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Technical Memorandum

title: MOTION MEASUREMENT EXPERIMENT: TEST EXECUTION AND DATA SUMMARY, VOLUME I

author: R. Zueck, D. Shields, B. Harris, and W. Bartel

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NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

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Technical Memorandum

6149TM

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By

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EXECUTIVE SUMMARY

This document describes the chronological execution of the Motion Measurement Experiment (MME) and summarizes the data collected. This is the fifth document in a series of related NCEL Technical Memorandums:

(1) "Offshore Air Combat Training Facilities Technology Development Plan", Shields (1983).

(2) "Motion Measurement Installation Plan", Taylor et al. (1986)

(3) Column Stabilized Platform Software (CSPS) with Quasi-Static Mooring Systems", Zueck et al. (1985)

(4) "Motion Measurement Experiment: Description and Test Plan", Zueck et al. (1986)

The MME was operational through two storm seasons: May 1986 through May 1987 and January 1988 through March 1988. The MME was executed to provide a database for validating computer methods which simulate the nonlinear response of small deepwater semisubmersible platforms to a range of ocean environmental loading. The goal of the MME was to subject this small, deepwater semisubmersible platform to a sequence of known environmental events and measure the resulting response.

The MME site, located in the Santa Monica Basin off Southern California, was chosen because of its proximity to NCEL, our knowledge of conditions at the site, and budgetary constraints. During winter months, the site received large directional swell from the northwest and during the summer months the site received smaller swell from the south. These directional environmental conditions will result in fewer modeling unknowns and thus more precise validation.

The MME semisubmersible platform was designed to a scale which gave high probability of experiencing extreme environmental conditions in one annual storm season. The natural periods of the structure were designed to be in the range of expected wave periods to assure semisubmersible motion at frequencies above and below resonance. In addition, the semisubmersible hull was designed to be simple in form to ease the burden of numerically modeling the structure and improve validation accuracy.

During the execution of the MME, we performed instrument maintenance and generator refueling on a regular basis and as needed. We also added an instrumented test cylinder to the MME semisubmersible hull to measure hydrodynamic loads directly. This cylinder was successful in collecting data from a few moderate environmental events before failing. The acoustic positioning system was partially replaced several times and completely replaced once before it operated to our fullest satisfaction. Most of the other instrumentation performed admirably considering the high level of exposure, remoteness of the site, and the long length of service.

All instrumentation was calibrated prior to deployment and during execution of the MME to ensure accurate measurement quality. Obviously, more measurement uncertainty is acceptable for a long-term at-sea experiment than for a short-term laboratory test.

In order to provide baseline data for calibrating the simulation models, we performed several controlled free vibration and imposed displacement tests on the semisubmersible platform. These tests were important in determining simple modeling properties such as damping factors, and natural periods.

A tremendous volume of data was collected during the course of the MME. Using a remote environmental data collection subsystem, we periodically collected statistical data characterizing the local wave, current and wind conditions at the MME site.

At selected regular time intervals and especially during significant environmental events, we collected time-series data using the semisubmersible instrument subsystem. With proper data reduction and processing, information can be obtained from this time series data to characterize the immediate environment near the semisubmersible platform and the platform's response to this environment. Of the 1600 hours or 112 gigabytes of this raw time-series data, we have identified several moderate and one very extreme environmental event. No significant environmental event passed without being recorded.

Several specific data sets from the 1987 winter season have been identified, transferred to appropriate magnetic media, processed into meaningful measurements, analyzed for quality, reduced for platform motion, and organized into a database for validation. They represent a wide spectrum of storm conditions including events of high, long-period swell, events of steep, short-period wind waves, and combinations of both swell and wind waves. Extensive review has insured that these data sets possess good measurement quality.

A "50-year" storm occurred during the 1988 winter season. The environmental conditions measured during this storm exceeded those used in designing the platform. The platform survived and only minor damage was sustained. With this storm we surpassed the Motion Measurement Experiment (MME) data collection goal of 20 feet significant wave height by 6 feet.

Section one of this report introduces the reader to the MME. It provides background information and the design and analysis philosophy and defines the project objectives, validity of the experiment, and a summary of the data collected.

Section two provides a description of the MME, the purpose of the experiment, a description of the instrumentation, data acquisition, power, telemetry, remote environmental subsystems, and a description of the direct load measurements made by the instrumented test cylinder.

Section three presents details of the test execution including a chronological summary of the events of the MME, the weather conditions encountered, instrument performance, data collection and availability, and an assessment of the biofouling.

Section four provides instrumentation calibration information, including pre-test physical calibration, real-time electrical calibration, and instrumented test cylinder calibration.

Section five is a review of the remote environmental data, the NDBC directional wave buoy and the NAVOCEANO current meter array. This section includes a description of the various storm events selected for model validation, and a description of storm probability for the MME site.

Section six describes the Semisubmersible environmental data, including the winds, waves, and currents. Section seven summarizes the semisubmersible response data from the extinction and imposed displacement tests and from selected storm events. Platform modeling properties are also presented. Section eight is a conclusive summary of the MME.

With the experiment concluded, the MME database is now generally sufficient for validating the deepwater dynamic response numerical models for the proposed OCEANA Tactical Aircrew Combat Training System (TACTS). We have data for both the extreme design and less severe operational hydrodynamic regimes of the proposed OCEANA deepwater platforms. We have selected appropriate data sets or weather windows for a "full spectrum" validation.

The extremely interesting platform responses observed in this storm data set should lead to a significantly enhanced understanding of TACTS range deepwater small semisubmersible platforms and their associated dynamic response simulation models.

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1.0 BACKGROUND

1.1 Project Objectives

The Motion Measurement Experiment (MME) is a significant part of the Offshore Aircrew Combat Training Facilities Technology Development Program at the Naval Civil Engineering Laboratory (NCEL). The objective of this program is to develop technology necessary to design and construct reliable and cost effective unmanned ocean platforms for deepwater, 182 to 3,050 m (600 to 10,000 ft) applications. The specific objectives of this development program which directly apply to the MME are:

A. Develop, modify, integrate and validate computer algorithms for simulating the motions of deepwater moored platforms.

B. Develop a data base on the performance of deepwater moored buoyant platforms in extreme seas.

C. Develop an installation methodology which may be extrapolated to prototype platforms.

Investigations of various candidate platforms, e.g., discus buoys, boat buoys, spar buoys, semisubmersible, etc., identified the semisubmersible concept as the most suitable platform type, Shields et al. (1983). Technology deficiencies were identified and a research program was developed based on the use of the small semisubmersible platform concept with research in four areas: hydrodynamics, motion simulation models, reliability, and mooring components. The work breakdown structure (WBS) developed in the technical development plan is shown in Figure 1.1. The Motion Measurement Experiment comes under Platform Motion Prediction WBS 2.0.

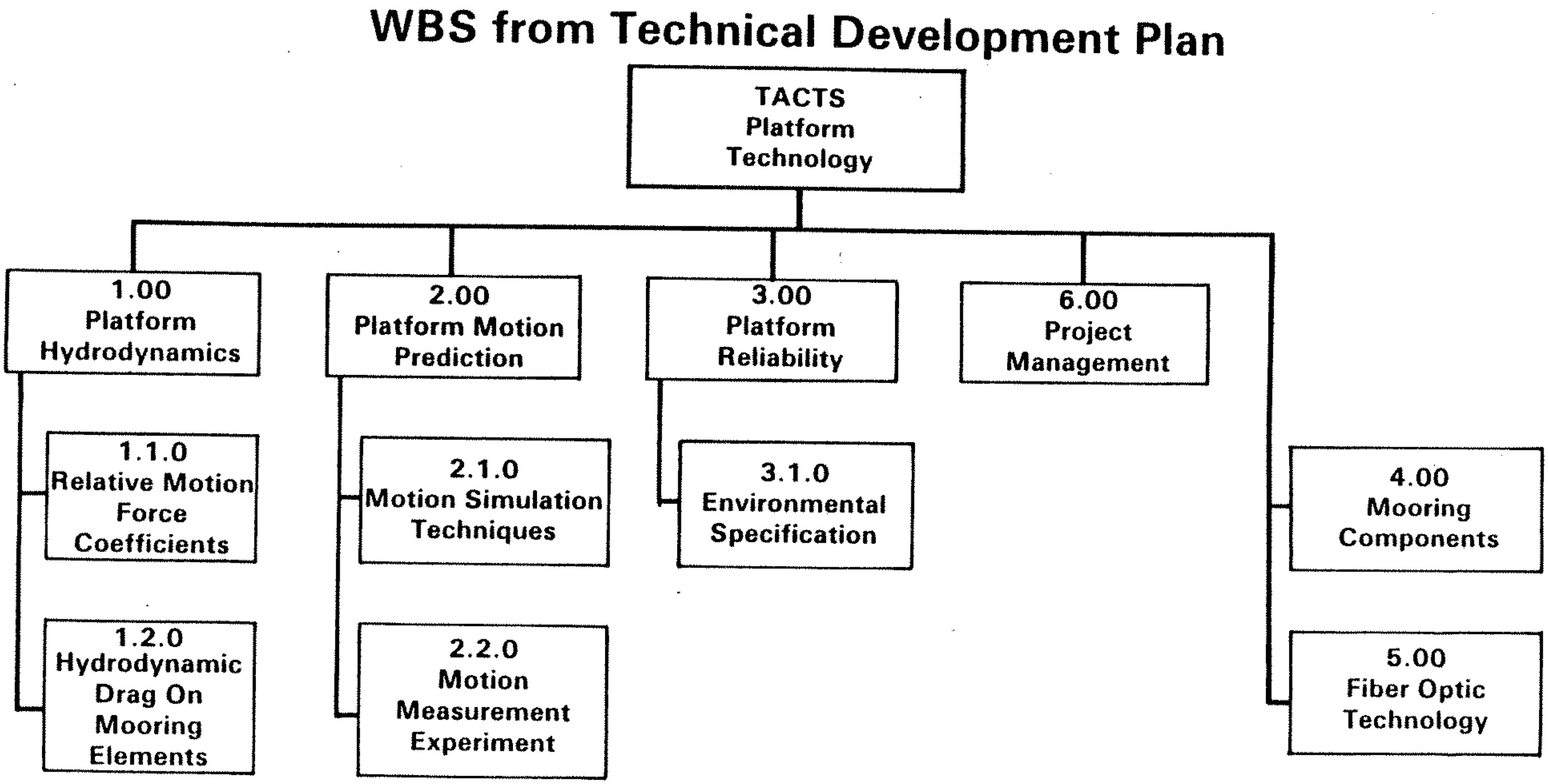


Figure 1.1. Work Breakdown Structure

1.2 Design and Analysis Philosophy

At NCEL, the procedures for the design and analyses of moored floating structures include three steps:

(1) static mooring analysis to obtain the equilibrium position due to gravity and dead loads.

(2) static mooring analysis to obtain a mean offset position due to assumed static loads produced by current, wind, wave drift forces, etc.

(3) nonlinear dynamic motion analysis produced by time-varying wave and wind loads.

Techniques for modeling the mooring system range from simple linear springs to complex finite elements as shown in Figure 1.2. Presently suitable techniques for simulating the dynamic response of large semi-submersibles, model the mooring system with either linear springs or catenary equations. For large semisubmersibles moored in shallow water these techniques have proven to be adequate. For small semisubmersible buoys in deep water, the current-induced hydrodynamic loading on the mooring legs may become equal to or greater than the hydrodynamic force on the floating platform alone. In this case, finite elements were found to be most appropriate to model the mooring legs, Shields and Zueck (1984). The finite element model provides an excellent representation of a three dimensional mooring shape, restoring force, and static environmental load along the entire mooring length. This results in a more accurate prediction of the restoring force, tension and mooring shape.

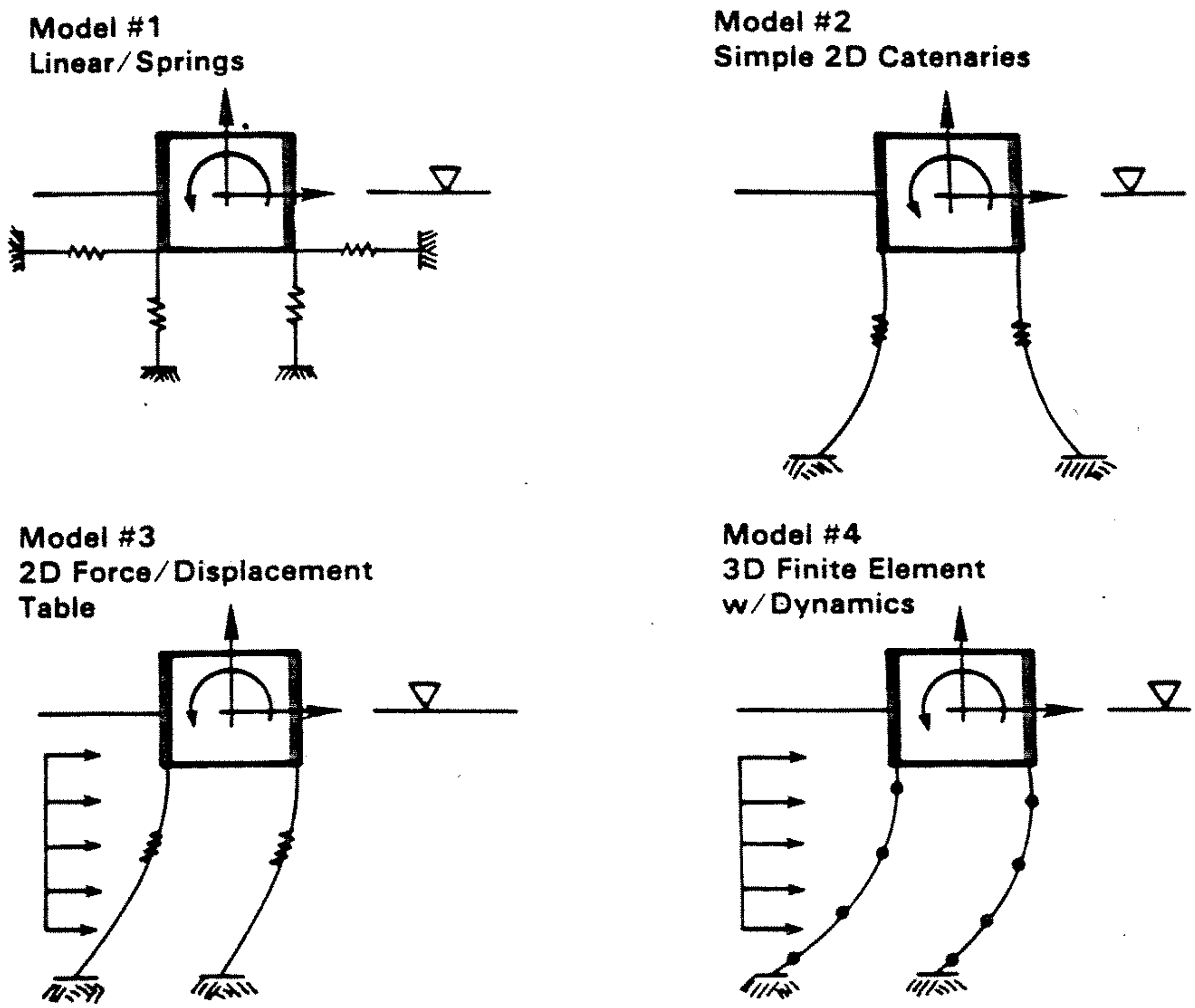


Figure 1.2. Mooring Models for Deep Water Platforms

Techniques for modeling the wave-induced hydrodynamic loadings on space-frame structures such as the semisubmersible hull depend on both the member size (the member diameter, D, is commonly used) and the design wave conditions (wave height, H, and wave length, L). It is generally acknowledged that for $L/D < 10$ and $H/D < 1$, potential theory for an ideal fluid should be used, Shields and Hudspeth (1985). For $L/D > 10$ and $H/D > 1$, an approach which includes viscous effects should be used. The hyrodynamic loading regimes are shown in Figure 1.3.

For fixed pile-founded steel jacket structures where the second condition usually exists, the Morison Equation is applied to compute the wave-induced hydrodynamic force, Shields and Hudspeth (1985). In the Morison equation, $\mathbf{F}$ is the force vector per unit length acting normal to the member axis, and is given as

$$\mathbf{F} = 1/2\ \rho\ C_D\ D\ \mathbf{u}|\mathbf{u}| + \rho \frac{\Pi}{4} D^2\ C_M\ \dot{\mathbf{u}} \qquad (1.1)$$

where ρ = mass density of water,

C_D = drag coefficient

$\mathbf{u}$ = fluid velocity vector (wave + current) normal to the member axis

C_M = inertia coefficient

$\dot{\mathbf{u}}$ = fluid acceleration vector normal to the member axis Equation (1.1) has been extended to compliant structures, e.g., guyed towers, articulated towers, tension leg platforms and moored semisubmersibles, in the form of the relative-motion Morison equation (also referred to as the modified wave force equation (MWF)), and is given as

$$\mathbf{F} = 1/2\ \rho\ C\ \ D|\mathbf{u}_D - \mathbf{x}|\ (\mathbf{u} - \mathbf{x}) + \rho \frac{\Pi}{4} D^2\ (C_M - 1)\ (\mathbf{u} - \ddot{\mathbf{x}}) + \rho \frac{\Pi}{4} D^2\ \dot{\mathbf{u}} \qquad (1.2)$$

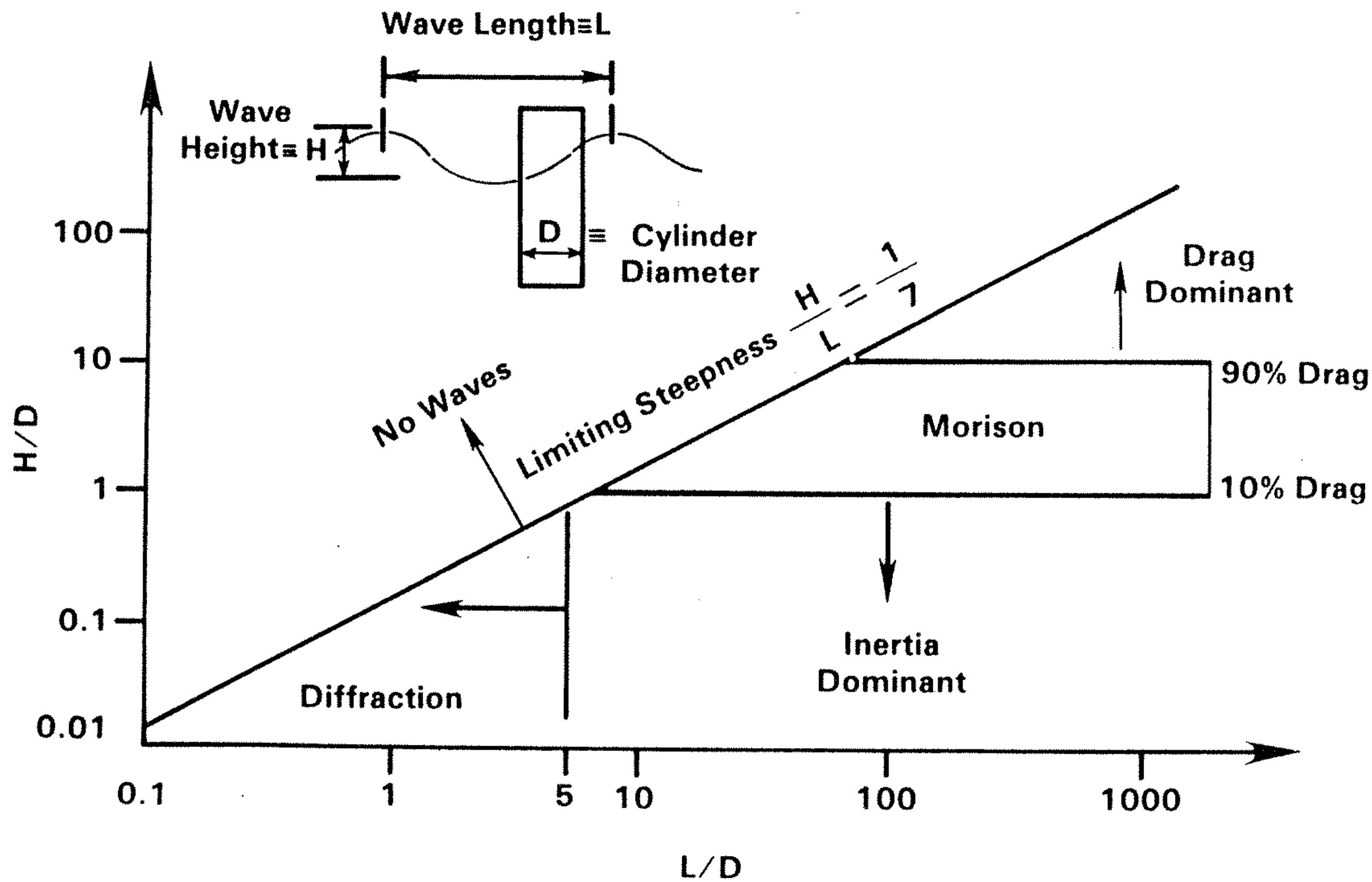


Figure 1.3. Hydrodynamic Loading Regimes

where:

$\dot{x}$ and $\ddot{x}$ = velocity and acceleration vectors of the member normal to its axis.

Kim and Hibbard (1975) and Miller and McGregor (1978) have discussed the problem of obtaining design values for C_D and C_M for Equation (1.1) from wave tank studies due to the inability to simultaneously satisfy the hydrodynamic similitude for both Reynolds and Keulegan-Carpenter numbers with respect to Froude number. This problem has led to numerous large-scale ocean tests to obtain design values for C_D and C_M.

Studies involved in the dynamic analysis of the small deepwater semisubmersible concept indicates that a coupled dynamic analysis of the coupled platform and mooring system should be used, Zueck and Shields (1986). In order to perform accurate dynamic analysis of small semisubmersible platforms moored in deep water, the SEADYN computer program, Palo et al. (1983) has been coupled with Column Stabilized Platform Software (CSPS), Zueck et al. (1985). The coupling concept is discussed in Zueck and Shields (1986) and the basic CSPS models are described in Paulling (1970 and 1977). Problems with the SEADYN computer program has lead to the abandoning of the coupled CSPS/SEADYN package.

The replacement general purpose coupled software models now being developed by NCEL are based on automatic self-sensing non-linear solution schemes. The basis for this model is ANSR-III, Oughourlian (1982), which has been extended to include hydrodynamic effects for the analysis of tethered buoys, platforms, semisubmersibles, flexible risers, fixed base platforms and compliant towers. This extended software model called SEASTAR uses similar elements to model both the semisubmersible hull and the mooring systems.

When complex simulation models are developed, comprehensive validation is required to assess the accuracy of its simulation techniques. To acquire validation data, a representative experiment is usually conducted. For ocean engineering problems in general, it is most desirable to conduct a large-scale model experiment of the prototype as previously discussed, because of the lack of effects introduced by the hydrodynamic similitude problem.

1.3 Validating Experiment

The Motion Measurement Experiment (MME) was designed to:

(a) acquire benchmark data that can be used to validate the coupled SEASTAR model and evaluate similar response simulation models which commercial engineering design firms may propose to use on Navy designs;

(b) acquire performance data on the small semisubmersible concept and on synthetic mooring lines for developing improved design procedures;

(c) develop a baseline installation procedure for the platform and mooring system;

(d) develop instrumentation data processing systems for use in prototype platform monitoring and verification.

The advantages of this large-scale model ocean test are that:

(a) hydrodynamic similitude problems are minimized;

(b) the scale ratio was selected so that an extreme environmental event has a high probability of occurrence during the experimental period and;

(c) realistic platform response is obtained because mooring system dynamics are being correctly modeled.

The MME was conducted at a site 46.9 km (25.3 nm) south-southeast of Port Hueneme, California, in a water depth of 887 m (2,910 ft) (Figure 1.4). The experiment was operational from April 1986 until June 1987 and again from January 1988 until March 1988. Meteorologic, oceanographic, platform motion, mooring tension and platform position data were collected during this time frame.

The MME field test layout is schematically illustrated in Figure 1.5. The MME consisted of a specially built semisubmersible platform and associated remote environmental sensing systems. A full description of the MME is given in Section 2.0. A three-column semisubmersible was designed for use in the MME. This triangular-spaced platform was composed of 1.5-m (5-ft) diameter columns connected at their base by 1.4-m (4.5-ft) diameter pontoons. The columns were on 15.2-m (50-ft) center-lines and were 10.1 m (33 ft) in length. The platform had a draft of 6.1 m (20 ft) and displaced 97,942 kg (96.4 long tons). Operation components on the deck included: instrumentation house, battery box, generator, and diesel fuel tank. A three-point mooring was used. Each mooring leg was 1,341 m (4,400 ft) long and was composed of a chain platform pendant, polyester line, anchor chain, and anchor.

The semisubmersible was instrumented for daily time-series measurement of the local environment and the platform response to that environment. Sensors measuring relative wave height, relative water particle velocity components, relative wind speed, and direction, mooring line tension and six degree of freedom platform motion were sampled and recorded at 3.3 Hz for specified lengths of time (usually four hours)

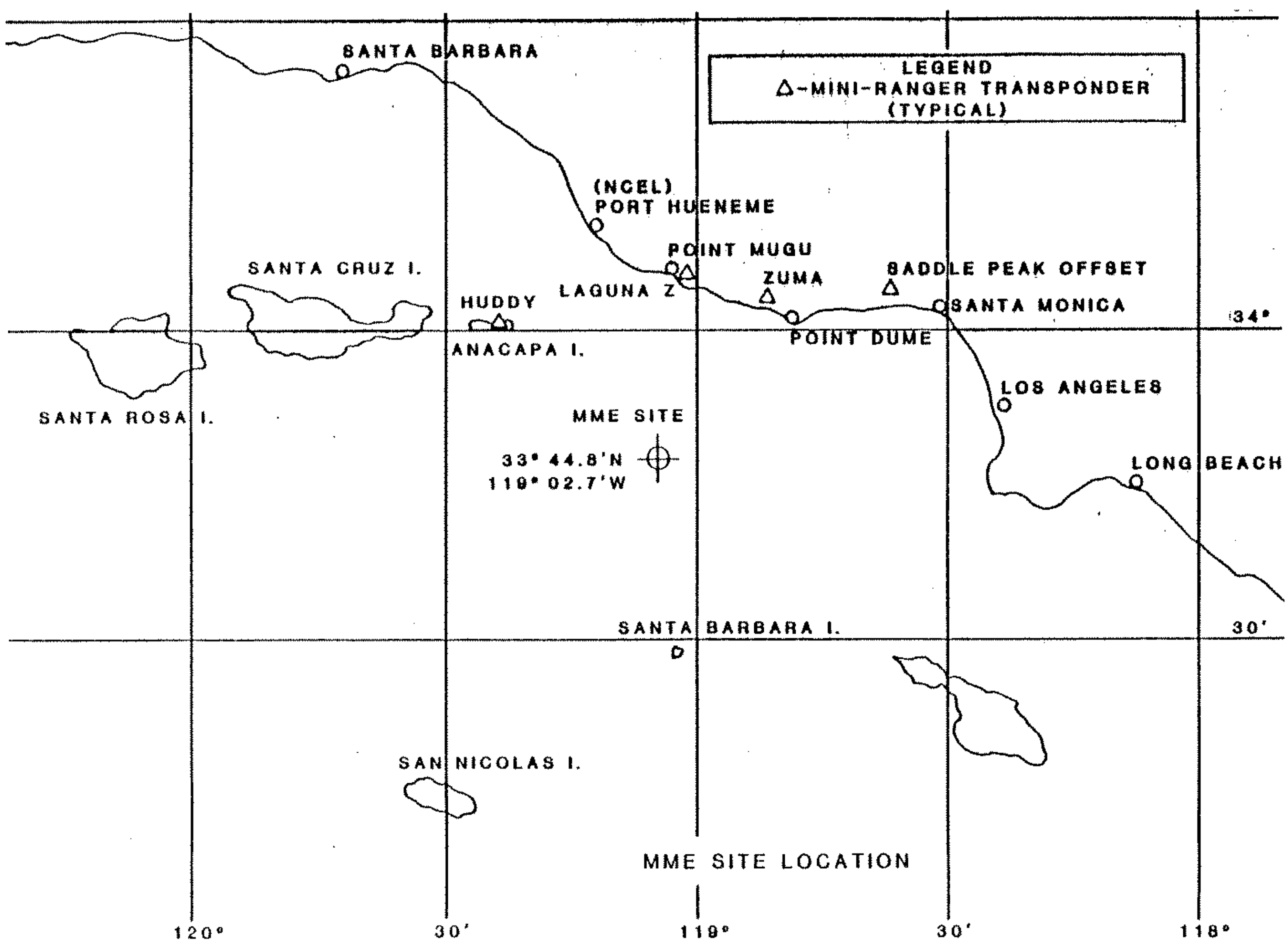


Figure 1.4. MME Site Location

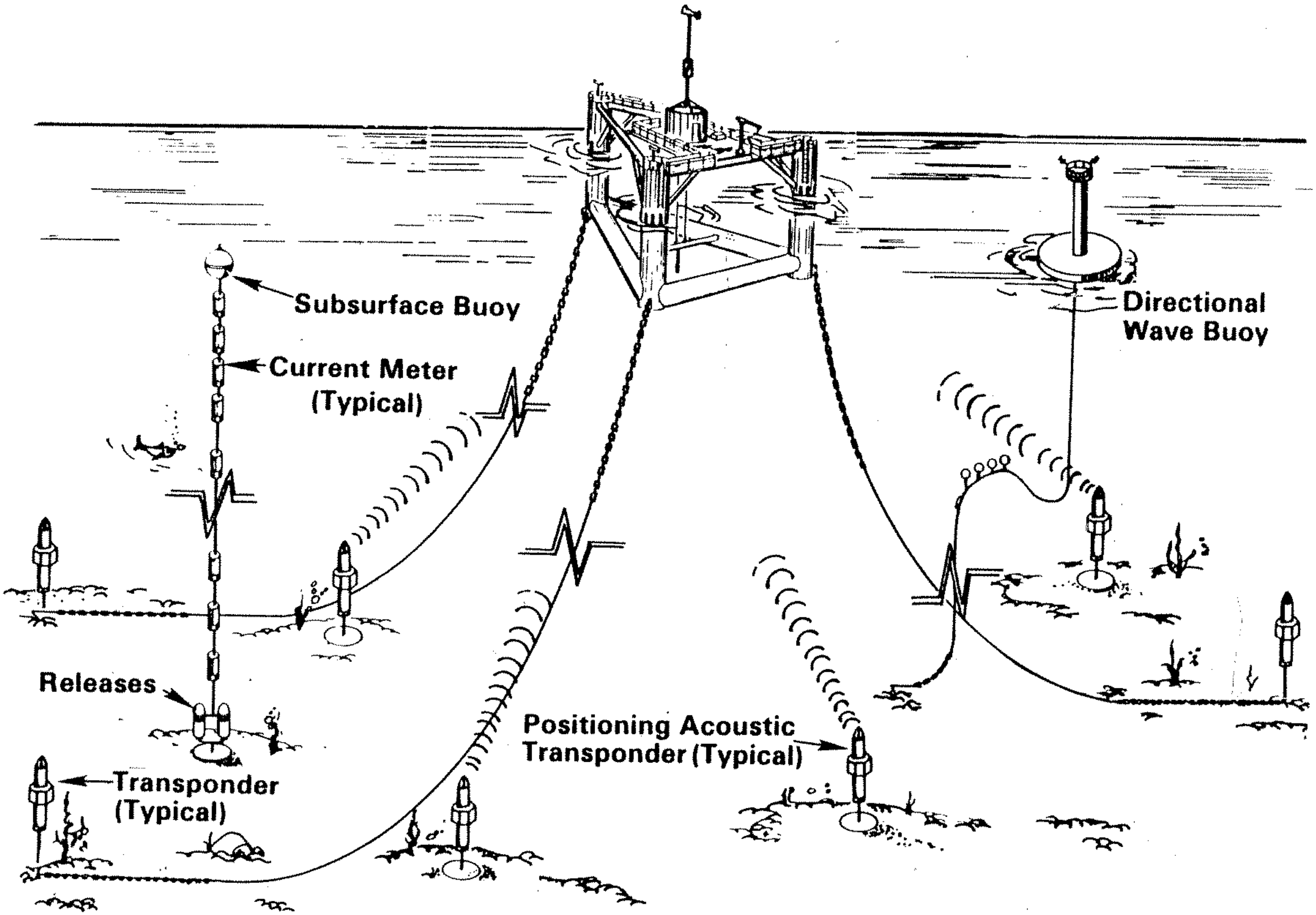


Figure 1.5. MME Field Test Layout

each week day. Platform position in its watch circle and anchor position was calculated by the acoustic positioning system every seven or eight seconds (approximately 0.14 Hz).

Direct wave and current loads were measured by an instrumented test cylinder. The cylinder was instrumented with 8 pressure sensors arranged circumferentially and two force load cells at each end of the cylinder. Calibration of the instruments aboard the semisubmersible and of the acoustic position system is given in Section 4.0.

Several controlled tests were performed to determine significant properties about the semisubmersible hull and its mooring system. These tests included the following:

(a) An inclining experiment, performed in the Port Hueneme Harbor, to determine hydrostatic properties.

(b) An extinction test, performed in the Port Hueneme Harbor, to determine heave, pitch and roll natural periods and damping properties.

(c) An imposed displacement test, performed at the ocean test site, to determine surge, sway and yaw motion characteristics.

The data for these tests provide a fundamental baseline behavior for initial calibration of numerical models of the semisubmersible. The numerical models must predict the fundamental properties measured by these controlled tests before they can be expected to predict response to a confused storm environment. The particulars of these controlled tests are given in Section 7.0.

Separate sensors system packages were used to measure general meteorological and oceanographic conditions. A vertical current meter array measured the spatial distribution of current velocities and temperature for 15 minute averages. A 10-m (33-ft) discus buoy provided directional and nondirectional wave spectra, wind speed and direction, and other environmental parameters once every hour. Information from these remote sensors helped identify storm events and characterize the site environmental conditions preceeding, during and proceeding the periodic recording sessions of semisubmersible platform data.

Based on actual data collected, the MME has been a success. The MME platform was deployed for two annual time frames. The MME platform was designed to survive a storm with a probable maximum wave height of 13.4 m (44 ft). The largest recorded wave was approximately 13.7 m (45 ft). This event occurred January 17, 1988. The platform survived and no significant damage occurred despite some probable slight column over-topping and waves slapping the deck bottom. Several significant environmental events other than the one described above were captured. These included storms dominated by long-period swell, storms dominated by short-period wind-waves, and events with fairly high currents.

The MME instrumentation, with periodic scheduled maintenance, performed almost flawlessly, except for initial problems with the long-baseline acoustic position system. This system was replaced with that of another manufacture on March 4, 1987, and performed satisfactorily thereafter. The instrumented test cylinder was installed on February 26, 1987, but failed within two days. It was removed, repaired, and re-installed on May 13, 1987. The test cylinder performed satisfactorily until sheared off during a storm on December 16, 1987. All other instrument failures were either covered by redundancy, repaired immediately or considered insignificant. A detailed summary of the experiment is given in Section 3.0.

1.4 Data Summary

Over 1 gigabyte of raw digital data were collected aboard the semisubmersible platform during the operational time frame of the MME. A smaller amount of summary data was collected from the remote environmental sensors, i.e. the directional wave buoy and the current meter array. The remote environmental summary data are available on 1/2-inch nine-track magnetic tape. This data is also represented in plots in Appendix C. The digital data from the semisubmersible is contained in raw binary format on 1/4-inch cassette tape and on 1/2-inch nine-track magnetic tape.

Raw digital data from significant storms have been identified, processed into meaningful engineering measurements, analyzed for quality, and organized into various databases. Eight one-hour segments of significant storm data have been selected for use in validating the accuracy of the numerical response simulation models. Each of these eight data sets are available in a binary-formated file as multiplexed, time series values in engineering units on 1.27 cm (0.5 in.) nine-track magnetic tape. These same data sets are available as individual channel ASCII-formatted files of time series values in engineering units on MS-DOS 13.3 cm (5.25 in.) floppy disks. A short summary of each data set is given in Table 1.1.

The five data sets from the 1987 winter season represent minor but uniquely significant storm events. Data sets were chosen to include varying combinations of wind, wave, current loading. Data sets were also chosen so that peak wave energy was at frequencies below, above and

Data Set	Calendar Date	Julian Date	Pacific Standard Time	Significant Wave Height (m)	Peak Period (sec)	Swell and Wind Wave Direction (deg)	Mean Wind Speed (m/sec)	Wind Direction (deg)
1	3/5/87	64	1009-1109	2.6	14.3	270/63	3.18	63
2	3/5/87	64	2209-2309	2.3	12.5	270/105	8.46	107
3	3/6/87	65	0909-1009	2.4	14.3	226/86	5.92	86
4	4/3/87	93	0909-1009	2.3	14.3	270/260	12.04	260
5	5/25/87	145	0909-1009	1.9	6.7	180/270	9.23	274
6	1/17/88	17	1609-1709	6.0	11.1	310/230	13.38	230
7	1/17/88	17	1809-1909	8.0	16.7	310/300	11.33	300
8	1/18/88	18	0349-0449	6.7	16.7	310/290	15.44	290

Table 1.1. Selected Data Sets from Significant Storms

at the natural frequencies of the semisubmersible. These natural frequencies as calculated from the extinction test results are 10.80, 12.90, and 13.0 seconds in heave, pitch, and roll, respectively.

The April 3, 1987 (J93) data set represents a unidirectional, bimodal sea with significant wave energy at both 6 and 14 seconds. Wave direction was generally restricted to a westerly direction for all data sets due to the sheltering effects of the nearby coast and channel islands. This unidirectional nature of the waves is generally preferable to a fully confused storm sea to reduce the uncertainty in predicting wave kinematics.

The most significant storm event is represented by the three data sets from the storm which began January 17, 1988. Significant wave height for this storm peaked at 8.0 m (26 ft) which statistically translates to an estimated maximum probable single wave height of 13.4 m (44 ft). Preliminary investigation of the calculated wave elevation time series measured from the moving MME platform indicates that a wave height of 12.5 m (41 ft) may actually have passed through the platform during this storm. This storm exceeded our goal of 6.1 m (20 ft) significant wave height for continuing the MME into the winter 1988 season. Figure 1.6 shows the cumulative probability distribution for the encounter probability of significant wave height. On this figure are shown two sets of data collected by a 10-m (33-ft) NOAA wave buoy; the old 3-year wave data encompassing the severe "El Nino" event of 1982 taken at a site 18.5 km (10 nm) away from the MME site and new 1-year wave data from the relatively benign 1987 winter season taken at the MME site. A conservative cumulative probability distribution was assumed

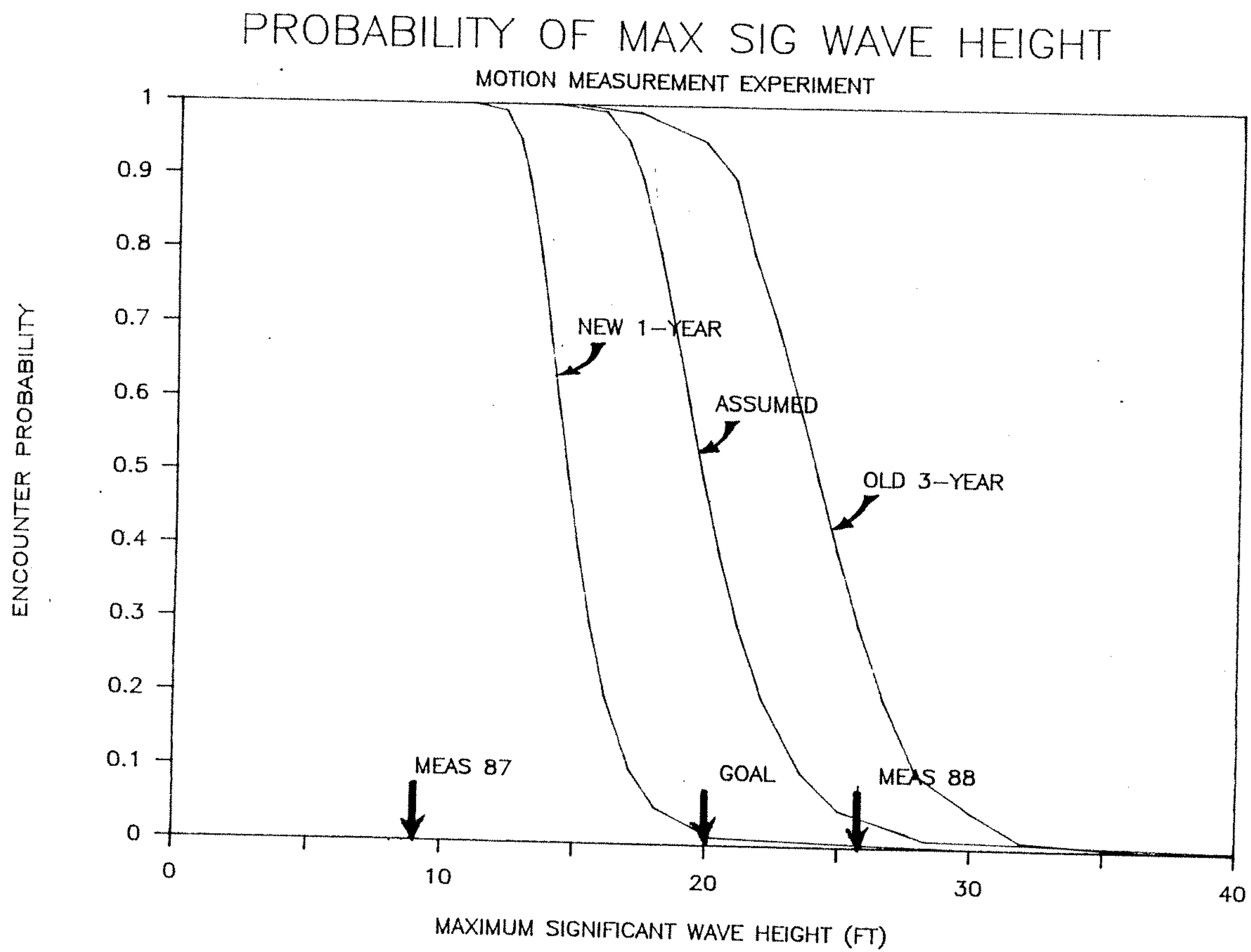


Figure 1.6. Probability of Maximum Significant Wave Height

half way between these high and low distributions. Based on this assumed significant wave height cumulative probability distribution, the January 17, 1988 (J17) storm had about 0.02 percent encounter probability.

With these eight data sets, the MME database is generally sufficient for validating deepwater dynamic response numerical simulation programs for proposed OCEANA Tactical Aircrew Combat Training System (TACTS) range deep water platforms. For proper validation, data must be available for both extreme design and less severe operational hydrodynamic regimes. Figure 1.7 depicts hydrodynamic regimes characterized using nondimensional parameters. Wave height, H, and wave length, L, are nondimensionalized by cylinder diameter, D, (the semisubmersible column diameter is used) to characterize both the design and maximum operational conditions of anticipated OCEANA TACTS platforms. The January 17, 1988 storm (MME88), falls within the depicted design range, and the winter 1987 (MME87) data was generally sufficient for the maximum operational range.

Wave directionality and surface current velocity were not measured during the January 17, 1988 storm but can be reasonably estimated using other measurements and hindcast data. The platform survived and suffered no significant damage despite waves breaking across the deck. The extremely interesting platform responses observed in these data sets should lead to a significantly enhanced understanding of dynamic response numerical simulation models for TACTS range deep water small semisubmersible platforms.

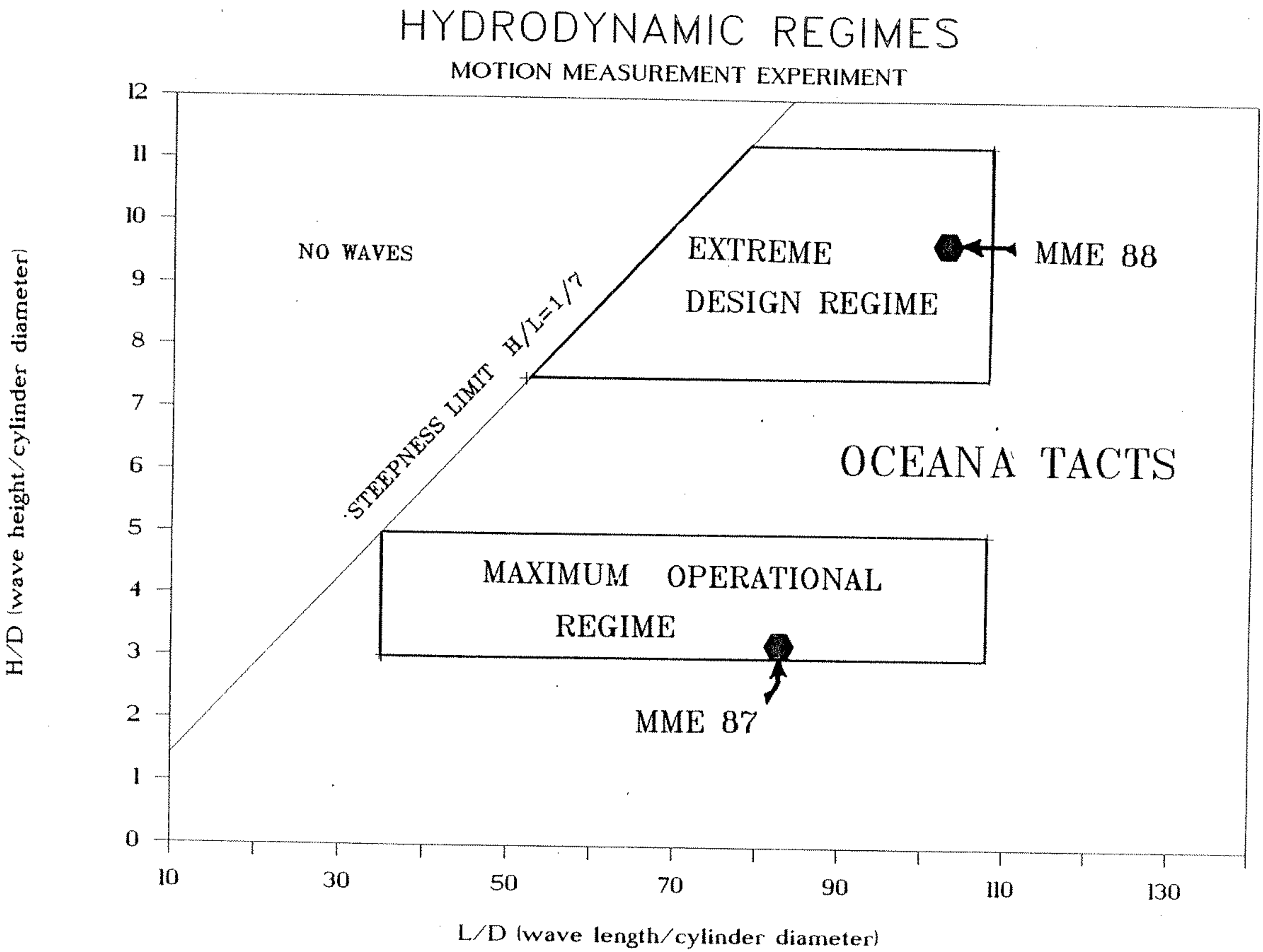


Figure 1.7. Hydrodynamic Regimes for OCEANA TACTS

2.0 MOTION MEASUREMENT EXPERIMENT DESCRIPTION

2.1 Experimental Purpose

The Motion Measurement Experiment (MME) was designed for the following specific purposes:

(a) acquire benchmark data that can be used to validate the coupled platform/mooring computer algorithms and evaluate similar response simulation models;

(b) acquire performance data on the small semisubmersible concept and on synthetic mooring lines for developing improved design procedures;

(c) develop a baseline installation procedure of the platform and mooring system; and

(d) develop instrumentation data processing systems for use in prototype platform monitoring.

The advantages of this large-scale model ocean test are that:

(a) hydrodynamic similitude problems are minimized,

(b) the scale ratio was selected so that an extreme environmental event has a high probability of occurrence during the experimental period, and

(c) realistic platform response is obtained because mooring system dynamics are being correctly modeled.

2.2 System Description

The MME was operational from April 1986 until June 1987 and from January 1988 through February 1988 at a site 46.9 km (25.3 nm) south-southeast of Port Hueneme, California, in a water depth of 887 m (2910 ft) (Figure 1.1). A three-column semisubmersible hull, shown in Figure 2.1 & 2.2, was designed for use in the MME. The semisubmersible hull was designed in accordance with American Bureau of shipping rules,

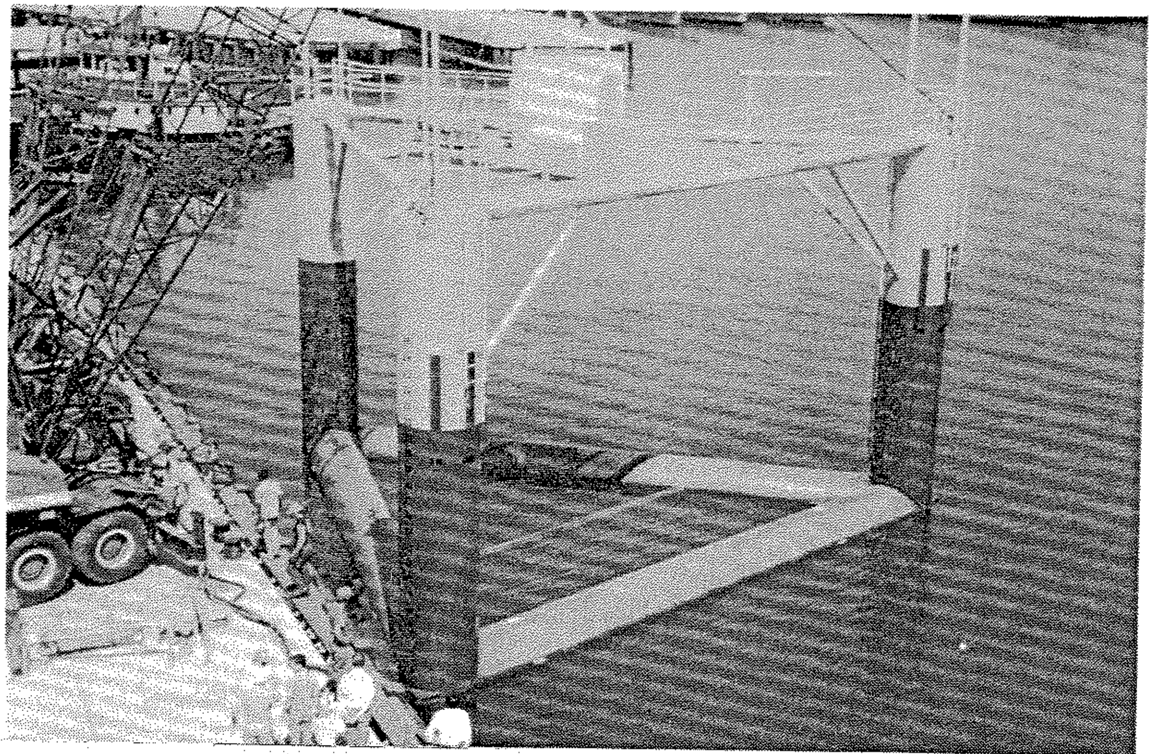


Figure 2.1. MME Semisubmersible (lightship condition)

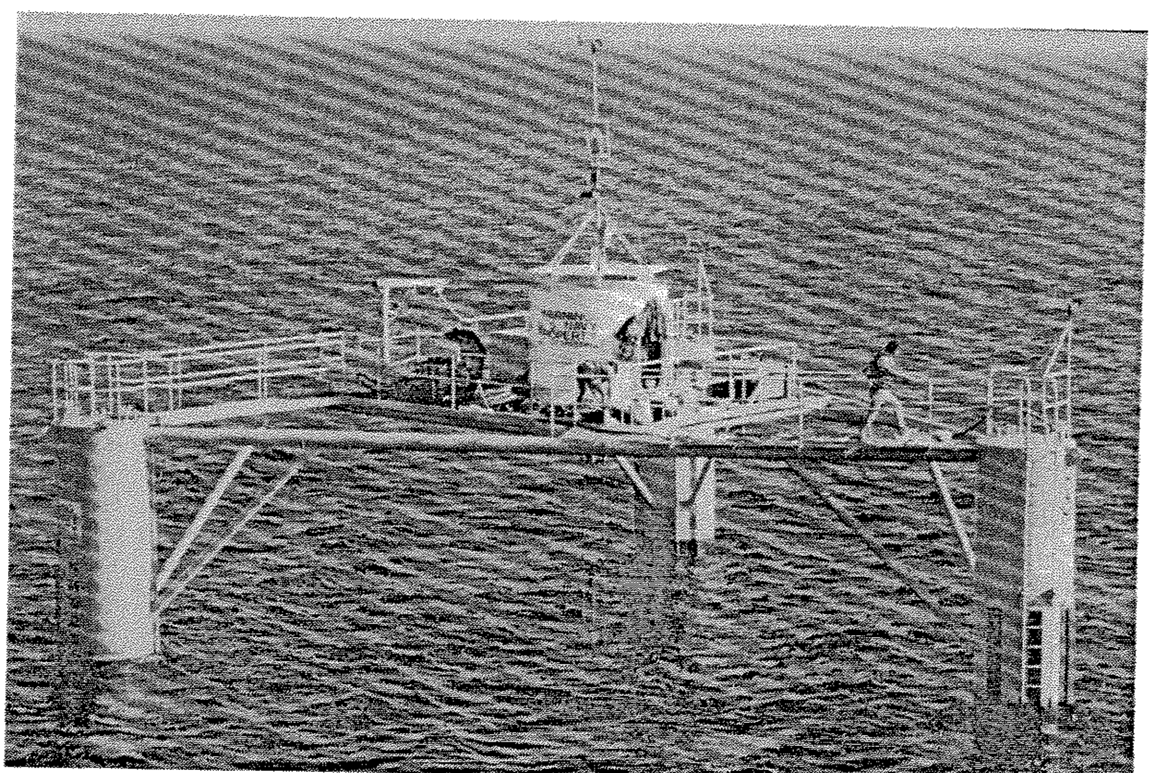


Figure 2.2. MME Semisubmersible (moored condition)

ABS (1980). The triangular platform was composed of 1.5-m (5-ft) diameter vertical columns connected at their base by 1.4-m (4.5-ft) diameter horizontal pontoons. The columns were on 15.2-m (50-ft) centerlines and are 10.1 m (33 ft) in length. The platform had a nominal draft of 6.1 m (20 ft) and displaced 97,942 kg (96.4 long-tons). Located on the deck were an instrumentation house, battery box, generator, and diesel fuel tank. The design details of the platform and principal particulars are given in Rajabi et al. (1986).

A three-point mooring was used. Each mooring leg was 1341 m (4400 ft) long and was composed of 152.4 m (500 ft) of 2.54 cm (1-in) stud link chain at the platform attachment, a chain platform pendant, 1067 m (3500 ft) of 3.8-cm (1.5-in) diameter polyester line, 122 m (400 ft) of 5-cm (2-in) stud link chain attached to either a 1000-lb NAVMOOR or 3000 lb STATO anchor. Mooring design details are given in Taylor et al. (1987) and Ottsen et al. (1986). Figure 1.2 shows a schematic representation of the MME field test layout. A marine data collection system was developed to collect the required marine data and was composed of six subsystems as shown in block diagram form in Figure 2.3. The six subsystems were: (1) a remote environmental sensor subsystem; (2) an instrument subsystem; (3) a data acquisition and control subsystem; (4) a telemetry subsystem; (5) the electrical power subsystem; and (6) a control and recording subsystem. Block diagrams for each subsystem are given in Zueck et al. (1987).

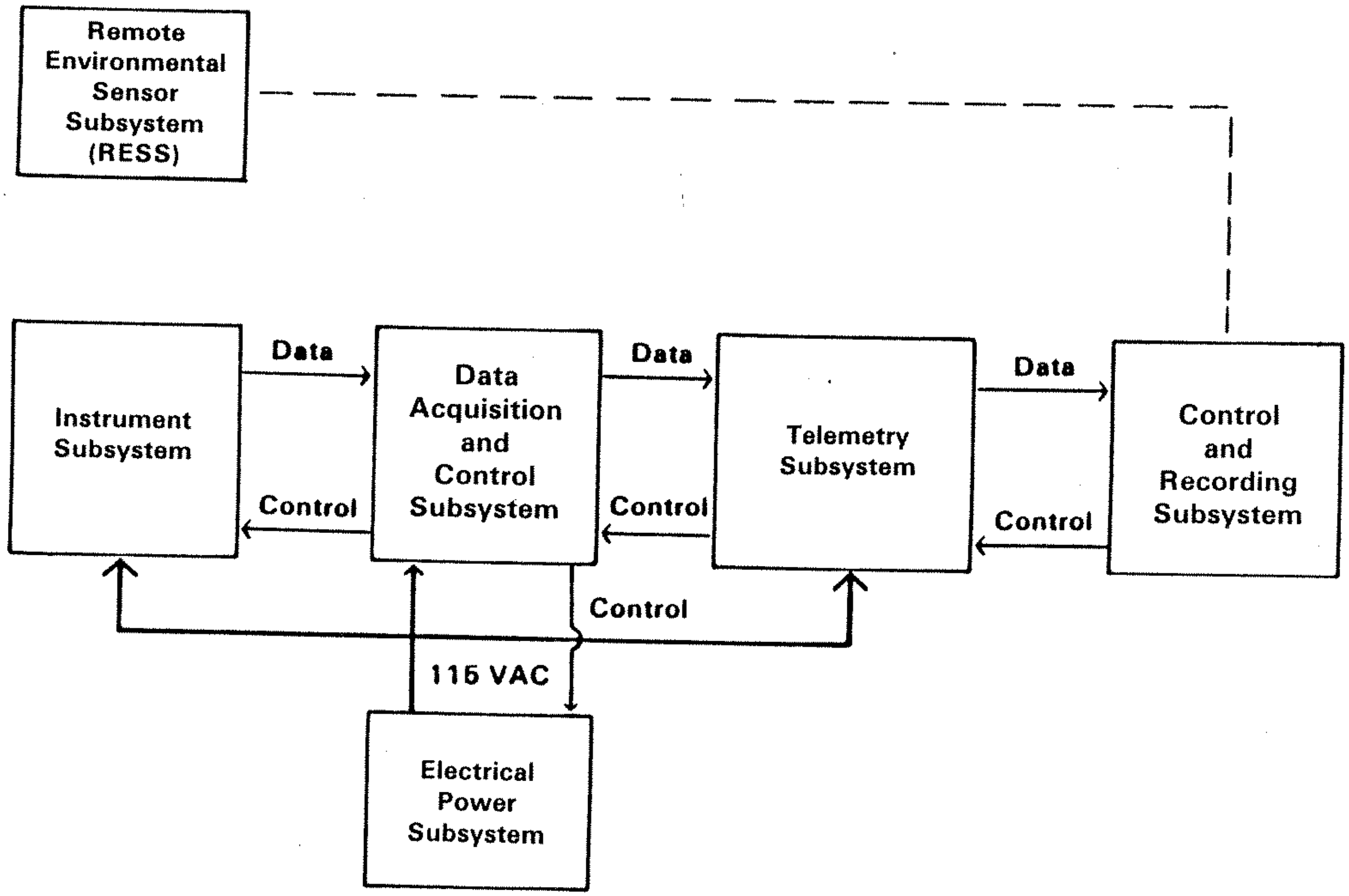


Figure 2.3. MME Data Collection System

2.2.1 Remote Environmental Sensor Subsystem

The remote environmental sensor subsystem was comprised of: a National Data Buoy Center (NDBC) discus buoy providing wave measurements, and a Naval Oceanographic Office (NAVOCEANO) vertical current meter array providing current measurements.

A 10-m (32.8 ft) NDBC directional wave buoy was deployed at the test site for nearly the entire duration of the MME. A NDBC 3-m (10-ft) non-directional wave buoy was deployed at the MME site during a maintenance and repair period of the 10-m (33-ft) directional wave (Oct 87-Jan 88). The buoy transmitted hourly scalar and directional wave spectra; wind speed and direction; sea water and air temperature; and barometric pressure. This information was available in near-real-time via the Geostationary Operational Environmental Satellite. A detailed description of the buoy is given in Zueck et al. (1987) and the references provided therein.

There were a total of four deployments of the current meter arrays which provided a near continuous data set over a period from September 1985 to June 1988. The arrays were comprised of 15 self-recording EG&G vector averaging current meters (VACM's). The fourth array had an Aanderaa current meter in addition to the 15 VACM's.

The VACM's collected and internally recorded 15-minute averages of the following data: Magnetic North and East velocity components; scalar speed; temperature; pressure; and Julian day.

2.2.2 Instrument Subsystem

The instrument subsystem was composed of sensors that measure meteorologic, oceanographic, platform, and mooring response parameters. The location of the sensors on the platforms are shown in Figure 2.4. A detailed description of the sensors is given in Zueck et al. (1987). A summary of the sensors is given below.

R. M. Young wind sensors model 05103 measured wind speed and direction at three locations on the semisubmersible. One wind sensor was mounted on the central mast above the deckhouse at 10 m (32.8 ft) elevation above still water level. The other two were mounted on two of the vertical columns at a 5.8 m (19 ft) elevation above the still water level.

Two Baylor wave staffs model 23766 were used to measure wave height with respect to the semisubmersible. They are mounted under the deckhouse directly below the motion package. The two staffs were used to provide redundancy. A shorting bar method was used for in-service checking of the wave staff's calibration.

Two Marsh-McBirney electromagnetic current meters model 511 measured relative water particle velocity. This relative velocity was composed of wave water particle velocity, water current velocity, and structural velocity. The meters were mounted on the hydrophone support structure directly below the wave staffs in an area which has minimal flow disturbance. A biaxial flotsam cage was installed to provide protection from seaweed and other debris.

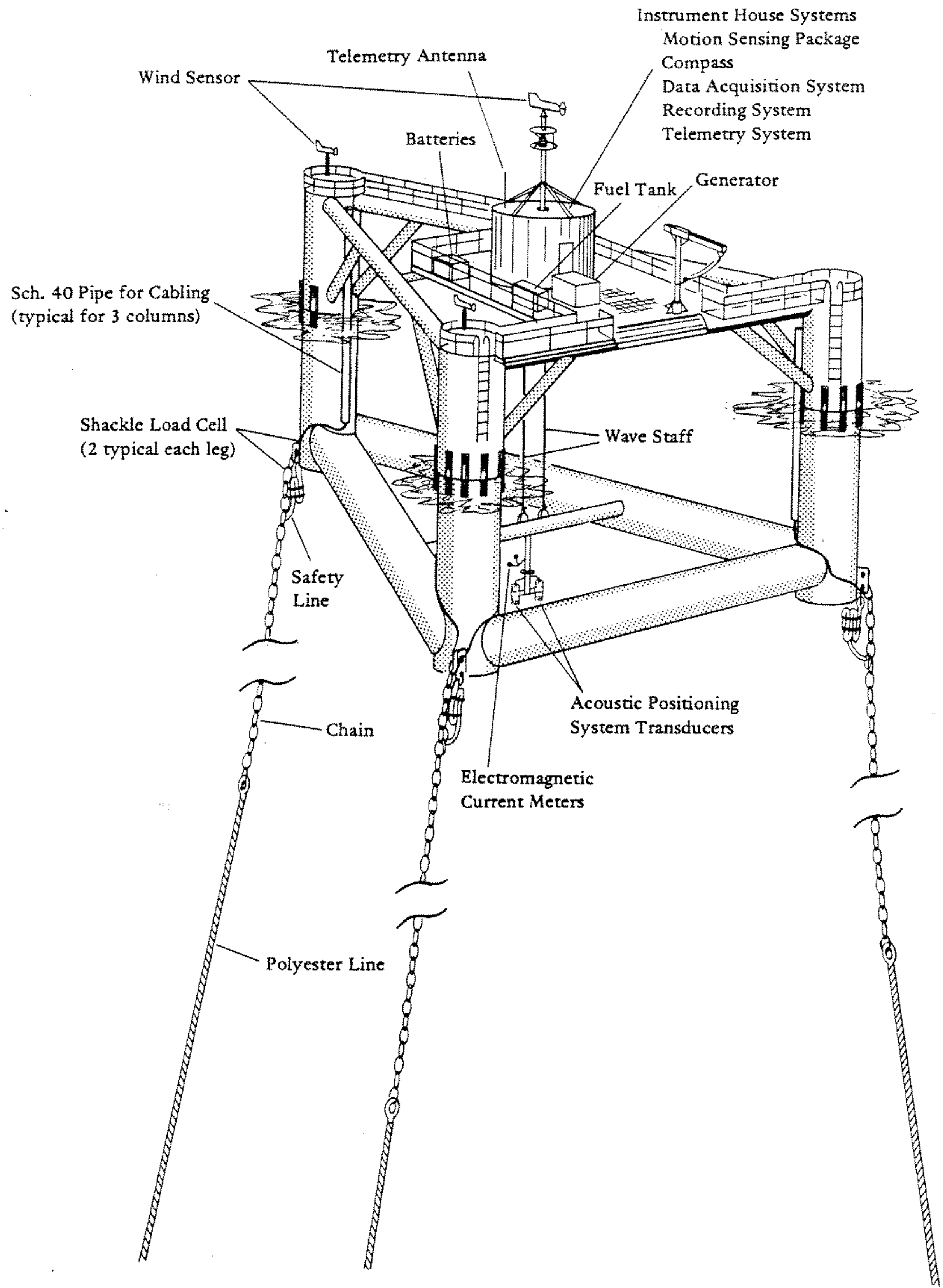


Figure 2.4. Sensor Locations on Semisubmersible

A Humphrey motion sensor package, Model SA07-0902-1 in 1987 and Model CF18-0908-1 in 1988, provided platform motion information. Surge, sway, and heave accelerometers were mounted on a gyroscopic stabilized platform. Potentiometers mounted on the gyroscope's gimbals provided direct measurement of pitch and roll displacement in the vertical direction as shown in Figure 2.5 Also included in this package are two rate gyroscopes which provide nonstabilized pitch and roll angular rate information. This package is mounted in the geometric center of the deckhouse.

Metrox Shackle type load cells Model 2037-102-30K measured the mooring line tensions. The load cells are standard anchor shackles with instrumented pins. They were mounted in-line in the mooring legs between the platform mooring padeyes and platform pendant chain. Two shackles were used in each mooring line to provide redundancy.

An Endeco flux gate compass, type 869 Solid State, mounted above the deckhouse measured platform heading. A swing test of the platform was conducted using a gyro compass to provide a correction curve for the flux gate compass (see Section 4.1 for more detail).

An air temperature and humidity sensor measured the ambient air temperature and humidity inside the instrumentation deckhouse.

Platform position data was provided by a Long Baseline acoustic positioning System (LBS). The as-designed LBS had one transponder located at each anchor and four located on the sea floor forming a tracking grid. The anchor transponders were useful to verify that there was no change in any anchor position. Two platform transducers, one redundant, were mounted directly below the wave staffs on a pipe support

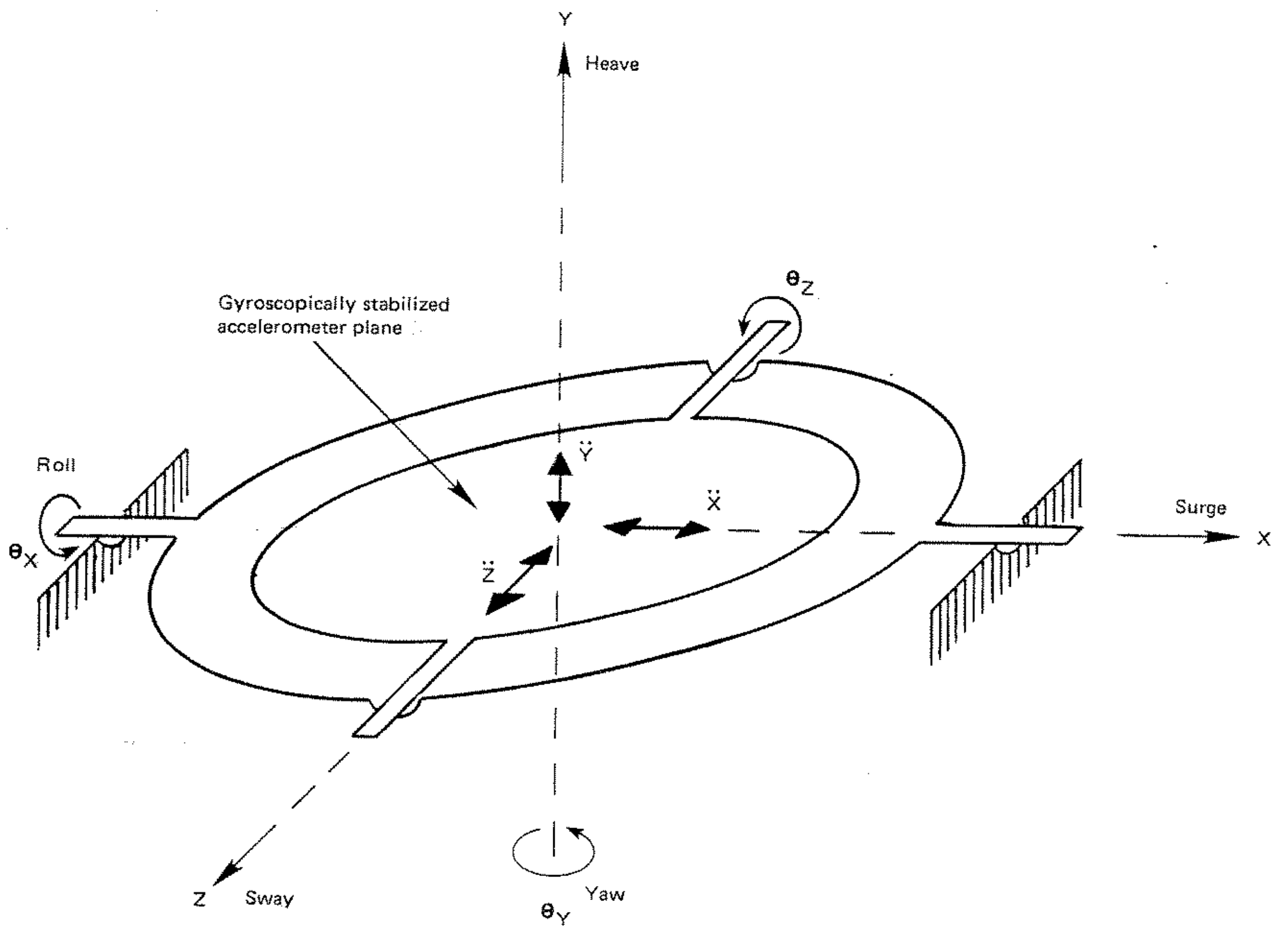


Figure 2.5. Motion Sensor Gimbal

and far enough away from other members to minimize acoustic noise. The LBS interrogator was located in the deckhouse. Due to acoustic travel time constraints, the LBS provided position information only every 7 to 8 seconds.

Platform position was calculated by an on-board Hewlett Packard 310 computer using acoustic range times as measured from the platform transducer to each grid transponder. The position computation involved 1) multiplication by the speed of sound to each measured range, 2) reduction to an ellipsoidal value, 3) conversion a lambert grid, and 4) calculation of horizontal position by least squares solution. Both range times and platform position was recorded every 7 to 8 seconds.

The initial Geodata-brand LBS consisted of MARAC Mode A5102 seafloor transponders, a Model A5203 remote head transducer, and a Model A5004 interrogator control unit. Continual failures of seafloor transponders resulted in replacement of the entire LBS. This replacement Sonardyne-brand LBS utilized COMPATT Model 7421/A seafloor transponders, a Model 7204/100D dunking transducer and a Model 7145B programmable acoustic navigation unit. Section 4.5 describes the location of all initial and replacement transponders.

2.2.3 Data Acquisition and Control Subsystem

The platform-based Data Acquisition and Control Subsystem (DACS) was specially designed and built by NCEL to control all operations on the platform. It was based on the NSC800 microprocessor and was always on, as it was powered directly from the battery pack. During data collection, the DACS scanned, sampled, digitized, and formatted all analog signals from the instrument subsystem. The DACS also received digital data from the LBS. The instrument subsystem data was sampled at 3.3 Hz. The DACS formatted all data channels into an RS-232 serial bit stream. The "raw" digitized data was recorded on the platform and also transmitted to shore. Sensor calibration checks were also implemented before and after each data collection period.

For data storage, the DACS controlled two high-density Advanced Digital Information Corporation (ADIC) digital magnetic tape cassettes, (67-M bytes each). The tapes were retrieved and replaced as part of the routine maintenance schedule.

The DACS also responded to various commands received from shore. This made it possible to have shore-based control over the platform operation.

2.2.4 Telemetry Subsystem

The DACS sent an RS-232 serial digital bit stream to the RF Telemetry Subsystem. This system was an RF link used to telemeter data from the platform to shore and control signals from shore to the platform. It consisted of two complete systems, one onboard the platform and one on shore. The platform system had a RF transmitter (brand Tele-Dynamics Type X) and a solid state receiver (brand Defense Electronics Model TR 711) with separate antennas for each. The onshore system had a similar transmitter, receiver, and a 3-m (10-ft) solid parabolic dish antenna located at Laguna Peak, California. Data was transmitted from Laguna Peak to NCEL via a telephone data line (modem) hookup.

2.2.5 Electrical Power Subsystem

The primary platform electrical source was a 3-kW (4 hp) (ONAN Model 3.0 DVA-3CR) diesel generator. It provided standard 115-volt AC power to the platform instruments and equipment. It operated approximately 5 hours each day and was controlled by the DACS. If the generator had failed, a lead-acid battery pack would have provided power to the system through an inverter (Powermark Model 1000-GZ-12/24-60-115).

2.2.6 Control and Recording Subsystem

The Control and Recording Subsystem was at the Shore Station located at NCEL. It transmitted control signals and received, recorded, and monitored all incoming data. It consisted of a Digital MINC-11 (PDP 11/23) computer, a Pertec Model T8840A 9-track digital tape recorder, microprocessor controller and digital-to-analog converter. The computer received digital data from Laguna Peak via modem. Data was displayed in essentially real time for quick look/integrity checks. The 9-track digital tape recorder provided long term storage of all incoming data. The microprocessor controller provided various equipment/operational commands for transmission to the platform. The digital-to-analog converter prepared the data so that any data channel could be examined on a strip-chart recorder, spectrum analyzer or other analog instrument.

2.3 Direct Wave Load Measurement

Direct wave loads and pressure were measured using an instrumented test cylinder, Figure 2.6. This cylinder was capable of measuring directly the hydrodynamic forces and pressures caused by the relative motion between the platform and the ocean environment.

The test cylinder consisted of a 50.80-cm (20 in) outside diameter steel pipe extending from the platform pontoon to the deck framing. Two load cells were mounted at the upper and lower extremities of the cylinder for measuring horizontal wave forces in surge and sway directions as shown in Figure 2.7. The test cylinder was connected to the platform hull through two universal joints. The universal joints greatly reduced the effect of bending moments on the lateral force measurement. In addition, a vertical slip joint at the lower extremity prevented transmission of the hull deformations to the load cells.

Load cells were made from 8.9 cm (3.5 in) x 8.9 cm (3.5 in) x 25.4 cm (10 in) high stainless steel blocks. The central portion of each block was machined to provide orthogonal double cantilevered beams on which strain gages were mounted. The primary and back-up strain gages were bonded to these 0.76 cm (0.3 in) thick beam walls. The orthogonal axes of the load cells were aligned with the surge (x) and sway (z) directions of the platform to provide direct force measurement in these directions as given in Section 4.7.

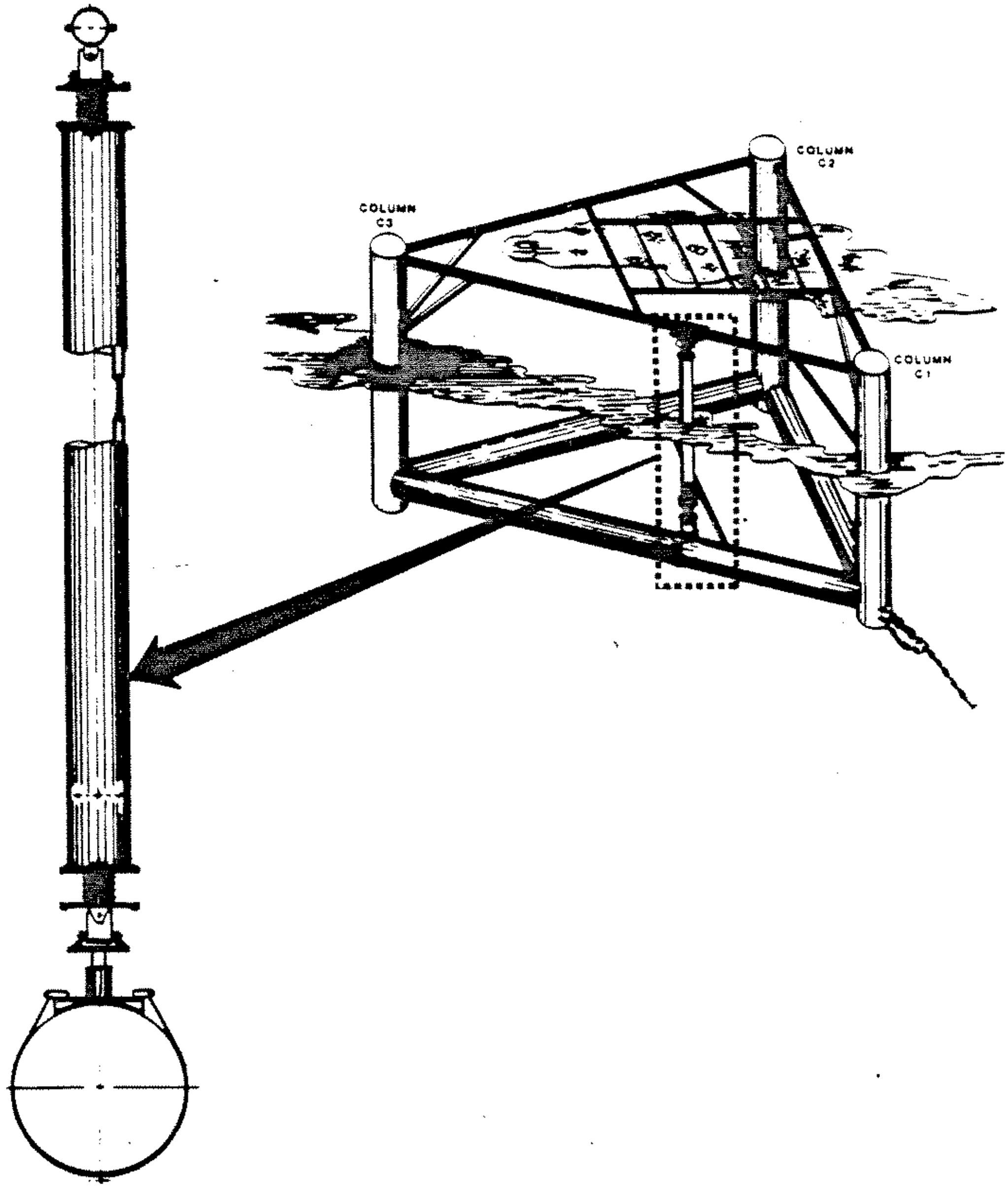


Figure 2.6. Instrumented Test Cylinder

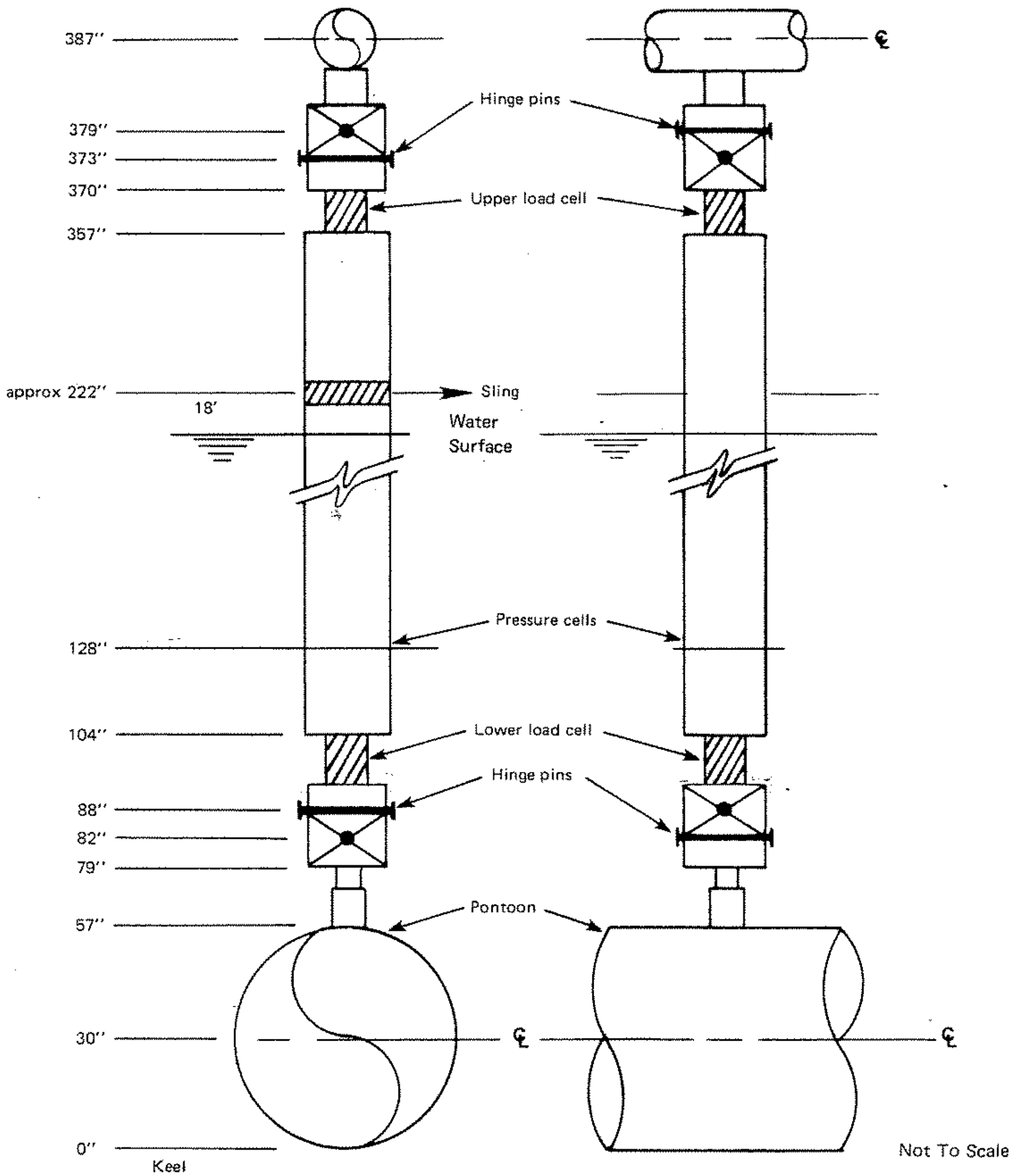


Figure 2.7. Sensor Locations on Instrumented Test Cylinder

The lower load cell malfunctioned two days after installation. The test cylinder was then removed from the semisubmersible and repaired. The test cylinder was reinstalled in May 1987, but sheared off during a storm in December 1987.

The load cells provided integrated wave loads acting on the instrumented cylinder. In order to gain some insight into the local wave loads, a set of eight pressure transducers were installed circumferentially about 0.76 m (2.5 ft) above the lower load cell transducer. This arrangement provided the instantaneous pressure distribution on a unit length of the cylinder which could be correlated to the integrated force measured by the load cell. Results from this correlation will eventually lead to a better understanding of the nature of the hydrodynamic loads caused by the relative motion of a body and flow environment. One immediate result of this measurement will be a realistic evaluation of the force coefficients.

3.0 MME TEST EXECUTION

3.1 Experiment Chronology

26 September 85	NAVOCEANO installed the first current meter array at 33° 45' 34" N; 119° 03' 35" W.
10 October 85	The MME semisubmersible construction was completed and the semisubmersible was launched in Port Hueneme Harbor.
11/12 October 85	Inclining Experiment and Dead Weight Test was performed by Brown and Root Development, Inc. to determine the semisubmersible's center of gravity and the center of buoyancy. The semisubmersible was taken out of the water and positioned dockside.
21 October 85	Platform Vibration Test was performed. All modes of vibration of the steel deck were found to have natural frequencies significantly greater than the choosen instrument sampling frequency.
November 85	Meridian Ocean Systems (MOS) received the GEODATA Long Base Line Acoustic Positioning System from the United Kingdom. The transponders had a sensitivity problem and the GEODATA surface control unit (ICU) was locking up. They were repaired.
8 January 86	The GEODATA acoustic transponders were pressure tested at the NCEL Deep Ocean Lab (DOL) to 914 m (3,000 ft).
22 January 86	The National Data Buoy Center (NDBC) deployed a 10-m discus directional wave buoy on-site at 33.8°N; 119.1° W. The General Service Buoy Payload (GSBP), meterlogical and nondirectional wave measurements, became operational, but the Data Acquisition and Telemetry (DACT) with the Directional Wave Analyzer (DWA) was not operational.
February 86	The semisubmersible had to be moved a few times due to dockside space problems. Each time, two or three cranes were used to move the platform. The anti-fouling paint, AMERON E70, was forming tiny cracks due to a lack of moisture. The semisubmersible was sprayed with fresh water once a week by the Construction Battalion Center (CBC) Fire Department to control the drying, and cracking of the paint. The Superline mooring lines were received from their source in the U.K.

22 Feb/1,2 March	The Superline mooring lines were stretched, measured, checked for imperfections, and elastic characteristics were recorded at the Construction Battalion Center (CBC) in Port Hueneme.
10 March 86	Pressure tests were conducted to 914 m (3,000 ft) in the DOL on all repaired GEODATA acoustic transponders.
18/19 March 86	The grid transponders at the MME site were deployed, but the remote master range did not perform properly, and the grid transponders were recovered. It was later found that there was a problem with the system relating to premature triggering of acoustic response due to reflected signals. The temporary construction buoy and its mooring were deployed at the MME site.
March 86	Sea trials were conducted by Meridian Ocean Systems and GEODATA at the MME site using delay equipped transponders to confirm a solution to the reflection problem.
21 March 86	NDBC replaced the DACT package. This package became operational producing directional wave data for the MME site. Modifications were made to the transponders to allow for attenuation of acoustic signals in the MME environment.
3 April 86	The GEODATA grid transponders were redeployed and calibrated at the MME site.
9 April 86	Heave, pitch & roll extinction tests were conducted on the semisubmersible in the Port Hueneme Harbor. The natural periods for heave, pitch, and roll were determined for the semisubmersible without the mooring lines. The platform was then taken back out of the water again so that the instrumentation installation could be completed. The mass of all instrumentation was accounted for in the extinction tests.
12 April 86	The semisubmersible was put back in the water and ballasted to 3.9 m (13 ft) draft.
14 April 86	A cruise was conducted, with the Offshore Supply Vessel (OSV), and the Ocean Research Craft (ORC), to install 2 mooring legs for the platform. During the mooring installation a GEODATA grid transponder failure occurred, and two GEODATA anchor transponders failed shortly after their deployment on the mooring legs. The two mooring legs were, however, successfully installed. In Port Hueneme, the C1 upper load cell on the semisubmersible failed due to a leak. The semisubmersible was taken out of the water and the load cell was replaced.

16 April 86	The ORC and OSV returned to port. The semi-submersible was put back in the Water and again ballasted to 3.9 m (13 ft) draft.
17 April 86	The ORC departed the harbor at 1300 hrs. The OSV departed the harbor at 1730 hrs with the semi-submersible in tow. The OSV arrived on site at 2200 hrs, and maintained position until dawn to begin the installation.
18 April 86	The third mooring leg and semisubmersible were installed.
19 April 86	The positioning equipment was installed on the semisubmersible. The OSV and ORC returned to port.
21 April 86	The platform powered up on the inverter. The generator did not operate.
22 April 86	The first real-time data was received by the NCEL shore station, but the signal was very weak. Replacement of a burned out pre-amplifier at Laguna Peak improved signal strength.
27 Apirl 86	Daylight savings time begins.
29 April 86	Clock on platform reset one hour earlier for daylight savings time.
1 May 86	Cruise to the platform was made to determine the problem with the generator. The generator heater solenoid coil was burned out.
8 May 86	Another cruise to the semisubmersible was made and the generator relay start-up circuit was removed. At this time it was determined that three of the GEODATA transponders were not working properly. The generator remained inoperable.
22 May 86	The generator start-up circuit was replaced.
23 May 86	The NCEL shore station received real-time data properly. The lower load cell on C2 failed.
1 June 86	The upper load cell on C3 failed. It appeared that the load cells were developing leaks.
2 June 86	The Deep Submergence Rescue Vehicle (DSRV) and NCEL removed and replaced the GEODATA anchor transponders.
29 May 86	The NDBC directional wave package battery died.
3 July 86	Cruise was made to the MME site to remove the GEODATA acoustic position system ICU.

8 July 86	GEODATA ICU reinstalled.
14 July 86	NAVOCEANO retrieved the first current meter array.
15 July 86	NAVOCEANO deployed the second current meter array. NDBC replaced the battery for the NDBC directional wave package and installed some upgraded software for the DACT.
30 July 86	The semisubmersible telemetry system was repaired.
20 August 86	MOS changed the EPROMs on the HP310 computer for the LBS.
27 August 86	Another cruise was made to return the EPROMs.
28 August 86	Permanent power was provided at Laguna Peak after temporary power lines were disconnected. The NCEL shore station began receiving quality data.
22 September 86	There was another generator mechanical failure. The generator was running continuously for 24 hour periods.
26 September 86	The generator stopped running completely due to fuel exhaustion.
29 September 86	The semisubmersible powered up on the inverter.
30 September 86	The semisubmersible batteries ran out of power.
1 October 86	The NDBC directional package failed.
2 October 86	A cruise was made to the semisubmersible to investigate the generator problems and secure the system.
16 October 86	The generator was replaced and an investigation of the NDBC buoy was made.
26 October 86	Daylight savings time ends.
27 October 86	Clock on platform reset one hour later to coincide with Pacific Standard Time.
29 October 86	MOS replaced the three failed GEODATA grid transponders and NCEL repaired wavestaff #2.
5 November 86	MOS replaced all four GEODATA grid transponders with new designed transponders.
18 November 86	A cruise was made to enter the platform codes for the new trans ponders. The acoustic data received by NCEL shore station was still questionable.

20 August 86	The acoustic system was turned off.
2 December 86	Signals through Laguna Peak were being overpowered by offshore Naval exercises.
11 December 86	Problems with the filter in front of the pre-amplifier at Laguna Peak were discovered.
16 December 86	The NDBC directional package was repaired.
17 December 86	A cruise to inspect the generator was made.
4/5 January 87	The NCEL shore station collected their first storm data less the acoustic positioning data.
7 January 87	New GEODATA transponders, with modified release seals, were tested in the NCEL DOL.
8 January 87	Another cruise was conducted to check out the . generator problems and do a ping count on the GEODATA transponders.
12 January 87	Five new GEODATA transponders were deployed to supplement the grid transponders by providing two transponders at each grid point. The three remaining transponders had failed and two of the new transponders failed shortly after deployment.
15 January 87	The acoustic system still needed the transponder codes changed when the second storm data was collected.
19 January 87	New transponder codes were entered in the software for the three remaining acoustic transponders.
16 January 87	A pressure test was conducted in the DOL on the new acoustic system, Sonardyne LBS acoustic system.
28 Jan-5 Feb 87	The SUBDEV MV Transquest and DSV Sea Cliff removed the GEODATA transponders and replaced the anchor transponders with the new GEODATA transponders.
10 February 87	NAVOCEANO recovered the second current meter array and deployed the third current meter array.
11 February 87	New Sonardyne LBS acoustic transponders were deployed for the MME grid, the system was calibrated, and a new platform transducer assembly and PAN unit were installed. Still poor acoustic position data.
19 February 87	The pre-rigging on the semisubmersible was accomplished for the installation of the Force Cylinder, but the seas and winds became extreme on February 20, and the task was aborted.

26 February 87	The ITC and a Neil Brown acoustic current meter were installed. The Neil Brown meter were needed to check the Marsh McBirney electromagnetic meters.
27 February 87	The ITC was calibrated and the new acoustic transponder codes were entered.
28 February 87	The first complete set of data for the MME was recorded.
1 March 87	The second complete set of data was recorded. The acoustic system was working properly.
4 March 87	The bottom Z strain gage failed on the Instrumented Test Cylinder.
11 March 87	The bottom X strain gage failed on the Instrumented Test Cylinder. It appeared that the gages were shorting to sea water.
March 87	Various storms were captured during March that produced good data sets for analysis purposes.
April 87	Data from various storm events were recorded.
5 April 87	Daylight savings time begins.
6 April 87	Clock on board semisubmersible reset one hour earlier to coincide with daylight saving time.
8 April 87	A cruise was conducted to replace the magnetic tape and C3 wind sensor on the semisubmersible.
17 April 87	The ITC was removed so that the bottom strain gage could be repaired.
28 April 87	Cruise to install OTC inclinometers and perform routine platform maintenance.
13 May 87	The ITC was re-installed.
18 May 87	The NDBC directional package began having some problems again. The battery was getting weak.
1 June 87	NAVOCEANO recovered the third current meter array. The MME was officially ended, since there would no longer be a complete set of data available.
22 June 87	The NDBC directional package went out. The battery had died again. Taken off the air.

26 June 87	Cruise to check Humphrey filter and calibration of instruments. OTC people removed computer, left inclinometers. MME maintenance. Post-cal of wavestaffs, load cells and force cylinder signal conditioning.
15 July 87	Cruise to repair navlight on MME buoy. Installed new battery for navlight on construction buoy.
28 July 87	Cruise to photograph MME platform after sailboat collision. A piece of wood was stuck in conduit, and a hole in conduit was detected.
2 September 87	Cruise to change 3M tapes and brought back NCEL Humphrey Motion package due to a melted wire inside transformer unit.
30 September 87	NDBC recovers 10-m directional wave buoy and deploys 3-m nondirectional wave buoy on-site.
14 October 87	Cruise to replace 12v battery in generator. Replaced primary and secondary fuel filters. Replaced Raycor fuel filter. Installed a new muffler assembly, and performed a fresh water wash down.
25 October 87	Daylight savings time ends.
27 October 87	Clock on platform reset one hour later to coincide with Pacific Standard Time.
23 November 87	Cruise to attempt to clean biofouling from submerged MME platform hull, and release Sonardyne transponders, but the current was to intense and seas were too high.
30 November 87	NAVOCEANO deployed 4th current meter array at MME site.
11 December 87	Cruise to recover Sonardyne grid transponders, but too fogged in on-site to attempt release. Took electric potential measurement on MME platform. MME routine platform maintenance.
16 December 87	Storm: 4.8m (15.6 ft) significant wave height and 15.4 m/sec (30 kt) wind. ITC sheared off at top and bottom connection. No data collected; no Humphrey package installed; no directional wave buoy.
19 December 87	Recovered grid transponders #701, #703, #705, #706 (#706 dead). Installed Coast Guard Humphrey Motion Package and 3M, ADIC tape drives. Noticed cylinder missing and construction buoy missing.

8 January 88	Install and calibrate 4 grid Sonardyne transponders #701, #702, #703, #705 (#706 on seafloor). #702 failed test. Dunking transducer severed by vessel propeller.
13 January 88	Cruise to enter new grid coordinates into HP310 and transponder delay.
18 January 88	Humphrey Motion Package Model CF18-0908-1 failed at 0500 due to blown fuse.
21 January 88	Determine if #703 is inoperative. #708 replaces #703. Installed NCEL Humphrey package model SA07-0902-1 and removed U.S.C.G. Humphrey package model CF18-0908-1. (Noticed wave slamming effects on MME platform).
26 January 88	NDBC removed 3-m buoy and replaced it with 10-m directional wave buoy.
1 February 88	Cruise to recover #708 and test transponders.
2 February 88	M/V DOUG C, M/V TRANSQUEST, DSV TURTLE Operation. Recover Geodata anchor transponder #229, #230, #231 and grid transponders #705 and #706 anchor transponders and replace with Sonardyne #708, #702, #703. Made video of anchor chain movement.
12 February 88	Cruise to obtain MME anchor positions and modify HP software for latest revisions to acoustic system. MME platform routine maintenance. Humphrey package has power supply problems.
25 February 88	Cruise to install repaired Humphrey package. (New power unit parts).
1 March 88	NCEL divers cleaned MME platform. Took video and still pictures of heavily fouled MME platforms. Cleaned 9.1 m (30 ft) mooring chain each leg, C.M. flotsam cage and C.M. probes, wavestaffs.
4 March 88	Recover Humphrey Motion Package. Modify HP code for grid check, check acoustics with oscilloscope to reduce cycle time.
9 March 88	Termination of MME data collection.
24 March 88	Recover P.A.N. and acquire biofouling samples with divers.
29 March 88	Cruise to post-calibrate transponders and recover #702, #703, #708, #705, #707.

Figure 3.1 is an operations history time line for each of the components in the Motion Measurement Experiment.

There were four sets of log books kept during the preparation and execution of the MME experiment: the MME Cruise Log; the MME Data Collection Logs, the MME Data Conversion Logs, and various other field logs. An attempt was made to record all detail about significant events during the course of the experiment. The MME Cruise Logs show date, event, mode of transportation, instrumentation checked or repaired, and other observations relating to every visit made to the platform. The MME Data Collection Logs contain date, time, weather and calibration checks for all data recording periods. The MME Data Conversion Logs show particulars about converting data segments from one database to another. The logs are kept on file at NCEL for reference.

3.2 Instrument Perfromance

The performance of any given instrument is best measured as a percentage of the time that the instrument was available to collect data given the fact that electrical power was available. Figure 3.2 shows this percentage for each instrument and/or measurement system that was a part of the MME. The percentage calculation for the Instrumented Test Cylinder (ITC) is based on an installed time frame starting 26 February 1986 and ending 16 December 1987 when the ITC sheared off. The percentage calculation for all other instrumentation including the remote environmental sensors is based on the two data collection periods 18 April 1986 through 1 June 1987 and 30 November 1987 through 9 March 1988.

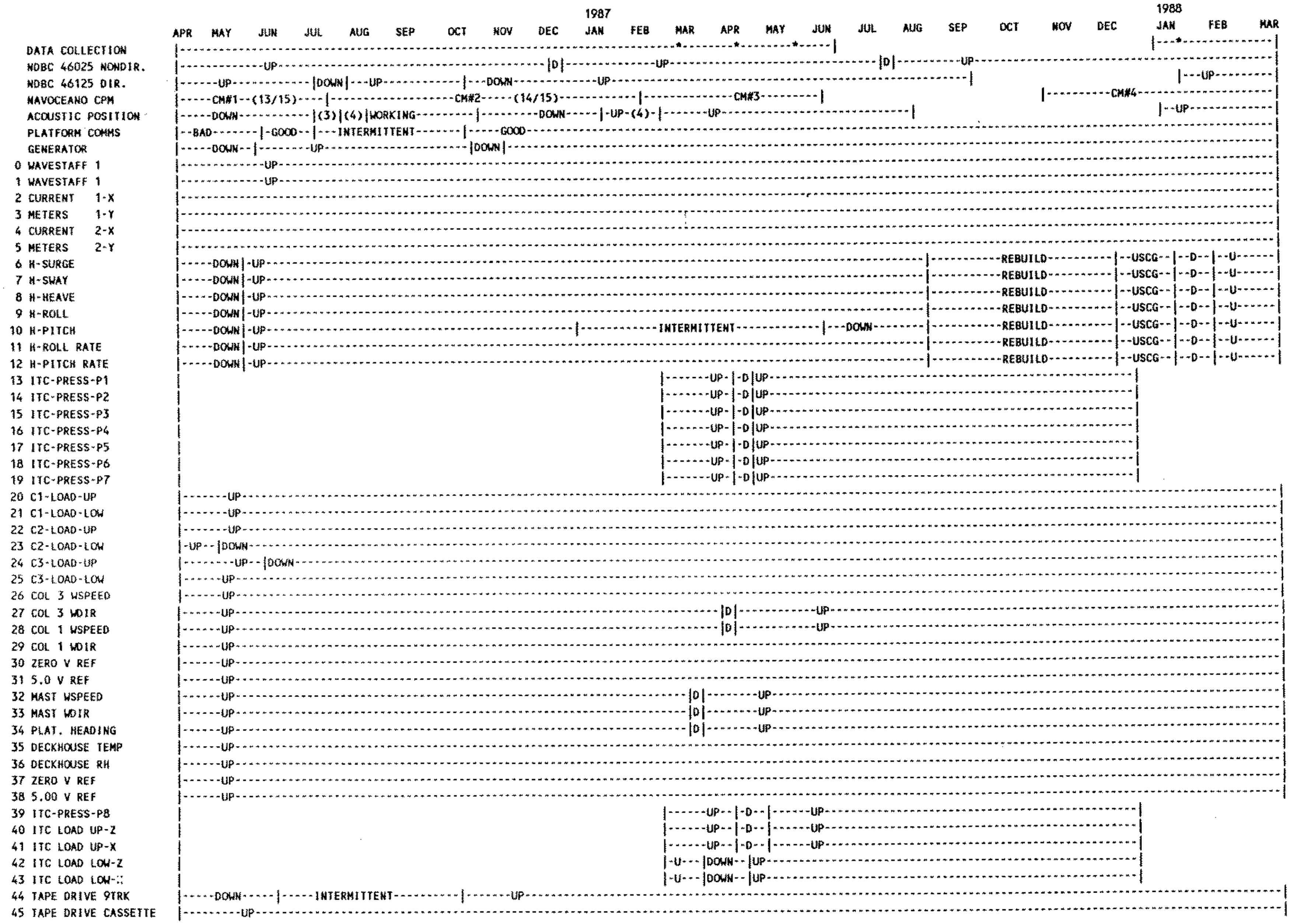


Figure 3.1. MME Operations History

KEY

*	- Key data sets collected
U/Up	- Instrumentation operational
D/Down	- Instrumentation not operating properly
USCG	- U.S. Coast Guard Humphrey operational

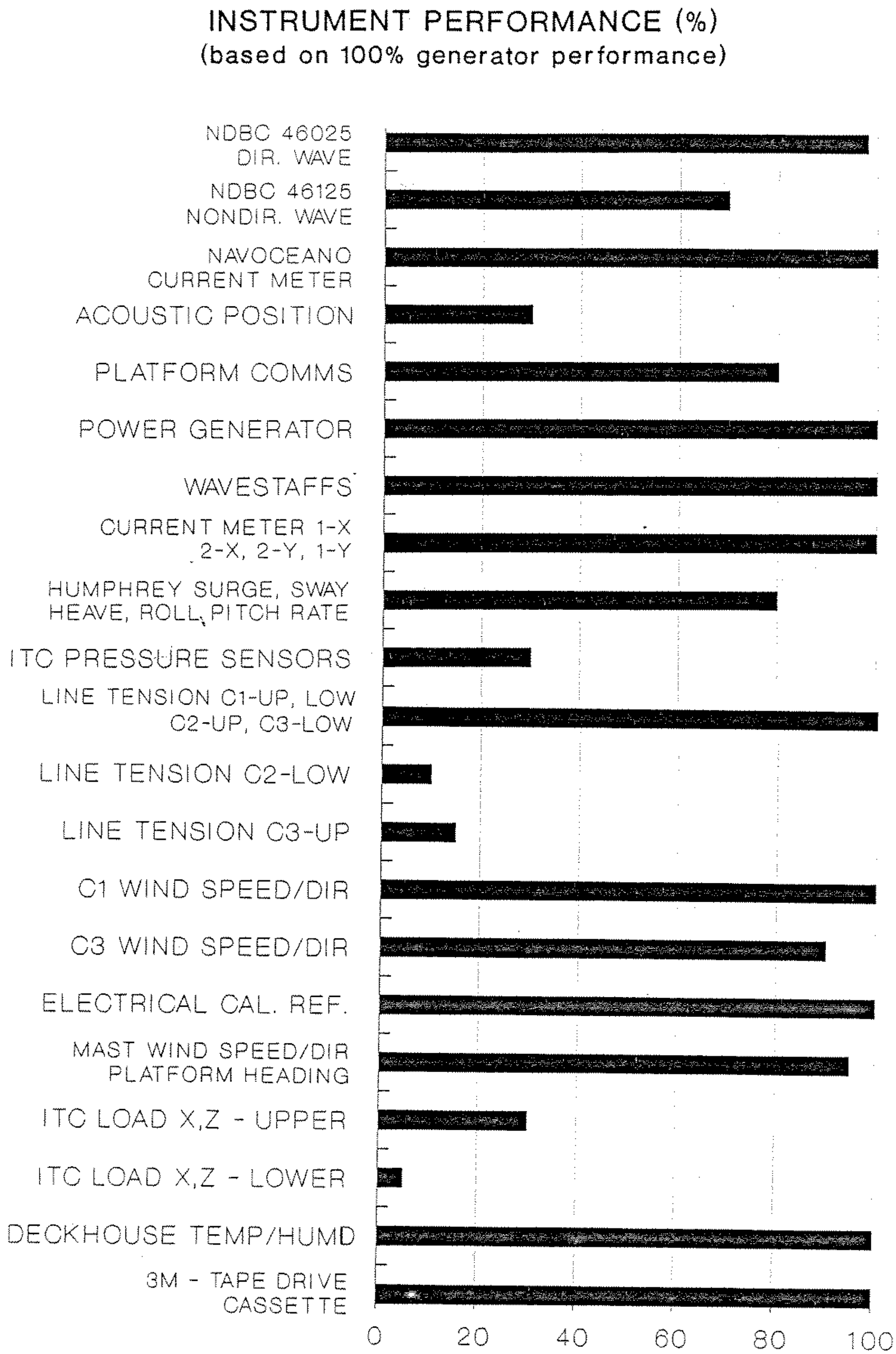


Figure 3.2. MME Instrument Performance

The MME semisubmersible had a few instruments that operated 100 percent of the duration of the experiment. These components included the #1 and #2 wavestaffs, C1 upper load cell, C1 lower load cell, C2 upper load cell, and C3 lower load cell, C3 wind speed, C1 wind direction, platform references, and the deck house temperature and humidity sensors. The Humphrey motion package experienced power supply related failure and was replaced by a U.S.C.G Humphrey motion package December 1987 - January 21, 1988.

The MME was successful in capturing all significant storm events or portions of those events. One hundred percent availability was not achieved because of several factors including the following:

- Weather prediction uncertainty as already described
- Remote Control from shore station due to weather conditions instrumentation, or microwave interference.
- Fuel and data storage limitations

The Naval Oceanographic Office (NAVOCEANO) data collection system was operational for the entire duration of the MME. Each array deployed had a few meters that did not record data properly, due to pinched wires, shorts to sea water or low battery voltages. There were a total of 10 failed VACM's out of 60 deployed. This is a good record for at-sea work. Since the failed meters were at different water depths for each deployment, the current profile for the entire water column can still be characterized for the duration of the experiment.

The National Data Buoy Center (NDBC) 10-m (33-ft) buoy with a non-directional wave data collection package (46025) and a directional wave data collection package (46125) was operational for the majority of the MME. The directional wave data collection package did have a few software, hardware and battery problems during the course of the MME. The problems were corrected as soon as possible by NDBC. The entire 10-m (33-ft) wave buoy collection system was removed from the site on 30 September 1987 and temporarily replaced with a 3-m (10-ft) non-directional wave buoy system. Once maintenance and repair operation had been performed, the 10-m (33-ft) wave buoy was redeployed at the same site on 26 January 1988.

3.3 DATA COLLECTION SCHEME

The data collection scheme for the Naval Oceanographic Office (NAVOCEANO) utilized a total of four deployments and retrievals of current meter arrays which provided a nearly continuous data set over a period from September 1985 to June 1988. The arrays were comprised of 15 self-recording vector averaging current meters (VACMs). The fourth array was comprised of an Aandera current meter at -56.4 m (-185 ft) in addition to the 15 VACM's. The VACMs collected 15-minute averages of North and East velocity components, scalar speed, temperature, pressure, and Julian day.

Each array was deployed for approximately 7 months. After each array was recovered, the data cassette tapes were removed from the VACM's, and the tapes were taken to NAVOCEANO for processing and quality checking. The data were recorded on 9-track tape at NAVOCEANO and sent to NCEL. The data were analyzed and computations for directional and amplitude stability within the water column were performed by Bratkovich (1987).

The National Data Buoy Center (NDBC) data collection scheme utilized a 10-m (33-ft) directional wave buoy and, a 3-m (10-ft) nondirectional wave buoy during the 10-m maintenance period. One buoy was deployed at the test site for the entire duration of the MME. They provided hourly scalar (3-m and 10-m) and directional (10-m) wave spectra, wind speed and direction, sea water and air temperature, and barometric pressure. This information was available in near-real-time via a Geostationary Operational Environmental Satellite (GOES). NDBC stored the scalar and directional data on 9-track magnetic tapes for each month. The tapes were sent to NCEL each month where the environmental data was reviewed and plotted.

The MME data collection was controlled from the Shore Station at NCEL. The MME Data Recording System was preprogrammed to record data from 0800-1200 PST Monday through Friday. The local marine weather was monitored for the platform site by using three forecasting centers: (1) Pacific Missile Test Center, Geophysics Department, Code 3220; (2) National Weather Service, Los Angeles; (3) Fleet Numerical Weather Service, Monterey, CA. Daily weather updates were obtained directly from the forecast centers and hourly on-site marine reports were obtained directly from the NDBC Buoy 46025.

If an interesting event, such as, a summer Southern Hemisphere tropical storm, or a Northern Pacific storm, or extreme high and low pressure gradients existed in the area, the MME platform was programmed again to record data during the course of the event. This was a difficult task since there are not any proven methods for predicting exactly when a storm will peak at a particular site. Pacific Missile Test Center (PMTC) used a computer program called WAVES for predicting a significant wave height, peak wave period, and time of arrival, from wind speed, fetch, and storm duration input (Lyons, 1983).

The WAVES computer program was written to compliment existing PMTC wave measuring systems active in the sea test range by predicting wave conditions for the coastal area 24 hours in advance. The method uses an operational point source ocean wave and swell forecast method derived from the Bretschneider significant wave computation (Bretschneider, 1969). The Bretschneider wave forecast scheme is based on classical linear wave theory, but utilized ocean wave measurements to derive coefficients and corresponding curves which represent wave development, propagation, and decay. Wind-wave characteristics, namely height and period are dependent upon wind speed, fetch length, and wind duration and to a lesser extent on fetch width.

Swell, distinct from wind-waves, is usually defined as any wave which propagates out of a wave generation region and ceases to be acted upon by overlying winds. Swell computation is similar to the wave computation, but swell decay must be included. Swell decay is primarily a function of distance traveled, wave period, and fetch length. Swell speed is a function primarily of swell period; longer period waves move faster than short period waves. Period is dependent upon wind speed, fetch length, and wind duration. High winds, long fetches, and long durations produce long period waves.

The accuracy of the wind-wave and swell forecasts is most sensitive to the reliability of the input parameters. Primary errors include: improper estimation of meteorological parameters; and lack of meteorological information in the area of interest. There are also some other short comings to the theory of the program (Lyons, 1983).

3.4 Marine Biofouling Assessment

This section presents the marine biofouling data for the MME semisubmersible. The marine biofouling data is required to (1) estimate the increased mass and mass distribution due to the marine biofouling as it has increased the virtual mass of the platform; and (2) choosing the appropriate coefficients of drag and inertia used in the relative-motion Morison equation for the MME platform response calculations and simulations in a heavily marine biofouled state.

There has not been any data recorded and documented of the characteristics of marine biofouling on steel structures located in the Santa Monica Basin, but there has been reported data of the marine biofouling on steel structures in the Santa Barbara Channel, such as on the 'Hondo A' platform (Sharma, 1983).

The Santa Barbara Channel has a history of having extreme quantities of marine biofouling on steel structures from the water surface to -36.6 m (-120 ft). The extreme marine biofouling condition is due to the year around ideal water temperatures 15° C (59° F) for mussels (Mytilus Edulus) and barnacles (Mytilus Californianus). The Santa Monica Basin appears to have similar marine biofouling conditions. Sea water temperature, current, and other biofouling factors are similar for both the Santa Barbara Channel and the Santa Monica Basin.

The MME semisubmersible pontoon and column members remained relatively smooth (without biofouling) from the installation date of April 1986 until April 1987 (approximately 1 year) before the semisubmersible members became lightly roughened with marine biofouling. After 1 year and 5 months (October 1987) the semisubmersible members could be classified as very roughened with marine biofouling. The slightly roughened semisubmersible members were primarily covered with algae, where **e**, the roughness height was approximately 0.13 cm (0.05 in.), and **k**, the marine growth thickness was approximately 0.25 cm (0.98 in.). The very roughened semisubmersible members were primarily covered with barnacles and mussels, here **e** is 0.51 cm (0.20 in.), **k** is 1.26 cm (0.50 in.).

The biofouled condition of the MME semisubmersible was carefully assessed by divers on 1 March 1988. The biofouling was easily removed from the 2.54 cm (1 in.) stud link mooring chains, biaxial flotsam electromagnetic current meter cage, wavestaffs, and acoustic transducer mount using paint scrapers and gloved hands. Removal of the biofouling from other parts of the platform was not attempted because it resulted in removal of the antifouling paint. The MME platform was heavily fouled with mussels and barnacles that had attached themselves to areas on the platform pontoons and columns where the Ameron Amercoat antifouling paint had become inactive or had been chipped so that bare metal was exposed. See Figures 3.3 - 3.11.

The MME semisubmersible pontoon and column members below the fully ballasted draft mark, had been painted with 1 coat of Ameron Amercoat E70, a primer (2 mils) and 2 coats of Ameron Amercoat 71 (3 mils) antifouling paint in September 1985.

The MME semisubmersible platform was temporarily stored at a shore site while waiting installation. During this period of storage, the paint received direct exposure to the atmosphere and direct sunlight. The life of the antifouling paint was shortened because tiny cracks in the paint formed due to the sun's drying effects. Upon recommendation of a technical representative for the the Ameron paint manufacturer, the platform was hosed down once a week with fresh water to deter the tiny drying cracks, but the life of the paint could not be prolonged. The antifouling paint was expected to have a life of approximately 2 years. The heavy biofouling began to occur approximately 1 year and 3 months after the structure had been deployed.

It was determined from the samples collected on 1 March 1988 that there are two species of organisms inhabiting the MME semisubmersible: (1) Barnacles (Megabalanus Californicus) and (2) Mussels (Mytilus Edulis), a bivalve mollusk. See Figures 3.12 - 3.14. Both species are very common for the Southern California coastal waters. The mussels attach themselves to a structure (the culmination of a series of events in the reproductive cycle) when the temperature of the water is low, 10-14° C (50-57° F), usually during the months of January through June. Barnacles prefer the warmer water temperatures, 14.5-18° C (58-64° F) for the reproduction and attachment of barnacles. The attachment of barnacles appears to fluctuate throughout the year with the varying warmer/colder water temperatures.

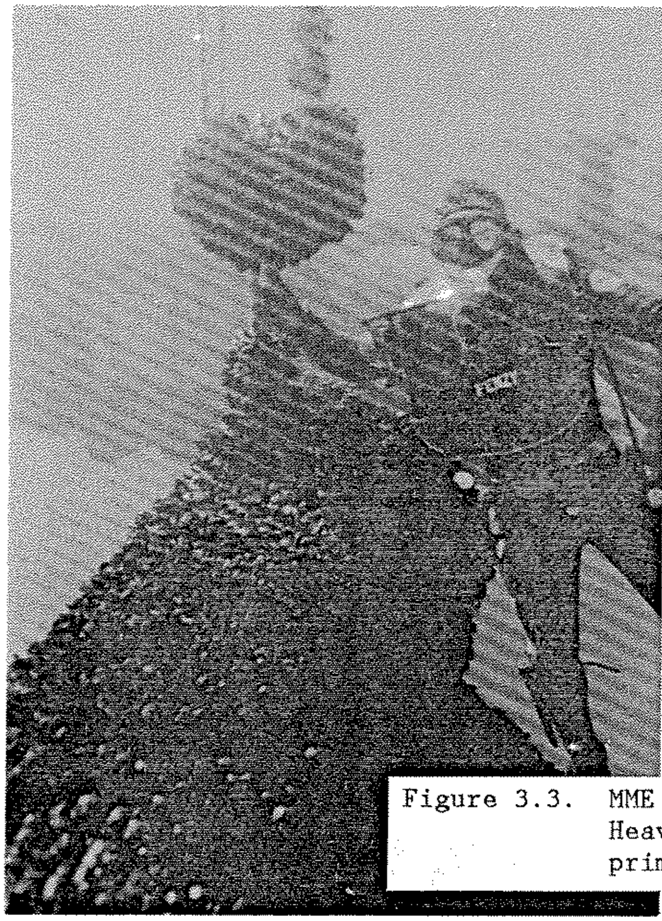


Figure 3.3. MME Baylor Wave Staffs With Heavy Marine Growth (consisting primarily of mussels and barnacles)

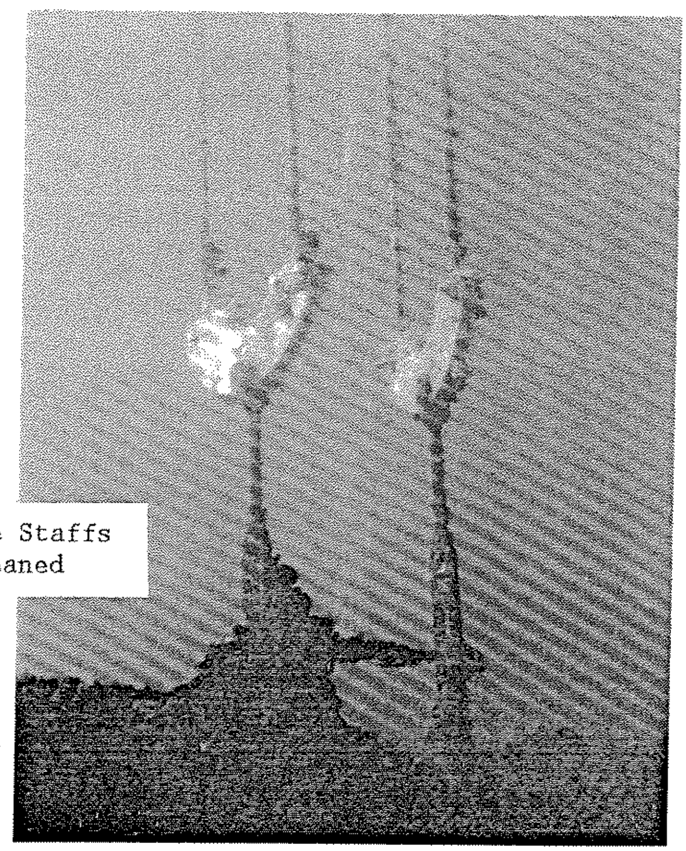


Figure 3.4. MME Baylor Wave Staffs After Being Cleaned

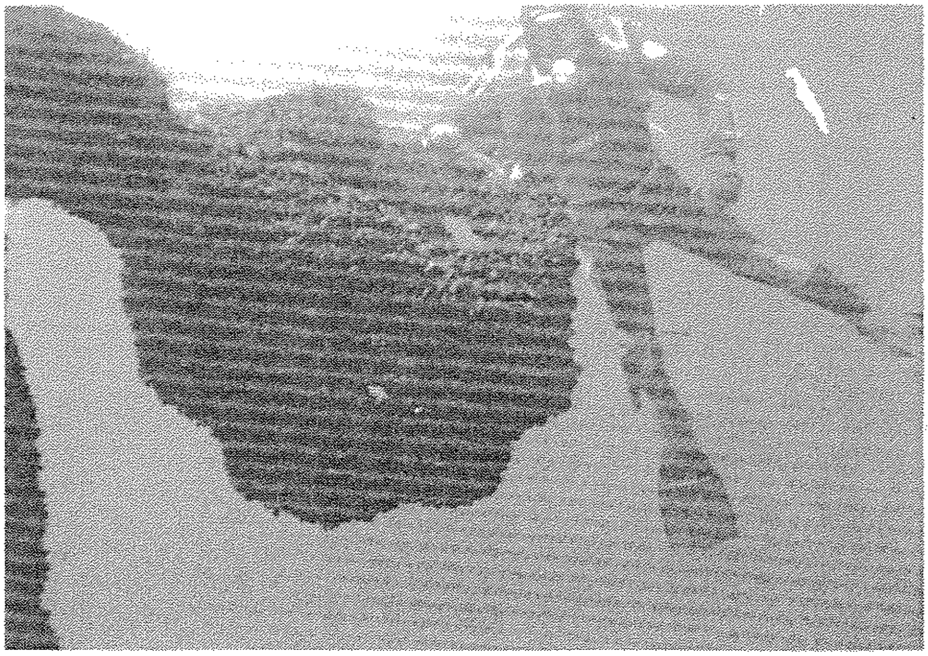


Figure 3.5. MME Current Meter Cage
With Heavy Marine Growth

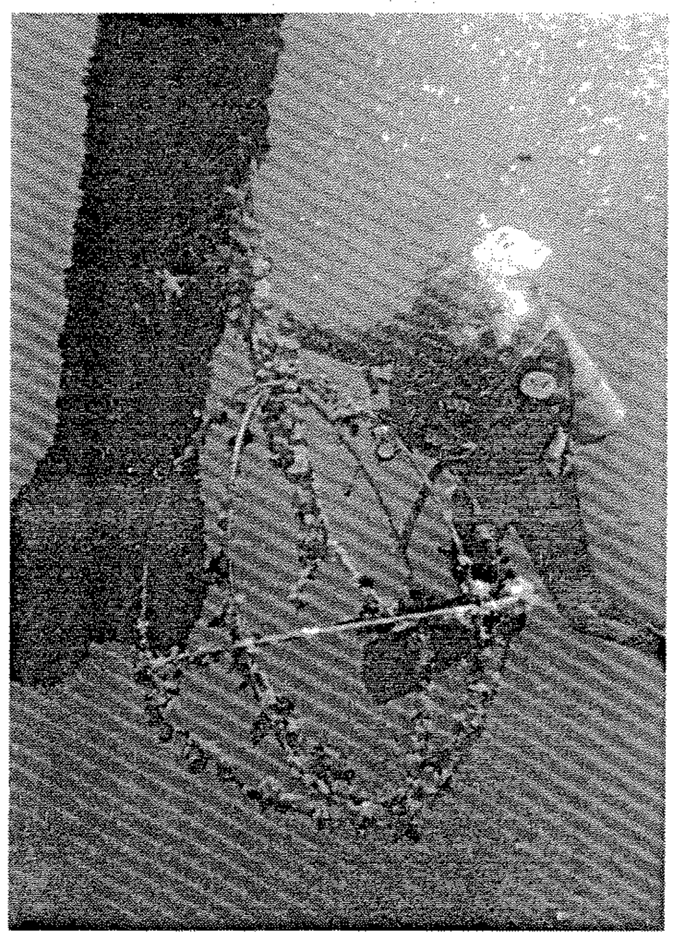


Figure 3.6. MME Current Meter Cage
After Being Cleaned

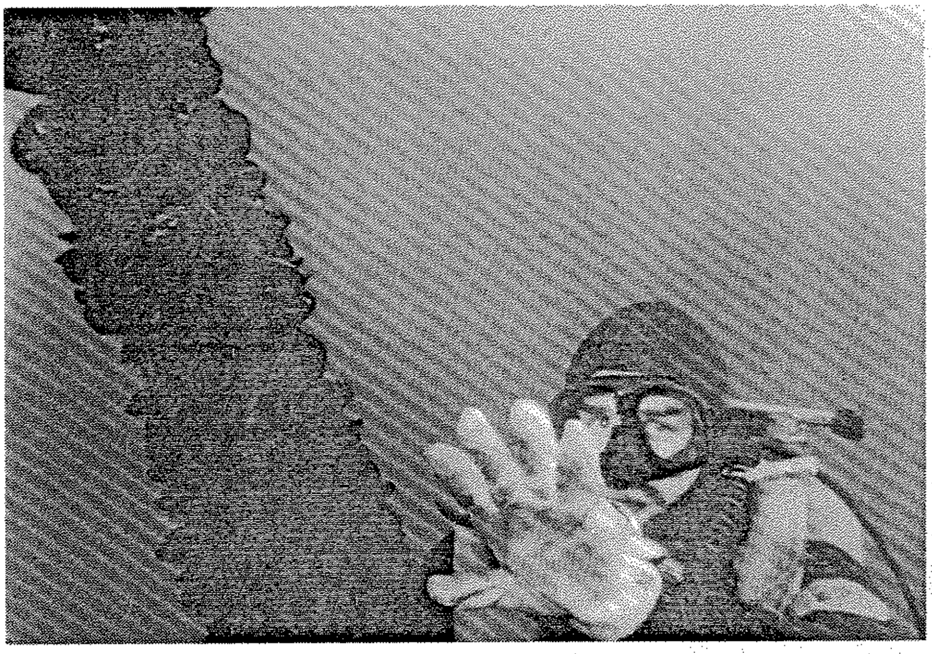


Figure 3.7. MME 1-inch Stud Link Mooring Chain With Heavy Marine Growth

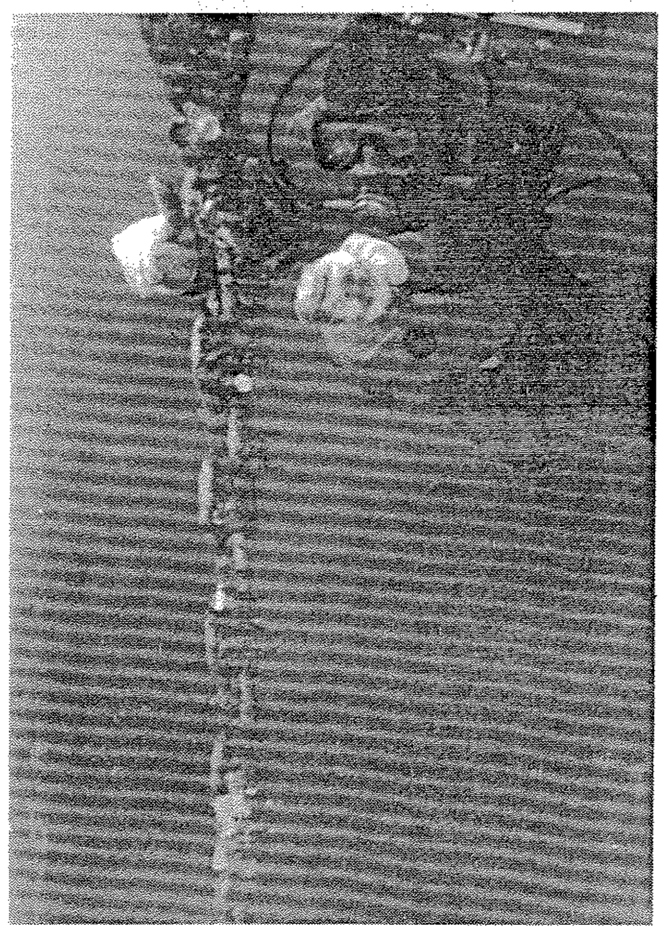


Figure 3.8. MME 1-inch Stud Link Mooring Chain After Being Cleaned

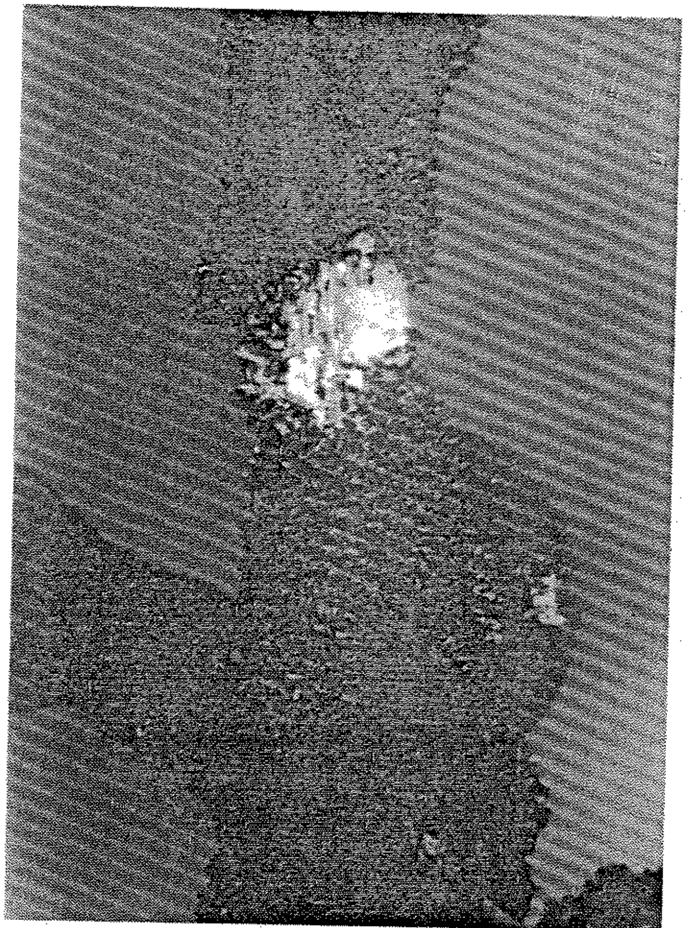


Figure 3.9. MME Platform Cross Member Showing Thickness of Marine Growth

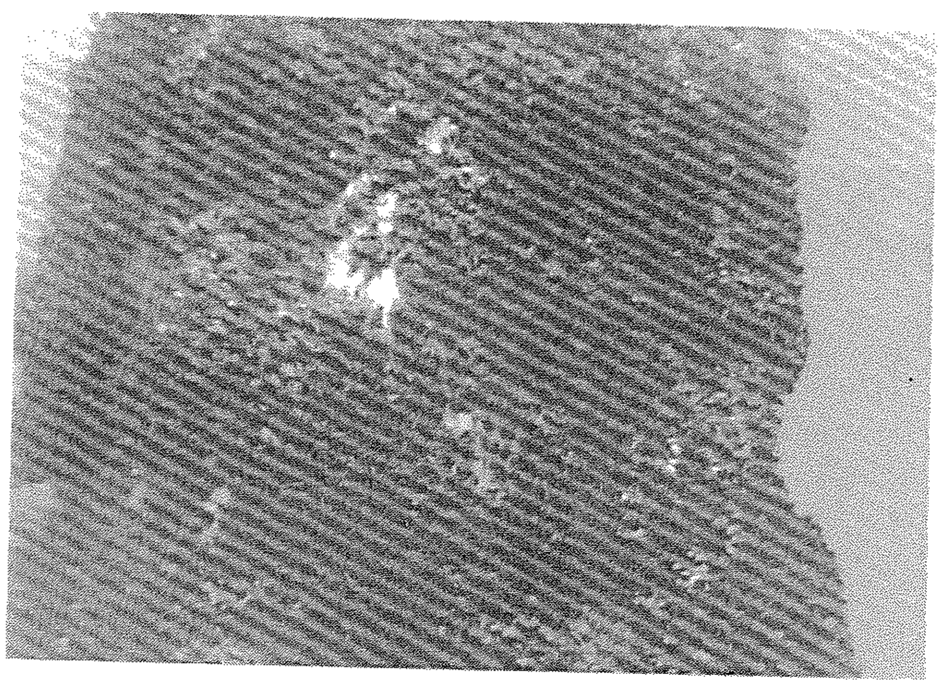


Figure 3.10. MME Platform Vertical Column Showing Marine Growth

Figure 3.11. MME Platform Pontoon Horizontal Member Topside With Marine Growth

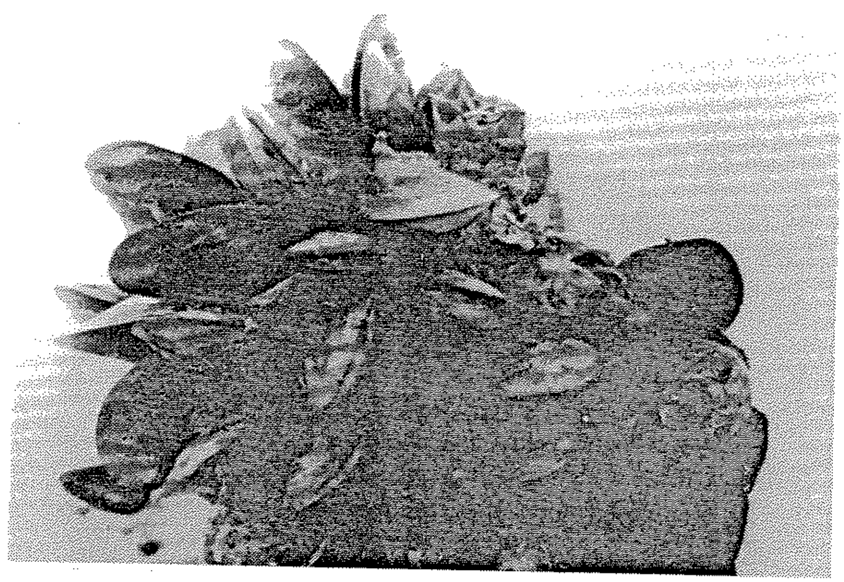


Figure 3.12. Specimen of Mytilus Edilus (mussels)

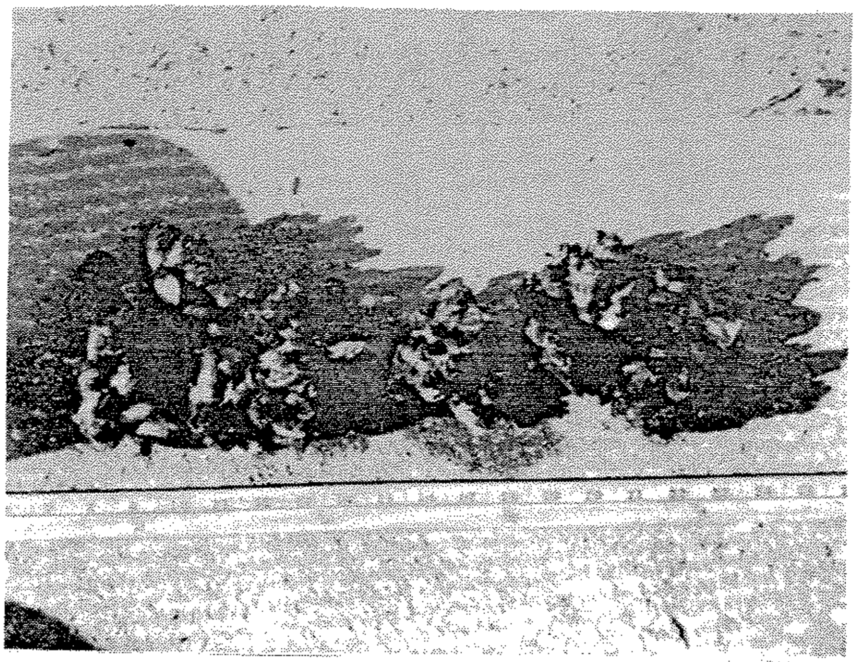


Figure 3.13. Specimen of Megabalamus Californicus (barnacles)

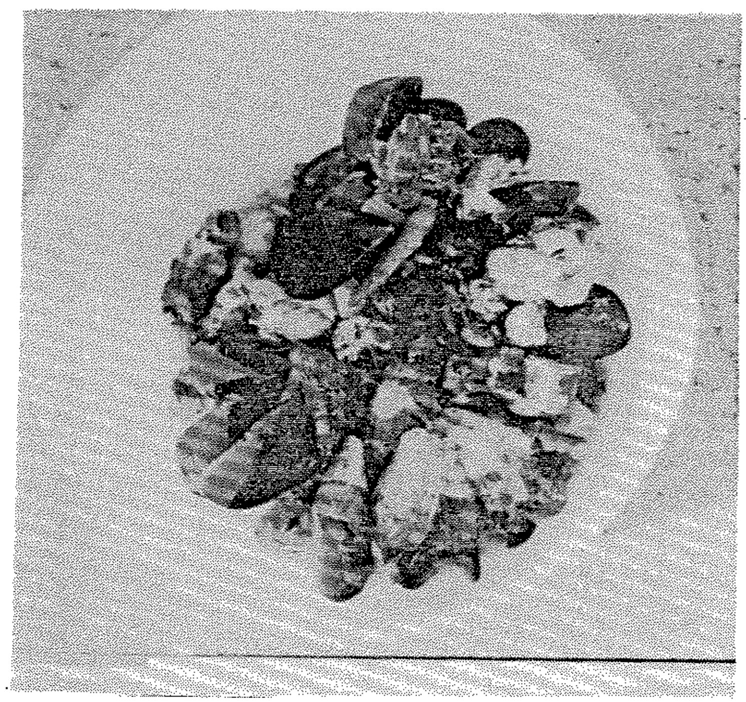


Figure 3.14. Specimen of Mytilus Edulis (mussels)
Attached to Megabalamus Californicus (barnacles)

At the time of the MME biofouled platform inspection cleaning, the structure had acquired approximately 6.8 cu m (240 cu ft) of marine growth. It was determined that 60 percent of the marine growth was comprised of mussels and 40 percent of the marine growth was comprised of barnacles. The specific gravity of the barnacles (Megabalanus Californicus) at the MME site was computed to be 1.63, and the unit weight of the barnacles was computed to be 1.65 g/ml (103 lb/cu ft). The specific gravity of the mussels (Mytilus Edulus) was computed to be 1.51 and the unit weight of the mussels was computed to be 1.53 g/ml (95.5 lb/cu ft). The in-air weight of the marine biofouling with entrained water on the MME semisubmersible is estimated to be approximately 11,000 kg (23,743 lbs) including the entrained water, but this computes to about 3,136 kg (6,914 lbs) submerged. This computes to an increase of the draft of 0.54 m (1.77 ft) larger than actually observed. If the specific gravity of the biofouling is reduced to 1.2, Nath (1987), the mass of the marine growth in the water is computed to be 1,496 kg (3,298 lbs), an increase in draft of 0.26 m (0.88 ft). This seems to be a more reasonable value. Figure 3.15 gives a conceptual view of the amount of biofouling on the MME semisubmersible. Table 3.1 gives values for the platform without marine growth and values for the increased mass attributed to marine growth.

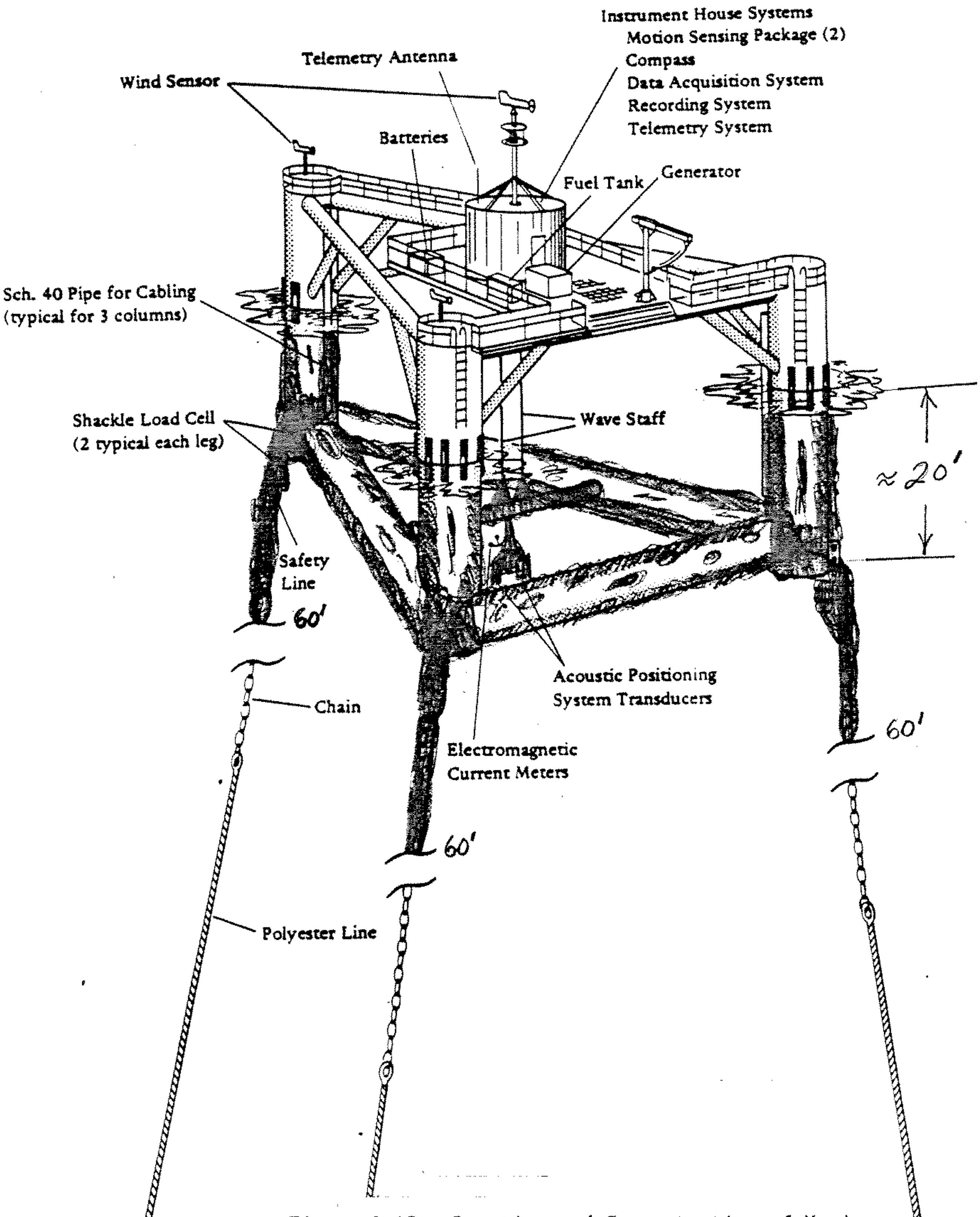


Figure 3.15. Location and Concentration of Marine Biofouling on MME Platform

Table 3.1 Semisubmersible Displacement with Biofouling

MME SEMI DEPLOYED WITH MOORING LINES	
LIGHTSHIP WT	95,540 LBS
BALLAST WT	92,250 LBS
MOORING WT	19,100 LBS
OTHER	500 LBS
DISPLACEMENT WO/BIOFOULING	207,390 LBS
BIOFOULING	3,298 LBS
TOTAL DISPLACEMENT	210,688 LBS

4.0 INSTRUMENT CALIBRATION

The MME Semisubmersible Instrument Subsystem (SIS) incorporates a complex network of instrumentation to sample, condition, transmit, and record up to 44 channels of time series data. MME environmental and semisubmersible response information was measured on up to 38 of these channels. The number of data channels varied as instruments were added or replaced. The remaining six channels were used to monitor information about the condition of the instrumentation network. These included temperature and relative humidity inside the deckhouse, and voltage reference levels as processed through the instrumentation network.

To ensure the accuracy of the data recorded, three levels of instrument calibration were performed. These include a pre-deployment physical, a real-time electrical, and a post-deployment physical calibration. Physical calibration means physically applying a known environment to each sensor and recording the measured voltage output. These physical calibrations establish the accuracy of each sensor based upon known standards of greater accuracy. Electrical calibration means shunting the sensor or applying a known voltage in place of or in line with the sensor. These electrical calibrations establish the daily repeatability of each sensor.

Immediately prior to deployment of the MME, the instrumentation system was exercised and calibrated to insure accurate data conditioning, transmitting, and recording. The SIS time channel was synchronized with Universal Co-ordinated Time as broadcast from the U.S. Navy Observatory. The values obtained from these calibration procedures have been used to determine the absolute and relative level of uncertainty in the data collected from each sensor. A greater level of measurement uncertainty is acceptable for this long-term, remote at-sea experiment than what would normally be acceptable for a standard laboratory experiment.

4.1 Pre-Deployment Physical Calibration

The pre-deployment physical calibration involved physically applying a known input to each sensor and recording the measured voltage output. The NCEL instrumentation staff performed physical calibration of each SIS sensor as accurately as possible. If the sensor manufacturer supplied calibration information which was collected in a more accurate manner, then this value was used for data conversion. These manufacturer supplied calibration values, however, were compared against those measured by the NCEL instrumentation staff and discrepancies were resolved. This insured accurate performance of each sensor immediately prior to deployment of the MME.

The results of the pre-deployment physical calibration showed a linear relationship between physical measurement and voltage for all SIS instruments except the yaw compass. A least squares regression was applied to each set of calibration data. The results are illustrated in Appendix B showing the calibration data points, best fit lines, and equations necessary to convert recorded voltages to engineering units.

Tables 4.1 and 4.2 contain multiplication factors and addition constants for converting sensor voltages to units which have physical meaning. These values were compiled from the pre-deployment physical

CHL #	INSTRUMENT or MEASUREMENT		PHYS. UNITS	VOLTAGE RANGE		PHYSICAL RANGE		Y=M*VOLTS+B NOMINAL		Y=M*VOLTS+B CALIBRATED	
				MIN	MAX	MIN	MAX	M	B	M	B
0	WAVE	1	FT	0	5	0	25	-5.00	25.00	-5.01	25.02
1	STAFFS	2	FT	0	5	0	25	-5.00	25.00	-4.94	24.91
2	CURRENT	1X	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
3	METERS	1Y	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
4		2X	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
5		2Y	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
6	HUMPHREY	SURGE	FT/S**2	-5	5	-32.2	32.2	6.44	0.00	6.467	0.3865
7	MOTION	SWAY	FT/S**2	-5	5	-32.2	32.2	6.44	0.00	6.338	0.1264
8	PACKAGE	HEAVE	FT/S**2	-5	5	-64.4	64.4	12.87	-32.17	12.627	-32.142
9	(SA07-0902-1)	ROLL	DEG	-5	5	-30	30	6.00	0.00	6.094	0.2936
10	(1987)	PITCH	DEG	-5	5	-30	30	6.00	0.00	5.987	-0.0337
11		ROLL R	DEG/S	-5	5	-15	15	3.00	0.00	3.037	-0.1235
12		PITCH R	DEG/S	-5	5	-15	15	3.00	0.00	2.983	-0.0626
13	PRESSURE	0 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
14	SENSORS	45 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
15		90 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
16		135 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
17		180 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
18		225 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
19		270 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
20	C1 LOAD CELL	UPPER	KLBS	0	11	0	30	2.81	0.00	2.8135	-0.067
21		LOWER	KLBS	0	11	0	30	2.90	0.00	N/A	N/A
22	C2 LOAD CELL	UPPER	KLBS	0	11	0	30	2.71	0.00	2.7661	-0.224
23		LOWER	KLBS	0	11	0	30	2.92	0.00	2.9434	-0.095
24	C3 LOAD CELL	UPPER	KLBS	0	11	0	30	2.74	0.00	2.7751	-0.201
25		LOWER	KLBS	0	11	0	30	2.87	0.00	2.9223	-0.207
26	C3 WIND	SPEED	M/S	0	5	0	50	10.00	0.00	9.96	-0.13
27	SENSOR	DIR	DEG	0	7.1	0	355	50.00	0.00	N/A	N/A
28	C1 WIND	SPEED	M/S	0	5	0	50	10.00	0.00	10.23	-0.12
29	SENSOR	DIR	DEG	0	7.1	0	355	50.00	0.00	N/A	N/A
30	VOLTAGE #1	ZERO	VOLT	-	-	-	-	-	0.00	N/A	N/A
31	REFERENCE	+5.0	VOLT	-	-	-	-	-	0.00	N/A	N/A
32	MAST WIND	SPEED	M/S	0	5	0	50	10.00	0.00	10.25	-0.2
33	SENSOR	DIR	DEG	0	7.1	0	355	50.00	0.00	N/A	N/A
34	COMPASS	HEADING	DEG	0	3.6	0	360	10.00	0.00	SEE BELOW	
35	DECKHOUSE	TEMP	DEG	0	5	0	100	20.00	0.00	N/A	N/A
36	AIR SENSOR	HUMID	%	0	5	0	100	20.00	0.00	N/A	N/A
37	VOLTAGE #2	ZERO	VOLT	0	5	-	-	-	0.00	N/A	N/A
38	REFERENCE	+5.0	VOLT	0	5	-	-	-	0.00	N/A	N/A
39	PRESSURE SNSR	315 DEG	PSIG	0	5	0	25	2.50		N/A	N/A
40	MODULAR	Z UPPER	KLBS	-5	5	0	6	1.00	-5	1.167	-7.766
41	FORCE (BARDI CALS)	X UPPER	KLBS	-5	5	0	6	1.00	-5	1.215	-5.988
42	GAGES	Z LOWER	KLBS	-5	5	0	6	1.00	-5	1.073	-4.626
43		X LOWER	KLBS	-5	5	0	6	1.00	-5	1.192	-6.352

Table 4.1. Voltage-to-Physical-Units Conversion for 1986-1987 Data Sets

CHL #	INSTRUMENT or MEASUREMENT		PHYS. UNITS	VOLTAGE RANGE MIN	VOLTAGE RANGE MAX	PHYSICAL RANGE MIN	PHYSICAL RANGE MAX	Y=M*VOLTS+B NOMINAL M	Y=M*VOLTS+B NOMINAL B	Y=M*VOLTS+B CALIBRATED M	Y=M*VOLTS+B CALIBRATED B
0	WAVE	1	FT	0	5	0	25	-5.00	25.00	-5.01	25.02
1	STAFFS	2	FT	0	5	0	25	-5.00	25.00	-4.94	24.91
2	CURRENT	1X	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
3	METERS	1Y	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
4		2X	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
5		2Y	FT/S	-1	1	-10	10	10.00	0.00	N/A	N/A
6	HUMPHREY	SURGE	FT/S**2	-5	5	-16.09	16.09	3.22	0.00	3.0208	1.7351
7	MOTION	SWAY	FT/S**2	-5	5	-16.09	16.09	3.22	0.00	3.2560	-0.0508
8	PACKAGE	HEAVE	FT/S**2	-5	5	-16.09	16.09	3.22	0.00	3.2142	-0.0964
9	(CF18-0908-1)	ROLL	DEG	-5	5	-25	25	5.00	0.00	5.1567	-0.1861
10	(1988)	PITCH	DEG	-5	5	-25	25	5.00	0.00	5.2575	-0.1548
11		ROLL R	DEG/S	-5	5	0	10	2.00	0.00	2.0186	-0.4912
12		PITCH R	DEG/S	-5	5	0	10	2.00	0.00	1.9473	-1.0191
13	PRESSURE	0 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
14	SENSORS	45 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
15		90 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
16		135 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
17		180 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
18		225 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
19		270 DEG	PSIG	0	10	0	25	2.50	0.00	N/A	N/A
20	C1 LOAD CELL	UPPER	KLBS	0	11	0	30	2.81	0.00	2.8135	-0.067
21		LOWER	KLBS	0	11	0	30	2.90	0.00	N/A	N/A
22	C2 LOAD CELL	UPPER	KLBS	0	11	0	30	2.71	0.00	2.7661	-0.224
23		LOWER	KLBS	0	11	0	30	2.92	0.00	2.9434	-0.095
24	C3 LOAD CELL	UPPER	KLBS	0	11	0	30	2.74	0.00	2.7751	-0.201
25		LOWER	KLBS	0	11	0	30	2.87	0.00	2.9223	-0.207
26	C3 WIND	SPEED	M/S	0	5	0	50	10.00	0.00	9.96	-0.13
27	SENSOR	DIR	DEG	0	7.1	0	355	50.00	0.00	N/A	N/A
28	C1 WIND	SPEED	M/S	0	5	0	50	10.00	0.00	10.23	-0.12
29	SENSOR	DIR	DEG	0	7.1	0	355	50.00	0.00	N/A	N/A
30	VOLTAGE #1	ZERO	VOLT	-	-	-	-	-	0.00	N/A	N/A
31	REFERENCE	+5.0	VOLT	-	-	-	-	-	0.00	N/A	N/A
32	MAST WIND	SPEED	M/S	0	5	0	50	10.00	0.00	10.25	-0.2
33	SENSOR	DIR	DEG	0	7.1	0	355	50.00	0.00	N/A	N/A
34	COMPASS	HEADING	DEG	0	3.6	0	360	10.00	0.00	SEE BELOW	
35	DECKHOUSE	TEMP	DEG	0	5	0	100	20.00	0.00	N/A	N/A
36	AIR SENSOR	HUMID	%	0	5	0	100	20.00	0.00	N/A	N/A
37	VOLTAGE #2	ZERO	VOLT	0	5	-	-	-	0.00	N/A	N/A
38	REFERENCE	+5.0	VOLT	0	5	-	-	-	0.00	N/A	N/A
39	PRESSURE SNSR	315 DEG	PSIG	0	5	0	25	2.50	0.00	N/A	N/A
40	MODULAR	Z UPPER	KLBS	-5	5	0	6	1.00	-5	1.167	-7.766
41	FORCE (BARDI CALS)	X UPPER	KLBS	-5	5	0	6	1.00	-5	1.215	-5.988
42	GAGES	Z LOWER	KLBS	-5	5	0	6	1.00	-5	1.073	-4.626
43		X LOWER	KLBS	-5	5	0	6	1.00	-5	1.192	-6.352

Table 4.2. Voltage-to-Physical-Units Conversion for 1988 Data Sets

calibrations. Table 4.3 shows the nominal resolution of the instruments for the two major measurement time frames 1986-1987 and 1988. The calibration values are obviously different for instruments which were replaced. Table 4.4 presents a short description of each instrument.

A Humphrey Model SA07-0902-1 Motion Package with a vertically stabilized accelerometer platform provided the MME platform high frequency motions during the majority of the MME. A Humphrey Model CF18-0908-1 Motion Package was used in 1988 as an interim replacement. Both units were calibrated by the manufacturer. Calibration data are shown in Appendix B, Figures B.2-B.8 for 1986-1987, and Figures B.9-B.15 for 1988. Both packages measure the frequency content of the semisubmersible accelerations accurately down to about 0.067 hertz. Acceleration information with frequency less than 0.067 hertz is subject to error because the vertically stabilizing gyroscope is corrected to match the direction of gravity at about that frequency.

A functional check of the SA07-0902-1 motion package was performed at the National Data Buoy Center (NDBC), National Space Technology Laboratories (NSTL), Mississippi prior to deployment of the MME. Their wave orbital motion machine was utilized to perform functional checks on motions in heave, roll, roll rate, pitch, pitch rate, surge and sway. The results of these tests agreed with the manufacturer's calibrations. Table 4.1 shows the calibration conversion values for the SA07-0902-1 package during its 1986-1987 usage, and Table 4.2 shows the same for the CF18-0908-1 package during its 1988 usage.

The Metrox Model 2037-102-30K Shackle Load Cells which measured the mooring line tensions at the platform were calibrated at NCEL on a load machine. The load cells were also tested to determine the long-term

Formula for calculating channel resolution:

VOLTAGE RESOLUTION = VOLTAGE RANGE / NUMBER OF QUANTIZATION LEVELS

= +/- 10 VOLTS / 2^12 = 20 /4096 =0.004882

NOMINAL RESOLUTION = PHYSICAL RANGE / NUMBER OF QUANTIZATION LEVELS

CHANNEL	NOMINAL RESOLUTION 1986-1987
WAVE STAFFS	0.02440 FEET = 0.2928 INCHES
SURGE ACCEL *	0.00098 G'S = 0.031427 FT/S**2
HEAVE ACCEL *	0.00195 G'S = 0.062854 FT/S**2
SWAY ACCEL *	0.00098 G'S = 0.031427 FT/S**2
ROLL RATE *	0.01464 DEG/S
PITCH RATE *	0.01464 DEG/S
ROLL ANGLE *	0.02928 DEG
PITCH ANGLE *	0.02928 DEG
YAW ANGLE	0.56471 DEG
CURRENT METERS	0.04880 FT/S
LOAD CELLS	0.01415 KIPS = 14.152 POUNDS
ITC PRESSURE CELLS	0.01220 PSI
ITC FORCE TRANS.	0.00586 KIPS = 5.856 POUNDS
WIND SPEED	0.16006 FT/S
WIND DIRECTION	0.24400 DEG
TEMPERATURE	0.17568 DEG
HUMIDITY	0.02440 %

NOTE: * for Humphrey motion package SA07-0902-1

CHANNEL	NOMINAL RESOLUTION 1988
WAVE STAFFS	0.02440 FEET = 0.2928 INCHES
SURGE ACCEL *	0.00049 G'S = 0.015713 FT/S**2
HEAVE ACCEL *	0.00049 G'S = 0.015713 FT/S**2
SWAY ACCEL *	0.00049 G'S = 0.015713 FT/S**2
ROLL RATE *	0.00976 DEG/S
PITCH RATE *	0.00976 DEG/S
ROLL ANGLE *	0.02440 DEG
PITCH ANGLE *	0.02440 DEG
YAW ANGLE	0.56471 DEG
CURRENT METERS	0.04880 FT/S
LOAD CELLS	0.01415 KIPS = 14.152 POUNDS
ITC PRESSURE CELLS	0.01220 PSI
ITC FORCE TRANS.	0.00586 KIPS = 5.856 POUNDS
WIND SPEED	0.16006 FT/S
WIND DIRECTION	0.24400 DEG
TEMPERATURE	0.17568 DEG
HUMIDITY	0.02440 %

NOTE: * for Humphrey motion package CF18-0908-1

Table 4.3. MME Data Acquisition Resolutions

Parameter	Instrument	Range	Output Signal	Accuracy	Redundancy/ Spares	Mounting	Pre-Installation Checkout/Calibration	Operational Checkout/Calibration
Platform Motion	Humphrey Model SA07-0902-1	S&S Accel ± 1G Heave ± 2G P&R Pos. ± 30° P&R Rate ± 15°/s	All ± 5 VDC	Accelerometers 0.5% of full-scale (max) P&R Pos. ± .5° P&R Rate ± 1 to 2%	See Systron Donner	Geometric Center of Deckhouse	1) Bench Test- Functional (A) P&R Position (B) Acceleration - Earth's Gravity 2) Calibrate at NDBC	None
Platform Motion	Humphrey Model CF18-0908-1	S&S Accel ± .5G Heave ± .5G P&R Pos. ± 25° P&R Rate ± 10°/s	All ± 5 VDC	"	"	"	1) Bench Test - Functional (A) P&R Position (B) Acceleration - Earth's Gravity	"
Mooring Line Tension	Metrox Model 2037-102-30K Shackle Load Cell	0-30,000 lbs.	0-10 VDC	1-2% of full-scale	2 in ea. line (1 primary & 1 back-up)	1) In-line in mooring legs btw platform padeyes & upper mooring chain 2) Connected together via a load trans blk	1) Bench Test- Functional (A) Shunt, zero, voltage substitution calibrations 2) Calibration in NCEL load machine 3) Dive tank wet test 4) Test mounted shorting bar	1) Low & high shunt calibration 2) Zero calibration 3) Voltage substitution calibration
Relative Wave Height	Baylor Model 23766 Wave Measuring System	Approx. 0-24 Ft.	0-5 VDC		2 staffs (1 primary & 1 back-up)	Staffs directly under deck-house	1) Measure distance from lower spreader to spacer 2) Land Test - shorting bar every foot 3) Test switch - max wave height	1) Relay actuated test switch-max H 2) Relay actuated mounted shorting bar 3) Visual noting spacer vs water level
Wind Speed Direction	R.M. Young Model 05103 Wind Monitor with Model 05602 Sensor Interface Circuit	Speed - 0-50m/sec (113 MPH) Direction - 360° mechanical 355° electrical	Speed 0-5 VDC Direction 0-7.2 VDC	1-2%	1 primary at 10 meters 2 backup at 6 meters (NDBC buoy-2 at 10m level)	1) one on mast above deckhouse 2) one each on C1 and C3	1) Record mounting Ht. 2) Bench calibration of dir. 3) Speed calibration at NDBC	1) Monitor direction voltage ref.
Platform Heading	ENDECO Type 869 Solid State Compass	0 - 360°	0-3.6 VDC	± 1° (referred to Cal data)	1 prim. on platform; 1 backup at NCEL	in canister on mount above deckhouse	1) Bench test - Functional (A) Rotate away from all ferrous materials 2) Platform must be swung to calibrate	1) zero cal 2) full-scale cal
Relative Water Particle Velocity	Marsh-McBirney Model 511 EM Current Meter	0 - 10 ft/sec (305 cm/sec or 6 kts)	± 1 VDC	± 2% of reading	None	bottom center of platform on own mount adj. to hydro-phones	1) Zero check - still water 2) Calibrate check (switch) 3) Supply check 4) Wash electrodes	1) Relay actuate test switch
Filtering		1.0 Hz cut-off frequency						

Table 4.4. Sensor Descriptions

drift of the voltage output. A wet test in the NCEL Dive Tank facility was also performed. The wet test included additional check for electrical drift. Plots of these calibration data with a least squares linear fit are shown in Appendix B, Figures B-16 through B-20.

The calibration data for Load Cell C1-Lower are not provided because the original Metrox shackle load cell failed and was replaced with a Strainsert Model STL-30 load sensing tension link just prior to tow-out of the MME semisubmersible. Post-calibration of the replacement instrument and all others will be performed once the platform is recovered.

The R.M. Young Model 05103 Wind Anemometers measured wind speed and direction at three locations on the MME platform. The wind speed sensors on these instruments were calibrated by NDBC. Wind direction sensors for these instruments were calibrated at NCEL after being installed on the semisubmersible. Plots of these calibration data are shown in Appendix B, Figures B-21 through B-23.

The Endeco Type 869 Solid State Compass which measures MME platform heading was first bench tested at NCEL. The compass was installed on the MME platform within an aluminum housing and strategically placed on top of the deck house where deviations to the magnetic field caused by steel in the MME semisubmersible would be minimized. Once installed, the compass was calibrated against a gyro compass by spinning the MME semisubmersible in the middle of Port Hueneme Harbor. Several tests were performed in both the clockwise and counterclockwise directions. The data from this test are provided in Appendix B, Figure B-24. The MME Imposed Displacement Test also included another calibration of the buoy compass against a gyro compass for large angular velocities and displacements of 2 deg/sec and 60 deg., respectively (See Figure 7.14).

The MME platform deckhouse temperature and relative humidity were monitored with a Vaisala Humicap Mode HMP 111A. A calibration for these sensors was performed but is not critical to experiment performance or results, and thus not presented here.

Two Baylor Wave Staffs, model 23766 measured the free surface elevation of the ocean with respect to the MME platform. The staffs were calibrated on land with shorting bars at 0.03 m (1 ft) increments over their 7.6 m (25 ft) lengths. Wave staff output was also checked with draft readings in Port Hueneme Harbor as the MME platform was ballasted and deballasted. Results of the calibration data are illustrated in Appendix B, Figures B-25 and B-26.

Two Marsh-McBirney Model 511 electromagnetic current meters provided the ocean surface current measurements. A certified calibration was obtained from the manufacturer. The accuracy of the water particle velocities measured by these meters are affected by marine growth which may alter the water flow. The sensors for these meters were mounted well below the keel to minimize flow disturbances by the semisubmersible hull.

The Sonardyne Long Baseline Acoustic Positioning System with type 7421a LF COMPATTS and version 7.5 firmware measured MME platform low frequency motions. This system replaced a similar GEODATA brand system which did not function adequately. Acoustic data ranges were sampled at the fastest rate possible, approximately every 7.8 seconds. Because of the digital nature of this data and the long sampling interval, aliasing from position information below periods of 7.8 seconds may occur in the recorded data.

The Sonardyne long baseline acoustic positioning system was calibrated at sea against a Motorola Falcon 484 surface navigation system at various times during the MME. The estimated accuracy of the surface navigation system was ± 2.4 meters (± 7.9 feet) under given survey triangulation conditions.

The relative location of each acoustic transponder on the sea-floor was determined by a rigorous baseline grid calibration between successive transponders. The absolute position of this grid was estimated to be accurate to within 15 feet. Successive direct range measurements from the platform to each seafloor transponder are accurate to within ±. 6 meter (2 feet).

The Instrumented Test Cylinder (ITC) calibrations are described in Section 4.3.

4.2 Real-Time Electrical Calibration

A real-time electrical calibration was programmed into the start-up and shut-down operations of the MME data acquisition cycle. Although not really a true method for calibrating instruments, this electrical calibration served to check the integrity and accuracy of the complete at-sea instrument circuitry in a real-time fashion.

Normally each cycle of data acquisition consisted of four modes of real-time electrical calibration, followed by the normal data mode, and followed by the same four modes of calibration. The order and time length of each mode was operator-controllable and was changed throughout the MME. Typically, each calibration mode was set for 10 minutes and the data mode was set for 4 hours. The MME had four different electrical calibration modes (C0, C1, C2, C3).

Mean, Min/Max, and standard deviation statistics were calculated and noted for each calibration mode of each data acquisition cycle. These calibration values were monitored for early signs of possible instrument failure. These values when compared between start-up and shut-down served to identify any voltage drifts during a given data collection period. These values when compared day-to-day provided a means of measuring long term instrumentation stability.

During each calibration mode, the SIS instruments were switched to various electrical self-tests depending on the specific instrument. These include zero-cal, voltage-cal, and shunt-cal tests either supplied by the manufacturer or specially-built by NCEL. Table 4.5 shows the nominal values expected during each mode. The data generated during calibration modes are the same as that generated during the normal data mode (mode 4) except as indicated in Table 4.5.

The following specific operations were performed during each mode:

Mode 0: All SIS instruments except the motion measurement package were energized. Fifteen data channels were affected by this calibration mode. All six load cells were electrically replaced by a short circuit. The yaw compass was electrically forced to give a nominal zero degree output. This produced zero calibrations for the load cells and the

CHL #	INSTRUMENT or MEASUREMENT		UNITS	0	1	2	3	4
0	WAVE	1	FT	DATA	25.0	18.0	DATA	DATA
1	STAFFS	2	FT	DATA	25.0	18.0	DATA	DATA
2	CURRENT	1X	FT/S	DATA	DATA	5.0	DATA	DATA
3	METERS	1Y	FT/S	DATA	DATA	5.0	DATA	DATA
4		2X	FT/S	DATA	DATA	5.0	DATA	DATA
5		2Y	FT/S	DATA	DATA	5.0	DATA	DATA
6	HUMPHREY	SURGE	FT^2/S	OFF	OFF	OFF	OFF	DATA
7	MOTION	SWAY	FT^2/S	OFF	OFF	OFF	OFF	DATA
8	PACKAGE	HEAVE	FT^2/S	OFF	OFF	OFF	OFF	DATA
9		ROLL	DEG	OFF	OFF	OFF	OFF	DATA
10		PITCH	DEG	OFF	OFF	OFF	OFF	DATA
11		ROLL R	DEG/S	OFF	OFF	OFF	OFF	DATA
12		PITCH R	DEG/S	OFF	OFF	OFF	OFF	DATA
13	PRESSURE	0 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
14	SENSORS	45 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
15		90 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
16		135 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
17		180 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
18		225 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
19		270 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
20	C1 LOAD CELL	UPPER	KLBS	-0.48	22.12	DAT+1.8	DAT+10.9	DATA
21		LOWER	KLBS	1.11	24.35	DAT+1.7	DAT+11.0	DATA
22	C2 LOAD CELL	UPPER	KLBS	-1.15	21.34	DAT+1.8	DAT+10.9	DATA
23		LOWER	KLBS	-0.13	23.20	DAT+1.7	DAT+11.1	DATA
24	C3 LOAD CELL	UPPER	KLBS	-1.80	20.90	DAT+1.7	DAT+10.9	DATA
25		LOWER	KLBS	1.51	25.40	DAT+1.8	DAT+11.5	DATA
26	C3 WIND	SPEED	M/S	DATA	DATA	DATA	DATA	DATA
27	SENSOR	DIR	DEG	DATA	DATA	DATA	DATA	DATA
28	C1 WIND	SPEED	M/S	DATA	DATA	DATA	DATA	DATA
29	SENSOR	DIR	DEG	DATA	DATA	DATA	DATA	DATA
30	VOLTAGE #1	ZERO	VOLT	DATA	DATA	DATA	DATA	DATA
31	REFERENCE	+5.0	VOLT	DATA	DATA	DATA	DATA	DATA
32	MAST WIND	SPEED	M/S	DATA	DATA	DATA	DATA	DATA
33	SENSOR	DIR	DEG	DATA	DATA	DATA	DATA	DATA
34	COMPASS	HEADING	DEG	-2.9	360	DATA	DATA	DATA
35	DECKHOUSE	TEMP	DEG	DATA	DATA	DATA	DATA	DATA
36	AIR SENSOR	HUMID	%	DATA	DATA	DATA	DATA	DATA
37	VOLTAGE #2	ZERO	VOLT	DATA	DATA	DATA	DATA	DATA
38	REFERENCE	+5.0	VOLT	DATA	DATA	DATA	DATA	DATA
39	PRESSURE SNSR	315 DEG	PSIG	20.0	DATA	DATA	DATA	DATA
40	MODULAR	Z UPPER	KLBS	-1.367	1.784	DATA	DATA	DATA
41	FORCE	X UPPER	KLBS	-1.444	1.92	DATA	DATA	DATA
42	GAGES	Z LOWER	KLBS	-	-	DATA	DATA	DATA
43		X LOWER	KLBS	-	-	DATA	DATA	DATA

NOTE: The Humphrey Package is on (DATA) for the shut-down calibration
The Humphrey Package is not on for the start-up calibration

Table 4.5. Electrical Calibration Cycles

yaw compass. The pressure cells on the ITC were electrically replaced by a known voltage. All other energized instruments recorded normal data. The acoustic position system went through an initialization/procedure.

Mode 1: All six load cells were electrically replaced by a known voltage. The yaw compass was forced to give 360 degree output. The two wave staffs were switched to full scale readings. All other energized instruments recorded normal data. The acoustic positioning system clock was sent a synchronization time and began to enable all transponders.

Mode 2: All six load cells were shunted with a known resistance to shift the normal data to a higher value. The two wave staffs were electrically shorted at the 18-foot level. The two current meters were switched internally to output a constant value. All other energized instruments recorded normal data. The acoustic positioning system was commanded to switch to "Grid Check" and began ranging between grid transponders only when all transponders were enabled.

Mode 3: All six load cells were shunted with a different resistance to shift the normal data to a higher value. All other instruments recorded normal time series data. The acoustic positioning system was commanded to switch to "Anchor Position" and began ranging to the anchor transponders when finished with "Grid Check."

Mode 4: The motion measurement package was energized and normally took between 5 and 20 minutes to stabilize. The acoustic positioning system was commanded to switch to "Platform Position" and began ranging to the grid transponders when finished with "Anchor Position".

A Hewlett Packard HP310 computer was used to command the long baseline acoustic positioning system and calculate calibration positions. The MME transponder grid layout is given in Figure 4.1. In summary, measurements between grid transponders were made and recorded in calibration mode 2, positions of anchor transponders were calculated and recorded in calibration mode 3, and positions of the semisubmersible platform were calculated and recorded in mode 4. A complete description of the long baseline acoustic positioning system is given in Zueck et al. (1987).

4.3 Instrumented Test Cylinder Calibration

The Instrumented Test Cylinder (ITC) was installed at-sea some time after the original MME deployment. See Section 2.2 for a complete description of this cylinder. Several tests and calibrations were performed on the ITC (See Figure 4.2) at Brown and Root Development, Inc. (BARDI), at NCEL, and at-sea. These tests included the following: hydrostatic test, pressure transducer confirmation test, force transducer calibration and confirmation tests. The following is a brief description of each test, each calibration procedure and the results obtained. The schematics of the ITC are shown in Figures 4.3 and 4.4.

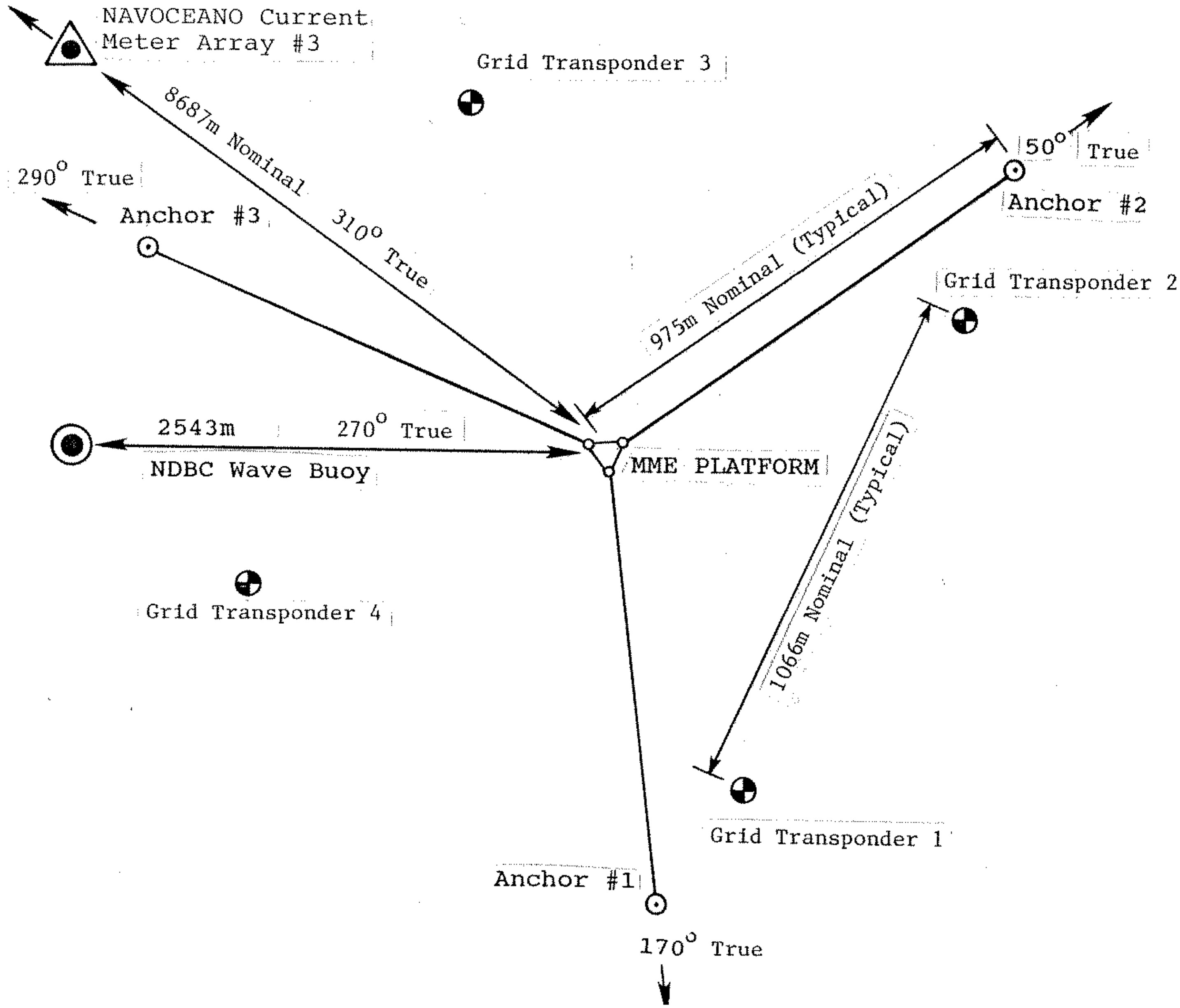


Figure 4.1. MME Mooring and Transponder Grid Layout

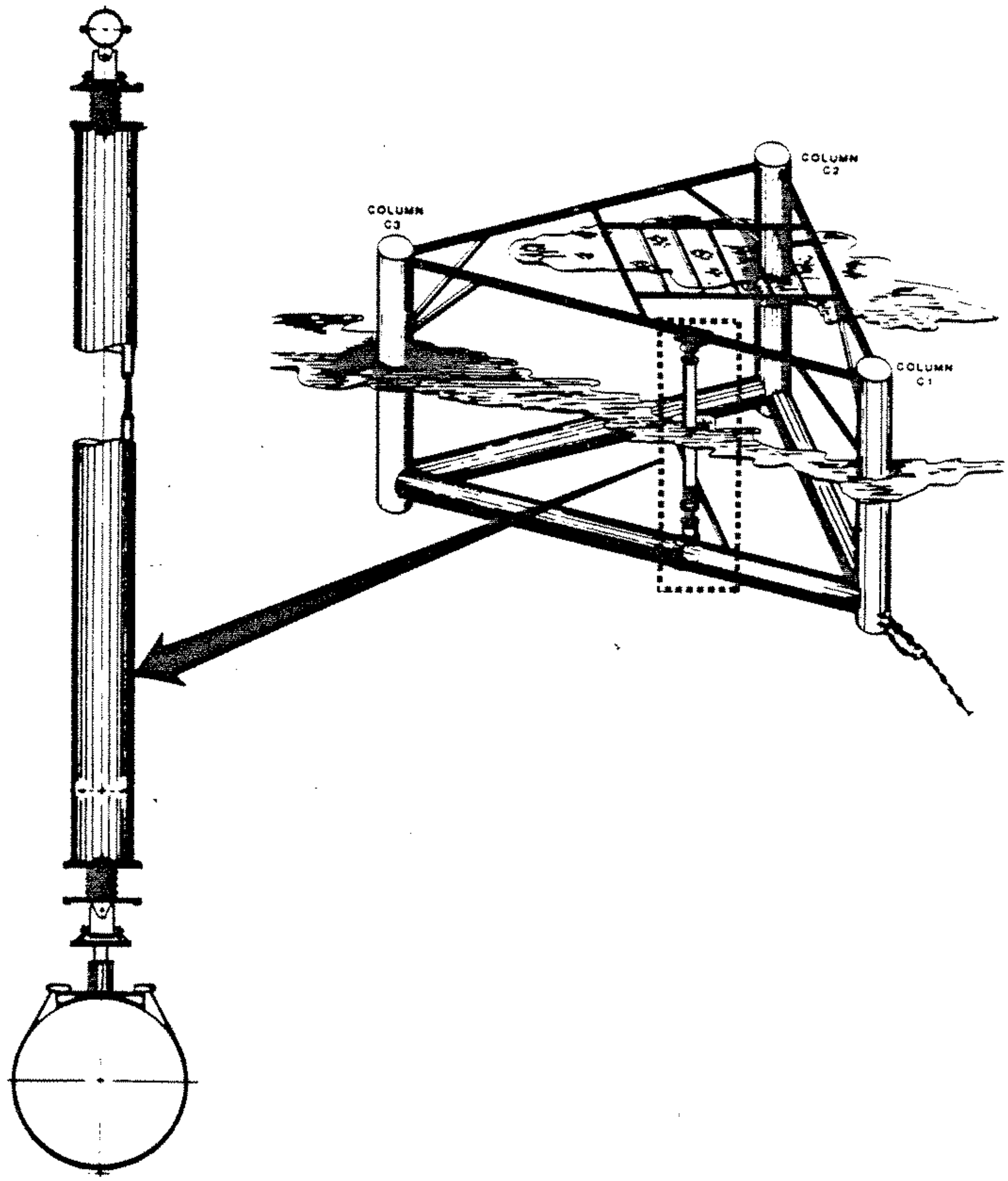


Figure 4.2. Instrumented Test Cylinder Location

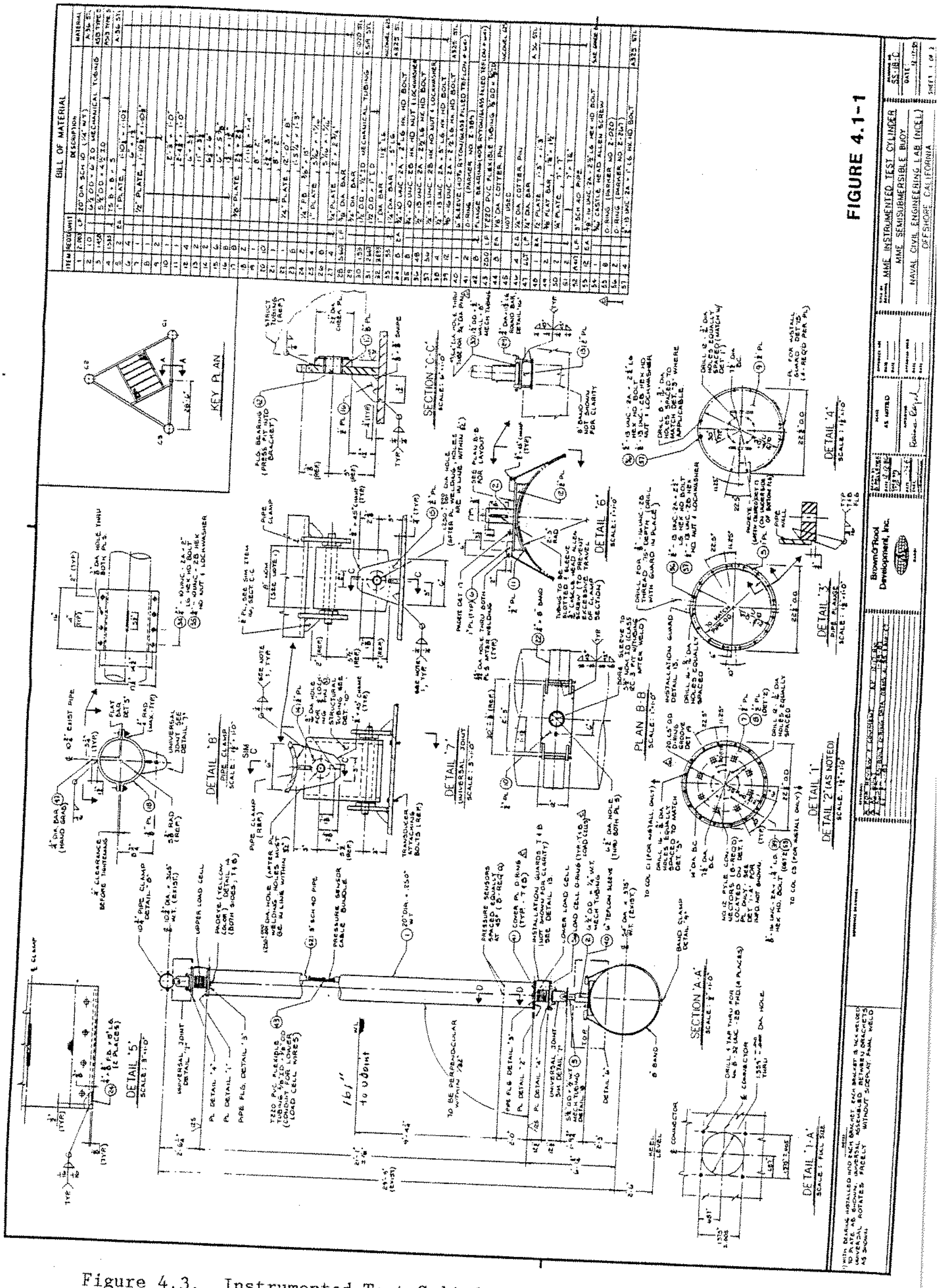


Figure 4.3. Instrumented Test Cylinder Schematics

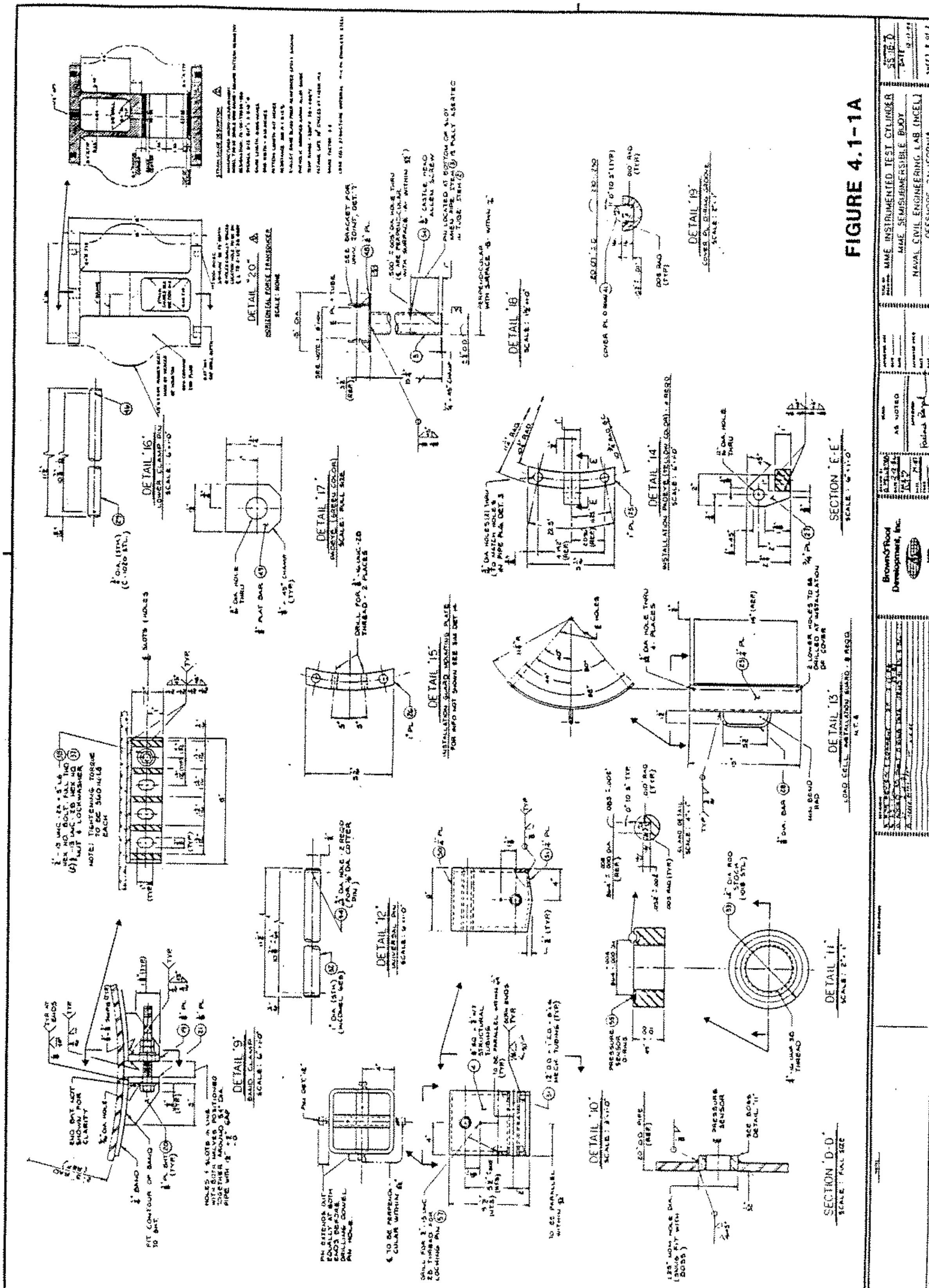


Figure 4.4. Instrumented Test Cylinder Schematics

A hydrostatic test was conducted using a 60.9 cm (24 in.) O.D. cylindrical pressure chamber. Both water tight integrity and proper functioning of the pressure transducers were assessed. The pressure chamber cover plate was cut to fit around the 51 cm (20 in.) O.D. of the cylinder body. The cover plate was welded to the cylinder to provide the necessary hydrostatic seal. The other end of the cylinder was left open to allow visual inspection of the cylinder interior. Water supply was connected to the pressure chamber through a valve, regulator and pressure gage, Figure 4.5. The cylinder and pressure transducers were subjected to 25 psig. No leakage was detected and watertight integrity was considered acceptable. The bottom load cell was also subject to a soak test in a 3 m (10 ft) deep swimming pool. No leakage was detected.

Calibration certificates for all pressure transducers, Dynisco model G869-900-25-K28, were supplied by the manufacturer. During the hydrostatic test described above, pressures were measured by the pressure transducers and recorded. The pressures were varied from 5 psig to 25 psig at 5 psig intervals and monitored by a regulator and calibrated manometer. This pressure transducer confirmation test was performed twice and all output agreed with the manufacturer's calibration certificate. The locations of each pressure cell or transducer are shown in Figure 4.6.

The force transducer calibration test was conducted at BARDI shops in Houston as well as at NCEL. A force transducer test and calibration was carried out for every 30 degrees of the cylinder section as shown in Figure 4.7. At each angle, the applied load started at zero lbs and increased to 2,722 kg (6,000 lbs) with increments of 454 kg (1,000 lbs)

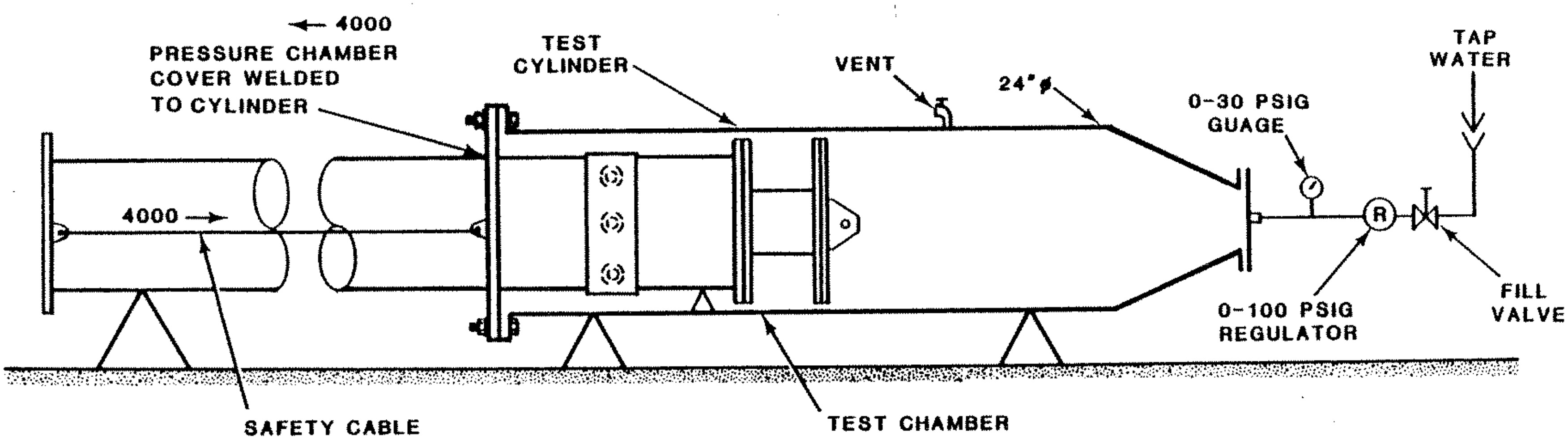
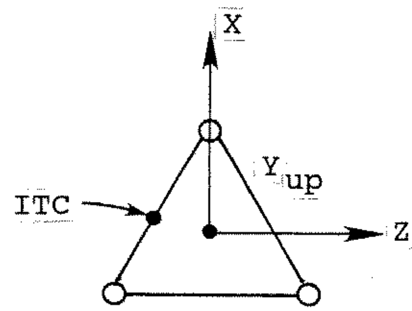


Figure 4.5. ITC Hydrostatic Test

Pressure Cell Polar Directions

#1	60°
2	105°
3	155°
4	195°
5	240°
6	285°
7	330°
8	15°



Coordinate Location
of Cylinder Center

(X,Z) = (0.79 ft, -14.25 ft)

Pressure Cell
Elevation = 10.67'

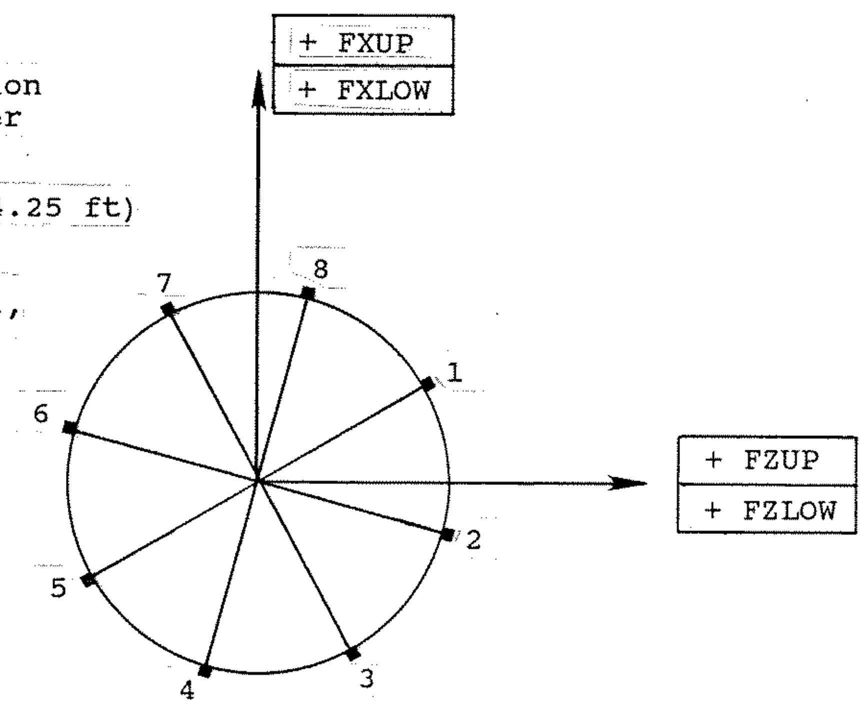


Figure 4.6. ITC Pressure Cell Location

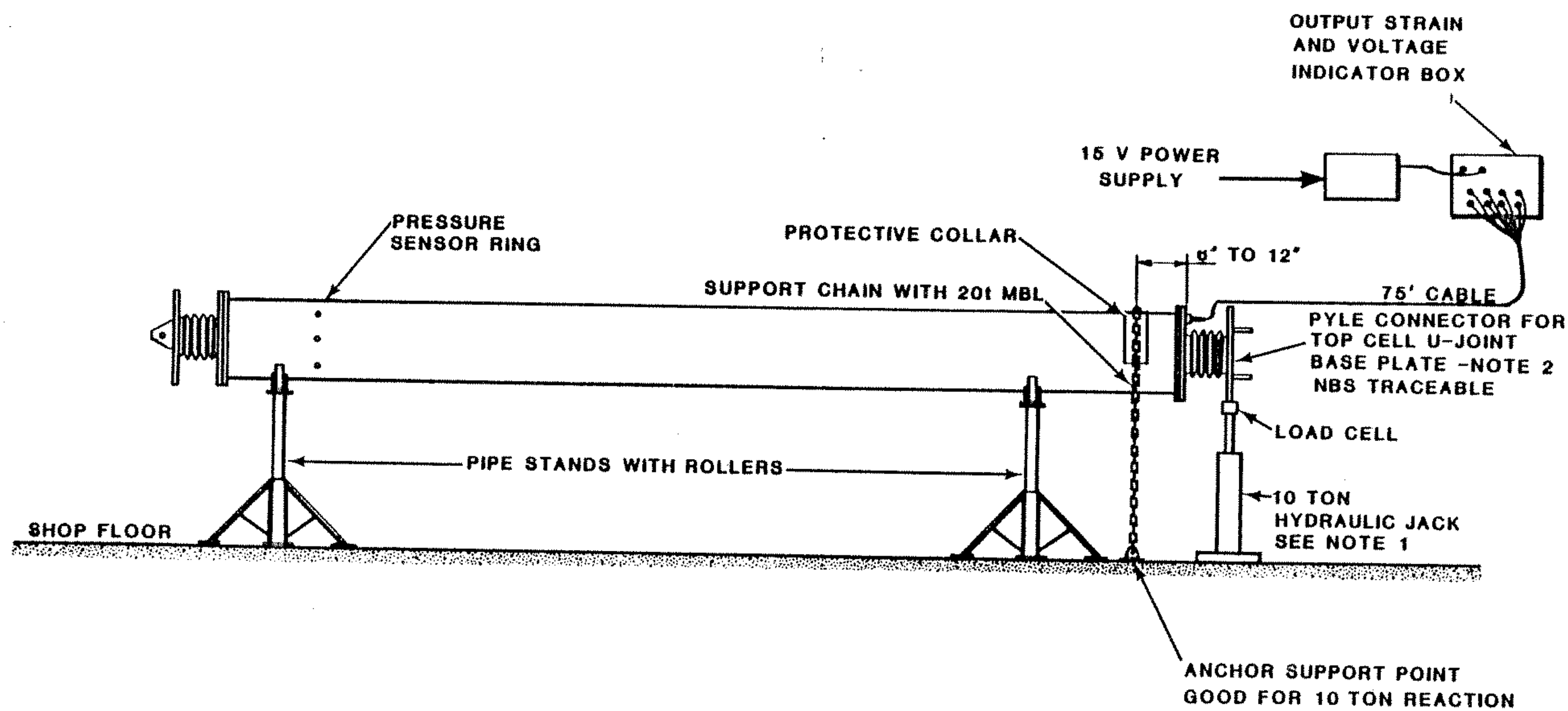


Figure 4.7. ITC Force Transducer Test Setup

and then downloaded to zero with 454 kg (1000 lb) decrements. Figure 4.8 shows the force transducer axis system and its relation to the platform adopted coordinate system. At each increment/decrement, the outputs of the primary and secondary strain gages in the X and Z direction were recorded. The calibration curves for top and bottom load cells are available in Appendix B, Figures B27-B30. Excellent agreement between loading and unloading readings indicated negligible hysteresis in the system. The results of these ITC calibrations are reflected in the voltage-to-physical unit values shown in Tables 4.1 and 4.2.

A force transducer confirmation test was conducted at-sea on the upper and lower force of the ITC at-sea after it was installed. A tension load was applied between the ITC and column C1 and the ITC and column C2 using slings and a griphoist (See Figures 4.9 and 4.10). The recorded voltages for 4.45 kN (1000 lb), and 8.89 kN (2000 lb) loads are shown in Appendix B, Figures B31-B38 for tests on 2-27-88. The recorded voltages for 1.2 kN (260lb) and 2.22 kN (500 lb) nominal loads are shown in Appendix B, Figures B39-B48 for tests on 5-13-87. Differences between results from the at-sea confirmation and the laboratory calibration tests can be attributed to inexact placement of slings and griphoists. Undamaged placement of the ITC was confirmed by the test results.

4.4 Post-Deployment Physical Calibration

A post-deployment physical calibration of the SIS instruments is planned when the MME semisubmersible and its associated SIS instrumentation is recovered. Differences between the pre- and post-deployment

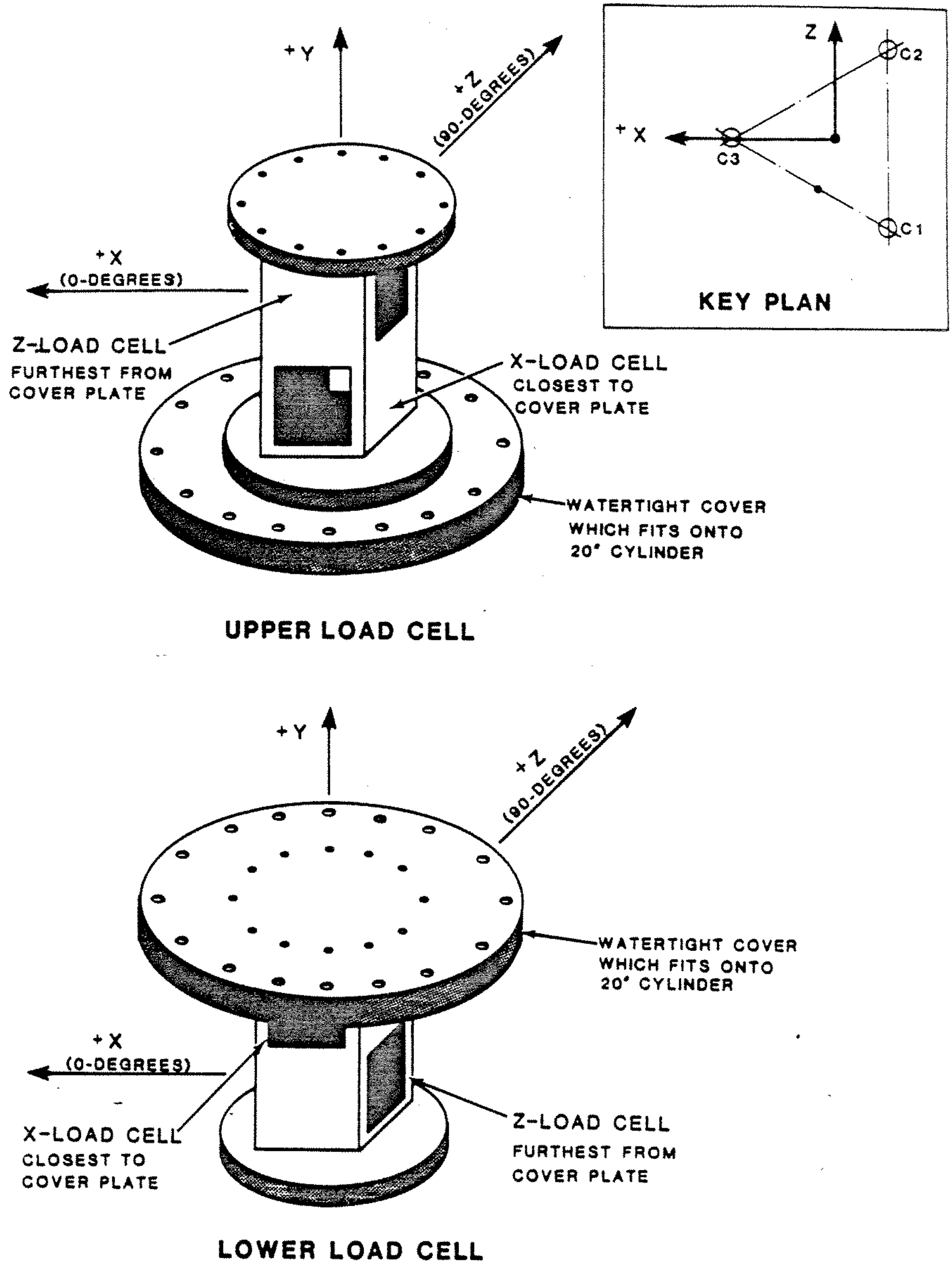


Figure 4.8. Load Cell Axis System

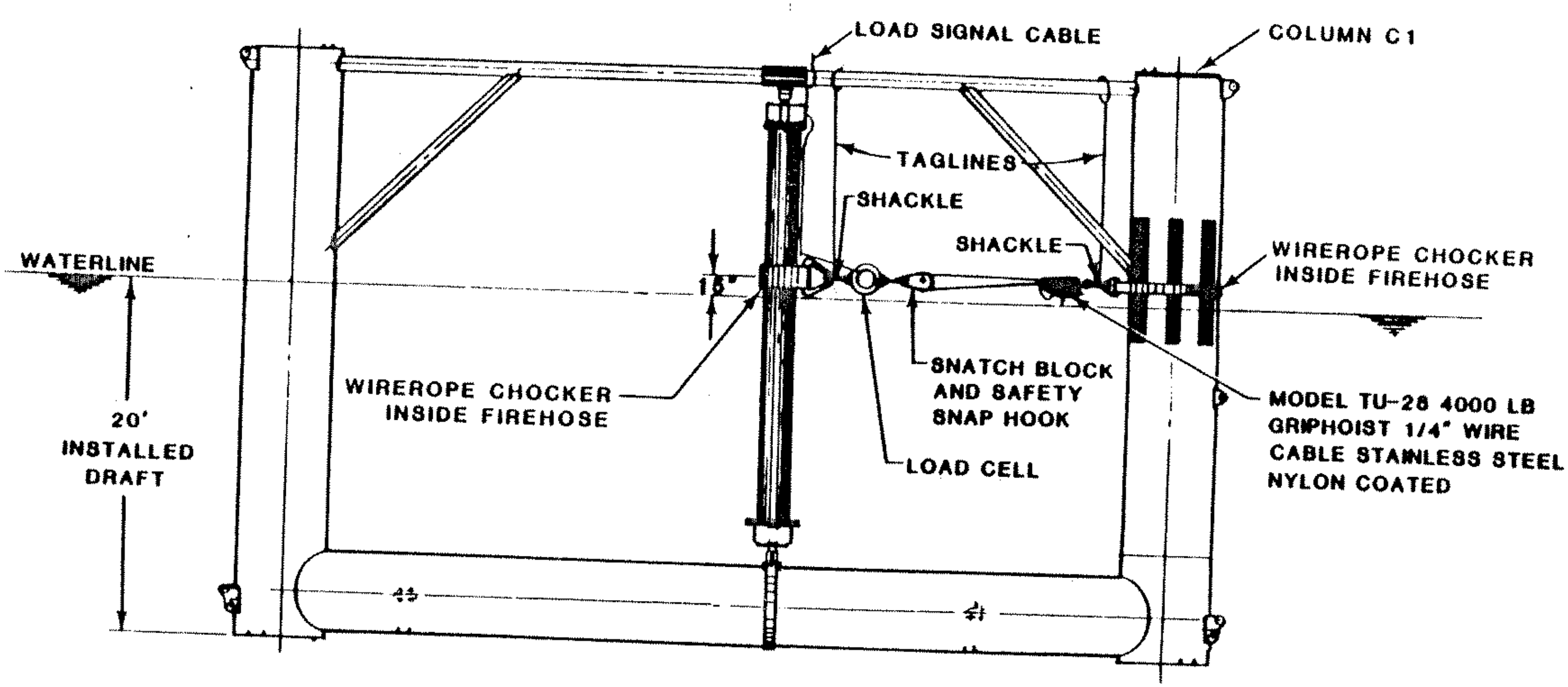


Figure 4.9. ITC-to-Column-C1 Confirmation Test

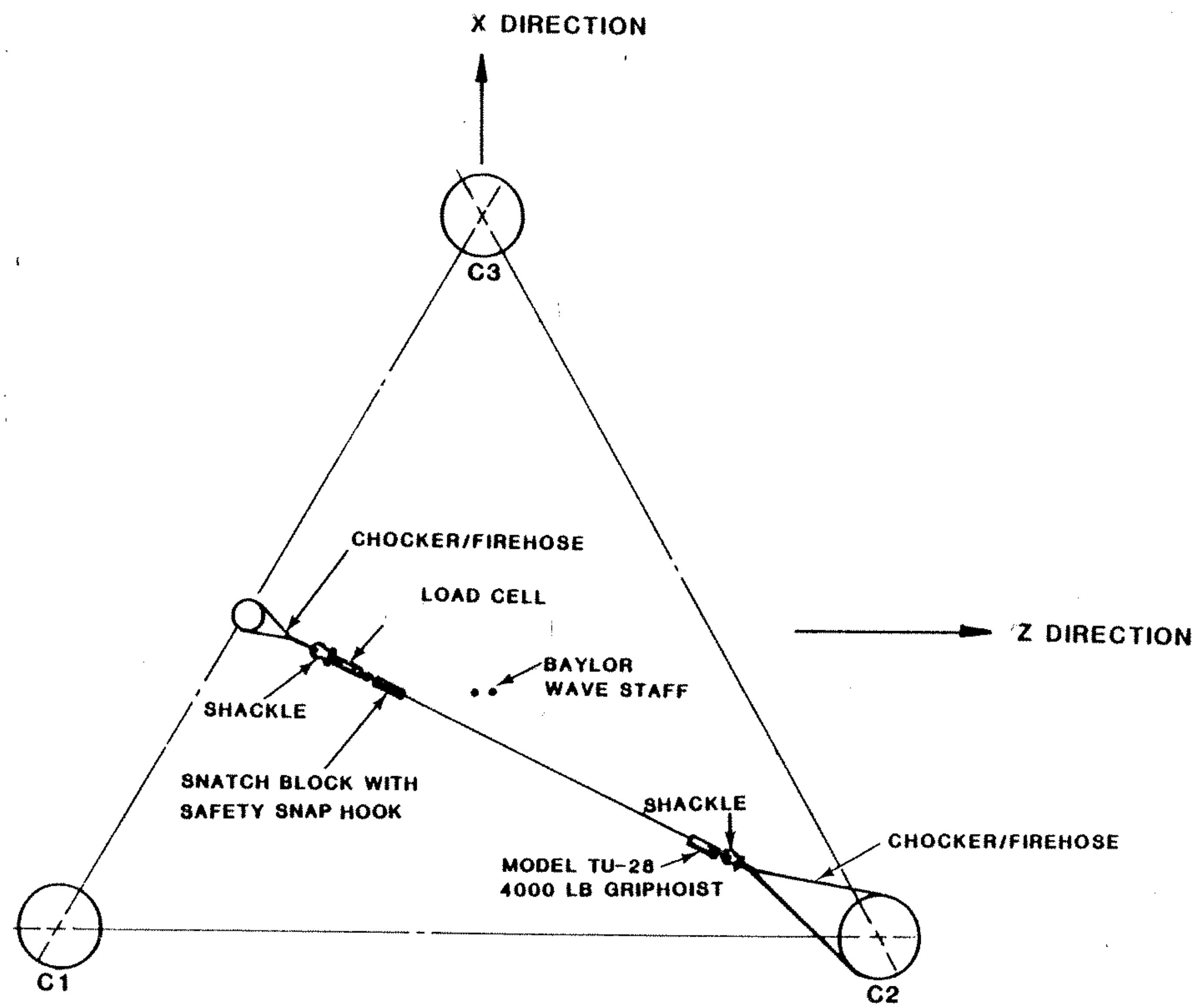


Figure 4.10. ITC-to-Column-C2 Confirmation Test

calibrations will provide a gage for quantifying any effect time and exposure has had on each of the instruments. Several instruments appear to have failed either during or after the experiment and therefore cannot be properly post-calibrated. These include five of the load cells, the motion measurement package, and the current meters.

4.5 Data Reference and Coordinate Systems

The NDBC wave buoy, NAVOCEANO current meter array, semisubmersible's anchors, and acoustic position transponders were positioned using surface navigation as shown in Figure 4.1. Location coordinates in units of feet are given in Table 4.6. The NDBC wave buoy was approximately 2543 meters (8343 ft) west (bearing 270 degrees) from the semisubmersible. The NDBC wave buoy had a 794 m (2457 ft) maximum watch circle radius. The NAVOCEANO current meter arrays #1, #2, #3 and #4 were placed in slightly different locations. Array #3 was located approximately 8687 m (28,502 ft) northwest (bearing 310 degrees) from the semisubmersible. Acoustic transponders attached to the anchors were used to confirm the location of the semisubmersible's anchors. At the conclusion of the MME, these same transponders were used to show that the anchors have never been dragged from their original positions. The water depth is approximately 887.2 m (2,910 ft) with a fairly flat seafloor.

Each of the four acoustic grid transponders were released and replaced at various times during the MME due to transponder failures. A complete list of transponders and their coordinates in the regional offshore survey grid, Lambert Cal Zone 5 (MOS, 1987) are given in

ITEM	LAMBERT CAL ZONE 5 EASTING / NORTHING	GEOGRAPHIC N. LAT / W. LONG.
MME BUOY CENTER	1 683 429 / 91 549	33°44'49.4" / 119°02'28.6"
MME BUOY ANCHOR #1	1 683 939 / 88 413	33°44'18.5" / 119°02'22.2"
MME BUOY ANCHOR #2	1 685 945 / 93 574	33°45'09.8" / 119°01'59.4"
MME BUOY ANCHOR #3	1 680 447 / 92 670	33°45'00.1" / 119°03'04.2"
NAVOCEANO CURRENT METER STRING #1	1 677 867 / 96 131	33°45'34.1" / 119°03'35.1"
NAVOCEANO CURRENT METER STRING #2	1 678 348 / 95 745	33°45'30.4" / 119°03'29.3"
NAVOCEANO CURRENT METER STRING #3	1 678 630 / 95 333	33°45'26.3" / 119°03'25.9"
NAVOCEANO CURRENT METER STRING #4	1 678 300 / 95 800	33°45'31.0" / 119°03'30.0"
NOAA WEATHER BUOY #1 (directional, 10m)	1 675 086 / 91 475	33°44'47.8" / 119°04'07.4"
NOAA WEATHER BUOY #2 (nondirectional, 3m)	1 675 086 / 91 475	33°44'47.8" / 119°04'07.4"
CONSTRUCTION MOORING	1 688 454 / 98 635	33°46'00.0" / 119°01'30.0"

Table 4.6. MME Location Coordinates

Tables 4.7a, b, and c. The tables also show which transponders were active or inactive in the grid at the indicated service/deployment date. An attempt was made to place replacement transponders close to the original locations to maintain accurate triangulation.

For normal operation of the acoustic long baseline system, various time delays were set in each transponder between reception of a direct range signal and when the transponder replied. These delays are given in Table 4.7. The Geodata-brand transponders had no delays.

Acoustic ranges were recorded as the time difference between transmission of a transducer acoustic signal and reception of the signal at the transponder less the transponder delay. Given the time between transmission and reception of over 3 seconds, it would be fair to assume that the transducer moves substantially during measurement of each range.

Due to acoustic reverberation a certain amount of time was necessary to wait for acoustic noise to die off before transmitting the next transducer acoustic signal. On the average platform positions were measured acoustically every 7 or 8 seconds. Additional information on acoustic positioning system specifics can be found in MOS, 1987.

The center of the watch circle for the MME semisubmersible was calculated to be Lambert coordinates of 1 683 429 easting and 91 549 northing. Real-time positions of the semisubmersible were calculated in Lambert coordinates using acoustically measured ranges from the semisubmersible to each operating transponder and the speed of sound.

The mean speed of sound averaged in the water column was approximately 1485.9 m/s (4875 ft/sec). The mean speed of sound at the sea bottom was approximately 1484.8 m/sec (4872 ft/sec). Both the original ranges and the calculated coordinates were recorded.

*

DEPLOYMENT /SERVICE DATE	TRANSPONDER LOCATION	CODE	TYPE	ACTIVE OR INACTIVE	EASTINGS (FEET)	NORTHINGS (FEET)	DEPTH (FEET)	DELAY (SEC)
3/18/86	G1	128	G	A	1684514	89160	N/A	0.000
	G2	169	G	A	1685779	92448	N/A	0.000
	G3	170	G	A	1682572	93779	N/A	0.000
	G4	171	G	A	1681261	90501	N/A	0.000
4/19/86	G1	128	G	A	1684514	89160	N/A	0.000
	G2	169	G	A	1685779	92448	N/A	0.000
	G3	170	G	I	1682572	93779	N/A	0.000
	G4	171	G	A	1681261	90501	N/A	0.000
6/9/86	G1	128	G	A	1684514	89160	N/A	0.000
	G2	169	G	A	1685779	92448	N/A	0.000
	G3	170	G	I	1682572	93779	N/A	0.000
	G4	171	G	A	1681261	90501	N/A	0.000
	A1	197	G	A	1683939	88418	2890	0.000
	A2	126	G	A	1685883	93558	2901	0.000
	A3	198	G	A	1680441	92665	2890	0.000
7/14/86	G1	195	G	A	1684436	89270	N/A	0.000
	G2	169	G	A	1685779	92448	N/A	0.000
	G3	196	G	A	1682537	94108	N/A	0.000
	G4	171	G	A	1681261	90501	N/A	0.000
	A1	197	G	A	1683939	88418	2890	0.000
	A2	126	G	I	1685883	93558	2901	0.000
	A3	198	G	I	1680441	92665	2890	0.000
10/29/86	G1	232	G	A	1684357	89257	2890	0.000
	G2	233	G	A	1685648	92662	2890	0.000
	G2	169	G	A	1685779	92448	N/A	0.000
	G3	196	G	I	1682537	94108	N/A	0.000
	G3	234	G	I	1682504	94011	2890	0.000
	G4	171	G	A	1681261	90501	N/A	0.000
	G4	235	G	A	1681052	90560	2890	0.000
	A1	197	G	I	1683939	88418	2890	0.000
	A2	126	G	I	1685883	93558	2901	0.000
	A3	198	G	I	1680441	92665	2890	0.000

LEGEND: S = SONARDYNE BRAND
G = GEODATA BRAND
G1 = GRID #1
G2 = GRID #2
G3 = GRID #3
G4 = GRID #4
A1 = ANCHOR #1
A2 = ANCHOR #2
A3 = ANCHOR #3

Table 4.7a. Acoustic Transponder Locations (3/86 - 10/86)

*

DEPLOYMENT /SERVICE DATE	TRANSPONDER LOCATION	CODE	TYPE	ACTIVE OR INACTIVE	EASTINGS (FEET)	NORTHINGS (FEET)	DEPTH (FEET)	DELAY (SEC)
1/12/87	G1	232	G	A	1684357	89257	N/A	0.000
	G1	195	G	I	1684436	89270	N/A	0.000
	G1	196	G	I	1684560	89273	N/A	0.000
	G2	233	G	A	1685648	92662	N/A	0.000
	G3	51	G	I	1683988	93889	N/A	0.000
	G3	234	G	I	1682504	94011	N/A	0.000
	G4	73	G	I	1681717	93480	N/A	0.000
	G4	169	G	I	1685779	92448	N/A	0.000
	G4	171	G	I	1681261	90501	N/A	0.000
	G4	235	G	A	1681052	90560	2890	0.000
	A1	197	G	I	1683939	88418	2890	0.000
	A2	126	G	I	1685883	93558	2901	0.000
	A3	198	G	I	1680441	92665	2890	0.000
1/19/87	G1	229	G	A	1684495	89311	N/A	0.000
	G1	232	G	I	1684357	89257	N/A	0.000
	G1	195	G	I	1684436	89270	N/A	0.000
	G1	196	G	I	1684560	89273	N/A	0.000
	G2	233	G	I	1685648	92662	N/A	0.000
	G3	51	G	I	1683988	93889	N/A	0.000
	G3	234	G	I	1682504	94011	N/A	0.000
	G4	73	G	I	1681717	93480	N/A	0.000
	G4	169	G	I	1685779	92448	N/A	0.000
	G4	171	G	I	1681261	90501	N/A	0.000
	G4	230	G	A	1681309	90535	N/A	0.000
	A1	197	G	I	1683939	88410	N/A	0.000
	A2	126	G	I	1685883	93558	N/A	0.000
	A3	198	G	I	1680441	92665	N/A	0.000
2/6/87	G1	229	G	A	MOVED TO A1		N/A	0.000
	G1	232	G	I	RECOVERED	RECOVERED	N/A	0.000
	G1	195	G	I	RECOVERED	RECOVERED	N/A	0.000
	G1	196	G	I	RECOVERED	RECOVERED	N/A	0.000
	G2	233	G	I	RECOVERED	RECOVERED	N/A	0.000
	G3	51	G	I	RECOVERED	RECOVERED	N/A	0.000
	G3	234	G	I	RECOVERED	RECOVERED	N/A	0.000
	G4	73	G	I	RECOVERED	RECOVERED	N/A	0.000
	G4	169	G	I	RECOVERED	RECOVERED	N/A	0.000
	G4	171	G	I	RECOVERED	RECOVERED	N/A	0.000
	A1	197	G	I	RECOVERED	RECOVERED	N/A	0.000
	A2	126	G	I	RECOVERED	RECOVERED	N/A	0.000
	A3	198	G	I	RECOVERED	RECOVERED	N/A	0.000
	A1	229	G	A	1683939	88418	2890	0.000
	A2	230	G	A	1685918	93586	2926	0.000
	A3	231	G	A	1680441	92665	2890	0.000

Table 4.7b. Acoustic Transponder Locations (1/87 - 2/87)

DEPLOYMENT /SERVICE DATE	TRANSPONDER LOCATION	CODE	TYPE	ACTIVE OR INACTIVE	EASTINGS (FEET)	NORTHINGS (FEET)	DEPTH (FEET)	DELAY (SEC)
2/11/87	G1	701	S	A	1684577	89355	2883	0.250
	G2	703	S	A	1685839	92508	2887	0.375
	G3	705	S	A	1682728	93700	2889	0.000
	G4	706	S	A	1681321	90462	2890	0.125
	A1	229	G	A	1683939	88418	2890	0.000
	A2	230	G	A	1685918	93586	2926	0.000
	A3	231	G	A	1680441	92665	2890	0.000
12/19/87	G1	701	S	I	RECOVERED	RECOVERED	N/A	0.250
	G2	703	S	I	RECOVERED	RECOVERED	N/A	0.375
	G3	705	S	I	RECOVERED	RECOVERED	N/A	0.000
	G4	706	S	I	1681321	90462	2890	0.125
	A1	229	G	A	1683939	88418	2890	0.000
	A2	230	G	A	1685918	93586	2926	0.000
	A3	231	G	A	1680441	92665	2890	0.000
1/8/88	G4	706	S	I	1681321	90462	2890	0.125
	A1	229	G	I	1683939	88418	2890	0.000
	A2	230	G	I	1685918	93586	2926	0.000
	A3	231	G	I	1680441	92665	2890	0.000
	G1	701	S	A	1684521	89383	2885	0.375
	G2	702L	S	I	N/A	N/A	N/A	N/A
	G3	703	S	A	1682646	93831	2879	0.500
	G4	705	S	A	1681278	90610	2889	0.125
1/13/88	G4	706	S	I	1681321	90462	2890	0.125
	A1	229	G	I	1683939	88418	2890	0.000
	A2	230	G	I	1685918	93586	2926	0.000
	A3	231	G	I	1680441	92665	2890	0.000
	G1	701	S	A	1684521	89383	2885	0.375
	G2	707	S	A	1685631	92601	2861	0.250
	G3	703	S	A	1682646	93831	2879	0.500
	G4	705	S	A	1681278	90610	2889	0.125
1/21/88	G4	706	S	I	1681321	90462	2890	0.125
	A1	229	G	I	1683939	88418	2890	0.000
	A2	230	G	I	1685918	93586	2926	0.000
	A3	231	G	I	1680441	92665	2890	0.000
	G1	701	S	A	1684521	89383	2885	0.375
	G2	707	S	A	1685631	92601	2861	0.250
	G3	708	S	A	1682464	93932	2895	0.500
	G4	705	S	A	1681278	90610	2889	0.125

Table 4.7c. Acoustic Transponder Locations (2/87 - 1/88)

DEPLOYMENT /SERVICE DATE	TRANSPONDER LOCATION	CODE	TYPE	ACTIVE OR INACTIVE	EASTINGS (FEET)	NORTHINGS (FEET)	DEPTH (FEET)	DELAY (SEC)
2/1/88	G4	706	S	I	1681321	90462	2890	0.125
	A1	229	G	I	1683939	88418	2890	0.000
	A2	230	G	I	1685918	93586	2926	0.000
	A3	231	G	I	1680441	92665	2890	0.000
	G1	701	S	A	1684521	89383	2885	0.375
	G2	707	S	A	1685631	92601	2861	0.250
	G3	708	S	I	RECOVERED	RECOVERED	RECOVERED	0.500
	G4	705	S	A	1681278	90610	2889	0.125
2/2/88	G4	706	S	I	RECOVERED	RECOVERED	RECOVERED	0.125
	A1	229	G	I	RECOVERED	RECOVERED	RECOVERED	0.000
	A2	230	G	I	RECOVERED	RECOVERED	RECOVERED	0.000
	A3	231	G	I	RECOVERED	RECOVERED	RECOVERED	0.000
	G1	701	S	A	1684521	89383	2885	0.375
	G2	707	S	A	1685641	92567	2861	0.250
	G4	705	S	A	1681260	90648	2889	0.125
	A1	708L	S	A	1683939	88413	2886	0.500
	A2	702L	S	A	1685945	93574	2906	0.375
	A3	703	S	A	1680447	92670	2879	0.250
2/12/88	G1	701	S	I	RECOVERED	RECOVERED	RECOVERED	0.375
	G2	707	S	A	1685641	92567	2861	0.250
	G4	705	S	A	1681260	90648	2889	0.125
(ACTED AS G1)	A1	708L	S	A	1683939	88413	2886	0.500
	A2	702L	S	A	1685945	93574	2906	0.375
	A3	703	S	A	1680447	92670	2879	0.250

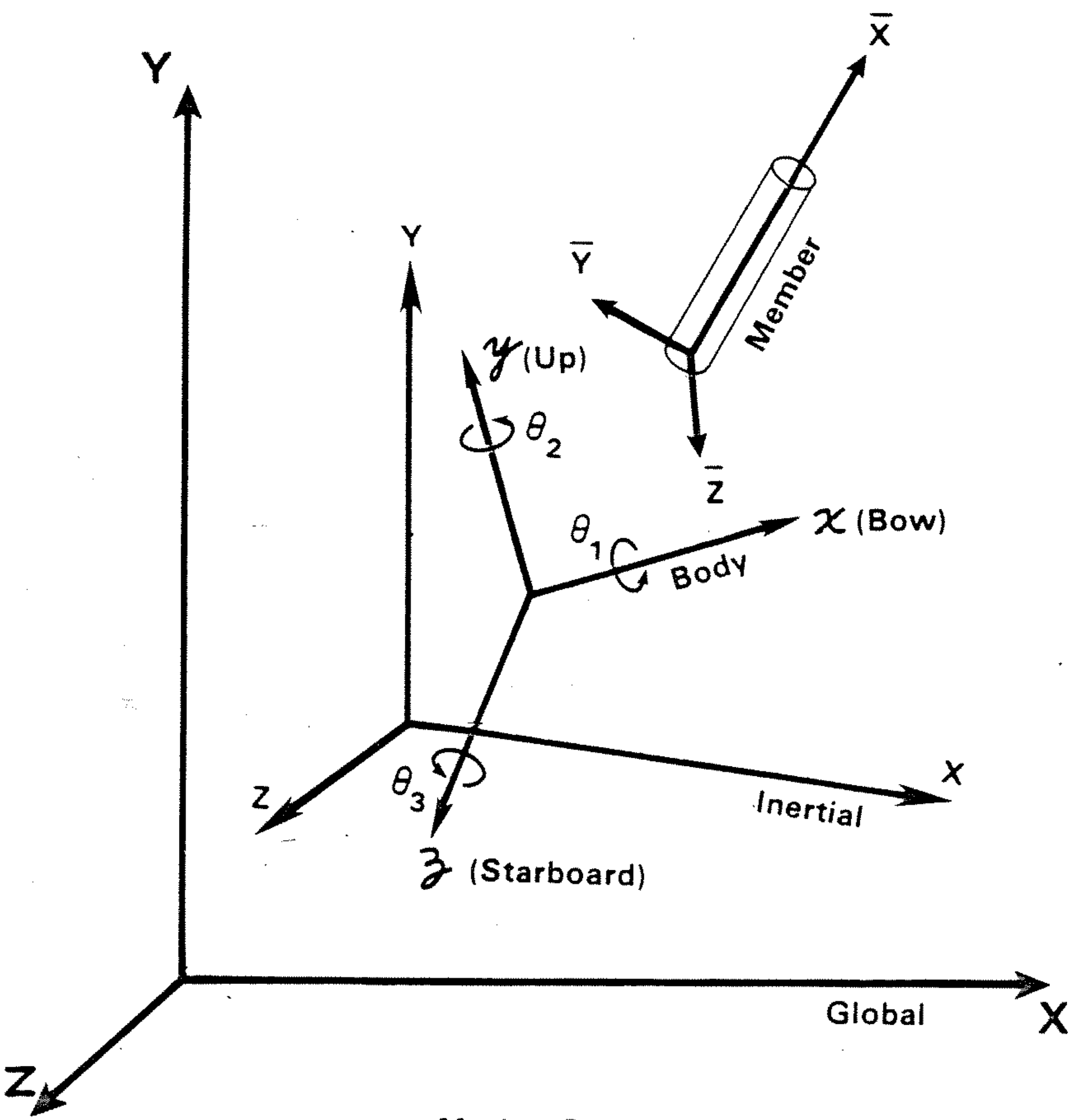
Table 4.7d. Acoustic Transponder Locations (2/88 - 2/88)

The coordinate system convention for the MME semisubmersible is given in Figure 4.11. Four right-handed coordinate systems are used to represent various aspects of the semisubmersible motion and response. Each member or element of the MME semisubmersible has a local "member" coordinate system. Member loads and resulting end forces are referenced in "member" coordinates. The origin of this coordinate system varies but is usually assigned to one end of the member.

The rigid body of the semisubmersible platform is best represented by a translating and rotating "body" coordinate system. The "body" coordinate system has its origin at the geometric center of the baseline plan of the semisubmersible hull. The x-axis always points towards the bow (column C3) and the y-axis always points perpendicular to the deck in an upward manner. This coordinate system remains aligned with the relatively rigid semisubmersible body, hence its name.

The gyroscopic stabilized platform where translational accelerations are measured is best represented by an "inertial" coordinate system. The origin of this coordinate system is at the center of the motion measurement package, a fixed distance from the origin of the "body" coordinate system. The y-axis of the "inertial" coordinate system always points parallel to the upward vertical sense of gravity.

The "global" coordinate system represents the "inertial" coordinate system when the semisubmersible rests in its equilibrium position. When in equilibrium, the semisubmersible is level, mooring line tensions are balanced, and only buoyancy and gravity based loads are applied. Since the MME semisubmersible has never achieved this condition, it was necessary to calculate this theoretical position as given in Table 4.6.



Motion Convention

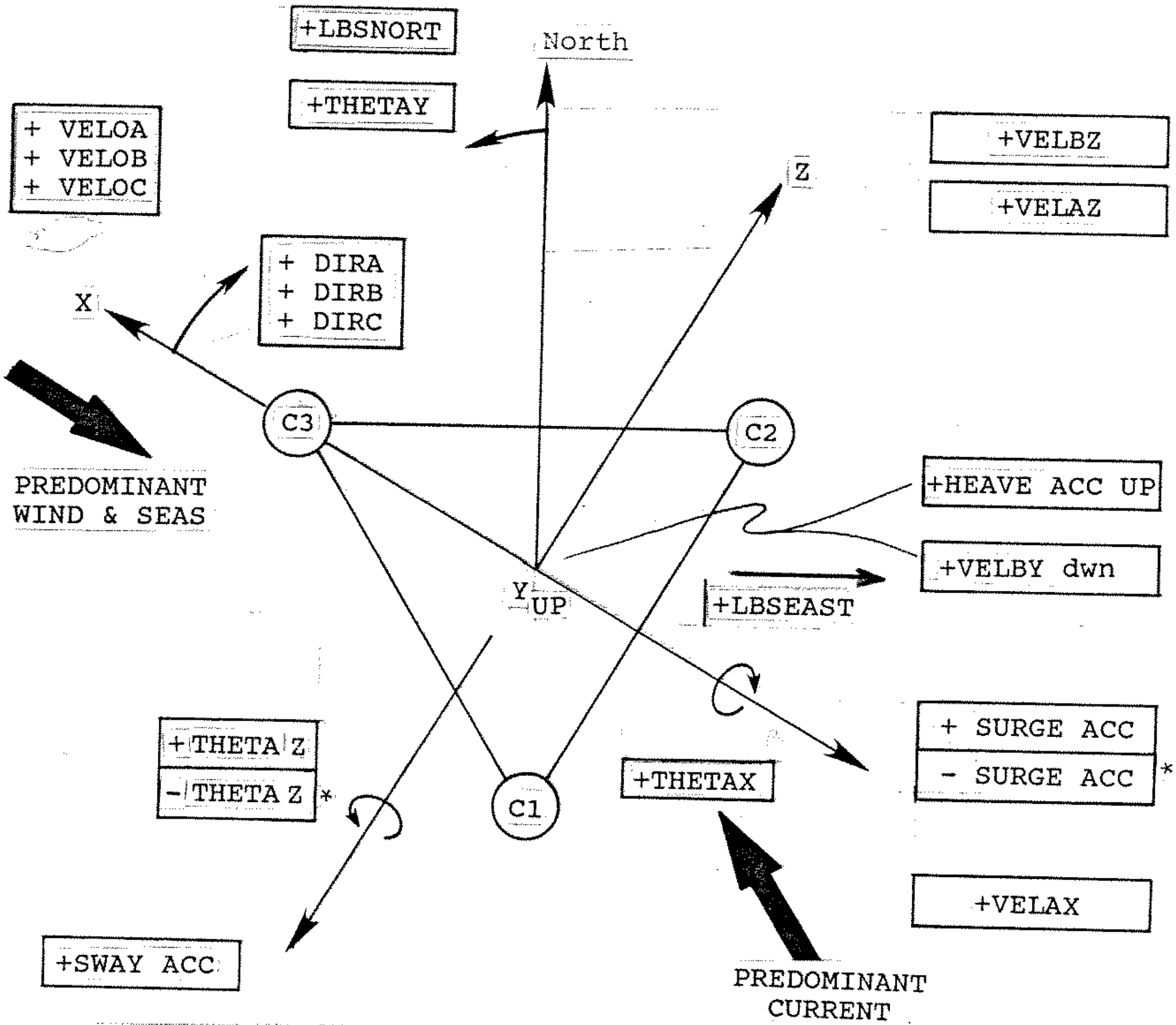
X = Surge	θ_1 = Roll
Y = Heave	θ_2 = YAW
Z = Sway	θ_3 = Pitch
(Inertial)	(Body)

Figure 4.11. MME Semisubmersible Coordinate Systems

Table 4.6 gives this calculated position in "survey" coordinates. Geographic survey coordinates are given in degrees, minutes, and seconds measured in north latitude and east longitude. Lambert survey coordinates are given in feet measured on a northing and easting grid from an arbitrarily assigned origin in Southern California (MOS, 1987). The "global" coordinate system has x-axis bearing 290 degrees from North as shown in Figure 4.12. Acoustic position data which is calculated in survey coordinates must be rotated to be represented accurately in the MME "global" coordinate system.

Each instrument on-board the semisubmersible has a local direction of measurement which has been aligned with an appropriate MME "body" coordinate direction as shown in Figure 4.12. The instrument or data channel represented by each direction abbreviation in Figure 4.12 is given in Table 4.8. The surge, sway and heave accelerations were measured and recorded with respect to the vertically stabilized "inertial" coordinate system.

The roll, yaw and pitch angles are a measurement of the angle between the gimbals of the vertically stabilized acceleration package. These angles, called Euler angles, are order-dependent (Thompson, 1961). The roll angle is the rotation of the outer gimbal with respect to the "body" coordinate system. The pitch angle is the rotation of inner gimbal relative to the outer gimbal, and the yaw angle is the rotation of the inner gimbal relative to the "global" coordinate system. Figure 4.13 shows this gimbal arrangement. The yaw angle is actually measured by the gravity stabilized yaw compass. This yaw angle equals the angle of rotation between the "inertial" and "global" coordinate systems. All other SIS data is measured relative to the "body" coordinate system.



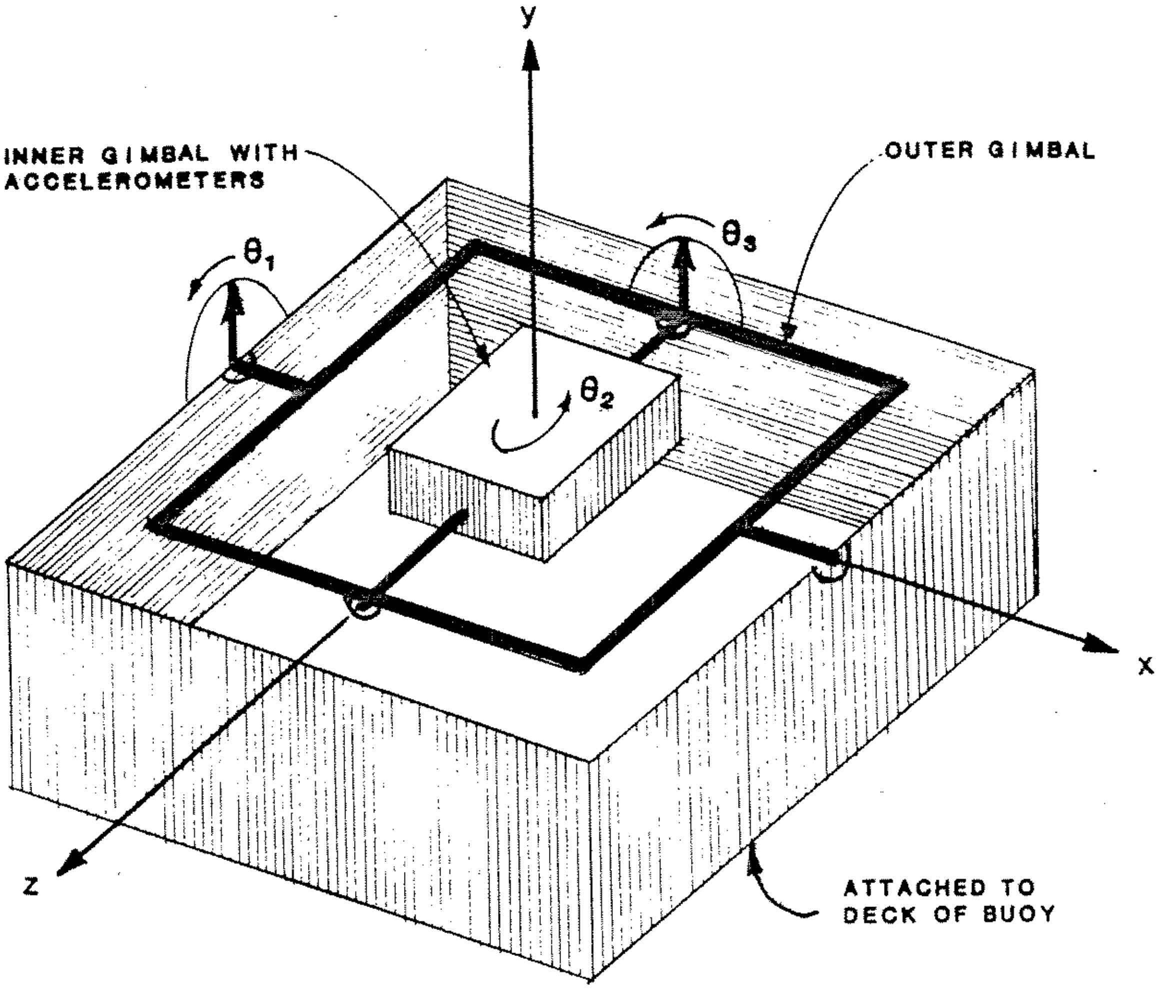
Axis shown is Body Coordinate System.
THETAY reads 290 at platform equilibrium position shown.
Wind and current are positive in direction of flow.
WAVEDAT1 and WAVEDAT2 are positive up from bottom of wave staff.

* For 19 Dec 87 to 18 Jan 88 (USCG package)

Figure 4.12. Positive Sense of Measurements

INSTRUMENT	MEASUREMENT	PHYSICAL UNITS	ABBREV./ FILENAME	RAW CHAN
DAS CLOCK	TIME	SEC	TIME	-
WAVE	1	FT	WAVEDAT1	0
STAFFS	2	FT	WAVEDAT2	1
CURRENT	1X	FT/S	VELAX	2
METERS	1Y	FT/S	VELAZ	3
	2X	FT/S	VELBY	4
	2Y	FT/S	VELBZ	5
HUMPHREY	SURGE	FT^2/S	SURGACC	6
MOTION	SWAY	FT^2/S	SWAYACC	7
PACKAGE	HEAVE	FT^2/S	HEAVACC	8
	ROLL	DEG	THETAX	9
	PITCH	DEG	THETAZ	10
COMPASS	HEADING	DEG	THETAY	34
PRESSURE	0 DEG	PSIG	FC-P1	13
SENSORS	45 DEG	PSIG	FC-P2	14
	90 DEG	PSIG	FC-P3	15
	135 DEG	PSIG	FC-P4	16
	180 DEG	PSIG	FC-P5	17
	225 DEG	PSIG	FC-P6	18
	270 DEG	PSIG	FC-P7	19
	315 DEG	PSIG	FC-P8	39
LOAD	C1-UPPER	KLBS	TENAC1	20
CELLS	C2-UPPER	KLBS	TENB1	22
	C3-LOWER	KLBS	TENC2	25
WIND	C3-DIRECTION	DEG	DIRC	27
SENSORS	C1-DIRECTION	DEG	DIRA	29
	MAST-DIR	DEG	DIRB	33
	C3-SPEED	FT/S	VELOC	26
	C1-SPEED	FT/S	VELOA	28
	MAST-SPEED	FT/S	VELOB	32
MODULAR	Z UPPER	KLBS	FCZUP	40
FORCE	X UPPER	KLBS	FCXUP	41
GAGES	Z LOWER	KLBS	FCZLOW	42
	X LOWER	KLBS	FCXLOW	43
LBS ACOUSTIC	NORTHING	FT	LBSNORT	-
POSITION	EASTING	FT	LBSEAST	-

Table 4.8. Abbreviations/ASCII Filenames



GIMBALLED MOUNTING OF ACCELEROMETERS SHOWING ROTATION SENSORS

θ_1 = Roll	x = Surge
θ_2 = Yaw	y = Heave
θ_3 = Pitch	z = Sway

Figure 4.13. Gimballed Mounting of Accelerometers

All SIS analog data except data from the temporary Neil Brown current meter were passed through a low-pass anti-aliasing filter with a cutoff frequency of 1.0 Hertz and then digitized at 3.333 Hertz. Figure 4.14 shows the frequency relationship between the sampling rate, the range of significant wave energy excitation and the range of response natural periods.

The acoustic position system data channel was also sampled at 3.333 Hz but ranges were measured at a much lower frequency of approximately 0.13 Hz. The lower frequency (longer time between samples) was necessary for several reasons. The acoustic wave took about 4 sec to propagate to the seafloor and return. Small delays of up to 0.5 sec were programmed into each transponder. A delay of approximately 3 sec was needed to allow sound reverberations to cease before sampling again. This totaled on average to about 7.5 sec, which is equivalent to a 0.13 Hz sample rate.

The data resolution from each SIS instrument is the greater of either the instruments resolution or the resolution inherent in the digitization process. Table 4.3 shows the calculated resolution of each SIS instrument due to digitization. This resolution is calculated by dividing the full-scale measurement range (in physical measurement units) by the instrument output (in volts) and multiplying by the digitizer voltage resolution (0.00488 volts per quantization level). This calculated resolution was always greater than the physical measurement sensitivity of each instrument.

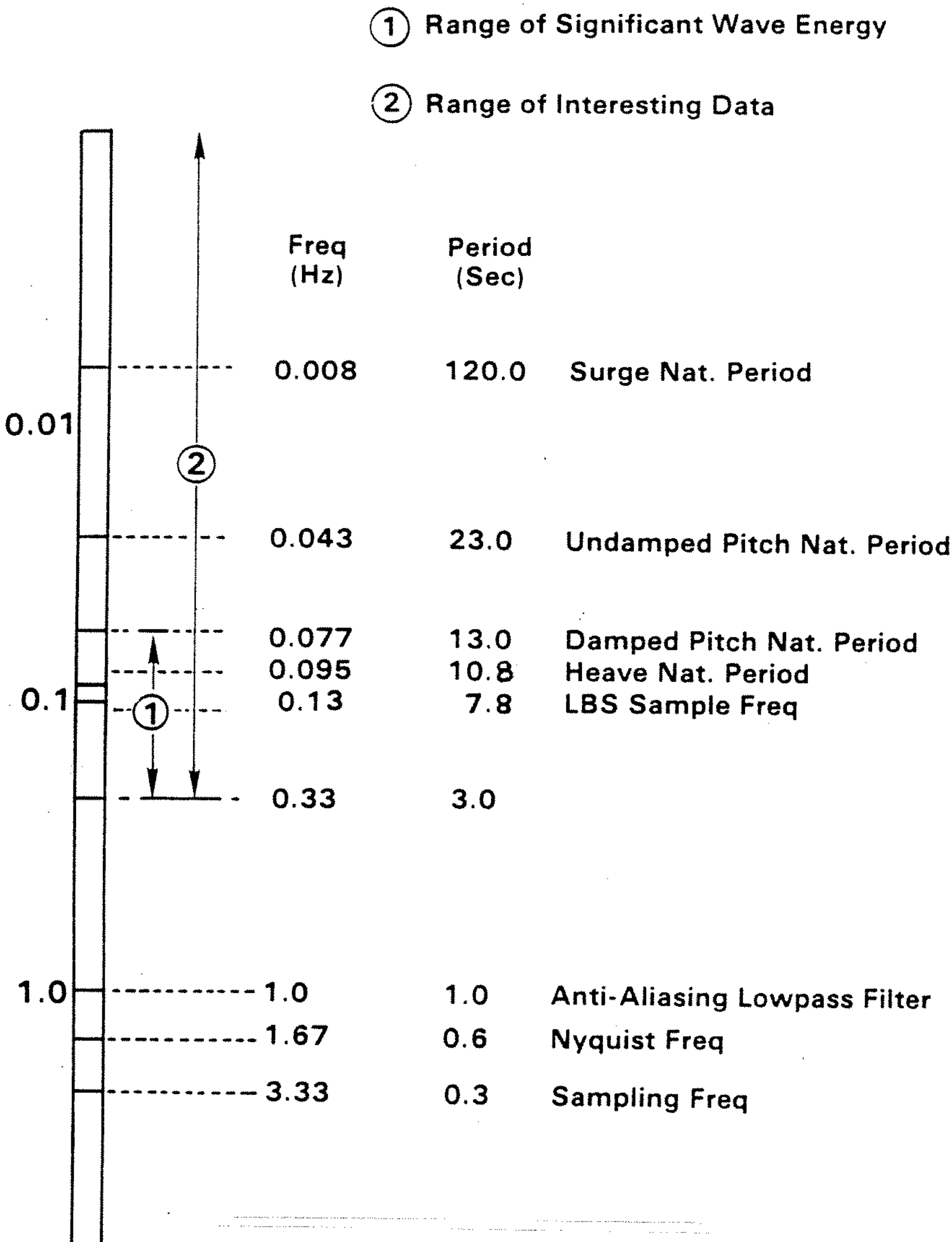


Figure 4.14. MME Frequency Line

5.0 REMOTE ENVIRONMENTAL DATA DESCRIPTION

This section describes the remote environmental data instrumentation components necessary to characterize the Motion Measurement Experiment (MME) site. The environmental data description members were tagged with the acronym RESS for Remote Environmental Sensor Subsystem. The RESS is composed of two measuring systems: (1) a National Data Buoy Center (NDBC) 10-m (33-ft) diameter discus wave buoy for directional wave measurements or a NDBC 3-m (10-ft) diameter discus buoy providing non-directional wave measurements (during service, maintenance and repair of the 10-m (33-ft) directional buoy); (2) a Naval Oceanographic Office (NAVOCEANO) vertical current meter array. The NAVOCEANO current meter array provided discrete current information, subsurface to seafloor, while the NDBC buoy provided directional wave spectra information as well as wind speed and direction, sea water and air temperature, and barometric pressure. Both the buoy and array were installed prior to the installation of the MME platform and remained on-site throughout the duration of the experiment.

The NDBC 10-m (33-ft) directional wave buoy was deployed from January 22, 1986 through June 22, 1987 and redeployed January 26, 1988 and operated through August 1988. A nondirectional 3-m (10-ft) discus buoy was deployed September 30, 1987 through January 26, 1988) at coordinates: 33.8° N; 119.1° W. The hull of the 10-m (33-ft) directional wave buoy is shown in Figure 5.1. On board the NDBC 10-m (33-ft) directional wave buoy is a Magnavox-built Directional Wave

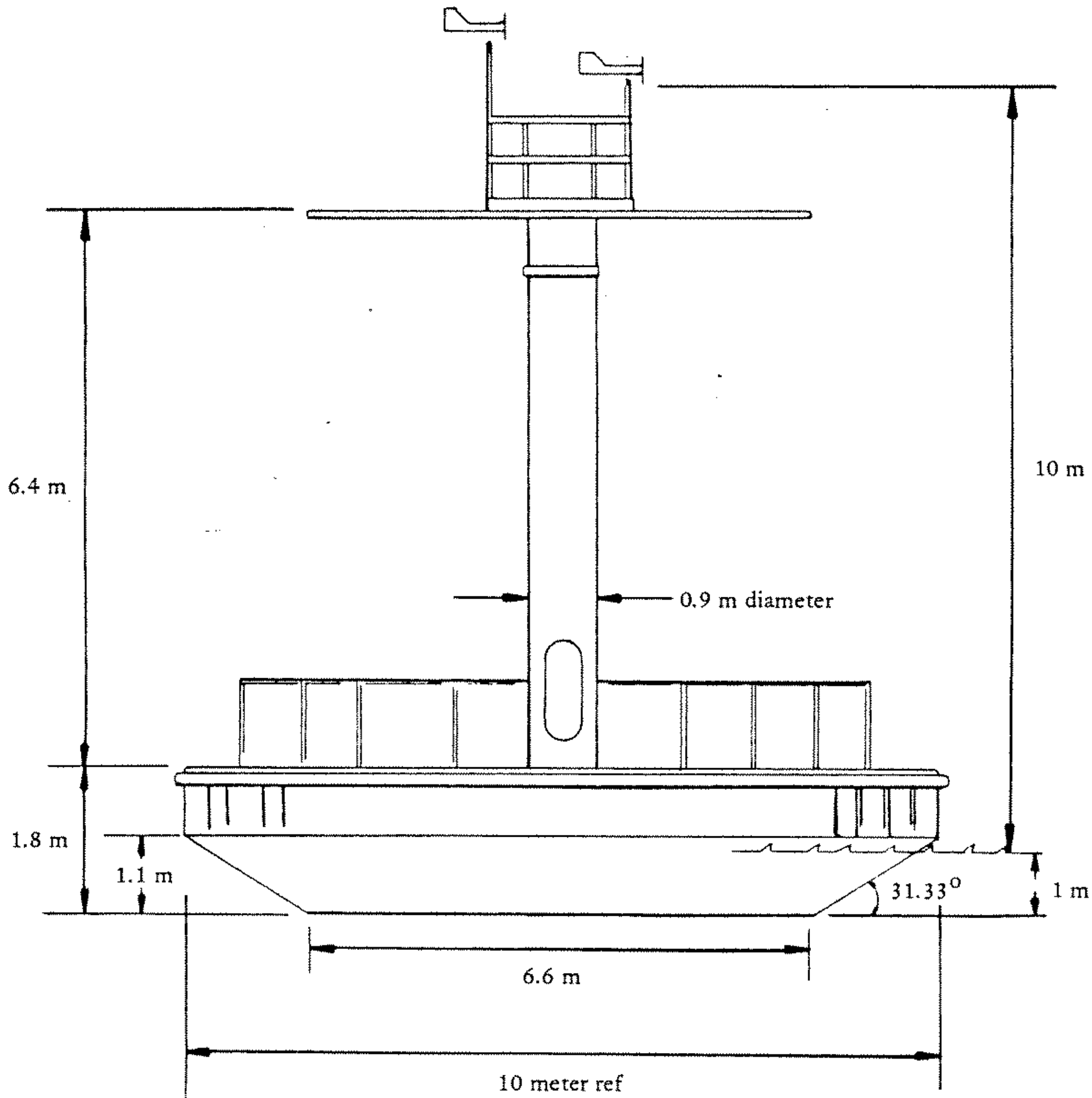


Figure 5.1. NDBC 10-Meter Discus Directional Wave Buoy

Analyzer (DWA) connected to a Data Acquisition and Control Telemetry (DACT) System. The DWA is a new card inserted in the already commonly used DACT system (Steele et al., 1985).

There were four sequential deployments of the NAVOCEANO current meter array located at the MME site at different times. Each array was installed for approximately 7 months. The first three arrays were comprised of 15 self-recording EG&G vector averaging current meters (VACM's). The fourth array had an Aandera current meter at -56.4 m (-185.0 ft), in addition to the 15 VACM's. Figure 5.2 shows the first array configuration where depth is given in meters below the mean water level. The VACM's were spaced at various depth intervals starting from a depth of -40 m (-131 ft) and extending to approximately -875 m (-2,871 ft) for all four arrays. The data were collected continuously and averaged over 15 minutes intervals. Additional information about the RESS instrumentation can be found in Zueck et al. (1986).

5.1 NDBC Buoy Data

At the National Data Buoy Center (NDBC) the data from the NDBC buoys (site number 46025) at the MME site was quality checked and stored on 9-track magnetic tapes. The 9-track magnetic tapes were sent to NCEL each month during the MME. Fortran programs utilizing DISSPLA graphics (ISSCO, 1985) subroutines were written to provide plots of the data.

For each month, four plots were produced from the hourly non-directional wave data. These plots are furnished in Appendix C. The plots are in Greenwich mean time (Z), the mean solar time of the

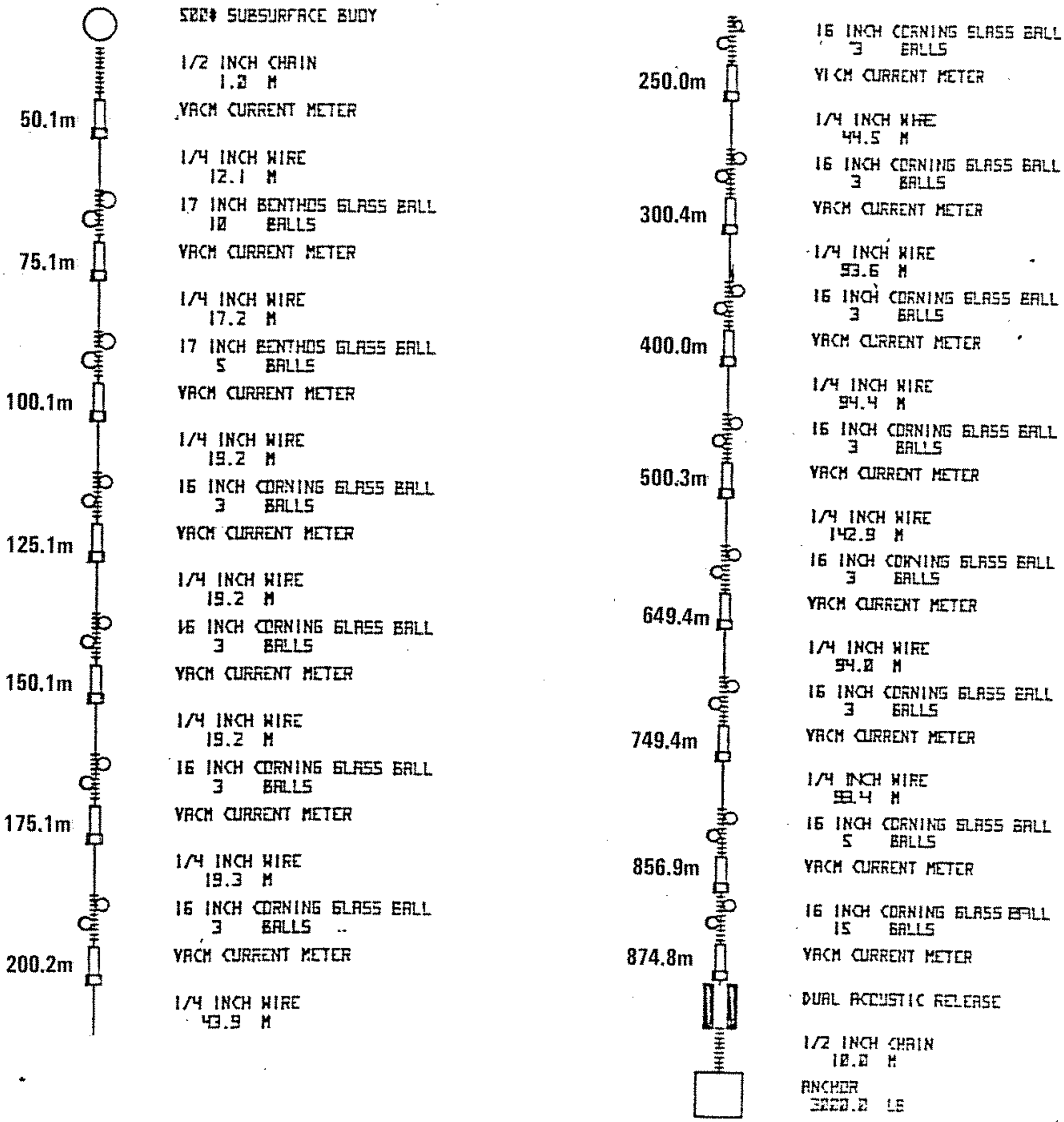


Figure 5.2. NAVOCEANO Current Meter Array #1

meridian of Greenwich, England used as the prime basis of standard time throughout the world. Local time is dependent on the calendar month, whether it's Pacific Standard Time (PST) or Pacific Daylight Savings Time (PDT). To obtain PST, subtract 8 hours from (Z). To obtain PDT, subtract 7 hours from (Z). (The energy spectrum and directional wave plots have already been converted to local time.) The plots in Appendix C include: (1) significant wave height (H_s) versus time in hours and days, (2) average wind speed (Wspd) versus time in hours and days, (3) average wave period (T_z) versus time in hours, (4) peak period (T_p) versus time in hours and days and (5) directional wave spectra, (6) energy spectrum plots.

The significant wave height (H_s) is defined with statistical parameters as the average of the highest 1/3 waves and is computed from spectral analysis as

$$H_s = 4\sqrt{m_o} \tag{5.1}$$

where m_o is the total area under the wave energy density spectrum in the frequency domain,

$$m_o = \int_o^\infty S(f)df \tag{5.2}$$

where S(f) is the frequency domain representation of a wave or the wave spectral energy density in a given set of data. Here, the data is taken at a 2 Hz rate for 20 minutes (minute 29 through 49 of each hour). The following coefficients of proportionality can be used for computing other wave heights from the reported significant wave height using m_o and the root-mean-square wave height (H_{RMS}), Chakrabarti (1987) where

$$H_{RMS} = 2\sqrt{2\ m_o} \qquad (5.3)$$

or by substituting Eq.5.1 into Eq. 5.3 the following is obtained

$$H_{RMS} = .707 H_s \qquad (5.4)$$

H_{max} can be computed using the most probable maximum wave height using the Gumbel scale parameter.

$$H_{max} = -\ln N * (H_{RMS}) \qquad (5.5)$$

or by substituting Eq. 5.4 into Eq. 5.5, the following is obtained

$$H_{max} = -\ln N * (0.707\ H_s) \qquad (5.6)$$

where N is the sample time divided by the average wave period.

Other wave heights of interest are:

$$H_{1/10} = 5.091\ m_o = 1.27 H_s \qquad (5.7)$$

$$H_{1/100} = 6.672\ m_o = 1.66 H_s \qquad (5.8)$$

The Average Wind Speed (m/sec) is the average speed recorded during the 20 minute recording session (minute 29-49 of each hour). The Average Wave Period (sec) is the average period between successive zero up-crossings during the 20 minute recording session. The Peak Wave Period (sec) is the period at which S(f) is a maximum during the 20 minute recording session. The Air Pressure (Pa), Air Temperature (°C), Sea Temperature (°C), Wind direction (deg) true, Wind Gust (m/sec), directional ($S(f,\theta)$ and non-directional ($S(f)$)) Spectral Densities (m^2/Hz) for (.03 (.01) .35) Hz are also collected during the 20 minute recording time. A description of the spectral processing, telemetered payloads and database corrections are given in Zueck et al., (1986). The format for the received and processed GOES data message is given in Appendix E.

5.2 NAVOCEANO Current Meter Data

The analysis of the current meter array data was performed by Dr. Alan Bratkovich, Geological Sciences Dept., University of Southern California, Los Angeles, CA to characterize natural variability in the current and temperature fields near the site and to provide stability criteria that will help identify time periods during which the time evolution and vertical structure of ocean currents are desirable. Figure 5.3 shows a timeline for the 3 array mooring deployments for each current meter at its installed depth.

During the first deployment, (September 26, 1985 to July 10, 1986) the mean currents were relatively weak, and biased towards the west-northwest in the upper water column, and directionally variable at each depth. Current fluctuations tend to be 10 cm/sec (0.33 ft/sec) or less and directionally variable with time. During the second deployment (July 14, 1986 to February 3, 1987) the mean currents were larger in the upper water column 7 cm/sec (2.8 in./sec) in amplitude compared to the first deployment and directed towards the northwest. At depths greater than 250 m (820 ft), mean currents were significantly weaker less than 5 cm/sec (0.16 ft/sec), and more directionally stable than at depths less than 250 m (820 ft). The most energetic daily average current component fluctuations were approximately 20 cm/sec (0.66 ft/sec) and were correlated with depth and penetrated to the 400 m (1312 ft) level.

```
NOMINAL
DEPTH (m)

 40                                                                  ++++ ++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
 50XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
 56                                                                                                      oooooooooooooooooooooooooo
 75....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
100....................................XXXXXXXXXXXXXXXXXXXXXXXXXXXXX+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
125XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
150....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
175....................................-----------------------------
200....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
250....................................-----------------------------XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
300....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
400XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
500....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
600                                                                 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXoooooooooooooooooooooooooo
650....................................-----------------------------
750....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
857....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
875....................................-----------------------------+++++++++++++++++++++++++++++++++++++oooooooooooooooooooooooooo
   1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
   |        |                 |                 |              |                 |                 |
   Oct85    Jan86             Jul86             Jan87          Jun87             Dec87             Jun88

Key
===================================
...    1st Deployment
---    2nd Deployment
+++    3rd Deployment
ooo    4th Deployment
XXX    Meter Malfunction
(blnk) No meter at this depth
```

Fig. 5.3 Current Meter Array Deployment Time Line

During the third deployment (February 6, 1987 to June 1, 1987), the mean currents in the upper 200 m (1312 ft) of the water column were directed towards the west-northwest (as in the first deployment) again with amplitudes in the 5-7 cm/sec (0.16-0.22 ft/sec) range. At mid water column and deeper, the mean currents were smaller in amplitude (less than 4 cm/sec (0.13 ft/sec) and directed towards the southwest.

During the fourth deployment period (December 1,1987 through June 10, 1988), mean currents were directed towards the west-northwest in the upper 400 m of the water column with amplitudes greater than 10 cm/s above 100 m diminishing to less than 3 cm/s at 300 m depth. Beneath 400 m, average currents are weaker (<2 cm/s) and tend to be directed towards the southeast. The standard deviations of subtidal current components tended to be ~70% of the mean component amplitude in the upper 400 m and larger than the mean component amplitudes at greater depths. The maximum value of daily average current component fluctuations seldom exceeded 25 cm/s in the upper 100 m of the water column. These fluctuations were typically 10 cm/s or less at depths greater than 150 m.

Temperature of the seawater was mostly correlated with current flows. An upper level (<100 m (<328 ft)) warming trend occurred during the last two months of the 1986 year which appears to be associated with a relatively energetic flow to the north-northwest during that time frame. A substantial drop in temperature occurred in the upper 100 m (328 ft) of the water column around March 23, 1987. This may have been associated with upwelling, and favorable wind conditions that persisted during spring season. Subtidal temperature fluctuation levels were typically 0.5° - 0.9°C (32.9°-33.6°F) in the upper 100 m (328 ft), decreasing to 0.3° - 0.1°C (32.5°-32.3°F) at mid water column and decreasing further to less than 0.1°C (32.2°F) in the lower third of the water column. This pattern of subtidal temperature variability levels was similar for all four deployments.

The character of current and temperature variations can be attributed to tides, internal waves, wind, solar heating, and/or topography. At higher frequencies, the current and temperature variability was dominated by near-tidal and internal wave induced fluctuations. In the upper third of the water column, diurnal time scale variability was more apparent, this may be due to diurnal sea breeze and solar input effects. At the MME latitude, the inertial frequency is nearly 1 cycle/day, so some of the apparent diurnal variability may actually be due to near-inertial effects. Deeper in the water column, semidiurnal fluctuations dominated current and temperature variations. This is most probably due to the presence of semidiurnal internal waves which may be enhanced locally through the interaction of currents driven by tides, bottom topography and density structure. Subtidal current fluctuations were strong (greater than 9 cm/s) near the sea surface and weak (less than 5 cm/sec (0.16 ft/sec)) near the seafloor.

Roughly characterized, currents tended to be more stable directionally than in amplitude over three hour averaging periods. An amplitude stability index was employed to initially sort data to select suitable time intervals. Procedures were developed to characterize the amplitude and directional stability of these measured horizontal currents as a function of time and depth. The variability levels for these measured currents were also characterized as a function of frequency using power spectral methods.

The coordinate system and variable specification employed is shown in Figure 5.4. Coordinate directions given in parentheses correspond to the current meter array measurements. They are mapped in Figure 5.4 to the conventional MME coordinate directions (Y up). Magnetic north is directed approximately 14.5 degrees east of true north. The velocity components (u,v,w) have positive values when currents are flowing towards the (east, north, up).

Variable fields are separated into mean and average components according to the following convention where u(t) is the full data sequence of averaging interval, τ, and u'(t) is perturbation about the average value, $\bar{U}$. Overbars denote time averages. Specifically,

$$u(t) = \bar{U} + u'(t) \qquad (5.9)$$

$$\bar{U} = \int_0^\tau \frac{u(t)\,dt}{\tau} \qquad (5.10)$$

Other values and functions are calculated according to the following definitions.

MEAN $$\bar{U} = \int_0^\tau \frac{u(t)\,dt}{\tau} \quad \text{and} \quad \bar{V} = \int_0^\tau \frac{v(t)\,dt}{\tau} \qquad (5.11)$$

VARIANCE $$\text{var } u = \int_0^\tau \frac{(u(t)-\bar{U})^2 dt}{\tau} \quad \text{and} \quad \text{var } v = \int_0^\tau \frac{(v(t)-\bar{V})^2 dt}{\tau} \qquad (5.12)$$

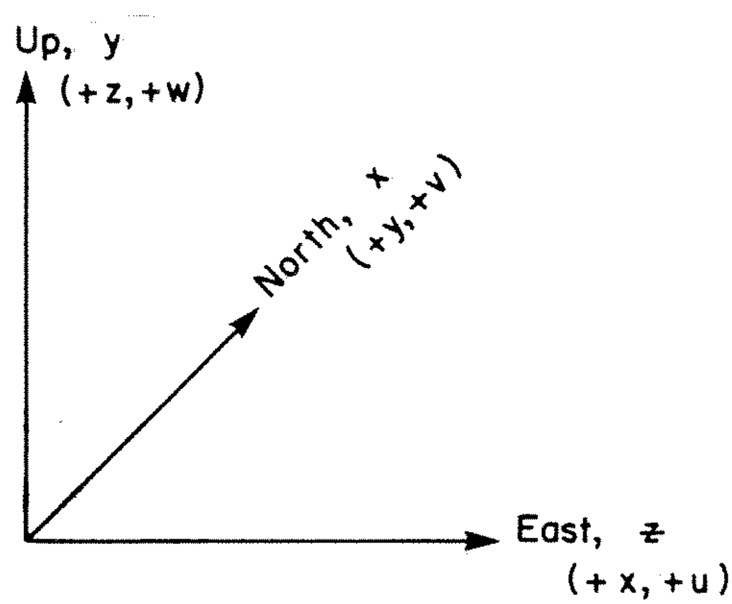


Figure 5.4. Current Meter Coordinate System

STD DEV

$$sd\ u = (var\ u)^{1/2} \quad \text{and} \quad sd\ v = (var\ v)^{1/2} \tag{5.13}$$

SPECTRAL DENSITY

$$var\ u = \int_{o}^{\Delta F} S_u(f)\ df \text{ and } var\ v = \int_{o}^{\Delta F} S_v(f) df \tag{5.14}$$

DIRECTIONAL STABILITY

$$ST1 = \frac{(\bar{U}^2 + \bar{V}^2)^{1/2}}{\int_{o}^{\tau} \frac{((u(t)^2 + v(t)^2)^{1/2}\ dt}{\tau}} \tag{5.15}$$

AMPLITUTDE STABILITY

$$ST2 = \frac{(\bar{U}^2 + \bar{V}^2)^{1/2}}{(sd\ u + sd\ v)} \tag{5.16}$$

The two current stability functions ST1 and ST2 characterize the directional and amplitude stability, respectively, for each 3 hour time period. ST1 is the ratio of vector mean speed to scalar mean speed. These vary from 0 to 100 with values near 100 corresponding to directionally steady current. ST2 is the ratio of vector mean current amplitude to the amplitude of typical variations from the local mean. This quantity varies from 0 to infinity with higher values corresponding to states for which the currents are constant amplitude. Tables of ST1 and ST2 are available in Bratkovich (1987).

Power spectral density is computed for velocity components and temperature fluctuations to characterize the variance distribution as a function of frequency. This helps identify dominant processes such as ocean tides, which tend to be associated with recognizable time scales of variability. Energy spectral density computations and analysis are outlined in Bendat and Piersol (1980). Energy spectral density for horizontal and vertical current velocity and water temperature are shown in Figures 5.5 and 5.6 for the third deployment at 50 m (164 ft) and 750 m (2,461 ft) depths. Figures 5.6 shows a diurnal variation where as Figure 5.5 shows a semi-diurnal variation.

Time history plots of daily average current components (u/v is positive to the east/north respectively) and temperature are given in Appendix C for all three deployments. Current profiles for the March 5, 1987 storm are shown in Figure 5.7, note the high variability with depth.

Daily average current fluctuations were typically larger in the upper water column (upper 300 m (984 ft)) compared to locations deeper within the water column. The largest daily average fluctuations were <20 cm/sec (0.66 ft/sec). However, it was not unusual for significantly smaller currents (5 cm/sec (0.16 ft/sec) or less) to persist for periods of several weeks. Maximum amplitude near-surface currents (upper 50 m (164 ft)) should be significantly (a factor of two or more) larger. Allen et al. (1983) gives an overview of typical variability levels for currents in continental shelf environments.

5.3 Storm Events Identified

For numerical model validation and concept performance analysis, it is desirable to investigate a full range of environmental events from the quiescent sea to the extreme storm. The quiescent condition is desirable as a zero baseline to investigate sources of static error in the data. An environmental event with only steady current is useful for validating the static offset created by different current loading

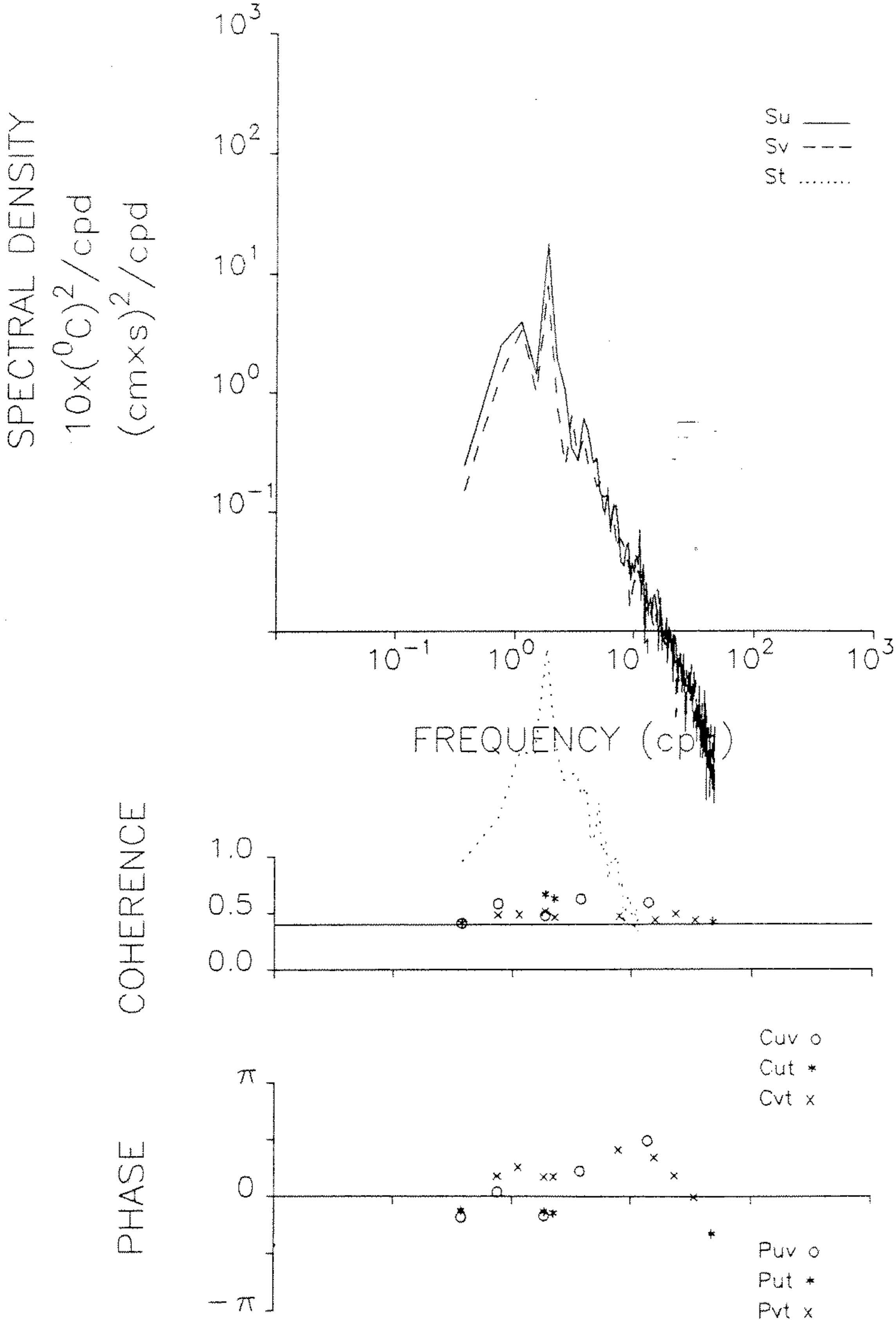


Figure 5.5. Spectral Density for 3rd Array at 749 m Depth

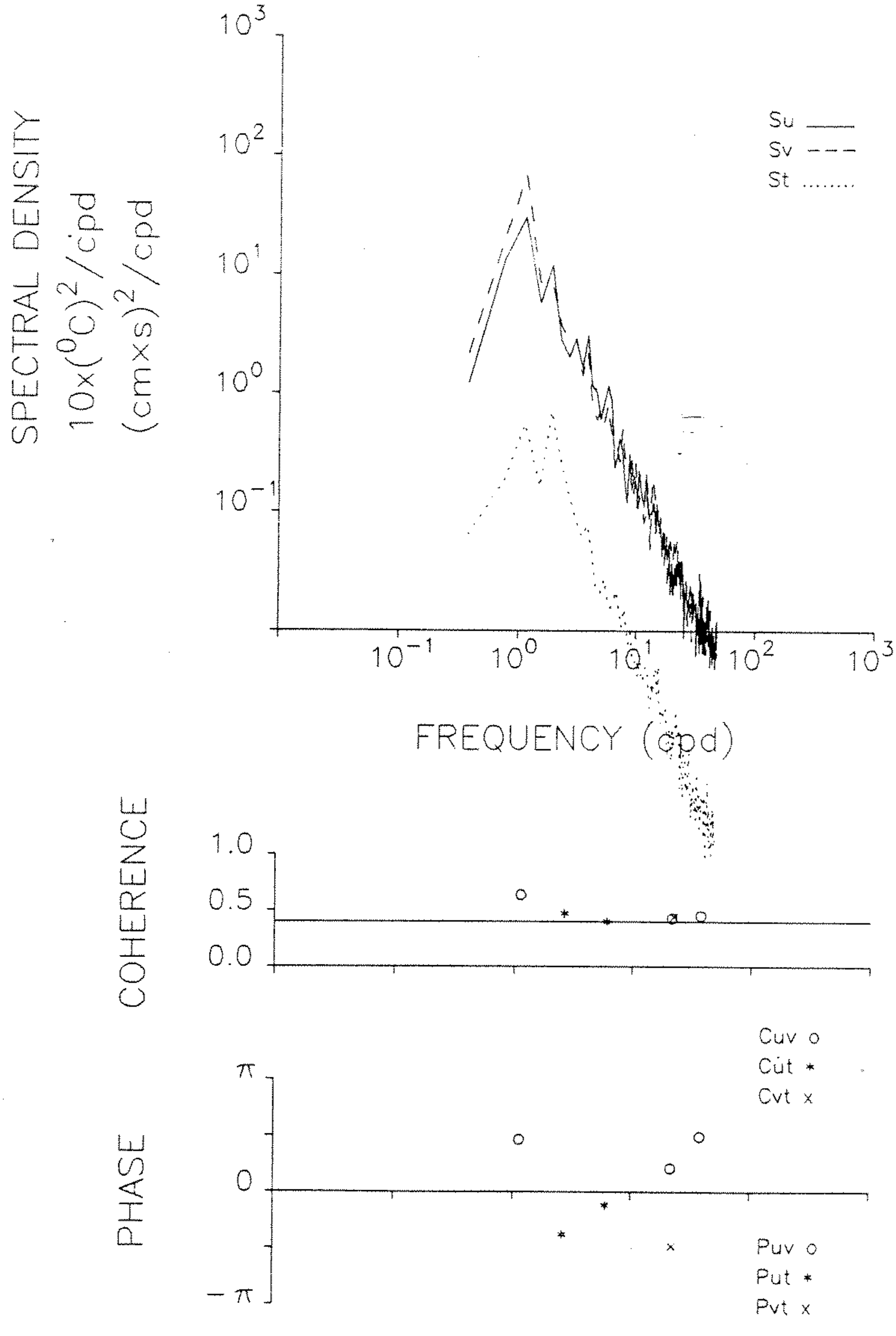


Figure 5.6. Spectral Density for 3rd Array at 50 m Depth

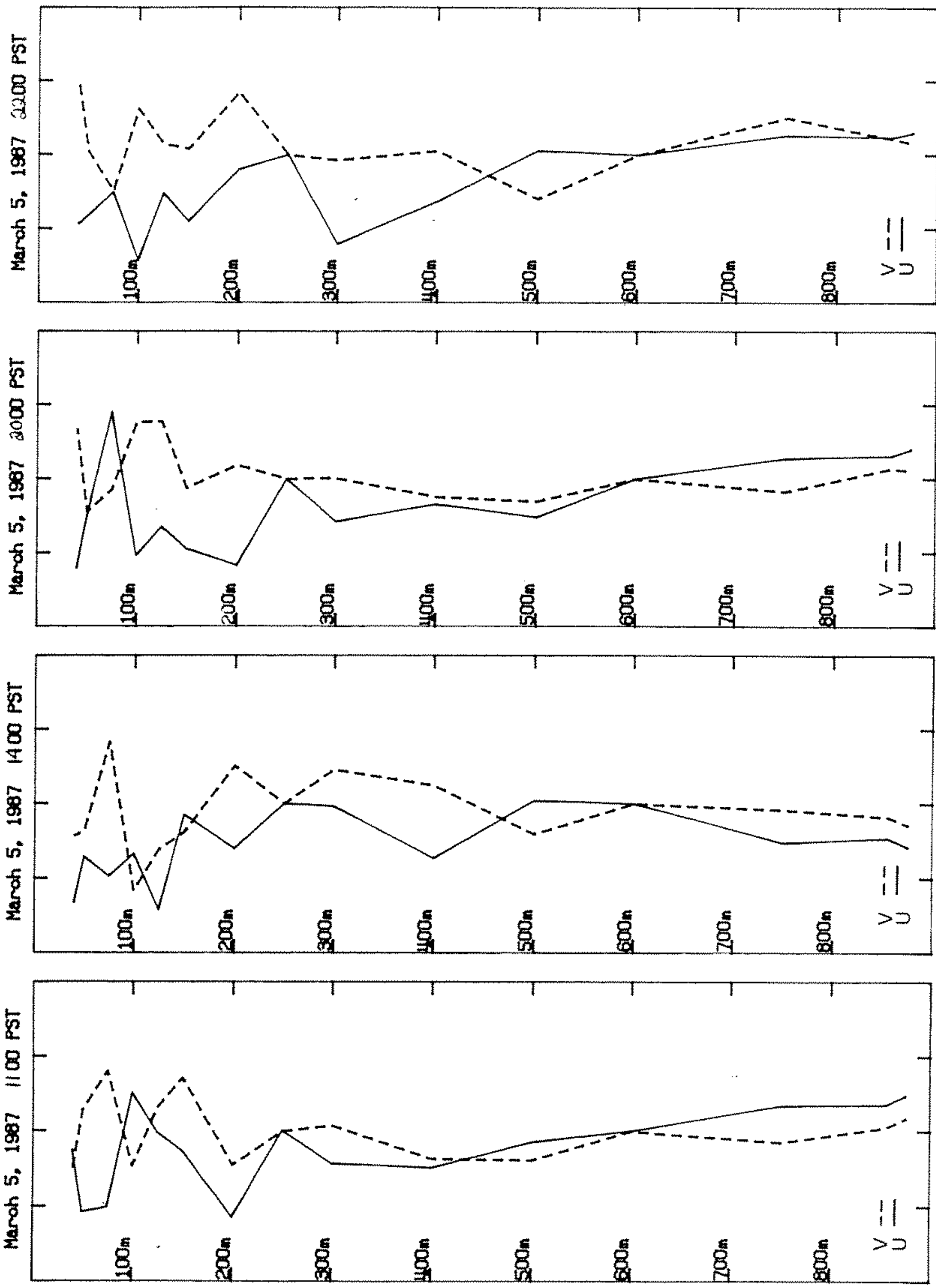


Figure 5.7. Current Profiles for March 5, 1987

theories. An environmental event dominated by swell (long-crested, long-period waves) is desirable for validating regular wave loading theories, and an event dominated by wind waves is desirable for confused, short-period waves.

The natural periods of motion for the MME semisubmersible hull was designed to be in the range of expected wave periodicity (8 to 12 seconds) so that long and short period waves produce different degrees of compliant motion. Final validation is performed against extreme storm data with strong nonlinear interaction of swell and wind waves, winds, and currents. As the storm becomes more extreme, the response of the platform becomes more nonlinear.

During the course of the Motion Measurement Experiment (MME), the Southern California coast experienced a full range of desirable environmental events. As is expected in any normal yearly distribution of weather, there were more days of quiescent sea than days with extreme storms. Unfortunately, the normal distribution of weather for 1986 year was skewed and the statistically expected annual storm event (significant wave height equal to 4.6 m (15 ft) did not occur. The largest storm event of winter 1987 produced a significant wave height of only 2.6 m (8.5 ft).

However, continuation of the MME through the 1988 storm season resulted in the measurement of a storm three times as large as the largest storm during 1987. This storm produced a significant wave height of 8 m (26 ft). An abundance of useful environmental and platform response data was collected from this significant storm event.

Plots of the Remote Environmental Sensor System (RESS) data were generated to help identify these significant environmental events throughout the course of the experiment. These plots included hourly significant wave height, peak wave period, average wave period, and average wind speed from the NDBC wave buoy and daily averaged velocity components and temperatures from the NAVOCEANO current meter arrays. Wave buoy plots for winter 1987 and winter 1988 and current meter plots for each current meter deployment are presented in Appendix C.

In addition, plots of directional wave spectra are presented in Appendix C for specified storm events, except January 1988; the 10-m (33-ft) directional wave buoy had been temporarily replaced with a 3-m (10-ft) non-directional wave buoy during January 1988. The plots were generated to help clarify the frequency content, directionality and nature of the seas. Generally, low frequency spectral energy density (less than 0.1 Hz) indicate long period, regionally generated swell. High frequency spectral density energy (greater than 0.1 Hz) indicates short period, locally generated wind waves. Long and short period waves generally approached from different directions.

The directional spectrum is given as

$$S(f,\Theta) = C_{11} \cdot D(f,\Theta) \qquad (5.17)$$

where C_{11} is the nondirectional spectrum and $D(f,\Theta)$ is the spreading function. The Longuet-Higgins spreading function used for computing these directional spectra is:

$$D(f,\Theta) = \frac{1}{\Pi} \left[\frac{1}{2} + r_1 \cos(\Theta-\Theta_1) + r_2 \cos(2(\Theta-\Theta_2)) \right] \qquad (5.18)$$

where:

f = frequency in Hertz

θ = the azimuth angle measured clockwise from North to the direction the wave is from

θ_1 = mean wave direction

θ_2 = the principle wave direction

r_1 and r_2 = dimensionless parameters in terms of the Longuet-Higgins Fourier coefficients (Steele et al. (1985)).

During the 1987 winter storm season, one major storm event occurred in January, two in February, six in March, one in April, and one in May. These storms were all characterized by significant wave heights in excess of 2.2 m (7.38 ft). The wave heights in these storms generally peaked rapidly and sharply with the entire storm event usually passing in less than 12 hours. As a reminder the MME was operational during most of the 1986 and 1987 storm season (Figure 3.2), except for the acoustic positioning system, which was intermittently operational and unreliable until it was replaced in late February 1987.

On March 5, 1987 the MME captured the most significant storm event of the 1987 winter season. The MME was fully operational during this storm and the storm lasted long enough for statistically rare wave heights to occur. Current velocity components reach a maximum of 16 cm/sec (0.32 ft/sec) and were extremely directionally variable at each depth as shown in Figure 5.7. This storm event was characterized by a strong swell from the west-southwest with a peak period of 14.3 sec (see Figure 5.8). A significant wave height was measured by the NDBC buoy to be 2.6 m (8.5 ft).

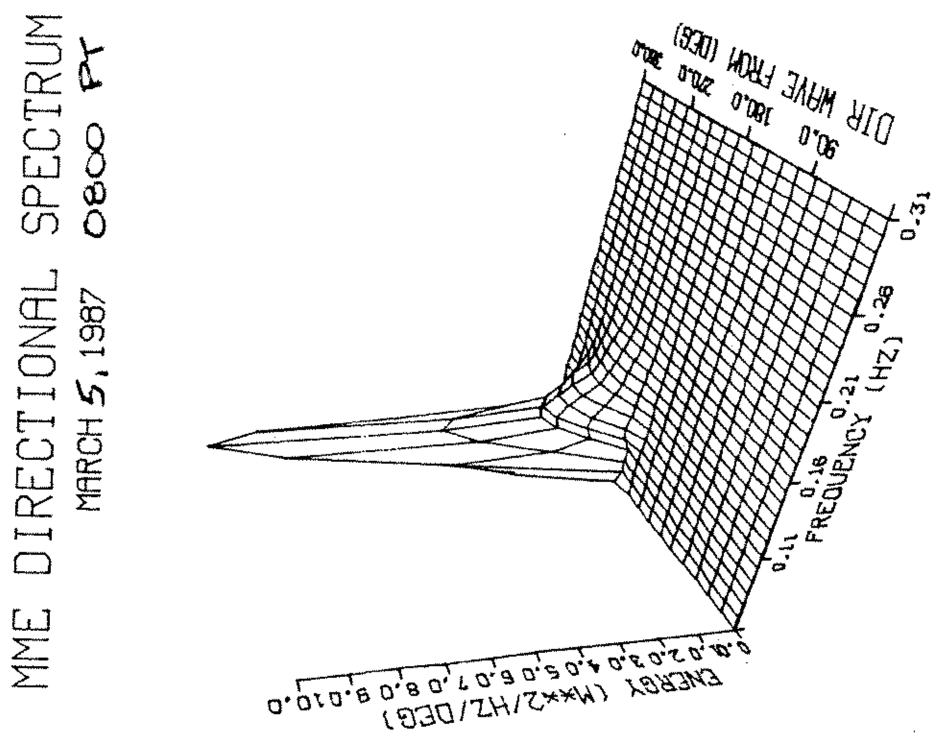


Figure 5.8. NDBC Directional Wave Spectra

On January 17, 1988, the MME captured the most significant storm of the entire experiment. The MME was almost fully operational during this storm with all key instruments functioning properly. Wave directionality and surface current velocity were not recorded but can be reasonably estimated using other measurements and hindcast data. Significant marine growth on the platform had also occurred and must be accounted for in the validation effort. (See Section 3.4 for marine biofouling assessment).

The January 17, 1988 storm event was characterized by strong wind waves plus swell from the north-west with an average peak period of 10.5 seconds. The significant wave height was measured by the NDBC buoy to be 8.0 m (26 ft). Figure 5.9 shows the rapid rise of the significant wave height prior to the storm waves peaking at 1900 PST on January 17. The average wave period also peaked at 1900 PST as shown in Figure 5.10. Wave steepness approached the breaking limit. The corresponding drop in average wind speed as shown in Figure 5.11 indicated that the low pressure center of the storm may have passed close to the MME platform. There was also a 60° change in wind direction just before the peak of the storm as indicated in Figure 5.12. The wind direction appears to be aligned with the swell direction as indicated by the increased peak period, Figure 5.13. The current componenets (u,v) for January 17, 18, 1988, are given in Appendix C.

The actual wave height which occurred at the MME semisubmersible platform is calculated by reducing out platform motion from the moving wave staff measurements (Pawsey et al. (1986)). These calculations are part of the data processing effort now underway. Maximum wave height at

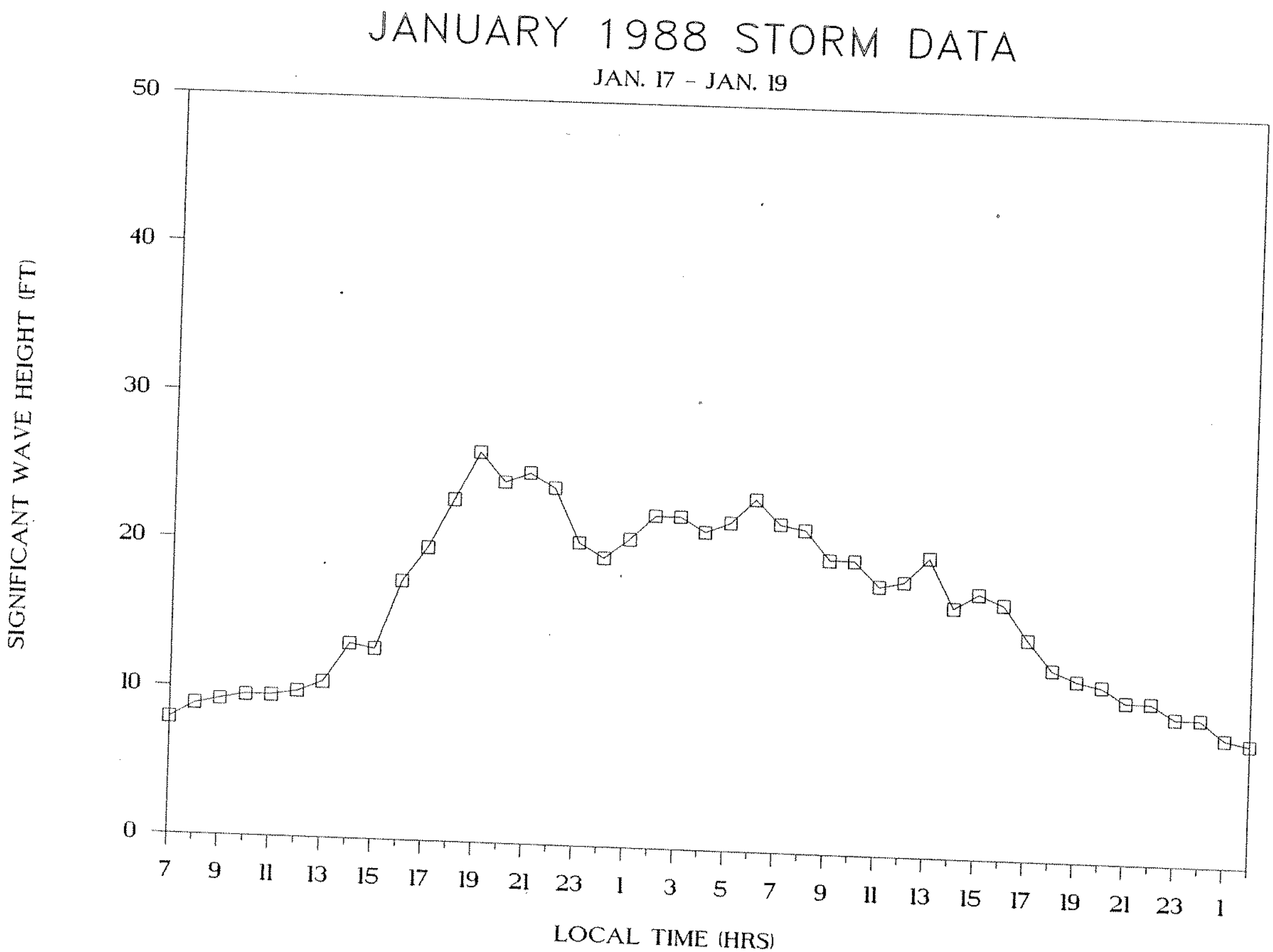


Figure 5.9. Significant Wave Height, January 17, 1988

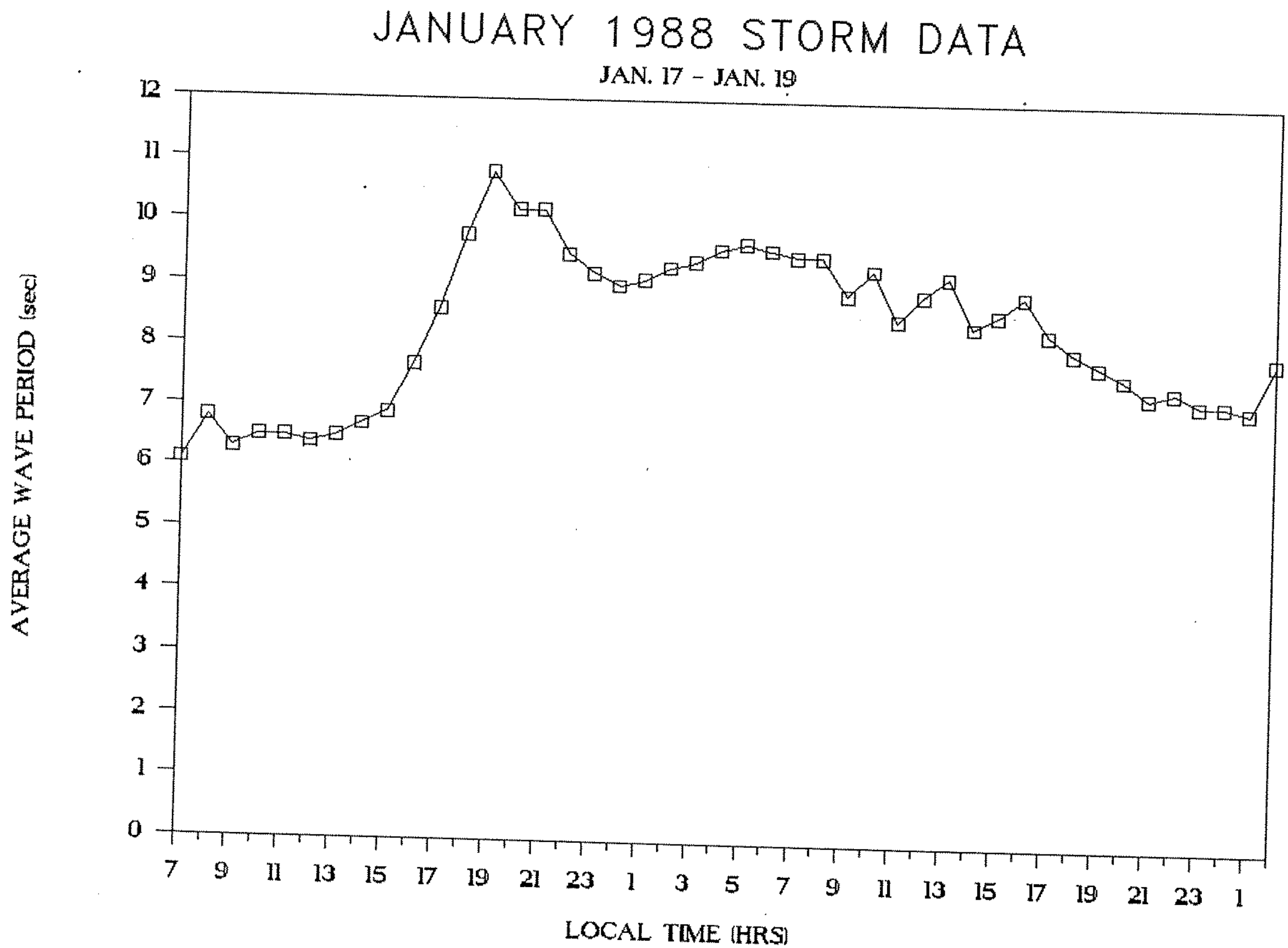


Figure 5.10. Average Wave Period, January 17, 1988

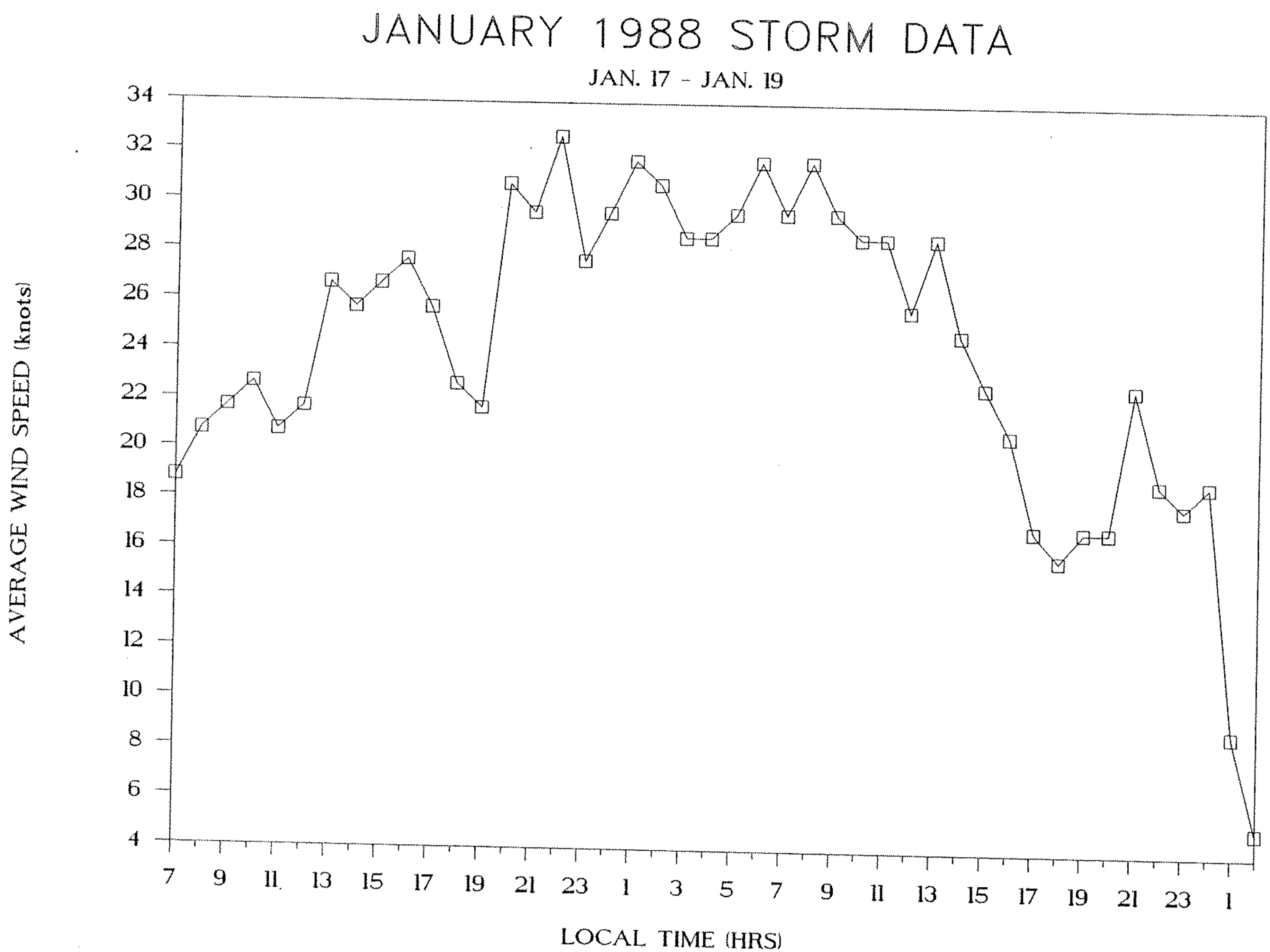


Figure 5.11. Average Wind Speed, January 17, 1988

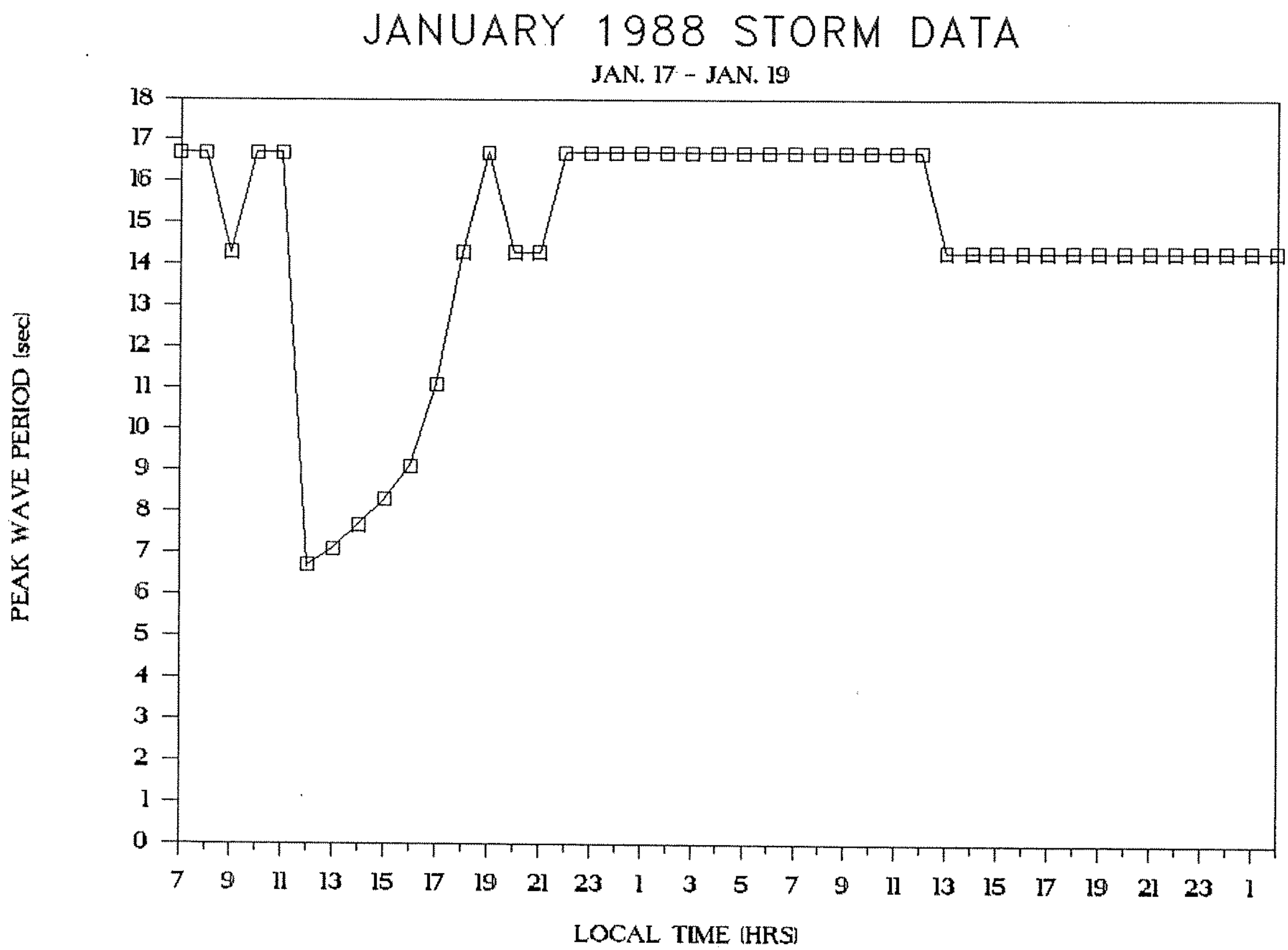


Figure 5.12. Peak Wave Period, January 17, 1988

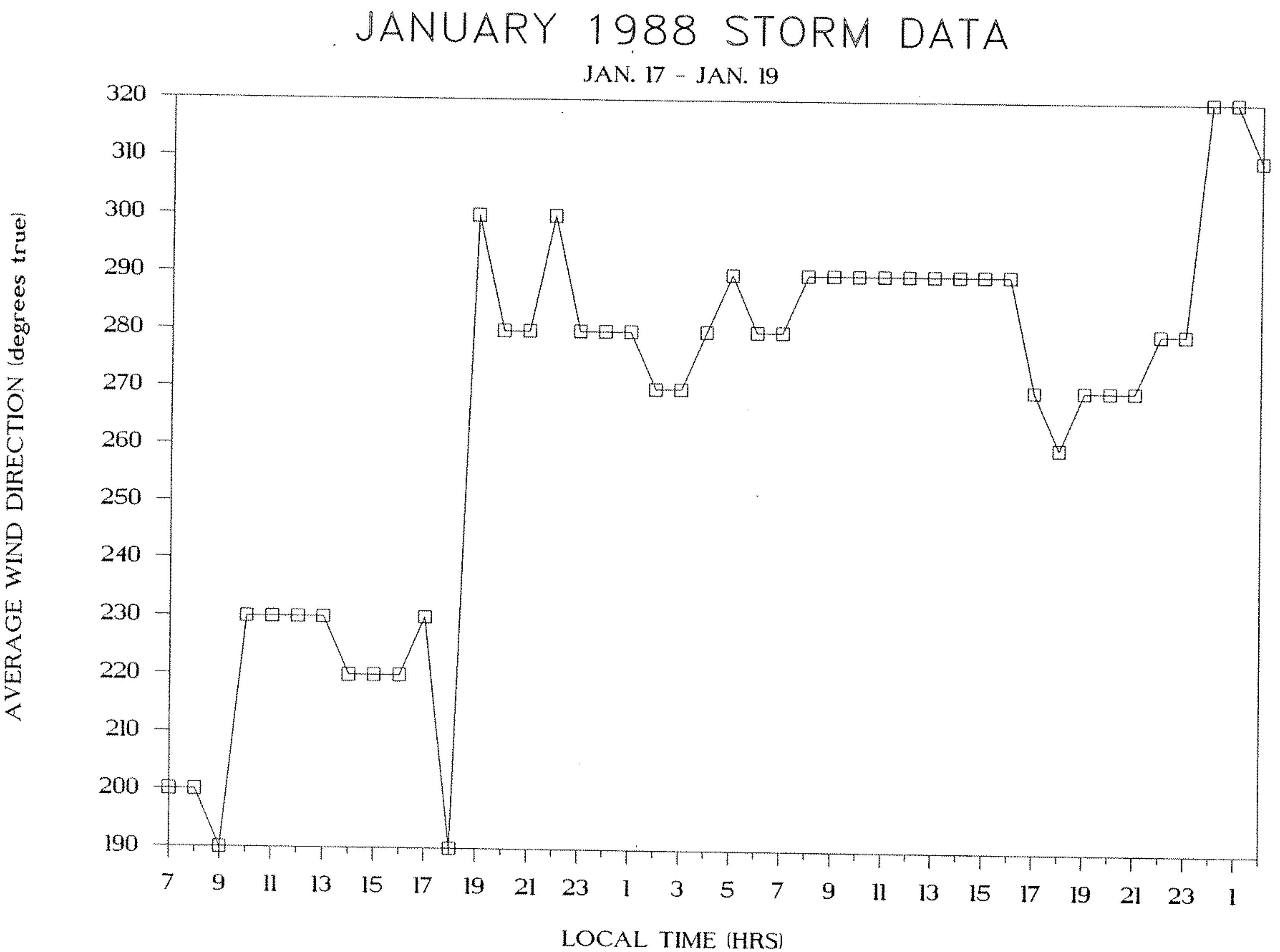


Figure 5.13. Average Wind Direction, January 17,1988

the semisubmersible buoy would not necessarily have occurred simultaneously with maximum significant wave height recorded at the NDBC buoy because of the laws of probability and the travel distance between the two buoys.

Several significant environmental events were identified for validation purposes as shown in Table 5.1. Five environmental scenarios or cases were of interest, particularly Case #1 with storms characterized by strong winds, fast currents, and a combination of wind generated waves and large swell. Identification of storm events centered not only around identifying desirable environmental events, but also around identifying the exact time frame when the largest waves were observed. Plots of wave spectra and current profile for each of these signifiacnt environmental events are presented in Appendix C.

Many other environmental events were captured, but those presented in Table 5.1 will be processed and used for MME model simulation purposes because they represent the desirable conditions for validation. Other less significant environmental events and data recording times for each day of the MME are indicated in the Experiment Calendar of Appendix A.

5.4 Probability of Future Storm Events

The probability of encountering a larger wave by continuing the MME another year into the 1988 winter season was determined. The routines were applied to the NDBC wave data to determine the encounter probabilities of maximum wave heights for one, two and three years. Two sets of data were exercised. The first set of data was collected with the NDBC buoy 10D 46025 stationed at 33.60° N, 119.00° W, April 1982 to

MME DATA SET SUMMARY
(Rev. 6/8/88)

Case Studies	Calendar Date	Julian Date	Pacific Standard Time	Significant Wave Height (m)	Peak Period (sec)	Mean Period (sec)	Swell/Wind Direction (deg)	Mean Wind Speed (m/sec)	Wind Direction (deg)
CASE #1 Waves, Swell, Wind, Current	4/3/87	93	0909-1009	2.3	14.3	6.0	270/260	12.04	260
	5/25/87	145	0909-1009	1.9	6.7	5.5	180/270	9.23	274
	1/17/88	17	1609-1709	6.0	11.1	8.6	310/230	13.38	230
	1/17/88	17	1809-1909	8.0	16.7	10.8	310/300	11.33	300
	1/18/88	18	0349-0449	6.7	16.7	9.7	310/290	15.44	290
CASE #2 Swell, Current No Wind	3/5/87	64	1009-1109	2.6	14.3	10.3	270/63	3.18	63
	3/6/87	65	0909-1009	2.4	14.3	8.5	226/86	5.92	86
CASE #3 Waves, Wind No Current	3/5/87	64	2209-2309	2.3	12.5	7.9	270/105	8.46	106.7
CASE #4 Current Only	4/18/87	108	1009-1109	1.1	16.7	5.6	270/300	2.04	309
CASE #5 Quiescence State	3/1/87	91	0909-1009	0.4	12.5	4.7	265/260	2.59	257

Table 5.1. Significant Environmental Events

September 1984 obtained from the NOAA NDBC Climatic Summaries, (NDBC (1986)). This data set encompasses 2-5 years of data which includes the extreme "El Nino" events of 1983. "El Nino" refers to increased seasonal meteorological activity due to a general warming trend in Pacific Ocean subtropical surface waters. The second set of data was collected with the NDBC buoy 10D 46025/46125 stationed at 33.8° N, 119.1° W, January 22, 1986 to June 1987. This recent wave data was collected for 1.5 years given a relatively benign 1987 winter season.

The following statistical procedures obtained from Dr. Leon Borgman, Statistics Department, University of Wyoming, Laramie, Wyoming were applied to the data:

1) The hourly significant wave height (H_s) values were computed and plotted on lognormal paper to produce functions for hourly H_s values.

2) Raised extrapolations of the monthly cumulative distribution functions to the power of the equivalent number of monthly independent events to produce monthly distribution functions for the maximum hourly H_s values.

3) Computed the annual distribution function for the maximum hourly H_s values from a product of the monthly distribution functions.

4) Calculated probabilities for 1, 2 and 3 year encounters of maximum hourly H_s values from the annual distribution function.

Shown in Figure 1.6 are probability of maximum significant wave height distribution plots for the 3-year data set and the 1-year data set. A conservative annual probability distribution was assumed half-way between these high and low distributions based on this assumed distribution, there is about a 50% chance of encountering a 6.1 m (20 ft) maximum significant wave height. The 8.0 m (26 ft) significant wave height of the January 17, 1988 storm had an estimated encounter probability equal to 0.2.

6.0 SEMISUBMERSIBLE ENVIRONMENTAL DATA

Meteorological and oceanographic parameters were measured on the semisubmersible for comparison to remote environmental parameters as described in section 5.0 and will be used for input into the validation models. A listing of these parameters is provided below. These parameters were measured with respect to the buoy coordinate system and so they must be corrected by including the motions of the semisubmersible. Sections 6.1 and 6.2 provide a more detailed description of the semisubmersible wave staff data and wind data. Time series plots representative of each environmental parameter with respect to the buoy for the March 5, 1987 storm as well as statistical data are provided in Appendix D.

Environmental Parameters:

- Wave Height
- Wave Height (Redundant)
- Surface Current X Component
- Surface Current Y Component
- Surface Current Z Component
- Surface Current Z Component (Redundant)
- Wind Speed at Column 1
- Wind Speed at Column 3
- Wind Speed at Center Mast
- Wind Direction at Column 1
- Wind Direction at Column 3
- Wind Direction at Center Mast
- Deckhouse Temperature
- Deckhouse Humidity

6.1 Wind Measurements

Three anemometers provided wind speed and direction on the semisubmersible. The mast anemometer was located 10 m (33 ft) above the Mean

Water Line (MWL) of the semisubmersible in the center of the semi-submersible above all obstructions where flow interference would be minimized. The other two anemometers were located above the bow column (C3) and above the port column (C1) since these were the predominant windward corners. Both of these anemometers were located at 6 m (20 ft) above the MWL.

Time series plots of wind speed and direction for the mast anemometer for data sampled during the March 5, 1987 storm are shown in Figures 6.1 and 6.2. The peak mean wind speed for the storm was only 9 m/sec (30 ft/sec). The mean wind speed and direction supplied by NDBC from Buoy 46025 averaged over approximately the same time period are in good agreement with the averages of the mast anemometer. The other two anemometers were not compared as their elevations are lower than the 10 meter elevation of the NDBC anemometer.

The NDBC anemometer was located 2.5 km (1.4 nm) to the west. Since the wind direction is at approximately 82 degrees for this comparison, and the average wind speed was approximately 10 m/sec (33 ft/sec), the semisubmersible anemometer recorded the wind approximately 4 minutes earlier. Therefore the MME mast anemometer data has been averaged over a time period beginning 4 minutes earlier for best comparison. Considering the 2.5 km (1.4 nm) distance between the two anemometers, it may be assumed that the two anemometer readings agree quite well. Wind speed values for January 1988 storm showed peak means of 20 m/sec (40 kt) with gusts of 28 m/sec (55 kt).

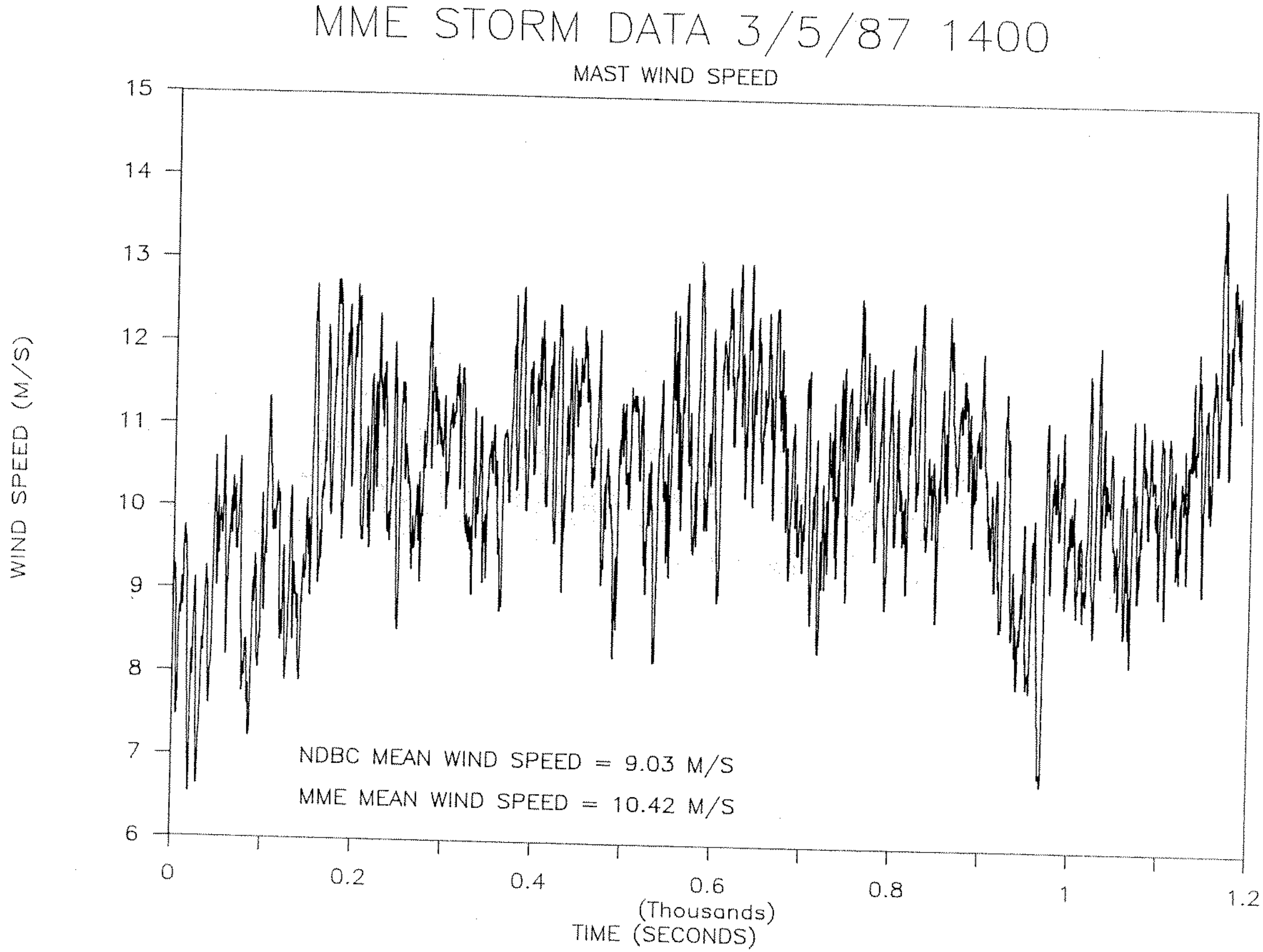


Figure 6.1. Wind Speed, Mast Anemometer, March 5, 1987

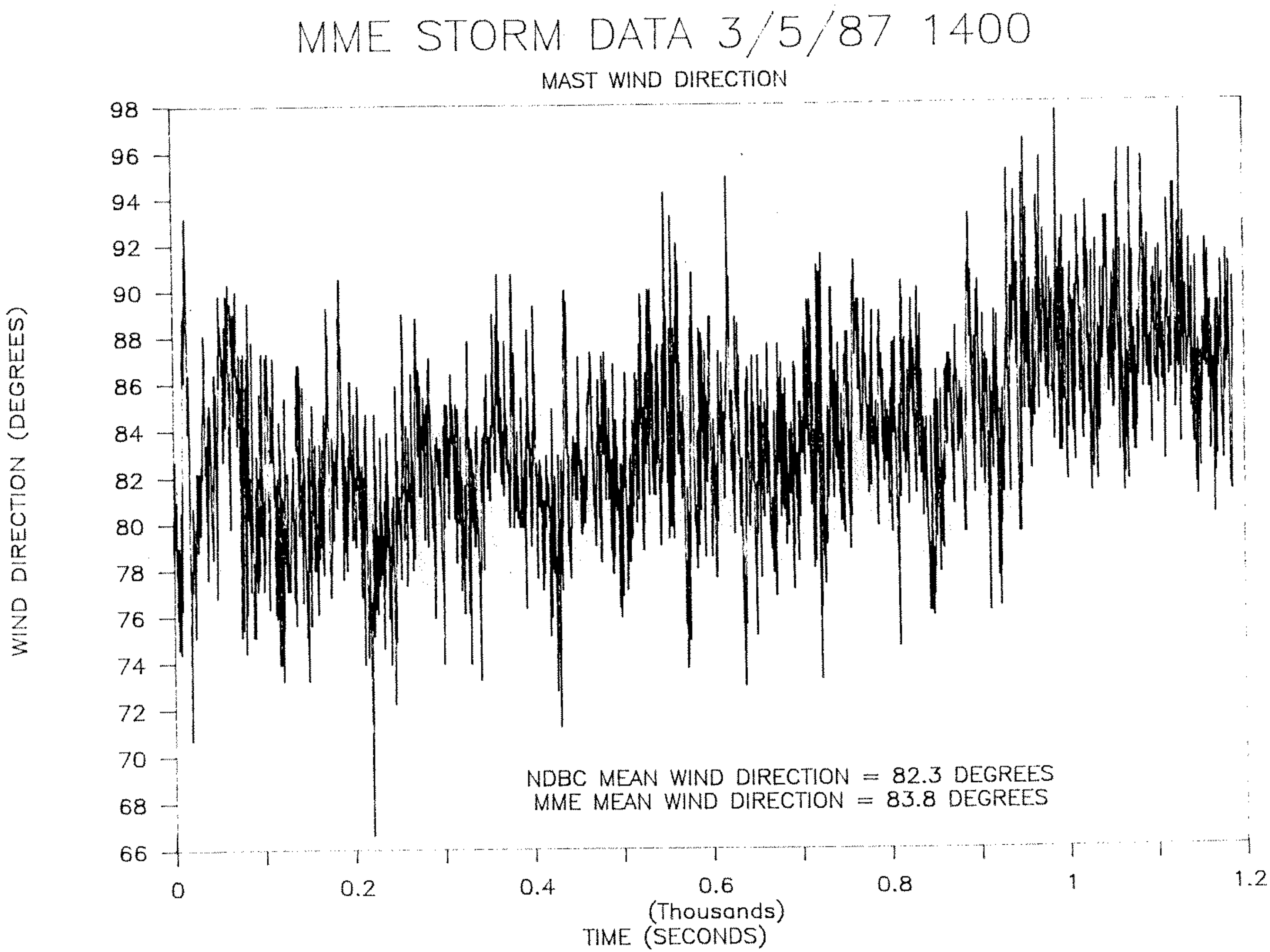


Figure 6.2. Wind Direction, Mast Anemometer, March 5, 1987

6.2 Wave Measurements

Ocean free surface elevation was measured with respect to the semisubmersible by two wave staffs. Both staffs were located in the geometric center of the buoy at 8 m (26 ft) from the inner edges of each of the three 1.5 m (5.0 ft) diameter columns to minimize flow interference. As with the other environmental parameters, the semisubmersible's 6 modes of motion must be reduced out of the wave staff readings to arrive at true wave height.

Data processing techniques for this reduction are being developed; a rough approximation of true wave height is provided in this report as a plot in Figure 6.3. This approximation of true free surface elevation has been synthesized by algebraically adding the wave staff time series to the doubly integrated heave acceleration time series. Although the time series in Figure 6.3 is only approximate, it nevertheless demonstrates that the free surface measurement made by the wave staff is comparable to that made by the NDBC wave buoy.

The NDBC measured significant wave height is 2.6 m (8.5 ft) for the measured time frame. The peak wave height for this time is estimated to be 4.3 (14.1 ft). The plot in Figure 6.3 shows a peak wave height of about 3.7 m (12.1 ft) for this segment which is within reason.

Figure 6.4 compares NDBC buoy 46025 wave height spectral density and the MME semisubmersible wave height spectral density for 20 minutes of data. The MME semisubmersible wave height is only an approximation created by methods described earlier in this section. The shift in peak

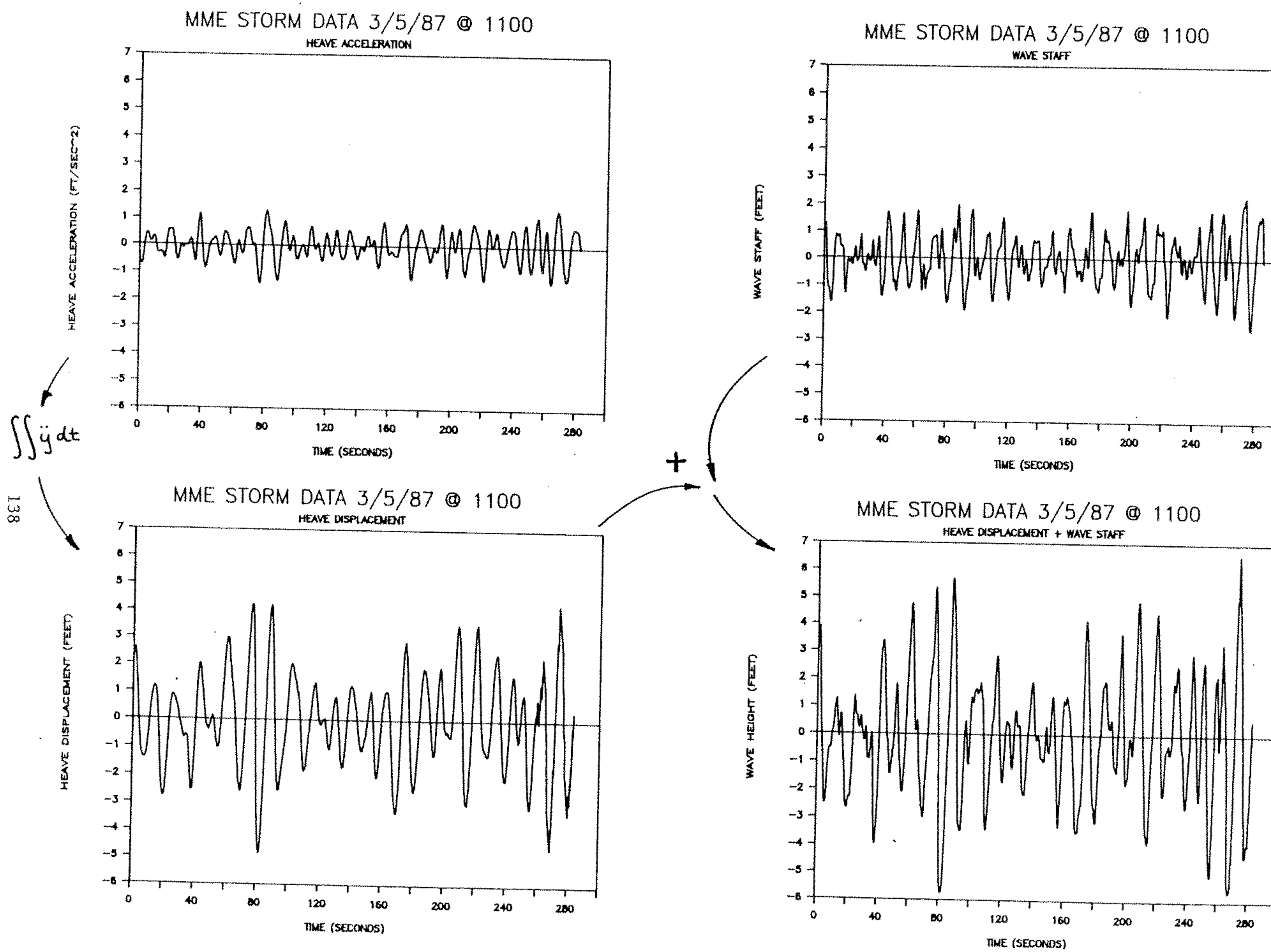


Figure 6.3. Approximated Free Surface Elevation, March 5, 1987

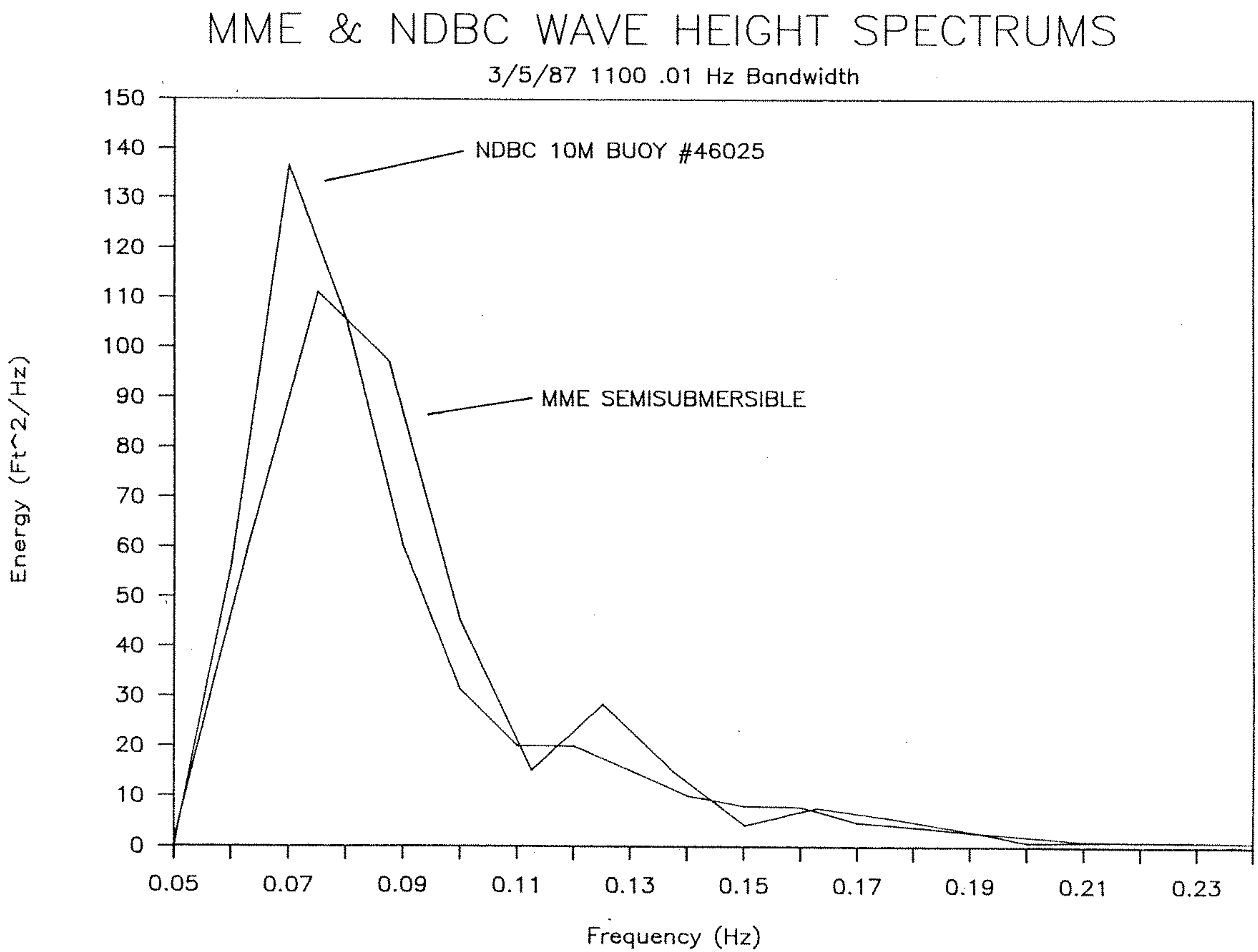


Figure 6.4. Spectra Comparison of Wave Heights

energy demonstrates the need to include surge, sway, roll, pitch and yaw in the calculation. Nevertheless, the comparison is reasonable considering the spatial separation of 2.5 km (1.4 nm) between the NDBC wave buoy and the MME platform.

6.3 Current Measurements

Two Marsh-McBirney electromagnetic current meters provided the ocean surface current data and will provide the wave water particle kinematics 6.7 m (22.0 ft) below the mean water line. These meters are located directly below the geometric center of the platform, 6.7 m (2.0 ft) below the keel. The water particle velocities are measured in three directions with +X towards the bow, +Y up, and +Z pointing to starboard. Note however that these component directions are MME platform directions and differ from local current meter directions (Figure 4.12).

The Marsh-McBirney electromagnetic current meters are quite sensitive to disturbance of the flow field by marine growth. Figure 6.5 shows a comparison of the redundant z-direction current meter time series. A bias difference is obvious but relative amplitude agrees. Time series plots of current meter data are provided in Appendix C for the 5 March 1987 storm data. This data will serve as the ocean current values for the top portion of the water column to be meshed with the data provided by the NAVOCEANO deep-ocean vector-averaging current meter array at the MME site. Note that component directions for the NAVOCEANO current meter array (northing and easting) differ from the Marsh-McBirney current meter.

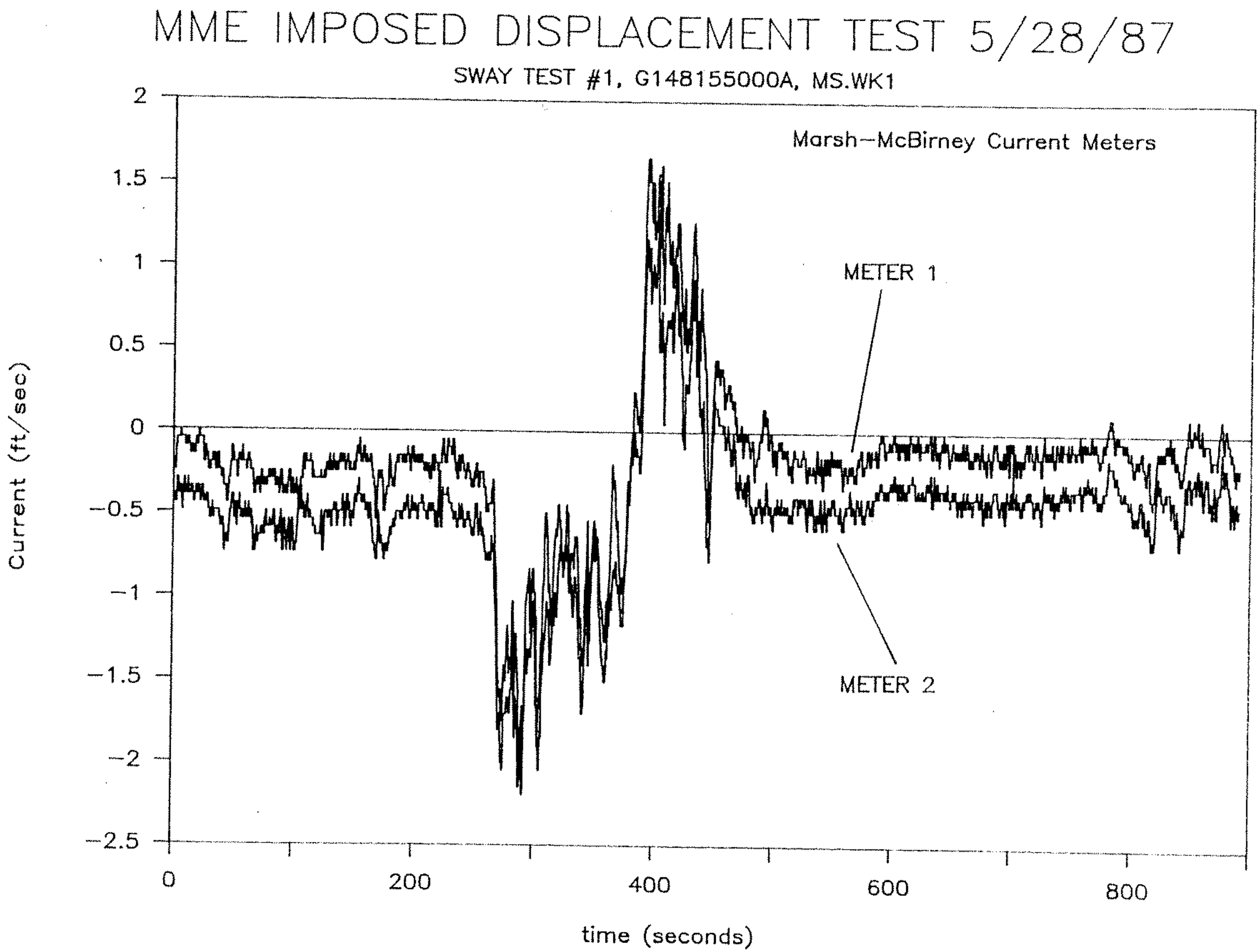


Figure 6.5. Current Meter Comparison - Z-Direction

7.0 SEMISUBMERSIBLE RESPONSE DATA

The static and dynamic response data measured and collected during the course of the experiment include the semisubmersible's six modes of motions, mooring line tensions, and instrumented test cylinder hydrodynamic loads and pressures. Time series plots of each of the semisubmersible's response parameters are provided in Appendix D for the March 5, 1987 storm.

The semisubmersible motions are divided into high frequency motions and low frequency motions. The Humphrey Motion Package supplied the response data for the higher frequency oscillations and the Sonardyne long baseline acoustic positioning system furnished the low frequency platform drift. The two motion response histories will be merged in post-processing to produce one continuous and accurate response history that encompasses the full range of frequency response (Pawsey et al., 1986).

Mooring line response tensions at the platform were also measured at the top of the three mooring lines. The mooring line tensions will provide information on low frequency platform drift and dynamics due to wind, current, and wave excitation. The mooring line tension at the top for the January 1988 storm varied dynamically over a range of 26.7 kN (6.0 kips). The mean tensions will help verify the low frequency position information and ocean current directions.

Section 7.2 contains time history plots of the mooring line tensions as measured at the platform for the Imposed Displacement Test and March 5, 1987 storm.

The Instrumented Test Cylinder (ITC) mounted on the port side of the platform measured the hydrodynamic loads due to waves and currents, and due to the hydrodynamic forces produced by relative motion between the hull and the seawater. For practical purposes, the wind load may be assumed to be negligible as compared to the wave and current loads. The ITC load data includes measured orthogonal components of forces at the upper and lower ends of the cylinder and hydrostatic plus dynamic circumferential pressures measured at a level below the water surface.

A set of extinction tests was conducted in Port Hueneme Harbor to measure the semisubmersible's inherent response characteristics in heave, roll and pitch motions and to determine the undamped free vibration natural periods in these directions. The extinction tests consisted of displacing the semisubmersible in the three directions, releasing it, and measuring the resultant response. These tests were performed without a mooring system attached since the heave, roll and pitch natural periods are determined mostly by the semisubmersible hull characteristics. A detailed description of the most characteristic heave, roll, and pitch tests is provided in Section 7.1.

A similar set of tests was conducted at sea to determine the combined semisubmersible and mooring system natural periods in surge, sway and yaw. This known imposed displacement and measured mooring line tensions also allows the determination of mooring system stiffness. The tests consisted of applying a tow force to the moored semisubmersible, releasing it and measuring the exponentially decaying response. A detailed description of this test is described in Section 7.2.

The time series data measured and recorded on the semisubmersible buoy are composed of a total of 44 environmental, response, and other parameters. The listing below states the response parameters as measured relative to the semisubmersible coordinate system. Euler angles are order dependent measurements between the moving semisubmersible coordinate system and the fixed global coordinate system. Redundant measurements are indicated. The environmental parameters are described in Section 6.0.

Response Parameters:

Surge Acceleration (High Frequency Motion)
Sway Acceleration (High Frequency Motion)
Heave Acceleration (High Frequency Motion)
Acoustic Distance to Transponder #1
Acoustic Distance to Transponder #2
Acoustic Distance to Transponder #3
Acoustic Distance to Transponder #4
Roll Angle (Euler Angle)
Roll Rate
Pitch Angle (Euler Angle)
Pitch Rate
Yaw Angle (Euler Angle)
Mooring Leg 1 Upper Tension
Mooring Leg 1 Upper Tension (Redundant)
Mooring Leg 2 Upper Tension
Mooring Leg 2 Upper Tension (Redundant)
Mooring Leg 3 Upper Tension
Mooring Leg 3 Upper Tension (Redundant)
Wave Height @ Center (Staff #1)
Wave Height Off Center (Staff #2) (Redundant)
Water Particle Motion in Surge Direction
Water Particle Motion in Sway Direction
Water Particle Motion in Sway Direction (Redundant)
Water Particle Motion in Heave Direction
Wind Speed @ Column C1
Wind Speed @ Column C3
Wind Speed @ Mast
Wind Direction @ Column C1
Wind Direction @ Column C3
Wind Direction @ Mast
Temperature Inside Deckhouse
Relative Humidity Inside Deckhouse
Instrumented Test Cylinder Upper Load X Direction
Instrumented Test Cylinder Upper Load Z Direction
Instrumented Test Cylinder Lower Load X Direction
Instrumented Test Cylinder Lower Load Z Direction

Instrumented Test Cylinder Pressure at Port 1
Instrumented Test Cylinder Pressure at Port 2
Instrumented Test Cylinder Pressure at Port 3
Instrumented Test Cylinder Pressure at Port 4
Instrumented Test Cylinder Pressure at Port 5
Instrumented Test Cylinder Pressure at Port 6
Instrumented Test Cylinder Pressure at Port 7
Instrumented Test Cylinder Pressure at Port 8
Time as Measured by Onboard Clock

7.1 Platform Extinction Tests

A series of damped free vibration tests were conducted in Port Hueneme Harbor to determine the damped natural periods of oscillation in heave, roll and pitch.

These tests consisted of displacing the semisubmersible in each of the three response directions and recording the resultant time-history response upon release. Data from the Humphrey motion package, the Baylor wave staffs and the Endeco compass were recorded on a strip chart for these tests.

The tests were conducted in Port Hueneme Harbor in calm water in April 1986, just prior to the at-sea installation of the semisubmersible. The semisubmersible was ballasted to the operational draft of 6 m (20 ft) by flooding the ballast tanks with sea water.

The heave test consisted of lifting the semisubmersible vertically with a 100-ton crane approximately 1.1 m (3.6 ft), releasing it with a pelican hook and measuring the resultant response. The test configuration is shown in Figure 7.1. The wave staffs on board the semisubmersible measured the heave directly. Analysis of the data revealed heave response with little or no pitch, roll sway, surge or yaw motion. The response is sinusoidal with an amplitude decreasing logarithmically. The

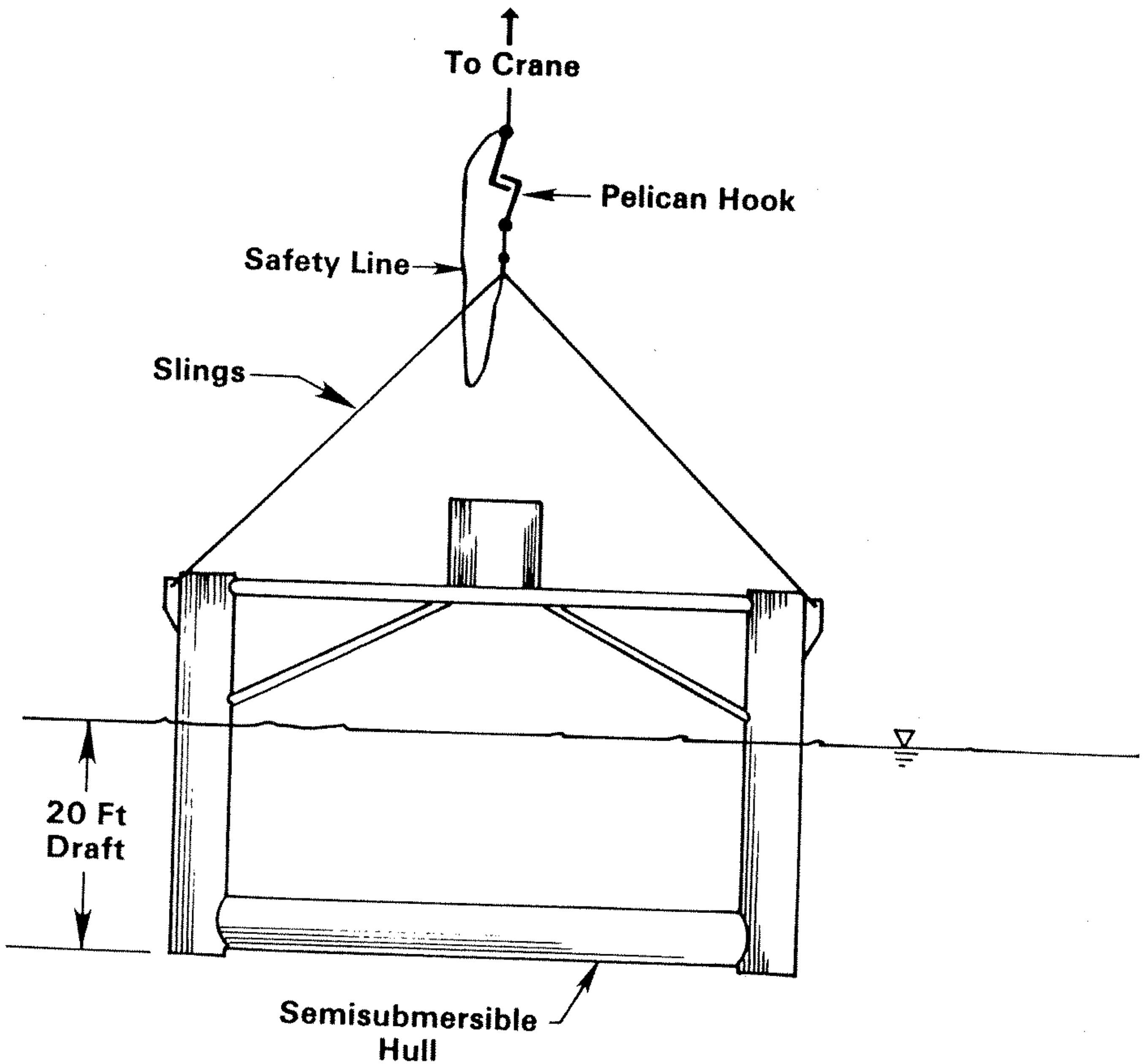


Figure 7.1. Heave Test Rigging

damped natural period was calculated by dividing the total test period time by the number of cyclic periods. This damped free vibration natural period in heave was calculated as 10.80 seconds. A time history plot of the heave response is shown in Figure 7.2.

The pitch and roll tests were performed by rotating the semisubmersible approximately 10 degrees, releasing it and measuring the resultant response. The semisubmersible was rotated by the use of a 100-ton YD crane barge, a clump weight, and an arrangement of sheaves and lines as shown in Figure 7.3. A pelican hook was used as the release mechanism. The damped free vibration natural periods for pitch and roll were calculated as 13.0 and 12.90 seconds, respectively. Time history plots of pitch and roll responses are detailed in Figures 7.4 and 7.5, respectively. Table 7.1 compares the semisubmersible damped natural periods in heave, roll and pitch. Damping varied from 3 to 5% of critical damping. The damping factor was calculated using logarithmic decrement method (Meirovitch, 1986).

7.2 Imposed Displacement Tests

In May 1987, tests were conducted at sea to determine the combined semisubmersible and mooring system damped vibration natural periods in surge, sway and yaw. These imposed displacement tests consisted of towing the moored platform away from equilibrium, releasing it and measuring the response motions. Figure 7.6 shows the attachment point and direction of towing for each test. The tests were also conducted to determine the mooring stiffness and check the accuracy of the buoy

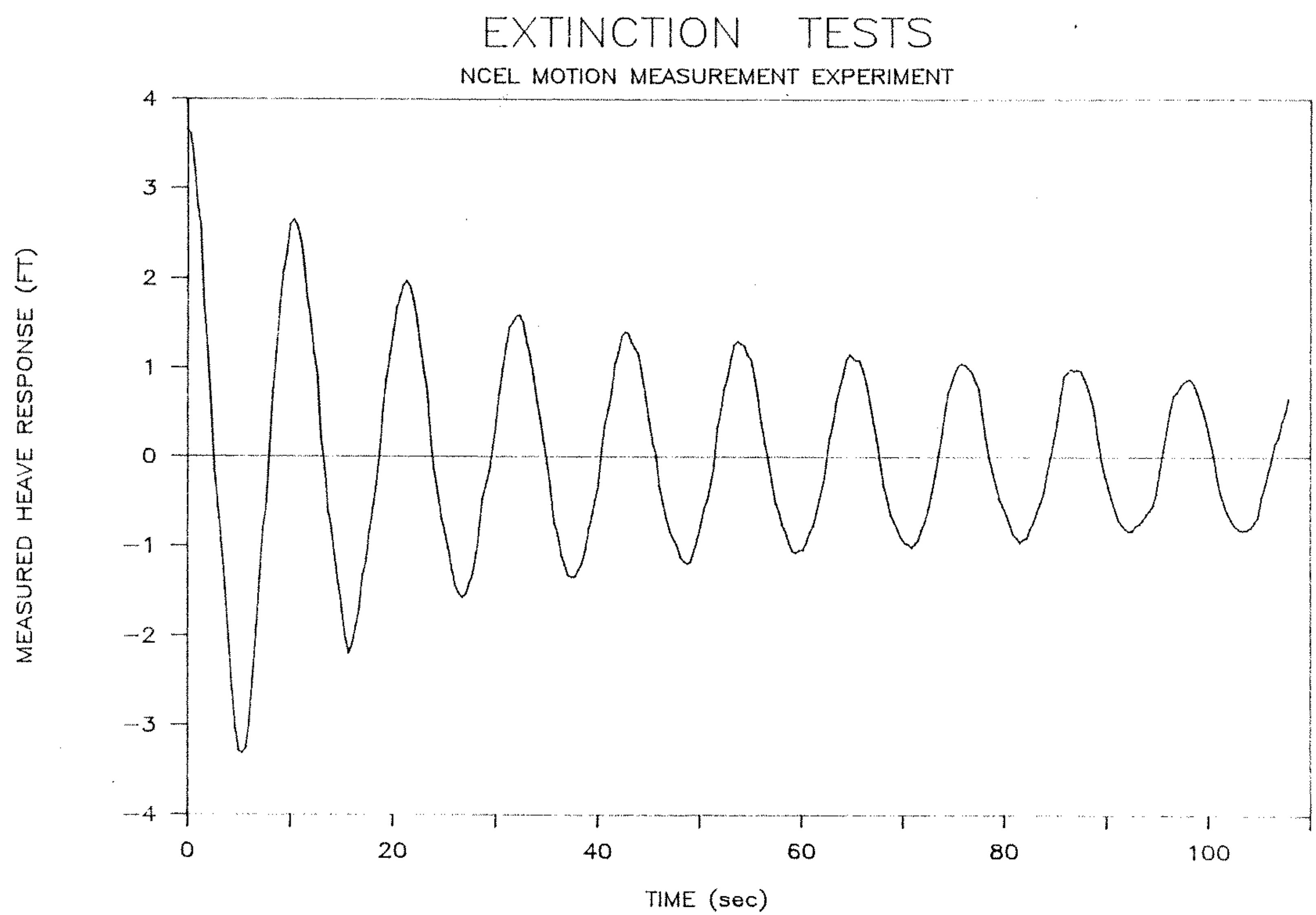


Figure 7.2. Measured Heave Response, Heave Test

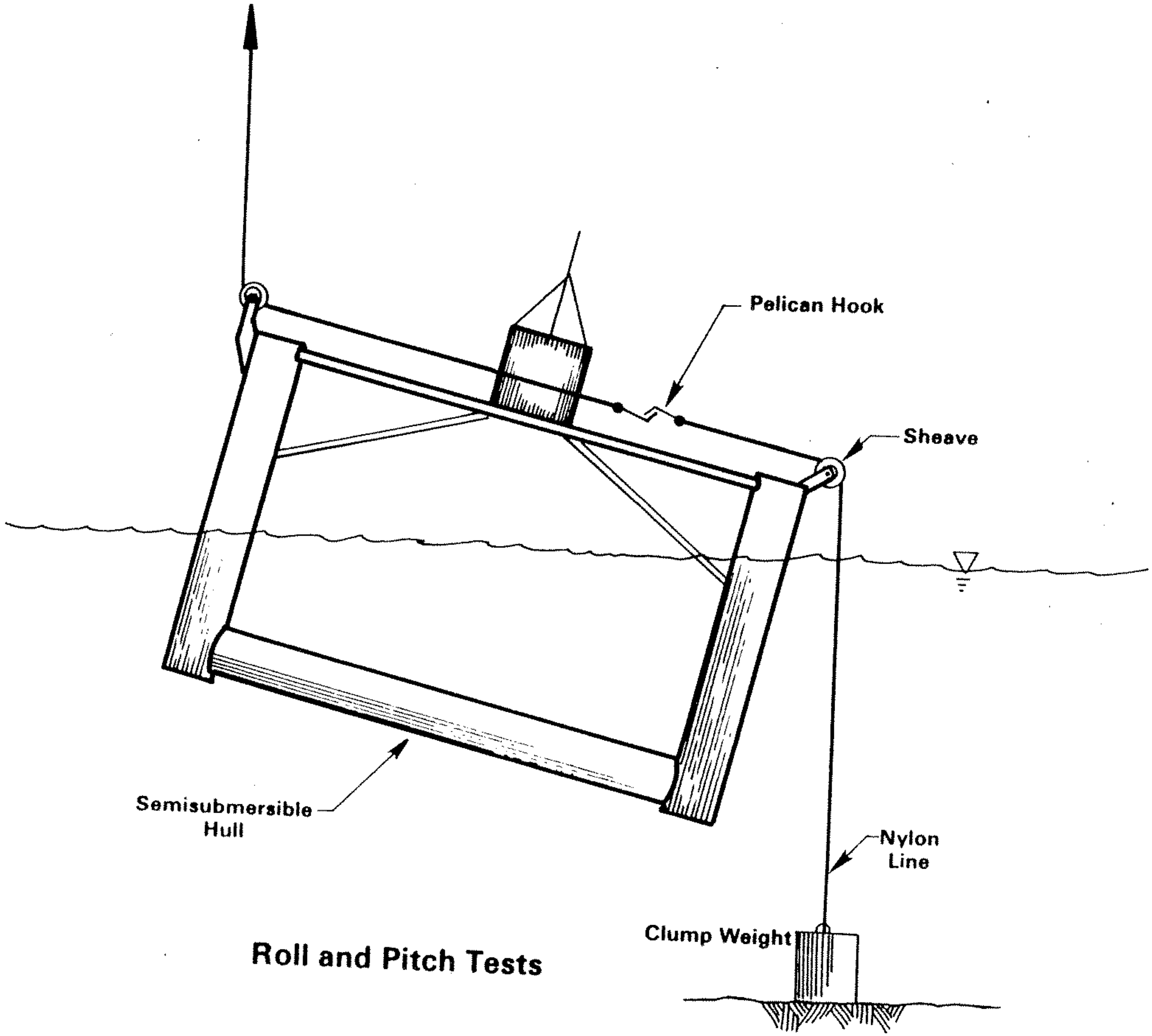


Figure 7.3. Roll and Pitch Test Rigging

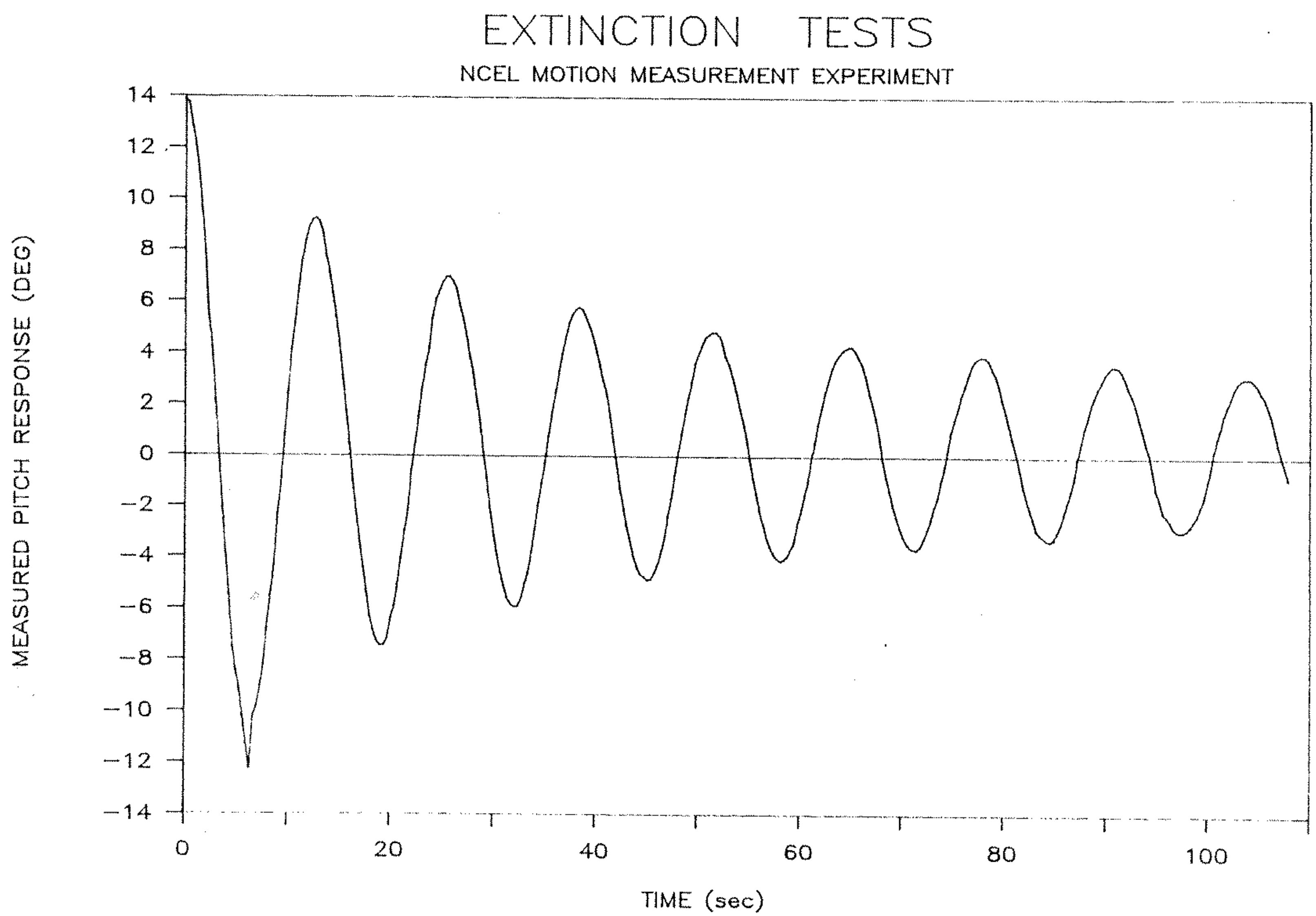


Figure 7.4. Measured Pitch Response, Pitch Test

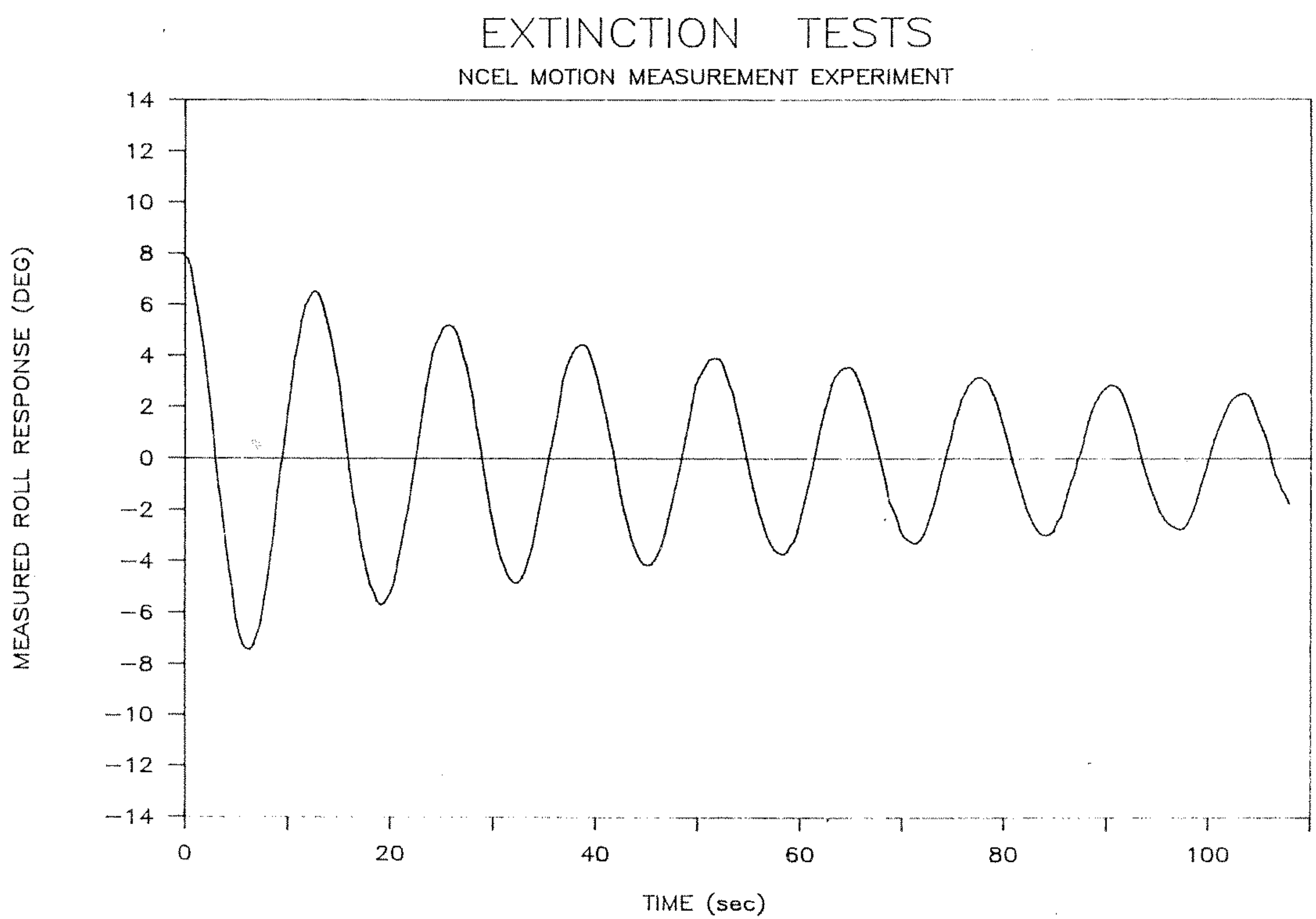


Figure 7.5. Measured Roll Response, Roll Test

Test	Natural Periods (sec)	Damping Factor (% crit)	Maximum Ampl of Motions		
			Heave (ft)	Roll (deg)	Pitch (deg)
Heave	10.80	0.050	3.66	0.25	0.19
Roll	12.90	0.035	0.24	7.94	1.20
Pitch	13.00	0.055	0.36	1.20	13.87

Table 7.1 Extinction Test Results

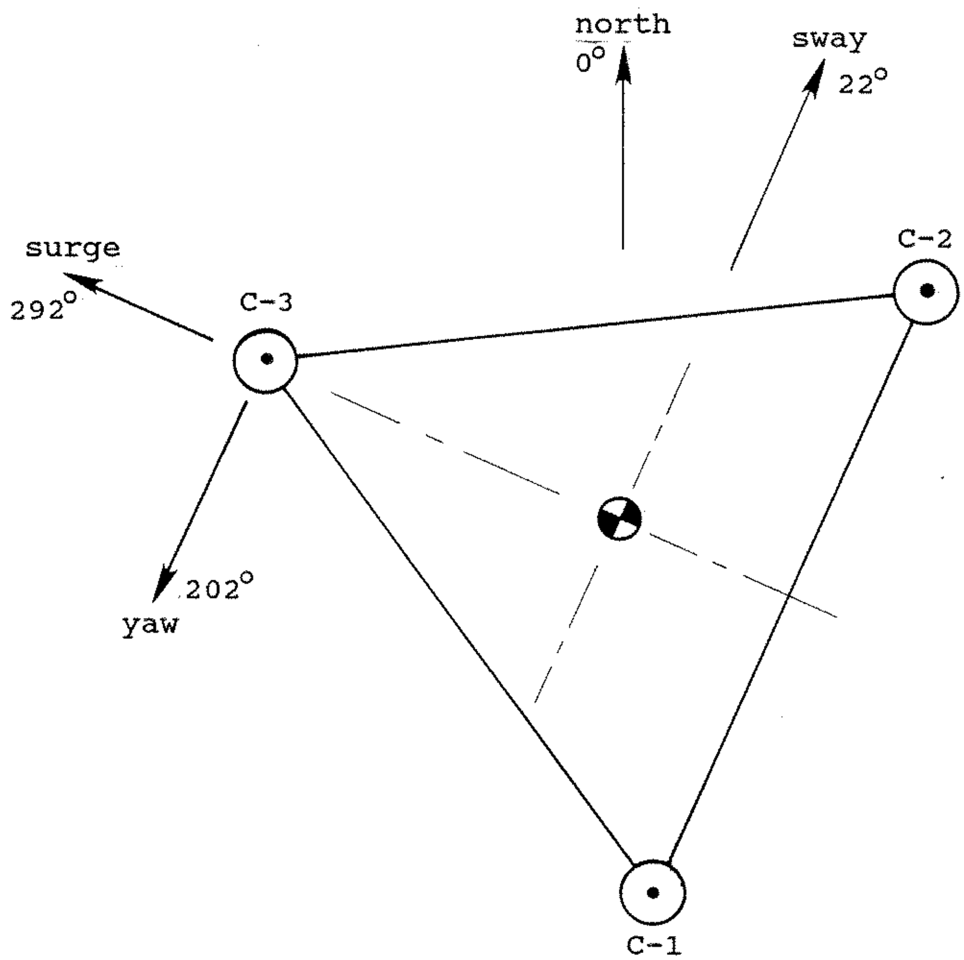


Figure 7.6. Imposed Displacement Test Directions

compass and the Long Baseline acoustic positioning System (LBS). The accuracy of the buoy compass was checked using an independent gyro compass, brand name Measurement Devices Limited. The gyro was located in the deckhouse near the center. The accuracy of the LBS was checked using an independent surface navigation system, brand name Mini-Ranger Falcon 484. This surface navigation system was also used to calibrate the LBS as described in Section 4.1.

The Semisubmersible Instrumentation Subsystem (SIS) provided the measurement and data acquisition of the regular environmental and response parameters as listed in Section 7.0. A separate Hewlett-Packard HP9825 was used to acquire the data as measured by the temporary gyro compass and surface navigation system.

The LBS and the temporary surface navigation system monitored the semisubmersible's position with sample rates of 0.128 Hz and 0.5 Hz, respectively. The surface navigation system using a separate receiver also monitored the tow vessel's position. Figure 7.7 shows time history plots of the tow vessels position as measured by the surface navigation system for the surge, sway and yaw tests.

7.2.1 Surge Test

The surge test was conducted by attachment of a towline to the bit on top of C3 column and slowly towing the semisubmersible in the surge direction to a mean position of about 61 m (200 ft) from static equilibrium. Desired semisubmersible horizontal displacement was predetermined from

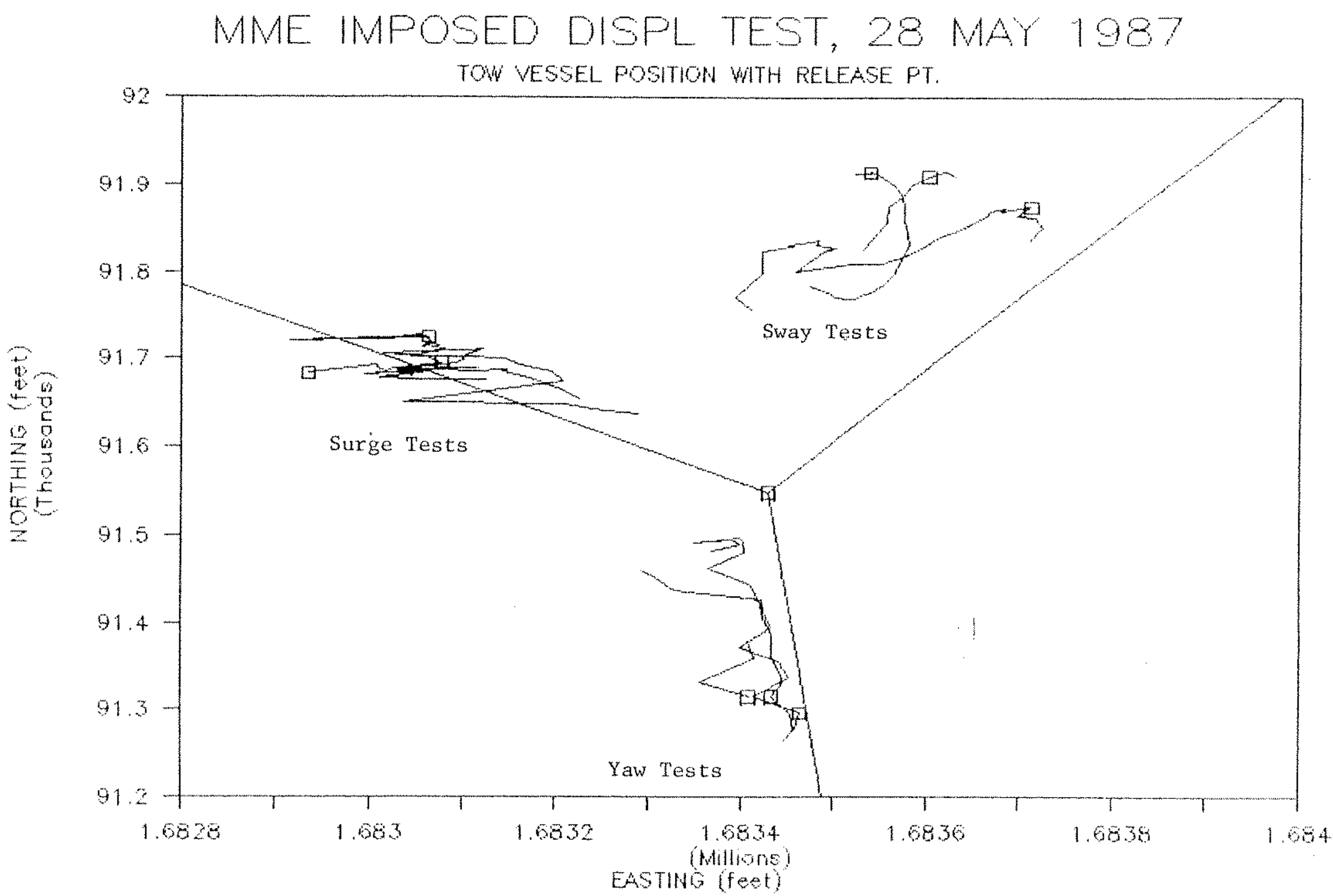


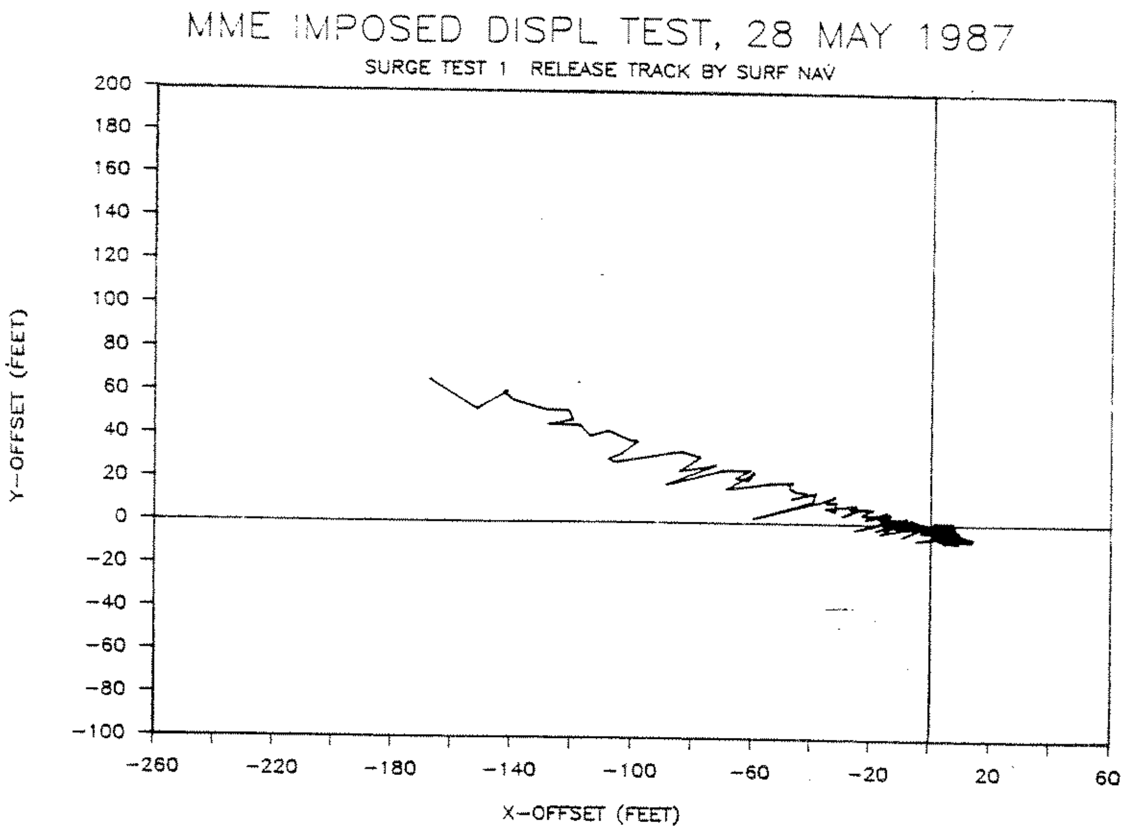
Figure 7.7. Imposed Displacement Test Tow Vessel Positions

force-displacement tables of the mooring system. Upon release the semisubmersible was allowed to settle back to equilibrium for 15 minutes. The test was repeated twice.

A set of time history plots of the response for the first surge test are shown in Figure 7.8 through 7.13. Figure 7.8 shows a comparison between the surface navigation system and the LBS. The release point occurred 68 m (224 ft) from the initial position along the surge axis. The X-offset and Y-offset axes represent the semisubmersible horizontal displacement in the water plane where +X is East and +Y is North, respectively. Figures 7.9 and 7.10 are representations of Figure 7.8 for semisubmersible offset versus time. Again, +X corresponds to East heading and +Y corresponds to North heading. The surge response is heavily over-damped due to the added viscosity of the coupled hull-mooring system. The damped natural period in surge appears to be about 150 seconds.

An interesting observation noticeable from this surge test is the platform set-down with horizontal offset as demonstrated from the wave staff record in Figure 7.11. The mean wave staff reading increased from 4 m (13 ft) to 5 m (15 ft) for the 68 m (224 ft) offset in surge.

Because the towline was attached to the C3 column bit located above the center of gravity of the platform, some pitch displacement was imposed in the surge tests in addition to the surge displacement. Figure 7.12 presents a time history of the rapidly decaying pitch response after release. The first oscillation in pitch reveals a period of 11 seconds.



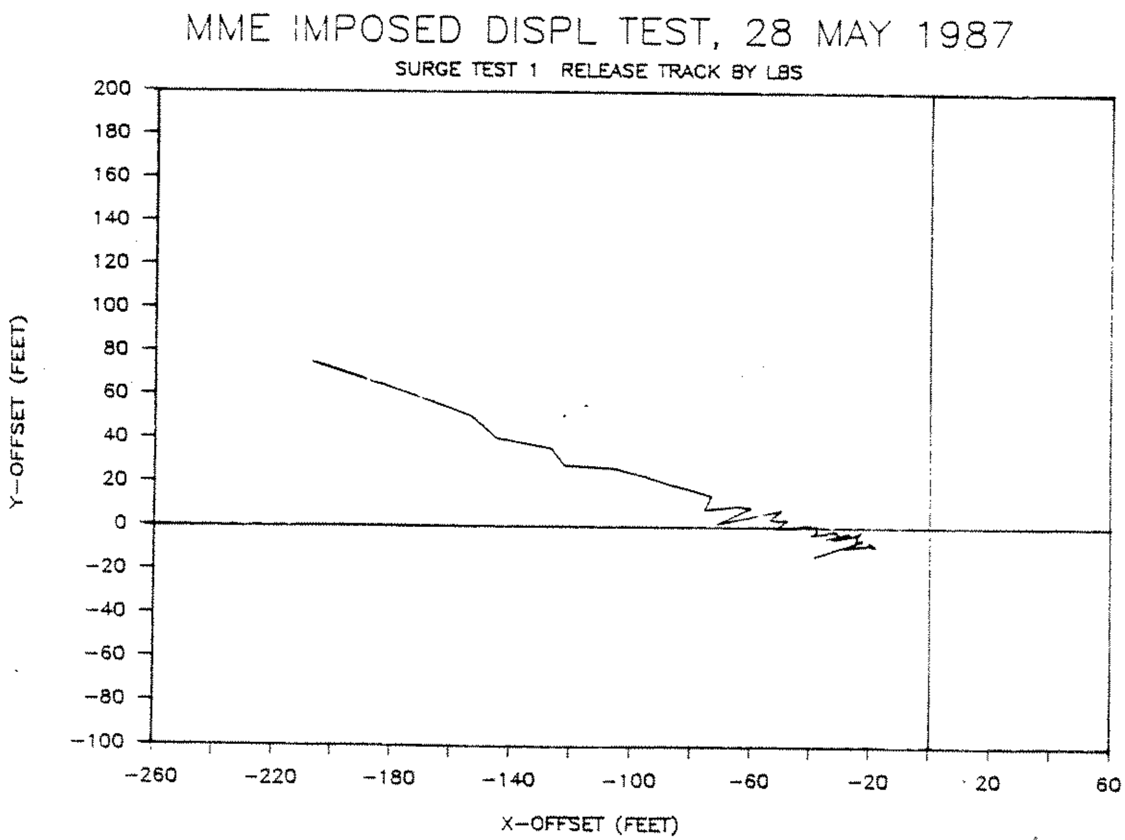


Figure 7.8. Release Track Comparison, Surge Test

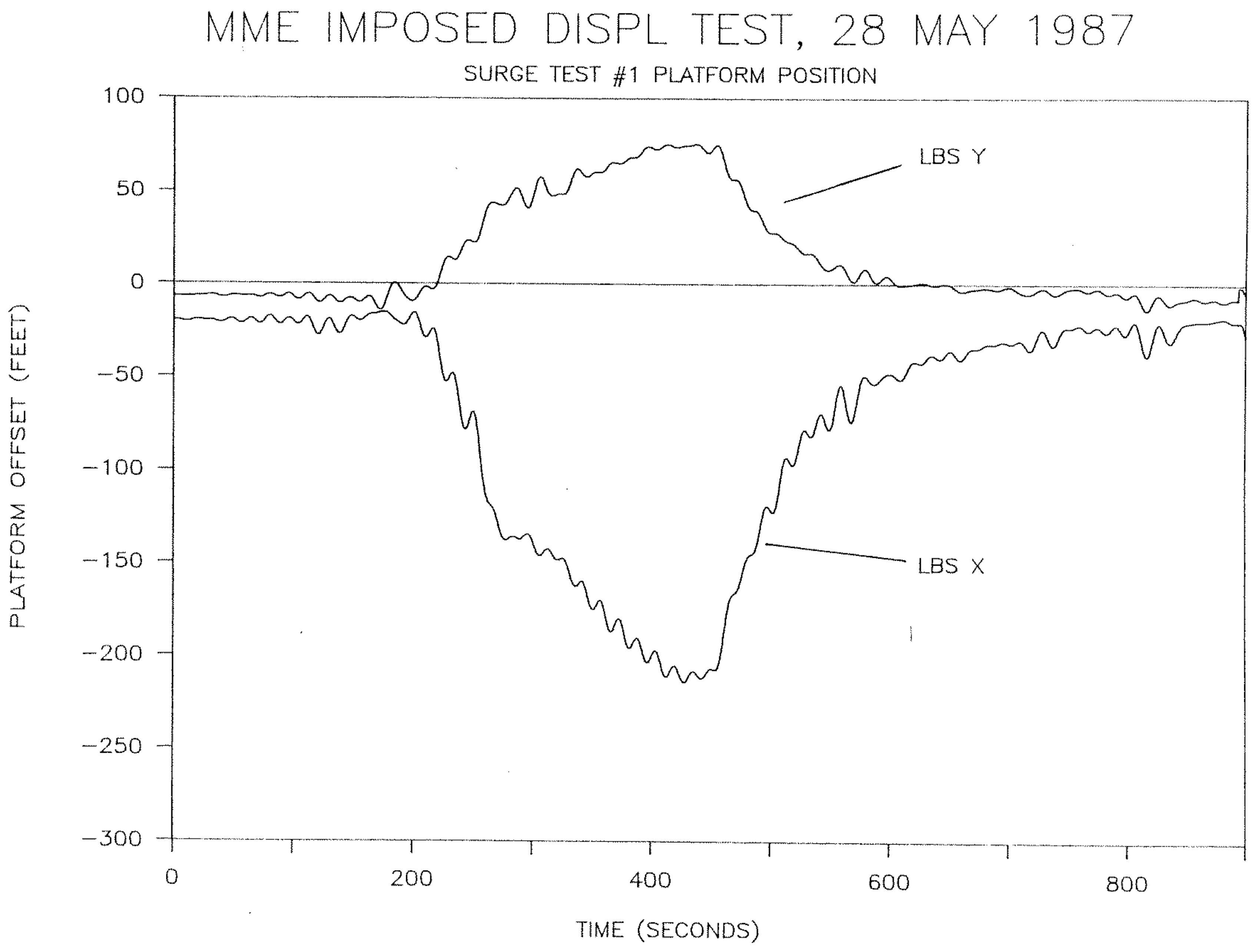


Figure 7.9. Platform Position (Acoustic), Surge Test

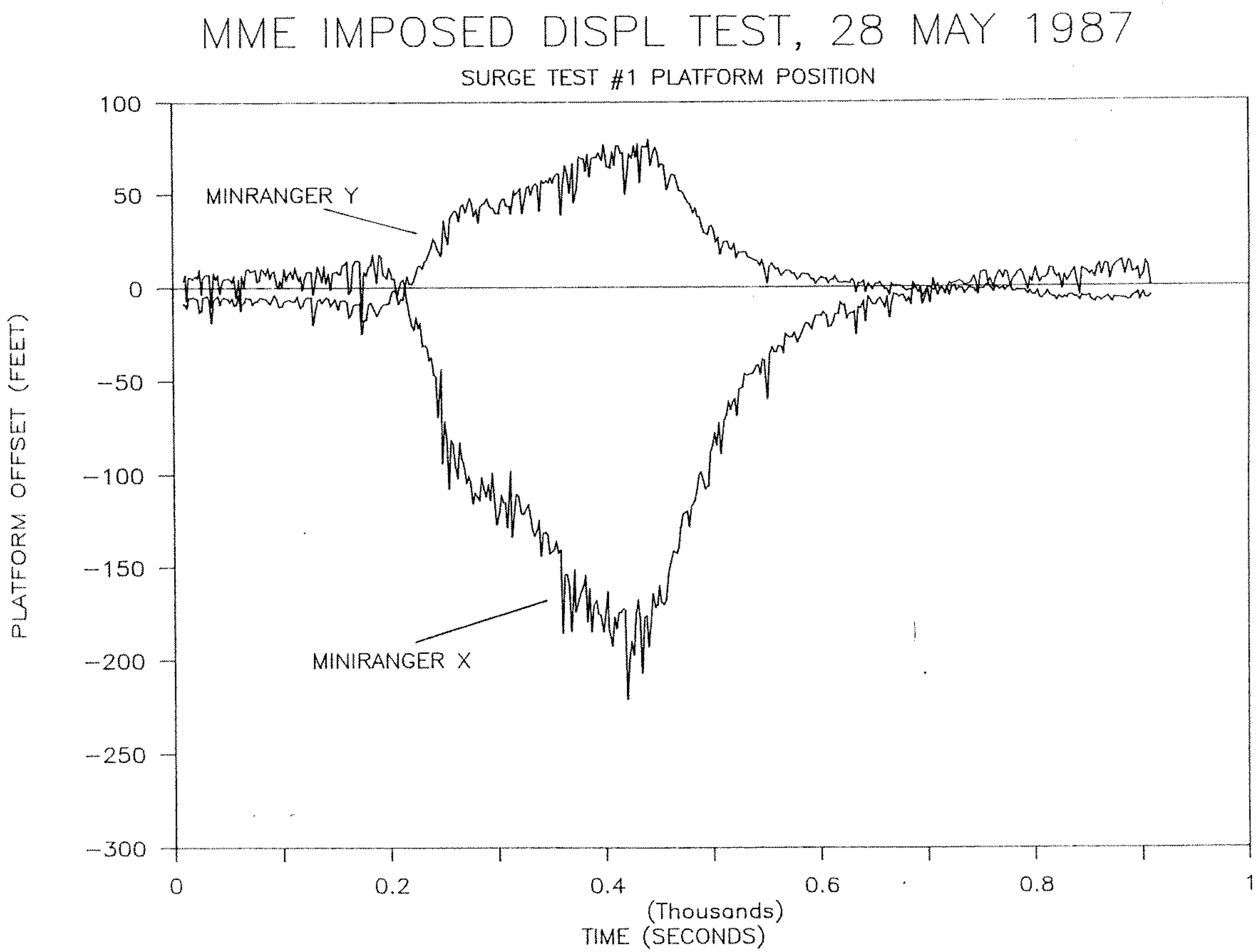


Figure 7.10. Platform Position (Surface Nav.), Surge Test

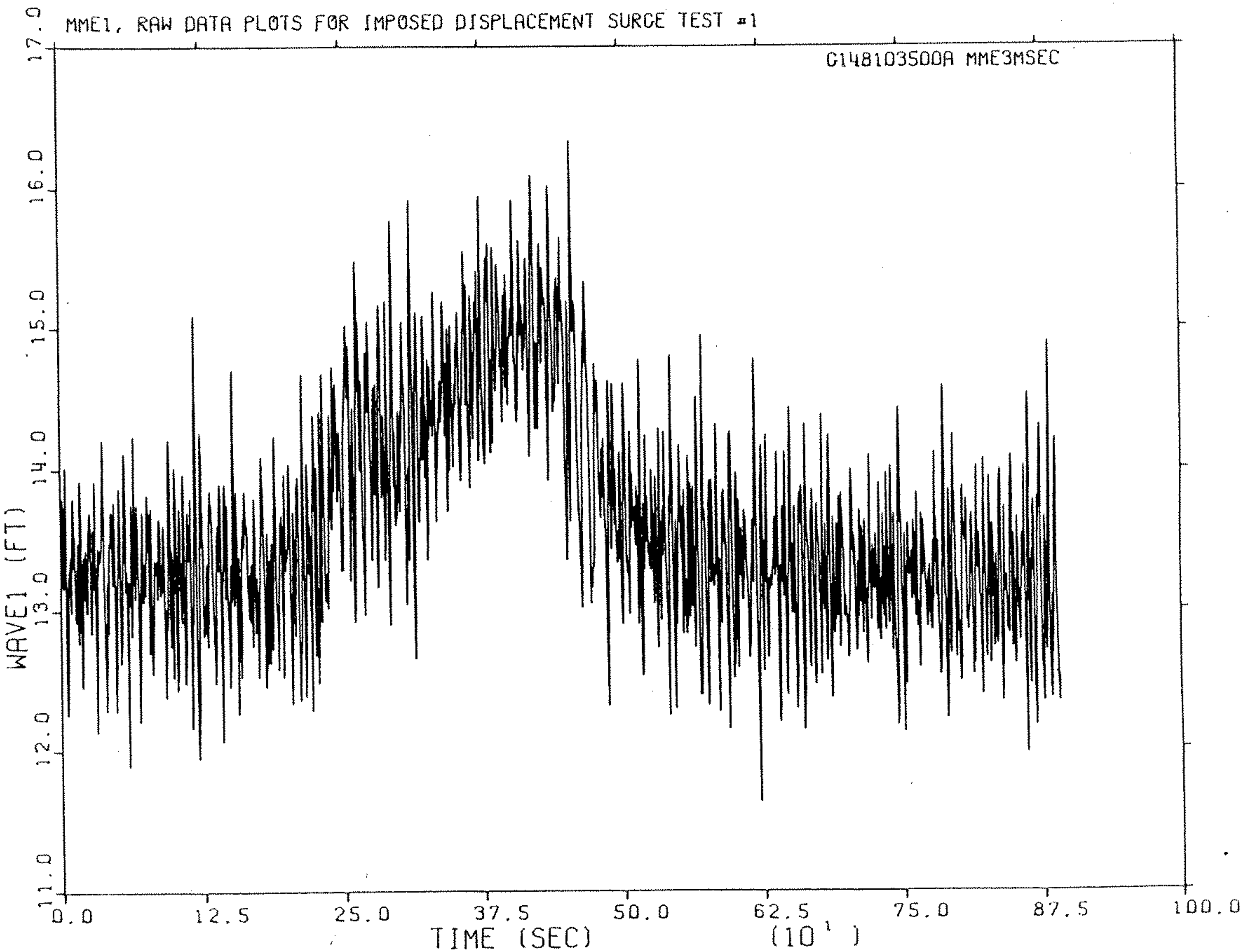


Figure 7.11. Wave Staff Time History, Surge Test

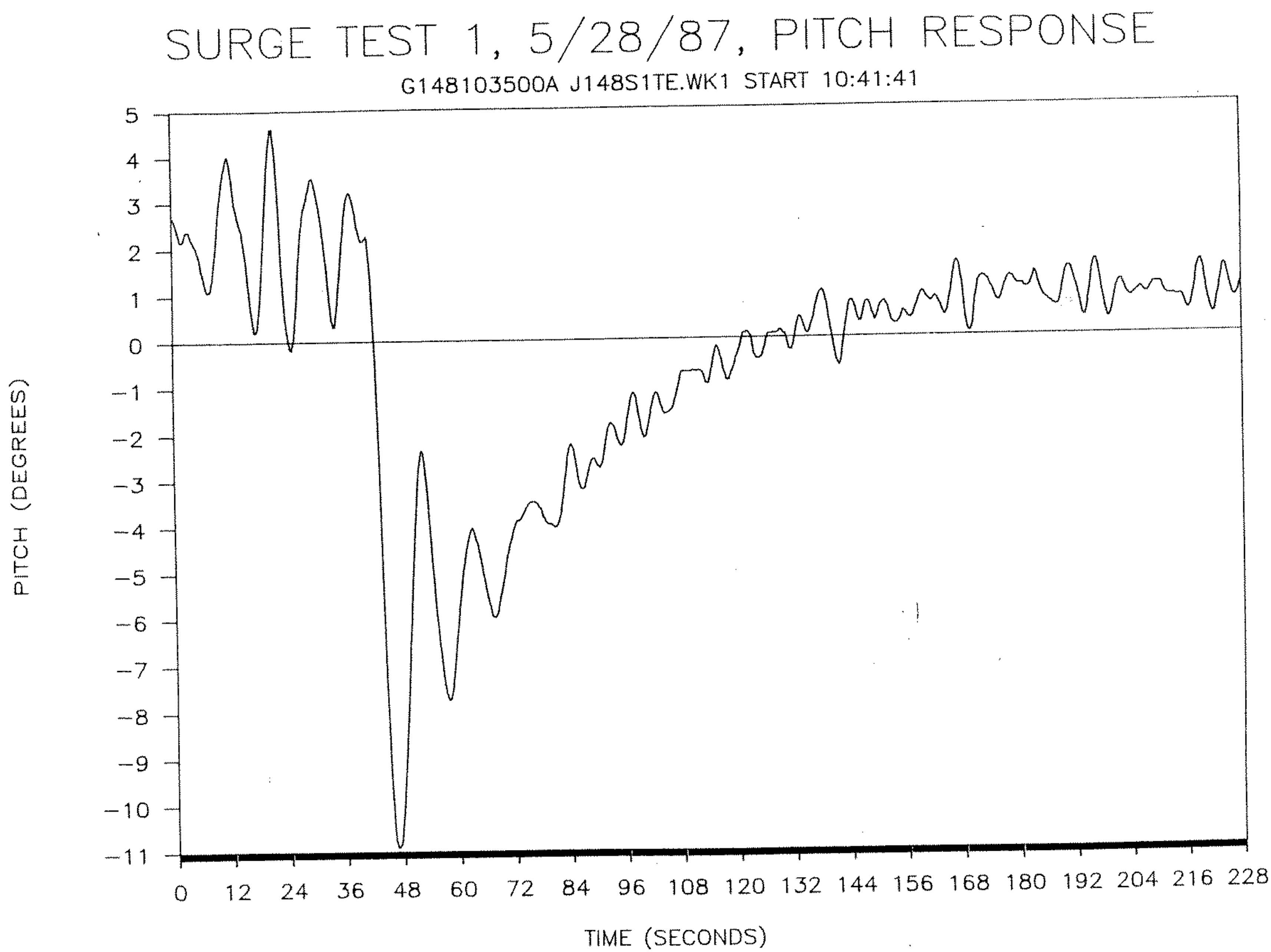


Figure 7.12. Pitch Response, Surge Test

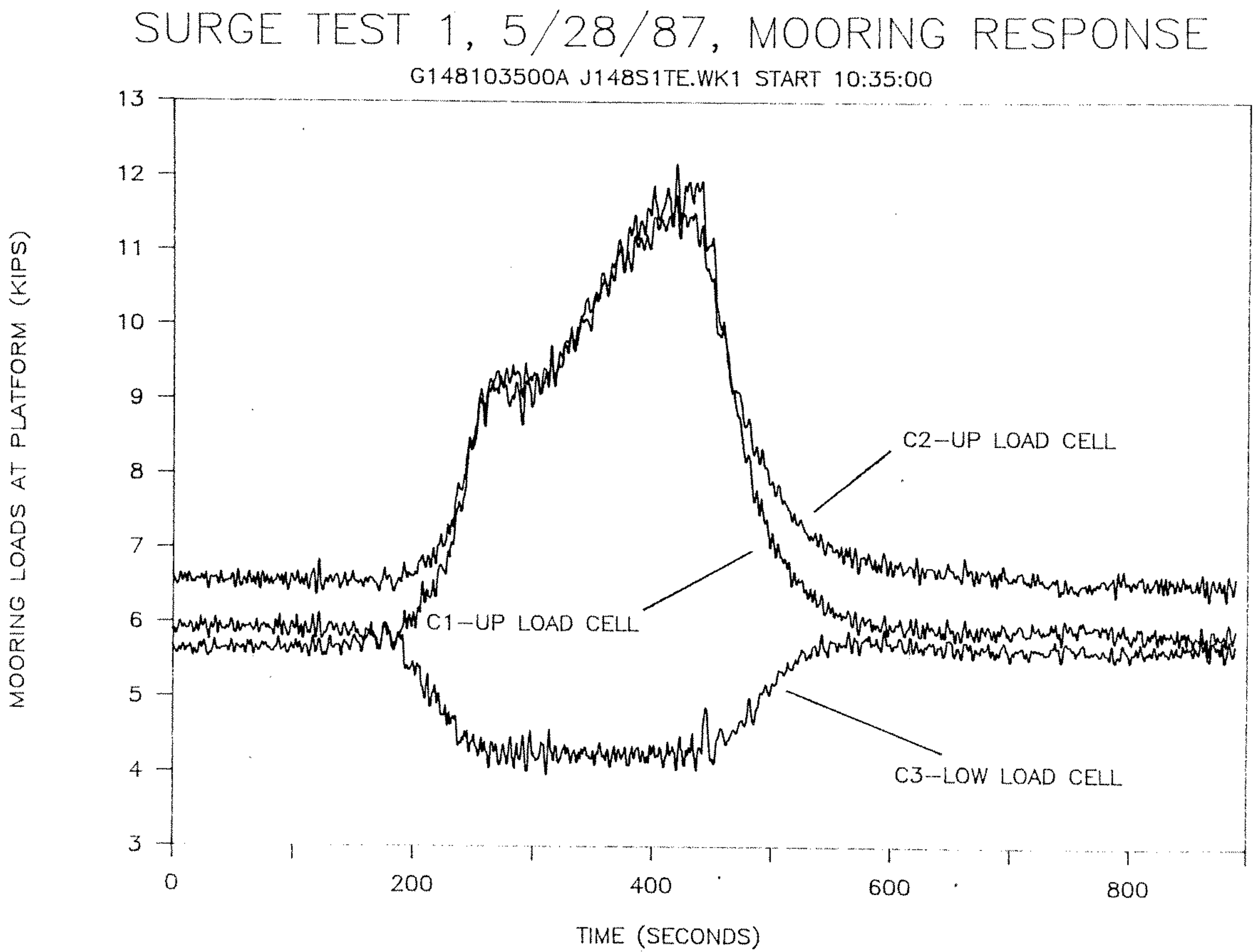


Figure 7.13. Mooring Tension Response, Surge Test

In Figure 7.13, the tensions for the aft mooring lines increased from a mean 26.7-28.9 kn (6.0-6.5 kips) to 51.2-53.5 kN (11.5-12.0 kips) while the bow line decreased from 26.7 kN (6.0 kips) to 18.90 kN (4.25 kips) as the semisubmersible was displaced 68 m (224 ft) in surge. These values agree quite well with force-displacement tables created from numerical models. Also notice that the tension in the bow line levels to a constant 18.90 kN (4.25 kips) as increased load is applied signifying all anchor chain has been laid along the sea floor. The 18.90 kN (4.25 kips) is solely the weight of the upper mooring chain and polyester line.

Appendix D contains time history plots of all 44 channels measured by the SIS for Surge Test #1.

7.2.2 Yaw Test

The yaw test was conducted essentially in the same manner as the surge test with the only major difference being in the tow direction. The gyro compass installed on the deck of the semisubmersible verified the buoy compass readings as shown in Figure 7.14. A maximum yaw rotation of 60 degrees was imposed, the tow line was released and the subsequent yaw motion was over-damped. The yaw test was repeated twice and both showed this type of response.

The over-damped response makes it difficult to determine the natural period in yaw but Figure 7.14 shows a period of about 30 seconds. The buoy compass agrees quite well with the gyro compass values during displacement except at the beginning of the test when

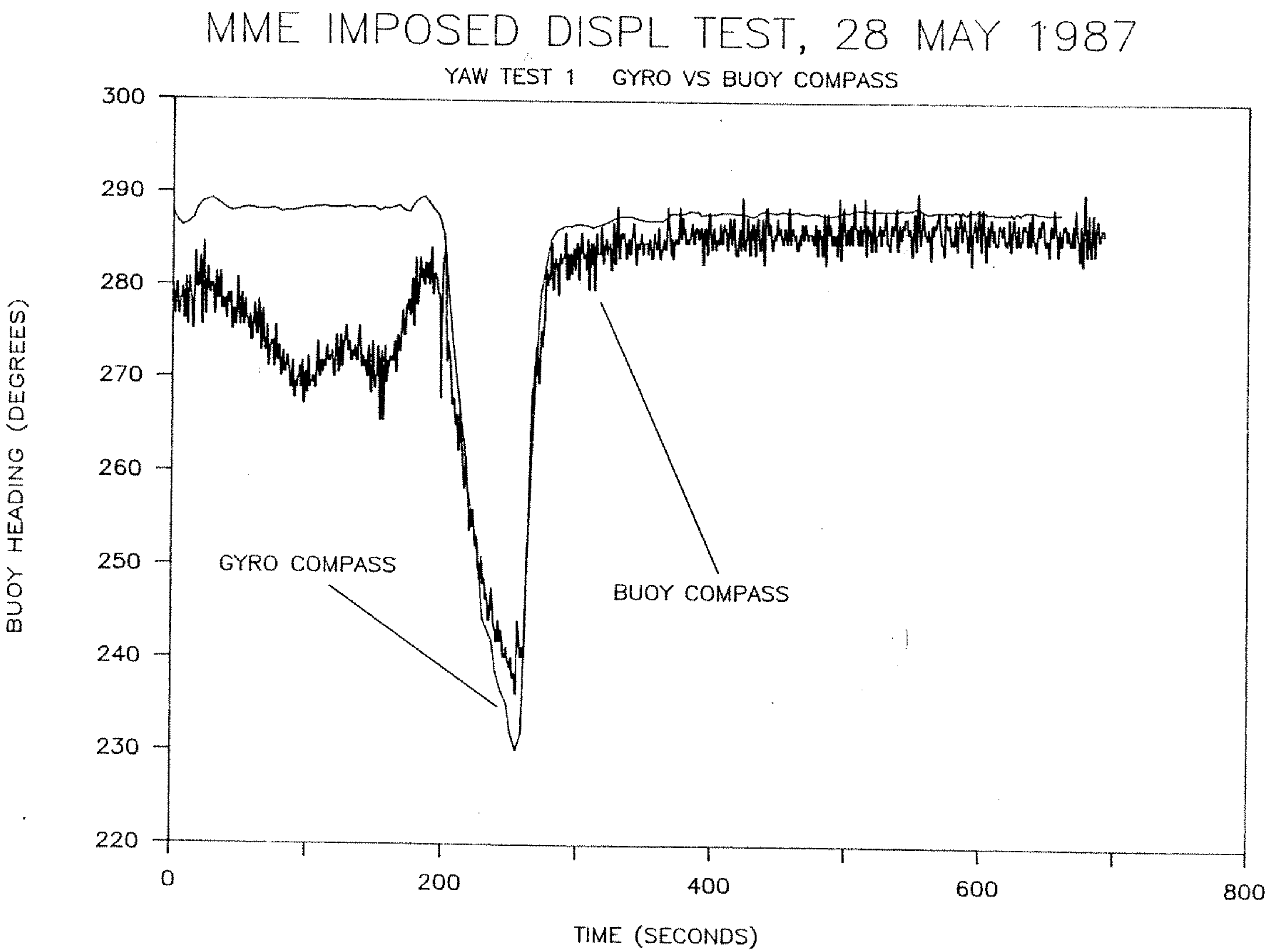


Figure 7.14. Buoy Heading Comparison, Yaw Test

the semisubmersible was at equilibrium. This may be attributed to deviation of the magnetic field as the tow vessel neared the semisubmersible for towline reattachment. The gyro compass is more accurate at the beginning of the test when the tow vessel was near the semisubmersible.

7.2.3 Sway Test

In the sway test, a new tow bridle arrangement was employed between columns C2 and C3 to impose sway displacement. The bridle configuration was designed so that the resultant line of tow action acted through the horizontal geometric center of the semisubmersible as shown in Figure 7.6. Because the bridle was connected at the column bits located above the semisubmersibles center of gravity, some roll displacement in addition to the desired sway displacement was introduced.

Plot in Figure 7.15 shows time histories of the upper mooring loads for the first sway test that correspond to a 40.2 m (132 ft) semisubmersible horizontal displacement and subsequent release. The damped natural period in sway from this plot is about 150 seconds. Comparative plots of the surface positioning system data and acoustic long baseline system data are shown in Figures 7.16 and 7.17. The +Y value corresponds to North semisubmersible displacement and +X, to a West displacement.

Since uncertainty from noise appeared in the surface navigation data for this test, the time series had to be smoothed by simple moving averages. There appears to be a constant average displacement between the data from the two systems. This difference is probably attributable

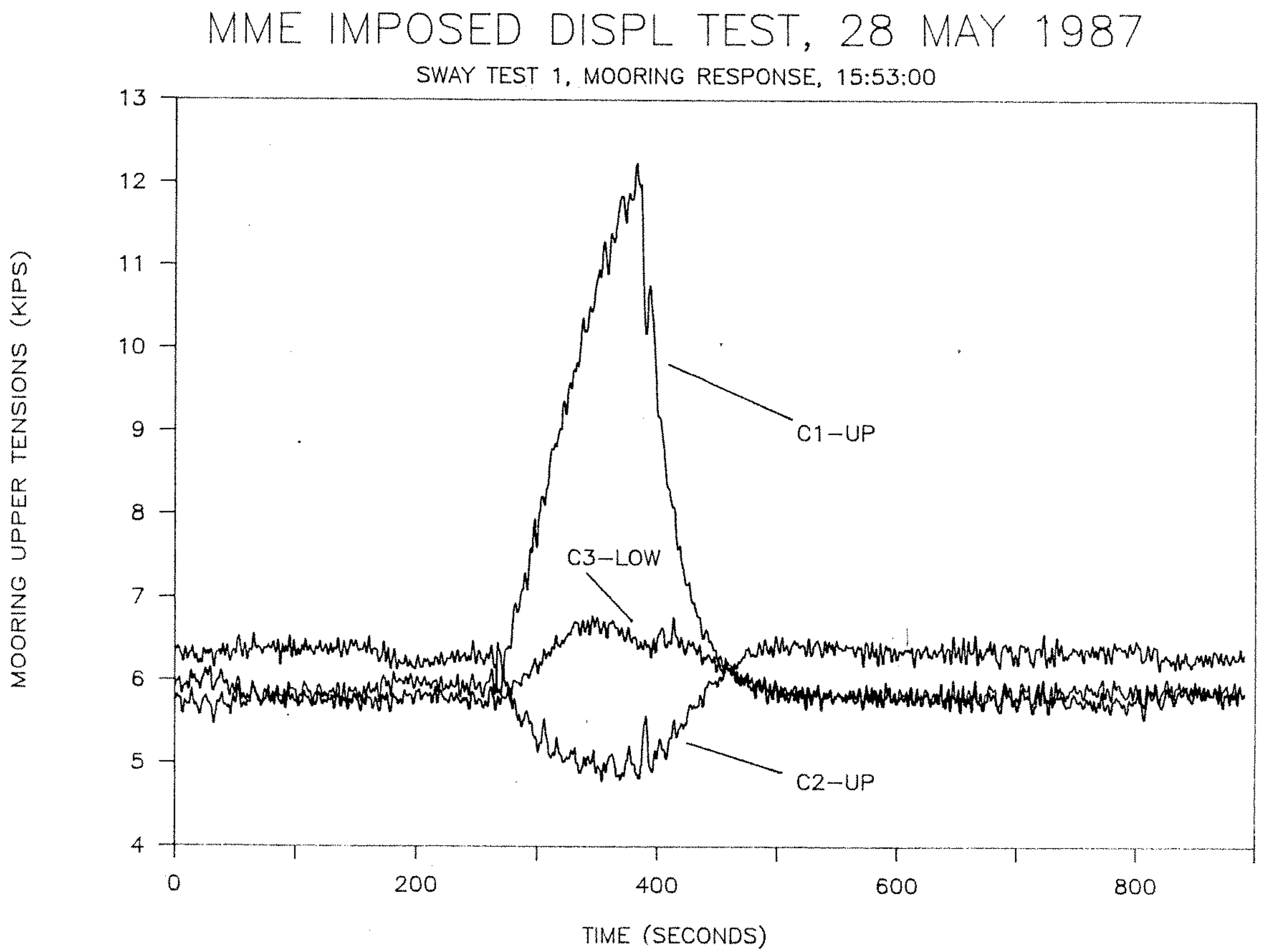


Figure 7.15. Mooring Tension Response, Sway Test

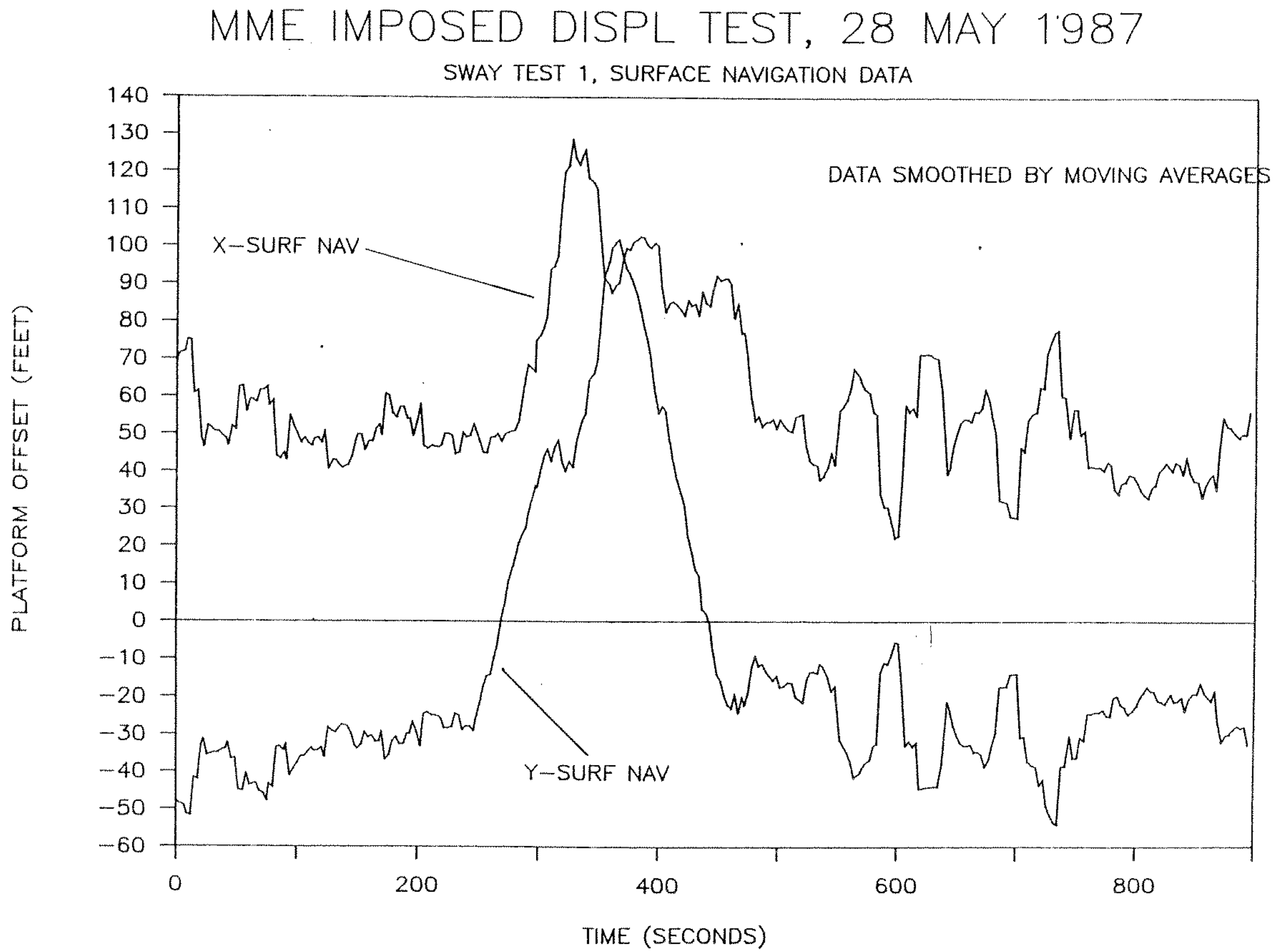


Figure 7.16. Surface Navigation Position, Sway Test

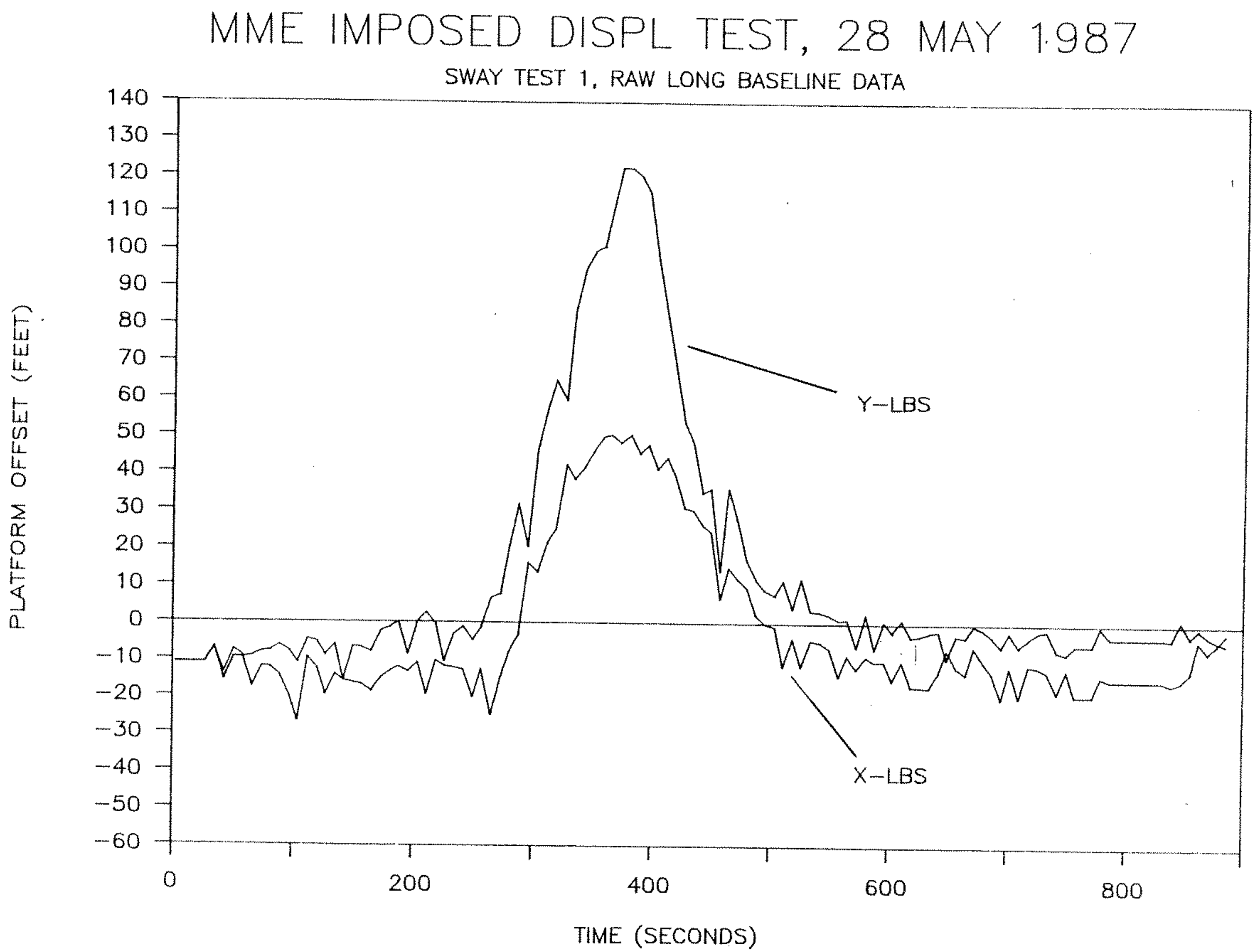


Figure 7.17. Long Baseline Position, Sway Test

to the fact that a loss of signal from one of the shore stations for the surface navigation system decreased its accuracy.

Because the towline acted above the center of gravity of the platform some roll displacement and subsequent motion was generated in the sway test. Figure 7.18 shows the roll motion whose first oscillation after release had a period of a approximately 11.7 sec.

7.3 Storm Events

The events classified as storm days are described in Section 5.3. The 1987 storms would probably not be classified as severe but provided a higher degree of environmental loads and/or response as compared to the average daily readings measured over the course of the year.

The Semisubmersible Instrument Subsystem (SIS) was programmed to measure and record data on a daily routine Monday through Friday for 5 hours and 20 minutes each day. This allowed for 40 minutes of electrical calibration at the beginning and the end of the session and 4 hours of recording real data in between. If a storm event were forecasted to occur near or at the MME site, then the SIS was activated from the NCEL control center and set to record throughout the storm duration. Pre- and post-electrical calibrations were also performed. Nine-track data tapes provided backup data at the NCEL shore station in the event of failure of the cartridge tape recorder at sea. Of the eight storm events characterized in Section 5.3, the time series data from the 5 March 1987 storm are presented here for discussion.

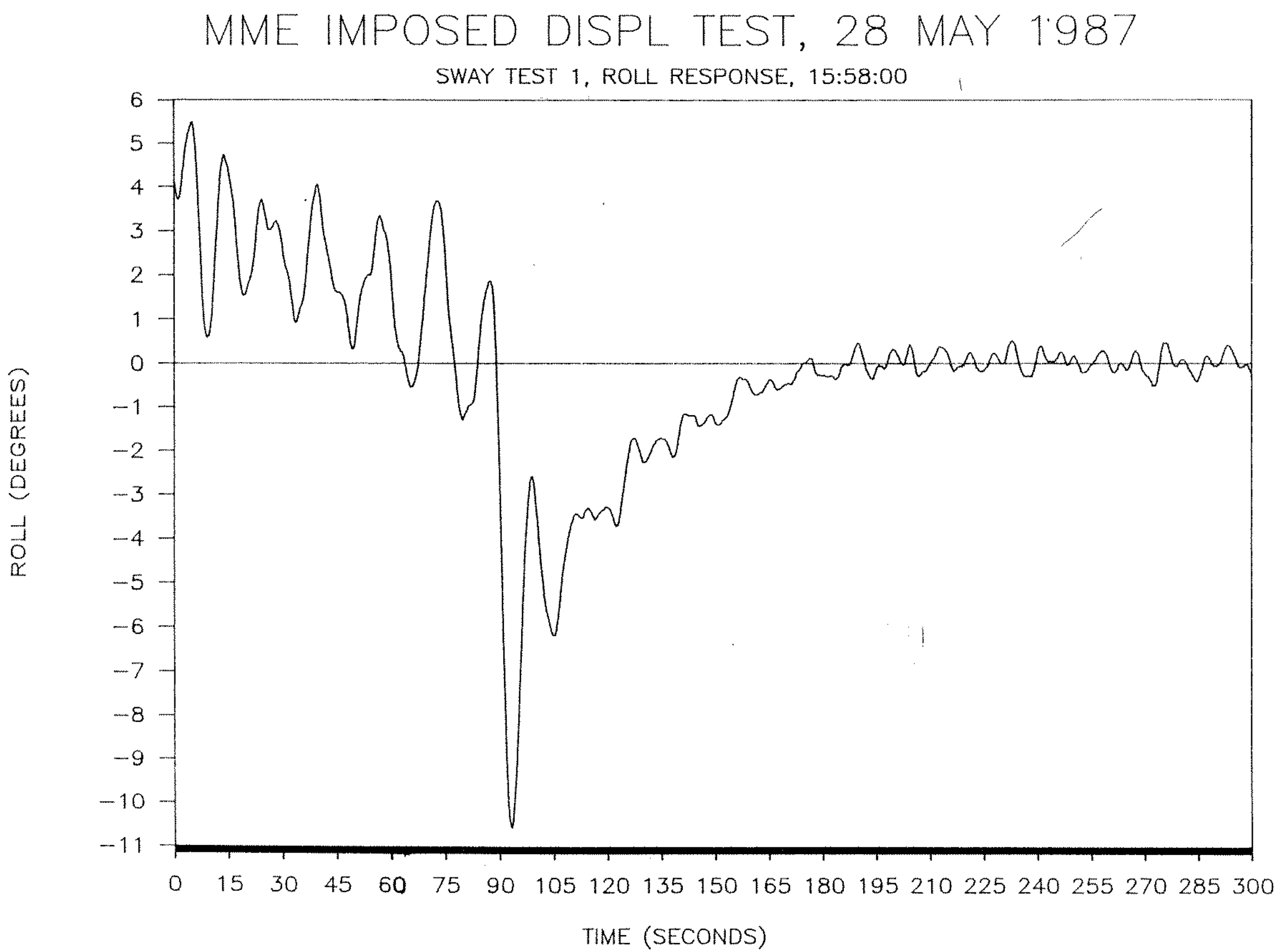


Figure 7.18. Roll Response, Sway Test

As described in Section 5.3, a significant Pacific Ocean storm. passed through the MME site during 17-19 January 1988. This storm was historic in that it was a result of the lowest pressure ever measured off Southern California. The MME buoy was in data acquisition mode throughout the duration of the storm and captured 21 continuous hours of useful response data. Response data was collected as the storm began building the morning of January 17, 1988 and through the peak at 1900 PST. Response data for the decay of the storm was collected from 1900 PST to 0500 PST on 18 January 1988 at which point in time the Humphrey Motion Package failed.

The response motions of the MME buoy due to this storm event may be characterized as exceptionally significant in magnitude. The mean wave periods of the storm changed from 6 seconds to 10.8 seconds at the storm peak, and then back to 9 seconds. Since the damped natural period in heave is 10.8 seconds, resonant responses in heave should have occurred. Measured maximum values in heave were 6.1 m (20 feet). Maximum values for the dynamic range of surge and sway motion were 6 m (20 ft) and static drift motion values were 31 m (100 ft). The peak wave periods passed from 16.7 seconds to 6.7 seconds right before the storm peaked and then changed back to 16.7 seconds shortly thereafter. Since the natural periods in roll and pitch are 13.0 and 12.9 seconds, respectively, resonant responses in roll and pitch also should have occurred. Dynamic roll and pitch motions ranged from 8-17°.

Inspection of the data revealed several events of maximum response in tension, surge, sway, heave, roll, pitch and yaw that demonstrated the MME buoy would pass through an excitation phase then decay rapidly. Typical maximum response values are listed in Table 7.2. The most extreme excitations occurred randomly every 20 to 60 seconds and were characterized by extremely large motions, particularly a yaw motion in excess of 70 degrees. These large yaw values are quite intriguing in that they did not always occur at maximum wave heights nor at the time of maximum roll and pitch responses.

7.4 Semisubmersible Modeling Properties

In comparing measured response analysis and simulated response analysis results, it is necessary to model the stiffness, damping, inertia and loading properties of the MME semisubmersible hull and mooring system. Pertinent information about the semisubmersible system is summarized in this section for purposes of numerically modeling the overall motion of the semisubmersible hull and the tension response at the top of the mooring lines. More detailed information may be obtained directly from the design and installation reports. These include the design and fabrication report for the MME semisubmersible hull (BARDI, 1985), the installation of the MME mooring system (Taylor et al., 1986), the instrumented test cylinder design report (BARDI, 1987), and the MME description and test plan (Zueck et al., 1987).

MME STORM COMPARISON

	17 JAN 88	5 MAR 87
SIG WAVE HGT (ft)	26	8.5
MAX PROB HGT (ft)	43.7	15.9
MAX MEAS HGT (ft)	42 ±	13 ±
PEAK PERIOD (sec)	10.5	14.3
MEAN WIND SPD (kt)	39	6
STATIC OFFSET (ft)	110	25
DYN PITCH/ROLL (deg)	± 8	± 3
DYN YAW (deg)	−20 to 80	± 5
DYN TENSION (kip)	7 to 10	5 to 7

Table 7.2. MME Storm Comparison

The MME semisubmersible hull consists of a triangular steel structural frame, composed primarily of slender tubular members. Figures 7.19 through 7.21 show some sketches of the hull and the dimensions of its major structural members. The complex arc intersections of several members with their end members should be considered when modeling the hull. Table 7.3 details the dimensional particulars of the hull.

The ballast tank locations are shown in Figures 7.22 and 7.23. There are nine ballast tanks, one at the bottom of each of the three columns and one at each end of each of the three pontoons. Table 7.4 gives an analysis of the quantity of ballast in each tank at various conditions and stages of the MME. It was assumed that tanks could only be filled to 98% of their capacity because of the impossibility of forcing out all of the air. All significant voids not designated as a ballast tank were filled with polyurethane flotation foam.

The design lightship condition represents no mooring lines, empty ballast tanks, and no fuel. For the free vibration or extinction tests, equipment and personnel of about 1.95 kips and each mooring load cell and flounder plate was added. In addition, the hull was ballasted to about 20.5 feet. For towing to the MME site, the hull was ballasted to about 4 m (14 ft), fuel was added to the fuel tank and one shot of 2.54 cm (1.00 in.) pendant chain was added to each mooring leg flounder plate.

In the initially deployed condition, the hull was ballasted to about 79 kN (18 kips). The total vertical force from all three mooring legs was estimated to be approximately 85 kN (19 kips) when the platform is in static equilibrium. After attaching the instrumented test cylinder,

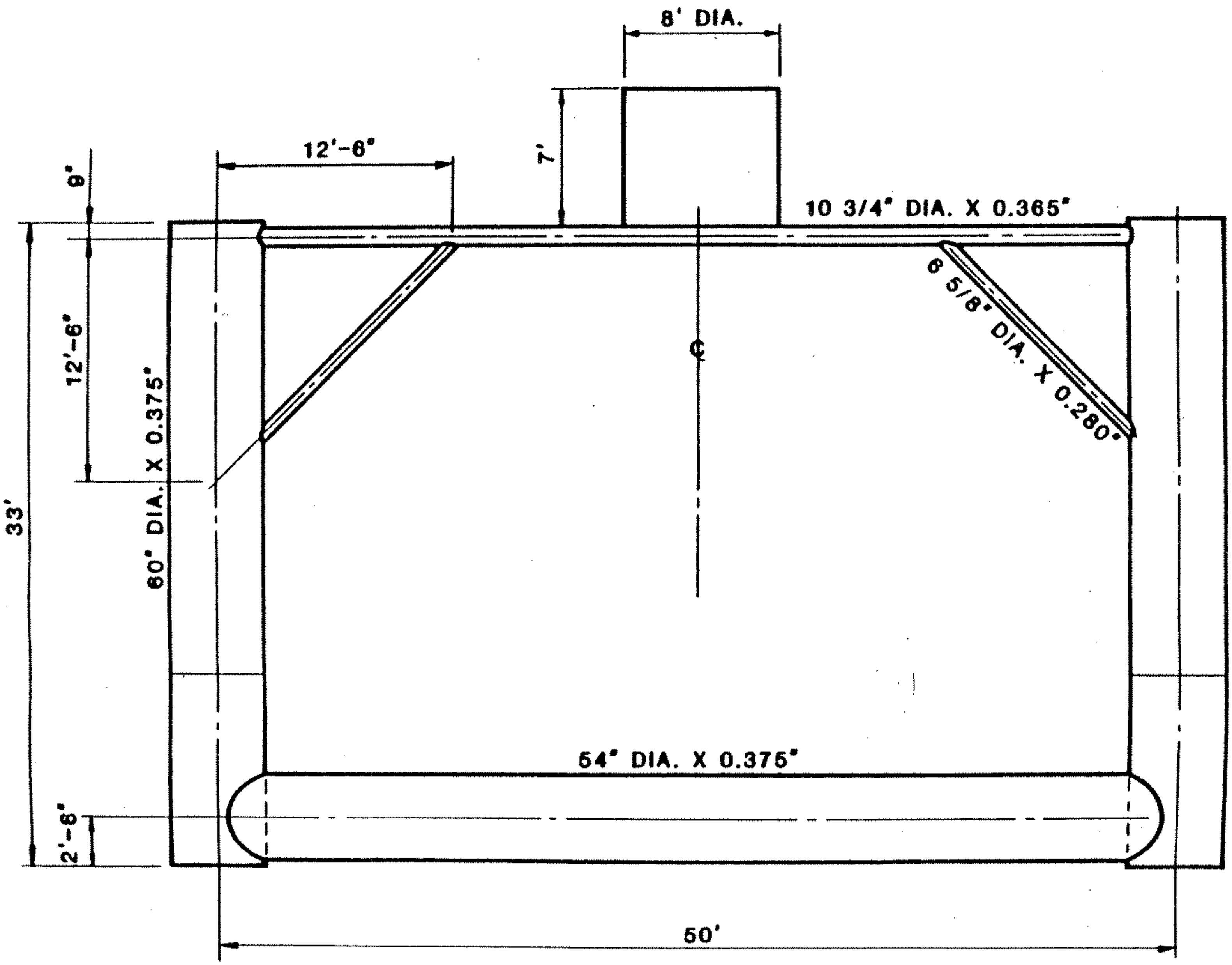


Figure 7.19. Elevation of MME Semisubmersible

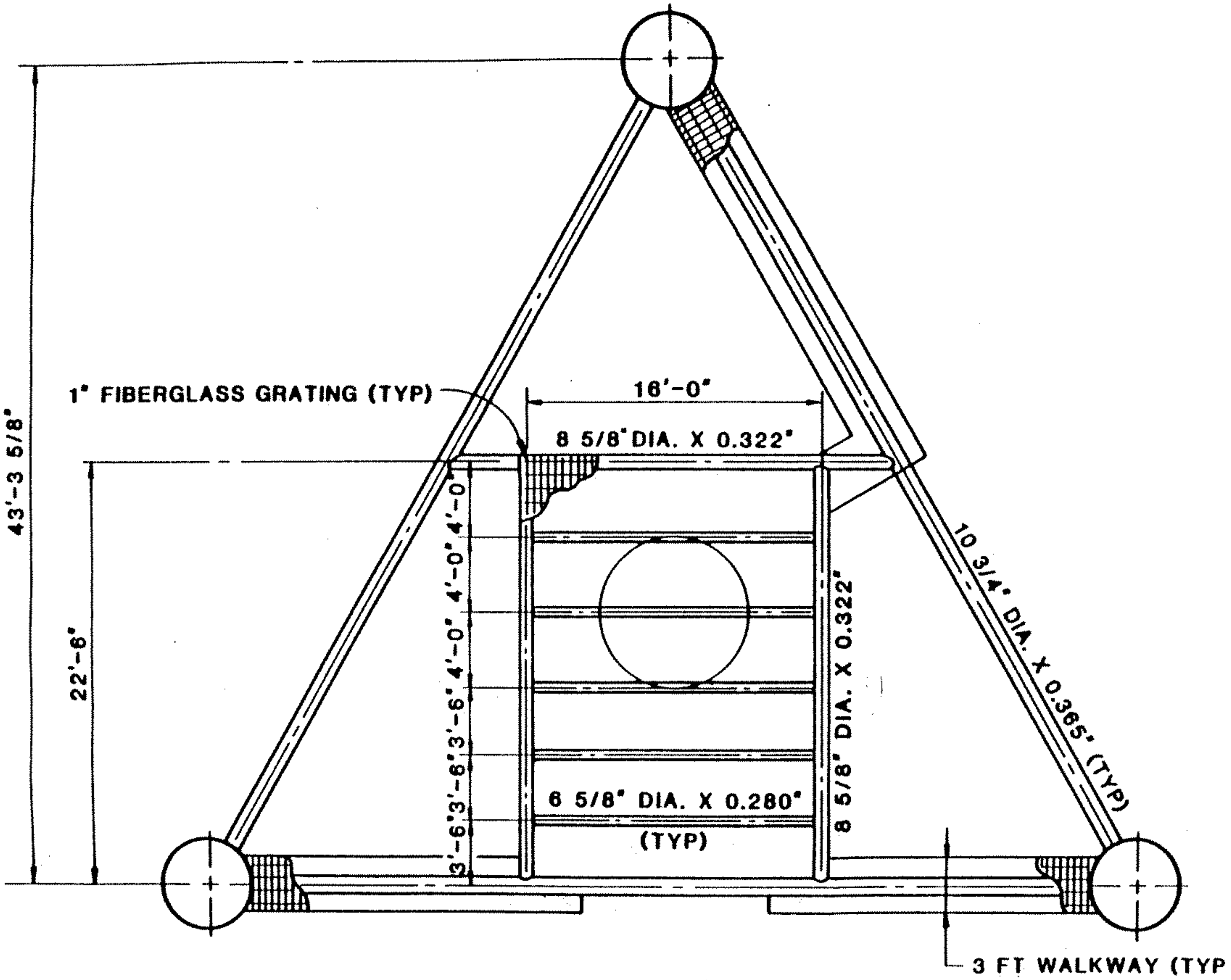


Figure 7.20. Deck Framing of MME Semisubmersible

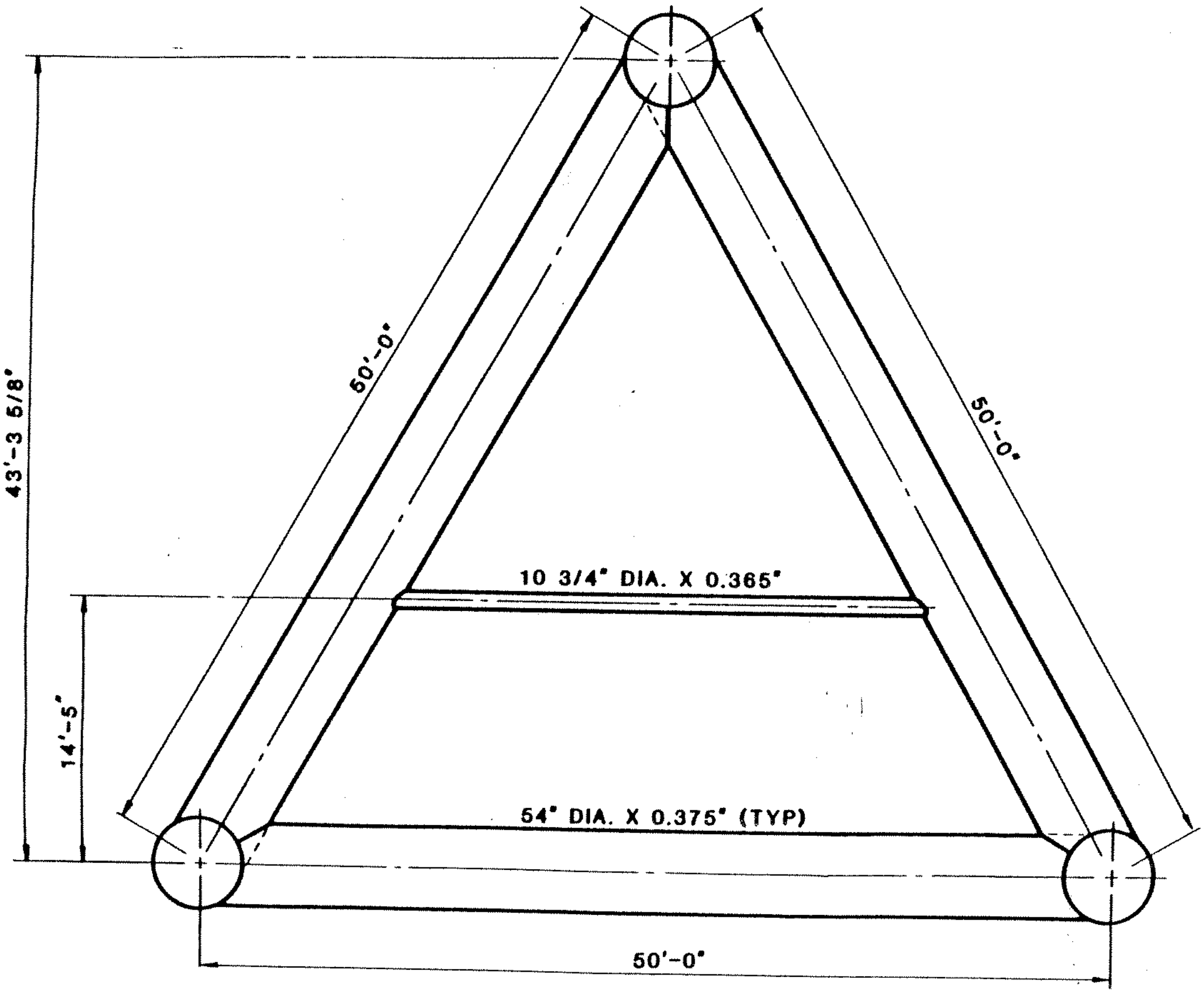


Figure 7.21. Plan of Pontoons of MME Semisubmersible

Item	Particulars
Vertical columns:	
Distance, center to center	50 ft (15.24 m)
Diameter	5 ft (1.52 m)
Wall thickness	3/8 in. (.95 cm)
Height	33 ft (10.06 m)
Pontoons:	
Diameter	4.5 ft (1.37 m)
Wall thickness	3/8 in. (.95 cm)
Pontoon to Column Connection:	
Height	6 ft (1.83 m)
Wall thickness	5/8 in. (1.59 cm)
Upper Diagonals:	
Diameter	6-5/8 in. (16.83 cm)
Wall thickness	0.280 in. (.71 cm)
Deck Frame:	
Diameter	10-3/4 in. (27.30 cm)
Wall thickness	0.365 in. (.93 cm)
Deck Support:	
Diameter	8-5/8 in. (21.91 cm)
Wall thickness	0.322 and 1.280 in. (.82 and .71 cm)
Access:	
Catwalks	3 ft (.9 m) wide with fiberglass grating
Deck area	360 ft^2 (33.4 m^2) with fiberglass grating
Hand Rails	3.5 ft (1.07 m) high by 1 in. (2.54 cm) steel pipe
Removable Aluminum Ladder	10 ft (3.05 m)
Deck House:	
Double roof	
Diameter	8 ft (2.44 m)
Wall thickness	3/16 in (4.8 mm)
Two watertight hatches	
Removable Davit:	
Height	6.5 ft (1.98 m)
Capacity	500 lb (227 kg)
9 Ballast Tanks:	
Column	1 tank/column with 11.8 kips (5,352 kg) capacity
Pontoons	1 tank/pontoon with 10 kips (4,536 kg) cap 1 tank/pontoon with 18.5 kips (8,392 kg) cap
Condition Drafts and Displacements:	
Lightship, unballasted	97 kips (43,999 kg)
Towing Condition:	
Draft	15 ft (4.58 m)
Displacement	195 kips (88,452 kg)
Estimated GM	3.03 ft (.92 m)
Operating Condition:	
Draft	20 ft (6.10 m)
Displacement	214 kips (97,070.4 kg)
GM	3.91 ft (1.24 m)

Table 7.3. MME Semisubmersible Principal Particulars

BALLAST CAPACITIES:

TANK	CAPACITY
P1	18.5K
P2	18.5K
P3	18.5K
P4	10K
P5	10K
P6	10K

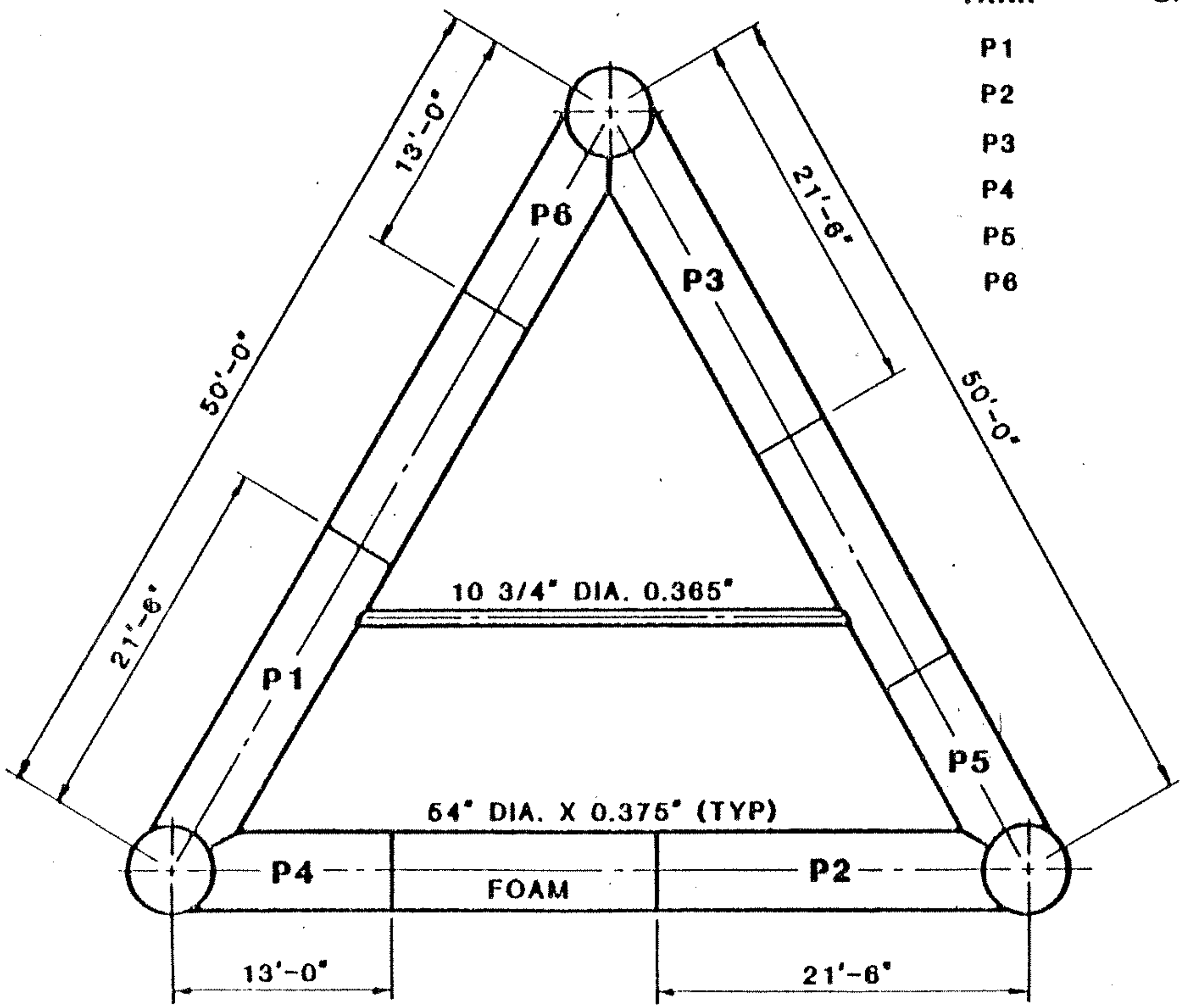


Figure 7.22. Pontoon Ballast Tanks of MME Semisubmersible

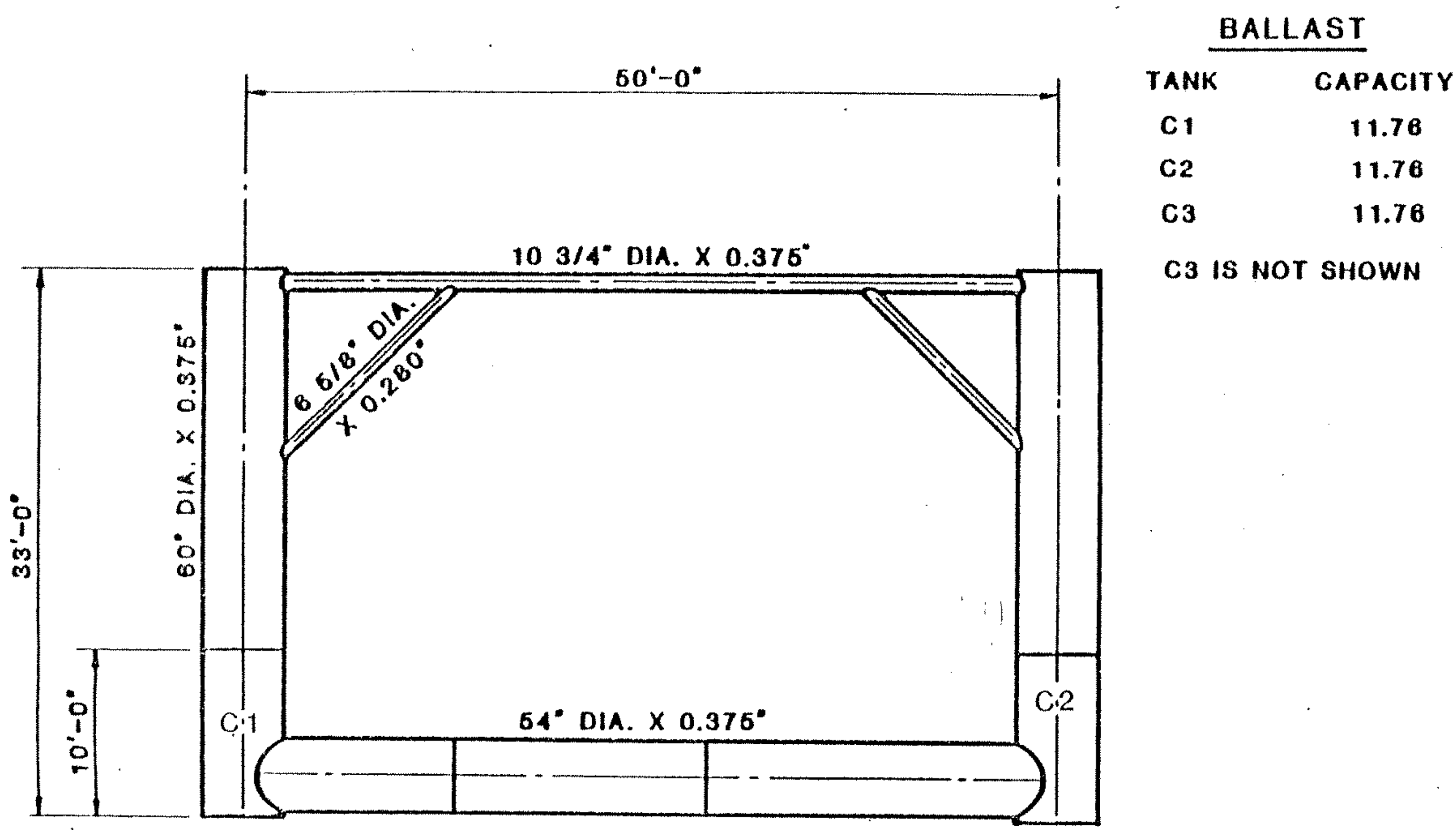


Figure 7.23. Column Ballast Tanks of MME Semisubmersible

BALLAST ITEM	UNITS	DESIGN LGTSHIP DEC 85	FREEVIB HARBOR APR 86	UNDER TOW APR 86	DEPLOYED W/MRNGS MAY86	DESIGN W/ITC JAN 87	DEPLOYED W/ITC MAR 87
DRAFT	mean ft	0.0	20.5	14.0	17.8	0.0	18.0
BALLAST LEVEL	C1 ft	0.0	9.2	0.0	2.3	0.0	1.5
	C2 ft	0.0	10.0	0.0	1.6	0.0	2.3
	C3 ft	0.0	10.2	1.3	1.6	0.0	2.4
BALLAST WEIGHT	C1 kip	0.00	10.86	0.00	2.75	0.00	1.83
	C2 kip	0.00	11.73	0.00	1.93	0.00	2.74
	C3 kip	0.00	12.05	1.60	1.95	0.00	2.93
	P1 kip	0.00	18.51	18.51	18.51	0.00	18.51
	P2 kip	0.00	18.19	18.19	18.19	0.00	18.19
	P3 kip	0.00	18.51	18.51	18.51	0.00	18.51
	P4 kip	0.00	10.03	10.03	10.03	0.00	10.03
	P5 kip	0.00	10.35	10.35	10.35	0.00	10.35
	P6 kip	0.00	10.03	10.03	10.03	0.00	10.03
	total kip	0.00	120.27	87.22	92.25	0.00	93.13
LGTSHIP WT	kip	95.54	95.54	95.54	95.54	97.90	97.90
MOORING WT	kip	0.00	0.30	1.50	19.10	0.00	19.10
OTHER WEIGHT	kip	0.00	1.95	1.00	0.50	0.00	0.45
DISPLACEMENT	kip	95.5	218.1	185.3	207.4	97.9	210.6
BUOYANCY	kip	0.0	217.7	193.3	207.7	0.0	210.2
CENTER OF GRAVITY	X ft	-0.18	0.00		0.01	-0.14	-0.23
	Y ft	14.68	8.10		8.24	14.73	8.83
	Z ft	-0.18	0.00		0.00	-0.47	-0.32
CENTER OF BUOYANCY	X ft	0.00	0.00		0.01	0.00	0.00
	Y ft	0.00	5.25		5.12	0.00	4.68
	Z ft	0.00	0.00		0.00	0.00	-0.13
STATIC STABILITY	GM ft				4.19		
	KG ft				8.24		
	BM ft				7.32		
	KM ft				12.44		
NATURAL PERIOD	HEAV sec		10.8				
	PITC sec		12.7				
	ROLL sec		12.7				

Table 7.4. MME Semisubmersible Hull Ballast Analysis

the hull was deballasted, to account for the eccentricity of the test cylinder mass. Hydrostatic calculations are shown in Table 7.4 for several of the hull conditions. These calculated hydrostatic values agreed well with the incline test results and the calculated natural periods agreed well with those measured from the extinction tests.

The MME hull is shown modeled with nodes and elements in Figure 7.24. This represents the simplest numerical model of the hull in its deployed condition including the instrumented test cylinder. The hull is shown at the design draft of 6 m (20 ft).

Table 7.5 presents the location coordinates and point mass properties for each node of the hull. Point masses were adjusted slightly for nodes 3, 6 and 9 to give zero trim. With zero trim, the first moment of all masses including distributed masses sums to zero. However due to unsymmetrical mass distribution, the second moment of masses does not sum to zero and accounts for significant radii of gyration in the cross coordinate directions.

Table 7.6 presents nodal connectivity, hydrodynamic diameter, effective length, and unit mass properties for each element of the hull. Element masses including steel pipe, foam, appendages, and walkways are shown distributed evenly along the effective length of corresponding elements. Multiplication of the unit mass with the effective length of each element will give the mass of corresponding element. The mass properties were derived directly from the weight and moment tables produced from the design drawings (Bardi, 1985). Consideration was given to all pertinent hydrostatic, inertia, and geometric details given the accuracy of all measured values in deriving mass values.

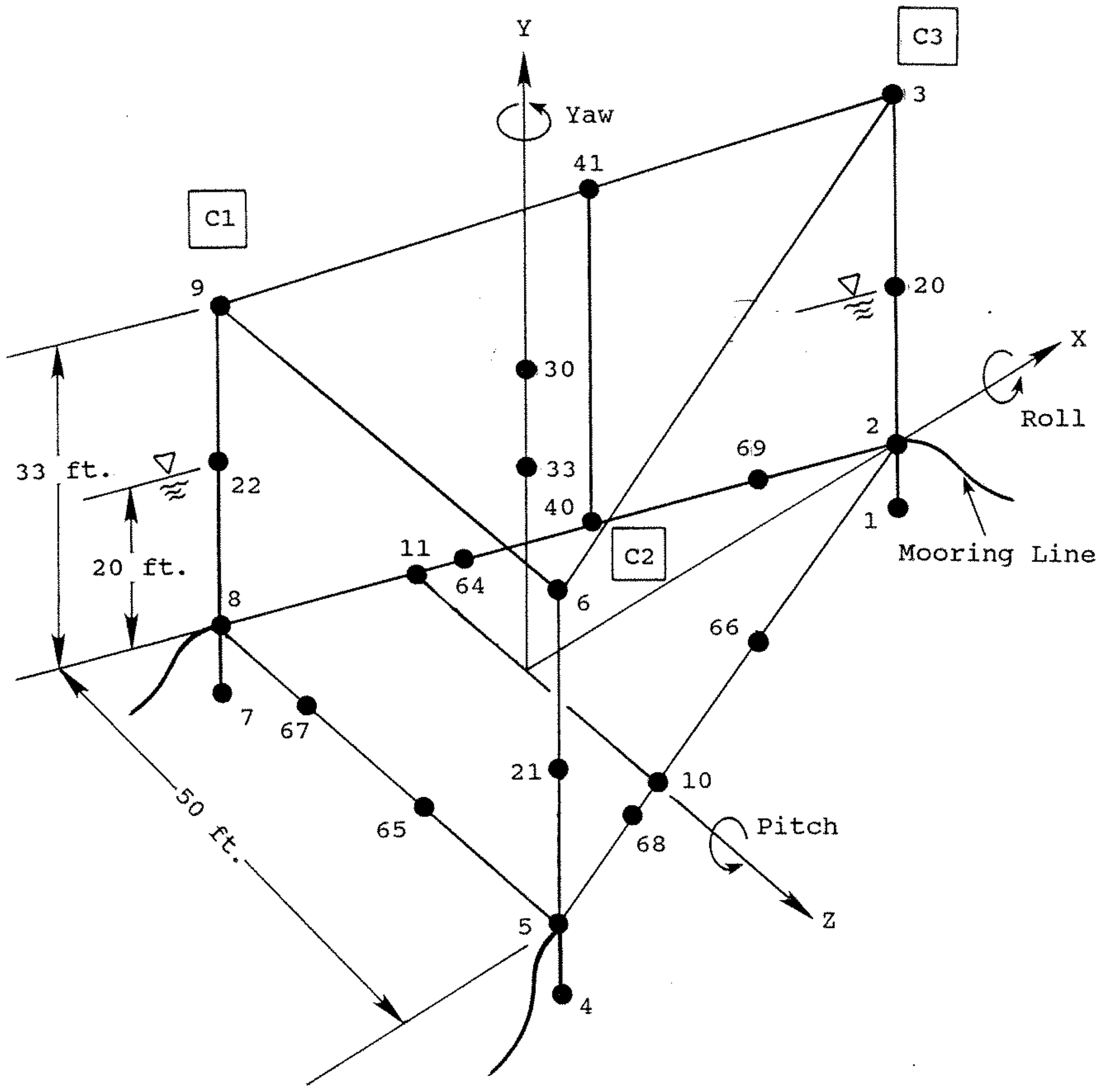


Figure 7.24. MME Semisubmersible Hull Model

NODE NUMBER	COORDINATES X (ft)	Y (ft)	Z (ft)	POINT MASS (lbs)	NODAL DESCRIPTION
1	28.87	0	0	0	column 3 at baseline
2	28.87	2.5	0	1830	ballast tank C3
3	28.87	33	0	1042	column 3 at top
4	-14.44	0	25	0	column 2 at baseline
5	-14.44	2.5	25	2746	ballast tank C2
6	-14.44	33	25	1042	column 2 at top
7	-14.44	0	-25	0	column 1 at baseline
8	-14.44	2.5	-25	2930	ballast tank C1
9	-14.44	33	-25	1042	column 1 at top
10	0	2.5	16.67	0	starboard end of brace
11	0	2.5	-16.67	0	port end of brace
20	28.87	18	0	0	column 3 at MWL
21	-14.44	18	25	0	column 2 at MWL
22	-14.44	18	-25	0	column 1 at MWL
26	31.4	2.5	0	749	padeye at column 3
27	-15.7	2.5	27.2	749	padeye at column 2
28	-15.7	2.5	-27.2	749	padeye at column 1
30	0	33	0	0	center of deck
33	0	8.24	0	0	approx. c. g. of hull
40	0.79	2.5	-14.25	0	bottom of test cylinder
41	0.79	33	-14.25	0	top of test cylinder
50	-3.2	33	0	3573	misc deck mass
51	0	37	0	4786	instrumentation mass
52	-1.9	33	-5.3	2710	generator & fuel mass
64	4.19	2.5	-14.25	0	ballast tank P1 bulkhead
65	-14.44	2.5	3.5	0	ballast tank P2 bulkhead
66	10.25	2.5	10.75	0	ballast tank P3 bulkhead
67	-14.44	2.5	-12	0	ballast tank P4 bulkhead
68	-3.71	2.5	18.5	0	ballast tank P5 bulkhead
69	17.61	2.5	-6.5	0	ballast tank P6 bulkhead

Table 7.5. MME Semisubmersible Hull Nodal Properties

MEMBER NUMBER	Ith NODE (ft)	Jth NODE (ft)	CYLDR. DIA. (ft)	EFF. LENGTH (ft)	MASS/ LENGTH (lbs/ft)	MEMBER DESCRIPTION
1	1	3	5	33	398.5	column 3
2	4	6	5	33	398.5	column 2
3	7	9	5	33	398.5	column 1
4	2	5	4.5	45.6	244.5	starboard pontoon
5	5	8	4.5	45.6	244.5	stern pontoon
6	8	2	4.5	45.6	244.5	port pontoon
7	3	6	0.9	45.5	40.5	starboard deck beam
8	6	9	0.9	45.5	40.5	stern deck beam
9	9	3	0.9	45.5	40.5	port deck beam
10	10	11	0.9	28.8	40.5	pontoon brace
11	40	41	1.67	27.5	85	instrumented test cylind
21	64	8	0.001	21.5	860.9	ballast tank P1
22	65	5	0.001	21.5	860.9	ballast tank P2
23	66	2	0.001	21.5	860.9	ballast tank P3
24	8	67	0.001	13	771.5	ballast tank P4
25	5	68	0.001	13	771.5	ballast tank P5
26	2	69	0.001	13	771.5	ballast tank P6

Table 7.6. MME Semisubmersible Hull Member Properties

Each mooring leg consists of three major components: an upper segment pendant chain, a middle segment of synthetic line, and a lower segment of anchor chain as shown in Figure 7.25. The modeling properties for each mooring leg are shown in Table 7.7. Due to unique stretch properties of each synthetic line segment, different stiffness and length properties are shown for the synthetic line. These properties were obtained experimentally by pre-stretching the lines on land prior to deployment. Axial stiffness was found to be significantly different for dynamic loading of the lines. This dynamic value of AE was measured at about 3.94 kN (885 kips) for a dynamic loading range of about 3 - 80 kN (3 - 18 kips) in 13 N (3 kip) increments and dynamic load frequency of about 3 cycles per hour.

Each mooring leg was installed in a controlled deployment fashion to insure proper positioning and tensioning. The pretension of each mooring leg was designed to be 9 kN (2 kips) horizontal or about 24.6 kN (5.5 kips) total. The exact pretension of each line can only be estimated from balancing the load cell measurements at any given time because the semisubmersible hull and mooring system are always subject to some environmental loading and therefore is never found in its unloaded equilibrium position.

The coordinate locations for key on-board instruments are given in Table 7.8. Each instrument location was measured from the center of the sensor. The center of the accelerometer was measured from the center of the gimbal arrangement shown in Figure 2.5. The measured angle when the semisubmersible was at equilibrium position is given in Table 7.8 for the compass bearing and each wind meter.

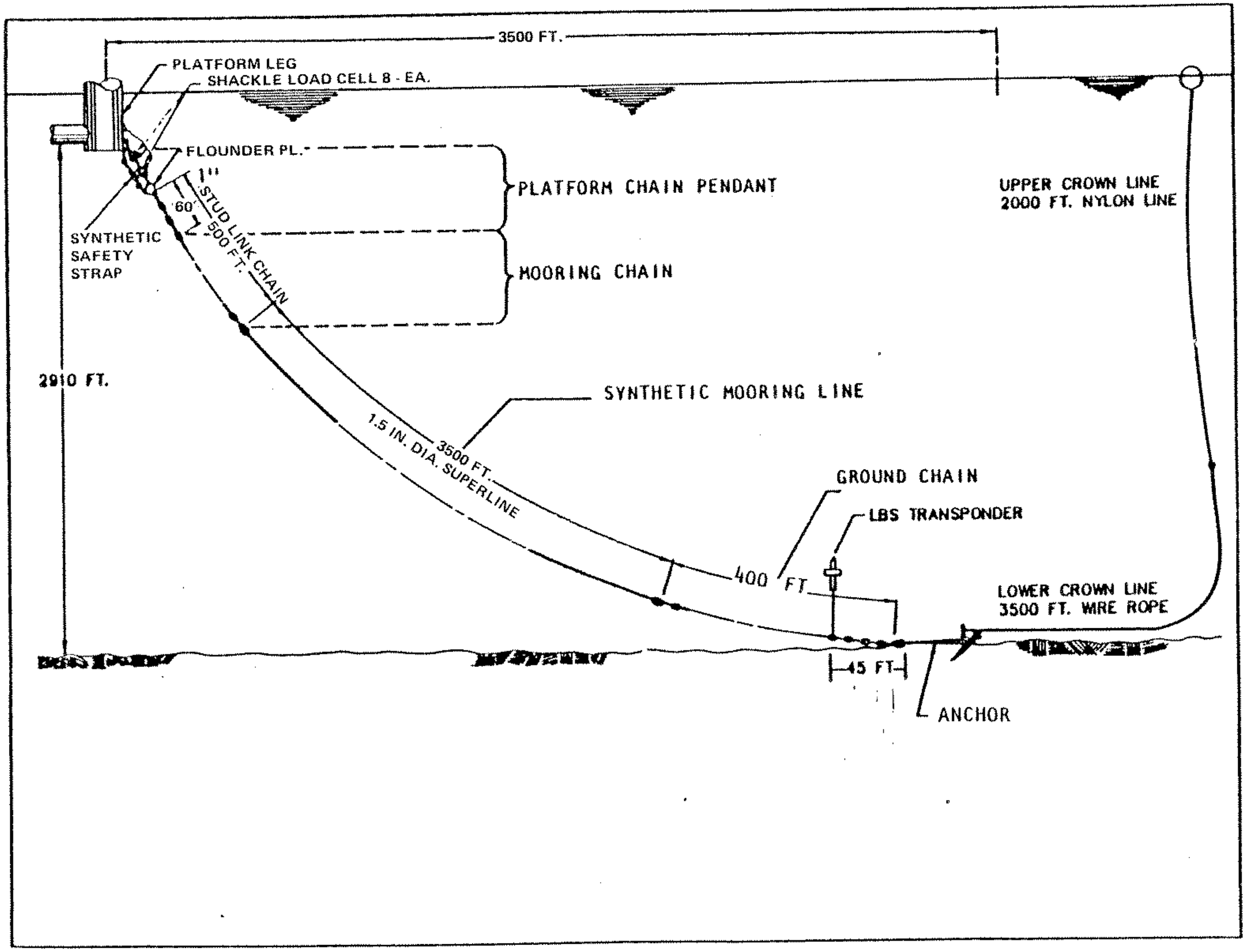


Figure 7.25. Typical MME Semisubmersible Mooring Leg

PROPERTIES / SEGMENT	UPPER	MIDDLE	LOWER
SIZE	1 in dia	1.5in dia	2 in dia
MATERIAL	STUD LINK CHAIN	POLYESTER SUPERLINE	STUD LINK CHAIN
HYDRODYNAMIC DIAMETER (in)	3.56	1.60	7.19
WET UNIT WEIGHT (lbs/ft)	8.27	0.18	32.43
BREAKING STRENGTH (kips)	83.55	73.50	318.10
MOORING LEG 1			
LENGTH (ft)	500.00	3493.00	400.00
AXIAL STIFFNESS AE (kips)	8500.00	917.00	34380.00
ANCHOR SIZE			3 KIP
ANCHOR TYPE			STATO
MOORING LEG 2			
LENGTH (ft)	500.00	3500.00	400.00
AXIAL STIFFNESS AE (kips)	8500.00	817.00	34380.00
ANCHOR SIZE			1 KIP
ANCHOR TYPE			NAVMOOR
MOORING LEG 3			
LENGTH (ft)	500.00	3511.00	400.00
AXIAL STIFFNESS AE (kips)	8500.00	922.00	34380.00
ANCHOR SIZE			3 KIP
ANCHOR TYPE			STATO

Table 7.7. Mooring System Particulars

Coordinates are in english units on the body coordinate system
Origin of body coordinate system is at center of platform keel
X points to column 3 (bow), Y points up, and Z points starboard
When the platform rests in the center of its watch circle,
the X-axis bears 292 degrees north and
the origin is at (0,0,0) in global coordinates

SENSOR/ INSTRUMENT	NOTE	position angle	X (ft) (deg)	Y (ft) (deg)	Z (ft) (deg)
Accelerometers/					
model SA07-0902-1	position @ gymbal		0.0	33.7	0.0
model CF18-0908-1	position @ gymbal		0.0	33.9	0.2
Hydrophones	avg position of pair		0.0	-5.0	0.0
Wave Staff #1	pos @ 18.5 ft draft		0.0	18.5	0.0
Wave Staff #2	pos @ 18.5 ft draft		0.0	18.5	1.0
Wind Meter @ C1	position		-14.5	40.1	-27.5
Wind Meter @ Mast	position		0.0	54.0	0.0
Wind Meter @ C3	position		30.1	40.1	-2.2
Current Meter #1	position		4.2	-2.8	0.0
Current Meter #2	position		5.0	-2.0	0.0
Compass Bearing	angle at zero yaw		292.0		
Wind Meter C1,M,C3	angles at zero yaw		180.0	180.0	180.0

Table 7.8. Coordinate Location of Sensors

The location of each sensor relative to the platform center of gravity must be considered when reducing out platform motion effects inherent in measurements made on a moving platform.

Wind loading on the platform structure above the mean water line may be calculated using American Bureau of Shipping Rules (ABS, 1980) and projected wind areas given in Table 7.9. The total moment created by the wind loading is calculated by summing up the wind load on each projected area times it's respective moment arm. The moment arms are measured from the center of gravity of the platform to the centroid of each projected area.

INSTRUMENT	NOTE	x (ft) X (ft**2)	y (ft) Y (ft**2)	z (ft) Z (ft**2)
Column Wind Area	moment arm to centroid	0.0	25.8	0.0
Diagonal Wind Area	moment arm to centroid	0.0	26.8	0.0
Deckhouse Wind Area	moment arm to centroid	0.0	37.0	0.0
Deck Wind Area	moment arm to centroid	0.0	33.0	0.0
Column Wind Area	projected area	108.8	0.0	108.8
Diagonal Wind Area	perpendicular,	14.7	0.0	14.7
Deckhouse Wind Area	to given axis	32.0	0.0	32.0
Deck Wind Area		80.6	391.0	80.6

Table 7.9. MME Semisubmersible Projected Wind Areas

8.0 CONCLUSION

This document provides a thorough summary of the execution and data collection for the Motion Measurement Experiment (MME) for anyone desiring to review or use the MME data. Well over 1 gigabyte of raw digital data was collected, including NAVOCEANO current meter and NDBC wave buoy data. Data sets for certain significant environmental events have been identified and processed into meaningful engineering measurements and organized into various databases for internal use. Some of these data sets, however, can be made available for use by other researchers.

The data in these data sets has been converted to engineering units, checked against calibration data, and reviewed for accuracy. As with any data collected in the field, there exists some error in all measurements. The level of accuracy of each measurement may be assessed using the information presented throughout this document.

The MME data base as summarized in this document is now generally sufficient for validating dynamic response simulation programs of deep water platforms for the proposed East Coast OCEANO TACTS range. Data is available for validation in both the extreme design and less severe operational hydrodynamic regimes for several possible environmental loading cases. The extremely interesting platform responses observed in the available data should lead to a significantly enhanced understanding of deepwater platforms and their associated dynamic response simulation models.

Before comparisons can be made between the response output of numerical simulation models with the measured response data from the MME, significant data processing must be accomplished. Computer algorithms have to be improved for reducing out the effects of platform motion, for merging environmental data collected on the semisubmersible with environmental data collected remotely, and for preparing environmental data appropriate for input to the numerical simulation models. Both frequency and time domain methods will be used to compare the simulated with the measured response data. These comparisons will be used to determine the accuracy of the numerical simulation models and identify possible improvements in these models.

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Technical Memorandum

6149TM

MOTION MEASUREMENT EXPERIMENT: TEST EXECUTION AND DATA SUMMARY, VOLUME II (APPENDICES)

By

R. Zueck, D. Shields, B. Harris, and W. Bartel

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APPENDIX A

EXPERIMENT CALENDAR

The following pages show the history of the Motion Measurement Experiment in a month to month calendar form. The calendars were put together from each of the log books that were kept (1. Cruise Log Book, 2. Field Log Book, 3. MME 3M 9 Track Log Book, and 4. PDP 11 Log Book). The information given concerns the status of the Shore Station (NCEL), the relay station at Laguna Peak (L.P.), the MME semisubmersible buoy (semi), and the instrumentation system. The numbers at the bottom of each data box in the calendar indicate the beginning and end times when the 3M tape on the MME platform was recording. Environmental and response data from the semisubmersible are available during these indicated time intervals. The hours are noted on the calendars in local time. To obtain Greenwich mean time (Z) add 7 hours to Pacific Daylight Savings Time (PDT) or add 8 hours to Pacific Standard Time (PST). Daylight Savings Time begins in October and ends in April. The experiment calendar indicates exactly when local time is PST and when it is PDT.

SEPTEMBER 1985

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26 Current array #1 deployed	27	28	29
30						

JANUARY 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1	2	3	4	5
6	7	8 Ysdr pressure test in DOL to 3000 ft	9	10	11	12
13	14	15	16	17	18	19
20	21	22 NDBC buoy deployed	23 NDBC GSBP operational DACT not operational	24	25	26
27	28	29	30	31		

FEBRUARY 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22 Stretched poly lines on land	23
24	25	26	27	28		

MARCH 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
					1 Stretched poly lines on land	2 Stretched poly lines on land
3	4	5	6	7	8	9
10 xpdr pressure test in DOL	11	12	13	14	15	16
17	18 Cruise for MME grid deployment ORC	19 Cruise con't xpdr probs xpdrs recovered	20	21 NDBC DACT operational	22	23
24	25	26 MOS xpdr sea trials at MME site	27	28	29	30
31						

APRIL 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	1 Begin installing instruments on semi	2	3 Grid xpdrs redeployed	4	5	6
7	8	9 Roll/Pitch Extinction Test in harbor	10	11	12 Platform deballast to 13ft	13
14 Cruise installed mooring legs 1 & 2	15 Cruise con't xpdrs problems	16 ORC & OSV in port Load cell replaced on semi lw C1	17 ORC departs 1300 OSV departs w/ semi in tow 1730	18 Cruise con t leg 3 & platform installed	19 Positioning equipment installed on platform	20
21 Platform up on inverter No gen.	22 1st data on scope weak trans. No data	23 Cruise 4 grid attenuation No Problem No data	24 No data	25 No Comm No data	26 Bad preamp. at L. Peak No data	27 Daylight Savings Time starts
28 Burned preamp at L.P.	29	30 Platform up on inverter 0823-1020				

MAY 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
			1 Cruise gen. heater solenoid removed 08-1510	2 Generator down 08-0911	3 Generator down	4
5 Generator down	6 Generator down	7 Generator down	8 Cruise removed gen relay start up circuit	9 Generator down	10 Generator down	11
12 Generator down	13 Generator down	14 Generator down	15 Generator down	16 Generator down	17 Generator down	18
19 Generator down	20 Generator down	21 Generator down	22 Cruise fixed gen.	23 Data OK C2low out CM2 out 0915-1141	24	25
26	27 0830-1600	28 0830-1055	29 1st day of stnd calibration routine 0801-1125	30 0801-1218	31	

JUNE 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
						1
2 C3 upper load cell out 08-1218	3 Working on microwave link at Laguna Pk	4 08-0948	5 Reciever at L.P. working 08-0948	6 08-1218	7	8
9 DSRV & NCEL at site to r/r anchor xpdrs 08 0936	10 08-1224	11 08-0940	12 08-0953	13 08-1454	14	15
16 08-1145	17 08-0921	18 08-1342	19 08-1412	20 08-1454	21	22
23 08-1153	24 08-0933	25 08-0952	26 08-0923	27 08-1039	28	29 NWBC dir. payload off battery dead
30 08-1237						

JULY 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	1 08-0916	2 Cruise cancelled 08-1157	3 Cruise w/ MOS tech to get ICU SeaJay 08-1521	4 Holiday 08-1300	5	6
7 08-0949	8 Cruise to re-install new ICU, 1 xpdr out. 08-1305	9 08-1305	10 Current Mtr #1 retreived 08-1155	11 08-0933	12	13
14 Current Mtr #2 deployed & acoustic tests. 08-1240	15 Cruise NOSC DACT bat. and softwr rep. 08-0914	16	17 Acoustic system still not working	18	19	20
21 08-0916	22 08-0916	23 Problem w/ reciever 08-0842	24 08-1200	25 Problem w/ modulat. on pltfm. 08-1200	26	27
28 No comm. 08-1200	29 0928-2014	30 Cruise to repair pltf. telemetry 08-1250	31 0801-1250			

AUGUST 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
				1 08-1250	2	3
4 08-1250	5 08-1349	6 08-1355	7 08-1250	8 08-1249	9	10
11 08-1225	12 08-0946	13 08-1103	14 08-1250	15 08-0956	16	17
18 08-1002	19 08-0955	20 MOS Cruise change out EPROMS and maintainance	21 08-1250	22 08-1143	23	24
25 08-1243	26 08-1250	27 Cruise w/ MOS to reburn EPROMS Seajay	28 permanent wire for AC at L.P.	29 Shore sta. data signal good 08-1250	30	31

SEPTEMBER 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
1 Holiday 08-1250	2 08-1109	3 08-1016	4 08-0933	5 08-1057	6	7
8 08-1035	9 08-0959	10 08-0949	11 08-1146	12 08-1100	13	14
15 08-1249	16 08-0947	17 08-1034	18 08-1210	19 08-1250	20	21
22 Generator failure 08-0958	23 Generator running continuously 08-1026	24 08-0941	25 08-1249	26 Generator has stopped running & 9-track crashed.	27	28
29 System on inverter 08-0855	30 System on inverter. Batteries died at 0824.					

OCTOBER 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1 Platform on 0801-0813. NDBC dir. pkg. out	2 Cruise to inspect generator problems Sys. secured	3 No generator	4 No gen.	5
6 No gen.	7 No gen.	8 No gen.	9 No gen.	10 No gen.	11 No gen.	12
13 No gen.	14 No gen.	15 No gen.	16 Cruise to replace gen. & repair NDBC buoy	17 08-1250	18	19
20 08-0959	21 08-1152	22 08-1228	23 08-0858	24 08-1112	25	26 Daylight Savings Time ends
27 NDBC dir. pkg. still out. 07-0848	28 08-1152	29 Cruise w/ MOS to deploy xpdrs & rep w.s.2 08-1228	30 Acoustic Position questionable 08-0058	31 08-0916		

NOVEMBER 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
					1	2
3 Position data is questionable 08-0917	4 08-0901	5 MOS Cruise to replace 4 grid xpdrs 08-1055	6 08-0858	7 08-0855	8	9
10 08-1148	11 Holiday 08-1250	12 08-0902	13 08-1118	14 08-1157	15	16
17 08-1016	18 Cruise to enter platform codes 08-1250	19 Positon data is questionable 08-1042	20 Acoustics turned off 08-0934	21 08-1250	22	23
24 08-0902	25 08-1250	26 08-1227	27 Holiday 08-1250	28 08-1250	29	30

DECEMBER 1986

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
1 NDBC DACT not operat. all week 08-1250	2 Bad data L.P. signal Highest high tide 08-1056	3 MOS at platform No Data	4 Generator problems	5	6	7
8 NDBC DACT not operat. all week 08-1322	9 08-1322	10 08-1322	11 Problems w/ filter in front of pre-amp at L.P.	12 Laguna Pk down 08-1322	13	14
15 NDBC DACT not operat. Signal probs at L.P. No data	16 NDBC dir. pkg. fixed 08-1420	17 Cruise to check gen. 08-1214	18 08-1322	19 08-1108	20	21
22 08-1322	23 No LBS 08-1322	24 No LBS 08-1322	25 Holiday 08-1250	26 Holiday 08-1250	27	28
29 No LBS 08-1236	30 No LBS 08-1312	31 No LBS 08-1322				

JANUARY 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
			1 Holiday	2 08-0852	3	4
5 Storm 7ft 6sec wind seas 08-1428	6 08-0938	7 Xpdr pressure test in DOL No data	8 Cruise check gen probs and do ping ct Doug C	9 No data	10	11
12 Cruise deploy (5) new xpdr and fix 3M	13 Acoustic system needs codes changed 08-1028	14 Acoustic system needs codes changed 08-1324	15 Storm 6ft 10 sec 20kt wind waves 08-1726	16 DOL xpdr test 08-1324	17 Cruise grid test Dolphin	18
19 Cruise enter xpdr codes & coordinates 09-1711	20 07-1202	21 Current Meter 2Y bad 08-0934	22 08-1324	23 Platform positions are zeros. L. Peak pwr inc.	24	25
26 No Acoustic Solutions 08-1055	27 No Acoustic Solutions 08-1324	28 SUBDEV Cruise Transquest 08-1324	29 SUBDEV Cruise Transquest 08-1152	30 08-1025	31 SUBDEV DSV Sea Cliff Transquest	

FEBRUARY 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
						1 SUBDEV Cruise Transquest
2 SUBDEV EOD Team Tranquest Sea Cliff 08-1020	3 SUBDEV DSV NAV DOT & c.m.#2 recovery 08-1237	4 SUBDEV Transquest 08-0930	5 SUBDEV Transquest 08-0928	6 Current array #3 deployment 08-1052	7	8
9 No 9-track No LBS No comms 08-1322	10 No comms 08-1237	11 Cruise Sonardyne deployed new nav lite 08-1139	12 No LBS 08-1713	13 No LBS 08-1322	14	15
16 Holiday No LBS 08-1250	17 Have comm No LBS 08-1137	18 No LBS 08-1111	19 Cruise Force Cyl t. plat. rigging Brazos	20 Cr. aborted 8 ft seas 30 kt wind video No LBS 08-1322	21	22
23 No LBS 08-1322	24 No LBS 08-1322	25 No LBS 08-0959	26 Cruise Force Cyl and c.m. installed Brazos	27 Cr. con't Force Cyl calibrated	28 1st complete data set recorded! 08-1718	

MARCH 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
						1 2nd complete data set recorded! 08-1320
2 Good Acoustics 08-1312	3 Cruise panfuse Big Mama 08-1510	4 Bot Z out on Force Cyl. 08-1322	5 Swell 8ft 15sec 12kt wind 08-2000	6 08-1320	7	8
9 08-1100	10 08-1200	11 Bot X out 08-1100	12 08-1030	13 Swell 8ft 17sec 08-2400	14 08-1200	15
16 08-1322	17 08-1322	18 Cruise to refuel repl tape set redun FC Bot X	19 08-1320	20 08-1321	21	22 08-1220
23 08-0940	24 Storm 20kt wind 1.5m 7sec 08-1322	25 Swell 3ft 17sec 08-1322	26 08-1100	27 08-1320	28	29
30 08-1055	31 08-0920					

APRIL 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1 08-1200	2 08-1320	3 Swell 7.5ft 17sec from 290deg 08-2200	4 Swell 6ft 13sec from 300deg 2200-0300 08-1322	5 Daylight Savings Time Starts
6 08-1200	7 08-1351	8 Cruise repl tape refuel C3 wind sen 08-1410	9 Swell 4.5ft 18sec from 290deg 08-1321	10 08-1321	11 08-1340	12
13 08-1320	14 08-1321	15 08-1040	16 08-1321	17 Cruise Removal of Force Cylinder Tampa	18 08-1321	19
20 08-1321	21 08-1321	22 08-1320	23 No Comms 08-1320	24 08-0930	25 08-1321	26
27 08-0940	28 08-1622	29 08-1000	30 08-1030			

MAY 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
				1 08-1320	2 08-1320	3
4 08-1320	5 08-1042	6 Cruise plat. main. 08-1335	7 08-0930	8 08-0944	9	10
11 08-0933	12 08-1421	13 Re-install Force Cylinder 08-1846	14 Good data But Wrong Cal Const. 08-1321	15 08-1321	16	17
18 Recorded 1m 17sec 4kt wind 08-1321	19 NDBC buoy directional pkg. battery problems 08-1240	20 08-0937	21 08-1030	22 08-1322	23 08-1320	24
25 Recorded 6ft 20kt 08-1300	26 Recorded 6.5ft 7sec 16kt wind 290 deg 08-1644	27 Recorded 1m 17sec 10kt 330 deg ??	28 Cruise Surge & Sway Test Allison 08-1230	29	30	31

JUNE 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
1 Curr. Met. Array #3 recovered DeSteiguer 08-1040	2 08-1206	3 08-0935	4 08-1210	5 1310-1820	6	7
8 08-1100	9 08-1322	10 Sailboat collides w/ semi at 2230 hrs?? 08-0936	11 08-1054	12 08-0924	13	14
15 08-0949	16 System not on	17 08-0928	18 System not on	19 08-0927	20	21
22 NDBC Buoy Dir. pkg. battery out No Dir Data 08-1250	23 System not on	24 08-0938	25 System not on	26 Cruise to do cal checks	27	28
29 08-0929	30 System not on					

JULY 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1 Cruise platform maintenance 08-0926	2 System not on	3 Holiday	4	5
6 08-1153	7 System not on	8 08-0928	9 System not on	10 Message Nav light out on Navy buoy	11	12
13 System not on	14 08-1034	15 Cruise fixed nav lights on semi and const. buoys	16 System not on	17 08-1250	18	19
20 System not on	21 08-0934	22 System not on	23 Notified of sailboat-semi collision	24 08-0925	25	26
27 System not on	28 Cruise to photo semi damage	29 System not on	30 System not on	31 08-0925		

AUGUST 1987

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	08-0930			08-0930	1	2
3	4 08-0930	5	6	7 08-0930	8	9
10	11 08-0930	12	13	14 08-0930	15	16
17	18 08-0930	19	20	21 08-0930	22	23
24	25 08-0930	26	27	28 08-0930	29	30
31						

SEPTEMBER 87

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	1 08-0847	2	3	4 08-0846	5	6
7	8 questionable acoustics 08-1322	9	10	11 08-0939	12	13
14	15 08-0854	16	17	18 0854-1323	19	20
21	22 08-1322	23	24	25 08-0929	26	27
28	29 08-1438	30				

OCTOBER 87

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
			1	2 good acoustics 08-1321	3	4
5	6 08-1100	7	8	9	10	11
12	13	14 Cruise replaced 12V gen. batt. fuel filters muffler	15	16 08-1215	17	18
19	20 No 3M tape on semi 0840-0925	21	22	23 MINC PDP-11 does not boot 08-1322	24	25 Day Light Savings Time Ends
26	27 08-1225	28	29	30 0815-0929	31	

NOVEMBER 87

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
						1
2	3 #705,#706 not ranging 08-1056	4	5	6 08-0934	7	8
9	10 08-1106	11	12	13 08-1132	14	15
16	17 No acoustics 08-1321	18	19	20 1024-1149	21	22
23 Cruise attempt to recover xpdr Too Rough	24	25	26	27	28	29
30						

DECEMBER 87

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	1 08-0957	2	3	4 08-1322	5	6
7	8 08-0921	9	10	11 Cruisè attempt to recover xpdr Too Foggy 08-0831	12	13
14	15 08-0855	16 Storm 8m wave 30kt wind	17	18 08-1322	19 Cruise ITC & C. Buoy gone. Grid xpdrs recovered	20
21 08-1527	22	23	24	25 Christmas	26	27
28	29	30 08-1322	31			

JANUARY 88

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
				1	2	3
4 08-1322	5 08-1320	6 08- 0929	7 08-0846	8 Cruise install grid xpdrs. Cut dunking tr. 08-1053	9	10
11 08-1042	12 08-0844	13 Cruise entered new grid coord. 08-0900	14	15 No acoustics 08-0930	16 Storm 8m wave 30 kt wind 08-1935	17
18 USCG Humphrey out 08-1053	19 08-0934	20 08-0935	21 Cruise remove USCG Humphrey rec. #703 08-0850	22 08-1322	23 08-0927	24 08-0925
25 08-0951	26 08-0947	27 08-0910	28 08-1217	29 08-0953	30 08-0848	31 08-1014

FEBRUARY 88

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
1 Cruise recovered #708 & test xpdrs 08-1001	2 Operation: M/V Doug C Transquest & DSV Turtle 08-0942	3 08-1635	4 08-0937	5	6	7
8 Lost signal 08-0813	9 Receiver out at L.P.	10	11	12 Cruise Hump. pwer & acoustics probs	13	14
15 08-1100	16 No acoustics No Humphrey 08-1342	17 08-1525	18 08-1322	19 09-1015	20	21
22 08-0935	23 08-0942	24 08-1305	25 Cruise install new Hump. pwer unit parts 08-1200	26 08-1543	27	28
29 08-1632						

MARCH 88

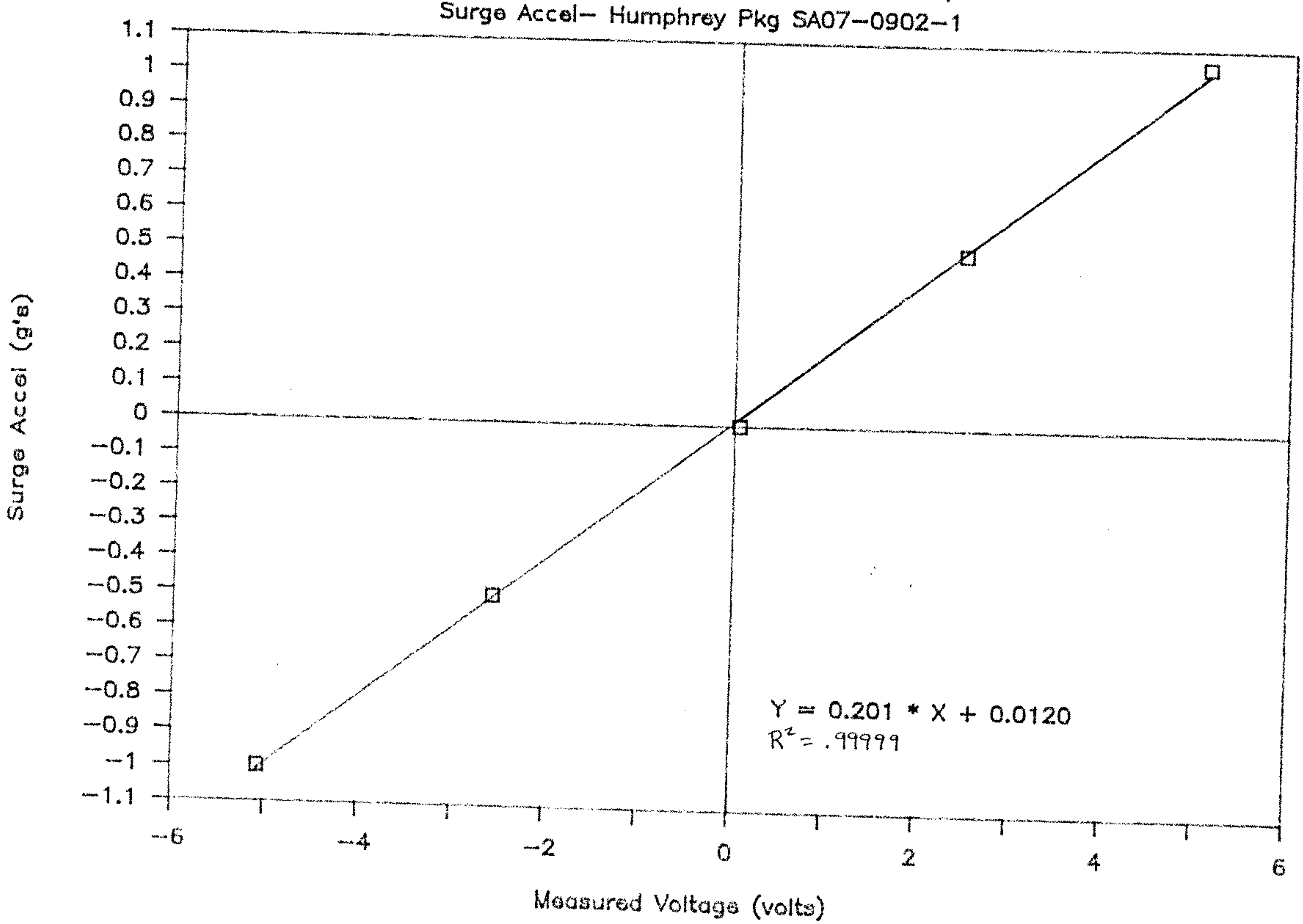
MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
	1 Cruise divers clean semi, video 08-1322	2 08-1051	3 08-1221	4 Cruise recover NCEL Humphrey grid check 08-0945	5	6
7 08-0947	8 08-0945	9 MME terminated 08-1322	10 08-0927	11 08-0936	12	13
14	15 08-1205	16	17	18 08-1322	19	20
21	22 08-0933	23	24 Cruise recover PAN biofouling samples	25 08-1035	26	27
28	29 Cruise post-cal xpdrs,rec. #702-708 08-1015	30	31			

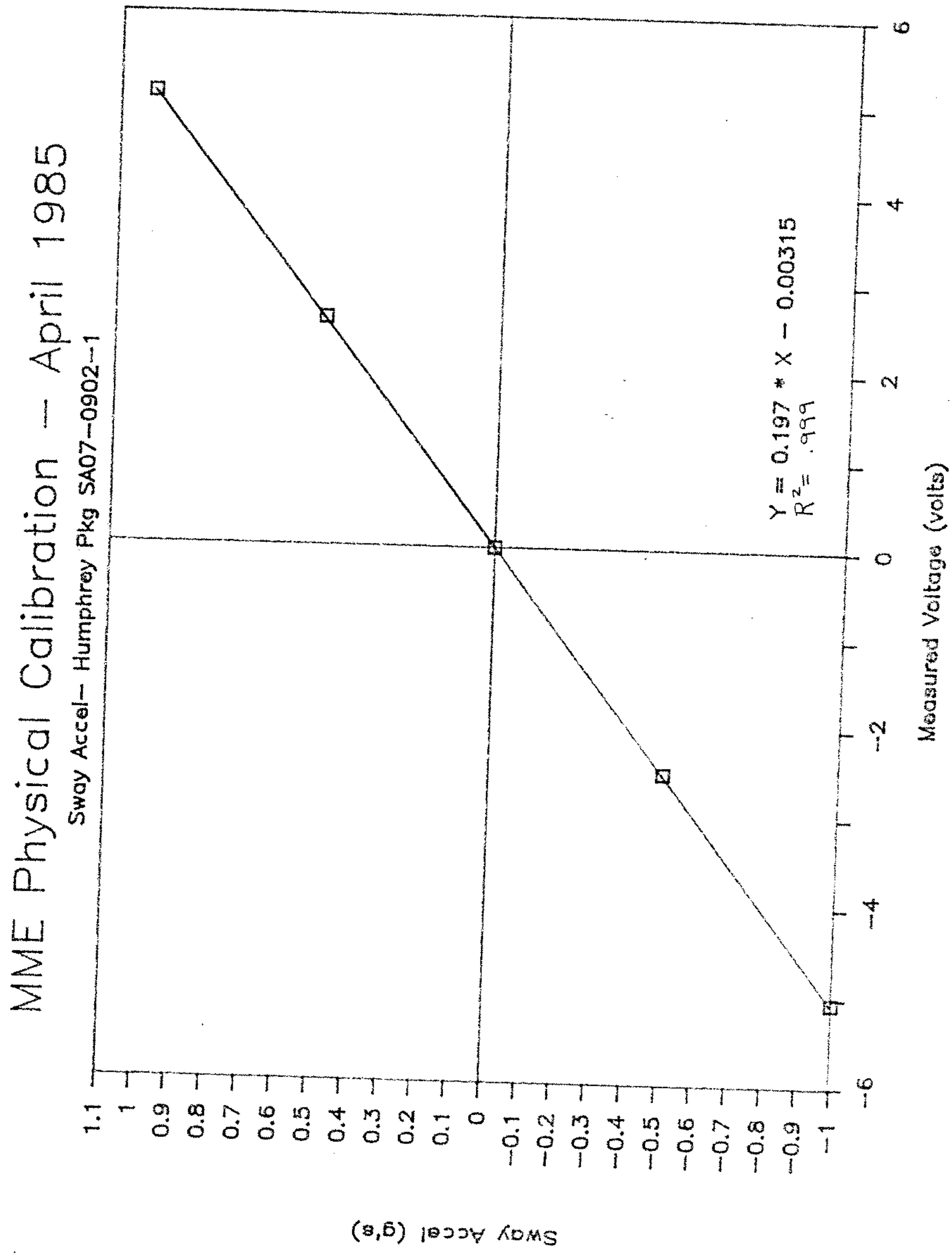
APPENDIX B

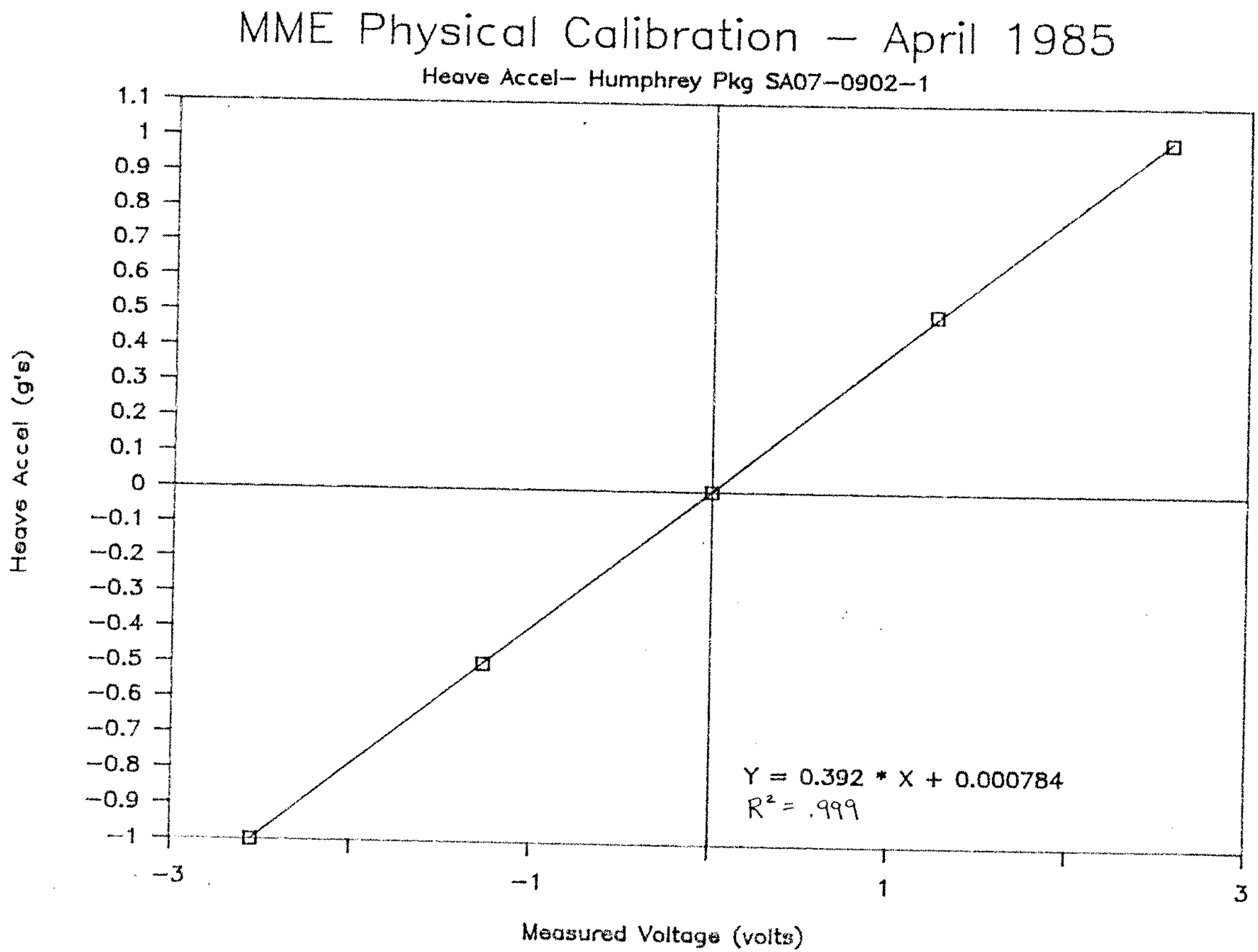
CALIBRATION DATA

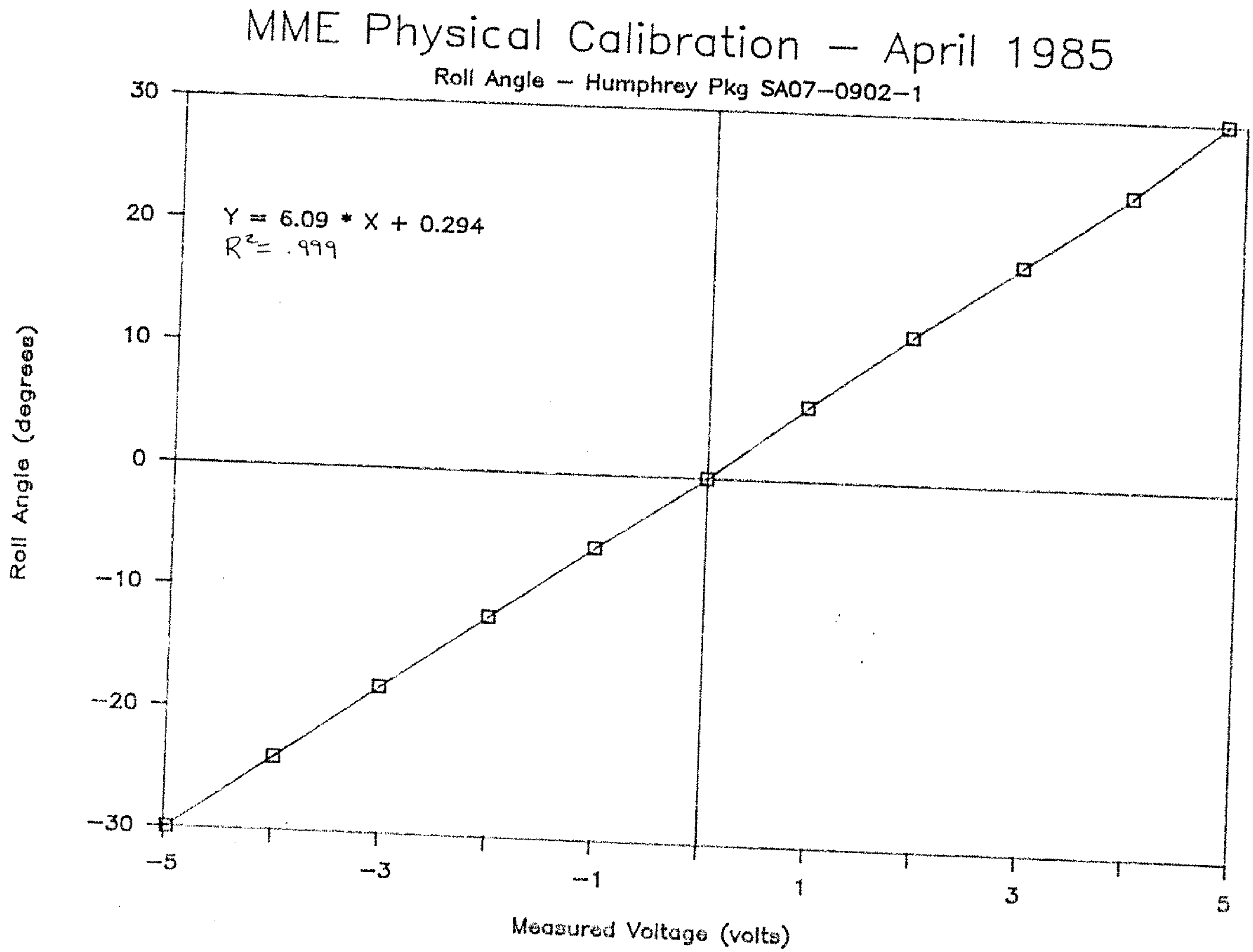
The following pages present the physical precalibration data collected for each environmental or response sensor onboard the semisubmersible. See Section 4 of main report for description of how each physical precalibration was conducted.

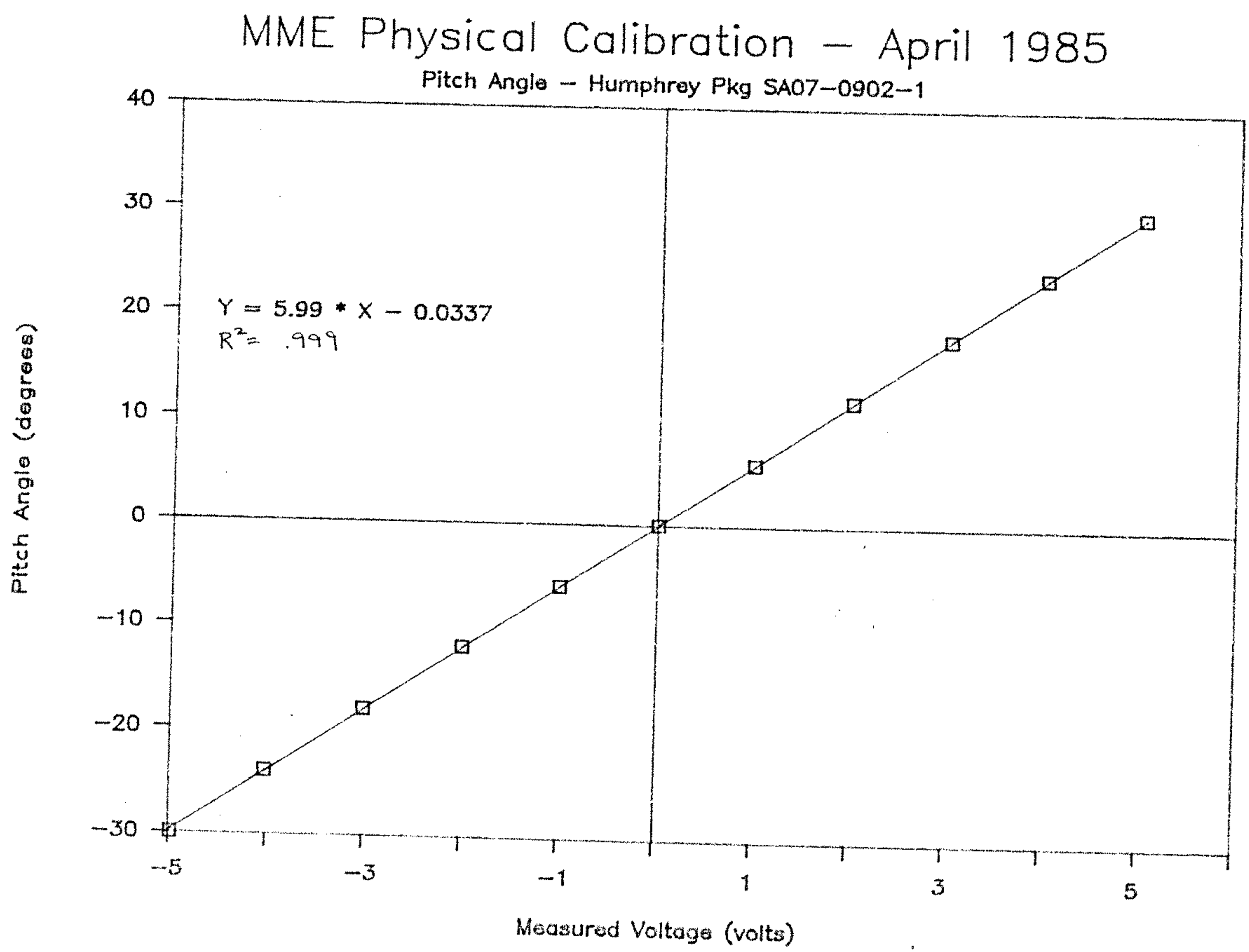
MME Physical Calibration – April 1985



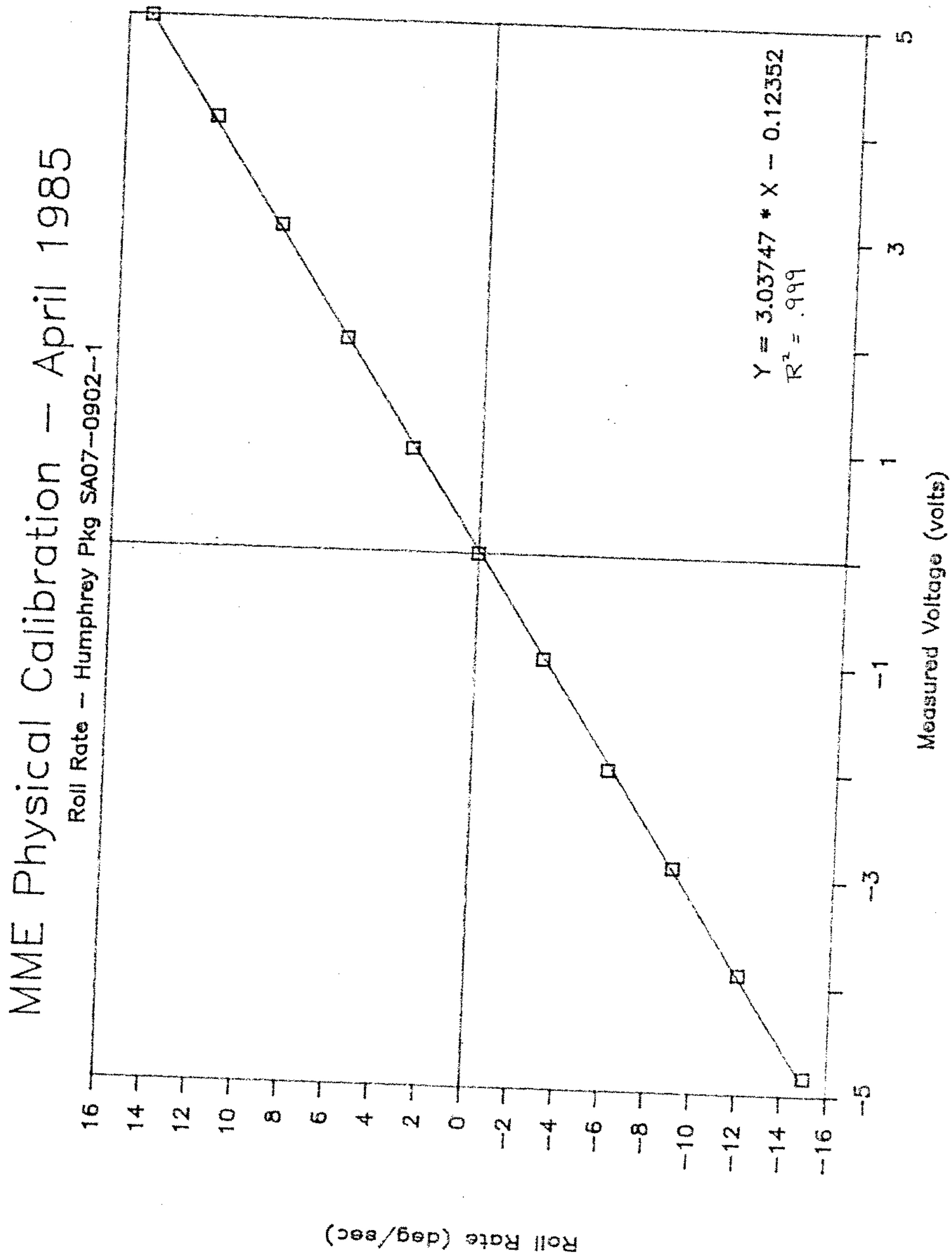

MME Physical Calibration — April 1985
Sway Accel– Humphrey Pkg SA07–0902–1
Y = 0.197 * X – 0.00315
R² = .999
Measured Voltage (volts)
Sway Accel (g's)
-6
-4
-2
0
2
4
6
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1


MME Physical Calibration — April 1985
Heave Accel— Humphrey Pkg SA07-0902-1
Heave Accel (g's)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1
−3
−1
1
3
Measured Voltage (volts)
Y = 0.392 * X + 0.000784
R² = .999


MME Physical Calibration – April 1985
Roll Angle – Humphrey Pkg SA07–0902–1
Y = 6.09 * X + 0.294
R² = .999
Roll Angle (degrees)
30
20
10
0
–10
–20
–30
–5
–3
–1
1
3
5
Measured Voltage (volts)

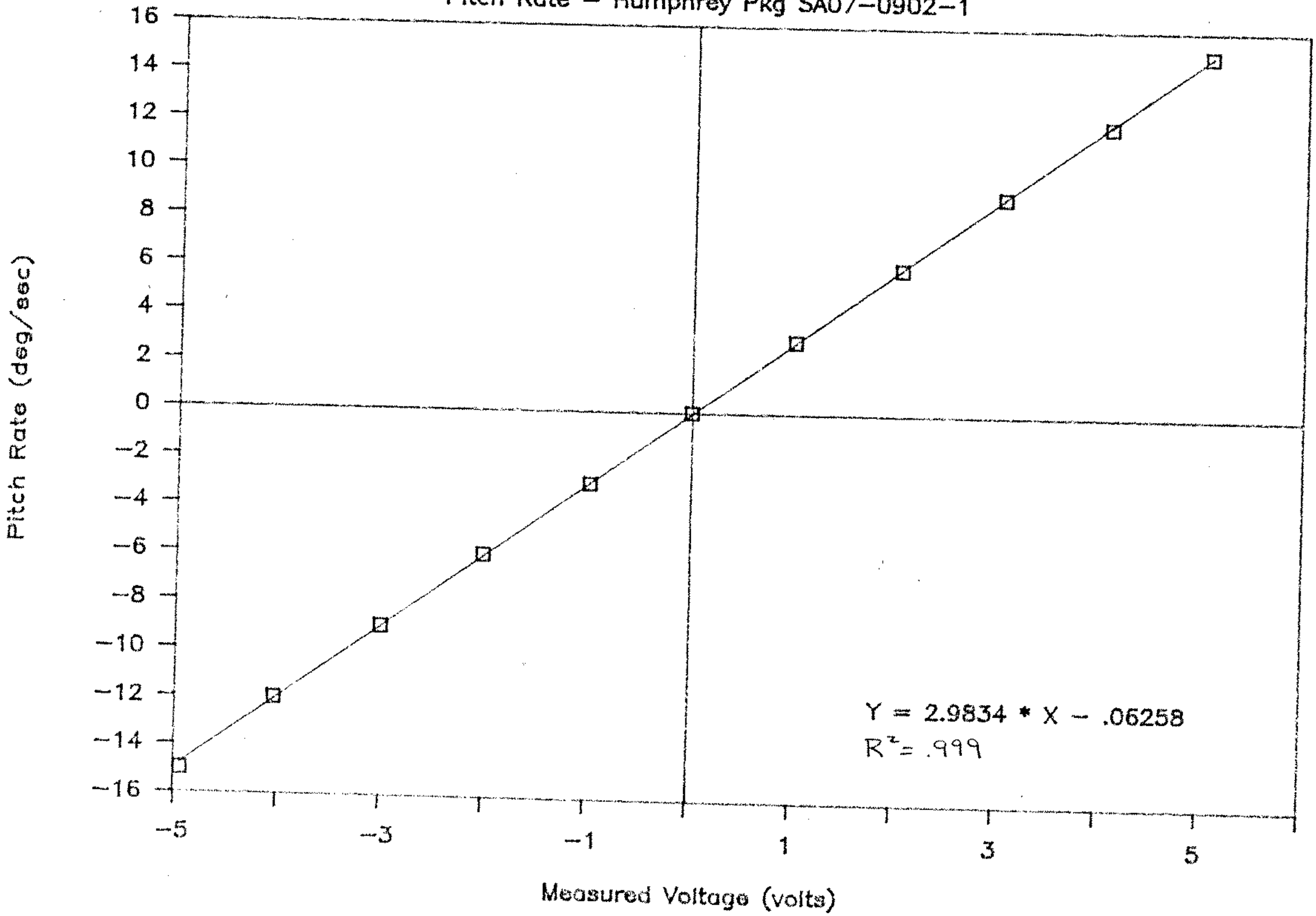


MME Physical Calibration – April 1985
Pitch Angle – Humphrey Pkg SA07–0902–1
Y = 5.99 * X – 0.0337
R² = .999
Pitch Angle (degrees)
40
30
20
10
0
–10
–20
–30
–5
–3
–1
1
3
5
Measured Voltage (volts)


MME Physical Calibration — April 1985
Roll Rate — Humphrey Pkg SA07–0902–1
Y = 3.03747 * X – 0.12352
R² = .999
Measured Voltage (volts)
Roll Rate (deg/sec)
16
14
12
10
8
6
4
2
0
–2
–4
–6
–8
–10
–12
–14
–16
–5
–3
–1
1
3
5

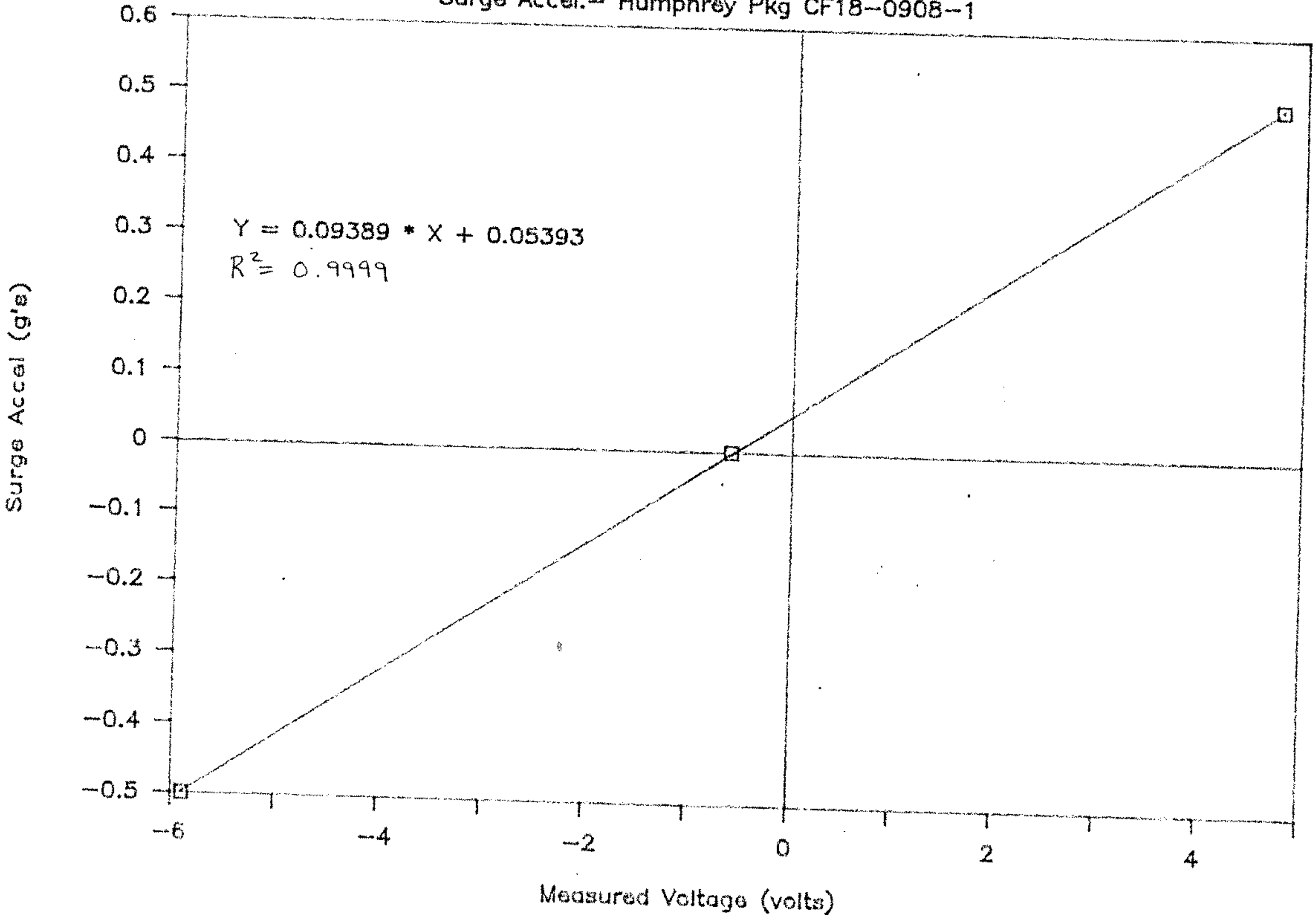
MME Physical Calibration — April 1985

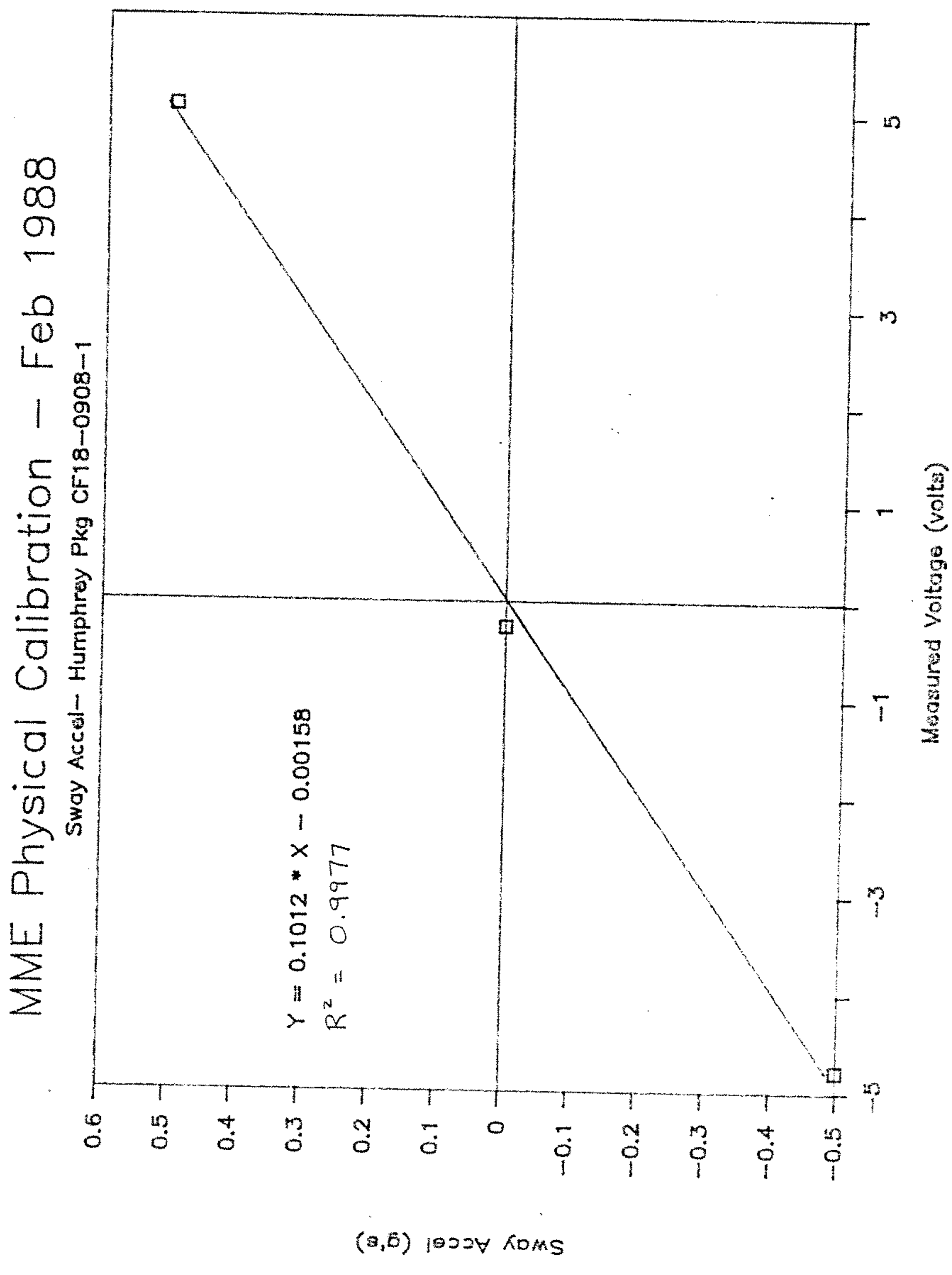
Pitch Rate — Humphrey Pkg SA07-0902-1

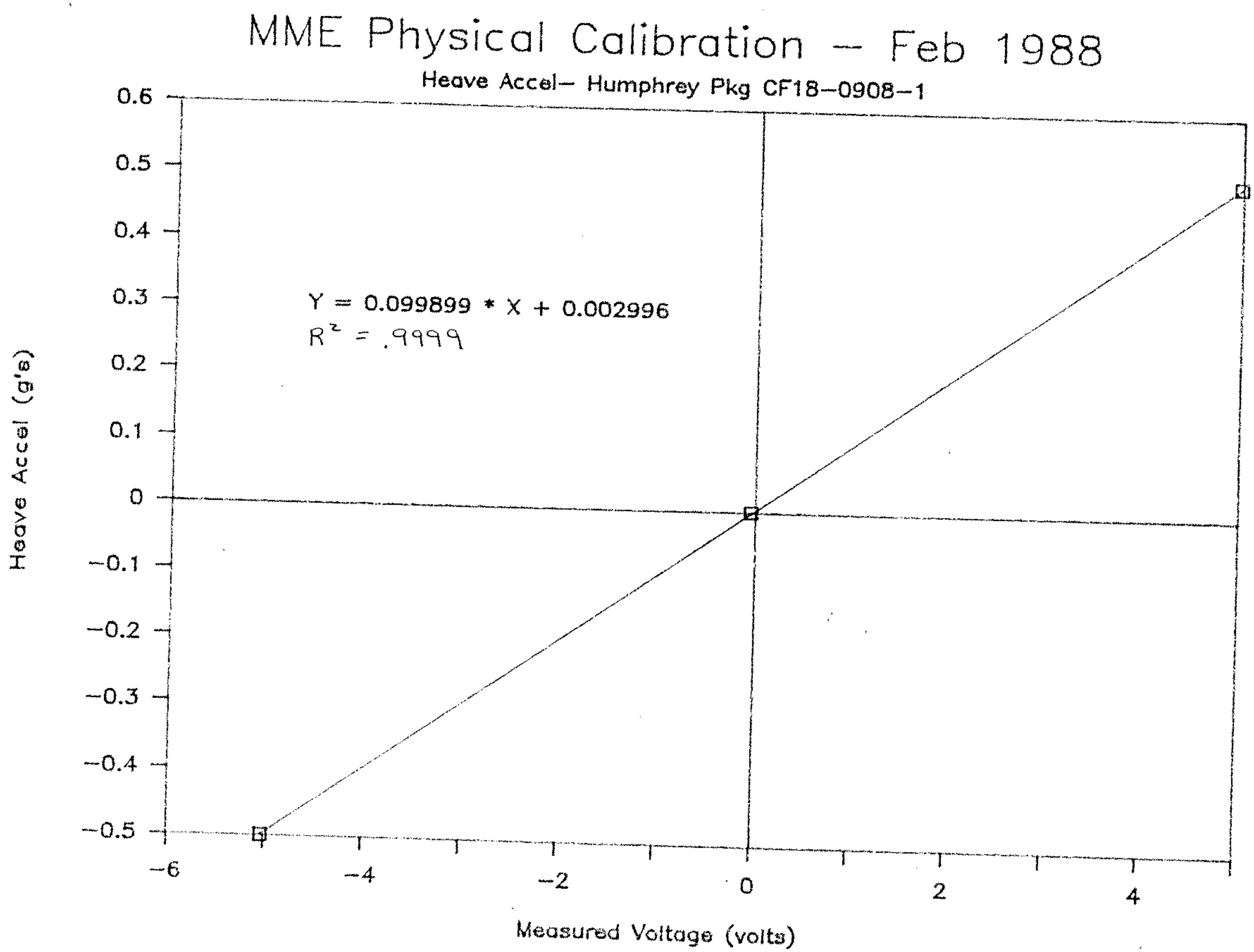


MME Physical Calibration — Feb 1988

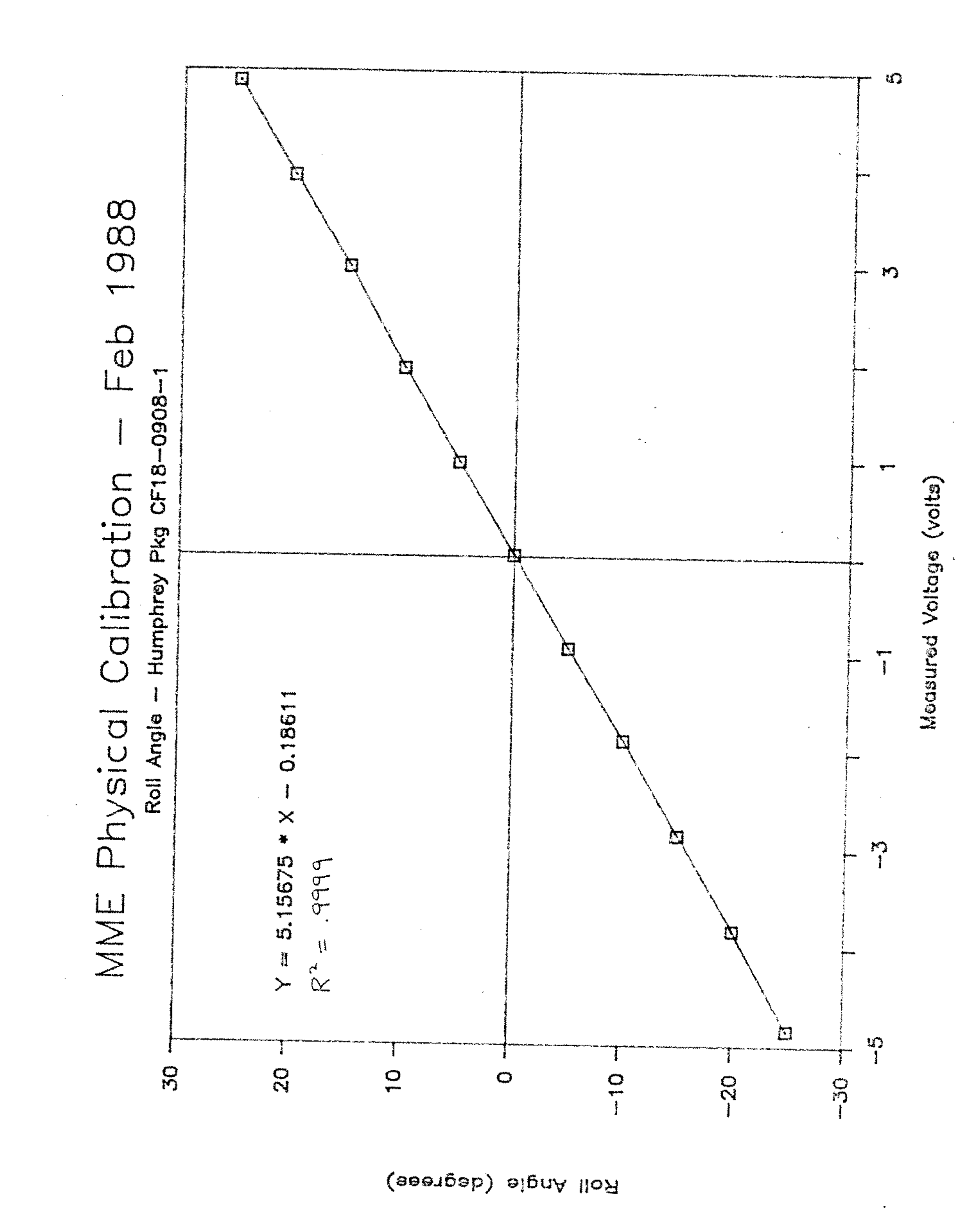
Surge Accel.– Humphrey Pkg CF18–0908–1

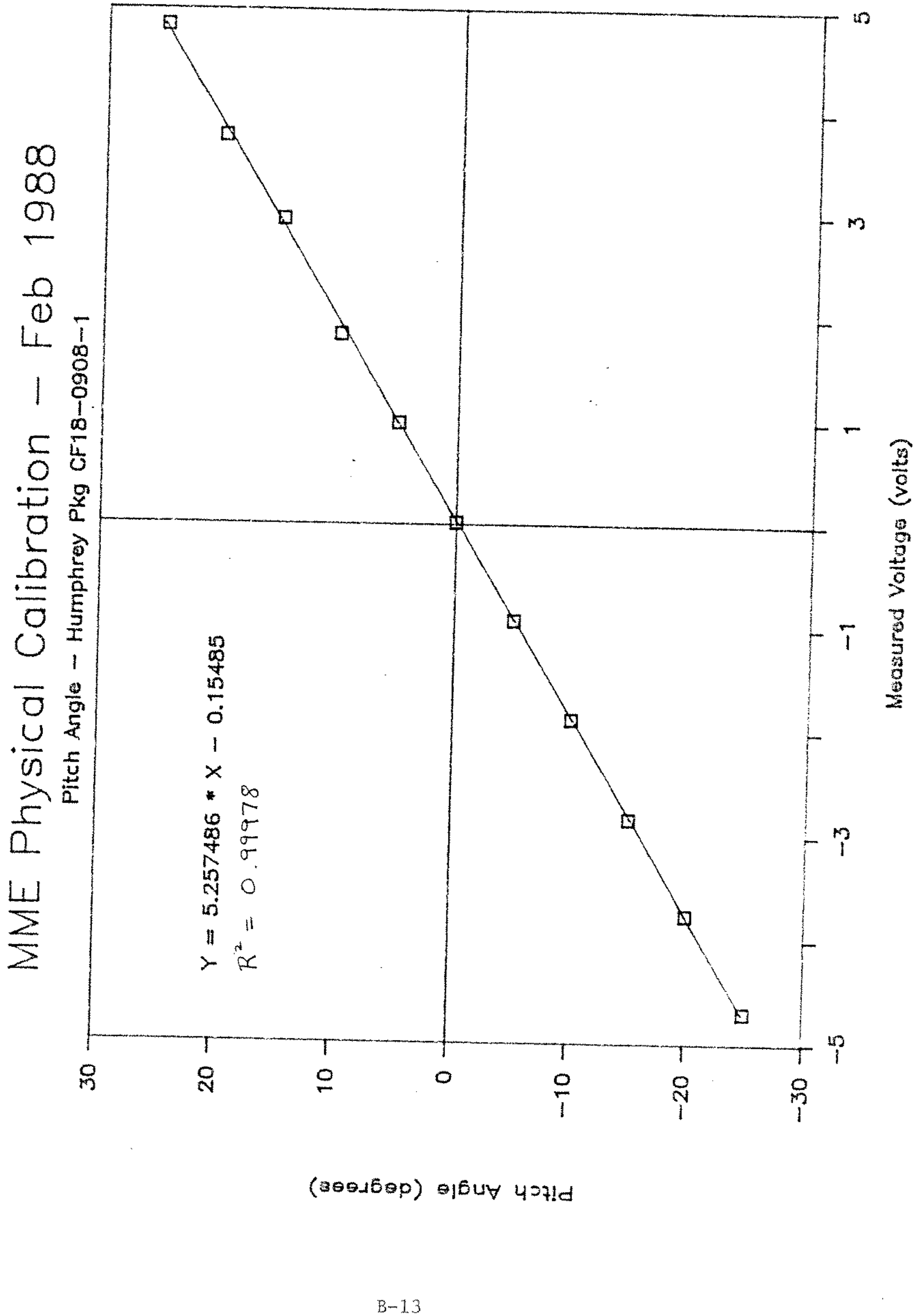


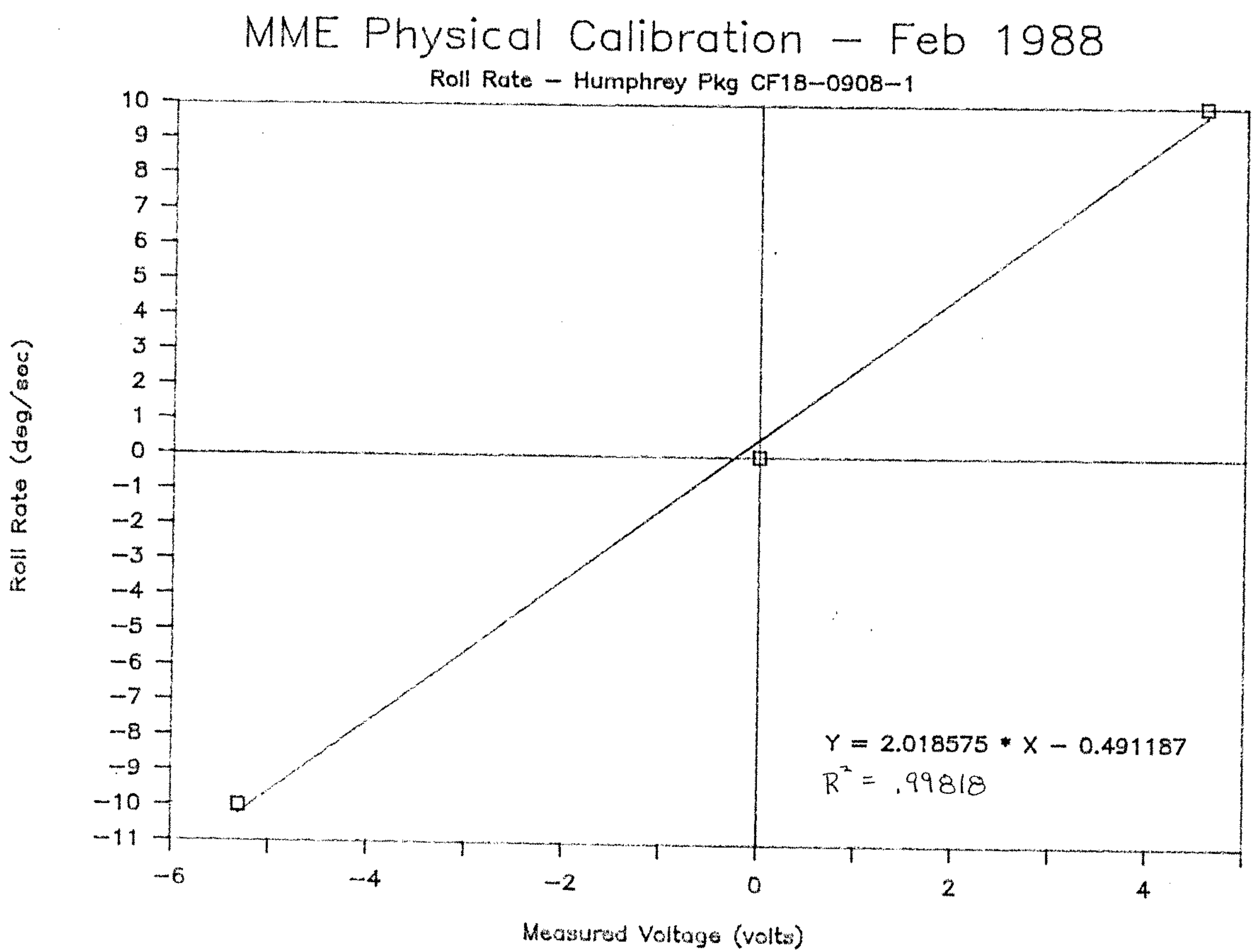

MME Physical Calibration – Feb 1988
Sway Accel– Humphrey Pkg CF18–0908–1
Y = 0.1012 * X – 0.00158
R² = 0.9977
Measured Voltage (volts)
Sway Accel (g's)
-5
-3
-1
1
3
5
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5

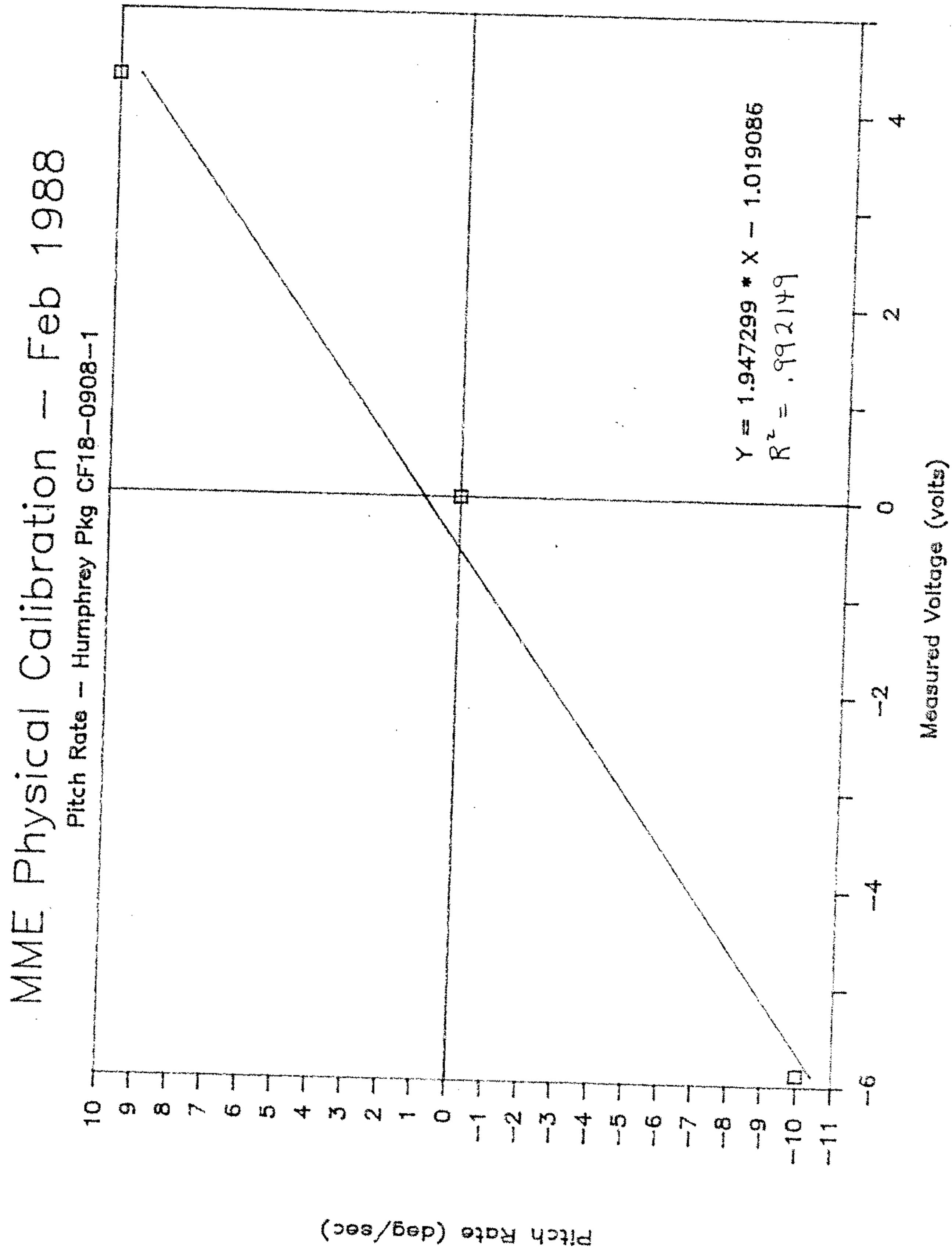


MME Physical Calibration — Feb 1988
Heave Accel— Humphrey Pkg CF18—0908—1
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
Heave Accel (g's)
Y = 0.099899 * X + 0.002996
R² = .9999
−6
−4
−2
0
2
4
Measured Voltage (volts)

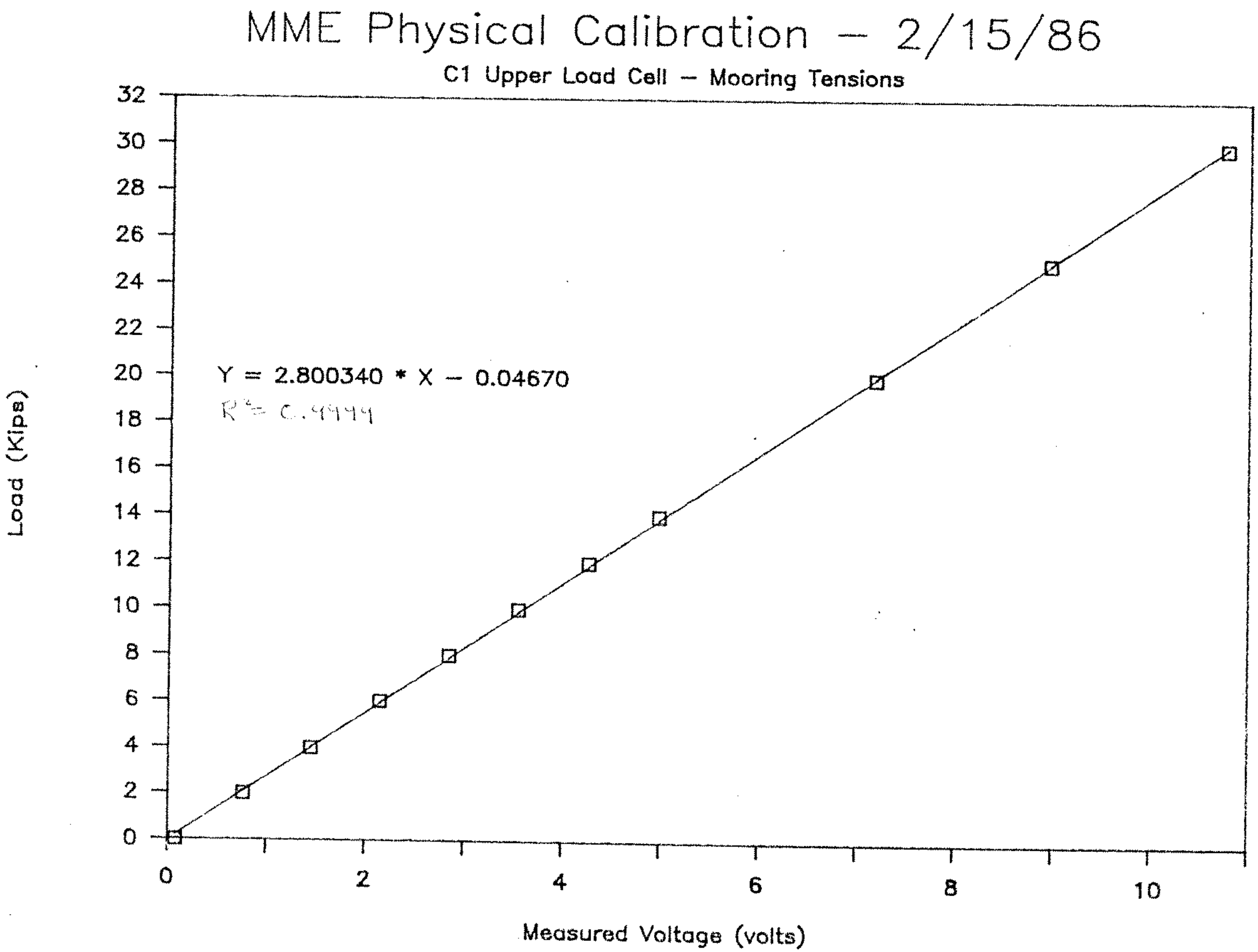

MME Physical Calibration — Feb 1988
Roll Angle — Humphrey Pkg CF18-0908-1
Y = 5.15675 * X — 0.18611
R² = .9999
Roll Angle (degrees)
Measured Voltage (volts)
30
20
10
0
-10
-20
-30
-5
-3
-1
1
3
5

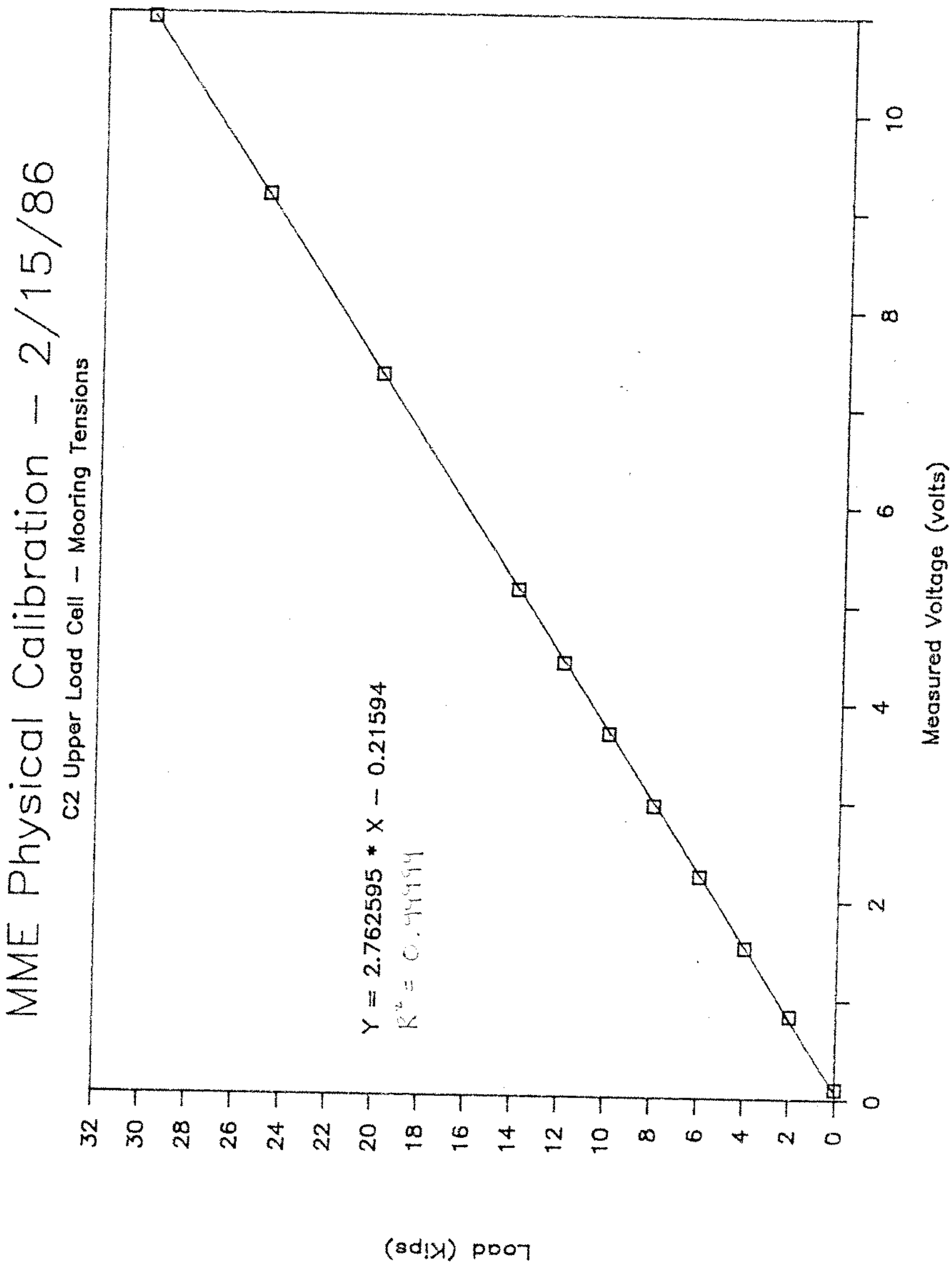

MME Physical Calibration — Feb 1988
Pitch Angle — Humphrey Pkg CF18-0908-1
Y = 5.257486 * X − 0.15485
R² = 0.99978
Measured Voltage (volts)
Pitch Angle (degrees)
30
20
10
0
−10
−20
−30
−5
−3
−1
1
3
5

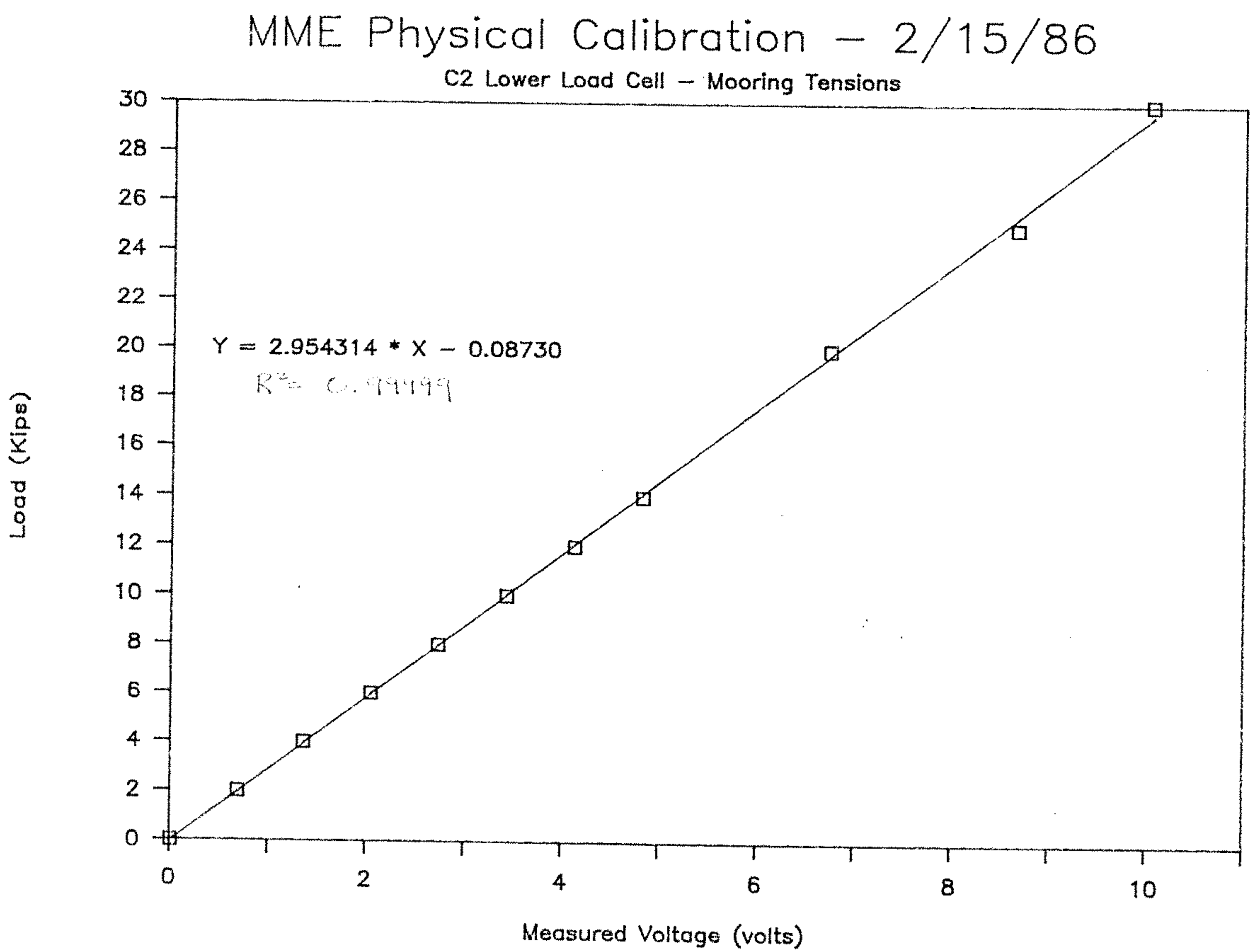

MME Physical Calibration — Feb 1988
Roll Rate — Humphrey Pkg CF18—0908—1
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
Roll Rate (deg/sec)
−6
−4
−2
0
2
4
Measured Voltage (volts)
Y = 2.018575 * X − 0.491187
R² = .99818



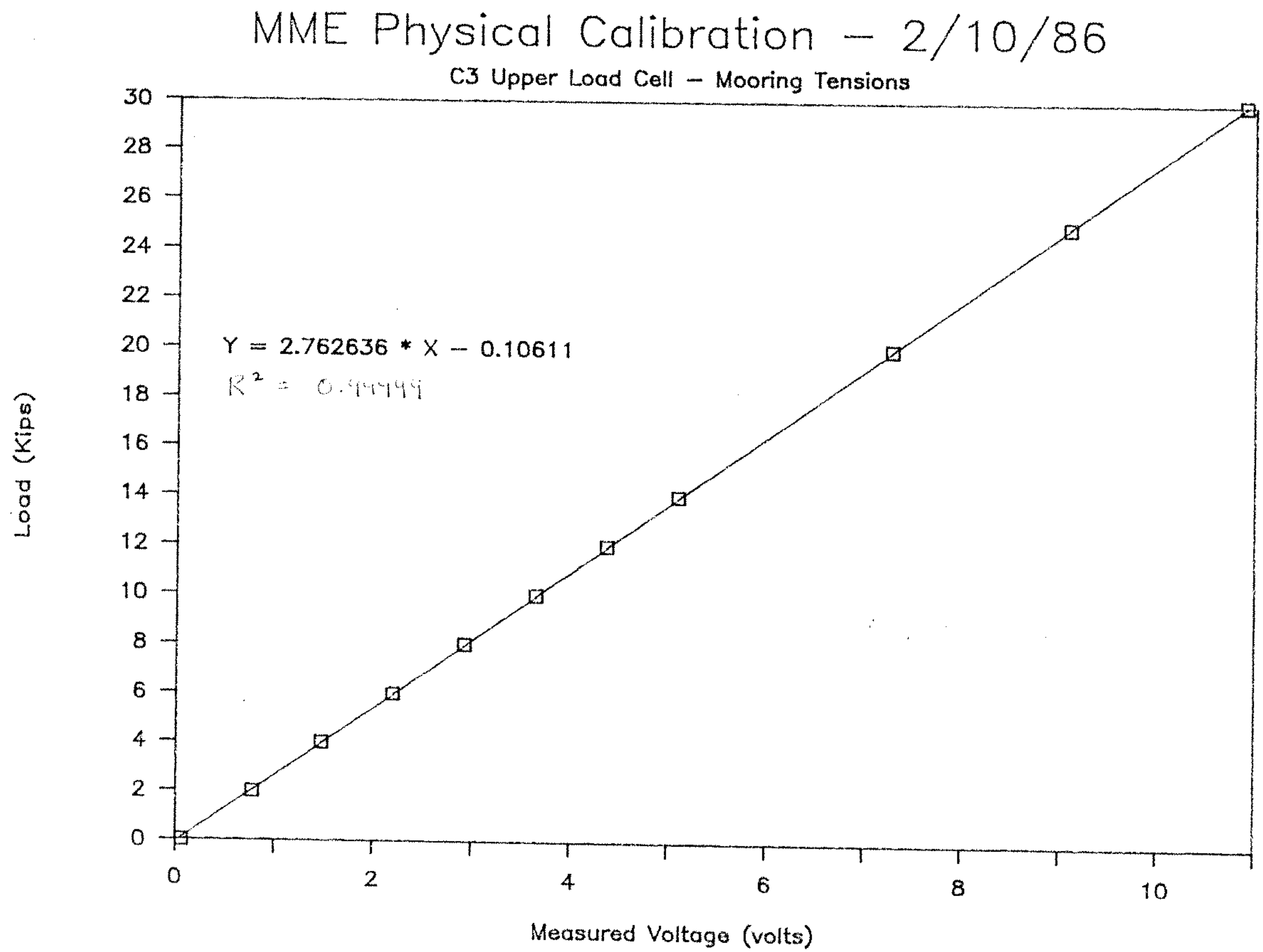
MME Physical Calibration — Feb 1988
Pitch Rate — Humphrey Pkg CF18-0908-1
Y = 1.947299 * X − 1.019086
R^2 = .992149
Measured Voltage (volts)
Pitch Rate (deg/sec)
−6
−4
−2
0
2
4
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11


MME Physical Calibration - 2/15/86
C1 Upper Load Cell - Mooring Tensions
Y = 2.800340 * X - 0.04670
R² = 0.9999
Load (Kips)
Measured Voltage (volts)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32


MME Physical Calibration — 2/15/86
C2 Upper Load Cell — Mooring Tensions
Y = 2.762595 * X — 0.21594
R² = 0.9999
Load (Kips)
Measured Voltage (volts)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32



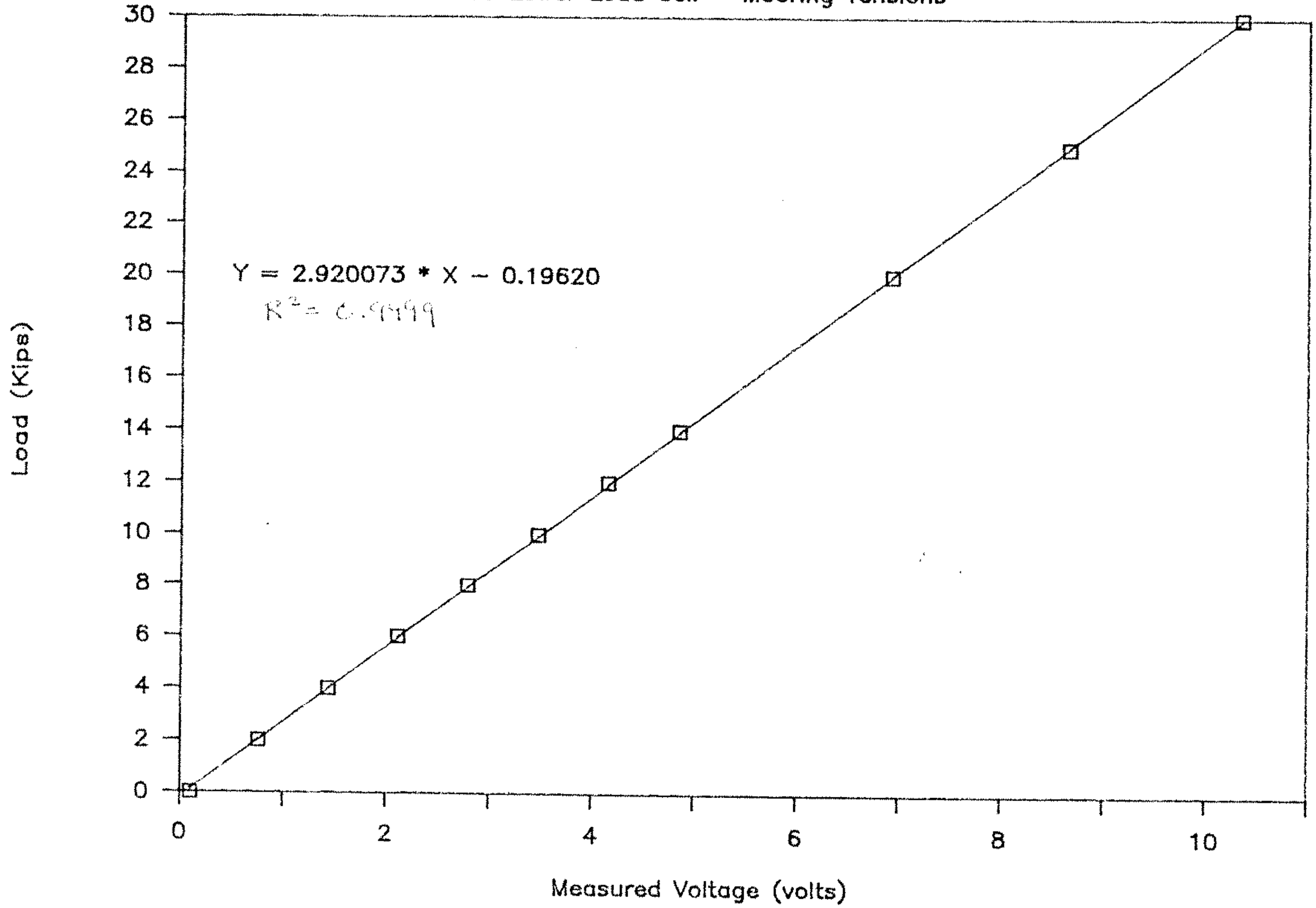
MME Physical Calibration – 2/15/86
C2 Lower Load Cell – Mooring Tensions
Y = 2.954314 * X – 0.08730
R² = 0.99999
Load (Kips)
Measured Voltage (volts)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

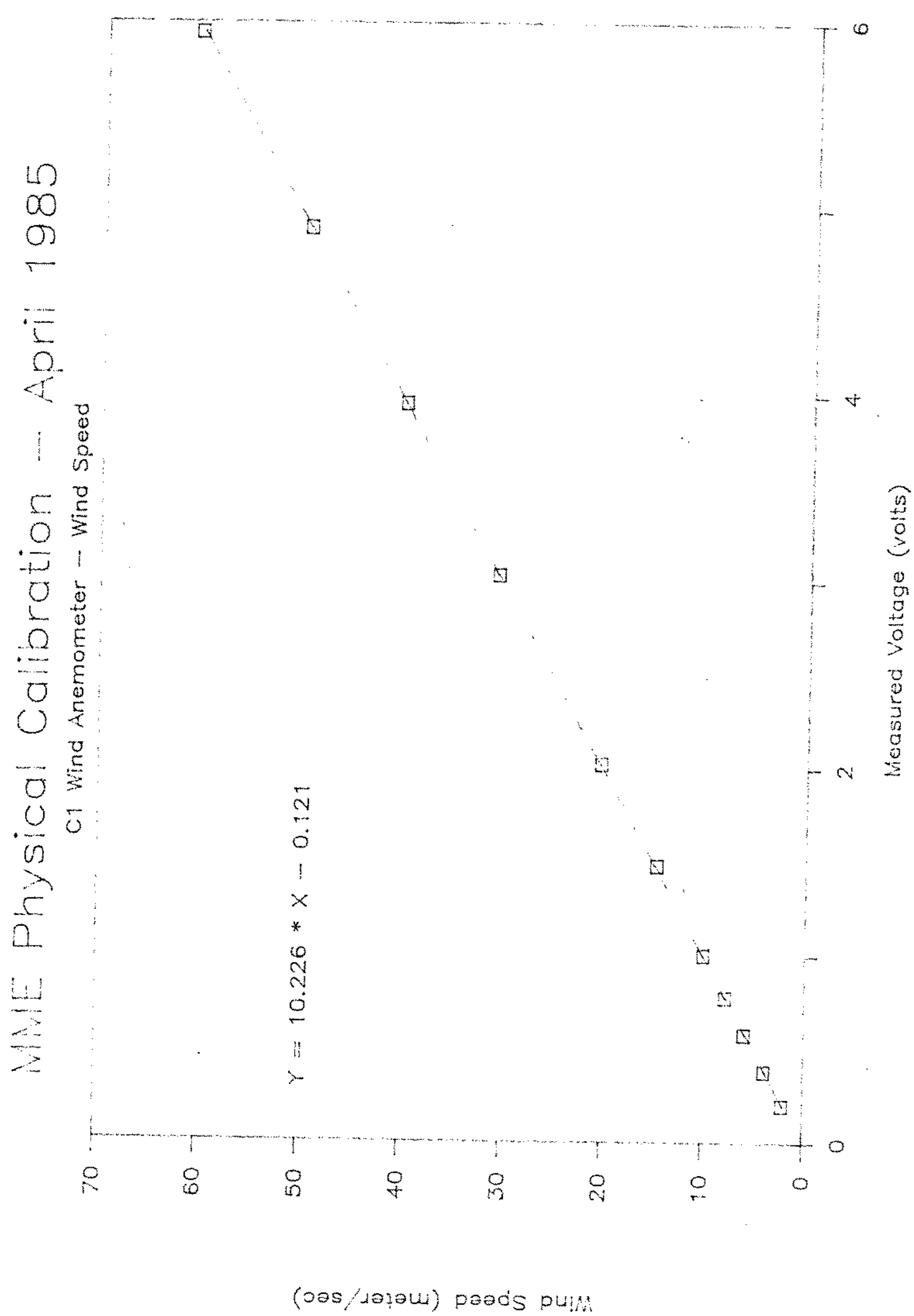


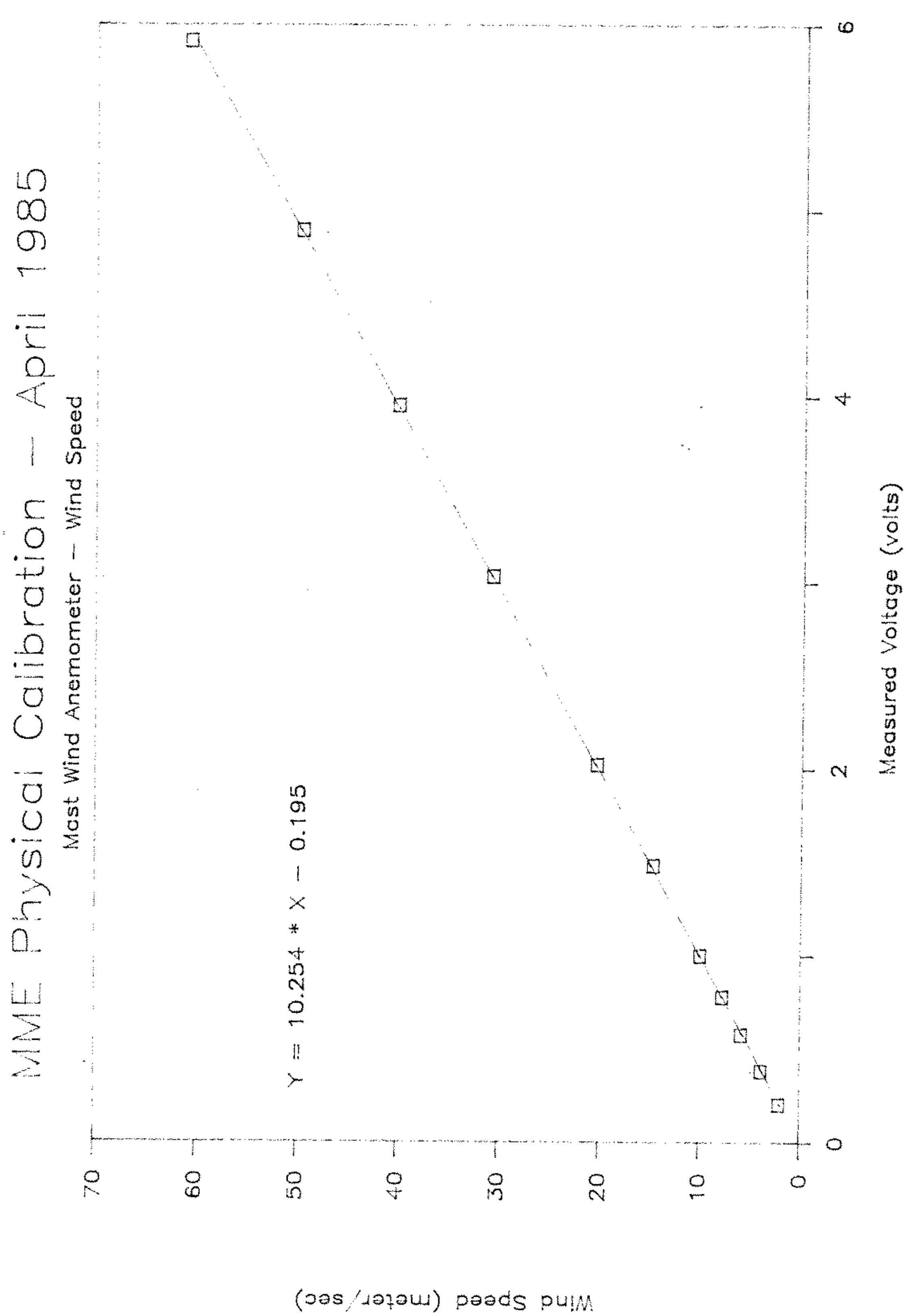
MME Physical Calibration — 2/10/86
C3 Upper Load Cell – Mooring Tensions
Y = 2.762636 * X – 0.10611
R² = 0.99999
Load (Kips)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Measured Voltage (volts)
0
2
4
6
8
10

MME Physical Calibration – 2/10/86

C3 Lower Load Cell – Mooring Tensions

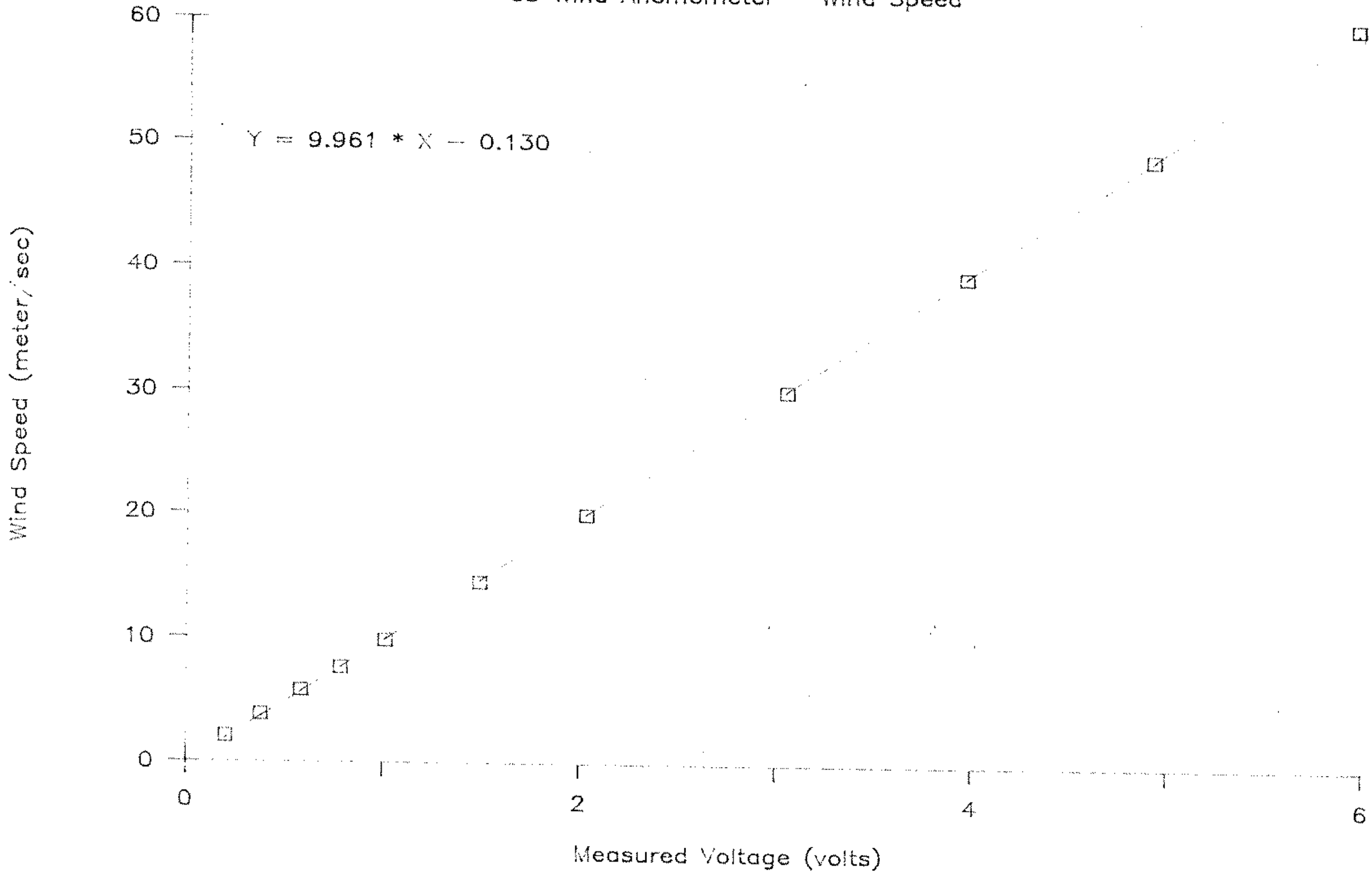



MME Physical Calibration — April 1985
C1 Wind Anemometer – Wind Speed
Y = 10.226 * X – 0.121
Wind Speed (meter/sec)
Measured Voltage (volts)
0
10
20
30
40
50
60
70
0
2
4
6


MME Physical Calibration – April 1985
Mast Wind Anemometer – Wind Speed
Y = 10.254 * X – 0.195
Wind Speed (meter/sec)
Measured Voltage (volts)
0
10
20
30
40
50
60
70
0
2
4
6

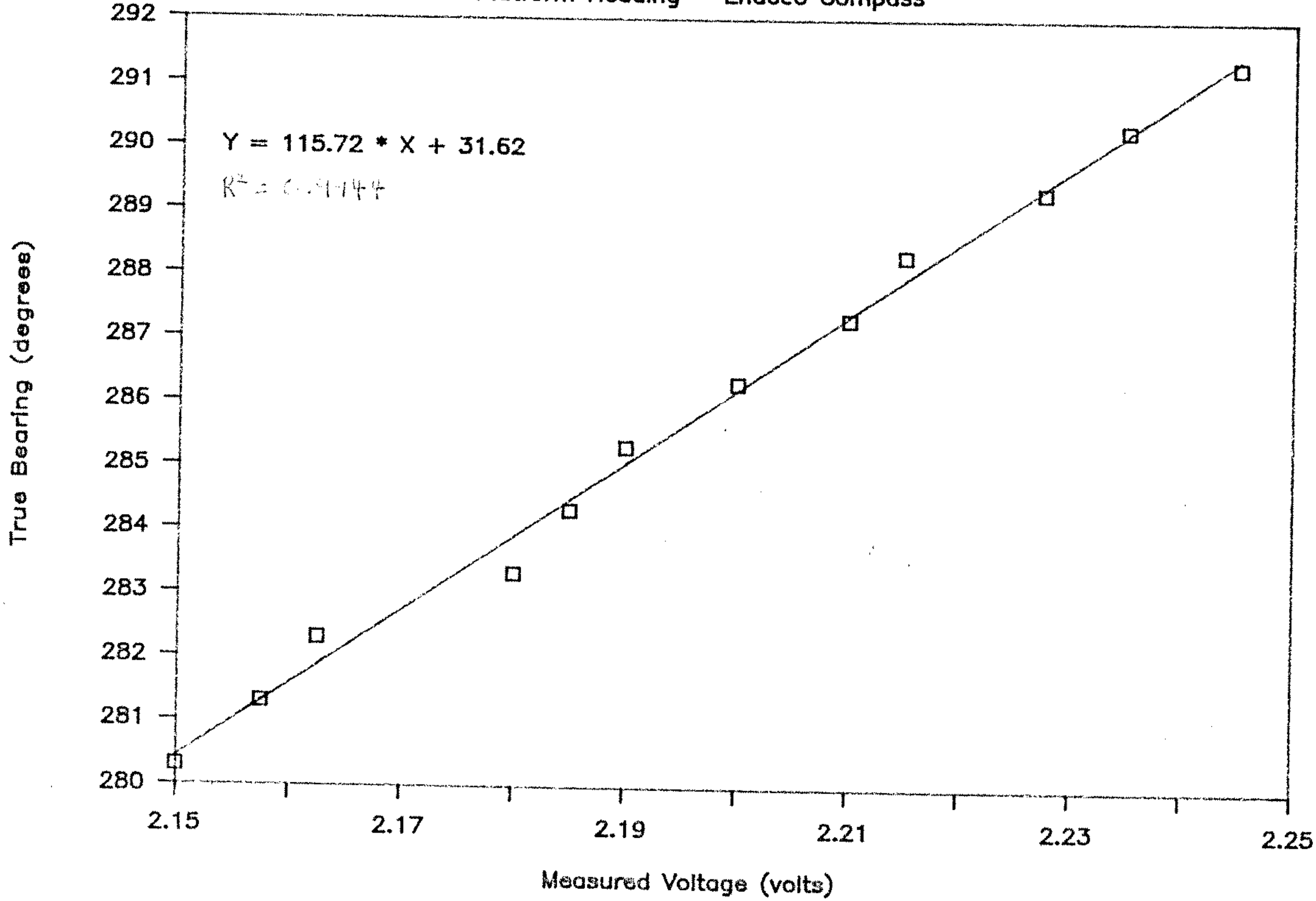
MME Physical Calibration -- April 1985

C3 Wind Anemometer - Wind Speed

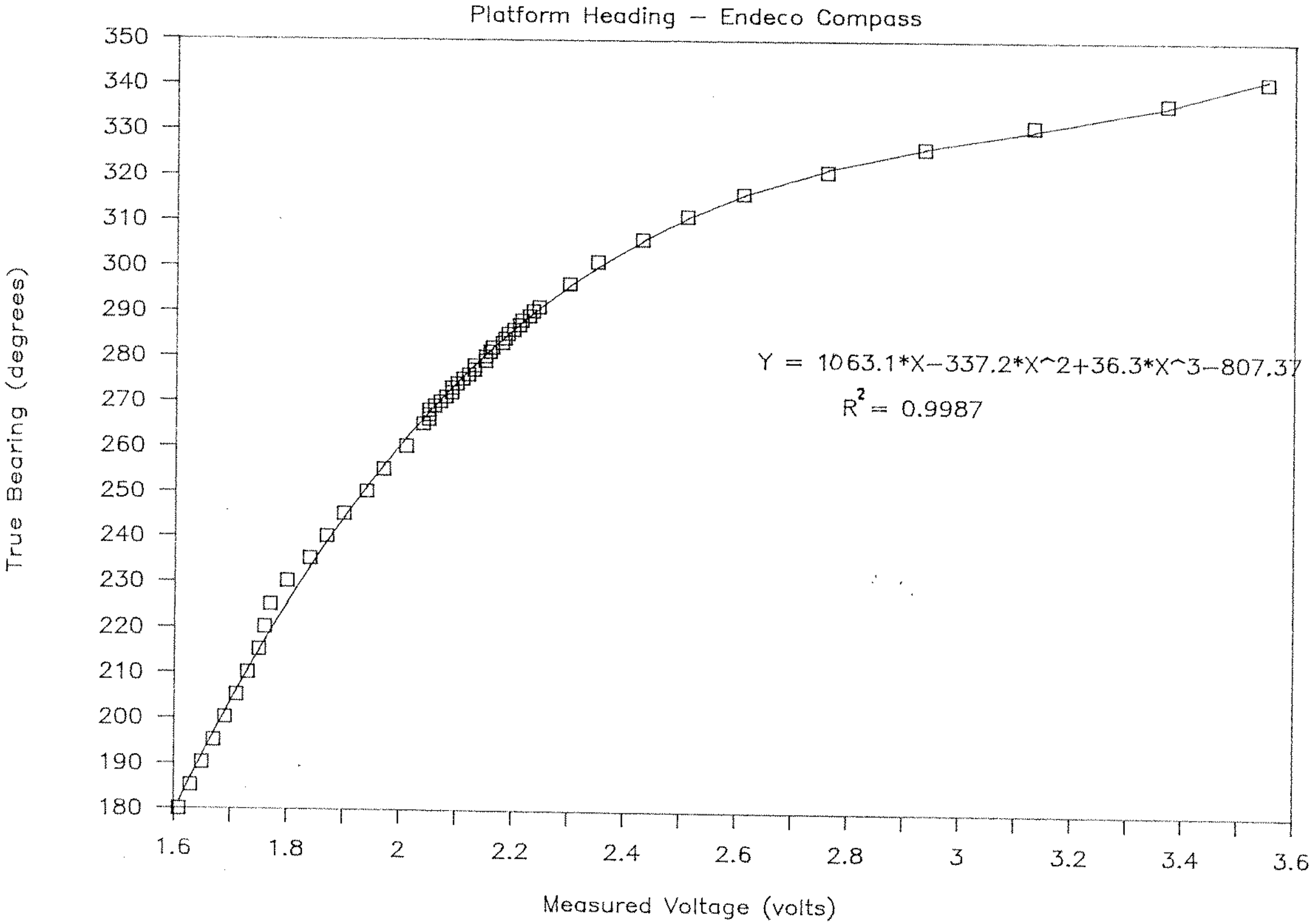


MME Physical Calibration — April 1985

Platform Heading — Endeco Compass

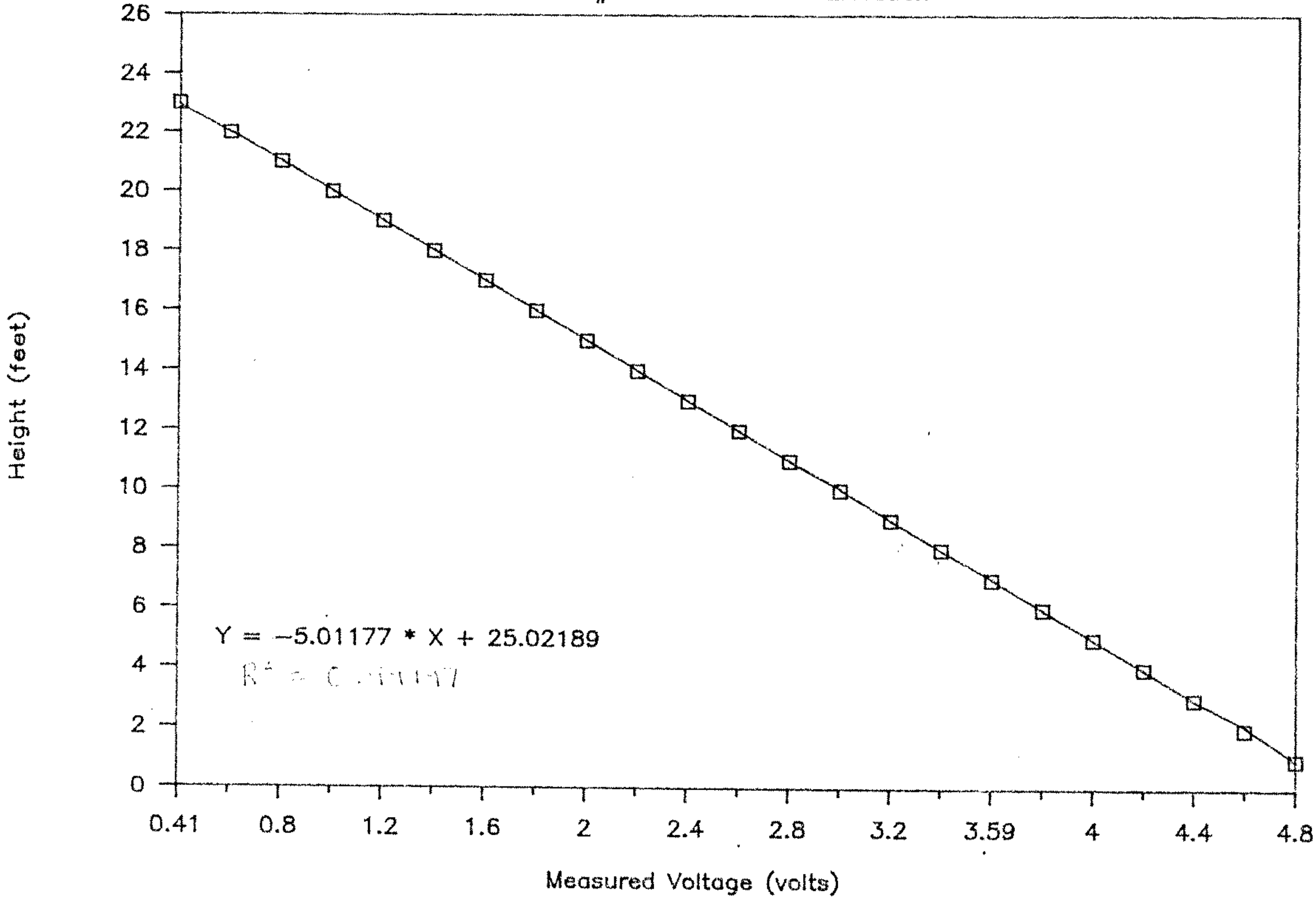


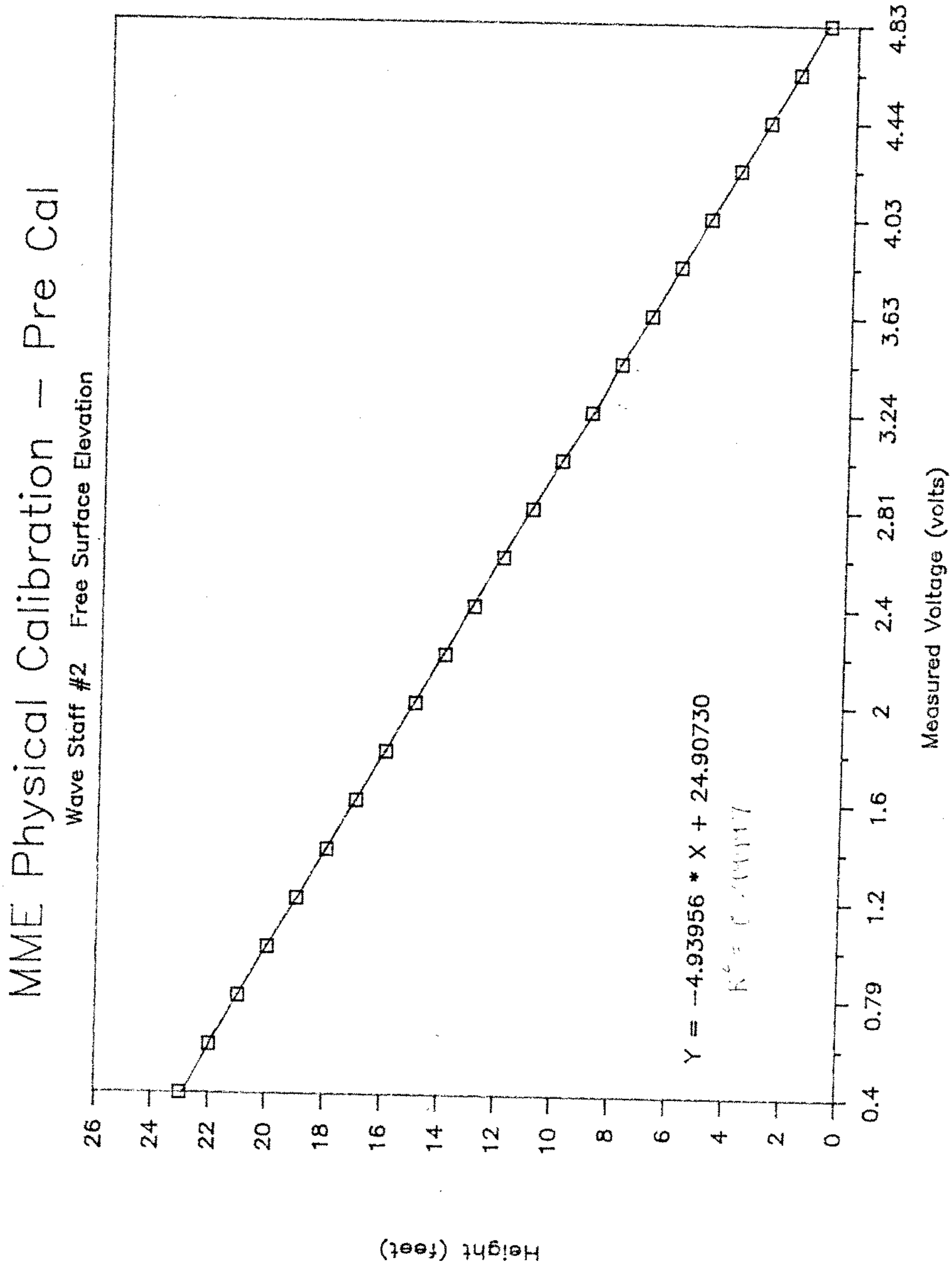
MME Physical Calibration – April 1986

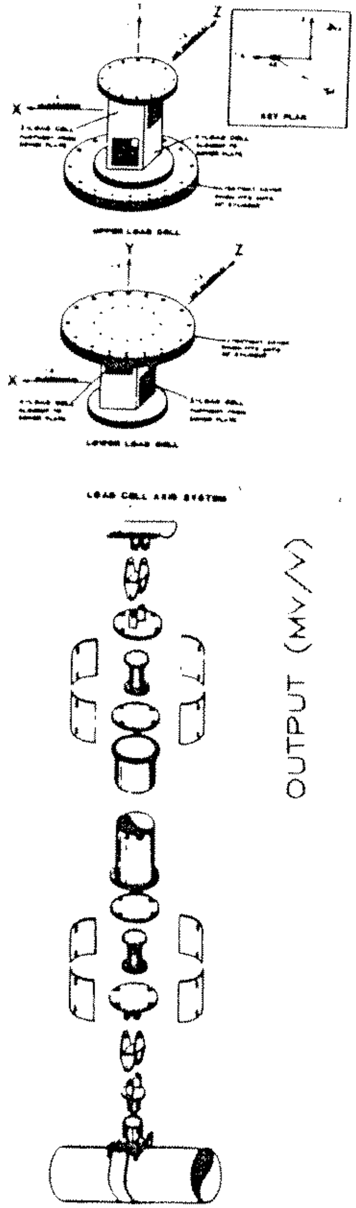


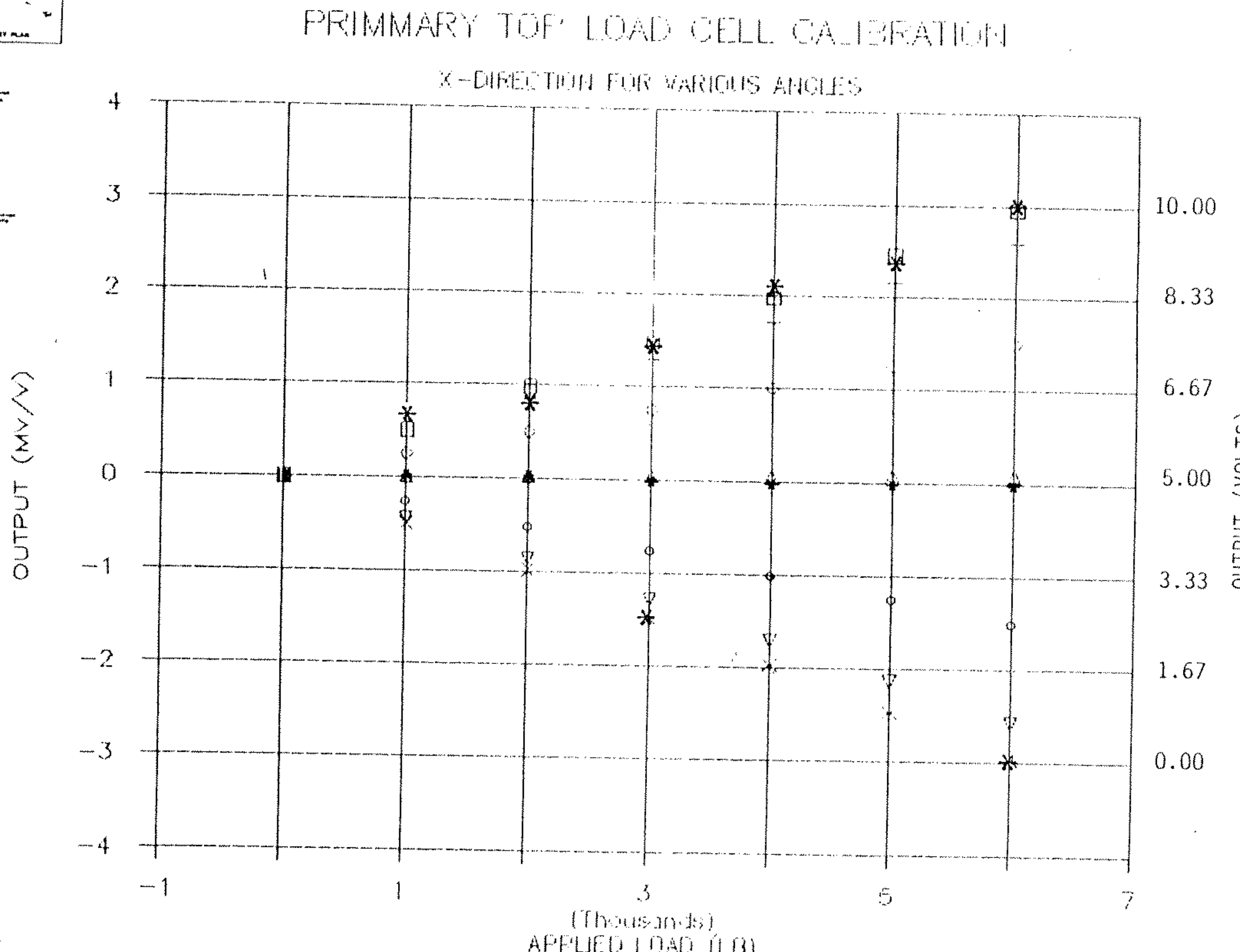
MME Physical Calibration — Pre Cal

Wave Staff #1 Free Surface Elevation



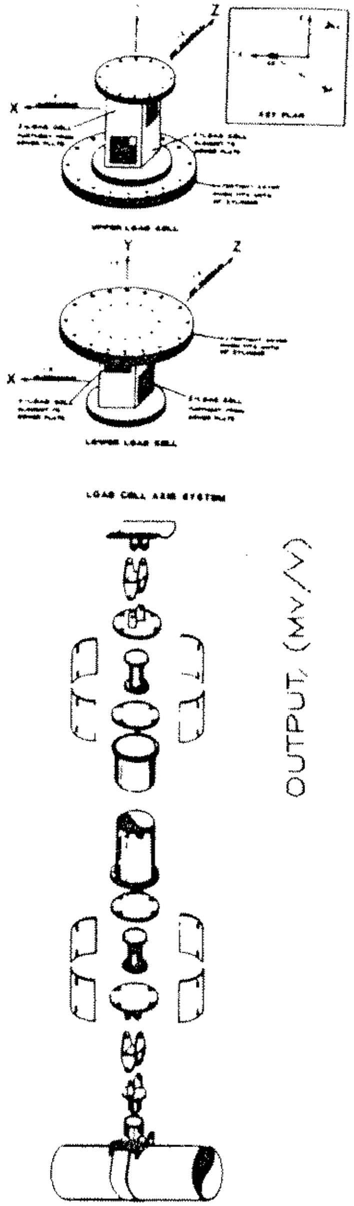

MME Physical Calibration — Pre Cal
Wave Staff #2 Free Surface Elevation
Y = -4.93956 * X + 24.90730
Height (feet)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0.4
0.79
1.2
1.6
2
2.4
2.81
3.24
3.63
4.03
4.44
4.83
Measured Voltage (volts)

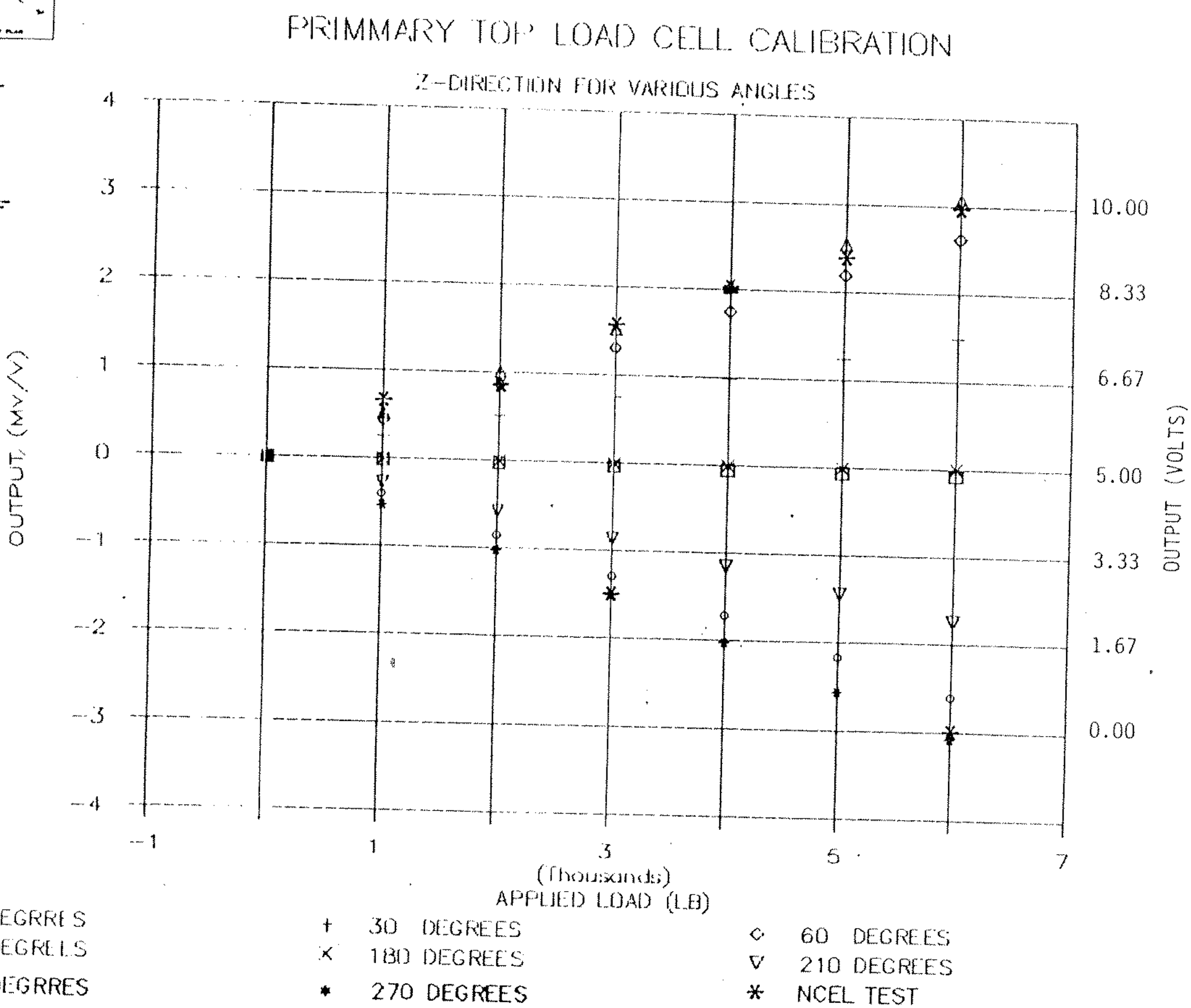




□ 0 DEGRRES	+ 30 DEGREES	◇ 60 DEGREES
△ 90 DEGREES	× 180 DEGREES	▽ 210 DEGREES
○ 240 DEGRRES	✱ 270 DEGREES	* NCEL TEST

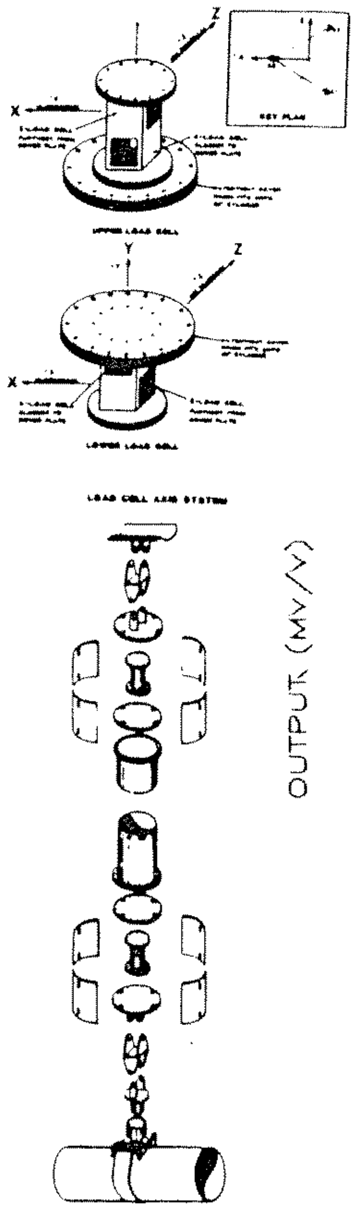
F RE -2





PRIMMARY TOP LOAD CELL CALIBRATION
Z-DIRECTION FOR VARIOUS ANGLES
OUTPUT (MV/V)
4
3
2
1
0
-1
-2
-3
-4
OUTPUT (VOLTS)
10.00
8.33
6.67
5.00
3.33
1.67
0.00
-1
1
3
5
7
(Thousands)
APPLIED LOAD (LB)
□ 0 DEGRRES
Δ 90 DEGRELS
○ 240 DEGRRES
+ 30 DEGREES
× 180 DEGREES
* 270 DEGREES
◇ 60 DEGREES
▽ 210 DEGREES
✳ NCEL TEST

FIGURE 8.0-3



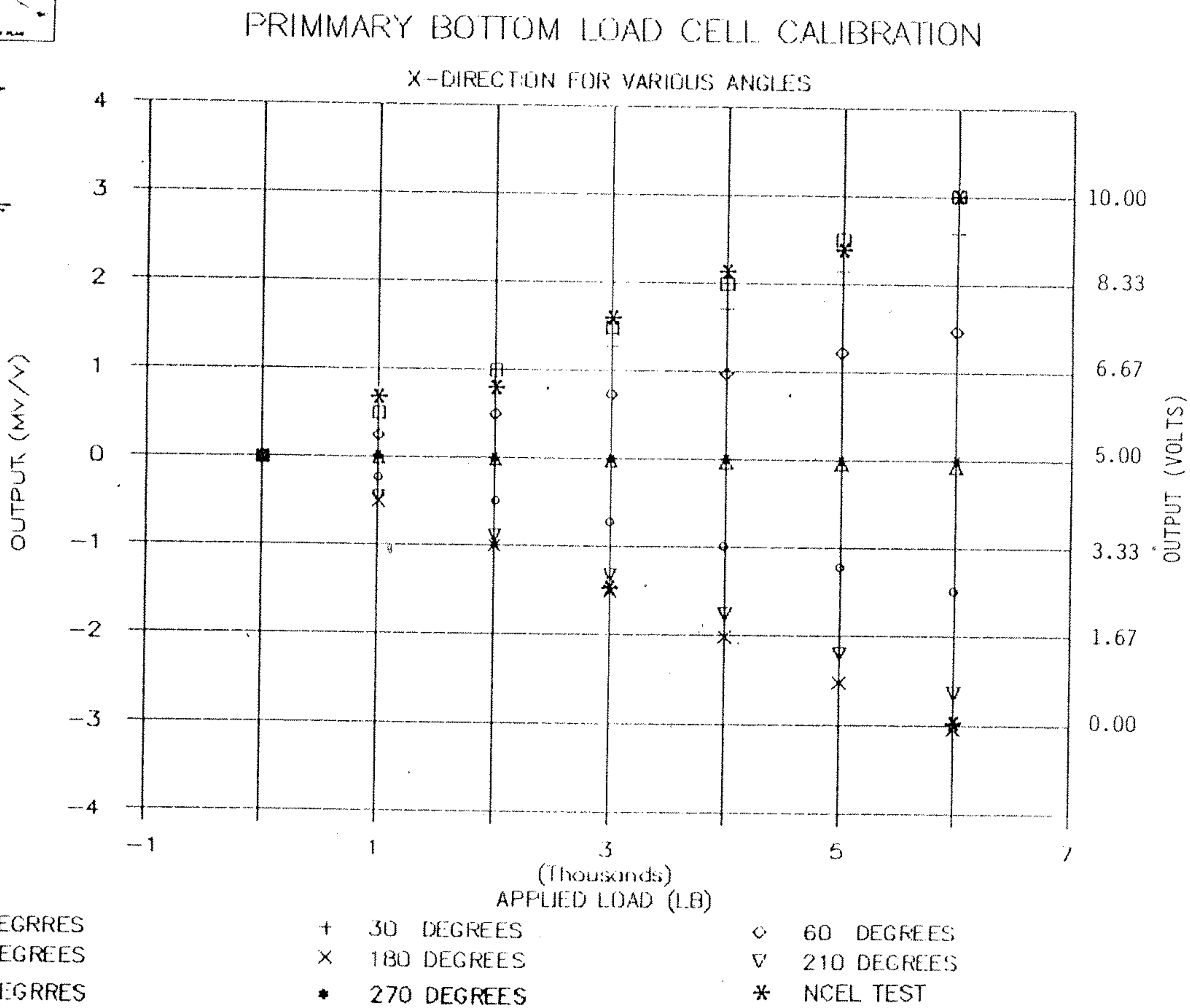
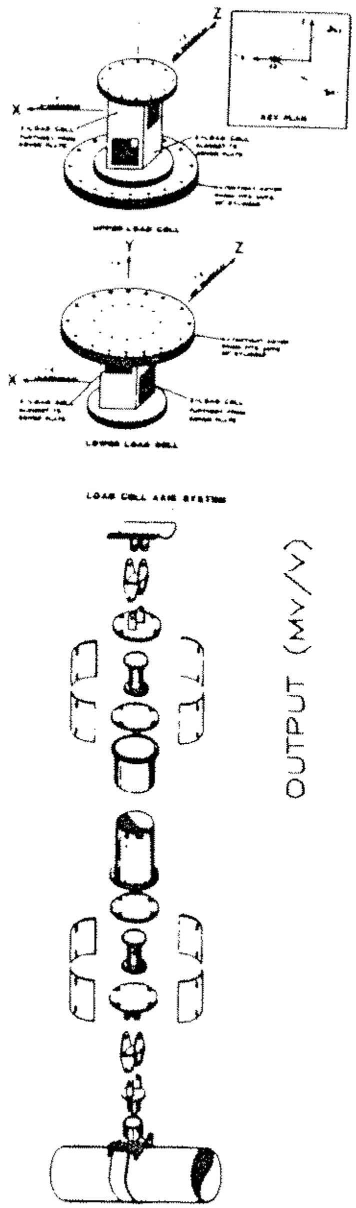
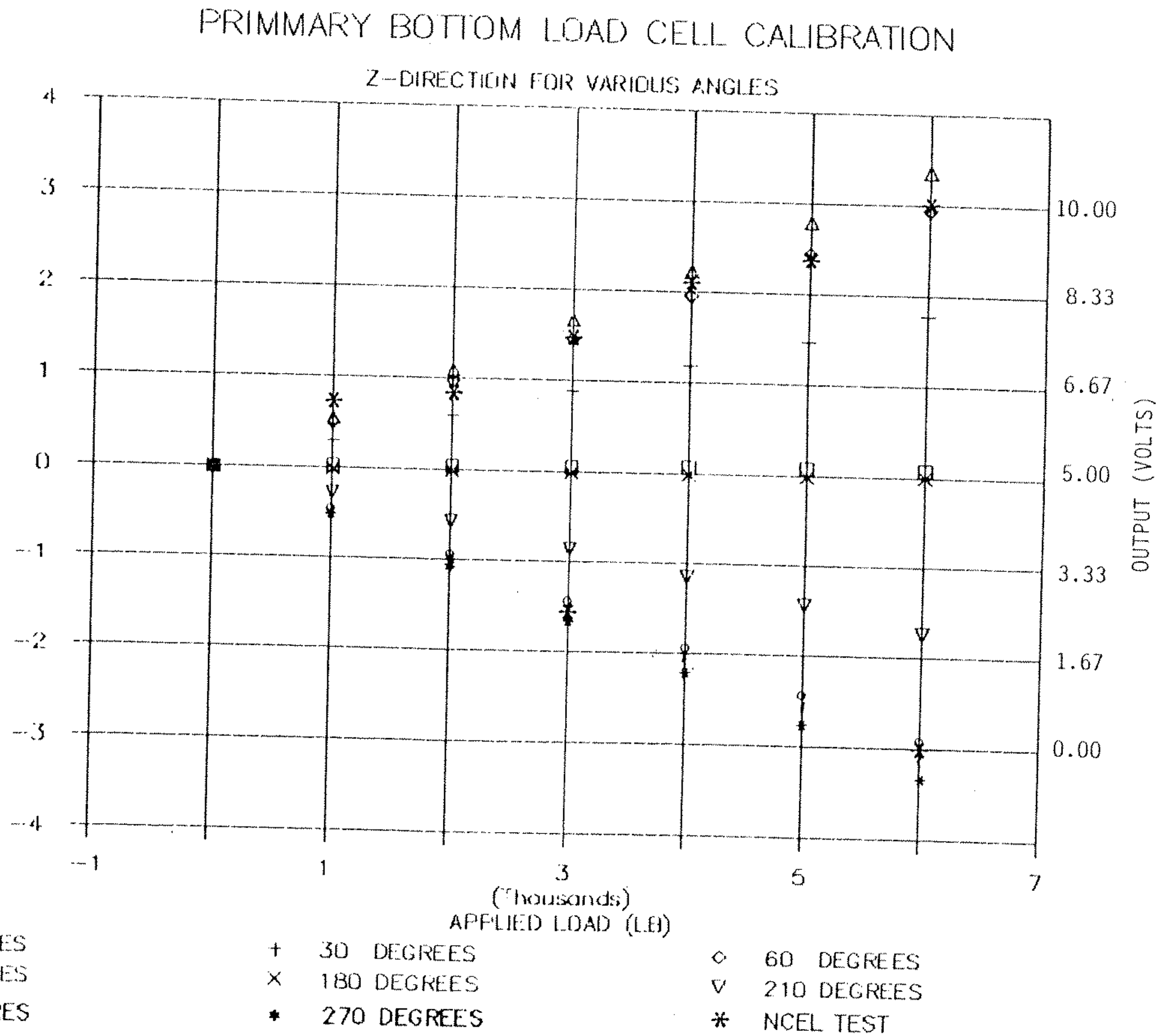

PRIMMARY BOTTOM LOAD CELL CALIBRATION
X-DIRECTION FOR VARIOUS ANGLES
OUTPUT (MV/V)
OUTPUT (VOLTS)
4
3
2
1
0
-1
-2
-3
-4
10.00
8.33
6.67
5.00
3.33
1.67
0.00
-1
1
3
5
7
(Thousands)
APPLIED LOAD (LB)
□ 0 DEGRRES
Δ 90 DEGREES
o 240 DEGRRES
+ 30 DEGREES
× 180 DEGREES
✱ 270 DEGREES
◇ 60 DEGREES
∇ 210 DEGREES
* NCEL TEST

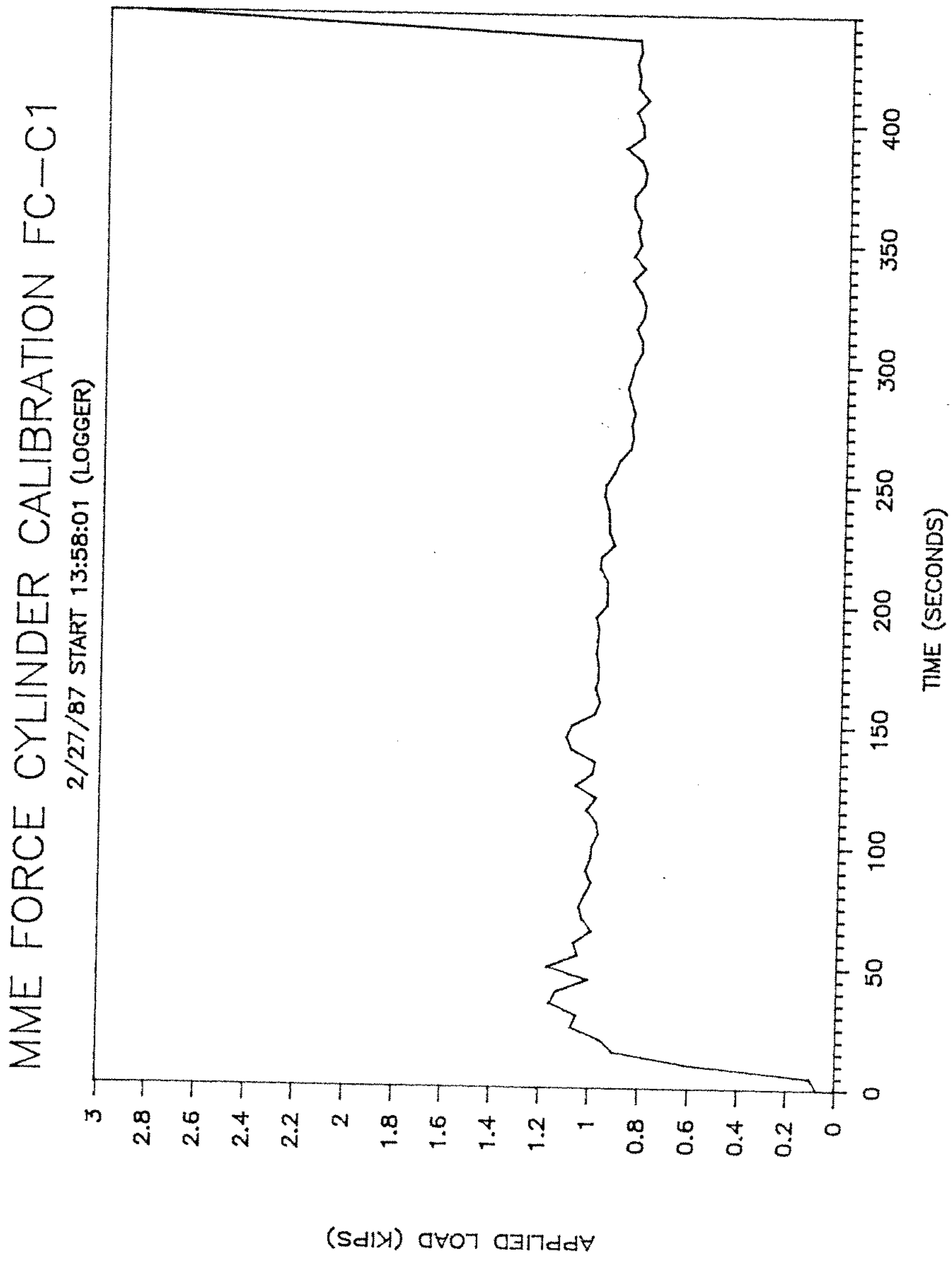
FIGURE 0-4





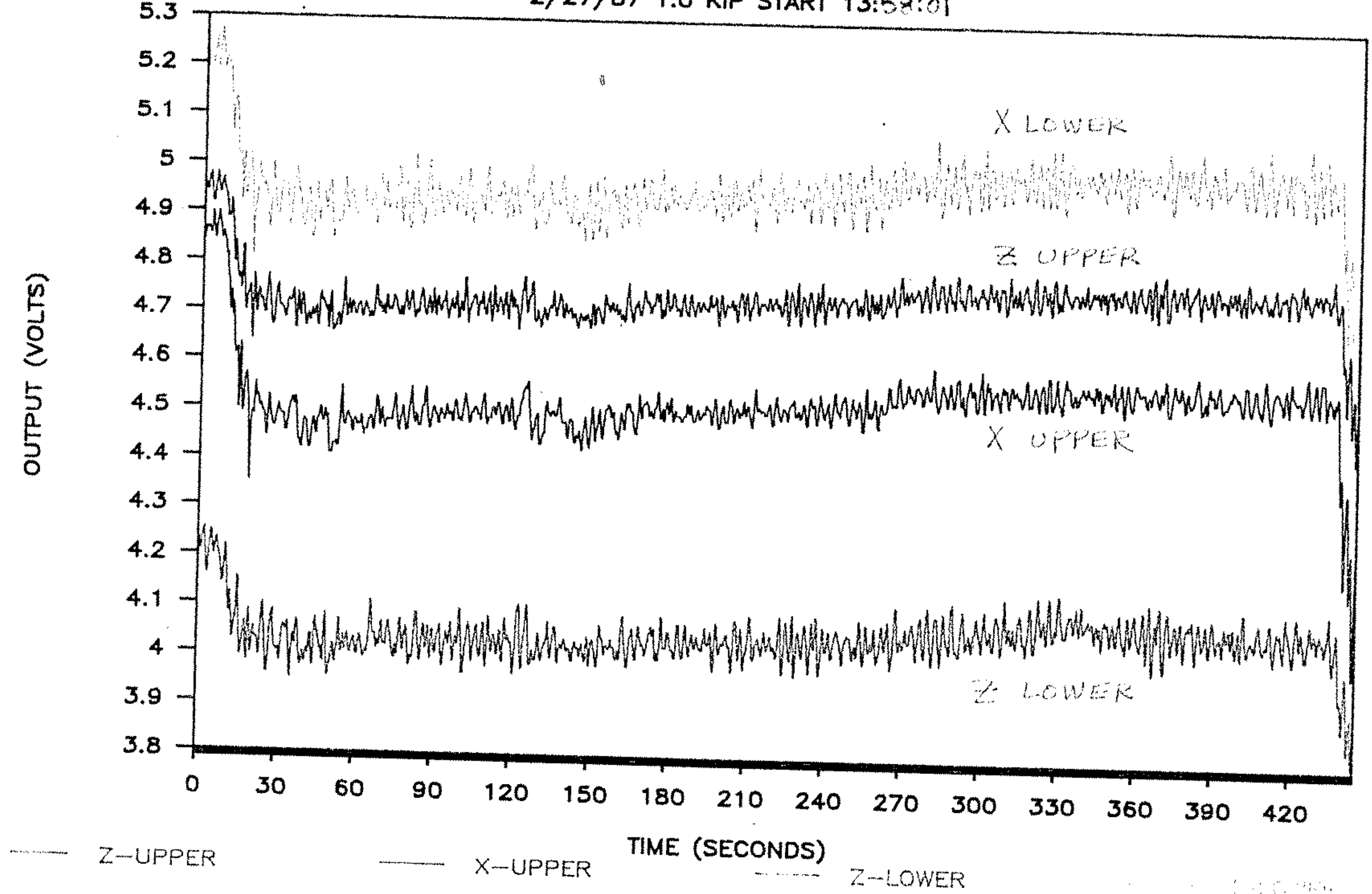
PRIMMARY BOTTOM LOAD CELL CALIBRATION
Z-DIRECTION FOR VARIOUS ANGLES
OUTPUT (MV/V)
OUTPUT (VOLTS)
4
3
2
1
0
-1
-2
-3
-4
10.00
8.33
6.67
5.00
3.33
1.67
0.00
-1
1
3
5
7
(Thousands)
APPLIED LOAD (LB)
□ 0 DEGRRES
Δ 90 DEGREES
o 240 DEGRRES
+ 30 DEGREES
× 180 DEGREES
* 270 DEGREES
◇ 60 DEGREES
∇ 210 DEGREES
* NCEL TEST

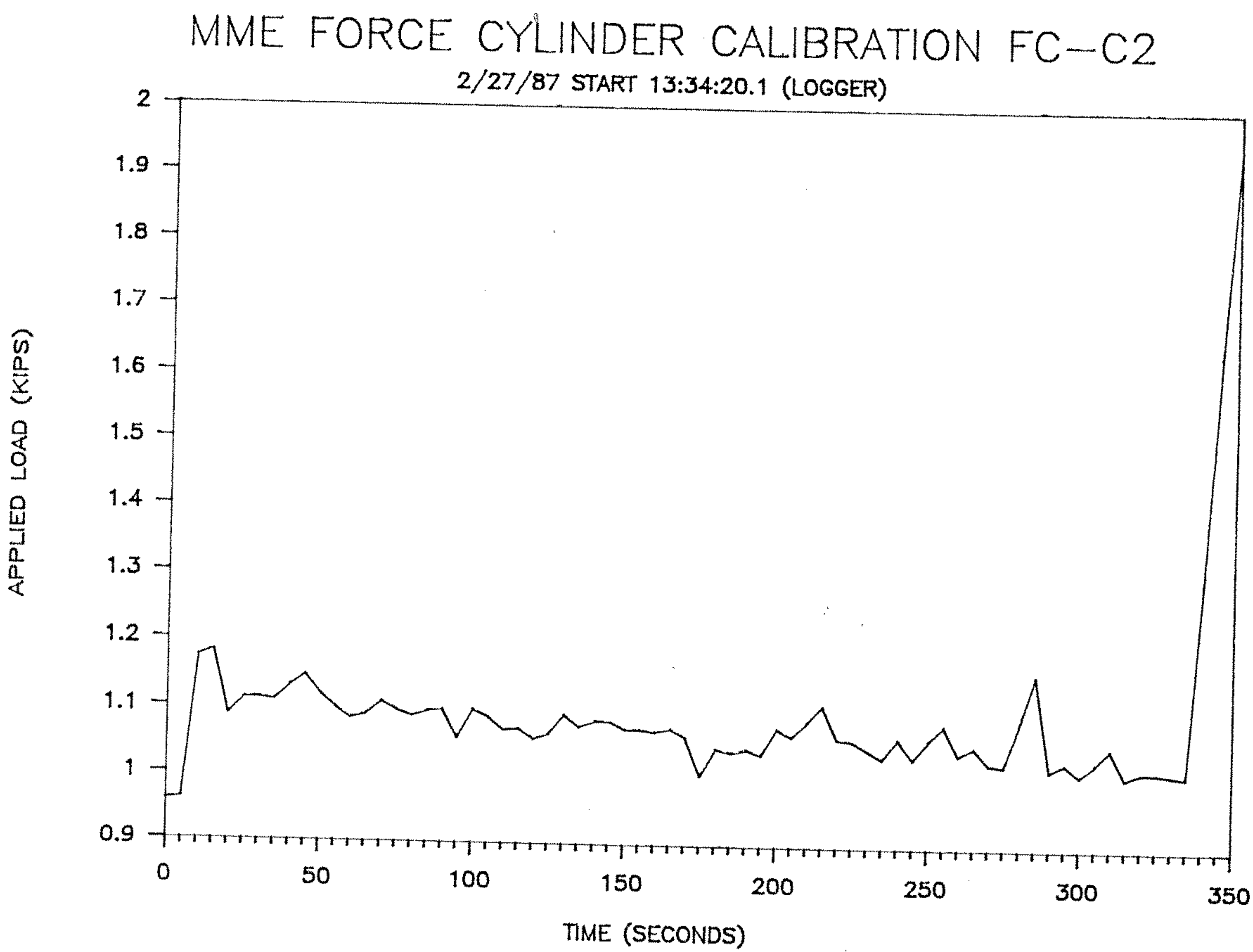
FIGURE 8.0-5

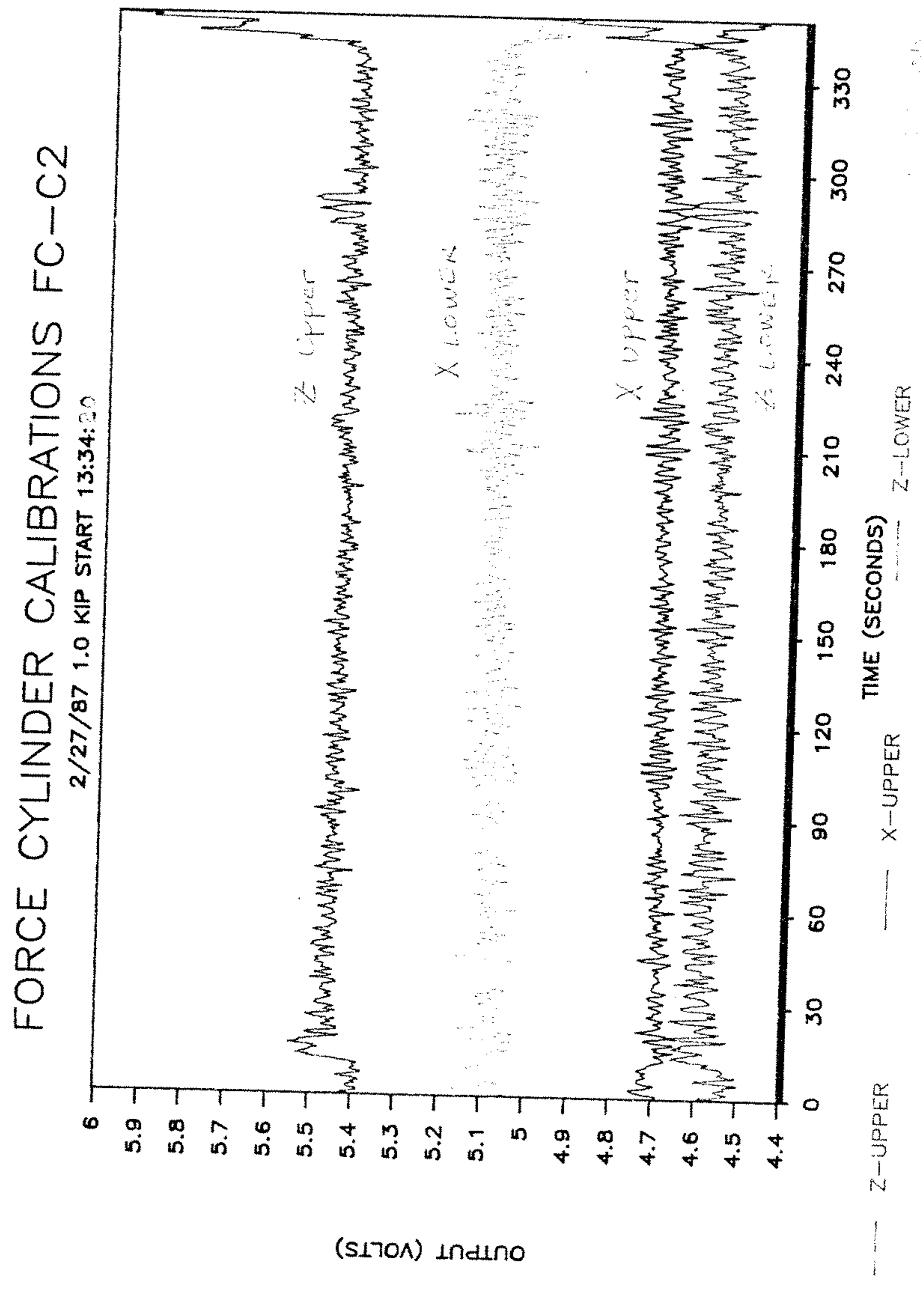

MME FORCE CYLINDER CALIBRATION FC—C1
2/27/87 START 13:58:01 (LOGGER)
APPLIED LOAD (KIPS)
TIME (SECONDS)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
50
100
150
200
250
300
350
400

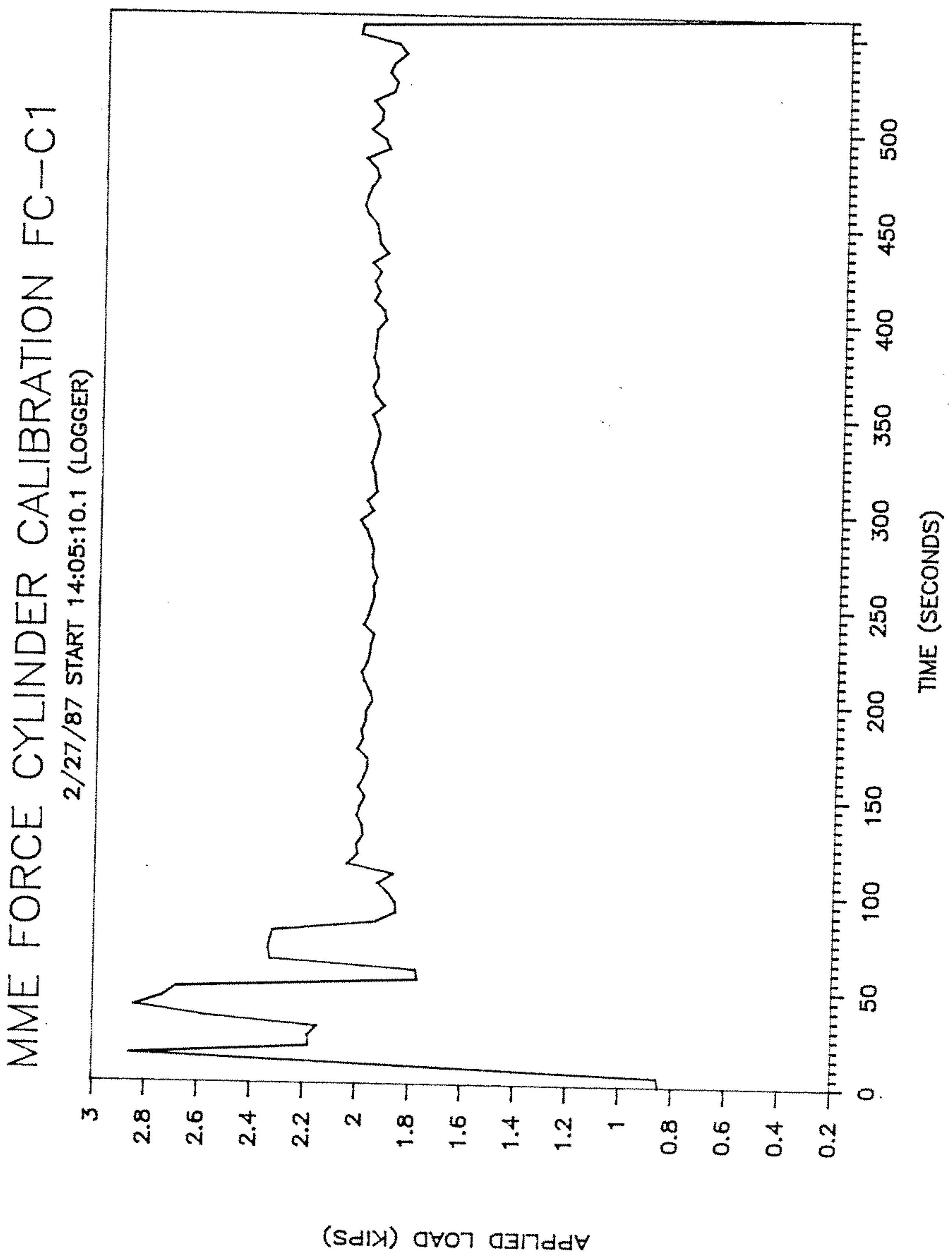
FORCE CYLINDER CALIBRATIONS FC—C1

2/27/87 1.0 KIP START 13:58:01



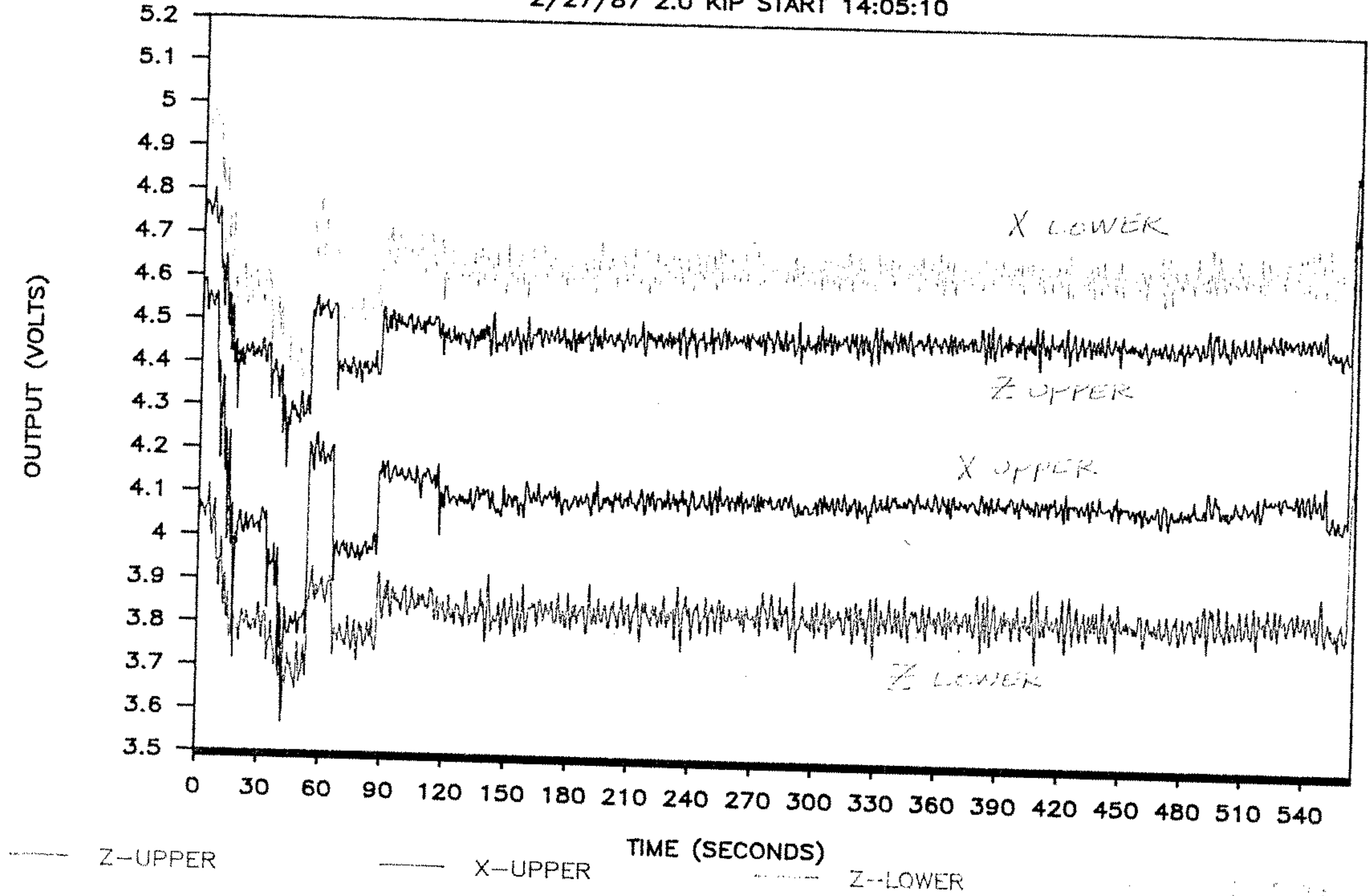

MME FORCE CYLINDER CALIBRATION FC—C2
2/27/87 START 13:34:20.1 (LOGGER)
APPLIED LOAD (KIPS)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0
50
100
150
200
250
300
350
TIME (SECONDS)


FORCE CYLINDER CALIBRATIONS FC—C2
2/27/87 1.0 KIP START 13:34:20
OUTPUT (VOLTS)
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
0
30
60
90
120
150
180
210
240
270
300
330
TIME (SECONDS)
Z Upper
X Lower
X Upper
Z Lower
Z—UPPER
X—UPPER
Z—LOWER


MME FORCE CYLINDER CALIBRATION FC—C1
2/27/87 START 14:05:10.1 (LOGGER)
APPLIED LOAD (KIPS)
TIME (SECONDS)
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
0
50
100
150
200
250
300
350
400
450
500

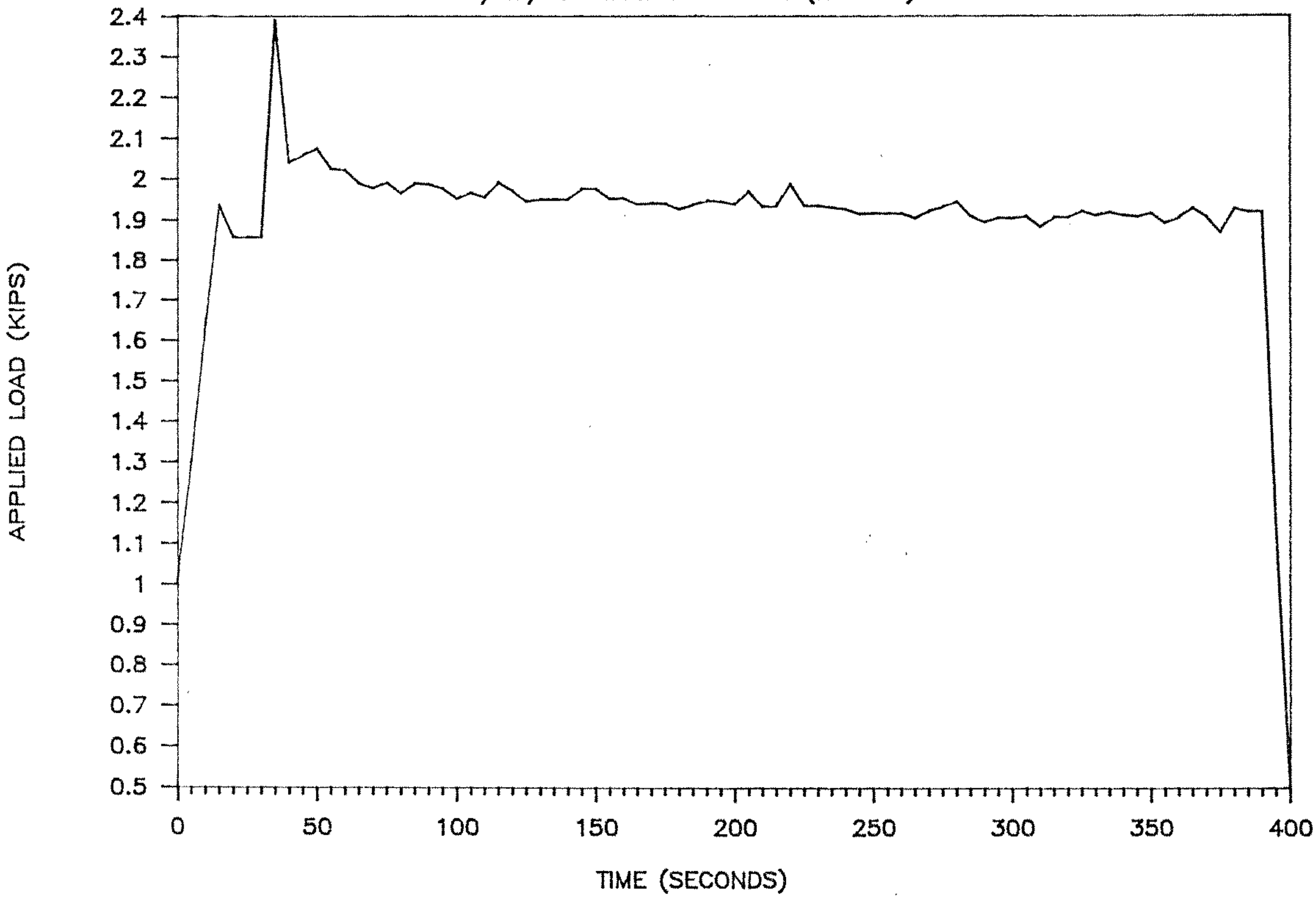
FORCE CYLINDER CALIBRATIONS FC—C1

2/27/87 2.0 KIP START 14:05:10



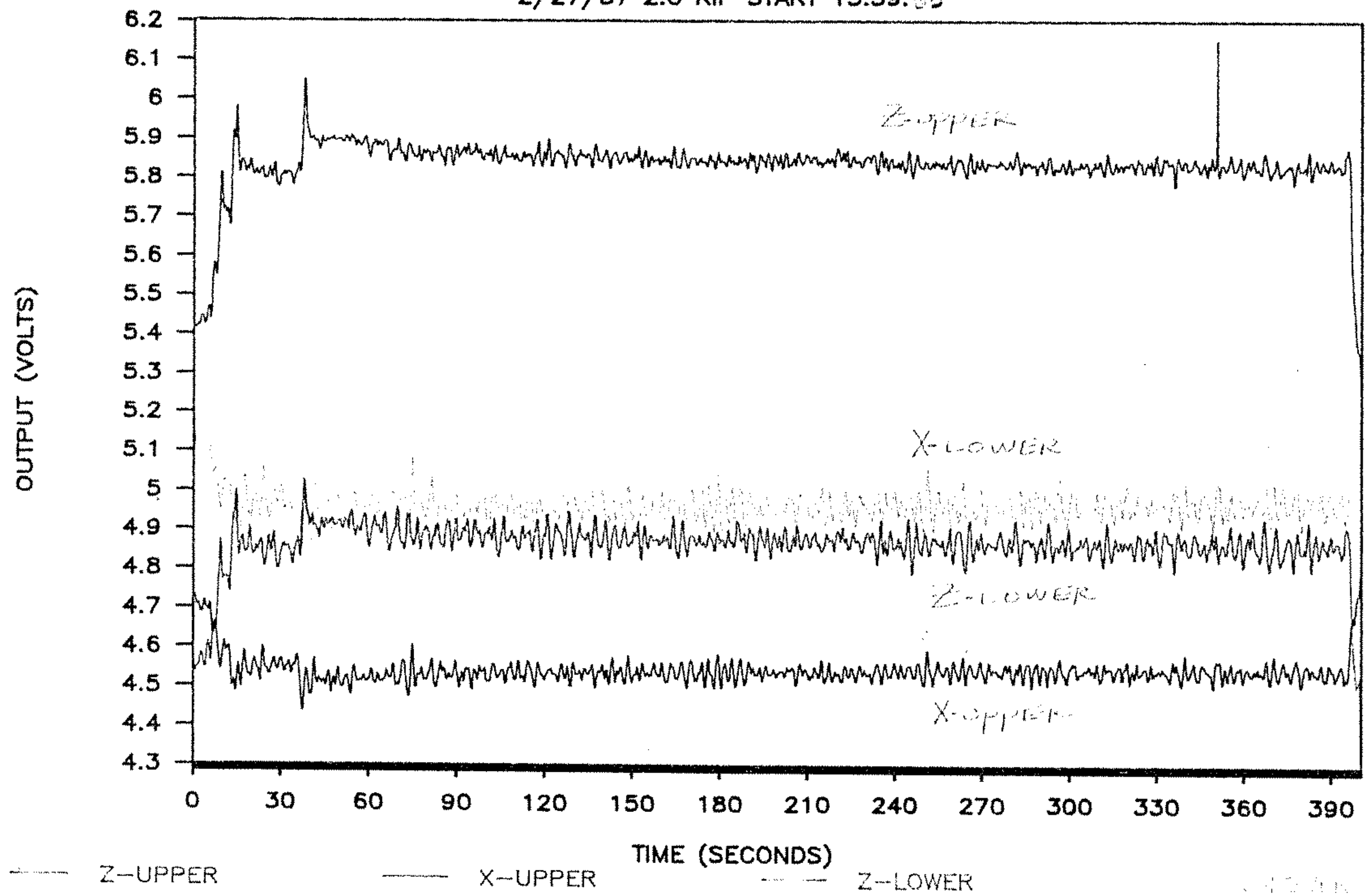
MME FORCE CYLINDER CALIBRATION FC—C2

2/27/87 START 13:39:55.1 (LOGGER)



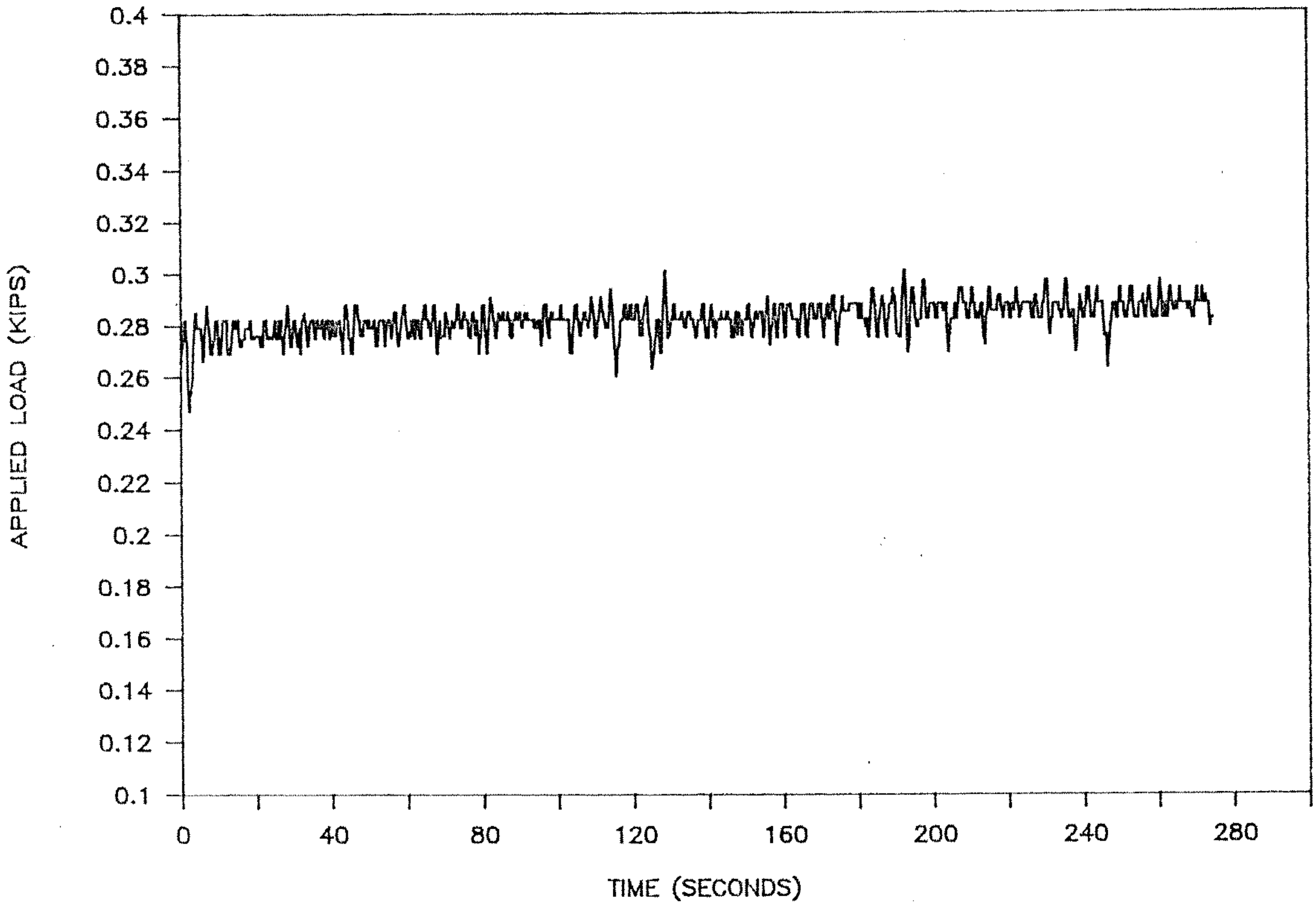
FORCE CYLINDER CALIBRATIONS FC–C2

2/27/87 2.0 KIP START 13:39:55



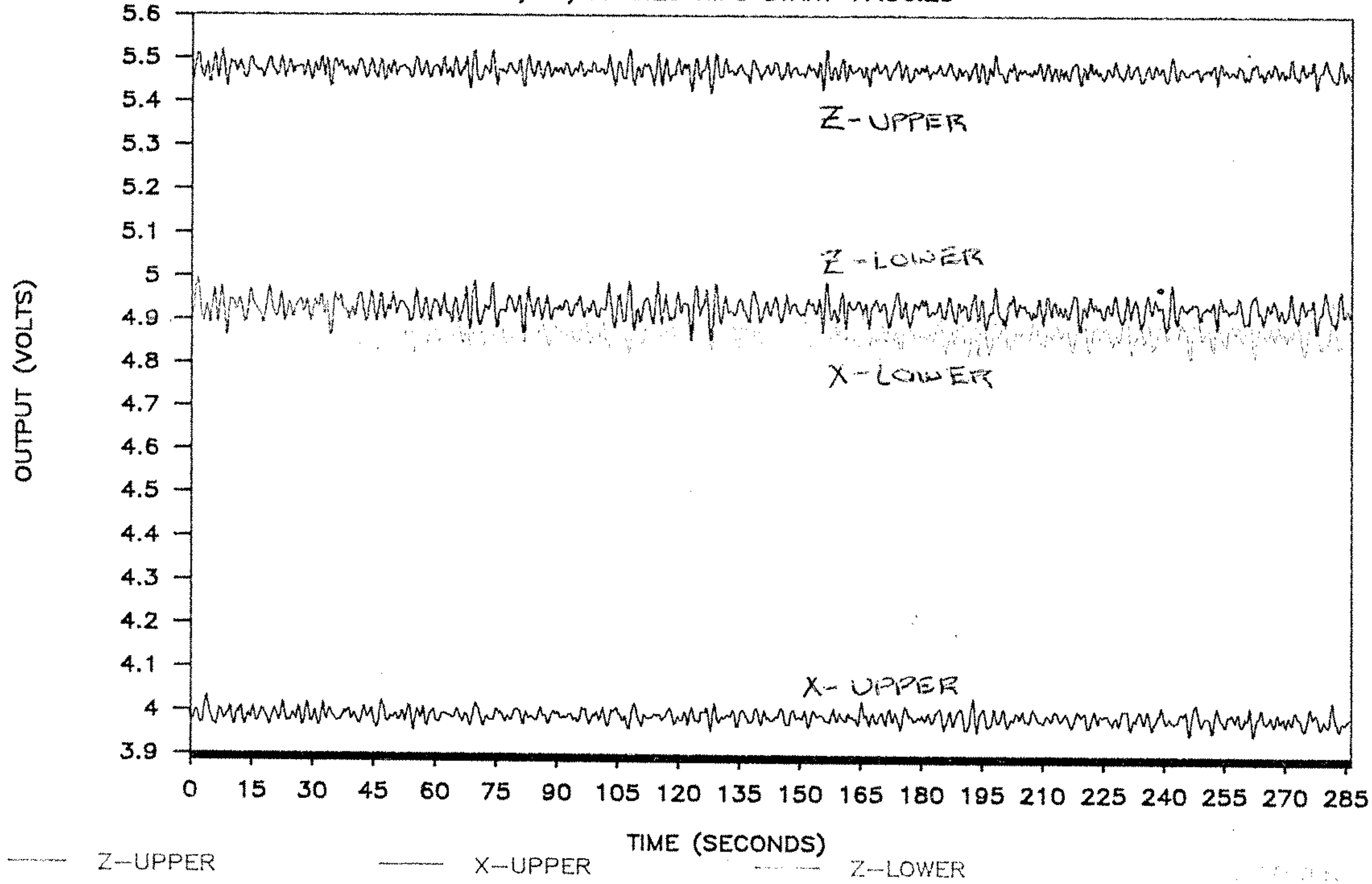
FORCE CYLINDER CALIBRATION FC—C1

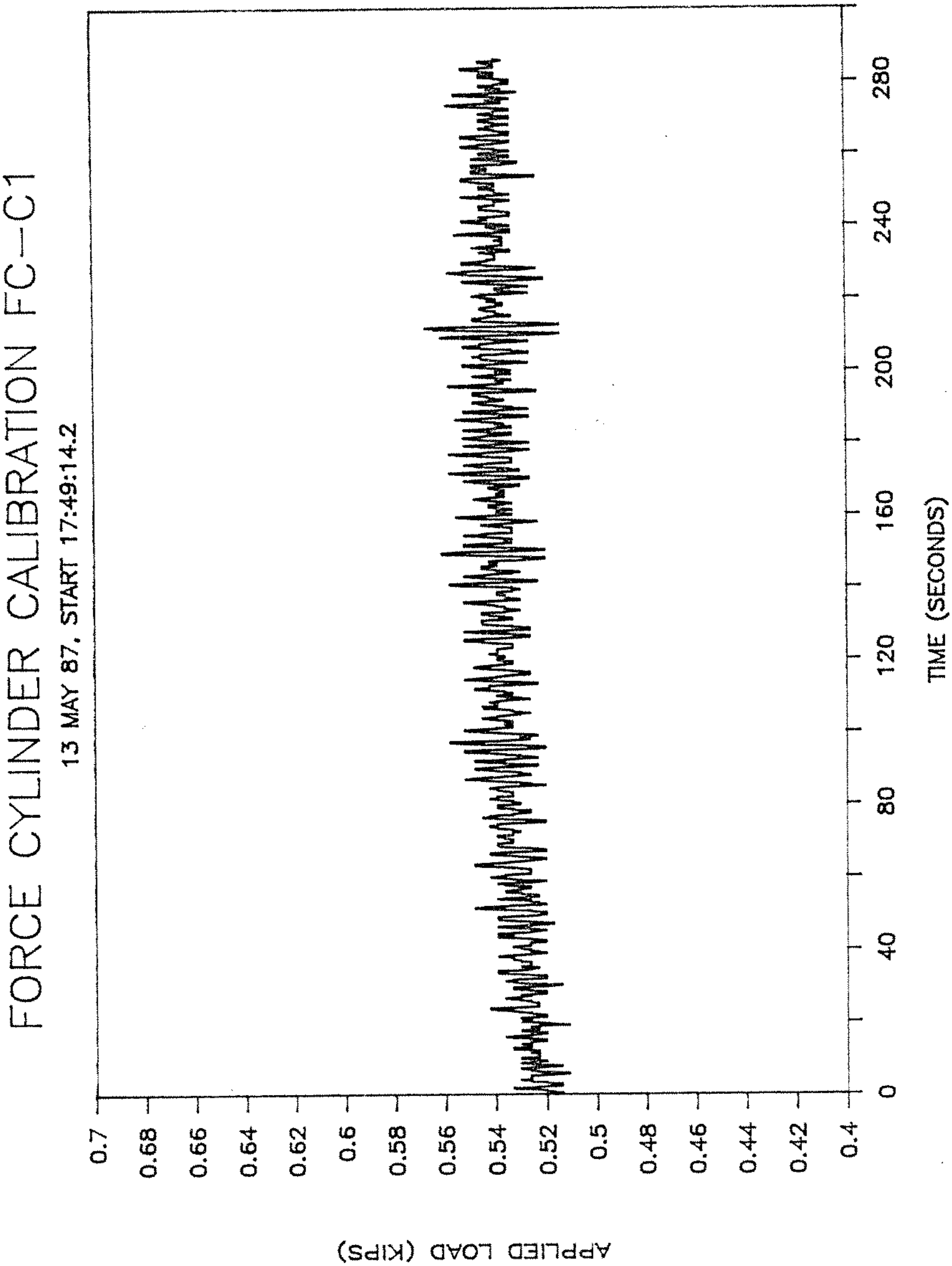
13 MAY 87, START 17:56:24.2



FORCE CYLINDER CALIBRATIONS FC—C1

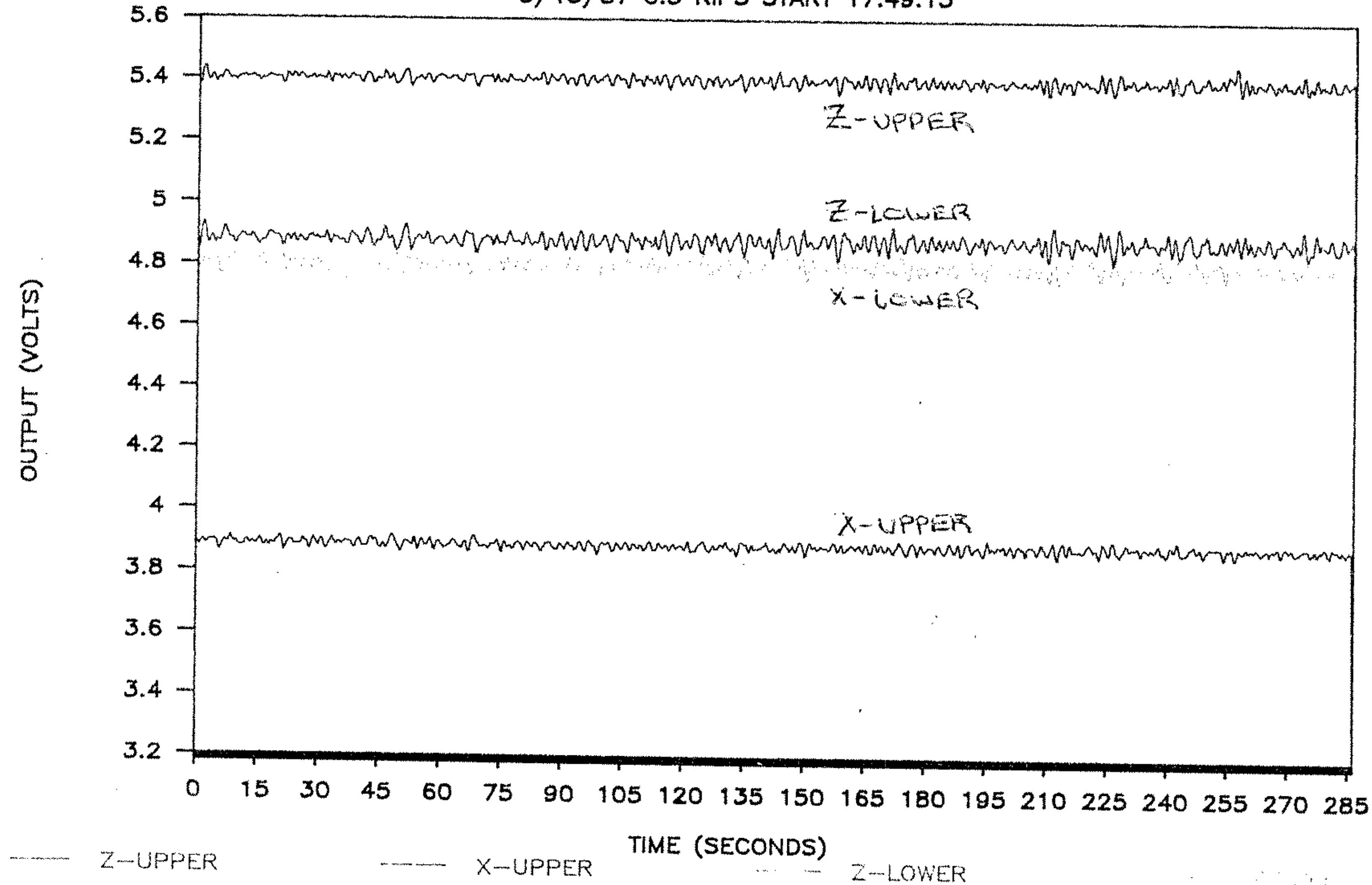
5/13/87 0.25 KIPS START 17:56:25

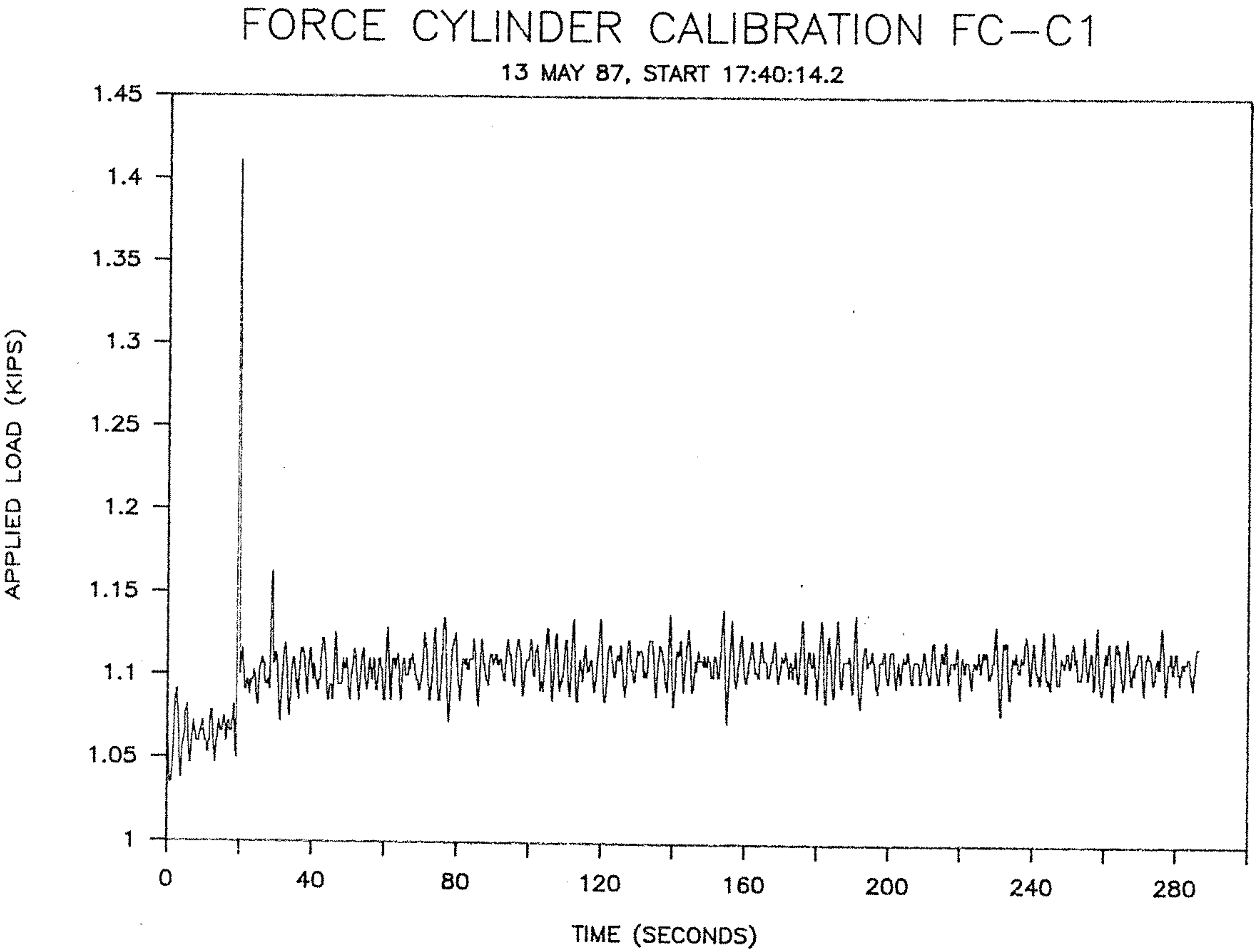



FORCE CYLINDER CALIBRATION FC—C1
13 MAY 87, START 17:49:14.2
APPLIED LOAD (KIPS)
0.7
0.68
0.66
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0.5
0.48
0.46
0.44
0.42
0.4
TIME (SECONDS)
0
40
80
120
160
200
240
280

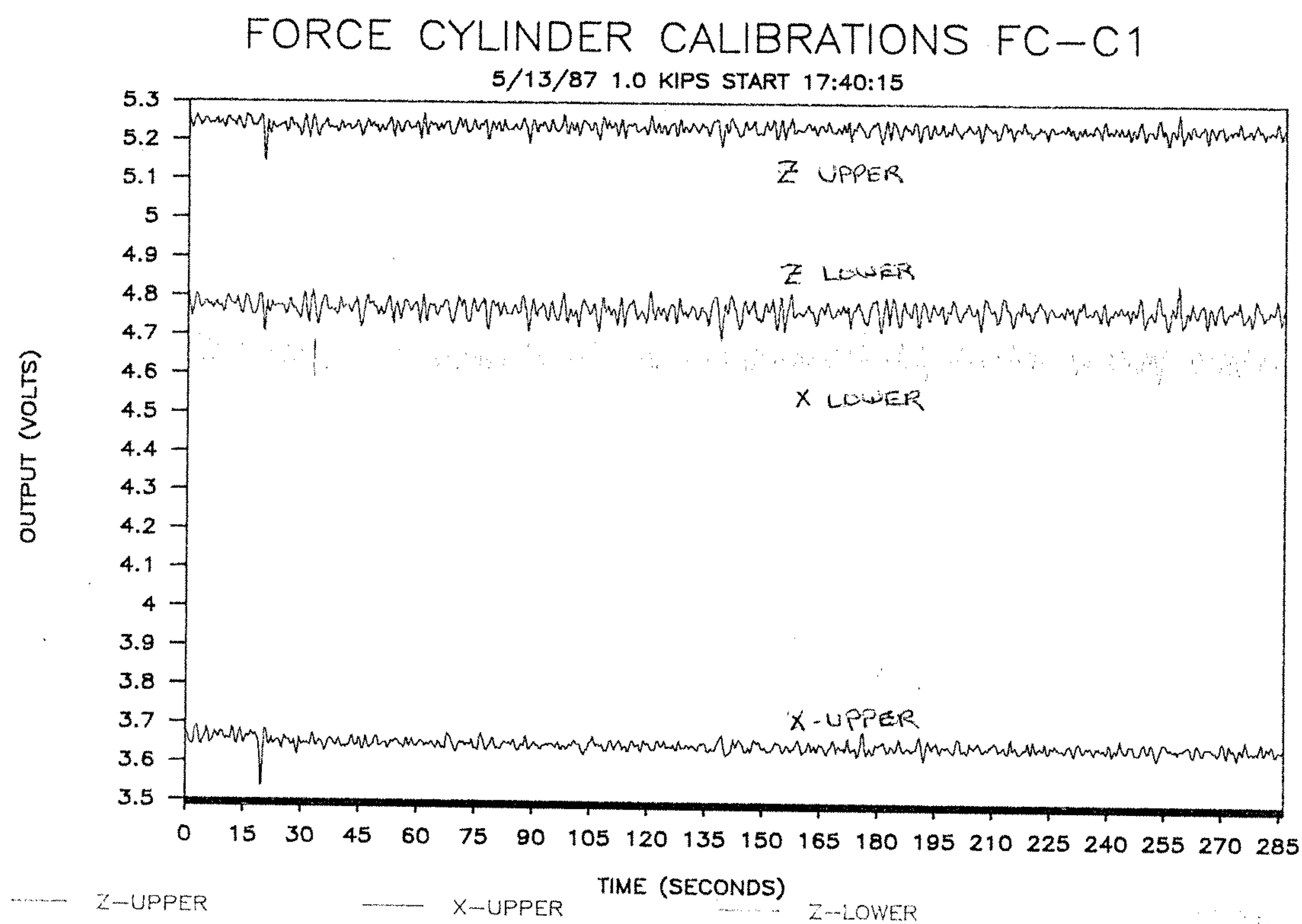
FORCE CYLINDER CALIBRATIONS FC—C1

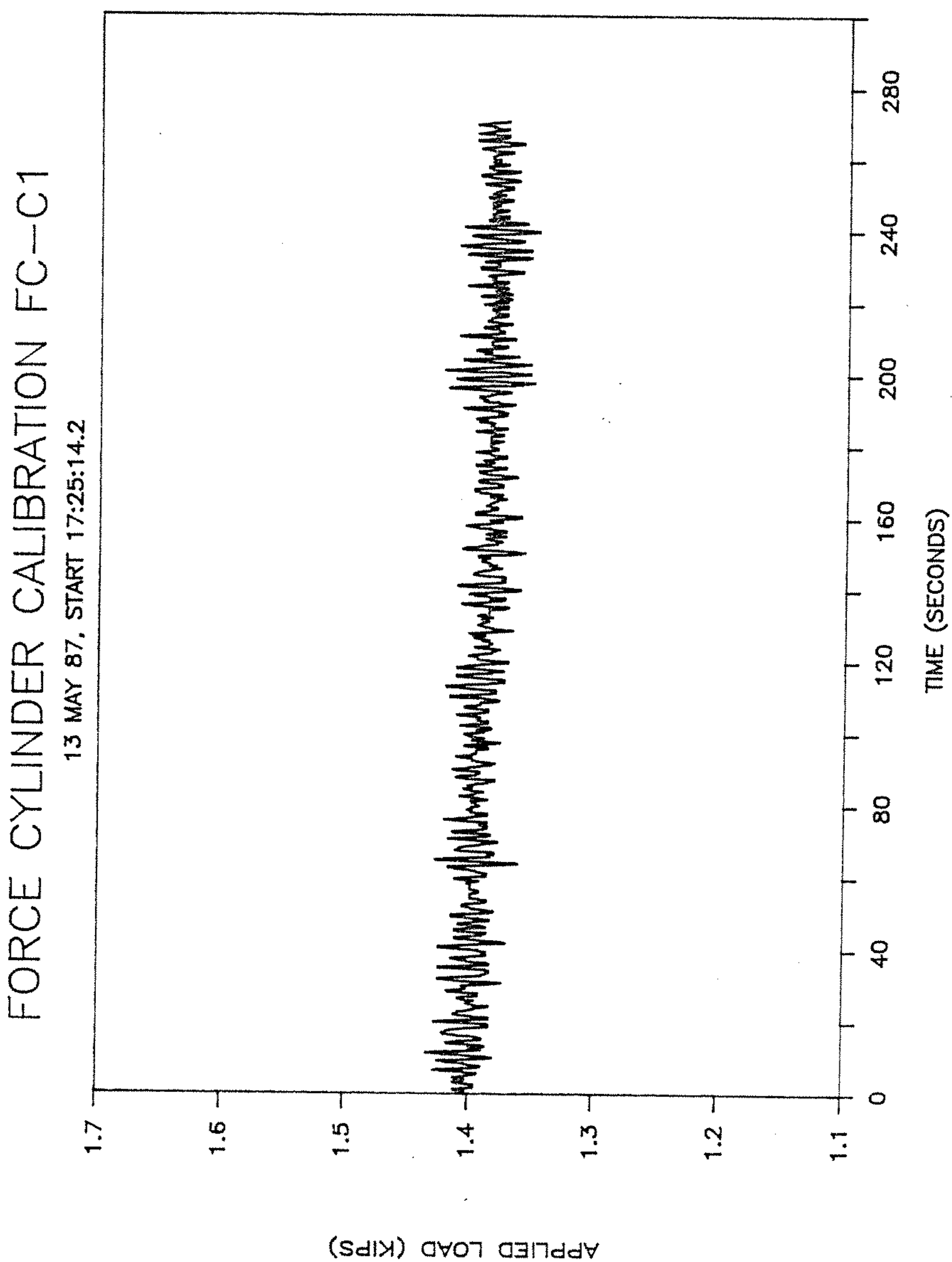
5/13/87 0.5 KIPS START 17:49:15





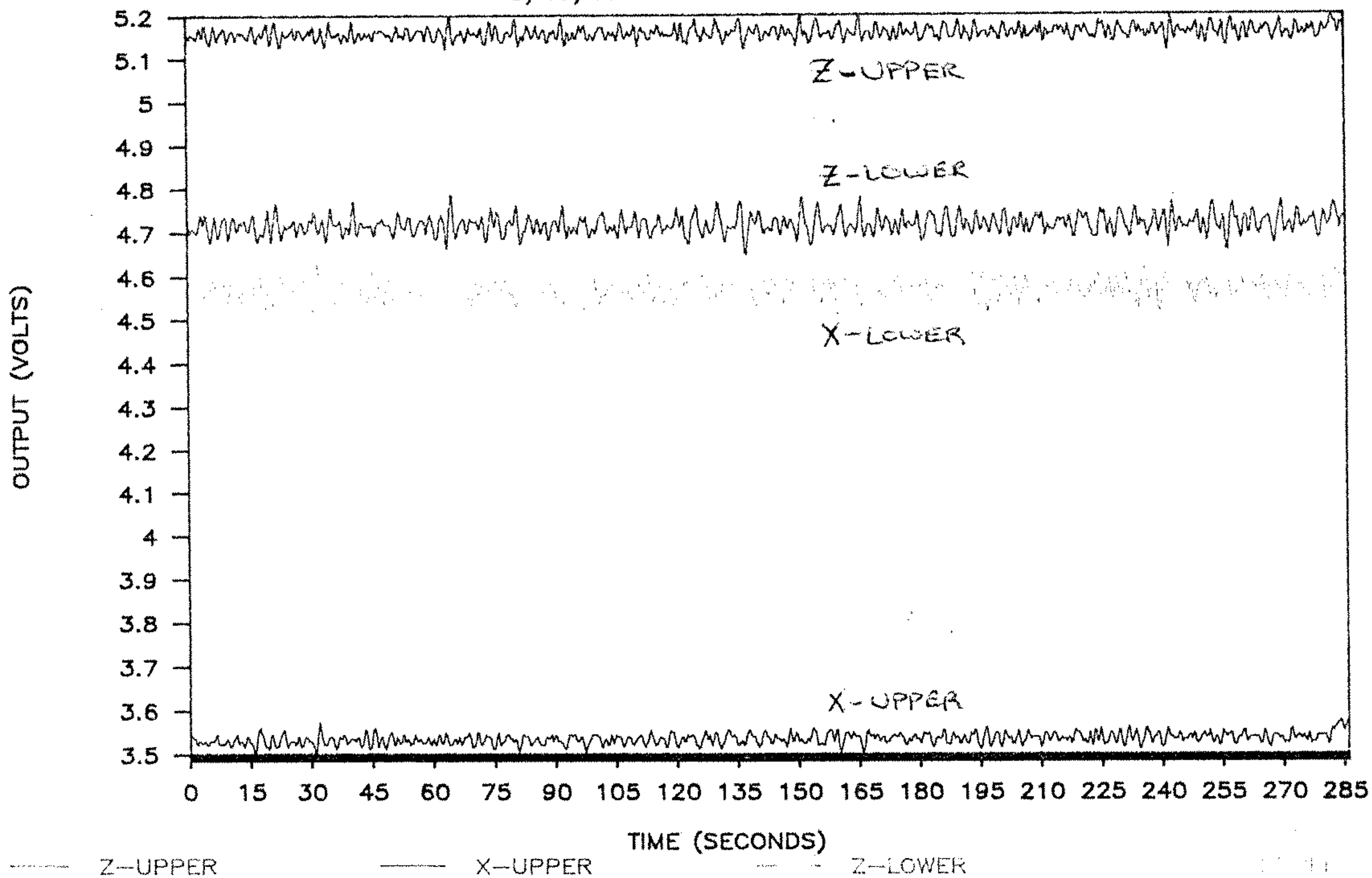
FORCE CYLINDER CALIBRATION FC—C1
13 MAY 87, START 17:40:14.2
APPLIED LOAD (KIPS)
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0
40
80
120
160
200
240
280
TIME (SECONDS)


FORCE CYLINDER CALIBRATIONS FC—C1
5/13/87 1.0 KIPS START 17:40:15
OUTPUT (VOLTS)
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
Z UPPER
Z LOWER
X LOWER
X-UPPER
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285
TIME (SECONDS)
Z—UPPER
X—UPPER
Z--LOWER


FORCE CYLINDER CALIBRATION FC—C1
13 MAY 87, START 17:25:14.2
APPLIED LOAD (KIPS)
1.7
1.6
1.5
1.4
1.3
1.2
1.1
TIME (SECONDS)
0
40
80
120
160
200
240
280

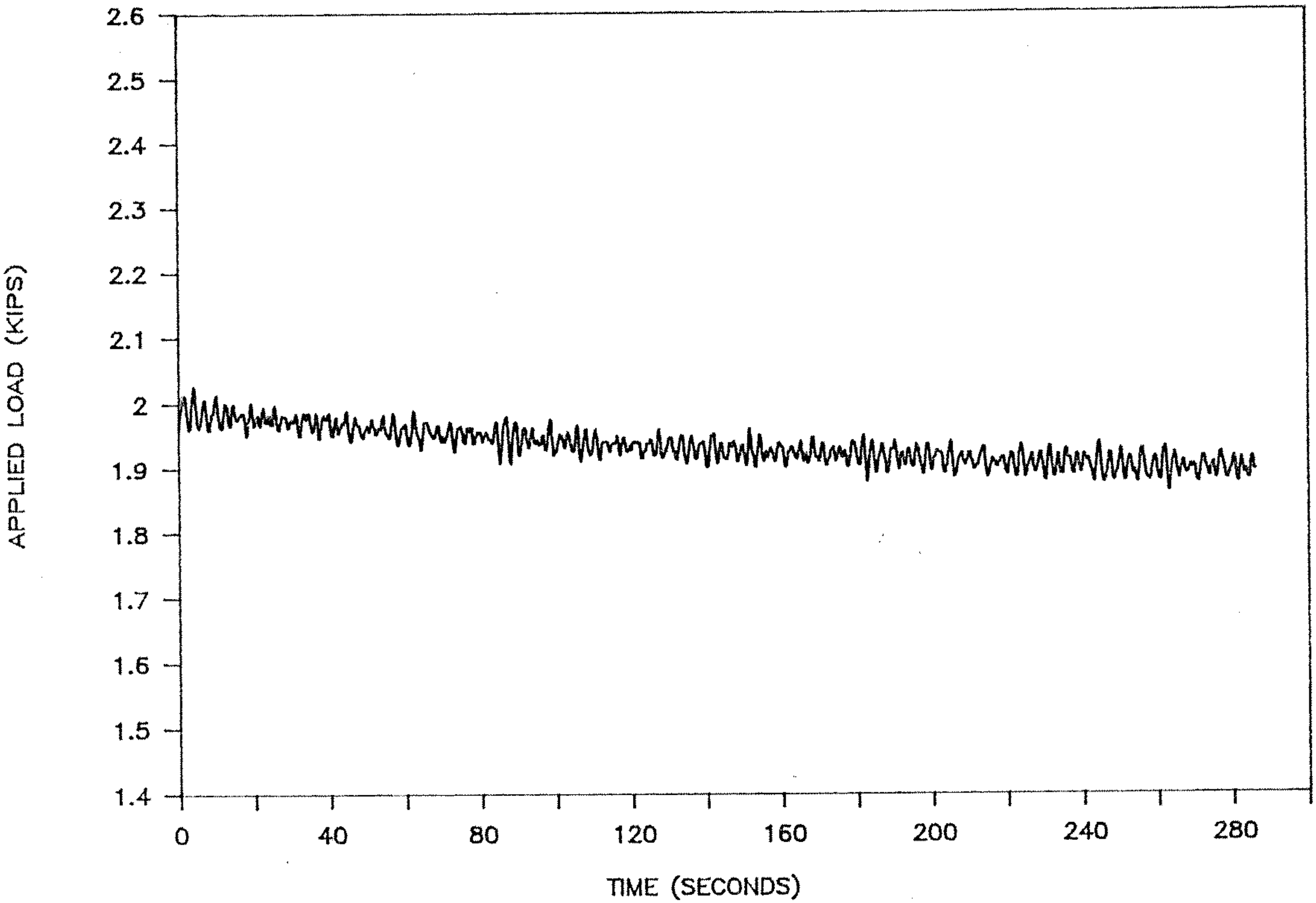
FORCE CYLINDER CALIBRATIONS FC—C1

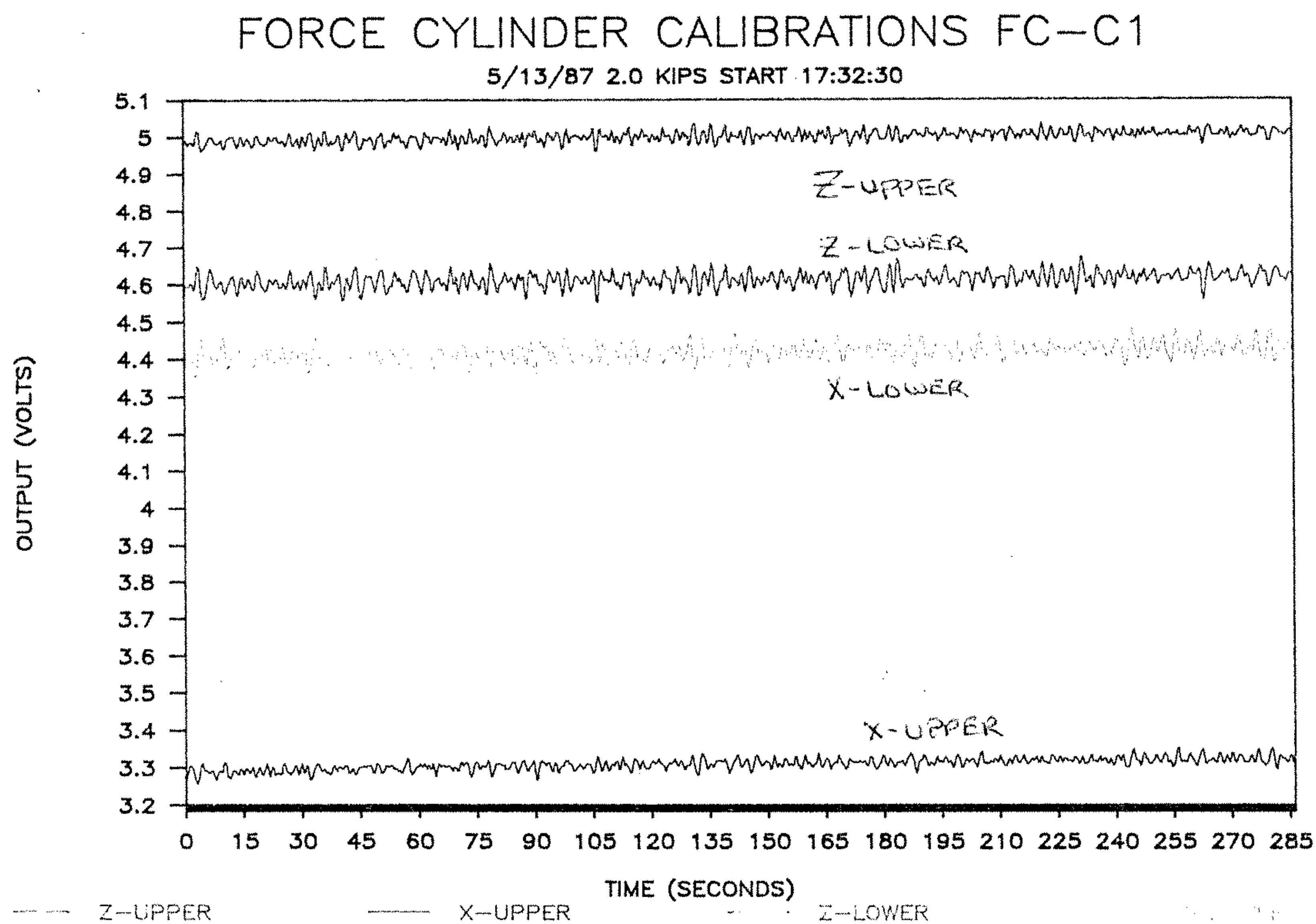
5/13/87 1.5 KIP START 17:25:15



FORCE CYLINDER CALIBRATION FC—C1

13 MAY 87, START 17:32:29.2




FORCE CYLINDER CALIBRATIONS FC—C1
5/13/87 2.0 KIPS START 17:32:30
OUTPUT (VOLTS)
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285
TIME (SECONDS)
Z-UPPER
Z-LOWER
X-LOWER
X-UPPER
Z—UPPER
X—UPPER
Z—LOWER

APPENDIX C

ENVIRONMENTAL DATA

Appendix C consists of data plots produced from the remote environmental data collection systems. A technical description of the plots were produced as listed:

NDBC Buoy, plots of Significant Wave Height, Average Wave Period, Peak Wave Period and Wind Speed (MME waves for ******, Averaged Recorded Hourly)

NDBC Buoy, Directional Wave Spectrum Plots

NDBC Buoy, Non-directional Wave Spectrum Plots (MME Energy Spectrum)

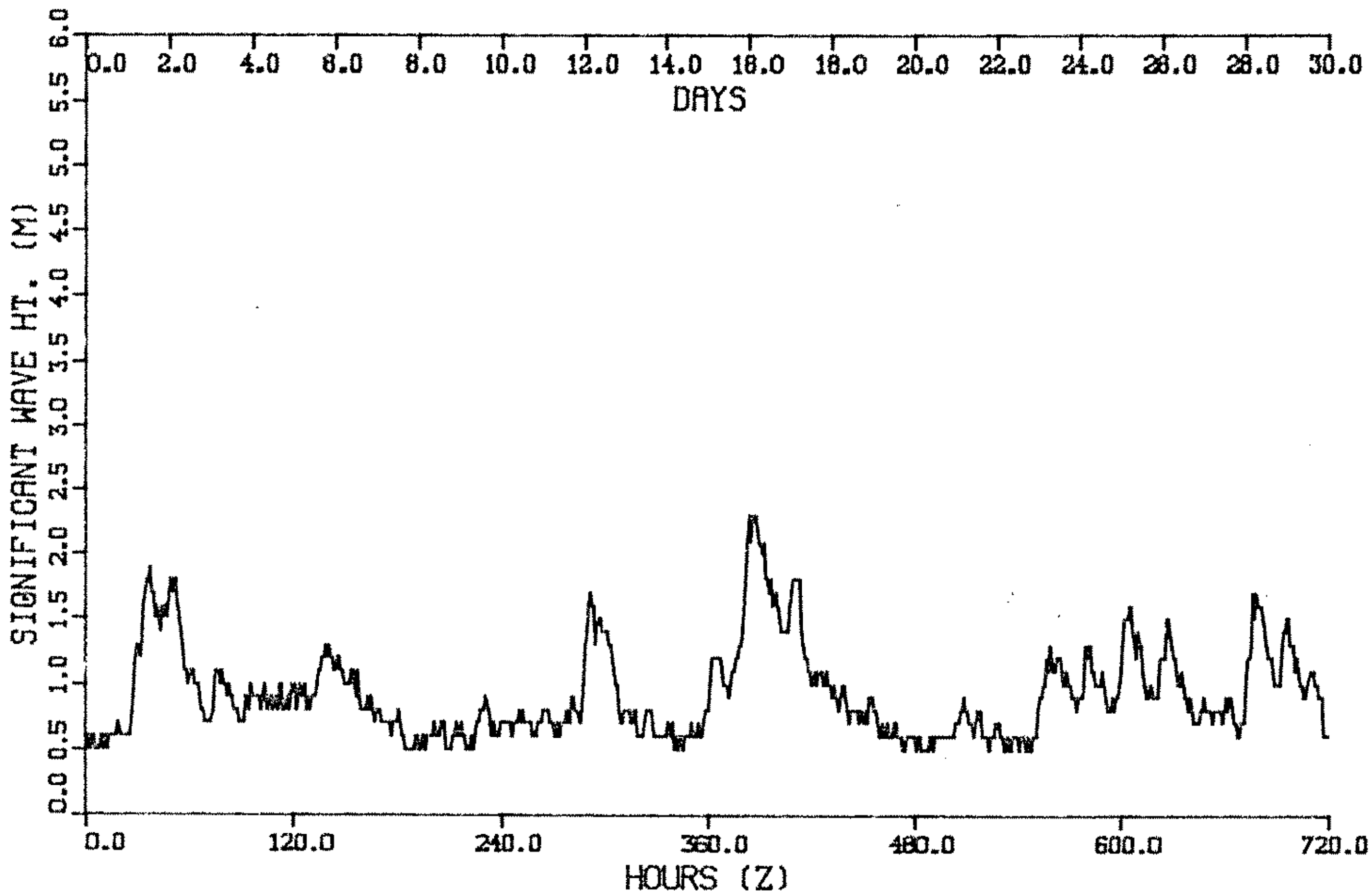
NAVOCEANO Current Meter (#1,2,3,& 4) Daily Average Data for Northward and Eastward Velocity Components (U&V) and Temperature (T)

15-minute Average U,V&T Profile Plots

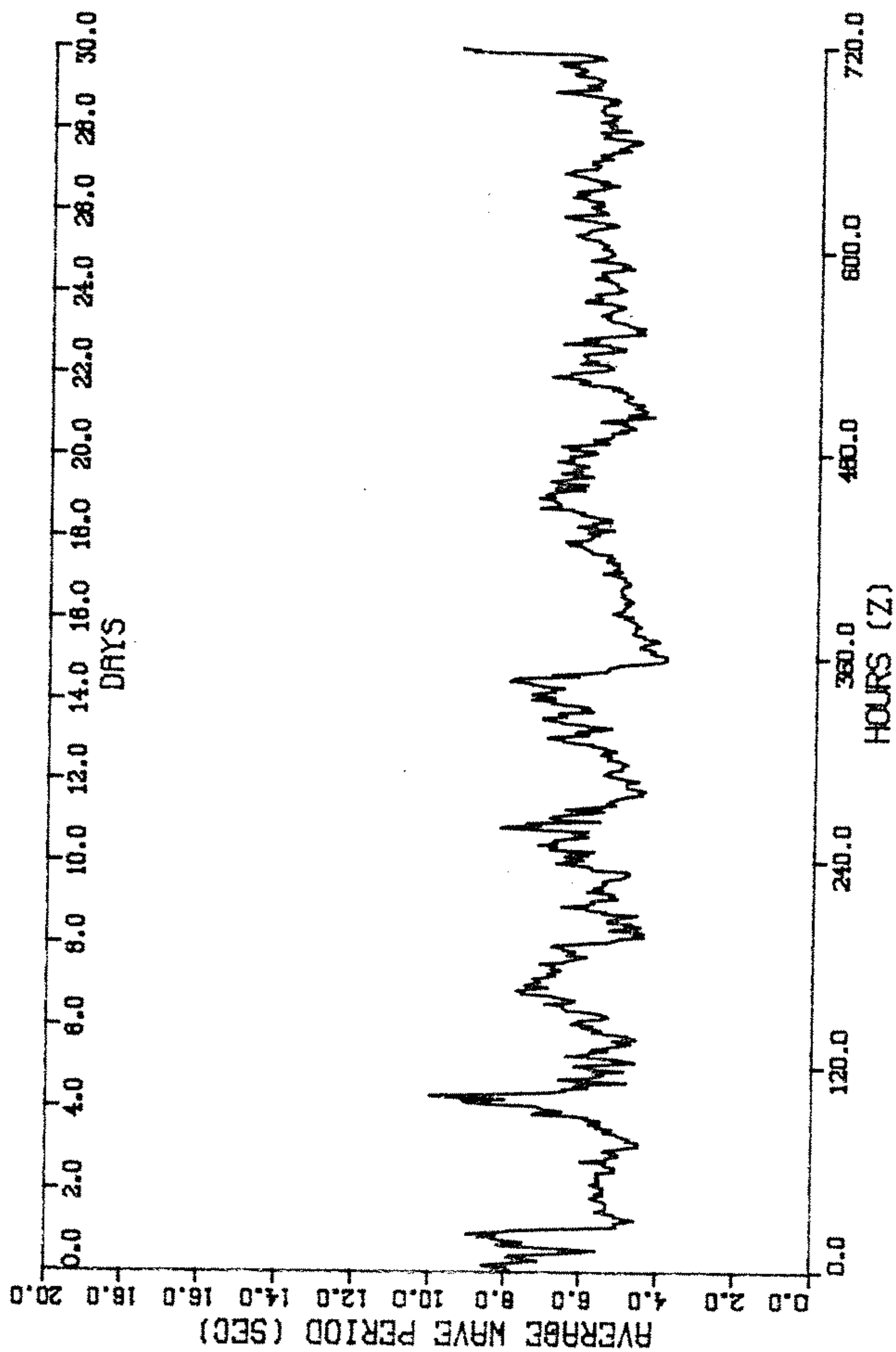
15-minute Average U&V Vectors and T Profile Plots (Top of page is 0° or true North)

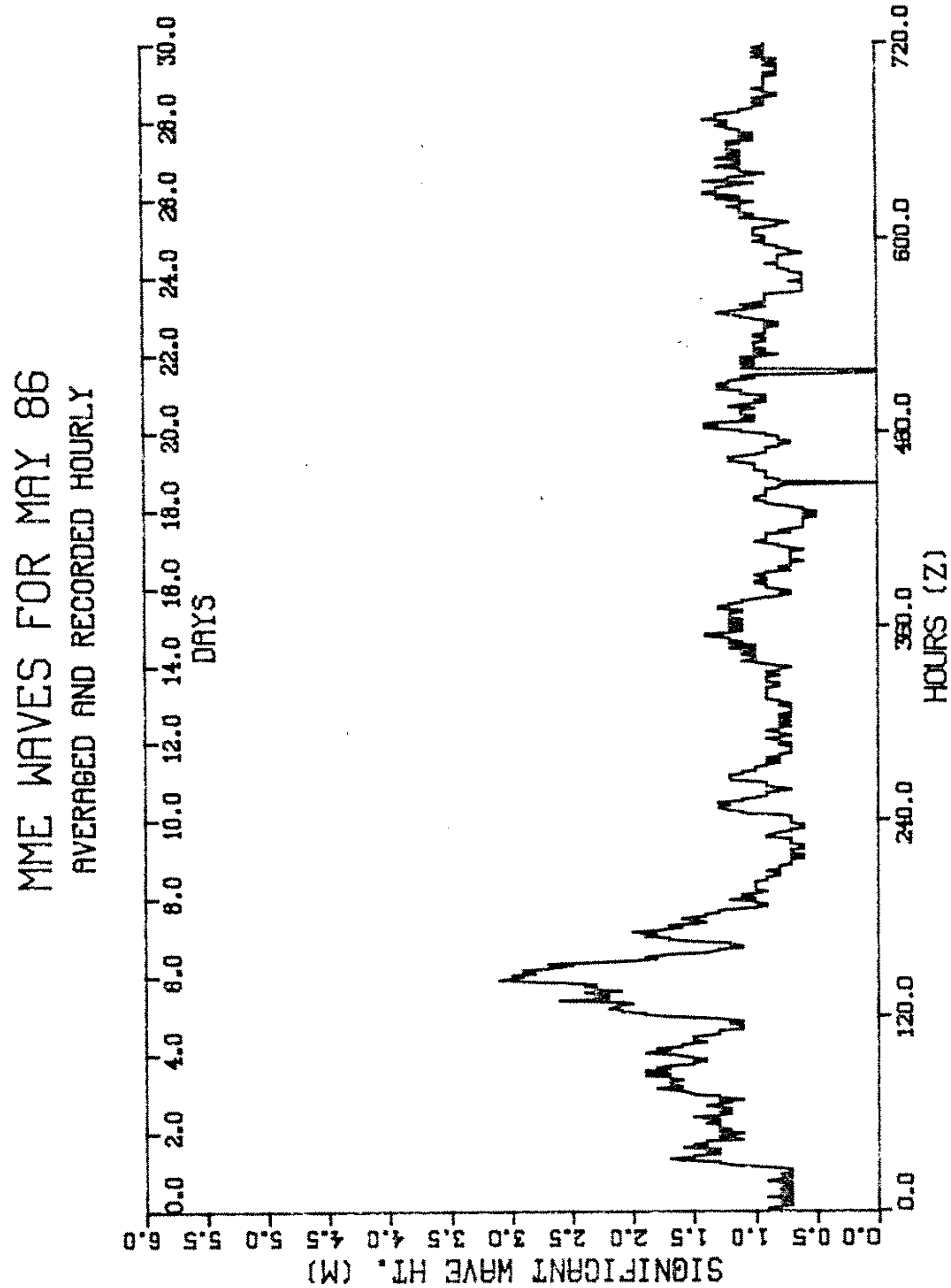
MME WAVES FOR APR 86

AVERAGED AND RECORDED HOURLY



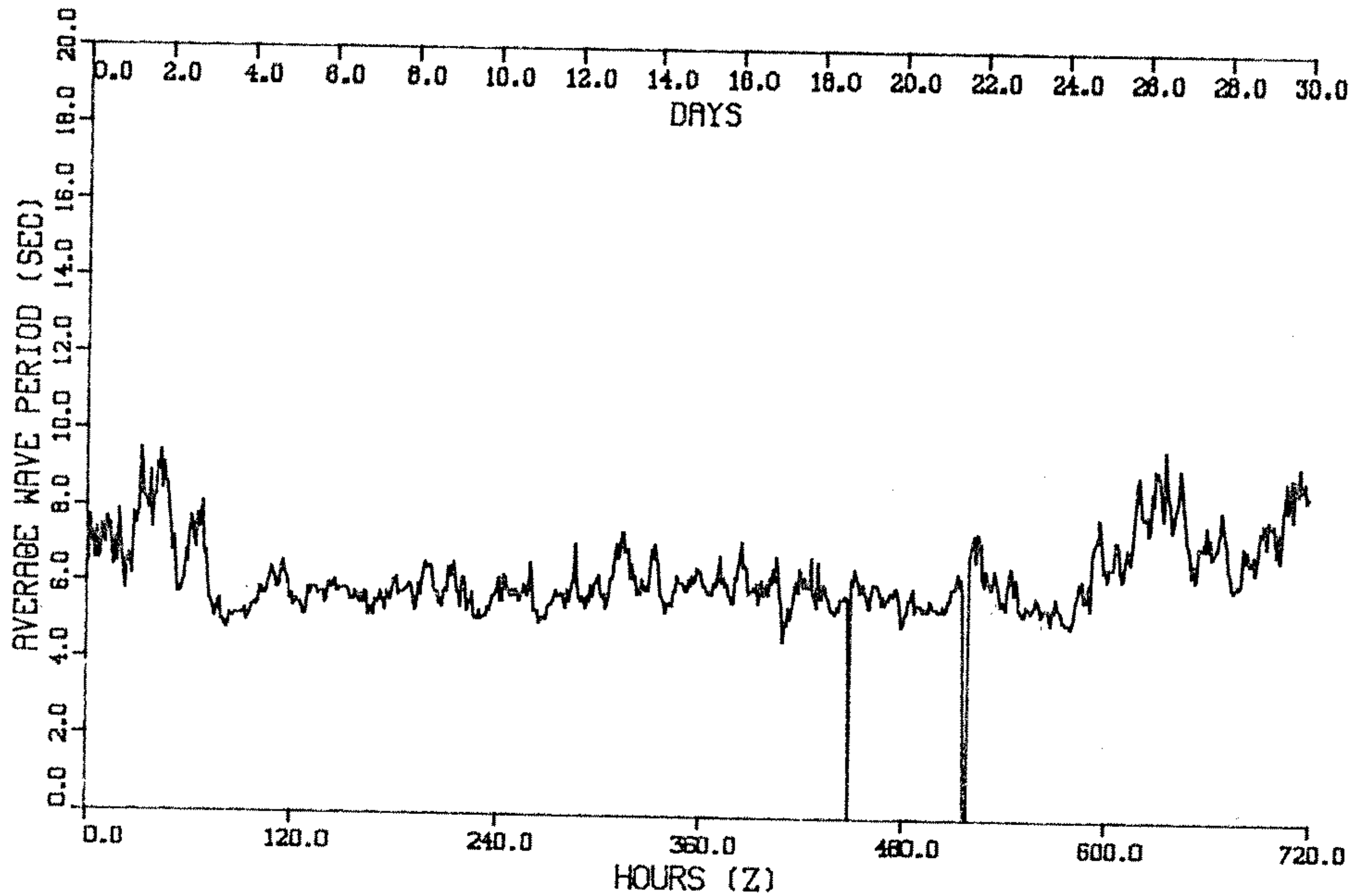
MME WAVES FOR APR 86

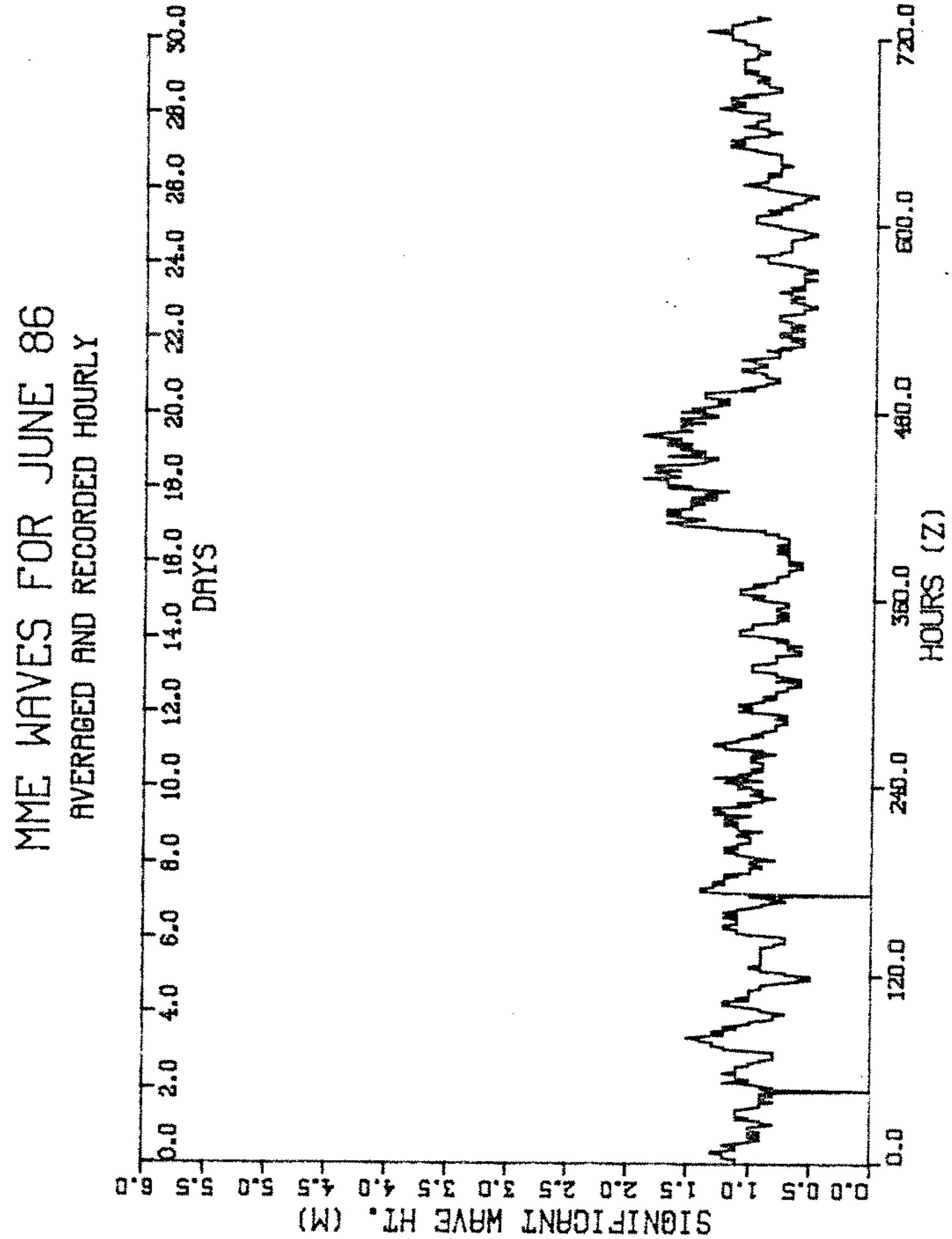




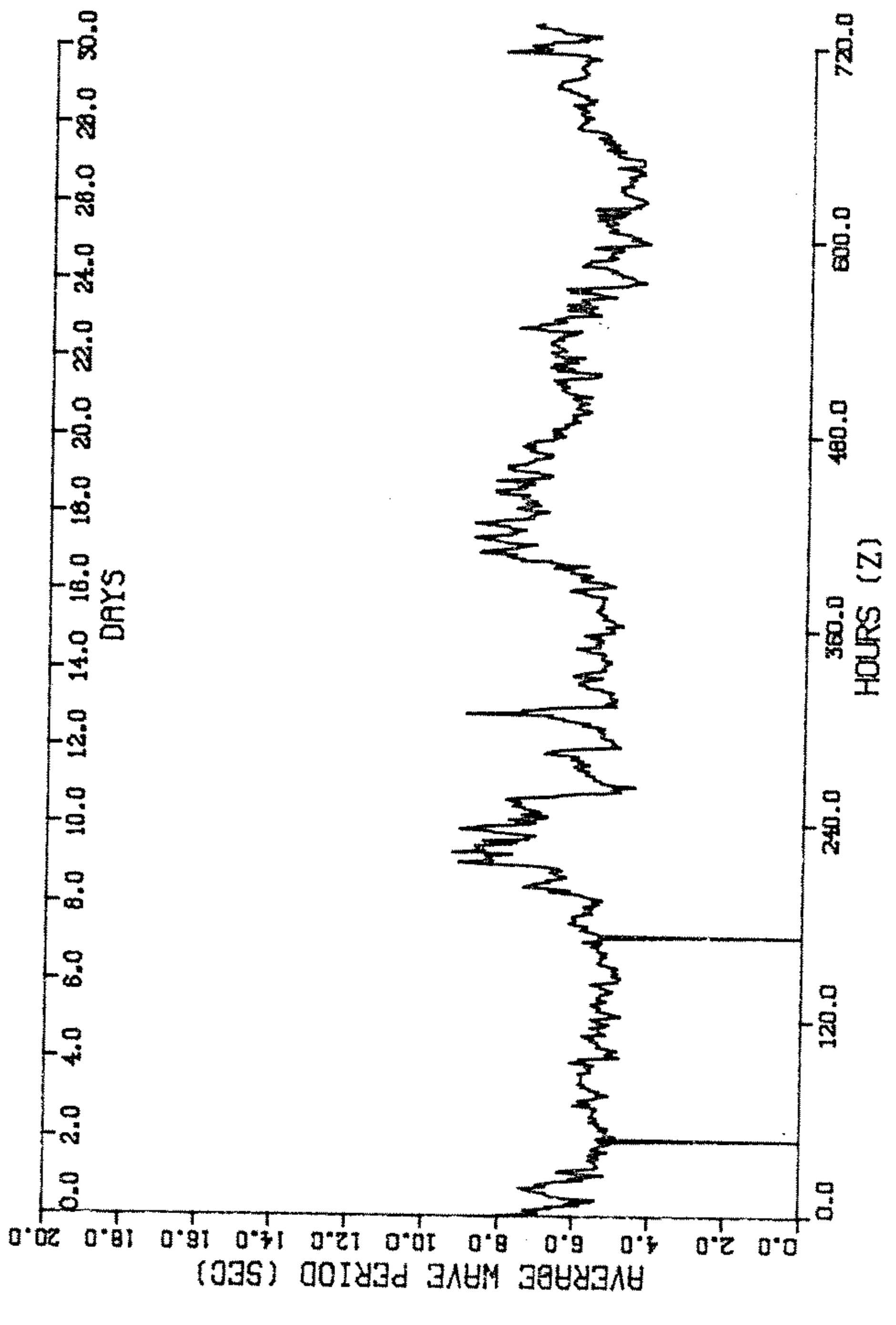
MME WAVES FOR MAY 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

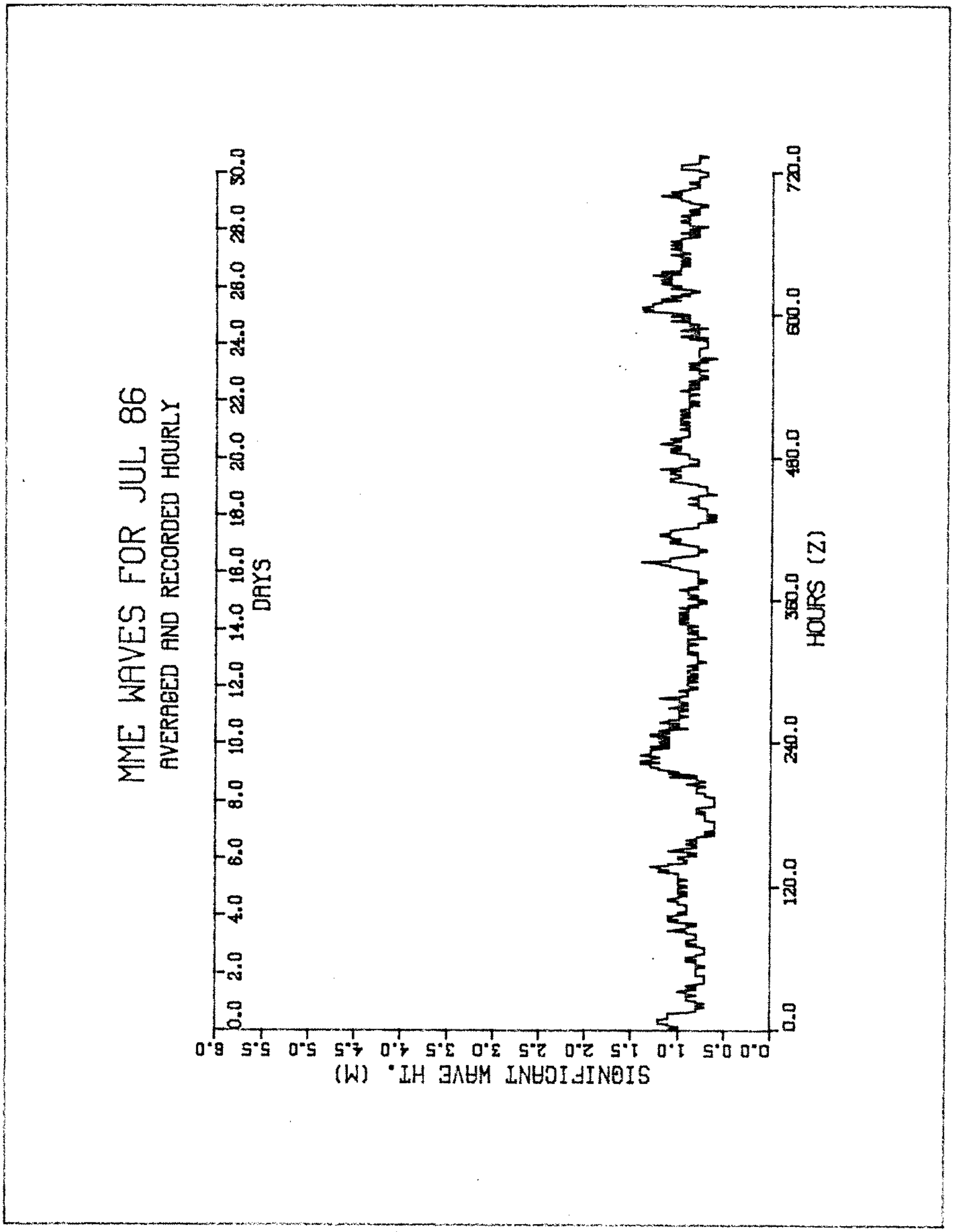
MME WAVES FOR MAY 86

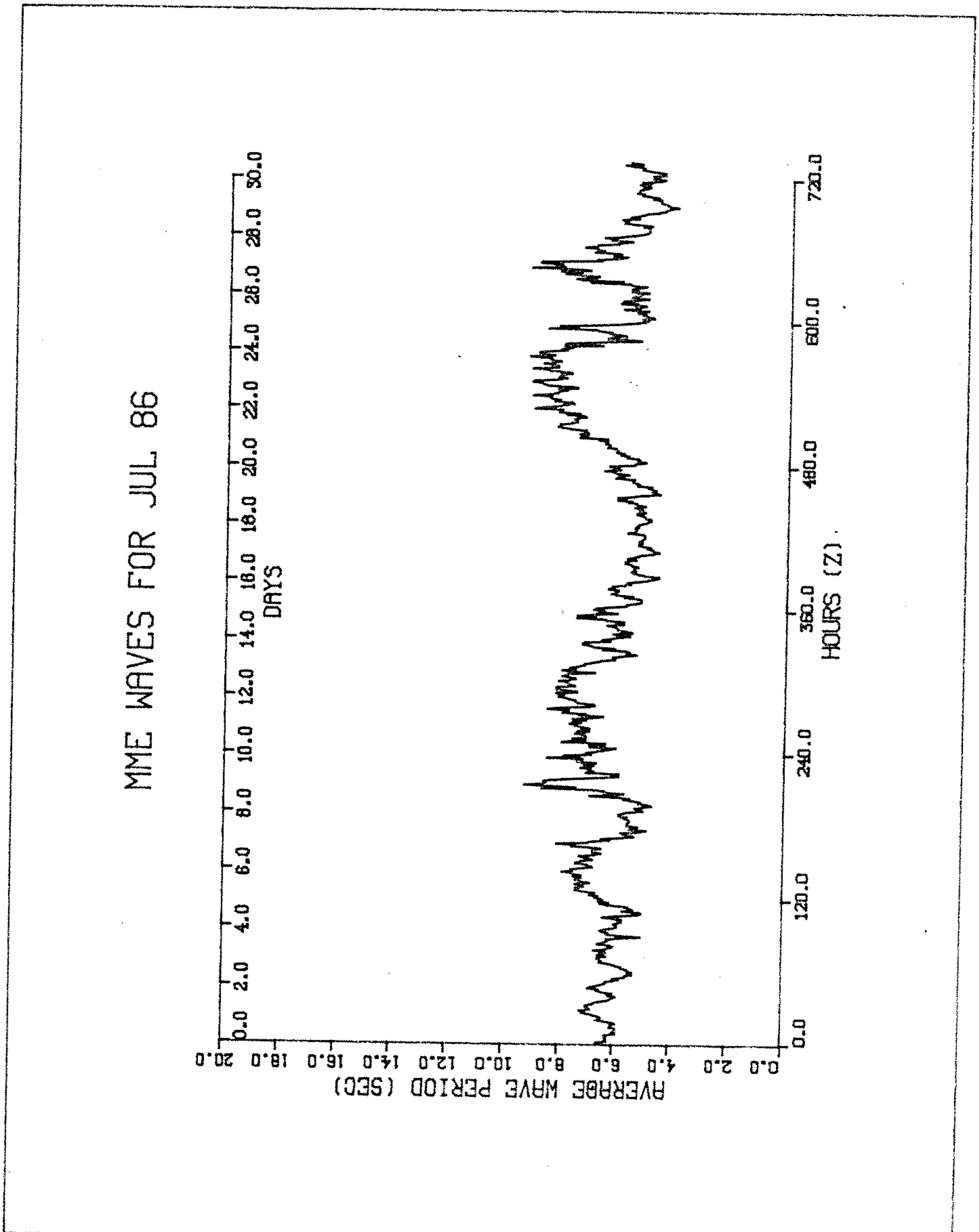



MME WAVES FOR JUNE 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

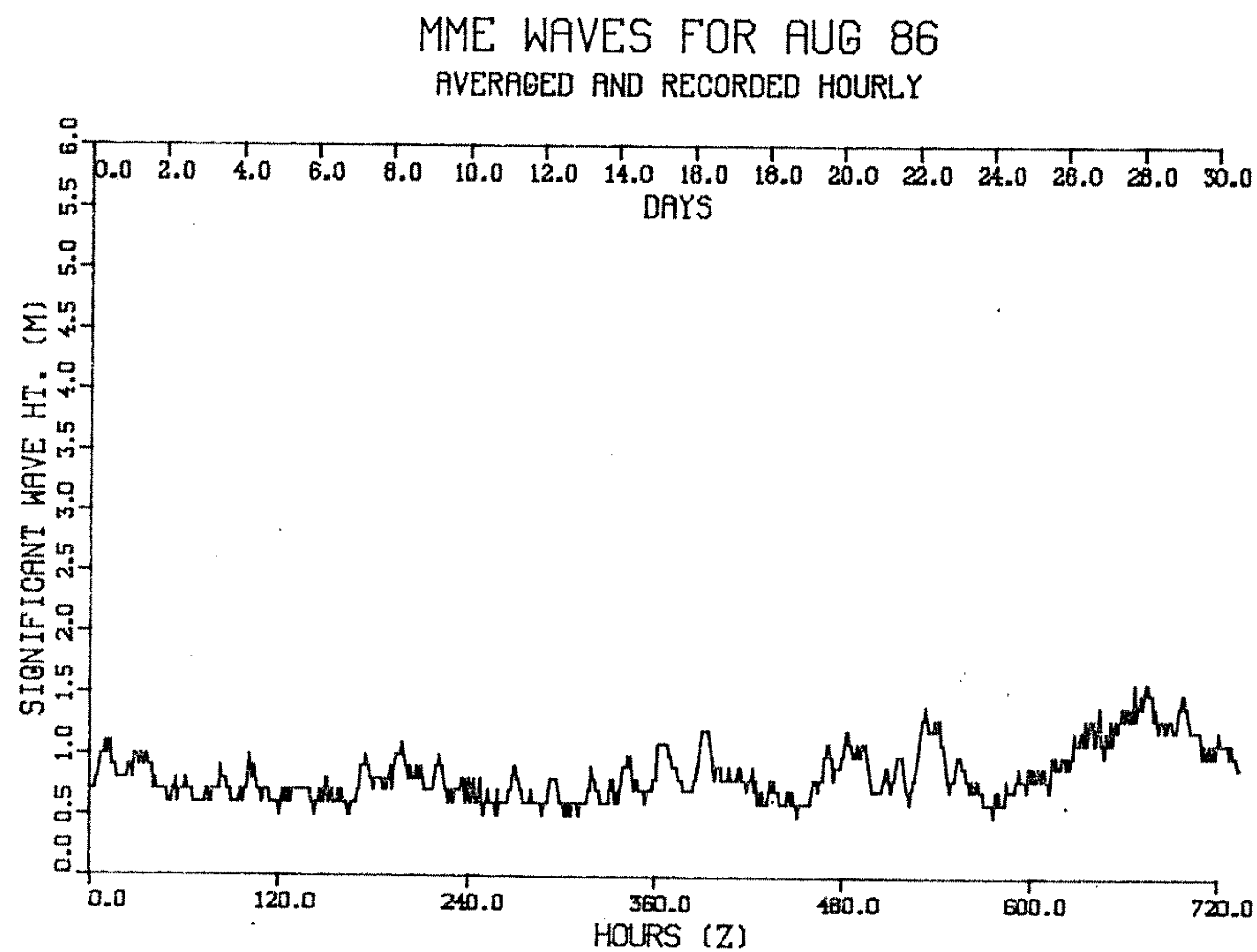
MME WAVES FOR JUNE 86



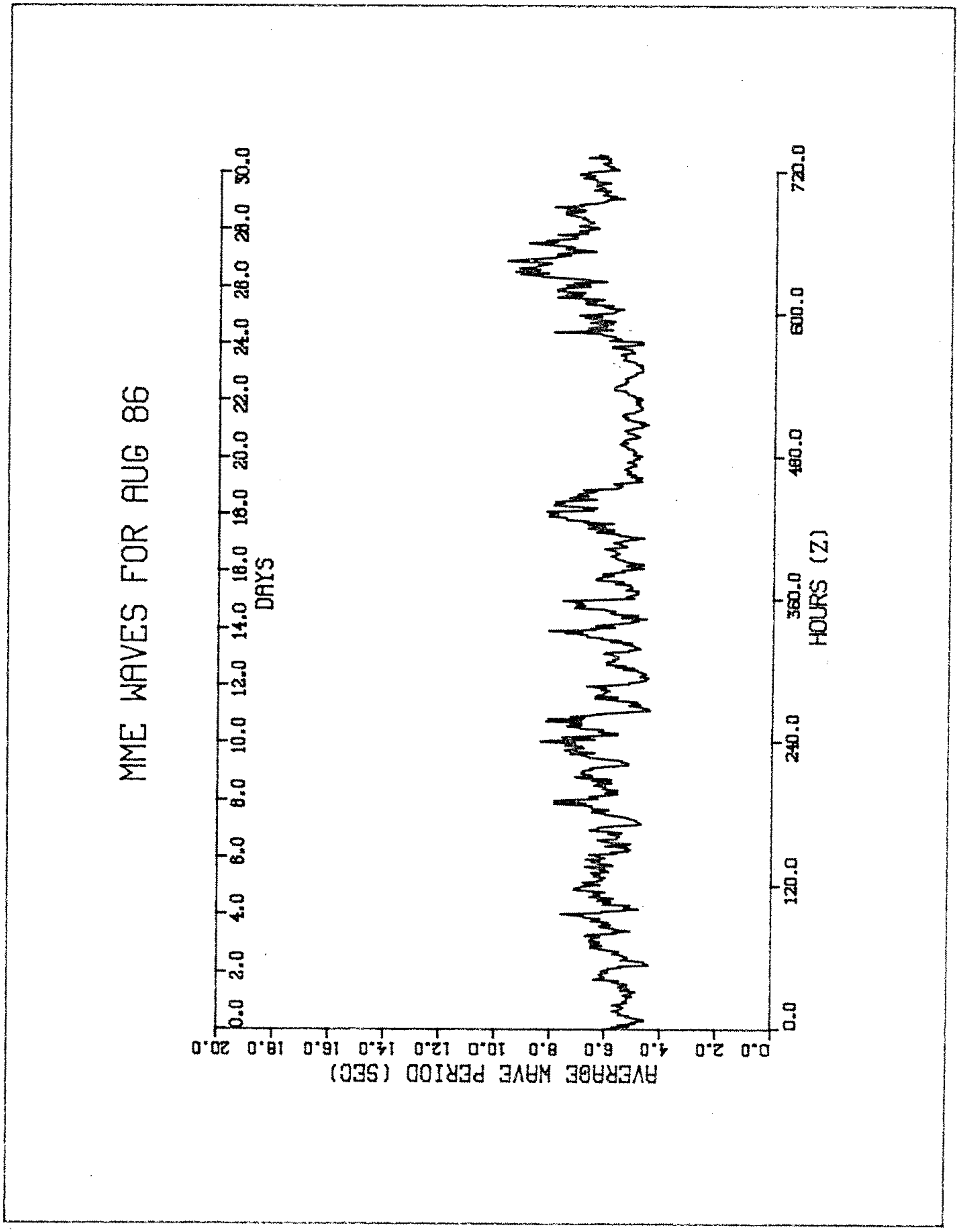

MME WAVES FOR JUL 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0



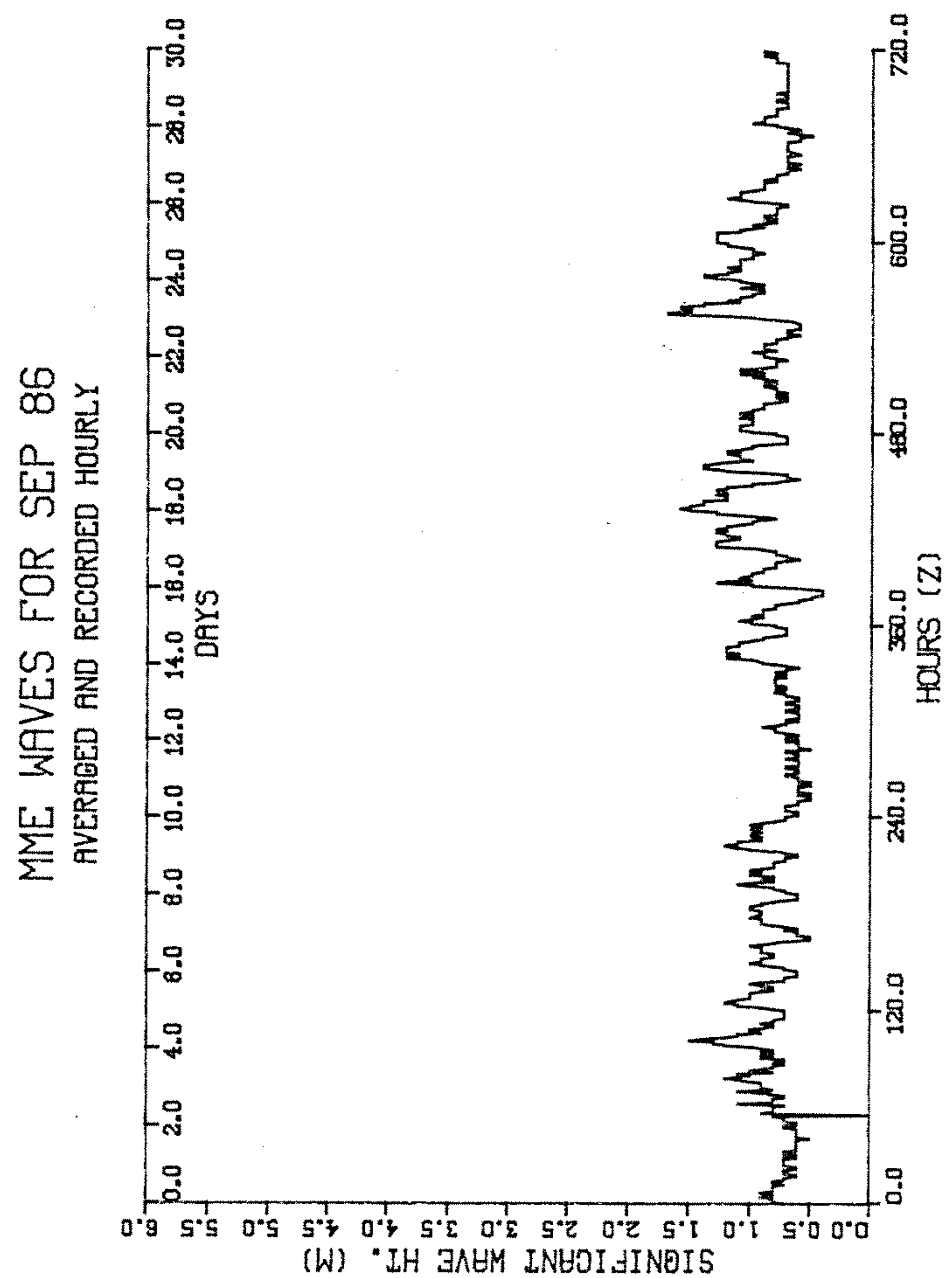
MME WAVES FOR JUL 86
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0

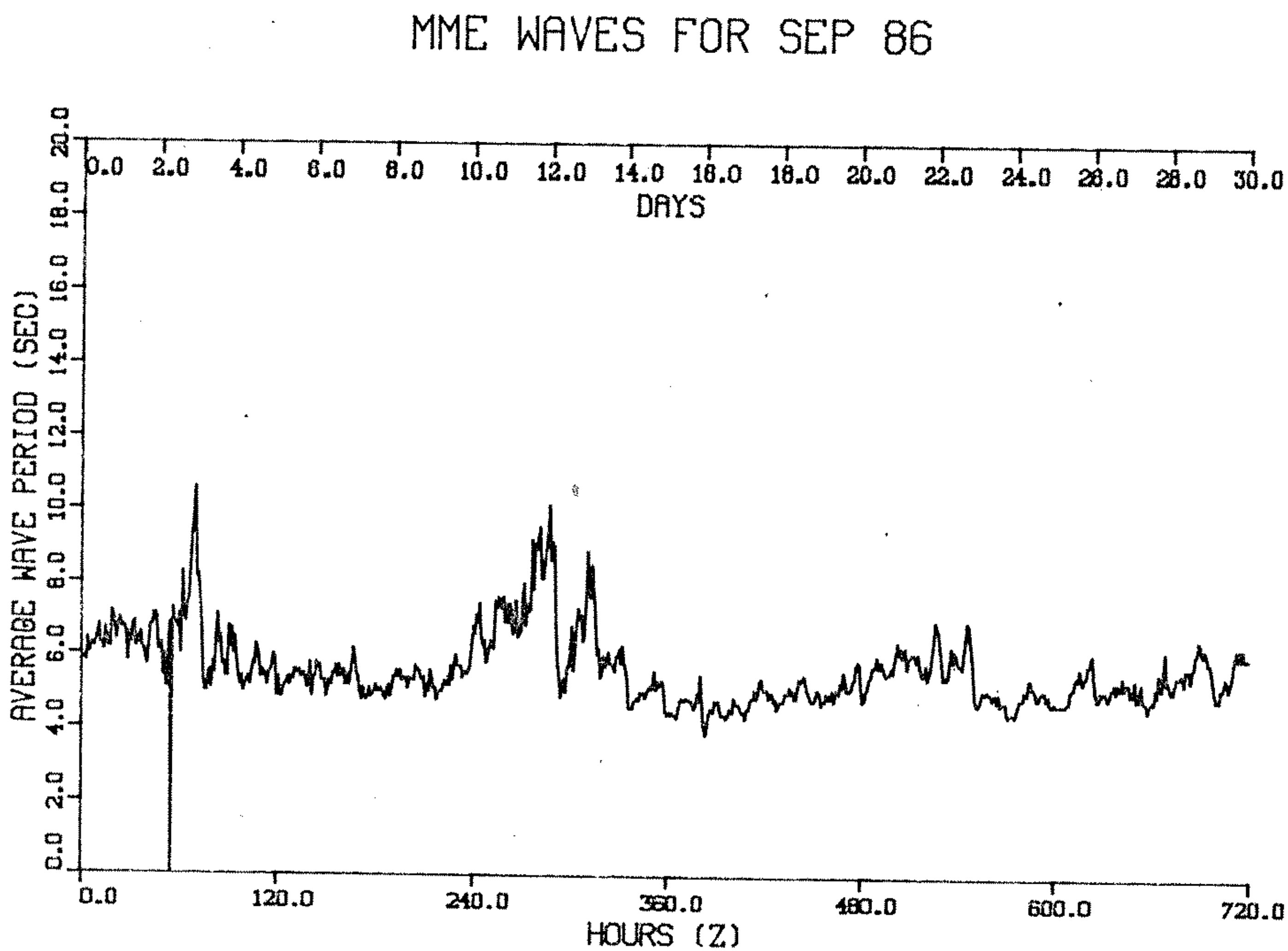


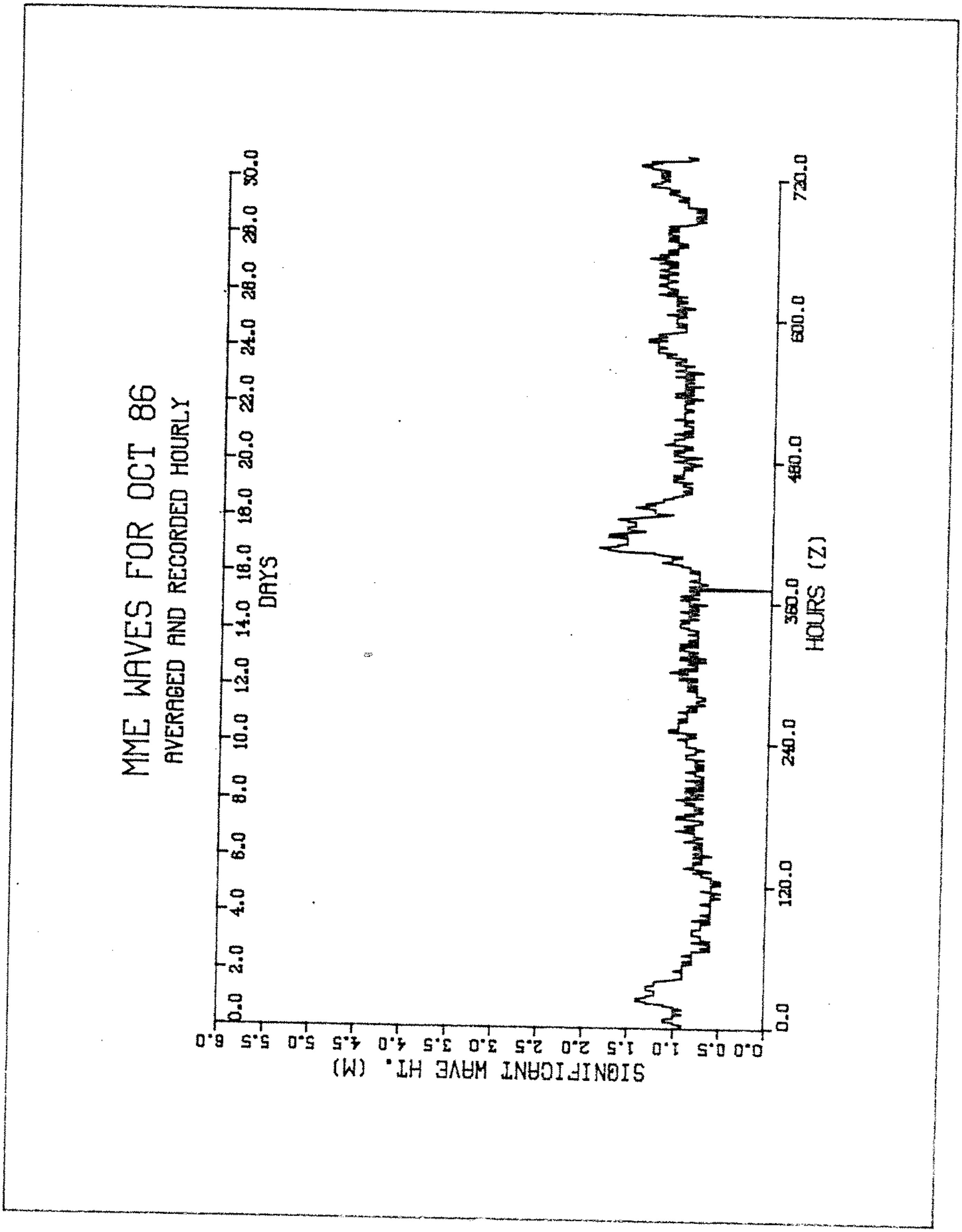
MME WAVES FOR AUG 86
AVERAGED AND RECORDED HOURLY
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
DAYS
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
0.0 120.0 240.0 360.0 480.0 600.0 720.0
HOURS (Z)

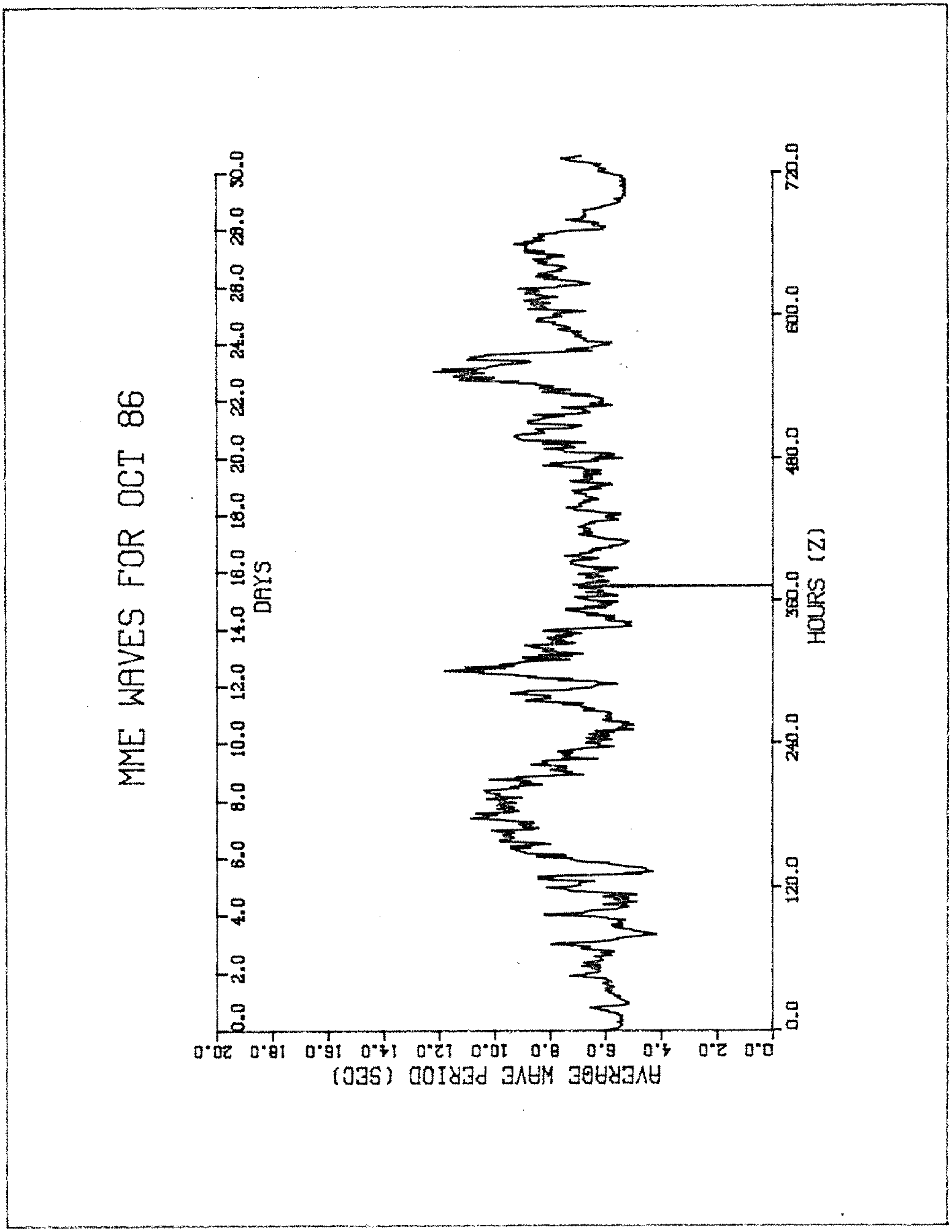


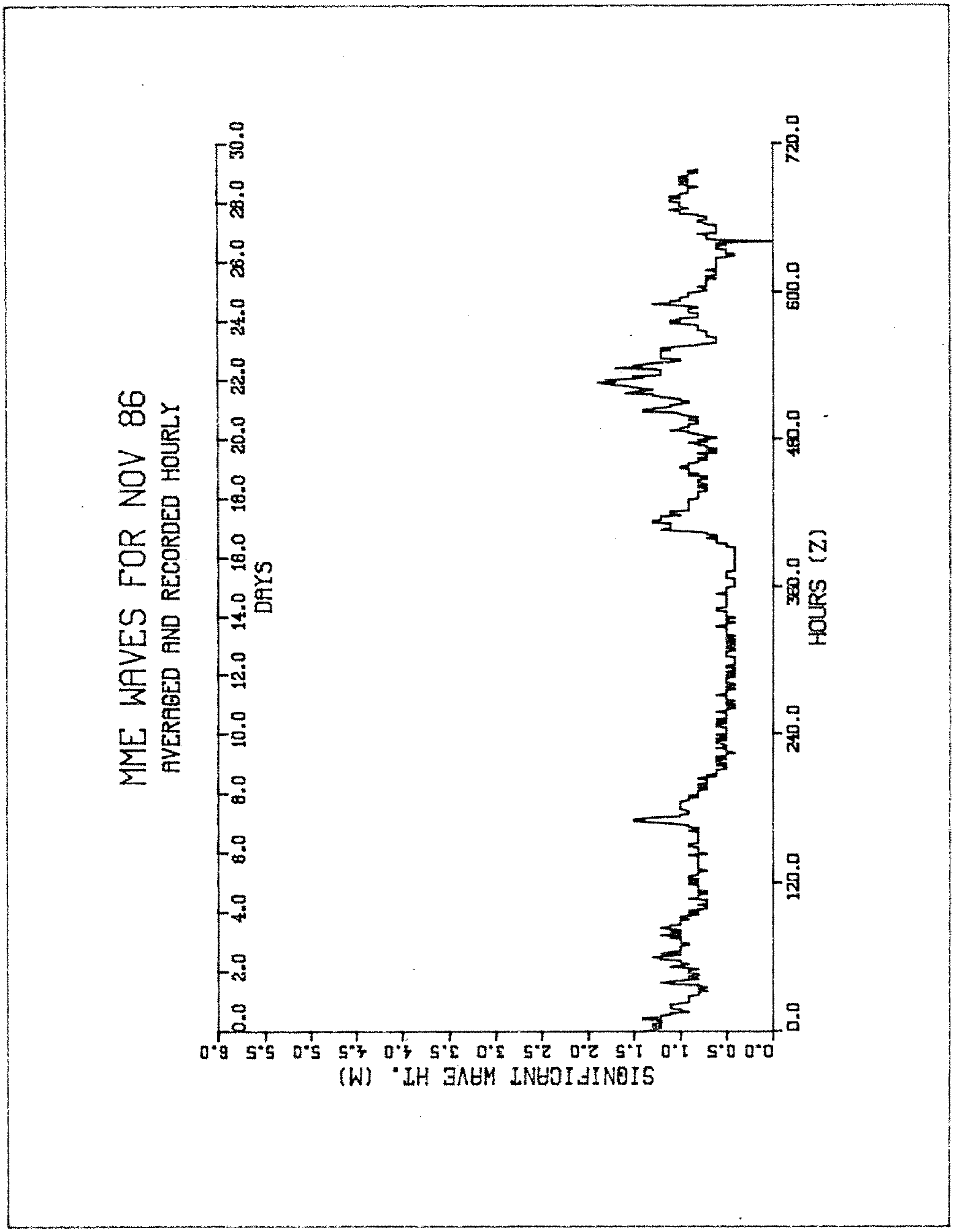
MME WAVES FOR AUG 86
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0

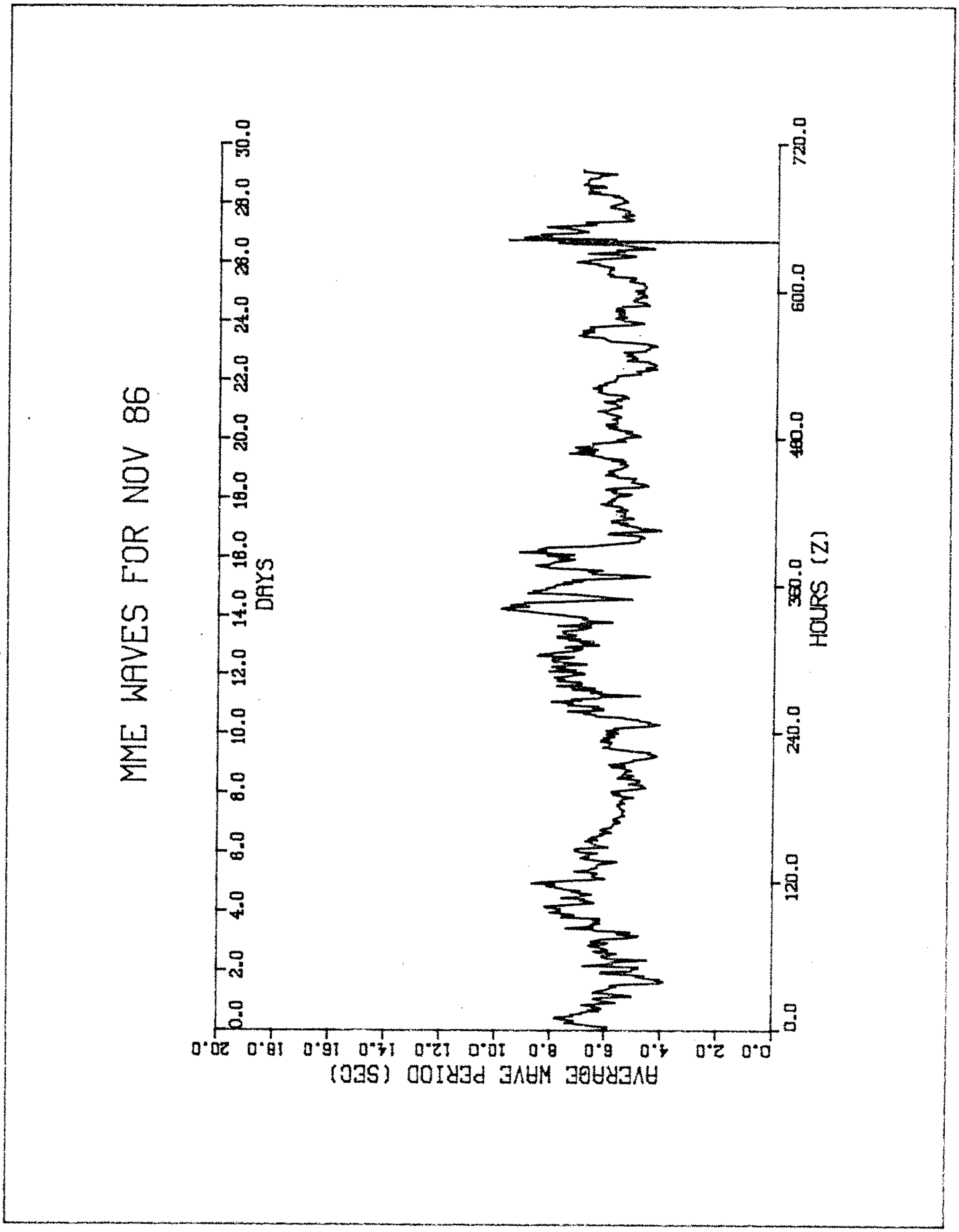

MME WAVES FOR SEP 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

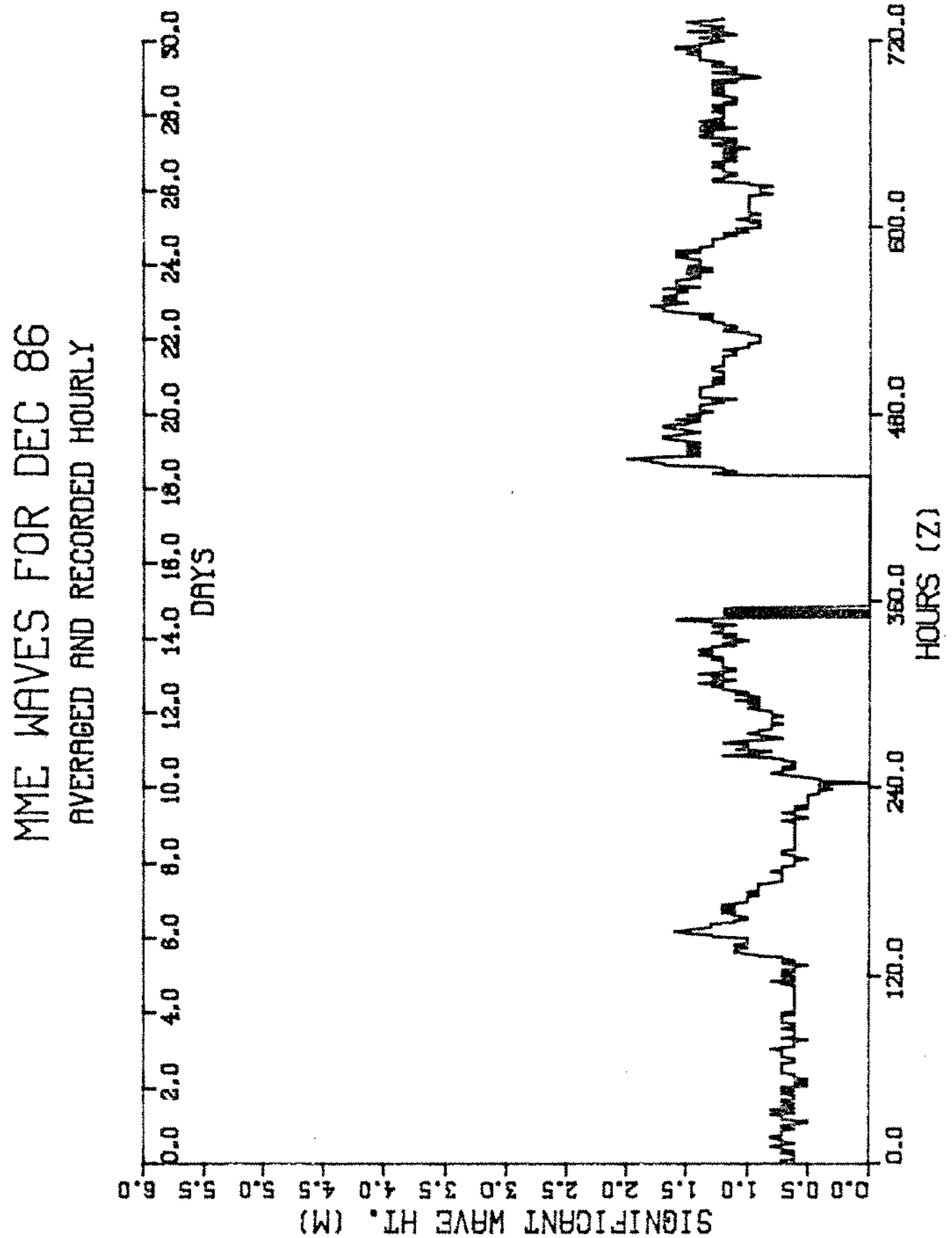

MME WAVES FOR SEP 86
DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
AVERAGE WAVE PERIOD (SEC)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0


MME WAVES FOR OCT 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

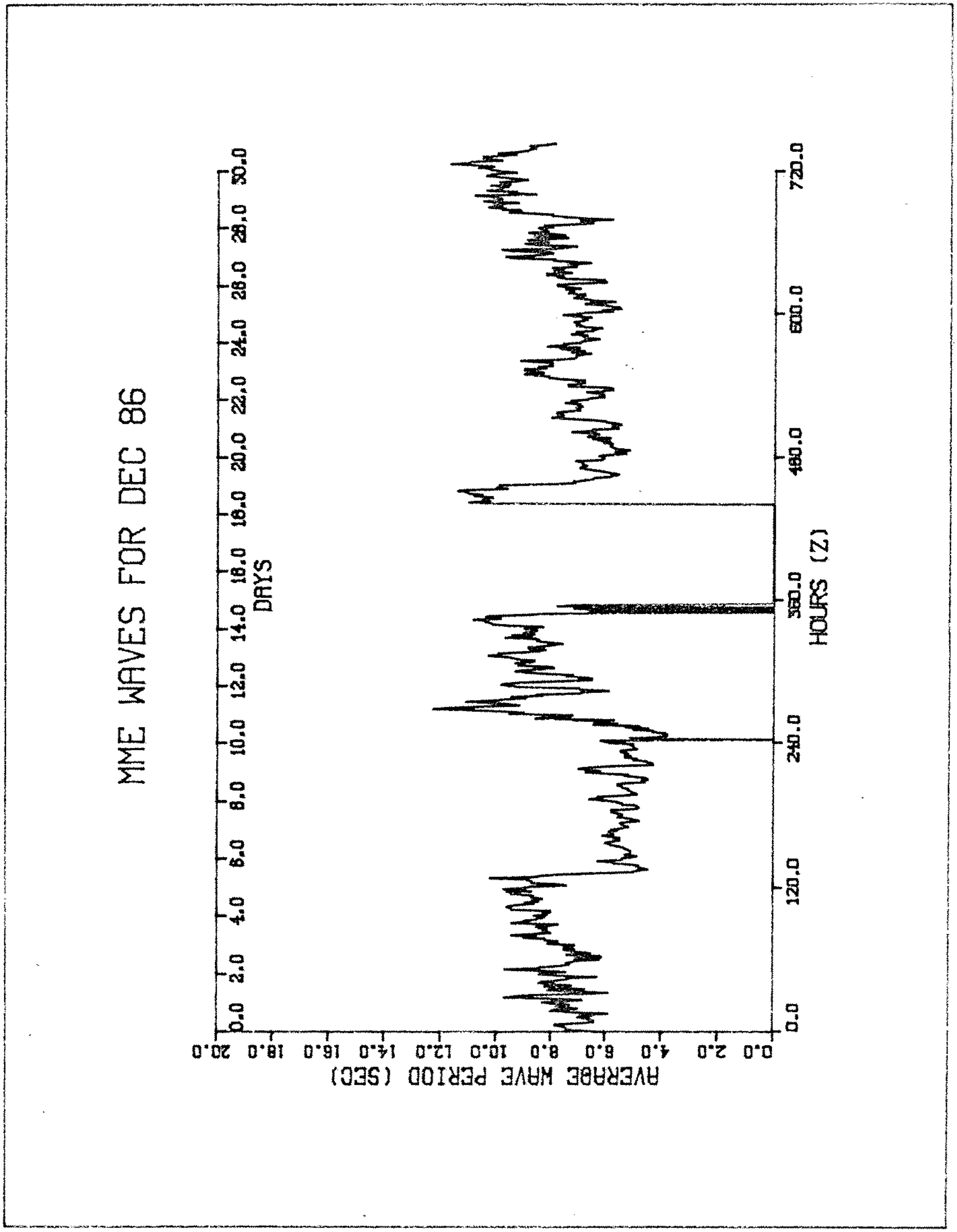

MME WAVES FOR OCT 86
DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0
AVERAGE WAVE PERIOD (SEC)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0


MME WAVES FOR NOV 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

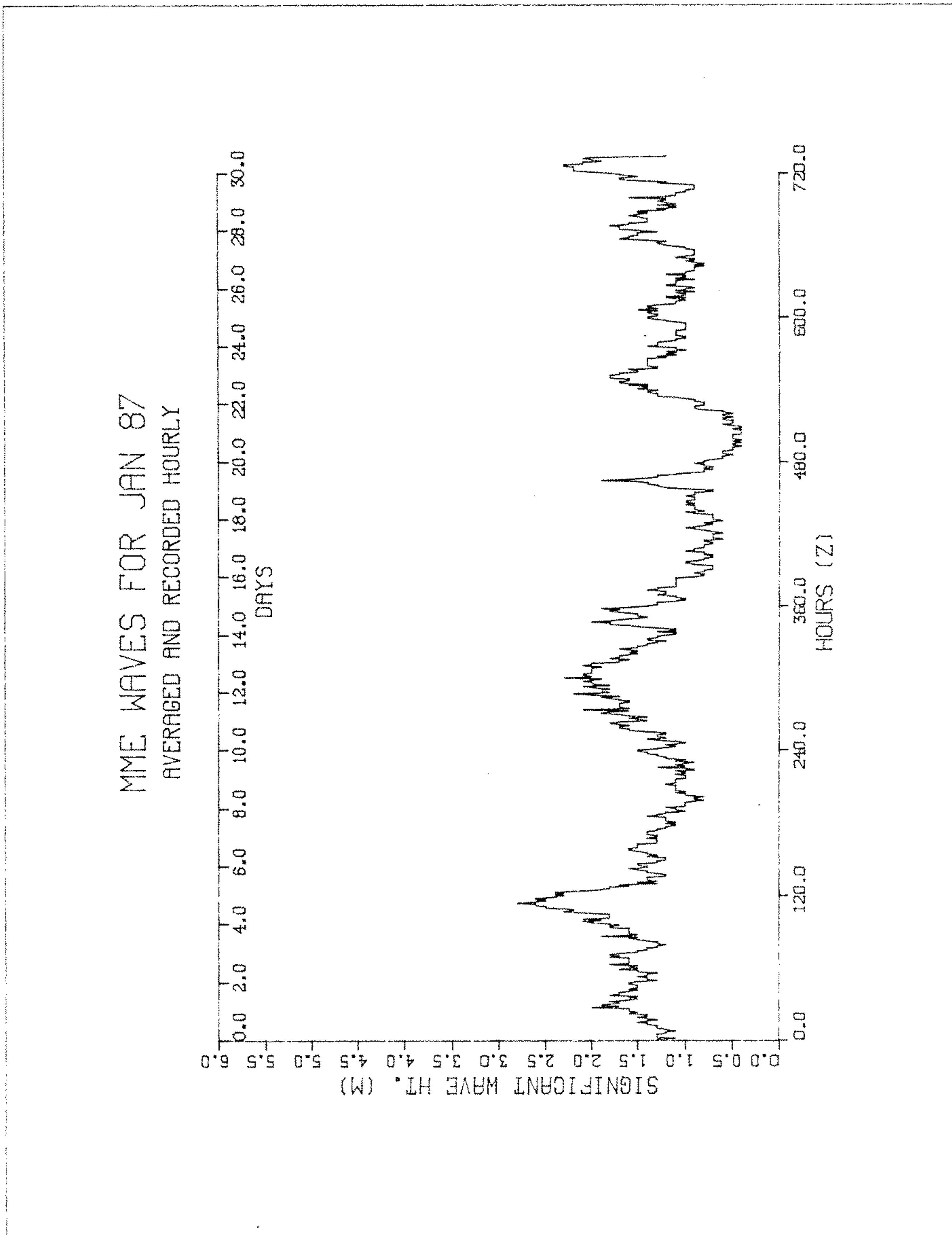

MME WAVES FOR NOV 86
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0

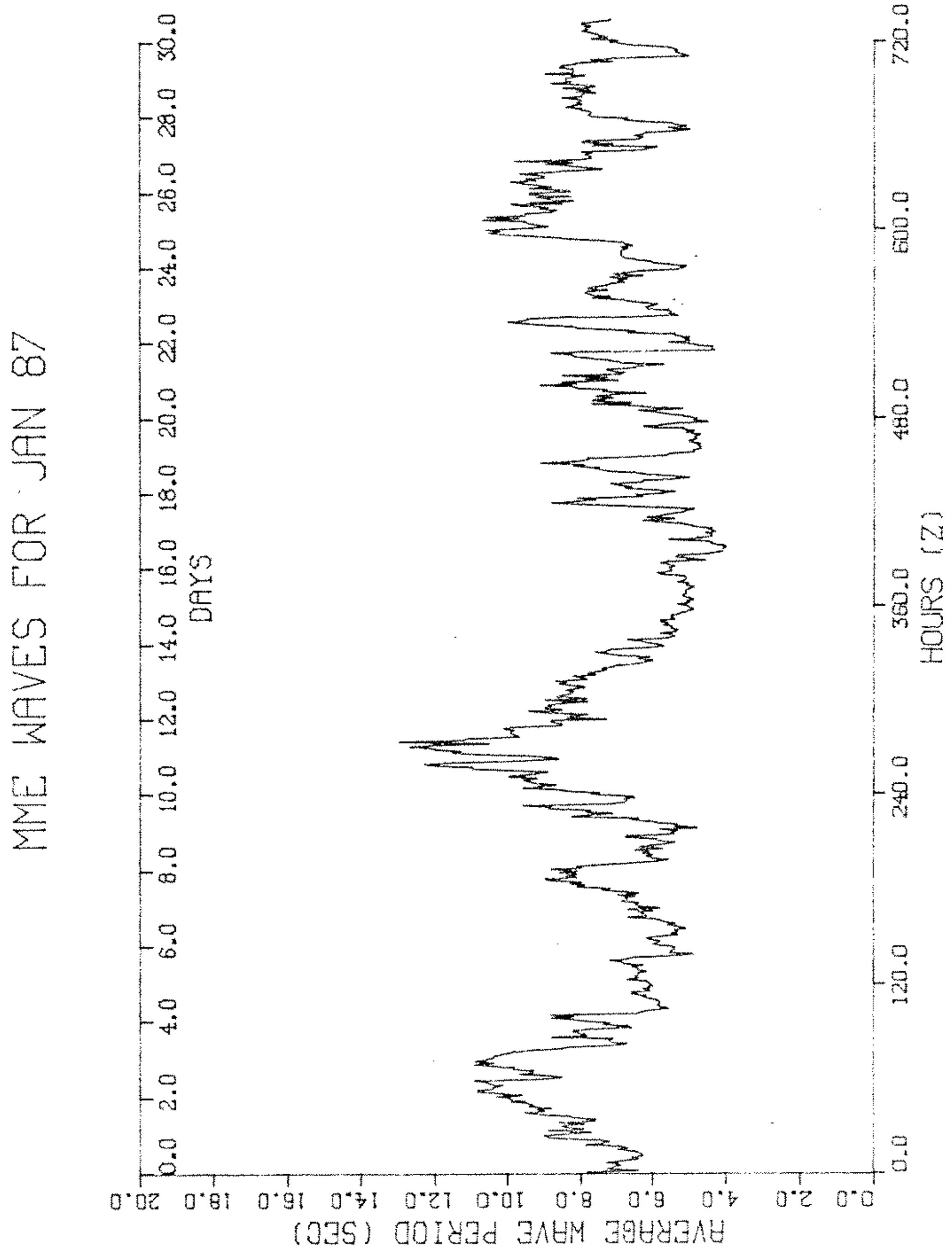


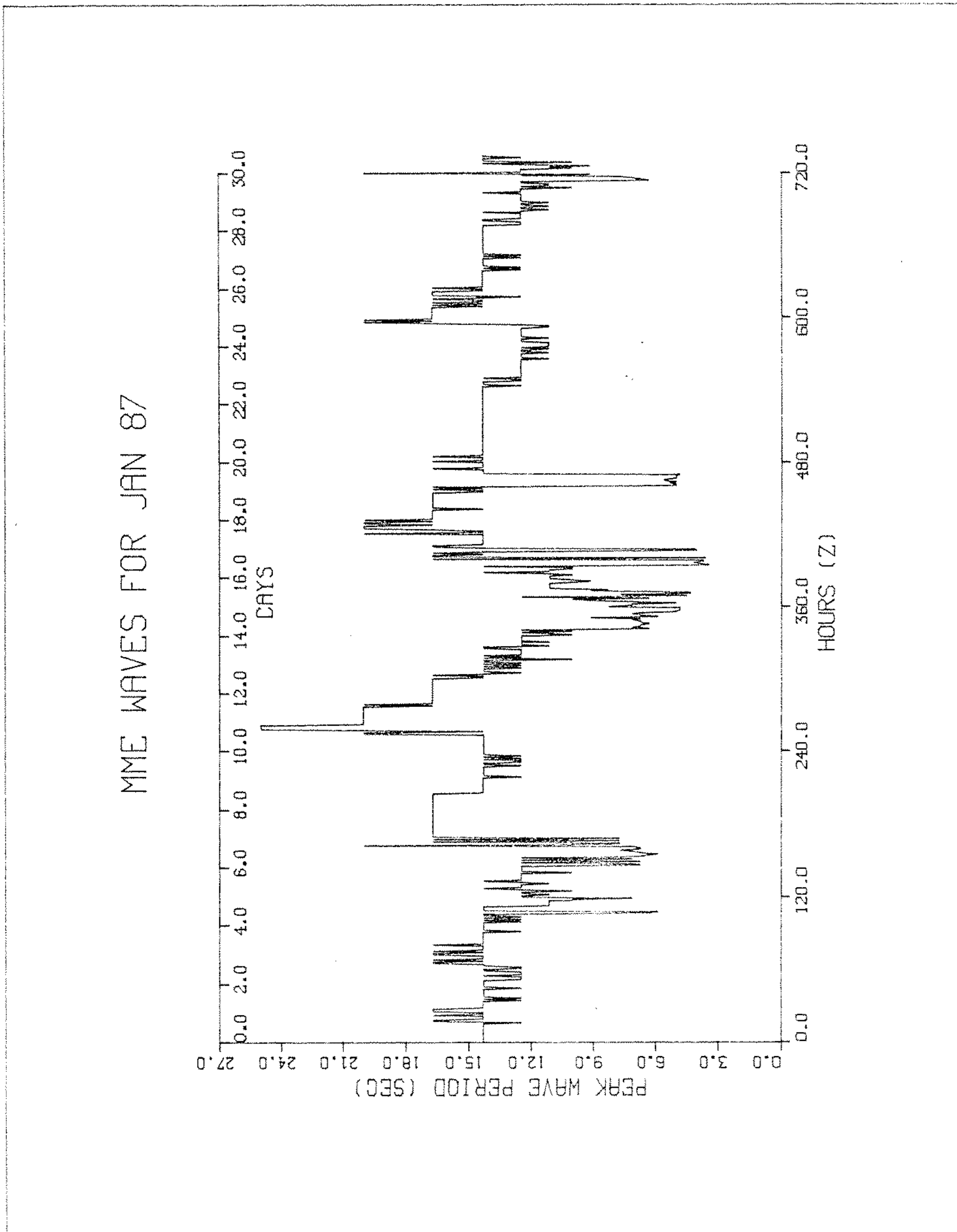
MME WAVES FOR DEC 86
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

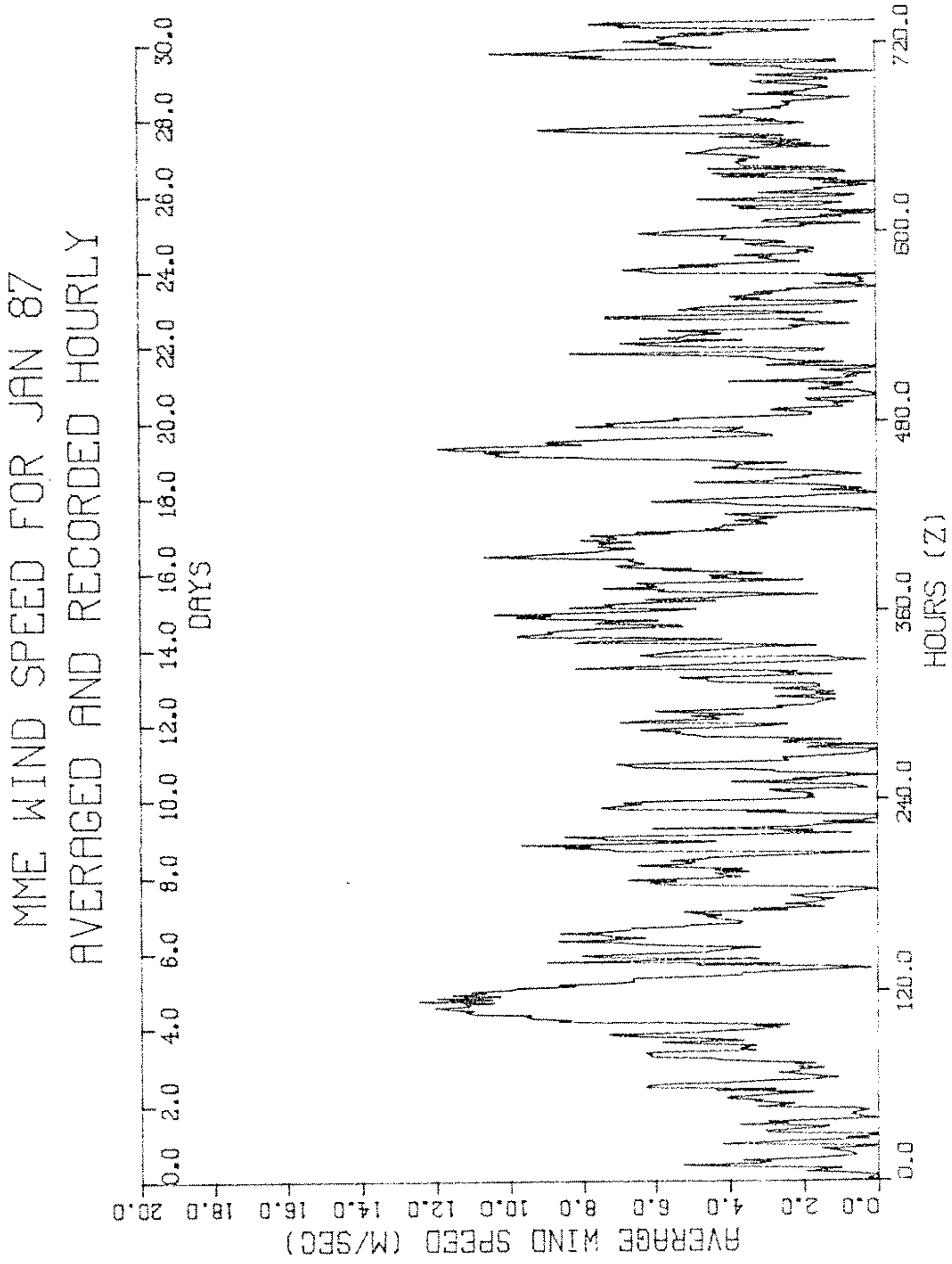


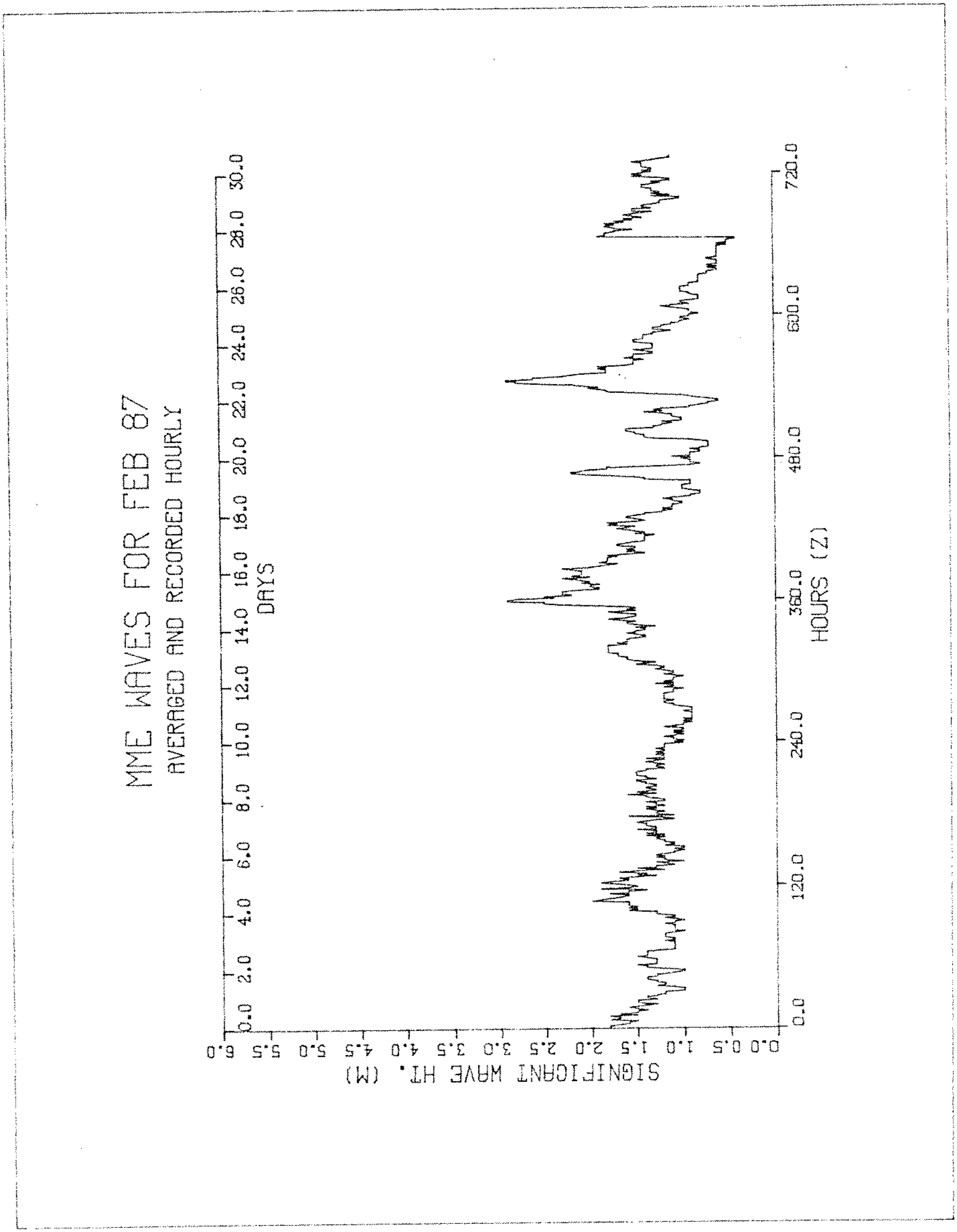
MME WAVES FOR DEC 86
DAYS
HOURS (Z)
AVERAGE WAVE PERIOD (SEC)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
120.0
240.0
360.0
480.0
600.0
720.0

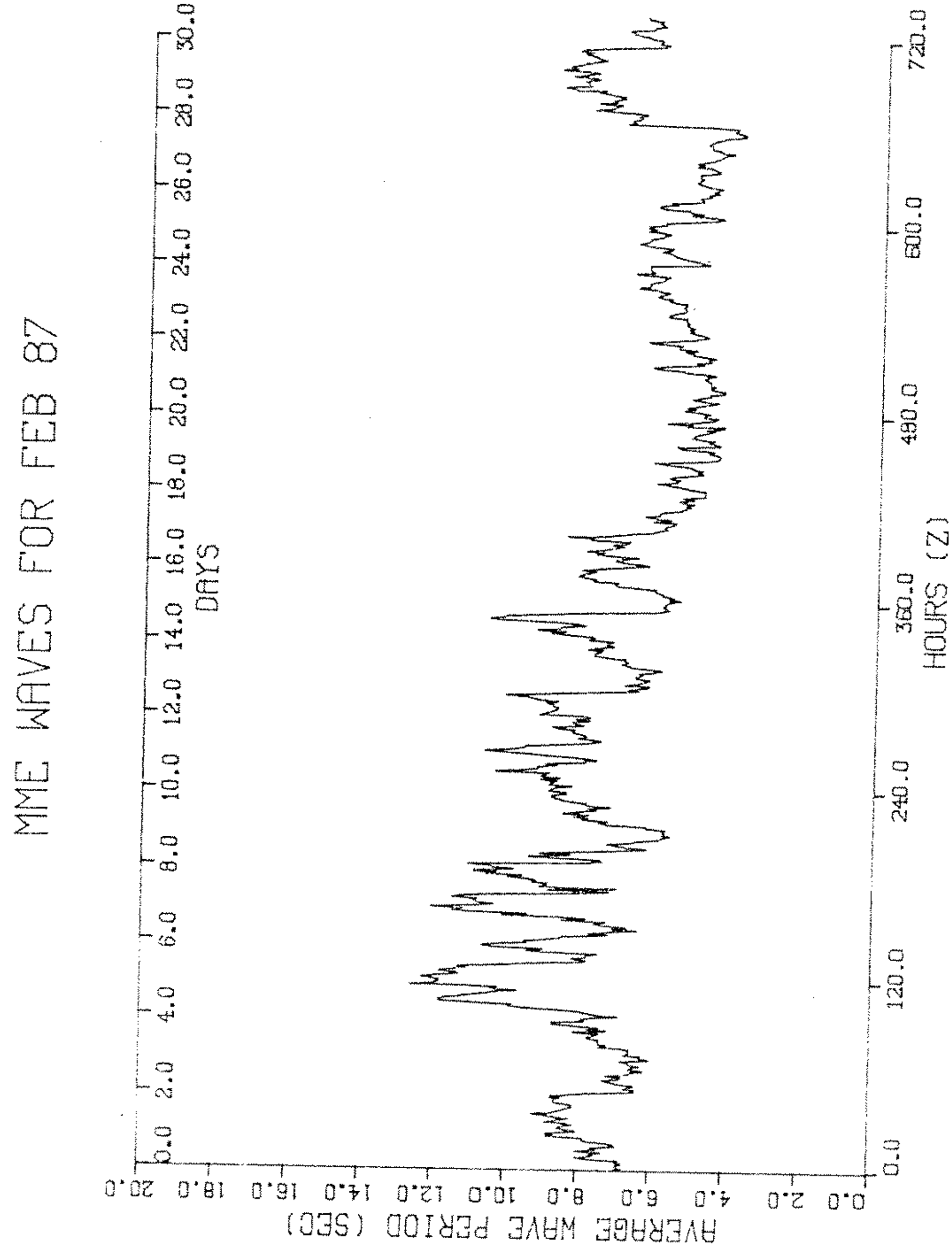

MME WAVES FOR JAN 87
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

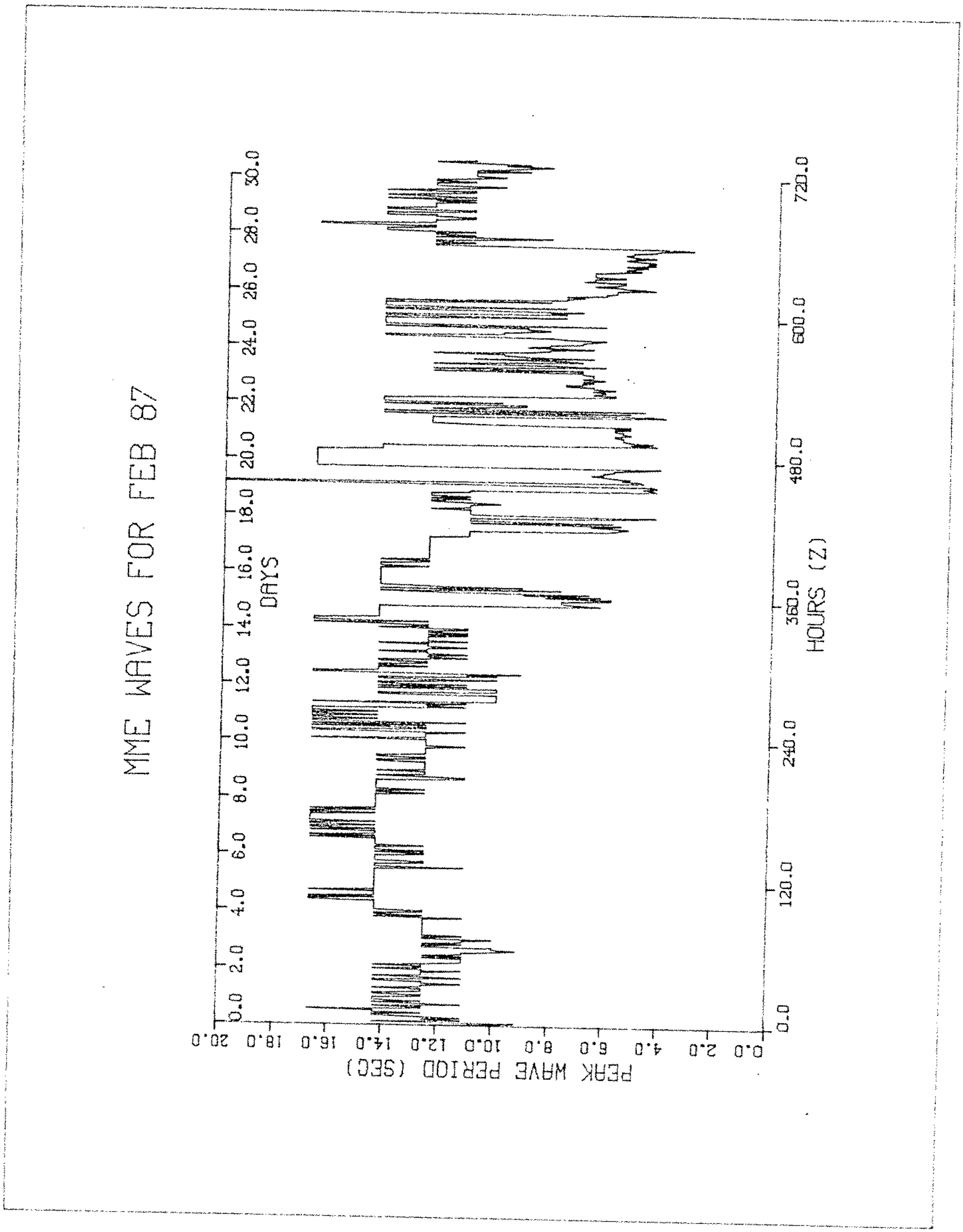

MME WAVES FOR JAN 87
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0

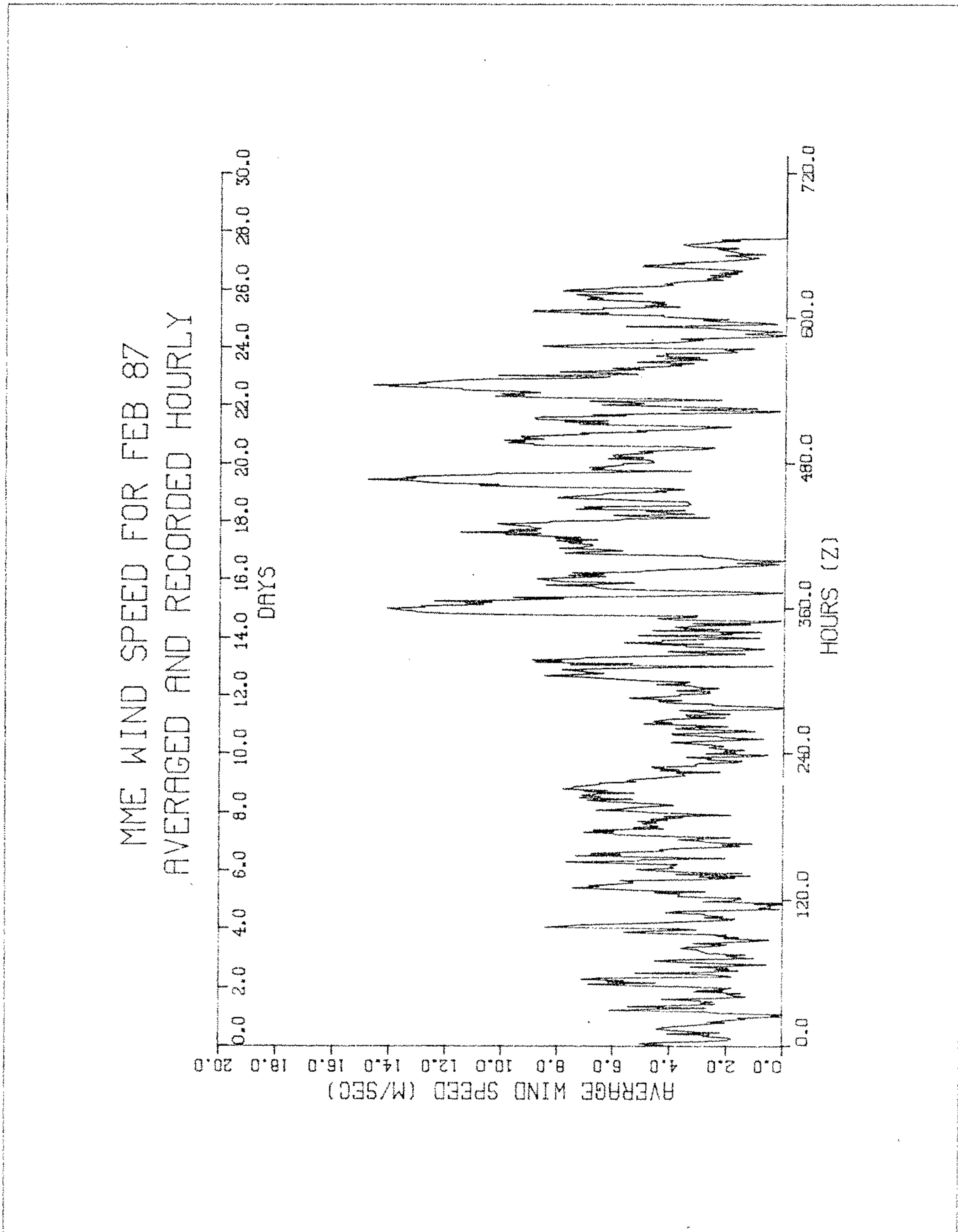

MME WAVES FOR JAN 87
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
PEAK WAVE PERIOD (SEC)
0.0 3.0 6.0 9.0 12.0 15.0 18.0 21.0 24.0 27.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0

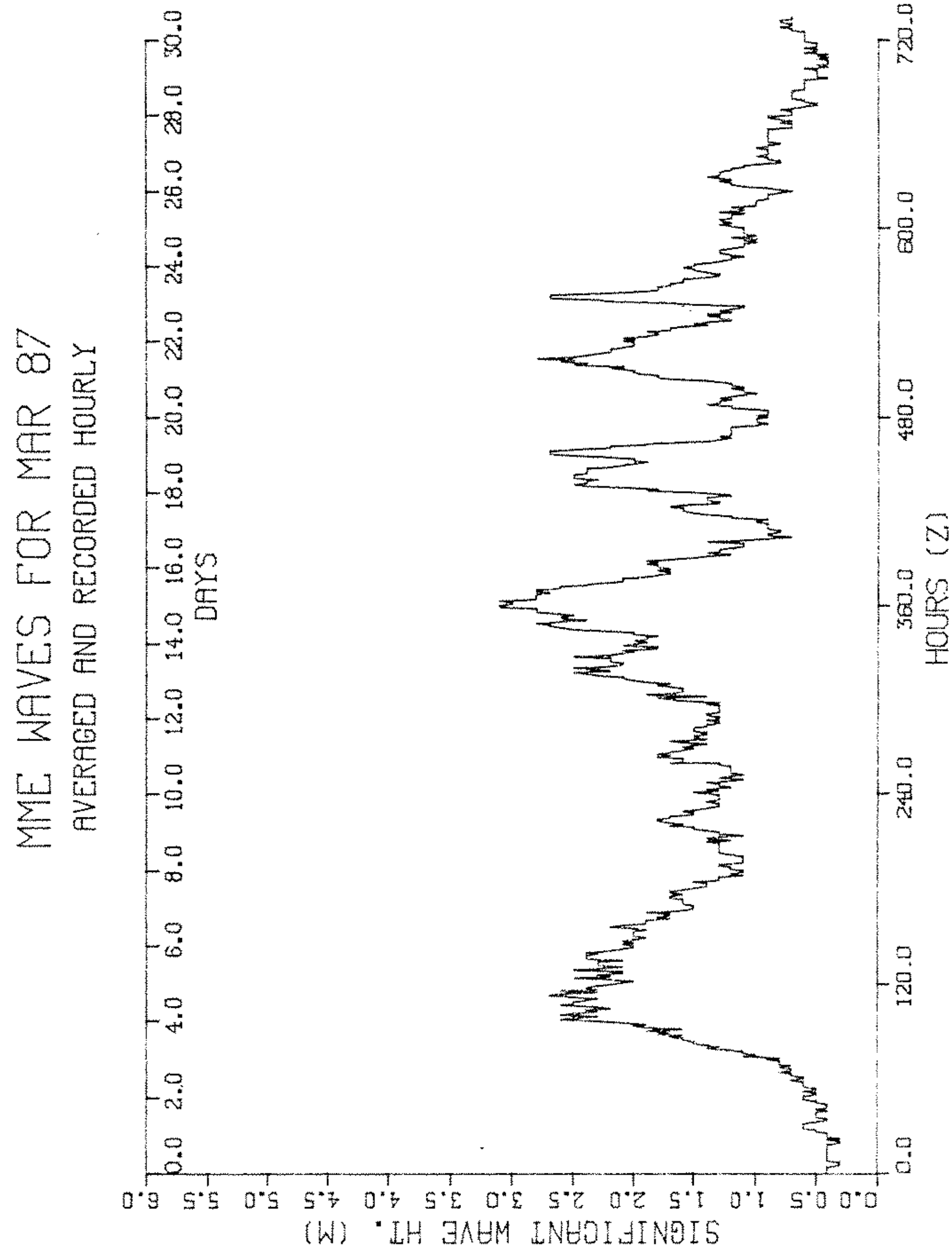

MME WIND SPEED FOR JAN 87
AVERAGED AND RECORDED HOURLY
DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0
AVERAGE WIND SPEED (M/SEC)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0


MME WAVES FOR FEB 87
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0

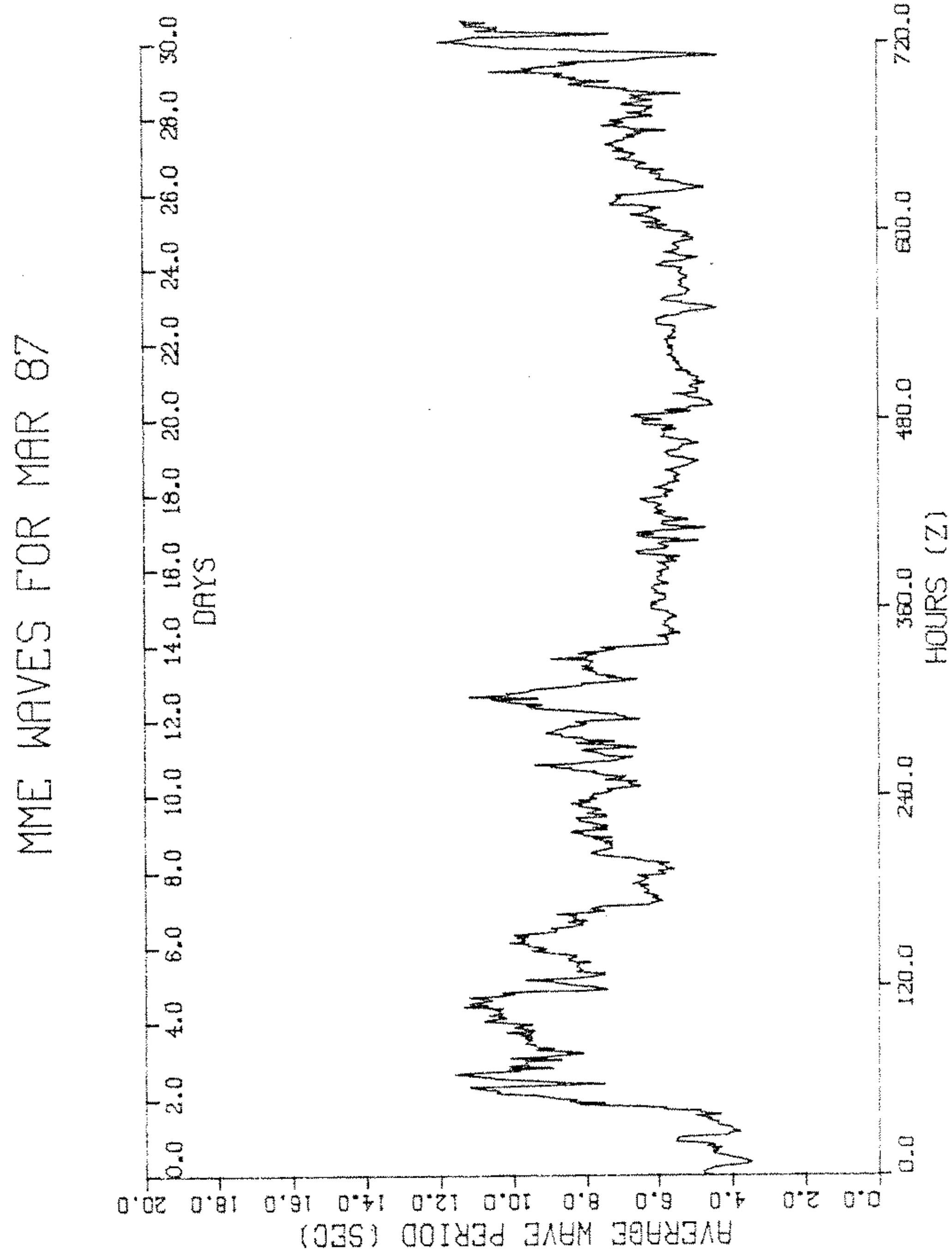

MME WAVES FOR FEB 87
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0


MME WAVES FOR FEB 87
PEAK WAVE PERIOD (SEC)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0

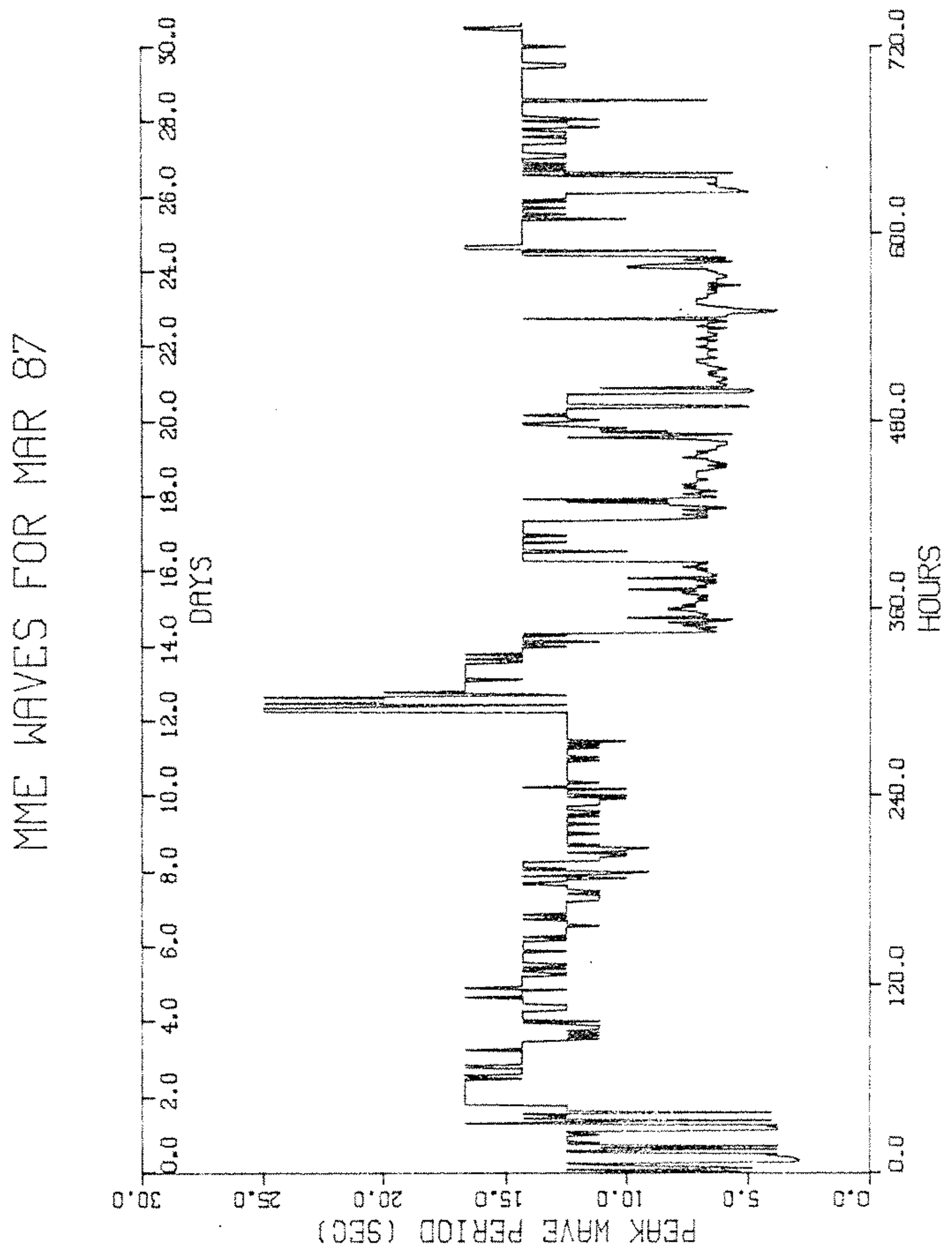

MME WIND SPEED FOR FEB 87
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WIND SPEED (M/SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0



MME WAVES FOR MAR 87
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0



MME WAVES FOR MAR 87
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0



MME WAVES FOR MAR 87
DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
PEAK WAVE PERIOD (SEC)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
HOURS
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120.0
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360.0
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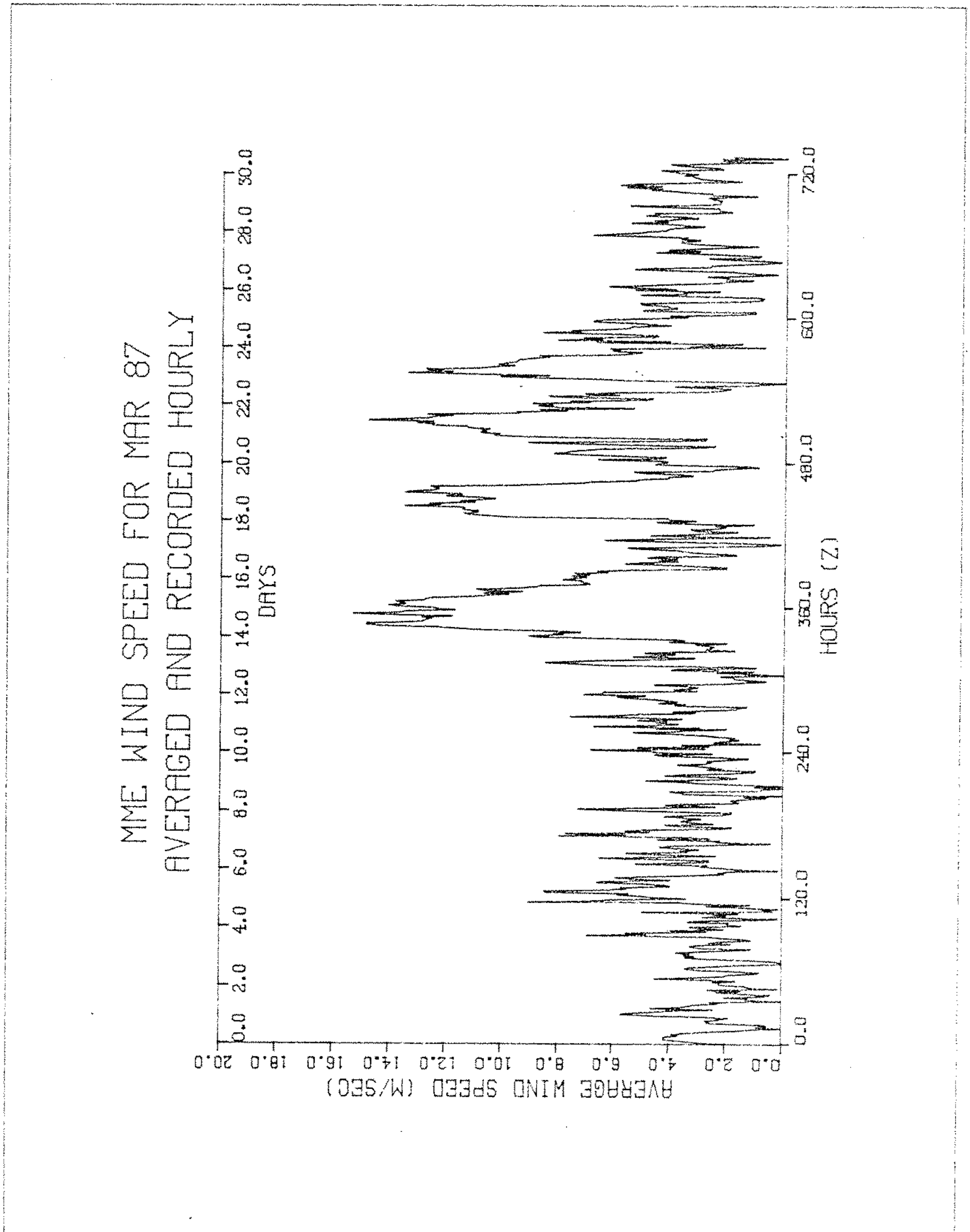
600.0
720.0



MME WIND SPEED FOR MAR 87
AVERAGED AND RECORDED HOURLY
DAYS
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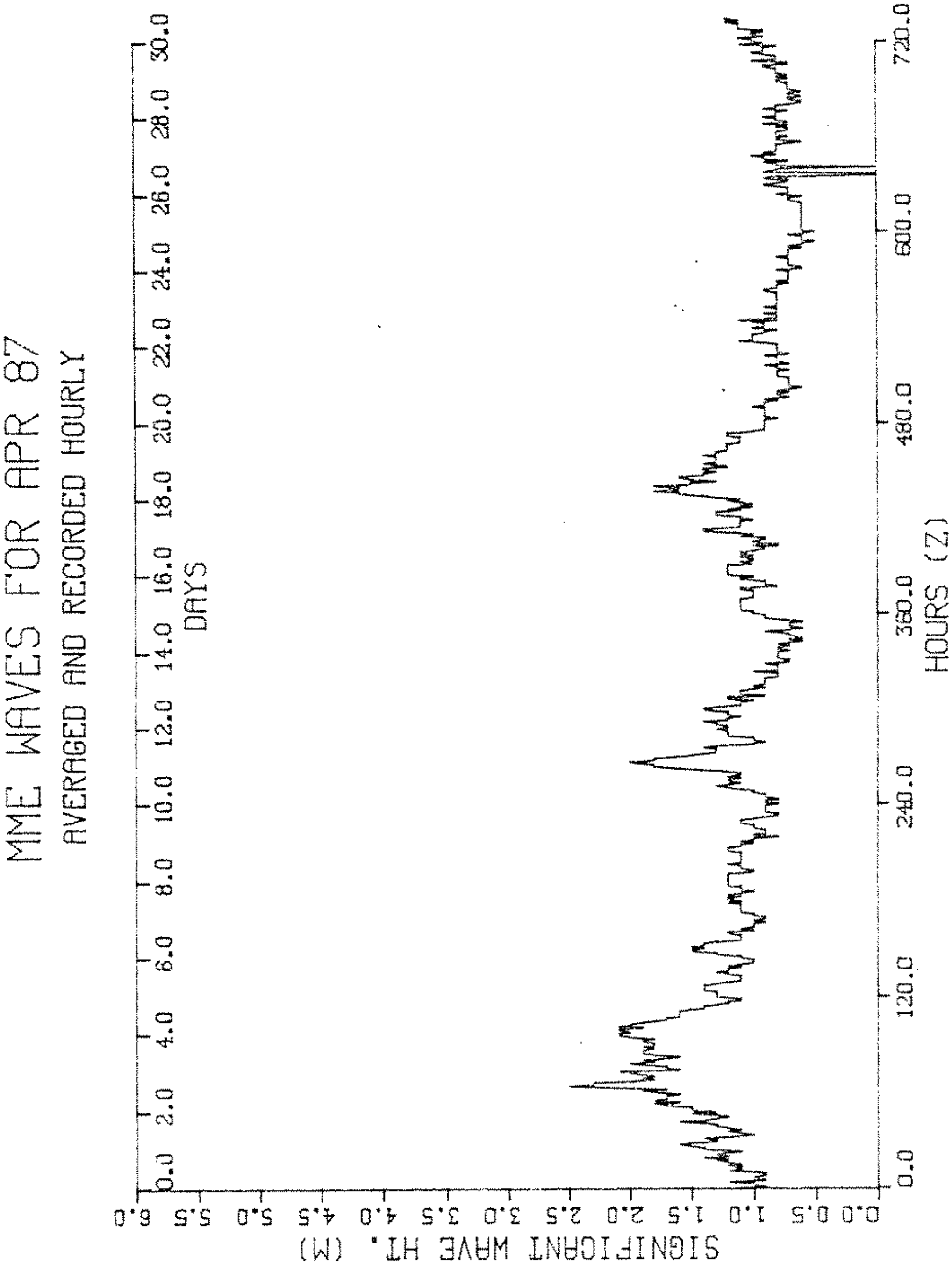
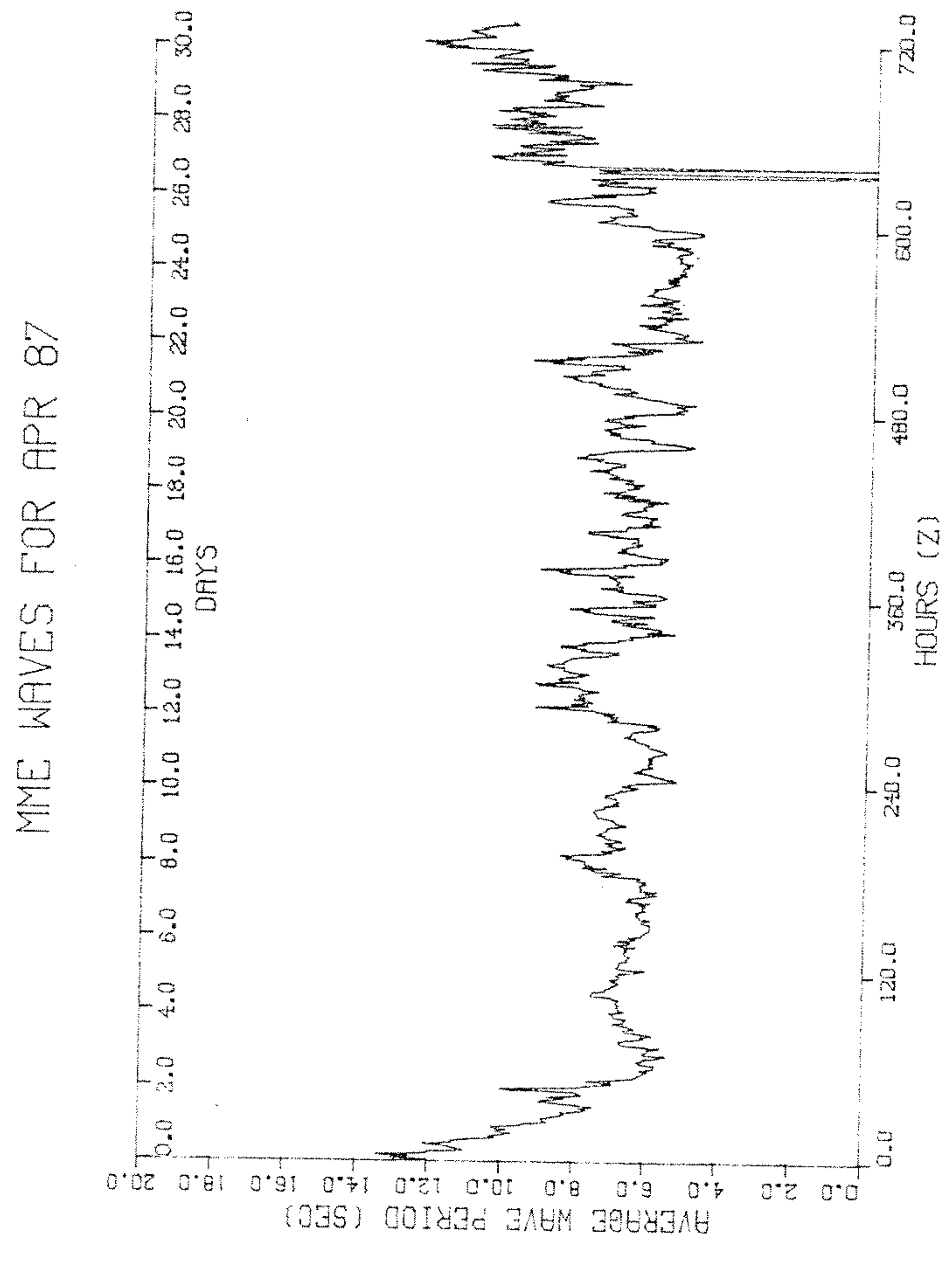
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WIND SPEED (M/SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0



MME WAVES FOR APR 87
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0


MME WAVES FOR APR 87
DAYS
0.0
2.0
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14.0
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22.0
24.0
26.0
28.0
30.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0
AVERAGE WAVE PERIOD (SEC)
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2.0
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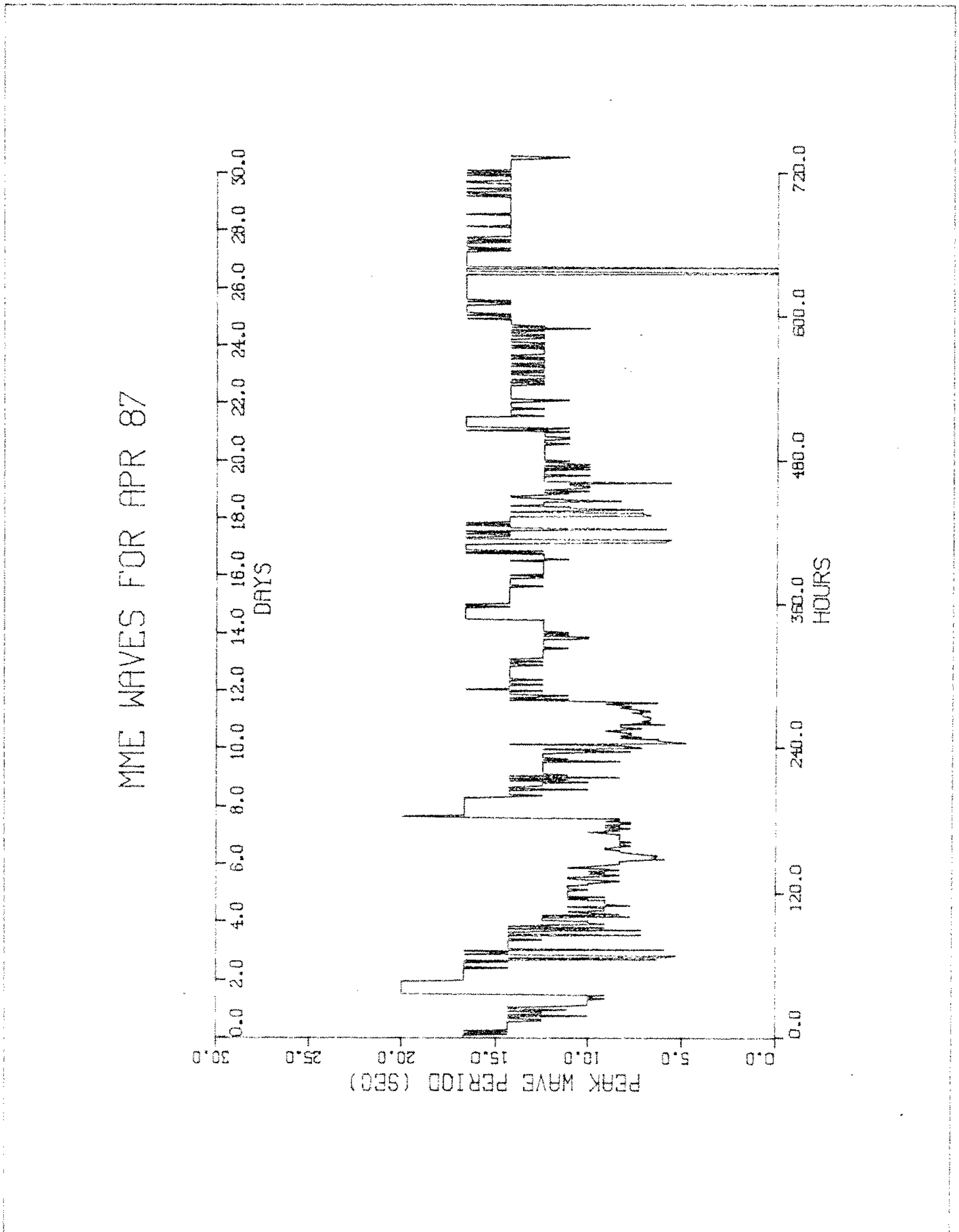
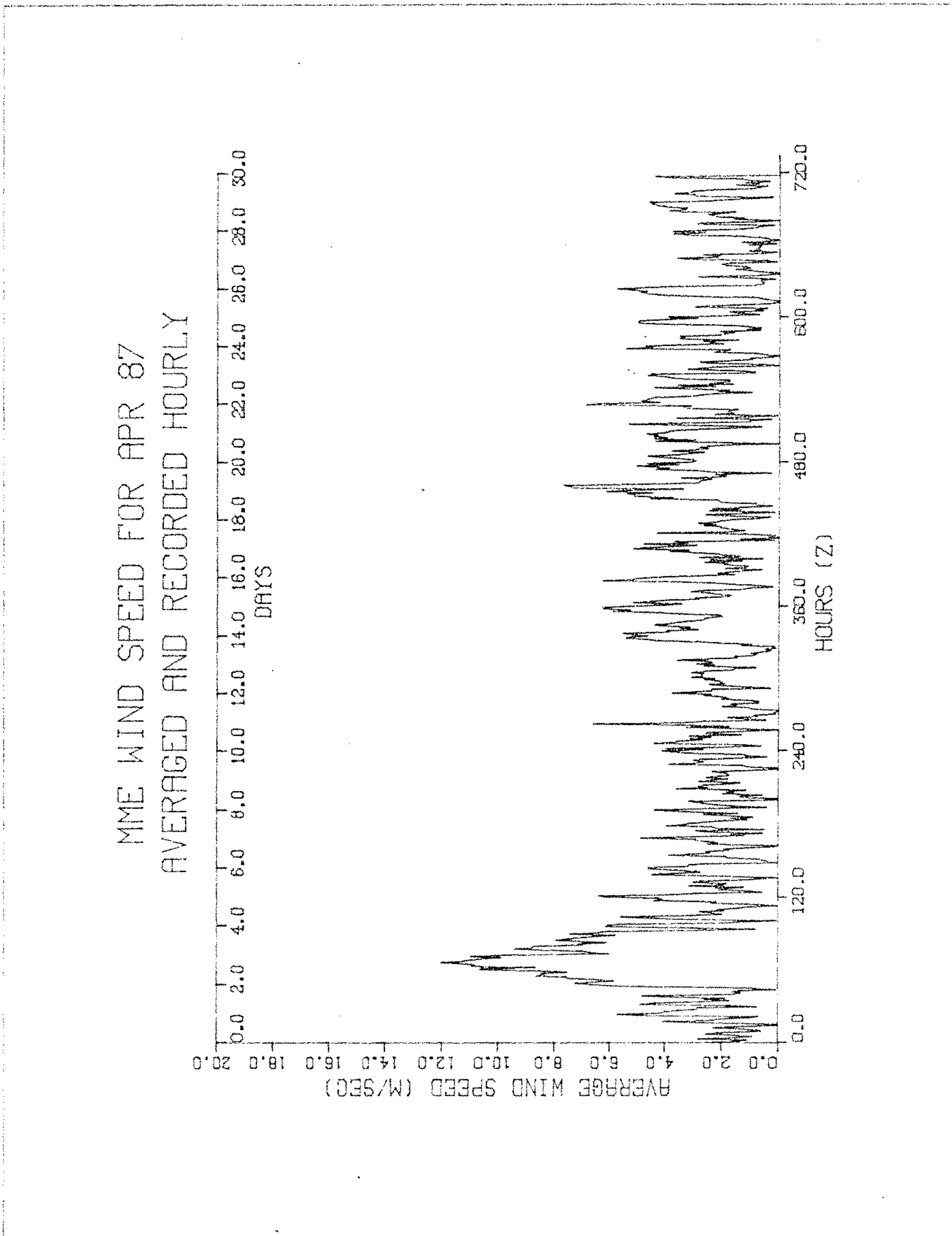
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0


MME WAVES FOR APR 87
DAYS
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
HOURS
0.0
120.0
240.0
360.0
480.0
600.0
720.0
PEAK WAVE PERIOD (SEC)
0.0
5.0
10.0
15.0
20.0
25.0
30.0



MME WIND SPEED FOR APR 87
AVERAGED AND RECORDED HOURLY
DAYS
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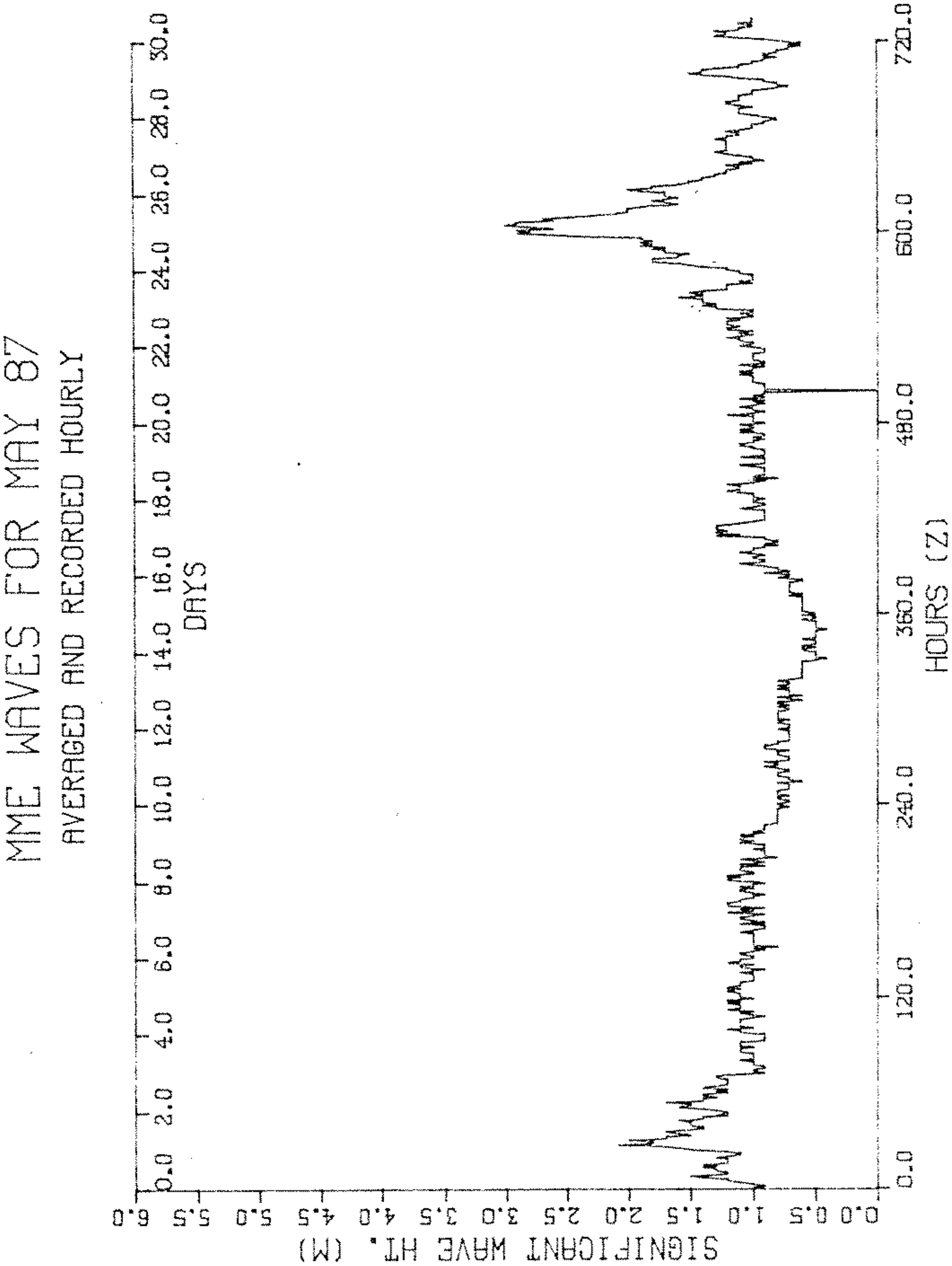
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WIND SPEED (M/SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0


MME WAVES FOR MAY 87
AVERAGED AND RECORDED HOURLY
DAYS
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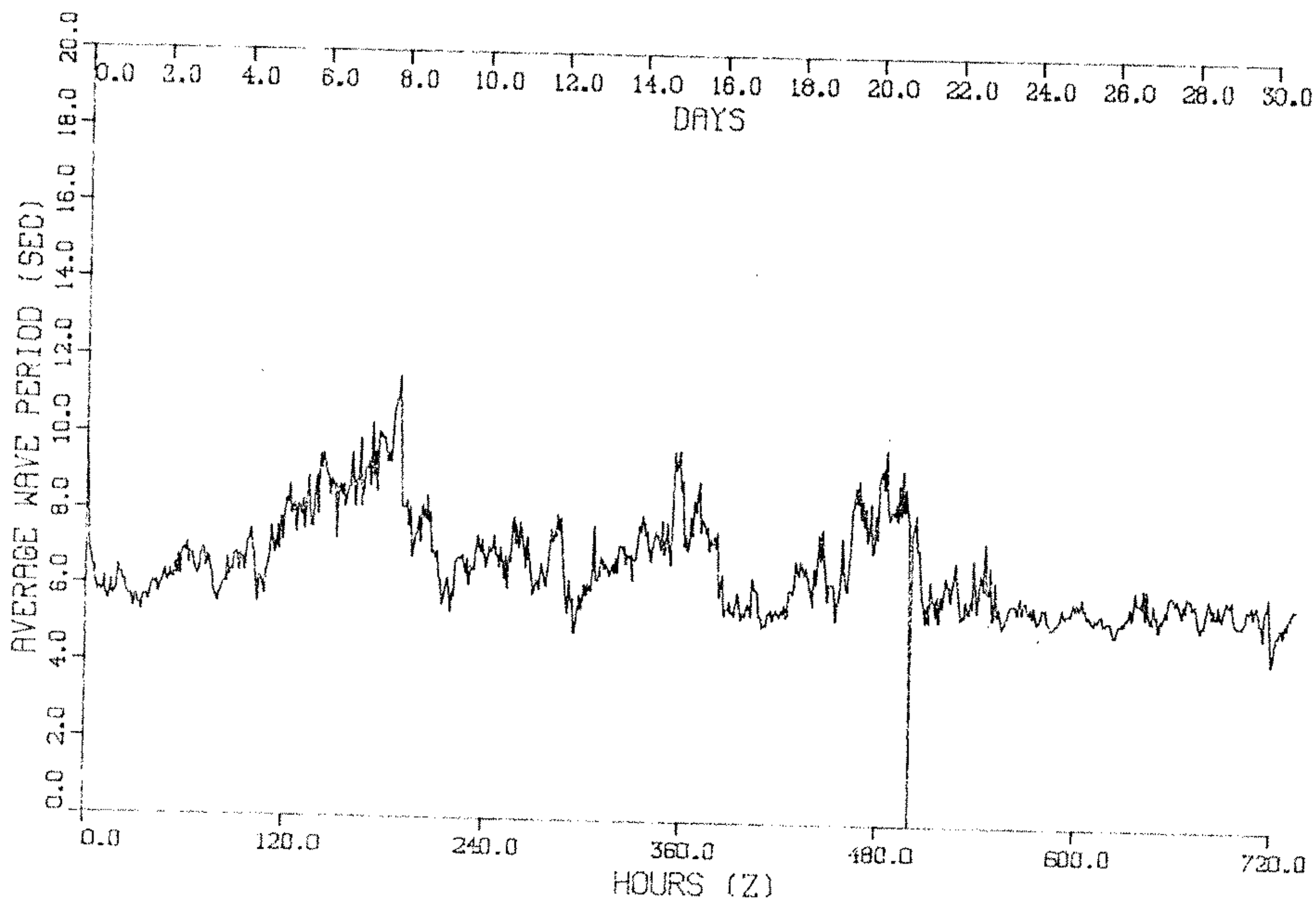
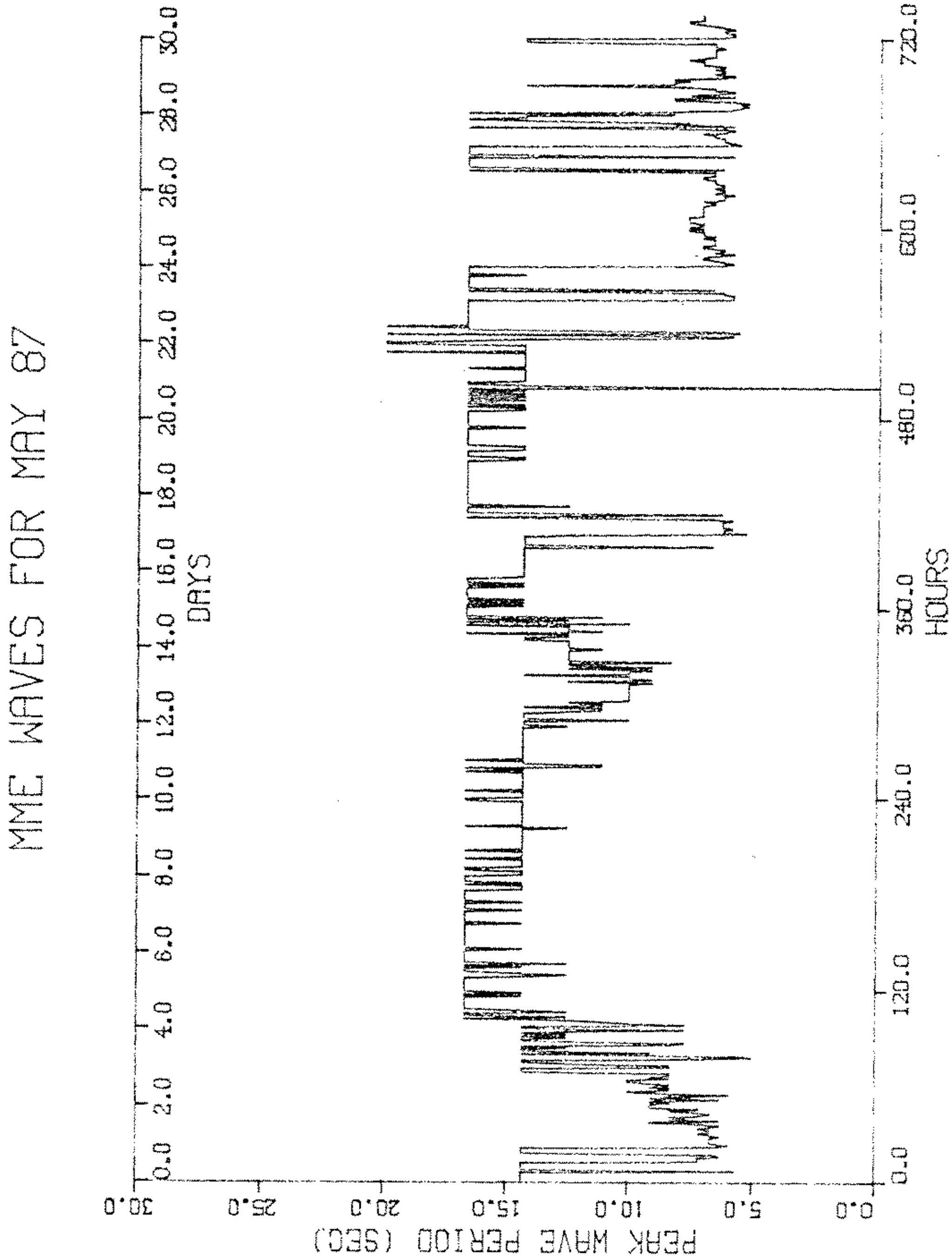
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0
SIGNIFICANT WAVE HT. (M)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

MME WAVES FOR MAY 87




MME WAVES FOR MAY 87
DAYS
0.0
2.0
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6.0
8.0
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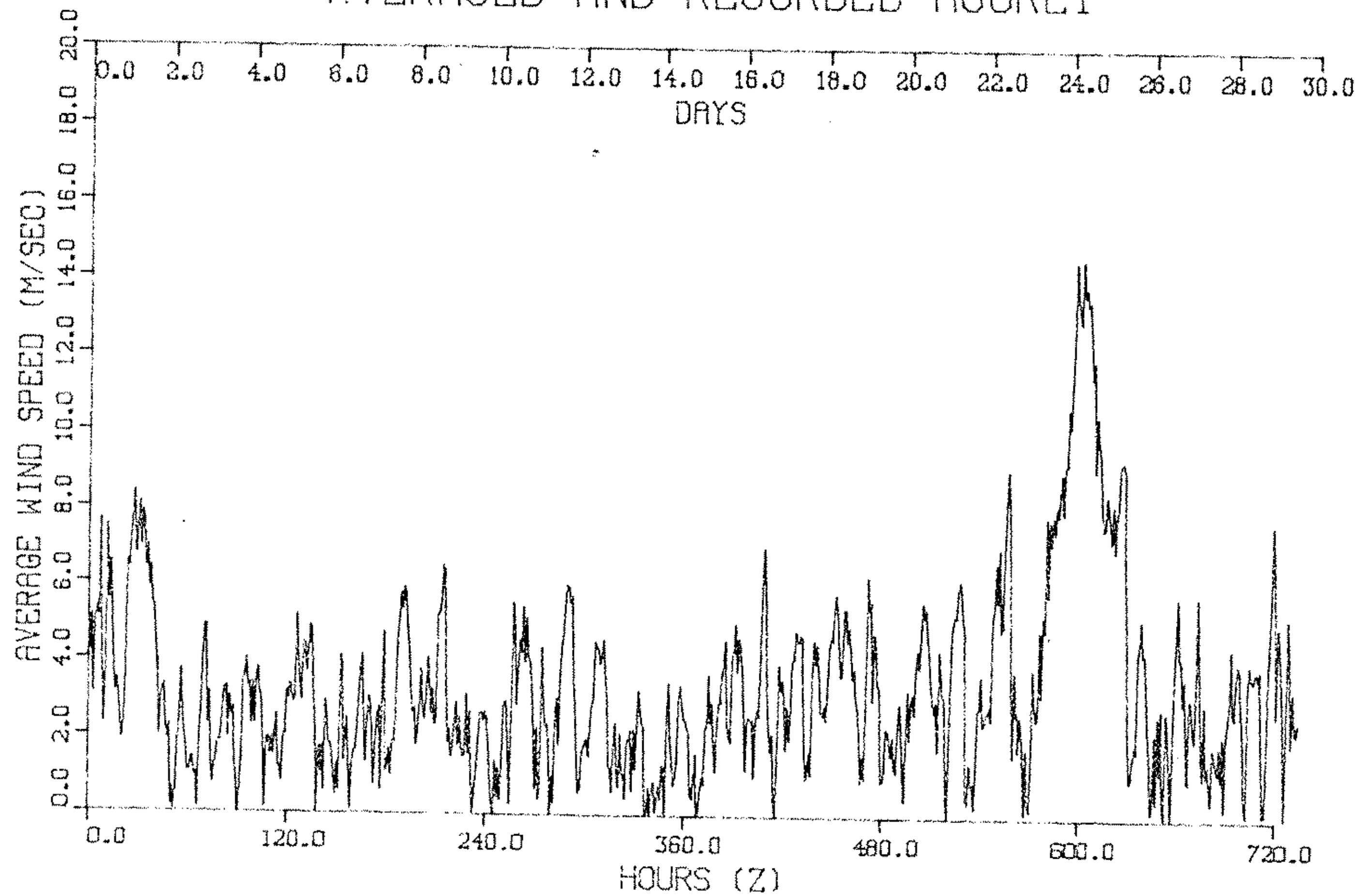
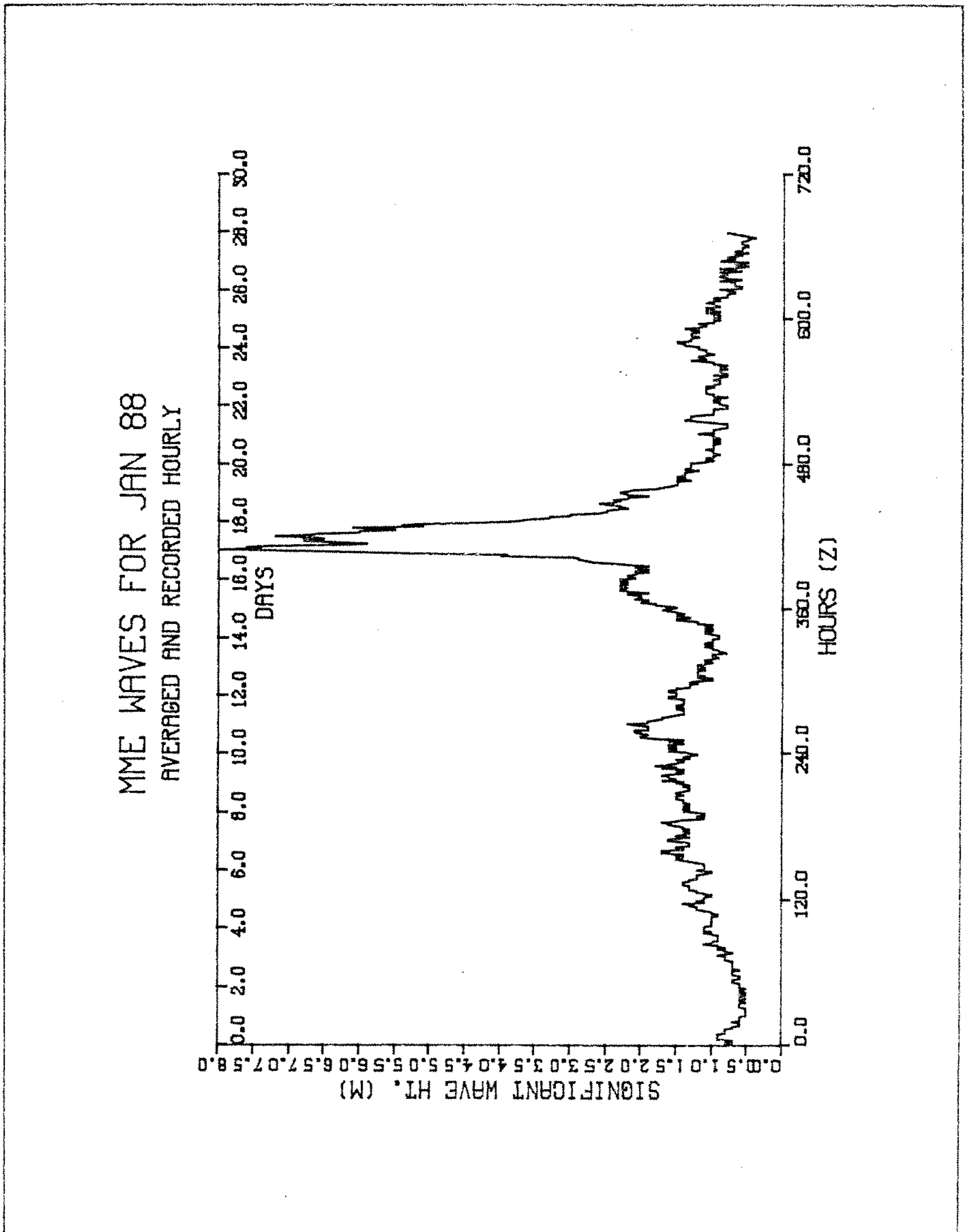
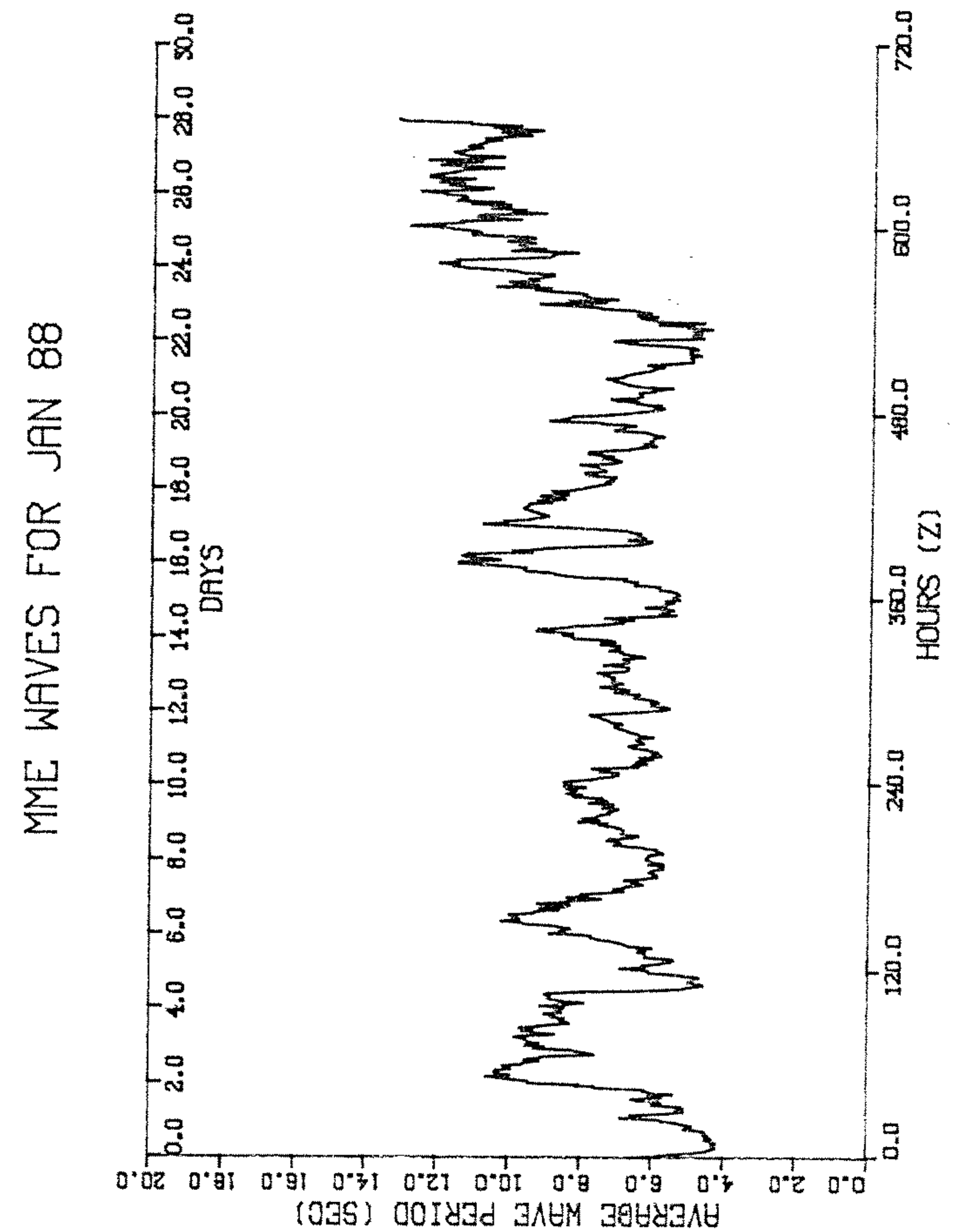
14.0
16.0
18.0
20.0
22.0
24.0
26.0
28.0
30.0
HOURS
0.0
120.0
240.0
360.0
480.0
600.0
720.0
PEAK WAVE PERIOD (SEC)
0.0
5.0
10.0
15.0
20.0
25.0
30.0

MME WIND SPEED FOR MAY 87
AVERAGED AND RECORDED HOURLY




MME WAVES FOR JAN 88
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0


MME WAVES FOR JAN 88
DAYS
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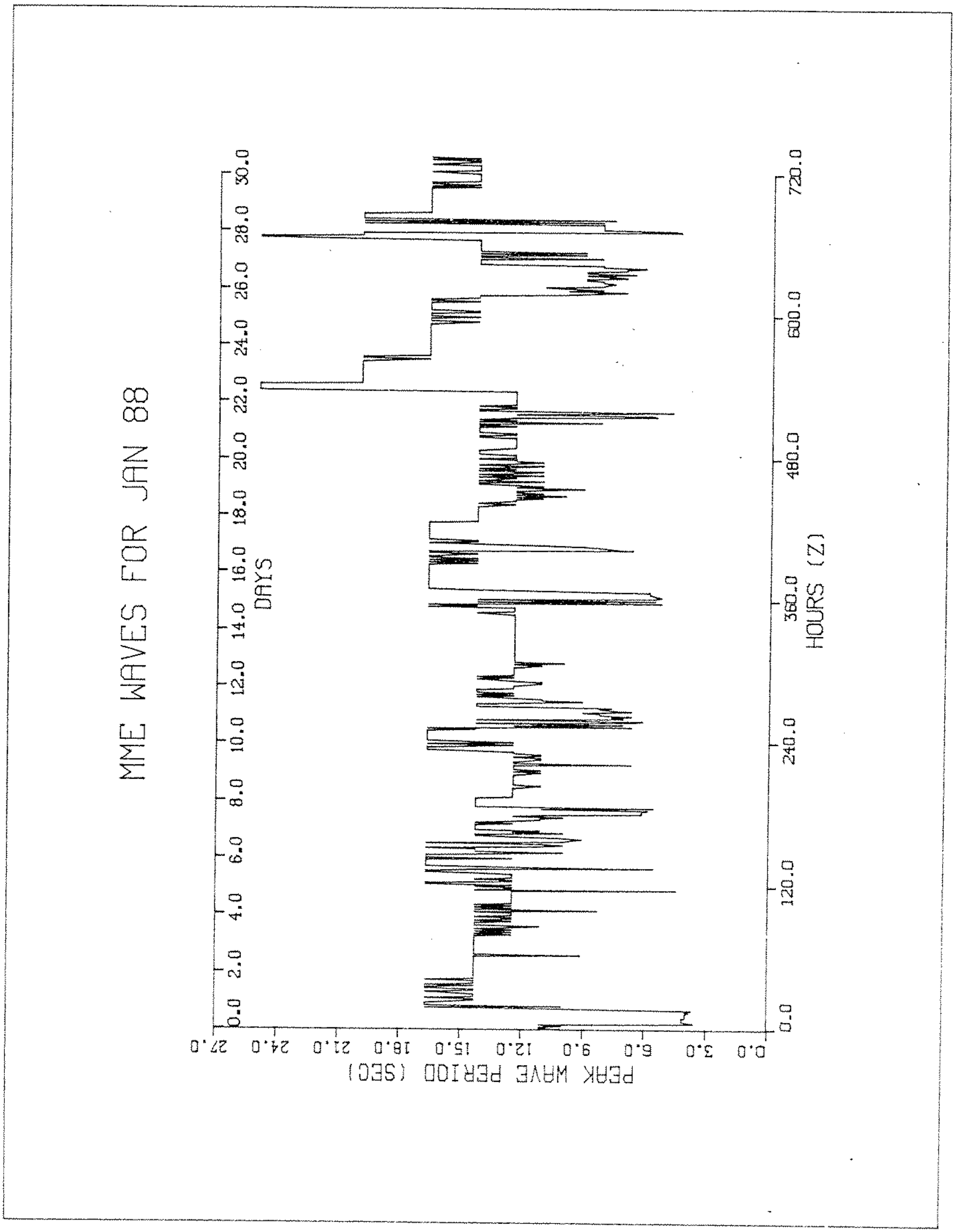
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0



MME WAVES FOR JAN 88
DAYS
0.0
2.0
4.0
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8.0
10.0
12.0
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16.0
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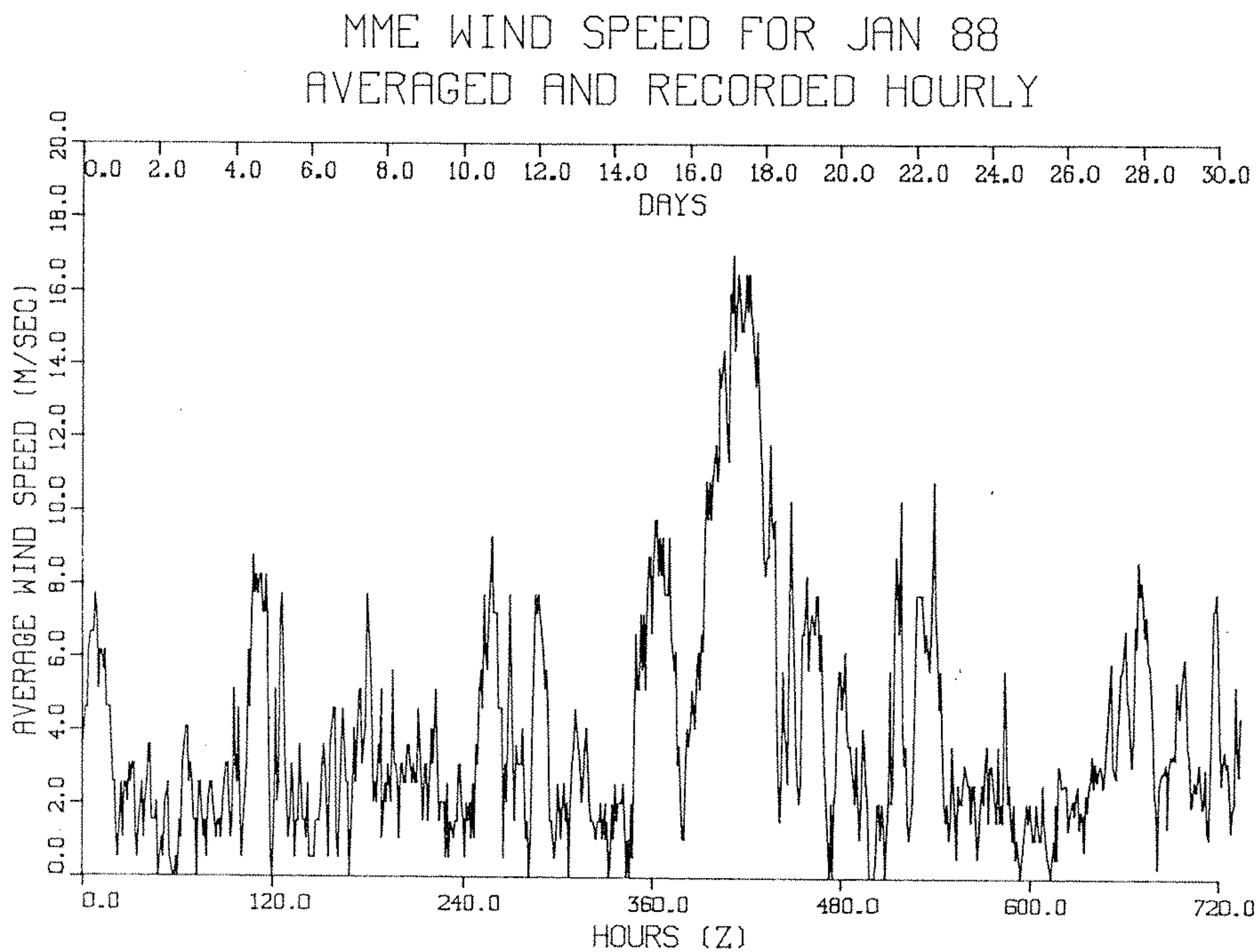
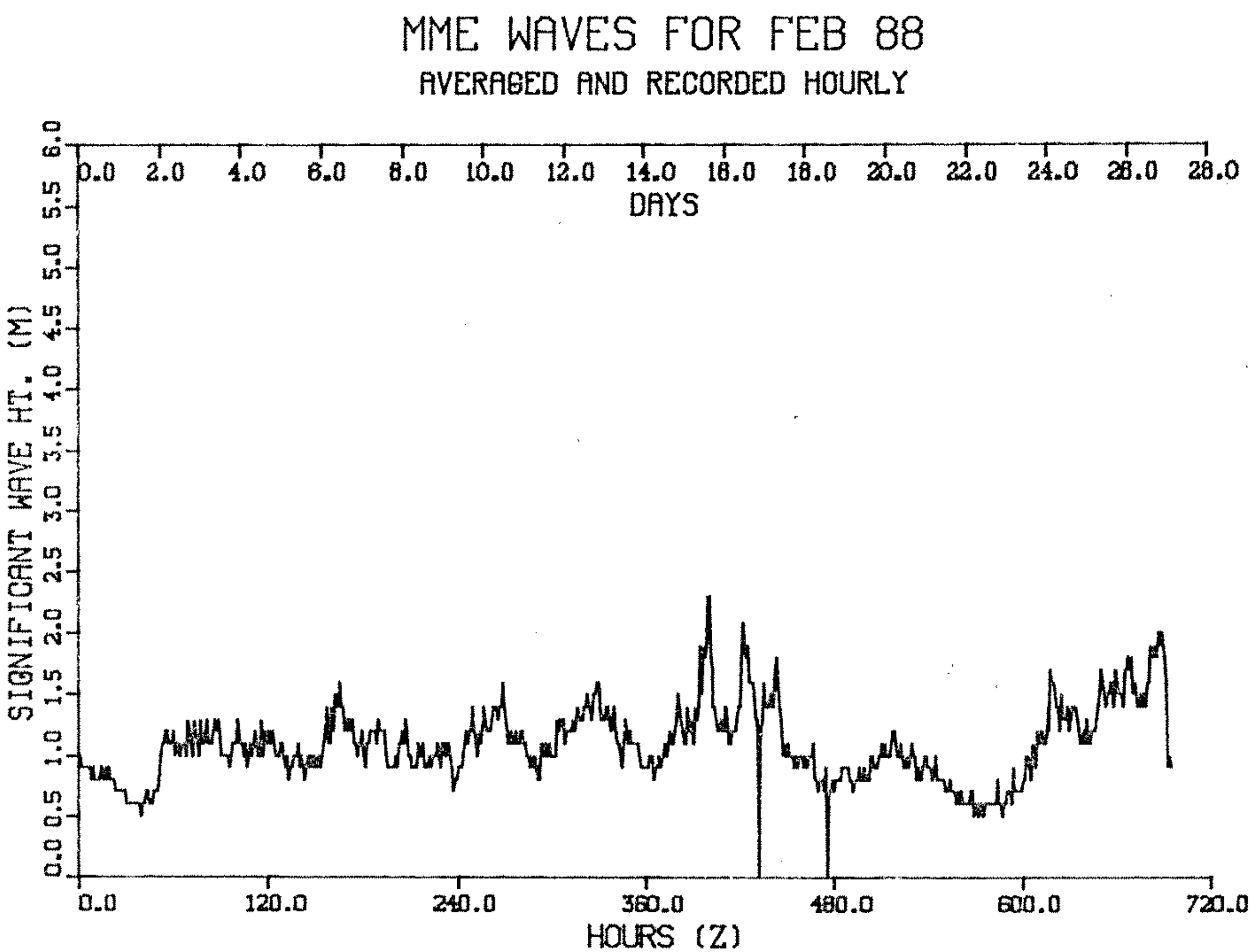
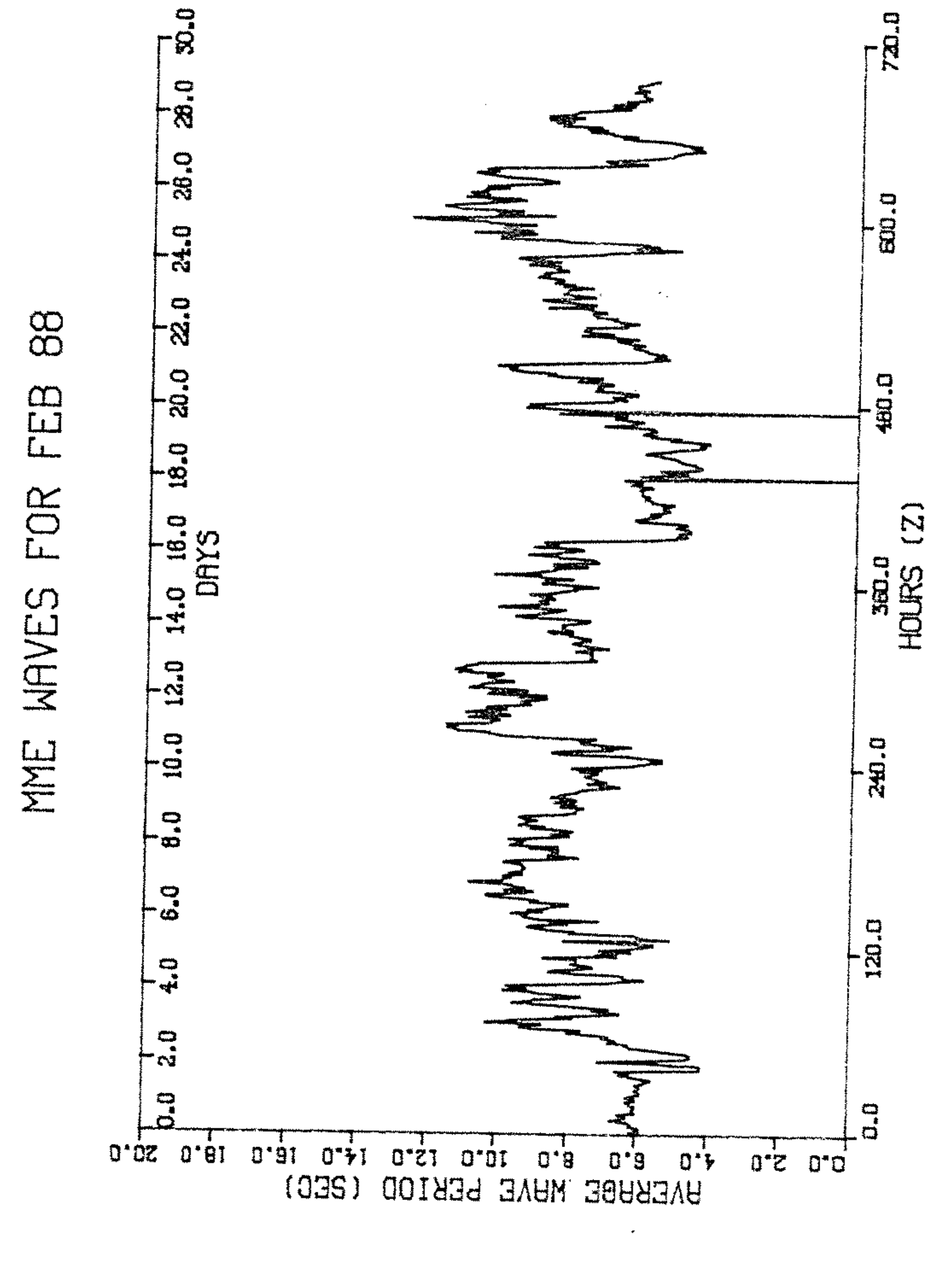
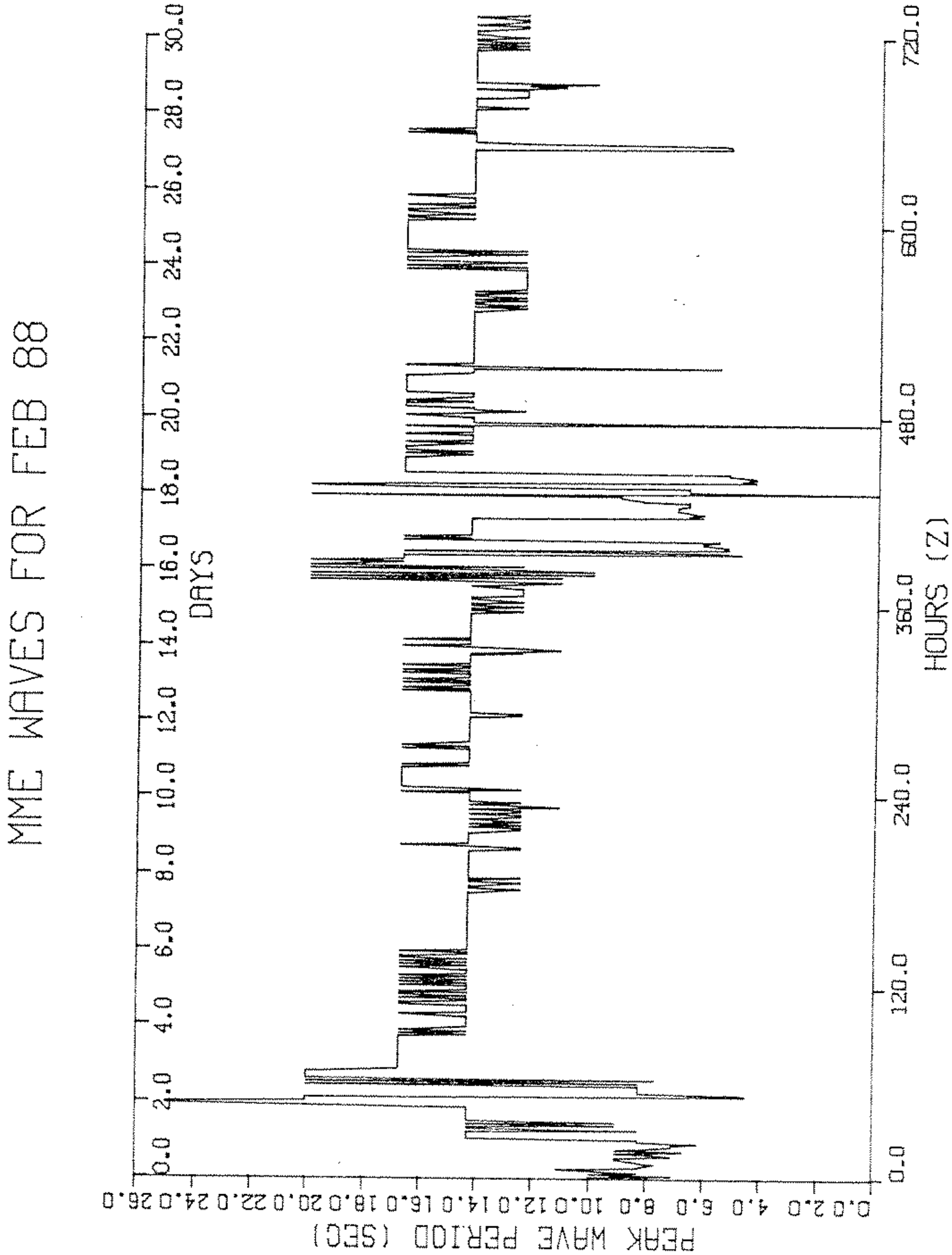
20.0
22.0
24.0
26.0
28.0
30.0
HOURS (Z)
0.0
120.0
240.0
360.0
480.0
600.0
720.0
PEAK WAVE PERIOD (SEC)
0.0
3.0
6.0
9.0
12.0
15.0
18.0
21.0
24.0
27.0


MME WIND SPEED FOR JAN 88
AVERAGED AND RECORDED HOURLY
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
DAYS
AVERAGE WIND SPEED (M/SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
0.0 120.0 240.0 360.0 480.0 600.0 720.0
HOURS (Z)


MME WAVES FOR FEB 88
AVERAGED AND RECORDED HOURLY
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0
DAYS
SIGNIFICANT WAVE HT. (M)
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
0.0 120.0 240.0 360.0 480.0 600.0 720.0
HOURS (Z)



MME WAVES FOR FEB 88
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
AVERAGE WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0


MME WAVES FOR FEB 88
DAYS
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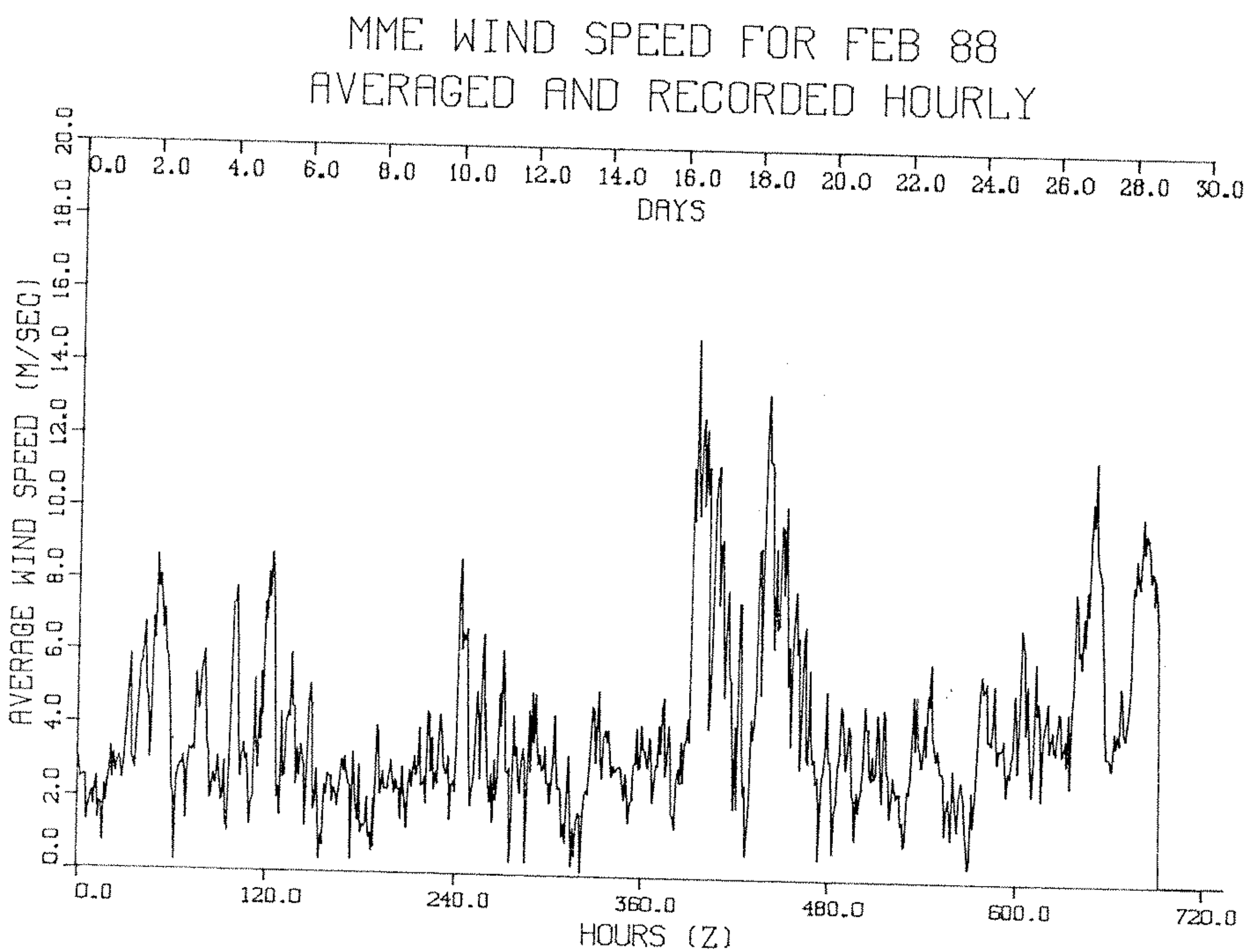
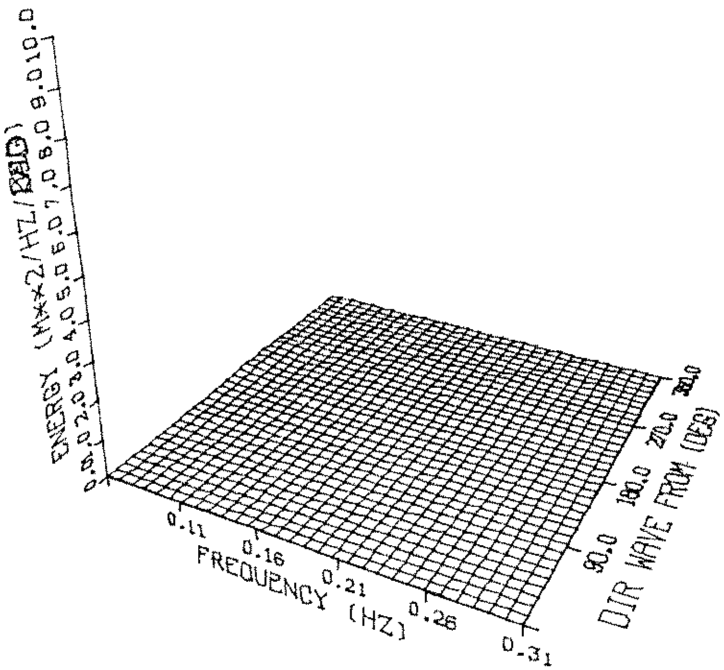
HOURS (Z)
0.0 120.0 240.0 360.0 480.0 600.0 720.0
PEAK WAVE PERIOD (SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0


MME WIND SPEED FOR FEB 88
AVERAGED AND RECORDED HOURLY
DAYS
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0 22.0 24.0 26.0 28.0 30.0
AVERAGE WIND SPEED (M/SEC)
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
0.0 120.0 240.0 360.0 480.0 600.0 720.0
HOURS (Z)

NDBC BUOY DIRECTIONAL SPECTRUM

MARCH 1, 1987 0900 P.S.T.



NDBC BUOY DIRECTIONAL SPECTRUM

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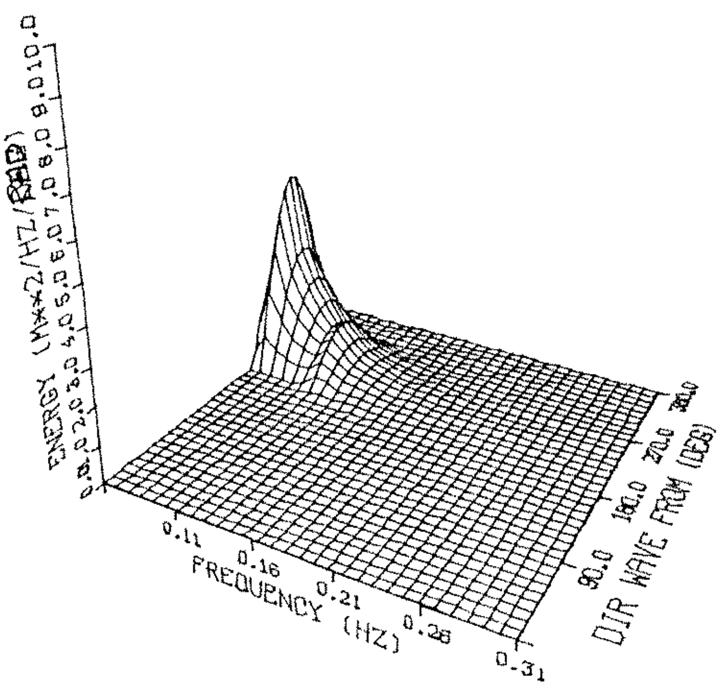

NDBC BUOY DIRECTIONAL SPECTRUM

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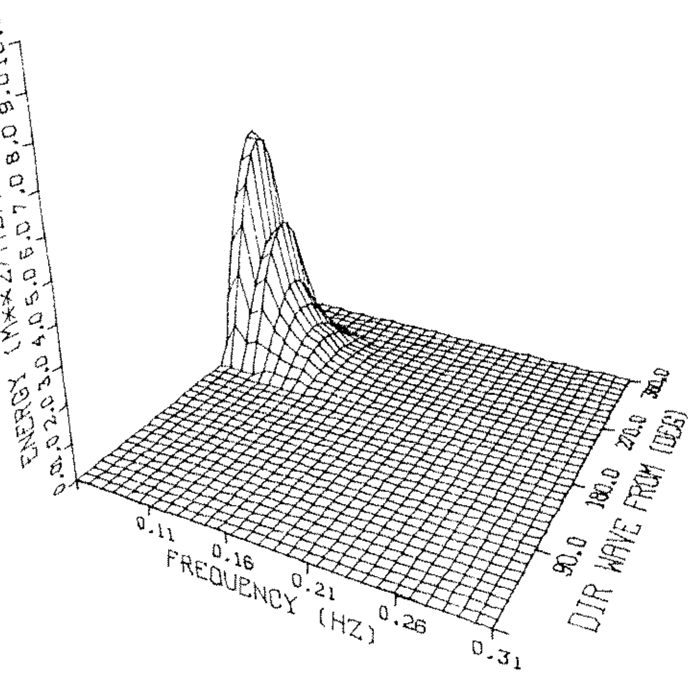

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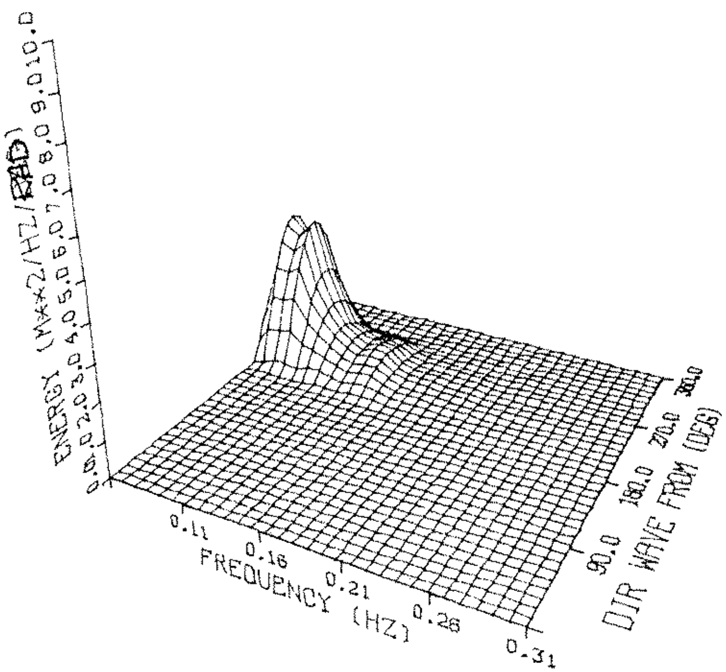
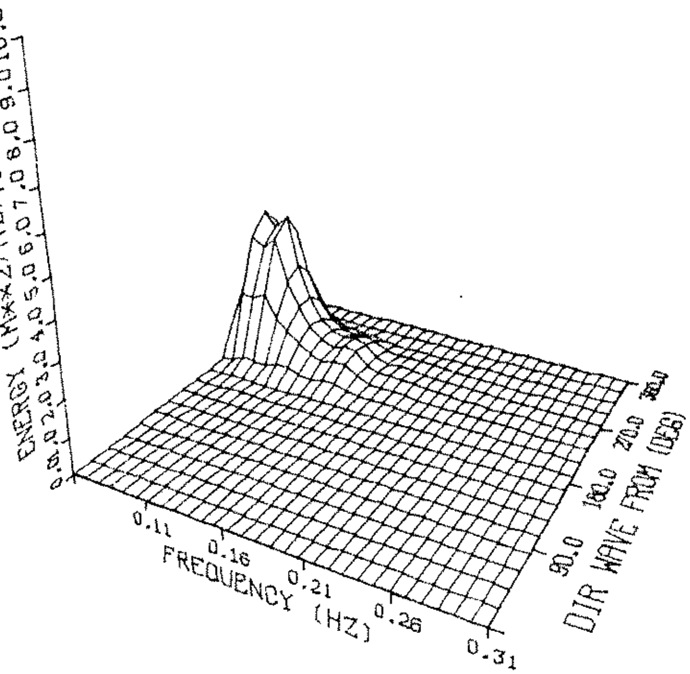


MME DIRECTIONAL SPECTRUM

MARCH 5, 1987 2000 P.S.T.



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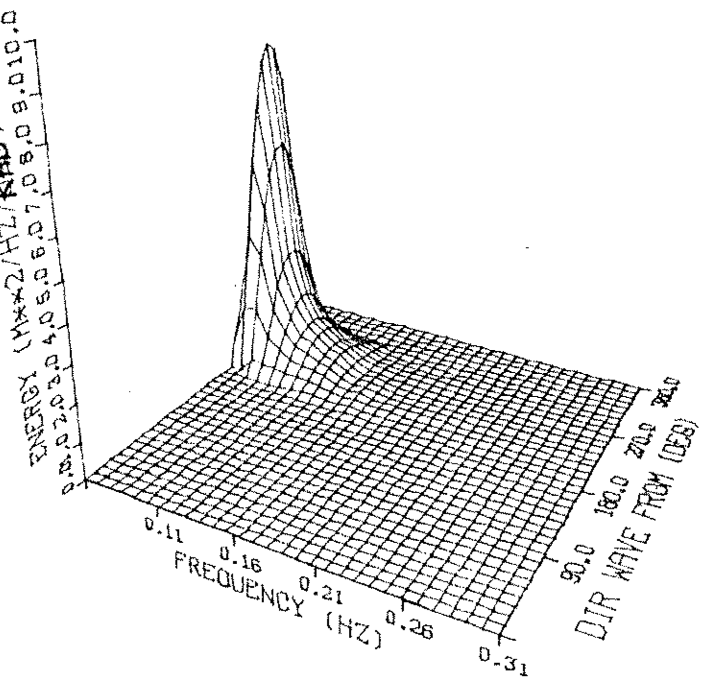

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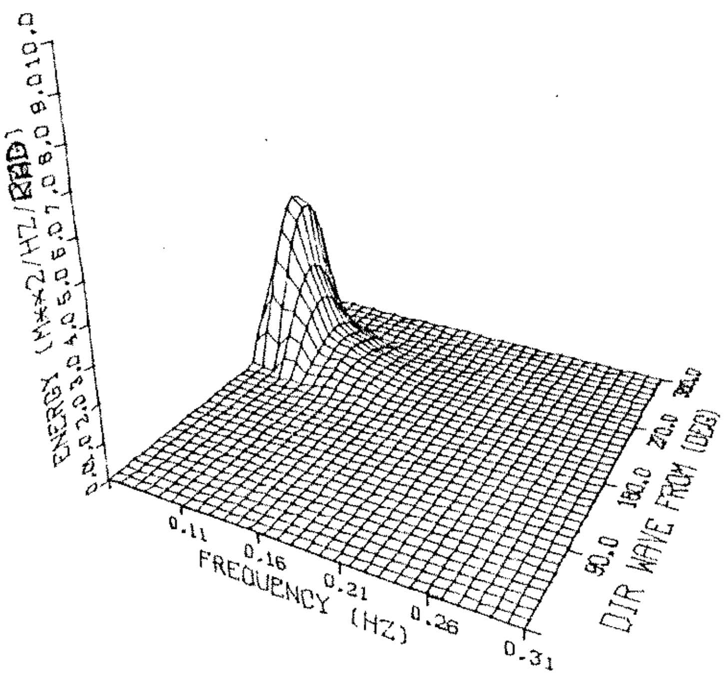

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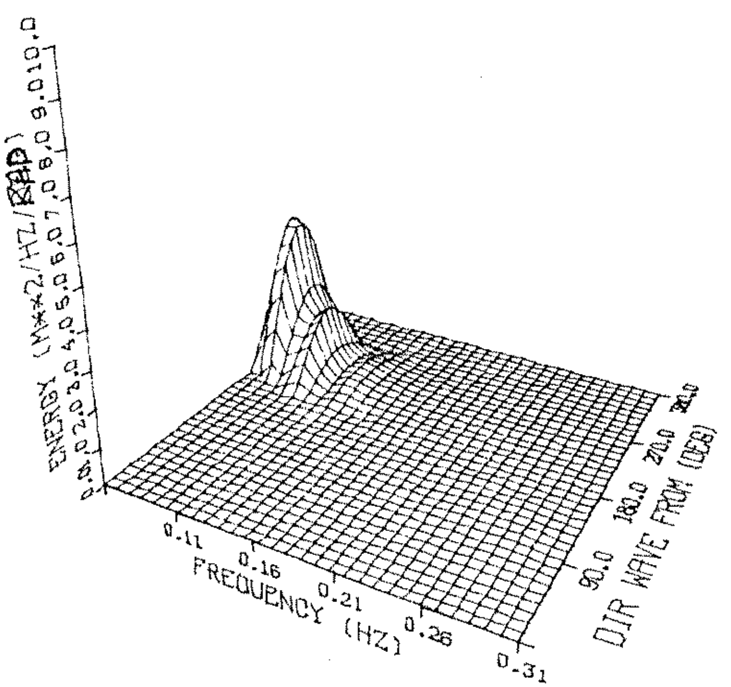

NDBC BUOY DIRECTIONAL SPECTRUM

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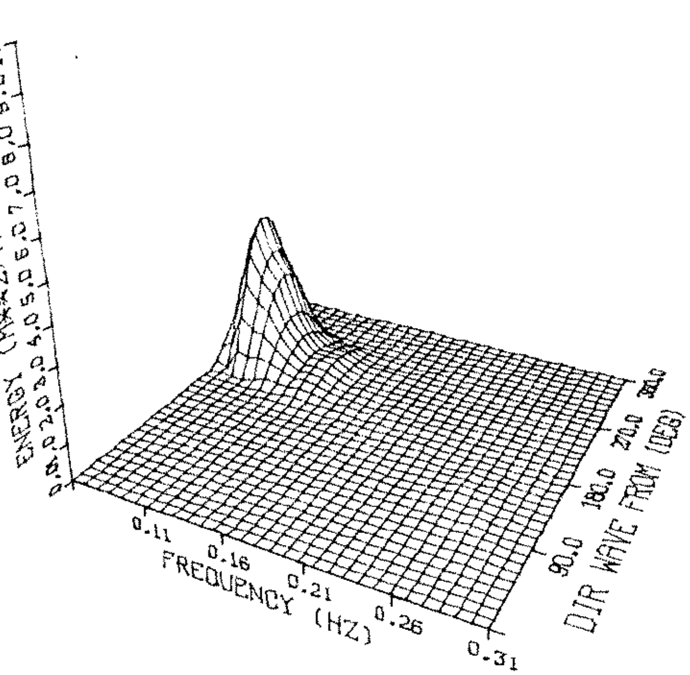
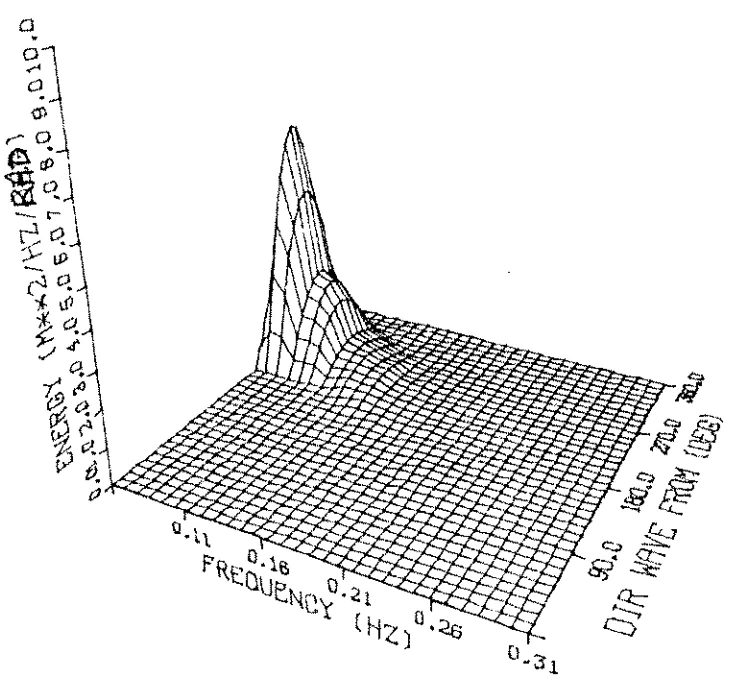


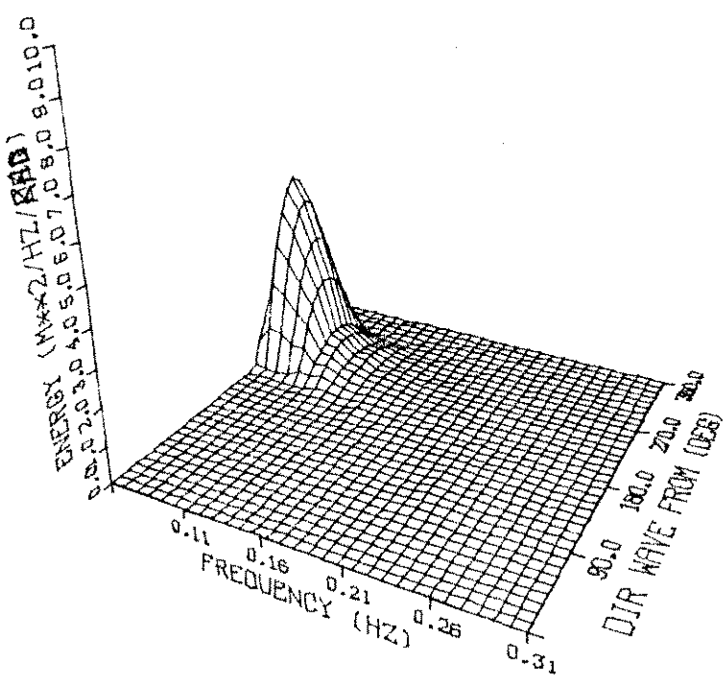
NDBC BUOY DIRECTIONAL SPECTRUM

MARCH 6, 1987 0900 P.S.T.



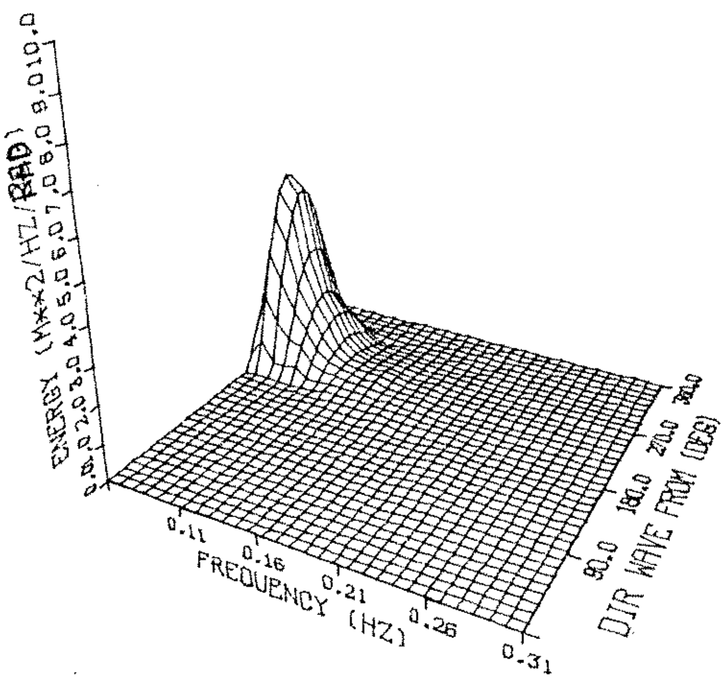
NDBC BUOY DIRECTIONAL SPECTRUM

MARCH 6, 1987 1000 P.S.T.



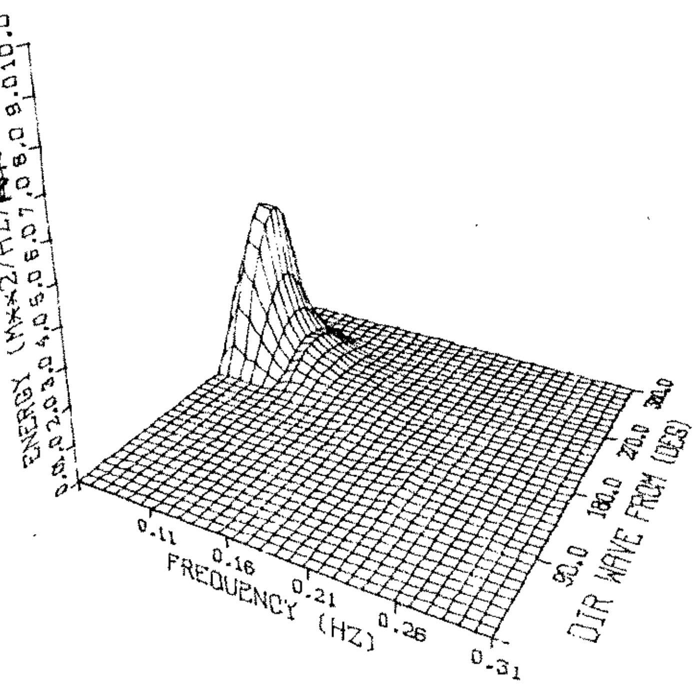
NDBC BUOY DIRECTIONAL SPECTRUM

MARCH 6, 1987 1100 P.S.T.



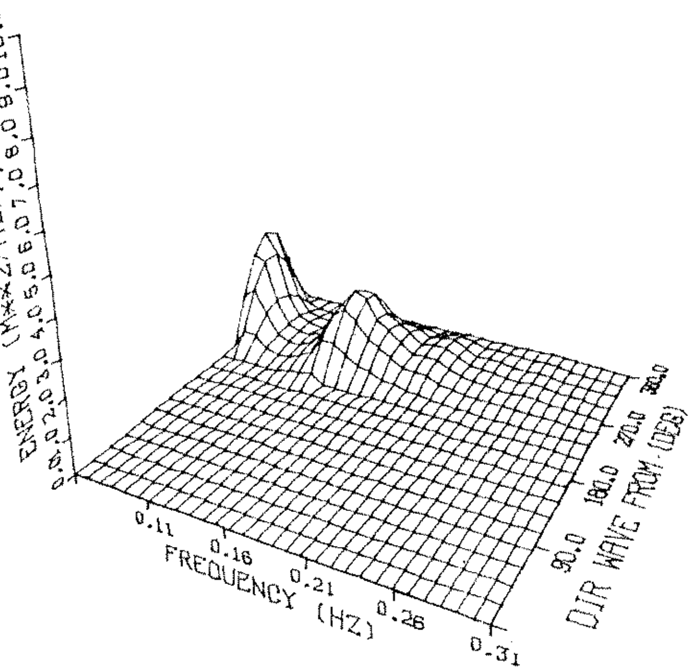
NDBC BUOY DIRECTIONAL SPECTRUM

MARCH 6, 1987 1200 P.S.T.



MME DIRECTIONAL SPECTRUM

APRIL 3, 1987 0900 P.S.T.



MME DIRECTIONAL SPECTRUM

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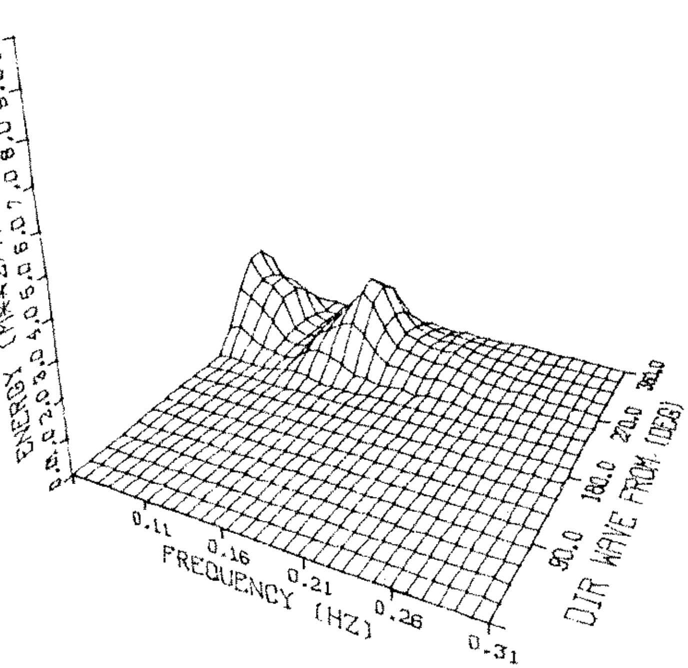
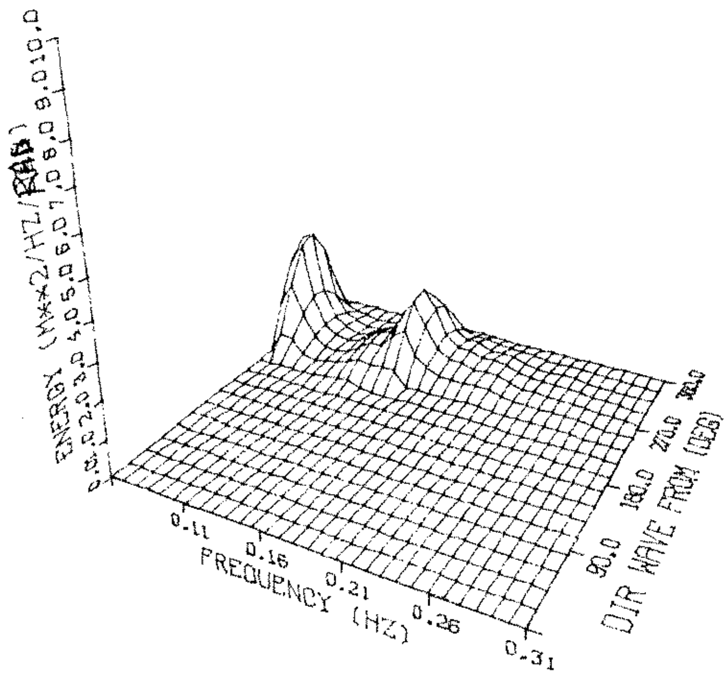


MME DIRECTIONAL SPECTRUM

APRIL 3 1987 *1100 P.S.T.*



MME DIRECTIONAL SPECTRUM

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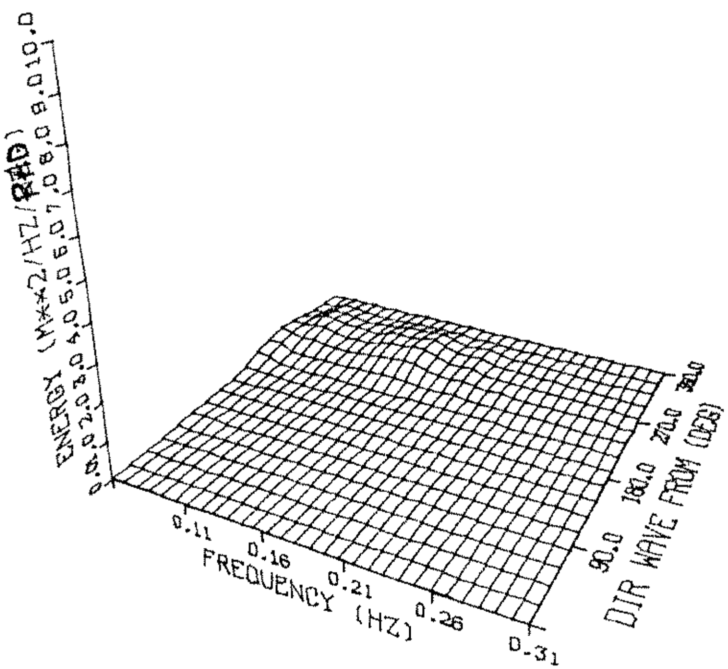

MME DIRECTIONAL SPECTRUM

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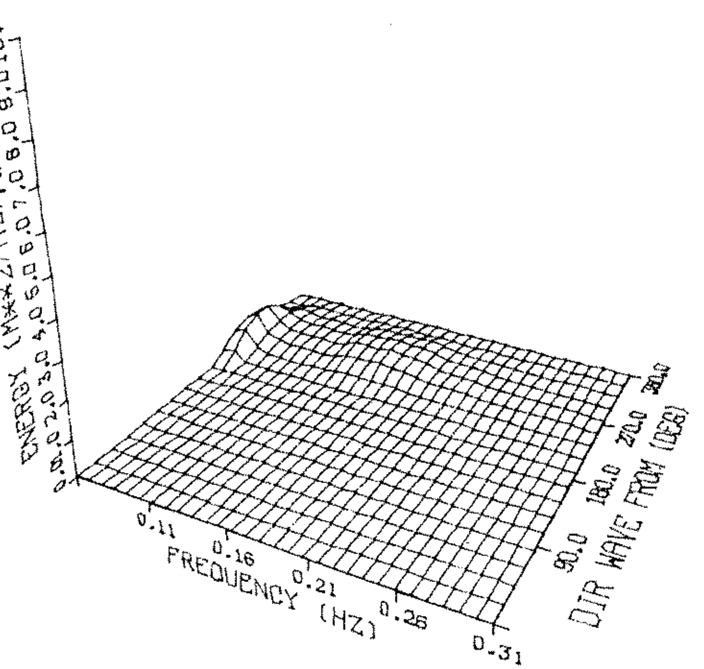

MME DIRECTIONAL SPECTRUM

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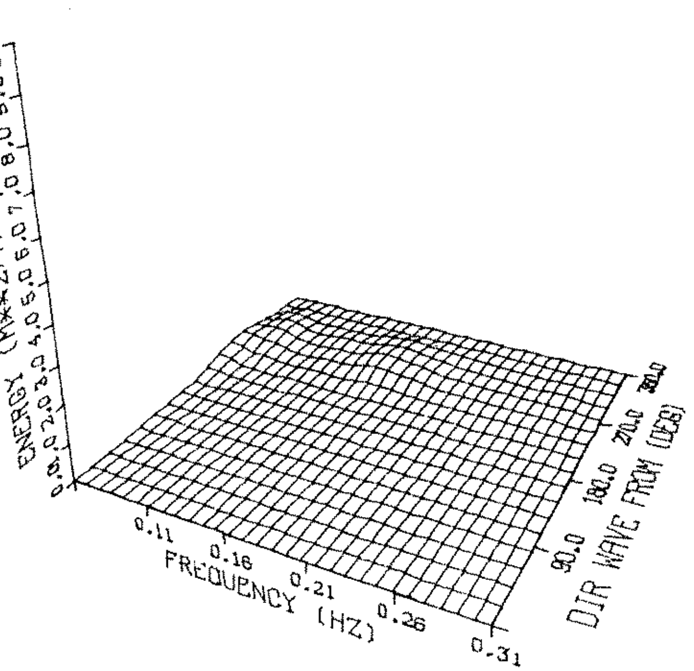
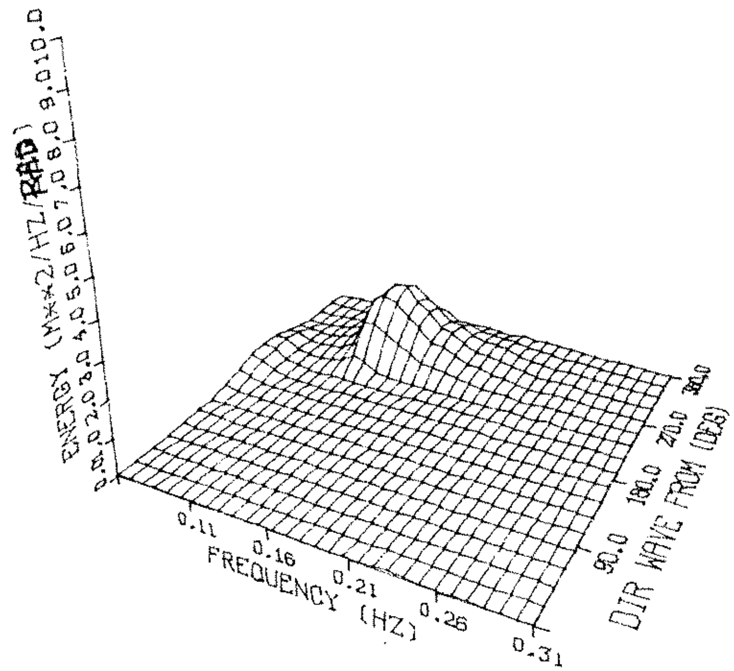


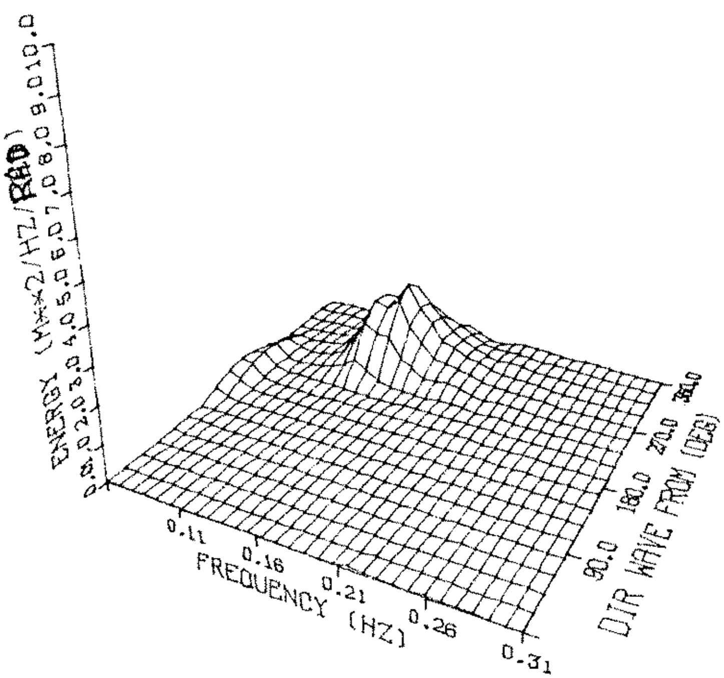
MME DIRECTIONAL SPECTRUM

MAY 25 1987 0900 P.S.T.



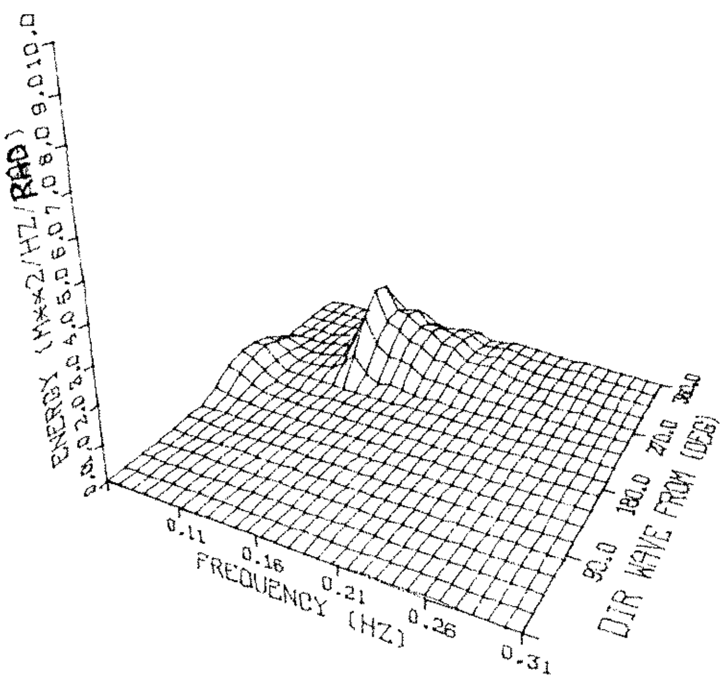
MME DIRECTIONAL SPECTRUM

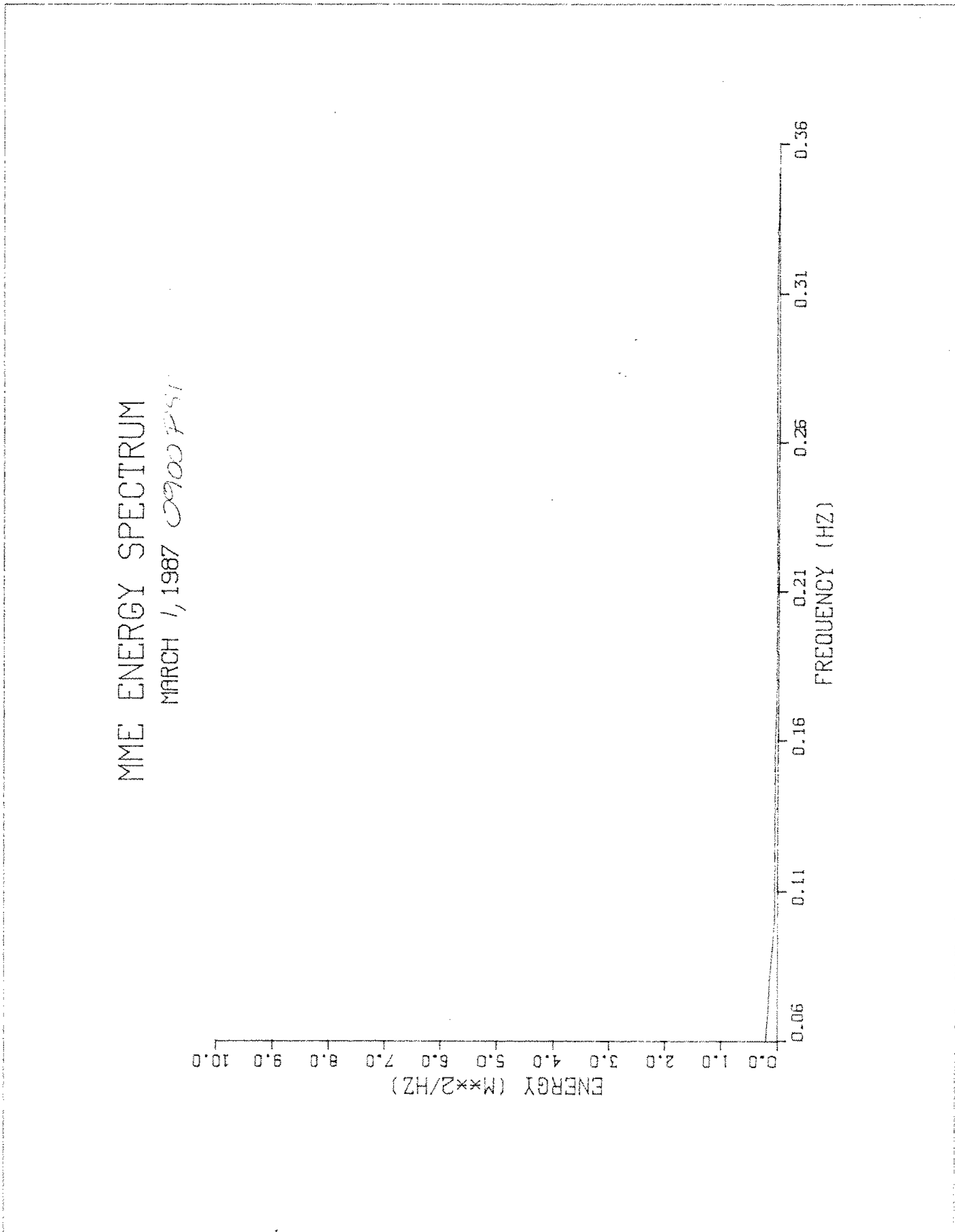
MAY 25 1987 1000 P.D.T.



MME DIRECTIONAL SPECTRUM

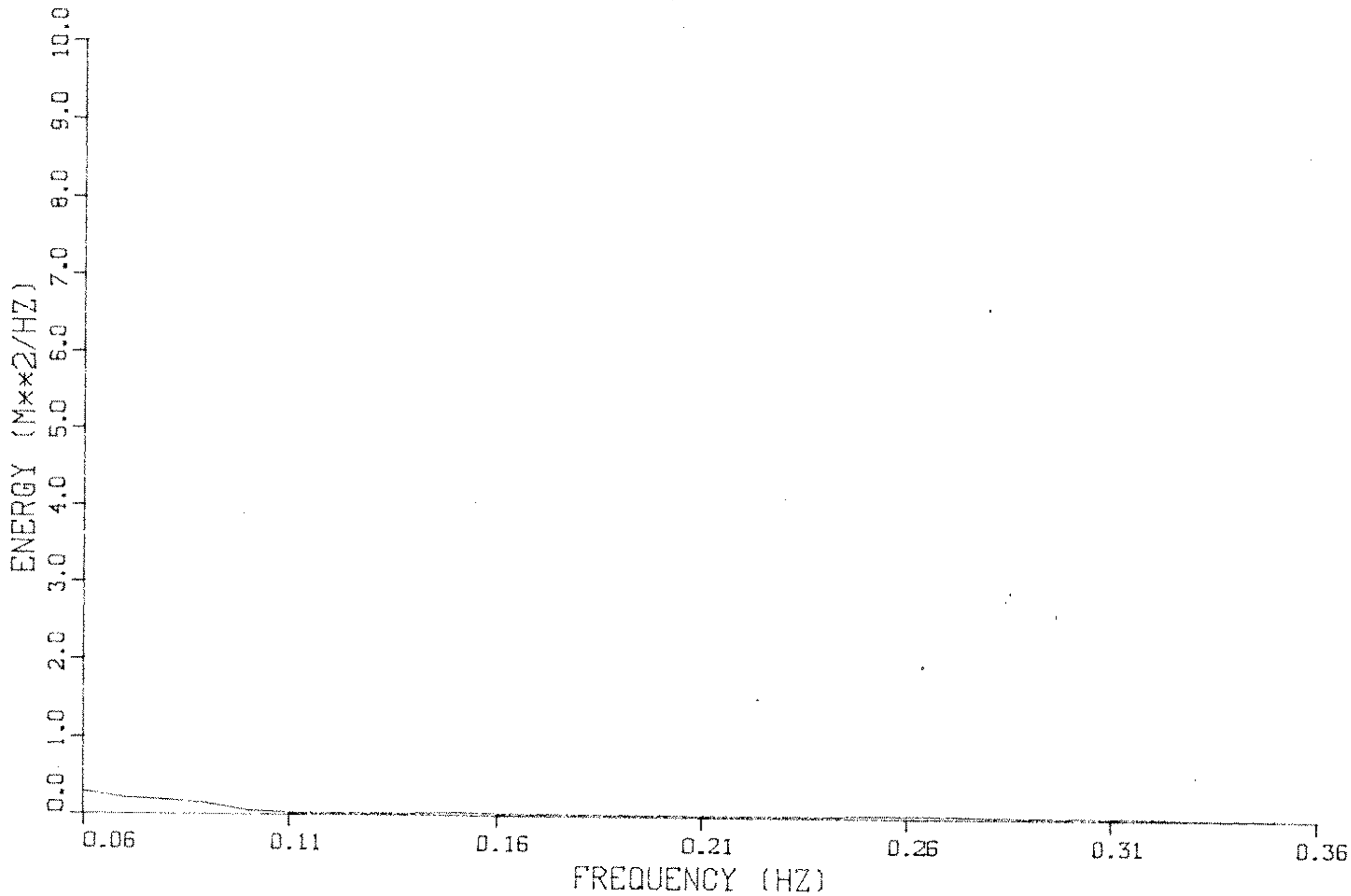
MAY 25 1987 1100 P.D.T.

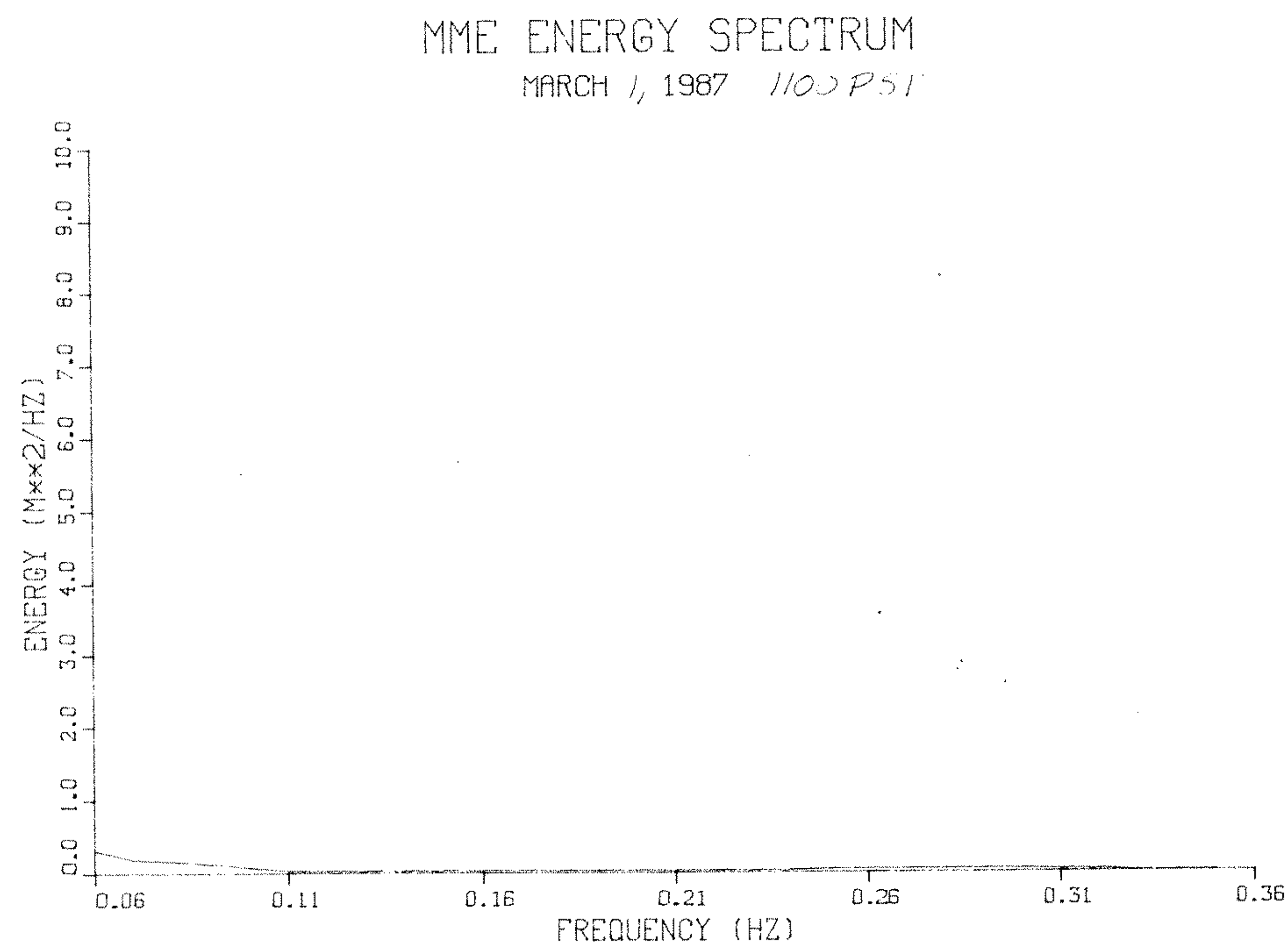



MME ENERGY SPECTRUM
MARCH 1, 1987
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

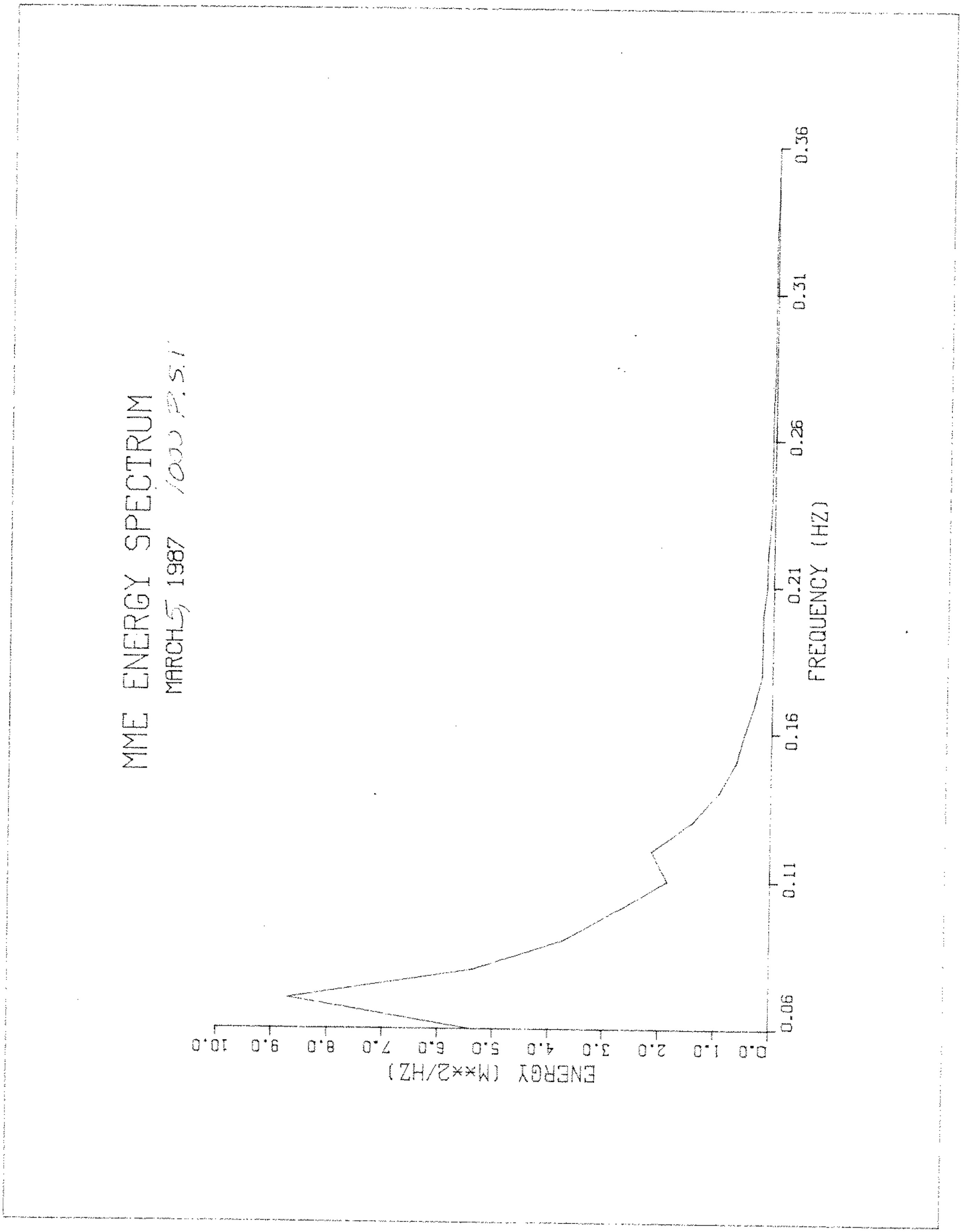
MME ENERGY SPECTRUM

MARCH 1, 1987 1000 P.S.I





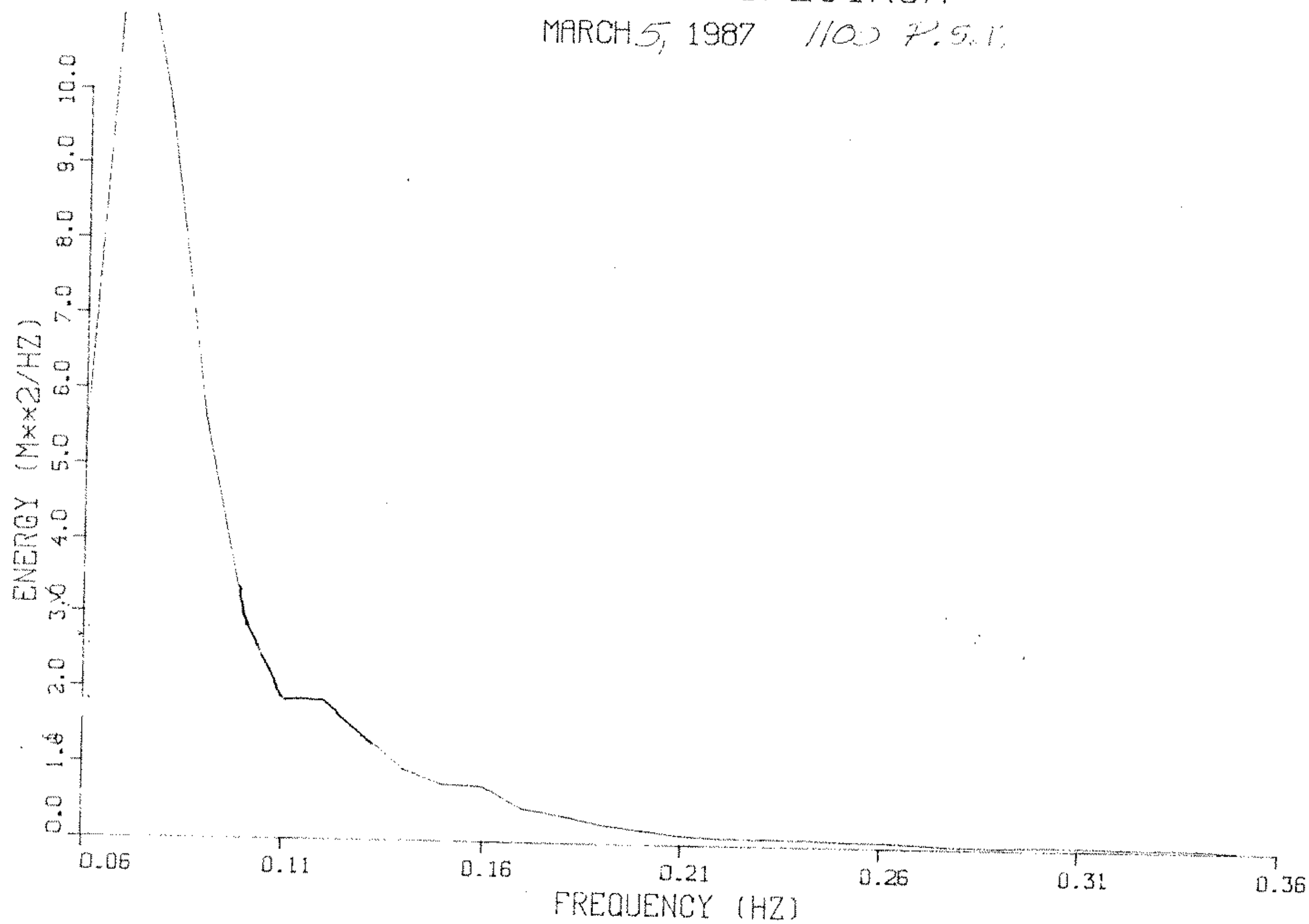
MME ENERGY SPECTRUM
MARCH 1, 1987 1100 PST
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)



MME ENERGY SPECTRUM
MARCH 5, 1987
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36

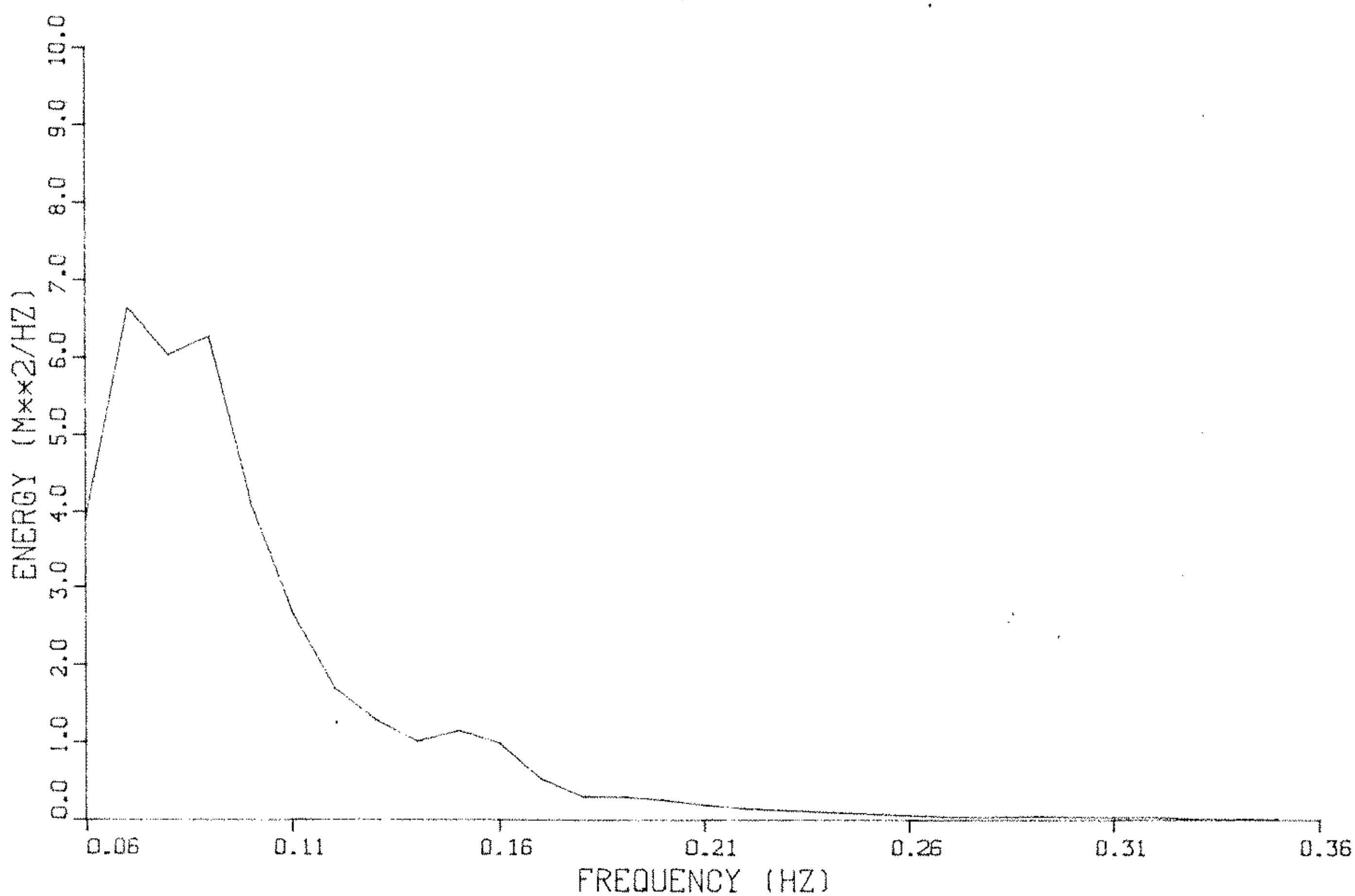
MME ENERGY SPECTRUM

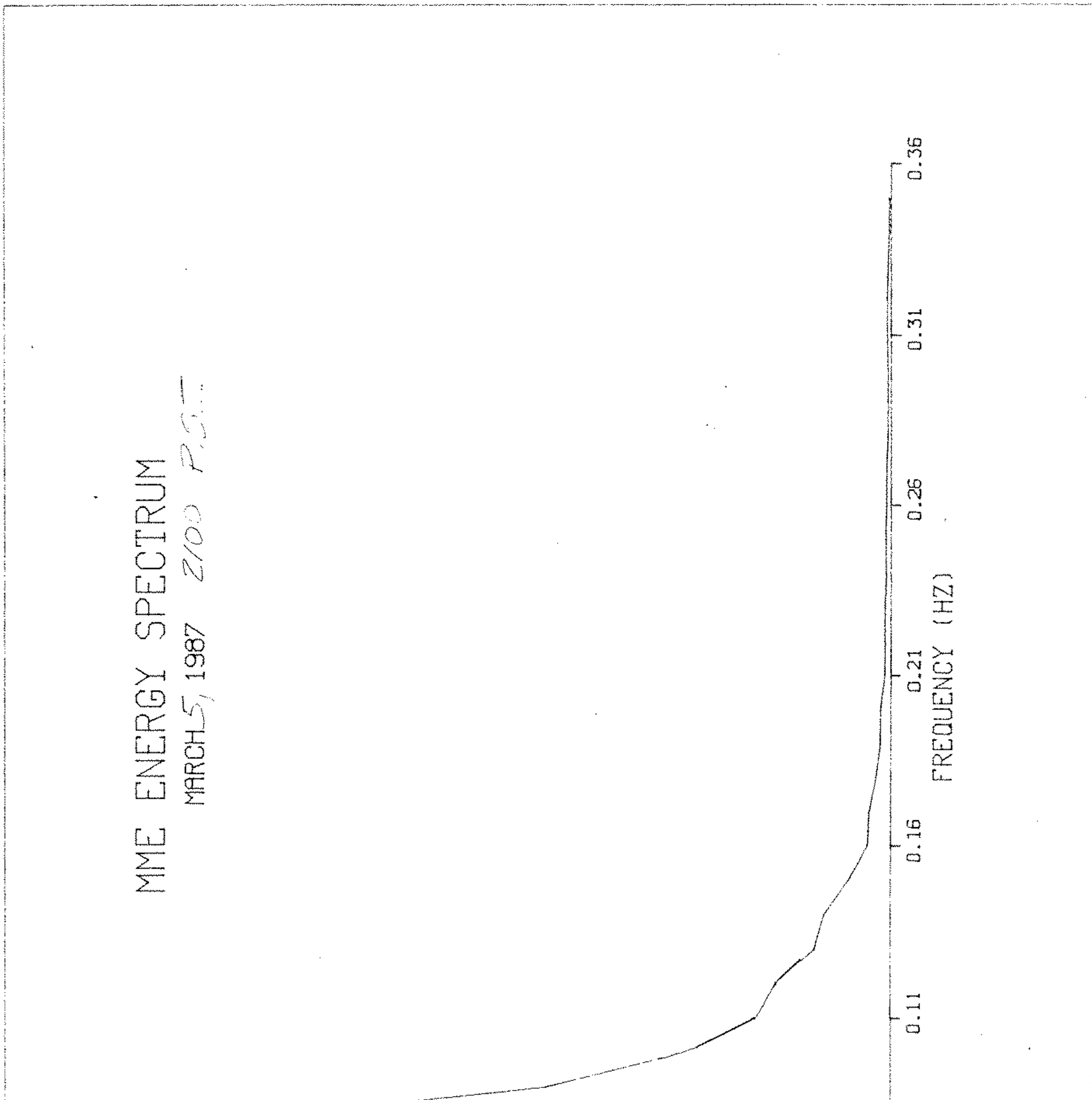
MARCH 5, 1987 1100 P.S.T.

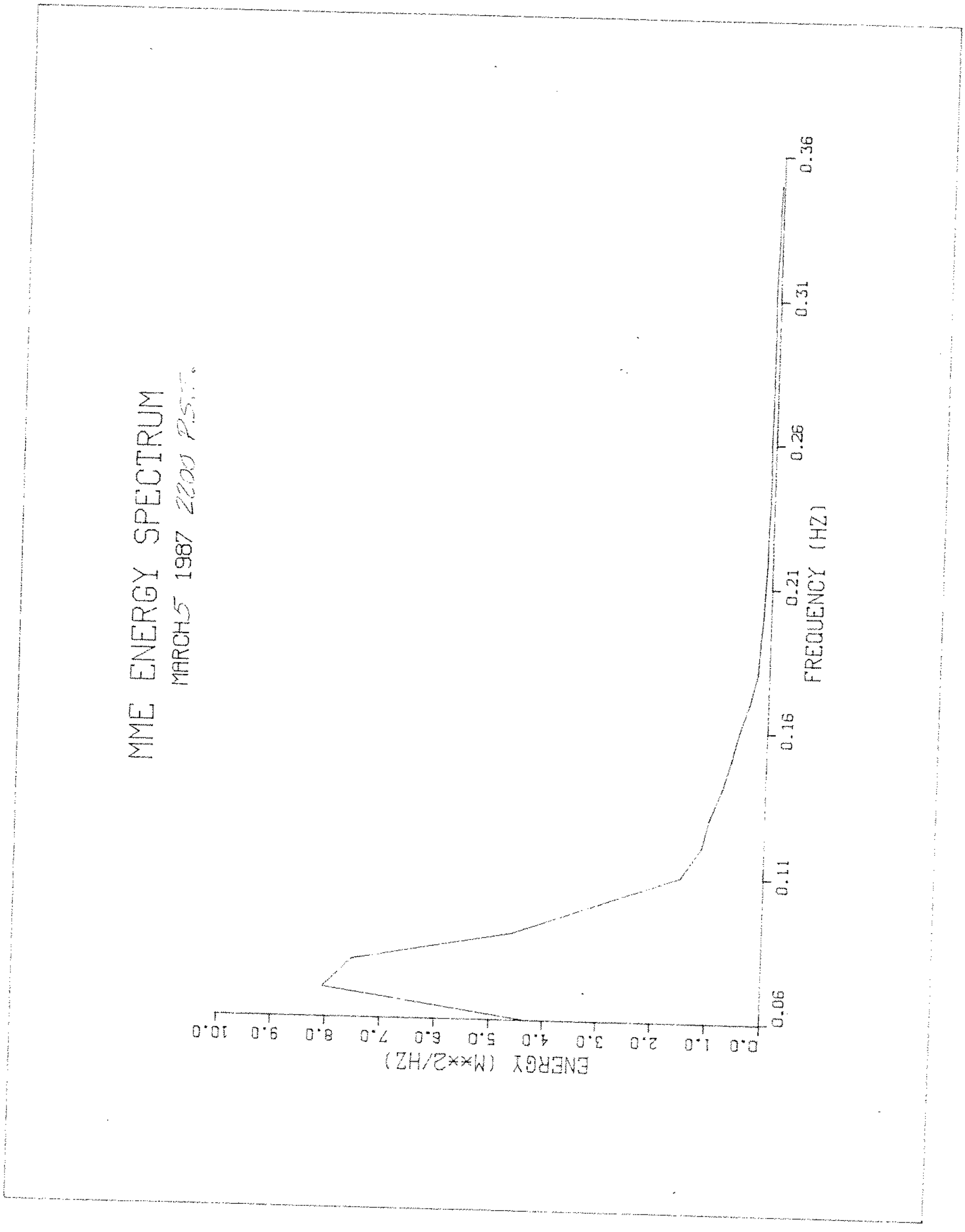


MME ENERGY SPECTRUM

MARCH 5, 1987 1200 P.S.T.




MME ENERGY SPECTRUM
MARCH 5, 1987 2100 P.S.T.
FREQUENCY (HZ)
ENERGY (M**2/HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0



MME ENERGY SPECTRUM
MARCH 5 1987 2200 PST
ENERGY (M**2/HZ)
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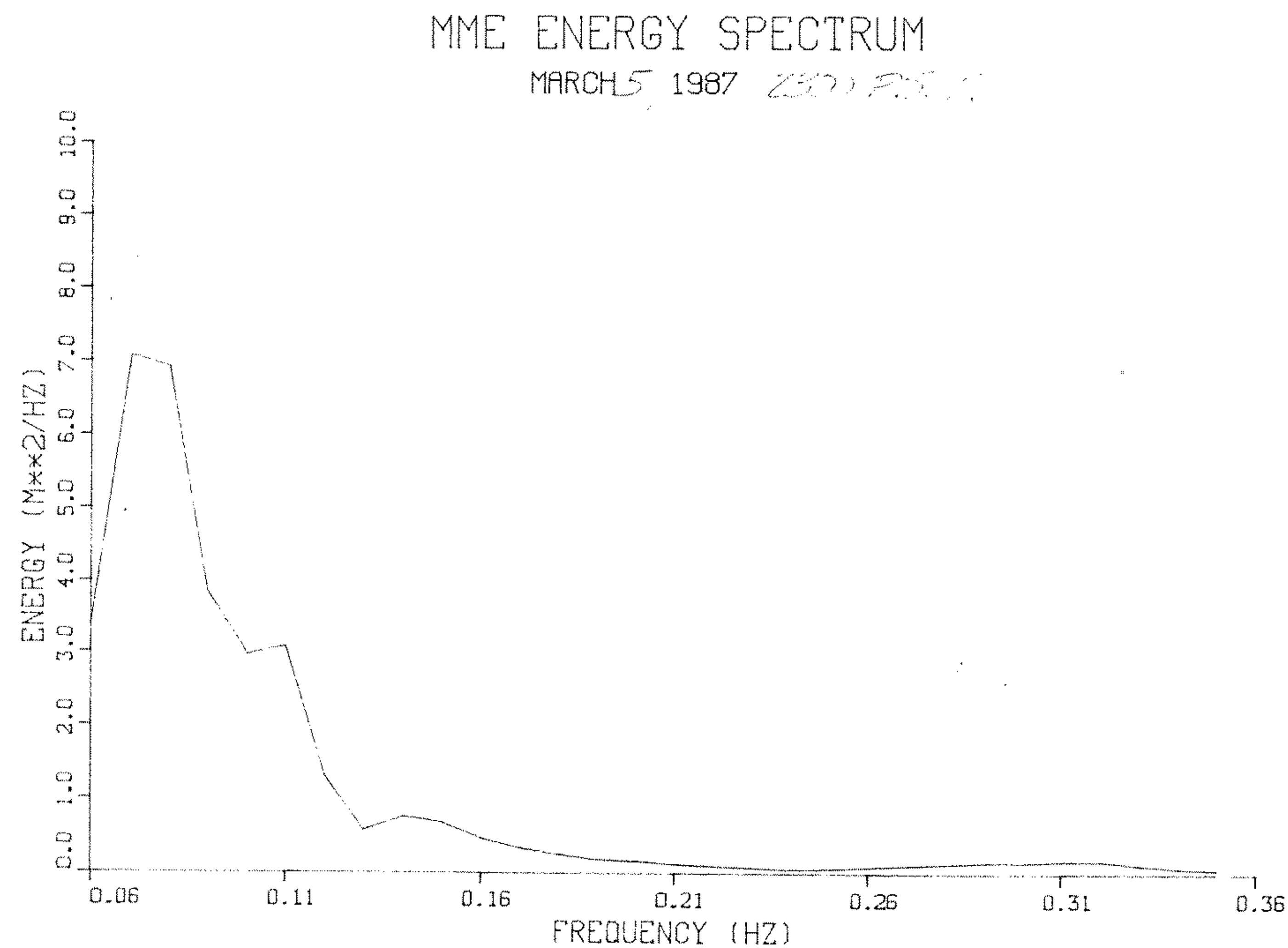
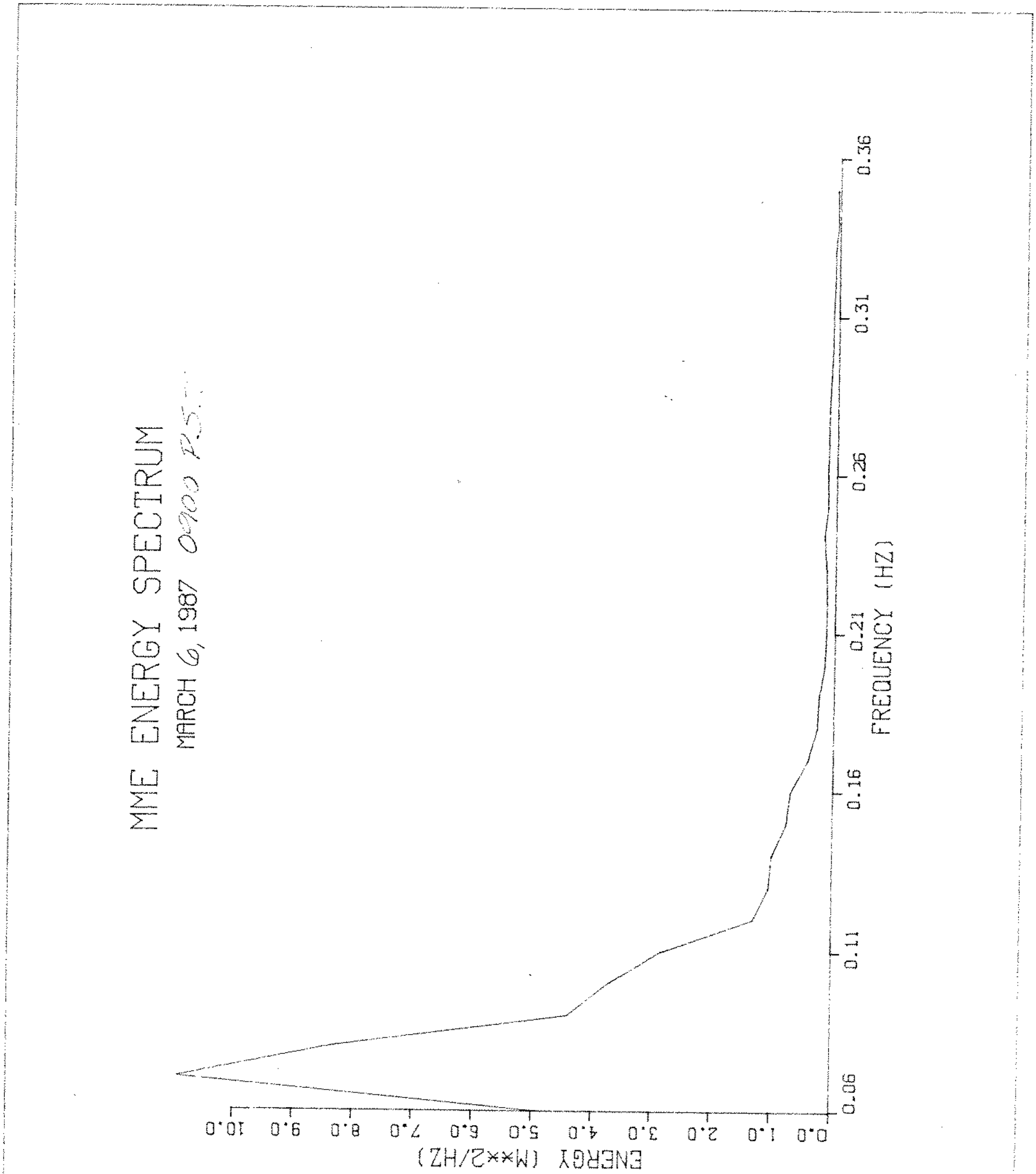
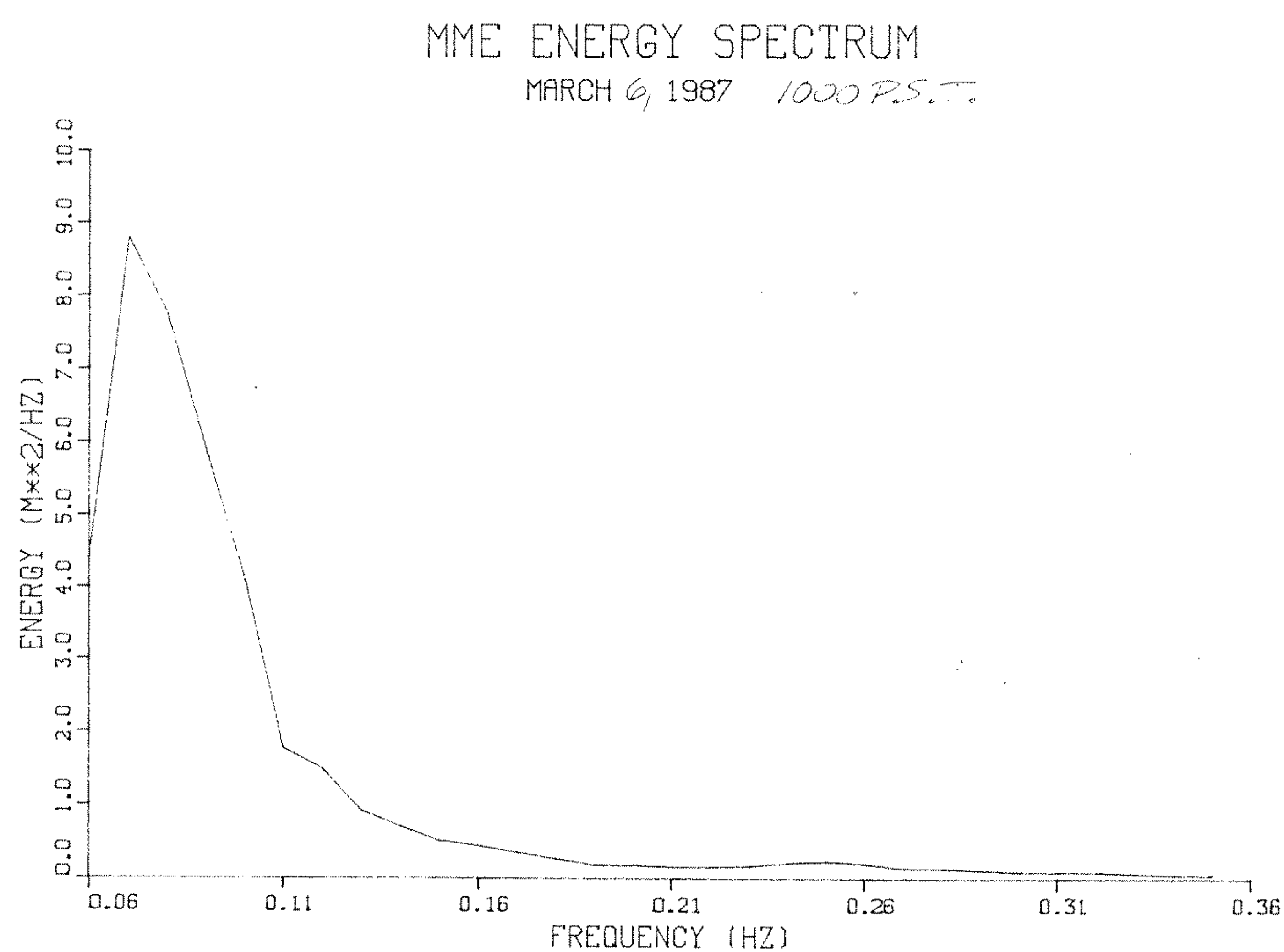
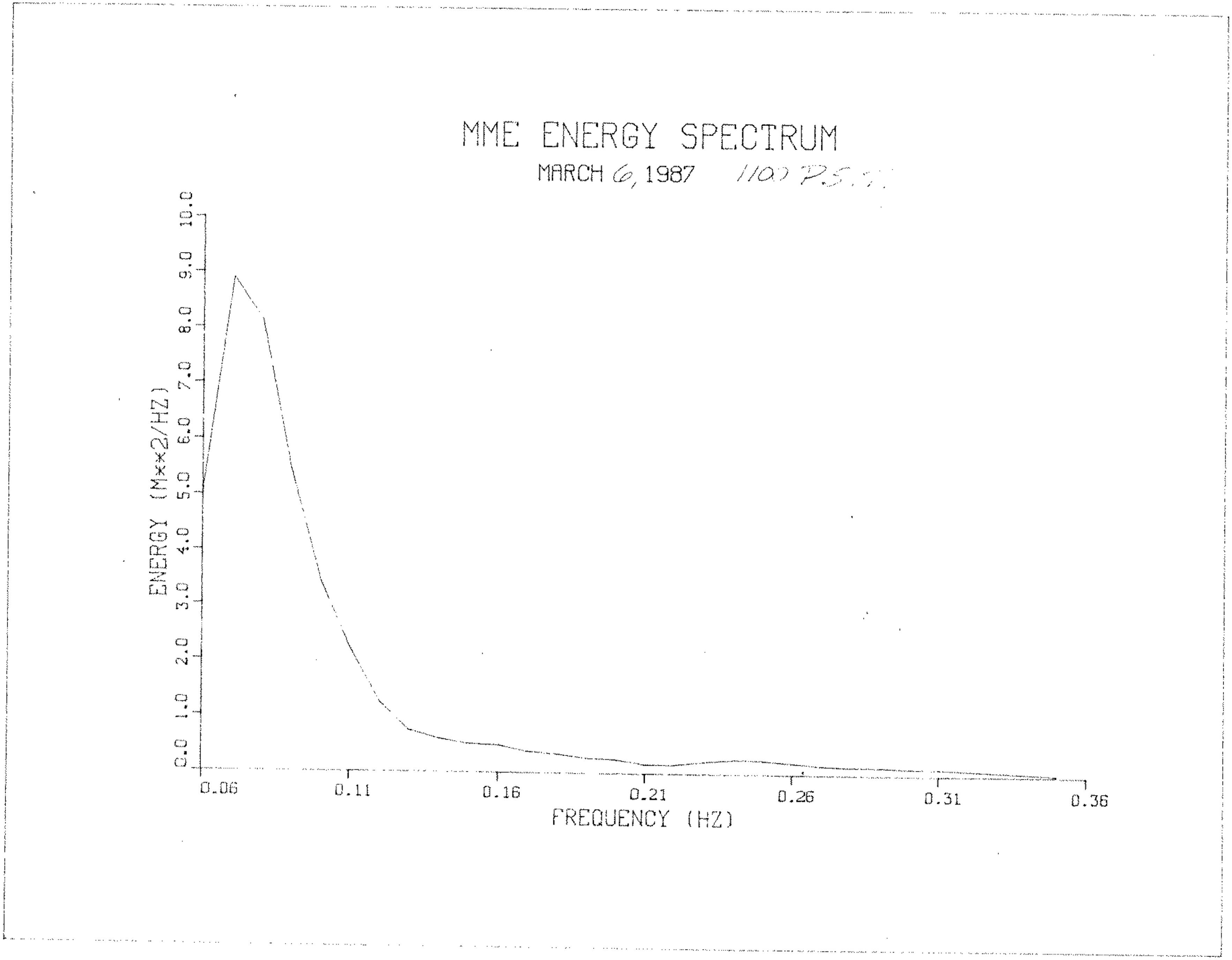
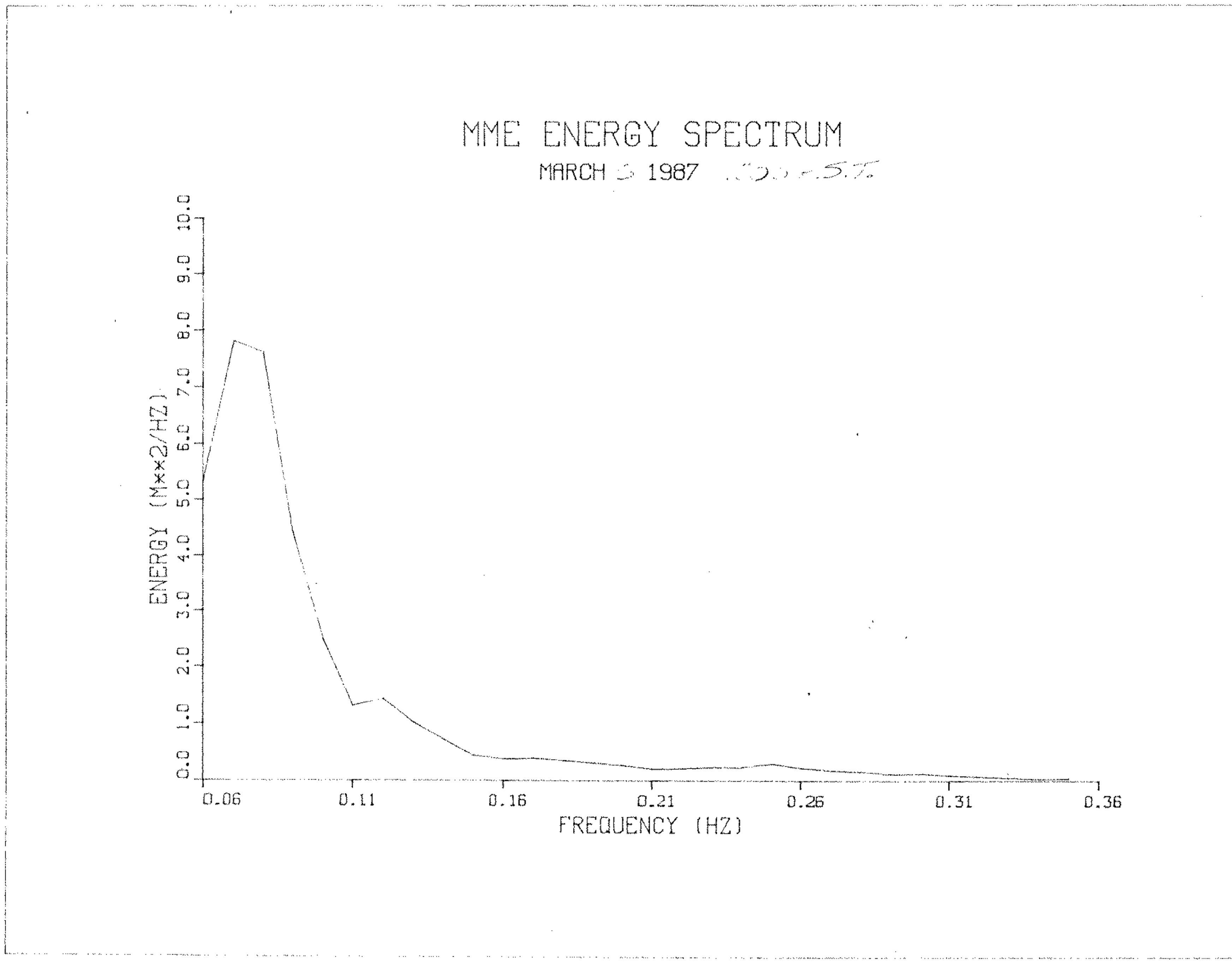
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36

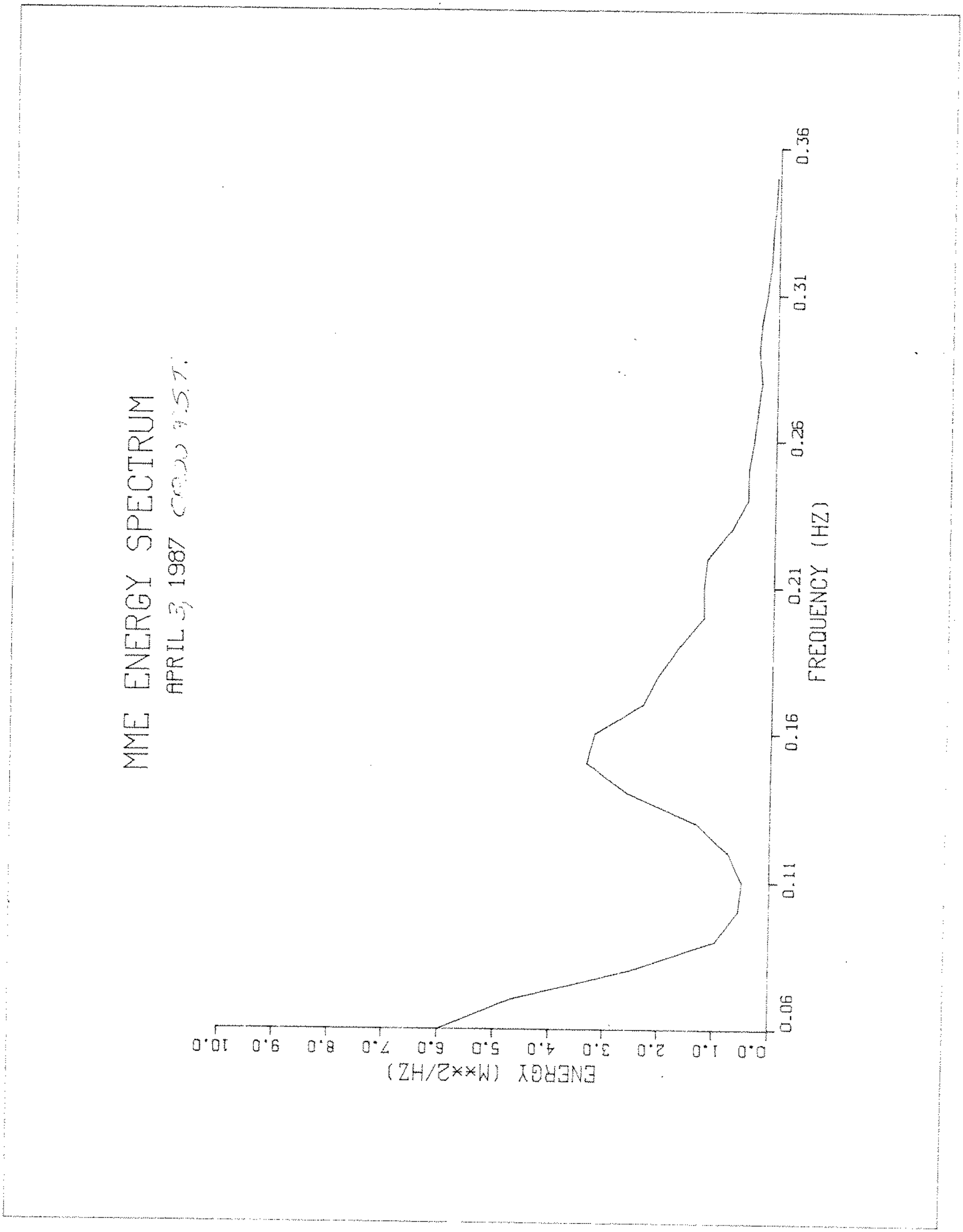

MME ENERGY SPECTRUM
MARCH 5 1987
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)

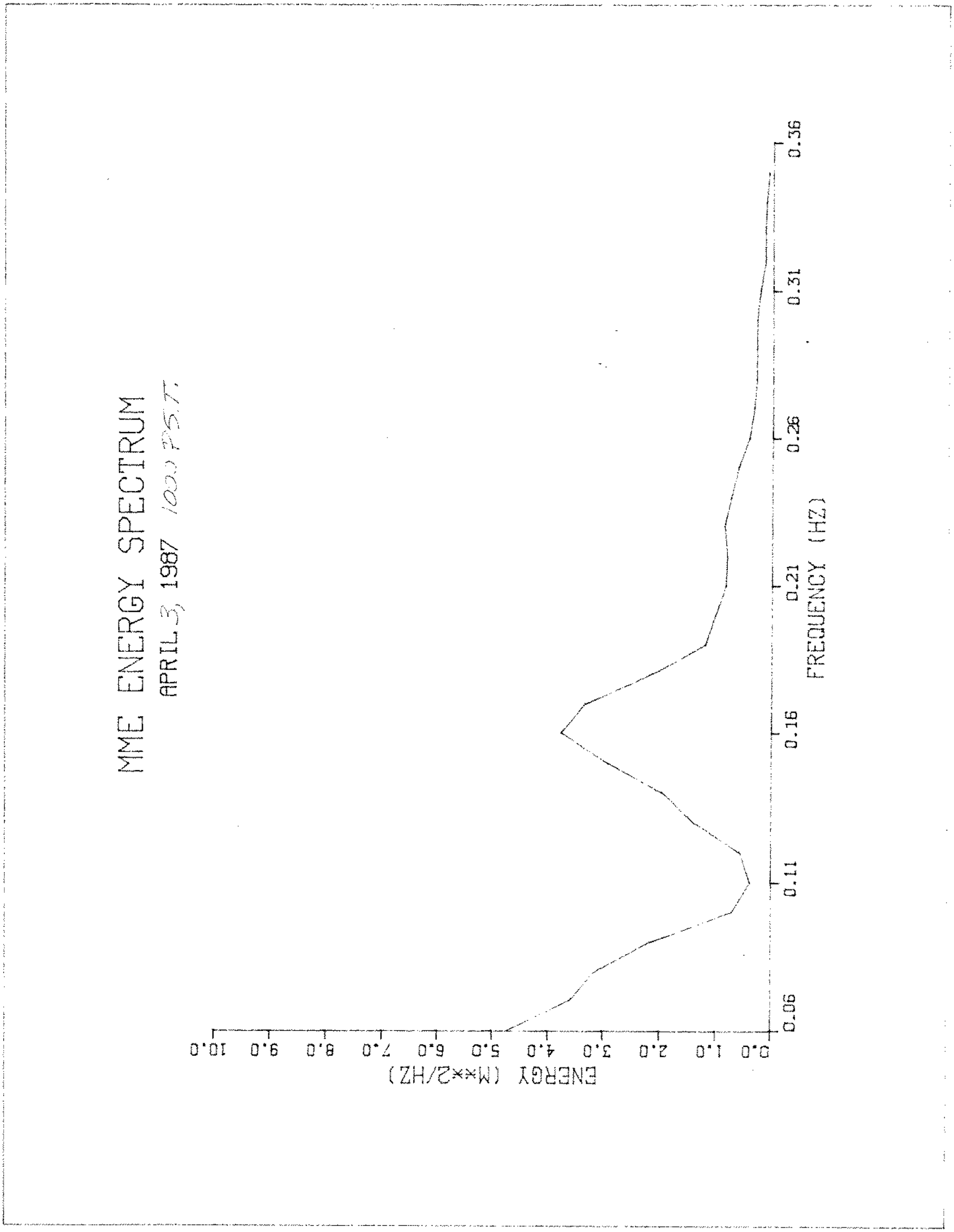

MME ENERGY SPECTRUM
MARCH 6, 1987 0900 R5
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36

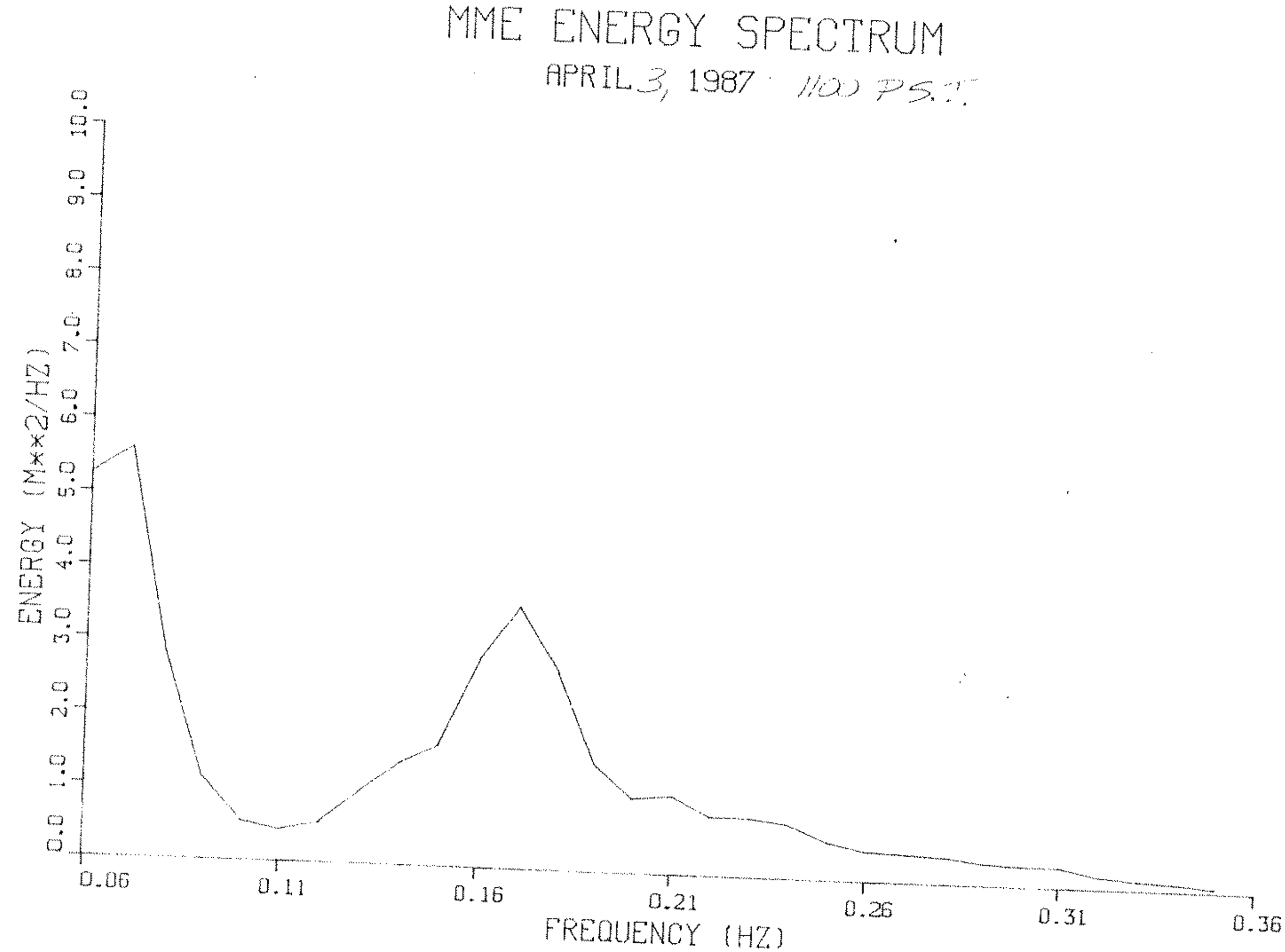

MME ENERGY SPECTRUM
MARCH 6, 1987 1000 P.S.T.
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)


MME ENERGY SPECTRUM
MARCH 6, 1987 1100 P.S.T.
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)


MME ENERGY SPECTRUM
MARCH 5 1987
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)

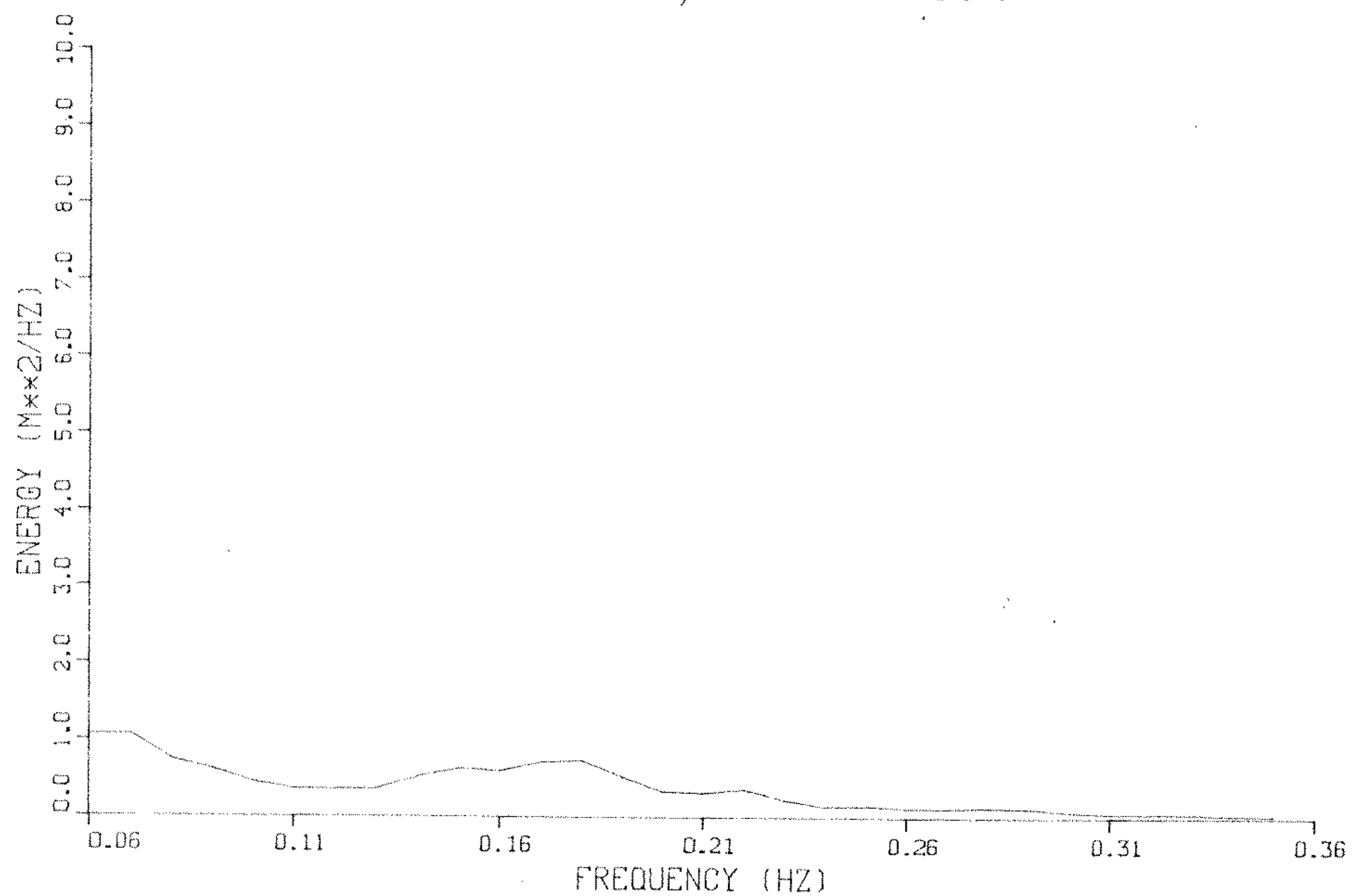

MME ENERGY SPECTRUM
APRIL 3, 1987
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

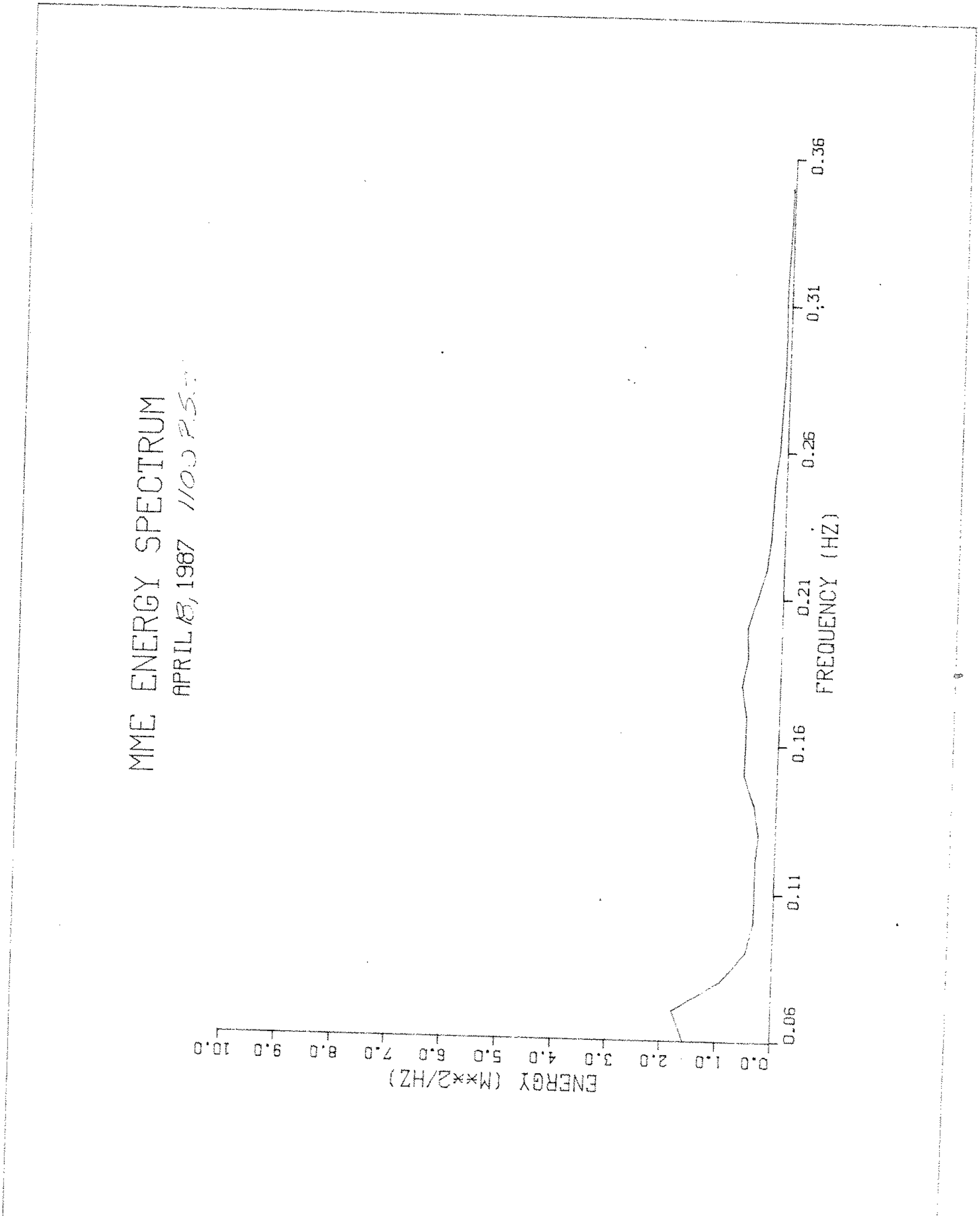

MME ENERGY SPECTRUM
APRIL 3, 1987 1000 P.S.T.
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36

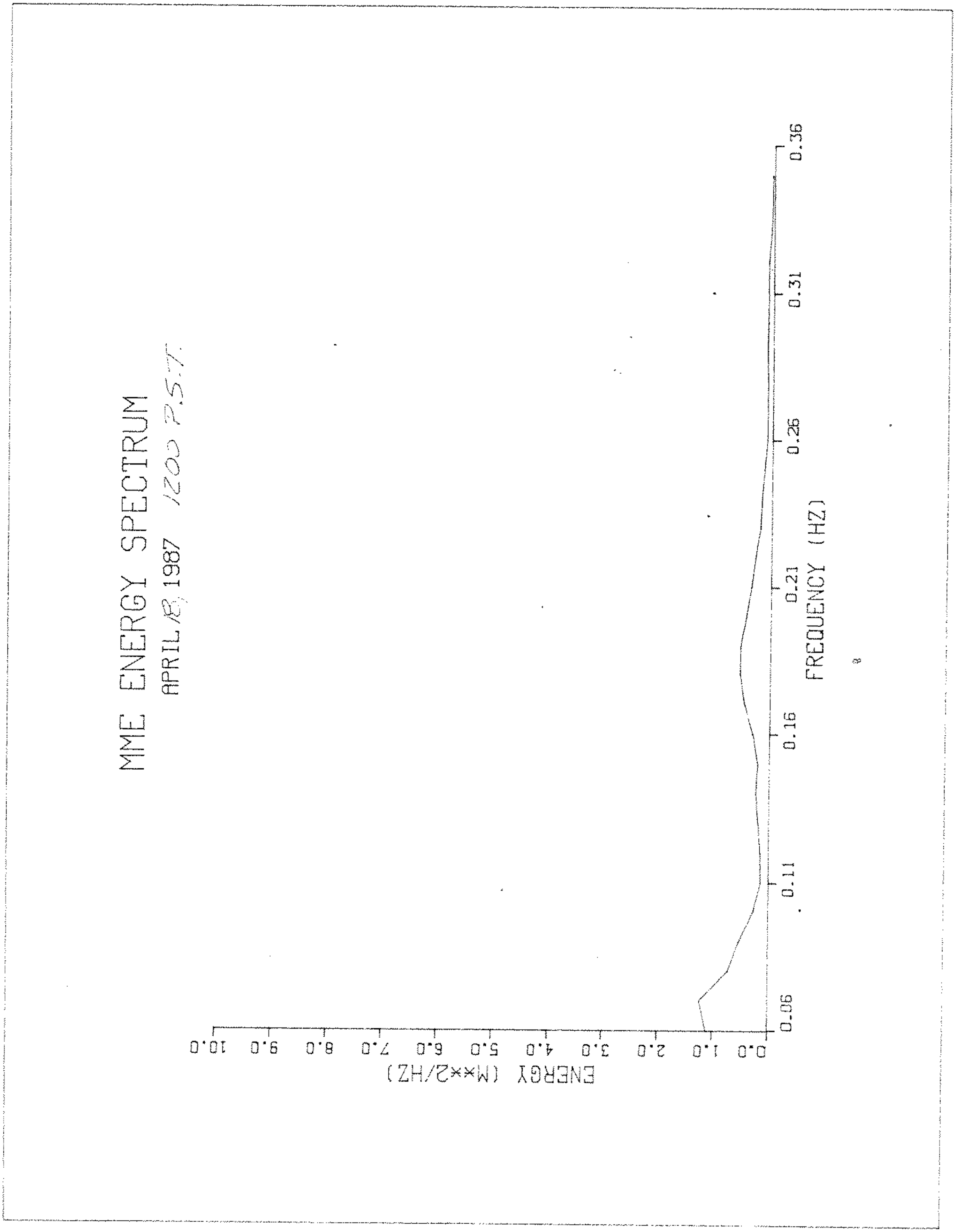

MME ENERGY SPECTRUM
APRIL 3, 1987 1100 PST
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)

MME ENERGY SPECTRUM

APRIL 18, 1987

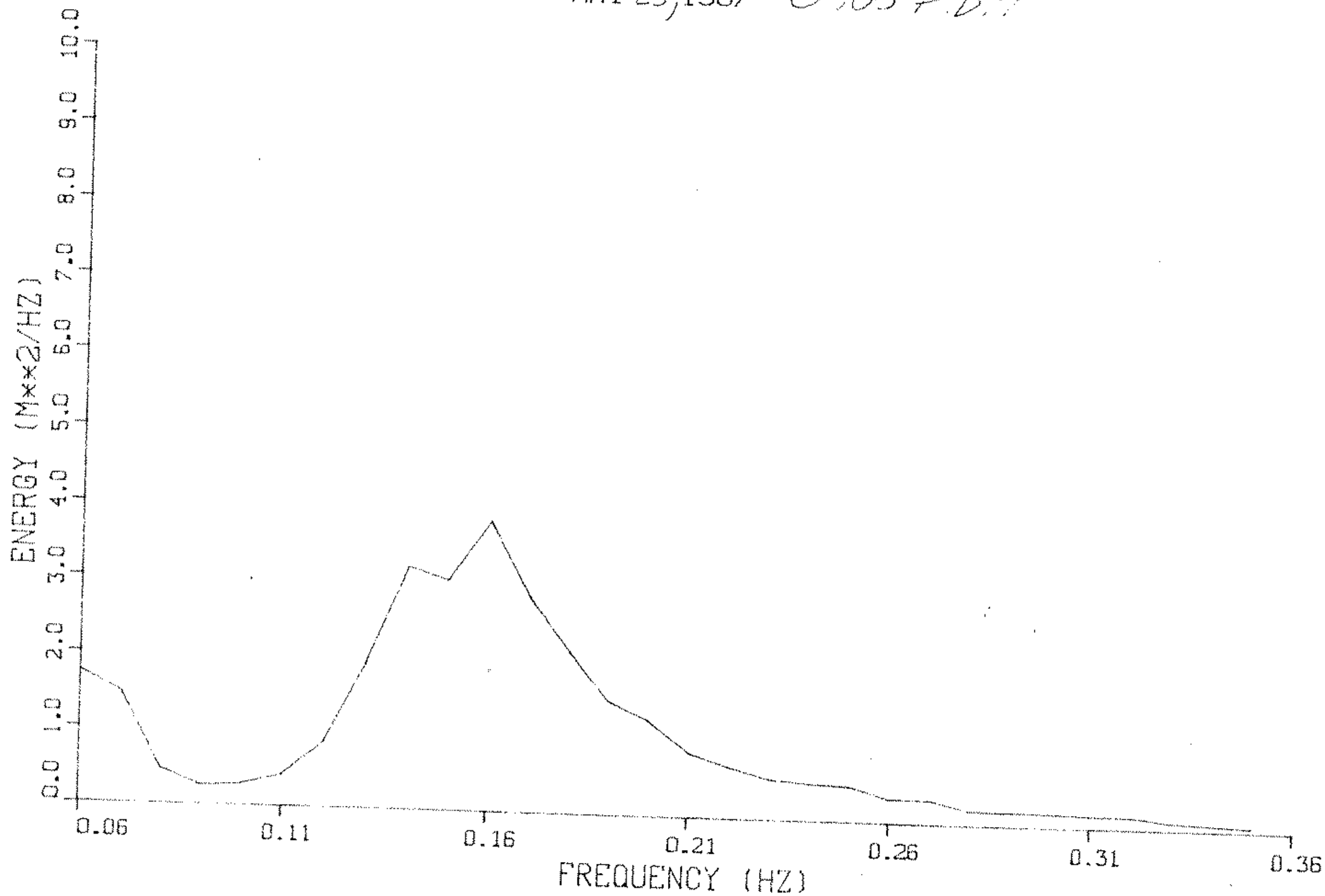



MME ENERGY SPECTRUM
APRIL 18, 1987 1100 PST
FREQUENCY (HZ)
0.06
0.11
0.16
0.21
0.26
0.31
0.36
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0


MME ENERGY SPECTRUM
APRIL 8, 1987 1200 P.S.T.
ENERGY (M**2/HZ)
0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
FREQUENCY (HZ)
0.06 0.11 0.16 0.21 0.26 0.31 0.36

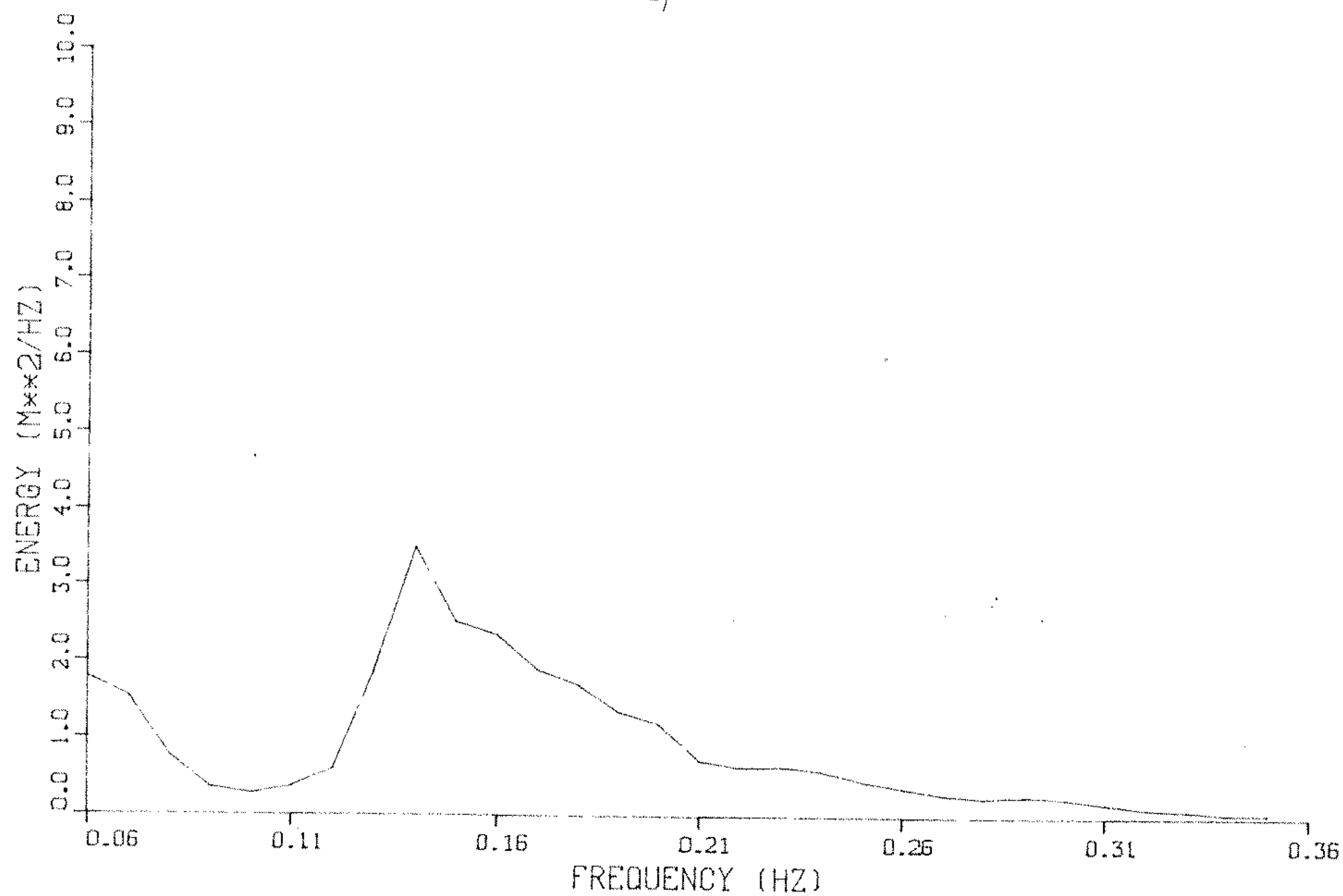
MME ENERGY SPECTRUM

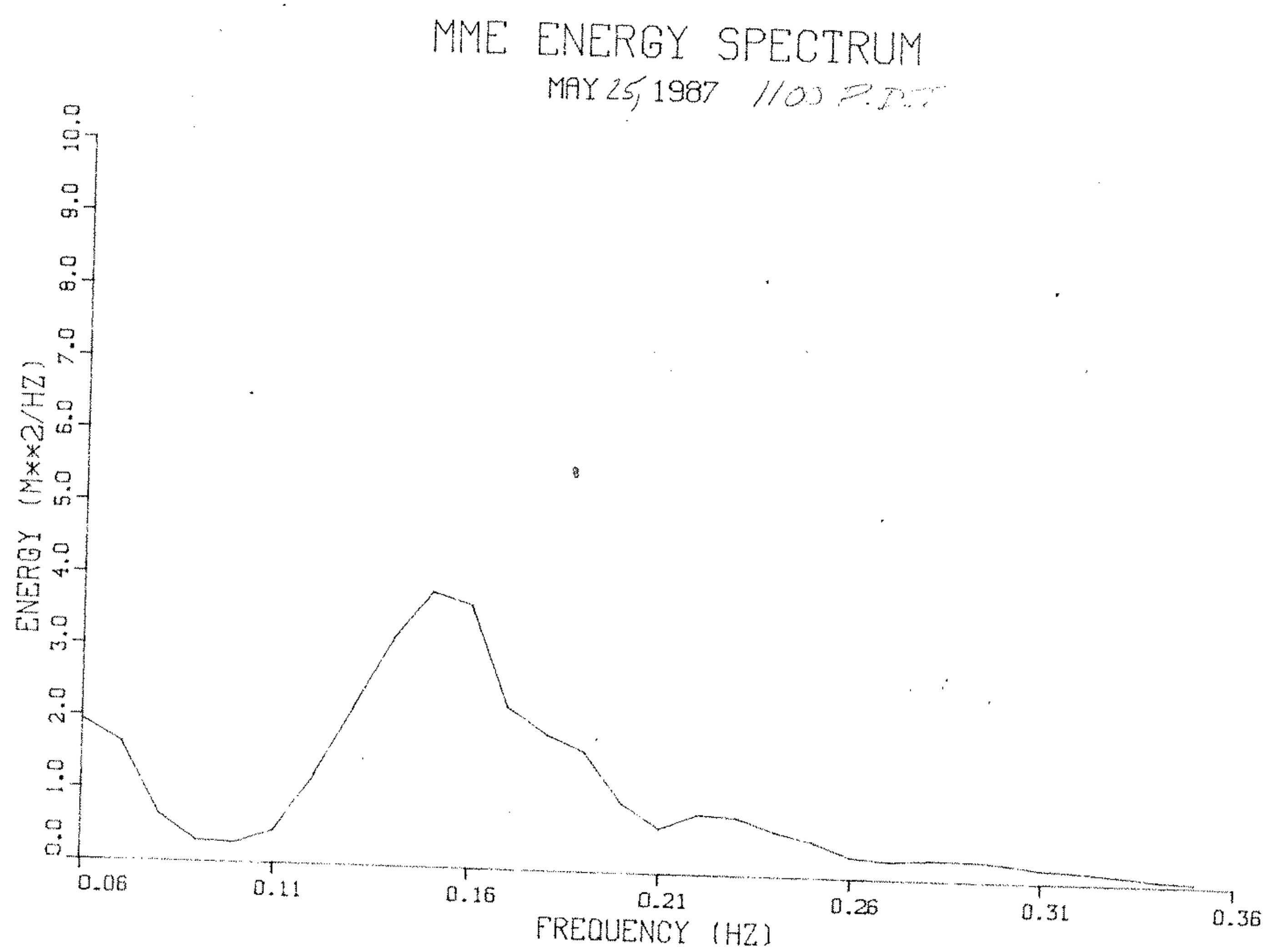
MAY 25,1987 0900 P.D.T

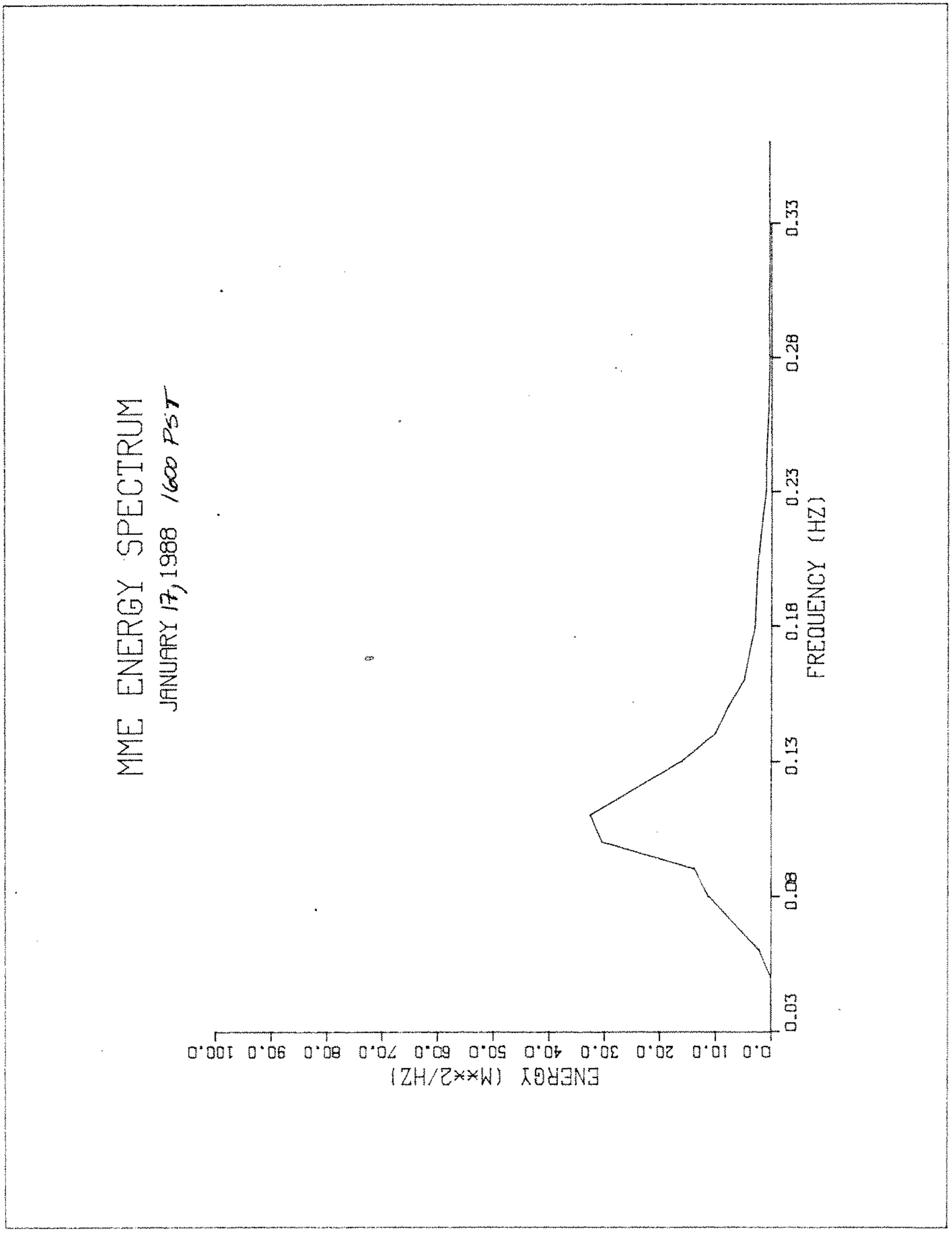


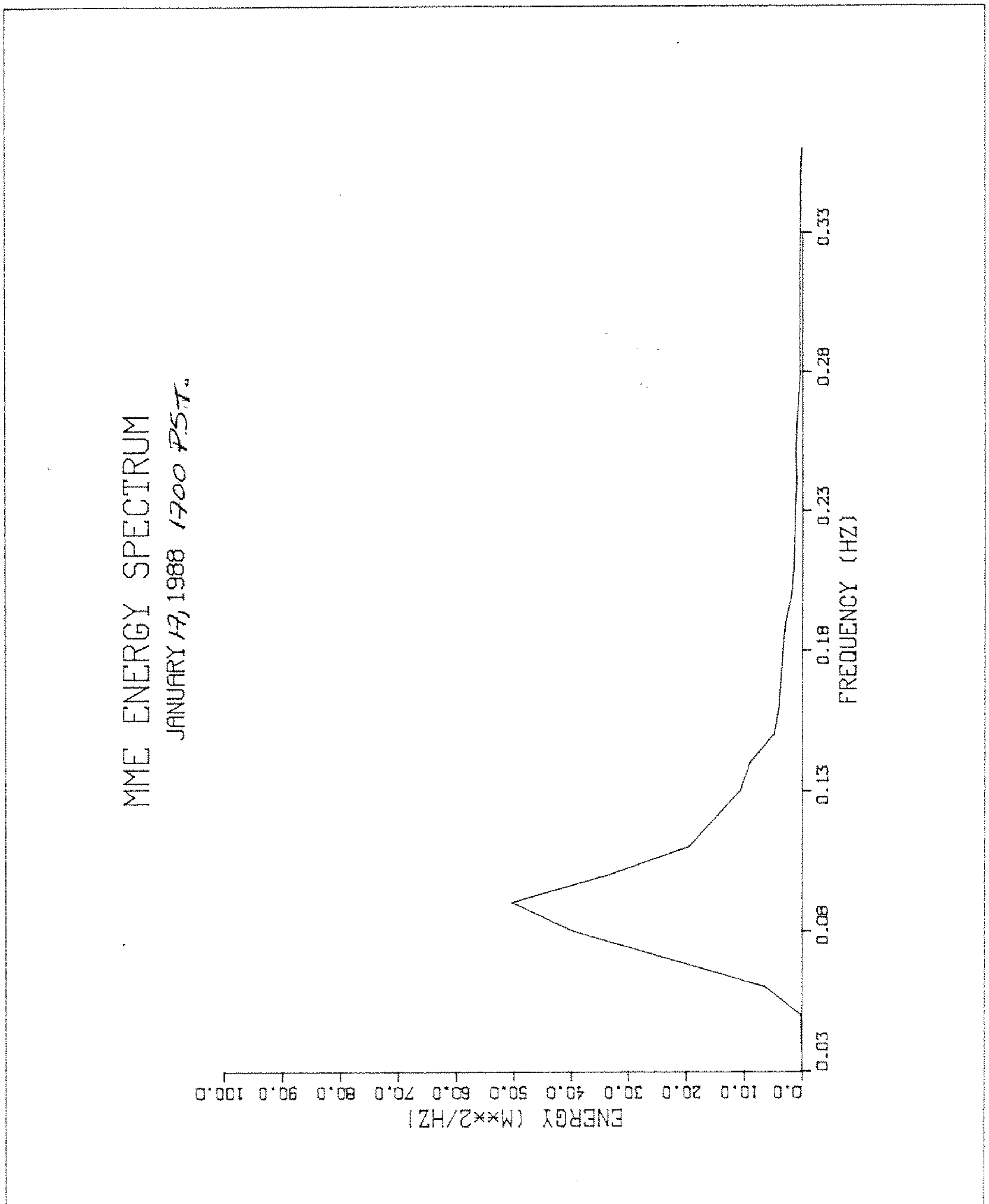
MME ENERGY SPECTRUM

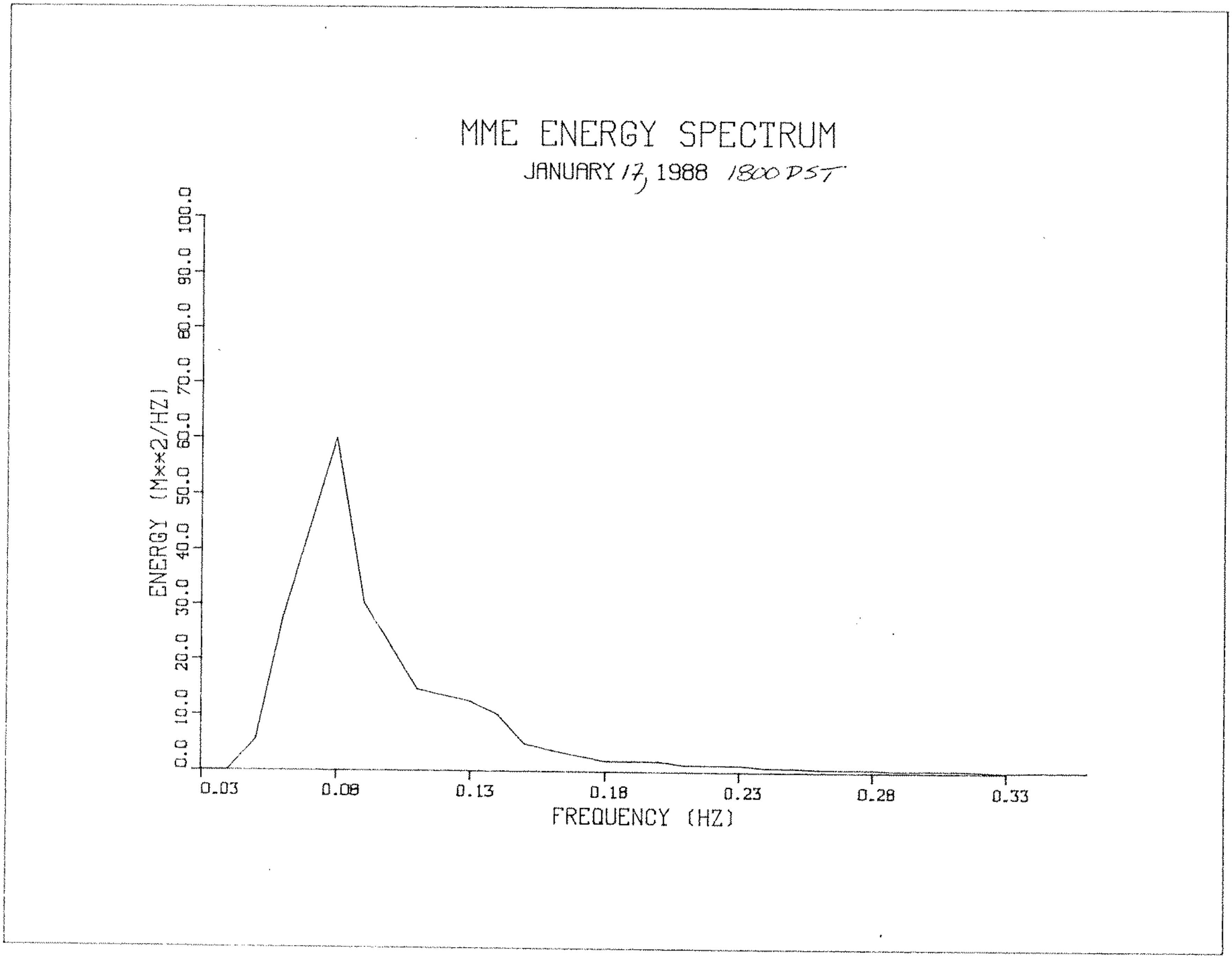
MAY 26, 1987 1000 PDT

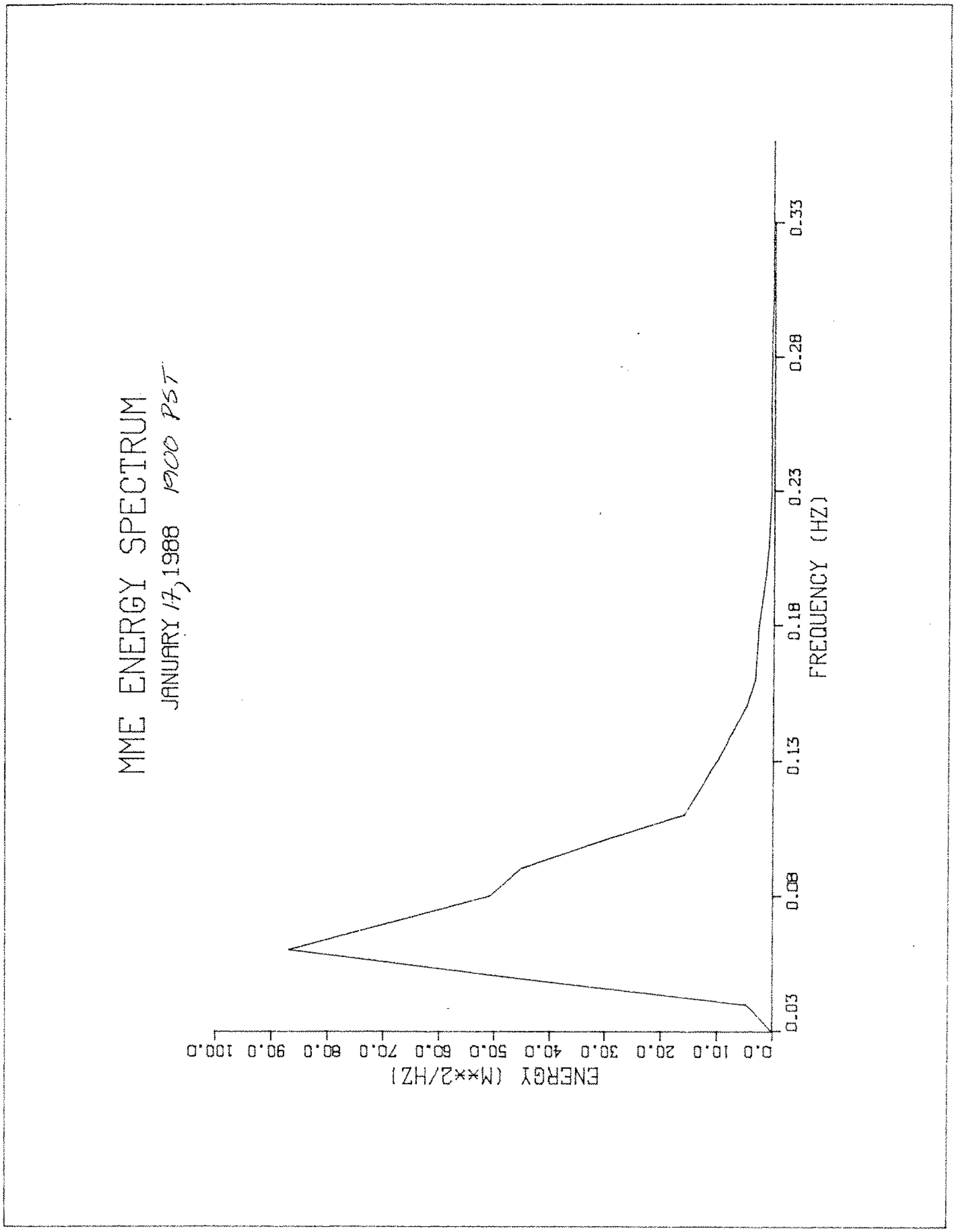


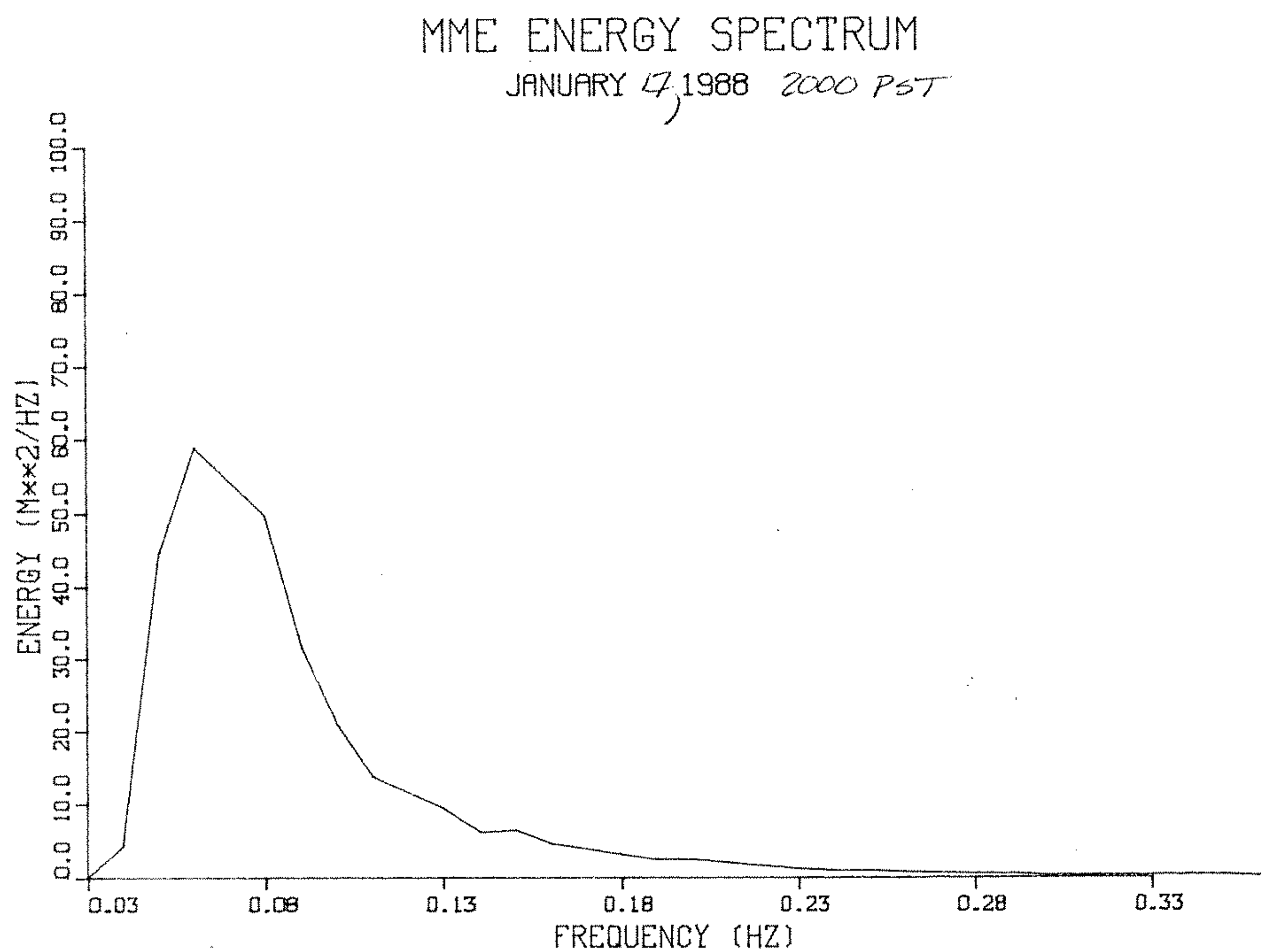

MME ENERGY SPECTRUM
MAY 25, 1987 1100 P.D.T.
ENERGY (M**2/HZ)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
0.06
0.11
0.16
0.21
0.26
0.31
0.36
FREQUENCY (HZ)

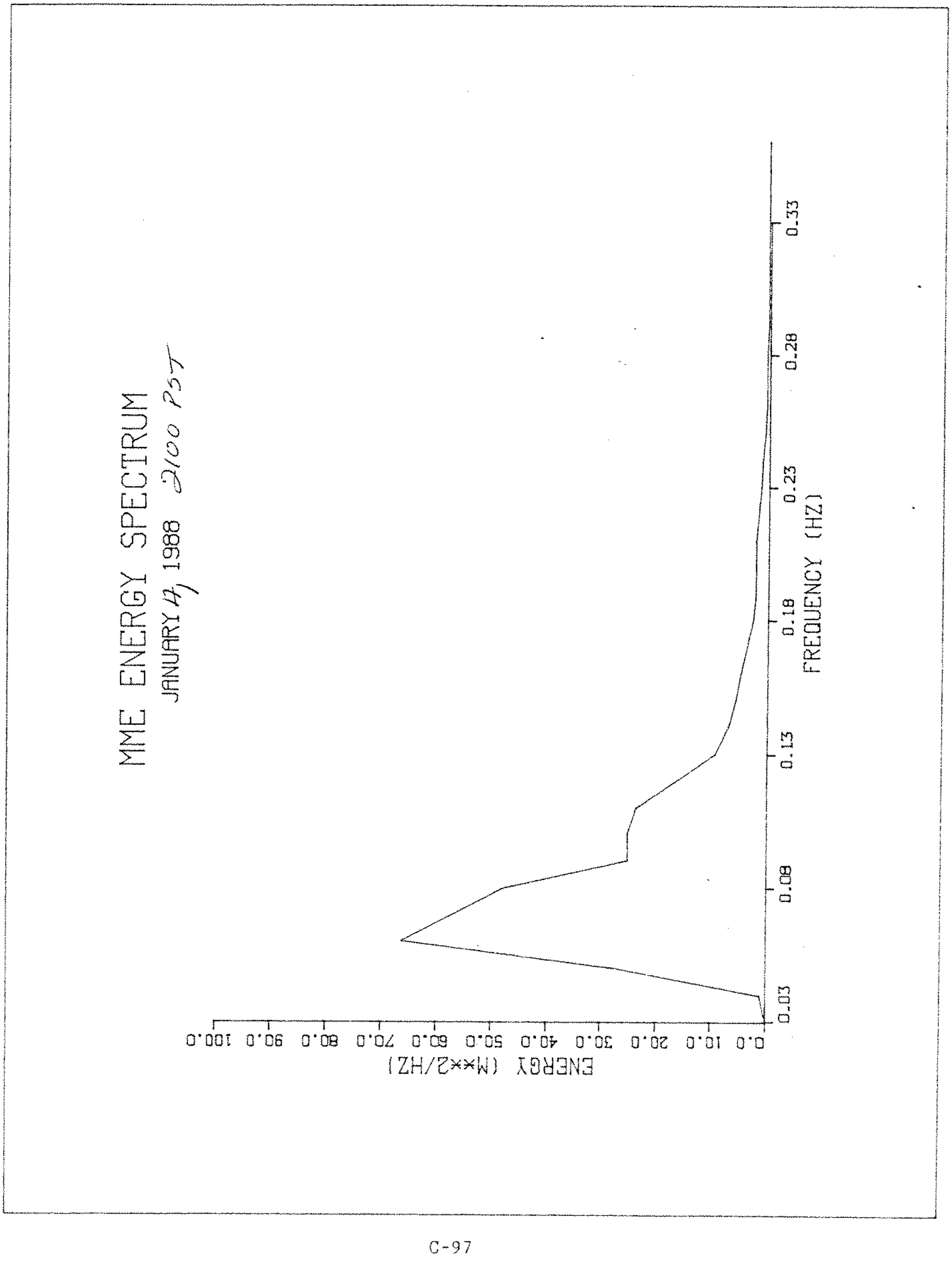

MME ENERGY SPECTRUM
JANUARY 17, 1988 1600 PST
ENERGY (M**2/HZ)
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
FREQUENCY (HZ)
0.03 0.08 0.13 0.18 0.23 0.28 0.33

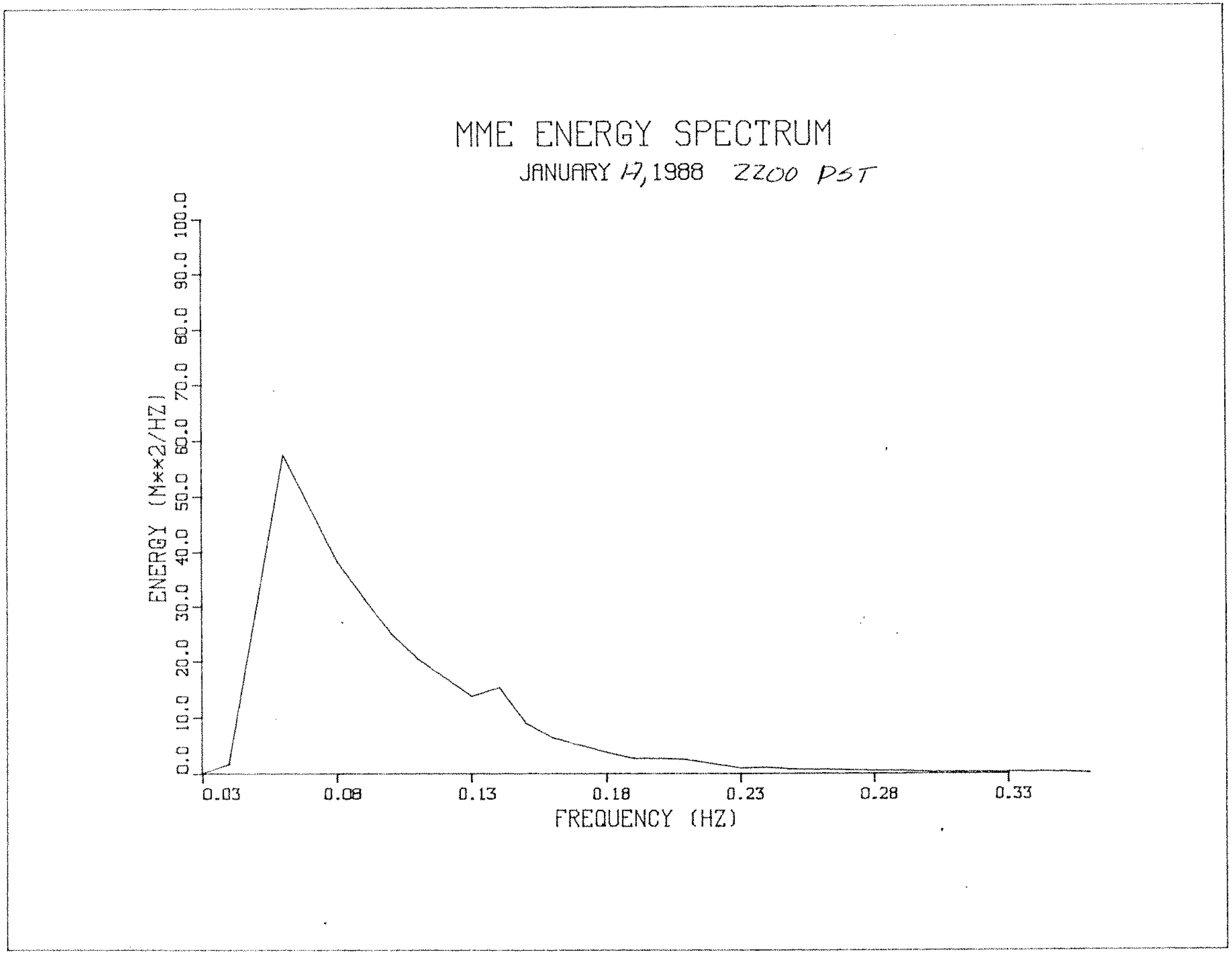

MME ENERGY SPECTRUM
JANUARY 17, 1988 1700 P.S.T.
ENERGY (M**2/HZ)
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
FREQUENCY (HZ)
0.03 0.08 0.13 0.18 0.23 0.28 0.33

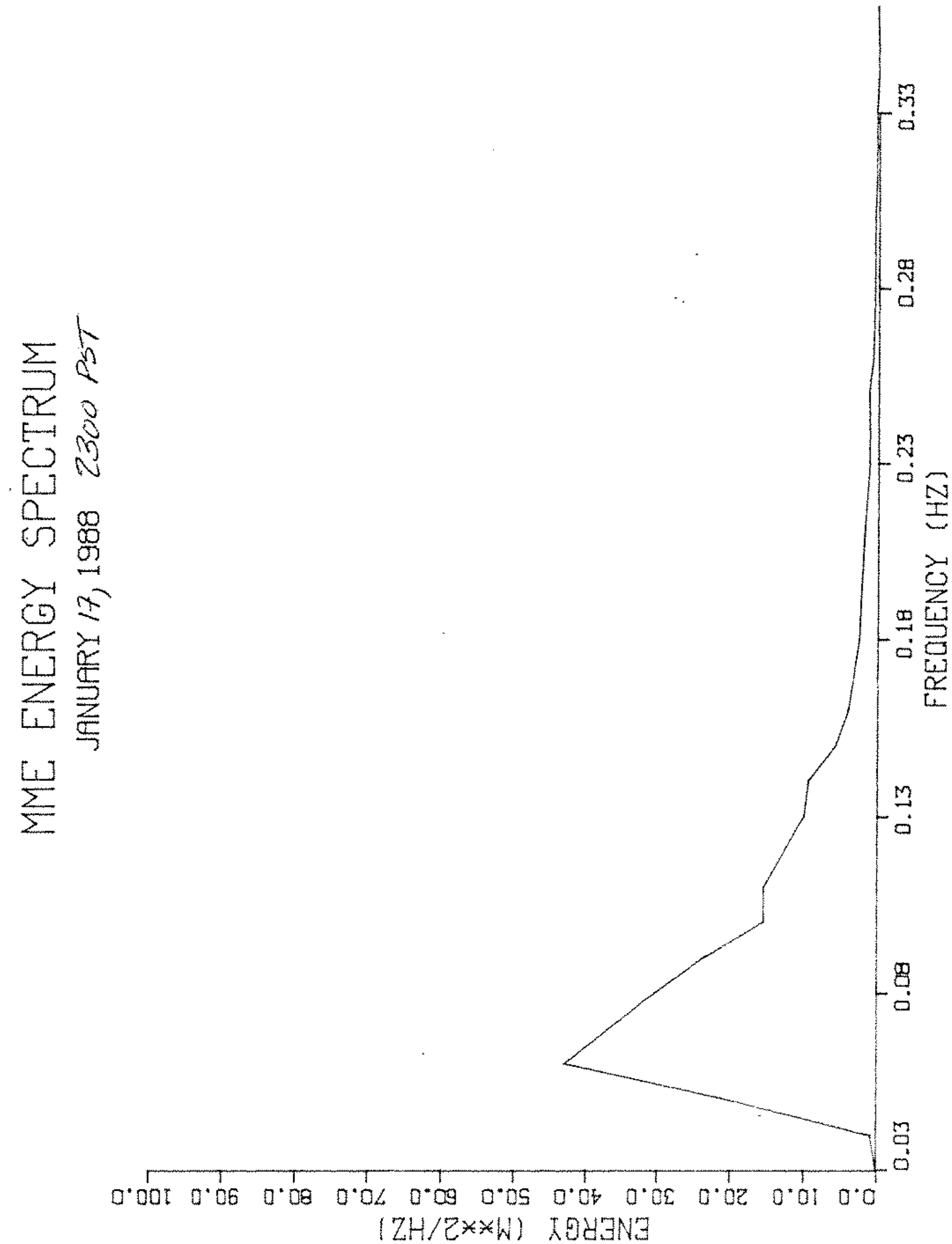

MME ENERGY SPECTRUM
JANUARY 17, 1988 1800 DST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
0.03
0.08
0.13
0.18
0.23
0.28
0.33
FREQUENCY (HZ)

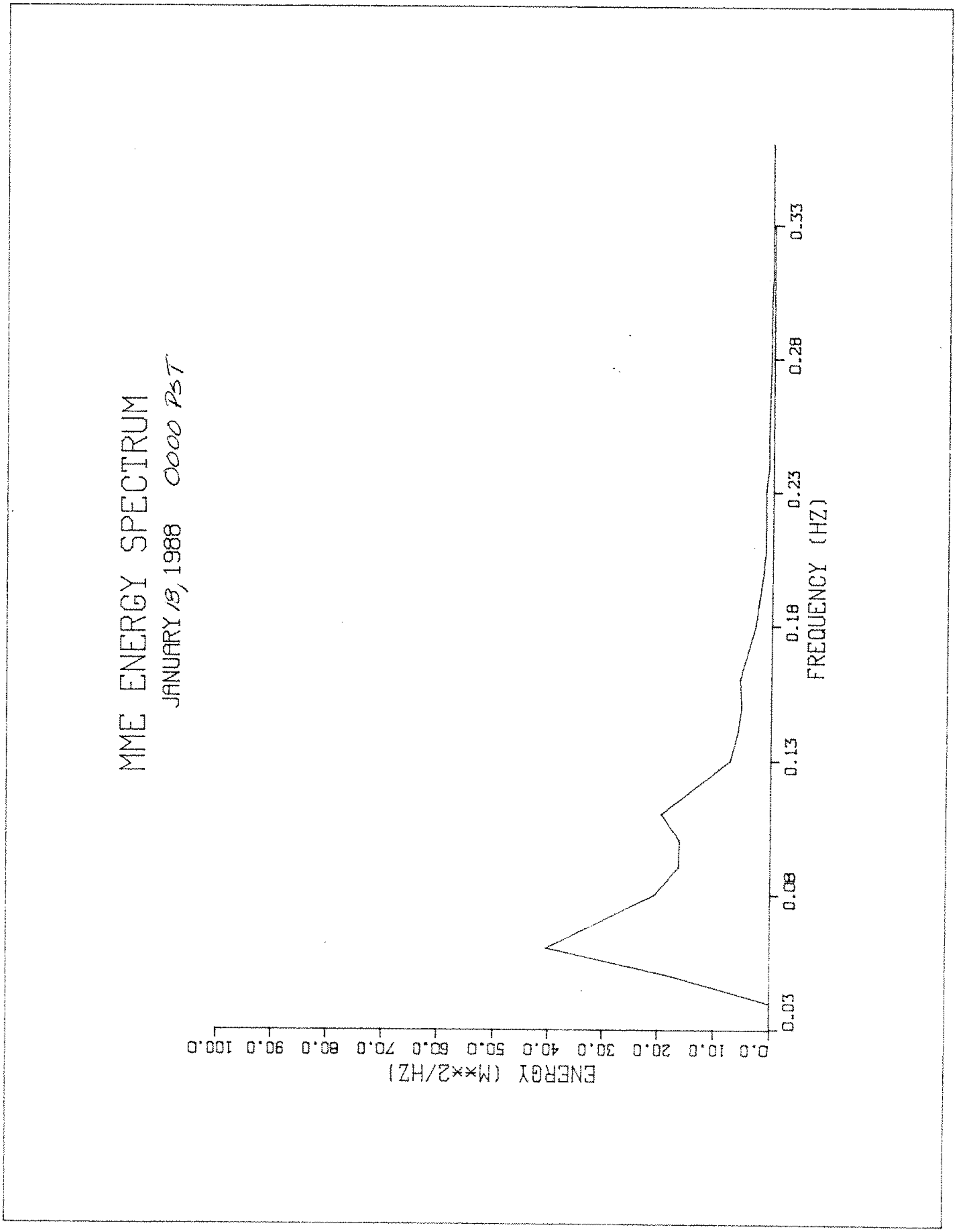

MME ENERGY SPECTRUM
JANUARY 17, 1988 1900 PST
ENERGY (M**2/HZ)
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
FREQUENCY (HZ)
0.03 0.08 0.13 0.18 0.23 0.28 0.33

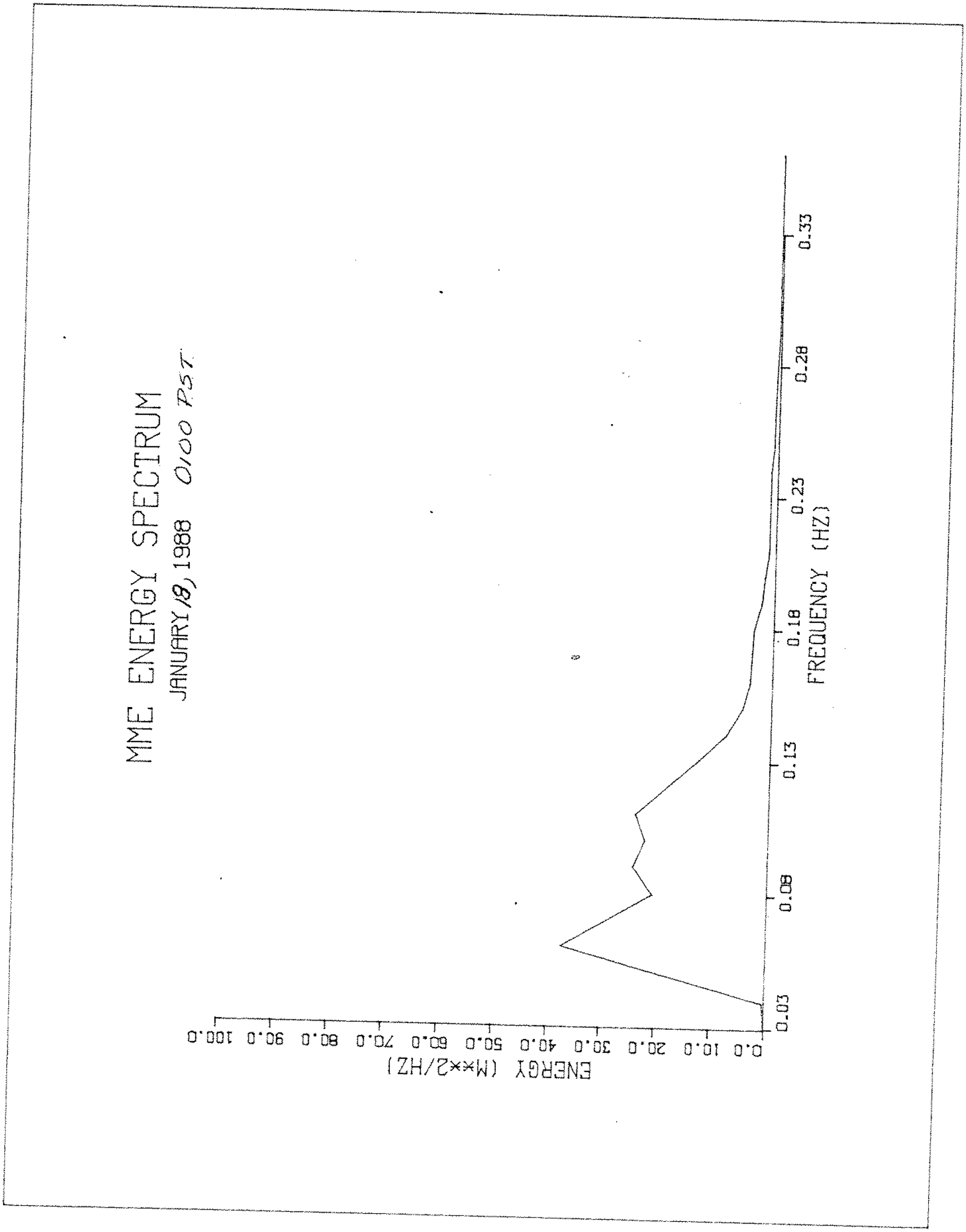

MME ENERGY SPECTRUM
JANUARY 7, 1988 2000 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
0.03
0.08
0.13
0.18
0.23
0.28
0.33
FREQUENCY (HZ)

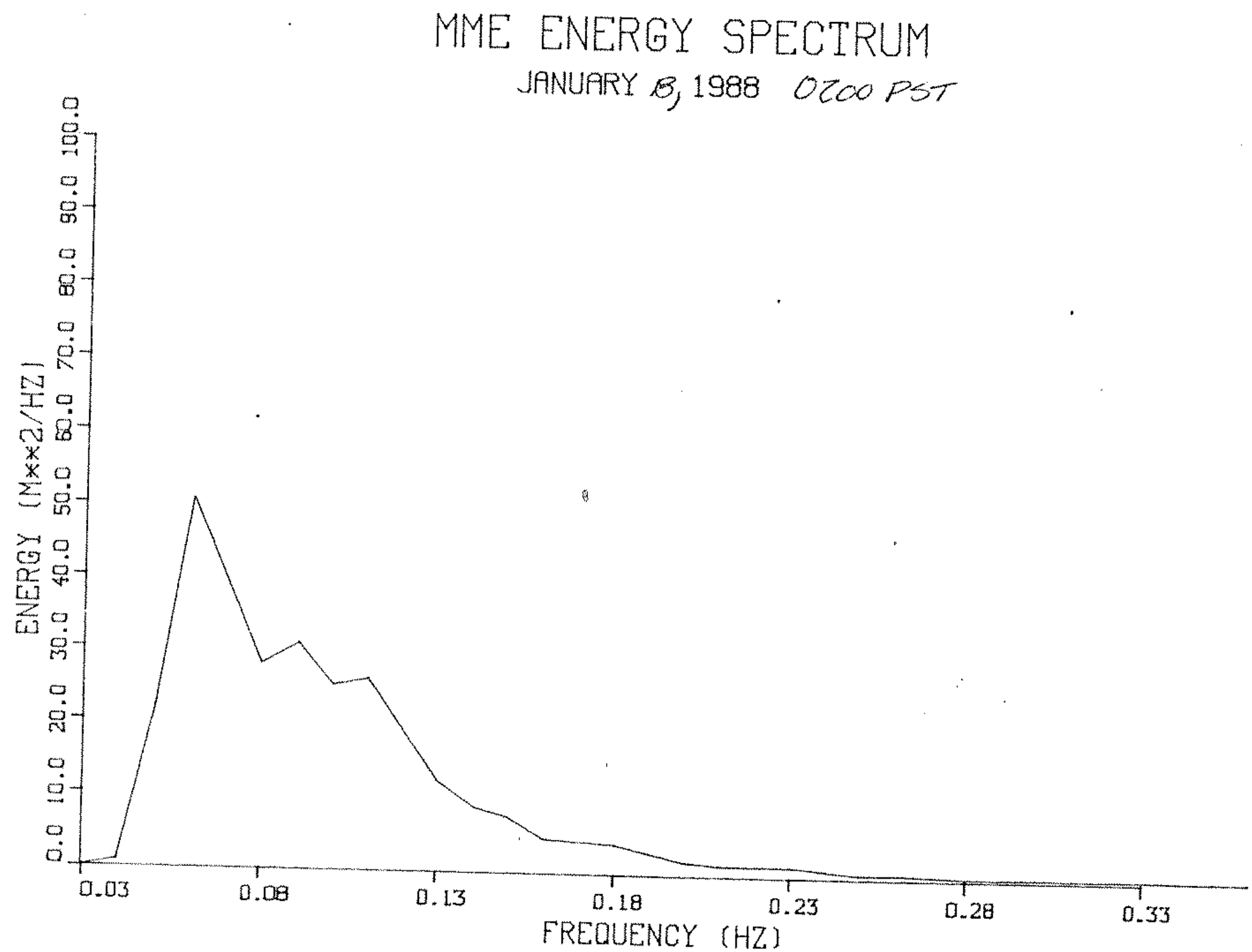

MME ENERGY SPECTRUM
JANUARY 4, 1988 2100 PST
FREQUENCY (HZ)
0.03 0.08 0.13 0.18 0.23 0.28 0.33
ENERGY (M**2/HZ)
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0

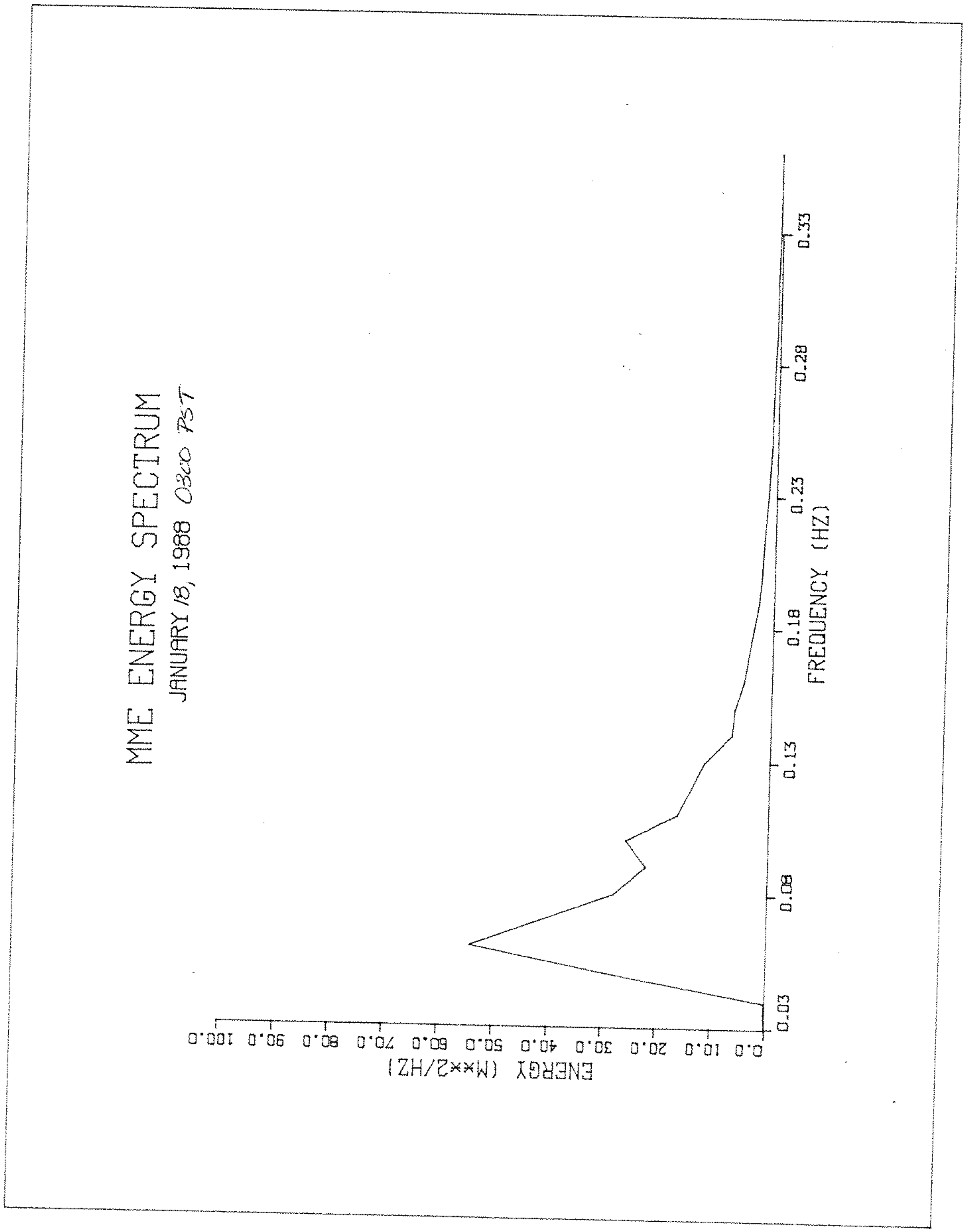

MME ENERGY SPECTRUM
JANUARY 17,1988 2200 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
0.03
0.08
0.13
0.18
0.23
0.28
0.33
FREQUENCY (HZ)


MME ENERGY SPECTRUM
JANUARY 17, 1988 2300 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
FREQUENCY (HZ)
0.03
0.08
0.13
0.18
0.23
0.28
0.33


MME ENERGY SPECTRUM
JANUARY 13, 1988 0000 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
FREQUENCY (HZ)
0.03
0.08
0.13
0.18
0.23
0.28
0.33

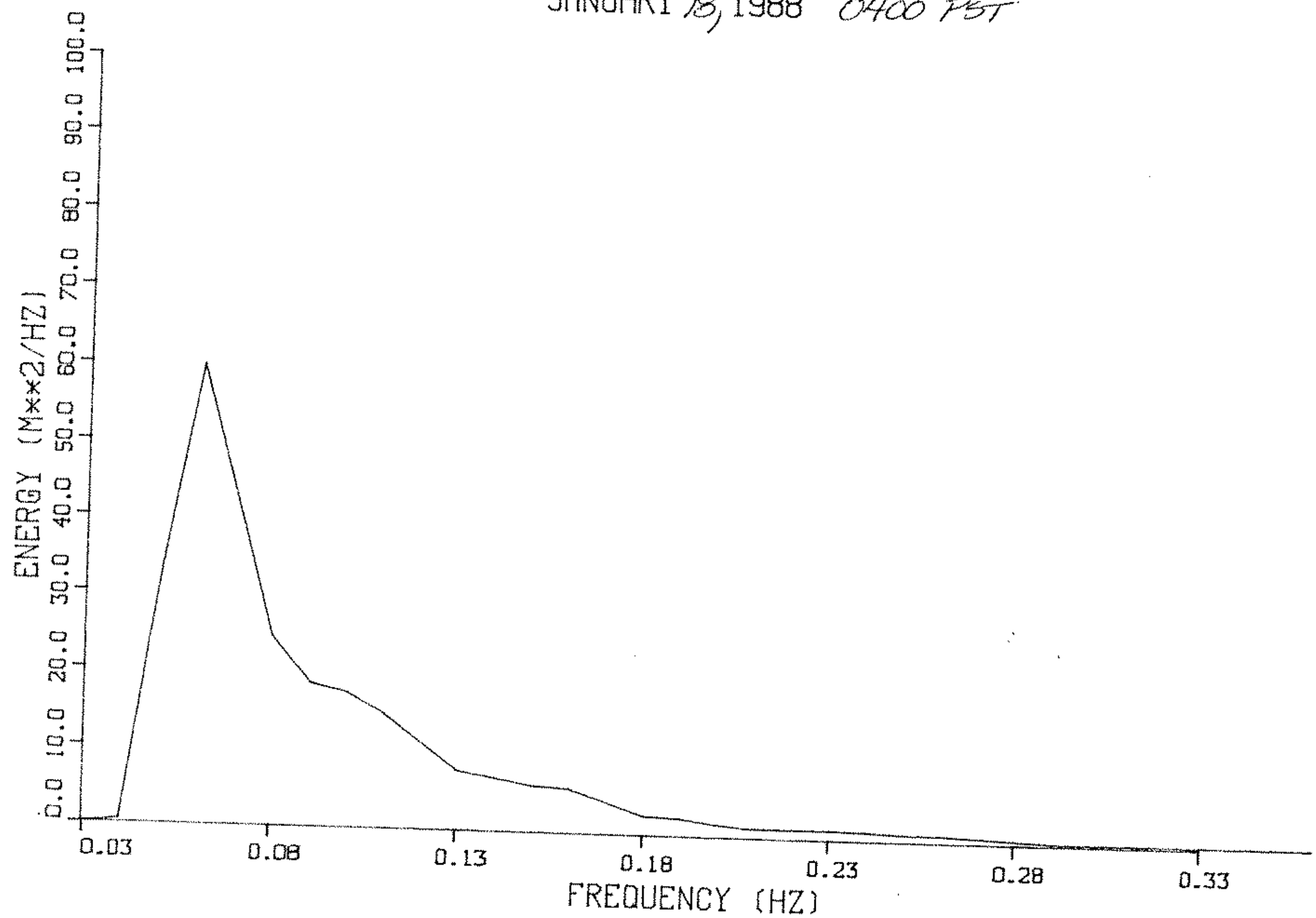

MME ENERGY SPECTRUM
JANUARY 18, 1988 0100 PST
ENERGY (M**2/HZ)
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
FREQUENCY (HZ)
0.03 0.08 0.13 0.18 0.23 0.28 0.33

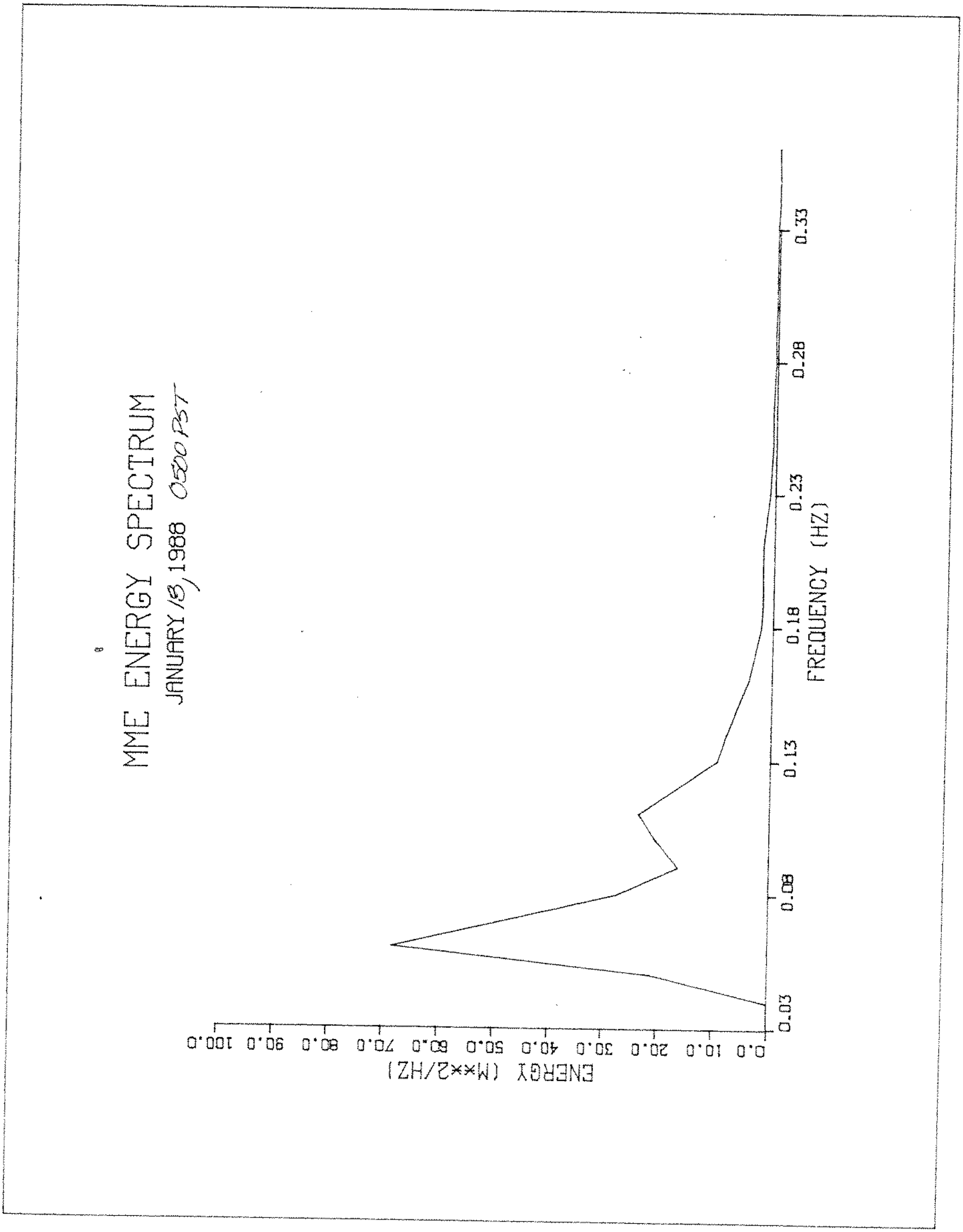

MME ENERGY SPECTRUM
JANUARY 13, 1988 0200 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
0.03
0.08
0.13
0.18
0.23
0.28
0.33
FREQUENCY (HZ)

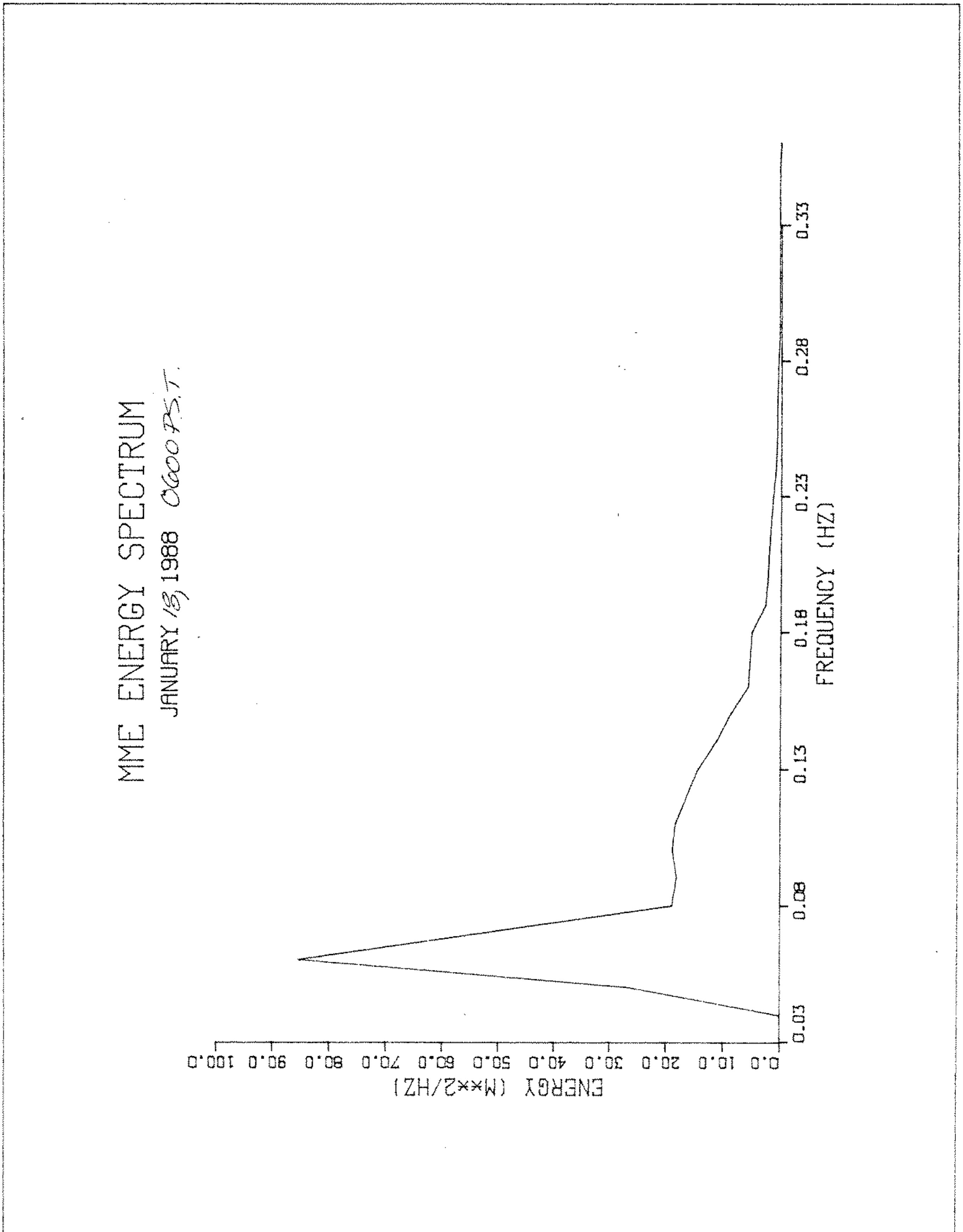

MME ENERGY SPECTRUM
JANUARY 18, 1988 0300 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
FREQUENCY (HZ)
0.03
0.08
0.13
0.18
0.23
0.28
0.33

MME ENERGY SPECTRUM

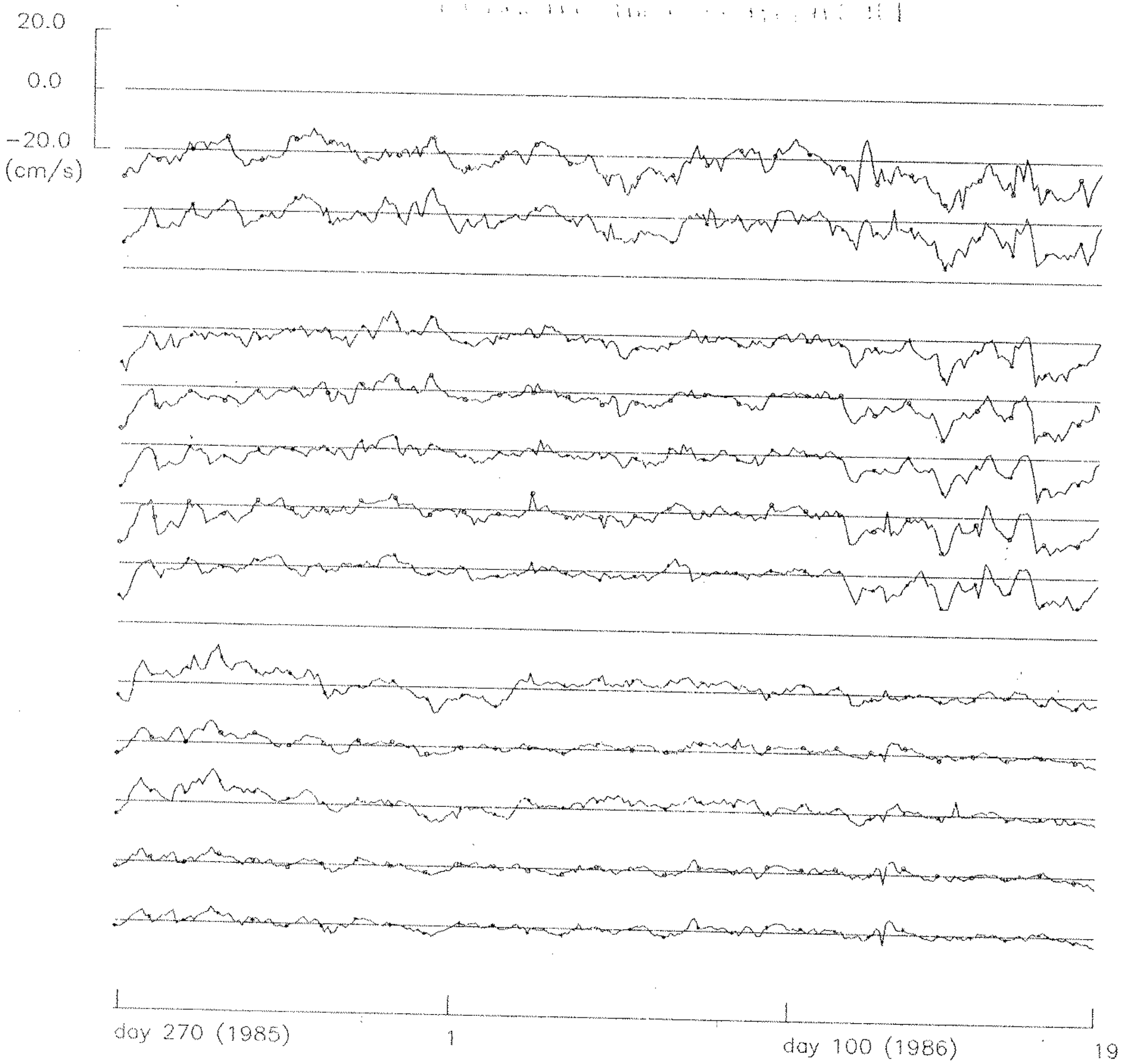
JANUARY 18, 1988 0400 PST




MME ENERGY SPECTRUM
JANUARY 15, 1988 0500 PST
ENERGY (M**2/HZ)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
FREQUENCY (HZ)
0.03
0.08
0.13
0.18
0.23
0.28
0.33

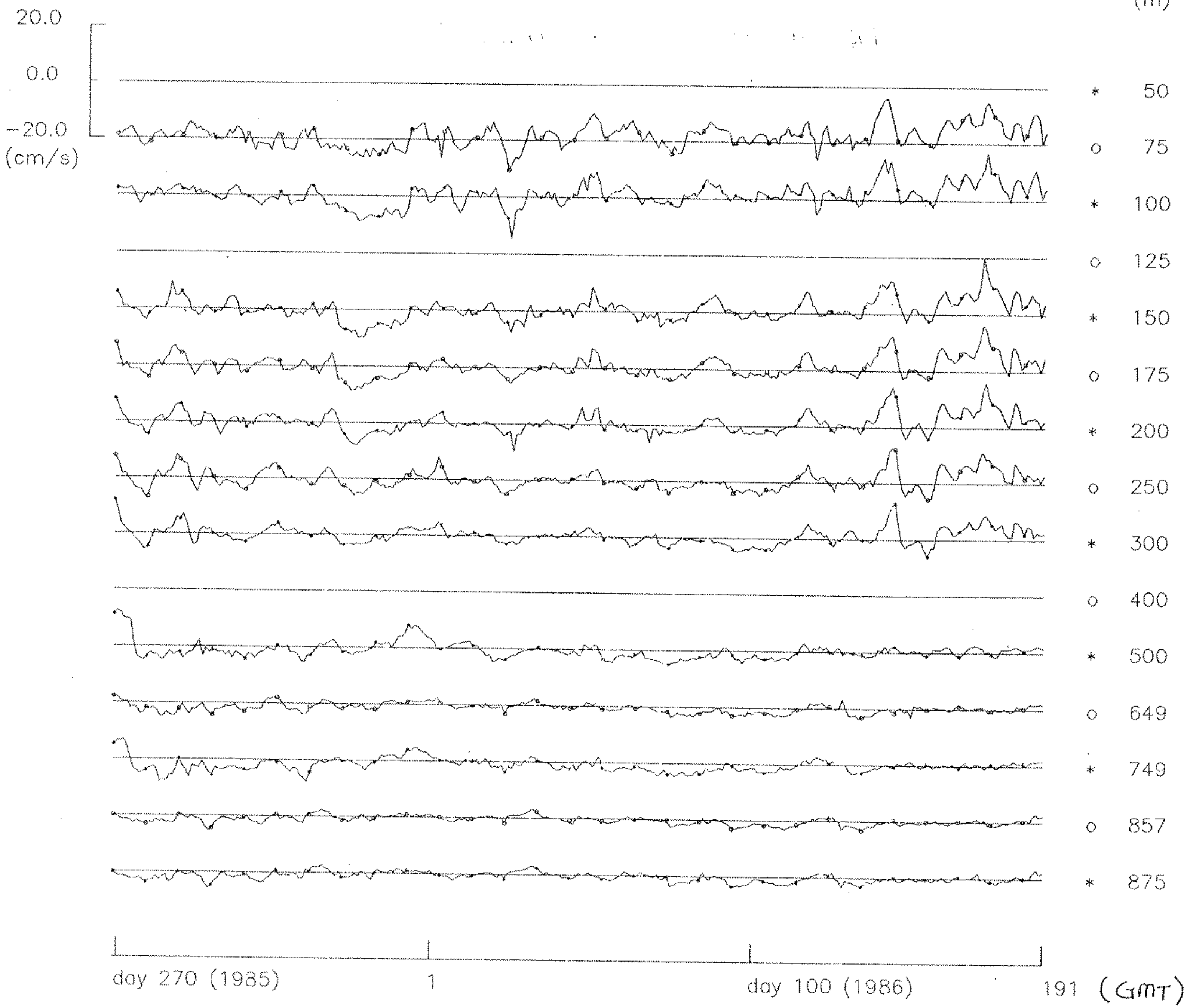

MME ENERGY SPECTRUM
JANUARY 18, 1988 0600 P.S.T.
ENERGY (M**2/HZ)
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0
FREQUENCY (HZ)
0.03 0.08 0.13 0.18 0.23 0.28 0.33

DAILY AVERAGE DATA FOR U



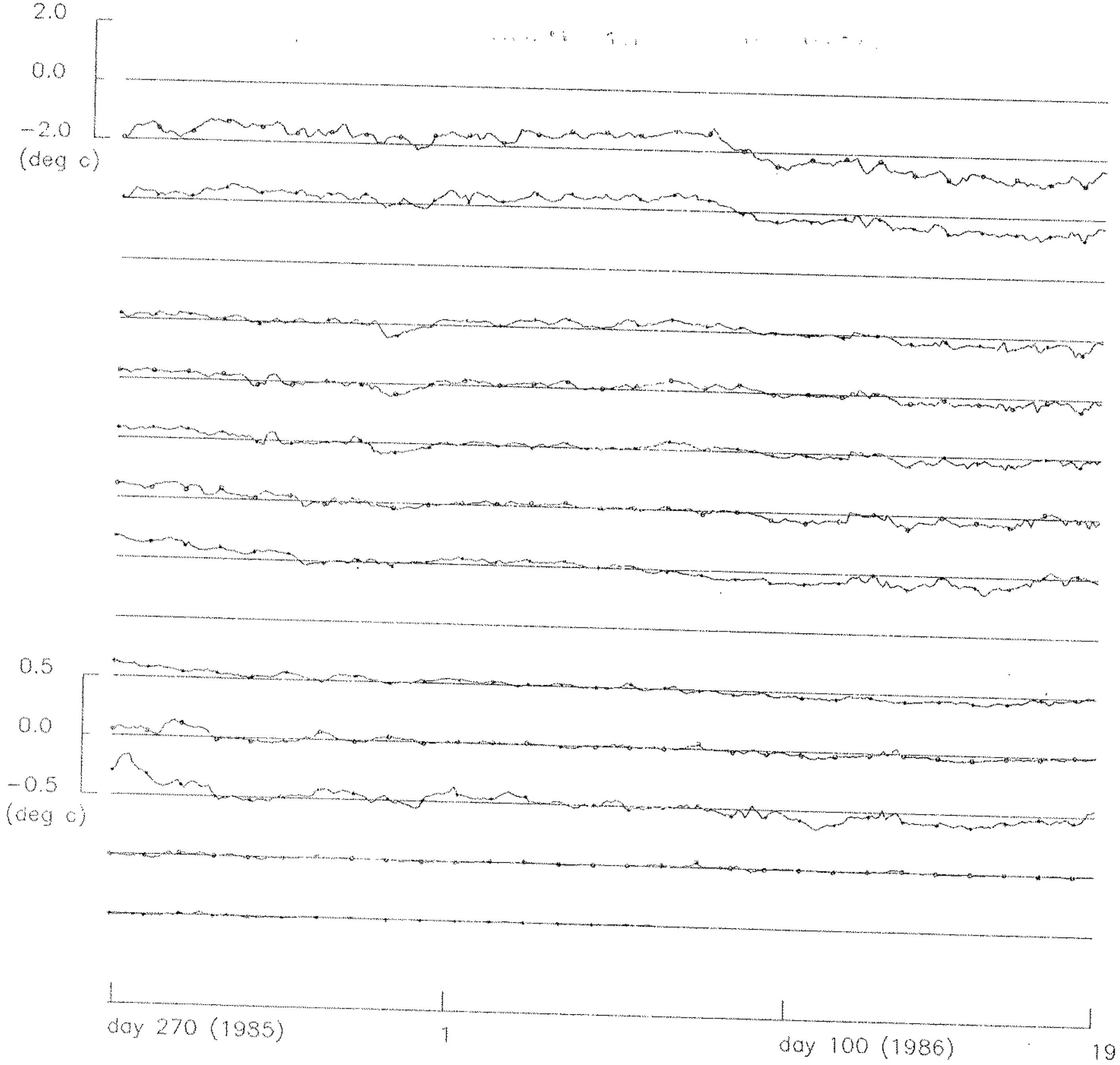
	depth (m)	mean (cm/s)	s.d. (cm/s)
*	50	0.00	0.00
o	75	-2.96	7.54
*	100	-3.26	6.91
o	125	0.00	0.00
*	150	-3.20	5.73
o	175	-3.15	5.51
*	200	-2.59	4.88
o	250	-2.64	5.17
*	300	-1.93	4.63
o	400	0.00	0.00
*	500	0.64	4.00
o	649	0.59	3.38
*	749	0.98	3.79
o	857	0.18	3.40
*	875	0.18	3.69

DAILY AVERAGE DATA FOR V



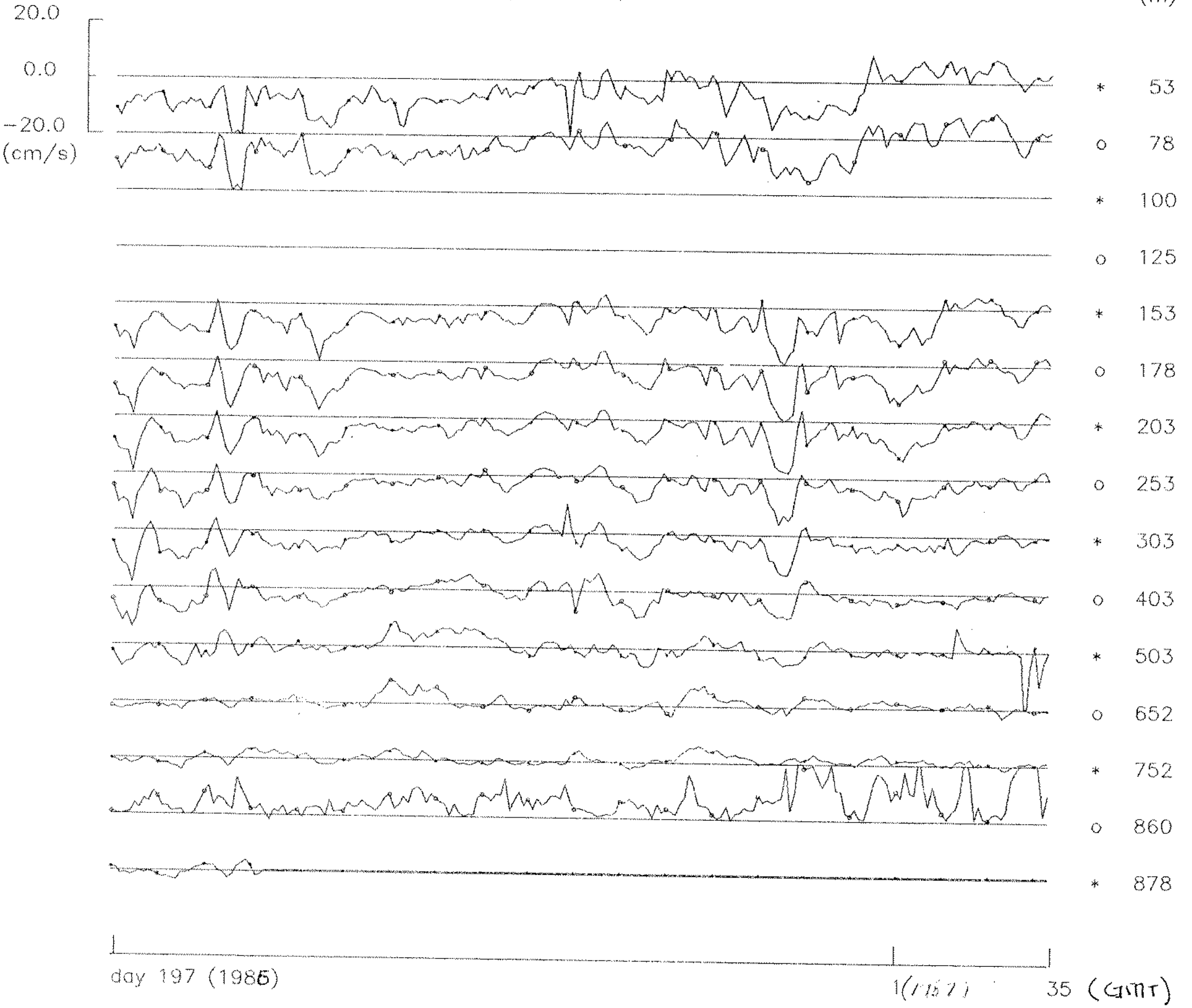
	depth (m)	mean (cm/s)	s.d. (cm/s)
*	50	0.00	0.00
o	75	2.16	6.93
*	100	1.43	6.57
o	125	0.00	0.00
*	150	1.08	5.87
o	175	0.95	5.49
*	200	0.66	5.07
o	250	0.53	4.82
*	300	0.68	4.28
o	400	0.00	0.00
*	500	-0.34	3.77
o	649	-0.62	2.74
*	749	-0.92	3.28
o	857	-0.48	2.77
*	875	-0.55	2.99

DAILY AVERAGE DATA FOR T



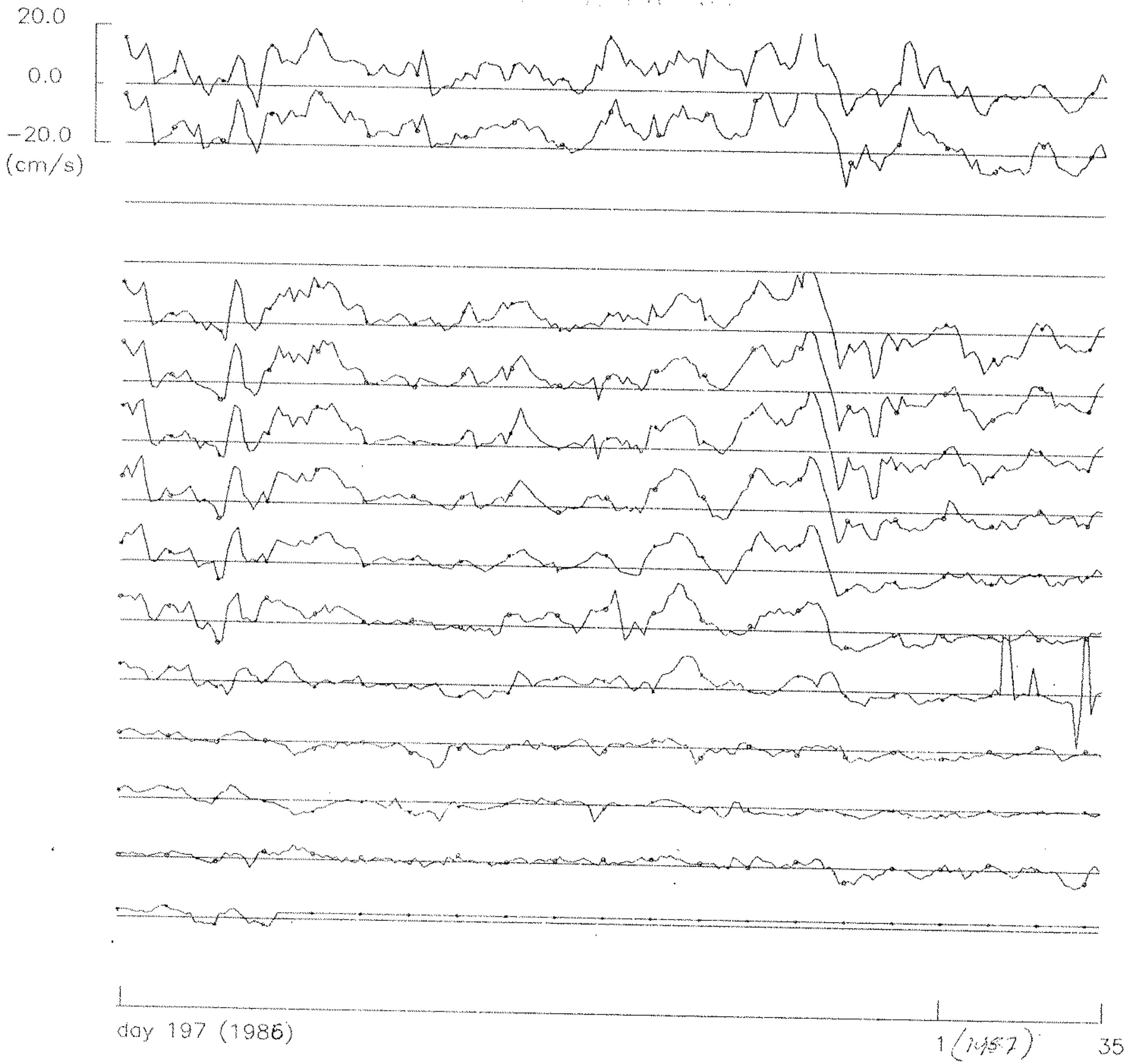
	depth (m)	mean (deg c)	s.d. (deg c)
*	50	0.00	0.00
o	75	10.70	0.55
*	100	10.10	0.38
o	125	0.00	0.00
*	150	9.32	0.22
o	175	8.74	0.19
*	200	8.19	0.18
o	250	8.30	0.20
*	300	7.97	0.27
o	400	0.00	0.00
*	500	6.33	0.18
o	649	5.21	0.04
*	749	5.49	0.09
o	857	5.02	0.01
*	875	5.03	0.02

DAILY AVERAGE DATA FOR U



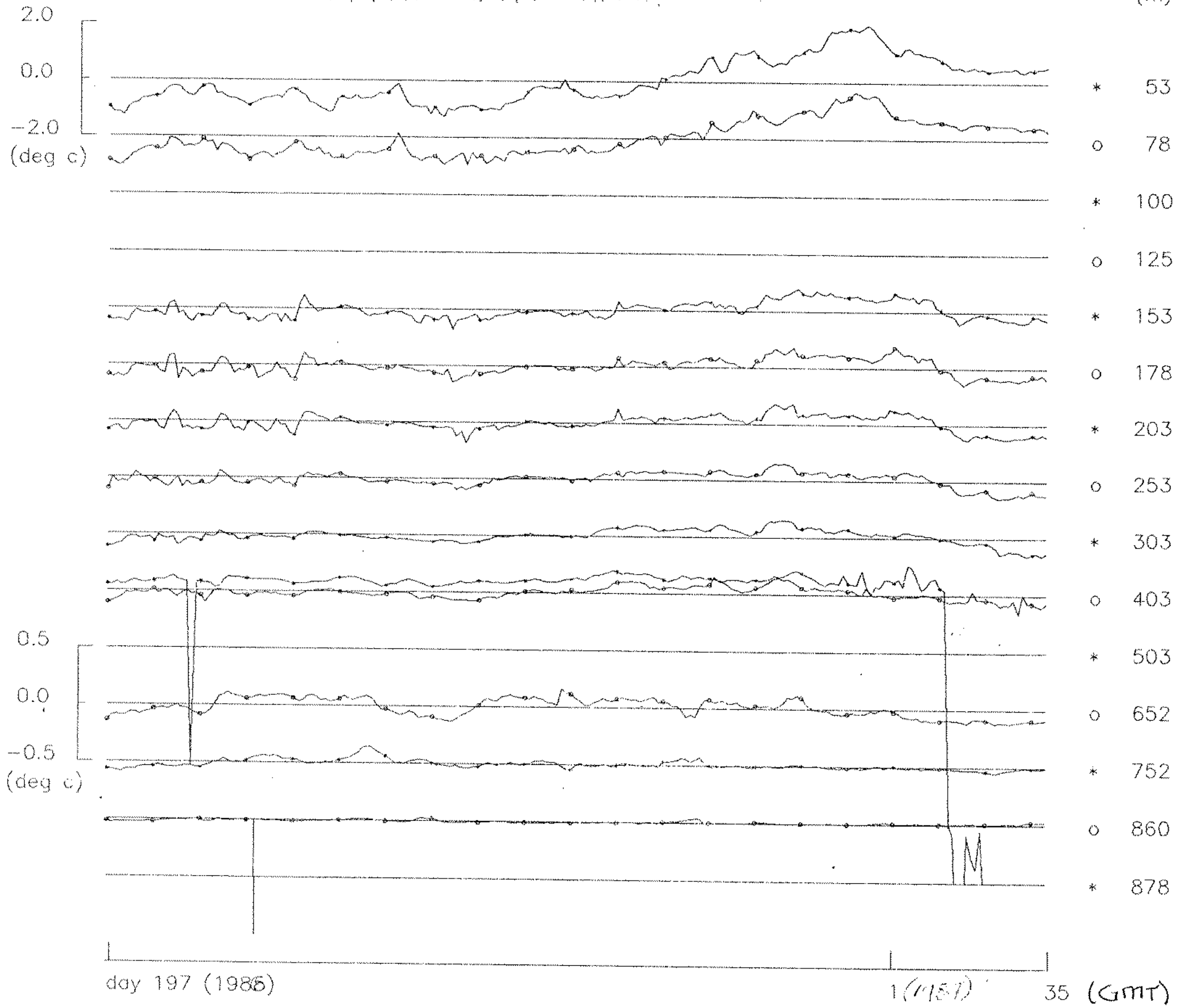
	depth (m)	mean (cm/s)	s.d. (cm/s)
*	53	−4.75	7.92
o	78	−4.02	7.15
*	100	0.00	0.00
o	125	0.00	0.00
*	153	−5.13	5.82
o	178	−5.17	5.72
*	203	−4.62	5.21
o	253	−3.65	4.68
*	303	−3.00	4.57
o	403	−1.80	4.55
*	503	−0.32	5.97
o	652	0.67	3.59
*	752	0.74	3.42
o	860	6.21	11.60
*	878	0.39	1.44

DAILY AVERAGE DATA FOR V



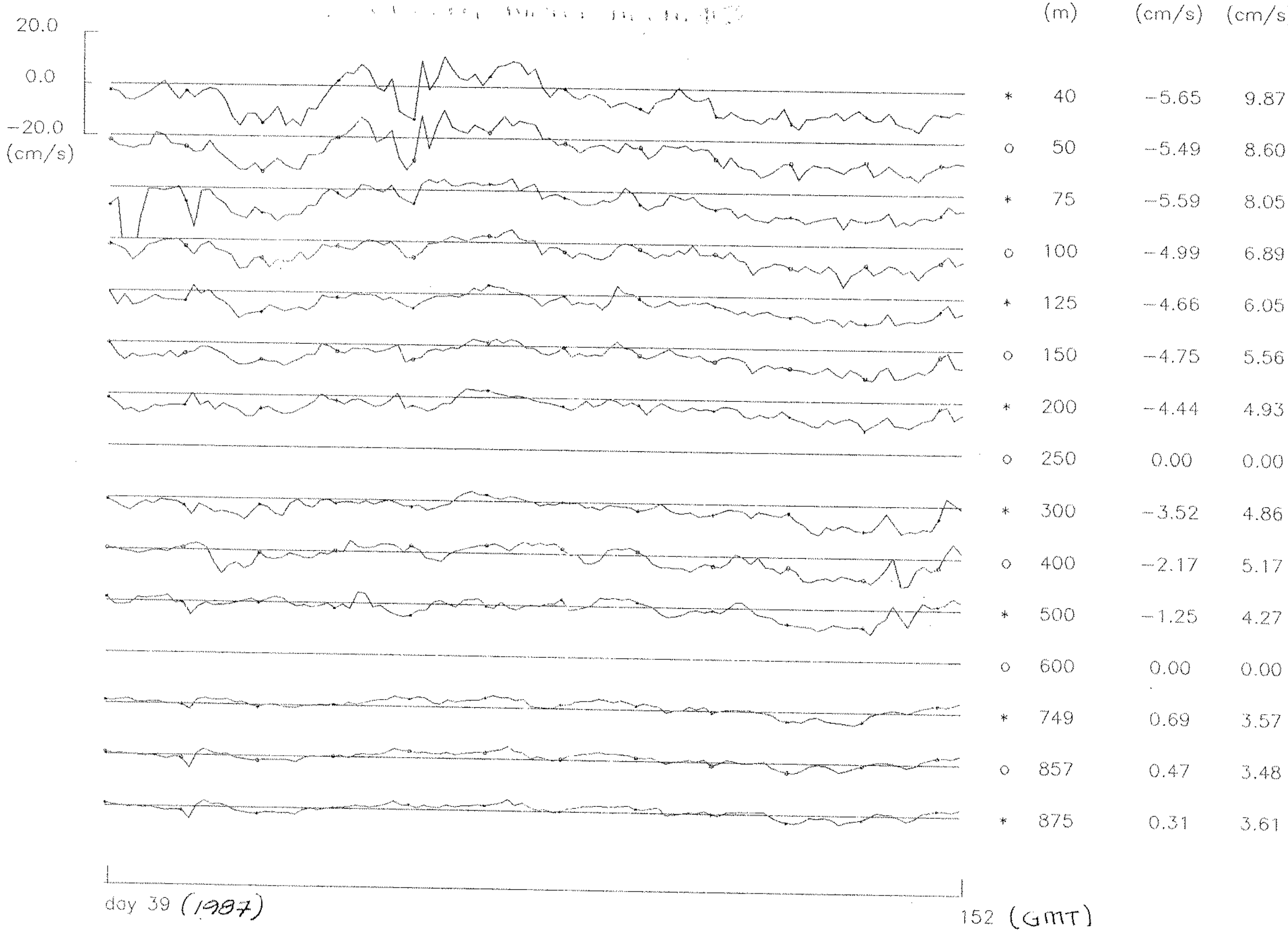
	depth (m)	mean (cm/s)	s.d. (cm/s)
*	53	5.87	7.93
o	78	5.73	8.19
*	100	0.00	0.00
o	125	0.00	0.00
*	153	3.05	7.65
o	178	2.50	7.10
*	203	2.51	6.82
o	253	2.36	6.19
*	303	1.91	5.47
o	403	1.65	5.19
*	503	1.09	12.49
o	652	−0.53	3.02
*	752	−0.56	2.77
o	860	0.36	3.25
*	878	1.75	1.30

DAILY AVERAGE DATA FOR T

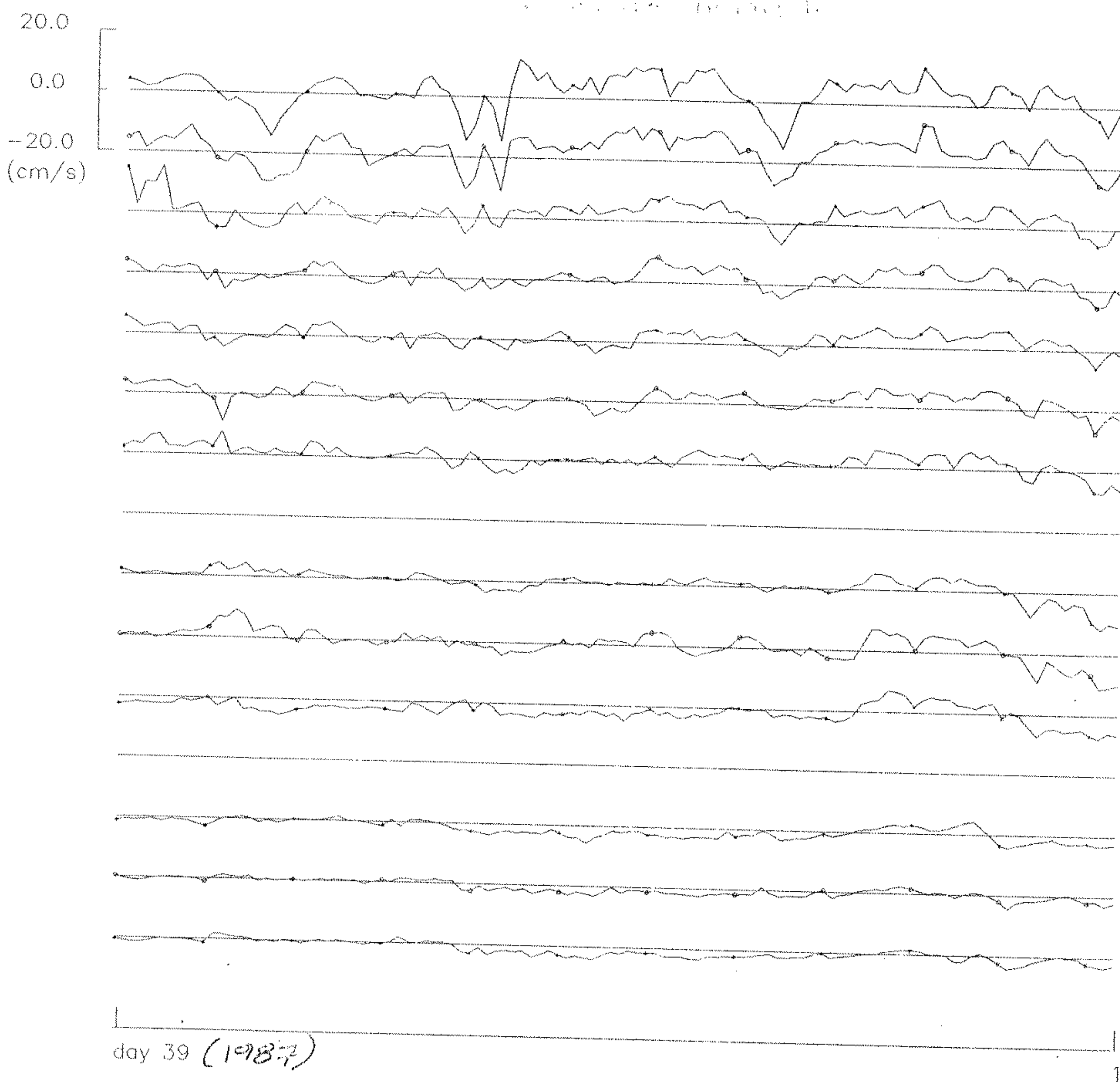


	depth (m)	mean (deg c)	s.d. (deg c)
*	53	10.72	0.84
o	78	10.35	0.67
*	100	0.00	0.00
o	125	0.00	0.00
*	153	9.32	0.33
o	178	9.27	0.32
*	203	8.92	0.30
o	253	8.53	0.27
*	303	8.13	0.26
o	403	7.32	0.26
*	503	4.12	11.05
o	652	5.61	0.09
*	752	5.17	0.04
o	860	4.95	0.00
*	878	0.79	1.84

DAILY AVERAGE DATA FOR U

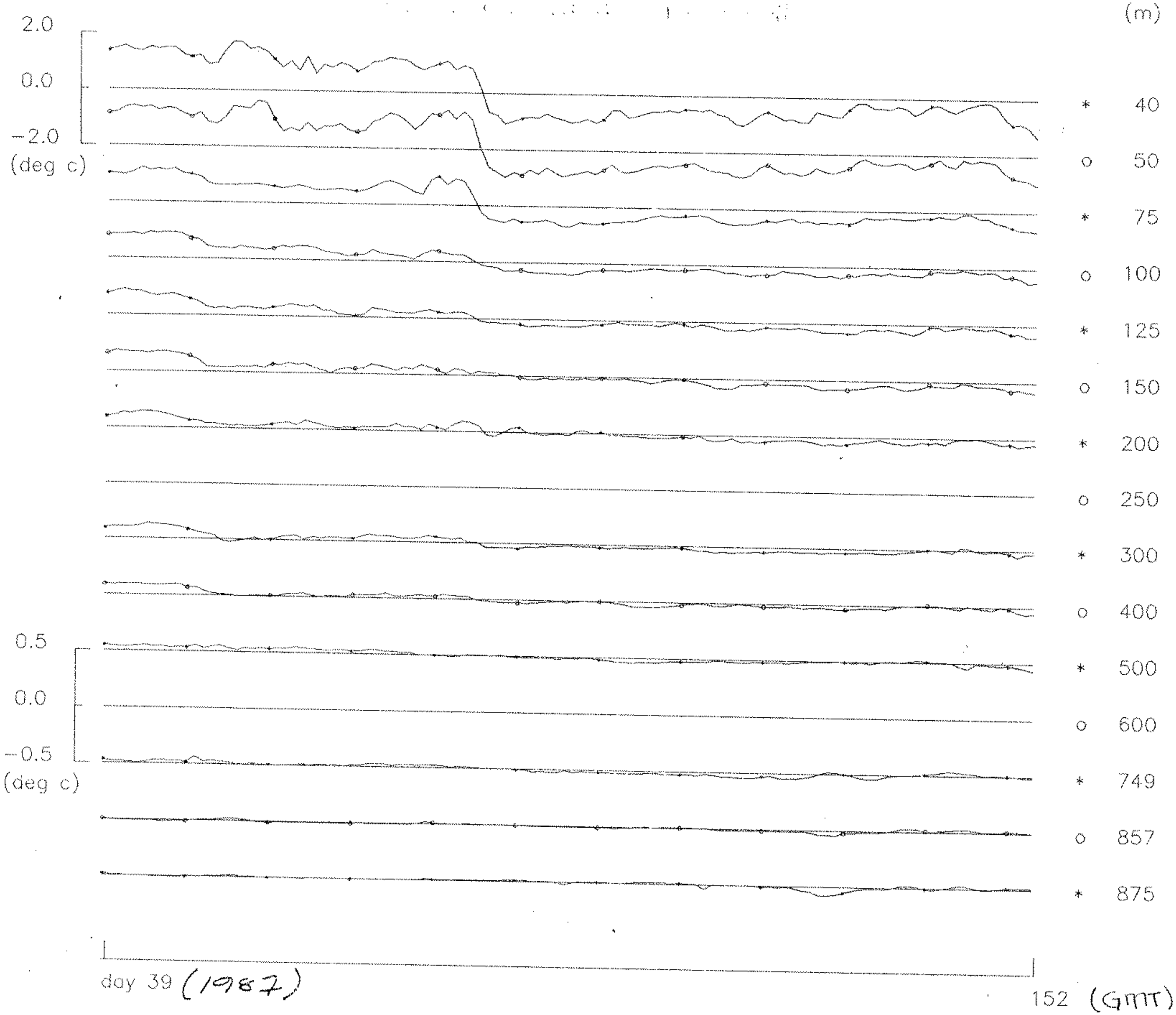


DAILY AVERAGE DATA FOR V



	depth (m)	mean (cm/s)	s.d. (cm/s)
*	40	2.25	9.06
o	50	3.05	8.48
*	75	2.34	7.38
o	100	1.56	6.36
*	125	1.48	5.55
o	150	1.15	4.97
*	200	1.00	4.67
o	250	0.00	0.00
*	300	-0.30	4.65
o	400	-0.23	5.00
*	500	-1.82	4.08
o	600	0.00	0.00
*	749	-1.18	3.12
o	857	-0.77	2.52
*	875	-1.17	2.79

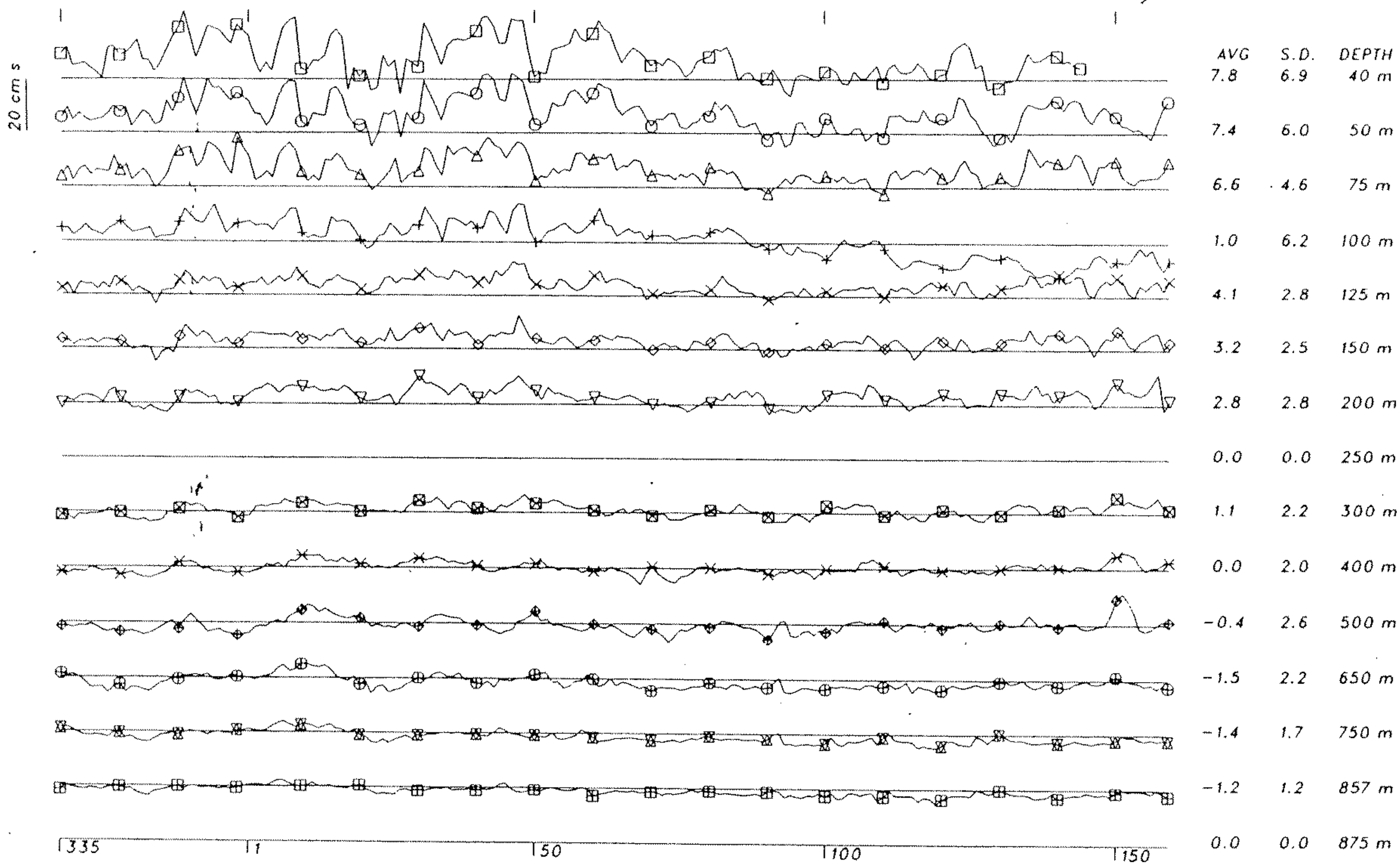
DAILY AVERAGE DATA FOR T



	depth (m)	mean (deg c)	s.d. (deg c)
*	40	12.14	0.92
o	50	11.54	0.85
*	75	10.52	0.59
o	100	9.73	0.39
*	125	9.36	0.32
o	150	9.00	0.29
*	200	8.49	0.22
o	250	0.00	0.00
*	300	7.57	0.19
o	400	6.76	0.15
*	500	6.15	0.12
o	600	0.00	0.00
*	749	5.15	0.03
o	857	5.06	0.01
*	875	5.02	0.02

CURRENT METER ARRAY #4

DAILY AVERAGE DATA FOR NORTHWARD(+) CURRENTS (V)

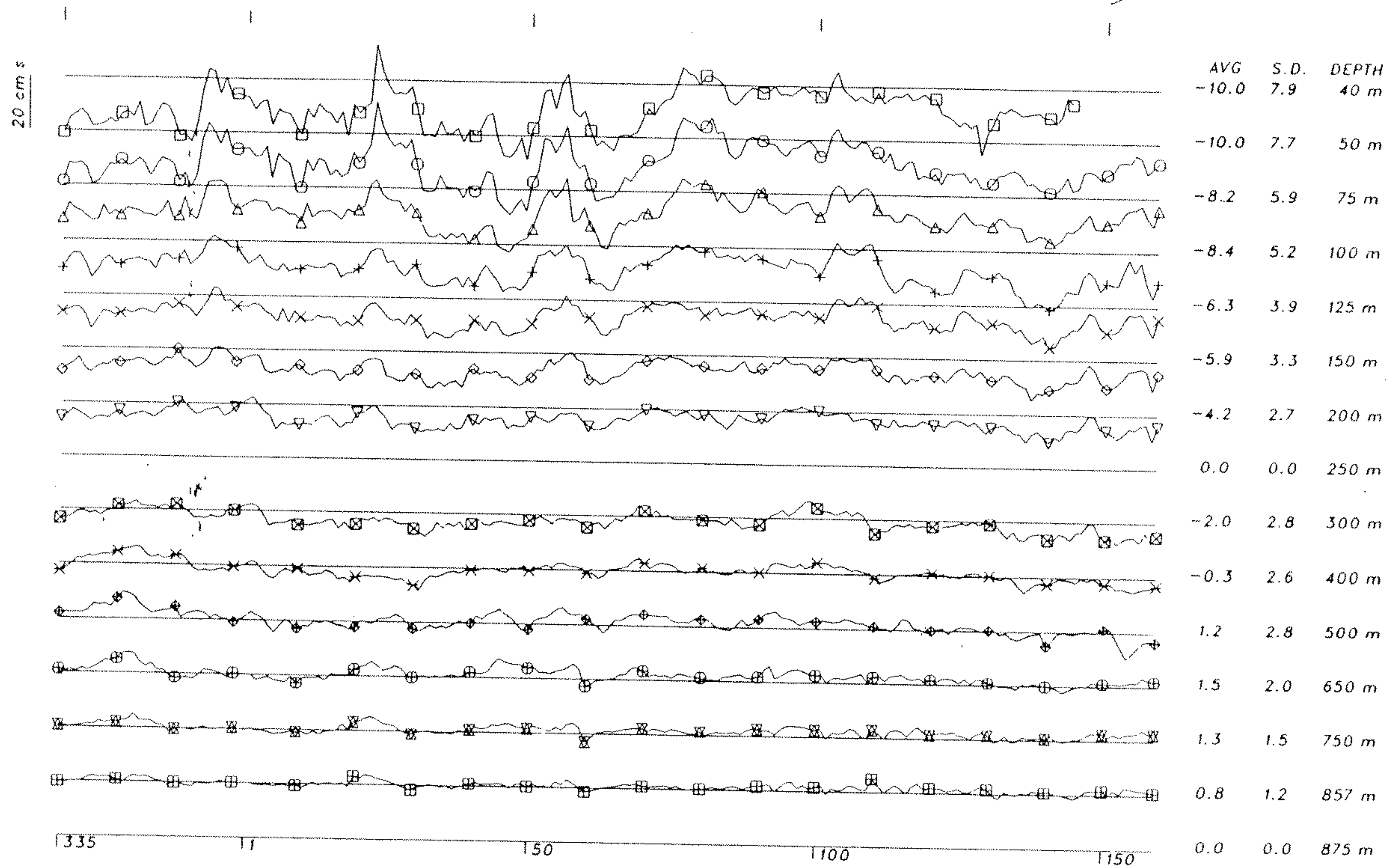


JULIAN CALENDAR DAYS (1987–88, GMT)

PLOT 2 16.16.11 THUR 29 DEC, 1988 JOB-BRATKOVI1 NOAA GREAT LAKES LAB DISSPLA 11.0

CURRENT METER ARRAY #4

DAILY AVERAGE DATA FOR EASTWARD(+) CURRENTS (U)

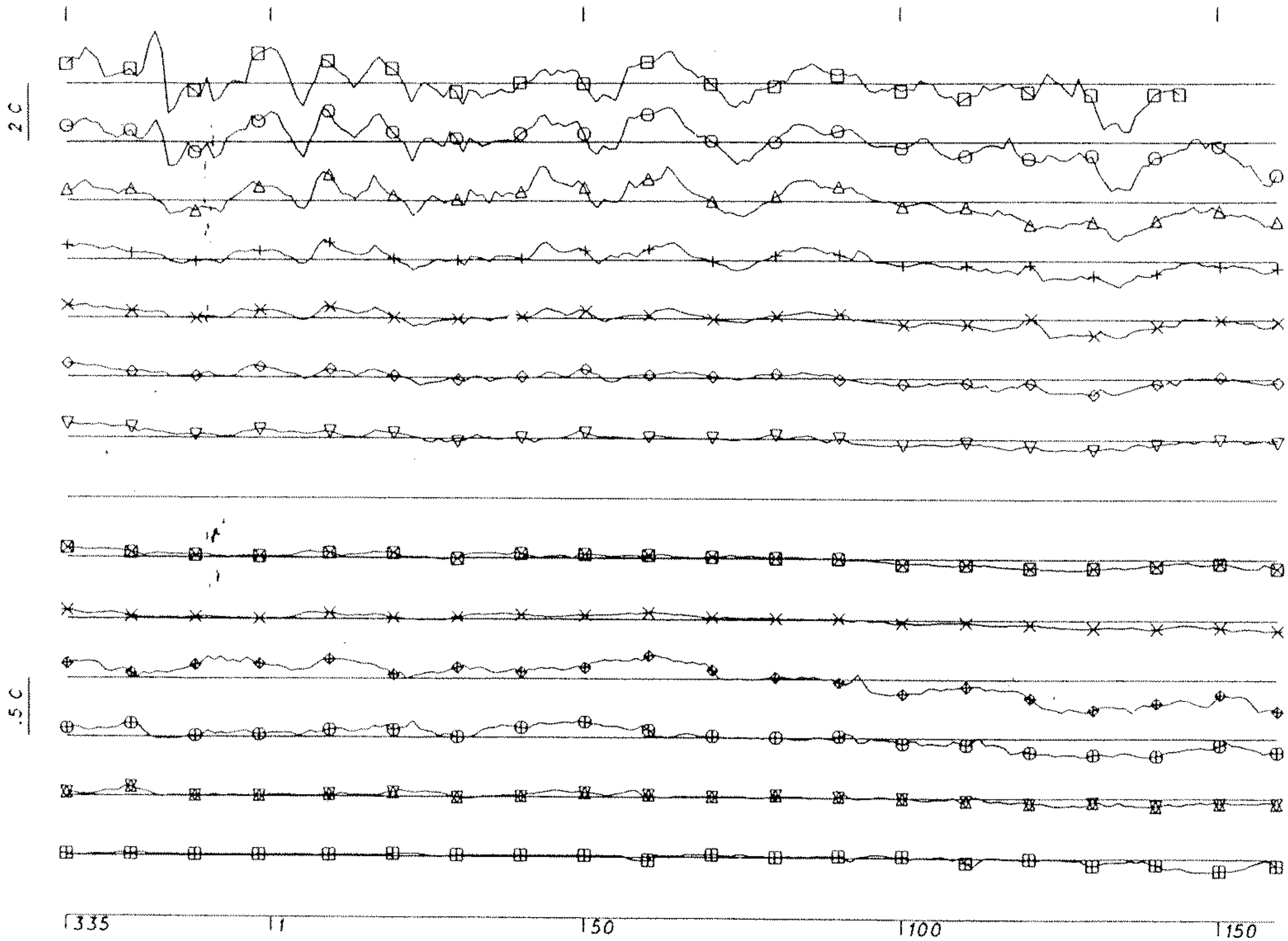


JULIAN CALENDAR DAYS (1987–88, GMT)

PLOT 1 16.15.24 THUR 29 DEC, 1988 JOB-BRATKOVI1 NOAA GREAT LAKES LAB DISSPLA 11.0

CURRENT METER ARRY #4

DAILY AVERAGE DATA FOR TEMPERATURE–MEAN TEMP. (T)



AVG	S.D.	DEPTH
12.52	0.57	40 m
11.81	0.59	50 m
10.69	0.50	75 m
9.82	0.32	100 m
9.25	0.24	125 m
8.90	0.21	150 m
8.25	0.18	200 m
0.00	0.00	250 m
7.66	0.17	300 m
7.07	0.16	400 m
6.22	0.14	500 m
5.47	0.08	650 m
5.18	0.03	750 m
5.04	0.03	857 m
0.00	0.00	875 m

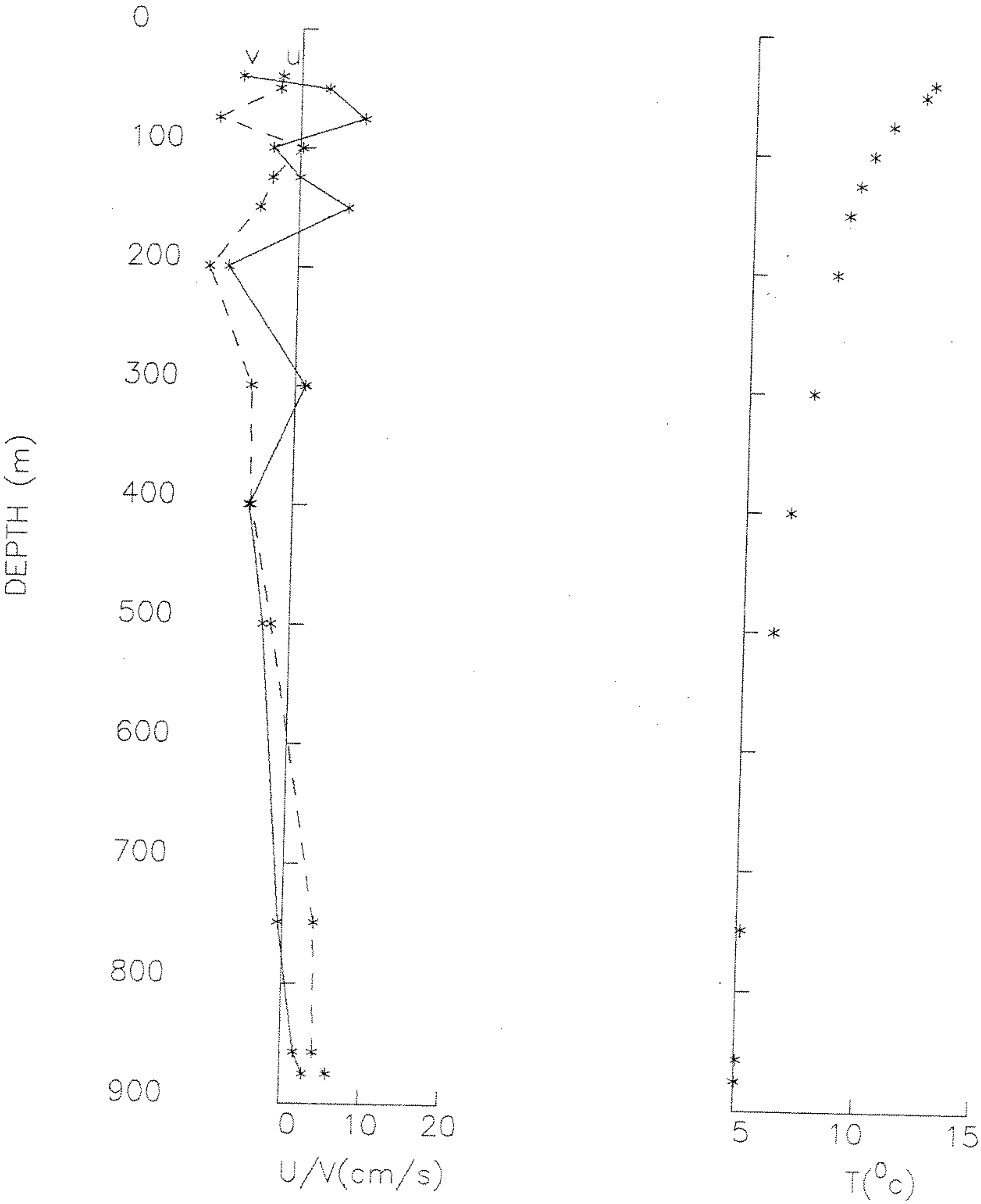
JULIAN CALENDAR DAYS (1987–88, GMT)

PLOT 3 16.16.57 THUR 29 DEC, 1988 JOB-BRATKOV11 NOAA GREAT LAKES LAB DISSPLA 11.0

15-MINUTE-AVERAGE U&V&T PROFILE PLOTS

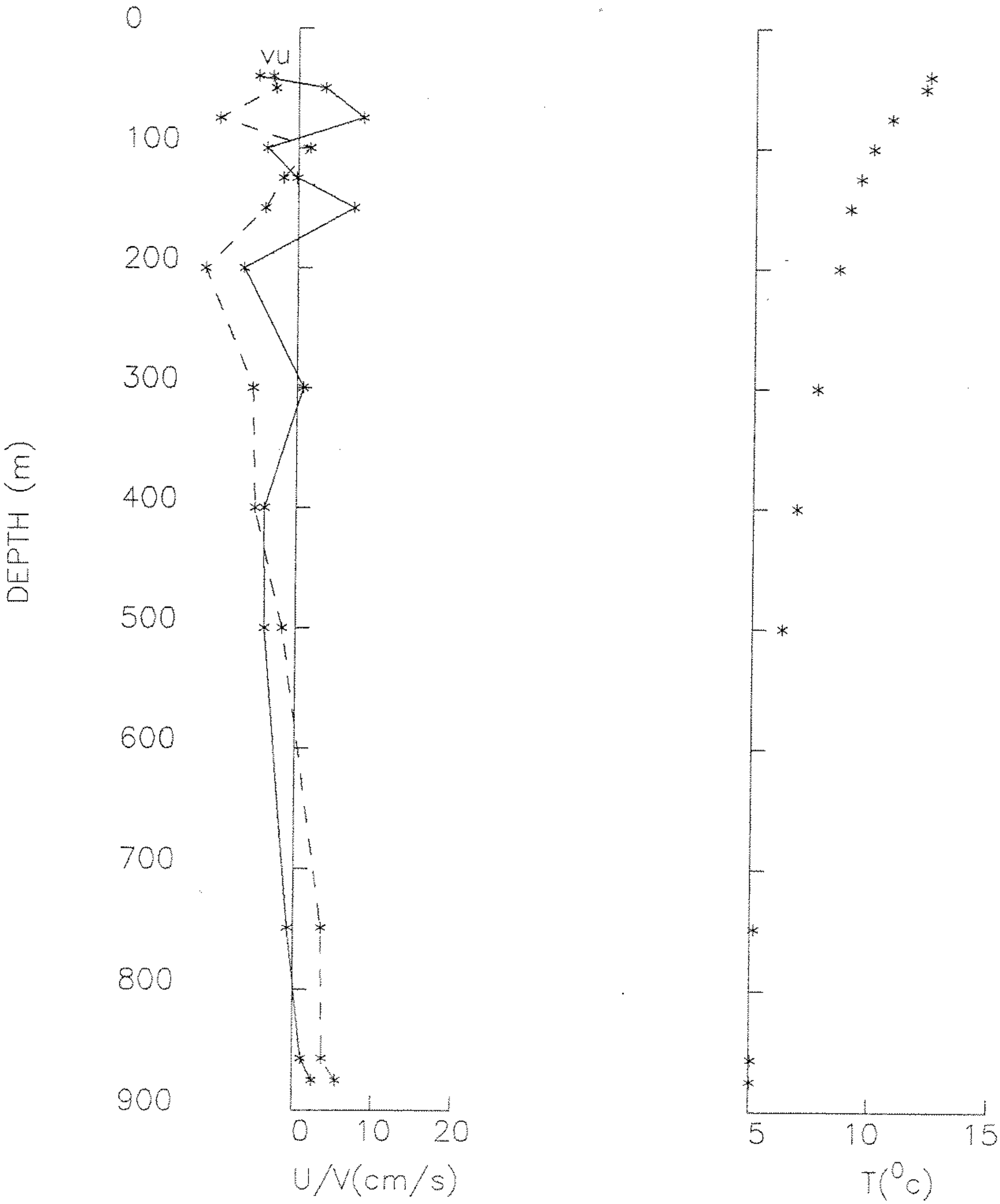
5 MAR 1987 1015 PST

TIME: 64.76042
GMT 1987



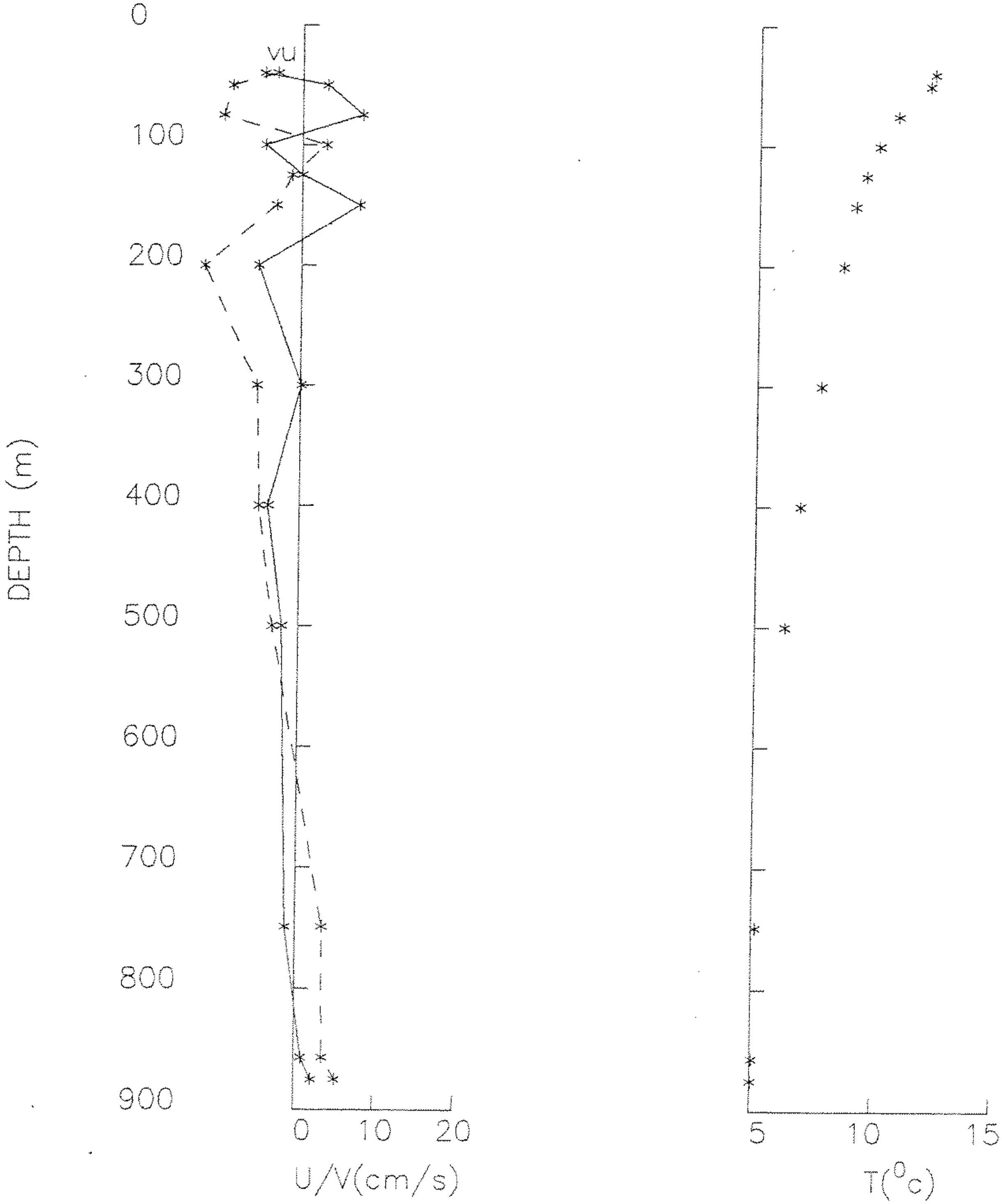
5 MAR 1987 1030 PST

TIME: 64.77084
GMT 1987



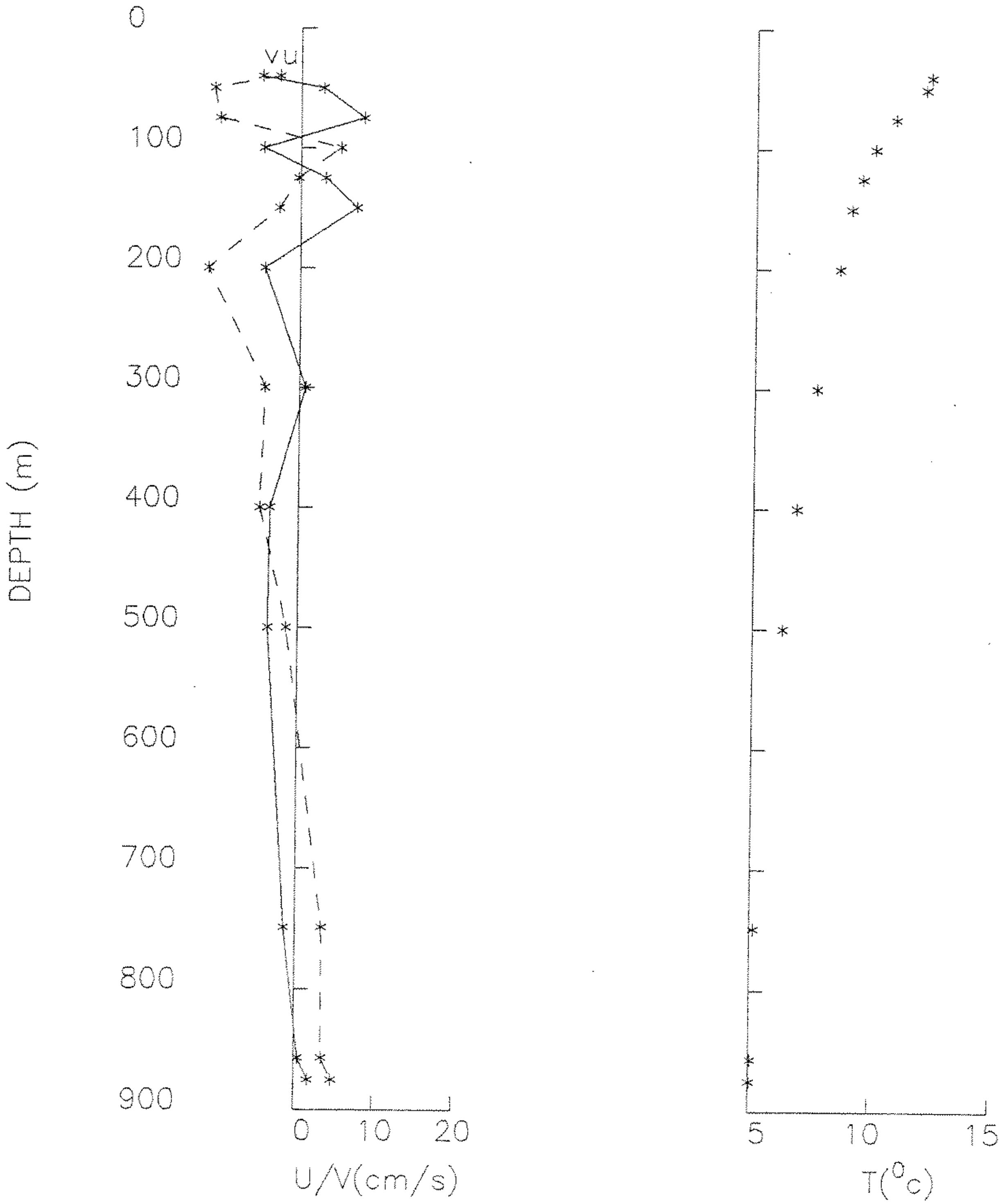
5 MAR 1987 1045 PST

TIME: 64.78125
GMT 1987



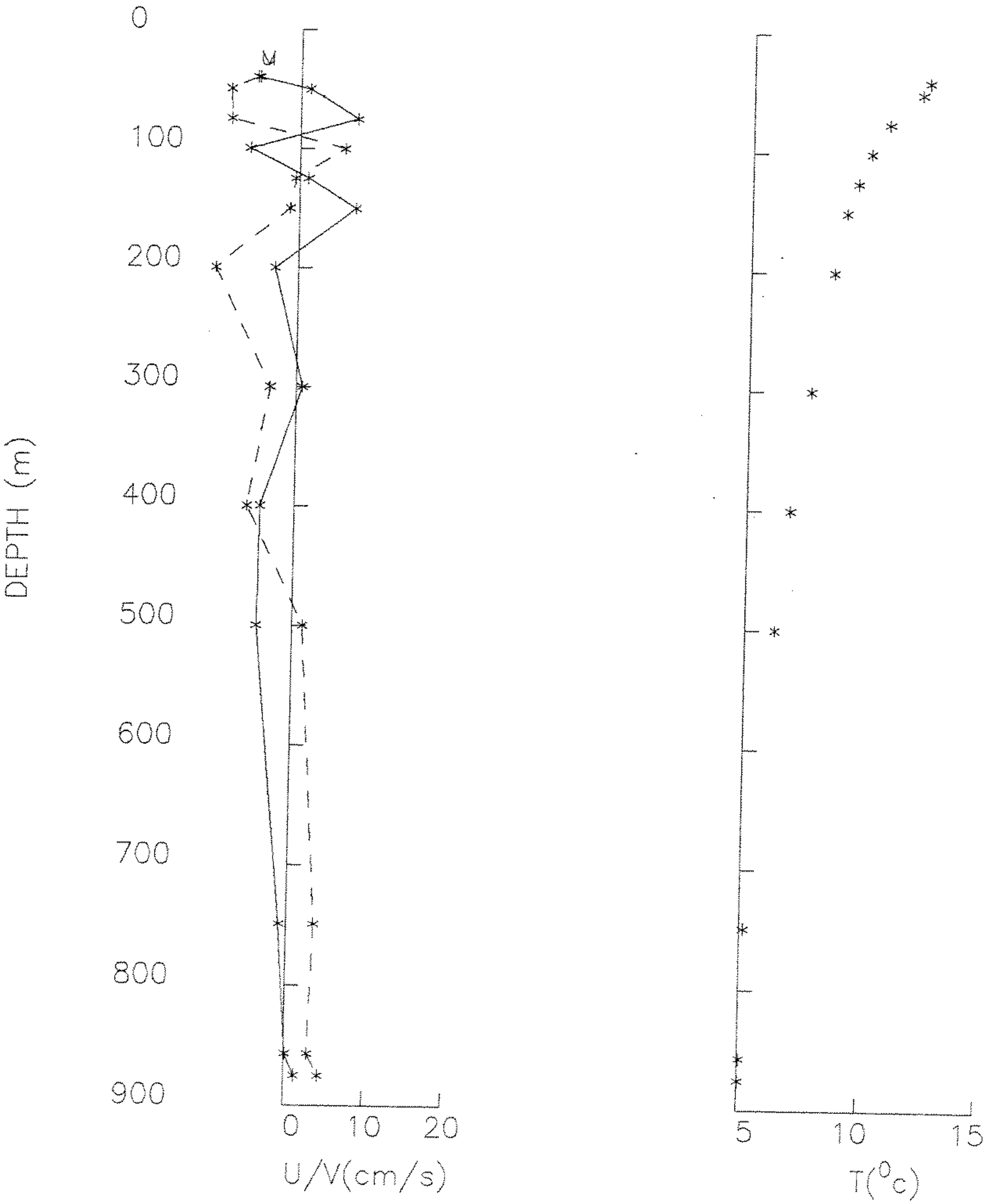
5 MAR 1987 1100 PST

TIME: 64.79167
GMT 1987



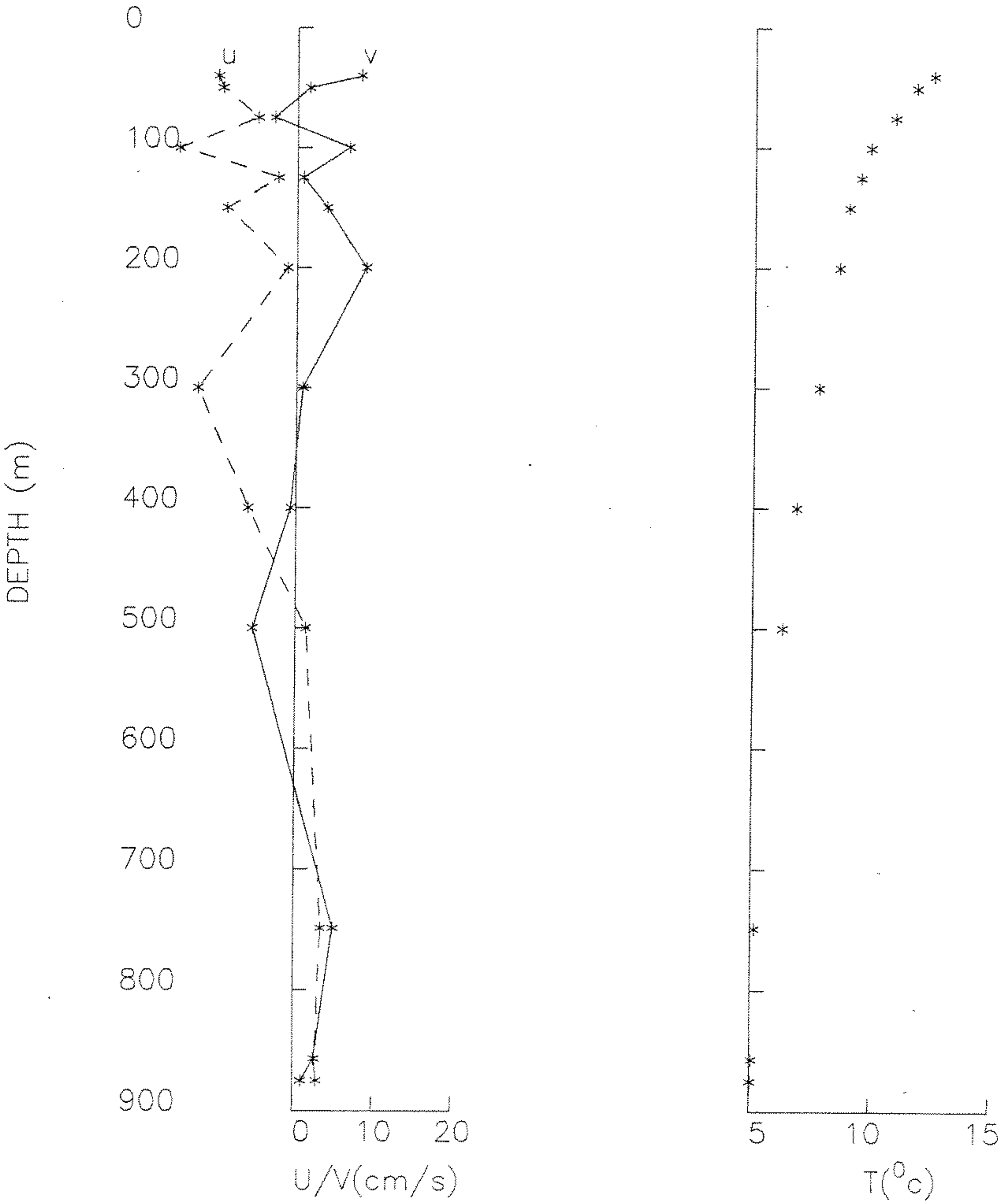
5 MAR 1987 1115 PST

TIME: 64.80209
GMT 1987



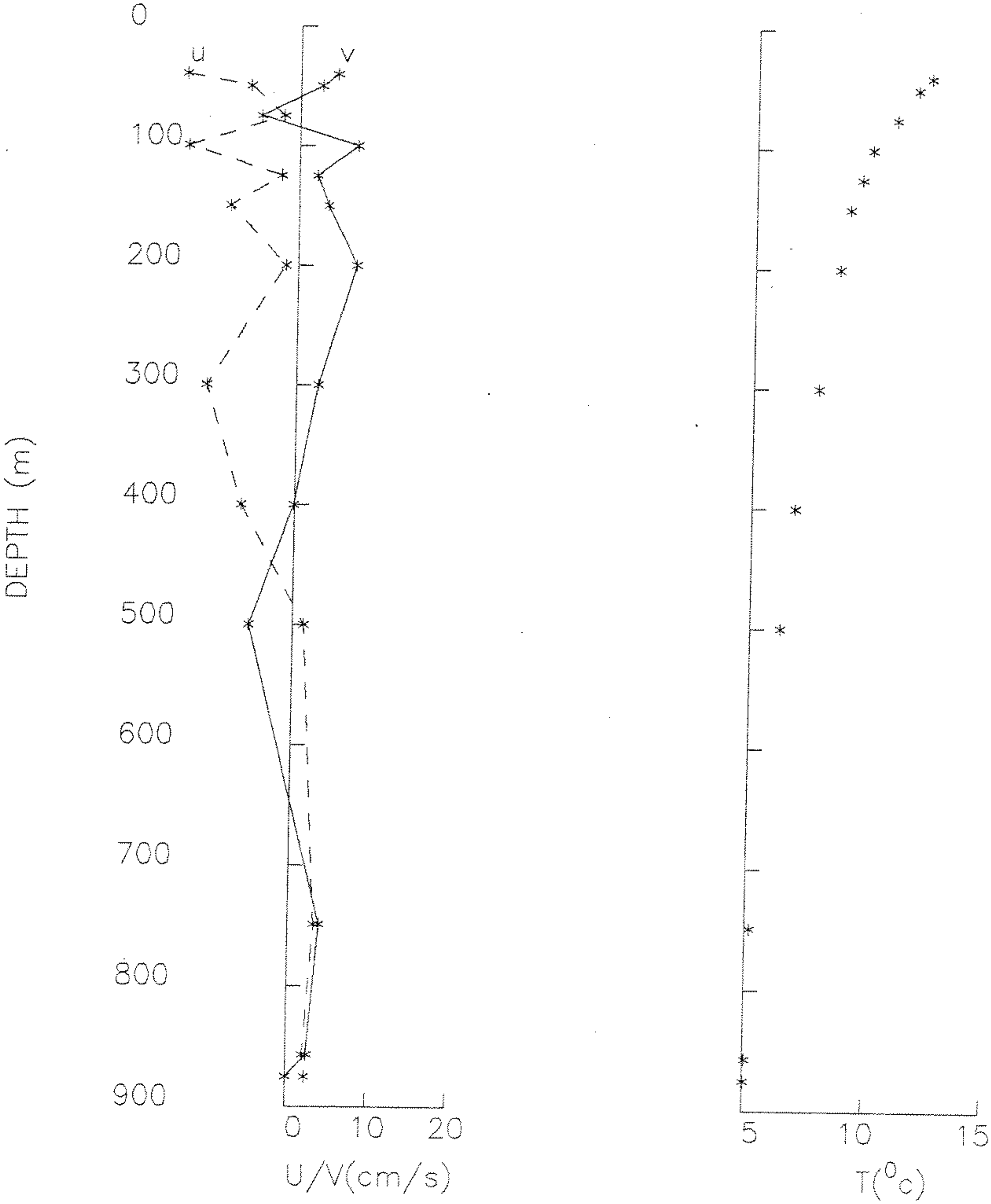
5 MAR 1987 2215 PST

TIME: 65.26042
GMT 1987



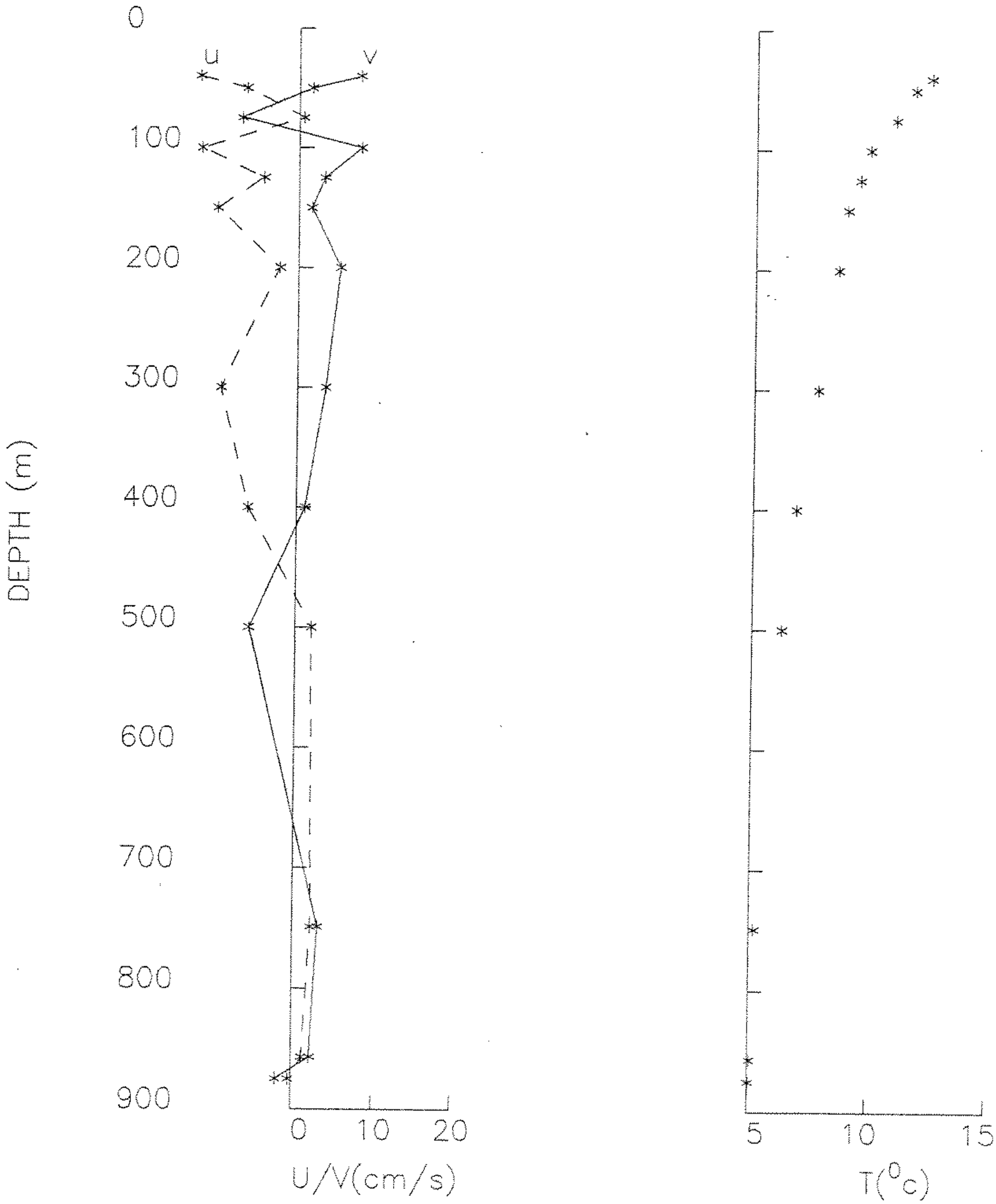
5 MAR 1987 2230 PST

TIME: 65.27084
GMT 1987



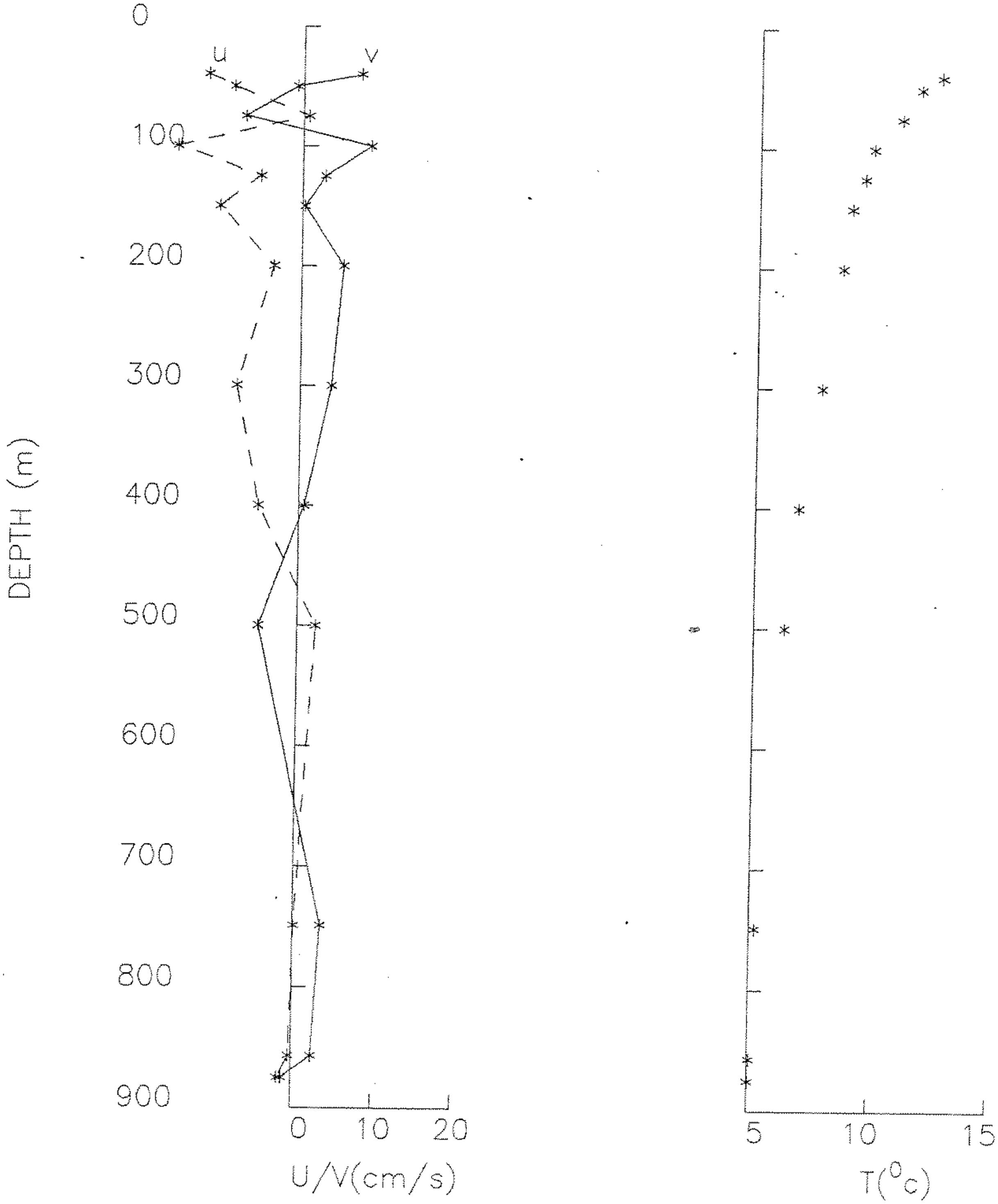
5 MAR 1987 2245 PST

TIME: 65.28125
GMT 1987



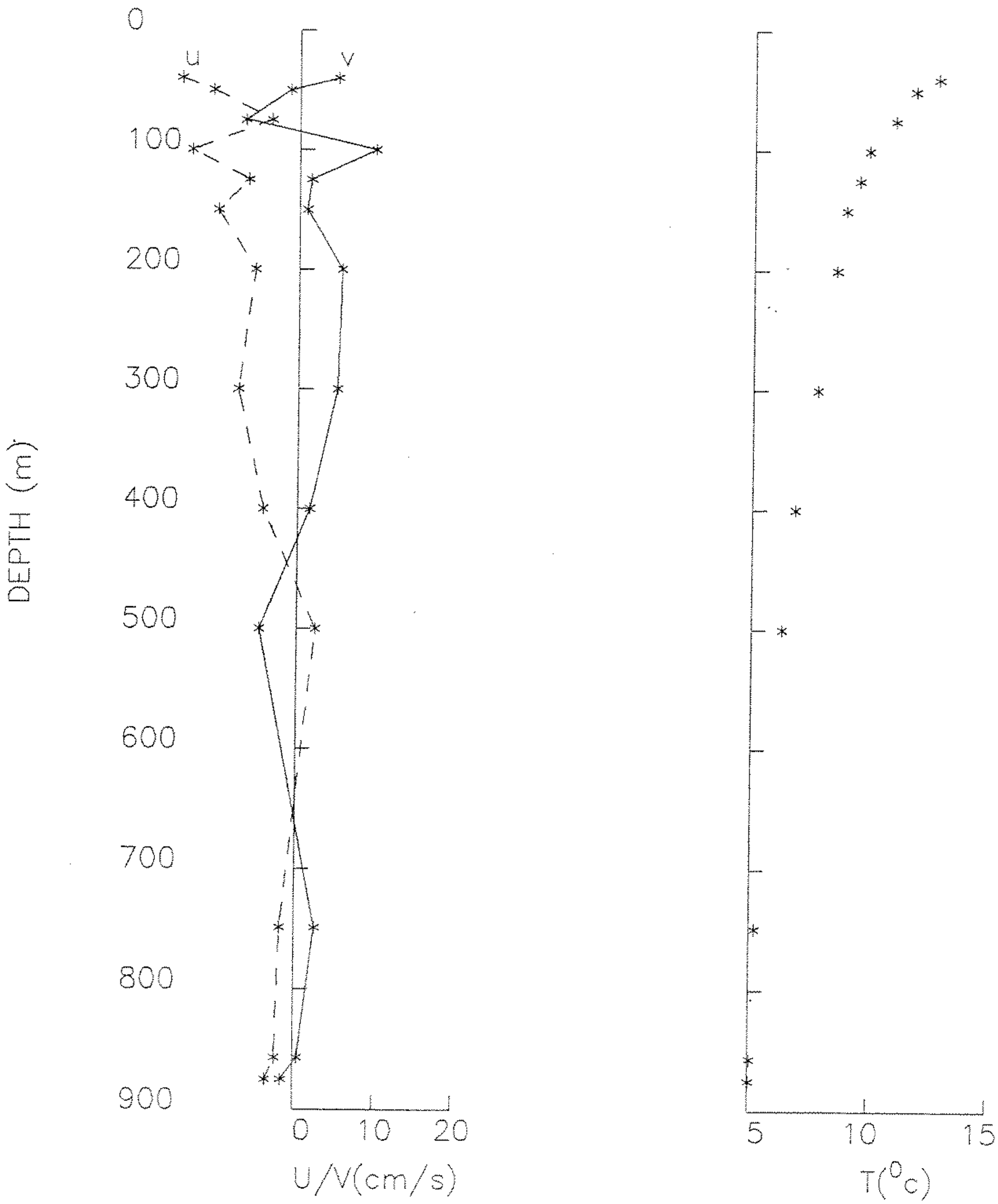
5 MAR 1987 2300 PST

TIME: 65.29167
GMT 1987



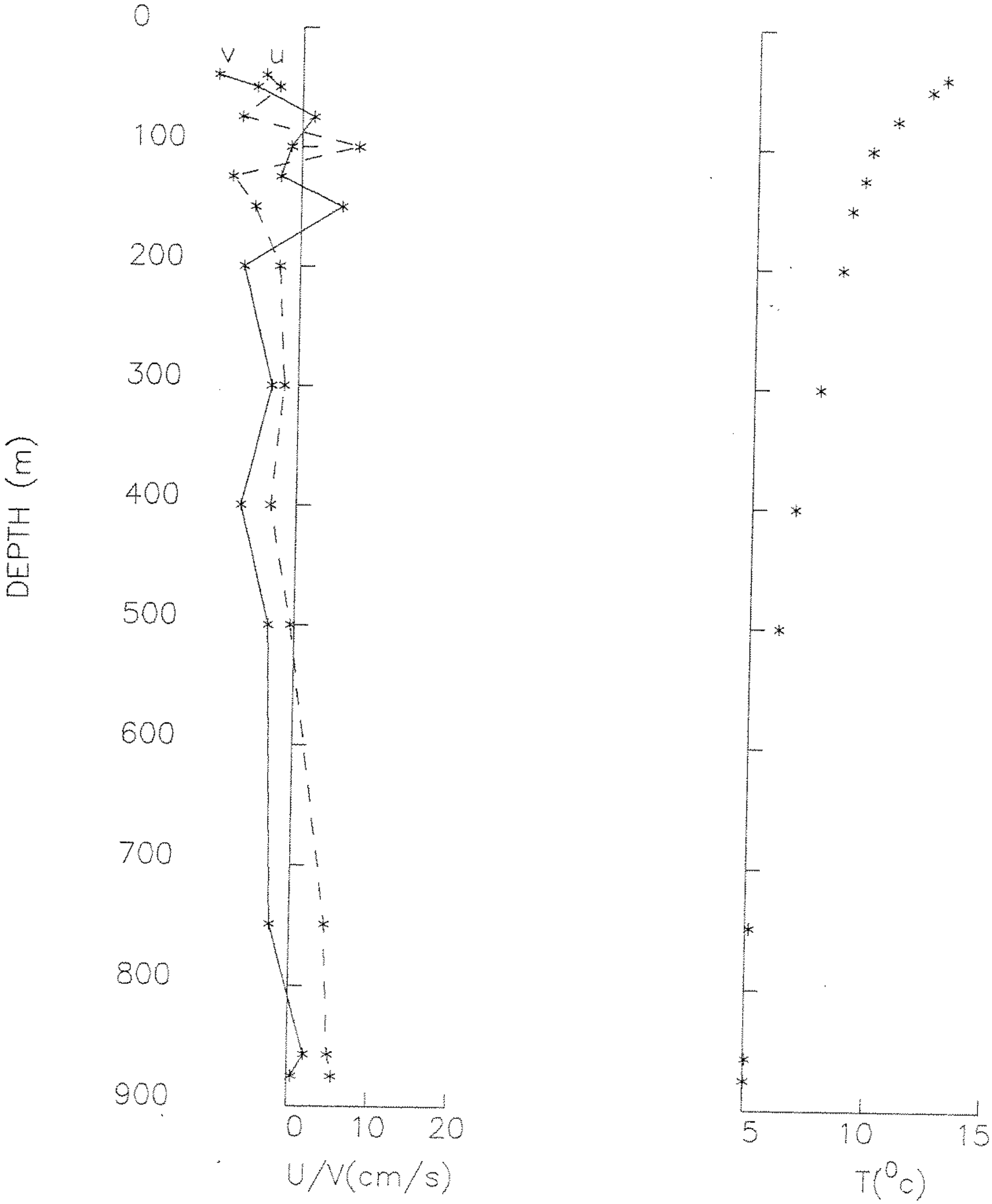
5 MAR 1987 2315 PST

TIME: 65.30209
GMT 1987



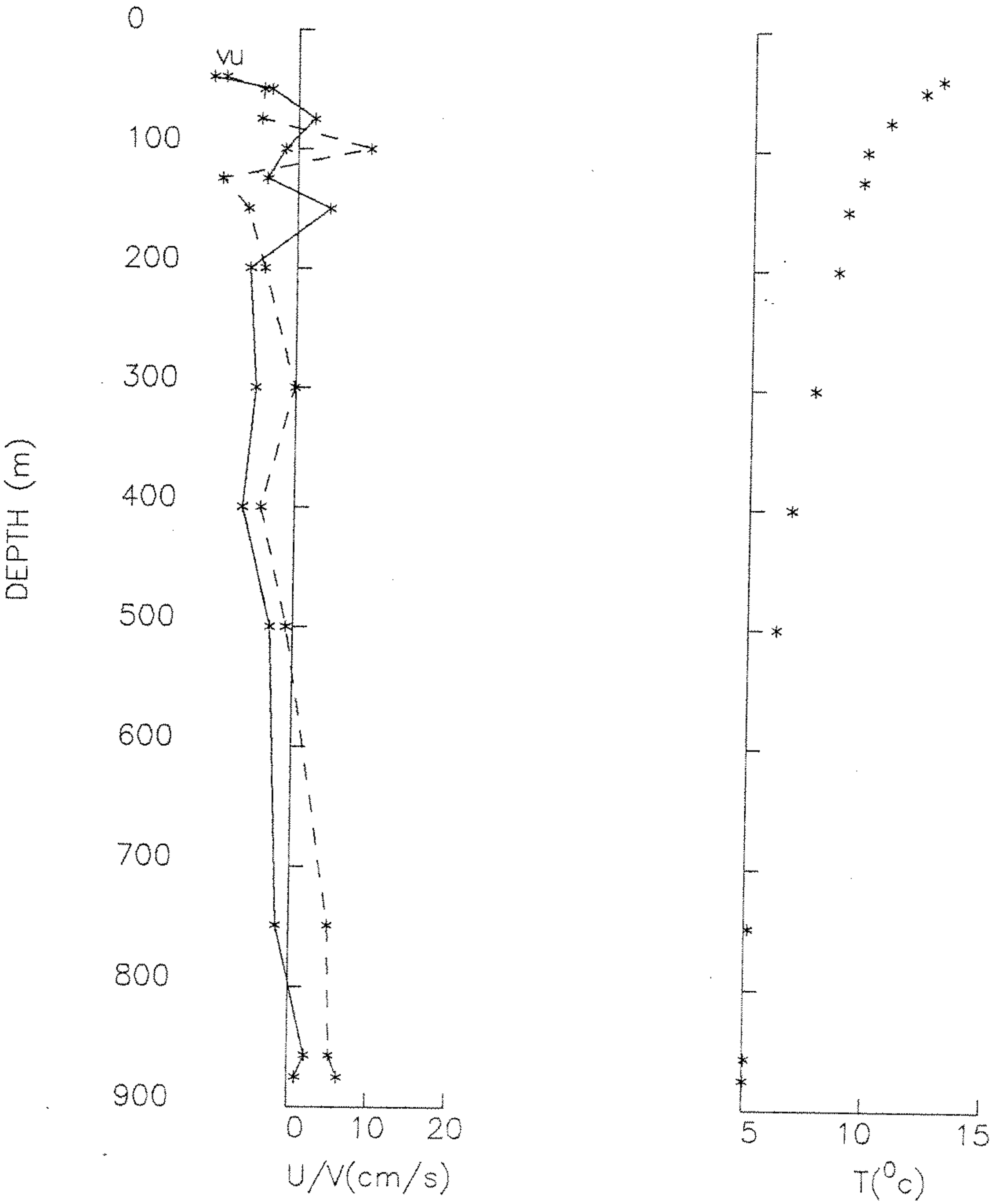
6 MAR 1987 0915 PST

TIME: 65.71876
GMT 1987



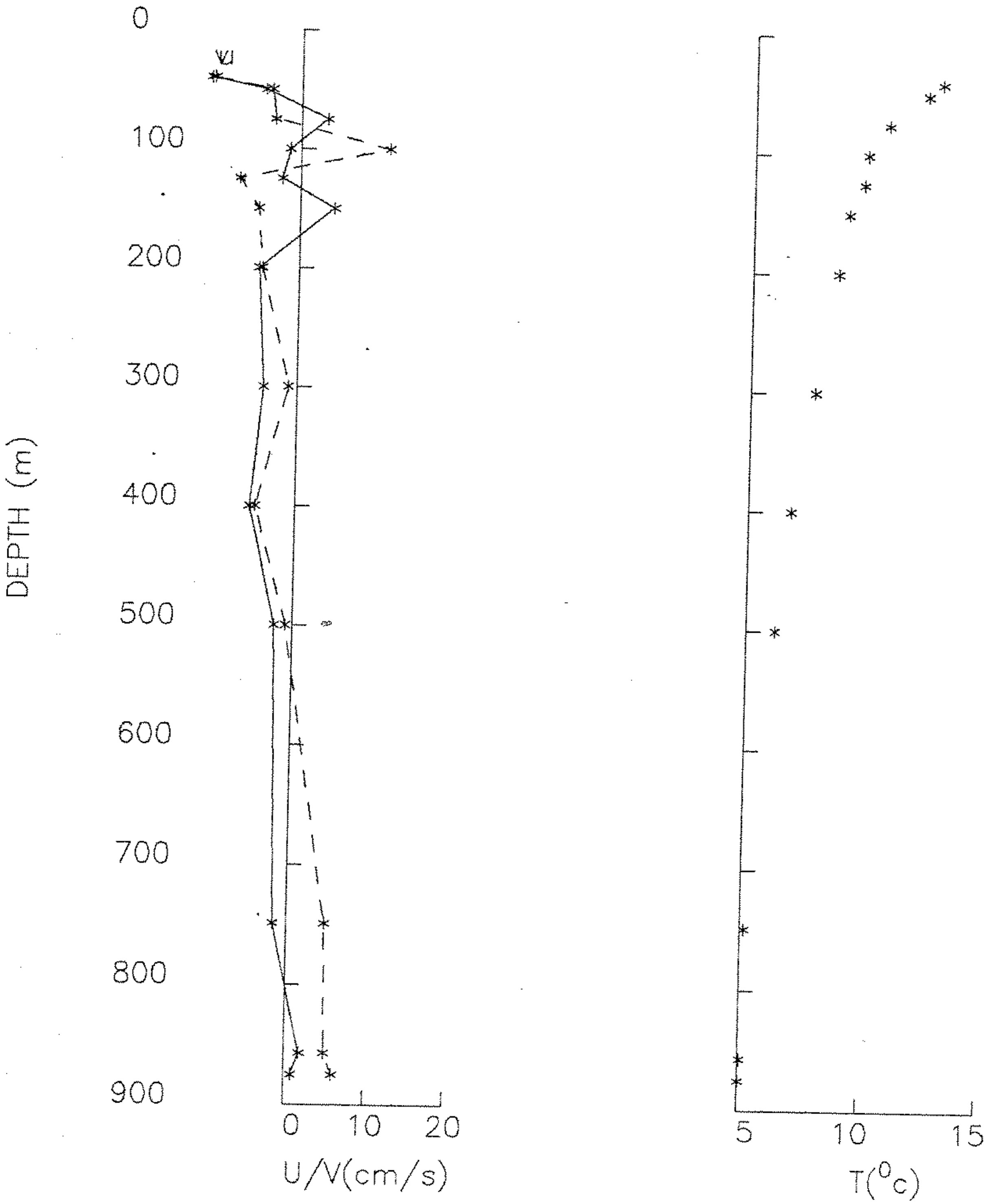
6 MAR 1987 0930 PST

TIME: 65.72917
GMT 1987



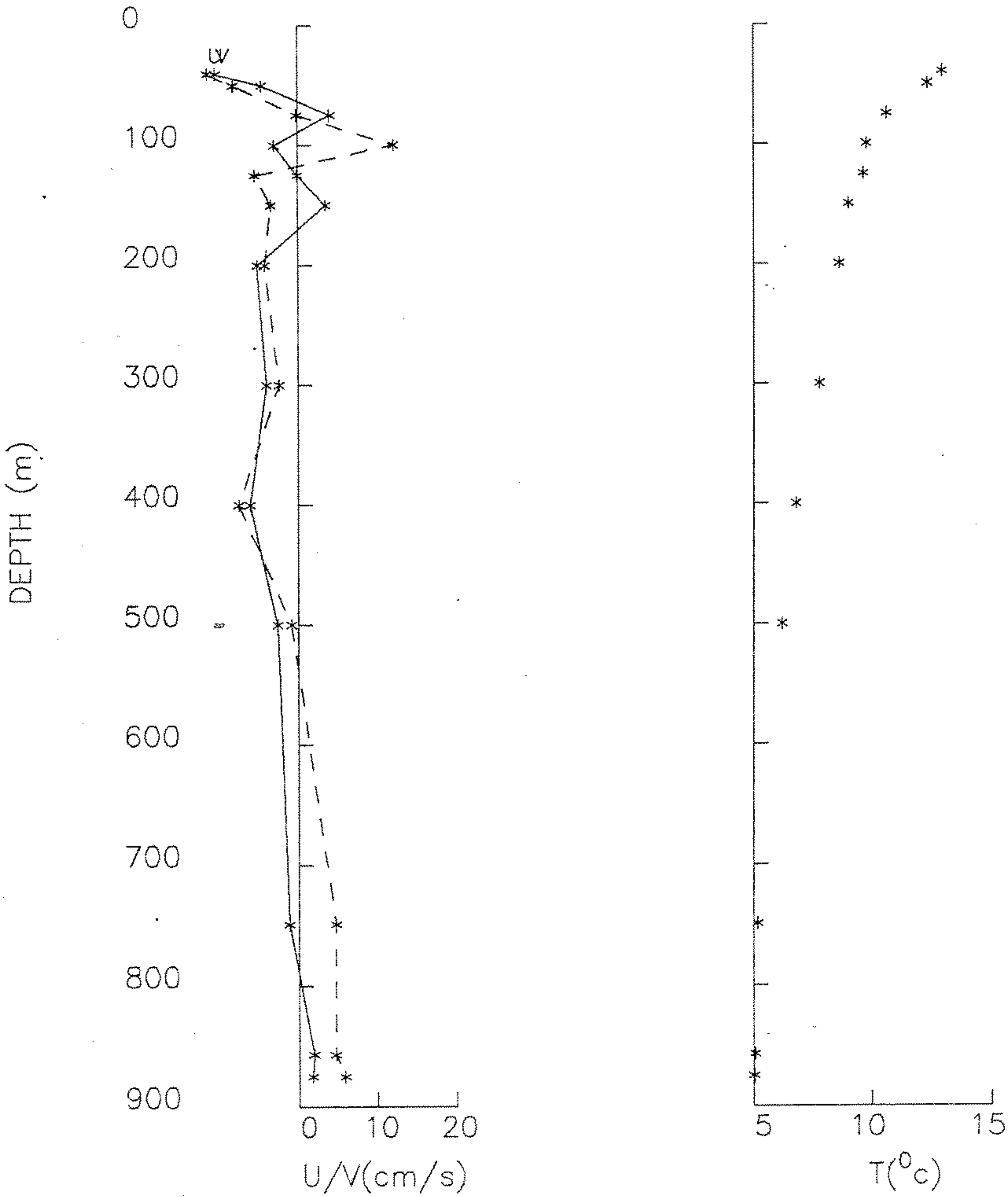
6 MAR 1987 0945 PST

TIME: 65.73959
GMT 1987



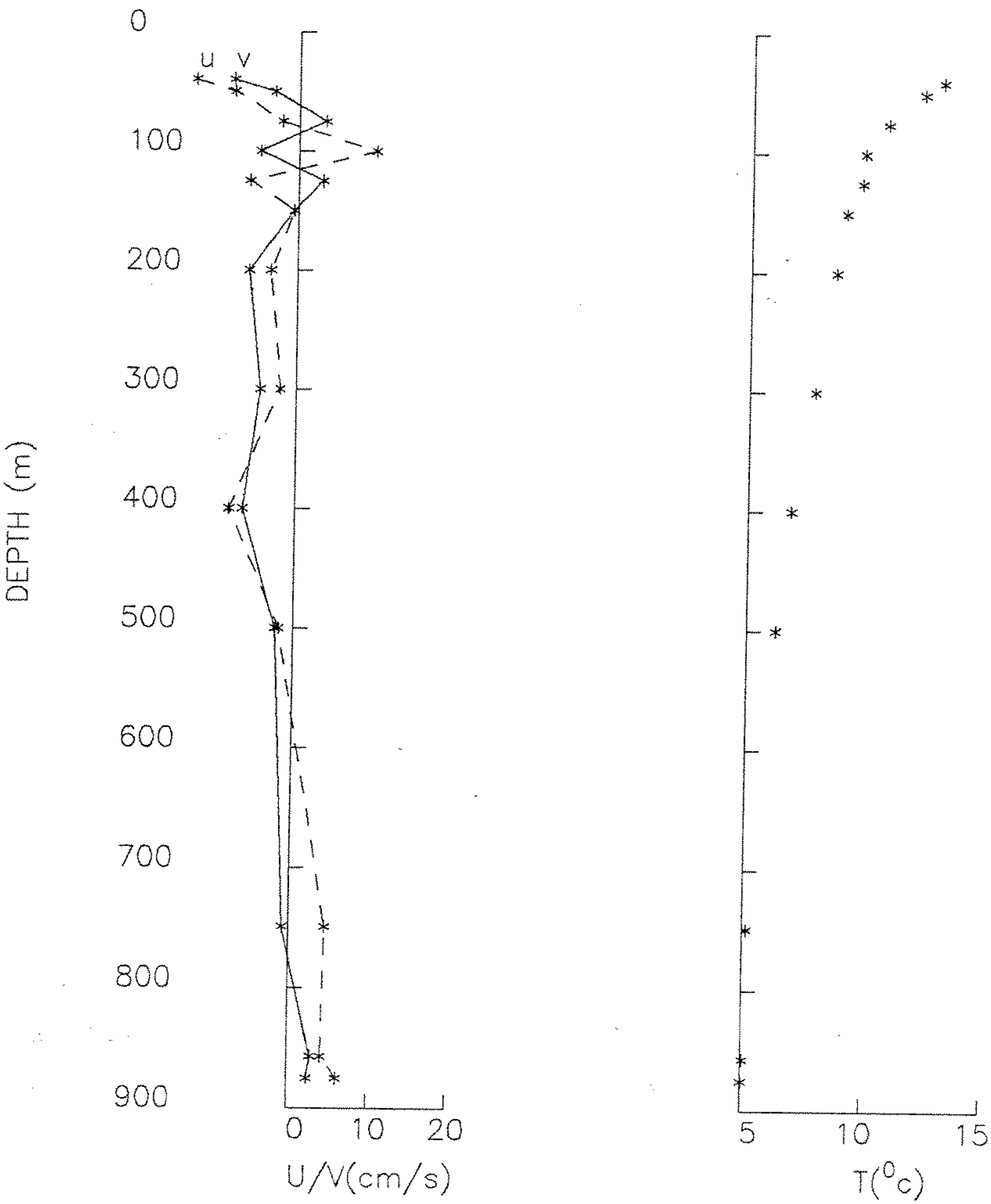
6 MAR 1987 1000 PST

TIME: 65.75001
GMT 1987



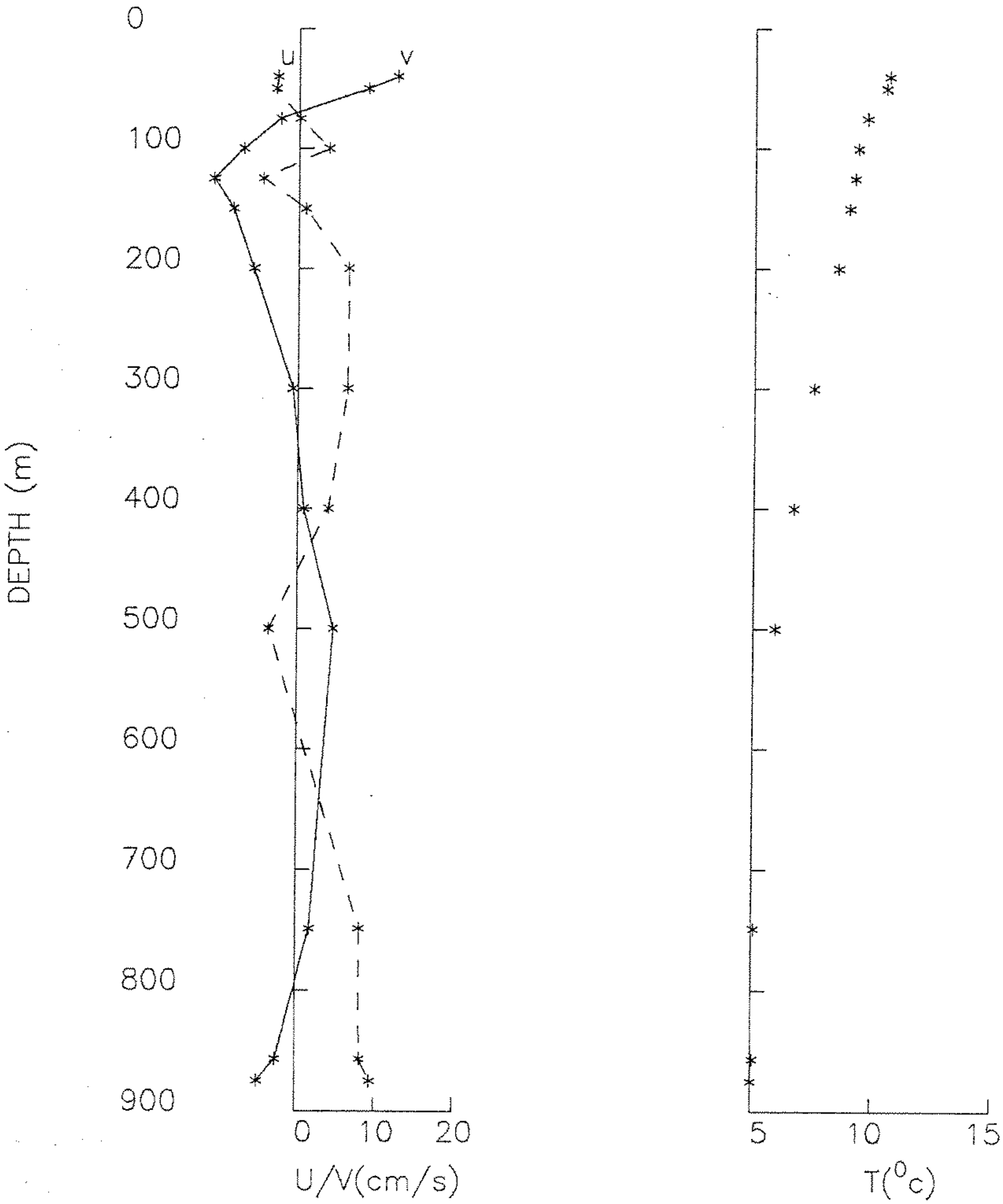
6 MAR 1987 1015 PST

TIME: 65.76042
GMT 1987



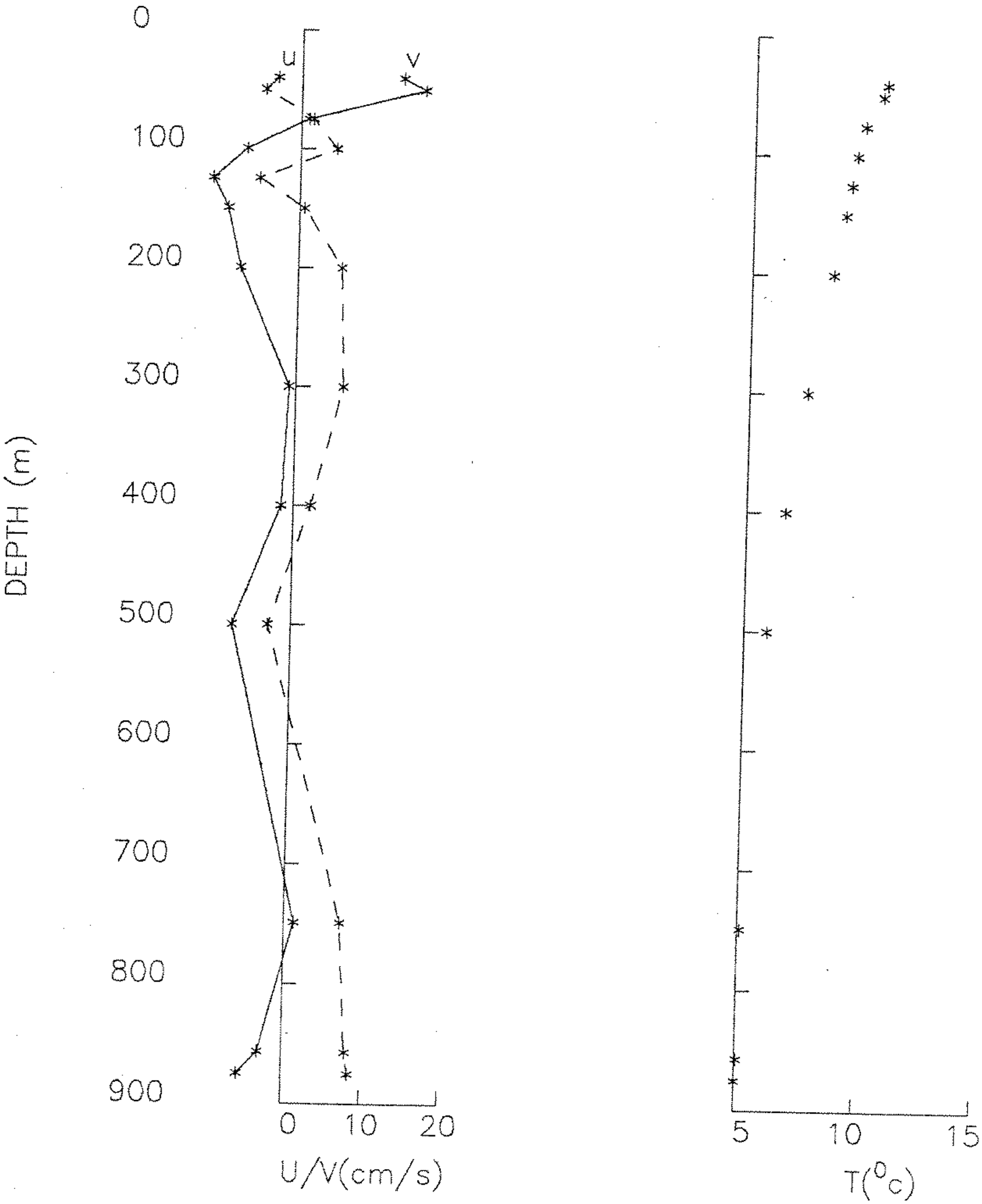
3 APR 1987 0915 PST

TIME: 93.71875
GMT 1987



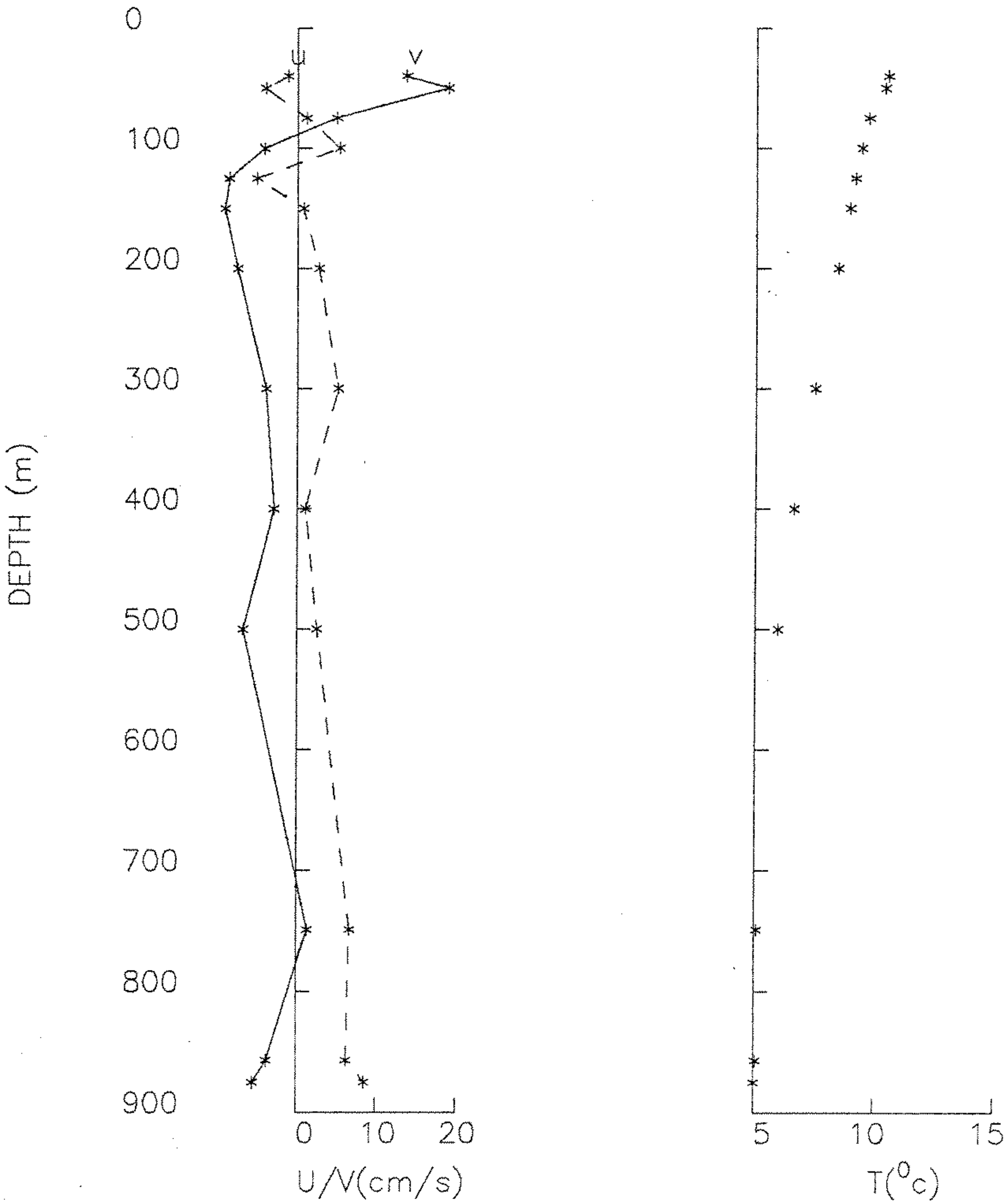
3 APR 1987 0930 PST

TIME: 93.72917
GMT 1987



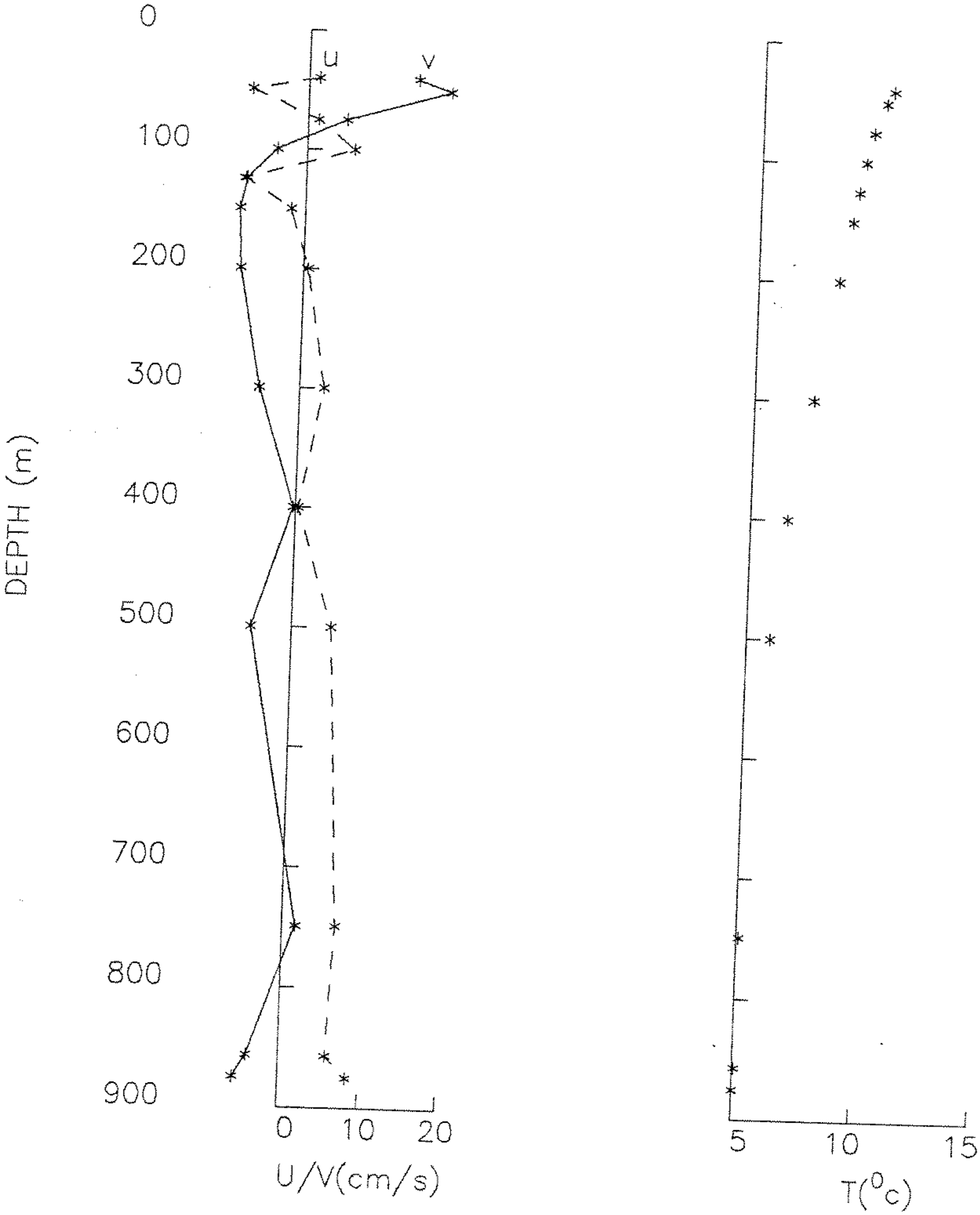
3 APR 1987 0945 PST

TIME: 93.73959
GMT 1987



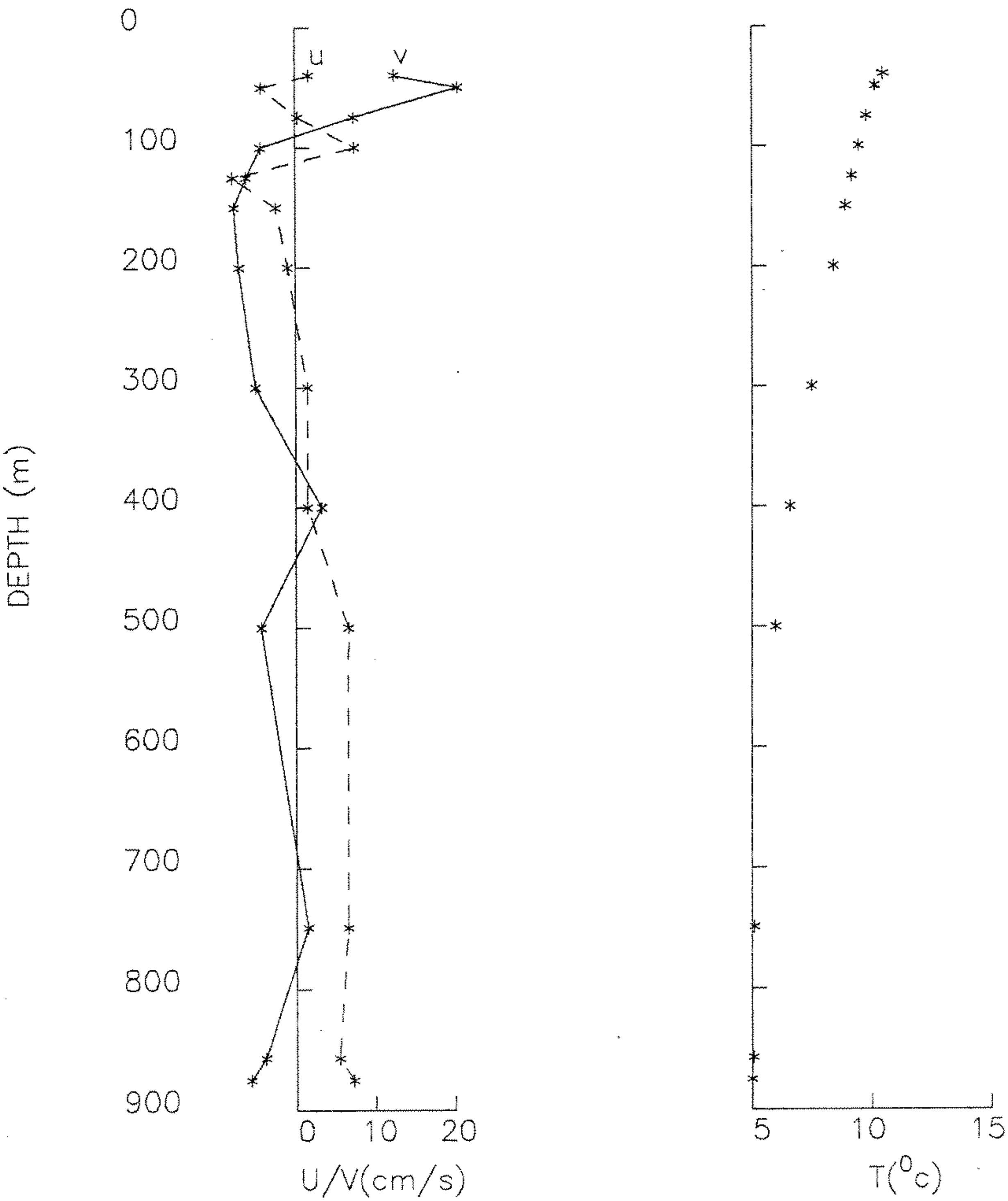
3 APR 1987 1000 PST

TIME: 93.75000
GMT 1987



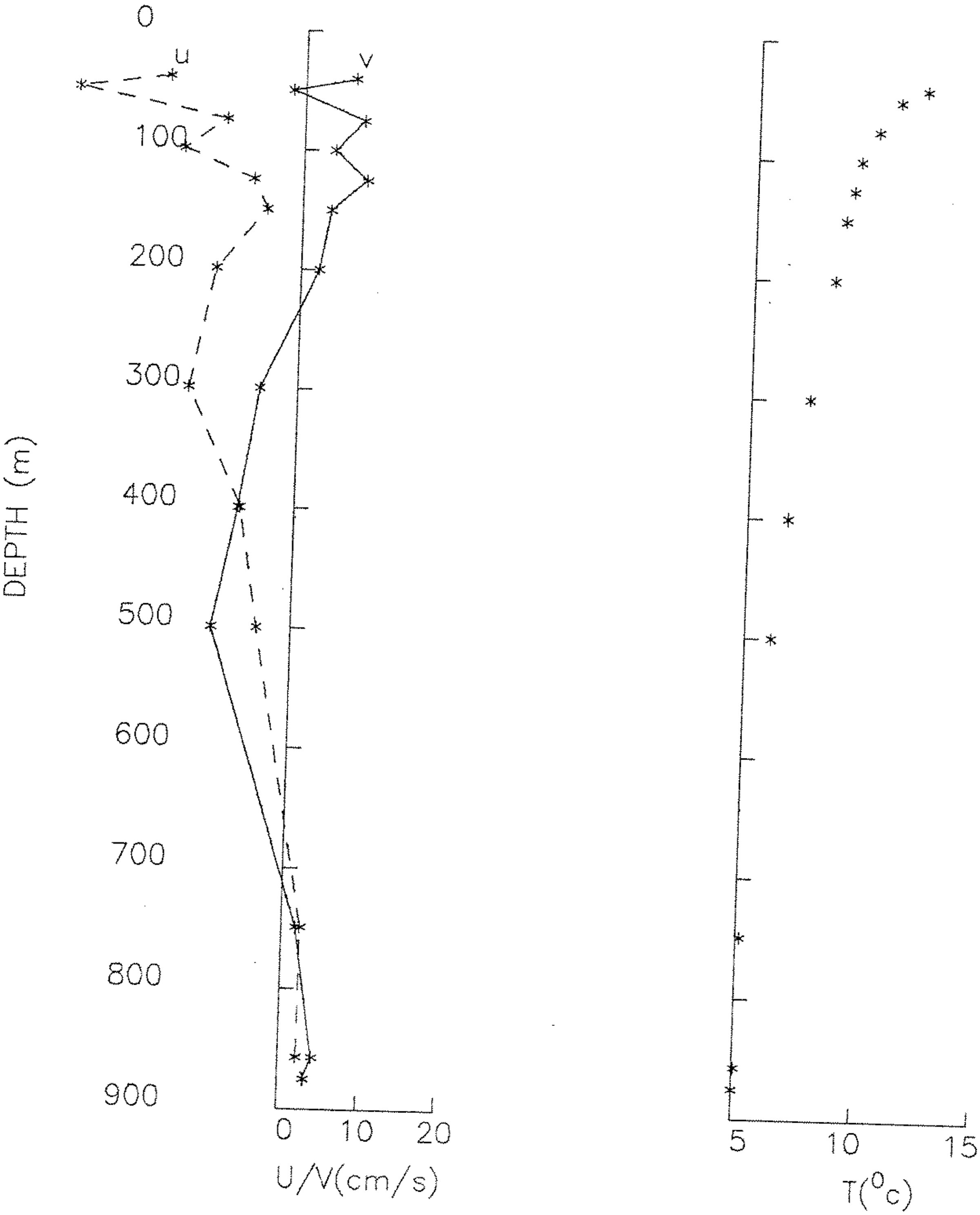
3 APR 1987 1015 PST

TIME: 93.76042
GMT 1987



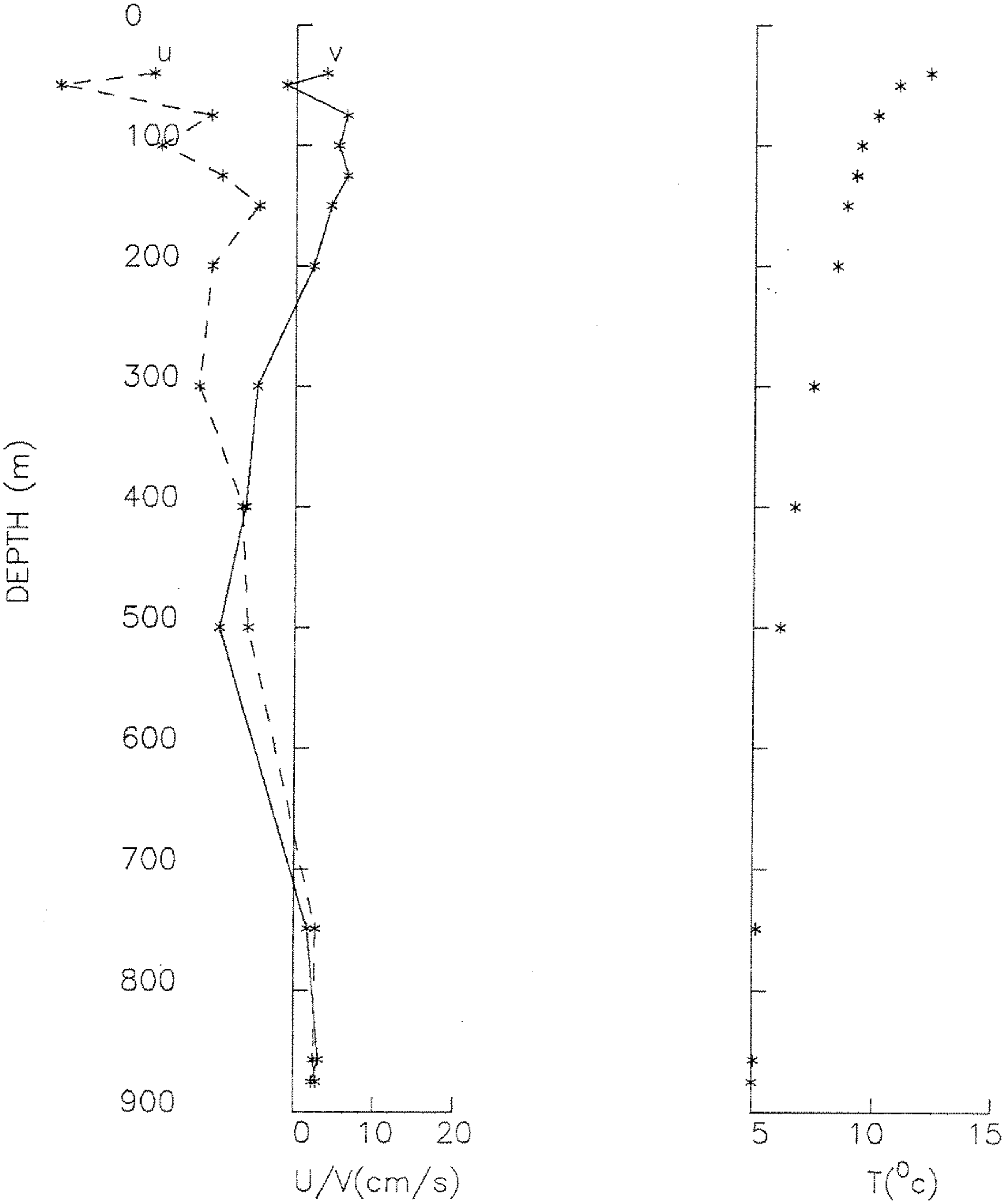
25 MAY 1987 0915 PST

TIME:145.67708
GMT 1987



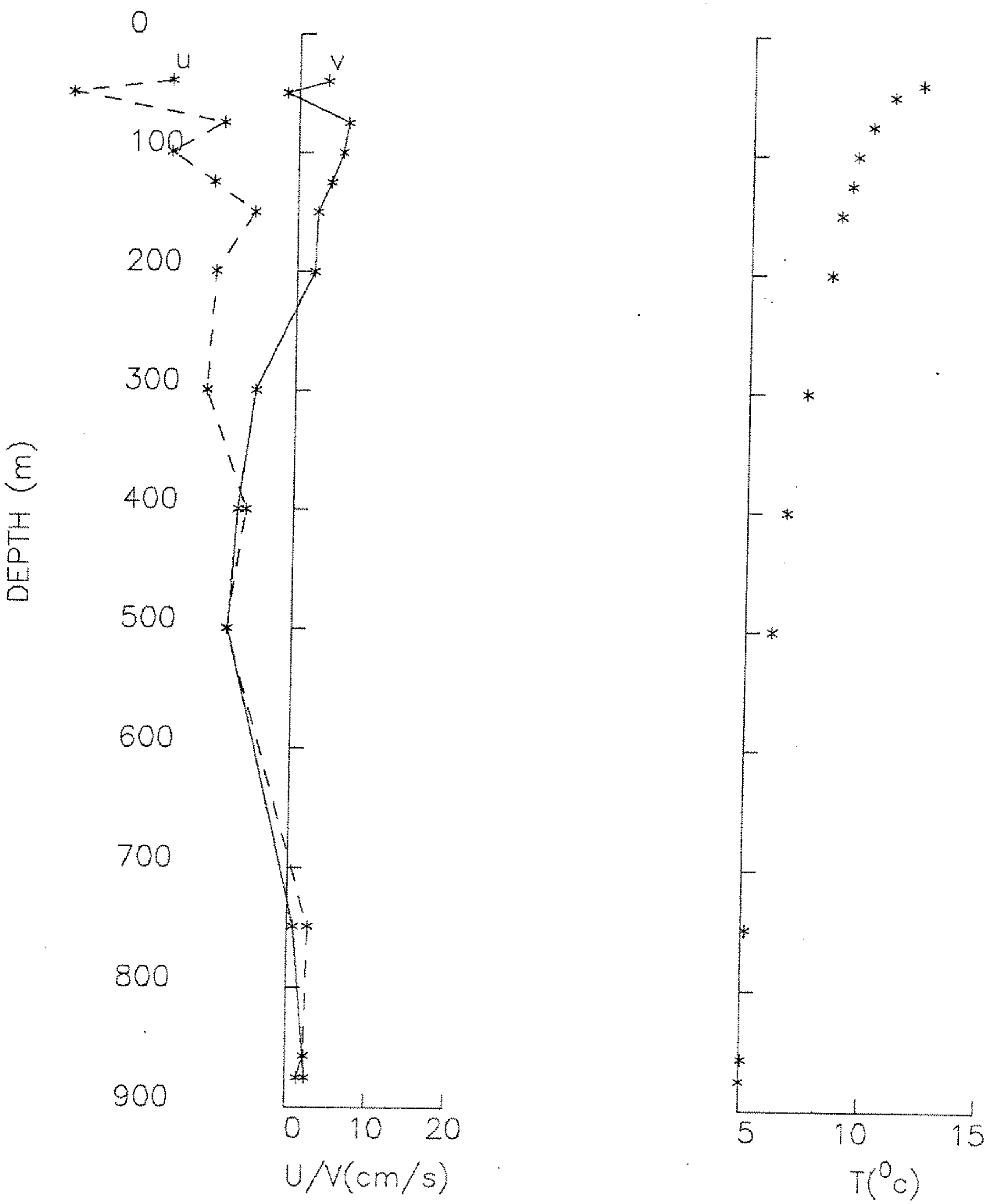
25 MAY 1987 0930 PST

TIME:145.68750
GMT 1987



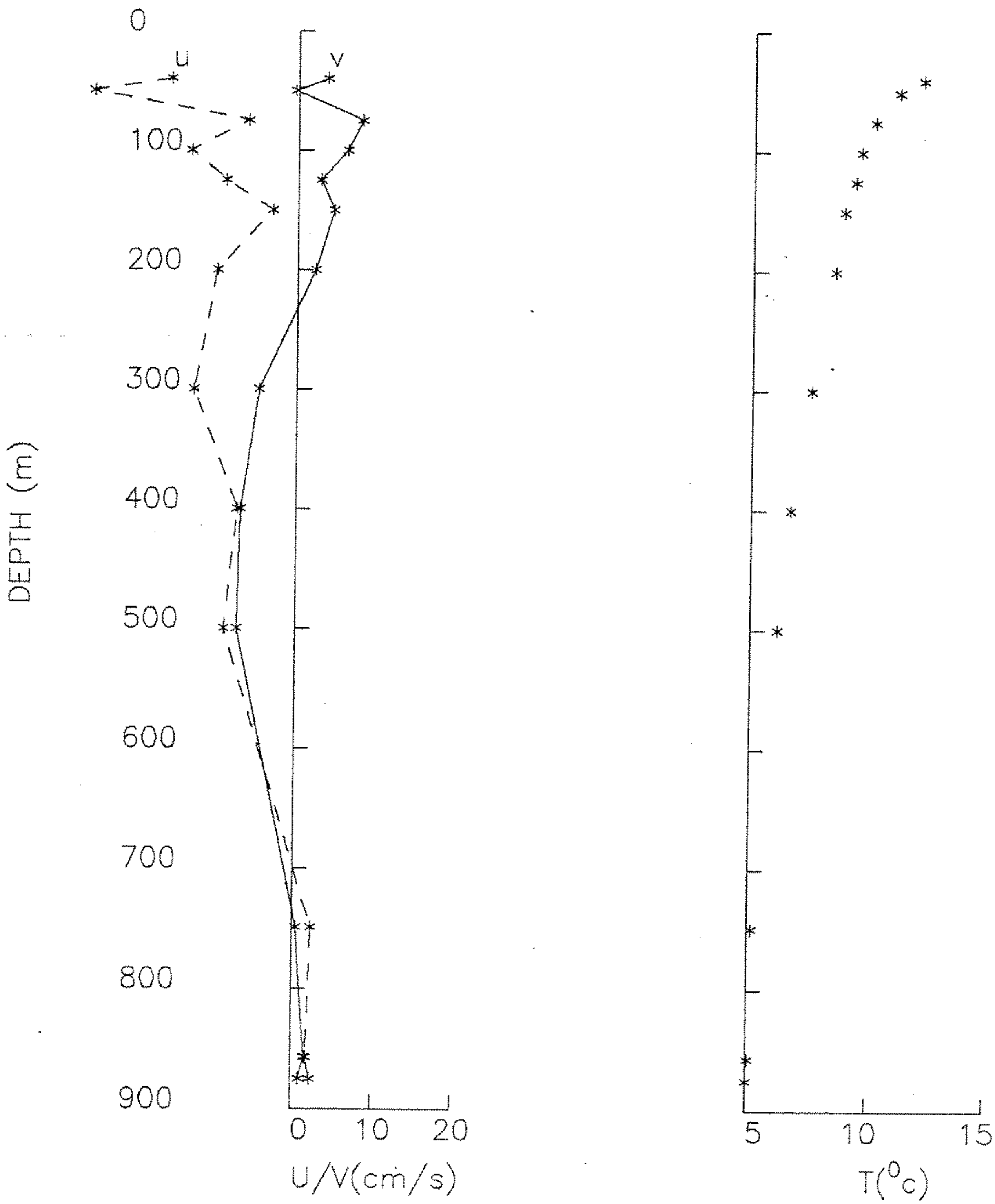
25 MAY 1987 0945 PST

TIME:145.69791
GMT 1987



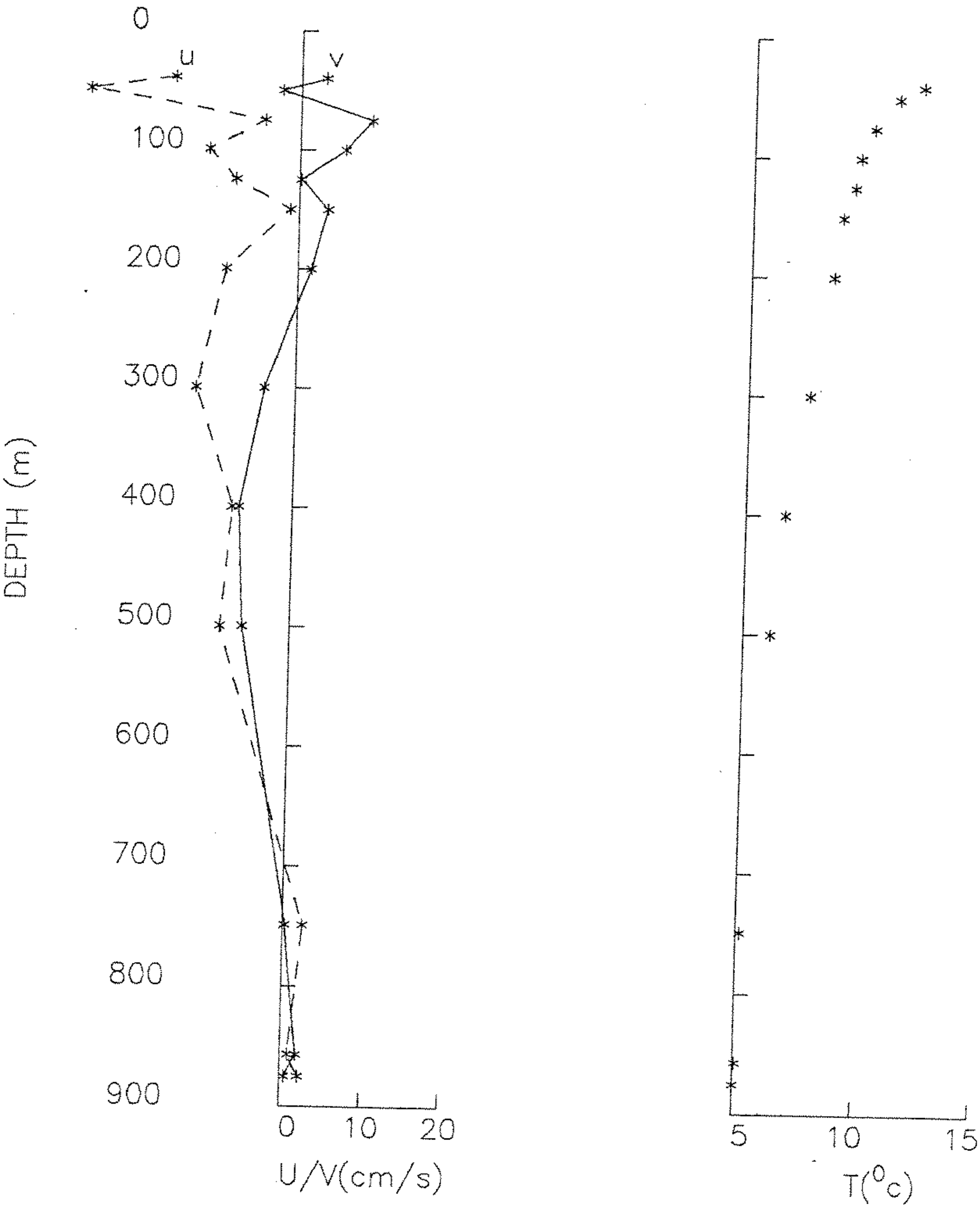
25 MAY 1987 1000 PST

TIME:145.70833
GMT 1987

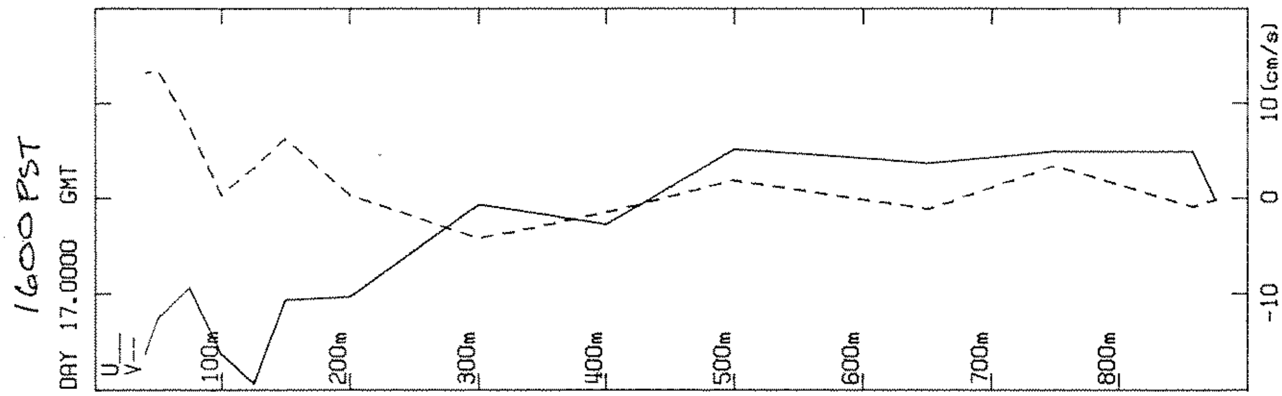


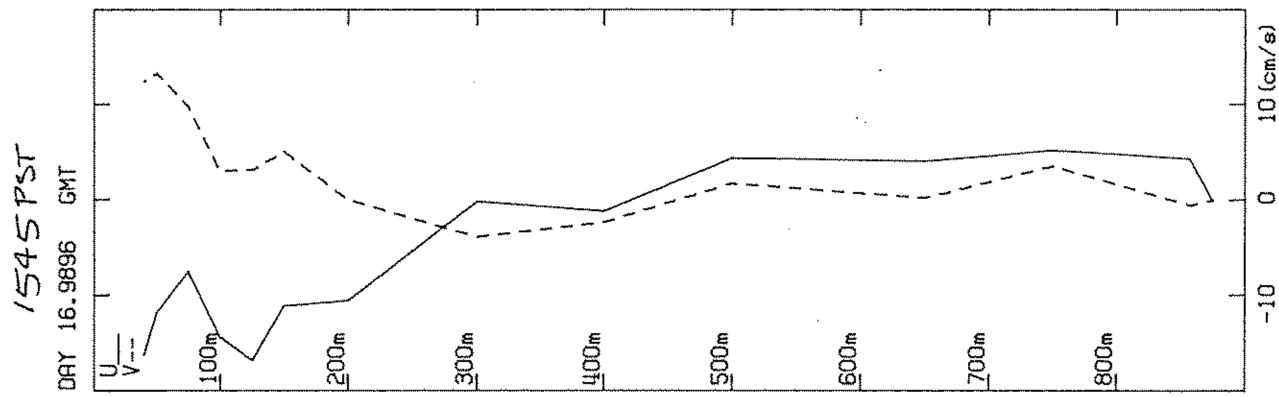
25 MAY 1987 1015 PST

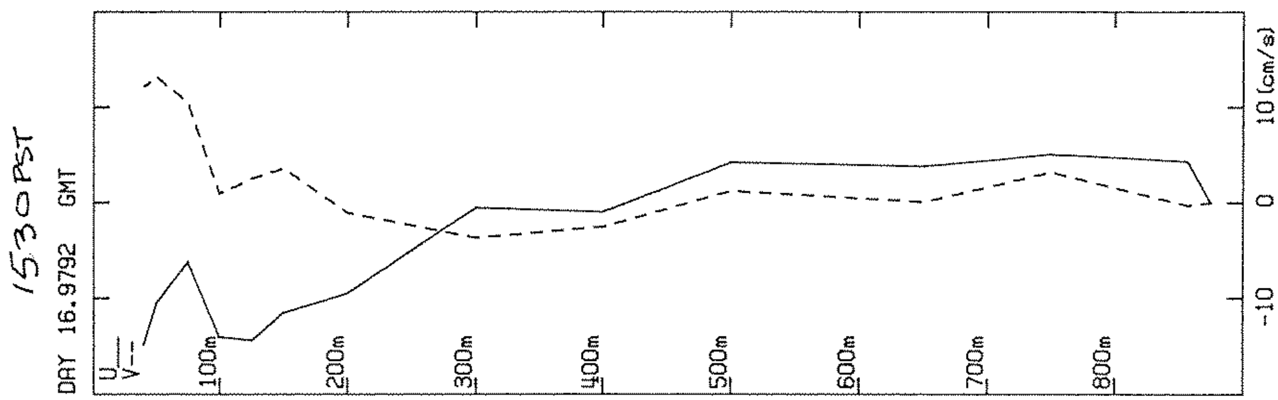
TIME:145.71875
GMT 1987

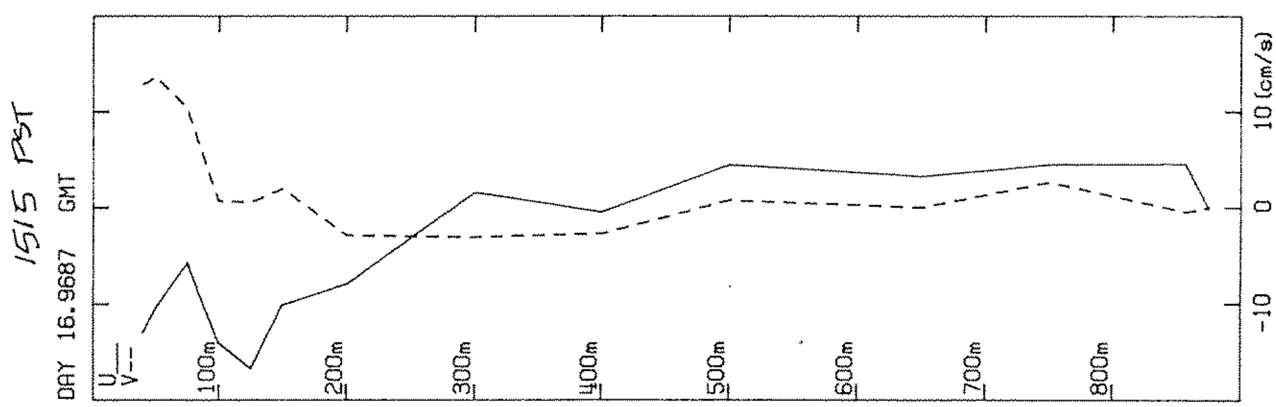


15-MINUTE-AVERAGE U&V PROFILE PLOTS

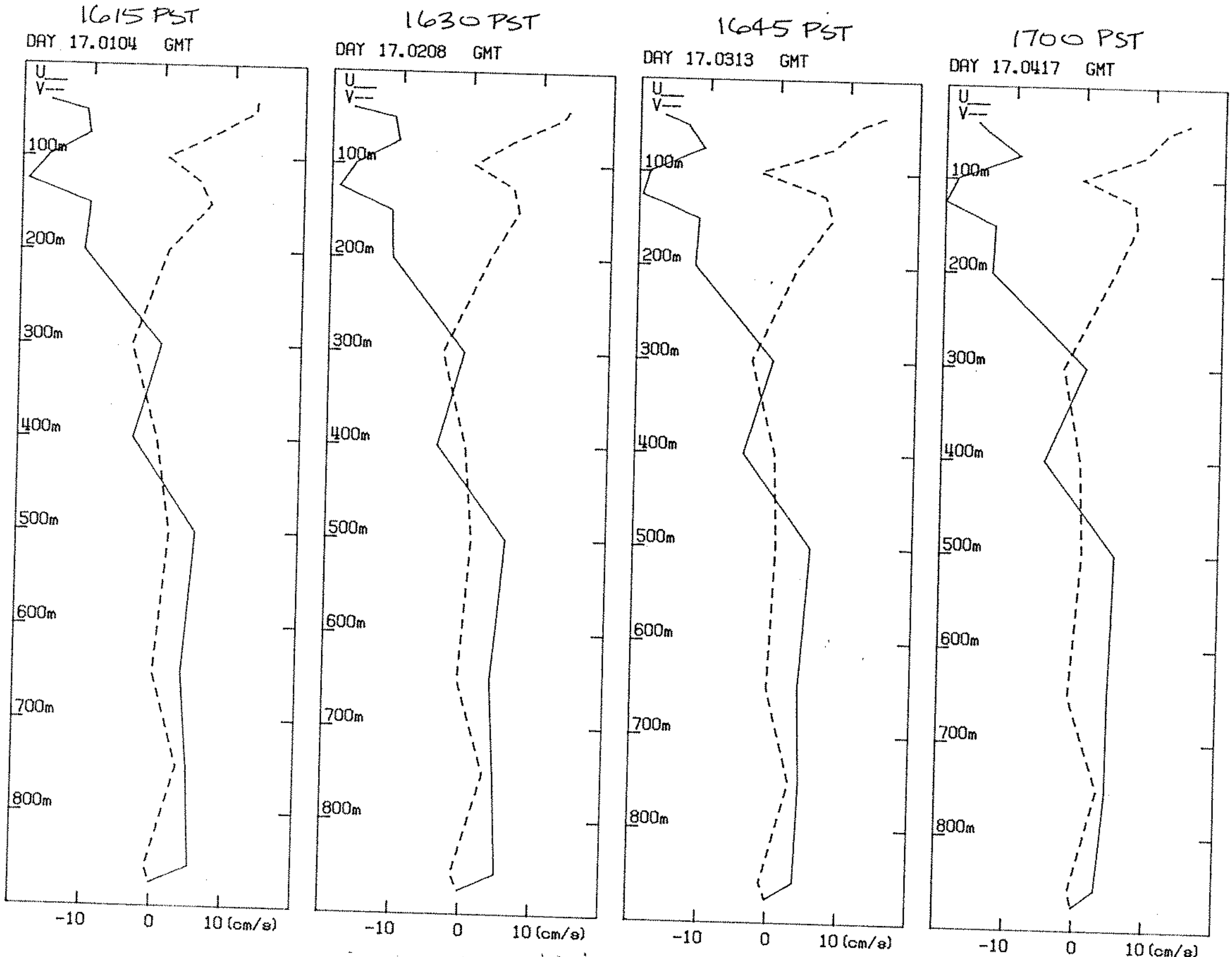








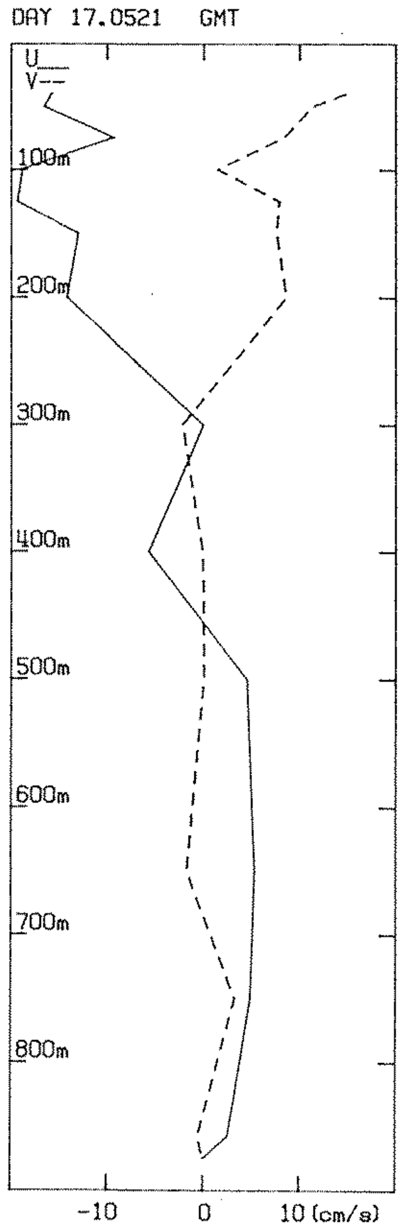
JAN 16 1988



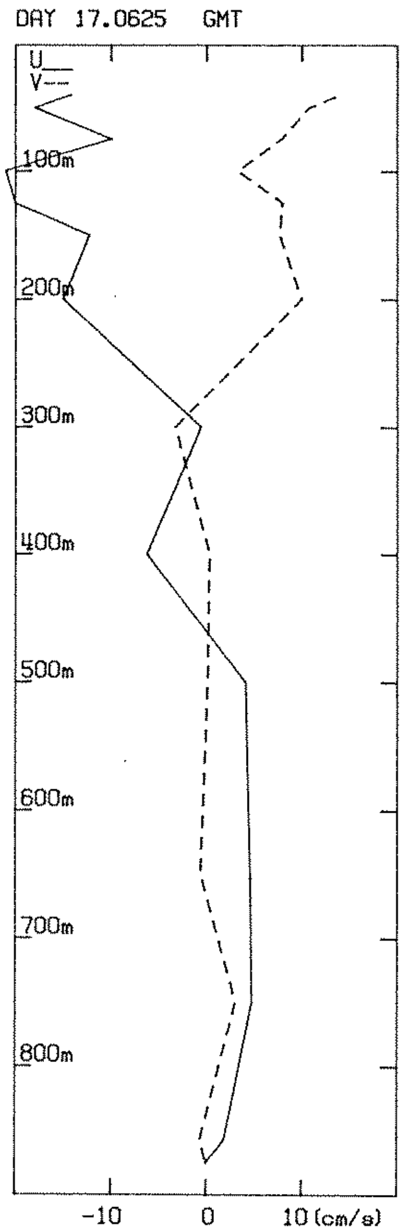
1615 PST
DAY 17.0104 GMT
1630 PST
DAY 17.0208 GMT
1645 PST
DAY 17.0313 GMT
1700 PST
DAY 17.0417 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 16, 1988

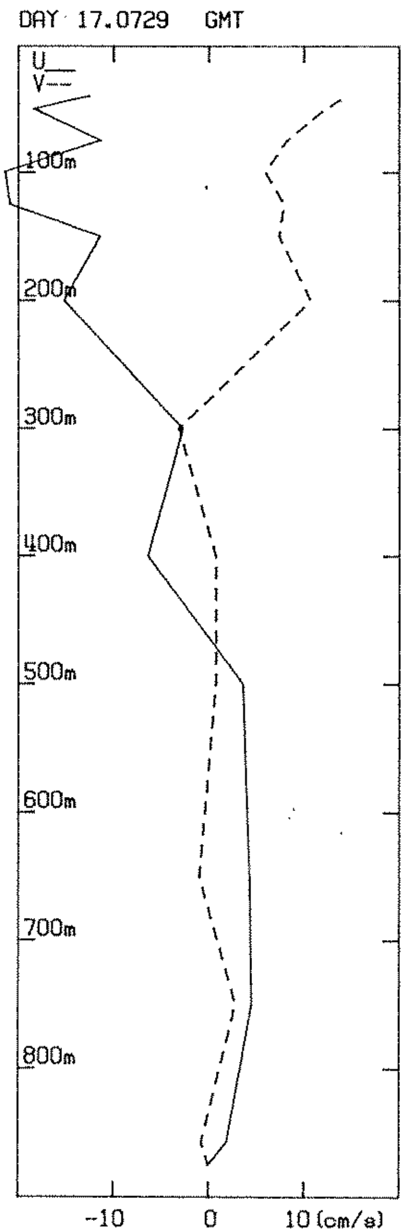
1715 PST



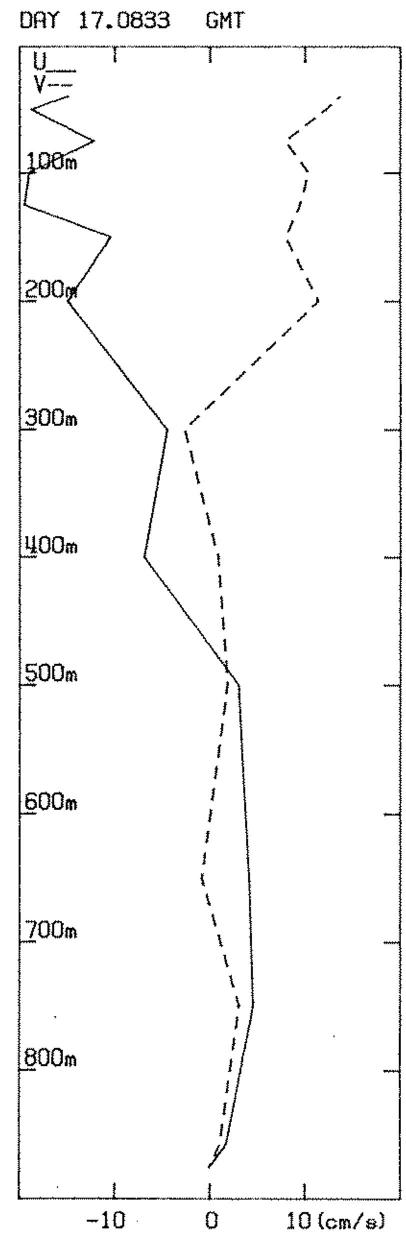
1730 PST



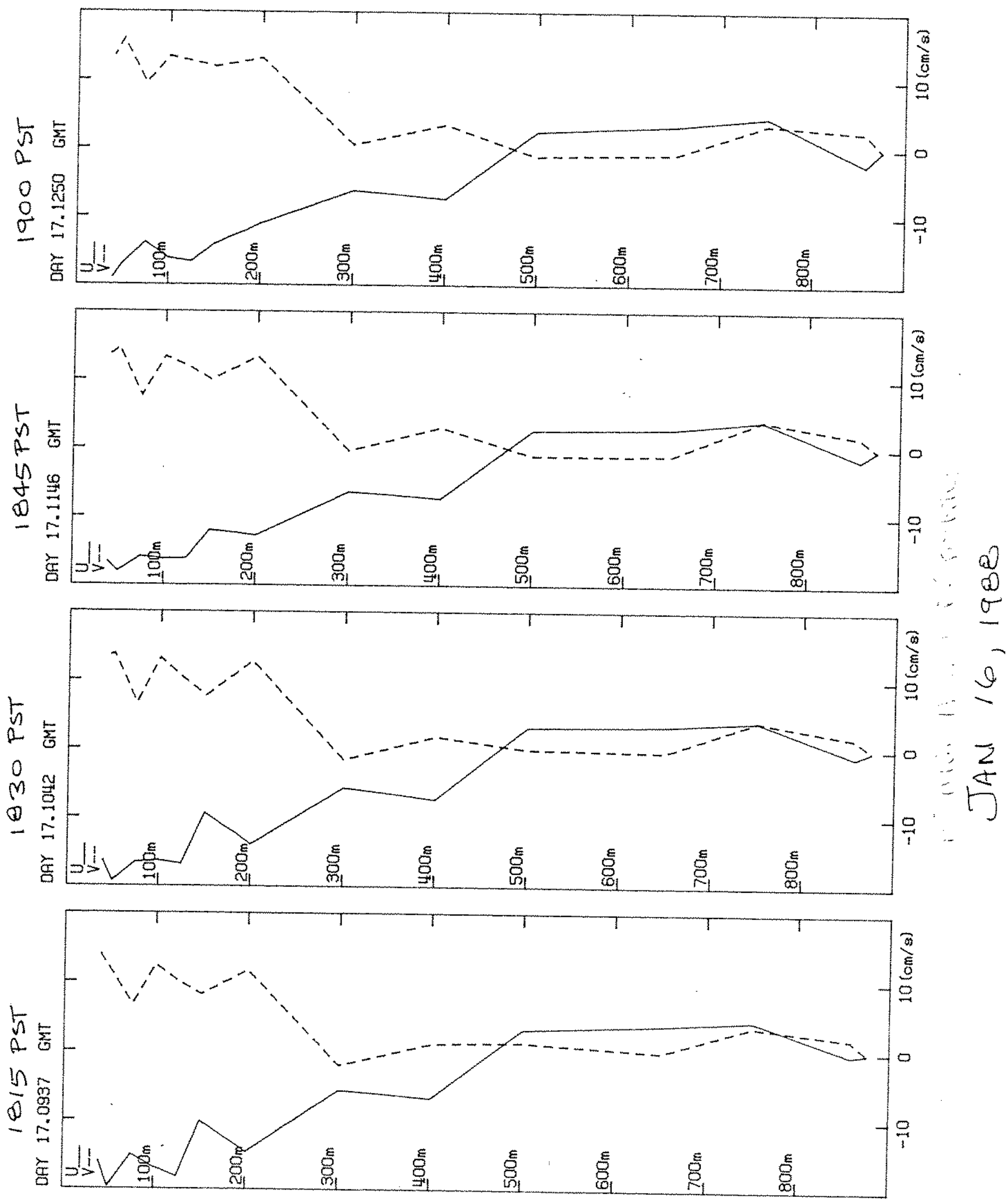
1745 PST

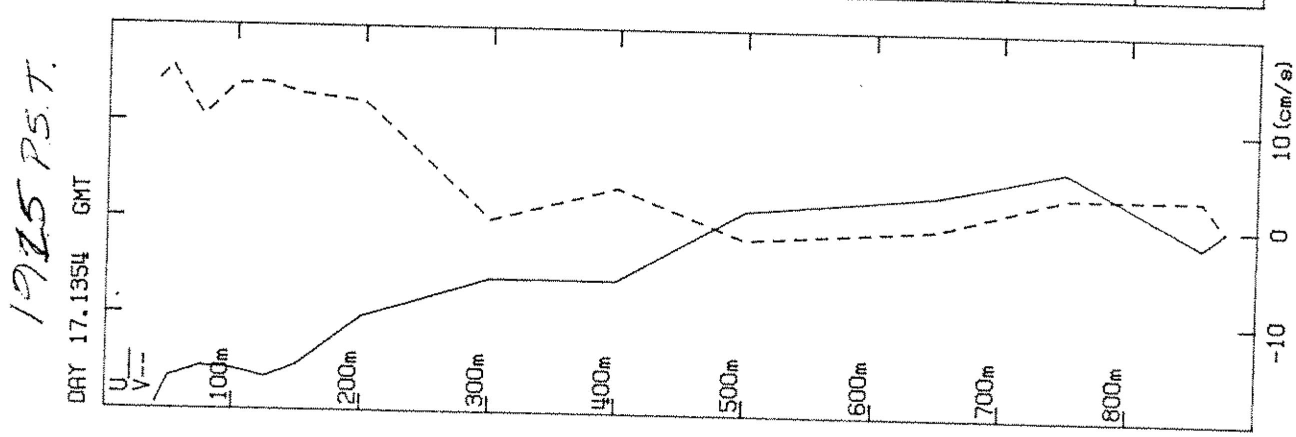


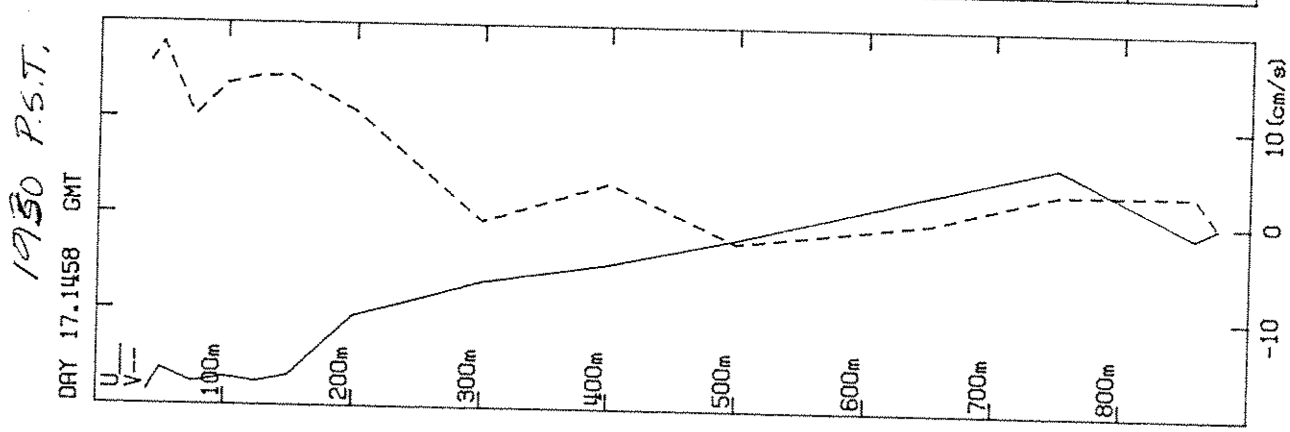
1800 PST

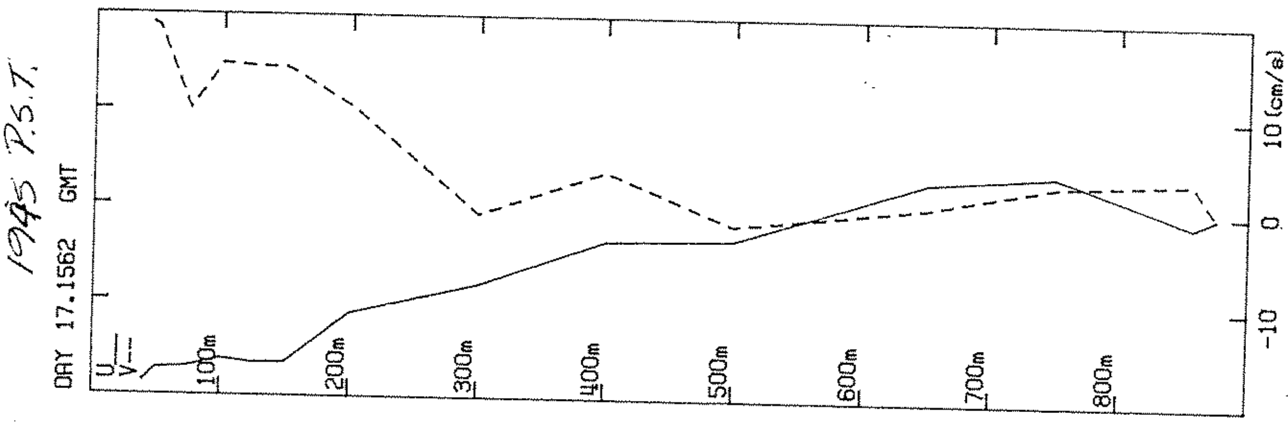


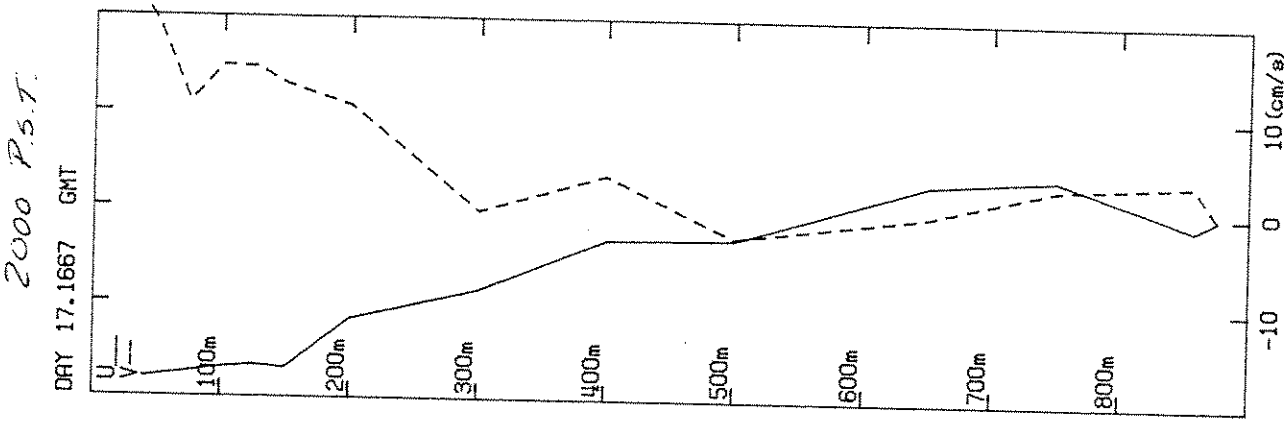
JAN 16, 1988


1900 PST
DAY 17.1250 GMT
1845 PST
DAY 17.1146 GMT
1830 PST
DAY 17.1042 GMT
1815 PST
DAY 17.0937 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10
JAN 16, 1988

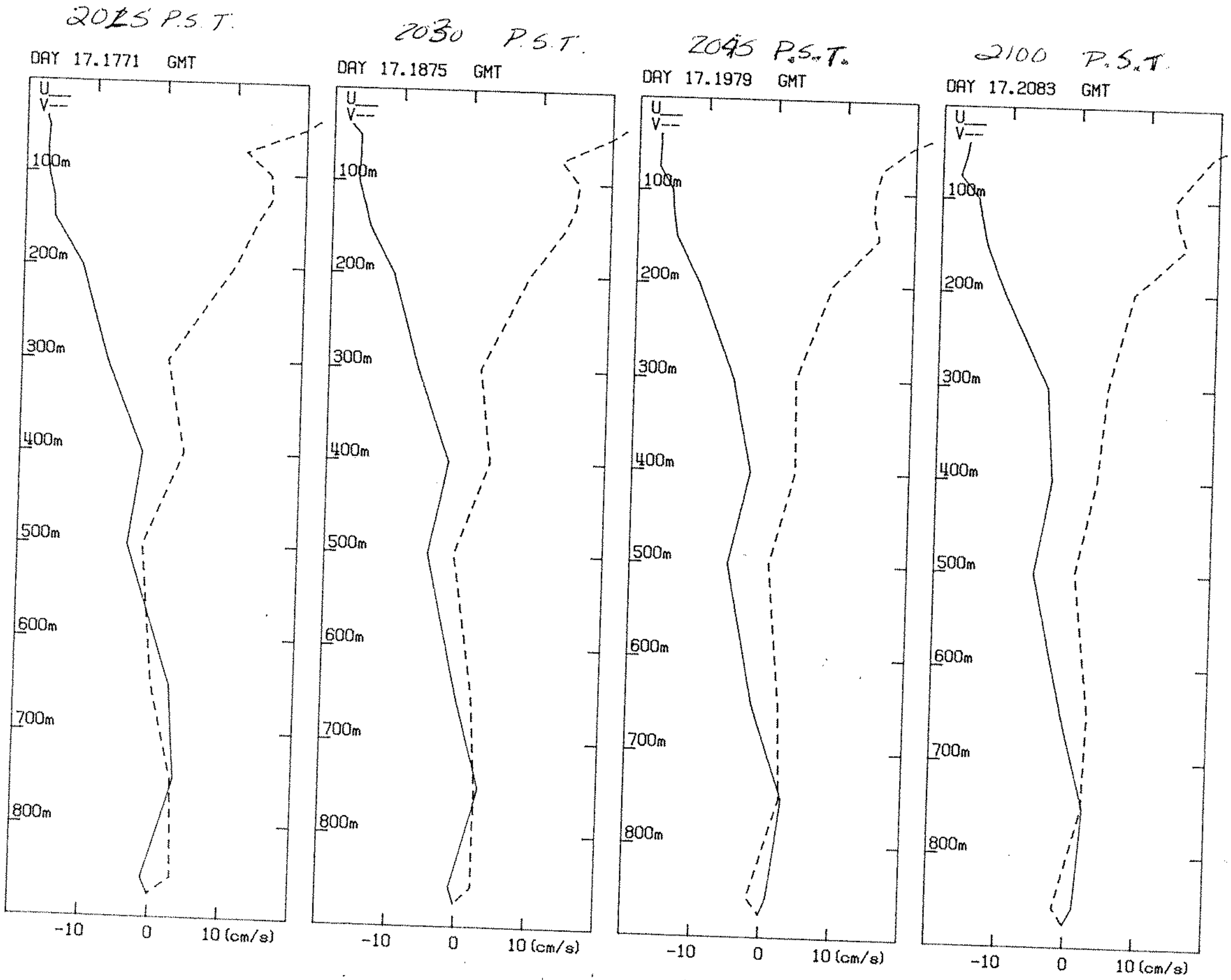

1915 P.S.T.
DAY 17.1354 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


1930 P.S.T.
DAY 17.1458 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

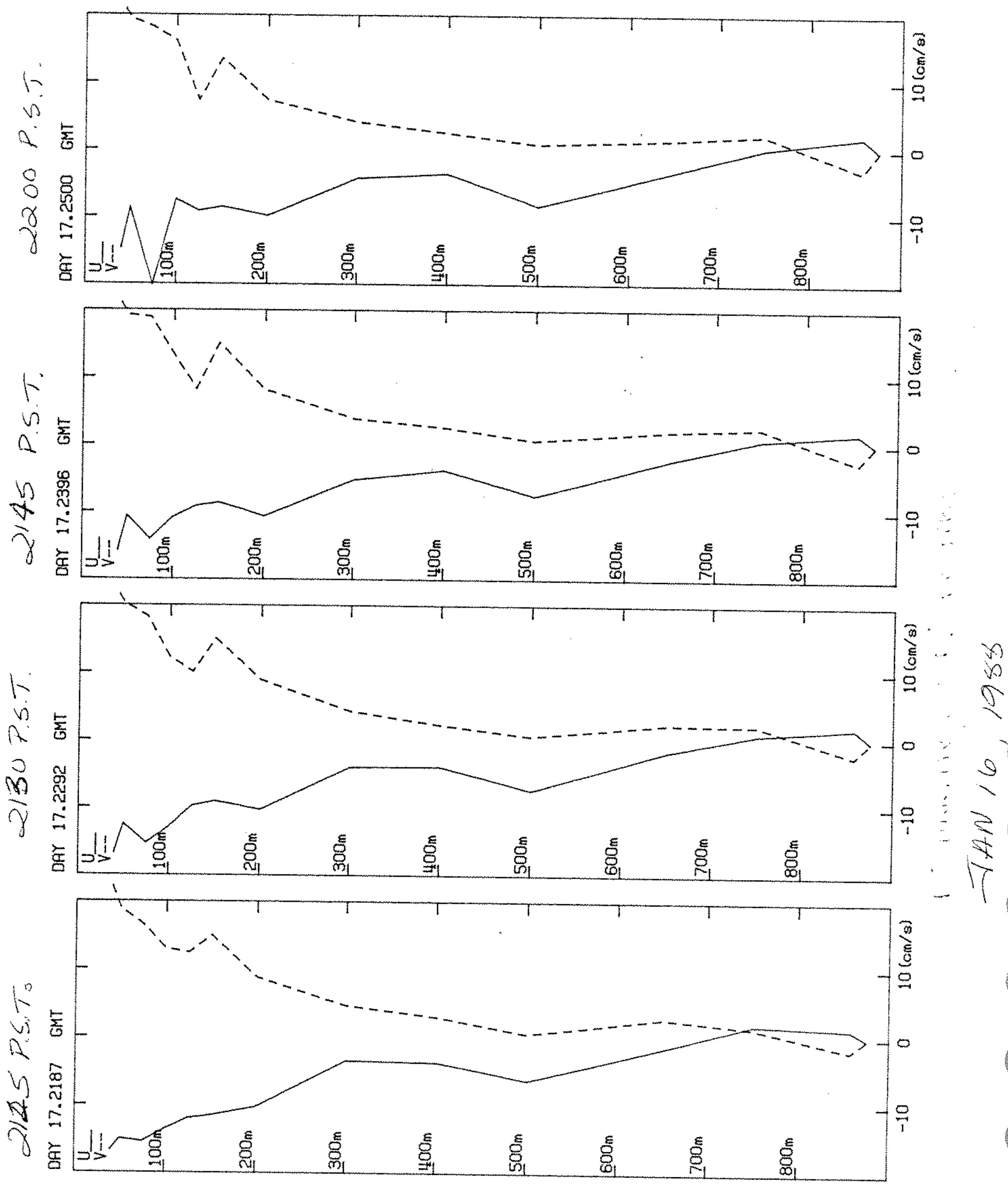

1945 P.S.T.
DAY 17.1562 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

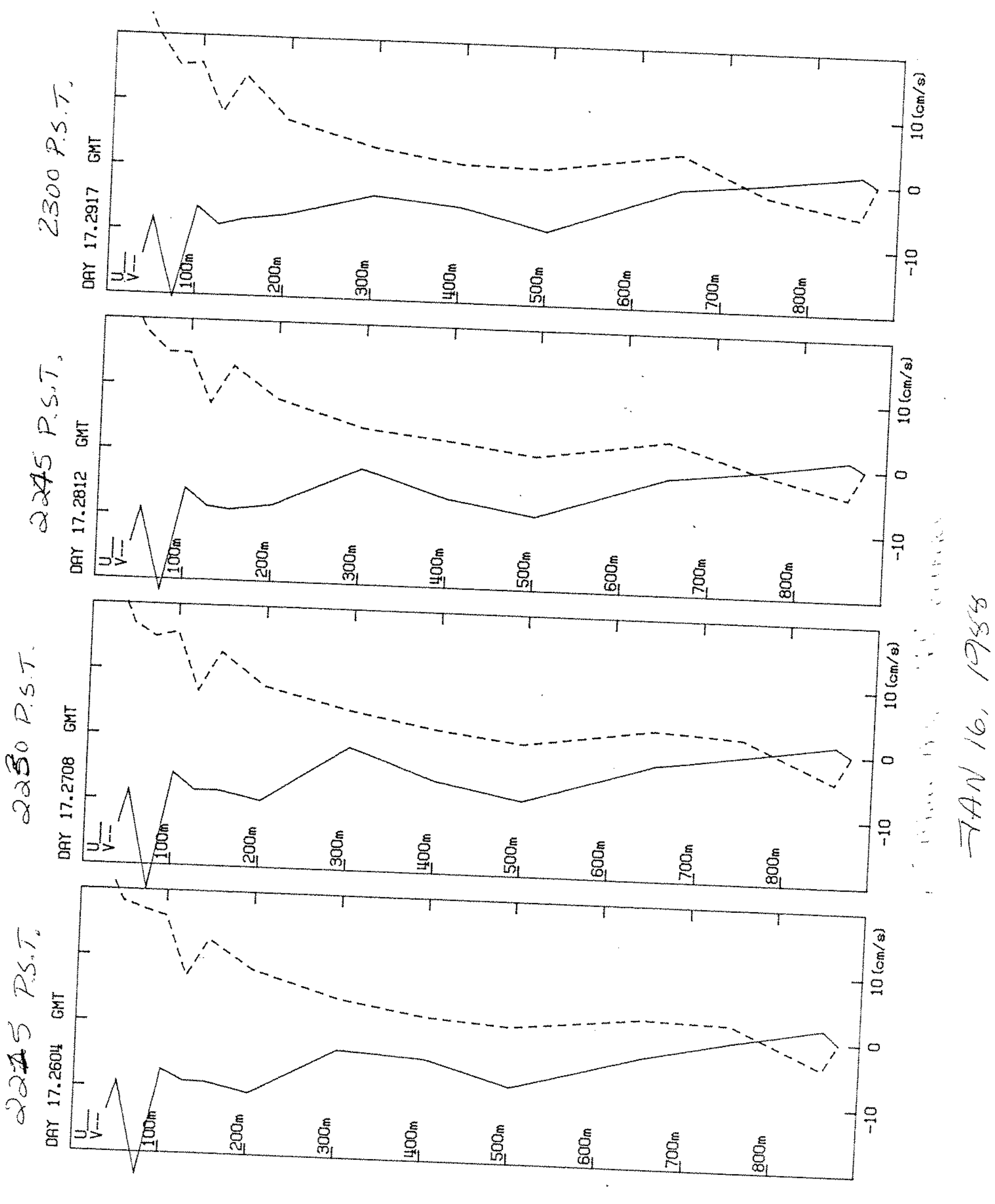

2000 P.S.T.
DAY 17.1667 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

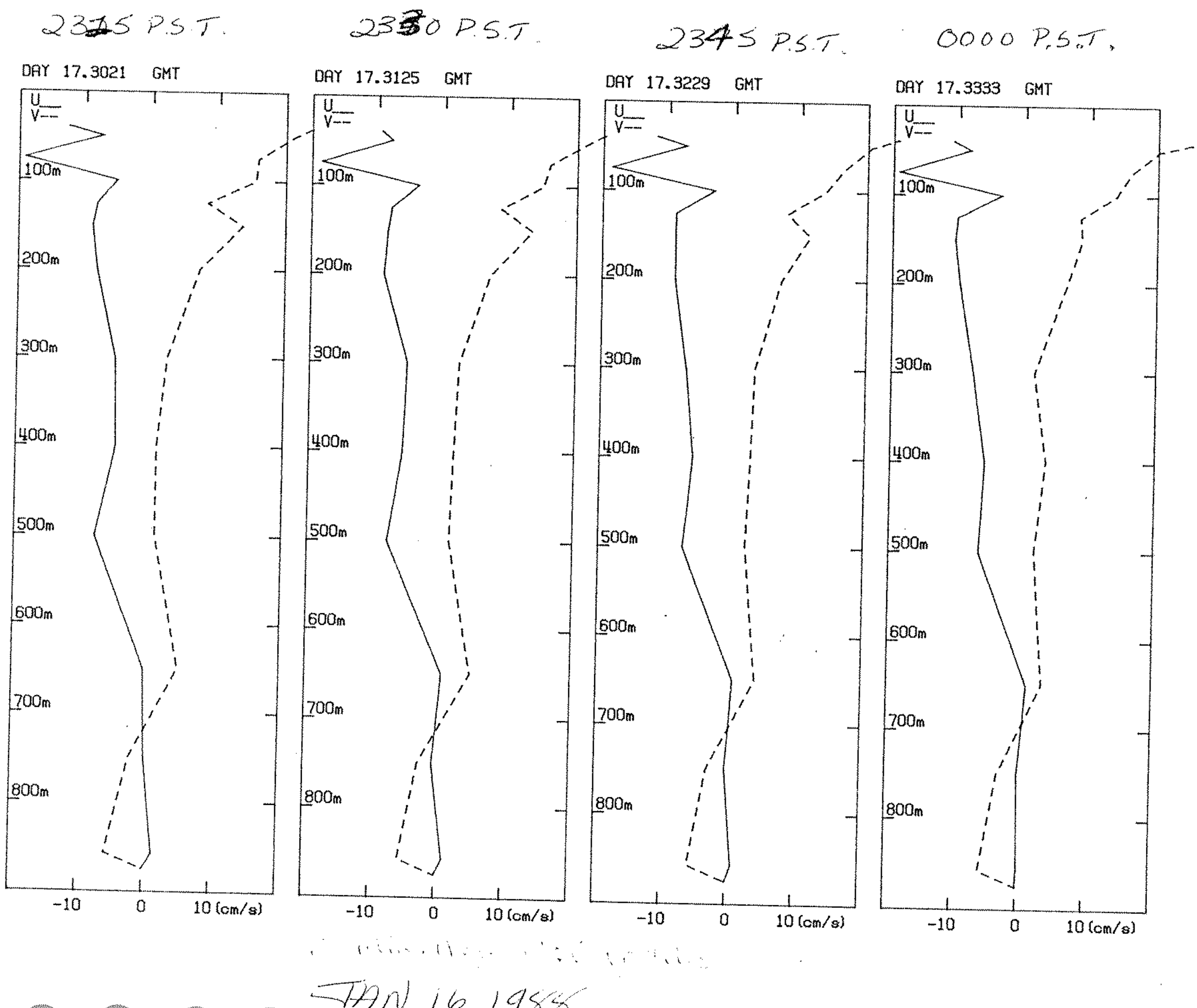
JAN 16, 1968

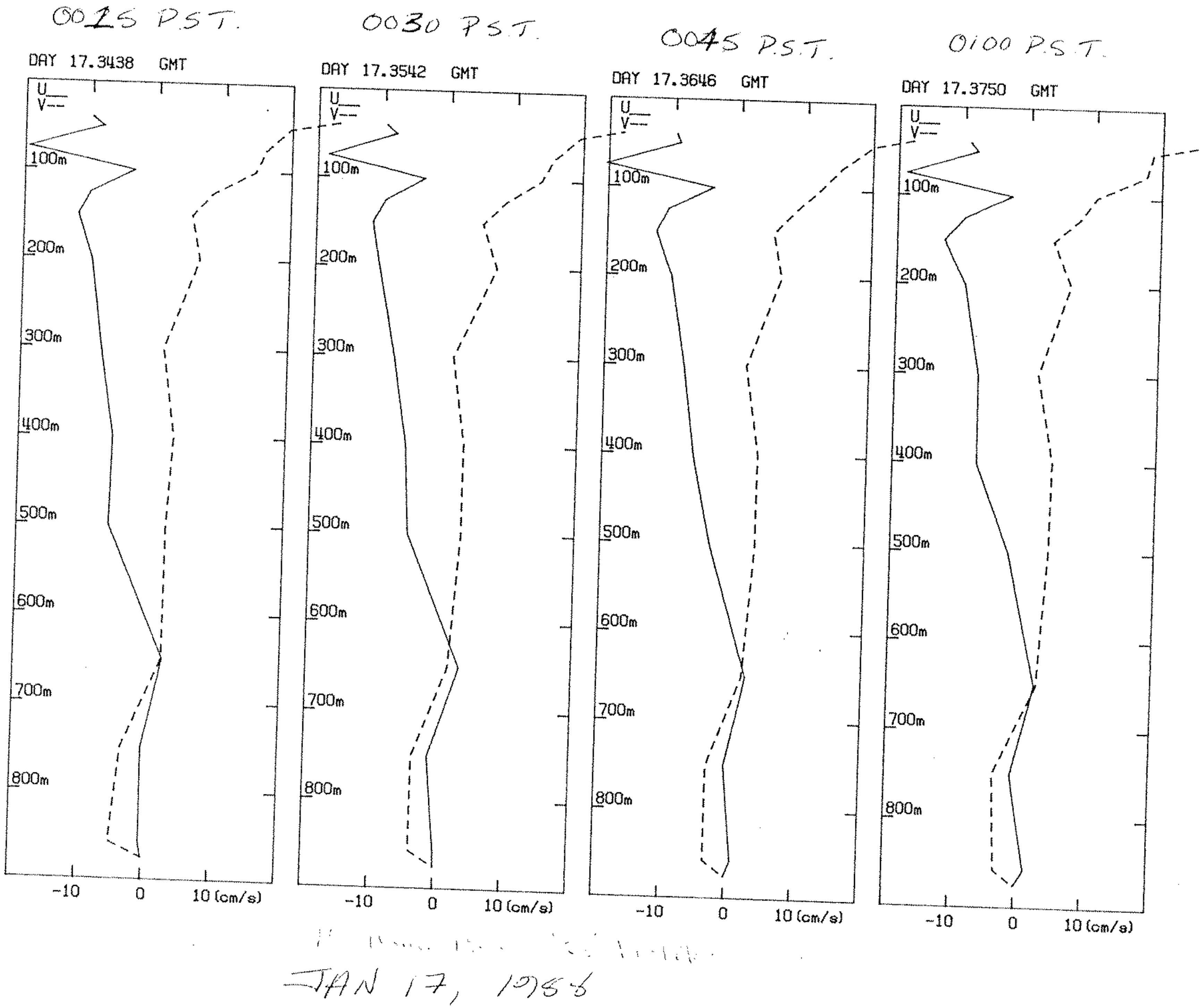

2025 P.S.T.
DAY 17.1771 GMT
2030 P.S.T.
DAY 17.1875 GMT
2045 P.S.T.
DAY 17.1979 GMT
2100 P.S.T.
DAY 17.2083 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 16, 1988

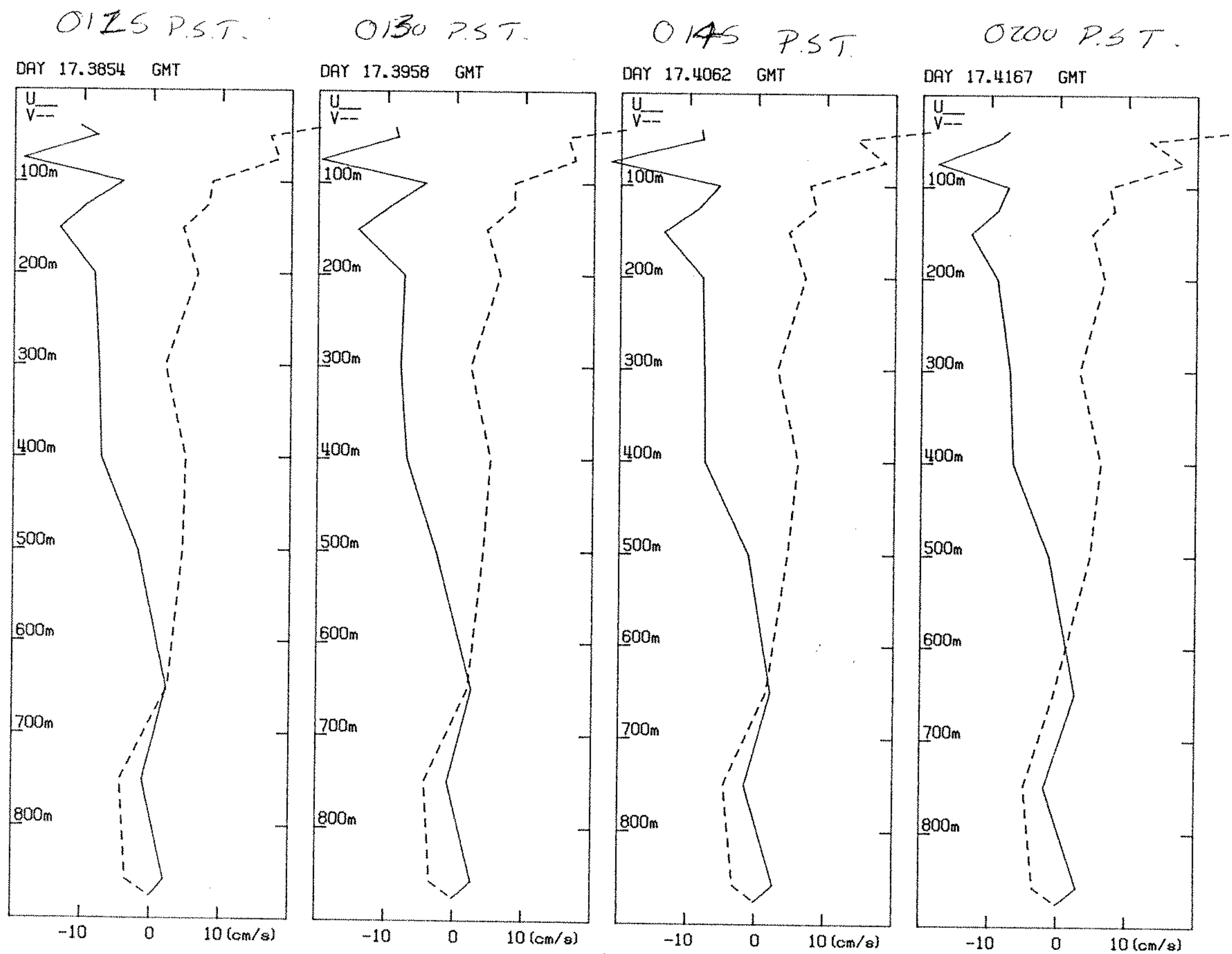

2200 P.S.T.
DAY 17.2500 GMT
2145 P.S.T.
DAY 17.2396 GMT
2130 P.S.T.
DAY 17.2292 GMT
2115 P.S.T.
DAY 17.2187 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 16, 1988


2300 P.S.T.
DAY 17.2917 GMT
2245 P.S.T.
DAY 17.2812 GMT
2230 P.S.T.
DAY 17.2708 GMT
2215 P.S.T.
DAY 17.2604 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10
JAN 16, 1988


2315 P.S.T.
DAY 17.3021 GMT
2330 P.S.T.
DAY 17.3125 GMT
2345 P.S.T.
DAY 17.3229 GMT
0000 P.S.T.
DAY 17.3333 GMT
U
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 16, 1988

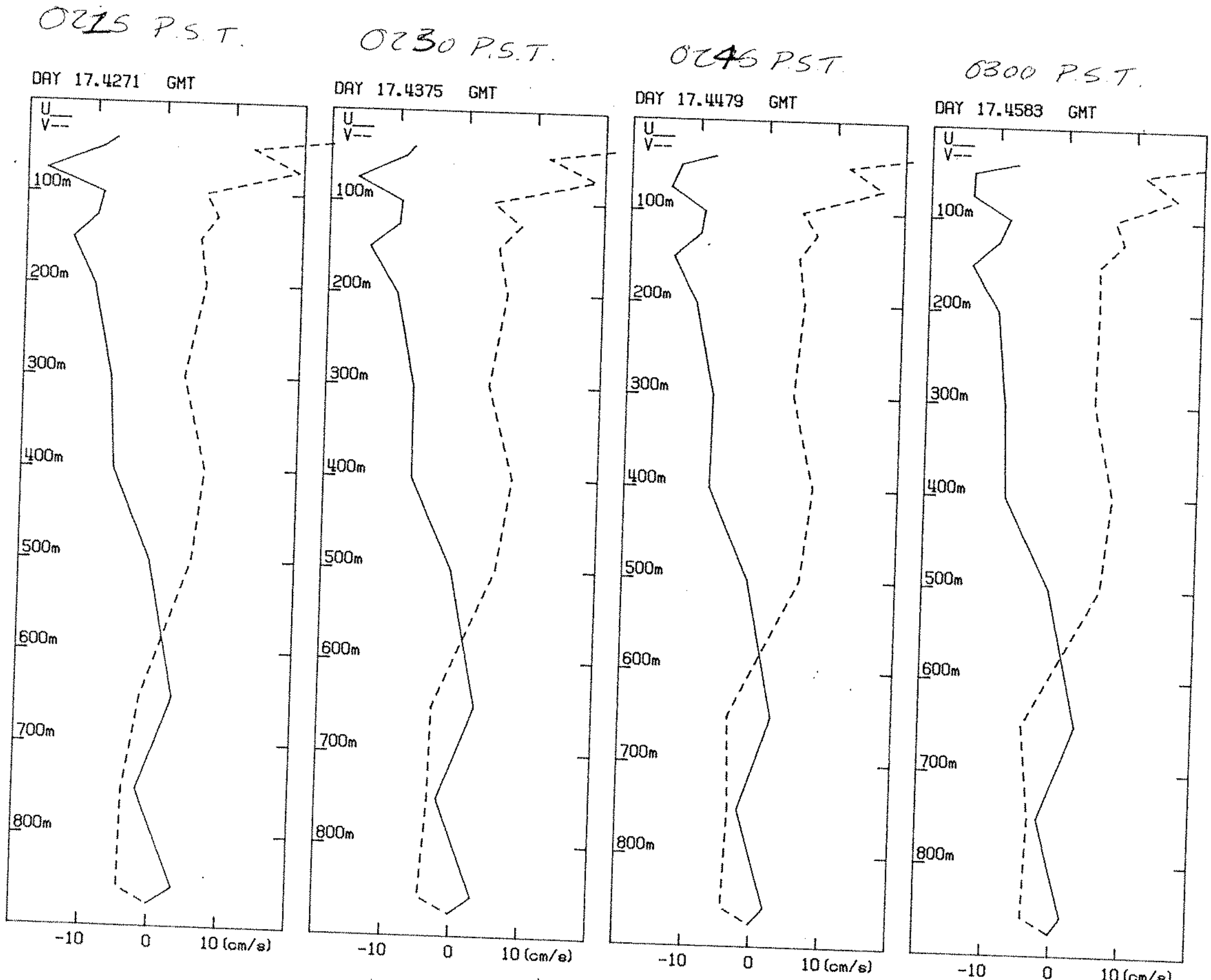


0015 P.S.T.
DAY 17.3438 GMT
0030 P.S.T.
DAY 17.3542 GMT
0045 P.S.T.
DAY 17.3646 GMT
0100 P.S.T.
DAY 17.3750 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 17, 1988

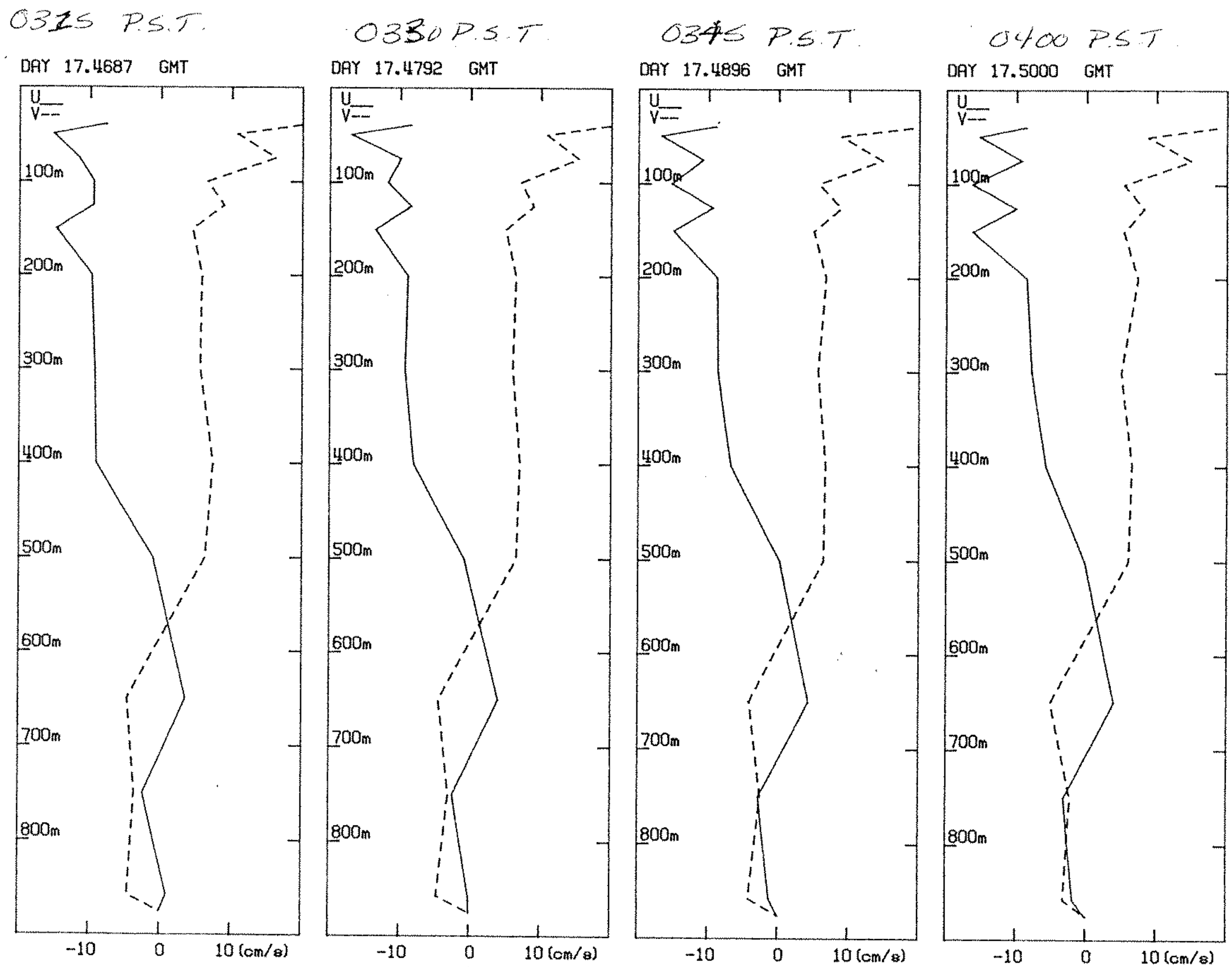


0125 P.S.T.
DAY 17.3854 GMT
0130 P.S.T.
DAY 17.3958 GMT
0145 P.S.T.
DAY 17.4062 GMT
0200 P.S.T.
DAY 17.4167 GMT
U___
V---
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 17, 1985

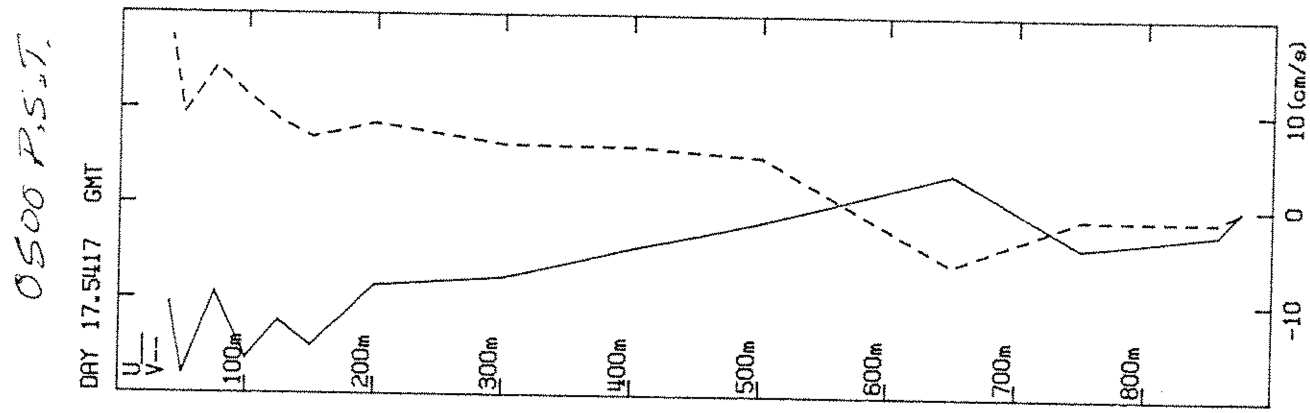

0215 P.S.T.
DAY 17.4271 GMT
0230 P.S.T.
DAY 17.4375 GMT
0245 P.S.T.
DAY 17.4479 GMT
0300 P.S.T.
DAY 17.4583 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

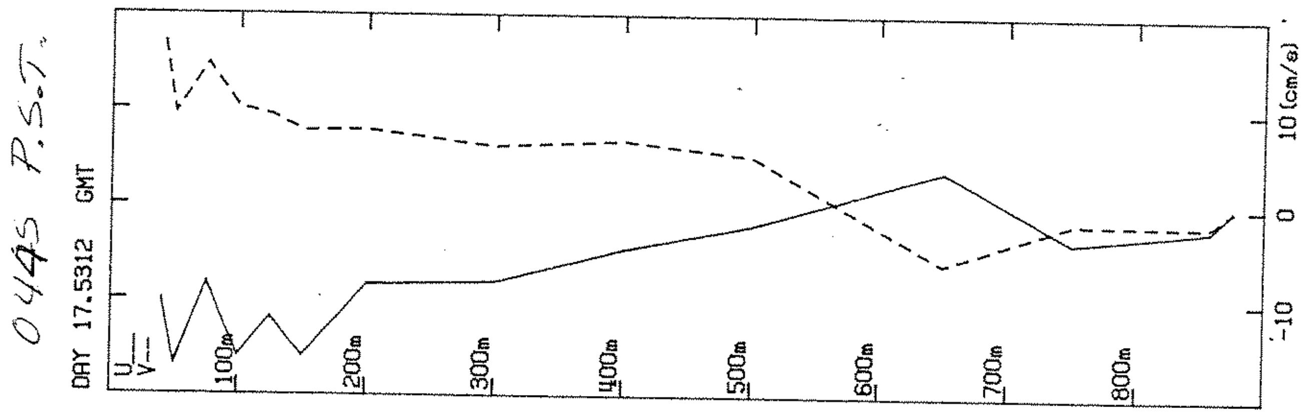
JAN 17, 1988

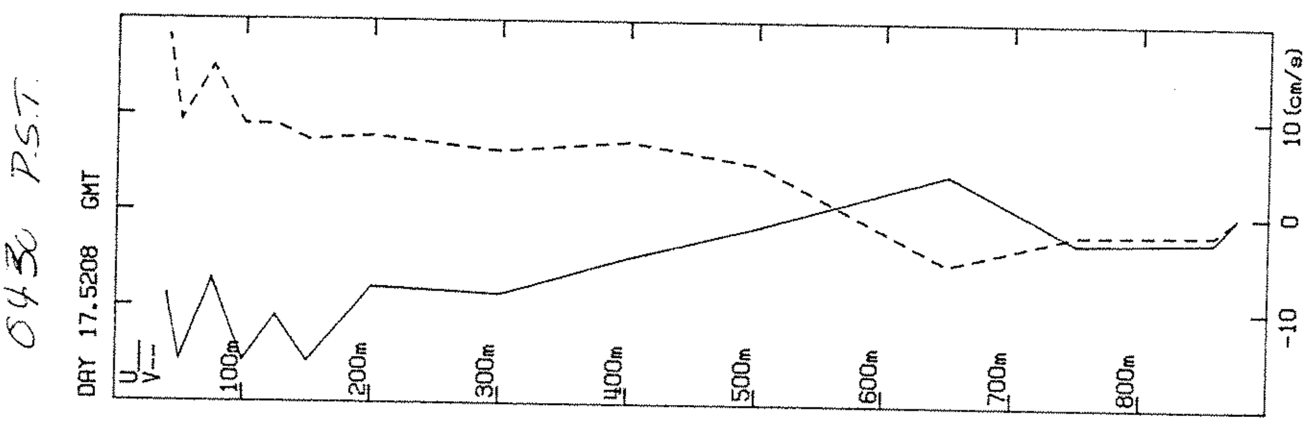


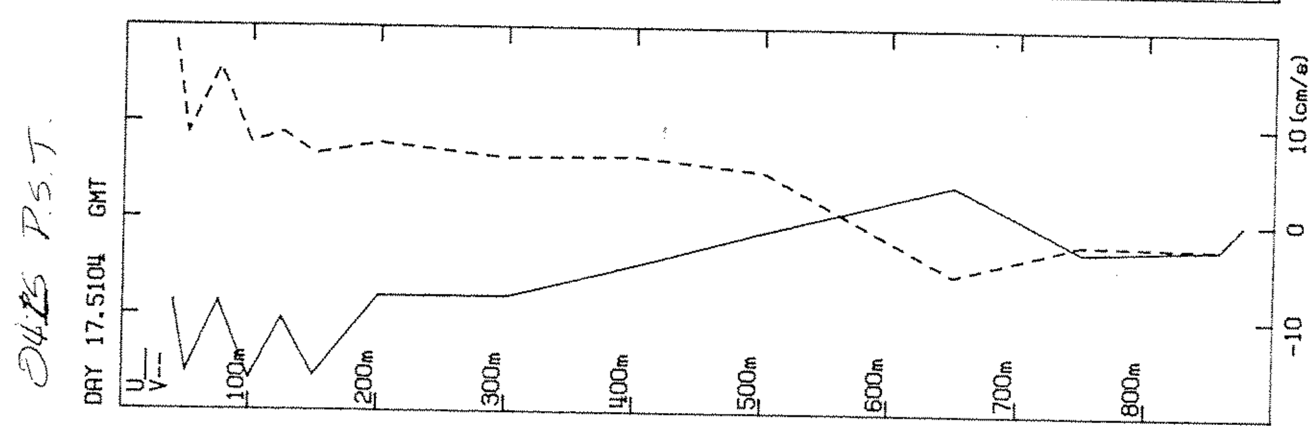
0315 P.S.T.
DAY 17.4687 GMT
0330 P.S.T.
DAY 17.4792 GMT
0345 P.S.T.
DAY 17.4896 GMT
0400 P.S.T.
DAY 17.5000 GMT
U___
V---
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 17, 1988

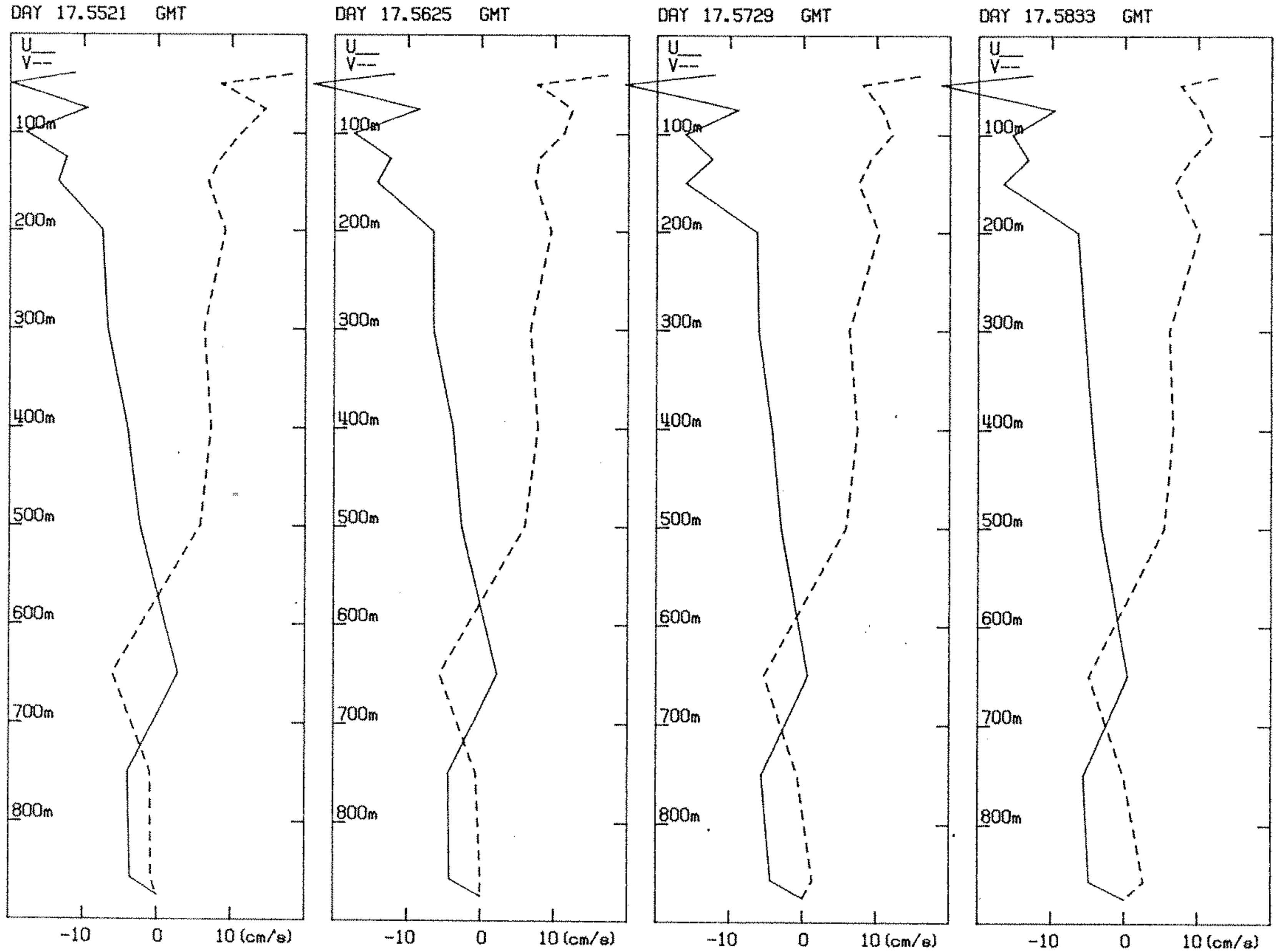

0500 P.S.T.
DAY 17.5417 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10


0445 P.S.T.
DAY 17.5312 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10

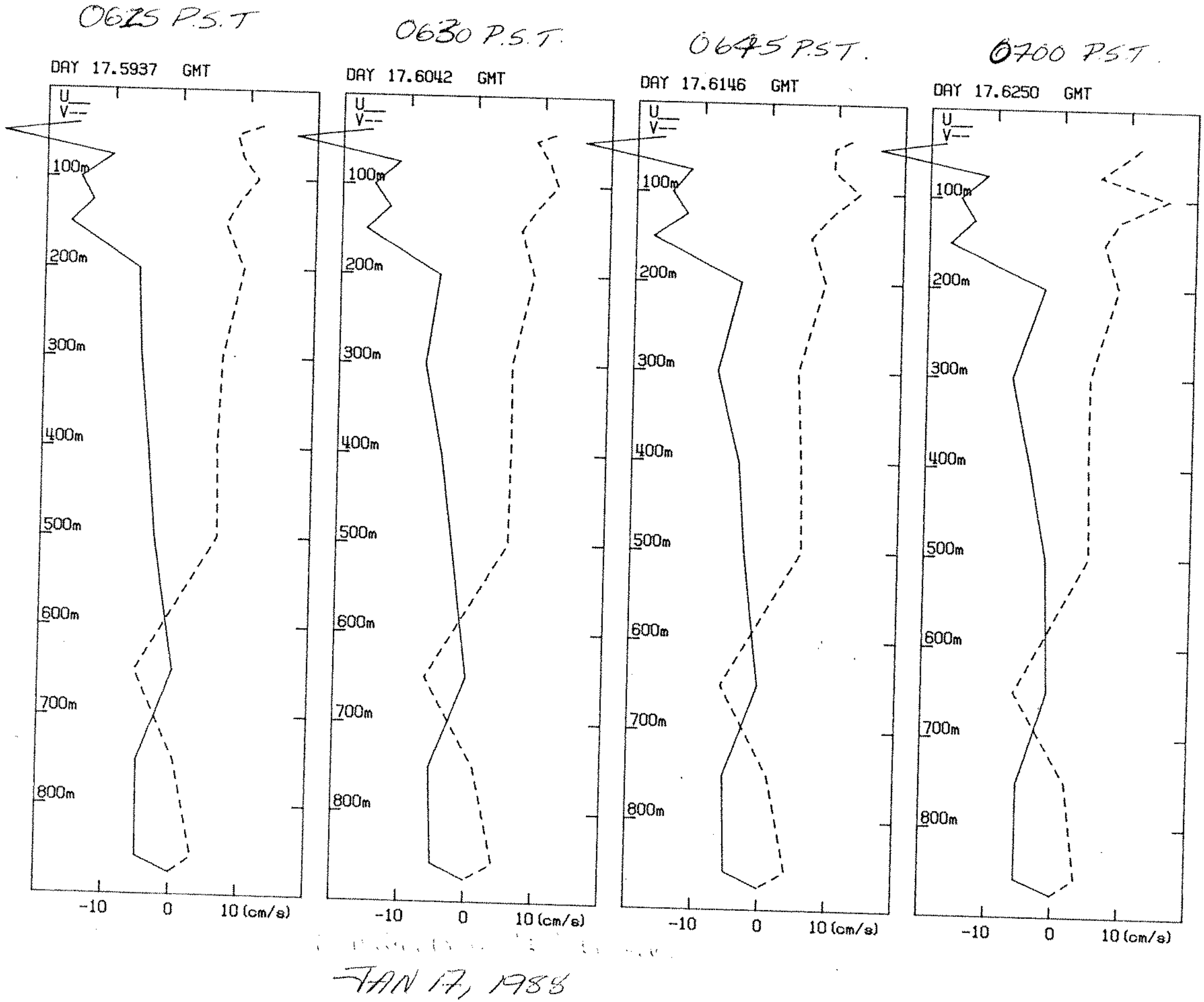

0430 P.S.T.
DAY 17.5208 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10

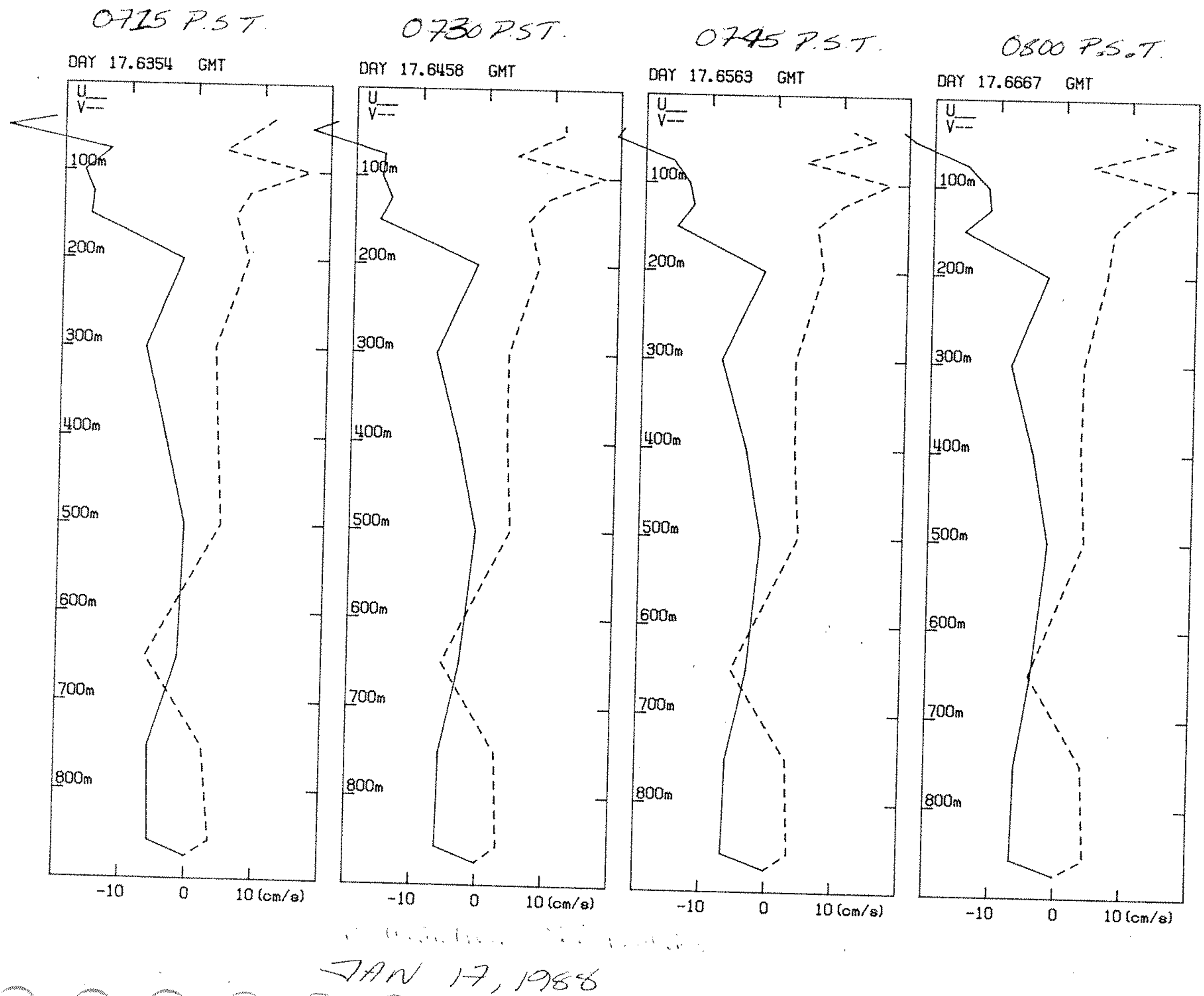

0415 P.S.T.
DAY 17.5104 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10

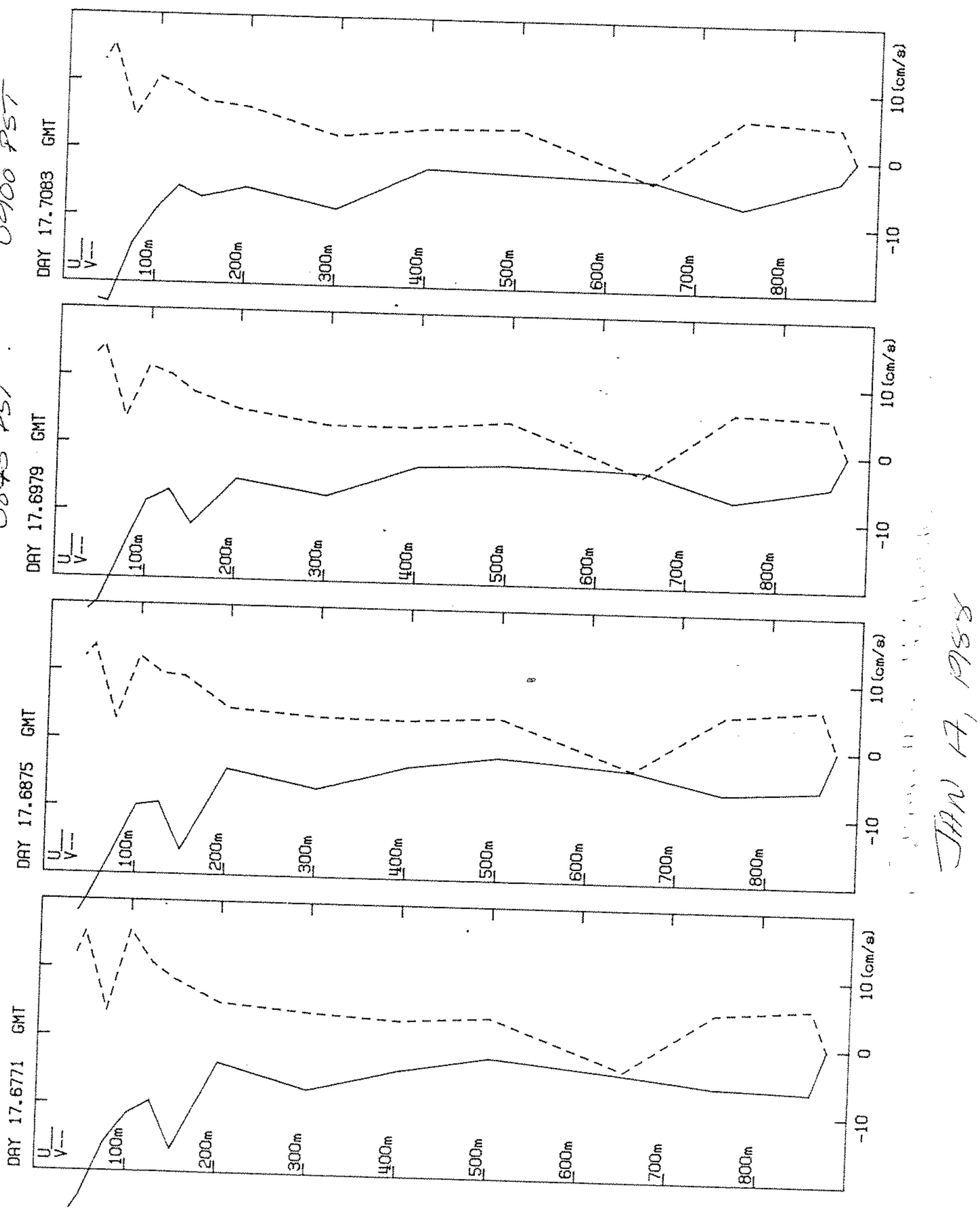
0525 P.S.T. 0530 P.S.T. 0545 P.S.T. 0600 P.S.T.

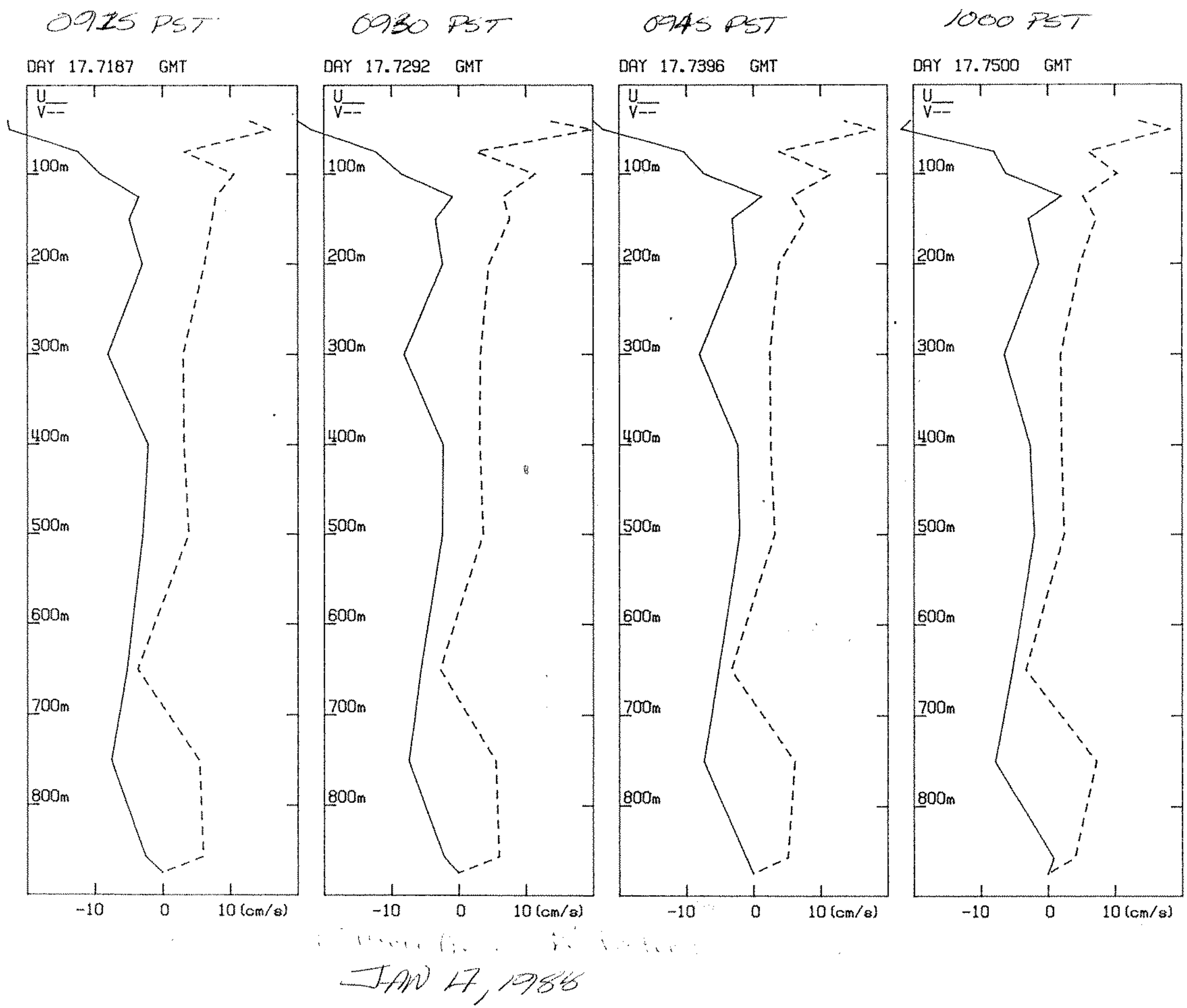


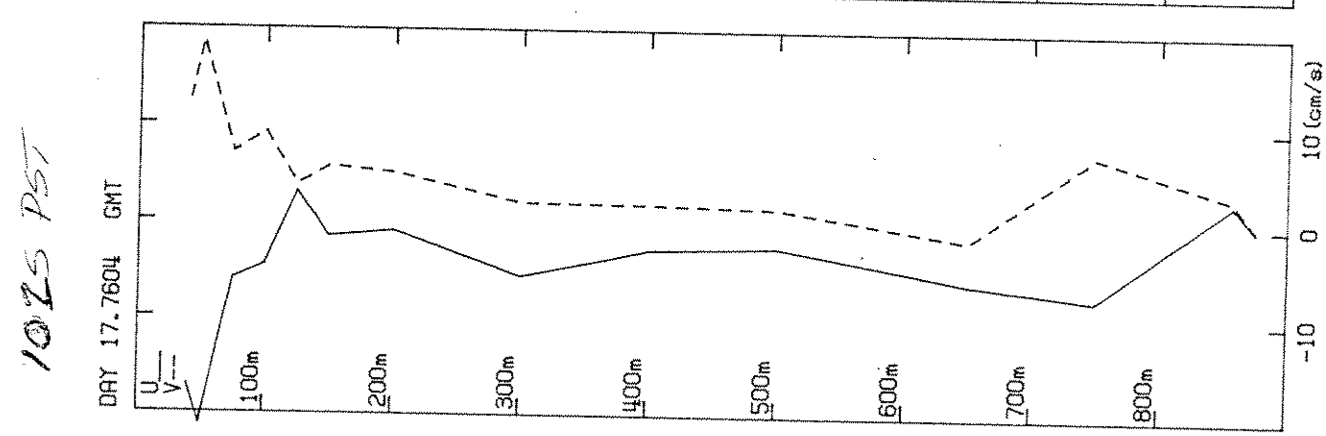
JAN 17, 1988

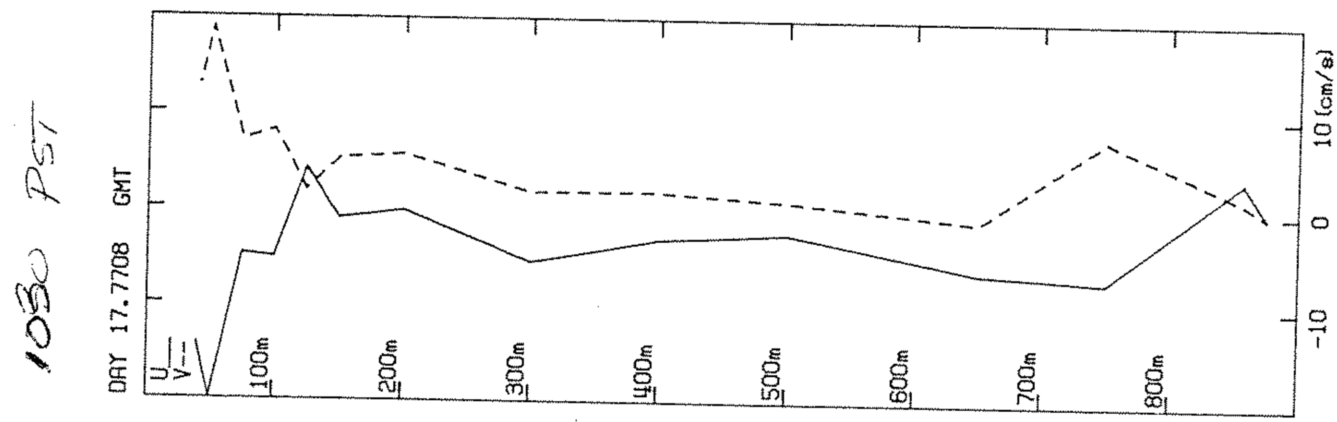

0625 P.S.T
DAY 17.5937 GMT
0630 P.S.T.
DAY 17.6042 GMT
0645 P.S.T.
DAY 17.6146 GMT
0700 P.S.T.
DAY 17.6250 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 17, 1988

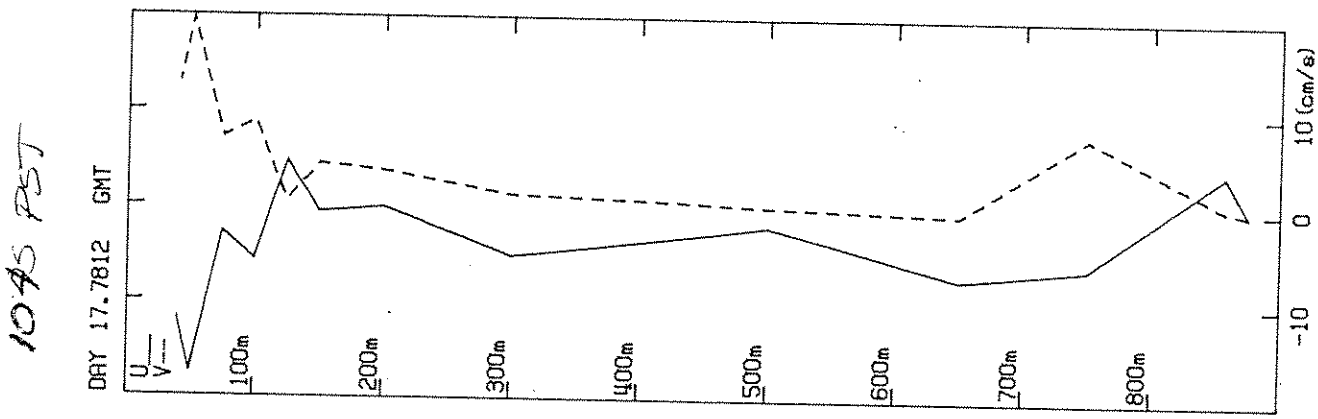

0715 P.S.T.
DAY 17.6354 GMT
0730 P.S.T.
DAY 17.6458 GMT
0745 P.S.T.
DAY 17.6563 GMT
0800 P.S.T.
DAY 17.6667 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 17, 1988

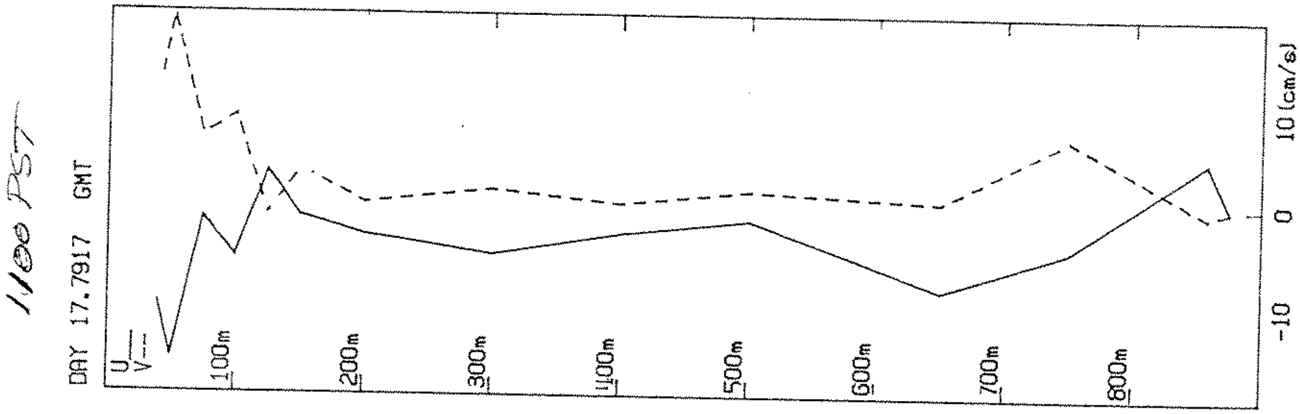

0900 PST
DAY 17.7083 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
0845 PST
DAY 17.6979 GMT
0830 PST
DAY 17.6875 GMT
0825 PST
DAY 17.6771 GMT
Jan 17,

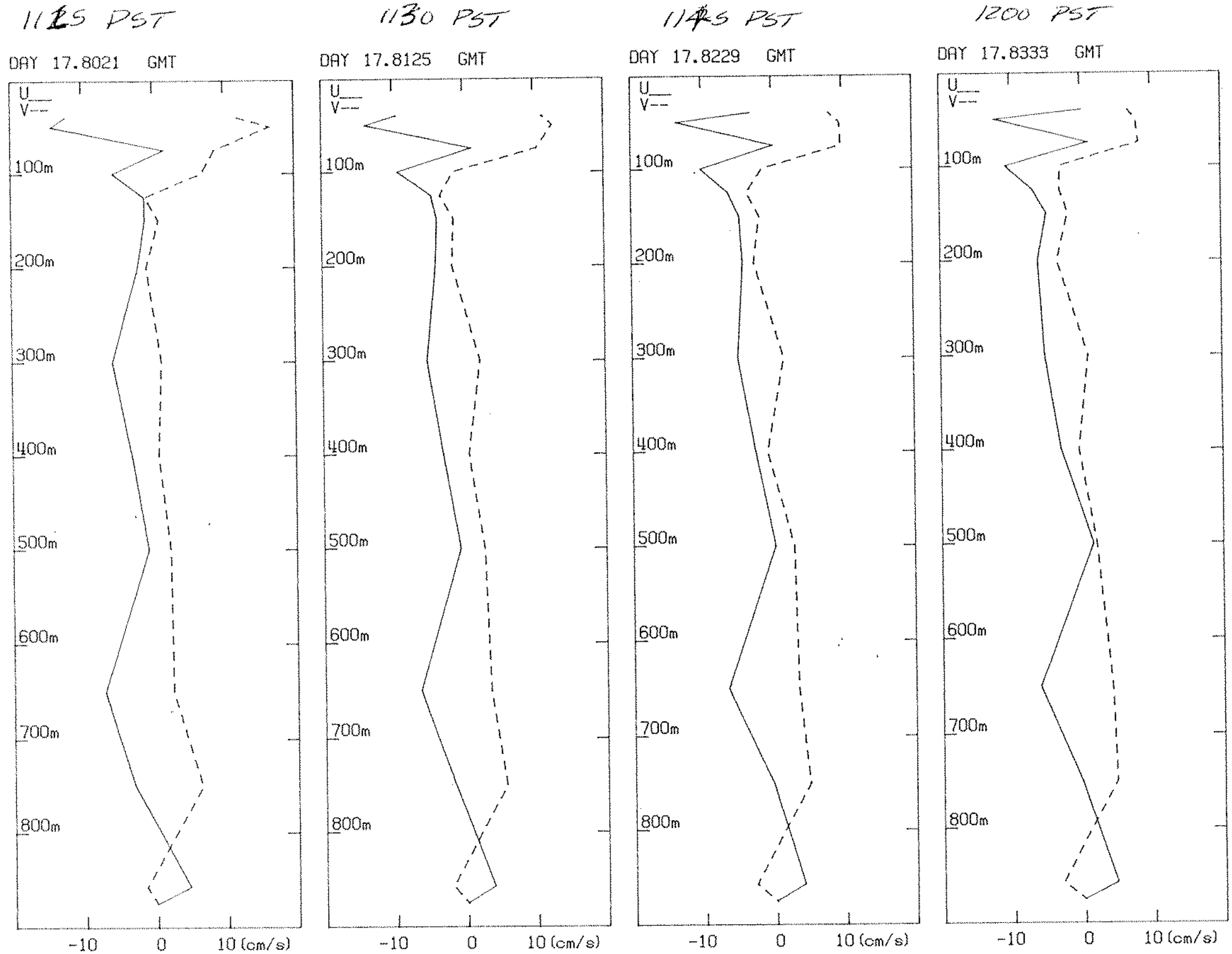

0915 PST
DAY 17.7187 GMT
0930 PST
DAY 17.7292 GMT
0945 PST
DAY 17.7396 GMT
1000 PST
DAY 17.7500 GMT
U___
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 17, 1986


1025 PST
DAY 17.7604 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


1030 PST
DAY 17.7708 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


1045 PST
DAY 17.7812 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


1100 PST
DAY 17.7917 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

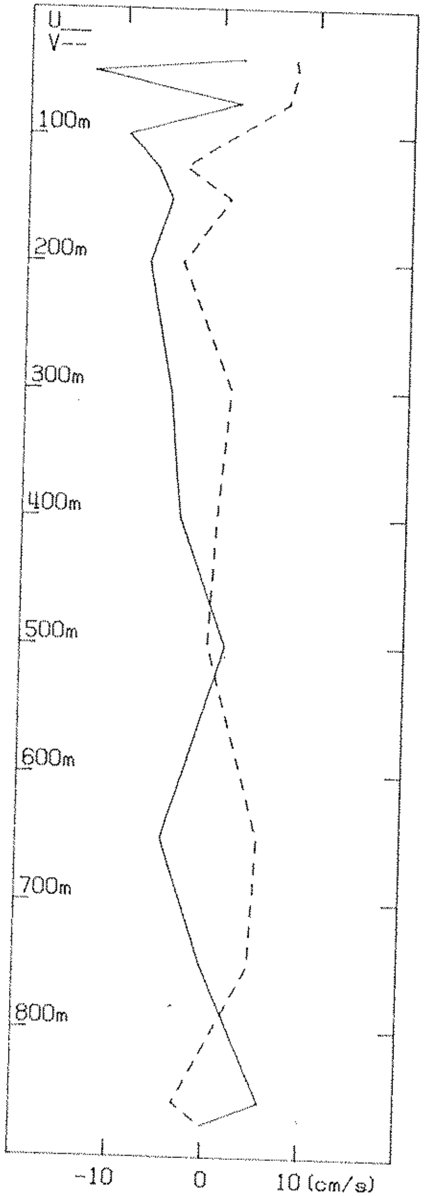


1115 PST
DAY 17.8021 GMT
1130 PST
DAY 17.8125 GMT
1145 PST
DAY 17.8229 GMT
1200 PST
DAY 17.8333 GMT
U___
V---
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 17, 1988

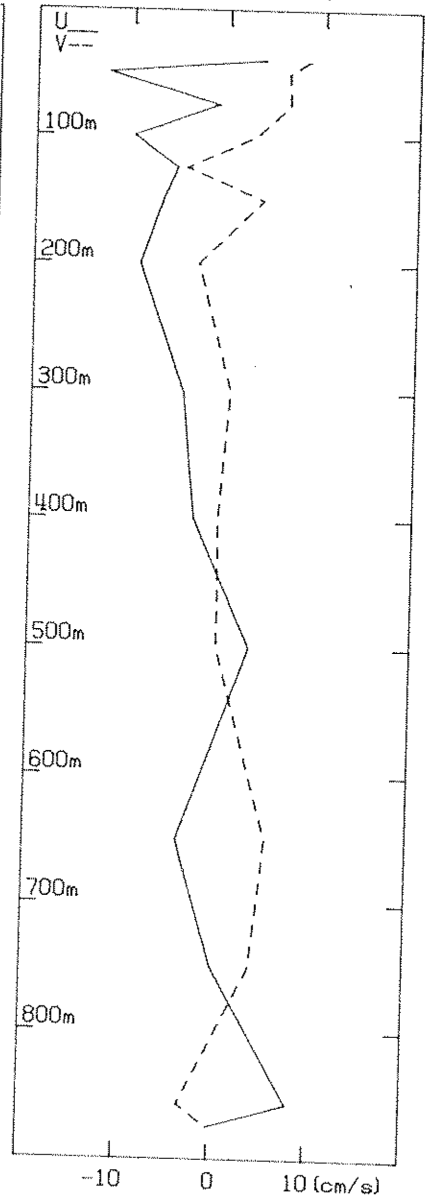
1225 PST

DAY 17.8437 GMT



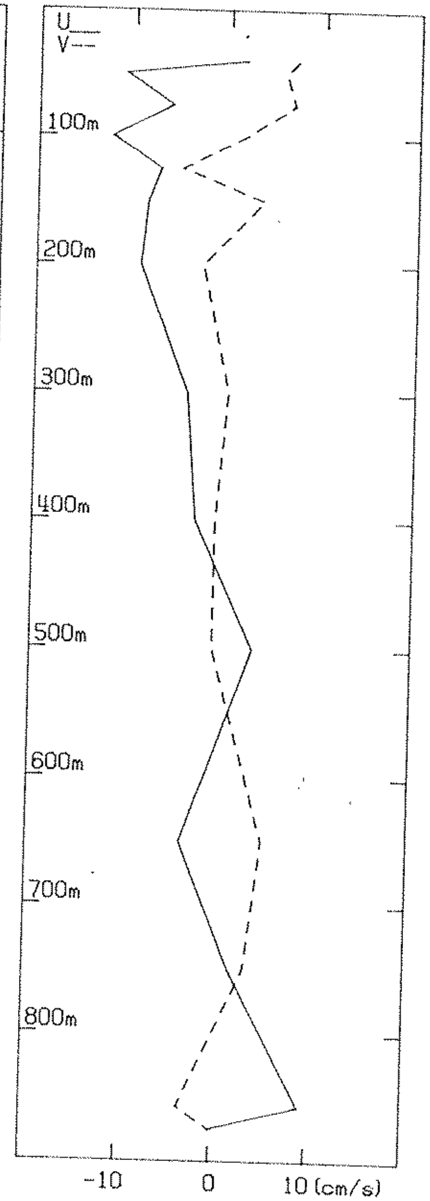
1230 PST

DAY 17.8542 GMT



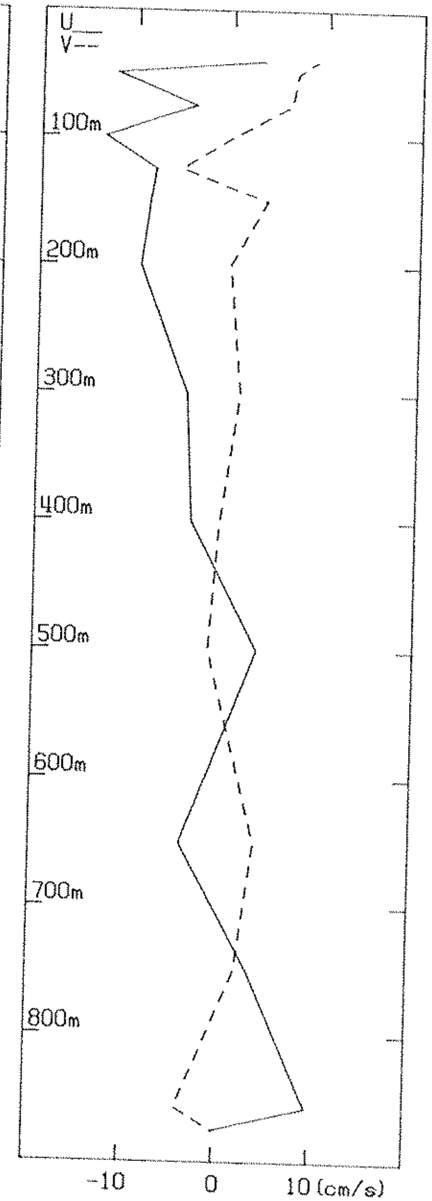
1245 PST

DAY 17.8646 GMT

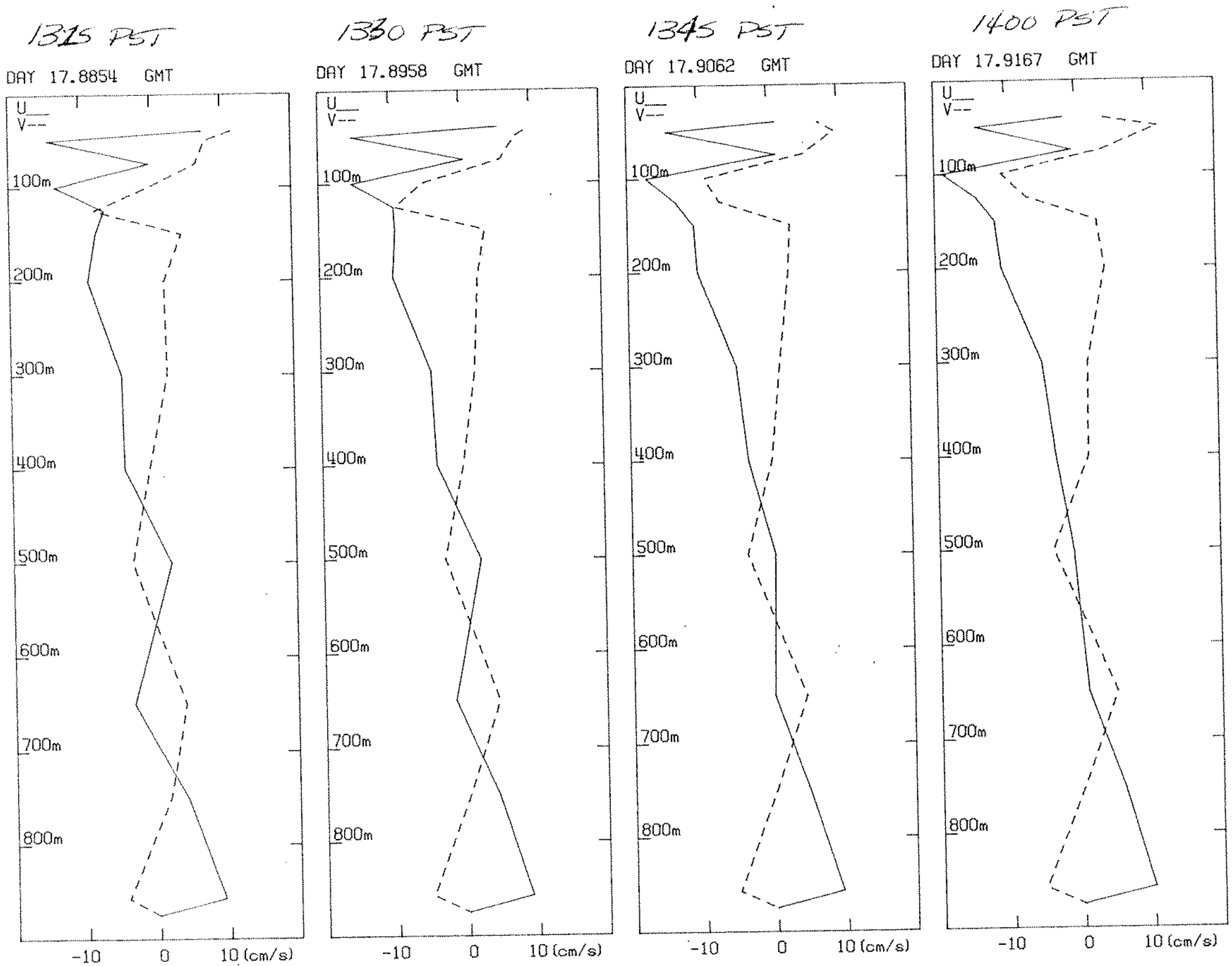


1300 PST

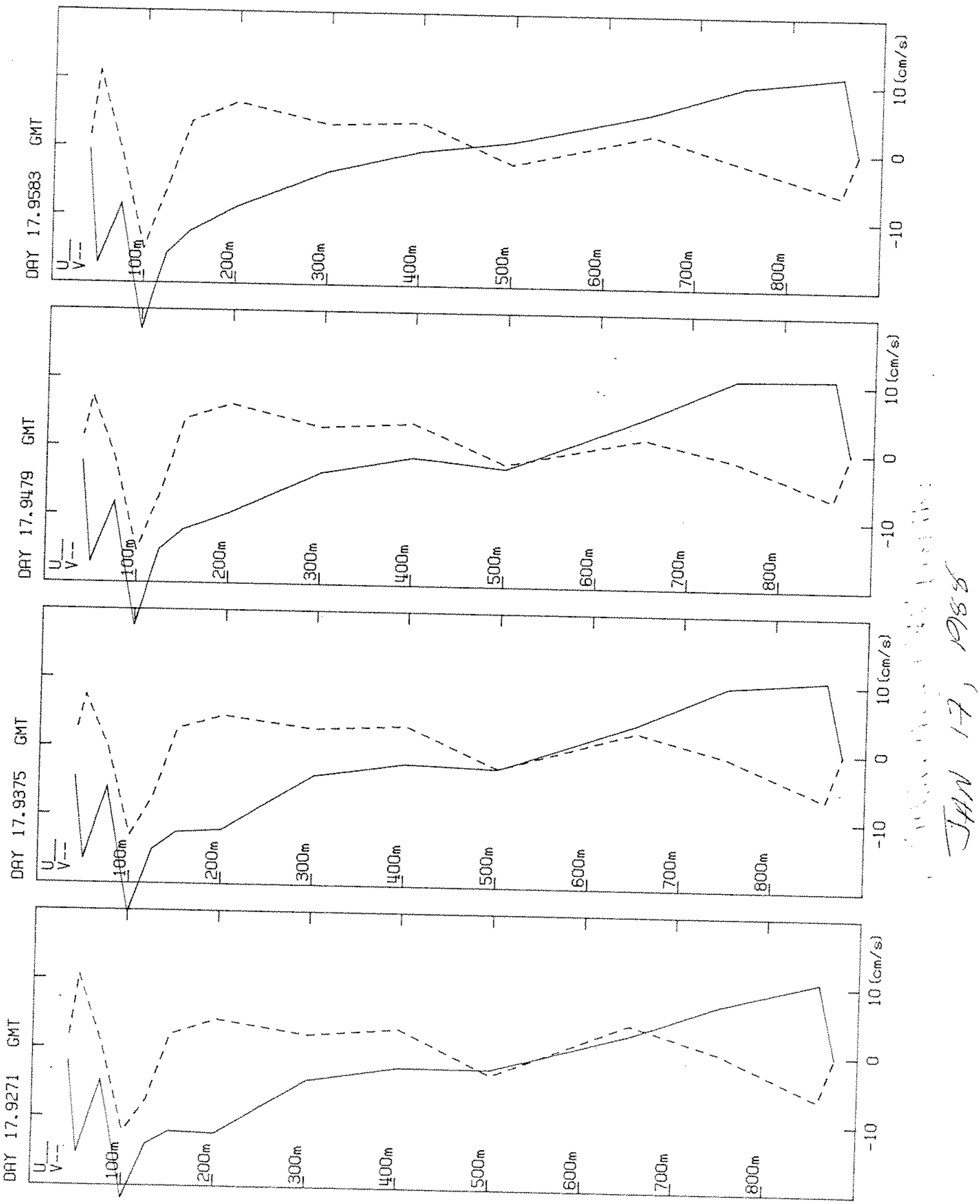
DAY 17.8750 GMT

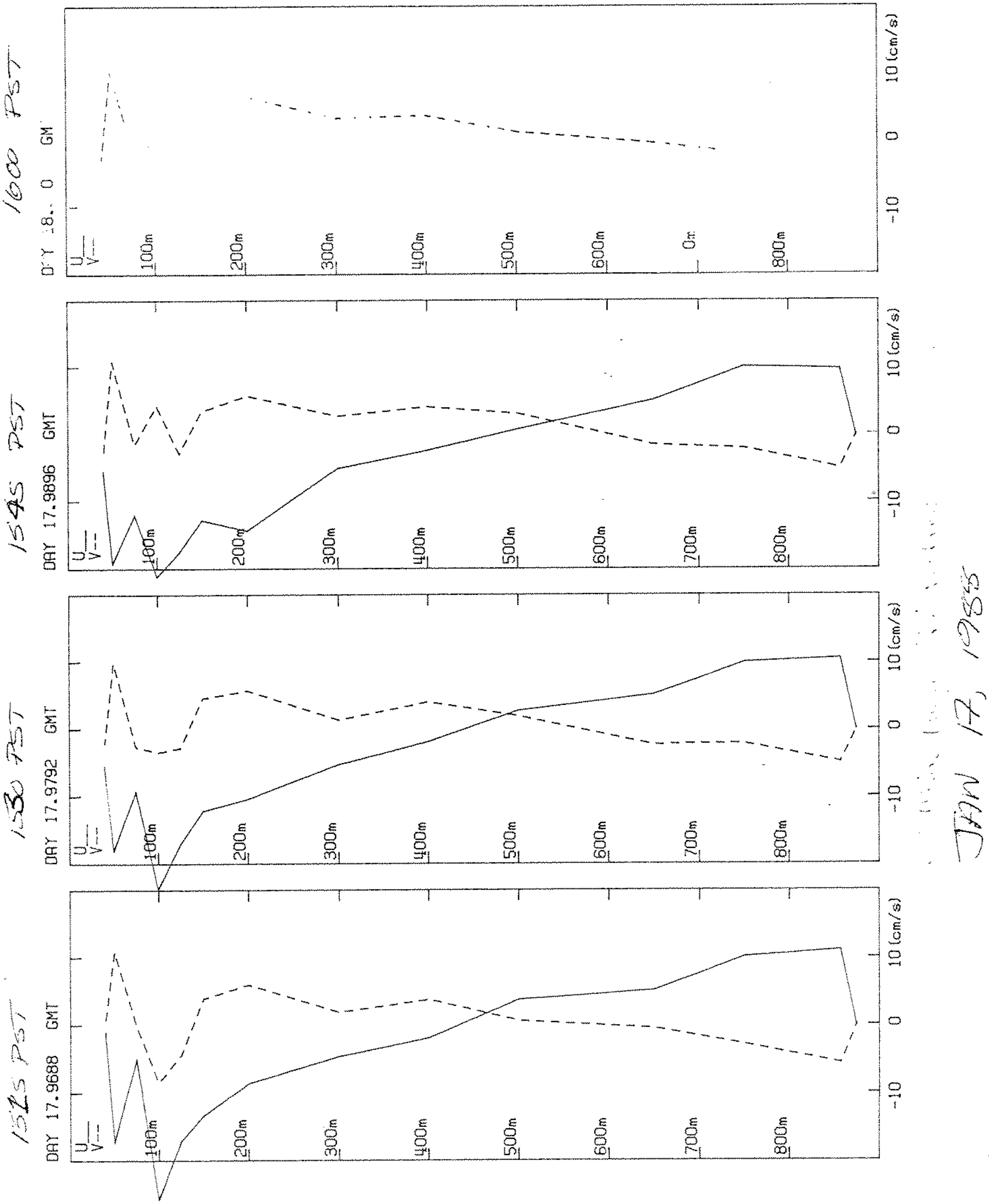


JAN 17, 1988

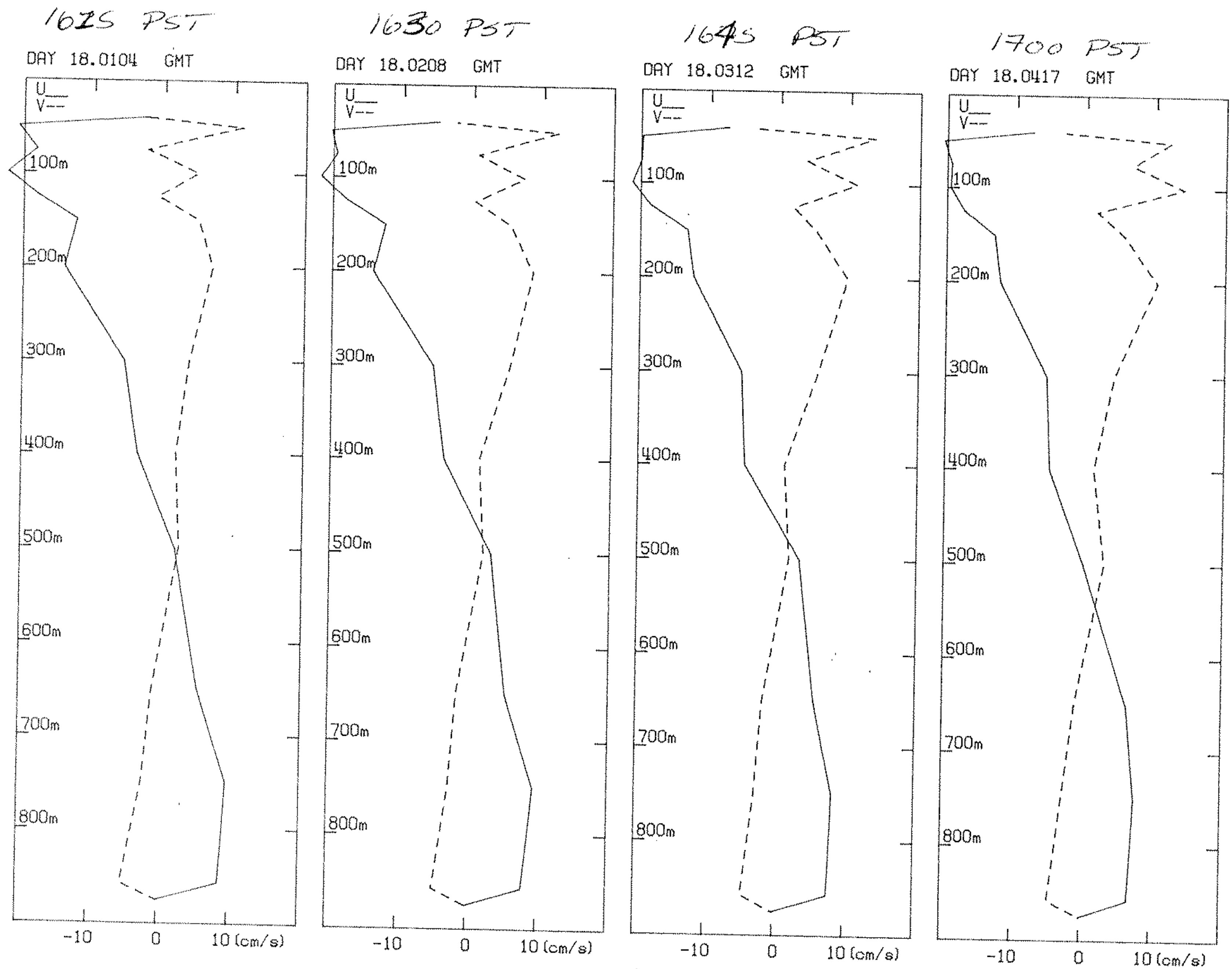

1315 PST
DAY 17.8854 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
1330 PST
DAY 17.8958 GMT
1345 PST
DAY 17.9062 GMT
1400 PST
DAY 17.9167 GMT

JAN 17, 1988


1500 PST
DAY 17.9583 GMT
1445 PST
DAY 17.9479 GMT
1430 PST
DAY 17.9375 GMT
1415 PST
DAY 17.9271 GMT
U —
V --
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 17, 1985

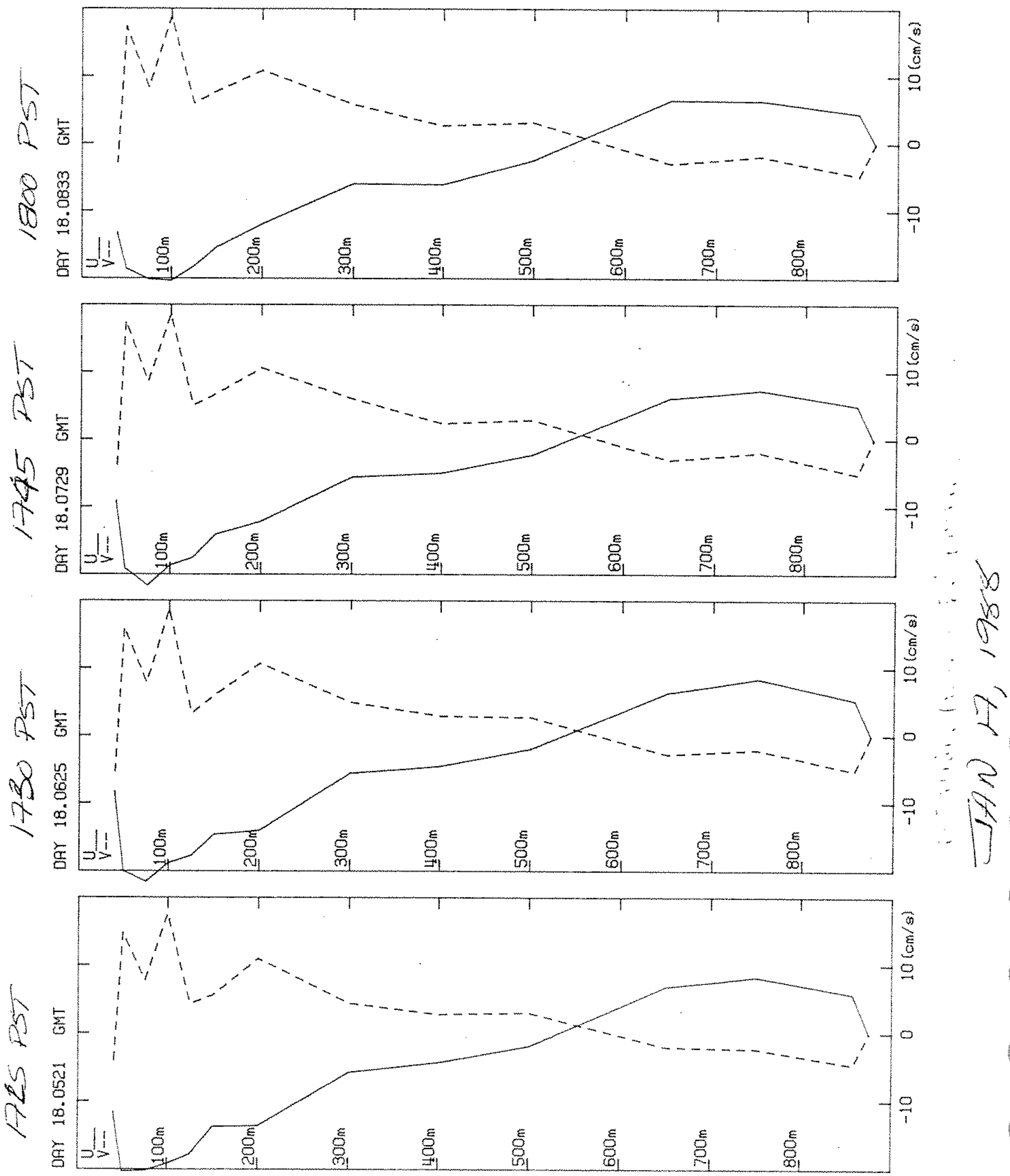


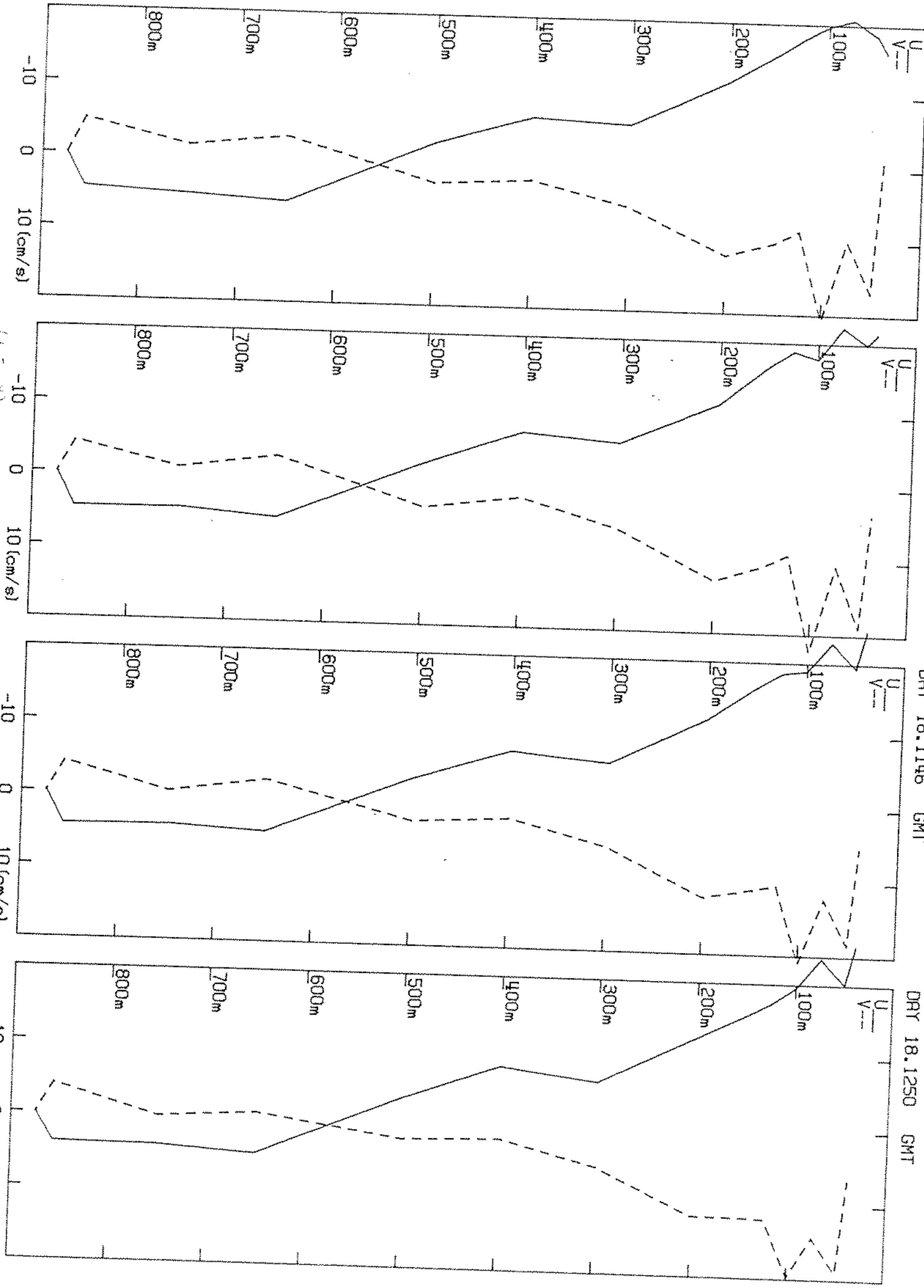
1600 PST
DAY 18.. 0 GMT
1545 PST
DAY 17.9896 GMT
1530 PST
DAY 17.9792 GMT
1515 PST
DAY 17.9688 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
10 (cm/s)
0
-10
JAN 17, 1985



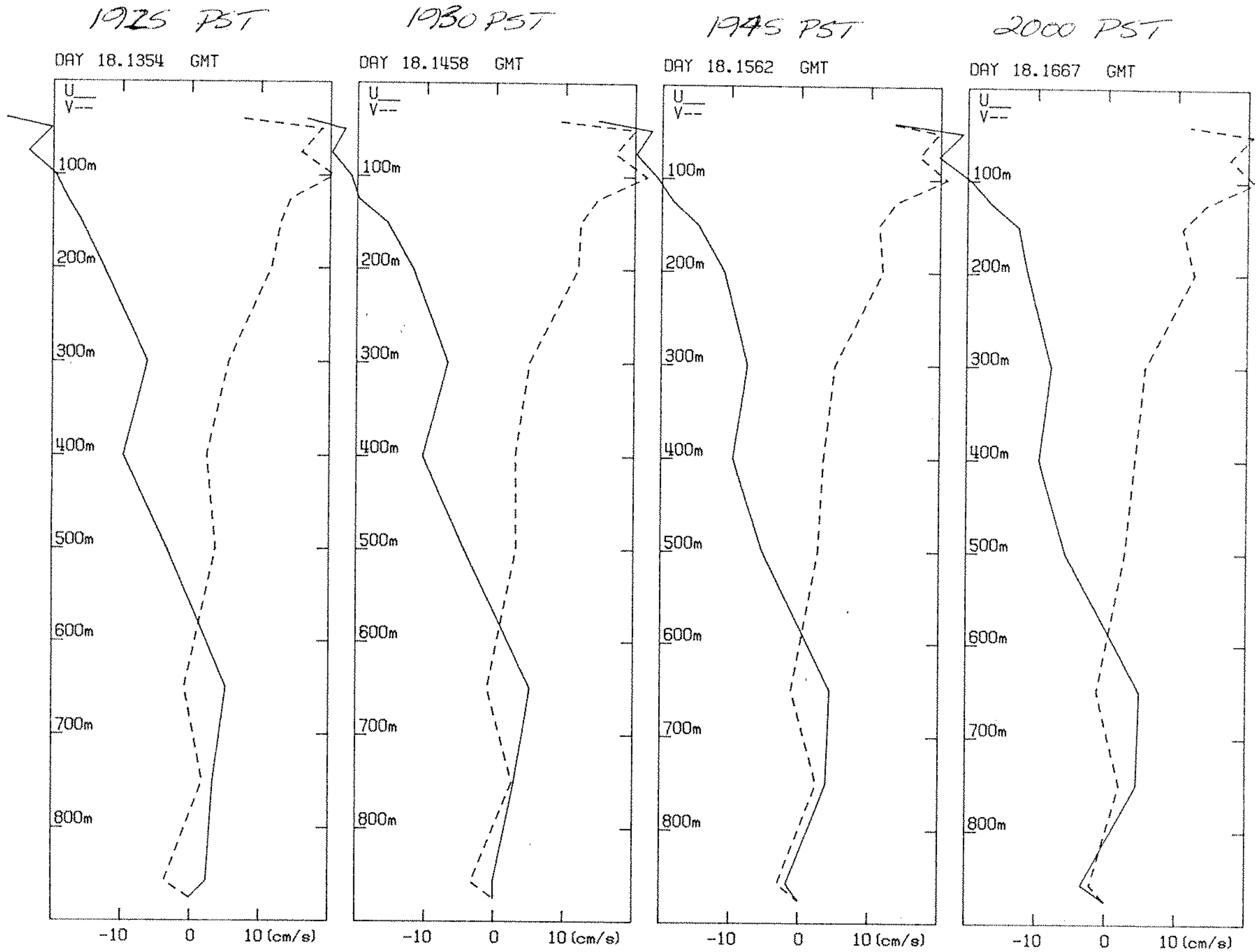
1625 PST
DAY 18.0104 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
1630 PST
DAY 18.0208 GMT
1645 PST
DAY 18.0312 GMT
1700 PST
DAY 18.0417 GMT

JAN 17, 1988

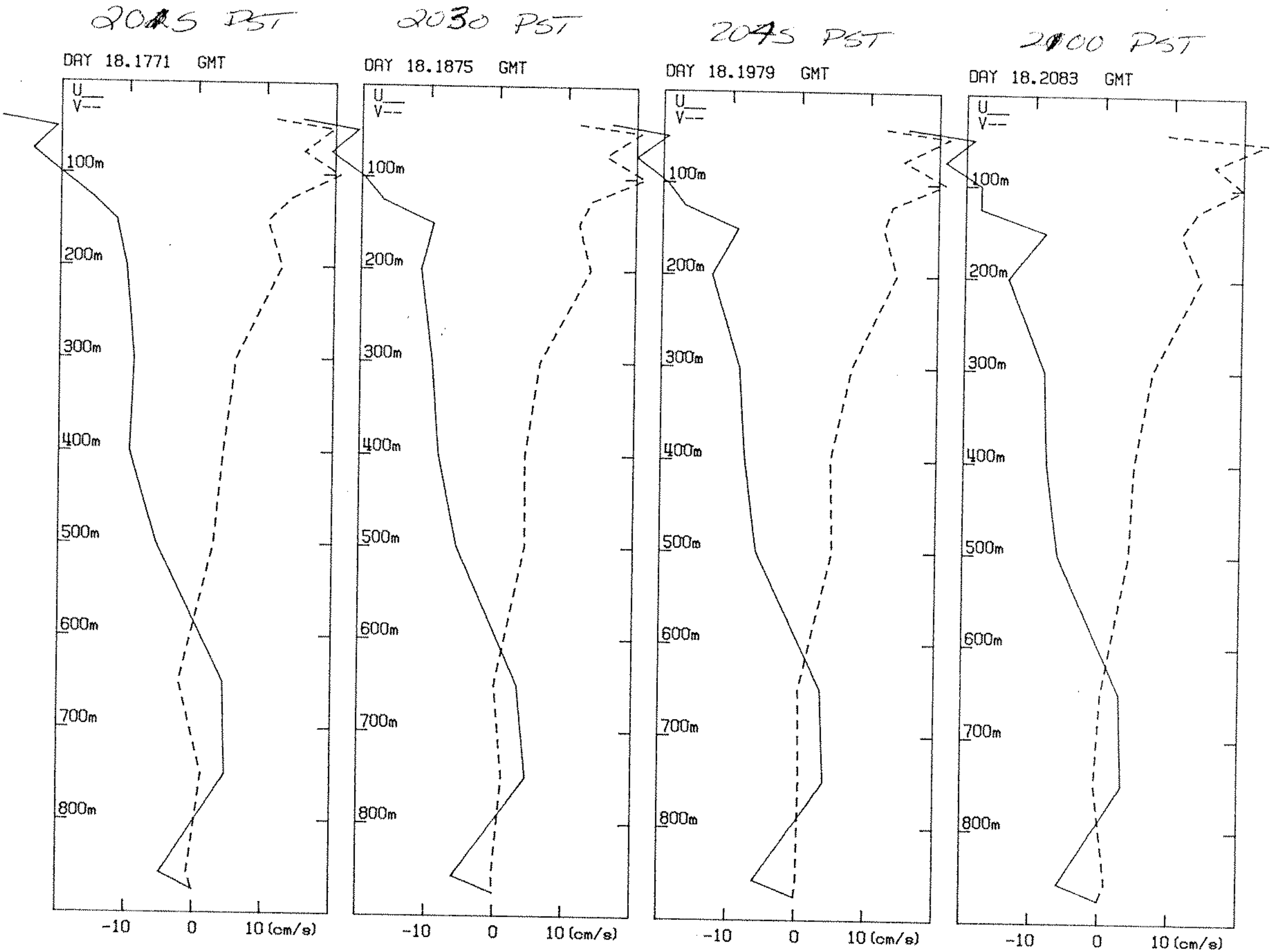

1800 PST
DAY 18.0833 GMT
1745 PST
DAY 18.0729 GMT
1730 PST
DAY 18.0625 GMT
1715 PST
DAY 18.0521 GMT
U—
V--
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)
JAN 17, 1988



DAY 18.0937 GMT
DAY 18.1042 GMT
DAY 18.1146 GMT
DAY 18.1250 GMT
U —
V - -
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

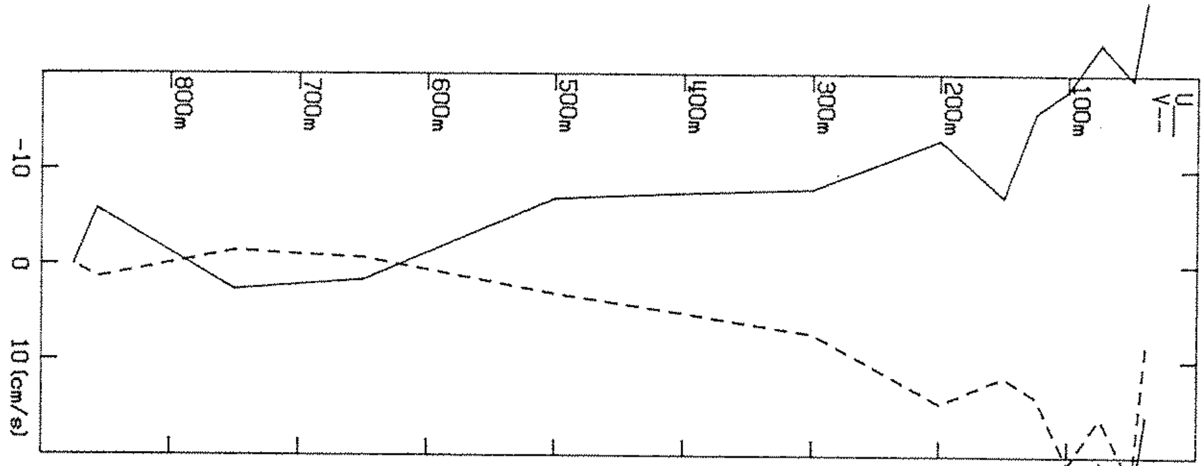


15 Min. Avg. U&V Profiles
JAN 17, 1988

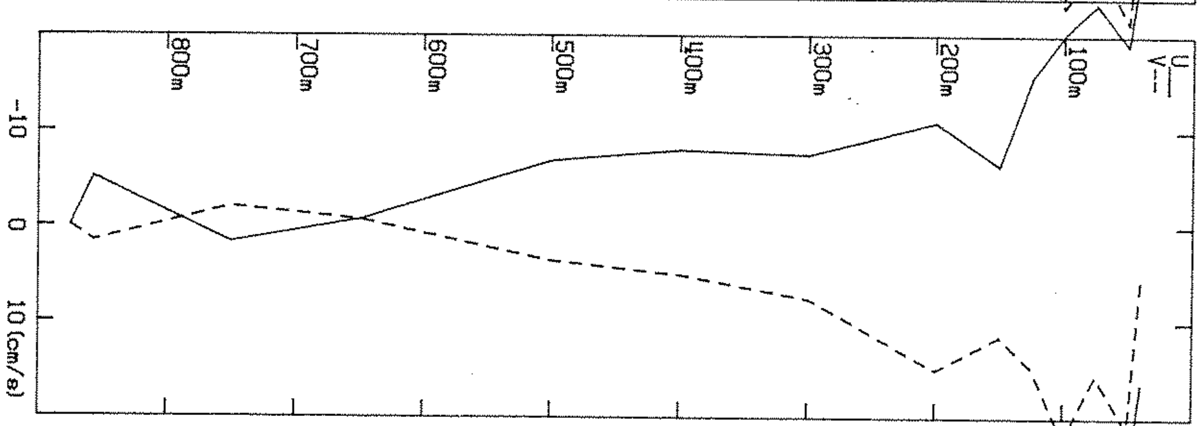

2030 PST
DAY 18.1771 GMT
DAY 18.1875 GMT
DAY 18.1979 GMT
DAY 18.2083 GMT
U___
V---
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 17, 1988

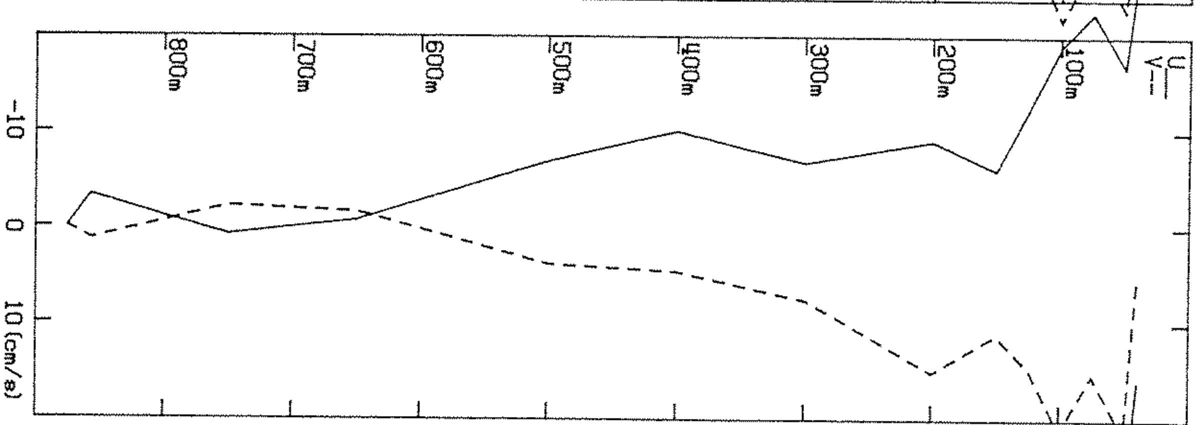
2115 PST



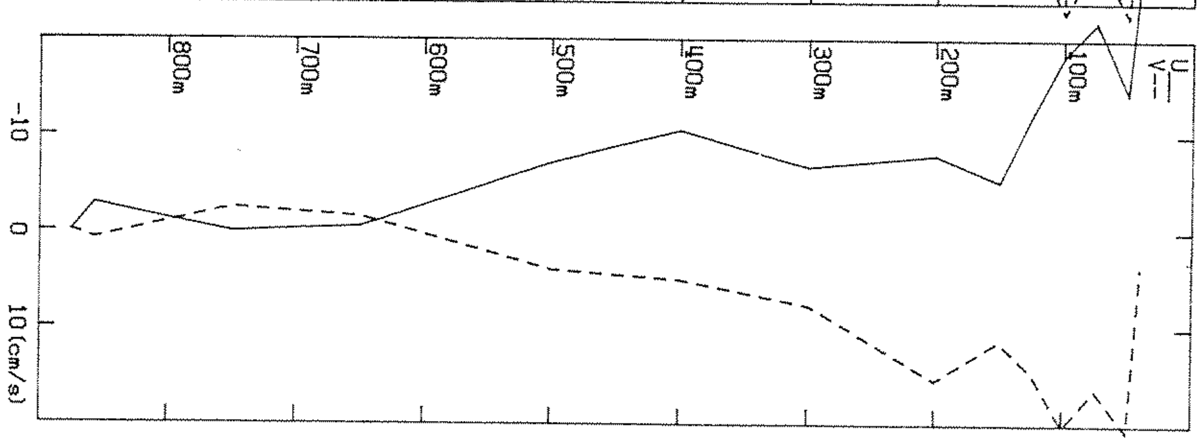
2130 PST



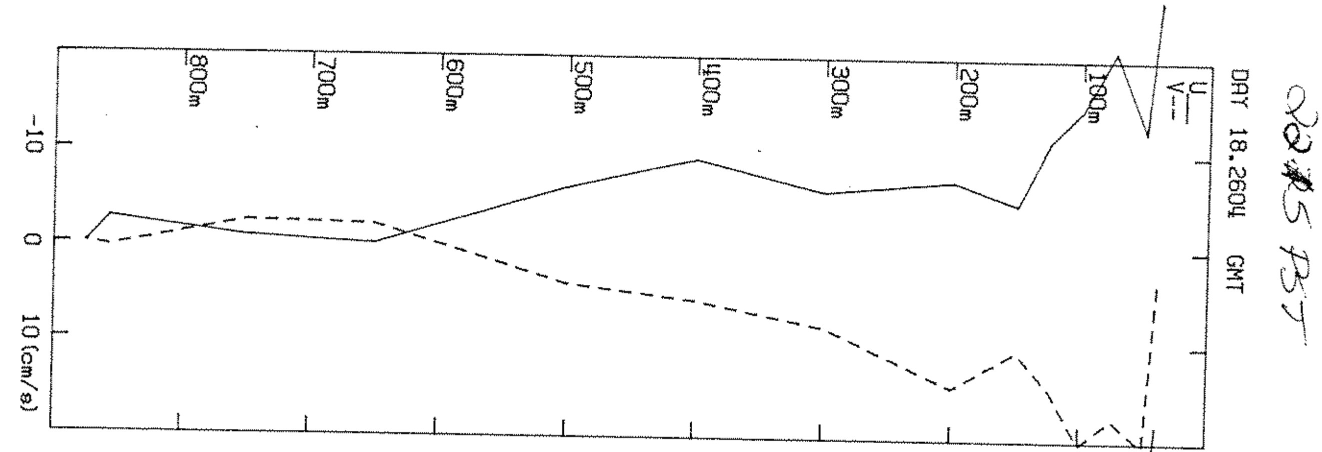
2145 PST

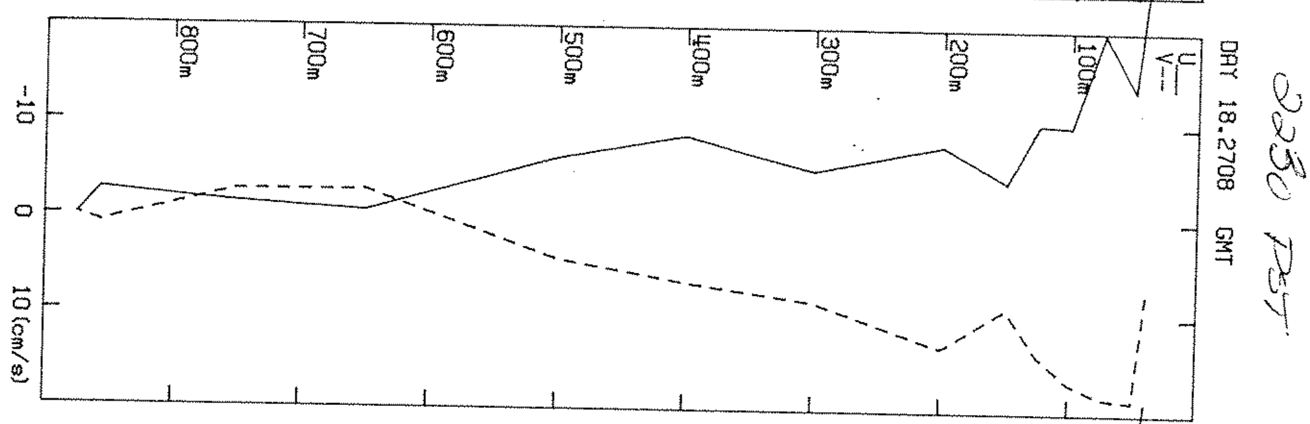


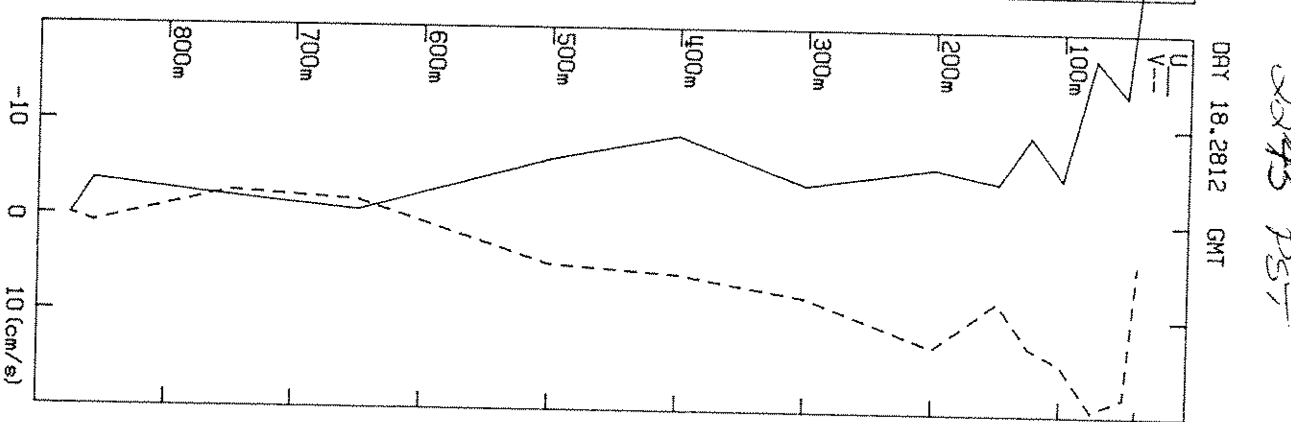
2200 PST

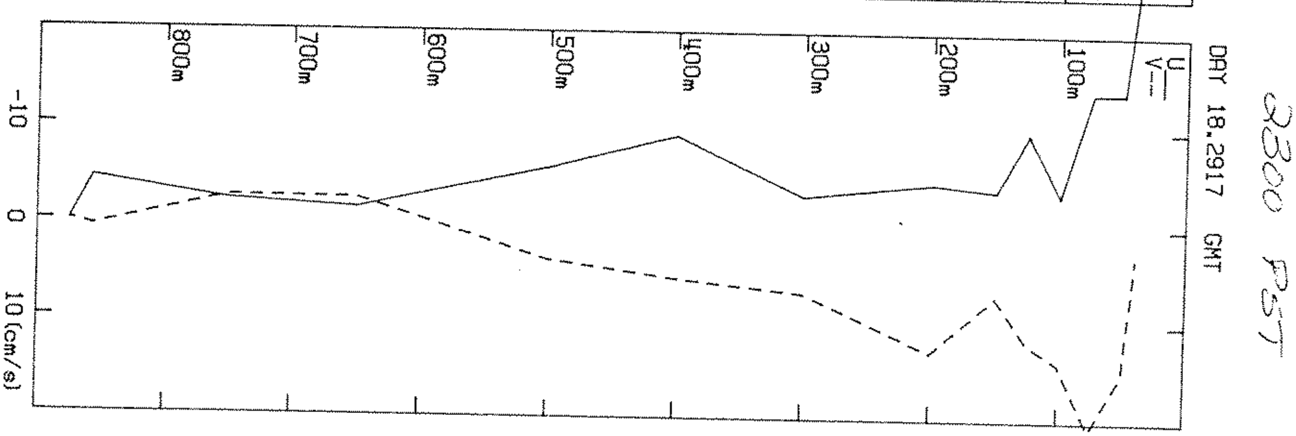


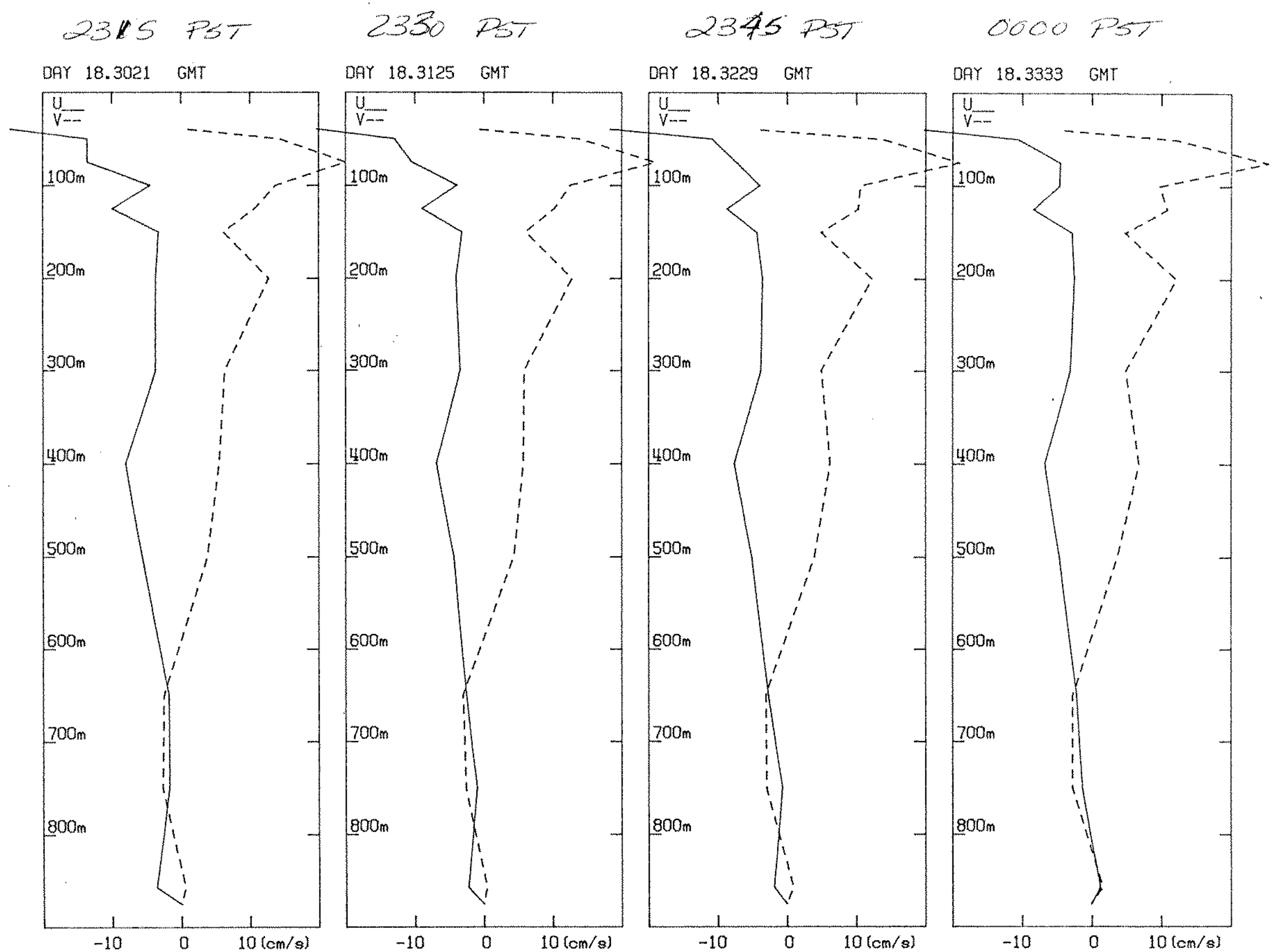
Jan 17 1988


DAY 18.2604 GMT
2215 PST
U —
V --
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

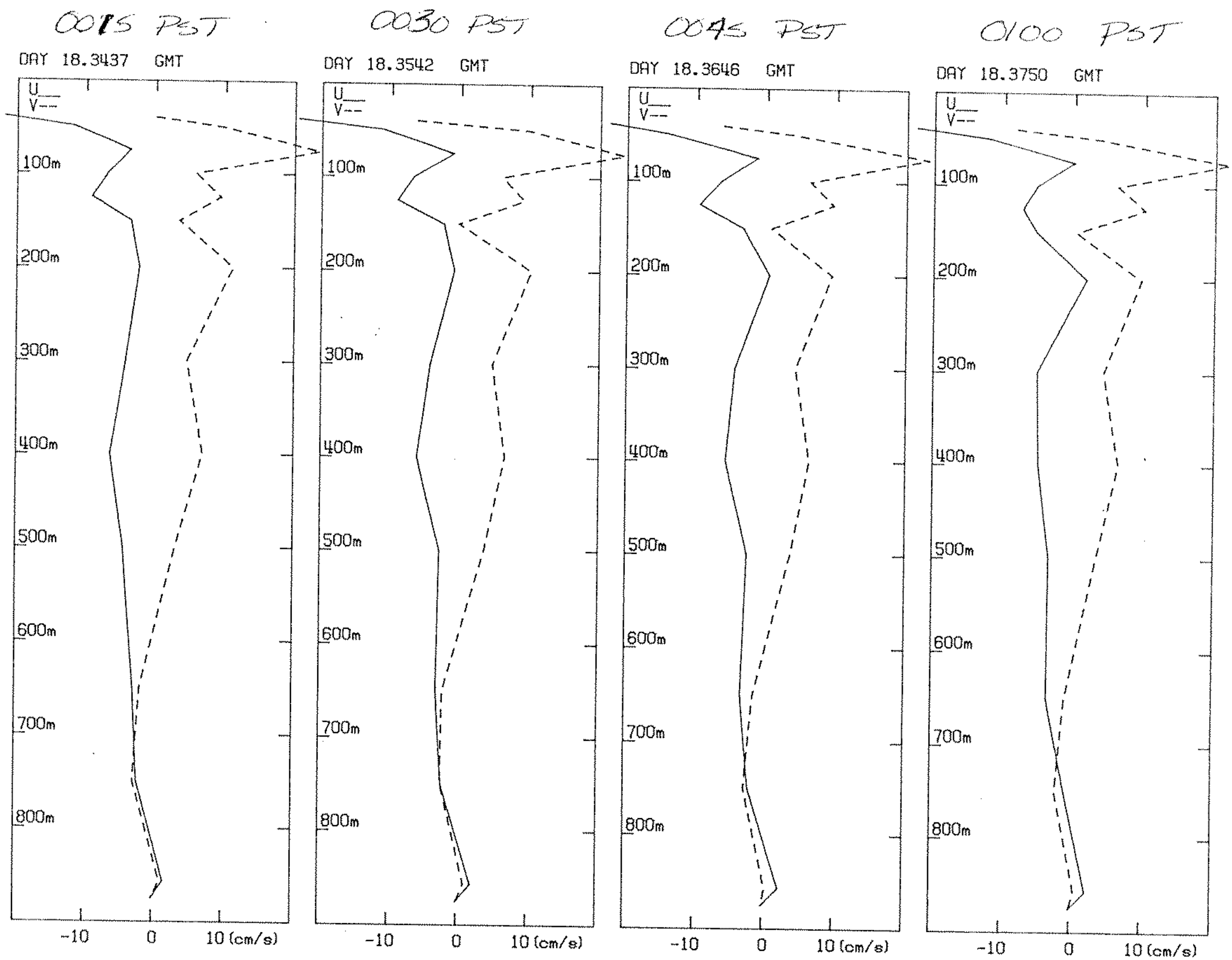

DAY 18.2708 GMT
2230 PST
U —
V --
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


DAY 18.2812 GMT
2245 PST
U —
V --
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

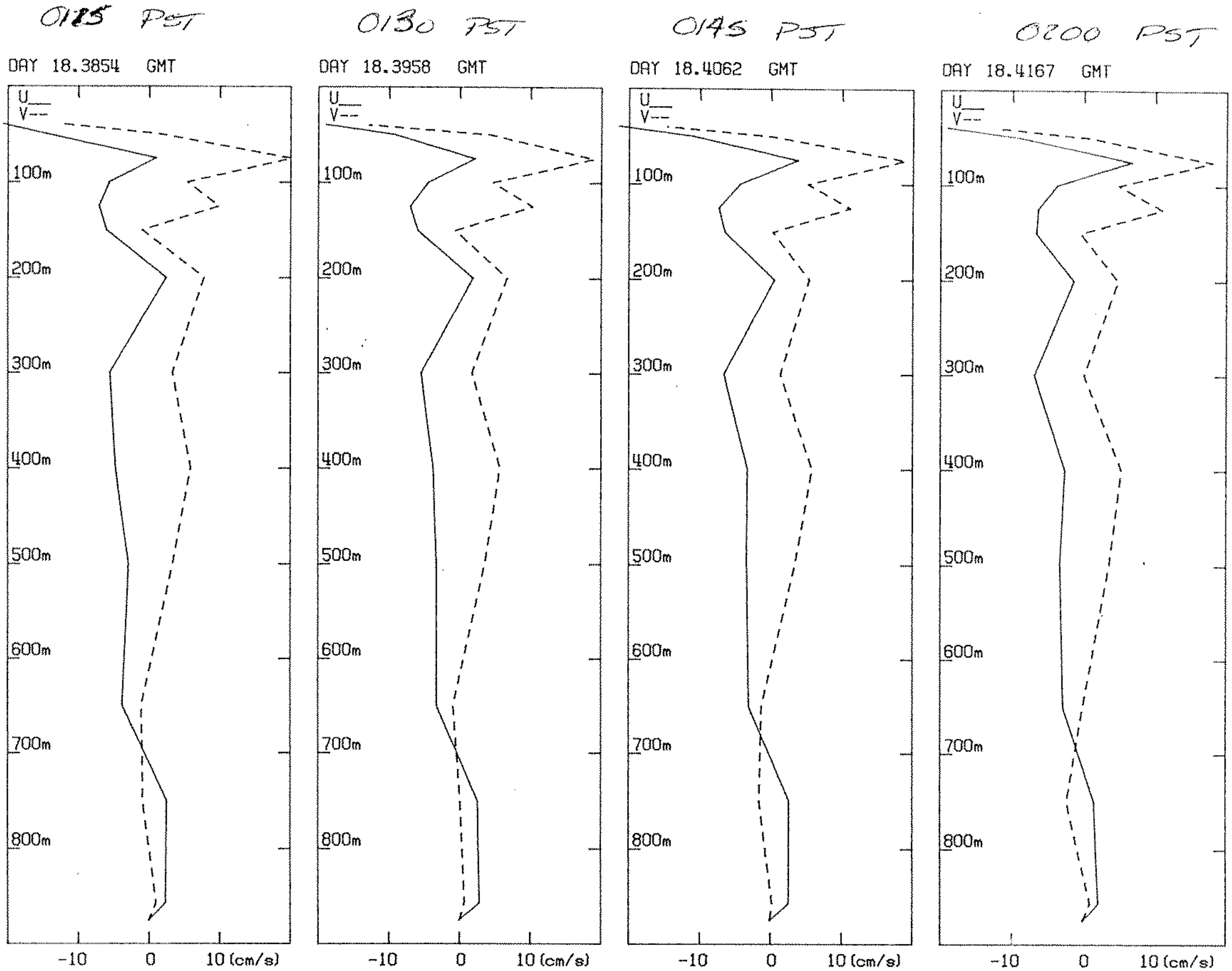

DAY 18.2917 GMT
2300 PST
U —
V --
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


2315 PST
DAY 18.3021 GMT
2330 PST
DAY 18.3125 GMT
2345 PST
DAY 18.3229 GMT
0000 PST
DAY 18.3333 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

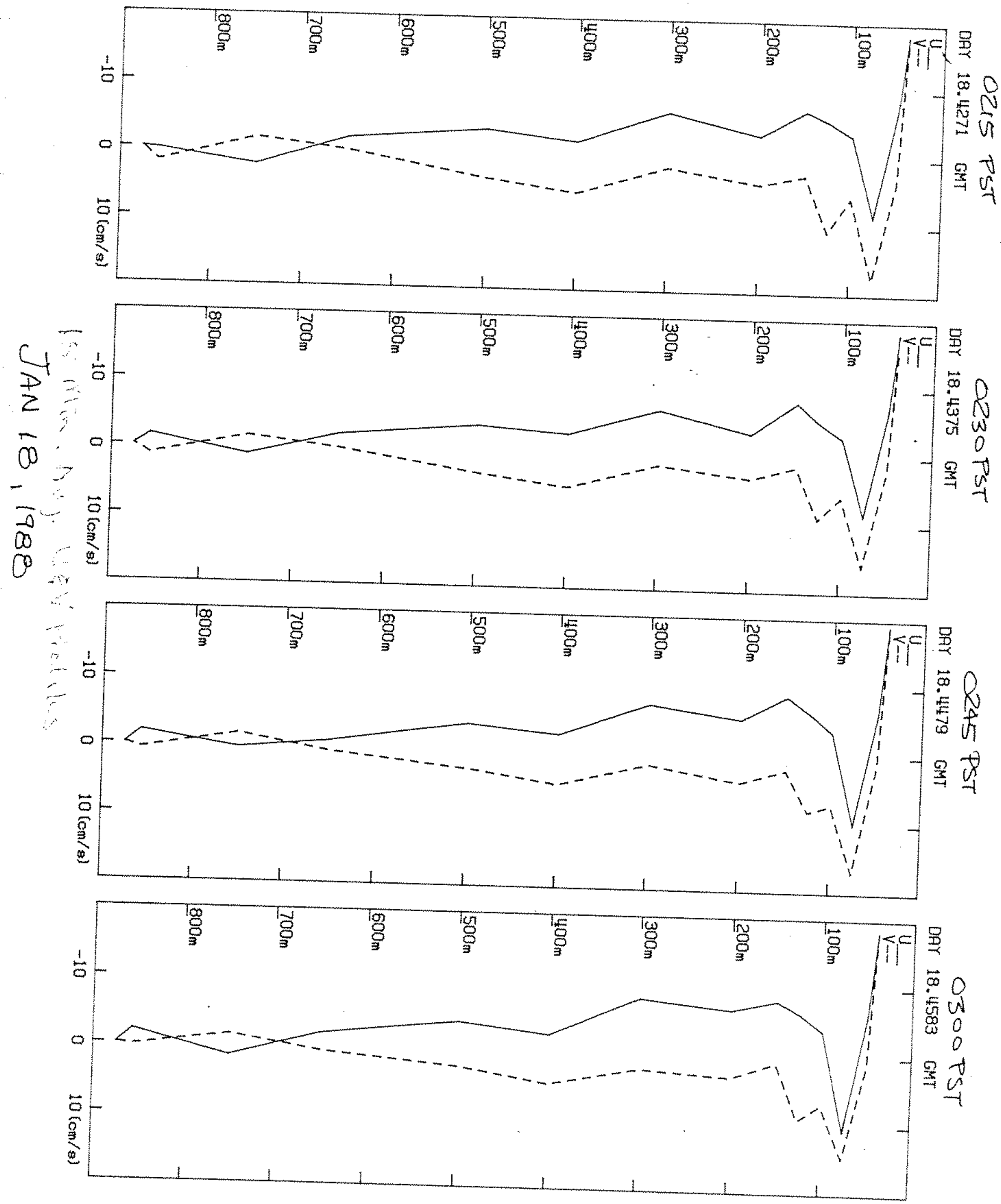
JAN 17, 1988

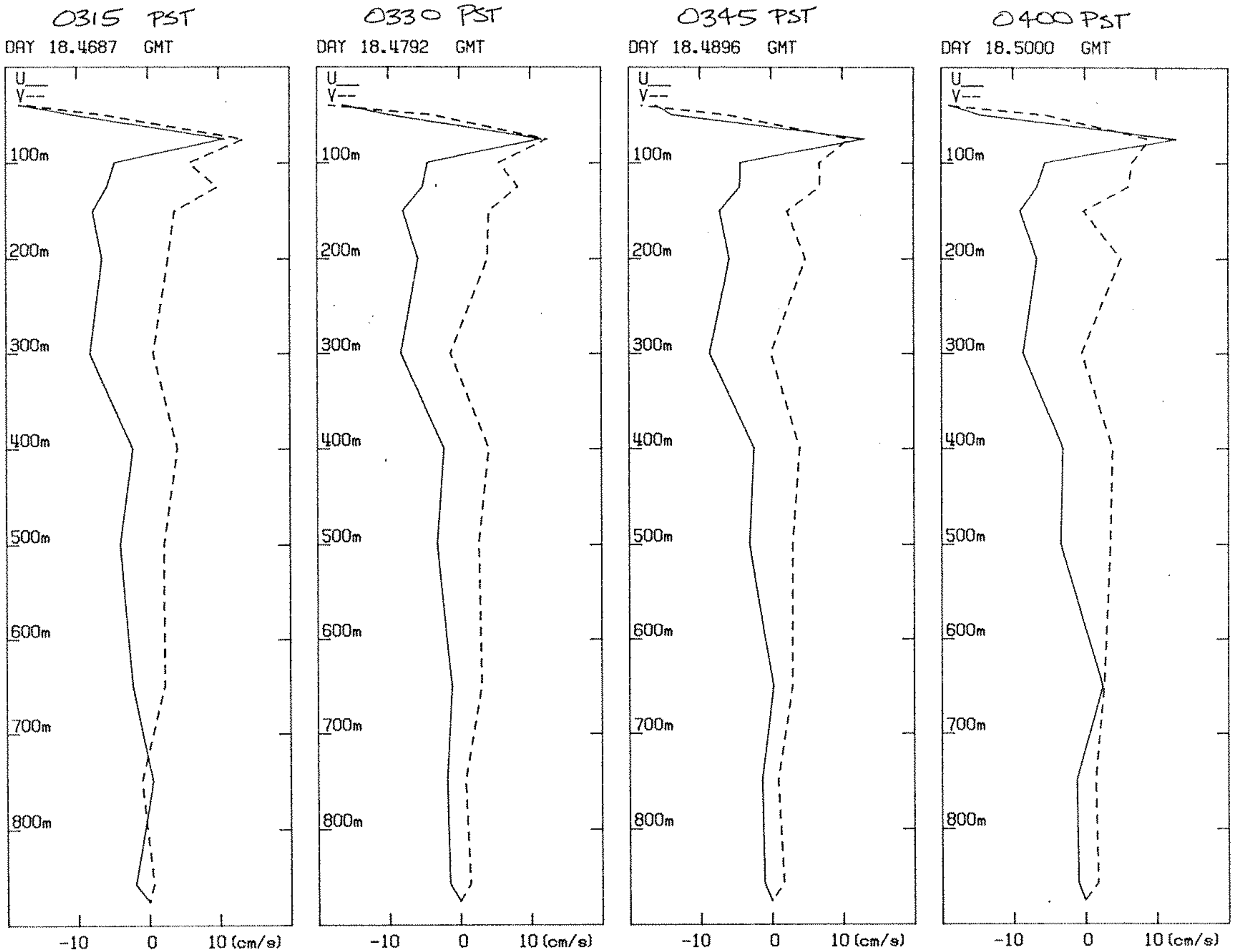

0015 PST
DAY 18.3437 GMT
0030 PST
DAY 18.3542 GMT
0045 PST
DAY 18.3646 GMT
0100 PST
DAY 18.3750 GMT
U___
V---
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 18, 1988

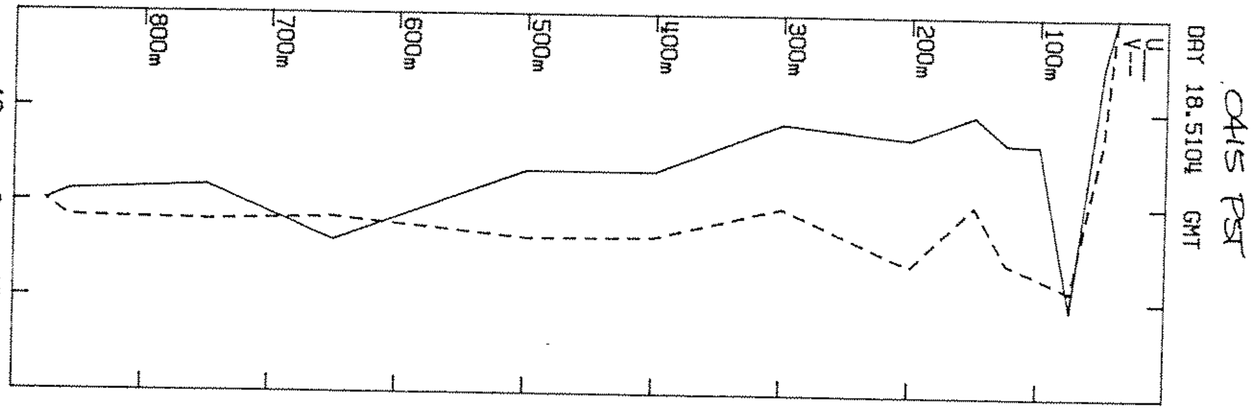

0115 PST
DAY 18.3854 GMT
0130 PST
DAY 18.3958 GMT
0145 PST
DAY 18.4062 GMT
0200 PST
DAY 18.4167 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 18, 1988


JAN 18, 1988
0215 PST
DAY 18.4271 GMT
0230 PST
DAY 18.4375 GMT
0245 PST
DAY 18.4479 GMT
0300 PST
DAY 18.4583 GMT
U —
V --
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


0315 PST
DAY 18.4687 GMT
0330 PST
DAY 18.4792 GMT
0345 PST
DAY 18.4896 GMT
0400 PST
DAY 18.5000 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

JAN 18, 1988


0415 PST
DAY 18.5104 GMT
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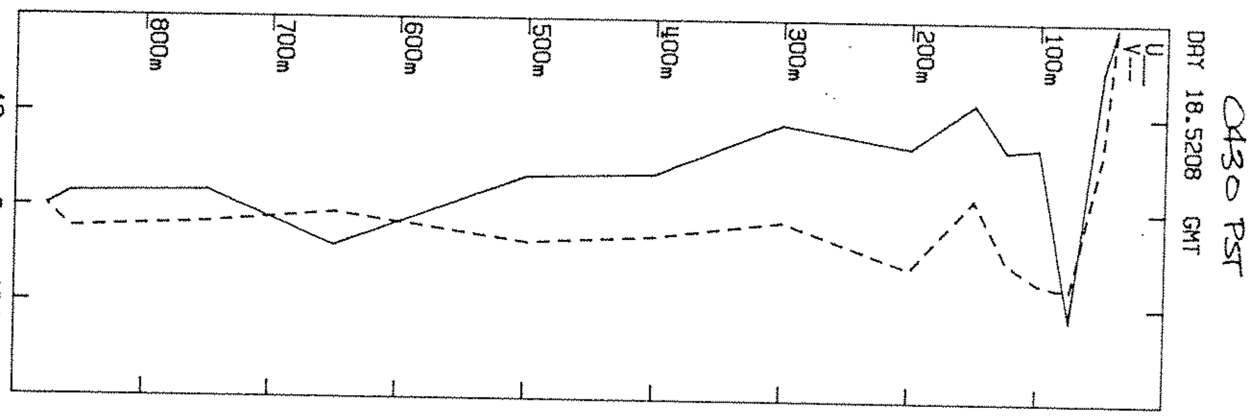
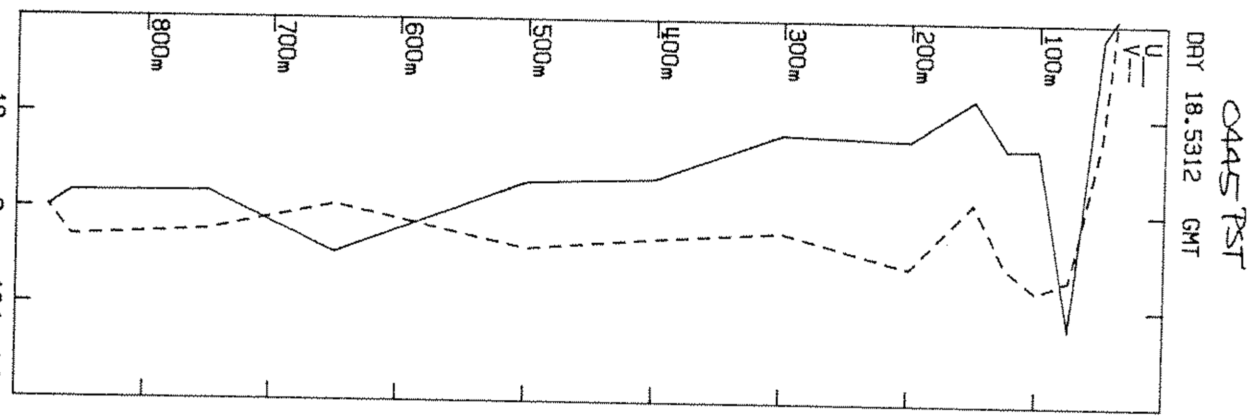
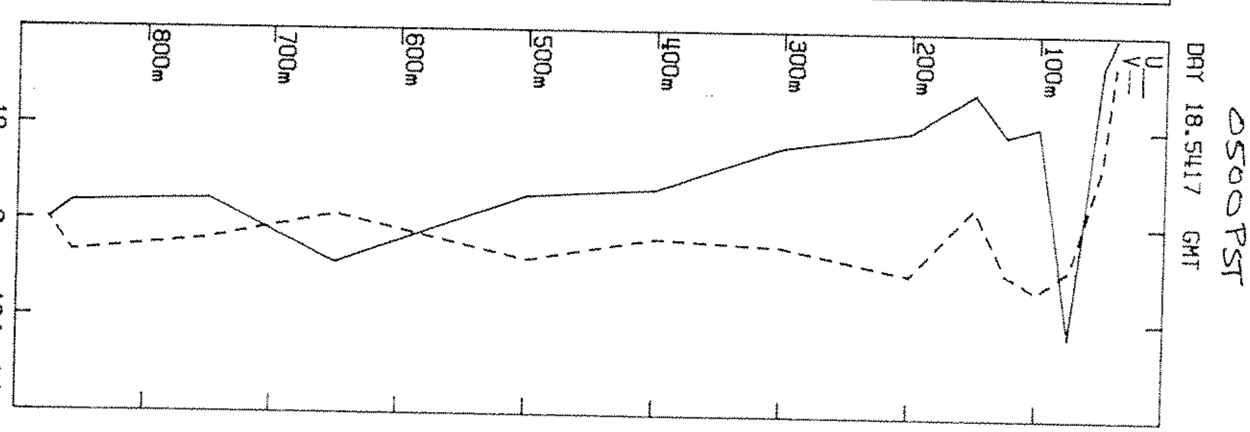
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


0430 PST
DAY 18.5208 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

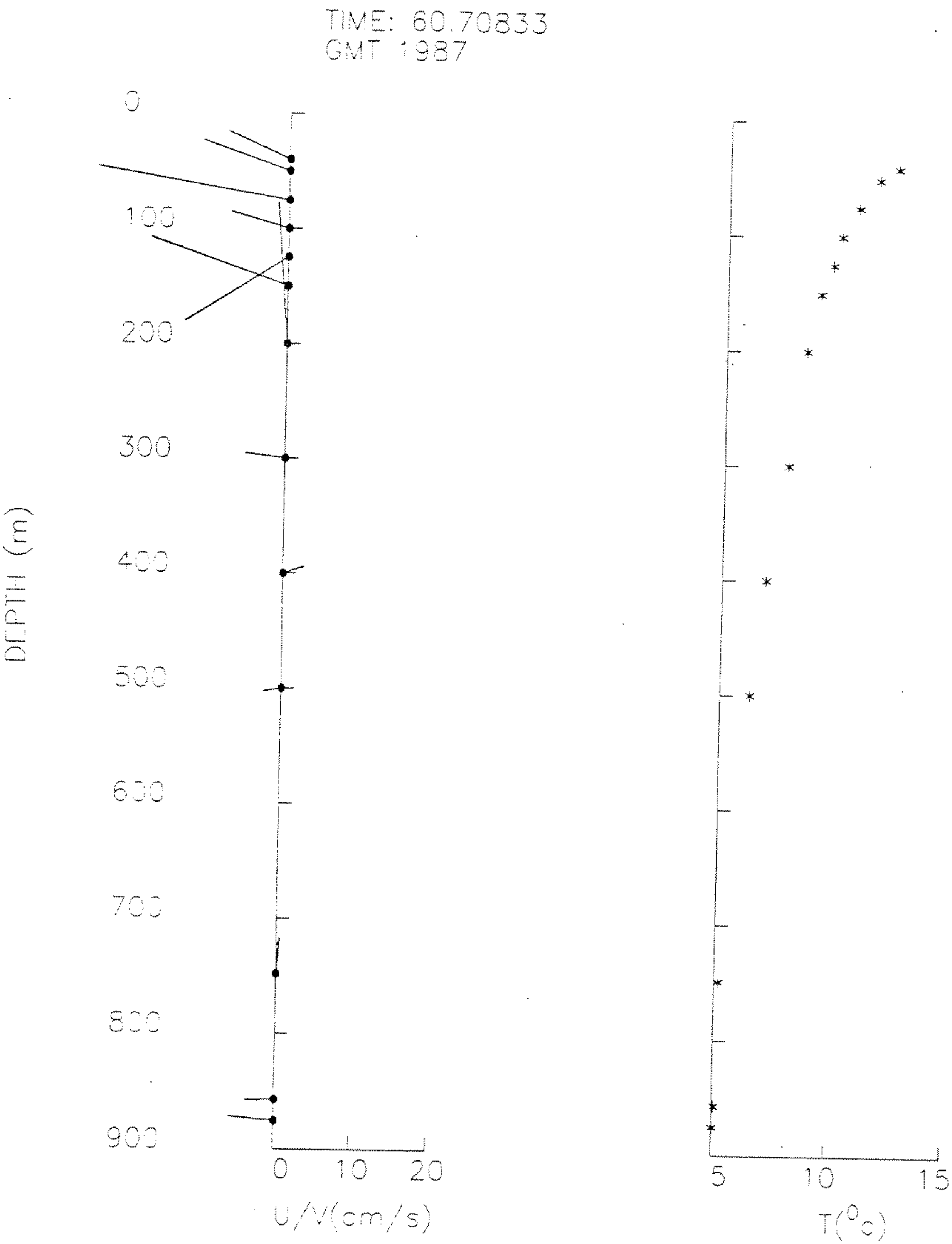

0445 PST
DAY 18.5312 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)


0500 PST
DAY 18.5417 GMT
U
V
100m
200m
300m
400m
500m
600m
700m
800m
-10
0
10 (cm/s)

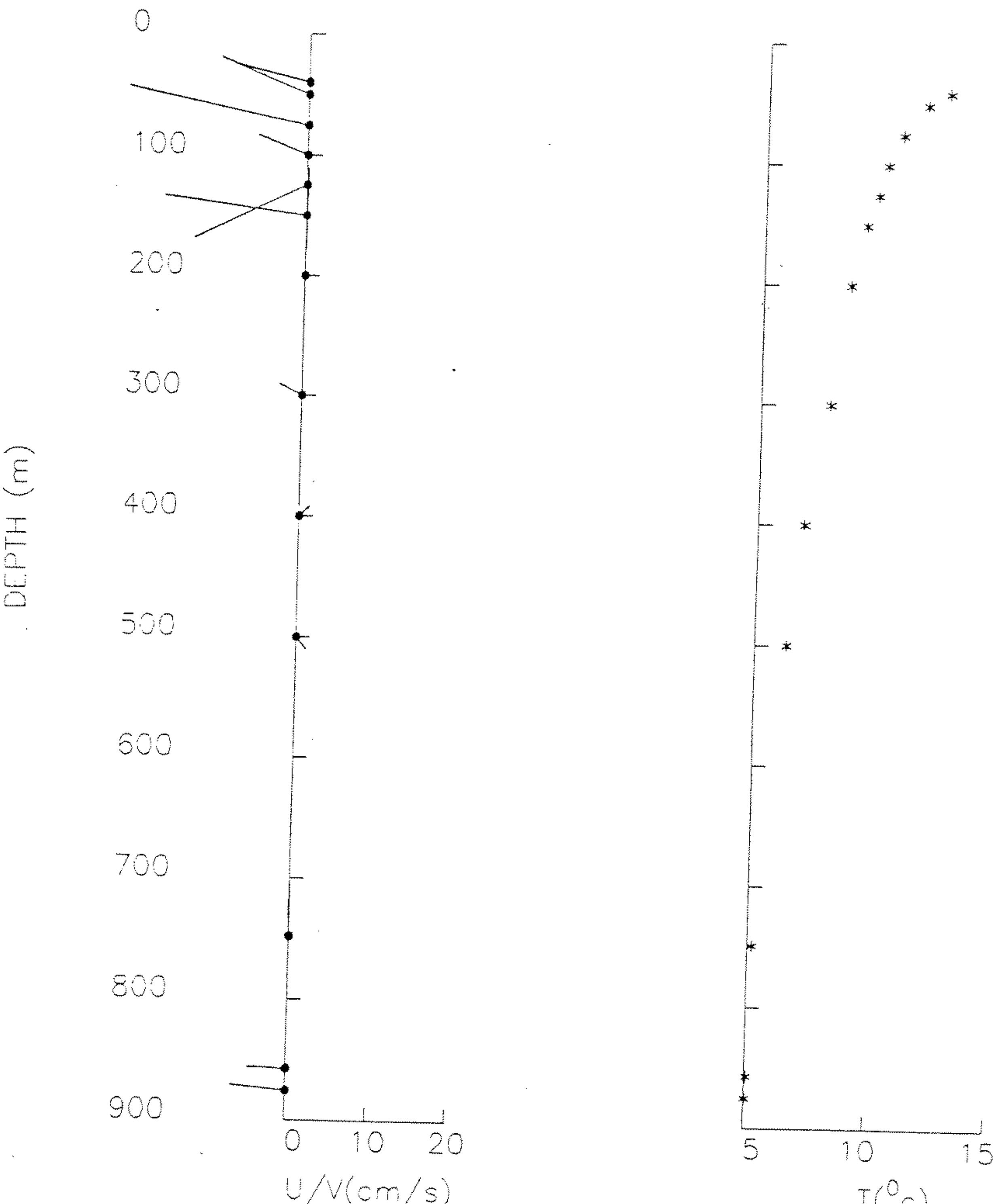
JAN 18 1988

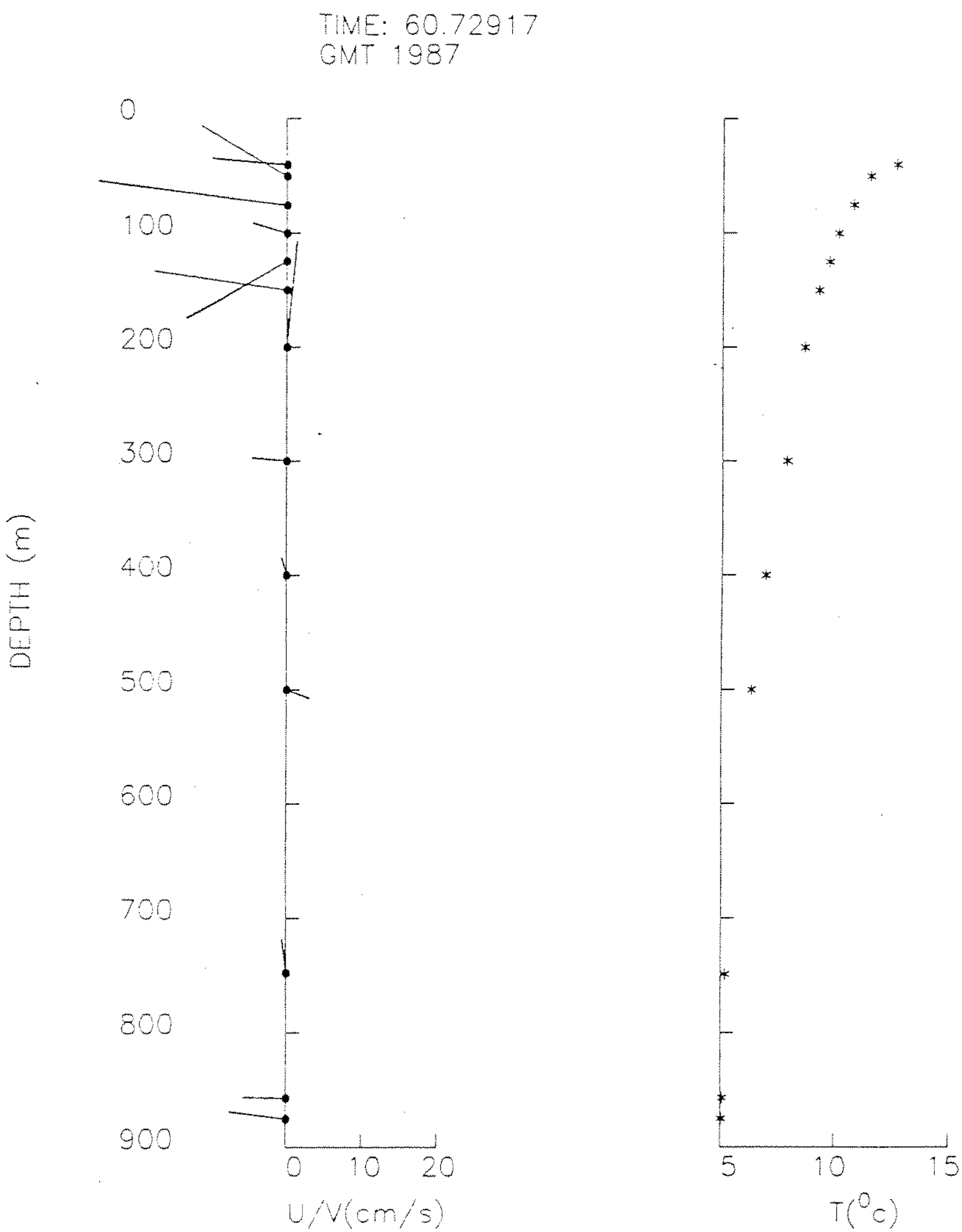
15-MINUTE-AVERAGE U&V Vectors and T Profile Plots

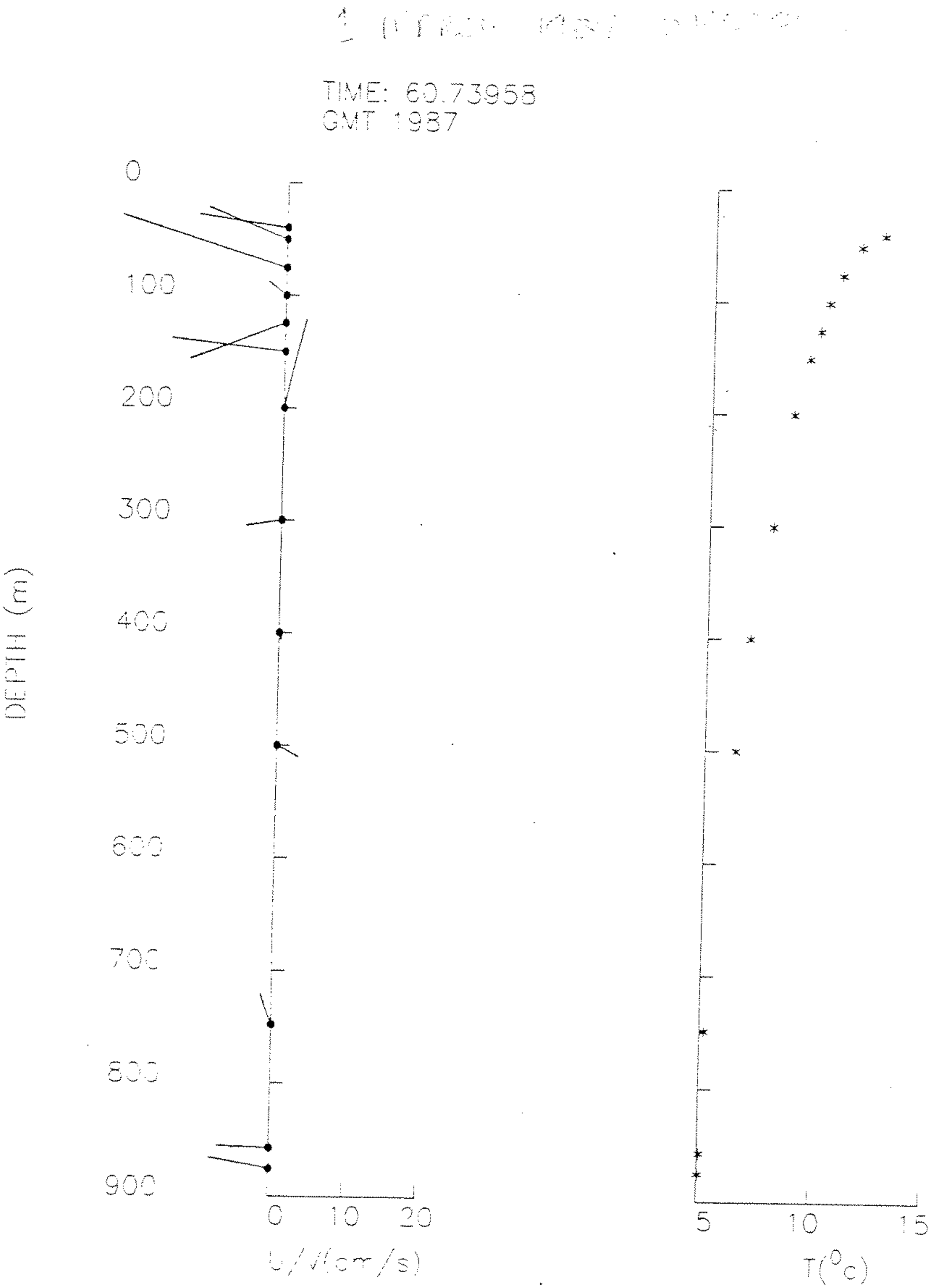
1 MARCH 1987



TIME: 60.71875
GMT 1987

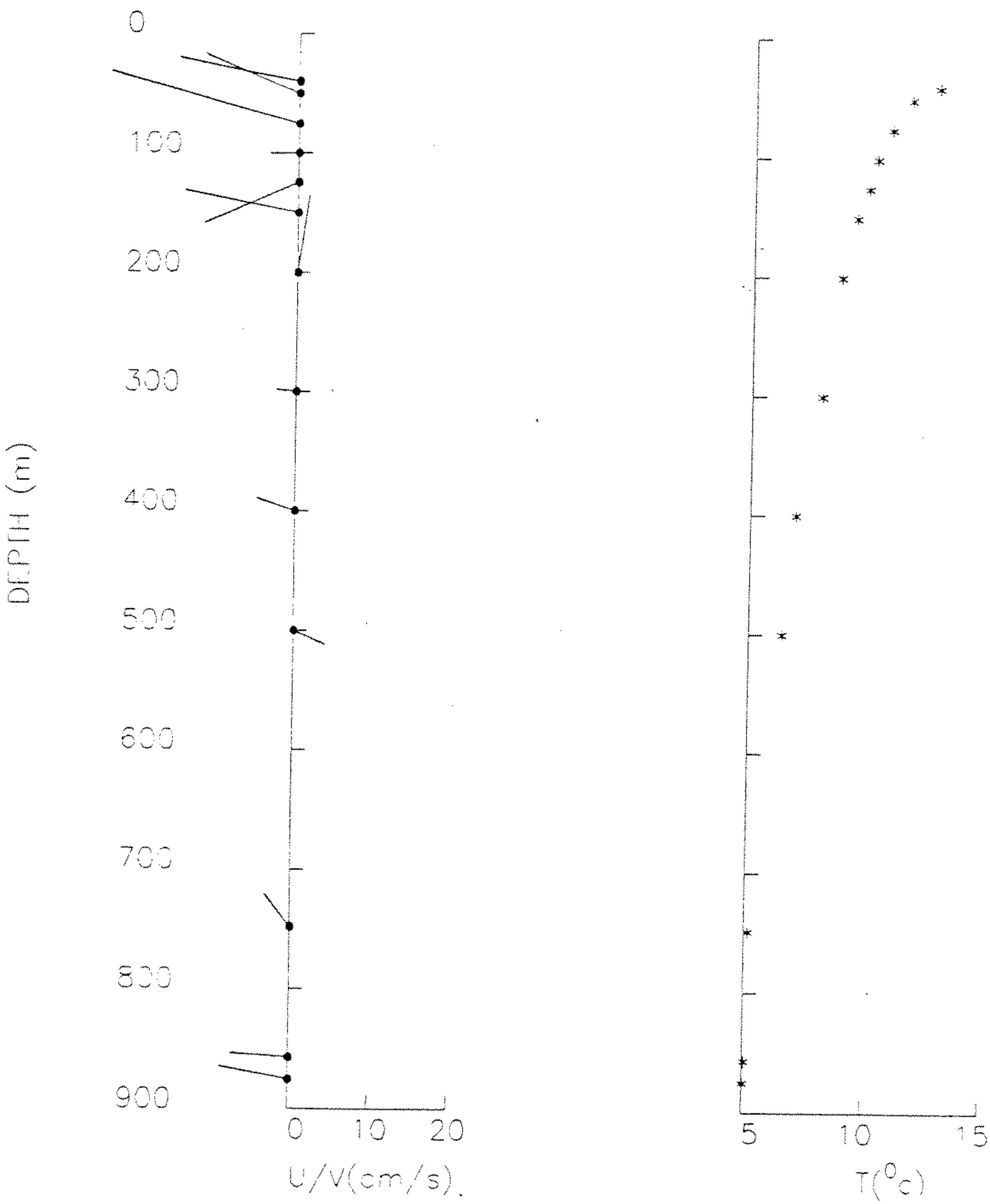



TIME: 60.72917
GMT 1987
0
100
200
300
400
500
600
700
800
900
DEPTH (m)
0
10
20
U/V(cm/s)
5
10
15
T(⁰c)


TIME: 60.73958
GMT 1987
0
100
200
300
400
500
600
700
800
900
DEPTH (m)
0 10 20
u/v(cm/s)
5 10 15
T(°c)

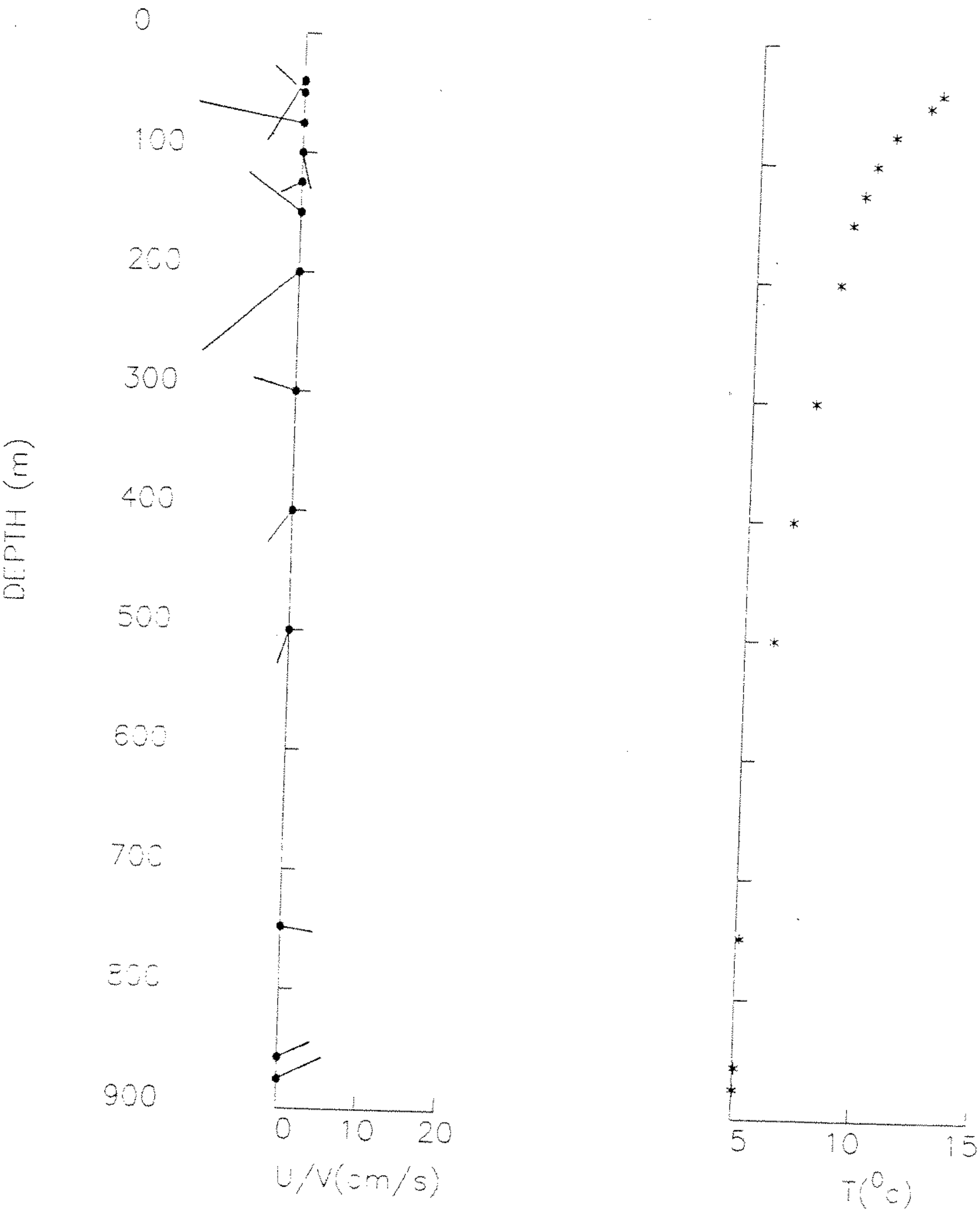
1 MARCH 1987

TIME: 60.75000
GMT 1987



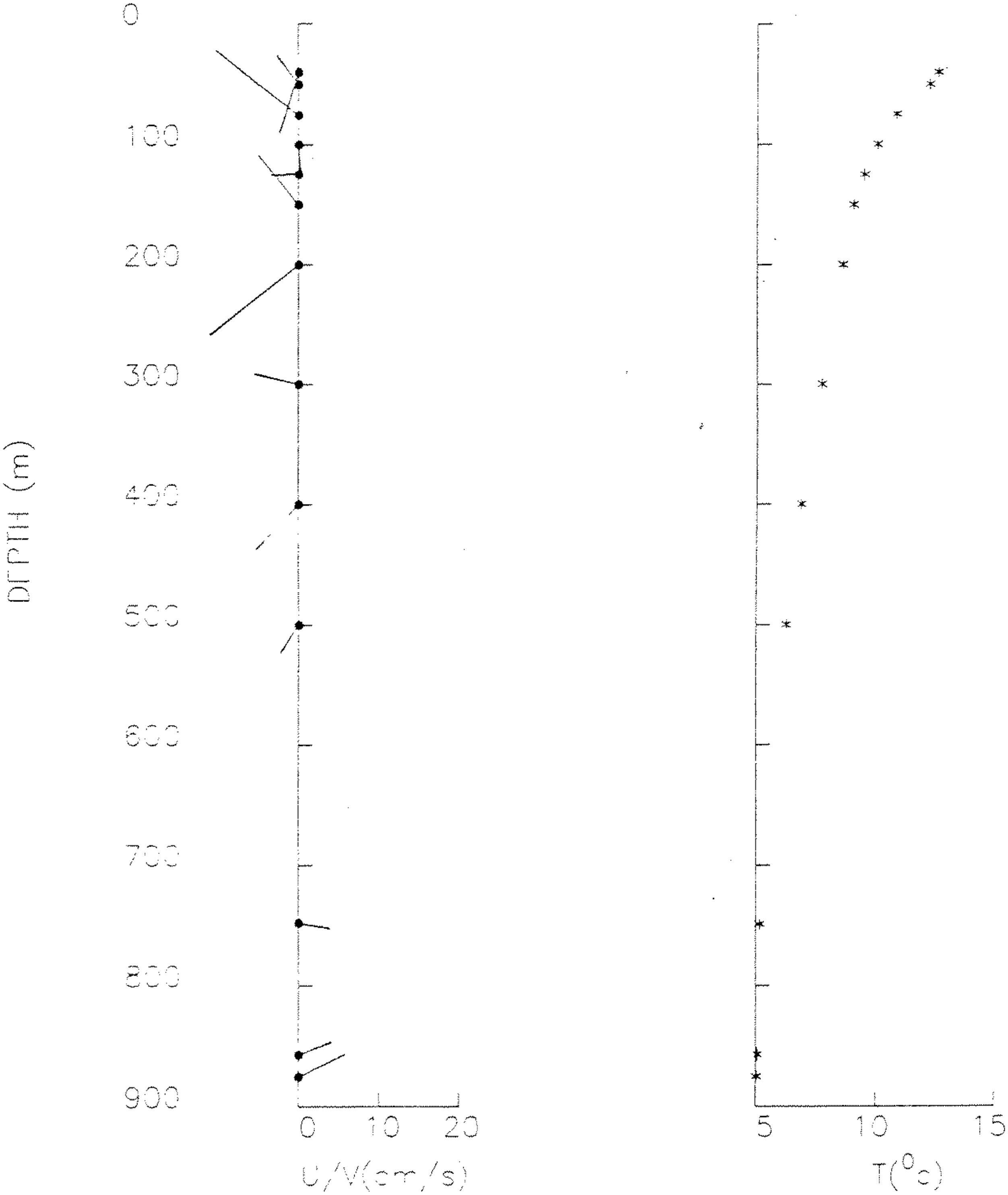
5 MAR 1987 1000 PST

TIME: 64.75000
GMT 1987



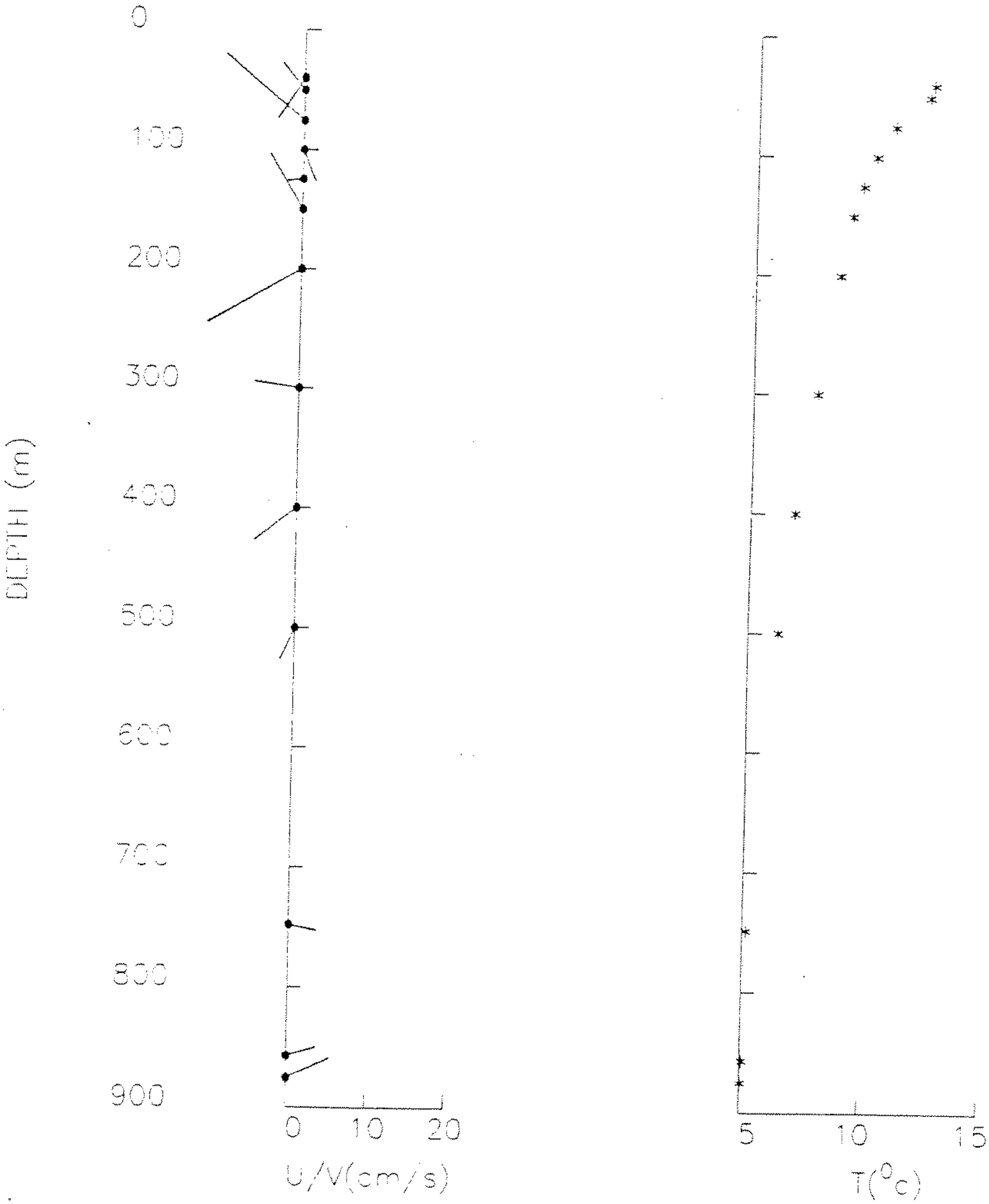
5 MARCH 1984 1015 PST

TIME: 64.76042
GMT 1987



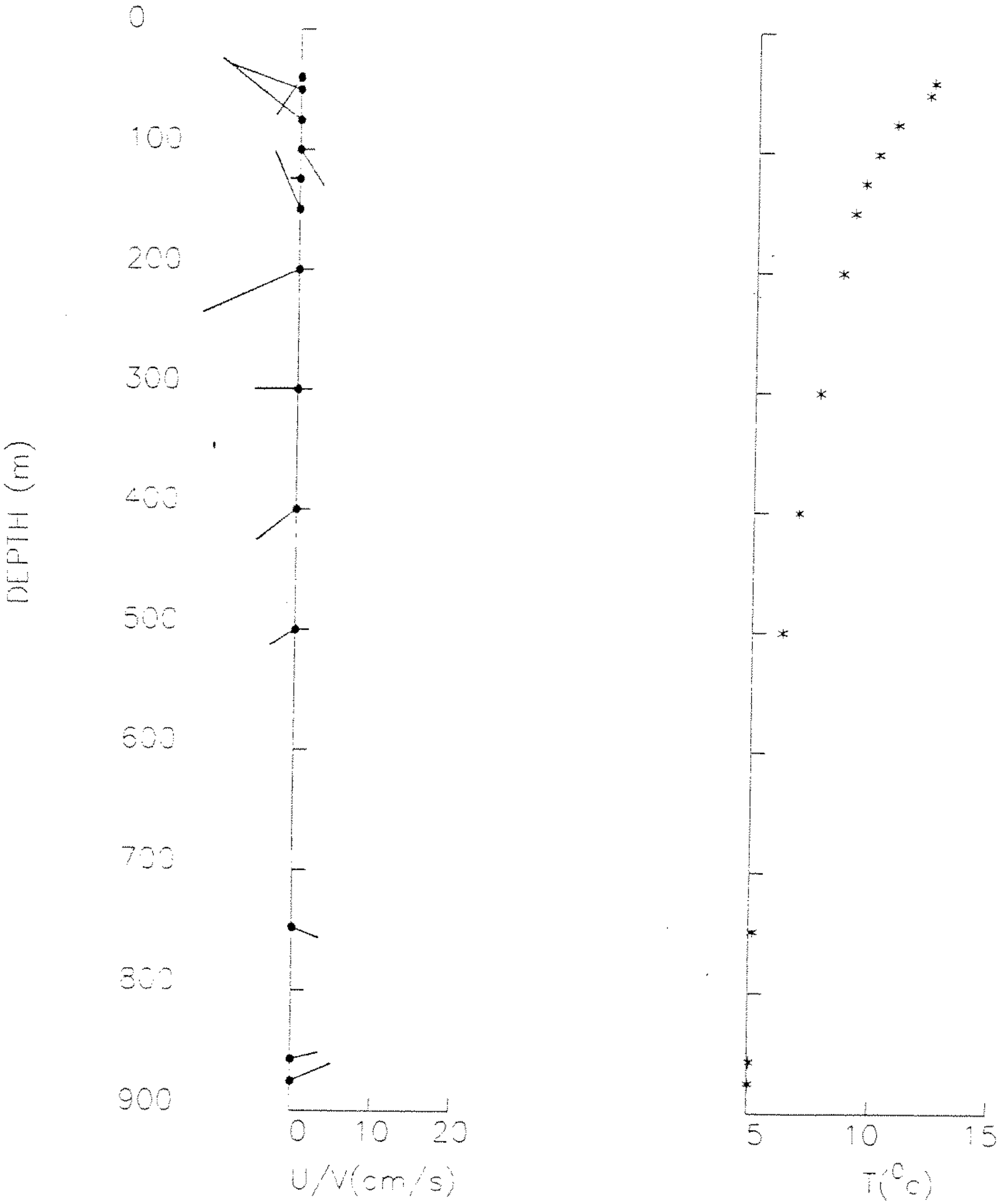
5 MARCH 1985 1030 [illegible]

TIME: 64.77084
GMT 1987



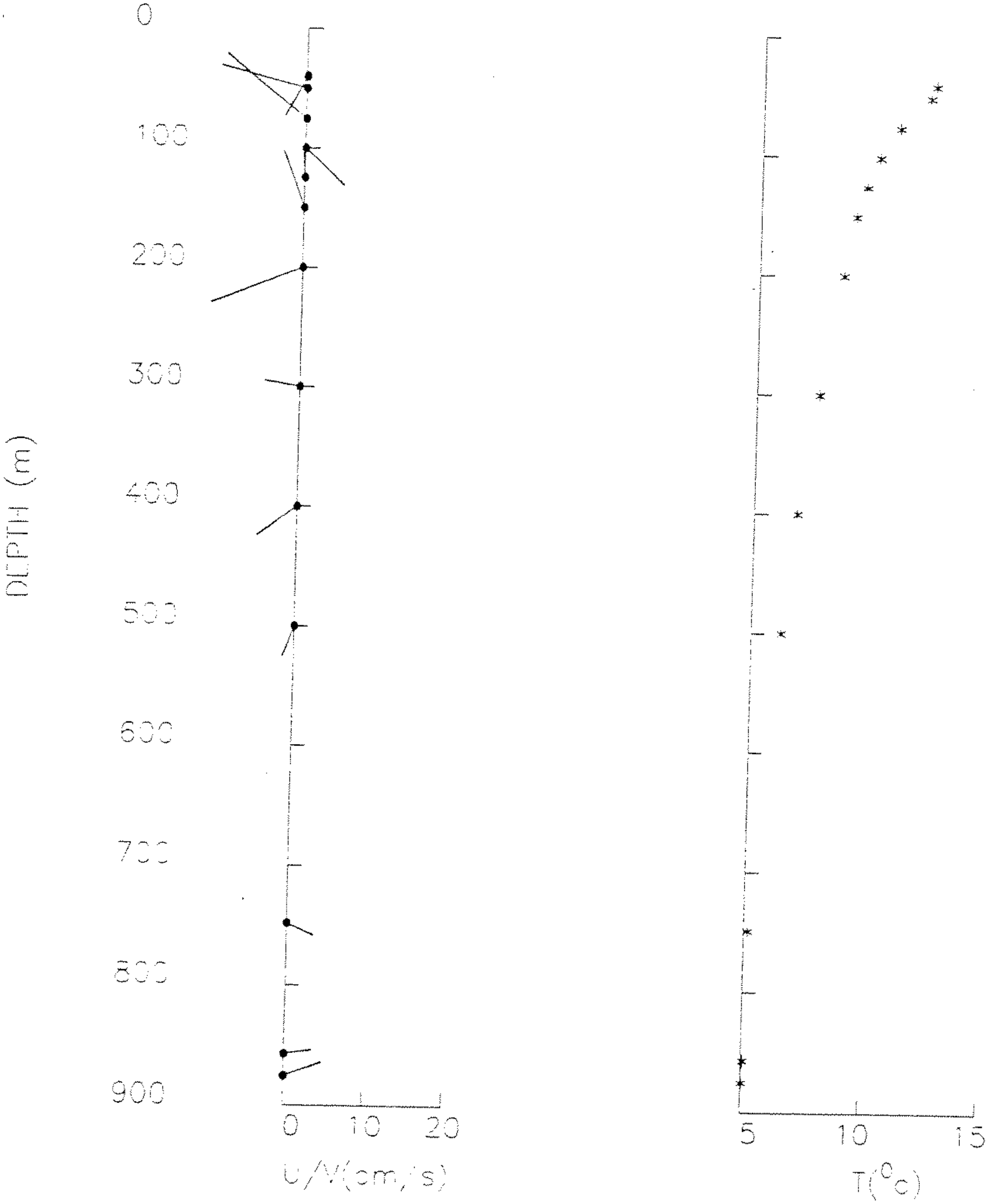
5 MARCH 1987 1045

TIME: 64.78125
GMT 1987



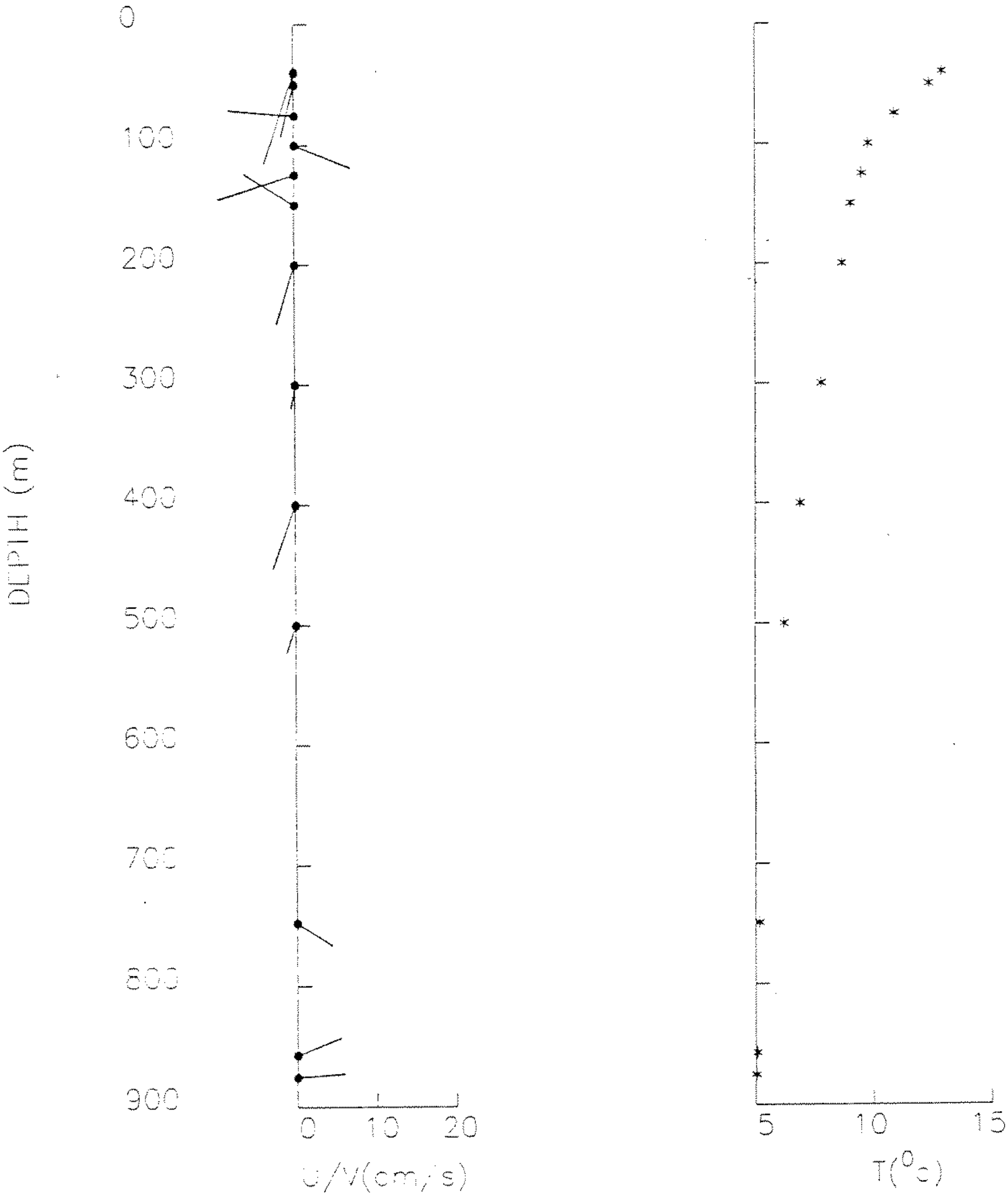
5 MARCH 1987 1100 PST

TIME: 64.79167
GMT 1987

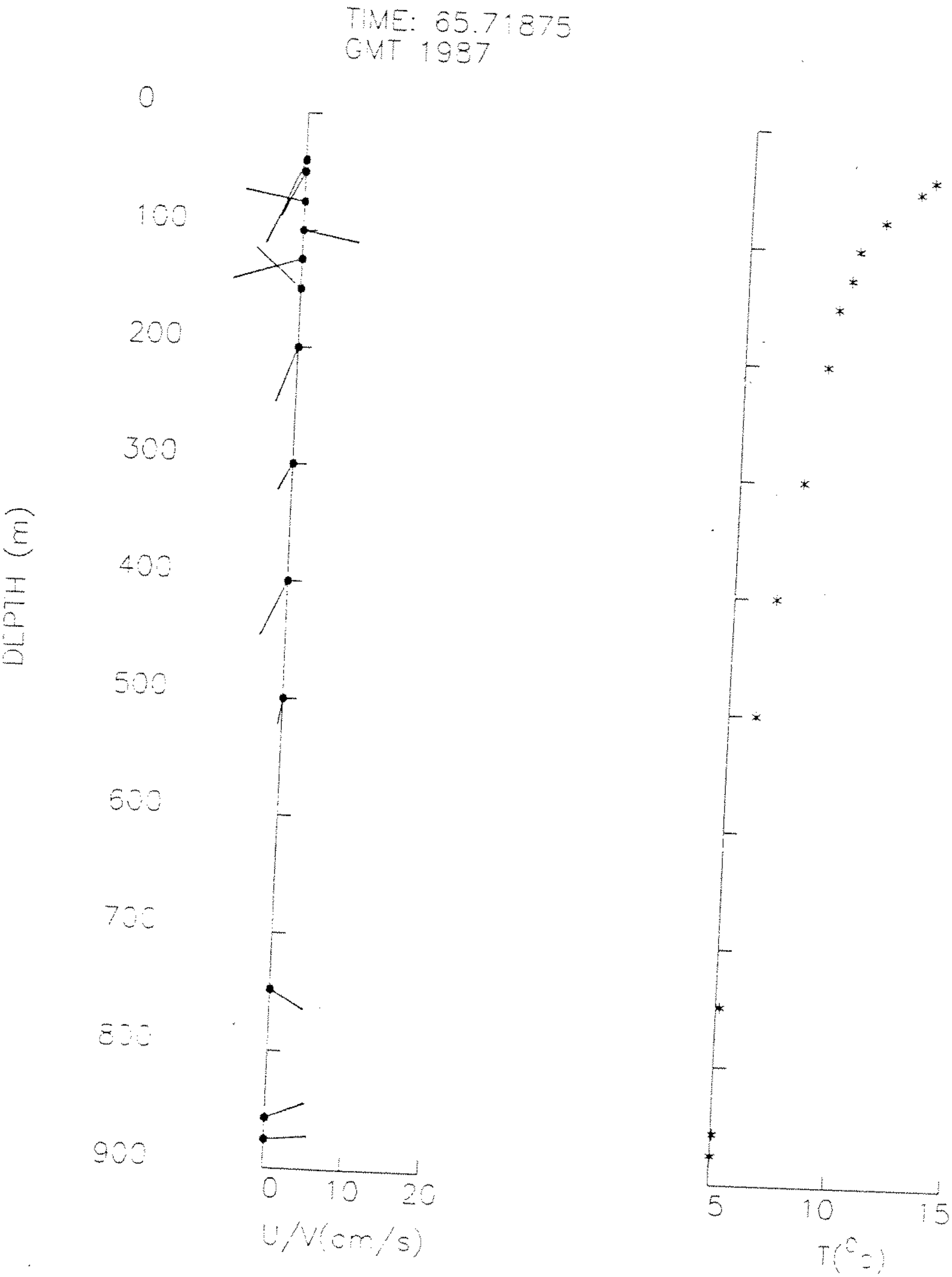


6 MARCH 1987 0900 PST

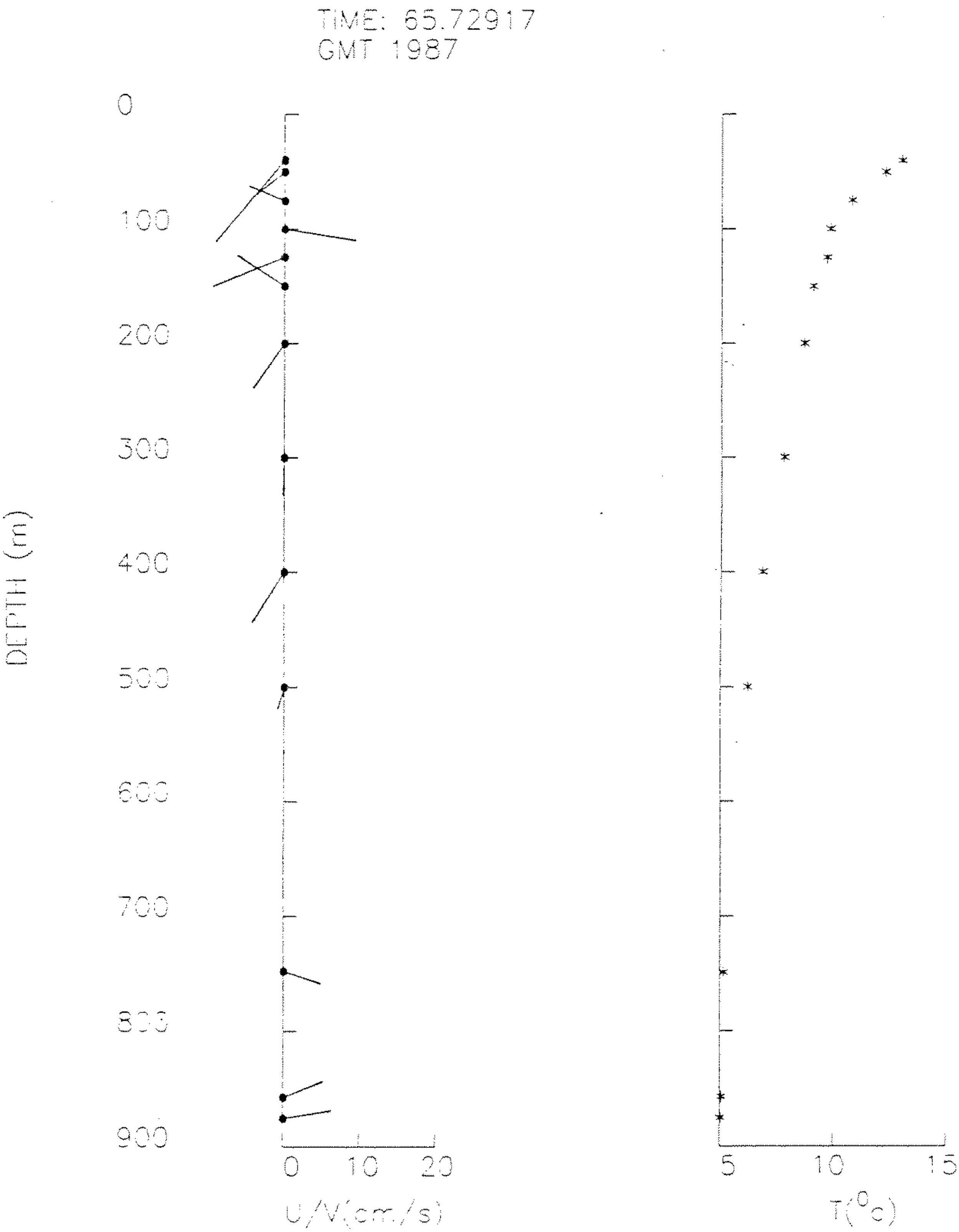
TIME: 65.70834
GMT 1987



6 MARCH 1987 09:15 PST

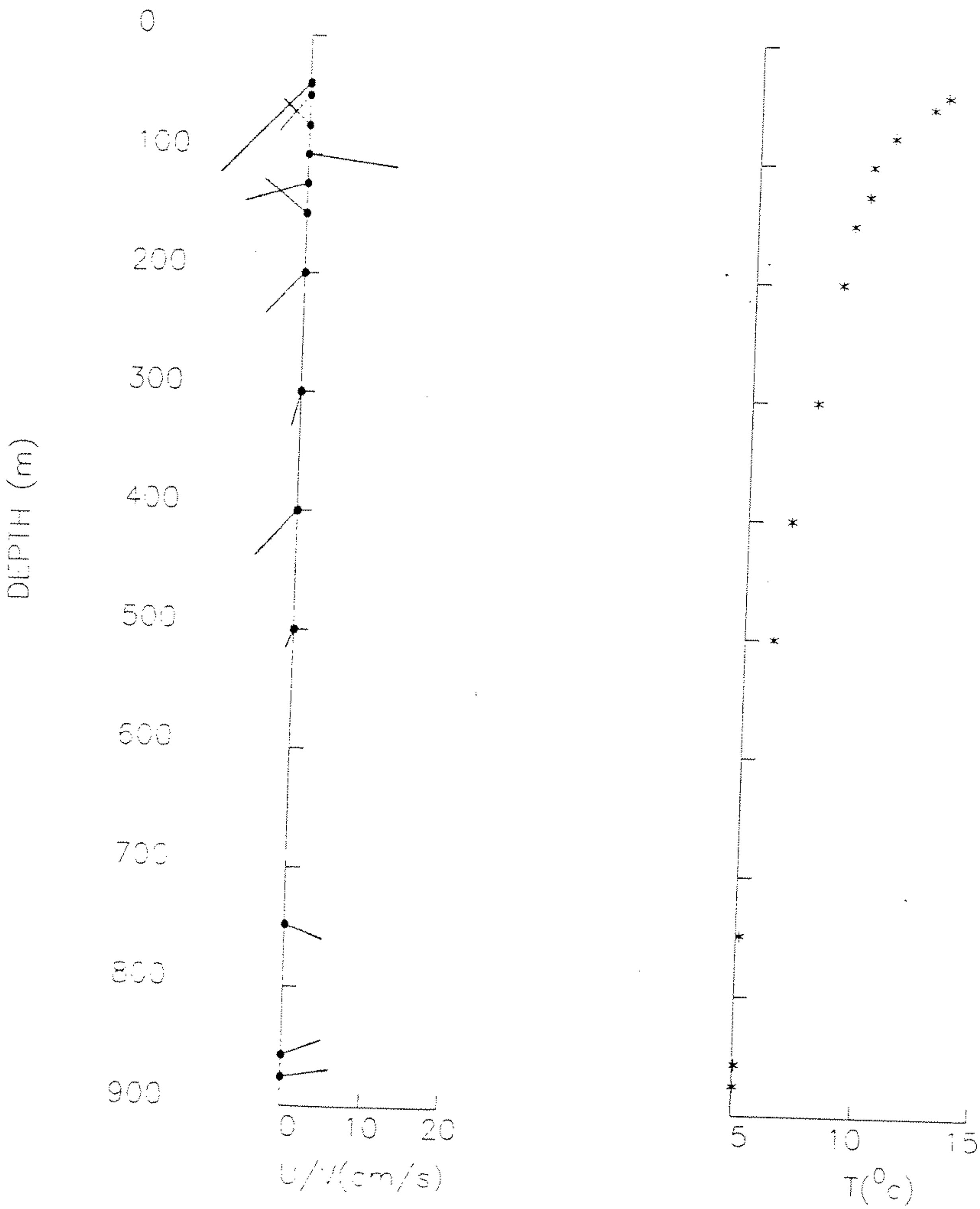


6 MARCH 1987 0930

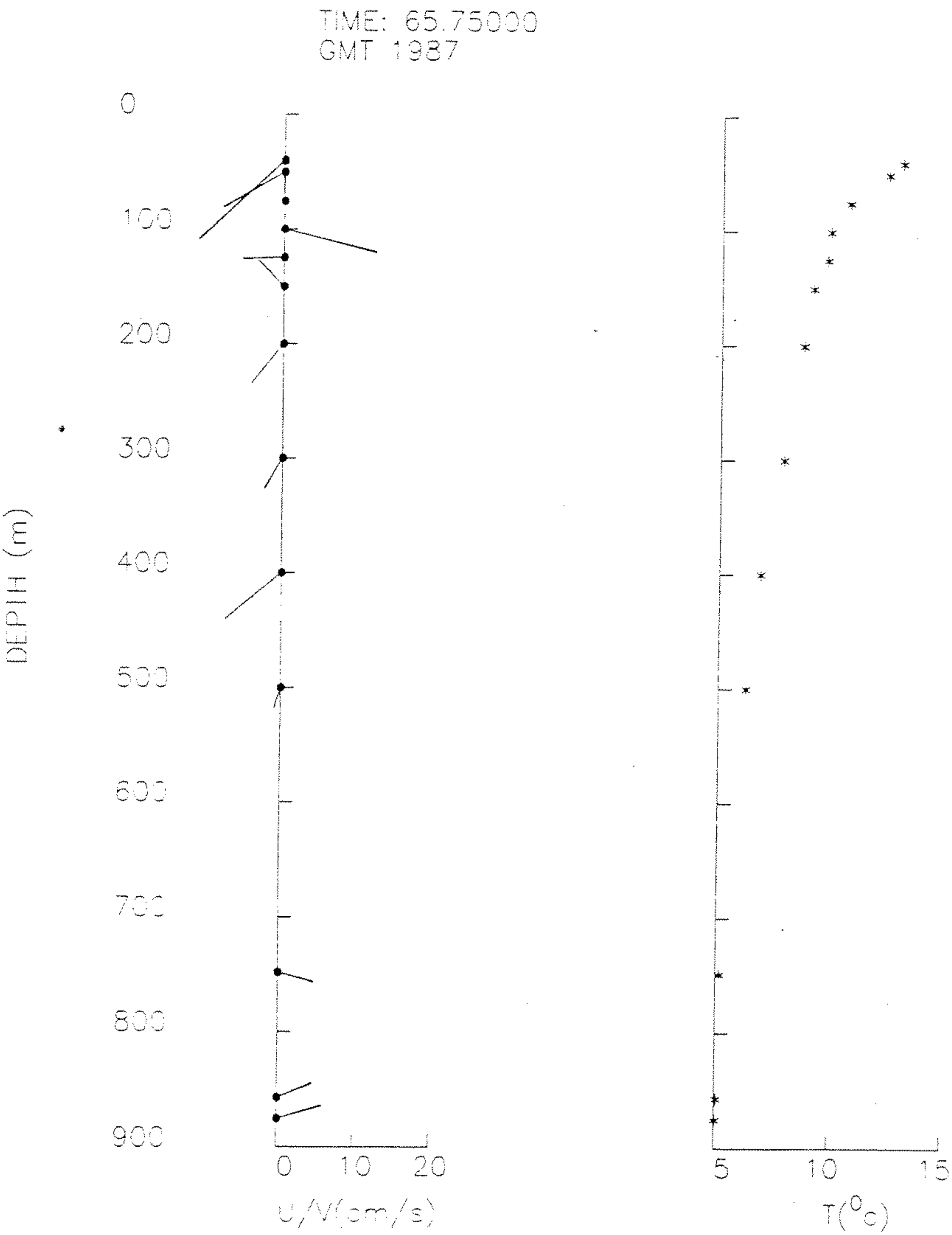


6 MARCH 1987

TIME: 65.73959
GMT 1987

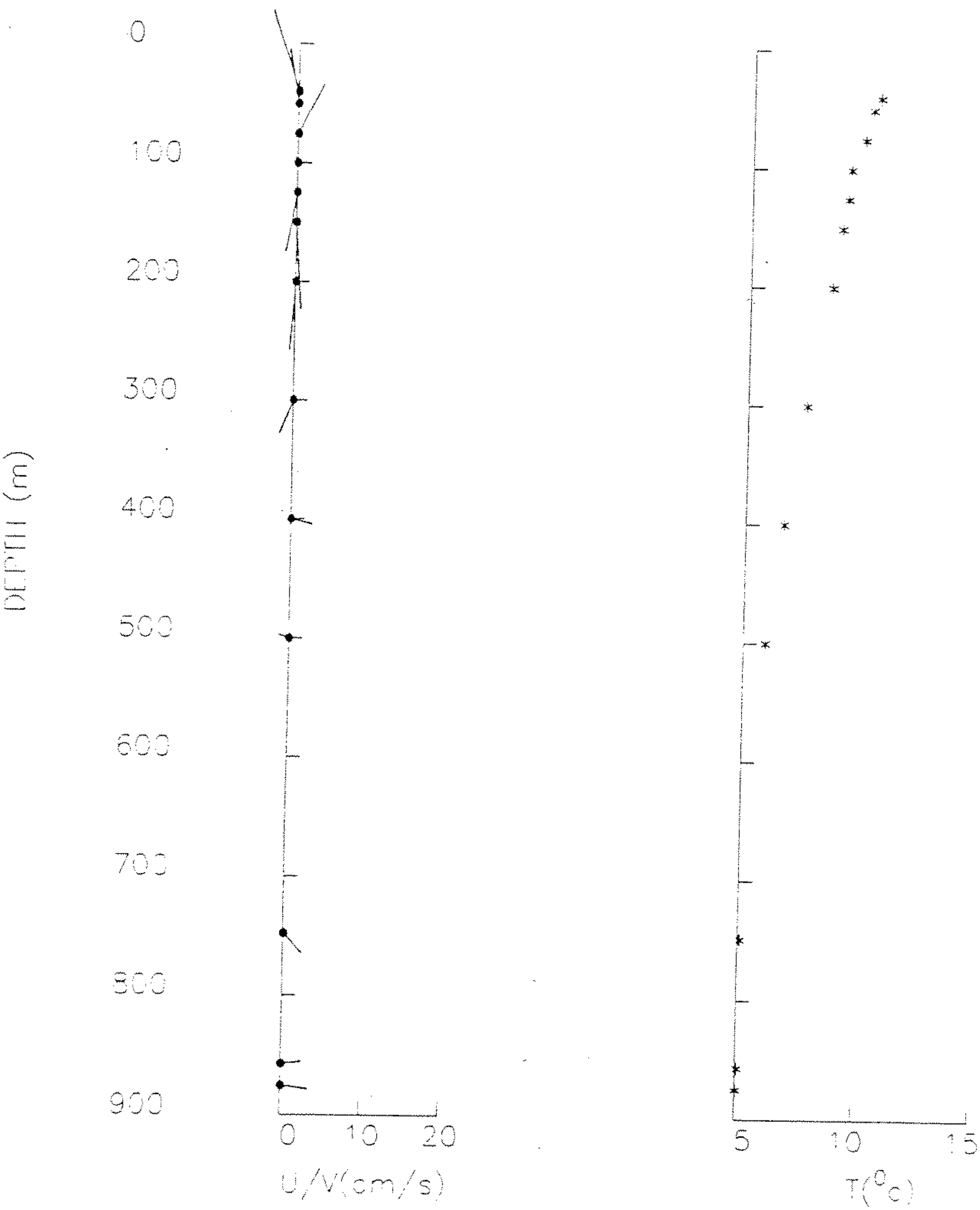


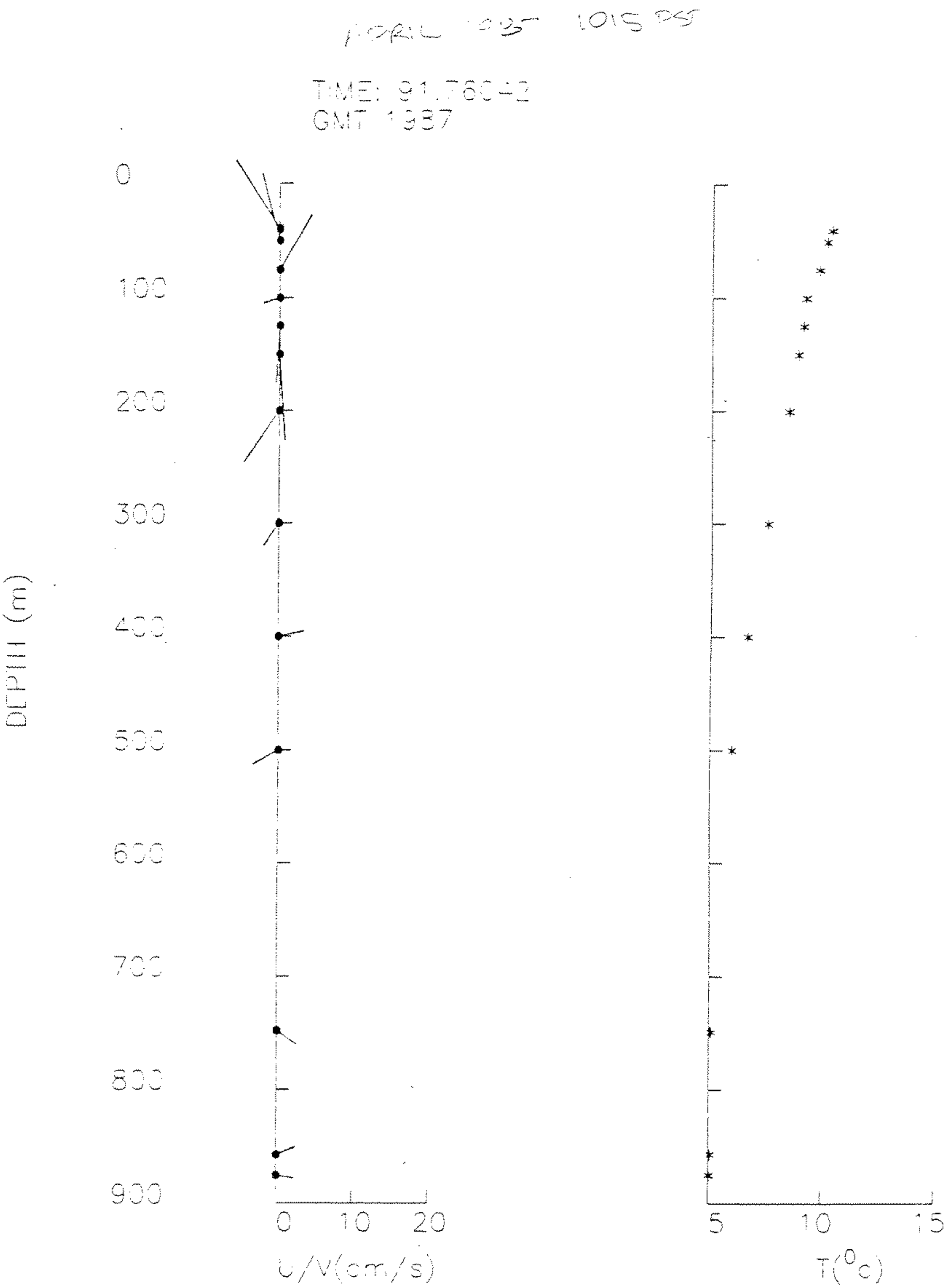
6 MARCH 1987 1000



1 APR 1987 1800 PST

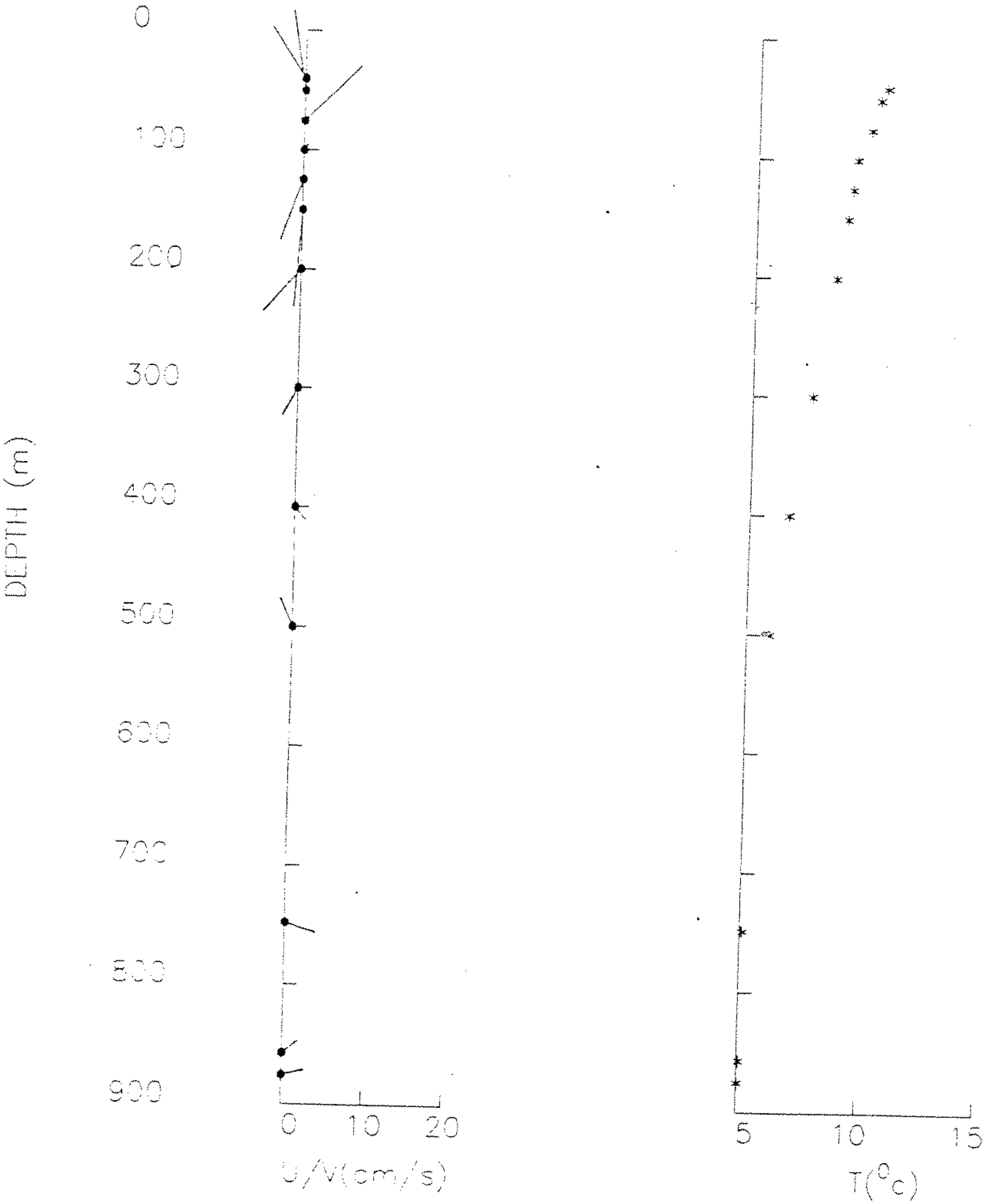
TIME: 91.75000
GMT 1987




APRIL 1985 1015 PST
TIME: 91.76042
GMT 1937
DEPTH (m)
0
100
200
300
400
500
600
700
800
900
0 10 20
U/V(cm/s)
5 10 15
T(°c)

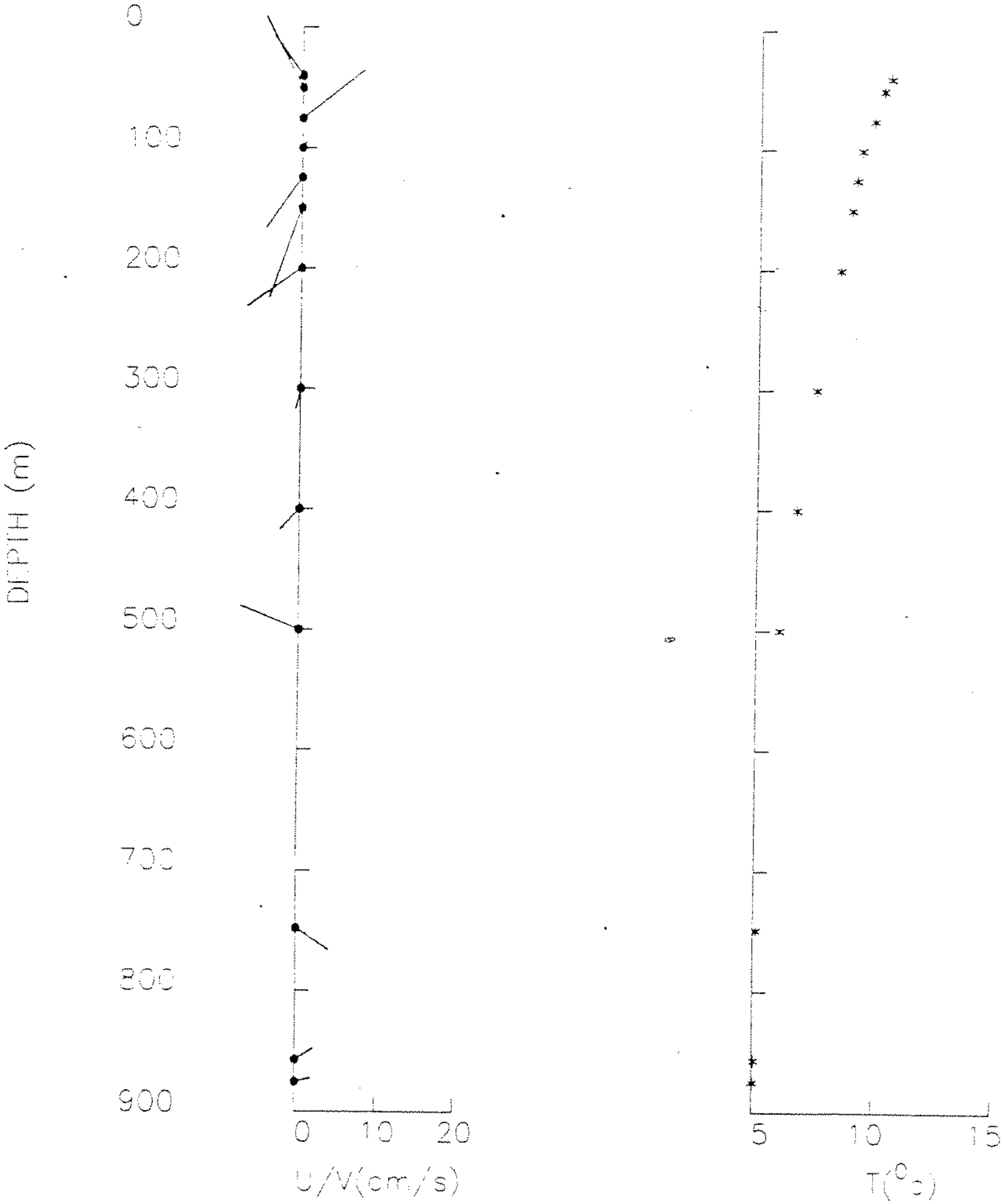
1 APRIL 1987

TIME: 91.77084
GMT 1987



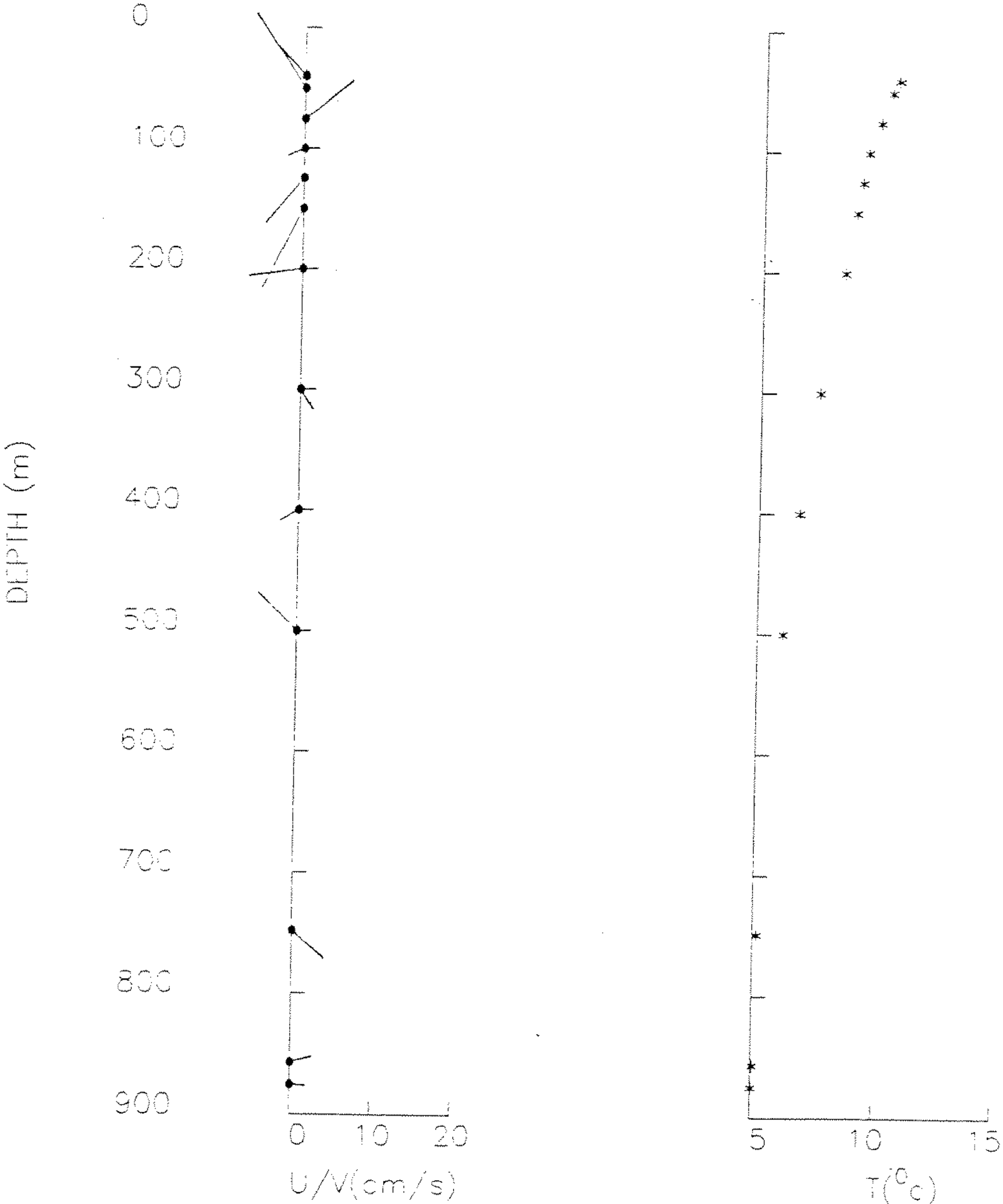
1 APR 1987

TIME: 91.78125
GMT 1987

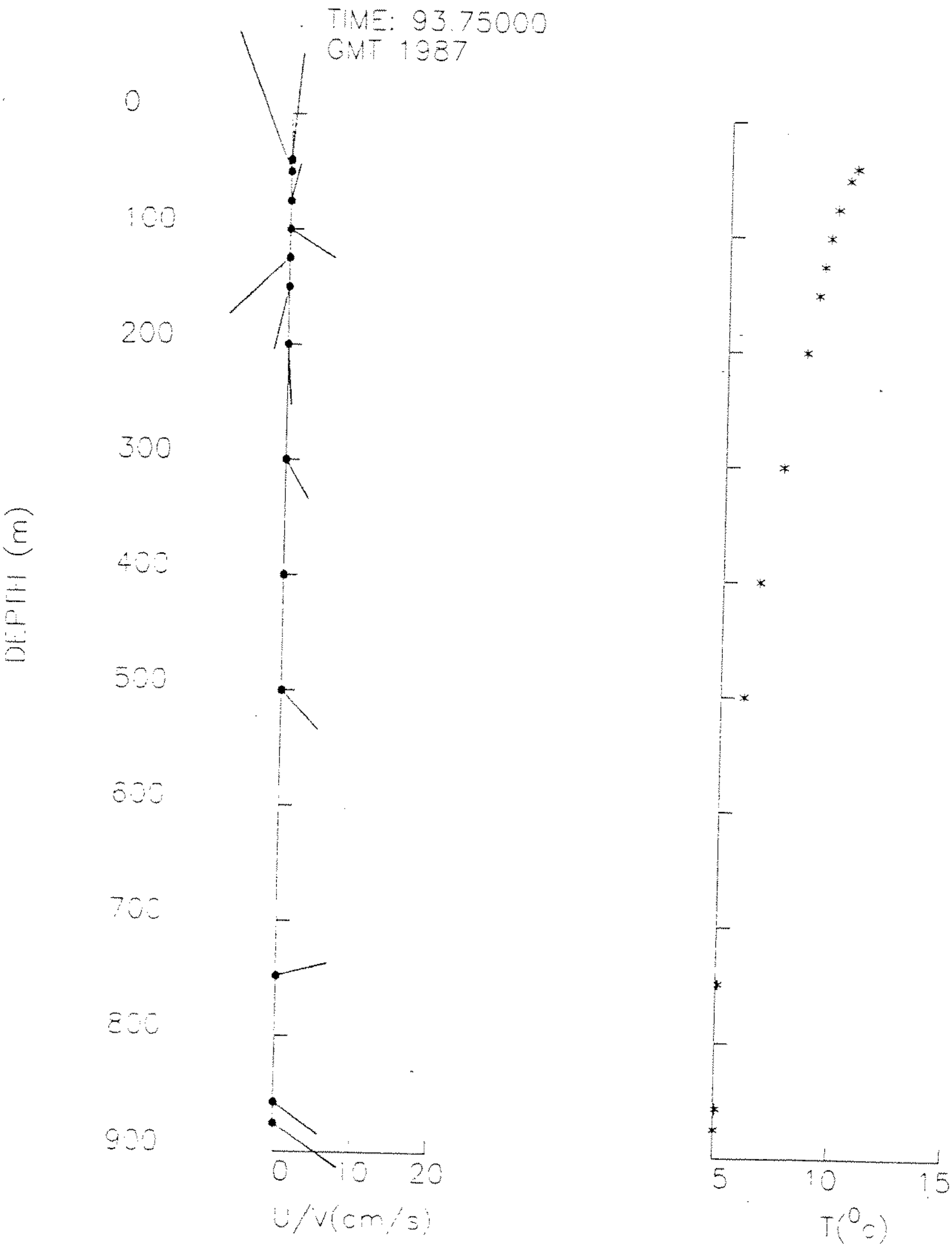


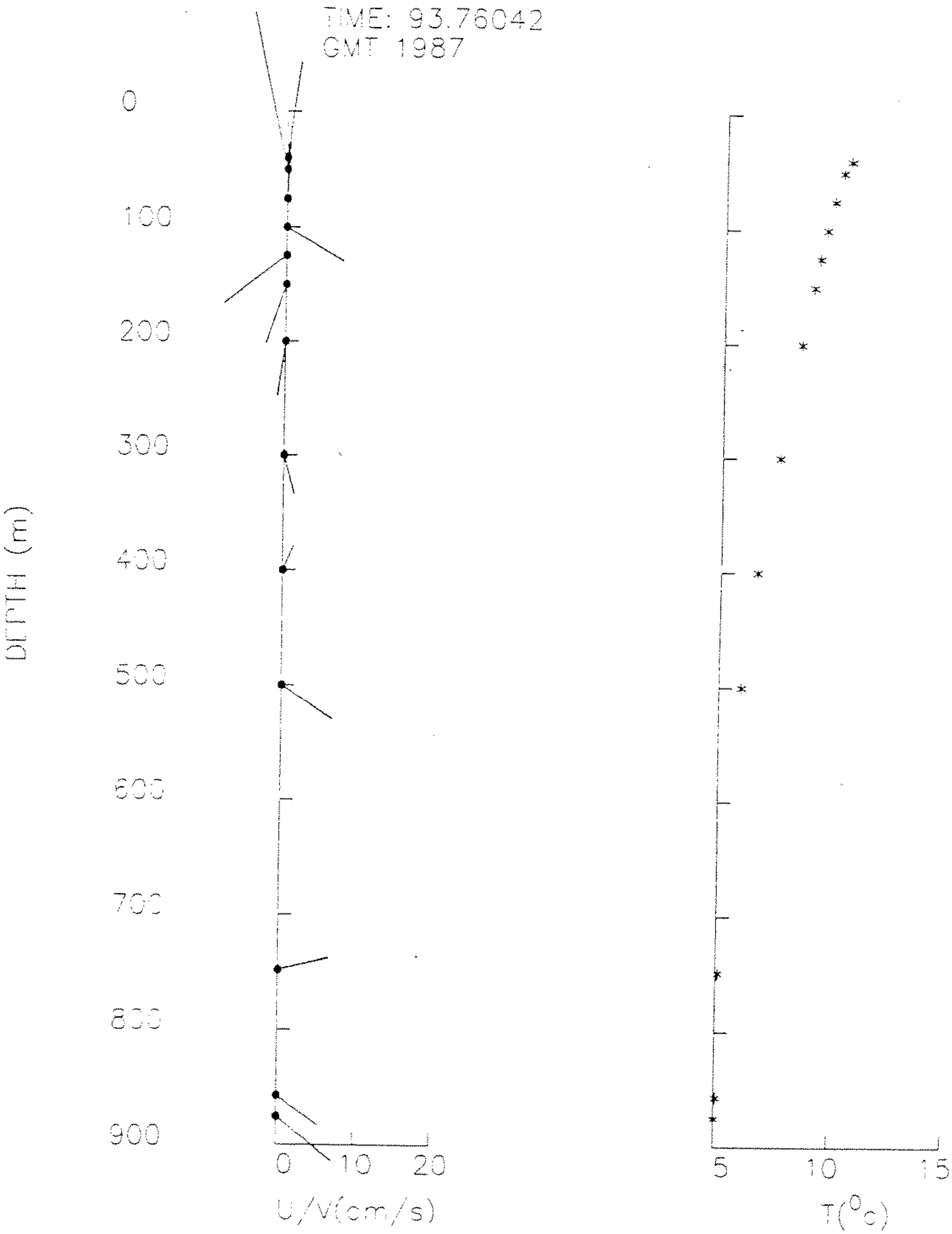
1100

TIME: 91.79167
GMT 1987



3 APR 1987 1000 PST




TIME: 93.76042
GMT 1987
DEPTH (m)
0
100
200
300
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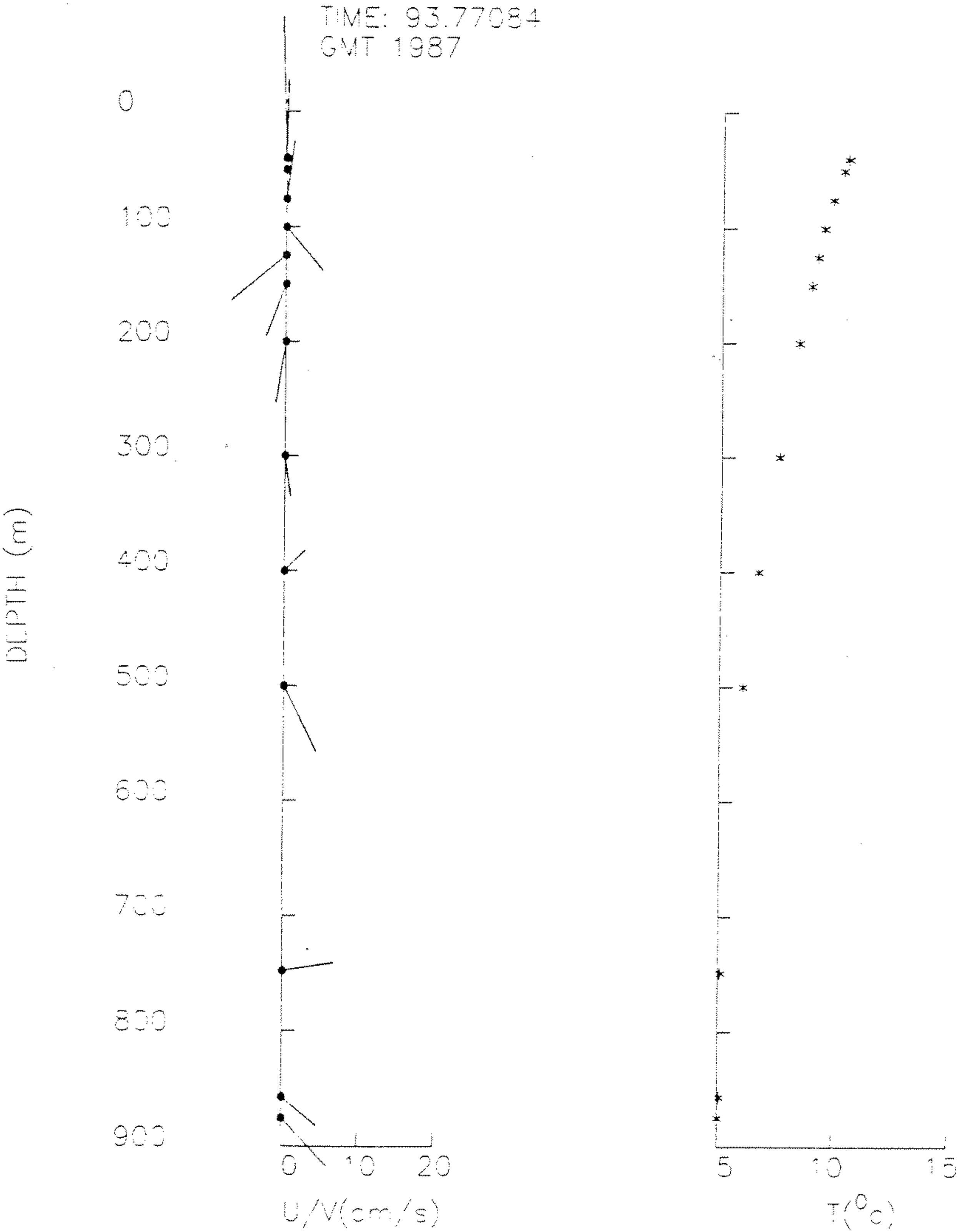
500
600
700
800
900
0
10
20
U/V(cm/s)
5
10
15
T(°c)

3AMF



TIME: 93.77084
GMT 1987
DEPTH (m)
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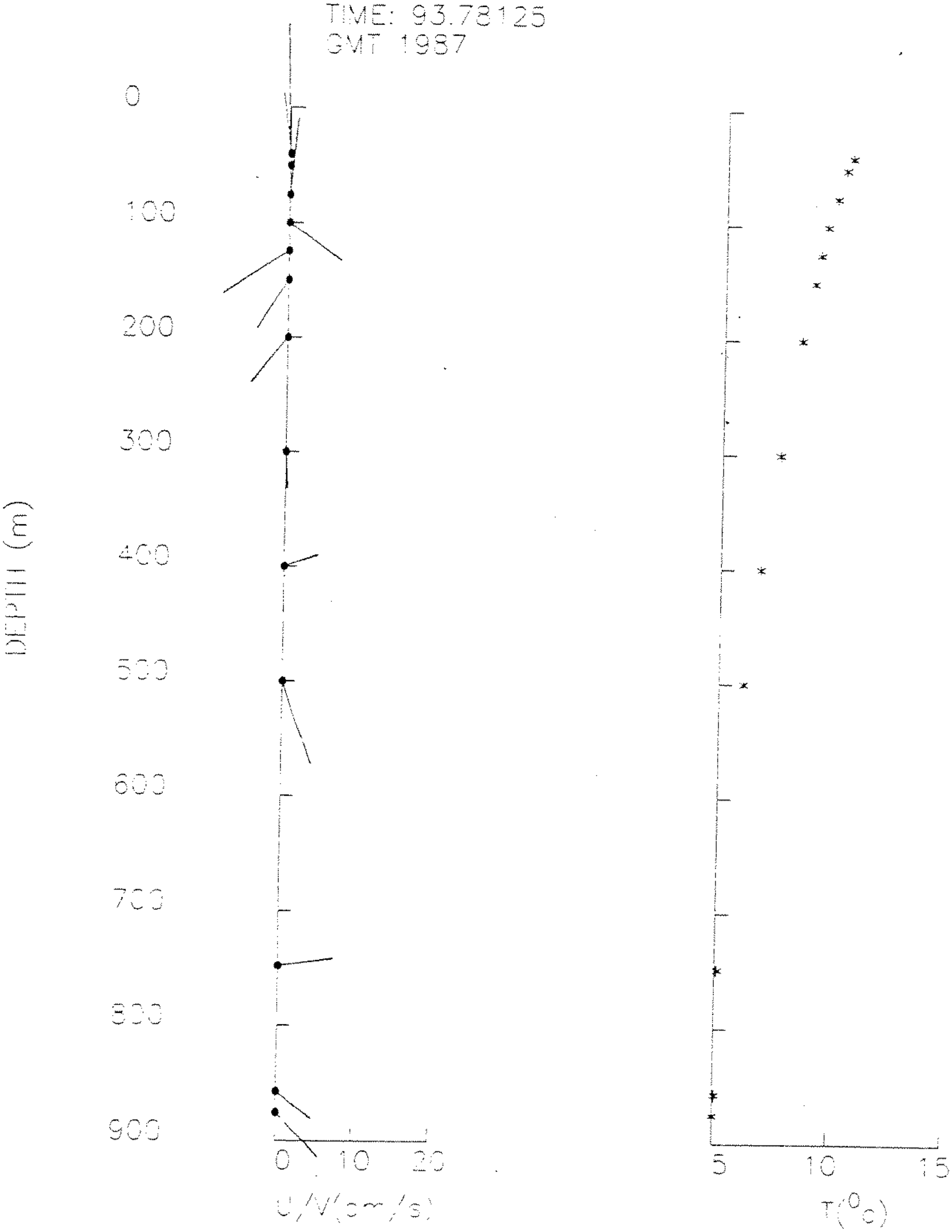
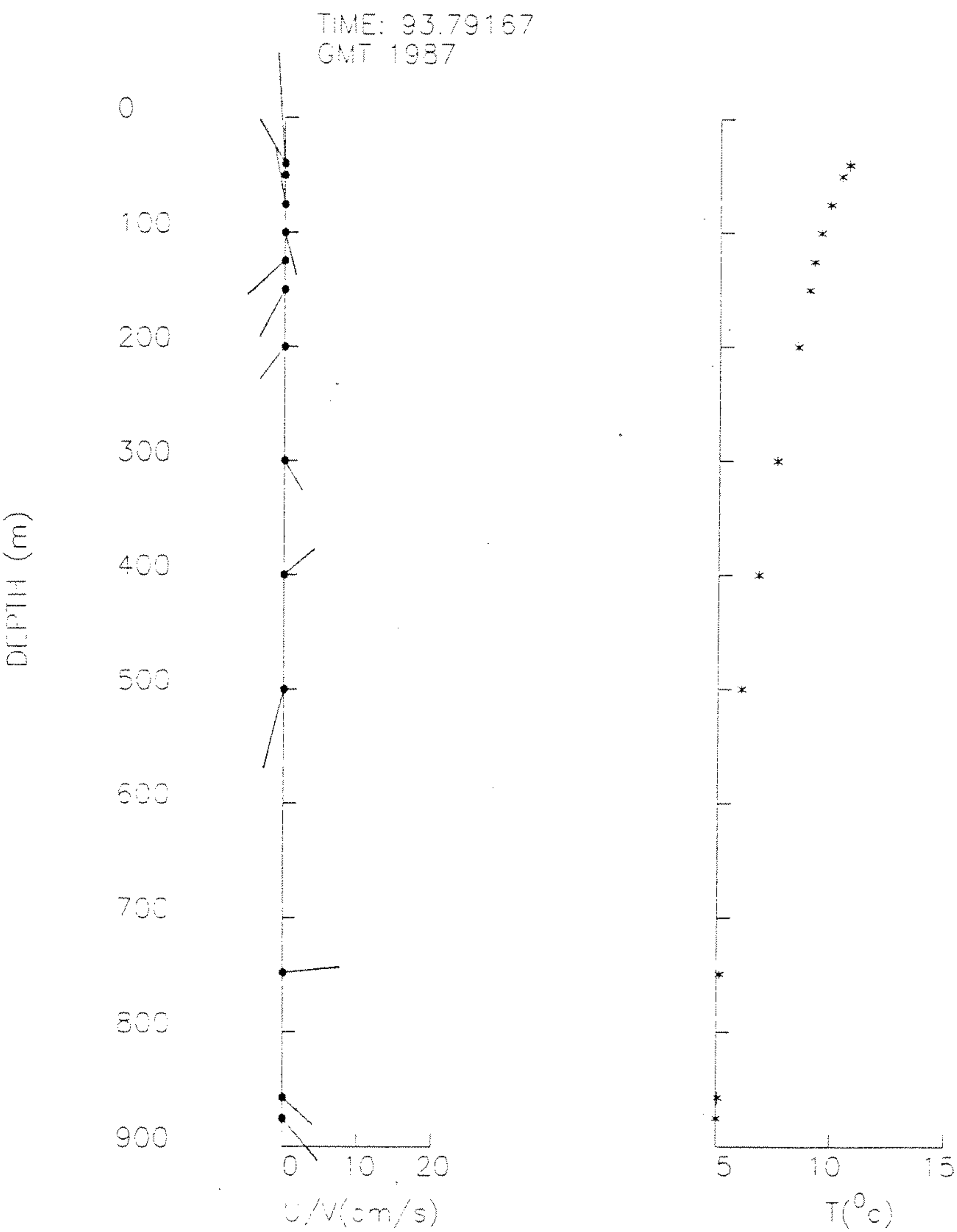
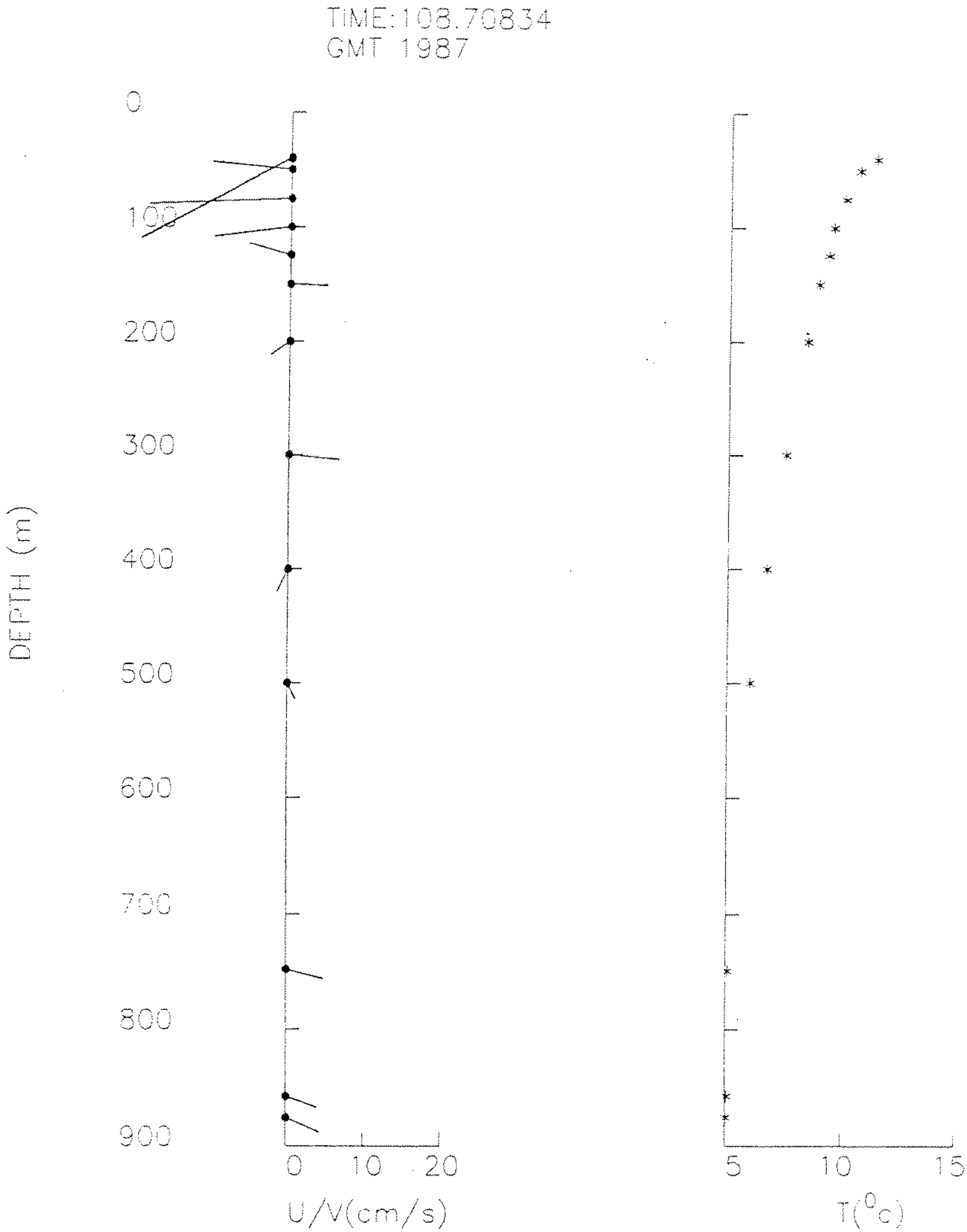
100
200
300
400
500
600
700
800
900
0
10
20
U/V(cm/s)
5
10
15
T(°c)

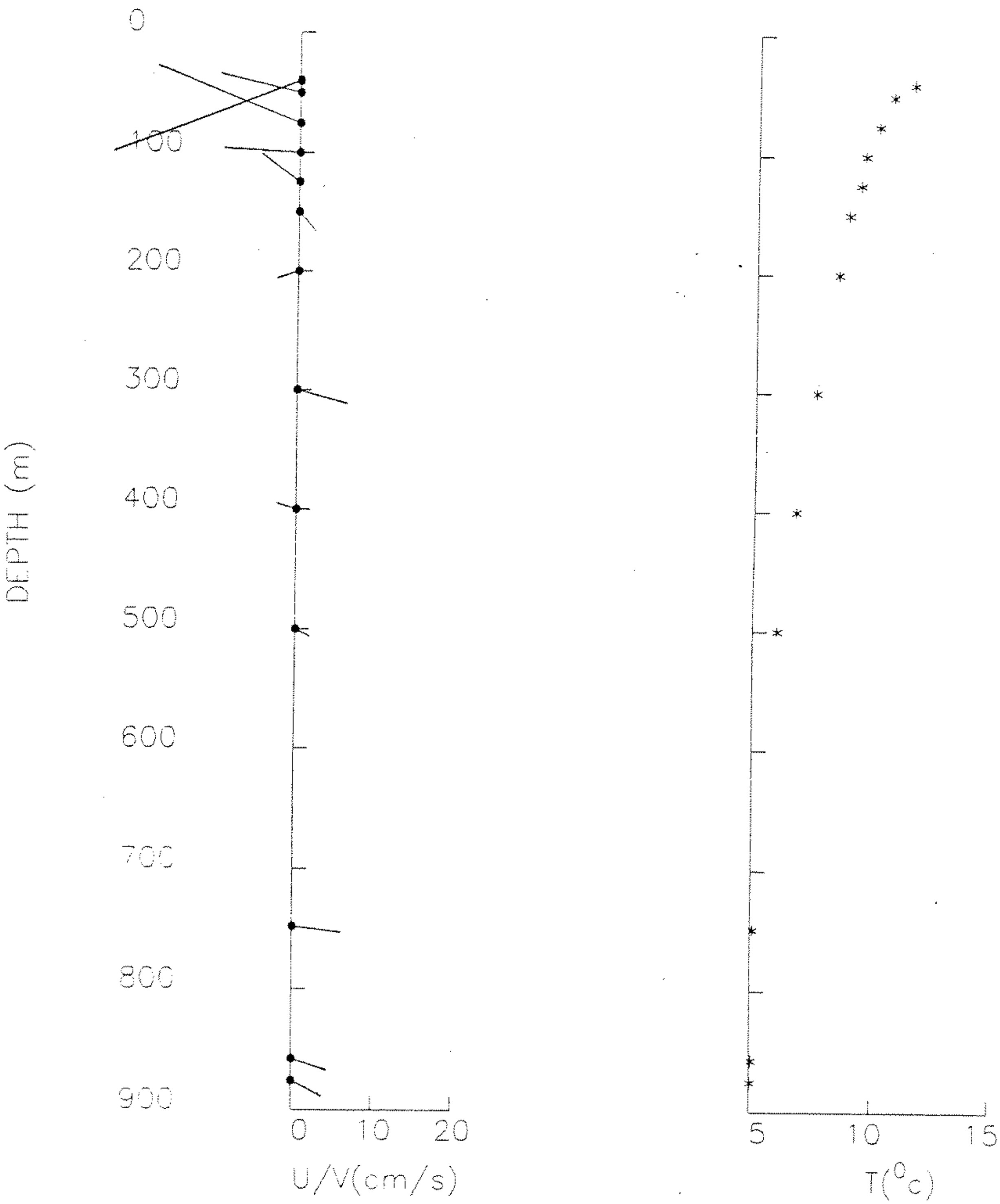

TIME: 93.78125
GMT 1987
0
100
200
300
400
500
600
700
800
900
DEPTH (m)
0
10
20
U/V(cm/s)
5
10
15
T(°C)


TIME: 93.79167
GMT 1987
DEPTH (m)
0
100
200
300
400
500
600
700
800
900
0
10
20
U/V(cm/s)
5
10
15
T(°c)

18 APR PEF


TIME:108.70834
GMT 1987
0
100
200
300
400
500
600
700
800
900
DEPTH (m)
0
10
20
U/V(cm/s)
5
10
15
T(⁰c)

TIME:108.71875
GMT 1987



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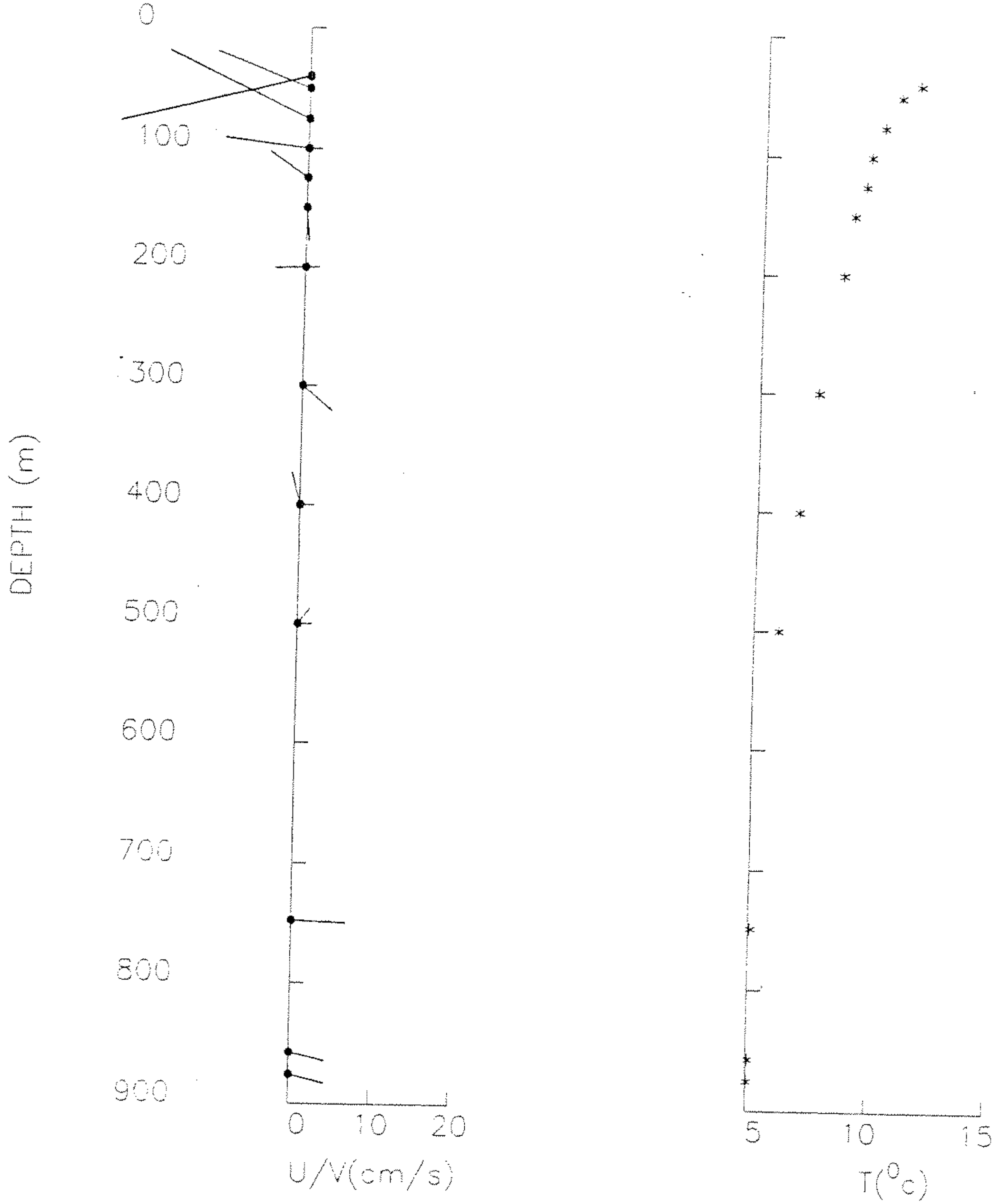
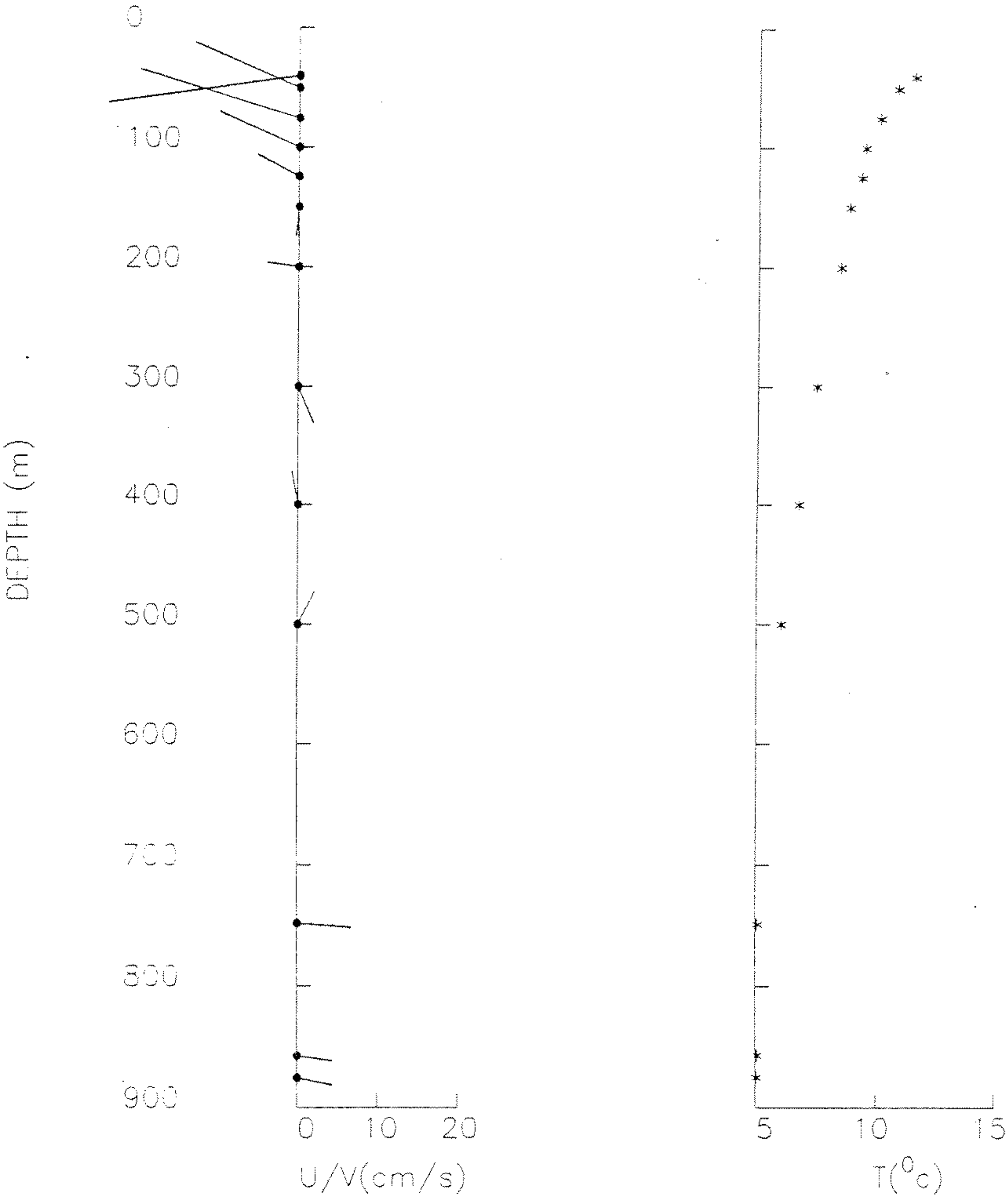
GMT 1987



TIME:108.73959
GMT 1987



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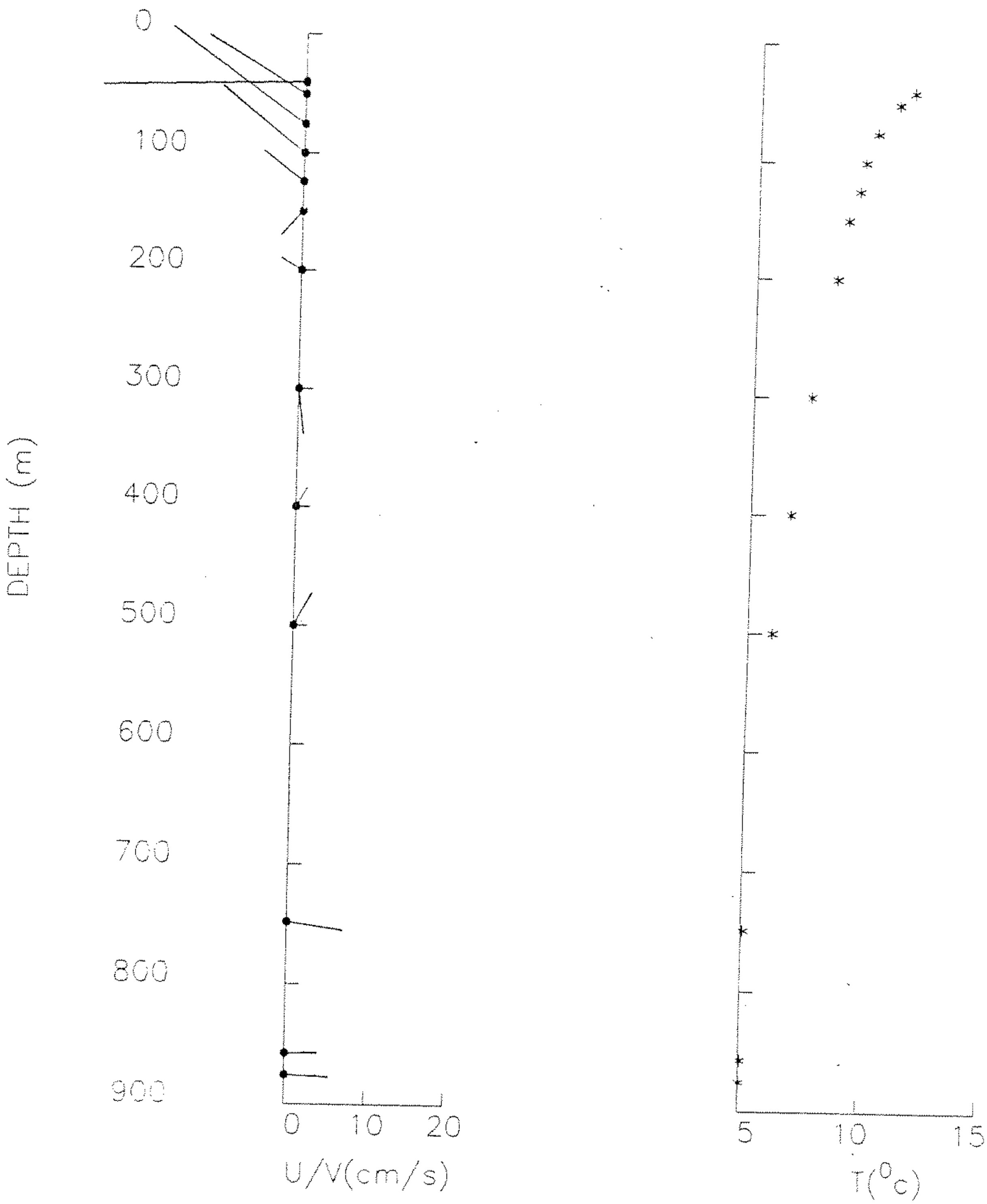
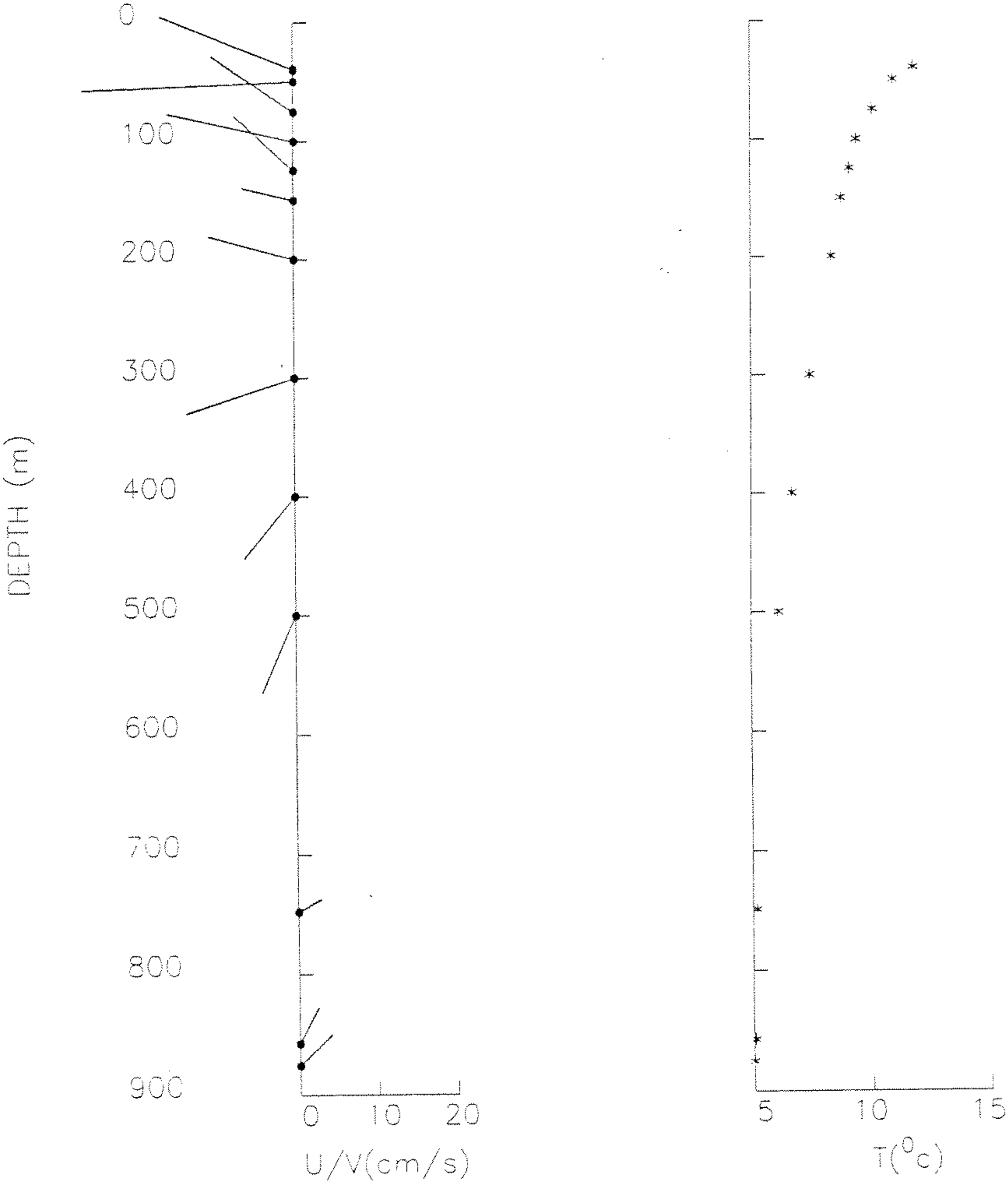
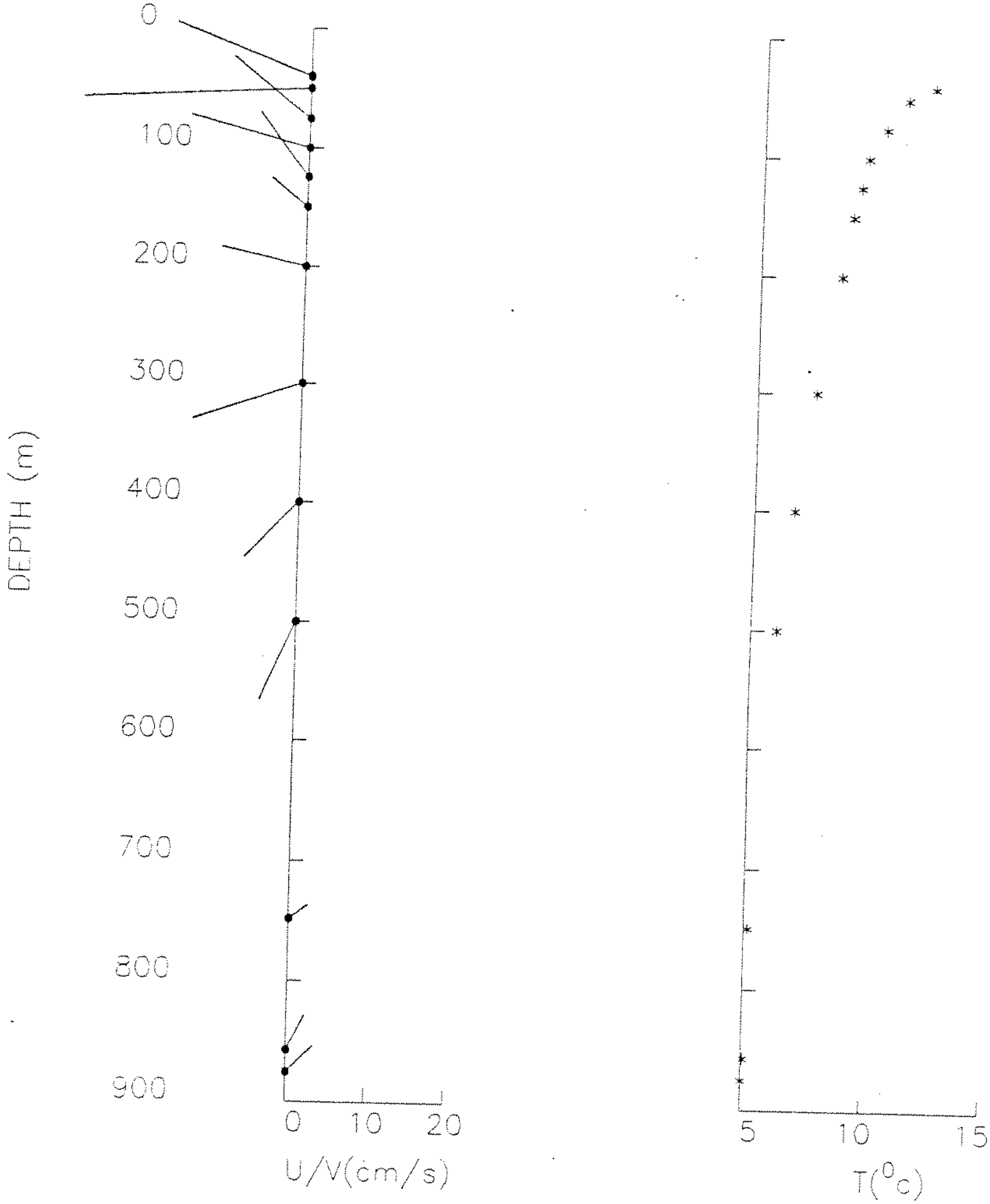


25 MAY 1987

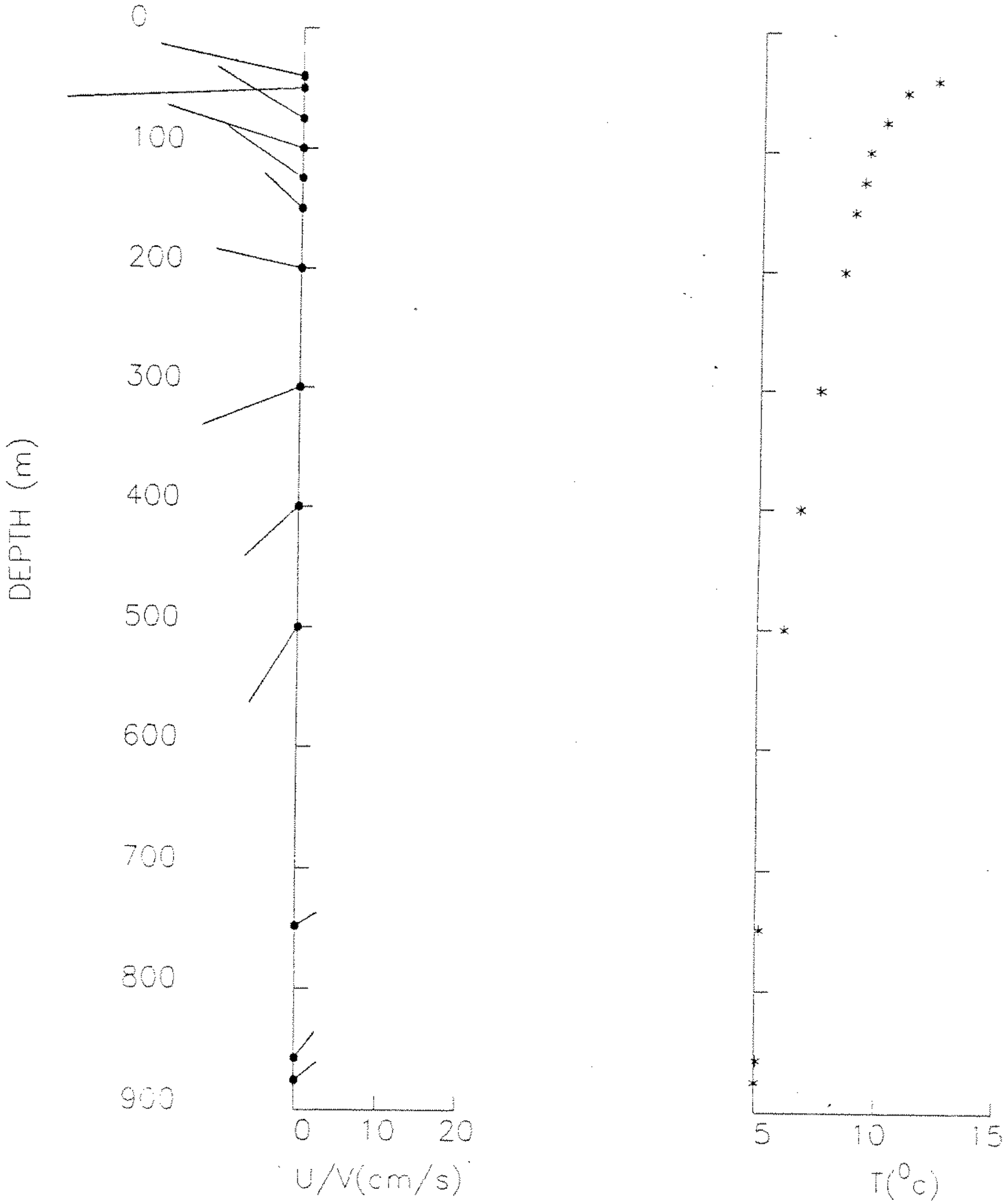
TIME:145.66666
GMT 1987



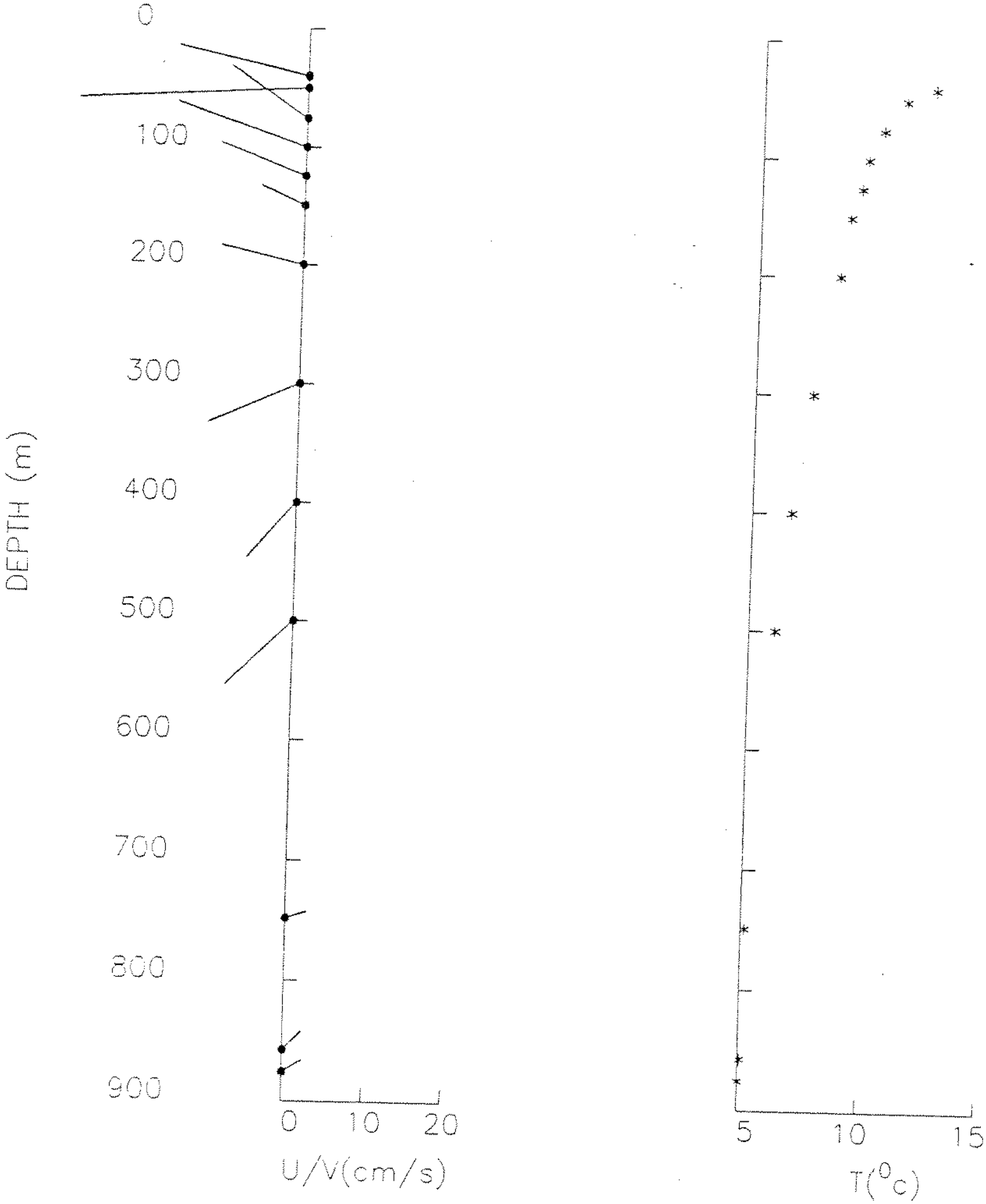
TIME:145.67708
GMT 1987



TIME:145.68750
GMT 1987

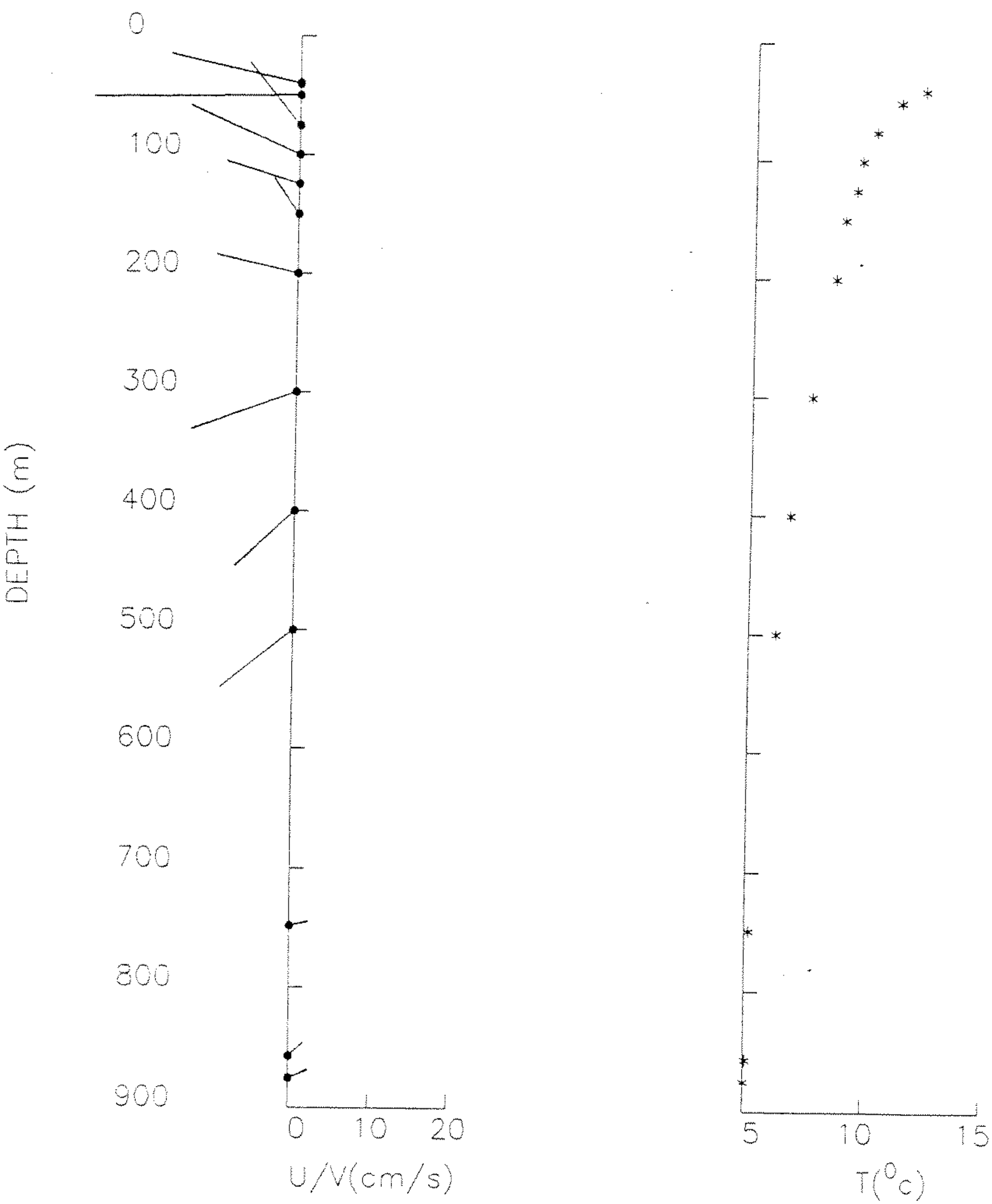


TIME:145.69791
GMT 1987



25 MAY 87

TIME:145.70833
GMT 1987



APPENDIX D

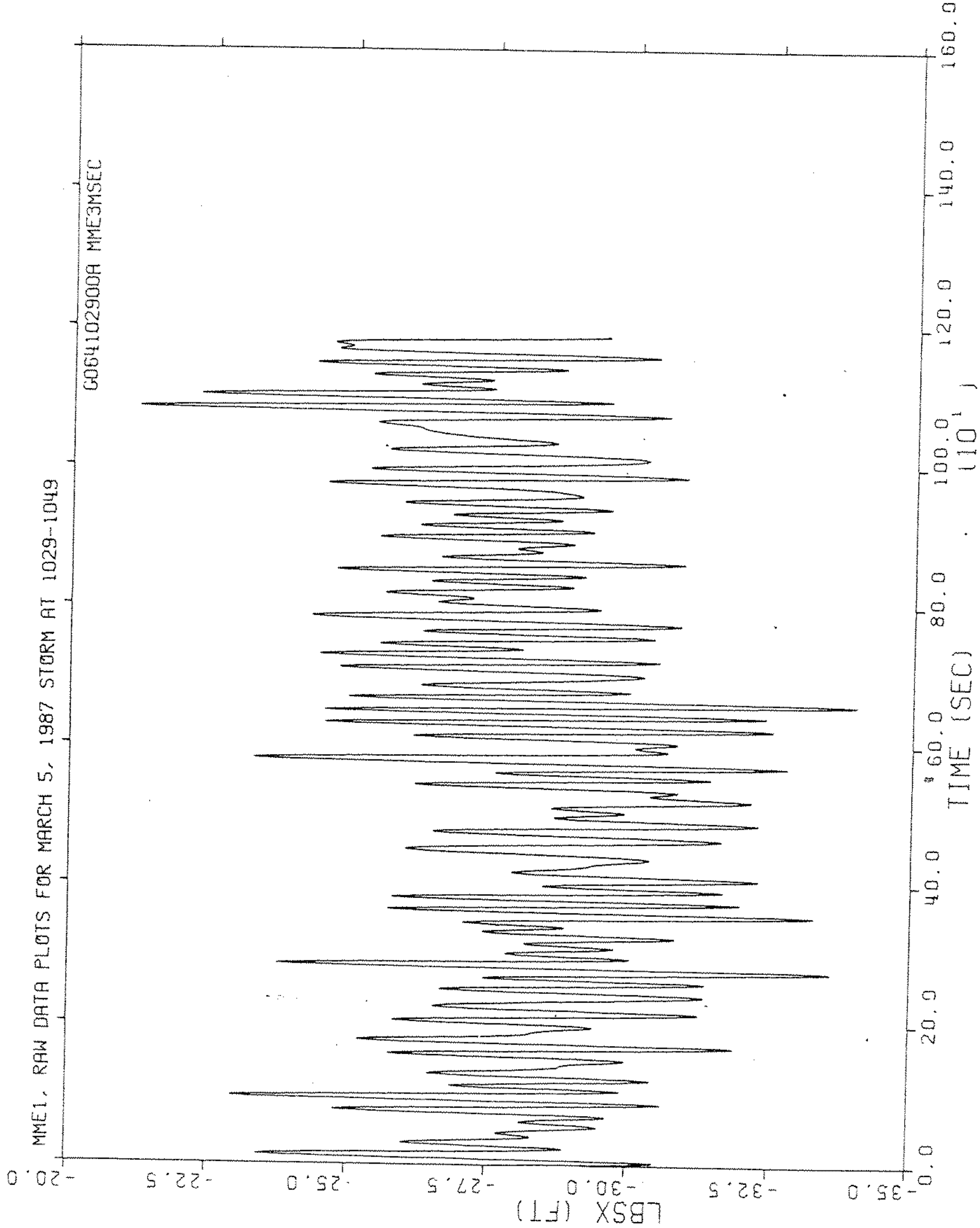
RESPONSE DATA

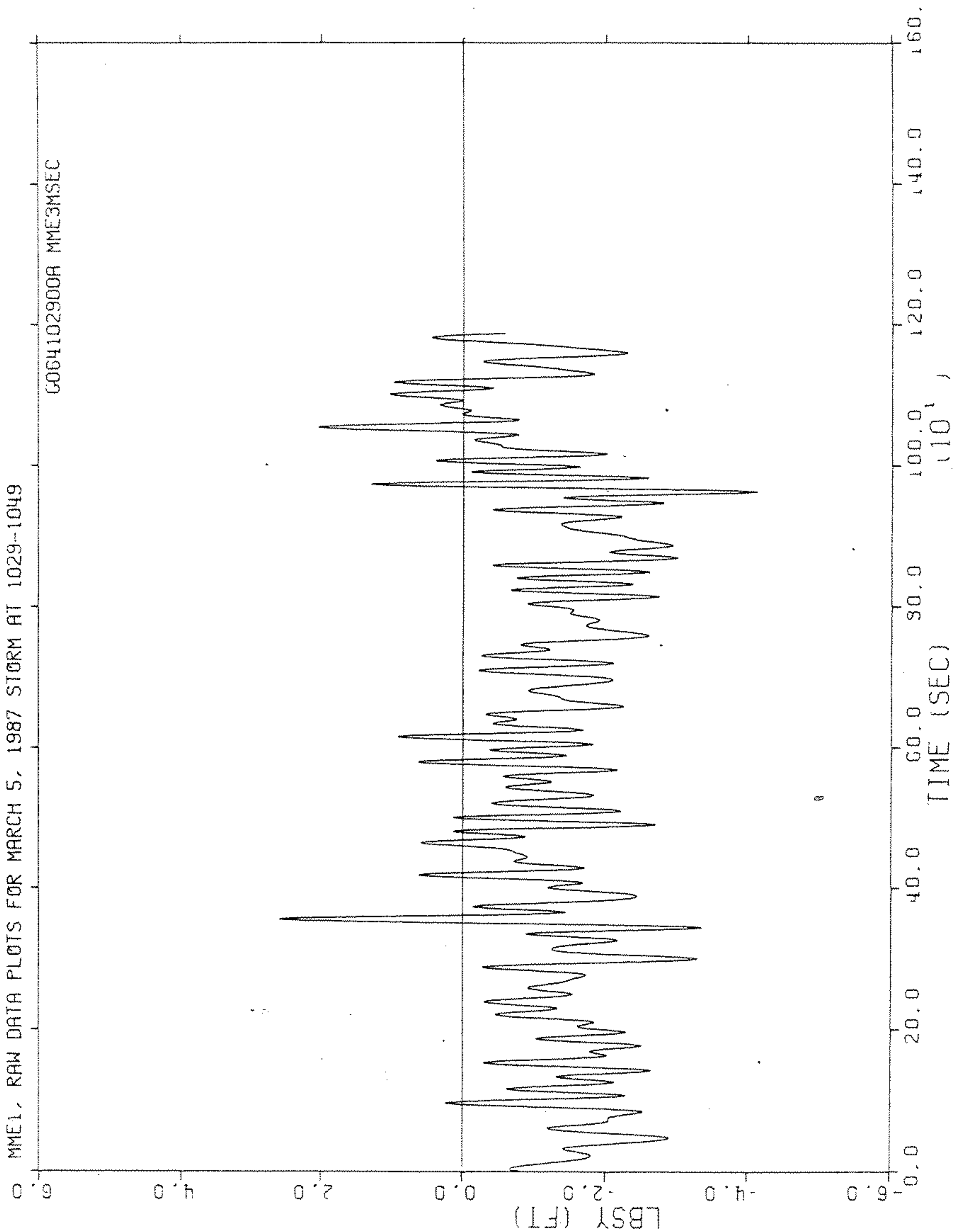
The following pages present plots of environmental and response time series data from the semisubmersible for 5 March 1987 from 10:29 a.m. to 10:49 a.m. All non-redundant instrumentation was functioning except the lower Z-direction load cell for the force cylinder. Plots of non-working redundant channels are not presented here.

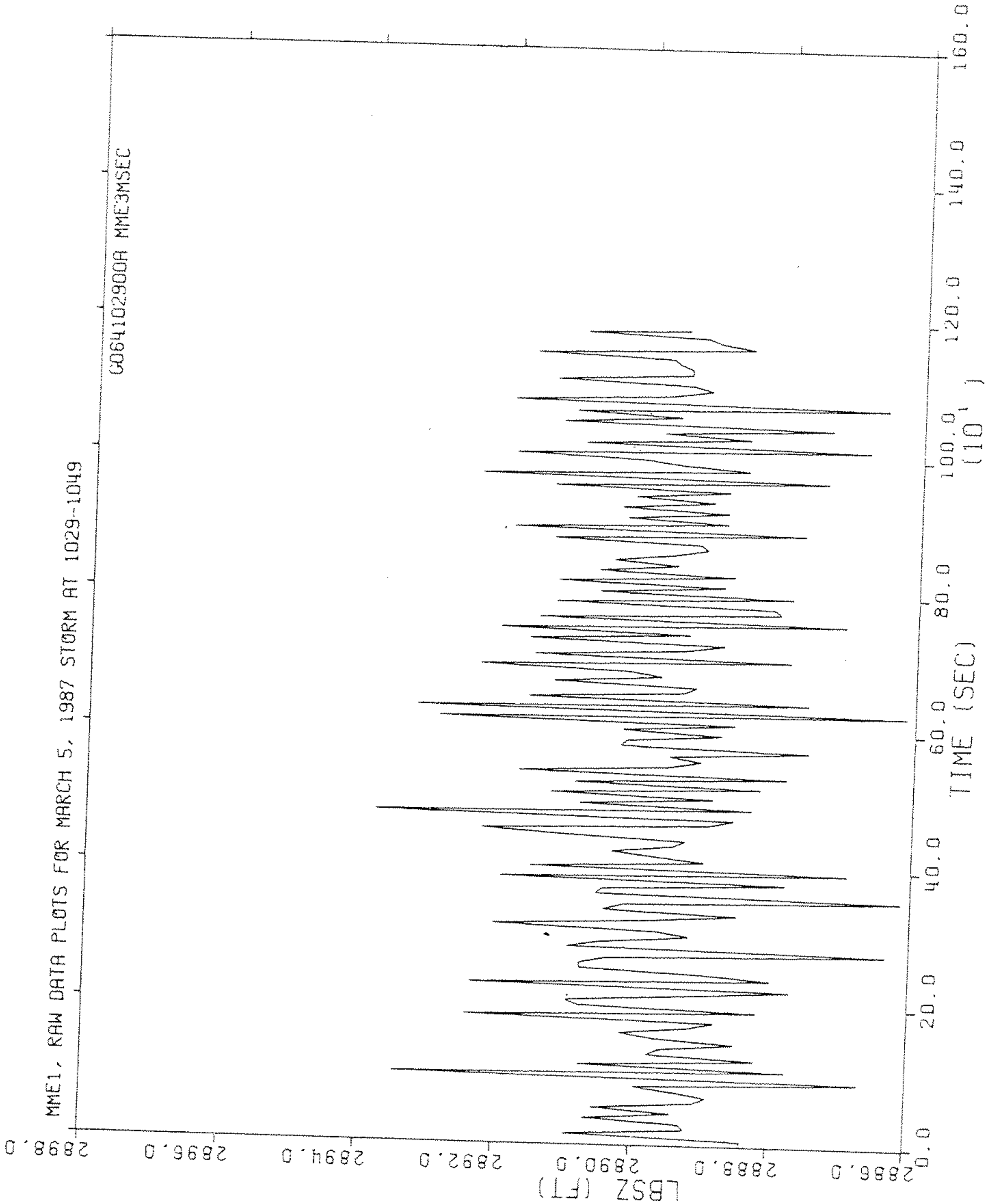
MOTION MEASUREMENT EXPERIMENT
Secondary Database Statistics

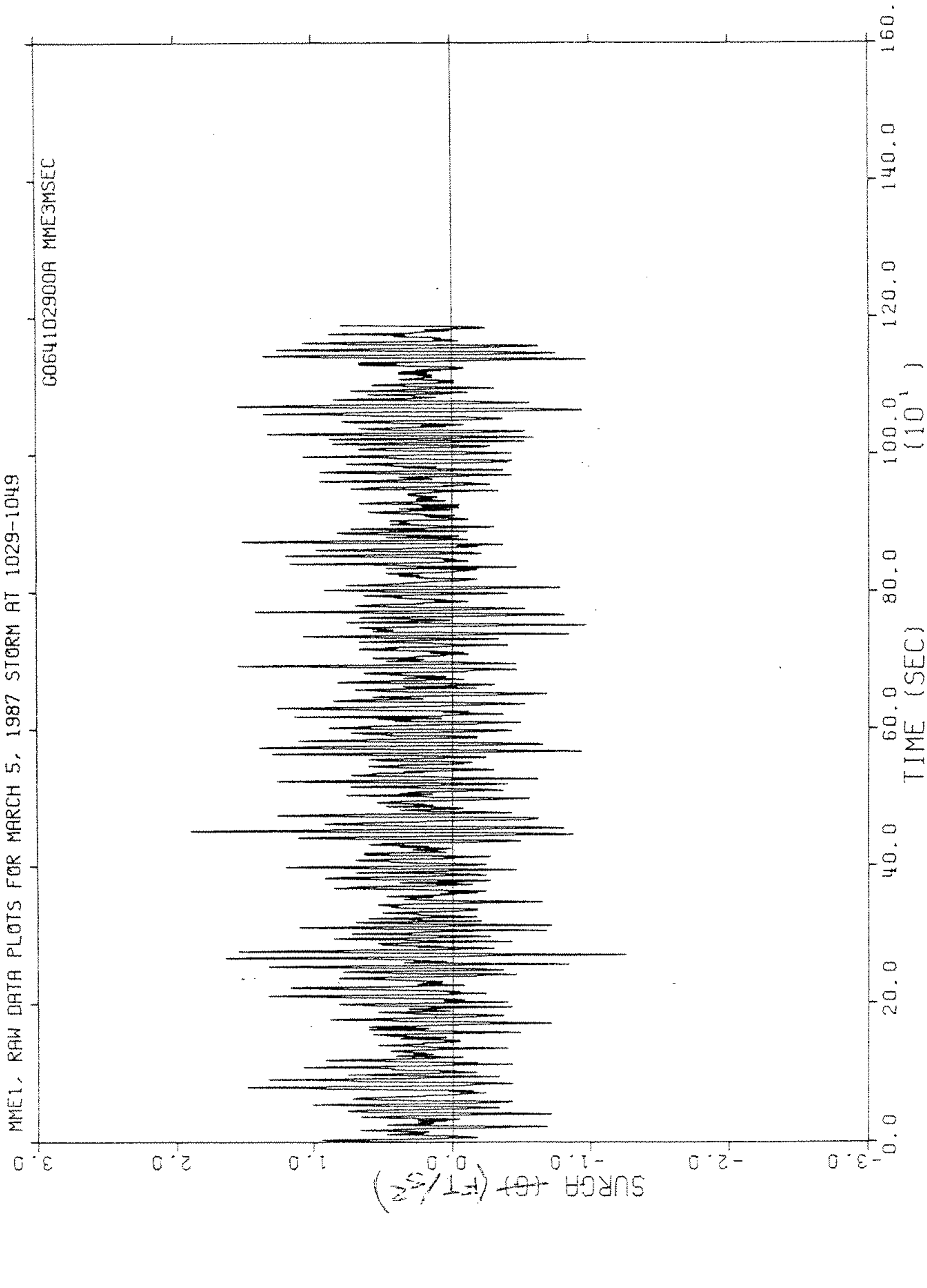
File=G064102900 Type=MME3MSEC Mode= 4 Analysis Time= 1188 Seconds

CHANNEL	AVERAGE	RMS	MIN	MAX	UNITS
1A TIME	593.7960	343.0275	0.0000	1187.6999	SECONDS
- LBSX	-28.0881	2.0022	-33.9994	-21.1542	FEET
- LBSY	-1.2010	0.9505	-4.1239	2.6023	FEET
- LBSZ	2889.1977	42.0513	2886.1152	2893.8433	FEET
2A LBSX	-28.0731	2.1063	-33.4000	-21.2000	FEET
3A LBSY	-1.2019	0.9507	-3.4000	2.6000	FEET
4A LBSZ	2889.7148	5.4505	2886.0996	2893.8999	FEET
5A SURGEA	0.2336	0.4483	-1.2576	1.9041	FT/(S**2)
6A HEAVEA	0.0483	0.5378	-1.6241	1.4586	FT/(S**2)
7A SWAYA	-0.3161	0.4458	-1.7661	1.0801	FT/(S**2)
8A ROLLV	0.0652	0.4487	-1.6260	1.4795	DEG/S
9A PITCHV	0.5717	0.3350	-1.0840	1.4648	DEG/S
10A ROLLD	-0.5728	0.7529	-3.0389	1.7218	DEGREES
11A PITCHD	0.1750	0.8472	-2.6065	2.7729	DEGREES
12A YAWD	285.0789	3.2657	279.6762	290.9770	DEGREES
13A WAVE1	12.9734	0.9419	9.6680	16.3330	FEET
14A WAVE2	12.8971	0.9412	9.5703	16.4307	FEET
15A CUR1X	-0.2896	0.2163	-0.9766	0.4395	FT/S
16A CUR1Y	-0.1215	0.1870	-0.7812	0.5371	FT/S
17A CUR2X	-0.2559	0.3575	-1.4648	0.9766	FT/S
18A CUR2Y	-0.4537	0.1604	-0.9766	0.0977	FT/S
19A LOAD1U	6.0851	0.2477	5.3764	6.8714	KIPS
20A LOAD1L	6.0098	0.1606	5.5762	6.5103	KIPS
21A LOAD2U	6.2189	0.1870	5.6768	6.8412	KIPS
22A LOAD2L	-0.2170	0.0035	-0.2278	-0.2135	KIPS
23A LOAD3U	-2.0294	0.0431	-2.0601	-2.0066	KIPS
24A LOAD3L	5.4564	0.2348	4.8127	6.2859	KIPS
2B WIND1S	10.5222	2.4659	4.0049	18.2623	FT/S
3B WIND1D	324.0532	8.6095	294.4336	347.6562	DEGREES
4B WIND3S	10.5816	2.6023	3.5243	18.5827	FT/S
5B WIND3D	315.5607	8.4552	290.7715	345.2148	DEGREES
6B WINDMAS	10.5683	2.3195	3.8447	17.4613	FT/S
7B WINDMAD	321.4481	8.1954	297.8516	342.5293	DEGREES
8B TEMP	74.8008	0.7012	74.3633	75.2422	DEG FAHR
9B HUMID	35.3419	0.3096	35.1562	35.6445	PERCENT
10B FC-P1	4.0664	0.3692	2.6245	5.2368	PSI
11B FC-P2	4.3116	0.3705	2.8442	5.4810	PSI
12B FC-P3	4.5344	0.3689	3.0640	5.7007	PSI
13B FC-P4	4.2732	0.3668	2.8198	5.4199	PSI
14B FC-P5	4.2347	0.3715	2.7588	5.3955	PSI
15B FC-P6	3.7758	0.3627	2.3560	4.9072	PSI
16B FC-P7	3.7780	0.3667	2.3315	4.9194	PSI
17B FC-P8	3.9810	0.3686	2.5269	5.1392	PSI
18B FC-Z-UP	-1.9293	0.0410	-1.9937	-1.8683	KIPS
19B FC-X-UP	-0.0732	0.0118	-0.1206	-0.0317	KIPS
20B FC-Z-LOW	2.6028	0.3820	2.0279	3.4739	KIPS
21B FC-X-LOW	-0.0552	0.0223	-0.1417	0.0271	KIPS

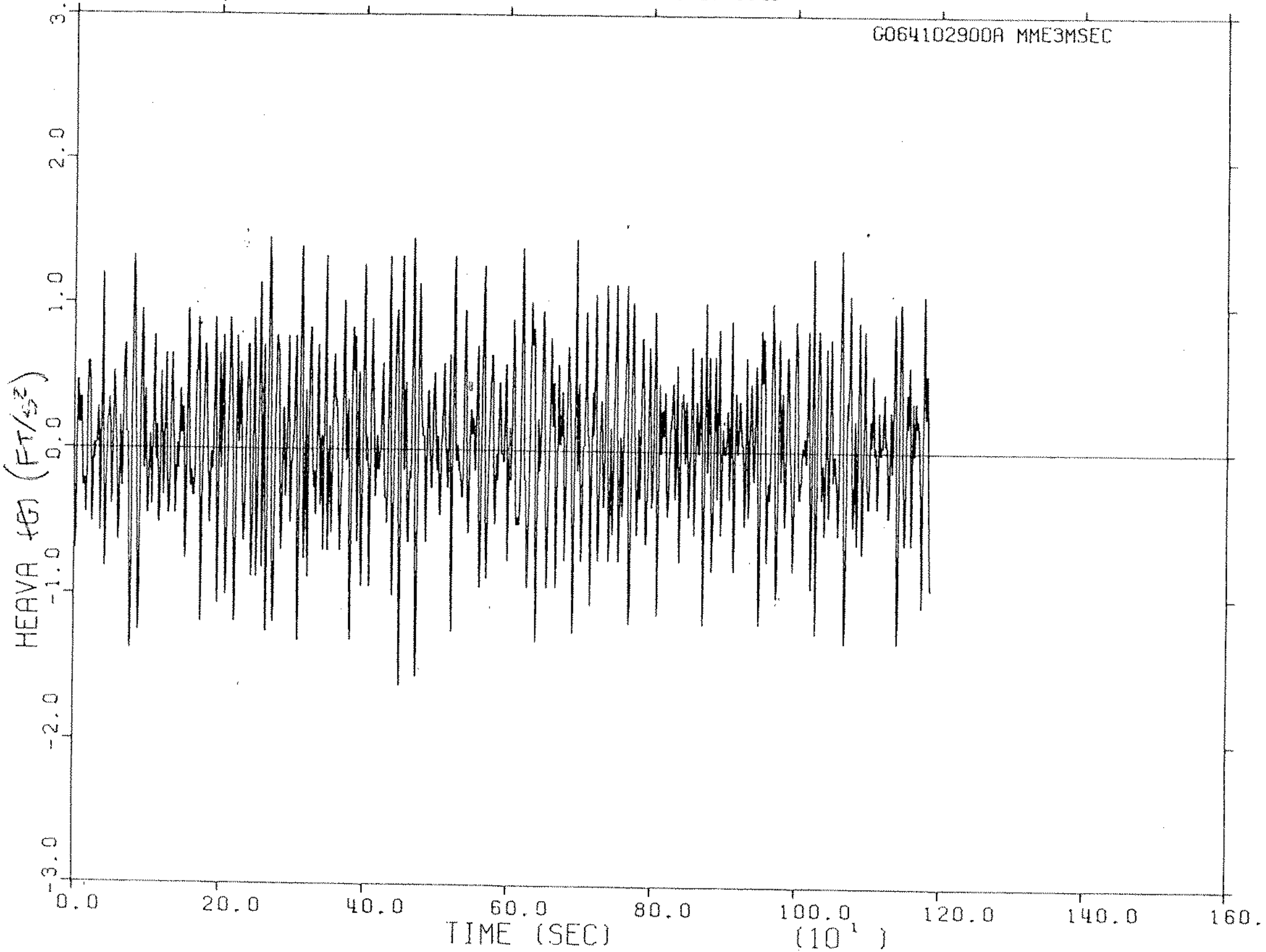

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029000A MME3MSEC
LBSX (FT)
-20.0
-22.5
-25.0
-27.5
-30.0
-32.5
-35.0
TIME (SEC)
(10^1)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

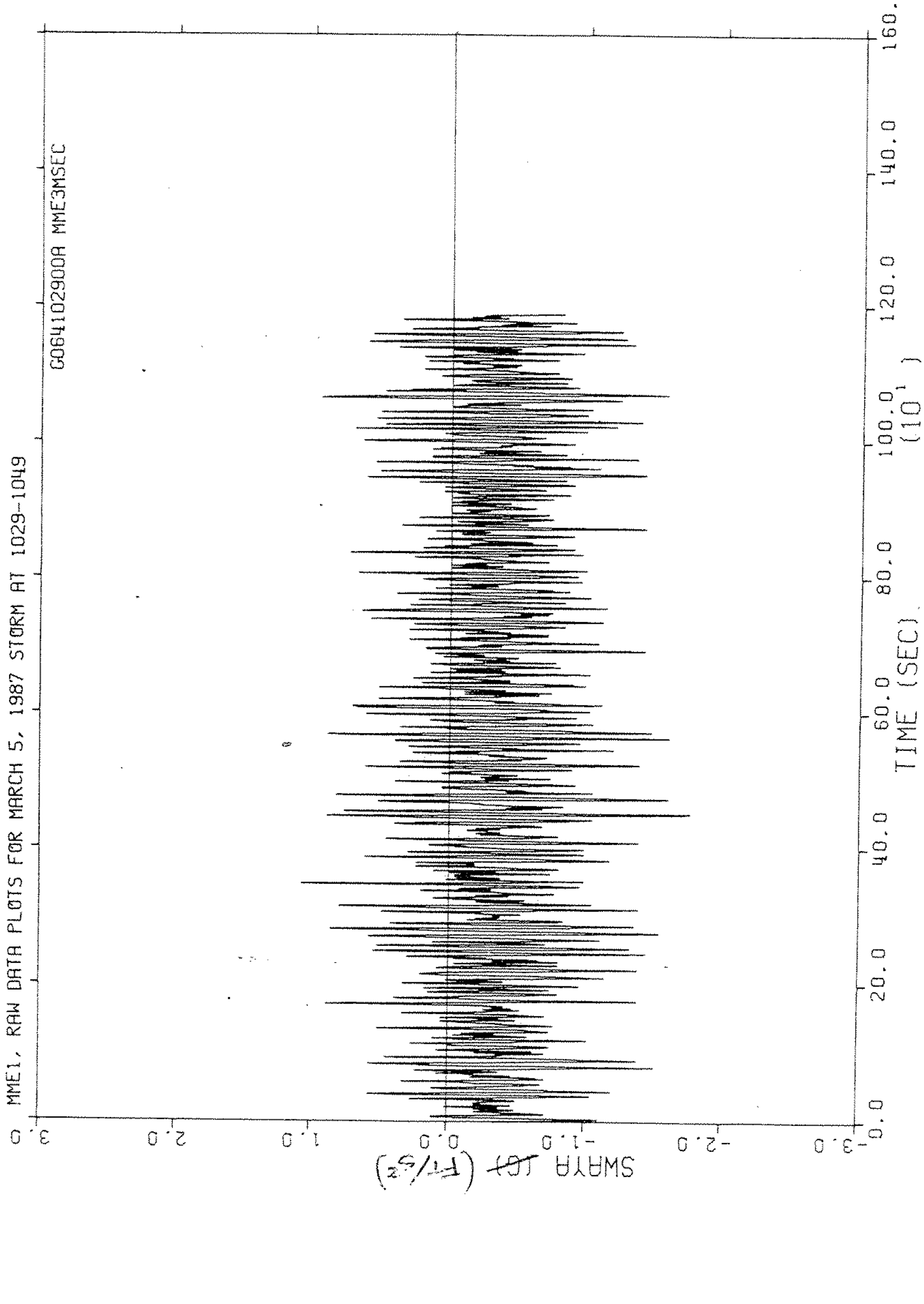

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
GO641D2900A MME3MSEC
LBSY (FT)
TIME (SEC) (10¹)
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

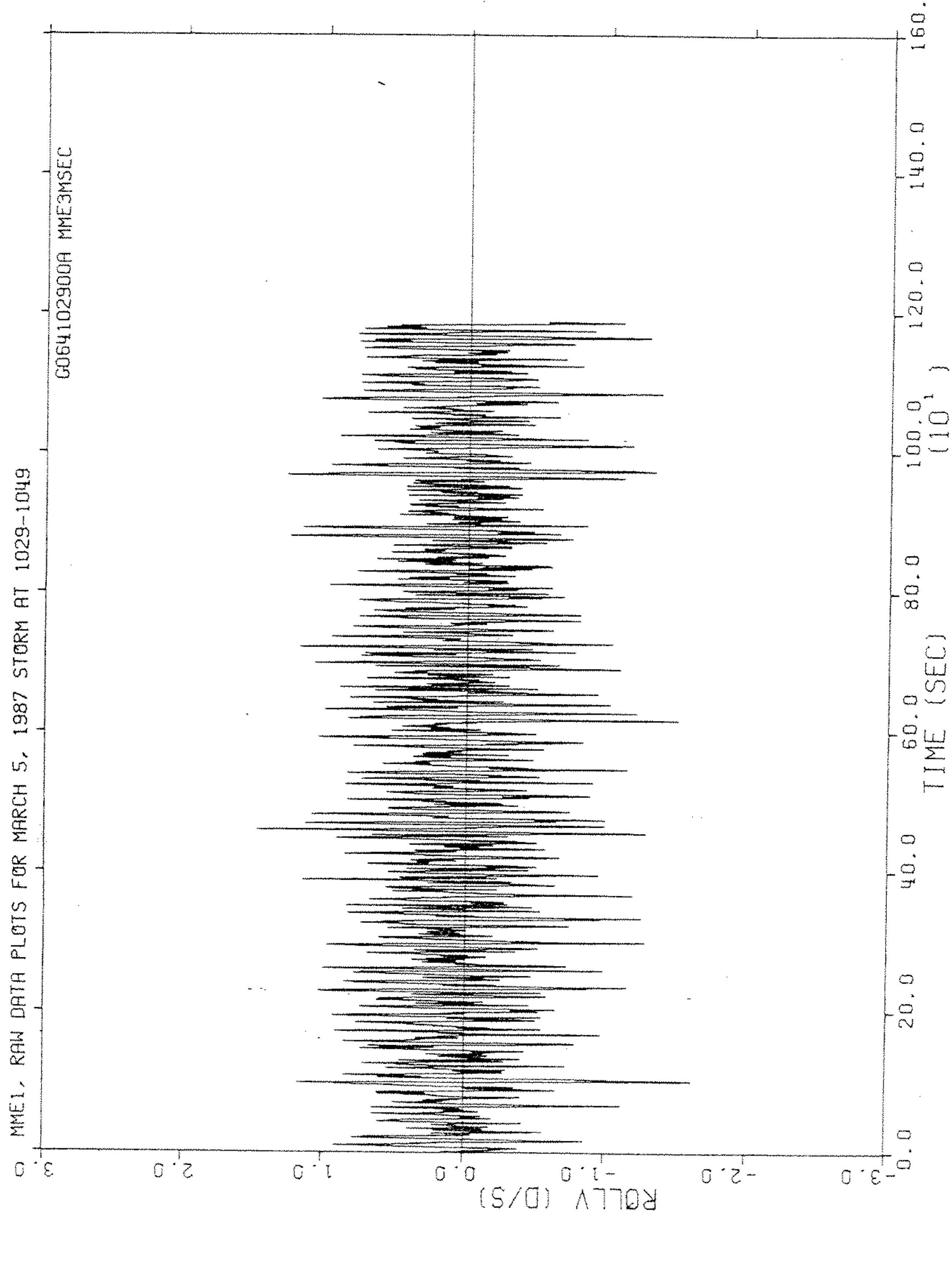

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029O0A MME3MSEC
LBSZ (FT)
2886.0
2888.0
2890.0
2892.0
2894.0
2896.0
2898.0
TIME (SEC) (10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

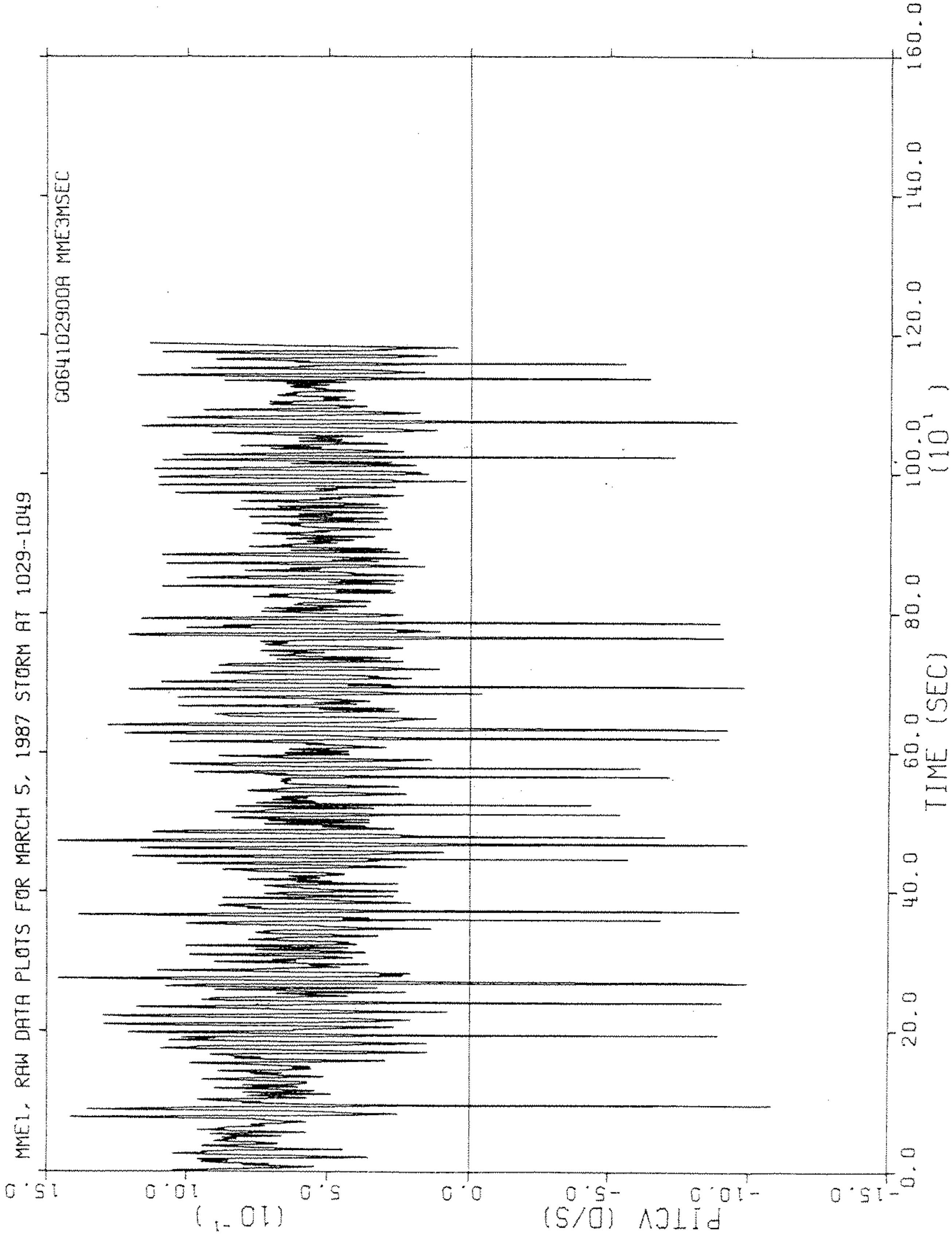

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029008 MME3MSEC
SURGA (G) (FT/S²)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)

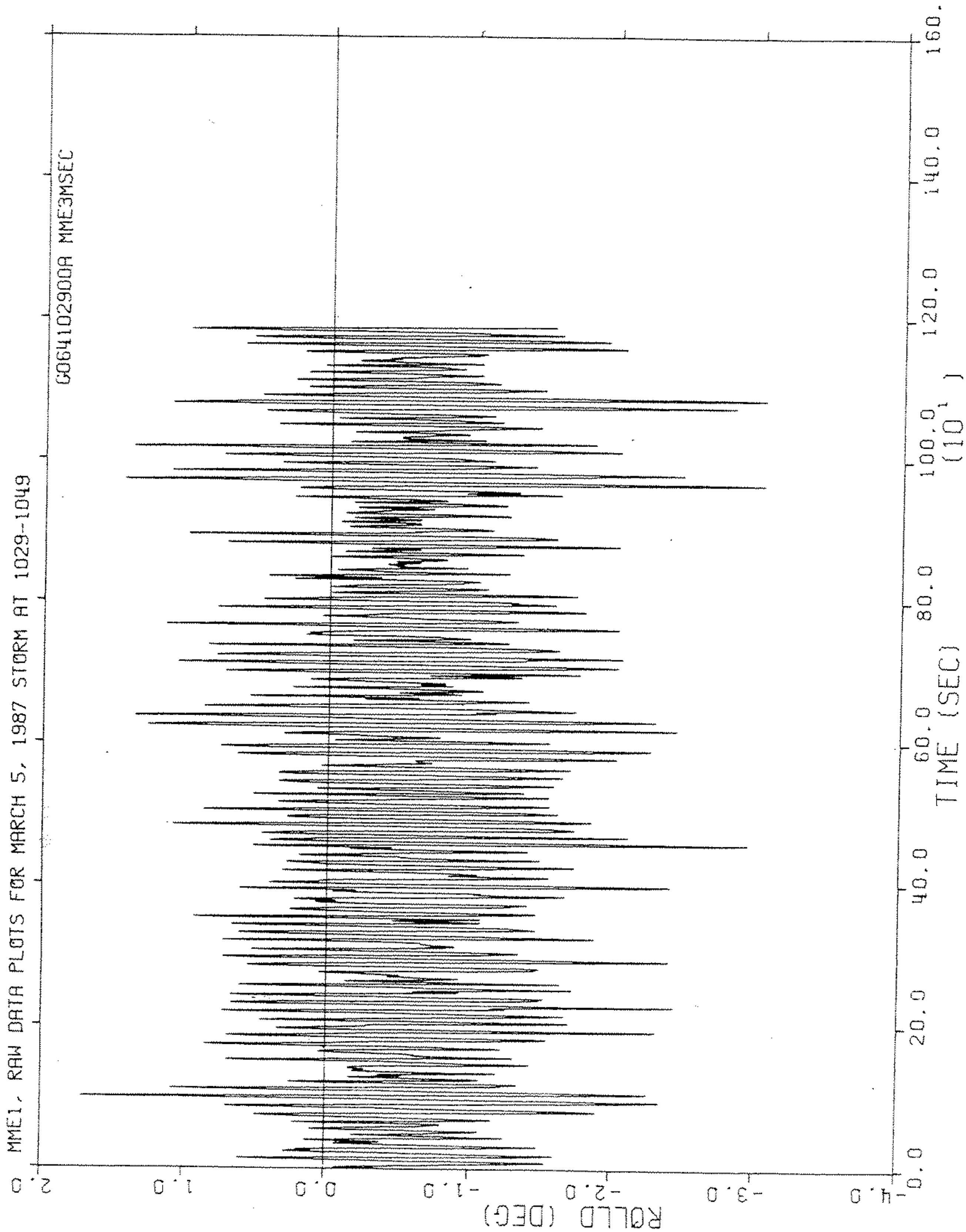
MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049

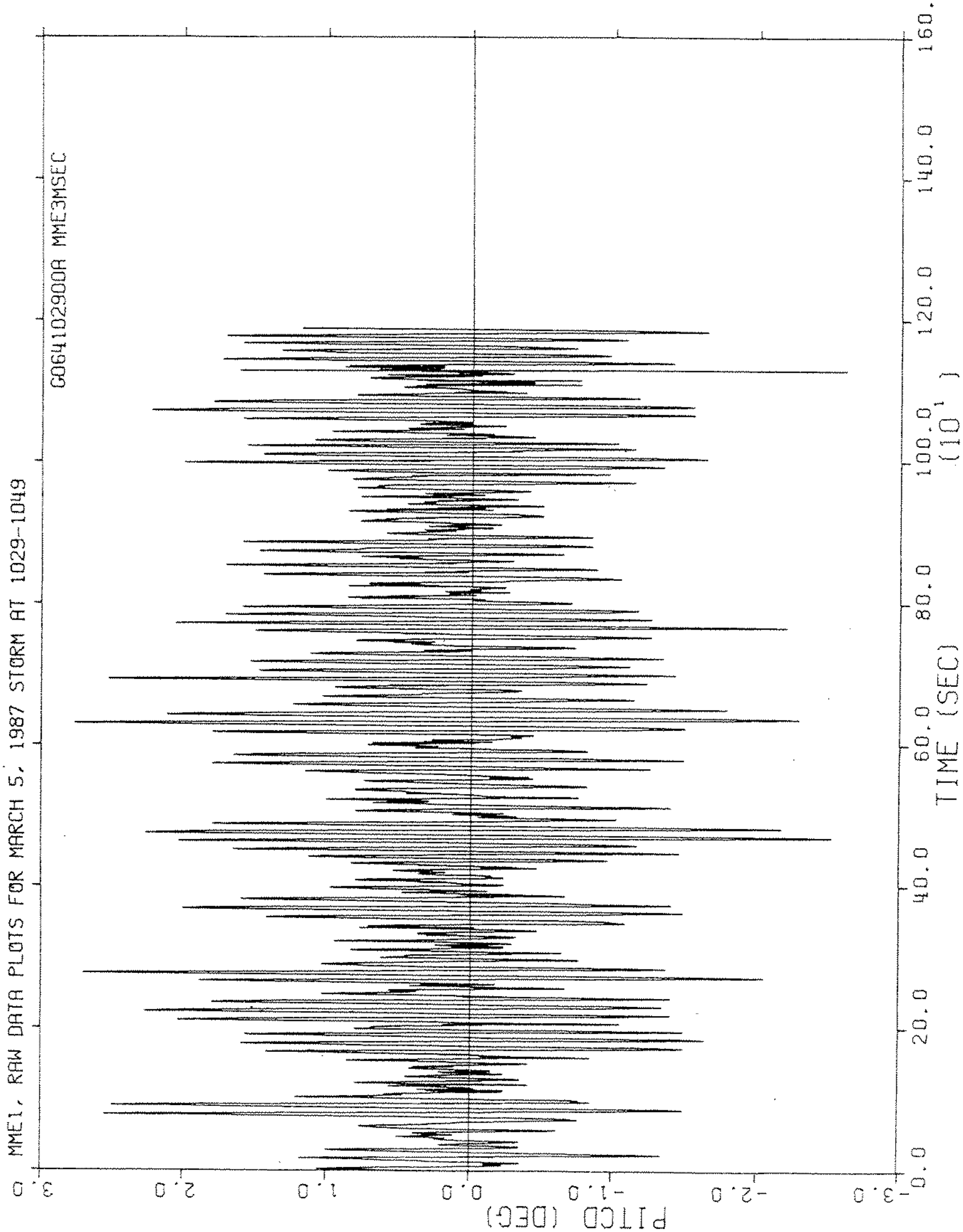


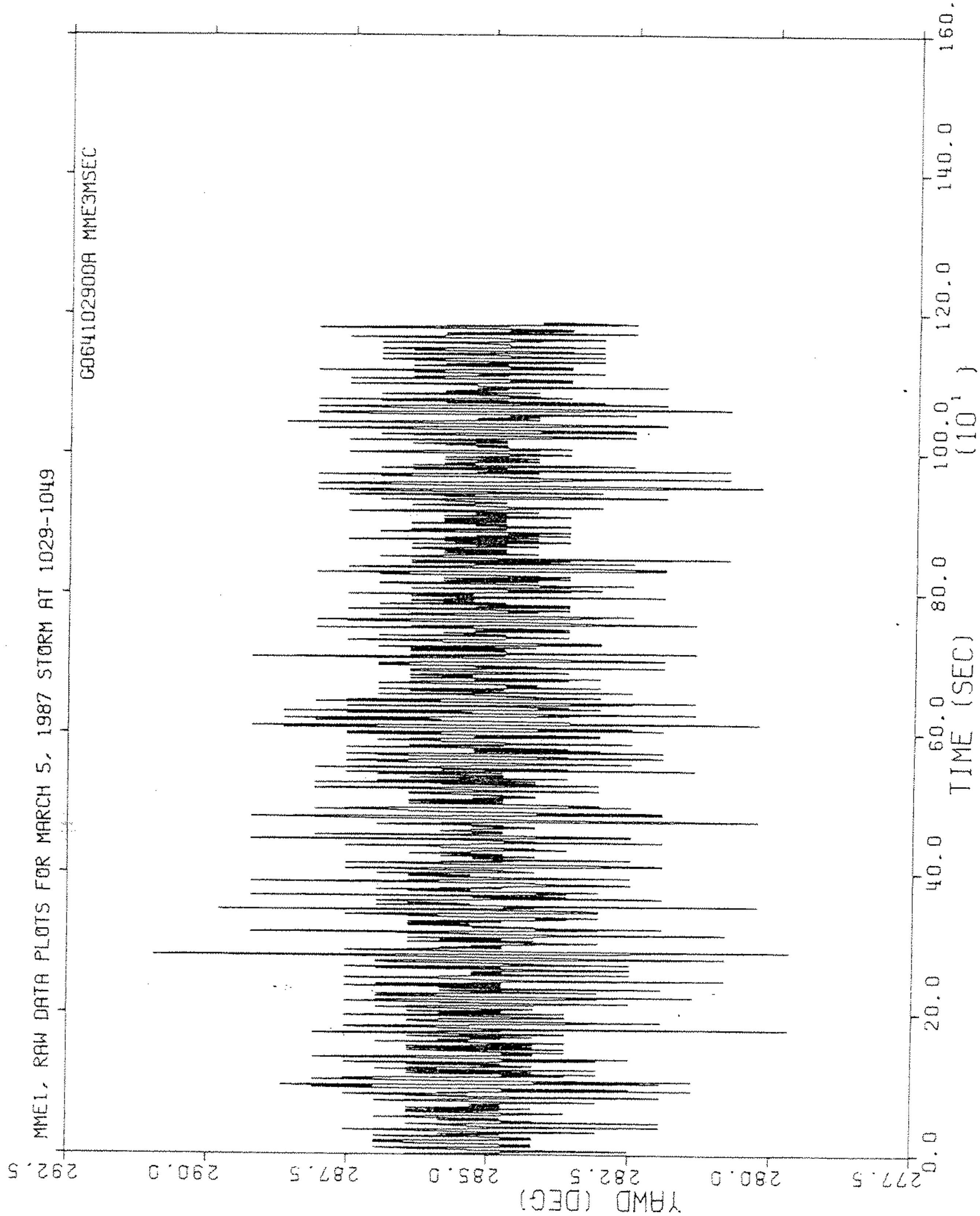

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900A MME3MSEC
SWAYA (G) (FT/S²)
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0

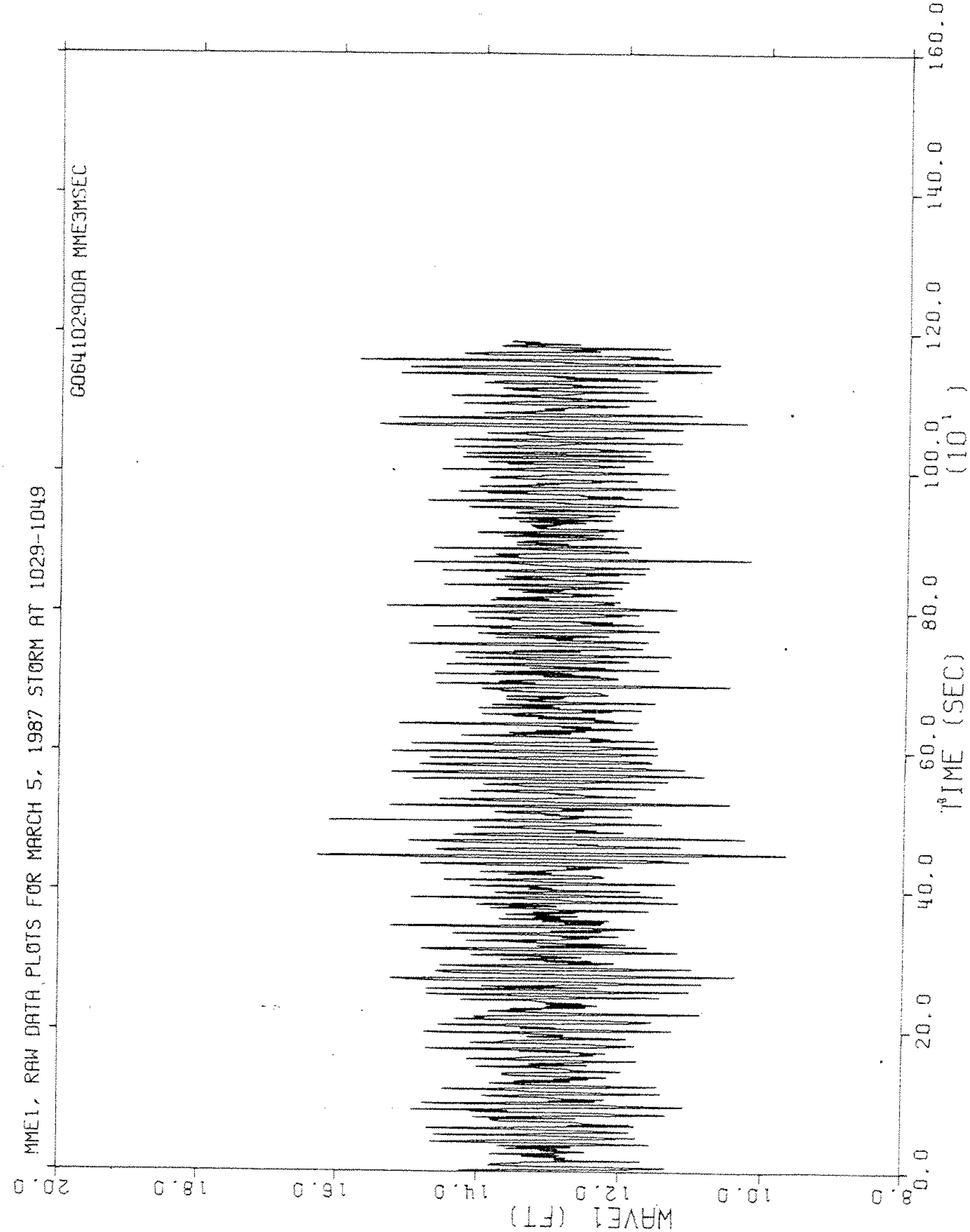

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
GO641029OOA MME3MSEC
ROLLV (D/S)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
TIME (SEC) (10^1)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

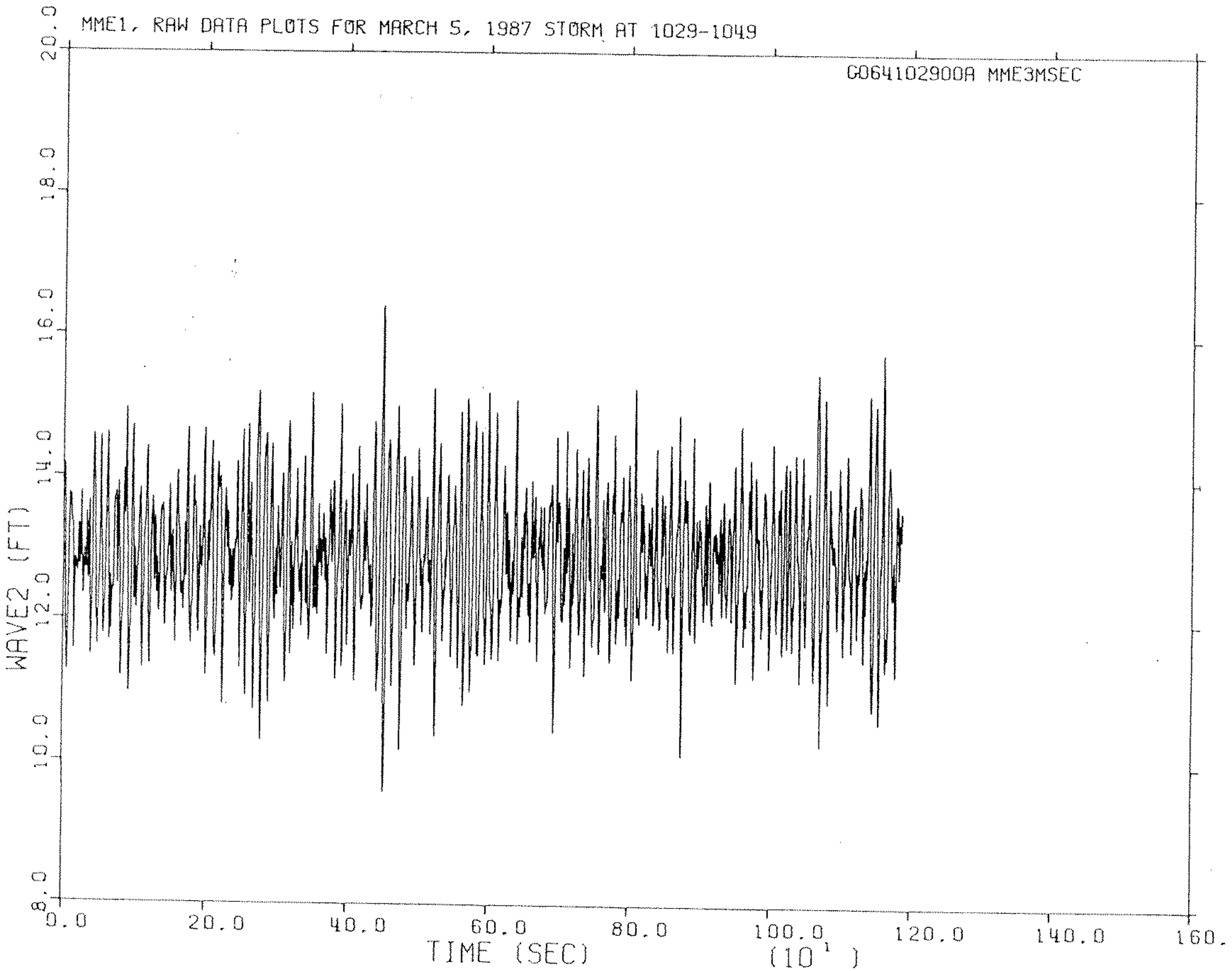

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900A MME3MSEC
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10^1)
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
PITCV (D/S)
(10^-1)

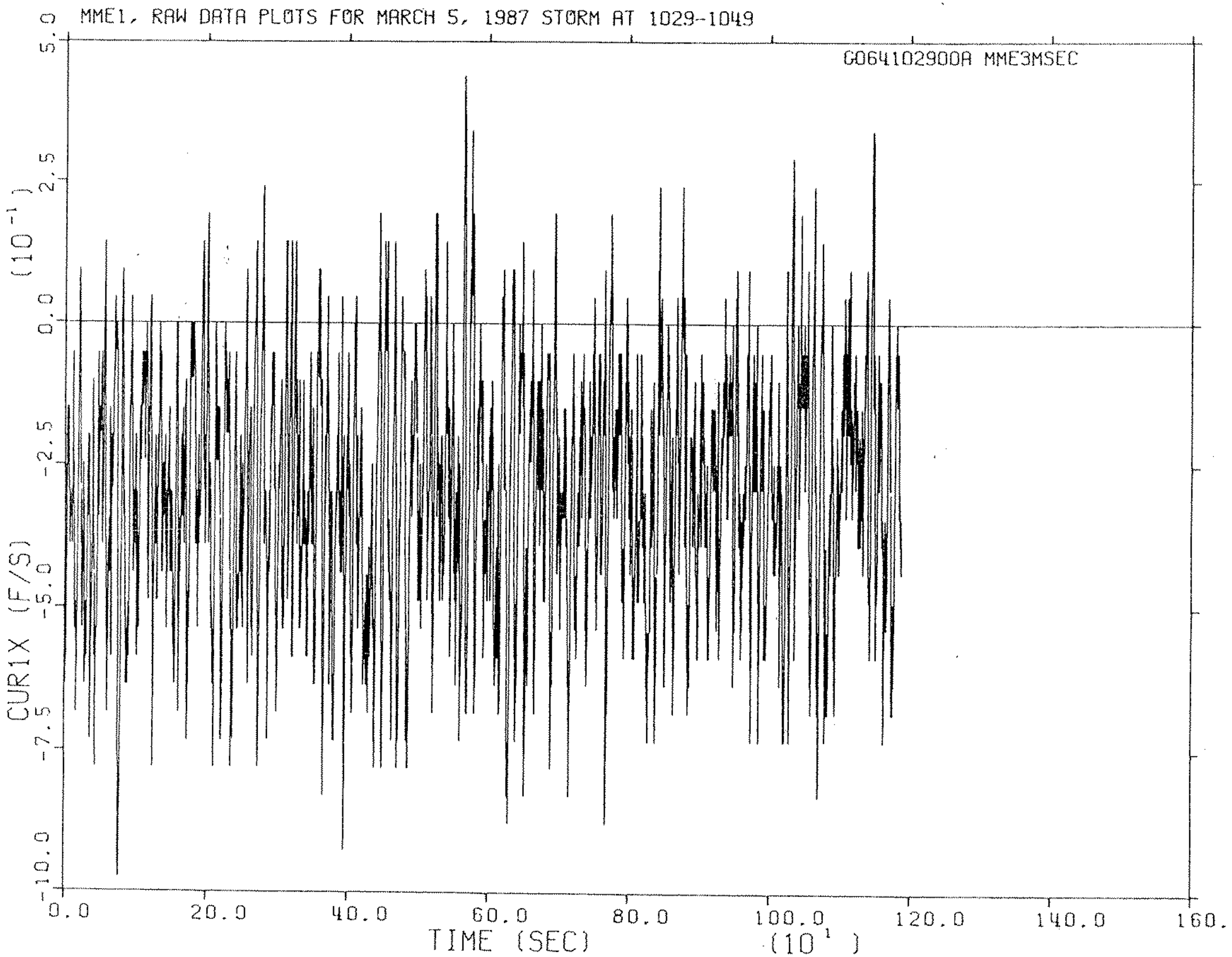

MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STORM AT 1029-1049
G0641029000A MME3MSEC
RØLLD (DEG)
TIME (SEC) (10¹)
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0


MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900A MME3MSEC
TIME (SEC) (10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
PITCD (DEG)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0

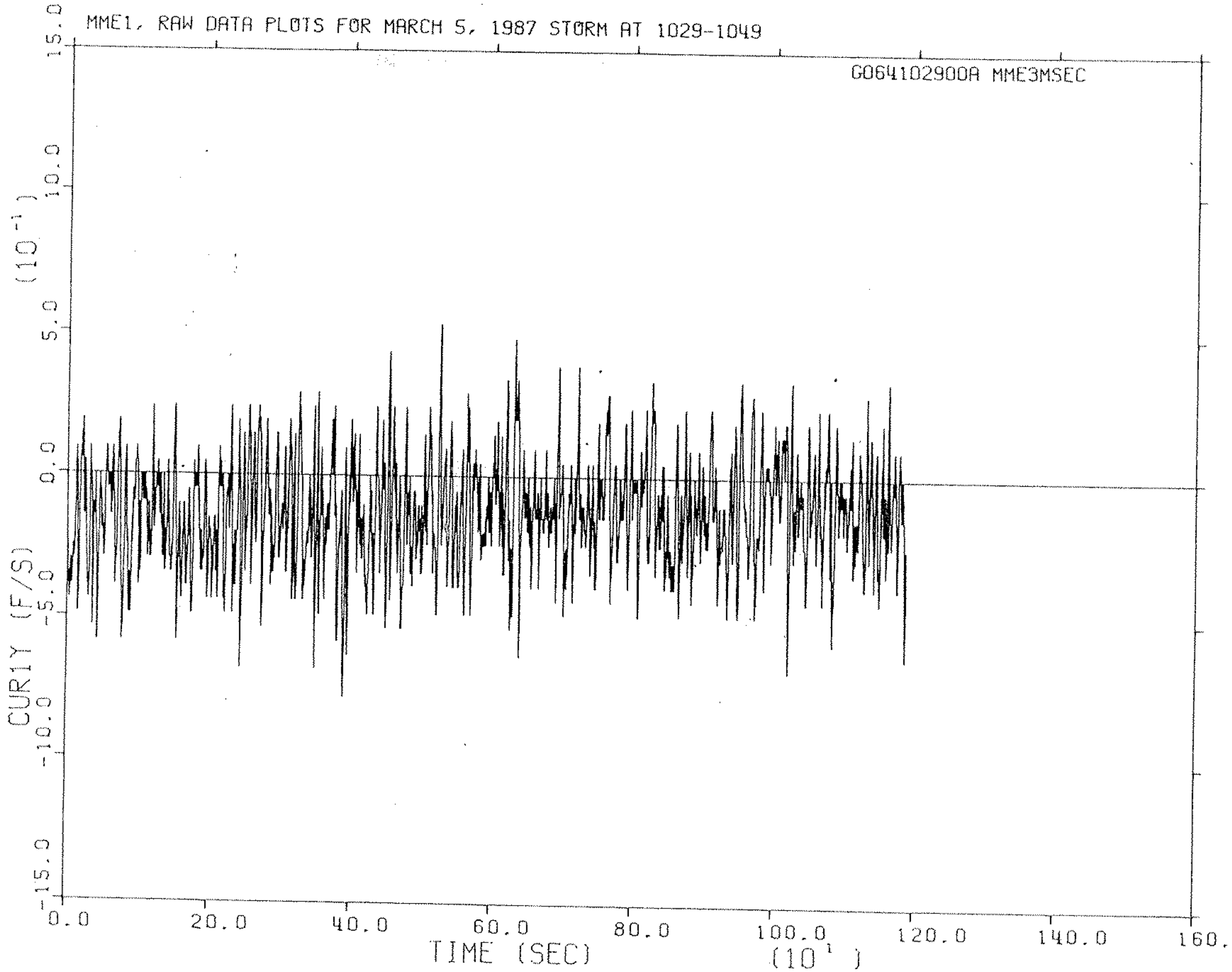

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029ODA MME3MSEC
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC) (10¹)
277.5
280.0
282.5
285.0
287.5
290.0
292.5
YAWD (DEG)

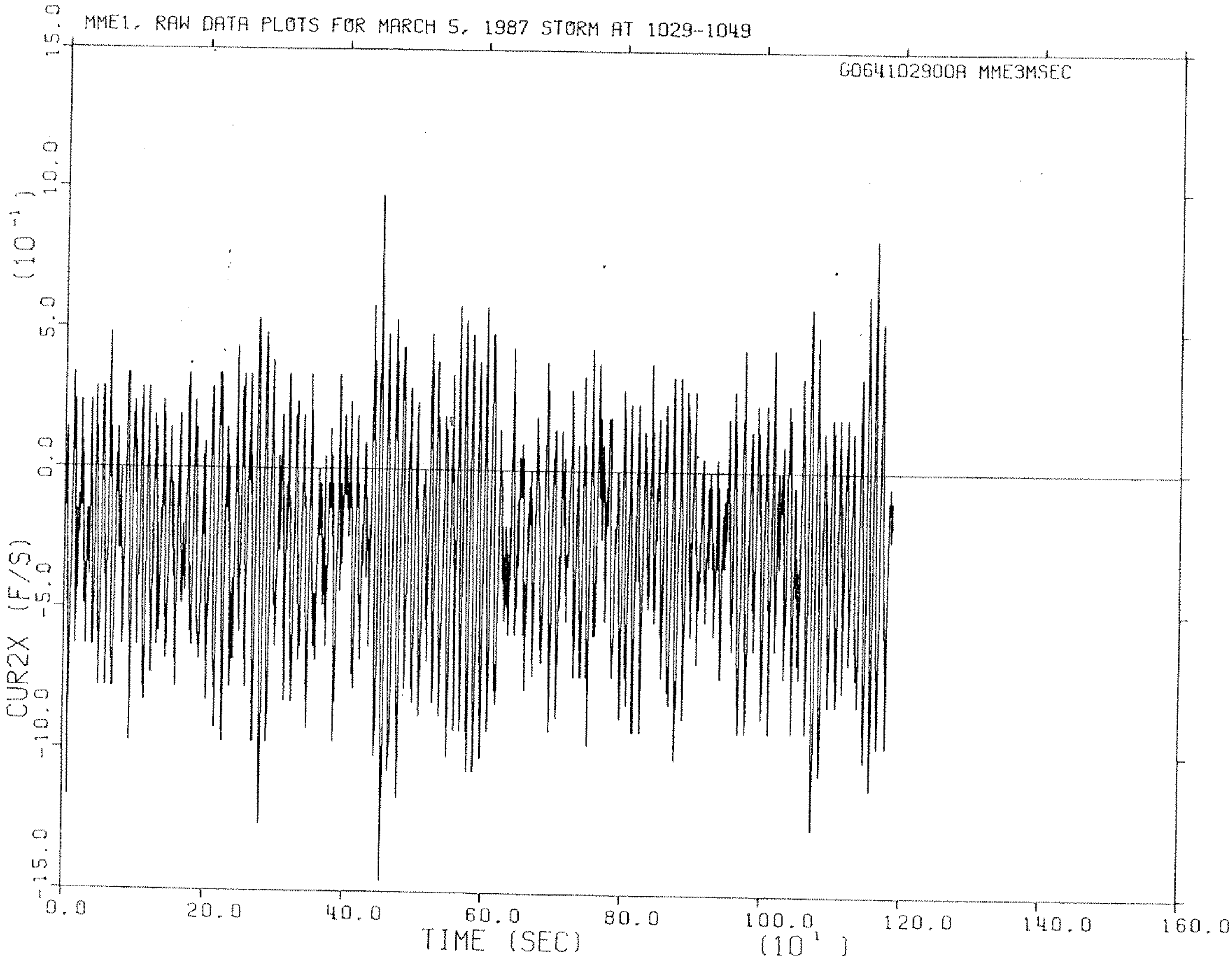

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G06410290OA MME3MSEC
WAVE1 (FT)
8.0
10.0
12.0
14.0
16.0
18.0
20.0
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

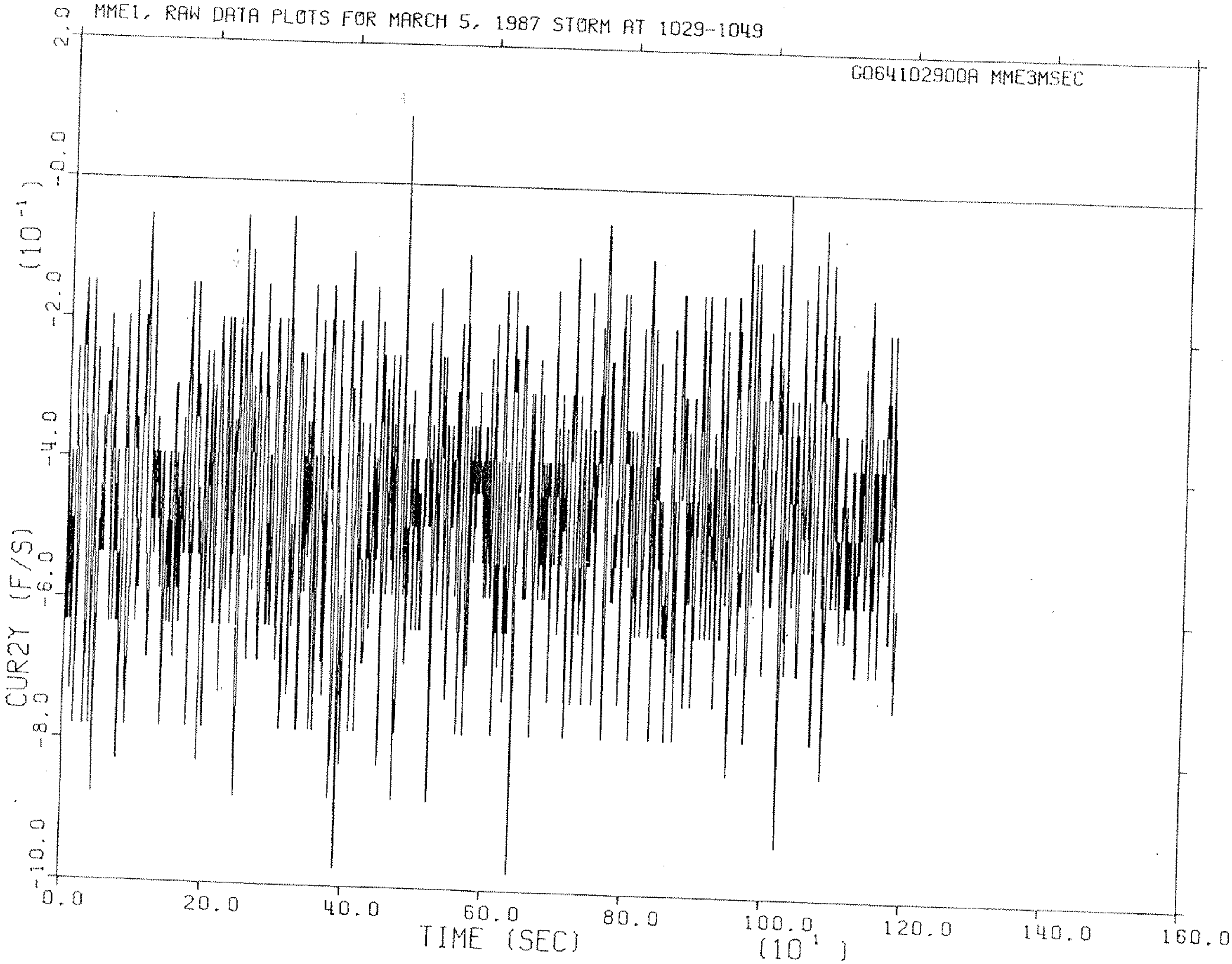

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900A MME3MSEC
WAVE2 (FT)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)

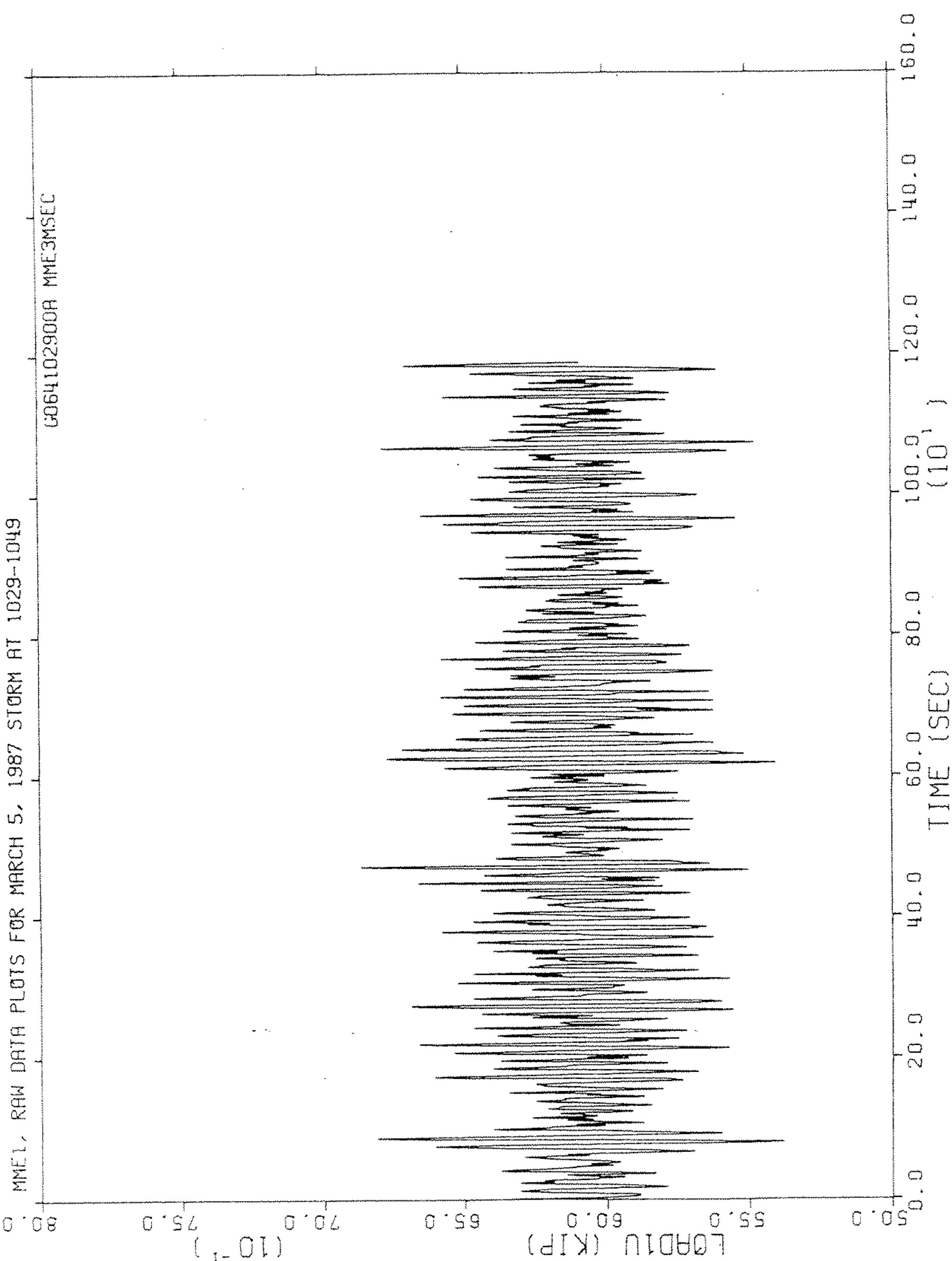


MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900A MME3MSEC
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
CUR1X (F/S)
(10⁻¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)

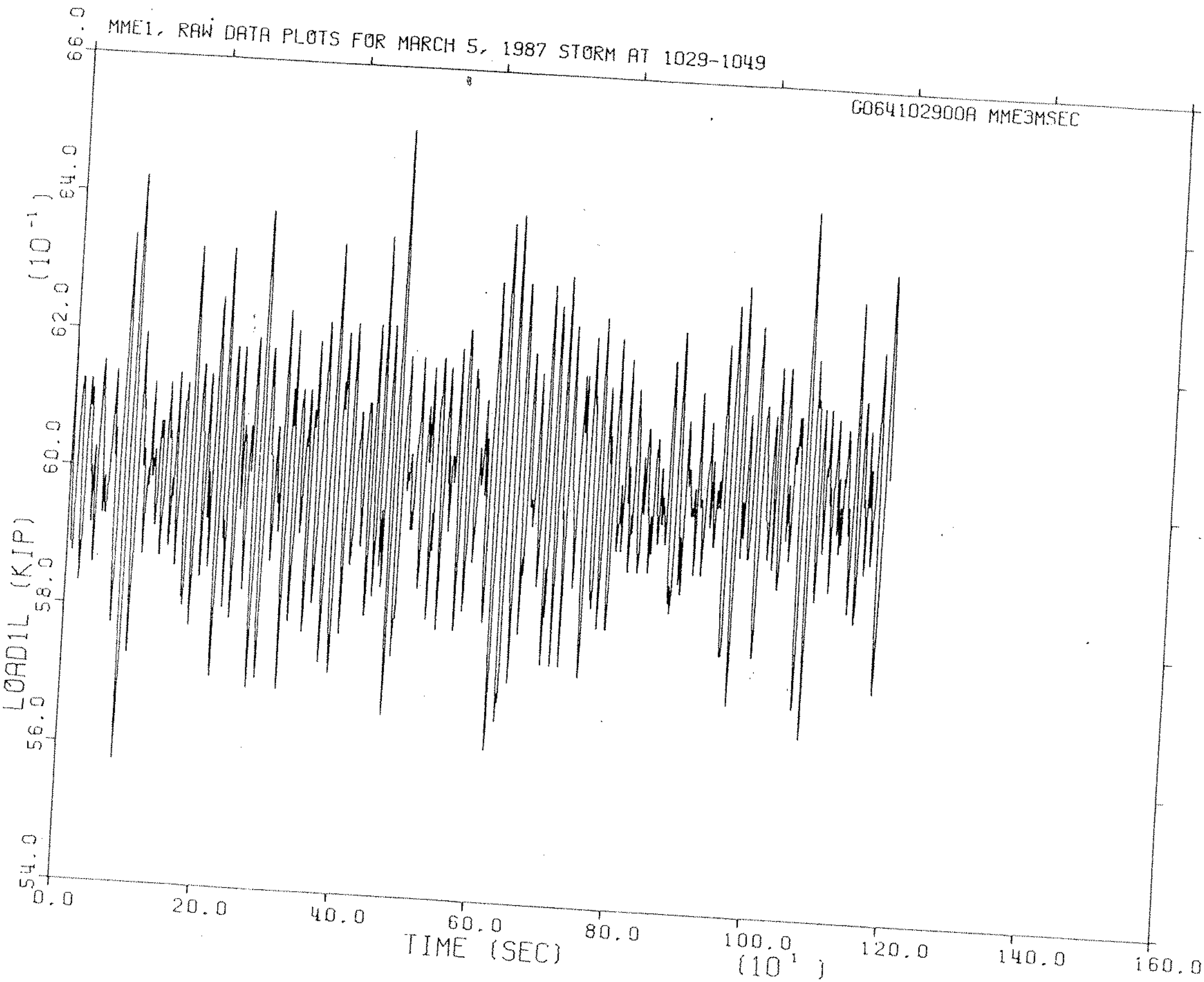

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900A MME3MSEC
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
CUR1Y (F/S)
(10^{-1})
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
TIME (SEC)
(10^{1})

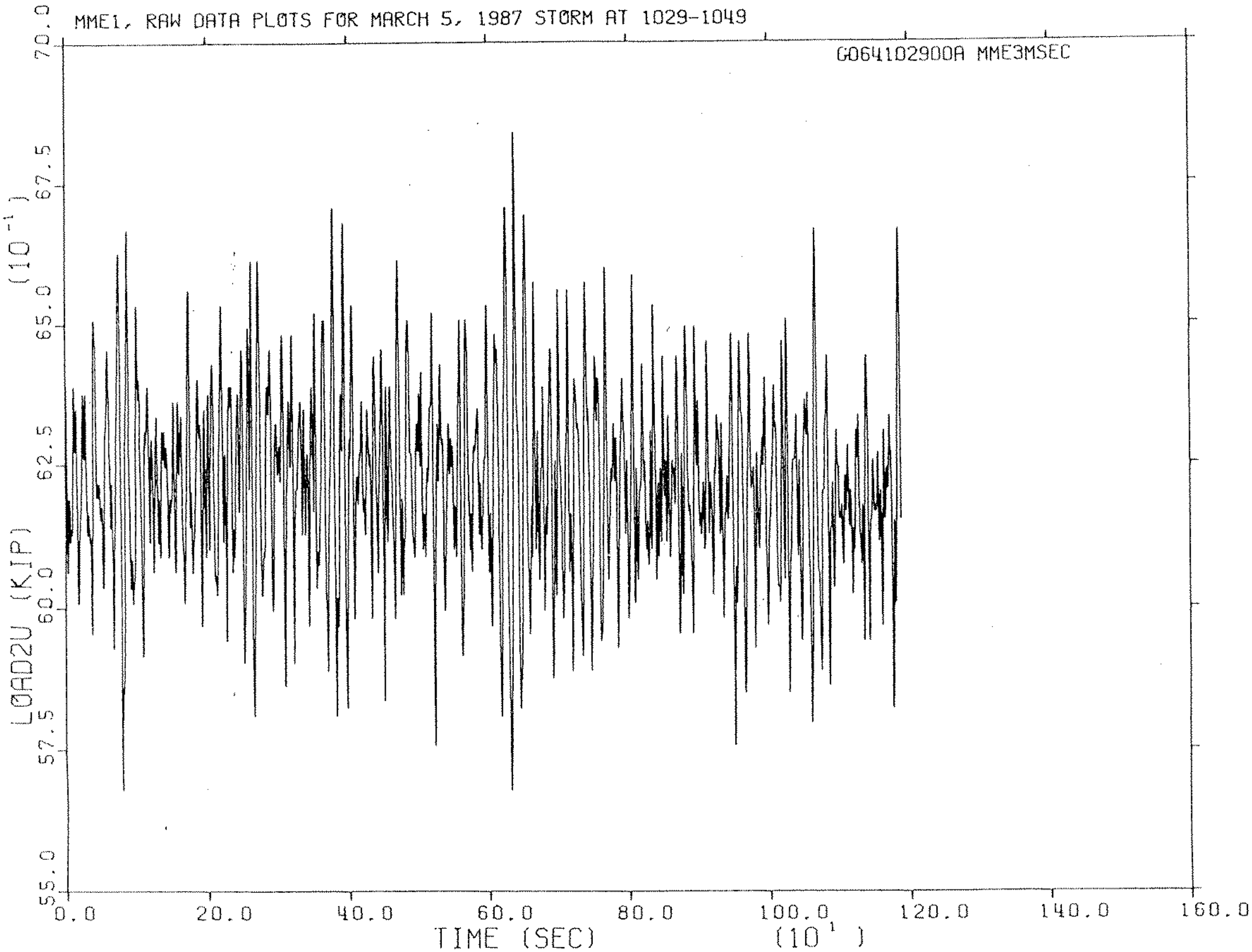

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900A MME3MSEC
CUR2X (F/S)
(10⁻¹)
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

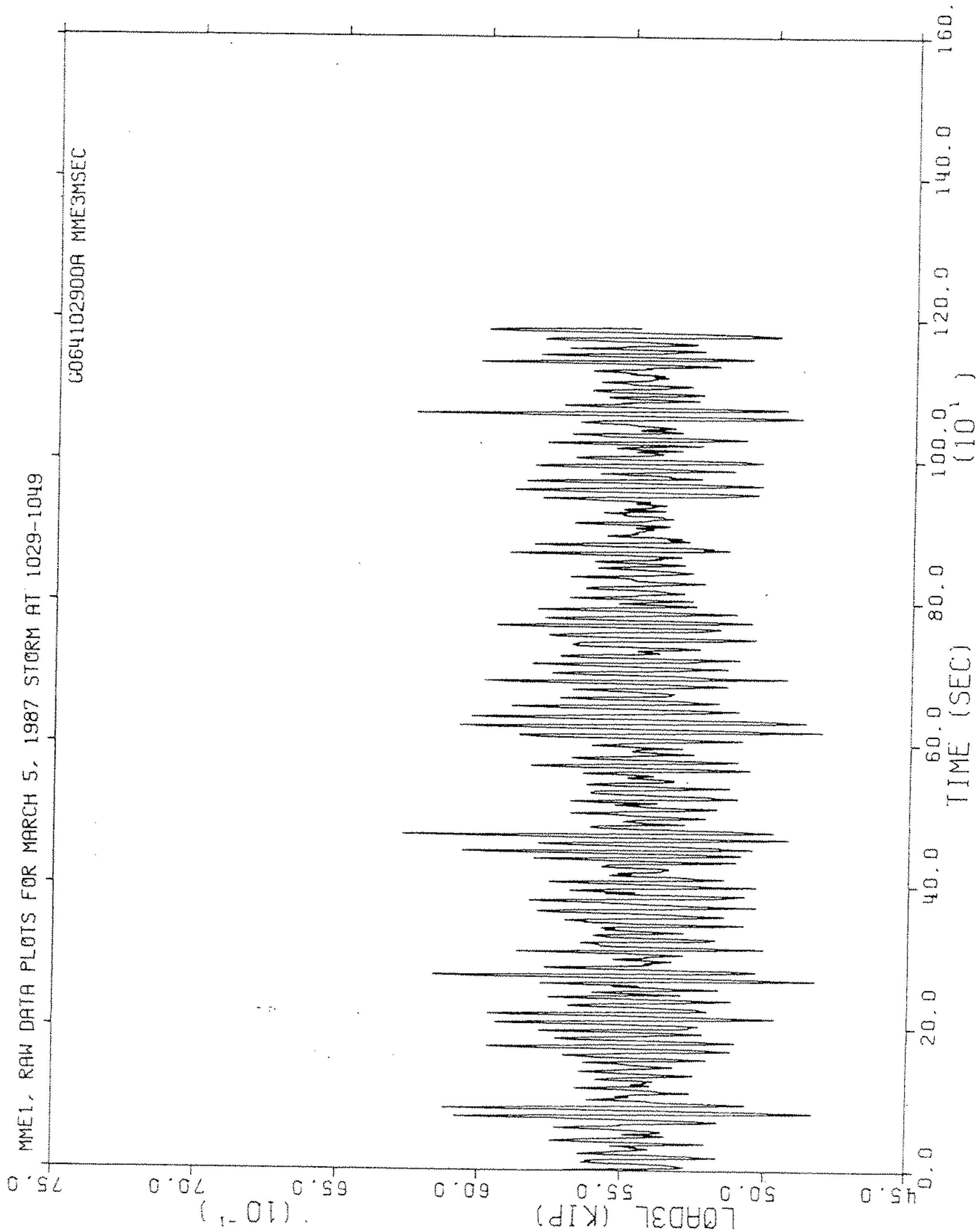

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900A MME3MSEC
CUR2Y (F/S)
(10⁻¹)
2.0
-0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)



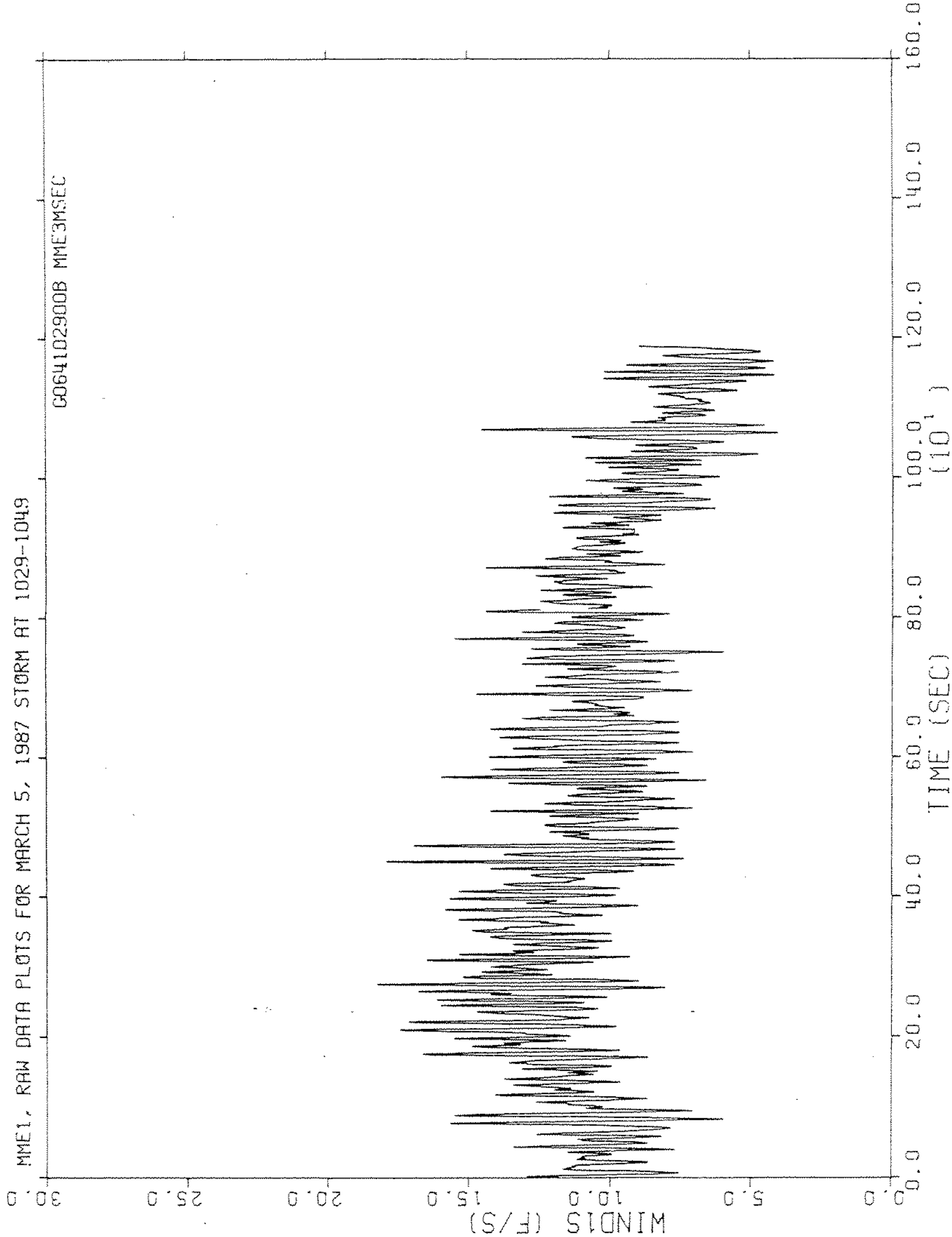
MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G064102900A MME3MSEC
TIME (SEC)
(10^1)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
LØAD1U (KIP)
(10^-1)
50.0
55.0
60.0
65.0
70.0
75.0
80.0

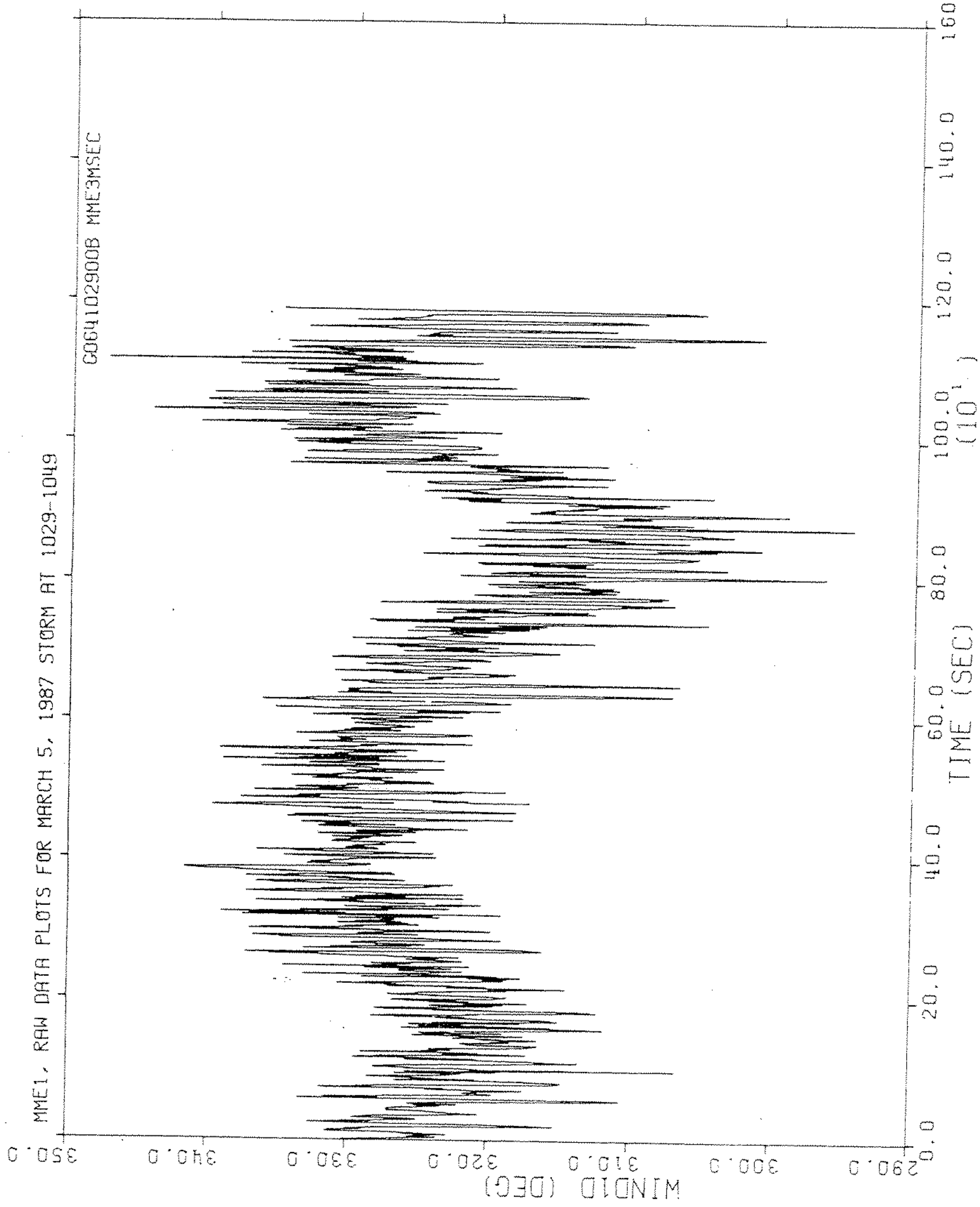

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029000A MME3MSEC
LOAD1L (KIP)
(10⁻¹)
66.0
64.0
62.0
60.0
58.0
56.0
54.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)

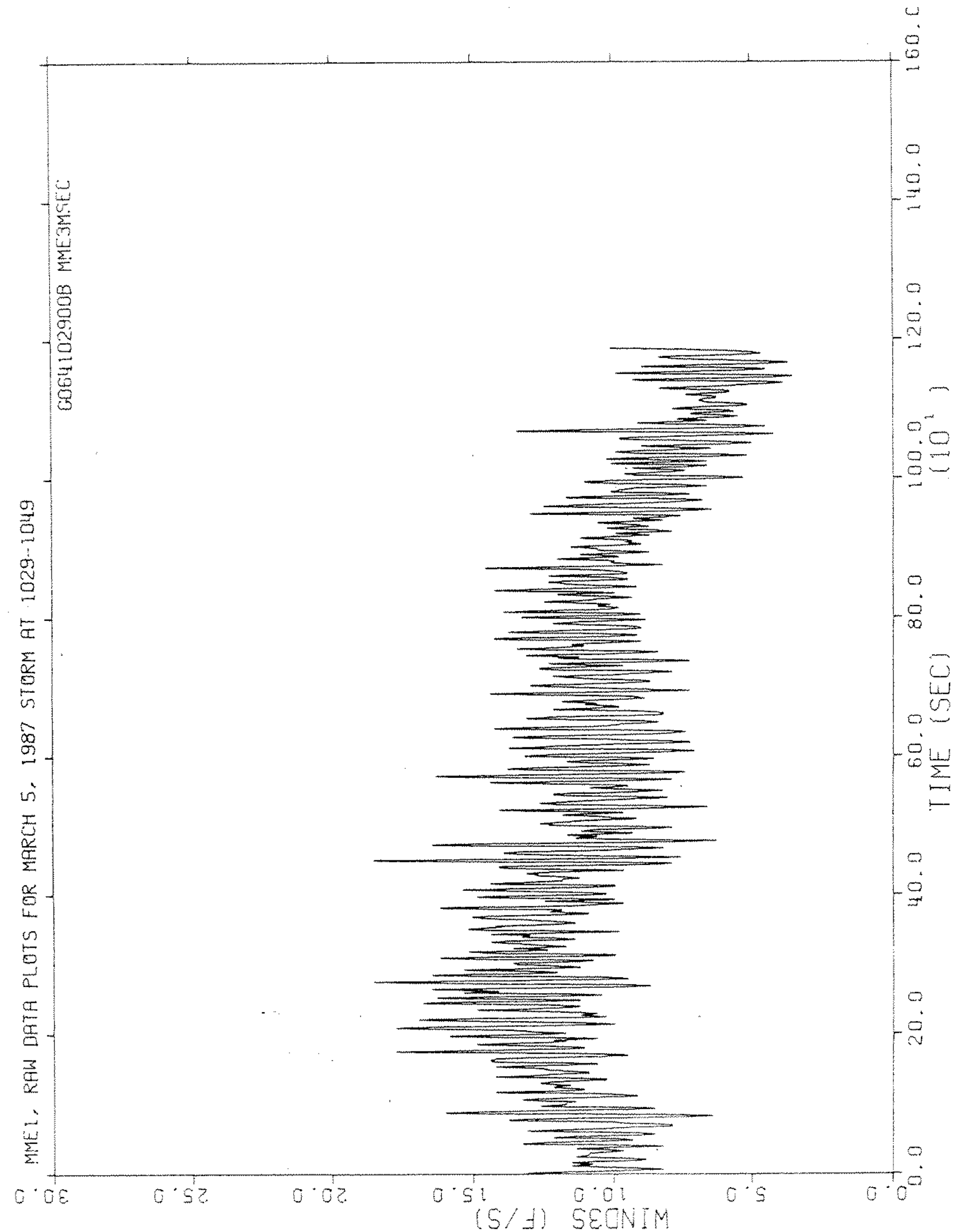

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900A MME3MSEC
LOAD2U (KIP)
(10 -1)
70.0
67.5
65.0
62.5
60.0
57.5
55.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10 1)

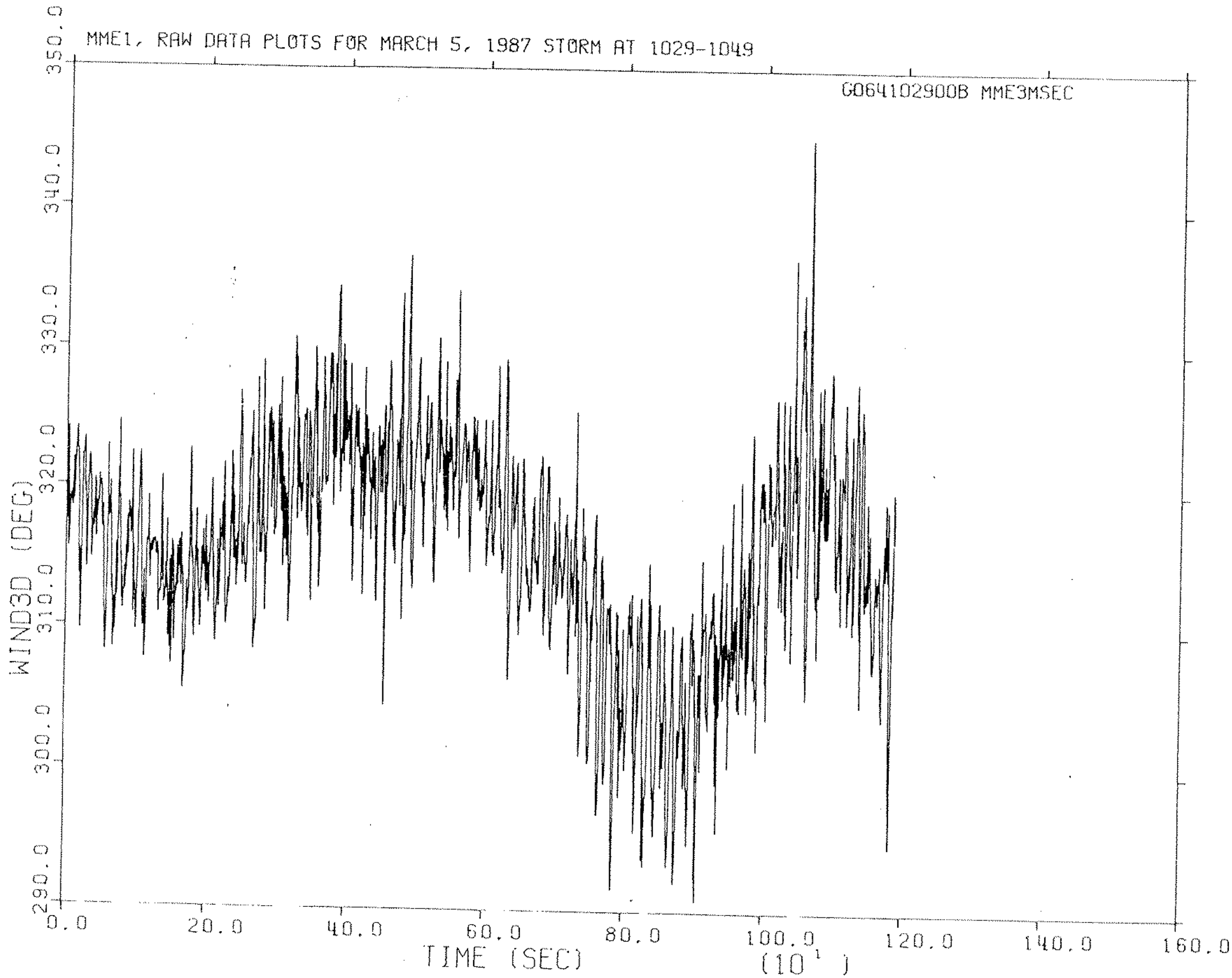


MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029OOA MME3MSEC
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
LOAD3L (KIP)
(10⁻¹)
45.0
50.0
55.0
60.0
65.0
70.0
75.0

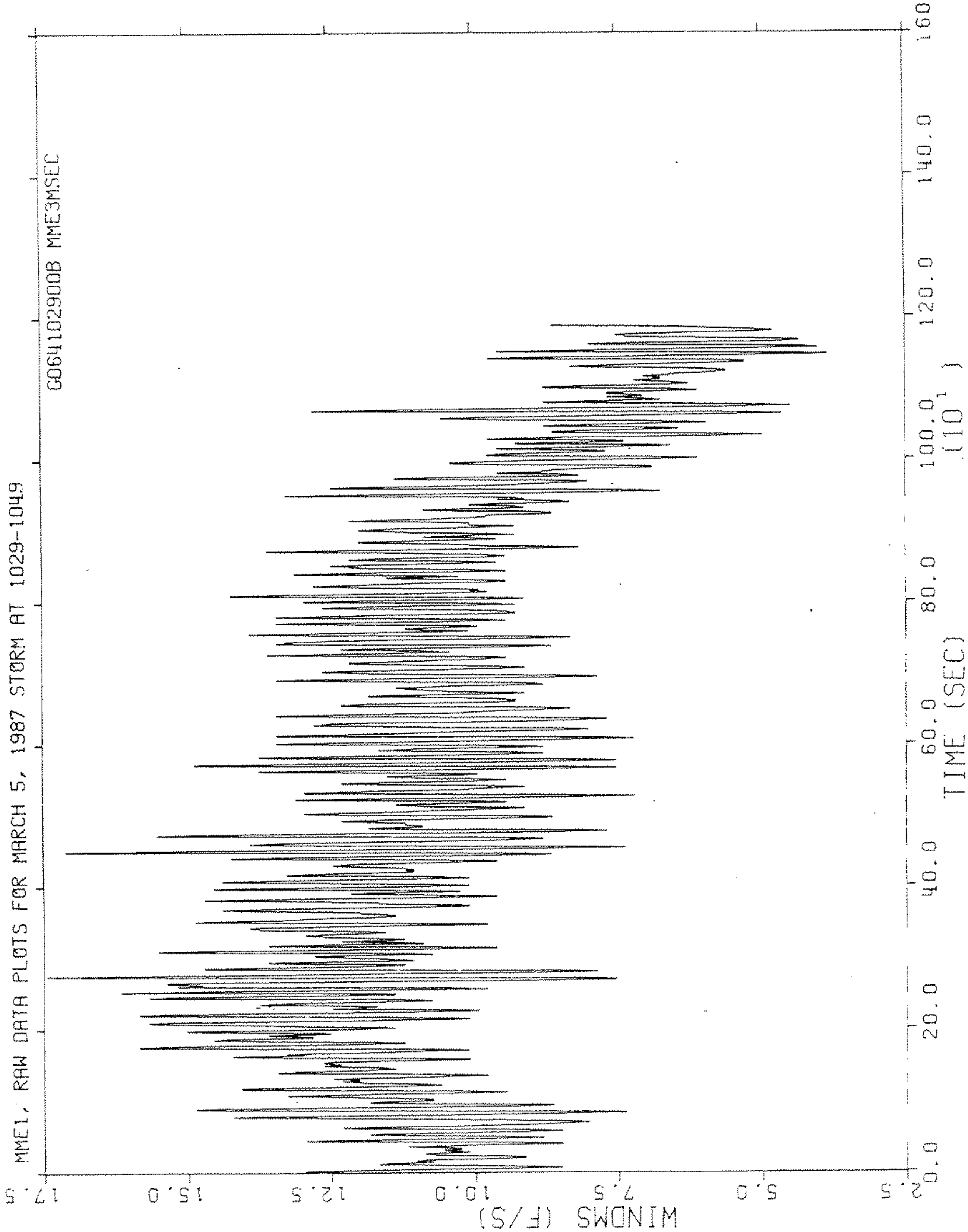

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029008 MME3MSEC
WIND1S (F/S)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

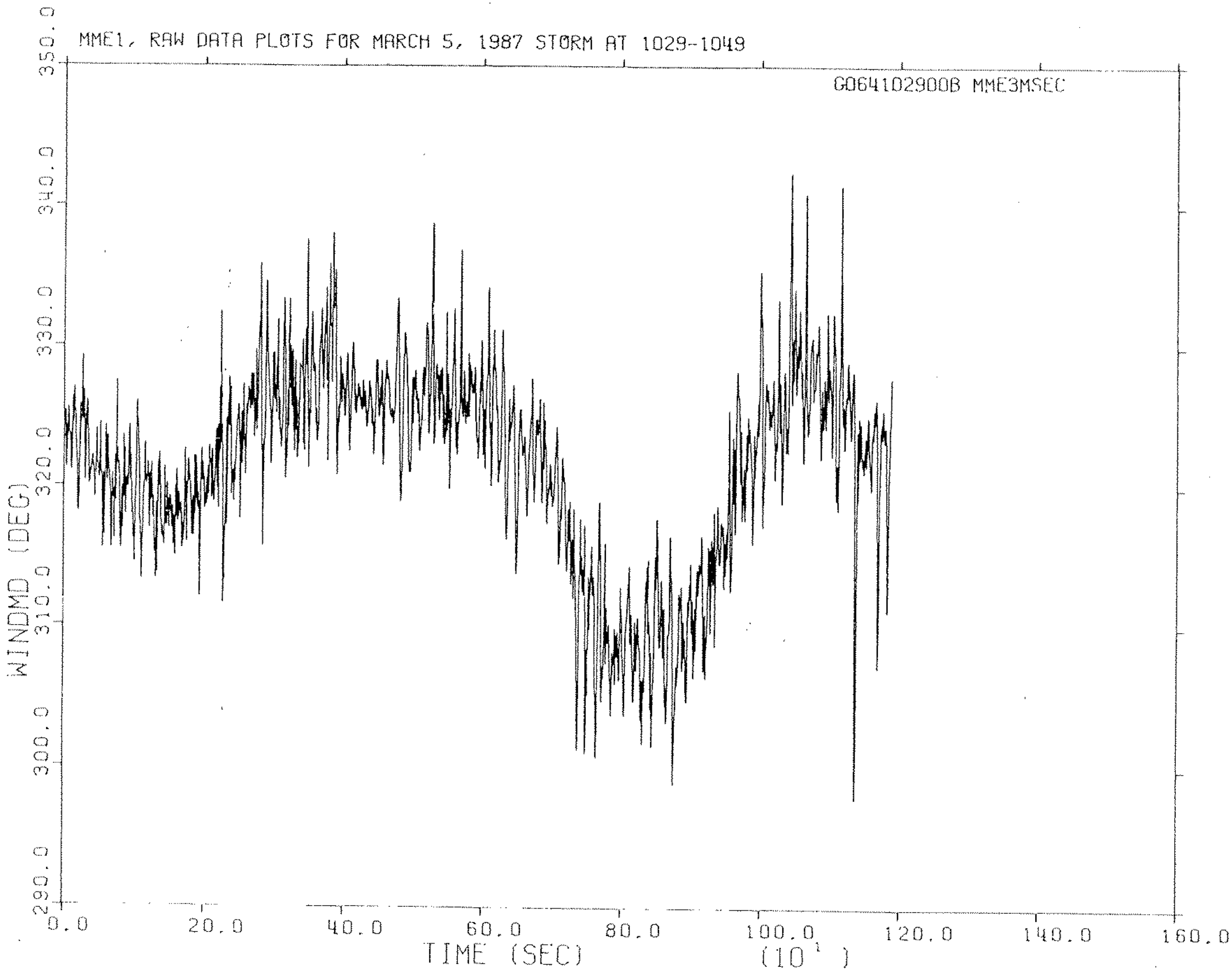

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900B MME3MSEC
WINDID (DEG)
350.0
340.0
330.0
320.0
310.0
300.0
290.0
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0


MMEL, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
GO641D2900B MME3MSEC
WIND3S (F/S)
TIME (SEC) (10¹)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

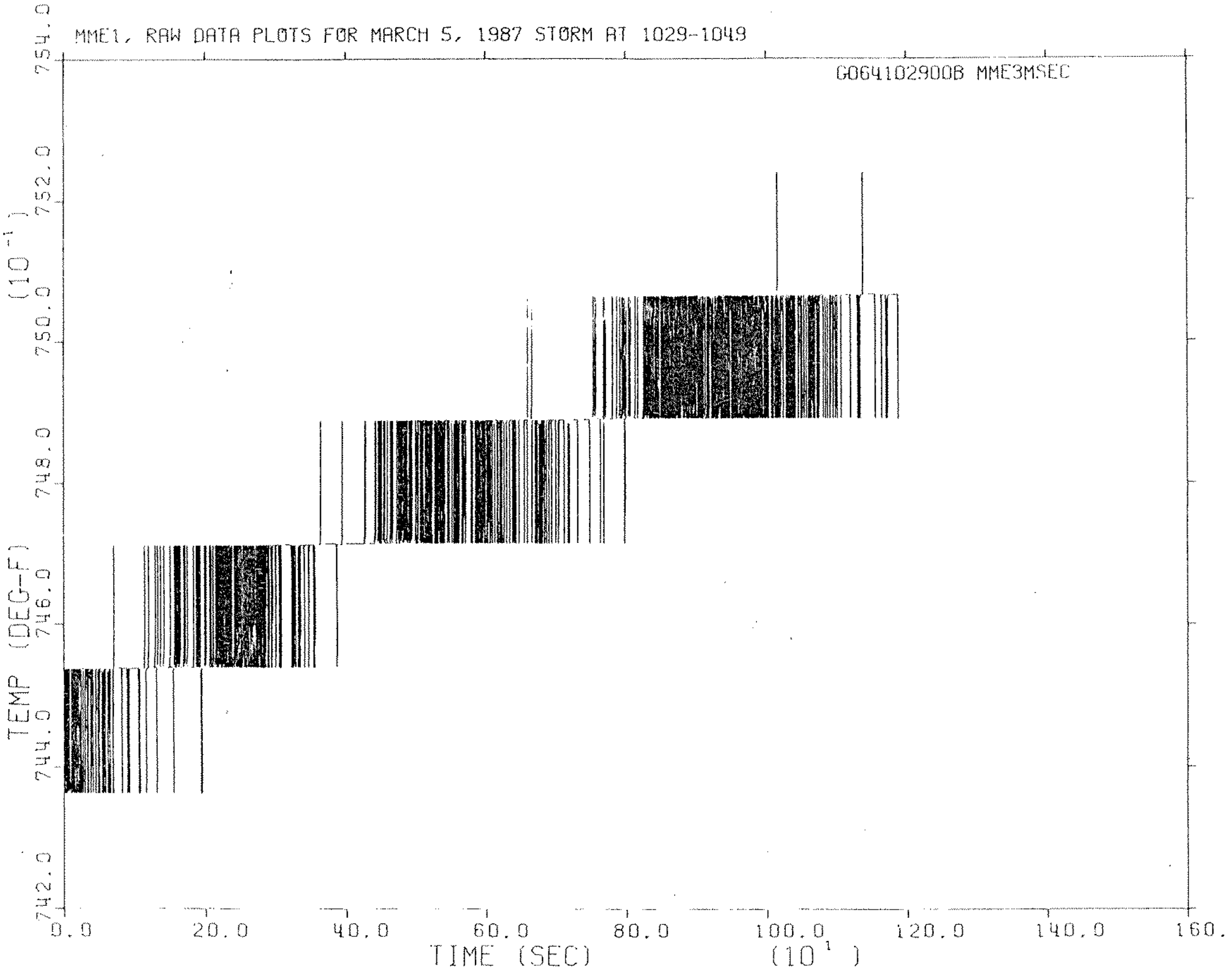


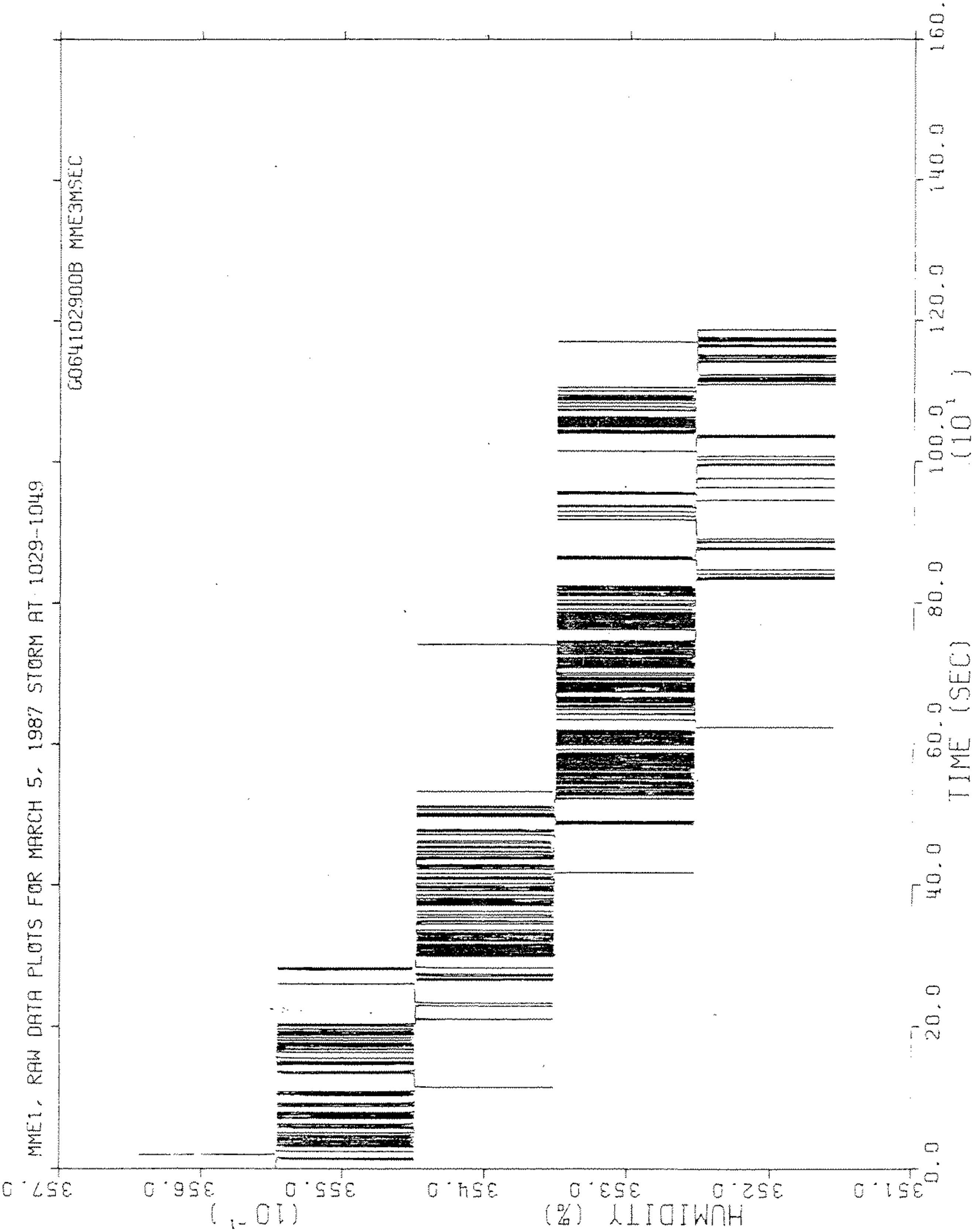
MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900B MME3MSEC
WIND3D (DEG)
350.0
340.0
330.0
320.0
310.0
300.0
290.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)


MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G0641029008 MME3MSEC
TIME (SEC)
(10^1)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
WINDMS (F/S)
2.5
5.0
7.5
10.0
12.5
15.0
17.5

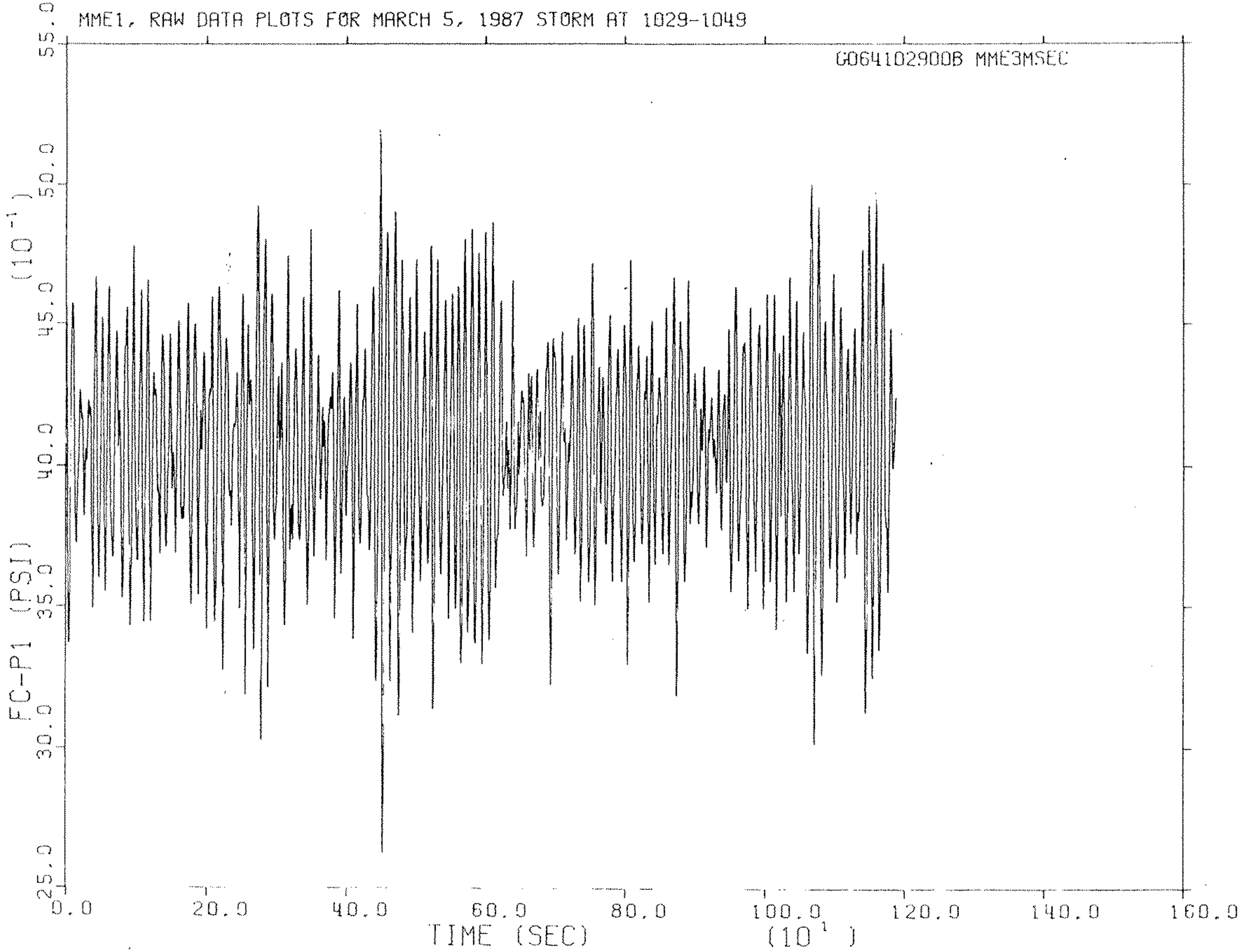


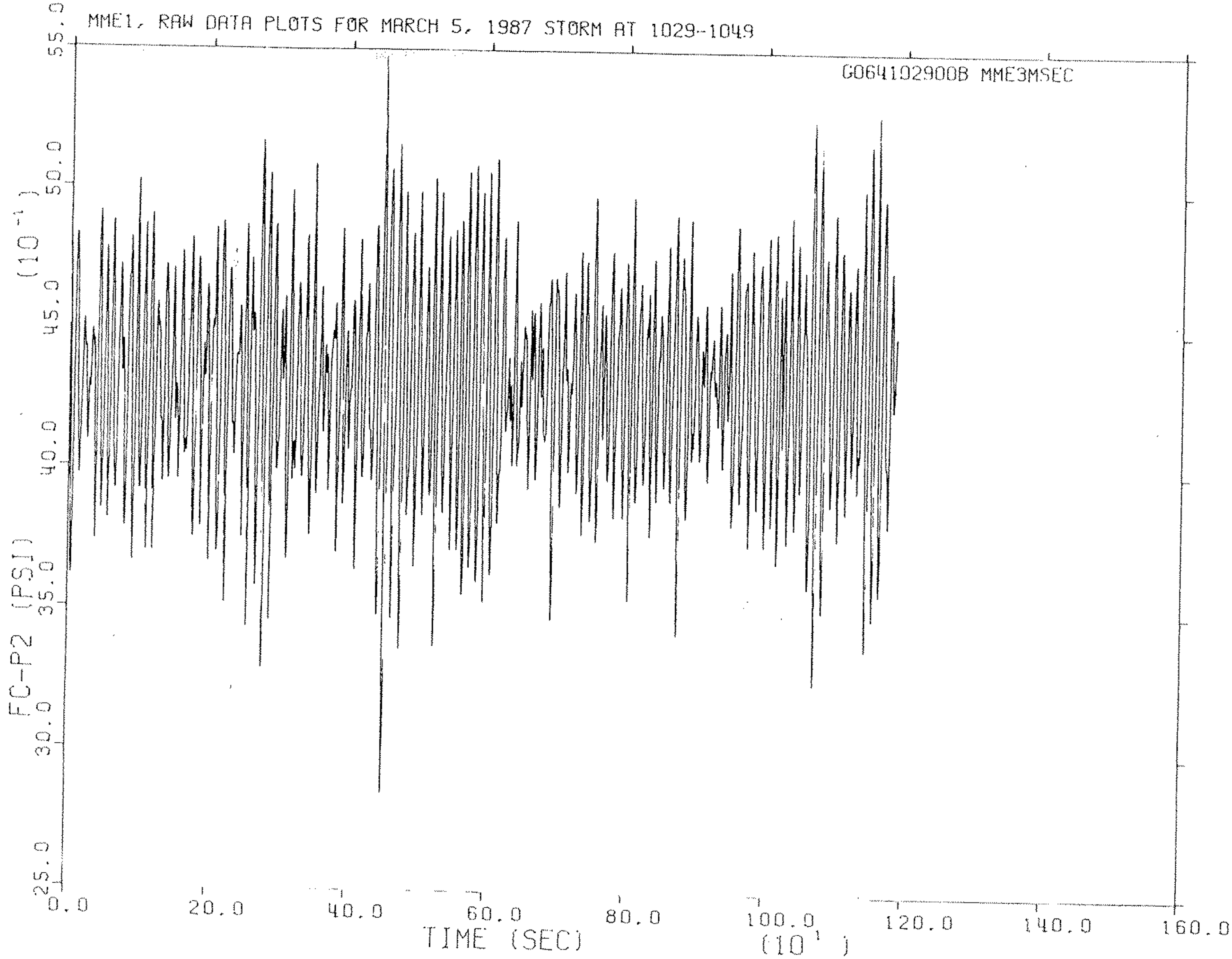
MME1, RAW DATA PLØTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G0641029008 MME3MSEC
WINDMD (DEG)
350.0
340.0
330.0
320.0
310.0
300.0
290.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10^1)


MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G0641029OOB MME3MSEC
TEMP (DEG-F) (10⁻¹)
754.0
752.0
750.0
748.0
746.0
744.0
742.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC) (10¹)

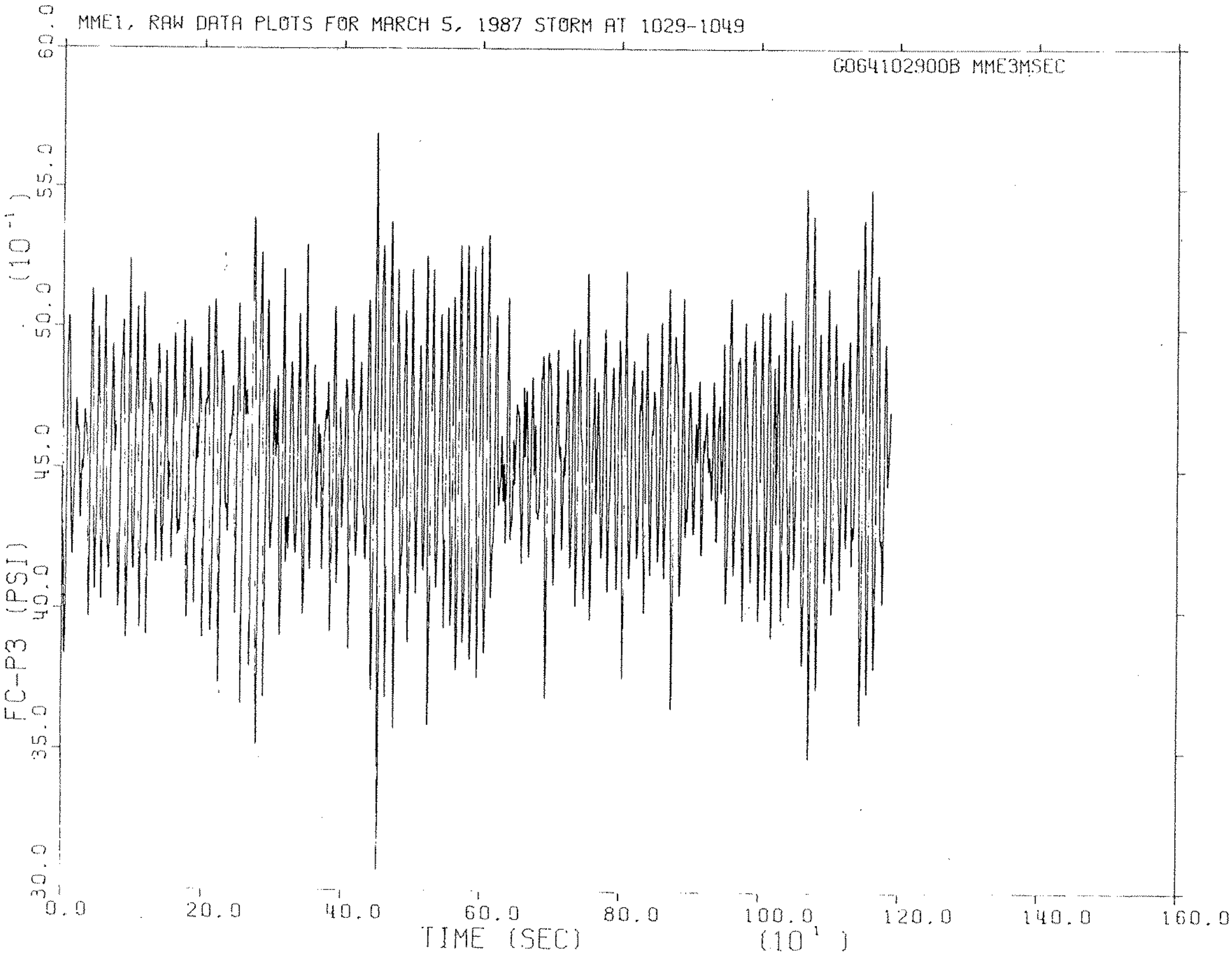


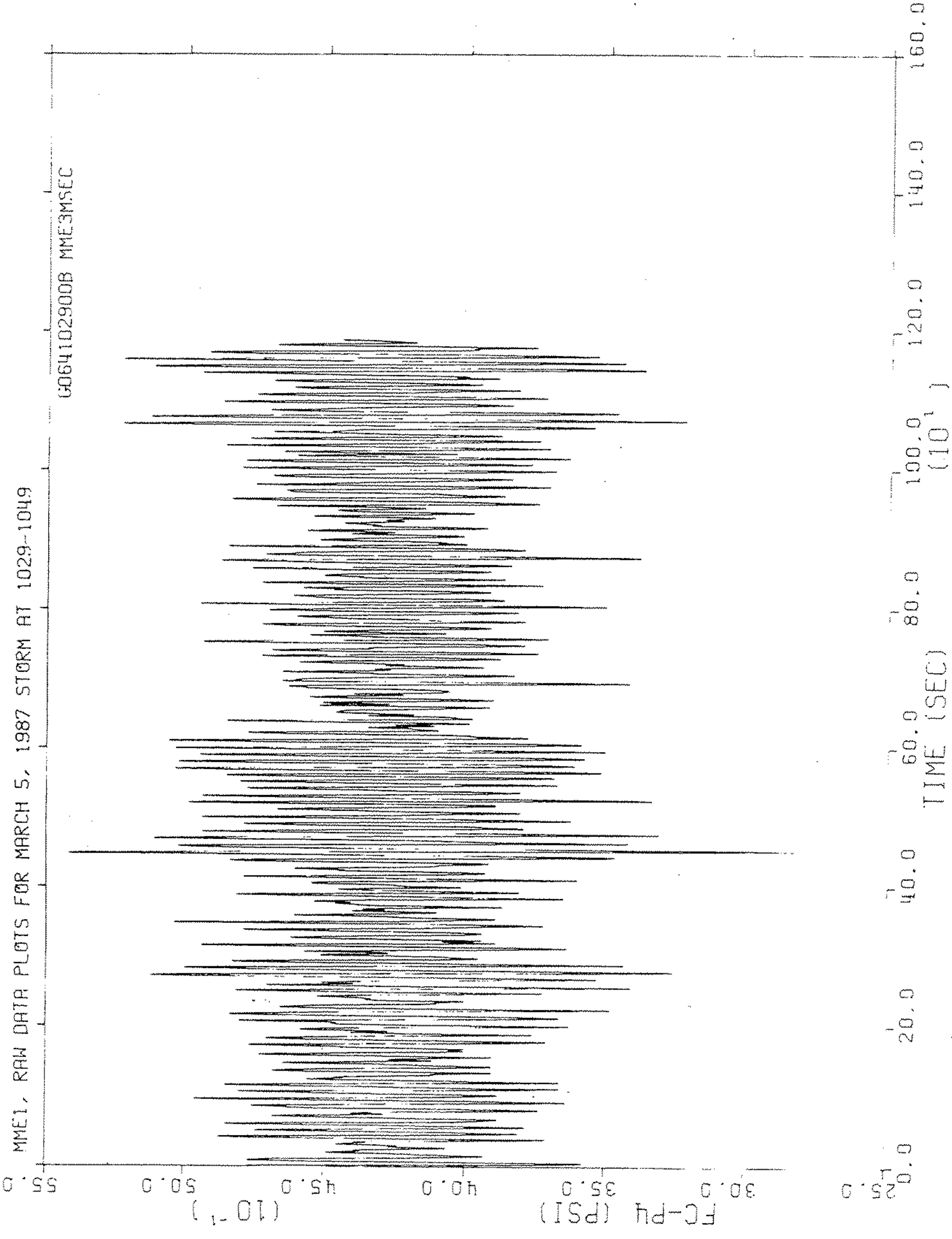
MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G0641029008 MME3MSEC
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10^1)
351.0
352.0
353.0
354.0
355.0
356.0
357.0
HUMIDITY (%)
(10^-1)

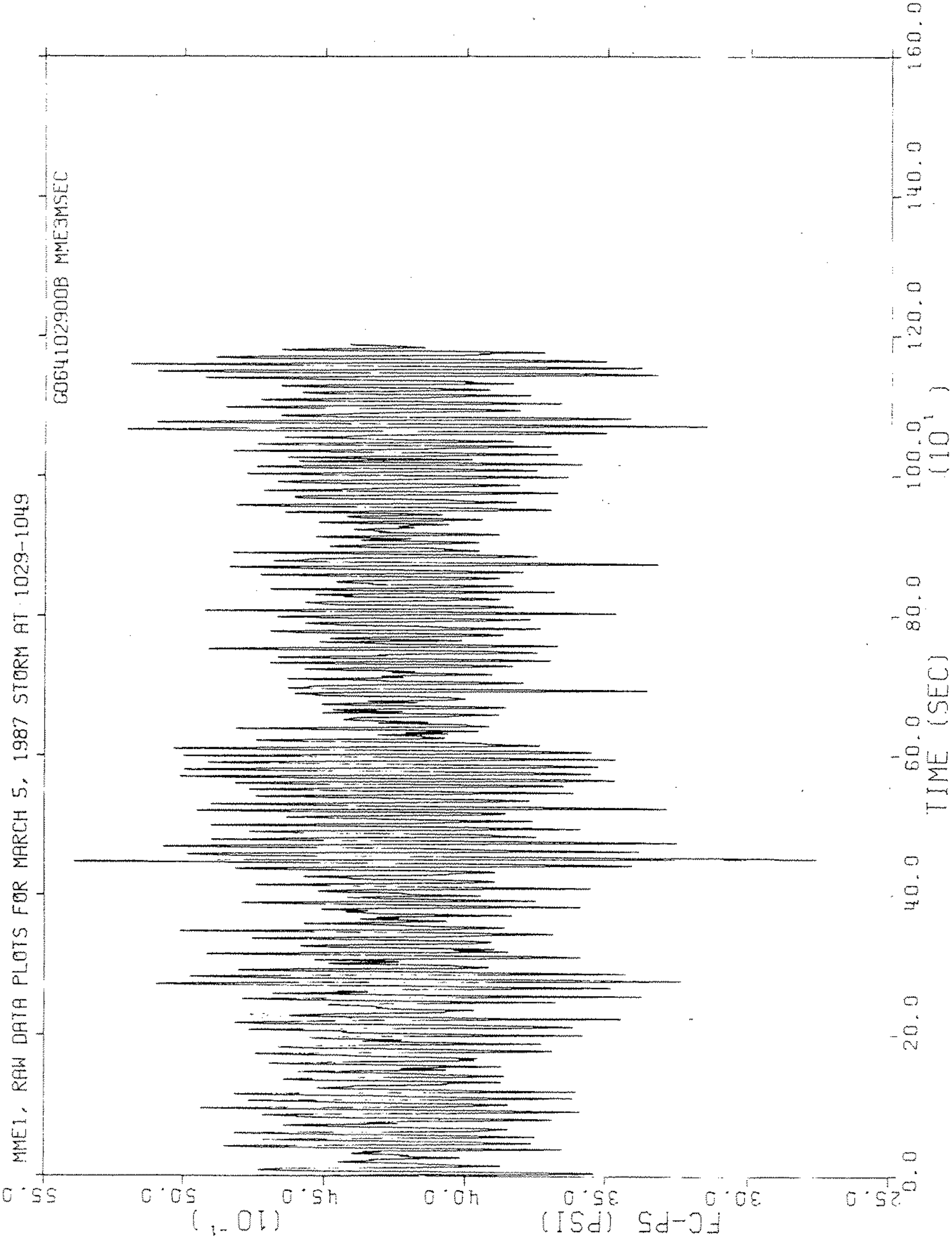

MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G064102900B MME3MSEC
55.0
50.0
45.0
40.0
35.0
30.0
25.0
FC-P1 (PSI) (10⁻¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC) (10¹)

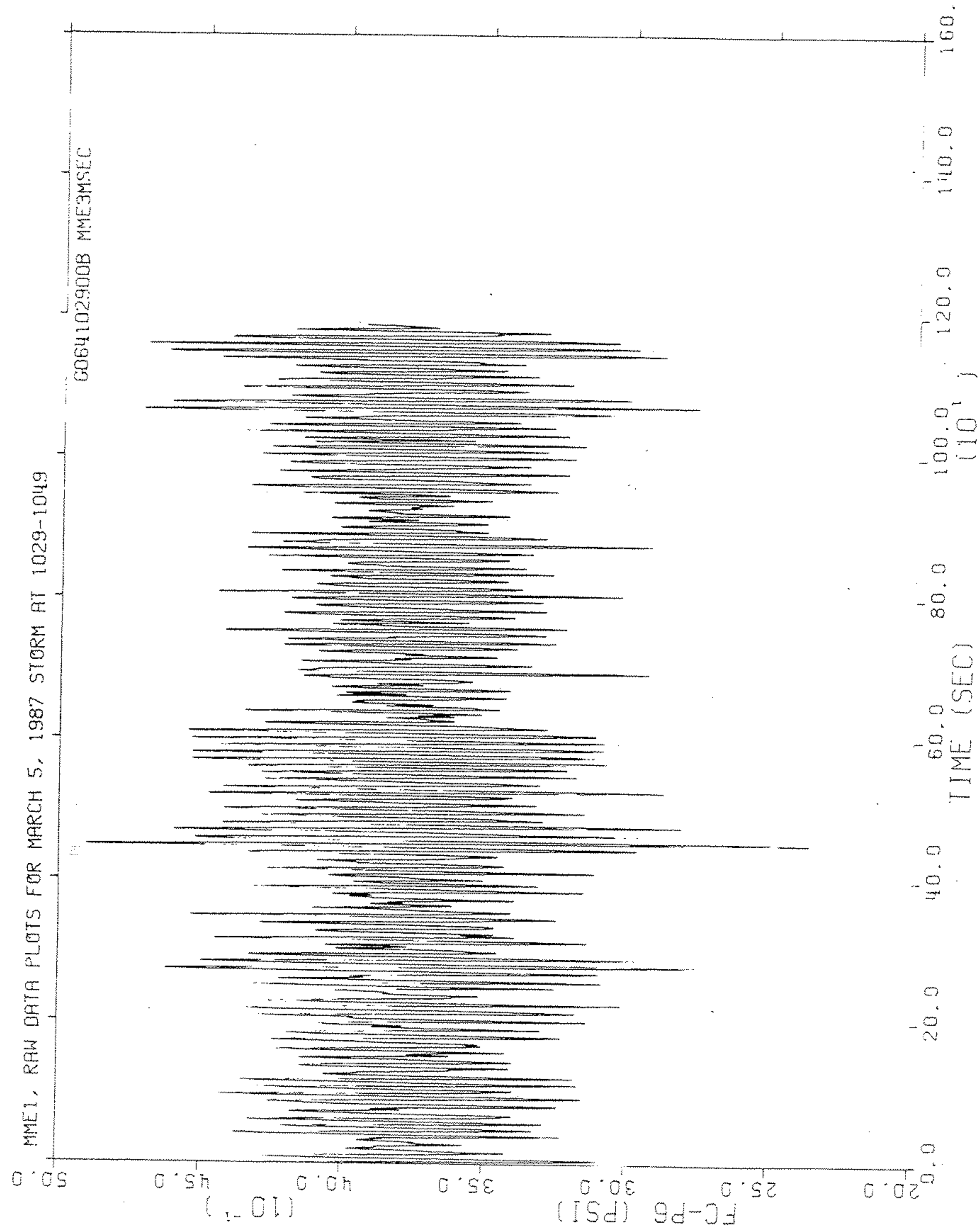

MME1, RAW DATA PLOTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G064102900B MME3MSEC
FC-P2 (PSI)
(10⁻¹)
55.0
50.0
45.0
40.0
35.0
30.0
25.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)

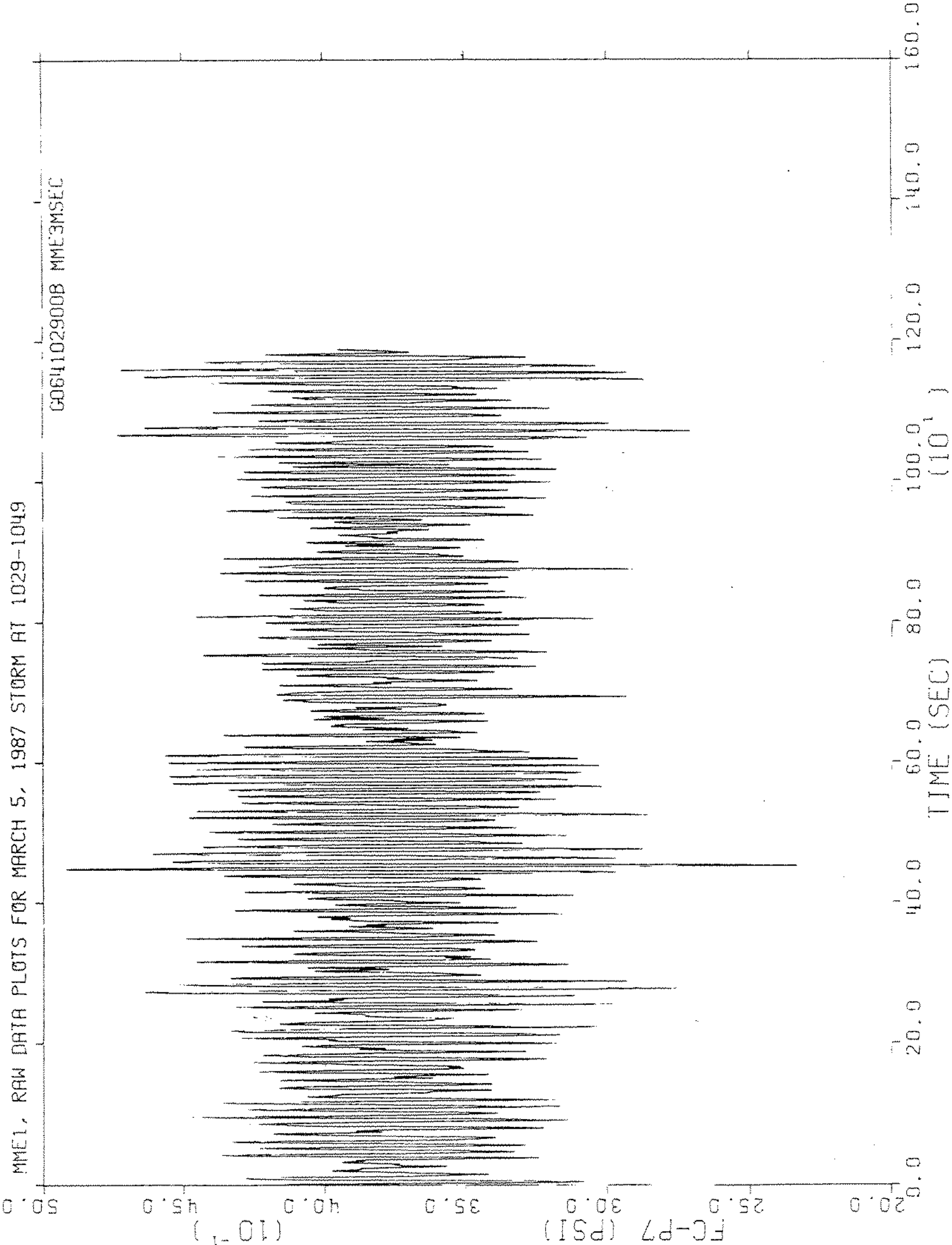
MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049

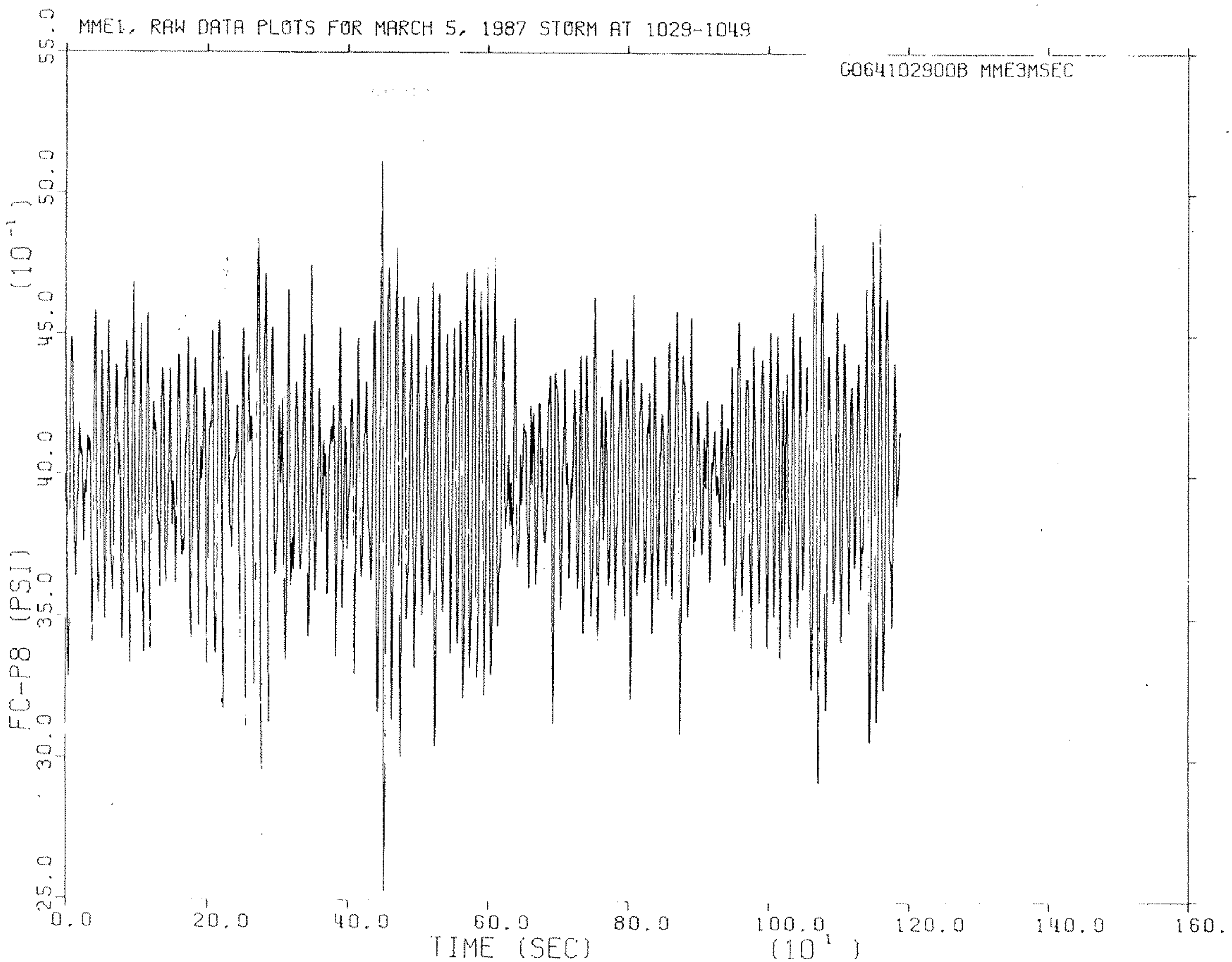



MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900B MME3MSEC
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)
25.0
30.0
35.0
40.0
45.0
50.0
55.0
FC-P4 (PSI)
(10⁻¹)

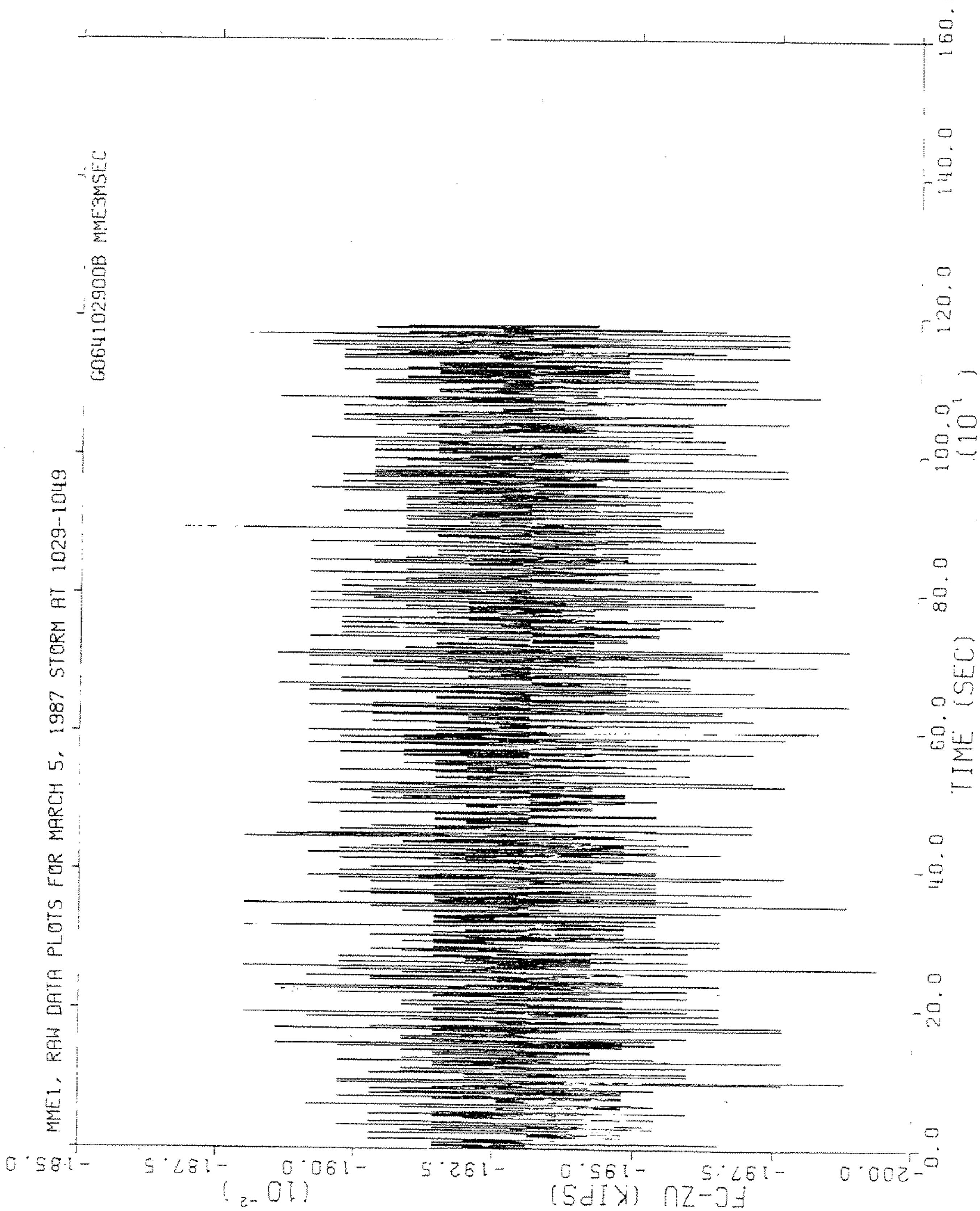

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029008 MME3MSEC
FC-PS (PSI) (10⁻¹)
55.0
50.0
45.0
40.0
35.0
30.0
25.0
TIME (SEC) (10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0


MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641029008 MME3MSEC
TIME (SEC)
(10¹)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
FC-P6 (PSI)
(10⁻¹)
20.0
25.0
30.0
35.0
40.0
45.0
50.0

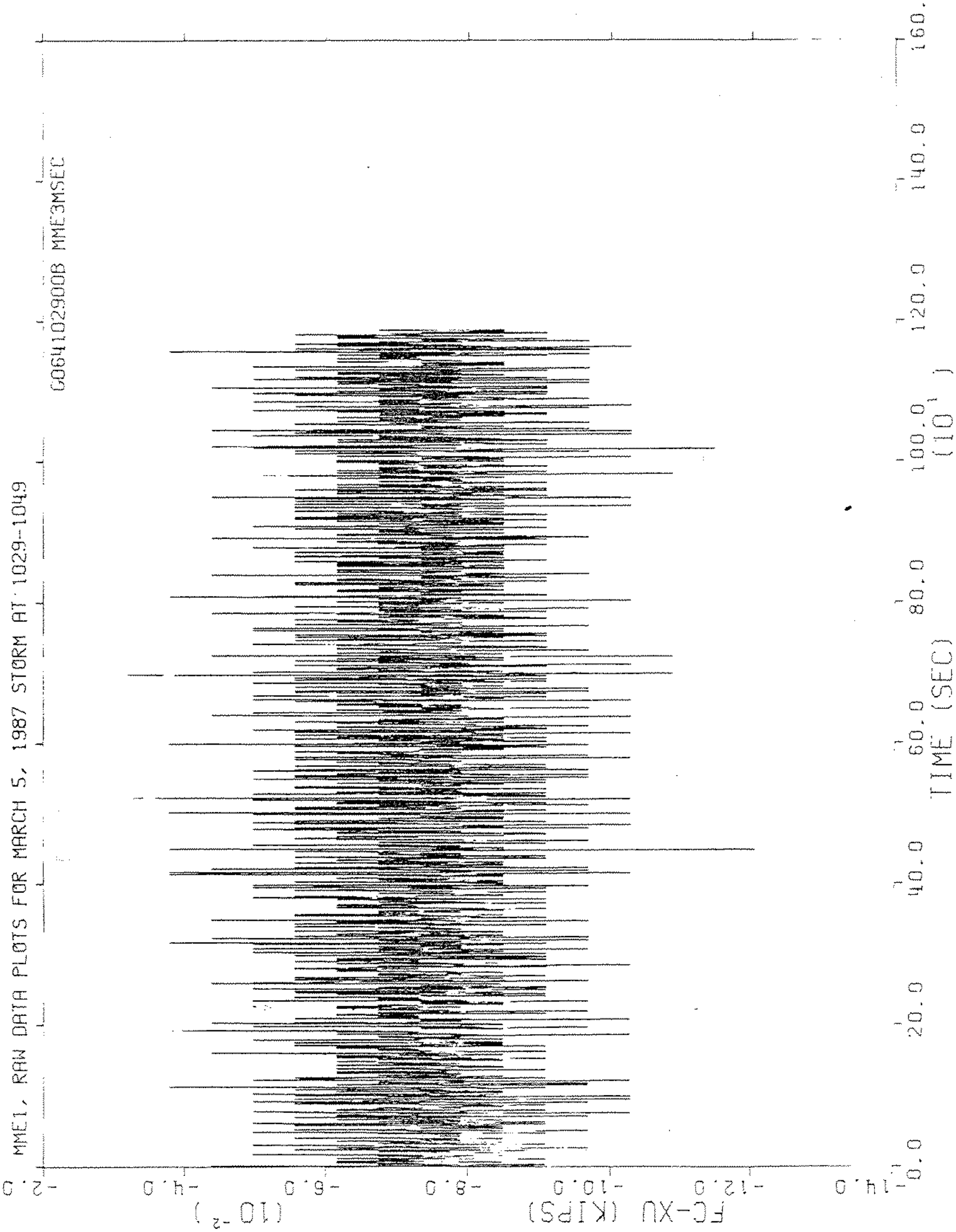

MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G06410290OB MME3MSEC
FC-P7 (PSI)
(10⁻¹)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)

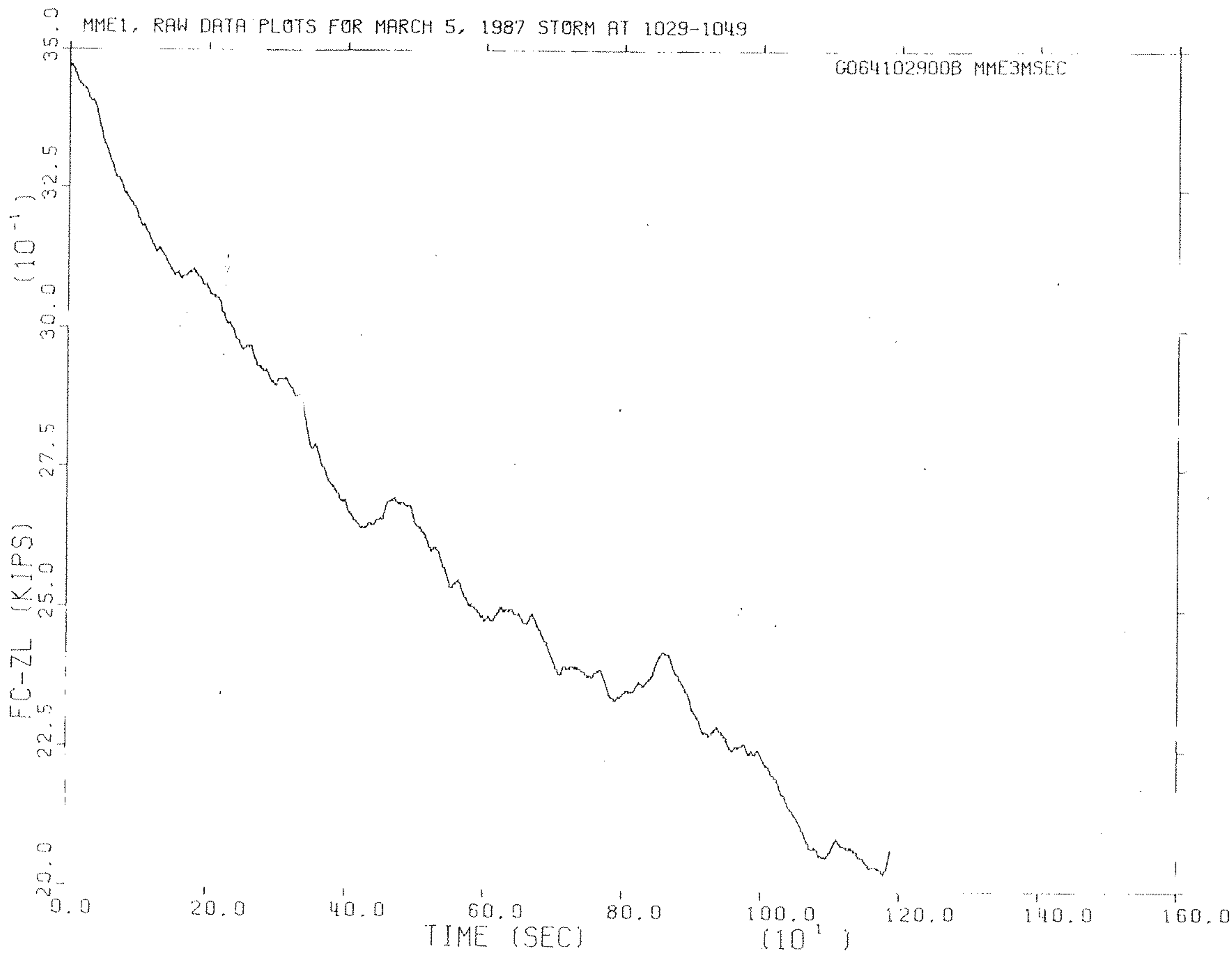


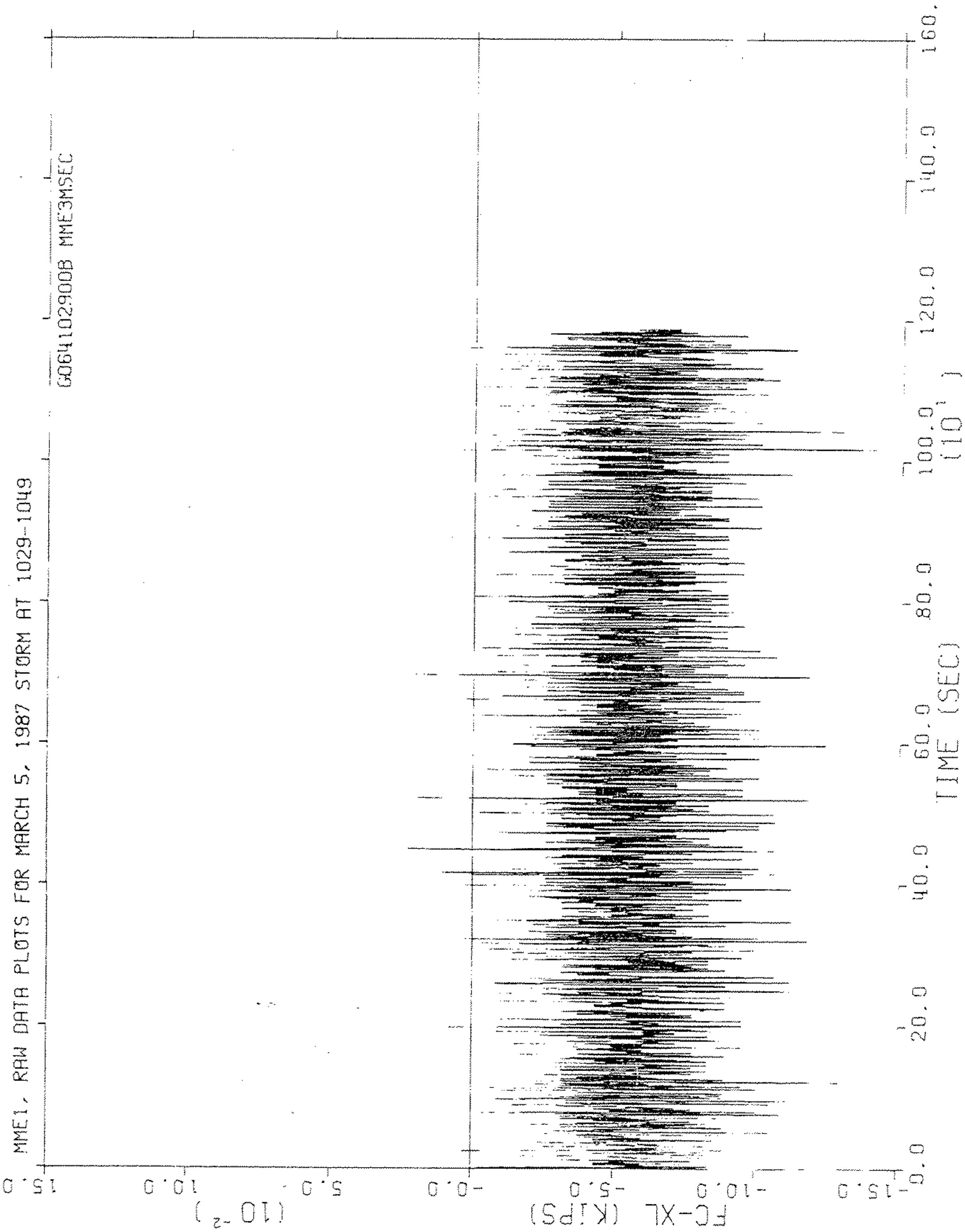
MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G0641D2900B MME3MSEC
FC-P8 (PSI)
(10⁻¹)
55.0
50.0
45.0
40.0
35.0
30.0
25.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)



MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G06410290OB MME3MSEC
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)
-185.0
-187.5
-190.0
-192.5
-195.0
-197.5
-200.0
FC-ZU (KIPS)
(10⁻²)


MME1, RAW DATA PLØTS FØR MARCH 5, 1987 STØRM AT 1029-1049
G064102900B MME3MSEC
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
FC-XU (KIPS)
(10^{-2})
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10^{1})


MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900B MME3MSEC
FC-ZL (KIPS)
(10⁻¹)
35.0
32.5
30.0
27.5
25.0
22.5
20.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
TIME (SEC)
(10¹)


MME1, RAW DATA PLOTS FOR MARCH 5, 1987 STORM AT 1029-1049
G064102900B MME3MSEC
FC-XL (KIPS)
(10^-2)
15.0
10.0
5.0
-0.0
-5.0
-10.0
-15.0
TIME (SEC)
(10^1)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0

APPENDIX E

DATA BASE FORMATS

The following pages present the various mediums and formats used for storage and archiving of the data associated with the Motion Measurement Experiment. An effort was made to archive this raw data before any processing was performed. These raw data sets or databases are identified as follows:

- NAVOCEANO Current Meter Array Database
- NDBC Directional Wave Buoy Array Databases
- Semisubmersible Raw Data Base

The NAVOCEANO Current Meter Array data were stored on a 9 track magnetic tape with the following specifications: ASCII format; 1600 BPI;f 8 bit; 120 characters per line. The data on the tape were formatted as given in Table E-1. This format is standard for data released by NAVOCEANO and was obtained from the U.S. Naval Oceanographic Office, NSTL Station, Bay St. Louis, MS, 39522-5001, Attn: M.J. Carron, Physical Oceanography Branch.

The NDBC directional wave data were stored on 9 track magnetic tapes with the following specifications: ASCII format; odd parity; 1600 BPI, 8 bytes per bit; 4080 bytes per block. NCEL received data type 1,2,3, and 8, as given in Table E.2a. This format is standard for data released by NDBC and was obtained from the National Data Buoy Center (NDBC), NSTL, Bay St. Louis, MS, 39529, Attn: Ken Steel, Directional Wave Spectral and Buoys.

The raw time series data measured by the Semisubmersible Instrument Subsystem (SIS) were digitized and then recorded on one-quarter-inch, 67-megabyte cartridge tape on the semisubmersible. The data were simultaneously telemetered to shore and recorded on nine track magnetic tape at NCEL. Both sets of recorded data contain twelve-bit representations of each analog signal digitized at 3.33 Hz. Data from the long baseline acoustic positioning system were supplied digitally.

The data on the cartridge tapes were later converted to nine track tape at NCEL and are in a format similar to the recorded telemetry data. Both formats contain data recorded in blocks of 1024 words, two bytes per word, where one block represents 5.4 seconds of measured data. Since the sample rate is 3.33 hertz, one block represents 18 digital time series values for each of the 44 channels. Thus, there are 18 frames of data per block.

For notation purposes, raw SIS data transferred from the one-quarter-inch cartridges to nine track tape were classified as format type "A" and data telemetered to shore and recorded directly on nine track tape were classified as format type "B". A description of each of the two data formats are described in Tables E.3 and E.4. The data with format type "B" was considered backup data in the event that the cartridge tapes were unrecoverable.

The PRIME Magnet Utility Commands for loading raw database files from nine track tape onto NCEL's PRIME 9755 minicomputer are listed in Figure E.1. The FORTRAN F77 code for reading these files is listed in Figure E.2.

This F77 code was used to read the data in blocks of 1024 words at 2 bytes per word and where each block represents 5.4 seconds of time series data. The buoy time is used as the independent parameter for all processing.

Selected time segments of the Semisubmersible Raw Database were processed through Level I processing (Zueck et al., 1987) to produce a Semisubmersible Secondary Database. Within Level I processing, the raw time series data are converted to voltages and then to engineering units. The raw acoustic positions provided every 7 or 8 seconds are curve fitted to give data points every .3 seconds. All data in the Semisubmersible Secondary Database is thus stored at 3.333 Hertz.

The raw digital data are converted to voltages by multiplying the data bits by 20/4096. In other words, there are a maximum 20 volts per 12 bits of data (4096=2^12). The data is recorded using 6 bit bytes but secondary database processing employs 8 bit bytes due to system requirements. The voltage to engineering units conversions are based upon physical and electrical calibrations performed to the measurement and recording instrumentation at an earlier date. These conversions are provided in Section 4.

Each time segment of Semisubmersible Secondary Data is stored in a file as multiplexed, time series values in engineering units according to a Standard Data Format (SDF). This SDF may be used by the MAC/RAN Time Series Data Analysis System software (Agbabian, 1987) for processing. This format is described in Figure E.3. There are 44 possible data channels of data for analysis. The MAC/RAN software requires that no more than 25 channels of data should be processed at any one time. Thus, the 45 channels (including time) have been divided into two MAC/RAN SDF input files with 24 channels in the first one and 21 channels in the second, as given in Table E.5.

Selected time segments of Semisubmersible Secondary data have been converted to individual channel ASCII formatted files. Each file contains time series values in engineering units for each individual measurement channel as indicated in Table E.6.

ADOC ARRAY

(1-3)	Region
(4-5)	Latitude (deploy)
(6-7)	Longitude (deploy)
8	Array
9	Current Meter Number
10	Meter depth/Profile depth
11	Water depth
12	Magnetic Variation
13	Calculated # of Cycles (first cycle (15-17) to last cycle (30-32)
14	Cycles Recorded (unchopped total)
* (15-17)	First Cycle Recorded Time
* (18-20)	First Cycle After Plant Time
* (21-23)	First Cycle in file Time (i.e. after chop:2 hrs before plant)
* (24-26)	Last Cycle in file Time (i.e. 2 hours after recovery)
* (27-29)	Meter Released Time
* (30-32)	Last Cycle Recorded Time
33	Sampling Interval (min) Delta t
34	Serial Number (meter)
(35-36)	Latitude (recovered),
(37-38)	Longitude (recovered)
39	Depth upper profile limit
40	Blank

* TIME FORMAT
_HHMMZ_DD_MON_YEAR

** AD = Anchor Drop Time
FT = Fall Time to Bottom (Rate = 60 M/min)
Delta t = Sampling Interval
(use next even sampling interval)

IDOC ARRAY

1 End of Series Flag (=1 for last seg in series)
2 Cruise Number
3 Meter number + designator
(10000 AAN)
(20000 GEOD)
(30000 VACM)
4 Relative seg. number
5 Series sequence number (each meter)
6 Segment no. of first seg in series
7 Number of seg in series
8 Number of series in file
9 Number of segs in file
10 Record sequence number (Hapgood's #)

FDOC ARRAY

1 Delta time (mins)
2 First Cycle in File (Julian days)
3 Latitude degrees (deploy)
4 Longitude degrees (deploy)
5 Variation
6 Lat degrees (recover)
7 Long degrees (recover)
8 Last cycle in file (J.D.)

Table E.1 NAVOCEANO Data Base Format

ARCHIVAL 191 TAPE FORMAT

File structure -

Nine 120-character records: (1) Descriptive Header Record, (2) Environmental Data Record, (3) Wave Spectra Data Record, (4) Subsurface Temperature Data Record, (5) Subsurface Data Record, (6) Wave Data Record, and (7) Wave Fourier Data Record, (8) Wave Data Record Type 8, (9)Continuous Wind Measurement. NCEL received types 1,2,3,8.

File format -

Meteorology and Wave Spectra (F191)

PARAMETER	DESCRIPTION	SC
FILE TYPE	ALWAYS '191'	01
FILE DATE	YR,MO,DY OF FILE GEN.	04
RECORD TYPE	'1' DESC. HEADER	10
STATION	SIX-CHARACTER UNIQUE NAME OF OBSERVATION POINT	11
OBSERVED DATE (GMT)	YYMMDD	17
OBSERVED TIME (GMT)	HHMM	23
LATITUDE	DEGREES,MINUTES,SECONDS	27
LAT. HEMISPHERE	HEMISPHERE 'N' OR 'S'	33
LONGITUDE	DEGREES,MINUTES,SECONDS	34
LAT. HEMISPHERE	HEMISPHERE 'E' OR 'W'	41
BOTTOM DEPTH	xxxxx - METERS TO TENTHS	42
MAGNETIC VARIATION	xxxx - WHOLE DEGREES FROM TRUE NORTH (SIGNED VALUE)	47
BUOY HEADING	xxx - WHOLE DEGREES FROM TRUE NORTH	51
SAMPLING RATE	xxxx - ORIGINAL MEASUREMENTS PER MINUTE, TO TENTHS	54
SAMPLING DURATION	xxxx - MINUTES TO HUNDREDTHS	58
TOTAL INTERVALS	xxx - NUMBER OF FEQUENCY INTERVALS	62
CHIEF SCIENTIST	20-CHARACTER FIELD FOR SCIENTIST NAME	65
INSTITUTION	20-CHARACTER FIELD FOR DATA SOURCE	85
WIND SAMPLING DURATION	xxx - MINUTES TO TENTHS	105
COMMENTS	13-CHARACTER FIELD	108

TABLE E.2(a) NDBC DATABASE FORMAT

ENVIRONMENTAL DATA RECORD	ALWAYS '2'	10
STATION	SEE RECORD '1'	11
OBSERVED DATE (GMT)	YYMMDD	17
OBSERVED TIME (GMT)	HHMM	23
ALTITUDE	xxx - METEOROLOGY (METERS TO TENTHS)	27
AIR TEMPERATURE	xxxx NEGATIVE TEMPERATURES ARE PRECEDED BY A MINUS SIGN ADJACENT TO TEMPERATURE VALUE - DEG C TO TENTHS	30
DEW POINT	xxxx - DEGREES C TO TENTHS	34
BAROMETER	xxxxx - REDUCED TO SEA LEVEL (MB TO TENTHS)	38
WIND SPEED (8.5 MIN AVG)	xxxx - M/SEC TO HUNDREDTHS	43
WIND DIRECTION(8.5 MIN AVG)	xxxx - DEGREES FROM TRUE NORTH TO TENTHS	47
WEATHER	ONE-CHARACTERE CODE - USE CODE 0108	51
VISIBILITY	xxx - NAUTICAL MILES TO TENTHS	52
PRECIPITATION	xxxx - ACCUMULATION IN MILLIMETERS	55
SOLAR RADIATION	xxx - LANGLEYS/MIN TO HUNDREDTHS. WAVE LENGTH LESS THAN 3.6 MICRONS	59
SOLAR RADIATION	xxx - LANGLEYS/MIN TO HUNDREDTHS. WAVE LENGTH 4.0 TO 50 MICRONS	62
SIGNIFICANT WAVE HEIGHT	xxx - CORRECTED FOR LOW FREQUENCY NOISE (METERS TO TENTHS)	65
AVERAGE WAVE PERIOD	xxx - SECONDS TO TENTHS	68
AVERAGE WAVE DIRECTION	xxx - DIRECTION OF PREDOMINANT WAVES IN WHOLE DEGREES FROM TRUE NORTH	71
HIGHEST CREST	xxx - FROM REFERENCE LEVEL (METERS TO TENTHS)	74
DEEPEST TROUGH	xxx - FROM REFERENCE LEVEL (METERS TO TENTHS)	77
TEMPERATURE	xxxx - SEA SURFACE NEGATIVE TEMPERATURES ARE PRECEDED BY A MINUS SIGN ADJACENT TO TEMPERATURE VALUE	80
SALINITY	xxxxx - PARTS PER THOUSAND TO THOUSANDTHS	84
CONDUCTIVITY	xxxxx - MILLIMHOS/CM TO THOUSANDTHS	89
DOMINANT WAVE PERIOD	xxx- SECONDS TO TENTHS	94
MAXIMUM WAVE HEIGHT	xxx - METERS TO TENTHS	97
MAXIMUM WAVE STEEPNESS	xxx	100
WIND GUST	xxxx - METERS/SECOND TO HUNDREDTHS	103
WIND GUST AVERAGING PD	xx - SECONDS	107
WIND GUST	xxxx - METERS/SECOND TO HUNDREDTHS	109
WIND GUST AVERAGING PERIOD	xx - SECONDS	113
WIND SPEED (58 MIN AVG)	xxx - MS TO TENTHS	115
WIND DIRECTION(58 MIN AVG)	xxx - WHOLE DEGREES	118

TABLE E.2(b)

WAVE SPECTRA DATA RECORD	ALWAYS '3'	10
STATION	SEE RECORD '1'	11
OBSERVED DATE (GMT)	YYMMDD	17
OBSERVED TIME (GMT)	HHMM	23
INTERVALS PER DIRECTION	xxx - TOTAL NUMBER OF FEQUENCIES IN THIS DIRECTION OR ZERO FOR NON-DIRECTIONAL	27
DIRECTION	xxxx - DEGREES TO TENTHS FROM TRUE NORTH OR '9999' FOR NON-DIRECTIONAL	30
COUNT	x - NUMBER OF FEQUENCIES ON THIS RECORD	34
DATA	UP TO 5 FEQUENCY, RESOLUTION, AND DENSITY FIELDS. NULL FIELDS ARE ZERO OR BLANK	
FREQUENCY	xxxx - CENTER FREQUENCY OF INTERVAL IN HERTZ TO THOUSANDS	35
RESOLUTION	xxxx - RESOLUTION OF INTERVAL IN HERTZ TO TEN-THOUSANDTHS	39
DENSITY	xxxxxx - SPECTRAL DENSITY OF INTERVAL IN M2/HZ TO THOUSANDTHS	43
FREQUENCY	xxxx - SEE ABOVE	49
RESOLUTION	xxxx - SEE ABOVE	53
DENSITY	xxxxxx - SEE ABOVE	57
FREQUENCY	xxxx - SEE ABOVE	63
RESOLUTION	xxxx - SEE ABOVE	67
DENSITY	xxxxxx - SEE ABOVE	71
FREQUENCY	xxxx - SEE ABOVE	77
RESOLUTION	xxxx - SEE ABOVE	81
DENSITY	xxxxxx - SEE ABOVE	85
FREQUENCY	xxxx - SEE ABOVE	91
RESOLUTION	xxxx - SEE ABOVE	95
DENSITY	xxxxxx - SEE ABOVE	99
BLANKS		105

TABLE E.2 (c)

WAVE	DATA RECORD TYPE 8	ALWAYS '8'	10
	STATION	SEE RECORD '1'	11
	OBSERVED DATE (GMT)	YYMMDD	17
	OBSERVED TIME	HHMM	23
	ICOUNT	x - NUMBER OF GROUPS PER LINE	27
	IFREQ	xxxx - FREQUENCY OF VALUES	28
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 58 AND 88		
	IRES	xxxx - RESOLUTION OF VALUES	32
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 62 AND 92		
	IR1	xxxx - R1 VALUE TO HUNDREDS	36
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 66 AND 96		
	IR2	xxxx - R2 VALUE TO HUNDREDS	40
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 70 AND 100		
	IALPHA_1	xxxx - ALPHA 1 VALUE TO TENTHS	44
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 74 AND 104		
	IALPHA_2	xxxx - ALPHA 2 VALUE TO TENTHS	48
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 78 AND 108		
	IC11	xxxxxx - SPECTRAL VALUE TO THOUSANDS	52
	*THIS FIELD IS REPEATED 2 TIMES IN COLS 82 AND 112		
	BLANKS		118

TABLE E.2 (d)

Nine Track Tape Format Type A:

Word Index (2 bytes per word)	Byte Index	Data Description
1	1	NCEL Information
	2	Calibration Mode Number (lowest 3 bits)
2	3	NCEL Information
	4	Buoy Time: Julian Date, 100's units
3	5	Buoy Time: Julian Date, 10's units
	6	Buoy Time: Hour units
4	7	Buoy Time: Minute units
	8	Buoy Time: Seconds units
5	9	Buoy Time: 1/10 seconds units
	10	Block begins indicator
6	11	Acoustic Position ID code
	12	Acoustic Position data
7	13	Acoustic Position data
	14	Acoustic Position data
8	15	Acoustic Position data
	16	Acoustic Position data
9	17	Acoustic Position data
	18	Acoustic Position data
10	19	Acoustic Position data
	20	Acoustic Position data
11	21	Acoustic Position data
	22	Acoustic Position data
12	23	Ocean Wave Elevation, Staff 1
	24	" " " " "
13	25	Ocean Wave Elevation, Staff 2
	26	" " " " "
14	27	Ocean Current Meter 1-X Direction
	28	" " " " "
15	29	Ocean Current Meter 1-Y Direction
	30	" " " " "
16	31	Ocean Current Meter 2-X Direction
	32	" " " " "
17	33	Ocean Current Meter 2-Y Direction
	34	" " " " "
18	35	Buoy Motion Surge Acceleration
	36	" " " "
19	37	Buoy Motion Sway Acceleration
	38	" " " "
20	39	Buoy Motion Heave Acceleration
	40	" " " "
21	41	Buoy Motion Roll Displacement
	42	" " " "
22	43	Buoy Motion Pitch Displacement
	44	" " " "
23	45	Buoy Motion Roll Angular Velocity
	46	" " " " "
24	47	Buoy Motion Pitch Angular Velocity
	48	" " " " "

TABLE E.3(a) SEMISUBMERSIBLE RAW DATA BASE FORMAT TYPE A

25	49	Force Cylinder Pressure Port 1
	50	" " " "
26	51	Force Cylinder Pressure Port 2
	52	" " " "
27	53	Force Cylinder Pressure Port 3
	54	" " " "
28	55	Force Cylinder Pressure Port 4
	56	" " " "
29	57	Force Cylinder Pressure Port 5
	58	" " " "
30	59	Force Cylinder Pressure Port 6
	60	" " " "
31	61	Force Cylinder Pressure Port 7
	62	" " " "
32	63	Mooring Tension Column 1 Upper Cell
	64	" " " "
33	65	Mooring Tension Column 1 Lower Cell
	66	" " " "
34	67	Mooring Tension Column 2 Upper Cell
	68	" " " "
35	69	Mooring Tension Column 2 Lower Cell
	70	" " " "
36	71	Mooring Tension Column 3 Upper Cell
	72	" " " "
37	73	Mooring Tension Column 3 Lower Cell
	74	" " " "
38	75	Wind Speed Column 3
	76	" " "
39	77	Wind Direction Column 3
	78	" " "
40	79	Wind Speed Column 1
	80	" " "
41	81	Wind Direction Column 1
	82	" " "
42	83	Zero Voltage Reference
	84	" " "
43	85	Maximum Voltage Reference
	86	" " "
44	87	Mast Wind Speed
	88	" " "
45	89	Platform Heading
	90	" "
46	91	Deck House Temperature
	92	" " "
47	93	Deck House Humidity
	94	" " "
48	95	Zero Voltage Reference
	96	" " "
49	97	Maximum Voltage Reference
	98	" " "
50	99	Force Cylinder Pressure Port 8
	100	" " " "
51	101	Force Cylinder Z-Upper Load
	102	" " " "

TABLE E.3(b)

52	103	Force Cylinder X-Upper Load
	104	" " " "
53	105	Force Cylinder Z-Lower Load
	106	" " " "
54	107	Force Cylinder X-Lower Load
	108	" " " "
55	109	Data Transmission Checks
	110	" " "
56	111	" " "
	112	" " "
57	113	Not Used
57-112	114-225	Repeat of Words 1-57
113	226	Not Used
113-168	227-238	Repeat of Words 1-57
169	339	Not Used
169-224	344-451	Repeat of Words 1-57
225	452	Not Used
225-280	453-564	Repeat of Words 1-57
281	565	Not Used
281-336	566-677	Repeat of Words 1-57
337	678	Not Used
337-392	679-790	Repeat of Words 1-57
393	791	Not Used
393-448	792-903	Repeat of Words 1-57
449	904	Not Used
449-504	905-1016	Repeat of Words 1-57
505-512	1017-1024	Not Used
513-1012	1025-2048	Repeat of 1-1024

TABLE E.3(c)

Nine Track Tape Format Type B:

Word Index (2 bytes per word)	Byte Index	Data Description
1-4	1-8	NCEL Information
5	9	ASCII CHR$(125)
	10	Calibration Mode Number (lowest 3 bits)
6	11	NCEL Information
	12	Buoy Time: Julian Date, 100's units
7	13	Buoy Time: Julian Date, 10's units
	14	Buoy Time: Hour units
8	15	Buoy Time: Minute units
	16	Buoy Time: Seconds units
9	17	Buoy Time: 1/10 seconds units
	18	Block begin indicator
10	19	Acoustic Position ID code
	20	Acoustic Position data
11	21	Acoustic Position data
	22	Acoustic Position data
12	23	Acoustic Position data
	24	Acoustic Position data
13	25	Acoustic Position data
	26	Acoustic Position data
14	27	Acoustic Position data
	28	Acoustic Position data
15	29	Acoustic Position data
	30	Acoustic Position data
16	31	Ocean Wave Elevation, Staff 1
	32	" " " " "
17	33	Ocean Wave Elevation, Staff 2
	34	" " " " "
18	35	Ocean Current Meter 1-X Direction
	36	" " " " "
19	37	Ocean Current Meter 1-Y Direction
	38	" " " " "
20	39	Ocean Current Meter 2-X Direction
	40	" " " "
21	41	Ocean Current Meter 2-Y Direction
	42	" " " "
22	43	Buoy Motion Surge Acceleration
	44	" " " "
23	45	Buoy Motion Sway Acceleration
	46	" " " "
24	47	Buoy Motion Heave Acceleration
	48	" " " "
25	49	Buoy Motion Roll Displacement
	50	" " " "
26	51	Buoy Motion Pitch Displacement
	52	" " " "

TABLE E.4(a) SEMISUBMERSIBLE RAW DATA BASE FORMAT TYPE B

27	53	Buoy Motion Roll Angular Velocity
	54	" " " " "
28	55	Buoy Motion Pitch Angular Velocity
	56	" " " " "
29	57	Force Cylinder Pressure Port 1
	58	" " " "
30	59	Force Cylinder Pressure Port 2
	60	" " " "
31	61	Force Cylinder Pressure Port 3
	62	" " " "
32	63	Force Cylinder Pressure Port 4
	64	" " " "
33	65	Force Cylinder Pressure Port 5
	66	" " " "
34	67	Force Cylinder Pressure Port 6
	68	" " " "
35	69	Force Cylinder Pressure Port 7
	70	" " " "
36	71	Mooring Tension Column 1 Upper Cell
	72	" " " "
37	73	Mooring Tension Column 1 Lower Cell
	74	" " " "
38	75	Mooring Tension Column 2 Upper Cell
	76	" " " "
39	77	Mooring Tension Column 2 Lower Cell
	78	" " " "
40	79	Mooring Tension Column 3 Upper Cell
	80	" " " "
41	81	Mooring Tension Column 3 Lower Cell
	82	" " " "
42	83	Wind Speed Column 3
	84	" " "
43	85	Wind Direction Column 3
	86	" " "
44	87	Wind Speed Column 1
	88	" " "
45	89	Wind Direction Column 1
	90	" " "
46	91	Zero Voltage Reference
	92	" " "
47	93	Maximum Voltage Reference
	94	" " "
48	95	Mast Wind Speed
	96	" " "
49	97	Platform Heading
	98	" "
50	99	Deck House Temperature
	100	" " "
51	101	Deck House Humidity
	102	" " "
52	103	Zero Voltage Reference
	104	" " "
53	105	Maximum Voltage Reference
	106	" " "

TABLE E.4(b)

54	107	Force Cylinder Pressure Port 8
	108	" " " "
55	109	Force Cylinder Z-Upper Load
	110	" " " "
56	111	Force Cylinder X-Upper Load
	112	" " " "
57	113	Force Cylinder Z-Lower Load
	114	" " " "
58	115	Force Cylinder X-Lower Load
	116	" " " "
59	117	Data Transmission Checks
	118	" " "
60	119	" " "
	120	" " "
61-116	121-234	Repeat of Words 6 through 60
117-172	235-346	Repeat of Words 6 through 60
173-228	347-458	Repeat of Words 6 through 60
229-284	459-570	Repeat of Words 6 through 60
285-340	571-682	Repeat of Words 6 through 60
341-396	683-794	Repeat of Words 6 through 60
397-452	795-906	Repeat of Words 6 through 60
453-508	907-1018	Repeat of Words 6 through 60
509-564	1019-1130	Repeat of Words 6 through 60
565-620	1031-1242	Repeat of Words 6 through 60
621-676	1243-1354	Repeat of Words 6 through 60
677-732	1355-1366	Repeat of Words 6 through 60
733-788	1367-1478	Repeat of Words 6 through 60
789-844	1489-1590	Repeat of Words 6 through 60
845-900	1591-1702	Repeat of Words 6 through 60
901-956	1703-1814	Repeat of Words 6 through 60
957-1012	1815-1926	Repeat of Words 6 through 60
1013-1024	1927-2038	No data - reserved for future
025-2048	1 - 2038	Repeat of Words 1 through 1024
etc.	etc.	etc.

TABLE E.4(c)

PRIME 9755 COMPUTER PRIMOS COMMANDS TO READ
9 TRACK MAGNETIC TAPES

FORMAT TYPE A: (CARTRIDGE DATA CONVERTED TO 9 TRACK TAPE)

1) MAGNET
2) READ
3) MTU# ?: 0 OR 1 (TAPE DRIVE NUMBER)
4) FILE# ? 1 (NO HEADER)
5) LOGICAL RECORD SIZE ? 1024
6) BLOCKING FACTOR ?: 1
7) ASCII, BCD, BINARY OR EBCDIC ?: BINARY
8) INPUT FILE ?: filename

FORMAT TYPE B: (TRANSMITTED DATA RECORDED ON 9 TRACK TAPE)

1) MAGNET
2) READ
3) MTU# ?: 0 OR 1 (TAPE DRIVE NUMBER)
4) FILE# ? 2 (THERE IS A HEADER)
5) LOGICAL RECORD SIZE ? 512
6) BLOCKING FACTOR ?: 1
7) ASCII, BCD, BINARY OR EBCDIC ?: BINARY
8) INPUT FILE ?: filename

FIGURE E.1 PRIME MAGNET COMMANDS

```
C    SUBROUTINE  (called by RAW.F77) TO READ A MAGNET FILE
      SUBROUTINE READ
      COMMON /A/ BUFF,BBUFF,FUNIT,RUNIT,RECNUM,EOF
      COMMON /F/ IRTOFF,ICHOFF,MODE,IFRAM,IASK,NUM
      COMMON /K/ TYPE
      DIMENSION BUFF(1024),BBUFF(2048)
      INTEGER*2  BUFF,ITEMP,IFRAM,IASK
      INTEGER*2 IRTOFF,ICHOFF
      INTEGER*2 FOUR,K$CURR,K$IMFD
      INTEGER*2 RECSIZ,NMREAD,CODE,RECNUM,FUNIT
      INTEGER*2 RUNIT
      INTEGER*2 K$READ,K$PREA
      INTEGER*4 POSITN
      LOGICAL EOF
      INTEGER*2 BBUFF,MODE
      CHARACTER*1 TYPE
      PARAMETER RECSIZ=1024
      PARAMETER K$READ=:1,K$PREA=:10
      POSITN=INTL(RECSIZ)*INTL(RECNUM)
      FOUR=4
      FOUR=4
      CALL ATCH$$('BART',FOUR,K$CURR,' ',K$IMFD,CODE)
      CALL PRWF$$(K$READ+K$PREA ,FUNIT,LOC( BUFF),RECSIZ,POSITN,
     X                              NMREAD,CODE)
      IF (CODE.EQ.1)GOTO 10
      IF (CODE.NE.0) GOTO 6500
      DO 4000  I=1,1024
      BBUFF(I*2)=AND( BUFF(I),:177400)/256
      BBUFF((I*2)-1)=AND( BUFF(I),:377)
      IRUAL=BBUFF(I*2)*64+BBUFF((I*2)-1)
4000  CONTINUE
      IF(TYPE.EQ.'B'.OR. TYPE.EQ.'b') RETURN
      J=1
      I1=1
      I2=1016
```

FIGURE E.2(a) FORTRAN 77 CODE FOR READING SIS DATA

```
      DO 111 K=1,2
      LCHK=1
      DO 112 I=I1,I2
      IF( MOD(LCHK,113).EQ.0) GOTO 119
      BBUFF(J)=BBUFF(I)
      J=J+1
119   LCHK=LCHK+1
112   CONTINUE
      I1=I1+1024
      I2=2040
111   CONTINUE
      DO 114 I=2024,9,-1
         BBUFF(I)=BBUFF(I-8)
         IF (BBUFF(I).EQ.69) BBUFF(I)=27
114   CONTINUE
115   RETURN
10    EOF=.TRUE.
      RETURN
6500  WRITE(1,*)'ERROR IN PRWF$$  ',CODE
      RETURN
      END
```

FIGURE E.2(b)

MAC/RAN IV STANDARD DATA FILE (SDF) STRUCTURE

All files generated by the MAC/RAN IV System are generated in a FORTRAN compatible format; that is, unformatted, direct access with each record being the equivalent byte length of 256 single-precision, floating point words.

A standard Data File contains a header record followed by data records. Each data record contains the maximum number of complete frames which can be stored in 256 single-precision, floating-point words. Therefore, the Standard Data File format is characterized as follows:

NF = INT (256 / P)

R = INT (N/NF)

M = NF * P

where:

- P - The total number of channels stored in the standard data file, including the independent parameter or first channel
- N - The total number of data frames or time slices stored in the standard data file
- NF - The number of data frames contained within a standard data file data record
- R - The number of data records, exclusive of the header record, contained within a standard data file
- M - The number of data values contained within a standard data file data record

A. Header Record

The contents of a Standard Data File header record is as follows:

FIGURE E.3(a) MAC/RAN IV STANDARD DATA FILE STRUCTURE

Word Location	Content Description
1	Floating-point representation of the number of data frames contained within the standard data file, N
2	Floating-point representation of the number of data channels, including the independent parameter of first channels, contained within the SDF, P
3-5	Three 4-character left-justified Hollerith strings representing the data Source annotation
6-8	Three 4-character left-justified Hollerith strings representing the data Type annotation
9	Reserved for special TRANS matrix files
10-12	Three 4-character left-justified Hollerith strings representing the first channel identifier
13	Floating-point representation of the minimum data value of the first channel
14	Floating-point representation of the maximum data value of the first channel
15	Floating-point representation of the mean value of the first channel
16	Floating-point representation of the sample variance of the first channel
17	Floating-point representation of the independent parameter value corresponding to the minimum data value of the first channel
18	Floating-point representation of the independent parameter value corresponding to the maximum data value of the first channel
19-21	Three 4-character left-justified Hollerith strings representing the second channel identifier.
22	Floating-point representation of the minimum data value of the second channel
23	Floating-point representation of the maximum data value of the second channel

FIGURE E.3(b)

24	Floating-point representation of the mean value of the second channel
25	Floating-point representation of the sample variance of the second channel
26	Floating-point representation of the independent parameter value corresponding to the maximum data value of the second channel
27	Floating-point representation of the independent parameter value corresponding to the maximum data value of the second channel
9(P+1)	Floating-point representation of the independent parameter value corresponding to the maximum data value of the Path channel

B. Data Record

The contents of a Standard Data File data record is as follows:

Word Location	Content Description
1	Floating-point representation for the first frame data value of the first data channel
2	Floating-point representation for the first frame data channel
P	Floating-point representation for the first frame data value of the P(th) data channel
M	Floating-point representation for the i(th) frame data value of the P(th) data channel where i is an arbitrary data frame within the present data record
M+1	Reserved for future use
256	Reserved for future use

FIGURE E.3(c)

CHANNEL DIRECTORY - SECONDARY DATA BASE

CHNL #	IDENTIFIER MAC/RAN	RANGE + or -	ACCURACY + or -	INSTRUMENT / MEASUREMENT
A1	TIME (SEC)	-	0.1 sec	Clock / hhmmssd format
A2	LBSX (FT)	9999 ft	2.0 m	Acoustic Positioning System
A3	LBSY (FT)	9999 ft	2.0 m	HP310 processed data/
A4	LBSZ (FT)	9999 ft	2.0 m	long baseline coordinates
A5	SURGA (G)	1.0 G	.001 G	Humphrey Motion Package
A6	HEAVA (G)	2.0 G	.002 G	stabilized accelerometers/
A7	SWAYA (G)	1.0 G	.001 G	surge, heave & sway accels
A8	ROLLV (D/S)	15 deg/s	.015 deg/s	roll & pitch rates
A9	PITCV (D/S)	15 deg/s	.015 deg/s	roll & pitch euler angles
A10	ROLLD (DEG)	30 deg	0.03 deg	
A11	PITCD (DEG)	30 deg	0.03 deg	
A12	YAWD (DEG)	360 deg	1.0 deg	Endeco Compass/ yaw angle
A13	WAVE1 (FT)	25 ft	0.01 ft	Center Baylor Wave Staff
A14	WAVE2 (FT)	25 ft	0.01 ft	Offset Baylor Wave Staff
A15	CUR1X (F/S)	10 ft/s	.05 ft/s	Marsh McBirney Current Meters
A16	CUR1Y (F/S)	10 ft/s	.05 ft/s	2 meters/
A17	CUR2X (F/S)	10 ft/s	.05 ft/s	water particle velocities
A18	CUR2Y (F/S)	10 ft/s	.05 ft/s	x, y & z components
A19	LOAD1U (KIP)	30 kips	.015 kips	Metrox Tension Load Cells
A20	LOAD1L (KIP)	30 kips	.015 kips	3 mooring lines: C1, C2 & C3
A21	LOAD2U (KIP)	30 kips	.015 kips	upper & lower cell per line/
A22	LOAD2L (KIP)	30 kips	.015 kips	mooring line tensions
A23	LOAD3U (KIP)	30 kips	.015 kips	
A24	LOAD3L (KIP)	30 kips	.015 kips	

TABLE E.5(a) CHANNEL DIRECTORY SECONDARY DATABASE

CHANNEL DIRECTORY - SECONDARY DATA BASE

CHNL #	IDENTIFIER MAC/RAN	RANGE + or -	ACCURACY + or -	INSTRUMENT / MEASUREMENT
B1	TIME (SEC)	-	0.1 sec	Clock / hhmmssd format
B2	WIND1S (F/S)	15.2 f/s	.0015 f/s	R.M. Young Wind Sensors
B3	WIND1D (DEG)	360 deg	1.0 deg	one sensor on column C1
B4	WIND3S (F/S)	15.2 f/s	.0015 f/s	one sensor on column C3
B5	WIND3D (DEG)	360 deg	1.0 deg	one sensor on deckhouse mast
B6	WINDMS (F/S)	15.2 f/s	.0015 f/s	wind speed and direction
B7	WINDMD (DEG)	360 deg	1.0 deg	
B8	TEMP (DEG-F)	100 deg	0.3 deg C	Vaisala Humicap Sensor / Deck
B9	HUMIDITY (%)	100 %	3 %	House Temperature & Humidity
B10	FC-P1 (PSI)	0-25 psig	.25 psif	Pressure Transducers
B11	FC-P2 (PSI)	0-25 psig	.25 psif	45 degree radial spacing
B12	FC-P3 (PSI)	0-25 psig	.25 psif	around force cylinder
B13	FC-P4 (PSI)	0-25 psig	.25 psif	
B14	FC-P5 (PSI)	0-25 psig	.25 psif	
B15	FC-P6 (PSI)	0-25 psig	.25 psif	
B16	FC-P7 (PSI)	0-25 psig	.25 psif	
B17	FC-P8 (PSI)	0-25 psig	.25 psif	
B18	FC-ZU (KIPS)	14 kips	280 lbs	Force Transducer, using Micro-
B19	FC-XU (KIPS)	14 kips	280 lbs	Measurement Strain Gages,
B20	FC-ZL (KIPS)	14 kips	280 lbs	upper z, upper x, lower z,
B21	FC-XL (KIPS)	14 kips	280 lbs	lower x directions

TABLE E.5(b)

DIRA	- Wind direction, column C1 (deg)
DIRB	- Wind direction, mast (deg)
DIRC	- Wind direction, column C3 (deg)
FC-P1	- Pressure, cell #1, Instrumented Test Cylinder ITC (psig)
FC-P2	- Pressure, cell #2, ITC (psig)
FC-P3	- Pressure, cell #3, ITC (psig)
FC-P4	- Pressure, cell #4, ITC (psig)
FC-P5	- Pressure, cell #5, ITC (psig)
FC-P6	- Pressure, cell #6, ITC (psig)
FC-P7	- Pressure, cell #7, ITC (psig)
FC-P8	- Pressure, cell #8, ITC (psig)
FCXLOW	- Lower load, x direction, ITC (kips)
FCXUP	- Upper load, x direction, ITC (kips)
FCZLOW	- Lower load, z direction, ITC (kips)
FCZUP	- Upper load, z direction, ITC (kips)
HEAVACC	- Buoy motion, heave acceleration (ft/s^2)
LBSEAST	- Curve-fitted acoustic position, east (feet)
LBSNORT	- Curve-fitted acoustic position, north (feet)
PITCHV	- Buoy motion, pitch velocity (ft/s)
ROLLV	- Buoy motion, roll velocity (ft/s)
RANGE	- Acoustic ranges [time (sec)],[range #1, #2, #3, #4 (sec)]
LBSRAW	- Raw acoustic position time (sec), east, north, depth (ft)
STAT	- Statistics for each file [avg, rms, min, max, units]
SURGACC	- Buoy motion, surge acceleration (ft/s^2)
SWAYACC	- Buoy motion, sway acceleration (ft/s^2)
TENA1	- Mooring tension, leg C1, upper cell (kips)
TENB1	- Mooring tension, leg C2, upper cell (kips)
TENC2	- Mooring tension, leg C3, lower cell (kips)
THETAX	- Buoy motion, roll (deg)
THETAY	- Platform heading or yaw (deg)
THETAZ	- Buoy motion, pitch (deg)
TIME	- Pacific Standard or Daylight Savings Time (sec)
VELAX	- Water particle velocity, x direction (ft/s)
VELAZ	- Water particle velocity, z direction (ft/s)
VELBY	- Water particle velocity, y direction (ft/s)
VELBZ	- Water particle velocity, z direction (ft/s)
VELOA	- Wind speed, column C1 (ft/s)
VELOB	- Wind speed, mast (ft/s)
VELOC	- Wind speed, column C2 (ft/s)
WAVEDAT1	- Wave elevation, staff #1 (ft)
WAVEDAT2	- Wave elevation, staff #2 (ft)

TABLE E.6 SEMISUBMERSIBLE SECONDARY DATABASE ASCII FORMAT