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ANALYSIS OF DATA FROM THE CALGARY FROST HEAVE TEST FACILITY

L.E.C. Engineering

Earth Physics Branch Open File Number 84-26
Dossier public de la Direction de la Physique du Globe No. 84-26

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240 pages
Price / Prix $47.00

This document was produced by scanning the original publication.

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ABSTRACT
The report presents a detailed review and analysis of the operational history of the Calgary Frost Heave Test Facility. Included is information on the physical characteristics of the site, the construction and operation of the facility, and data presentation on the temperature and frost heave and frost bulb growth records.

RÉSUMÉ
Ce rapport présente en détail une révision et une analyse du fonctionnement de l'installation d'essai Calgary Frost Heave. Les données sur les caractéristiques physiques de l'emplacement, sur la construction et l'exploitation de l'installation, ainsi que les enregistrements de la température, du soulèvement dû au gel et de la croissance du front de gel y sont compris.

ANALYSIS of DATA

from the

CALGARY FROST HEAVE TEST FACILITY

for

EARTH PHYSICS BRANCH

DEPARTMENT of ENERGY, MINES & RESOURCES

OTTAWA, CANADA

JULY 1984

L.E.C. ENGINEERING LTD.

ANALYSIS of DATA

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CALGARY FROST HEAVE TEST FACILITY

FOREWARD

This report fullfils the requirements of Contract No. ØSQ83-ØØ271, Analysis of Data from the Calgary Frost Heave Test Facility, sub-projects 1 and 2. Sub-progect 1 consists of detailing the Operational History of the Facility, while Sub-project 2 consists of a detailed analysis of the data.

The test facility was constructed in 1974 by Northern Engineering Services Ltd., for Canadian Arctic Gas Study Ltd. It's operation was taken over by Foothills Pipe Lines Ltd. in 1977; EMR became a joint operator of the facility in 1982.

Data results have been published by Slusarchuck et al. (1978) and by Carlson et al. (1982).

Four non-insulated pipe sections were included in the original test facility. One, buried under standard pipelining conditions served as a reference for the behaviour of the other three. A second was buried deeper under the ground surface, in order to observe the reduction in heave due to the increased pressure on the base of the pipe. A third section had the frost susceptable soil removed from under the pipe and replaced with gravel, in order to see the reduction in heave due to this soil replacement. The fourth section had restraining jacks installed, so that the effect of very high pressures, which would simulate very deep burial at river crossings, could be observed.

Two insulated pipe sections were installed in late 1977 by Foothills Pipe Lines, to investigate the benefits of insulating a chilled gas pipeline. The first of these had a geometry very similar to the original Control section, and the second had a geometry similar to the original Gravel section.

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1. INTRODUCTION

1.1 The Pipeline Route

The development of the Prudhoe Bay oil field and the oil pipeline across Alaska stimulated plans to transport the associated gas across land through Alaska and Canada to the lower U.S.A.

In the early 1970's a plan was developed to transport gas from Prudoe Bay east along the Arctic coast to the Mackenzie River Delta, picking up gas from the Canadian gas fields, then heading south down the Mackenzie River valley into Alberta and the lower U.S.A. The proposed Canadian Arctic Gas Pipeline Limited route is presented in Figure 1.1-1.

In the later half of the 1970's, after several years of government hearings, the proposed pipeline project was transferred to a route going south from Prudoe Bay to Fairbanks and then south east, following along the Alaska Highway through the Yukon Territory, and south through B.C. and Alberta to the lower U.S.A. This Foothills Pipeline route is shown in Fig. 1.1-2.

1.2 The Engineering Problems

The northern section of any pipeline from Prudoe Bay must traverse the continuous permafrost zone in its journey south. In order to maintain the physical integrity of the permafrost, the gas line will be operated as a chilled gas pipeline in these northern regions. This keeps the permafrost frozen, but creates a soil freezing problem where the chilled pipeline passes through unfrozen zones.

For fine-grained soils, the freezing may cause volumetric expansion of both in-situ pore water and water migrating to the frost front. This volumetric expansion may lead to "frost heaving" of the pipeline, which in turn may create mechanical failures of the pipeline.

In order to gain further understanding of the interaction of a chilled gas pipeline with frozen fine-grained soil, the pipeline sponsors have established several frost heave test facilities. The first major frost heave test facility was constructed in Calgary in 1974 by Canadian Arctic Gas Study Ltd. Foothills Pipeline and Northwest Alaskan established a second major frost heave facility in 1878 in Fairbanks, Alaska.

The main objectives of these large scale test facilities are:

1. To obtain a better understanding of the frost heave mechanism. (Calgary and Fairbanks).

2. To obtain field results to help develop empirical and theoretical models of the frost heave process (Calgary and Fairbanks).

3. To test the effectiveness of mitigation designs (Calgary and Fairbanks).

4. To provide field data on the structural aspects of the pipe-soil interaction (Fairbanks).

This report presents a detailed review and analysis of the operation and data results from the Calgary Frost Heave Test Facility. Chapter two covers the operational history of the test facility. Information pertaining to the physical characteristics of the site and its construction were taken from the Northern Engineering Services "Interm Report on Frost Effects Study" (Ref. NES). This section also includes historical data on the air duct temperatures and ground and ambient air temperatures. Results of the data analysis are presented in chapter three. This includes the frost heave and frost bulb growth records for both the non-insulated and insulated pipe sections.

2. FIELD TEST FACILITY

2.1 GENERAL DISCUSION of ORIGINAL TEST FACILITY

A full scale frost effects test facility was constructed in the Research park area of the university of Calgary by Canadian Arctic Gas Study Limited in the winter of 1973-74. The facility was constructed to study the behaviour of a four foot diameter pipeline buried in unfrozen frost susceptible soil when operated at below water freezing temperatures.

Four separate sections of pipe, each fourty feet long, were buried under different conditions at the test facility. These conditions were represented by the control, deep burial, restrained and gravel sections. At the control section the pipe was buried in a 6.5 foot deep trench with its top 2.5 feet below nominal ground surface. This represented the "normal" burial situation and was taken to be the base condition with which the other test sections were compared. The pipe at the deep burial section was buried 3 feet deeper, i.e. 5.5 feet below nominal ground surface. The effect of the additional overburden pressure on the rate of heave was studied at this sec-tion. At the restrained section the pipe was buried 2.5 feet below nominal ground surface similar to the control section. The pipe at this section could be restrained, however, by applying a constant load to the top of the pipe (it is important to note that the restraint was a loading restraint and not a "no strain restraint"). The additional loading on the pipe represented deeper burial such as anticipated at river crossings. At the gravel section the pipe was again buried 2.5 feet below nominal ground surface. In addition, the trench was dug three feet deeper and backfilled with gravel so that the pipe rested on a three foot layer of gravel. It was the effect of replacing the frost susceptible soil that was studied at this section. At all sections the excess spoil from the trench was mounded over the pipeline.

The temperature in all sections was maintained at about 10 Deg. F by circulating chilled air through the pipes. The air inside the pipe was at atmospheric pressure. The chilled air began to circulate through the buried pipe sections on March 20, 1974. This date is refered to as "Day 0" in the report.

Temperatures, vertical displacements (heave), and pore water pressures were measured in the ground around the freezing pipe to monitor the performance of the buried pipe sections. Temperatures were also monitored in the air, in local undisturbed ground, in the "In" and "Out" air ducts and on the inside wall of the pipe in the control section to measure the heat flow through it. In addition extensometers were placed inside the pipes in the control and restrained sections to measure the change in the roundness of the pipes.

2.2 DESCRIPTION OF TEST FACILITY

2.2.1 Site Selection

The dominant criteria for the selection of a site for the test facility was that many of the most troublesome conditions likely to be

encountered along the route would be realized at the test site. These conditions may be listed as follows:

(a) The upper soil strata at the site should be of a frost susceptible nature. Clayey silts are traditionally the more frost susceptible soils. These soils possess both the ability to attract water to a freezing front, and also have a high enough permeability to allow the passage of water through the soil to the freezing front.

(b) The presence of a high water table was required to ensure a ready supply of water to the freezing front, along a short drainage path.

(c) A sufficient depth of frost susceptible soil was necessary to ensure that the frost line would stay within the material over the lifetime of the test. Based on preliminaty assessments of the depth and frost penetration, a minimum depth of 20 feet was required.

(d) The site should also have easy access to existing services such as electricity, water and sewer, and to office and laboratory facilities.

Several different sites around the city were considered. A site was selected in the University of Calgary area that met the specifications described above.

2.2.2 Site Description

The site chosen for the test facility was located at the University of Calgary Research Park as shown on Figure 2.2-1. The site was relatively flat, and easy access was available from 33 Street in N.W. Calgary. Electricity, water and sewer connections were also available nearby.

The overburden at the site is comprised of lacustrine sediments deposited in glacial Lake Calgary in late glacial times. These sediments in this area have a thickness of 80 to 90 feet.

A test hole drilled at the site provided undisturbed thin-walled shelby tube samples and disturbed samples for the determination of moisture contents and Atterburg limits. A drilling log is given on Figure 2.2-2. The moisture content varied between 18% and 22%. The plastic limit of the soil varied between 14% and 18%, with a liquid limit of 24% to 31%. Grain size distributions were determined for five samples of soil from different depths (see Figure 2.2-3). The results showed that, in general, the overburden at the site contained 13% sand size, 64% silt size and 23% clay size particles. Based on the grain size and consistency limits, the upper 25 feet of soil at the site was classified as an inorganic clayey silt of low to medium plasticity.

In-situ field permeability tests were carried out, and the Darcy coefficient of permeability was found to lie between 0.6 and 1.0 E-4 cm/sec. Visual inspection of undisturbed shelby tube samples indicated that a number of fissures were present in the soil. Such fissures were likely responsible for the high permeability values obtained in the field tests for a soil of this type.

Although the soil at the site would be termed frost susceptible, based on grain size classification, further confirmation was obtained by carrying out preliminary frost heave tests. Four samples of the Calgary silt were frozen unidimensionally in clear plastic tubes under low temperature gradients in an attempt to model realistically the temperature gradients around the test pipeline segments. Heaving of between 12% and 25% of the depth of soil frozen was observed during the tests. It was concluded that the silt could support ice segregation processes, thereby confirming the suitability of the site for the frost effects test facility.

2.2.3 Water Table

The depth to the free ground water table was monitored in open standpipes, and at the time of reading in August 1973, was found to lie between 7.5 and 8.5 feet below original ground surface. The ground water history of the test site is discussed in section 2.5.

2.2.4 Meteorological Data

Ambient air temperatures were recorded once daily by the site operator. However, as this one temperature is not representative of the daily average value, these measurements were not used in compiling the air temperature history. Instead, the Annual Meteorlogical Summary of the Atmospheric Environment Department for the Calgary Airport have been used. Plots of the mean monthly and normal temperatures are presented in section 2.4.

2.2.5 Test Section Layout

2.2.5.1 Original Test Site

The test facility consisted of four buried sections of 48 inch diameter steel pipe, having a wall thickness of .4 inches. Each section of pipe was 40 feet long and the sections were arranged as shown on Figure 2.2-4. Some surface stripping and site levelling were necessary to prepare the site for installation of the pipe sections. An area extending approximately 30 feet around each proposed pipe section was stripped and levelled to a final elevation of about 3,626 feet. This involved the removal of between one to four feet of soil cover. The soil removed was placed around the test site as shown on Figure 2.2-4.

The trenches for the buried pipeline sections were excavated using a Barber-Greene ditcher. This ditcher excavated a trench 5 feet wide to a maximum depth of 7 1/2 feet. For two of the test sections where excavation to a depth of 9 1/2 feet was required, a Hopto 900A Backhoe was used to complete the trench. The pipe sections were lowered into trenches with a mobile crane. Backfilling was carried out by pushing the native soil into

the trench with a bulldozer. The excess spoil was mounded over the pipe as shown in the ditch profiles of Figure 2.2-5, which provide a schematic comparison between the four different test sections.

The first pipeline section was the Control section. The pipe was placed in a trench 6.5 feet deep so that the top of the pipe was 2.5 feet below nominal ground surface. This configeration is the standard one for a pipeline. The section operated until mid 1977 when it had to be removed due to building construction.

The second section was the Deep burial section. In this case, the trench was excavated 3 feet deeper to 9.5 feet, and the pipe laid at the bottom of the trench. Thus, the top of the pipe was 5.5 feet below nominal ground surface.

The third pipe section was the Gravel section. This section was essentially the same as the control section, except that the trench was excavated 3 feet deeper to 9.5 feet, and backfilled with 3 feet of gravel. The pipe segment was then laid on the gravel and backfilled as before.

The fourth section was the Restrained section. This section was designed to monitor the performance of a pipe which is partially or completely restrained from upward displacement. Two restraint beams were installed at distances of 5 feet from each end of the pipe section. Each beam was in turn anchored to two concrete reaction piles buried in the ground on each side of the pipe. The piles were 25 feet long with a depth of cover of 15 feet. As shown on Figure 2.2-6A the piles were formed with a bell to resist upward motion. Loading of the pipe through the restraint beam was achieved using two hydraulic jacks located on each restraint beam. A more detailed drawing of the pipe restraint assembly is given on Figure 2.2-6B.

2.2.5.2 Foothills Pipeline Additions

Foothills Pipelines purchased the Test Facility from Canadian Arctic Gas Study Limited in 1977. In the winter of 1978, they added two insulated test sections to the site as shown in the site layout of Figure 2.2-7. Both of these new four foot diameter pipes were insulated with a nominal 0.6 inch (16 mm) thick waterproofed polyurethane coating. The insulation thickness, based on Geothermal computer simulations, was chosen to allow significant ground freezing during the winter period and substantial thawback of the frost bulb in the summer period.

For the Insulated silt section, the insulated pipe was placed in a 1 metre (3 foot) deep trench. The geometry of this section is similar to the original control section.

For the Insulated gravel section the insulated pipe was placed in a geometry similar to the original Gravel section. That is, the pipe rests on a 1 metre thick gravel bedding. In this case, though, the ditch was backfilled around the pipe with gravel.

The ditch profiles for these two sections are presented as Figure 2.2-8.

Chilled air flow commenced on February 19, 1979 (day # 0 for the Insulated sections).

2.2.6 Process Equipment

To provide a system for heat removal from the soil surrounding the four buried 40 foot lengths of 48 inch diameter pipe, air at about +10 F and atmospheric pressure was circulated through the pipes by means of a flooded-ammonia type mechanical refrigeration system.

The refrigeration system, housed in a pre-fabricated 20 foot by 28 foot metal building, included a standard reciprocating industrial type ammonia compressor (V-belt driven by a 25 H.P. electric motor),a liquid ammonia receiver, and a multi-row cooling coil (ammonia) mounted in the blower unit.

The blower had a capacity to circulate 24,800 CFM of air through the cooling coils, and therefore about 6200 CFM was circulated through each burial section, at a velocity of 785 feet per minute. The refrigeration system had a capacity of 12.55 tons (150,000 BTU/HR), thus ample capacity was available for cooling the ground.

Galvanized-iron rectangular ductwork was used to connect the buried pipe test sections to the air chilling chamber in the refrigeration unit so that a closed loop system was formed. The ductwork was insulated with a 1.5 inch thick fiberglass insulation which was covered with a 0.016 inch thick aluminum sheeting for weather protection. The ductwork entering and leaving the refrigeration building was equipped with sliding metal panels such that the discharge from the circulating air system could be diverted from the buried pipe sections to the atmosphere. Using this feature, an effective defrost cycle could be carried out in a very short period of time without disturbing the air temperatures in the buried pipe sections.

Each pipe sections had a 28 inch diameter pipe inside the 48 inch diameter pipe as shown on Figure 2.2-9. The air passed through the inner pipe and returned along the annulus between the two pipes. The air then returned to the chilling chamber.

2.3 INSTRUMENTATION AT ORIGINAL TEST SECTIONS

2.3.1 Temperature sensors

One of the important aspects of the frost effects program was the determination of the thermal regime in the soil around the buried chilled sections of the pipeline. In particular, a knowledge of the position of the frost line with time was of paramount importance when assessing the effects of freezing the ground on the behavior of the pipe.

The movement of the frost line (32 Deg. F or 0 Deg. C isotherm) around the buried sections of pipe at the test facility was monitored by installing temperature sensing devices at carefully chosen vertical and horizontal intervals. To monitor temperatures at different positions in the ground

around the pipe, thermistors were selected principally for reasons of economy, reliability and ease of data acquisition. The thermistors chosen were the Atkins PR-99-3 type, which are suited to measuring temperatures in the range of -4 Deg. F to +85 Deg. F with an accuracy of +/-0.5 Deg. F (-20 to +30 with +/- 0.3 Deg. C).

Vertical strings of thermistors were fabricated by cementing thermistor beads in the outside wall of a 2 inch (5 cm.) plastic pipe and running the lead wires up the center of the pipe. The center of the pipe was then filled with zonolite. The plastic pipes were made water tight.

Each pipeline section, initially, had five vertical thermistor strings installed at a cross section running at right angles to the axis of the pipe. (See Figures 2.3-1A to 2.3-4A). An additional pair of deeper thermistor strings were installed at each section in November 1976. Their locations relative to the origional strings are shown in Figures 2.3-1B to 2.3-4B. It was possible, therefore, to delineate the position of the frost line with reasonable resolution for the lifetime of the test. The positioning of the thermistors was the same for the control, restrained and gravel sections, while the deep burial section had a somewhat different thermistor configuration. The cross sections for the original strings are shown on Figure 2.3-5, and for the deep strings on Figure 2.3-6. In addition to the thermistors installed in the vicinity of the buried pipe sections, two additional thermistor strings were placed in areas adjacent to the control and restrained pipe sections. The plan positions of these strings are shown on Figures 2.3-1 and 2.3-4, and the vertical spacing of the thermistors within the string is shown on Figure 2.3-5. These strings were designed to monitor the ground thermal regime outside of the zones which were directly affected thermally by the chilled pipe. A summary of the initial elevations of the thermistor strings is given in Appendix B.

The cables from the thermistor probes were led to the instrument trailer at the test site where they were connected to a switching box. The thermistors were read manually using an Atkins meter, which provided a reading directly in degrees Fahrenheit. The temperatures were recorded manually on a standard form sheet by the operator.

In addition to the thermistor strings installed in the ground five heat flux transducers and five thermistors were installed on the inside surface of the 48 inch diameter pipe of the control section as shown on Figure 2.3-7. These units were installed to measure the heat flow out of the pipe and the temperature of the pipe wall. The heat flux tranducers were obtained from Hy-Cal Engineering, California (Model No. BI-6 and BI-7). They were designed to be read with a Biddle potentiometer used as a millivoltmeter.

2.3.2 Heave Gauges

One of the most important facets of the interaction between a chilled pipeline and the frost susceptible soil upon which it is founded is the vertical displacement which may occur in the soil during freezing. In order to investigate the soil behavior as the freezing front moved outwards from the pipe, several heave gauges were installed at each section of the test pipeline (see Plan View in Figures 2.3-1 to 2.3-4).

Each gauge consisted of a horizontal plate, 3 inch (7.5 cm) in diameter, attached to a vertical steel rod. The rod was encased in a plastic pipe and the annular space between the rod and pipe was filled with grease. The assembly was placed in a borehole to the desired depth, and the hole was backfilled with native material with a 4 inch (10 cm) betonite seal being placed every 5 feet during backfilling to prevent the formation of a preferred drainage path. The movement of the plate was monitored by surveying the top of the vertical rod which protruded from the ground surface. A diagram of a typical heave gauge is shown on Figure 2.3-8.

Approximately 25 of these gauges were installed at each of the four sections (see Figures 2.3-9 to 2.3-12). Nine of these were placed close to the ground surface at various distances from the longitudinal axis of the pipeline sections, in order to establish the surface heave pattern around the pipe. The remainder of the gauges were positioned around and below the pipeline sections to determine the subsurface heave pattern. A summary of the initial elevations of the heave gauges is given in Table A.2.

A deep 40 foot (12 m) bench mark was installed at the test site. With this bench mark and the instruments used for obtaining levels, changes in elevation of the heave gauges were measured with an accuracy of about +/- 0.003 feet (+/- 0.1 cm). The benchmark elevation is 3627.770 feet (1105.744 m) above sea level.

2.3.3 Piezometers

One of the characteristics of frost susceptible soils is their ability, under certain conditions, to attract water towards a freezing front, and thereby facilitate the growth of ice lenses and cause heaving. For water to migrate towards (or away from) a frost front, an excess pore pressure gradient must be set up so that water will flow from a region of high pore pressure to one of low pressure. To obtain quantitative data on water migration within the unfrozen soil, several piezometers were installed at each of the test pipeline sections as shown on Figures 2.3-1 to 2.3-4.

A total of 50 Terra Tec (Model P-1022) pneumatic piezometers were installed at different depths beneath the pipeline segments as shown on Figures 2.3-13 to 2.3-16. This type of piezometer was chosen for reasons of durability and economy. Their accuracy was rated at approximately +/- 0.1 psi (+/-3 in. of water). The piezometers were equipped with a preload, enabling them to monitor pore water pressures in the range -12 psi to +17 psi (-25 feet of water to +35 feet of water). These units were read individually using a Terra Tec control unit (Gauge C-6300).

In view of the high degree of accuracy required when obtaining piezometric measurements, it was decided to calibrate each piezometer tip before placement in the ground. This was performed by applying a known head of water to the piezometer tip and comparing the known water pressure with the reading

obtained for the piezometer on the control unit. By applying pressures of approximately -10, -5, 0, +5, and +10 psi to each piezometer, a calibration curve was drawn for each tip. The value of the preload (the reading from the piezometer under zero pressure) could then be determined and the linearity of each instrument checked. A typical set of calibration curves is shown on Figure 2.3-17. The calibration curves for the piezometers were found to be independent of temperature for the range 70 Deg. F. to 33 Deg. F (21 to 0.5 Deg. C).

Each piezometer tip was saturated with water in the laboratory using a vacuum pump, and stored under water until required in the field. A small porous plate was attached to each tip to prevent water from flowing out of the saturated piezometer during installation.

The piezometers were installed in augered holes 5 inches (13 mm) in diameter. Approximately 9 inches (23 cm) of saturated sand was placed in the hole. A few inches of clear water was maintained over the sand, into which the piezometer was lowered. Sand was then placed around the tip level with the top of each piezometer, as shown on Figure 2.3-18. An 18 inch (46 cm) long bentonite seal was placed above the sand. Tamped sand was then placed over the bentonite in preparation for the next piezometer tip, and the above procedure repeated until the piezometer string was completed. The remainder of the hole was backfilled with tamped native material.

The hydraulic leads from the piezometers were protected inside plastic piping leading to the instrument trailer. During operation, two or three minutes were allowed to pressurize the lines leading from the control unit to the piezometer tip to the ground. The readings were recorded manually on a standard form sheet by the operator.

Two open standpipes were installed at the site to monitor the position of the free ground water table. Their locations are given in Figure 2.2-4

2.3.4 Instrumentation on Pipeline Segments

It was necessary to monitor the performance of the pipe sections themselves under the stresses arising from frost heaving. In order to observe the vertical displacement of each pipe section while freezing was taking place, 3/4 inch (19 mm) diameter vertical steel rods were welded to the pipe at the positions shown on Figure 2.3-19. The rods protruded above the ground surface and the elevations of the tops of the rods could be obtained by conducting an elevation survey at regular intervals. In this manner, the amount of heaving and bending of the pipe was determined.

The number of vertical displacement rods present on the restrained section was increased to five as shown on Figure 2.27, as this pipe segment was anticipated to experience the greatest stresses. A summary of the initial elevations of the pipe movement rods is also included in Appendix B.

In addition to measuring vertical displacements, extensometer gauges were also installed inside the pipe on the control and restrained sections to measure the change in pipe diameter. As shown on Figure 2.27, the control

section had two extensometer gauges. One was placed on the vertical pipe diameter, and the other on the horizontal diameter. Each extensometer measured the change in diameter across that section so that the pair of gauges was capable of providing a measure of the change in "roundness" of the pipe under the external loading. The restrained pipe section had three sets of extensometers installed as shown on Figure 2.27.

Each extensometer consisted of a Houston Scientific Position Transducer (Model 1800-02A) fixed to one side of the pipe. A fine wire was connected from the spring loaded transducer to the opposite side of the pipe. As the diameter of the pipe changed, the wire moved in or out of the transducer which resulted in a change in the voltage signal from the instrument. A more detailed drawing of an extensometer set-up is shown on Figure 2.3-20.

2.3.5 Other Instrumentation

Two types of additional instrumentation were installed at the test facility by Dr. R.O. Van Everdingen of the Department of Environment of Canada. Two specially designed electrical transducer piezometers were installed at the control section. Ceramic cups were used to separate the surrounding soil from the electrical transducers, but still maintaining fluid continuity. The intermediate cavity was filled with a 50% glycol solution. The performance of these electrical transducer piezometers will be compared with that of the pneumatic type used at the facility.

Both of the electrical piezometers were installed in the control section, and are denoted by CP2-V1 and CP3-V2 on Figures 2.3-1 and 2.3-13.

The second type of instrumentation was electrical resistance frost gauges. These instruments consisted of varying lengths of P.V.C. pipe, joined together with galvanized steel couplings. Wires were led from each of the steel couplings to the surface through the center of the plastic pipe. The electrical "AC" resistance between any adjacent pair of couplings was used to determine whether the soil between the couples was frozen (high resistance) or unfrozen (low resistance). These gauges were placed at the control, deep burial and gravel sections, and their plan positions are indicated by CEI, DEI and GEI on Figures 2.3-1, 2.3-2 and 2.3-3 respectively. Dr. Van Everdingen was very pleased with the results obtained over a three year period and he is in the process of data interpretation.

2.4 INSTRUMENTATION OF THE INSULATED SECTIONS

2.4.1 Temperature Sensors

The temperature string layout for the non-insulated sections has two vertical strings placed beside (1 foot away)
the pipe. There is no temperature string directly below the pipe. This geometry is adequate for the non-insulated sections which have relatively large frost bulbs. However, for insulated sections, the frost bulbs were expected to be much smaller and it was deemed imperative to have temperature monitors directly beneath the pipe to monitor the growth and decay of the

small frost bulb below the pipe sections.

A geometry as shown in Figures 2.4-1 & 2.4-2 , which has one string directly below the pipe and two on each side of the pipe was chosen.

The central string was constructed with a greased slip joint so that the pipe section close to the pipe would be able to move, or heave and settle, with the pipe section, while the bottom section would remain fixed in the unfrozen ground.

The design of the temperature monitoring strings and data collection equipment for both this addition to the Calgary Facility and the new Fairbanks Frost Heave Facility was carried out by a local engineering firm. It was decided to use temperature sensitive sensistors for these new sections, instead of thermistor beads, as these devices were claimed to be more accurate and reliable than thermistors. This claim, it turns out, was not upheld by their operation at both test facilities. At the Calgary facility, these sensitor strings, installed in 1978, were used over a two year period and finally retired when the sensistor strings did not provide sufficient temperature reliability to accurately determine the position of the 32 Deg.F. (0 Deg. C.) isotherm. They were replaced with thermistor strings in December 1980.

Three thermistor strings were installed at the insulated silt sections and one at the insulated gravel section. These strings were installed directly beneath the test sections by drilling through pipes into the soil below, as shown in Figure 2.4-3. The thermistor spacing is shown in the x-section drawings of Figure 2.4-4.

2.4.2 Heave Rods

In order to observe the heave and settlement of these two sections, four heave rods,equally spaced along the section (Figure 2.4-5),were installed on each section. The rods were welded to saddles which were in turn banded to the pipe.

2.5 OPERATING PROCEDURES AND HISTORY

2.5.1 Refrigeration System

Under normal operating conditions, little maintenance was necessary by the operator at the test facility. Temperature control of the chilled air passing through the buried test sections was achieved by an automatic control system which sensed the temperature of the air returning to the chiller, and adjusted the rate of refrigeration accordingly.

Initially the operators checked the performance of the refrigeration equipment every two hours. Temperatures of the air at the inlet and outlet of the ducts was also measured and recorded every two hours.

Due to the presence of some water that collected in two of the buried test sections (gravel and deep burial) at the outset of the test,

considerable quantities of water in the form of ice were deposited on the refrigeration coils in the early stages of the test. By using the sliding metal panels in the ductwork described in Section 2.2.5 warm air at ambient temperature was blown across the refrigeration coils, and then discharged to the atmosphere. In this way, the ice on the refrigeration coils was melted, caught in a drip pan and removed. While the defrost cycle was in progress, the sliding metal panels ensured that no air entered or left the buried pipe sections. The defrost procedure lasted approximately one half-hour, and was necessary every 24 hours during the earlier part of the test. In subsequent years, the defrost procedure was required every two to three days in winter and daily in the summer months. Currently, the defrost proceedure takes 1.5 to 2 hours.

2.5.2 Data Collection

The frequency of data collection was greatest when rapid changes were expected. and lowest when the readings changed little with time. The most rapid advance of the frost line occurred in the early stages of the test, so data was collected at shorter time intervals in the initial test period, and the time interval between readings was increased as the test proceeded.

A complete elevation survey of the heave gauges was conducted three times a week during the first month of the test. Each survey usually took two men about 3 hours to complete. The number of surveys was reduced to twice a week after the first month, to weekly after three months and to twice a month since 1978.

Piezometers were read every 2 days during the test period, and were recorded on a standard form sheet by the operator The water levels in the standpipes were also recorded at that time using an electrical resistance water level indicator. After 6 weeks of operation these readings were taken twice a week.

The ground temperature thermistors were recorded twice weekly for the first three months and weekly thereafter. These readings were also recorded on a standard form sheet. Using the temperature data, the position of the 32 Deg. F (Ø Deg. C) isotherm was plotted at regular intervals to locate the position of the frost bulb around the buried test sections. The air duct temperatures for all four sections were recorded hourly (24 per day) for the first two months, reducing to four or five daytime readings in 1975 and down to a single daily reading late in 1976.

The thermistors and heat flux transducers mounted on the control pipe section were read every two hours, as were the extensometer gauges.

Several sets of temperature, heave gauge and piezometer readings were obtained in the three week period prior to start up. This information ensured that good initial conditions at the site were obtained.

2.6 OPERATIONAL HISTORY OF TEST FACILITY

2.6.1 Operational Day Number Calendar

The data records for the test site are tabulated according to the operational day number for the test facility. Day # 0 is March 20, 1974. Appendix C is provided to enable conversion of the operational day numbers into the corresponding calendar day for the original test sections. The insulated pipe test sections started chilling (Day # 0) on 17 February 1979. The conversion table for these two sections is given in Appendix D. For quick reference, the conversion table for the original test sections is presented in graphical form in Figure 2.6-1.

2.6.2 On-off History of Test Facility

Chilled air (about 10 Deg. F, -10 Deg. C) has been circulated through the test sections at atmospheric pressure continuously, except for daily maintenance and the downtime indicated on Figure 2.6-2. The process equipment ran quite smoothly for the first four years, until the summer of 1978. The refrigeration unit compressor was overhauled during a 12 day shut-down in December 1978. However, there were still several compressor outages in the summer of 1979, and subsequent summers.

The 36 day shut-down of the deep burial and insulated sections, at the end of 1980, was necessitated by the installation of thermistor strings to replace the sensitor strings installed with the insulated pipes in late 1978.

2.6.3 Air Duct Temperature Measurements

The temperature of the air going into and coming out of each of the 6 test sections is presented in a series of graphs. As stated in section 2.5.2, these measurements were taken hourly for the first two months. The hourly variation in these temperatures for the Control section is presented in Figure 2.6-3. All 24 readings are used near day 20, dropping down to 4 a day by day 60. It is seen that there is an hourly variation in the order of 4 Deg F The daily average "IN" and "OUT" temperatures are seen in Figure 2.6-4. It is seen that the temperature difference remained at 2 Deg. F throughout this two month period. This temperature difference is shown for the operating life of the Control section in the next figure (Fig. 2.6-5), followed by the "IN" and "OUT" temperature histories (Figures 2.6-6 & 2.6-7).

Similar triads of graphs are presented for the other five sections in Figures 2.6-8 to 2.6-19. These graphs are split into two time groupings: the first (A) covers the 1974-1979 period, and the second (B) the 1980-1984 time period.

Further discussion of the air duct temperatures will be with respect to the restrained section (Figures 2.6-14 to 2.6-16). Looking at the "IN" graph (Figure 2.6-15A) the two peaks in the Day 1600 region reflect compressor outages in the summer of 1978, one for four days as shown on the Operational

Record (Figure 2.6-2). The group of peaks in the 60-70 Deg. F range reflect the series of outages in the summer of 1979. Figure 2.6-15B covering the 1980-1984 time period shows the increases in the average air winter duct temperatures from the 10 Deg. F range to the 30 Deg. F range in summer. This trend also shows up for the other sections. It will be discussed later in section 2.7.

Another anomaly in the "DIFFERENCE" graph (Figure 2.6-14B) for the Restrained section is the abrupt jump in the difference from the 3 Deg. F to the 10 Deg. F range. This jump occurred following a nine day shut-down in April 1982. The following three months had high rainfalls. The effects of excessive rainfall and a high watertable in 1981 are duscussed further in section 2.7.

2.6.4 Ground Water Level Observations

Two standpipes, the Control and South, were installed in the test facility in 1974. Their positions are shown on the site layout (Figure 2.2-4). The Control standpipe was removed in late 1977 when this test section was removed.

A third standpipe, the North one, was subsequently installed just east of the deep burial section (Figure 2.2-7). Water level readings commenced on January 8, 1981.

Figure 2.6-20 shows the depth of the water table below ground level at the Control and North standpipes, and Figure 2.6-21 that for the South standpipe.

It is seen that the water table rose to the ground surface, at the North standpipe, in the summer of 1981. This excessively high ground water table level led to operational problems through water leaking into the air duct inlets, partially filling up the buried test pipe sections and impeding chilled air flow. These problems are discussed further in section 2.7.

2.6.5 Ground Temperatures Away from the Pipe

Two graphs are presented (Figures 2.6-22 & 2.6-23) which show the ground temperature time history at the 0.5 and 10 foot depth level for temperature strings CT6 and RT6 respectively. The thermistor at 0.5 feet is strongly influenced by the average ambient air temperature, having a range of temperature between 20 and 80 Deg. F.

The cyclic temperature range at the 10 foot depth is much smaller (between 35 and 50 Deg. F) as expected.

An increase in the average ground temperature at the 10 foot depth of 3 to 5 Deg. F is apparent at both locations. This trend, however, is not apparent in the ten foot depth ground temperature at the University of Calgary (Figure 2.6-24), which is just a few blocks away from this test facility.

2.6.6 Ground Temperatures Beside the Pipe

A series of graphs are presented (Figure 2.6-25 to 2.6-28) showing the ground temperature beside the original four test sections. The annual summer warmup of the soil at this location, which is one foot away from the pipe, is quite prominent for the Control, Gravel, and Restrained sections, and still observable for the Deep Burial section. At the Gravel section this thermistor bead temperature rose above 32 Deg. F (Ø Deg. C) during the summer of 1981. The Restrained section (temperature bead RT3-4) also showed a temperature close to 32 Deg. F (Ø Deg. C) this same summer. The next year (1982), bead RT3-4 increased in temperature to about 31.7 Deg. F (-Ø.2 Deg. C) again, but this time the temperature remained in this range for about 1.5 years. This effect is symptomatic of the ice blockage of air flow for this test section. Its timing is close to that of the anamoly in the Restrained Section Duct Temperature Difference graph (Figure 2.6-14B), which was discussed in section 2.6.3

The ground temperature at the bottom of the insulated silt section (bead 2) is presented in Figure 2.6-29, along with the temperature 1 foot (Ø.3 m) lower down (bead 4). It is seen that the pipe and ground temperatures rose well above freezing in the summer 1981. It is also seen that in the summer of both 1982 and 1983, the ground temperature approached close to the thawing temperature.

Figure 2.6-3Ø shows the temperature time history of these beads for the Insulated Gravel section.

2.6.7 Meteorological Data

The ambient air temperature at the Calgary Airport , over the time duration for the test site, is shown in Figure 2.6-3Ø. This plot shows the maximum, average and minimum mean monthly temperatures. A comparison of the average temperature to the ten-year normal temperatures is presented in Figure 2.6-31.

2.7 DISCUSSION of OPERATIONAL PROBLEMS

2.7.1 Temperature Data Collection

Several problems have occurred in this very fundamental phase of the test operation. These problems fall into four basic categories: first is the complete loss of all bead resistance readings for a given temperature string; second is the loss of one (or a few) temperature bead reading(s) on a string; third is a sudden jump in one bead's resistance readings which persists for a considerable time period. The resistance readings may finally jump back to the "original" trend line. The fourth category is a slow drifting of one bead's resistance readings away from the trend line (as defined by the adjacent beads).

Now, the first two types of problems are irritating in that they result

in the loss of further data if the beads cannot be replaced. These problems do not lead to extensive data analysis problems in that there are no data readings to analyse. The third and fourth types of problems, however, do pose a problem of data interpretation, if the variations from the trend line are not distinct. Examples of these four types of problems are discussed below.

Loss of a complete string of readings (type 1 failure) occurred at the Deep Burial section. String DT3 ceased to give reading at about day 2000 (as seen in Figure 3.3-12). An individual bead failure (type 2) is illustrated in Figure 2.6-10 for the Deep Burial outlet air duct, over the time period from day 1,300 to 2,100 and again at days 2,600 to 2,800. Examples of bead failure on the buried strings are seen in Figure 3.3-2 where there are no readings for bead CT1-12, and in Figure 3.3-3 where bead CT3-13 ceased to function about day 900.

An example of the type 3, or sudden jump, failure is seen for bead CT1-13 in Figure 3.3-2. At about day 436 the bead temperature suddenly jumped about 3 Deg. F. After a period of 427 days the temperature jumped back down by about 3 Deg. F, close to a trend line derived from bead CT1-11.

An example where several beads (in fact, all the beads in the string) increased in temperature reading is seen for string DT7 in Figure 3.3-14.

There are other examples which can be placed into this third category. However, in these cases the thermistor bead temperature time histories show prominent discontinuities as the bead temperature passes through the freezing temperature of water. Examples of this behaviour are beads DT1-15 (Figure 3.3-11), DT3-14 (Figure 3.3-12), GT3-12 (Figure 3.3-21), and RT1-13 (Figure 3.3-29). As the ground temperature decreases towards the freezing temperature, the bead temperature readings seem to remain above 32 Deg. F (0 Deg. C) sometimes rising several degrees above the freezing point. Once the soil temperature arround the bead drops below freezing, i.e. the bulk of the soil moisture has frozen, the bead temperature reading jumps down to or slightly below 32 Deg. F (0 Deg. C). Later on, when the frost bulb was shrinking back and these same beads warmed up to the melting temperature, the bead temperature readings jumped up sharply several degrees.

These bead readings (using the Atkins meter) are reported to be very stable when their temperature is below freezing, but unstable when their temperature reading is at or slightly above the freezing point.

Examples of drifting temperatures (type 4 failures) are seen for bead DT6-3 in Figure 3.3-22 and RT3-10 in Figure 3.3-30.

2.7.2 Cooling Duct Air Temperature Control

The test facility refrigeration and air circulation ductwork system functioned very well for the first several years as seen on the "Gravel Section-Duct Average Temperature" plot of Figure 2.6-12A. By the summer of 1979, however, the air cooling system was unable to maintain the required chilled air conditions, as illustrated by the high temperature spikes (up to 70 Deg. F.) seen in Figure 2.6-12A in the summer of 1979, and also by the compressor outages shown in the facility "Operational Record" of Figure 2.6-2. Even after being repaired, the compressor system still had problems in maintaining the duct air temperature at about 10 Deg. F. This is seen in Figure 2.6-12B which shows that the duct inlet temperatures, for the Gravel Section, still exceed 32 Deg. F in the summers. This failure of the cooling system to cope with the warm ambient summer air is also seen in the plots for the Deep Burial, Restrained, and Insulated Sections Duct inlet temperatures (Figures 2.6-10B, 2.6-15B and 2.6-18).

2.7.3 Ice Blockage of the Chilled Air Flow

Reference has been made in section 2.5.4 to the effects caused by water leaking into the various pipe sections through cracks in the air duct system.

The occurrence of ice blockage of chilled air flow was first observed in the insulated silt pipe section, when this section was opened up in order to install the new thermistor bead strings in December, 1980. The two insulated sections were "de-iced" and chilling was recommenced. A visual inspection inside the insulated pipe sections later in the spring of 1981 found more ice in the pipe, due to water leakage through the joint where the duct joins onto the end of the steel pipe. The relative movement of the pipe and ducting had created this water leak. The joint was caulked in May 1981. Unfortunately, this measure to waterproof the joint was not successful; following a long period of heavy rain in July 1981, the water table again rose to the bottom of the air duct and the pipe was partially filled with water. These sections were closed down, the ice removed in late July 1981, and the joint re-caulked. This second effort, however, did not end the icing problems. Again, In October, 1981, the insulated sections had to be de-iced. A better caulking compound called "Thioplast" was used to re-caulk the joints in April 1982, and these sections remained dry during the summer of 1983.

The plots of the air duct "Out-In" temperature for both the Deep Burial and Restrained sections, show quite sudden jumps in 1982, to the 10 to 15 Deg. F range. These jumps may be indicators of the massive water seepage and subsequent blockage of duct air flow. Both of these sections showed a rapid decrease in their heave (settlement) shortly after the jumps in the air duct difference temperature occurred.

The Deep Burial section was de-iced in March 1983 and the Restrained section in April, 1983.

Visual inspection inside the Gravel section showed that this section has remained dry.

As of May, 1984, all sections were functioning properly.

2.8 Site Shutdown

Experiments which might be undertaken during the shutdown of the test facility fall into two general time frames, late winter and summer.

2.8.1 Late Winter Projects

Trenches could be dug, using backhoes, at the three non-insulated test sections and possibly also at the insulated ones. The distribution of ice lenses around the pipe and to the base and edges of the frost bulb can then be mapped. This inspection will locate a final ice lens at the freezing front or adjacent to the pipe. The ice mapping is very difficult to carry out in the summer as the warw air tends to melt the surface ice lenses and produce a mud mask over the frost bulb face being mapped.

It may prove informative to reduce the temperature gradient within the frost bulb and look for ice redistribution and ground heave. If this is carried out in the summer it would probably just result in a general thawback of the frost bulb.

2.8.2 Summer Projects

Core samples could be obtained if trenching was not undertaken.

Having stopped the circulation of chilled air, the settlement of the pipe and ground plates could be observed as the warming summer ground temperature thaws back the frost bulb.

A variation of the above thawing proceedure is to thaw the frost bulb from the inside out by circulating warm air through the section ductwork. This could be done to just one section, while the others undergo different proceedures.

3. DATA ANALYSIS

3.1 Heave of Thermistor Strings

Data was recorded during 1976 of the elevation of the temperature strings for the Gravel and Restrained test sections. This data enables a comparison to be made of the heave elevation change relative to the "as installed" value of the pipe and the thermistor strings. These elevation readings were continued through 1977 and 1978 for the Gravel section. The placement of the eight foot high berm on the Restrained section in December of 1976 precluded continuing thermistor string elevation measurements at this section.

The placement of the thermistor strings relative to the pipe section is shown in Figure 2.3-3A.

The heave of the Gravel section strings GT1 and GT3 is shown in Figure 3.1-1, for this three year period (day 170 to 1800). It is seen that the temperature strings and pipe have heaved and settled in unison. This unison of motion is illustrated in Figure 3.1-2, which presents the ratios of the two temperature string (GT1 and GT3) elevation changes to that of the pipe. It is seen that these ratios remain fixed to within +/- 2% over this three year observation period. The ratio of the restrained section thermistor strings (RT1 and RT3) elevation change relative to that of that pipe over the 1976 observation period (day 600 to 1000) is shown in Figure 3.1-3. The variation of this ratio is within 1% of the mean value.

These measurements show that these temperature strings are locked within the frost bulb along with the pipe sections and that the pipe and thermistor strings move together as the base of the frost bulb heaves and settles. Although similar measurements were not obtained for the Control and Deep burial sections, due to the mid-1975 burm placement at these sections, it is resolved that these temperature strings (CT1, CT3, DT1 and DT3) are also locked into the frost bulbs.

It is concluded that the relative geometry of these thermistor beads and pipe sections remained very close the to the "as installed" values presented earlier in Figures 2.3-5 and Table 2.

The deep thermistor strings GT6 and GT7 which are discussed in the next section were installed in late 1976 just outside strings GT1 and GT3, respectively. They are well within the frost bulb. The heave of these temperature strings and the pipe is shown in Figure 3.1-4. These three curves appear to follow each other quite closely as the pipe moves up and down. The heave ratios for strings GT7 and GT8 relative to the pipe is shown in Figure 3.1-5. The heave ratio for GT7 starts off at 1.09 and decreases over its first thaw season to a ratio of 1.04, a 5% change. This ratio remained constant within 1% for the next year. The heave ratio for GT8 is constant within 1.5% over the full period of observation.

It is concluded that strings GT7 and GT8, like strings GT1 and GT3, remain locked within the frost bulb. That is, the relative elevations of the pipe and the thermistor beads of these strings remains fixed at the values presented in Table 2 (the pipe elevation when the deep strings

were installed is the initial elevation plus the pipe heave of Dec. 3, 1976).

What about the strings further away from the pipe? The heave of strings GT4 and GT5 is shown in Figure 3.1-6. Again the GT4 heave curve follows that for the pipe very closely. In fact, the curve for GT4 has been artificially lowered to separate it from the pipe curve, for display purposes in this figure. The actual heave ratio is seen in Figure 3.1-7. The ratio for GT4 goes from 0.97 to 1.00. The temperature string, therefore, is also locked within the frost bulb.

The heave ratio for GT5, however, on day 688 (Figure 3.1-7) is only 0.62; the actual difference in heave of GT5 and the average pipe heave is 12 cm. Now the frost bulb width did not engulf string GT5 until the winter of 1975. The pipe heave on Jan 1, 1975 was 13 cm.

3.2 The Deep Thermistor Strings

In November 1976, Northern Engineering Services installed new deep thermistor strings at the Calgary Frost Heave Test Facility. The original instrumentation layout for the site was based on a two year operational period. By mid-1976 the frost bulbs at the four test sections were close to or deeper than the bottom thermistor beads of strings #1 and #3 and it proved desirable to install deeper thermistors near and below the base of the frost bulbs to better track the movement of the frost front. Two thermistor strings were installed at each of the four test sections. The locations of these new strings are shown on the plan views of Figures 2.3-1B through 2.3-4B, relative to the original plane of thermistor strings. These two strings straddled the pipe in a similar fashion to strings #1 and #3. The installed elevations of these new deep strings, as taken from Northern Engineering Services (NES) files are given in Appendix B. Their positions are also shown in the instrumentation cross-sections of Figure 2.3-6 . It is important to note that these Figures show the "as installed" elevations of the pipe and thermistor strings. By the installation time of these deep strings in Nevember 1976, the pipe sections and original thermistor strings had heaved (risen in elevation) by one to two feet, as indicated in Table 3.1.

A more detailed discussion of data obtained from the deep strings and how it suppliments the temperature data from the original thermistor strings, is presented in Appendix A.

3.3 Data Results for the Non-Insulated Sections

The data results are presented on a section by section basis. The data presentation for each test section starts out with the frost heave history of the test section, followed by the temperature time history of selected thermistor beads. It then follows on with the time history plots of the depth of the frost front (32 Deg. F or 0 Deg. C isotherm), the frost bulb cross-section development and the temperature gradients within the frost bulb. This presentation concludes with plots of the heave and corresponding frost penetration (H vs. X plots).

3.3.1 Control Section

The frost heave of the Control section is presented in Figure 3.3-1. This section operated from startup in March 1974 until September 1977. An average pipe heave of about 65 cm (2 ft) occurred during this period.

Time history plots are presented in Figures 3.3-2 to 3.3-5 for temperature strings CT1, CT3, CT7 and CT8 respectively. The string CT1 plot (Figure 3.3-2) shows beads #11 and #13. Bead # 12 has never functioned. The Bead #13 data readings suddenly increased by about 2 Deg. F on day 436, the period when the burm was being enlarged. However, none of the other beads of this string showed this behavior, which is an example of a thermistor bead which is sensitive to the freezing of the ground water (a type 3 failure). The bead #13 readings remained high until day 863.

The time history for beads #12 and #13 of string CT3 are shown in Figure 3.3-3. The bead #12 temperature passes the 32 Deg. F (0 Deg. C) value about day 1035 (Jan. 19, 1977).

The temperature histories of the top beads of strings CT8 and CT9 are shown next. Figure 3.3-4 shows that beads CT8 #1 and #2 follow each other very closely, as expected. Bead #1 & #2's average temperature was about 32.5 Deg. F (0.4 Deg. C), that is, this string was just outside or below the frost bulb.

It is seen in Figure 3.3-5 that bead CT9 #1's temperature was about 32 Deg. F (0 Deg. C) and therefore this bead, was just at the edge of the frost bulb. The increasing temperatures near day 1200 reflect the operation of the deep heaters during this time period.

Time histories of the depth of the 32 Deg. F (0 Deg. C) isotherm below pipe level, at temperature strings CT1 and CT3 are presented next (Figure 3.3-6). Previously in section 3.1, it was shown that these temperature strings heave with the pipe. These depths represent the location of this isotherm at the location of the thermistor string, minus the burial depth of the base of the pipe. These depths also define the local base of the frost bulb.

Cross-section plots, showing the growth of the frost bulb are seen in Figure 3.3-7.

It is interesting, in studying the frost heave mechanism, to plot the data in the form of heave (H) versus frost front distance (X) as pointed out in Carlson et al (1982). A plot of H versus X for the Control section data (taken from this reference) is presented in Figure 3.3-8. A discussion of these results is presented in this reference.

Lastly, for this section, the time history of the temperature gradients at the base of the frost bulb is presented in Figure 3.3-9. The data points are the temperature gradient values of temperature strings CT1 and CT3.

3.3.2 Deep Burial Section

The frost heave time history for the Deep Burial section is seen in Figure 3.3-10. The heave increased to about 67 cm (2 ft) by day 2400 (Oct. 1980) and then decreased through 1981, 1982 and 1983. This decline in the section heave is quite probably a result of ice blockages of the chilled air flow during the spring and summer of 1981 and 1982. The positive peaks in Figure 2.6-8, the air duct "Out - In" difference plot, in the day 2900 to 3300 region (1982 & 1983), could be signals of this buildup of the ice. This data was not obtained during the summer of 1981, due to thermistor bead failures. Since the ice was melted out of this section in March 1983 and the ductwork waterproofed, the frost bulb has again started to grow and the pipe to heave, as seen by the increasing heave for 1984 in this Figure.

Temperature-time history plots for strings DT1 and DT3 are presented in Figures 3.3-11 and 3.3-12 respectively, for the lower beads on these strings. Temperature string DT3 ceased to function in the summer of 1979 (Day 2000). An abrupt increase in the frost bulb temperatures near day 2700 (Aug.-Sept. 1981) is very prominent in the DT1 string plot. (Figure 3.3-11). A smaller but still distinct temperature increase is apparent near day 2300 (Jul. 1980).

Temperature-time history plots for strings DT6 (Figure 3.3-13) and DT7 (Figure 3.3-14) show that the top two temperature beads of both of the strings are inside the frost bulb up to February 1983 (day 3250) for string DT7 and Apr. 1983 (day 3300 for string DT6.

The depth of the frost front below the base of the pipe, at the temperature strings DT1 and DT3, is presented in Figure 3.3-15. In a pattern similar to the pipe heave of Figure 3.3-15, the frost front depth increased to about 10 feet (3 m) by 1980, followed by a thawback of about 3 feet (1 m) during the 1981 to 1983 period. However, the frost front depth is now on the increase, as seen in this Figure for 1984.

The growth of the frost bulb is shown in Figure 3.3-16 and a plot of the heave versus frost front penetration (H versus X) is seen in Figure 3.3-17.

Finally, the temperature gradient time history for strings DT1 and DT3 is presented as Figure 3.3-18.

3.3.3 Gravel section

The frost heave time history for the Gravel section is seen in Figure 3.3-19. The average heave of this section peaked at 45 cm (18 in) about day 2000 (Jan. 1980). A distinct decline in the heave is apparent about day 2700 (Jan. 1982). An annual cycle of heave and subsequent settlement is very prominent in this data since 1977.

Temperature-time history plots are presented for the lower beads of string GT1 (Figure 3.3-20) and GT3 (Figure 3.3-21). Annual summer-winter cyclic temperature variations are evident in the curves for GT1-11 and GT3-11. This seasonal cyclic trend appears to be damped out at the lower beads GT1-13 and GT3-12, which are in the outer edge (frozen fringe) of the frost

bulb. Similar temperature-time history plots for the top beads of string GT6 and GT7 are seen in Figures 3.3-22 and 3.3-23 respectively. These latter two strings are outside the frost bulb.

The depth of the frost front, below the base of the pipe, at temperature strings GT1 and GT3, is shown in Figure 3.3-24.
This depth peaked at about 8.6 feet (2.6 m).

The growth of the frost bulb is shown in Figure 3.3-25 and a plot of the heave versus frost front penetration (H versus X) is seen in Figure 3.3-26.

This section ends with a plot of the time history of the temperature gradients of the frost front at strings GT1 and GT3.
(Figure 3.3--27

3.3.4 Restrained Section

The frost heave time history for the Restrained section is seen in Figure 3.3-28. The heave increased steadily, peaking at 42 cm for RM1 by day 2700 (Aug 1981) and then rapidly collapsed by 25%. About day 3000 (May 1982), the heave collapsed totally down to only 8 cm by day 3456 (Sep 1983). However, as seen for 1984, the pipe heave is again on the increase.

The temperature string RT1 and RT3 plots (Figures 3.3-29 and 3.3-30 respectively) show three major ground temperature increases. The first, and smallest, occurred over a twenty day period around day 2440 (Nov 1980); the second occurred over a longer period of about 150 days, peaking at day 2739 (Sep 1981); the final increase started about day 2960 and has persisted to day 3500 (Oct 1983). During this period, the frost bulb temperature profile became almost isothermal (31.2 to 31.8 Deg. F / -0.4 to -0.1 Deg. C), as shown in the temperature profile plots presented in Appendix A. Since then, the frost bulb has been cooling off during 1984, as shown by bead RT1-11.

Ground temperature time history plots of strings RT7 and RT8 are presented in Figures 3.3-31 and 3.3-32, respectively. These temperatures also show an increasing trend after day 3000.

A time history of the depth of the frost front, below the base of the pipe at temperature strings RT1 and RT3, is shown in Figure 3.3-33. The frost front depth at the location of strings RT1 and RT3 was about 10 feet (3 m) in 1980.

The frost bulb growth is pictured in Figure 3.3-34 and a plot of the heave versus frost front penetration distance (H versus X) is seen in Figure 3.3-35. This section ends with a plot of the time history of the temperature gradients of the frost front at strings RT1 and RT3, in Figure 3.3-36.

3.4 Comparison of Heave at the Non-Insulated Sections

The average pipe heave for the four original sections is shown in Figure 3.4-1. The effectiveness of the three mitigative measures studied at the test site is seen in this figure, through the reduced heave of the Deep

Burial, Gravel and Restrained sections relative to the Control section. At day 440, just before the additional berms were placed on the Control and Deep Burial sections, the relative pipe heave was 69%, 47% and 42% for the Deep Burial, Gravel and Restrained sections, respectively. By day 1244, just before the Control section was shut down, these ratios were 84%, 60% and 40% for the Deep Burial, Gravel and Restrained sections, respectively. The additional pressure on the frost front at the Deep Burial and Restrained sections has reduced, but not prevented, the frost heave. Also, it is seen that the placement of 1 metre (3 ft) of gravel beneath the pipe has reduced the heave by 40% to 50%.

The pipe at the Deep Burial, Gravel and Restrained sections had heaved 0.69, 0.43 and 0.39 metres (2.3, 1.4, and 1.3 ft), respectively, by late 1980. During 1981 through 1983 the pipe heave declined for all three of these sections. The recent data for the winter of 1983-84 shows that the pipe heave at these sections is once more on the increase.

The Gravel section heave has shown quite prominent annual (winter-summer) oscillations since 1977. Although, the annual cyclic heave fluctuation is assumed to be caused by the effect of summer temperatures warming the soil at depth and thawing back the frost bulb, the accuracy of the temperature determinations is not sufficient to determine minor changes in the depth of the frost line, and thereby correlate heave fluctuations with the advance and retreat of the frost bulb.

The next two Figures #3.4-2 and #3.4-3, present the slope of the pipe frost heave, i.e. the heave rate. The initial heave rate for the control section (Figure 3.4-2) of about 5 cm./month is twice as high as that for the three mitigated test sections. The winter-summer cycle shows up clearly for the Gravel section after day 1000.

The prominent negative spikes near day 440 for the Control and Deep Burial sections represent the placement of the additional burms in May and June of 1975. A similar, though less prominent, negative spike is seen near day 1000 for the Restrained section. It represents the placement of the additional burm at this section in December 1976.

3.5 Data Results for the Insulated Sections

Chilled air operation of the insulated pipe sections commenced in Feb 1979. Ground temperatures around and directly beneath the insulated pipe sections were monitored using "sensitor strings" as shown in Figures 2.4-land 2.4-2. However, by the end of 1980, the sensitor strings were not providing sufficient temperature reliability to accurately determine the position of the 32 Deg. F (0 Deg C) isotherm and four thermistor strings were installed in Jan 1981. Thermistor readings began on Jan 20, 1981 (day 703 for these sections and 2498 for the test site) for the three insulated silt strings (IS1, IS2, and IS3) and on May 8, 1981 (Day 811 for this section) for the insulated gravel string IG1.

The heave and sensitor based frost penetration depth time histories are presented in Figure 3.5-1, which is taken from Carlson et al (1982). Pronounced annual fluctuations in both the heave and frost front depths

occurred at both of these insulated sections. The maximum seasonal heave at the Insulated Silt and Insulated Gravel sections was approximately 100 mm (4.0 inches) and 35 mm (1.4 inches), respectively. At both sections, the warm summer ground thawed back the frost bulbs, negating the heave accumulated during the winter. The overall negative heave (settlement) experienced at the Insulated Gravel section is likely due to settlement and consolidation of the underlying three feet (1 m) of gravel, when the frost bulb thawed out. The vertical bars on Figure 3.3-37 represent the possible depth range of the frost front.

The average heave of the Insulated silt section is seen in Fig. 3.5-2 for entire operating period of this section. The frost bulb depth below the pipe, for the Insulated Silt section is seen in Fig. 3.5-3, for temperature strings IS1, IS2 and IS3. The IS2 frost bulb depths for 1981, 1982 and 1983 of from 2 to 3 feet (0.6 to 1 metre) are consistent with the 1979 and 1980 sensitor values. The temperature gradients from thermistor string IS2 are presented in Figure 3.5-4. It's annual cycle is quite pronounced, with the temperature gradient dropping close to zero as the frost bulb thaws back in the late summer.

The average heave of the Insulated Gravel section is seen in Figure 3.5-5. The strong consolidation effect of 1979 and 1980 continued through to 1983. The frost bulb depth below the pipe, for the Insulated Gravel section is seen in Figure 3.5-6.

It is seen from these figures, that the general trends seen in the 1979 and 1980 data, carry on through the observation period to 1983.

3.6 Differential Heave Along the Pipe

Pipe differential heave along each non-insulated section is plotted in Figures 3.6-1 to 3.6-4. The pipe differential heave values are defined as the difference between the individual heave rod elevation changes and the average change of all the heave rods. It is immediately evident that the amount of heave varies along the pipe. A continuously increasing differential heave or tilting occured at the Control and Gravel Sections. At the Control section, the heave difference between rods CM1 and CM3 increased to 12 cm (5 in) by day 440, when the additional burm was constructed. Subsequently, this section showed very little differential heave. The Gravel section heave difference has increased, more or less continuously over its entire lifespan, to it's current value of about 12 cm (5 in). The Deep Burial section has undergone a relatively small heave difference of only 3 cm (1 in). As seen in Figure 3.6-2, the heave difference for this section did not increase continuously as it did for the Control and Gravel sections, but it has tended to osillate between its maximum value and zero. Figure 3.6-4 shows that the Restrained section has undergone severe bending. The heave difference between rods RM1 and RM3 is only about 2 cm (0.8 in), whereas the heave difference between rods RM3 and RM5 is about 8 cm (3.1 in),at day 2500.

Tilting or differential heave along a pipe section may be due to:

1. Variation of ice segregation and thus frost heave longitudinally along the pipe section, even though the soil properties and pipe temperature are

considered to be generally uniform.

2. End restraint due to duct connections or other restraint at the end of the pipe.

3. End effect of thermal regime due to temperature boundary conditions at the pipe-duct connections.

The pipe differential heave of the Insulated Silt pipe section is presented in Figure 3.6-5. The majority of the heave difference movement occurs during the time periods when the pipe is settling, as a result of the annual thaw back of the frost bulb, rather than as a result of differential heave along the pipe. The dramatic drop off in the heave difference, during the late summer of 1981, corresponds to the complete thawback of the frost bulb and consolidation of the soil under the pipe (see Figure 3.5-2).

The pipe differential heave of the Insulated Gravel pipe section is presented in Figure 3.6-6. Again, the majority of the heave difference movement occurs during the time periods when the pipe is settling, as a result of the annual thaw back of the frost bulb, rather than as a result of differential heave along the pipe. In fact, for this section the fall and winter heave has tended to straightened out the pipe, thus reducing the heave difference.

3.7 Heave in Frozen Soils

Heave gauges were installed at each of the original test sections to monitor the heave of the soil in the vicinity of the chilled pipes. Figures 3.7-1 and 3.7-2 show the heave of several ground plates at the Control, Deep Burial, Gravel and Restrained Sections. The ground plate heave is seen to follow the trend of the pipe heave quite closely, for all sections.

The ground plate seperation histories, between three plates at each of the non-insulated sections, are presented in Figures 3.7-5 to 3.7-8. Once the frost heave passes the upper gauge, the soil element between the gauge pair starts to heave, which is illustrated by the sloping line in the initial portion of the plate seperation curve. As the frost line advances and the frost bulb engulfs the lower heave gauge, the relative heave of both gauges remains relatively constant, as shown by the levelling off of the curve. Between mid 1975 and mid 1982, only small changes in the relative heaves of the gauge pairs has occurred; thus the distance between the gauge pairs has remained approximately constant for more than 7 years.

Gauge pairs buried deeper beneath the pipe exhibit greater relative heave than those closer to the pipe. This occures because the frost front advances slower at depth, thus allowing a greater amount of heave and therefore plate separation to occur.

4. CONCLUSIONS

Operation of the Calgary Test Site for more than 10 years has provided data on frost bulb growth and pipe heave. Data presented in this report illustrates that:

1. Frost depths at the non-insulated pipe sections remained relatively constant from 1977 to 1981, then thawed back 2 to 3 feet (0.6 to 1 m) during 1982 and 1983.

2. The initial heave rate of the Control section was about twice that of the other non-insulated sections.

3. The average heave rate of the non-insulated sections continued to decrease over the years to 1981, when the ice blockage problems led to the prominent negative spikes in the heave rate for all of these sections.

4. Seasonal fluctuations in pipe heave and heave rate are observed at the Gravel, Insulated Silt and Insulated Gravel sections.

5. Pronounced seasonal fluctuations occured in the frost depth for both insulated sections.

6. The magnitude of frost heave varies along each pipe test section, i.e. there has been some differential heave.

7. Heave occurs predominently near the frost front rather than within the frost bulb. This is demonstrated by the relatively constant ground plate separation, which follows the initial seperation of the heave plates installed adjacent to the uninsulated pipe sections.

5. ACKNOWLEDGEMENTS

The cooperation and assistance of Dr. T. Ersoy and Mr. J. Woolmer of Foothills Pipe Lines Ltd. is greatefully acknowledged. They made available both current data from the test site, and the archived site records obtained by Foothills Pipe Lines from Northern Engineering Ltd.

The University of Calgaary ground temperature records were supplied courtisy of Mr. T. Rhodes, of the departement of Geography.

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PROFESSIONAL ENGINEER ALBERTA
Lorne E. Carlson

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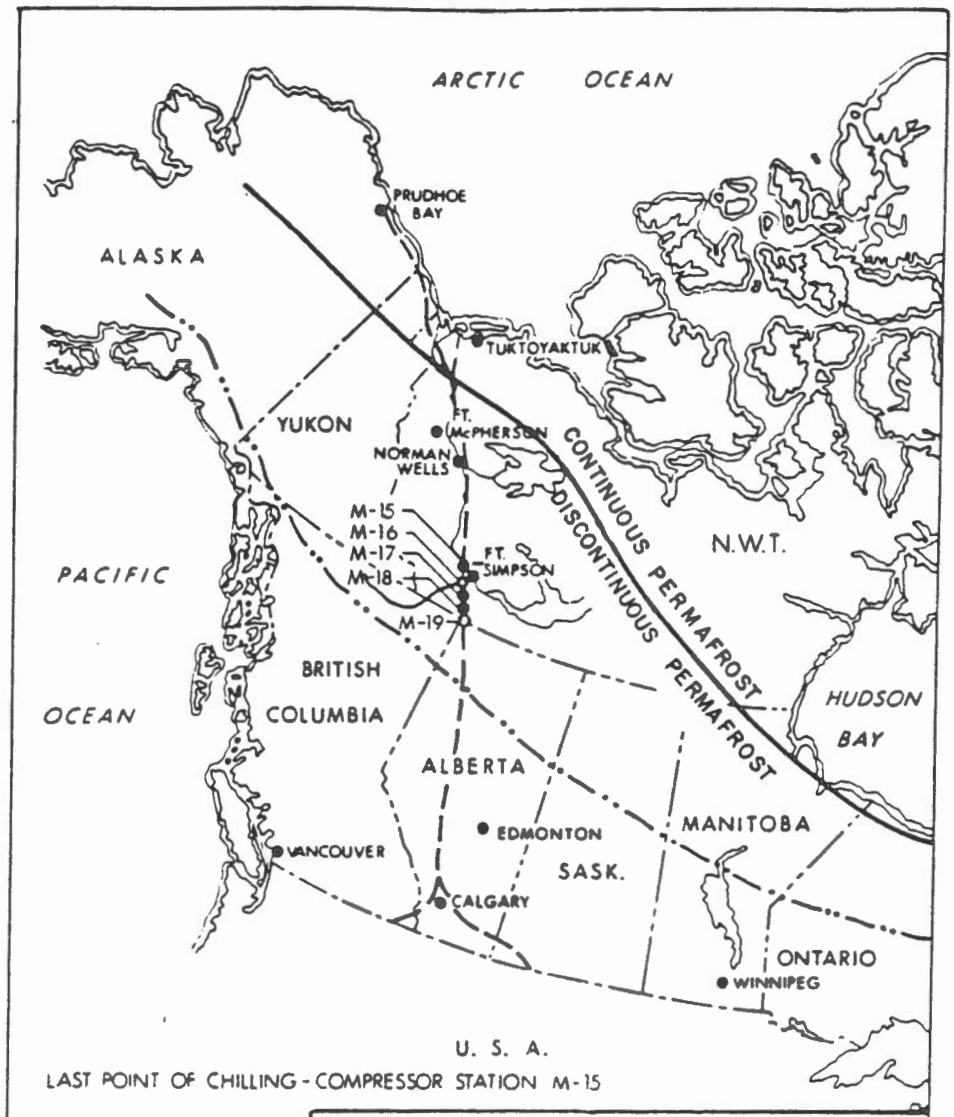


NORTHERN ENGINEERING SERVICES COMPANY LIMITED
CALGARY ALBERTA
ENGINEERS FOR
CANADIAN ARCTIC GAS PIPELINE LIMITED

PIPELINE ROUTE, PERMAFROST ZONES
AND
LAST POINT OF CHILLING

FIG 1.1

L.E.C. **ENGINEERING LTD.**	CALGARY FROST HEAVE TEST FACILITY PIPELINE ROUTE MACKENZIE VALLEY
PREPARED BY L. CARLSON	FIGURE 1.1-1

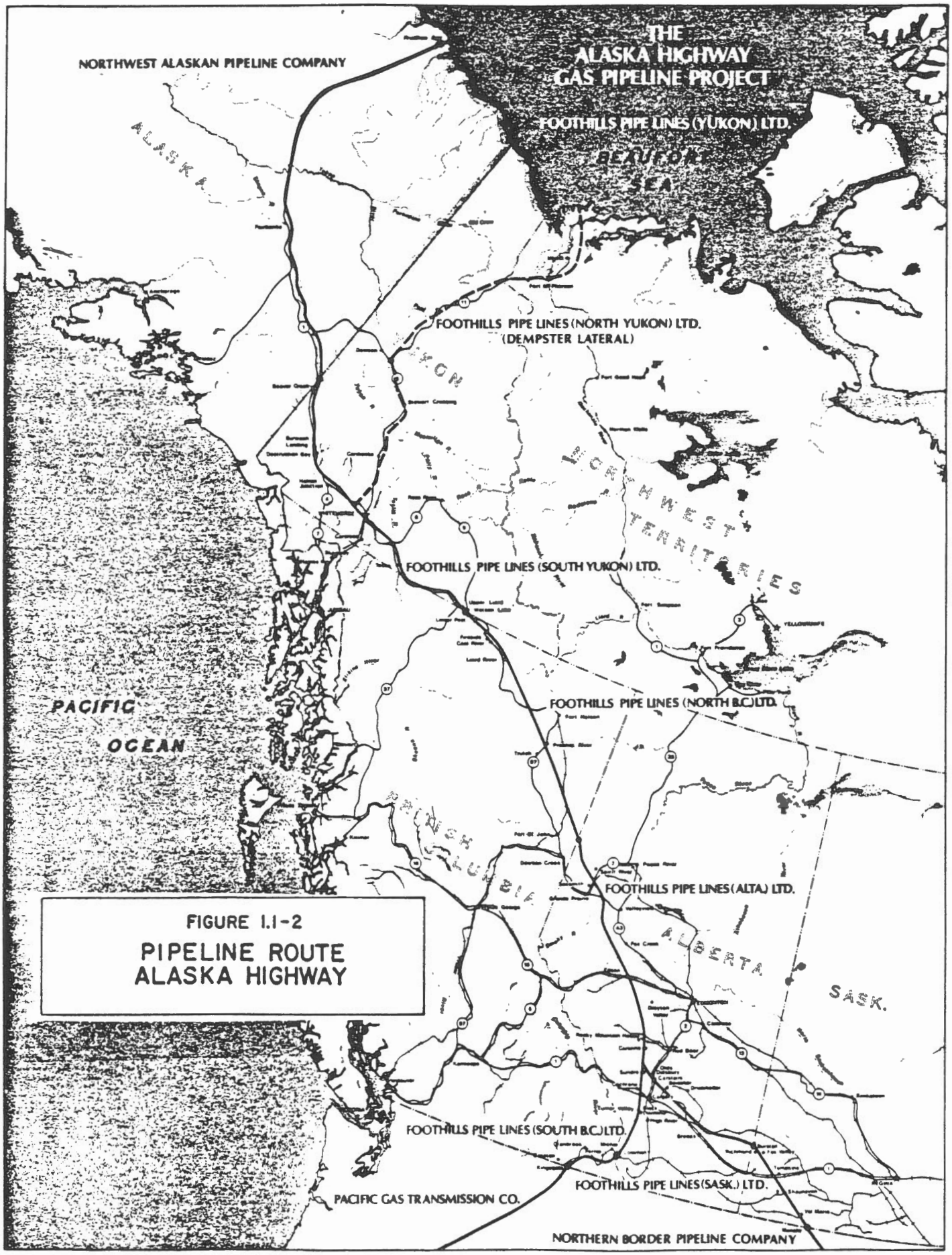
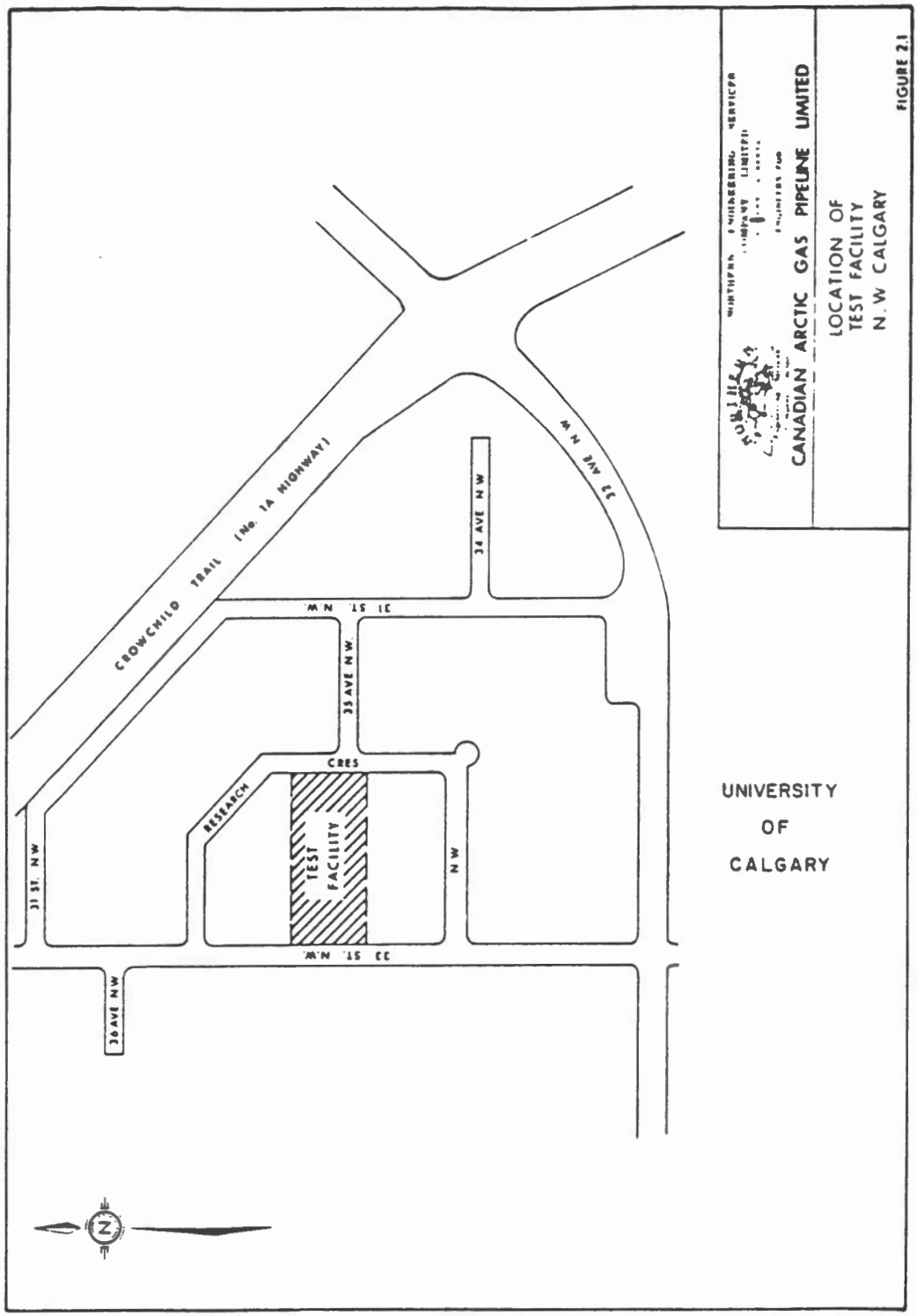


FIGURE 1.1-2
PIPELINE ROUTE
ALASKA HIGHWAY



L.E.C.
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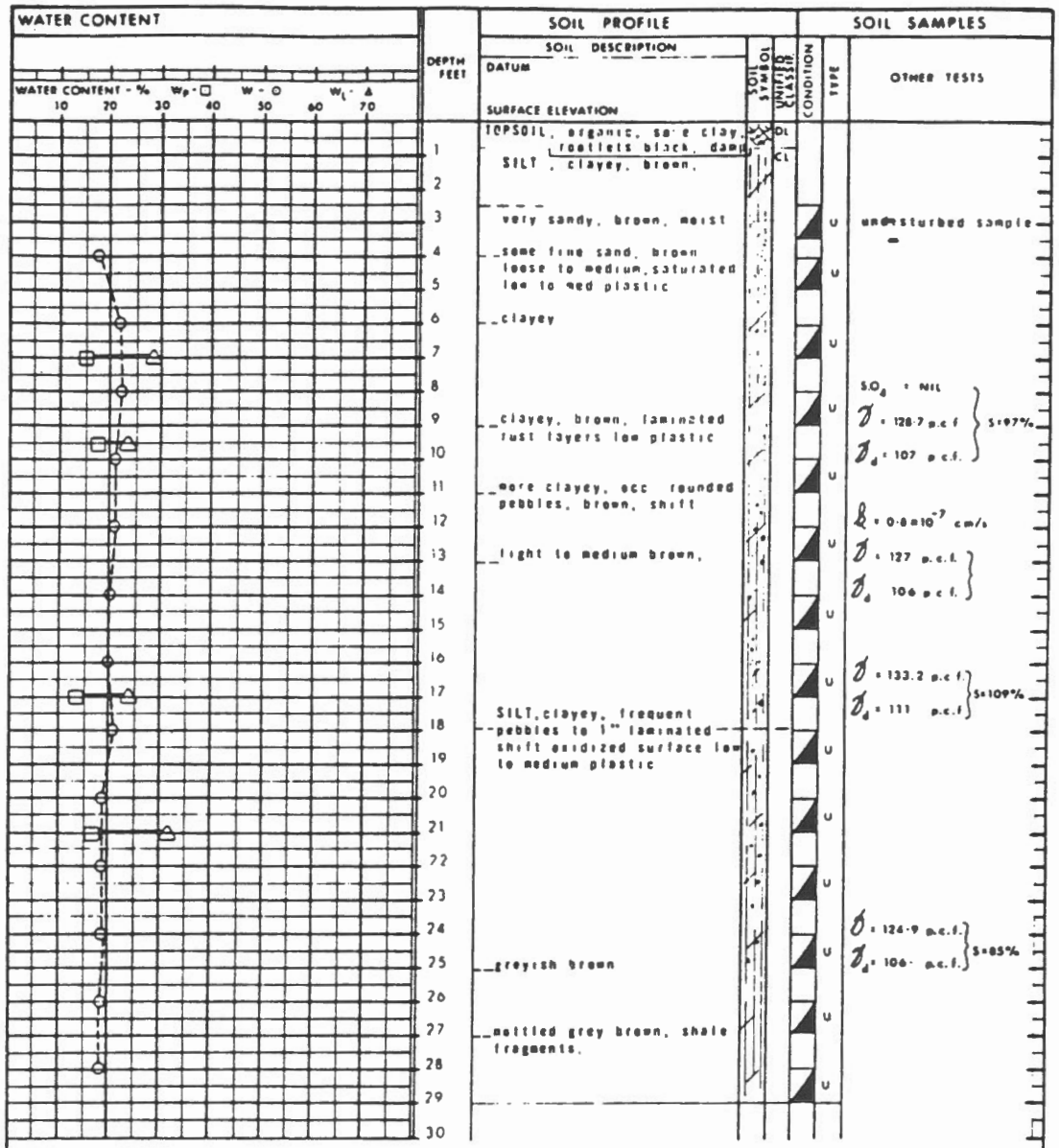
CALGARY FROST HEAVE TEST FACILITY

LOCATION OF TEST FACILITY
IN N.W. CALGARY

PREPARED BY L. CARLSON

FIGURE 2.2-1



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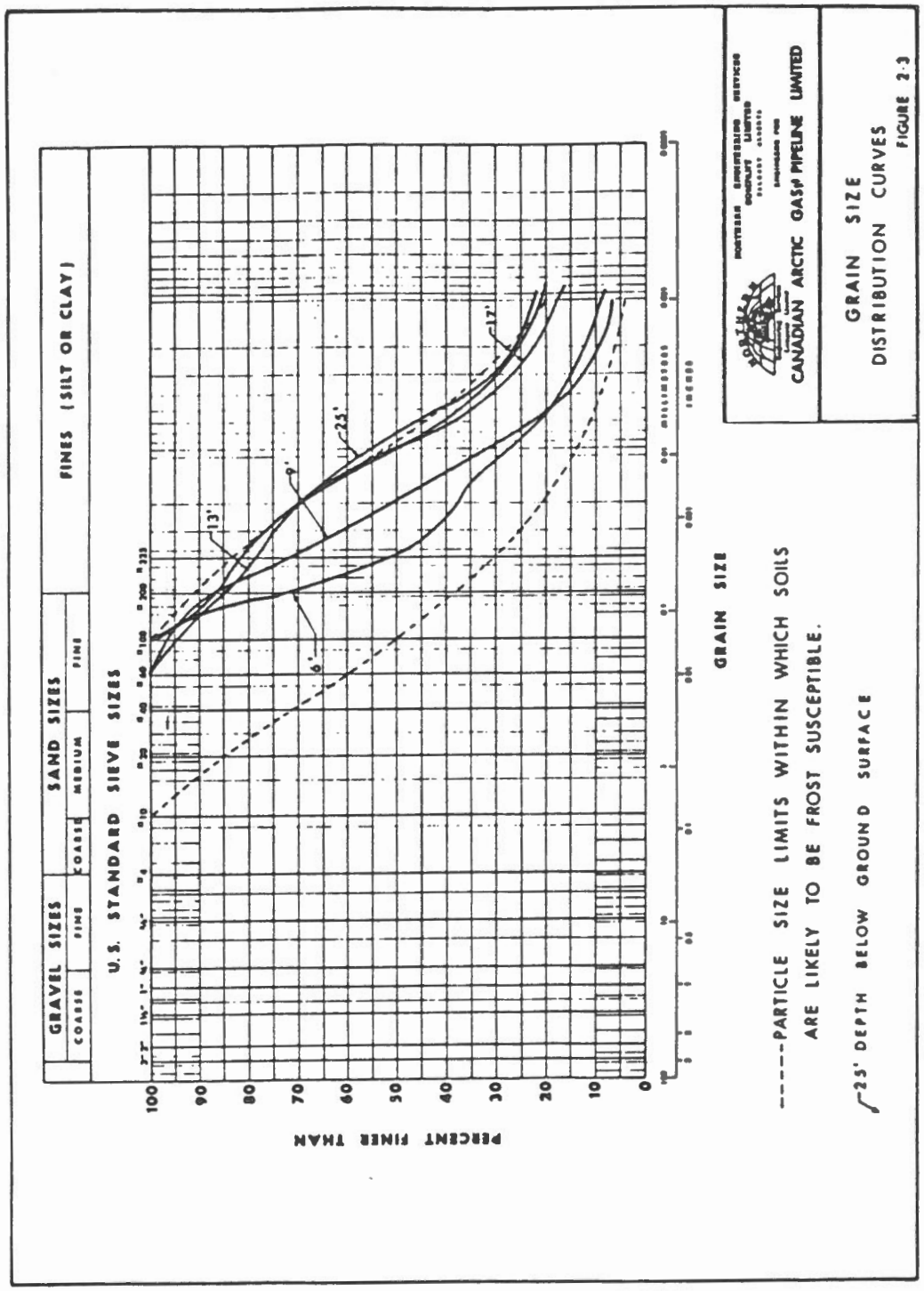
CALGARY FROST HEAVE TEST FACILITY

DRILLING LOG FROM TEST SITE

PREPARED BY L. CARLSON

FIGURE 2.2-2



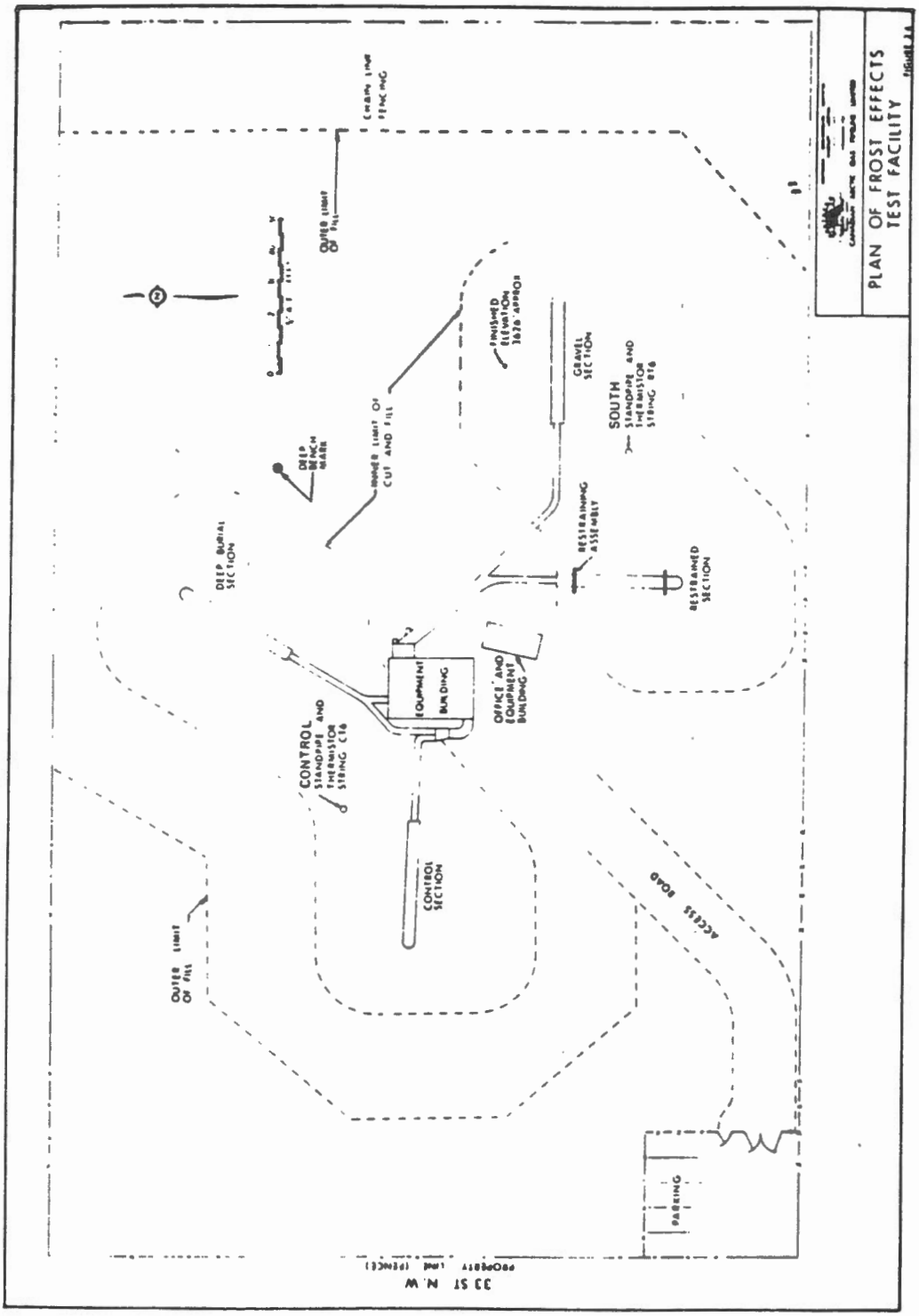
L.E.C.
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

GRAIN SIZE
DISTRIBUTION CURVES

PREPARED BY L. CARLSON

FIGURE 2.2-3



L.E.C.
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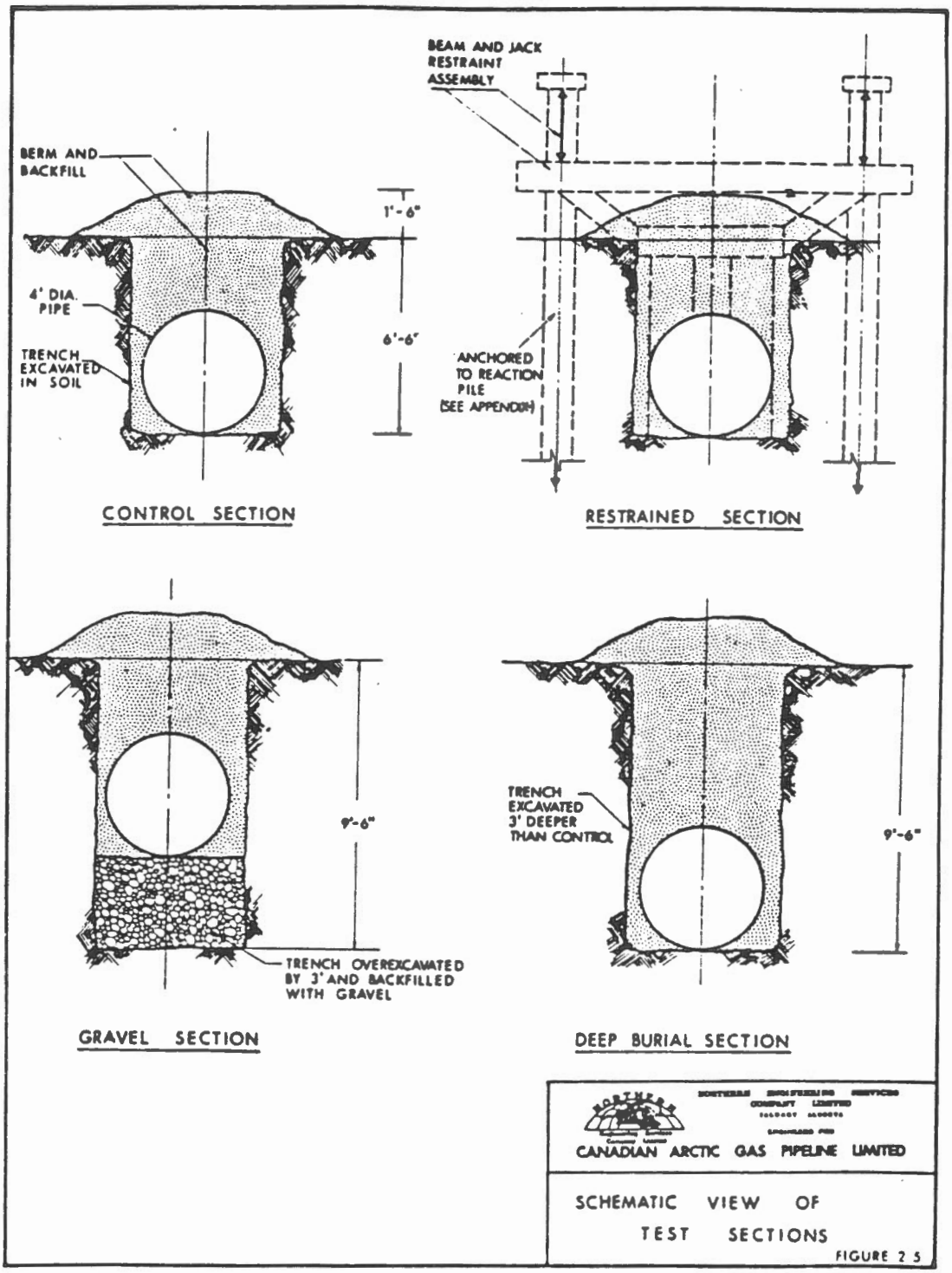
CALGARY FROST HEAVE TEST FACILITY

PLAN VIEW

1974

PREPARED BY L. CARLSON

FIGURE 2.2-4



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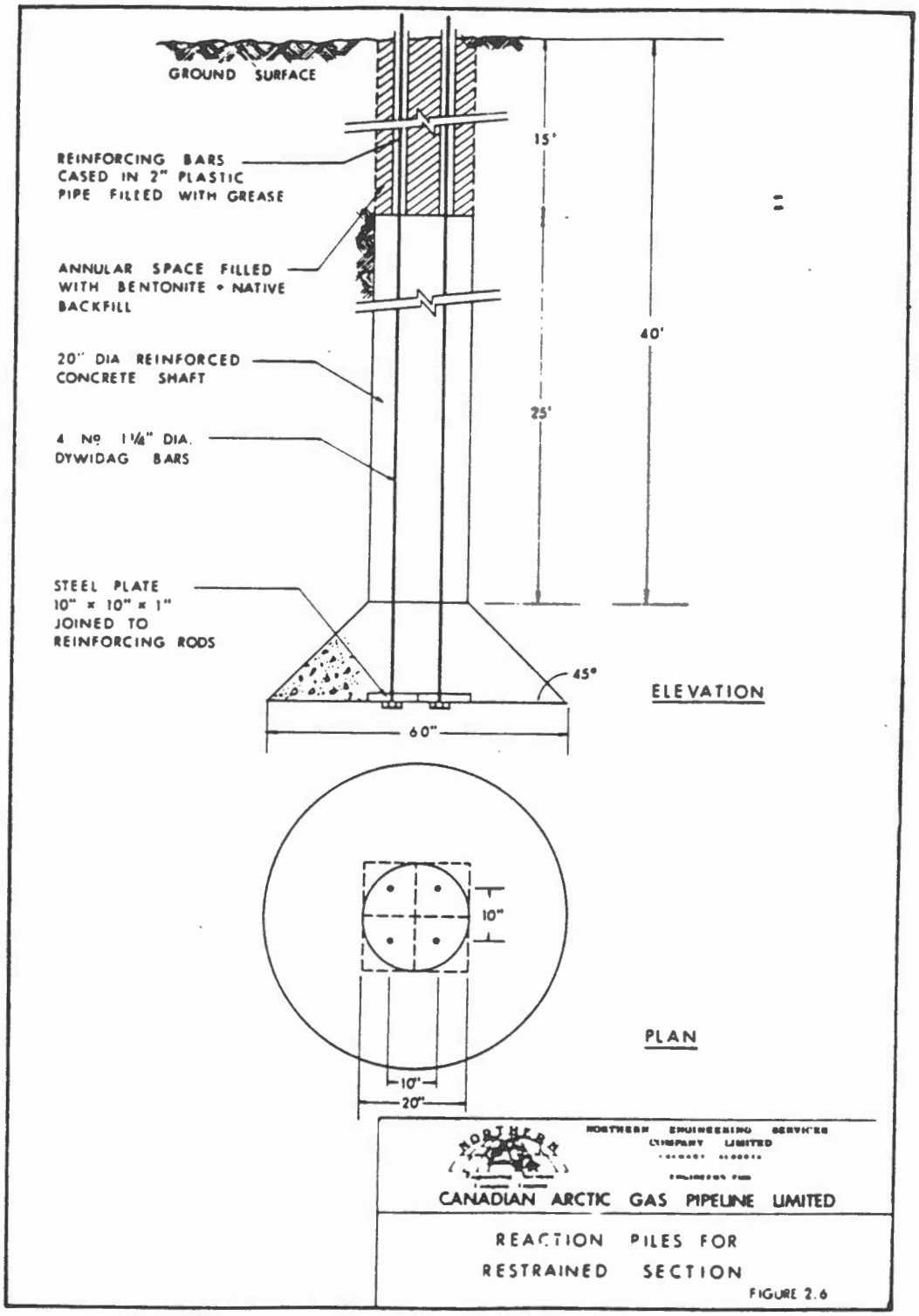
CALGARY FROST HEAVE TEST FACILITY

DITCH PROFILE
ORIGINAL TEST SECTIONS

PREPARED BY L. CARLSON

FIGURE 2.2-5



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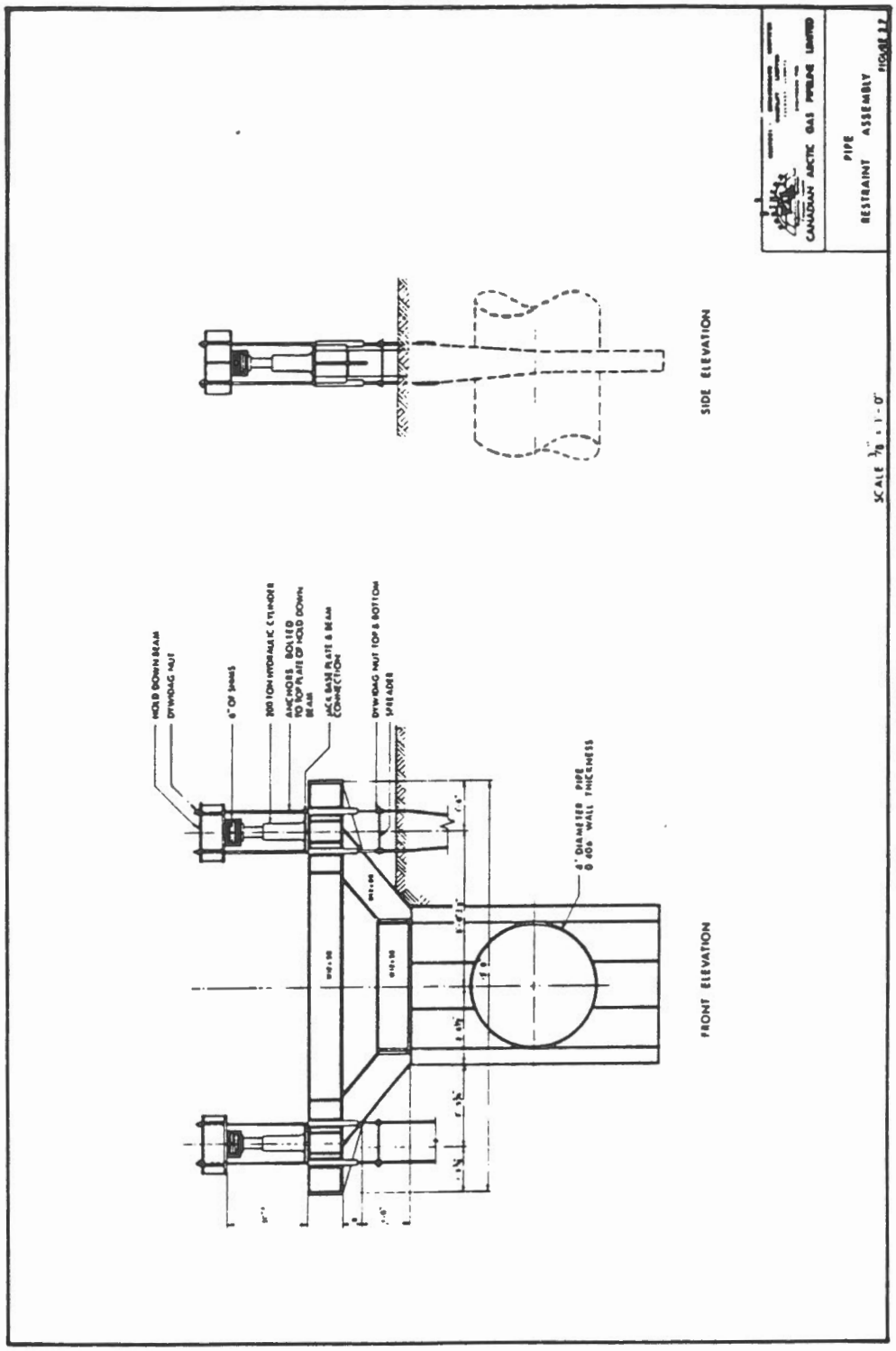
CALGARY FROST HEAVE TEST FACILITY

REACTION PILES FOR RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.2-6A



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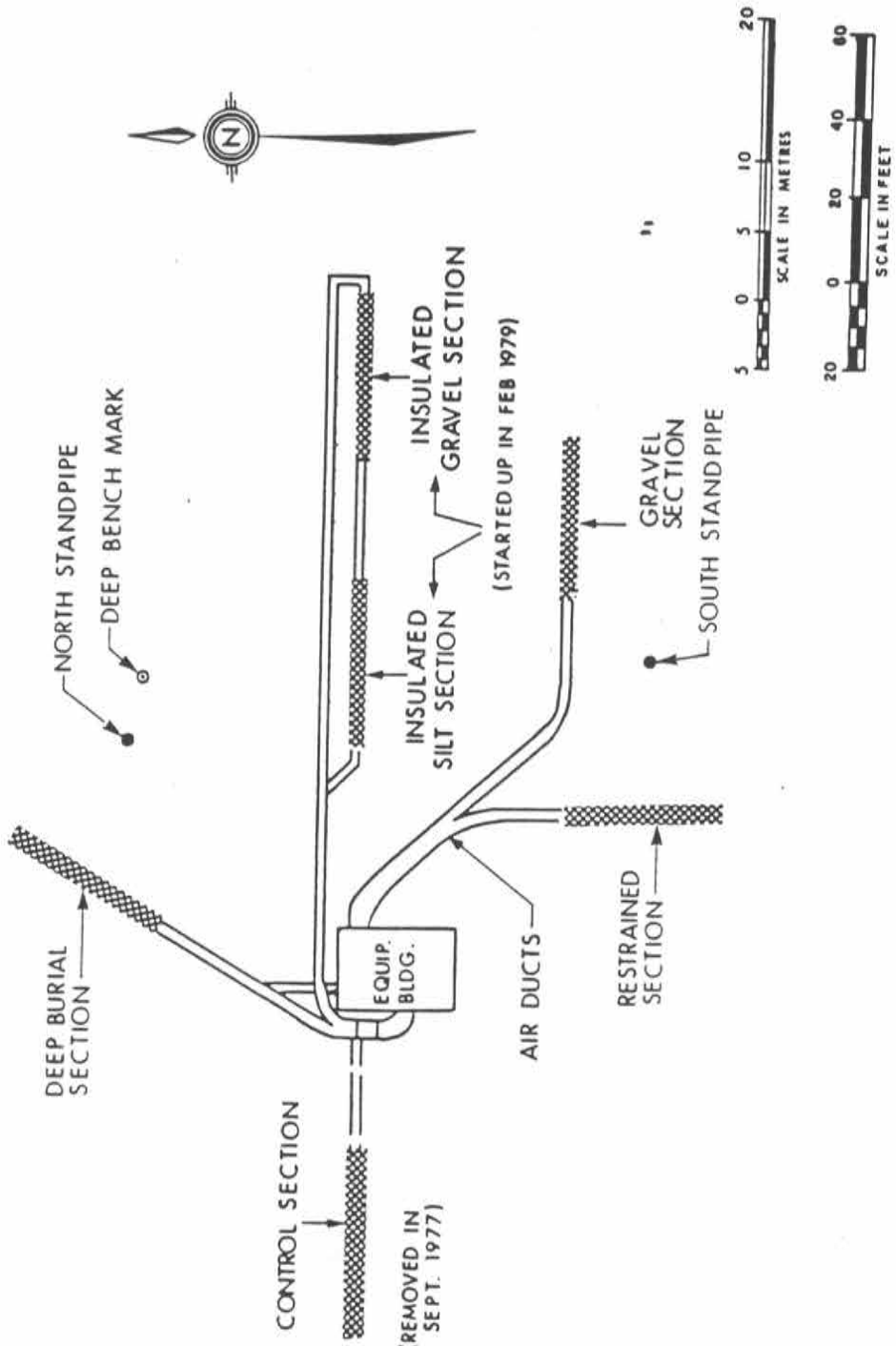
CALGARY FROST HEAVE TEST FACILITY

PIPE RESTRAINT ASSEMBLY FOR RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.2-6B



L.E.C.
ENGINEERING LTD.

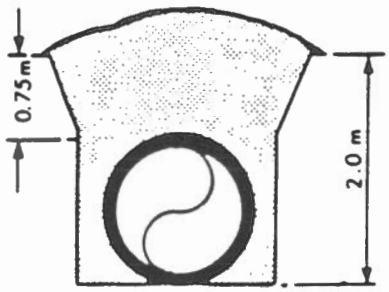
CALGARY FROST HEAVE TEST FACILITY

PLAN VIEW

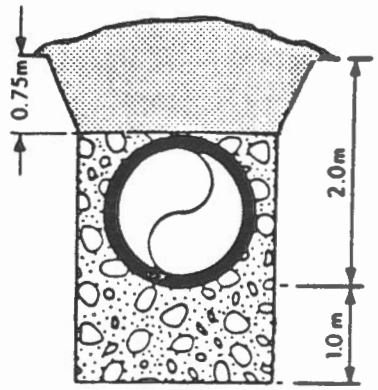
1979

PREPARED BY L. CARLSON

FIGURE 2.2-7



1. CROSS SECTION OF INSULATED SILT SECTION



2. CROSS SECTION OF INSULATED GRAVEL SECTION

GRAVEL

SILT

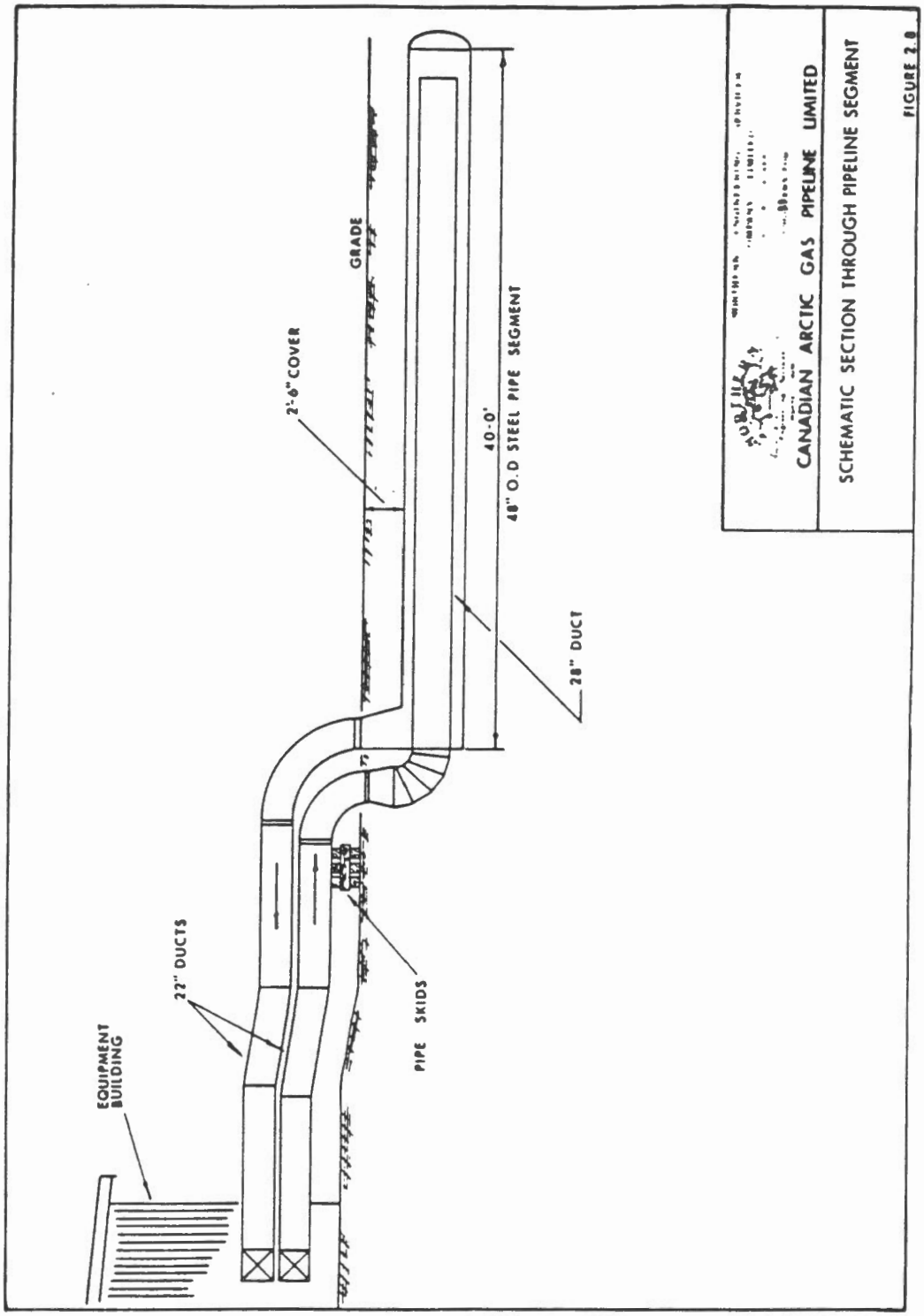
L.E.C.
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

DITCH PROFILE
INSULATED PIPE SECTIONS

PREPARED BY L. CARLSON

FIGURE 2.2-8



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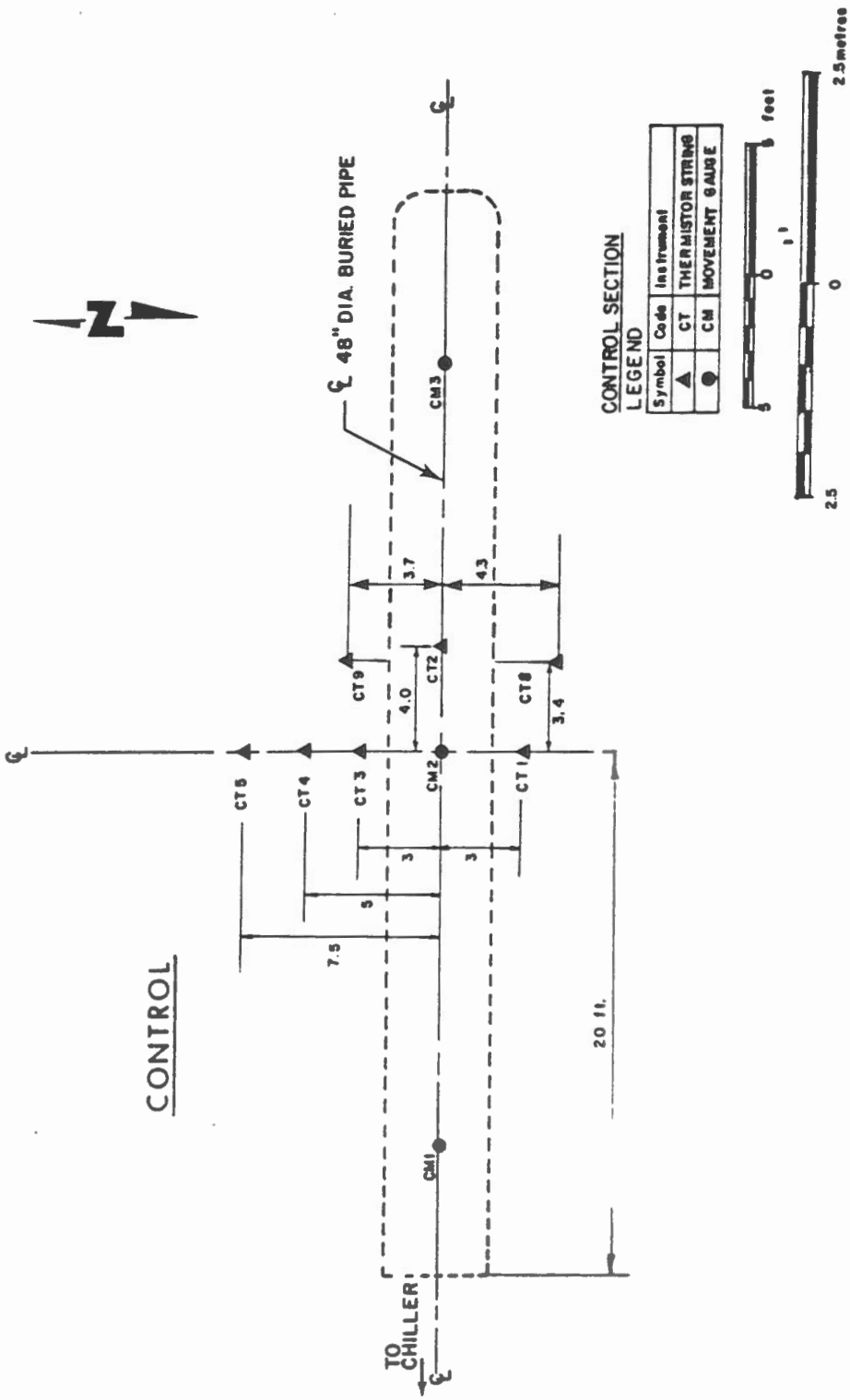
CALGARY FROST HEAVE TEST FACILITY

SCHEMATIC SECTION
THROUGH PIPELINE SEGMENT

PREPARED BY L. CARLSON

FIGURE 2.2-9



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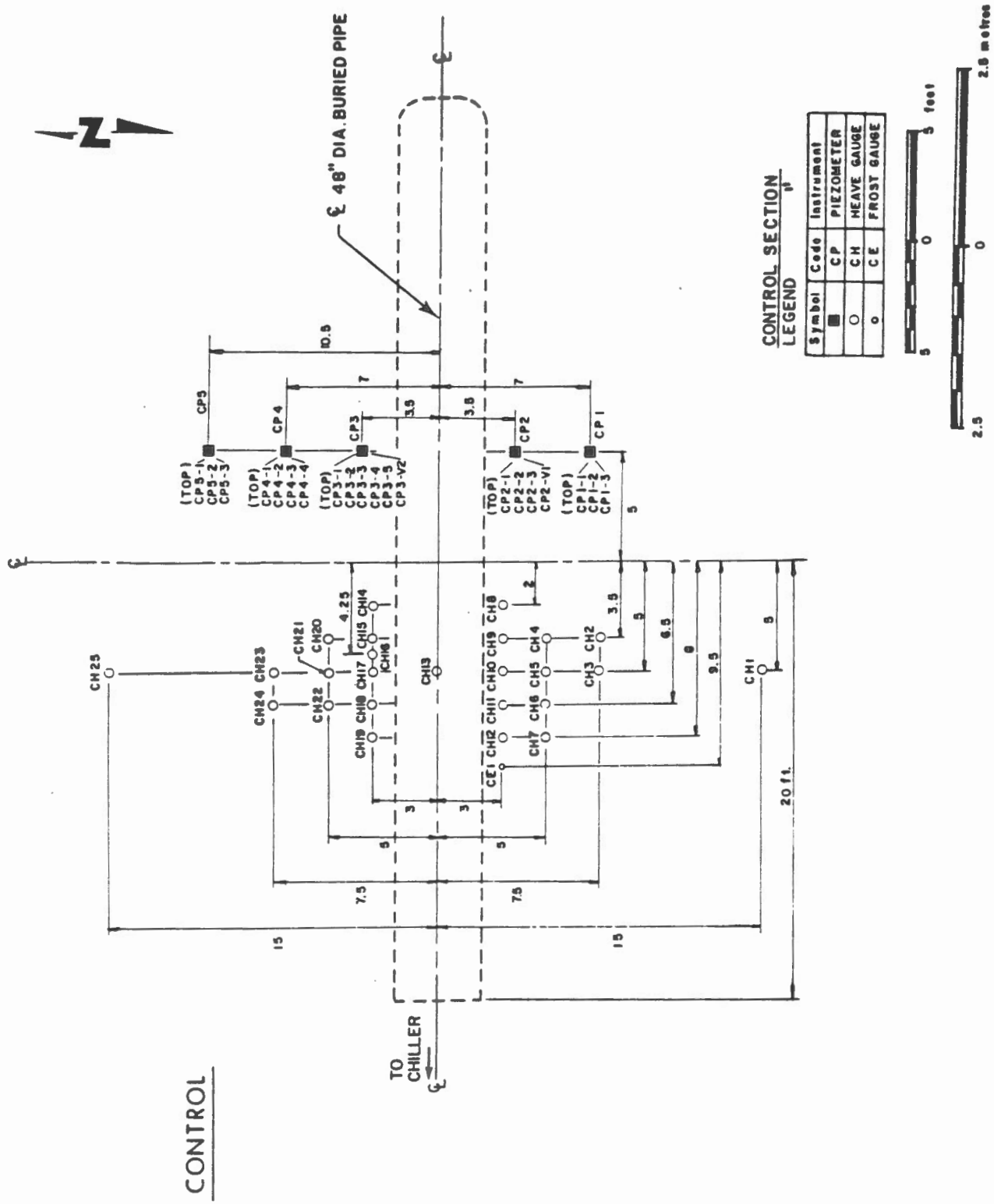
CALGARY FROST HEAVE TEST FACILITY

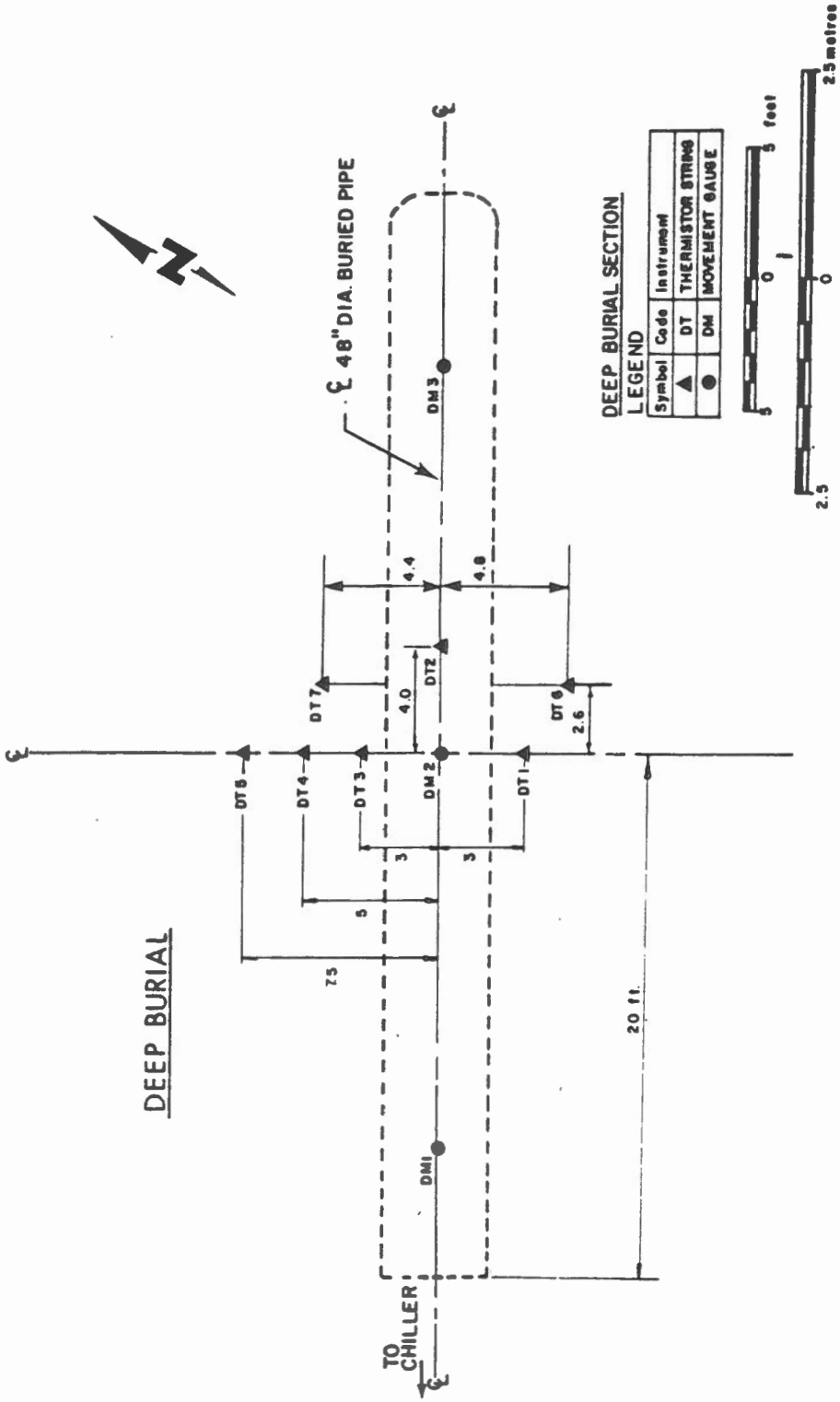
INSTRUMENTATION LAYOUT
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-1A



L.E.C. ENGINEERING LTD.	CALGARY FROST HEAVE TEST FACILITY INSTRUMENTATION LAYOUT CONTROL SECTION
PREPARED BY L. CARLSON	FIGURE 2.3-1B



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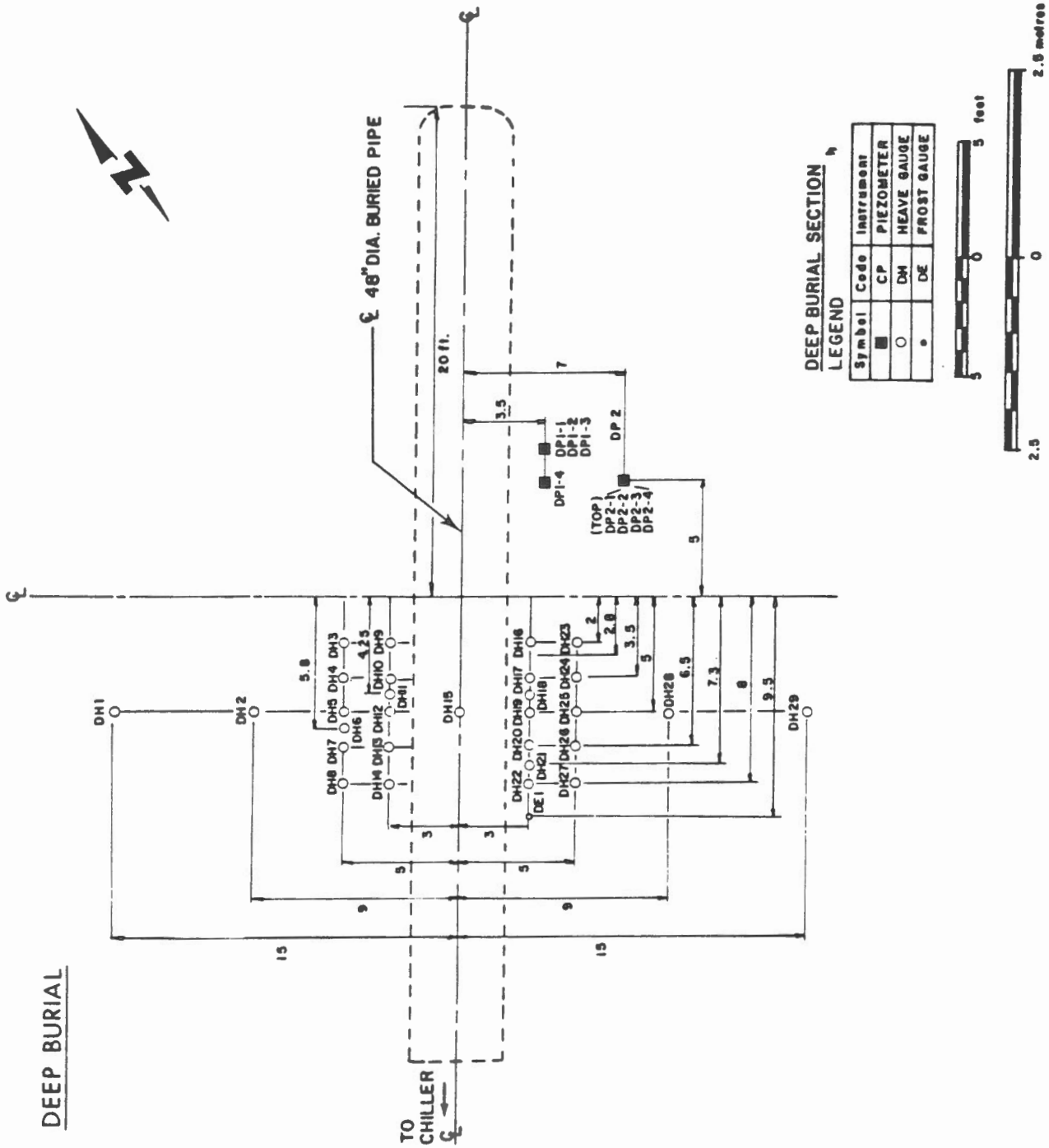
CALGARY FROST HEAVE TEST FACILITY

INSTRUMENTATION LAYOUT
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-2A



L.E.C.
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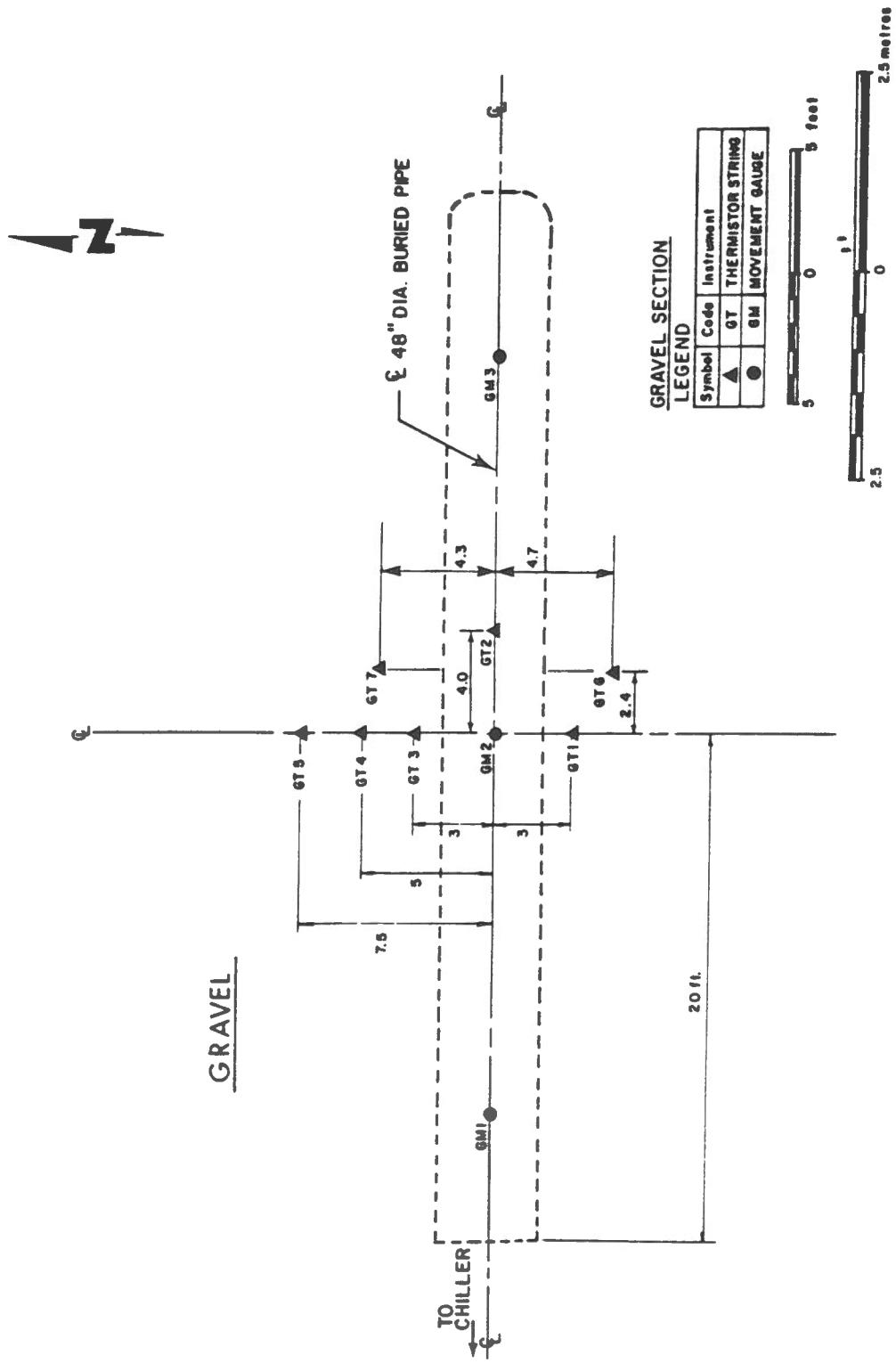
CALGARY FROST HEAVE TEST FACILITY

INSTRUMENTATION LAYOUT
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-2B



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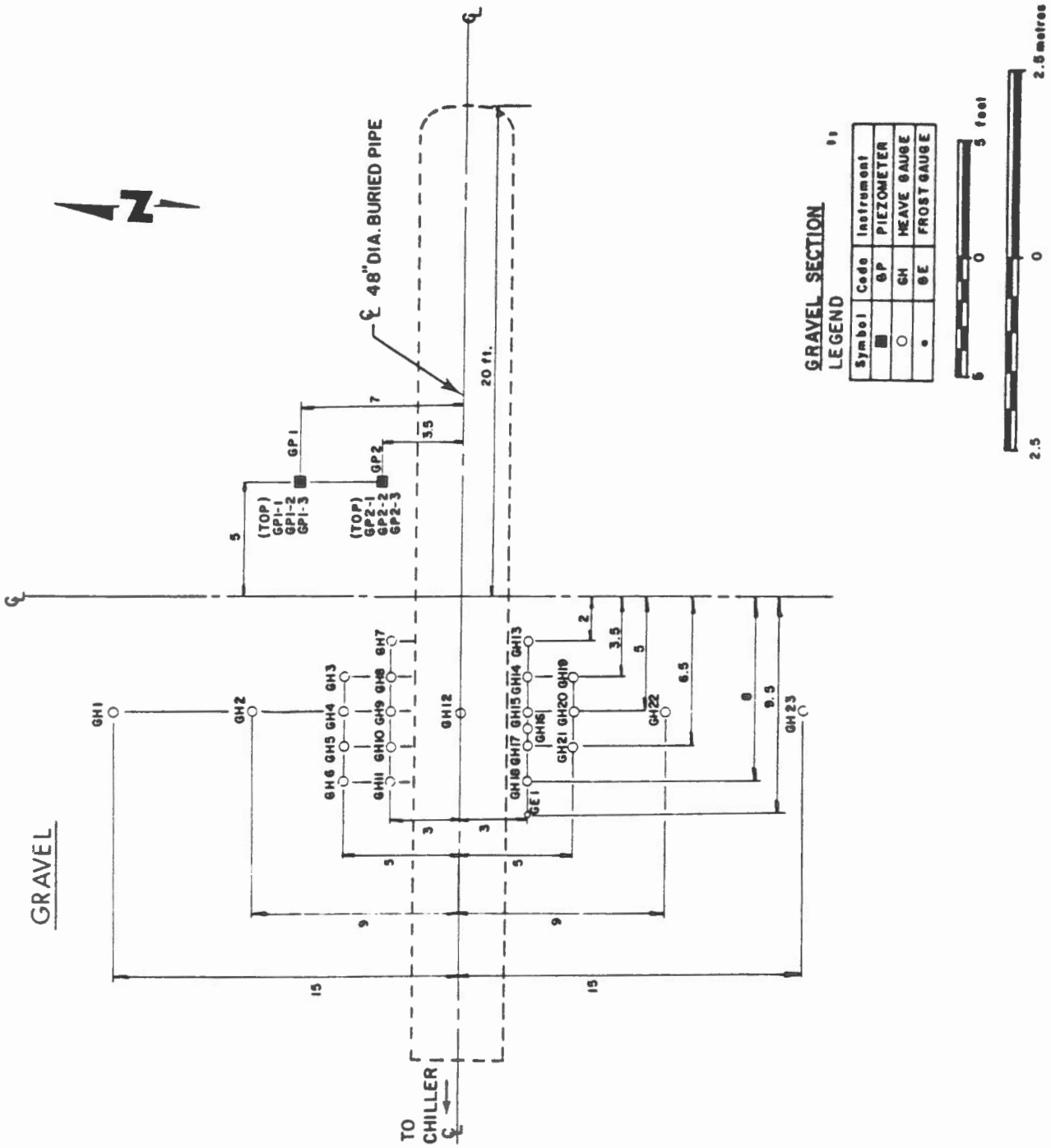
CALGARY FROST HEAVE TEST FACILITY

INSTRUMENTATION LAYOUT
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-3A



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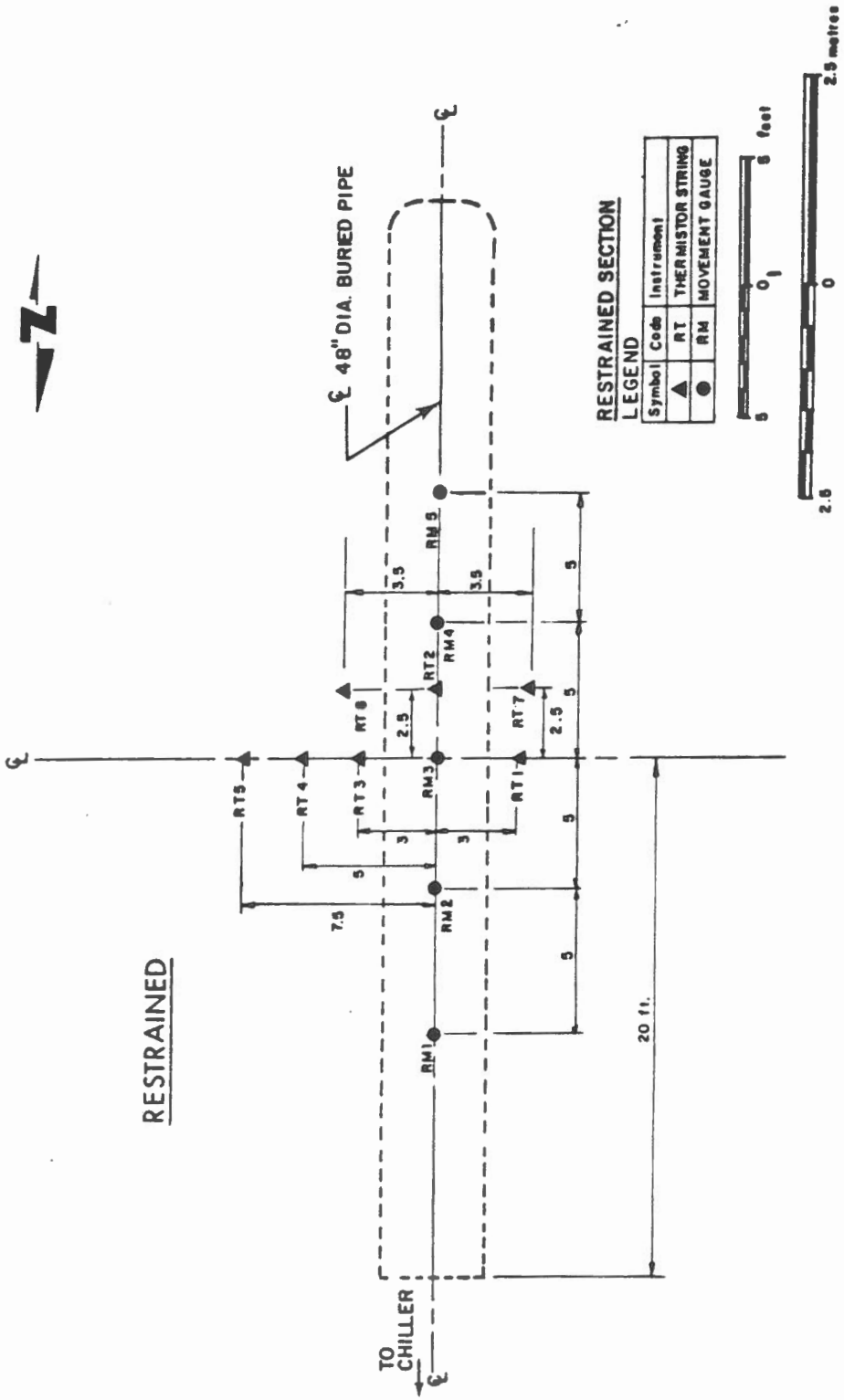
CALGARY FROST HEAVE TEST FACILITY

INSTRUMENTION LAYOUT
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-3B



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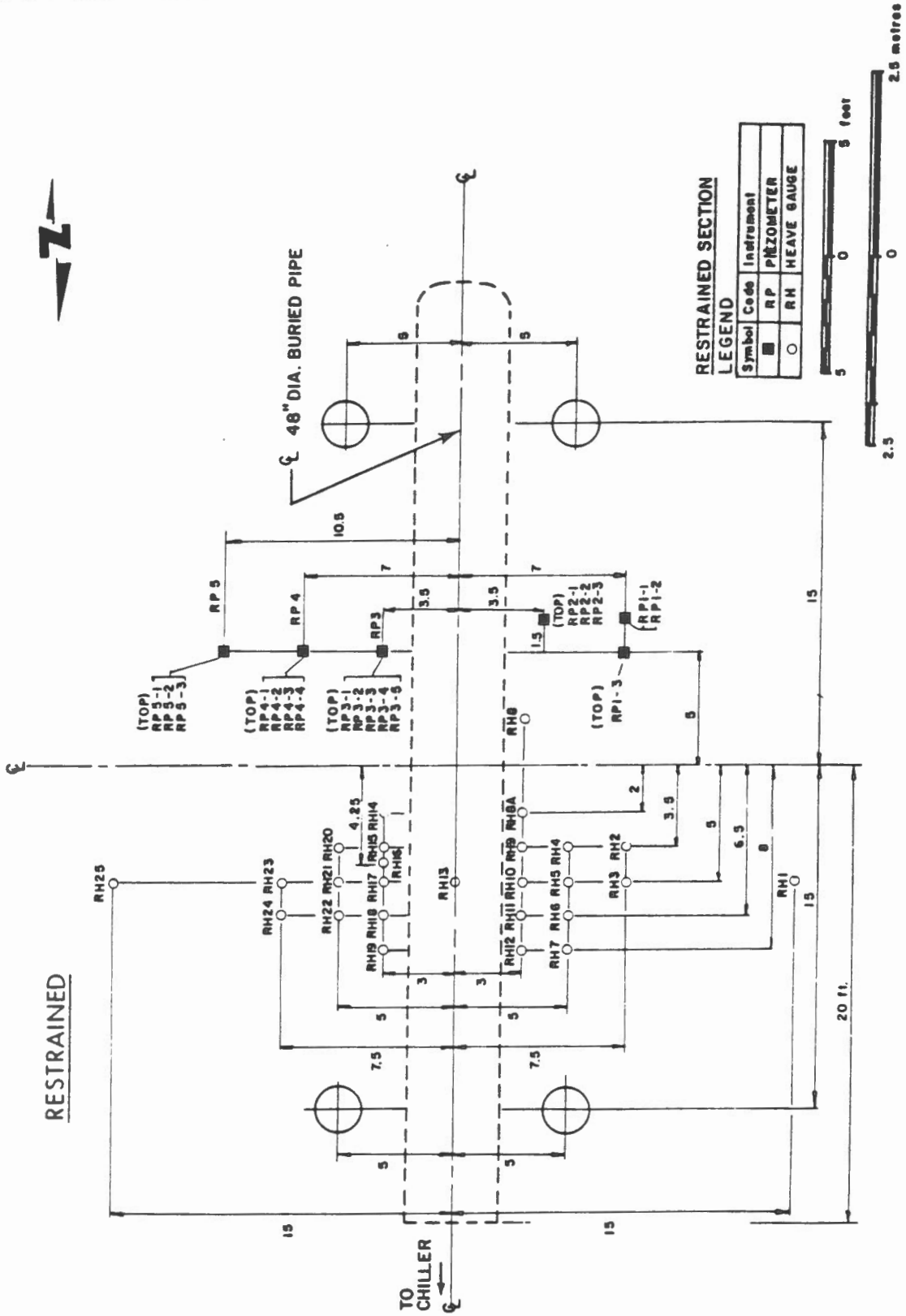
CALGARY FROST HEAVE TEST FACILITY

INSTRUMENTATION LAYOUT
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-4A



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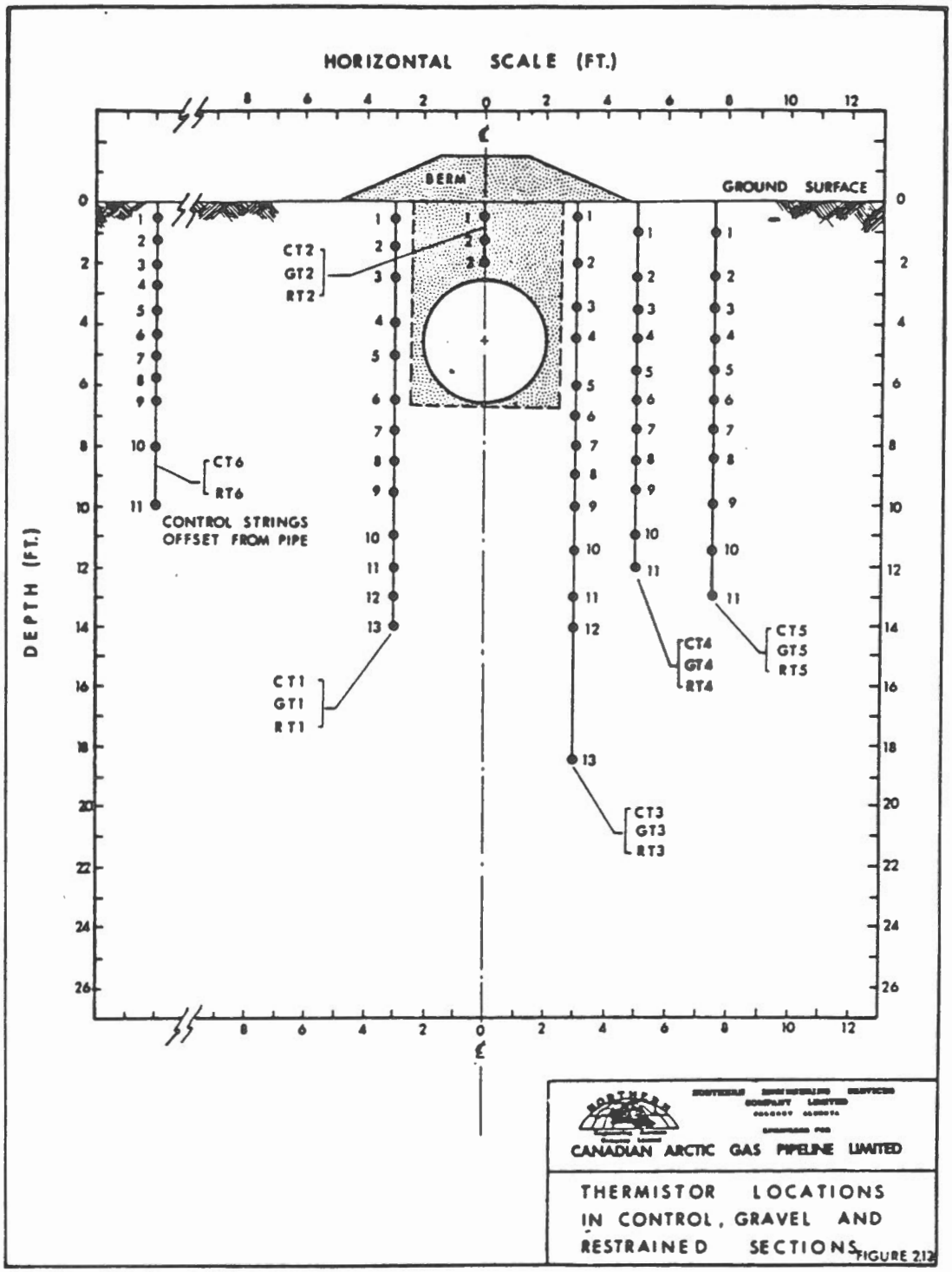
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

INSTRUMENTATION LAYOUT
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-4B



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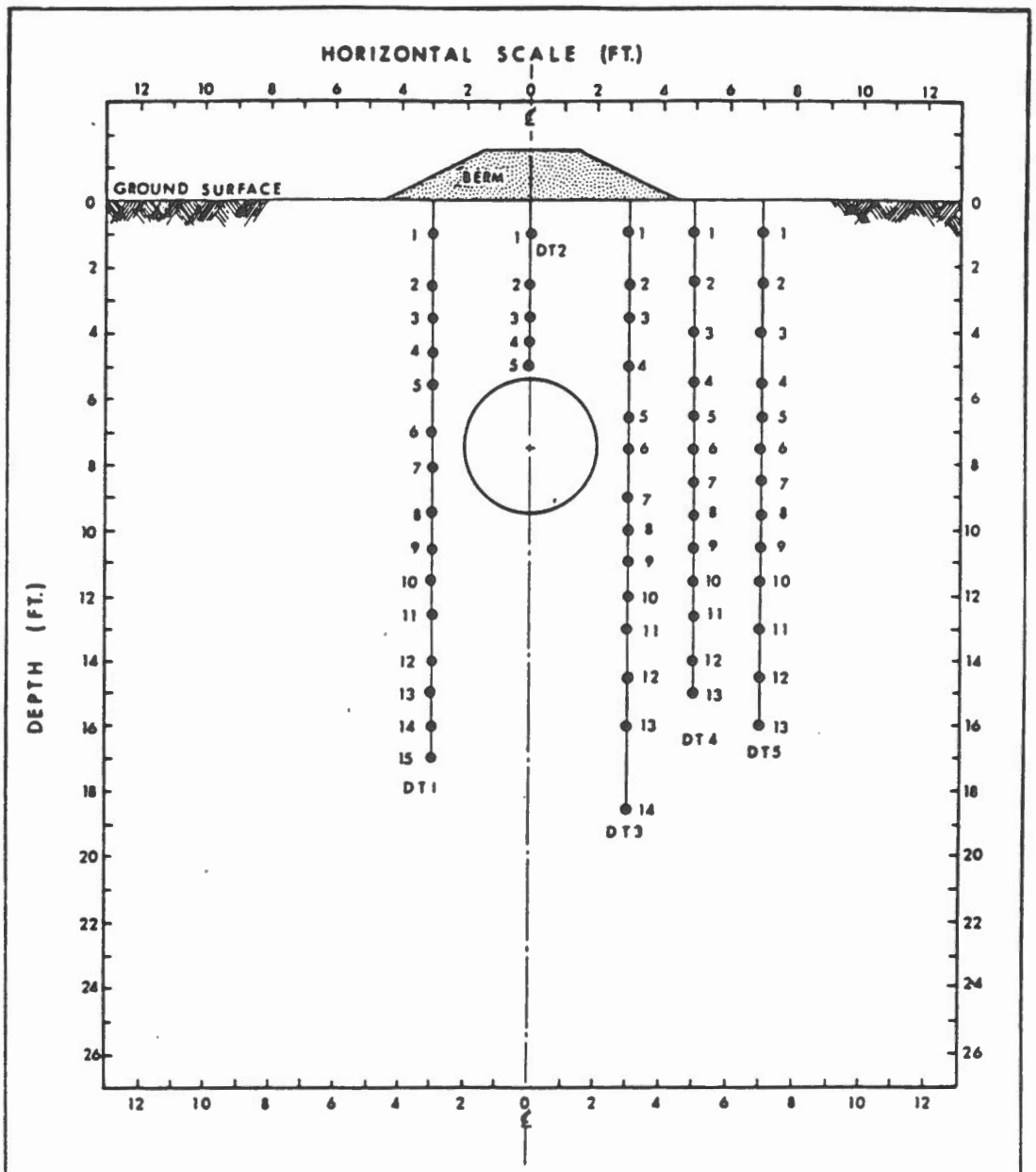
CALGARY FROST HEAVE TEST FACILITY

THERMISTOR LOCATIONS
ORIGIONAL SECTIONS

PREPARED BY L. CARLSON

FIGURE 2.3-5 A



CANADIAN ARCTIC GAS PIPELINE LIMITED

THERMISTOR LOCATIONS IN DEEP BURIAL SECTION

FIGURE 2.14

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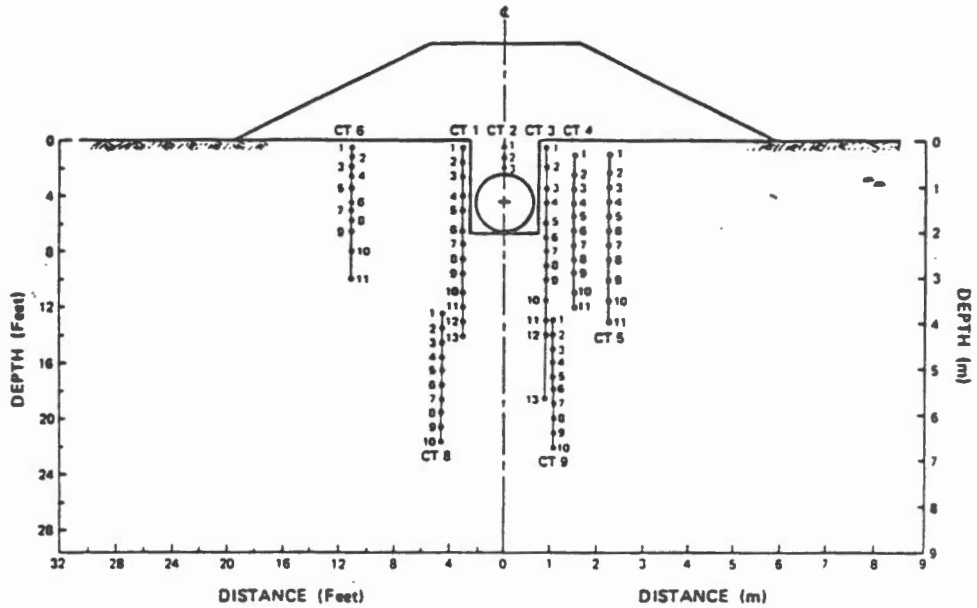
CALGARY FROST HEAVE TEST FACILITY

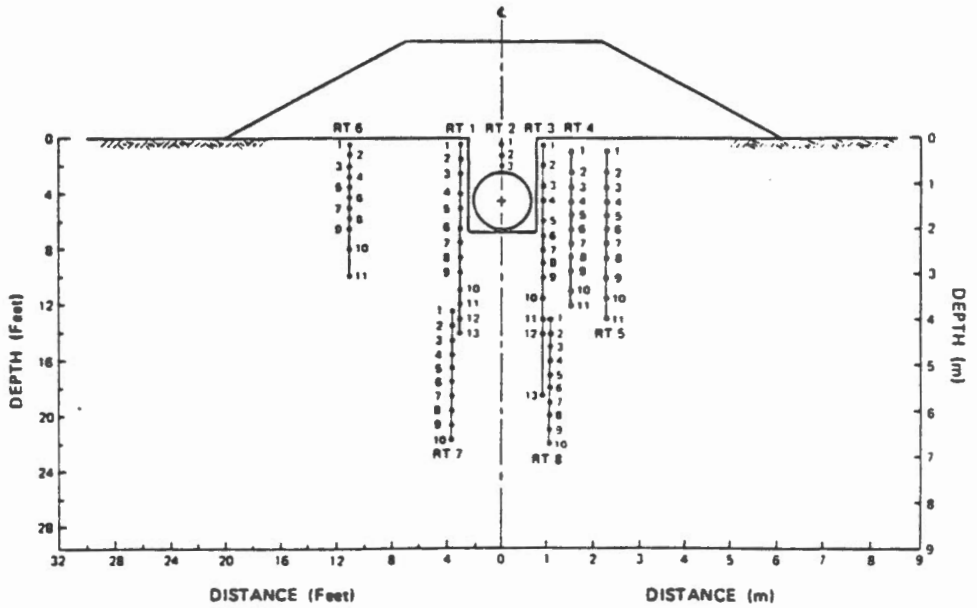
THERMISTOR LOCATIONS ORIGIONAL SECTIONS

PREPARED BY L. CARLSON

FIGURE 2.3-5 B

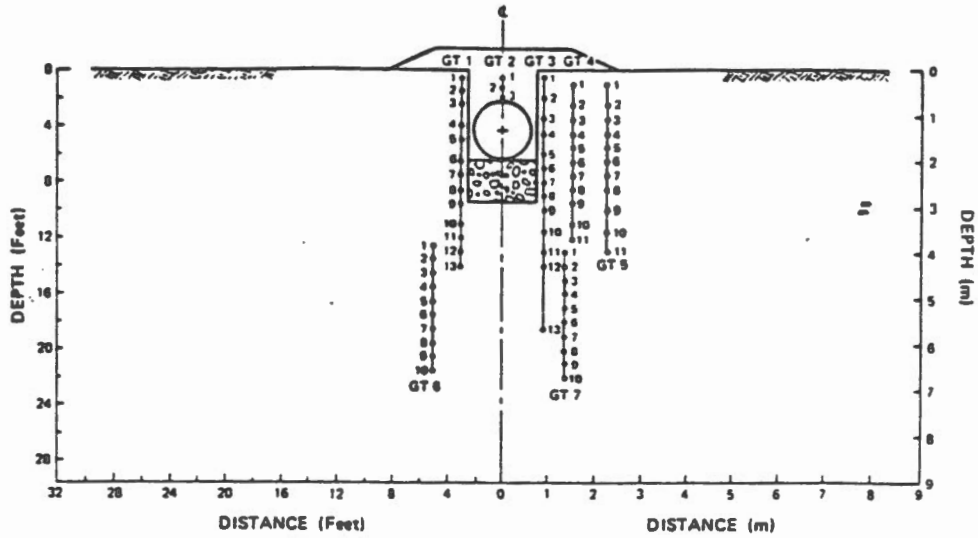


CONTROL SECTION

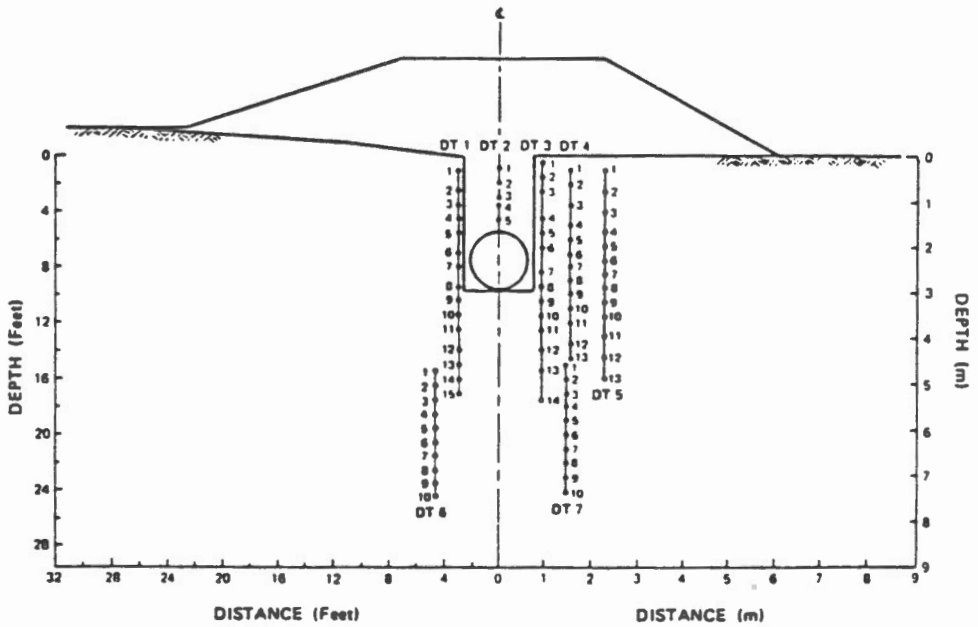


RESTRAINED SECTION

L.E.C. ENGINEERING LTD.	CALGARY FROST HEAVE TEST FACILITY THERMISTOR LOCATIONS DEEP STRINGS
PREPARED BY L. CARLSON	FIGURE 2.3-6A



GRAVEL SECTION



DEEP BURIAL SECTION

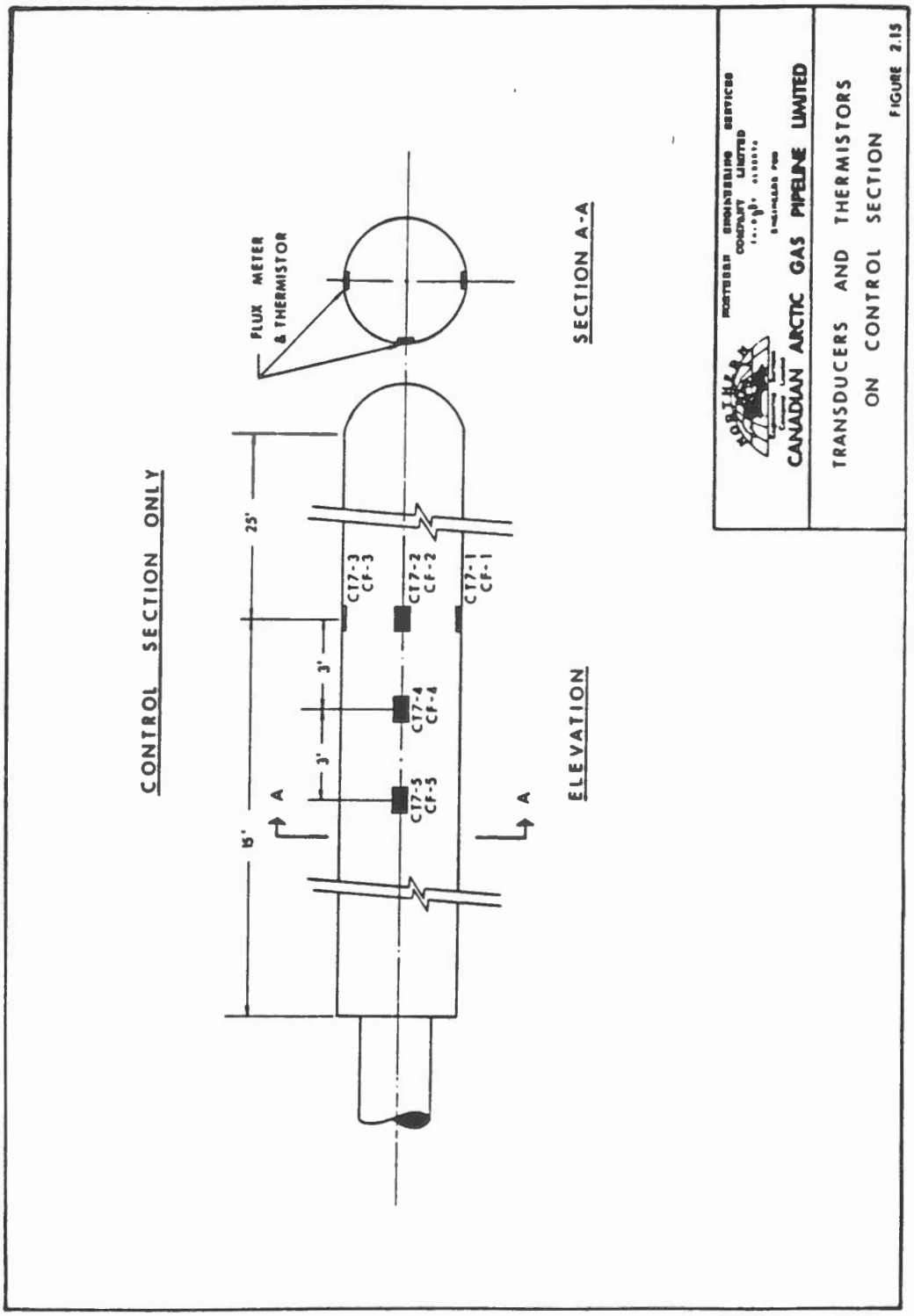
L.E.C.
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

THERMISTOR LOCATIONS
DEEP STRINGS

PREPARED BY L. CARLSON

FIGURE 2.3-6B



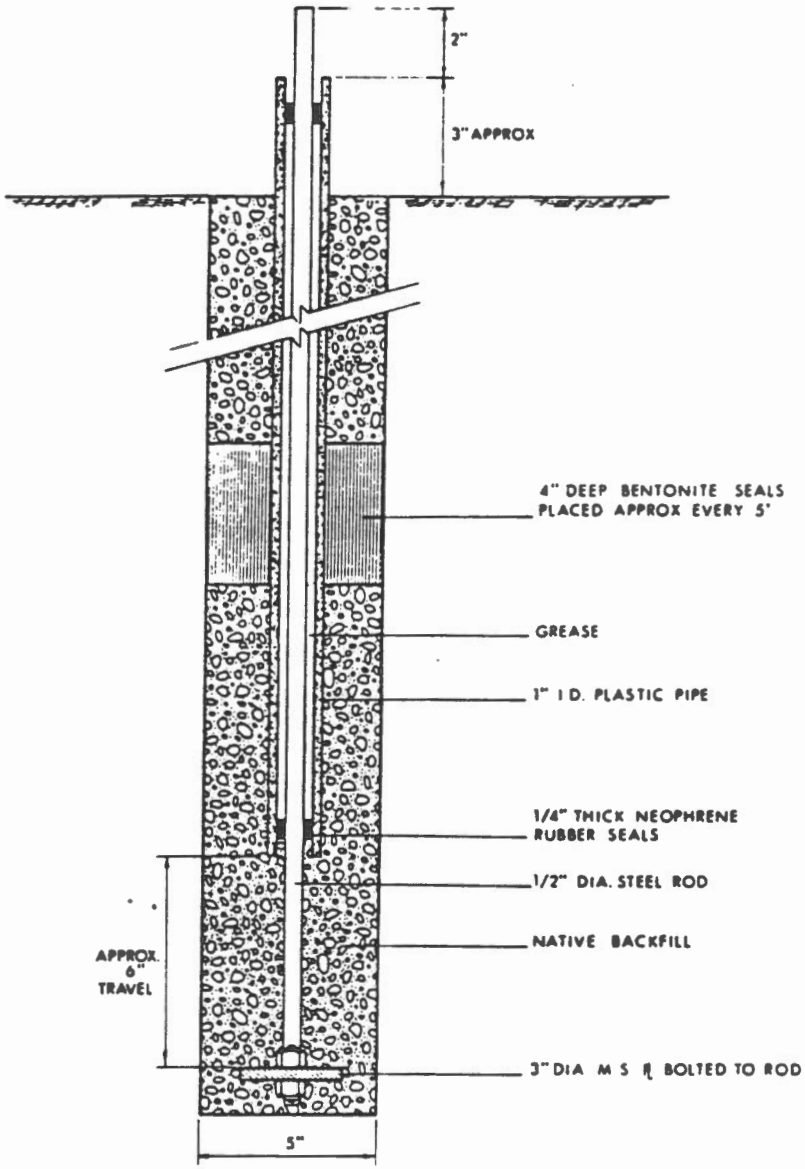
L.E.C.
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

TRANSDUCERS AND THERMISTORS ON CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-7



NORTHERN ENGINEERING SERVICES COMPANY LIMITED

CALGARY ALBERTA

ENGINEERED FOR

CANADIAN ARCTIC GAS PIPELINE LIMITED

HEAVE GAUGE INSTALLATION

FIGURE 2.16

L.E.C.

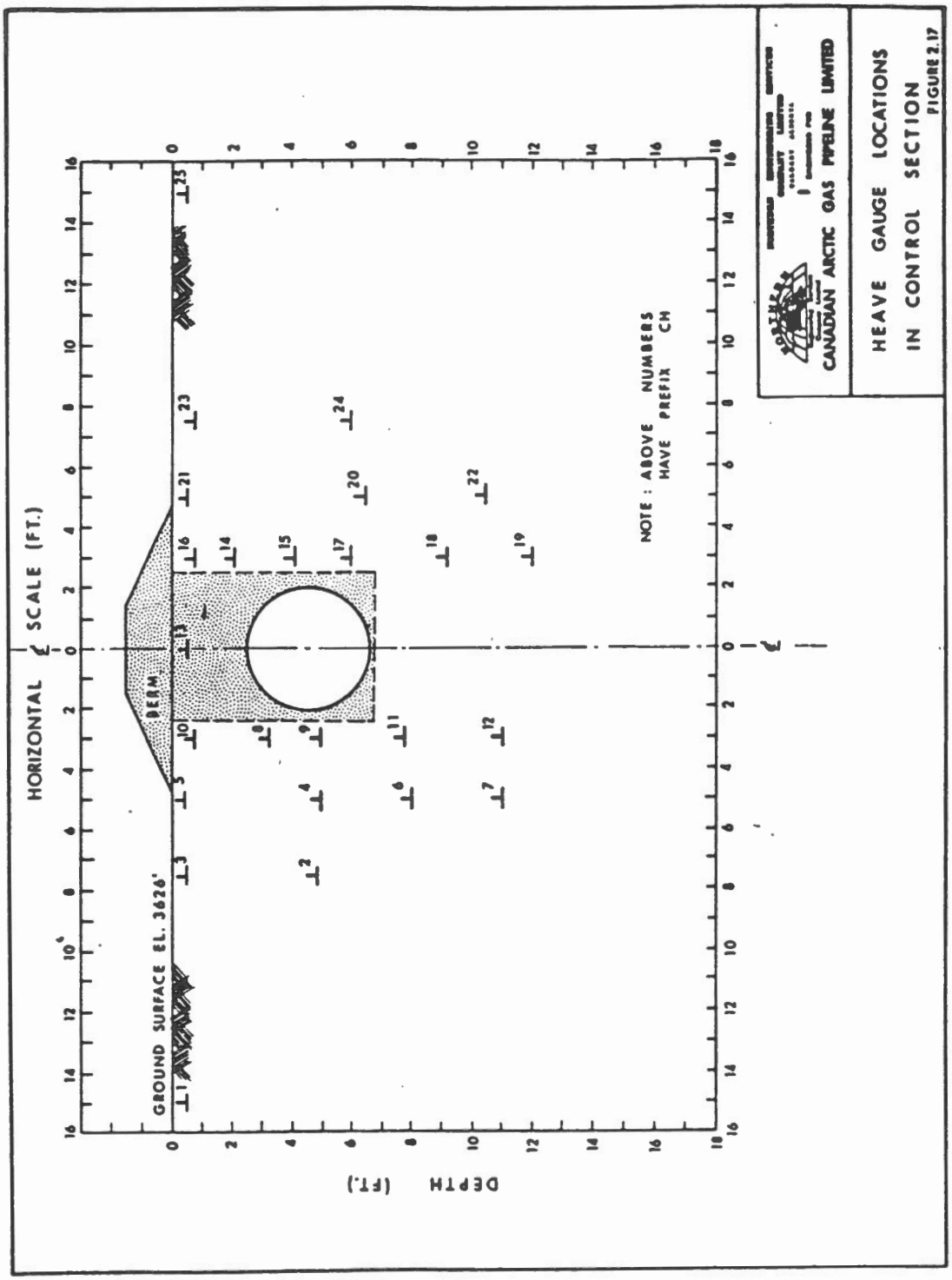
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

HEAVE GAUGE INSTALLATION

PREPARED BY L. CARLSON

FIGURE 2.3-8



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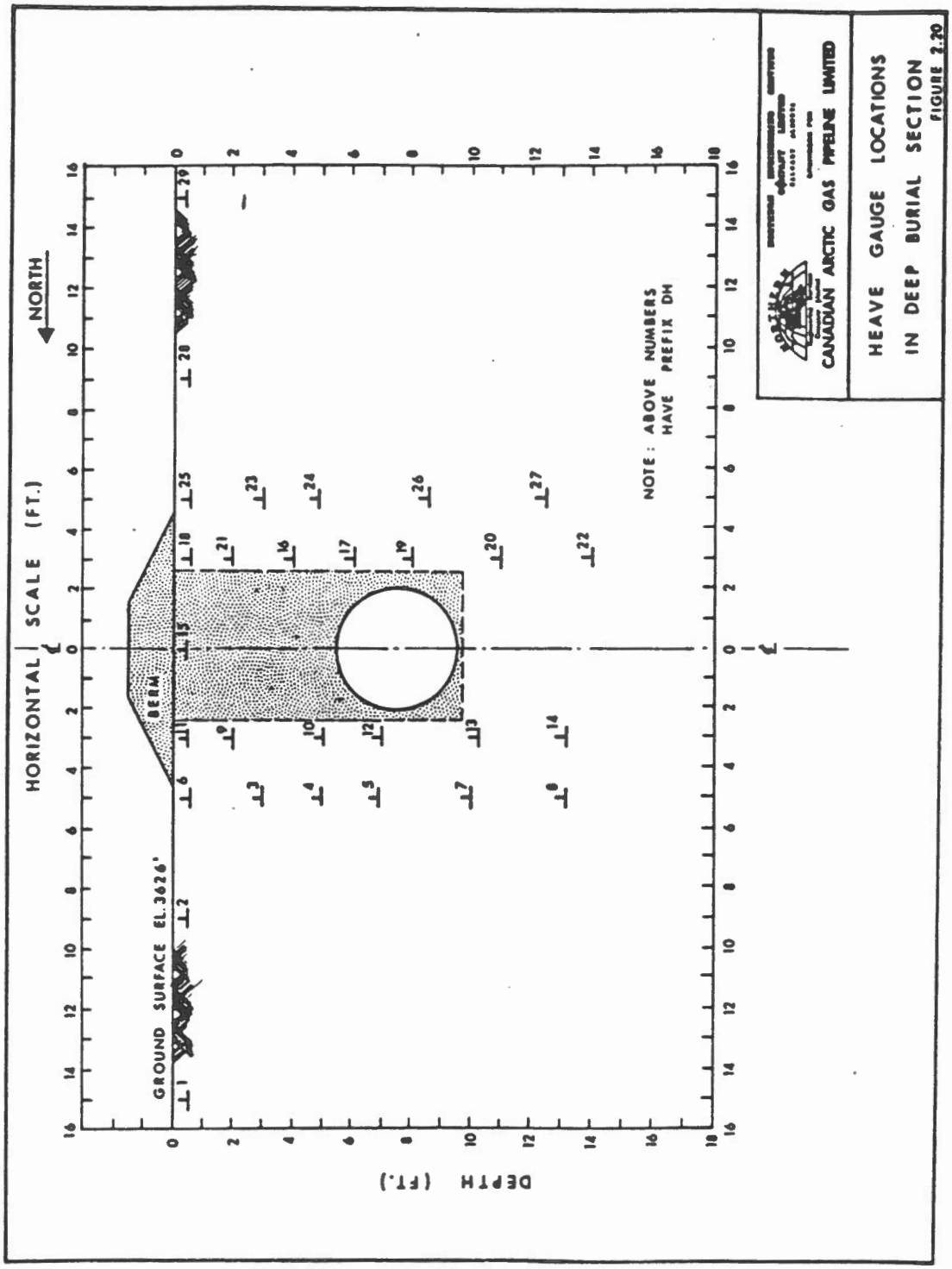
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

HEAVE GAUGE LOCATIONS
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-9



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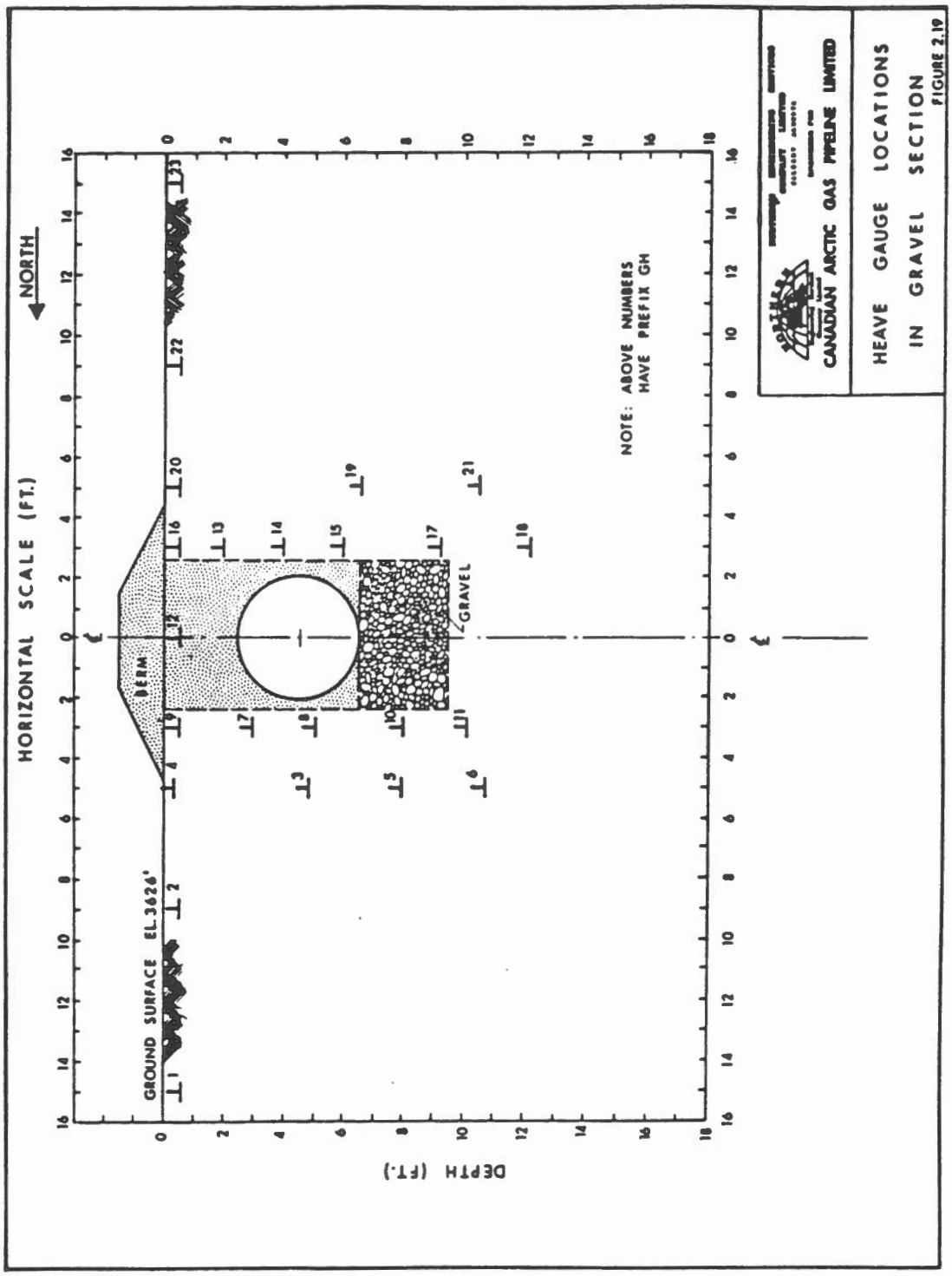
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

HEAVE GAUGE LOCATIONS
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-10



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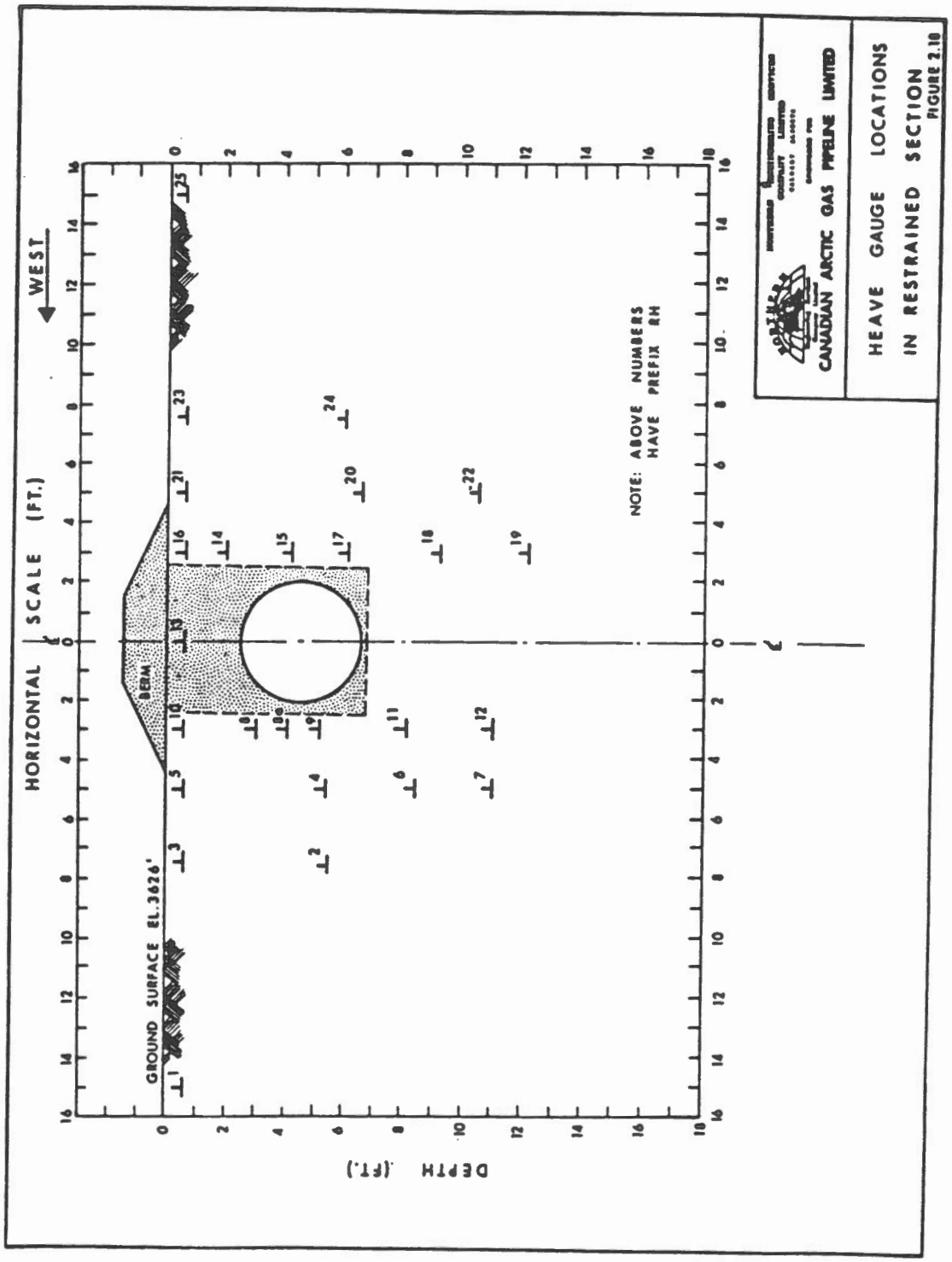
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

HEAVE GAUGE LOCATIONS
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-11



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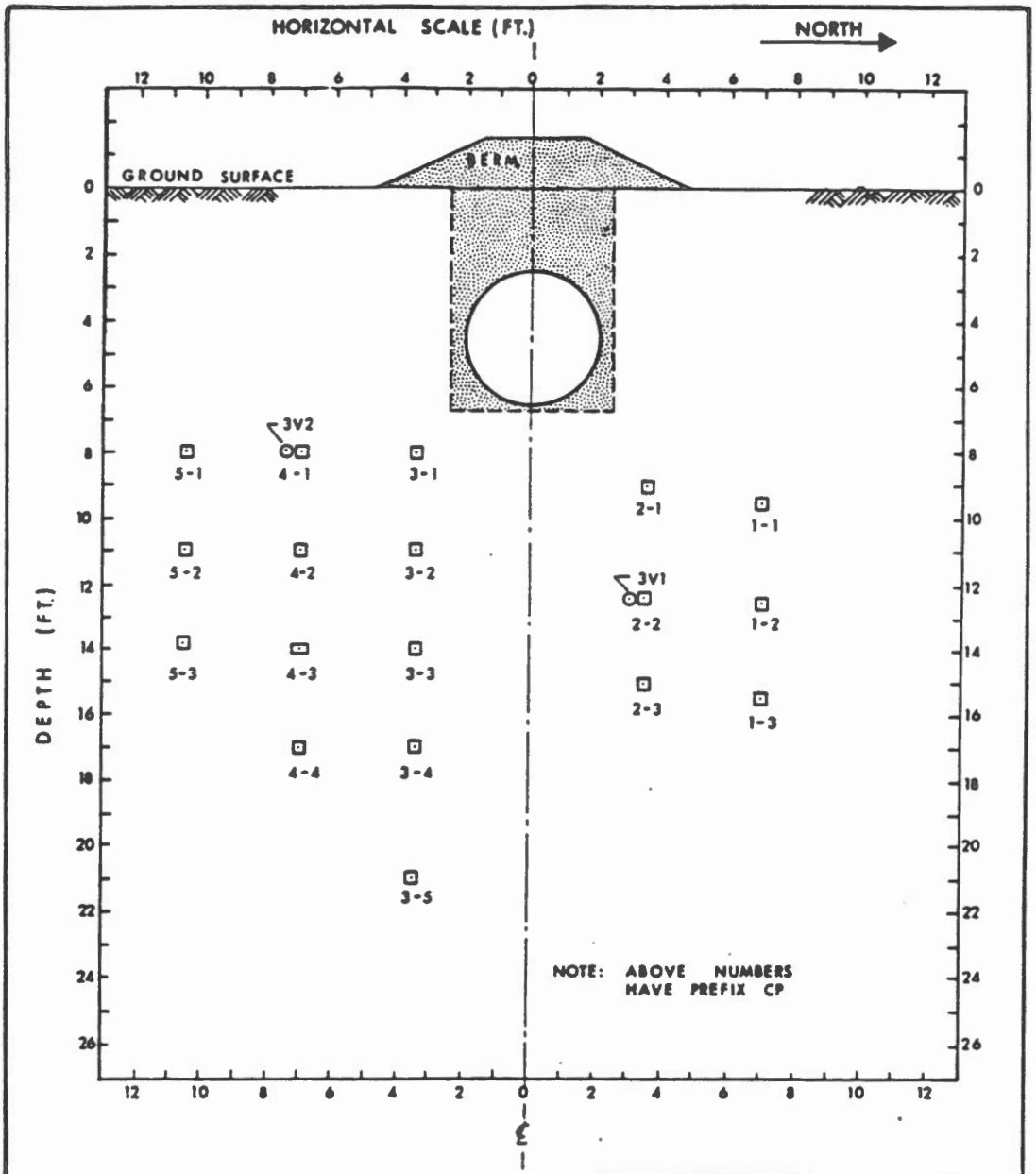
CALGARY FROST HEAVE TEST FACILITY

HEAVE GAUGE LOCATIONS
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-12



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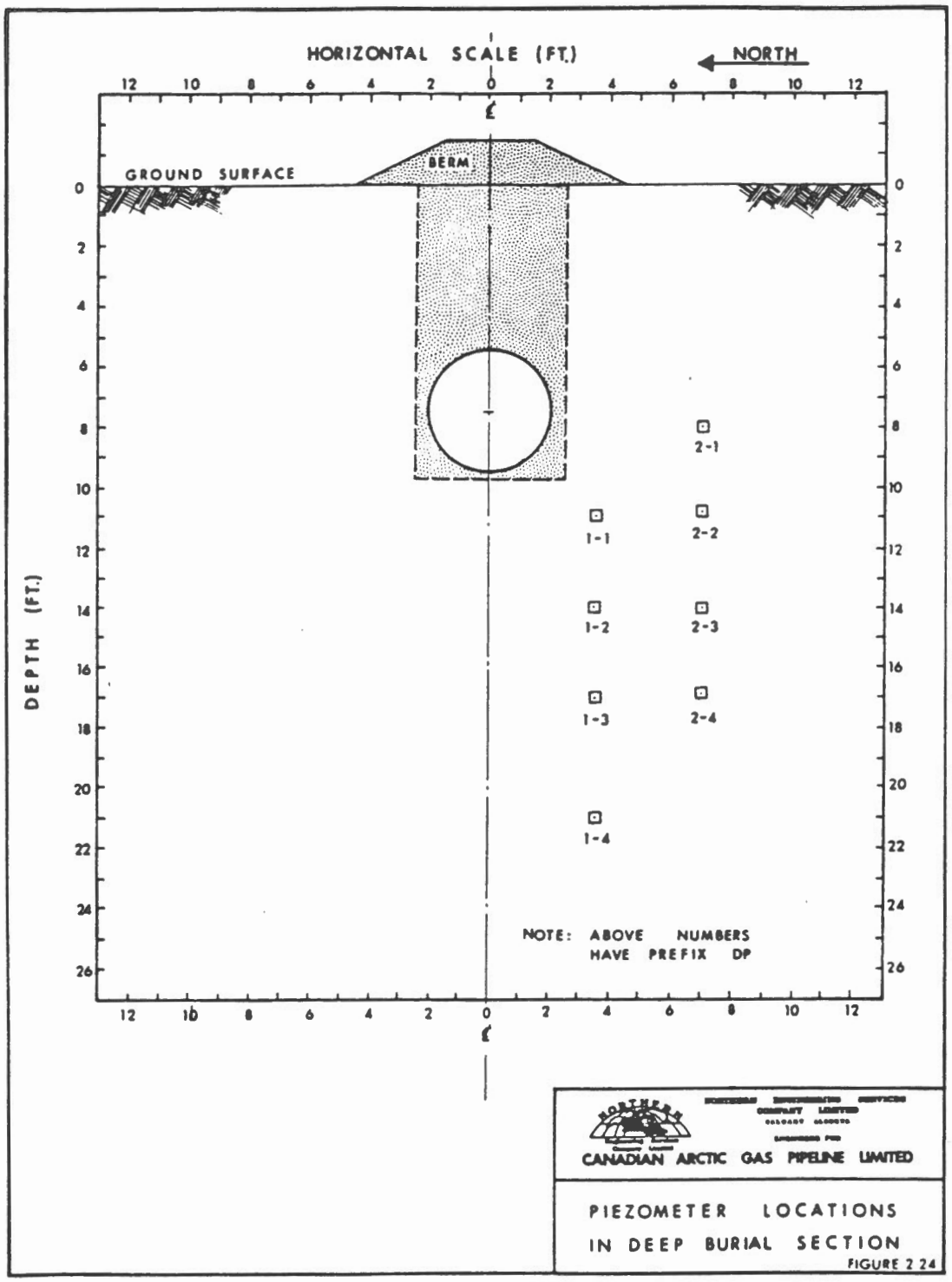
CALGARY FROST HEAVE TEST FACILITY

PIEZOMETER LOCATIONS
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-13



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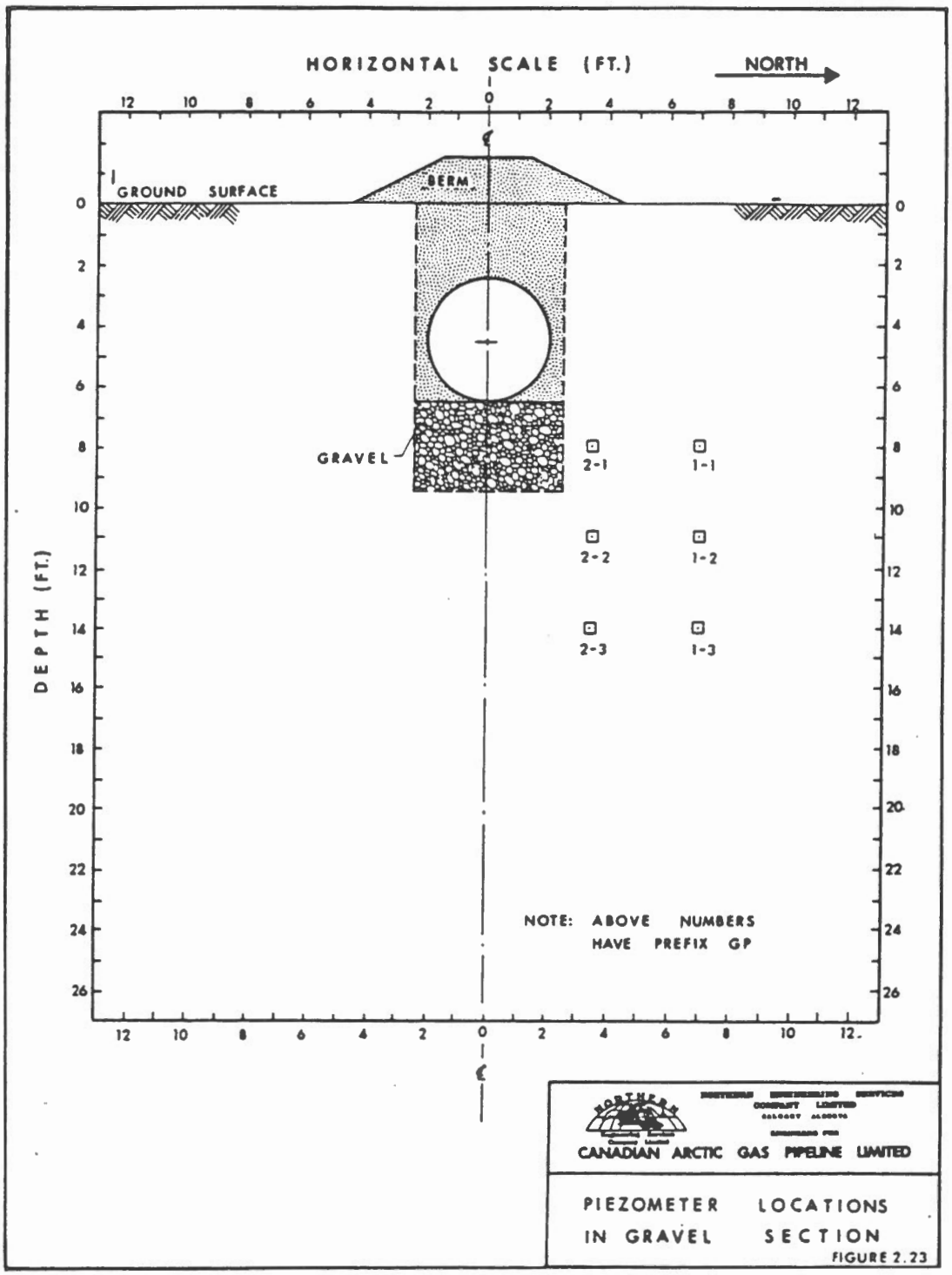
CALGARY FROST HEAVE TEST FACILITY

PIEZOMETER LOCATIONS
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-14



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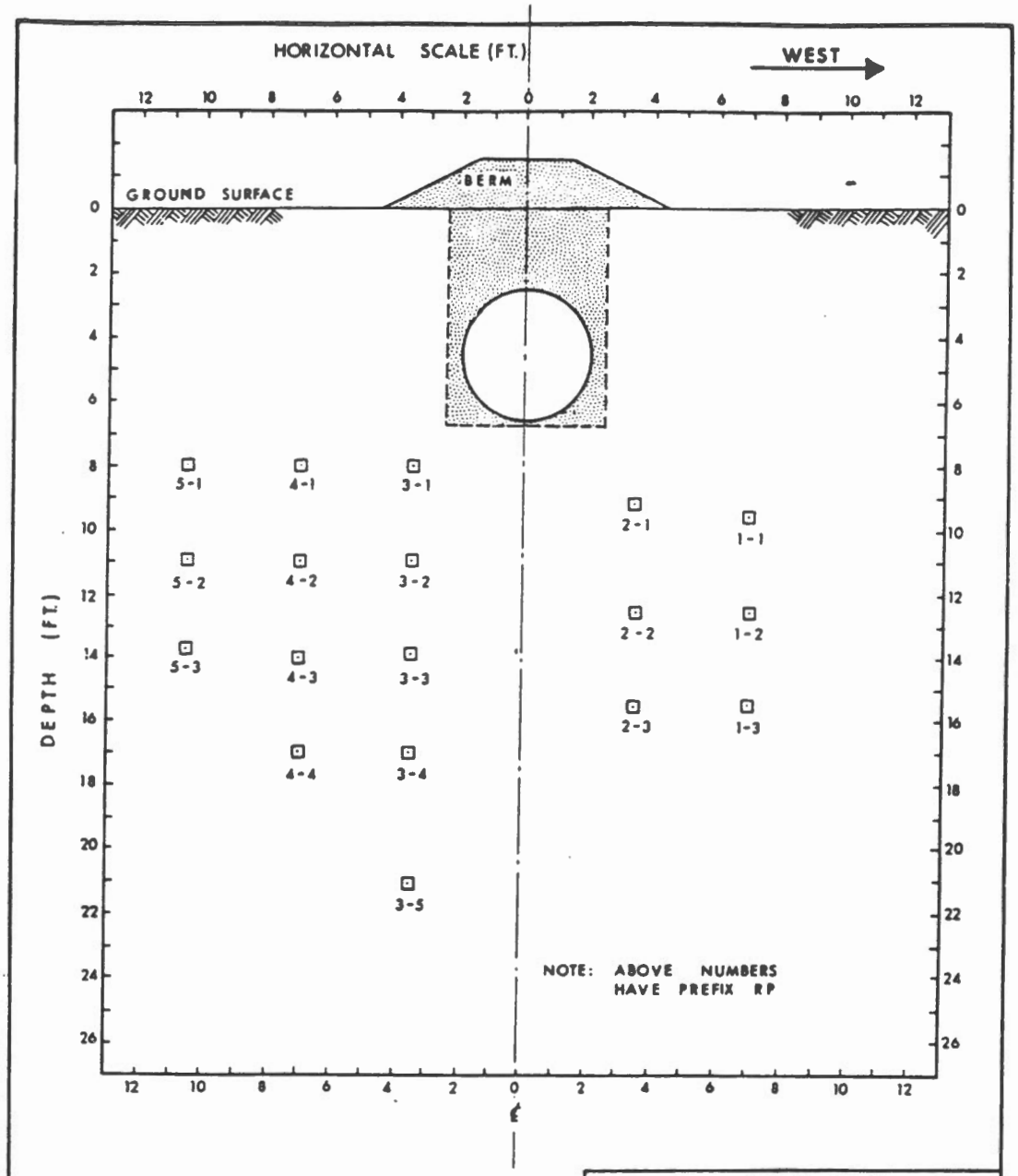
CALGARY FROST HEAVE TEST FACILITY

PIEZOMETER LOCATIONS
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-15



CANADIAN ARCTIC GAS PIPELINE LIMITED

PIEZOMETER LOCATIONS IN RESTRAINED SECTION

FIGURE 2.22

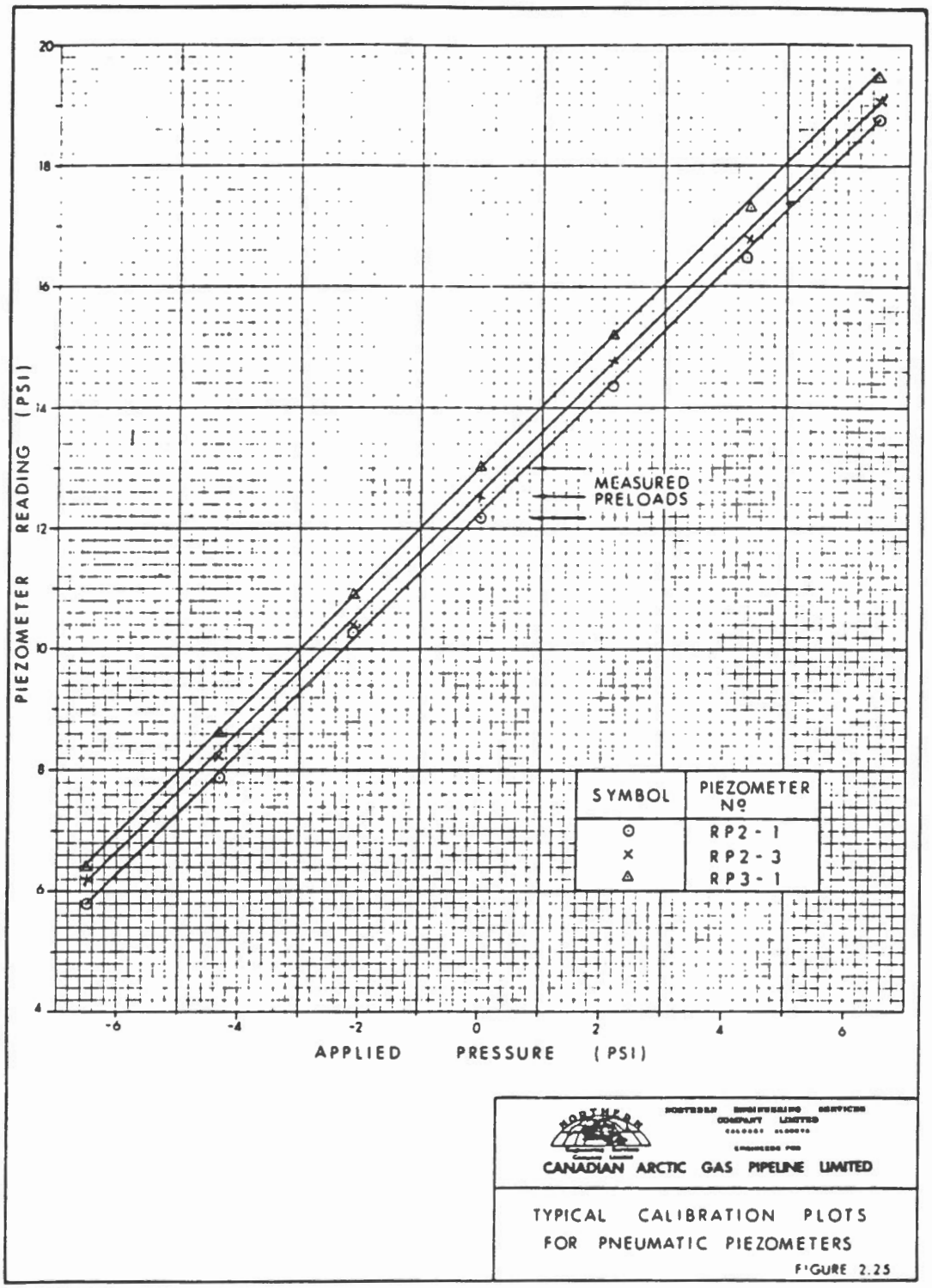
L.E.C. ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

PIEZOMETER LOCATIONS RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.3-16



CANADIAN ARCTIC GAS PIPELINE LIMITED

TYPICAL CALIBRATION PLOTS FOR PNEUMATIC PIEZOMETERS

FIGURE 2.25

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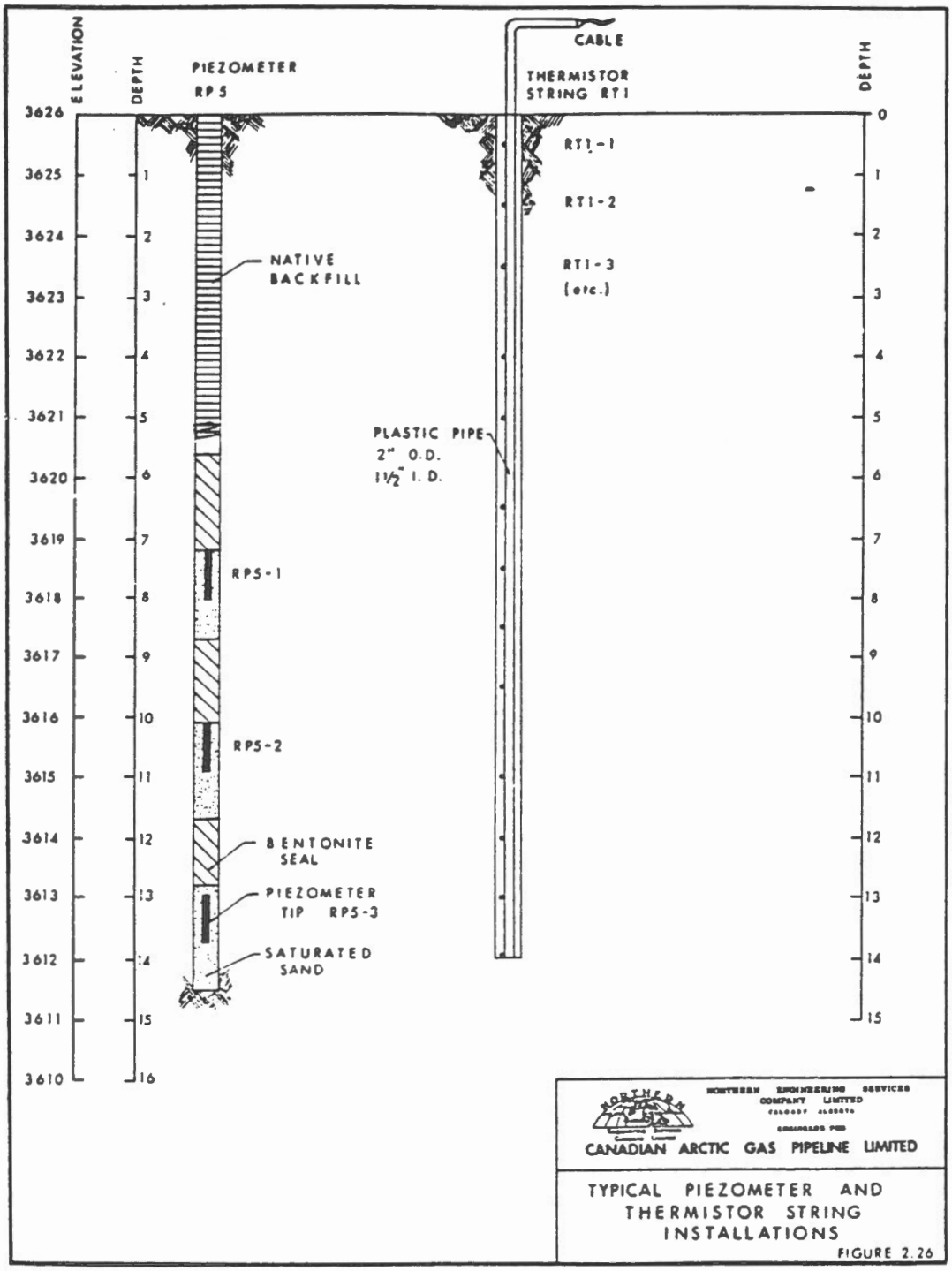
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

TYPICAL CALIBRATION PLOTS FOR PNEUMATIC PIEZOMETERS

PREPARED BY L. CARLSON

FIGURE 2.3-17



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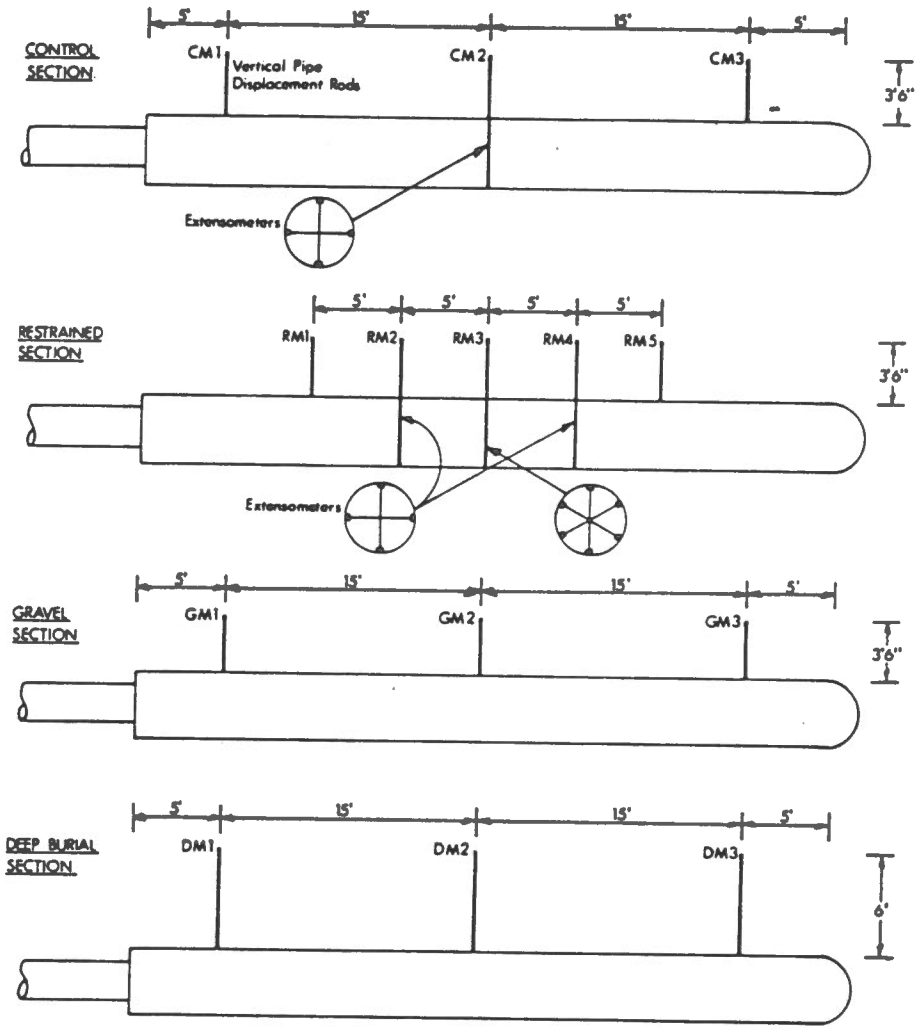
CALGARY FROST HEAVE TEST FACILITY

TYPICAL PIEZOMETER AND THERMISTOR STRING INSTALLATION

PREPARED BY L. CARLSON

FIGURE 2.3-18



NORTHERN ENGINEERING SERVICES COMPANY LIMITED

CANADIAN ARCTIC GAS PIPELINE LIMITED

SCHEMATIC LOCATION OF PIPE MOVEMENT GAUGES

FIGURE 2 27

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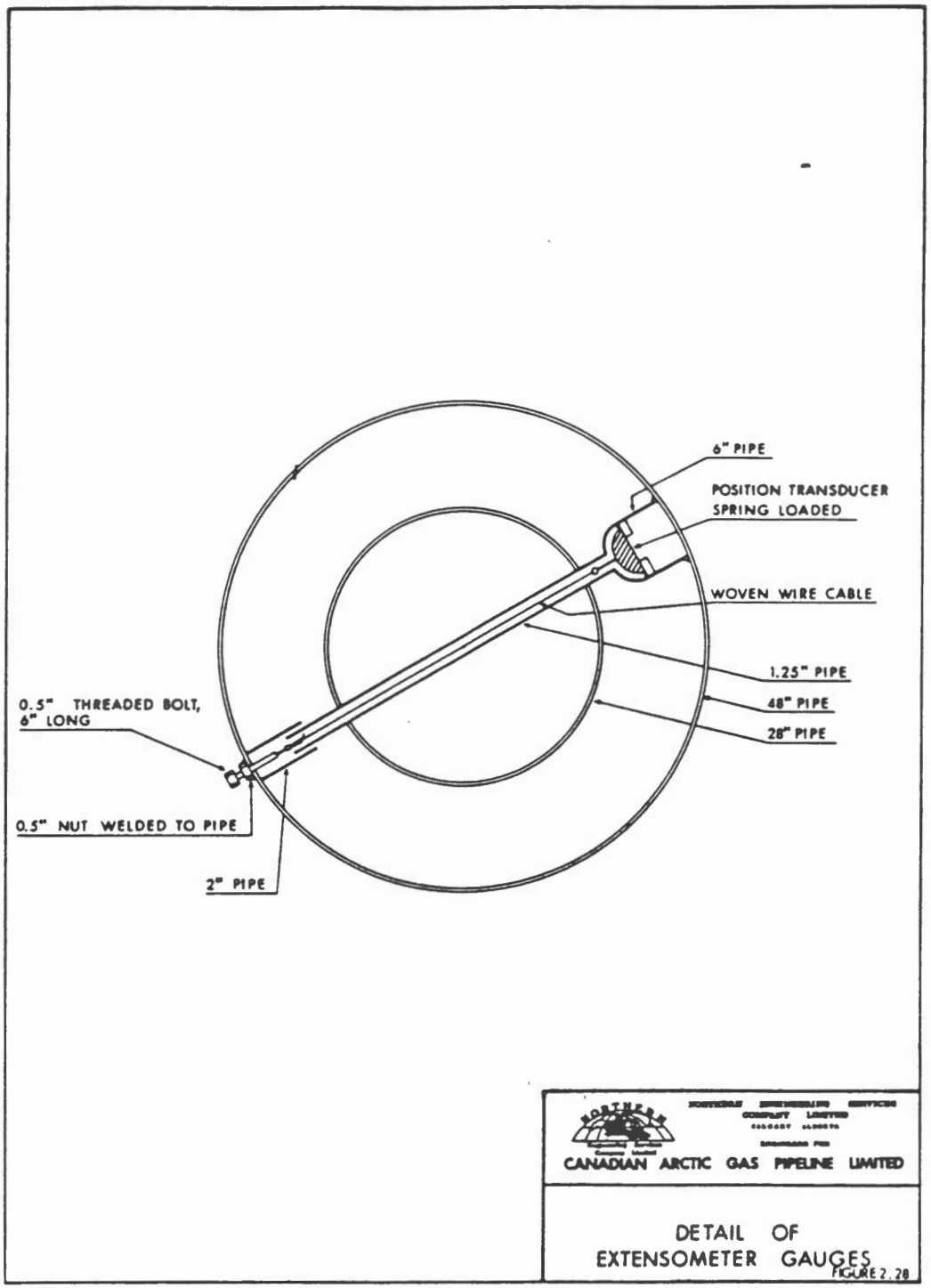
CALGARY FROST HEAVE TEST FACILITY

SCHEMATIC LOCATION OF PIPE MOVEMENT GAUGES

PREPARED BY L. CARLSON

FIGURE 2.3-19



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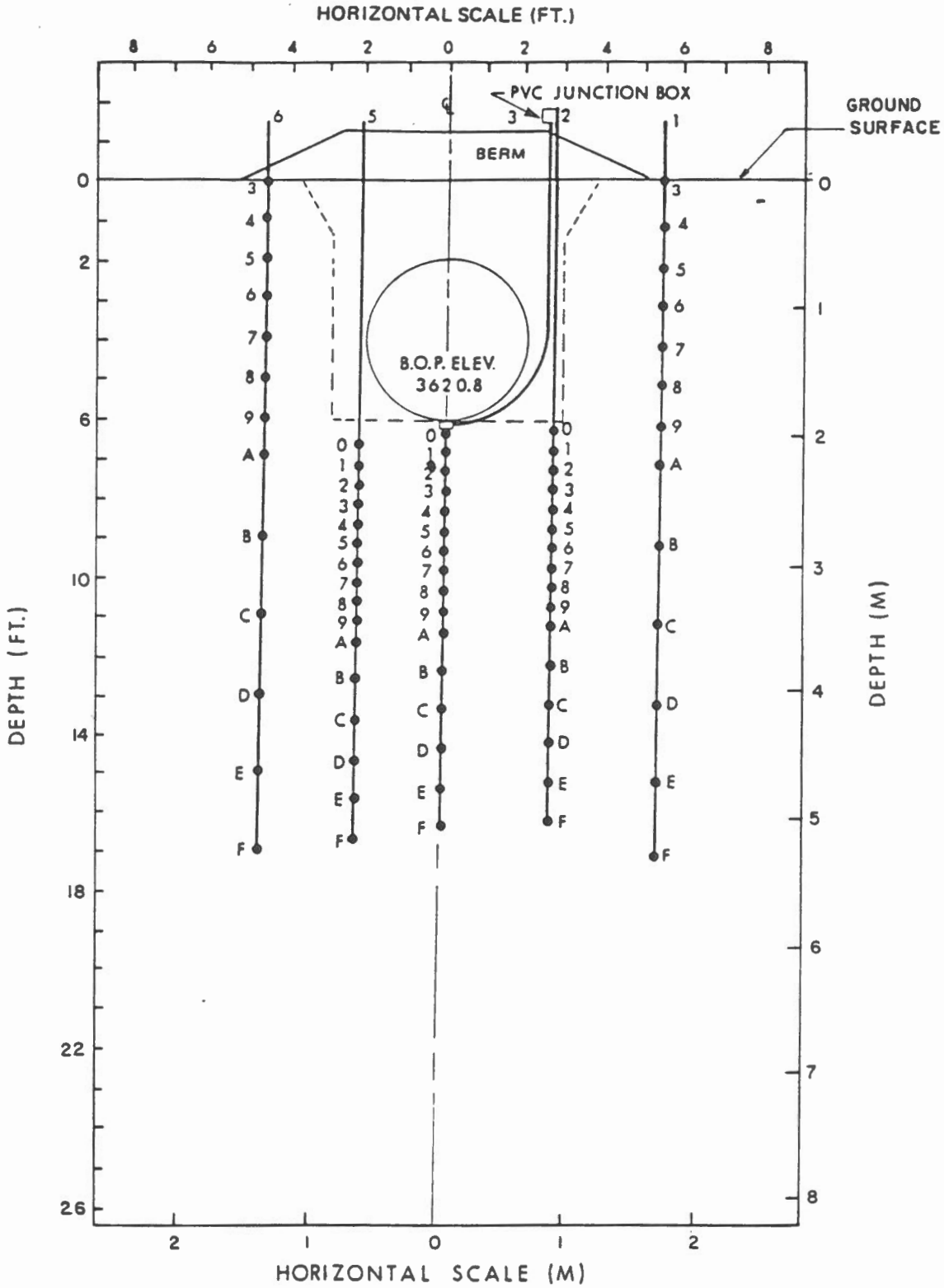
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

DETAIL OF
EXTENSOMETER GAUGES

PREPARED BY L. CARLSON

FIGURE 2.3-20



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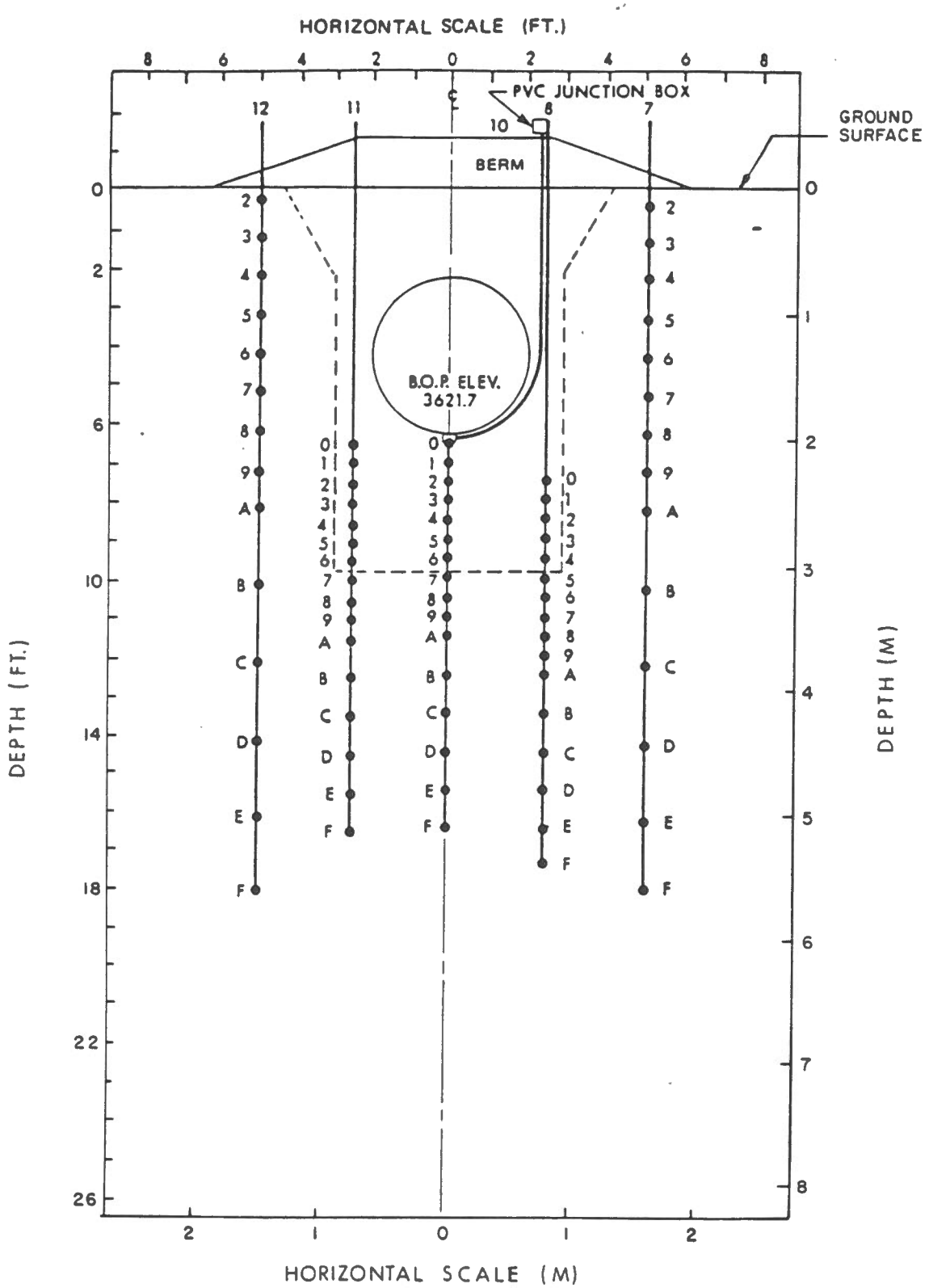
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

SENSISTOR LOCATIONS
INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 2.4-1



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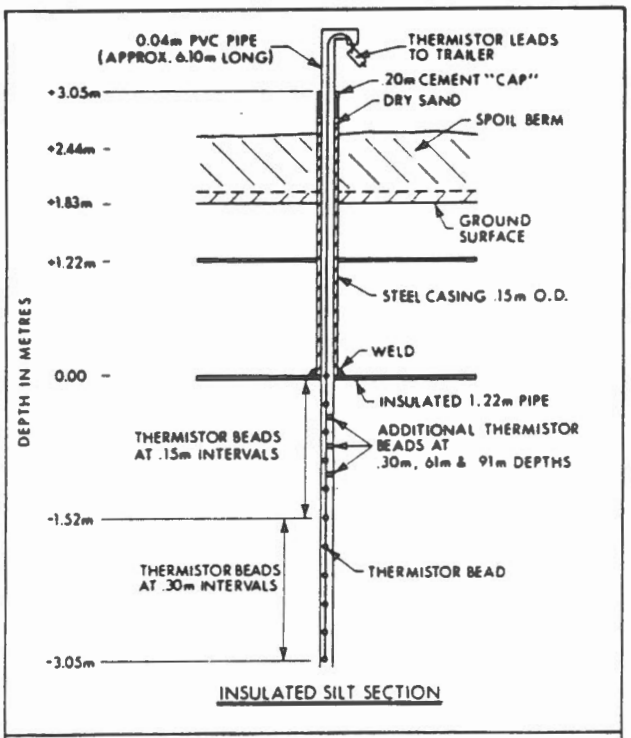
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

SENSISTOR LOCATIONS
INSULATED GRAVEL SECTION

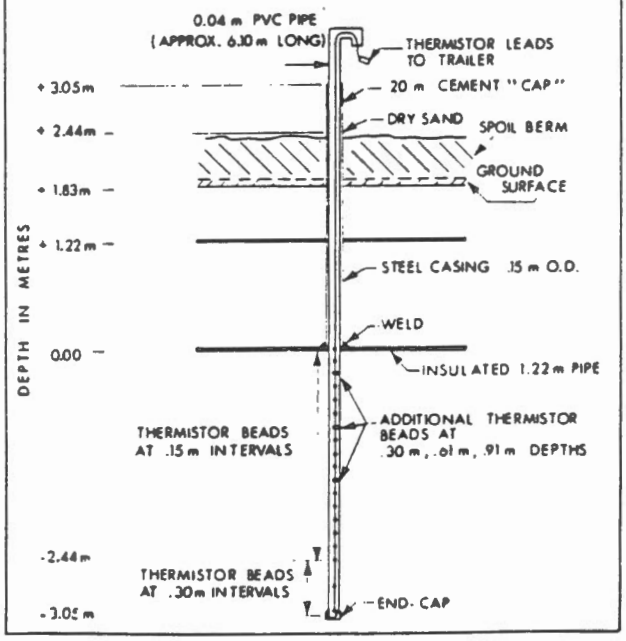
PREPARED BY L. CARLSON

FIGURE 2.4-2

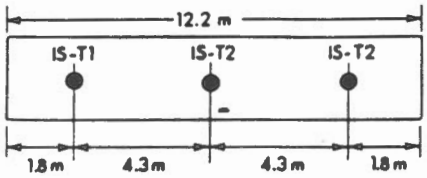


INSULATED SILT SECTION

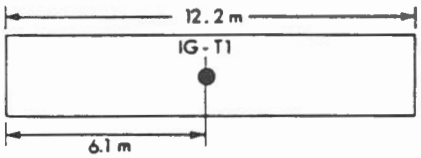
INSULATED GRAVEL SECTION



PLAN VIEW
INSULATED SILT SECTION



PLAN VIEW
INSULATED GRAVEL SECTION



AFTER FOOTHILLS PIPE LINES (YUKON) LTD.

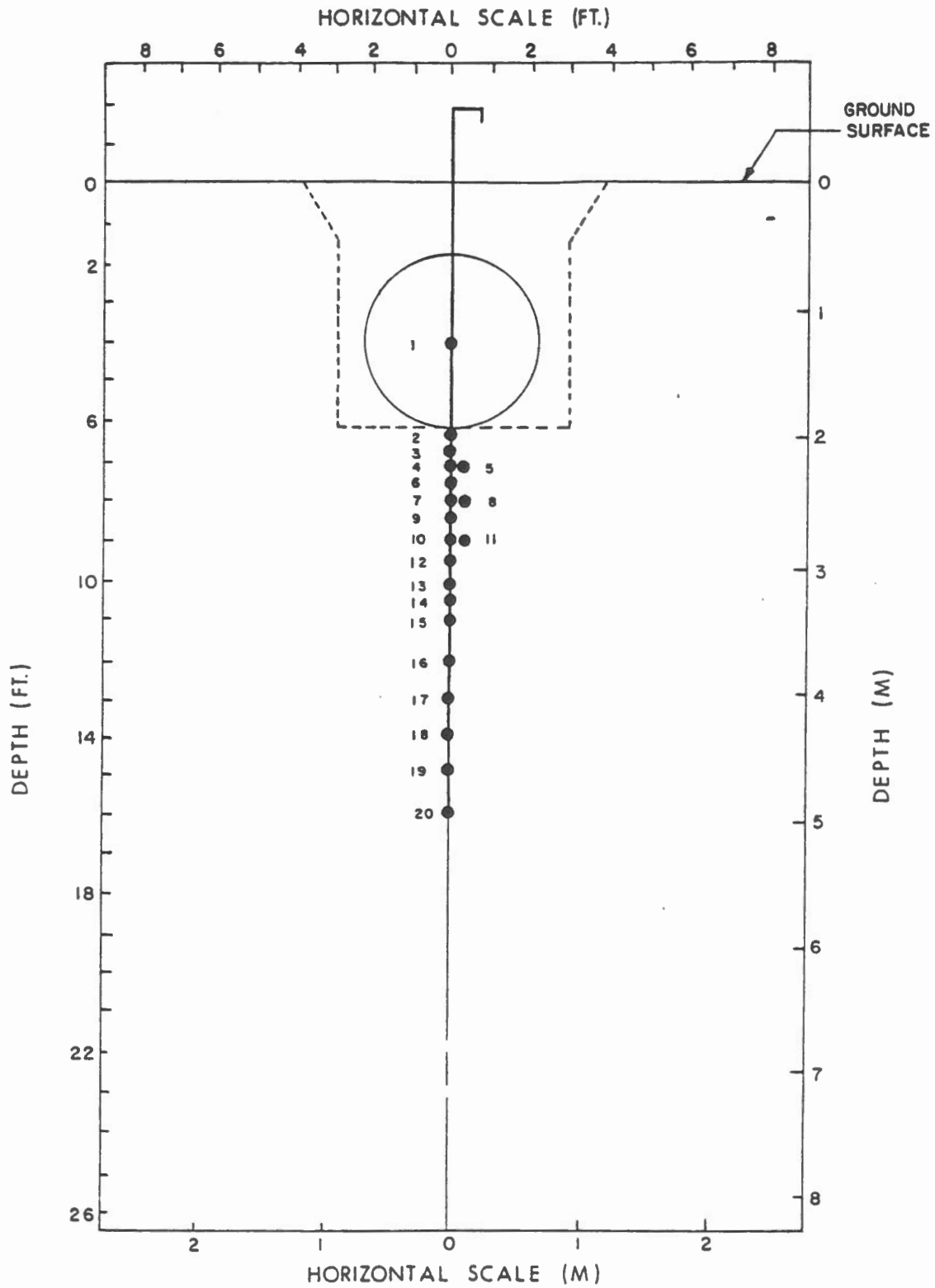
L.E.C.
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

THERMISTOR STRING INSTALLATION

PREPARED BY L. CARLSON

FIGURE 2.4-3



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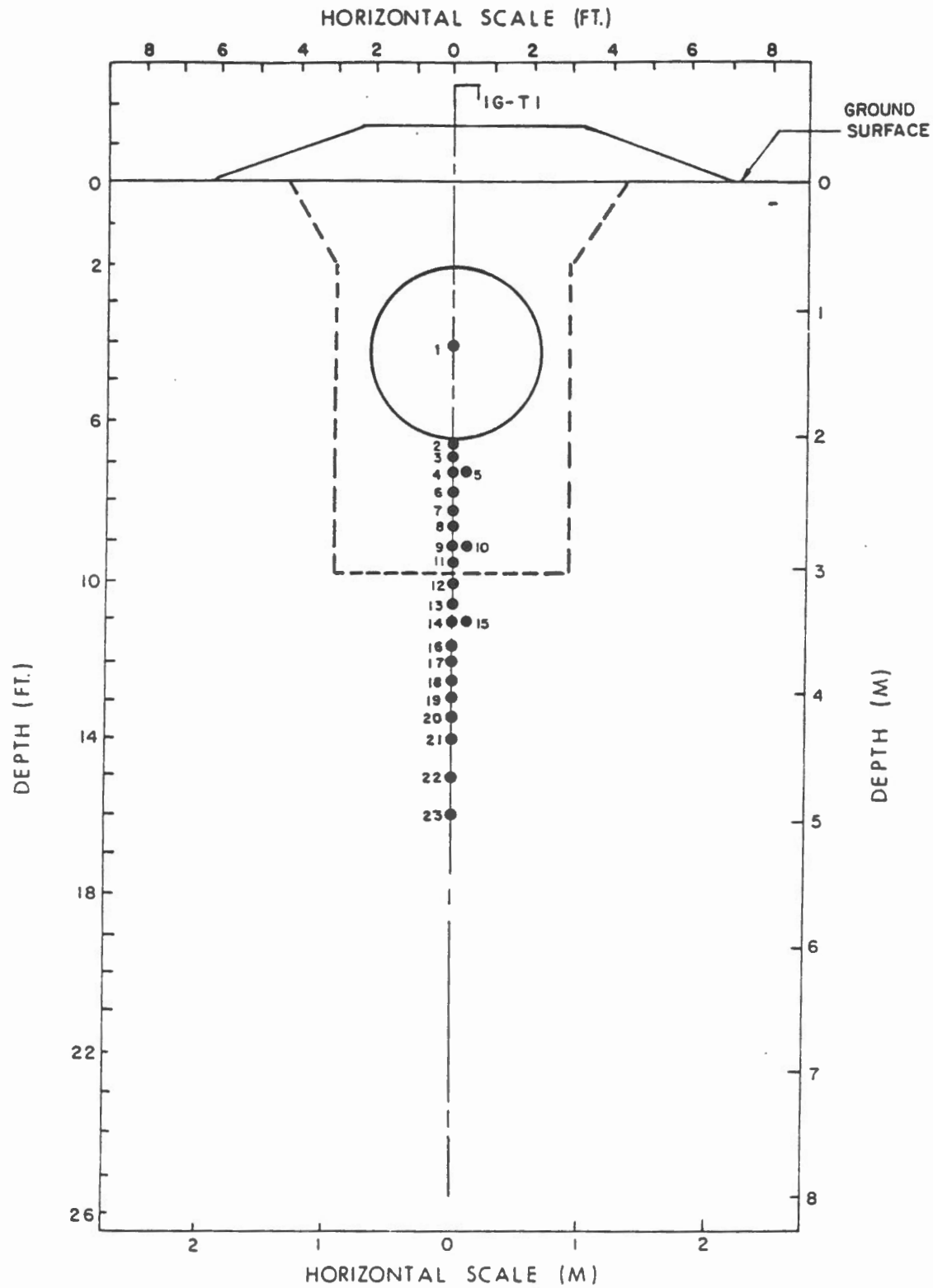
CALGARY FROST HEAVE TEST FACILITY

THERMISTOR LOCATIONS
INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 2.4-4



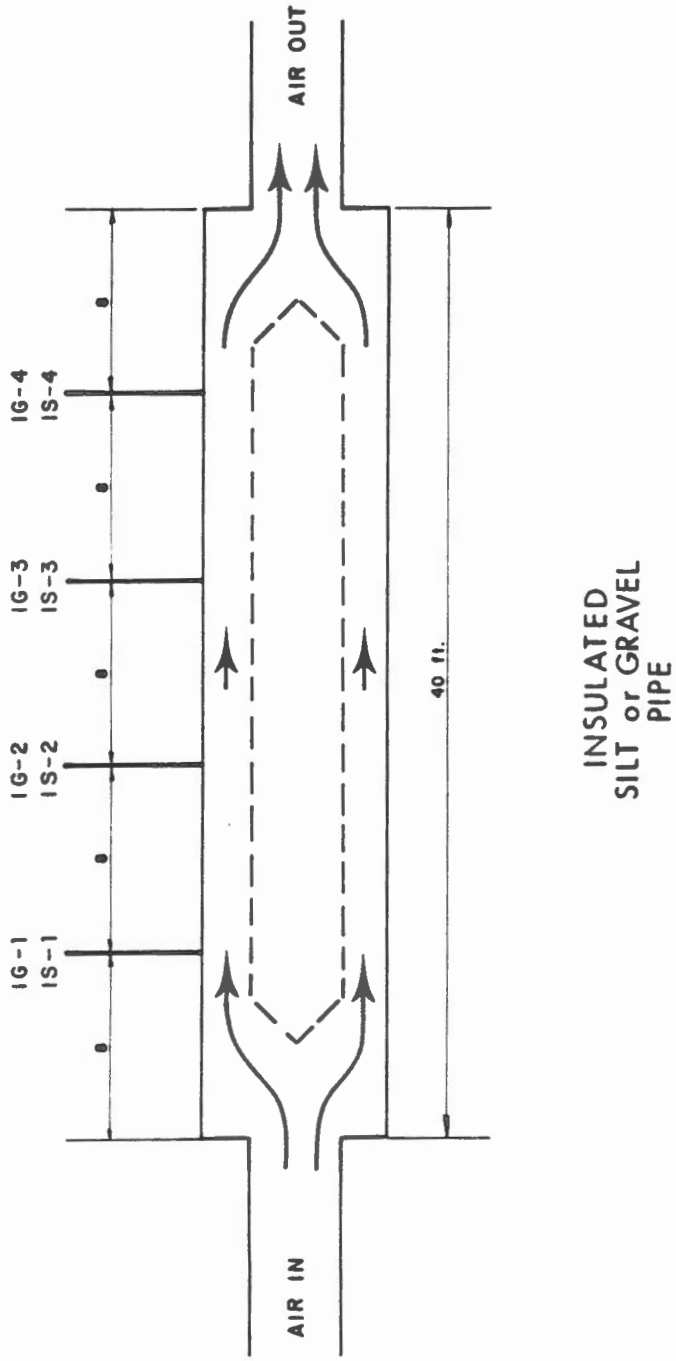
L.E.C.
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

THERMISTOR LOCATIONS
INSULATED GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.4-5



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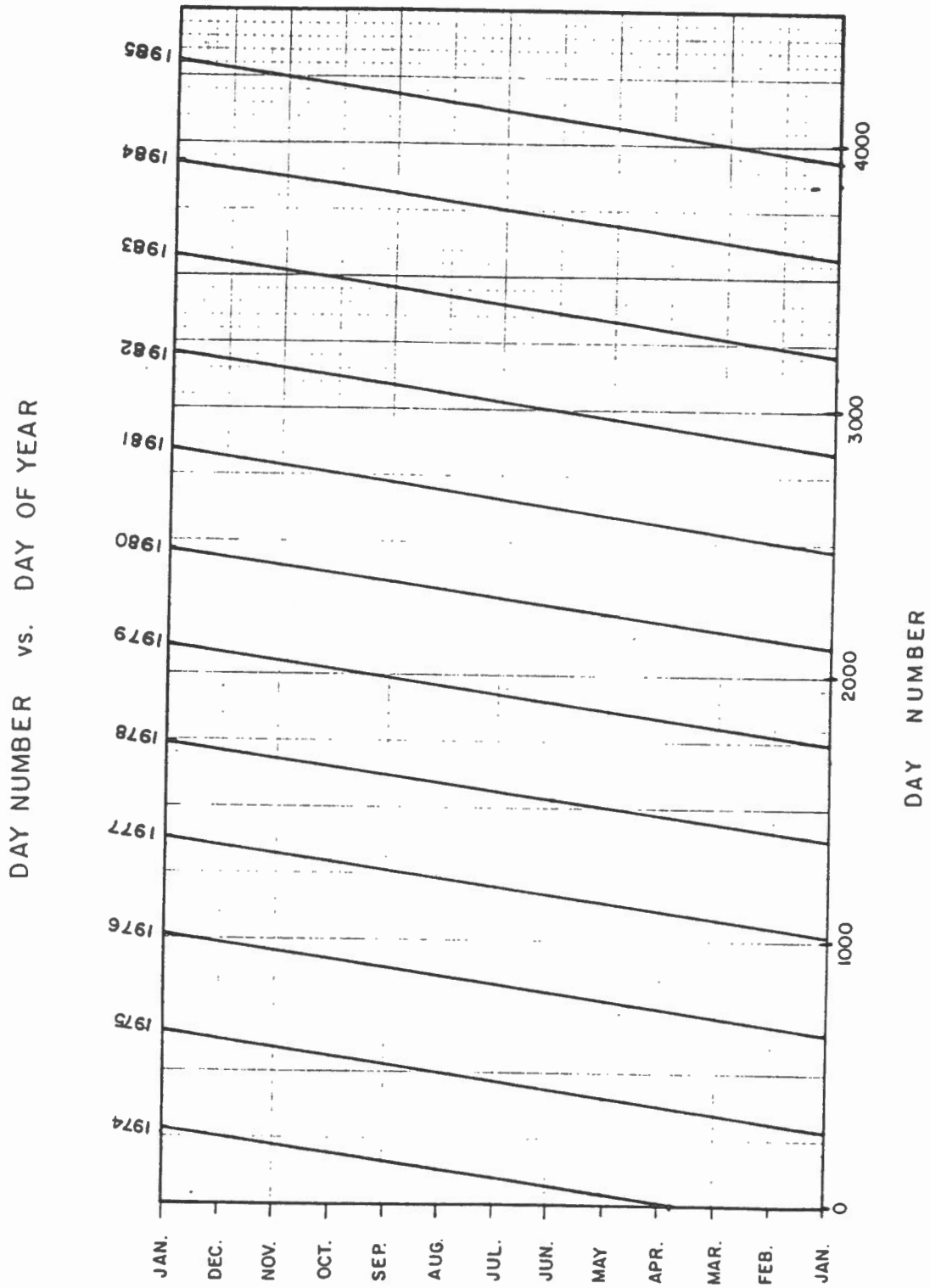
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

SCHEMATIC LOCATION
OF
PIPE MOVEMENT GAUGES

PREPARED BY L. CARLSON

FIGURE 2.4-6



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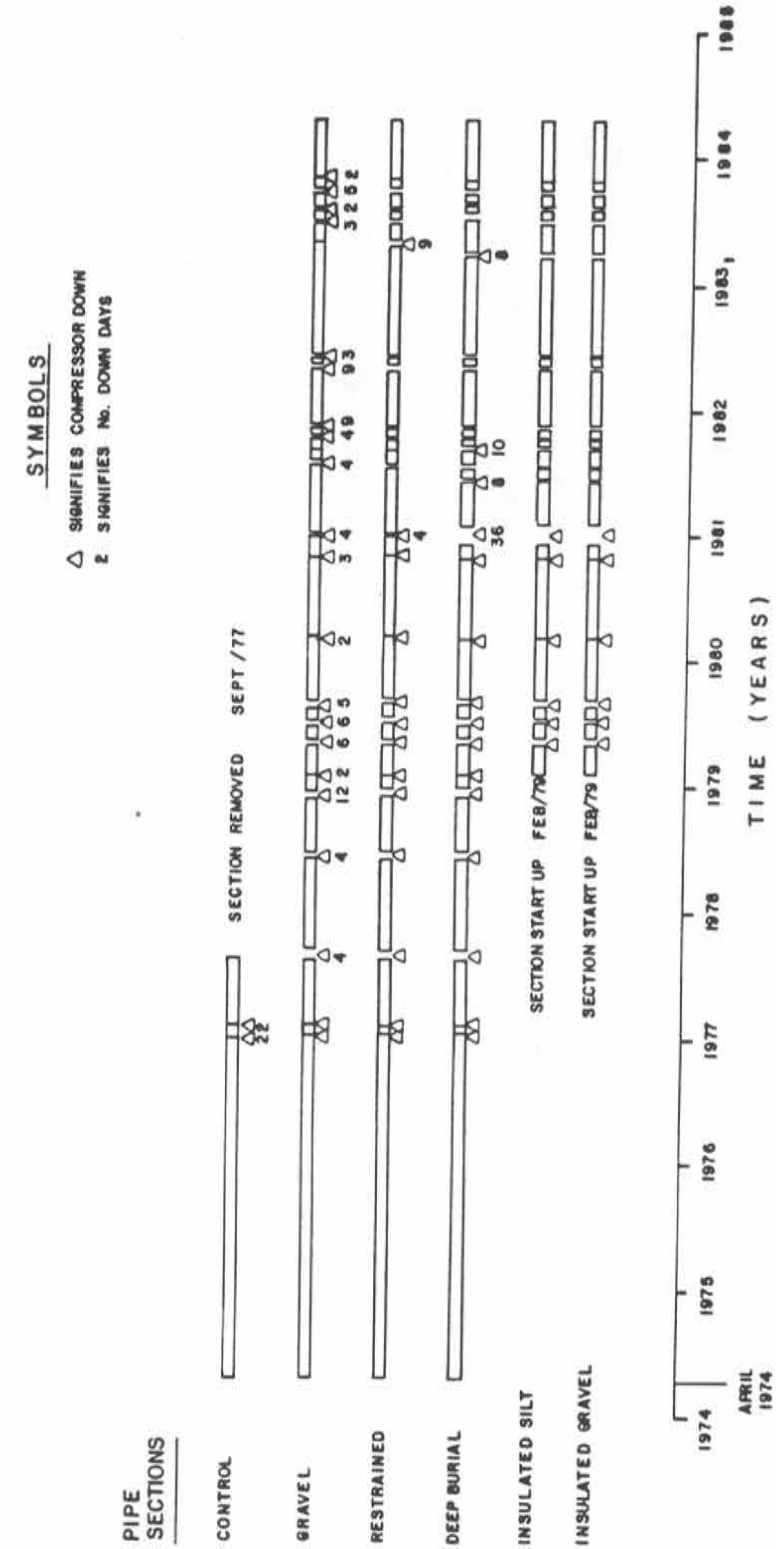
CALGARY FROST HEAVE TEST FACILITY

DAY NUMBER
VERSUS
DAY OF YEAR

PREPARED BY L. CARLSON

FIGURE 2.6-1



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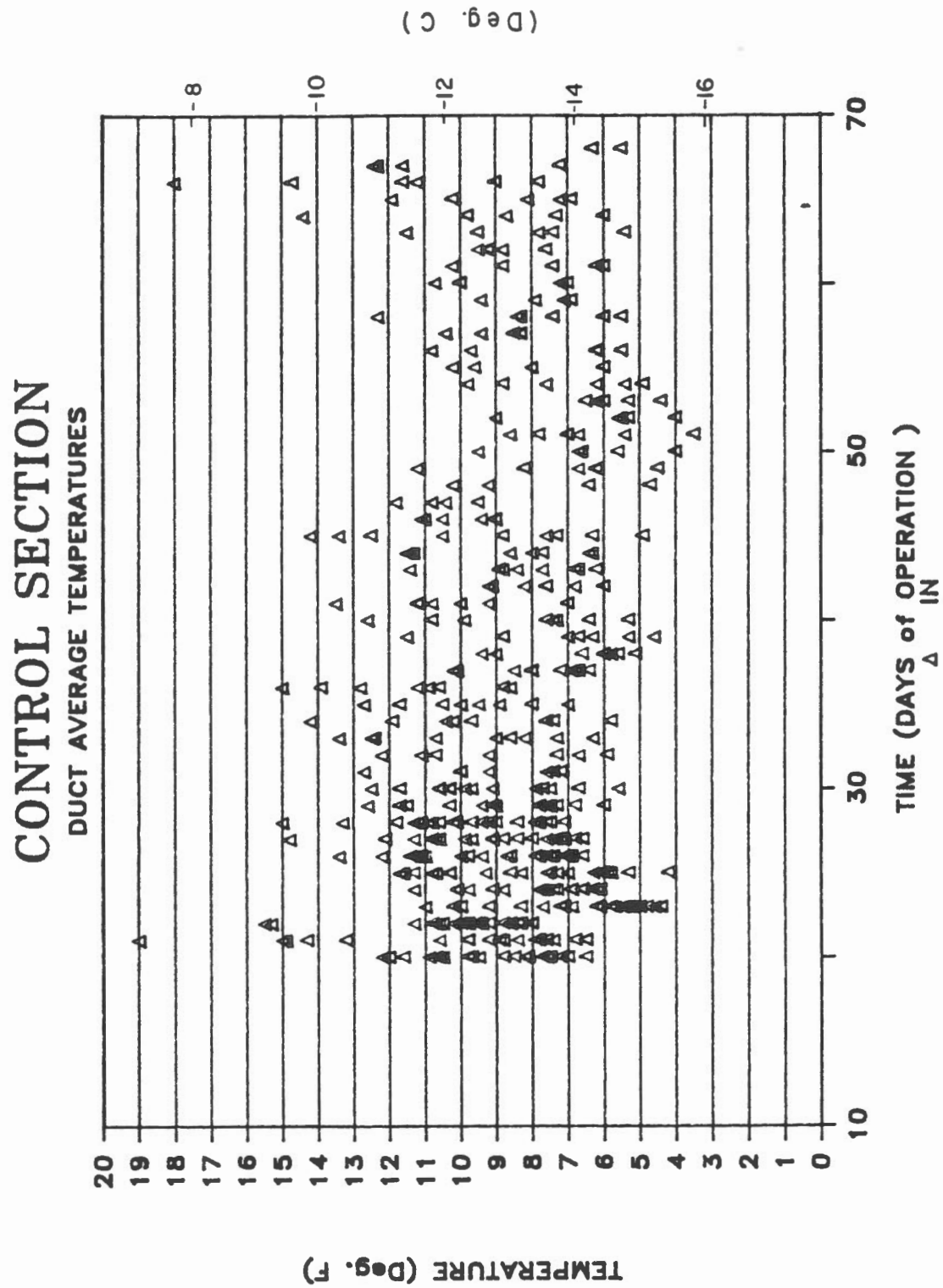
CALGARY FROST HEAVE TEST FACILITY

OPERATIONAL RECORD

PREPARED BY L. CARLSON

FIGURE 2.6-2



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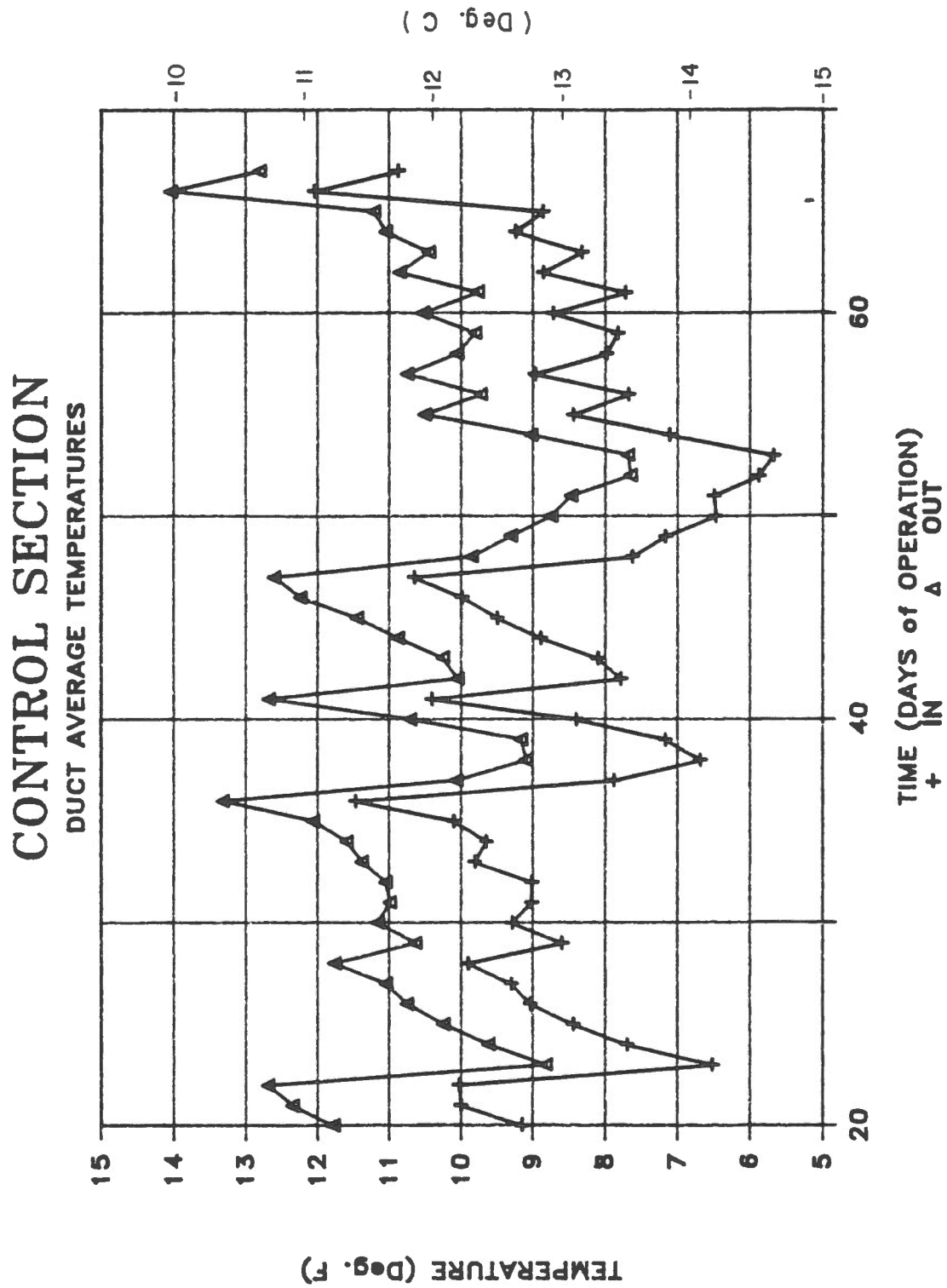
CALGARY FROST HEAVE TEST FACILITY

CONTROL SECTION
DUCT AVERAGE TEMPERATURES
(IN, DAY 20 to 66)

PREPARED BY L. CARLSON

FIGURE 2.6-3



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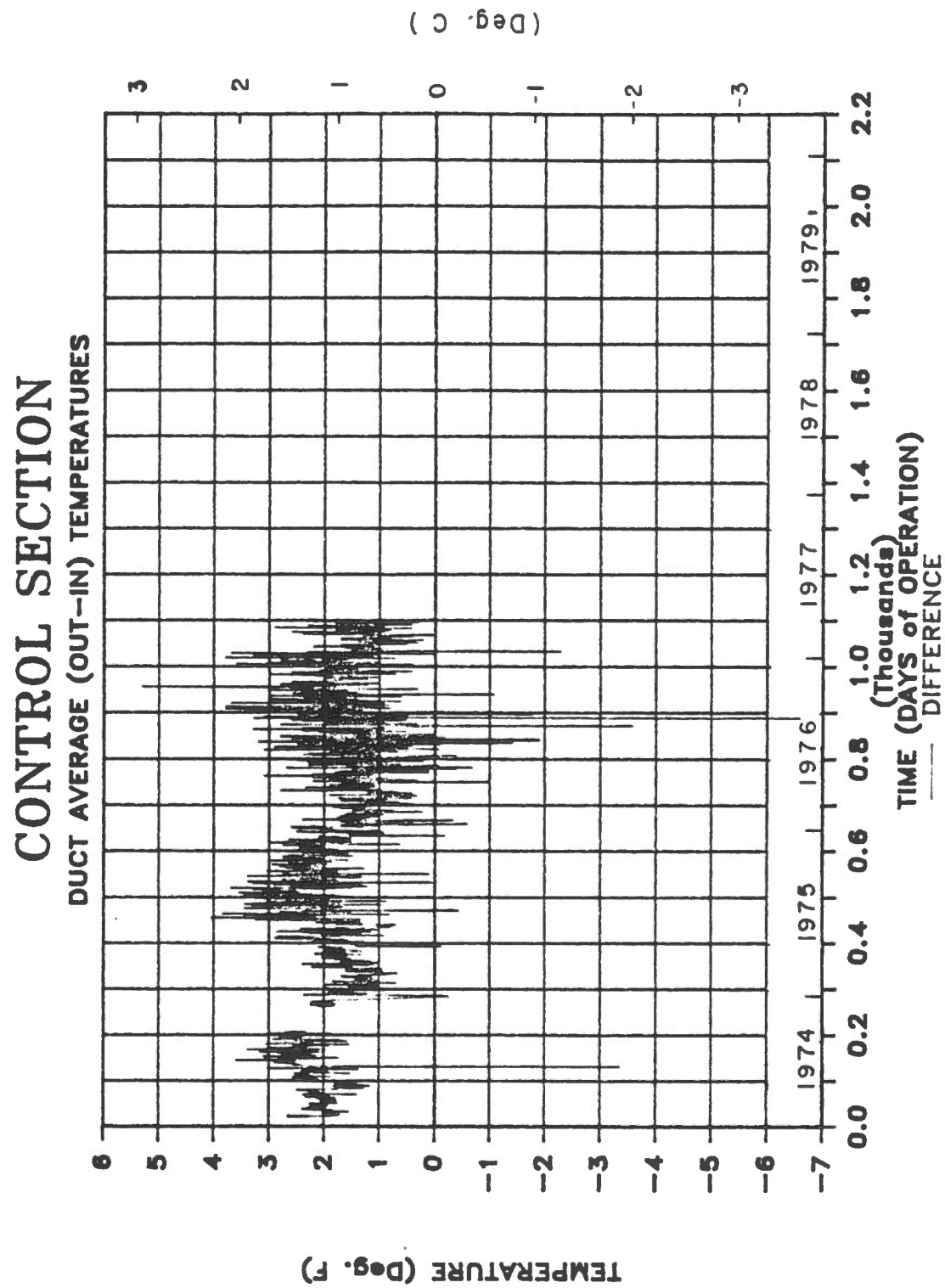
CALGARY FROST HEAVE TEST FACILITY

CONTROL SECTION
DUCT AVERAGE TEMPERATURES
(OUT, DAY 20 to 66)

PREPARED BY L. CARLSON

FIGURE 2.6-4



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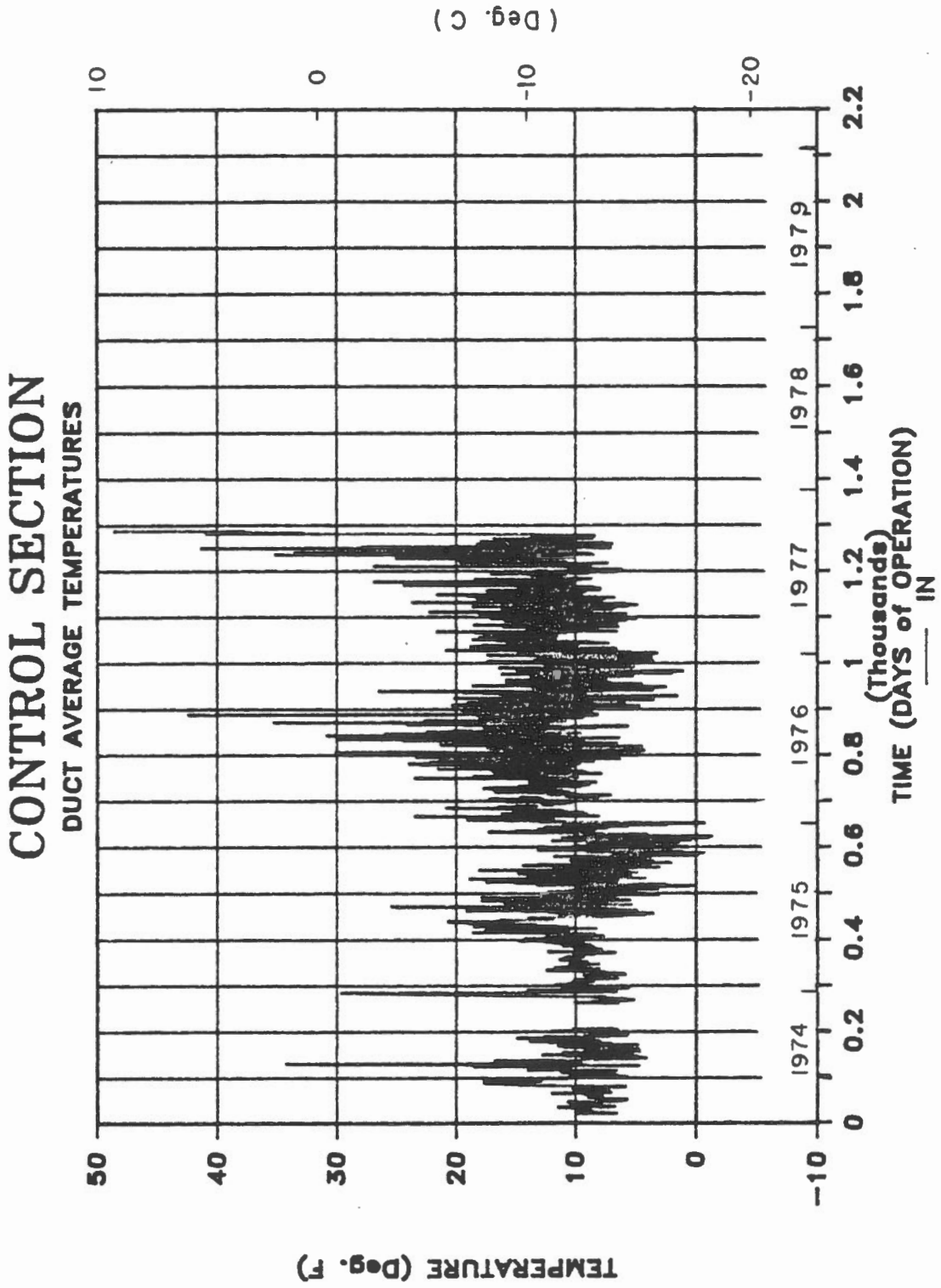
CALGARY FROST HEAVE TEST FACILITY

CONTROL SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-5



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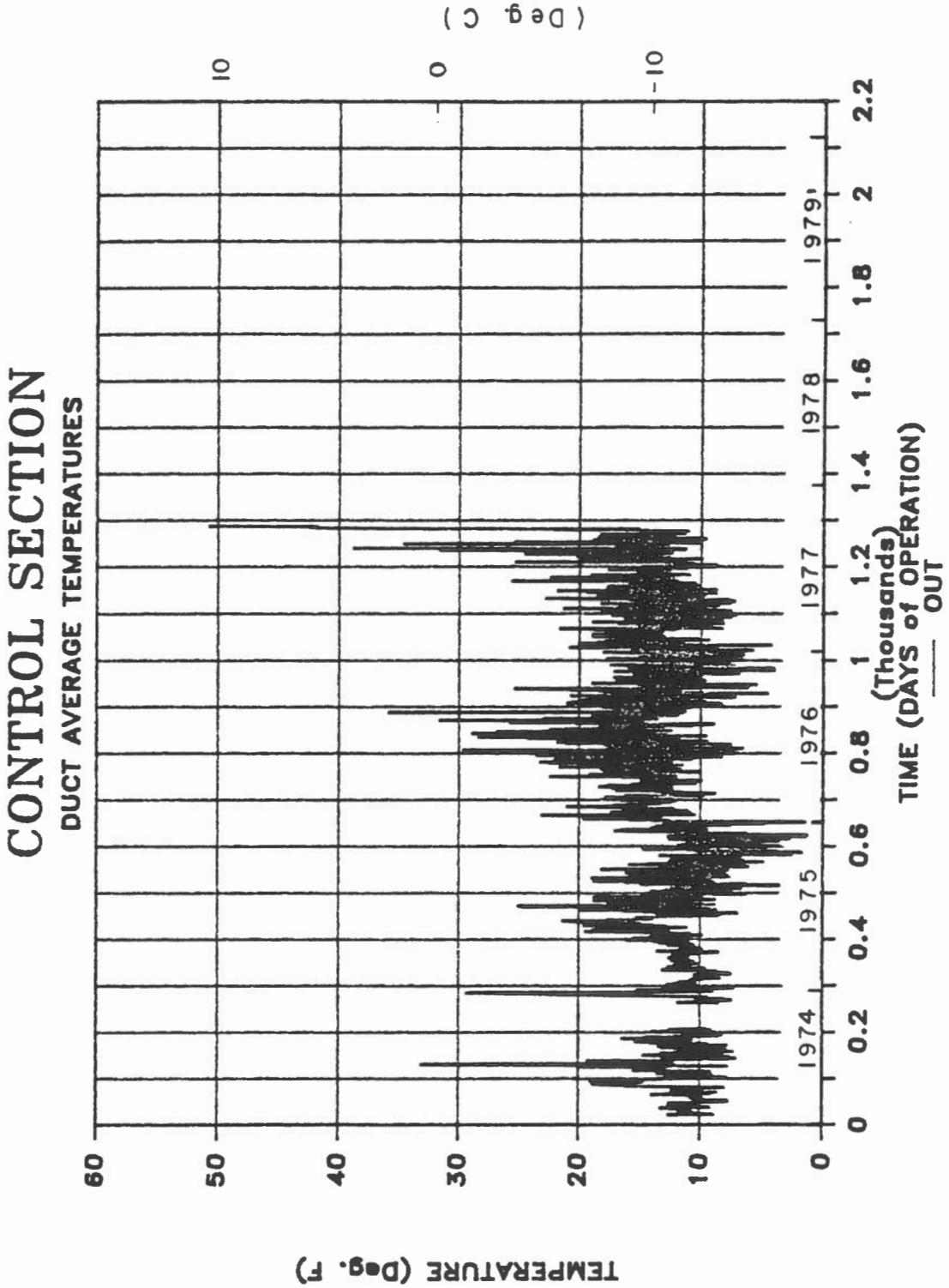
CALGARY FROST HEAVE TEST FACILITY

CONTROL SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-6



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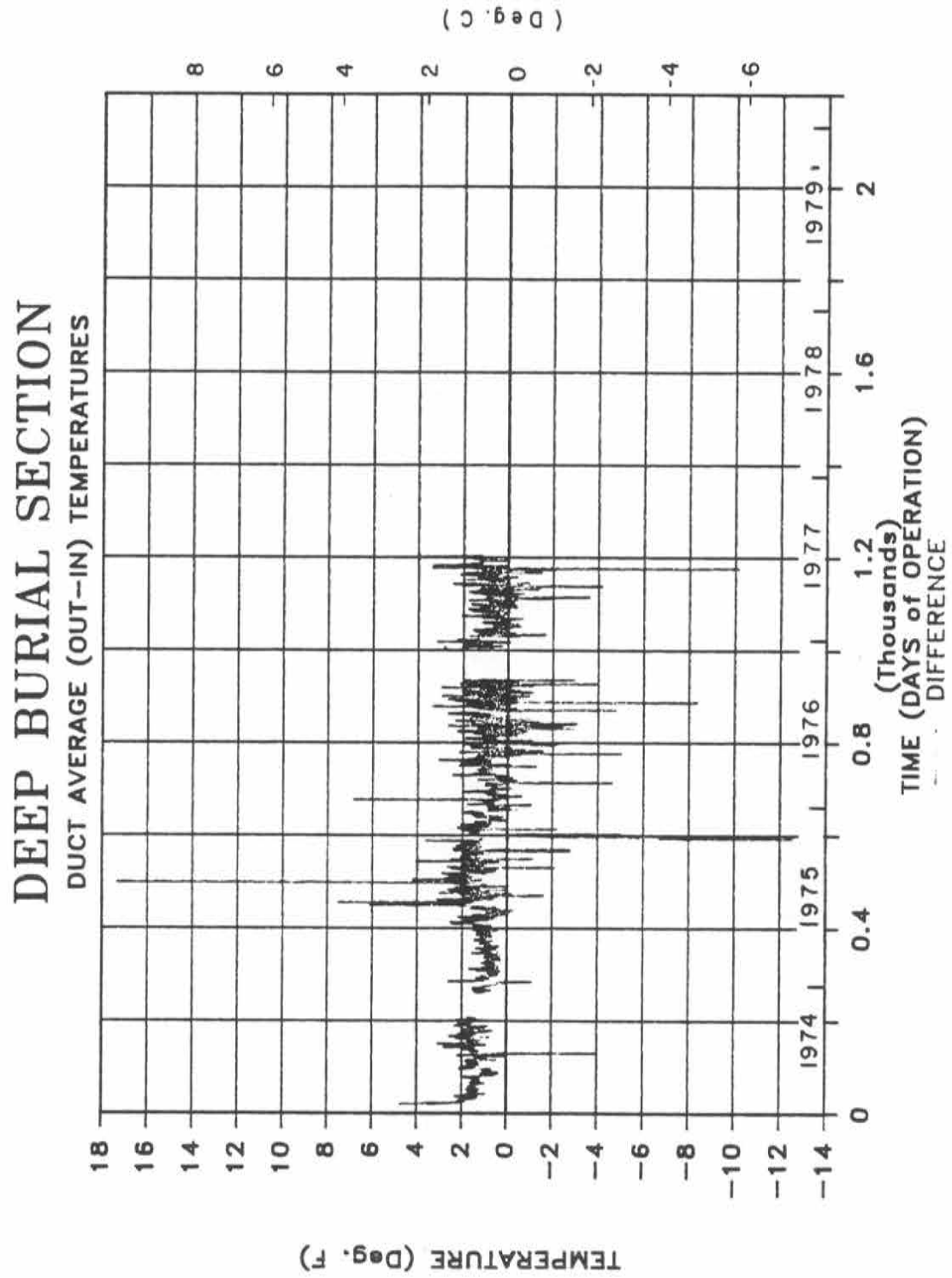
CALGARY FROST HEAVE TEST FACILITY

CONTROL SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-7



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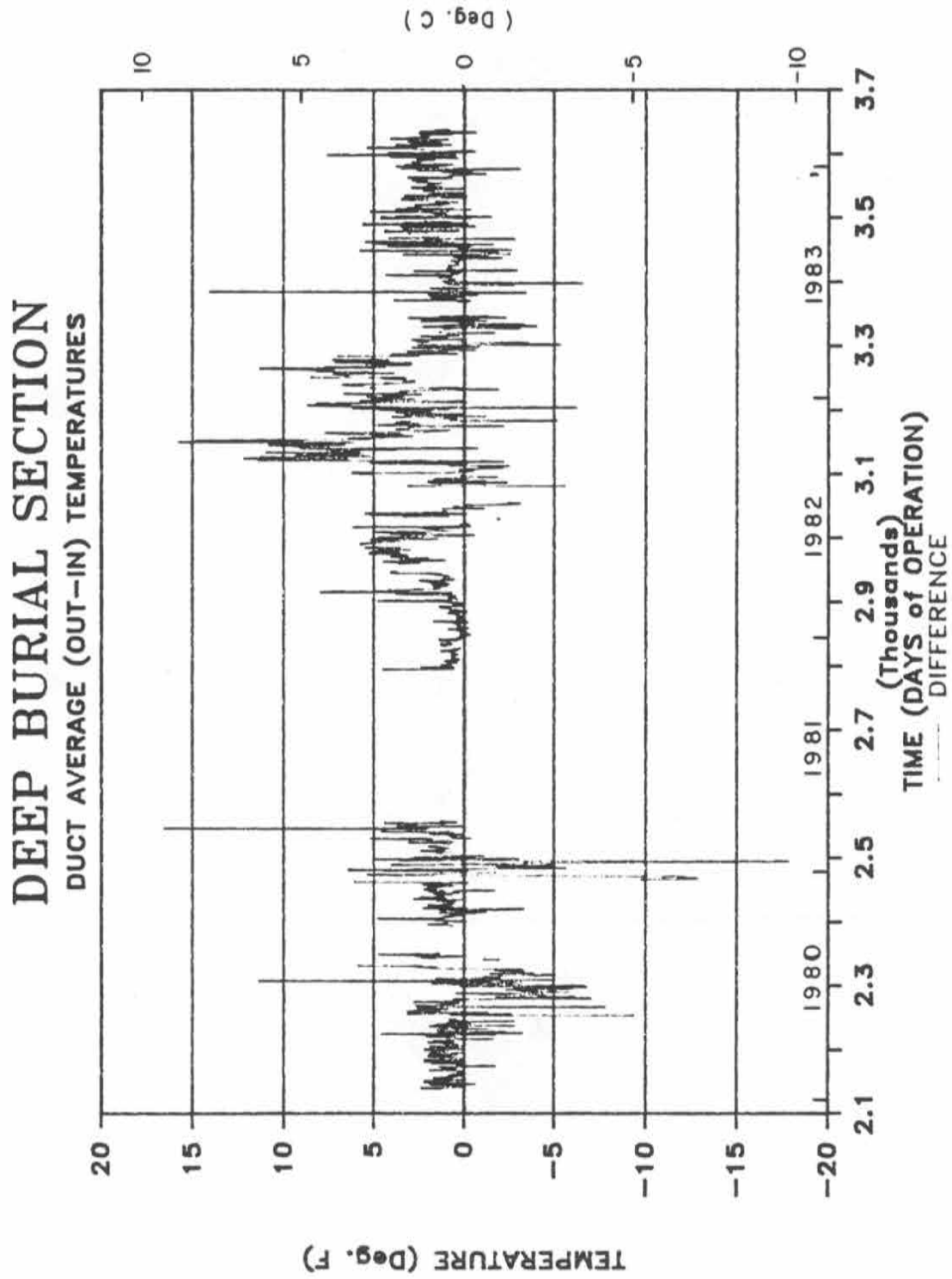
CALGARY FROST HEAVE TEST FACILITY

DEEP BURIAL SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-8A



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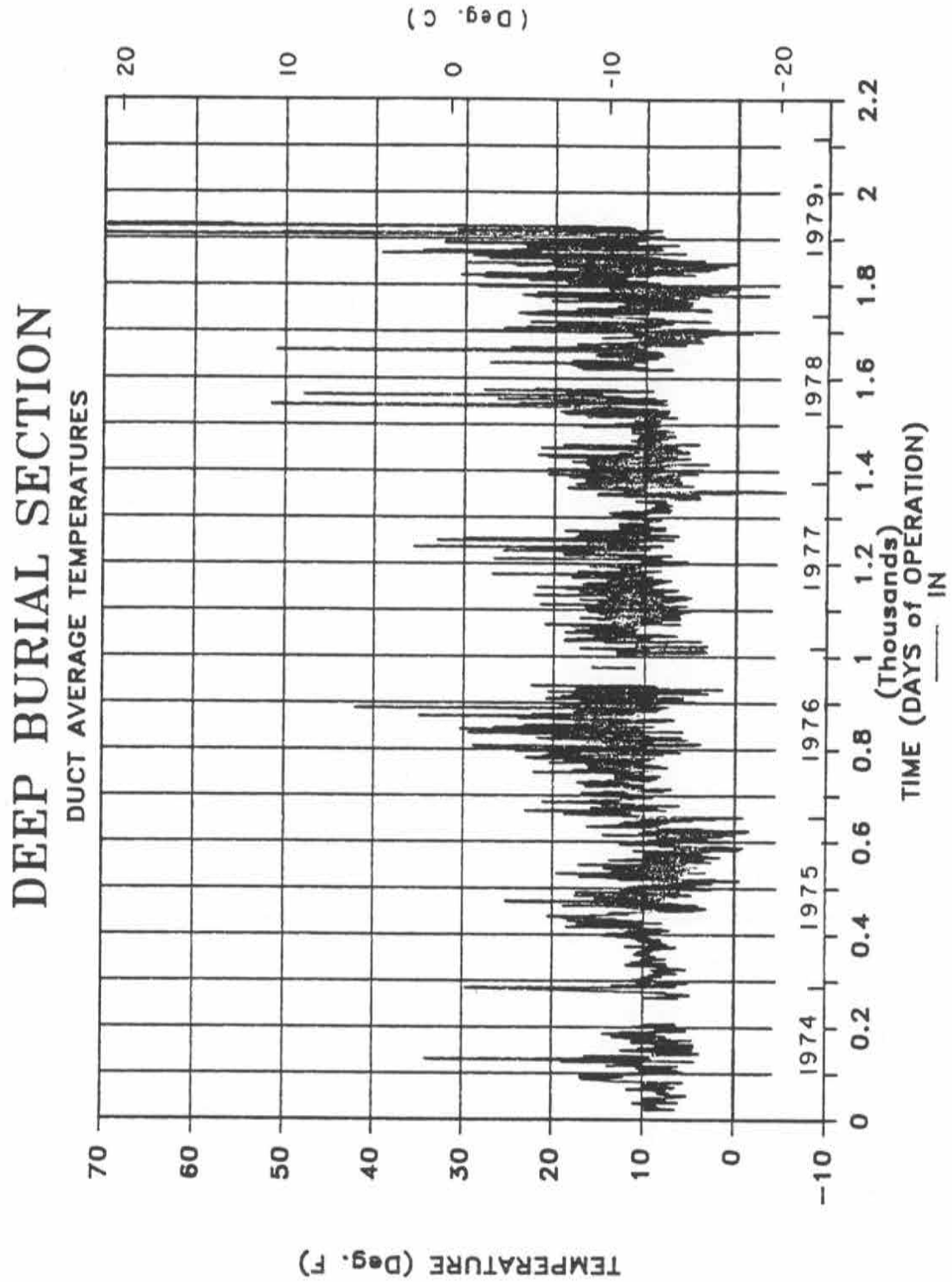
CALGARY FROST HEAVE TEST FACILITY

DEEP BURIAL SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-8B



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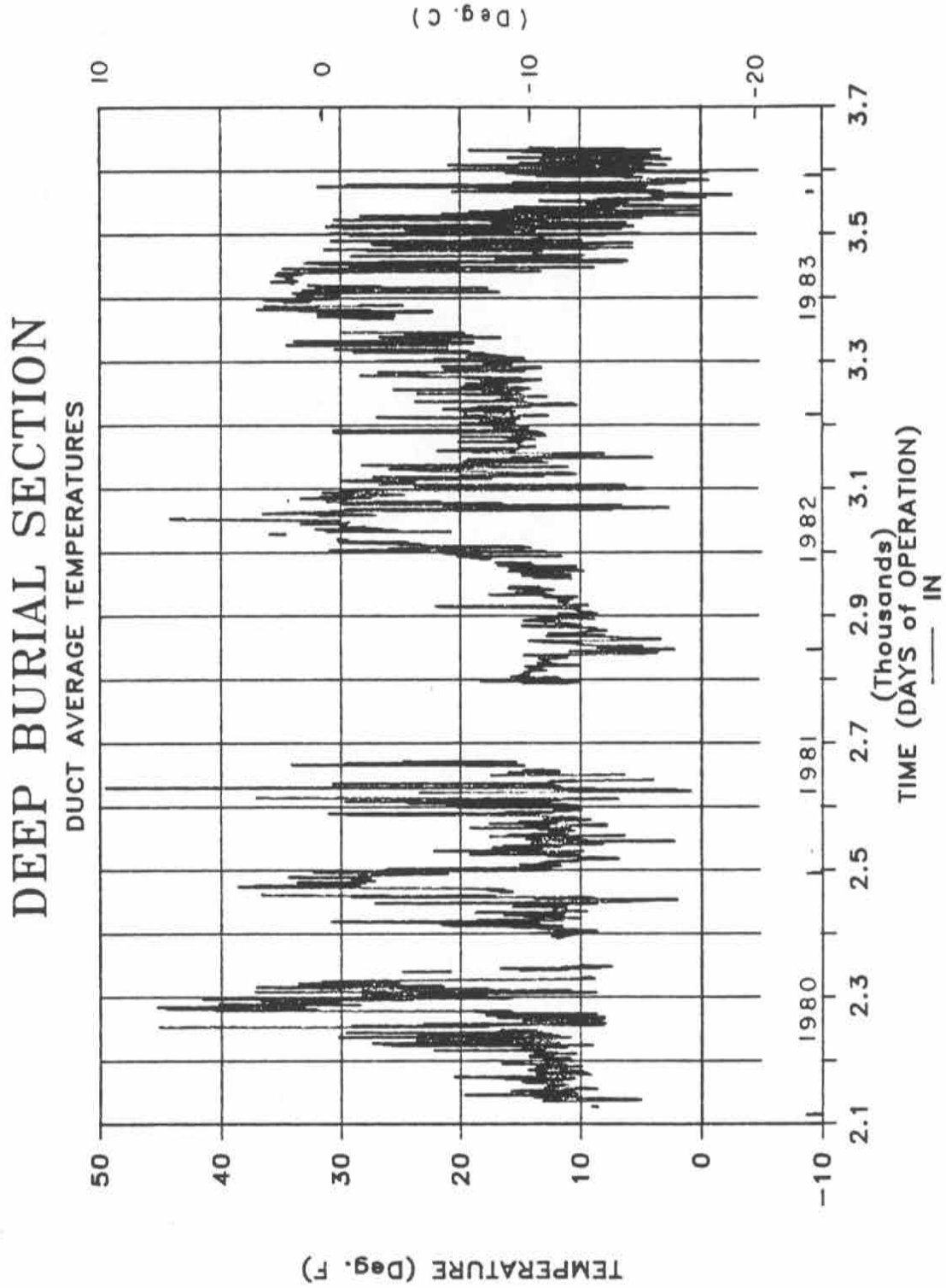
CALGARY FROST HEAVE TEST FACILITY

DEEP BURIAL SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-9A



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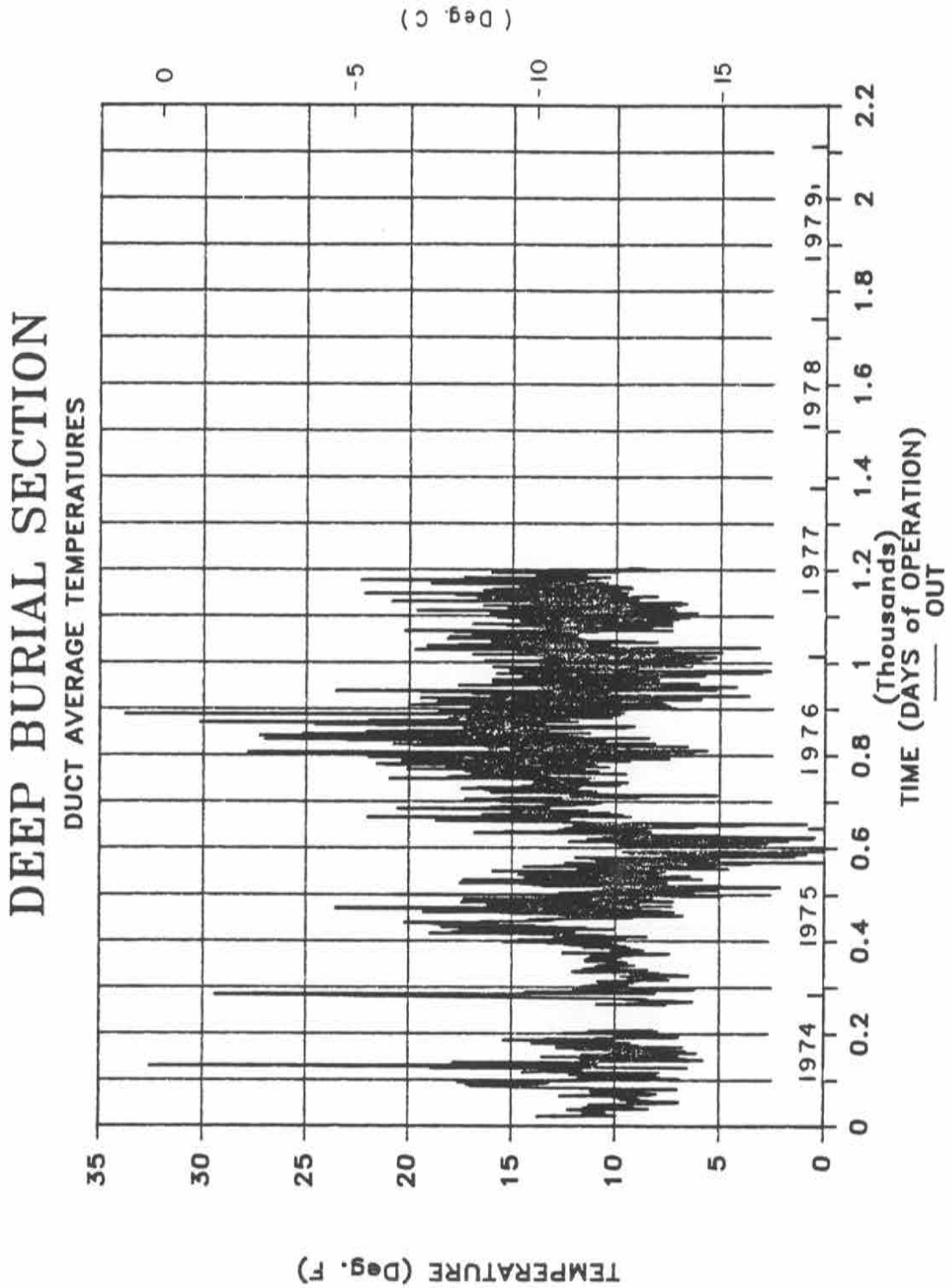
CALGARY FROST HEAVE TEST FACILITY

DEEP BURIAL SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-9B



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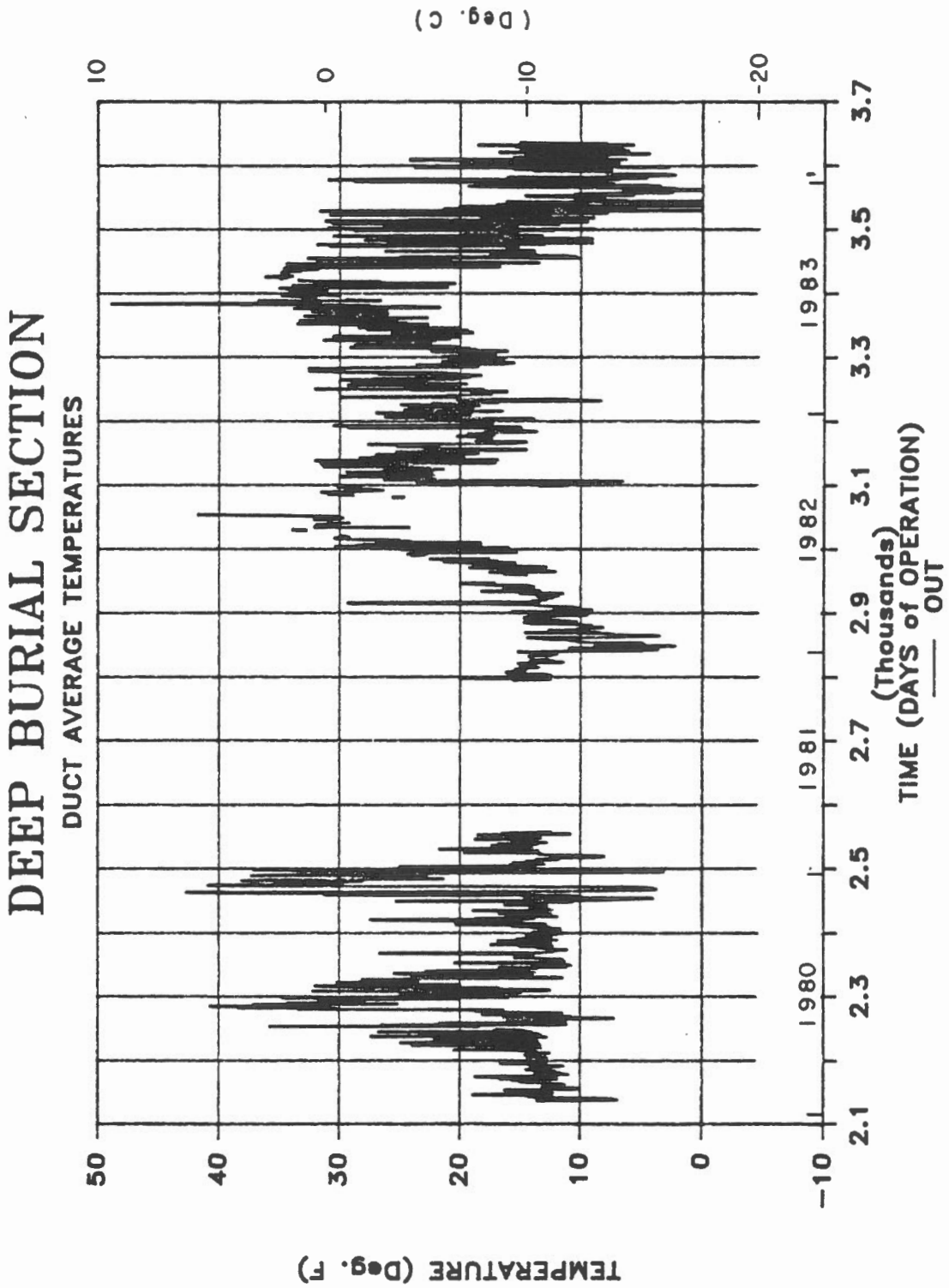
CALGARY FROST HEAVE TEST FACILITY

DEEP BURIAL SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-10A



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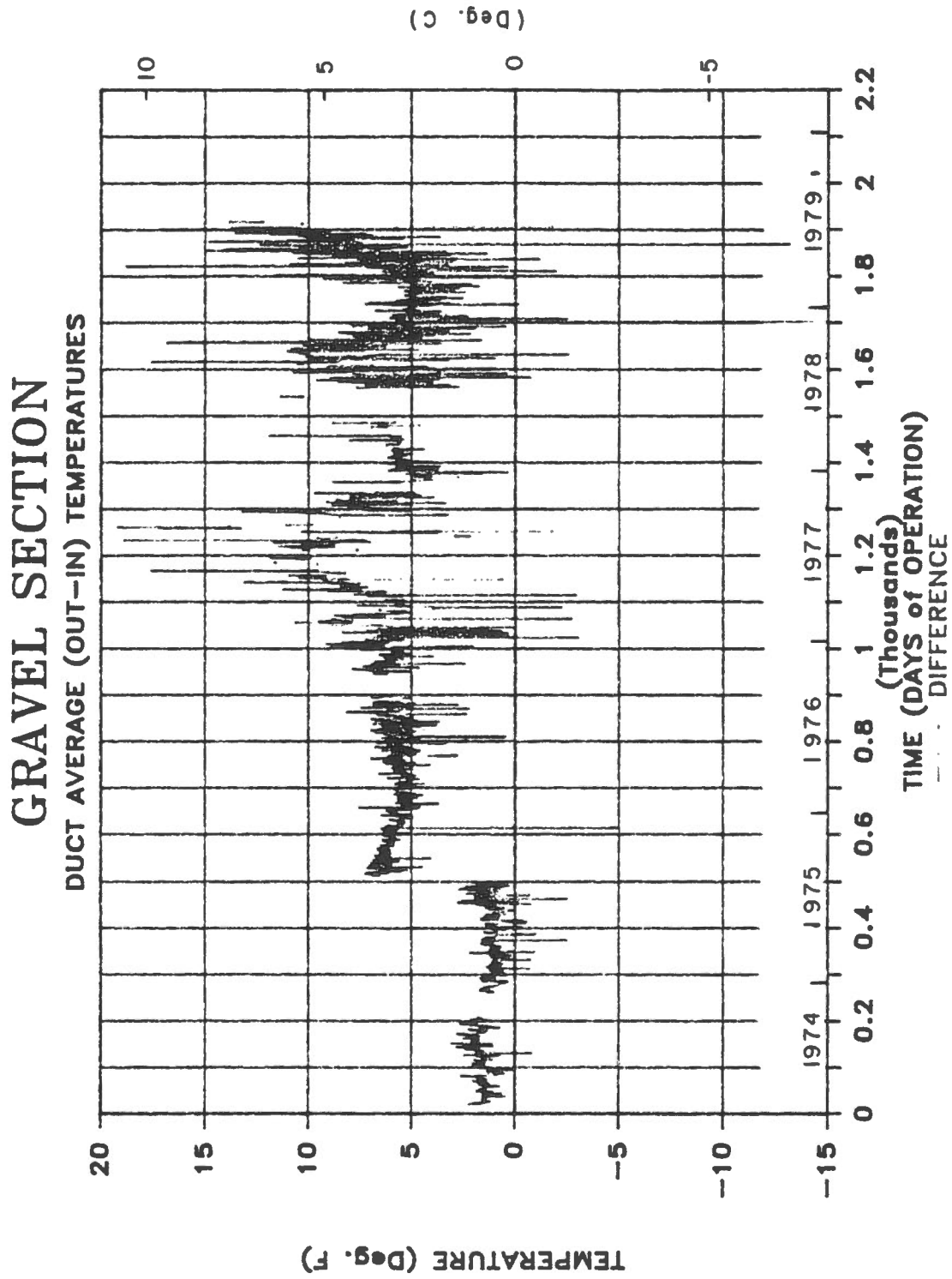
CALGARY FROST HEAVE TEST FACILITY

DEEP BURIAL SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-10B



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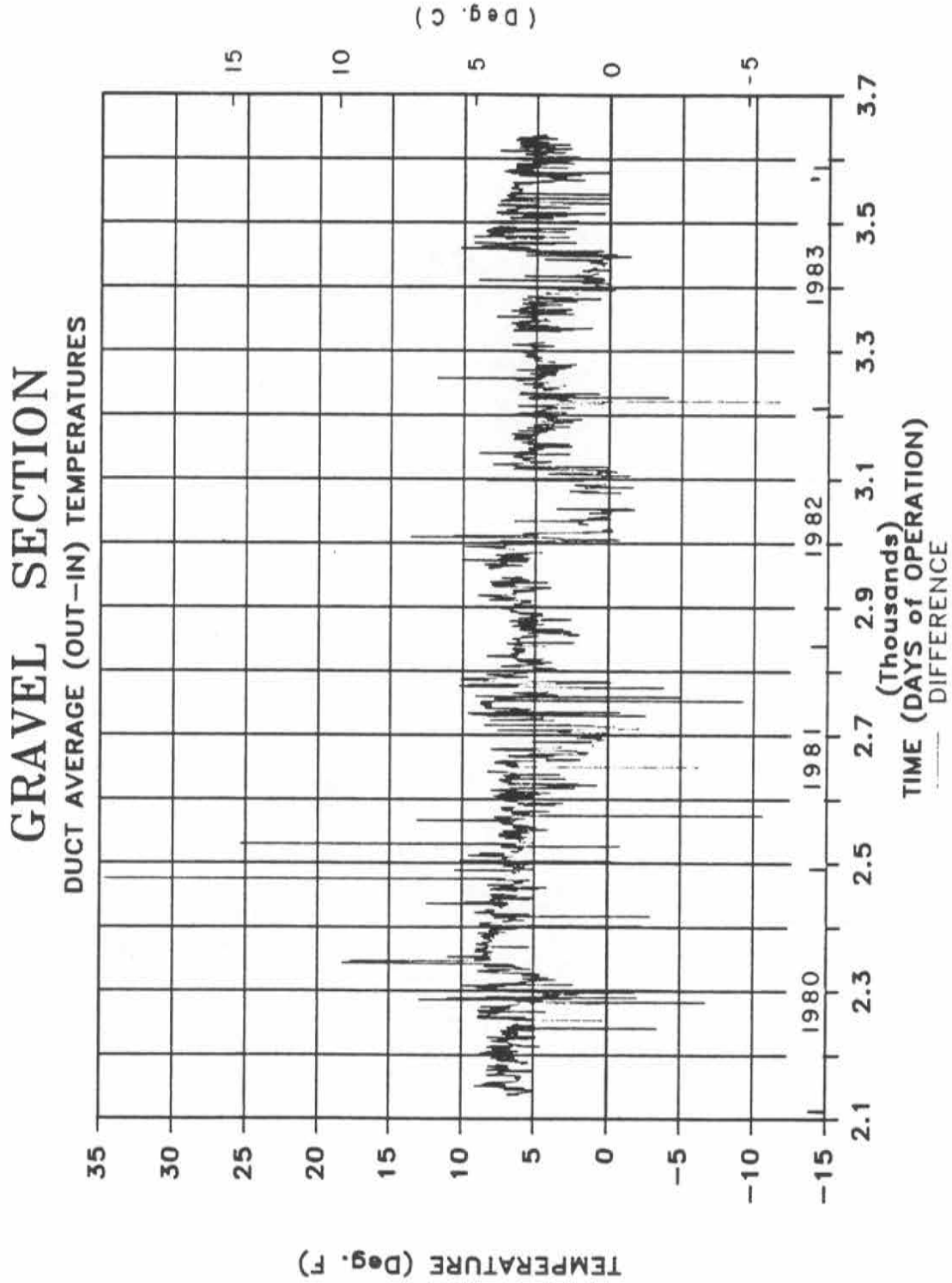
CALGARY FROST HEAVE TEST FACILITY

GRAVEL SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-11A



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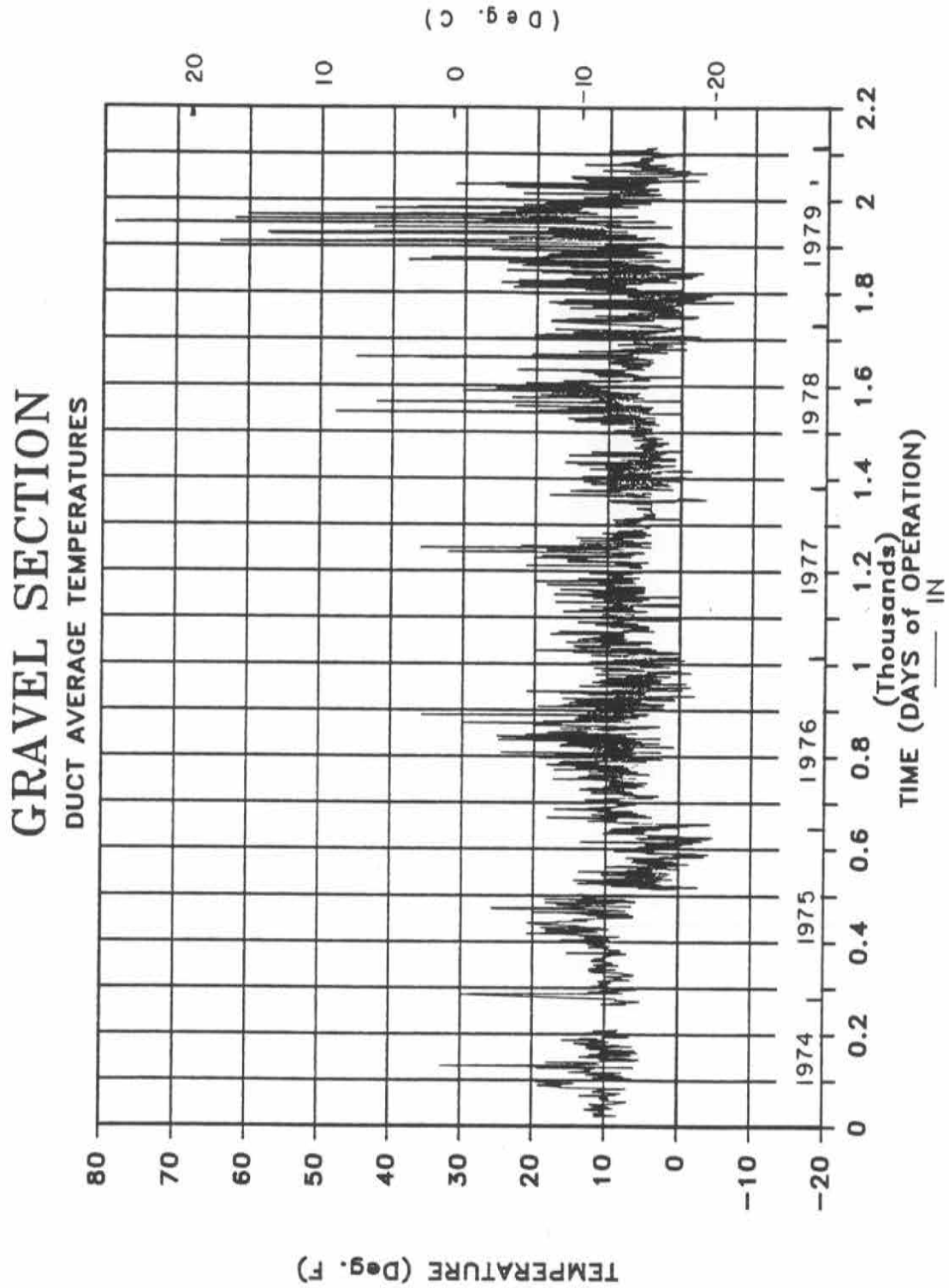
CALGARY FROST HEAVE TEST FACILITY

GRAVEL SECTION
DUCT AVERAGE TEMPERATURES
(OUT – IN)

PREPARED BY L. CARLSON

FIGURE 2.6-11B



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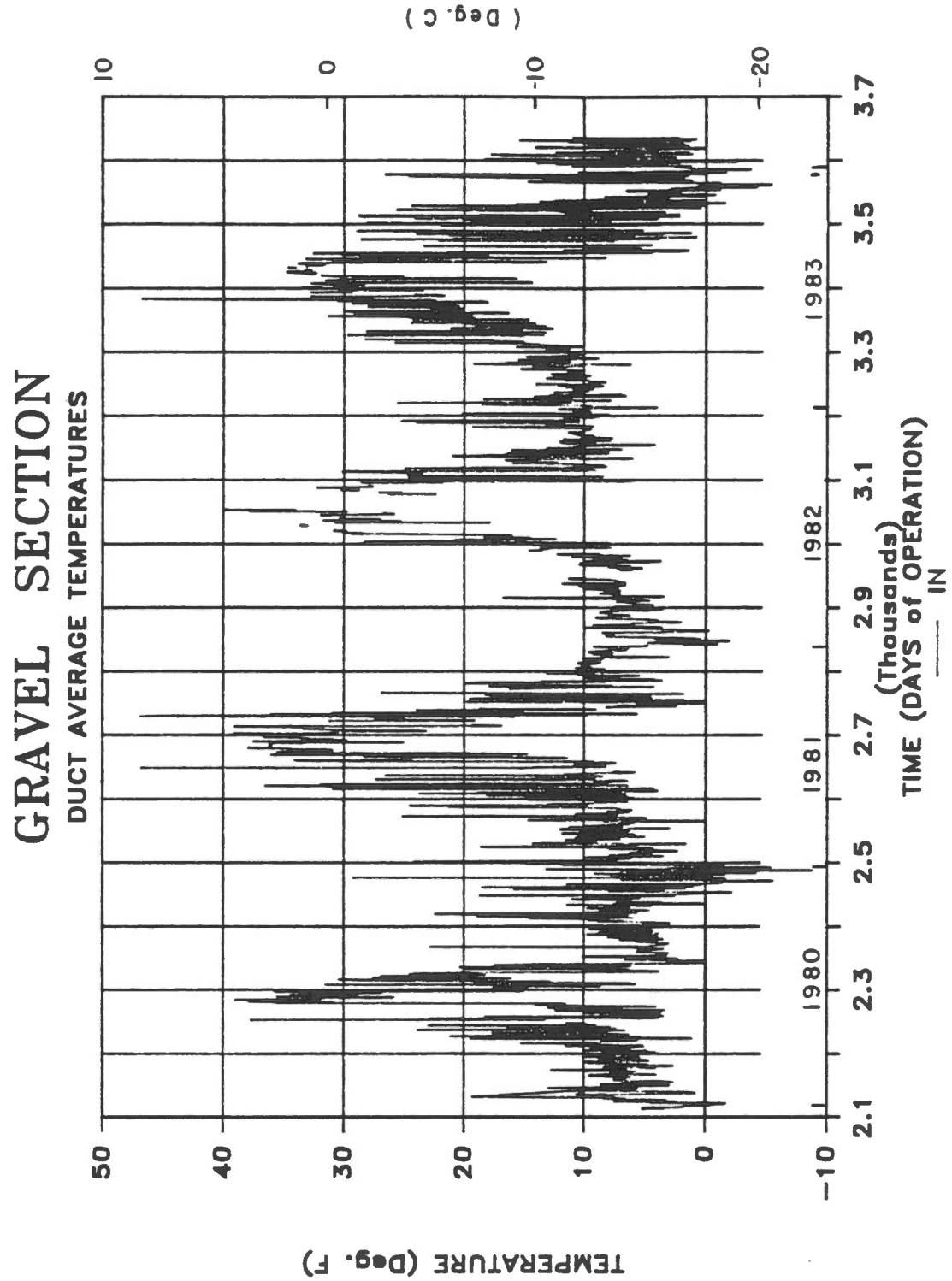
CALGARY FROST HEAVE TEST FACILITY

GRAVEL SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-12A



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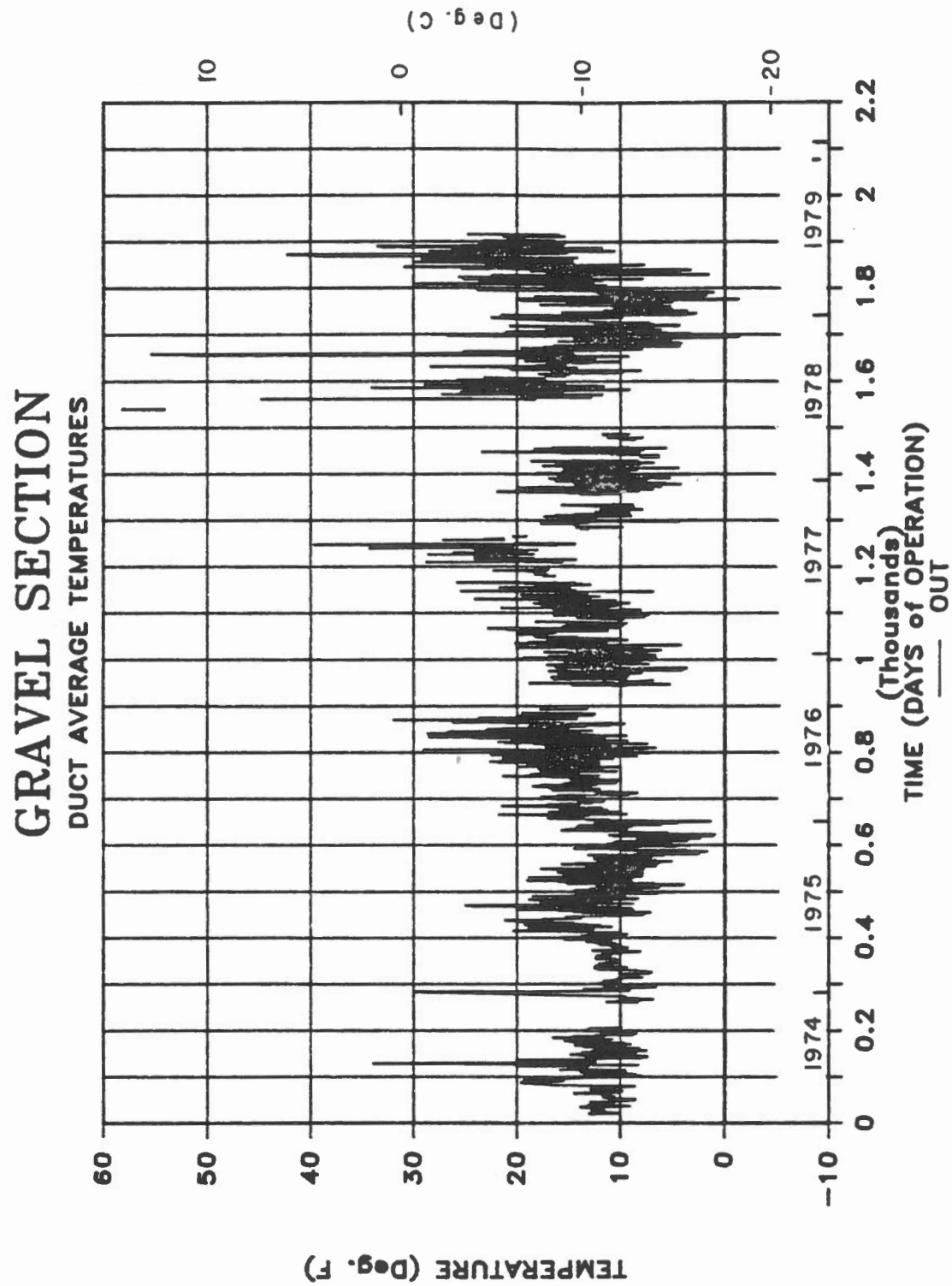
CALGARY FROST HEAVE TEST FACILITY

GRAVEL SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-12B



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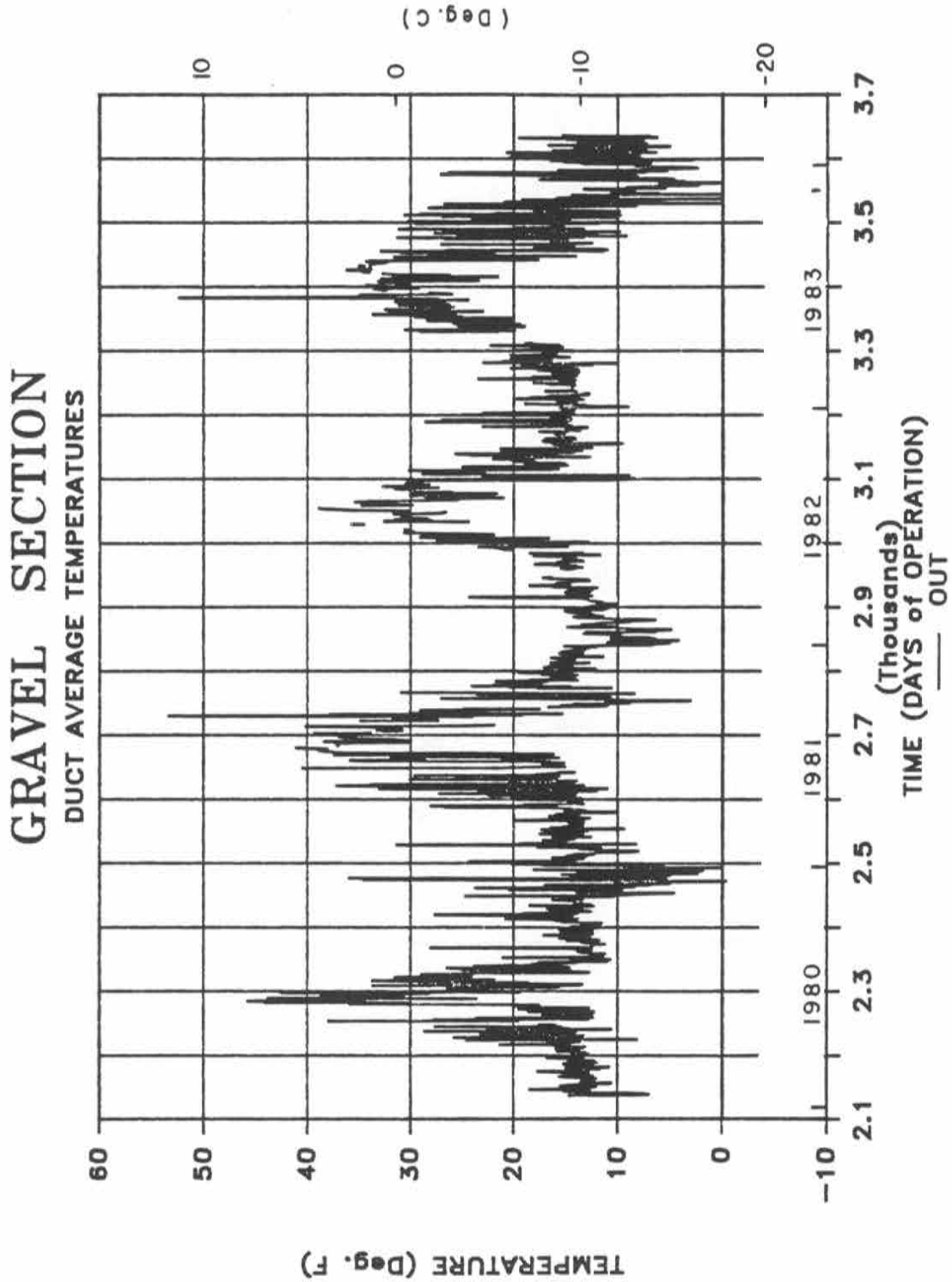
CALGARY FROST HEAVE TEST FACILITY

GRAVEL SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-13A



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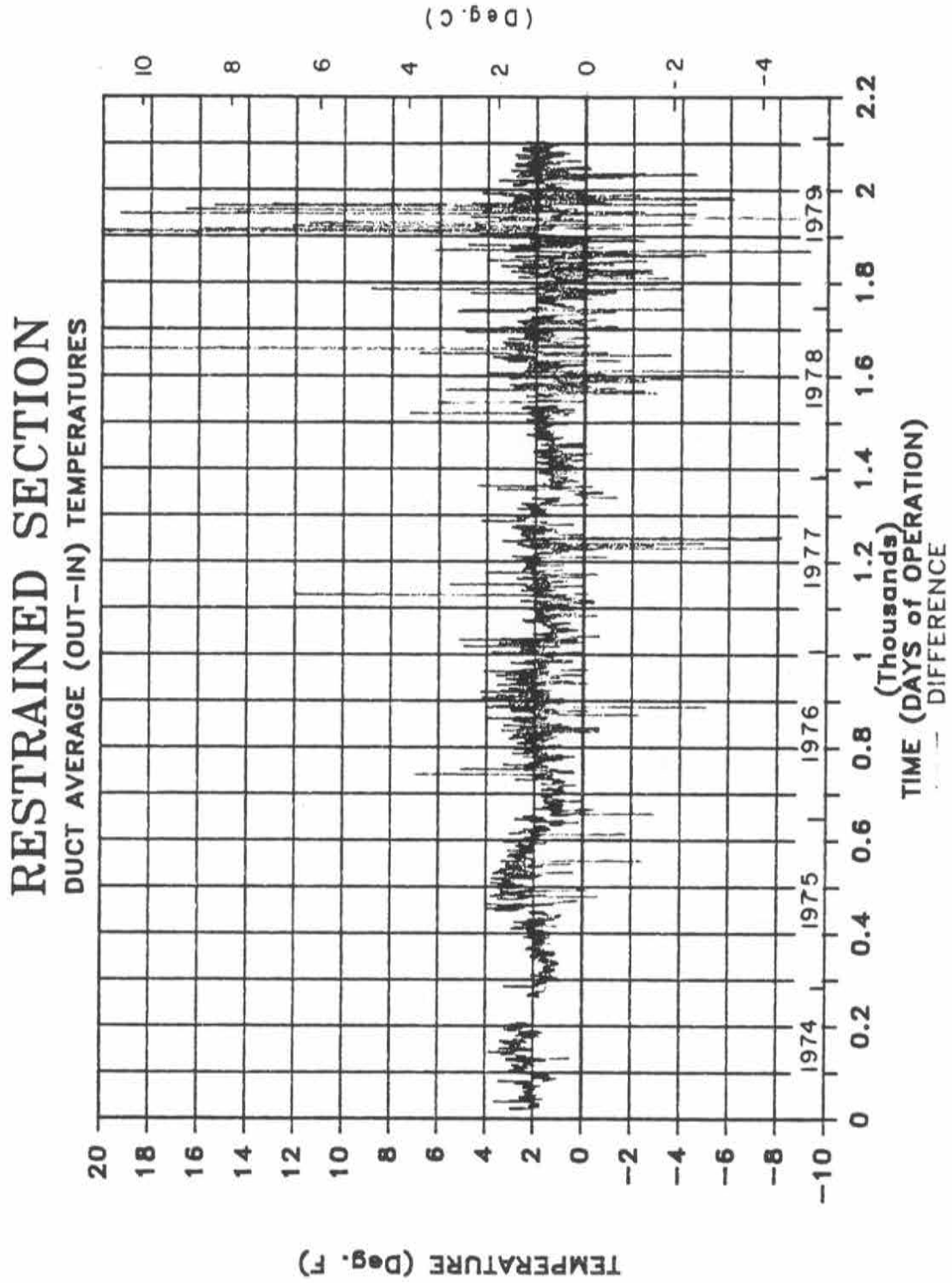
CALGARY FROST HEAVE TEST FACILITY

GRAVEL SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-13B



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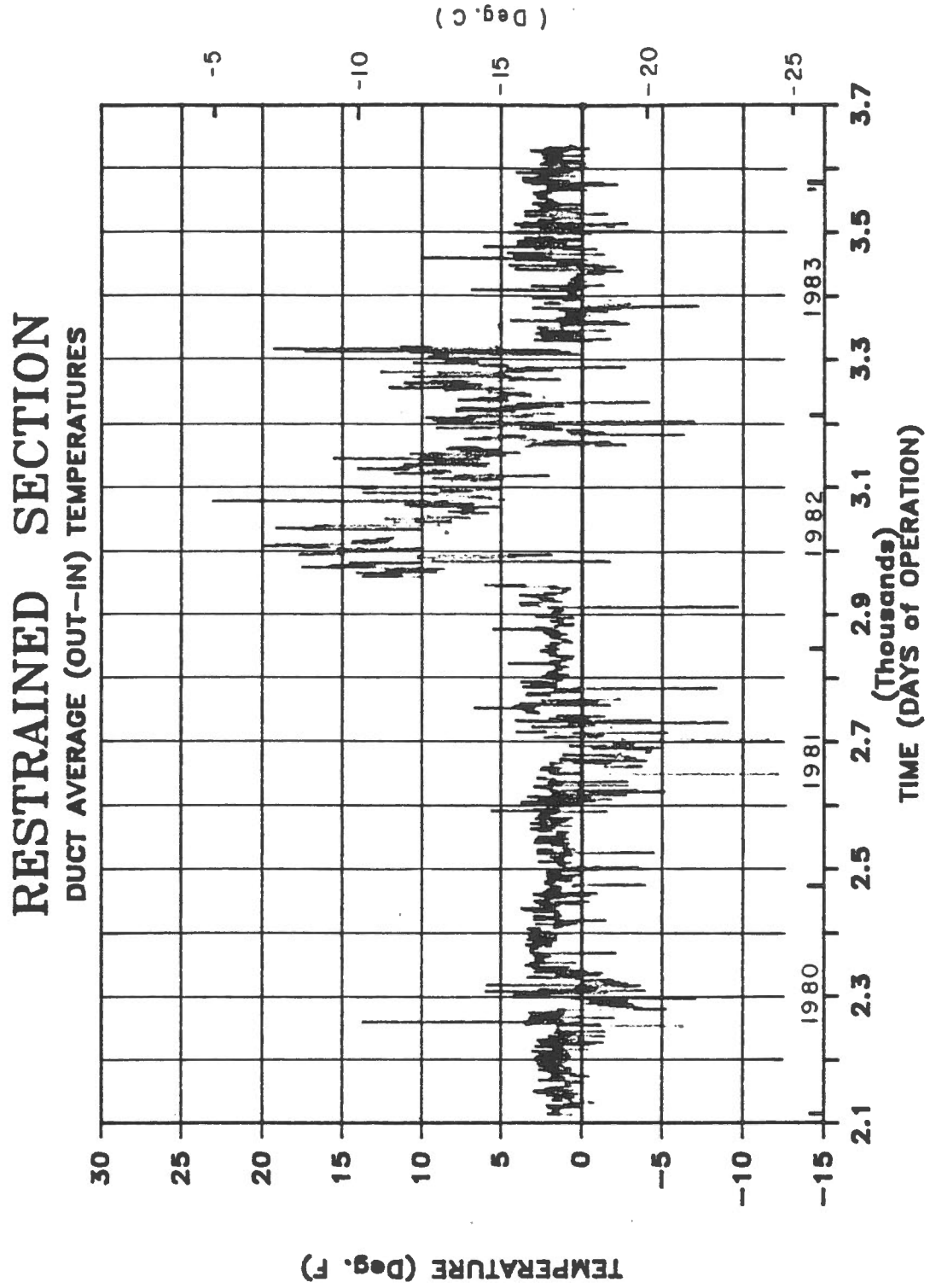
CALGARY FROST HEAVE TEST FACILITY

RESTRAINED SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-14 A



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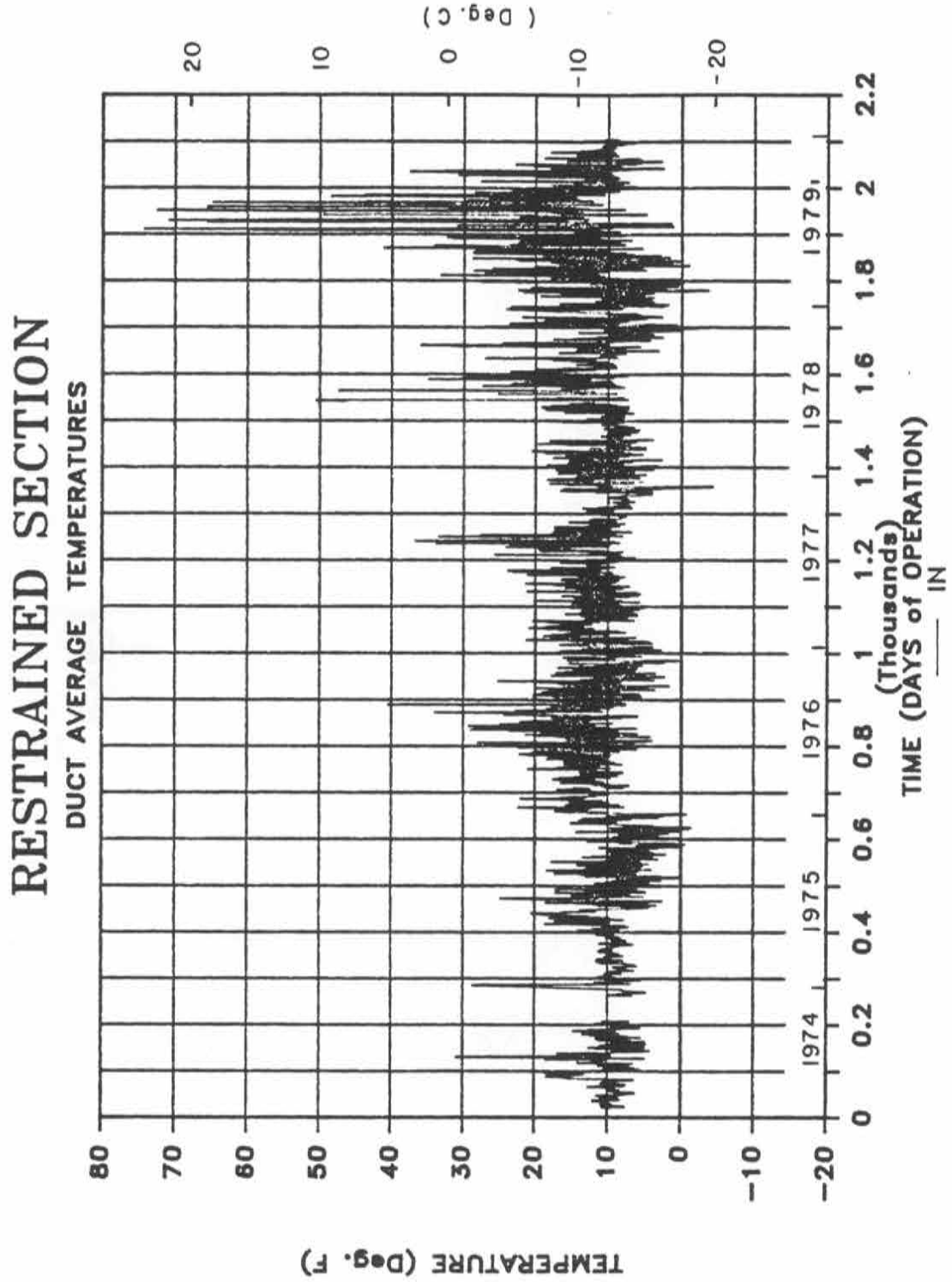
CALGARY FROST HEAVE TEST FACILITY

RESTRAINED SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-14 B



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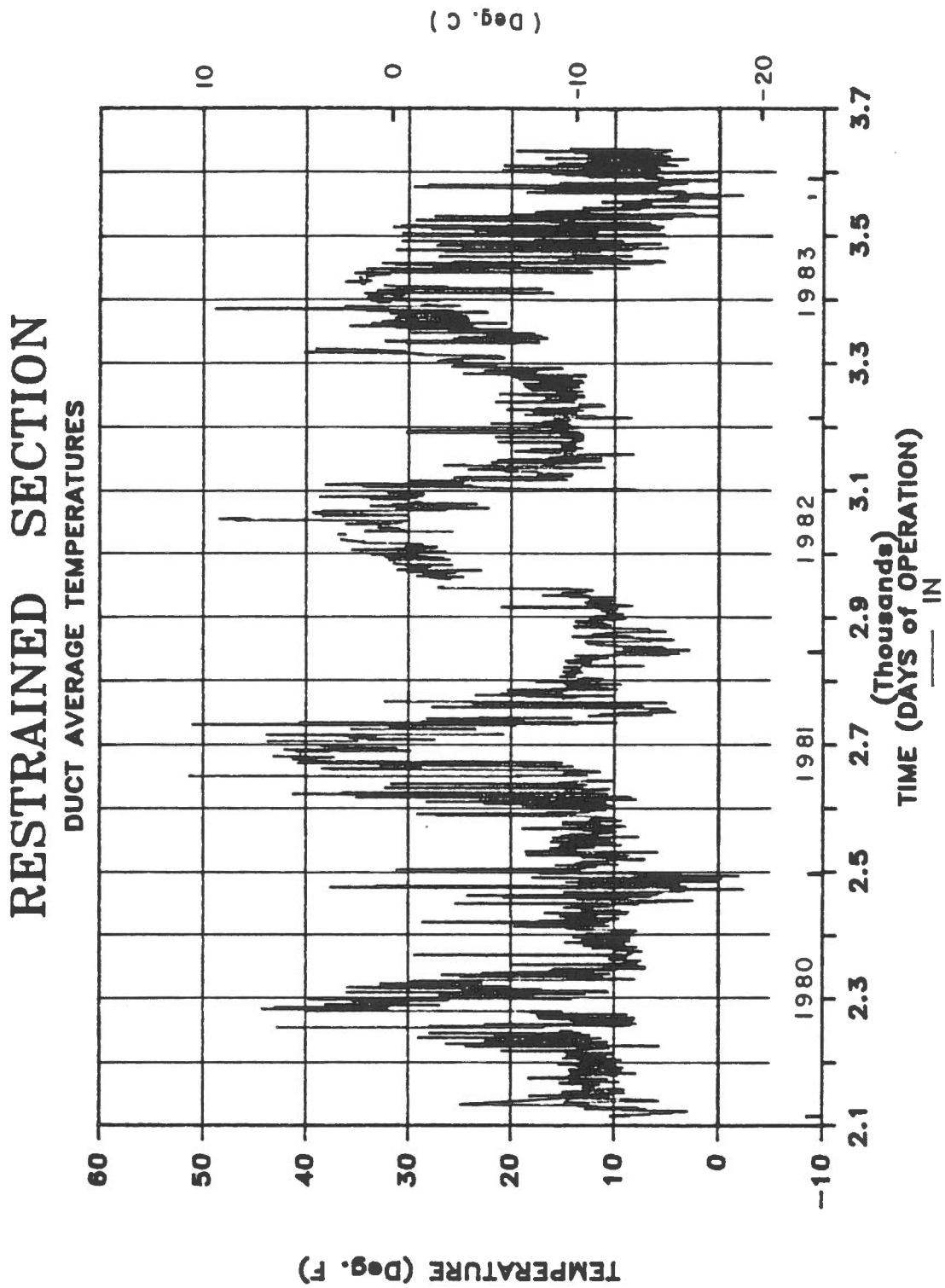
CALGARY FROST HEAVE TEST FACILITY

RESTRAINED SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-15A



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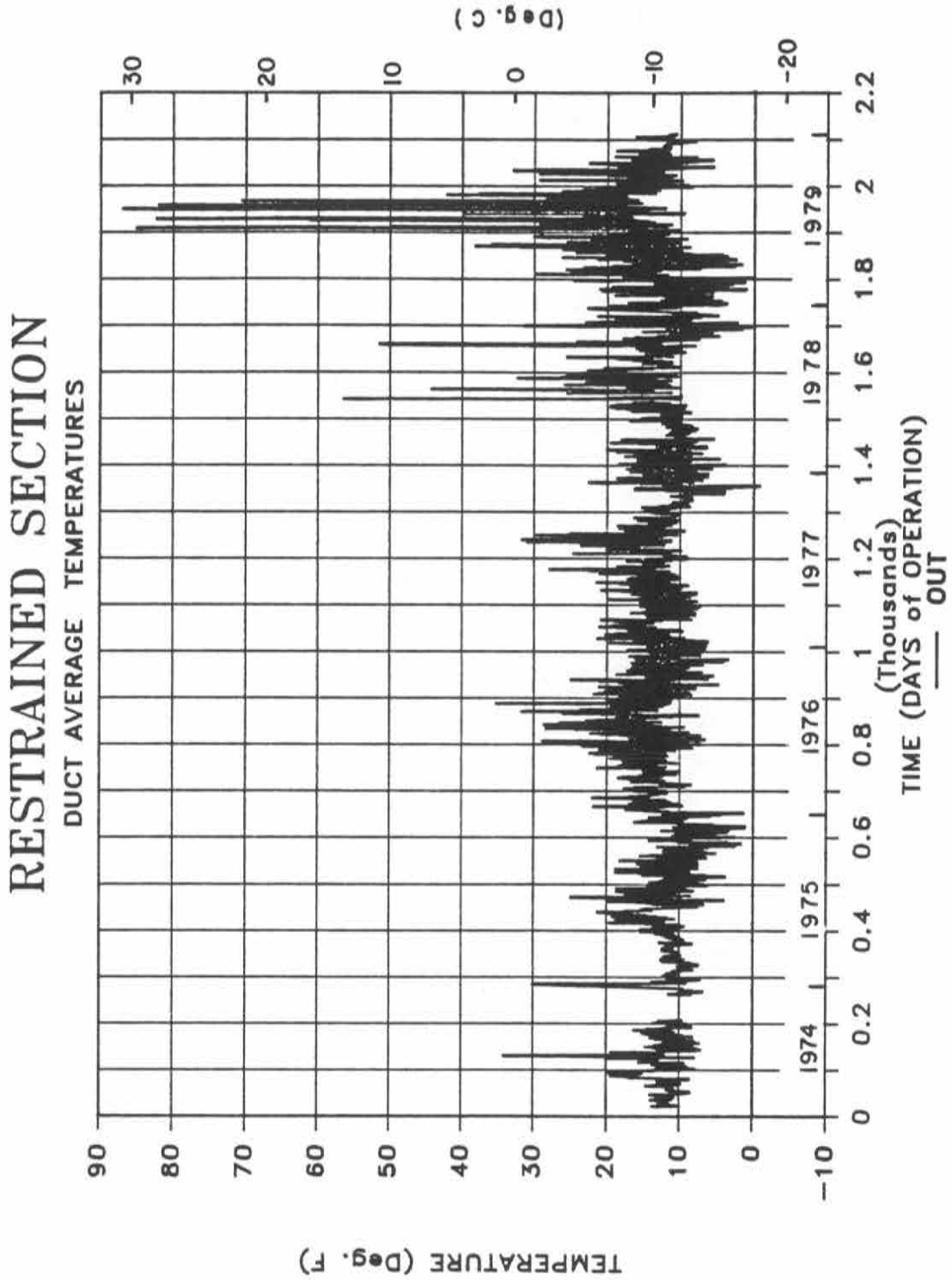
CALGARY FROST HEAVE TEST FACILITY

RESTRAINED SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-15B



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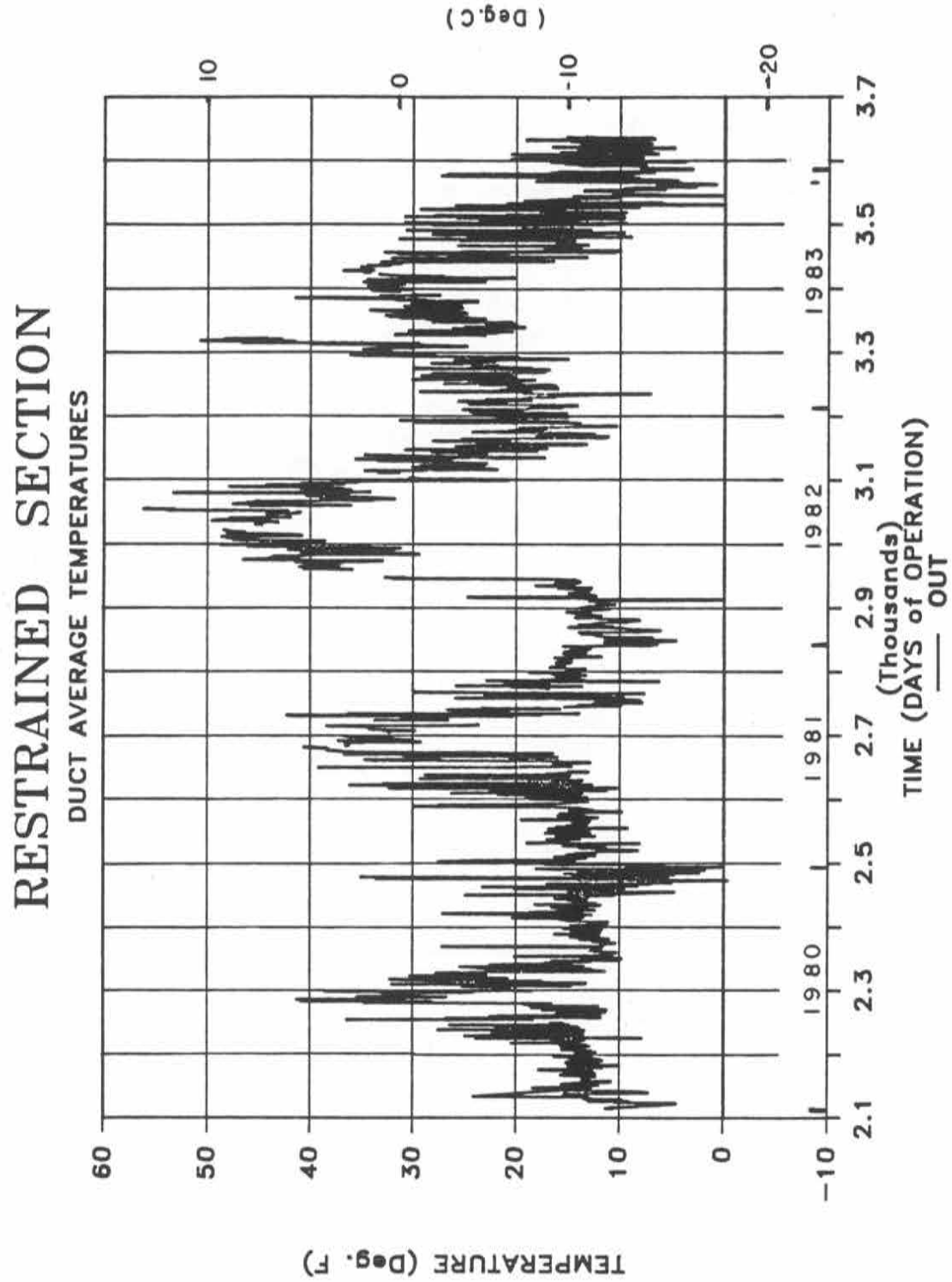
CALGARY FROST HEAVE TEST FACILITY

RESTRAINED SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-16A



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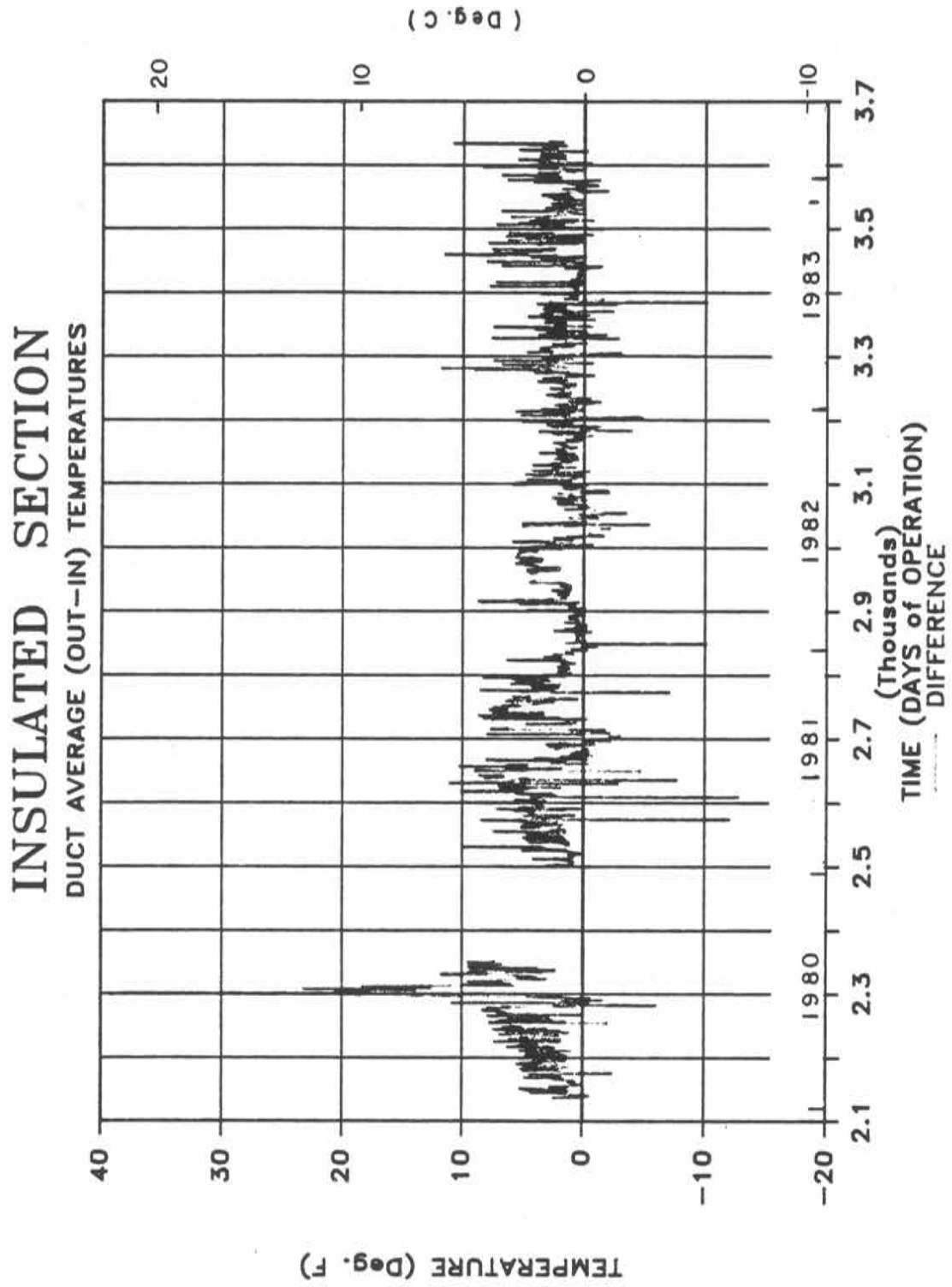
CALGARY FROST HEAVE TEST FACILITY

RESTRAINED SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-16B



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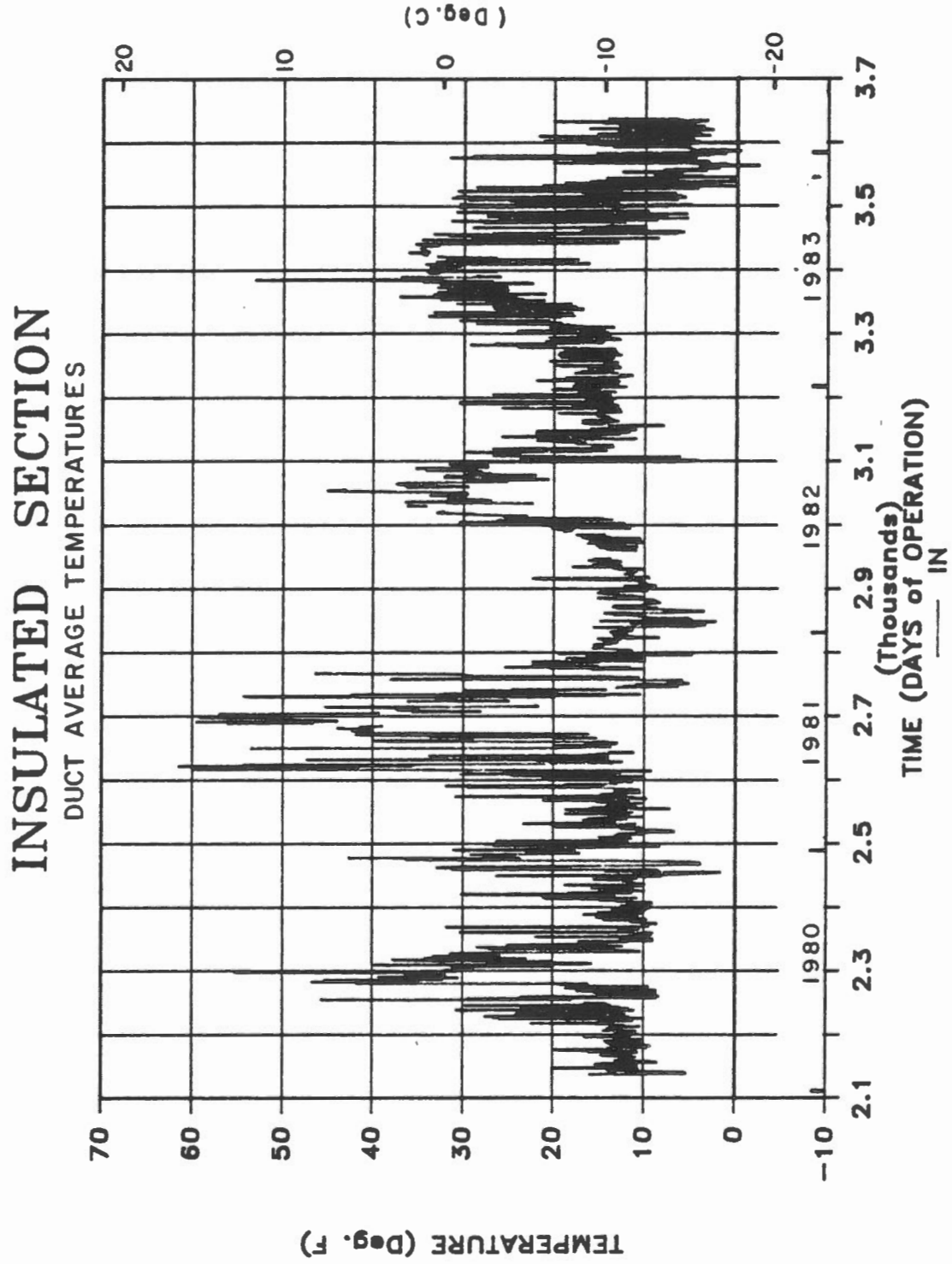
CALGARY FROST HEAVE TEST FACILITY

INSULATED SECTION
DUCT AVERAGE TEMPERATURES
(OUT-IN)

PREPARED BY L. CARLSON

FIGURE 2.6-17



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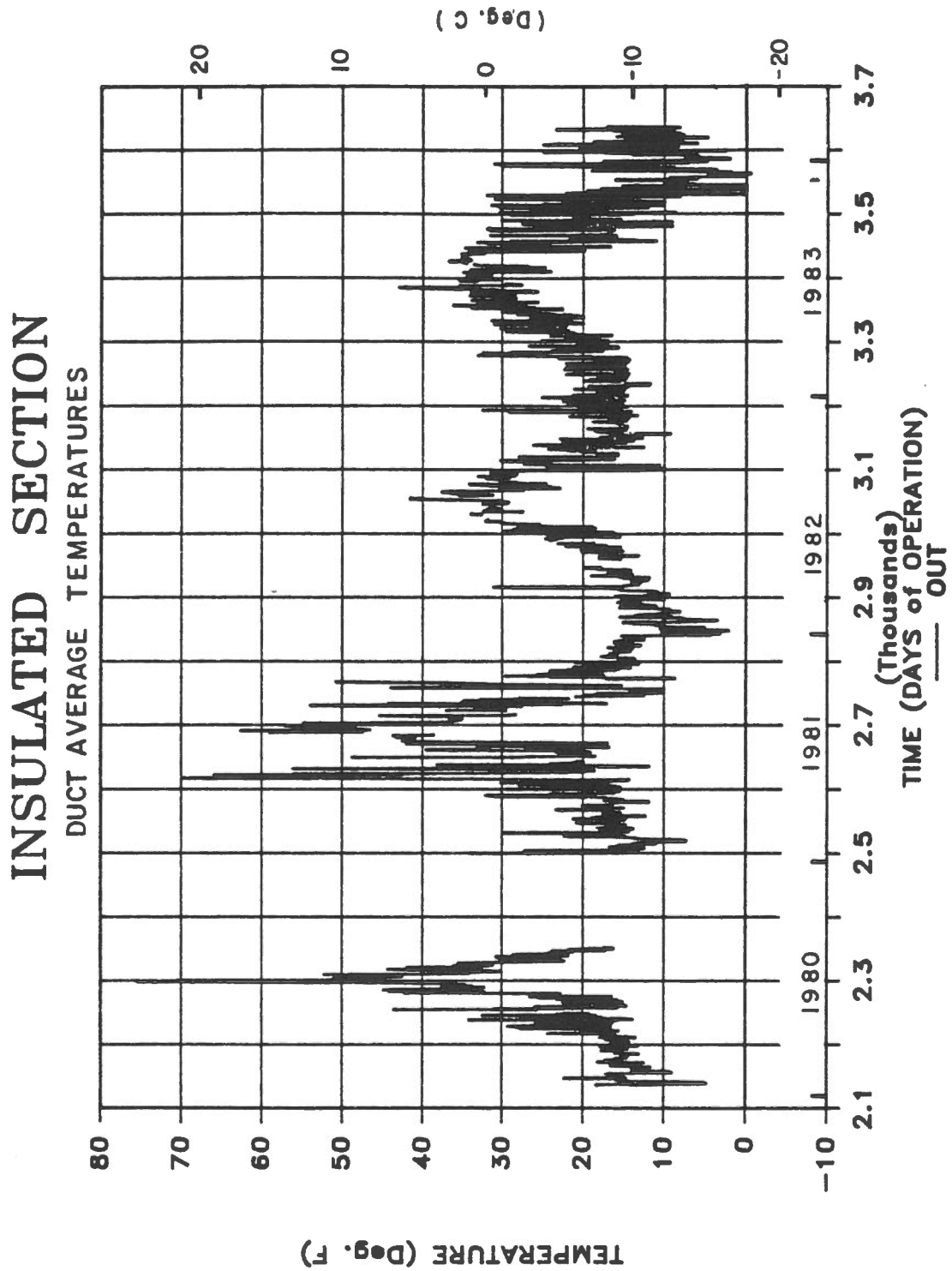
CALGARY FROST HEAVE TEST FACILITY

INSULATED SECTION
DUCT AVERAGE TEMPERATURES
(IN)

PREPARED BY L. CARLSON

FIGURE 2.6-18



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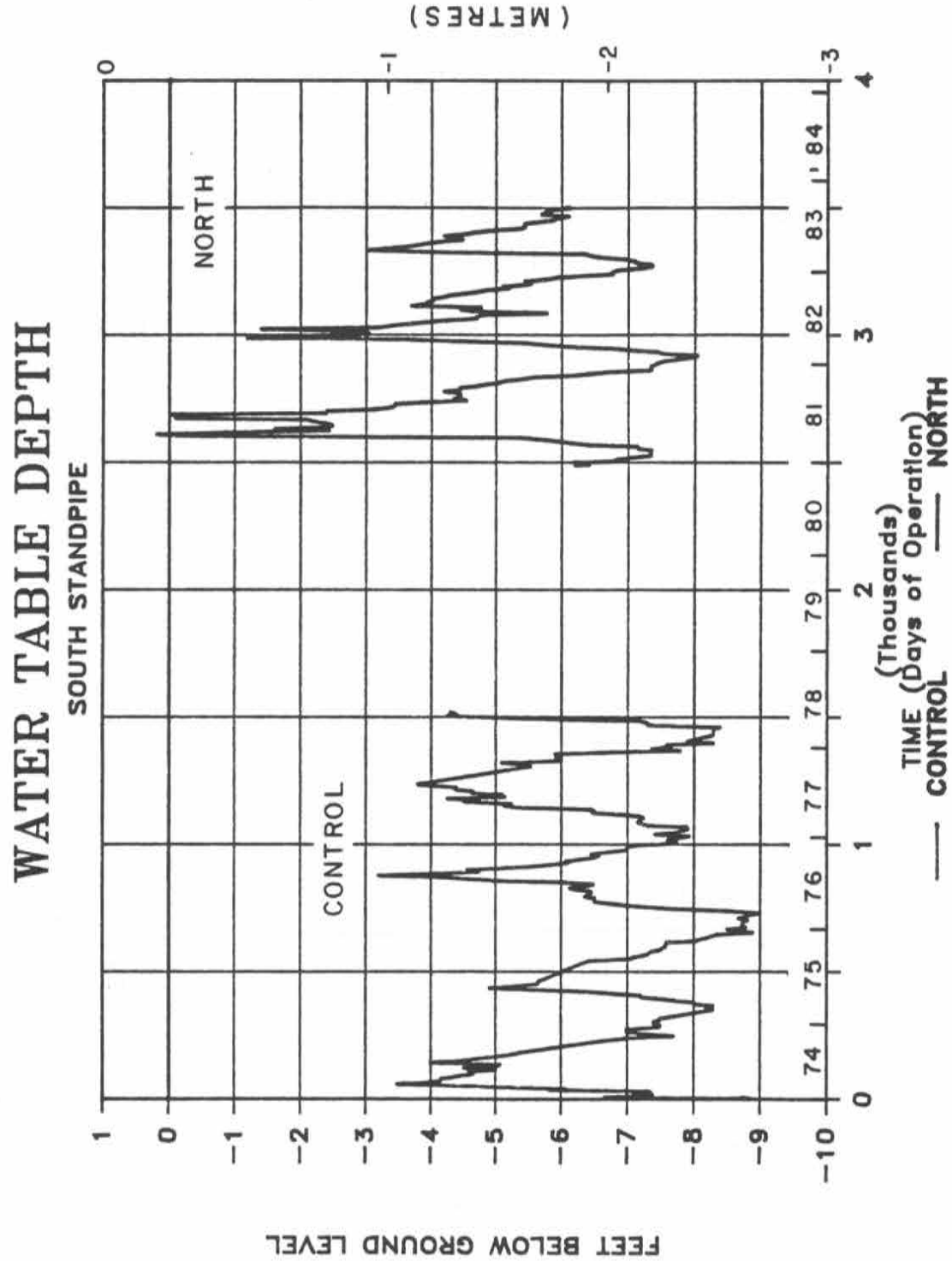
CALGARY FROST HEAVE TEST FACILITY

INSULATED SECTION
DUCT AVERAGE TEMPERATURES
(OUT)

PREPARED BY L. CARLSON

FIGURE 2.6-19



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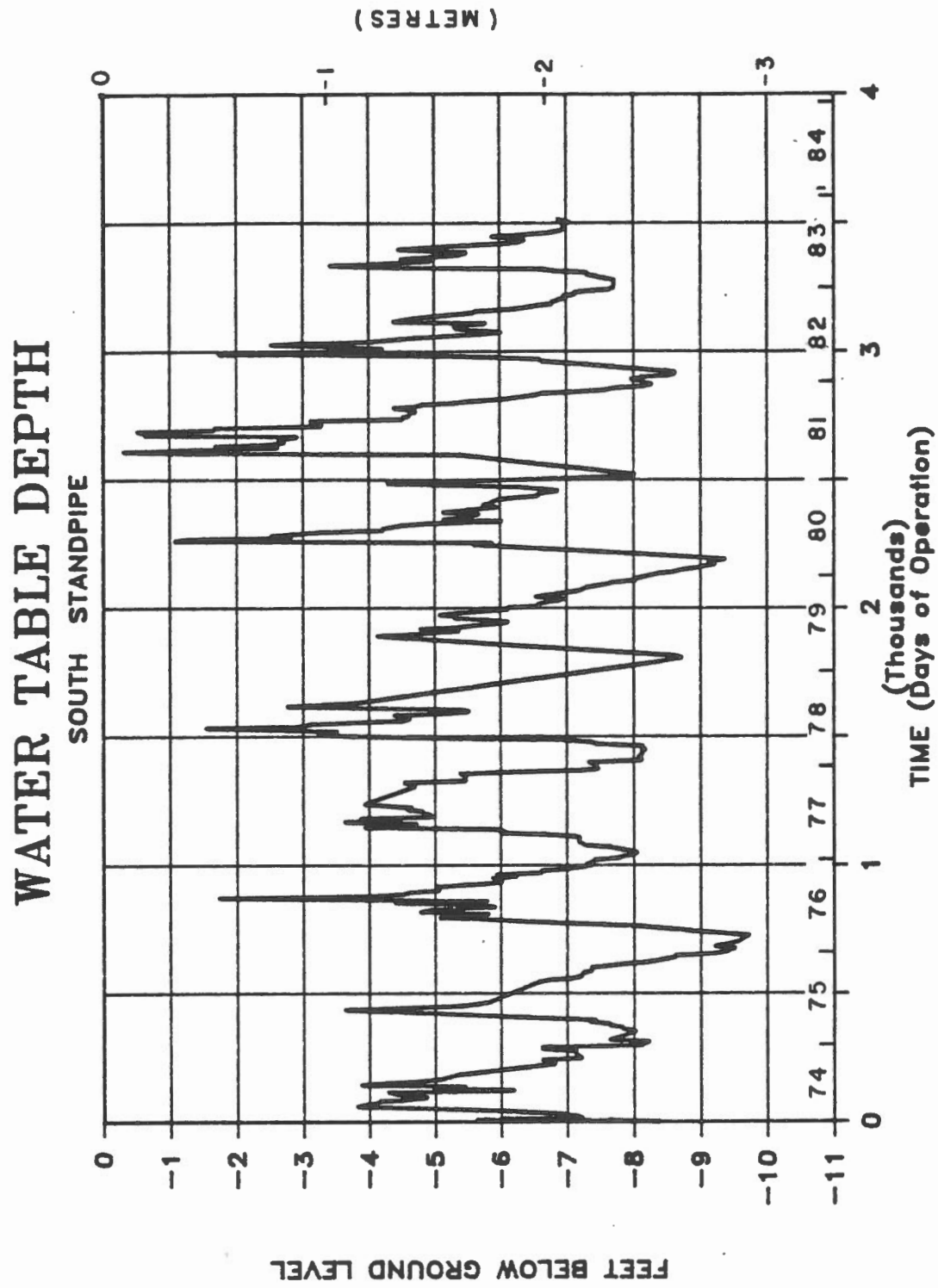
CALGARY FROST HEAVE TEST FACILITY

WATER TABLE DEPTH
BELOW GROUND LEVEL

PREPARED BY L. CARLSON

FIGURE 2.6-20



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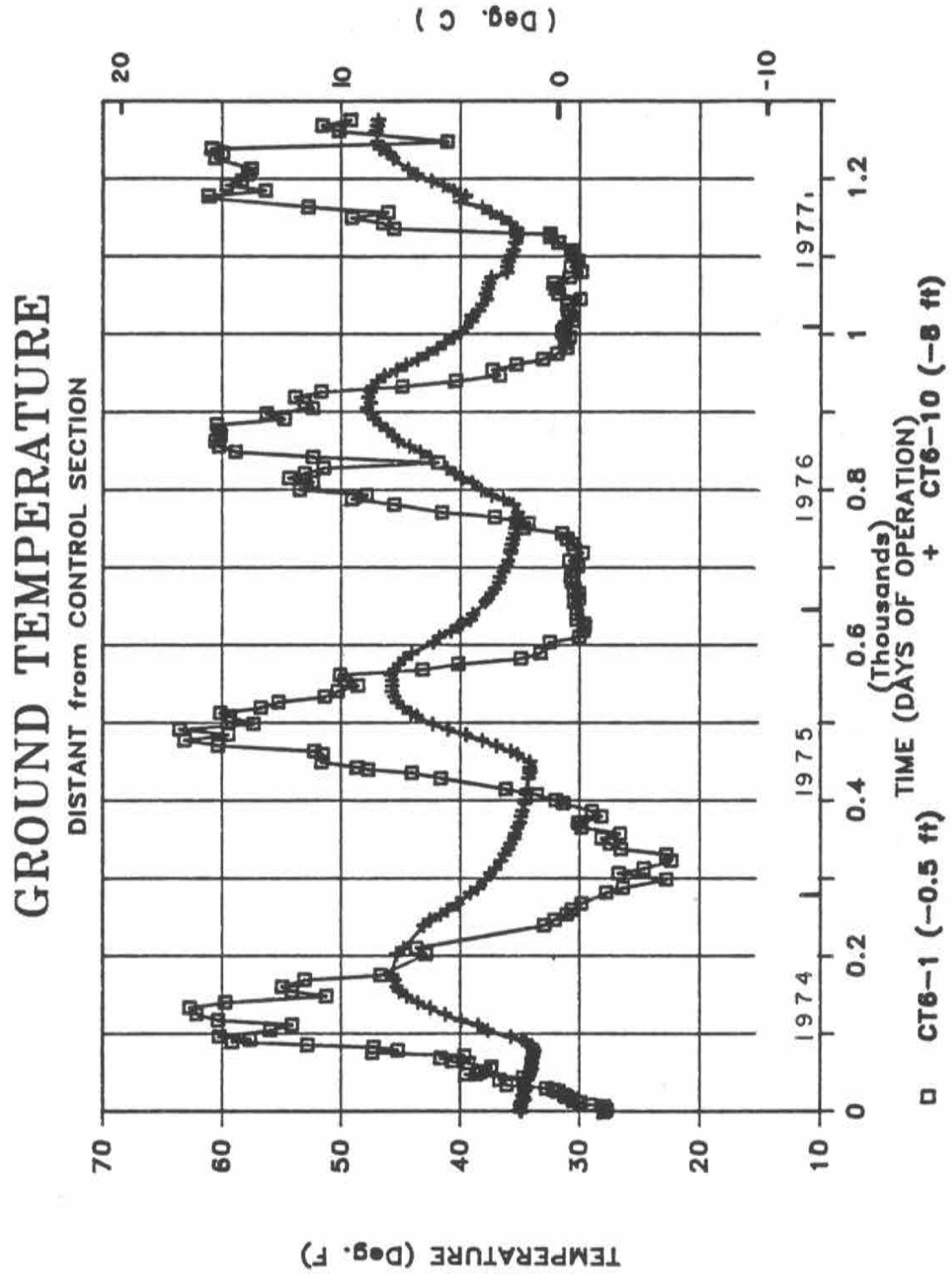
CALGARY FROST HEAVE TEST FACILITY

WATER TABLE DEPTH
SOUTH STANDPIPE

PREPARED BY L. CARLSON

FIGURE 2.6-21



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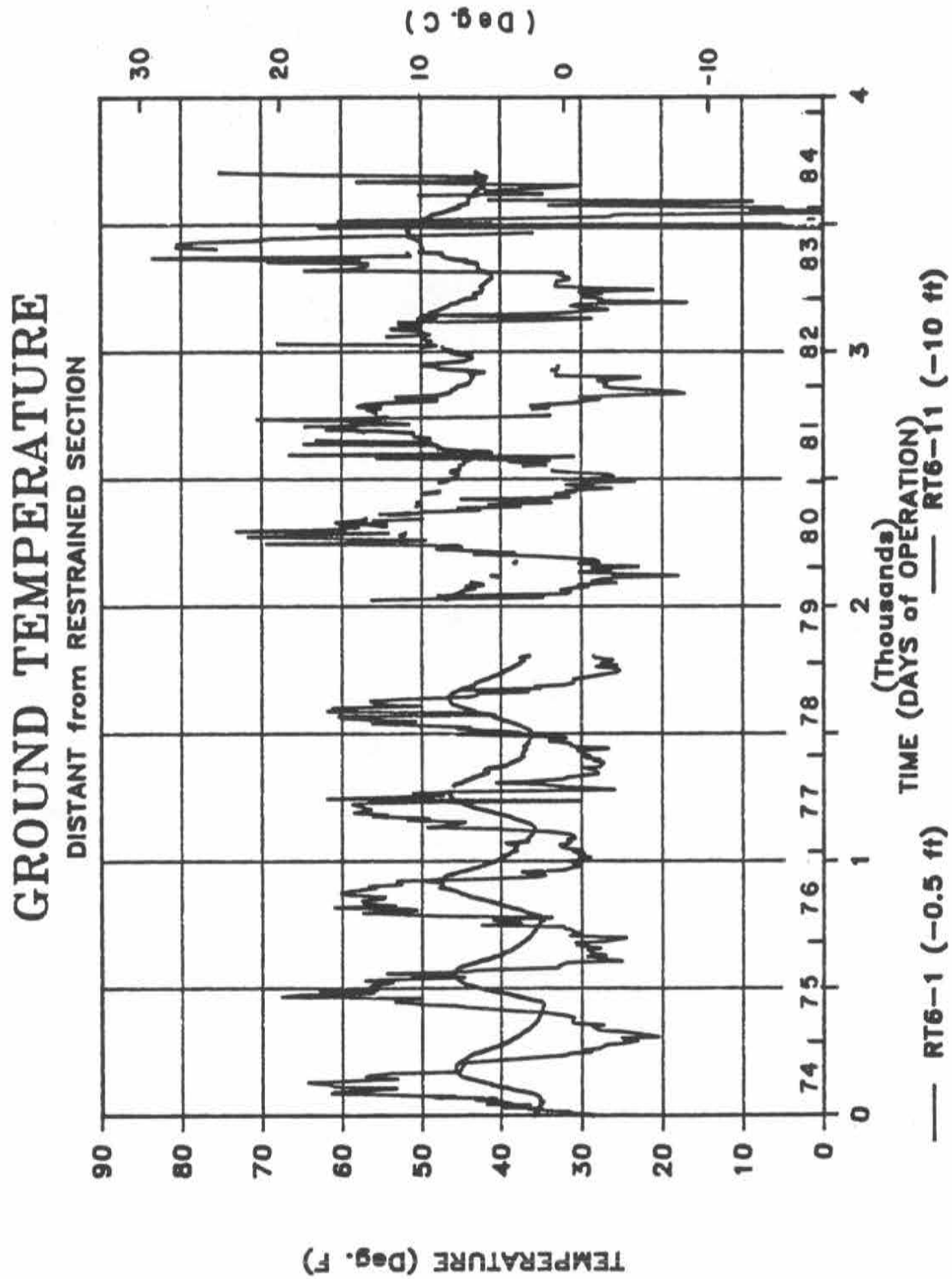
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE DISTANT FROM CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 2.6 - 22



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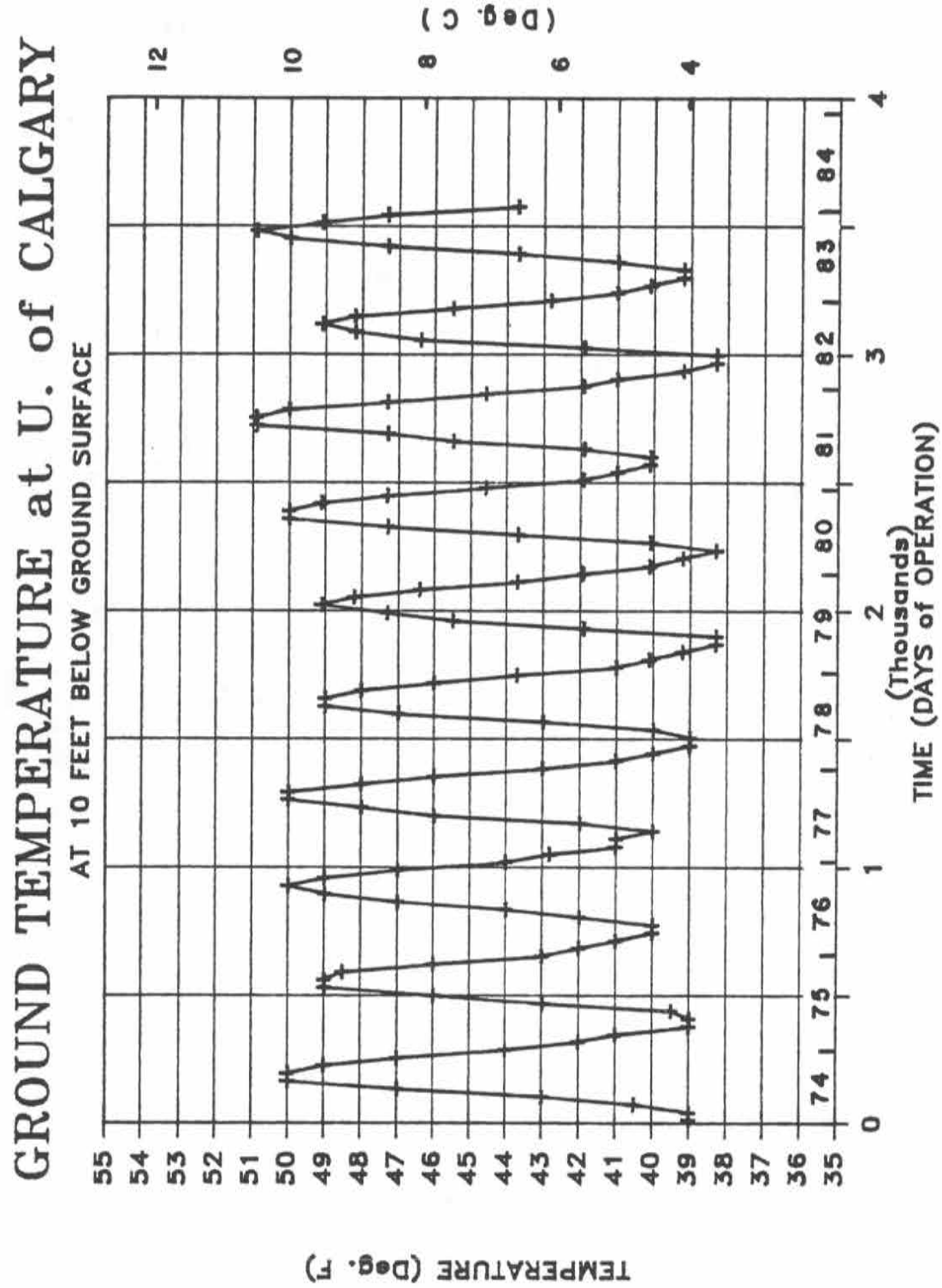
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE DISTANT FROM RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-23



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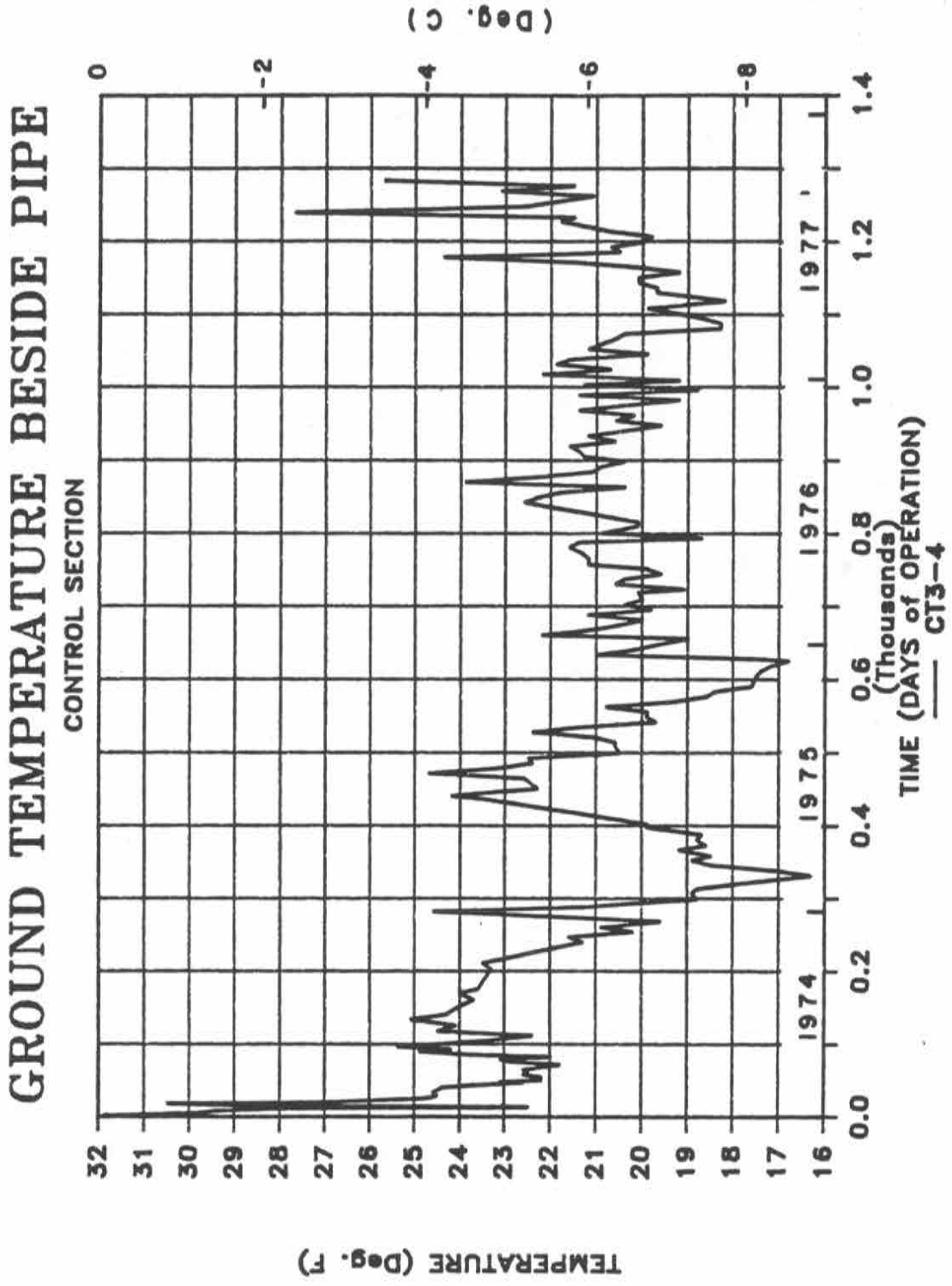
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE
AT THE
UNIVERSITY OF CALGARY

PREPARED BY L. CARLSON

FIGURE 2.6-24



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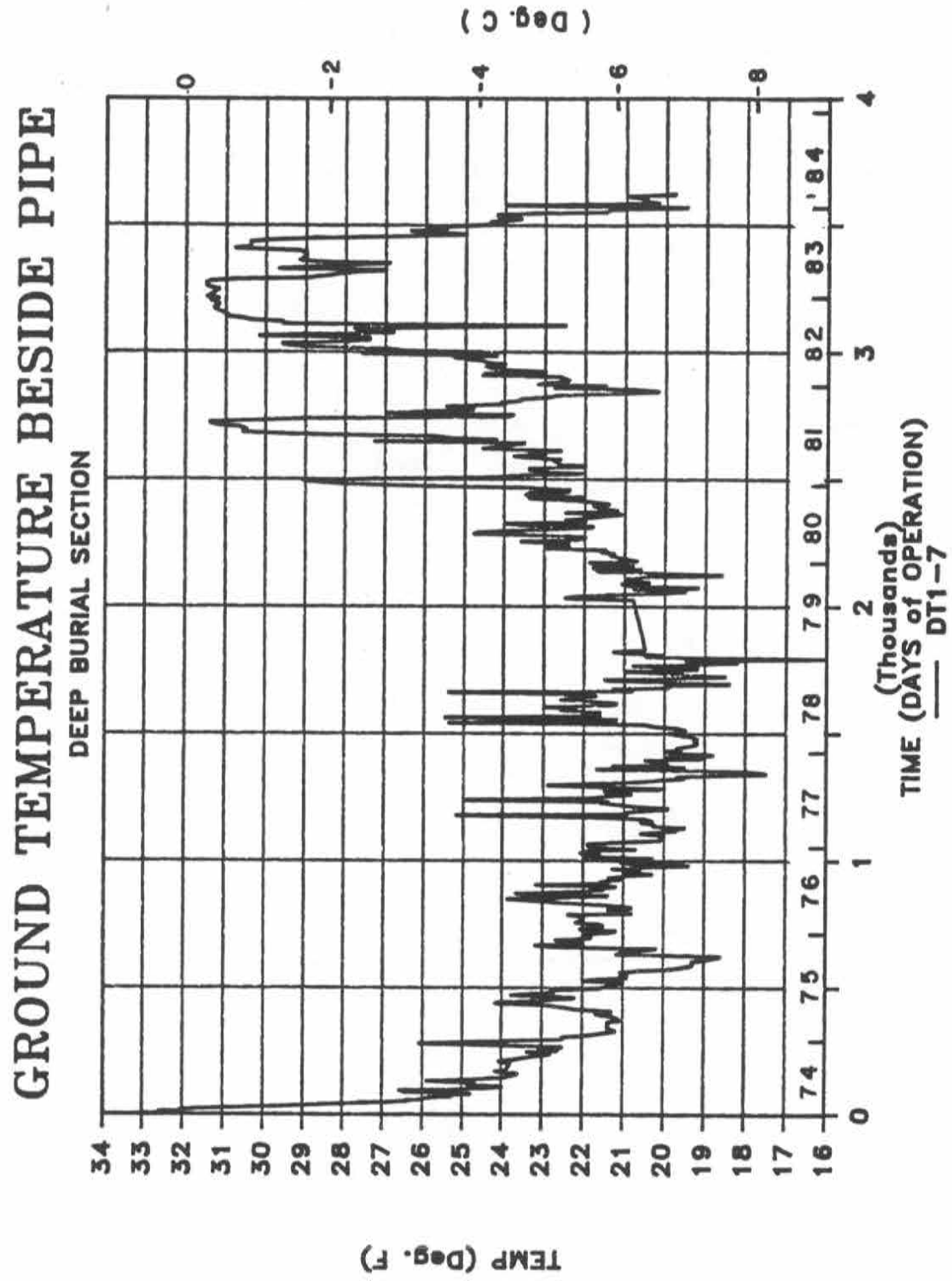
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE
BESIDE PIPE
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-25



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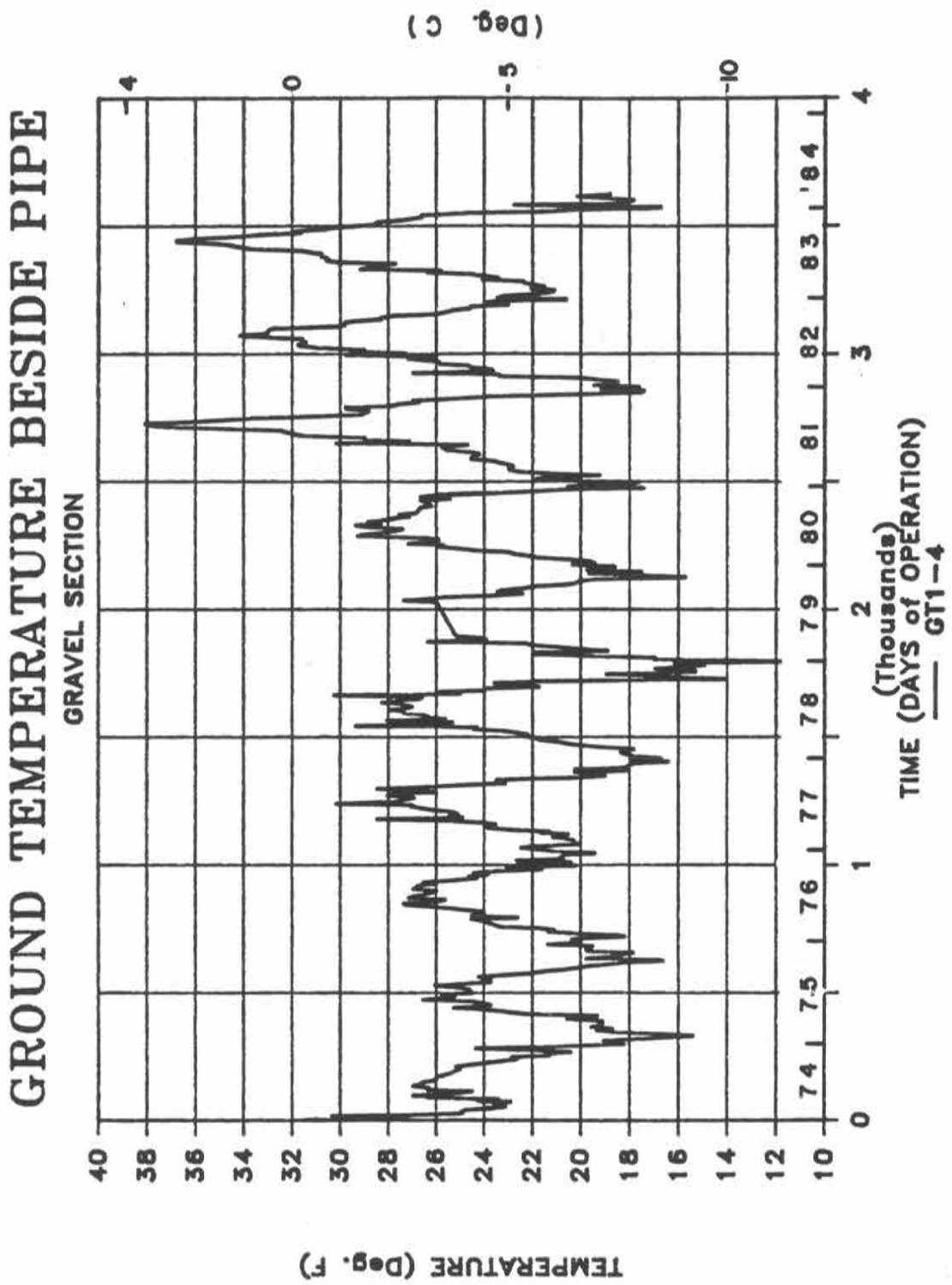
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE
BESIDE PIPE
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-26



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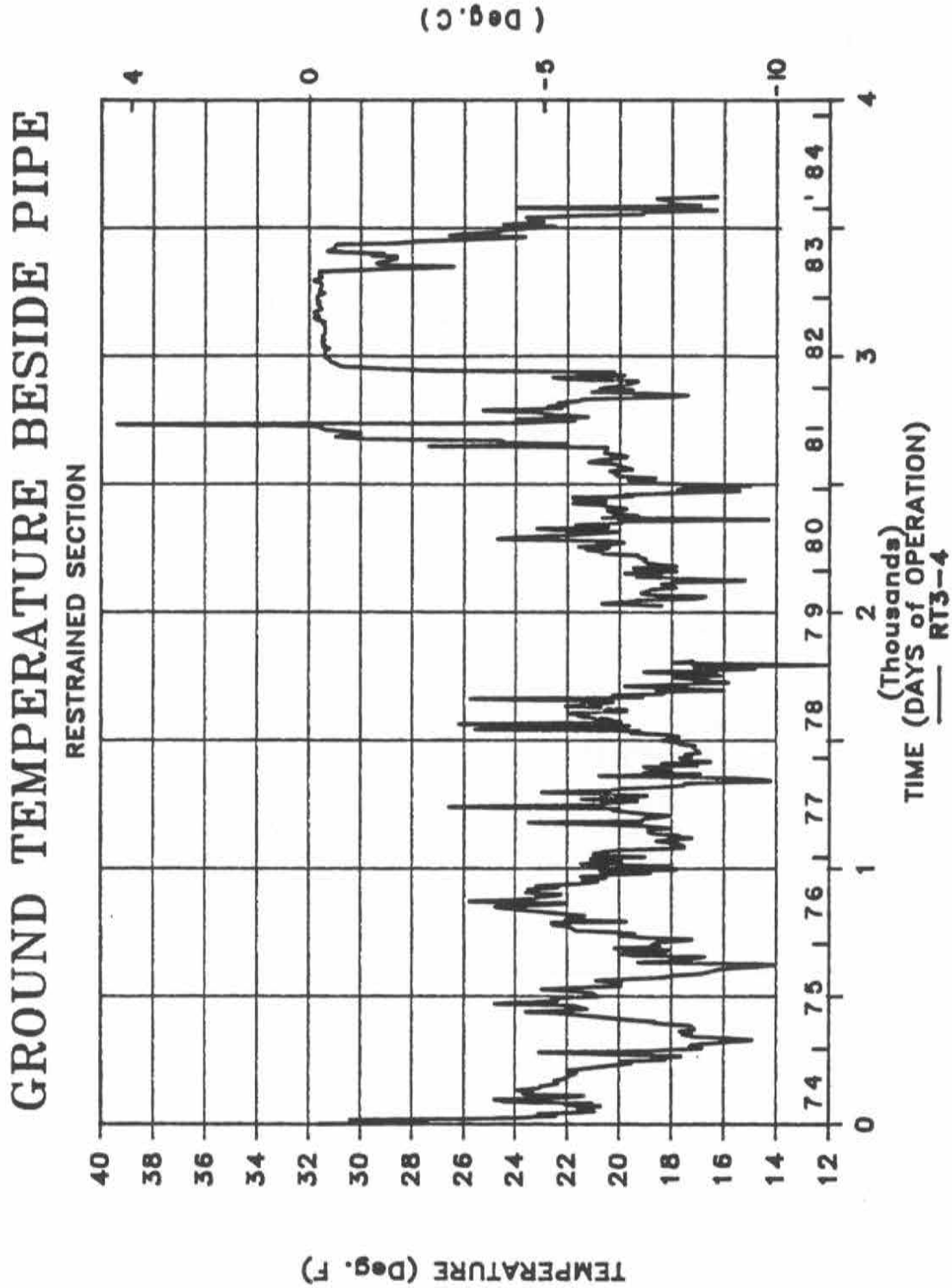
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE
BESIDE PIPE
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-27



L.E.C.
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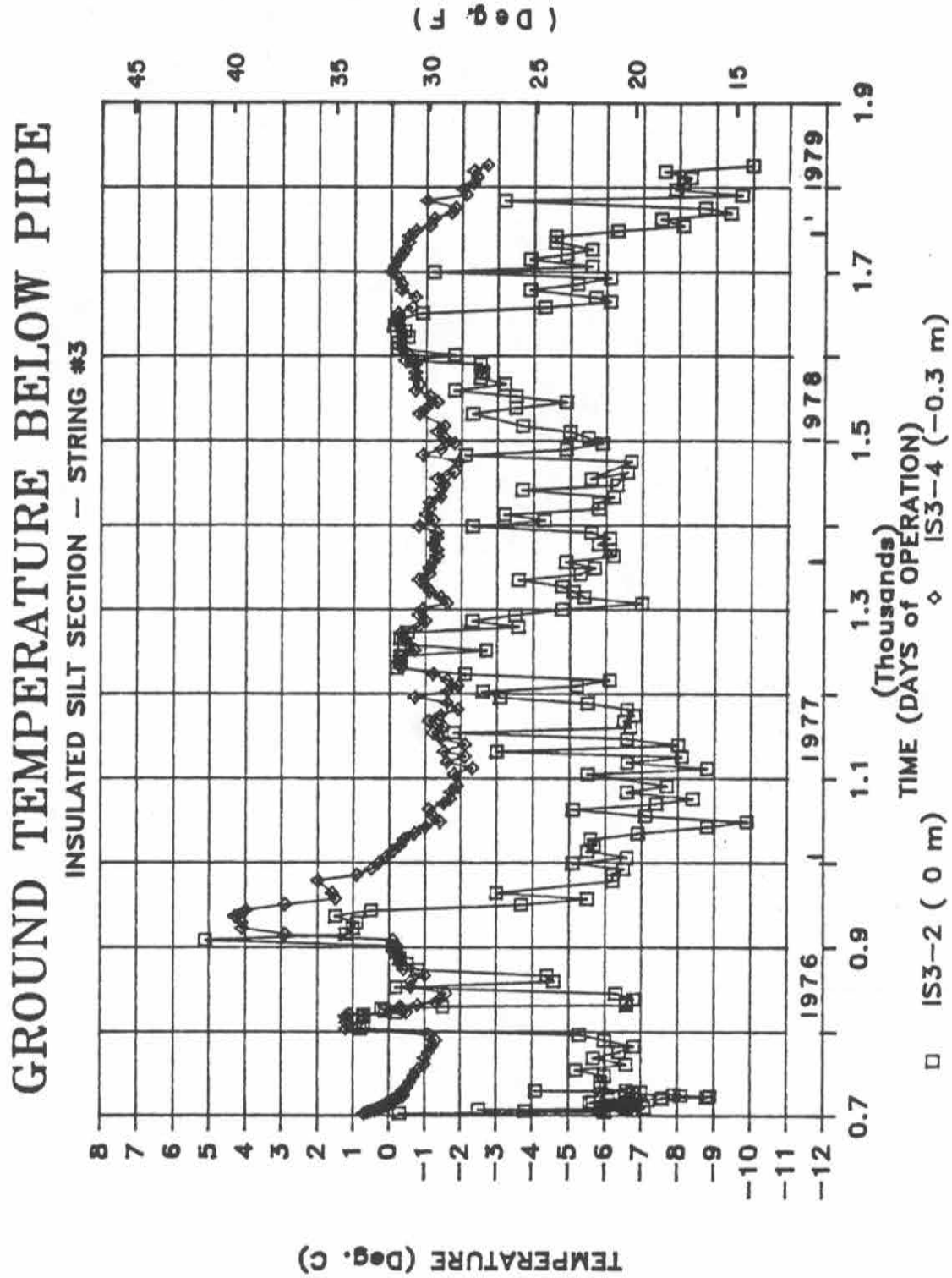
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE
BESIDE PIPE
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-28



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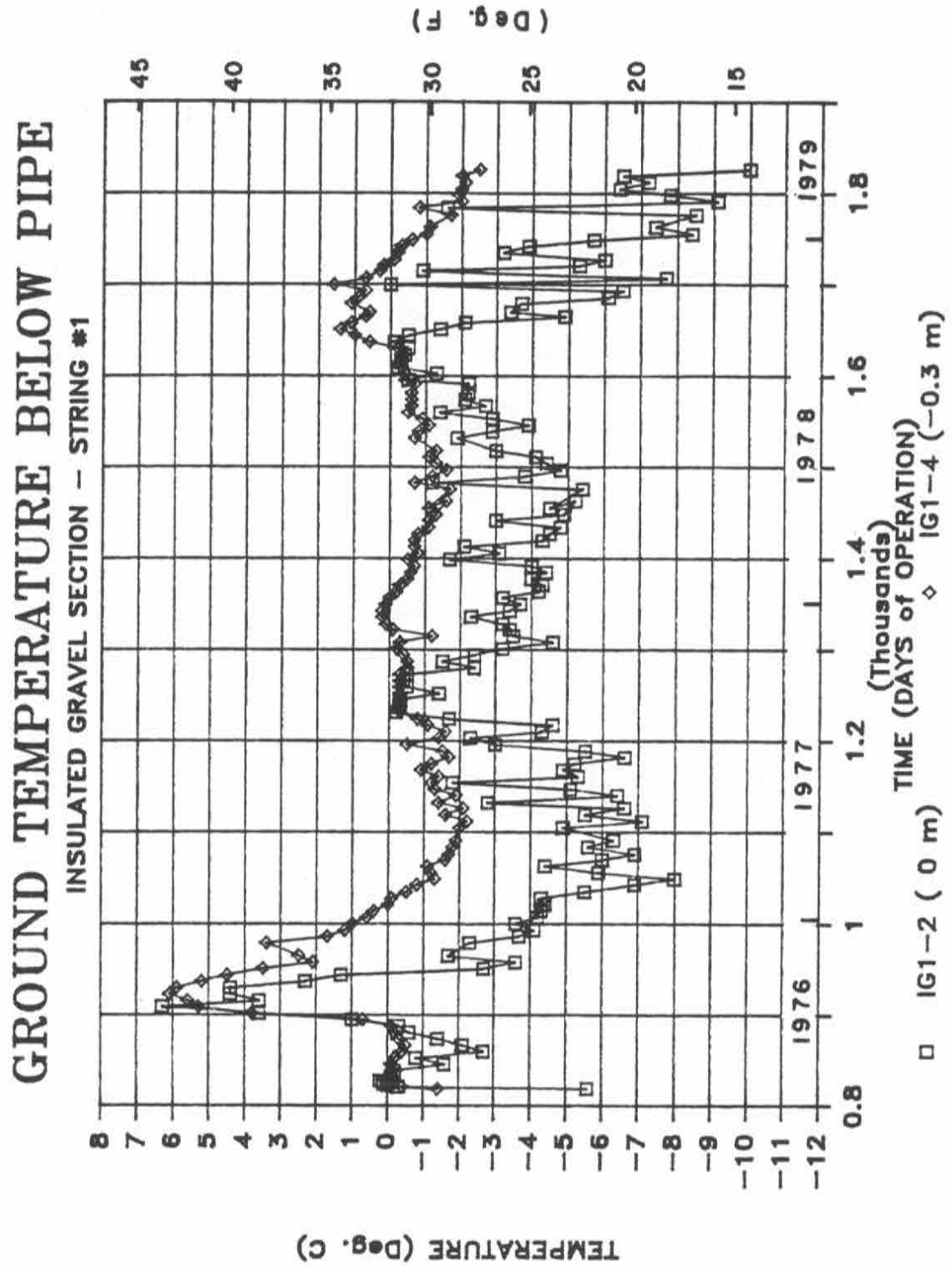
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE
BELOW PIPE
INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-29



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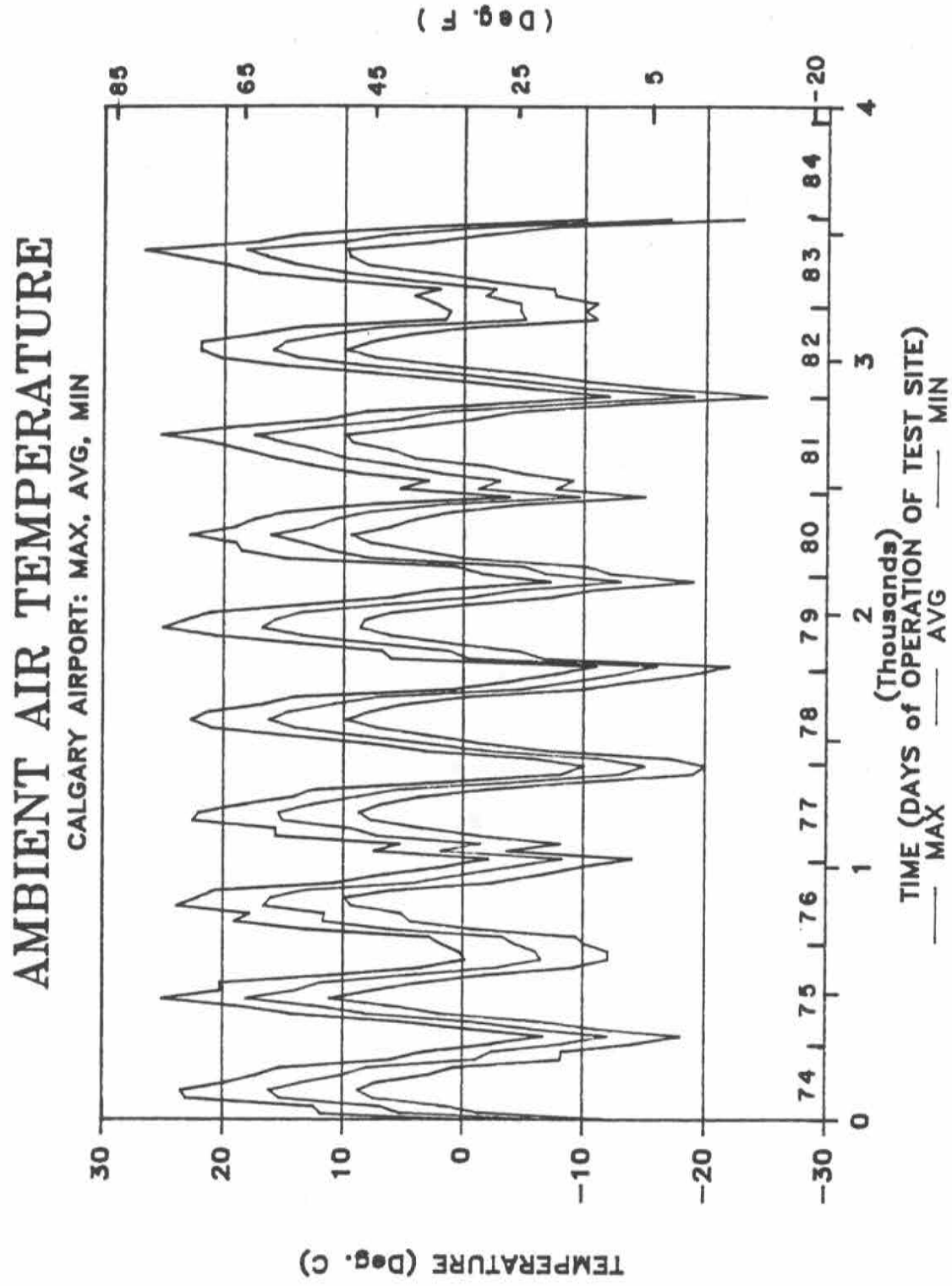
ENGINEERING LTD.

CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE BELOW PIPE INSULATED GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 2.6-30



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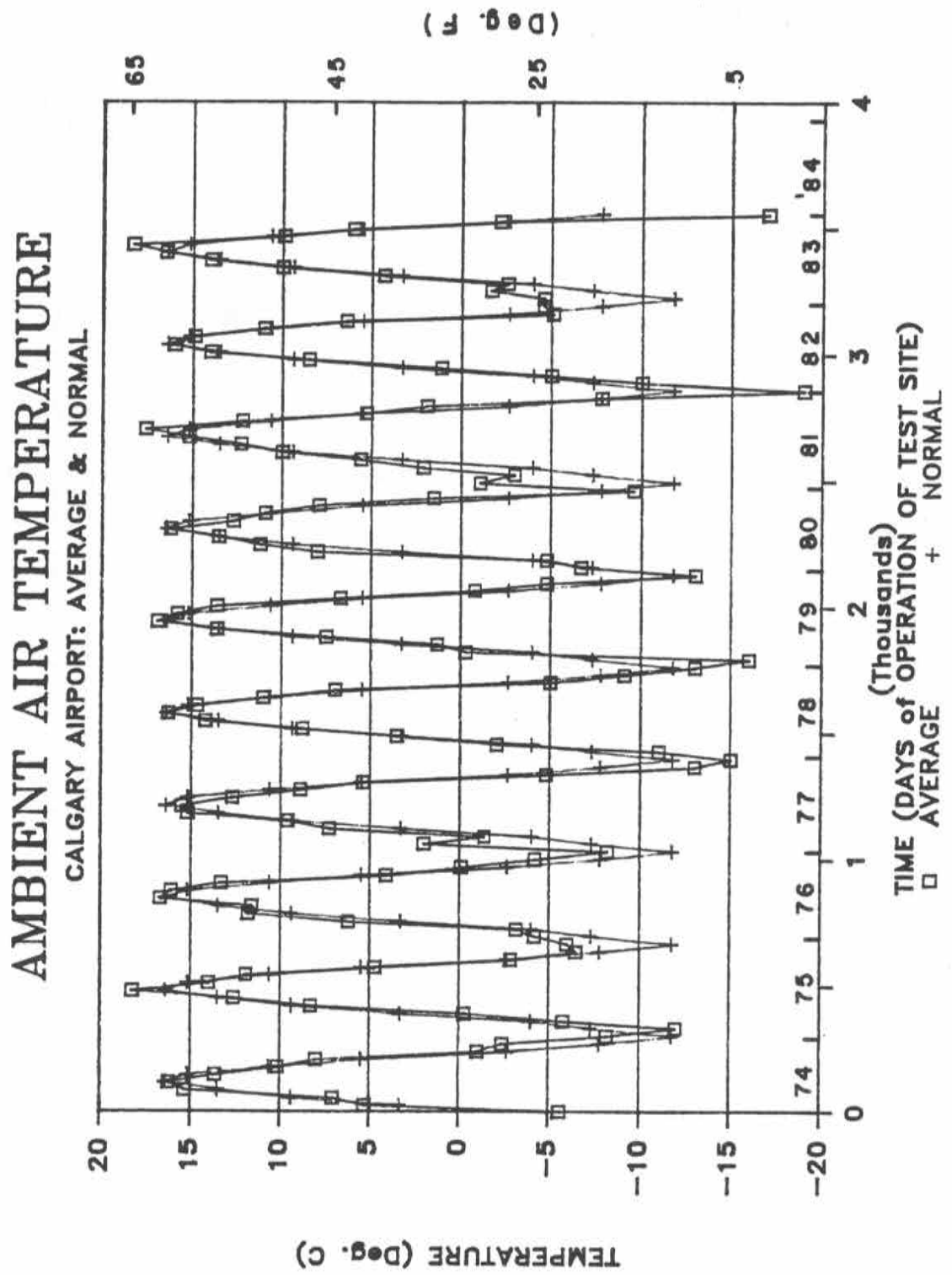
CALGARY FROST HEAVE TEST FACILITY

AMBIENT AIR TEMPERATURE
AT CALGARY AIRPORT
(MAX., AVG., MIN.)

PREPARED BY L. CARLSON

FIGURE 2.6-31



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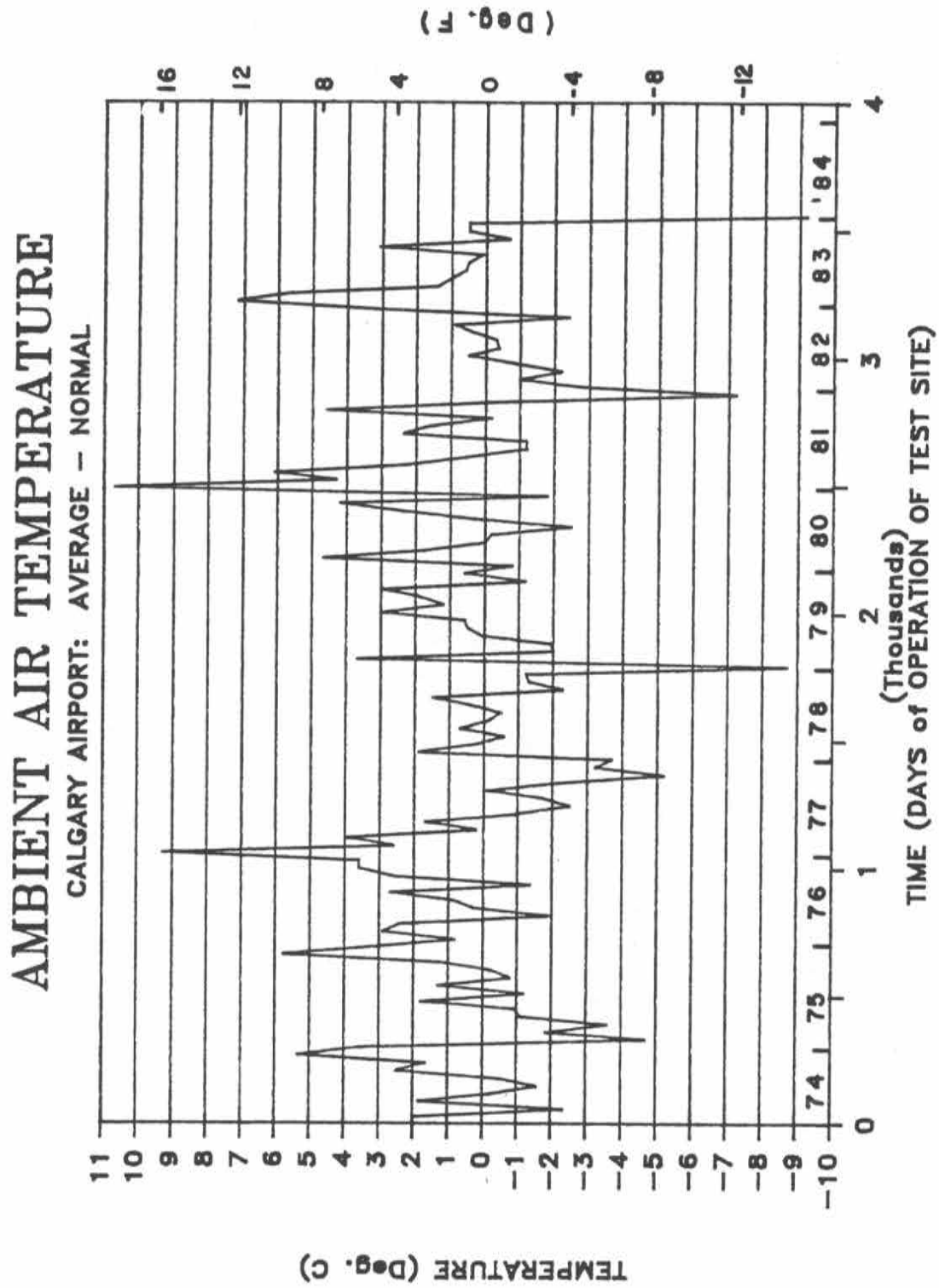
CALGARY FROST HEAVE TEST FACILITY

AMBIENT AIR TEMPERATURE
AT CALGARY AIRPORT
(AVG. & NORMAL)

PREPARED BY L. CARLSON

FIGURE 2.6-32



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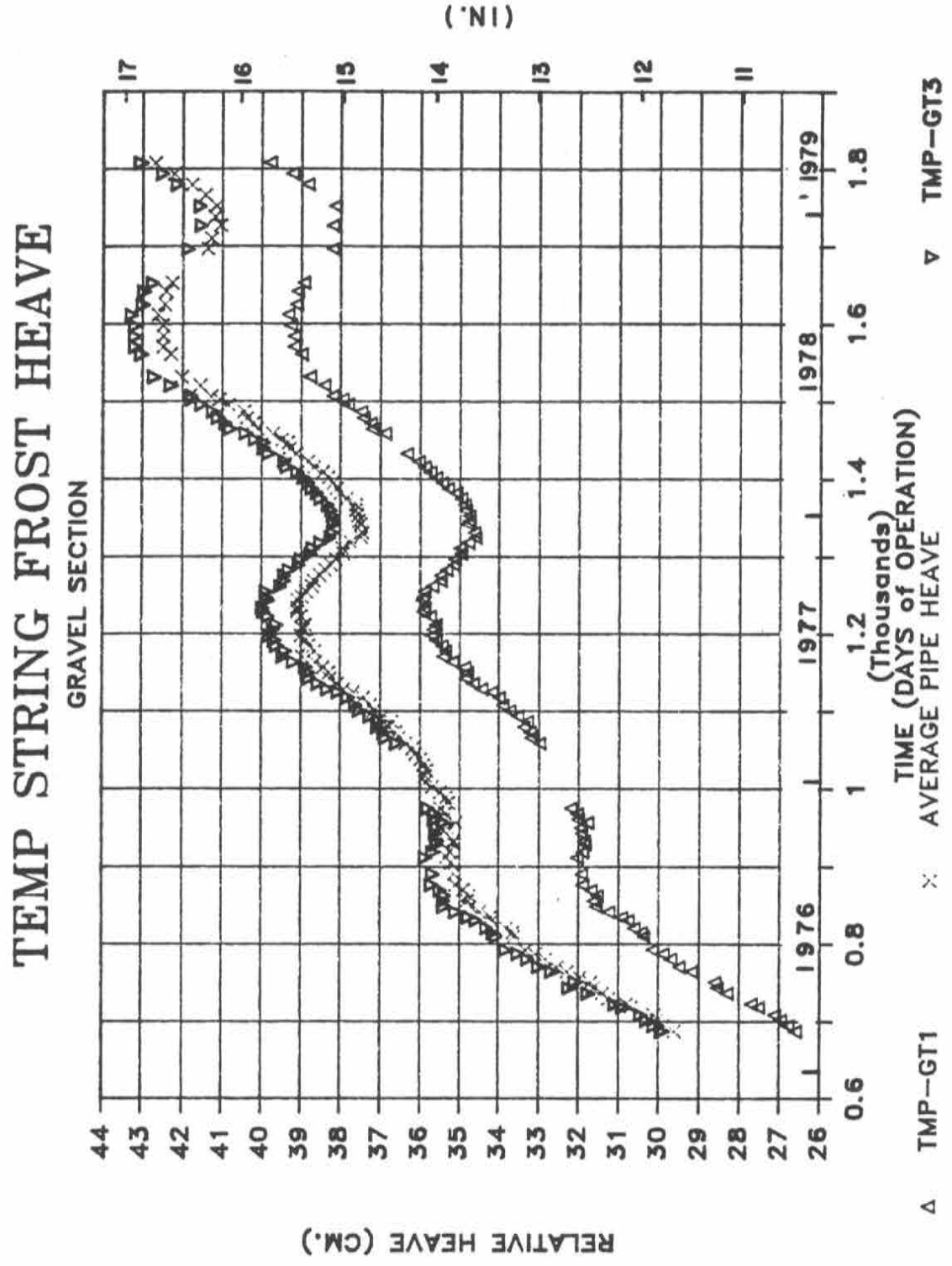
CALGARY FROST HEAVE TEST FACILITY

AMBIENT AIR TEMPERATURE
AT CALGARY AIRPORT
(AVG. — NORMAL)

PREPARED BY L. CARLSON

FIGURE 2.6-33



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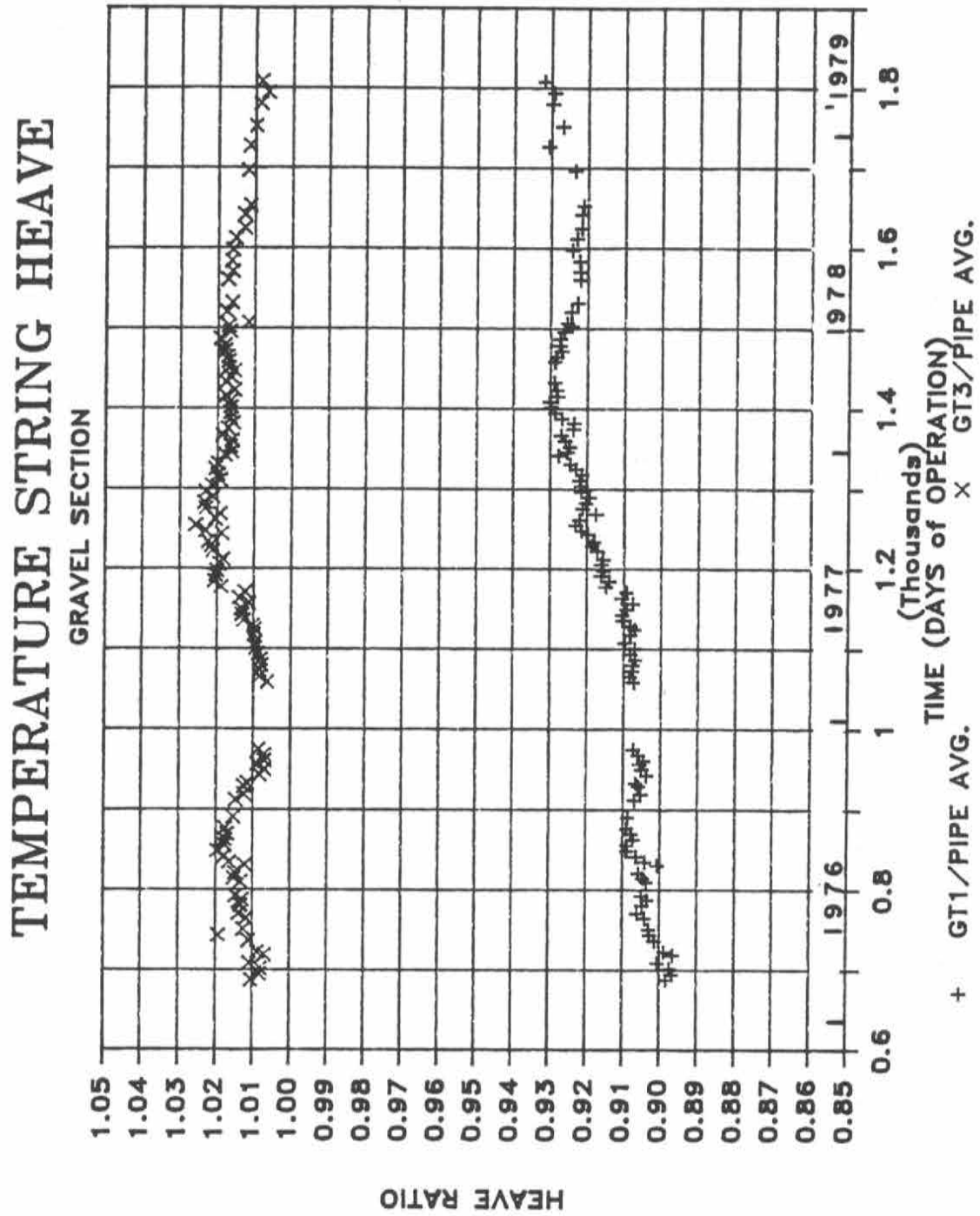
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE STRING HEAVE
GRAVEL SECTION
STRINGS #1 & #3

PREPARED BY L. CARLSON

FIGURE 3.1-1



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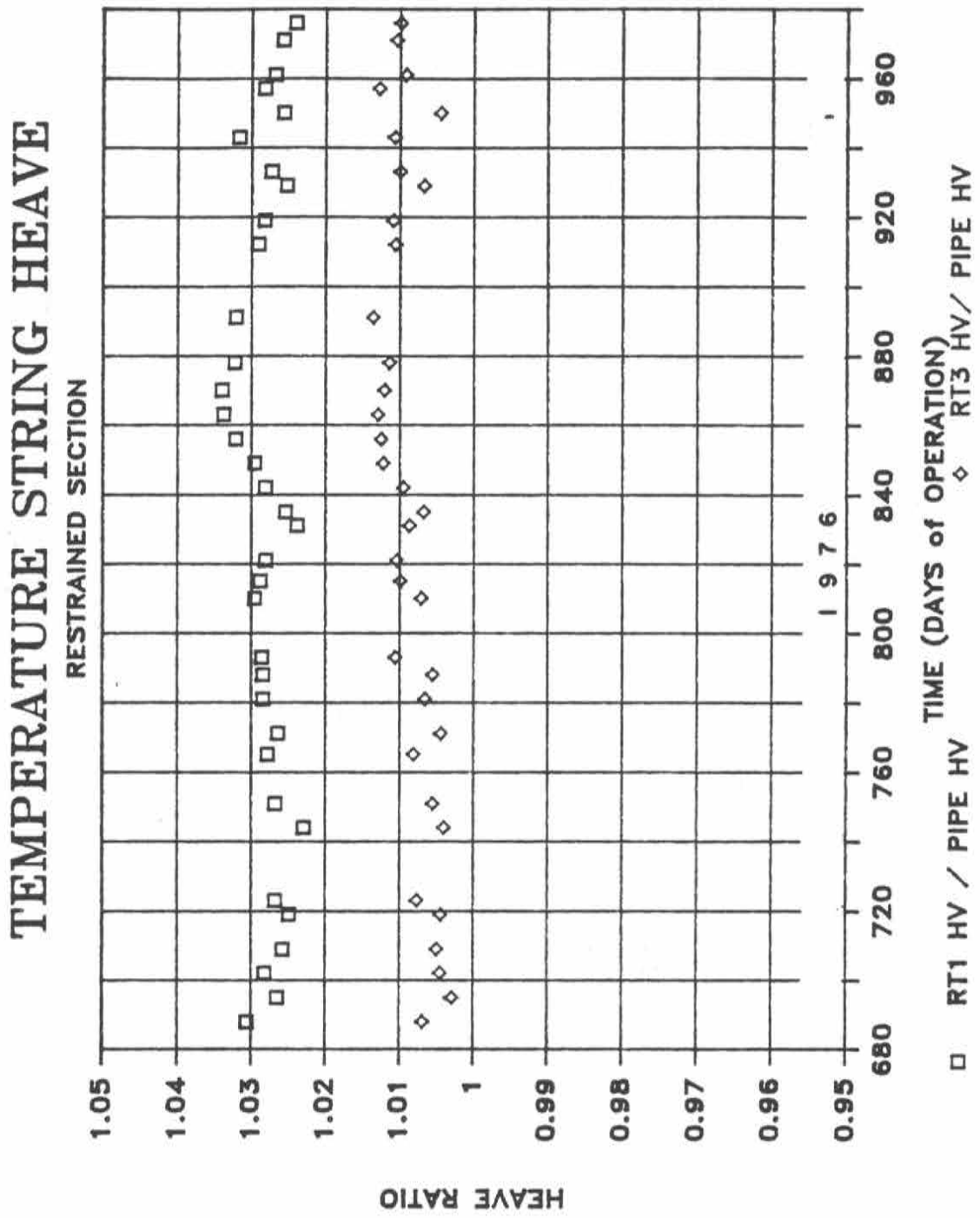
CALGARY FROST HEAVE TEST FACILITY
TEMPERATURE STRING
HEAVE RATIO
GRAVEL SECTION
STRINGS # 1 & # 3

PREPARED BY L. CARLSON

FIGURE 3.1-2



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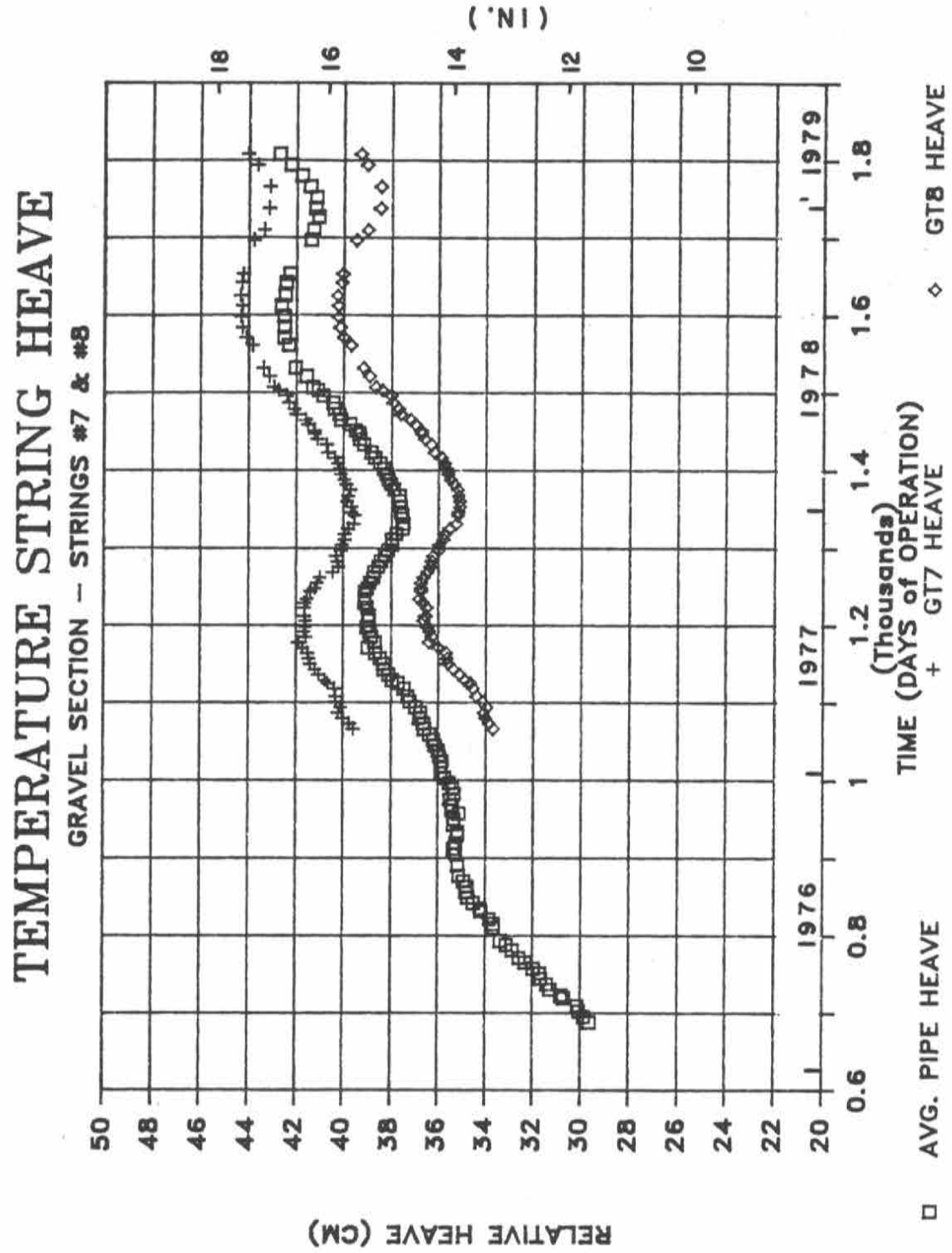
CALGARY FROST HEAVE TEST FACILITY
TEMPERATURE STRING
HEAVE RATIO
RESTRAINED SECTION
STRINGS # 1 & #3

PREPARED BY L. CARLSON

FIGURE 3.1-3



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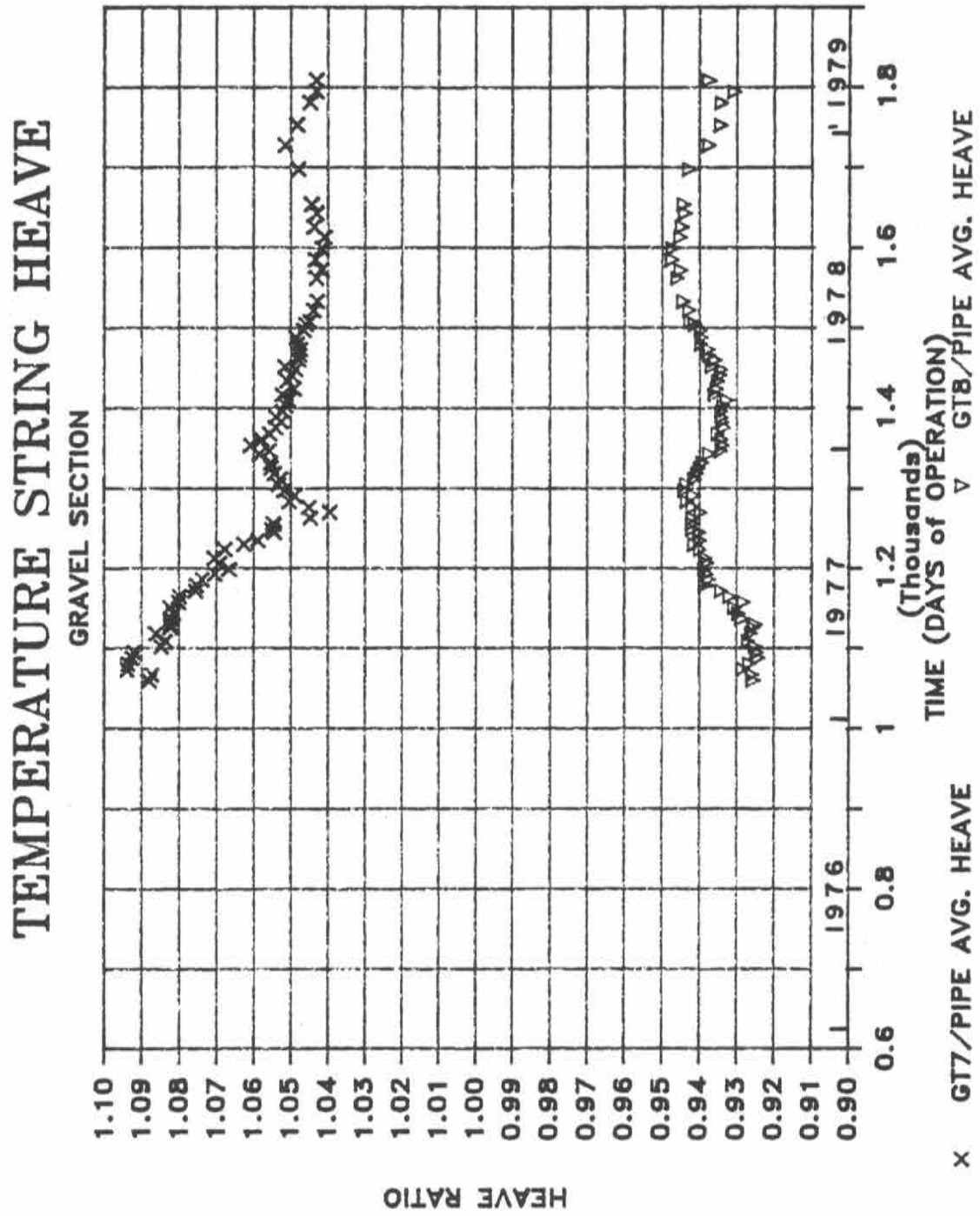
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE STRING HEAVE
GRAVEL SECTION
STRINGS # 7 & # 8

PREPARED BY L. CARLSON

FIGURE 3.1-4



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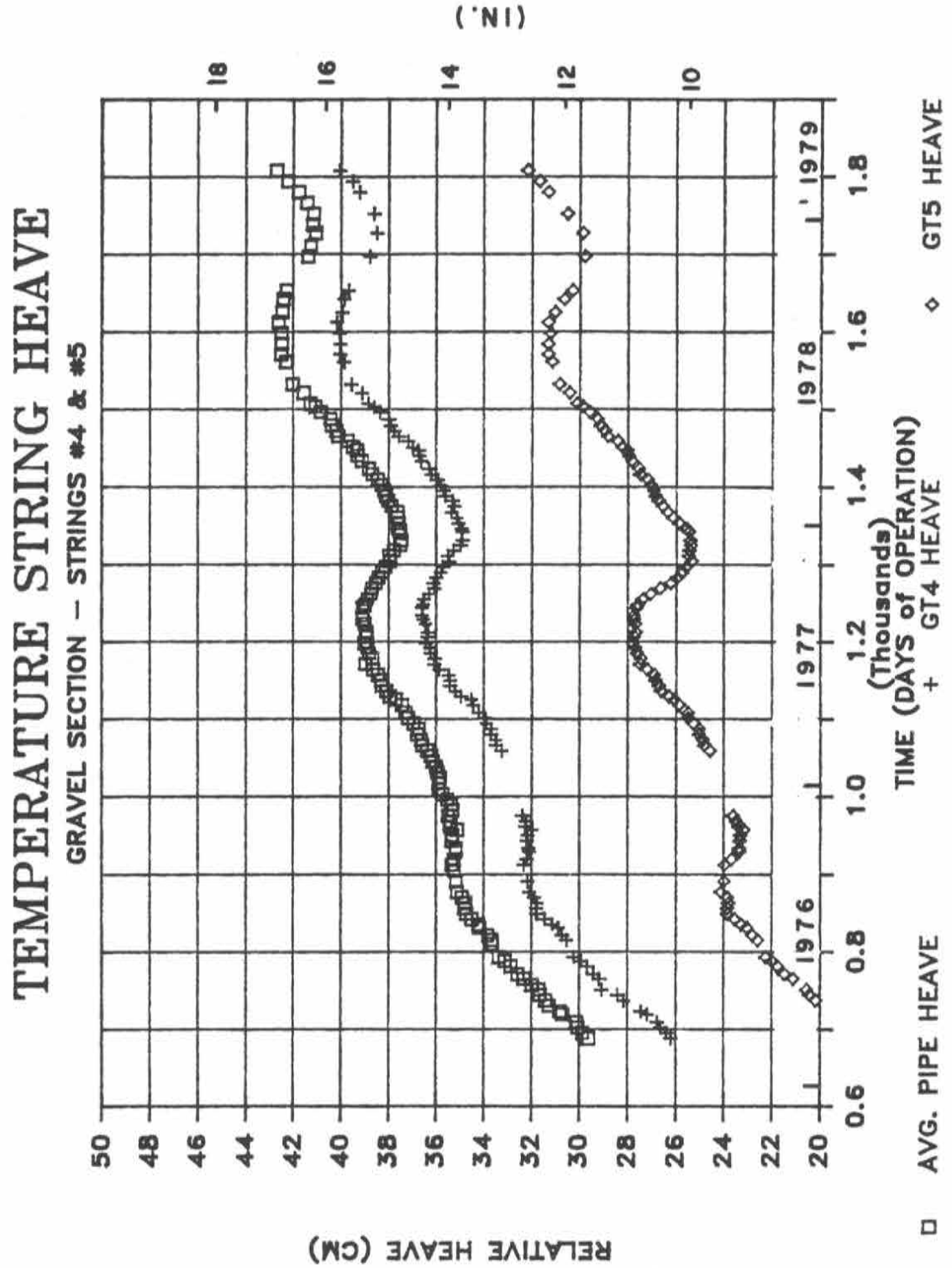
CALGARY FROST HEAVE TEST FACILITY
TEMPERATURE STRING
HEAVE RATIO
GRAVEL SECTION
STRINGS #7 & #8

PREPARED BY L. CARLSON

FIGURE 3.1-5



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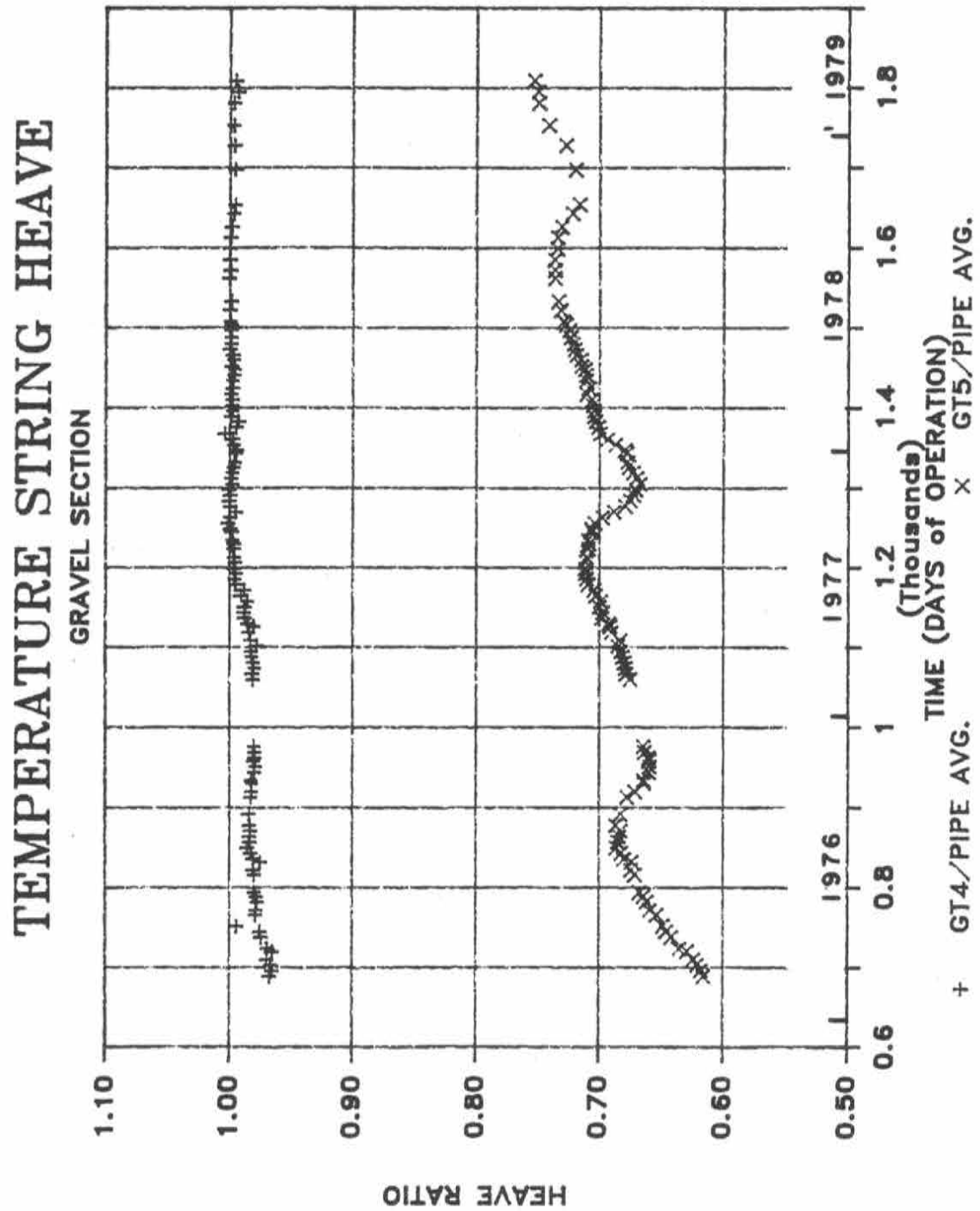
CALGARY FROST HEAVE TEST FACILITY
TEMPERATURE STRING HEAVE
GRAVEL SECTION
STRINGS # 4 & # 5

PREPARED BY L. CARLSON

FIGURE 3.1-6



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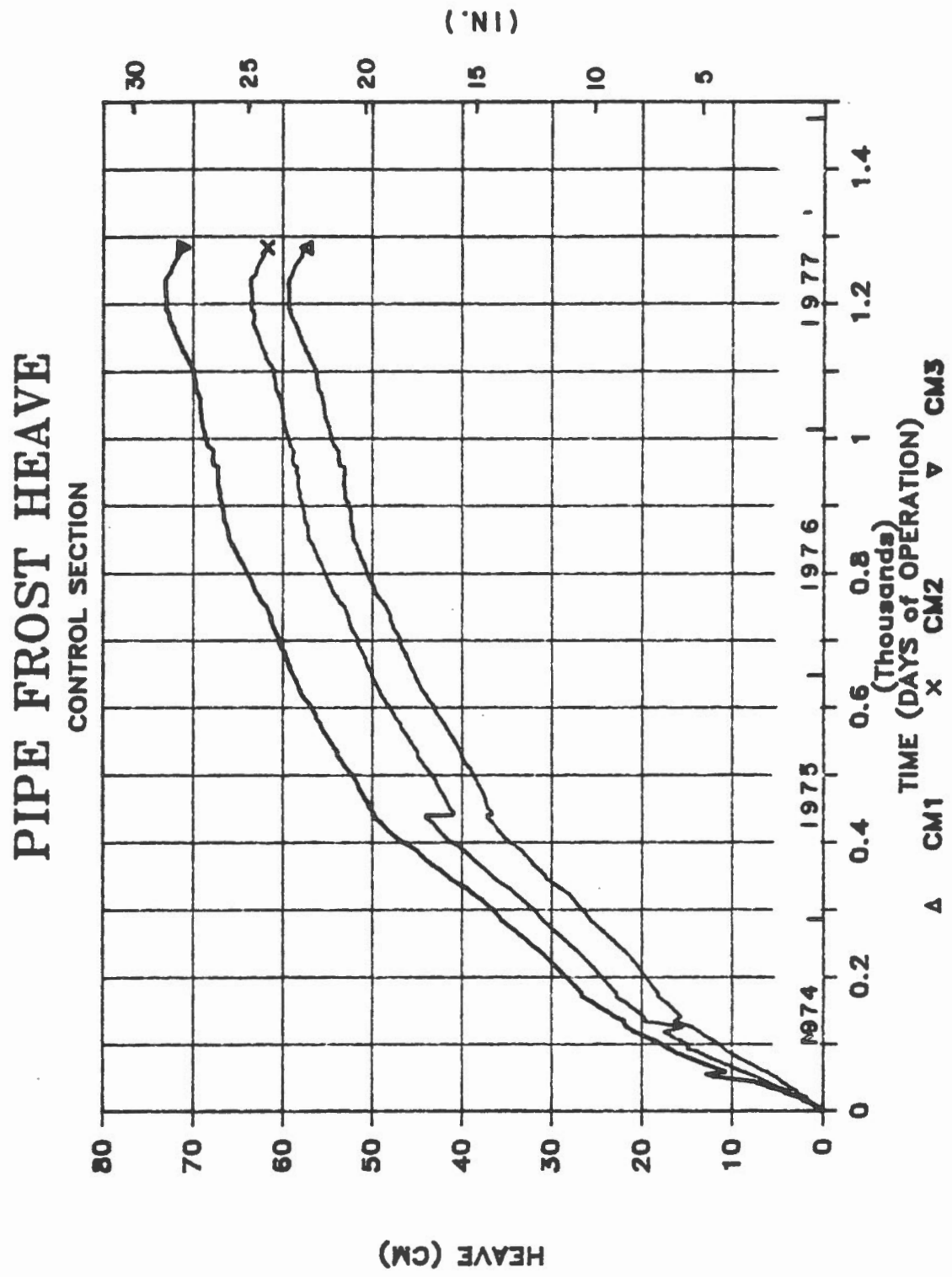
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE STRING
HEAVE RATIO
GRAVEL SECTION
STRINGS #4 & #5

PREPARED BY L. CARLSON

FIGURE 3.1-7



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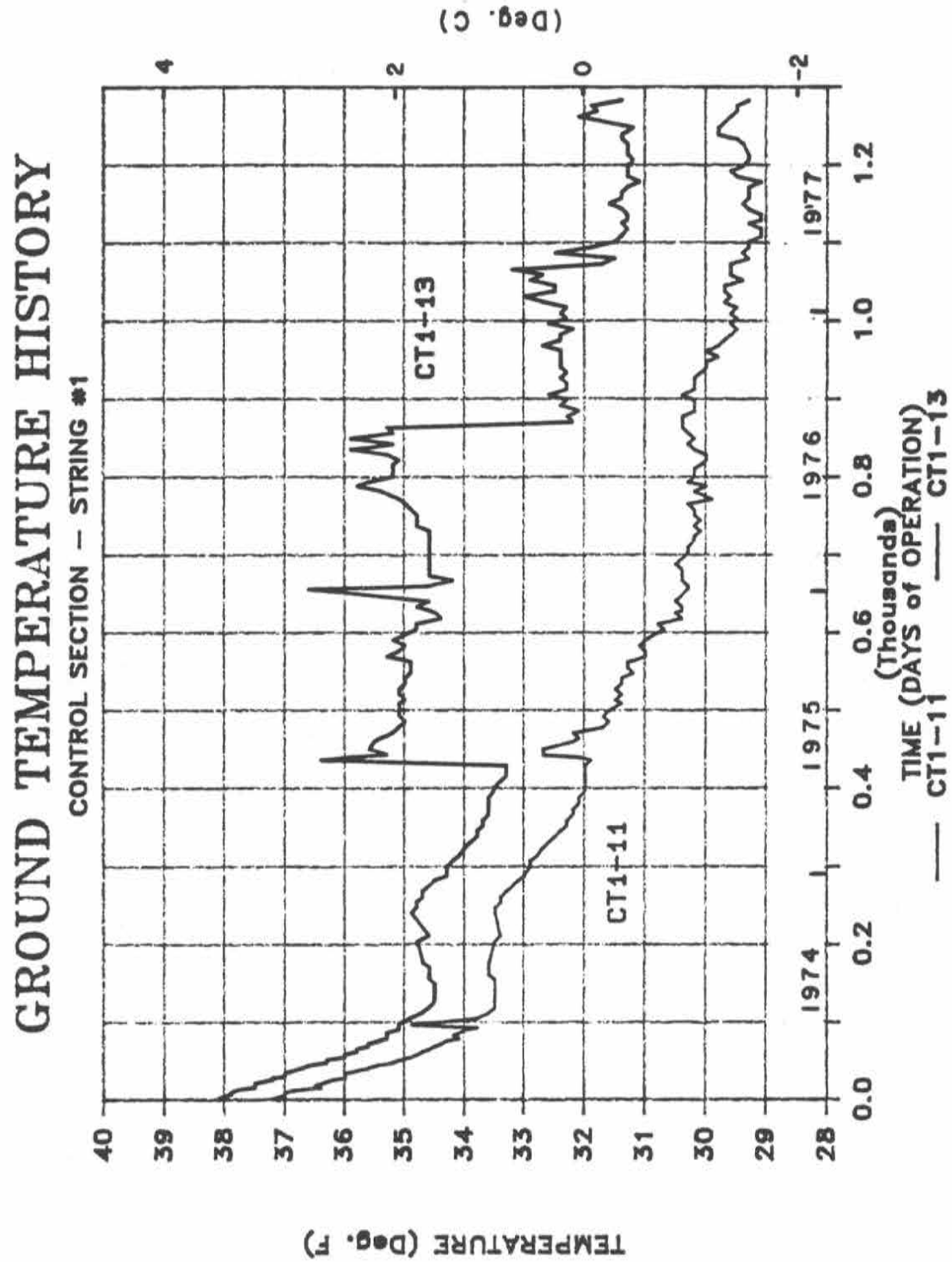
CALGARY FROST HEAVE TEST FACILITY

FROST HEAVE
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-1



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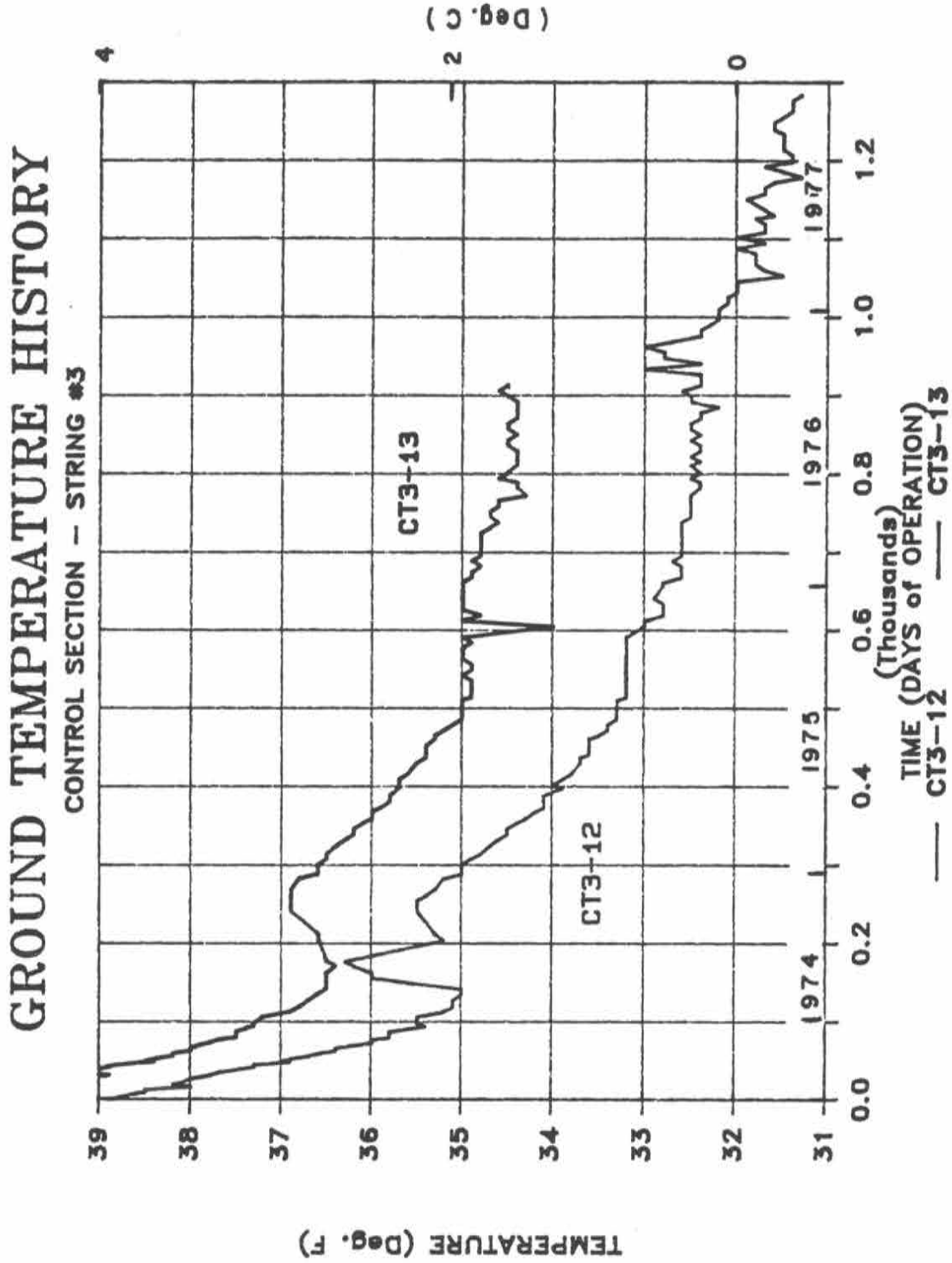
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
CONTROL SECTION
STRING # 1

PREPARED BY L. CARLSON

FIGURE 3.3-2



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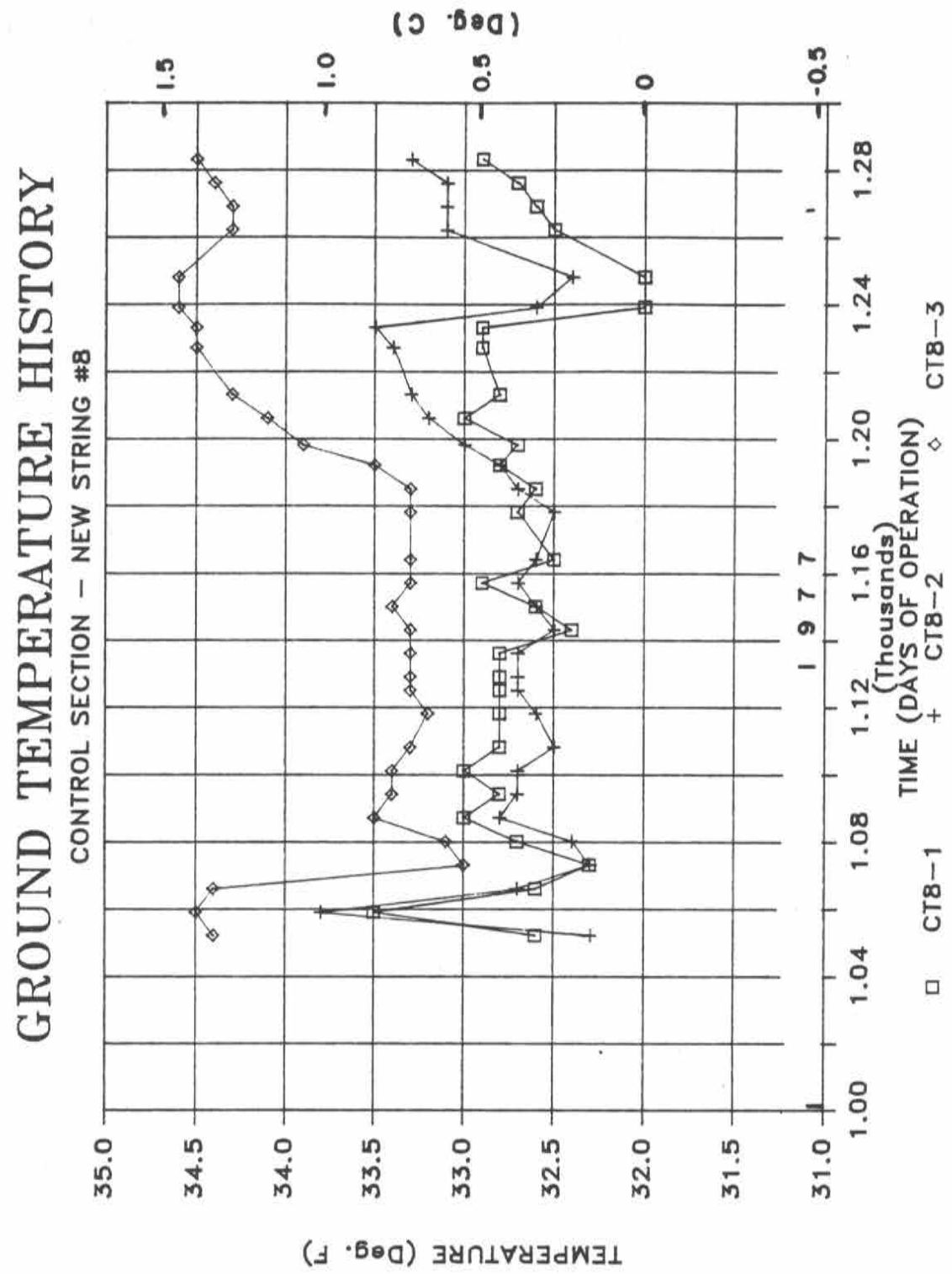
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
CONTROL SECTION
STRING # 3

PREPARED BY L. CARLSON

FIGURE 3.3-3



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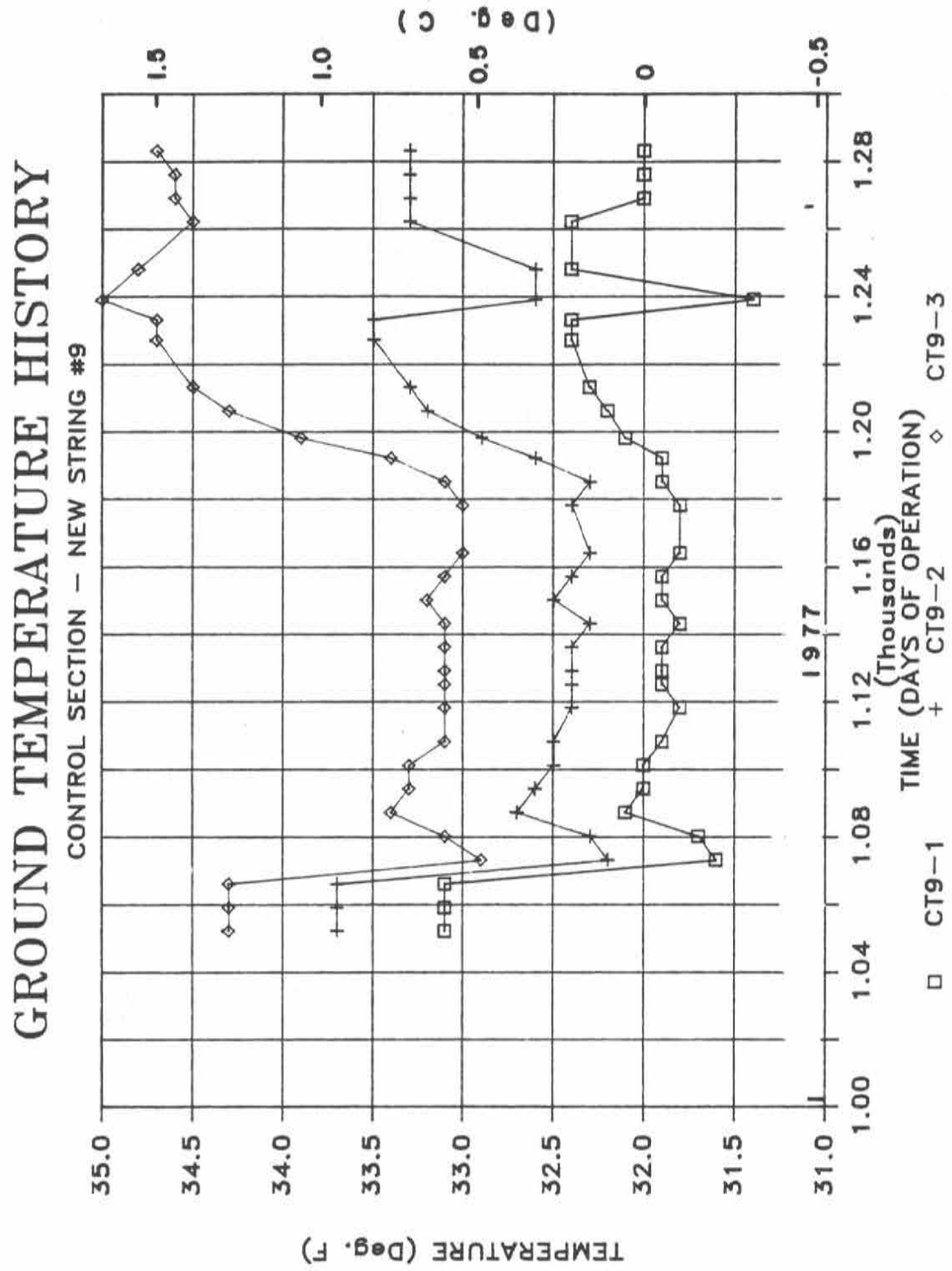
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
CONTROL SECTION
NEW STRING # 8

PREPARED BY L. CARLSON

FIGURE 3.3-4



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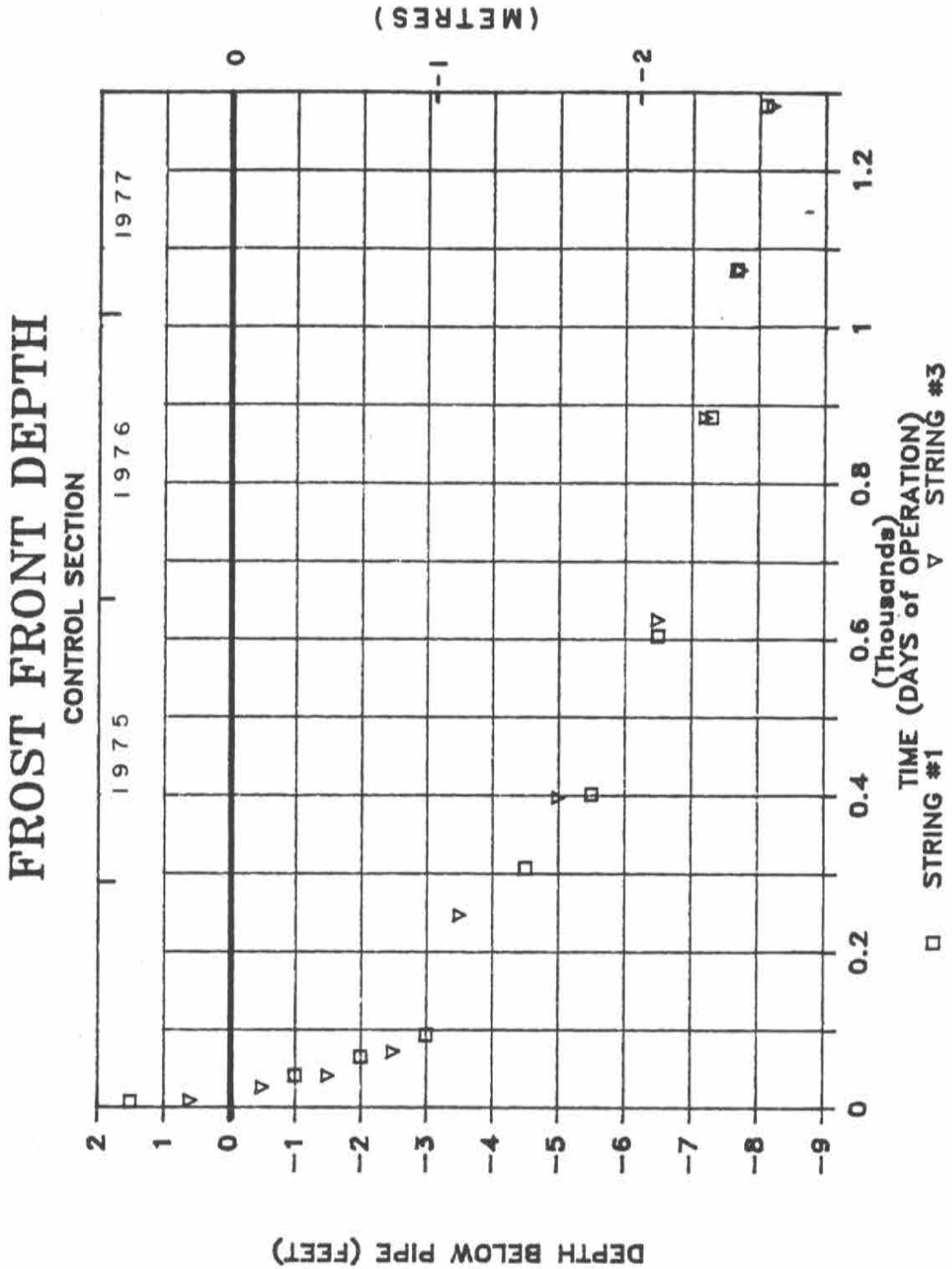
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
CONTROL SECTION
NEW STRING # 9

PREPARED BY L. CARLSON

FIGURE 3.3-5



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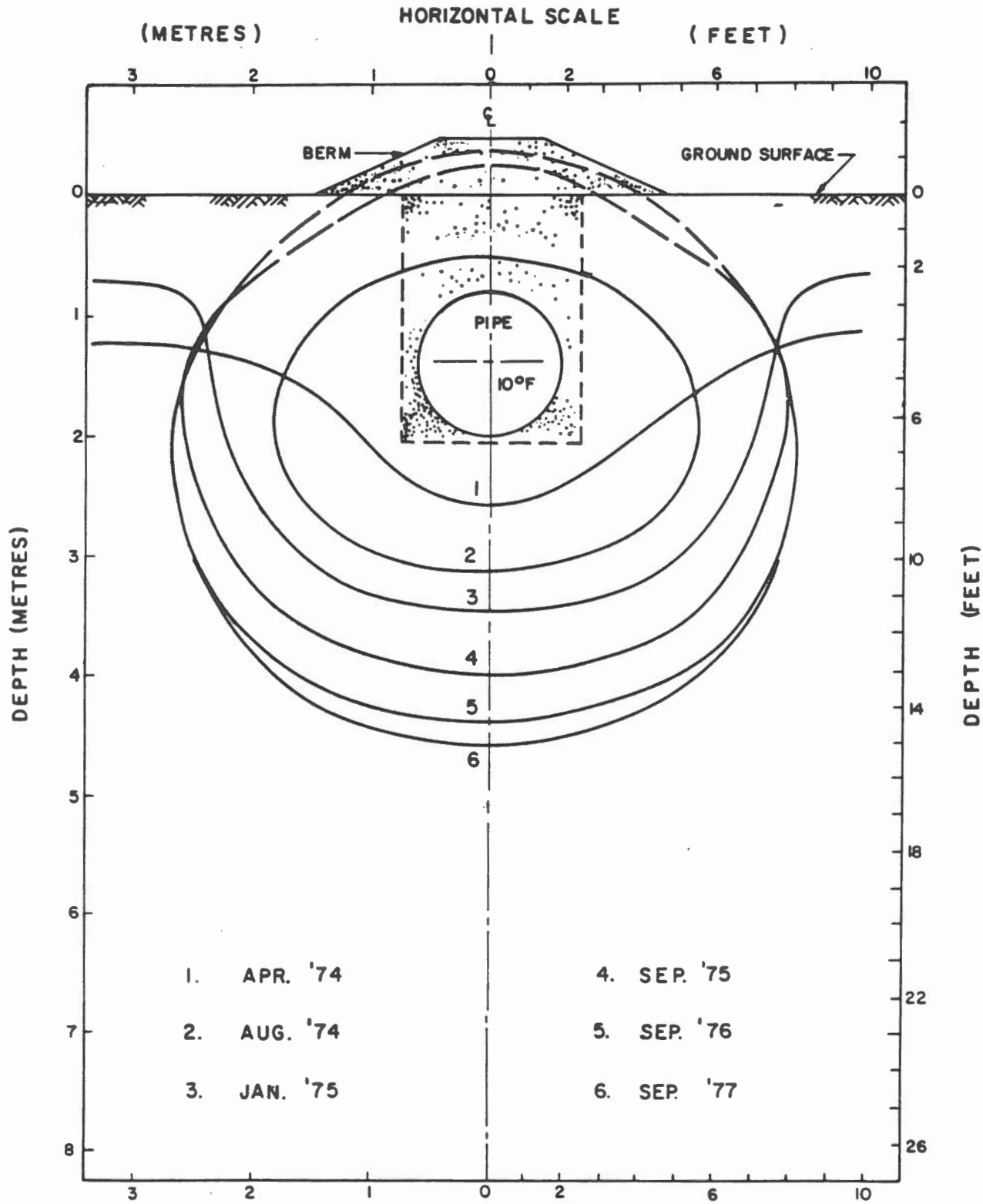
CALGARY FROST HEAVE TEST FACILITY

FROST FRONT DEPTH
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-6



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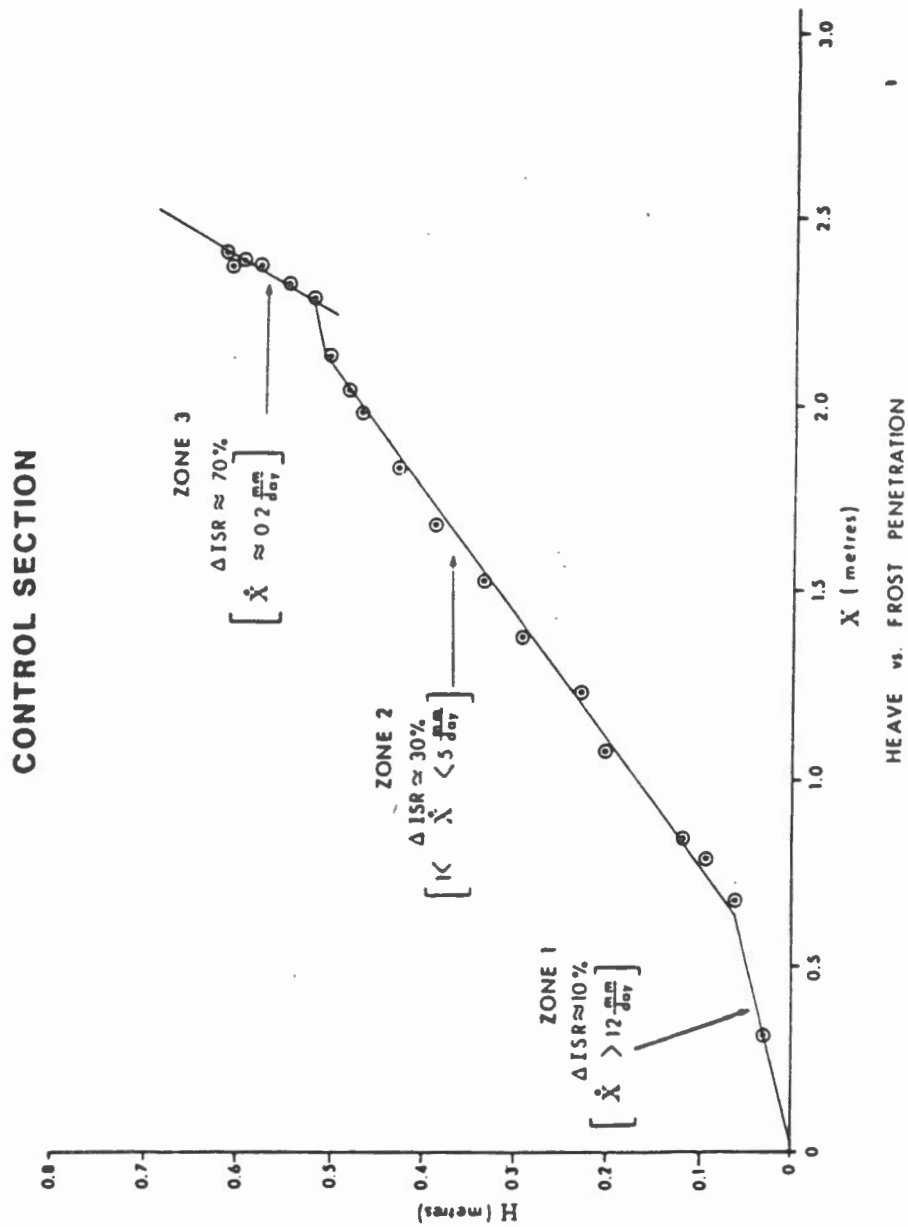
CALGARY FROST HEAVE TEST FACILITY

FROST BULB GROWTH CONTROL SECTION

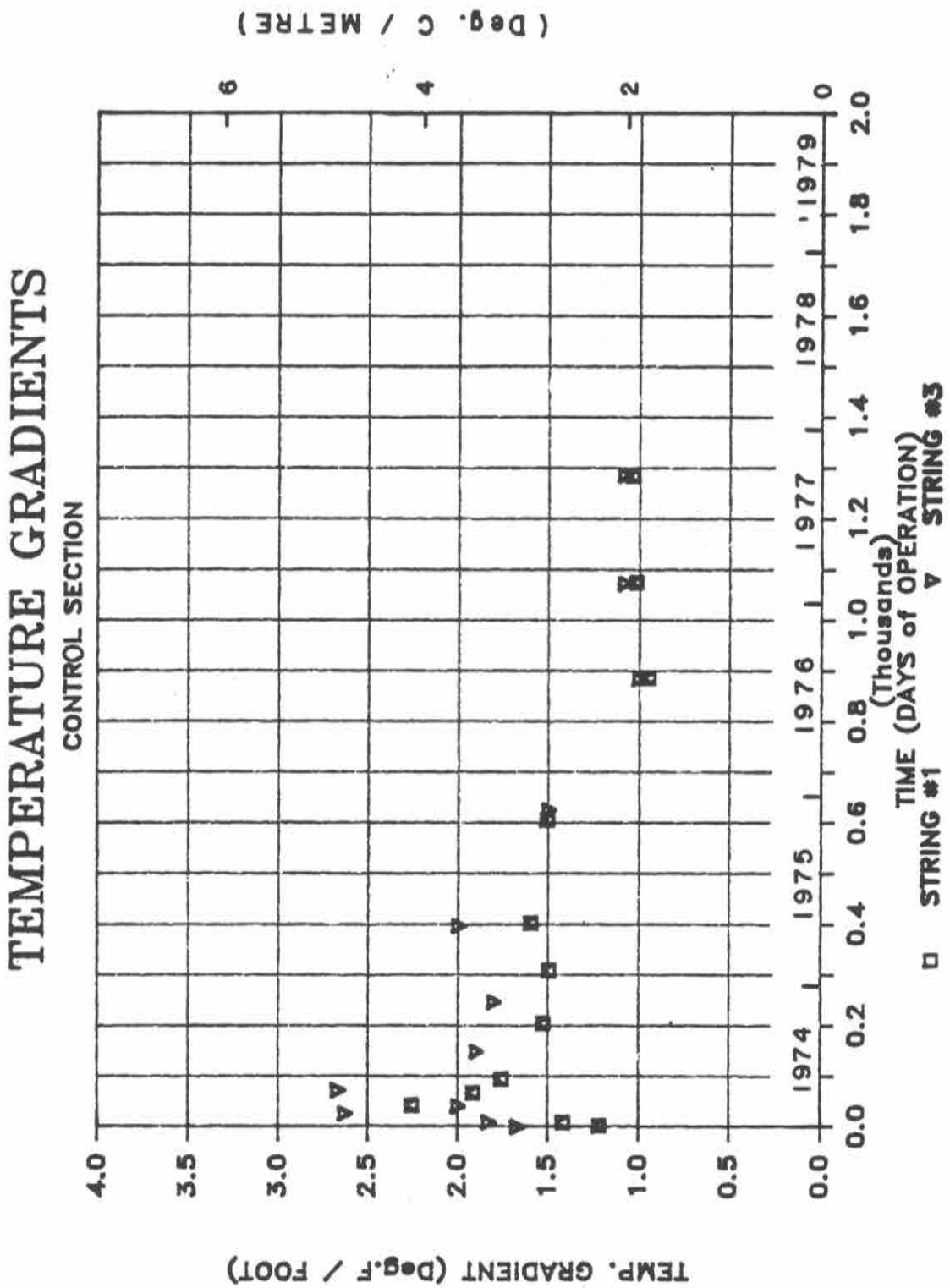
PREPARED BY L. CARLSON

FIGURE 3.3-7



After Carlson et. al. 1982

L.E.C. **ENGINEERING LTD.**	CALGARY FROST HEAVE TEST FACILITY HEAVE VERSUS FROST PENETRATION CONTROL SECTION
PREPARED BY L. CARLSON	FIGURE 3.3-8



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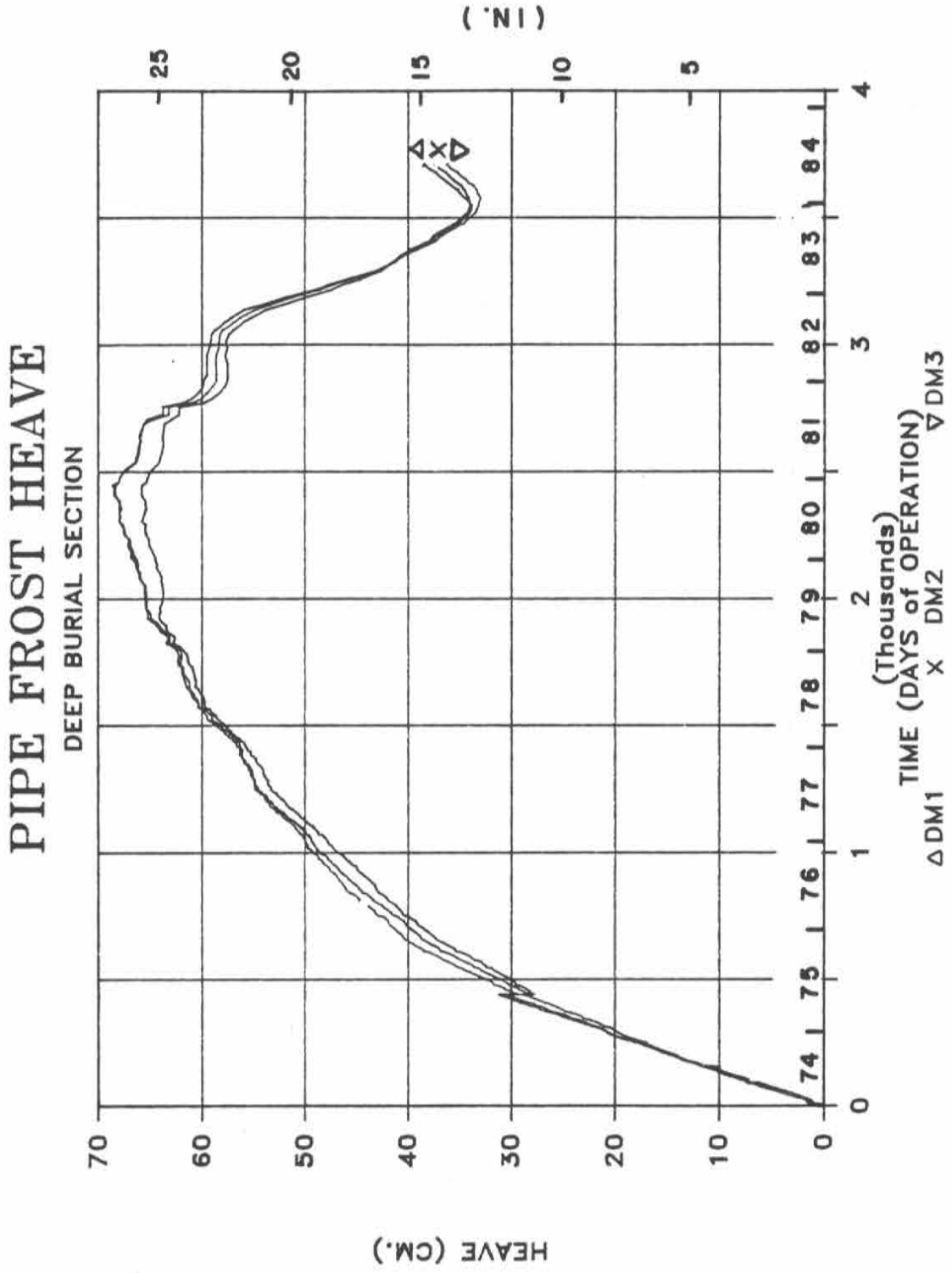
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE GRADIENTS
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-9



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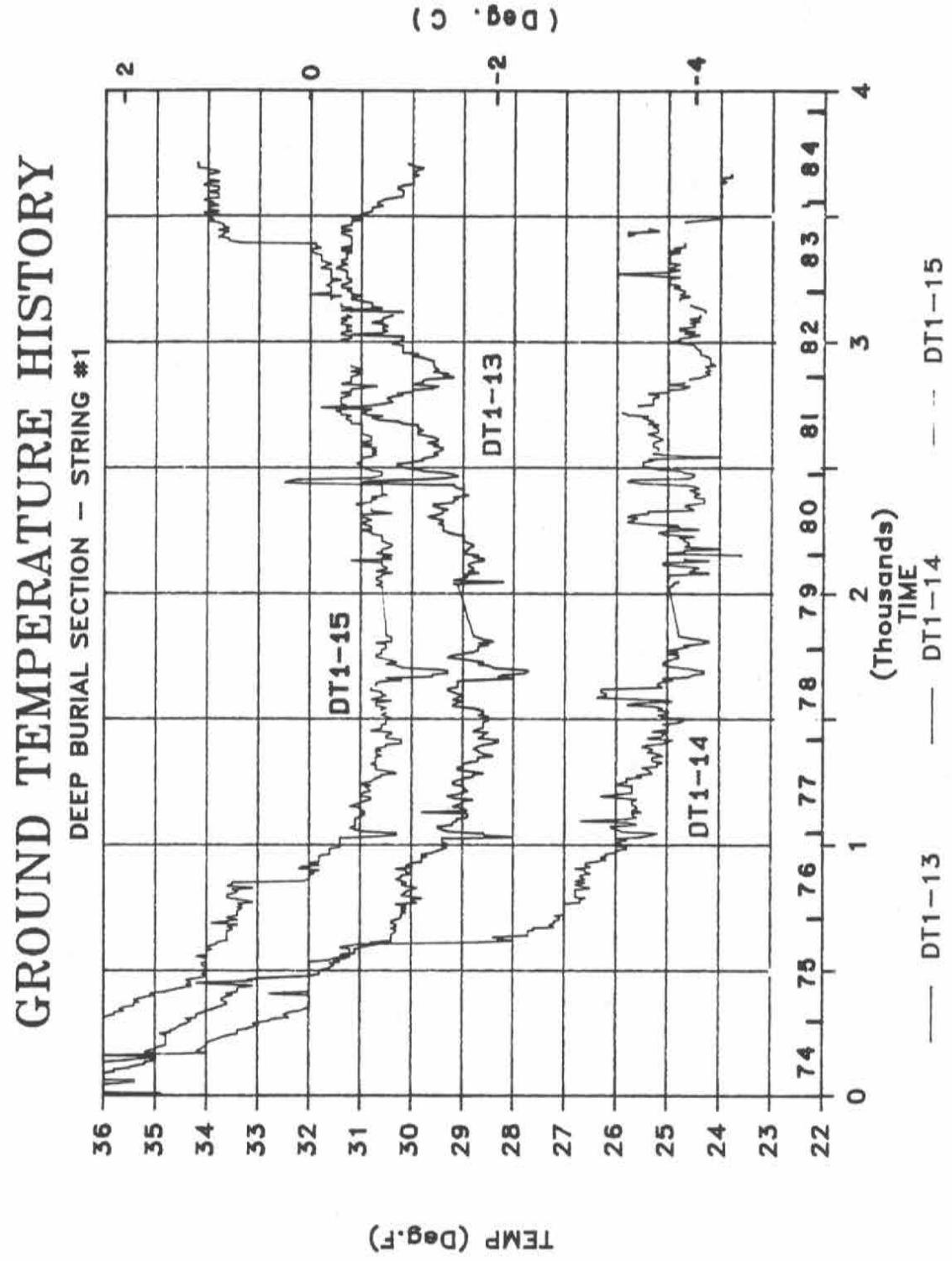
CALGARY FROST HEAVE TEST FACILITY

FROST HEAVE
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-10



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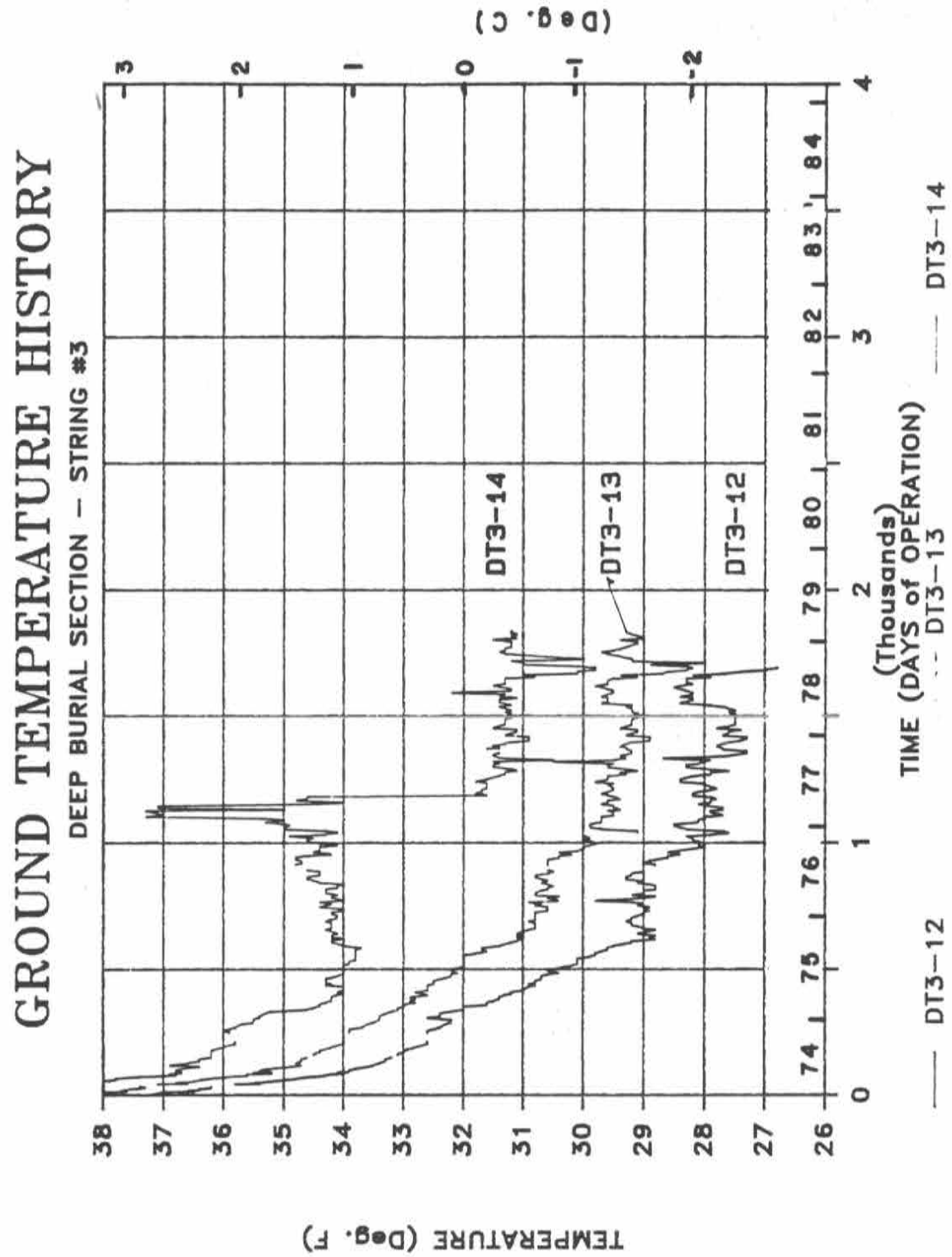
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
DEEP BURIAL SECTION,
STRING # 1

PREPARED BY L. CARLSON

FIGURE 3.3-11



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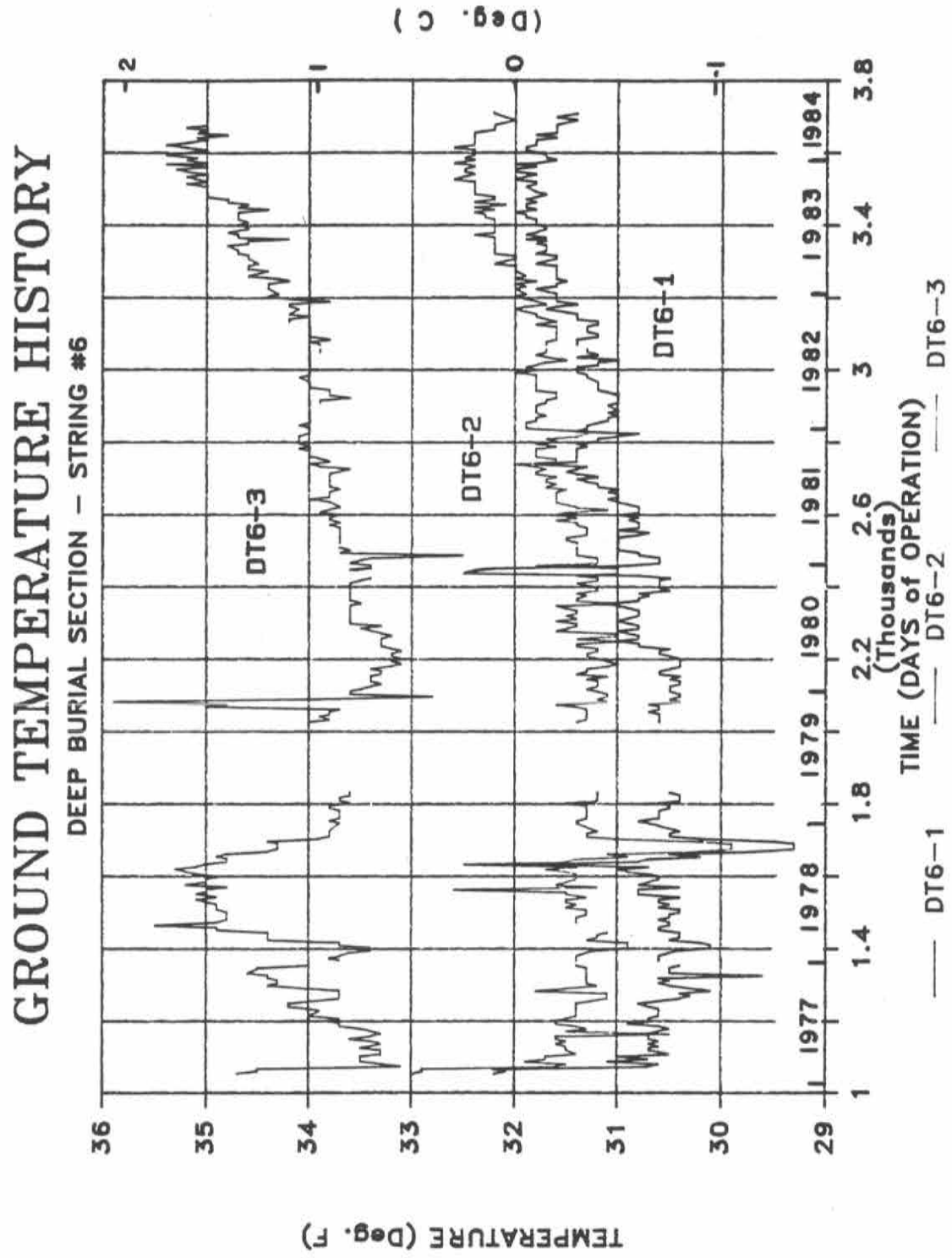
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
DEEP BURIAL SECTION
STRING # 3

PREPARED BY L. CARLSON

FIGURE 3.3-12



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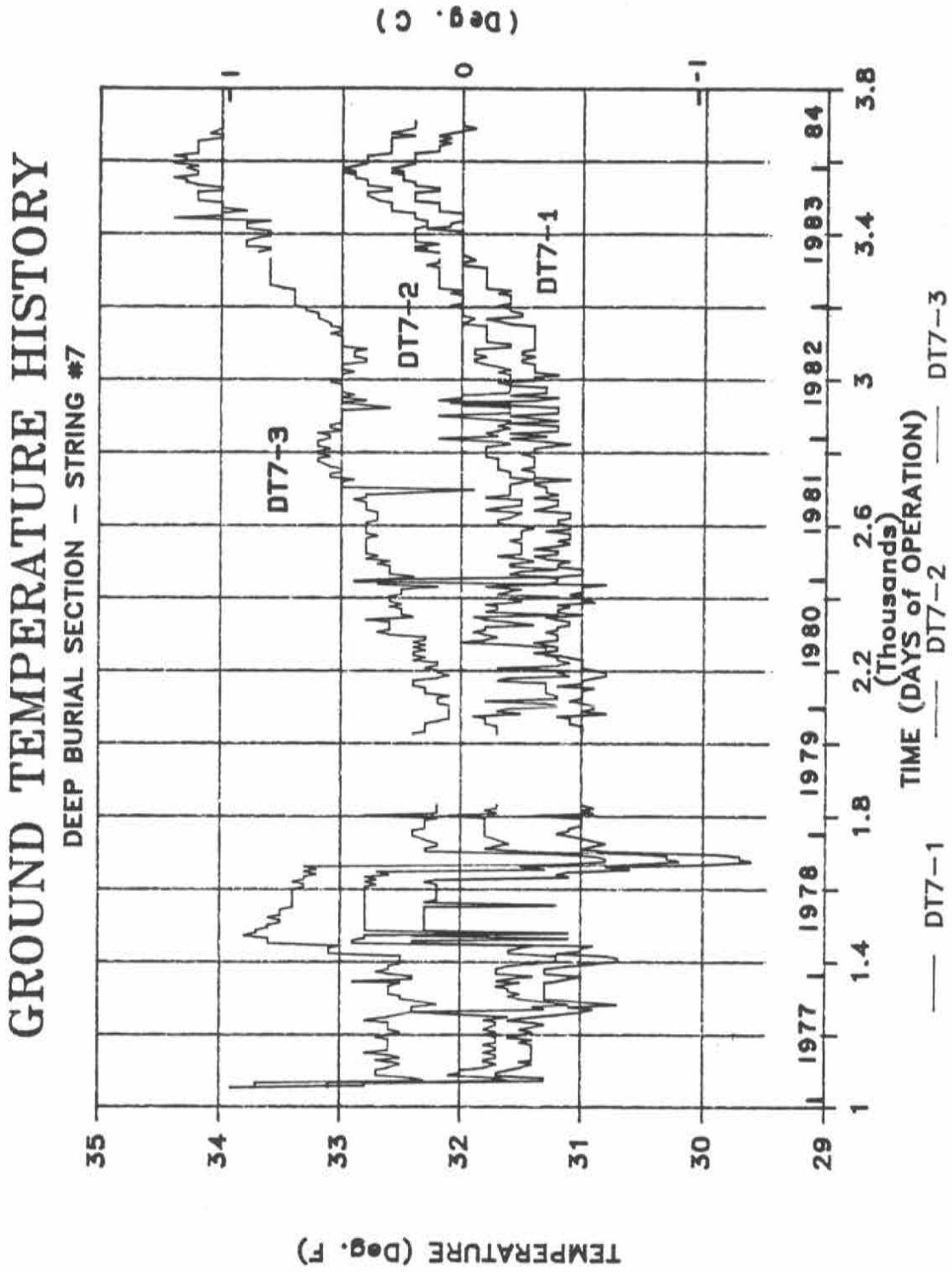
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE HISTORY
DEEP BURIAL SECTION
NEW STRING # 6

PREPARED BY L. CARLSON

FIGURE 3.3-13



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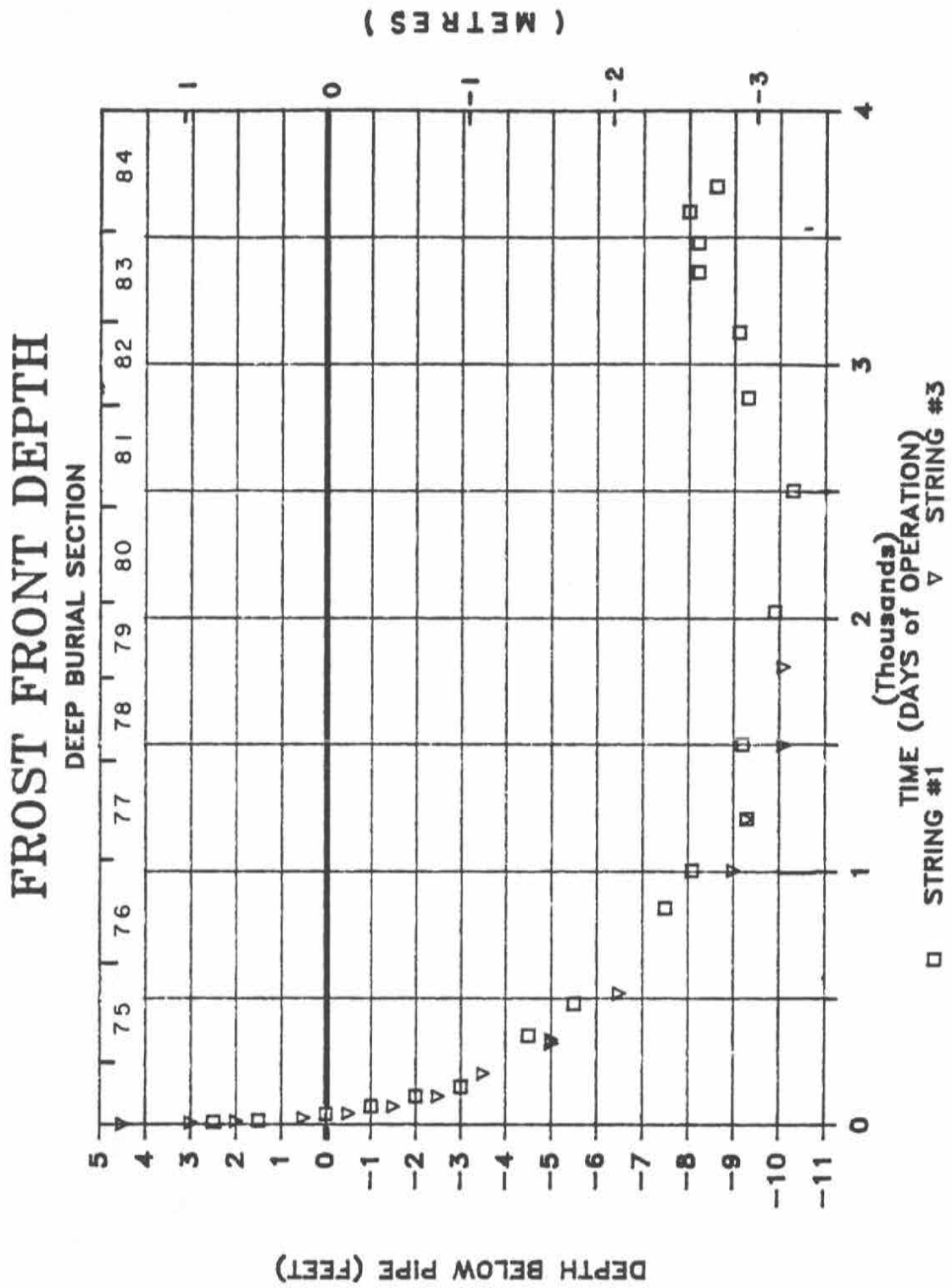
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE HISTORY
DEEP BURIAL SECTION
NEW STRING # 7

PREPARED BY L. CARLSON

FIGURE 3.3-14



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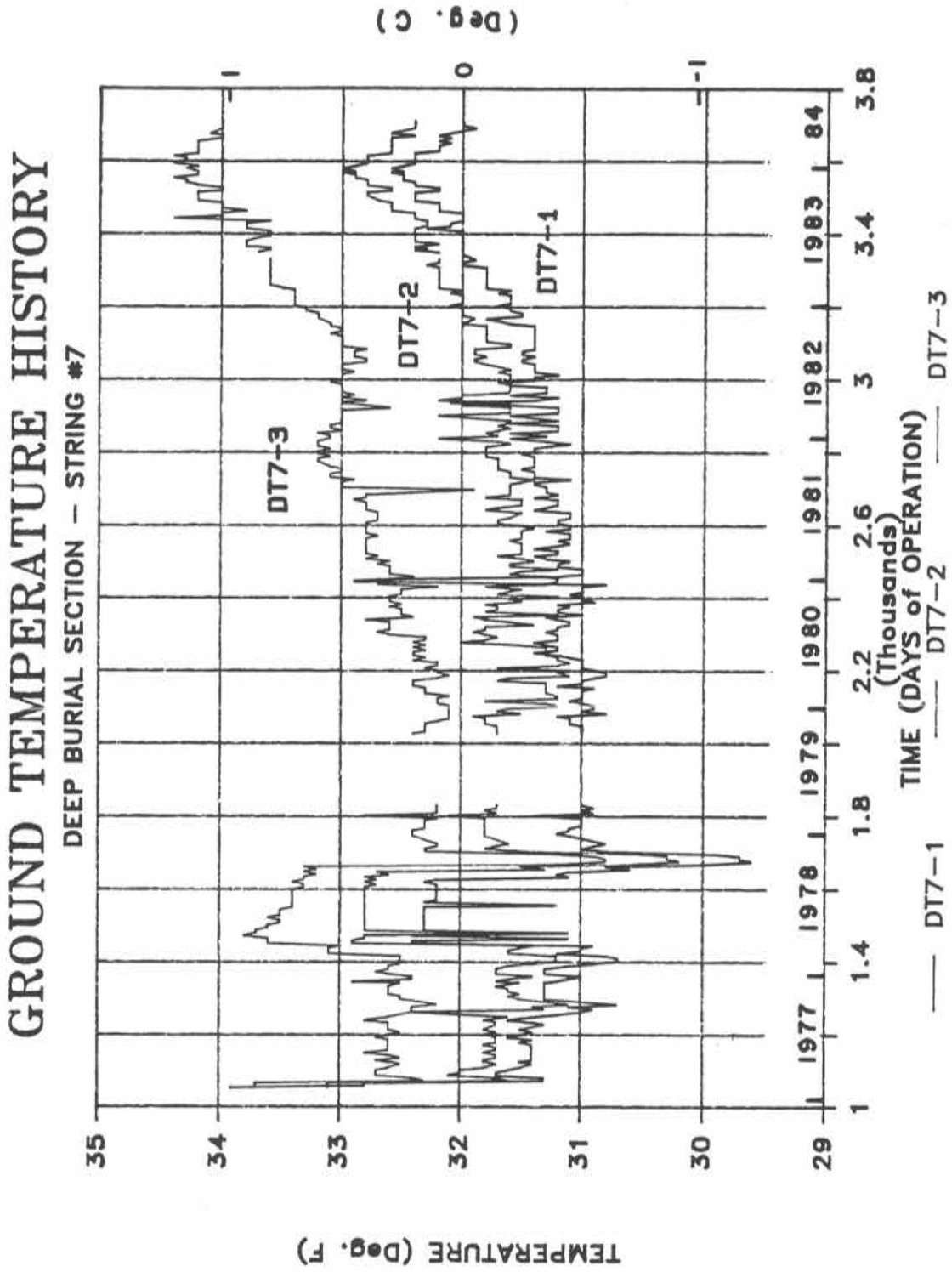
CALGARY FROST HEAVE TEST FACILITY

FROST FRONT DEPTH
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-15



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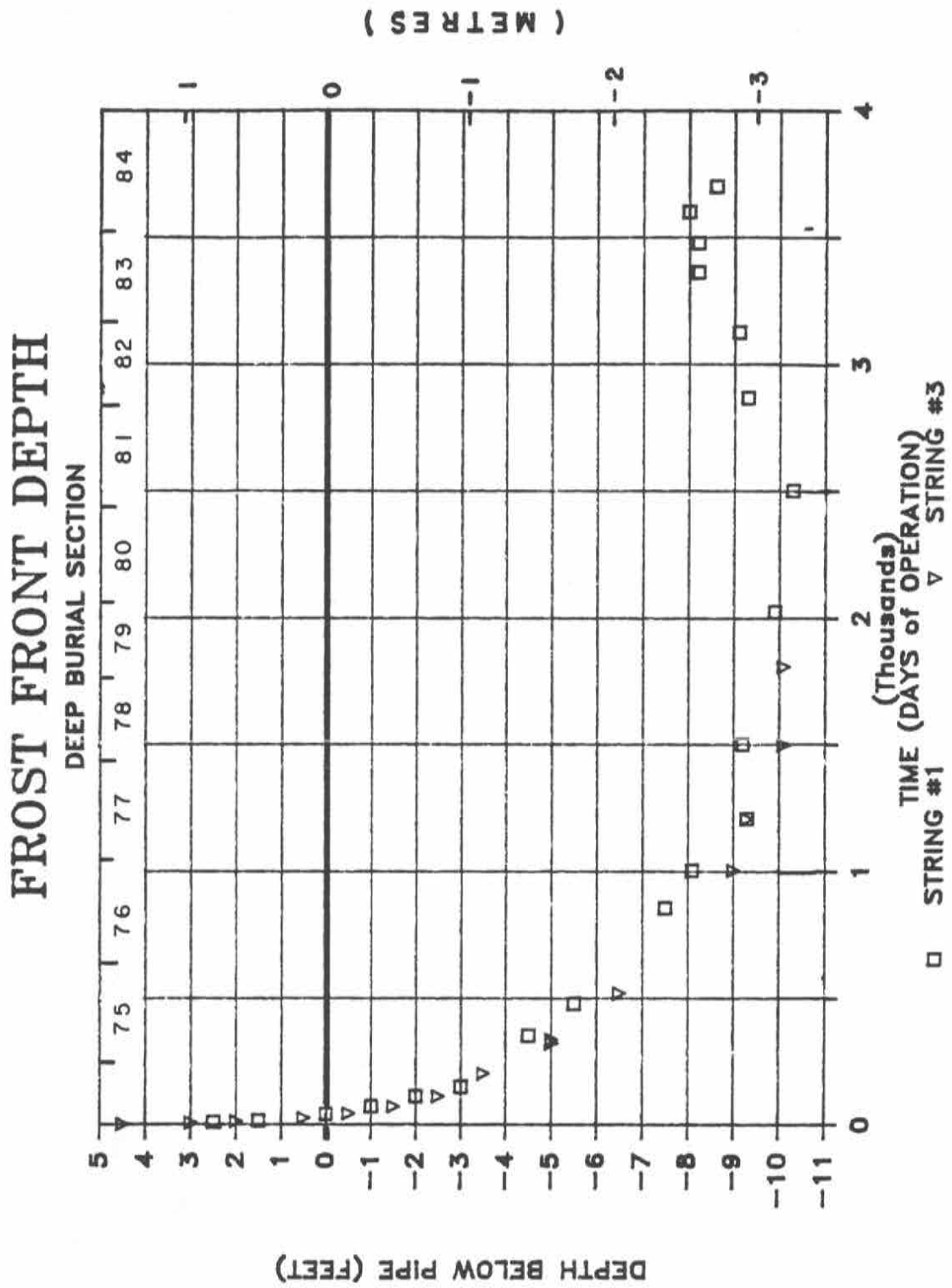
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE HISTORY
DEEP BURIAL SECTION
NEW STRING # 7

PREPARED BY L. CARLSON

FIGURE 3.3-14



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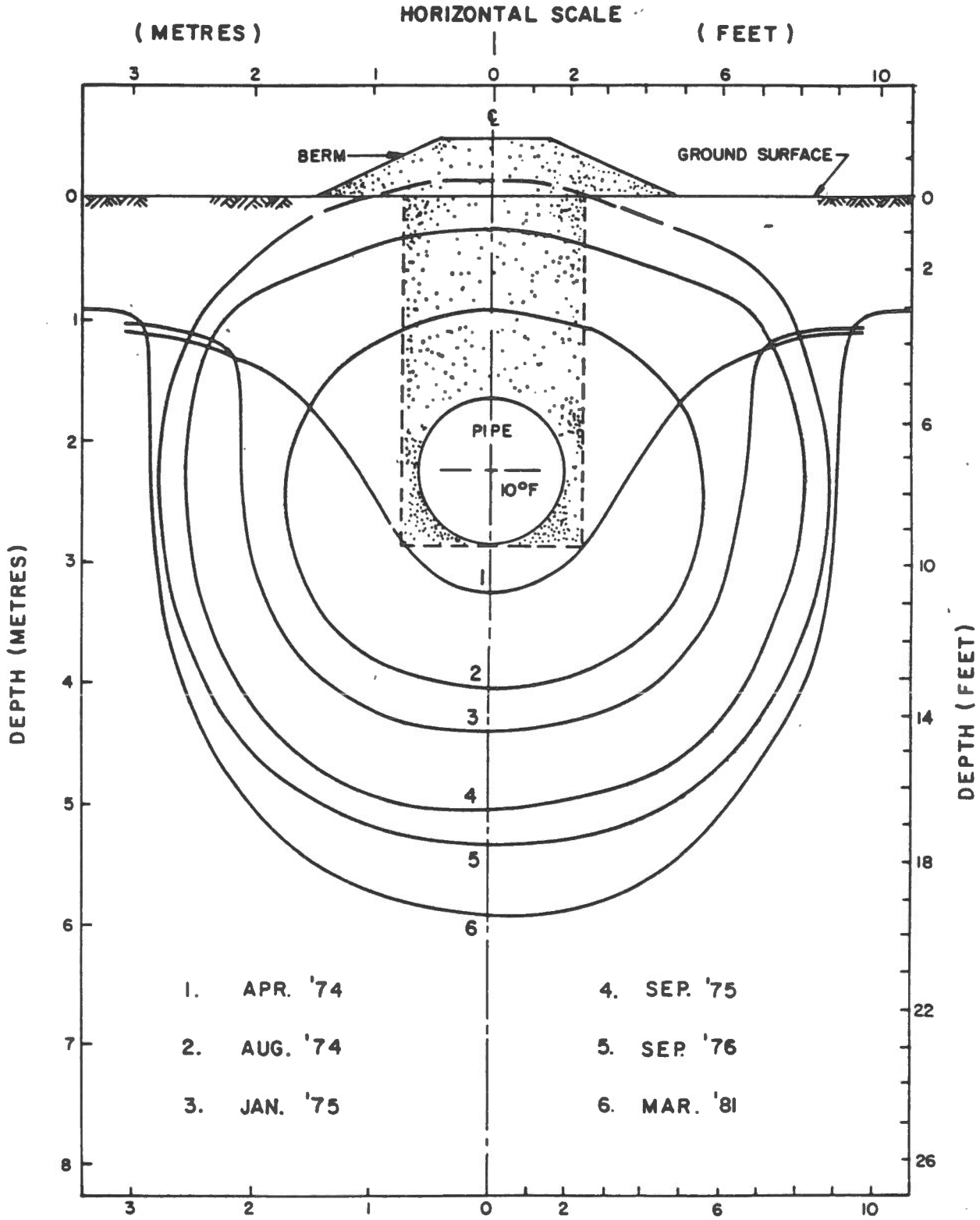
CALGARY FROST HEAVE TEST FACILITY

FROST FRONT DEPTH
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-15



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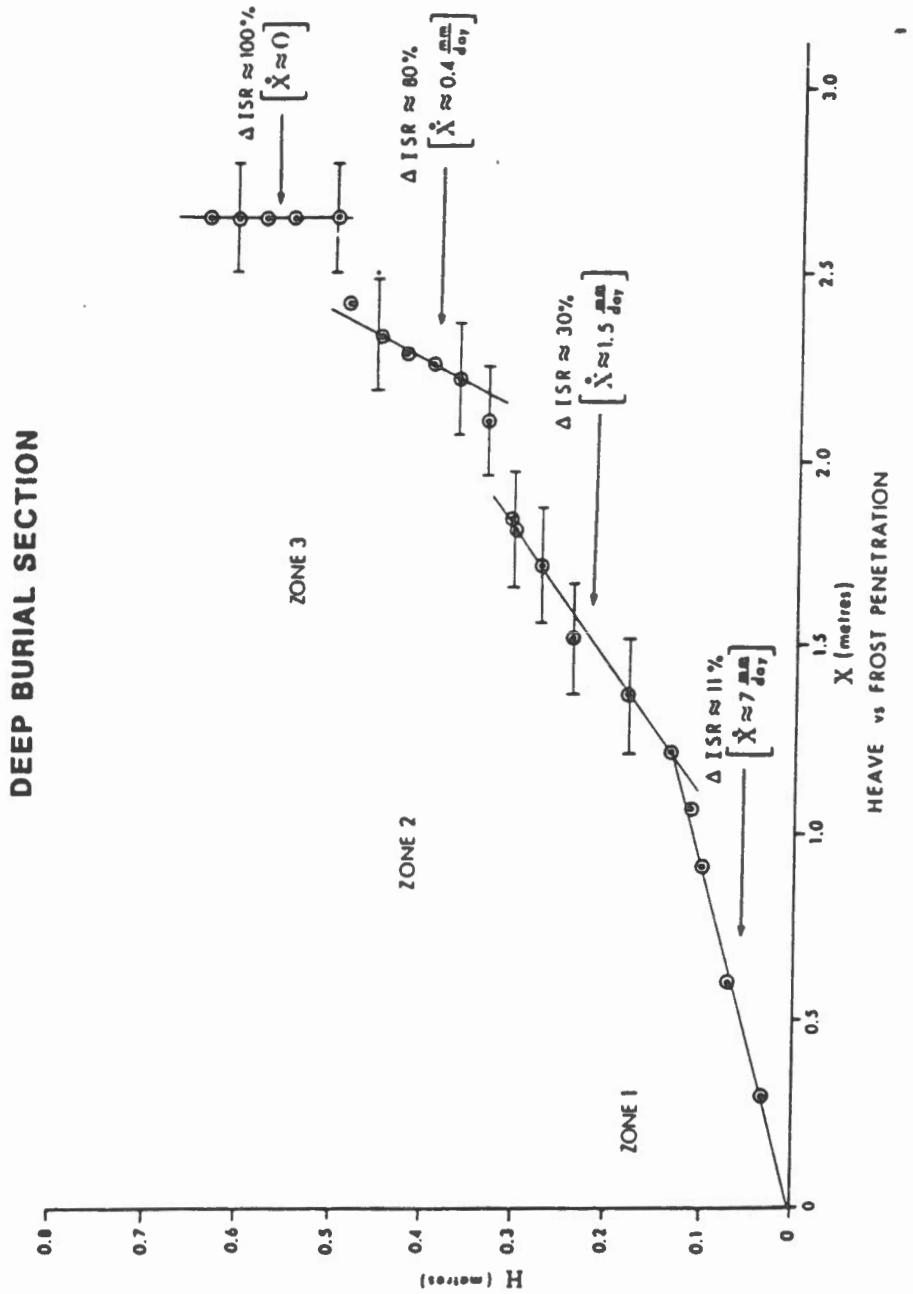
FROST BULB GROWTH
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-16



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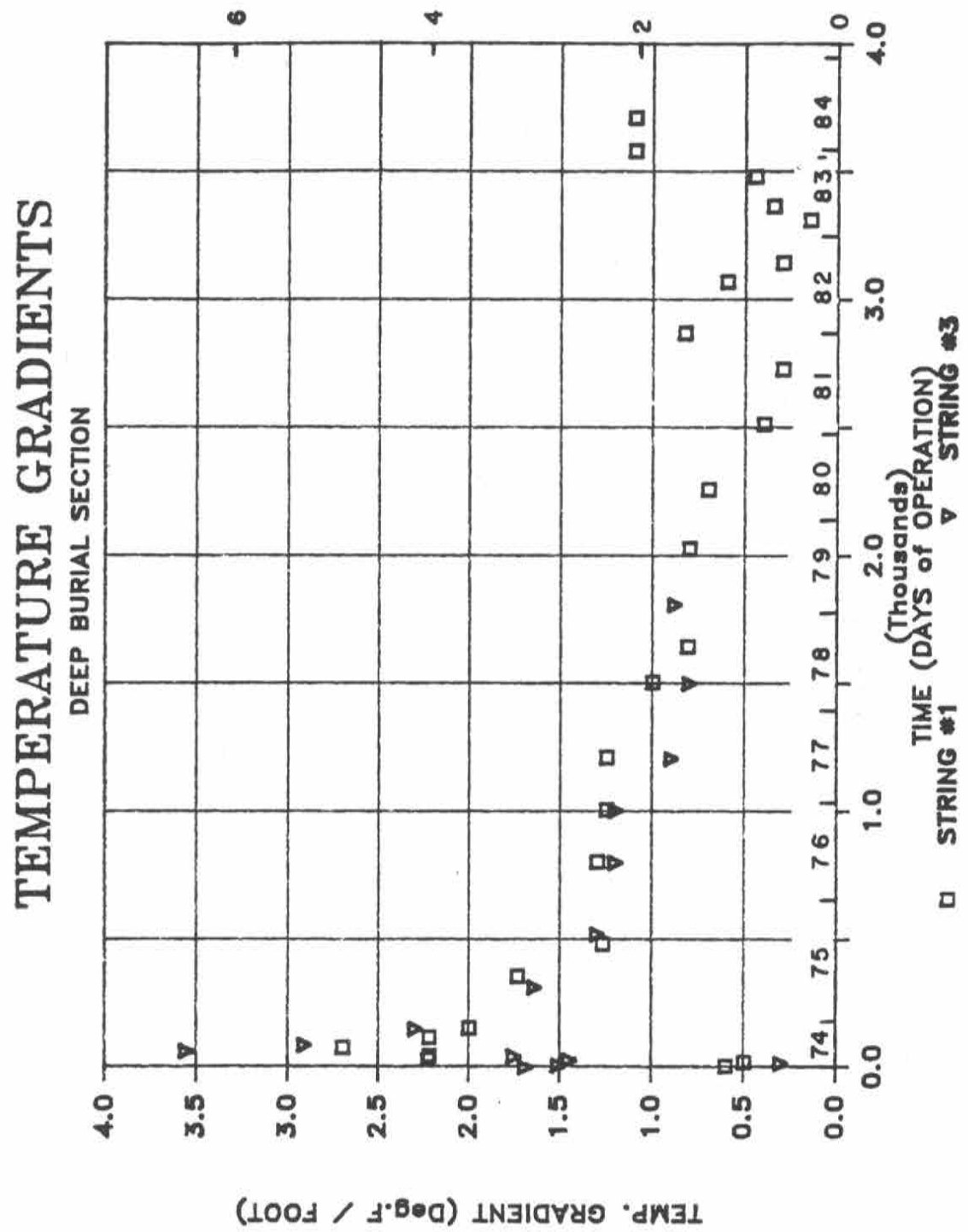
CALGARY FROST HEAVE TEST FACILITY

HEAVE VERSUS FROST PENETRATION
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-17



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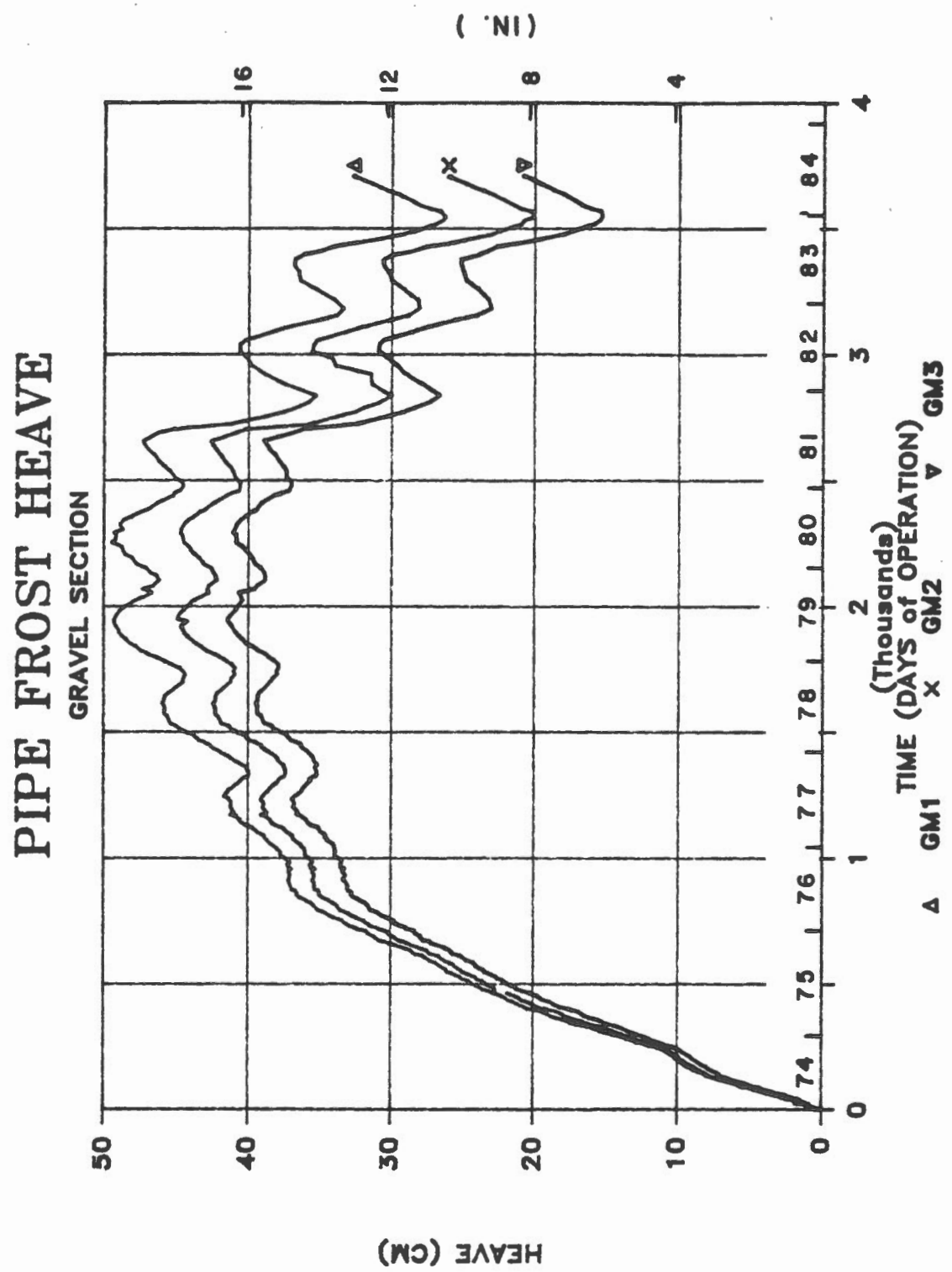
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE GRADIENTS
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-18



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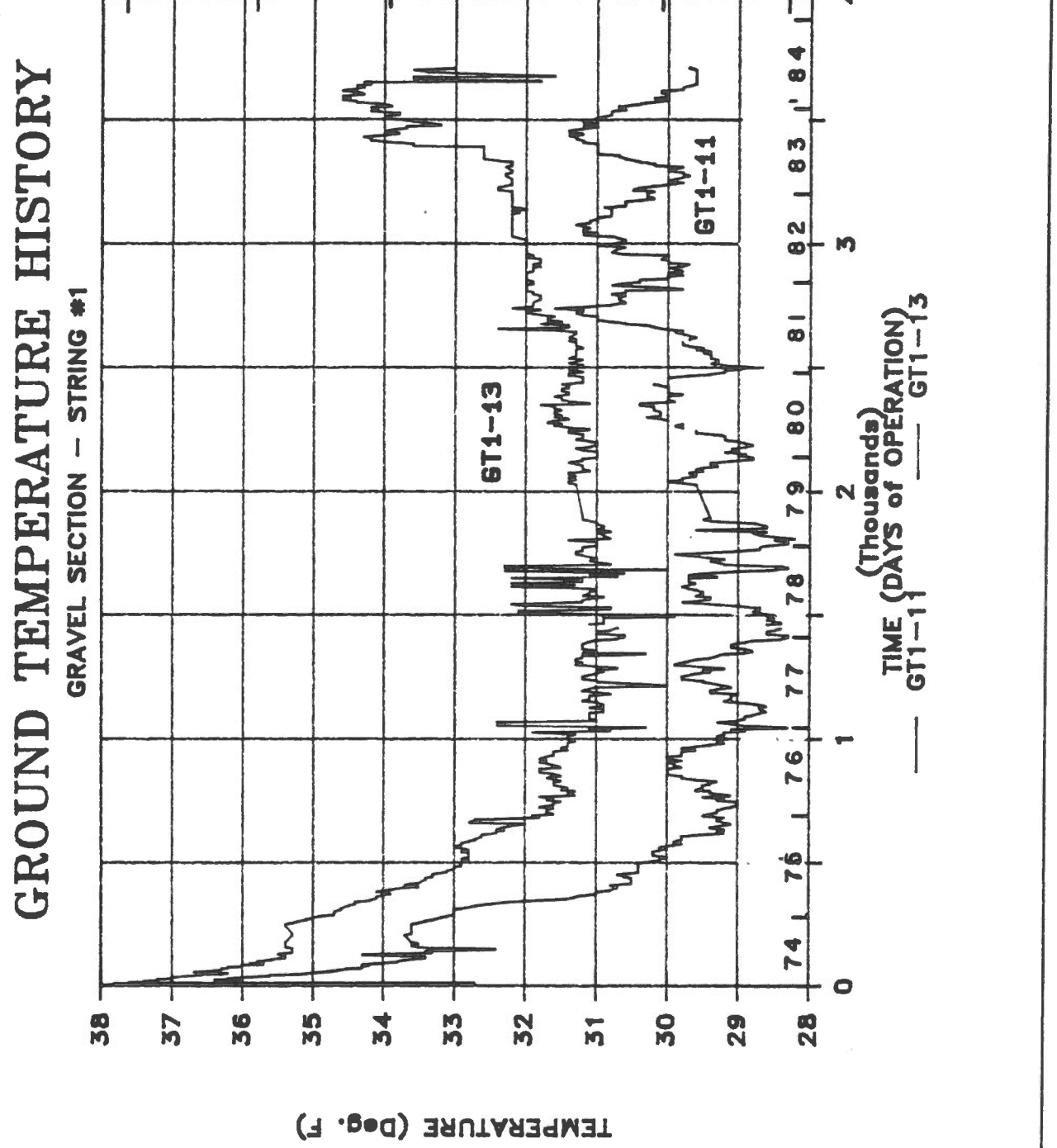
FROST HEAVE
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-19



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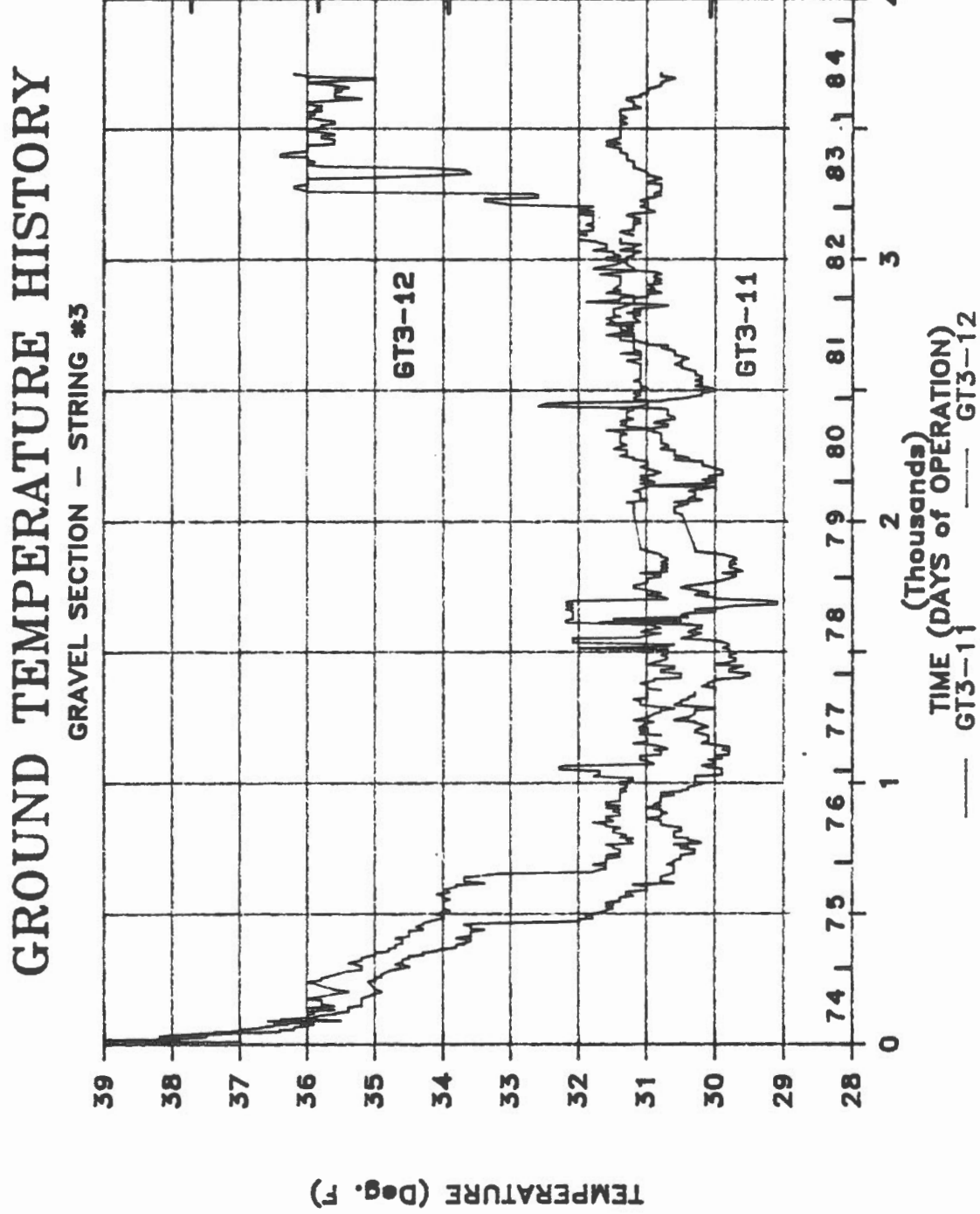
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE HISTORY
GRAVEL SECTION
STRING #1



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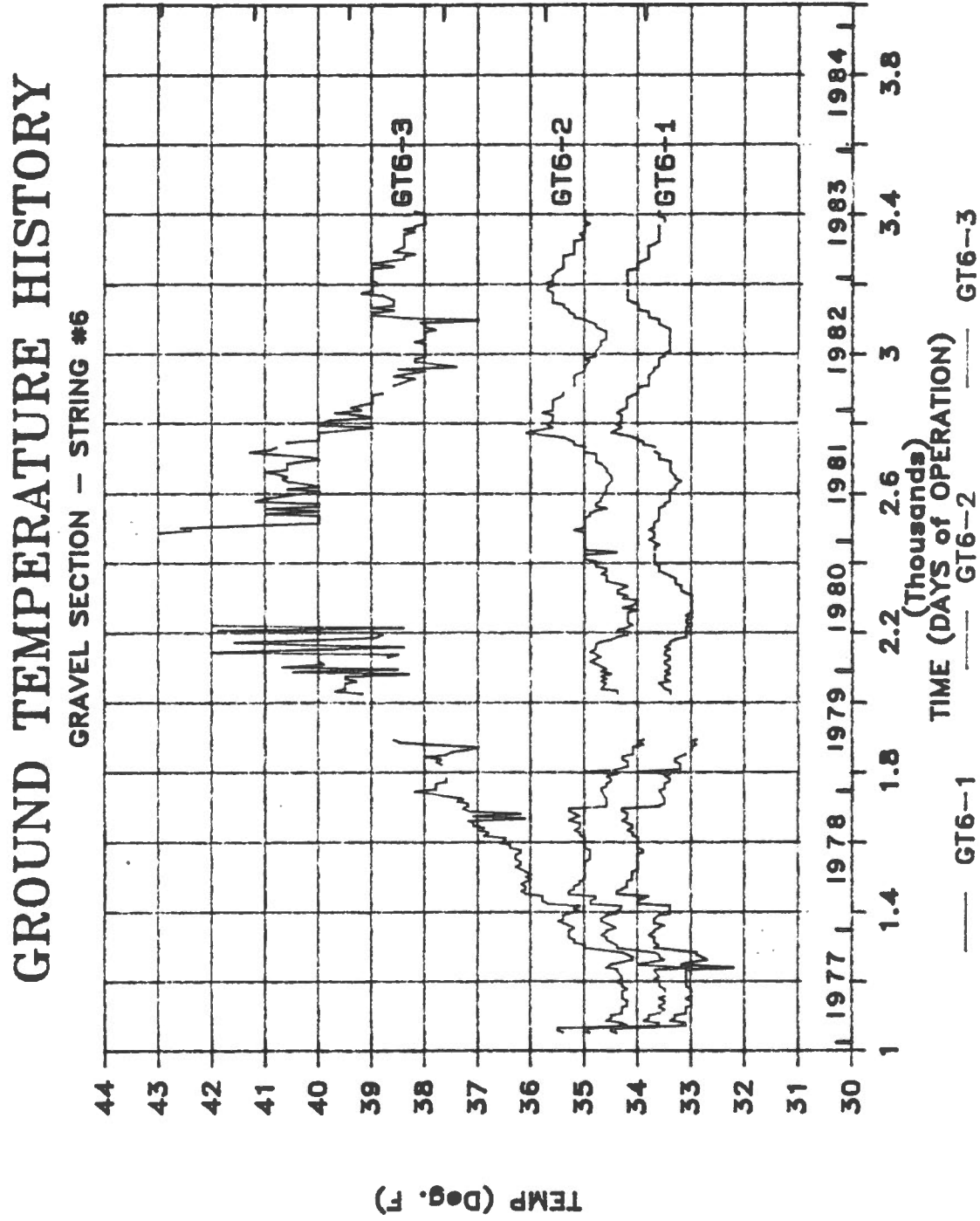
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
GRAVEL SECTION



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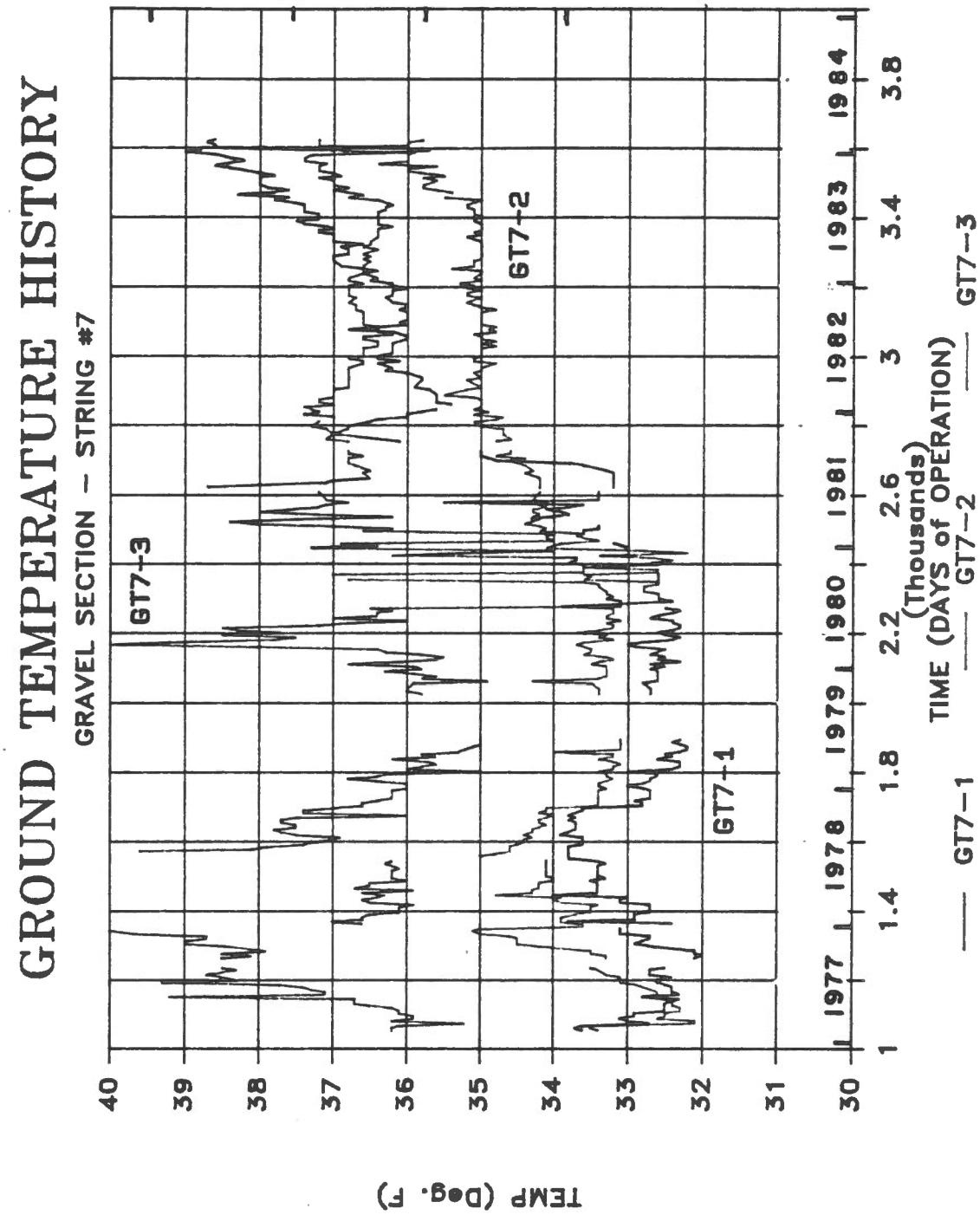
GROUND TEMPERATURE HISTORY

GRAVEL SECTION



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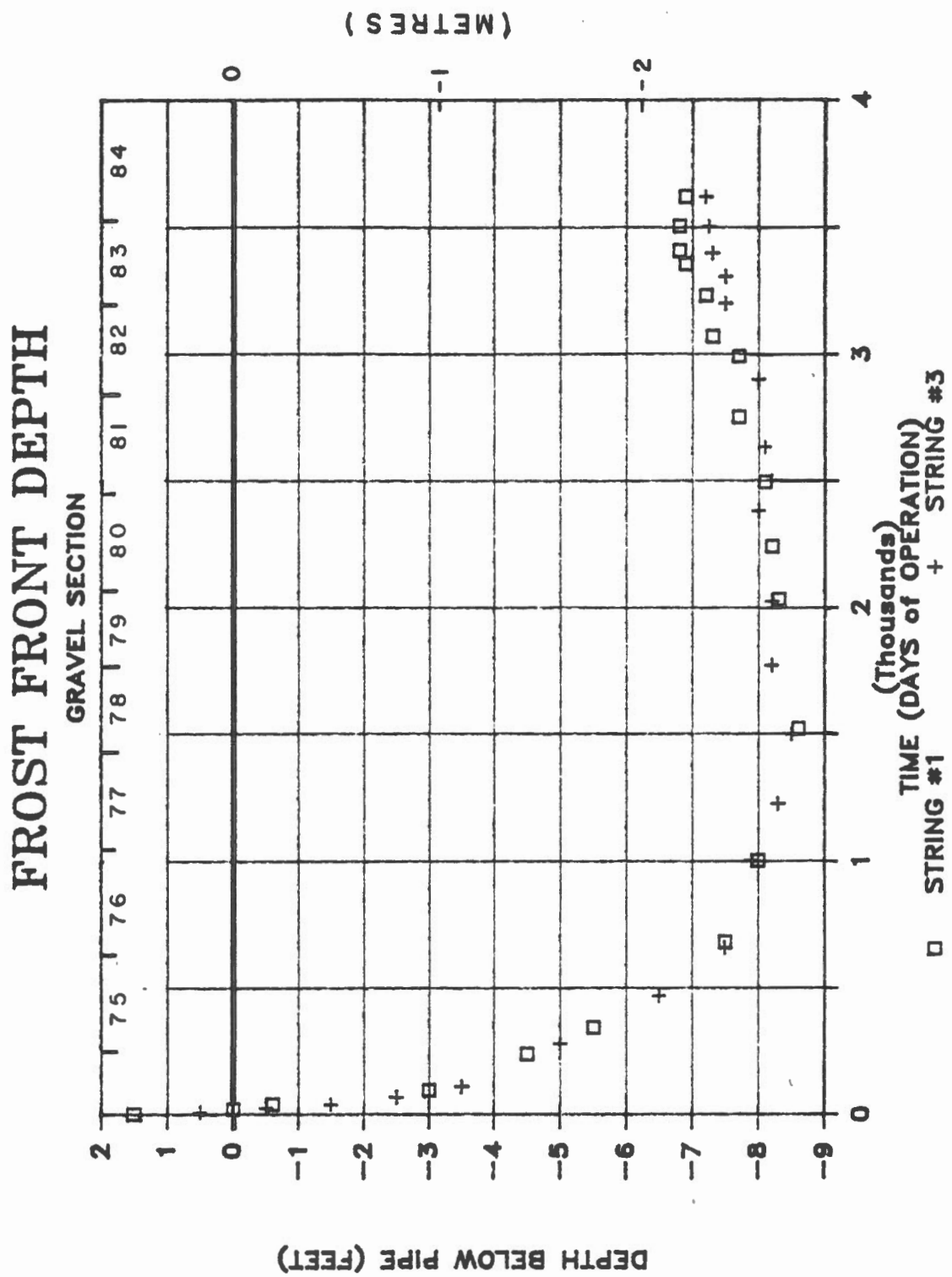
GROUND TEMPERATURE HISTORY



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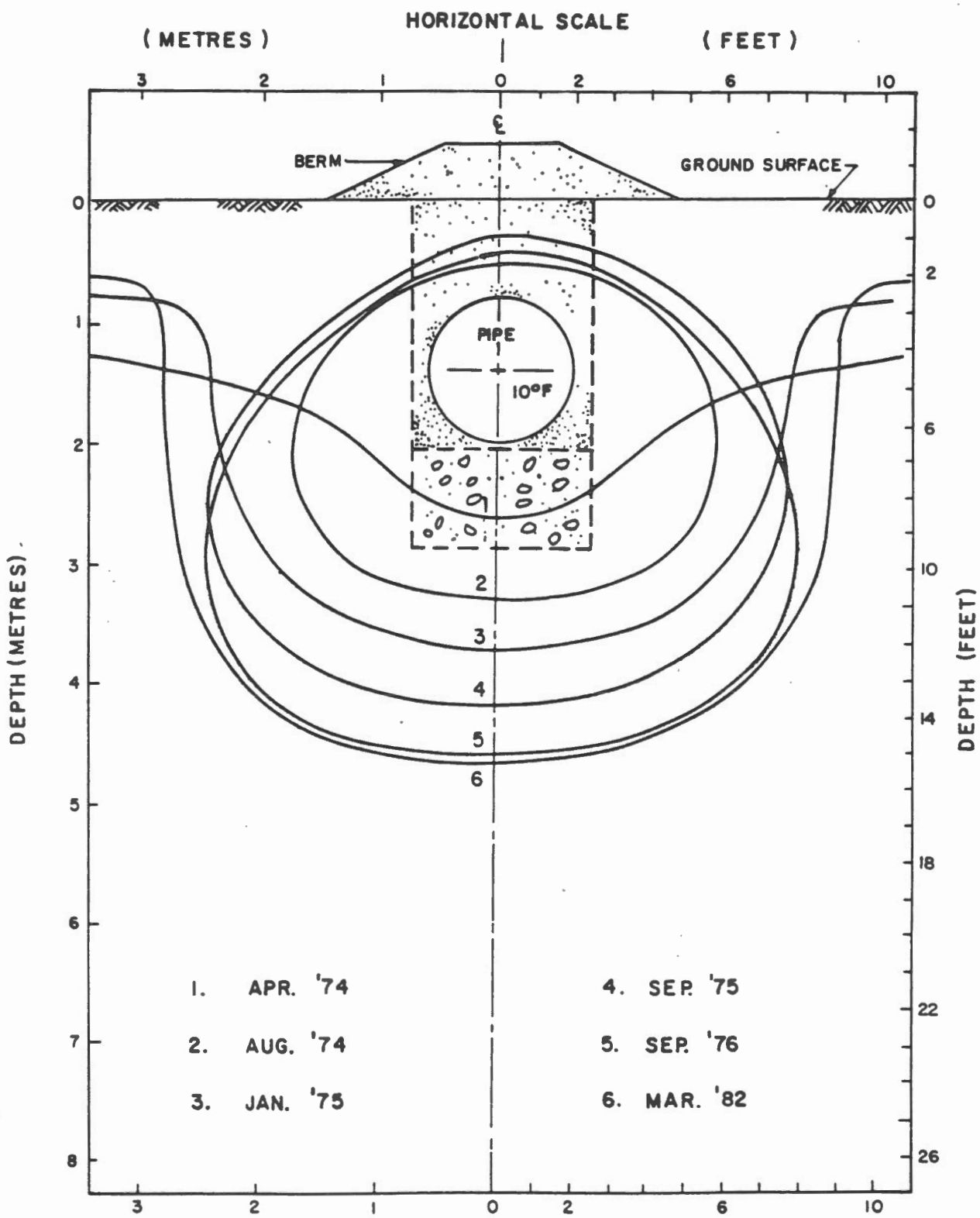
CALGARY FROST HEAVE TEST FACILITY

FROST FRONT DEPTH
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3 - 24



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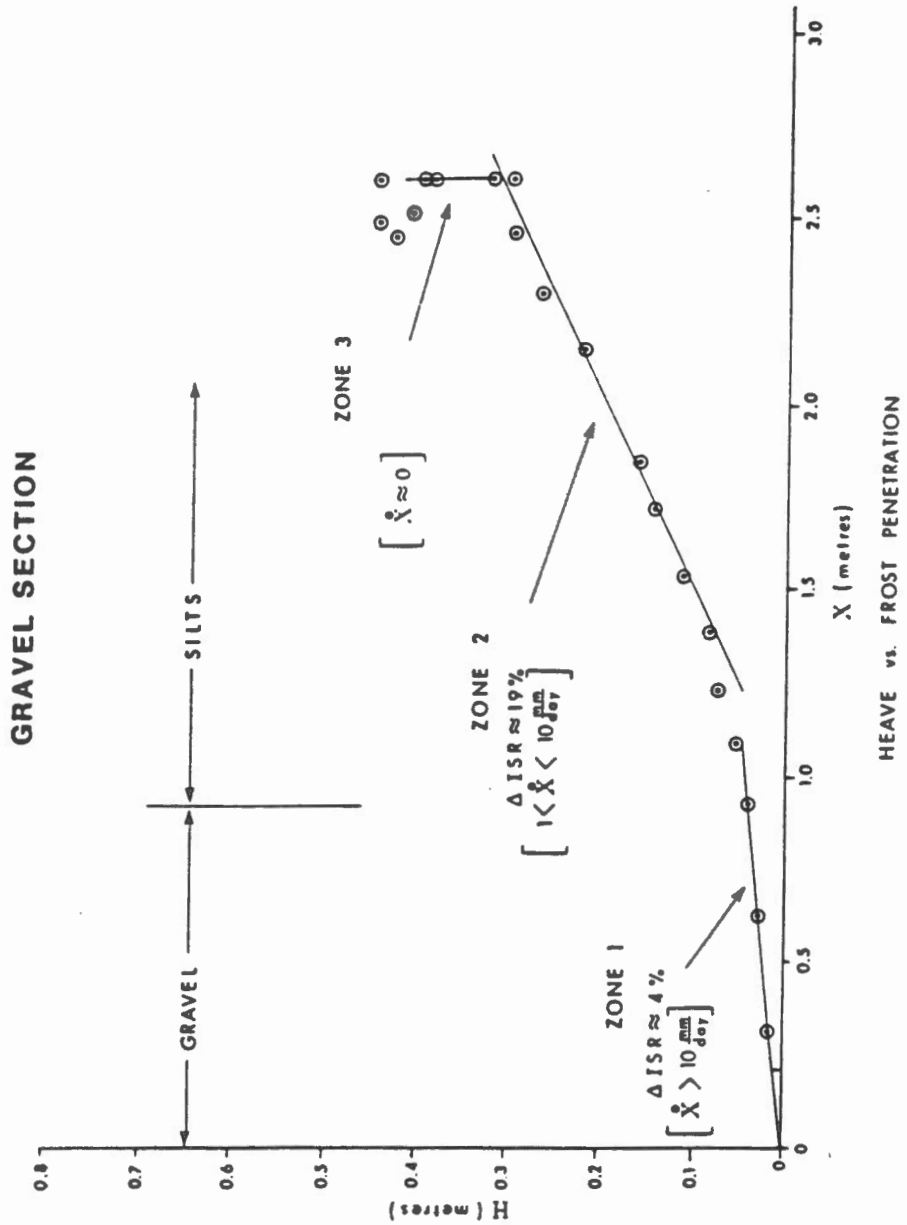
CALGARY FROST HEAVE TEST FACILITY

FROST BULB GROWTH
GRAVEL SECTION

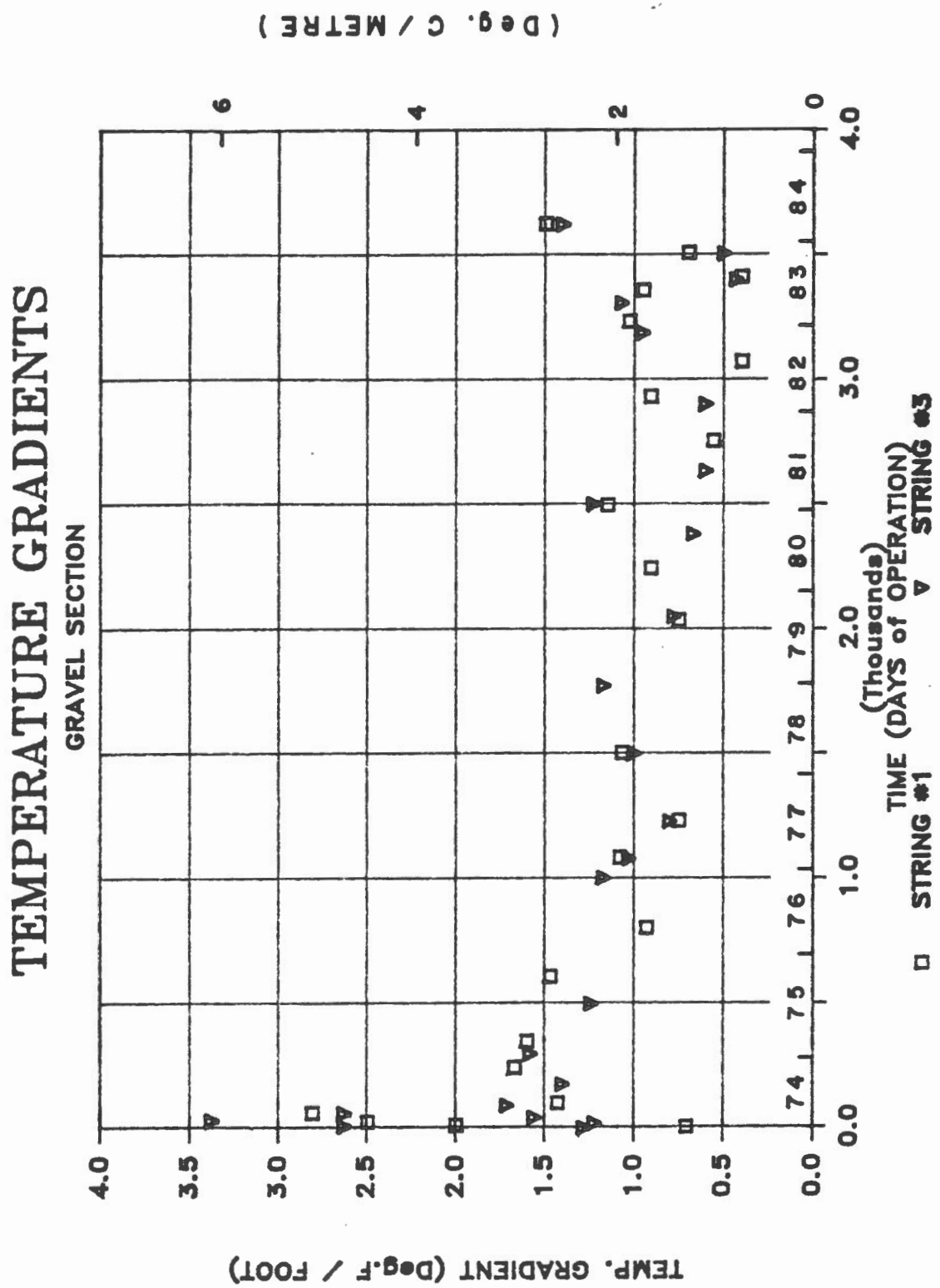
PREPARED BY L. CARLSON

FIGURE 3.3-25



After Carlson et. al. 1982

L.E.C. **ENGINEERING LTD.**	CALGARY FROST HEAVE TEST FACILITY HEAVE VERSUS FROST PENETRATION GRAVEL SECTION
PREPARED BY L. CARLSON	FIGURE 3.3-26



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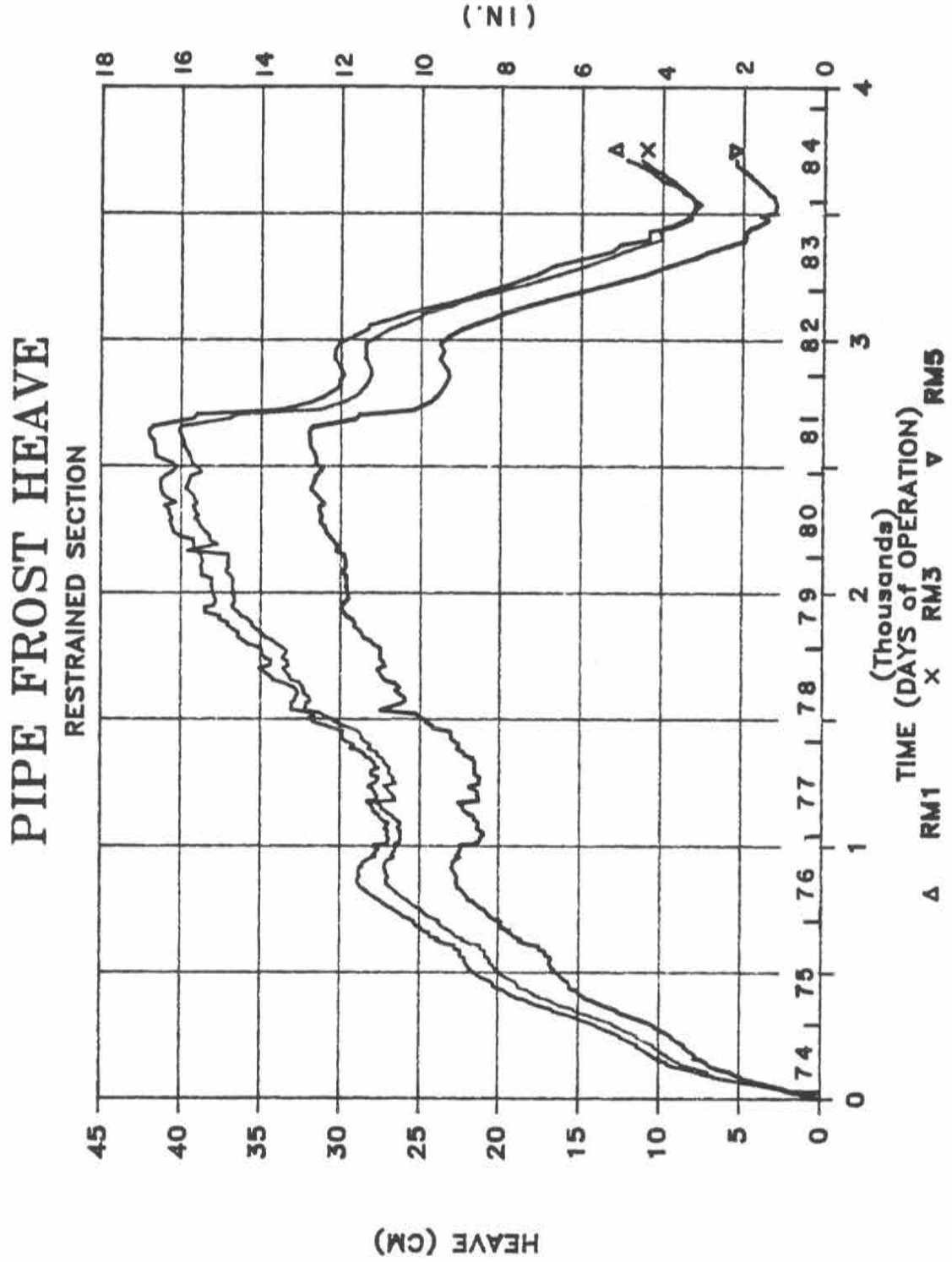
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE GRADIENTS

GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-27



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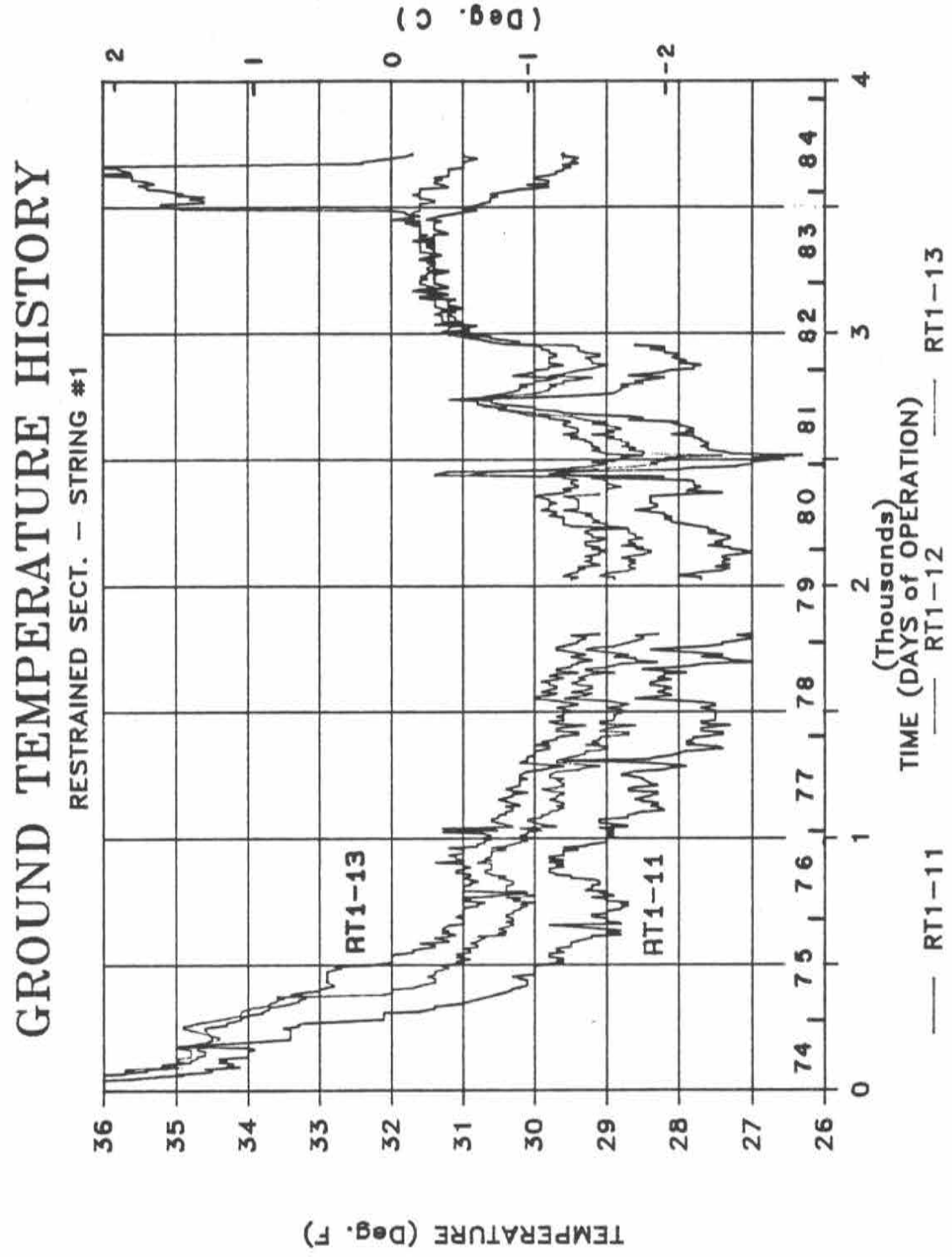
CALGARY FROST HEAVE TEST FACILITY

PIPE FROST HEAVE
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-28



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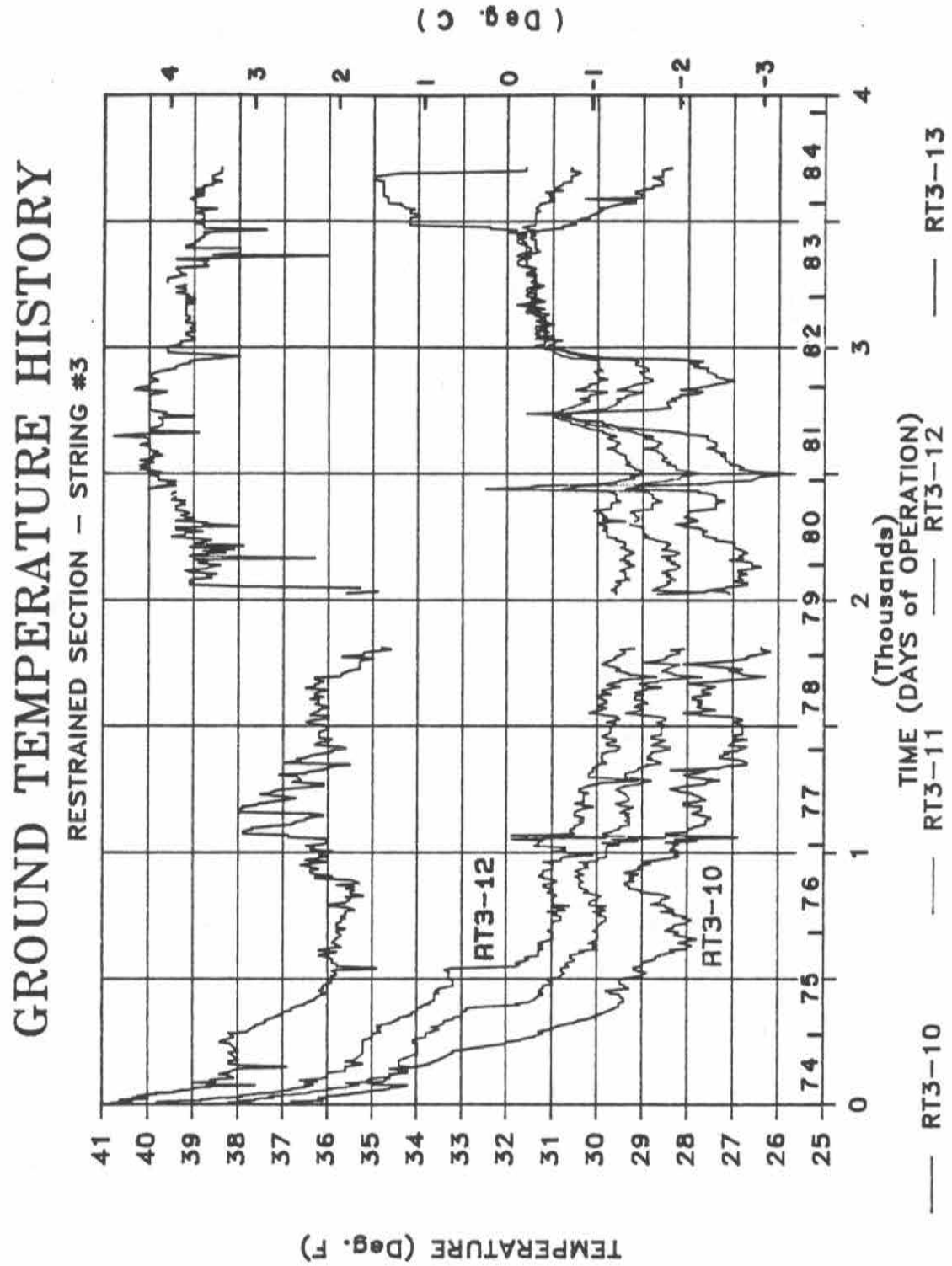
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE HISTORY
RESTRAINED SECTION
STRING # 1

PREPARED BY L. CARLSON

FIGURE 3.3-29



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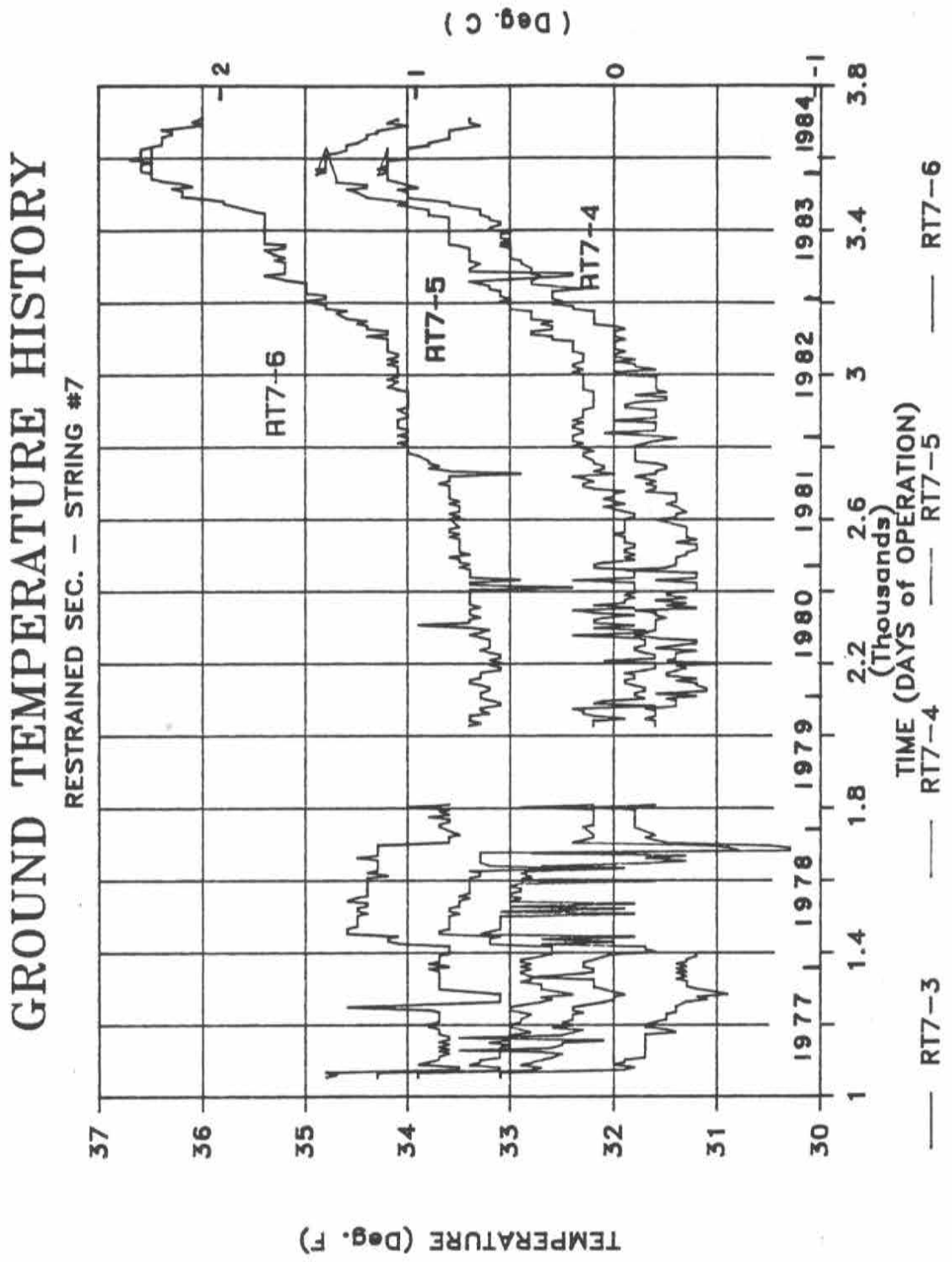
CALGARY FROST HEAVE TEST FACILITY

GROUND TEMPERATURE HISTORY
RESTRAINED SECTION
STRING # 3

PREPARED BY L. CARLSON

FIGURE 3.3-30



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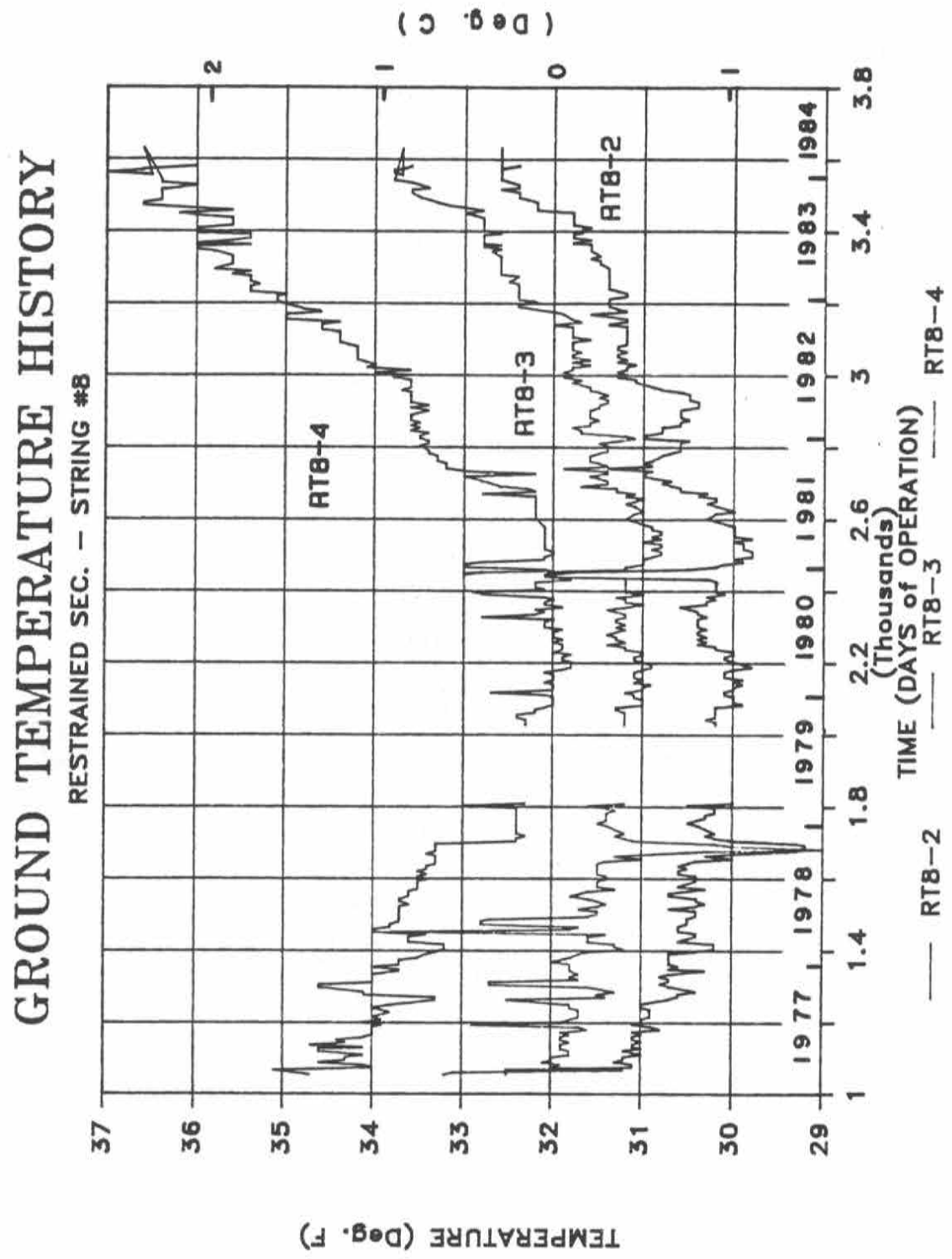
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
RESTRAINED SECTION
STRING # 7

PREPARED BY L. CARLSON

FIGURE 3.3-31



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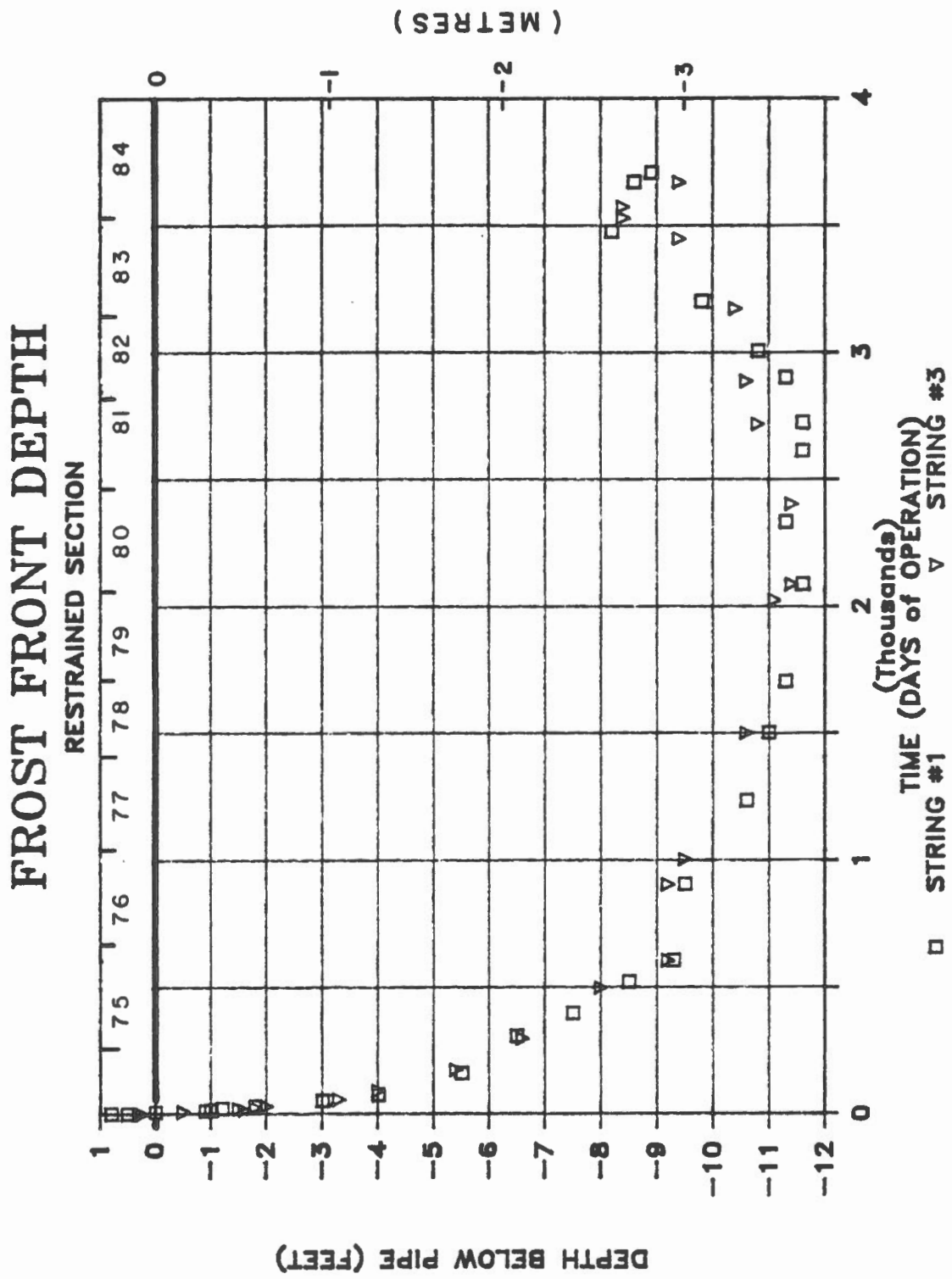
CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE HISTORY
RESTRAINED SECTION
STRING # 8

PREPARED BY L. CARLSON

FIGURE 3.3 - 32



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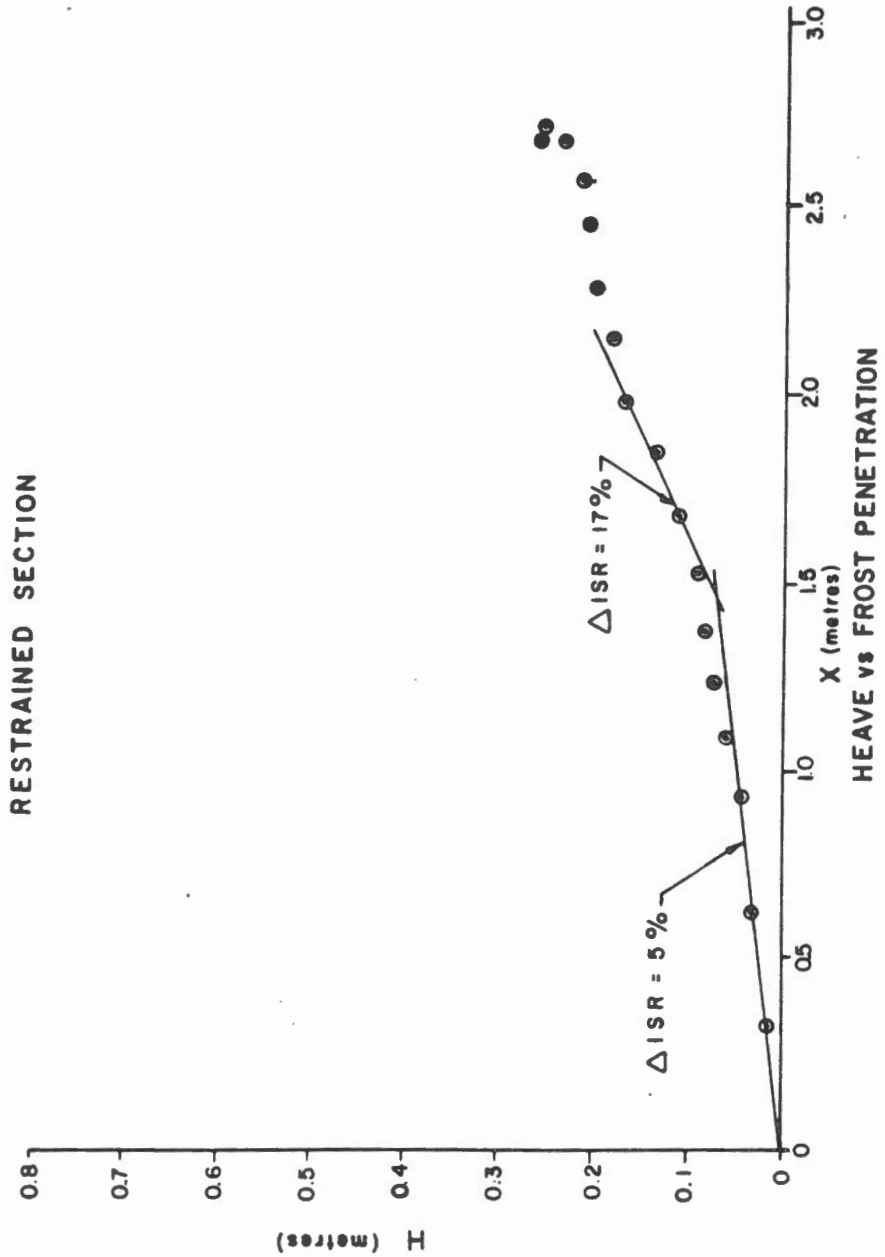
CALGARY FROST HEAVE TEST FACILITY

FROST FRONT DEPTH
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-33



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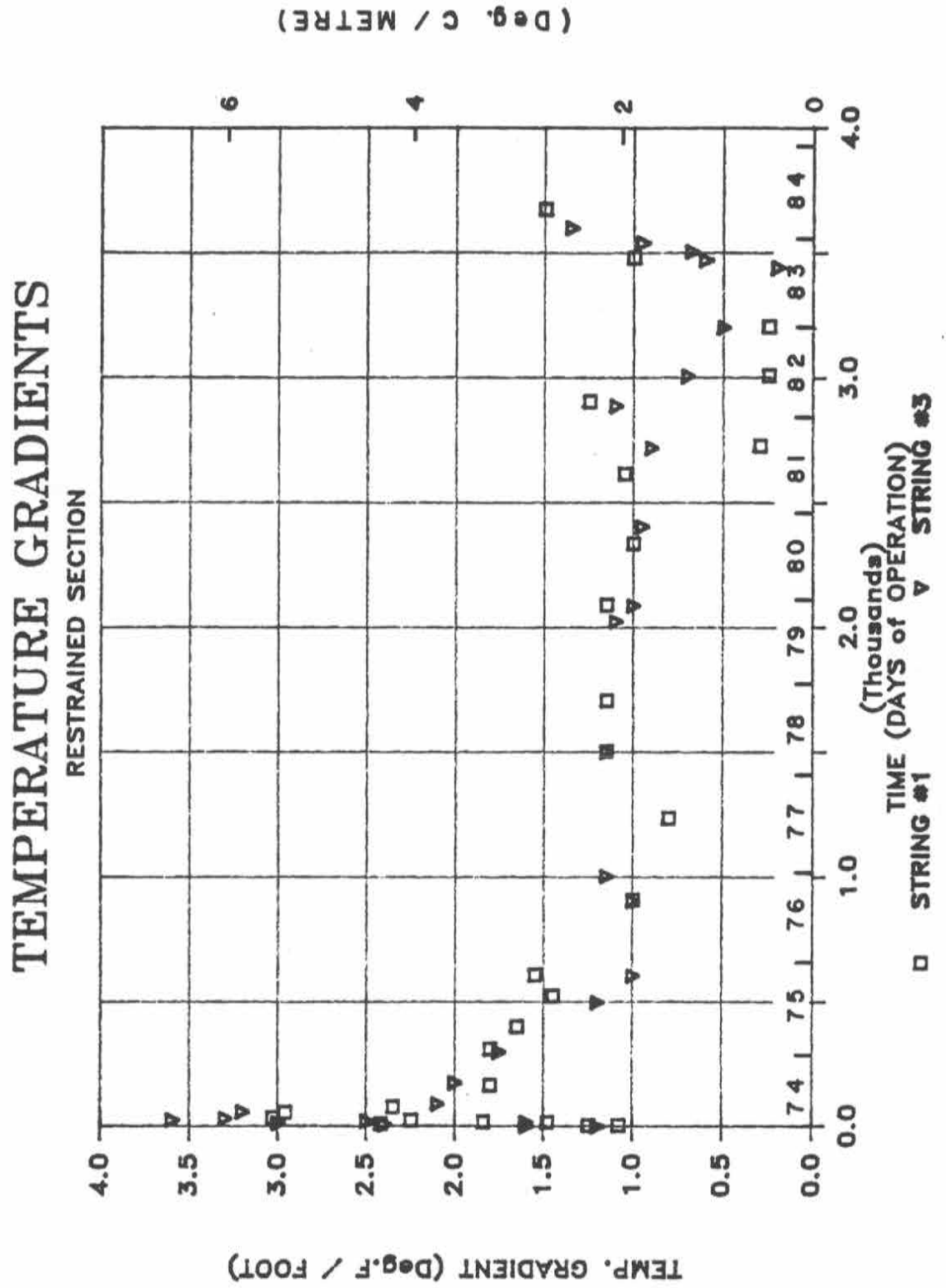
CALGARY FROST HEAVE TEST FACILITY

HEAVE VERSUS FROST PENETRATION
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-35



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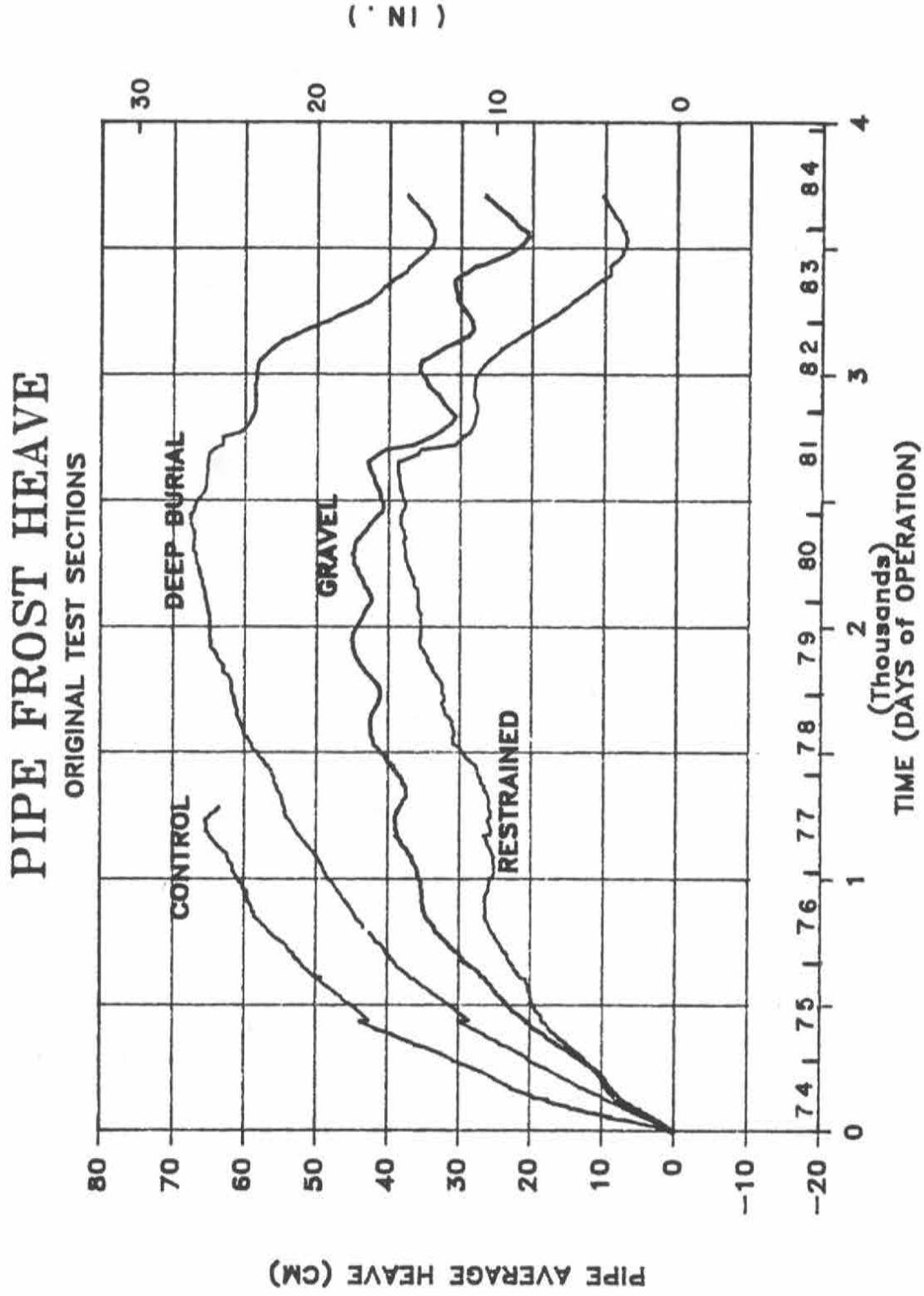
CALGARY FROST HEAVE TEST FACILITY
TEMPERATURE GRADIENTS
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.3-36



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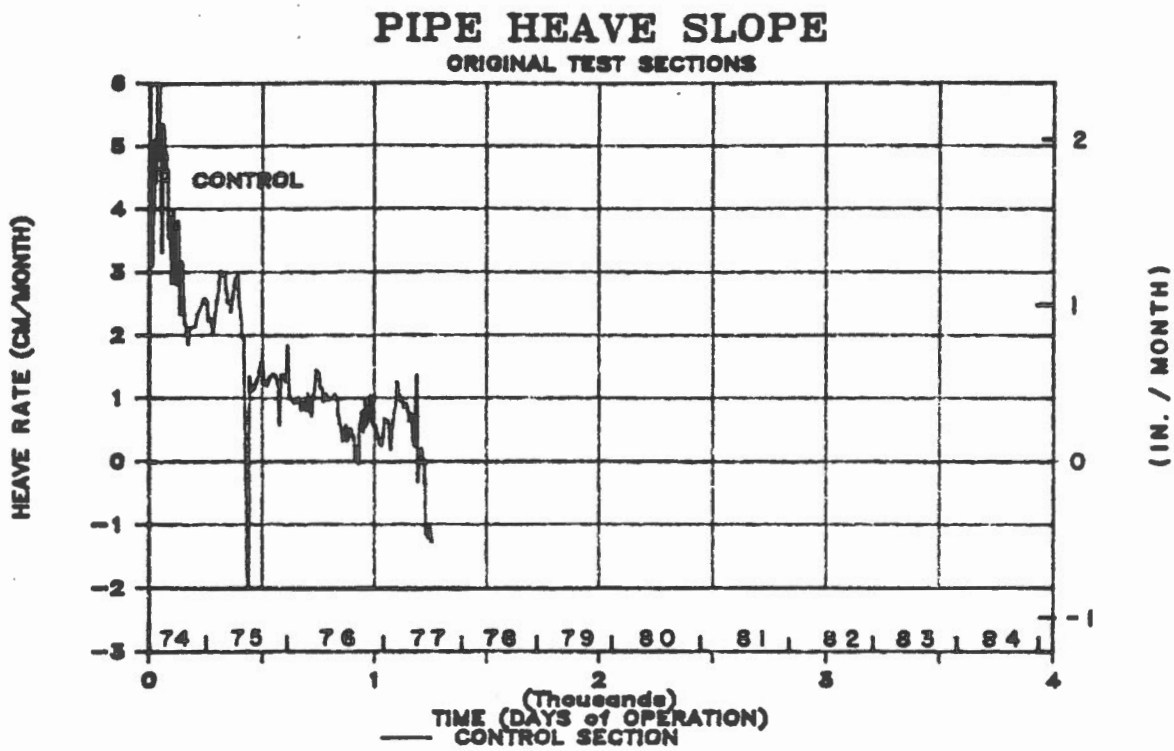
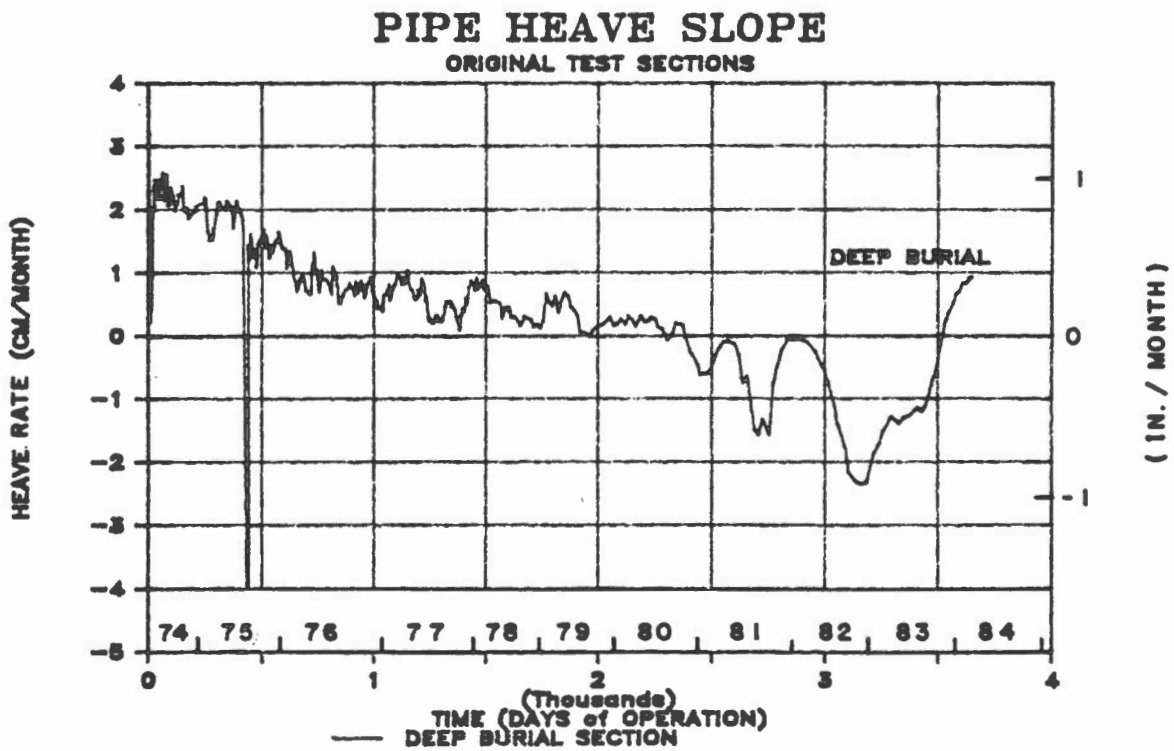
CALGARY FROST HEAVE TEST FACILITY

PIPE FROST HEAVE
ORIGINAL TEST SECTIONS

PREPARED BY L. CARLSON

FIGURE 3.4-1





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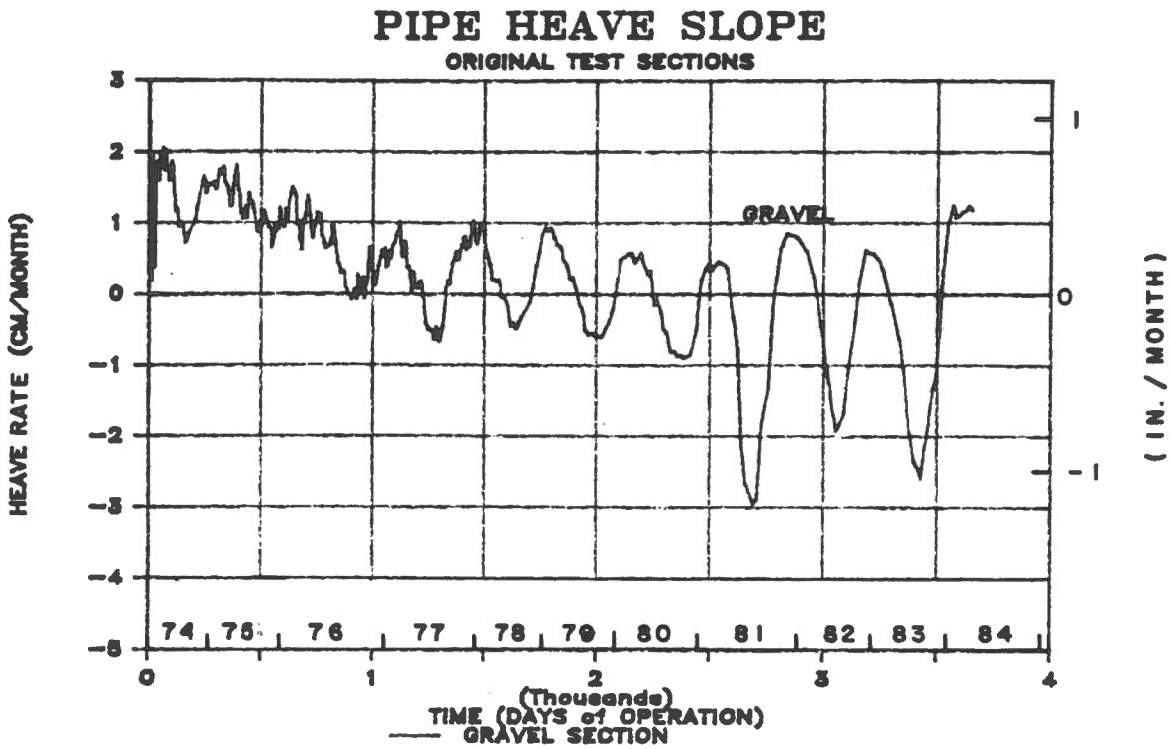
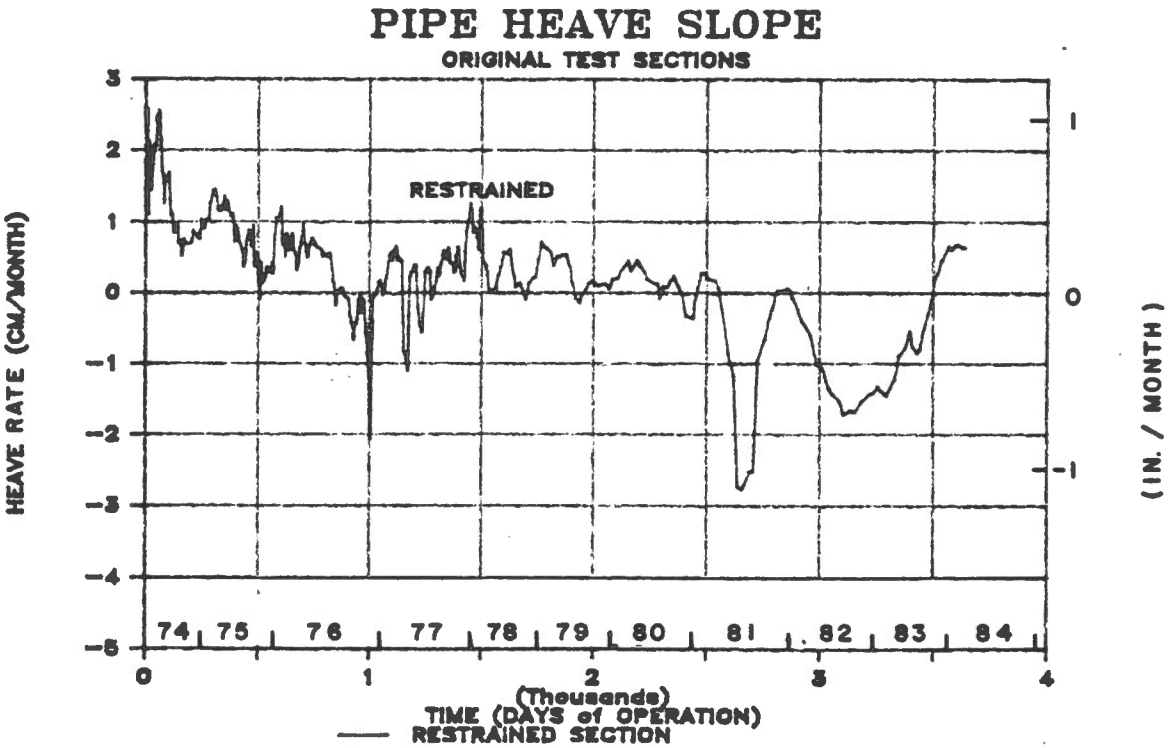
CALGARY FROST HEAVE TEST FACILITY

PIPE HEAVE SLOPE
CONTROL & DEEP BURIAL SECTIONS

PREPARED BY L. CARLSON

FIGURE 3.4 - 2





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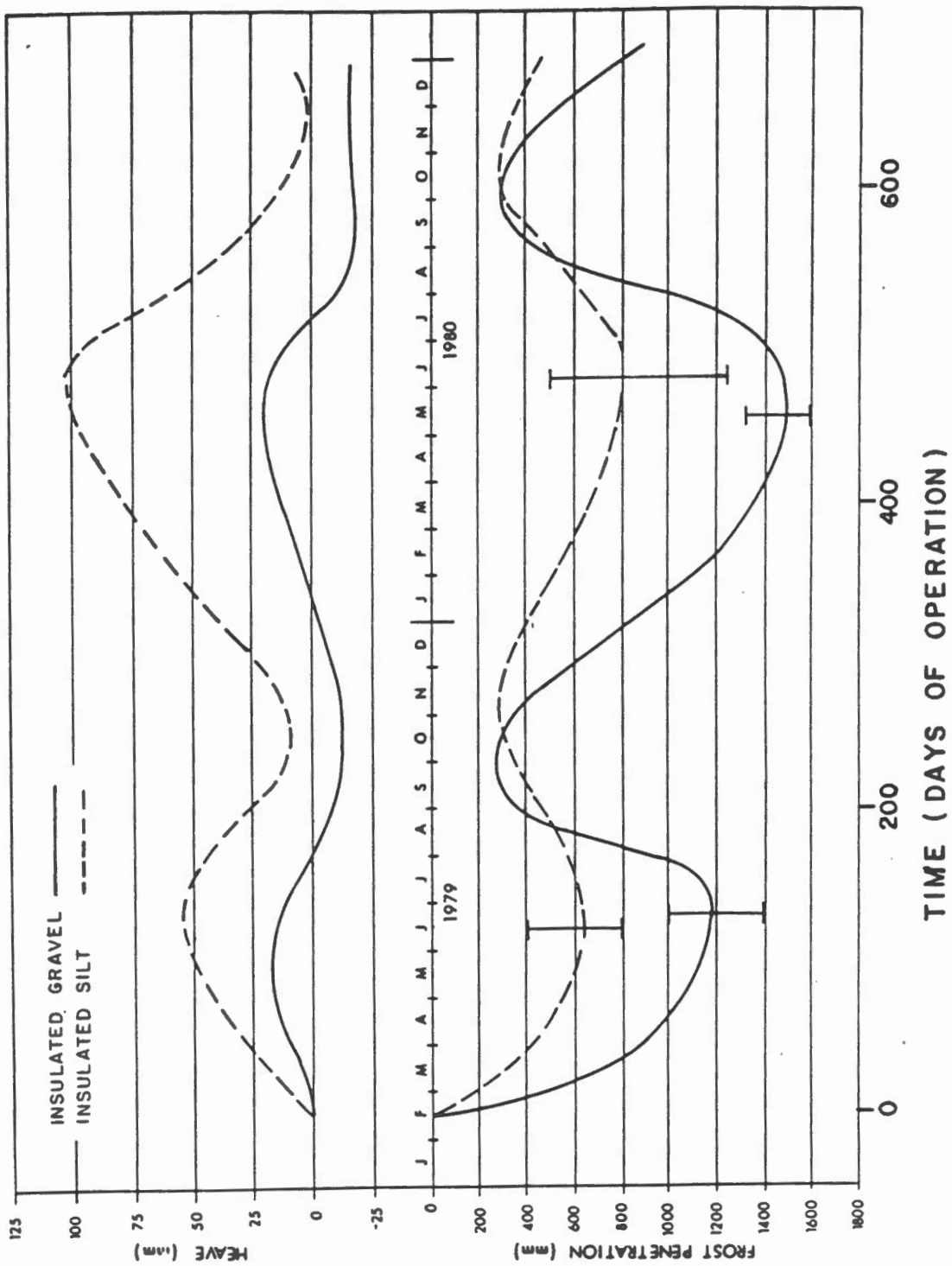
CALGARY FROST HEAVE TEST FACILITY

PIPE HEAVE SLOPE
GRAVEL & RESTRAINED SECTIONS

PREPARED BY L. CARLSON

FIGURE 3.4-3



After Carlson et. al, 1982

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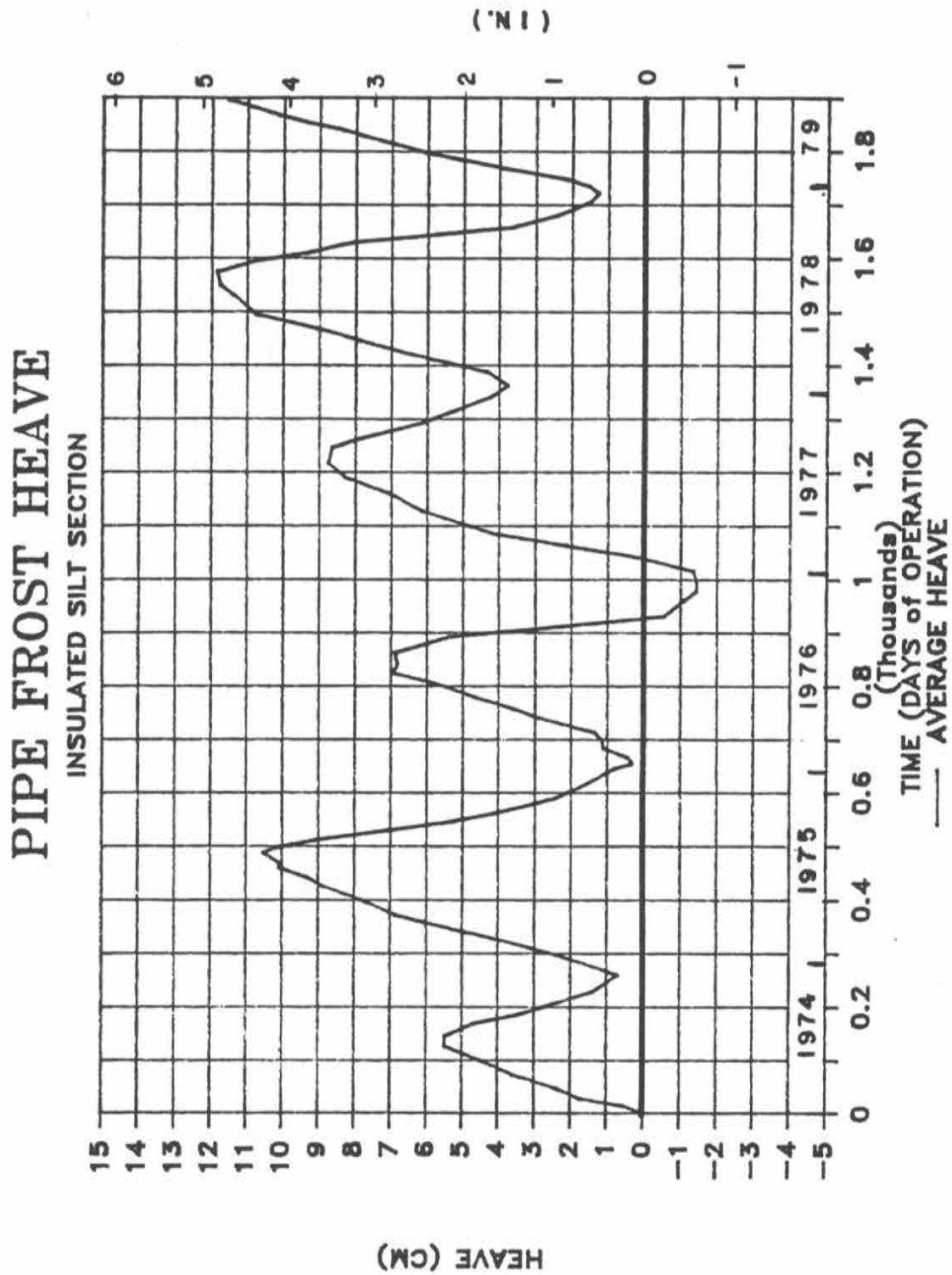
CALGARY FROST HEAVE TEST FACILITY
HEAVE AND FROST PENETRATION FOR INSULATED PIPE SECTIONS (1979, 1980)

PREPARED BY L. CARLSON

FIGURE 3.5 – 1



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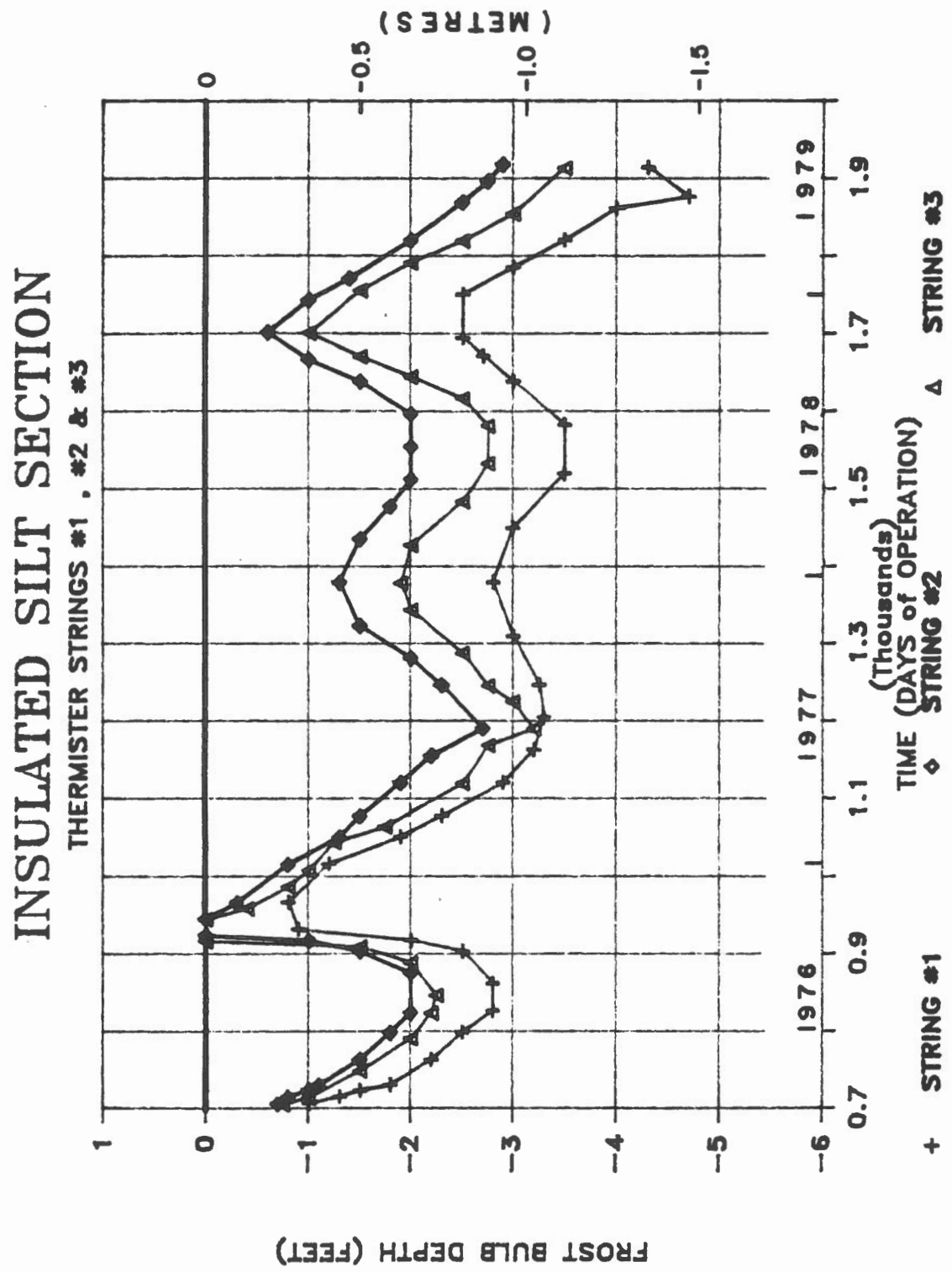
CALGARY FROST HEAVE TEST FACILITY

PIPE FROST HEAVE

INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 3.5-2



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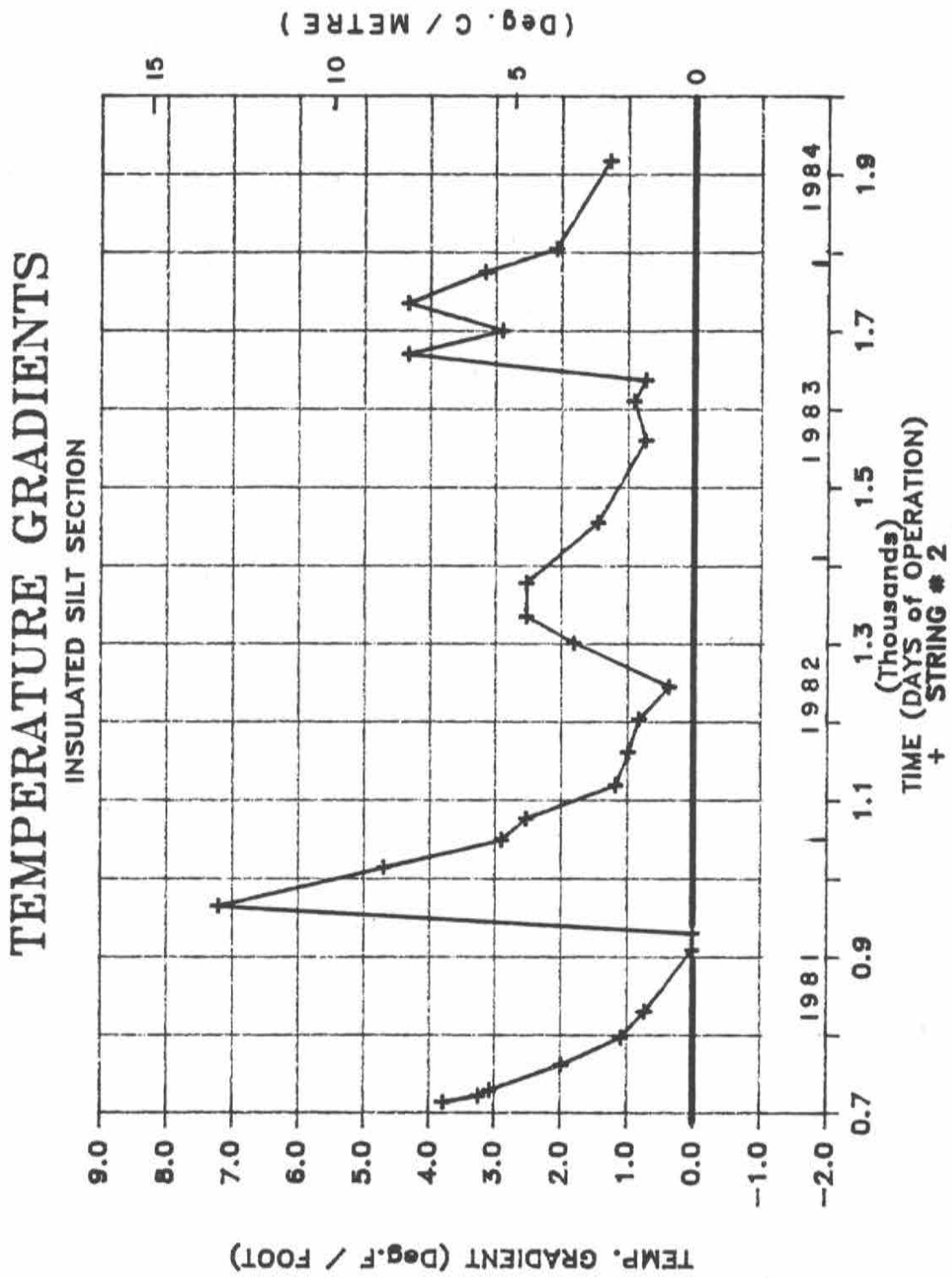
CALGARY FROST HEAVE TEST FACILITY

FROST BULB DEPTH
INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 3.5 – 3



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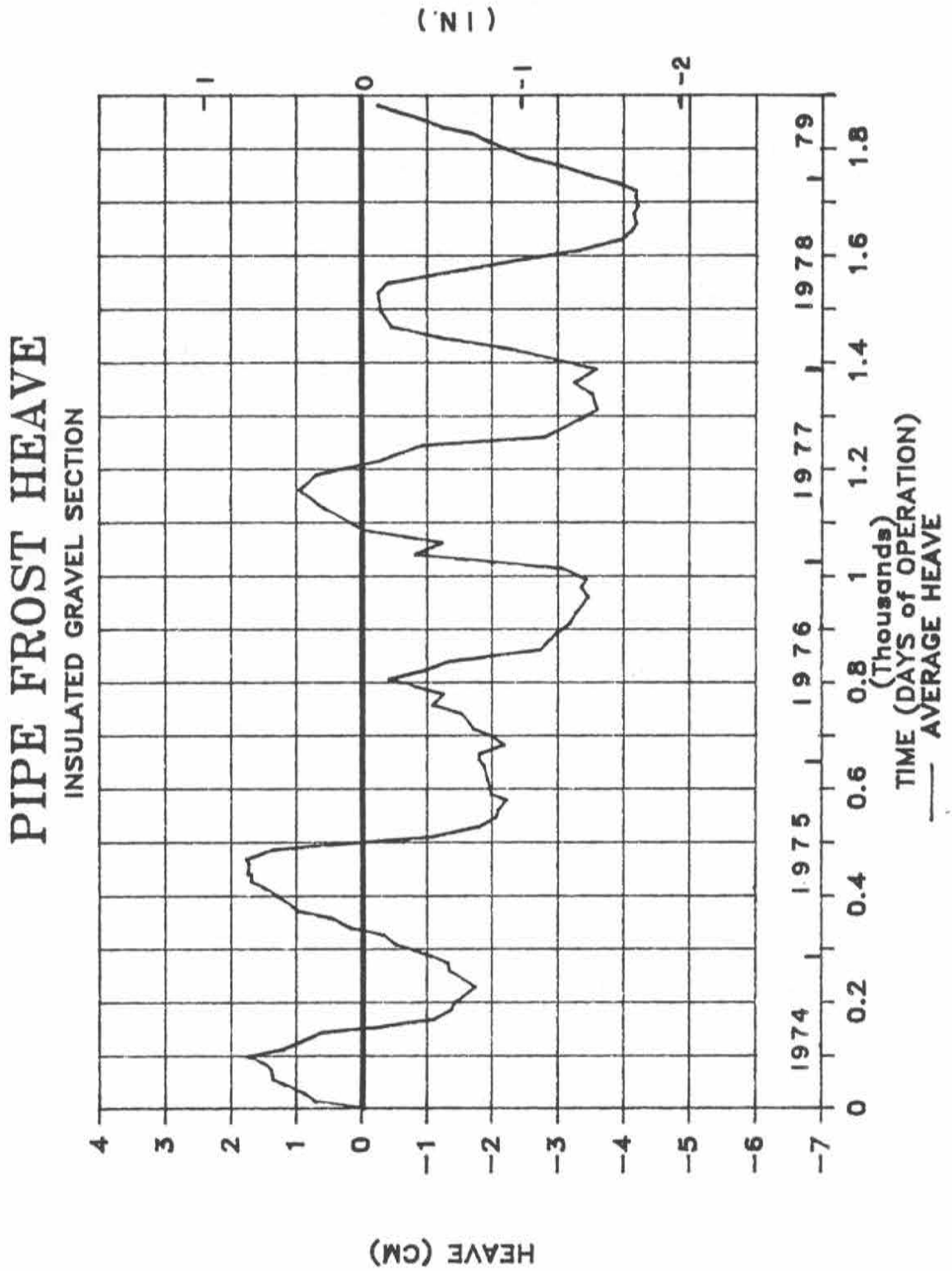
CALGARY FROST HEAVE TEST FACILITY

TEMPERATURE GRADIENTS
INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 3.5 – 4



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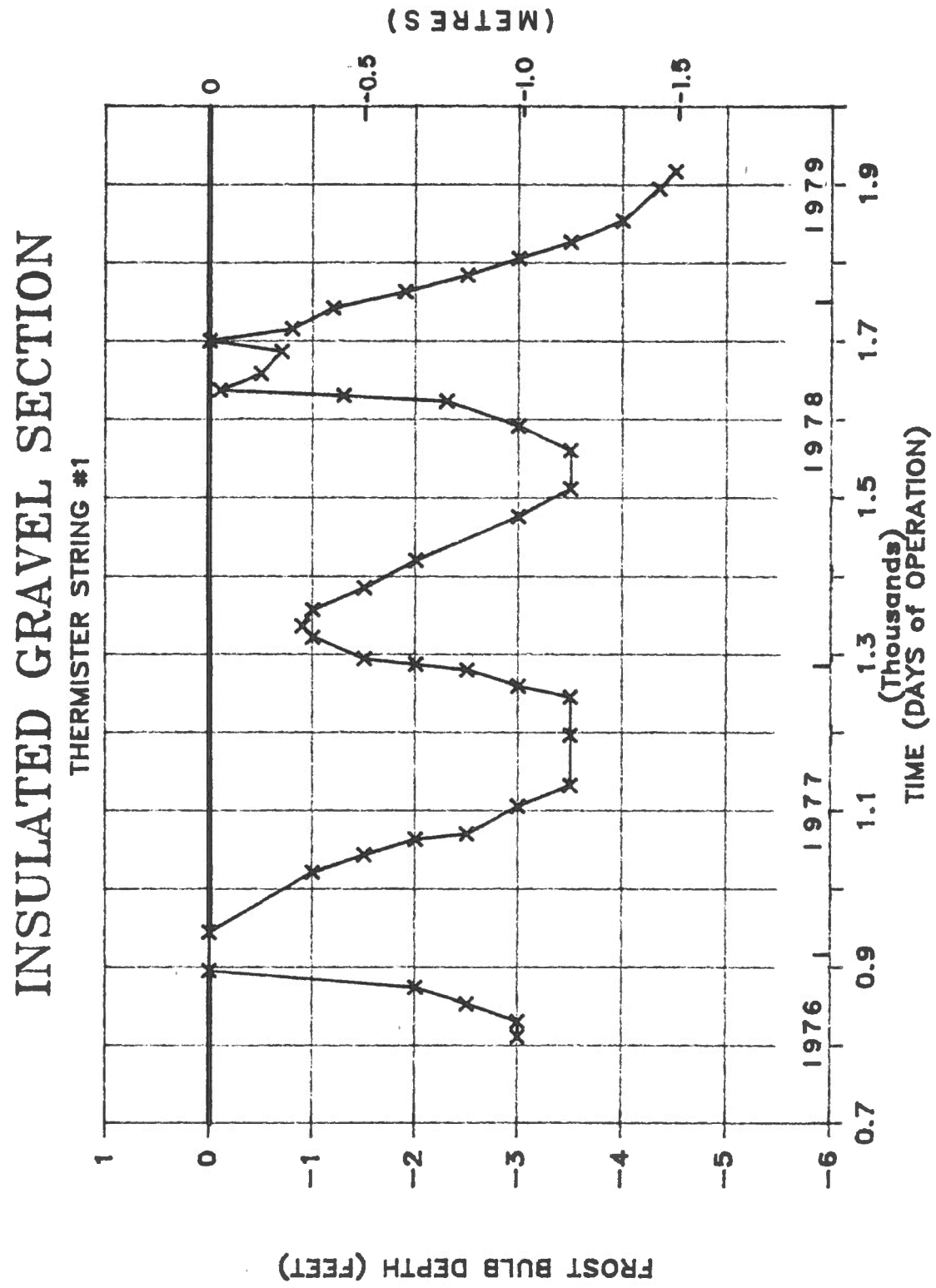
CALGARY FROST HEAVE TEST FACILITY

PIPE FROST HEAVE
INSULATED GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.5-5



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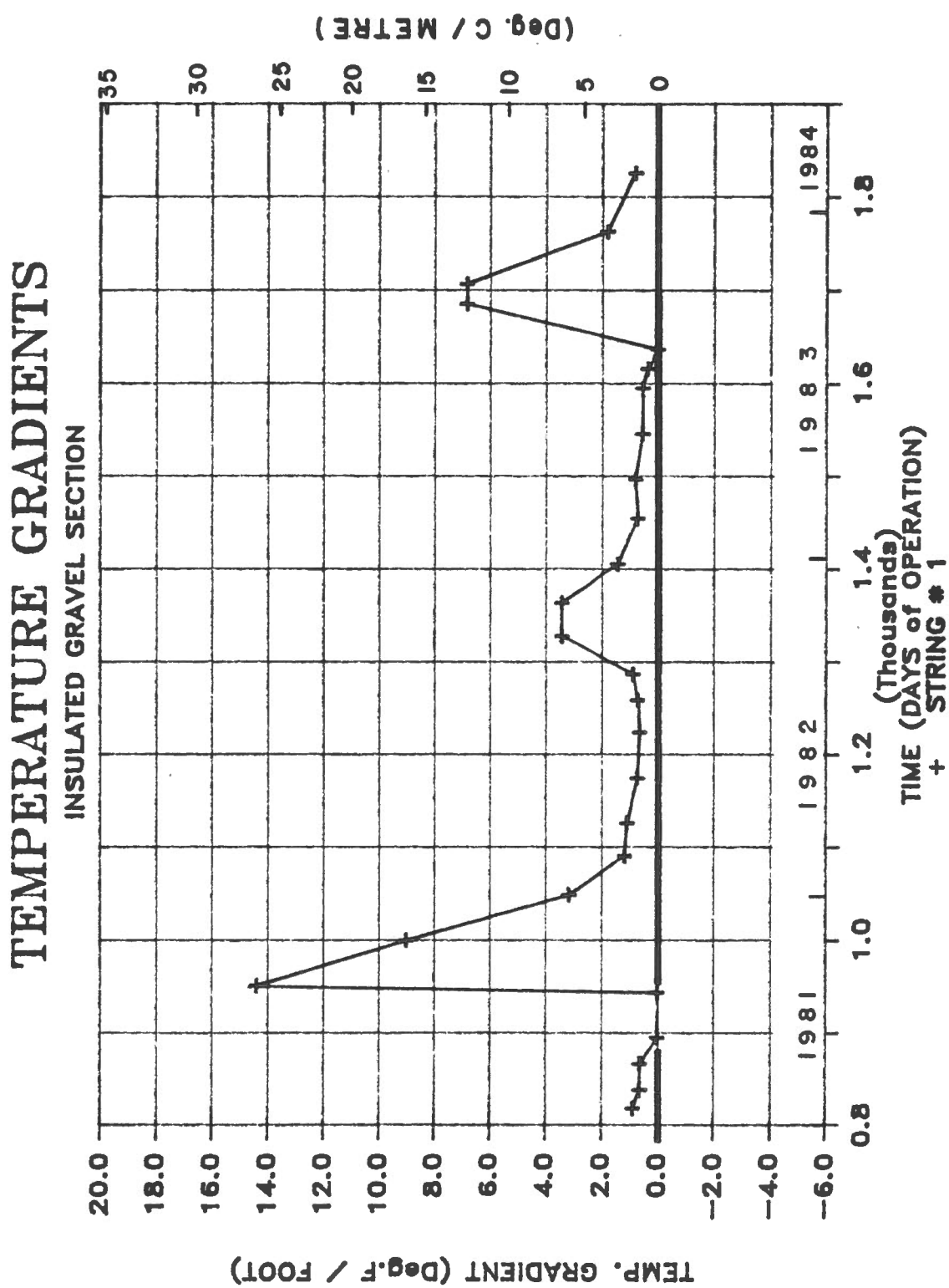
CALGARY FROST HEAVE TEST FACILITY

FROST BULB DEPTH
INSULATED GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.5 – 6



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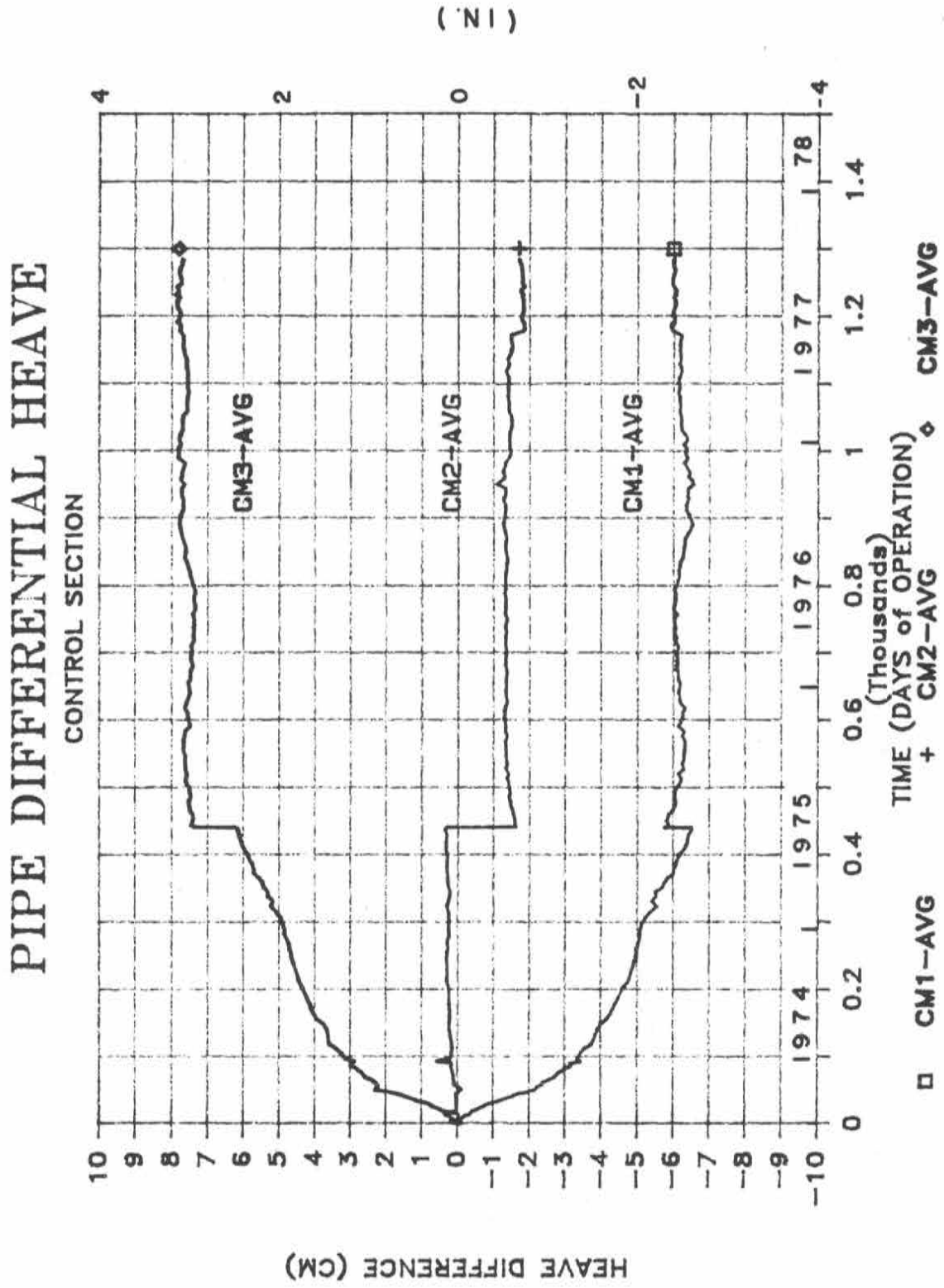
CALGARY FROST HEAVE TEST FACILITY
TEMPERATURE GRADIENTS
INSULATED GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.5-7



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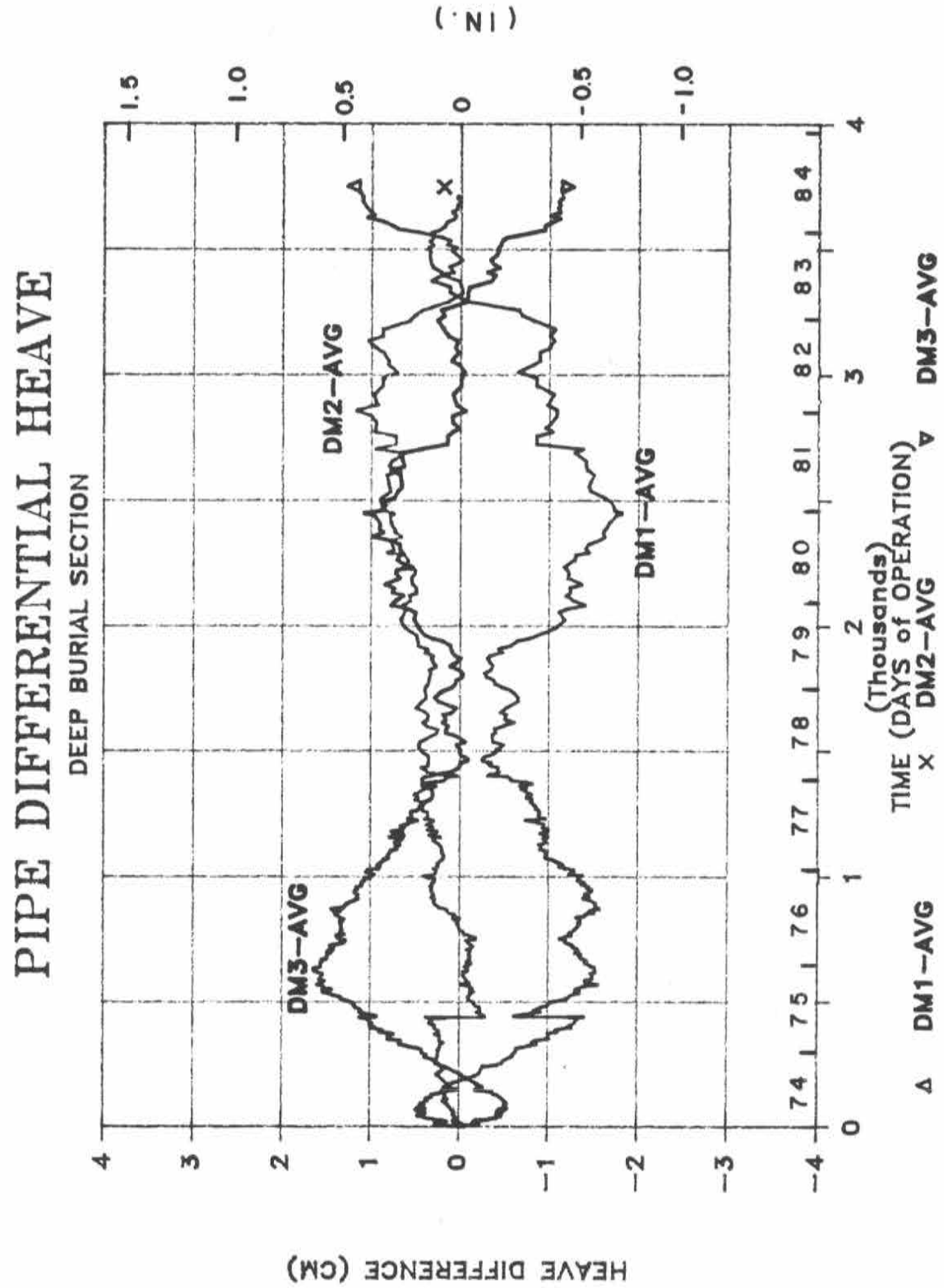
CALGARY FROST HEAVE TEST FACILITY

PIPE DIFFERENTIAL HEAVE
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.6-1



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CALGARY FROST HEAVE TEST FACILITY

PIPE DIFFERENTIAL HEAVE
DEEP BURIAL SECTION

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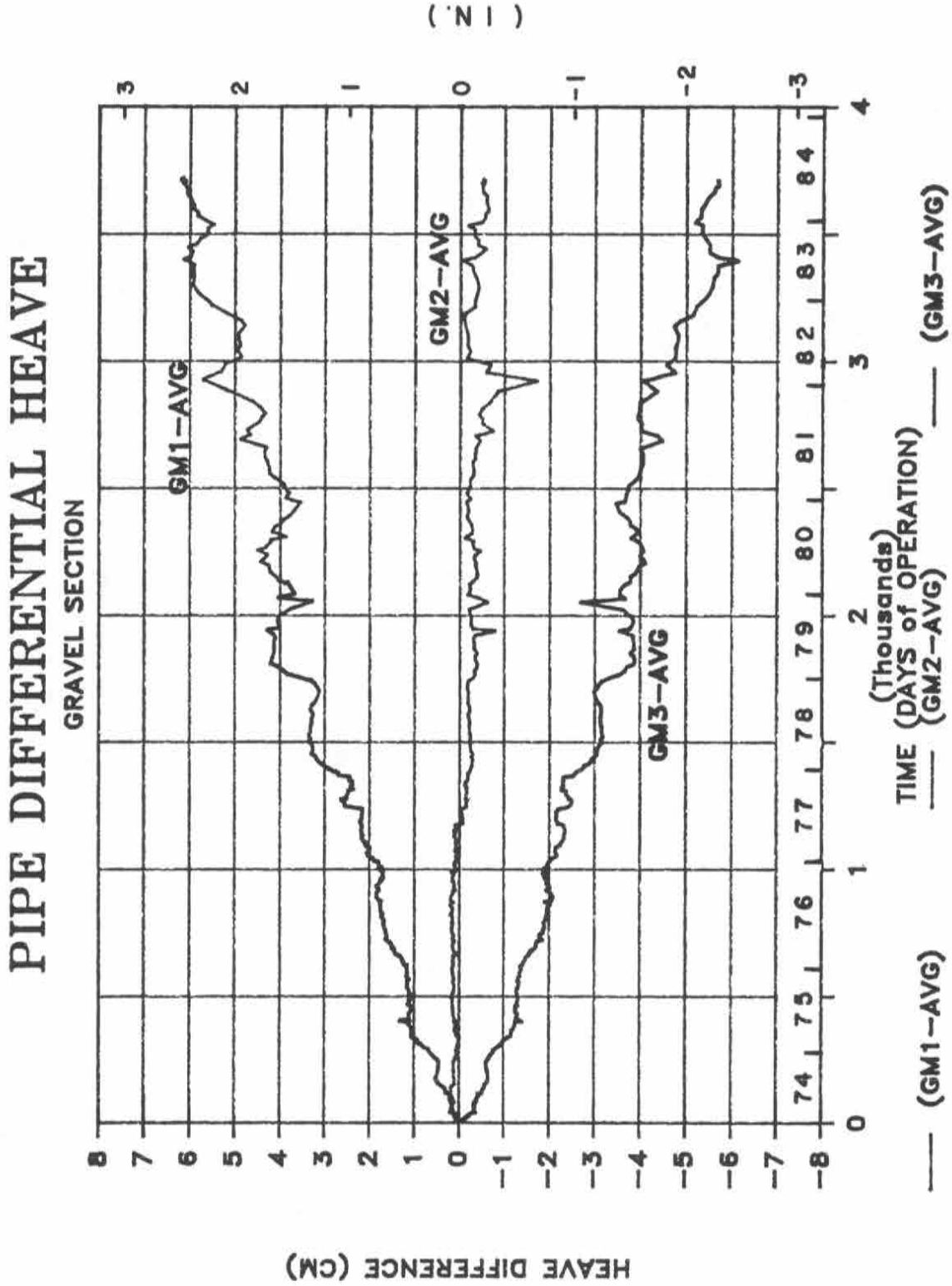
FIGURE 3.6 – 2



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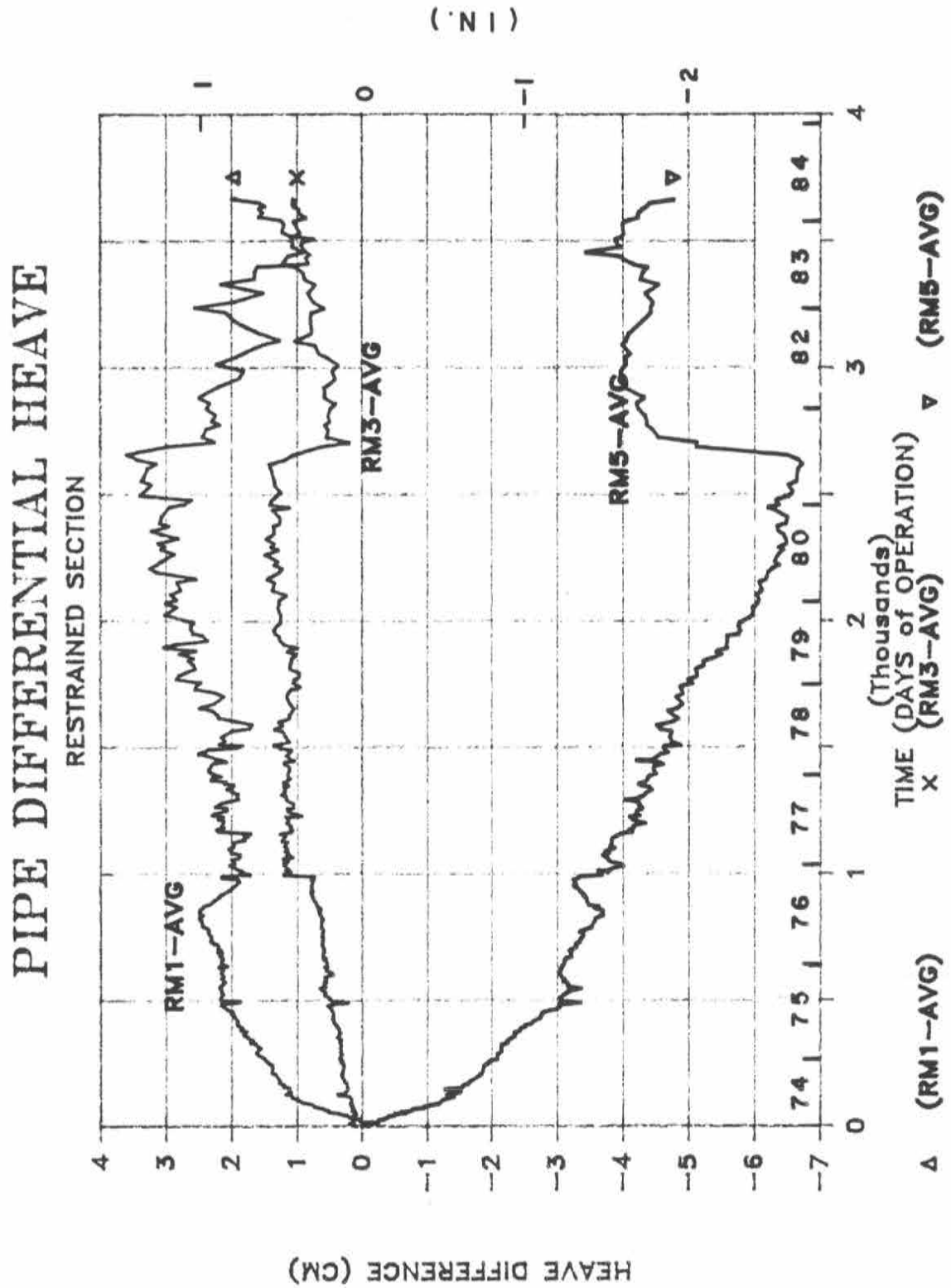
PIPE DIFFERENTIAL HEAVE
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.6 — 3



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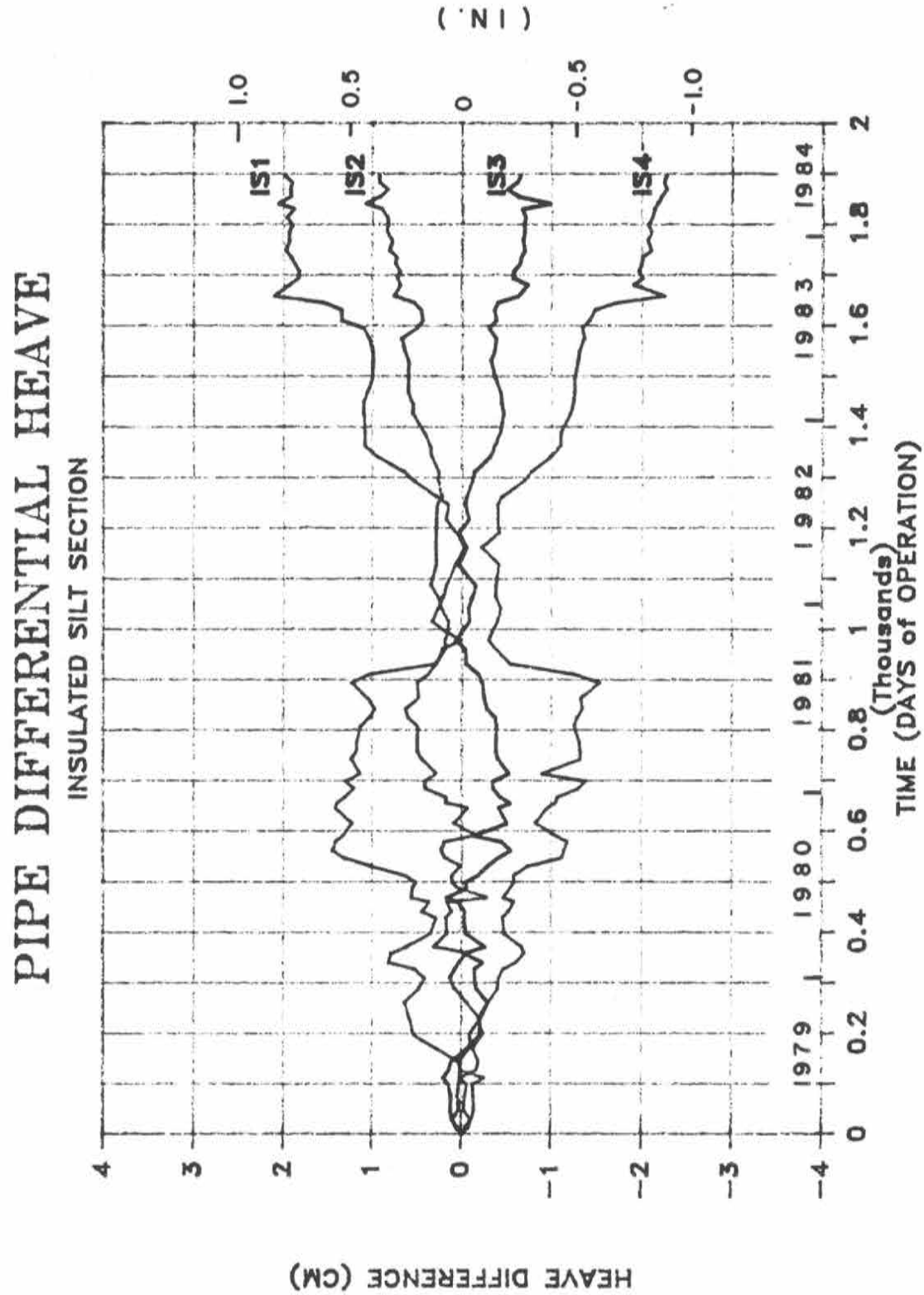
CALGARY FROST HEAVE TEST FACILITY

PIPE DIFFERENTIAL HEAVE
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.6-4



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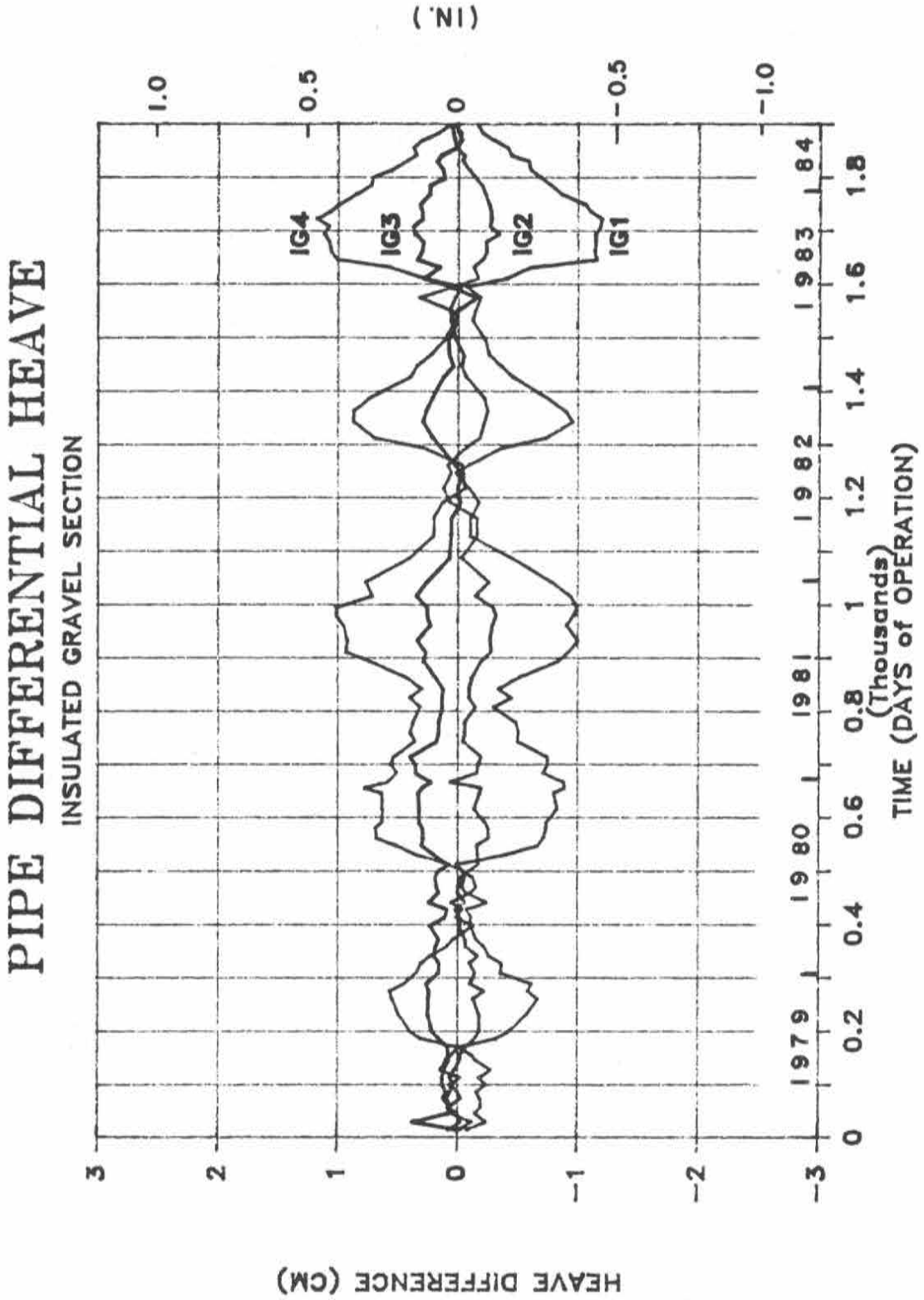
CALGARY FROST HEAVE TEST FACILITY

PIPE DIFFERENTIAL HEAVE
INSULATED SILT SECTION

PREPARED BY L. CARLSON

FIGURE 3.6-5



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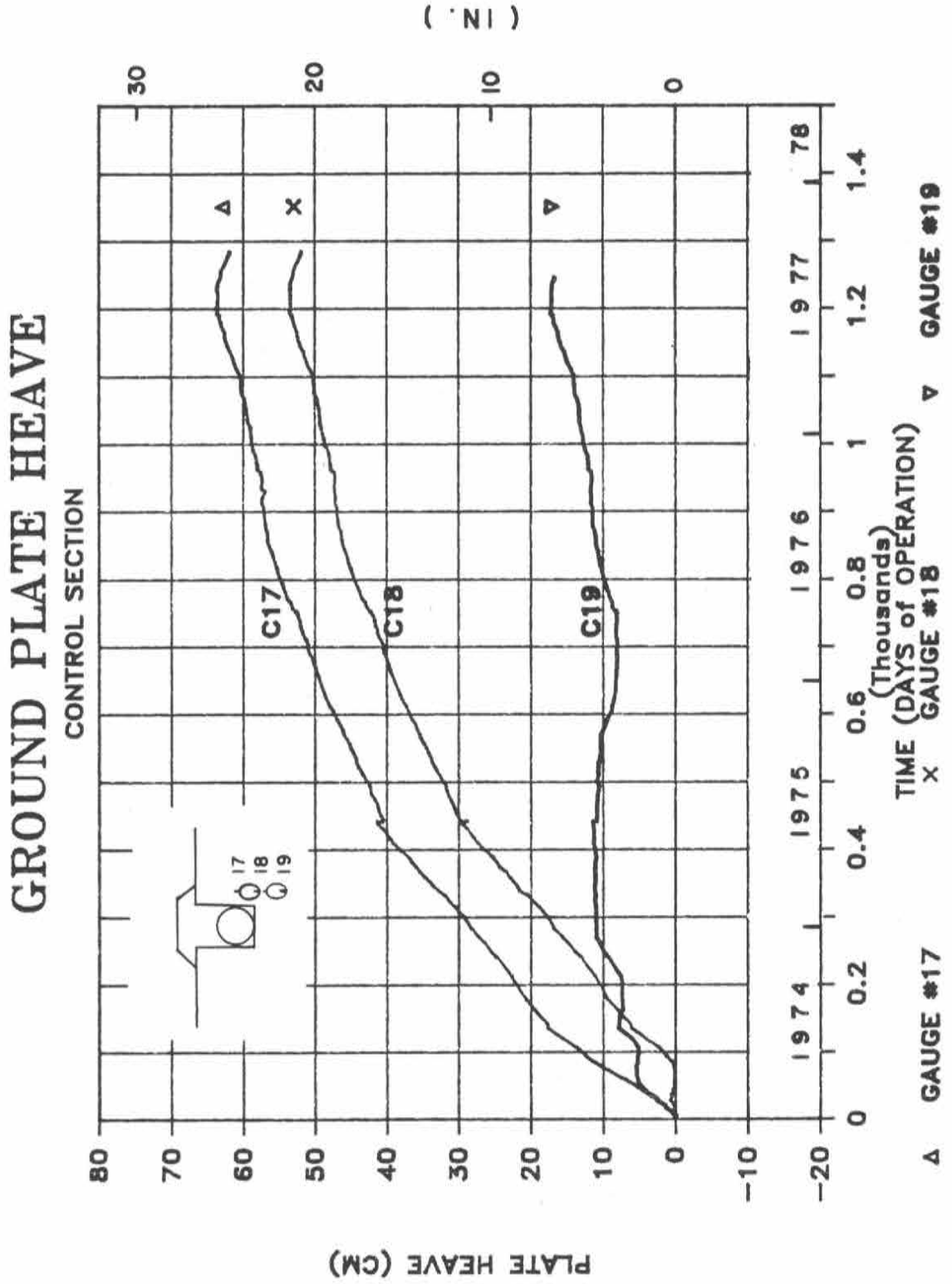
CALGARY FROST HEAVE TEST FACILITY

PIPE DIFFERENTIAL HEAVE
INSULATED GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.6-6



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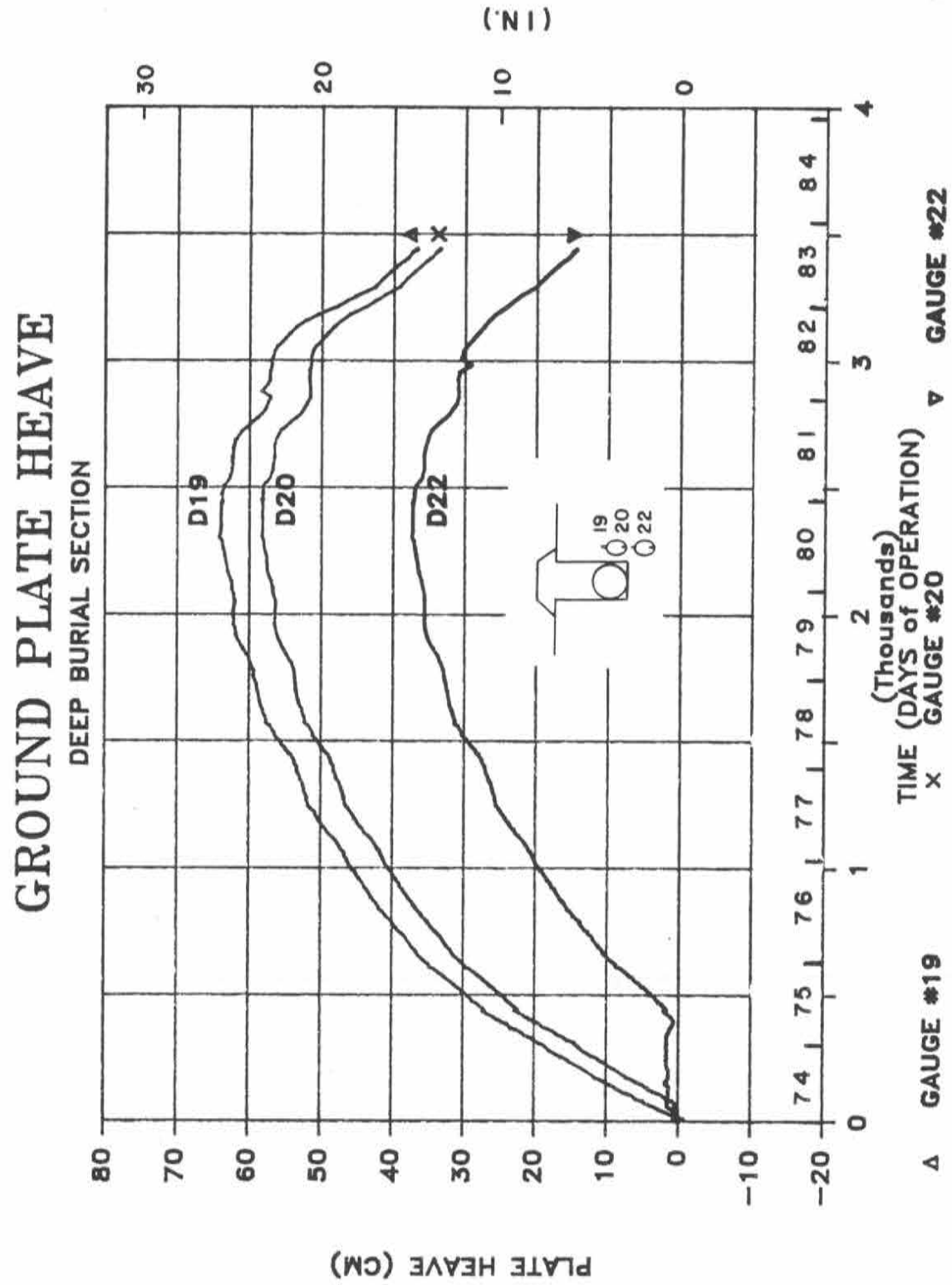
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE HEAVE
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 – 1



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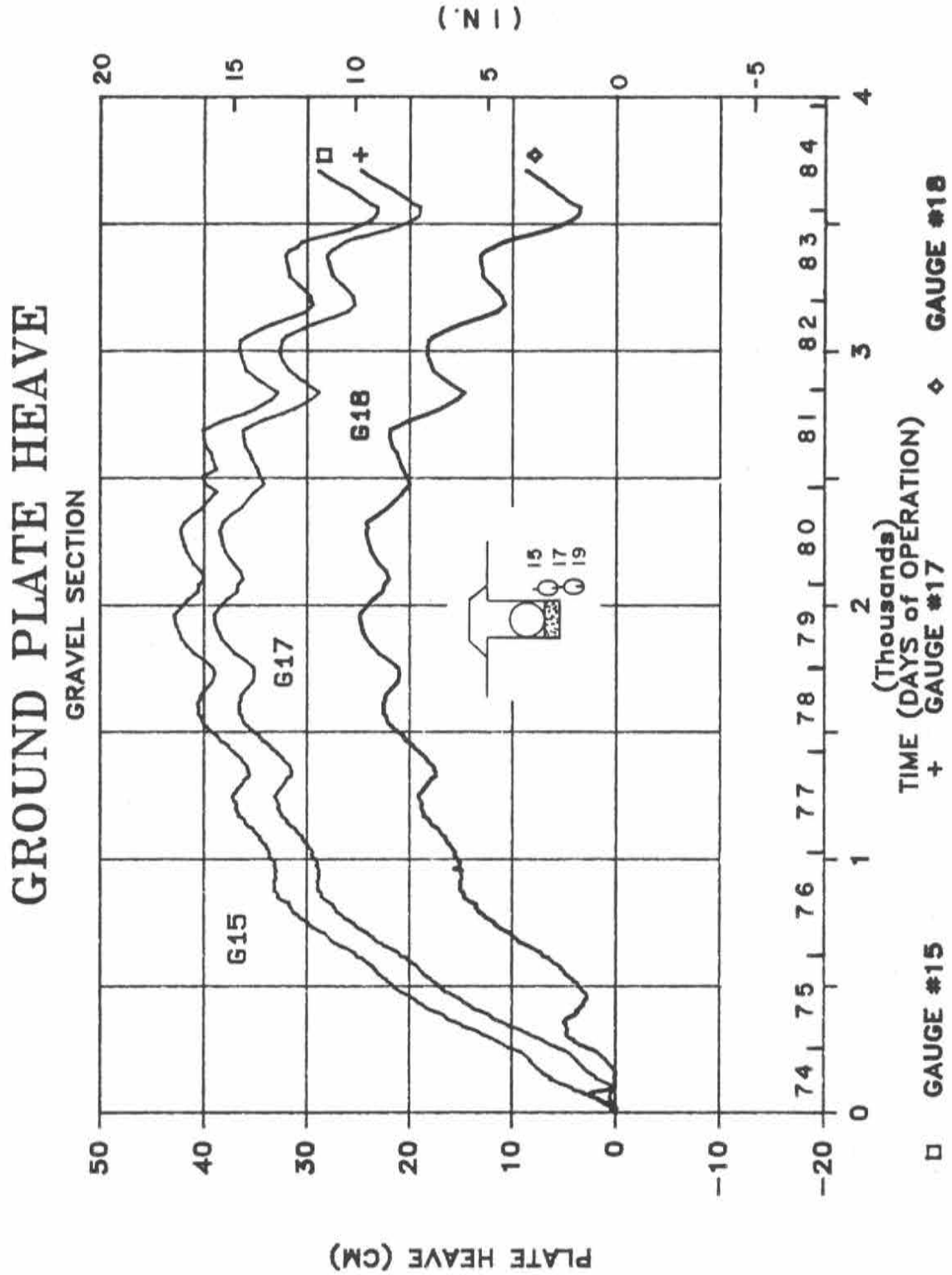
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE HEAVE
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 – 2



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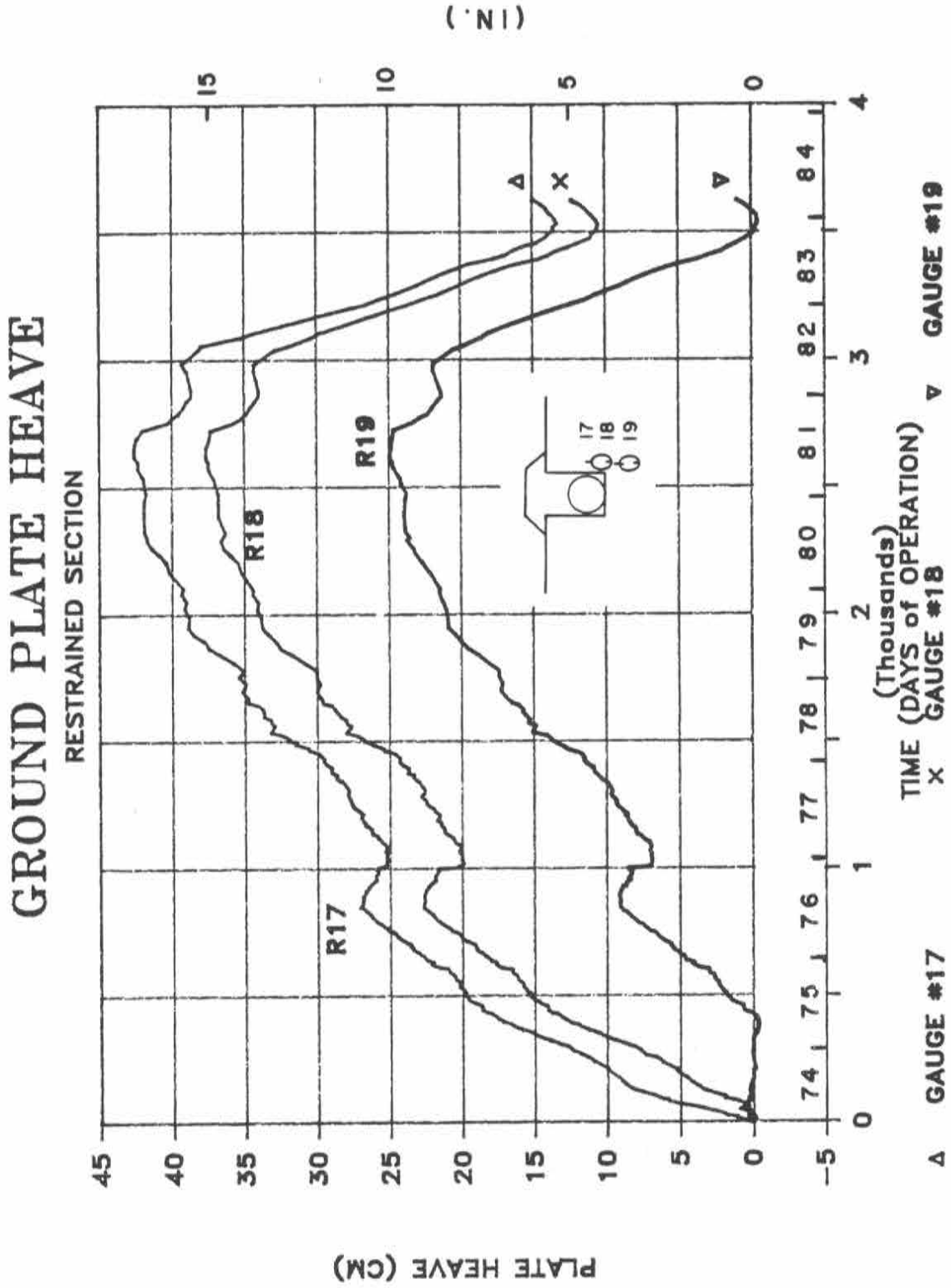
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE HEAVE
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 – 3



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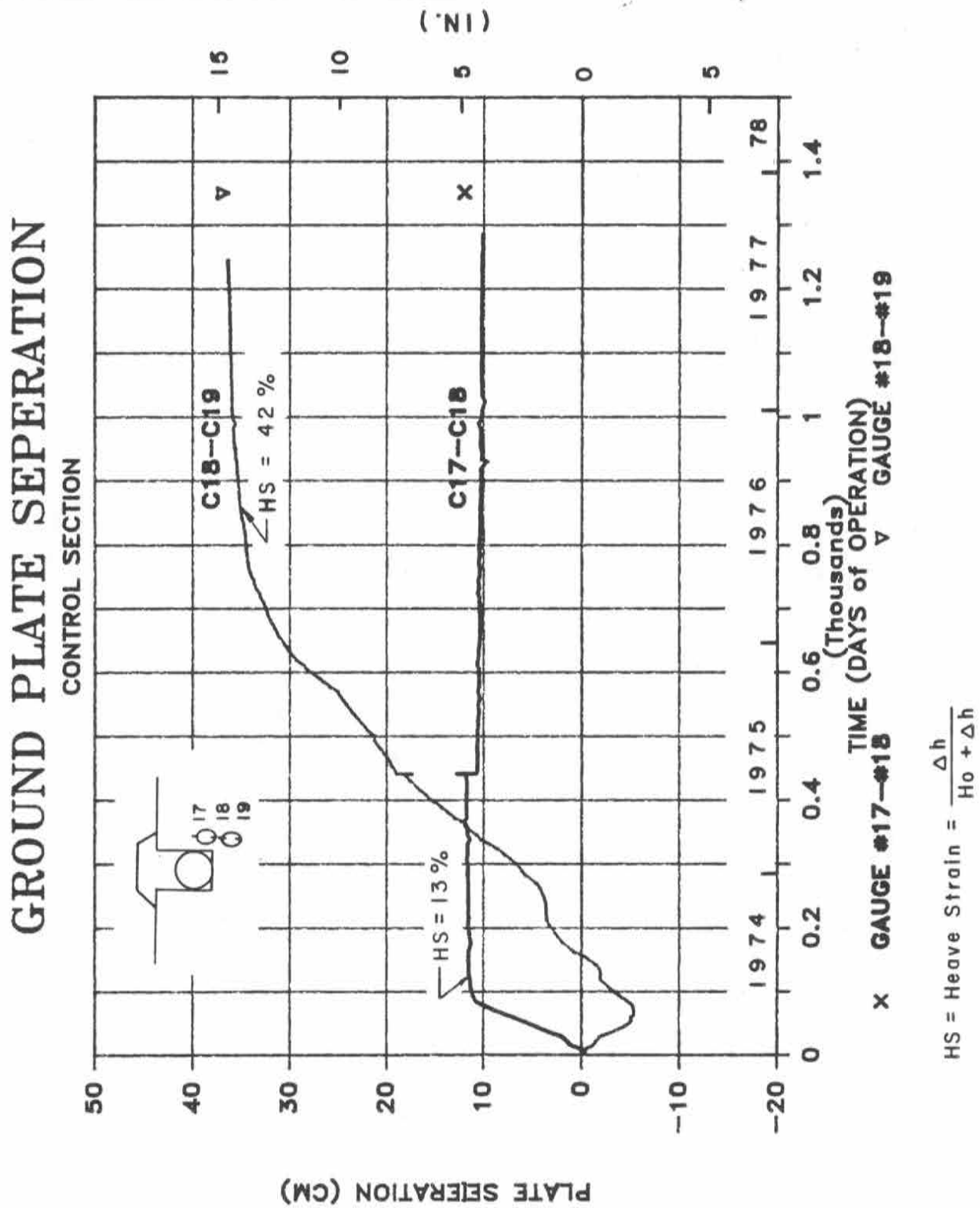
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE HEAVE
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.7-4



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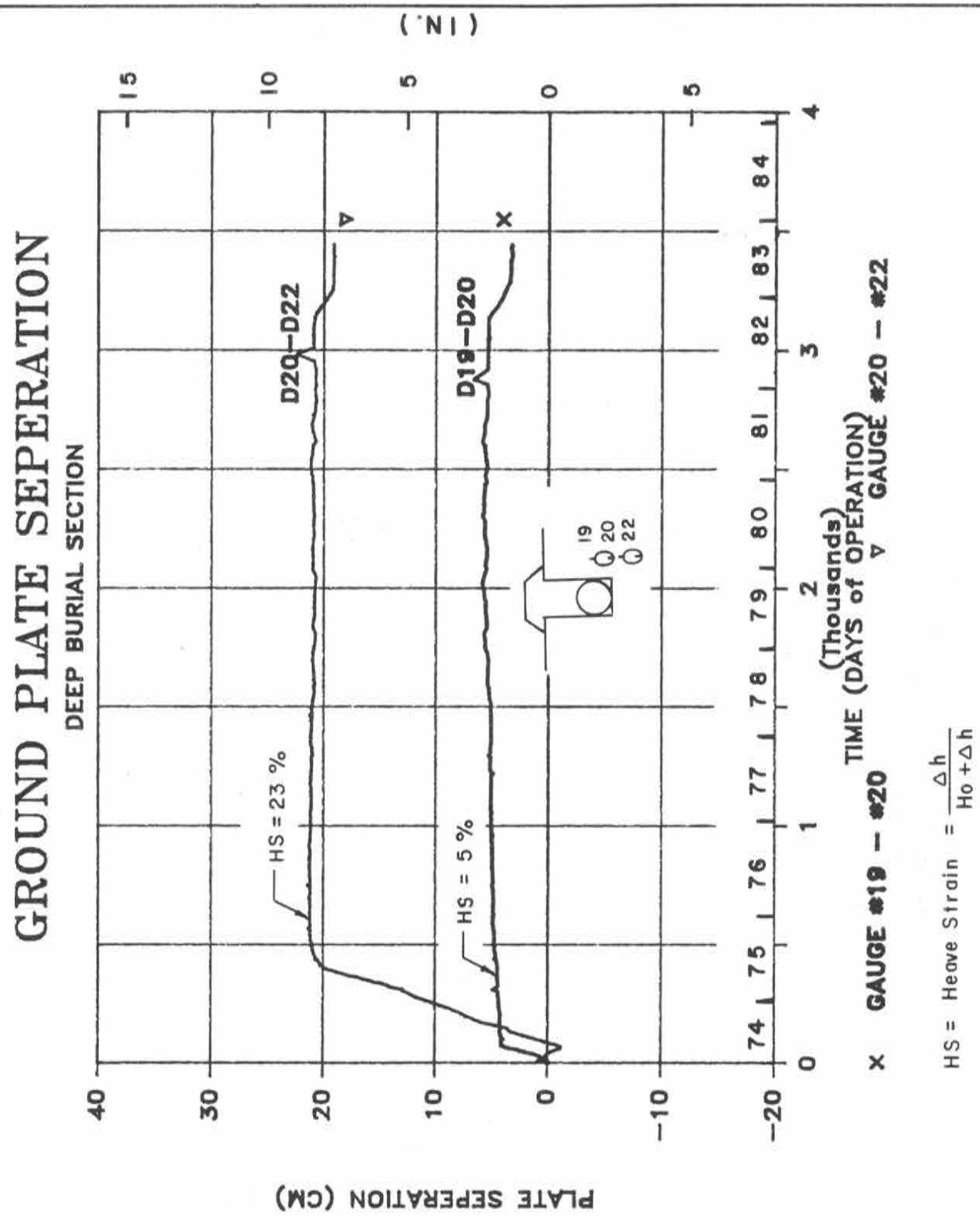
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE SEPERATION
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 - 5



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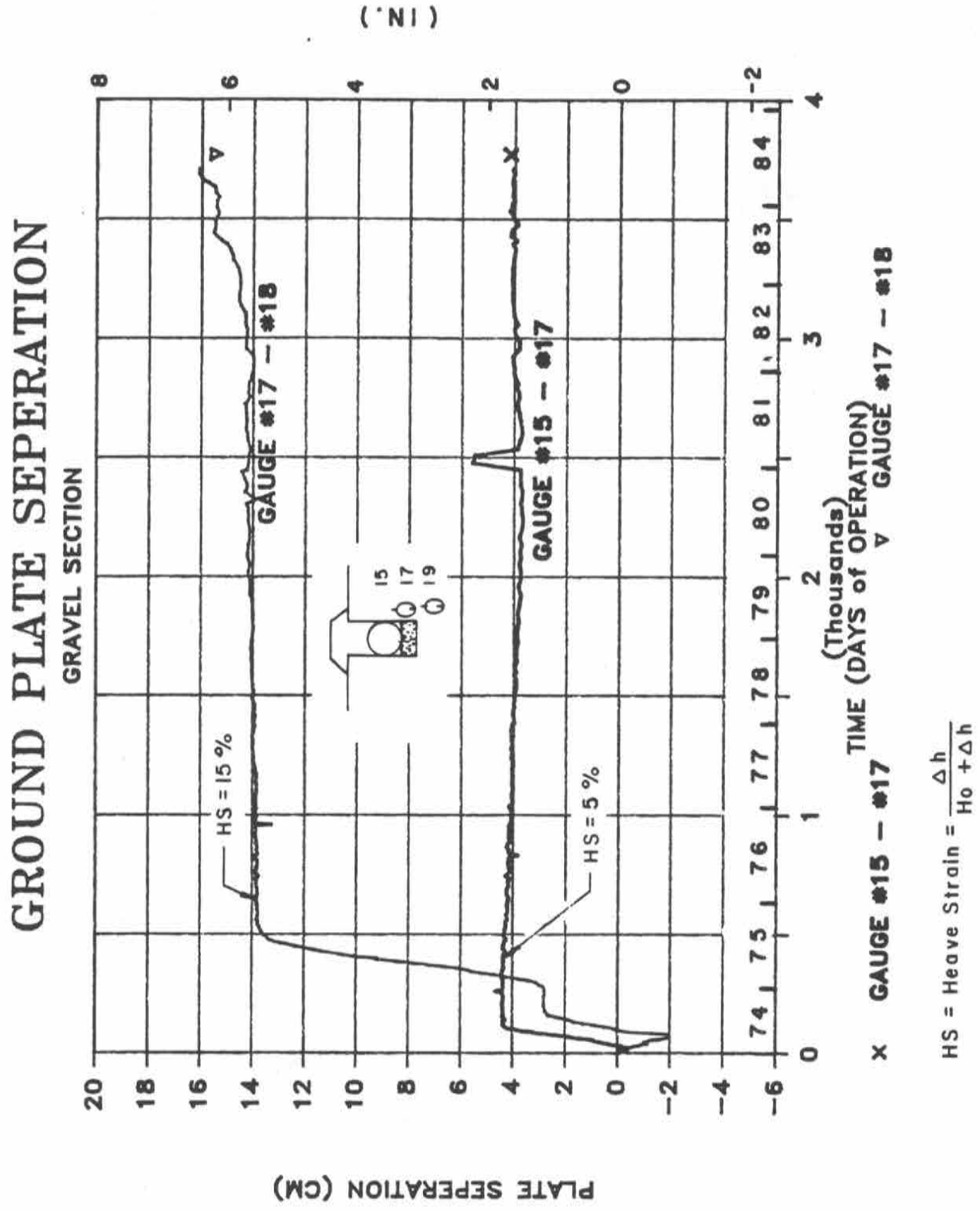
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE SEPERATION
DEEP BURIAL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 – 6



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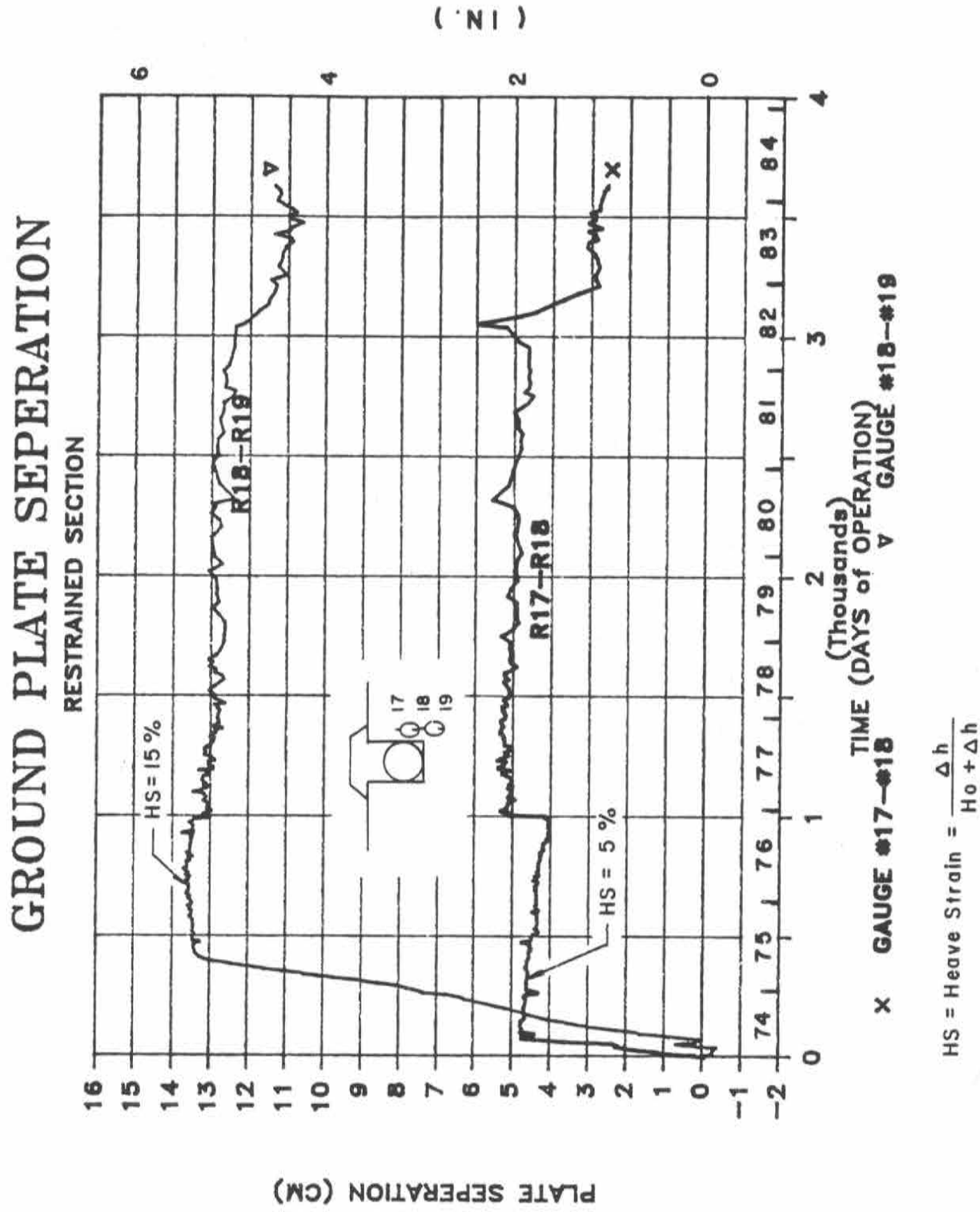
CALGARY FROST HEAVE TEST FACILITY
GROUND PLATE SEPERATION
GRAVEL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7-7



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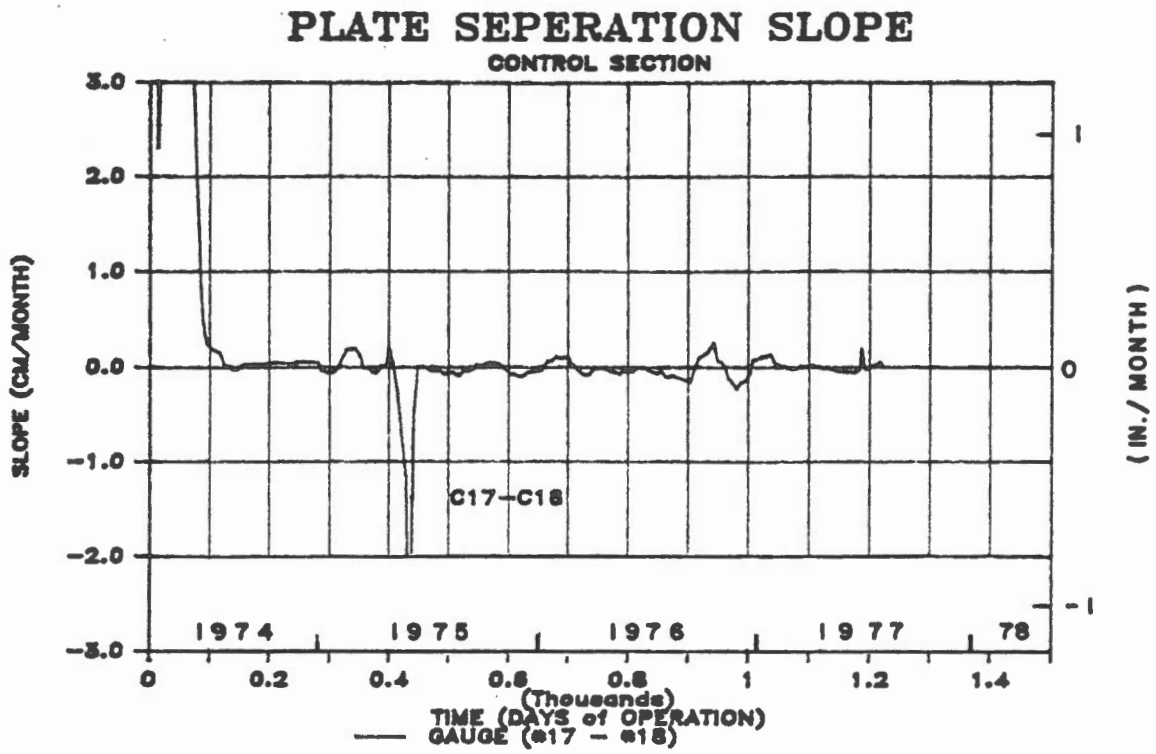
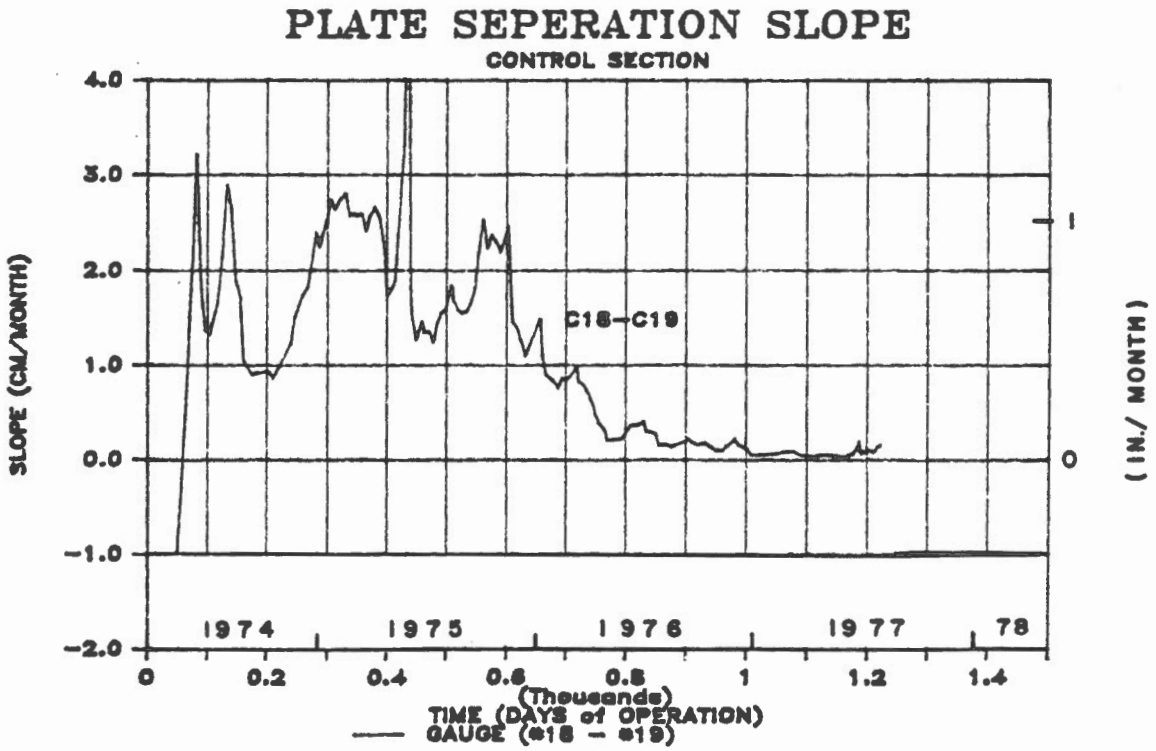
CALGARY FROST HEAVE TEST FACILITY

GROUND PLATE SEPERATION
RESTRAINED SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 – 8





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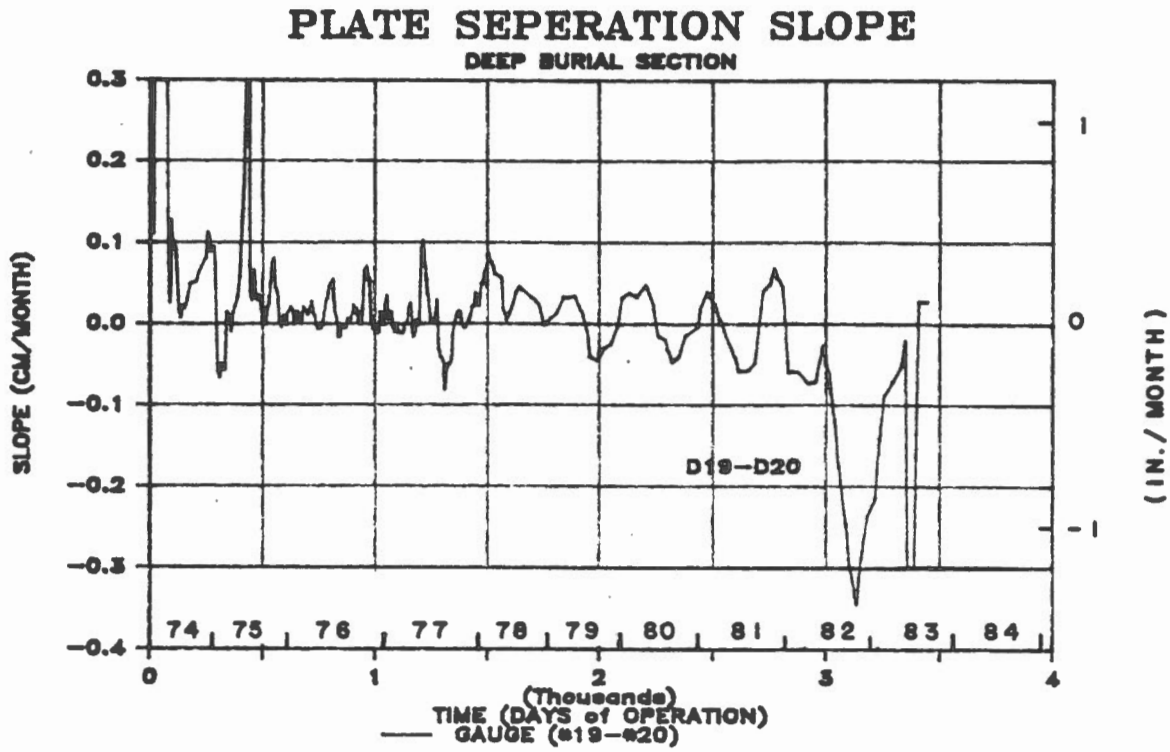
CALGARY FROST HEAVE TEST FACILITY

PLATE SEPERATION SLOPE
CONTROL SECTION

PREPARED BY L. CARLSON

FIGURE 3.7 – 9



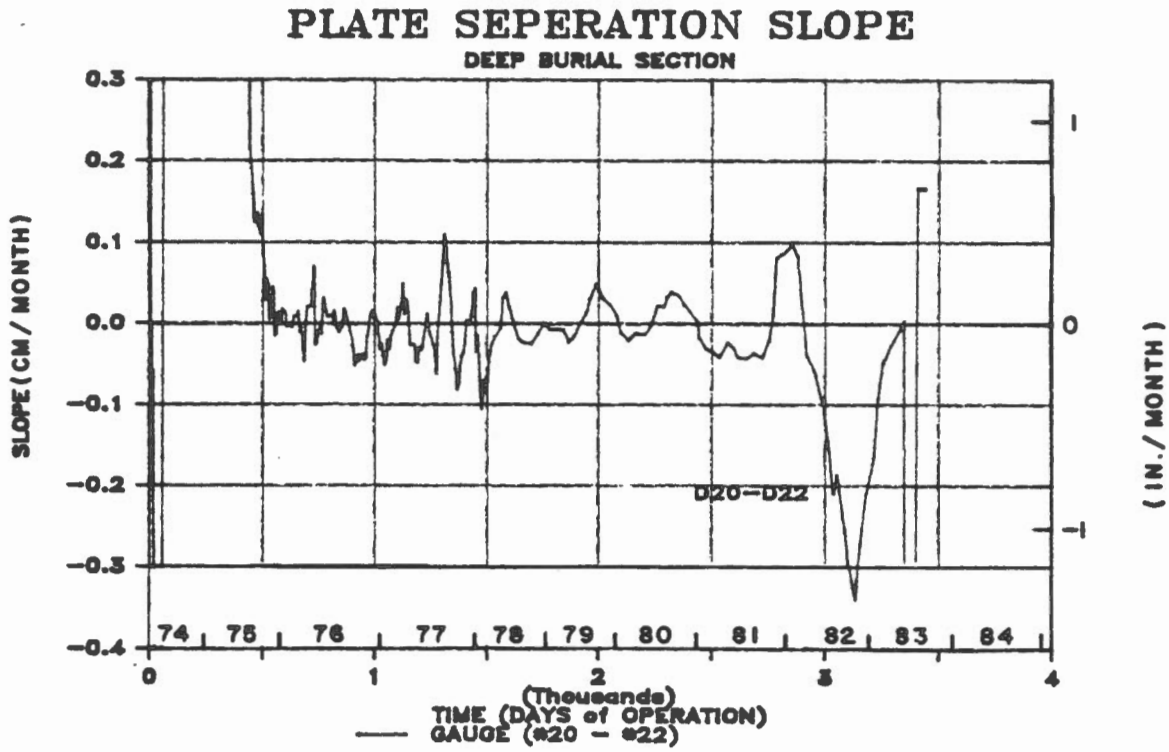


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PLATE SEPERATION SLOPE
DEEP BURIAL SECTION

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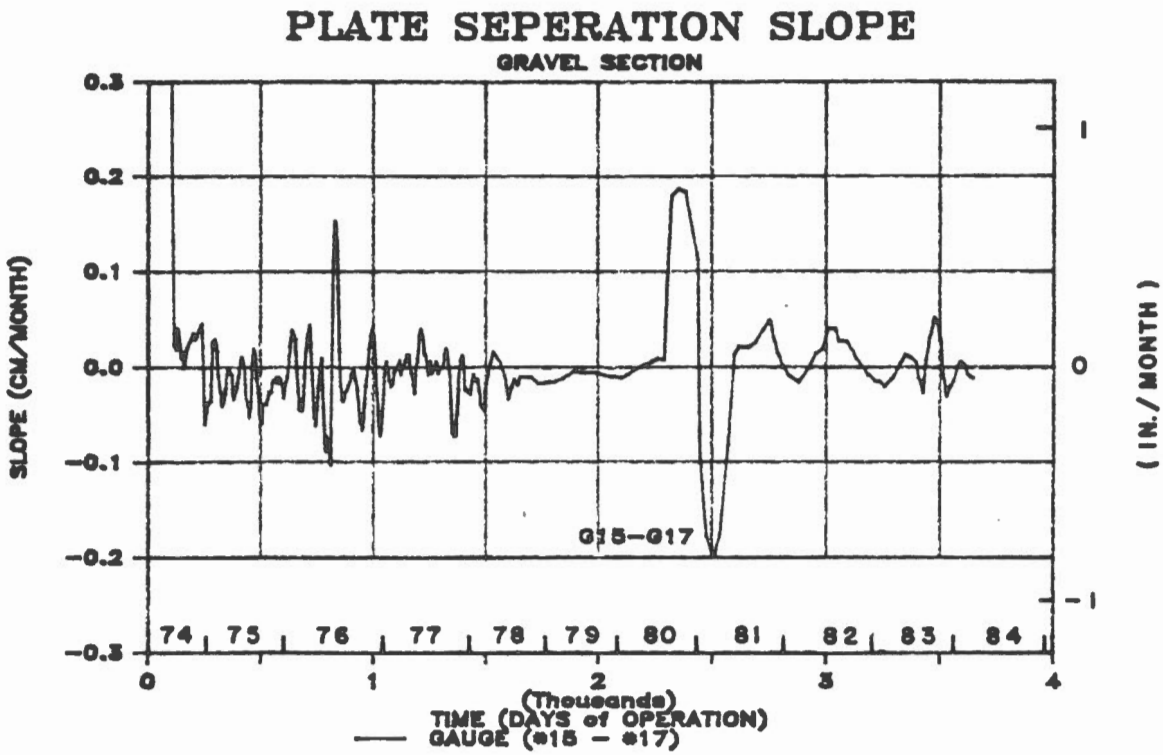
FIGURE 3.7–10



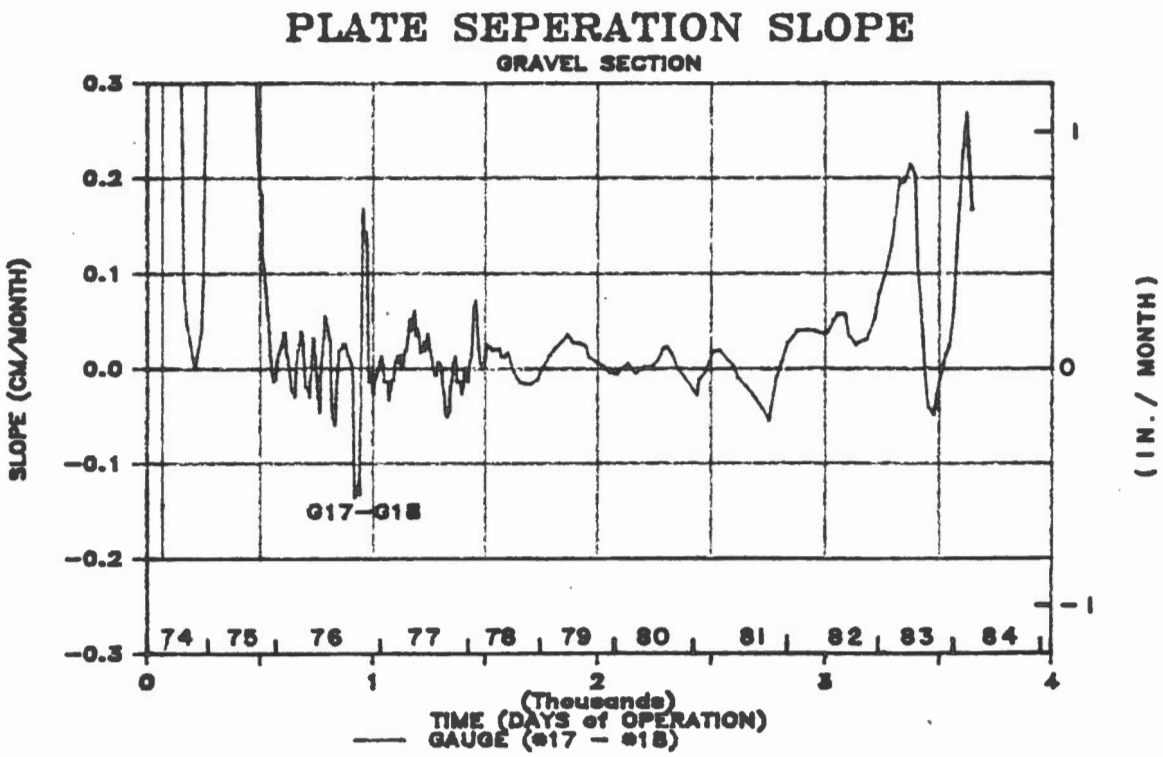


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PLATE SEPERATION SLOPE
GRAVEL SECTION

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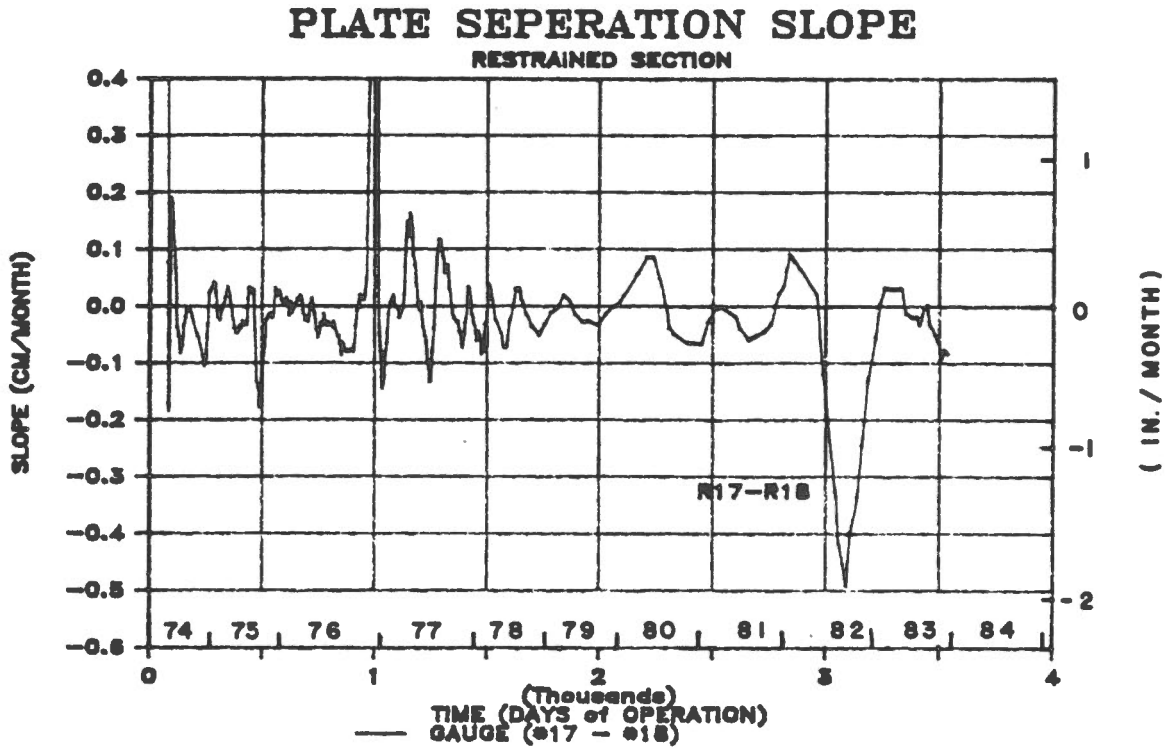
FIGURE 3.7 - 11



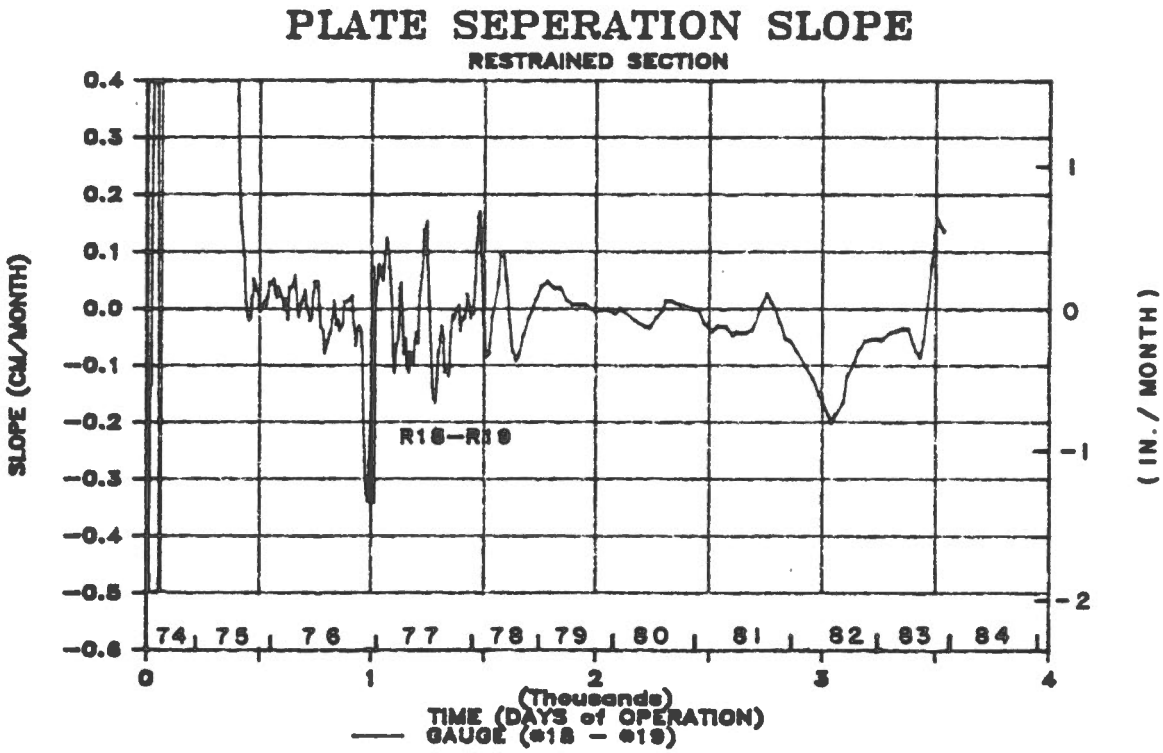


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PLATE SEPERATION SLOPE
RESTRAINED SECTION

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FIGURE 3.7-12

Appendix A

This appendix presents temperature profiles measured by the origial and deep thermistor strings of the four non-insulated test sections. Thermistor bead temperature is plotted against the thermistor's depth below the ground surface, as presented in the tables of appendix B. Figure A-1, which presents the ground temperature profile for strings 1 and 8 of the control section on days 1080 and 1283, is used as an example. The "depth below ground" for bead CTI-13 is seen on table B-1 to be 14.1 feet, and it's temperature on day 1080 as 31.5 Deg. F. Now, as stated in chapter 3.1, the thermistor strings adjacent to the pipe (#1 and #3) are locked into the frost bulb and heaves along with the pipe. When the deep strings were installed, CT8 & 9 in this case, the pipe and strings CT1 & 3 had heaved 2.0 feet (see table B-1). In plotting Figure B-1, this heave value was added to the initial depth value for the deep strings, CT8 & 9; i.e. The top bead (#1) of string CT8 has an initial depth below ground value of 12.5 feet (from Table B-1), and a "corrected depth" on Figure B-1 of 12.5 + 2.0 = 14.5 feet.

Ground temperature profiles from strings CT3 and CT8 are seen in Figure A-2 again for days 1080 and 1283. The temperature gradient inside the frost bulb, for day 1080, is about 1.1 degrees F per foot, while below the frost bulb it is about 0.6 Deg. F per foot. the higher temperature gradient for Day 1283 below the frost bulb, of about 1.6 Deg. F per foot, was caused by the application of deep heaters under this section, just before the section was shut down.

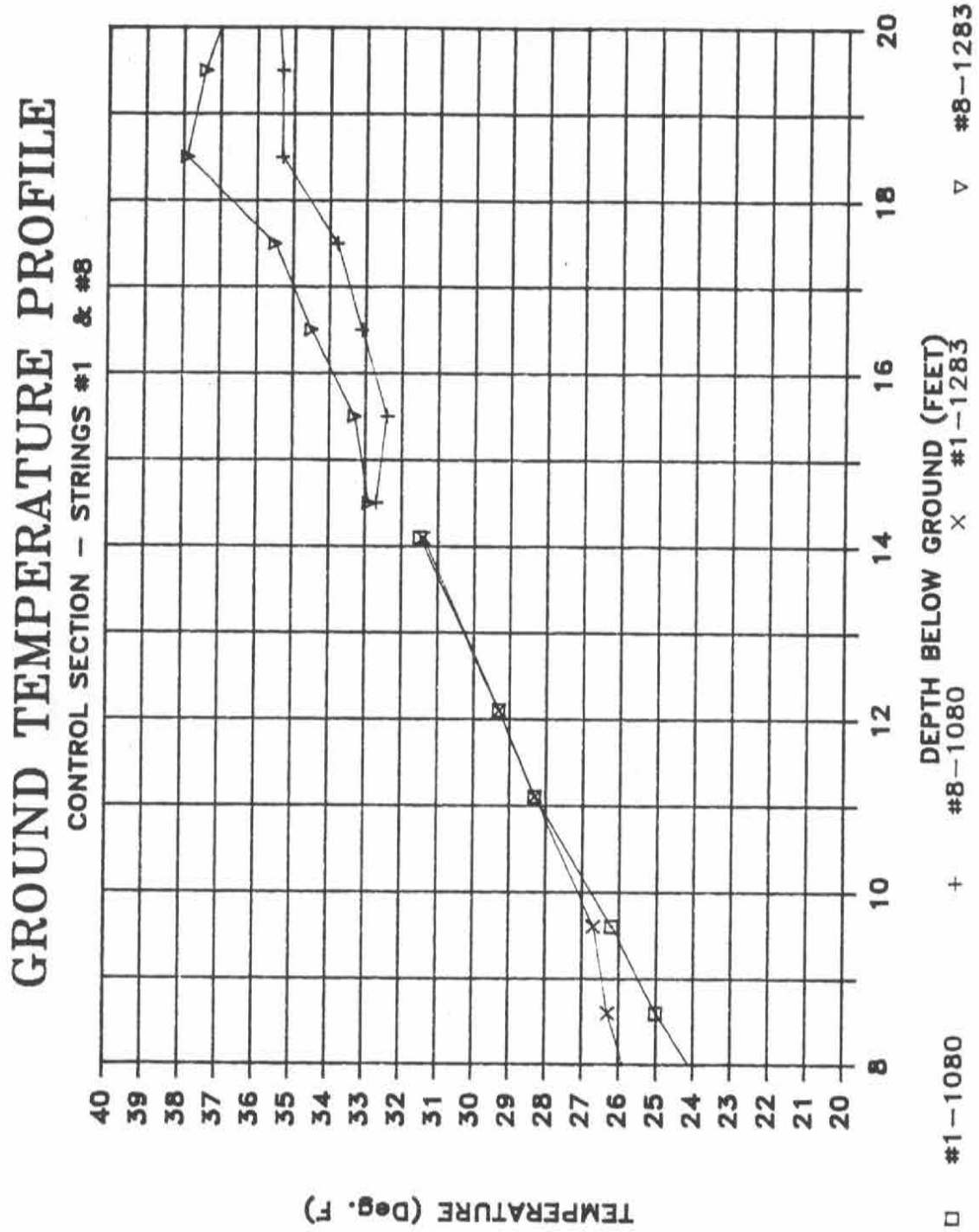
The ground temperature profile, for these same days, from strings CT8 &9 are compared in Figure A-3. The warming effect of the deep heaters, which were placed about 11.5 feet below the base of the pipe (at 18 feet below ground on these plots), shows up strongly in this comparison for days 1080 and 1283. This warming effect is also seen very strongly around day 1200 (July 1977) in the Ground Temperature History plots for temperature strings CT8 & 9 of Figures 3.3-4 and 3.3-5, respectively.

Deep Burial section ground temperature profiles are presented in Figures A-4 & 5 for strings 1 and 6. The former is for days 1206 and 2025 and the latter for days 2403 and 3477. The string 3 and 7 profiles are presented in Figure A-6 for days 1206 and 1808. As seen for day 1206, the top temperature beads of strings DT6 & 7 were installed inside the frost bulb.

Similar ground temperature profiles for the Gravel section are seen in Figure A-7 & 8, for strings GT1 & 6, and GT3 & 7. The ground temperature profiles of strings GT6 & 7 are NOT compatible with each other. String GT6 has a temperature gradient of about 0.4 Deg. F per foot, while that for string GT7 is about 1.3 Deg. F per foot. The lower value from string GT6 is consistent with that from other deep temperature strings of about 0.5 + or - 0.1 Deg. F per foot.

The Restrained section ground temperature profiles are seen in

Figures A-9 through A-12. The top thermistor beads of strings RT7 & 8 were installed well within the frost bulb. Day 3006 temperature profiles for all of these strings show that the frost bulb became practically isothermal during this time period.



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GROUND TEMPERATURE PROFILE
CONTROL SECTION
STRINGS # 1 & 8

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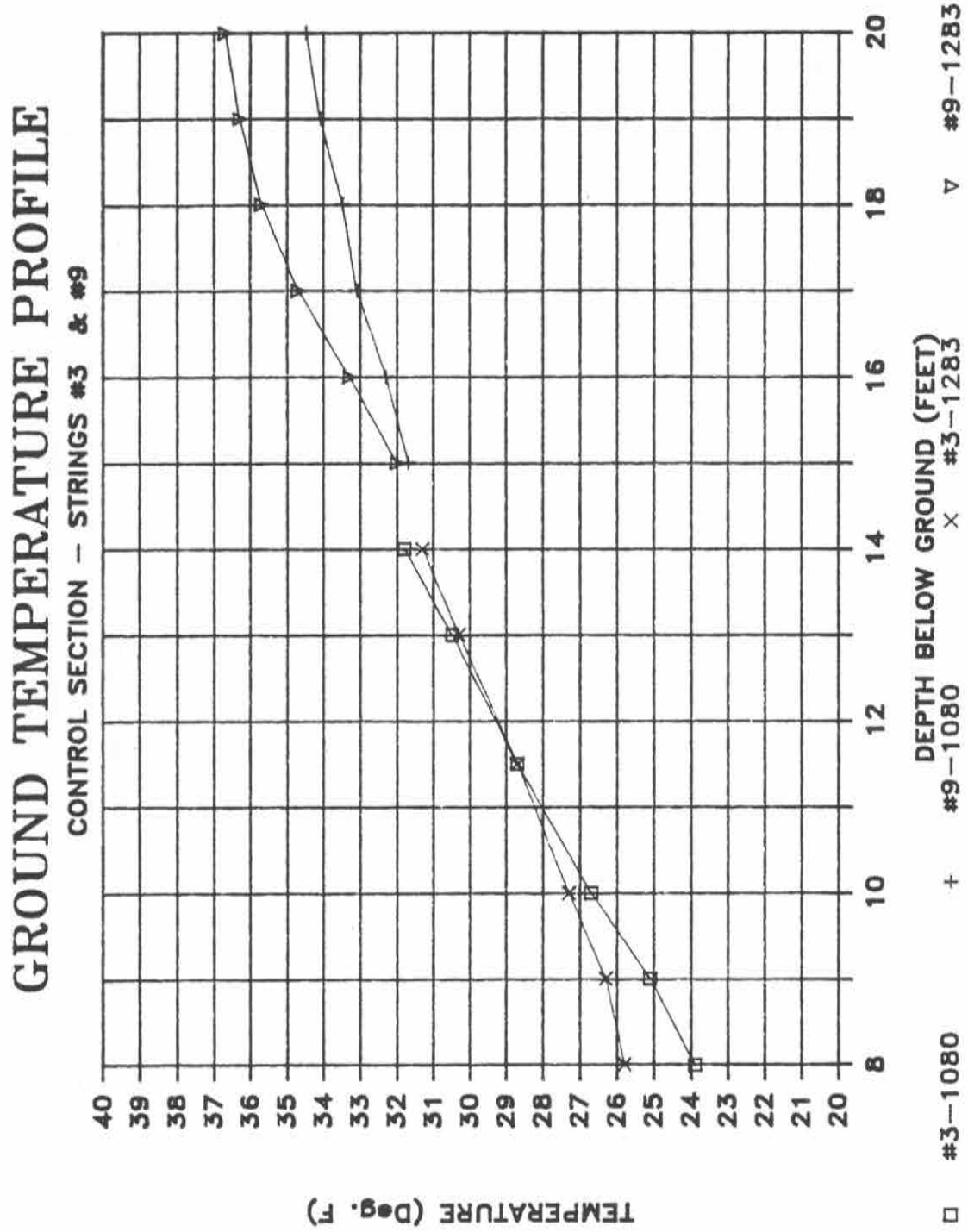
FIGURE A – 1



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
CONTROL SECTION
STRINGS # 3 & 9

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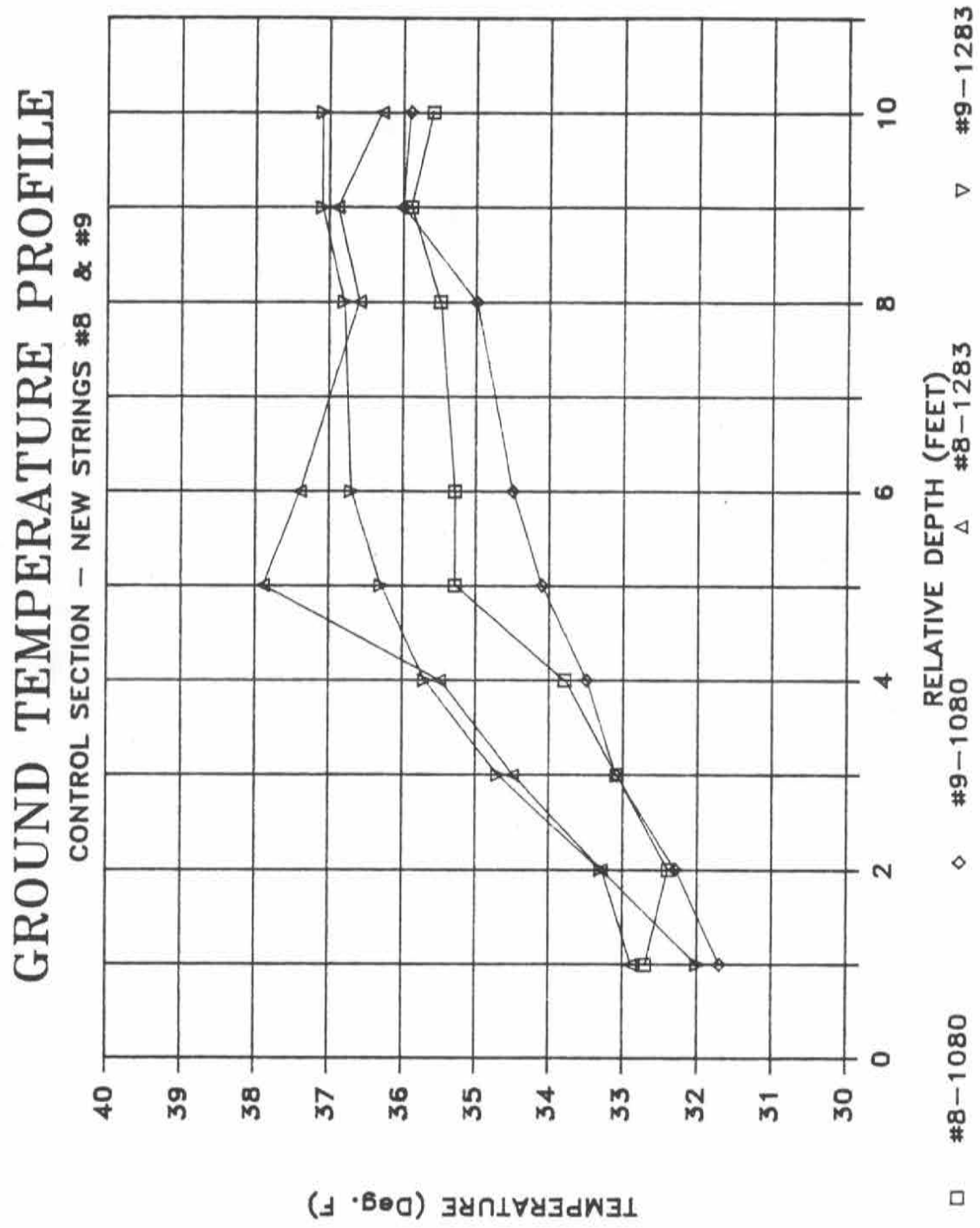
FIGURE A-2



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
CONTROL SECTION
STRINGS # 8 & 9

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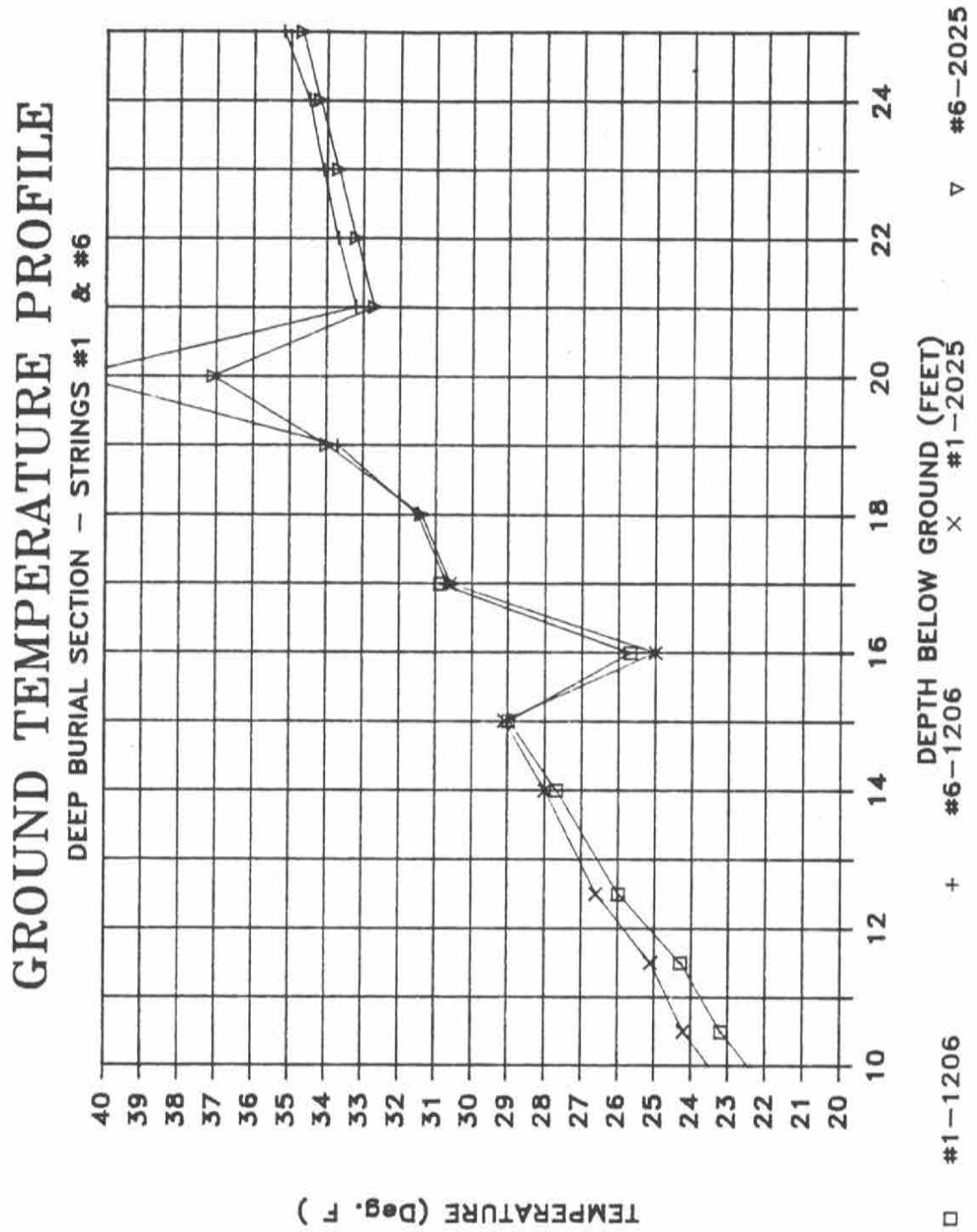
FIGURE A – 3



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GROUND TEMPERATURE PROFILE
DEEP BURIAL SECTION
STRINGS # 1 & 6

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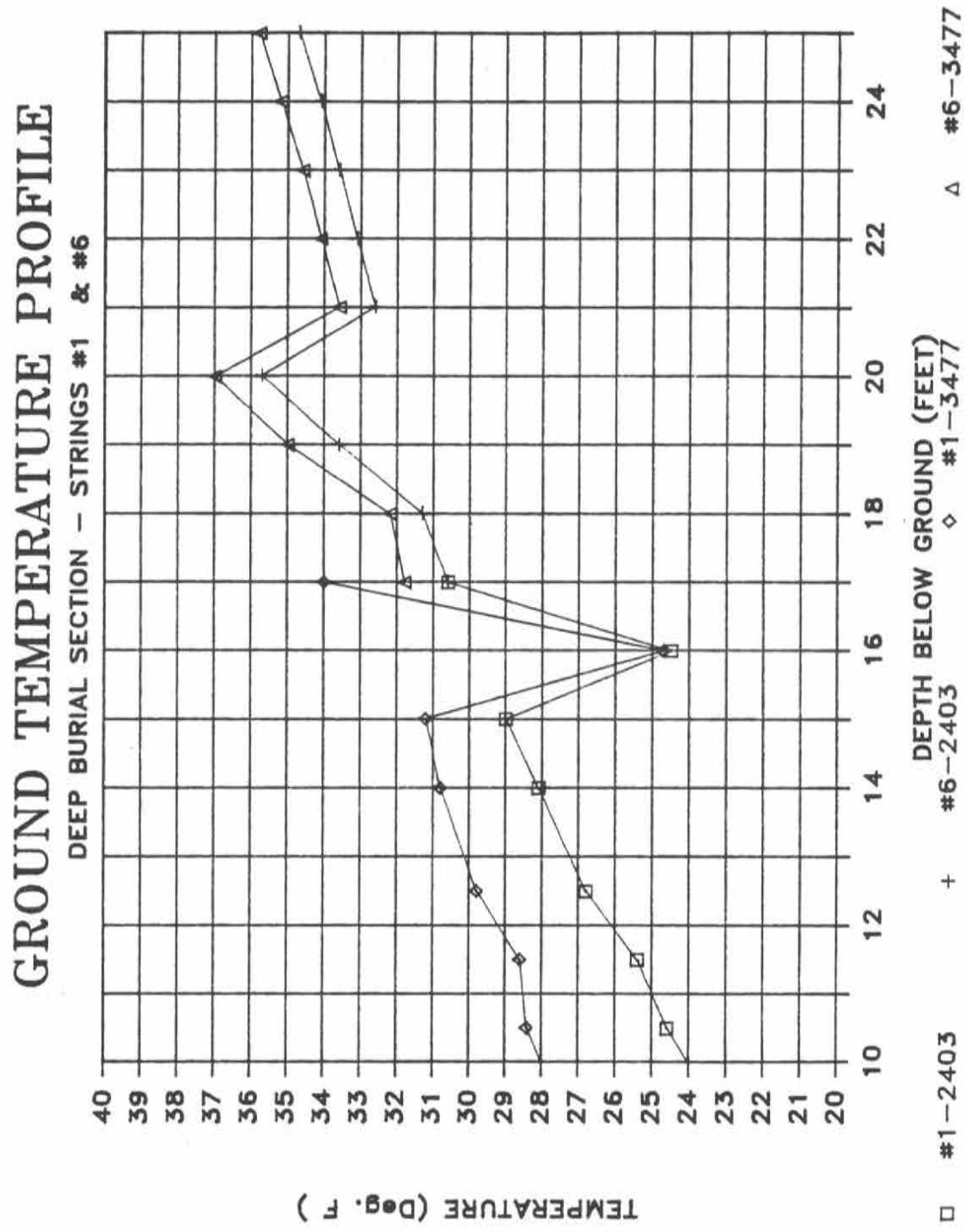
FIGURE A-4



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GROUND TEMPERATURE PROFILE
DEEP BURIAL SECTION
STRINGS # 1 & 6

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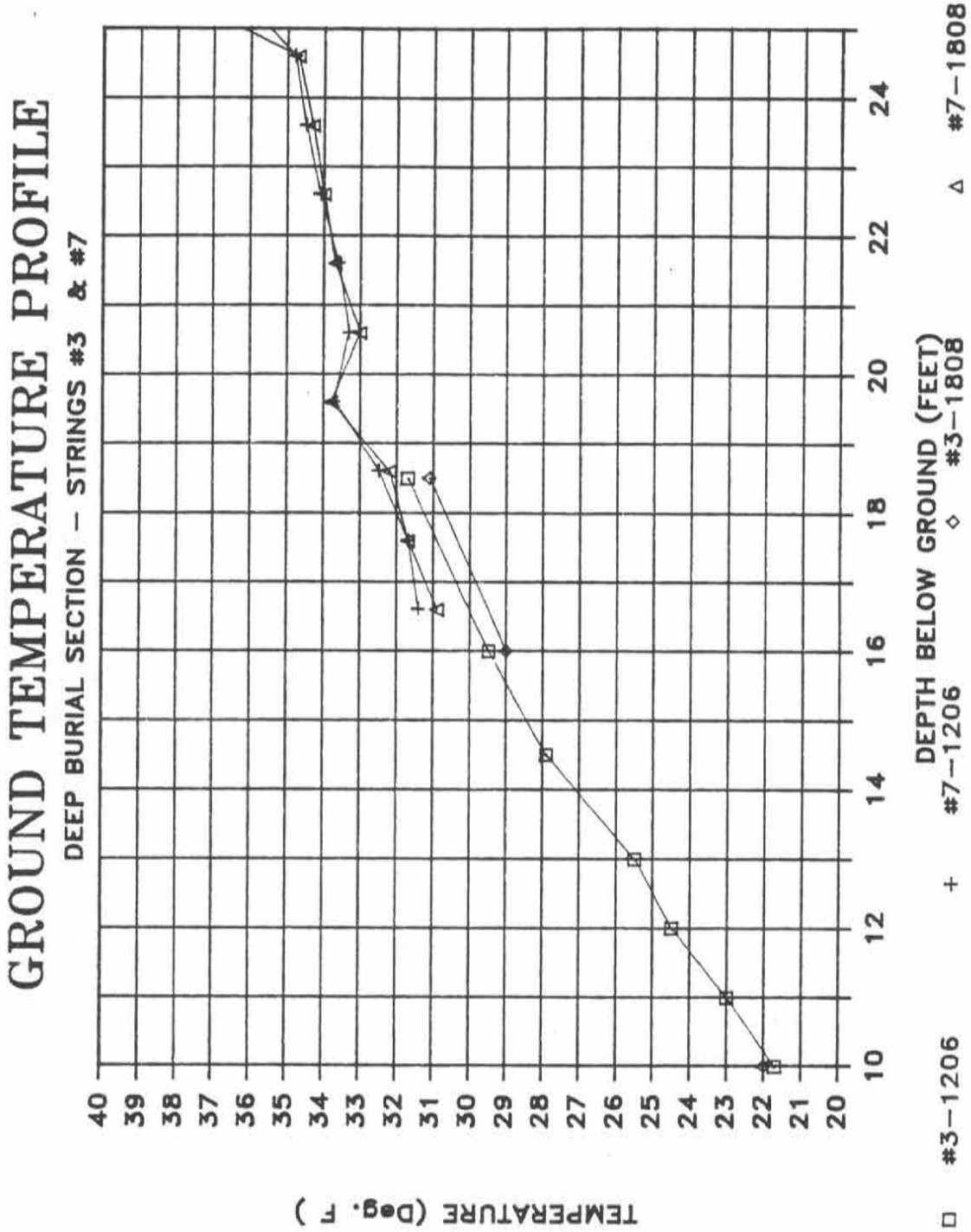
FIGURE A – 5



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GROUND TEMPERATURE PROFILE
DEEP BURIAL SECTION
STRINGS # 3 & 7

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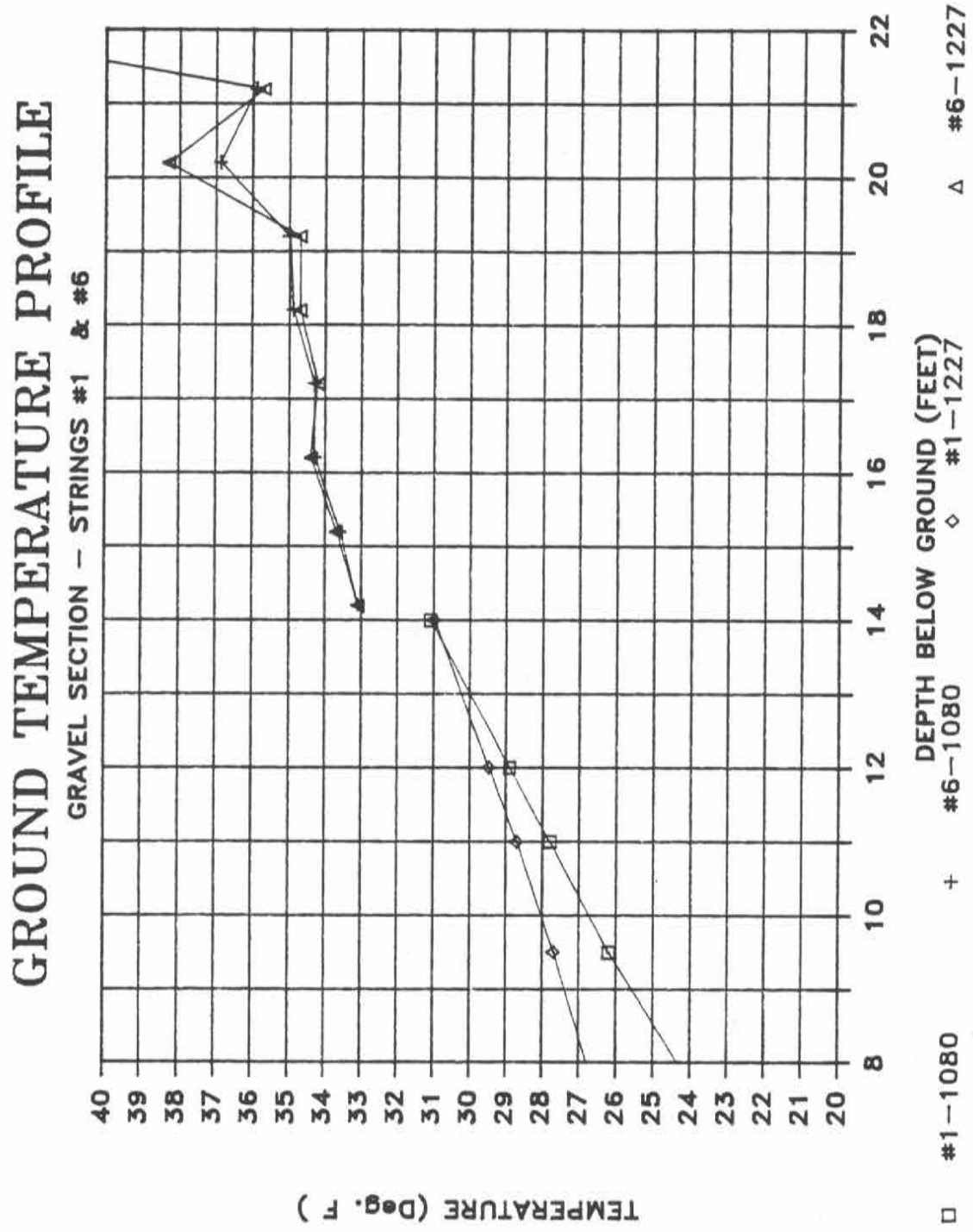
FIGURE A – 6



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
GRAVEL SECTION
STRINGS # 1 & 6

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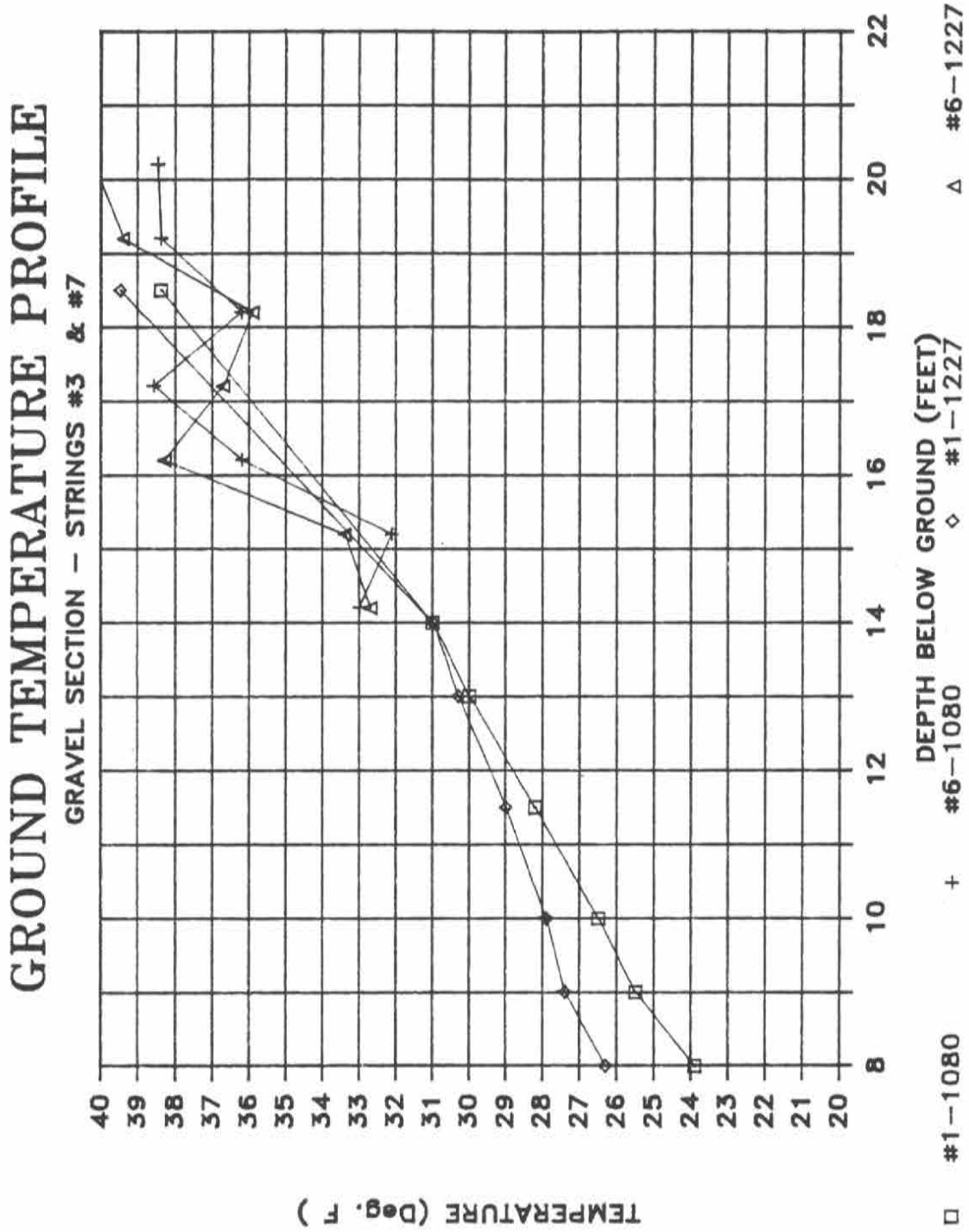
FIGURE A – 7



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
GRAVEL SECTION
STRINGS # 3 & 7

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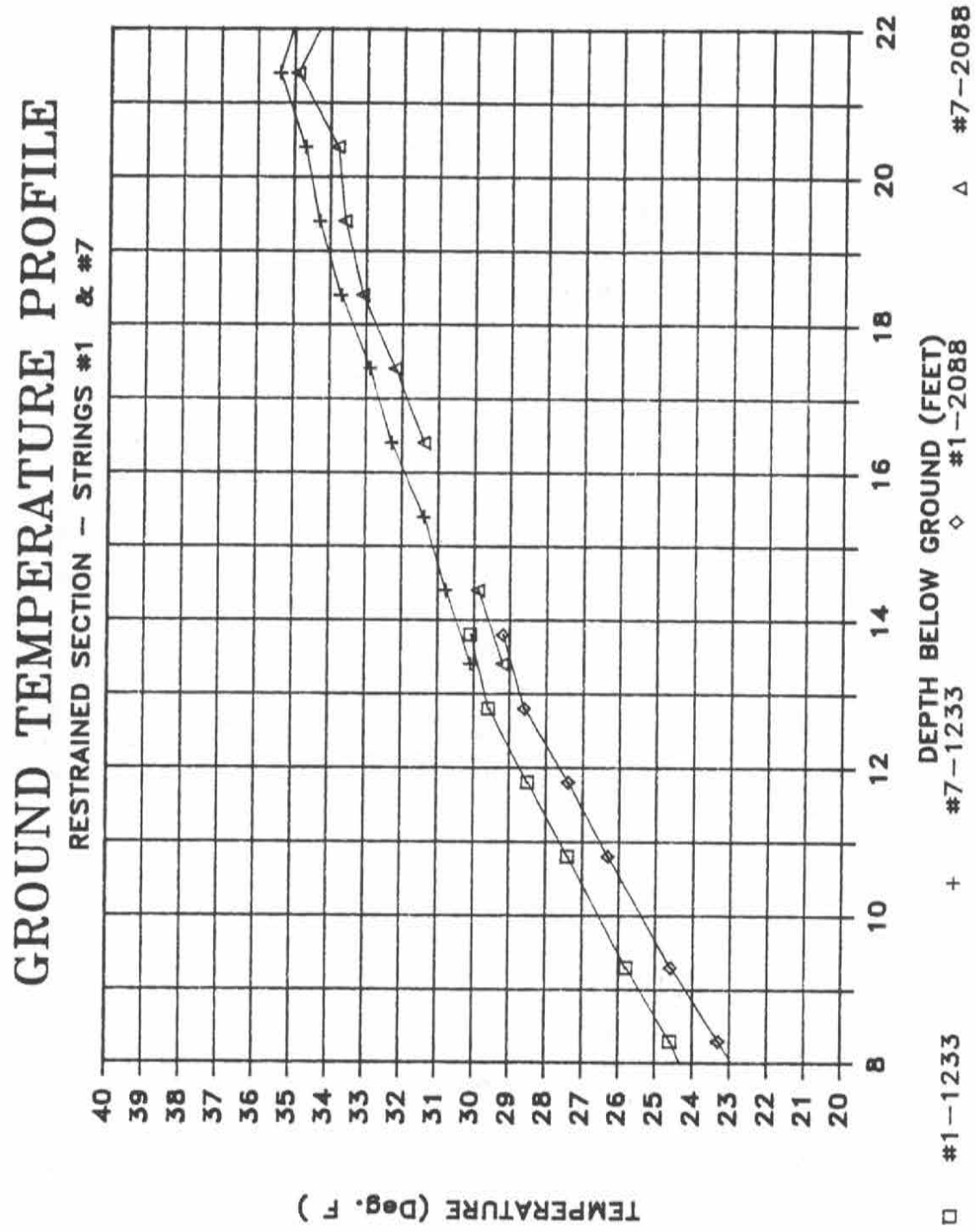
FIGURE A – 8



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
RESTRAINED SECTION
STRINGS # 1 & 7

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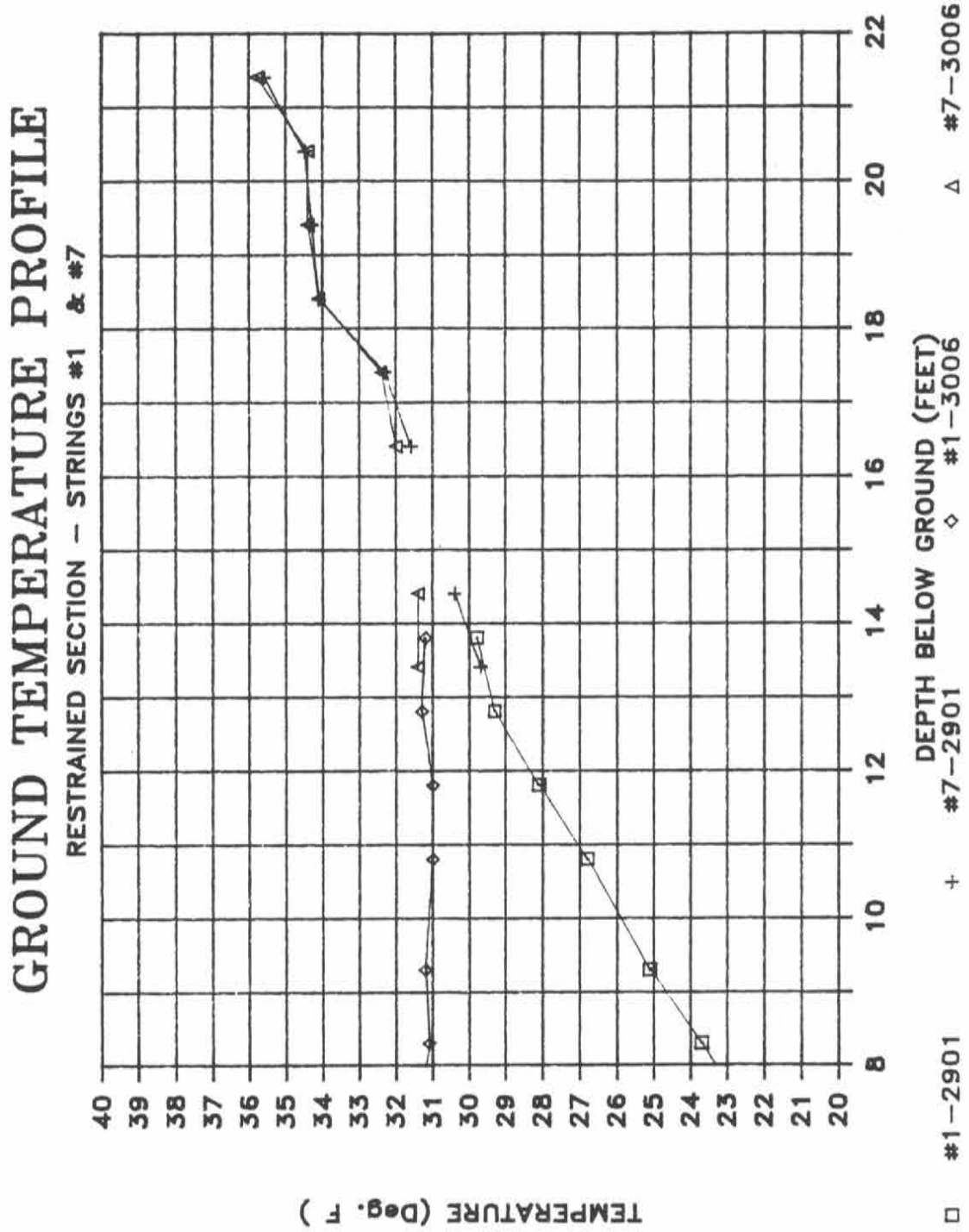
FIGURE A-9



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
RESTRAINED SECTION
STRINGS #1 & 7

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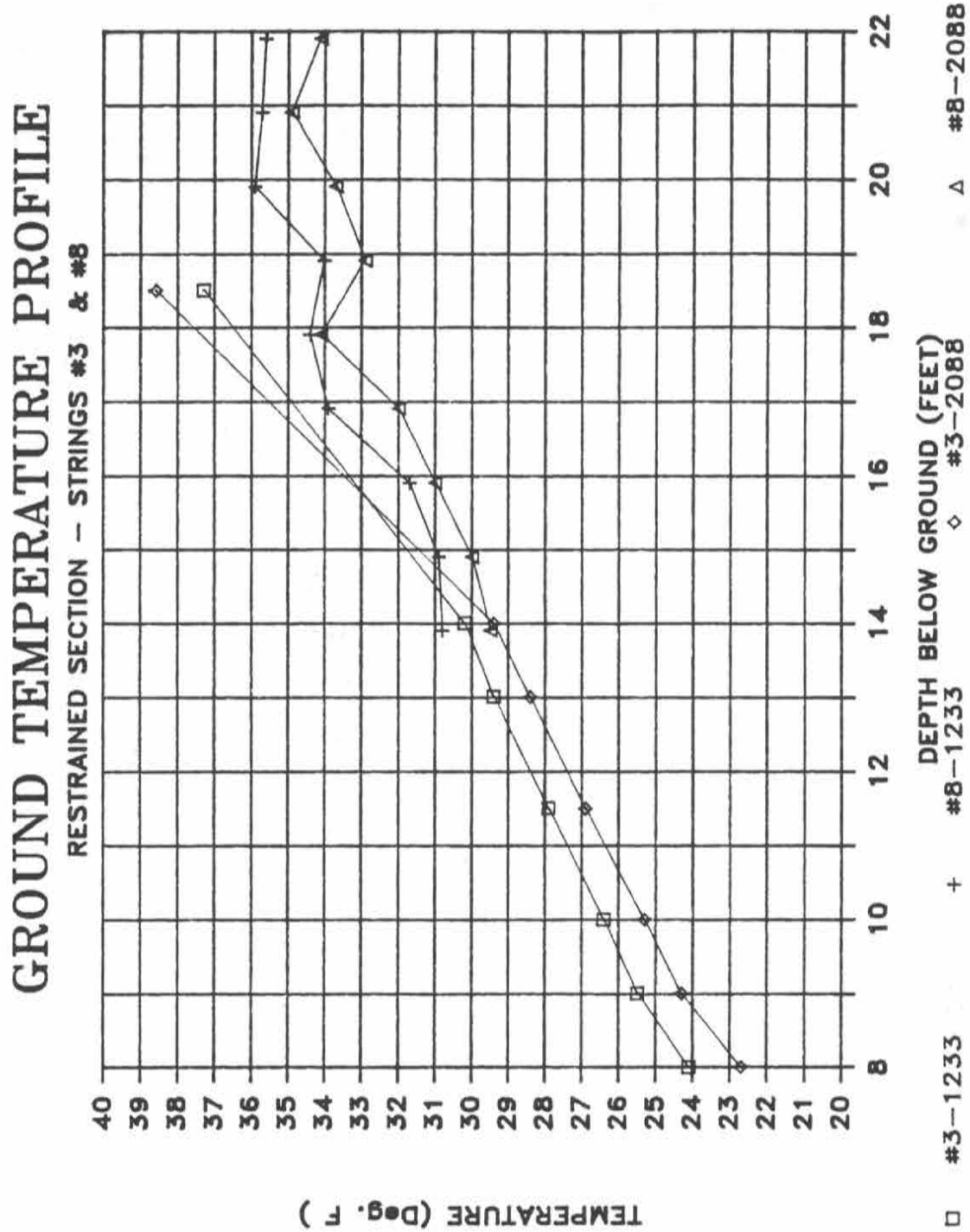
FIGURE A – 10



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
RESTRAINED SECTION
STRINGS # 3 & 8

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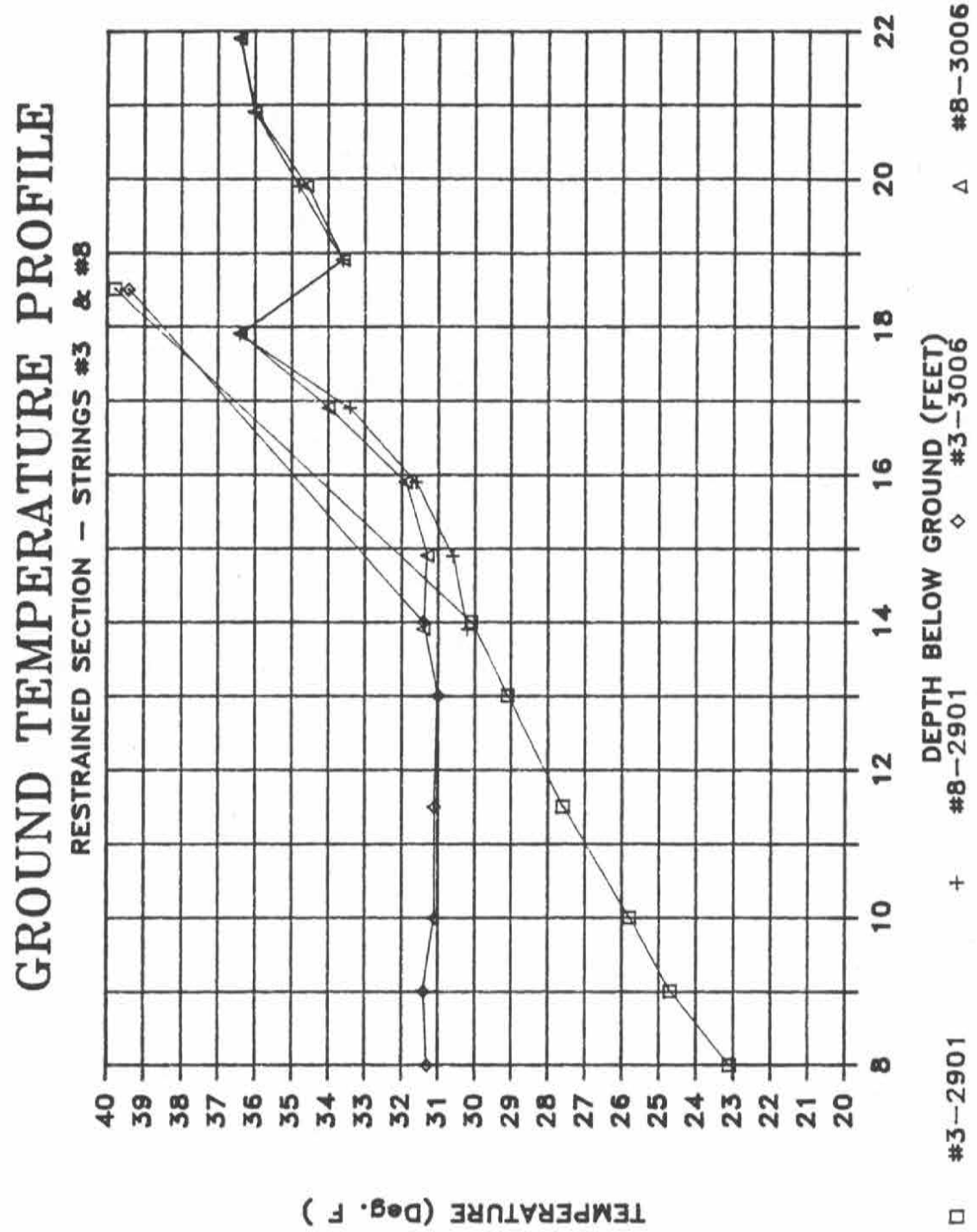
FIGURE A-11



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CALGARY FROST HEAVE TEST FACILITY
GROUND TEMPERATURE PROFILE
RESTRAINED SECTION
STRINGS # 3 & 8

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FIGURE A-12

CONTROL SECTION	BEAD ELEVATION (INITIAL)							
	STRING #				(FEET)			
BEAD #	1	2	3	4	5	6	8	9
1.0	25.42	25.72	25.50	25.02	24.95	25.47	13.50	13.00
2.0	24.42	24.97	24.00	23.52	23.45	24.72	12.50	12.00
3.0	23.42	24.22	22.50	22.52	22.45	23.97	11.50	11.00
4.0	21.92	NA	21.50	21.52	21.45	23.22	10.50	10.00
5.0	20.92	NA	20.00	20.52	20.45	22.47	9.50	9.00
6.0	19.42	NA	19.00	19.52	19.45	21.72	8.50	8.00
7.0	18.42	NA	18.00	18.52	18.45	20.97	7.50	7.00
8.0	17.42	NA	17.00	17.52	17.45	20.22	6.50	6.00
9.0	16.42	NA	16.00	16.52	15.95	19.47	5.50	5.00
10.0	14.92	NA	14.50	15.02	14.45	17.97	4.50	4.00
11.0	13.92	NA	13.00	14.02	12.95	15.97	NA	NA
12.0	12.92	NA	12.00	NA	NA	NA	NA	NA
13.0	11.92	NA	7.50	NA	NA	NA	NA	NA

CONTROL SECTION	DEPTH BELOW GROUND LEVEL							
	STRING #				(FEET)			
BEAD #	1	2	3	4	5	6	8	9
1.0	0.58	0.28	0.50	0.98	1.05	0.53	12.50	13.00
2.0	1.58	1.03	2.00	2.48	2.55	1.28	13.50	14.00
3.0	2.58	1.78	3.50	3.48	3.55	2.03	14.50	15.00
4.0	4.08	NA	4.50	4.48	4.55	2.78	15.50	16.00
5.0	5.08	NA	6.00	5.48	5.55	3.53	16.50	17.00
6.0	6.58	NA	7.00	6.48	6.55	4.28	17.50	18.00
7.0	7.58	NA	8.00	7.48	7.55	5.03	18.50	19.00
8.0	8.58	NA	9.00	8.48	8.55	5.78	19.50	20.00
9.0	9.58	NA	10.00	9.48	10.05	6.53	20.50	21.00
10.0	11.08	NA	11.50	10.98	11.55	8.03	21.50	22.00
11.0	12.08	NA	13.00	11.98	13.05	10.03	NA	NA
12.0	13.08	NA	14.00	NA	NA	NA	NA	NA
13.0	14.08	NA	18.50	NA	NA	NA	NA	NA

NOMINAL GROUND SURFACE ELEVATION = 26 FEET
ELEVATION DATUM = 3600 FEET
PIPE HEAVE (3 DEC. 1976) = 2.0 FEET
INITIAL ELEVATION of PIPE BASE = 19.5 FEET

TEMPERATURE BEAD ELEVATIONS - CONTROL SECTION

TABLE B-1

DEEP BURIAL SECTION — BEAD ELEVATION (INITIAL)

BEAD #	STRING # 1	2	3	4	5	6	7	8
	(FEET)							
1.0	25.05	25.33	25.63	25.31	24.95	10.50	11.00	NA
2.0	23.55	23.83	24.13	23.81	23.45	9.50	10.00	NA
3.0	22.55	22.83	23.13	22.31	21.95	8.50	9.00	NA
4.0	21.55	22.08	21.63	20.81	20.45	7.50	8.00	NA
5.0	20.55	21.33	20.13	19.81	19.45	6.50	7.00	NA
6.0	19.05	NA	19.13	18.81	18.45	5.50	6.00	NA
7.0	18.05	NA	17.63	17.81	17.45	4.50	5.00	NA
8.0	16.55	NA	16.63	16.81	16.45	3.50	4.00	NA
9.0	15.55	NA	15.63	15.81	15.45	2.50	3.00	NA
10.0	14.55	NA	14.63	14.81	14.45	1.50	2.00	NA
11.0	13.55	NA	13.63	13.81	12.95	NA	NA	NA
12.0	12.05	NA	12.13	12.31	11.45	NA	NA	NA
13.0	11.05	NA	10.63	11.31	9.95	NA	NA	NA
14.0	10.05	NA	8.13	NA	NA	NA	NA	NA
15.0	9.05	NA	NA	NA	NA	NA	NA	NA

DEEP BURIAL SECTION — DEPTH BELOW GROUND LEVEL

BEAD #	STRING # 1	2	3	4	5	6	7	8
	(FEET)							
1.0	0.95	0.67	0.37	0.69	1.05	15.50	15.00	NA
2.0	2.45	2.17	1.87	2.19	2.55	16.50	16.00	NA
3.0	3.45	3.17	2.87	3.69	4.05	17.50	17.00	NA
4.0	4.45	3.92	4.37	5.19	5.55	18.50	18.00	NA
5.0	5.45	4.67	5.87	6.19	6.55	19.50	19.00	NA
6.0	6.95	NA	6.87	7.19	7.55	20.50	20.00	NA
7.0	7.95	NA	8.37	8.19	8.55	21.50	21.00	NA
8.0	9.45	NA	9.37	9.19	9.55	22.50	22.00	NA
9.0	10.45	NA	10.37	10.19	10.55	23.50	23.00	NA
10.0	11.45	NA	11.37	11.19	11.55	24.50	24.00	NA
11.0	12.45	NA	12.37	12.19	13.05	NA	NA	NA
12.0	13.95	NA	13.87	13.69	14.55	NA	NA	NA
13.0	14.95	NA	15.37	14.69	16.05	NA	NA	NA
14.0	15.95	NA	17.87	NA	NA	NA	NA	NA
15.0	16.95	NA	NA	NA	NA	NA	NA	NA

NOMINAL GROUND SURFACE ELEVATION = 26 FEET
ELEVATION DATUM = 3600 FEET
PIPE HEAVE (3 DEC. 1976) = 1.6 FEET
INITIAL ELEVATION of PIPE BASE = 16.5 FEET

TEMPERATURE BEAD ELEVATIONS - DEEP BURIAL SECTION

TABLE B-2

BEAD #	GRAVEL SECTION STRING # 1	2	3	4	5	6	7	8
	BEAD ELEVATION (INITIAL) (FEET)							
1.0	25.79	25.83	25.52	25.02	25.33	13.00	13.00	NA
2.0	24.79	25.08	24.02	23.52	23.83	12.00	12.00	NA
3.0	23.79	24.33	22.52	22.52	22.83	11.00	11.00	NA
4.0	22.29	NA	21.52	21.52	21.83	10.00	10.00	NA
5.0	21.29	NA	20.02	20.52	20.83	9.00	9.00	NA
6.0	19.79	NA	19.02	19.52	19.83	8.00	8.00	NA
7.0	18.79	NA	18.02	18.52	18.83	7.00	7.00	NA
8.0	17.79	NA	17.02	17.52	17.83	6.00	6.00	NA
9.0	16.79	NA	16.02	16.52	16.33	5.00	5.00	NA
10.0	15.29	NA	14.52	15.02	14.83	4.00	4.00	NA
11.0	14.29	NA	13.02	14.02	13.33	NA	NA	NA
12.0	13.29	NA	12.02	NA	NA	NA	NA	NA
13.0	12.29	NA	7.52	NA	NA	NA	NA	NA

BEAD #	GRAVEL SECTION STRING # 1	2	3	4	5	6	7	8
	DEPTH BELOW GROUND LEVEL (FEET)							
1.0	0.21	0.17	0.48	0.98	0.67	13.00	13.00	NA
2.0	1.21	0.92	1.98	2.48	2.17	14.00	14.00	NA
3.0	2.21	1.67	3.48	3.48	3.17	15.00	15.00	NA
4.0	3.71	NA	4.48	4.48	4.17	16.00	16.00	NA
5.0	4.71	NA	5.98	5.48	5.17	17.00	17.00	NA
6.0	6.21	NA	6.98	6.48	6.17	18.00	18.00	NA
7.0	7.21	NA	7.98	7.48	7.17	19.00	19.00	NA
8.0	8.21	NA	8.98	8.48	8.17	20.00	20.00	NA
9.0	9.21	NA	9.98	9.48	9.67	21.00	21.00	NA
10.0	10.71	NA	11.48	10.98	11.17	22.00	22.00	NA
11.0	11.71	NA	12.98	11.98	12.67	NA	NA	NA
12.0	12.71	NA	13.98	NA	NA	NA	NA	NA
13.0	13.71	NA	18.48	NA	NA	NA	NA	NA

NOMINAL GROUND SURFACE ELEVATION = 26 FEET
ELEVATION DATUM = 3600 FEET
PIPE HEAVE (3 DEC. 1976) = 1.2 FEET
INITIAL ELEVATION of PIPE BASE = 19.5 FEET

TEMPERATURE BEAD ELEVATIONS - GRAVEL SECTION

TABLE B-3

RESTRAINED SECTION	BEAD ELEVATION (INITIAL)							
	STRING #				(FEET)			
BEAD #	1	2	3	4	5	6	7	8
1.0	25.71	25.86	25.65	25.01	25.00	25.50	13.50	13.00
2.0	24.71	25.11	24.15	23.51	23.50	24.75	12.50	12.00
3.0	23.71	24.36	22.65	22.51	22.50	24.00	11.50	11.00
4.0	22.21	NA	21.65	21.51	21.50	23.25	10.50	10.00
5.0	21.21	NA	20.15	20.51	20.50	22.50	9.50	9.00
6.0	19.71	NA	19.15	19.51	19.50	21.75	8.50	8.00
7.0	18.71	NA	18.15	18.51	18.50	21.00	7.50	7.00
8.0	17.71	NA	17.15	17.51	17.50	20.25	6.50	6.00
9.0	16.71	NA	16.15	16.51	16.00	19.50	5.50	5.00
10.0	15.21	NA	14.65	15.01	14.50	18.00	4.50	4.00
11.0	14.21	NA	13.15	14.01	13.00	16.00	NA	NA
12.0	13.21	NA	12.15	NA	NA	NA	NA	NA
13.0	12.21	NA	7.65	NA	NA	NA	NA	NA

RESTRAINED SECTION	DEPTH BELOW GROUND LEVEL							
	STRING #				(FEET)			
BEAD #	1	2	3	4	5	6	7	8
1.0	0.29	0.14	0.35	0.99	1.00	0.50	12.50	13.00
2.0	1.29	0.89	1.85	2.49	2.50	1.25	13.50	14.00
3.0	2.29	1.64	3.35	3.49	3.50	2.00	14.50	15.00
4.0	3.79	NA	4.35	4.49	4.50	2.75	15.50	16.00
5.0	4.79	NA	5.85	5.49	5.50	3.50	16.50	17.00
6.0	6.29	NA	6.85	6.49	6.50	4.25	17.50	18.00
7.0	7.29	NA	7.85	7.49	7.50	5.00	18.50	19.00
8.0	8.29	NA	8.85	8.49	8.50	5.75	19.50	20.00
9.0	9.29	NA	9.85	9.49	10.00	6.50	20.50	21.00
10.0	10.79	NA	11.35	10.99	11.50	8.00	21.50	22.00
11.0	11.79	NA	12.85	11.99	13.00	10.00	NA	NA
12.0	12.79	NA	13.85	NA	NA	NA	NA	NA
13.0	13.79	NA	18.35	NA	NA	NA	NA	NA

NOMINAL GROUND SURFACE ELEVATION = 26 FEET
ELEVATION DATUM = 3600 FEET
PIPE HEAVE (3 DEC. 1976) = 0.9 FEET
INITIAL ELEVATION of PIPE BASE = 19.5 FEET

TEMPERATURE BEAD ELEVATIONS - RESTRAINED SECTION

TABLE B-4

INSULATED SILT SECTION

THERMISTOR STRING DEPTH AND CALLIBRATION

THERMISTOR #	DEPTH (FEET)	CALIBRATION FACTOR IS-1	IS-2	IS-3
1	2.0	-0.08	-0.06	-0.07
2	0.0	-0.10	-0.08	-0.08
3	-0.5	-0.07	-0.10	-0.11
4	-1.0	-0.05	-0.07	-0.09
5	-1.0	-0.07	-0.07	-0.09
6	-1.5	-0.09	-0.09	-0.08
7	-2.0	-0.08	-0.10	-0.10
8	-2.0	-0.08	-0.09	-0.08
9	-2.5	-0.05	-0.08	-0.10
10	-3.0	-0.06	-0.22	-0.08
11	-3.0	-0.11	-0.07	-0.07
12	-3.5	-0.09	-0.08	-0.09
13	-4.0	-0.16	-0.09	-0.08
14	-4.5	-0.08	-0.07	-0.09
15	-5.0	-0.06	-0.10	-0.10
16	-6.0	-0.06	-0.08	-0.11
17	-7.0	-0.09	-0.06	-0.10
18	-8.0	-0.07	-0.08	-0.08
19	-9.0	-0.07	-0.12	-0.04
20	-10.0	-0.08	-0.07	-0.08

DEPTH IS RELATIVE TO THE BOTTOM OF THE PIPE

THE CALLIBRATION FACTOR IS OBTAINED FROM AN ICE BATH CALIBRATION

THE CALIBRATION FACTOR (in K OHMS) IS TO BE ADDED TO THE MEASURED THERMISTOR RESISTANCE

TABLE B-5

INSULATED GRAVEL SECTION

THERMISTOR STRING DEPTH AND CALLIBRATION

THERMISTOR #	DEPTH (FEET)	CALIBRATION FACTOR IG-1
1	2.0	-0.189
2	0.0	-0.137
3	-0.5	-0.198
4	-1.0	-0.223
5	-1.0	-0.143
6	-1.5	-0.178
7	-2.0	-0.242
8	-2.5	-0.140
9	-3.0	-0.106
10	-3.0	-0.107
11	-3.5	-0.229
12	-4.0	-0.087
13	-4.5	-0.091
14	-5.0	-0.109
15	-5.0	-0.059
16	-5.5	-0.085
17	-6.0	-0.084
18	-6.5	-0.099
19	-7.0	-0.110
20	-7.5	-0.125
21	-8.0	-0.093
22	-9.0	-0.085
23	-10.0	-0.160

DEPTH IS RELATIVE TO THE BOTTOM OF THE PIPE

THE CALLIBRATION FACTOR IS OBTAINED FROM AN ICE BATH CALIBRATION

THE CALIBRATION FACTOR (in K OHMS) IS TO BE ADDED TO THE MEASURED THERMISTOR RESISTANCE

FIGURE B-6

CONTROL SECTION — GROUND PLATE ELEVATION (INITIAL)

HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)	HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)
CH-1	25.29	CH-14	23.89
CH-2	21.18	CH-15	21.85
CH-3	25.49	CH-16	25.36
CH-4	21.07	CH-17	19.76
CH-5	25.66	CH-18	16.81
CH-6	17.95	CH-19	13.94
CH-7	15.03	CH-20	19.62
CH-8	22.72	CH-21	25.54
CH-9	20.71	CH-22	15.57
CH-10	25.39	CH-23	25.30
CH-11	18.24	CH-24	20.08
CH-12	14.95	CH-25	25.45
CH-13	25.51		

DEEP BURIAL SECTION — GROUND PLATE ELEVATION (INITIAL)

HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)	HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)
DH-1	25.59	DH-16	21.93
DH-2	25.52	DH-17	19.89
DH-3	23.01	DH-18	25.43
DH-4	21.10	DH-19	18.05
DH-5	19.10	DH-20	15.08
DH-6	25.56	DH-21	23.98
DH-7	15.97	DH-22	12.03
DH-8	12.88	DH-23	22.96
DH-9	24.00	DH-24	21.12
DH-10	21.01	DH-25	25.44
DH-11	25.50	DH-26	17.46
DH-12	18.92	DH-27	13.56
DH-13	15.77	DH-28	25.45
DH-14	12.88	DH-29	25.66
DH-15	25.50		

NOMINAL GROUND SURFACE ELEVATION = 26 FEET
ELEVATION DATUM = 3600 FEET

GROUND PLATE ELEVATION - CONTROL & DEEP BURIAL SECTIONS

TABLE B-7

GRAVEL SECTION — GROUND PLATE ELEVATION (INITIAL)

HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)	HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)
GH-1	25.56	GH-13	26.01
GH-2	25.68	GH-14	21.95
GH-3	21.22	GH-15	19.96
GH-4	25.74	GH-16	25.46
GH-5	18.07	GH-17	16.80
GH-6	15.36	GH-18	13.84
GH-7	23.01	GH-19	19.51
GH-8	20.97	GH-20	25.53
GH-9	25.49	GH-21	15.47
GH-10	18.04	GH-22	25.53
GH-11	15.93	GH-23	25.51
GH-12	25.50		

RESTRAINED SECTION — GROUND PLATE ELEVATION (INITIAL)

HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)	HEAVE GAUGE #	ELEVATION HEAVE GAUGE (FEET)
RH-1	25.36	RH-13	25.45
RH-2	20.57	RH-14	23.96
RH-3	25.41	RH-15	21.80
RH-4	20.69	RH-16	25.38
RH-5	25.36	RH-17	19.85
RH-6	17.61	RH-18	16.77
RH-7	14.90	RH-29	13.83
RH-8	22.92	RH-20	19.38
RH-8A	21.90	RH-21	25.52
RH-9	20.80	RH-22	15.53
RH-10	25.41	RH-23	25.38
RH-11	17.88	RH-24	19.93
RH-12	14.95	RH-25	25.42

NOMINAL GROUND SURFACE ELEVATION = 26 FEET
ELEVATION DATUM = 3600 FEET

GROUND PLATE ELEVATION - GRAVEL & RESTRAINED SECTIONS

TABLE B-8

DAY NUMBER CALENDAR for ORIGINAL TEST SECTIONS

DAY ZERO IS 20 MAR 1974

1974		1	2	3	4	5	6	7	8	9	10	
MAR	00	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	0	0	0	0	0	0	
	20	1	2	3	4	5	6	7	8	9	10	11
APR	00	12	13	14	15	16	17	18	19	20	21	
	10	22	23	24	25	26	27	28	29	30	31	
	20	32	33	34	35	36	37	38	39	40	41	
MAY	00	42	43	44	45	46	47	48	49	50	51	
	10	52	53	54	55	56	57	58	59	60	61	
	20	62	63	64	65	66	67	68	69	70	71	72
JUN	00	73	74	75	76	77	78	79	80	81	82	
	10	83	84	85	86	87	88	89	90	91	92	
	20	93	94	95	96	97	98	99	100	101	102	
JUL	00	103	104	105	106	107	108	109	110	111	112	
	10	113	114	115	116	117	118	119	120	121	122	
	20	123	124	125	126	127	128	129	130	131	132	133
AUG	00	134	135	136	137	138	139	140	141	142	143	
	10	144	145	146	147	148	149	150	151	152	153	
	20	154	155	156	157	158	159	160	161	162	163	164
SEP	00	165	166	167	168	169	170	171	172	173	174	
	10	175	176	177	178	179	180	181	182	183	184	
	20	185	186	187	188	189	190	191	192	193	194	
OCT	00	195	196	197	198	199	200	201	202	203	204	
	10	205	206	207	208	209	210	211	212	213	214	
	20	215	216	217	218	219	220	221	222	223	224	225
NOV	00	226	227	228	229	230	231	232	233	234	235	
	10	236	237	238	239	240	241	242	243	244	245	
	20	246	247	248	249	250	251	252	253	254	255	
DEC	00	256	257	258	259	260	261	262	263	264	265	
	10	266	267	268	269	270	271	272	273	274	275	
	20	276	277	278	279	280	281	282	283	284	285	286

1975		1	2	3	4	5	6	7	8	9	10	
JAN	00	287	288	289	290	291	292	293	294	295	296	
	10	297	298	299	300	301	302	303	304	305	306	
	20	307	308	309	310	311	312	313	314	315	316	317
FEB	00	318	319	320	321	322	323	324	325	326	327	
	10	328	329	330	331	332	333	334	335	336	337	
	20	338	339	340	341	342	343	344	345			
MAR	00	346	347	348	349	350	351	352	353	354	355	
	10	356	357	358	359	360	361	362	363	364	365	
	20	366	367	368	369	370	371	372	373	374	375	376
APR	00	377	378	379	380	381	382	383	384	385	386	
	10	387	388	389	390	391	392	393	394	395	396	
	20	397	398	399	400	401	402	403	404	405	406	
MAY	00	407	408	409	410	411	412	413	414	415	416	
	10	417	418	419	420	421	422	423	424	425	426	
	20	427	428	429	430	431	432	433	434	435	436	437
JUN	00	438	439	440	441	442	443	444	445	446	447	
	10	448	449	450	451	452	453	454	455	456	457	
	20	458	459	460	461	462	463	464	465	466	467	
JUL	00	468	469	470	471	472	473	474	475	476	477	
	10	478	479	480	481	482	483	484	485	486	487	
	20	488	489	490	491	492	493	494	495	496	497	498
AUG	00	499	500	501	502	503	504	505	506	507	508	
	10	509	510	511	512	513	514	515	516	517	518	
	20	519	520	521	522	523	524	525	526	527	528	529
SEP	00	530	531	532	533	534	535	536	537	538	539	
	10	540	541	542	543	544	545	546	547	548	549	
	20	550	551	552	553	554	555	556	557	558	559	
OCT	00	560	561	562	563	564	565	566	567	568	569	
	10	570	571	572	573	574	575	576	577	578	579	
	20	580	581	582	583	584	585	586	587	588	589	590
NOV	00	591	592	593	594	595	596	597	598	599	600	
	10	601	602	603	604	605	606	607	608	609	610	
	20	611	612	613	614	615	616	617	618	619	620	
DEC	00	621	622	623	624	625	626	627	628	629	630	
	10	631	632	633	634	635	636	637	638	639	640	
	20	641	642	643	644	645	646	647	648	649	650	651

1976		1	2	3	4	5	6	7	8	9	10	
JAN	00	652	653	654	655	656	657	658	659	660	661	
	10	662	663	664	665	666	667	668	669	670	671	
	20	672	673	674	675	676	677	678	679	680	681	682
FEB	00	683	684	685	686	687	688	689	690	691	692	
	10	693	694	695	696	697	698	699	700	701	702	
	20	703	704	705	706	707	708	709	710	711		
MAR	00	712	713	714	715	716	717	718	719	720	721	
	10	722	723	724	725	726	727	728	729	730	731	
	20	732	733	734	735	736	737	738	739	740	741	742
APR	00	743	744	745	746	747	748	749	750	751	752	
	10	753	754	755	756	757	758	759	760	761	762	
	20	763	764	765	766	767	768	769	770	771	772	
MAY	00	773	774	775	776	777	778	779	780	781	782	
	10	783	784	785	786	787	788	789	790	791	792	
	20	793	794	795	796	797	798	799	800	801	802	803
JUN	00	804	805	806	807	808	809	810	811	812	813	
	10	814	815	816	817	818	819	820	821	822	823	
	20	824	825	826	827	828	829	830	831	832	833	
JUL	00	834	835	836	837	838	839	840	841	842	843	
	10	844	845	846	847	848	849	850	851	852	853	
	20	854	855	856	857	858	859	860	861	862	863	864
AUG	00	865	866	867	868	869	870	871	872	873	874	
	10	875	876	877	878	879	880	881	882	883	884	
	20	885	886	887	888	889	890	891	892	893	894	895
SEP	00	896	897	898	899	900	901	902	903	904	905	
	10	906	907	908	909	910	911	912	913	914	915	
	20	916	917	918	919	920	921	922	923	924	925	
OCT	00	926	927	928	929	930	931	932	933	934	935	
	10	936	937	938	939	940	941	942	943	944	945	
	20	946	947	948	949	950	951	952	953	954	955	956
NOV	00	957	958	959	960	961	962	963	964	965	966	
	10	967	968	969	970	971	972	973	974	975	976	
	20	977	978	979	980	981	982	983	984	985	986	
DEC	00	987	988	989	990	991	992	993	994	995	996	
	10	997	998	999	1000	1001	1002	1003	1004	1005	1006	
	20	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017

1977		1	2	3	4	5	6	7	8	9	10	
JAN	00	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	
	10	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	
	20	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048
FEB	00	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	
	10	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	
	20	1069	1070	1071	1072	1073	1074	1075	1076			
MAR	00	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	
	10	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	
	20	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107
APR	00	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	
	10	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	
	20	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	
MAY	00	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	
	10	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	
	20	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168
JUN	00	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	
	10	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	
	20	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	
JUL	00	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	
	10	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	
	20	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229
AUG	00	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	
	10	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	
	20	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260
SEP	00	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	
	10	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	
	20	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	
OCT	00	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	
	10	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	
	20	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321
NOV	00	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	
	10	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	
	20	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	
DEC	00	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	
	10	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	
	20	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382

1978		1	2	3	4	5	6	7	8	9	10	
JAN	00	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	
	10	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	
	20	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413
FEB	00	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	
	10	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	
	20	1434	1435	1436	1437	1438	1439	1440	1441			
MAR	00	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	
	10	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	
	20	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472
APR	00	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	
	10	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	
	20	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	
MAY	00	1503	1504	1505	1506	1507	1508	1509	1510	1511	1512	
	10	1513	1514	1515	1516	1517	1518	1519	1520	1521	1522	
	20	1523	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533
JUN	00	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	
	10	1544	1545	1546	1547	1548	1549	1550	1551	1552	1553	
	20	1554	1555	1556	1557	1558	1559	1560	1561	1562	1563	
JUL	00	1564	1565	1566	1567	1568	1569	1570	1571	1572	1573	
	10	1574	1575	1576	1577	1578	1579	1580	1581	1582	1583	
	20	1584	1585	1586	1587	1588	1589	1590	1591	1592	1593	1594
AUG	00	1595	1596	1597	1598	1599	1600	1601	1602	1603	1604	
	10	1605	1606	1607	1608	1609	1610	1611	1612	1613	1614	
	20	1615	1616	1617	1618	1619	1620	1621	1622	1623	1624	1625
SEP	00	1626	1627	1628	1629	1630	1631	1632	1633	1634	1635	
	10	1636	1637	1638	1639	1640	1641	1642	1643	1644	1645	
	20	1646	1647	1648	1649	1650	1651	1652	1653	1654	1655	
OCT	00	1656	1657	1658	1659	1660	1661	1662	1663	1664	1665	
	10	1666	1667	1668	1669	1670	1671	1672	1673	1674	1675	
	20	1676	1677	1678	1679	1680	1681	1682	1683	1684	1685	1686
NOV	00	1687	1688	1689	1690	1691	1692	1693	1694	1695	1696	
	10	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	
	20	1707	1708	1709	1710	1711	1712	1713	1714	1715	1716	
DEC	00	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	
	10	1727	1728	1729	1730	1731	1732	1733	1734	1735	1736	
	20	1737	1738	1739	1740	1741	1742	1743	1744	1745	1746	1747

1979		1	2	3	4	5	6	7	8	9	10	
JAN	00	1748	1749	1750	1751	1752	1753	1754	1755	1756	1757	
	10	1758	1759	1760	1761	1762	1763	1764	1765	1766	1767	
	20	1768	1769	1770	1771	1772	1773	1774	1775	1776	1777	1778
FEB	00	1779	1780	1781	1782	1783	1784	1785	1786	1787	1788	
	10	1789	1790	1791	1792	1793	1794	1795	1796	1797	1798	
	20	1799	1800	1801	1802	1803	1804	1805	1806			
MAR	00	1807	1808	1809	1810	1811	1812	1813	1814	1815	1816	
	10	1817	1818	1819	1820	1821	1822	1823	1824	1825	1826	
	20	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837
APR	00	1838	1839	1840	1841	1842	1843	1844	1845	1846	1847	
	10	1848	1849	1850	1851	1852	1853	1854	1855	1856	1857	
	20	1858	1859	1860	1861	1862	1863	1864	1865	1866	1867	
MAY	00	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	
	10	1878	1879	1880	1881	1882	1883	1884	1885	1886	1887	
	20	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898
JUN	00	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	
	10	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	
	20	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	
JUL	00	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	
	10	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	
	20	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
AUG	00	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	
	10	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	
	20	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
SEP	00	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
	10	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
	20	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
OCT	00	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
	10	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	
	20	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051
NOV	00	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	
	10	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	
	20	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	
DEC	00	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	
	10	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	
	20	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112

1981		1	2	3	4	5	6	7	8	9	10	
JAN	00	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	
	10	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	
	20	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509
FEB	00	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	
	10	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	
	20	2530	2531	2532	2533	2534	2535	2536	2537			
MAR	00	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	
	10	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	
	20	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568
APR	00	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	
	10	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	
	20	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	
MAY	00	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	
	10	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	
	20	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629
JUN	00	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	
	10	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	
	20	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	
JUL	00	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	
	10	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	
	20	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690
AUG	00	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	
	10	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	
	20	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721
SEP	00	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	
	10	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	
	20	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	
OCT	00	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	
	10	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	
	20	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782
NOV	00	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	
	10	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	
	20	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	
DEC	00	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	
	10	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	
	20	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843

1982		1	2	3	4	5	6	7	8	9	10	
JAN	00	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	
	10	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	
	20	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874
FEB	00	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	
	10	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	
	20	2895	2896	2897	2898	2899	2900	2901	2902			
MAR	00	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	
	10	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	
	20	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933
APR	00	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	
	10	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	
	20	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	
MAY	00	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	
	10	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	
	20	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994
JUN	00	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	
	10	3005	3006	3007	3008	3009	3010	3011	3012	3013	3014	
	20	3015	3016	3017	3018	3019	3020	3021	3022	3023	3024	
JUL	00	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	
	10	3035	3036	3037	3038	3039	3040	3041	3042	3043	3044	
	20	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055
AUG	00	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	
	10	3066	3067	3068	3069	3070	3071	3072	3073	3074	3075	
	20	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086
SEP	00	3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	
	10	3097	3098	3099	3100	3101	3102	3103	3104	3105	3106	
	20	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	
OCT	00	3117	3118	3119	3120	3121	3122	3123	3124	3125	3126	
	10	3127	3128	3129	3130	3131	3132	3133	3134	3135	3136	
	20	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147
NOV	00	3148	3149	3150	3151	3152	3153	3154	3155	3156	3157	
	10	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167	
	20	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	
DEC	00	3178	3179	3180	3181	3182	3183	3184	3185	3186	3187	
	10	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	
	20	3198	3199	3200	3201	3202	3203	3204	3205	3206	3207	3208

1983		1	2	3	4	5	6	7	8	9	10	
JAN	00	3209	3210	3211	3212	3213	3214	3215	3216	3217	3218	
	10	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	
	20	3229	3230	3231	3232	3233	3234	3235	3236	3237	3238	3239
FEB	00	3240	3241	3242	3243	3244	3245	3246	3247	3248	3249	
	10	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	
	20	3260	3261	3262	3263	3264	3265	3266	3267			
MAR	00	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	
	10	3278	3279	3280	3281	3282	3283	3284	3285	3286	3287	
	20	3288	3289	3290	3291	3292	3293	3294	3295	3296	3297	3298
APR	00	3299	3300	3301	3302	3303	3304	3305	3306	3307	3308	
	10	3309	3310	3311	3312	3313	3314	3315	3316	3317	3318	
	20	3319	3320	3321	3322	3323	3324	3325	3326	3327	3328	
MAY	00	3329	3330	3331	3332	3333	3334	3335	3336	3337	3338	
	10	3339	3340	3341	3342	3343	3344	3345	3346	3347	3348	
	20	3349	3350	3351	3352	3353	3354	3355	3356	3357	3358	3359
JUN	00	3360	3361	3362	3363	3364	3365	3366	3367	3368	3369	
	10	3370	3371	3372	3373	3374	3375	3376	3377	3378	3379	
	20	3380	3381	3382	3383	3384	3385	3386	3387	3388	3389	
JUL	00	3390	3391	3392	3393	3394	3395	3396	3397	3398	3399	
	10	3400	3401	3402	3403	3404	3405	3406	3407	3408	3409	
	20	3410	3411	3412	3413	3414	3415	3416	3417	3418	3419	3420
AUG	00	3421	3422	3423	3424	3425	3426	3427	3428	3429	3430	
	10	3431	3432	3433	3434	3435	3436	3437	3438	3439	3440	
	20	3441	3442	3443	3444	3445	3446	3447	3448	3449	3450	3451
SEP	00	3452	3453	3454	3455	3456	3457	3458	3459	3460	3461	
	10	3462	3463	3464	3465	3466	3467	3468	3469	3470	3471	
	20	3472	3473	3474	3475	3476	3477	3478	3479	3480	3481	
OCT	00	3482	3483	3484	3485	3486	3487	3488	3489	3490	3491	
	10	3492	3493	3494	3495	3496	3497	3498	3499	3500	3501	
	20	3502	3503	3504	3505	3506	3507	3508	3509	3510	3511	3512
NOV	00	3513	3514	3515	3516	3517	3518	3519	3520	3521	3522	
	10	3523	3524	3525	3526	3527	3528	3529	3530	3531	3532	
	20	3533	3534	3535	3536	3537	3538	3539	3540	3541	3542	
DEC	00	3543	3544	3545	3546	3547	3548	3549	3550	3551	3552	
	10	3553	3554	3555	3556	3557	3558	3559	3560	3561	3562	
	20	3563	3564	3565	3566	3567	3568	3569	3570	3571	3572	3573

1984		1	2	3	4	5	6	7	8	9	10	
JAN	00	3574	3575	3576	3577	3578	3579	3580	3581	3582	3583	
	10	3584	3585	3586	3587	3588	3589	3590	3591	3592	3593	
	20	3594	3595	3596	3597	3598	3599	3600	3601	3602	3603	3604
FEB	00	3605	3606	3607	3608	3609	3610	3611	3612	3613	3614	
	10	3615	3616	3617	3618	3619	3620	3621	3622	3623	3624	
	20	3625	3626	3627	3628	3629	3630	3631	3632	3633		
MAR	00	3634	3635	3636	3637	3638	3639	3640	3641	3642	3643	
	10	3644	3645	3646	3647	3648	3649	3650	3651	3652	3653	
	20	3654	3655	3656	3657	3658	3659	3660	3661	3662	3663	3664
APR	00	3665	3666	3667	3668	3669	3670	3671	3672	3673	3674	
	10	3675	3676	3677	3678	3679	3680	3681	3682	3683	3684	
	20	3685	3686	3687	3688	3689	3690	3691	3692	3693	3694	
MAY	00	3695	3696	3697	3698	3699	3700	3701	3702	3703	3704	
	10	3705	3706	3707	3708	3709	3710	3711	3712	3713	3714	
	20	3715	3716	3717	3718	3719	3720	3721	3722	3723	3724	3725
JUN	00	3726	3727	3728	3729	3730	3731	3732	3733	3734	3735	
	10	3736	3737	3738	3739	3740	3741	3742	3743	3744	3745	
	20	3746	3747	3748	3749	3750	3751	3752	3753	3754	3755	
JUL	00	3756	3757	3758	3759	3760	3761	3762	3763	3764	3765	
	10	3766	3767	3768	3769	3770	3771	3772	3773	3774	3775	
	20	3776	3777	3778	3779	3780	3781	3782	3783	3784	3785	3786
AUG	00	3787	3788	3789	3790	3791	3792	3793	3794	3795	3796	
	10	3797	3798	3799	3800	3801	3802	3803	3804	3805	3806	
	20	3807	3808	3809	3810	3811	3812	3813	3814	3815	3816	3817
SEP	00	3818	3819	3820	3821	3822	3823	3824	3825	3826	3827	
	10	3828	3829	3830	3831	3832	3833	3834	3835	3836	3837	
	20	3838	3839	3840	3841	3842	3843	3844	3845	3846	3847	
OCT	00	3848	3849	3850	3851	3852	3853	3854	3855	3856	3857	
	10	3858	3859	3860	3861	3862	3863	3864	3865	3866	3867	
	20	3868	3869	3870	3871	3872	3873	3874	3875	3876	3877	3878
NOV	00	3879	3880	3881	3882	3883	3884	3885	3886	3887	3888	
	10	3889	3890	3891	3892	3893	3894	3895	3896	3897	3898	
	20	3899	3900	3901	3902	3903	3904	3905	3906	3907	3908	
DEC	00	3909	3910	3911	3912	3913	3914	3915	3916	3917	3918	
	10	3919	3920	3921	3922	3923	3924	3925	3926	3927	3928	
	20	3929	3930	3931	3932	3933	3934	3935	3936	3937	3938	3939

1985		1	2	3	4	5	6	7	8	9	10	
JAN	00	3940	3941	3942	3943	3944	3945	3946	3947	3948	3949	
	10	3950	3951	3952	3953	3954	3955	3956	3957	3958	3959	
	20	3960	3961	3962	3963	3964	3965	3966	3967	3968	3969	3970
FEB	00	3971	3972	3973	3974	3975	3976	3977	3978	3979	3980	
	10	3981	3982	3983	3984	3985	3986	3987	3988	3989	3990	
	20	3991	3992	3993	3994	3995	3996	3997	3998			
MAR	00	3999	4000	4001	4002	4003	4004	4005	4006	4007	4008	
	10	4009	4010	4011	4012	4013	4014	4015	4016	4017	4018	
	20	4019	4020	4021	4022	4023	4024	4025	4026	4027	4028	4029
APR	00	4030	4031	4032	4033	4034	4035	4036	4037	4038	4039	
	10	4040	4041	4042	4043	4044	4045	4046	4047	4048	4049	
	20	4050	4051	4052	4053	4054	4055	4056	4057	4058	4059	
MAY	00	4060	4061	4062	4063	4064	4065	4066	4067	4068	4069	
	10	4070	4071	4072	4073	4074	4075	4076	4077	4078	4079	
	20	4080	4081	4082	4083	4084	4085	4086	4087	4088	4089	4090
JUN	00	4091	4092	4093	4094	4095	4096	4097	4098	4099	4100	
	10	4101	4102	4103	4104	4105	4106	4107	4108	4109	4110	
	20	4111	4112	4113	4114	4115	4116	4117	4118	4119	4120	
JUL	00	4121	4122	4123	4124	4125	4126	4127	4128	4129	4130	
	10	4131	4132	4133	4134	4135	4136	4137	4138	4139	4140	
	20	4141	4142	4143	4144	4145	4146	4147	4148	4149	4150	4151
AUG	00	4152	4153	4154	4155	4156	4157	4158	4159	4160	4161	
	10	4162	4163	4164	4165	4166	4167	4168	4169	4170	4171	
	20	4172	4173	4174	4175	4176	4177	4178	4179	4180	4181	4182
SEP	00	4183	4184	4185	4186	4187	4188	4189	4190	4191	4192	
	10	4193	4194	4195	4196	4197	4198	4199	4200	4201	4202	
	20	4203	4204	4205	4206	4207	4208	4209	4210	4211	4212	
OCT	00	4213	4214	4215	4216	4217	4218	4219	4220	4221	4222	
	10	4223	4224	4225	4226	4227	4228	4229	4230	4231	4232	
	20	4233	4234	4235	4236	4237	4238	4239	4240	4241	4242	4243
NOV	00	4244	4245	4246	4247	4248	4249	4250	4251	4252	4253	
	10	4254	4255	4256	4257	4258	4259	4260	4261	4262	4263	
	20	4264	4265	4266	4267	4268	4269	4270	4271	4272	4273	
DEC	00	4274	4275	4276	4277	4278	4279	4280	4281	4282	4283	
	10	4284	4285	4286	4287	4288	4289	4290	4291	4292	4293	
	20	4294	4295	4296	4297	4298	4299	4300	4301	4302	4303	4304

1986		1	2	3	4	5	6	7	8	9	10	
JAN	00	4305	4306	4307	4308	4309	4310	4311	4312	4313	4314	
	10	4315	4316	4317	4318	4319	4320	4321	4322	4323	4324	
	20	4325	4326	4327	4328	4329	4330	4331	4332	4333	4334	4335
FEB	00	4336	4337	4338	4339	4340	4341	4342	4343	4344	4345	
	10	4346	4347	4348	4349	4350	4351	4352	4353	4354	4355	
	20	4356	4357	4358	4359	4360	4361	4362	4363			
MAR	00	4364	4365	4366	4367	4368	4369	4370	4371	4372	4373	
	10	4374	4375	4376	4377	4378	4379	4380	4381	4382	4383	
	20	4384	4385	4386	4387	4388	4389	4390	4391	4392	4393	4394
APR	00	4395	4396	4397	4398	4399	4400	4401	4402	4403	4404	
	10	4405	4406	4407	4408	4409	4410	4411	4412	4413	4414	
	20	4415	4416	4417	4418	4419	4420	4421	4422	4423	4424	
MAY	00	4425	4426	4427	4428	4429	4430	4431	4432	4433	4434	
	10	4435	4436	4437	4438	4439	4440	4441	4442	4443	4444	
	20	4445	4446	4447	4448	4449	4450	4451	4452	4453	4454	4455
JUN	00	4456	4457	4458	4459	4460	4461	4462	4463	4464	4465	
	10	4466	4467	4468	4469	4470	4471	4472	4473	4474	4475	
	20	4476	4477	4478	4479	4480	4481	4482	4483	4484	4485	
JUL	00	4486	4487	4488	4489	4490	4491	4492	4493	4494	4495	
	10	4496	4497	4498	4499	4500	4501	4502	4503	4504	4505	
	20	4506	4507	4508	4509	4510	4511	4512	4513	4514	4515	4516
AUG	00	4517	4518	4519	4520	4521	4522	4523	4524	4525	4526	
	10	4527	4528	4529	4530	4531	4532	4533	4534	4535	4536	
	20	4537	4538	4539	4540	4541	4542	4543	4544	4545	4546	4547
SEP	00	4548	4549	4550	4551	4552	4553	4554	4555	4556	4557	
	10	4558	4559	4560	4561	4562	4563	4564	4565	4566	4567	
	20	4568	4569	4570	4571	4572	4573	4574	4575	4576	4577	
OCT	00	4578	4579	4580	4581	4582	4583	4584	4585	4586	4587	
	10	4588	4589	4590	4591	4592	4593	4594	4595	4596	4597	
	20	4598	4599	4600	4601	4602	4603	4604	4605	4606	4607	4608
NOV	00	4609	4610	4611	4612	4613	4614	4615	4616	4617	4618	
	10	4619	4620	4621	4622	4623	4624	4625	4626	4627	4628	
	20	4629	4630	4631	4632	4633	4634	4635	4636	4637	4638	
DEC	00	4639	4640	4641	4642	4643	4644	4645	4646	4647	4648	
	10	4649	4650	4651	4652	4653	4654	4655	4656	4657	4658	
	20	4659	4660	4661	4662	4663	4664	4665	4666	4667	4668	4669

1980		1	2	3	4	5	6	7	8	9	10	
JAN	00	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	
	10	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	
	20	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143
FEB	00	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	
	10	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	
	20	2164	2165	2166	2167	2168	2169	2170	2171	2172		
MAR	00	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	
	10	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	
	20	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203
APR	00	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	
	10	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	
	20	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	
MAY	00	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	
	10	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	
	20	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264
JUN	00	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	
	10	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	
	20	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	
JUL	00	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	
	10	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	
	20	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325
AUG	00	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	
	10	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	
	20	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356
SEP	00	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	
	10	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	
	20	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	
OCT	00	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	
	10	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	
	20	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417
NOV	00	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	
	10	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	
	20	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	
DEC	00	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	
	10	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	
	20	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478

DAY NUMBER CALENDAR for INSULATED TEST SECTIONS

DAY ZERO IS 17 FEB 1979

1979		1	2	3	4	5	6	7	8	9	10	
FEB	00	0	0	0	0	0	0	0	0	0	0	
	10	0	0	0	0	0	0	0	1	2	3	
	20	4	5	6	7	8	9	10	11			
MAR	00	12	13	14	15	16	17	18	19	20	21	
	10	22	23	24	25	26	27	28	29	30	31	
	20	32	33	34	35	36	37	38	39	40	41	42
APR	00	43	44	45	46	47	48	49	50	51	52	
	10	53	54	55	56	57	58	59	60	61	62	
	20	63	64	65	66	67	68	69	70	71	72	
MAY	00	73	74	75	76	77	78	79	80	81	82	
	10	83	84	85	86	87	88	89	90	91	92	
	20	93	94	95	96	97	98	99	100	101	102	103
JUN	00	104	105	106	107	108	109	110	111	112	113	
	10	114	115	116	117	118	119	120	121	122	123	
	20	124	125	126	127	128	129	130	131	132	133	
JUL	00	134	135	136	137	138	139	140	141	142	143	
	10	144	145	146	147	148	149	150	151	152	153	
	20	154	155	156	157	158	159	160	161	162	163	164
AUG	00	165	166	167	168	169	170	171	172	173	174	
	10	175	176	177	178	179	180	181	182	183	184	
	20	185	186	187	188	189	190	191	192	193	194	195
SEP	00	196	197	198	199	200	201	202	203	204	205	
	10	206	207	208	209	210	211	212	213	214	215	
	20	216	217	218	219	220	221	222	223	224	225	
OCT	00	226	227	228	229	230	231	232	233	234	235	
	10	236	237	238	239	240	241	242	243	244	245	
	20	246	247	248	249	250	251	252	253	254	255	256
NOV	00	257	258	259	260	261	262	263	264	265	266	
	10	267	268	269	270	271	272	273	274	275	276	
	20	277	278	279	280	281	282	283	284	285	286	
DEC	00	287	288	289	290	291	292	293	294	295	296	
	10	297	298	299	300	301	302	303	304	305	306	
	20	307	308	309	310	311	312	313	314	315	316	317

1980		1	2	3	4	5	6	7	8	9	10	
JAN	00	318	319	320	321	322	323	324	325	326	327	
	10	328	329	330	331	332	333	334	335	336	337	
	20	338	339	340	341	342	343	344	345	346	347	348
FEB	00	349	350	351	352	353	354	355	356	357	358	
	10	359	360	361	362	363	364	365	366	367	368	
	20	369	370	371	372	373	374	375	376	377		
MAR	00	378	379	380	381	382	383	384	385	386	387	
	10	388	389	390	391	392	393	394	395	396	397	
	20	398	399	400	401	402	403	404	405	406	407	408
APR	00	409	410	411	412	413	414	415	416	417	418	
	10	419	420	421	422	423	424	425	426	427	428	
	20	429	430	431	432	433	434	435	436	437	438	
MAY	00	439	440	441	442	443	444	445	446	447	448	
	10	449	450	451	452	453	454	455	456	457	458	
	20	459	460	461	462	463	464	465	466	467	468	469
JUN	00	470	471	472	473	474	475	476	477	478	479	
	10	480	481	482	483	484	485	486	487	488	489	
	20	490	491	492	493	494	495	496	497	498	499	
JUL	00	500	501	502	503	504	505	506	507	508	509	
	10	510	511	512	513	514	515	516	517	518	519	
	20	520	521	522	523	524	525	526	527	528	529	530
AUG	00	531	532	533	534	535	536	537	538	539	540	
	10	541	542	543	544	545	546	547	548	549	550	
	20	551	552	553	554	555	556	557	558	559	560	561
SEP	00	562	563	564	565	566	567	568	569	570	571	
	10	572	573	574	575	576	577	578	579	580	581	
	20	582	583	584	585	586	587	588	589	590	591	
OCT	00	592	593	594	595	596	597	598	599	600	601	
	10	602	603	604	605	606	607	608	609	610	611	
	20	612	613	614	615	616	617	618	619	620	621	622
NOV	00	623	624	625	626	627	628	629	630	631	632	
	10	633	634	635	636	637	638	639	640	641	642	
	20	643	644	645	646	647	648	649	650	651	652	
DEC	00	653	654	655	656	657	658	659	660	661	662	
	10	663	664	665	666	667	668	669	670	671	672	
	20	673	674	675	676	677	678	679	680	681	682	683

1981		1	2	3	4	5	6	7	8	9	10	
JAN	00	684	685	686	687	688	689	690	691	692	693	
	10	694	695	696	697	698	699	700	701	702	703	
	20	704	705	706	707	708	709	710	711	712	713	714
FEB	00	715	716	717	718	719	720	721	722	723	724	
	10	725	726	727	728	729	730	731	732	733	734	
	20	735	736	737	738	739	740	741	742			
MAR	00	743	744	745	746	747	748	749	750	751	752	
	10	753	754	755	756	757	758	759	760	761	762	
	20	763	764	765	766	767	768	769	770	771	772	773
APR	00	774	775	776	777	778	779	780	781	782	783	
	10	784	785	786	787	788	789	790	791	792	793	
	20	794	795	796	797	798	799	800	801	802	803	
MAY	00	804	805	806	807	808	809	810	811	812	813	
	10	814	815	816	817	818	819	820	821	822	823	
	20	824	825	826	827	828	829	830	831	832	833	834
JUN	00	835	836	837	838	839	840	841	842	843	844	
	10	845	846	847	848	849	850	851	852	853	854	
	20	855	856	857	858	859	860	861	862	863	864	
JUL	00	865	866	867	868	869	870	871	872	873	874	
	10	875	876	877	878	879	880	881	882	883	884	
	20	885	886	887	888	889	890	891	892	893	894	895
AUG	00	896	897	898	899	900	901	902	903	904	905	
	10	906	907	908	909	910	911	912	913	914	915	
	20	916	917	918	919	920	921	922	923	924	925	926
SEP	00	927	928	929	930	931	932	933	934	935	936	
	10	937	938	939	940	941	942	943	944	945	946	
	20	947	948	949	950	951	952	953	954	955	956	
OCT	00	957	958	959	960	961	962	963	964	965	966	
	10	967	968	969	970	971	972	973	974	975	976	
	20	977	978	979	980	981	982	983	984	985	986	987
NOV	00	988	989	990	991	992	993	994	995	996	997	
	10	998	999	1000	1001	1002	1003	1004	1005	1006	1007	
	20	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	
DEC	00	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	
	10	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	
	20	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048

1982		1	2	3	4	5	6	7	8	9	10	
JAN	00	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	
	10	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	
	20	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079
FEB	00	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	
	10	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	
	20	1100	1101	1102	1103	1104	1105	1106	1107			
MAR	00	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	
	10	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	
	20	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138
APR	00	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	
	10	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	
	20	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	
MAY	00	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	
	10	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	
	20	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199
JUN	00	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	
	10	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	
	20	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	
JUL	00	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	
	10	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	
	20	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260
AUG	00	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	
	10	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	
	20	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291
SEP	00	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	
	10	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	
	20	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	
OCT	00	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	
	10	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	
	20	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352
NOV	00	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	
	10	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	
	20	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	
DEC	00	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	
	10	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	
	20	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413

1983		1	2	3	4	5	6	7	8	9	10	
JAN	00	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	
	10	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	
	20	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444
FEB	00	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	
	10	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	
	20	1465	1466	1467	1468	1469	1470	1471	1472			
MAR	00	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	
	10	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	
	20	1493	1494	1495	1496	1497	1498	1499	1500	1501	1502	1503
APR	00	1504	1505	1506	1507	1508	1509	1510	1511	1512	1513	
	10	1514	1515	1516	1517	1518	1519	1520	1521	1522	1523	
	20	1524	1525	1526	1527	1528	1529	1530	1531	1532	1533	
MAY	00	1534	1535	1536	1537	1538	1539	1540	1541	1542	1543	
	10	1544	1545	1546	1547	1548	1549	1550	1551	1552	1553	
	20	1554	1555	1556	1557	1558	1559	1560	1561	1562	1563	1564
JUN	00	1565	1566	1567	1568	1569	1570	1571	1572	1573	1574	
	10	1575	1576	1577	1578	1579	1580	1581	1582	1583	1584	
	20	1585	1586	1587	1588	1589	1590	1591	1592	1593	1594	
JUL	00	1595	1596	1597	1598	1599	1600	1601	1602	1603	1604	
	10	1605	1606	1607	1608	1609	1610	1611	1612	1613	1614	
	20	1615	1616	1617	1618	1619	1620	1621	1622	1623	1624	1625
AUG	00	1626	1627	1628	1629	1630	1631	1632	1633	1634	1635	
	10	1636	1637	1638	1639	1640	1641	1642	1643	1644	1645	
	20	1646	1647	1648	1649	1650	1651	1652	1653	1654	1655	1656
SEP	00	1657	1658	1659	1660	1661	1662	1663	1664	1665	1666	
	10	1667	1668	1669	1670	1671	1672	1673	1674	1675	1676	
	20	1677	1678	1679	1680	1681	1682	1683	1684	1685	1686	
OCT	00	1687	1688	1689	1690	1691	1692	1693	1694	1695	1696	
	10	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	
	20	1707	1708	1709	1710	1711	1712	1713	1714	1715	1716	1717
NOV	00	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727	
	10	1728	1729	1730	1731	1732	1733	1734	1735	1736	1737	
	20	1738	1739	1740	1741	1742	1743	1744	1745	1746	1747	
DEC	00	1748	1749	1750	1751	1752	1753	1754	1755	1756	1757	
	10	1758	1759	1760	1761	1762	1763	1764	1765	1766	1767	
	20	1768	1769	1770	1771	1772	1773	1774	1775	1776	1777	1778

1984		1	2	3	4	5	6	7	8	9	10	
JAN	00	1779	1780	1781	1782	1783	1784	1785	1786	1787	1788	
	10	1789	1790	1791	1792	1793	1794	1795	1796	1797	1798	
	20	1799	1800	1801	1802	1803	1804	1805	1806	1807	1808	1809
FEB	00	1810	1811	1812	1813	1814	1815	1816	1817	1818	1819	
	10	1820	1821	1822	1823	1824	1825	1826	1827	1828	1829	
	20	1830	1831	1832	1833	1834	1835	1836	1837	1838		
MAR	00	1839	1840	1841	1842	1843	1844	1845	1846	1847	1848	
	10	1849	1850	1851	1852	1853	1854	1855	1856	1857	1858	
	20	1859	1860	1861	1862	1863	1864	1865	1866	1867	1868	1869
APR	00	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879	
	10	1880	1881	1882	1883	1884	1885	1886	1887	1888	1889	
	20	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	
MAY	00	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	
	10	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	
	20	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
JUN	00	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	
	10	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	
	20	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	
JUL	00	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	
	10	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	
	20	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
AUG	00	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	
	10	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
	20	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
SEP	00	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	
	10	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	
	20	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	
OCT	00	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	
	10	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	
	20	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083
NOV	00	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	
	10	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	
	20	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	
DEC	00	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	
	10	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	
	20	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144

1985		1	2	3	4	5	6	7	8	9	10	
JAN	00	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	
	10	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	
	20	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175
FEB	00	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	
	10	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	
	20	2196	2197	2198	2199	2200	2201	2202	2203			
MAR	00	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	
	10	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	
	20	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234
APR	00	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	
	10	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	
	20	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	
MAY	00	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	
	10	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	
	20	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295
JUN	00	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	
	10	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	
	20	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	
JUL	00	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	
	10	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	
	20	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356
AUG	00	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	
	10	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	
	20	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387
SEP	00	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	
	10	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	
	20	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	
OCT	00	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	
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NOV	00	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	
	10	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	
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DEC	00	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	
	10	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	
	20	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509

1986		1	2	3	4	5	6	7	8	9	10	
JAN	00	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	
	10	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	
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FEB	00	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	
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	20	2561	2562	2563	2564	2565	2566	2567	2568			
MAR	00	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	
	10	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	
	20	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599
APR	00	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	
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	20	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	
MAY	00	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	
	10	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	
	20	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660
JUN	00	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	
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	20	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	
JUL	00	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	
	10	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	
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AUG	00	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	
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	20	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752
SEP	00	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	
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	20	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	
OCT	00	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	
	10	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	
	20	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813
NOV	00	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	
	10	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	
	20	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	
DEC	00	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	
	10	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	
	20	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874