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Mr. Edwin (Al) Kuhn
Director, Government Affairs
Northwest Alaskan Pipeline Company
1120 20th Street, NW, Suite #700
Washington, DC 20036

Subject: Design Criteria Manual - Appendix 21A, Frost Heave Criteria and Methodology, Dated May 25, 1983

Dear Mr. Kuhn:

The OFI, with the assistance of the Cold Regions Engineering and Technical Committee, has completed review of the subject criteria document. As a part of the review, twelve additional supporting reports were evaluated. These are listed on the enclosure to this letter.

NWA has done pioneering work in developing data, strategies, analyses, and procedures for dealing with the frost heave phenomena. With this acknowledegment of the fine work that has been performed, and the degree of confidence that reasonably may be placed in the result to date, the OFI conditionally approves Appendix 21A of the Design Criteria Manual (DCM). The term "conditional approval" is used to recognize that certain aspects of the work are incomplete and to require that certain additional confirmatory work be done because of the criticality of the frost heave problem. The further testing, analyses and documentation required are discussed in the following paragraphs. When you have completed this work and other work that you may conduct along some of these same lines, the OFI will expect to again review the effort. The OFI is optimistic that the gaps can be removed to a satisfactory degree and that the Frost Heave Criteria and Methodology can be approved at that time. As a positive step in reaching this goal the OFI expects to monitor the progress through briefings from NWA staff on an approximately monthly basis. The same people will be monitoring who had the lead role in the past review that led to this letter.

While all the sub-elements of the methodology are interdependent, the required work can best be discussed as if the sub-elements were independent.

° Prediction of Heave - Heave Correlation Equation (HCE)

- Since the HCE is empirical, assess range of test samples to insure that they are inclusive as to geographical locations and soil type and origin.

- Continue the lab test program until there is coverage with good (category 1 & 2) tests as discussed above.

- At the completion of the testing, re-evaluate the HCE.

- Test revised HCE against field test data (CPTS and Fairbanks).

° Field Tests

- Continue data collecting from the five Chilled Pipe Test Sites until at least mid summer of 1984 unless it can be demonstrated that no data needed for further development of criteria is being generated on a site-by-site basis.

- Continue Fairbanks Test Site until it can be demonstrated that no data needed for further criteria development is being generated. Test sections 9, 11, and 12 are especially critical as sufficient strains must be developed to adequately test the predictive capabilities of FROSTY.

- Upon closure of a test site, validate the instrumentation and sample insulation for moisture and deterioration tests.

- At some point in time after work on HCE and Frosty has been completed, make predictions for all available field tests to extend at least to the estimated closing date and provide OFI with the predictions.

° Battelle Thermal Model (BTM) - The model appears to work well for predicting frost bulb development around an uninsulated pipe.

- Very little verification was presented in the report on the model. If such verification and testing has not been done, it should be performed and furnished to the OFI.

- The Geodyne model is coupled with the BTM in predicting frost bulb development. Provide OFI with a report on the model along with validation data.

- Design climate data should be updated for use in frost heave design and provided to the OFI.

- Apply the model to fully insulated pipe test sections and compare to test data.

- Apply the model to the partially insulated pipe (300°) and show effects for various soil conditions.

° Frosty - Frost Heave Analysis of an Inelastic Pipe in a Rate Dependent Soil Medium - The model appears to be a substantial improvement over Piplin III for use in the frost heave analysis, although the simulation of strains for Test Sections 9, 11, and 12 were not sufficiently close

to the measured values to provide full assurances of the validity. Such simulations eventually will provide the final verification for the program, however, additional validation should be done before then and provided to the OFI.

- Uplift resistance values are critical inputs to the Frosty program and these have been developed by relatively weak application of standard soil mechanic analyses and very limited field testing. The input values need to be strengthened. Your attempt to model the uplift resistance curves may be helpful but you still may have to provide conservative bounds for the values.

- Frosty is a two-dimensional program that can be used only on straight pipe. It is understood that you are developing a subroutine, Frosty B, to analyze effects of bends on pipe stress. This program should be validated and submitted with the additional validation on Frosty.

° Application of system to mile-by-mile design.

- Density and total gradation of a soil, as well as the fraction passing the 200 mesh screen, have a strong influence on heave potential. It is not clear that the simple criteria for selecting the design soil at a given location will result in a conservative frost heave evaluation. The HCE should be exercised on many soil gradations and an attempt made to better define critical parameters for selecting the design soil.

- Evaluate mitigative modes to determine threshold where each would be used.

- Evaluate effect of total heave where 300° insulation is used and identify conditions that would prohibit use because of the amount of heave.

- Evaluate design strategies, other than designing specifically for each location, that eliminate the need for extremely accurate selection of design soil type. As an example, maximum restrained heave for the worst restrained condition to keep pipe strain within 0.4% could be established. Any soil condition that indicated equal free heave would require mitigation. Other strategies could be developed.

- Evaluate the 300° insulation mode from the standpoint of insulation reliability, effectiveness, and cost. It may be so attractive that it could be used very freely to avoid having to completely "fine tune" the design system. In the evaluation analyze the elements of conservatism that are built into the system to show that it is a reasonable value.

In addition to the general commments outlined above, the following specific comments on Appendix 21A are provided:

Par 1.0 - The second sentence is a little misleading as the chilled gas will have little effect on thawing, settlement, or slope stability. These are more related to the broader effects of the workpad. Revise the sentence to read "The design chosen to mitigate the undesirable effects from such conditions on pipe integrity is the transportation of the gas at a temperature less than 32°F (0°C)".

Page 21 A-5 2nd and 3rd bullets. It is unlikely that you will ever have sufficient information to change these assumptions to a less conservative value. For the water table, it would probably be more realistic to consider seasonal effects of the active layer on the adverse effects of the water table.

Par 3.1.4 Does the last sentence of the second paragraph still hold? If not, revise.

Par 3.2.5 Because of minor effects, consider dropping downward compression from the model.

Par 3.3 Predictions and comparisons are certainly encouraging but it has not been thoroughly demonstrated that they can be made accurately. Additional analyses need to be made after continued movement has occurred in the field.

Par 3.5 1st bullet - After the first sentence add "The insulation will enhance thaw of the backfill in the summer which will assist in the release of strain in the pipe."

Although neither of the insulated modes above have been fully demonstrated as to effectiveness, this should be accomplished by studies outlined under the third bullet above.

The heat-pipe mode would appear to be acceptable but has no stress analysis to back it up.

How will the point for start of measurement be determined for the 100 foot extension?

Each of the modes may introduce problems that have not been addressed in other sections of the Design Criteria Manual. For example, the 300° insulation with unrevegetated backfill above could cause erosion problems and will cause cross drainage problems. Animal crossings would have to be considered for an elevated line. Criteria for handling such problems must be developed and added by addenda to criteria sections at an appropriate time.

Par 4.1 Add bullet "Ill-defined transition between heaving and non-heaving zone".

Par 4.2 The OFI considers a monitoring system for detecting movement of the line is a critical element for pipelines in arctic or subarctic soils. Further, development may require new technology. On any schedule for remobilization, development of a monitoring system should start early and be funded adequately for a strong effort.

Sincerely,

William T. Black

William T. Black
Director
Office of Engineering Review

cc:
Rhett
Kari
Ott
Fisher
Legg
Myrick
Hauser
Sotak

Enclosure
(To letter "Design Criteria Manual Appendix 21A, Frost Heave Criteria and Methodology", dated August 16, 1983).

LISTING OF SUPPORTING REPORTS REVIEWED

1. FROST HEAVE LABORATORY TEST REPORT, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

2. BATTELLE THERMAL MODEL, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

3. FROST BULB HEAVE RESISTANCE PROVIDED BY SIDE SHEAR OF UNFROZEN SOIL, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

4. MODEL SIMULATION OF UNRESTRAINED FROST HEAVE, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

5. PREDICTION AND COMPARISON OF FROST PENETRATION AND FROST HEAVE, Volumes I and II, June 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

6. SITE DESCRIPTION AND SUBSURFACE INVESTIGATION REPORT FOR THE SIX CHILLED-PIPE TEST SITES, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

7. CHILLED-PIPE TEST SITES FACILITY PRESENTATION AND INTERIM PERFORMANCE REPORT, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

8. UPLIFT LOAD-DISPLACEMENT FUNCTIONS FOR PIPELINES IN FROZEN SOILS, May 1983, Prepared by R & M Consultants, Inc. under direction of Alaskan Northwest Natural Gas Transportation Company.

9. DOWNWARD COMPRESSION OF UNFROZEN SOIL UNDER THE GROWING FROST BULB, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

10. FROST HEAVE ANALYSIS OF AN INELASTIC PIPE IN A RATE DEPENDENT SOIL MEDIUM, April 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

11. FROST HEAVE SENSITIVITY ANALYSIS, June 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.

12. THIRD INTERIM REPORT - FAIRBANKS FROST HEAVE TEST FACILITY, June 1983, Prepared by Alaskan Northwest Natural Gas Transportation Company.