PE pressure pipes made from PE 100-RC

Design and calculation of gas- or water pipelines for a minimum service life of 100 years

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1. Overview on Failure Modes

Failure Modes

- **Logarithmic graph**
  - *σ* [N/mm²] on the y-axis
  - *t* [h] on the x-axis

- **Ductile Failures**
  - Through stretching of material

- **Brittle Failures**
  - Through stress cracking

- **Thermal Ageing**
  - Failures independent of stress level
  - Onset of thermal ageing at 80 °C after 1 year*

- **Relevant for Service Life**

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* DVS directive DVS 2205-1, sup. sheet 19
1. Overview on Failure Modes

Test to detect stress cracking resistance: FNCT

Advantage:

The results out of FNCT correlate with results out of pipes under internal pressure

Test time reduction by using surface active solutions

Test fluid – e.g. ARKOPAL N-100

(VA 2.1-4, ISO 16770; DIN EN 12814-3 (2005-10), Anhang A.1; DVS 2203-4)
Influence of medium

- Water
- Gas
- Surface active solution (e.g., 2% ARKOPAL N-100)

Same slope but different rupture times
2. Progress in raw material development

Increasing rupture times

Rupture Time in Hours

<table>
<thead>
<tr>
<th>Year</th>
<th>PE 63</th>
<th>PE 80</th>
<th>PE 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>4</td>
<td>11</td>
<td>10462</td>
</tr>
<tr>
<td>1980</td>
<td>31</td>
<td>51</td>
<td>259</td>
</tr>
<tr>
<td>1999</td>
<td>338</td>
<td>359</td>
<td>14460</td>
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Test temperature 80 °C
Tensile load 4 N/mm²
2 % Arkopal N-100

Specimens show brittle failure

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### Requirements to PE 100-RC raw material (PAS 1075)

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3. Requirements of PAS 1075

Requirements to PE 100-RC raw material (PAS 1075)

| FNCT | > 8760 h (> 1 year) at 80 °C 4 N/mm², in 2 % Arkopal N-100 |

⇒⇒⇒⇒ no brittle failure until 1 year

⇒⇒⇒⇒ onset of thermal ageing after 1 year at 80°C in water *

\[ \log t [h] \]

\[ \log \sigma [N/mm^2] \]

4 N/mm²

* DVS directive DVS 2205-1, sup. sheet 19

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# Requirements to PE 100-RC raw material (PAS 1075)

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4. Thermal ageing

**Influencing variables for thermal ageing**

- Oxygen concentration
- Temperature
- Flow rate of medium
- Stabilization package
- Local strain situation

**NOT taken into account in ISO 9080**

⇒ values are too optimistic

⇒ For PE 100-RC materials thermal ageing has to be tested additionally
4. Thermal ageing

Extrapolation of results  Arrhenius-Diagram

reciprocal slope of regression curve is proportional to activation energy $E_A$ for thermal ageing

Reciprocal absolute temperature [$1/K$]

$log t$ [h]

> 100 years

80 °C

90 °C

100 °C

-20 °C

-80 °C

-90 °C

-100 °C
4. Thermal ageing

Minimum required activation energy for thermal ageing

1. Requirement: no failure until 100 years @ 20°C

Minimum required activation energy for thermal ageing:

\[ E_A \geq 67 \text{ kJ/mol} \]

2. no failure until 1 year @ 80°C

* DVS directive DVS 2205-1, sup. sheet 19

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5. New creep rupture curves for PE 100-RC

PE 100-RC exceeds standard creep rupture curves

PE 100 according to DIN 8075

PE 100-RC

log \sigma [N/mm^2] vs. log t [h]

flat ‘branch’

5 N/mm²

steep ‘branch’

thermal ageing

1000 h

1 year at 80 °C

?
5. New creep rupture curves for PE 100-RC

New creep rupture curves for PE 100-RC in PAS 1075

Hoop stress [N/mm²]

Rupture time [h]

Creep rupture curves according to DIN 8075

Creep rupture curves according to PAS 1075
6. Conclusion

Conclusion

• PE 100-RC - thermal ageing becomes the relevant failure mechanism

• PE 100-RC exceeds standard creep-rupture curves

• PE 100-RC are raw materials with very high stress crack resistance
  ⇒ High chemical resistance
  ⇒ Extended application alternative installation techniques

• PE 100-RC - New creep rupture curves have been established in PAS 1075
Thank you for your attention !