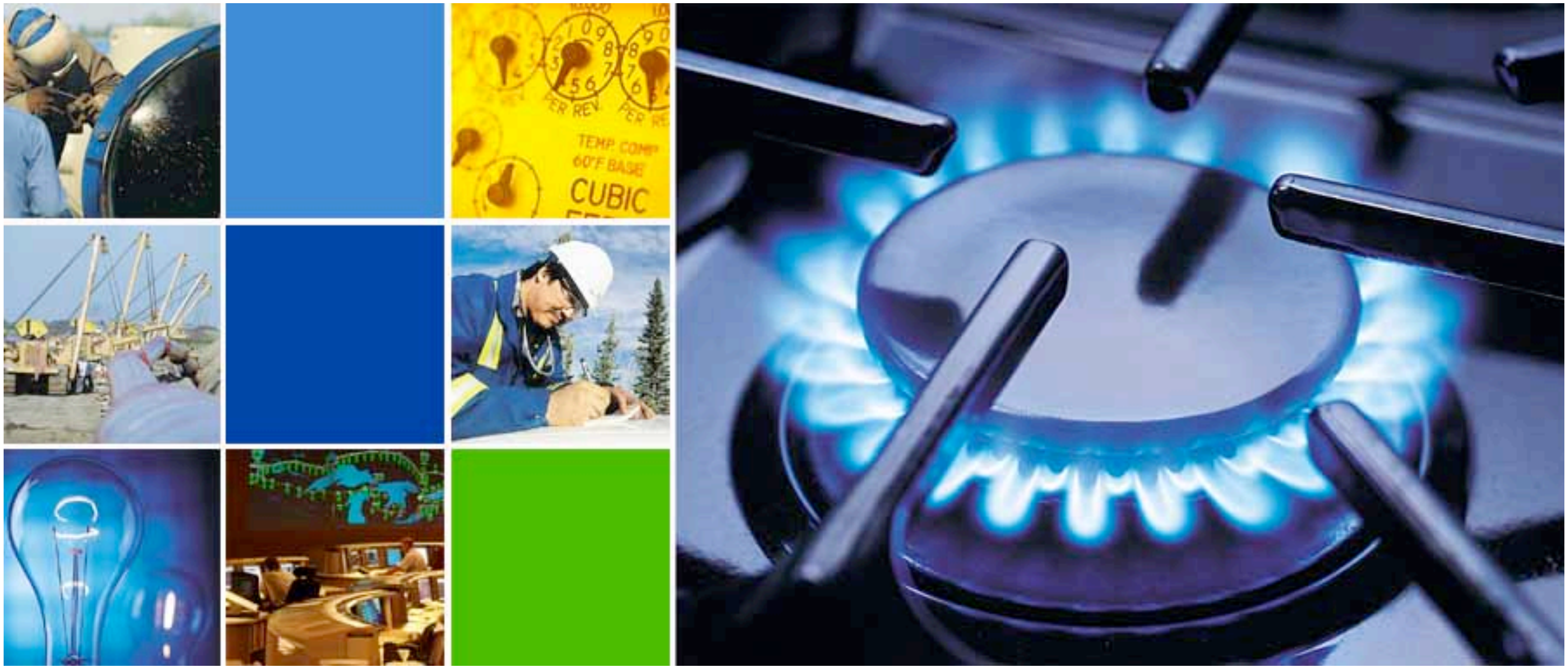

Track 5: Pipelining in Challenge Areas
Arctic Pipeline Design and Construction

PHMSA R&D Forum

Crystal City, Virginia, June 24-25, 2009

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In business to deliver

Outline

- Brief Overview of Arctic Pipeline Projects
- Strain-Based Design (SBD)
- Reliability-Based Design and Assessment (RBDA)
- Quality Management System

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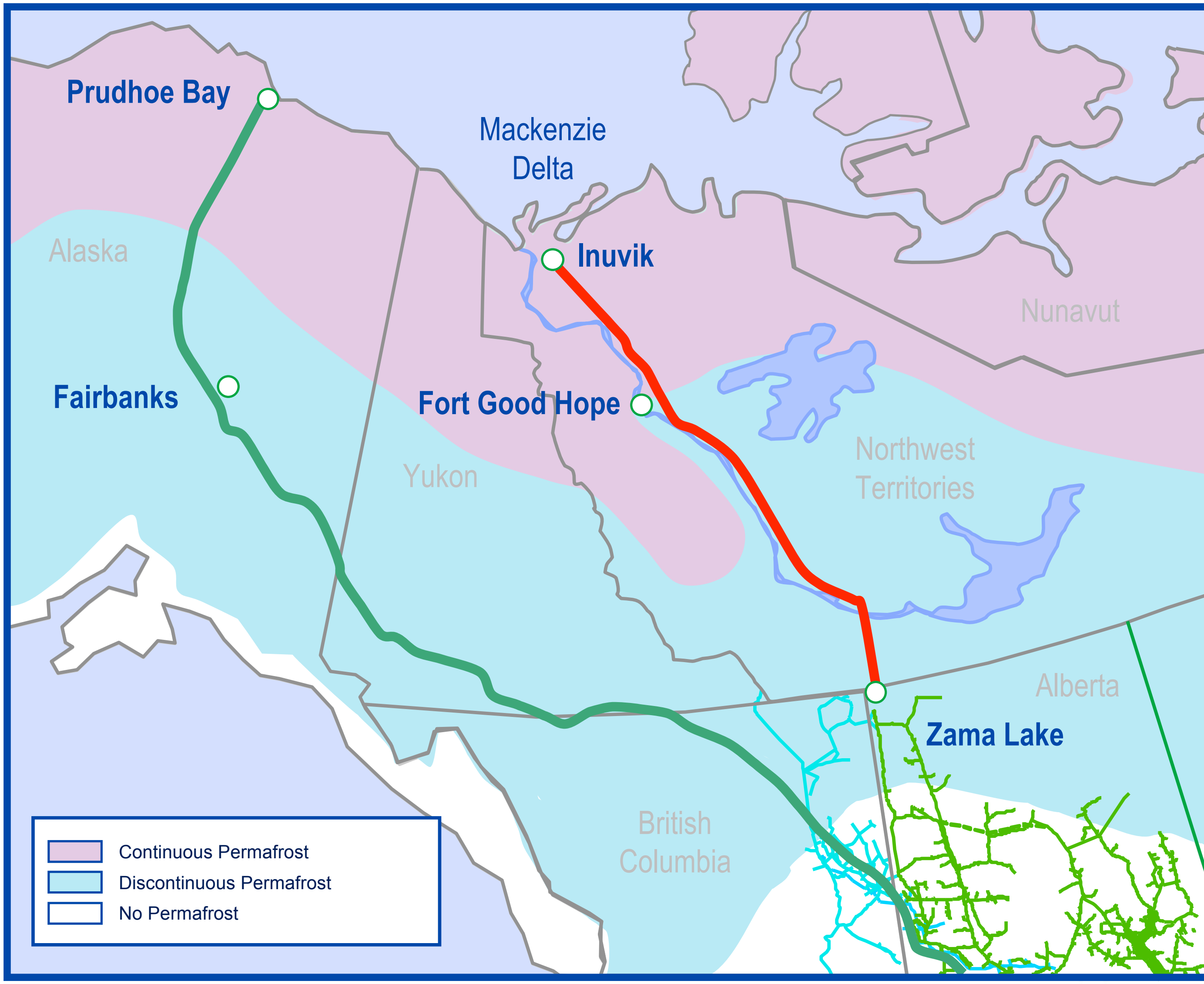
Arctic Pipeline Projects



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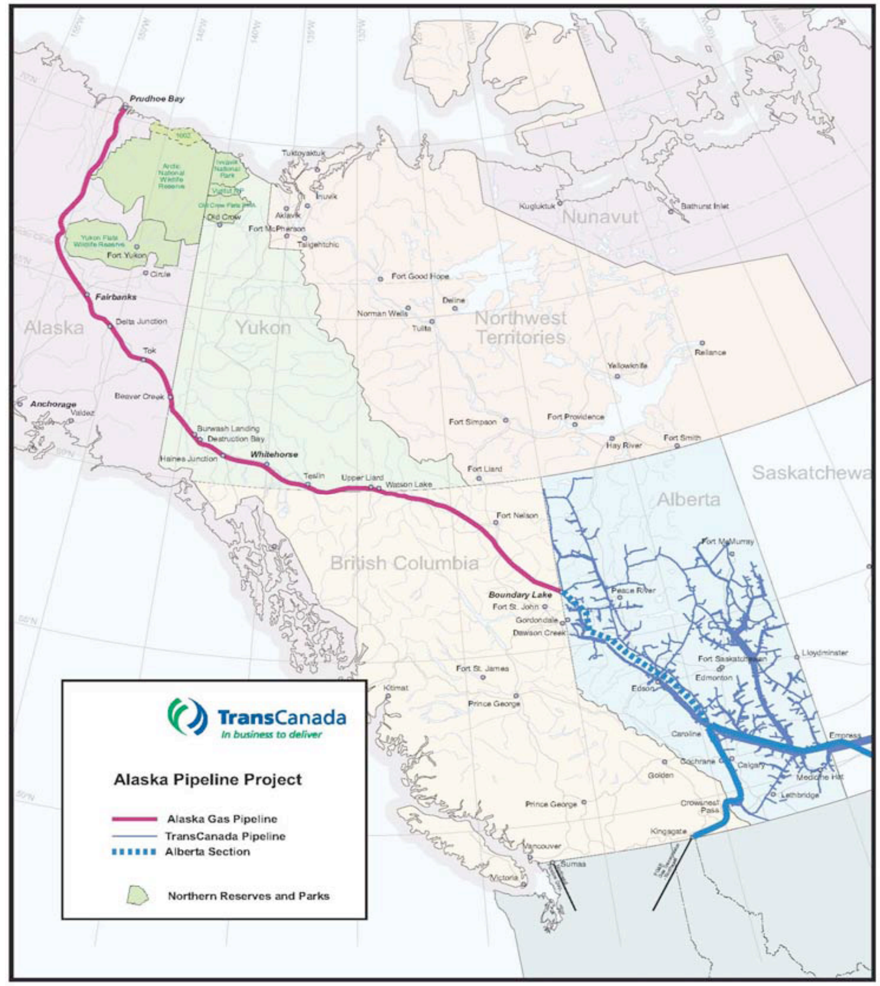
Project Scope and Description

- Gas treatment plant at Prudhoe Bay
  - 5 Bcf/d initial capacity
- Natural gas pipeline from Prudhoe Bay to Alberta Hub
  - 4.5 Bcf/d initial capacity
  - Expansion to 5.9 Bcf/d with compression only
  - 48-inch diameter; 2500 psig
  - 750 miles in Alaska, 6 c/s
  - 965 miles in Canada, 10 c/s
- Alberta Hub to Lower 48
- LNG pipeline alternative to Valdez



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Many Challenges

- Alaska Gas Pipeline challenges the limits of current technologies and practices in many fronts:
  - Ultra high pressure, large diameter and low temperature rating
  - Permafrost and other geo-hazards are paramount
  - Pipe and components to specifications
  - Welding processes with overmatching and high productivity
  - Excavation in complex soil conditions including permafrost
  - Challenging the limits of conventional construction equipment
  - Tight temperature control and compressor station design
  - HDD for large diameter and heavy wall pipe in permafrost
  - Remote and limited access and extreme climate conditions
  - Limited water resources in winter
  - Environmental protection and constraints
  - Demonstrate safety and integrity and regulatory review and approval

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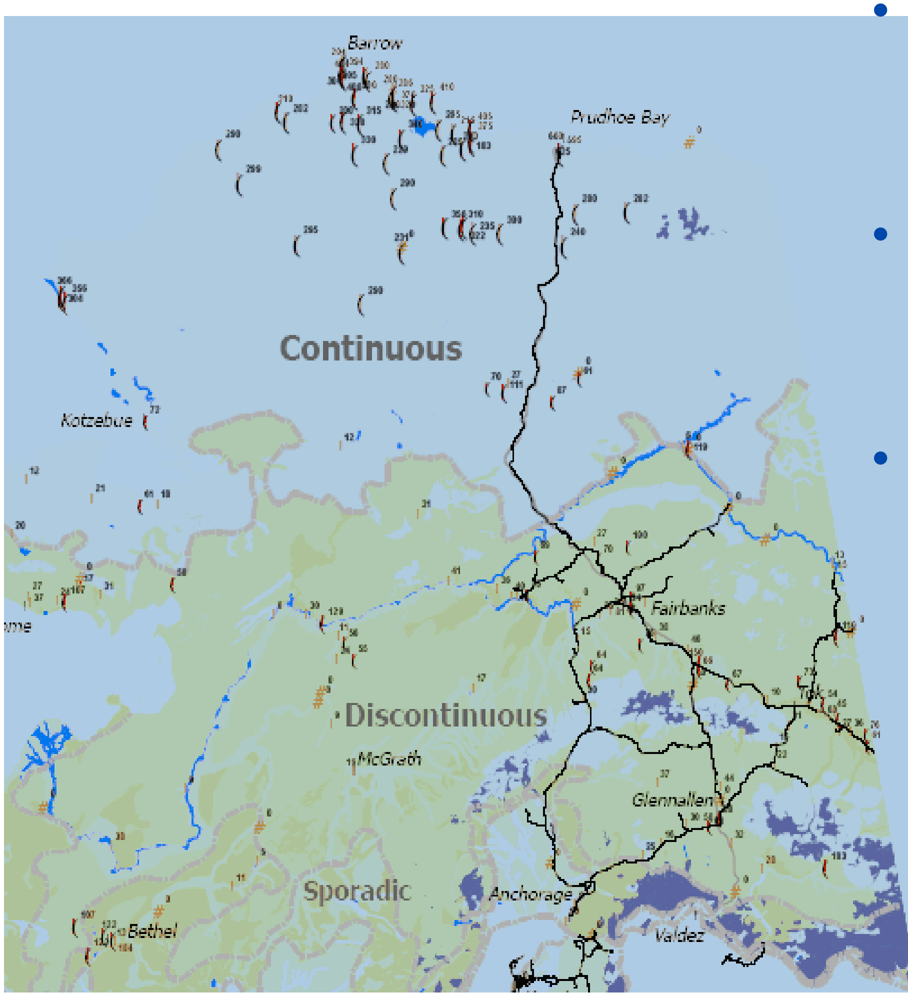
Permafrost in Alaska



- Continuous permafrost between MP 0-389 and between MP 624-633
- Isolated permafrost between MP 560-562 and between MP 577-585
- Valdez extension has some continuous permafrost

Legend

Permafrost Distribution

- Glacier
- Continuous (>90%)
- Discontinuous (50-90%)
- Sporadic (10-50%)
- Isolated (>0-10%)
- Absent (0%)
- Large Waterbodies (unfrozen below)

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Seismic Hazards

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Extreme Climate Conditions

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Strain Based Design

- Applicable to displacement controlled design conditions by ensure the strain demands are less than strain capacities (tensile and compressive)
  - Strain demands resulted from frost heave and thaw settlement
  - Compressive strain capacity
  - Tensile strain capacity
  - Safety margin, safety factor or reliability

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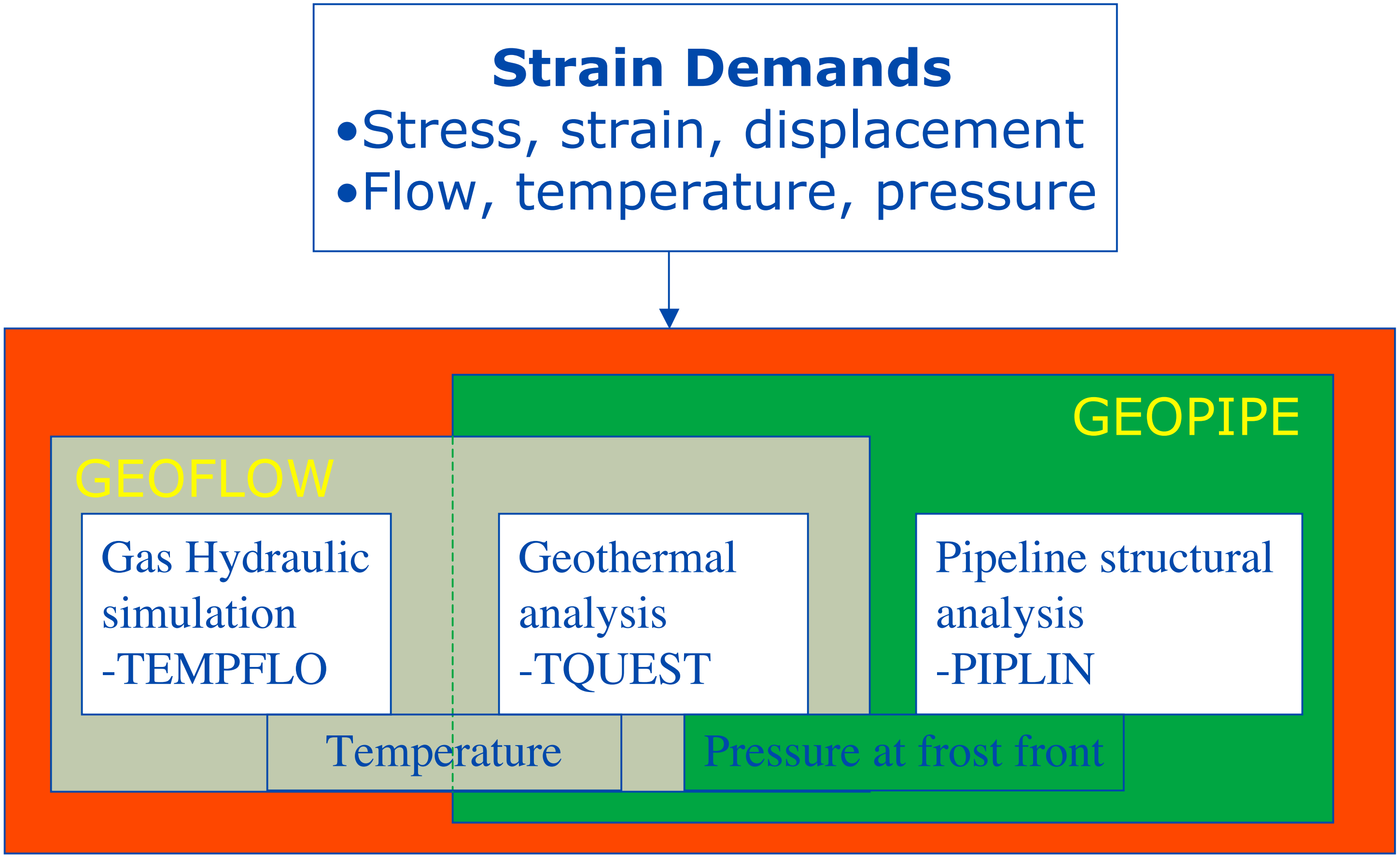
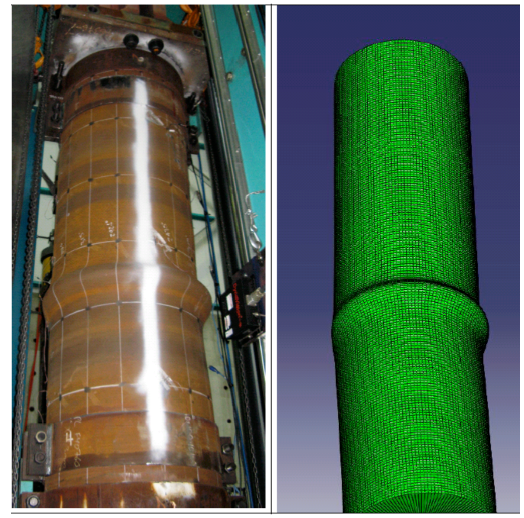
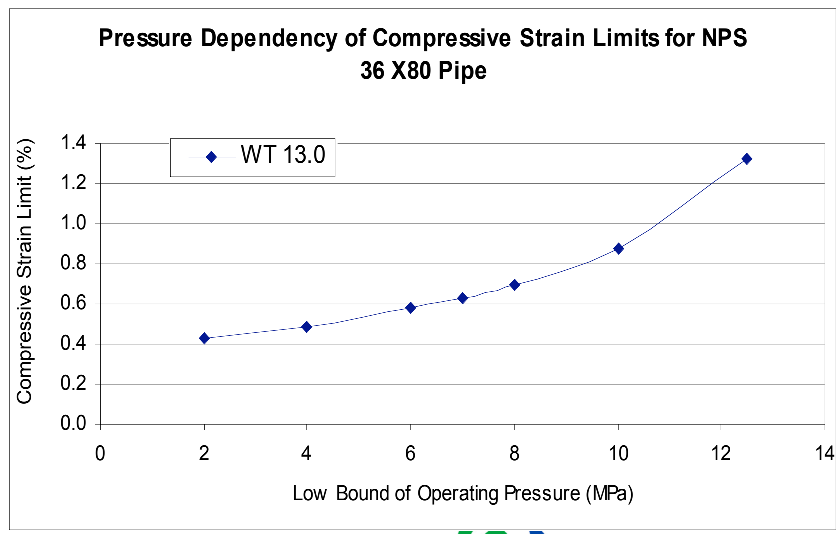
Strain Demand



Compressive strain limit

- Based on local buckling behavior
- Significantly influenced by
  - D/t ratio
  - Internal pressure
  - Geometric imperfection and girth weld misalignment
  - Does not lead to immediate failure
- Prediction model and process validated by tests





Tensile Strain Limit

- Based fracture mechanics, small scale tests, wide plate tests and full scale tests
- Significantly influenced by
  - Biaxial stress state
  - Weld strength overmatch pipe
  - Adequate toughness in both welds and pipes
  - Weld defects
- Lead to immediate failure
- Prediction model and process validated by tests

SBD Status and Gaps

- Practices for strain demand resulted from permafrost have been established by specialized consultants
  - Guidelines are needed for broad acceptance and consistent application
- Significant efforts by industry on compressive strain capacity, including large scale full scale tests
  - Access to company database is limited
  - Various models in literature but lack of universal recognition
  - Guidelines are needed for model development, validation and calibration
- Substantial efforts funded by PRCI, PHMSA and industry on tensile strain capacity are in progress
  - DTPH56-06-000014 (ABD-1), limited scope in full scale tests
  - Access to other industry data are limited
  - Follow-up is need to expand test database and complete the development of guidelines

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SBD – Proposed Research Program

- Develop comprehensive guidelines for SBD
  - Guidelines for strain demands from permafrost related hazards
  - Guidelines for compressive strain capacity
  - Guidelines for tensile strain capacity

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Reliability Based Design and Assessment (RBDA)

- RBDA is a probabilistic methodology to ensure acceptable safety by maintaining minimum reliability equal or higher than target reliability that is
  - Dependent on safety consequence
  - Calibrated based on the performance of natural gas pipelines designed and maintained to current codes
- RBDA can be effectively used to
  - Quantify variability and rationally included them in the design process
  - Establish appropriate safety margin
  - Optimize design on a system basis
  - Quantify the expected level of maintenance during the operation phase

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RBDA Gaps and Proposed Research Program

- Generic RBDA standard published by ISO 16708 in 2006
- RBDA standard for natural gas pipelines
  - Adopted by CSA Z662 and published as a non-mandatory Annex O in 2007
  - Review process in ASME B31.8 started in 2003 and continuing
- Proposed research program
  - Complete the standard development with B31.8 and publish the RBDA standard as a supplement
  - Extend the RBDA methodology to other type of pipelines
  - Gain regulatory acceptance

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Quality Management System (QMS) for Pipelines

- Pipeline projects, from design to commissioning, involve a large number of complex processes and QMS is essential to high quality product
- QMS would typically include the following components
  - Management commitment (policy, goal and objective, organization and responsibilities)
  - QA/QC processes and procedures
  - Risk management plan
  - Communication plan
  - Monitoring and assessment plan
  - Management of changes
  - Document management
  - Training and development

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QMS Status and Proposed Research Program

- Various forms of QA/QC program widely implemented
  - Ranging from based on minimum standards to substantial supplemental company specific program
  - Varying performance
- TransCanada has piloted QMS approach as the basis for a number of pre-service hydrotest waivers
- Proposed research program: develop a QMS for pipeline projects (from design to commissioning) to ensure consistent and acceptable quality that is
  - Comprehensive in scope
  - Flexible in process and procedure
  - Effective in achieving consistent and acceptable quality
  - Adequate to demonstrate pipeline safety and integrity without pre-service hydrotest where applicable

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Thanks