USE OF INSULATION TO ATTENUATE FROST HEAVING

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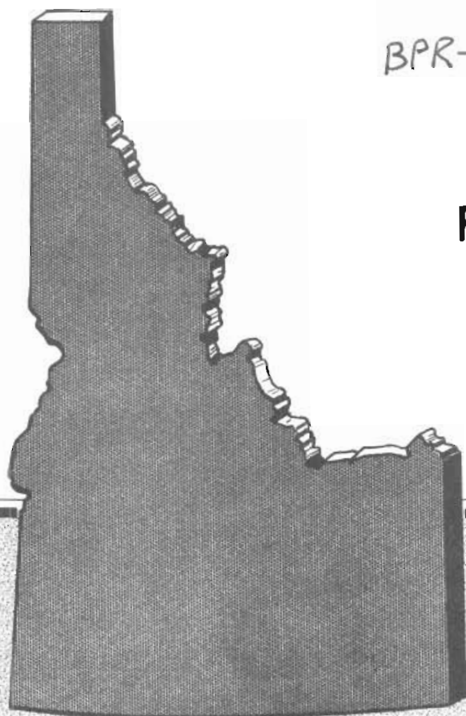

FEBRUARY 1969

RESEARCH PROJECT NO. 38

STATE OF IDAHO DEPARTMENT OF HIGHWAYS
in cooperation with
U.S. DEPARTMENT OF TRANSPORTATION BUREAU OF PUBLIC ROADS

USE OF INSULATION

TO

ATTENUATE FROST HEAVING

Research Report Number 38

by

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Associate Research Engineer

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IDAHO DEPARTMENT OF HIGHWAYS

Boise, Idaho

In cooperation with the U. S. Department of Transportation
Federal Highway Administration, Bureau of Public Roads.

ACKNOWLEDGMENTS

The help of many people was required to conduct this research project, including both engineering and maintenance personnel, who helped design and construct the test section and those who helped gather the test data.

Special mention must be made of the following E.I.T's, Gene Wortham, Jack Larsen and Clint Kingsford who helped in the project design, construction and installation of the frost tubes and thermisters. During the first year of study, Clint Kingsford was responsible for the collection of data. His records of the project construction and his resulting E.I.T. report were a source of information.

Fred Anderson, Engineering Technician from the Central Materials Lab, was responsible for the construction and installation of the frost tubes and assited in the thermister installation and other phases of the work.

Thomas Markland, District Six Geologist, was present and assisted in every phase of the field work for this project, including the soil sampling and the obtaining of the data at the beginning of the study period.

Steve Koegler, Drill Operator from the Central Materials Lab., operated the drill equipment for the installation of all the frost tubes.

Ted Gwin, District Materials Engineer, had overall responsibility for the project from the District level.

Lief Erickson, Materials and Research Engineer, was responsible for the project and gave assistance where needed from the State level.

Mr. Everett Kidner, District VI Maintenance Engineer, furnished the men and equipment from the maintenance force and supervised the construction of the test section. We wish to thank not only him but each of the operators of equipment and the flagmen who helped so much in making this project a success.

The Carl E. Nelson Construction Company deserves credit for the assistance rendered in laying the plantmix surfacing.

Our thanks is extended to the engineers of the Dow Chemical Corporation for their advice and technical assistance.

And finally, to those who helped by reviewing the manuscript, to Larry Hippler, who drew the charts and graphs and to Mrs. Nancy McConaughey, our Secretary, who did the typing and made so many revisions.

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INTRODUCTION

Frost heaving is a problem of major concern, not only to Idaho, but to all states and countries having extremely cold winters. Much effort and money has been expended by the Department in an effort to eliminate or to minimize frost heaving and its detrimental effects upon the pavement structure and riding surface.

It has been known for years that frost heaves are a result of ice segregation. In order for ice segregation to occur the following factors must be present:

1. A frost susceptible soil
2. Freezing temperatures
3. A source of water

In order to solve the problem of frost action in our highways, the effect of one or more of these three factors must be greatly reduced or eliminated entirely.

In 1965, the Department became interested in eliminating one of these factors by providing an insulating layer between the pavement structure and the frost susceptible subgrade soil.

Through correspondence with the B.P.R., the State of Maine and others who had a certain amount of experience along these lines, it was decided to use an insulating material called "Styrofoam HI", which is a product of the Dow Chemical Company. Styrofoam is a plastic foam insulation which is rigid in nature with adequate strength and a minimum of thermal conductivity and absorption. It is designed and manufactured especially to insulate highways against frost action.

The test site chosen was on I-15 and US-91 near Monida and is approximately 2 miles south of the Montana state line (Figure 1) at an elevation of 6,700 feet.

It was estimated that the degree-days* below 32° would be about 2,000. This section of highway has a high water table in two cut sections. A drainage system was built at the time of construction in an attempt to prevent water from entering the subgrade. This did not prevent serious heaving, however. During the spring of 1965 it was observed that "the most severe frost heave bumps had elevated the pavement from 3" to 6", causing a very rough, hazardous condition". It was hoped by this research project to compare the effect of an insulating blanket with the effect of drainage as a means of preventing frost heaving and to determine if this method can be used economically.

A proposal to conduct this investigation was submitted to the Bureau of Public Roads with a request for Federal participation in the financing. This was approved in October 1965.

*The degree-days for one day equals the difference between the average daily air temperature and 32°F.

CONCLUSIONS

In general the project was a success in obtaining the desired information. From the results of the investigation the following conclusions appear to be warranted:

1. For the climate at this project site 2" Styrofoam would be required to prevent excessive frost penetration of the subgrade.
2. The Styrofoam HI insulation was more effective in reducing or eliminating frost heaving than either the drainage system installed during construction, or the granular backfill used on adjacent frost heaving sections.
3. When considered on the basis of a linear foot of roadway, the cost of installation of Styrofoam on this project was considerably more than for the subdrain which was laid during the highway construction. It is common procedure in designing and constructing subdrains for the system to extend beyond the affected area or the area to be protected, whereas Styrofoam can be limited to the affected area. Had the drainage system been designed to remove the water from the subgrade sufficiently to eliminate frost heaving the cost per linear foot of roadway receiving protection would have increased considerably, more nearly equaling, if not exceeding, the cost of installing Styrofoam.

RECOMMENDATIONS

On the basis of the evidence gathered on this project it is recommended that:

1. In known areas of frost heaving Styrofoam or an equivalent highway insulation should be used to reduce or eliminate frost heaving. This may be done either by maintenance forces on existing roadways or by contract on new construction.
2. On construction projects on new alignment where conditions are such that frost heaving may be suspected, soils shall be tested for frost susceptibility. In those cases where the soils prove to be frost susceptible and a special design is necessary to prevent frost heaving, Styrofoam or other insulation should be considered. The Materials and Research Division should be consulted and comparative cost studies made.
3. Other products be investigated for their insulating value.

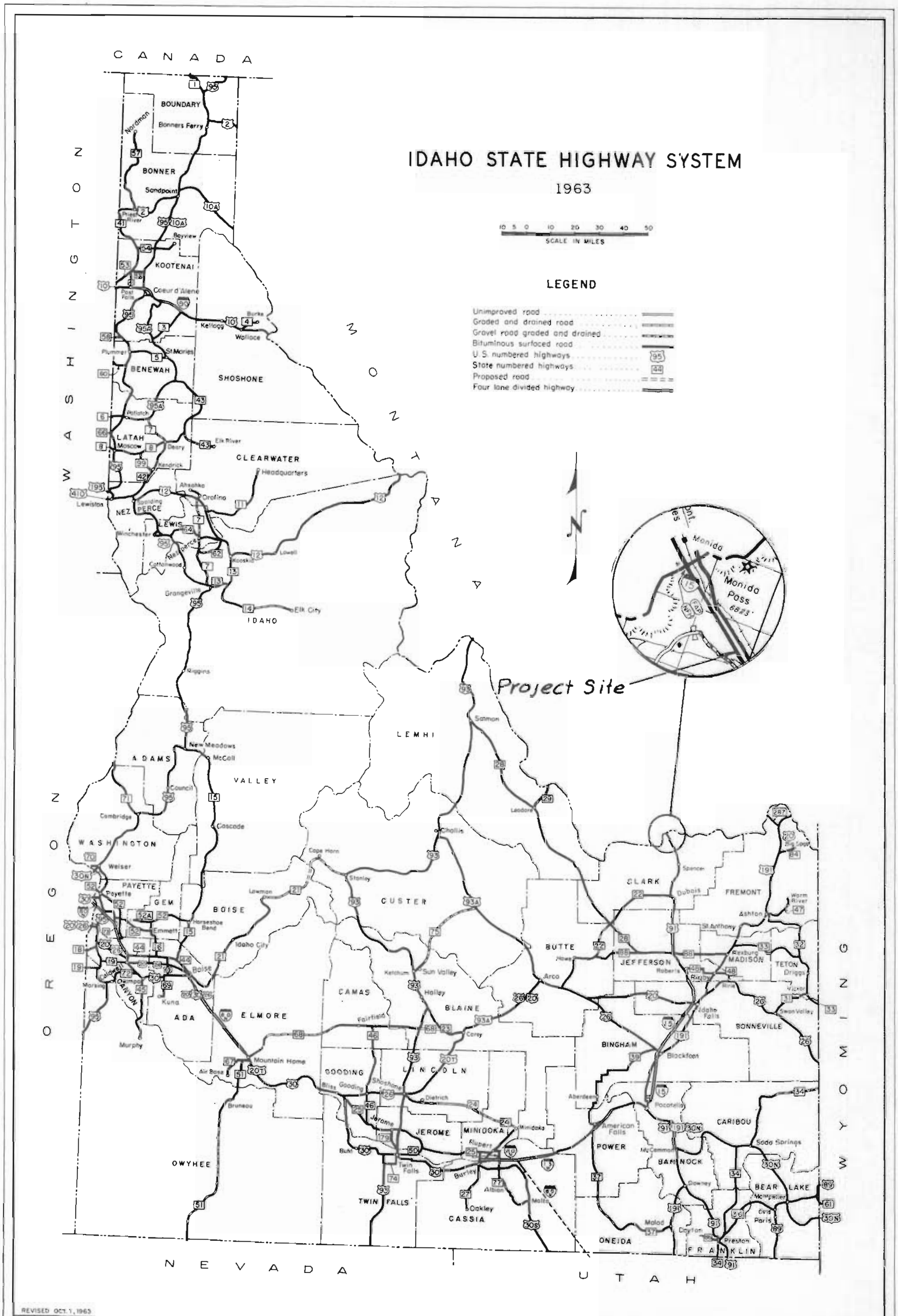


Figure 1 - Project Location

DESIGN AND CONSTRUCTION

After consultation and correspondence with engineers of the B.P.R. and the Dow Chemical Company, it was decided to use three different thicknesses of Styrofoam in the test: 1", 1½" and 2", placed in adjacent sections, 44 feet wide. The Styrofoam was placed at a depth of 1.5 ft. as shown in the typical section, Figure 2.

In order to help make this decision soil and moisture samples were obtained at various depths throughout the test section. The resulting tests showed these soils to be frost susceptible, as they had as high as 56% of grains smaller than 0.02 mm in diameter; the base had up to 7% smaller than 0.02 mm in diameter. According to Dr. A. Casagrande, and supported by the Corps of Engineers (1)*, "most inorganic soils containing 3% or more of grains finer than 0.02 mm in diameter by weight are frost susceptible for pavement design purposes". The Corps of Engineers(1) goes further to state that "Gravels, well graded sands and silty sands, especially those approaching the theoretical maximum density curve, which contain 1½ to 3 percent finer by weight than 0.02 mm size should be considered as possibly frost susceptible and should be subjected to a standard laboratory frost-susceptibility test to evaluate actual behavior during freezing".

In an exchange of correspondence, Mr. M. D. Oosterbaan, a Civil Engineer, with the Dow Chemical Company, calculated that for a freezing index of 2,000 degree days the temperature below the 2" Styrofoam would reach 30°F. with the insulation placed beneath 21" of surfacing and base. The temperature below the 1" Styrofoam would fall to 25°F. At 1,500 degree days the temperature below the 2" and 1" Styrofoam would be 35°F. and 30°F. respectively.

Thermisters were placed at various depths in each section to monitor the temperature variation due to the insulation. Thermisters were also placed in control sections outside the limits of the Styrofoam at each end of the test section to compare temperatures in a normal section with those in an insulated

* This number refers to the Bibliography.

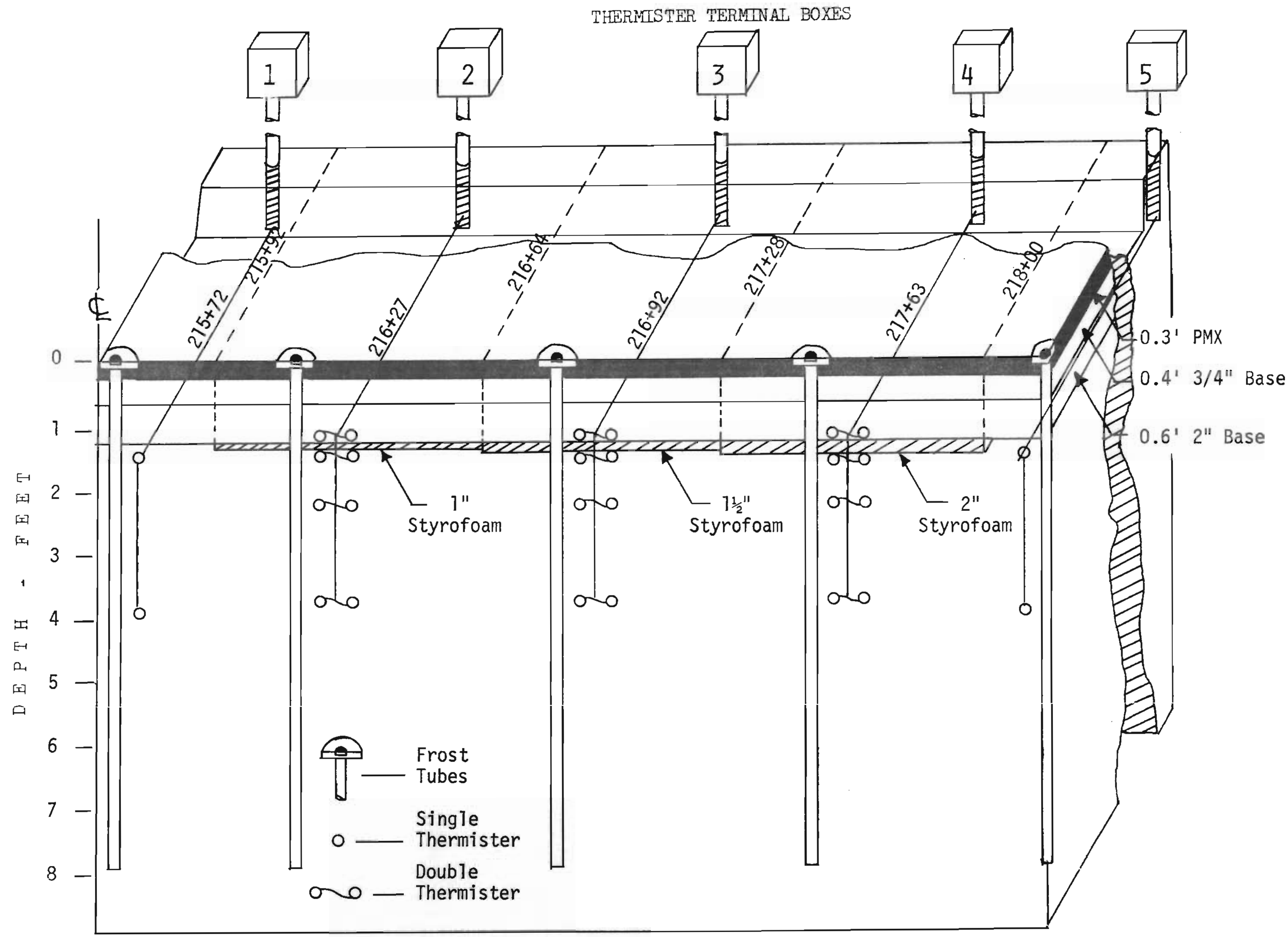


Figure 2 - Sectioned View of Test Section

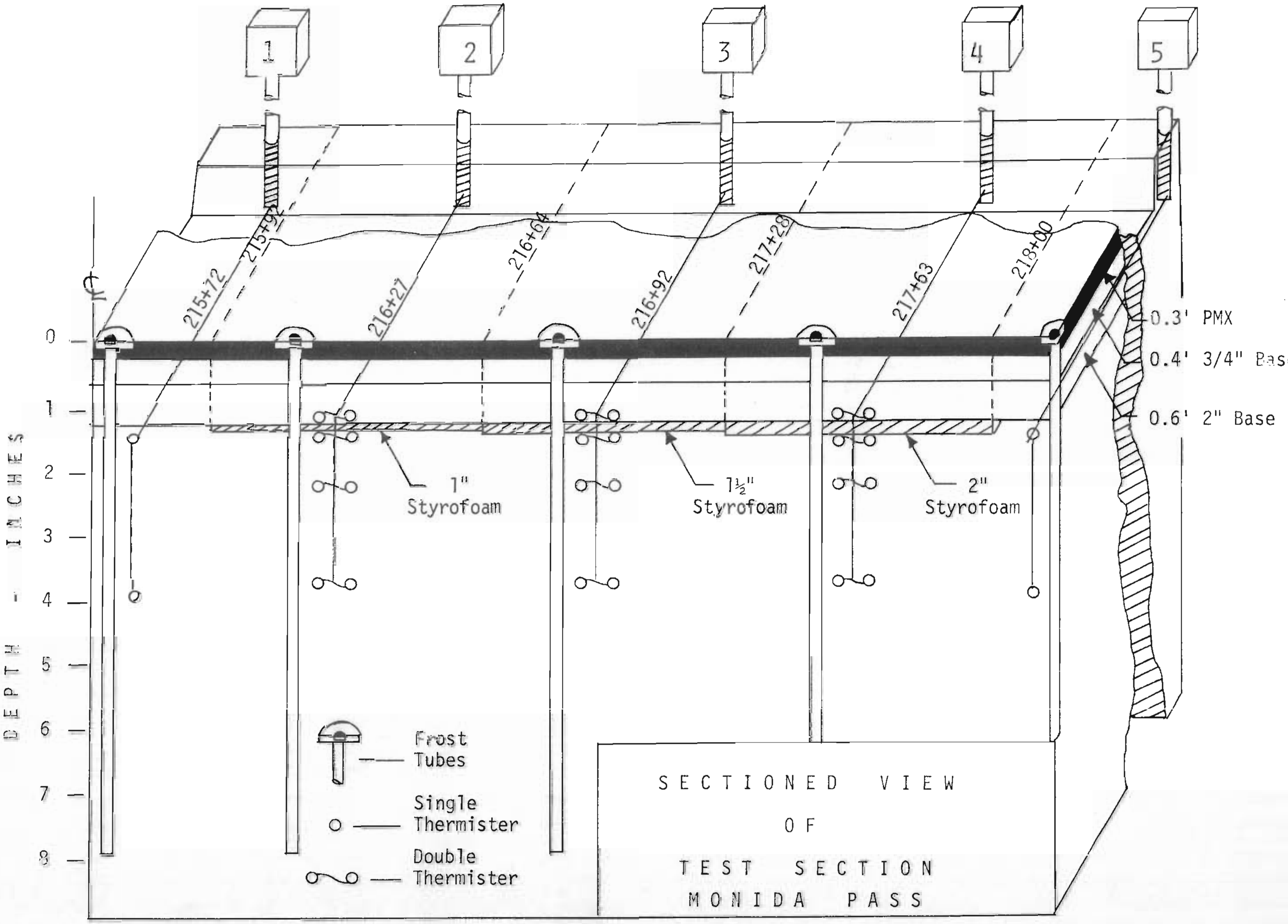


Figure 2 - Thermister Terminal Boxes

section. The thermisters in the insulated sections were placed in pairs as a check on each other and so that there would still be one operative in case one should cease to function. In each insulation section two thermisters were placed on top of the Styrofoam, two just below the Styrofoam, two were placed 1.0 foot below and two 2.5 feet below the Styrofoam. In each of the two control sections, outside the ends of the Styrofoam, 1 thermister was placed at 1.5 feet and 1 at 4.0 feet below the roadway surface. Figure 2 is a typical section showing the location of the Styrofoam and the thermisters.

To further check the value of the insulation in preventing frost penetration, frost tubes or frost depth indicators, were installed, one in each Styrofoam section and one in each control section. A frost tube design is shown in Appendix A. This is a modification of the frost tube designed and used by Sweden(3), and modified and used by Canada in their frost studies. The frost tubes are so designed and constructed that the fluid in the tube freezes and changes color at the frost line making it possible to measure the depth to which the frost has penetrated, and, during a thawing period, the depth of the thaw.

A maximum-minimum temperature thermometer was installed at the site in 1965, and read daily during the freeze-thaw periods. This made it possible to correlate air temperatures with those in the roadway and with the frost penetration.

A series of levels were run both for construction purposes and to help determine the effect of the insulation in preventing or attenuating frost heaving. A line of levels was run at centerline and at 12' right and left of centerline before construction, and in the fall and spring of both seasons, 1966-67 and 1967-68.

RESULTS

The investigation was to have lasted through one season, based on the freezing indices of previous years. During the 1966-67 season the freezing index was only 1610 the maximum accumulated degree-days was -1412 on March 31. It was felt that this was probably too mild a winter to adequately test the Styrofoam.

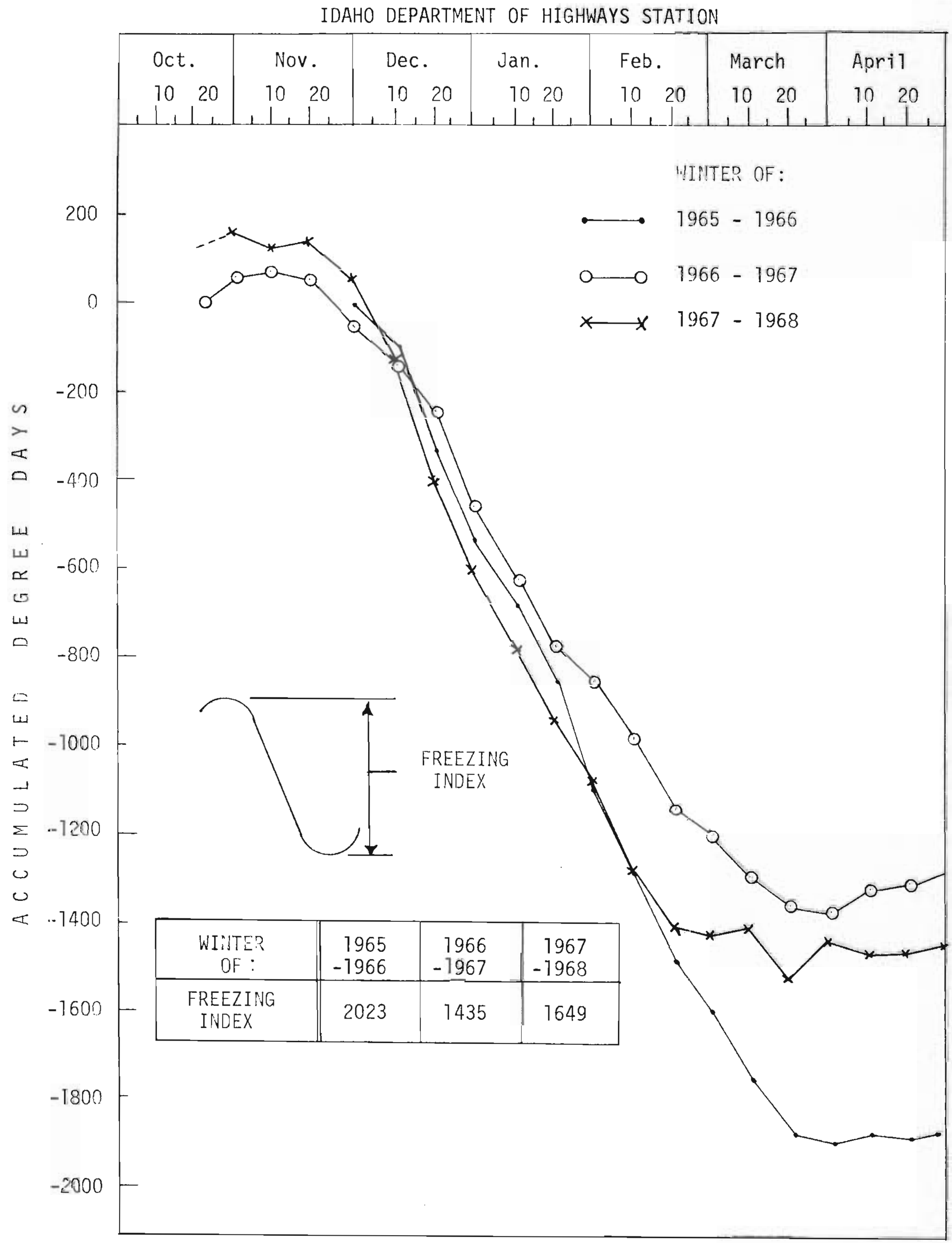


Figure 3 - Accumulated Degree Days With Time

The project was therefore extended through the 1967-68 season in the hope that this would be a cold season. By the end of December it seemed that our hopes were justified, but by the middle of January the weather had moderated and the year ended much like the 1966-67 season with a freezing index of 1630, and maximum accumulated degree-days of -1482 on April 23. These are both shown in Figure 3.

THERMISTERS

Figures 4 through 9 show the results of the thermister readings during the two test seasons. It is quite evident that the temperatures above the insulation are very sensitive to the ambient temperatures. The temperatures recorded by the thermisters above the insulation, and those directly beneath and at 2.5' below the insulation are plotted. These show the large temperature differences above and below the insulation.

The temperature differences between the thermisters below the insulation are very small, ie. the temperature at 4.0' below the surface is only a few degrees, at most, higher than that immediately below the Styrofoam, even in the coldest weather. Between November 22 and November 28, 1967, both thermisters above the 2" Styrofoam began to malfunction indicating a possible line failure. However, the temperatures above the Styrofoam in the other two sections are near enough the same to provide a comparison.

The graphs show that the temperatures below the Styrofoam follow the general pattern of those above without the large fluctuations, and the temperature of the thermister directly below the Styrofoam is more susceptible to fluctuation than the one at 2.5' below the Styrofoam.

During the 1966-67 season there were no freezing temperatures recorded below the 2" Styrofoam. Only two readings in late February reached the freezing temperature under the 1½" section of insulation. The 1" Styrofoam allowed the temperature to reach 30° F. the end of December 1966 and to get as low as 28° the end of February 1967. There were temperature fluctuations between, with

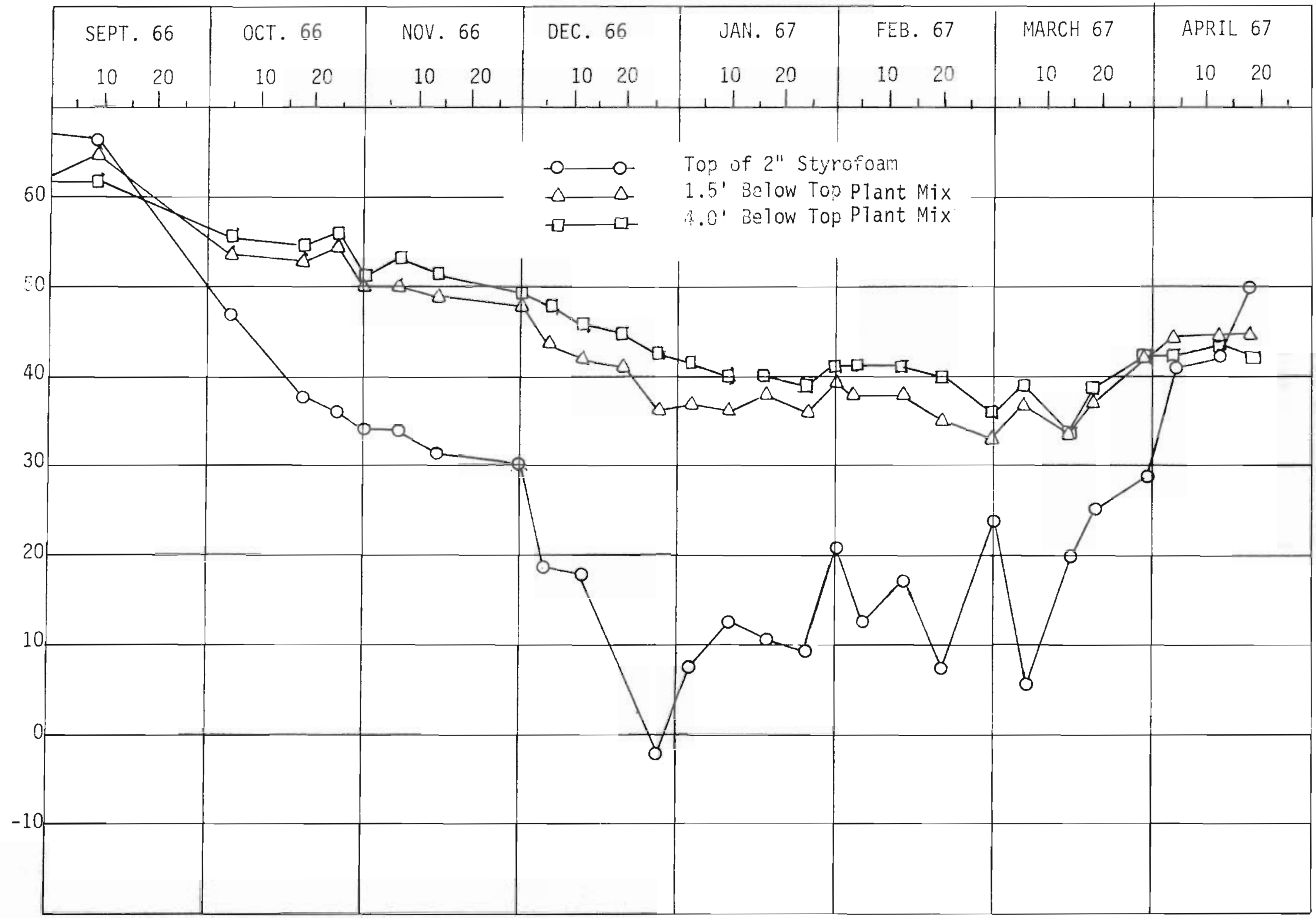


Figure 4 - Temperature Comparison Above and Below 2" Styrofoam

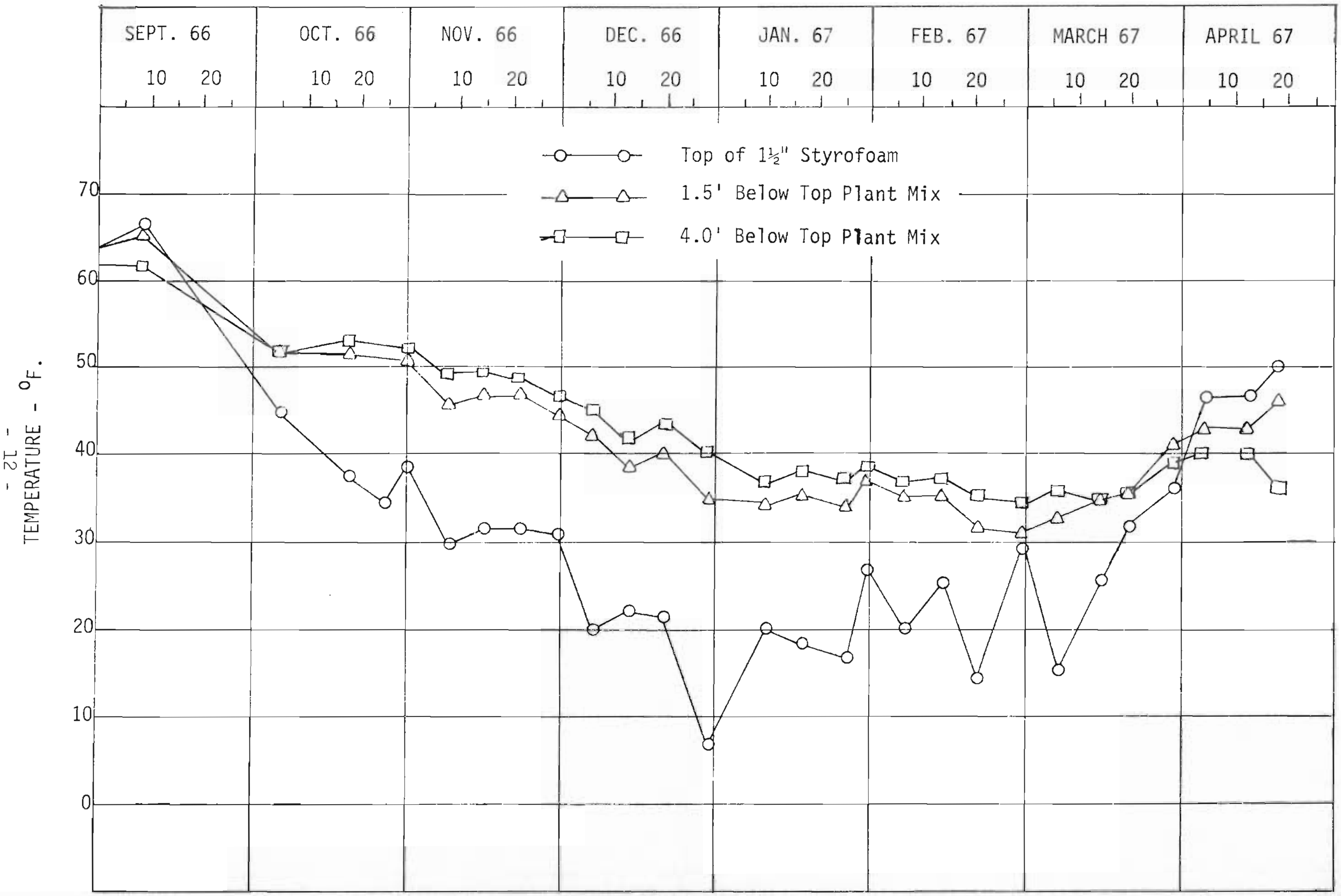


Figure 5 - Temperature Comparison Above and Below 1½" Styrofoam

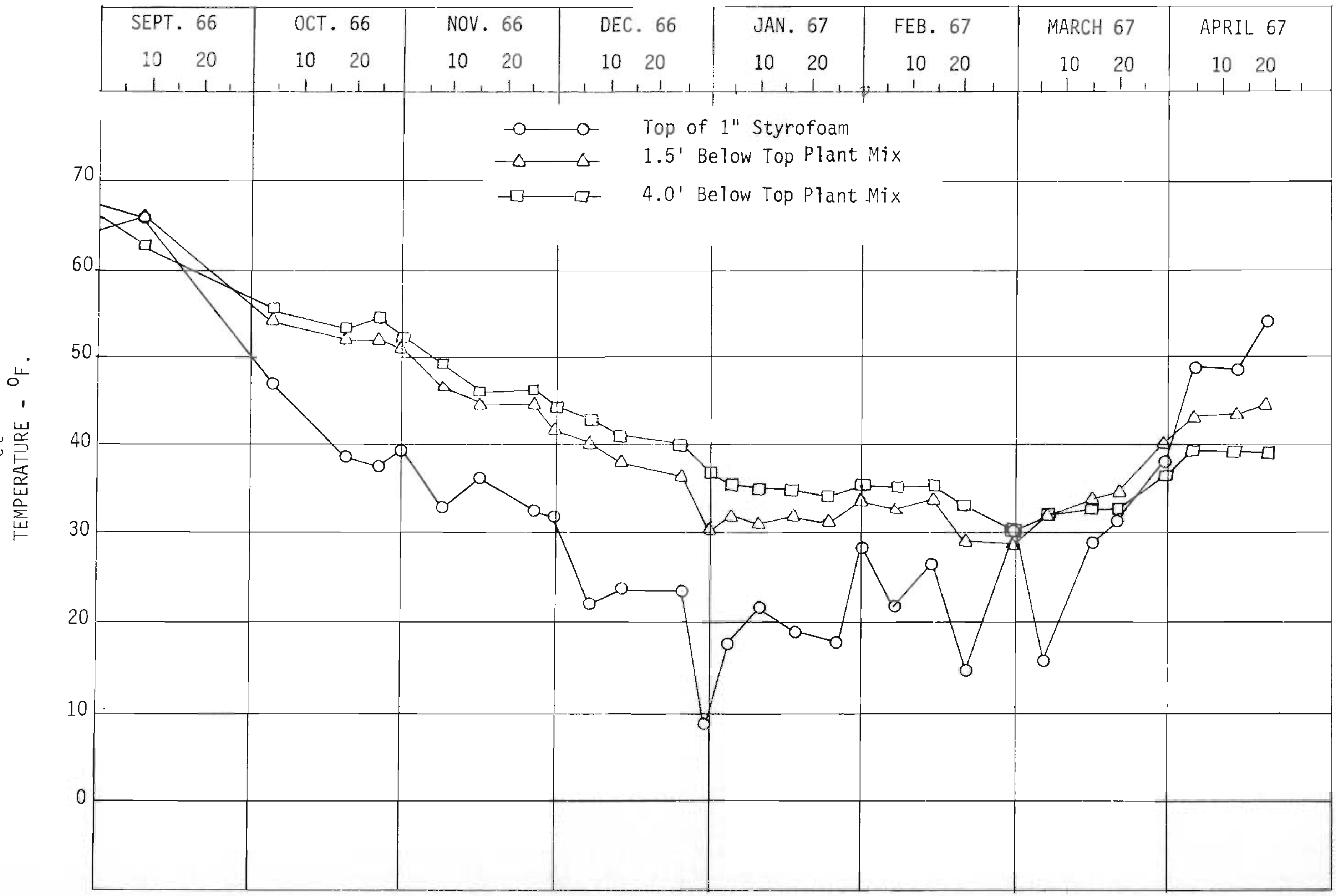


Figure 6 - Temperature Comparison Above and Below 1" Styrofoam

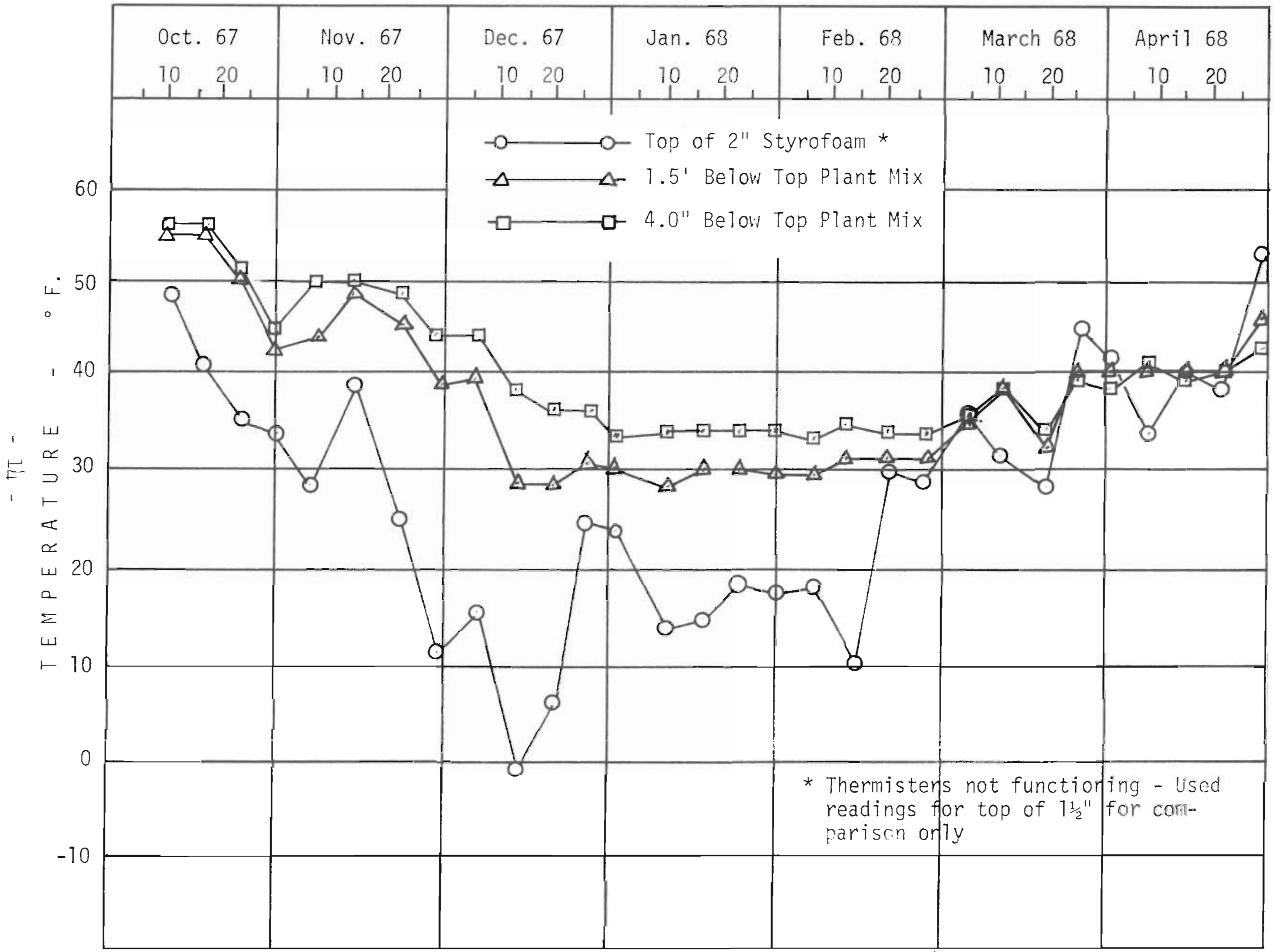


Figure 7 - Temperature Comparison Above and Below 1" Styrofoam

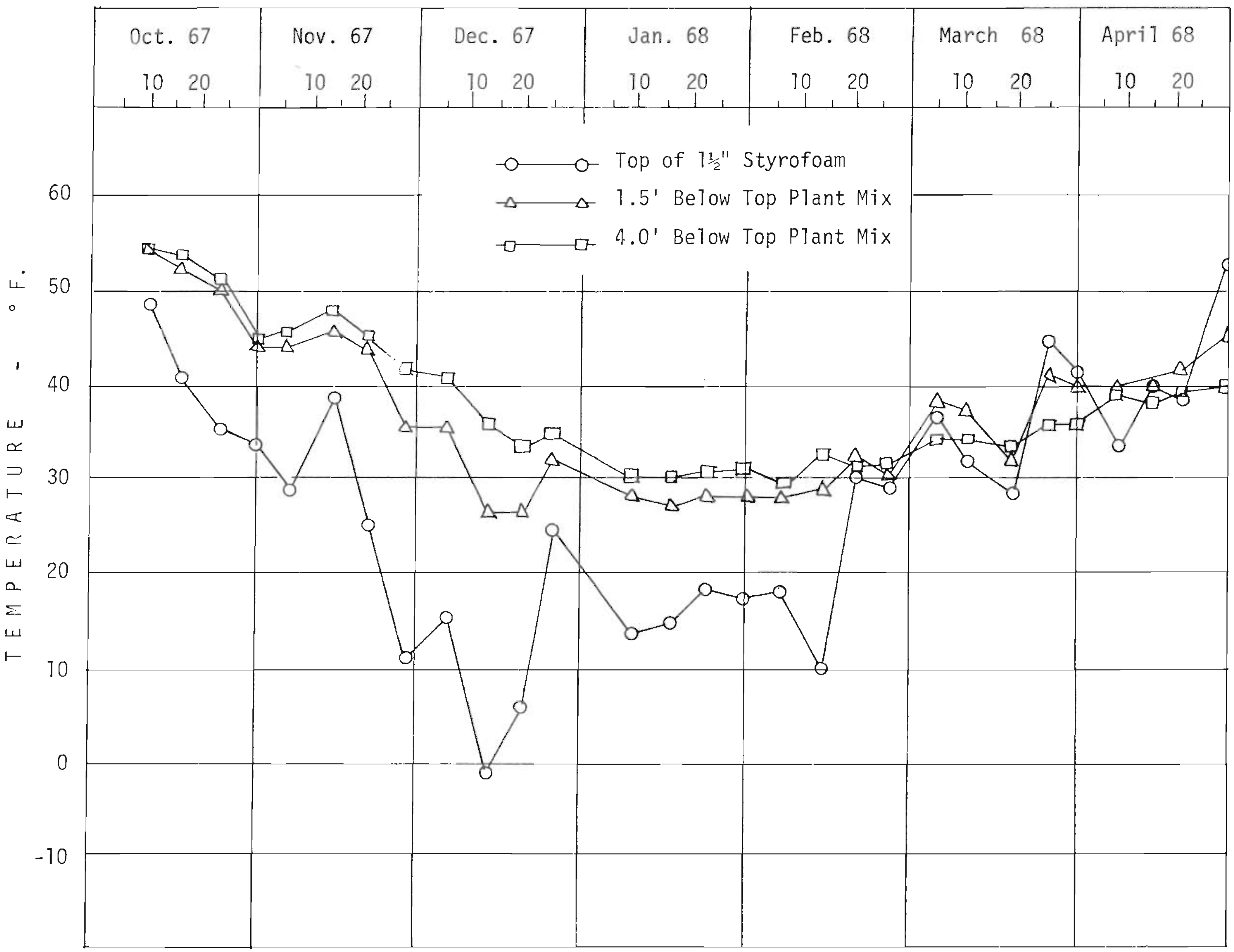


Figure 8 - Temperature Comparison Above and Below 1½" Styrofoam

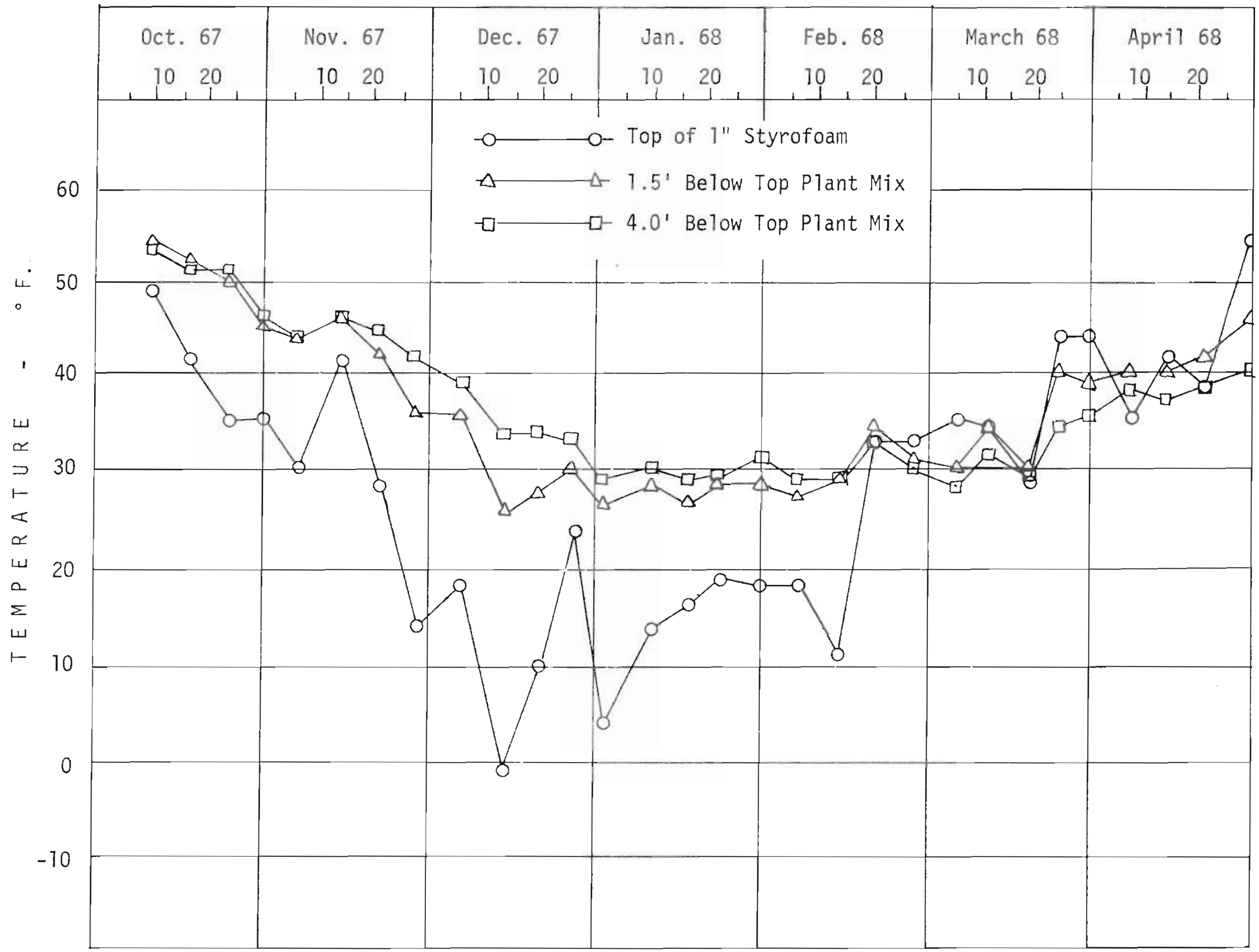


Figure 9 - Temperature Comparison Above and Below 1" Styrofoam

thawing temperatures being evidenced during the first half of February.

Temperatures as low as 28°F. were recorded under the 2" Styrofoam during the 1967-68 season. Freezing temperatures were sustained for nearly two months, probably allowing the frost to penetrate the subgrade several inches.

Under the 1" and 1½" Styrofoam freezing temperatures extended down to the thermisters at 2.5' and at 4.0' below the surface of the roadway.

FROST TUBES

The frost tubes provided a good record of the apparent frost penetration, except for the one in the 2" Styrofoam section, which was broken the middle of March 1967. It provided enough record up to that time to show the effectivenss of the 2" layer of insulation in comparison to the 1" and the 1½" layers. There was apparent frost penetration of the 2" Styrofoam during the 1966-67 season.

The broken tube was not replaced and no frost depths were obtained in the 2" insulation section during the 1967-68 season. The 1" and 1½" Styrofoam allowed the frost to penetrate to 24" below the roadway during the 1966-67 season and as much as 36" during the 1967-68 season. These depths of penetration in the insulated sections are shown in Figures 10 and 11 and compare with frost depths up to 72" in the control sections at Stations 215+82 and 218+11 shown in Figures 12 and 13.

There was no frost heaving observed in the test section during the period of frost penetration. The control sections and the areas both north and south of the test section heaved considerably making the highway very rough and hazardous to drive at high speeds.

AIR TEMPERATURE

Maximum and minimum temperatures were taken daily during the freezing seasons. From these the degree-days for each day were computed and the cumulative degree-days were plotted and are shown in Figure 3. The freezing index for each year was calculated by taking the maximum and minimum points on each

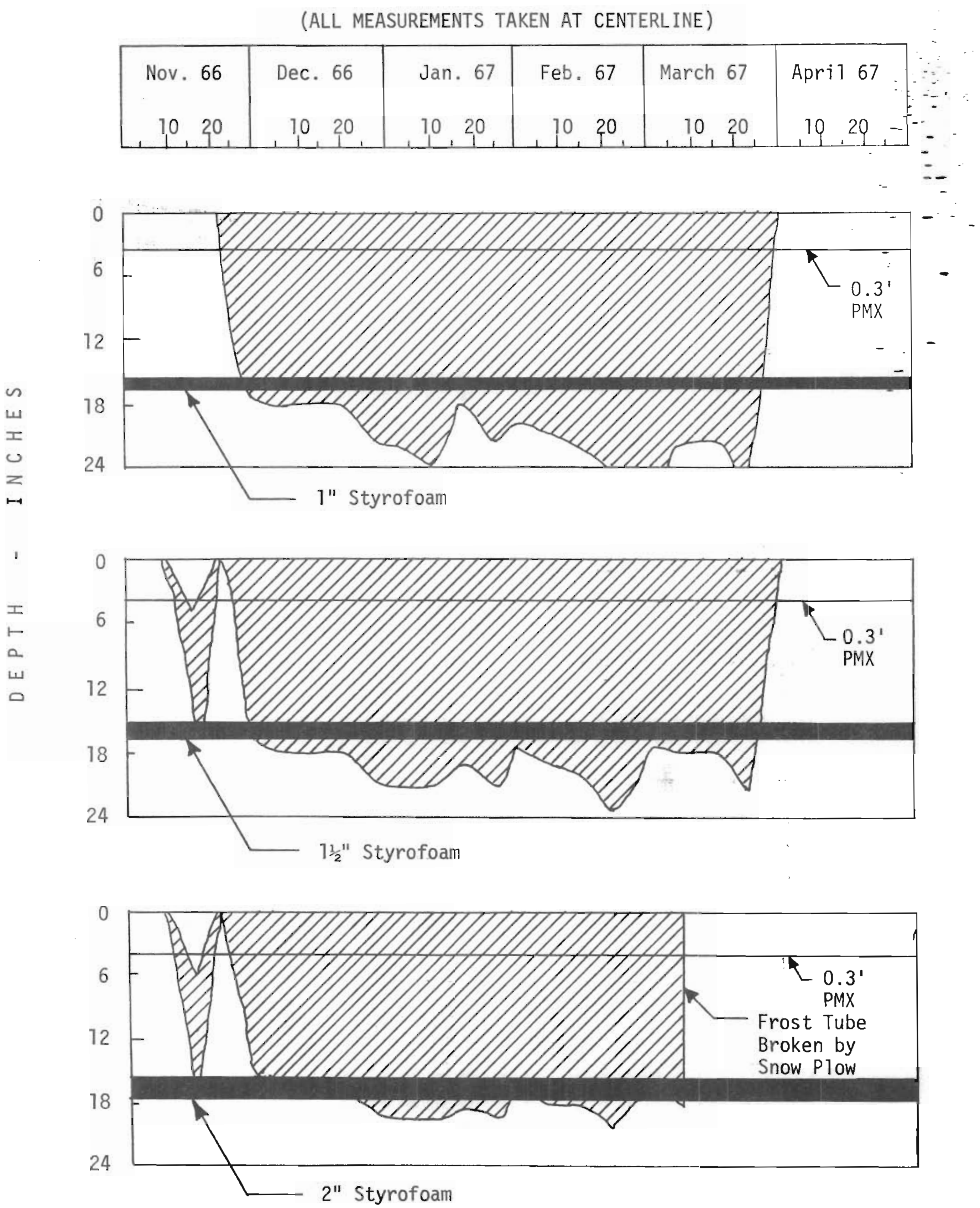


Figure 10 - Depth of 32°F. Isotherm With Time

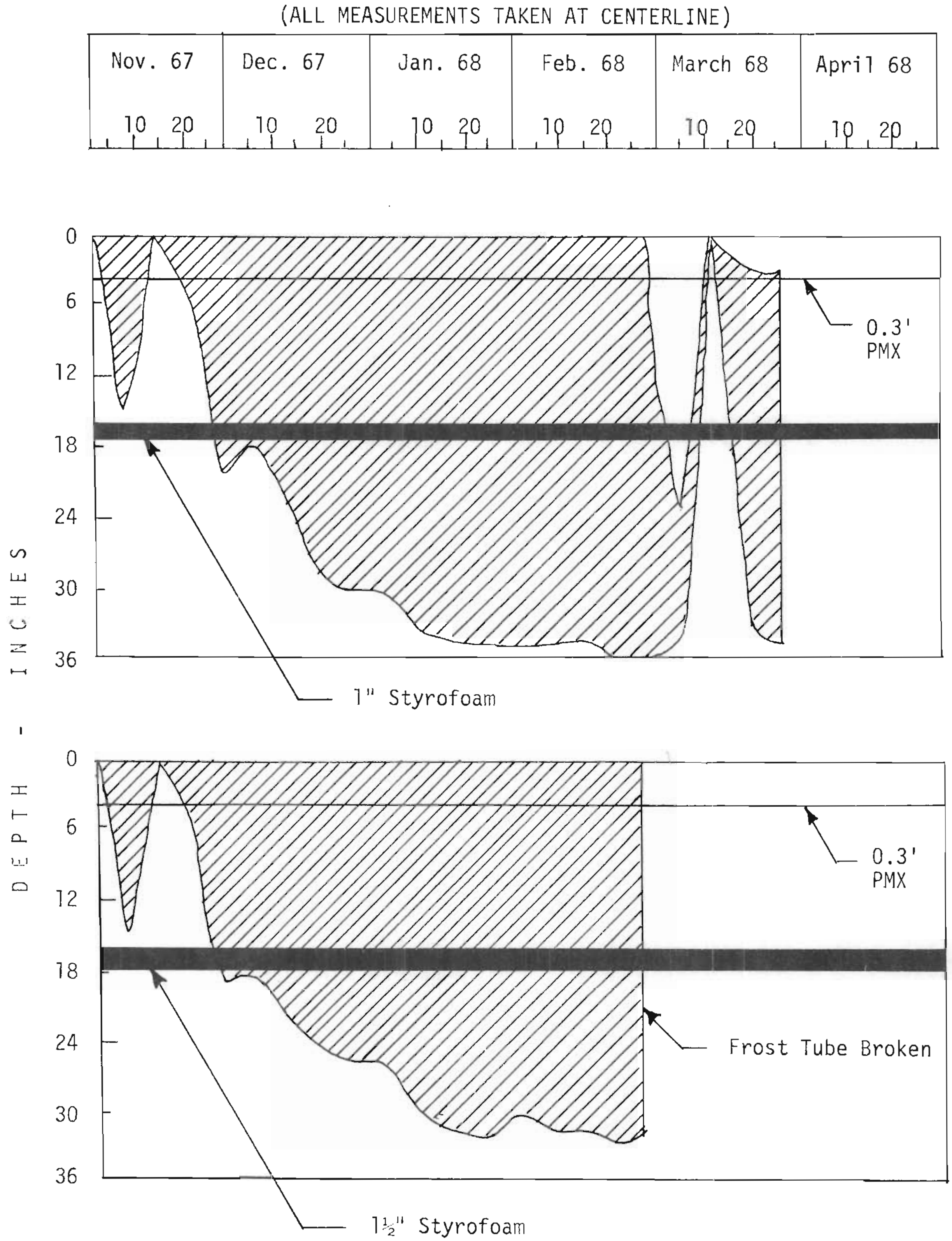


Figure 11 - Depth of 32°F. Isotherm With Time

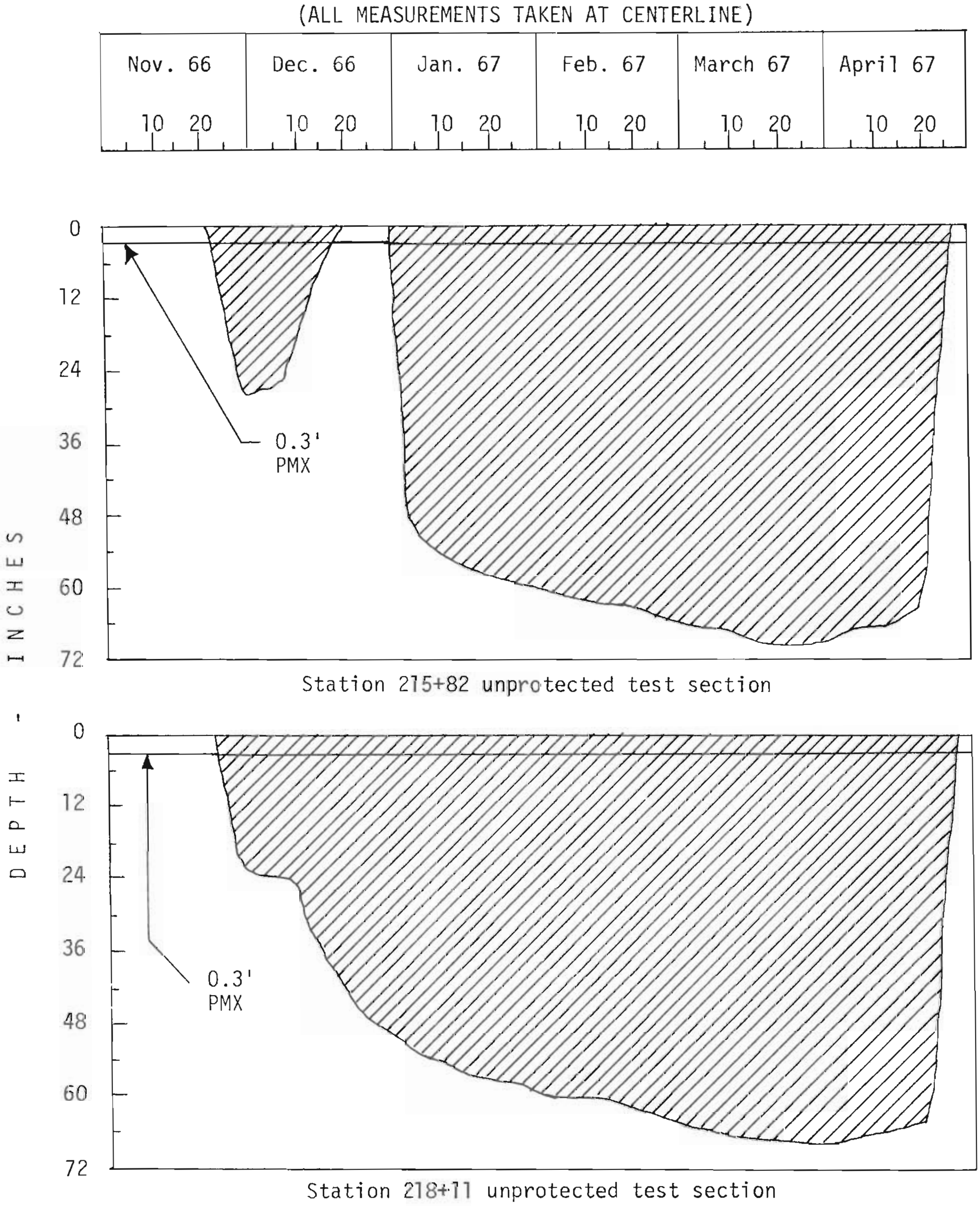


Figure 12 - Depth of 32°F. Isotherm With Time

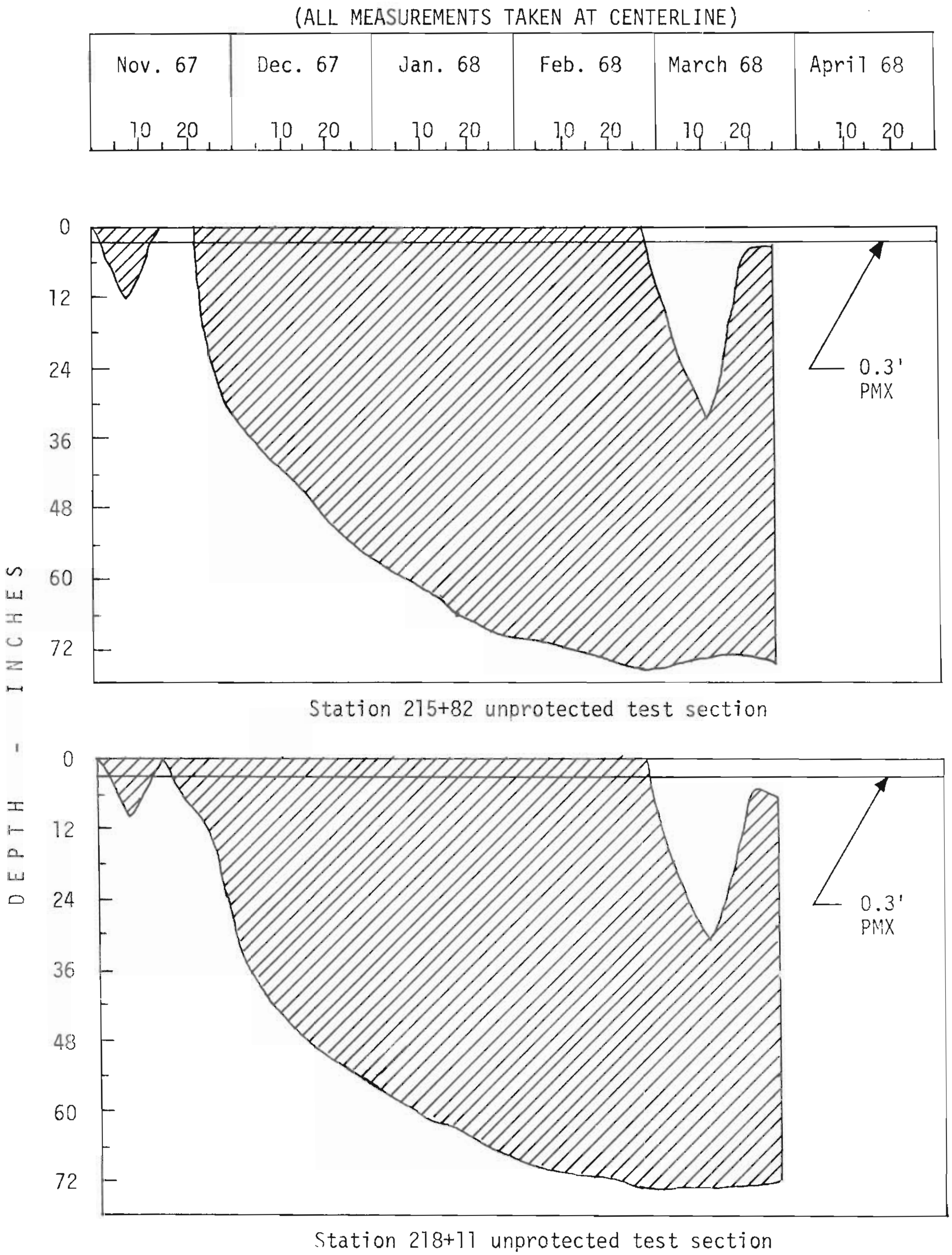
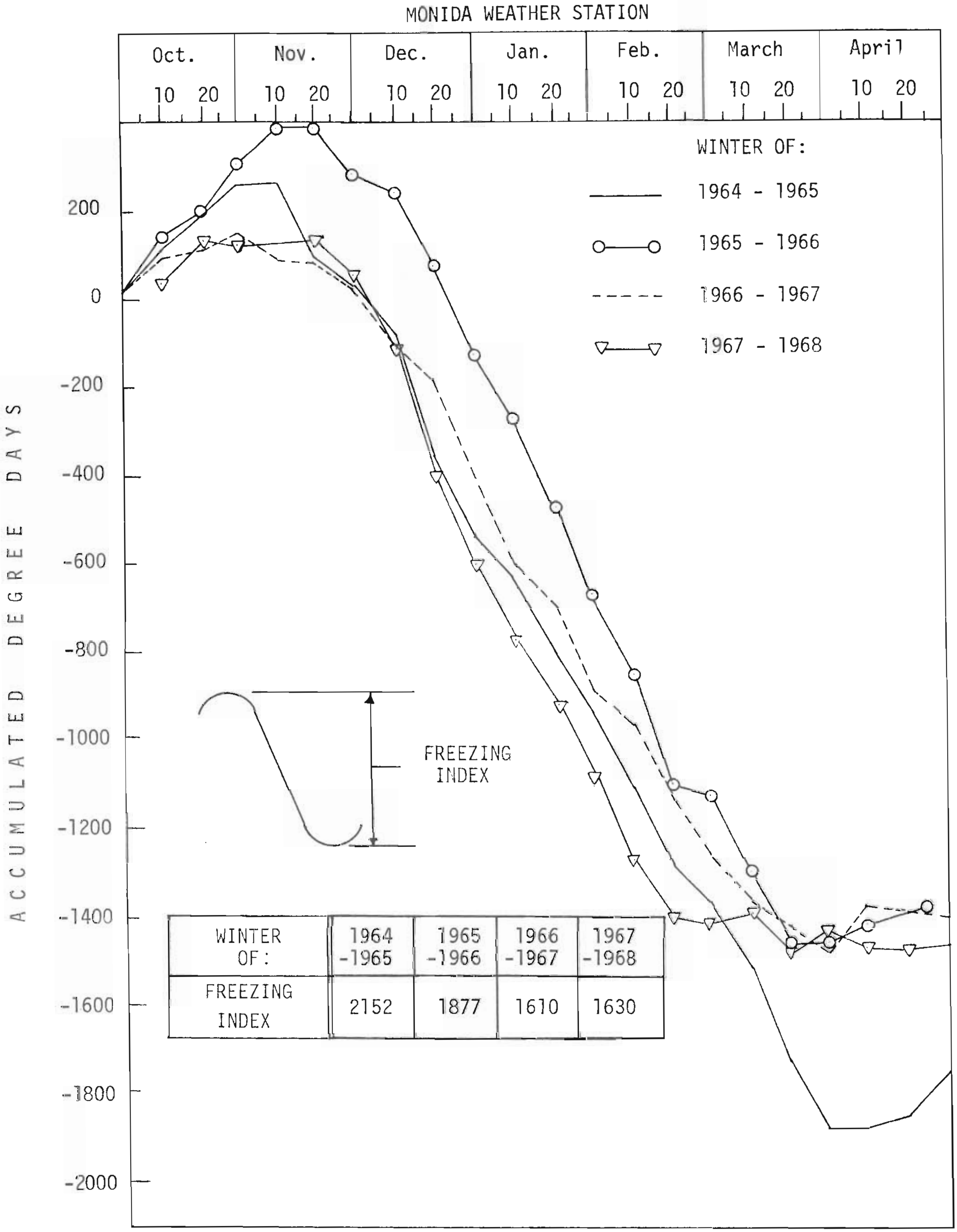


Figure 13 - Depth of 32°F. Isotherm With Time



WINTER OF:	1964 -1965	1965 -1966	1966 -1967	1967 -1968
FREEZING INDEX	2152	1877	1610	1630

Figure 14 - Accumulated Degree Days With Time

curve and adding them algebraically. For the years 1966-67 and 1967-68 the freezing indices were 1435 and 1642 degree-days respectively.

Temperatures were obtained for the U. S. Weather Bureau station at Monida for the years 1962 through 1968 for comparative purposes. The accumulative degree-days for the years 1964-65, 1965-66, 1966-67, 1967-68 are shown as plots in Figure 14. They show freezing indices as follows:

1964-65 -	2152	degree	days
1965-66 -	1877	"	"
1966-67 -	1610	"	"
1967-68 -	1630	"	"

According to the data received the F. I. for 1963-64 was 2528 degree-days at the Monida weather station. This indicates moderation in the weather for the years of the test. Had the freezing index for these years been over 2,000 degree-days the frost may have penetrated the Styrofoam to a greater depth than it did and could feasibly have caused frost heaving.

DEFLECTIONS

Deflection measurements, using the Benkelman Beam were made in the outer wheel path of both the northbound and southbound lanes in September of 1966 after construction of the section, and in September 1967 after the insulation had been in place one year. The deflection data are shown in Figures 15 and 16. The greatest deflections were measured in 1966 and may have been partially due to incomplete compaction in the base.

It is believed that the use of insulation will tend to reduce deflections to tolerable limits during the spring by reducing the strength loss due to frost penetration of the subgrade. It may also act as a moisture barrier.

LEVELS

Levels run at centerline and at 12' each side of centerline in November 1965 and March 1966 show a heave of over 0.2' in the section of highway which became the test section. These are shown in Figure 17.

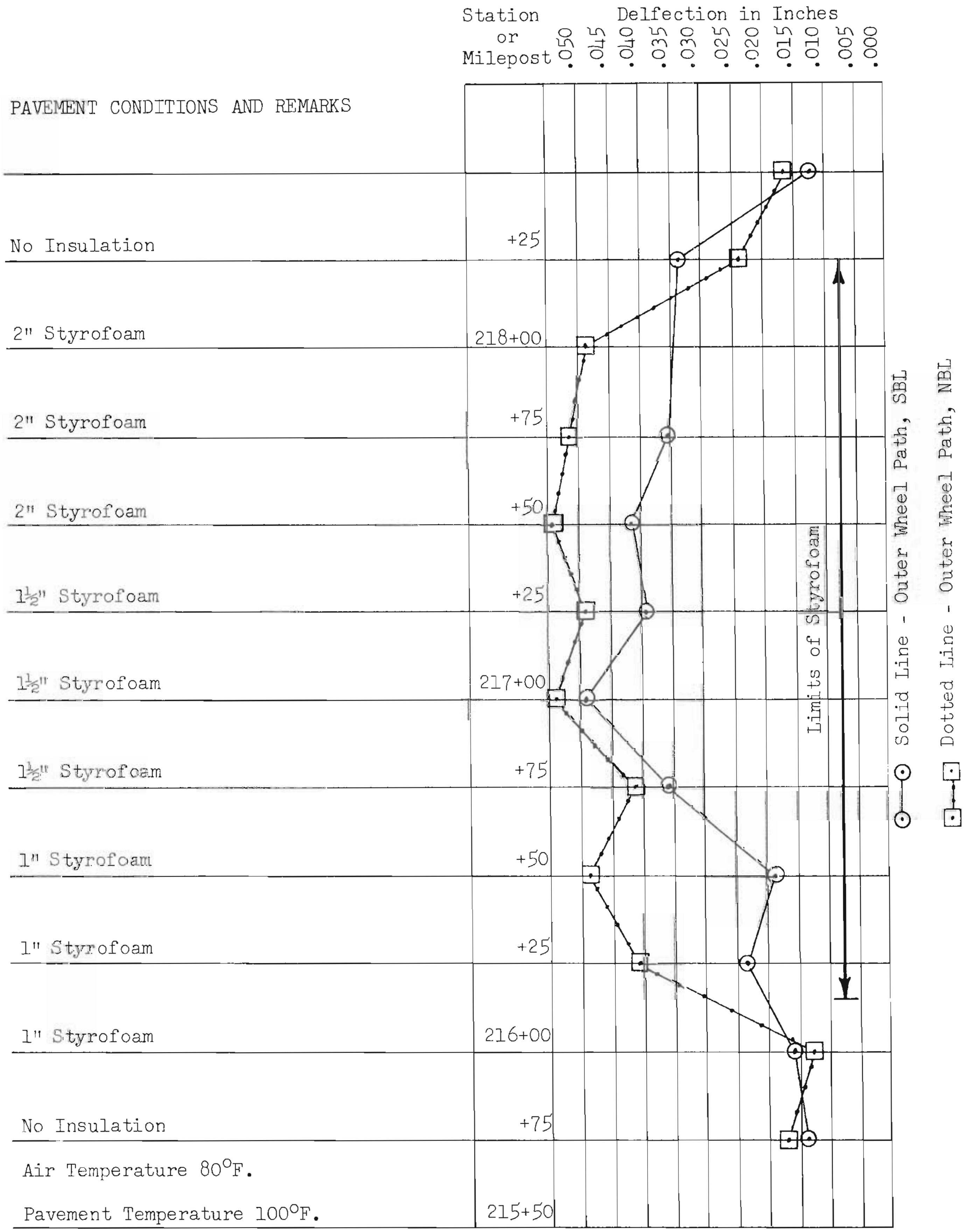


Figure 15 - Benkelman Beam Deflection Data

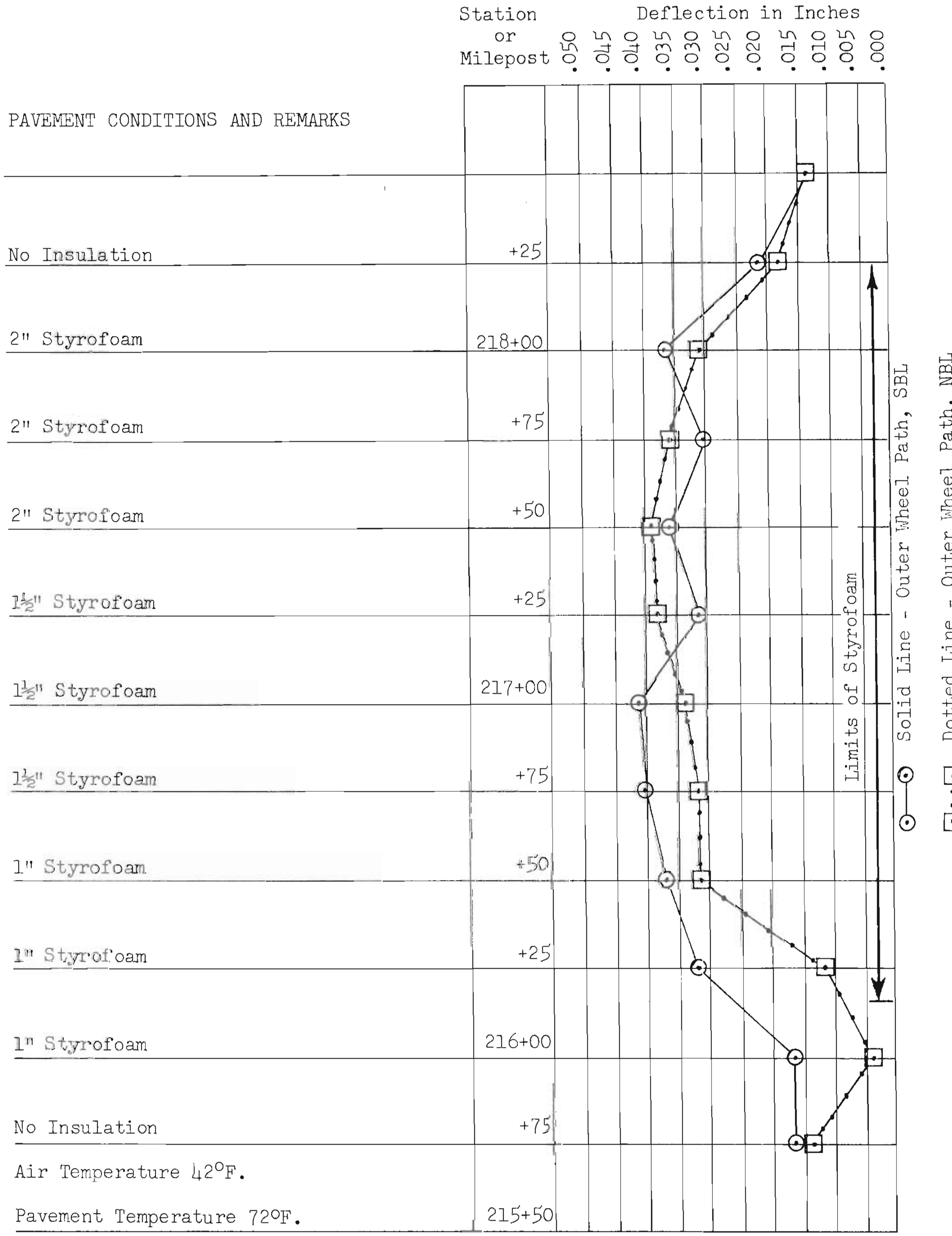


Figure 16 - Benkelman Beam Deflection Data

Zero frost heave established by November 19, 1965 levels
Levels of March 15, 1966 defined the heaving

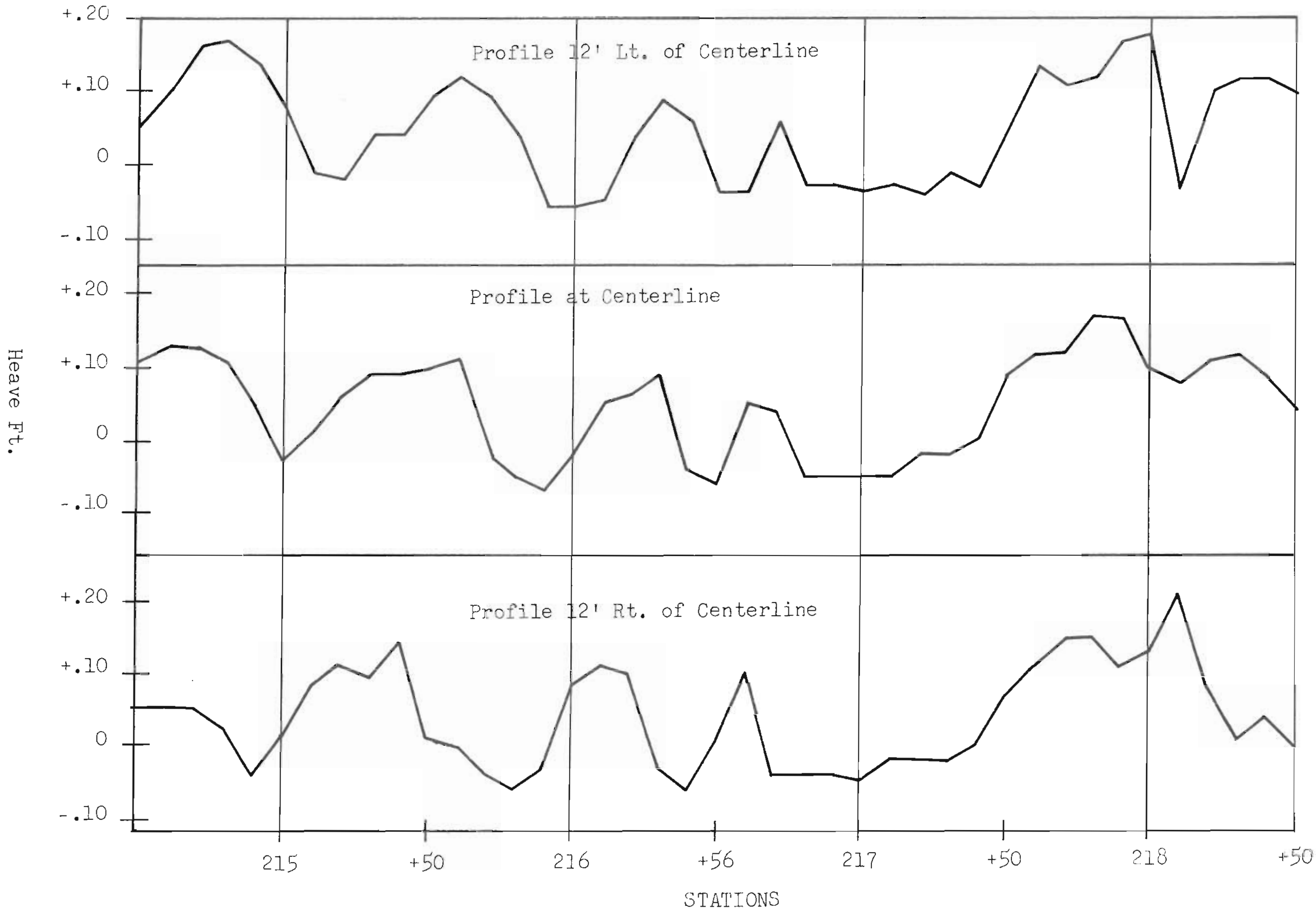


Figure 17 - Profile of Frost Heaving Before Installation of Insulation.

As was stated earlier, it was observed during the spring of 1965 the most severe heaving bumps had elevated the pavement from 3" to 6".

As there was no heaving observed in the test section during the test period, no levels were run during the time the frost was in the ground. Levels run in the spring after the frost left the ground showed no effects from the cold weather.

CONSTRUCTION COST ANALYSIS

The construction of this test section, including the installation of the Styrofoam, the thermisters and the frost tubes was accomplished by Department engineering and maintenance personnel and equipment, except the plantmix paving. This was done by a contractor who was working on an interstate highway project in the area. A report of the construction of the section, including the detours and the costs is included in Appendix B.

Part of the purpose of this project was to determine if it would be economical to use this material to attenuate frost heaving. It was therefore necessary to compare it with another method or system. During the construction of this section of highway in 1959 it became evident that water in the subgrade would cause some serious problems. A 12" perforated C.M. Pipe was therefore installed at depth of 5' below the ditchline 41 feet left of centerline. The cost of this installation was $4,985. This installation cost is for 970 linear feet of pipe.

The costs for constructing the Styrofoam section are as follows:

Equipment, work time	$ 716.00
Equipment, stand-by time	1,139.00
Wages	1,262.50
Material cost	2,606.20
Total Project Cost	$5,723.70

The construction included the construction of detour roads, removal and waste of the existing oil mat, removal and stockpiling of the existing base course, fine grading of the subgrade, placement of a thin sand leveling course, the placement of the Styrofoam including the installation of the thermisters, replacement of the base material, including compaction with a vibratory roller, placement of new plantmix, obliteration of the detours and installation of the frost tubes.

Obviously with the variety of construction operations involved much of the equipment used was idle during much of the construction time. This is shown in the cost for equipment stand-by time of $1,139.00. Undoubtedly there were men standing idle for short periods, too, but this time was not recorded. The project costs shown do not include salaries for the supervisory and design engineers, and the observers. The total cost of construction only, without the equipment stand-by time, was approximately $4,585.00.

As you consider the installation of "Styrofoam HI" or other sheet insulation on new construction the only items of work or material which would reflect an increase in contract cost would be Grade Shaping, Placement of Sand Leveling Course, Placement of Base, Styrofoam (or insulation) Placement and Cost of Insulation. All other costs are related to work which would not be necessary or would be part of the normal construction contract. The placement of base, would only reflect additional cost because of the special handling which is necessary in placing and compacting the base on the insulation and would increase the contract cost only a few cents per ton of base material over the insulation.

Even using the costs listed for this project the increased project cost would be only approximately $2,460. Of this cost $1,894 is for the Styrofoam. If 2" Styrofoam had been used throughout the entire project the cost of material would have been approximately $2,600 and the whole project cost would have been $3,100 or approximately $1,000 per 100 feet of roadway, laid 44 feet wide. In a more moderate climate the thinner insulation could be used and the cost reduced. The unit cost of the insulation is reduced as the volume is increased. Therefore a further cost reduction would be realized as the size of the project increased.

Another method used for trying to eliminate frost heaving of the roadway is to eliminate the frost susceptible soil from the subgrade by excavating and backfilling with a non-frost susceptible granular material. This was done on original construction on portions of this project but proved ineffective in preventing frost heaves, probably because of inadequate excavation and backfill; or the select borrow used for backfill may be frost susceptible in accrodance with the statement of the Corps of Engineers(1). The cost associated with this work was approximately $550 per station for the excavation and backfill.

There has been evidence gathered through research and observation, indicating that the gravels crushed aggregates have little or no insulating effect. In the Highway Research Board report of the WASHO Road Test, Special Report 22, Page 144, is a table showing the depth of frost penetration into the roadway using varying depths of surfacing, ie pavement, base and subbase. The table is reproduced in part below and shows that "considering only the centerline data, it can be stated that in the 1952-53 season the penetration into the basement soil (subgrade) was 11±2 inches and in the 1953-54 season, it was 15±2 inches regardless of the depth of cover (pavement structure) present above the soil. This indicates that gravel and surfacing material had little or no insulating qualities."(4)

Maximum Depth Reached By 32°F. Isotherm

Section	Position	Depth Below Surface 1952-53	Depth Below Surface 1953-54	Depth Below Sub-base 1952-53	Depth Below Sub-base 1953-54
		Inches		Inches	
22 in.	℄	35	39	13	17
14 in.	"	23	29	9	15
6 in.	"	16	19	10	13

The Alaska State Highway Department has reportedly excavated and backfilled with granular material to a depth of 10 feet and still experienced frost in the subgrade.

In his brochure titled "The Swing to Full-Depth" Mr. W. L. Hinderman, Managing Engineer, Northern Division, Asphalt Institute, presented a drawing taken from a research report by Mr. Harry Carlson with the U. S. Corps of Engineers and Dr. Miles Kersten, Professor of Civil Engineering at the University of Minnesota. This figure shows that with increases in depth of granular base the frost penetration also increased, going from approximately 8 feet deep with 3 feet of granular cover to over 14 feet deep with 12 feet of granular cover.

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II. Design Considerations
Corps of Engineers' Pavement Design in Areas of Seasonal Frost

2. Highway Research Record # 101 pp 11 - Use of Insulating Layer to Attenuate Frost Action in Highway Pavements, Oosterbaan & Leonards

3. "Determination of the Ground Frost Line by Means of a Simple Type of Frost Depth Indicator" by Rune Gundahl, Report 30A of the National Swedish Road Research Institute, Translated and Revised by P. T. Hodgins.

4. Highway Research Board, Special Report #22, The WASHO Road Test, Part 2 Test Data, Analyses, Findings p. 144 Table 5-a-2.

APPENDIX A

APPENDIX A

PROCEDURE FOR INSTALLING FROST GAGES

1. Auger 10-inch hole through the mat.
2. Auger 3-inch hole through the base.
3. Extend hole into subgrade to required depth by best means, keeping hole as small as possible.
4. Grease outer case of frost gage up to "O" ring, and connect string or wire to rubber band holding 3-inch wings of anchor bolt closed.
5. Place sufficient soil-cement slurry in hole to cover anchor bolt. (Insert into hole through a piece of PVC conduit.)
6. Insert entire gage (less base plate) into hole and remove rubber band from anchor by means of the string or wire.
7. Insure that bottom part of tube is firmly seated on bottom of hole; holding bottom tube in place, seat top tube level with roadway surface.
8. Backfill hole around gage in the subgrade. Use fine sand or subgrade material the same as removed from hole. Tamp lightly.
9. Backfill base material to base plate seat.
10. Install base plate and replace asphalt surfacing.
11. Insert tube containing Methylene Blue solution and replace brass plug.

MATERIAL NEEDED

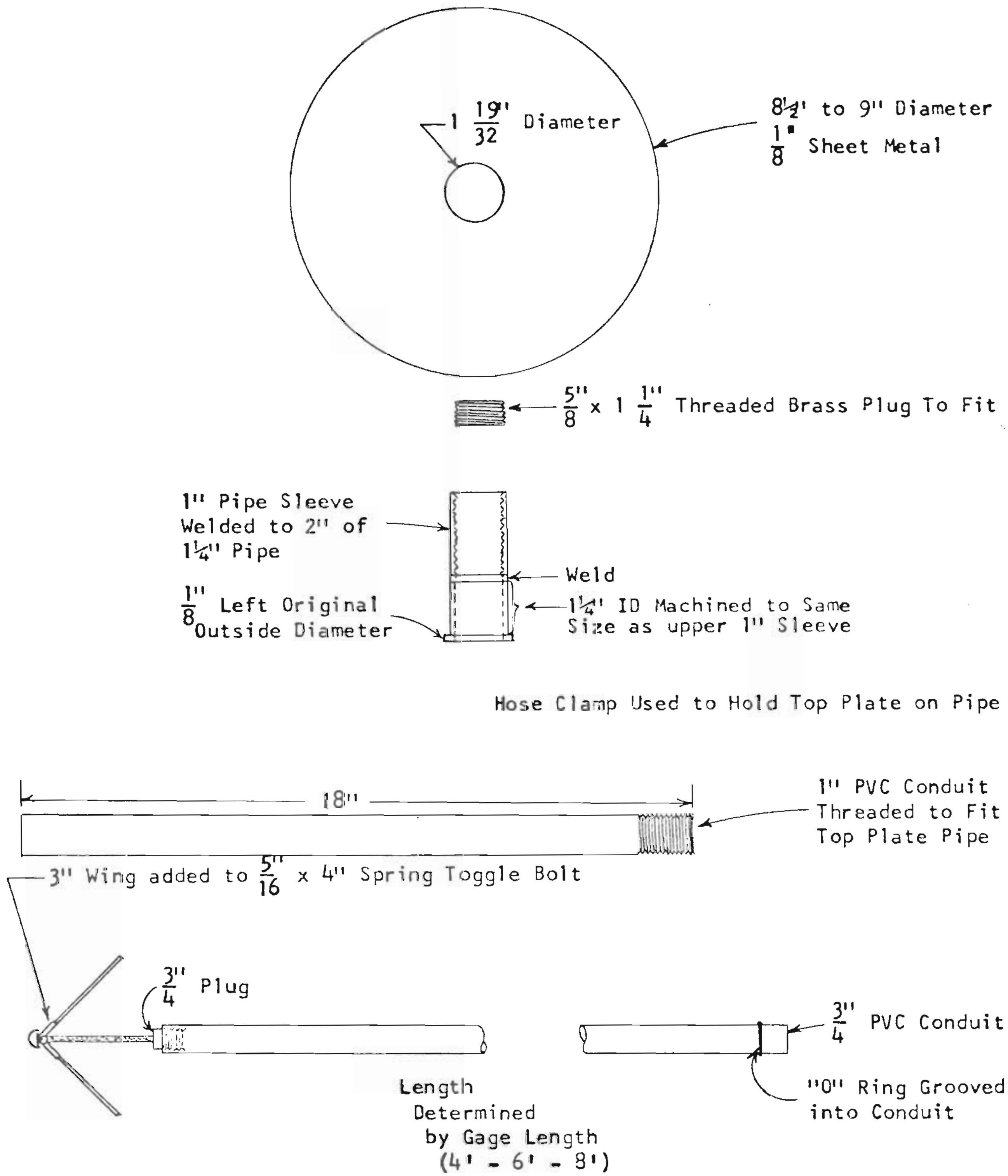
1. Frost gage assembly to include:

    (a) Outer protective shell-see attached figure.
    (b) Inner frost gage tube-see attached figure.

2. Extra Methylene Blue solution(0.05%).
3. Grease
4. Soil-cement mixture.
5. Subgrade and base backfill material and surface material.
6. Appropriate tools for drilling holes, mixing soil-cement, etc.

TOP PLATE ASSEMBLY FOR FROST GAGES

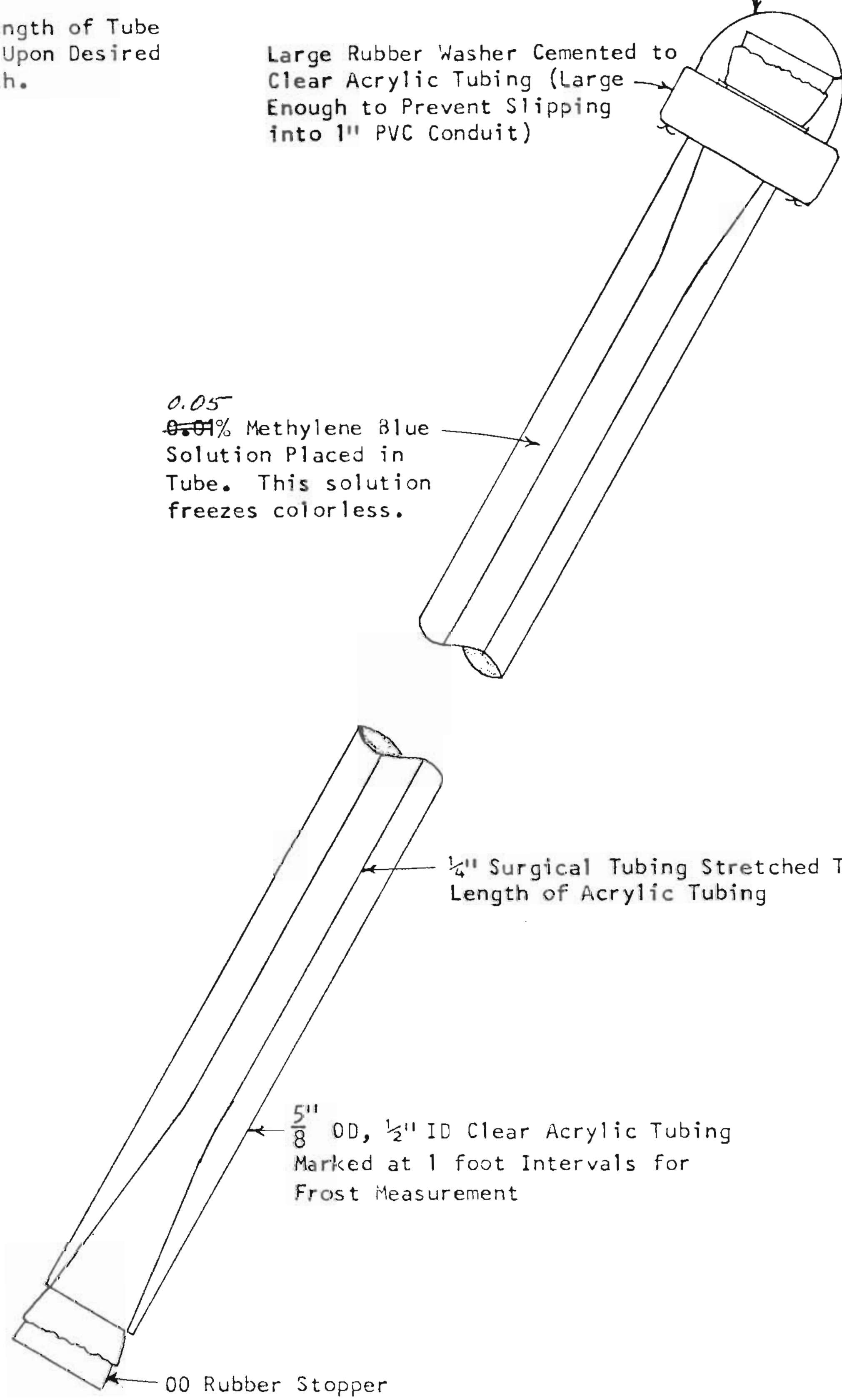
Scale ¼' = 1"



INSIDE FROST GAGE TUBE

Scale 1" = 1"

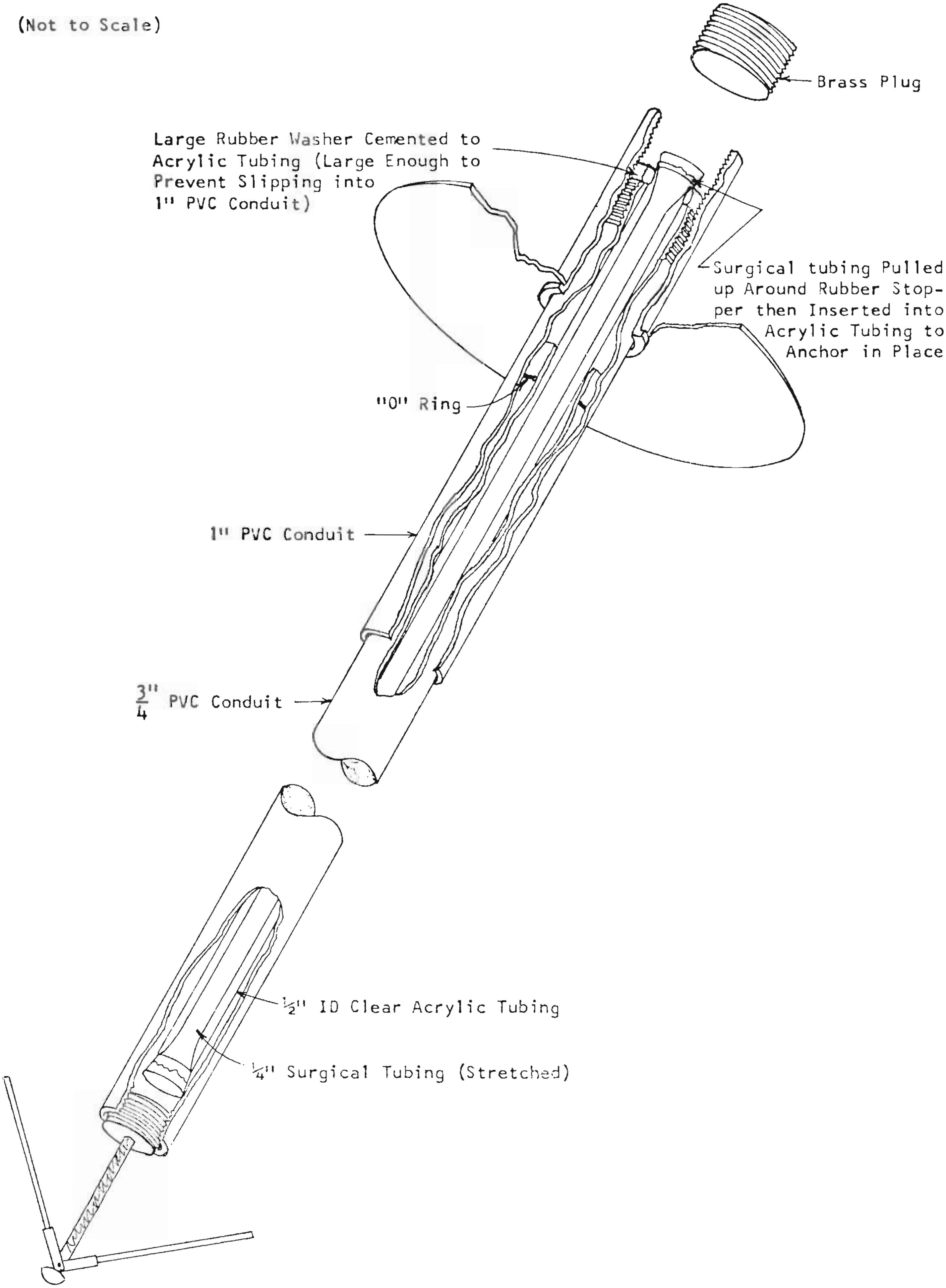
Overall Length of Tube Dependent Upon Desired Gage Length.



Surgical Tubing is for expansion and contraction of indicator solution as it freezes and thaws. It also prevents the frozen solution from moving.

CUT AWAY VIEW

(Not to Scale)



APPENDIX B

APPENDIX B

-Construction Report-

STYROFOAM INSTALLATION

On August 30, 1966, approximately 210 feet of styrofoam was installed in the roadbed of I-15, two miles south of the Idaho-Montana State line. The complete installation was accomplished by the State's engineering and maintenance forces with the exception of laying the plantmix. The plantmix was supplied and placed by a contractor working on a local Interstate project.

Before construction began, a detour for each lane of traffic was built on top of the cut slopes with the detour sign layout being designed and installed by the District Traffic Section.

The oil mat was removed by a T-D-18 crawler tractor and a Scoopmobile loader, then wasted in a nearby pit.

The base material was excavated 1.5 feet below the finished grade and stockpiled for later replacement over the styrofoam.

A Wabco patrol graded the subgrade to an approximate grade and then a thin layer of sand was used to bring the grade to the proper elevation for the styrofoam installation. The sand was used as a leveling course, and even though it made the surface much smoother, no great effort was made to remove every large rock. This was done to test the styrofoam under actual construction conditions.

Three different thicknesses of styrofoam were placed in the following locations, 44 feet in width: the 1" thickness from Station 215+92 to 216+64, the 1½" thickness from Station 216+64 to 217+28, and the 2" thickness from Station 217+28 to 218+00. The 2 x 8 foot sheets were laid in a brick like fashion so the joints would be staggered. The staggered section at each end allows for a transition from an area of deep frost penetration, where there is no styrofoam, to an area of shallow penetration under the styrofoam. The styrofoam was fastened to the subgrade with wooden skewers approximately 6-inches long and 3/8th-inch in diameter. The skewers were driven in at an angle to butt the sheets together in a tight joint.

Temperature detecting probes, called thermisters, were placed at various depths in the subgrade during the installation of the styrofoam. Eight thermisters, two sets of 4-each, were located in each of the three sections of styrofoam slightly to the right of the centerline. Two thermisters were placed on top of the styrofoam 1.4 feet below the finish grade, two immediately below the styrofoam; two, 1.0 foot below the styrofoam; and two, 2.5 feet below the styrofoam. Two thermisters were placed in each position as a check on each other. Leads were run from each probe through conduit to a terminal box mounted on a post set on top of the backslope where the temperatures can be obtained by a meter attached to the termini of the leads in the terminal box.

Two control sections were established 10 feet from each end of the test section. Thermisters were placed in each control section at 1.5 foot and 4 foot depths to check the temperatures where there was no styrofoam.

After the styrofoam and thermisters were installed, the base material was replaced by end dump trucks. The crawler tractor and loader then pushed the material over the styrofoam. The base was brought up to grade and compacted to 95% of standard density. The test section was capped with 0.3 foot of plantmix surfacing Class "B", by a Cedarapids Paver.

The total time required for the project, including excavation, installation, backfill and paving, was five days.

One month after the styrofoam installation, frost tubes were placed in each portion of the test section, including one in each control section. These frost depth indicators will be used to correlate the freezing temperatures obtained from the thermister readings to the actual frost depth, and also, to determine the effect the styrofoam has on attenuating frost penetration. The frost tubes and thermisters will be read weekly throughout the freezing season. Figure No. 1 is a sketch showing the different styrofoam sections, thermister locations and frost tube locations.

STYROFOAM LAYOUT

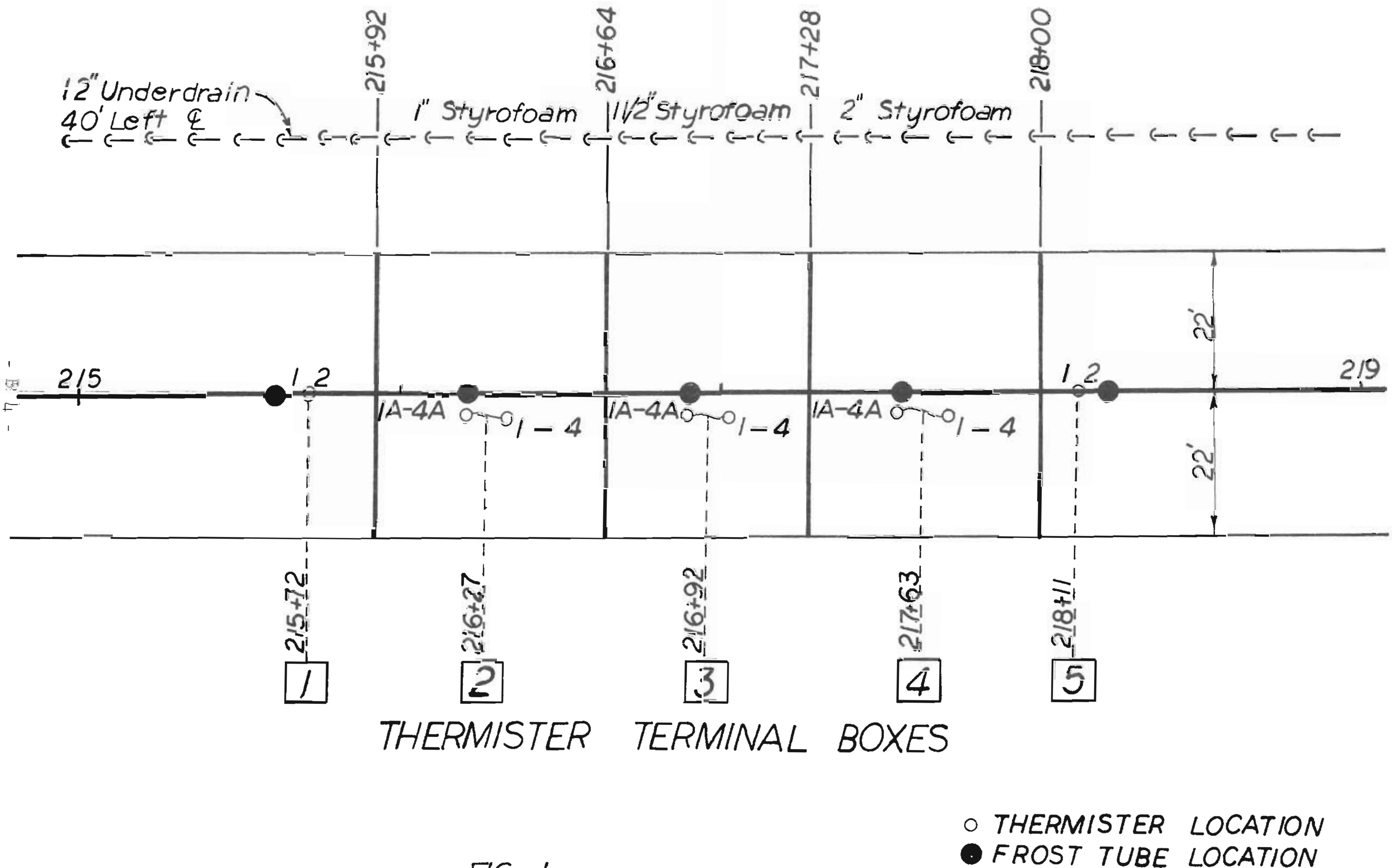


FIG. 1

-TABLE 1-

COST OF STYROFOAM INSTALLATION

Type of Charge	Hours Worked	Rate/Hour	Total
	DETOUR ROADS		
4-Trucks	8	$2.50	$20.00
Crawler Tractor	3	6.00	18.00
Patrol	2	5.00	10.00
Asphalt Distributor	1	5.00	5.00
Wages	80	3.50	280.00
		Item Total.........	$333.00
	MAT REMOVAL		
Loader	1½	$5.00	7.50
Crawler Tractor	1	6.00	6.00
Patrol	1½	5.00	7.50
Compressor	2	3.00	6.00
Wages	8	3.50	28.00
		Item Total.........	$ 55.00
	BASE REMOVAL		
Loader	5	$5.00	25.00
Crawler Tractor	3	6.00	18.00
Patrol	4½	5.00	22.50
Trucks	18	2.50	45.00
Wages	35	3.50	122.50
		Item Total.........	$233.00
	GRADE SHAPING		
Patrol	2½	$5.00	12.50
Wages	2½	3.50	8.75
		Item Total.........	$ 21.25
	PLACEMENT OF SAND LEVELING COURSE		
Loader	2	$5.00	10.00
4-Trucks	2	2.50	5.00
Wages	24	3.50	84.00
		Item Total..........	$99.00
	BASE REPLACEMENT		
Loader	7½	5.00	37.50
Crawler Tractor	3½	6.00	21.00
Patrol	7½	5.00	37.50
4-Trucks	30	2.50	75.00
Wages	63½	3.50	222.25
		Item Total.........	$393.25

Type of Charge	Hours Worked	Rate/Hour	Total	
	DITCH CLEANING			
Loader	3	$5.00	$15.00	
Crawler Tractor	4	6.00	24.00	
2-Trucks	4	2.50	10.00	
Wages	11	3.50	38.50	
		Item Total........	$87.50	
	MAT REPLACEMENT			
4-Trucks	8	2.50	20.00	
Roller	2	5.00	10.00	
Wages	10	3.50	35.00	
		Item Total.......	$65.00	
Survey Crew (Wages)			49.00	
Pickup Rental			248.00	
Styrofoam Installation			56.00	
		Sub Total.....	$1,640.00	
	ITEMS FOR RESEARCH			
Thermister Installation			73.50	
Frost Tube Installation			265.00	
		TOTAL.........	$1,978.50	
Equipment Stand-by Time			1,139.00	
		TOTAL.....................		$3,117.50

COST OF MATERIALS

Styrofoam 1" 3,300 B.F. @.132	435.60	
1½" 4,450 B.F. @.132	587.40	
2" 6,600 B.F. @.132	871.20	
Total........	$1,894.20	
Thermisters	400.75	
Wire, conduit, etc.	161.25	
Frost Tubes	100.00	
Plantmix	850.00	
Total Material Cost...............		$2,606.20
Total Project Cost................		$5,723.70

EQUIPMENT COSTS

Equipment	Rate/ Hour	Working Time - Hrs.	Working Cost	Standby Time - Hrs.	Standby Cost	Total Time - Hrs.	Total Cost
8 - Trucks	2.50	70	$175.00	148	$370.00	218	$545.00
2 - Diesel Trucks	5.00	2	10.00	22	110.00	24	120.00
Transport	6.00	8	48.00	-	-	8	48.00
Flatbed Trailer	2.50	8	20.00	-	-	8	20.00
Van Trailer	2.50	24	60.00	16	40.00	40	100.00
Water Truck	1.50	4	6.00	28	42.00	32	48.00
Compressor	3.00	2	6.00	22	66.00	24	72.00
Crawler Tractor	6.00	14½	87.00	17½	105.00	32	192.00
Loader	5.00	19	95.00	21	105.00	40	200.00
Patrol	5.00	22	110.00	26	130.00	48	240.00
Roller (Steel Wheel)	4.00	4	16.00	28	112.00	32	128.00
Roller (Pneumatic)	4.00	2	8.00	6	24.00	8	32.00
Asphalt Dist.	5.00	1	5.00	7	35.00	8	40.00
Pickup Rental			248.00				248.00
COST TOTALS...			894.00		1,139.00		2,033.00