ATTACHMENT 20

RFI 379 - Strain Based Design

ASAP

Alaska's In-State Gas Pipeline

Request

It is requested that AGDC prepare an analysis comparing the proposed strain-based design (SBD) for buried sections of pipeline versus a pipeline designed in accordance with 49 CFR Part 192 requirements. This analysis should compare/contrast the two approaches and describe potential environmental and safety impacts from designing, constructing, and operating a pipeline using SBD with special permit conditions versus 49 CFR Part 192 requirements (which do not allow SBD). Items to be considered include, but are not limited to:

- Relative pipe thickness (use of thicker pipe)
- Location (above or below grade)
- Monitoring requirements during construction and operations
- Examples of the use of each approach under similar conditions
- Difference in environmental impact based on Special Permit (SP). For example, impacts to permafrost ecosystem from below grade installation and maintenance.
- Tests implemented for SP: designs, destructive tests, material tests, soil tests, etc. and any impact on the environment.

Response

Foreword:
In this discussion, "Regulations" refer to the Federal Regulations that govern the ASAP pipeline: Title 49 – Transportation, Part 192—TRANSPORTATION OF NATURAL AND OTHER GAS BY PIPELINE: MINIMUM FEDERAL SAFETY STANDARDS, or 49 CFR 192. This document is publicly available at:
http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title49/49cfr192_main_02.tpl

"Code" refers to additional standards provided by industry and commonly used for supplemental guidance such as those produced by the American Society of Mechanical Engineers **ASME B31.8 – Gas Transmission and Distribution Piping Systems.** The 2003 edition of this document is publicly available at https://law.resource.org/pub/us/cfr/ibr/002/asme.b31.8.2003.pdf. This is the previous edition to the one (2007 edition) currently partially incorporated by reference into 49 CFR 192.

Strain Based Design:

An overview and introduction to the use of Strain Based Design (SBD) is provided in a document[1] on this subject produced for PHMSA, page iii:

> *Traditional pipeline designs primarily focus on pressure containment through limiting the hoop stress to a certain percentage of the specified minimum yield stress (SMYS). Pipeline failures due to longitudinal strains are relatively rare events. Strain-based design (SBD) refers to pipeline design methodologies which have a specific goal of maintaining pipeline services and integrity under high longitudinal plastic strains (typically defined as strains greater than 0.5 %). Such large strains may come from frost heave and thaw settlements in arctic regions, seismic activities, landslides, mine subsidence, slope movement, or other events that alter the support conditions of pipelines. For offshore pipelines, large longitudinal strains may be induced by upheaval or lateral buckling or pipeline movements due to underwater landslides. The principles and procedures of SBD may also be applied to the maintenance of existing pipelines in areas of ground movement. Such process is sometimes termed strain-based design and assessment (SBDA).*
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> *Contrary to some misconception, stress- and strain-based designs are not mutually exclusive. The traditional pipeline design lacks precise methodologies required to design against high longitudinal strains. Strain-based design provides systematic and quantitative procedures to count for the effect of high longitudinal strains. Therefore, strain-based design should be viewed as a complementary tool to the traditional stress-based design.*

As noted, SBD does not supplant the existing Regulations which focus on the pressure containment capability of the pipeline, but uses SBD in concert with the existing Regulations to add an integral tool for the consideration of displacements of the pipe after installation. For ASAP, the focus in this regard is on specific arctic loadings that may cause longitudinal bending, such as settlement of the pipe ditch bottom due to thawing of the subsurface (“thaw settlement.”) As noted in another document[2] on this subject produced for PHMSA, page 1:

> *Designing for large ground movement events is a complex undertaking. Although the owners and contractors are legally required to construct and operate pipelines safely under all anticipated conditions, design methods specifically for large ground movements are often lacking sufficiently actionable details.*

ASAP agrees with this observation and is using all available research, including the several

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[1] **Realistic Strain Capacity Models for Pipeline Construction and Maintenance**, Contract No. DTPH56-10-T-000016, Final Report Prepared for US Department of Transportation, Pipeline and Hazardous Materials Safety Administration, Office of Pipeline Safety, Prepared by Ming Liu, Yong-Yi Wang, Fan Zhang, and Kunal Kotian; Center for Reliable Energy Systems 5960 Venture Dr., Suite B , Dublin, OH 43017, December 9, 2013

[2] **Second Generation Models for Strain-Based Design,** Contract PR-ABD-1 – Project 2, Contract DTPH56-06-T000014, "Consolidated Research & Development Program on Validation & Documentation of Tensile Strain Limit Design Models for Pipelines" , Final Approved Report. Prepared by the Pipeline Research Council International, Inc.; Design, Materials, and Construction Technical Committee. For US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), July 31, 2011

studies undertaken with PHMSA oversight, to develop the details of SBD and ensure the integrity of the pipe under challenging arctic and subarctic conditions.

49 CFR 192 Requirements:

The Regulations address the minimum requirements for the ASAP pipeline and provide quantitative formulae for the evaluation of the pressure containment abilities of the pipe. The Regulations do not quantitatively address the methodology to be employed in the evaluation of other loadings, but addresses this qualitatively in 49 CFR 192.103:

> *Pipe must be designed with sufficient wall thickness, or must be installed with adequate protection, to withstand anticipated external pressures and loads that will be imposed on the pipe after installation.*

To meet this Regulation, the pipeline industry relies on supplemental industry Codes for specific guidance. The U.S. pipeline industry uses ASME B31.8 as guidance to fulfill the Regulatory requirements for natural gas pipelines (the companion code, ASME B31.4, is used in an analogous fashion for the design of liquid pipelines). The ASME B31.8 industry code has provisions for the use of criteria for longitudinal strains in excess of 0.5%, although it is emphasized that this provision is not recognized in the Regulations.

In February 2013, PHMSA provided a set of Draft Conditions for the implementation of SBD for ASAP, which have been the subject of consultations between PHMSA and ASAP. PHMSA has specified that these Conditions, once finalized, would accompany a Special Permit for SBD, as per 49 CFR 190.341. PHMSA has made a determination that the use of SBD would require a Special Permit since SBD allows the pipe to continue operating when the longitudinal strain exceeds 0.5%. Following this determination, this response will compare pipeline design using SBD to cases where the pipeline longitudinal strain does not exceed 0.5% and would therefore be considered by PHMSA to be compliant with 49 CFR 192.

Discussion of Alternatives (includes discussion of extra-heavy wall pipe and aboveground installation):

There is no single alternative methodology to the use of SBD, but a number of alternatives that must be considered dependent on the alignment conditions. These alternatives include:

1. *Route Avoidance* – This is the primary alternative, and ASAP has, and continues to explore routing options that avoid, to the extent possible, all geohazards. To the extent possible, ASAP identifies those alignment conditions that may cause ditch displacement and subsequent pipe curvature and distress. This requires experience in identification of those surface characteristics that have been shown to contribute to potential route hazards, followed by an extensive subsurface investigation program to identify the remaining hazard, and, finally, analytical design tools to quantify the effect on pipe behavior. This process continues with the ASAP alignment changes adopted this year, followed by the geotechnical field program. As the samples recovered from the boreholes are processed by soil laboratories, the results feed into the project Geospatial Information System (GIS) and geotechnical database, and then are used in the evaluation of route hazards. The process of route threat identification, evaluation, and avoidance is an ongoing process for which many aspects will continue throughout the operational life.

Routing the ASAP pipeline, however, involves resolving a number of criteria including environmental impacts, land-ownership, construction difficulty, and operational access. The use of SBD often allows other routing criteria to take precedence since the safety of the pipe, even in the presence of geohazards, can be assured through the defined material procurement and testing program, rigorous welding and construction specifications, and continued operational vigilance thorough specified monitoring and reporting tools.

2. *Extra-Heavy Wall Pipe* – For this alternative, the same outer diameter (OD) is retained, but the wall thickness is increased. This does nothing to change the extent of settlement beneath the pipe, but allows the pipe to conform more gradually to changes in ditch displacement, thus reducing the ensuing curvature and longitudinal strain. With an adequate increase in wall thickness the resulting reduction of curvature can be sufficient to reduce the longitudinal strain to the code compliant 0.5% longitudinal strain limit.

   The technical disadvantages are several. The inner flow area is reduced, thus decreasing throughput potential. The welds at the transition of wall thickness require special design and construction consideration, although this concern is not atypical in transmission lines. Additional logistics may have to be employed to ensure weight restrictions on rail and truck carriers are not exceeded. Additional construction time for welding and NDE may be required. The economic costs increase not only due to the increased direct material weight, but also due to the abovementioned logistic, handling, and construction concerns. Lastly, there is a practical upper limit on thickness due to welding considerations (on the order of 1-1/4 inches).

   Extra-heavy wall pipe is typically the alternative of choice for larger diameter, higher pressure pipes (which require thicker walls in any case for pressure containment) since large diameter pipes may practically reduce high curvatures caused by adjusting to pipe ditch displacements – i.e. their structural resistance overcomes the surrounding soil resistance to change. By the same argument, as the soil resistance increases, such as at deeper burial sites, extra-heavy wall pipe may not be sufficient.

3. *Aboveground installation* – For this alternative, the pipeline is supported at intervals by engineered structures, typically constructed of steel or concrete. The vertical separation of the pipe from the subsurface eliminates consideration for geohazards resulting from changes in subsurface support, such as thaw settlement. The support structure is typically a round structural member with embedment designed to resist axial and longitudinal loadings transmitted to the support from the pipeline. The pipe itself, not being constrained by surrounding soil, is thus free to expand and contract in response to such loadings as operational changes in temperature. Consequently, the longitudinal stresses induced in the pipeline are relatively small, provided the supports are spaced appropriately. However, the displacement of the pipe on the supports must be accounted for by installation of expansion loops.

   This type of installation is typical on the North Slope of Alaska where hot, buried pipelines could disrupt the permafrost conditions. It was also the solution of choice for the Trans Alaska Pipeline System (TAPS) to mitigate the effect of thaw settlement; approximately half of its length is aboveground (>400 miles). A Special Permit is not required for selection of this Alternative. Natural gas pipelines, which typically run chilled or near ambient, have less of a technical requirement to avoid burial.

   The technical disadvantages to this alternative include flow assurance considerations for the natural gas product to ensure there is no liquid dropout that could collect and cause internal corrosion. The pipe material may be subject to low temperatures from the ambient conditions, and may require special fracture control provisions. There are also well-known disadvantages for its use which may be more pronounced for ASAP, especially if used along the Parks Highway Corridor: the configuration is highly visible, must allow for passage beneath the pipe, must allow for lateral variations in the ROW to accommodate expansion loops, and would be subject to additional security concerns. The aboveground installation costs more than a buried pipeline installation, although the cost disparity has been reduced since the installation of TAPS due to experience gained on the North Slope in the intervening decades.

4. *Soil remediation* – For this alternative, the soil surrounding the buried pipe is modified to either remove the potential geohazard or mitigate its effects. This is of limited use for artic transmission lines in general, except in very specific instances. Typically, pipe ditch displacement is caused by a change in the frozen state of the subsurface and an accompanying change in the volume of soil – for thaw settlement, the newly thawed soil will consolidate as a function of its (previously) frozen moisture content. Soil displacements that cause pipe integrity concerns are on the order of feet, which in turn require high soil thaw strains integrated over a thaw depth typically on the order of tens of feet. Thus remediation of the top ditch material does not cause enough change to materially affect this concern except where, for example, massive ice is found in the construction ditch.

   In some cases, it may be possible to lower the pipe strain by ensuring the pipe resistance to curvature from the backfill soil strength is lowered – typically, by replacing the excavated ditch material with imported fill.

   In some cases, through geothermal evaluations of the potential effects of construction disturbance and operational temperature change from the pipe product, a potential to install free-standing thermos-syphons for heat extraction from the subsurface may be possible, thus preserving the thermal state of the subsurface. However, thermo-syphons have many of the same disadvantages as the aboveground installation discussed above, as well as requiring additional operational monitoring and maintenance.

5. *Burial Depth* – For this alternative, a soil strata susceptible to causing pipe ditch displacement may be clearly identified and avoided by increasing the burial depth – either by increased construction excavation or by alternative construction placement technique (boring, HDD, etc.). This option requires site specific detailed information on subsurface characteristics, as well as increased installation costs.

Monitoring Requirements

Construction

To prepare for construction, special Material Specifications are developed for use in SBD segments that focus on the development of high strain capacities to resist potential route strain demands. These specifications are used to procure pipe samples to verify the viability of these measures through small scale to full scale tests and, if found successful, further used in project pipe procurement. During Construction, the SBD approach requires increased attention to the measurement and recording of items that could adversely affect the development of the full capability of the pipe material to resist the demand placed upon it by route hazards. This capability – termed the "Strain Capacity" – can be adversely affected, for example, by minute flaws in welding or minor offsets in matching the pipe wall between adjacent joints - which would otherwise be perfectly acceptable for pipeline construction. Such items will require smaller tolerances for weld acceptance, as well as recording for review and development of site specific measures in the event of later high strain occurrences during operations.

Operations

During Operations, increased monitoring to detect the advent of longitudinal strain conditions and to track their increase toward the strain demand limit is required. The chief tool for this monitoring will be In-Line inspection (ILI) tools that can measure change in pipe position and thus changes in pipe curvature. Operational criteria are set at "trigger levels" that correspond to defined reporting, detailed site monitoring, and remedial requirements.

Environmental Impacts:

For ASAP, the main factor contributing to thaw settlement, currently considered the major geohazard requiring use of SBD, is the effect of clearing vegetation on the right-of-way to facilitate pipeline installation. Thus, all alternatives discussed above, Special Permit or not, will essentially result in equal environmental impacts.

Testing for SBD:

Extensive testing is anticipated to support use of an SBD approach. This will include comprehensive line pipe and girth weld material laboratory tests from small-scale (tensile and compressive tests to develop stress-strain relationships specifically associated with the pipe steel manufactured in accordance with the project material specification) to full-scale (generally pressurized bend tests considering a range of critical variables, such as hi-lo misalignment, weld strength overmatch, weld flaw sizes, etc.).

Comprehensive subsurface geotechnical investigation will also be completed, and is actually an ongoing program, to identify the extents and magnitudes of the geohazards which must be addressed along the alignment. The same level geotechnical investigation would be completed whether SBD was utilized or not, which will essentially result in equal environmental impacts.

Example of Alternative Approach:

As an example of the difference between the buried ASAP pipeline that experiences thaw settlement with the strain held to less than or equal to 0.5% and the SBD case for the same thaw settlement magnitude, a detailed two-dimensional pipe-soil interaction analyses was carried out for thaw settlement induced ground displacement scenarios. The analysis was completed using the commercial program PIPLIN[3]. In PIPLIN, the pipeline can be divided into several variable length segments (see Each segment can be then be further subdivided into several equal length members. Within each member, the pipe is modeled using beam-type elements with longitudinal fibers that are evenly spaced around the circumference. Data describing the pipeline and surrounding soil can vary by segment. Boundary conditions can be specified in terms of load, displacement, temperature and rotation. For each beam element, hoop and axial stresses and strains are determined at the pipe mid-thickness at the ends of the element. Stresses, strains, and axial curvature vary linearly along a member.

The pipe cross-section is assumed to remain circular and plane sections are assumed to remain plane. The pipe element also accounts for large displacement effects (i.e., changes in the equilibrium due to large displacements) by adding geometric stiffness coefficients to the element stiffness matrix.). Figure 1, below).

Each segment can be then be further subdivided into several equal length members. Within each member, the pipe is modeled using beam-type elements with longitudinal fibers that are evenly spaced around the circumference. Data describing the pipeline and surrounding soil can vary by segment. Boundary conditions can be specified in terms of load, displacement, temperature and rotation. For each beam element, hoop and axial stresses and strains are determined at the pipe mid-thickness at the ends of the element. Stresses, strains, and axial curvature vary linearly along a member.

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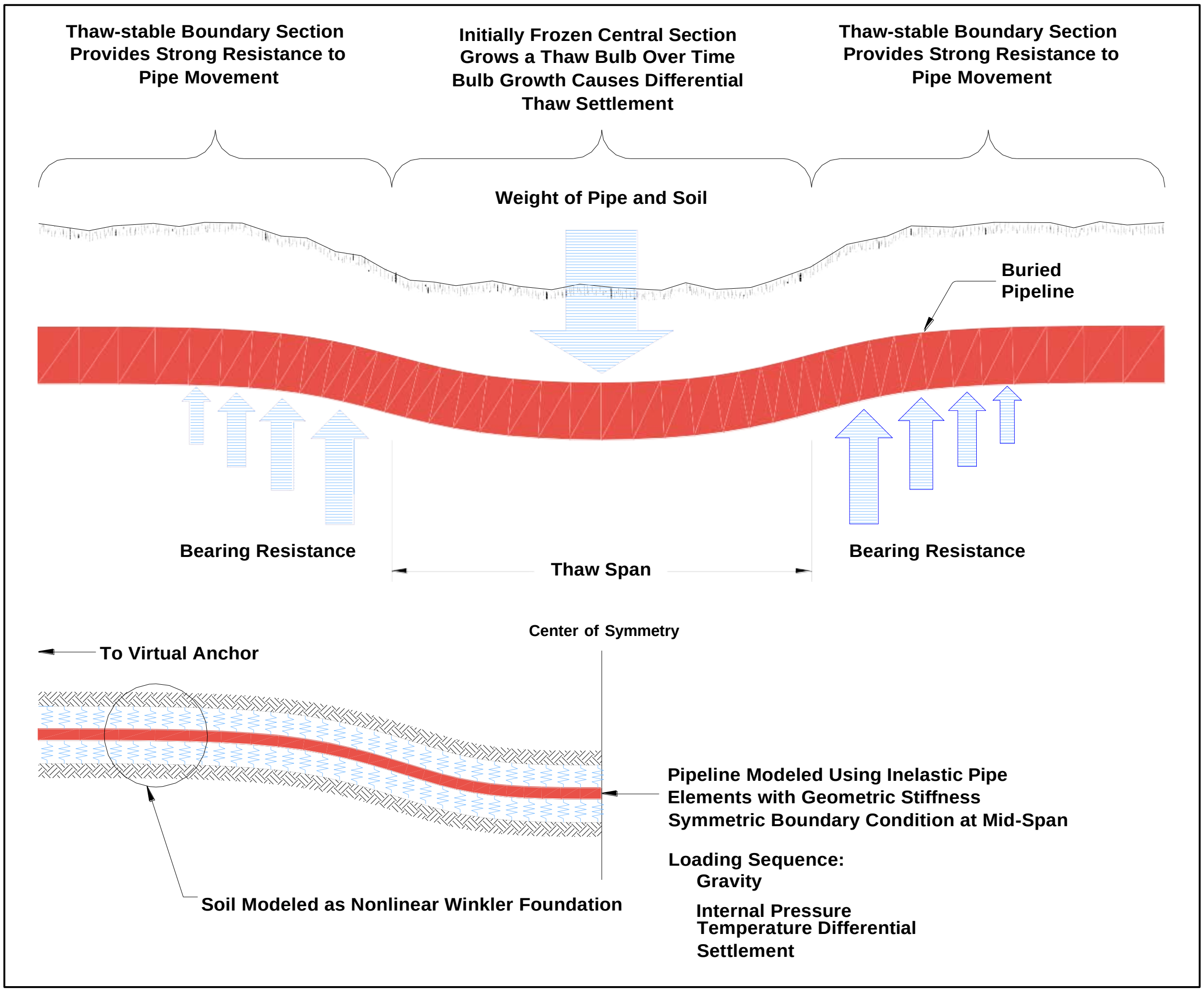
[3] SSD, Inc., "*PIPLIN: Stress and Deformation Analysis of Pipelines*", Version 4.58, User Reference and Theoretical Manual, Reno, Nevada, February 2011.

Figure 1 PIPLIN Model



The assumed ground displacement profiles are basically "block" downward movements. For these "block" movements, the abruptness of the imposed ground displacement profiles is characterized by 100% of the movement occurring over a very short distance on each end of the block. This is a conservative assumption since ground movement realistically ramps up over longer transition lengths. The effect of ramping is being investigated in separate analytical work; however, for this example analysis, the same assumption will be held for all cases to facilitate the comparison.

The pipeline is assumed to be running straight and horizontal, and the thaw settlement movement is assumed to occur in the vertical downward direction such that the ground motion and the pipe response occur in the vertical plane. A total of 20 span lengths ranging from 50 feet to 600 feet were considered using PIPLIN's multi-span analysis option (i.e., 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 250, 300, 400 and 600 feet). For all cases, a plane of symmetry was located at the center of the block ground movement so that only half of the configuration was modeled.

The diameter of the ASAP mainline is 36 inches - three wall thicknesses of 0.527, 0.632, and 0.758 inches, corresponding to design factors for evaluation of pressure containment based on 49 CFR 192.111 of 0.72, 0.60, and 0.50, respectively were investigated.

The pipeline is assumed to be buried under uniform cover with assumed cover depths of 3 feet, 5.5 feet, 7.5 feet and 10 feet. For all these cover depths cases, the water table is assumed to be at the bottom of the pipe. Two sets of soil properties were considered for the pipe-soil spring calculations: Soil A with bulk density γ=130 pcf, soil friction angle φ= 32° and a cohesion strength of c=0 psf and Soil B with bulk density γ=130 pcf, soil friction angle φ= 33° and a cohesion strength of c=100 psf for all the cover depth cases.

Bilinear (elastic-perfectly plastic) pipe-soil springs were calculated for these conditions using procedures based on the guidelines[4] presented by C-CORE. Table 1 summarizes the pipe-soil spring properties used for the thaw settlement analyses.

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[4] *"Guidelines for Constructing Natural Gas and Liquid Hydrocarbon Pipelines Through Areas Prone to Landslide and Subsidence Hazards",* Prepared by C-Core, D.G. Honegger Consulting and SSD, Inc. for PRCI, January 2009.

Table 1 Pipe-Soil Springs for Thaw Settlement Analysis –ASAP 36-inch Mainline

	Soil A Fine Grained Non-Cohesive (Water table at bottom of pipe) - $\gamma=130$ pcf, $\varphi = 32^o$, $c = 0$ psf, $f=0.6$, $Ko=0.42$											
	Axial Spring			Lateral Spring			Vertical Uplift Spring			Vertical Bearing Spring		
Cover Depth (ft)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)
3	0.100	1.359	13.59	2.880	9.442	3.278	0.540	1.447	2.680	3.600	48.60	13.50
5.5	0.100	2.114	21.14	3.600	16.78	4.661	0.840	3.502	4.169	3.600	71.20	19.78
7.5	0.100	2.718	27.18	3.600	23.73	6.591	1.080	5.789	5.360	3.600	89.27	24.80
10	0.100	3.473	34.73	3.600	33.76	9.377	1.380	9.452	6.849	3.600	111.9	31.08

	Soil B Combination Soil (Water table at bottom of pipe) - $\gamma=130$ pcf, $\varphi = 33^o$, $c = 100$ psf, $f=0.6$, $Ko=0.40$											
	Axial Spring			Lateral Spring			Vertical Uplift Spring			Vertical Bearing Spring		
Cover Depth (ft)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)	Yield Displacement (in)	Yield Strength (klf)	Stiffness (klf/in)
3	0.100	2.334	23.34	2.880	12.35	4.289	0.540	2.402	4.447	3.600	66.87	18.58
5.5	0.100	3.107	31.07	3.600	20.38	5.661	0.840	5.033	5.992	3.600	92.31	25.64
7.5	0.100	3.725	37.25	3.600	27.33	7.591	1.080	7.806	7.228	3.600	112.7	31.30
10	0.100	4.498	44.98	3.600	37.36	10.38	1.380	12.11	8.773	3.600	138.1	38.36

An X70 pipe steel stress-strain relationship was assumed based on a typical pipe steel scaled to specified minimum yield strength (SMYS) in the hoop direction of 70.3 ksi per the API-5L minimum values. In the analytical model, the anisotropy and strain hardening characteristics observed on the real data were preserved. This steel idealization was scaled to match the pipe SMYS for this example, and, to the extent that the strength of actual ASAP pipe samples will exceed the SMYS, the steel stress-strain input for this example results in conservative estimates of the pipe strain demand.

Three different values of the pipe temperature differential ΔT (i.e., between operating temperature and installation temperature) were assumed, namely ΔT = +50°F, +10°F and -35°F. In summary, the thaw settlement evaluations were conducted for combinations of the following parameters:

- Wall thickness (0.527, 0.632 and 0.758 inches)
- Operating pressure (1,250 psig)
- Temperature differential (+50°F, +10°F and –35°F)
- Soil type (A and B)
- Depth of cover (3, 5.5, 7.5 and 10 feet)
- Number of settlement spans (20).

For each analysis, the pipeline is first pressurized and subjected to the applied temperature differential. With the pipe subjected to operating and gravity loads, the thaw settlement profile is imposed through the base of the pipe-soil springs. For all cases, the analysis results were checked to verify the length of the boundary sections of the model extended beyond the location of the longitudinal virtual anchor. The ground movement profile is imposed in small steps up to 72 inches of settlement and the nonlinear solution is established using an event-to-event solution strategy for obtaining the resulting pipe-soil deformation state at every inch of imposed displacement.

The results of all the analyses were then reviewed to find the critical analysis, (i.e. the case which results in the minimum allowed thaw settlement). Since it is not practical to investigate the ASAP field alignment for distinct soil strata changes to the level required for the structural analysis (on the order of 40 feet), all analyzed spans were reviewed and the case resulting in the maximum strain response were conservatively used. The governing soil case was Case B, the stronger soil. In general, stronger pipe-soil spring resistance will result in increased pipe strain demands and smaller allowable thaw settlements. The governing change in operational pipe temperature was ΔT = +50F.

The results are shown in Table 2. As the cover depth increases for a given pipe thickness, the thaw settlement required to reach 0.5% decreases. As the pipe wall thickness increases for the same cover depth, the thaw settlement required to reach 0.5% increases.

Thus, if 54 inches of settlement was predicted at a site having a cover depth of 3-feet, it is evident the 0.527-inch wall thickness pipe would require a SBD approach since the strain would exceed 0.5%. For that same site, if pipe with a wall thickness of 0.632-inch was used, the strain would not exceed 0.5% and thus would not be subject to SBD.

Table 2 Settlement for Different Pipe Thicknesses to Reach ±0.5% Strain Limits (Pressure =1,250 psig, ΔT=+50°F, Soil B)

Cover Depth (feet)	Thaw Settlement (inches) to Reach Governing ±0.5% Strain		
	t=0.527”	t=0.632”	t=0.758”
3.0	38	54	>72
5.5	22	28	34
7.5	16	21	26
10	13	17	18

Summary:

The description of the details of this analysis indicate the amount of information, both in-situ and as proposed for construction that must be developed for the alignment analysis.

For the evaluation of the Strain Demand, each segment of the pipeline must be analyzed to find its current frozen/unfrozen state, the soil properties of the subsurface based on field borehole studies and soil laboratory tests, the thaw depth and associated soil thaw strain, the pipe operational pressure envelope, the pipe unit material response (stress-strain curve) based on material testing, and the construction conditions. All of these conditions are assembled into the project GIS for integration into the design analysis, and development of the appropriate design value for comparison to the available pipe Strain Capacity, for both tension and compression, reduced by a specified resistance factor to incorporate additional safety into the design – the reduced Strain Capacity value is termed the “Strain Demand Limit”.

The Strain Capacity must also be evaluated using pipe procured as per specialized high- performance specifications for use in SBD segments, weld procedure development, small/medium/full scale testing of the pipe material and calibration to evaluative processes for both the tensile and compressive strain capacities. Further detailed procedures to ensure that the predicted properties are not adversely impacted during construction are emplaced, with proper oversight and reporting procedures implemented. Finally, monitoring during Operations is key for assurance of the long term viability of the approach.