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AT-SEA MEASUREMENTS OF THE DYNAMIC RESPONSE OF A SINGLE-POINT M--ETC(U)
MAR 78 D J MEGGITT, D B DILLON

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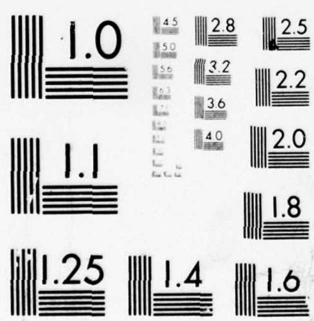

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TECHNICAL MEMORANDUM

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(6) **title:** AT-SEA MEASUREMENTS OF THE DYNAMIC RESPONSE OF A SINGLE-POINT MOORING DURING AN ANCHOR-LAST DEPLOYMENT

(10) **author:** D. J. MEGGITT [redacted] D. B. DILLON

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*EG&G WASHINGTON ANALYTICAL SERVICES CENTER, INC.

CIVIL ENGINEERING LABORATORY
NAVAL CONSTRUCTION BATTALION CENTER
Port Hueneme, California 93043

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I. INTRODUCTION AND SUMMARY

The design, construction and installation of large oceanic cable structures is a complex, expensive undertaking. In order to reduce the engineering uncertainties in the design of these structures, the Civil Engineering Laboratory, under the sponsorship of the Naval Facilities Engineering Command, is engaged in a major program to develop techniques for the static and dynamic analysis of oceanic cable structures (1). An extensive series of experiments in both laboratory and prototype sizes has been conducted to provide data for comparison to calculate results from numerical models of cable structures. This report presents the results of an at-sea measurement of the dynamic response of a 2,500-ft long single point mooring during an anchor-last deployment. The experiment reported herein was a part of the Mooring Dynamics Experiment (MDE) (2).

The anchor-last deployment experiment included measurement of tension and orientation at four locations on the cable, spatial position of four points on the cable and temperature and pressure at two points on the cable as functions of time during deployment. A nearby mooring supported an array of current meters. The experiment was conducted at the Pacific Missile Range Facility, Barking Sands, Kauai, Hawaii in October 1976. This report includes plotted current meter (for the entire MDE), tension, position and temperature/pressure data recorded during the deployment of the mooring. The data appear to be of exceptionally high quality and represent the most detailed measurements to date of the dynamic response of a full size oceanic cable structure.

II. DESCRIPTION OF THE MOORING DYNAMICS EXPERIMENT

A. Background

The Mooring Dynamics Experiment was a major inter-agency program to make measurements of the behavior of several different deep-sea moorings. These data may be compared to numerical models of mooring response to environmental forcing functions. A summary of the experiment is given in reference 2.

The lack of field data to verify computer models of mooring behavior led the NOAA Data Buoy Office (NDBO) and the Office of Naval Research (ONR) jointly to sponsor a program to make detailed measurements of mooring response to oceanic environmental loadings. The initial experimental program envisioned three types of surface moorings; this was expanded to include two sub-surface moorings, one a high-performance current meter mooring (for the Chesapeake Division, Naval Facilities Engineering Command) and the other a relatively simple mooring for a series of relaxation experiments (for the Civil Engineering Laboratory). The Woods Hole Oceanographic Institution (WHOI) provided the Principal Investigator (R. Walden), who directed the experiments. The participants and their responsibilities are listed in Table 1.*

*Tables 1 through 10 appear after end of text.

The MDE was conducted at Barking Sands during October 1976. The experiment was extremely successful, with an exceptionally high data recovery rate. Subsequently, the data were archived at NDBO. Each of the participating activities are reducing, analyzing, and reporting the data from their individual experiments.

B. Objectives

The overall objective of the MDE was to obtain detailed data of the response of several mooring configurations to the oceanic environment. This required measurement of the tension and position of points along the mooring cables as functions of time. In general, the experiments were designed to monitor the relatively long-period deformations due to ocean currents; however, the dynamic response of the surface buoys to wave action was measured for three of the moorings.

The objectives of the CEL experiment differed from the others in emphasizing the dynamic response of the mooring. The mooring was designed and deployed to provide at-sea dynamic data during the anchor-last deployment and during a series of relaxation experiments after installation. The mooring configuration was relatively simple to allow easier numerical simulation modeling. Buoyant forces were kept low in order to emphasize environmental forces.

III. THE CEL EXPERIMENT

A. Mooring Description

A sketch of the single-point mooring deployed for the CEL experiments is shown in Figure 1.* The primary flotation element was a 44-inch (1.1 meter) diameter sphere producing 1050 lb (48.2N) buoyancy in sea water. A Xenon flash lamp and radio beacon were mounted on top as recovery aids. The mooring line was 3/16-inch (4.76mm) diameter 3x19 jacketed steel wire rope with an overall diameter of 0.390 inch (9.9mm). As shown in Figure 1, short lengths of chain and nylon line were used for assembly convenience and to resist chafing. Two Temperature/Pressure Recorders, four Force Vector Recorders and five acoustic pingers were installed on the mooring as shown. Two 38-inch (.96 meter) aluminum spheres provided 847 lb (38.9N) emergency buoyancy in the event the primary buoyancy fialed. These two relatively large spheres were used on the CEL mooring instead of the multiple glass balls used on the other MDE moorings in order to simplify the mooring as much as possible for numerical simulation. Dual AMF acoustic releases were used to improve system reliability. The anchor on the CEL mooring was made of sandbags lashed together and held in a cargo net (donated by PMRF). A photograph of the anchor is shown in Figure 2. The sandbag anchor was used to reduce the possibility of damage to the range hydrophone cables on the sea floor. A 1500-ft (457 m) length of 1/4-inch (6.4 mm) polypropylene line with a small surface float was attached to the main buoy. It was used to displace the mooring during the relaxation experiments.

*Figures 1 through 9 appear at end of text following tables.

A complete list of the mooring components and physical data for them is given in Table 2. This table includes all of the parameters for each component that are considered to be important for simulation of mooring response. Drag coefficients have not been included since it is expected that modelers will prefer to make their own estimates.

B. Instrumentation

The mooring was instrumented with two temperature/pressure (T/P) recorders and four force vector recorders (FVR) developed by Charles Stark Draper Laboratories (CSDL). Five acoustic pingers supplied and maintained by the Naval Torpedo Station Detachment, Hawaii were used. The position of these pingers was tracked by the PMR hydrophone array and computer.

The T/P and FVR instruments developed by CSDL are described in detail in reference 3. Their characteristics and pertinent operating parameters are summarized below.

Two types of temperature/pressure recorders were used during the MDE, differing primarily in the data sampling rate. Both types used calibrated thermistors for temperature measurement and strain-gaged diaphrams for pressure measurements. The instruments are battery-powered and self recording; the data are digitized in the instrument and are recorded on a data tape cassette. The instruments are housed in 11-1/2-inch (292mm) diameter pressure spheres clamped beside a tension rod in the mooring line. A photograph of a T/P recorder is shown in Figure 3. The low-frequency T/P (LFTP) instruments sampled temperature, pressure and time every 3.75 seconds, but recorded only every 64-th sample (i.e., every 4 minutes). The high-frequency temperature every 2.08 seconds and pressure every 0.52 seconds so that four pressure words are recorded with each temperature word. For the CEL experiment, a burst lasted 28 minutes, 50.56 seconds, repeated every 43 minutes, 41.44 seconds. Ranges and scaling of the instruments used in the MDE are given in Table 3.

The Force Vector Recorder (FVR) is a self-contained motion and tension sensing package. The battery-operated instrument records digitized data on an internal tape cassette. The FVR has six sensor channels, including three mutually orgthogonal servo accelerometers, two magnetometers for azimuth reference and a strain-gage load cell for tension measurement. For the MDE, tension cells with a full scale range of 3,000 lb were used. In addition, an internal clock provides a reference time. The instrument can be used in a burst or sample mode; for the MDE the burst mode was used, with a burst duration of 15m 41.2s and a burst repetition period of 87m 22.88s. The data channels are sampled every 0.52 seconds. The instrumentation electronics are housed in a 13-inch diameter pressure shell which weighs 85 lb in air and 45 lb in water. In use, the pressure shell is surrounded by a 19-inch diameter syntactic foam flotation shell which renders the unit neutrally buoyant in sea water, with an air weight of 130 lb. The mooring attachments are aligned with the centerline of the unit. Characteristics of the instruments are summarized in Table 4. Photographs of an FVR are presented in Figures 3 and 4.

The T/P and FVR instruments are switched on by the removal of an external magnet. All of the instruments (T/P's and FVR's) were synchronized to a common time base by CSDL.

Five acoustic pingers were installed on the mooring to give position data using thr PMRF acoustic tracking range facilities. Two types of pingers were used; these are called Sub-Can and Deep-Can and are shown in the sketches in Figures 6 and 7 respectively. The pingers operated at frequencies between 13 and 24 kHz and were pulsed-coded for identification. The pulse repetition rate was 1 pulse/second.

C. Experiments

Two types of experiments were made on the CEL mooring during the MDE. The first of these was the anchor-last deployment of the mooring; and the other, termed a "relaxation" experiment, involved pulling the mooring to one side, releasing it and allowing it to return to equilibrium. Only data from the deployment are presented in this report.

The anchor-last technique is a common method for deploying single-point oceanographic moorings (see reference 4, for example). In this procedure, the following sequence of operations is followed. First, the main buoy is released with the mooring line attached. The ship steams slowly away from the buoy, paying out mooring line, with any instruments or distributed flotation attached. The line is paid out at approximately the same rate as the ship speed until only the anchor remains on the ship. The anchor is then released and falls to the seafloor, pulling the mooring line and buoy into the equilibrium configuration. During the anchor descent, significant transient forces act on the mooring line. The present experiment was intended to measure these forces and the trajectories followed by the anchor, mooring line and buoy during the deployment.

The CEL mooring was set from USNS De Steiguer (T-AGOR-12) on 1 November 1976, at 22°04'1.4"N, 159°53'38.4"W. The track followed by the ship during the deployment is shown in Figure 8. The points shown on the ship track correspond to the operations in the deployment sequence as follows:

ALPHA 6:	Main flotation buoy released
BRAVO 6:	All mooring line and instruments deployed (ship towing entire mooring with anchor on deck)
CHARLIE 6:	Anchor deployed
DELTA 6:	Anchor position on bottom

It will be noted that the mooring location is approximately in the center of the triangle formed by three of the range hydrophones. The current meter string location is shown in the upper left hand corner of the figure.

The Sea Operations Plan for deployment of the CEL mooring has been included as Appendix A to this report. The Moored Station Log kept by WHOI during the CEL mooring experiment has been reproduced in Appendix B. The times in the Log are Coordinated Universal Time (CUT) or Zulu (Z) which is 10 hours ahead of local time. The Moored Station Log is the definitive record of the mooring configuration and components.

The anchor was released at about 1714 CUT (0714 local); it reached the bottom at about 1723 CUT. The weather during the deployment was excellent; the wind and sea were nearly calm, with a 2-ft swell.

IV. RESULTS

A. Data Coverage

The data coverage for the CEL experiment is summarized in Figure 9. This figure shows the instrument burst times and the timing of the several events of the experiment. The anchor deployment, the relaxation experiments and the firing of the acoustic release were timed to coincide with FVR bursts. The instrument burst times and experimental events are shown in Table 5, which reproduces the log kept by the CSDL representative during the experiment. The data recovery rate for the CEL experiment was exceptionally high. The FVR's and T/P's provided a 100% data recovery throughout the experiment.

Pinger ALPHA was tracked during the deployment, but thereafter its signal was lost, apparently because it was mounted so close to the bottom, producing reflected signals and reverberation. Acoustic "track" was never established on pinger BRAVO.

Pinger CHARLIE seemed to be tracked during the experiment, but further processing afterwards revealed several large gaps in the data. Pingers DELTA and ECHO were tracked more reliably, with only occasional "holidays" in their records.

B. Current Meter Data for MDE Experiment 5

Currents in the MDE area were measured by a vertical array of WHOI Vector Averaging Current Meters (VACM's) mounted on a separate mooring nearby. The current meter mooring location is shown on Figure 8; the current meter numbers and depths are shown in Table 6. The data were reduced by the Pacific Marine Electronics Laboratory (PMEL) of NOAA. Four plots have been prepared for each of the five VACM's on the current meter mooring for a 14-hour period encompassing MDE Experiment 5, the CEL mooring. The first three plots show time histories of the Eastward, Northward and total speed of the current; the last is a polar plot of the current. The time base for the first three plots is in seconds relative to the start of the first FVR burst in the CEL experiment (15:47:37Z), starting one hour before that burst. The plotted current meter data are presented in Appendix C.

C. Temperature/Pressure Recorder Data

A low frequency temperature and pressure recorder was installed on the CEL mooring 1179 ft (358 m) below the main buoy at a nominal depth of 1385 ft (422m). This device, serial number 85, recorded a sample each four minutes continuously from 1530Z, 26 September 1976, throughout the entire MDE. Figures 10 and 11 show the plotted temperature and depth data recorded during the CEL experiment for a period from 2 hours before the first FVR burst until after LFTP 85 was recovered. The depth plot, Figure 11, clearly shows the four relaxation experiments. The minimum depth which would be recorded by the instrument was 1066 ft (325 meters).

A high frequency temperature/pressure recorder, serial number 90, was installed on the CEL mooring 33 ft (10m) below the main buoy at a nominal depth of 244 ft (24.5 meters). The burst repetition rate for the HFTP is twice that for an FVR. The instrument records four pressure readings in that interval. For economy in data reduction, only the pressure corresponding to the temperature and depth data from HFTP bursts 4, 8, 10, 12, 14, 16 and 18 are presented in Appendix D. These HFTP bursts are synchronized with FVR bursts 2, 4, 5, 6, 7, 8 and 9; this includes the deployment, five relaxation events and the mooring recovery.

The data from the temperature/pressure recorders (both low- and high-frequency) were reduced to engineering units by C. S. Draper Laboratory.

D. Force Vector Recorder Data for Deployment

Tensions measured by the Force Vector Recorders during the deployment of the CEL mooring are presented in plotted form in Appendix E. These data are on the same time base as the other data in this report; the times shown are elapsed time after the start of the first FVR burst at 15:47:37Z. The figures in Appendix E are in the order in which the instruments were installed on the mooring. The first plot is for FVR 1, installed nearest the top of the mooring, while the last plot is for FVR 4, nearest the top of the mooring, while the last plot is for FVR 4, nearest the anchor. The FVR locations are listed in Table 7.

E. Acoustic Position Data for Deploymemt

Five acoustic pingers mounted on the mooring were used to measure the positions of points on the mooring during the deployment. The pinger locations relative to the main buoy are given in Table 7. The range did not acquire a track on pinger BRAVO; position data for the other pingers are presented in Appendix F. The data were reduced to spatial coordinates as functions of time by PMRF using sound-velocity profiles based on expendable bathythermograph casts during the experiments. Four plots are shown for each pinger. Two plots give the North-South and East-West components of pinger motions during the deployment. A third plot shows the vertical component (depth), while the fourth plot is a plan view projection on a horizontal (map) surface.

Appendix G contains a second group of figures, which show "snapshots" of the mooring configuration (as defined by pinger positions) at various times during the deployment. Figures G-1 through G-4 show the trajectories of the four pingers following anchor release. Figure G-5 shows the configuration at intervals beginning at approximately the time of anchor release. The last four curves are at two-minute intervals, the last curve is after 7-1/2 minutes. The deployment configuration at one-minute intervals are shown in Figures G-6 through G-16; Figure G-17 shows the mooring 4.5 minutes after Figure G-16.

The snapshot plots were prepared by fitting a vertical plane through the pinger locations using the method of least squares. Then the pinger locations were projected horizontally onto the vertical plane. The origin of coordinates was located at the water surface directly above the deepest projected location for pinger ALPHA. The plan view plots (Figures F-4, F-8, F-12, and F-16) show relatively small out-of plane motion during the deployment. The data have been smoothed where it was considered appropriate to remove obviously specious values. The connection of the symbols in the figures by straight lines is not intended to represent the actual shape of the cable between pingers; in all probability, the cable hung in varying degrees of catenary during the deployment. The lines provide only a means of visualizing the overall behavior of the mooring as it descended.

Tabulated location data for the pingers are given in Table 9.

F. Data Plotting

The plots presented in Appendices C through G were prepared by EG&G WASC, Inc. Most of them were prepared using commercial computer plotter subroutines. A "quirk" in these subroutines leaves the coordinate axis definition in a slight ambiguity. This ambiguity is explained and clarified by considering the time axis on Figure C-1 which is labelled:

SECONDS AFTER 15-47-37Z $*10^2$.

The numbers along the axis run from -36.00 to 468.00 in increments of 36.

The ambiguity is that it is not uniquely clear whether the time scale is from -0.36 seconds after 15-47-37Z to 4.68 seconds or from -3600. to 46,800. seconds. In this case, the context makes it apparent that the latter is the case.

The rule is : multiply the numbers along the axis by the multiplier in the label and append the units in the label.

V. DISCUSSION

A. General

The data presented in Appendices C, D, E, F and G represent the first detailed experimental at-sea measurements of the behavior of a single-point mooring during an anchor-test deployment. A general examination of the data reveals the remarkably high quality of the data taken during the MDE. The data attest to the design of the instrumentation used in the experiment and the care with which the tests were carried out.

A general discussion of the Mooring Dynamics Experiment has been given in Reference 2; the present discussion pertains only to the deployment of the Civil Engineering Laboratory experiment and the data relating to it.

B. Current Measurements

The current meters returned an excellent history of the current variability at five depths near the CEL mooring site. Although the plots are a forceful reminder of the complexity of the ocean environment, with an array of seemingly random variations superimposed on an already complex tidal rotation, it should be noted that the maximum measured current at any depth was less than 30 cm/sec, or 0.6 knot.

This has a correspondingly small effect on the CEL mooring. The equilibrium of the HFTP does not vary by more than 1 m at any time, except during the deflection experiments.

C. Low-Frequency Temperature/Pressure Recorder

The LFTP data (Figure 10) represent the best concise log of the entire CEL experiment. The temperature trace clearly shows the instrument sinking into colder water while the mooring is being deployed by the USNS De Steiguer, then being abruptly pulled to its installed depth, where the water is much colder. The depth digitizer was set for a minimum depth of 325 m, thereby missing this feature. Similarly, the maximum temperature is "clipped" by the range assigned to the 8-bit digitizer. At the end of the experiment, the recovery is clearly indicated by the rise in temperature.

The effects of the pullover trials are hidden in the LFTP temperature trace, which shows apparently random 0.25C variations. The LFTP depth trace, however, is unambigious about the pullover trials, which are clearly delineated. The difficulty encountered by the crew of the Zodiac in making the first pullover is denoted. Unfortunately the trace shows that the pullover occured midway between FVR bursts 3 and 4, so that the FVR's did not record the event.

The pullover during FVR burst 6 is shown to be the strongest, followed by weaker events during FVR bursts 7 and 8.

D. High-Frequency Temperature/Pressure Recorder

The HFTP was the shallowest instrument, mounted only 11 m below the main buoyancy sphere. The pressure channel recorded every event with remarkable clarity. At first glance, the temperature trace seems equally flawless, but further study raises questions, such as: why does the deployment temperature trace on Figure D-1 show a 1-minute lag behind the deployment depth trace on Figure D-2; and why do the pullover temperature traces for bursts 10, 14, and 16 fail to detect any change, while the traces for bursts 4, 16 and 18 clearly respond in temperature?

Happily, the mooring modeler is more concerned with the depth trace which was clearly recorded.

E. Force Vector Recorders

The tension records (Figure E-1 through E-4) produced by the four FVR's during the mooring deployment represent a remarkable achievement in the history of ocean mechanical experimentation. This degree of clarity and agreement among the four instruments has rarely been achieved in at-sea trials. The resulting plots are so clear that qualitative interpretation is straightforward.

During the two minute portion of the trace before the anchor was released, all the traces show a constant tension with wave-induced variations superimposed. The constant tension is due to the steady towing speed of the De Steiguer plus the weight and buoyancy of the components. The average tension at the anchor end (FVR 4) is highest, since all the towing drag and a good share of the weight are supported there. The average tension at FVR 3 is somewhat less, since it supports less weight and less drag. The average tension at FVR 2 is less still. FVR 2 is apparently near the deepest part of the "catenary" of the mooring under tow. The average tension at FVR 1 is essentially the same as at FVR 2, because while it supports less drag, it supports more weight.

The large tension variation during this period is dominated by the motions of the De Steiguer in the seaway. This conclusion is supported by the reduction in tension amplitude from FVR 4 to FVR 1, away from the towing ship. It is further supported by the reduction in amplitude after the anchor is released and the ship cannot force the mooring.

The tension falls abruptly as the anchor is released, the drop-off being most abrupt at FVR 4 and less so at FVR 1, farthest from the anchor. One might speculate whether the "spikes" in the drop-off trace represent reflections of the initial tension wave produced at the moment of release.

In any case about 30 seconds after the anchor has been released, at say 5400 seconds into the FVR record, a new equilibrium is established. FVR 1 shows (Figure E-1) the tension required to tow the main buoy, afloat on the surface. The main float bobs on the waves, producing a spectrum like the pre-drop trace, but lacking the large low frequency spikes of the De Steiguer. These wave-induced pulses are much attenuated at FVR's 2, 3, and 4. FVR 2 is still near the bottom of the catenary, but because the anchor tows the float more slowly the drag is reduced between FVR 1 and FVR 2, but the weight does not change. The result is that the tension at FVR 2 (Figure E-2) is less than at FVR 1 (Figure E-1). The tension at FVR 3 (Figure E-3) is essentially the same, but at FVR 4 (Figure E-4) the entire towing drag is felt.

This equilibrium lasts for about 3 minutes, showing the "water pulley" effect whereby the cable tends to resist transverse motion and follow tangential motion, as if the water were a great pulley sheave. By about 5640 seconds into the FVR record, the "sheave" has been "worn away", and the anchor is beginning to pull the main buoy down with an ever-increasing force. During the next minutes the buoy becomes nearly directly above the anchor and the tension rises sharply to the maximum buoyancy of the main float as the buoy comes awash. During this time the wave induced oscillations are much greater, because the vertical motion of the buoy on the waves couples directly into the nearly vertical cable. At about 5730 seconds the buoy comes awash, and immediately the effects of small surface waves disappear. Only the swell remains, and its amplitude decreases as the buoy descends. The mean tension is set by the buoyancy and drag of the amin float as it is towed down at the system terminal velocity. By comparing the four figures, the distribution of weight along the mooring becomes apparent during this minute of near-equilibrium.

The impact of the anchor and its decay in time are clearly shown on each FVR trace; its decay with distance along the cable is also apparent, since the oscillations at FVR 1 are about half those at FVR 4.

Following impact, the tension produced by the drag of falling at terminal speed is removed, and only the nudgings of the swell on the main float remain.

These remarkable traces represent a convincing test for the validity of a mooring dynamics prediction model.

F. Acoustic Position Tracks

Of the five acoustic "pingers" installed on the CEL mooring, four functioned well during the deployment. Pinger BRAVO, 17 m above the anchor, was never tracked. Shortly after the deployment was complete, tracking failed for pinger ALPHA, about 25 m above the anchor. During the remainder of the CEL experiment, pingers CHARLIE, DELTA and ECHO were tracked most of the time. The track on pinger CHARLIE was apparently tenuous, however, because post-processing of the data from that channel by the Pacific Missile Range Facility left large "holidays" in the data record.

The four operative pingers resulted in moderately clear records of the deployment interval. The vagaries of acoustic measurement permit ambigious tracking solutions, but the data record is entirely adequate to provide a vigorous test of a deployment model.

Pinger ALPHA, near the anchor, provides the record most amenable to visual interpretation. The northward and westward position histories show the pinger being towed in the water by the De Steiguer on its southwestward course for about a minute prior to dropping the sandbag anchor. The anchor swung as a pendulum for 2-1/2 periods during its descent. The pendulum period for the anchor was continuously increasing as the anchor descended. The first period lasted about 2 minutes; the second period was about 2.8 minutes; and the final half-period lasted about 2.2 minutes, for a period of 4.4 minutes.

The "water-pulley" effect is demonstrated by the traces for the pinger ALPHA. The anchor falls nearly straight down, with the impact point only about 270 ft (82 m) back along the course of the De Steiguer from the release point. That is, in pulling the entire mooring around the "sheave" of water from the horizontal to the vertical, only 270 feet (82 m) of the "sheave" were "cut through" by the cable. Because part of that 270 feet (82 m) represents the last half-period of the anchor pendulum, the actual water pulley may be more effective than the number suggests.

The depth history of pinger ALPHA shows the separate terminal velocities of the anchor: about 346 ft/min (1.4 m/s) when it is towing the main buoy along the water surface around the water pulley, and about 273 ft/min (1.4 m/s) when it is sinking the fully immersed main buoy just prior to impact.

Finally, after impact, the depth history of pinger ALPHA shows a depth recovery of about 100 feet (30.5 m), lasting two minutes. This is much more than can be accounted for by assuming the mooring was not vertical at the moment of impact, since ALPHA was only about 82 ft (25 m) along the mooring from the sandbags, and since there is no corresponding horizontal recovery evident. Furthermore, pinger ECHO is shown to recover about 61 feet (18 m) after impact.

It is clear from the FVR traces that the overshoot interval lasted about 17 or 18 seconds. Since the impact speed was about 273 ft/min (1.4 m/s) about 40 feet (12 m) of depth overshoot can be expected.

This represents another specific test for a deployment model: to reconcile and explain the observed depth recovery with the impact parameters.

G. Data Evaluation

A static evaluation of some of the data gathered for the CEL mooring can be made by looking at the depth of the instruments. Table 10 gives a comparison of the depth of the instruments as expected from the length of wire and chain leading to the anchor for a vertical mooring with the measured depths of the T/P's and pingers.

It is apparent that the depths measured by the T/P's correlate very closely to the wire-length depths. The T/P's measure hydrostatic pressure which is converted to depth in reducing the data.

The depths at which the pingers were tracked are in substantial disagreement. The disagreement increases with pinger depth. This is assumed to be a limitation imposed by tracking from hydrophones on the bottom combined with the processing technique.

VI. CONCLUSIONS

The primary objective of the Mooring Dynamic Experiment was to gather at-sea engineering data describing the response of oceanographic moorings to their environment. These data were to be made available for evaluation and validation of oceanographic mooring models. The high quality of the data gathered during the deployment of the CEL mooring experiment goes a long way towards fulfilling this goal, and is a gratifying tribute to the people and organizations who designed and executed the experiment and especially its instrumentation.

The data contain evidence of responses that can be interpreted intuitively by the analyst, representing a test of a mooring model's ability to reproduce what we expect to see. But the data also contain responses whose cause has not been identified from intuitive reasoning. These represent tests of a model's ability to provide mathematical clues to the origin of these unexpected responses.

When these data are used to evaluate a computer model of the CEL mooring, the most emphasis should be placed on the model's ability to reproduce the tension data provided by the FVR's, because these are the data of the highest quality. We rank the T/P depth data at the second level for comparison. This is not because the T/P data are in themselves inferior to the FVR measurements, but because the depth is not associated with a horizontal position. The pinger plan-view data are third, because they lack the crisp consistency and clarity of the FVR and T/P data. The depth data for the pingers is the weakest class, and should be used selectively and evaluated carefully.

REFERENCES

1. Taylor, B. D., Zwibel, H. S., and Meggitt, D. J., "Research Plan for the Dynamic Response of Cables Suspended in the Ocean", Civil Engineering Laboratory, December 1974.

2. Walden, E. G., DeBok, D. H., Gregory, J. B., Meggitt, D. J. and Vachon, W. A., "The Mooring Dynamics Experiment - A Major Study of the Dynamics of Buoys in the Deep Ocean", Offshore Technology Conference Paper 2883, May 1977.

3. Vachon, W. A., and Scholten, J. R., "Final Report on the C. S. Draper Laboratory Role in the Mooring Dynamics Experiment", C. S. Draper Laboratory Report R-1093, April 1977.

4. Nath, J. H. and Thresher, R. W., "Anchor-Last Deployment for Buoy Moorings", Offshore Technology Conference Paper OTC 2364, May 1975

TABLES

TABLE 1. PARTICIPATION IN THE MOORING DYNAMICS EXPERIMENT.

PARTICIPANT	RESPONSIBILITY
National Data Buoy Office	funding, buoy motion instrumentation, data archiving and dissemination
Office of Naval Research	funding, contract support
Woods Hole Oceanographic Institution	experiment coordination and direction; principal investigator
Charles Stark Draper Laboratories	manufacture, preparation and operation of mooring line motion and temperature/pressure instruments; data reduction from instruments
Pacific Missile Range Facility, Barking Sands	acoustic and radar range tracking facilities, logistic support
Naval Torpedo Station Detachment, Hawaii	acoustic pinger preparation and operation
Naval Oceanographic Office	current meter preparation and refurbishment, data reduction
Civil Engineering Laboratory	funding, mooring hardware, technician support
Naval Facilities Engineering Command	funding, current meters
Pacific Marine Environmental Laboratories, NOAA	current meter preparation and refurbishment, data reduction
EG&G Washington Analytical Services Center, Inc.	services, equipment

TABLE 2. MOORING COMPONENTS AND PHYSICAL DATA

ITEM	COMPONENT	MATERIAL	FORM	ATTACHMENT	DIAMETER in (mm)	AIR WT. lb/ft (Kg/M)	SEAWATER lb/ft (Kg/M)	*	EA lb (N)	IN LINE LENGTH FT (M)	COMMENTS
1	Chain	Steel	Open-link	in-line	0.375 (9.52)	1.788 (2.660)	1.554 (2.313)	H	8.97×10^5 (3.99×10^6)	Variable	
2	Chain	Steel	Open-link	in-line	0.500 (12.7)	3.154 (4.694)	2.743 (4.082)	H	1.26×10^6 (5.59×10^6)	Variable	
3	Wire Rope	Steel Polyurethane	3/16-3x19 Jacketed	in-line	0.390 (9.9)	0.0549 (0.0817)	0.0469 (0.0698)	H	$3,12 \times 10^5$	Variable	
4	Line	Nylon	Braided	in-line	0.750 (19.1)	0.150 (0.223)	0.017 (0,025)	H	*non-linear*	32.8 (10.0)	
						Lbs (Kg)	Lbs (Kg)				
5	Main Buoy	Aluminum	Sphere	in-line	44.0 (1118.)	360 (163)	1050 (477)	B	–	3.67 (1.12)	
6	Reserve Buoy	Aluminum	Sphere	in-line	38.0 (965)	360 (163)	847 (384)	B	–	3.17 (9.65)	
7	Anchor	Sand	Bags piled in 5'x5' square	Cargo net	60 (1524)	–	2600 (1180)	H	–	4 (1.2)	Fig. 2
8	T/P Re-corder	–	Sphere	Clamp-on	11.5 (292)	6.51 (29.5)	20.0 (9.1)	H	–	1.33 (0.406)	Fig. 3
9	FVR	–	Sphere	in-line	19.0 (483)	130 (59.0)	4.0 (1.8)	B	–	1.85 (0.575)	Figs. 4,5
10	SUB CAN Pinger	–	16.5 inch cylinder	in-line	10.0 (254)	98.8 (44.8)	44.3 (20.1)	H	–	3.51 (1.07)	Fig. 6
11	DEEP CAN Pinger	–	26.0 inch cylinder	Clamp-on	12.2 (260)	143 (64.9)	75.9 (34.4)	H	–	–	Fig. 7
12	Acoustic Release	–	41.0 inch cylinger	Clamp-on	7.5 (190)	130 (59.0)	70.0 (31.7)	H	–	5.0 (1.5)	Two used in parallel

* H = "Heavy" in Seawater
B = Buoyancy in Seawater

TABLE 3. NOMINAL RANGES AND SCALING OF TEMPERATURE-PRESSURE RECORDERS EMPLOYED IN MOORING DYNAMICS EXPERIMENT

	High Frequency Temperature - Pressure Recorder (HFTP)				Low Frequency Temperature - Pressure Recorder (LFTP)		
Instrument Serial Number (S/N)	90	91	92	93	15	84	85
Temperature Range (°C)	2.86-30.31	2.86-30.31	2.86-30.31	10.68-29.67	0-20	10-26	0-20
Temperature Least Significant Bit, LSB_T (°C)	.027	.027	.027	.019	.02	.016	.02
Pressure Sensor Full Scale Capability (Meters of Water)	127	229	127	58.3	1703	683	683
Pressure Sensor Range (Meters)	0-127	60-229	60-100	0-20	1167-1667	120-320	325-525
Pressure Sensor Least Bit Significant Bit, LSB_p (cm)	12.7	16.9	4	2	50	20	20

TABLE 4. FORCE VECTOR RECORDER CHARACTERISTICS

Measurement	Sensor	Maximum Ranges	Sensor* Frequency Response	Maximum+ Resolution (10 bit word)
Acceleration - 3 mutually orthogonal axes	Force Balance Accelerometer	±2g	48 Hz	0.001 x Full Scale (e.g., 0.004g for ±2g unit)
Azimuth Reference - 2 axes orthogonal to mooring line	Magnetometer	0-360°	N.A.	~0.1° (Max)
Tension	Strain Gage Bridge Load Cell	0-3,000 pounds	~0-10 kHz	0.001 x Full Scale = 3 pounds
Pressure	Strain Gage Bridge	0-10,000 psi	0-10 kHz	0.001 x Full Scale
General Capabilities: Pressure: 10,000 psi maximum external pressure on case, 5,000 psi on load cell, 3,400 psi on flotation shell. Life: To approximately 6 months on internal battery package. Data Recording: Burst or continuous mode at 2,6-word scans/sec (10 bit words).				

* Overall FVR frequency response is limited to Nyquist frequency of $f_{Ny} = \frac{1}{2\Delta t} = 0.96$ Hz

\+ Resolution of least significant bit may be increased by reducing sensor range. Select Full Scale output for optimum accuracy and range in any application.

TABLE 5. EXPERIMENT #5 SUMMARY

MDE MOORING SUMMARY

MOORING NUMBER: 6	EXPERIMENT NUMBER: 5, CEL
DATE: 11-1-76	SYNCHRONIZATION DATE/TIME: 11-1-76 07:03:15Z
ANCHOR LAUNCH TIME: 11-1-76 17:17Z	ANCHOR RELEASE TIME: 11-2-76 03:27:35Z

BURST TIMES

FVR BURST NO.	FVR TIME (LOCAL & Z)	HFTP BURST NO.	HFTP TIME (ZULU)
1	05:47:37	1	15:03:56
	15:47:37Z	2	15:47:37
2	07:15:00	3	16:31:18
	17:15:00Z	4	17:15:00
3	08:42:23	5	17:58:41
	18:42:23Z	6	18:42:23
4	10:09:46	7	19:26:04
	20:09:46Z	8	20:09:46
5	11:37:09	9	20:53:27
	21:37:09Z	10	21:37:09
6	13:04:31	11	22:21:50
	23:04:31Z	12	23:04:31
7	14:31:54	13	23:48:12
	00:31:54Z	14	00:31:54
8	15:59:18	15	01:15:35
	01:59:18Z	16	01:59:18
9	17:26:40	17	02:42:59
	03:26:40Z	18	03:26:40
10		19	04:20:21
		20	
11		21	
		22	
12		23	
		24	

INSTRUMENT SUMMARY

SYSTEM S/N	F1	F2	F3	F4
MAGNET OFF TIME (i.e., ENABLE)	14:51Z 11-1-76	14:50Z 11-1-76	14:49Z 11-1-76	14:48Z 11-1-76
TIME IN WATER	15:12Z 11-1-76	15:04Z 11-1-76	15:58Z 11-1-76	16:12Z 11-1-76
TIME OUT OF WATER	04:28Z 11-2-76	04:49Z 11-2-76	05:07Z 11-2-76	05:18Z 11-2-76
TIME MAGNET ON	04:33Z 11-2-76	04:55Z 11-2-76	05:12Z 11-2-76	05:31Z 11-2-76
COMMENTS				
SYSTEM S/N	90	91	92	93
MAGNET OFF TIME (i.e., ENABLE)	14:52Z 11-1-76			
TIME IN WATER	15:19Z 11-1-76			
TIME OUT OF WATER	~04:20Z 11-2-76			
TIME MAGNET ON	04:27Z 11-2-76			
COMMENTS				

NOTE: FVR BD = 15M 41.2S, BRP = 87M 22.88S
HFTP BD = 28M 50.56S, BRP = 43M 41.44S

TABLE 6

NOMINAL CURRENT METER DEPTHS

Number	Depth (Feet)	Depth (Meters)
253	3281	1000
264	2461	750
290	4265	1300
293	1640	500
295	656	200

TABLE 7

FORCE VECTOR RECORDER POSITIONS

NOTE: This table gives the locations of the Force Vector Recorders as installed on the CEL moor relative to the base of the main flotation buoy. Add 210 feet (54 m) for nominal depth.

FVR Number	Location	
	Feet	Meters
F1	42	13
F2	847	258
F3	1625	495
F4	2217	676

TABLE 8

ACOUSTIC PINGER POSITIONS

Note: This table gives the locations of the acoustic pingers as installed on the CEL moor relative to the base of the main flotation buoy. Add 210 ft (64 m) for nominal depth.

Pinger	Location	
	Feet	Meters
ALPHA	2228	679
BRAVO	2258	688
CHARLIE	857	261
DELTA	1634	498
ECHO	51	16

TABLE 9. MDE EXPERIMENT T5: CEL MOORING DEPLOYMENT
SNAPSHOT DATA

PINGER	ECHO				CHARLIE				DELTA				ALPHA			
	FEET				FEET				FEET				FEET			
TIME SEC.	NORTH	WEST	R	DEPTH	NORTH	WEST	R	DEPTH	NORTH	WEST	R	DEPTH	NORTH	WEST	R	DEPTH
5310	-680	1190	2333	40	-1280	1200	1718		-2120	690	813	140	-2650	440	227	40
5370	-1000	1100	2004	55	-1600	940	1390	50	-2540	450	332	490	-2970	290	-126	40
5430	-1210	1070	1797	60	-1850	785	1099	325	-2600	500	297	250	-3090	315	-226	285
5490	-1370	1040	1641	80	-1940	765	1008	370	-2675	480	221	300	-3040	310	-182	650
5550	-1550	1010	1464	45	-2070	730	875	425	-2800	440	90	460	-3060	325	-194	935
5610	-1710	950	1293	65	-2230	680	709	585	-2860	400	19	570	-2950	300	-103	1305
5670	-1930	875	1061	120	-2370	640	564	570	-2860	350	-1	1370	-2940	235	-120	1700
5730	-2180	780	794	90	-2470	570	445	840	-2810	350	45	1910	-2920	305	-73	2010
5790	-1420	650	522	240	-2560	530	346	1125	-2780	440	108		-2880	360	-15	2250
5850	-2550	570	371	260	-2610	520	296	1170					-2870	375	0	2250
6120	-2820	430	68	225	-2810	410	69	1130								

TABLE 10. INSTRUMENT DEPTH COMPARISON

COMPONENT	LOCATION (m)	CENTER NOMINAL DEPTH (m)	MEASURED DEPTH (m)
Sphere	-.55	43.3	
HFTP	10.2	54.1	55
FVR 1	12.7	56.6	
PGR E	15.5	59.4	73
FVR 2	258.3	302.2	
PGR C	261.1	305.0	335
LFTP	357.8	401.7	406
FVR 3	495.3	539.2	
PGR D	498.1	542.0	580
FVR 4	675.9	719.8	
PGR A	679.2	723.1	663
PGR B	687.2	731.1	
Anchor	706.7	750.6	
Bottom	707.7	751.6	751.6 from Chart

NOTES:

(1) Assumes shackle differentials included in station log chain/wire. lengths per telecon R. Waldon, WHOI.
(2) Assumes 2.5 m. for release and bridle per WHOI.
(3) Assumes 2.0 m. for sandbag and sling height per photo.
(4) Neglects stretch of nylon or wire.
(5) Water Depth interpolated from 20 fathom contours on range chart.
(6) Location is distance below the bottom of the main buoy.
(7) Nominal depth assumes mooring is vertical.

FIGURES

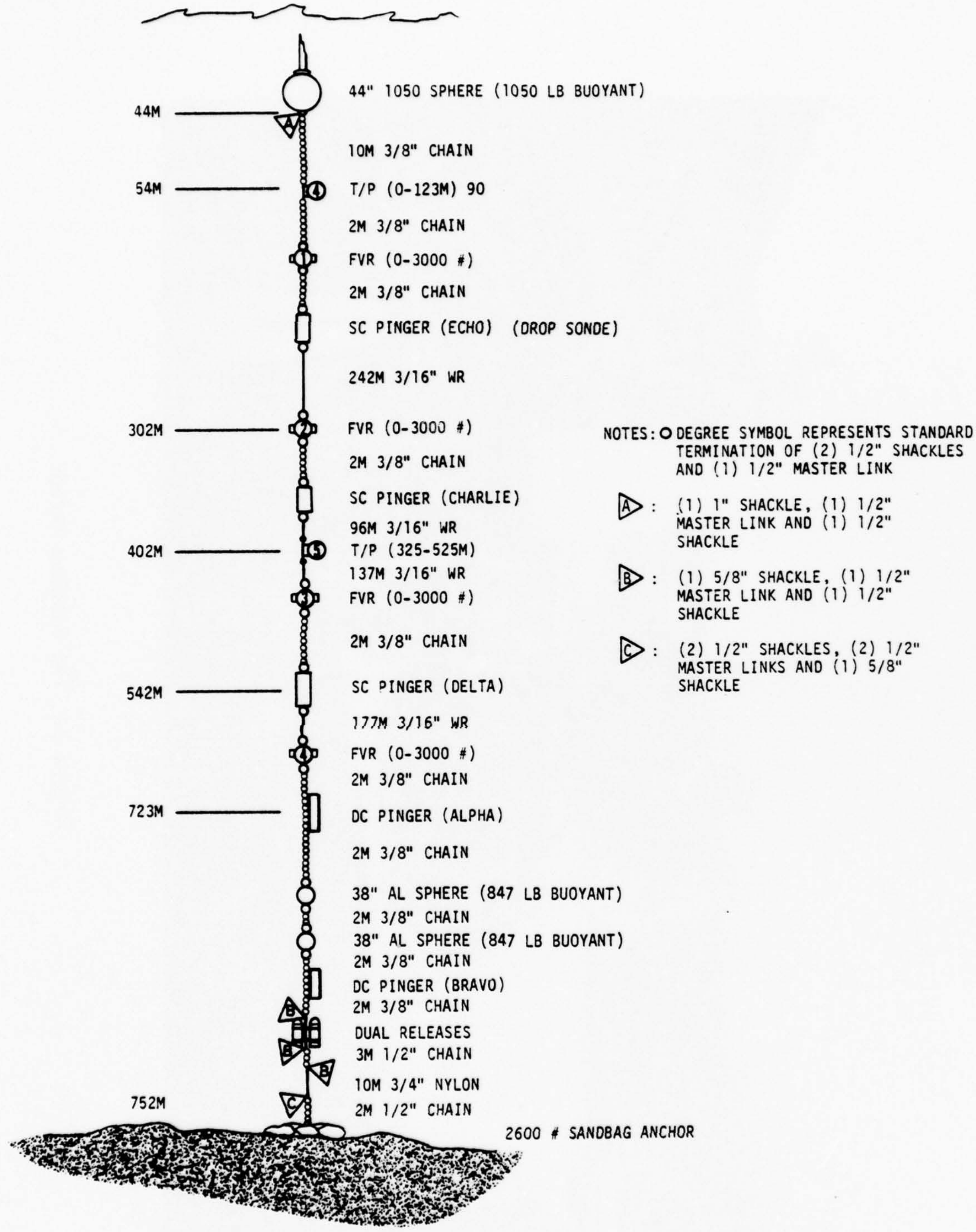


Figure 1. Schematic Drawing of the Civil Engineering Laboratory Mooring

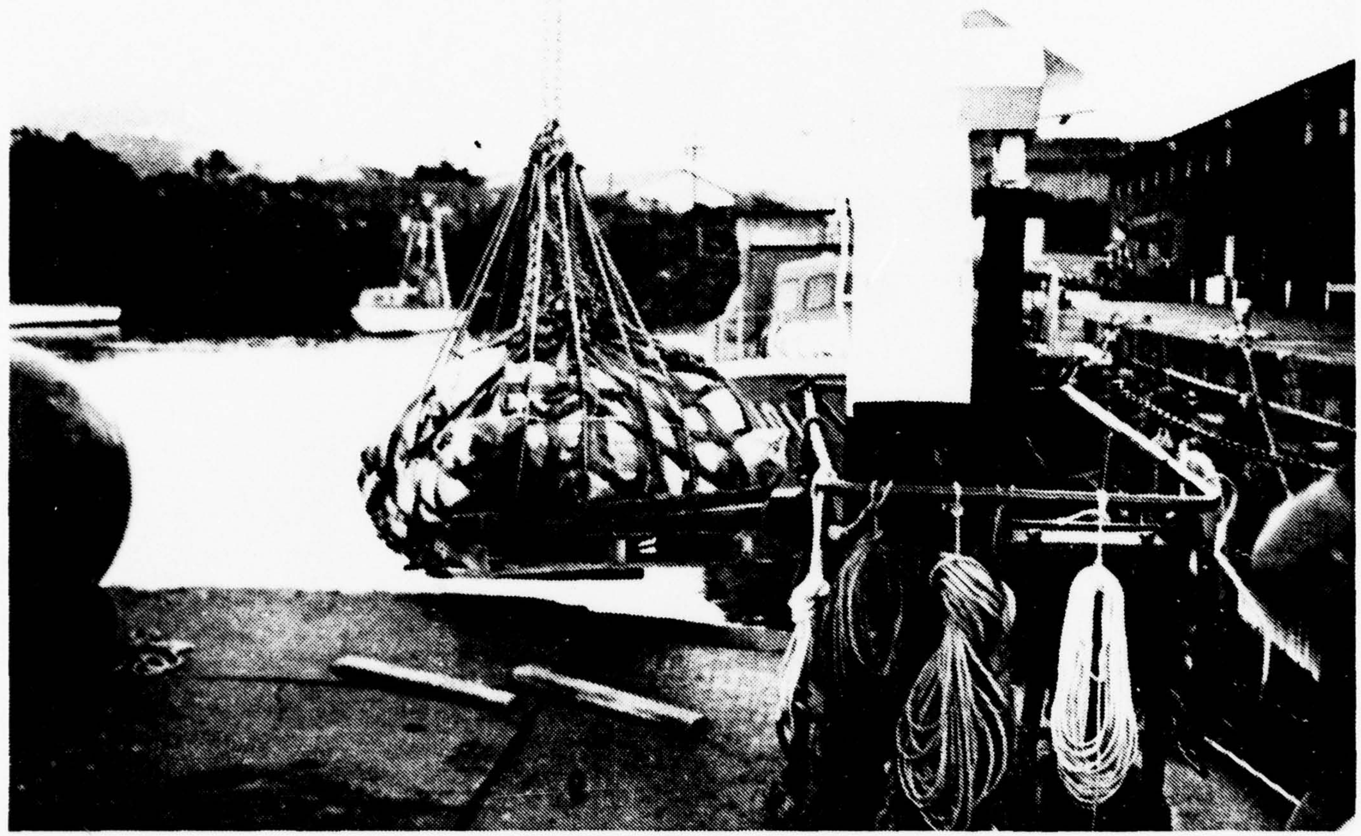


Figure 2. The Sandbag Anchor

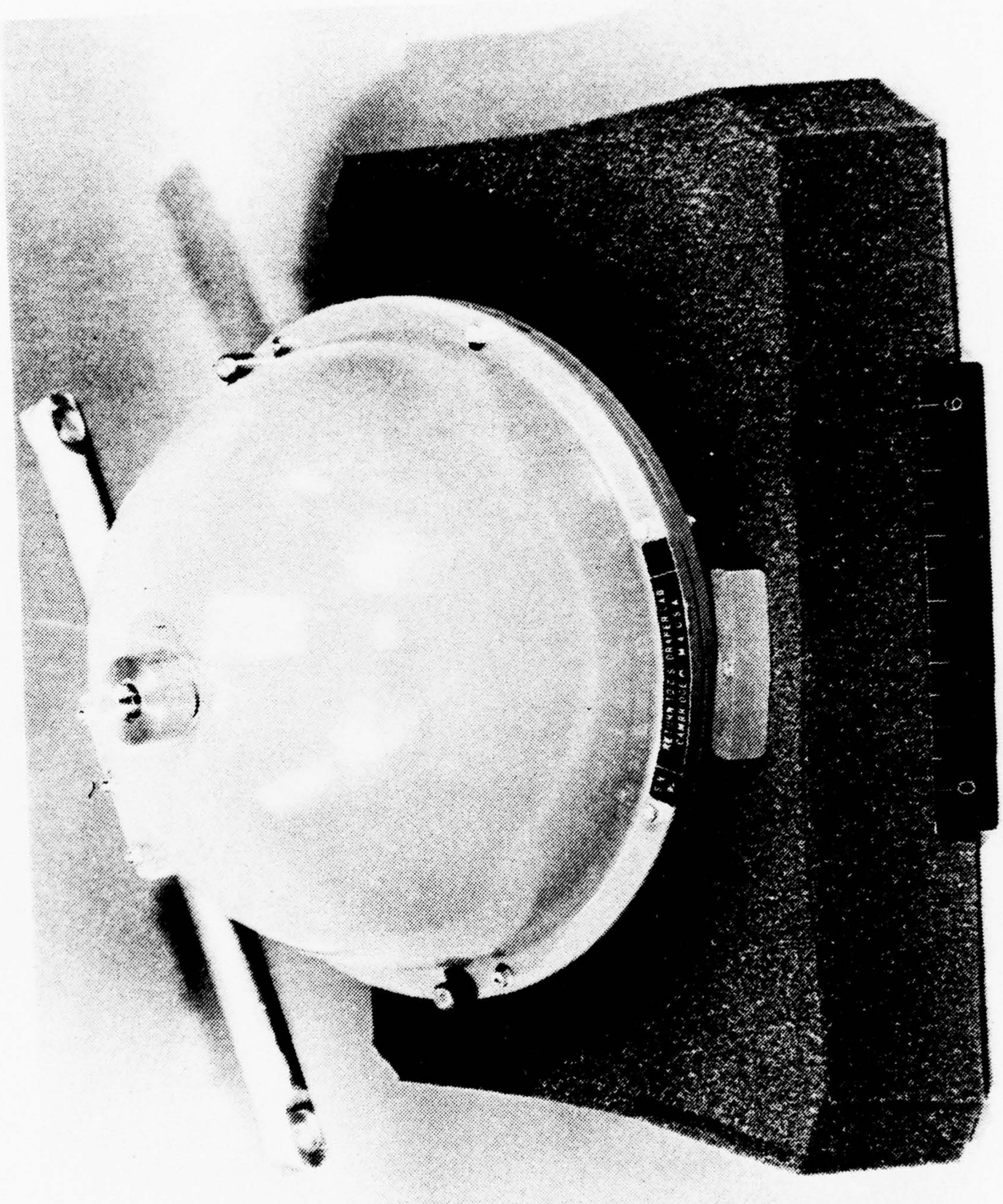


Figure 3. Temperature/Pressure Recorder

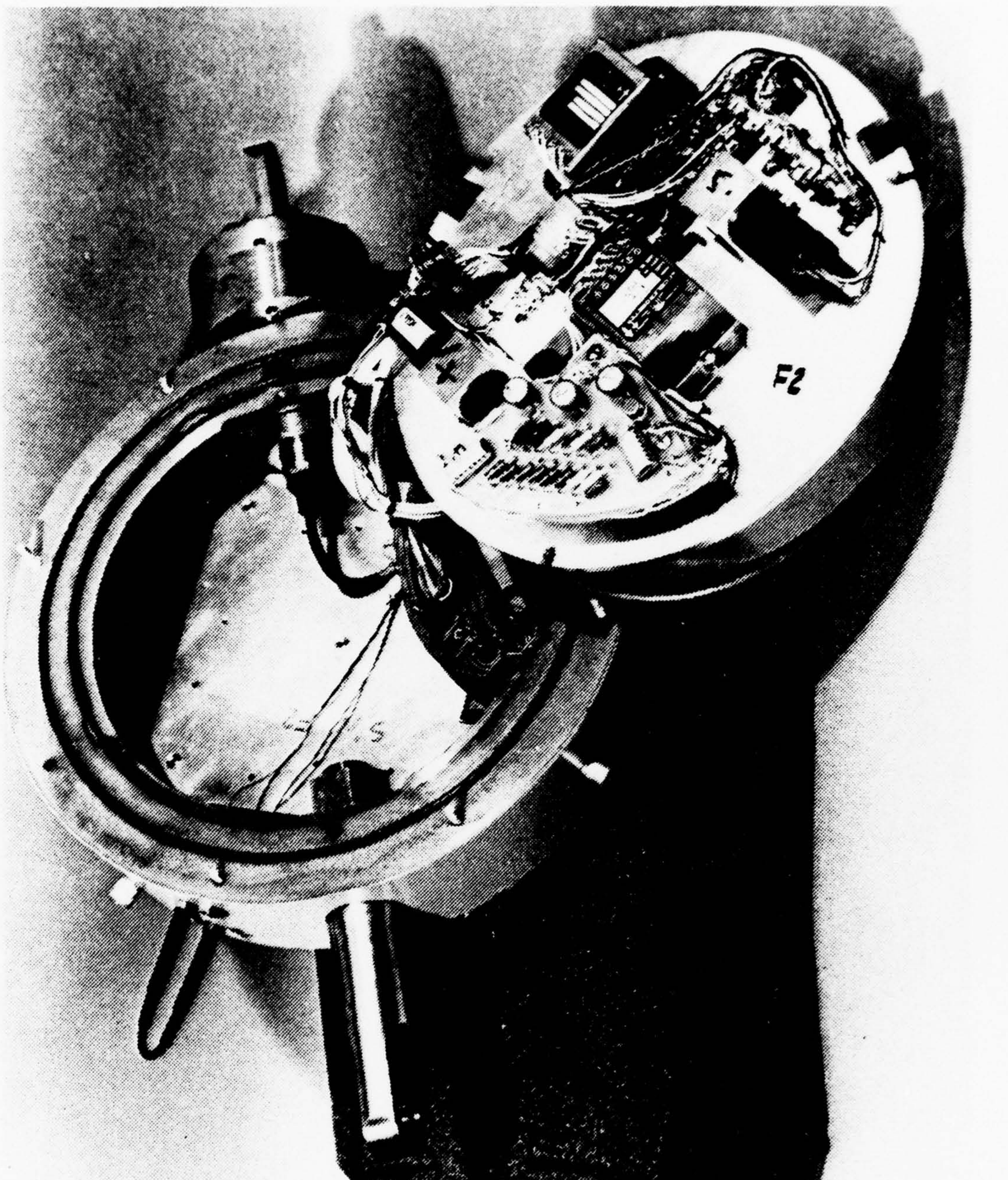


Figure 4. Force Vector Recorder Internal Assembly

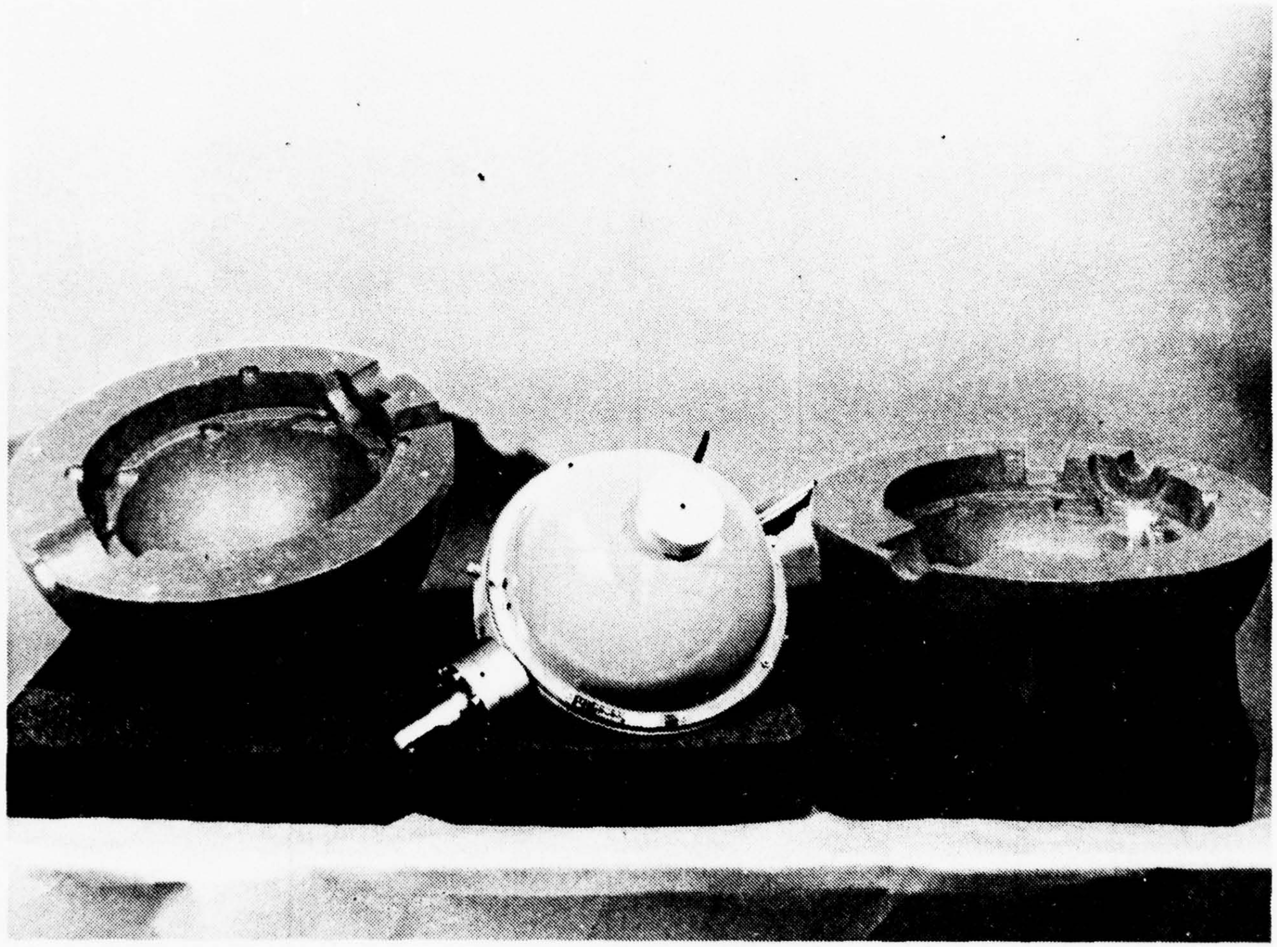


Figure 5. Force Vector Recorder with Flotation Shell

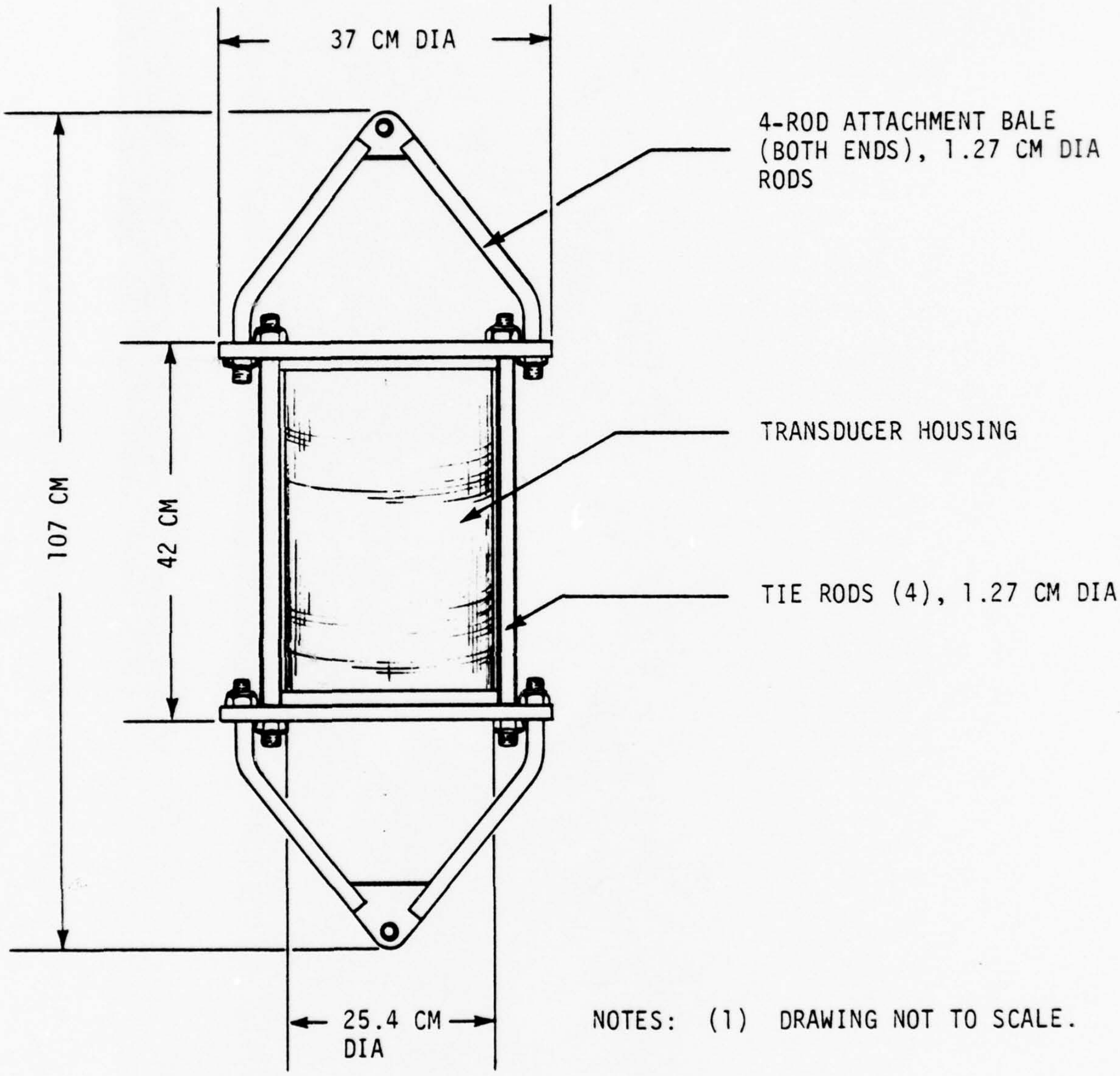
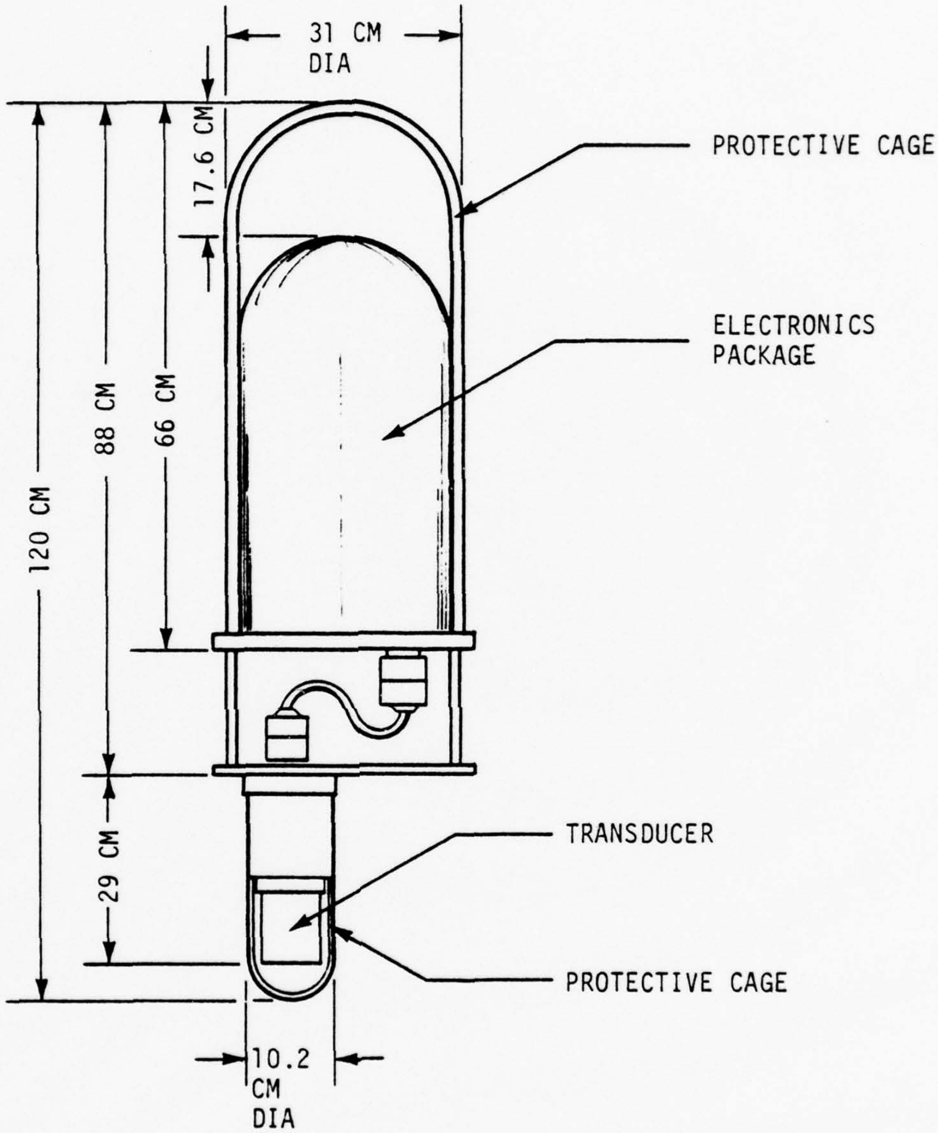


Figure 6. Sub-Can Pinger Outline Sketch

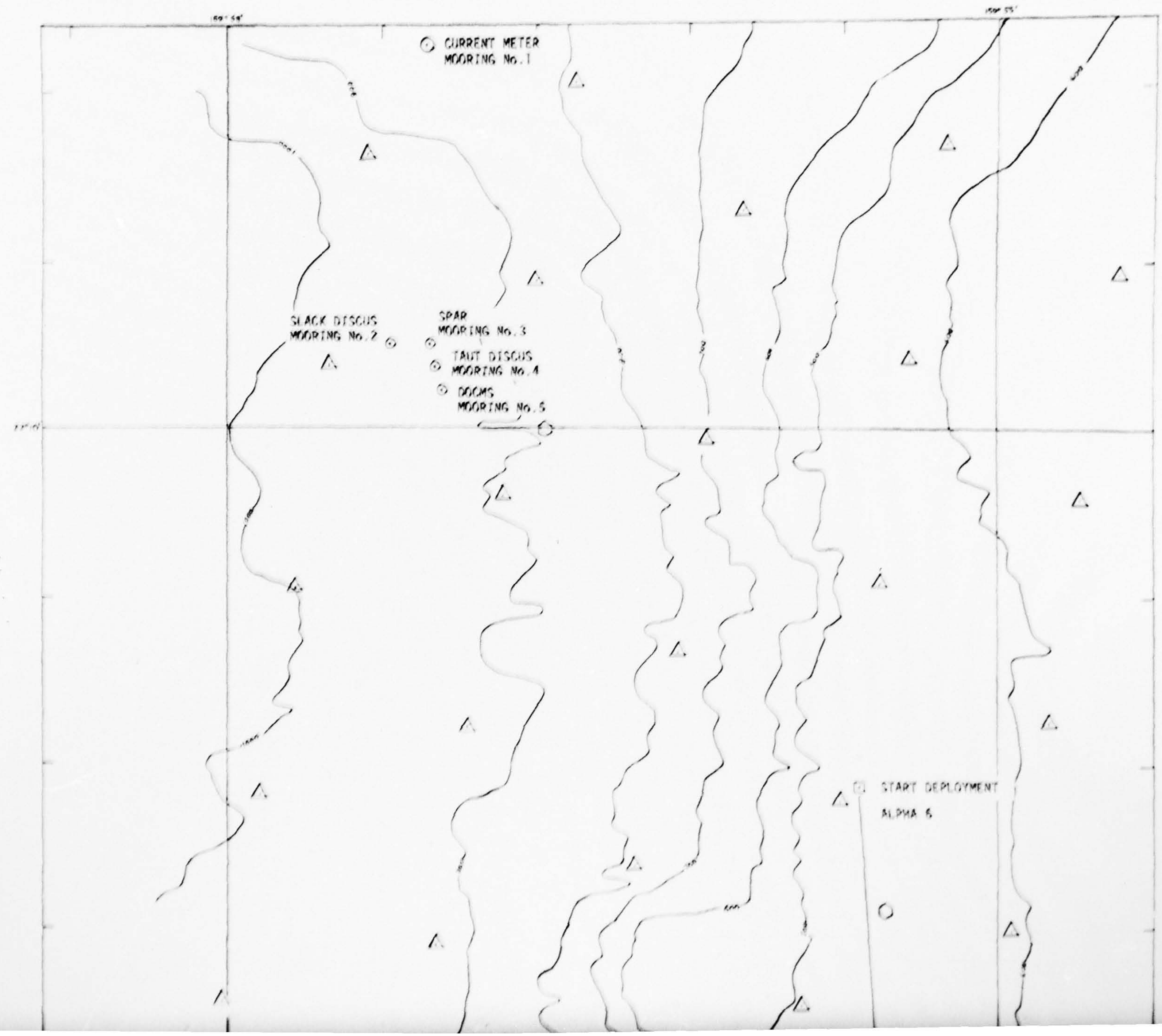


NOTES: (1) DRAWING NOT TO SCALE.

(2) PINGER ATTACHED TO AND IN PARALLEL WITH 2M, 3/8" CHAIN.

(3) WEIGHTS, EXCL OF CHAIN: 64.9 KG (IN AIR),
34.4 KG (IN WATER).

Figure 7. Deep-Can Pinger Outline Sketch



CURRENT METER
MOORING No. 1
SLACK DISCUS
MOORING No. 2
SPAR
MOORING No. 3
TAUT DISCUS
MOORING No. 4
DOOMS
MOORING No. 5
START DEPLOYMENT
ALPHA 6

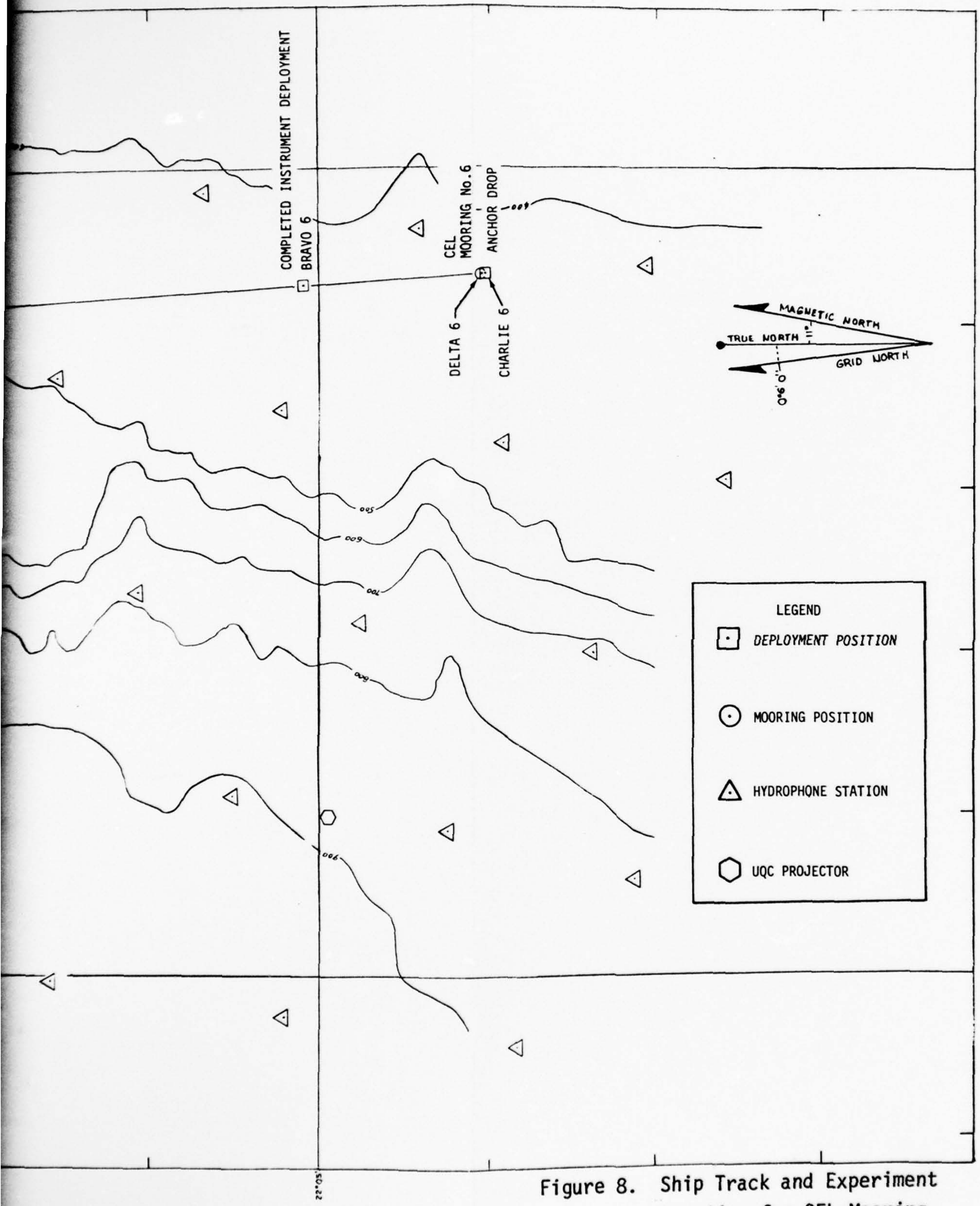


Figure 8. Ship Track and Experiment Location for CEL Mooring

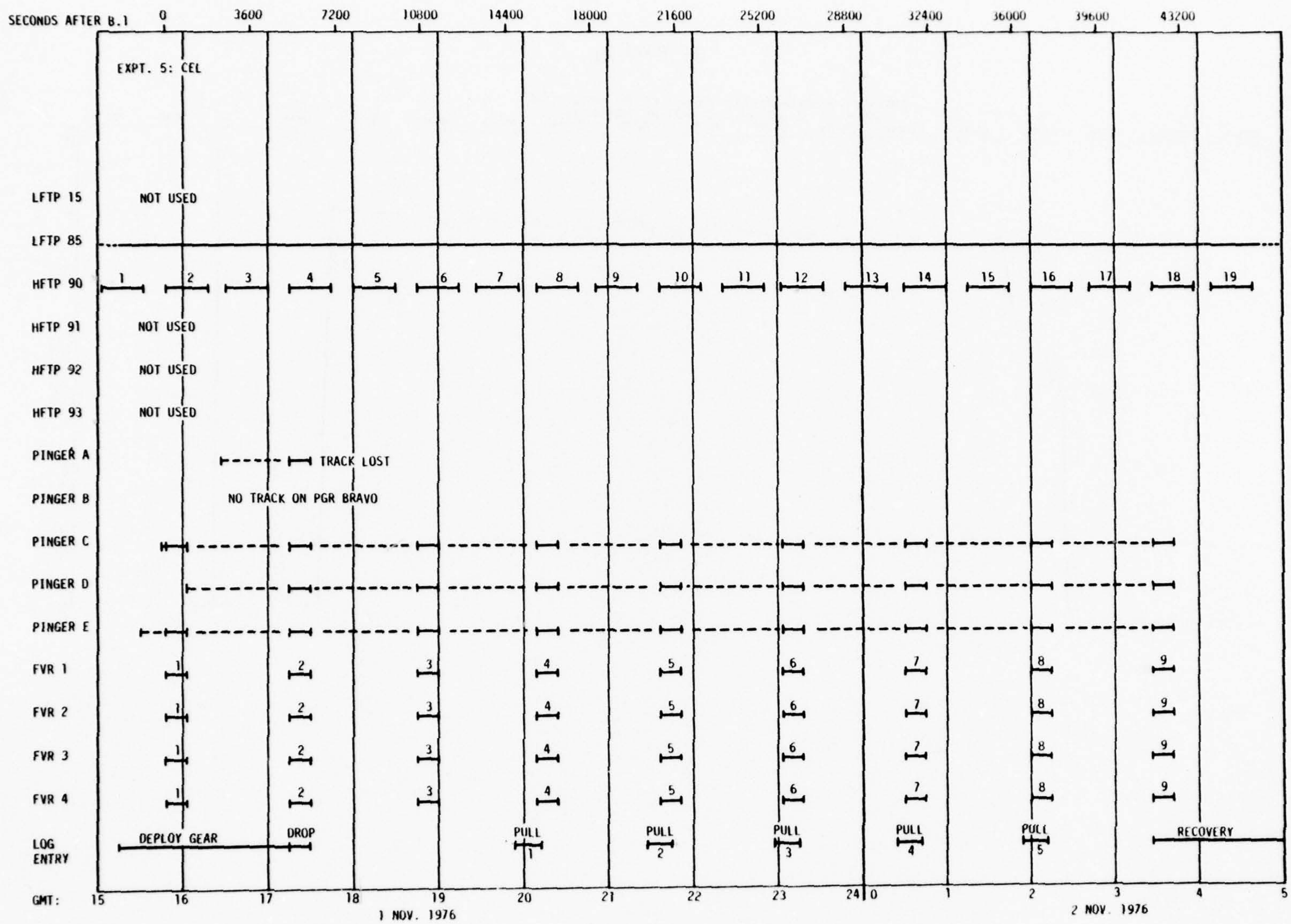


Figure 9. Data Coverage for MDE Experiment Five

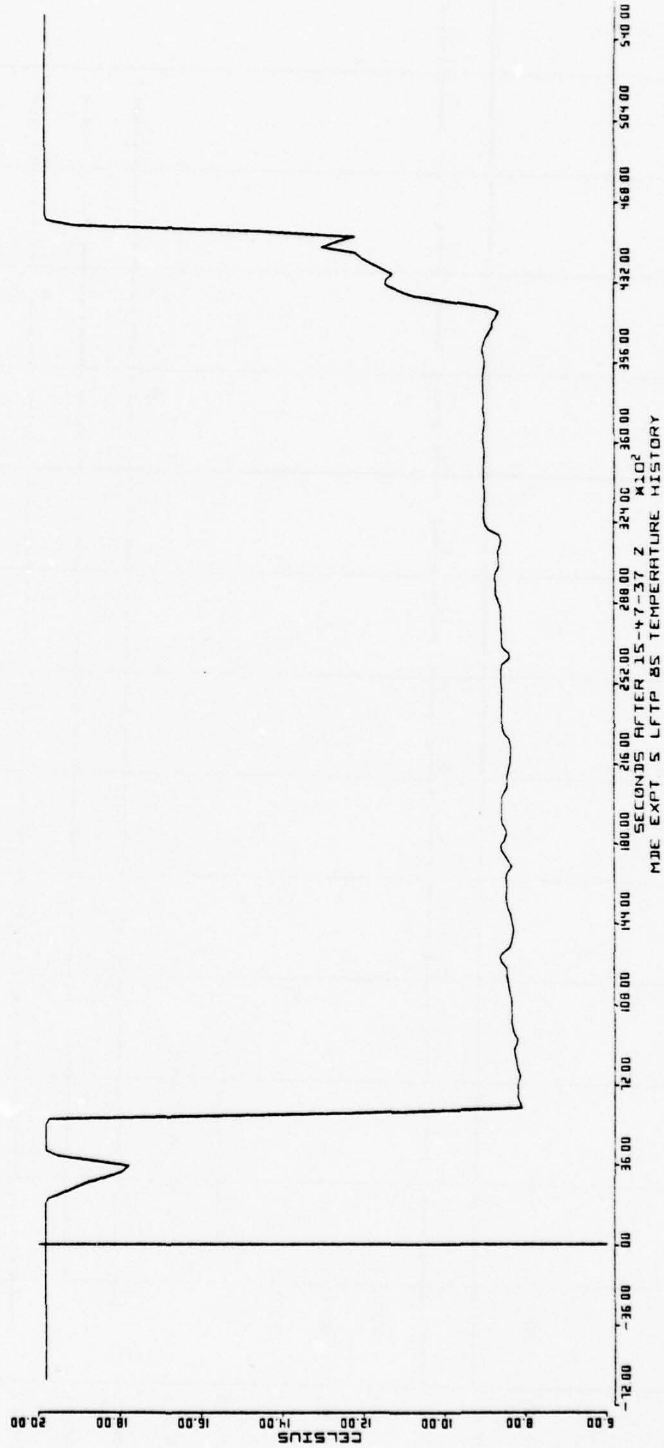

CELSIUS
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
-12.00
-36.00
00
36.00
12.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
504.00
540.00
SECONDS AFTER 15-47-37 Z ×10²
MIDE EXPT 5 LFTP 85 TEMPERATURE HISTORY

Figure 10.

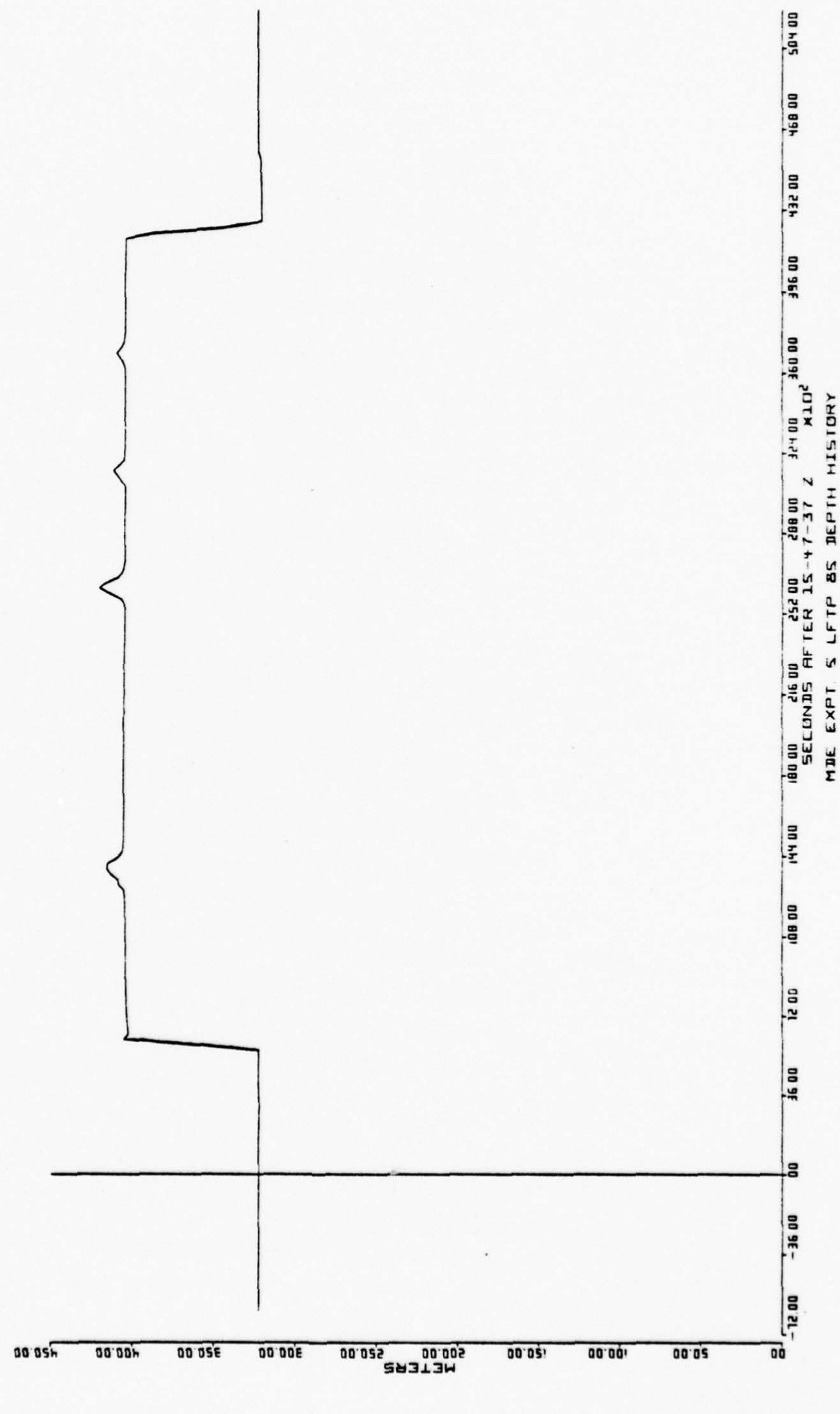

METERS
SECONDS AFTER 15-47-37 Z X10²
MDE EXPT 5 LFTP 85 DEPTH HISTORY

Figure 11.

APPENDICES

1. Vessel Loading.

   a. Load aboard the ship all instruments and other mooring components for Mooring No. 6.

   b. Remove the mooring line of Mooring No. 5 from the winch and wind on the line for Mooring No. 6, bottom end next to the drum.

2. Depart Port Allen and proceed to Point CHARLIE 6 (coordinates 85000N, 355300E) (Lat. 22-04.0N, Long. 159-53.65)

3. Bathymetric Survey.

   a. Conduct bathmetric survey of the area of CHARLIE 6, Point DELTA 6 (coordinates 85350N, 366400E) (Lat 22-04 Long. 159-53.65) and the track to Point ALPHA 6 (coordinates 10800, 365000E) (Lat. 22-07.9N, Long. 159-53.9W).

      (1) Approach Point CHARLIE 6 slowly on a course to make good approximately 356°T.

      (2) Notify the PDR station when passing over CHARLIE 6. Observe and record the depth.

      (3) Continue to the intended anchor location, Point DELTA 6. Observe and record the depth at that point. Depth to the bottom should be approximately 750 meters (410 fathoms, or 2460 feet).

      (4) Continue on the same course to Point ALPHA 6, observing and recording the depth along the track.

      (5) Heave to in the vicinity of Point ALPHA 6 for an acoustic release test.

4. Acoustic Release Test.

   a. Make acoustic release wire test as before, lowering the release to 600 meters. Caution: Do not transmit a firing command.

   b. Haul back the releases and haul in the transducer.

5. Mooring No. 6, CEL Mooring Deployment.

   a. Heave to a Point ALPHA at approximately 0400W and begin deployment of Mooring No. 6.

(1) Put over the subsurface float with its tether line and surface marker float attached, while hove to.

(2) Get under way on a course to make good approximately 176.5°T and establish a speed of 2 knots, or as determined by the PI.

(3) Pay out the mooring as for Moorings 1 and 5, launching the anchor at Point CHARLIE 6.

(4) After allowing the mooring to settle, the tether line will be picked up, attached to a tensiometer on deck, and pulled to a specified tension by the ship. This phase of the experiment will be performed at times specified by CEL personnel in the scientific party. Tension will be placed on the tether line at times when instruments on the mooring strings are in the recording mode, and will be repeated four to six times. The experiment is expected to take most of the daylight hours.

6. Mooring No. 6 Recovery.

a. At the conclusion of the experiment and when directed by the PI, the vessel will proceed to a position approximately 2000 yards upwind and/or upcurrent from Point DELTA 6. Heave to.

(1) Deploy the acoustic transducer. Interrogate the releases. Send firing command when ordered by the PI. Ascertain that the release has fired before hauling in the transducers.

(2) When the backup recovery spheres have been sighted on the surface, approach and begin recovery operations, bringing the mooring aboard top end first.

(3) On completion of recovery operations, prepare for recovery of Mooring No. 1.

7. Mooring No. 1 Recovery.

a. Proceed to a position 2000 yards upwind and/or upcurrent from Point DELTA 1. Heave to and deploy the acoustic transducer.

(1) Send firing command when ordered by the PI. Haul in the transducer after ascertaining that the release has fired.

(2) Recover the mooring using the same procedures as in Mooring No. 6 above. Wind the mooring line on the winch drum on top of the line of Mooring No. 6.

8. Return to Port Allen.

APPENDIX B

WHOI MOORED STATION LOG FOR CEL MOORING

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Mooring No. 6

MOORED-STATION LOG

Exp 5

Set		Recovered	
Date	1 November, 1976	Date	2 Nov. 1976
Time	1717 (0717 local) Zone GMT	Time	0532 (0732 local) Zone GMT
Lat.	22°-04-01" Long. 159°-53-35"	Lat.	22-04-01 Long. 159°-53-33"
Observer/Recorder	R.G. Walen	Observer/Recorder	R.G. Walen
Watch Checked:	Before ✓ After ✓	Watch Checked:	Before ✓ After ✓
Set By	R. G. Walden	Retrieved By	R. G. Walden
Ship & Cruise No.	DeSteiguer, 5	Ship & Cruise No.	DeSteiguer, 5

Depth: Rec. Reading 771, correct. ~~fm.~~ (m); Depth Corr. 11 total Corr. m. ______

Float Depth 60 + Meters (Varies with currents) Mag. Var. ______

Purpose of Mooring/Array CEL Sub-Surface Mooring

______ Other Designations ______

Location Kauai, Hawaii (Barking Sands Missile Test Range) Intended Duration 2 Actual Days at Sea 2

Main Float 44" Sphere Color(s) Orange Markings ______

No. of Glass-Sphere Clusters 0 Total No. of Spheres 2 on 30" Aluminum Hat Color(s) ______

Wire 3/16" WR

Rope 3/4" Nylon

Radio Mfg. & No. None Tension Telemetry: Light Mfg. & No. OAR

Freq. ______ Type ______ (Strobe)/Incand. White light

Char. ______ Code ______ Period ______ flashing every 2 seconds

AMF Release # 602045 / 503764 Time of Firing 0327 (1727 local), 2 November 1976

Receiver # 2 / 6 Remarks Int. 11.0 KHz, Disable Command 1 / " 11.0 KHz, 45° tilt sw, " 1

Rel. Command 3 / 3

Anchors: Stimson ______ lbs. Other(s): Sandbags 2600 wet lbs. ______ lbs.

Miscellaneous ______

Figure B-1.

Start Time 1500 (letting Poly-prop) 1509 Station Number Mooring 6

Item No.	Length in m.	1050# Item	Ident. No.	Over: Time Over	Over: Notes	Back: Time Back	Back: Notes	True Depth in m.	Data No.
1		44" (1000#) Sphere		1515	+1500# polyfloat	0419			
2	10	3/8" Chain							
3		T/P #4 (0-123M) 92%	90	1519		0425			
4	2	3/8" Chain							
5		FVR #1 (0-3000#)	1	1522		0428			
6	2	3/8 Chain							
7		DeepSonde Pinger (Echo)		1527	on 1524	0432			
8	242	3/16" WR.		1536		0448			
9		FVR #2 (0-3000#)	2	1540		0449			
10	2	3/8" Chain							
11		SC Pinger (Charlie)		1543	on 1542	0452			
12	96	3/16" WR		1546		0458			
13		T/P #5 (325-525 m) 30%	85	1548		0459			
14	137	3/16" WR		1552		0506			
15		FVR #3 (0-3000#)	3	1558		0507			
16	2	3/8" Chain							
17		SC Pinger (Delta)		1601+	on 1600	0509			
18	177	3/16" WR		1607		0517			
19		FVR #4 (0-3000#)	4	1612		0518			
20	2	3/8" Chain							

Date	Notes on Mooring, Sightings, Weather Difficulties, etc.
1 Nov. 76	Charlie @ 22°-04'-01.4", 159°-53'-?3.4"
2 Nov	0405, grapnel hooked on poly-line; Float out of water 0418

Figure B-1a.

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Morning
Station No. 6

BIOLOGY/METEOROLOGY/ENGINEERING NOTES

Wind Lt. Air force/knots Direction Indeterminate	Wind 12 force/knots Direction 355°
Sea State Calm code Swell 2', 070°	Sea State 1-2', 355° code Swell Confused, 3-4 ft
Observer Watch Officer	Observer Watch Officer

Item No.	Description and Location	Code(s)

These code letters are to be used in addition to (not instead of) the "Description and Location" column:

Biofouling

- FB Fishbite
- GB Goose Barnacles
- WW Wire Worms
- S Slime
- HH Hydroids, algae and other "hairy growth"
- SS Sea Snot
- BO Biology, other

Corrosion

- U Uniform
- C Crevice
- P Pitting
- G Galvanic
- CO Corrosion, other

Mechanical

- H Handling
- W Wave
- F Fatigue
- BI Biological Impact
- MO Mechanical, other

Figure B-1b.

Station Number Mooring 6

Item No.	Length in m.	Item	Ident. No.	Over: Time Over	Over: Notes	Back: Time Back	Back: Notes	True Depth in m.	Data No.
21		DC Pinger (Alpha)		1618	on 1614	0521			
22	2	3/8" Chain							
23		38" Al Sphere		1624		0524			
24	2	3/8" Chain							
25		38" Al. Sphere		1629		0527			
26	2	3/8" Chain							
27		DC Pinger (Bravo)		1634	on 1631	0529			
28	2	3/8" Chain							
29	1	Release	503764	1641	Pin out @ 1637	0532			
30	1	Release	602045	1641	Pin Out @ 1637	0532			
31	3	1/2" Chain							
32	10	3/4" Nylon		1643					
33	2	1/2" Chain		1714					
34		2600# Sandbags		1717					

Date	Notes on Mooring, Sightings, Weather Difficulties, etc.
1 Nov 76	Sandbags over stern @ 1714; Hit bottom 1723; tether float
	still on surface
2 Nov 76	

Figure B-1c.

APPENDIX C

PLOTTED CURRENT METER DATA FOR MDE EXPERIMENT FIVE

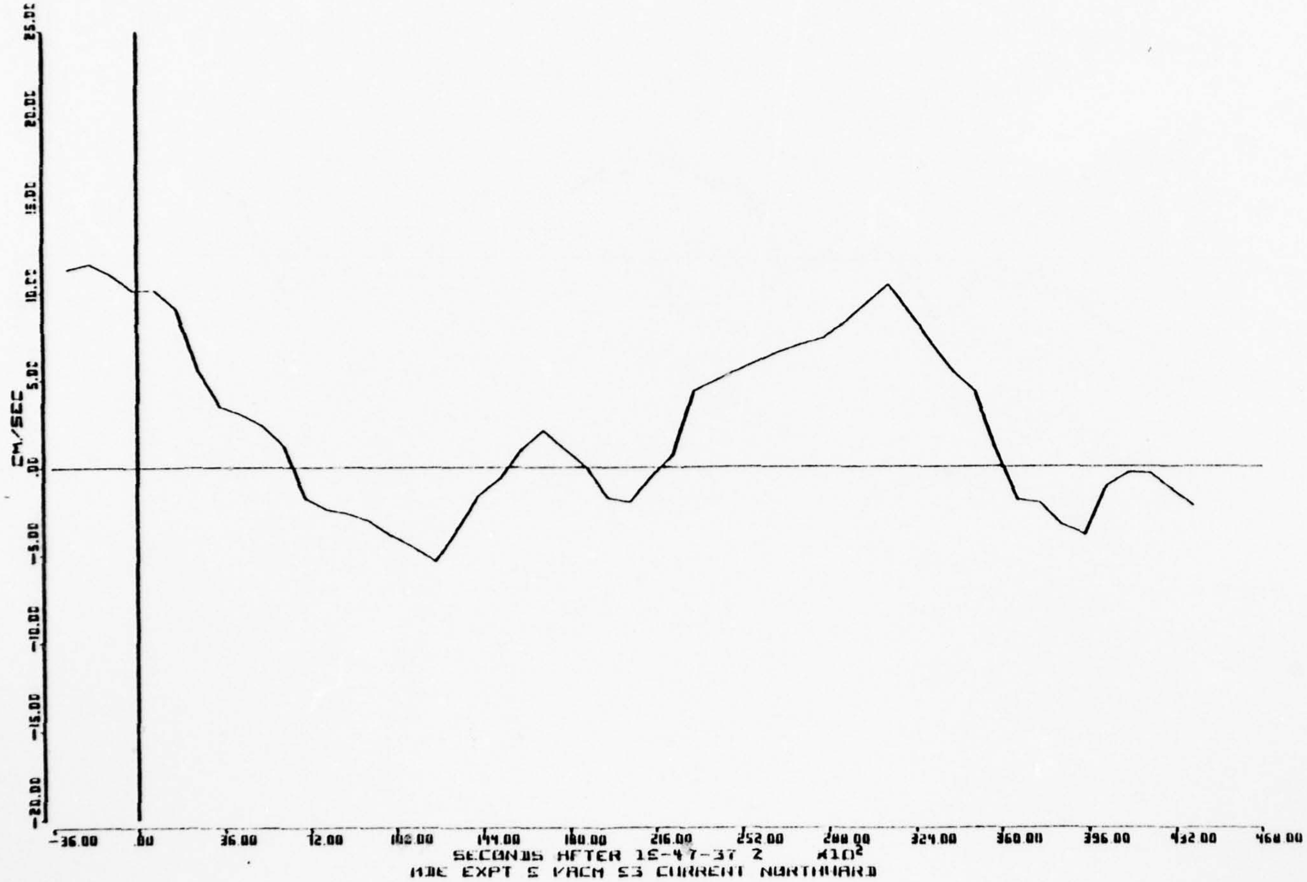

CM/SEC
SECONDS AFTER 15-47-37 2 X10²
MIDE EXPT 5 VACM 53 CURRENT NORTHWARD

Figure C-1.

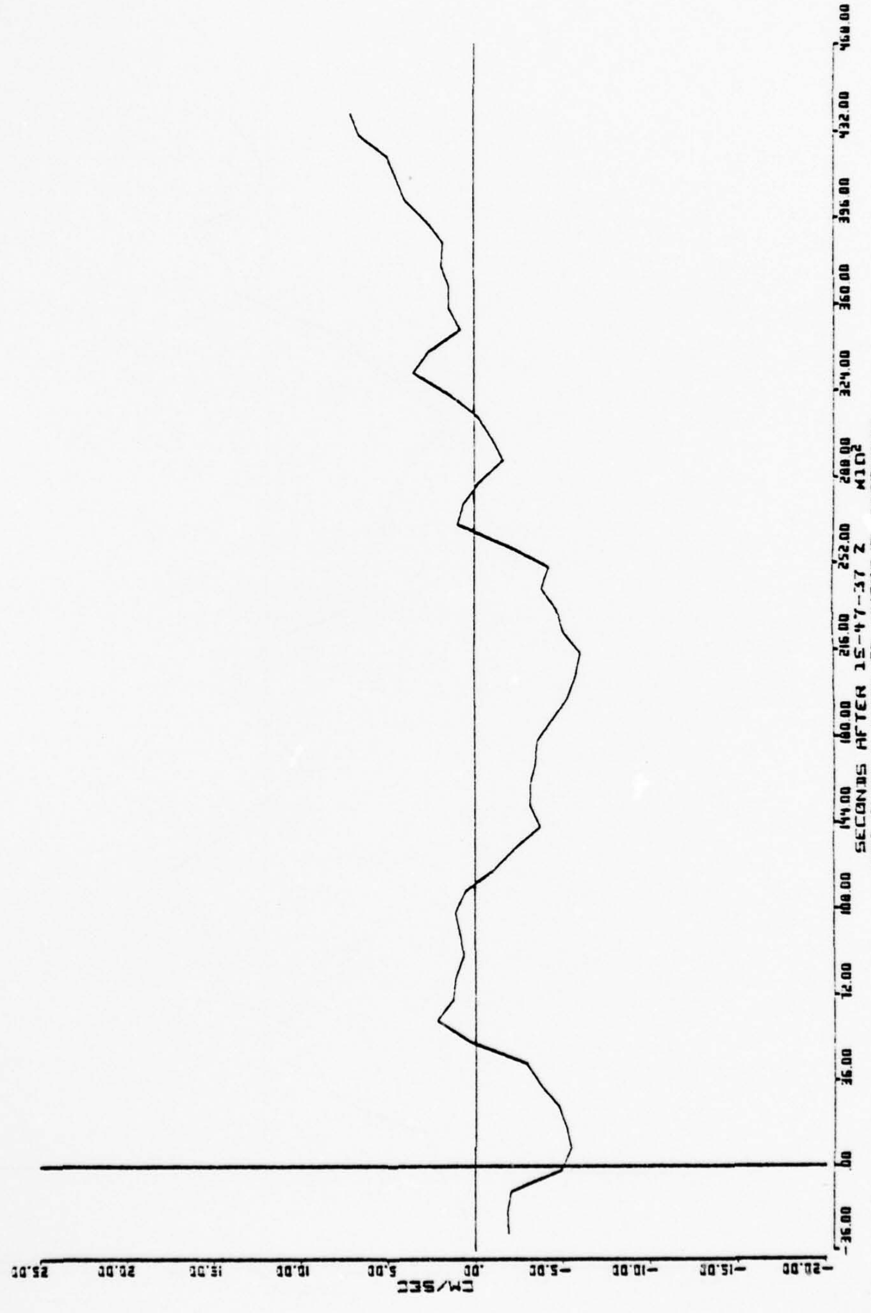
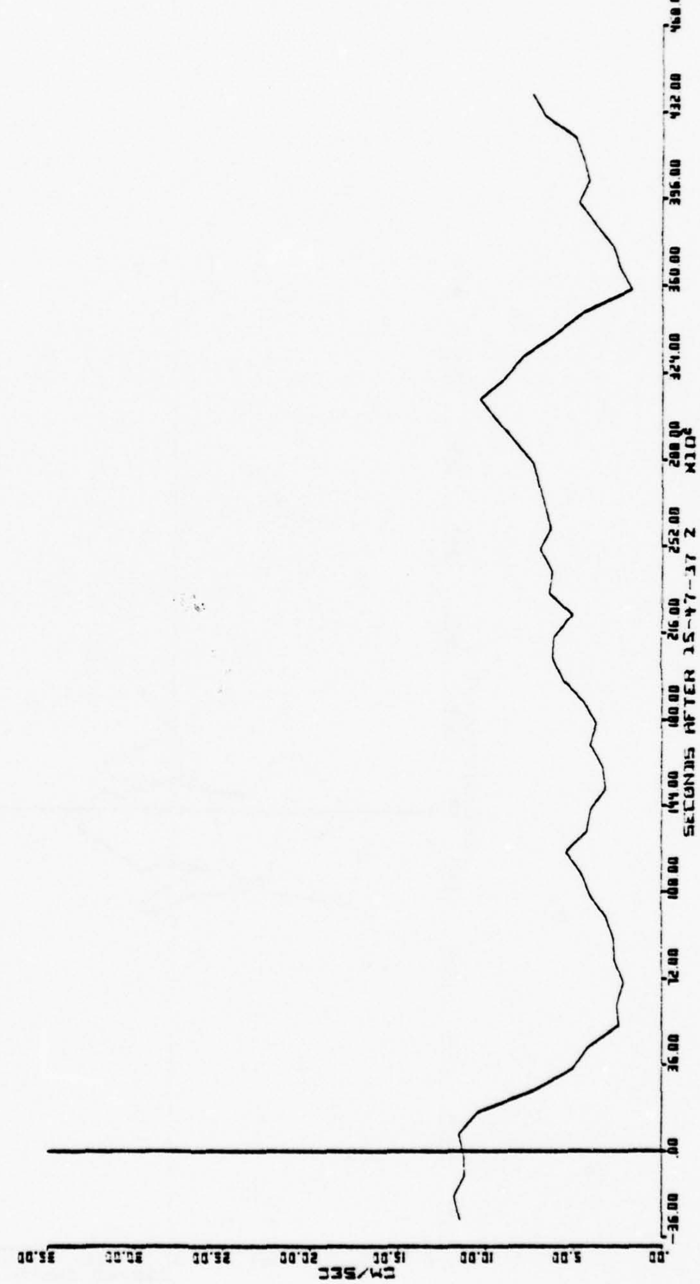

CM/SEC
SECONDS AFTER 15-47-37 Z
MIDE EXPT 5 VACM S3 CURRENT EASTWARD
X10²

Figure C-2.



CM/SEC
SECONDS AFTER 15-47-37 Z
MIDE EXPT 5 VACM 53 CURRENT SPEED

Figure C-3.

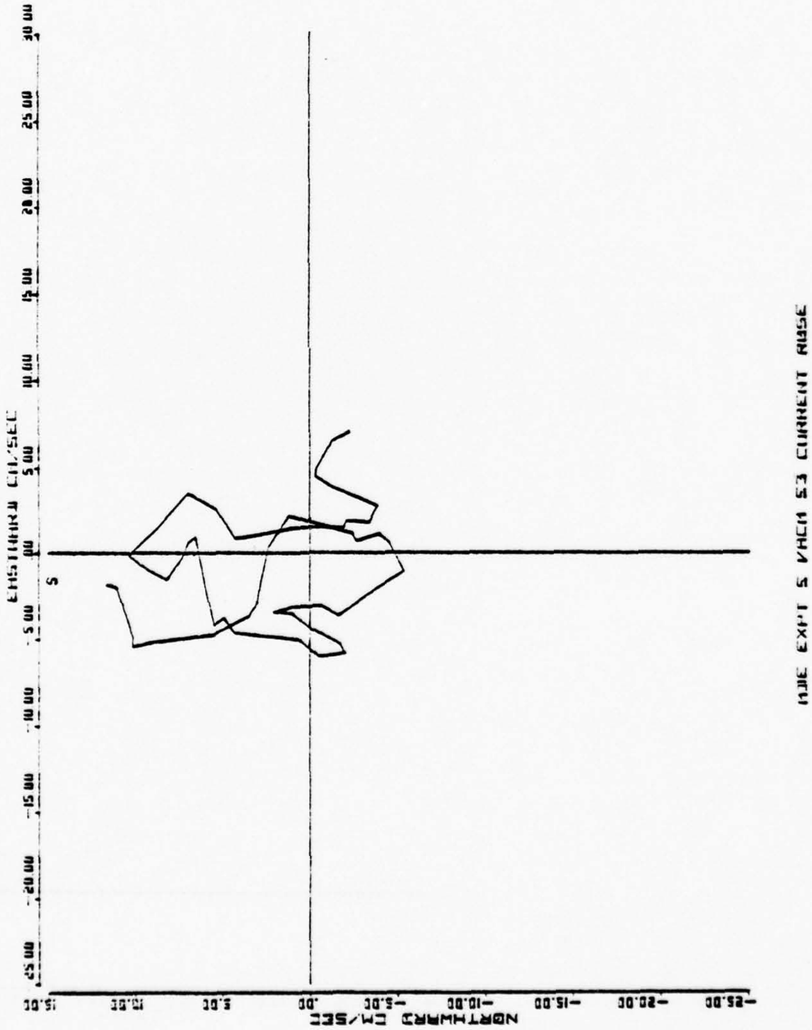
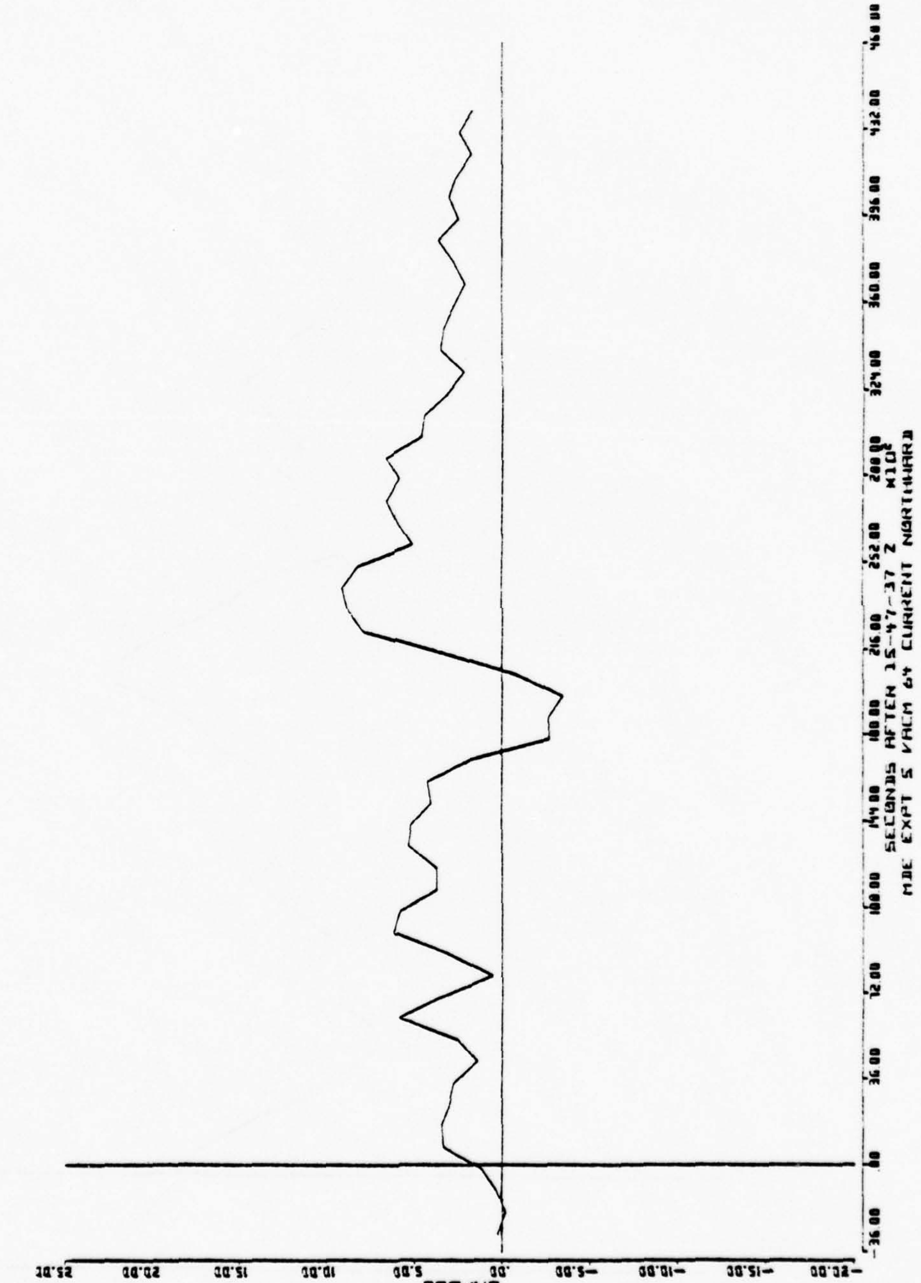
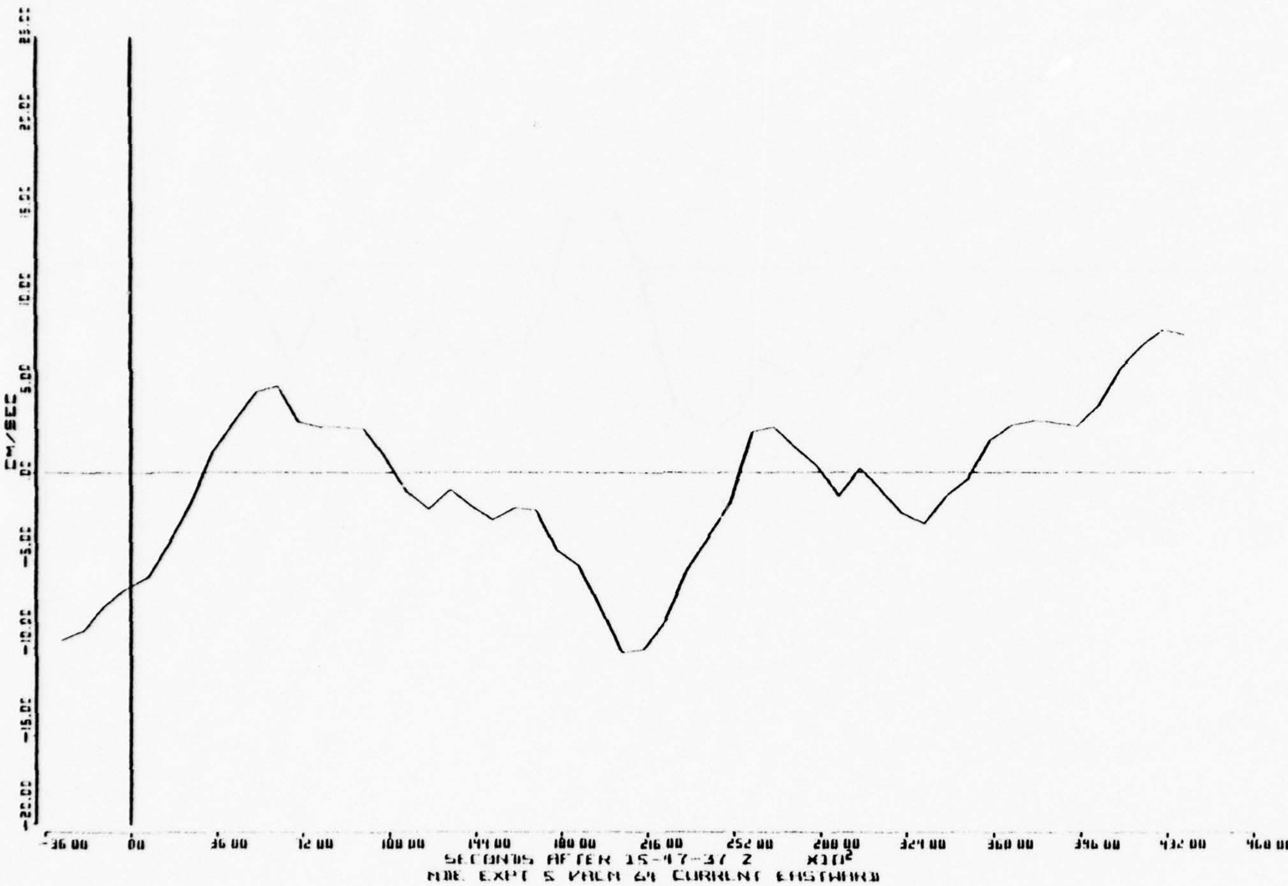


Figure C-4.



CM/SEC
SECONDS AFTER 15-47-37 Z
MDE EXPT 5 VACM 64 CURRENT NORTHWARD

Figure C-5.



CM/SEC
-20.00
-15.00
-10.00
-5.00
.00
5.00
10.00
15.00
20.00
25.00
-36.00
.00
36.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
SECONDS AFTER 15-47-37 Z
CURRENT EASTWARD

Figure C-6.

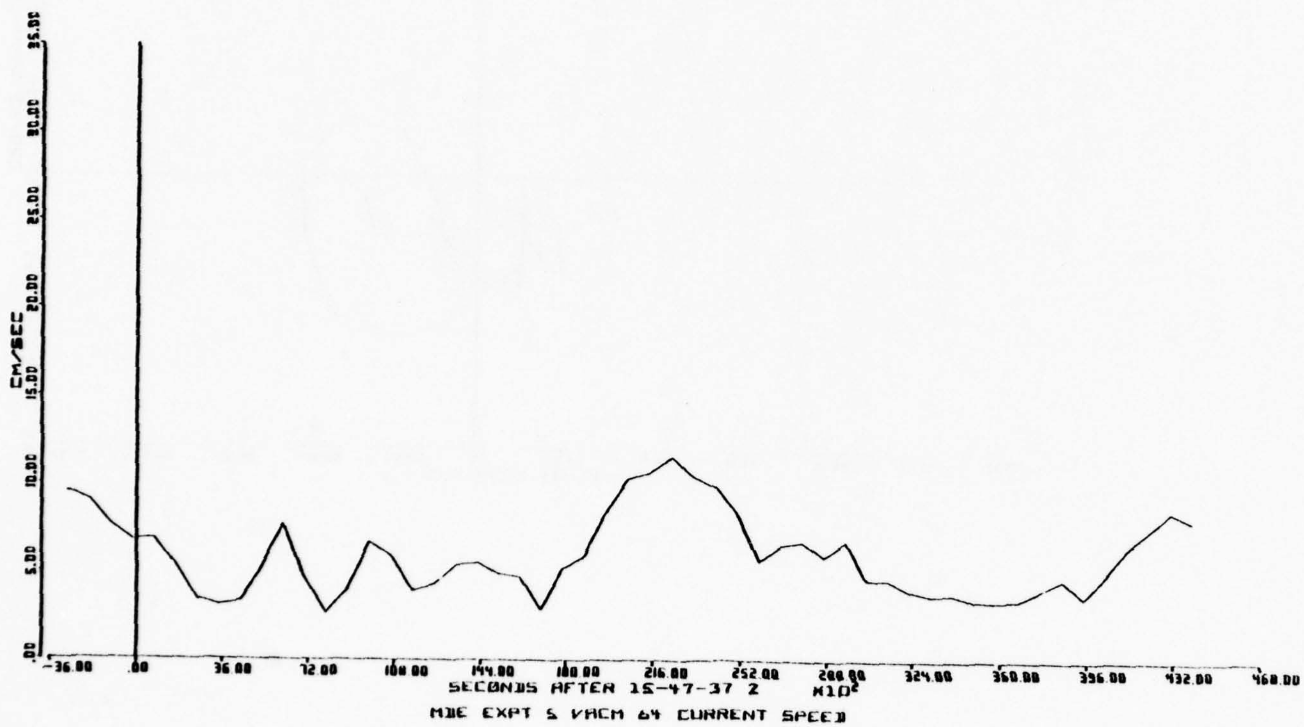
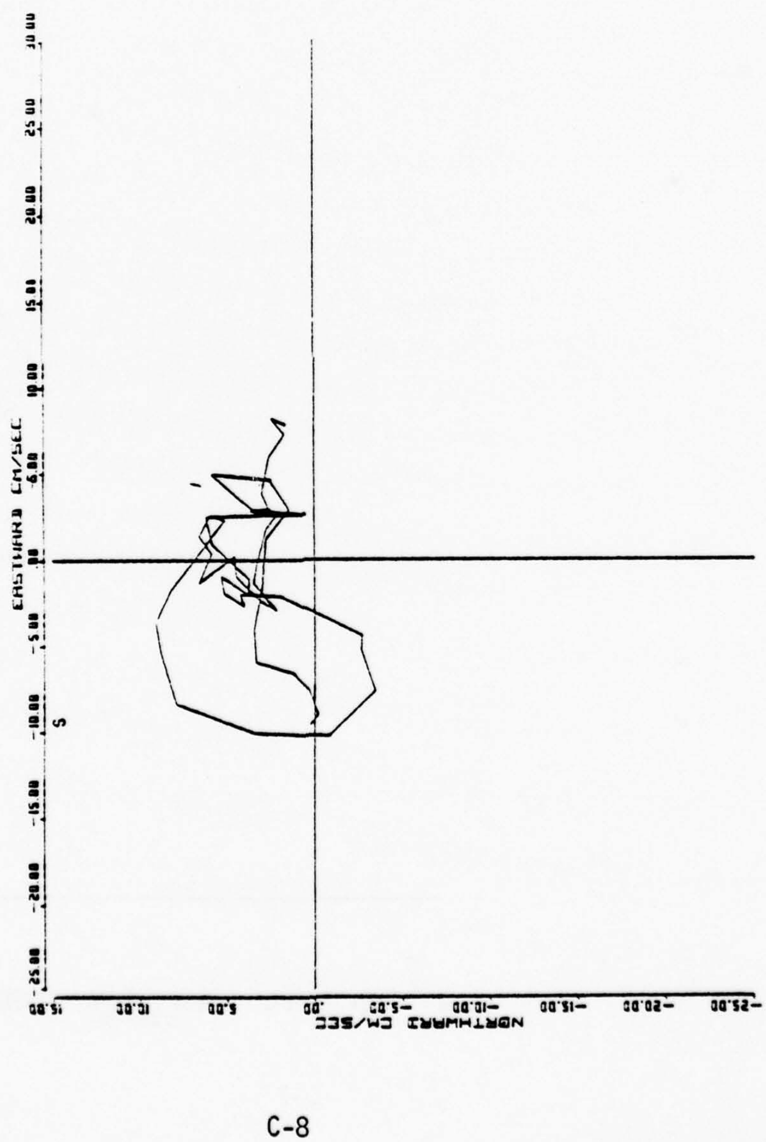

CM/SEC
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
SECONDS AFTER 15-47-37 Z X10²
MDE EXPT 5 VACM 64 CURRENT SPEED

Figure C-7.



MODE EXPT 5 VACM 64 CURRENT ROSE

Figure C-8.

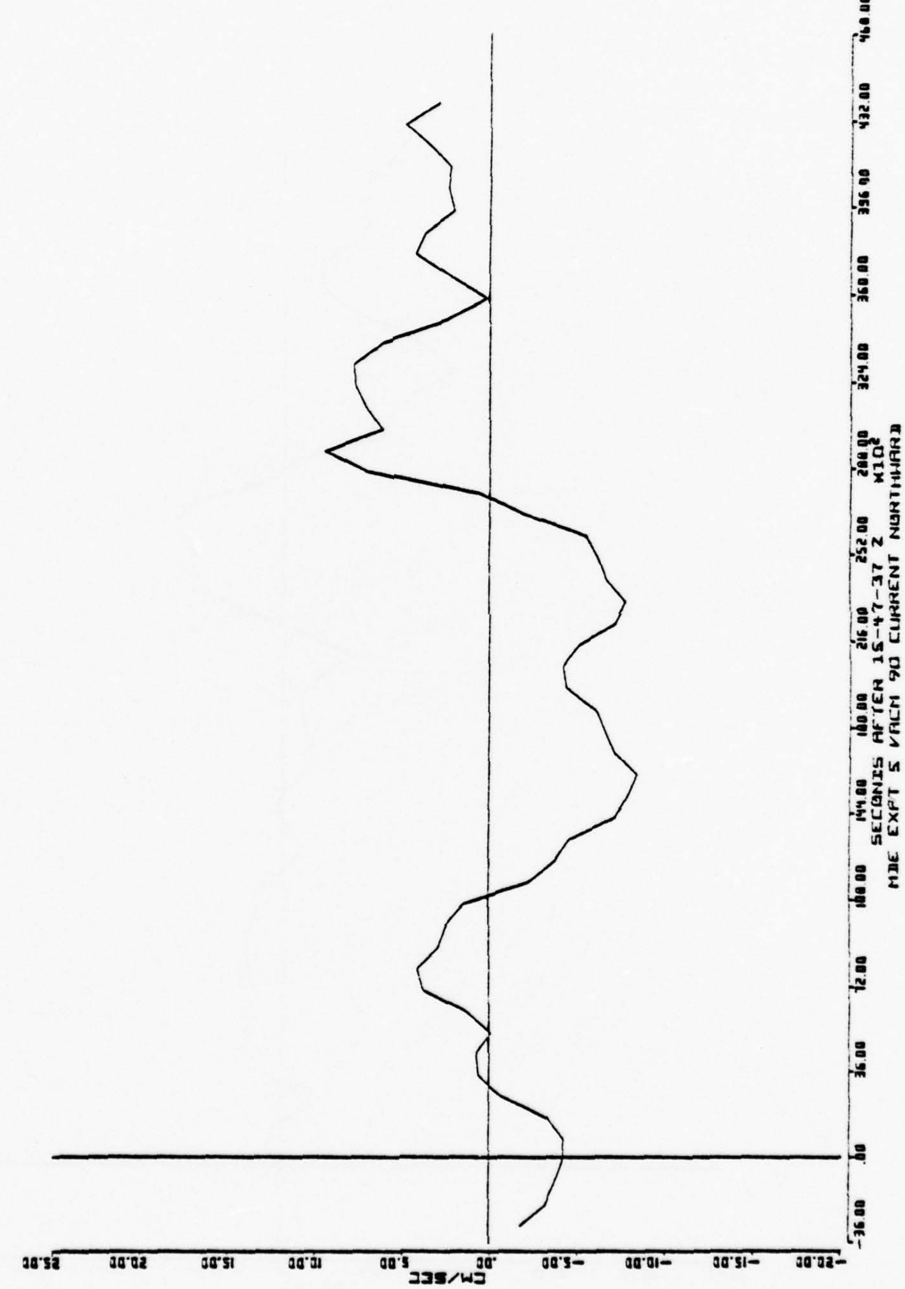

CM/SEC
-20.00
-15.00
-10.00
-5.00
.00
5.00
10.00
15.00
20.00
25.00
-36.00
.00
36.00
72.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
SECONDS AFTER 15-47-37 Z X10²
MIDE EXPT 5 VACM 90 CURRENT NORTHWARD

Figure C-9.

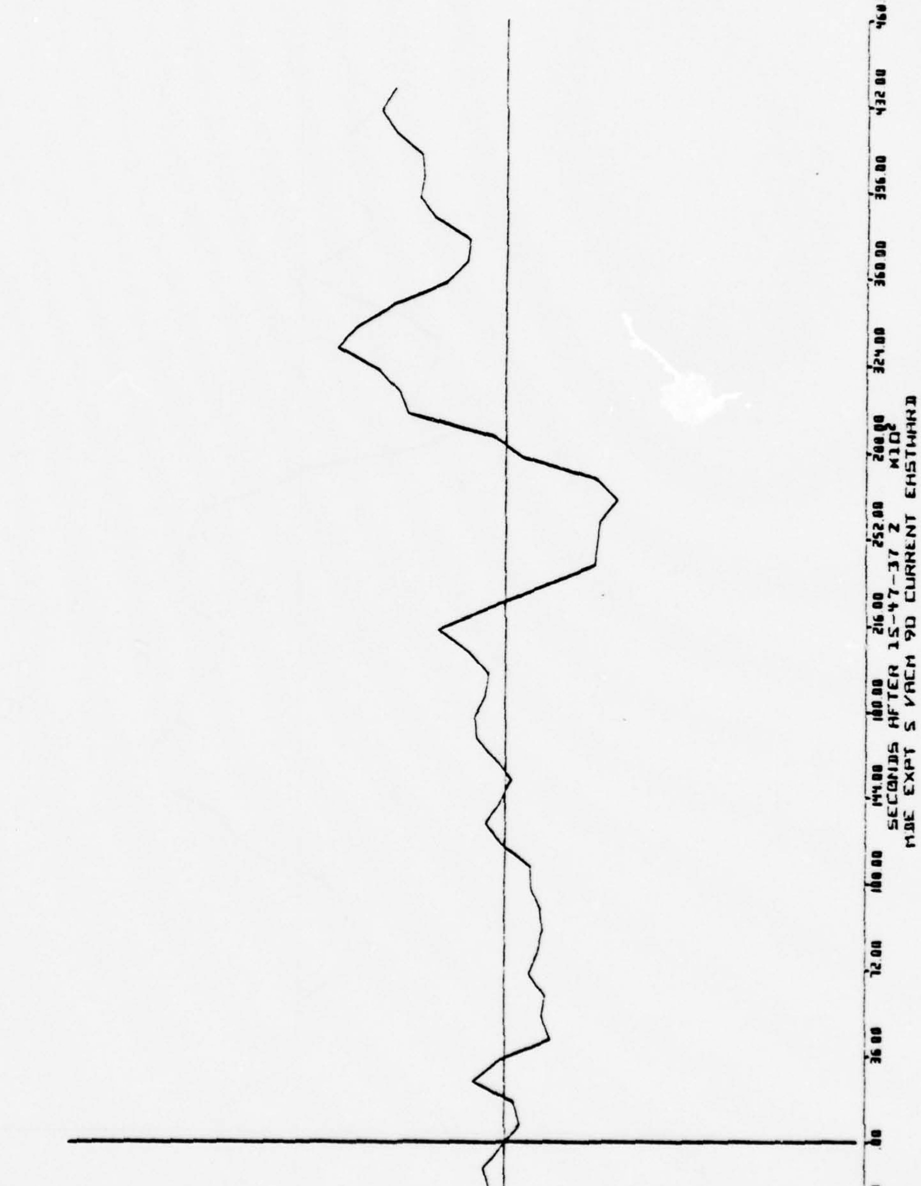

SECONDS AFTER 15-47-37 Z
M.DE EXPT S VACM 90 CURRENT EASTWARD
CM/SEC
X10²

Figure C-10.

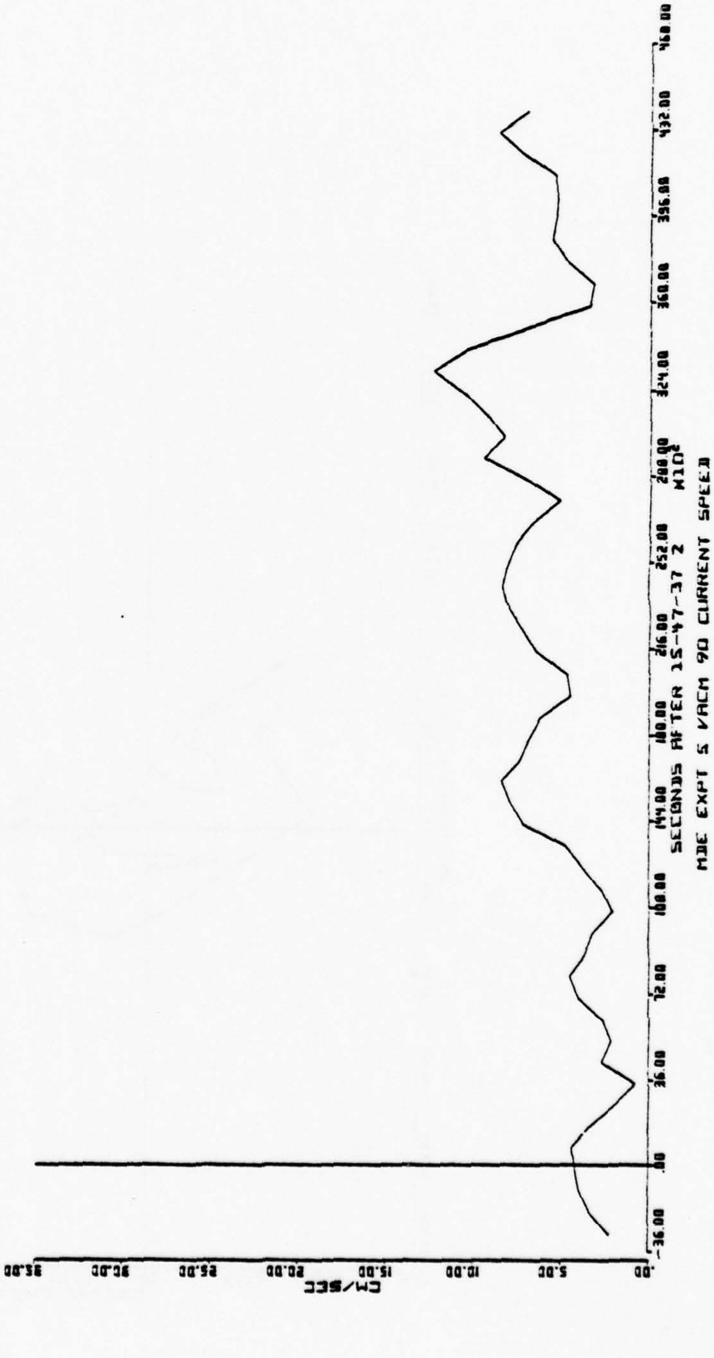

SECONDS AFTER 15-47-37 Z
MDE EXPT 5 VACM 90 CURRENT SPEED
CM/SEC
-36.00
.00
36.00
72.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00

Figure C-11.

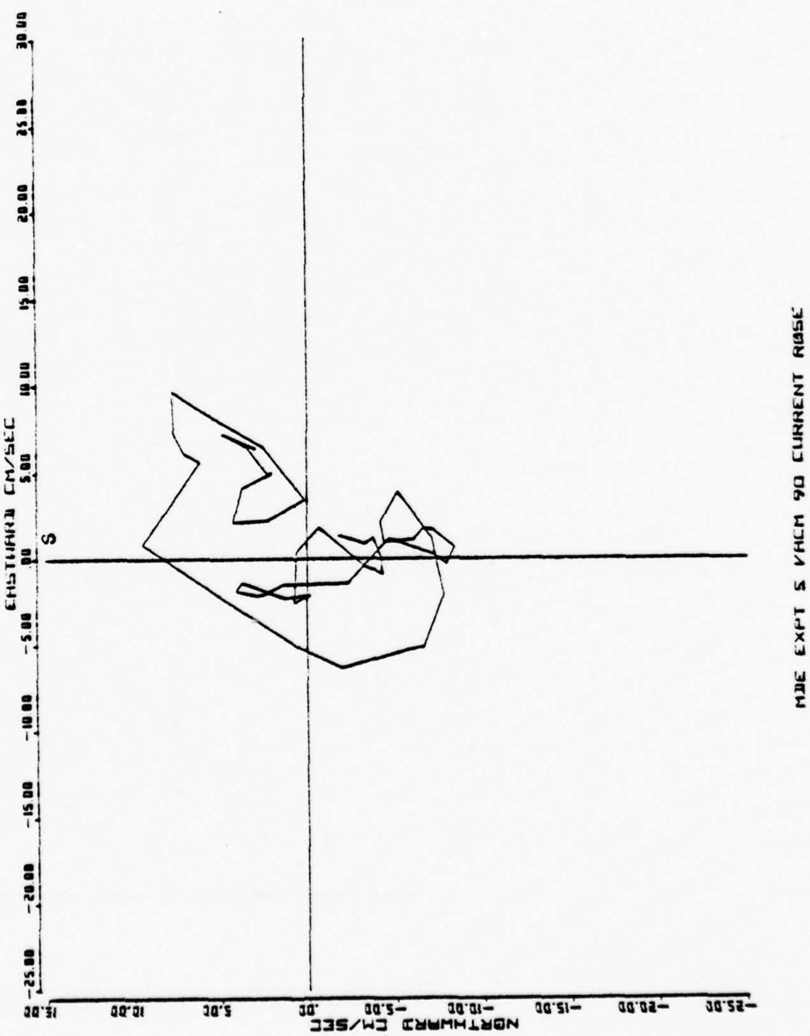

EASTWARD CM/SEC
NORTHWARD CM/SEC
MJE EXPT 5 VACM 90 CURRENT ROSE
S

Figure C-12.

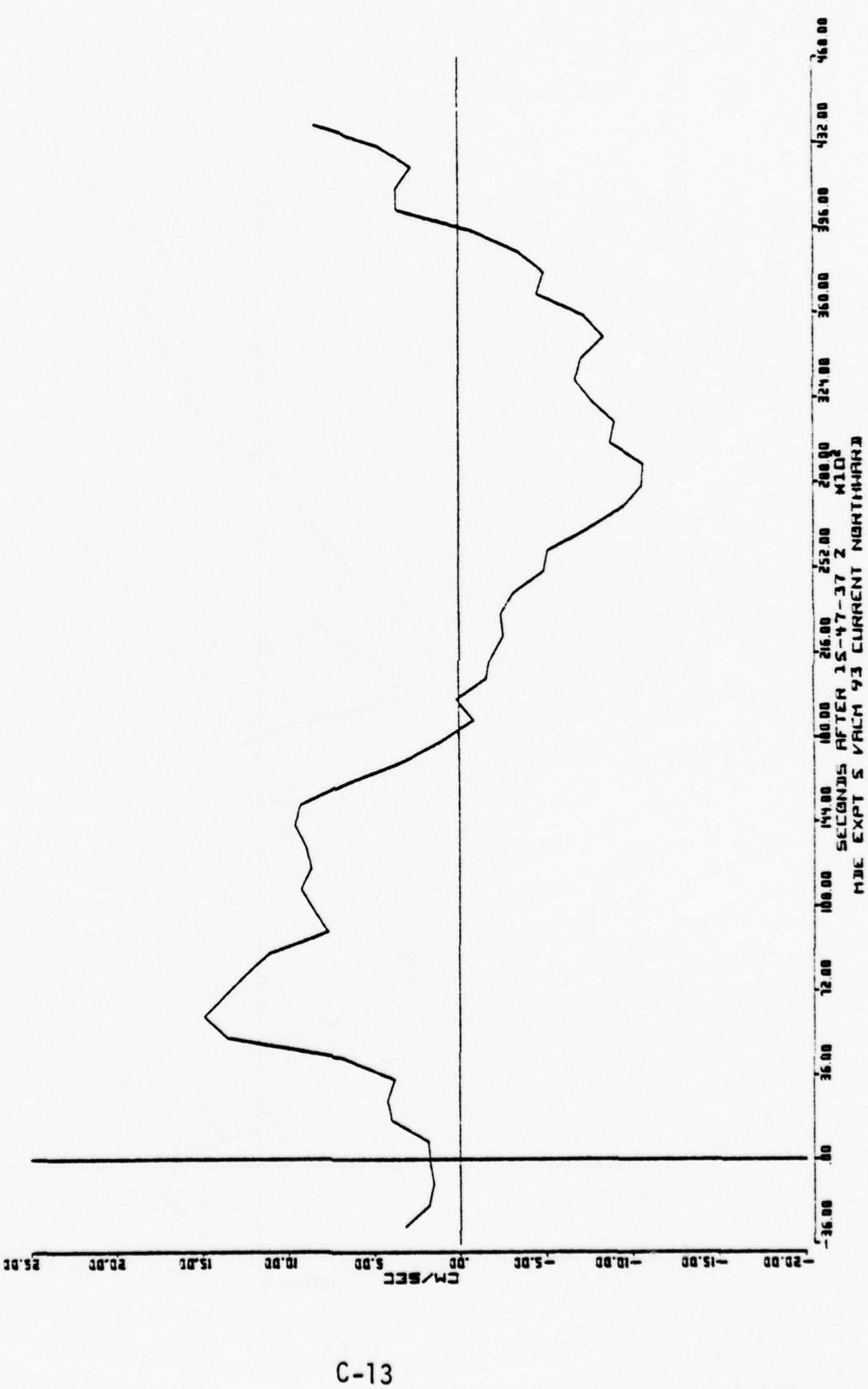

-36.00
.00
36.00
72.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
SECONDS AFTER 15-47-37 Z X10²
MODE EXPT S VACM 93 CURRENT NORTHWARD
-20.00
-15.00
-10.00
-5.00
.00
5.00
10.00
15.00
20.00
25.00
CM/SEC

Figure C-13.

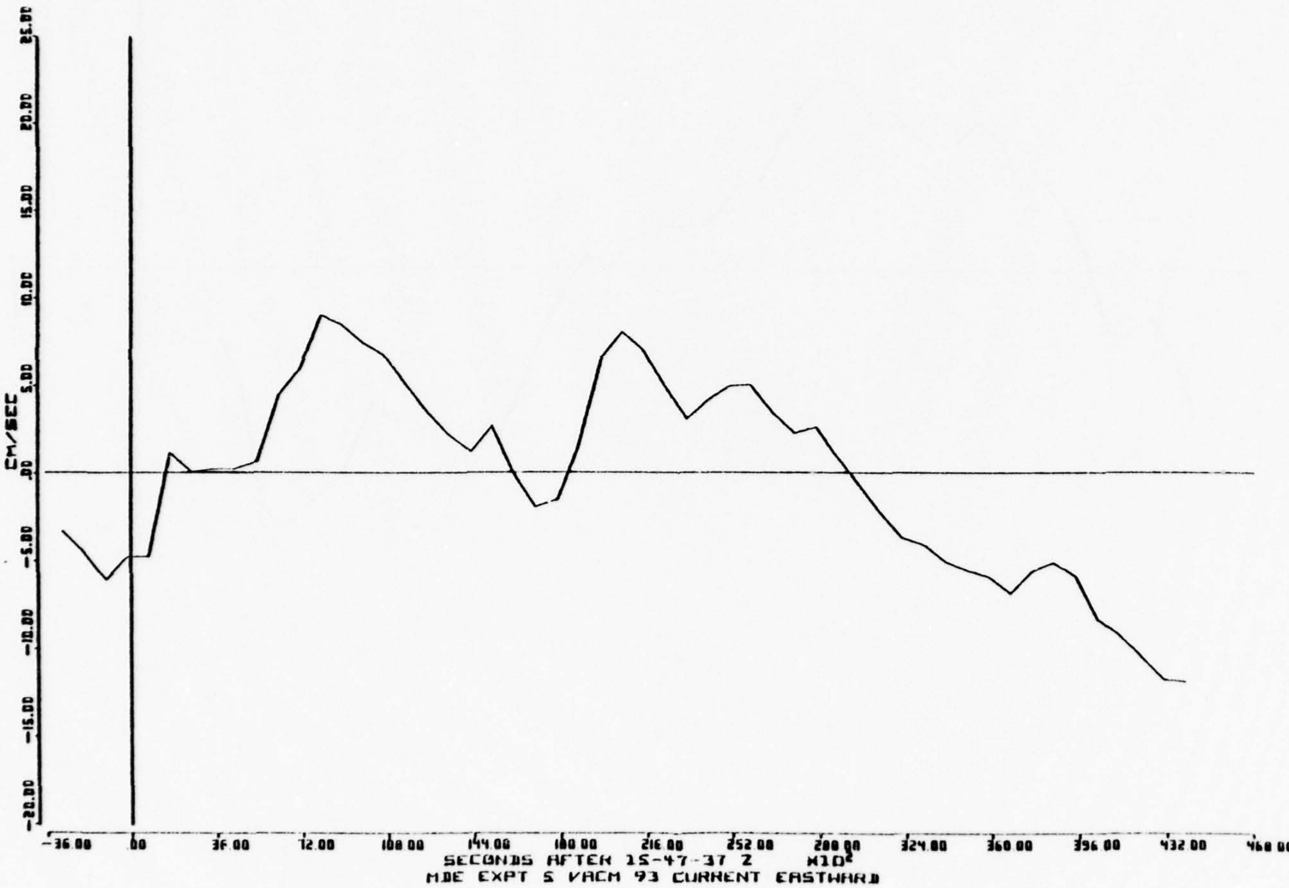
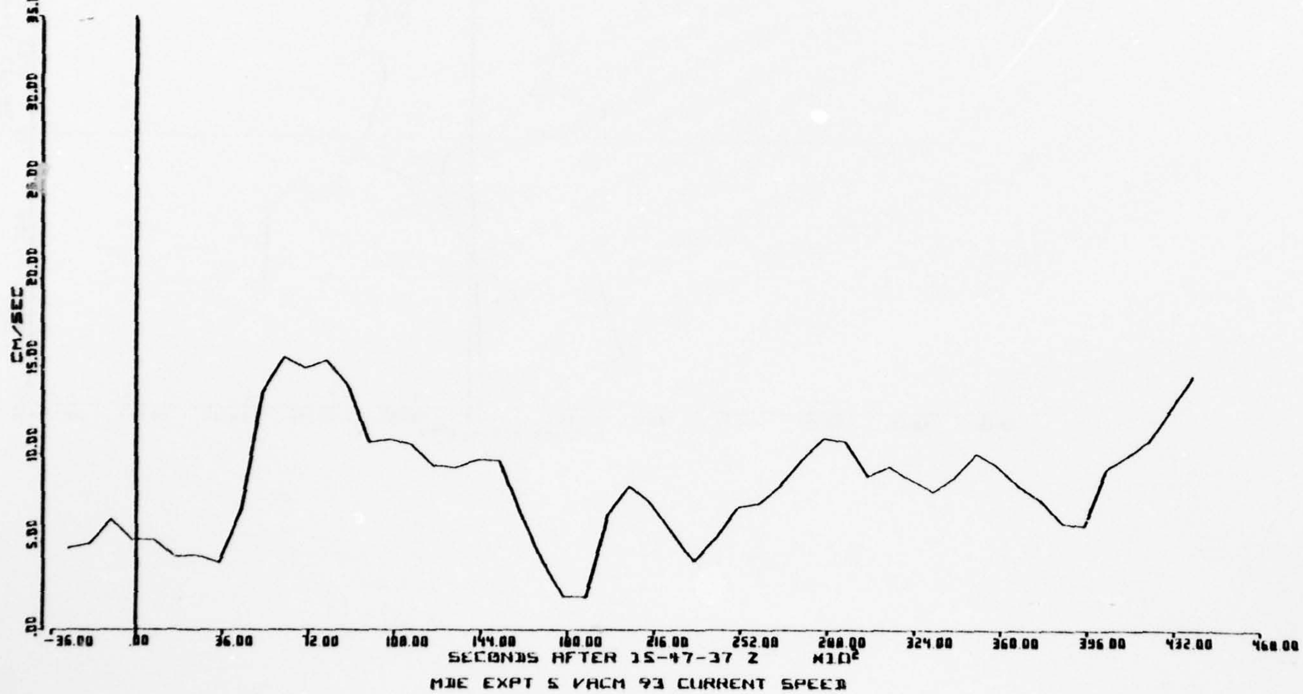

CM/SEC
25.00
20.00
15.00
10.00
5.00
.00
-5.00
-10.00
-15.00
-20.00
-36.00
.00
36.00
72.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
SECONDS AFTER 15-47-37 Z X10²
MDE EXPT 5 VACM 93 CURRENT EASTWARD

Figure C-14.



CM/SEC
.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
-36.00
.00
36.00
72.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
SECONDS AFTER 15-47-37 Z   X10¹
MIDE EXPT 5 VACM 93 CURRENT SPEED

Figure C-15.

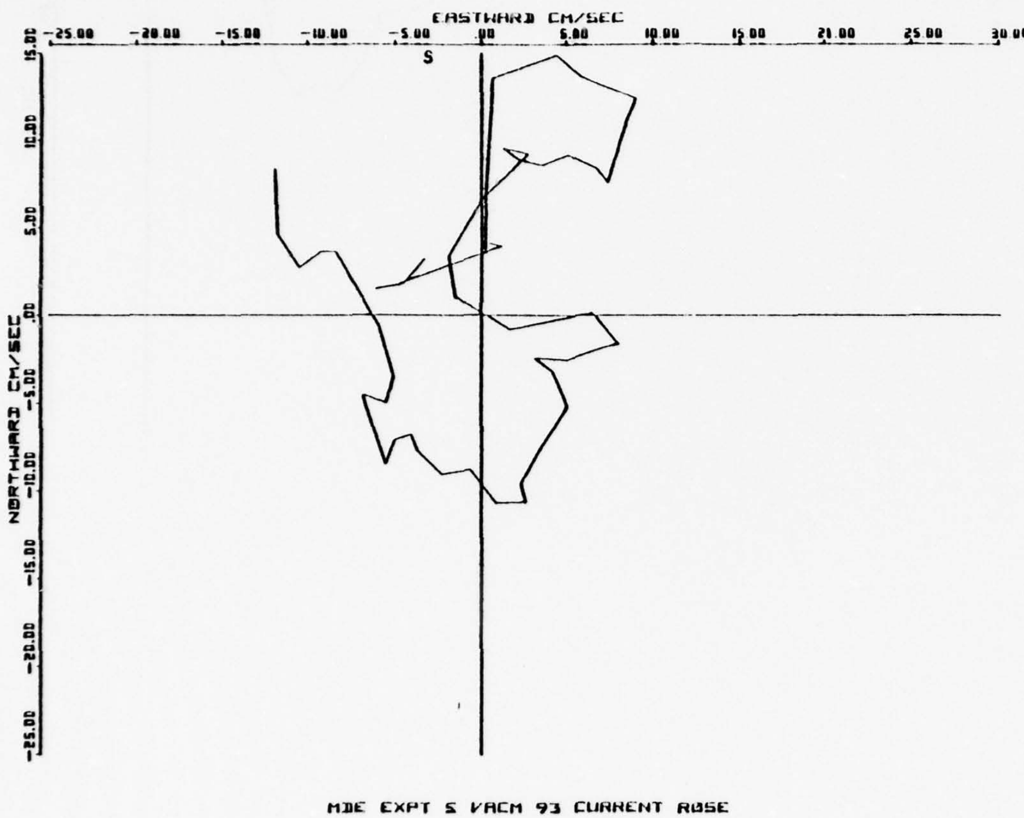

EASTWARD CM/SEC
-25.00
-20.00
-15.00
-10.00
-5.00
.00
5.00
10.00
15.00
21.00
25.00
30.00
NORTHWARD CM/SEC
15.00
10.00
5.00
-5.00
-10.00
-15.00
-20.00
-25.00
S
MDE EXPT S VACM 93 CURRENT ROSE

Figure C-16.

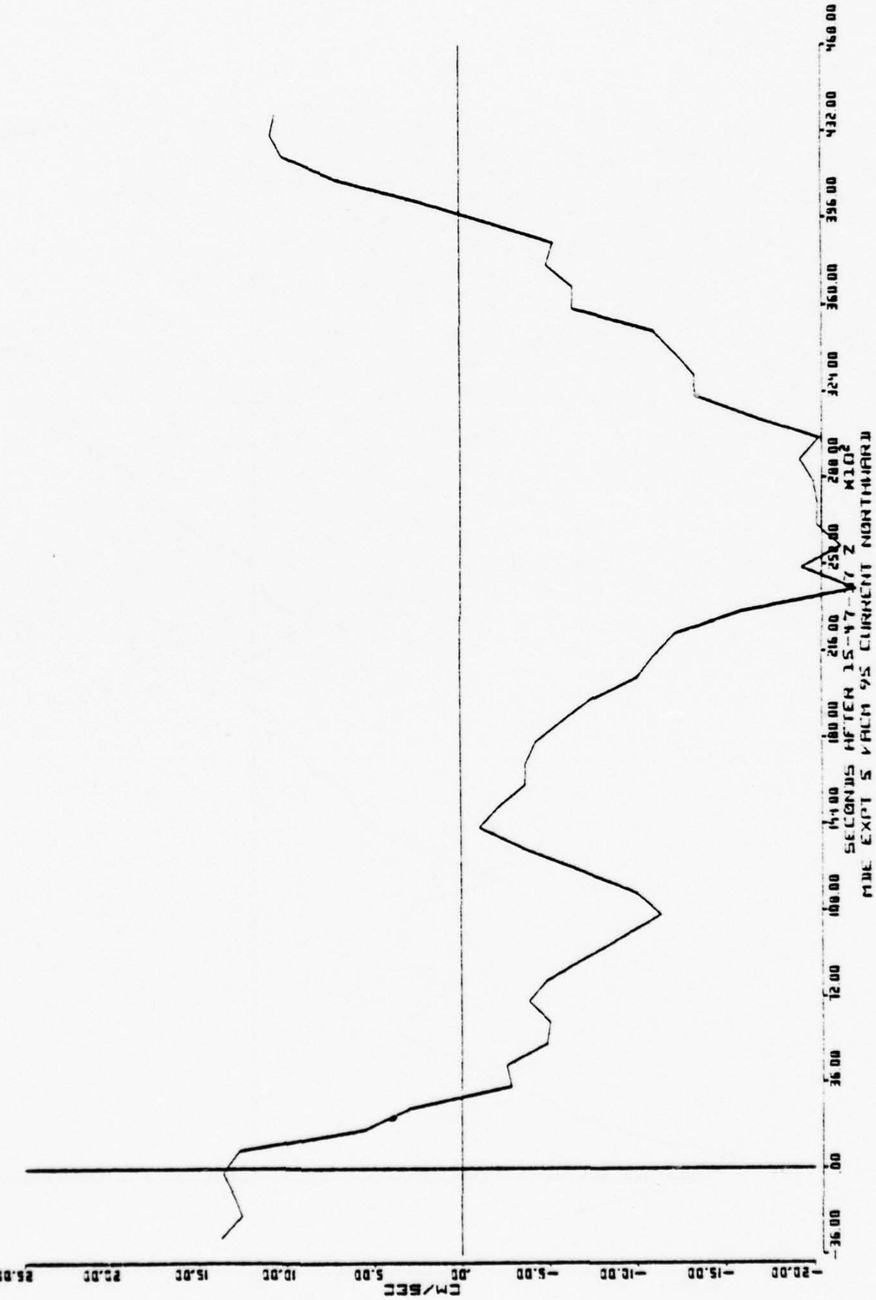


Figure C-17.

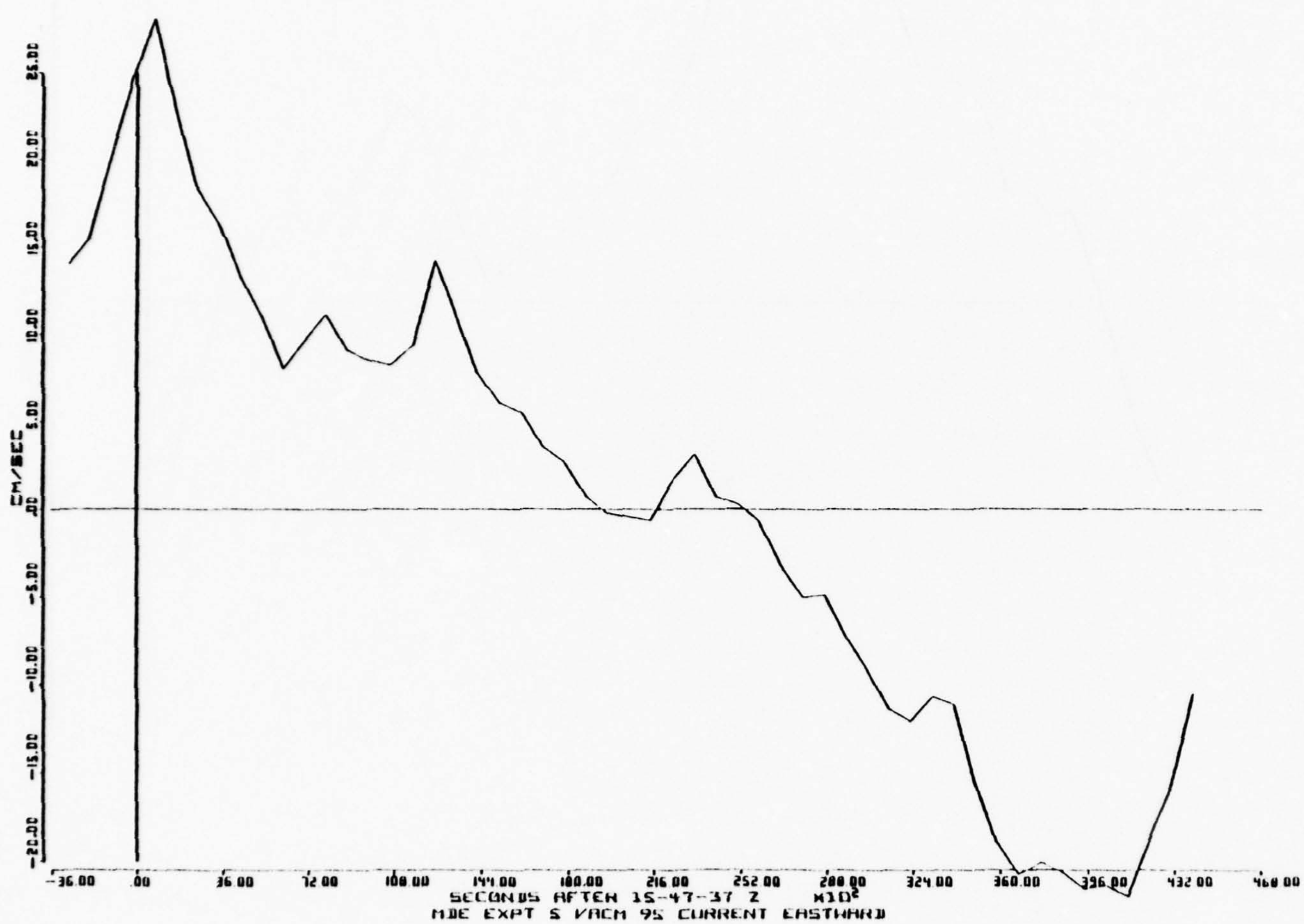

CM/SEC
25.00
20.00
15.00
10.00
5.00
.00
-5.00
-10.00
-15.00
-20.00
-36.00
.00
36.00
72.00
108.00
144.00
180.00
216.00
252.00
288.00
324.00
360.00
396.00
432.00
468.00
SECONDS AFTER 15-47-37 Z X10²
MDE EXPT 5 VACM 95 CURRENT EASTWARD

Figure C-18.

CM/SEC
SECONDS AFTER 15-47-37 Z
MIDE EXPT 5 VACM 95 CURRENT SPEED

Figure C-19.

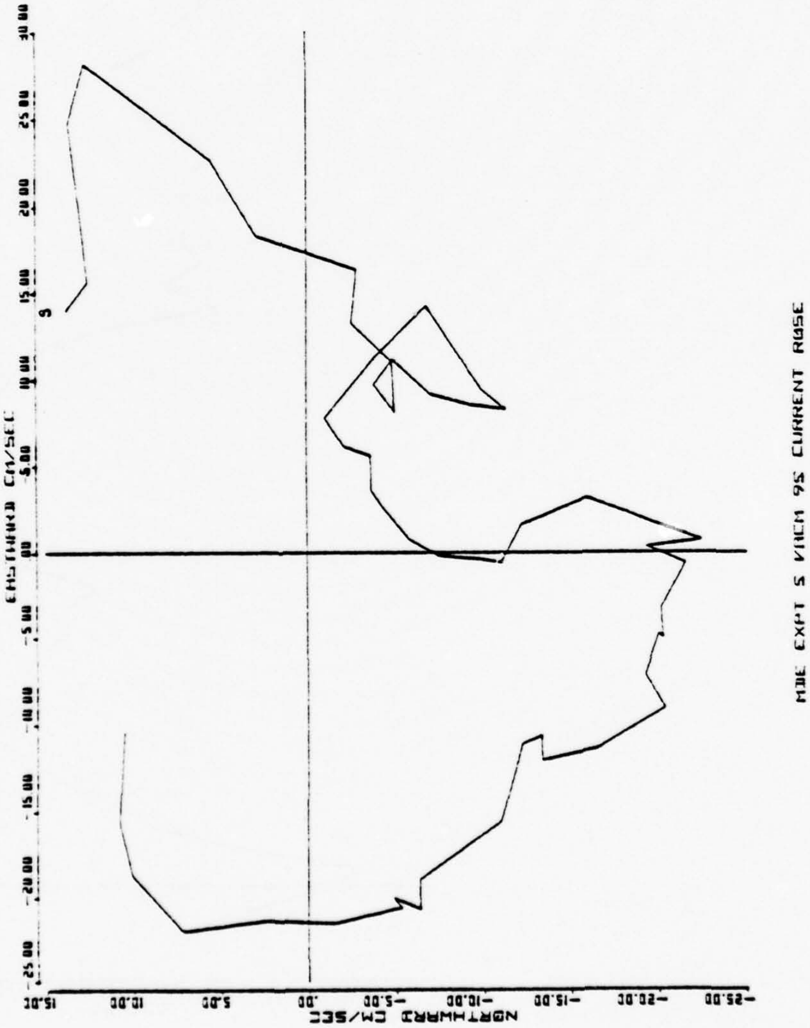

EASTWARD CM/SEC
NORTHWARD CM/SEC
MBE EXPT 5 VACM 95 CURRENT ROSE

Figure C-20.

APPENDIX D

HIGH-FREQUENCY TEMPERATURE/PRESSURE RECORDER DATA FOR MDE EXPERIMENT FIVE

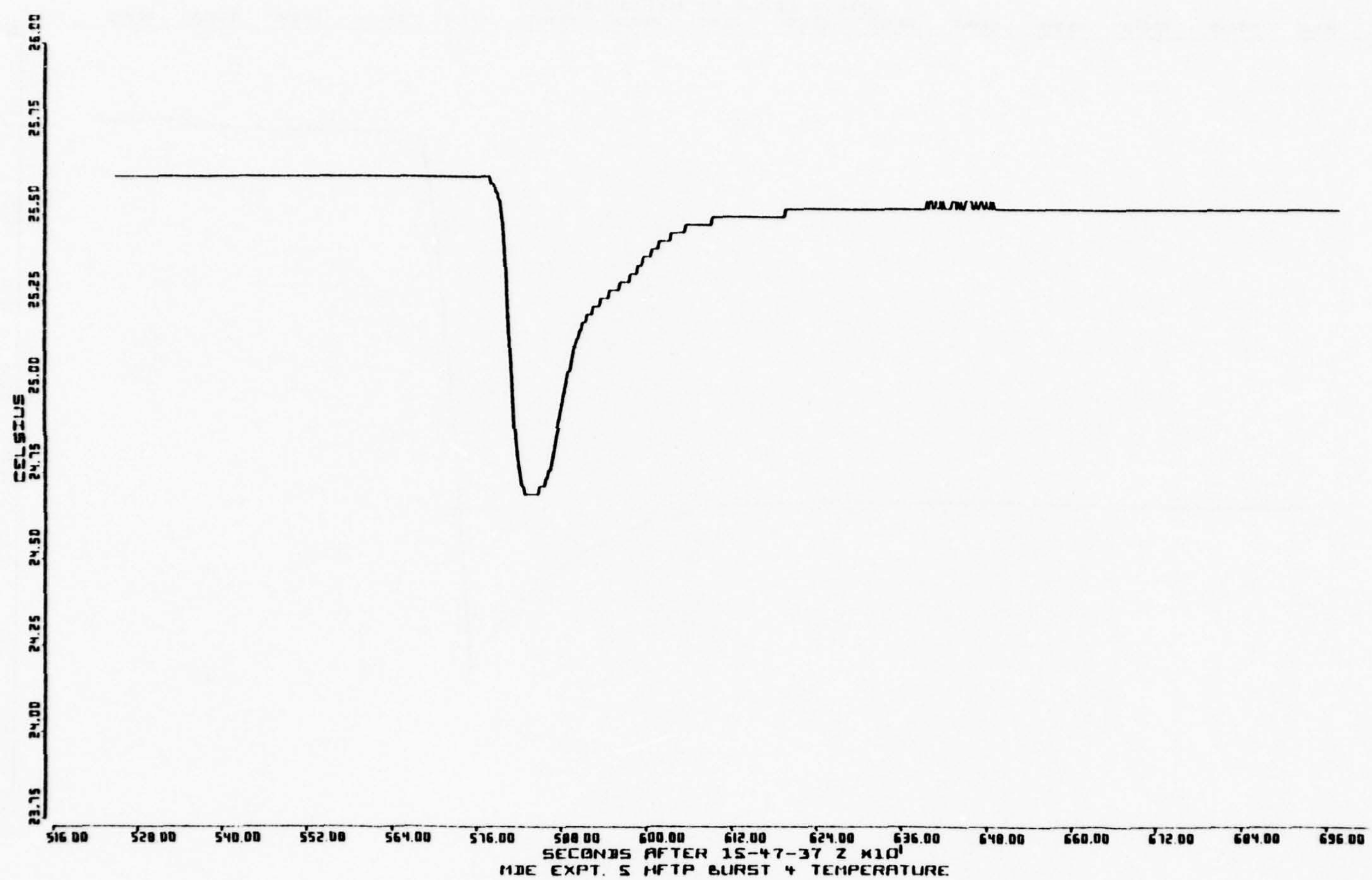
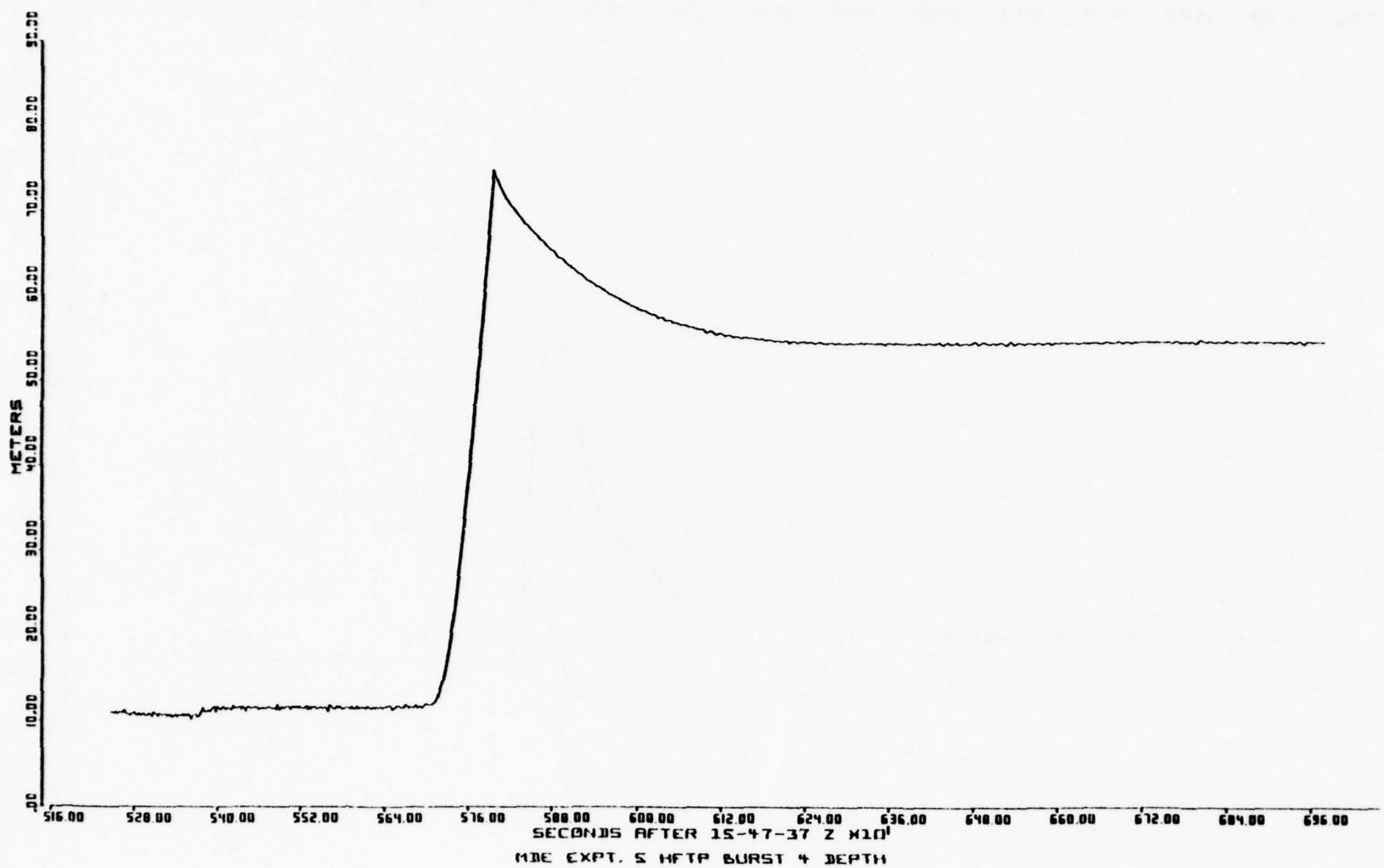
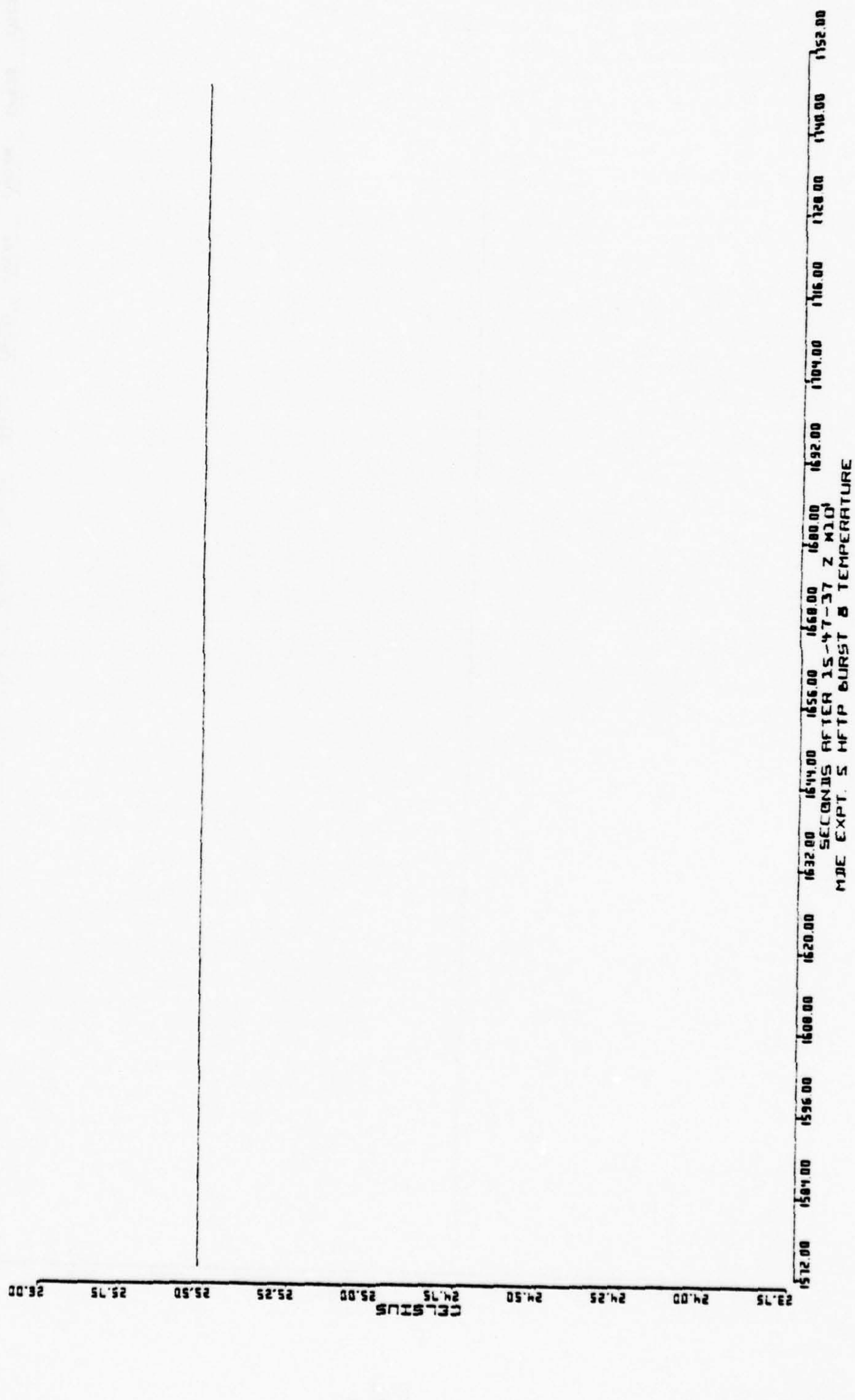

CELSIUS
26.00
25.75
25.50
25.25
25.00
24.75
24.50
24.25
24.00
23.75
516.00
528.00
540.00
552.00
564.00
576.00
588.00
600.00
612.00
624.00
636.00
648.00
660.00
672.00
684.00
696.00
SECONDS AFTER 15-47-37 Z X10¹
MDE EXPT. 5 HFTP BURST 4 TEMPERATURE

Figure D-1.



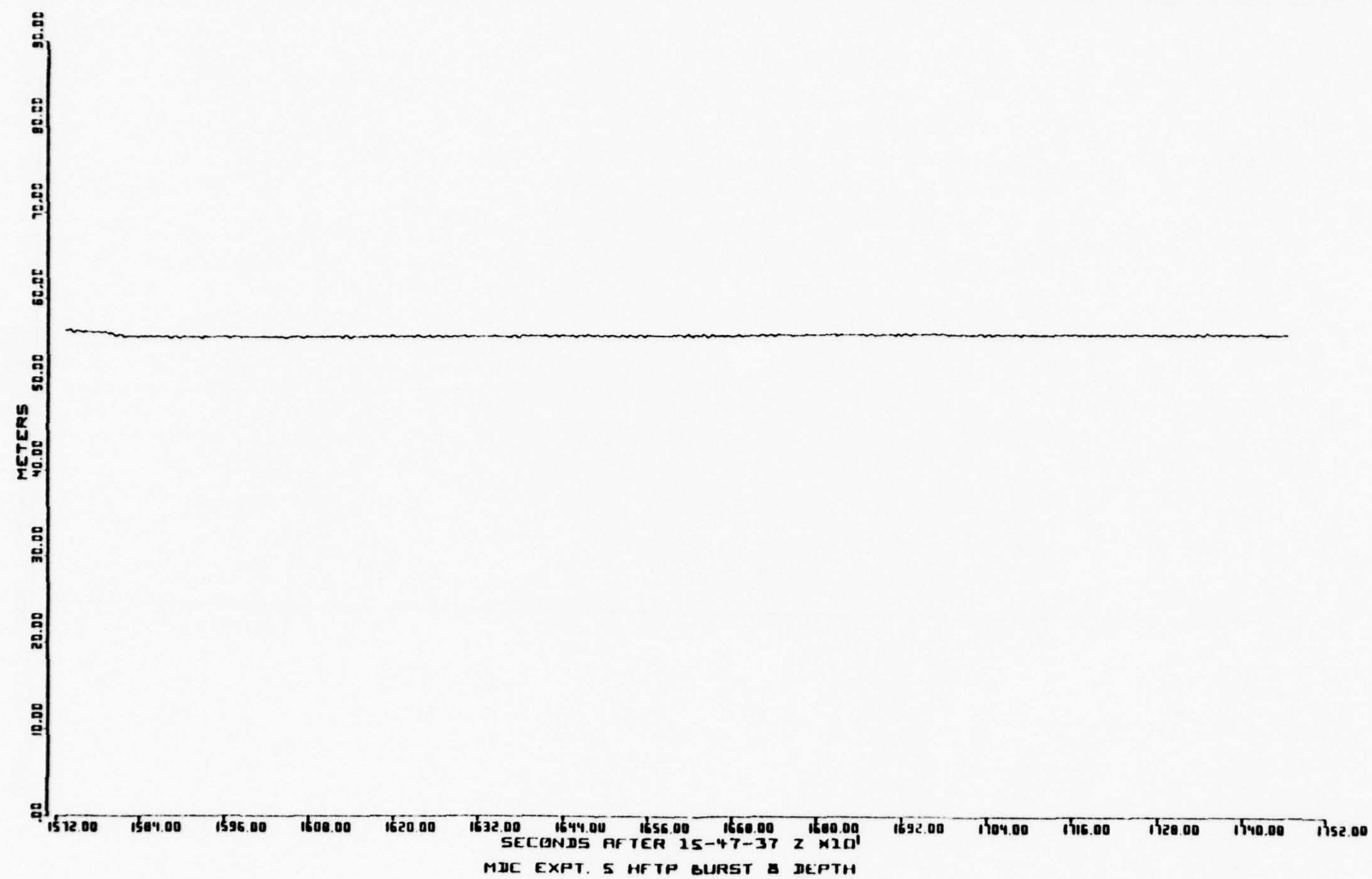
METERS
.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
516.00
528.00
540.00
552.00
564.00
576.00
588.00
600.00
612.00
624.00
636.00
648.00
660.00
672.00
684.00
696.00
SECONDS AFTER 15-47-37 Z X10[1]
MBE EXPT. 5 HFTP BURST 4 DEPTH

Figure D-2.



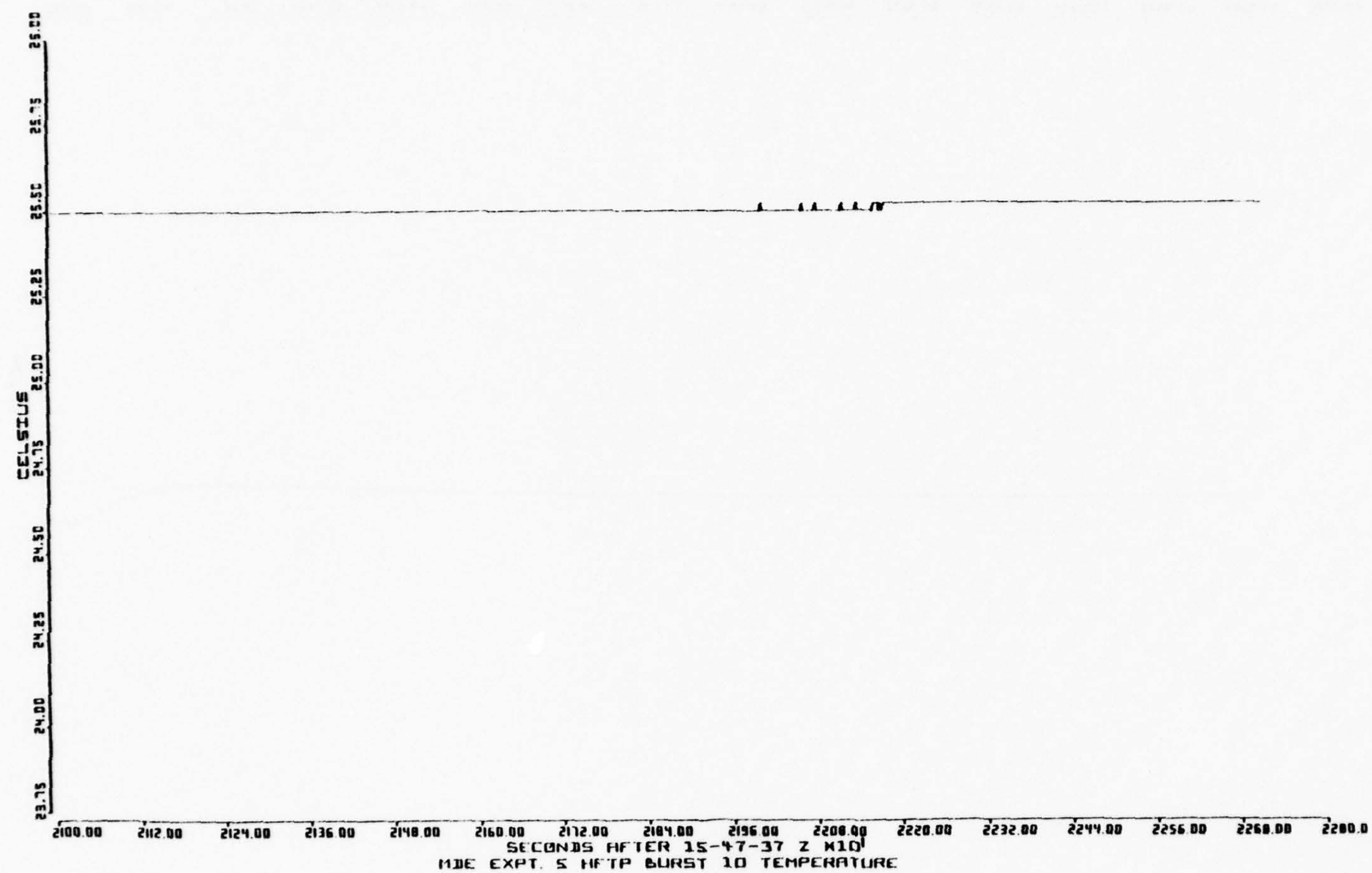
CELSIUS
23.75
24.00
24.25
24.50
24.75
25.00
25.25
25.50
25.75
26.00
1572.00
1584.00
1596.00
1608.00
1620.00
1632.00
1644.00
1656.00
1668.00
1680.00
1692.00
1704.00
1716.00
1728.00
1740.00
1752.00
SECONDS AFTER 15-47-37 Z X10¹
MDE EXPT. 5 HFTP BURST 8 TEMPERATURE

Figure D-3.



METERS
.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
1572.00
1584.00
1596.00
1608.00
1620.00
1632.00
1644.00
1656.00
1668.00
1680.00
1692.00
1704.00
1716.00
1728.00
1740.00
1752.00
SECONDS AFTER 15-47-37 Z X10[1]
MDC EXPT. 5 HFTP BURST 8 DEPTH

Figure D-4.



CELSIUS
25.75
25.50
25.25
25.00
24.75
24.50
24.25
24.00
23.75
2100.00
2112.00
2124.00
2136.00
2148.00
2160.00
2172.00
2184.00
2196.00
2208.00
2220.00
2232.00
2244.00
2256.00
2268.00
2280.0
SECONDS AFTER 15-47-37 Z X10
MIDE EXPT. 5 HFTP BURST 10 TEMPERATURE

Figure D-5.

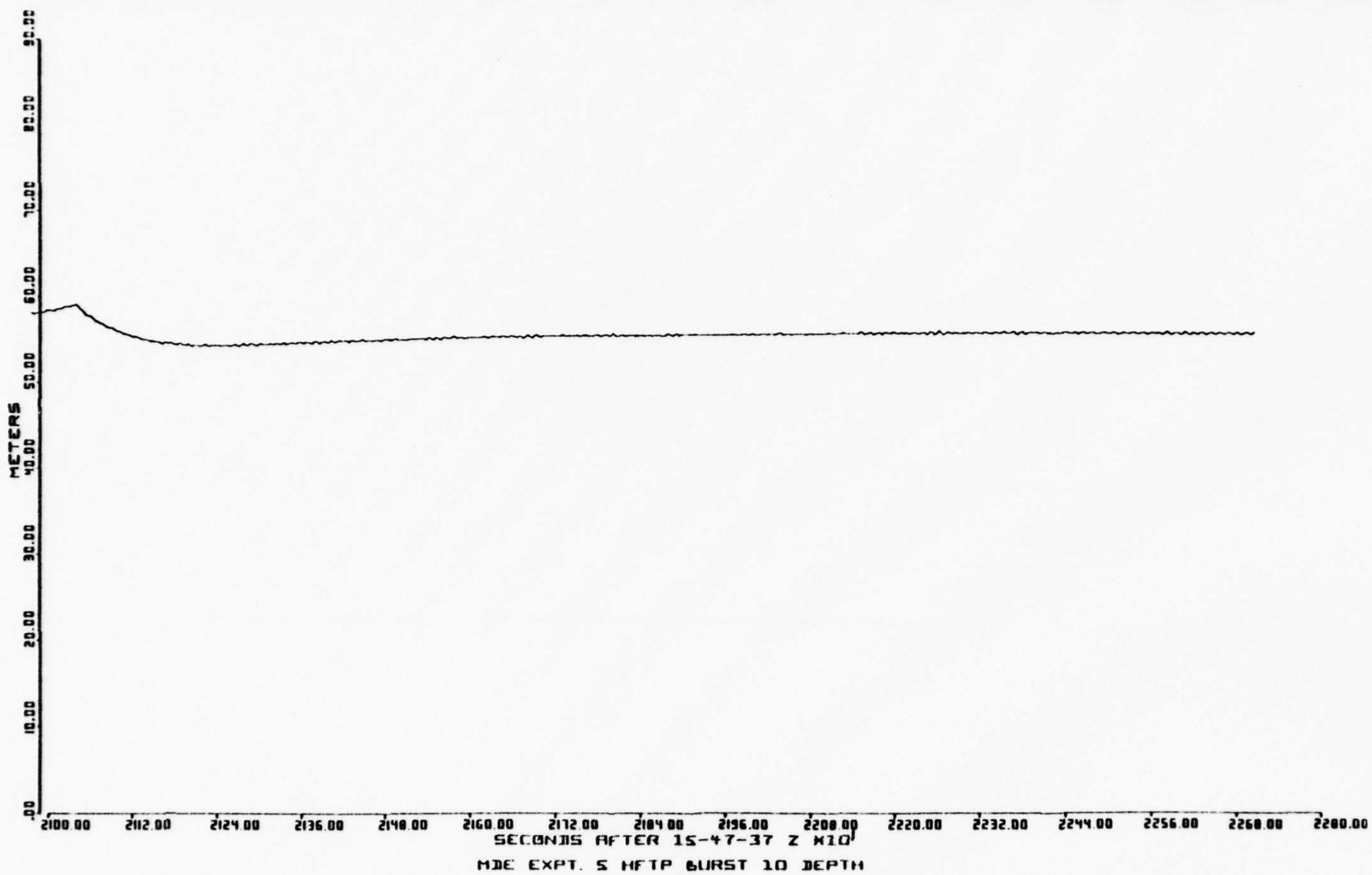

METERS
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
.00
2100.00
2112.00
2124.00
2136.00
2148.00
2160.00
2172.00
2184.00
2196.00
2208.00
2220.00
2232.00
2244.00
2256.00
2268.00
2280.00
SECONDS AFTER 15-47-37 Z X10
MDE EXPT. 5 HFTP BURST 10 DEPTH

Figure D-6.

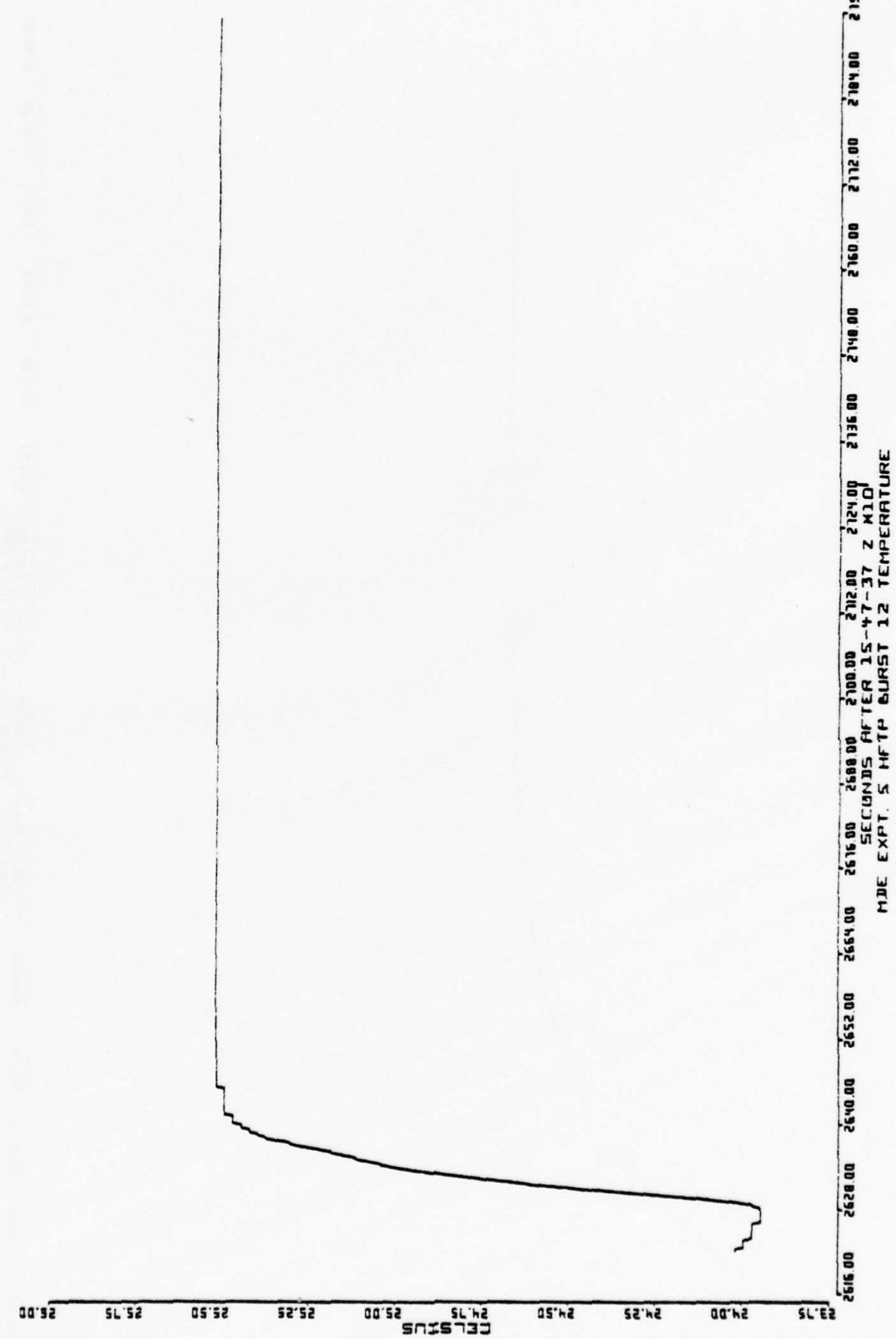

SECONDS AFTER 15-47-37 Z M10
MDE EXPT. 5 HFTP BURST 12 TEMPERATURE
CELSIUS
23.75
24.00
24.25
24.50
24.75
25.00
25.25
25.50
25.75
26.00

Figure D-7.

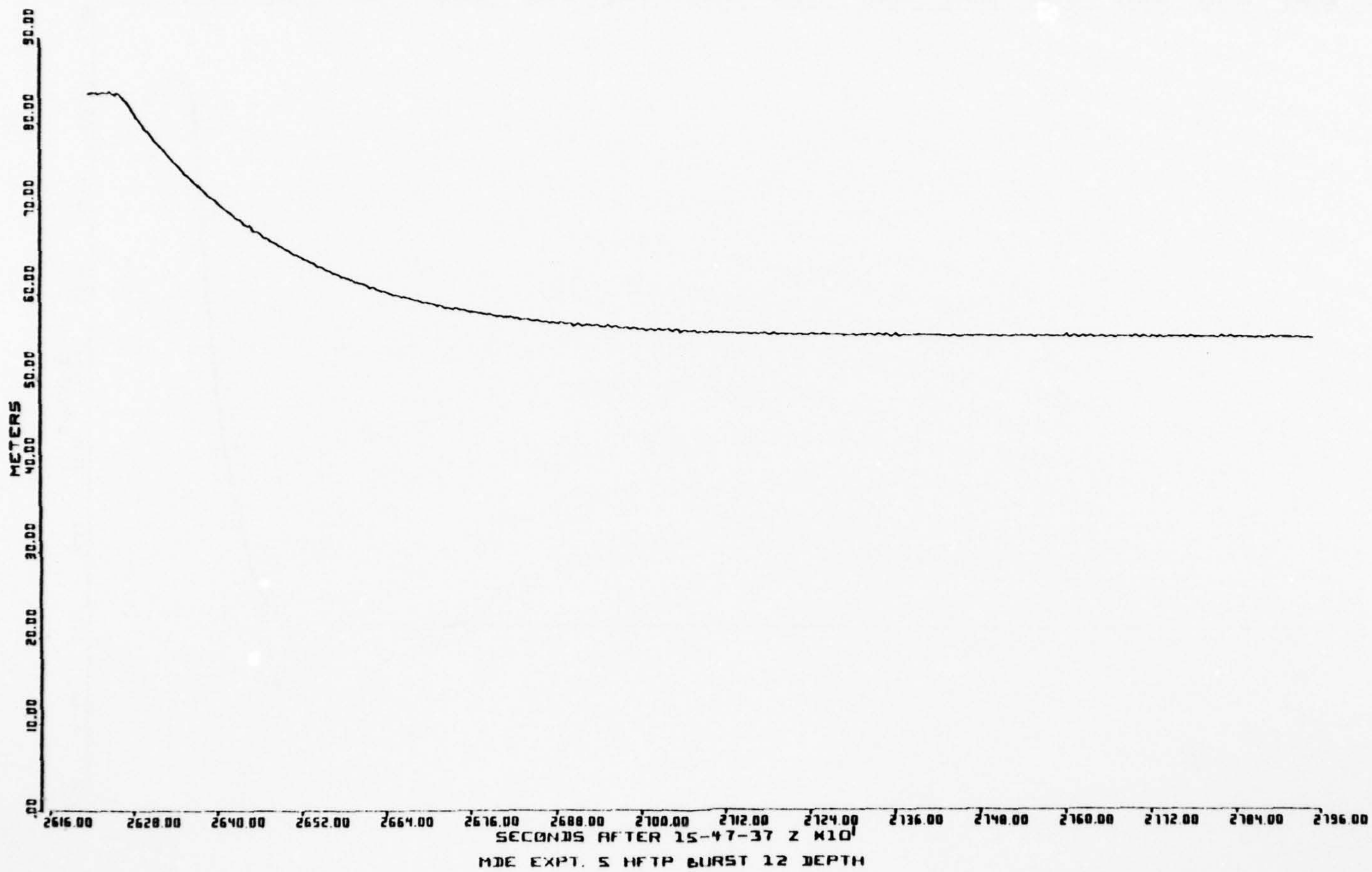
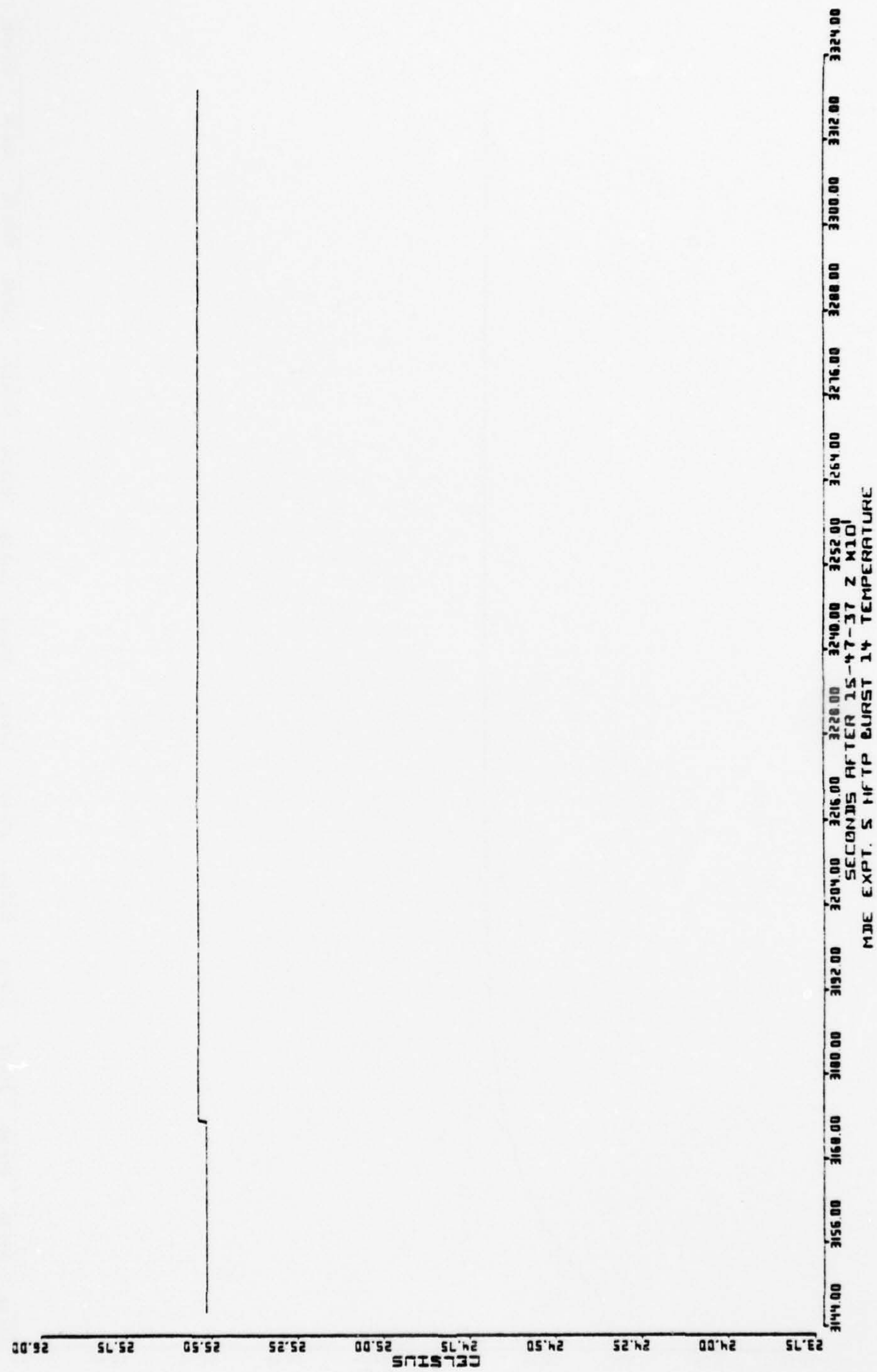

METERS
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
.00
2616.00
2628.00
2640.00
2652.00
2664.00
2676.00
2688.00
2700.00
2712.00
2724.00
2736.00
2748.00
2760.00
2772.00
2784.00
2796.00
SECONDS AFTER 15-47-37 Z M10
MDE EXPT. 5 HFTP BURST 12 DEPTH

Figure D-8.



CELSIUS
23.75
24.00
24.25
24.50
24.75
25.00
25.25
25.50
25.75
26.00
3144.00
3156.00
3168.00
3180.00
3192.00
3204.00
3216.00
3228.00
3240.00
3252.00
3264.00
3276.00
3288.00
3300.00
3312.00
3324.00
SECONDS AFTER 15-47-37 Z X10[1]
MIDE EXPT. 5 HFTP BURST 14 TEMPERATURE

Figure D-9.

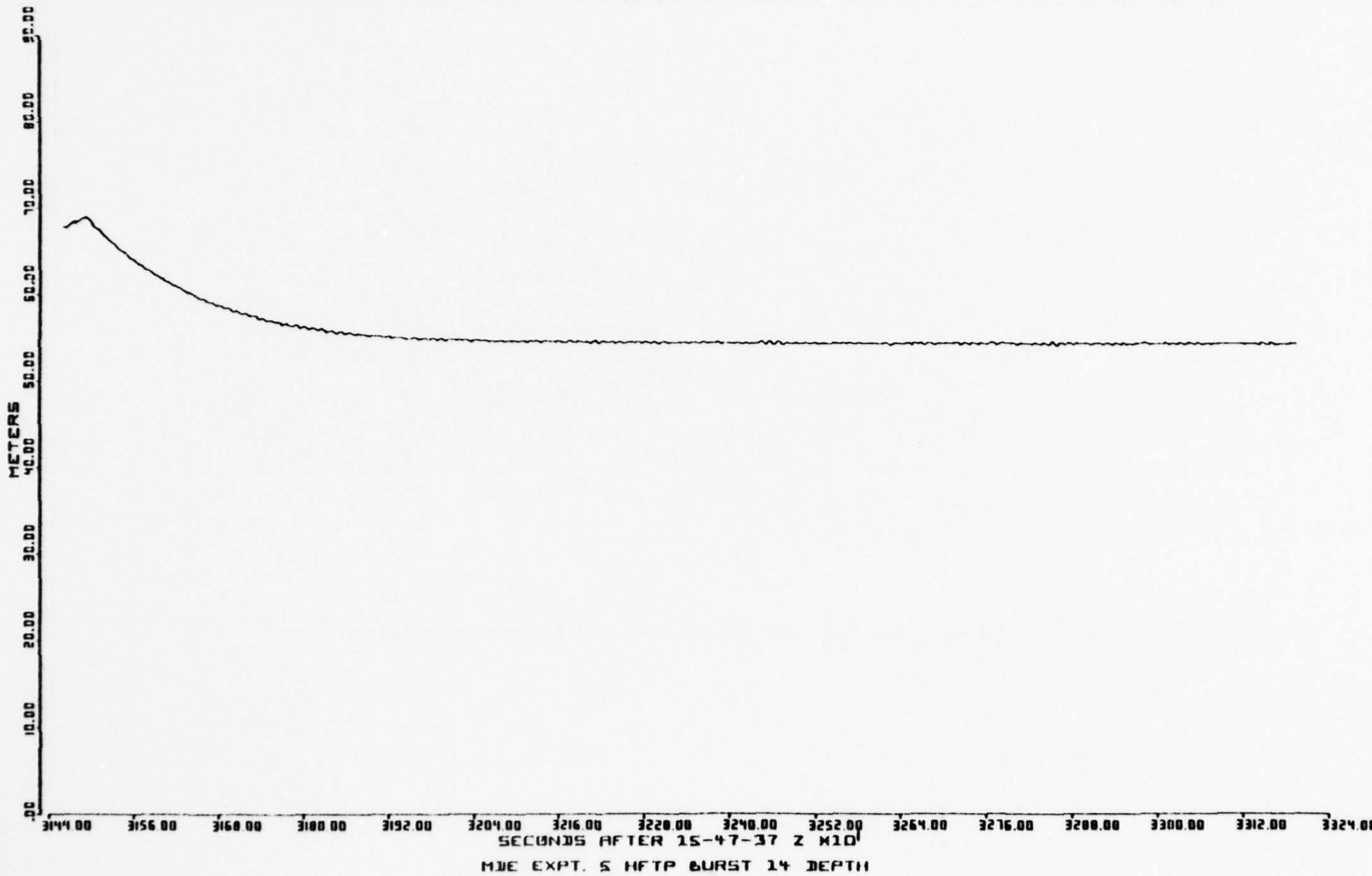

METERS
.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
3144.00
3156.00
3168.00
3180.00
3192.00
3204.00
3216.00
3228.00
3240.00
3252.00
3264.00
3276.00
3288.00
3300.00
3312.00
3324.00
SECONDS AFTER 15-47-37 Z X10
MIDE EXPT. 5 HFTP BURST 14 DEPTH

Figure D-10.

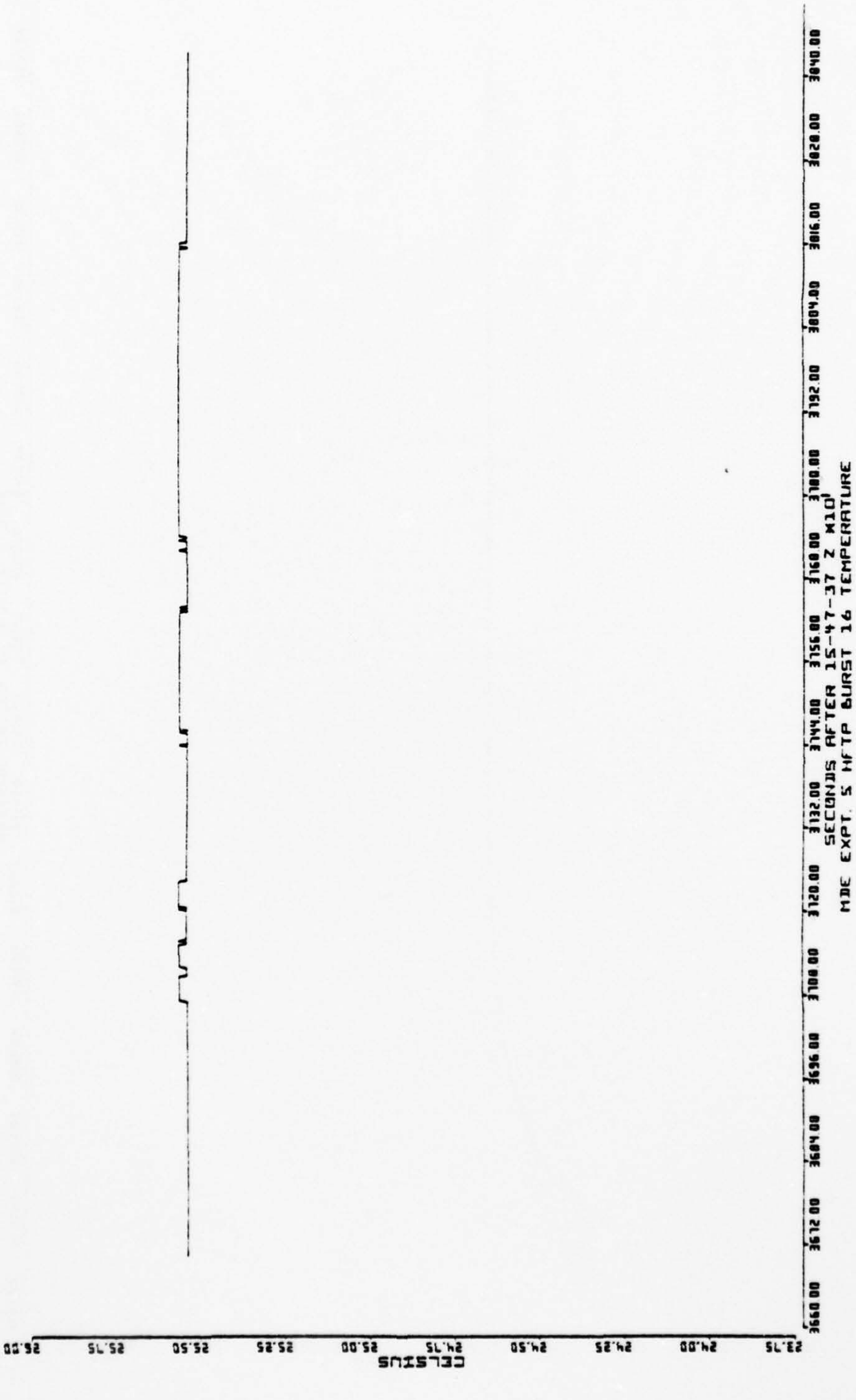
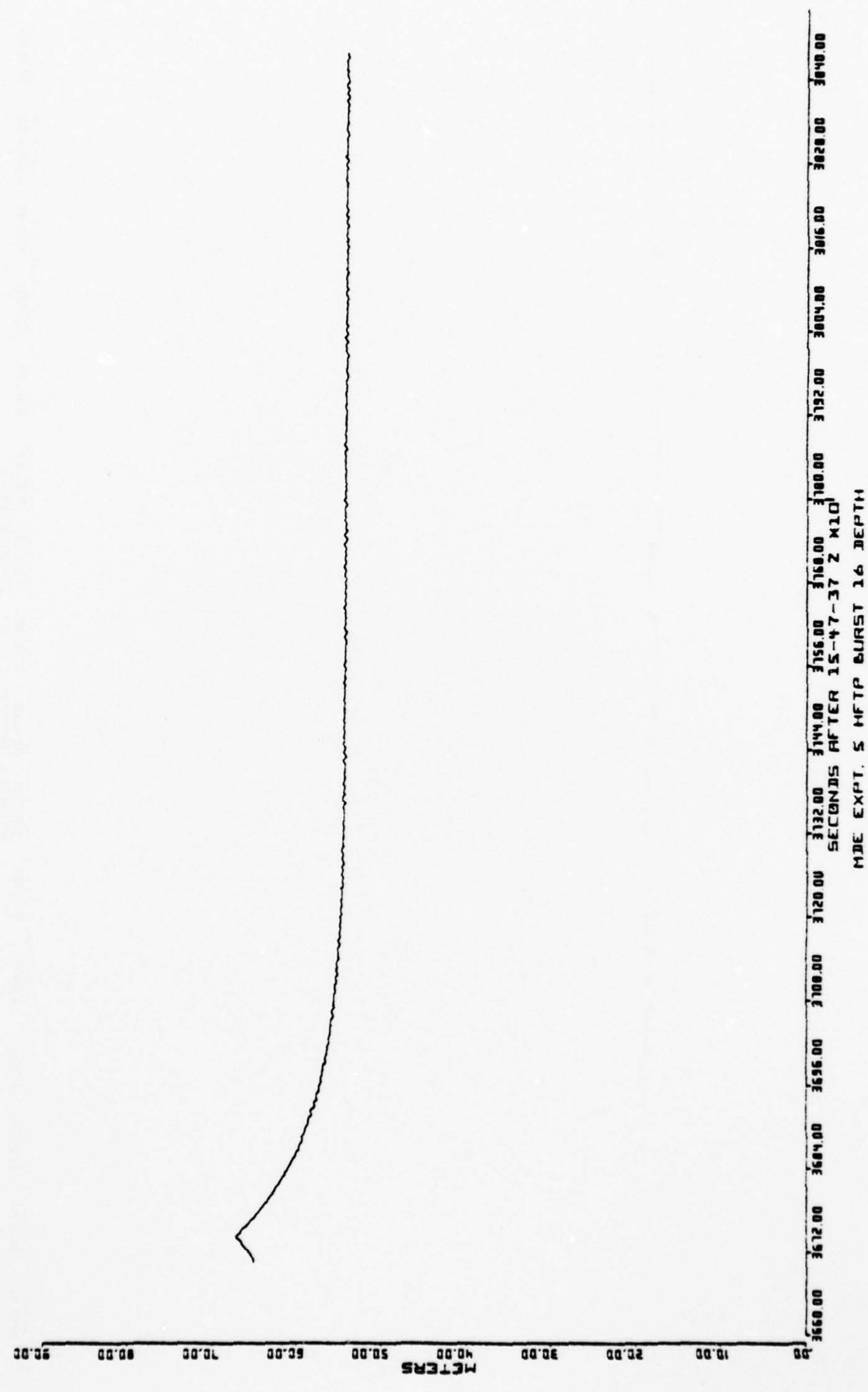
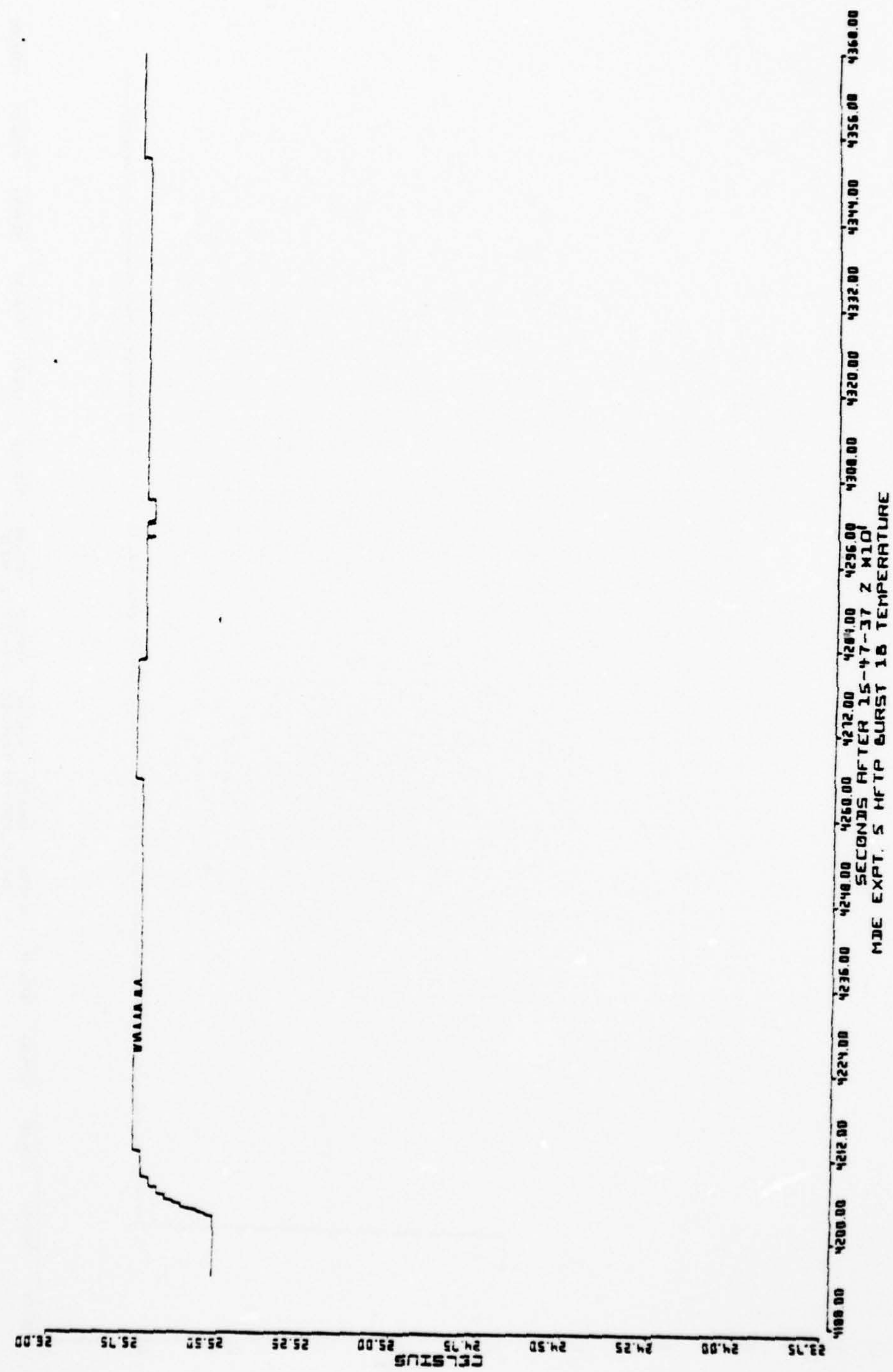

SECONDS AFTER 15-47-37 Z X10^1
MBE EXPT. 5 HFTP BURST 16 TEMPERATURE
CELSIUS

Figure D-11.



SECONDS AFTER 15-47-37 Z X10
MDE EXPT. 5 HFTP BURST 16 DEPTH
METERS
.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

Figure D-12.



SECONDS AFTER 15-47-37 Z X10^1
MDE EXPT. 5 HFTP BURST 18 TEMPERATURE
CELSIUS
4188.00
4200.00
4212.00
4224.00
4236.00
4248.00
4260.00
4272.00
4284.00
4296.00
4308.00
4320.00
4332.00
4344.00
4356.00
4368.00
23.75
24.00
24.25
24.50
24.75
25.00
25.25
25.50
25.75
26.00

Figure D-13.

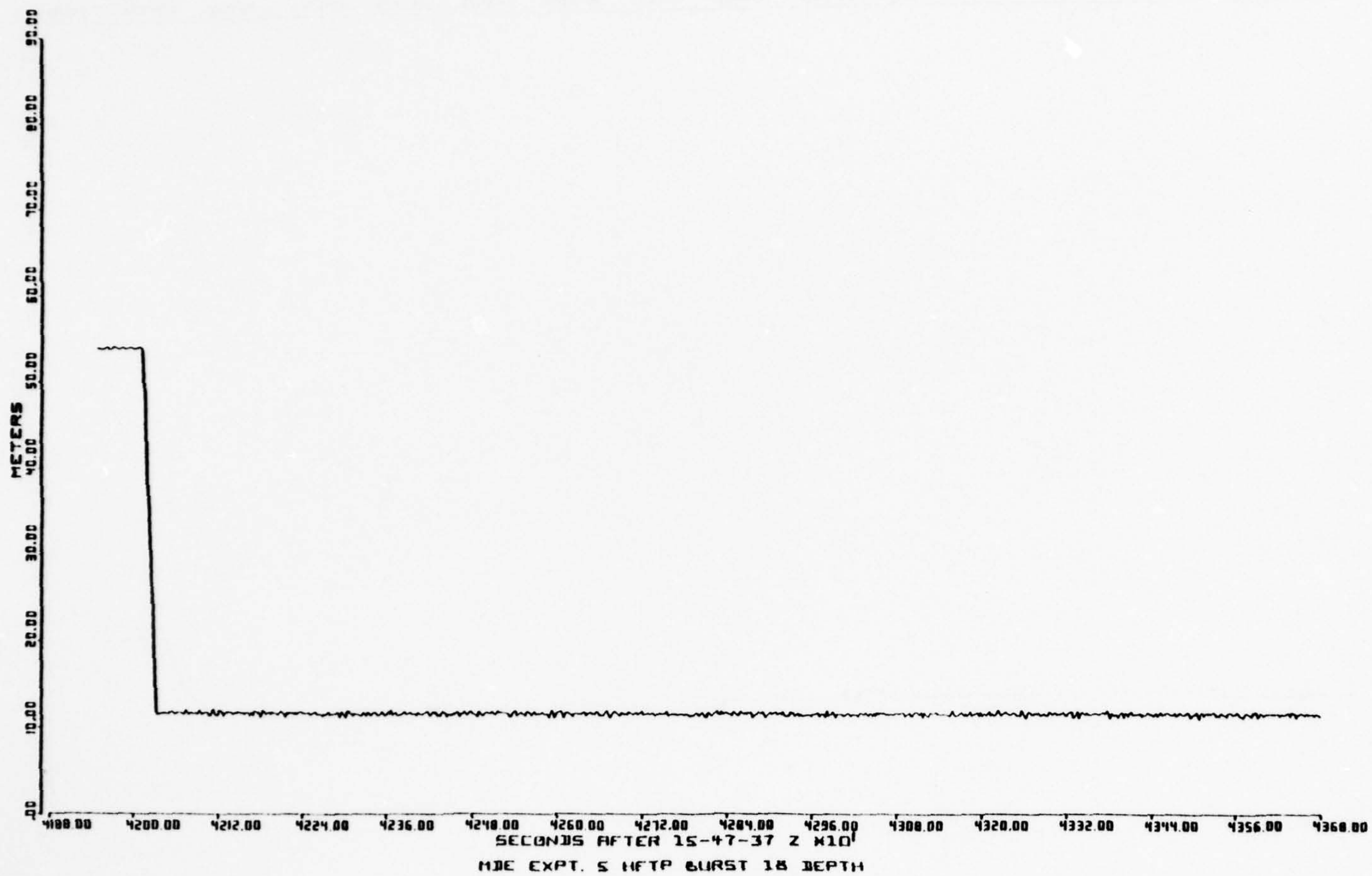

METERS
.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
4188.00
4200.00
4212.00
4224.00
4236.00
4248.00
4260.00
4212.00
4284.00
4296.00
4308.00
4320.00
4332.00
4344.00
4356.00
4368.00
SECONDS AFTER 15-47-37 Z X10[1]
MDE EXPT. 5 HFTP BURST 18 DEPTH

Figure D-14.

APPENDIX E

FORCE VECTOR RECORDER DATA FOR DEPLOYMENT

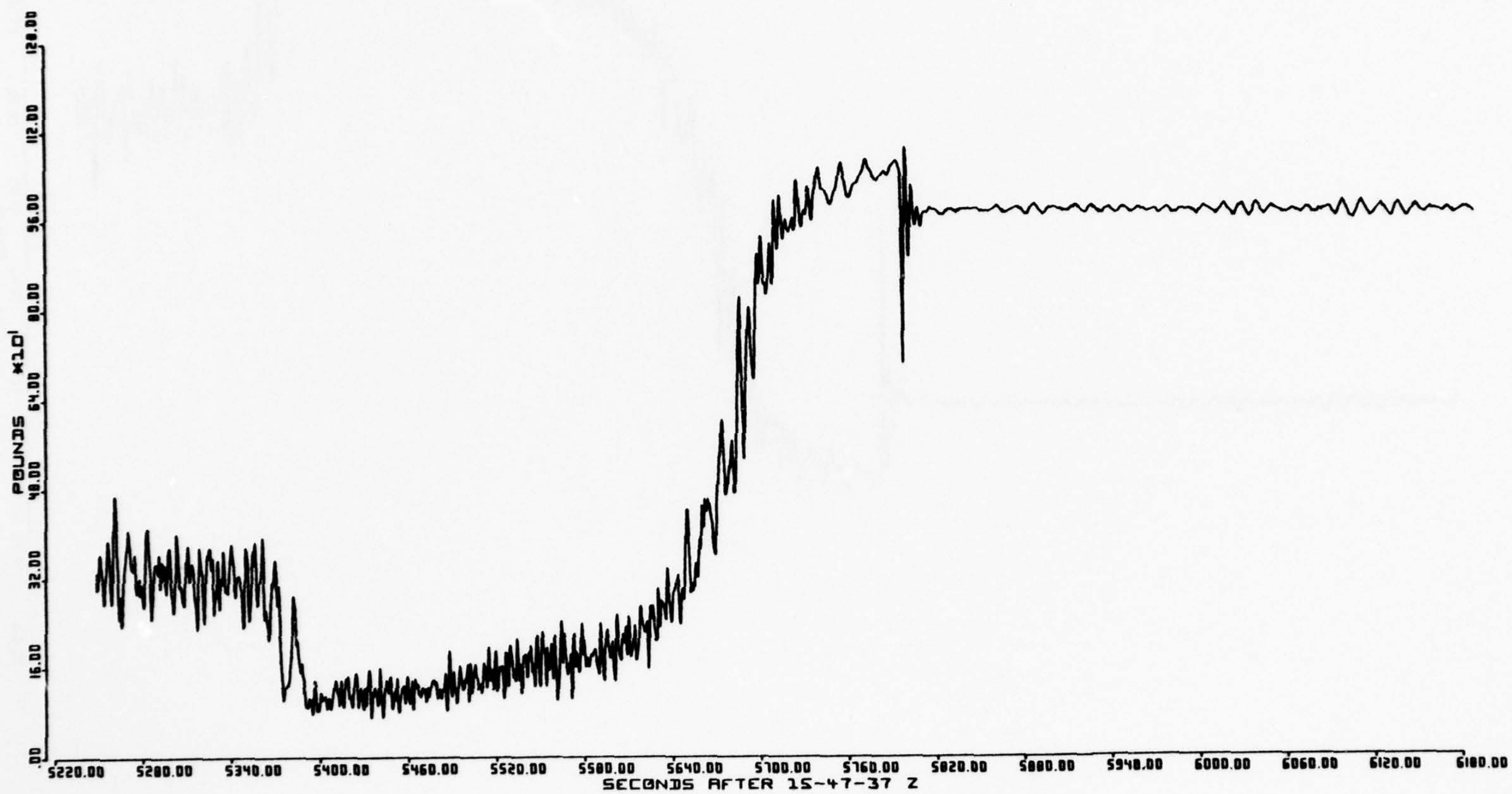


Figure E-1. MDE Expt. 5 FVR 1 Burst 2: Deployment Tension History

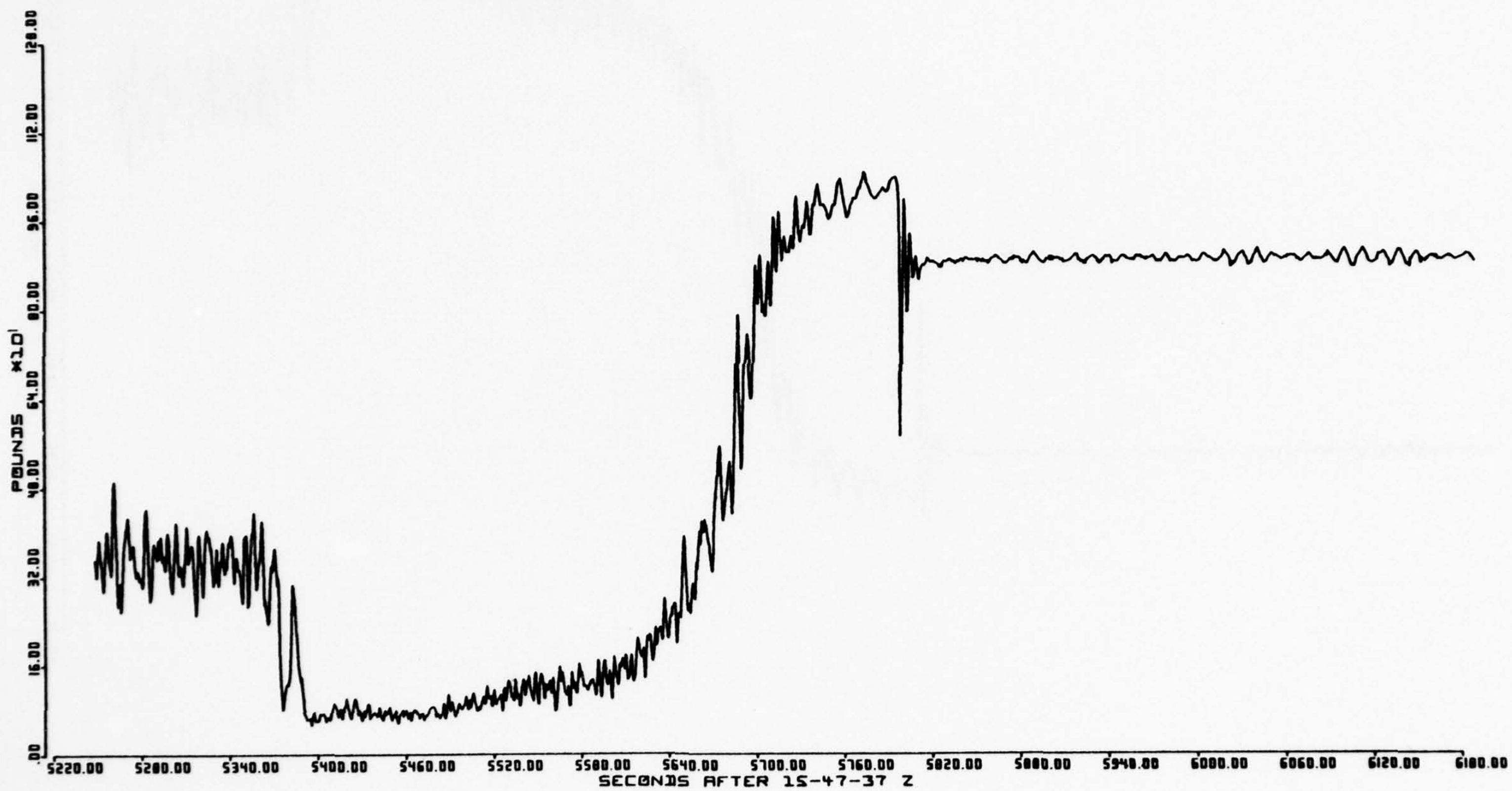


Figure E-2. MDE Expt. 5 FVR 2 Burst 2: Deployment Tension History

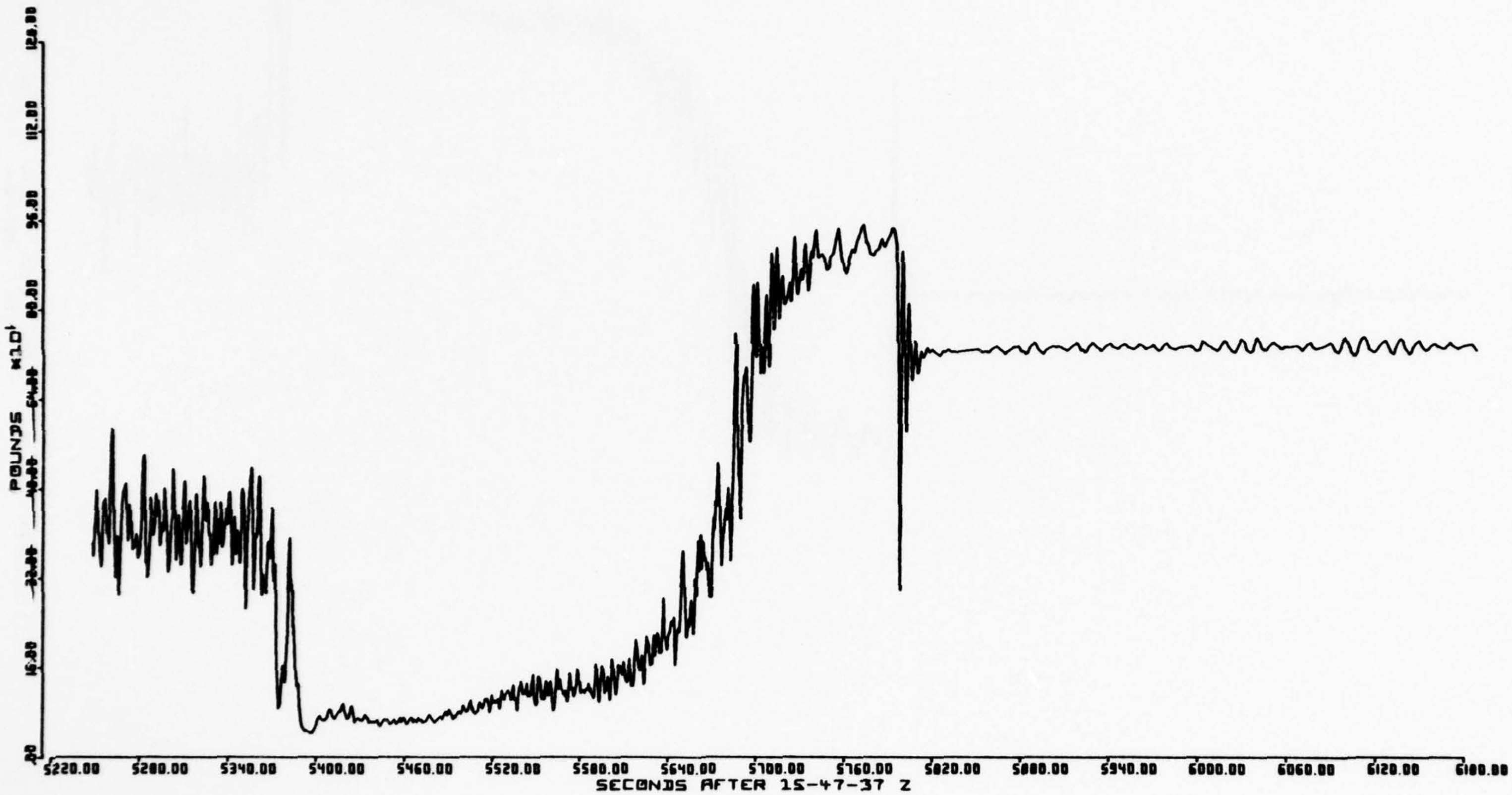


Figure E-3. MDE Expt. 5 FVR 3 Burst 2: Deployment Tension History

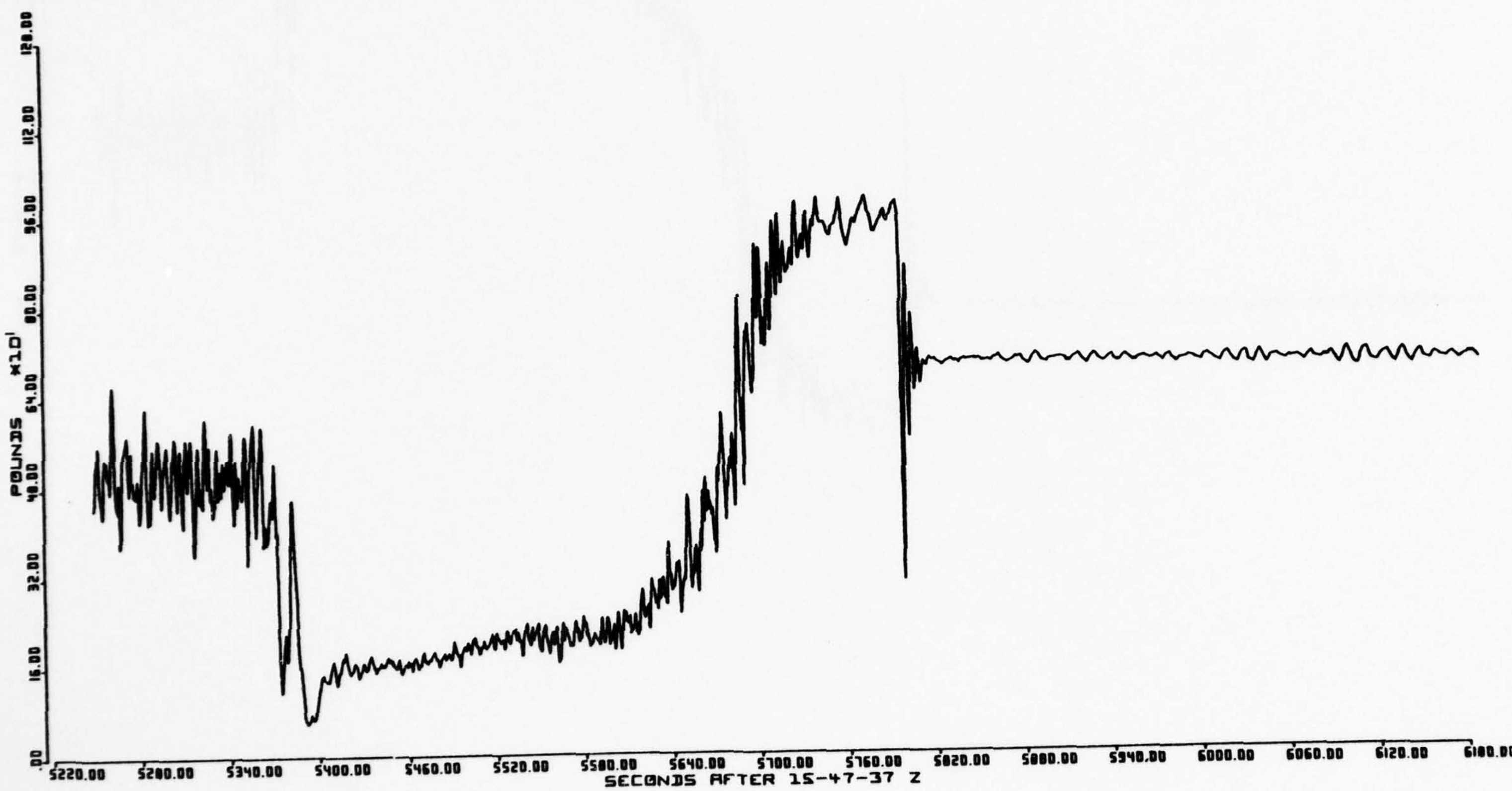
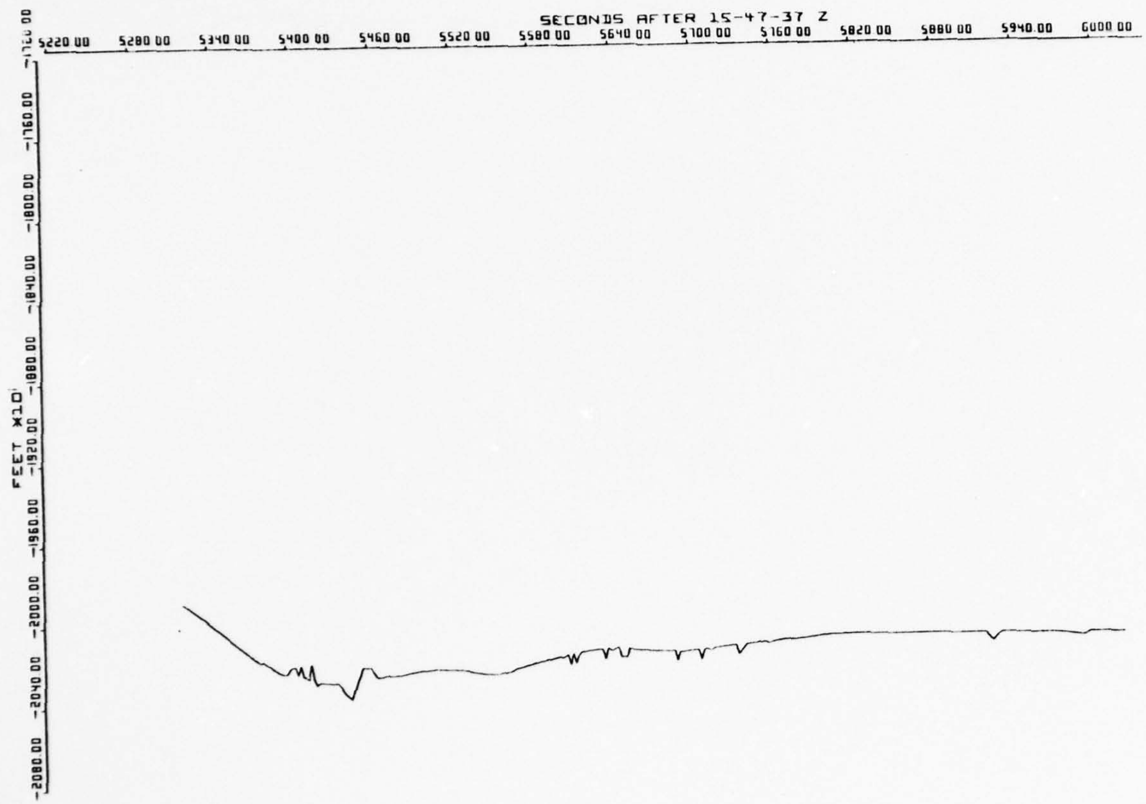


Figure E-4. MDE Expt. 5 FVR 4 Burst 2: Deployment Tension History

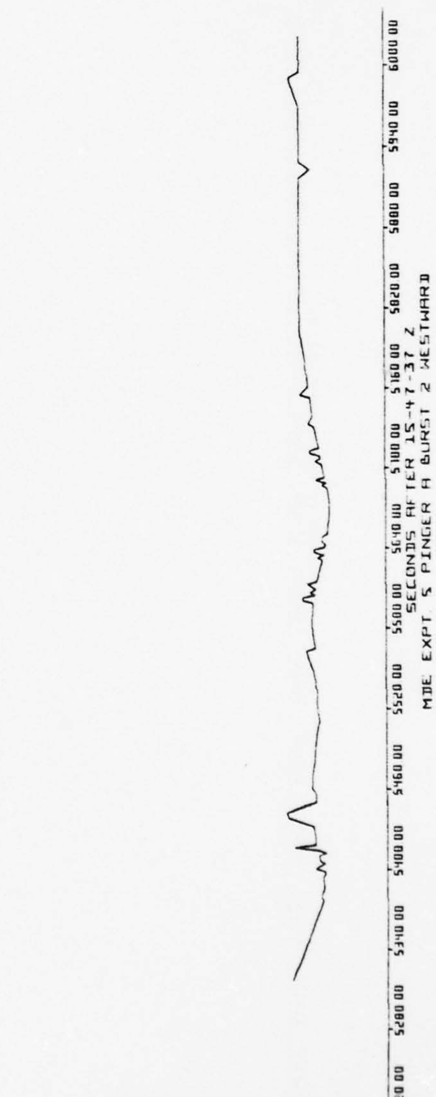
APPENDIX F

ACOUSTIC POSITION DATA FOR DEPLOYMENT



MDE EXPT 5 PINGER A BURST 2 NORTHWARD

Figure F-1.



5220.00
5280.00
5340.00
5400.00
5460.00
5520.00
5580.00
5640.00
5700.00
5760.00
5820.00
5880.00
5940.00
6000.00
SECONDS AFTER 15-47-37 Z
MDE EXPT 5 PINGER A BURST 2 WESTWARD
920.00
960.00
1000.00
1040.00
1080.00
FEET X10

Figure F-2.

AD-A058 329 CIVIL ENGINEERING LAB (NAVY) PORT HUENEME CALIF F/G 13/11
AT-SEA MEASUREMENTS OF THE DYNAMIC RESPONSE OF A SINGLE-POINT M--ETC(U)
MAR 78 D J MEGGITT, D B DILLON

UNCLASSIFIED CEL-TM-44-78-9 NL

2 OF 2

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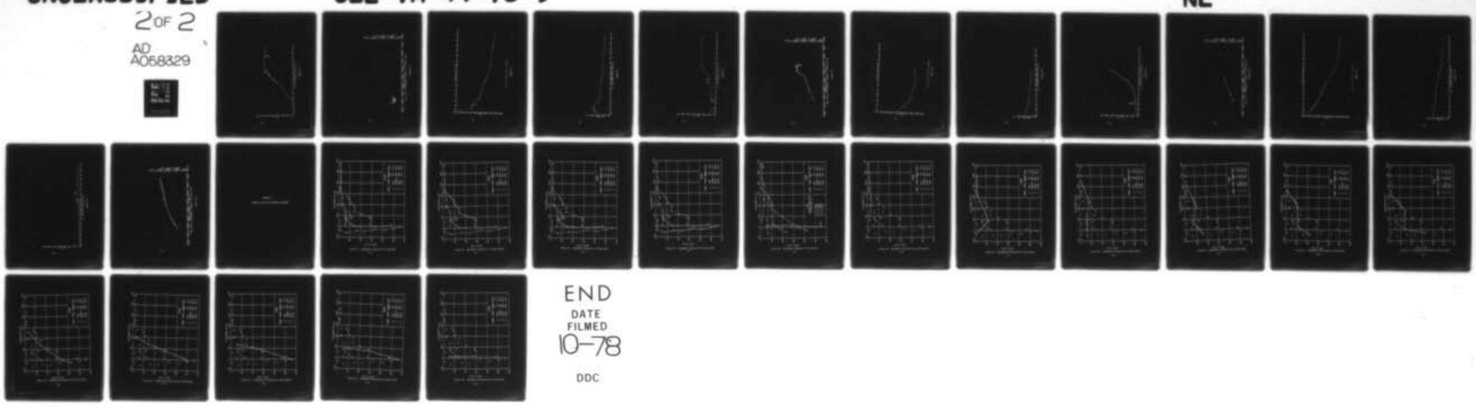
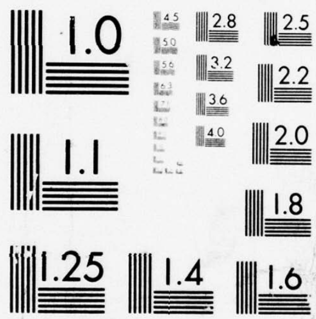
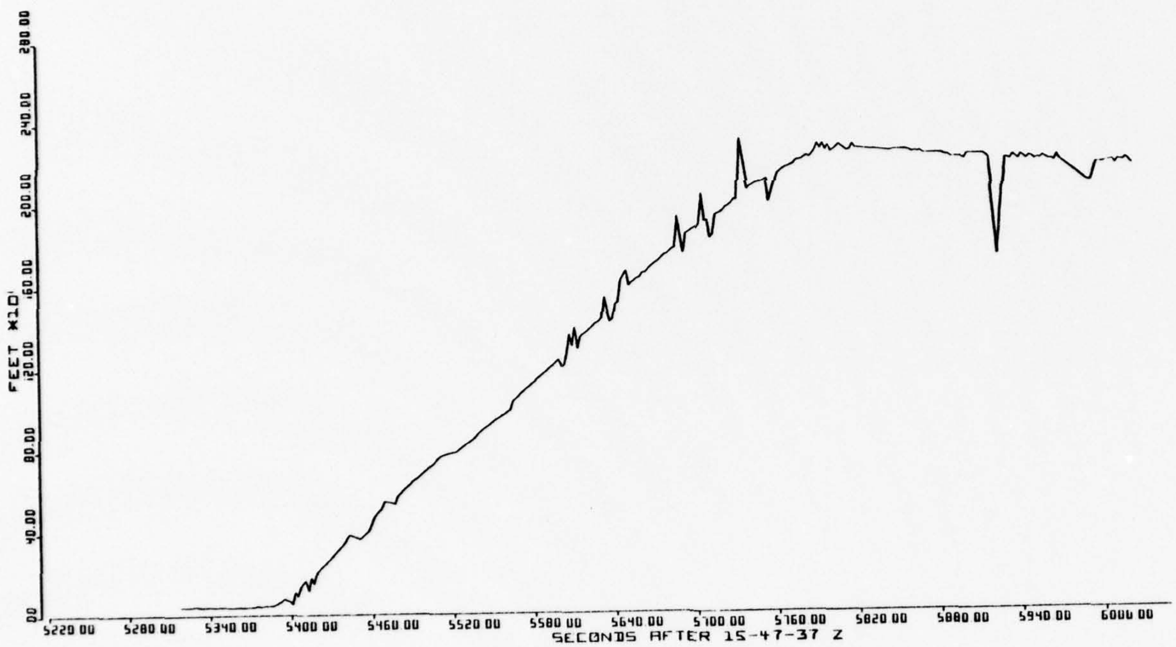


END
DATE
FILMED
10-78
DDC


1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6



MDE EXPT 5 PINGER A BURST 2 DEPTH

Figure F-3.

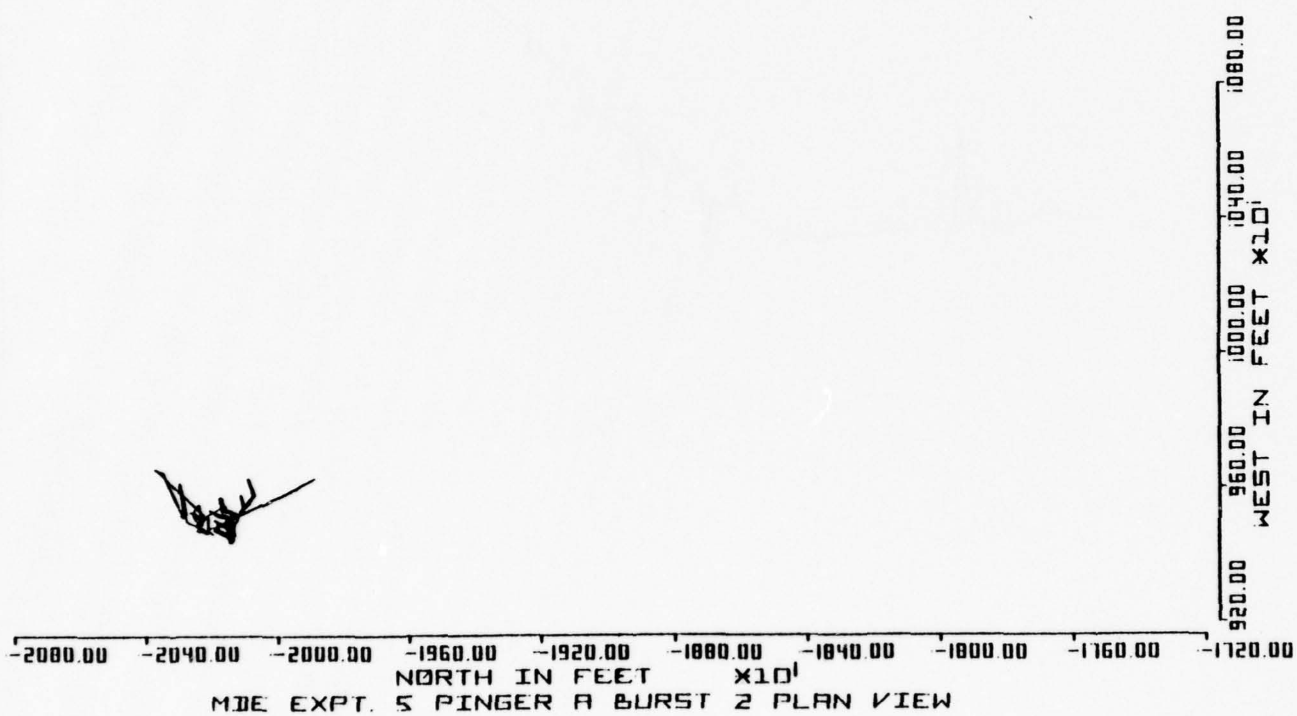

-2080.00
-2040.00
-2000.00
-1960.00
-1920.00
-1880.00
-1840.00
-1800.00
-1760.00
-1720.00
NØRTH IN FEET ×10¹
920.00
960.00
1000.00
1040.00
1080.00
WEST IN FEET ×10¹
MDE EXPT. 5 PINGER A BURST 2 PLAN VIEW

Figure F-4.

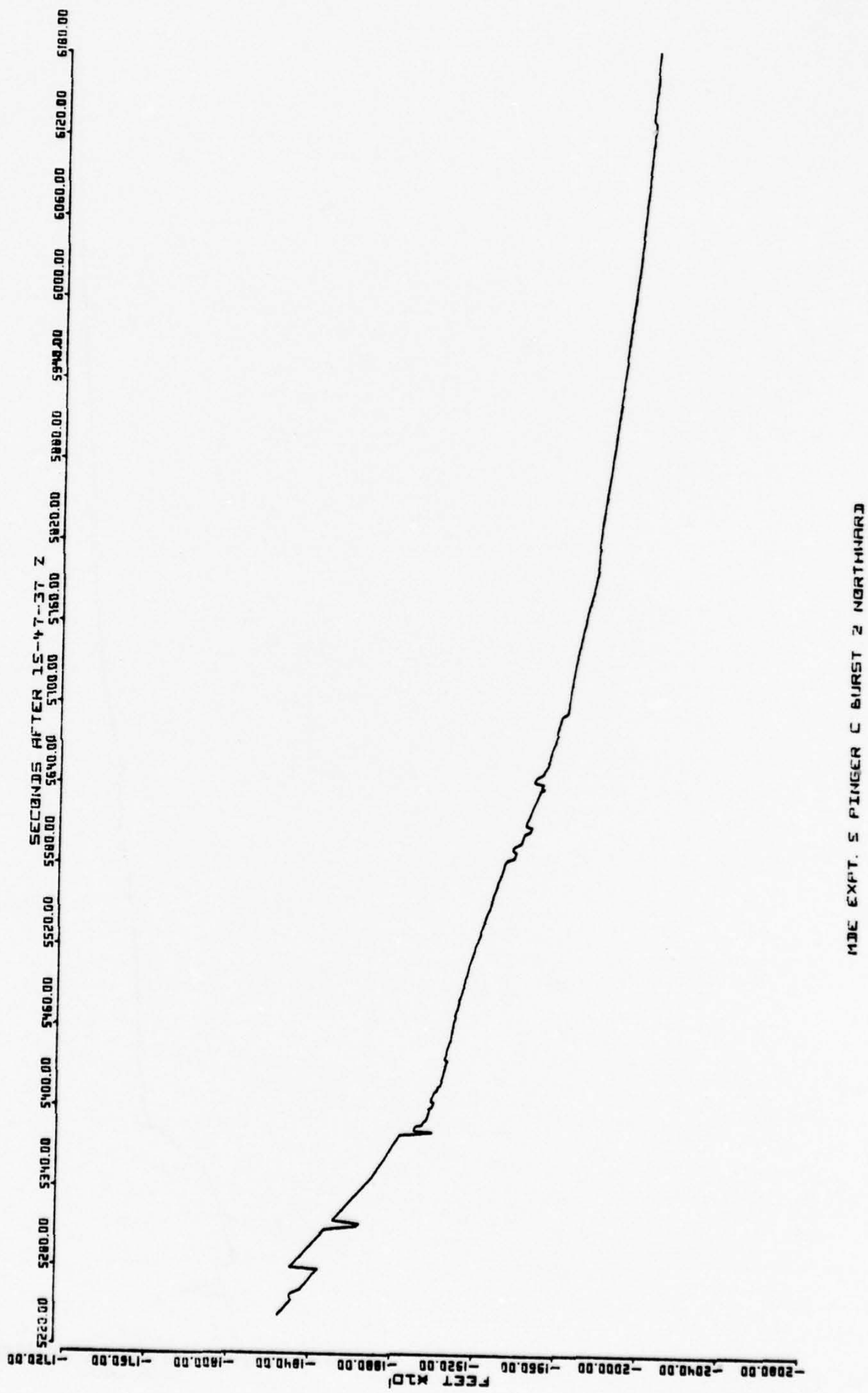
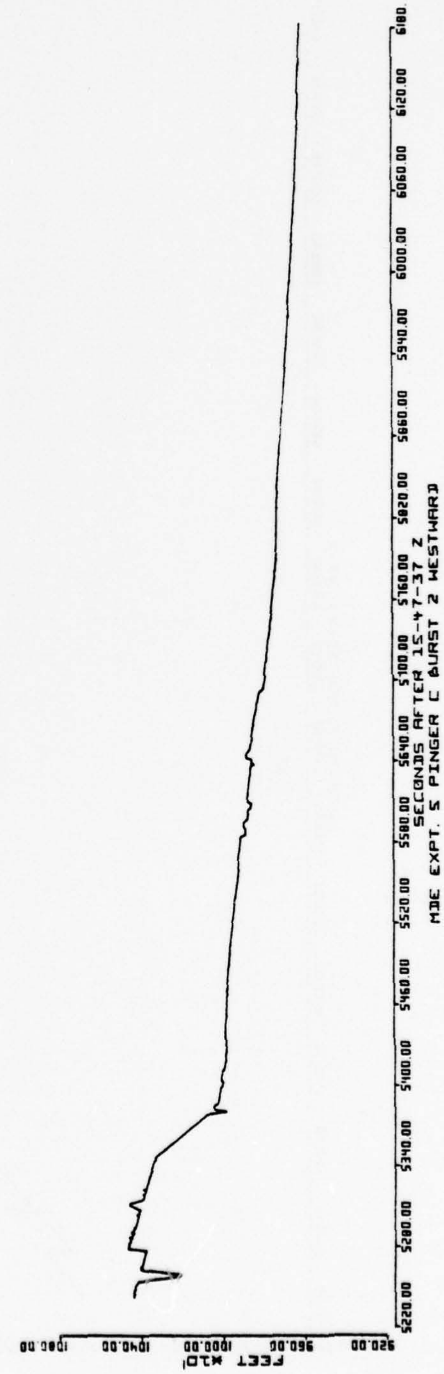
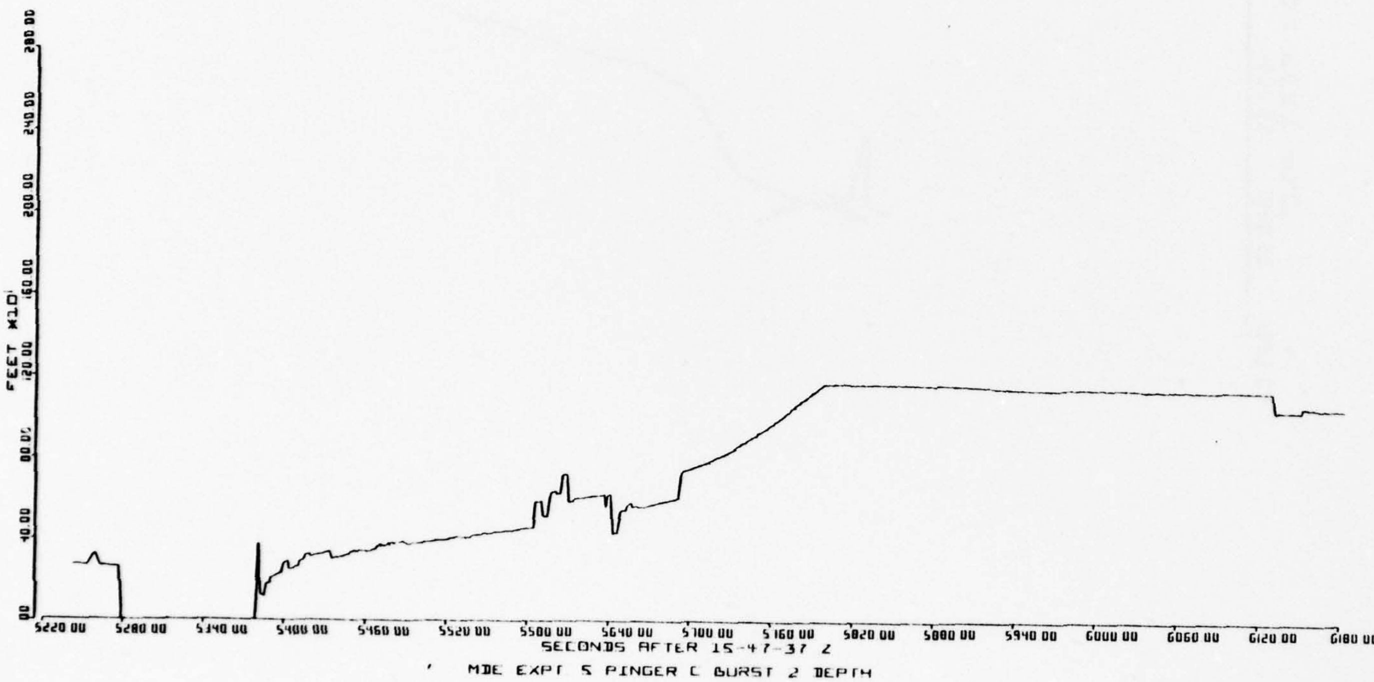

SECONDS AFTER 15-47-37 Z
5220.00
5280.00
5340.00
5400.00
5460.00
5520.00
5580.00
5640.00
5700.00
5760.00
5820.00
5880.00
5940.00
6000.00
6060.00
6120.00
6180.00
FEET X10¹
-1720.00
-1760.00
-1800.00
-1840.00
-1880.00
-1920.00
-1960.00
-2000.00
-2040.00
-2080.00
MJE EXPT. 5 PINGER C BURST 2 NORTHWARD

Figure F-5.



SECONDS AFTER 15-47-37 Z
MJE EXPT. 5 PINGER C BURST 2 WESTWARD
FEET x10¹

Figure F-6.



FEET x10'
SECONDS AFTER 15-47-37 Z
MDE EXPT 5 PINGER C BURST 2 DEPTH

Figure F-7.

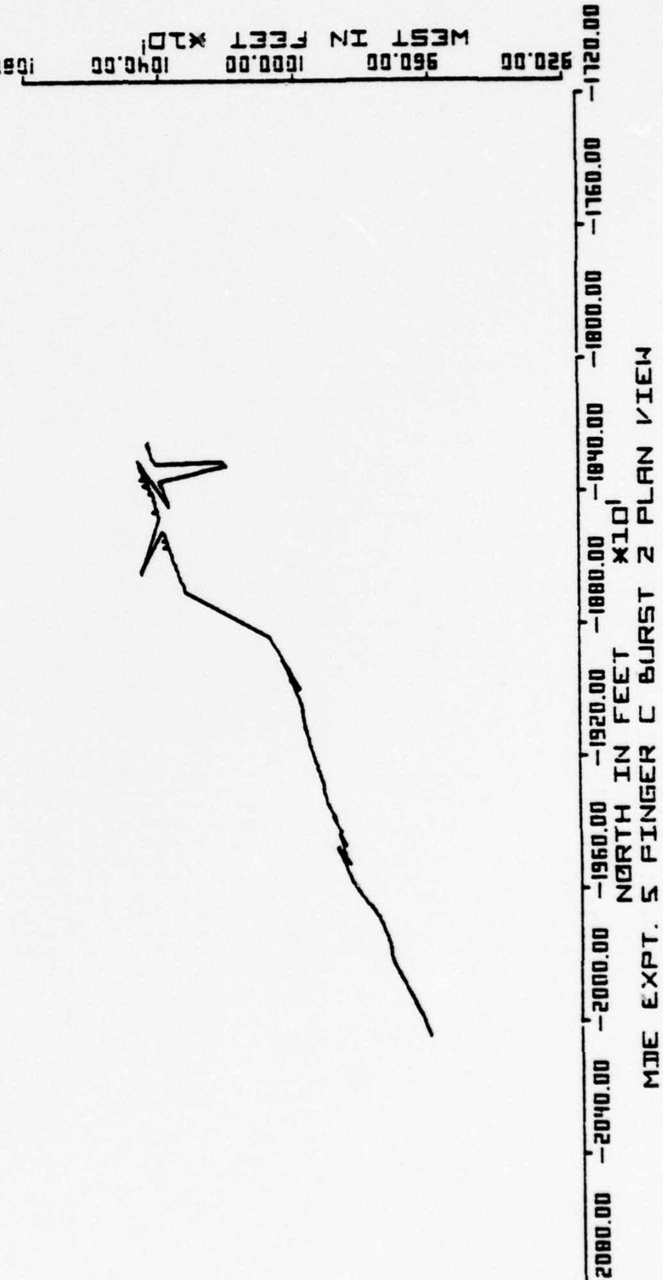
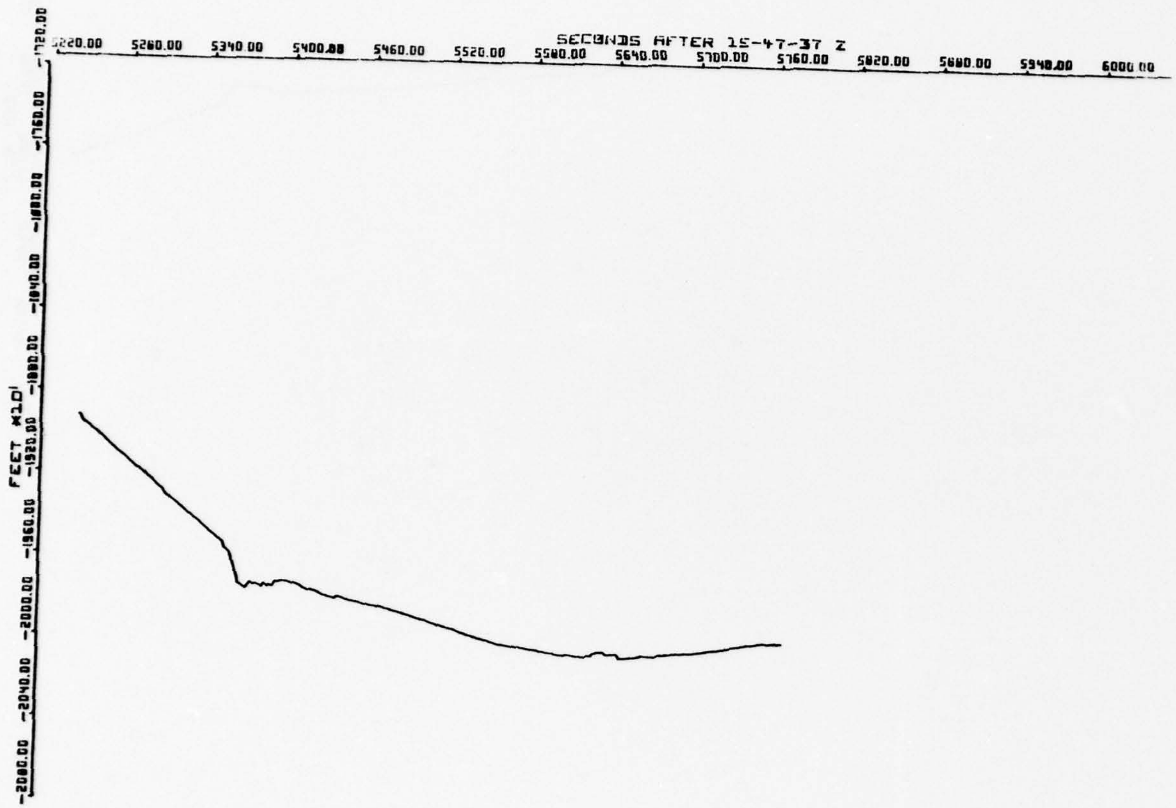

WEST IN FEET ×10¹
920.00
960.00
1000.00
1040.00
1080.00
-2080.00
-2040.00
-2000.00
-1960.00
-1920.00
-1880.00
-1840.00
-1800.00
-1760.00
-1720.00
NORTH IN FEET ×10¹
MJE EXPT. 5 FINGER C BURST 2 PLAN VIEW

Figure F-8.



MJE EXPT. 5 PINGER 3 BURST 2 NORTHWARD

Figure F-9.

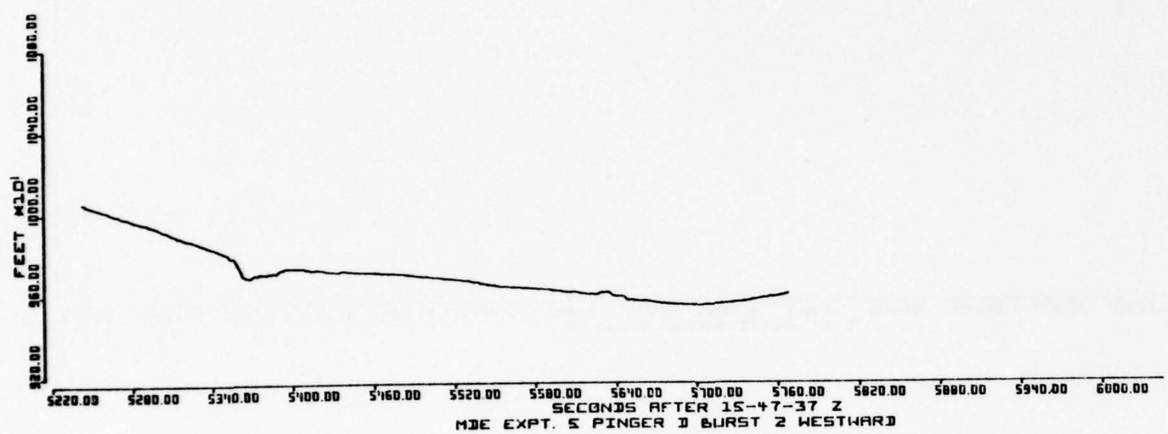

FEET *10[1]
920.00
960.00
1000.00
1040.00
1080.00
5220.00
5280.00
5340.00
5400.00
5460.00
5520.00
5580.00
5640.00
5700.00
5760.00
5820.00
5880.00
5940.00
6000.00
SECONDS AFTER 15-47-37 Z
MDE EXPT. 5 PINGER D BURST 2 WESTWARD

Figure F-10.

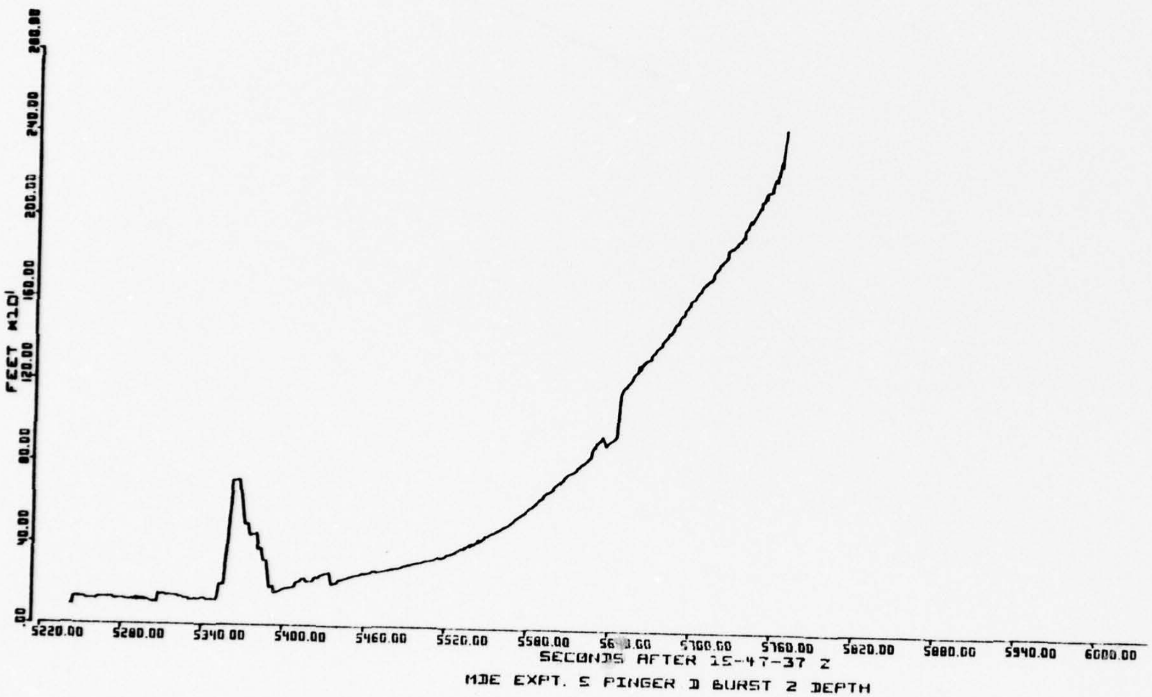

FEET H2O
.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
5220.00
5280.00
5340.00
5400.00
5460.00
5520.00
5580.00
5700.00
5760.00
5820.00
5880.00
5940.00
6000.00
SECONDS AFTER 15-47-37 Z
MDE EXPT. 5 PINGER D BURST 2 DEPTH

Figure F-11.

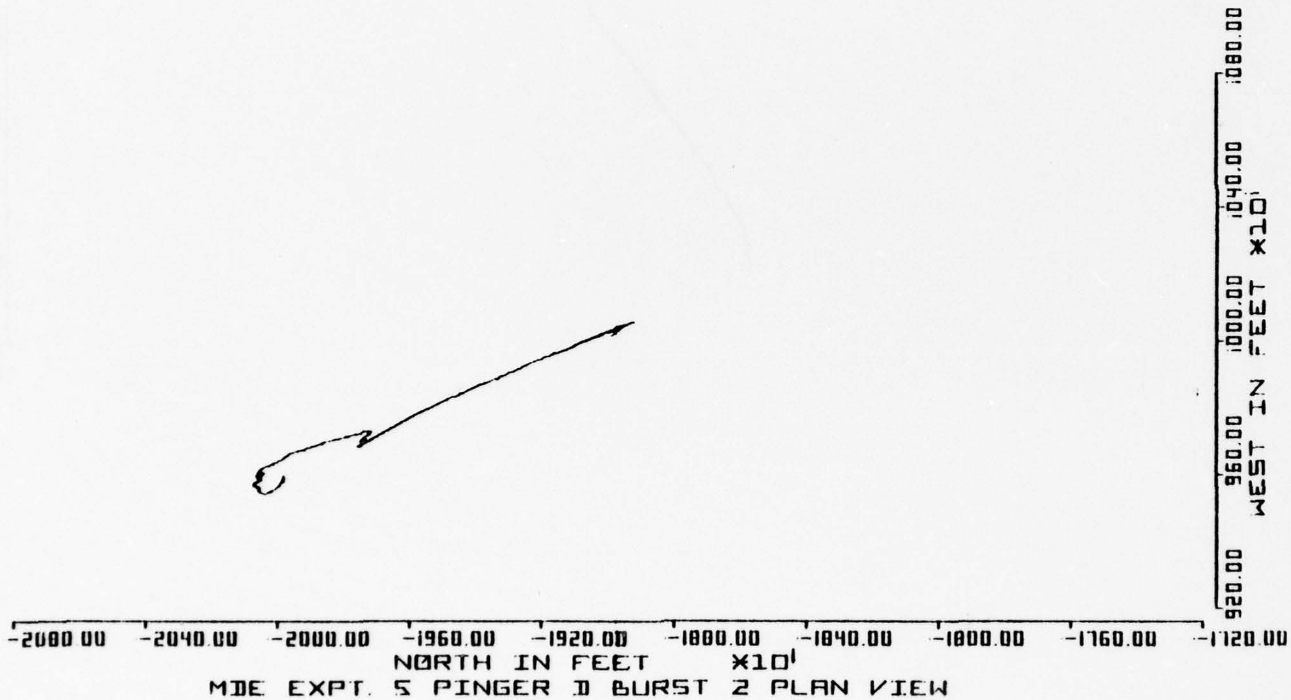
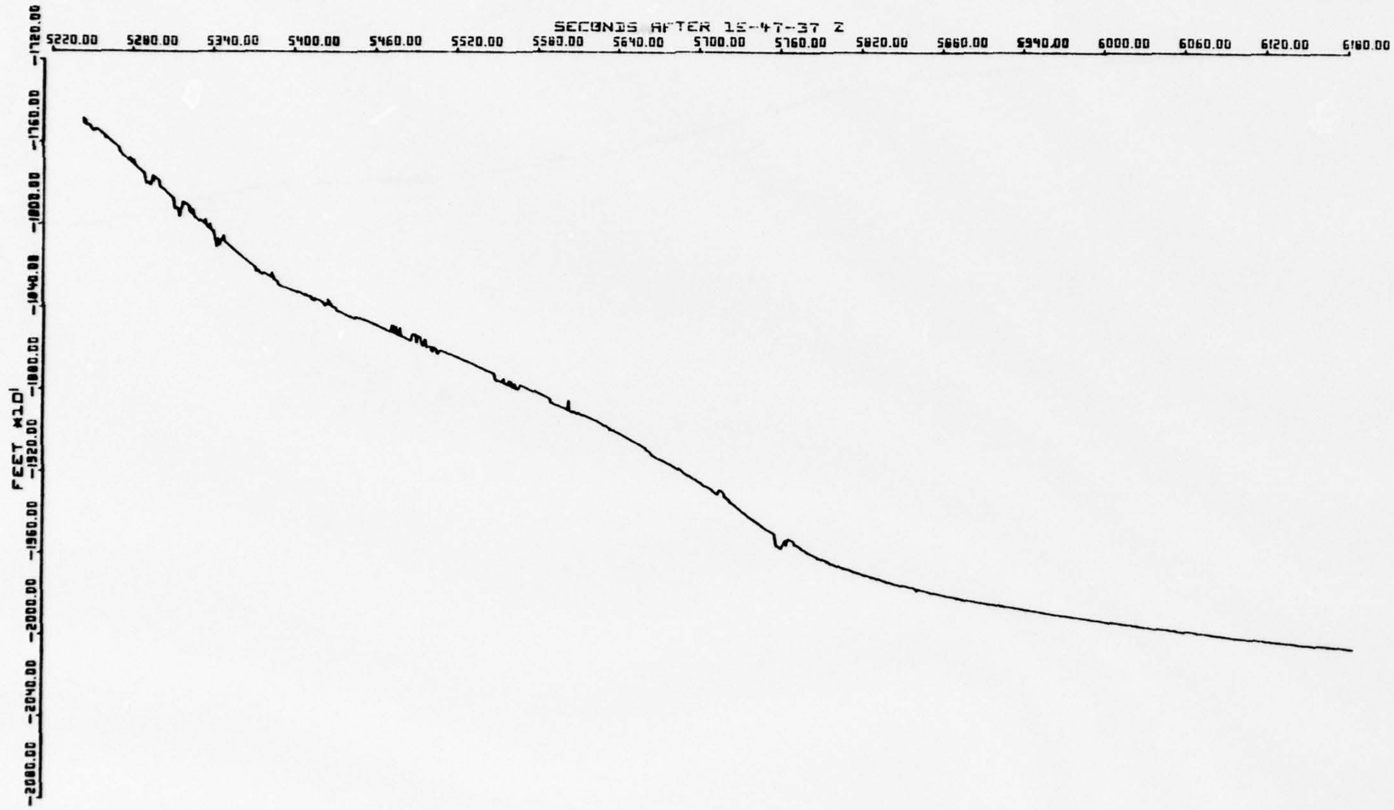

1080.00
1040.00
1000.00
960.00
920.00
WEST IN FEET ×10[1]
-2080.00
-2040.00
-2000.00
-1960.00
-1920.00
-1880.00
-1840.00
-1800.00
-1760.00
-1120.00
NØRTH IN FEET ×10[1]
MDE EXPT. 5 PINGER D BURST 2 PLAN VIEW

Figure F-12.



MIDE EXPT. 5 PINGER 6 BURST 2 NORTHWARD

Figure F-13.

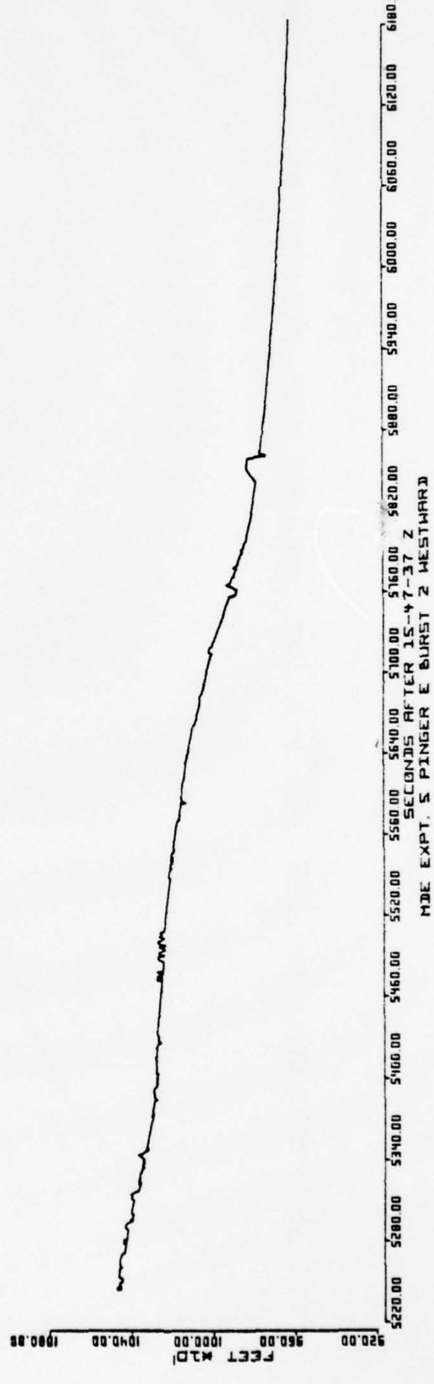

SECONDS AFTER 15-47-37 Z
MIE EXPT. 5 PINGER E BURST 2 WESTWARD
FEET MLD

Figure F-14.

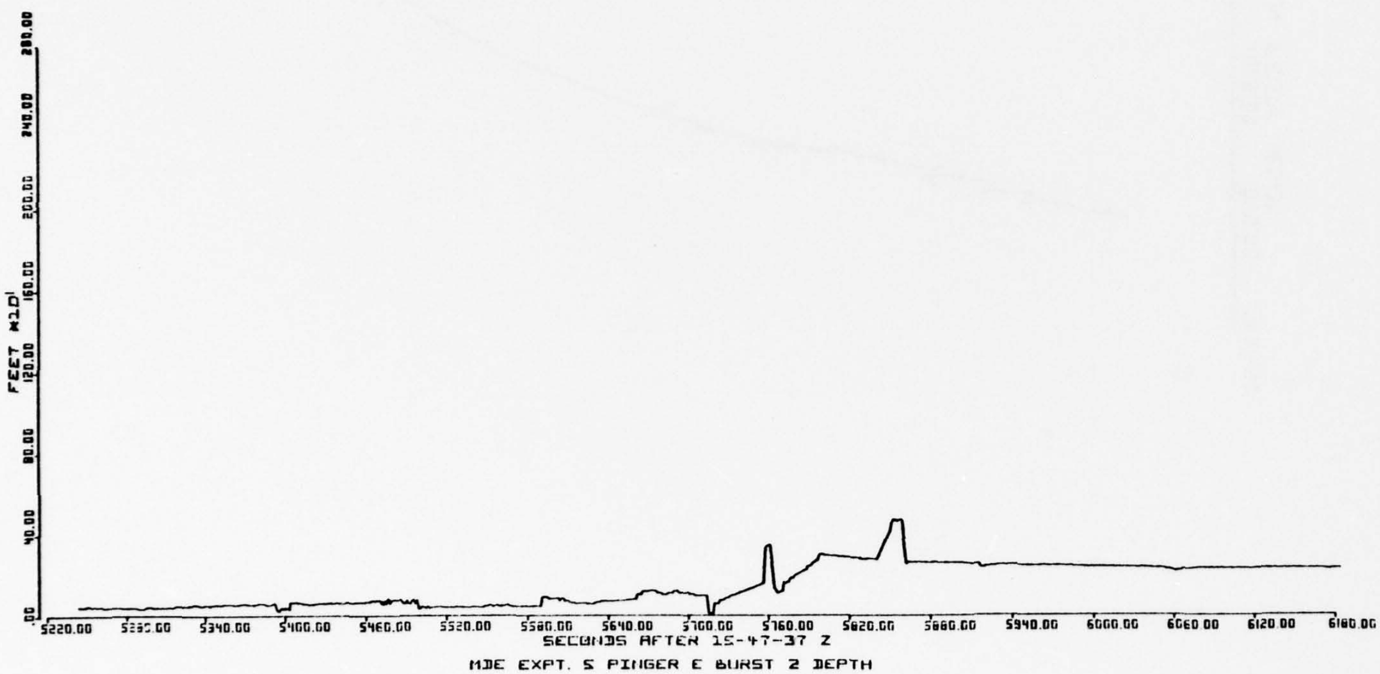

FEET ×10¹
.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
5220.00
5340.00
5400.00
5460.00
5520.00
5580.00
5640.00
5700.00
5760.00
5820.00
5940.00
6000.00
6060.00
6120.00
6180.00
SECONDS AFTER 15-47-37 Z
MDE EXPT. 5 PINGER E BURST 2 DEPTH

Figure F-15.

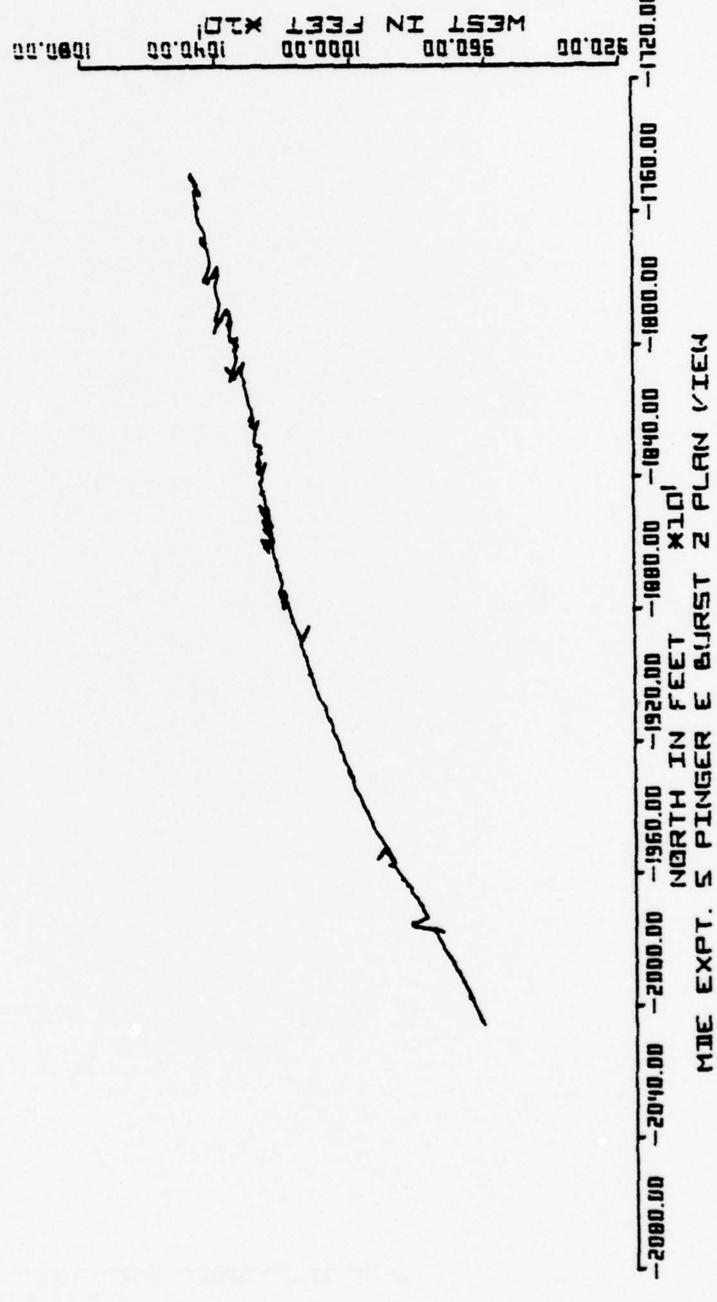

WEST IN FEET ×10¹
920.00
960.00
1000.00
1040.00
1080.00
-1720.00
-1760.00
-1800.00
-1840.00
-1880.00
-1920.00
-1960.00
-2000.00
-2040.00
-2080.00
NORTH IN FEET ×10¹
MIDE EXPT. 5 PINGER E BURST 2 PLAN VIEW

Figure F-16.

APPENDIX G

SNAPSHOT PLOTS OF CEL MOORING DEPLOYMENT

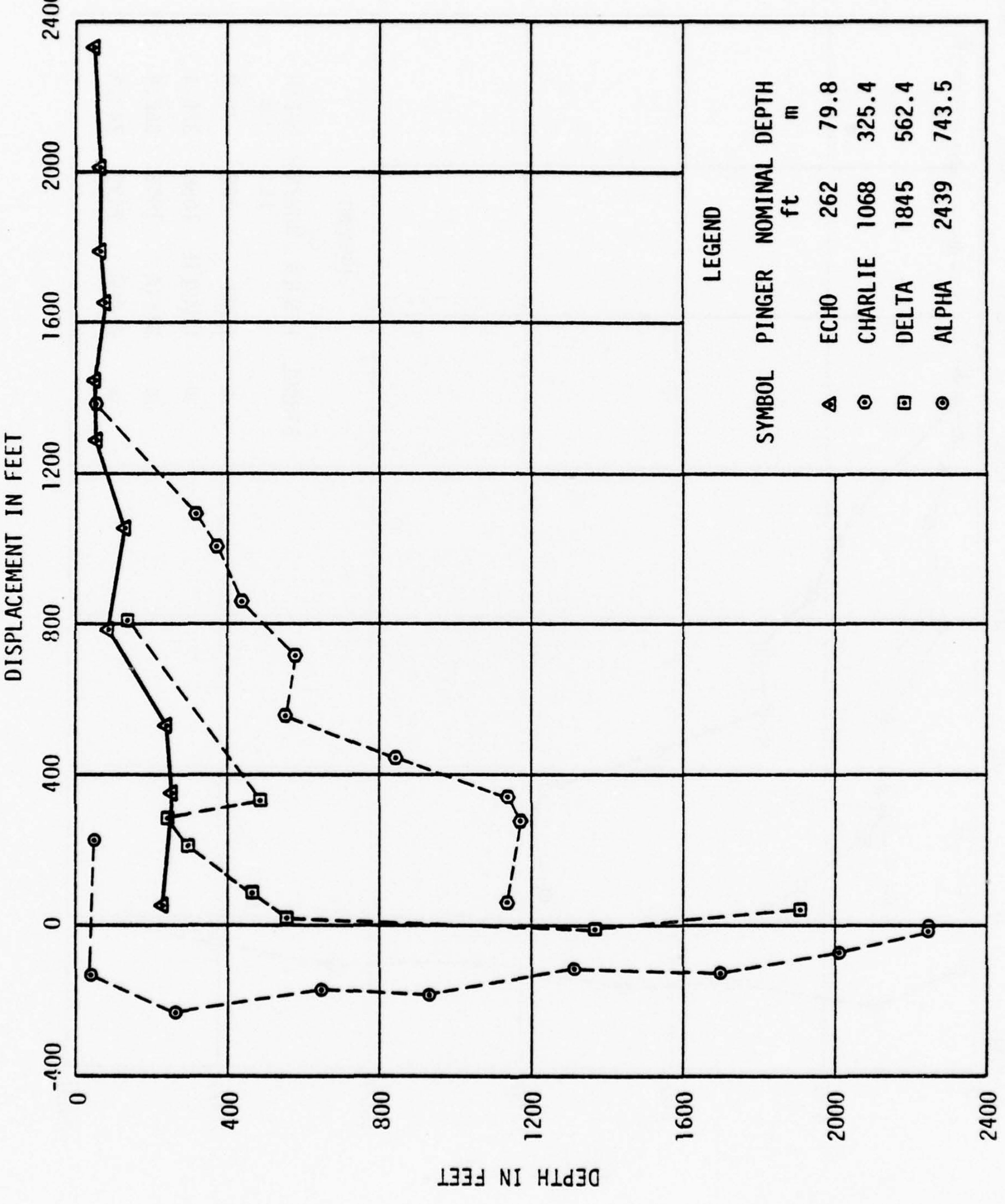


Figure G-1. Deployment Trajectory for Pinger ECHO

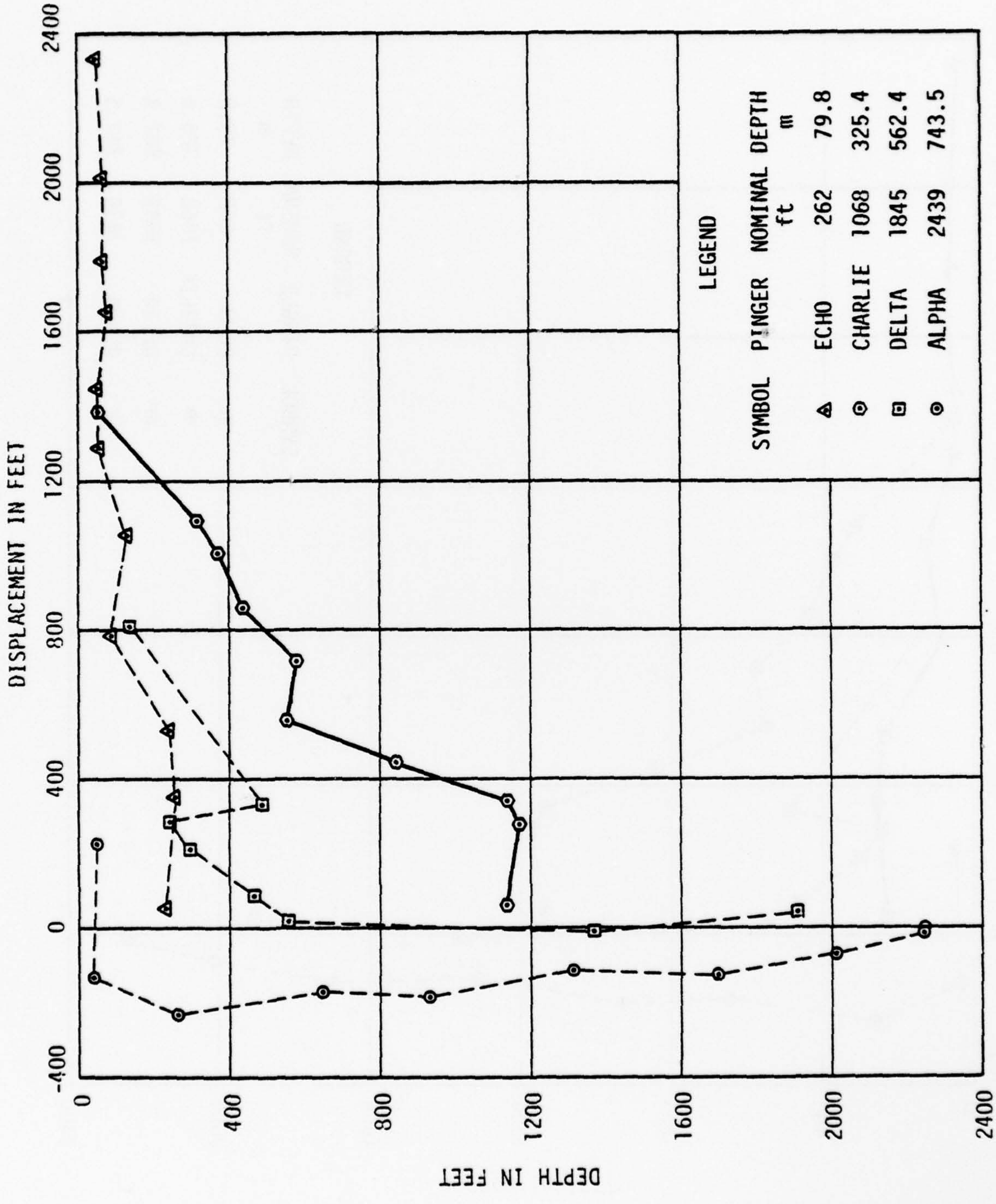


Figure G-2. Deployment Trajectory for Pinger CHARLIE

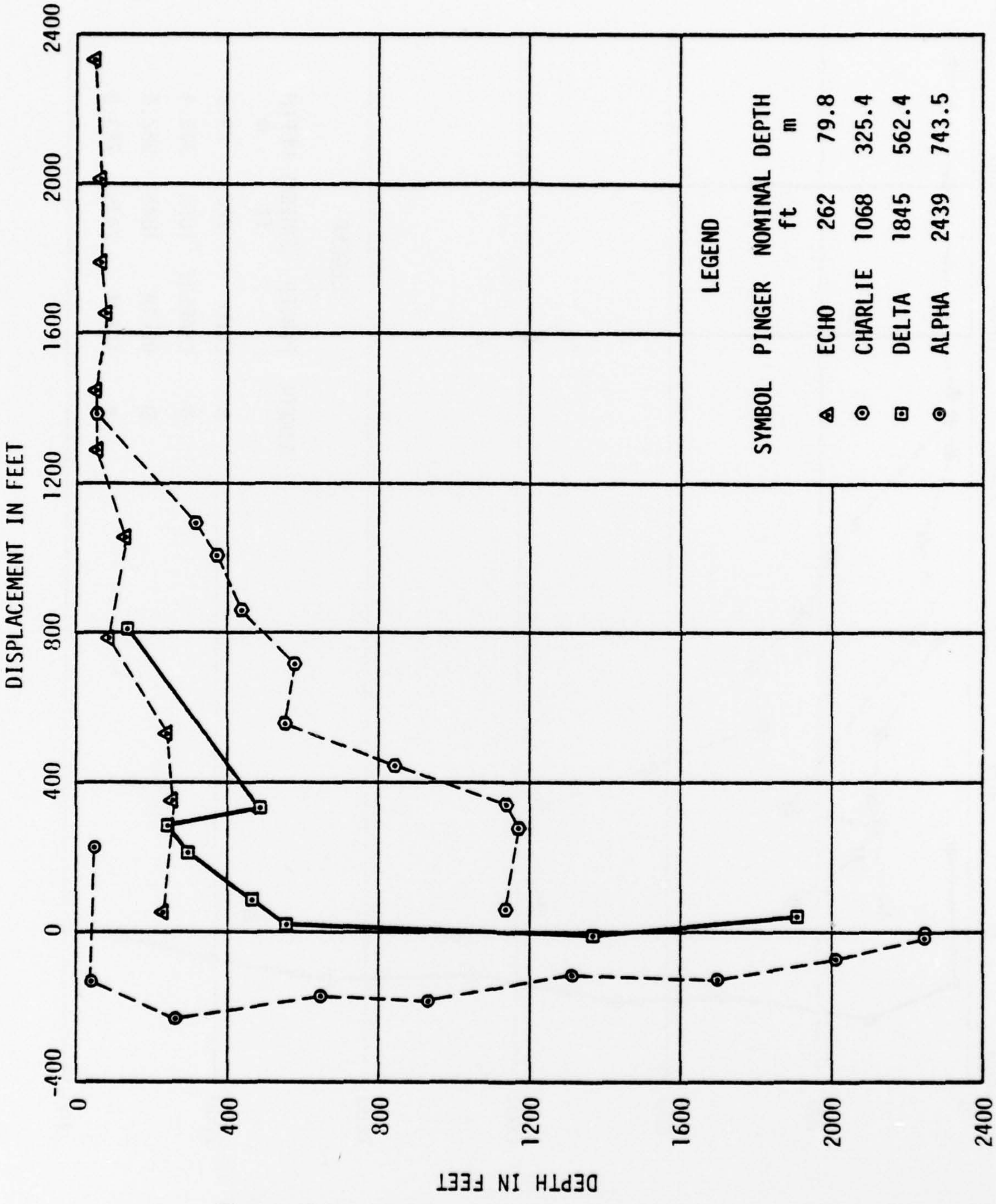


Figure G-3. Deployment Trajectory for Pinger DELTA

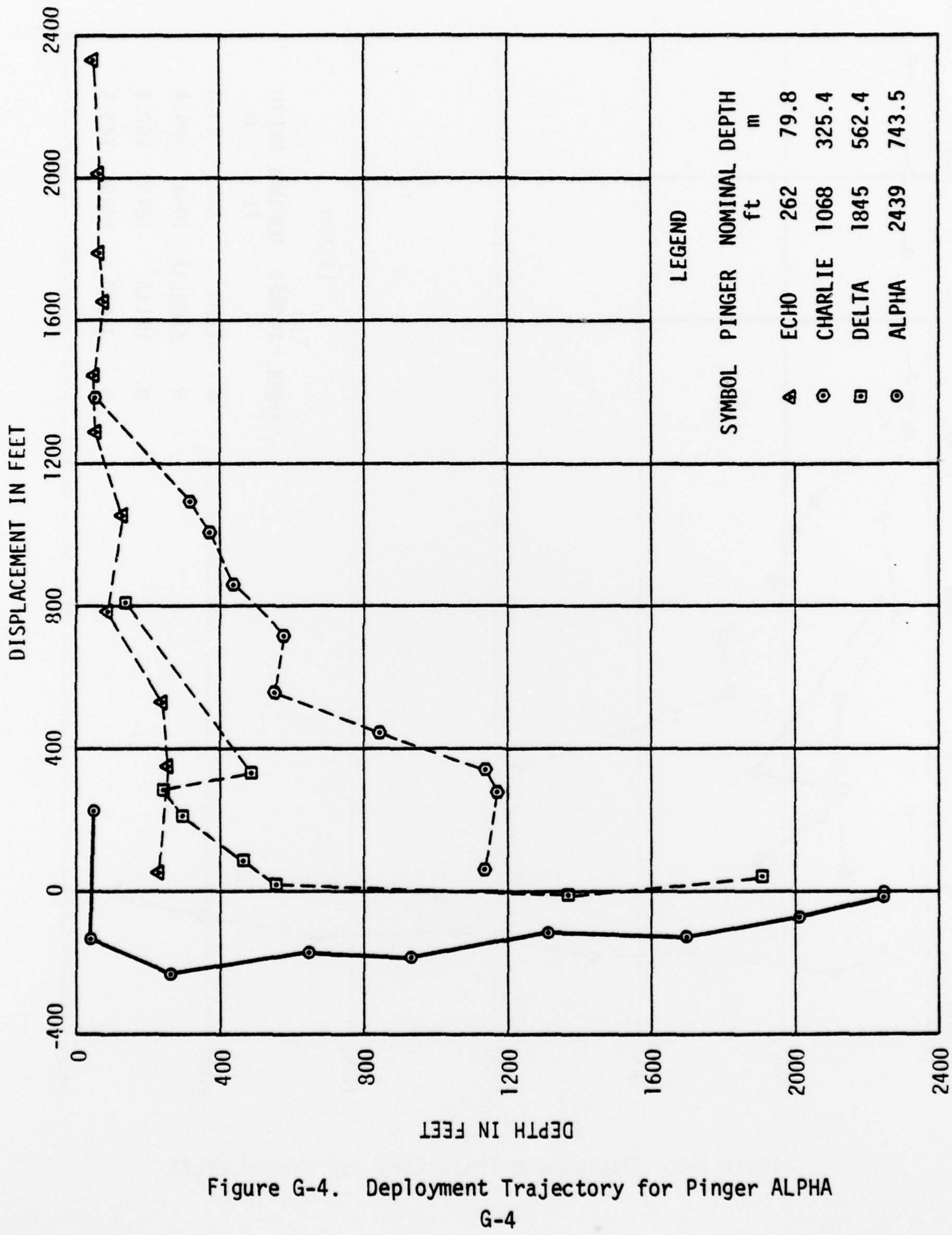


Figure G-4. Deployment Trajectory for Pinger ALPHA

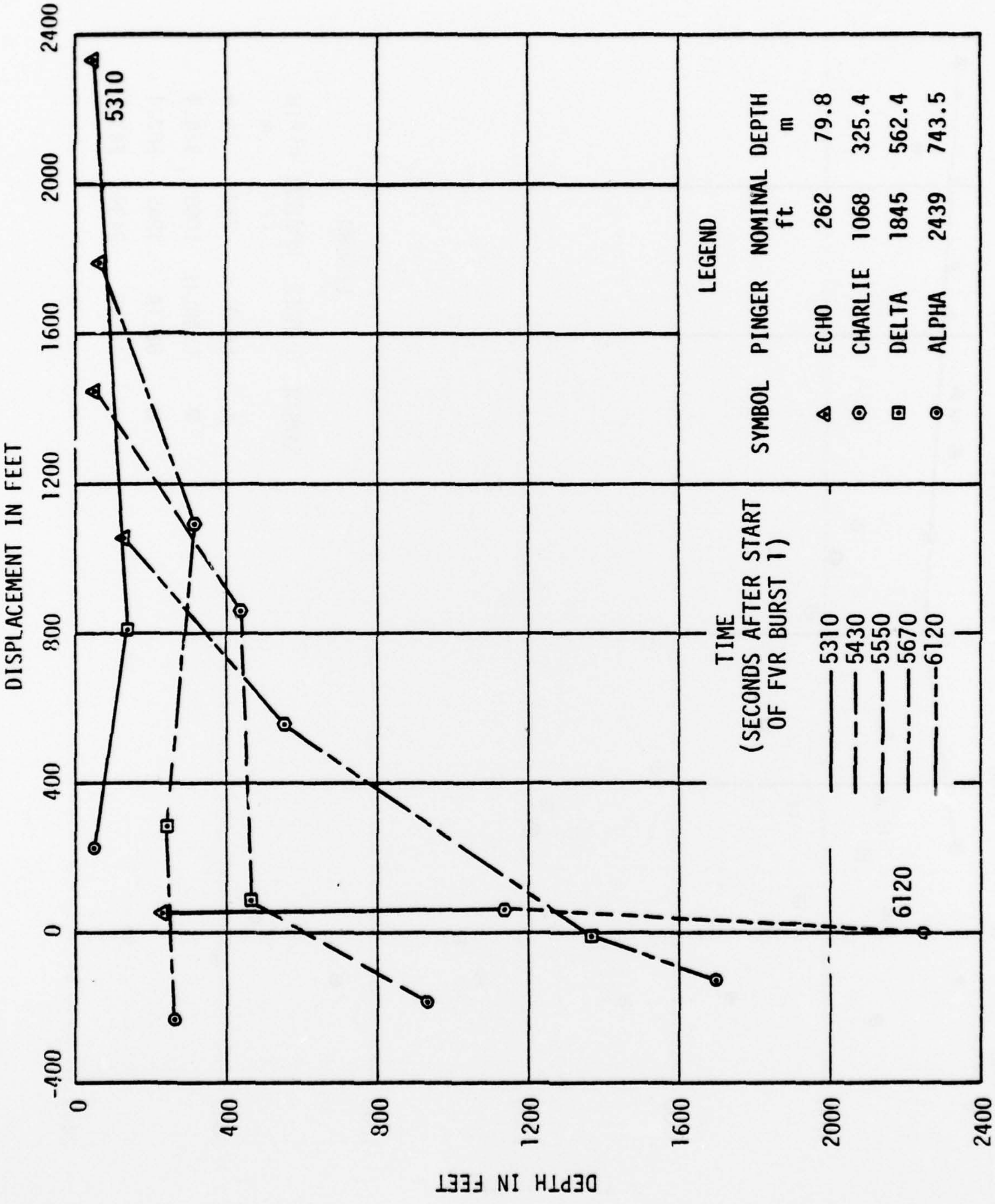


Figure G-5. Deployment "Snapshots" of CEL Mooring

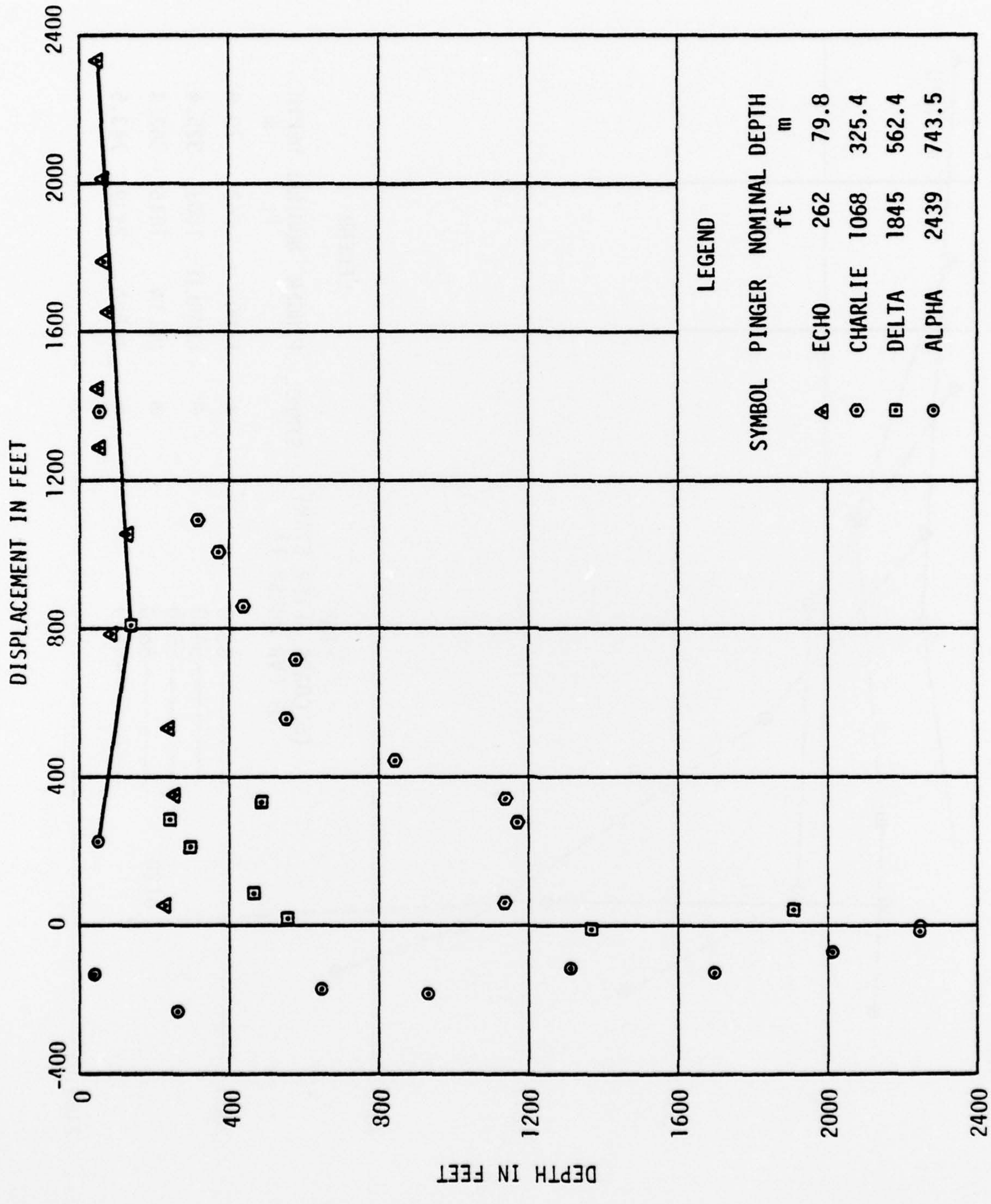


Figure G-6. Deployment Configuration at 5310 Seconds

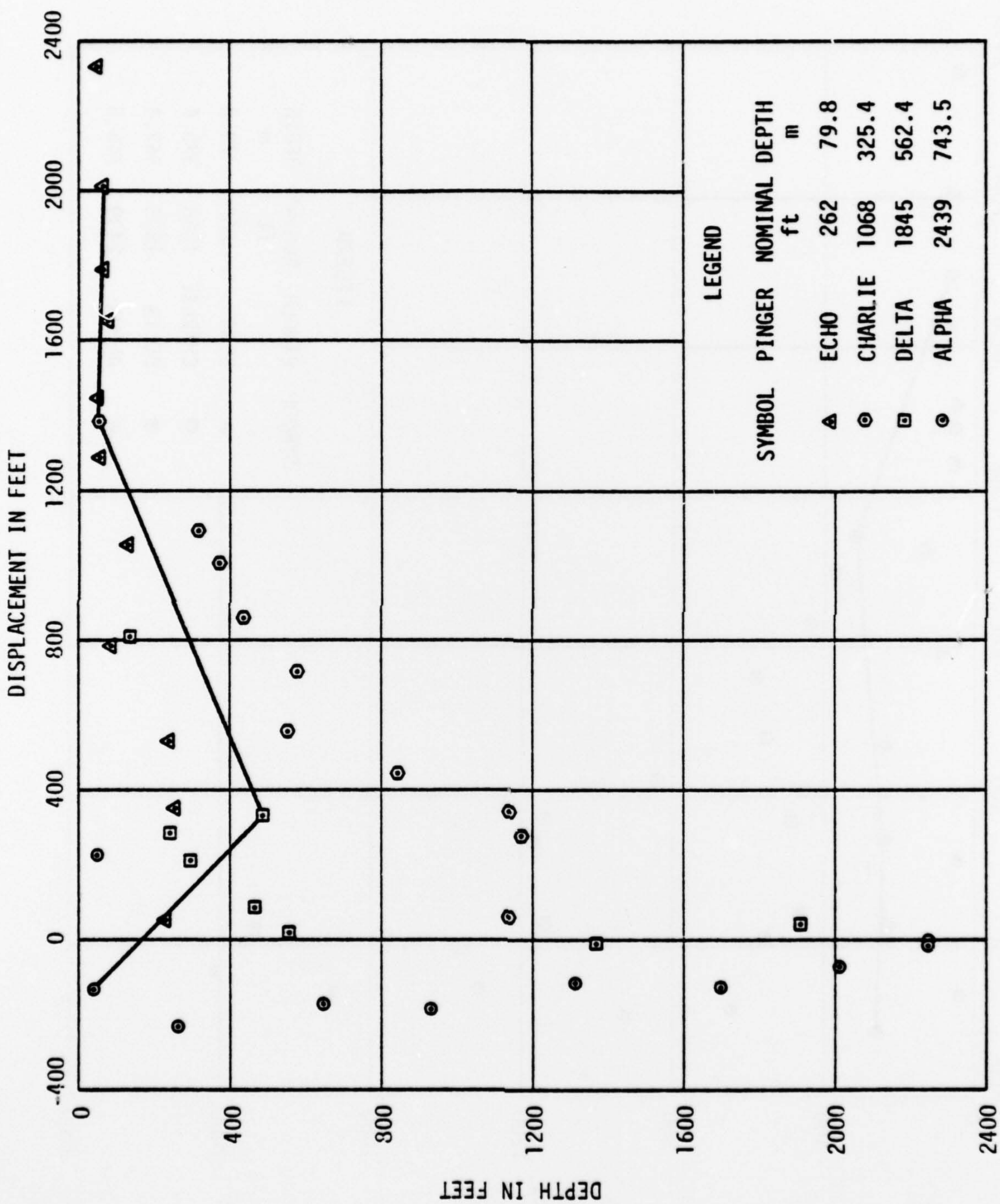


Figure G-7. Deployment Configuration at 7370 Seconds

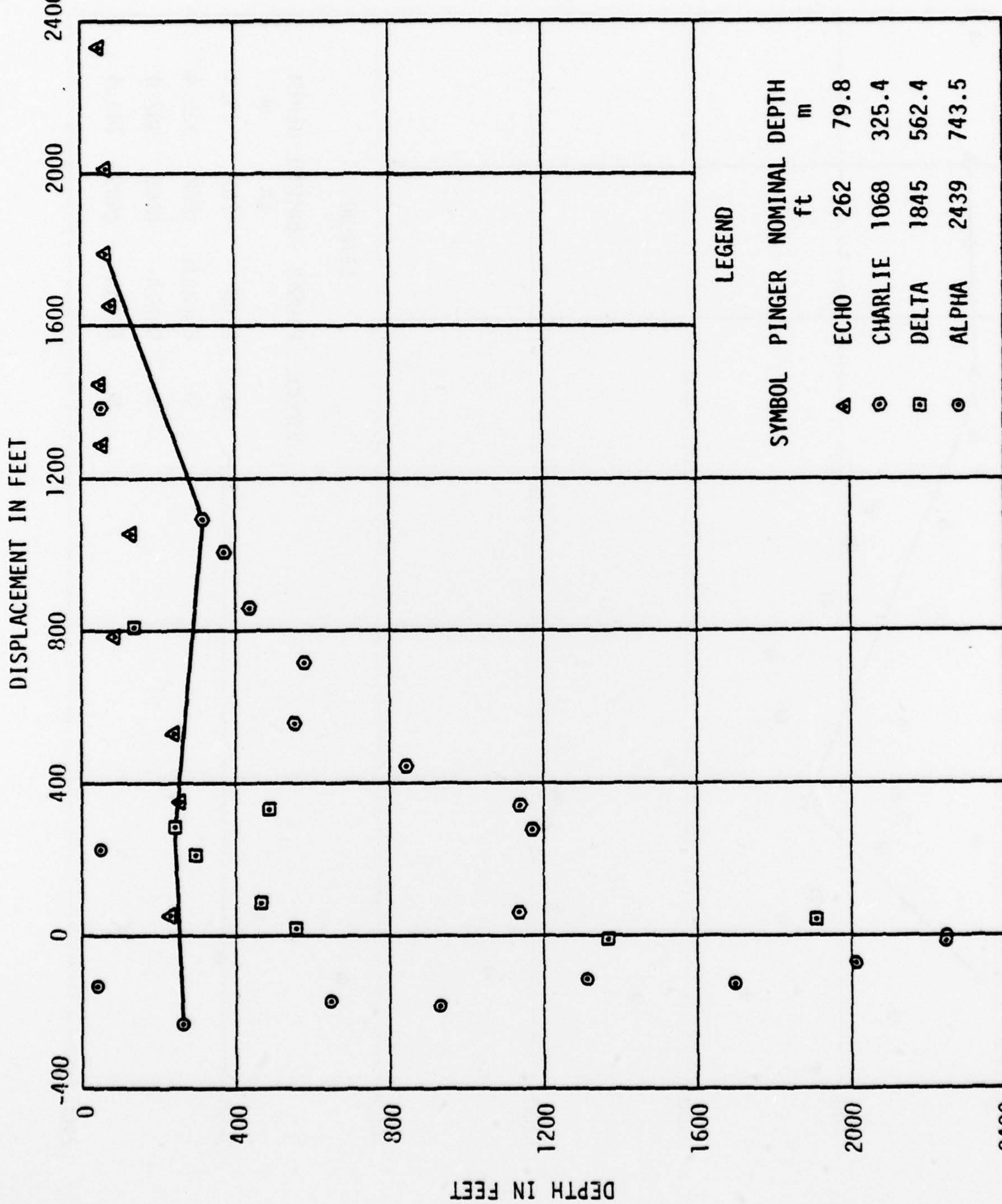


Figure G-8. Deployment Configuration at 5430 Seconds

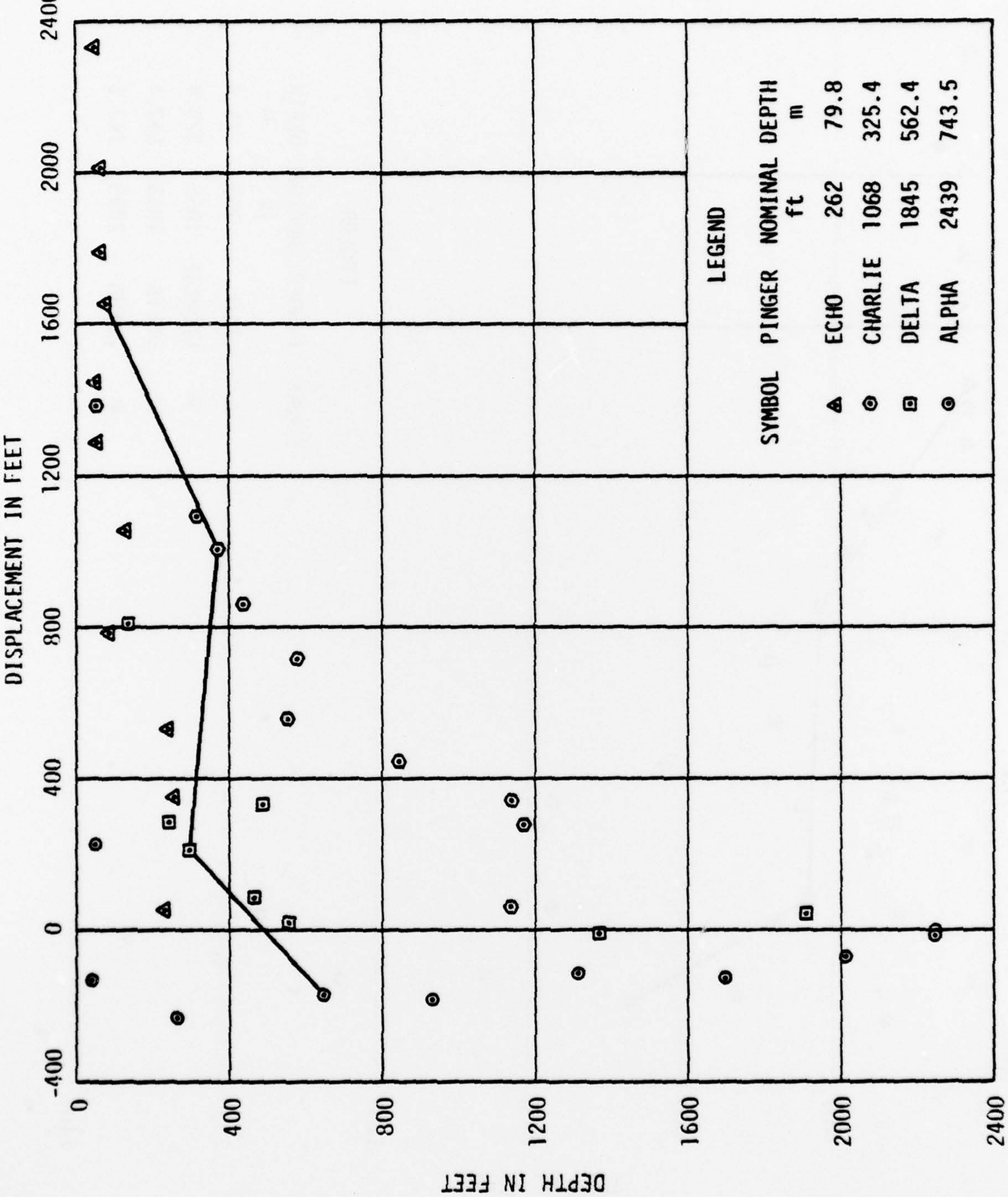


Figure G-9. Deployment Configuration at 5490 Seconds

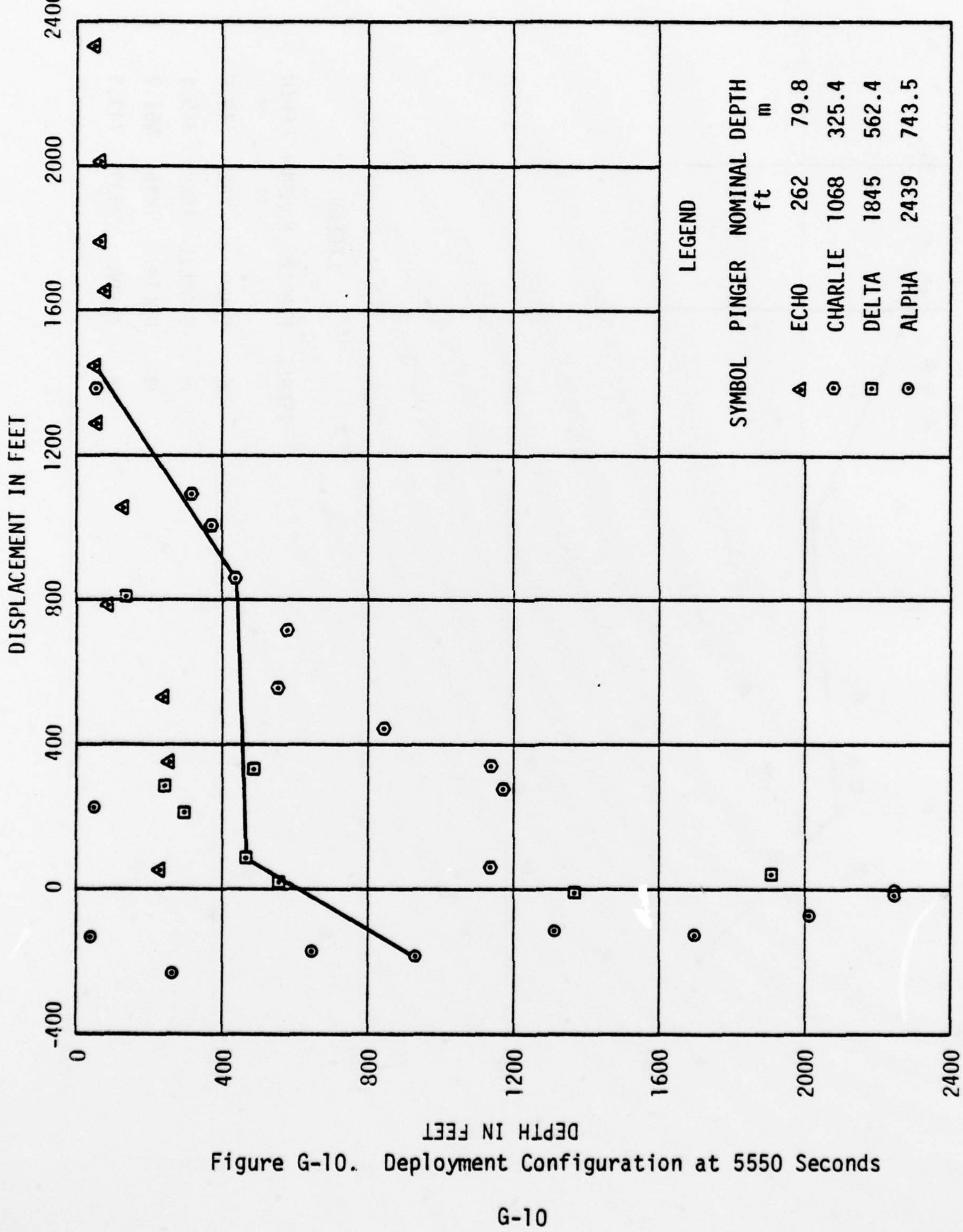


Figure G-10. Deployment Configuration at 5550 Seconds

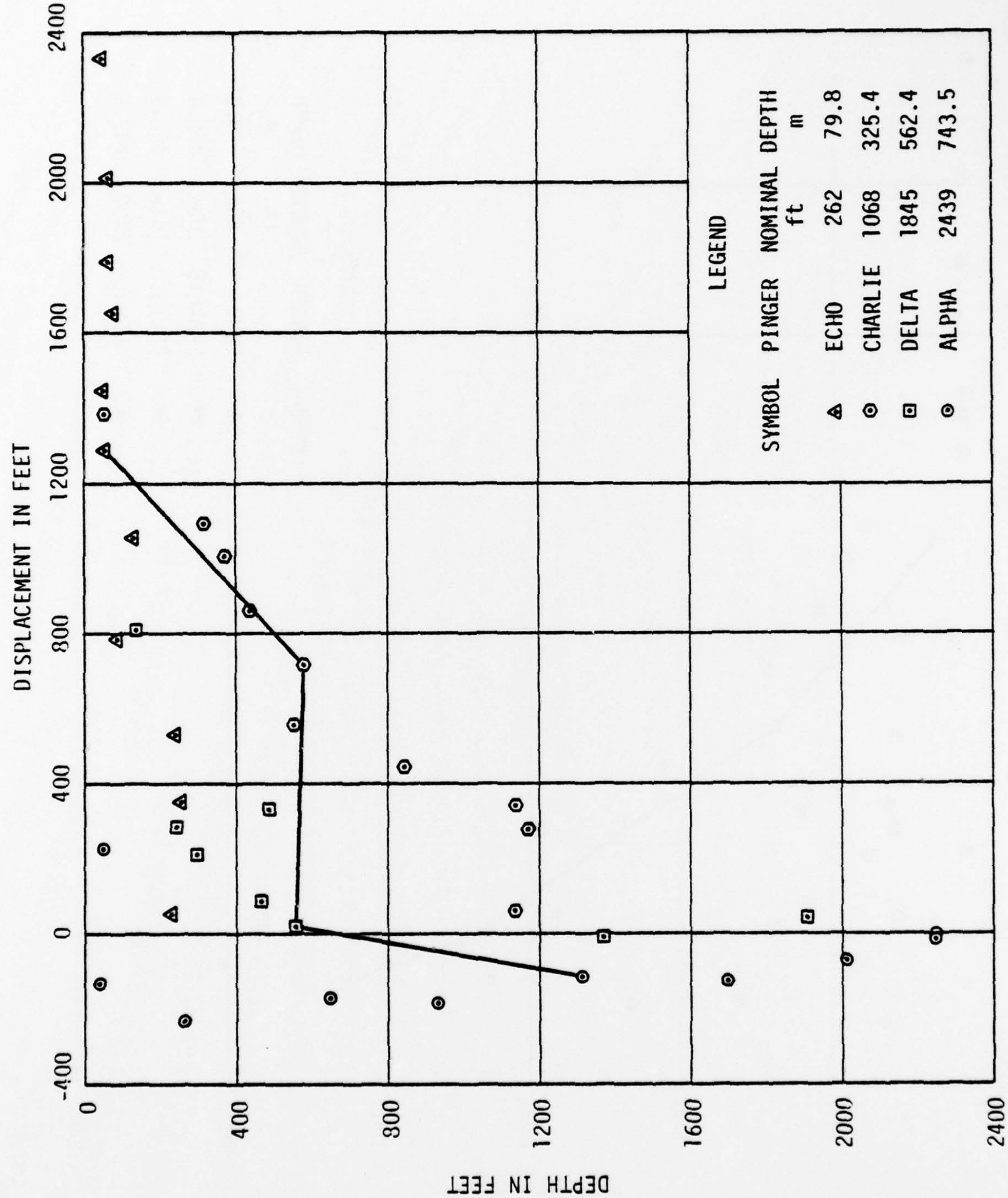


Figure G-11. Deployment Configuration at 5610 Seconds

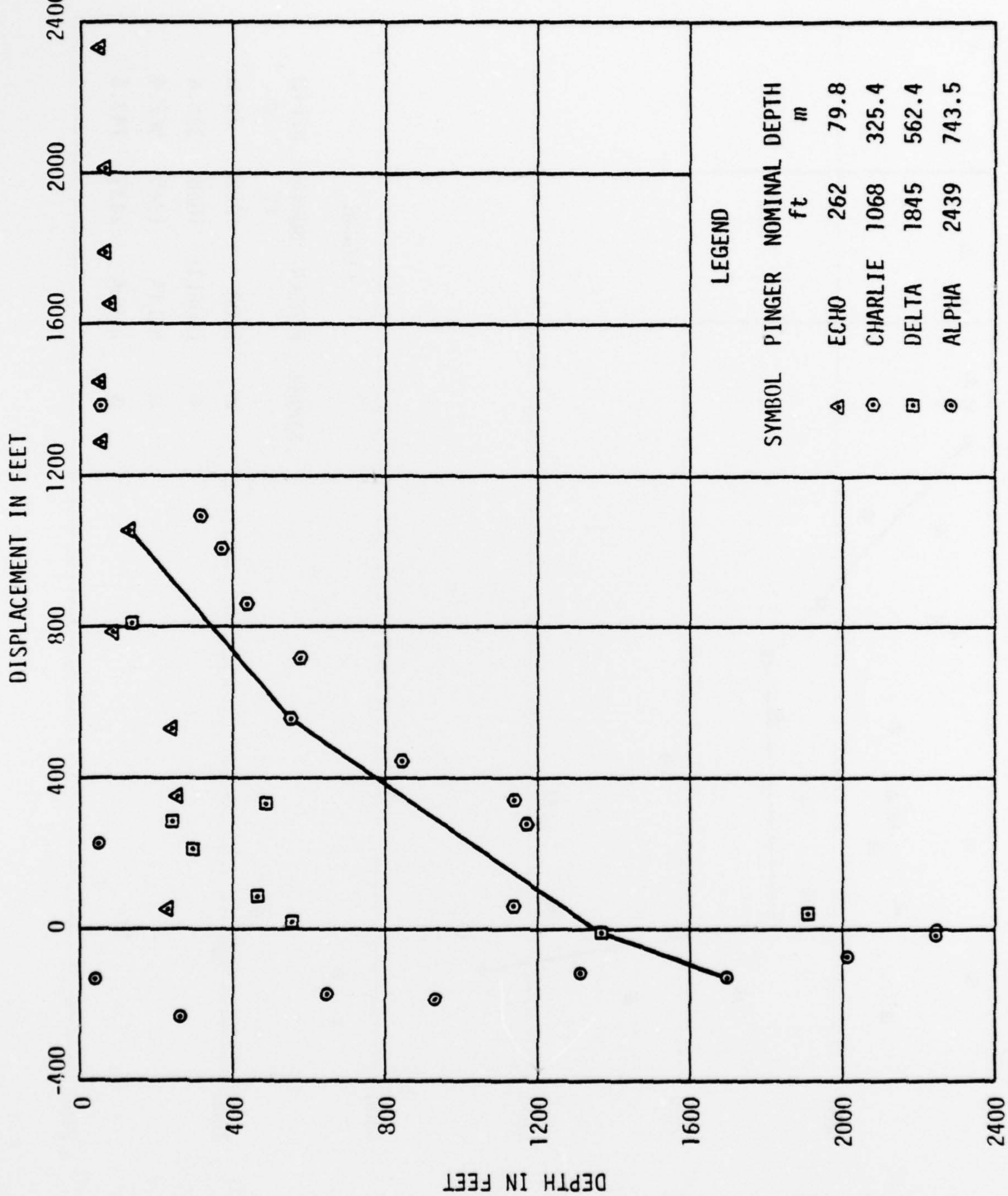


Figure G-12. Deployment Configuration at 5670 Seconds

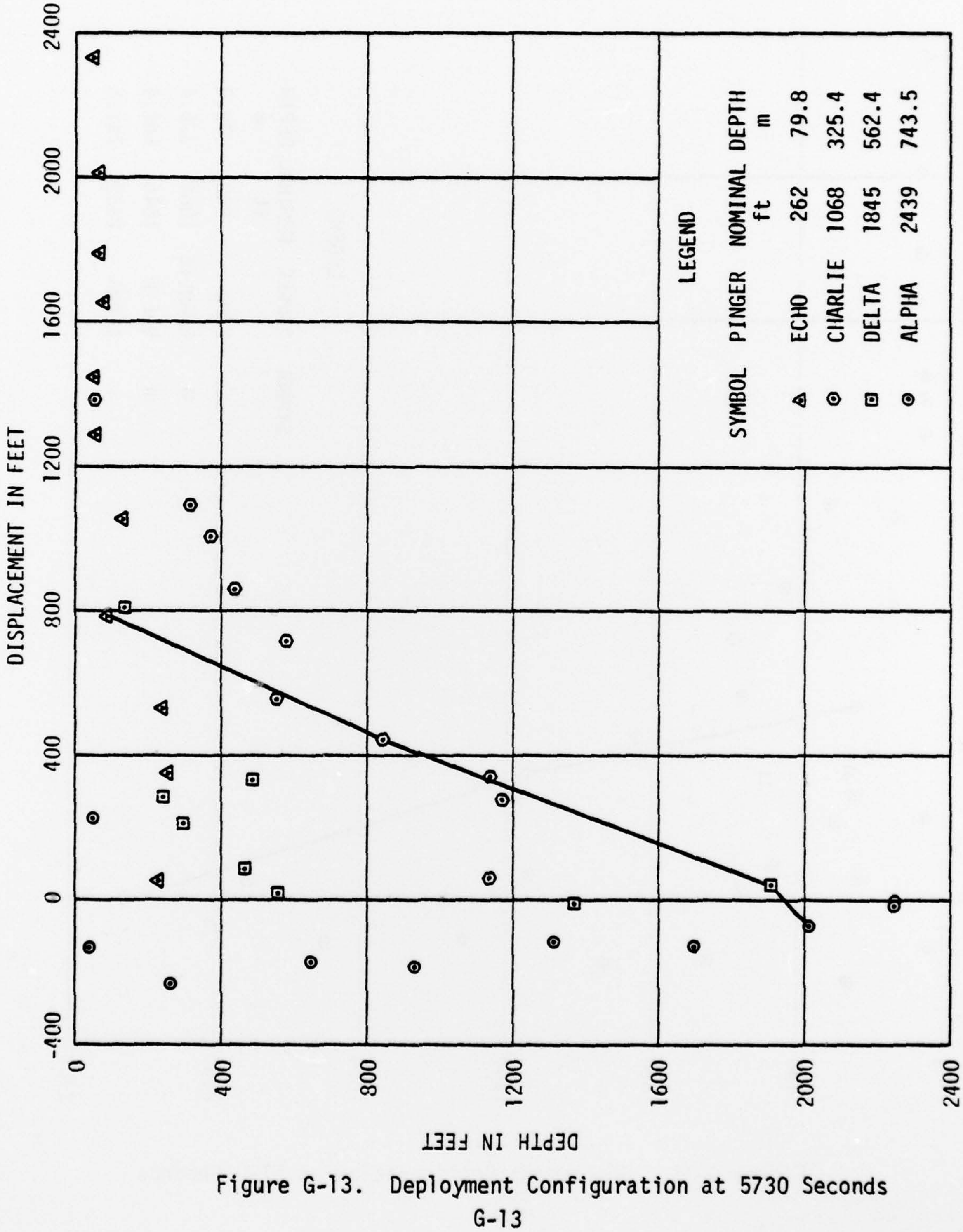


Figure G-13. Deployment Configuration at 5730 Seconds

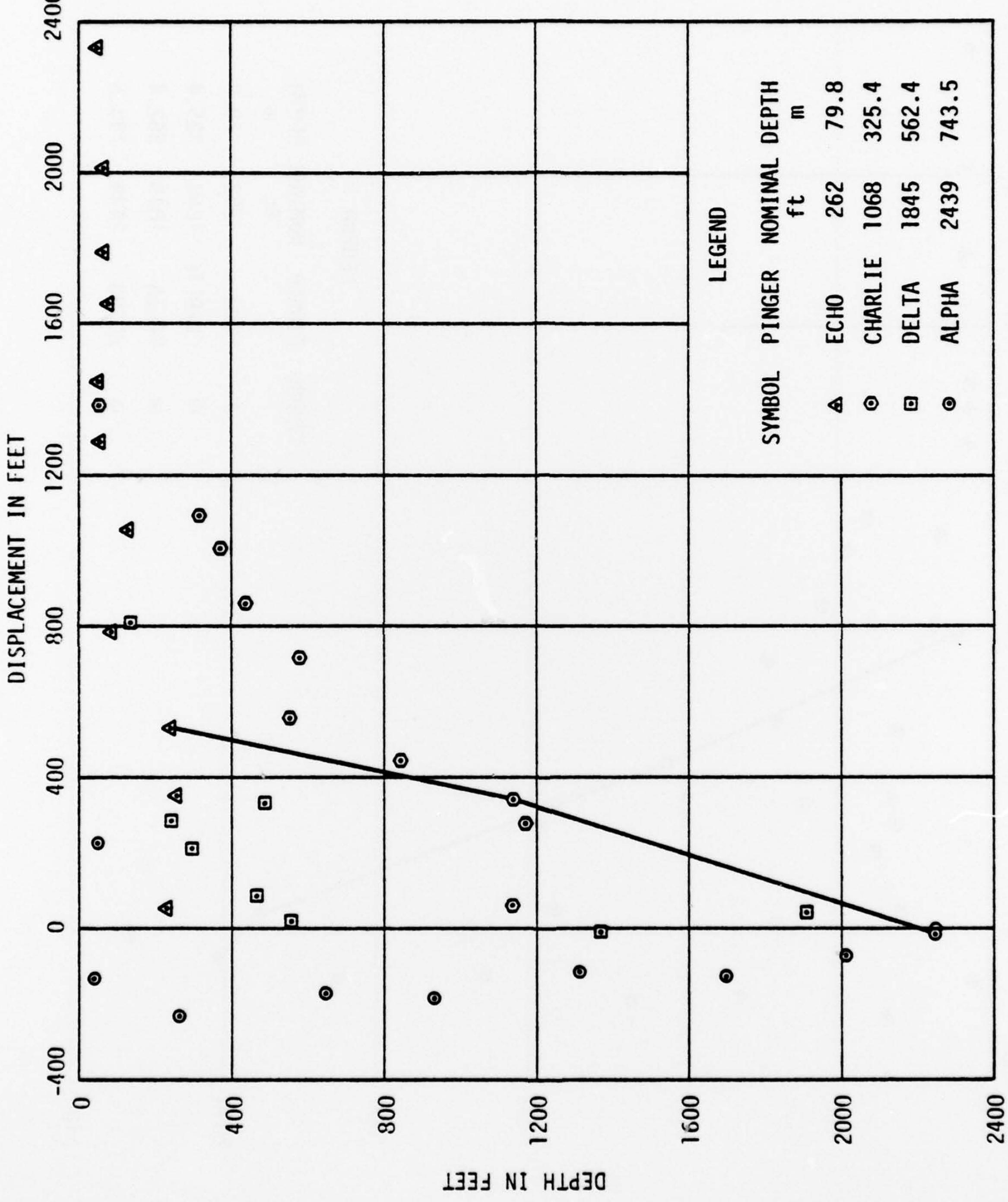


Figure G-14. Deployment Configuration at 5790 Seconds

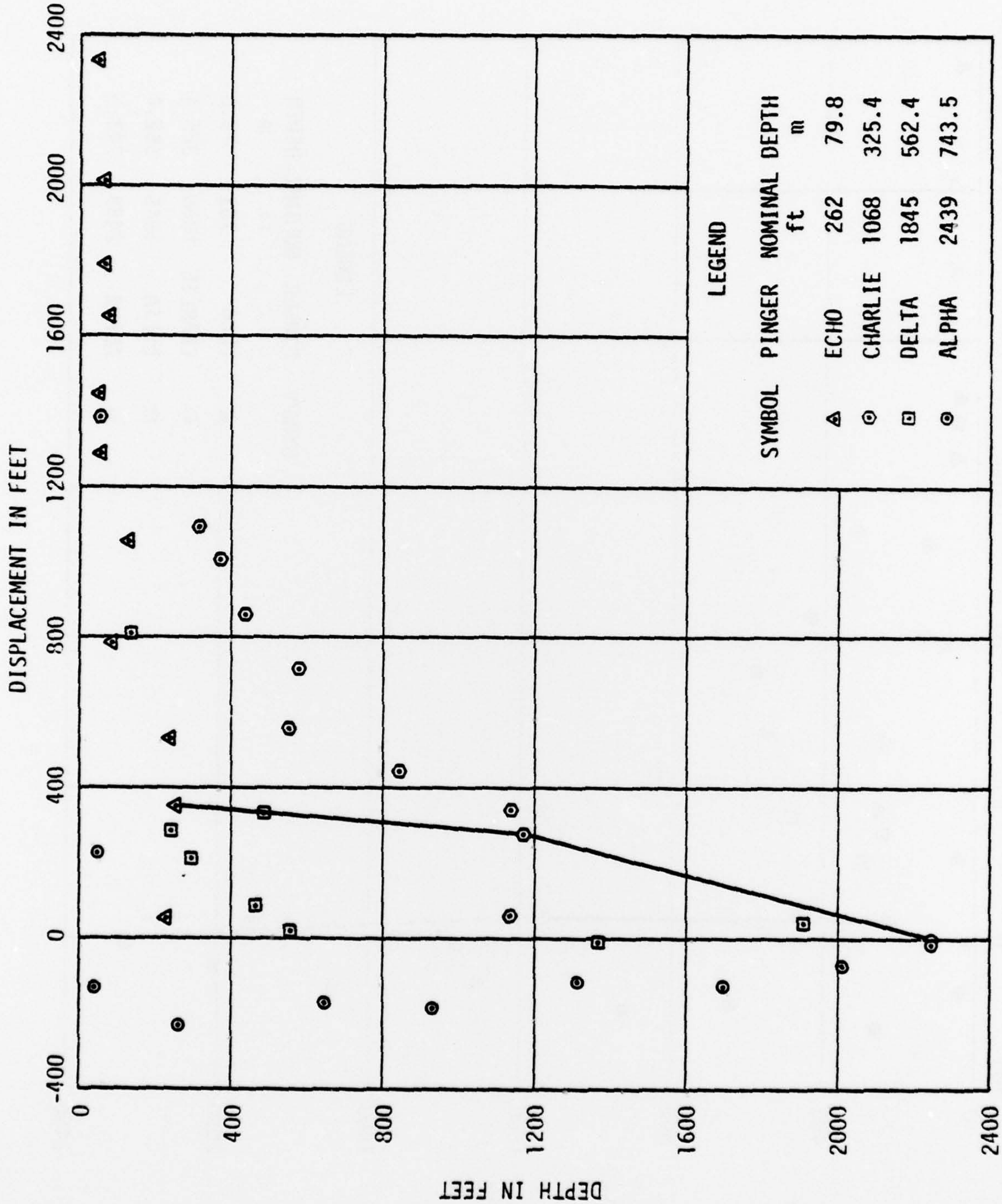


Figure G-15. Deployment Configuration at 5850 Seconds

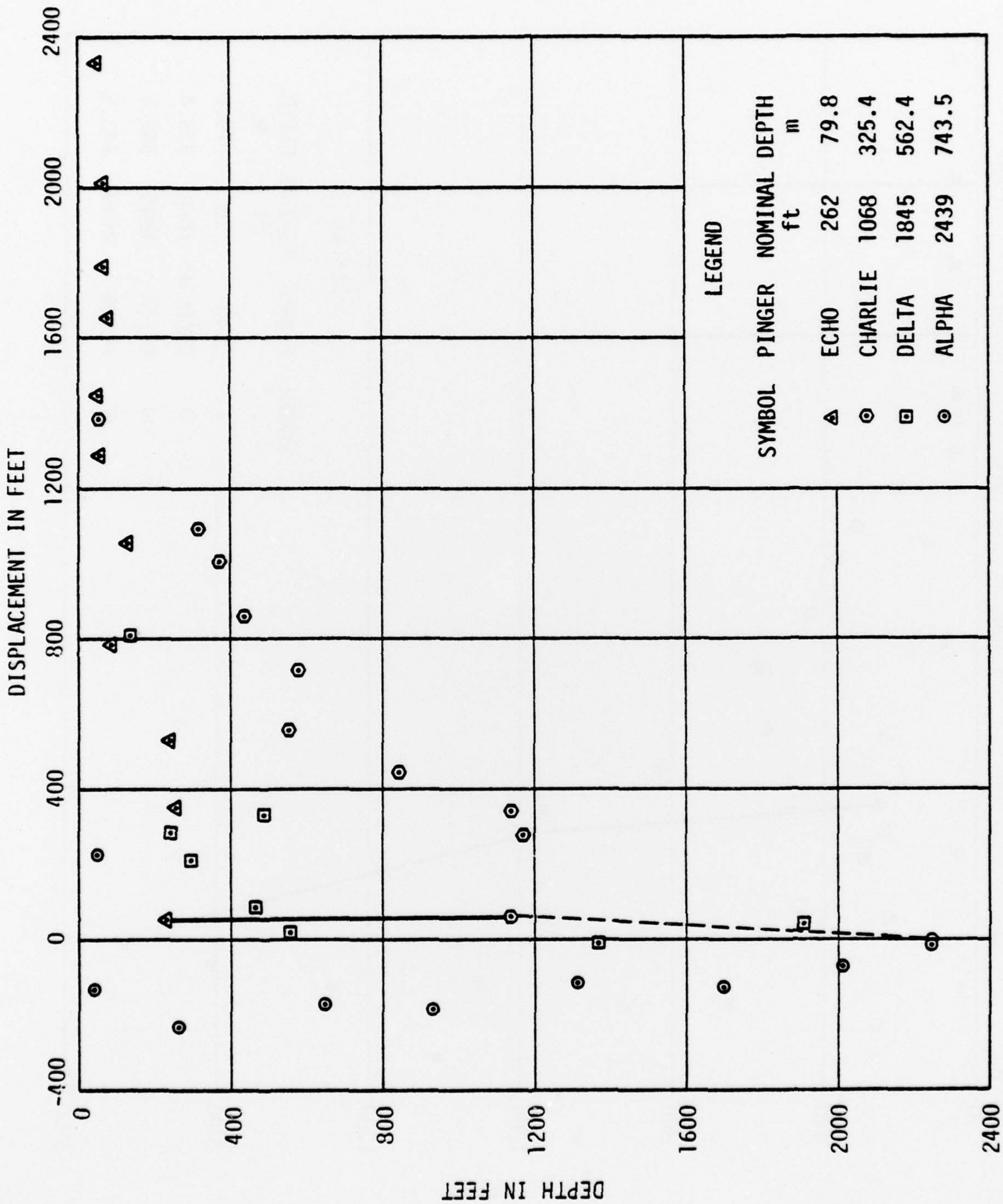


Figure G-16. Deployment Configuration at 6120 Seconds

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