

Status of Arctic Pipelines Standards and Technology

Final Presentation

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INTECSEA
WorleyParsons Group

 **PCCI**
Marine and Environmental Engineering



Agenda

- Welcome
- General Housekeeping, Emergency Exits, etc.
- Introductions
- OneWay Moment
- 1st Half of Presentation
- Break
- 2nd Half of Presentation
- Discussion and Questions

Welcome and Housekeeping

Introductions

OneWay Moment

OneWay™

Framework elements

- | | |
|----|--|
| 1 | Leadership and governance |
| 2 | Risk management |
| 3 | Caring for our people and the environment |
| 4 | Selection and competency |
| 5 | Working with our customers |
| 6 | Engineering |
| 7 | Working with the supply chain |
| 8 | Field activities |
| 9 | Management of change |
| 10 | Critical incident avoidance, response & recovery |
| 11 | Incident and behaviour analysis |
| 12 | Assessment and improvement |

OneWay™
to zero harm





OneWay Moment



Status of Arctic Pipelines Standards and Technology



Presentation Outline

- Background
- Project Scope
- Existing Offshore Arctic Pipelines
- Offshore Arctic Pipeline Design Challenges & Solutions
- Task 1: Regulations, Standards and Codes
 - Review of Industry Regulations, Standards and Codes
 - Gap Analysis Matrix and Results
- Task 2: Emerging Technology
 - Advancements in Arctic Pipeline Design
- Task 3: Suitability of Single Wall vs. Double Walled Pipelines
 - Design Considerations, Codes and Standards
 - Gap Analysis Criteria and Results
- Summary



Background

- Future offshore hydrocarbon developments in the Alaskan OCS may lead to new pipeline construction
- The offshore, subsea portion of the pipeline may be 10 miles in length and in less than 150 ft water depth.
- Burial protection may be required, specific to the proposed placement location and cross both Federal and State of Alaska waters.
 - 30 CFR Part 250, Subpart J provides for Dept. of Interior (DOI) oversight covering producer-operated pipelines extending upstream (generally seaward) of the last valve.
 - 49 CFR Parts 192 and 195 provides for Dept. of Transportation (DOT) oversight covering producer-operated pipelines downstream (generally shoreward) of the last valve.



Project Scope

- Task 1: Comprehensive review and gap analysis of US, State of Alaska and international regulations, standards, etc. regarding general requirements, design requirements, installation, testing, leak detection and repair for offshore hydrocarbon carrying pipelines in Arctic conditions.
- Task 2: Comprehensive review of the current state-of-the-art and emerging technology regarding offshore hydrocarbon carrying pipelines in Arctic conditions.
- Task 3: Comprehensive review and gap analysis of current US, State of Alaska and international regulations, standards, etc. regarding the suitability of single vs. Double walled offshore hydrocarbon carrying pipelines in Arctic conditions.



Deliverables

1. 9158-001-001: Comprehensive Review and Gap Analysis Report
 - Issued December 20th, 2017

 2. 9158-001-002: Gap Analysis Matrix (excel file)
 - Issued December 20th, 2017

 3. 9158-001-003: Final Report
 - Issued January 19th, 2018
- Project also included monthly team meetings and progress reports



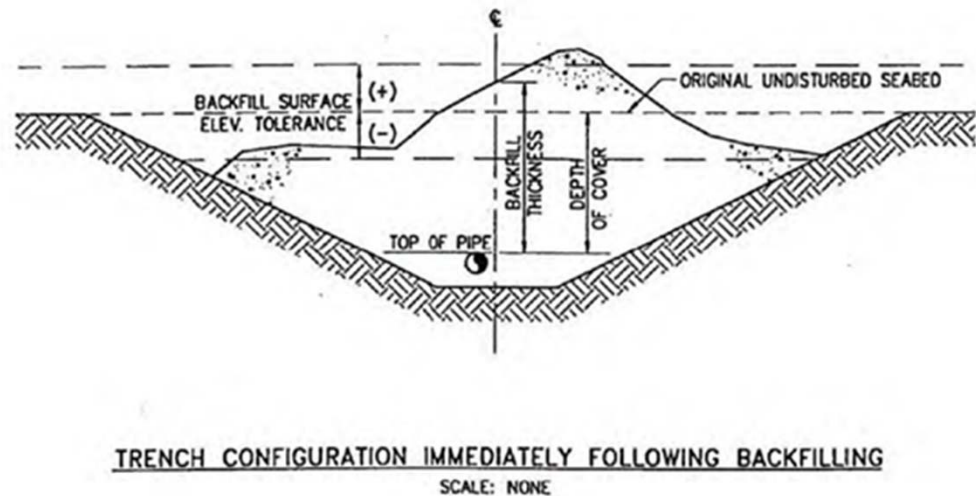
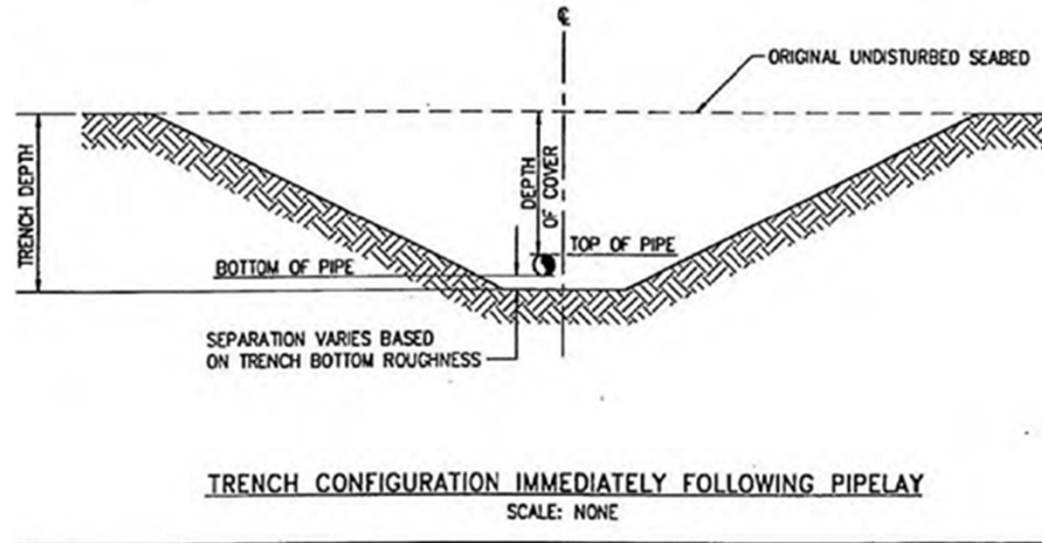
Definition of Offshore Arctic

- Most common definition of “Arctic” is area north of the Arctic Circle (66° 33’ North Latitude)
- A more functional definition for this study includes marine pipelines with Arctic loading and operating conditions:
 - Sea ice
 - Permafrost
 - Remote locations
 - Sensitive physical and social environments
- This definition includes the Arctic Ocean and areas with seasonal sea ice such as:
 - Barents Sea
 - Offshore Greenland / Newfoundland
 - Sea of Okhotsk (Offshore Sakhalin Island)
 - Northern Caspian Sea



Offshore Pipelines – Helpful Definitions

- Trench Depth
- Backfill
- Depth of Cover





Offshore Arctic Pipeline Applications

- Flowlines: unprocessed well fluid and utility lines
- Trunklines: processed oil and gas pipelines
- Combined offshore/overland pipeline systems
- Subsea field developments
- Cables and umbilicals: power, fiber optic communications cables and small diameter utility lines
- Alternative pipeline configurations (single wall steel pipe, pipe-in-pipe, flexible pipe, pipe-in-HDPE pipe)

Existing Offshore Arctic Pipelines



Existing Offshore Arctic Pipelines

Single-Walled

- Northstar (Alaska)
- Varanday Oil Terminal (Russian Pechora Sea)
- Baydaratskaya Bay Pipeline Crossing (Russian Kara Sea)
- Sakhalin 1 (Russian Sea of Okhotsk)
- Sakhalin 2 (Russian Sea of Okhotsk)
- Kashagan (Russian North Caspian)

Pipe-in-Pipe

- Drake Project (Canadian Arctic Archipelago)
- Oooguruk (Alaska)
- Nikaitchuq (Alaska)
- Liberty Proposal (Alaska)



Existing Offshore Arctic Pipelines



OOOGURUK ISLAND

Operated by: Caelus
Constructed in 2007
Island Surface: 6 acres
Water Depth: 4.5 feet
Subsea Pipeline: 5.7 miles



NIKAITSUQ ISLAND

Operated by: ENI Petroleum
Constructed in 2011
Island Surface: 11 acres
Water Depth: 8 feet
Subsea Pipeline: 3.8 miles



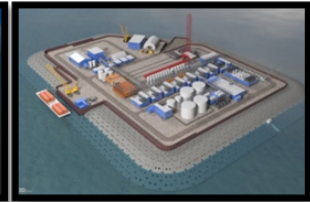
NORTHSTAR ISLAND

Operated by: Hilcorp
Constructed in 2000
Island Surface: 7 acres
Water Depth: 40 feet
Subsea Pipeline: 6 miles



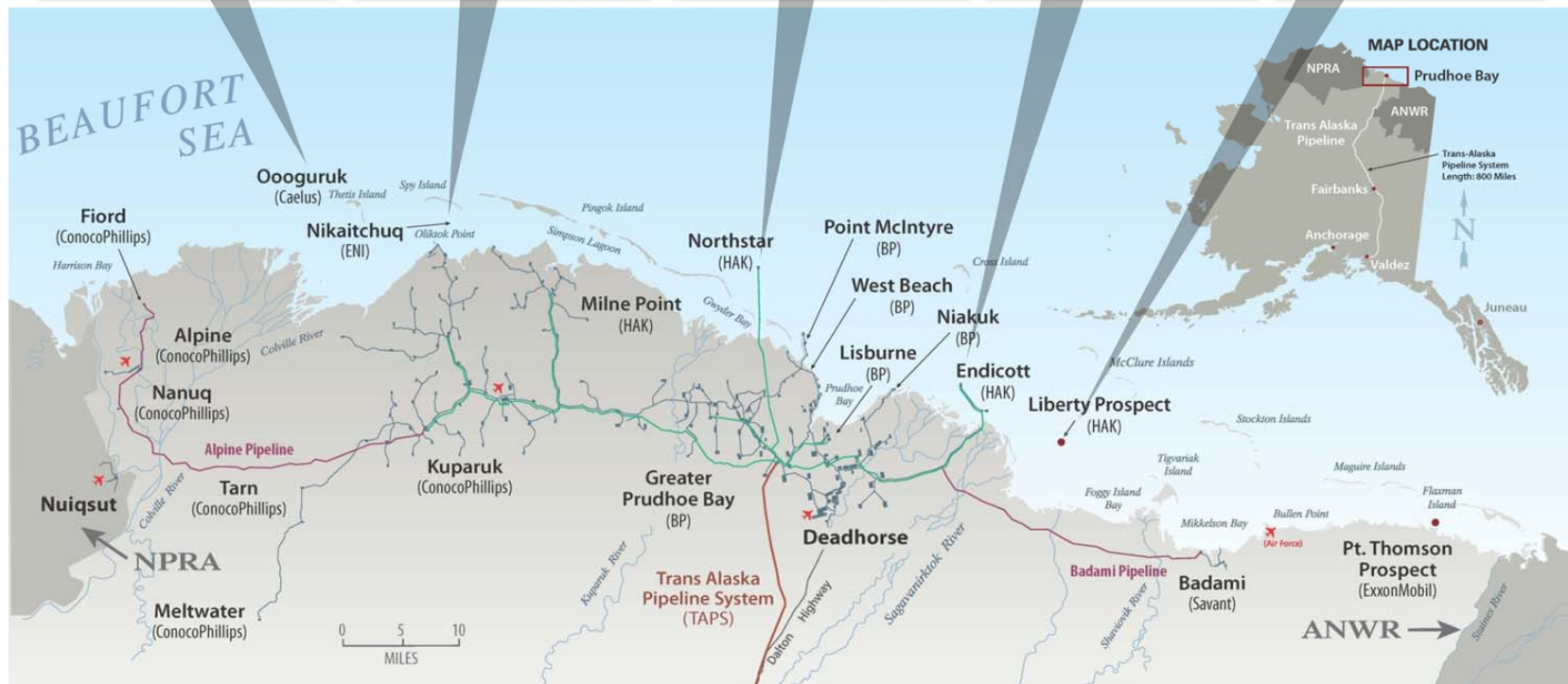
ENDICOTT

Operated by: Hilcorp
Constructed in 1987
Island Surface: 45 acres
Water Depth: ~4 feet
Subsea Pipeline: none



LIBERTY ISLAND

Operated by: Hilcorp
Construction: tbd - 2019
Island Surface: 9.3 acres
Water Depth: 19 feet
Subsea Pipeline: 5.6 miles





BP Alaska Northstar

- Pipeline Bundle: 2 x 10.75in OD x 0.594in WT
- 6mi offshore route with one small curve.
- Winter construction
- Used conventional onshore construction equipment
- Grounded ice 1/3rd of route, floating structural ice 2/3rds of route
- Design Min. Depth of Cover: 6ft in lagoon, 7ft majority of route, 9ft near island
- Min. Backfill Thickness requirement: 5ft
- Island departure method: Vertical Curve Sweep Lay
- Shore approach method: Vertical Riser w/ Casing
- Installed in the winter of 2000





BP Alaska Northstar Gravel Island





Caelus Oooguruk

- Flowline Bundle: 12in OD x 16in PIP Production, 8.625in OD Water injection, 6.625in OD Gas, 2in OD AHF line, FOC (305 lbs/ft in air)
- Cable Bundle in a separate trench (3 power cables and a FOC)
- Approximate 6mi offshore straight line route
- Winter construction
- Used conventional onshore equipment
- Grounded ice for entire route
- Design Min. Depth of Cover: 6ft
- Min. Backfill Thickness requirement: 6ft (dependent on installation temp.)
- Island departure method: vertical curve sweep lay
- Shore approach method: vertical curve sweep lay
- Installed in the winter of 2007



Oooguruk Gravel Island





ENI Nikaitchuq

- Flowline Bundle: 14in x 18in OD PIP Production, 12.75in OD Water injection line, 6.625in OD spare line, 2in x 4inch OD PIP AHF line, FOC (404 lbs/ft in air)
- Cable bundle in a separate trench (3 power cables and a FOC)
- Approx 3.5 mi offshore with route curve route (42°, 5000 ft radius)
- Winter construction
- Used conventional onshore equipment
- Grounded ice for entire route
- Design Min. Depth of Cover: 8ft
- Min. Backfill Thickness requirement: 7ft (dependent on install temp)
- Island departure method: vertical curve sweep lay
- Shore approach method: vertical curve sweep lay
- Installed in winter of 2009



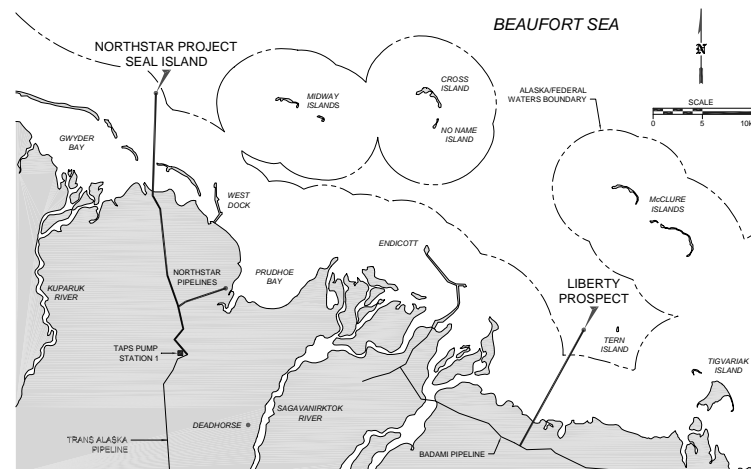
Nikaitchuq Spy Island Drill Site





Liberty, The First Iteration

- Offshore - approximately 6.1 miles of oil pipeline.
- Overland - approximately 1.5 miles of oil pipeline to Badami tie-in.
- Design trenching requirements:
 - 3 ft design gouge depth
 - Depth of cover = 7 ft
- Pipeline outer diameter of 12.75-inch





Exxon Neftegas Sakhalin – 1 Orlan Platform

- 36-inch multiphase flowline, hyperbaric tie-in
- 24-inch gas reinjection line, hyperbaric tie-in
- Sleeves under erosion protection for future line
- Design and installation of erosion protection





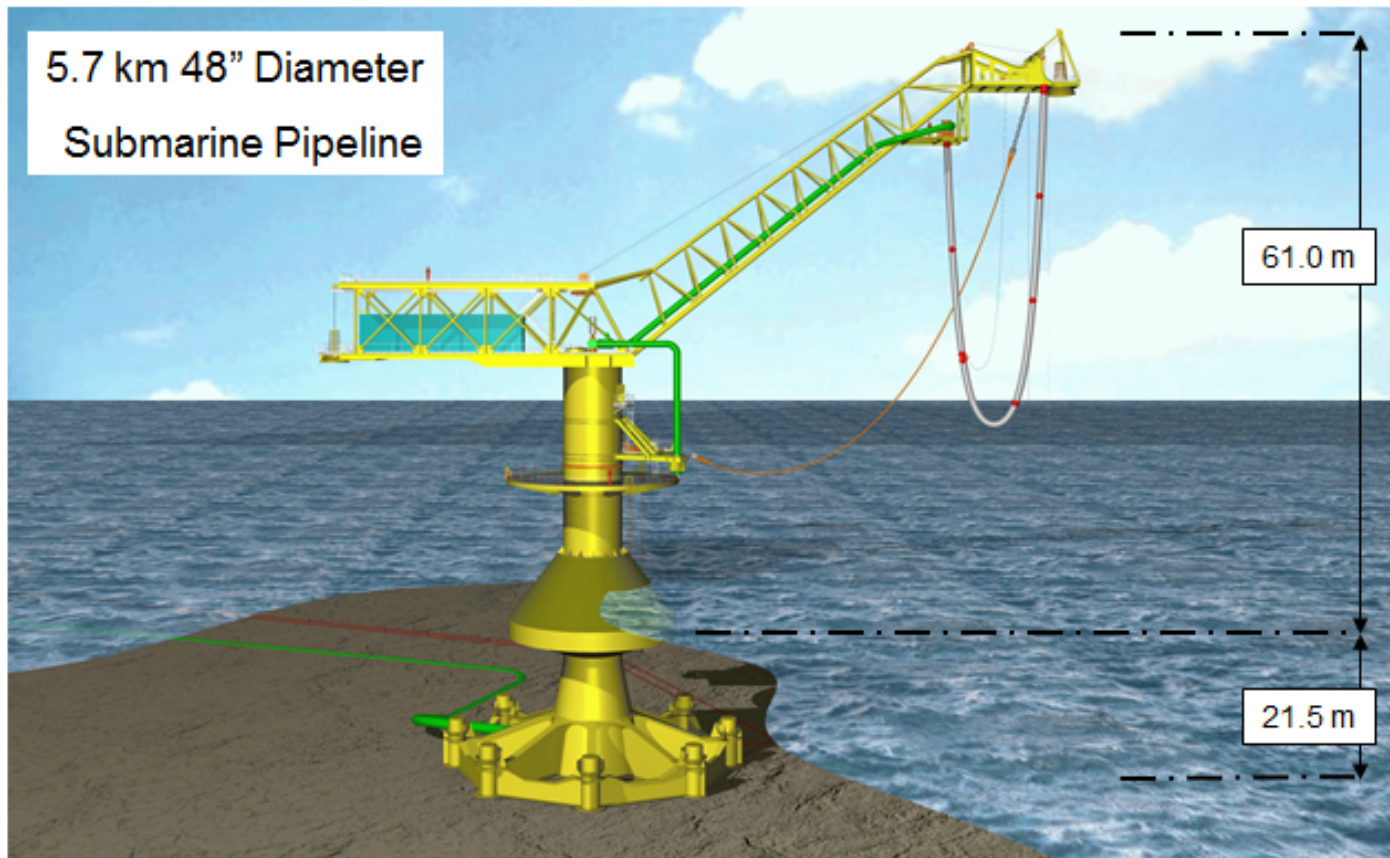
Sakhalin 1 Pipelines and Flowlines

- Offshore N.E. Sakhalin is a dynamic, first year sea ice environment
- Near shore ice zone – level ice, rafted ice & ice rubble build up
- Offshore ice zone – pressure ridge, rubble field & stamukha
- Offshore pipeline burial provides protection from direct ice contact & loads resulting from ice keel interaction with seabed





Sakhalin – 1 DeKastri Export Terminal & SPM





Offshore Arctic Pipeline Design Challenges and Solutions



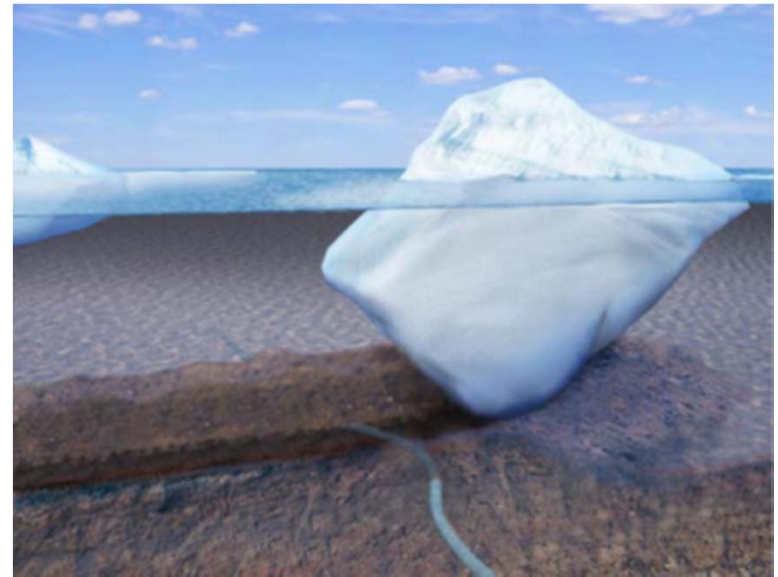
Offshore Arctic Pipeline Design Challenges

Ice Scouring

- Ice Scouring of the seafloor is a near-shore feature for most of the northern continents.
- An ice feature impacts the seabed with sufficient driving force & creates a characteristic furrow-like deformation
- Dependent on physical, environmental, & ice regime characteristics
- Single or multi-keeled event



Source: <http://www.bsstrpa.ca/NaturalResources.htm>

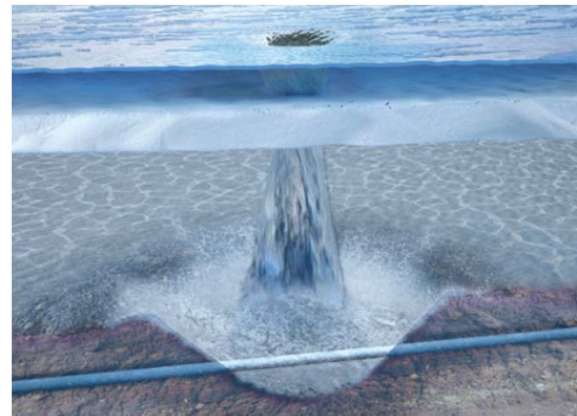




Offshore Arctic Pipeline Design Challenges

Strudel Scouring

- River overflow onto natural sea ice sheet
- Pipeline spanning and loads
- Usually occur in 6 to 30 ft of water offshore from river deltas
- Scour over a pipeline could result in an unacceptable span (which can be analyzed)
- Scours can be several feet deep and 100+ ft in diameter
- Warm pipelines may increase scour probability
- Ice thinning above warm pipelines





Colville River Overflood

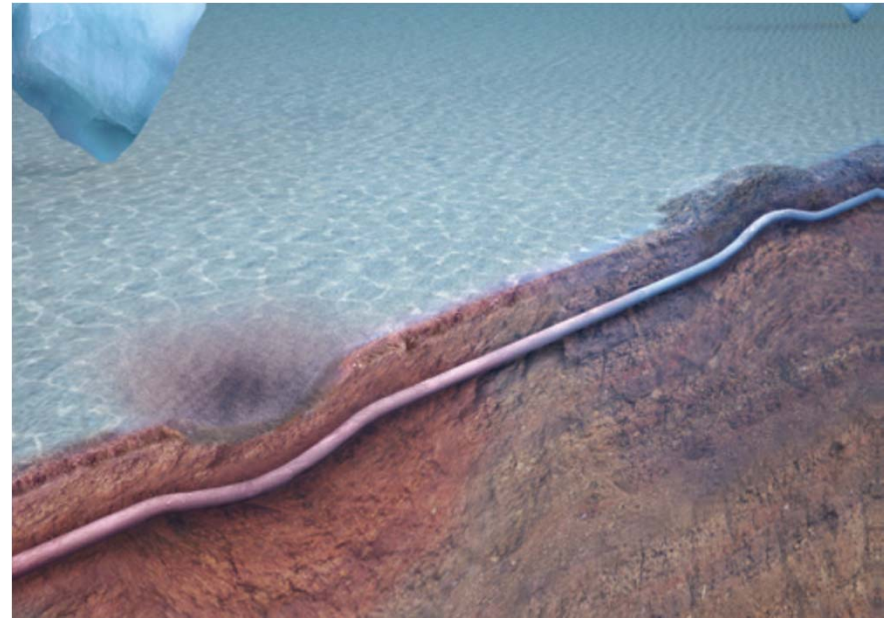




Offshore Arctic Pipeline Design Challenges

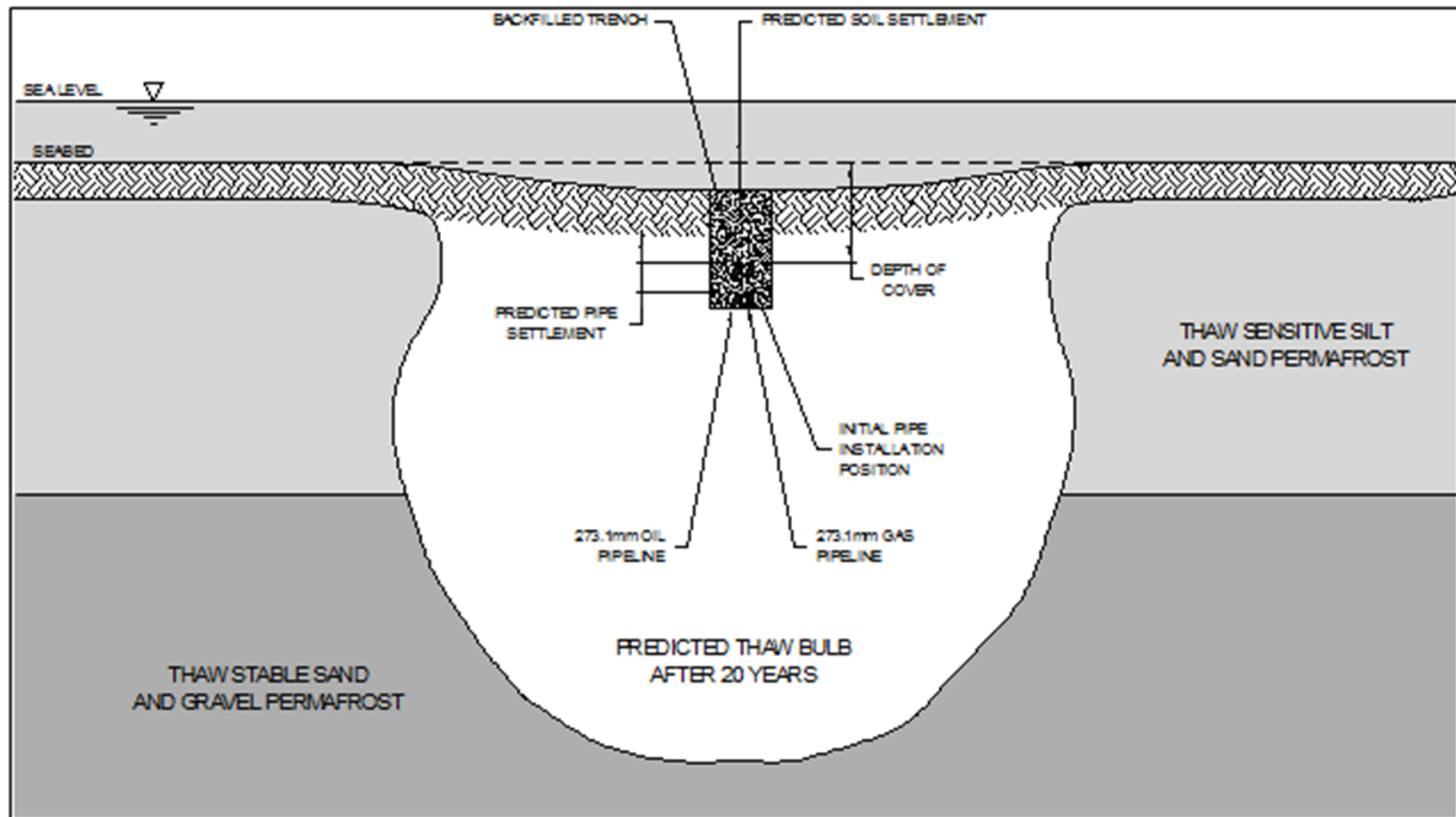
Permafrost Thaw Settlement

- Thaw consolidation of ice rich, thaw sensitive permafrost
- Thaw bulb growth
- Differential thaw settlement
- Frost heave
- Shallow gas and gas hydrate
- Geotechnical investigations provide information
- Geothermal analyses predict the thaw bulb extent
- FEA carried out to ensure pipeline strains acceptable





Thaw Bulb Growth Around a Warm Pipeline





Offshore Arctic Pipeline Design Challenges

Pipe-Soil Interaction

- Loads transmitted onto a buried pipeline via pipe-soil interaction can have higher strains.
- Pipe behavior is non-linear due to large deflection and plastic material properties.
- Limit state, strain based design necessary for design and should include geometric and material properties, where possible.
- Finite element analysis allows the modeling of non-linearities of the material, geometry, and pipe-soil interaction.



Offshore Arctic Pipeline Design Challenges

Monitoring and Leak Detection in the Arctic

- Pipelines in Arctic environments (and everywhere) are designed not to leak.
- The presence of seasonal ice cover can restrict offshore pipeline access highlighting the importance of dependable and accurate leak detection technology.
- Small leaks, which might normally be detectable on the open water surface during personnel/supply transport, may go undetected under ice cover.
- Any "external-to-the-pipe" leak detection must be compatible with the planned installation method.





Offshore Arctic Pipeline Design Challenges

Construction and Installation Techniques

- Installation window based on the length and method used
 - Open water (summer season)
 - On-ice construction (winter season)
- The summer season may be shorter for open water installation and could result in a multi-year operation depending on the length of the pipeline route.
- The use of bottomfast ice for construction in the winter season is dictated by the ability/necessity for ice roads for trucks and equipment.



Offshore Arctic Pipeline Design Challenges

Design Methods & Principles

- More advanced design procedures are needed to address the more complex design requirements for offshore Arctic pipelines.
- Limit state designs have been adopted to allow for higher strains that buried pipelines may experience.



Key Design Challenges & Solutions

Northstar

- Seabed ice and strudel scouring generally considered an obstacle.
 - Used historical data to support probabilistic analyses and supplemented by project site-specific surveys.
- Thermal modeling and geotechnical laboratory tests were used to assess the thaw settlement along the route.
- FEA was used to assess pipeline strains from thaw settlement, ice keel scouring and strudel scours.
- A winter test trench program was performed to estimate stable side slope configurations and confirm ability to trench and backfill from the winter ice sheet.



Example – Field Program for Northstar





Key Design Challenges & Solutions

Oooguruk

- Due to proximity to the Colville River Delta, challenges with flowline loading conditions due to thermal interactions and construction procedures.
 - Strudel scour would be the controlling event for trench depth
 - 3 years of location survey data collected to support notion
- Design analysis found that the combined bundle performed better than the smallest individual flowline in terms of maximum allowable free span length.
- To prevent permafrost thaw settlement, the production flowline was designed as an insulated PIP system.
- Flowline bundle was heavy and required sea ice to be bottomfast along the entire route.
 - Allowed for trench spoils to be stored adjacent to the trench.



Example – Strudel Drain from Colville River



Colville River Strudel Drain in June 2005



Key Design Challenges & Solutions

Nikaitchuq

- Used a PIP system to limit heat loss to the environment and associated thaw settlement
- The shore crossing used frozen gravel fill, insulation board laid above the waterline and beneath the pipes, and thermal heat pipes to limit thaw settlement.
- To reduce the temperature differential driving upheaval buckling, the flowlines were warmed with warm air as it was lowered into the trench.
 - This simplified field construction and reduced need for engineering trench backfill at prop location
- At the time, the flowline bundle was the heaviest to utilize bottomfast sideboom pipelayers and required two on each side of the trench with the bundle installed from a custom roller cradle on a beam assembly.



Example - Cradle Installation for Nikaitchuq



Task 1: Regulations, Standards & Codes



Industry Regulations, Standards & Codes

Reviewed documents have been categorized into the following 4 groups

Arctic Specific Regulations <ul style="list-style-type: none">• ISO 19906• API RP 2N• 30 CFR Parts 250, 254, 550	US Federal and State Regulations <ul style="list-style-type: none">• 49 CFR Part 192• 49 CFR Part 195
General Pipeline Design <ul style="list-style-type: none">• API RP 1111• CSA Z662-15• ASME B31.4• ASME B31.8• DNVGL-ST-F101• ISO 13623• RMRS 2-020301-005	Monitoring & Leak Detection <ul style="list-style-type: none">• API RP 1130• API TR 1149• API RP 1175• Alaska DEC 18 AAC 75• DNVGL-RP-F302



Industry Regulations, Standards & Codes

Arctic Specific Regulations

- ISO 19906 – Petroleum and Natural Gas Industries - Arctic Offshore Structures
- API RP 2N – Planning, Designing, and Constructing Structures for Arctic Conditions
- 30 CFR Parts 250, 254, 550 – Oil and Gas and Sulphur Operations on the Outer Continental Shelf – Requirements for Exploratory Drilling on the Arctic OCS

General Pipeline Design

- API RP 1111 – Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines (Limit State Design)
- CSA Z662-15 – Oil and Gas Pipeline System
- ASME B31.4 – Pipeline Transportation Systems for Liquids and Slurries
- ASME B31.8 – Gas Transmission and Distribution Piping System
- DNVGL-ST-F101 – Submarine Pipeline Systems
- ISO 13623 – Petroleum and Natural Gas Industries – Pipeline Transportation
- RMRS 2-020301-005 – Rules for the Classification and Construction of Subsea Pipelines



Industry Regulations, Standards & Codes

US Federal and State Regulations

- 49 CFR Part 192 – Transportation of Natural and Other Gas by Pipeline Minimum Federal Safety Standards
- 49 CFR Part 195 – Transportation of Hazardous Liquids by Pipeline

Monitoring & Leak Detection

- API RP 1130 – Computational Pipeline Monitoring for Liquids
- API TR 1149 – Pipeline Variable Uncertainties and Their Effects on Leak Detection
- API RP 1175 – Pipeline Leak detection – Program Management
- Alaska DEC 18 AAC 75 – Department of Environmental Conservations: Oil and Other Hazardous Substances Pollution Control
- DNVGL-RP-F302 – Offshore Leak Detection



Gap Analysis Matrix

Gap analysis performed for regulations, standards, & codes.

The matrix has been divided into 3 main categories for assessment:

- Environmental Loading
- Monitoring and Leak Detection
- Installation and Repair

All categories have been assessed against the following parameters

Red – No Arctic requirements discussed.

Yellow – The criteria have been mentioned as a “should be given consideration”, however, no detail is provided to aid the designer.

Green – The criteria have been mentioned as a “should be given consideration” and guidance is provided for methods to incorporate the criteria into the design.



Gap Analysis Matrix

Review of Spreadsheet



Gap Analysis Matrix - Results

Arctic Specific Regulations – Environmental Loading

Criteria		ISO 19906	API RP 2N	30 CFR Part250, 254, 550
Limit States Design		G	G	R
Ice Properties		G	G	R
Iceberg and Ice Ridge Scour		G	G	Y
Strudel Scour		G	G	R
Permafrost Thaw Settlement/Frost Heave		G	G	R
General Design Properties		G	G	R
Additional Requirements for General Pipeline Design Environmental Loadings	General	-	-	Y
	Seismic Actions	G	G	-
	Geohazards	Y	Y	-

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

Arctic Specific Regulations – Monitoring and Leak Detection

Criteria	ISO 19906	API RP 2N	30 CFR Part250, 254, 550
General	Y	Y	Y
Internal System Requirements	R	R	R
External System Requirements	R	R	R
Computational Monitoring	R	R	R
Survey Information	R	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

Arctic Specific Regulations – Installation and Repair

Criteria	ISO 19906	API RP 2N	30 CFR Part250, 254, 550
Seasonal Construction Requirements	R	R	R
Ice Road Details	G	G	R
Trenching Requirements	G	G	R
Inspection and Testing	R	R	R
Repair	R	R	R
Safety Equipment Requirement	G	G	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

US Federal Regulations (DOI & DOT) – Environmental Loading

Criteria		49 CFR Part 192	49 CFR Part 192
Limit States Design		R	R
Ice Properties		R	R
Iceberg and Ice Ridge Scour		R	R
Strudel Scour		R	R
Permafrost Thaw Settlement/Frost Heave		R	R
General Design Properties		R	R
Additional Requirements for General Pipeline Design Environmental Loadings	General	R	R
	Seismic Actions	R	R
	Geohazards	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

US Federal Regulations (DOI & DOT) – Monitoring and Leak Detection

Criteria	49 CFR Part 192	49 CFR Part 192
General	R	R
Internal System Requirements	R	R
External System Requirements	R	R
Computational Monitoring	R	R
Survey Information	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

US Federal Regulations (DOI & DOT) - Installation and Repair

Criteria	49 CFR Part 192	49 CFR Part 192
Seasonal Construction Requirements	R	R
Ice Road Details	R	R
Trenching Requirements	R	R
Inspection and Testing	R	R
Repair	R	R
Safety Equipment Requirement	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

General Pipeline Design – Environmental Loading

Criteria		API RP 1111	CSA Z662-15	ASME B31.4/31.8	DNVGL- ST-F101	ISO 13623	RMRS 2- 020301- 005
Limit States Design		R	Y	R	G	Y	R
Ice Properties		R	Y	R	R	R	R
Iceberg and Ice Ridge Scour		R	G	Y	Y	Y	G
Strudel Scour		R	R	R	R	Y	G
Permafrost Thaw Settlement/Frost Heave		R	Y	R	Y	Y	G
General Design Properties		R	Y	R	Y	G	G
Additional Requirements for General Pipeline Design Environmental Loadings	General	R	Y	R	Y	Y	G
	Seismic Actions	-	G	-	Y	-	-
	Geohazards	-	-	-	Y	-	-

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

General Pipeline Design – Monitoring and Leak Detection

Criteria	API RP 1111	CSA Z662-15	ASME B31.4/31.8	DNVGL-ST-F101	ISO 13623	RMRS 2-020301-005
General	R	R	R	R	R	R
Internal System Requirements	R	R	R	R	R	R
External System Requirements	R	R	R	R	R	R
Computational Monitoring	R	R	R	R	R	R
Survey Information	R	R	R	R	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

General Pipeline Design - Installation and Repair

Criteria	API RP 1111	CSA Z662-15	ASME B31.4/31.8	DNVGL-ST-F101	ISO 13623	RMRS 2-020301-005
Seasonal Construction Requirements	R	R	R	R	R	R
Ice Road Details	R	R	R	R	R	R
Trenching Requirements	Y	Y	Y	G	G	R
Inspection and Testing	Y	R	Y	Y	R	R
Repair	Y	R	R	Y	R	R
Safety Equipment Requirement	Y	R	R	Y	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Results

Leak Detection Regulations – Monitoring and Leak Detection

Criteria	API RP 1130	API RP 1175	Alaska DEC 18 AAC 75	DNVGL-RP- F302
General	R	R	G	R
Internal System Requirements	R	R	R	R
External System Requirements	R	R	R	R
Computational Monitoring	R	R	G	R
Survey Information	R	R	R	R

R – No requirements

Y – Mentioned, but no detail

G – Mentioned & guidance



Gap Analysis Matrix - Identified Gaps

- Lack of guidance, or directive provided for pipeline transportation systems in Arctic environments.
- Lack of guidance, or directive for installation and repair, with little emphasis on working conditions in a harsh environment.
- Gaps in the new Federal Arctic Rule
 - Does not address Arctic pipeline design requirements.
 - Reference made to API RP 2N, however it excludes requirements for offshore pipeline design or Arctic structure design. (See next slide)
- Generally a lack of regulations around operations and deviations from the operating philosophy used for design.



New Federal Arctic Rule Summary

- Stems from issues highlighted from the DOI's report on Shell's 2012 Chukchi Sea exploration program
- Reflects industry best practices to help ensure safe, effective, and responsible exploration of Arctic OCS oil and gas resources, while protecting marine, coastal, and human environments.
 - Conduct operations in a manner suitable for Arctic OCS conditions
 - Develop and submit to DOI an integrated operations plan
 - Have access to appropriate source control and containment equipment
 - Have access to a separate relief rig and the ability to drill a relief well within the same season
 - Have the capacity to predict and respond to ice conditions/adverse weather
 - Have effective contractor oversight
 - Submit oil spill response plans tailored to Arctic conditions



Exclusion from Federal Arctic Rule

From 30 CFR Part 250.470: <https://www.law.cornell.edu/cfr/text/30/250.470>

(g) Where it does not conflict with other requirements of this subpart, and except as provided in paragraphs (g)(1) through (11) of this section, you must comply with the requirements of API RP 2N, Third Edition “Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions” (incorporated by reference as specified in § 250.198), and provide a detailed description of how you will utilize the best practices included in API RP 2N during your exploratory drilling operations. **You are not required to incorporate the following sections of API RP 2N into your drilling operations:**

- (1) Sections 6.6.3 through 6.6.4;
- (2) The foundation recommendations in Section 8.4;
- (3) Section 9.6;
- (4) The recommendations for permanently moored systems in Section 9.7;
- (5) The recommendations for pile foundations in Section 9.10;
- (6) Section 12;
- (7) Section 13.2.1;
- (8) Sections 13.8.1.1, 13.8.2.1, 13.8.2.2, 13.8.2.4 through 13.8.2.7;
- (9) Sections 13.9.1, 13.9.2, 13.9.4 through 13.9.8;
- (10) **Sections 14 through 16; and** ← Section 14 applies to pipeline design
- (11) Section 18.

Best Practices and Challenges



Best Practices and Challenges

Environmental Data

- Changing climate conditions can affect design and operating criteria
- Potential varying environmental conditions may include:
 - Rate of coastal erosion
 - Oceanographic conditions
 - Onshore and subsea permafrost
 - Construction season durations due to length of ice season
 - Seabed erosion or accretion patterns
 - Seabed scouring due to ice wallowing
- Multi-year survey campaigns are the most effective for collection of historical data and probabilistic evaluation.



Best Practices and Challenges

Monitoring and Leak Detection

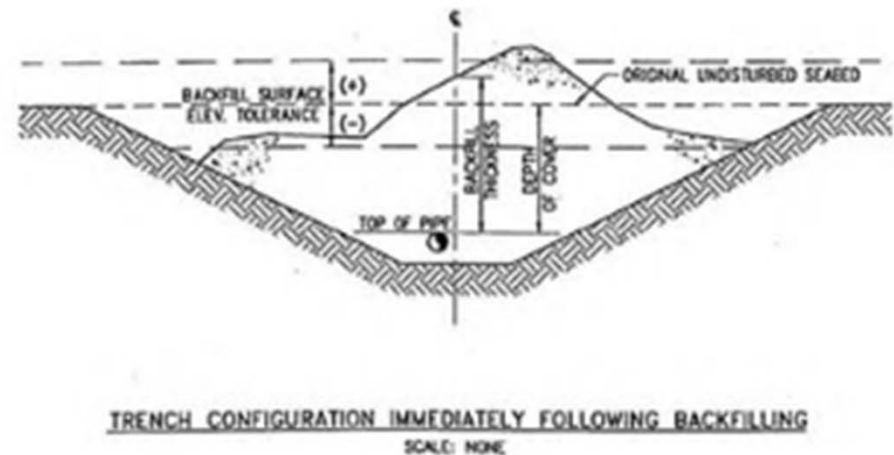
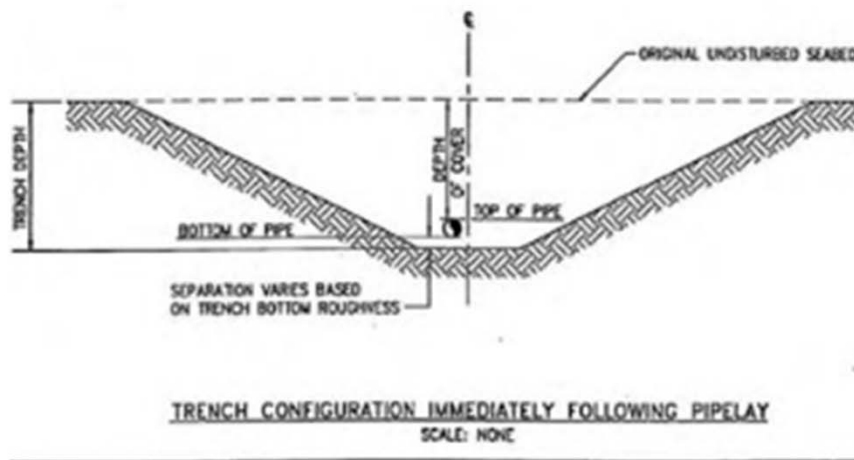
- Best practice has been to use a combination of a reliable internal/computational with an external LDS.
 - The type of system will be project-specific based on design and requirements.
- Periodic leak detection methods also valuable in monitoring and complementing active internal and external LDS.
- Industry development is needed to advance the Technology Readiness Level (TRL) of Fiber Optic Cable LDS for primary application in Arctic offshore pipeline LD.



Best Practices and Challenges

Trenching

- Clear definitions for trenching and backfill to be established at the beginning of a project.
 - Allows for less confusion during design, construction, and operational monitoring.
 - Regulatory requirements generally provide minimum values based on these definitions.





Best Practices and Challenges

Installation

- The 3 operating Alaskan offshore pipelines have each used on ice construction for assembly and installation.
 - Each in relatively shallow water that could be made bottomfast in winter
- Installation method selection based on pipeline design, water depth, construction schedule, logistics, etc.
- When water depths are beyond the limits of bottomfast ice, more traditional installation methods may be required.
 - May lead to the first summer open water installation for Alaskan waters



Best Practices and Challenges

Repair

Repair plans will be specific to the project, understanding the challenges related to repair of pipelines in buried trenches. These may include:

- Seasonal limitations, dependent on the repair needed
- Pipeline flexibility for lifting or removal onto the ice for repair
- If pipeline is bundled, unbundling may be required
- Limitations on divers
- Potential discharge from the pipeline and ice integrity
- Conditions may limit ability of ROV repairs

Task 2: Emerging Technology



Emerging Technology

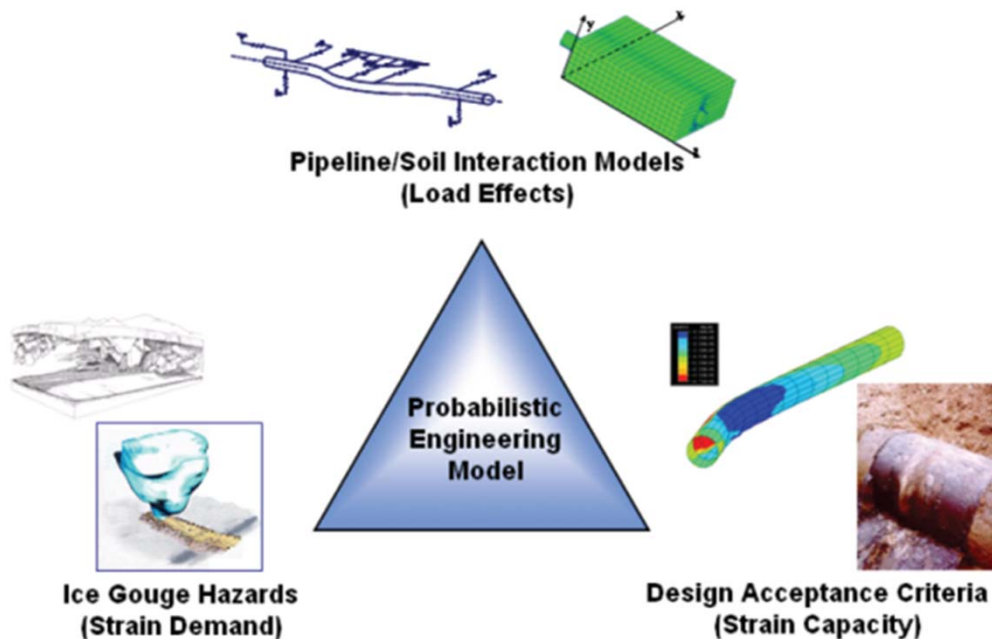
A review was completed on pipeline technology that is either applied to Arctic pipelines or could be with further research.

Categories included:

- Probabilistic Design Approaches
- Finite Element Methods
- Strain Based Design
- Materials
- Route Selection and Evaluation
- Pipelay Vessels for Installation
- Trenching Methods for Arctic Applications
- Leak Detection
- Operations



Probabilistic Design Approaches

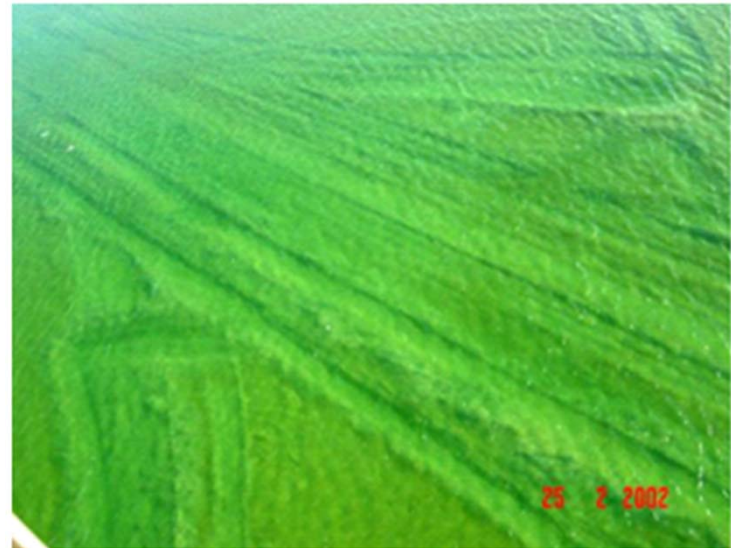


- Statistics of measured data can be used to predict extreme loading events.
- Data does not account for:
 - Resolution
 - Direction of scour
 - Potential infill
- Northstar pipelines first to use a probabilistic design approach.
 - Site-specific data collected to determine design return period scour depths (e.g., 1 in 100 year)



Probabilistic Design Approach

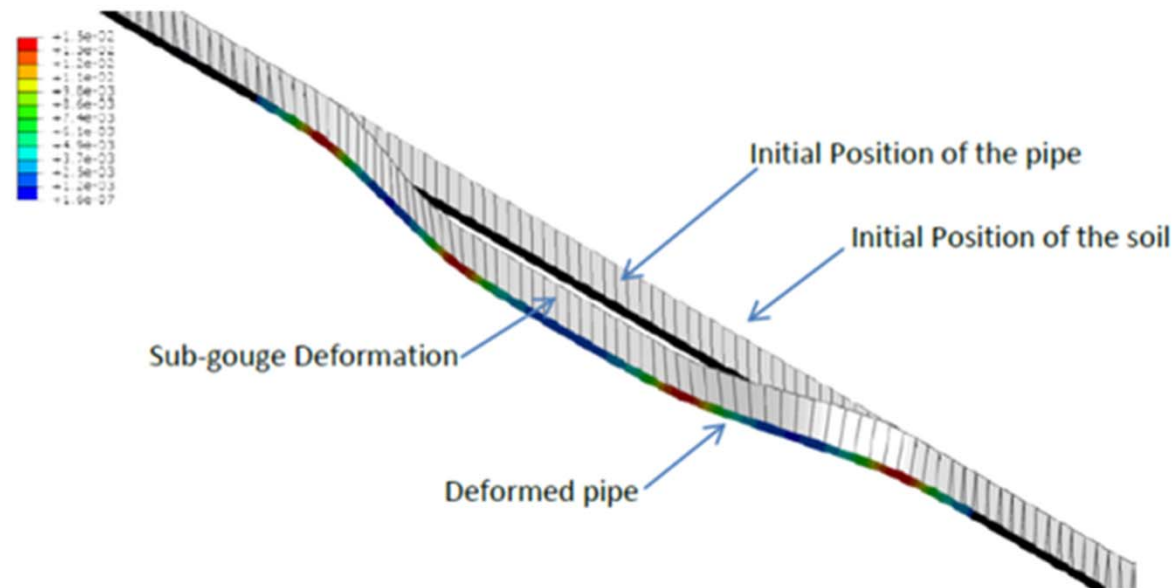
- Discussion around the conservatism in probabilistic models and which PDF fits extreme data (distribution tails) more appropriately
 - Exponential vs. Weibull distribution
- Emerging technology is focused on combined probabilistic analysis
 - Ice scour depth statistics
 - Subgouge pipe-soil interaction
 - Pipe failure mechanisms





Finite Element Methods

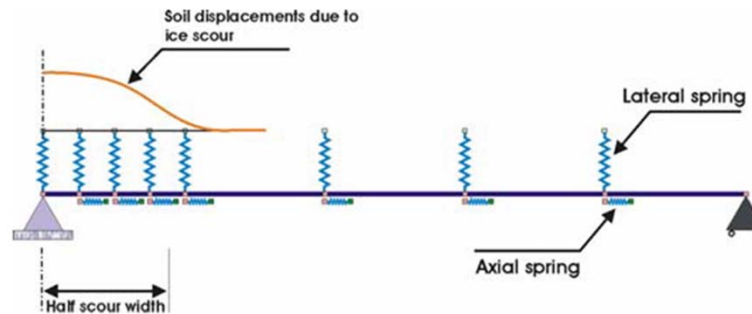
- FEA allows for the modeling of non-linearities of the material, geometry, and pipe-soil interaction
- Assess the integrity of the pipeline in the event of loading events
- Recently advancements in modeling the entire pipeline bundle, not just individual pipelines.



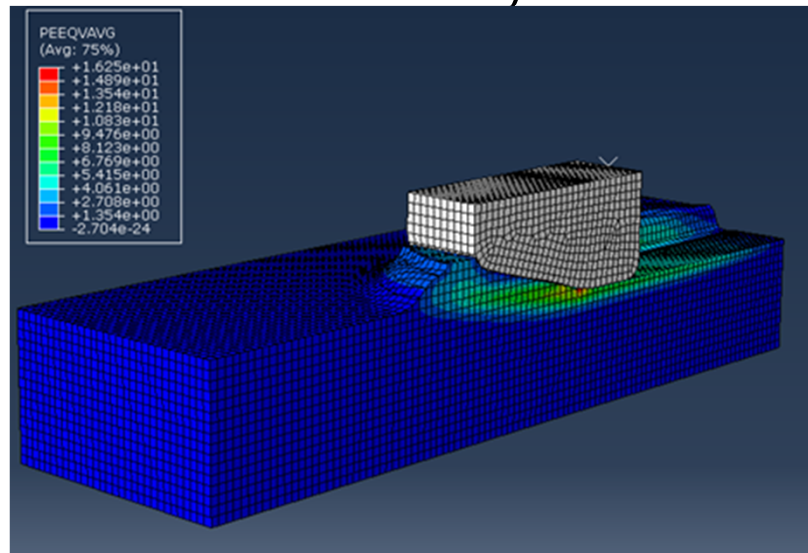


Finite Element Methods

- Traditionally soil-spring models have been used for the pipe-soil interaction processes.



- Advanced 3D modeling techniques, such as CEL and ALE, are now being used to more accurately model the soil behavior.





Strain Based Design

- Design approach for a subset of limit states that are applicable to pipeline response from displacement controlled events.
- Advancements have been progressing to capture material properties and the tensile strain capacity.
- Strain based design has been incorporated into the development of welded pipelines. Studies have investigated the following parameters on strain capacity:
 - Flaw depth
 - Flaw length
 - Yield-to-tensile (Y/T) ratio
 - Weld overmatch
 - Apparent crack tip opening displacement (CTOD) toughness
 - Weld cap height
- Tensile strain material is starting to be incorporated in Engineering Critical Assessments (ECA's)

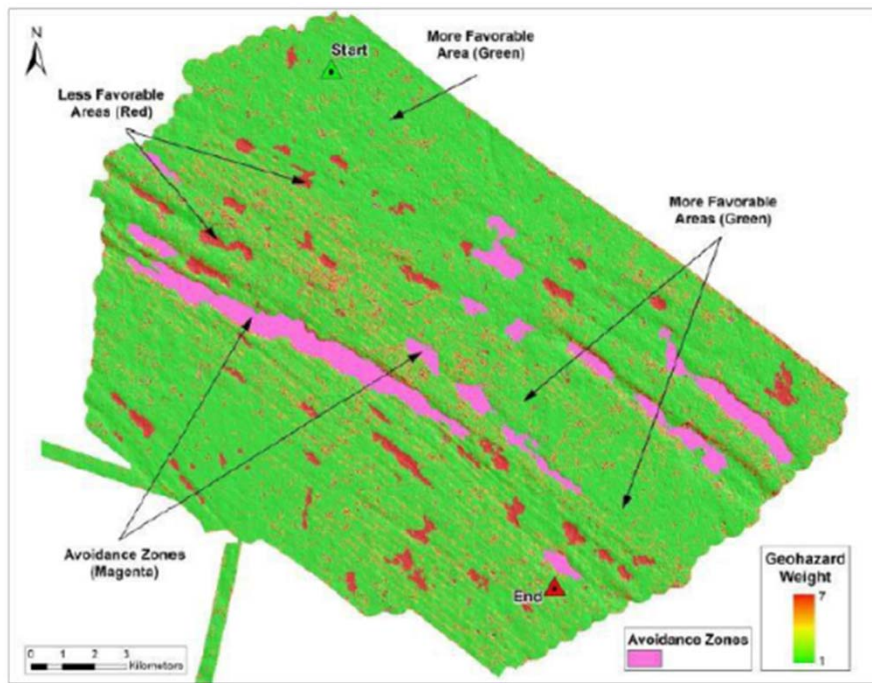


Materials

- Offshore Arctic projects use relatively lower strength (yield and ultimate tensile), high ductility line pipe grades.
 - Northstar, Oooguruk, Nikaitchuq – X52
 - Sakhalin - X60
- Corrosive resistant alloy materials (cladding or lined pipe) have been used in low temperature environments.
- Considerations should be made for materials and weld procedures to ensure suitable and qualified for strain-based design.
- Current research involves testing to enhance low temperature fracture resistance and technology for crack monitoring.
 - Offshore Arctic materials need to retain toughness and fatigue performance at low temperatures



Route Selection and Evaluation



GIS databases for:

- Bathymetry
- Geology
- Iceberg scouring and wallowing
- River discharge and strudel scour
- Infrastructure
- Navigation areas
- Fishing areas
- Animal migration paths
- Environmentally sensitive areas



Pipelay Vessels for Installation

- Pipelay vessels for summer installation could be used along the Western Coast, in the Chukchi or Bering Sea.
- Pipelay vessels may be exempt from the Jones Act.
- No new pipelay vessels have been built in the US.
 - Older pipelay vessels are starting to be replaced with newer engineering designs to allow for a more economical solution.
- Example is Subsea 7 Seven Navica being replaced by Royal IHC





Trenching Methods for Arctic Applications

Summer Trenching

- Conventional Excavation
- Hydraulic Dredging
- Ploughing
- Jetting
- Mechanical Trenching





Trenching Methods for Arctic Applications

Winter Trenching

- On-ice Excavation
- Ploughing





Trenching Methods for Arctic Applications

Advancements in trenching technology to make equipment suitable for Arctic projects may include the following:

- Burial depths greater than 10 ft, with potential trench depths as much as 23 ft.
- Trenching in soil conditions that are difficult and highly variable.
- Trenching in water depths up to 985 ft.
- Deployment from vessels or use from vessels that are capable of operating in harsh marine conditions.

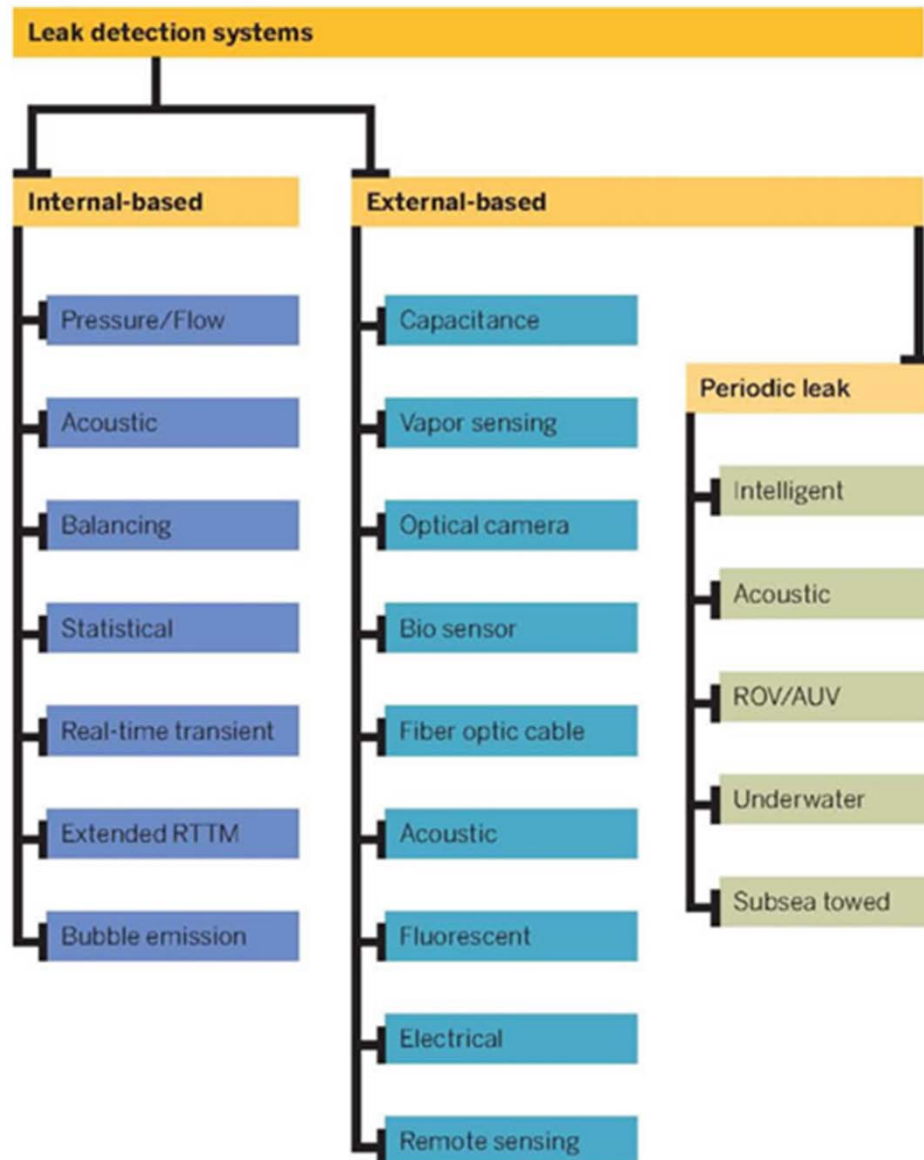


Leak Detection

- Industry best practice for Arctic offshore pipeline leak detection to use a combination of:
 - A reliable internal/computational pipeline monitoring system
 - External leak detection system
- Emerging technology for offshore Arctic application with fiber optic cables, acoustic pigging, or real time transient modeling.



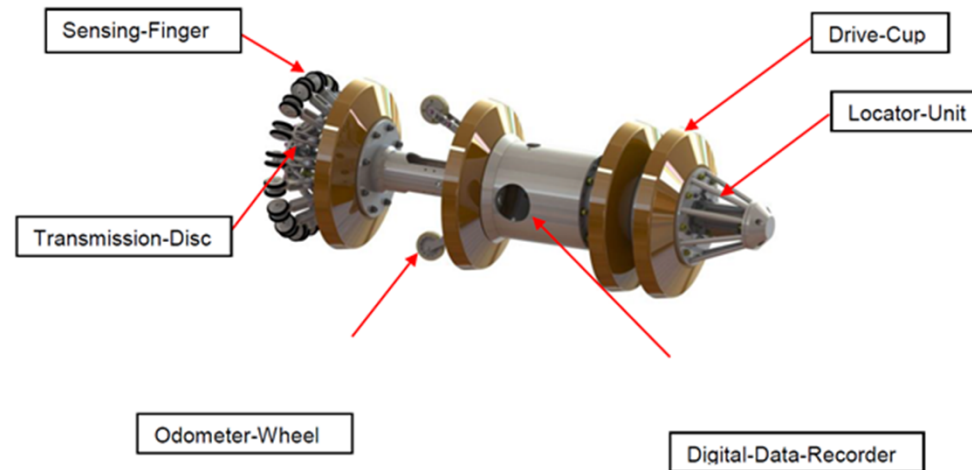
Leak Detection





Operations

- Monitoring the pipeline can be achieved through geometry deformation monitoring.
- In Line Inspection
 - Caliper pigging
 - Wall thickness inspection
 - Inertial 3D geometry pig inspection
 - Conventional operational pigging



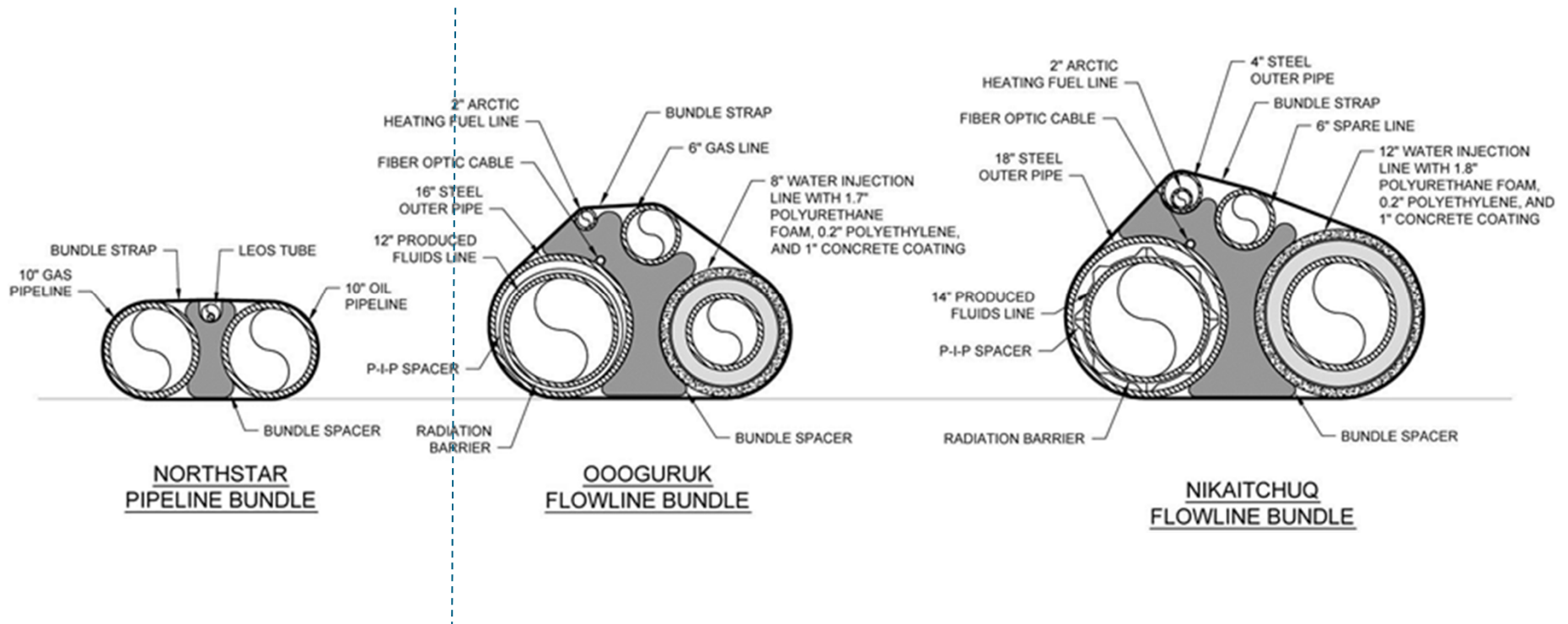
Task 3: Single Wall vs. Double-Walled Pipelines



Single Wall vs. Double-Walled (PIP)

Single Wall

Double-Walled



Reviewed Documents for Single Wall vs PIP



Design Considerations, Codes, & Standards

The following documents have been reviewed for discussion on single and double walled pipeline:

- TAPS Study 332
- Liberty Pipeline Systems Alternatives
- API RP 1111
- ASME B31.4
- Code of Federal Regulations
- DNVGL-ST-F101
- ISO 13628-1



TAPS Study 332

- Objective of study and workshop was to examine the current state of practice for Alaskan offshore pipeline design.
- The cost estimate found that PIP systems were ~1.27 times the cost of a single-walled design.
 - Trenching costs found to be the same for each system
- PIP system life cycle costs were ~1.09 times those of single-walled design, although repair costs not included.
- Over a 20-yr design life, operation and maintenance costs for a PIP system were ~1.04 times the cost of a single-walled design.
- Risk assessment found that a PIP system has greater associated operational risks, compared to a single wall.
 - Increased amount of material, welds and monitoring challenges.
- However, a PIP system has a lower risk of losing product to the environment in the event of a leak.



Liberty Pipeline Systems Alternatives

- Alternatives study considered 4 designs for a 20-yr design life, including both single-walled and PIP.
- Design depth was 7 ft for the single-walled and 5 ft for the PIP.
- Total installed cost was ~\$31 million for the single-walled and ~\$61 million for the PIP.
 - Due to differences in pipeline material, construction & fabrication costs.
- Primary difference with operations and maintenance of the PIP was that monitoring could not be performed for some structural parts.
- Overall risk of an oil spill to the environment was negligible for all alternatives.
 - Single-walled was proposed to be the safest due to a total system reliability and easiest to repair.



Design Codes, Standards & Recommended Practices

Relevant US and international general pipeline design codes were reviewed for commentary on PIP system design.

- API RP 1111
 - Guidance provided on loading conditions, axial collapse/burst for PIP.
- ASME B31.4
 - Minimal guidance provided and limited to commentary on external corrosion for thermally insulated pipelines.
- Code of Federal Regulations
 - No guidance on whether or not PIP systems should be used.



Design Codes, Standards & Recommended Practices

- DNVGL-ST-F101
 - Provides guidance on design of offshore PIP systems and bundles, including safety class, global system behaviour, design loads and limit states (for inner and outer pipes), buckling, collapse and on-bottom stability considerations, acceptable denting, anode design, bulkhead design and code breaks, reeling design, and construction (manufacturing and offshore), and operation.
- ISO 13628-1
 - addresses PIP as a viable means to provide pipeline mechanical protection from boat traffic and bottom-fishing activities, and makes high-level qualitative statements on flowline design considerations and installation, but provides no direct guidance on PIP design.

Comparative Assessment for Single Wall vs PIP



Traffic Light Criteria

Single wall vs. double-walled have been assessed in terms of the following criteria

- Safety in Design
- Leak Containment
- Leak Detection / Operational Monitoring
- Environmental Footprint
- Materials Requirements
- Installation
- Repair
- Cost
- Decommissioning



Traffic Light Criteria

All categories have been assessed against the following parameters

Red – Design option presents a clear disadvantage compared to the other.

Yellow – Design option presents no apparent advantage or disadvantage compared to the other.

Green – Design option presents a clear advantage over the other.



Traffic Light Summary

Criteria	Single-Walled	Pipe-in-Pipe
Safety in Design	G	R
Leak Containment	Y	Y
Leak Detection / Operational Monitoring	Y	Y
Environmental Footprint	Y	Y
Materials Requirements / Quantity	Y	R
Installation / Schedule	G	R
Repair	G	R
Decommissioning	Y	Y
Cost	G	R



Suitability & Gap Analysis

- Both single and double-walled used on the Alaskan North Slope.
- No basis to conclude that one design is 'better' than the other.
- PIP system allows for:
 - Vacuum monitoring of the annulus for leak detection
 - Secondary containment in the event of a leak in the inner line
- This however makes the system generally higher in construction and lifecycle cost, restrictions on monitoring and inspection, and more complex repair

The decision to adopt one design over the other should be made on project specific requirements and objectives.



Identified Gaps

1. Very few published design codes, standards, or guidance related to general PIP design.
2. No applicable design codes or guidance currently available that provide Arctic-specific information.

The following are technical gaps found for PIP systems during assessment:

- Operational inspection and monitoring of the PIP outer pipe for corrosion in annular space.
- Installation of PIP system during winter construction (on ice) poses challenges due to the weight of the system.

Summary



Summary

Task 1

- Generally a lack of guidance, or directive for pipeline transportation systems, installation, repair, operations, and deviations from operating philosophy in Arctic environments.
- Federal Arctic Ruling covers drilling and exploration, but does not address Arctic pipeline design requirements.

Task 2

- Advancements are continuing for pipeline technology and further research may be needed for use in an Arctic environment.

Task 3

- The decision to adopt single walled design or PIP design should be made on project specific requirements and objectives.
- Challenges in operational inspection monitoring for annulus corrosion.

Discussion & Questions



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