Buried High Density Polyethylene Pipe

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Background

- Recognized resistance of high density polyethylene (HDPE) piping material against galvanic corrosion, microbiological induced corrosion (MIC), and fouling compared to carbon steel
- Replacement of carbon steel piping with HDPE in ASME Section III safety related Class 3 buried piping applications (Service water)
- ASME prepared a Section III Code Case N-755 to address the use of polyethylene piping in Section III, Division 1, Class 3 buried piping systems

Background Cont'd:

- Some unique challenges requiring special design considerations due to HDPE's visco-elastic nature, very low material allowable stress, poor thermal conductivity & large coefficient of thermal expansion
- A need for relatively thick pipe walls associated with polyethylene piping
- Substantial differences in physical and mechanical properties compared to steel piping

- The NRC recently approved two relief requests on the use of buried HDPE piping as a replacement to degraded carbon steel piping in nuclear safety-related Class 3 applications
- The ASME Code Case N-755 on buried HDPE piping has not yet been endorsed by the NRC since some issues have yet to be resolved concerning design, material, fabrication, and examination
- Task Groups under ASME Special Working Group on Polyethylene Piping (SWG-PP) are working to resolve the issues

Material	Carbon Steel (Isotropic linear elastic)	Polyethylene (HDPE) (Visco-elastic)
Modulus of Elasticity (E)	27.9×10^6 psi (1.92×10^5 MPa)	2.8×10^4 psi (193 MPa)
Poisson's Ratio (v)	0.3	0.4 to 0.45
Coefficient of Thermal Expansion (α)	6.5×10^{-6} /^{o}F (1.17×10^{-5} /^{o}C)	6×10^{-5} /^{o}F (1.08×10^{-4} /^{o}C)
Thermal Conductivity (K)	26 BTU/hr-ft- ^{o}F (38.7 Kcal/hr-m-^{o}C)	≈ 0.25 BTU/hr-ft- ^{o}F (0.37 Kcal/hr-m-^{o}C)
Allowable Stress	15000 psi (103.4 MPa)	≈ 350 psi (2.41 MPa)

Design Factor (DF)

[To establish allowable stress for HDPE]

- Recommend a value for design factor of 0.5 or factor of safety of 2 to establish reasonable assurance for providing adequate safety margin
- DF of 0.5 for PE piping in potable water applications in North America has proved to be successful for over 40 years
- DF to capture a broad spectrum of uncertainties
  - Resin variation
  - Extrusion and processing variables in the production of PE piping
  - Handling during storage
  - Shipping and installation
  - Application temperatures

Design Factor Cont'd:

- Joining and bending methods
- Various soil conditions
- Typical installation methods
- Dynamic loading, surges and water hammer
- Higher temperatures (up to 175^{o}F) and higher pressures (up to 170 psig), with a need for large diameter and heavy wall thickness piping, compared with traditional non-safety related cold water applications
- New or improved grades or cell classifications are emerging (limited experience)
- Other unknown factors

Loads of Different Duration

- The behavior of HDPE materials is affected by the loads of different duration as the allowable stress is strongly influenced by temperature and time duration
- The cumulative effect from loads of different duration needs to be accounted for either conservatively or through the application of an equivalent Miner's rule type approach

Other Considerations:

- On-going research and testing programs to establish properties such as long term creep life, fatigue properties, effect of aging
- Butt fusion joint integrity
- NDE methods to detect flaws still evolving
- Very little experience on the use of HDPE in nuclear safety related applications
- Conventional testing methods to determine properties such as slow crack growth (SCG) resistance are inadequate, and new methodologies for testing are still evolving

Thermal Gradient Stress in Longitudinal & Circumferential Directions

- Compared to thin wall steel pipe, HDPE has Significant Thermal Gradient Stress due to
  - Low thermal conductivity
  - Large thermal expansion coefficient
  - Large wall thickness
- Recommend to use thick wall formula or other conservative approximation for stress evaluation of HDPE (D/t << 20)

- Modulus of elasticity for PE materials is likely dependent not only on temperature, and time, but, also on the stress level
- Considering that PE materials exhibit creep at much lower temperature compared to metallic materials, long term creep data is necessary to establish safe allowable stress for PE materials at stresses and temperatures of interest
- Need for verification of butt fusion joint integrity compared to parent materials at elevated (and varying) temperatures, sustained stress, and with an allowable flaw

- Resistance of butt joint to slow crack growth (SCG) relative to parent pipe material needs to be established
- 10% t flaws in the pipe wall may be unacceptable for thick wall PE pipe

Conclusions and Recommendations for HDPE Piping in Nuclear Safety Related Buried Piping Applications

- Use of design factor not higher than 0.5
- Use of thick wall vessel formulas or other conservative approximation for stress computation
- Inclusion of range of thermal gradient stress in thermal expansion and contraction evaluation
- Evaluation for cumulative effects for loads of different duration
- Special design considerations are recommended for updating ASME CC N-755