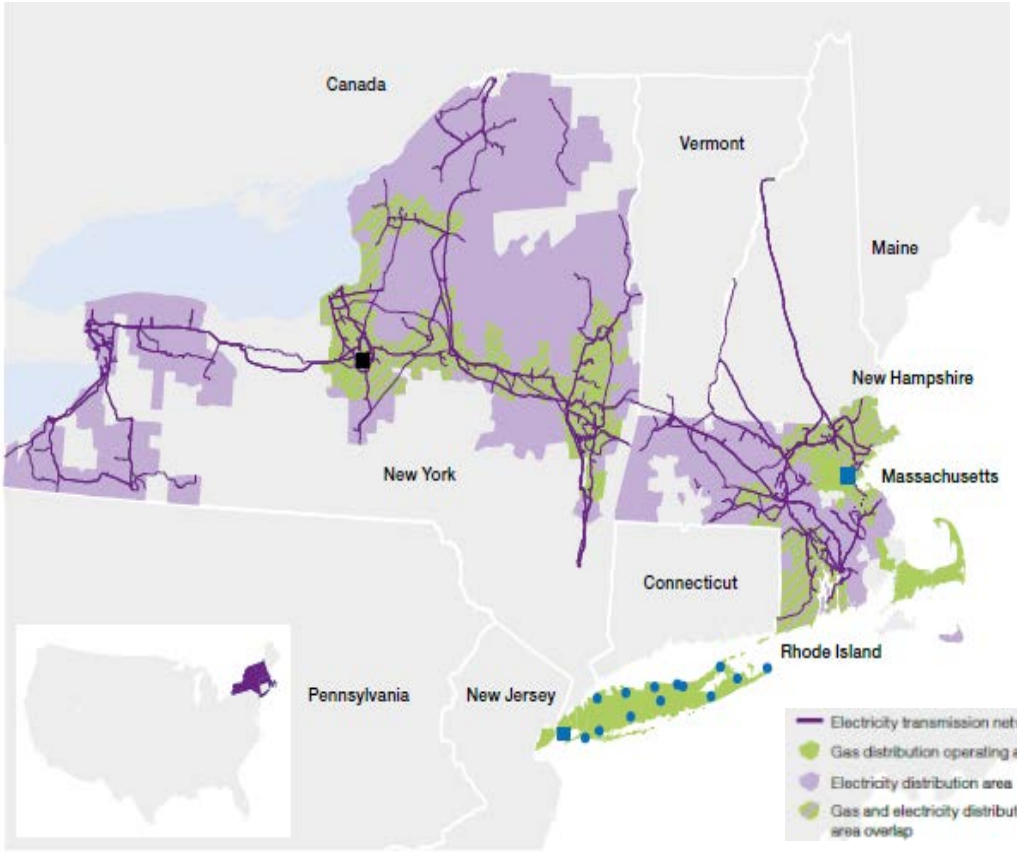
nationalgrid

Agenda

- Company’s Key Facts
- Polyethylene Pipes Materials of Choice
- Objective
- Elements
- Methods
- Recommendations
- Implementation
- Conclusion

National Grid's U.S. business

National Grid is one of the world's largest investor owned utilities, with more than 7 million gas and electricity US customers and 22,000 employees in the U.S. and U.K.

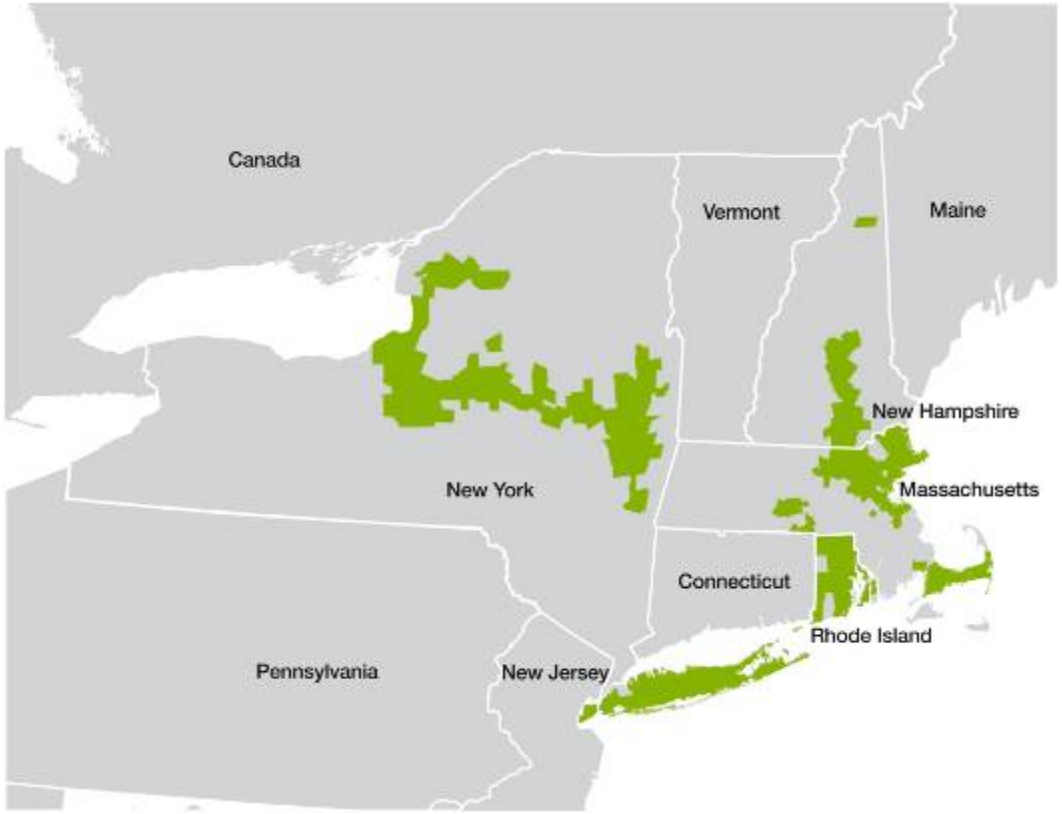


National Grid U.S. by the numbers

- 3.6 million gas customers
- Gas network of 35,000 miles of gas distribution pipeline; 490 miles of gas transmission pipeline
- 3.4 million electric customers
- Electricity transmission network of 8,800 miles of overhead line; 100 miles of underground cable, 380 transmission substations

Our Gas Distribution business - US

Gas Distribution US – operating area

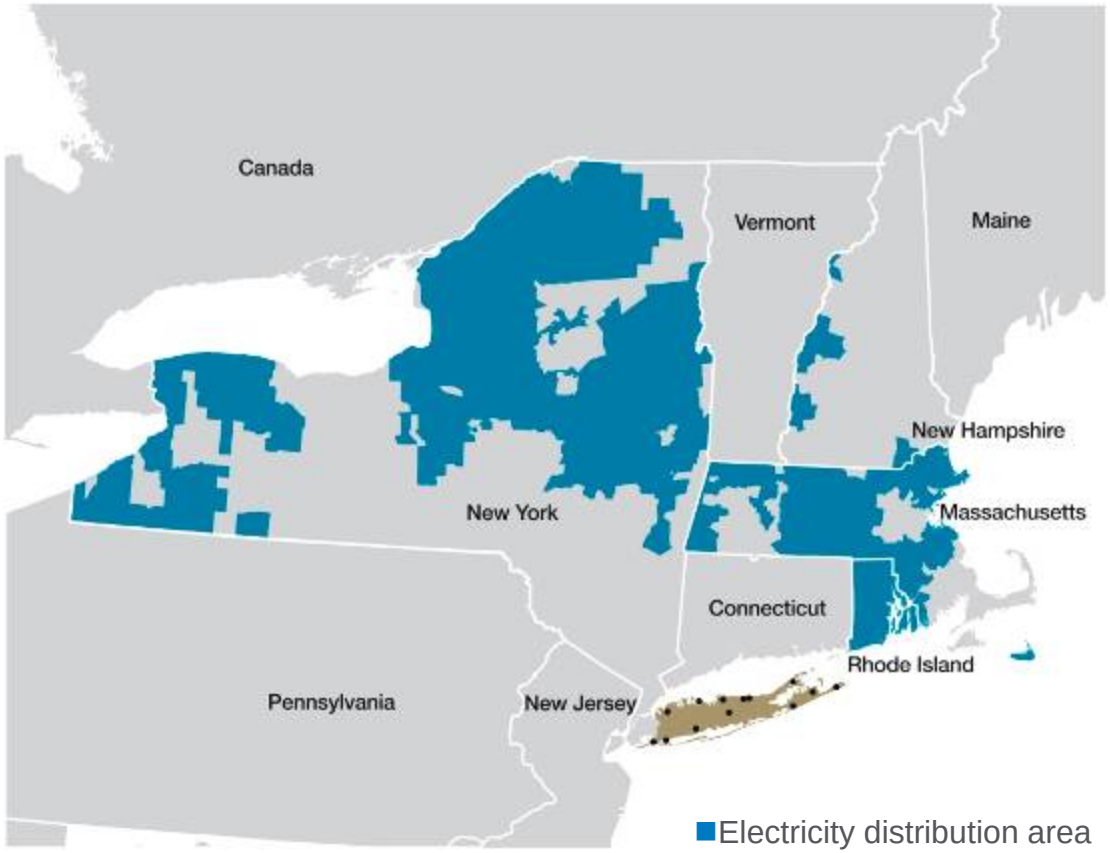


In the US, our Gas Distribution business consists of gas networks in upstate New York, New York City, Long Island, Massachusetts and Rhode Island

Delivers gas to 3.6 million consumers

Our Electricity Distribution & Generation business - US

Electricity Distribution & Generation – operating area



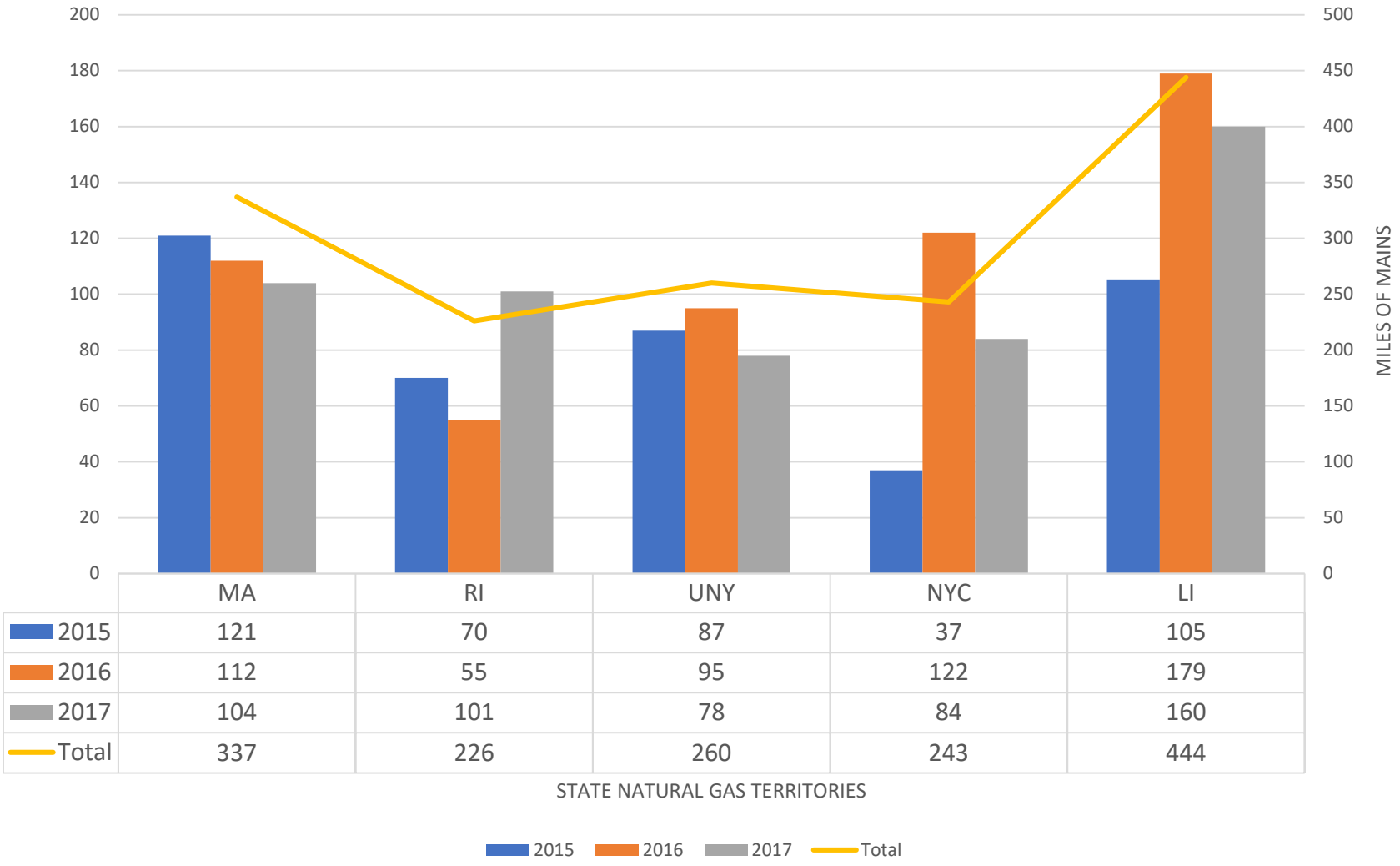
We supply electricity to approximately 3.4 million customers in the northeastern US

We also own generation plants with a capacity of over 4,000 megawatts

PIPE REPLACEMENT PROGRAM

- **Leak Prone Pipes (LPP)**
  1. Unprotected Bare Steel
  2. Unprotected Coted Steel
  3. Cast Iron
  4. Wrought Iron
  5. Copper
  6. Aldyl (Pre 1980)
- **Growth**
- **Public Works**
- **Reliability/Reinforcement**

Miles of Polyethylene Pipes Installed in Nationalgrid US Territories in Three Years



	MA	RI	UNY	NYC	LI
2015	121	70	87	37	105
2016	112	55	95	122	179
2017	104	101	78	84	160
Total	337	226	260	243	444

Five Elements of RCA

1. Data collection
2. Assessment
3. Corrective actions
4. Communication
5. Follow-up

Failure Analysis Methods

1. Visual examination
2. Identification analysis
3. Nondestructive testing
4. Mechanical testing
5. Stress analysis
6. Thermal analysis
7. Microstructure Examination or microtoming

Data Collections

1. Failure in-service or during installation
2. Date of failure & Date of installation
3. Geographic location
4. Failure location
5. Operating pressure & normal pressure range
6. Print line/Date/Lot Number of the failed component
7. Environment around the failed component e.g. chemical, hydrocarbons etc.
8. Type of soil
9. Installer identification if available
10. Installation procedure and equipment information if available
11. Depth of cover

PPDC DATA COLLECTION INITIATIVE – APPENDIX-A

MATERIALS SECTION

PLASTIC PIPE OR FITTING

1 IDENTIFICATION (Check one for Type of Material)

TYPE OF MATERIAL	OTHER SPECIFICATIONS:
ABS	MANUFACTURER:
CAB	
HDPE - 3306	PRINT
HDPE - 3406	LINE:
HDPE - 3408	
MDPE - 2306	(Circle one and enter value below)
MDPE - 2406	SDR, DR, SCHEDULE or
PB	WALL THICKNESS:
PVC	
OTHER(Describe):	NOMINAL SIZE:

2 DATE OF MANUFACTURE

INSTALLATION AND OPERATIONS SECTION

3 METHOD OF INSTALLATION (Check One)

- OPEN TRENCH
- BORED
- PLOWED IN
- INSERTION
- JOINT TRENCH
- PLANTED
- UNKNOWN
- OTHER(Describe):

4 TYPE of SOIL IN CONTACT W/ PIPE (Check One)

- SAND
- LOAM
- CLAY
- ROCKY
- SLURRY
- OTHER(Describe):

5 OPERATING PRESSURE

A. AT TIME OF FAILURE: psig

B. NORMAL RANGE (IF KNOWN) psig

6 DATE OF INSTALLATION (mo/day/yr)

FAILURE ANALYSIS SECTION

7a FAILURE LOCATION

- PIPE
- FITTING(**Complete 7b**)
- JOINT (**Complete 7c**)

7b FAILURE IN FITTING (Check as applies)

- TRANSITION
- VALVE (PLASTIC)
- METER RISER
- MECHANICAL FITTING
- HEAT FUSION FITTING
- ELECTROFUSION FITTING
- OTHER(Describe):

7c FAILURE IN JOINT (Check as applies)

- MECHANICAL
- ELECTROFUSION
- BUTT FUSION
- SOCKET FUSION
- SADDLE FUSION
- SOLVENT
- OTHER(Describe):

8 FAILURE CAUSE (Check all that apply)

- SQUEEZE OFF
- POINT LOADING
- EXCESSIVE EXPANSION /CONTRACTION
- EXCESS EXTERNAL EARTH LOADING
- INSTALLATION ERROR
- PREVIOUS IMPACT
- UNKNOWN
- OTHER(Describe):

9 DATE OF FAILURE (mo/day/yr)

NOTICE OF FORM SUBMITTAL:
This form should be submitted even if not all data elements are available.

CONTACT NAME	PHONE NUMBER

Failure Analysis Checklist

Description of the failure

Materials

Design

Processing

Installation

Environmental

Application Stresses

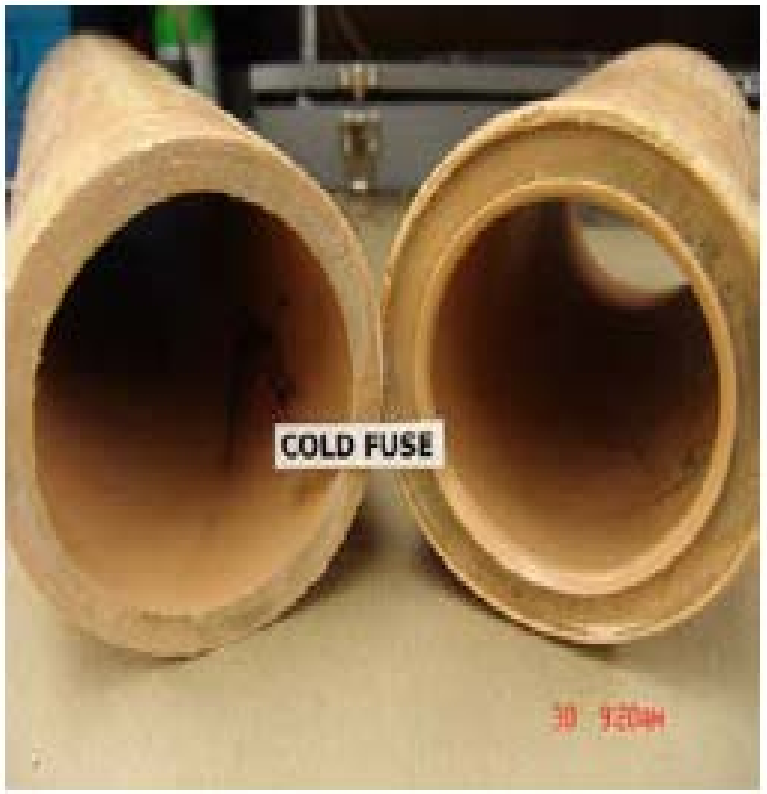
1. Visual Examination

- Fusion Joint Failure
- Slit type of failure
- Sinusoidal type of failure
- Micro holes
- Presence of foreign material
- Sink marks & weak knit lines
- Heavy marks and gouges
- Exposure to UV rays

Fusion Joint Failure

Bead appearance, alignment, tool marks, contamination, lack of fusion

Can easily identify operator's error by careful visual examination of failed component.



Slit Type of Failure

Longitudinal originated from inside wall of the pipe is generally attributed

Poor resistance to the slow crack growth.

Inferior resin quality with a very low PENT value

Sinusoidal type of failure

- Circumferentially originated from the outside wall of the pipe
- Generally attributed to the poor resistance to the rapid crack propagation called fast fracture or RCP

Micro Holes

- Migration of water during extrusion of pipe
- Static discharge resulting from the poor dielectric strength of pipe
- The failure to remove moisture from hydroscopic materials can lower the overall physical properties of PE materials and in some cases can cause them to become brittle
- This can be visually seen by just heating the outside surface of the pipe with a heating iron

Presence of Foreign Material

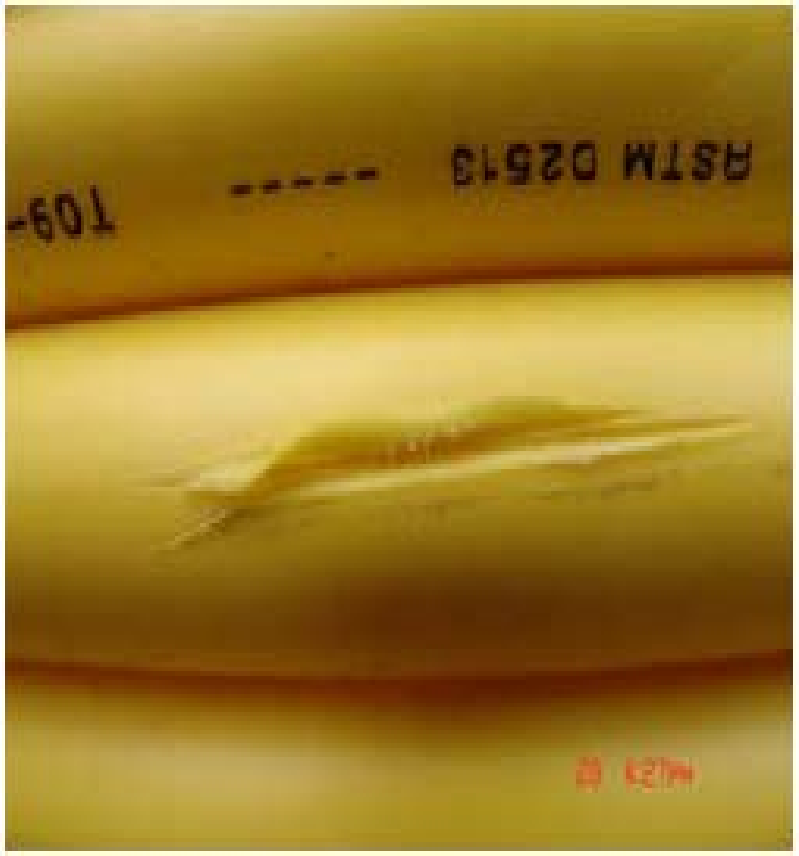
- **Contamination can cause the part to fail.**
- **Burn marks such as brown streaks and black spots can cause failure**
- **These marks indicate the possibility of material degradation during processing causing the breakdown of molecular structure leading to overall reduction in the physical properties**

Sink marks & weak knit lines

Are readily visible on molded fittings, represent poor processing practices and may contribute to a part failure

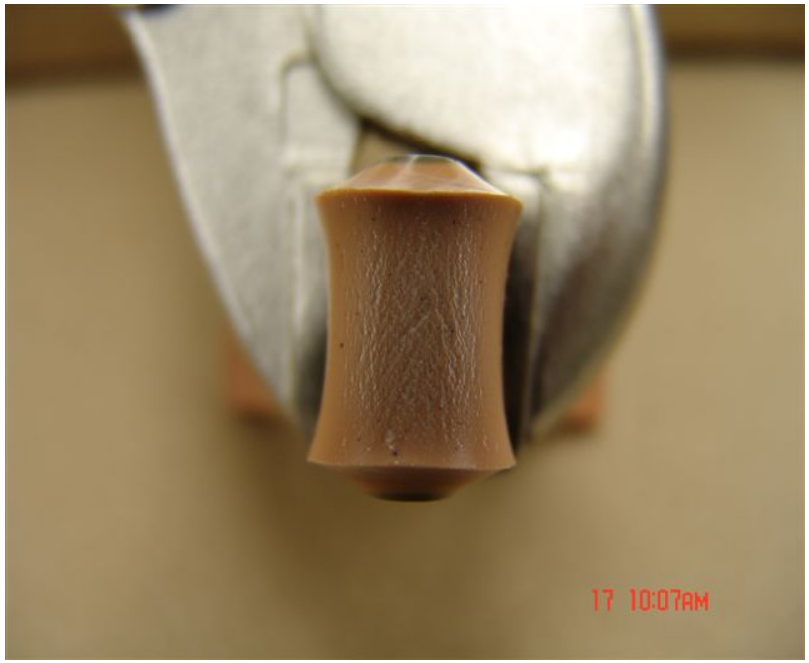
Heavy marks and gouges

Signs of excessively applied external force and may contribute to a pipe failure



Exposure to UV rays

A slight chalking, microscopic cracks and loss of color may contribute to a part failure.



2. Identification Analysis

Material Grade – Melt Index test

Effect of Regrind

- Higher the level of regrind material that is mixed with virgin, the lower the physical properties
- Higher processing temperature and long residence time degrade material

Effect of Regrind

- **Percentage of regrind used with virgin resin is almost impossible to determine by performing test on extruded pipe or molded fitting.**
- **A correlation between melt index value and the part failure rate can be established by conducting a series of tests to determine the minimum and maximum acceptable melt index.**
- **If the melt flow values are significantly higher than the control sample, then the higher melt flow is indicative of lower molecular weight, probably from the excessive use of regrind material.**
- **If the monomer content also varied from sample to sample, this is a confirming indication that indicating that the virgin material is not used in manufacturing of pipe.**
- **The FT-IR analysis and electron microscopic examination of outer, inner and middle layer of pipe should be conducted to check the material.**

Contamination & Impurities

- **Failure due to impurities and contamination of virgin material are common.**
- **Material contamination usually occurs during processing. A variety of materials are used to purge the previous material from the extruder barrel before using the new material. Not all of these purging materials are compatible. Such incompatibility can cause the loss of properties, brittleness, and delamination**
- **To identify such impurities techniques such as FT-IR analysis and GPC must be employed.**
- **Molecular weight distribution & HLMI/M15 ratio helps identify consistency**

3. Non Destructive Testing

- **Ultrasonic – Pulse echo, Transmission and Resonance techniques**
- **Gamma backscatter**
- **Beta transmission**
- **Optical laser**

4. Mechanical Testing

- **Impact or compression on actual part or a small sample cut out from the part**
- **Grind the defective plastic material of the part and prepare a compression molding standard test bar for conducting mechanical testing**

5. Thermal Analysis

Thermal analysis techniques are used extensively in failure analysis.

Thermal analysis consists of techniques in which a property of the sample is monitored against time or temperature while the temperature of the sample is programmed.

Thermal analysis consists of three primary techniques that may be used individually or in combination:

- **Differential scanning calorimetry (DSC)**
- **Thermo gravimetric analysis (TGA)**
- **Thermo mechanical analysis (TMA)**

6. Stress Analysis

- **Photo elastic**
- **Brittle Coatings**
- **Strain gauge**
- **Chemical**
- **Heat reversion**

7. Micro structural Analysis

- **This analysis begins with the skillful ultra thin slicing from a failed part and then mounting the slice on a transparent glass slide.**
- **The section is examined under a light transmission microscope equipped with a polarizer for photo elastic analysis. A high power (1000X) microscope which will permit photographic recording of the structure in color is preferred.**
- **By examining, the microstructure of a material, much useful information can be derived.**
- **Defects such as voids, contamination, poor pigment dispersion, presence of un-melted particles and shrinkage can be easily detected by microtoming.**

Conclusions

- **The root cause analysis of any failures causing an interruption to customers, safety concerns and inefficiency must be a customary practice for the utility.**
- **The approach and the various relevant methods discussed in this paper provide guidance to utility engineers in determining an exact cause of failure and developing corrective actions to prevent its recurrence.**
- **It is extremely important that the engineers engage, inspire and influence all field personnel in this process to enhance the gas distribution network safety.**
- **The recommendations that emerge as a result of root cause analysis must be communicated and implemented in a timely manner.**
- **A true partnership with various stakeholders would make this process a great success.**