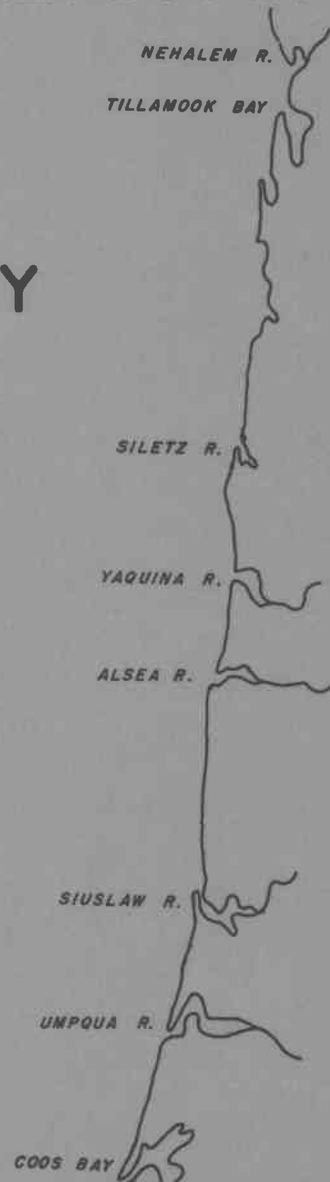
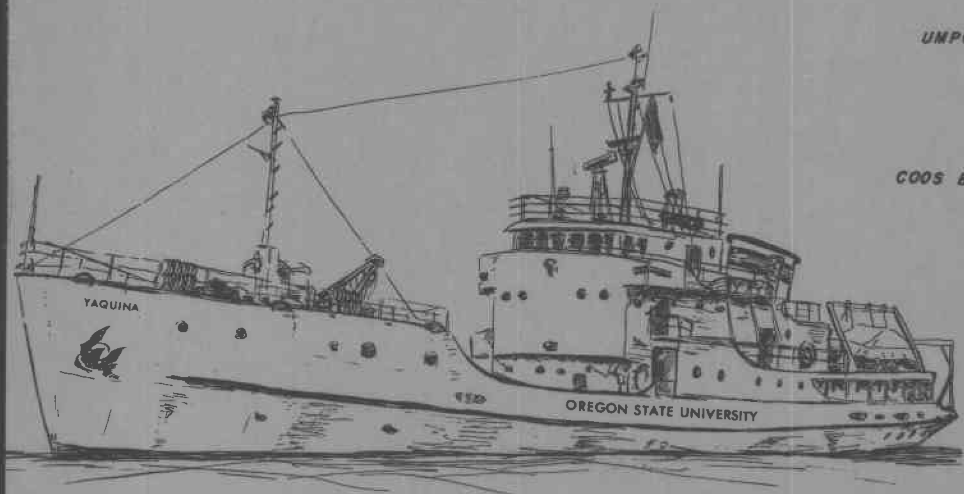
DEPARTMENT of OCEANOGRAPHY

SCHOOL of SCIENCE

OREGON STATE UNIVERSITY





A REPORT ON GEOMAGNETIC ELECTROKINETOGRAPH OBSERVATIONS OFF THE OREGON COAST

By

Thomas B. Curtin, Robert E. Still, and Steve Neshyba

OFFICE OF NAVAL RESEARCH
Contract Nonr 1286(10), Project NR 083-102

Date Report No. 32 **Reference 68-21**

September 1968

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Corvallis, Oregon 97331

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John V. Byrne
Chairman

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ABSTRACT

A summary of the first year's results in a program of current measuring techniques employing the electromagnetic method is presented. The data was taken on hydrographic survey cruises ranging to 165 miles offshore from Oregon. The measurements in this first phase consist solely of those taken by the method of towed electrodes behind a ship underway (GEK). Subsequent phases will include data from vertically moored arrays and from shallow water moored flow meter emplacements.

The emphasis in this data report lies in the first phase development of the electromagnetic method (towed electrodes) into a highly reliable tool for oceanographic research. In line with this accent both theoretical considerations and field testing are mentioned in this report. At this time the theoretical examination is in its embryonic stage, and the considerations included here are ones particularly applicable to the field work undertaken. This work is presented in a format of individual cruise reports. Some conclusions and avenues of future interest follow.

INTRODUCTION

In March 1967 the Department of Oceanography at Oregon State University received, on loan from the United States Naval Oceanographic Office, a geomagnetic electrokinetograph (GEK) recorder (Leeds and Northrup) with operating instructions and electrodes included. The purpose of this temporary acquisition was twofold: to undertake basic research on GEK data collection methods and interpretation improvement, and to develop a nucleus of experience in both methods and instrumentation around which to base a permanent GEK-hydrographic capability within the department as phase one of an electromagnetic methods program. In pursuit of these two goals several experiments were executed on a total of seven cruises in 1967. New equipment -- both purchased and developed -- will contribute to the more extensive and specific program planned for 1968.

THE GEK METHOD

GEK measurements in conjunction with hydrographic data can be extremely useful and perhaps unique in many particular areas and applications (see, for example, Von Arx, (1950), (1962)). General mass transport approximations (e. g. work presently being continued on the Gulf Stream by Manglesdorf (1962) of Woods Hole Oceanographic Institution) and horizontal current measurements in environments unfavorable to conventional current meters (e. g. areas of dense growth, the surf zone, etc.) are two of many such capabilities. Another is large scale velocity field scanning for the purpose of shear zone detection prior to employing high resolution techniques for more definitive study. However, the degree of utility depends heavily upon correct interpretive techniques. It is, therefore, of the upmost priority that not only the data presented here, but all GEK data, be examined carefully and accurately, with due regard to both the possibilities and the limitations of the content. A few of the major points relevant to the presented data are mentioned.

In applications of Maxwell's Equations with suitable initial and boundary conditions, Stommel (1948), Malkus (1952), Longuet-Higgins, Stern and Stommel (1954), Ryzhkov (1957), and Sanford (1967) have all formulated general expressions which relate the velocity field to the electrical potential field in the sea. Reasonable and pertinent analysis of electrical potential measurements within the limits of practical measuring devices, however, depends ultimately upon the model within which such measurements are formulated. The valid use of any model implies two important conditions -- that the assumptions made in constructing the model are satisfied, and that the resolution of the input data is compatible or at least on the same scale as that which the model produces as output results. For example, horizontal GEK measurements in shallow areas may necessitate the use of a model which accounts for variable earth currents. Vertical GEK probes may require a consideration of time variability of the earth's magnetic field. An indication of general main flow characteristics can be deduced from rough integration and averaging techniques, whereas a careful analysis of a particular current structure would call for a model capable of resolving hydromagnetic and Alfven waves (magneto-hydrodynamic waves with transverse type characteristics).

An insight into most of the data presented here can be gained by establishing some conditions which it seems to fulfill generally. First of all, the flow is broad compared with the depth. The continental shelf is approximately 15-35 miles wide off the central coast of Oregon. West of this distance the depth in the relevant localities is of the order of 2000 to 3000 meters. Thus, flows of over 7 kilometers in horizontal width are referred to under this condition. Secondly, the flow is narrow compared to $(\sigma_1/\sigma_2)h$, where σ_1 is the conductivity of the seawater, σ_2 that of the sea bed, and h the depth. Local temperature and salinity data of the surface water indicate σ_1 to be about $3.8\,\Omega^{-1}\,m^{-1}$ (Bein, Hirsekorn, and Moller, 1935). An analysis of thermal and electrical conductivities of ocean sediments off Oregon (Hutt, 1966) leads to an approximate value of σ_2 at $0.65\,\Omega^{-1}m^{-1}$. Therefore, the flow should be narrow compared to about six times the depth. Currents of between 7 and 8 kilometers in width should satisfy both requirements. Finally, the distance between the two points at which the potential is measured should also exhibit an upper bound of $(\sigma_1/\sigma_2)h$. This bound is met with in all measurements taken.

These conditions are particularly convenient because they allow the use of a two-dimensional approximation model, formulated by Sanford (1967), which is applicable to the method of towed electrodes at the surface. Assuming the validity of the above assumptions, and for a flow described in a right hand coordinate system with the x axis aligned with the flow and z measured positively upward, the vertical and the horizontal electric current densities are:

$$J_y = -\sigma\{F_z[V(y,z) - \bar{V}(y)] + F_y \frac{\partial}{\partial y}[\int_{-h}^{z} V(y,\xi)\,d\xi + \int_{-h}^{0} \frac{\xi}{h} V(y,\xi)\,d\xi]\} \qquad (I)$$

$$J_z = -\sigma\{F_z \frac{\partial}{\partial y} \int_{z}^{0} [V(y,\xi) - \bar{V}(y)]\,d\xi\} \qquad (II)$$

where F_z = vertical component of the earth's magnetic field

F_y = component of earth's magnetic field perpendicular to the flow

σ = conductivity of surface water

v = velocity of water in x direction

$\bar{v}$ = vertically averaged velocity in x direction

h = depth of water at point of measurement

For towed electrodes at the surface the horizontal current density, J_y, is of interest since this is essentially what is reflected in the measurements. By Ohm's law the expression in brackets represents the electric field associated with such a current, and this field is expressable as the gradient of a potential. It is this electric potential that the GEK electrodes measure.

It will be noted in the data presented here that only the north-south ocean current components have been charted and receive attention. There are three reasons for this procedure. First of all, patterns and changing trends are more easily recognized in this way. Secondly, the major transport of water in the region of GEK measurements occurs in these directions. Finally, local conditions lead to an interesting result in the above equations for currents in such directions. The ratio of vertical to horizontal components of the earth's magnetic field can be expressed by:

$$F_z/F_H = \cot \theta$$

where θ is the latitude. Since the measurements were made at approximately 45° N., this ratio is 1. The horizontal magnetic declination in this area is 20.5°. Therefore:

$$F_H = F_N / \cos 20.5° = F_N / .936$$

$$F_H = F_E / \cos 69.5° = F_E / .350$$

which gives,

$$F_z / F_N \approx 1.1$$

$$F_z / F_E \approx 3.3$$

For flow in the north-south direction, F_z and F_E would be the components of interest, and in equation (I) the first expression in the bracket, whose total value is the electric potential gradient, would be weighted more than three times the second expression due to the geomagnetic field terms only. (For east-west flow, both magnetic field componenet terms are about equal, and this argument does not hold.) Combining this observation with the fact that the second expression is small due to the assumptions made about the flow* enables a good approximation to be stated by using just the first expression. That is, the signal (electrical potential difference) measured by the GEK electrodes in the following data can be represented as follows:

$$\Delta \phi \approx -F_z \left[V(Y,0) - \bar{V}(Y) \right]$$

The term in brackets is the difference between surface velocity and vertically averaged velocity. This is an important fact to keep in mind in examining the contained GEK results.

Another point also merits some attention. All experiments were done with neutrally buoyant cables; some were carried out in rough weather. None of the data has been corrected for such environmental factors. However, the quantitative errors due to these factors should be noted where applicable. To appreciate the range of these errors with buoyant cables, the partial results of experiments carried out by Knauss and Reid (1957) are quoted. "Tests with a neutrally boyant cable towed in conjunction with a demolition (heavier than seawater) cable show that the difference in the two currents always results in a vector whose direction is 'down wind'. This current difference may be the result of shear, but it is more likely the result of the neutrally buoyant cable's making more leeway than the ship. This windage vector is of the order of 10 to 15 cm/sec and is independent of the magnetic latitude."

Finally, a meaningful understanding of this data-dependent as it is upon electrical field measurements-warrants some mention of the technological aspects involved. Towing a long (250 meters) dual-conductor cable at the surface behind the ship is essentially the method of gathering GEK data. Two electrodes are spaced 100 meters apart at the end of the cable, and, by means of the conducting wires within, are electrically in contact with the ship. Thus, the electrodes give a continuous record of the potential difference (caused by the motion of ion-filled water through the earth's magnetic field) 100 meters apart along the line of travel. See Figure 1, where a schematic representation of this process is presented.

The leads, represented by solid dots, are connected to a shipboard potentiometric recorder. α and β are the inherent potentials of the individual electrodes relative to seawater. Ψ is the potential difference between the electrodes due to the motion of the seawater through the earth's magnetic field. The average value of the signals measured on each leg of the turn gives the true value of the potential developed by the seawater motion alone.

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*That is, the flow was considered bounded, with no large shear lines within the bounds. If shear velocites do exist in the area to be measured, this term should be considered and this reasoning is somewhat altered.

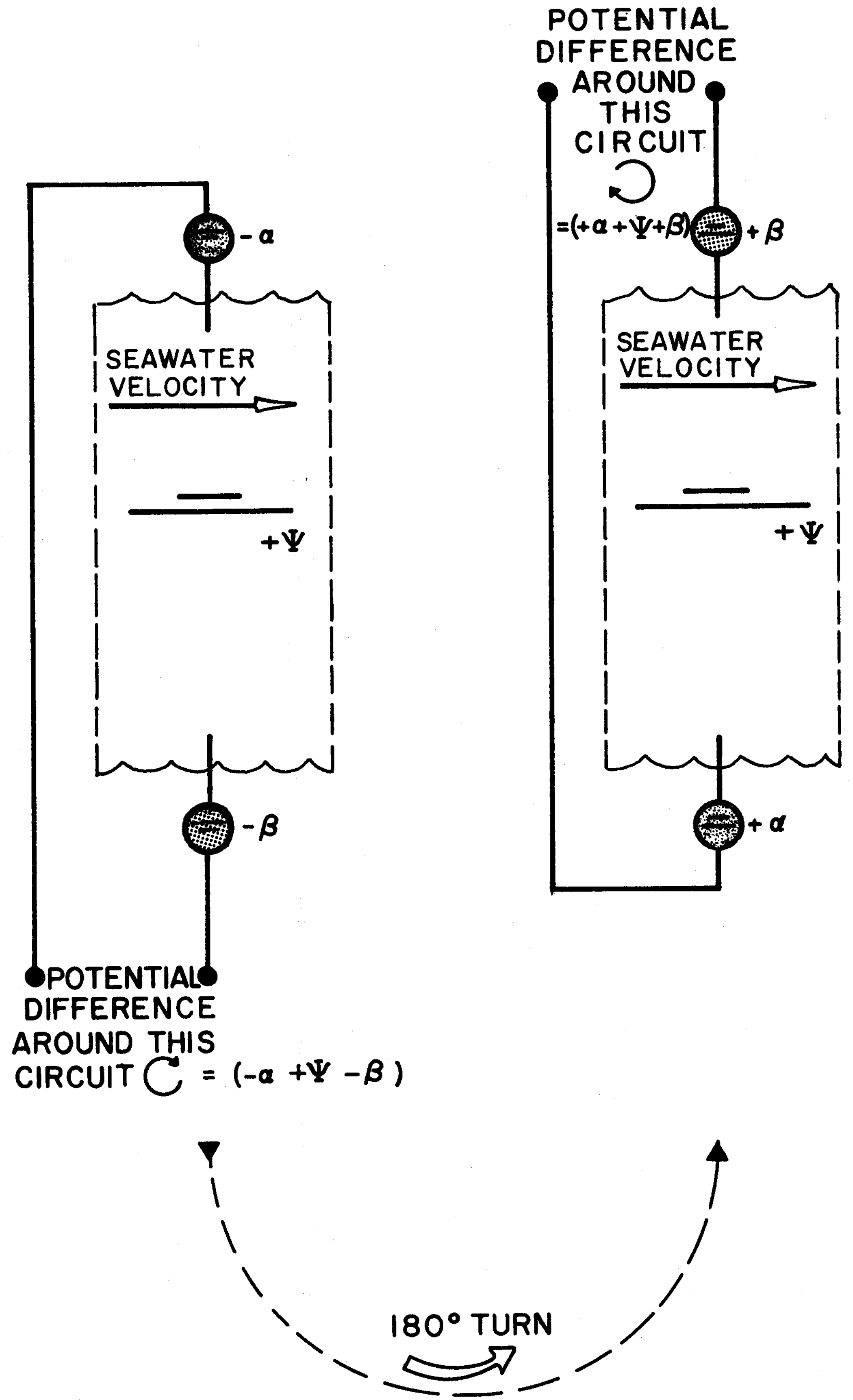


Figure 1.

Schematic representation of zero fix turn. Refer to text for details.

If the current is assumed to remain constant during the short period of time the turn requires, a zero reference point is thus also established (the mean value between each leg measurement). This point is called electrical zero. It provides a base reference on the record against which local magnitudes of potential difference can be measured.

The only method of eliminating electrode self potentials in the measurement is by physically reversing the electrodes in some manner. This is the reason for GEK turns (180°) in the cruise regime.

It would seem that once this zero point had been established, potentials could be measured everywhere by a glance of the record. But here is where "oceanography" has a full import. For electrodes towed at the surface, α and β are functions, to the first order, of temperature and salinity. As T, S characteristics change, α and β slowly vary in response. This causes a "drifting" of the electrical zero reference point. Since this "drift" is not accurately known, relatively frequent 180° turns must be executed ("zero fix" turns), in order to keep a careful watch on the zero reference point. A potential measurement is useless without a precise specification of its reference point, since it is an essential difference that is registered. A "floating" reference must be shrewdly monitored.

In most of what follows, the "drift" of electrical zero is recorded on a plot with a surface temperature history. This provides a record of past performance for future comparison. New electrodes and electrode case design are now being developed and experimented with in the attempt to control within small tolerances the "drift" of the inherent electrode potentials. If this can be done, frequent "zero fix" turns can be eliminated-a significant savings and an advance in this method of current measurement.

Theoretical interpretive technique is not contained formally in this report, but is being studied and will be presented separately. Research on basic method improvement while at the same time developing a workable, permanent, and readily available system to produce desired results for such theoretical examination as well as for compilation of descriptive data is the motivating goal of what follows.

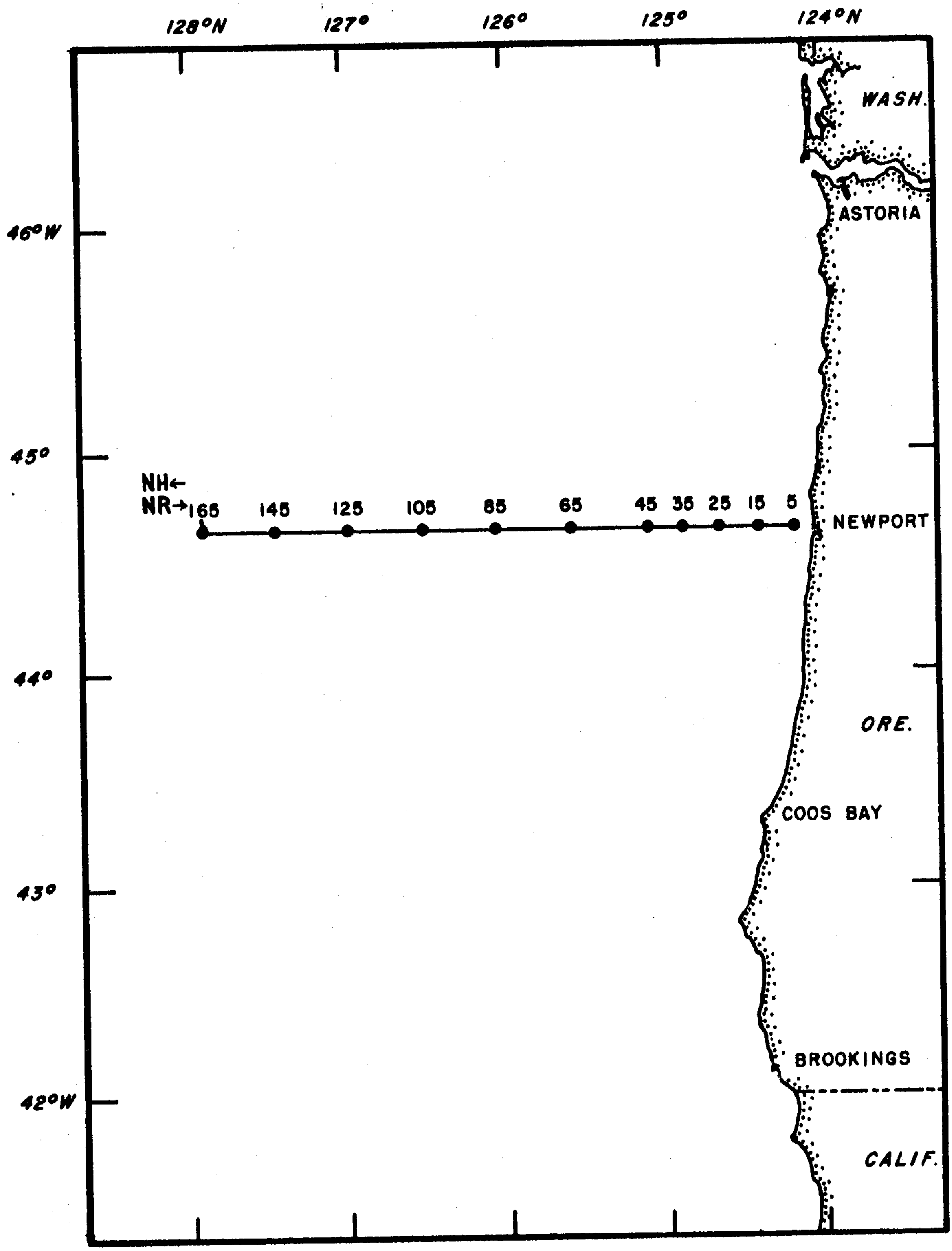


Figure 2

The indicated line shows the location in which the GEK measurements compiled herein were taken. In the following reports "NH" refers to Newport Hydro, "NR" to Newport Return, and the numbers following these designations to the miles offshore from Newport as indicated

CRUISE 6704*

Objectives

- To become familiar with techniques of handling and operating GEK equipment.
- To learn particulars involved in translating raw results to oceanographic parameters.

Equipment Employment

The GEK recorder was used in the dry lab with the connecting cable led out through the wire input port. The spool holding the cable with electrodes was mounted on the boat deck. The electrode cable was towed off the port side by feeding it through a block mounted on the Daybrook Crane. A boathook was used to pull in the last electrode when removing the cable from the water. When not in use the cable was secured while still threaded through the block. Electrodes were payed out and retrieved by hand with the ship cruising at half speed (5 knots). This system worked quite well. On the tows between stations about 100 meters of cable separated the nearest electrode and the ship.

Operation Schedule

The electrodes were towed on the surface at full speed (10 knots), and were brought in before the ship stopped at a hydro station. All recordings were made in deep water. Tows were made between the following stations:

NH 55 - NH 63
NH 65 - NH 83
NH 105 - NH 125
NH 125 - NH 145

Turns were made on each leg to find electrical zero. The results are presented in Figure 3.

*Note: In all cruise number designations, the first two digits refer to the year, the second two to the month of the cruise.

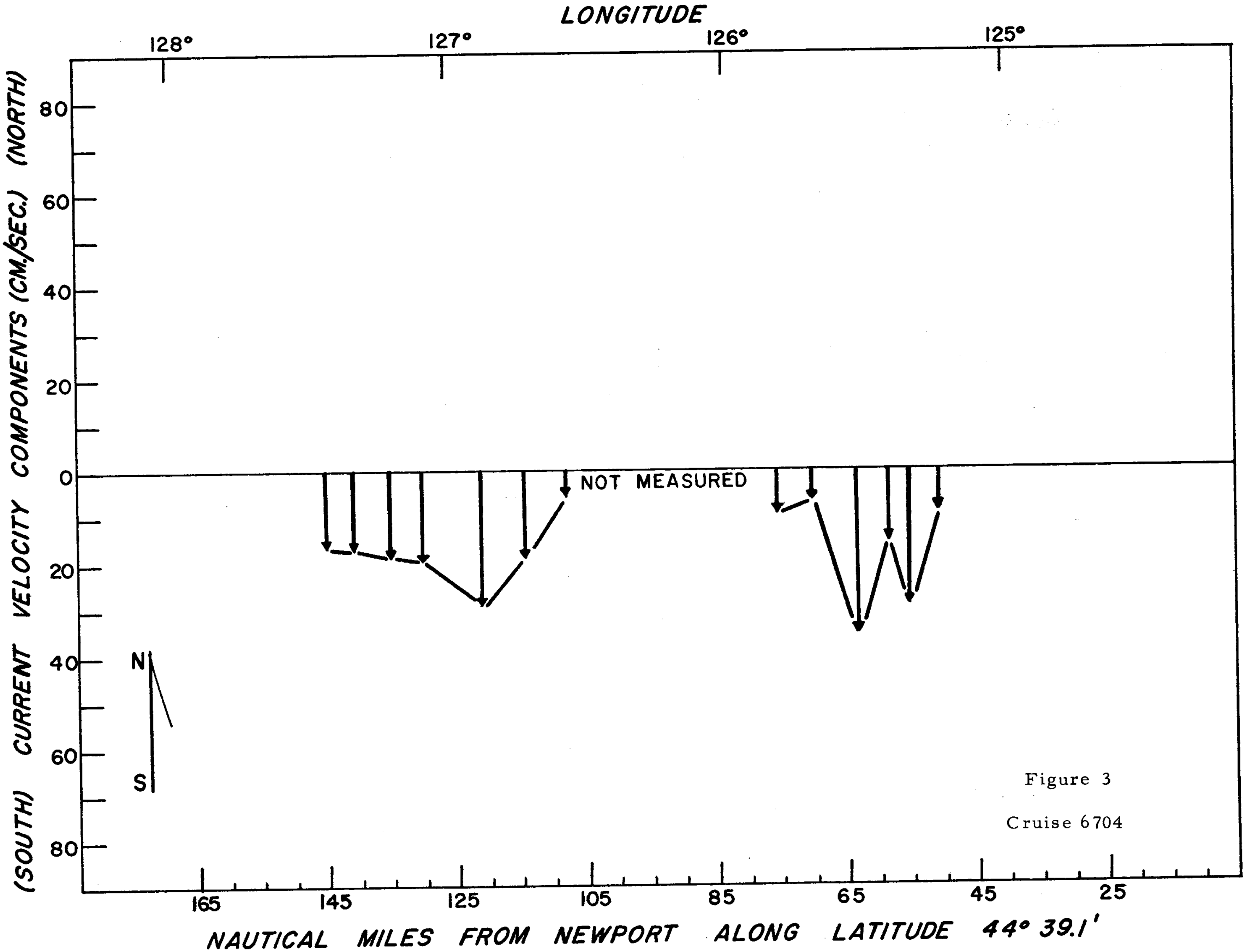


Figure 3

Cruise 6704

CRUISE 6705

Objectives

To obtain a continuous profile of currents along a line of constant latitude for 165 miles off Depoe Bay, Oregon.

Equipment Employment

The recorder, electrodes and cable, and auxiliary equipment were deployed in the same manner as on the previous cruise.

Operation Schedule

The electrodes were towed full speed (10 knots) at the surface on the return trip to the coast. A continuous record was obtained with electrical zero fix turns executed periodically along the way. The electrodes were retrieved approximately 20 miles off Newport due to signal masking by shallow water effects. Results are depicted in Figure 4.

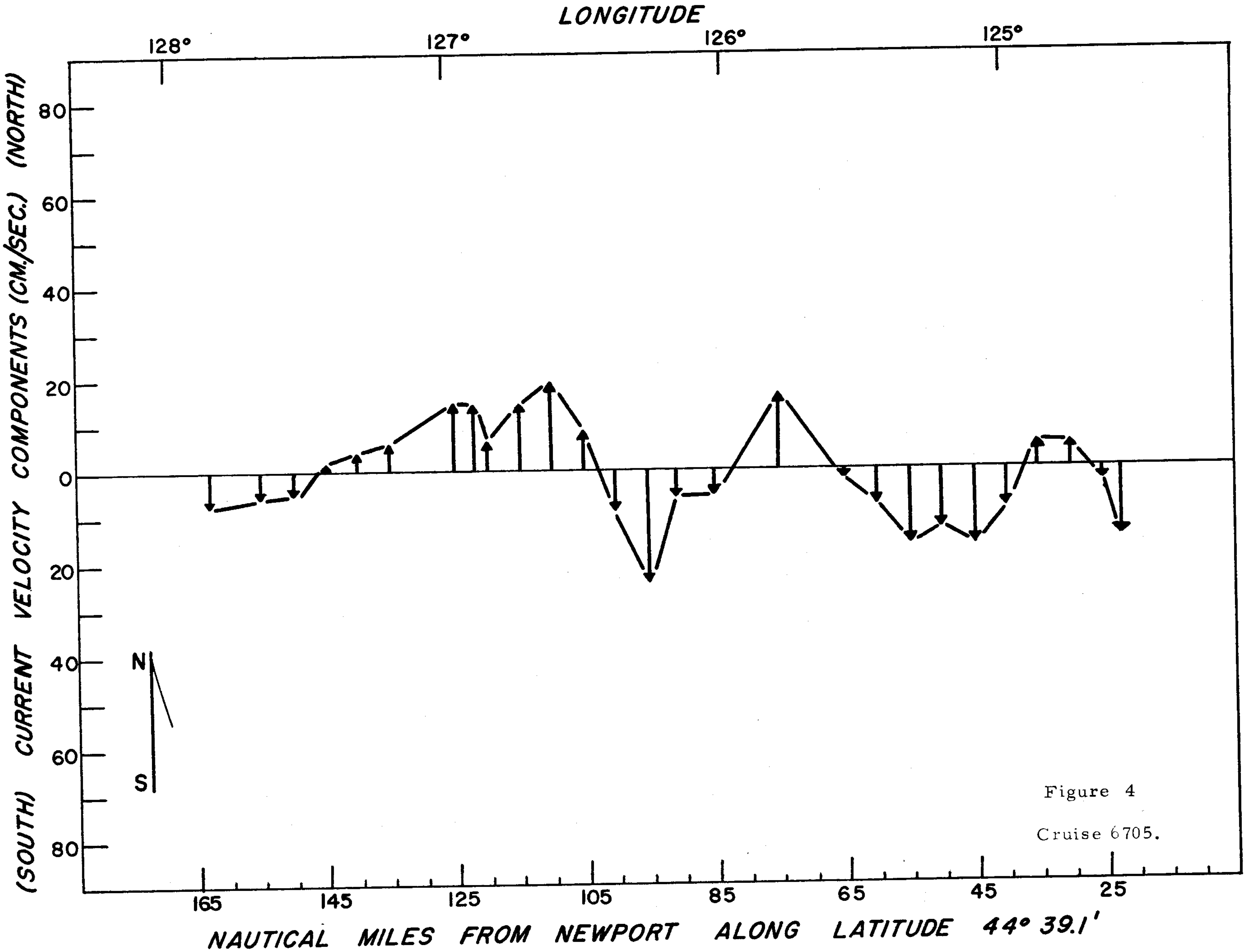


Figure 4

Cruise 6705.

CRUISE 6706-A

Objectives

- To continue monitoring the currents of the constant latitude line off Newport, Oregon.

- To examine the nature of the east-west currents along a short constant line of longitude for a certain period of time.

- To begin a collection and correlation of data on electrical zero drift and surface temperature profiles.

- To record data on U. S. N. Hydrographic Office GEK log sheet.

Equipment Employment

The recorder, electrodes and cable, and auxiliary equipment were deployed in the same manner as on the previous cruise.

Operation Schedule

A short run with ship speed of 10 knots was conducted along the Depoe Bay line of buoys on the 2nd of June. On this run only one electrical zero fix was executed at 1943 P. D. T. (Pacific Daylight Time)

On 3 June, a continuous measurement (10 knots speed) was attempted as the ship sailed from NH 35 to NH 165. The procedure began at 0633, but was interrupted at 1053 (near NH 75) due to the breakdown of electrodes. Before this failure, three electrical zero fixes were performed. The measurement was not resumed until 1800 (near NH 145). Two more zero fixes were carried out before the ship speed was reduced to 5 knots to undertake a mid-water trawl at 2025.

The short haul back and forth trawling lasted until early morning of 4 June. Seven zero fixes were executed during this time. *

Returning from NH 165 to Newport, GEK measurements were carried out while the ship was sailing between stations. The electrodes were pulled back to the ship when stopped on station. The numerical results indicated in Table 1 have been graphically depicted in Figures 6 and 7 along with the recorded surface temperature.

*Note on presentation of this data in Figure 5: the linear variation between accurate fix vectors is a crude approximation.

CABLE S - SHORT

TABLE I

OCEANOGRAPHIC LOG SHEET - GEK
PRNC-NHO 3167/7 (Rev. 5-55)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

VESSEL	CRUISE	YEAR	SURFACE GEOMAGNETIC ELECTROKINETOGRAPH NO.	COMPUTED BY	CHECKED BY
R/V YAQUINA	6706-A	1967		YAO, NENG-CHUN	

Specify algebraic signs and units of all measurements. In northern magnetic hemisphere: The current velocity vector lies 90° to the RIGHT of the resultant electric signal vector, and the more distant electrode should be connected to the POSITIVE input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.

GEK SERIAL NO.	DATE (Day, Month)	HOUR (GMT)	POSITION OF CURRENT FIX: LATITUDE (N or S)	POSITION OF CURRENT FIX: LONGITUDE (E or W)	SHIP'S AVERAGE SPEED Knots, m./Sec.	DEPTH OF WATER (m., fm.)	VERTICAL MAGNETIC INTENSITY (Millioersteds) STAND. I	VERTICAL MAGNETIC INTENSITY LOCAL II	INITIAL BASE-COURSE DIR. (°T) III	INITIAL BASE-COURSE SIG. cm./Sec. IV	FIRST FIX-COURSE DIR. (°T) V	FIRST FIX-COURSE SIG. cm./Sec. VI	SECOND FIX-COURSE DIR. (°T) VII	SECOND FIX-COURSE SIG. cm./Sec. VIII	RESUMED BASE-COURSE DIR. (°T) IX	RESUMED BASE-COURSE SIG. cm./Sec. X	ZERO POINT cm./Sec. XI	AVERAGE BASE-COURSE SIGNAL MAG. cm./Sec. XII	AVERAGE BASE-COURSE SIGNAL DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL MAG. cm./Sec. XIV	AVERAGE FIX-COURSE SIGNAL DIR. (°T) XV	RESULTANT SIGNAL VECTOR MAG. cm./Sec. XVI	RESULTANT SIGNAL VECTOR DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY SPEED cm./Sec. XIX	CURRENT VELOCITY SPEED (Knots) XX	CURRENT VELOCITY DIR. (°T) XXI
1	2 June 67	1941	44°52'	124°17'	10	75	0.500	0.505	115	47	205	17	025	25	115	50	21	27.5	115	4	025	27.8	86	1.03	88.6	1.720	176
2	3 June 67	0633	44°38.7'	124°58.7'	10	260	0.500	0.500	270	-35	000	-17	180	- 3	270	-32	-10	23.5	090	7	180	25	105	1.04	26	0.504	195
3	3 June 67	0907	44 38.9'	125°27.2'	10		0.500	0.500	270	-25	000	-15	180	25	270	- 7	5	16	090	21	180	24.8	140	1.04	25.8	0.500	230
4	3 June 67	1804	44°38.1'	127°21.6'	10		0.500	0.500	270	-50	000	-10	180	- 5	270	-40	-7.5	37.5	090	2.5	180	37.6	94	1.04	3 .9	0.755	184
5	3 June 67	2000	44°38.8'	127°45.9'	10		0.500	0.495	270	-45	000	-47	180	+12	270	-25	-17.5	17.5	090	29	180	33.9	148	1.05	35.6	0.691	238
6	3 June 67	2137	44°41.1'	127°56.4'	5		0.500	0.495	315	-25	045	-35	225	+ 7	135	0	-14	1.5	315	21	225	21	229	1.05	22	0.427	319
7	3 June 67	2239	44°38.6'	127°53.0'	5		0.500	0.495	135	- 5	045	-35	225	+ 5	315	-20	-15	30	135	20	225	36	170	1.05	37.8	0.733	260
8	3 June 67	2343	44°40.9'	127°56.2'	5		0.500	0.495	315	-10	045	-20	225	0	135	+ 2	-10	4	315	10	225	12	255	1.05	12.6	0.244	345
9	4 June 67	0045	44°38.4'	127°52.7'	5		0.500	0.495	135	-10	045	-17	225	+ 2	315	- 8	- 7.5	6.5	135	9.5	225	11	193	1.05	11.6	0.225	283
10	4 June 67	0151	44°40.6'	127°56.0'	5		0.500	0.495	315	0	045	-10	225	- 7	135	- 5	- 8.5	6	135	1.5	225	6	150	1.05	6.3	0.122	240
11	4 June 67	0255	44°37.4'	127°52.5'	5		0.500	0.495	135	+20	045	-10	225	+ 7	315	-30	- 1.5	26.5	135	8.5	225	28	153	1.05	29.4	0.570	243
12	4 June 67	0407	44°39.0'	127°55.0'	5		0.500	0.495	315	-12	045	+12	225	-15	315	-15	- 1.5	13.5	135	12	045	13	095	1.05	13.7	0.266	185
13	4 June 67	1005	44°40.1'	127°38.9'	10		0.500	0.495	090	+30	000	-17	180	+17	090	+15	0	22.5	090	34	180	40.8	146	1.05	42.8	0.830	236
14	4 June 67	1357	44°39.2'	127°10.3'	10		0.500	0.500	090	+32	180	+29	000	-12	090	+ 5	8.5	5	090	20.5	180	21	135	1.04	21.8	0.423	225
15	4 June 67	1727	44°39.6'	127°09.0'	10		0.500	0.500	270	+ 7	000	-17	180	+27	270	- 5	5	4	090	22	180	22.5	169	1.04	23.4	0.454	259
16	4 June 67	1839	44°39.2'	127°20.6'	10		0.500	0.500	270	-20	000	-18	180	+20	270	-12	1	17	090	19	180	25.5	140	1.04	26.5	0.514	230
17	5 June 67	1016	44°39.6'	126°22.3'	10		0.500	0.500	090	+ 7	000	-22	180	+32	90	- 5	5	6	090	27	180	26.5	168	1.04	27.6	0.535	258
18	5 June 67	1120	44°39.6'	126°11.2'	10		0.500	0.500	090	10	000	-10	180	+17	090	+ 8	3.5	10	090	18	180	20.59	151	1.04	21.4	0.415	241
19	5 June 67	1505	44°38.8'	125°46.4'	10		0.500	0.500	090	+35	180	+32	000	-33	090	+18	-0.5	27	090	32.5	180	42.3	140	1.04	43.9	0.852	230
20	5 June 67	2108	44°39.0'	125°33.3'	10		0.500	0.500	090	+ 8	000	-25	180	+15	270	-10	-5	14	090	30	180	33	155	1.04	34.32	0.666	245
21	5 June 67	2220	44°39.1'	125°39.8'	5		0.500	0.500	270	-35	180	-20	000	-30	090	-22	-25	38	090	5	180	38	098	1.04	39.52	0.767	188
22	6 June 67	0025	44°39.2'	125°29.1'	5		0.500	0.500	090	- 8	180	-26	000	-26	090	-30	-26	9	090	0	180	9	090	1.04	9.4	0.182	180
23	6 June 67	0123	44°38.9'	125°24.3'	5		0.500	0.500	090	-17	000	-30	180	- 5	090	0	-17.5	6.5	090	12.5	180	14.1	155	1.04	14.66	0.284	245
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

EQUATIONS

XI = ½ (VI + VIII)

Y = ½ (IV + X) - XI
XII = |Y|

XIII = III if Y ≥ 0
or = III ± 180° if Y ≤ 0

XIV = |VI - XI|

XV = V if VI ≥ VIII
or = VII if VI ≤ VIII

*XVI = $\sqrt{XII^2 + XIV^2}$

*tanA = XIV/XII

*XVII = XIII + A
If XIII + 90° = XV
or
*XVII = XIII - A
If XIII - 90° = XV

May be computed on Mark 3a Plotting Board

XVIII = 1.04 x I/II

XIX = XVIII x XVI

XX = .0194 x XIX

XXI = XVII + 90°
if II > 0
or
XXI = XVII - 90°
if II < 0

REMARKS

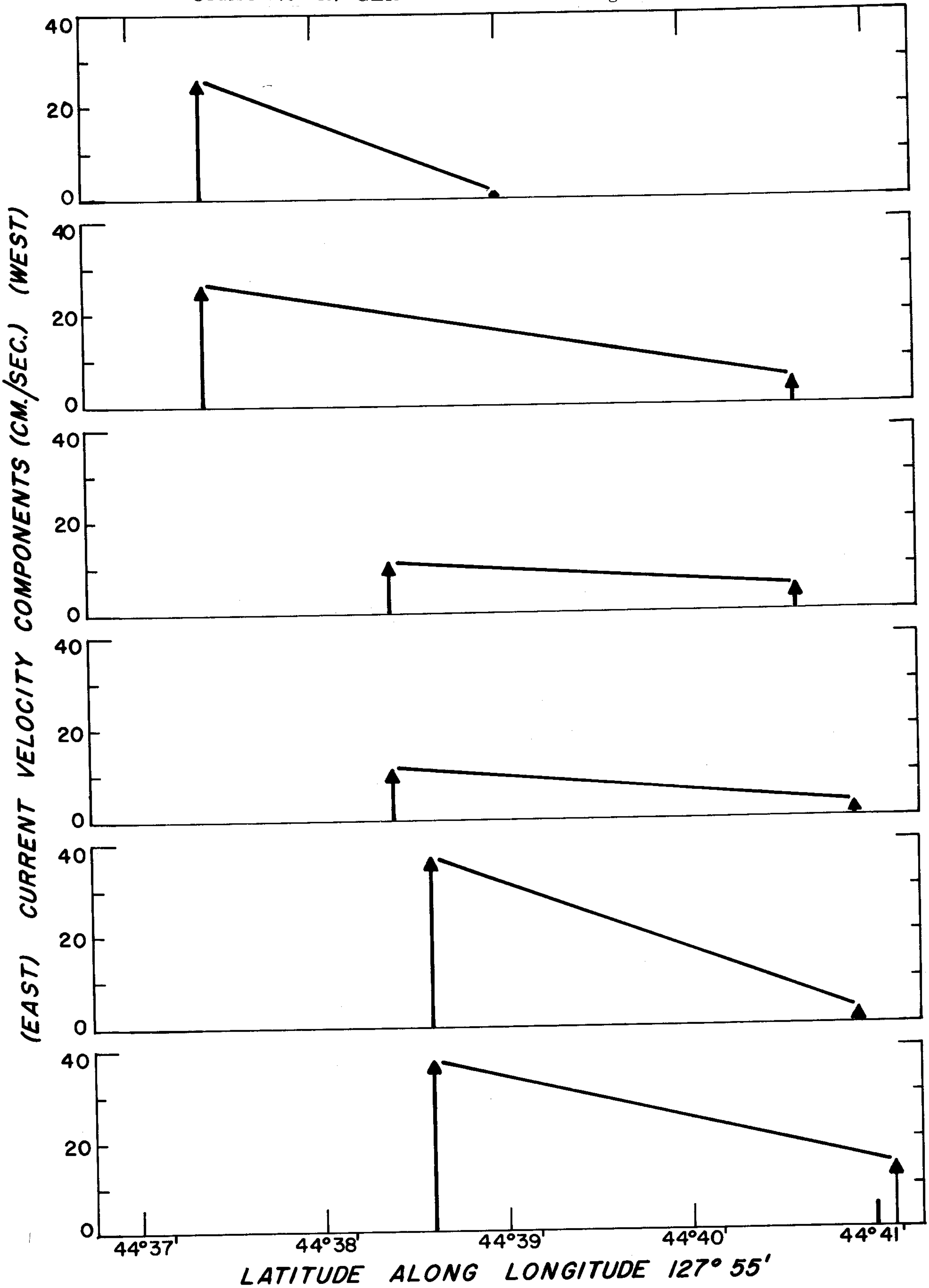
NAVY-DPPO PRNC, WASH., D.C.

TABLE 1 LEGEND

Column	Units
A	Pacific Daylight Time (PDT)
B	Latitude, North
C	Longitude, West
D	knots
E	fathoms
F and G	millioersteds
H, J, L, N, R, T, V, Z	degrees true
I, K, M, O, P, Q, S, V, X	centimeters/second
W	non-dimensional signal multiplier
Y	knots

Figure 5

Cruise 6706-A. GEK measurements during mid-water trawl.



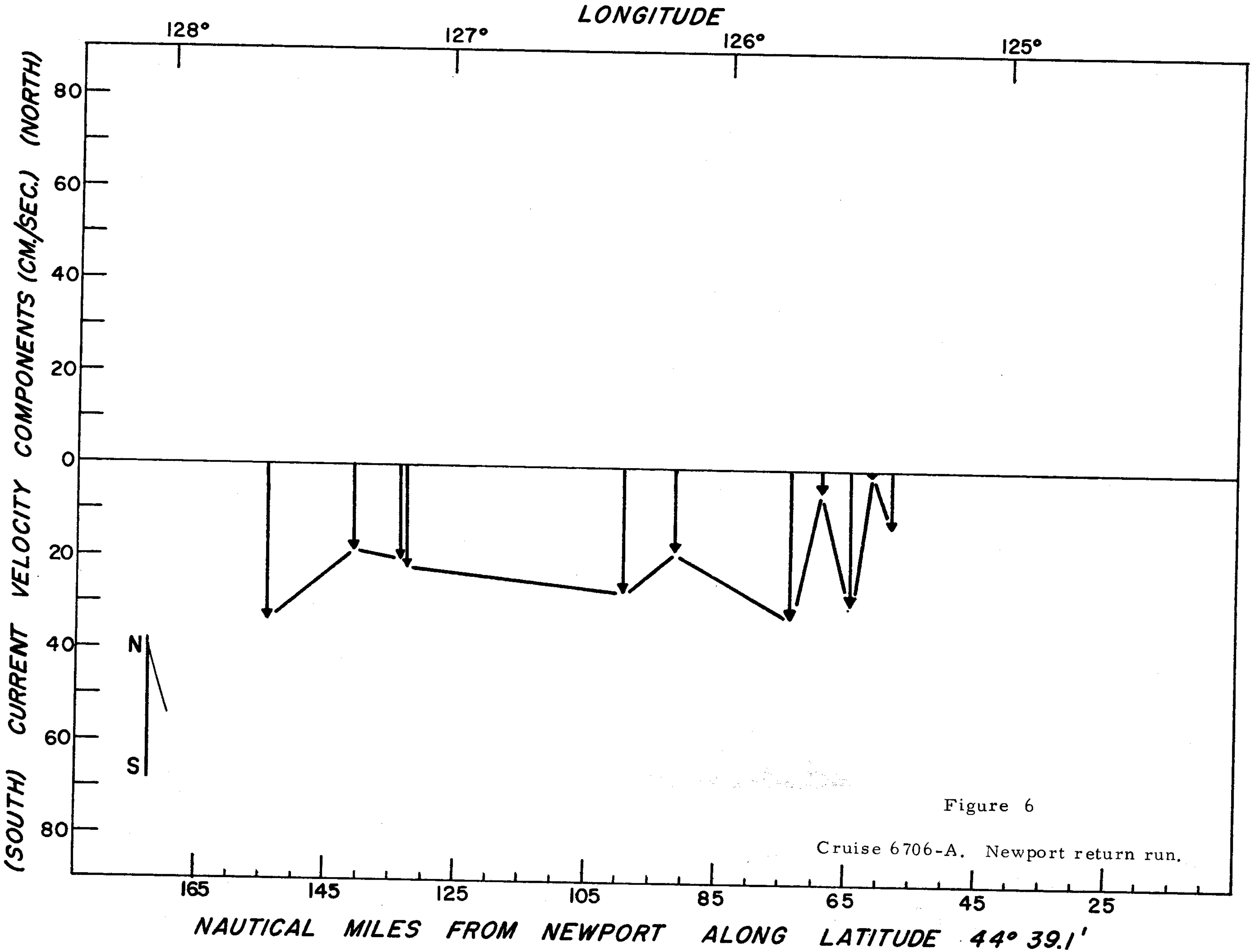


Figure 6

Cruise 6706-A. Newport return run.

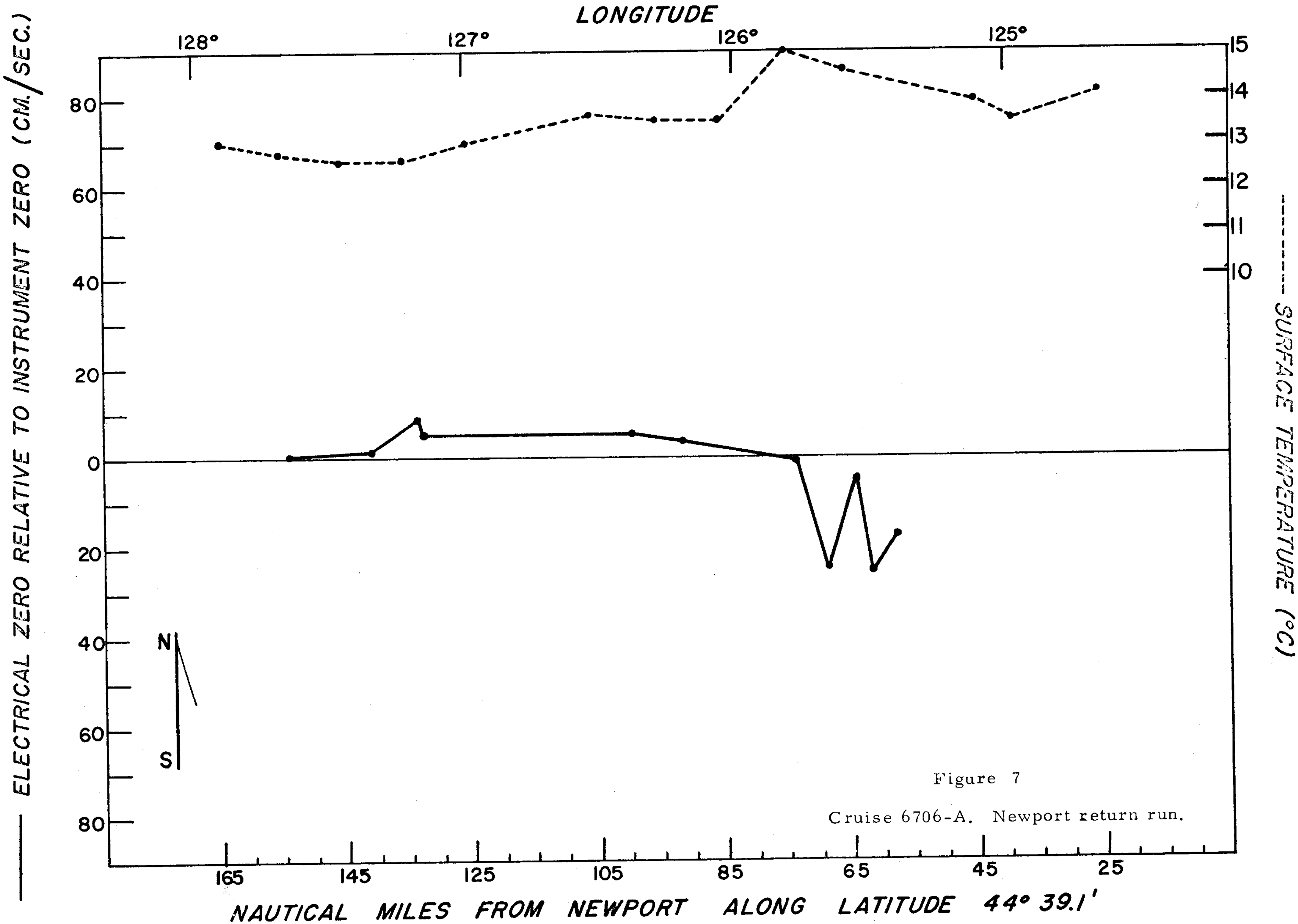


Figure 7

Cruise 6706-A. Newport return run.

CRUISE 6708-A

Objectives

- To deploy logistically two sets of electrodes on two separate cables.

- To test the characteristics of different cable arrangements.

- To continue gathering data on the continuous run from NH 165 to Newport, Oregon (using Hydrographic Office Log Sheet).

- To continue gathering data on electrical zero drift as related to surface temperature.

Equipment Employment

Two sets of newly manufacture neutrally buoyant GEK cables were tested on this cruise. One cable is 200 meters long, and the other is 250 meters with an elctrode positioned at the end of each cable. They are referred to as the short and long cables, respectively (inter-electrode distance on both cables is 100 meters). A 20-foot 3/8-inch manila line was attached to the outboard electrode of each cable. Both cables were connected to the GEK recorder through an electronic differential summation circuit, built especially for this purpose. A simplified equivalent circuit diagram of this device is shown in Figure 8. With appropriate connections the signals between any pairs of electrodes in the array can be added or subtracted by means of an operational amplifier. In addition a bias voltage of selected polarity and magnitude can be added to one input to adjust its value relative to the other signal. In this manner any electrode pair can be compared within a range of magnitudes at any time. Selection was facilitated by toggle switches on the face of the instrument. The two cables were towed side by side from the fantail of the ship. The recorder was lashed down in the aft lab. Figure 9 shows the cables under tow, and Figure 10 shows the recorder as it was used with the summation device.

The recorded trace of the potential difference during a GEK measurement ideally would be a smooth well-behaved curve with time. The actual record is oscillatory, exhibiting large noise spikes which may be due to wave action, magnetic fluctuations, and other local variables, as well as the constant corrections made to keep the ship on a mean course. The signal is usually filtered with a resistance-capacitance low-band pass filter to limit the noise to signal ratio. This filter introduces some time constant and the recorder system becomes somewhat sluggish in response to the actual electrical field. Since movement is through the field at a significant rate,

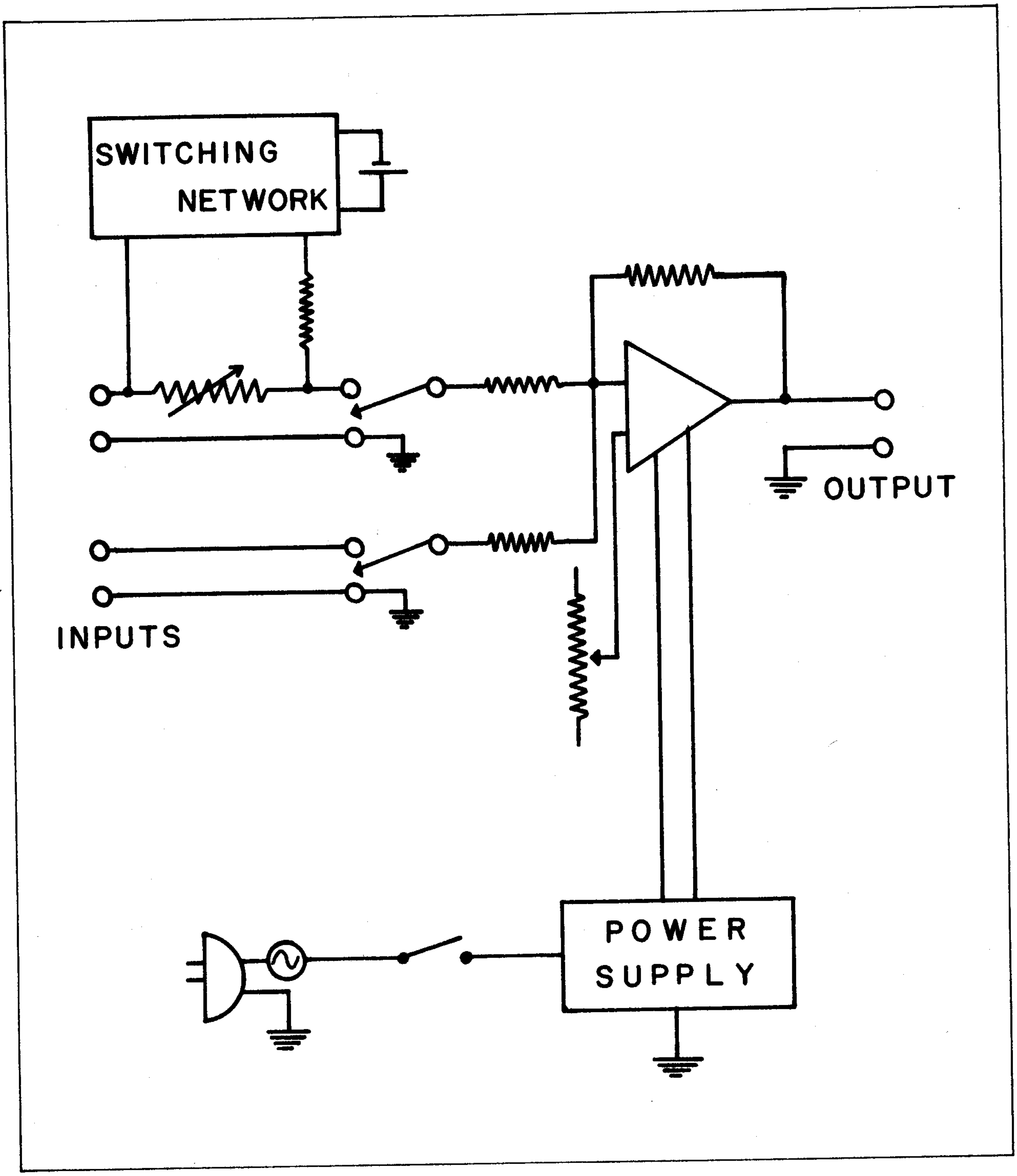


Figure 8

Simplified schematic of circuit used
for signal summation and selection.

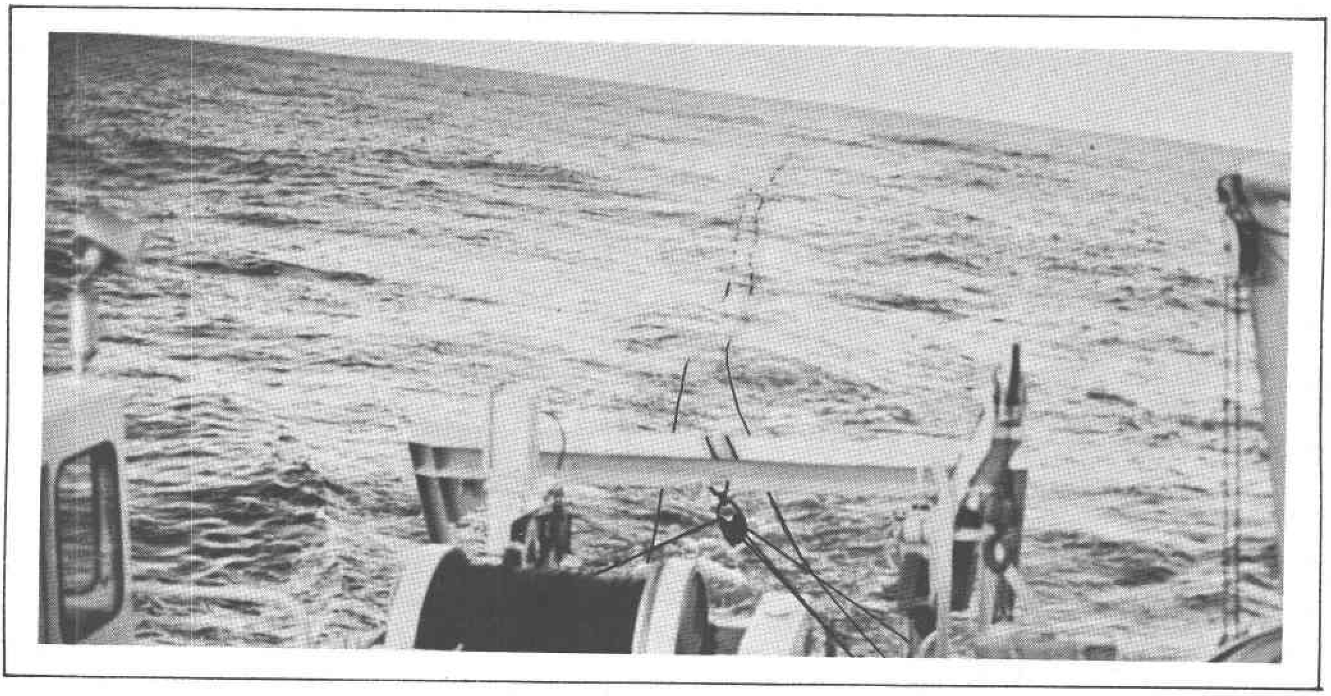


Figure 9

Two neutrally buoyant GEK cables simultaneously under tow from the fantail of the R/V YAQUINA.

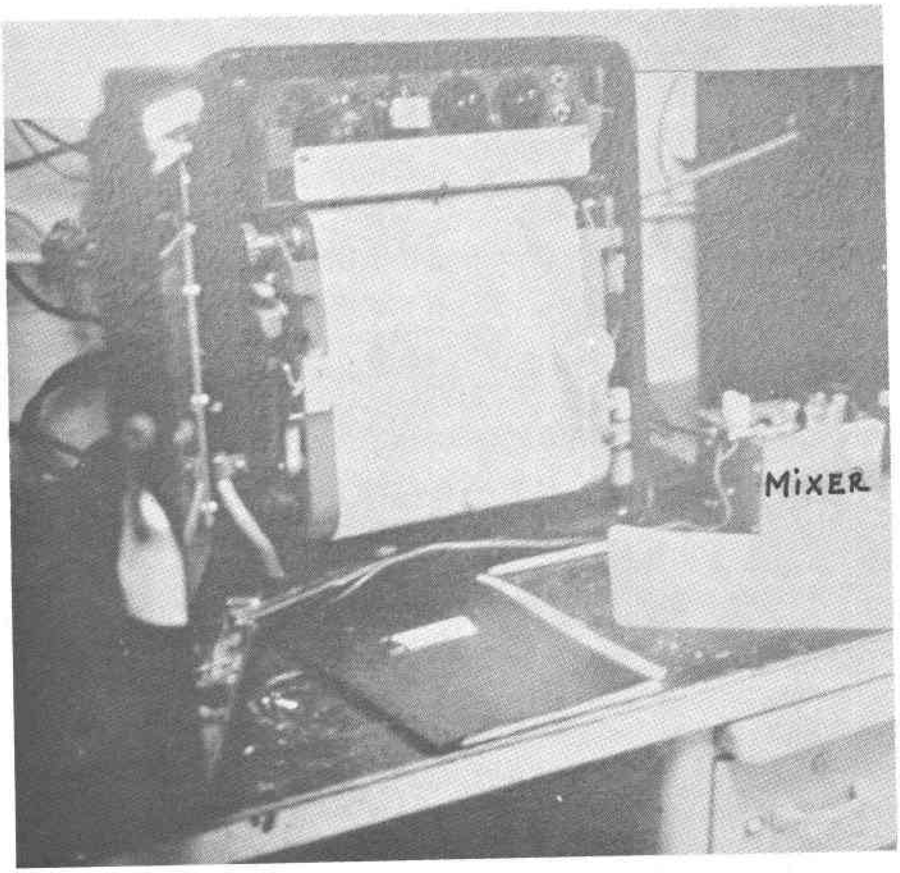


Figure 10

GEK Recorder and electronic summation circuit box as used in the aft lab of R/V YAQUINA.

any sluggishness in recording at one point may be recorded as the actual signal present as the system is now reacting to the next point in the field. Any damping time constant may prevent system equilibration at true field values. The overall result may be a somewhat distorted record.

The attempt in this experiment was to eliminate some of the signal noise due to wave action by superimposing signals from two electrodes appropriately spaced so that their noise components would be destructively out of phase. The results seem to be somewhat ambiguous due to a too brief record, not enough trial spacings, and perhaps some misunderstanding on the design and use of the differential amplifier circuit. Nevertheless, enough positive responses were exhibited to warrant a planned repetition of this idea with the necessary oversights corrected. Some of the more interesting results are presented here.

Operation Schedule

A. The experiment was initiated at 2330 PDT 10 August and continued until 0315 PDT 11 August. During this period several different connections of the electrodes were employed to test the possibility of supressing the signal noise.

1. From 2352 PDT 10 August to 0000 PDT 11 August, the outboard end electrodes of both cables were connected directly to the recorder as a pair of GEK electrodes--a 50-meter distance between them. The signal oscillations showed a slightly larger magnitude than that recorded by the two electrodes on one cable (100-meter spacing).

2. Next, the two inboard end electrodes were summed together to act as one lead of the input signal, and similarly the two outboard electrodes. The signals so obtained were recorded for 55 minutes. The general magnitude of the signal oscillation increased noticeably. A definable beat frequency with period of approximately one-half minute showed up on the recorded trace. This beat frequency was very close to the oscillation of the ship's heading as effected by the auto-pilot gear. A shift to manual control of the rudder made the period of the beat frequency change into a slightly irregular pattern. Figure 12 gives a record of this data.

3. At 0130 PDT 11 August, the electrode connections were switched to inputs from the electrodes on each individual cable. Signals from both cables were summed and sent into the GEK recorder. An even larger signal oscillation appeared (roughly 30 cm/sec, average).

At 0148 PDT 11 August, the long cable was pulled in 25 meters. Thus, the distances between the two outboard electrodes and the two inboard electrodes were both 25 meters, and the distance between the outboard electrode of the short cable and the inboard electrode of the long cable was 50 meters. The magnitude of the signal oscillation remained about the same as before. Refer to Figure 13.

4. A further change of relative cable length was made by letting out the long cable to full length and pulling in the short cable 25 meters. This arrangement gave a 25 meter distance between the inboard electrode of the long cable and the outboard electrode of the short cable. The magnitude of signal oscillation reduced to about 0. 15 millevolts. Further measurements with the filter resistance set at 4 and 10 (dimensionless dial settings) were carried out. The magnitude of the signal oscillation was thus reduced to a substantial extent. See Figure 14.

B. Continuous GEK measurement.

A continuous GEK measurement with the long cable was carried out from 2320 PDT 11 August to 1000 PDT 12 August. Eight GEK current fixes were obtained along the NH line from approximately NH 115 to NH 35. The fact that seven out of the eight zero fixes yielded north bound current components contrary to the general current trend off Oregon this time of year and to the observed ship's drift indicated that some reversed connection existed in the cable leads. Therefore, in compiling the Log sheet, all signal directions were shifted 180°, from those on the recorder chart to facilitate consistency with the general current condition in this area. Electrical zero, surface temperature, and north-south current components are plotted in Figures 15 and 16 from the results tabulated in Table 2.

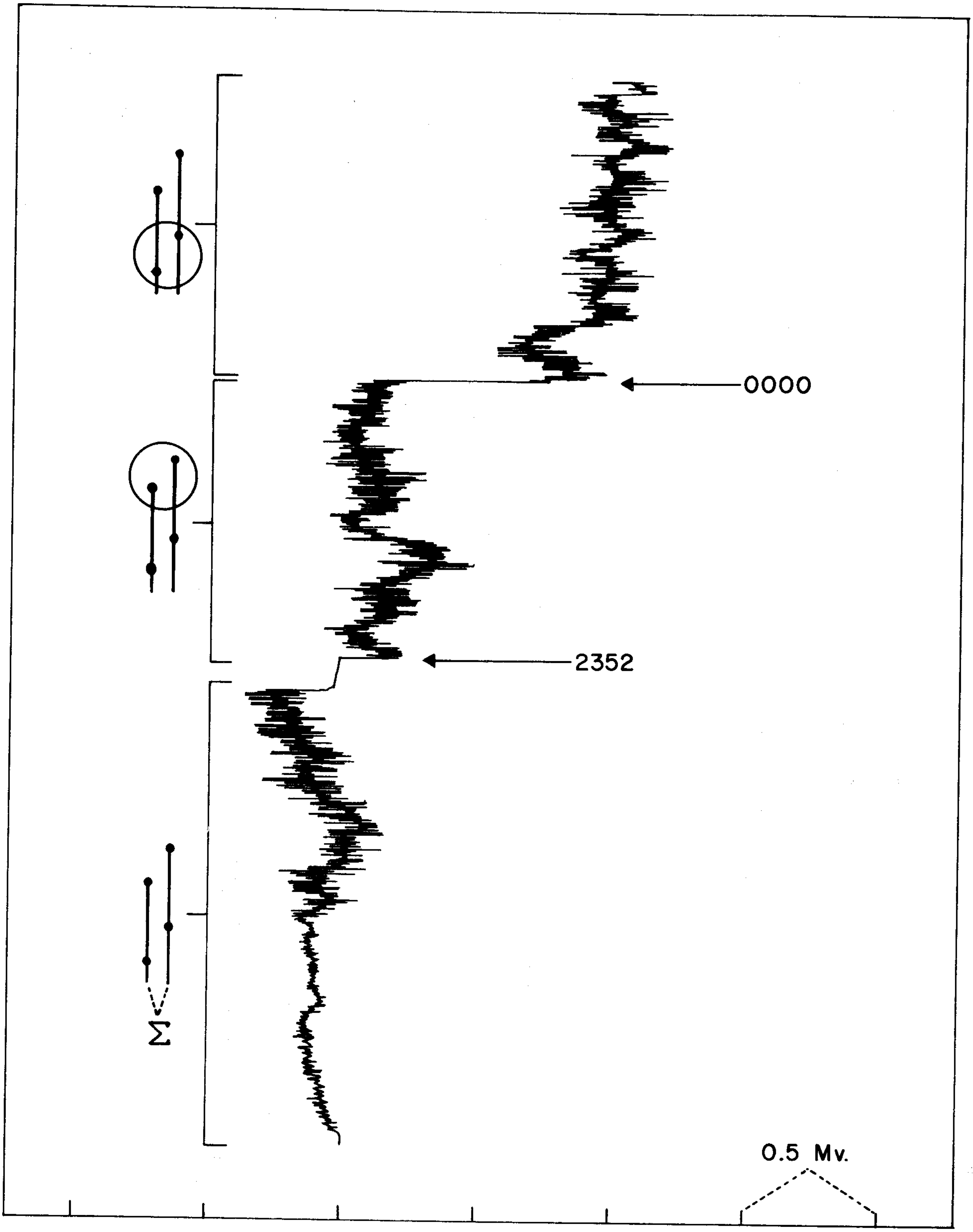


Figure 11

Signal recorded using various combinations of electrodes. For details refer to Operation Schedule, section A1.

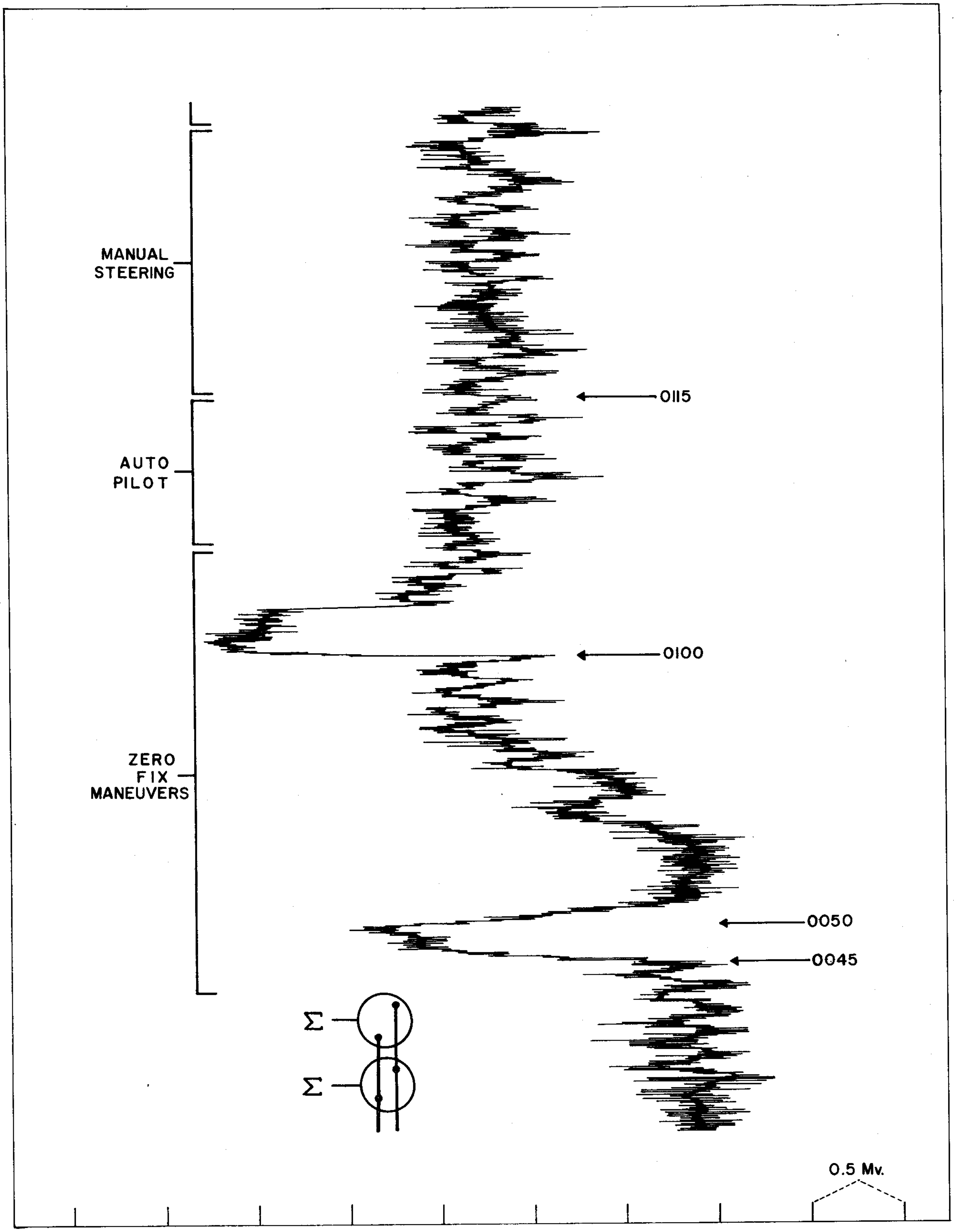


Figure 12

Signals recorded with electrode configuration shown and other variables modified as indicated. For details refer to Operation Schedule, section A2.

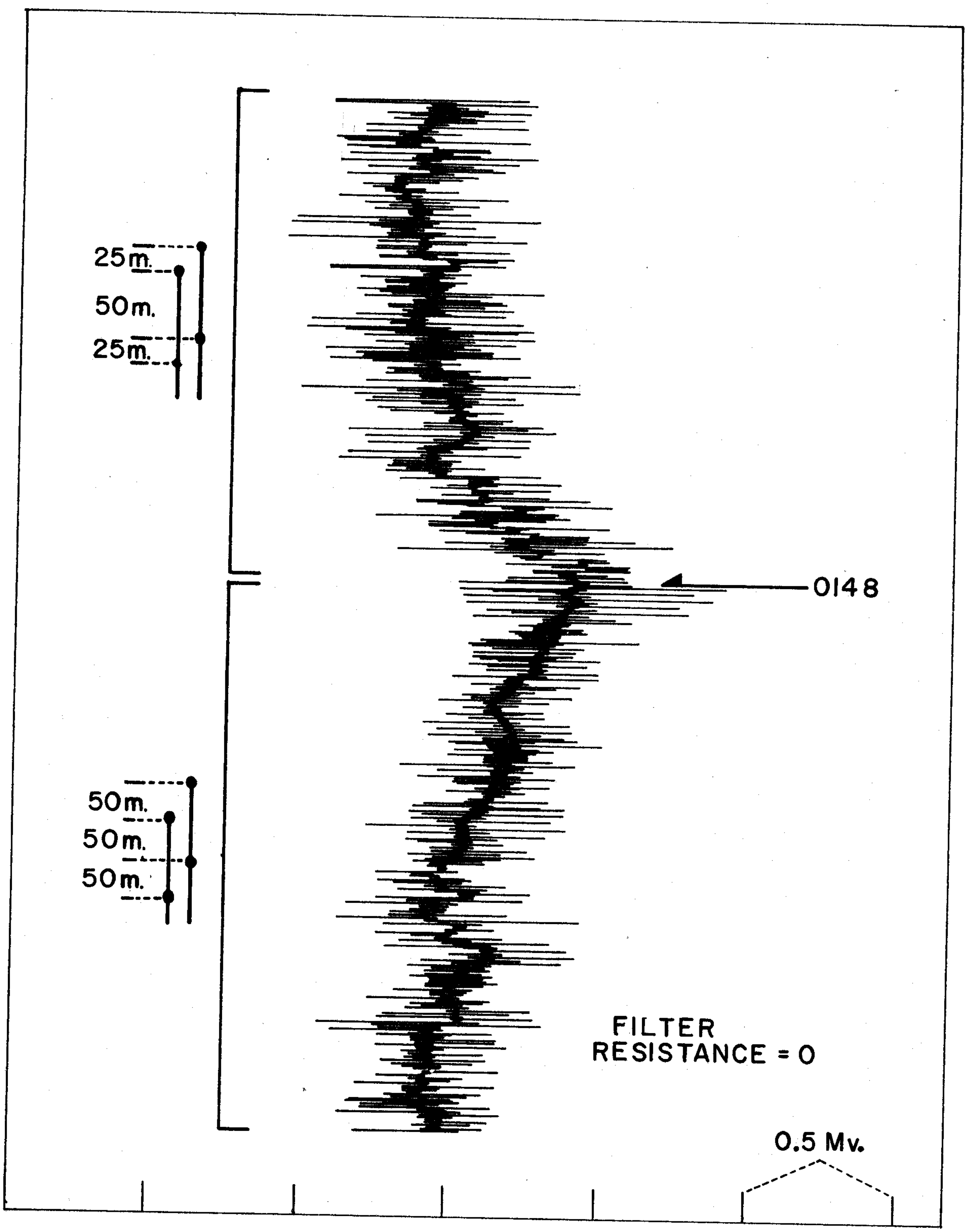


Figure 13

Signals received with various electrode spacings. Details are contained in Operations Schedule, section A3.

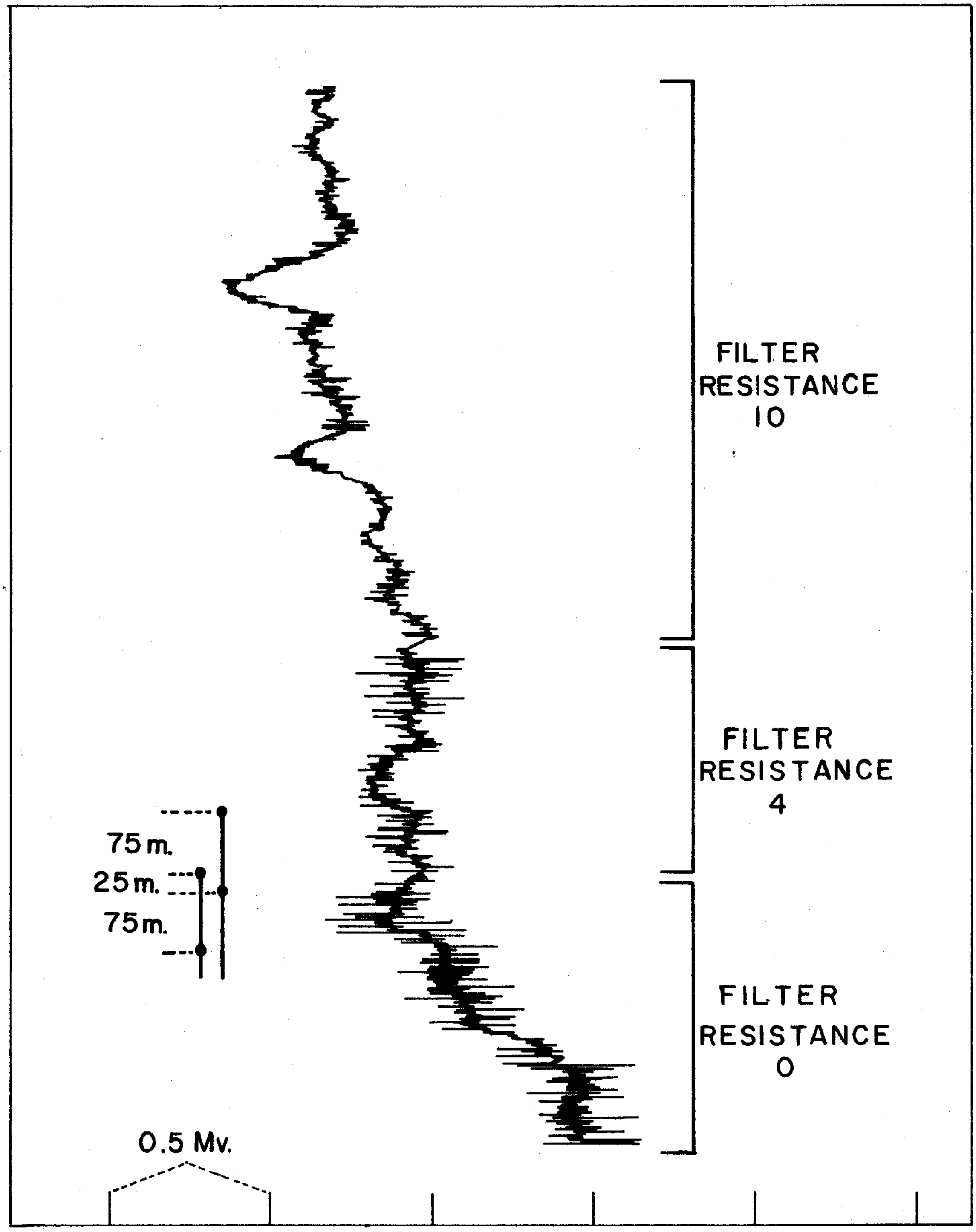


Figure 14

Signal received with electrode spacing shown subjected to various filter resistances. Refer to Operation Schedule, section A4.

TABLE 2

OCEANOGRAPHIC LOG SHEET - GEK
PRNC-NHO 3167/7 (Rev. 5-55)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

VESSEL	CRUISE	YEAR	SURFACE GEOMAGNETIC ELECTRO-KINETOGRAPH NO.	COMPUTED BY	CHECKED BY
R/V YAQUINA	6708-A	1967		YAO, NENG-CHUN	

Specify algebraic signs and units of all measurements. In northern magnetic hemisphere: The current velocity vector lies 90° to the RIGHT of the resultant electric signal vector, and the more distant electrode should be connected to the POSITIVE input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.

GEK SERIAL NO.	DATE (Day, Month)	HOUR (GMT)	POSITION OF CURRENT FIX: LATITUDE (N or S)	POSITION OF CURRENT FIX: LONGITUDE (E or W)	SHIP'S AVERAGE SPEED (Knots, m./Sec.)	DEPTH OF WATER (m., fm.)	VERTICAL MAGNETIC INTENSITY (Millioersteds): STAND. I	VERTICAL MAGNETIC INTENSITY (Millioersteds): LOCAL II	INITIAL BASE-COURSE: DIR. (°T) III	INITIAL BASE-COURSE: SIG. cm./Sec. IV	FIRST FIX-COURSE: DIR. (°T) V	FIRST FIX-COURSE: SIG. cm./Sec. VI	SECOND FIX-COURSE: DIR. (°T) VII	SECOND FIX-COURSE: SIG. cm./Sec. VIII	RESUMED BASE-COURSE: DIR. (°T) IX	RESUMED BASE-COURSE: SIG. cm./Sec. X	ZERO POINT cm./Sec. XI	AVERAGE BASE-COURSE SIGNAL: MAG. cm./Sec. XII	AVERAGE BASE-COURSE SIGNAL: DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL: MAG. cm./Sec. XIV	AVERAGE FIX-COURSE SIGNAL: DIR. (°T) XV	RESULTANT SIGNAL VECTOR: MAG. cm./Sec. XVI	RESULTANT SIGNAL VECTOR: DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY: SPEED cm./Sec. XIX	CURRENT VELOCITY: SPEED (Knots) XX	CURRENT VELOCITY: DIR. (°T) XXI
1	11 Aug 67	2230	44°39.0'	126°45.0'	10				090	8	180	18	000	20	090	12	19	9	270	1	000	9	277	1	9		007
2	12 Aug 67	0030	44°38.5'	126°33.2'	10				090	18	180	-12	000	42	090	38	15	8	090	27	180	28.2	164	1	28.2		254
3	12 Aug 67	0130	44°38.5'	126°24.1'	10				090	58	180	38	000	8	090	60	23	36	090	15	000	39	067	1	39		157
4	12 Aug 67	0230	44°38.5'	126°13.3'	10				090	32	180	72	000	-18	090	38	27	9	090	45	000	46	012	1	46		102
5	12 Aug 67	0330	44°38.5'	126°04.8'	10				090	32	180	55	000	-25	090	38	15	20	090	40	000	45	025	1	45		115
6	12 Aug 67	0430	44°38.8'	125°54.5'	10				090	46	180	62	000	-10	090	38	28	14	090	34	000	37	022	1	37		108
7	12 Aug 67	0530	44°38.6'	125°44.4'	10				090	40	180	60	000	-20	090	50	20	25	090	40	000	47	030	1	47		120
8	12 Aug 67	0730	44°38.2'	125°21.1'	10				087	5	180	- 2	000	- 2	090	12	- 2	10.5	090	0	000	105	090	1	10.5		180
9	12 Aug 67	1000	44°37.7'	124°51.0'	10				090	22	180	27	000	-25	090	37	1	28.5	090	28	180	40	135	1	40		225

EQUATIONS

XI = ½ (VI + VIII)

Y = ½ (IV + X) - XI
XII = |Y|

XIII = III if Y ≥ 0
or = III ± 180° if Y ≤ 0

XIV = |VI - XI|

XV = V if VI ≥ VIII
or = VII if VI ≤ VIII

$*XVI = \sqrt{XII^2 + XIV^2}$

*tanA = XIV/XII

*XVII = XIII + A
If XIII + 90° = XV
or
*XVII = XIII - A
If XIII - 90° = XV

May be computed on Mark 3a Plotting Board

XVIII = 1.04 x I/II

XIX = XVIII x XVI

XX = .0194 x XIX

XXI = XVII + 90°
if II > 0
or
XXI = XVII - 90°
if II < 0

REMARKS

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

NAVY-DPPO PRNC, WI

TABLE 2 LEGEND

Column	Units
A	Pacific Daylight Time (PDT)
B	Latitude, North
C	Longitude, West
D	knots
E	fathoms
F and G	millioersteds
H, J, L, N, R, T, V, Z	degrees true
I, K, M, O, P Q, S, V, X	centimeters/second
W	non-dimensional signal multiplier
Y	knots

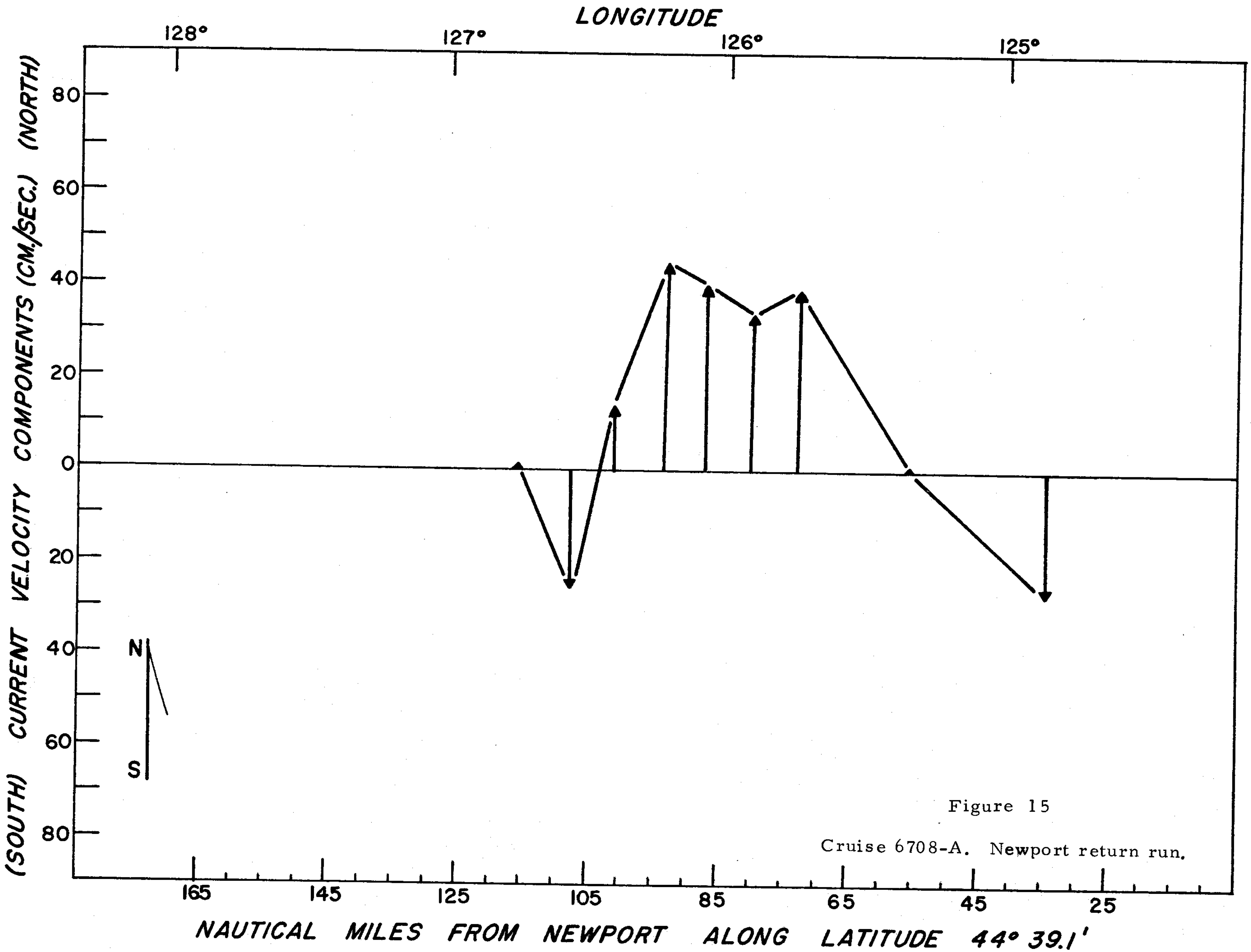


Figure 15

Cruise 6708-A. Newport return run.

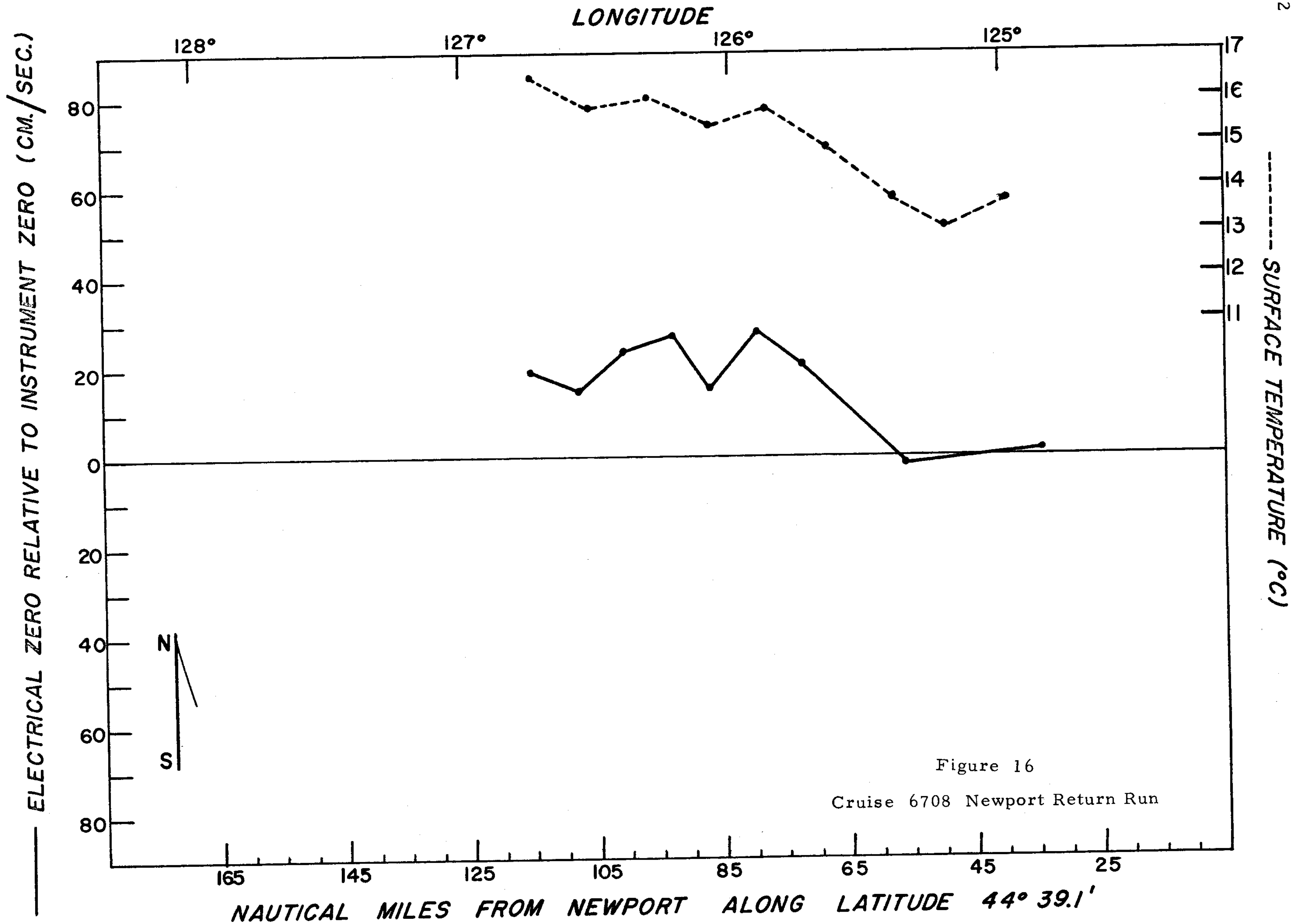


Figure 16

Cruise 6708 Newport Return Run

CRUISE 6708-D

Objectives

- To use both cables again for GEK measurements, employing a newly overhauled electronic comparator circuit with a built-in biasing voltage and polarity inversion.

- To repeat previous experiments on variations of the electrode inter-distances.

- To continue gathering data on currents measured from NH 165 to Newport, Oregon.

- To continue data collection on electrical zero drift and surface temperature measurements.

Equipment Employment

The cables, recorder, and electronic circuits were set up in an exactly similar manner as on the previous cruise. The polarity inversion within the overhauled mixer solved the problem of the sign reversal experienced and mentioned in the last cruise results.

Operation Schedule

A. Experiments on track west.

At 0015 PDT of August 30, the long cable was payed out overboard to check the cable leads and to test the new electronic bias voltage adjustment. The voltage range was found to be approximately ± 0.60 millevolts. The cable was retrieved at 0200 PDT 30 August before arrival at NH 65.

Again the next day at NH 85, both cables were payed out at 1110 PDT 31 August. Differences occurred between the signal magnitudes from each cable. A successful test of the bias circuit adjustment demonstrated, however, that the signals could be equalized by this means. No significant suppression of wave signal noise could be observed over those presented in the results of the previous cruise. The cables were pulled aboard at 1315 PDT on the same day.

B. Experiments on track east.

A continuous GEK measurement was obtained from 1012 PDT 31 August while sailing to Newport from NH 165. Fifteen zero fixes were obtained, using the signal received from the long cable. Surface temperatures, electrical zeros, and north-south components are plotted in Figures 17 and 18 from numerical results listed in Table 3.

Various experiments were also conducted between fixes. The different cable lengths and electrode connections executed on Cruise 6708-A were repeated between 1930 PDT 31 August and 2135 31 August with similar results. One obvious difference, however, was that no significant beat frequency due to the oscillation of the ship's heading appeared in this two-hour experiment.

TABLE 3

OCEANOGRAPHIC LOG SHEET - GEK
PRNC-NHO 3167/7 (Rev. 5-55)

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

VESSEL	CRUISE	YEAR	SURFACE GEOMAGNETIC ELECTRO-KINETOGRAPH NO.	COMPUTED BY	CHECKED BY
R/V YAQUINA	6708-D	1967		YAO, NENG-CHUN	

Specify algebraic signs and units of all measurements. In northern magnetic hemisphere: The current velocity vector lies 90° to the RIGHT of the resultant electric signal vector, and the more distant electrode should be connected to the POSITIVE input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.

GEK SERIAL NO.	DATE (Day, Month)	HOUR (GMT)	POSITION OF CURRENT FIX: LATITUDE (N or S)	POSITION OF CURRENT FIX: LONGITUDE (E or W)	SHIP'S AVERAGE SPEED (Knots, m./Sec.)	DEPTH OF WATER (m., fm.)	VERTICAL MAGNETIC INTENSITY (Milliorsteds): STAND. I	VERTICAL MAGNETIC INTENSITY: LOCAL II	INITIAL BASE-COURSE: DIR. (°T) III	INITIAL BASE-COURSE: SIG. cm./Sec. IV	FIRST FIX-COURSE: DIR. (°T) V	FIRST FIX-COURSE: SIG. cm./Sec. VI	SECOND FIX-COURSE: DIR. (°T) VII	SECOND FIX-COURSE: SIG. cm./Sec. VIII	RESUMED BASE-COURSE: DIR. (°T) IX	RESUMED BASE-COURSE: SIG. cm./Sec. X	ZERO POINT cm./Sec. XI	AVERAGE BASE-COURSE SIGNAL: MAG. cm./Sec. XII	AVERAGE BASE-COURSE SIGNAL: DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL: MAG. cm./Sec. XIV	AVERAGE FIX-COURSE SIGNAL: DIR. (°T) XV	RESULTANT SIGNAL VECTOR: MAG. cm./Sec. XVI	RESULTANT SIGNAL VECTOR: DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY: SPEED cm./Sec. XIX	CURRENT VELOCITY: SPEED (Knots) XX	CURRENT VELOCITY: DIR. (°T) XXI
1 (L)	Aug 31	1035	44°41.3'	127°45.0'	10				090	37	000	5	180	37	090	25	21	10	090	16	180	20	149	1	20		239
2 (S)	Aug 31	1145	44°41.6'	127°32.3'	10				090	5	000	15	180	-10	090	-20	2.5	10	270	35	000	37	343	1	37		073
3 (L)	Aug 31	1245	44°39.5'	127°21.0'	10				090	0	180	65	000	5	090	- 5	35	37.5	270	30	180	48	230	1	48		320
4 (L)	Aug 31	1345	44°39.5'	127°09.7'	10				090	20	000	75	180	5	090	30	40	15	270	35	000	38	337	1	38		067
5 (L)	Aug 31	1445	44°39.9'	126°58.6'	10				090	112	180	40	000	30	090	110	35	76	090	5	180	76	094	1	76		184
6 (L)	Aug 31	1545	44°39.8'	126°48.0'	10				090	72	180	35	000	35	090	72	35	37	090	0	180	37	090	1	37		180
7 (L)	Aug 31	1645	44°39.7'	126°38.8'	10				090	90	180	97	000	20	090	70	34	46	090	63	180	84	146	1	84		236
8 (L)	Aug 31	1745	44°39.4'	126°25.7'	10				090	75	180	150	000	-110	090	90	35	47.5	090	115	180	139	163	1	139		253
9 (L)	Aug 31	1845	44°39.2'	126°12.7'	10				090	62	180	125	000	- 75	090	50	25	31	090	94	180	88	162	1	88		252
10(B)	Aug 31	1945	44°39.7'	126°02.1'	10				090	65	180	25	000	- 75	090	60	-25	87.5	090	50	180	101	120	1	101		210
11(L)	Aug 31	2045	44°39.2'	125°51.8'	10				090	50	180	65	000	45	090	45	55	7	270	10	180	12	125	1	12		215
12(L)	Aug 31	2145	44°38.9'	125°39.8'	10				090	80	180	100	000	35	090	75	67	10.5	090	33	180	35	162	1	35		252
13(L)	Aug 31	2245	44°39.2'	125°27.6'	10				090	60	180	50	000	75	090	70	67.5	2.5	090	12.5	000	13	012	1	13		102
14(L)	Aug 31	2345	44°39.2'	125°15.0'	10				090	75	180	55	000	80	090	80	66.5	11	090	11.5	000	16	045	1	16		135
15(L)	Sept 1	0045	44°39.8'	125°03.8'	10				090	70	180	75	000	45	090	75	60	12.5	090	15	180	21	144	1	21		234

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

EQUATIONS

XI = ½ (VI + VIII)

Y = ½ (IV + X) - XI
XII = |Y|

XIII = III if Y ≥ 0
or = III ± 180° if Y ≤ 0

XIV = |VI - XI|

XV = V if VI ≥ VIII
or = VII if VI ≤ VIII

*XVI = $\sqrt{XII^2 + XIV^2}$

*tanA = XIV/XII

*XVII = XIII + A
If XIII + 90° = XV
or
*XVII = XIII - A
If XIII - 90° = XV

May be computed on Mark 3a Plotting Board

XVIII = 1.04 x I/II

XIX = XVIII x XVI

XX = .0194 x XIX

XXI = XVII + 90°
if II > 0
or
XXI = XVII - 90°
if II < 0

REMARKS

1. Continuous GEK mea. until 1845.
2. Diff. cables length trialed out 1920 to 2145 between current fix.

TABLE 3 LEGEND

Column	Units
A	Pacific Daylight Time (PDT)
B	Latitude, North
C	Longitude, West
D	knots
E	fathoms
F and G	millioersteds
H, J, L, N, R, T, V, Z	degrees true
I, K, M, O, P, Q, S, V, X	centimeters/second
W	non-dimensional multiplier
Y	knots

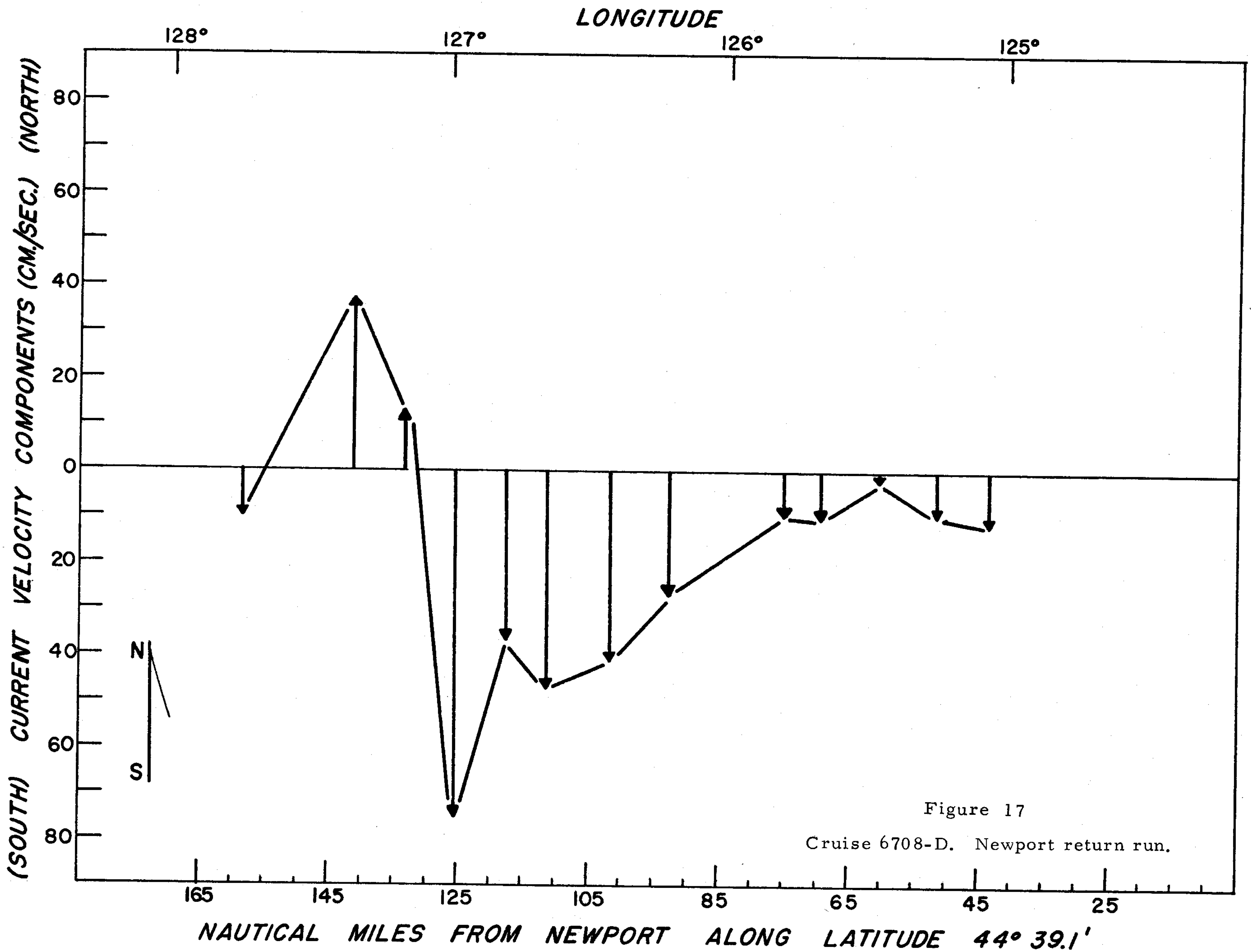


Figure 17

Cruise 6708-D. Newport return run.

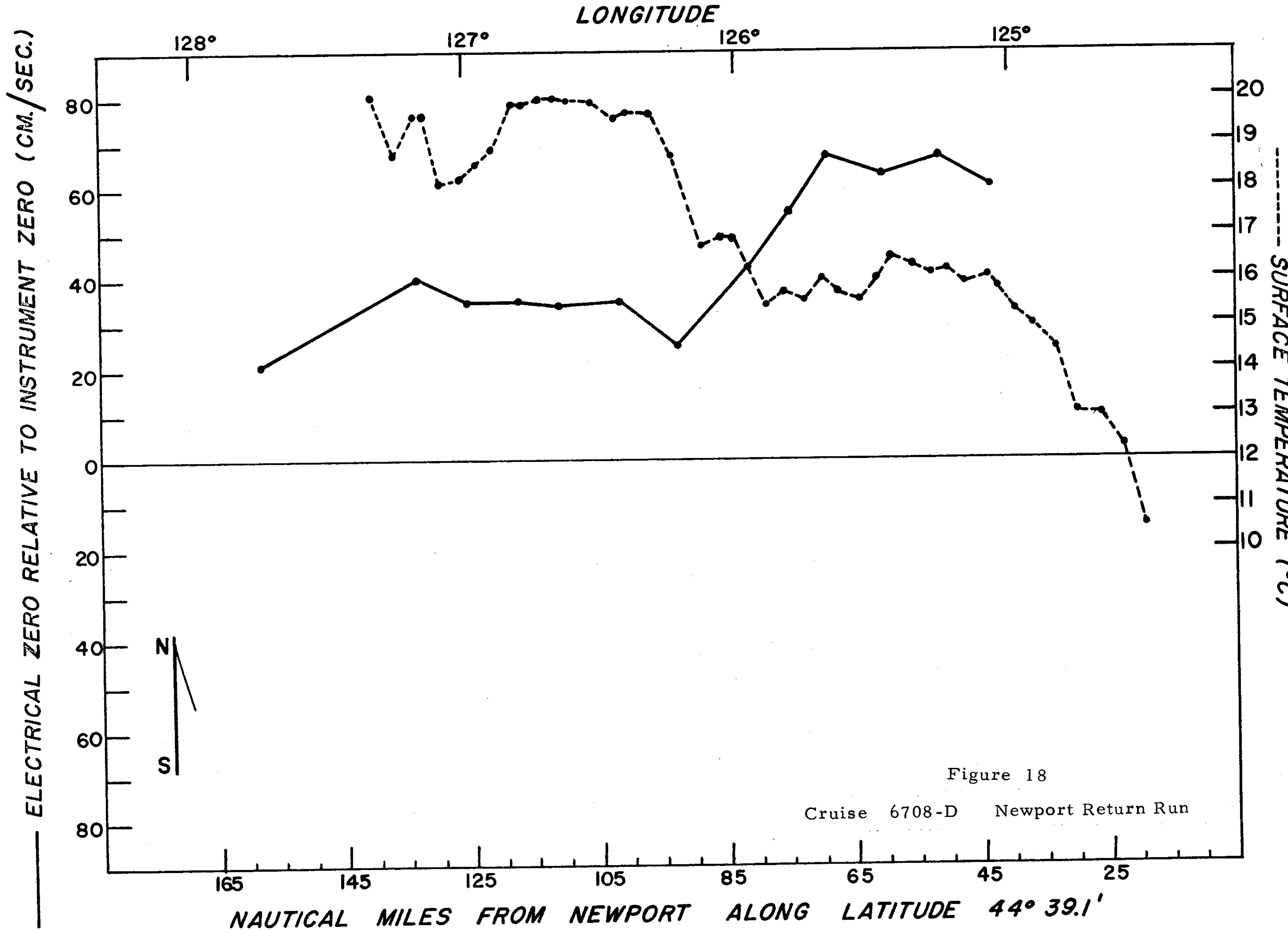


Figure 18

Cruise 6708-D Newport Return Run

CRUISE 6710-B

Objectives

- To compare GEK measurements by using the two previous cables, towed simultaneously, and each feeding separately into an independent recorder.

- To continue to gather GEK current measurements along the Newport Hydro line.

- To continue to obtain data on electrical zero drift and surface temperature conditions.

Equipment Employment

Two Leeds and Northrup strip chart recorders were lashed down in the aft lab at the start of this cruise. One recorder was specifically designed for GEK use and so-modified electronically. The other was a stock potentiometric recorder with a 20 mv scale capability and no special internal adaptations. The two cables were streamed aft to their full lengths in the same manner as the previous experiments. The electronic junction box was not used as a summation device, but merely employed as a straight switching device to facilitate cable selection.

Operation Schedule

All GEK measurements were taken on the track east from NH 165 to Newport. After all equipment had been set up and the cables streamed, each cable was connected separately to each recorder. At this time we noticed that the stock recorder had an extremely fast chart speed which could not be properly adjusted. If kept in continuous operation for GEK measurements, it would deplete the available supply of chart paper and produce well spread out and hard to average results. Thus an immediate change in plans had to be adapted. We still desired to obtain and compare the separate signals from each cable. With only one recorder to work with, the maneuvering scheme shown in Figure 19 was adopted. Selection of signals was facilitated by the junction box used only as a switch.

The reason for the five minute run of unfiltered signal was to monitor any effect the filter's time constant might have exhibited in changing the average signal value.

Surface temperature, electrical zero, and current components for each cable are graphed in Figures 20, 21, 22, and 23. Tables 4 and 5 list the numerical values represented by these figures.

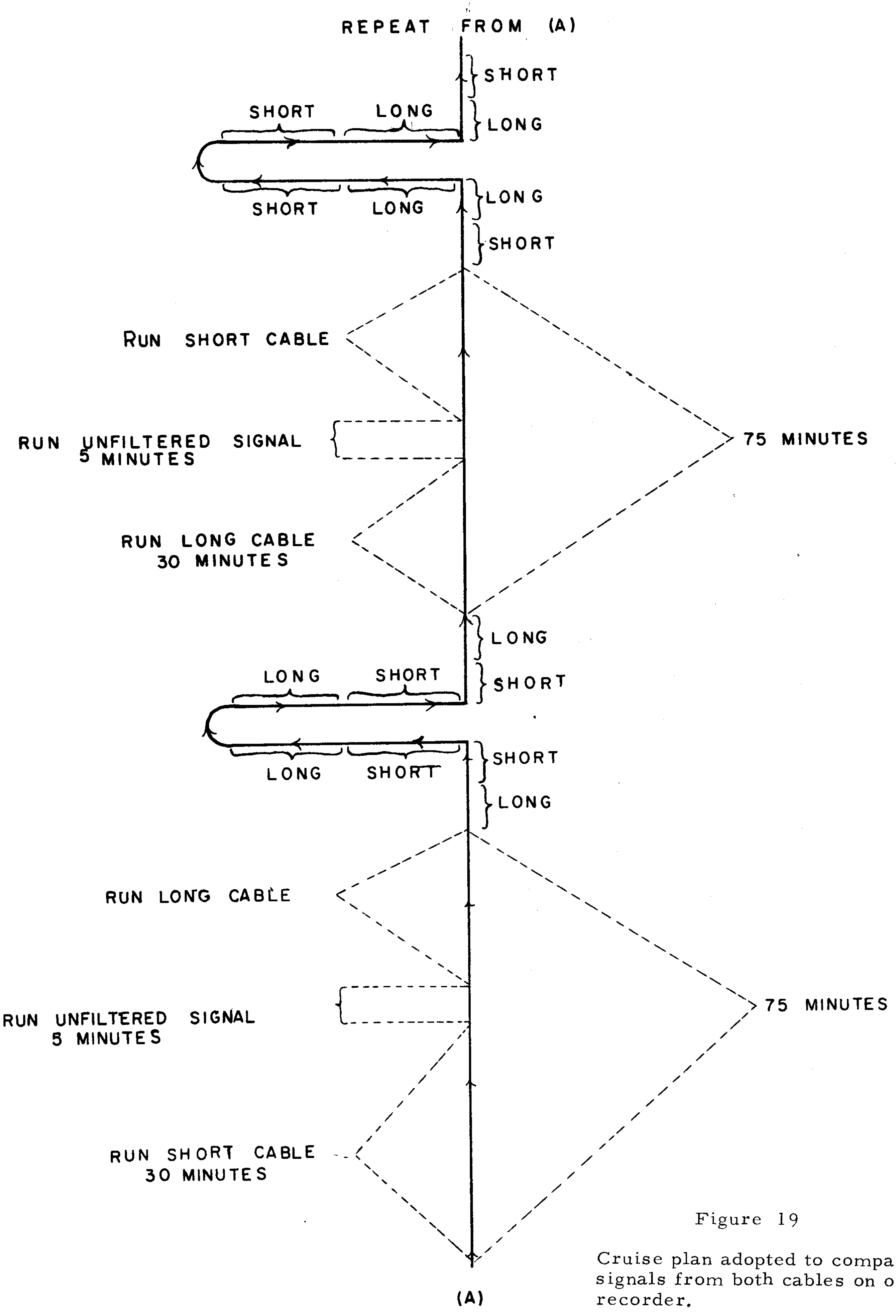


Figure 19

Cruise plan adopted to compare signals from both cables on one recorder.

CABLE L - LONG

OCEANOGRAPHIC LOG SHEET - GEK

PRNC-NHO 3167/7 (Rev. 5-55)

TABLE 4

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

VESSEL	CRUISE	YEAR	SURFACE GEOMAGNETIC ELECTRO-KINETOGRAPH NO.	COMPUTED BY	CHECKED BY
R/V YAQUINA	6710-B	1967		CURTIN, T. B.	

Specify algebraic signs and units of all measurements. In northern magnetic hemisphere: The current velocity vector lies 90° to the RIGHT of the resultant electric signal vector, and the more distant electrode should be connected to the POSITIVE input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.

GEK SERIAL NO.	DATE (Day, Month)	HOUR (GMT)	POSITION OF CURRENT FIX: LATITUDE (N or S)	POSITION OF CURRENT FIX: LONGITUDE (E or W)	SHIP'S AVERAGE SPEED (Knots, m./Sec.)	DEPTH OF WATER (m., fm.)	VERTICAL MAGNETIC INTENSITY (Millioersteds): STAND. I	VERTICAL MAGNETIC INTENSITY: LOCAL II	INITIAL BASE-COURSE: DIR. (°T) III	INITIAL BASE-COURSE: SIG. cm./Sec. IV	FIRST FIX-COURSE: DIR. (°T) V	FIRST FIX-COURSE: SIG. cm./Sec. VI	SECOND FIX-COURSE: DIR. (°T) VII	SECOND FIX-COURSE: SIG. cm./Sec. VIII	RESUMED BASE-COURSE: DIR. (°T) IX	RESUMED BASE-COURSE: SIG. cm./Sec. X	ZERO POINT cm./Sec. XI	AVERAGE BASE-COURSE SIGNAL: MAG. cm./Sec. XII	AVERAGE BASE-COURSE SIGNAL: DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL: MAG. cm./Sec. XIV	AVERAGE FIX-COURSE SIGNAL: DIR. (°T) XV	RESULTANT SIGNAL VECTOR: MAG. cm./Sec. XVI	RESULTANT SIGNAL VECTOR: DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY: SPEED cm./Sec. XIX	CURRENT VELOCITY: SPEED (Knots) XX	CURRENT VELOCITY: DIR. (°T) XXI
1	18 Oct 67	2135	44°38.5'	127°11.5'	10	--	0.500	0.500	180	20	270	8	270	8	180	7	+25	13.5	180°								
2	18 Oct 67	2331	44°39.3'	126°50.1'	10	--	0.500	0.500	- -	- -	090	8	090	8	180	12	+20	12.0	180°								
3	19 Oct 67	0130	44°40.0'	126°30.0'	10	--	0.500	0.500	180	12	090	16	090	16	180	12	+ 9	12.0	180°								
4	19 Oct 67	0330	44°38.9'	125°57.3'	10	--	0.500	0.500	180	24	090	31	090	31	180	24	+ 9	24.0	180°								
5	19 Oct 67	0530	44°38.9'	125°46.8'	10	--	0.500	0.500	180	2	090	48	090	48	180	31.5	+11.5	16.7	180°								
6	19 Oct 67	0730	44°39.1'	125°23.9'	10	--	0.500	0.500	180	25	090	35	090	35	180	17	+ 2.5	21.0	180°								
7	19 Oct 67	0930	44°39.1'	125°03.3'	10	--	0.500	0.500	180	19	270	11	270	11	180	19	- 1	19.0	180°								
8	19 Oct 67	1130	44°38.5'	124°40.7'	10	--	0.500	0.500	- -	- -	270	29	270	29	180	14	-16	14.0	180°								
9	19 Oct 67	1330	44°38.8'	124°22.8'	10	--	0.500	0.500	180	27.5	270	32.5	270	32.5	180	37.5	-30	32.5	180°								

EQUATIONS

XI = ½ (VI + VIII)

Y = ½ (IV + X) - XI
XII = |Y|

XIII = III if Y ≥ 0
or = III ± 180° if Y ≤ 0

XIV = |VI - XI|

XV = V if VI ≥ VIII
or = VII if VI ≤ VIII

*XVI = $\sqrt{XII^2 + XIV^2}$

*tanA = XIV/XII

*XVII = XIII + A
If XIII + 90° = XV
or
*XVII = XIII - A
If XIII - 90° = XV

*May be computed on Mark 3a Plotting Board

XVIII = 1.04 x I/II

XIX = XVIII x XVI

XX = .0194 x XIX

XXI = XVII + 90°
if II > 0
or
XXI = XVII - 90°
if II < 0

REMARKS

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

NAVY-DPI

TABLE 5

U.S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D.C.

ELECTROMAGNETIC CURRENT OBSERVATIONS
For use with H.O. Pub. No. 607

OCEANOGRAPHIC LOG SHEET - GEK
PRNC-NHO 3167/7 (Rev. 5-55)

VESSEL	CRUISE	YEAR	SURFACE GEOMAGNETIC ELECTRO-KINETOGRAPH NO.	COMPUTED BY	CHECKED BY
R/V YAQUINA	6710-B	1967		CURTIN, T. B.	

Specify algebraic signs and units of all measurements. In northern magnetic hemisphere: The current velocity vector lies 90° to the RIGHT of the resultant electric signal vector, and the more distant electrode should be connected to the POSITIVE input terminal. Consult H.O. Chart No. 1702 for local value of H_z and set recorder scale to value of nearest standard isodynamic line.

GEK SERIAL NO.	DATE (Day, Month)	HOUR (GMT)	POSITION OF CURRENT FIX: LATITUDE (N or S)	POSITION OF CURRENT FIX: LONGITUDE (E or W)	SHIP'S AVERAGE SPEED (Knots, m./Sec.)	DEPTH OF WATER (m., fm.)	VERTICAL MAGNETIC INTENSITY (Millioersteds): STAND. I	VERTICAL MAGNETIC INTENSITY: LOCAL II	INITIAL BASE-COURSE: DIR. (°T) III	INITIAL BASE-COURSE: SIG. cm./Sec. IV	FIRST FIX-COURSE: DIR. (°T) V	FIRST FIX-COURSE: SIG. cm./Sec. VI	SECOND FIX-COURSE: DIR. (°T) VII	SECOND FIX-COURSE: SIG. cm./Sec. VIII	RESUMED BASE-COURSE: DIR. (°T) IX	RESUMED BASE-COURSE: SIG. cm./Sec. X	ZERO POINT cm./Sec. XI	AVERAGE BASE-COURSE SIGNAL: MAG. cm./Sec. XII	AVERAGE BASE-COURSE SIGNAL: DIR. (°T) XIII	AVERAGE FIX-COURSE SIGNAL: MAG. cm./Sec. XIV	AVERAGE FIX-COURSE SIGNAL: DIR. (°T) XV	RESULTANT SIGNAL VECTOR: MAG. cm./Sec. XVI	RESULTANT SIGNAL VECTOR: DIR. (°T) XVII	CORRECTION TO STANDARD ISODYNAMIC LINE (Multiplier) XVIII	CURRENT VELOCITY: SPEED cm./Sec. XIX	CURRENT VELOCITY: SPEED (Knots) XX	CURRENT VELOCITY: DIR. (°T) XXI
1	18 Oct 67	2135	44°38.5'	127°11.5'	10	--	0.500	0.500	180	1	270	6	270	6	180	1	- 1.0	1.0	180°								
2	18 Oct 67	2331	44°39.3'	126°50.1'	10	--	0.500	0.500	---	---	090	7.5	090	7.5	180	7.5	+ 2.5	7.5	180°								
3	19 Oct 67	0130	44°40.0'	126°30.0'	10	--	0.500	0.500	180	5*	090	12	090	12	180	5*	+ 5.0	5.0	180°								
4	19 Oct 67	0330	44°38.9'	125°57.3'	10	--	0.500	0.500	180	10	090	20	090	20	180	0	+ 5.0	5.0	180°								
5	19 Oct 67	0530	44°38.9'	125°46.8'	10	--	0.500	0.500	---	---	090	30	090	30	180	27.5	+ 7.5	27.5	180°								
6	19 Oct 67	0730	44°39.1'	125°23.9'	10	--	0.500	0.500	180	27	090	14	090	14	180	16	+ 9	21.5	180°								
7	19 Oct 67	0930	44°39.1'	125°03.3'	10	--	0.500	0.500	180	31	270	19	270	19	180	34	+19	32.5	180°								
8	19 Oct 67	1130	44°38.5'	124°40.7'	10	--	0.500	0.500	180	55	270	20	270	20	180	45	+35	50.0	180°								
9	19 Oct 67	1330	44°38.8'	124°22.8'	10	--	0.500	0.500	180	50.5	270	22.5	270	22.5	180	65.5	+37.5	58.0	180°								

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

EQUATIONS

XI = ½ (VI + VIII)

Y = ½ (IV + X) - XI
XII = |Y|

XIII = III if Y ≥ 0
or = III ± 180° if Y ≤ 0

XIV = |VI - XI|

XV = V if VI ≥ VIII
or = VII if VI ≤ VIII

*XVI = $\sqrt{XII^2 + XIV^2}$

*tanA = XIV/XII

*XVII = XIII + A
If XIII + 90° = XV
or
*XVII = XIII - A
If XIII ± 90° = XV

*May be computed on Mark 3a Plotting Board

XVIII = 1.04 x I/II

XIX = XVIII x XVI

XX = .0194 x XIX

XXI = XVII + 90°
if II > 0
or
XXI = XVII - 90°
if II < 0

REMARKS

*Signal exhibits wide range oscillation here. Difficult to average.

NAVY-DC

TABLE LEGEND (Tables 4 and 5)

Column	Units
A	Pacific Daylight Time (PDT)
B	Latitude, North
C	Longitude, West
D	knots
E	fathoms
F and G	millioersteds
H, J, L, N, R, T, V, Z,	degrees true
I, K, M, O, P, Q, S, V, X,	centimeters/second
W	non-dimensional signal multiplier
Y	knots

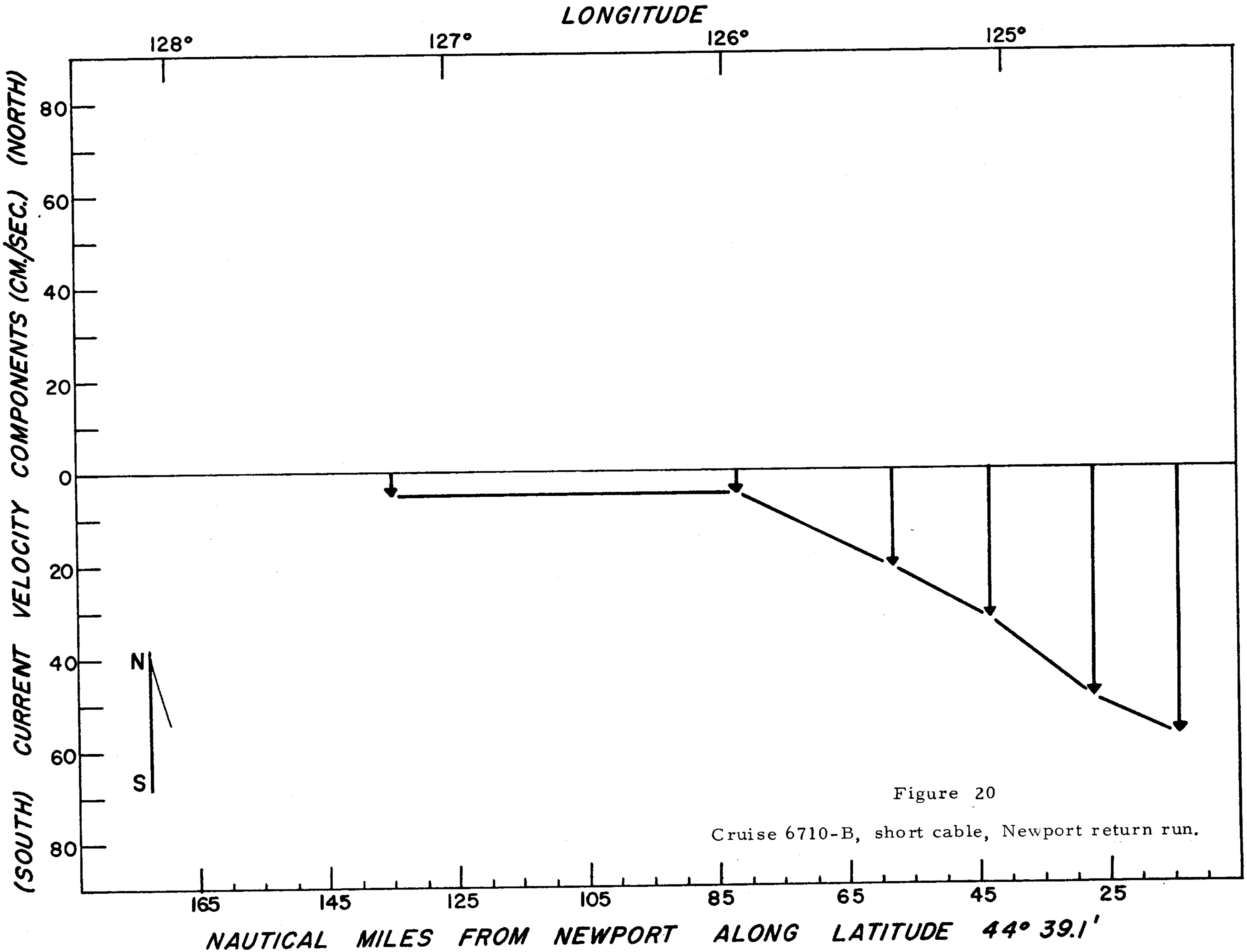


Figure 20

Cruise 6710-B, short cable, Newport return run.

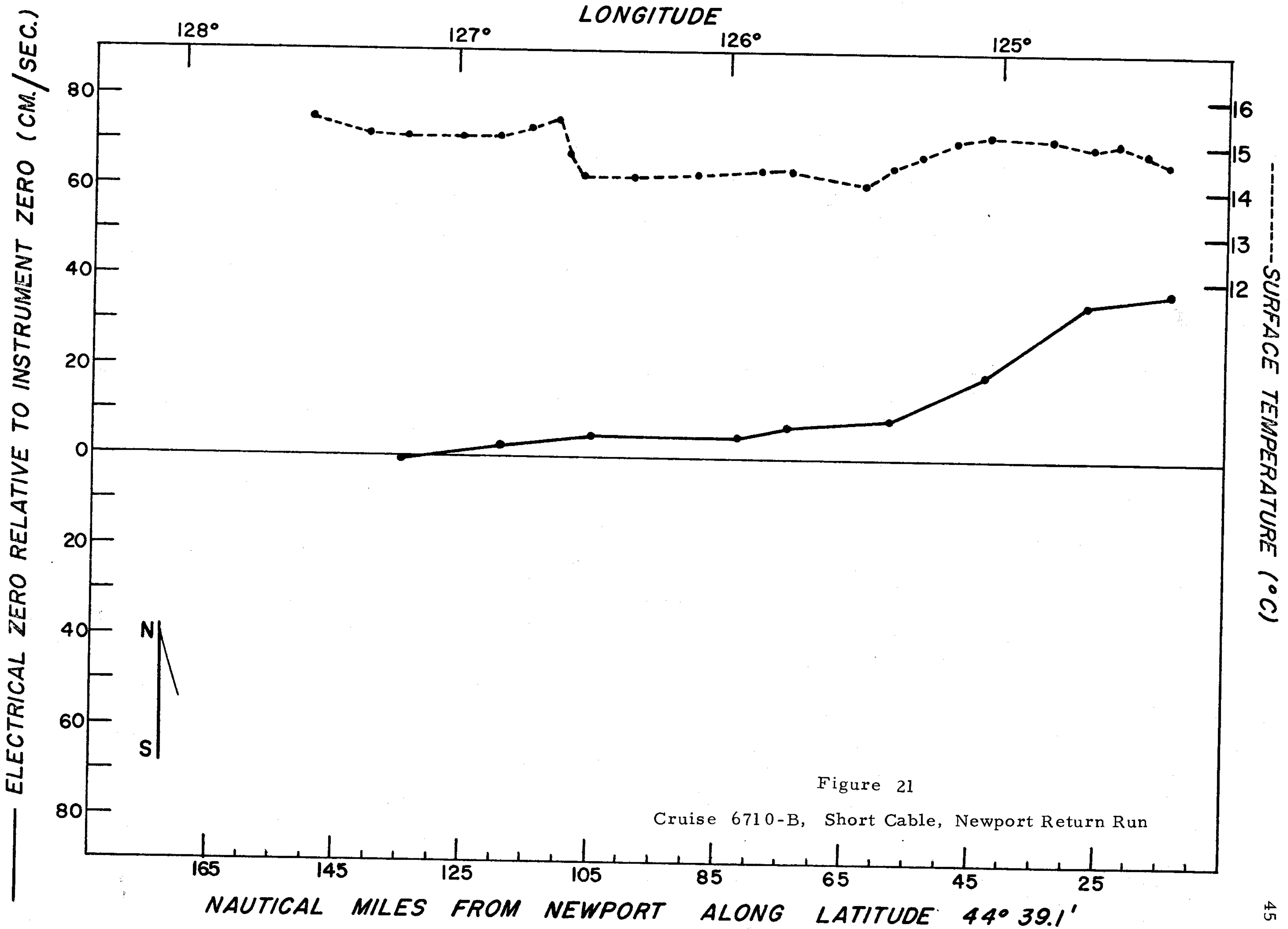


Figure 21

Cruise 6710-B, Short Cable, Newport Return Run

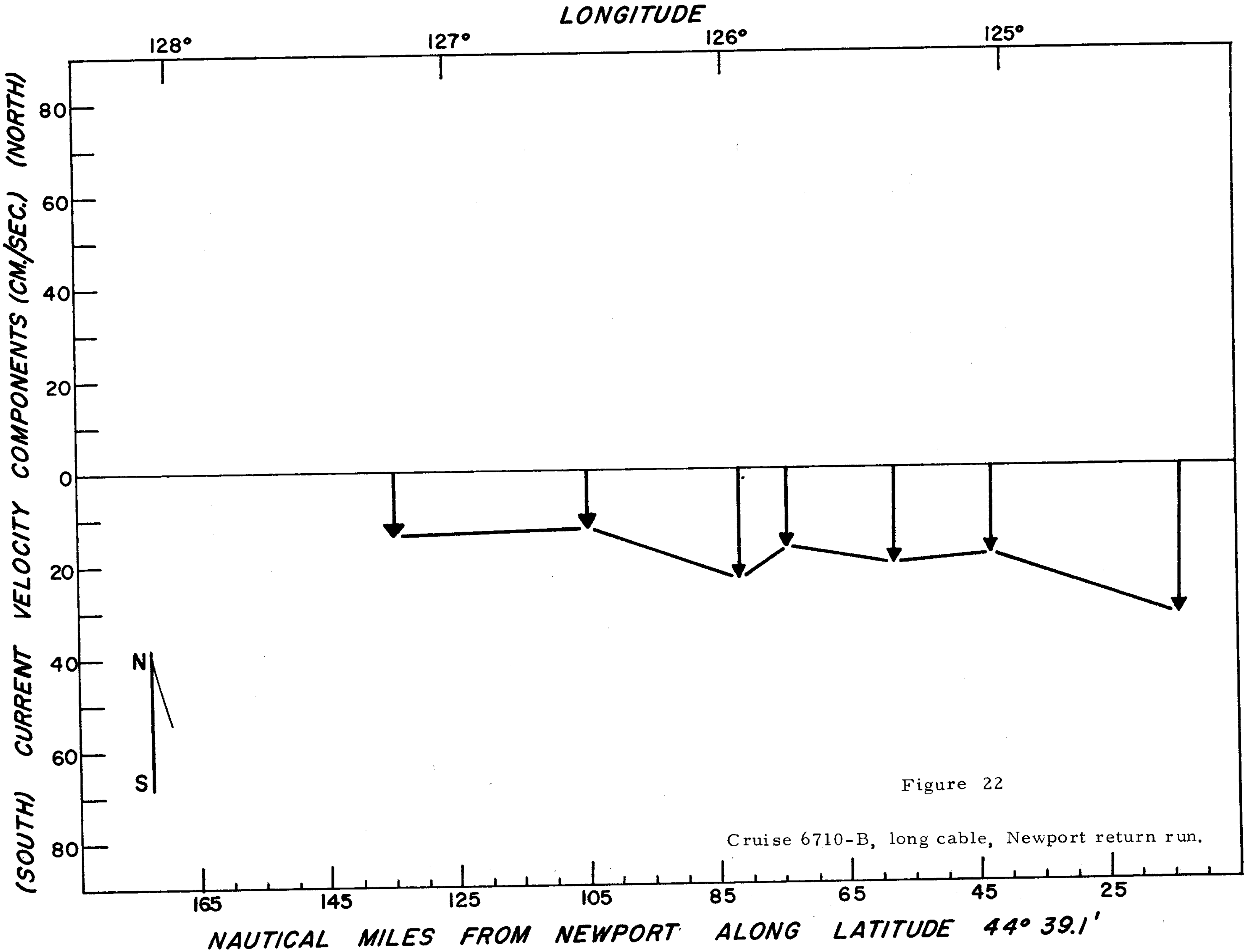


Figure 22

Cruise 6710-B, long cable, Newport return run.

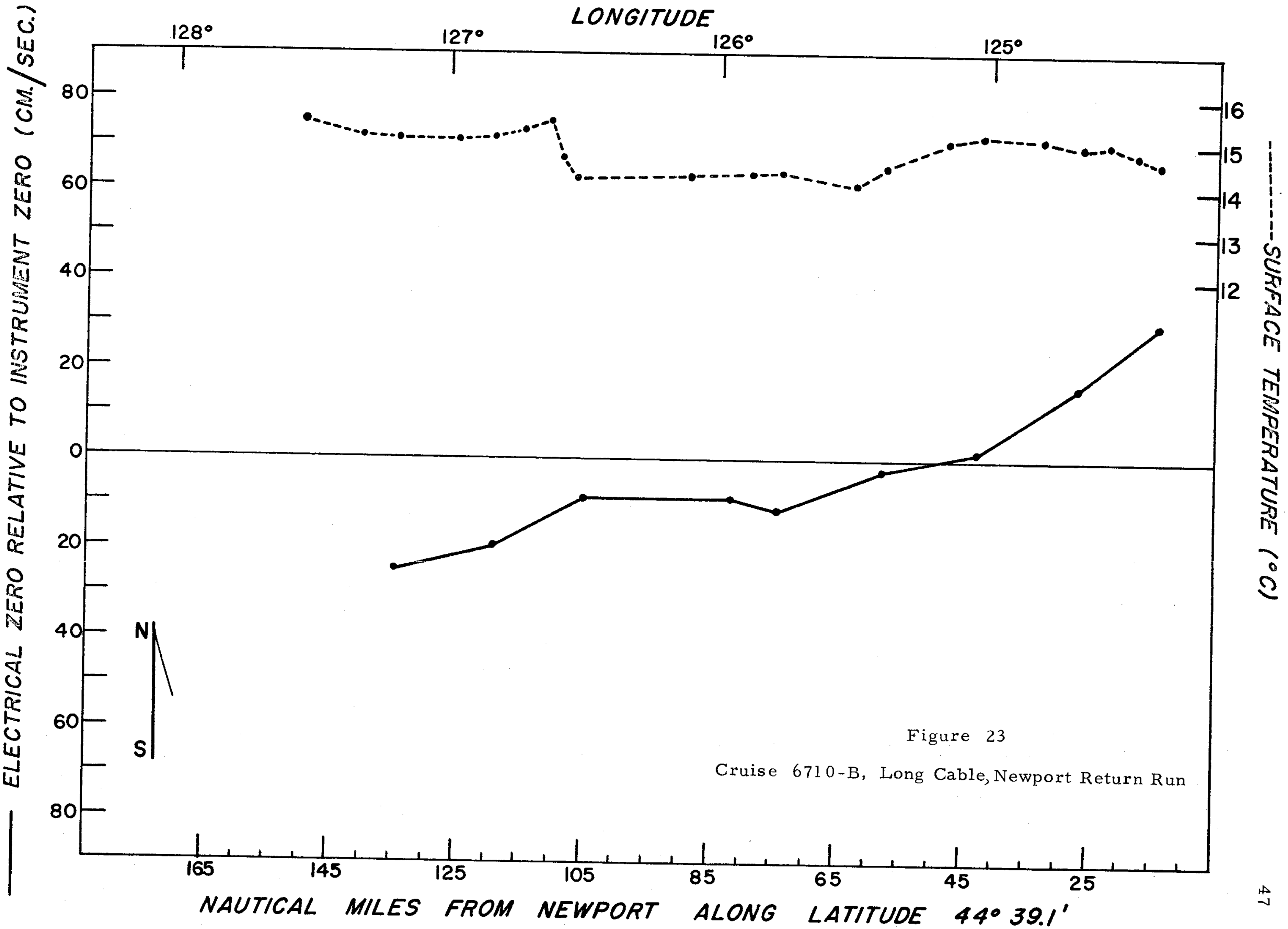


Figure 23

Cruise 6710-B, Long Cable, Newport Return Run

CRUISE - 6711

Objectives

- To implement a new winch reel for the GEK cables and electrodes.

- To initiate the use of new data recording sheets and bridge log sheets.

- To successfully compare GEK measurements by using the two cables towed simultaneously, each feeding separately into the independent recorders used previously.

- To obtain GEK measurements continuously for 24 hours over the same 20 mile distance.

- To continue to gather GEK current measurements along the Newport Hydro line.

- To continue to obtain data on electrical zero drift and surface temperature conditions.

Equipment Employment

The two Leeds and Northrup recorders referred to in the previous cruise were again lashed down in the aft lab at the start of this cruise. The appropriate gears for slowing down the fast recorder had not been received; however, a large supply of chart paper was obtained and the recorder was able to run continuously for the required measurements. The setup is shown in Figure 24.

The GEK cables with electrodes were spooled on a newly manufactured reel, made to fit the shaft of the boat deck trawl winch. This spool was brought on board via the mobile dock crane. Figure 25 shows the spool at sea after the electrodes had been streamed.

Before departing on the cruise, various calibration tests were run on both recorders by using signal generators monitored with a dual input oscilloscope. Response to various input frequencies, input voltages and resistance-capacitance filter settings were recorded. This was done to facilitate comparison of the data taken on the cruise. The most obvious difference between recorders was determined to be a difference in scale. The standard GEK recorder has a full scale deflection of 25 mv., whereas the stock recorder has a maximum full scale deflection of 20 mv. This difference had to be kept in mind when analyzing the current magnitudes. Examples of the calibration curves run are demonstrated in Figures 26 and 27.

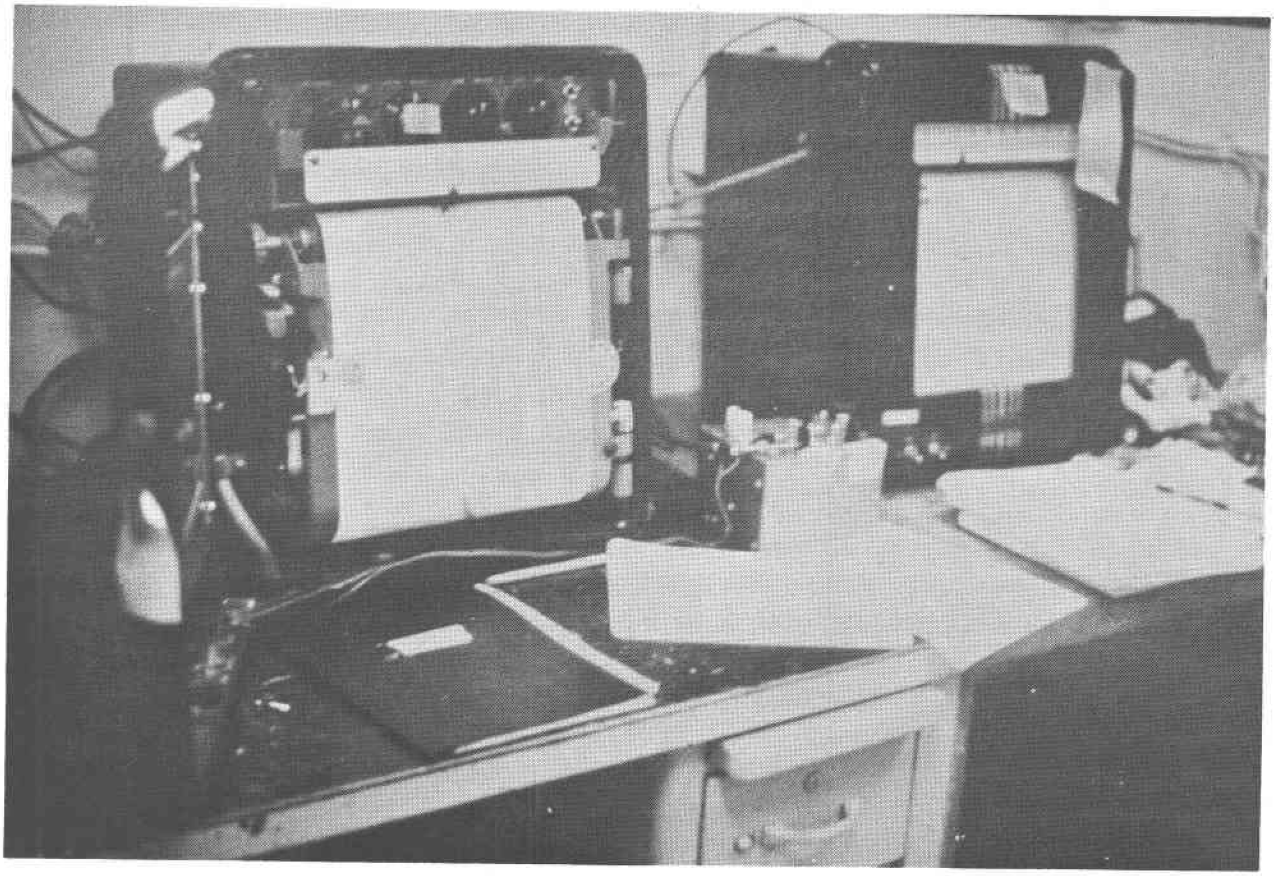


Figure 24

The two recorders employed on the R/V YAQUINA to simultaneously record the signals from two separate GEK cables.

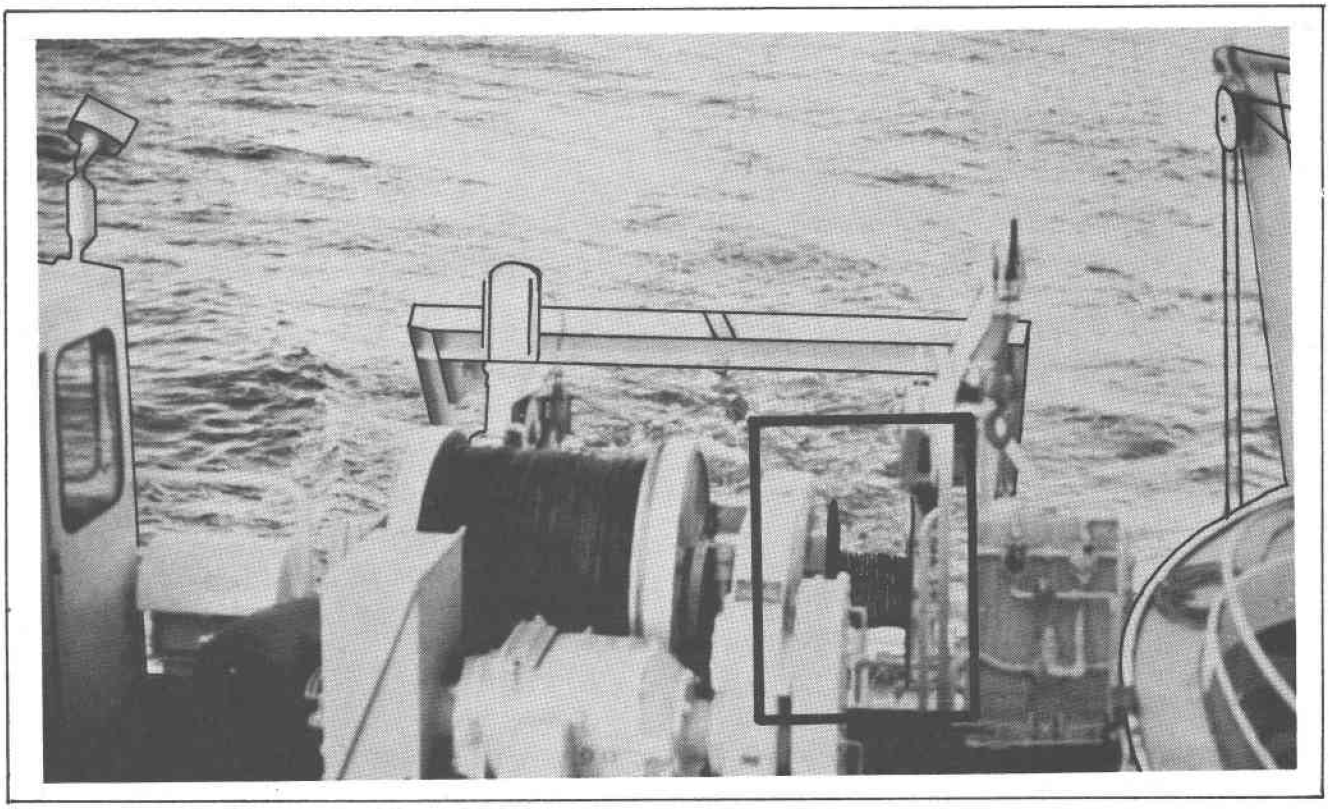


Figure 25

GEK cable spool mounted on shaft of deep-sea trawl winch during operations.

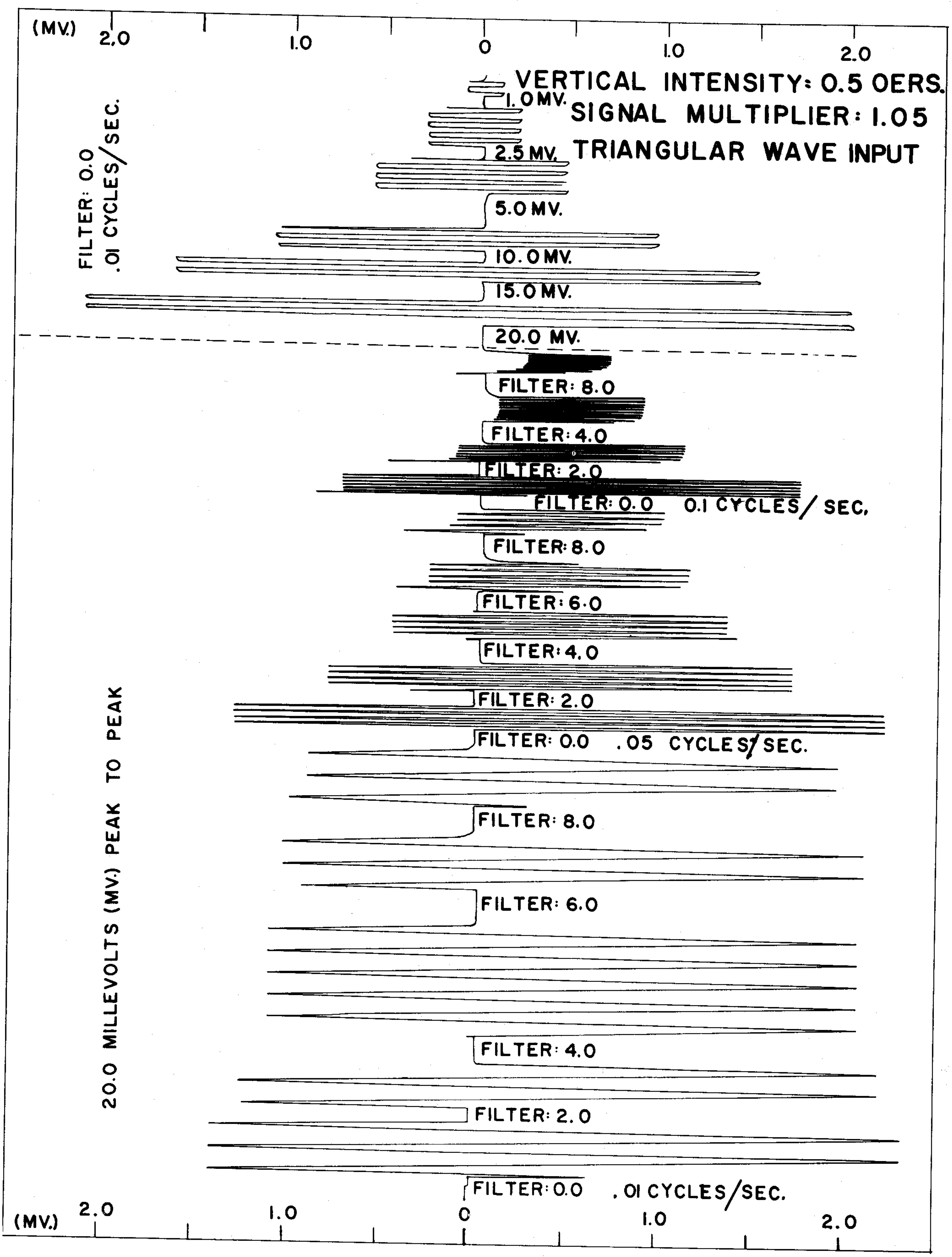


Figure 26. An example of some responses of the "GEK recorder" to various input signals. Refer to the text for details.

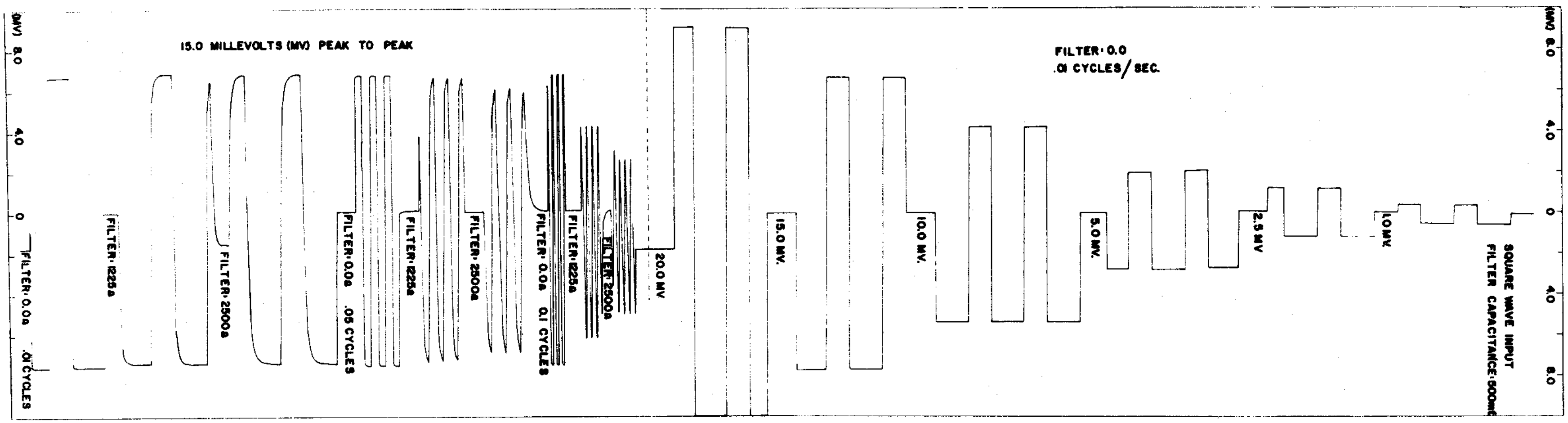


Figure 27. Examples of some responses of the unmodified recorder to various input signals. Note expanded scale due to faster chart speed.

The filter used on the stock recorder during these tests and on board ship was a low band pass R-C network consisting of a 1000 mfd. capacitor and a 2500 ohm resistor.

Operation Schedule

During the westward leg on the Newport Hydro line, hydrographic operations had to be suspended at NH 65 due to the onset of rough weather. It was decided to undertake the 24 hour GEK measurement at this time. Generally speaking, the weather was stormy during the entire cruise (wind speed averaged about 35 to 40 knots). Thus it may be propitious to examine all the data with the windage correction factor being given some weight. No correction was applied to the raw data presented here.

The cables were reeled out by using the boat deck winch. The new system worked well, although three or four people are needed to guide the two cables through the blocks and shackles. After the cables had been streamed, the connecting electrical cable was hooked up, but the upper cable jacks on the new reel were found to be faulty. These were eventually by-passed and the proper connections made.

The cruising procedure followed during this 24-hour run is outlined in Figure 28. This is followed by the bridge log (Table 6), and data sheets which were newly implemented on this cruise (Tables 7 and 8). Following these, the major results are graphed in Figures 29, 30, 31, and 32. A crude periodicity is hinted at and indicated by the lettering in the margin to the right of the grids.

Twenty-four hours later the weather had somewhat subsided and the hydrographic casts were continued out to NH 165. Here the GEK electrodes were again streamed and a continuous record was obtained back to NH 65. The results are presented in the same manner as the 24 hour run and following that data in Tables 9 and 10, and Figures 33, 34, 35, and 36.

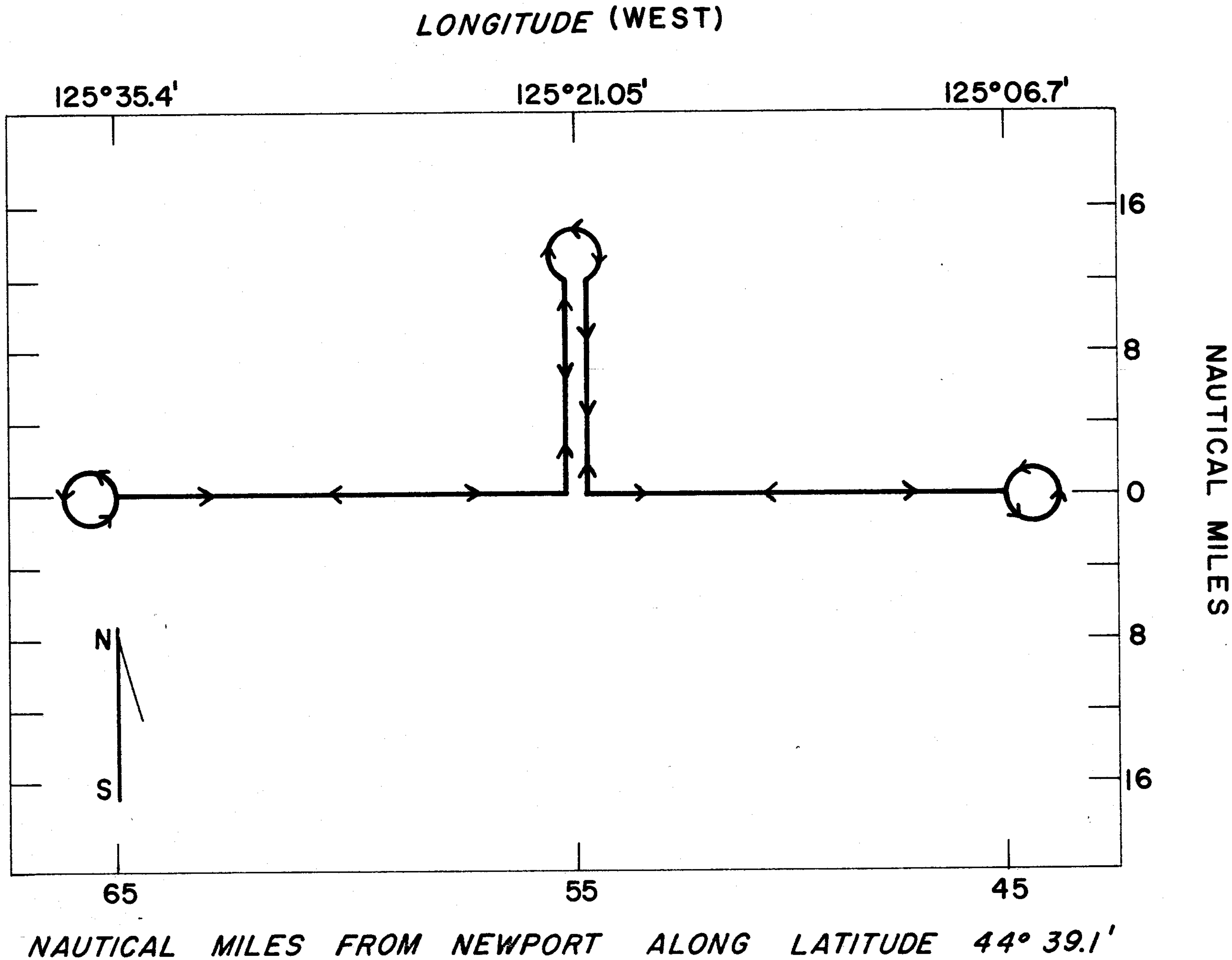


Figure 28

Cruise pattern traversed during 24 hour GEK measurement.

GEK BRIDGE LOG SHEET

(record the beginning of each GEK maneuver as follows)

Turn No.	Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Depth (if under 150 meters)	Remarks
1	11/20	1250	44° 39. 1'	125° 35. 4'	9. 0	- -	Time of Maneuver Completion 1312
2	11/20	1425	44° 39. 2'	125° 21. 0'	8. 0	- -	----
3	11/20	1604	44° 39. 3'	125° 06. 7'	8. 0	- -	----
4	11/20	1717	44° 39. 3'	125° 21. 1'	8. 0	- -	1743
5	11/20	1900	44° 39. 1'	125° 35. 0'	9. 0	- -	----
6	11/20	2038	44° 39. 5'	125° 21. 8'	8. 5	- -	2057
7	11/20	2223	44° 39. 6'	125° 07. 0'	9. 0	- -	----
8	11/20	2330	44° 39. 2'	125° 22. 0'	9. 0	- -	----
9	11/21	0105	44° 39. 7'	125° 35. 5'	9. 0	- -	----
10	11/21	0345	44° 39. 3'	125° 06. 7'	8. 0	- -	----
11	11/21	0505	44° 39. 8'	125° 21.05'	8. 0	- -	0530
12	11/21	0650	44° 39. 3'	125° 35. 4'	8. 5	- -	----
13	11/21	0815	44° 39. 1'	125° 21. 3'	9. 0	- -	0835
14	11/21	0948	44° 39. 6'	125° 07. 0'	9. 0	- -	----
15	11/21	1235	44° 39. 2'	125° 36. 0'	9. 0	- -	----

Basic GEK Sail Plan 24 Hr.Run Cruise No. 6711

TABLE 6

Annotation sheet implimented for use on the bridge during GEK maneuvers.

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/20/67

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A North-South Component(cm/sec)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
1/20	1250	44° 39.1'	125° 35.4'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-20.0	Reading I 15.0 Reading II 19.4 Average 17.2 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
1/20	1425	44° 39.2'	125° 21.0'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-19.0	Reading I 25.0 Reading II 23.0 Average 24.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
1/20	1604	44° 39.3'	125° 06.7'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-16.0	Reading I 31.0 Reading II 25.0 Average 28.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	1717	44° 39.3'	125° 21.1'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-21.0	Reading I 48.2 Reading II 37.8 Average 43.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	1900	44° 39.1'	125° 35.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-33.0	Reading I 61.3 Reading II 56.7 Average 59.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	2038	44° 39.5'	125° 21.8'	8.5	(Chart 1702) Stand. 0.500 Local 0.500	-21.0	Reading I 15.0 Reading II 13.0 Average 14.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

24 HR. RUN 1 of 3

TABLE 7

LONG CABLE

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/20-11/21

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component (cm/sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/20	2223	44° 39.6'	125° 07.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	-21.0	Reading I 11.5 Reading II 6.5 Average 9.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	2330	44° 39.2'	125° 22.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	no reading (recorder jammed)	Reading I -- Reading II -- Average -- Direction --	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0105	44° 39.7'	125° 35.5'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-16.0	Reading I 13.6 Reading II 10.4 Average 12.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0345	44° 39.3'	125° 06.7'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-22.0	Reading I 14.0 Reading II 18.0 Average 16.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0505	44° 39.8'	125° 21.05'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-29.0	Reading I 17.0 Reading II 18.0 Average 17.5 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0650	44° 39.3'	125° 35.4'	8.5	(Chart 1702) Stand. 0.500 Local 0.495	-22.0	Reading I 40.5 Reading II 35.5 Average 38.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

24 HR. RUN 2 of 3

LONG CABLE

Table 7, Continued

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/21/67

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south components (cm/sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/21	0815	44° 39.1'	125° 21.3'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	-25.0	Reading I 41.0 Reading II 41.0 Average 41.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0948	44° 39.6'	125° 07.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.500		Reading I 35.0 Reading II 33.0 Average 34.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1235	44° 39.2'	125° 36.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-22.0	Reading I 45.2 Reading II 38.8 Average 42.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

24 HR. RUN 3 of 3

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/20/67

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component(cm/sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/20	1250	44° 39.1'	125° 35.4'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-13.0	Reading I 20.0 Reading II 21.0 Average 20.5 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	1425	44° 39.2'	125° 21.0'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-7.0	Reading I 31.0 Reading II 27.0 Average 29.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	1604	44° 39.3'	125° 06.7'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-9.0	Reading I 38.5 Reading II 35.5 Average 37.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	1717	44° 39.3'	125° 21.1'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	-7.0	Reading I 47.0 Reading II 45.0 Average 46.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	1900	44° 39.1'	125° 35.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-16.0	Reading I 69.0 Reading II 63.0 Average 66.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/20	2038	44° 39.5'	125° 21.8'	8.5	(Chart 1702) Stand. 0.500 Local 0.500	+0.50	Reading I 16.0 Reading II 24.0 Average 20.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

24 HR. RUN 1 of 3

SHORT CABLE

able 7, Continued

omputed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/20-11/21

ate	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component(cm./sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
1/20	2223	44° 39.6'	125° 07.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	+2.0	Reading I 17.5 Reading II 18.5 Average 18.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
1/20	2330	44° 39.2'	125° 22.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	+4.0	Reading I 17.5 Reading II 18.5 Average 18.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0105	44° 39.7'	125° 35.5'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	+2.50	Reading I 19.0 Reading II 20.0 Average 19.5 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0345	44° 39.3'	125° 06.7'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	+1.0	Reading I 25.0 Reading II 17.0 Average 21.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0505	44° 39.8'	125° 21.05'	8.0	(Chart 1702) Stand. 0.500 Local 0.500	+11.0	Reading I 42.0 Reading II 43.0 Average 42.5 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0650	44° 39.5'	125° 35.4'	8.5	(Chart 1702) Stand. 0.500 Local 0.495	±0.0	Reading I 49.0 Reading II 43.0 Average 46.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

24 HR. RUN 2 of 3

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/21/67

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component (cm./sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/21	0815	44° 39.1'	125° 21.3'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	+14.0	Reading I 30.0 Reading II 29.0 Average 29.5 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	0948	44° 39.6'	125° 07.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.500	+2.5	Reading I 43.0 Reading II 38.0 Average 40.5 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1235	44° 39.2'	125° 36.0'	9.0	(Chart 1702) Stand. 0.500 Local 0.495	-4.0	Reading I 45.0 Reading II 47.0 Average 46.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

24 HR. RUN 3 of 3

SHORT CABLE

TABLE 8

24 HR. RUN TEMPERATURE RECORD
(at the surface)

LATITUDE	LONGITUDE	TEMPERATURE (°C)
44° 39.1'	125° 25.6'	13.42
44° 39.1'	125° 17.8'	13.40
44° 39.1'	125° 12.0'	13.30
44° 39.1'	125° 10.9'	13.29
44° 39.1'	125° 17.4'	13.36
44° 39.1'	125° 24.5'	13.46
"	125° 29.5'	13.24
"	125° 31.1'	13.10
"	125° 22.1'	13.38
"	125° 16.4'	13.35
"	125° 10.9'	13.12
"	125° 07.2'	13.10
"	125° 14.6'	13.20
"	125° 21.2'	13.36
"	125° 23.3'	13.34
"	125° 26.5'	13.39
"	125° 34.2'	13.19
"	125° 29.4'	13.19
"	125° 25.6'	13.31
"	125° 21.6'	13.28
"	125° 17.4'	13.21
"	125° 14.7'	13.19
"	125° 08.6'	13.18
"	125° 11.8'	13.06
"	125° 15.6'	13.18
"	125° 19.1'	13.21
"	125° 21.1'	13.22
"	125° 28.0'	13.32
"	125° 30.0'	13.13
"	125° 34.6'	12.93
"	125° 34.0'	12.93
"	125° 31.0'	13.12
"	125° 27.5'	13.33
"	125° 23.4'	13.24
"	125° 19.7'	13.22
"	125° 15.1'	13.08
"	125° 11.0'	13.00
"	125° 7.7'	13.13
"	125° 8.2'	13.13
"	125° 12.4'	13.04
"	125° 19.3'	13.27
"	125° 23.0'	13.28
"	125° 27.0'	13.35
"	125° 29.7'	13.11
"	125° 32.5'	12.93

(±002.0')

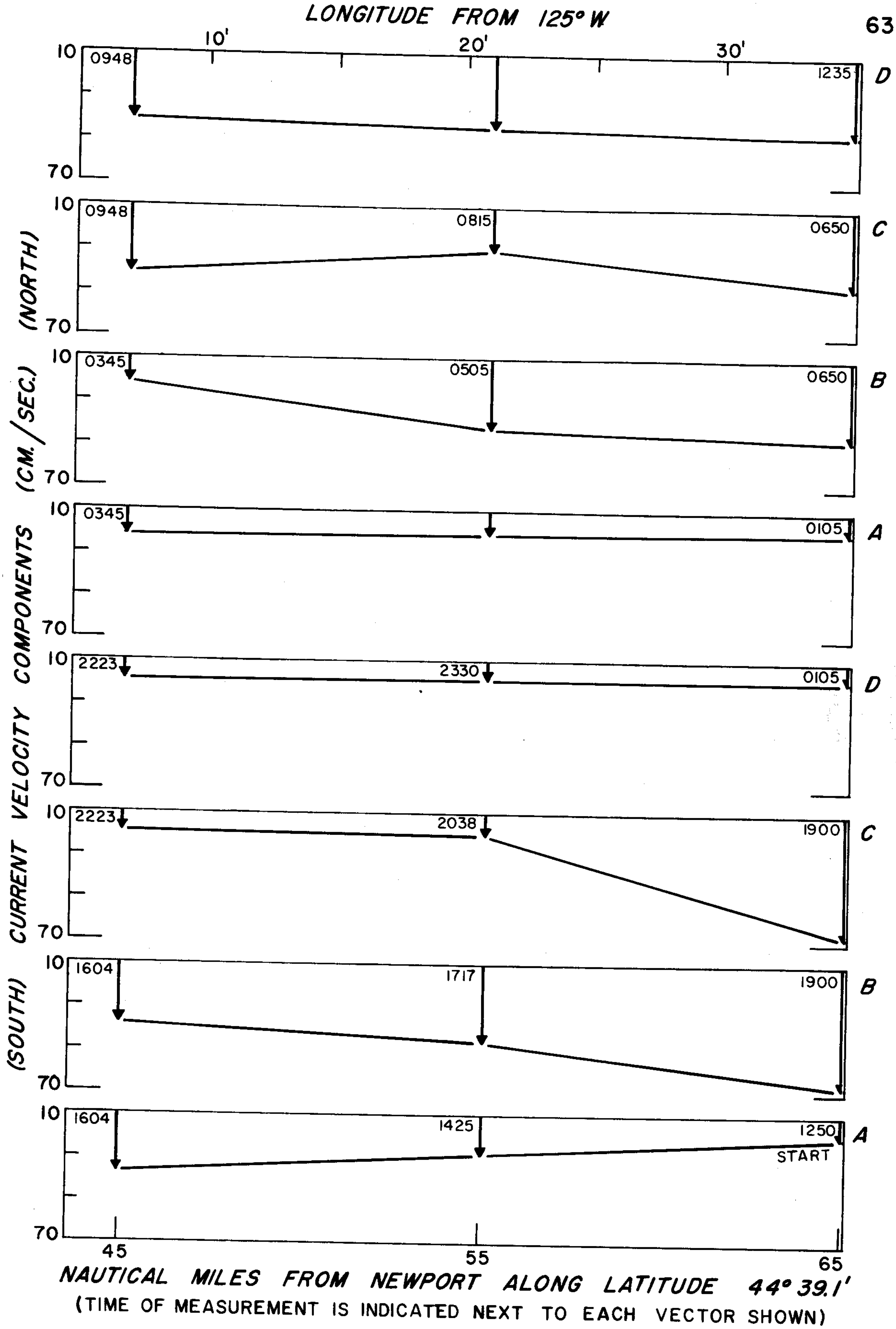


Figure 29

Cruise 6711, short cable, 24 hour run. Refer to text.

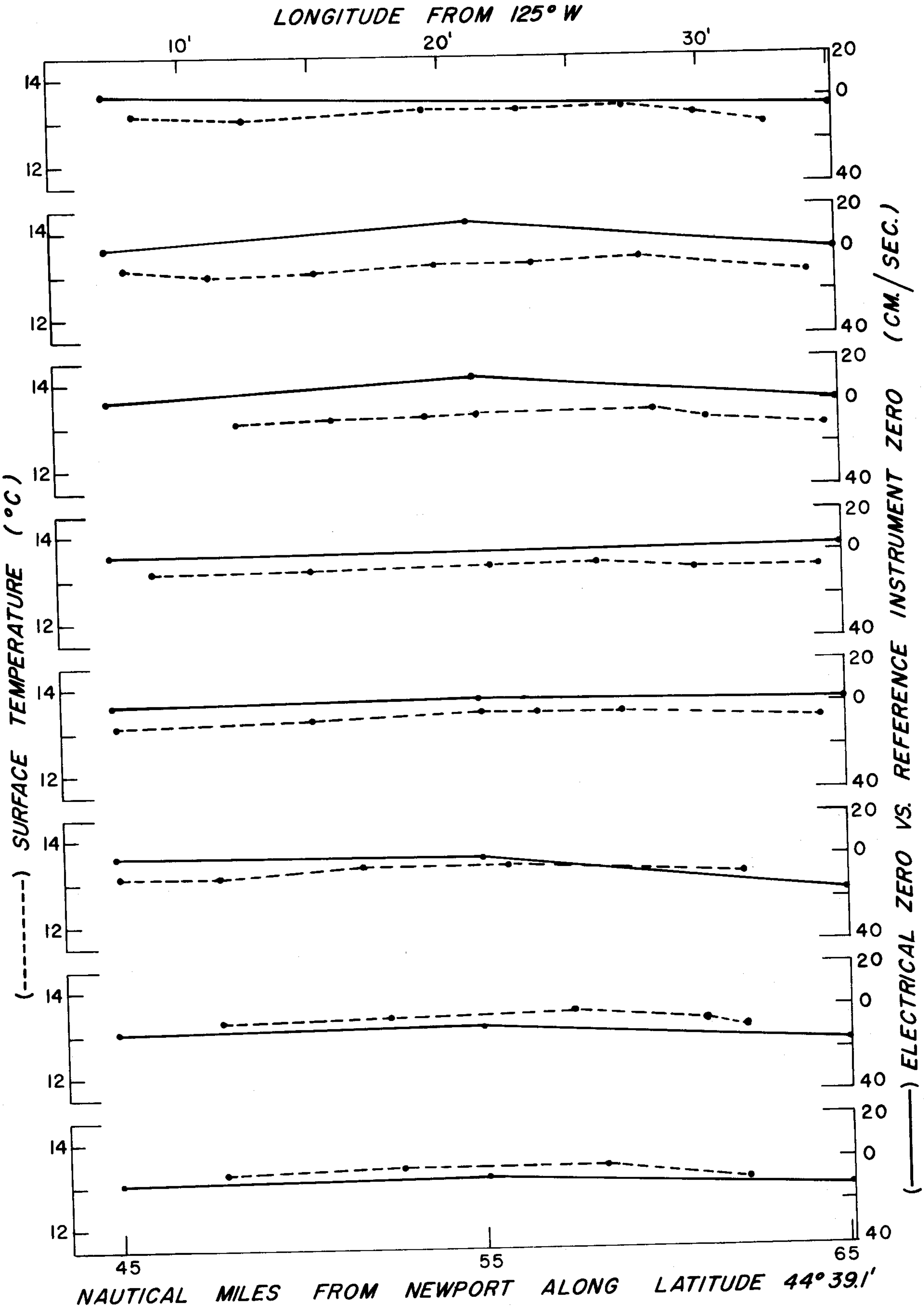


Figure 30

Cruise 6711, short cable, 24 hour run.

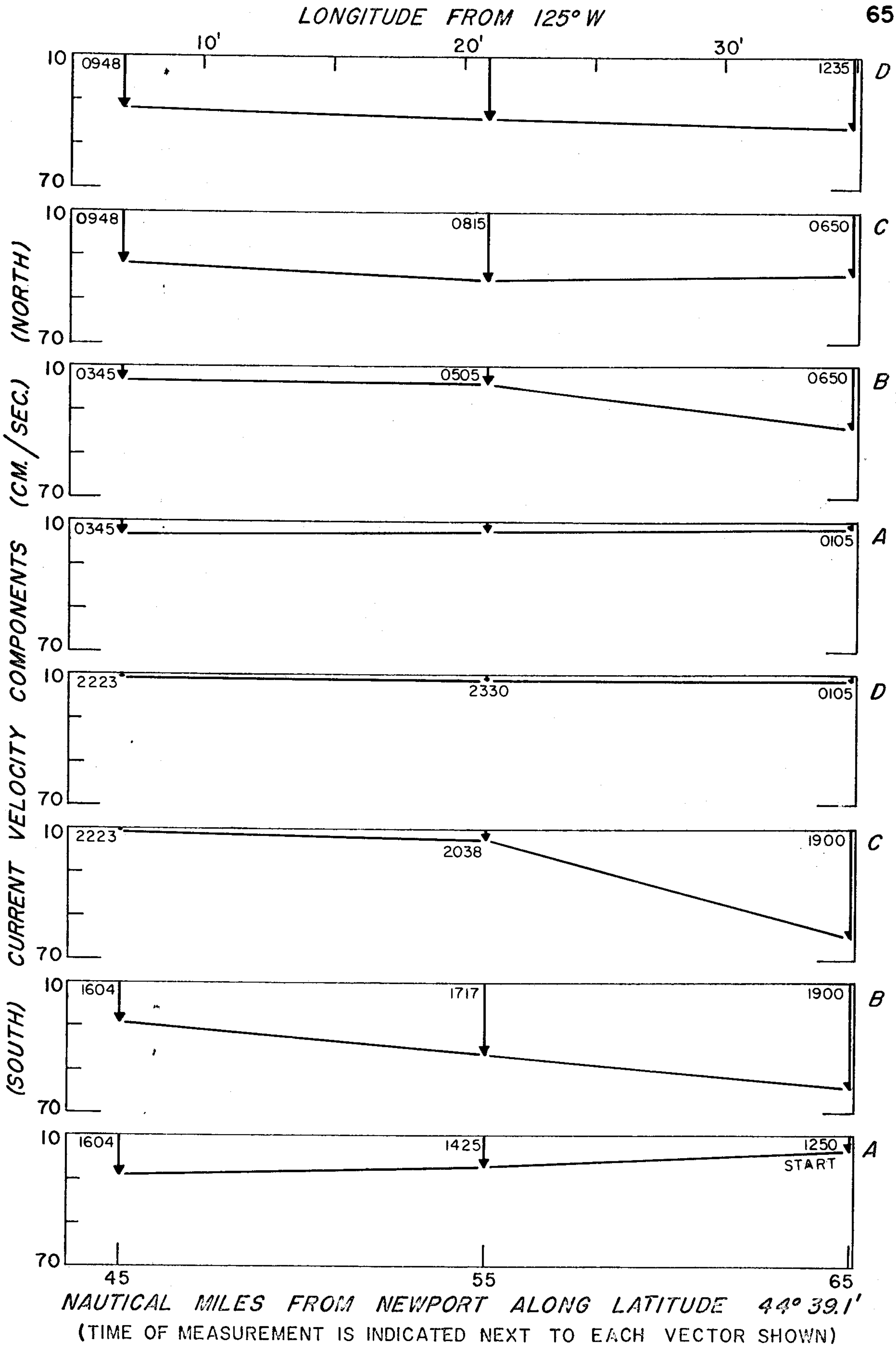


Figure 31

Cruise 6711, long cable, 24 hour run. Refer to text.

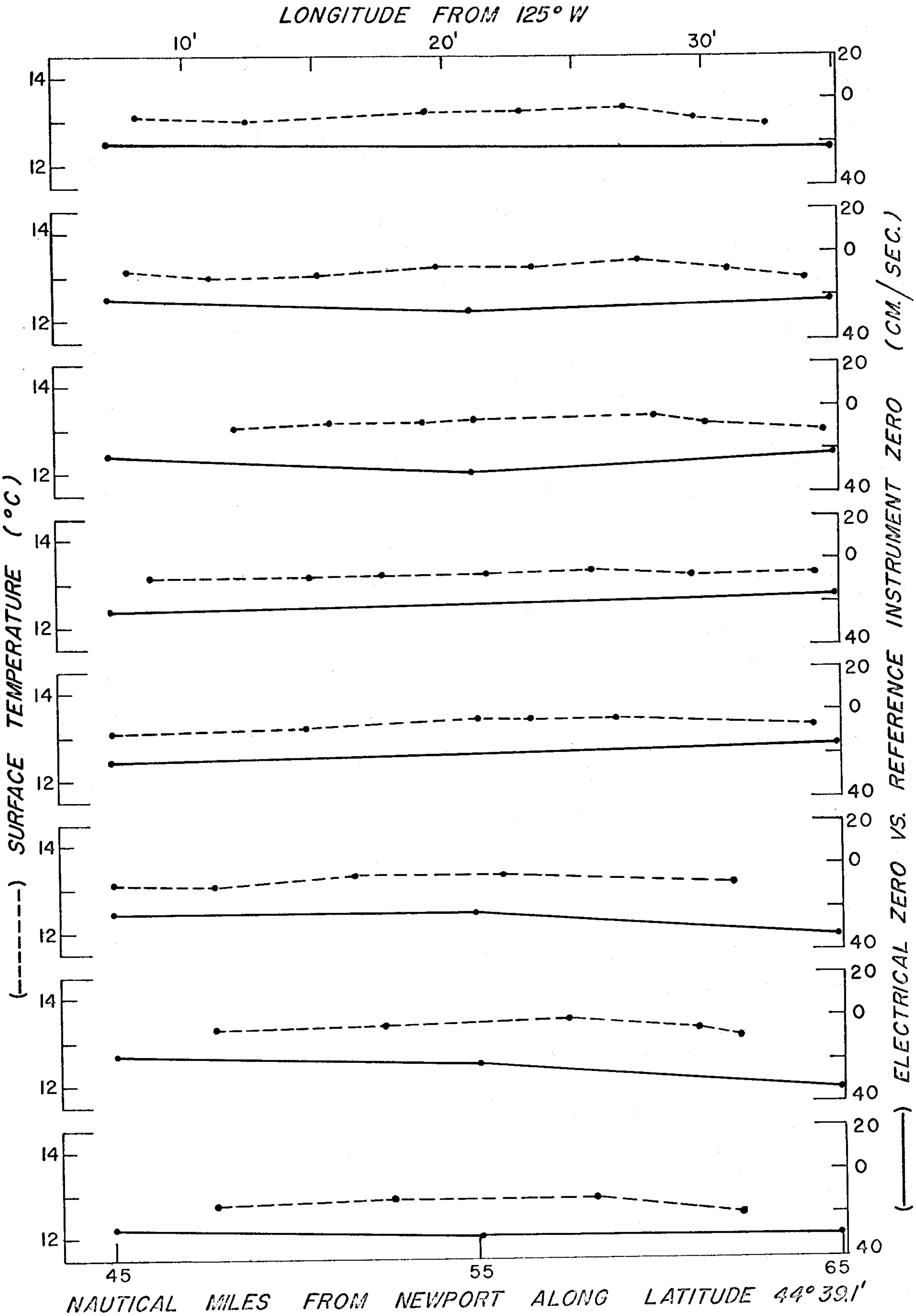


Figure 32

Cruise 6711, long cable, 24 hour run.

TABLE 9

GEK BRIDGE LOG SHEET

(record the beginning of each GEK maneuver as follows)

Turn No.	Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Depth (if under 150 meters)	Remarks
1	11/21	1412	44° 38.1'	126° 55.3'	10	---	
2	11/21	1515	44° 38.9'	126° 46.5'	10	---	
3	11/21	1615	44° 36.8'	126° 37.9'	10	---	
4	11/21	1715	44° 36.8'	126° 29.2'	10	---	
5	11/21	1815	44° 37.8'	126° 19.0'	10	---	
6	11/21	1915	44° 38.8'	126° 10.6'	10	---	
7	11/21	2015	44° 39.3'	126° 02.5'	10	---	
8	11/21	2150	44° 39.1'	125° 48.9'	10	---	
9	11/21	2330	44° 38.8'	125° 30.4'	10	---	
10	11/22	0047	44° 38.9'	125° 19.8'	10	---	
11	11/22	0210	44° 39.2'	125° 03.2'	10	---	
	11/22	0216	Commence	Recovering	GEK	---	
		0242	GEK Secure				

Basic GEK Sail Plan NR Run Cruise No. 6711

TABLE 10

GEK DATA SHEET

Computed by TBC

Vessel R/V YAQUINA
Cruise 6711
Date 11/21/67

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component(cm./sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/21	1412	44° 38.1'	126° 55.3'	10	(Chart 1702) Stand. 0.500 Local 0.495	+29.0	Reading I 20.0 Reading II 16.0 Average 18.0 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	1515	44° 38.9'	126° 46.5'	10	(Chart 1702) Stand. 0.500 Local 0.495	+31.0	Reading I 9.5 Reading II 6.5 Average 8.0 Direction 000°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	1615	44° 36.8'	126° 37.9'	10	(Chart 1702) Stand. 0.500 Local 0.495	+28.0	Reading I 20.0 Reading II 21.0 Average 20.5 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	1715	44° 36.8'	126° 29.2'	10	(Chart 1702) Stand. 0.500 Local 0.500	+28.5	Reading I 26.0 Reading II 22.0 Average 24.0 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	1815	44° 37.8'	126° 19.0'	10	(Chart 1702) Stand. 0.500 Local 0.500	+27.5	Reading I 6.0 Reading II 5.0 Average 5.5 Direction 000°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	1915	44° 38.8'	126° 10.6'	10	(Chart 1702) Stand. 0.500 Local 0.500	+29.0	Reading I 12.0 Reading II 9.0 Average 10.5 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir

NR RUN 1 of 2

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/21-11/22

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component(cm./sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/21	2015	44° 39.3'	126° 02.5	10	(Chart 1702) Stand. 0.500 Local 0.500	+34.0	Reading I 19.0 Reading II 15.0 Average 17.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	2150	44° 39.1'	125° 48.9'	10	(Chart 1702) Stand. 0.500 Local 0.500	+35.0	Reading I 29.5 Reading II 26.5 Average 28.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	2330	44° 38.8'	125° 30.4'	10	(Chart 1702) Stand. 0.500 Local 0.500	+36.0	Reading I 24.4 Reading II 26.0 Average 25.2 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/22	0047	44° 38.9'	125° 19.8'	10	(Chart 1702) Stand. 0.500 Local 0.500	+37.5	Reading I 11.0 Reading II 9.0 Average 10.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/22	0210	44° 39.2'	125° 03.2'	10	(Chart 1702) Stand. 0.500 Local 0.500	+21.0	Reading I 29.0 Reading II 23.0 Average 26.0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
					(Chart 1702) Stand. ___ Local ___		Reading I ___ Reading II ___ Average ___ Direction ___	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

NR RUN 2 of 2

SHORT CABLE

Table 10, Continued

Computed by ___TBC___

GEK DATA SHEET

Vessel ___R/V YAQUINA___
Cruise ___6711___
Date ___11/21/67___

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component (cm./sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/21	1412	44° 38. 1'	126° 55. 3'	10	(Chart 1702) Stand. 0. 500 Local 0. 495	-16. 0	Reading I 14. 0 Reading II 16. 0 Average 15. 0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1515	44° 38.9'	126° 46. 5'	10	(Chart 1702) Stand. 0. 500 Local 0. 495	-21. 0	Reading I 13. 5 Reading II 10. 5 Average 12. 0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1615	44° 36. 8'	126° 37. 9'	10	(Chart 1702) Stand. 0. 500 Local 0. 495	-20. 0	Reading I 37. 0 Reading II 29. 0 Average 33. 0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1715	44° 36.8'	126° 29. 2'	10	(Chart 1702) Stand. 0. 500 Local 0. 500	-20. 0	Reading I 39. 0 Reading II 35. 0 Average 37. 0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1815	44° 37. 8'	126° 19.0'	10	(Chart 1702) Stand. 0. 500 Local 0. 500	-20. 0	Reading I 13. 5 Reading II 10. 5 Average 12. 0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___
11/21	1915	44° 38.8'	126° 10. 6'	10	(Chart 1702) Stand. 0. 500 Local 0. 500	-19. 0	Reading I 28. 5 Reading II 23. 5 Average 26. 0 Direction 180°	Reading I ___ Reading II ___ Average ___ Direction ___	Speed ___ Dir ___		Speed ___ Dir ___

NR RUN 1 of 2

Computed by TBC

GEK DATA SHEET

Vessel R/V YAQUINA
Cruise 6711
Date 11/21-11/22

Date	Time (PST)	Latitude	Longitude	Ship Speed (knots)	Magnetic Intensity	Electrical Zero (cm./sec.)	Course A north-south component(cm./sec.)	Course B	Resultant Current Vector	Correction Factors	Final Current Value
11/21	2015	44° 39.3'	126° 02.5'	10	(Chart 1702) Stand. 0.500 Local 0.500	-18.0	Reading I 34.0 Reading II 38.0 Average 36.0 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	2150	44° 39.1'	125° 48.9'	10	(Chart 1702) Stand. 0.500 Local 0.500	-18.0	Reading I 45.5 Reading II 41.5 Average 43.5 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/21	2330	44° 38.8'	125° 30.4'	10	(Chart 1702) Stand. 0.500 Local 0.500	-17.0	Reading I 45.5 Reading II 41.5 Average 43.5 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/22	0047	44° 38.9'	125° 19.8'	10	(Chart 1702) Stand. 0.500 Local 0.500	-15.0	Reading I 26.0 Reading II 23.0 Average 24.5 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
11/22	0210	44° 39.2'	125° 03.2'	10	(Chart 1702) Stand. 0.500 Local 0.500	-7.0	Reading I 20.0 Reading II 22.0 Average 21.0 Direction 180°	Reading I Reading II Average Direction	Speed Dir		Speed Dir
					(Chart 1702) Stand. Local		Reading I Reading II Average Direction	Reading I Reading II Average Direction	Speed Dir		Speed Dir

NR RUN 2 of 2

LONG CABLE

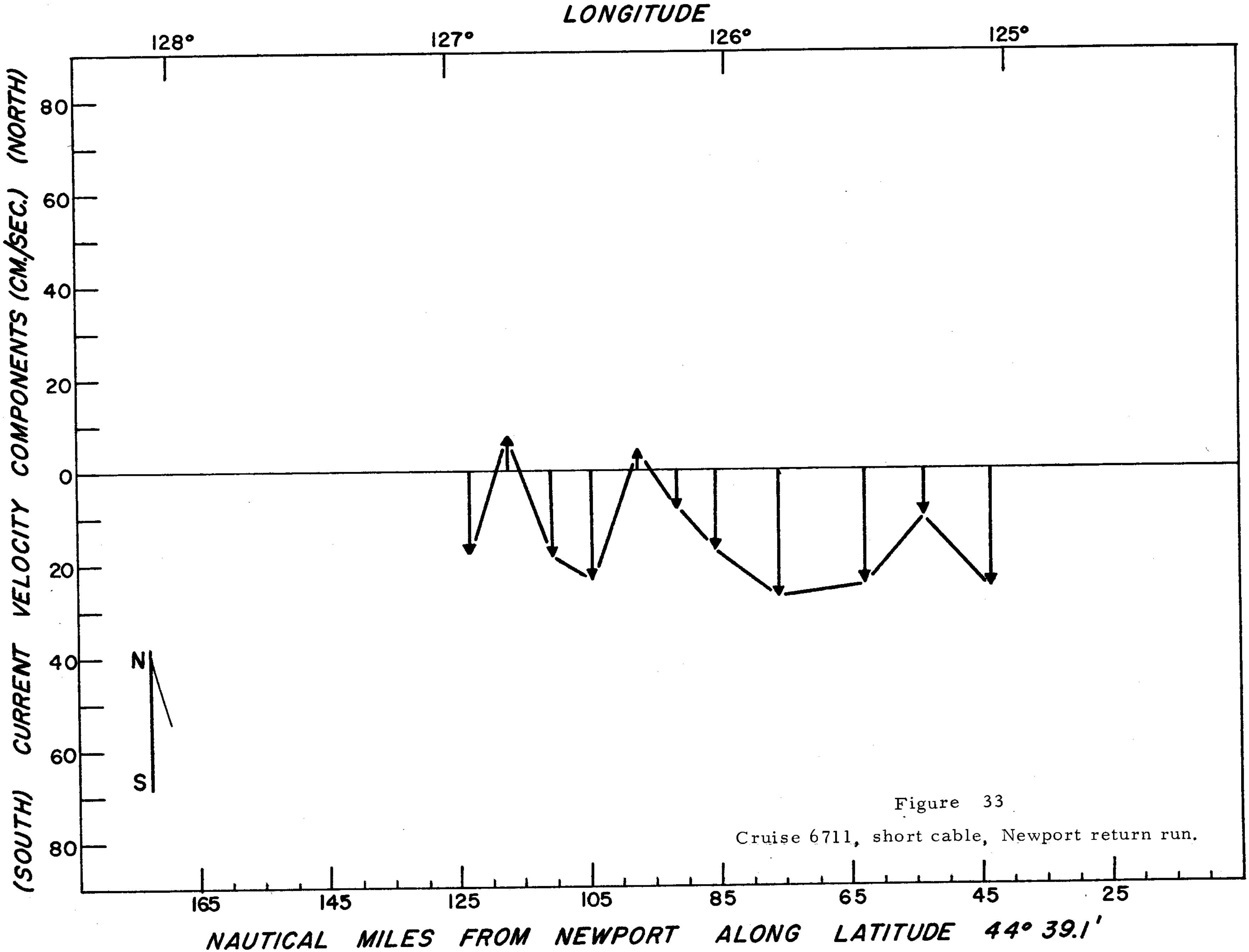


Figure 33

Cruise 6711, short cable, Newport return run.

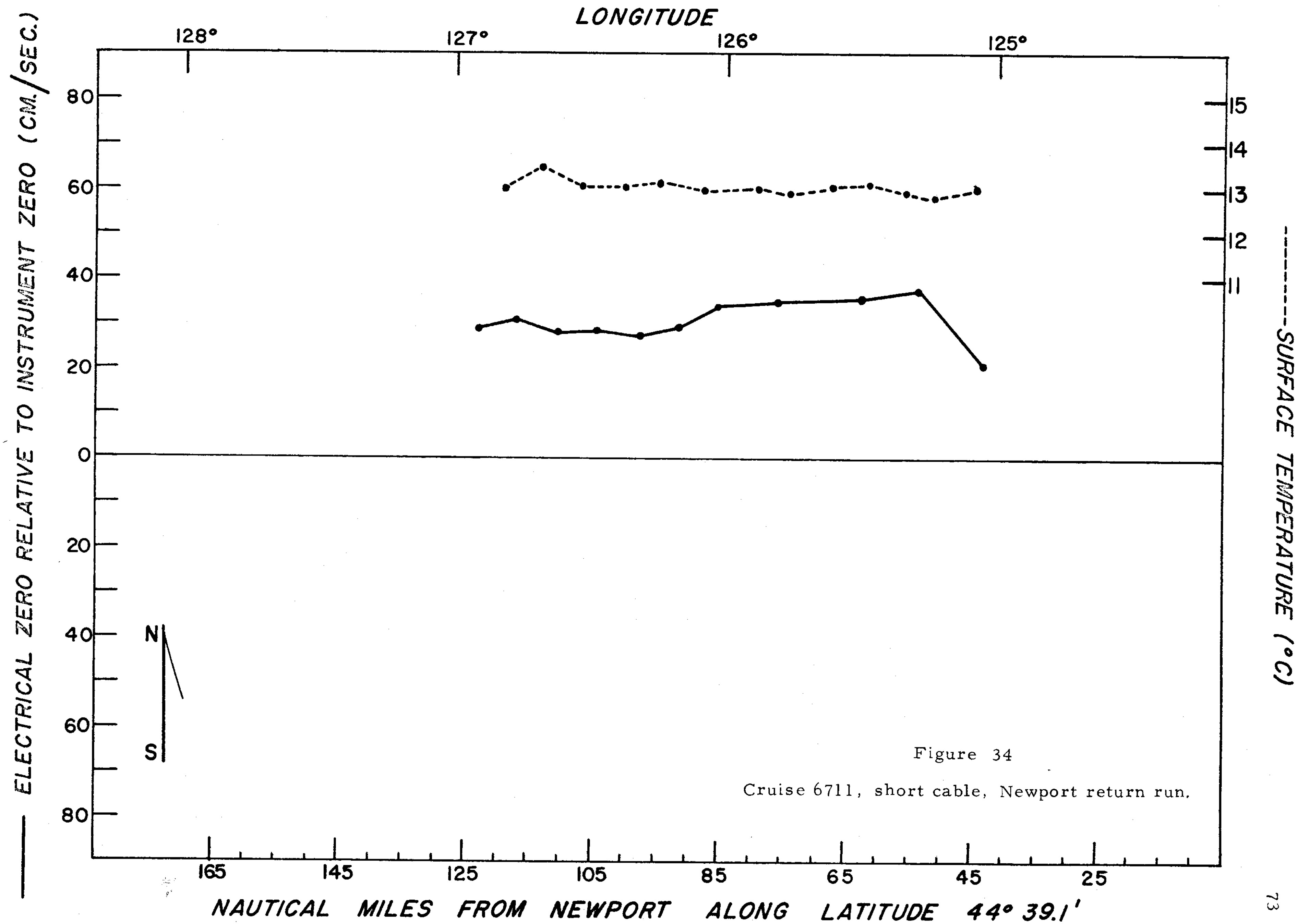


Figure 34

Cruise 6711, short cable, Newport return run.

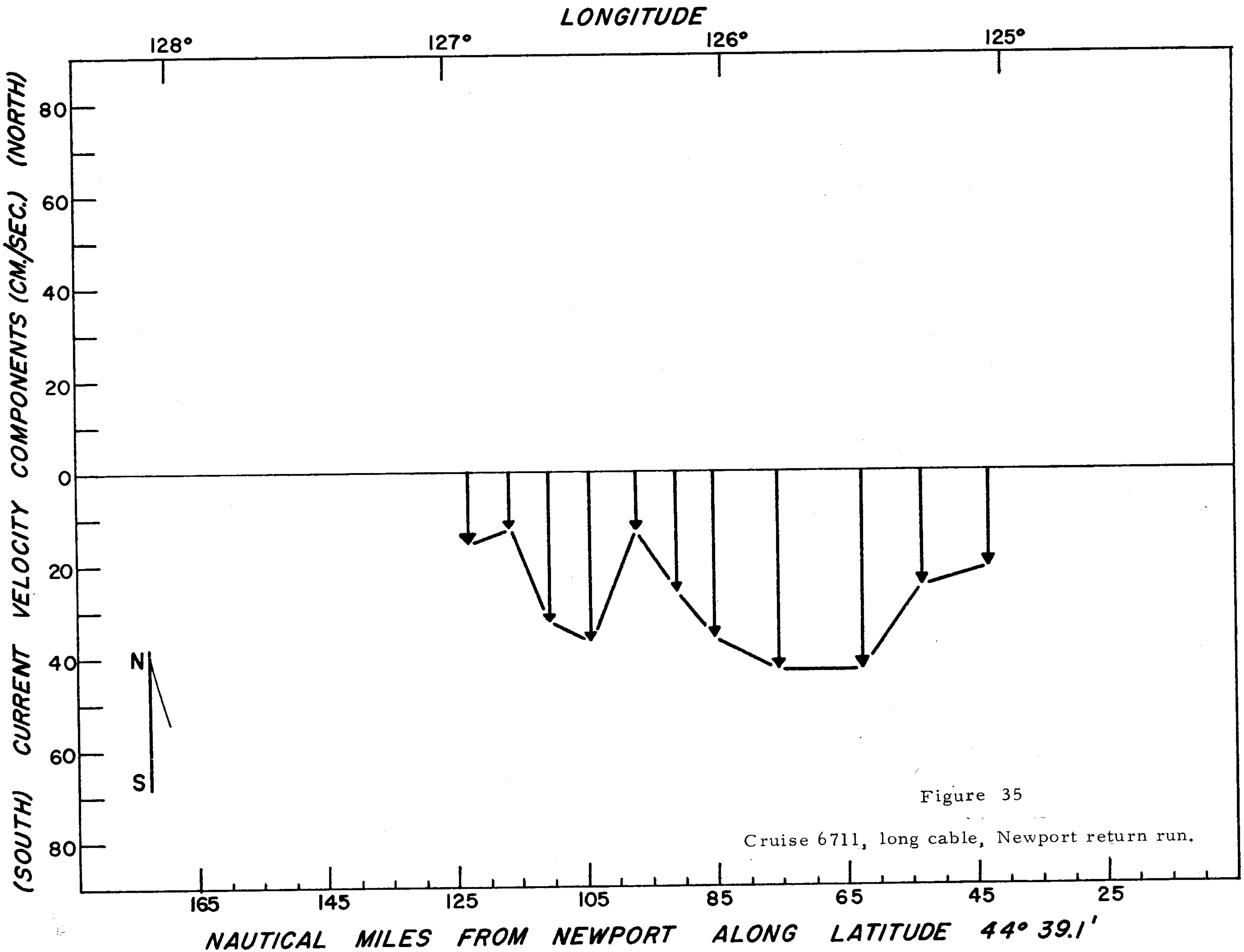


Figure 35

Cruise 6711, long cable, Newport return run.

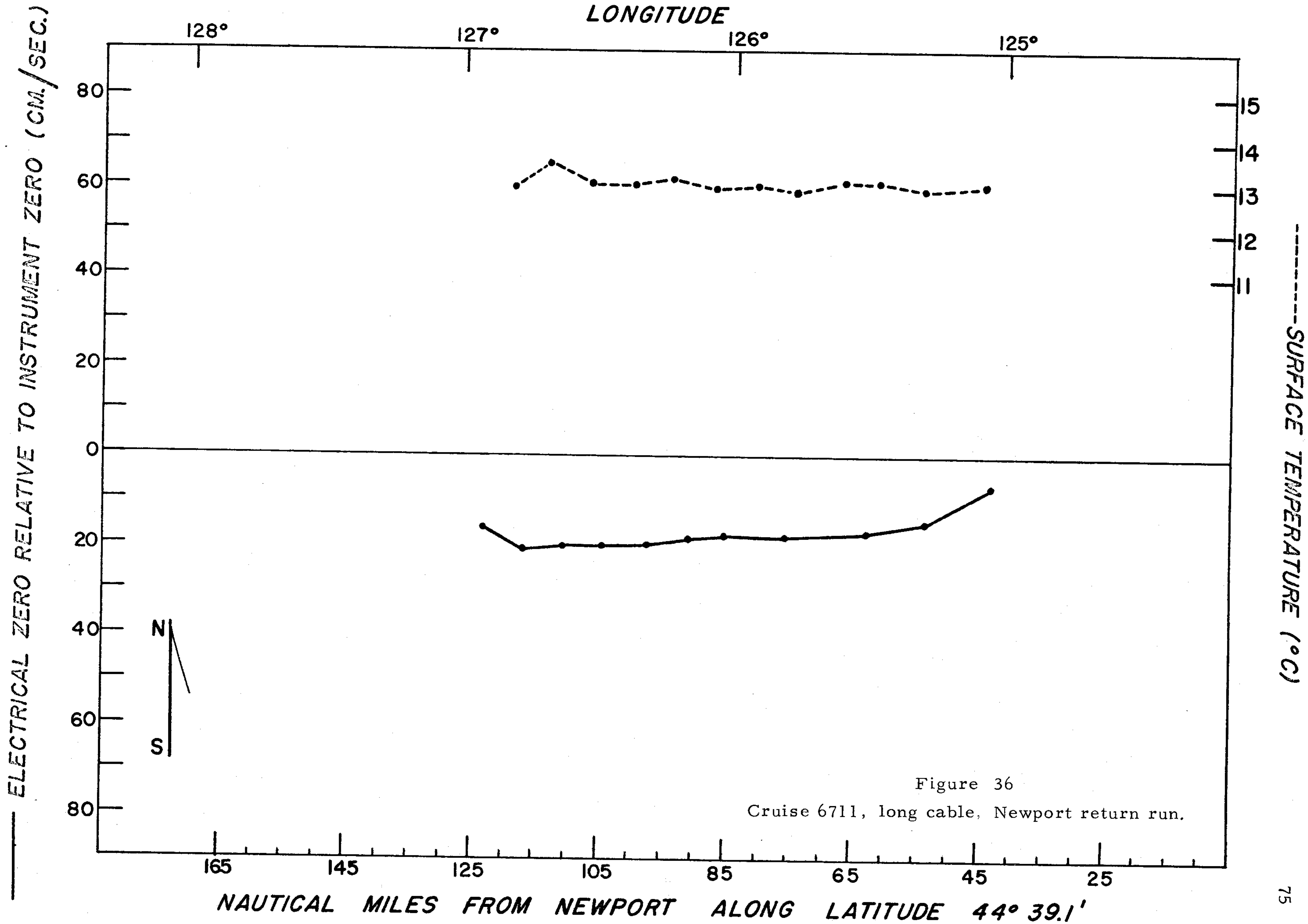


Figure 36
Cruise 6711, long cable, Newport return run.

CONCLUSIONS AND PROJECTIONS

The attempt has been made here to present as precisely and accurately as possible the results and the innovations of all GEK cruises to date. No attempt has been made to interpret these results or to make any inferences from them. At the present time theoretical work is being done with the objective of placing these results into a more precise and meaningful framework of oceanographic import and insight. The mathematical formulations are complex and understanding them in terms of the physics of the sea as provided by the collected data is the principal challenge involved here. Meanwhile raw data must be accumulated carefully and accurately to enable the convenient and reasonable testing of any sound hypothesis forwarded from theoretical study. This report is the beginning of such a series of factual data presentations of electromagnetic method results. It is intended to be complemented in the near future with consequent theoretical advances.

Presently work is being done to both improve and expand the GEK method. The following is a partial list of construction projects now being performed and serious near-future considerations.

1) New electrode-cases are being built which keep the electrodes in a quasi-constant environment. This new design will effectively keep the electrodes in situ at all times, thus avoiding or greatly reducing the previously needed long equilibration time. This design should improve operational electrode response to significant electrical signals and reduce the response to electro-chemical effects.

2) New electrodes of original design are being fabricated, balanced electrically, and tested environmentally. These will be used in the new cases hopefully to increase the level of reliability and signal response.

3) A completely new electronic recording system is being readied to replace the existing somewhat anachronous one now used. A dual input Hewlett-Packard strip chart potentiometric recorder is coupled to a newly designed input device employing operational amplifiers to provide infinite input impedence to the measuring electrodes and to "actively" filter existing signal noise. High reliability, compactness and portability, better signal quality and accuracy, and ruggedness with continued precision are all the considerations that will be combined in this new system.

4) Moored vertical GEK methods and interpretation are being studied for use in conjunction with Oregon State's 184 foot stable buoy, TOTEM and also with the instrument array deployment contained in the THEMIS project. In mind are ways to test the electrochemical effects on vertically spaced electrodes, as described by Sanford (1967).

5) "Free fall" vertical GEK is under consideration for deep current profile possibilities.

6) A careful study of GEK measurements obtained around vertically spaced free drifting drogues has been recently carried out. Such a study should produce a rough "calibration" of GEK current measurements in the area and indicate more clearly exactly what is being measured.

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