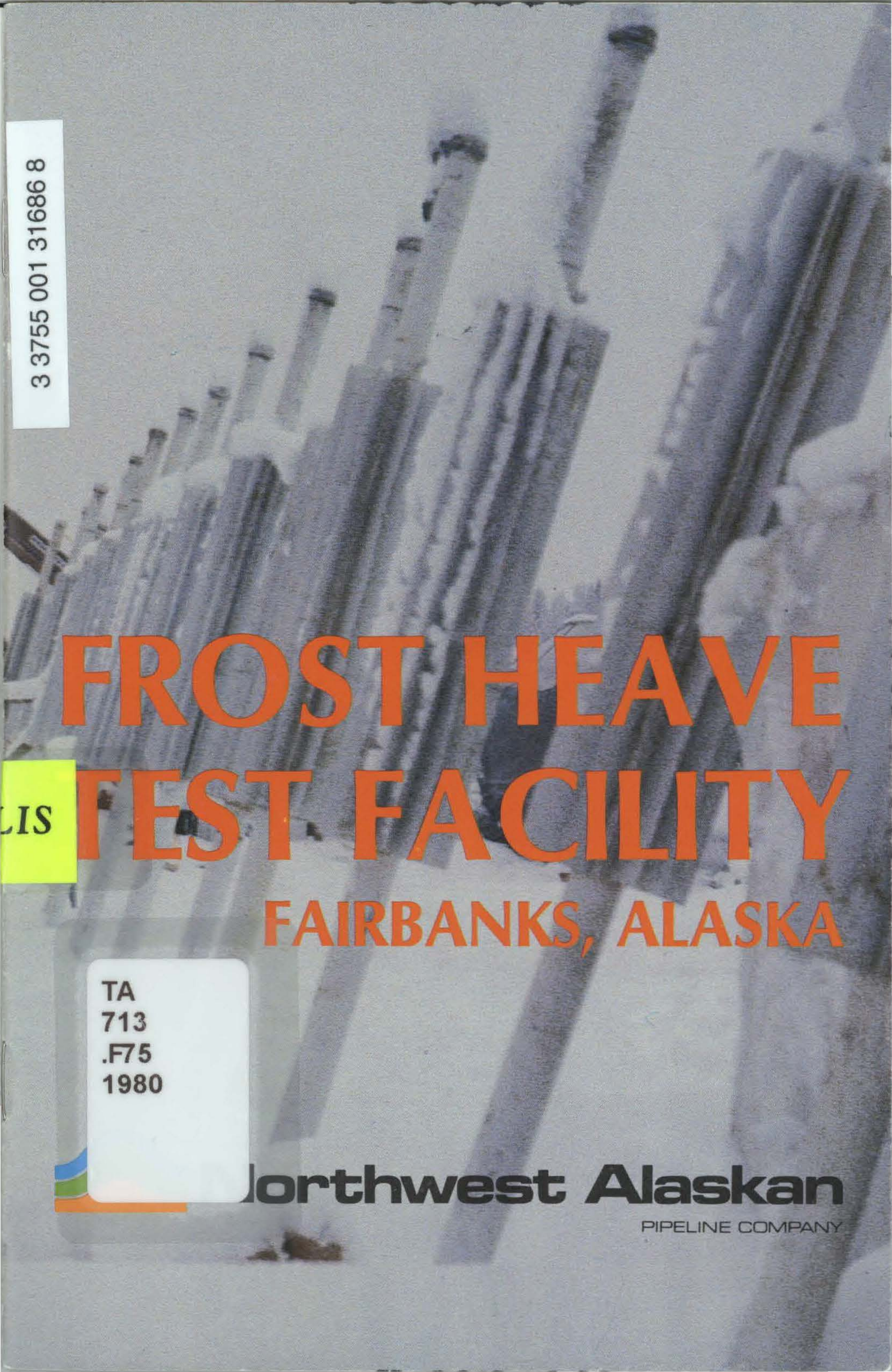
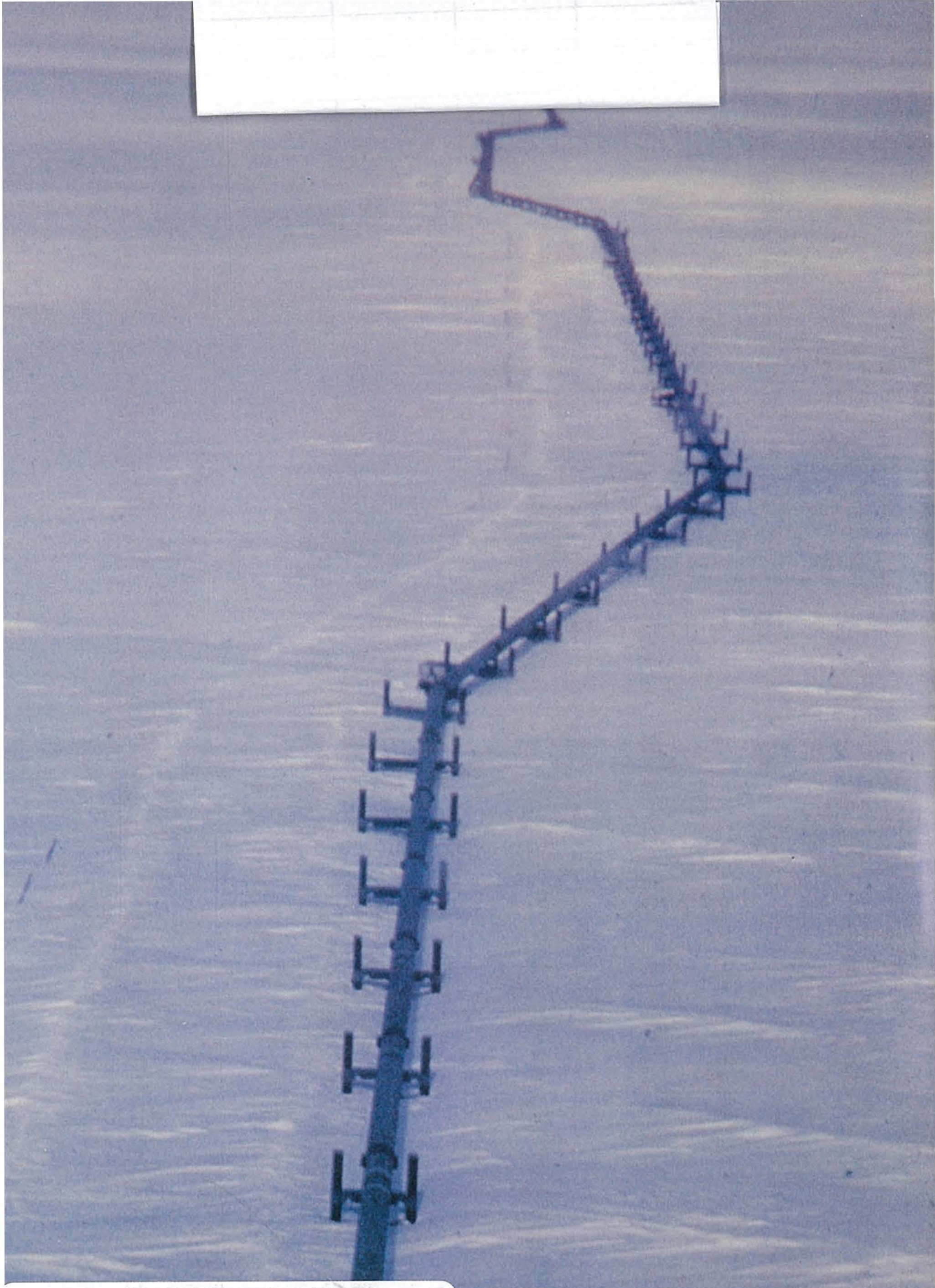


FROST HEAVE TEST FACILITY

FAIRBANKS, ALASKA

Northwest Alaskan
PIPELINE COMPANY



Trans Alaska pipeline above ground construction on the North Slope.

Alyeska Pump Station number one at Prudhoe Bay.

(Cover Picture) shows installation of chill pipes of test section 6 at the Fairbanks Frost Heave Test Facility.

INTRODUCTION

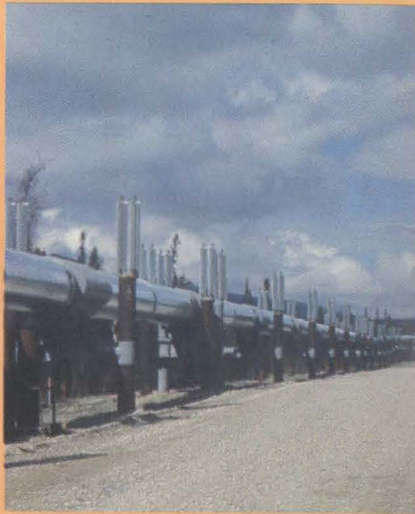
In 1968, the largest new source of oil and natural gas found in almost 50 years was discovered below frozen desert where temperatures plunge as low as minus 100°F, where the sun disappears into total darkness almost three months in the winter, where the ground remains frozen 12 months a year and where snow can accumulate as high as 360 inches over winter's time in one area. This formidable location is the North Slope of Alaska, beneath which lies approximately 25 percent of America's known oil and gas reserves.

How to bring this oil and gas out of the ground, across some of the most rugged terrain in North America--across earthquake zones, over mountain peaks, through avalanche danger areas, over and under several hundred streams and rivers, and through many Arctic wildlife migration areas--is the most challenging endeavor ever undertaken by private industry.

THE OIL PIPELINE

Although pipelining is not new to the oil and gas industry, the trans Alaska oil pipeline was a pioneering project. Never before had a project of this size been built through Alaska. New technology had to be developed to adapt to the unusual conditions that existed in this Arctic frontier. One of the biggest problems that had to be dealt with was how to prevent disruption to Alaska's mysterious and sensitive soils.

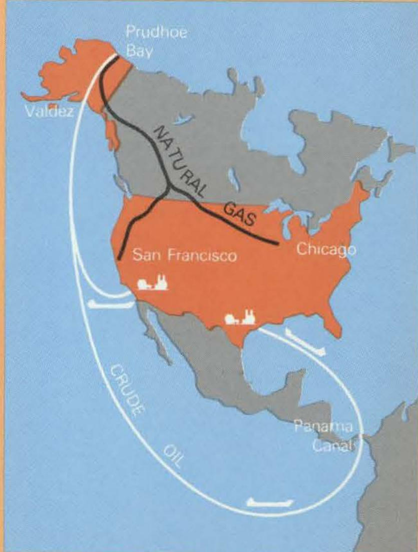
The hot oil, coming out of the ground at 180° F, is today being transferred by Alyeska Pipeline Service Company to markets in the U.S. by way of a 48-inch diameter pipeline, stretching from Prudhoe Bay to Valdez, an ice-free port located 800 miles away. It was buried below ground for approximately half its route and elevated above ground for the other half to avoid damage to some of Alaska's unusual soils and to the oil pipeline. From Valdez a portion of the oil is loaded aboard tankers and carried through the Panama Canal to U.S. refineries.



Elevated 48" Hot Oil Pipeline.

THE GAS PIPELINE

The natural gas will be transported through a separate pipeline, chilled below 32° F and buried, from Prudhoe Bay, through Alaska and western Canada, terminating at two points, one near Chicago and the other near San Francisco. Northwest Alaskan Pipeline Company is the operating entity of a partnership which will plan, design, construct and operate the gas line in Alaska.



Crews installing freeze pipes into the Vertical Support Members on elevated oil pipeline section.

PERMAFROST

The North Slope is covered with a fragile mass of delicate vegetation called tundra. Under this tundra is permanently frozen ground or permafrost. Preliminary studies indicate permafrost exists over approximately 30 percent of the gas line route. Permafrost is any rock or soil material that has remained below the freezing temperature of water (32° F) continuously for two or more years.

There is general agreement on just how permafrost actually formed. Several thousand years ago, Alaskan soil experienced the same seasonal changes which occur in midwestern states. The upper few feet of soil would freeze in winter and thaw during summer. This cycle was repeated, creating a thermal balance—summer thawing equal to winter freezing. But then the climate changed with the yearly average temperature dropping below freezing and all the soil that froze in the winter didn't thaw in the summer, disrupting the thermal balance. Permafrost began forming. The ground froze deeper and deeper until finally the heat from the earth's core stopped it. Thermal balance was achieved again.

Permafrost is a delicately balanced thermal phenomenon and, if damaged, heals very slowly, if ever. In order to avoid damaging the permafrost and over stressing the hot oil pipeline, it was built above the ground over sensitive areas. Of its 800 total miles, the oil line was elevated 420 miles on vertical support members (VSM's), totalling 78,000. This required numerous above-ground to below-ground mode changes.

FROST HEAVE

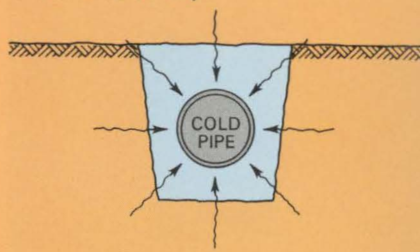
By refrigerating the gas and burying the pipeline in permafrost, we expect that the line will not adversely affect permafrost. The problem of a buried gas line may arise in the discontinuous permafrost areas. Both permanently frozen ground and seasonally frozen ground exist in discontinuous areas. In these areas, a small percentage of unfrozen soil within predominately permafrost regions may cause frost heave. This is caused by the expansion of moisture as it freezes and interacts with various kinds of soils.

Ground conditions in much of Alaska's permafrost areas generally are quite wet because of poor drainage. Where there is substantial moisture, ice can develop in permafrost through a process called ice segregation. Mositure migrates toward the freezing soil and collects into distinct lens-shaped pockets called ice lenses. During the freezing and ice segregation process, frost heaving occurs. Because the ice occupies more volume than it did as water, soil is displaced to make room for the accumulating ice. But the ground material can be displaced only upward because of the hard permafrost below. The resulting heaving or "jacking" can cause quite severe distortion at the surface.

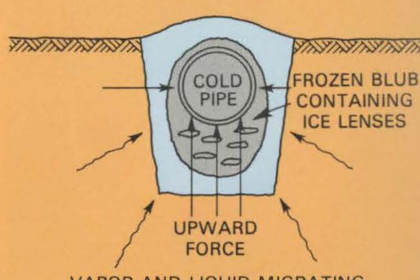
The results of the phenomenon of frost heave have long been known to constructors in Arctic regions. Rumpled roads and tilted buildings are the result of neglecting this condition in the design of Arctic structures.

The engineering problems associated with permafrost are not similar in

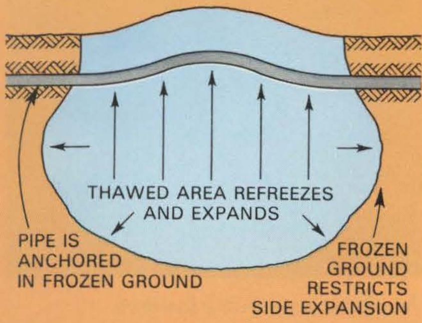
Moisture Migration
Toward Cold Pipe

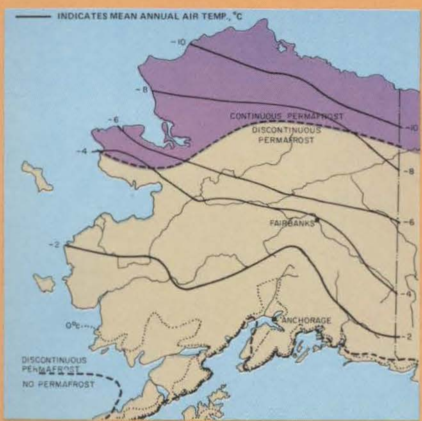


Subsurface Water Migration
Which Causes Ice Lenses



Pipe Stress Caused By Frost Heaving
In Discontinuous Permafrost Areas





Zones of Permafrost.

every type of ground material. The amount of frost heave which may occur depends on the quantity of moisture in the soil, the type of soil and the inter-mixture of the two. Studies are being conducted to classify soils along the route in terms of relative frost susceptibility. Laboratory analysis of bore hole samples is being conducted to establish soil properties, such as grain size, porosity and water content, and their effects on frost heave capability.

Bedrock that contains ice and well-drained, coarse-grained sediments create few, if any, construction problems. The engineering problems arise where permafrost occurs in poorly drained, fine-grained sediments, especially silts and clays. In such sediments, there generally are large amounts of ice and when the ice melts the thawing produces excessive moisture and the soils become unstable. Structures in these regions require that the settlement or instability be fully accounted for in the design, or that thaw is prevented by insulation, refrigeration or both.

Operating a chilled pipeline in frost susceptible soil may attract water which will freeze around the pipe creating a frost bulb. As this bulb continues to develop, it may exert an unbalanced upward force on the pipe, which could stress the pipeline steel beyond its elastic limits and cause fractures to develop.

FROST HEAVE TESTING

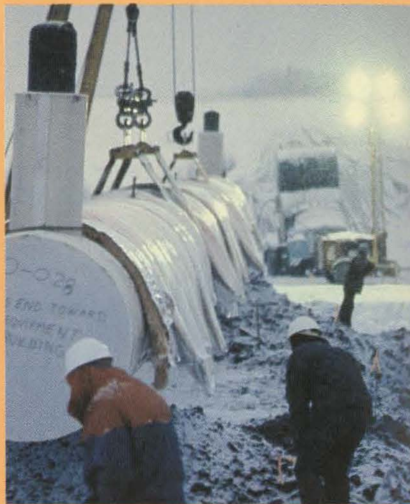
Northwest Alaskan Pipeline Company and Foothills Pipe Lines, the Canadian company responsible for a portion of the gas line project through Canada, are presently conducting a sophisticated, technical testing program to determine the effects of frost heave on a chilled, buried pipeline and various measures proposed to be used to control this phenomenon.

Laboratory and field test studies have been performed for several years on the frost heave mechanism in order to establish a proper design method for the gas pipeline. Northwest Alaskan and Foothills, in order to gain additional knowledge, have established a test facility just outside of Fairbanks, Alaska. This location was chosen for testing because it contains both permafrost and frost susceptible soils. At the facility, Northwest Alaskan is testing various measures for controlling or minimizing frost heave. Two of the basic control measures considered most likely to be effective are insulation and selected bedding material. Insulation, applied uniformly around the pipe, is most effective in reducing heat transfer. Selected bedding material can be used to replace frost-susceptible soil immediately below the pipe which reduces the overall heave capability of the soil.

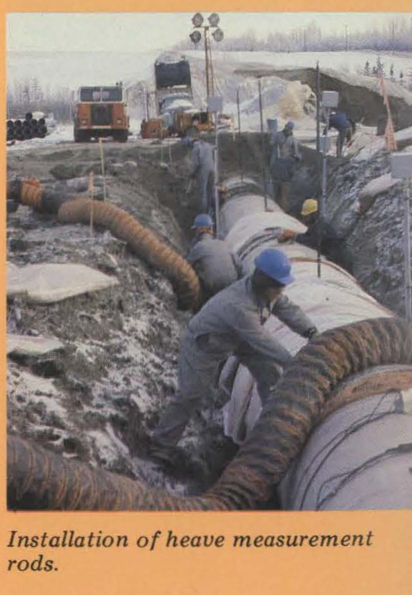
CONTROL MEASURES

The data obtained from the testing at the facility, utilizing combinations of gravel and insulation, will determine the most efficient control measures. Following are specific measures being tested:

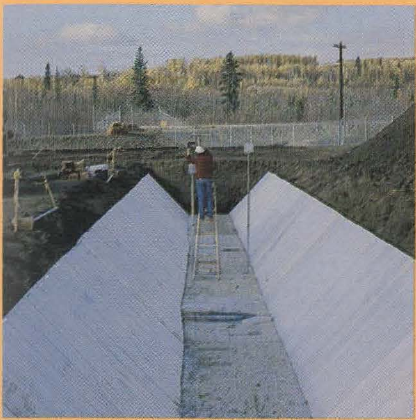
(1) **Soil Replacement**—replaces frost susceptible soil with various depths of non-frost susceptible material under the test sections.



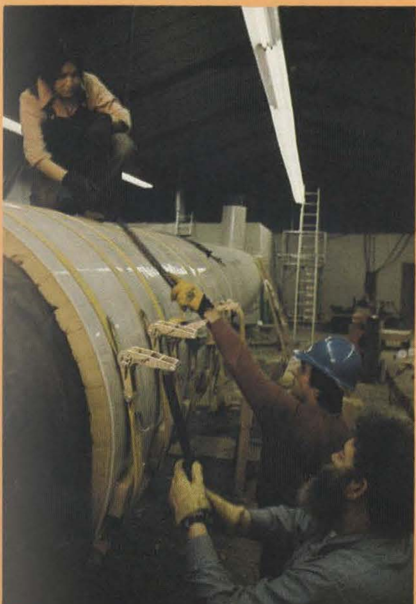
Insulated pipe being lowered into trench.



Installation of heave measurement rods.



Insulated trench test section.



Insulation being installed on pipe.

(2) **Pipe Insulation** – places insulation around the pipe sections. In one section, the trench is insulated rather than the pipe itself.

(3) **Shallow Burial** – insulates a section of pipe installed with a small berm of soil on top of the pipe.

(4) **Chill Pipes** – freeze the soil around and under the pipe by use of convection devices called chill pipes. These pipes are filled with a mixture of water and methanol and remove heat from the ground by fluid convection. The hot oil line uses similar methods for above-ground pipe supports to prevent permafrost thawing.

(5) **Pipe Insulation/Selected Bedding Material** – insulation placed around the pipe in various combinations with replacement soil under the pipes will show effectiveness of dual mitigating methods.

Test data will compare the effectiveness of the various mitigative measures.

TEST SECTIONS

There are 10 separate sections of 48"–diameter pipe at the test facility. Each section is being tested with a different control design measure or a combination of two or more measures.

The testing will assist in determining the following: (1) which measures will be the most effective in controlling frost heave; (2) how much secondary heave will occur in permafrost.

The test sections operate with chilled air (10°-15° F) circulating at 650 to 675 psig through the 48"-diameter steel test pipes. The chilled air simulates the chilled gas which will be transported in the pipeline.

Section One: Section one is a 120-foot, bare, uninsulated pipe installed in a trench backfilled with native soil. This is the quantifying or control section and should demonstrate maximum heave from the ground since it does not include mitigative measures.

Sections Two through Eight: Sections two through eight are equipped with various thicknesses of pipe insulation (up to 4") in different types of soil.

Section Two: 2" pipe insulation installed on native soil.

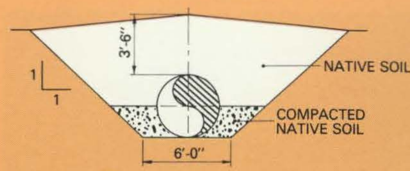
Section Three: 6" pipe insulation in the trench rather than on the pipe.

Section Four: bare pipe installed on 3' of non-frost susceptible soil.

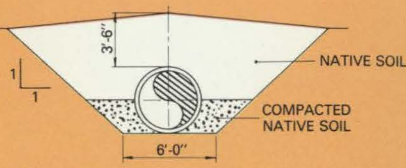
Section Five: 2" of insulation on pipe in combination with shallow burial in compacted gravel fill.

Section Six: bare pipe in native soil with chill pipes.

Section Seven: 2" insulation on pipe on 1' of non-frost susceptible soil.



T.S. No. 1



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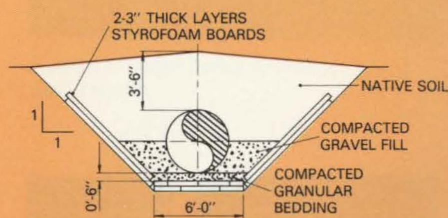

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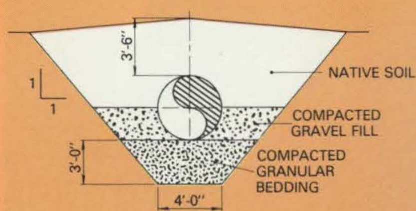

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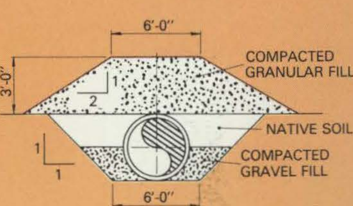

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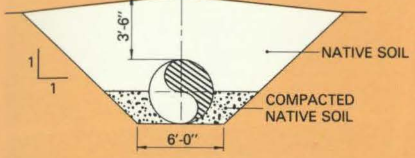

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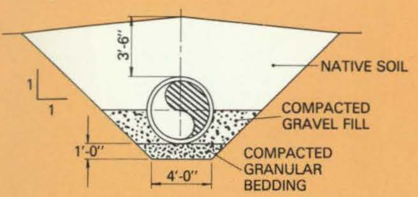

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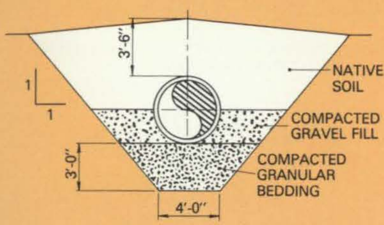

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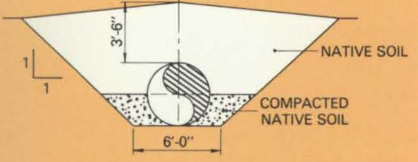
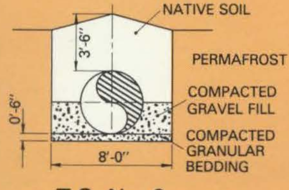


T.S. No. 9
West End



T.S. No. 9
East End
T.S. No. 10

Section Eight: 4" insulation on pipe installed in 2' of gravel on 3' of non-frost susceptible soil. This section should have the least frost heave since it has the best combination of control measures with the greatest amount of insulation and is installed on non-frost susceptible soil.

Section Nine: Section nine is a bare, uninsulated 400-foot long section buried partly in permafrost and partly in frost susceptible soil. This section will indicate the effect of stress on the pipe due to differentials in frost heave.

Section Ten: Section ten is a bare, uninsulated 40-foot long section wholly installed in permafrost. This section will indicate potential frost heave of a chilled pipe buried in permafrost.

INSTRUMENTATION

Instrumentation at the site is designed to gather data, measure the conditions of each pipe section and surrounding soil to better define the frost heave phenomenon and to verify the effectiveness of the proposed control measures. The instruments are placed on, within and next to each test pipe to measure conditions such as the soil temperatures, soil pressures, vertical displacement of the pipe and pipe stress due to deformation caused by heave. Data from the instruments is gathered automatically by a microprocessor computer and recorded on tape. Transcripts of the tapes are then sent to appropriate engineers and scientists for analysis, evaluation and verification. Instruments at the facility include:

Water Wells: The level of ground water is measured by temporarily installed wells at the site.

Temperature Detectors: The ground temperature is obtained by semi-conductor resistance temperature detectors buried beneath the soil and at the sides of all test sections where frost bulbs may occur.

Heave Rods: Vertical displacement of test sections are measured by rods attached to the top of the pipe. A laser beam survey instrument is used periodically to determine any movement of the pipes by reading the displacement of the rods.

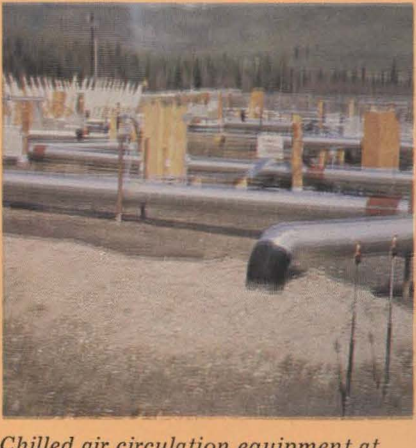
Pressure Belts: The soil pressure beneath and at the sides of the test sections are measured by pressure pads installed in "belts" around the pipe.

Strain Gauges: Stress on the pipe caused by any displacement from the frost bulb growth is measured by strain gauges.

SUPPORTING FACILITIES

Other facilities at the site include the equipment building, which contains a refrigeration system that chills the air before it enters the pipe sections, a compressor unit that circulates air through the pipes, a make-up compressor to maintain system pressure, and an instrument room containing data receiving and recording equipment. An emergency generator will provide power to maintain critical energy loads and supply the

Heave measurement rods with survey reflectors at Test Site.



Chilled air circulation equipment at use on shallow burial test.

power for the instrumentation in the event commercial power is lost.

SCHEDULE

Construction of the Fairbanks test facility began in August 1978. Data gathering began in March 1979 and is expected to contiue for approximately three years. Foothills Pipe Lines of Canada acquired, and continues to operate what was formerly the Canadian Arctic Gas Pipe Line Frost Effects Test Site in Northwest Calgary. It was built in 1973-74.

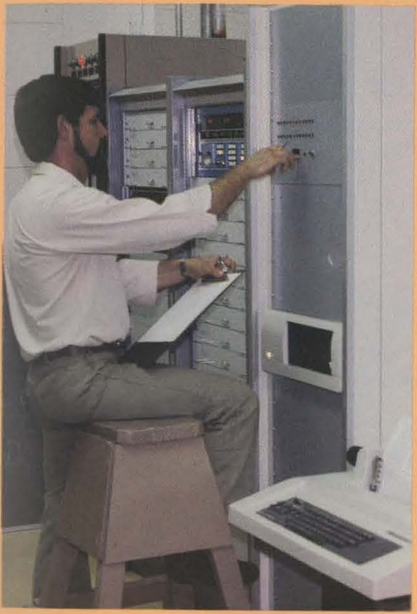
COST

Overall costs for the Fairbanks facility will be borne jointly by Foothills and Northwest.

NEED FOR ALASKAN GAS

The Alaska gas line will help meet United States energy needs for several decades. It is the single largest source of energy that can be brought to American consumers in the shortest period of time. And at a time when the U.S. is striving to become less dependent on foreign suppliers and OPEC prices and more dependent on domestic reserves, the Alaska gas line can provide a domestic energy corridor to bring North Slope proven and future gas reserves to the lower 48 states.

To put Alaska gas in perspective with total U.S. reserves, all proven reserves in the lower 48 today total 200 tcf. Proven reserves on Alaska's North Slope total 26 tcf and potential reserves may reach 50-75 tcf. Some es-



Control system manager checking data collection system.

timates of potential reserves reach as high as 225 tcf. North Slope reserves owned by the largest oil company today, Exxon Corp., represent 50 percent of its domestic oil reserves and 40 percent of its domestic gas supply. Alaska gas could displace almost 700,000 barrels of OPEC oil per day, thereby displacing more than 8 percent of the current daily volume of oil imports with domestic energy.

CONCLUSION

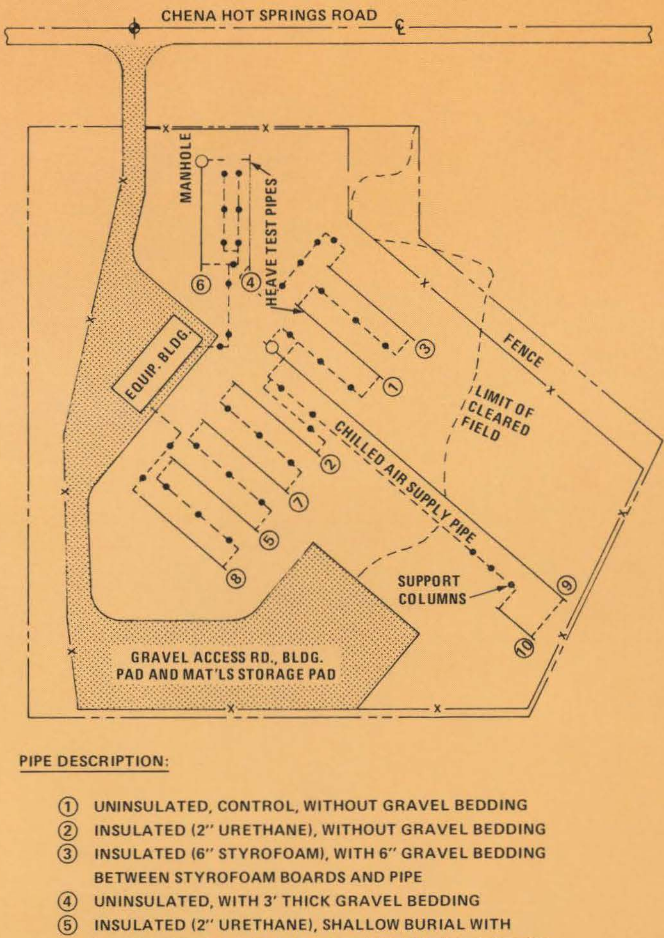
Selection of the Alaska gas pipeline was one of the most thoroughly studied projects in history. Some of the industry's most well respected Arctic environment engineers, who developed new technology for the oil pipeline, are now involved with design of the gas pipeline through Alaska. Northwest Alaskan Pipeline Company will base its final design for the gas line upon development of a method for anticipating the amount of frost heave that may be encountered in various soil types along the pipeline route. The most effective measures for controlling frost heave will be applied. The U.S. and Canadian governments are involved in monitoring the frost heave testing program and must also approve the final design measures.

Northwest is confident that a chilled, buried pipeline for bringing Alaska's much needed gas reserves to markets in the U.S. can be accomplished with appropriate construction quality, cost control, safety and environmental protection. The frost heave testing program is one of literally thousands of research programs that the pipeline owners have done or will carry out on aspects of the construction process.

Refrigeration unit at the Frost Heave Test Site.

Frost Heave technician checking compressor instrument panels.

FAIRBANKS TEST SITE LAYOUT



PIPE DESCRIPTION:

1. UNINSULATED, CONTROL, WITHOUT GRAVEL BEDDING
2. INSULATED (2" URETHANE), WITHOUT GRAVEL BEDDING
3. INSULATED (6" STYROFOAM), WITH 6" GRAVEL BEDDING BETWEEN STYROFOAM BOARDS AND PIPE
4. UNINSULATED, WITH 3' THICK GRAVEL BEDDING
5. INSULATED (2" URETHANE), SHALLOW BURIAL WITH 3' THICK GRAVEL BERM AND WITHOUT GRAVEL BEDDING
6. UNINSULATED, WITH ADJACENT HEAT TUBES, WITHOUT GRAVEL BEDDING
7. INSULATED (2" URETHANE), WITH 1' THICK GRAVEL BEDDING
8. INSULATED (4" URETHANE), WITH 3' THICK GRAVEL BEDDING
9. INTERFACE TEST PIPE
10. SECONDARY FROST HEAVE TEST PIPE

For further information contact:

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P.O. Box 60089 Fairbanks, Alaska 99706 or P.O. Box 1526 Salt Lake City, Utah 84110