Arctic Pipelines: Opportunities and Challenges for Technology

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DC&O Mission Statement

Develop safe, environmentally responsible, cost-effective and reliable solutions for the design, construction, and operation of energy pipelines
Key Emphasis Areas

- Onshore & Arctic
- Offshore
- Damage Prevention and Detection
- Reliability-based Design and Assessment
- Integrity Practice Standardization

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Prevention of Third Party Damage</td>
<td>$1,305k</td>
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<tr>
<td>2</td>
<td>Implementing Integrity Standards</td>
<td>$3,060k</td>
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<td>3</td>
<td>Reliability-based Design Alternatives</td>
<td>$918k</td>
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<tr>
<td>4</td>
<td>Determination of Max. Safe Surface Loads</td>
<td>$994k</td>
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<td>5</td>
<td>Leak Detection and Notification</td>
<td>$350k</td>
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<tr>
<td>6</td>
<td>Prevention of Critical Pipeline Strains</td>
<td>$1,363k</td>
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<tr>
<td>7</td>
<td>Solutions for Adverse Crossings</td>
<td>$245k</td>
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Total: $8,235k
Expectations for Arctic Pipelines

- **Economically optimized**
  - cost minimized

- **High level reliability**
  - limited access and continuous services

- **High level of efficiency**
  - high pressure and rich gas

- **Environmental impact minimized**
  - low temperature, environmental mitigation and reclamation
New Design Concept

- Chilled large diameter gas pipelines
  - maintain permafrost
  - control erosion
- Ultra high pressure
  - large throughput
  - efficiency
- Life cycle reliability
  - integration of design, construction & maintenance
  - acceptable reliability
Technology Development

- **Design methodology**
  - reliability-based design
- **Quantify loads and loads and load effects**
  - unique loads to Arctic pipelines
- **High strength material**
  - tensile and compressive strain limits, fracture control
- **Construction technology**
  - hydrotest, trenching, HDD, buoyancy control, welding and inspection
Design Methodology

- Quantifies the reliability for all relevant “failure” conditions (limit states)
- Takes account of all mitigation measures:
  - pipe material and geometric – e.g. grade, WT
  - inspection – e.g. pig runs, ROW surveillance
  - protection – e.g. burial
- Adaptable to include unique design conditions and new technology
- Optimization over life cycle to achieve acceptable reliability/risk levels
Design Methodology

PRCI has sponsored a suite of projects, e.g.

- limit states design framework for pipelines
- evaluation of pipeline design factors
- reliability-based prevention for mechanical damage
- reliability-based design for mechanical damage
- remote and automatic main line valve technology assessment
- reliability-based planning of inspection and maintenance
- development of seismic design guidelines
- development of reliability-based design and assessment guidelines
Reliability-based design and assessment (RBDA)

- Design and operate pipeline to maintain the predetermined reliability targets throughout its operating life for all relevant limit states.
- Reliability targets, as the minimum requirement, are calibrated to acceptable safety criteria.
- Business needs and life cycle cost optimization could raise reliability targets even further.
Design Methodology

Path forward

- complete the development of RBDA guidelines
- need to develop RBDA standards in both U.S. and Canada based on wide consensus from the industry and the regulatory communities
- acceptance and adoption of RBDA standards by the regulators and industry
- application and implementation in arctic pipelines
- extend the RBDA methodology to pipelines for services other than natural gas
Quantify Loads and Load Effects

- Challenging environment for Arctic pipelines
  - frost heave and thaw settlement
  - slope movement
  - seismic loads including ground shaking, landslide and fault displacement
Quantify Loads and Load Effects

- Evaluating and quantifying the processes and magnitudes of the all relevant loads
  - understand the mechanisms
  - collect data and establish databases
  - develop predictive models
  - estimate the variability of the predicted loads
Quantify Loads and Load Effects

» Predicting the load effects on pipelines in terms of stress, strain, displacement, etc.
  - understand load transfer mechanisms from ground to pipeline
  - quantify the transferred loads in terms of process, distribution and magnitude
  - develop models for prediction of pipeline response up to the failure conditions
Quantify Loads and Load Effects

PRCI has sponsored a suite of projects, e.g.

- experimental modeling of frost heave and thaw settlement
- seismic design guidelines
- pipe-soil interaction models for pipelines in permafrost
- improved models for pipe-soil interaction
- analysis and guidelines for deep water risers
- pipeline on-bottom stability
- effect of non-typical loading conditions on buried pipelines
- effect of static and cyclic surface loading on pipelines
Quantify Loads and Load Effects

Path Forward

- collect field and lab data to enhance databases and understanding of load mechanisms

- improve the models for quantifying loads to reduce uncertainty

- extend the models for pipeline response to predict the true failure conditions
High Strength Materials

- North American gas demand continues to increase
- System pressure continues to rise
- New gas supply are being developed
- Material is one of two major capital cost components
High Strength Materials

- Compressive strain limit
  - local buckling behavior
- Tensile strain limit
  - fracture mechanics and defect assessment
- Fracture arrest
  - fracture behavior and gas decompression behavior
High Strength Materials

PRCI sponsored numerous projects, e.g.
- local buckling of pipes
- local buckling of corroded pipes
- acceptance criteria for mild ripples in field bends
- guidelines for tensile strain limits
- decompression response of high pressure pipelines
High Strength Materials

Path forward

- extend models and database to high strength pipes and high pressure operations

- increase the compressive strain limits by utilizing the post-buckling capacity
Construction Technology

- Construction is a major capital cost component

- Productivity is the key
  - trenching
  - HDD
  - pressure test
  - buoyancy control
  - welding and inspection
Construction Technology

- Trenching by trenchers has major advantages
  - high productivity
  - better trench
  - less loss of backfill
  - minimum disturbance

- Need to understand
  - conditions that trenchers work well
  - productivity for various ground conditions
Construction Technology

Pressure test is a major challenge for Arctic pipelines
- limited water supply
- heating or additives (e.g. glycol)
- environmental concerns for disposal of water

Low cost alternatives needed
- air tests
- enhanced QA and inspections
HDD is common in typical construction

HDD in permafrost has challenges
- thawed/frozen interface
- stability of the drilling path
- further study and field tests are required
Construction Technology

- Weight-based buoyancy control has challenges in transportation

- Cost effective alternatives needed
  - screw anchors
  - installation and design method for permafrost area
Summary

- Arctic pipelines presented significant challenges and opportunities
- Focused and well planned R&D leads to technologies and innovative solutions
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Pipeline Research Council International, Inc.
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Construction Technology

- Welding and inspection impact the productivity
- High levels of quality and consistency are required
- Mechanized welding and UT inspection
  - extend to high strength pipe
  - increase productivity