Pipeline Design, Construction & Operations Technical Committee

Arctic Pipelines: Opportunities and Challenges for Technology

Joe Zhou
TransCanada PipeLines Limited

New Construction, Materials and Welding
Research & Development Forum
Washington, D.C.
December 2003

DC&O Mission Statement

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

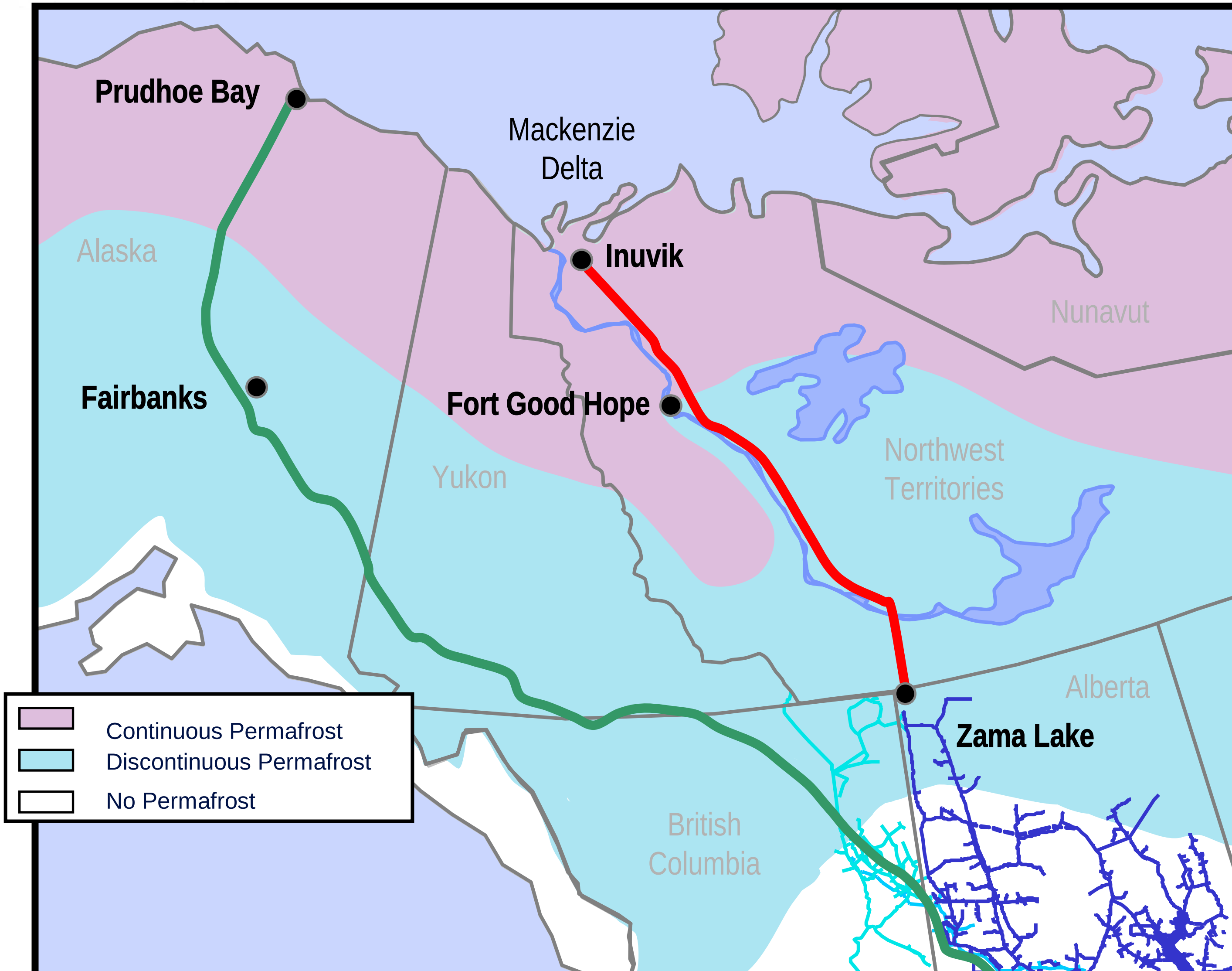
Key Emphasis Areas

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

Technology for Energy Pipelines

Technical Programs (2001 – 2004)

1.	Prevention of Third Party Damage	$1,305k
2.	Implementing Integrity Standards	$3,060k
3.	Reliability-based Design Alternatives	$918k
4.	Determination of Max. Safe Surface Loads	$994k
5.	Leak Detection and Notification	$350k
6.	Prevention of Critical Pipeline Strains	$1,363k
7.	Solutions for Adverse Crossings	$245k
		$8,235k



Prudhoe Bay
Mackenzie Delta
Inuvik
Alaska
Nunavut
Fairbanks
Fort Good Hope
Yukon
Northwest Territories
Alberta
Zama Lake
British Columbia
Continuous Permafrost
Discontinuous Permafrost
No Permafrost

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

Design Methodology

- **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

PRCI
Technology for Energy Pipelines

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

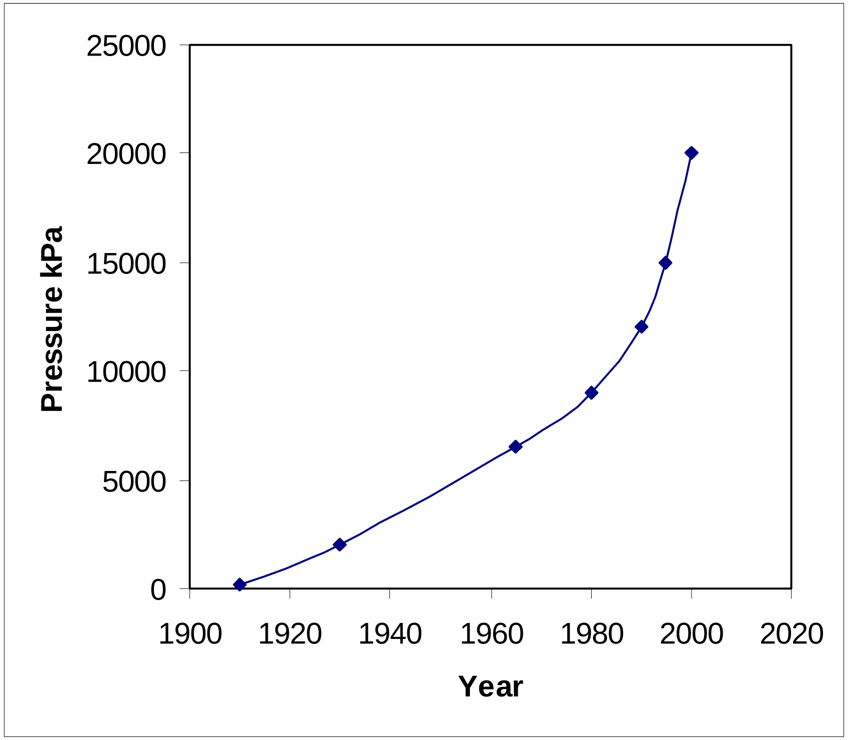
- **PRCI has sponsored a suite of projects, e.g.**
  - experimental modeling of frost heave and thaw settlement
  - seismic design guidelines
  - pipe-soil interaction models for pipelines in permafrost
  - improved models for pipe-soil interaction
  - analysis and guidelines for deep water risers
  - 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



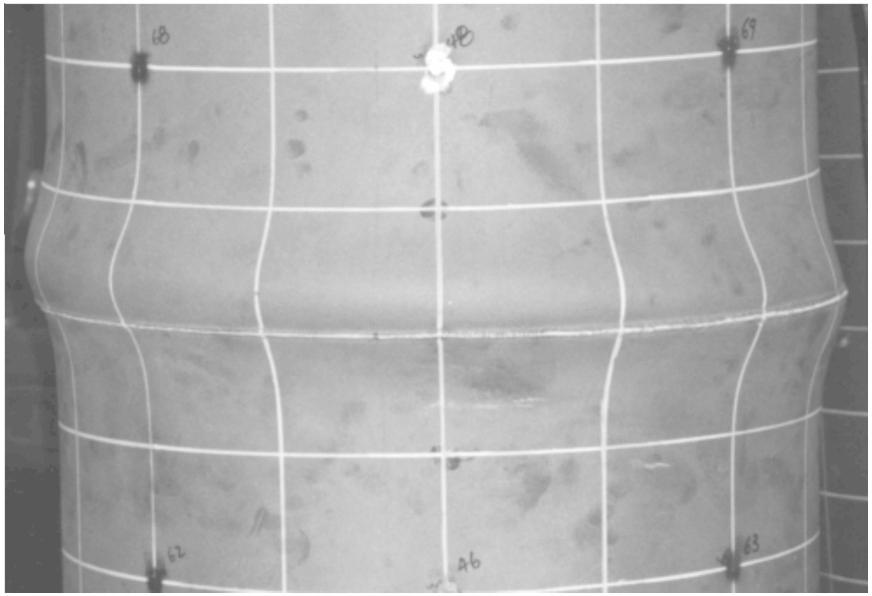
High Strength Materials

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

Technology for Energy Pipelines

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

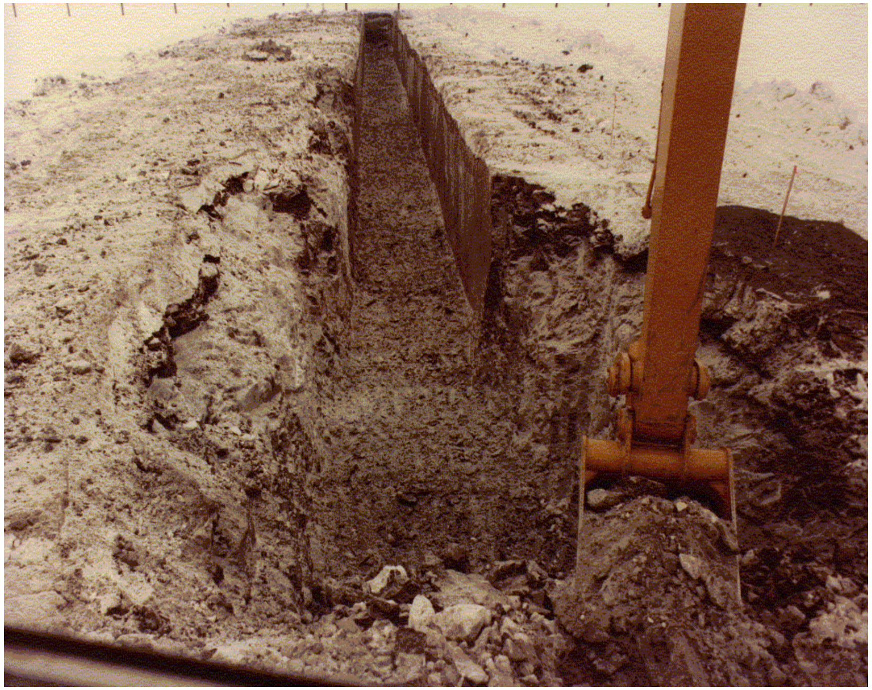
Construction Technology

- **Construction is a major capital cost component**

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

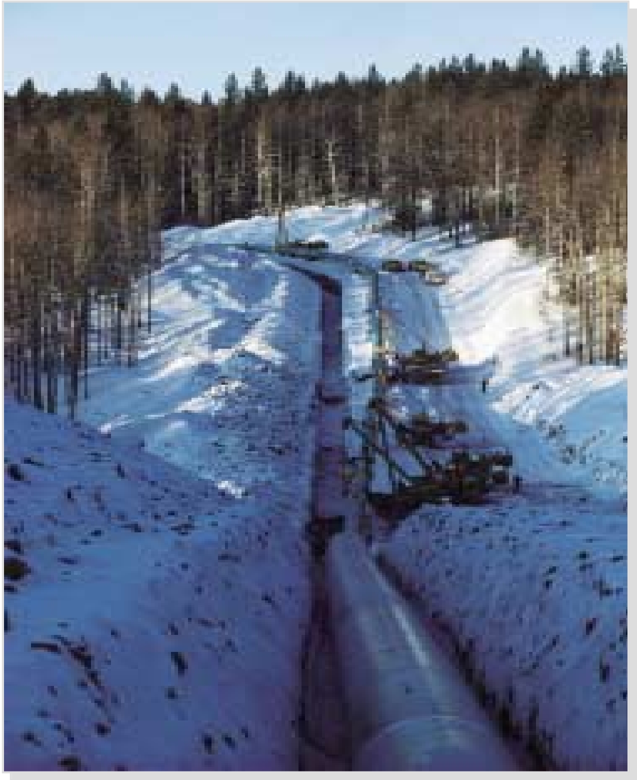
Construction Technology

- **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



Construction Technology

- 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

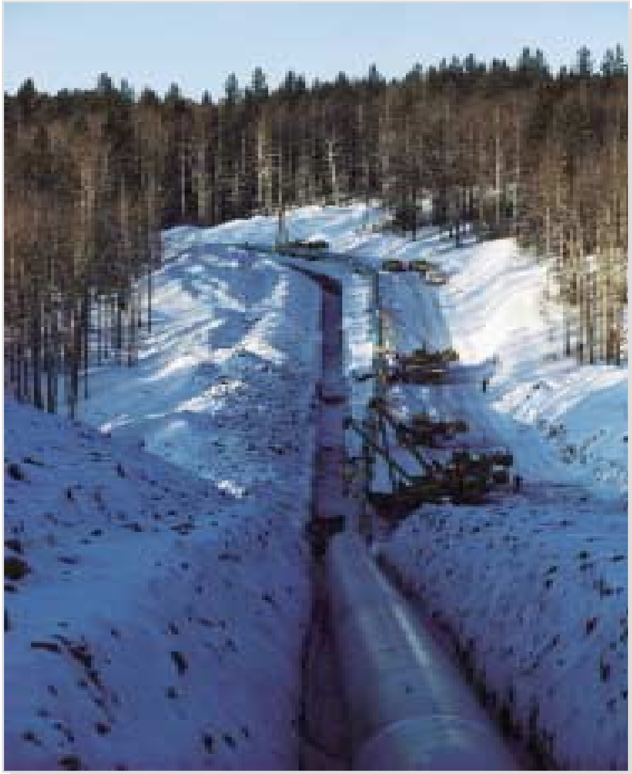
- **Weight-based buoyancy control has challenges in transportation**

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

Technology for Energy Pipelines

Summary

- Arctic pipelines presented significant challenges and opportunities
- Focused and well planned R&D leads to technologies and innovative solutions



PRCI
Technology for Energy Pipelines

Contact Details

TransCanada
In business to deliver

Joe Zhou

TransCanada PipeLines

(403) 920-7227

joe_zhou@transcanada.com

Pipeline Research Council International, Inc.

www.prci.org

PRCI
Technology for Energy Pipelines

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