Improvements in Magnetic Observatory Construction and Operation in Permafrost Areas

by

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Abstract

The operation of the Barrow, Alaska, magnetic observatory (lat. 71.32°N, long. 156.62°W) has been complicated because foundations for the instrument piers must be constructed on permafrost. Better understanding of environmental conditions and the availability of more modern instrumentation since the original construction have led to the design and construction of new piers to provide a more stable platform for the absolute and recording instruments. In May 1975, a digital- and analog-recording fluxgate and proton magnetometer system was installed to replace a conventional magnetograph. These changes in construction and recording instrumentation were made to permit unmanned operation, to provide digital data, and to improve the quality of the data collected. Nearly two years of observations under the new mode of operation have been examined and compared with prior observations. Preliminary results indicate that ranges in the baseline data were reduced by factors of 15.6 for horizontal intensity; 9.1 for declination; and 5.0 for vertical intensity.

INTRODUCTION

Located at the northern tip of Alaska about 500 miles (804 Km) north of Fairbanks and about 200 miles (322 Km) west of Prudhoe Bay, site of the much publicized north slope oil fields, is the Barrow Magnetic Observatory. Geographic coordinates are latitude 71.32°N and longitude 156.62°W.

Hostile polar environmental conditions have made it a difficult station to maintain and operate. The climate consists of long, dry, cold winters and short, moist, cool summers. Temperatures in this area remain below the freezing point most of the year, with the daily maximum reaching higher than the freezing point on the average of only 109 days a year. The daily minimum drops below the freezing point 324 days of the year and freezing temperatures have been observed in every month of the year. The mean annual temperature is 9.3° F (-12.6° C). Mean annual precipitation is 4.9 inches (12.4 cm) and the mean annual snowfall is 28.6 inches (72.6 cm). The annual mean wind speed is 11.9 Mi/hr (19.1 Km/hr) and the extreme winds near 50 Mi/hr (80 Km/hr) have been recorded for all months. The average mean relative humidity is 80%, but is extremely low inside heated buildings in the winter time.

The general elevation of the natural ground at the observatory site is about 8 feet (2.5 meters) above sea level. The terrain is slightly undulating tundra-covered silt, sand, and gravel with an active (seasonal freezing and thawing) layer 2-4 feet (0.6-1.2 meters) in depth. Permanently frozen soil (permafrost) lies below the active layer and extends to 1,330 feet (405 meters).

The observatory was constructed in 1948 and recording of data with a conventional storm magnetograph (D & H suspended fiber variometers & Z balance variometer) started in May 1949. In April 1957, the storm magnetograph was relocated to another building constructed on more stable soil to try to improve the quality of data and to permit the installation of a rapid run magnetograph for the IGY Program. In January 1964, an attempt was made to reduce the base line shifting by installing the storm magnetograph on a mercury floating pier. The installation of the floating pier resulted in some improvements, but not enough to eliminate the major problem with base line shifts. From 1964 to 1974, observations continued to show that the permafrost problems and extreme temperatures were still causing major shifts in the base line data. These shifts were believed to have been caused by influences on the absolute and recording instrument piers by:

1. Seasonal thawing and freezing of the active ground layer.
2. Cracking of the posts due to extreme temperature and humidity differential from inside to outside of the building.
3. Vibrations of the posts due to exposure to the wind.

Because of the availability of more modern instrumentation and improved knowledge about permafrost conditions, major changes in the design and construction of the absolute piers and modifications of the recording instrument building and pier were made in 1975.

EARLIER CONSTRUCTION & OPERATION

In 1948 and 1957 the instrument piers were constructed by freezing posts about 12 inches (30.5 cm) in diameter, 15 feet (4.6 meters) into the permafrost. Laminated plywood was secured to the top of the posts to provide a platform for installing the instruments. The buildings were constructed on posts that extended 1 to 2 feet (0.3 to 0.6 meters) above the surface of the ground to allow air circulation underneath so that heat from the buildings would not thaw the ground. The ground below the buildings and the piers inside and outside of the buildings were not insulated in the original construction.

With direction and support from the College Observatory in Fairbanks, one observer stationed at Barrow carried out routine operations including absolute and scale value observations.

NEW PIER DESIGN & CONSTRUCTION

New pier construction, absolute building relocation, and recording-instrument building modification was started in 1974 and completed in 1975. The absolute building, which was located near the village of Barrow and about 5 miles (0.8 Km) from the recording-instrument building, was relocated to the recording-instrument building site. New piers were designed for the absolute and recording instruments taking into consideration the problems with the active ground layer, cracking of the posts due to extreme temperature and humidity differential, and vibrations caused by exposure of the posts to the wind.

The absolute instrument piers were constructed by drilling holes and freezing 12 inch (30.5 cm) diameter wood posts into the permafrost, Figure 1. From one foot (0.3 meter) below ground level to the floor level of the building, a plastic jacket with 3 inches (7.6 cm) of styrofoam pellet insulation was placed around the post. Four inches (10.2 cm) of rigid styrofoam insulation was placed on the ground extending 4 feet (1.2 meters) out and around the post. About 14 inches (35.6 cm) of gravel, sand, and dirt mixture were placed around the area with 10 inches (25.4 cm) over the styrofoam leaving a 2 inch (5.1 cm) air space below the lower part of the building. Fourteen inches (35.6 cm) of fiberglass insulation was placed between the floor joists to insulate the floor of the building.

Inside the building a four inch (10.2 cm) high insulated bumper platform was installed on the floor, around but not touching the post. A 46 inch (116.8 cm) high corrugated aluminum jacket was placed around the post and supported by one inch (2.54 cm) blocks located on the platform during construction. The jacket extended 4 inches (10.2 cm) above the top of the post.

A concrete mixture of 2 parts white cement, 3 parts sand, 3 parts styrofoam pellets, 1 part vermiculite, and 1½ parts water was poured around and to the top of the post. The upper four inches (10.2 cm) of the jacket was filled with a mixture of 2 parts white cement, 3 parts sand, and 3/4 parts water. The objective was to get a concrete mixture to reduce the weight on the post, and along with the aluminum jacket, provide rigidity, insulation, and a stable environment for the post inside of the building.

Test blocks 6 X 4 X 3 inches (15.2 X 10.2 X 7.6 cm) were made to compare these mixtures with normal concrete. The following are results of tests after 7 days curing, made by the State of Alaska Materials Laboratory at the University of Alaska, Fairbanks:

Block Mixture	Block Weight	Weight PCF	% Weight to Normal Concrete	Strength Test
#1 Normal Mix	6.0 lbs. (2.7 Kg)	145 PCF	100%	3000 PSI
#2 Styrofoam Mix	2.8 lbs. (1.3 Kg)	66 PCF	46%	432 PSI
#3 Cap Mix	5.3 lbs. (2.4 Kg)	129 PCF	89%	4120 PSI

After the concrete was set, the one inch (2.54 cm) blocks, which supported the aluminum jacket during construction, were removed from the bumper platform and replaced with fiberglass insulation to insure that the post was isolated from the building and completely insulated.

The lower part of the building was enclosed with plywood to prevent the wind from blowing against the piers.

Construction costs prevented rebuilding the recording instrument pier, Figure 2. As a compromise the existing building and pier that had been used for a rapid run magnetograph was modified for housing the new fluxgate sensors. This building was a poorly insulated aluminum structure, so the floor, walls, and ceiling, were reframed inside with wood and insulated.

The existing pier of seven, 12 inch (30.5 cm) diameter posts with a 4 inch (10.2 cm) laminated plywood top was modified, Figure 3. The four posts that were nearest to the center of the building and evenly spaced were utilized. The other three posts were detached from the pier top. The 4 inch (10.2 cm) laminated plywood top was cut to fit and secured to the top of the four posts with brass screws. A plywood jacket was placed around the posts and insulated with styrofoam pellets from the floor level to the pier top.

The posts and ground around the posts under the building were insulated with rigid styrofoam and covered with gravel. The underneath part of this building was also enclosed with plywood to prevent the wind from blowing against the pier.

NEW INSTRUMENTATION & OPERATION

A digital and analog recording fluxgate and proton magnetometer system was installed in May 1975. The system included:[1]

Fluxgate Magnetometer (H, D, & Z) EDA Model FM 100B

Proton Recording Base Magnetometer (F) Geometrics Model 826

Data Logger Monitor Labs Model 9400

Tape Transport (7 track/556 characters per inch) Digi-Data Model 1337

Analog Recorder (4 pen) Soltec/Rikadenki Model B

Battery System 4 ea. 3CA5 6 Volt Exide Batteries 100 Amp

Battery Charger LaMarche Model A12B

DC/AC Inverter Nova Model 5064-24

Under the new mode of operation there is sufficient digital tape and analog recording paper to operate the station unattended for up to seven weeks without major service. The station is operated by the College Observatory at Fairbanks, and visits are made to the station by one of the staff periodically (about every seven weeks) to change tapes, make absolute and scale value observations, and to service the equipment. Through a cooperative arrangement with the NOAA Geophysical Monitoring for Climatic Change Laboratory at Barrow, someone from the laboratory checks the recording equipment weekly and advises the College Observatory staff of any obvious problems with the station. Operating costs were reduced by eliminating the need for a full time observer at Barrow.

[1]Brand names of equipment are used here only for descriptive purposes and in no way constitute endorsement by the USGS.

IMPROVEMENT OF BASE LINE STABILITY

The first 27 months (June 1975-August 1977) of base line data with the new mode of operation was compared with the last 27 months (January 1973-March 1975) of data from the old operation, Figures 4 thru 9. May, June, and July 1975 was considered a stablizing period for the new operation, allowing the concrete to cure and the posts to settle in the permafrost; therefore, the base line data for this period will not be used in comparing with the old operation.

The declination values of the old operation show the maximum easterly value occurring near the period of minimum outdoor temperatures in late winter 1973, and the minimum easterly value occurring just after the maximum temperatures were reached in late summer of 1973, Figure 4. This pattern repeats itself reasonably well through 1974 and until the magnetograph recording was discontinued to allow modification of the recording building and install the new instrumentation. The range in declination base line values for the old operation was 23°53.4'E-22°41.2'E or 72.2 minutes (207$^{\gamma}$).

The declination base line values, with the new mode of operation, Figure 5, shows the minimum easterly value occurring about February 1976, and remaining stable during the period February to May. In May the value starts increasing at about the time when the temperature goes above the freezing level and reaches the maximum easterly value in June and July. From July to October the value is stable. About the time the temperature drops below the freezing level in October or November the value starts decreasing until February 1977, when it again reaches the minimum easterly value and remains stable until sometime in May. This pattern continued up to the time that the latest data was available on August 9, 1977. The range in the declination base line value for the first two years of the new operation was 27°01.2'E-26°53.3'E or 7.9 minutes (23$^{\gamma}$).

Comparison of the 7.9 minute range of the new operation with the 72.2 minute range of the old operation shows the range in the declination base line data has been reduced by a factor of 9.1.

The vertical intensity base line values of the old system are not as easy to understand or interpret as the declination values, Figure 6. There are some unexplained shifts in the data during the fall of 1973 and spring of 1974, but it does appear that maximum values occur near the periods of minimum temperatures and minimum values occur near the periods of maximum temperatures. The range in the vertical intensity base line values for the old operation was 55981^{γ}-55786^{γ} or 195^{γ}.

The vertical intensity base line values with the new operation shows the maximum values occurring during the late winter months when the temperatures are the lowest and the minimum values occurring during the summer months when the temperatures are the highest, Figure 7. The range in the vertical intensity base line values for the new operation is 56728^{γ}-56689^{γ} or 39^{γ}.

Comparison of the 39^{γ} range of the new operation with the 195^{γ} range of the old operation shows the range in the vertical intensity base line data has been reduced by a factor of 5.0. Since the vertical element is least sensitive to level changes one would expect a lower improvement factor.

The horizontal intensity base line value of the old operation shows a dramatic shift that takes place at the time of maximum transition between winter and summer in May and June, Figure 8. A search of the available records does not indicate whether these are natural shifts or adjustments made by the observer. The minimum values appear to occur near or after the winter temperatures are the lowest, but in May and June a large shift occurs and the base line values increase sharply. This is near the time when the mean daily temperature goes above the freezing level. After this shift the base line drifts downward until the following summer when another large shift takes place. The range in the horizontal intensity base line value for the old operation was 9445^{γ}-8992^{γ} or 453^{γ}.

The horizontal intensity base line values with the new operation shows the minimum values occurring during the winter months when the temperatures are the lowest and the maximum values occurring during the summer months when the temperatures are the highest, Figure 9. This pattern repeated itself very well during the first two years of operation. The range in the horizontal base line values for the new operation is 9649^{γ}-9620^{γ} or 29^{γ}.

Comparison of the 29^{γ} range of the new operation with the 453^{γ} range of the old operation shows the range in the horizontal intensity base line data has been reduced by a factor of 15.6.

Two periods of data, September 1975 to August 1976 and September 1976 to August 1977, were compared to check the reliability of the new operation, Figure 10. The data shows good repeatability to the extent that unless there was an equipment or instrument failure, it appears that the base line values could be predicted within a few gammas for a three to six month period of time. Unfortunately it cannot always be known if there is a equipment or instrument failure unless the observations are made. It is important to note that with the stability and reliability of the system at Barrow, we have been able to reduce the absolute observation schedule from a weekly schedule to once every seven weeks.

SUMMARY & CONCLUSION

In summary, the first 27 months of operation with the modified recording pier, newly designed absolute piers, and the new instrumentation, shows that the quality and reliability of the base line data at Barrow has been improved by factors of 15.6 for horizontal intensity, 9.1 for declination, and 5.0 for vertical intensity.

The primary reason for this improvement is believed to be due to the modification of the recording instrument pier and new design of the absolute instrument piers, but the installation of the new magnetometer system, and building modification contributed to the improvement. Though not addressed in this paper there was a significant improvement in the stability of the instrument scale values and this is a primary result of the installation of the fluxgate magnetometer.

It is believed that additional improvements in the data can still be made with the complete reconstruction of the recording instrument pier and azimuth mark, using the same design and techniques as those used for the absolute instrument piers.

ACKNOWLEDGEMENTS

Appreciation and thanks are extended to: Dr. Victor Hessler, Professor of Geophysics, Emeritus, University of Alaska, for his review of and suggestions for improvement of this this paper; and Mr. Bruce Alderman of the State of Alaska Materials Laboratory, University of Alaska, Fairbanks, for testing the concrete samples.

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TABLE OF CONVERSION FOR FIGURES 1-10

1 gamma (γ) = 1 nanotesla (nT)
1 inch (") = 2.54 centimeters (cm)
1 foot (') = 30.48 centimeters (cm)

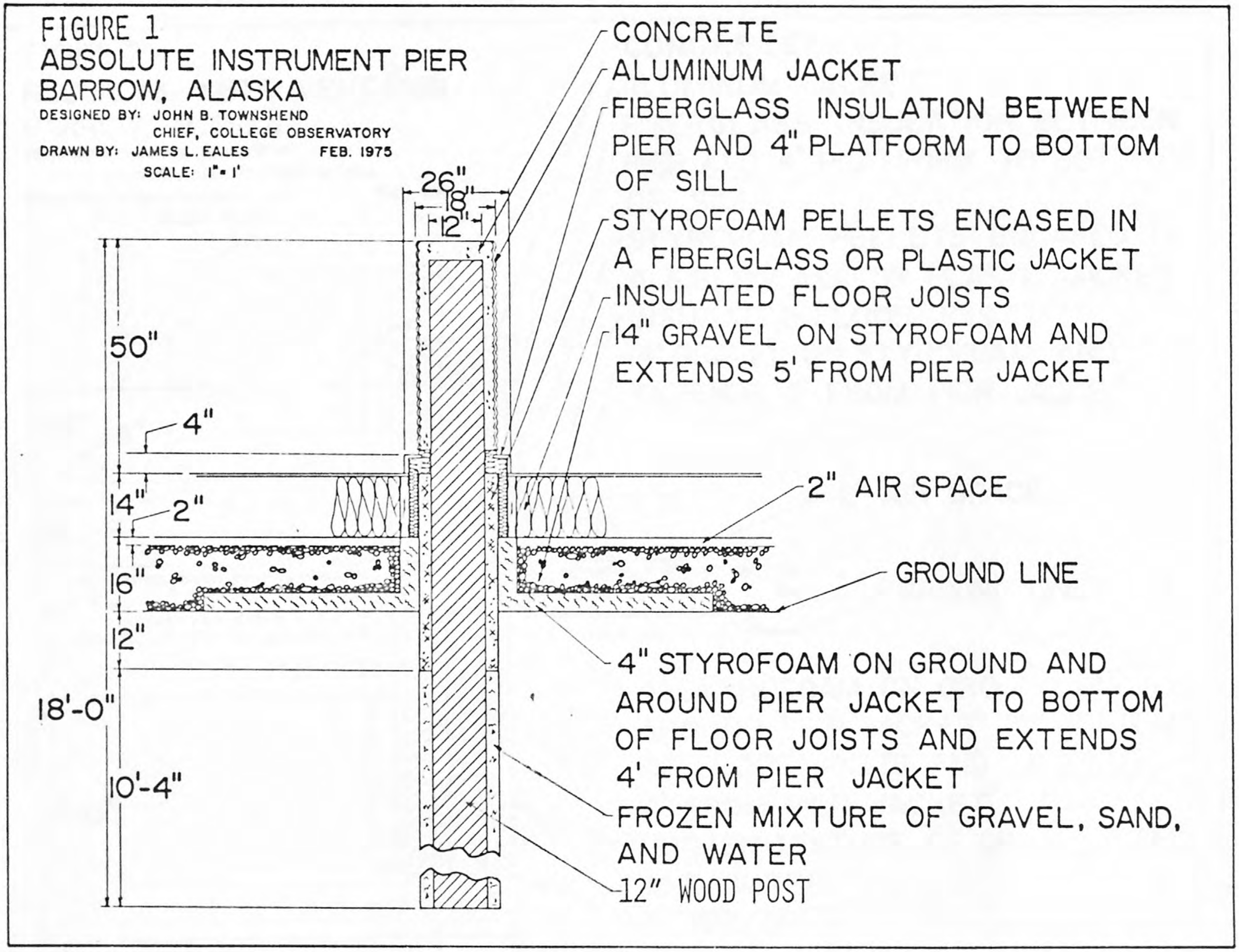


FIGURE 1
ABSOLUTE INSTRUMENT PIER
BARROW, ALASKA
DESIGNED BY: JOHN B. TOWNSHEND
CHIEF, COLLEGE OBSERVATORY
DRAWN BY: JAMES L. EALES FEB. 1975
SCALE: 1" = 1'
26"
18"
12"
50"
4"
14"
2"
16"
12"
18'-0"
10'-4"
CONCRETE
ALUMINUM JACKET
FIBERGLASS INSULATION BETWEEN PIER AND 4" PLATFORM TO BOTTOM OF SILL
STYROFOAM PELLETS ENCASED IN A FIBERGLASS OR PLASTIC JACKET
INSULATED FLOOR JOISTS
14" GRAVEL ON STYROFOAM AND EXTENDS 5' FROM PIER JACKET
2" AIR SPACE
GROUND LINE
4" STYROFOAM ON GROUND AND AROUND PIER JACKET TO BOTTOM OF FLOOR JOISTS AND EXTENDS 4' FROM PIER JACKET
FROZEN MIXTURE OF GRAVEL, SAND, AND WATER
12" WOOD POST

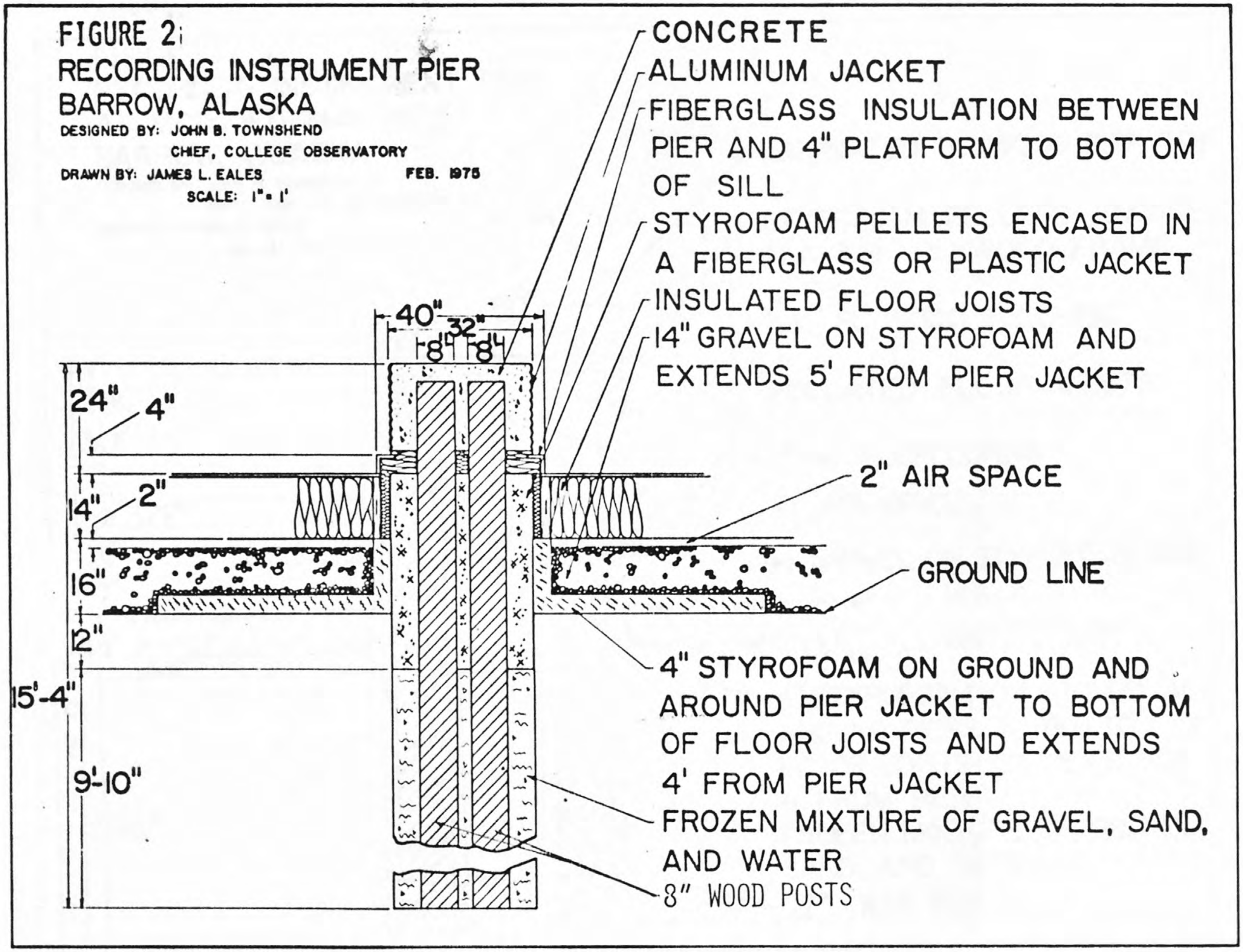


FIGURE 2
RECORDING INSTRUMENT PIER
BARROW, ALASKA
DESIGNED BY: JOHN B. TOWNSHEND
CHIEF, COLLEGE OBSERVATORY
DRAWN BY: JAMES L. EALES
FEB. 1975
SCALE: 1" = 1'
CONCRETE
ALUMINUM JACKET
FIBERGLASS INSULATION BETWEEN PIER AND 4" PLATFORM TO BOTTOM OF SILL
STYROFOAM PELLETS ENCASED IN A FIBERGLASS OR PLASTIC JACKET
INSULATED FLOOR JOISTS
14" GRAVEL ON STYROFOAM AND EXTENDS 5' FROM PIER JACKET
2" AIR SPACE
GROUND LINE
4" STYROFOAM ON GROUND AND AROUND PIER JACKET TO BOTTOM OF FLOOR JOISTS AND EXTENDS 4' FROM PIER JACKET
FROZEN MIXTURE OF GRAVEL, SAND, AND WATER
8" WOOD POSTS
40"
32"
8"
8"
14
14
24"
4"
14"
2"
16"
12"
15'-4"
9'-10"

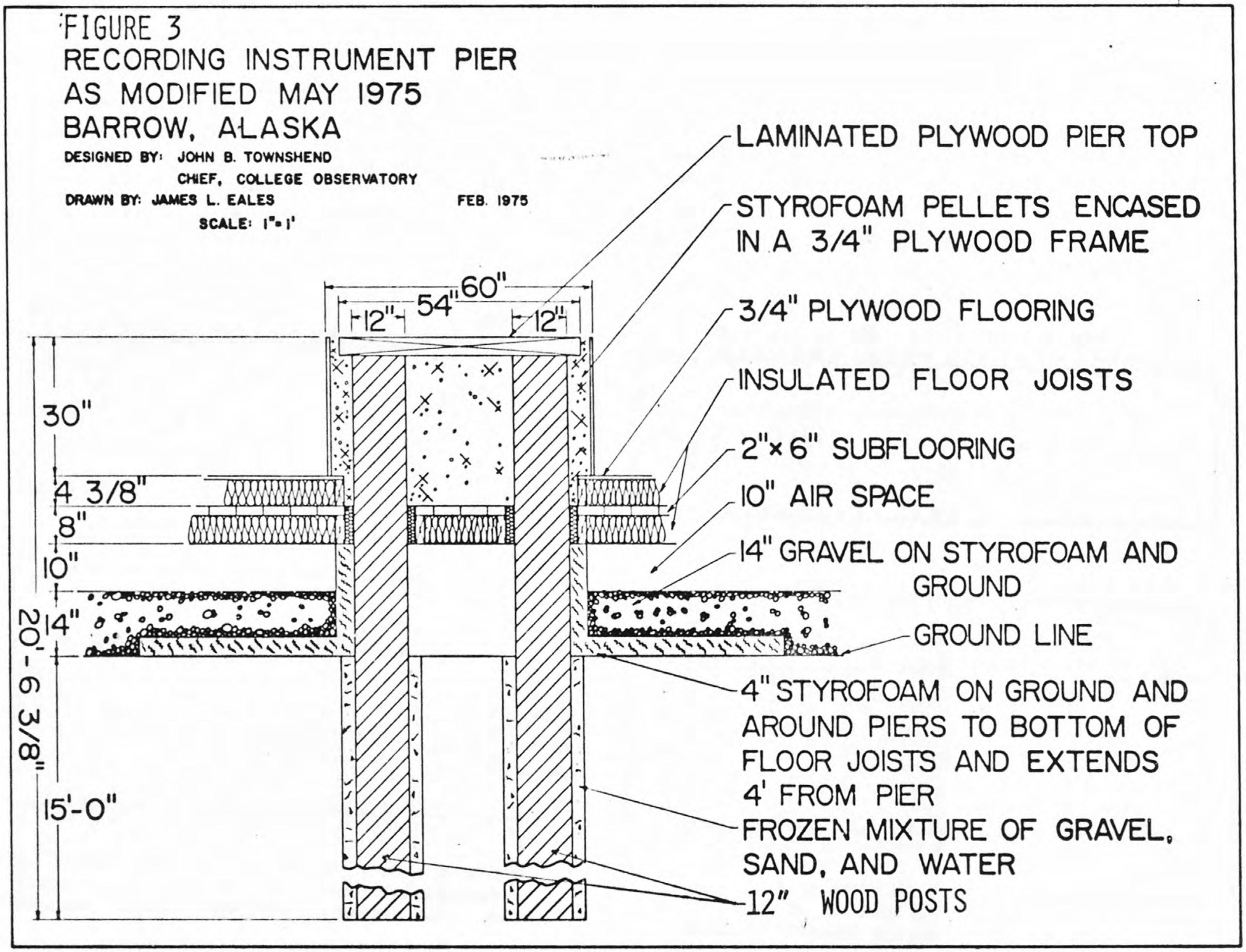


FIGURE 3
RECORDING INSTRUMENT PIER
AS MODIFIED MAY 1975
BARROW, ALASKA
DESIGNED BY: JOHN B. TOWNSHEND
CHIEF, COLLEGE OBSERVATORY
DRAWN BY: JAMES L. EALES
FEB. 1975
SCALE: 1"=1'
60"
54"
12"
12"
30"
4 3/8"
8"
10"
14"
20'-6 3/8"
15'-0"
LAMINATED PLYWOOD PIER TOP
STYROFOAM PELLETS ENCASED IN A 3/4" PLYWOOD FRAME
3/4" PLYWOOD FLOORING
INSULATED FLOOR JOISTS
2"×6" SUBFLOORING
10" AIR SPACE
14" GRAVEL ON STYROFOAM AND GROUND
GROUND LINE
4" STYROFOAM ON GROUND AND AROUND PIERS TO BOTTOM OF FLOOR JOISTS AND EXTENDS 4' FROM PIER
FROZEN MIXTURE OF GRAVEL, SAND, AND WATER
12" WOOD POSTS

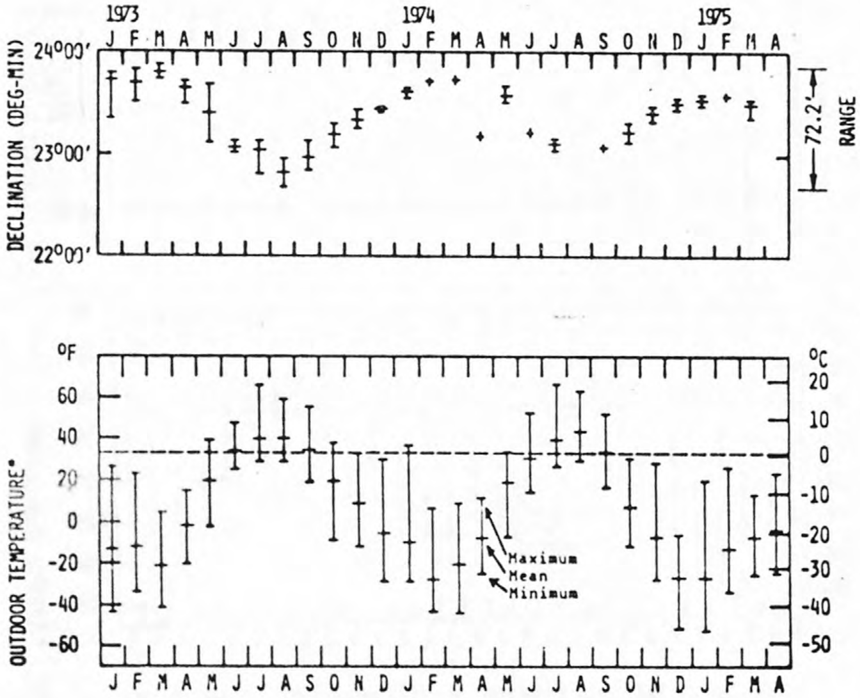


FIG. 4 BARROW OBSERVATORY DECLINATION BASE LINE VALUES AND OUTDOOR TEMPERATURE. JANUARY 1973-APRIL 1975. CONVENTIONAL MAGNETOGRAPH, PHOTOGRAPHIC RECORDING. *TEMPERATURE DATA-NOAA NWS, BARROW AIRPORT.

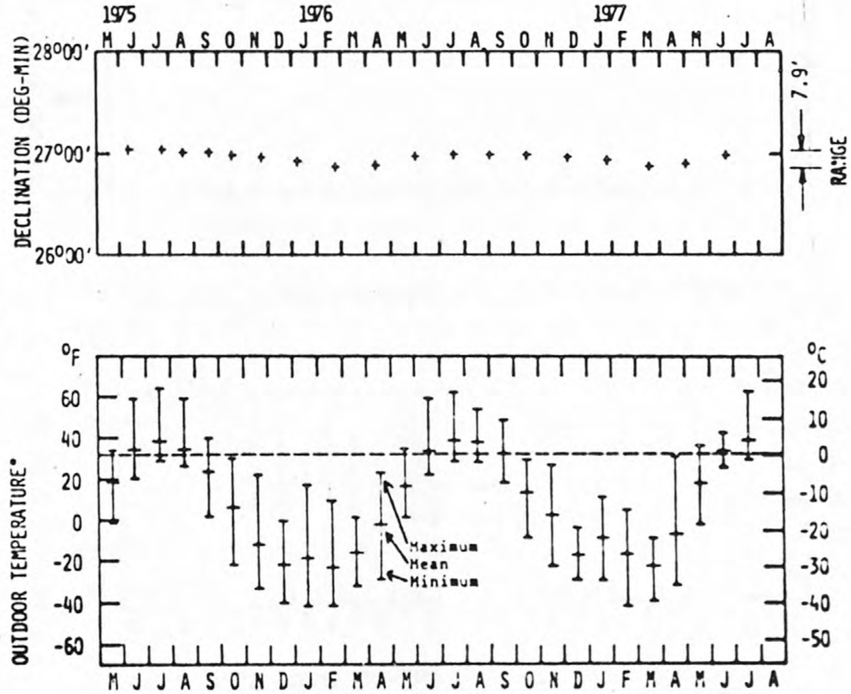


FIG. 5 BARROW OBSERVATORY DECLINATION BASE LINE VALUES AND OUTDOOR TEMPERATURE. MAY 1975-AUGUST 1977. FLUXGATE MAGNETOMETER, DIGITAL RECORDING. *TEMPERATURE DATA-NOAA NWS, BARROW AIRPORT.

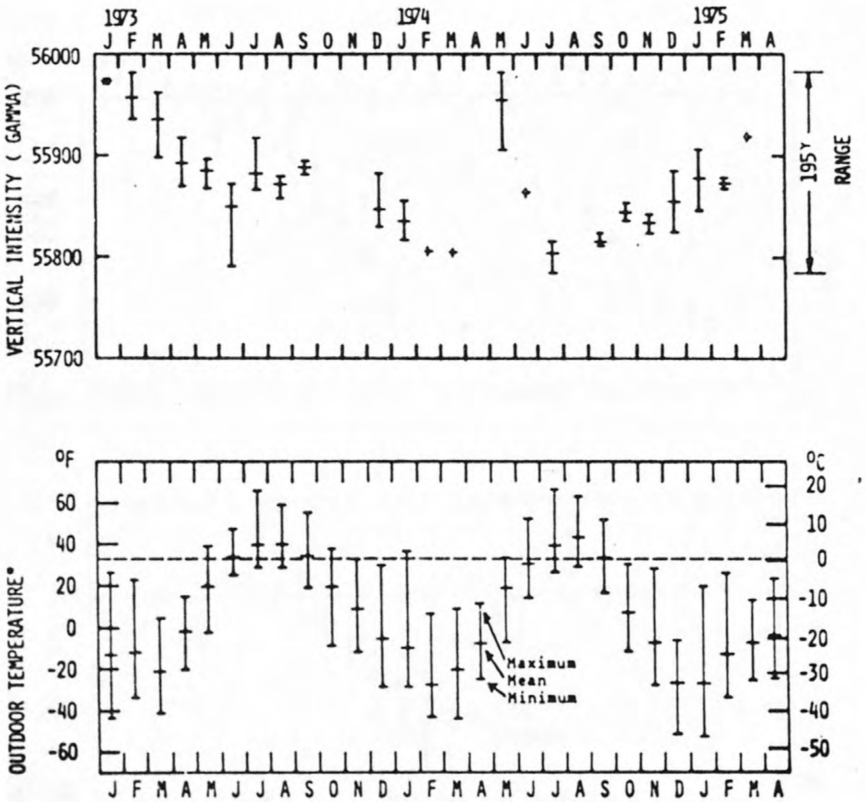


FIG. 6 BARROW OBSERVATORY VERTICAL INTENSITY BASE LINE VALUES AND OUTDOOR TEMPERATURE. JANUARY 1973-APRIL 1975. CONVENTIONAL MAGNETOGRAPH. *TEMPERATURE DATA-NOAA NWS, BARROW AIRPORT.

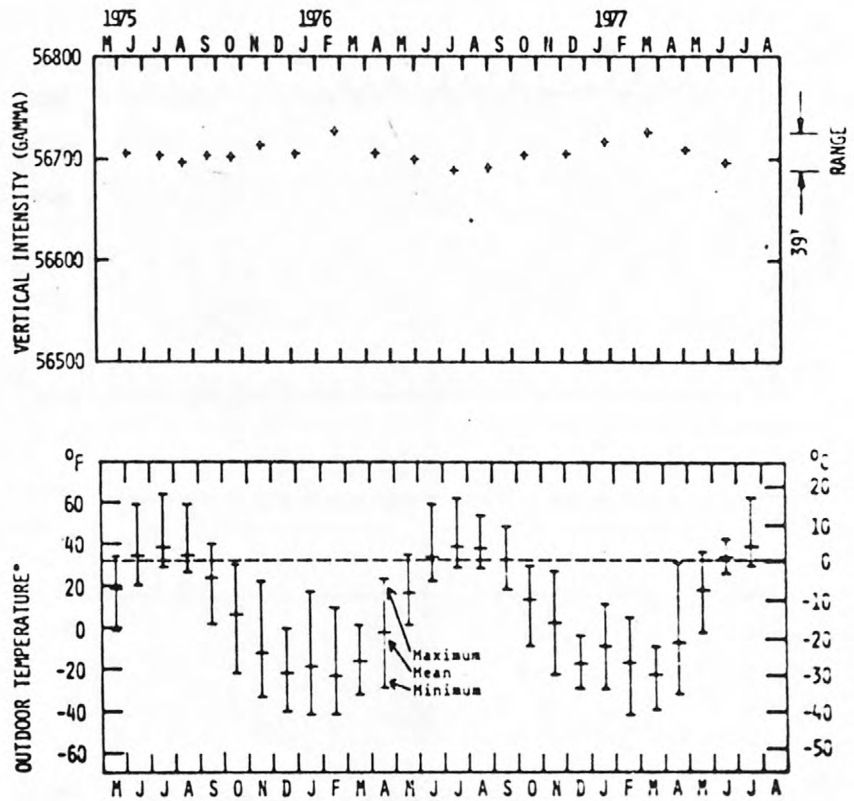


FIG. 7 BARROW OBSERVATORY VERTICAL INTENSITY BASE LINE VALUES AND OUTDOOR TEMPERATURE. MAY 1975-AUGUST 1977. FLUXGATE MAGNETOMETER. DIGITAL RECORDING. *TEMPERATURE DATA-NOAA NWS, BARROW AIRPORT.

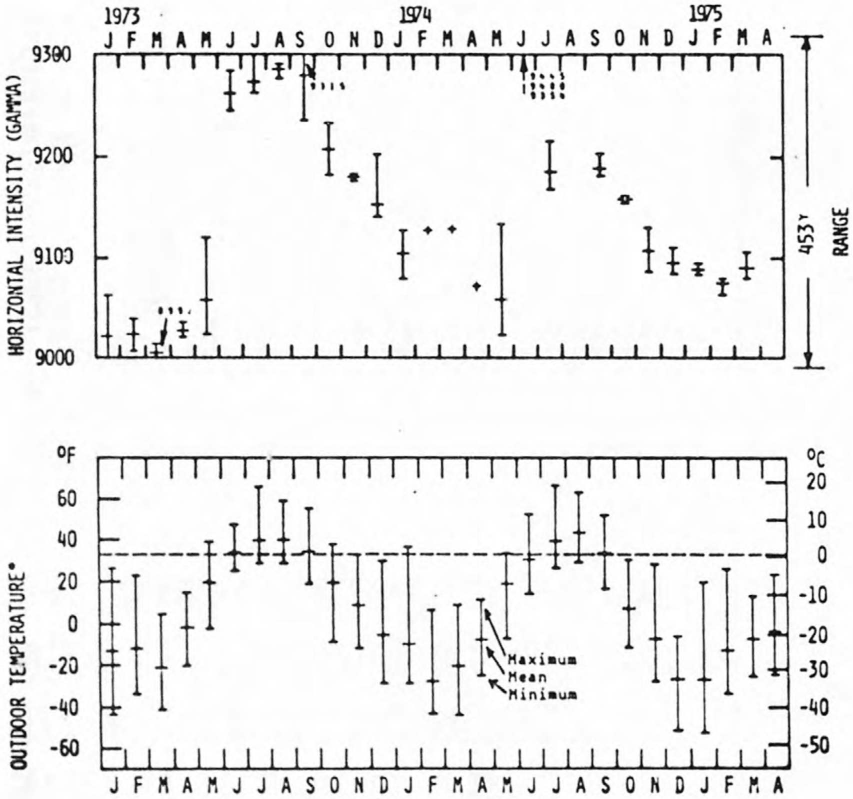


FIG. 8 BARROW OBSERVATORY HORIZONTAL INTENSITY BASE LINE VALUES AND OUTDOOR TEMPERATURE. JANUARY 1973-APRIL 1975. CONVENTIONAL MAGNETOGRAPH. *TEMPERATURE DATA-NOAA NWS, BARROW AIRPORT.

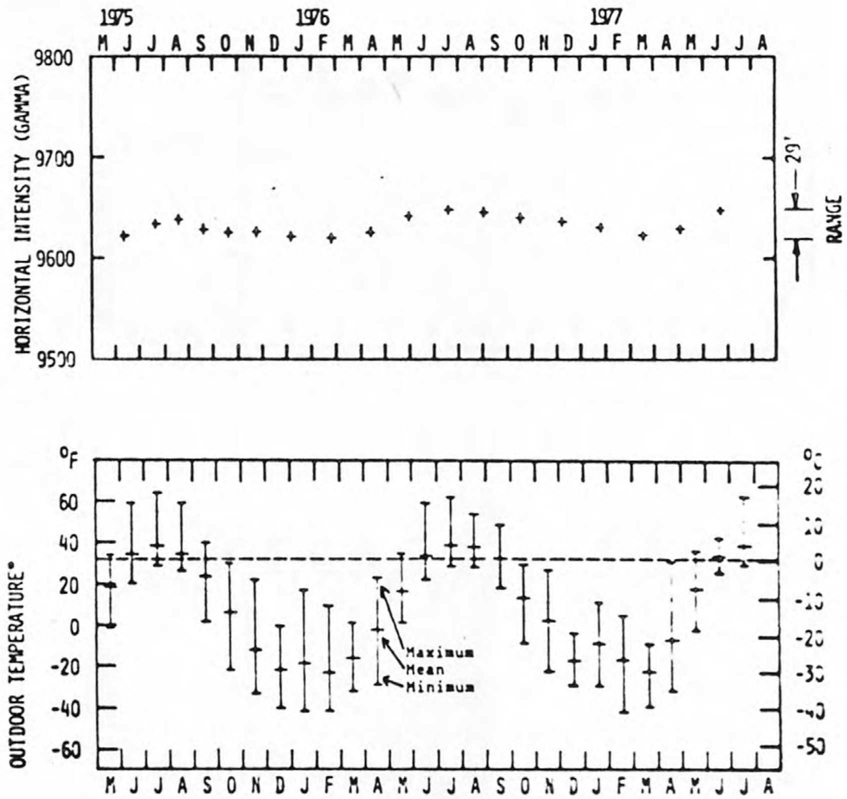
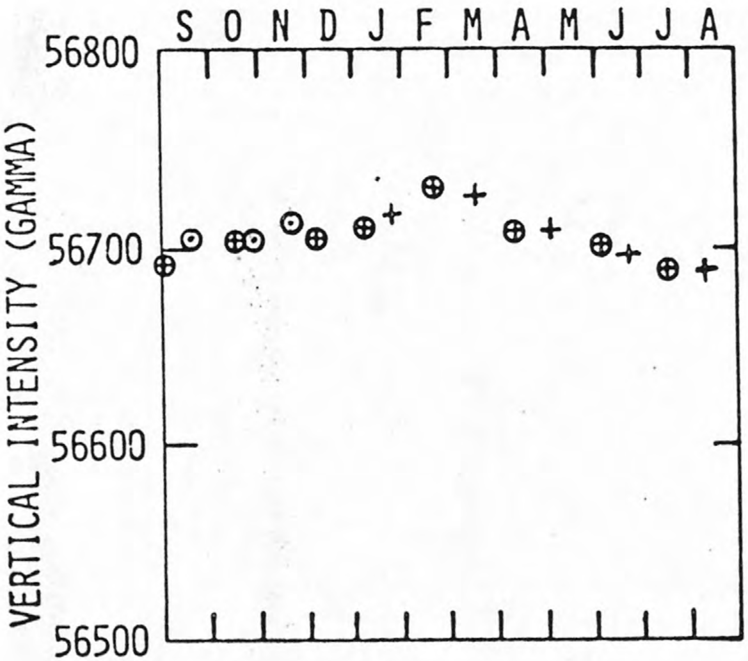


FIG. 9 BARROW OBSERVATORY HORIZONTAL INTENSITY BASE LINE VALUES AND OUTDOOR TEMPERATURE. MAY 1975-AUGUST 1977. FLUXGATE MAGNETOMETER. DIGITAL RECORDING. *TEMPERATURE DATA-NOAA NWS, BARROW AIRPORT.



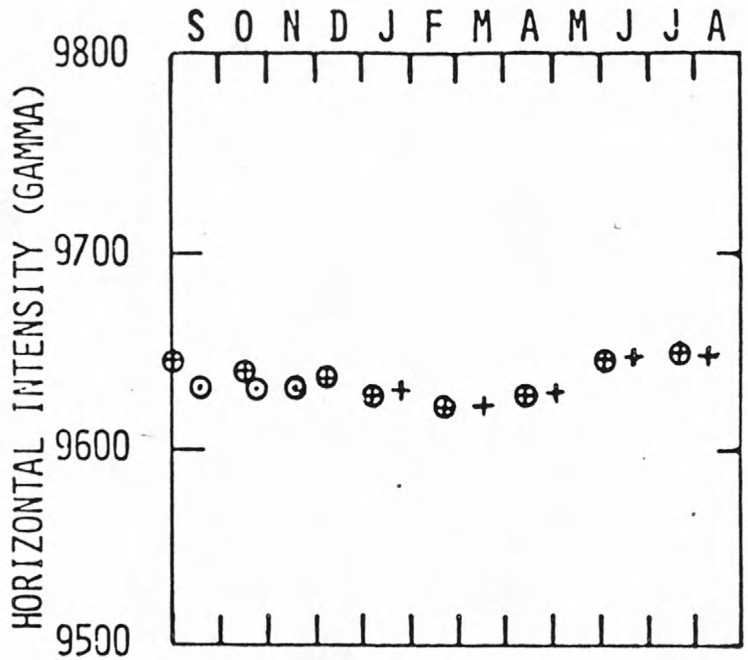


FIG. 10 BARROW OBSERVATORY VERTICAL INTENSITY, HORIZONTAL INTENSITY AND DECLINATION BASE LINE VALUES. SEPTEMBER 1975-AUGUST 1977.

+ 1977 : ⊕ 1976 : ⊙ 1975