THE LIFE-CYCLE OF POLYETHYLENE

ASTEE
Nice, 12th June 2009

Magali Rozental
(Technical Direction - CTD)
Polyethylene: Act I – Stage 1: LEAKS

UNDERSTAND BEFORE ACT

First premature failures observed on field
First R&D Program launched
CONTEXT 2004: key-facts

• Increasing number of leaks on PE service pipes on some sites
• less than 10 years old, Disinfection by chloride dioxide treatment

The Answer: 2005 – 2008 R&D Program

• Characterization of PE degradation
• Assessment of the impact of disinfectants
• Comparison & benchmarking of the best materials
• PE pipe market
Polyethylene: Act I – Stage 2: PURCHASING

HOW TO PURCHASE?

- 2005
- 2006
- 2007
- 2008
- 2009
- 2010-11

- Definition of LDE purchasing procedure
- First premature failures observed on field
- First R&D Program launched

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PE PIPE SUPPLIER SELECTION

1. Define the right specifications (commercial & technical ones)

2. Audit manufacturing facilities and relationship with suppliers

3. Short-list of certified PE pipe manufacturers

4. Secure the purchasing portfolio: product traceability

5. Improvement plan and performance follow-up

Procedure available in Lyonnaise des Eaux (99% of purchases approved)

On-going in Suez-Environnement
Polyethylene: Act I – Stage 3: FIELD FEEDBACK

IDENTIFY AND CHARACTERIZE THE RISK LEVEL

- First premature failures observed on field
- Definition of LDE purchasing procedure
- Field Study 45 networks 7 countries
- First R&D Program launched

2005 2006 2007 2008 2009 2010-11
Field study within SE: How to classify?

New methodology for ranking the level of degradation

Degradation
- Very HIGH
- HIGH
- MODERATE
- LOW
- NONE

Based on 4 tests

201 non-failed PE samples collected over 45 networks, 7 countries
About 1000 analyses
Degradation levels: contrasting situations

Chlorine

Northern Africa
8 samples

Southern Europe
29 samples

Southern Europe
17 samples

Chlorine Dioxide

Southern Europe
13 samples

France
31 samples

Eastern Europe
13 samples

Northern Europe
27 samples

France
50 samples
5 risk factors identified

This set of parameters define the PE lifetime
Polyethylene: Act I – Stage 4: DISINFECTANT IMPACT

UNDERSTAND THE AGEING MECHANISMS IN PRESENCE OF DISINFECTANTS

- First premature failures observed on field
- First R&D Program launched
- Definition of LDE purchasing procedure
- Field Study 45 networks 7 countries
- Set-up of the SE Accelerated Ageing Bench

2005 2006 2007 2008 2009 2010-11

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Accelerated Ageing Bench

- Simulate the natural ageing observed on field
- Determine the impact of different disinfectants
- Select the best resistant materials
  - PE80, PE100, PEX, PVC, PP

IDENTIFY THE BEST POLYETHYLENE
Impact of disinfectants: accelerated ageing

**Without disinfectant**

**With monochloramines**

- PE80 ref
- 6 bar
- 40 °C

**With chlorine**

**With chlorine dioxide**

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Impact of disinfectants: Field ageing

Same phenomena observed between field and accelerated ageing bench

ClO₂ Exposure

ODL (x45) Inner

HCIO Exposure

ODL (x45) Inner

→ No direct extrapolation with the ageing bench (case per case approach)
Different impacts according to disinfectants

Different degradation kinetics according to the disinfectant

Pipe Embrittlement

- **NH₂Cl**: Much slower than Cl₂
- **HClO / Cl₂**: Sevenfold slower than ClO₂
- **ClO₂**: Quick and strong

Similar degradation profiles mechanisms than those observed in the field but with an acceleration time factor

The developed ageing bench is a reliable and innovative tool
Polyethylene: Act I – Stage 5: **DIAGNOSIS**

**NEW DISCRIMINATING TESTS**

- 2005
  - First premature failures observed on field
  - First R&D Program launched

- 2006
  - Definition of LDE purchasing procedure
  - Field Study
    - 45 networks
    - 7 countries

- 2007
  - Set-up of the SE Accelerated Ageing Bench

- 2008
  - 4000 experimental analysis performed
  - New tests to assess PE pipe degradation state

- 2009

- 2010-11

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Characterization of the PE degradation

Chemical ageing
- Loss of anti-oxidant level
- Formation of oxidation products

Overall embrittlement
- Degradation of the inner pipe wall degradation

Mechanical Performance
- Degradation of the mechanical properties
Qualify the embrittlement of PE

Reverse Bend Back Test (RBBT)  An easy pre-diagnosis tool

Changes in deterioration
Quantify the mechanical performance

Nol Ring Test
(developed by LNE in partnership with Suez-Environnement)

- Diagnosis of the degradation state (confirm the risk level)
- Control quality of new pipes (purchases)
PE Ageing and loss of mechanical properties
Impact of laying conditions

Trench-less techniques do not impact the performance of PE pipe if they induce limited damages (<10% of thickness).

Rock impingement or any external loading point due to poor laying conditions reduce significantly the PE lifetime:

BE CAREFUL TOWARDS INSTALLATION!

Wrong handling

Rock impingement

Bending

Wrong fitting installation
Polyethylene: Act I – Stage 6: LIFETIME

PREDICT THE LIFETIME

- 2005
  - Definition of LDE purchasing procedure
  - First premature failures observed on field
  - First R&D Program launched

- 2006
  - Field Study 45 networks 7 countries

- 2007
  - Set-up of the SE Accelerated Ageing Bench

- 2008
  - 4000 experimental analysis performed
  - New tests to assess PE pipe degradation state

- 2009
  - Extrapolation of PE life expectancy Improved Model (T°C, P, ClO₂)

- 2010-11

4000 experimental analysis performed
New tests to assess PE pipe degradation state
Life expectancy of polyethylene

- Decision-tree diagram available for BU: what is the risk level?

<table>
<thead>
<tr>
<th>Risk level per criteria</th>
<th>Temperature</th>
<th>Disinfectant</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Risk</td>
<td>Risk Level associated to Temperature</td>
<td>Risk Level associated to Disinfectant</td>
<td>Risk Level associated to Pressure</td>
</tr>
<tr>
<td>Medium Risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Risk</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Risk</td>
<td>Combination of the three obtained risk levels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Determine critical area: where are located the priory areas for service pipe's replacement?
Polyethylene: Act I – Stage 7: BENCHMARKING

SELECT THE BEST PE

- Definition of LDE purchasing procedure
- Field Study 45 networks 7 countries
- First premature failures observed on field
- First R&D Program launched
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010-11
- Set-up of the SE Accelerated Ageing Bench
- 4000 experimental analysis performed
- New tests to assess PE pipe degradation state
- Extrapolation of PE life expectancy Improved Model (T°C, P, ClO₂)
- Pipe benchmarking

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Select the best materials

Still under ageing (not yet failed)

Still under ageing (not yet failed)

Normalized lifetime in accelerated conditions

10/06/09
### Surprising results: sustained hydrostatic pressure test at high temperature

The accelerated ageing bench is more discriminating than the hydrostatic pressure test (according to standard) for characterising the PE pipe degradation after chlorine dioxide exposure.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Material</th>
<th>Specimen status on the bench testing (ClO₂, 40°C, 6 bar)</th>
<th>Test time (hour)</th>
<th>Test status</th>
<th>Pass/Fail Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>80°C 4 Mpa</td>
<td>PE80 B</td>
<td>Failed</td>
<td>1270</td>
<td>Stopped</td>
<td>PASS</td>
</tr>
<tr>
<td>&gt;1000h?</td>
<td>PE80 C</td>
<td>Failed</td>
<td>1392</td>
<td>Stopped</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>PE80 D (reference)</td>
<td>Failed</td>
<td>1393</td>
<td>Stopped</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>PE80 F</td>
<td>Failed</td>
<td>1393</td>
<td>Stopped</td>
<td>PASS</td>
</tr>
<tr>
<td>90°C 4.5 Mpa</td>
<td>PE80 E</td>
<td>Failed</td>
<td>239</td>
<td>Stopped</td>
<td>PASS</td>
</tr>
<tr>
<td>&gt;165h?</td>
<td></td>
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Polyethylene: Act II – Stage 1: A NEW ASSET MANAGEMENT APPROACH

MASTER ALL RISK FACTORS TO IMPROVE THE PERFORMANCE

- SE recognized as a KEY player
- PE sustainable life-cycle approach

2005 - 2010
- Definition of LDE purchasing procedure
- Field Study 45 networks 7 countries
- First premature failures observed on field
- First R&D Program launched

2006
- Set-up of the SE Accelerated Ageing Bench

2007
- 4000 experimental analysis performed
- New tests to assess PE pipe degradation state

2008
- Extrapolation of PE life expectancy Improved Model (T°C, P, ClO₂)

2009
- Pipe benchmarking

2010-11

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The PE sustainable Life-Cycle

1. Technical specifications
2. Choice of suitable material
3. Choice of PE resin
4. Selecting pipe manufacturers
5. Purchasing procedure
6. Frequent Quality Control
7. Storage and Handling
8. Monitoring installation conditions
9. Potable Water Network Diagnostics
10. Operation and Maintenance
A new offer: master the cycle step by step

1. Technical Specifications
   - Definition of requirements according to local conditions
   - Impact made by temperature, pressure, disinfectant

2. Choice of suitable material
   - Selection of best material for local conditions
   - Risk auto assessment tool

3. Choice of PE resin
   - Improved longevity

4. Selecting pipe manufacturers
   - Technical Audits
   - Manufacturer guide and methodology

5. Purchasing procedure
   - Establishing and implementing the purchasing policy
   - Guaranteeing quality of procurement

6. Frequent Quality Control
   - Deploying the Quality Control process

7. Storage and Handling
   - Polyethylene guide

8. Monitoring installation conditions
   - Network Disciplines Manual
   - In-house training
   - Continuous subcontractor assessment

9. Potable Water Network Diagnostics
   - Assessing the state of deterioration
   - Aid in decision-making:
     - Rehabilitation or repair

10. Operation and Maintenance
    - Mastering and reducing the risk factors:
      - Pressure modulation (mechanical stress)
      - Choosing the water resource (temperature)
      - Choosing the disinfection treatment

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Polyethylene: Act II – Stage 2: RESEARCH STILL ON-GOING

WHAT’S ABOUT CHLORINE ???

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Pipe benchmarking

(SE recognized as a KEY player
PE sustainable life-cycle approach)
**CONCLUSION**

- LYONNAISE-DES-EAUX and SUEZ-ENVIRONNEMENT have improved their knowledge of the PE life-cycle
  - Each step has to be mastered
    - Towards a new asset management approach

- PE remains a good material for future if all steps of the life-cycle are observed
  - Flexible, Easy to use, Reasonable cost
  - Weldability
  - Trenchless techniques
  - 30 years of experience
  - 100% of service lines
  - Major part of pipes installed in France
CONCLUSION

ALL PE ARE NOT EQUIVALENT

MAKE THE RIGHT CHOICE

Taking into account

LIFETIME

T°C

Disinfection

Pressure

Installation

Material

5 OPTIMIZATION AXES

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THANK YOU FOR YOUR ATTENTION