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Morris, R. M.; Kusters, N. L.

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EDDY-CURRENT MAGNETIC FIELD MEASUREMENTS ON ALUMINUM-FRAMED MINESWEEPER HMCS "COMOX" (AMc 146) ESQUIMALT, B.C., AUGUST AND SEPTEMBER, 1955

R. M. MORRIS AND N. L. KUSTERS

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ABSTRACT

The National Research Council and the Royal Canadian Navy have conducted rolling trials on the aluminum-framed wooden minesweeper HMCS "Comox" in order to make an extensive survey of its eddy-current magnetic field and to study methods of compensating this field. This report covers the eddy-current magnetic field survey only. Both amplitude and phase angle of the athwartship-horizontal component and the vertical component of the eddy-current field were measured in two dry docks with headings of 358° and 239°, at depths of 19 ft., 24 ft., and 27 ft.

To compare the amplitude of the eddy-current field with other magnetic effects of the ship under the same conditions, measurements were made also of the static field of thw ship's iron and the static field of "tilt" at one depth. Maximum field components, at 24 ft. depth, North heading, Z = 520 milligauss for example, are as follows:

The eddy-current field, when the ship is rolling ± 25° in an 8-second period, has a maximum athwartship horizontal component of 18.3 milligauss single amplitude.

The undegaussed ship's iron has a maximum vertical component of 15.6 milligauss.

"Tilt" effect, when the degaussed ship is tilted to a static angle of 25°, gives a maximum horizontal component of 3.5 milligauss.

For purposes of analysis, eddy currents flowing in the ship's frame members are considered to consist of two components: (1) those caused by the ship rolling in the vertical component of the earth's field, and (2) those caused by the ship rolling in a horizontal-athwartship component of the earth's field. The results show that both these eddy-current components lag the emf's induced in framework loops by approximately 30° at the period of measurement (9.3 seconds). This lag is uniform over the whole field under the ship.

The magnetic field produced by component (1) was found to decrease as the inverse square power with depth. That produced by component (2) was found to decrease as the inverse 1.6 power with depth.

The maximum amplitude of the eddy-current field was found to be the same for the fitted ship "Comox" as for the bare hull "Cowichan" [1]. However, the location of the maximum is shifted from quarter fore for the bare hull towards a point under the engines and generator.

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EDDY-CURRENT MAGNETIC FIELD MEASUREMENTS ON ALUMINUM-FRAMED MINESWEEPER HMCS "COMOX" (AMc 146) ESQUIMALT, B.C., AUGUST AND SEPTEMBER 1955

- R.M. Morris and N.L. Kusters -

INTRODUCTION

In 1952, a limited number of measurements were carried out on the bare hull of the aluminum-framed, wooden minesweeper HMCS "Cowichan" to determine the magnitude of its eddy-current magnetic field [1]. Since those trials, the Royal Canadian Navy has decided to investigate the possibility of compensating this magnetic effect by suitable eddy-current degaussing equipment. For this purpose, more information was required about the magnitude and phase of the eddy-current magnetic field of completely fitted ships of this type. Such measurements were made on HMCS "Comox", a ship of the same design as HMCS "Cowichan". Eddy-current degaussing trials were carried out concurrently in order to minimize the time required to produce operational equipment. This report covers ship's field measurements only. The compensation study will be reported separately.

The proposed eddy-current degaussing system consists essentially of two main degaussing loops: the AE loop, used to compensate mainly for eddy currents caused by the ship rolling in the vertical component of the earth's field, and the ME loop, used to compensate mainly for eddy currents caused by the ship rolling in the horizontal-athwartship component of the earth's field. These two eddy-current components flow in vertical longitudinal framework loops and horizontal longitudinal framework loops, respectively. Since these two eddy-current loops are not of similar dimensions, the characteristics of their magnetic fields will be different. It would be desirable to measure the two characteristics separately in pure vertical and pure horizontal fields, respectively. A pure vertical field effectively can be realized by carrying out trials on a North-South heading since the horizontal component of the earth's magnetic field would then have no effect. However, a pure horizontal field cannot be realized in this latitude, and it was necessary to carry out trials on a heading as close to East-West as possible, thus obtaining a maximum ratio of horizontal-athwartship to vertical components of earth's field.

Two docks at Esquimalt, B.C., were used in the "Comox" trials, the RCN dock with a North-South longitudinal axis and the Department of Transport (DOT) dock with an axis about 30° off East-West.

The measured field variation caused by the rolling ship on each heading consisted of the superposition of an eddy-current component and a "tilt" component. The first is due to currents which flow as a result of emf's generated in closed framework loops as they oscillate in the earth's field [1]. This component will

lag the generated emf's (roll velocity) because of the inductance of the ship's framework. The second component is due to mismatch between the field of the static degaussing coils and the field of the iron parts (principally engines and generators) as the ship is tilted out of a level position [2]. It has been assumed here that this component is in phase with the roll angle.

The objectives of the tests reported here were to measure the field variation caused by the rolling ship in magnitude and phase, to determine its eddy-current and "tilt" components, and to compare its magnitude with that of the static field of the ship's iron.

DETAILS OF THE SHIP

HMCS "Comox" is a coastal minesweeper having the following dimensions: length overall 150 ft.; beam 28 ft.; height 14 ft. Her draft during these trials was: bow 6' 9", stern 8' 6". The ship has an aluminum-framed wooden hull with aluminum bulkheads and decks and is similar in construction to HMCS "Cowichan" (AMc 147) [1]. She was fitted with rolling platforms and then docked as shown in Figs. 1 and 2, while the bilge keels, rudders, and propellors were removed (to reduce roll damping). With these exceptions, the ship was in its normal sea-going condition and contained the usual amount of ferromagnetic material.

The static (iron) degaussing system consisted of an "M" coil, "L" coil, and "A" coil. The current settings on ship's N and W headings during these trials were as follows:

RCN Dock (358°): M = +3.5 amp, L = +1.5 amp, A = 0
DOT Dock (239°): M = +3.5 amp, L = -0.75 amp, A = -1.3 amp.

METHOD OF CONSTRAINING AND ROLLING THE SHIP

The rolling ship is shown in Figs. 3 and 4. She was held in position on the longitudinal center lines of the docks by two lines running from an eye plate on the roll axis at the bow to the two forward corners of the dock, and by similar fastenings at the stern. With these fastenings, lateral surge was about ±6 inches and longitudinal surge was negligible during rolling.

A rolling party of 30 men ran from side to side on the platforms as shown in Figs. 3 and 4. Twenty men were on the aft and ten men were on the forward platform. Roll amplitudes up to ±18° were produced but most measurements were made at about ±12°. The average periods were: RCN dock — 9.3 seconds; DOT dock — 9.8 seconds.

MAGNETIC FIELD INSTRUMENTATION

The magnetic range consisted of 30 magnetometers (15 vertical and 15 horizontal-athwartships) in the docks. These could be connected in groups of three through a switching system to three measuring channels in an instrument truck on the dock side. The system and its components are described in detail in Reference 2.

The range pattern is shown in Fig. 5 (a). The system was used in the RCN dock from August 13 to August 23, 1955; in the DOT dock from August 25 to September 3, 1955, and again in the RCN dock from September 6 to 9, 1955. Having arranged suitable supports for the magnetometers beforehand, the range could be transferred from one dock to the other in about one-half day. A diagram of the range pattern in each dock is given in Fig. 5 (b) and the range is shown in place in the N-S dock in Figs. 6 and 7.

During the course of the trials, the ship was positioned over the range in three locations. These are shown in Fig. 8 (a). The grid system (fixed with respect to the ship) to which all measurements are referred is given in Fig. 8 (b).

ROLL-MEASUREMENT INSTRUMENTATION

Amplitude and velocity of roll were measured by gyroscopic recorders supplied by NRC. Records were obtained on two photographic films. Sensitivities were 3-1/3 degrees/inch and 6.4 degrees/second/inch, respectively. Film speeds were 1/3 inch/second. The amplitude or roll-angle instrument was used as the phase reference in the interpretation of the records since there is no phase lag in its recording. This instrument is described in detail in Reference 2.

In addition to the above instruments, a Muirhead gyroscopic roll-angle and roll-velocity recorder was installed and operated by the RCN. It was used at sensitivities of 16 degrees/inch and 16 degrees/second/inch.

These instruments were mounted on a solid table in the generator room and were about 1'8" below the roll axis of the ship.

All records were provided with timing pulses from a single synchronous-motor-driven contactor mounted in the generator room. Timing pulses were at one-second intervals, with every tenth impulse omitted. On the magnetic recordings, timing pulses are superimposed on the traces.

EARTH'S FIELD COMPONENTS AT TEST SITES

The vertical component of the earth's field and the horizontal component — transverse to the longitudinal center lines of the docks — were surveyed prior to the measurements with a USN Mark 5 Mod. 5 magnetometer. Measurements

were made at a large number of points in a horizontal plane 24 feet above the dock floor (area to be occupied by the ship) in the RCN dock, and at the level of the magnetometer range in the DOT dock. All vertical measurements were well within 1% of the average reported in Table I below, and all horizontal components within 3% of the average.

TABLE I

EARTH'S FIELD COMPONENTS AT TEST SITES

Dock Heading	Exciting Field Components (milligauss)			
	Measured		Observatory Values	
	Vertical	Transverse Horizontal	Vertical	Transverse Horizontal
358°	520	-	537*	186* Sin 2° = 6.5
239°	520	160	537*	186* Sin 59° = 157

* Supplied by Dominion Observatory, Ottawa, for Esquimalt District.

SHIP'S FIELD MEASUREMENTS

a) Field of the Ship's Iron With the ship remote from the range, each of the 30 magnetometers was set to zero second harmonic output by adjusting the current in its field-balancing solenoid. Under this condition the solenoid field exactly opposed the earth's field at the magnetometer detecting element. The ship was then towed into position over the range with static degaussing turned off. After the tug had been removed from the vicinity, the servo-nulling system automatically recorded the field of the undegaussed ship. The static (iron) degaussing system was then turned on and the field of the degaussed ship was recorded under this condition.

The signatures of the field of the ship's iron at 25.5 feet depth are given in Fig. 9.

b) Tilt Field With the ship carefully positioned and levelled over the range and the static degaussing system operating, the static field (consisting of a component of the earth's field and the degaussed residual of the field of the ship's iron) was nulled at the detector of each magnetometer by a current in its balancing solenoid.

Static tilt was produced by placing trays of lead ingots on the deck near the rail by means of a dockyard crane. The tilt angle was increased in steps to port and then to starboard. At each tilt angle the crane was returned to the same position and held motionless while the magnetic field change due to tilt was being recorded. At the conclusion of the test, the ship was returned to a level position and zero settings

re-checked to determine drift.

The tilt angle was measured by an accurate clinometer on the ship as well as by the NRC gyro roll angle recorder.

As noted in Reference 2, there was considerable drift at some units during this type of measurement. Each measurement was corrected for drift and then the best linear fit to the corrected points was chosen.

The results of static tilt tests are given in Fig. 10 for North and West headings. Measurements were made at a depth of 25.5 ft. only. To determine the tilt field at other depths, the magnitude was considered to vary as the inverse 2.5 power with depth. This depth relationship was used on the advice of the RCN.

c) Dynamic Field The static field (earth's field + degaussed static field) was nulled at each magnetometer detector. Then the ship was rolled while roll recordings and magnetic recordings were made simultaneously. Fig. 11 shows the form in which results were obtained. Recording of roll amplitude and roll velocity was carried on continuously. First the outputs from H1, H6, H11 were sampled simultaneously on the three recording channels for two cycles, then H2, H7, H12 were switched to the magnetic recorders and sampled for two cycles. All horizontal units were sampled in this sequence, then vertical units in the sequence V1, V6, V11 and V2, V7, V12, and so on.

Simultaneous one-second-interval timing marks appeared on all records. For ease of correlation, every tenth timing pulse was omitted. In Fig. 11 an example of this timing correlation is clearly marked for units V1, V6, V11 which are being recorded between lines A and B. The dotted line C passes through a zero roll position on the roll record and proceeds to equivalent time positions on the roll velocity record and magnetic recordings.

METHOD OF SEPARATING THE EDDY-CURRENT FIELD COMPONENT FROM THE TOTAL DYNAMIC FIELD

Fig. 12 illustrates the method used for obtaining amplitude and phase of the fundamental eddy-current component from a magnetic record such as Fig. 11. Such a magnetic record consists of a superposition of the following main components: (1) fundamental eddy-current component (2) fundamental "tilt" component (3) harmonic components of both of these. Since it was estimated that only even harmonics are likely to occur in records taken, the method was designed to make the results independent of both amplitude and phase of all even harmonic components. If it is assumed that the tilt effect is in phase (or 180° out of phase) with the roll angle of the ship, it can then be shown that the magnitude and phase of the fundamental eddy-current component are obtained by the following equations:

$$\alpha = \tan^{-1} \frac{X'}{Y} ,$$

$$A = \frac{Y}{2 \cos \alpha} ,$$

where

α = phase angle between the fundamental of eddy-current field and the emf's generated in the ship's circuits,

A = single amplitude of fundamental eddy-current field,

X' = X - 2 tilt,

where X is total variation of magnetic signal between two consecutive peak roll-angle positions (Figs. 11 and 12), and "tilt" is 180° out-of-phase with roll record.

Y = total variation of magnetic signal between two consecutive even keel positions.

Table II contains a tabulation of the analysis of part of the record of Fig. 11. In addition, the peak-to-peak variation of the total magnetic signal "Z" is listed.

"COMOX" EDDY-CURRENT FIELD

The results are presented in Figs. 13, 14, and 15 in the form of transverse surveys at depths of 19 ft., 24 ft., and 27 ft., respectively, and in Fig. 16 which is a tabulation of phase angles.

The dotted curves, Figs. 13, 14, 15, give values for the total measured field "Z" which is the sum of eddy current and "tilt" components. The full curves give the maximum single amplitude of fundamental eddy-current components. Each figure contains the results obtained in the North-South and in the East-West docks and in addition gives the calculated results of the eddy-current field produced by the horizontal-athwartship components of the earth's magnetic field only. This last result is obtained by subtracting the eddy-current field produced by the vertical component of the earth's field (N-S dock measurements) from the field produced by combined vertical and horizontal-athwartship components of the earth's field (E-W dock measurements). It should be noted that these magnetic signals are not necessarily in phase, and the calculations referred to above include a vectorial superposition. Since the results thus obtained for pure horizontal-athwartship excited components are the differences of two quantities of about equal magnitudes, the

TABLE II

TYPICAL CALCULATION OF EDDY-CURRENT FIELD

TEST NO. 3 - 7

DEPTH 24'

SENSITIVITY 3 (.4mg/mm)

HEADING OF SHIP N

LATERAL (SURGE) DISPLACEMENT ≈±6"

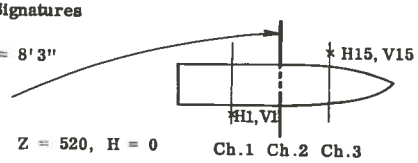
FERROMAGNETIC DEGAUSSING CURRENTS

DESCRIPTION OF TEST E.C. Signatures

TRIM OF SHIP B = 6'10" S = 8'3"

POSITION OF SHIP Center Line

EXCITING FIELD COMPONENTS Z = 520, H = 0



LONGITUDINAL (SURGE) DISPLACEMENT — Negligible

REMARKS

Date of Test: August 18, 1955

Unit No.	ATTITUDE RECORD		VELOCITY RECORD		TILT EFFECT			MAGNETOMETER RECORD				RESULTS								
	P - P Angle of roll (in)	P - P Angle of roll in (3.33) (degrees)	P - P velocity (in)	P - P velocity in (6.42) (deg/sec)	Tilt effect at 25.5' (mg/deg)	2 (tilt effect) at 24' t x 1.16 (mg)	2 (tilt effect) x 2.5 (mm)	Z P - P (mm)	Z P - P mm x 0.4 (mg)	X P - P at max. att. (mm)	Y P - P at zero att. (mm)	X' X-2 (tilt effect) (mm)	X'/Y tan α	α (degrees)	Cos α	Ampli-tude Y / 2 cos α (mm)	Field x .4 (mg)	E.C. Field A (mg/deg/sec)	Z E.C. Field + Tilt Field (mg/deg/sec)	Period "T" (sec)
H1	9.21	30.7	3.34	21.4	-0.022	- .78	-1.95	10.5	4.2	3.50	9.50	5.45	.575	30	.866	5.5	2.2	.206	.195	9.0
	9.34	31.1	3.37	21.6	-0.022	- .79	-2.0	11.0	4.4	3.75	10.0	5.75	.575	30	.866	5.8	2.32	.215	.204	9.1
H2	9.24	30.8	3.36	21.6	-0.030	-1.08	-2.7	27.0	10.8	10.0	24.5	12.7	.52	27.5	.887	13.8	5.5	.51	.50	9.1
	9.41	31.4	3.39	21.7	-0.030	-1.13	-2.9	27.2	10.9	11.5	25.5	14.4	.565	29.5	.871	14.6	5.85	.535	.50	9.1
H3	9.24	30.8	3.36	21.6	-0.100	-3.58	-8.9	36.0	14.4	13.75	34.0	22.6	.66	33.5	.834	20.4	8.2	.76	.665	9.2
	8.29	27.6	3.02	19.4	-0.100	-3.20	-8.0	33.7	13.5	13.5	31.0	21.5	.69	34.5	.824	18.8	7.5	.77	.695	9.2
H4	8.11	27.0	2.87	18.4	-0.063	-1.98	-4.90	24.2	9.7	9.75	21.5	14.65	.68	34.5	.824	13.0	5.2	.565	.525	9.3
	8.16	27.2	2.86	18.4	-0.063	-2.00	-5.0	23.7	9.5	10.5	21.0	15.5	.74	36.5	.803	13.0	5.2	.565	.515	9.3
H5	8.06	26.9	2.90	18.6	-0.032	-1.00	-2.5	9.0	3.6	2.75	8.0	5.25	.66	33.5	.834	4.8	1.92	.206	.193	9.2
	8.16	27.2	2.97	19.0	-0.032	-1.01	-2.6	9.0	3.6	2.75	8.0	5.35	.67	34.0	.830	4.8	1.92	.202	.190	9.2
V1	8.16	27.2	2.97	19.0	-0.040	-1.26	-3.15	23.0	9.2	10.75	21.2	13.90	.655	33.0	.840	12.6	5.05	.53	.484	9.2
	8.23	27.4	2.95	18.9	-0.040	-1.27	-3.18	23.2	9.3	9.2	21.5	12.38	.575	30.0	.866	12.4	4.95	.52	.49	9.3
V2	8.06	26.9	2.90	18.6	-0.052	-1.62	-4.05	19.5	7.8	9.0	16.5	13.05	.79	38.0	.788	10.4	4.15	.45	.42	9.2
	7.93	26.4	2.84	18.2	-0.052	-1.60	-4.0	19.5	7.8	8.0	16.2	12.0	.74	37.0	.798	10.1	4.04	.445	.43	9.2
V3	7.74	25.8	2.76	17.7	+0.010	+0.30	+0.75	0	0	0	0	-.75	-							
	7.45	24.8	2.65	17.0	+0.010	+0.29	+0.72	0	0	0	0	-.72	-							9.2
																				9.2

accuracy achieved is rather poor.

Fig. 16 is a tabulation of the phase angles "α" of the fundamental of the eddy-current field component.

The variation of the eddy-current magnetic field with depth (depth law) was determined by making log-log plots of the functions "maximum ship's field components of eddy currents in mg/deg/sec" vs. "depth in feet". The three points on each plot corresponding to the three measured depths, fall very closely on a straight line. This indicates that the depth laws are of the form

$$\text{Field Component} = k(\text{depth})^n.$$

Values of "n" were found by determining slopes of log-log plots. These are given in Table III below.

TABLE III

DEPTH LAWS

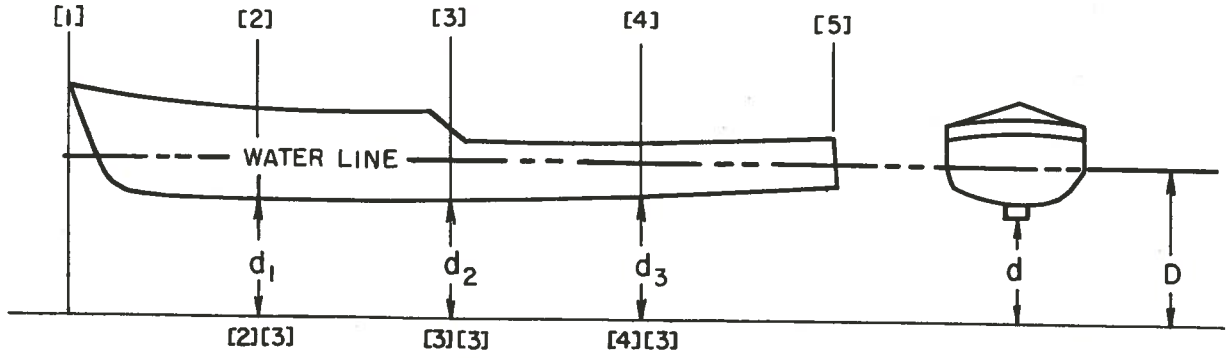
Component	Depth Law Index "n"	
	E.C. Component Produced by Earth's Vertical Component	E.C. Component Produced by Earth's Horizontal Component
Vertical	-1.8	-1.6
Horizontal	-2.0	—

COMPARISON WITH EDDY-CURRENT FIELD OF "COWICHAN"

Fields of the fully fitted "Comox" and the bare hull "Cowichan" are compared in Table IV for the same conditions of exciting field, depth, and trim. The maxima of the eddy-current fields are of the same value, but the position of the maximum occurs forwards of midship in the bare hull "Cowichan" and at midship in the fully fitted "Comox". A similar result is reported by the Royal Navy in Plate 3, Reference 3, where the bare hull CMs 36 and the fully fitted HMS "Bildeston" are compared.

REFERENCES

1. "Eddy Current Magnetic Field Measurements on Class AMc 143 Aluminum Framed Minesweeper HMCS 'Cowichan'", N.L. Kusters and R.M. Morris, National Research Council, Radio and Electrical Engineering Divisional Report ERA-231 (Secret).



DEPTHS		POSITION	FIELD COMPONENT	EDDY CURRENT FIELDS MG / DEG / SEC.	
D FT.	d FT.			"COMOX" Z = 520 MG. (ERA 300)	"COWICHAN" Z = 520 MG. (ERA 231)
24	d_1=16'10"	[2] [3]	HORIZONTAL ATHWARTSHIP	.78	.94
24	d_2=16'6"	[3] [3]	"	.93	.90
24	d_3=16'2"	[4] [3]	"	.73	.69
27	d_1=19'8"	[2] [3]	"	.63	.72
27	d_2=19'4"	[3] [3]	"	.76	.75
27	d_3=19'	[4] [3]	"	.62	.53
24	d_2=16'6"	[3] [3]	MIDSHIP VERTICAL	.47 (H=160 Mg)	.48 (H=160 Mg)
27	d_2=19'4"	[3] [3]	" "	.37 (H=160 Mg)	.30 (H=160 Mg)

NOTE: FIGURES FOR "COWICHAN" ARE CORRECTED TO "COMOX" CONDITIONS OF DEPTH AND TRIM BY INVERSE SQUARE LAW AND TO "COMOX" EXCITING FIELD BY LINEAR RELATIONSHIP.

COMPARISON BETWEEN EDDY-CURRENT FIELDS OF "COMOX" AND "COWICHAN"

TABLE IV

2. "Measurement of Static and Dynamic Variations of Magnetic Field with Roll Angle — Wooden Minesweeper HMCS 'Cordova' (YMS 420)" Esquimalt, B.C., Sept., 1955, R.R. Jackson and R.M. Morris, National Research Council, Radio and Electrical Engineering Divisional Report ERA-294 (Secret).

3. "The Magnetic Condition of Coastal Minesweeper Type I - IV — Eddy Current Compensation", H.M. Underwater Countermeasures and Weapons Establishment, U.C.W.E. Informal Report No. 1618/54 (Secret).

FIG. 1

BOW VIEW OF HMCS "COMOX" IN N-S DRY DOCK

PHOTO COURTESY RCN

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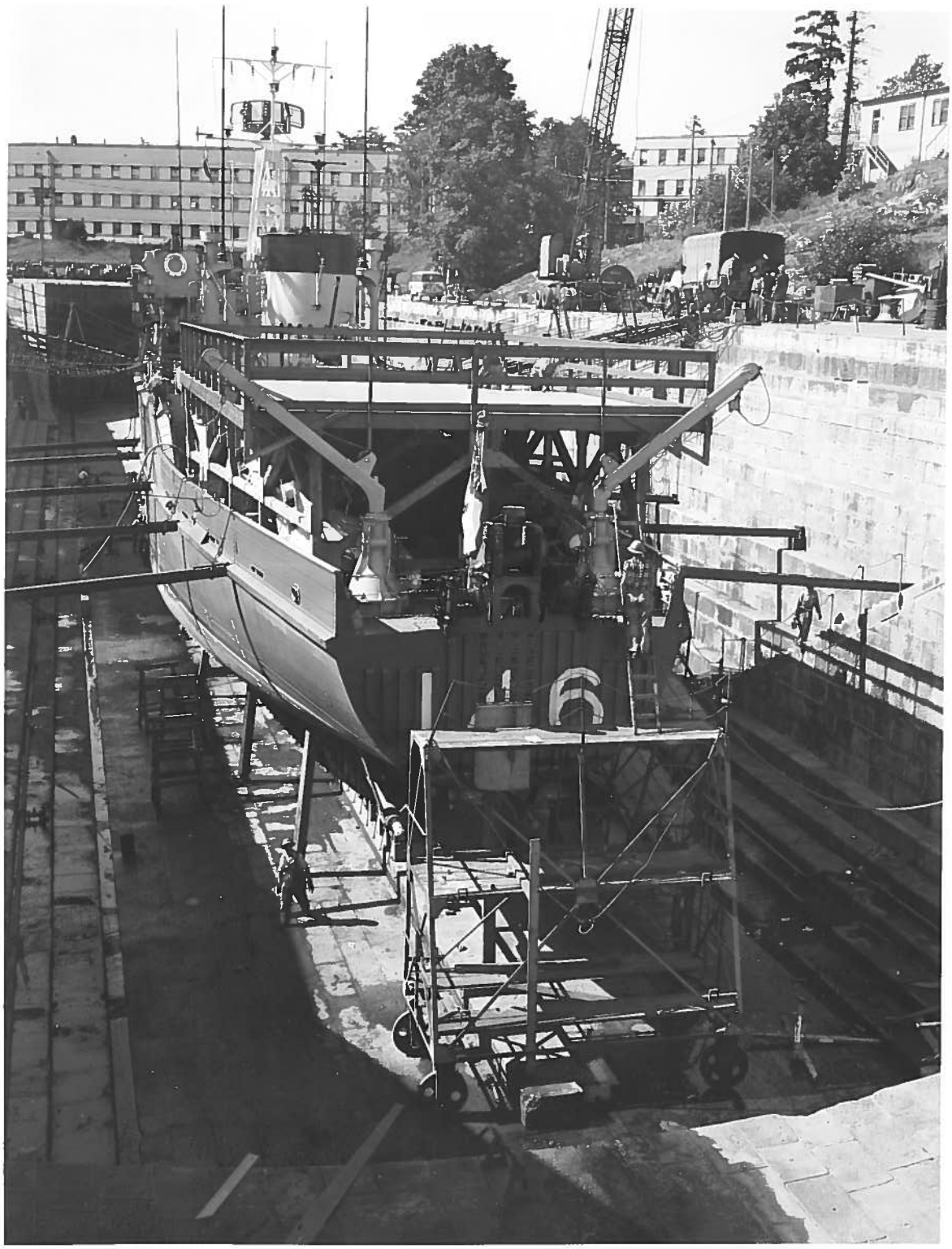

FIG. 2

STERN VIEW OF HMCS "COMOX" IN N-S DRY DOCK

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FIG. 3

BOW VIEW — ROLLING SHIP IN N-S DRY DOCK

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FIG. 4

STERN VIEW — ROLLING SHIP IN N-S DRY DOCK

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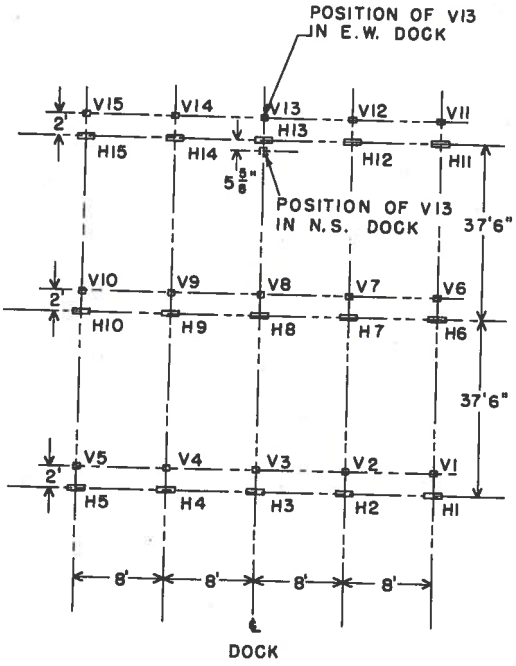
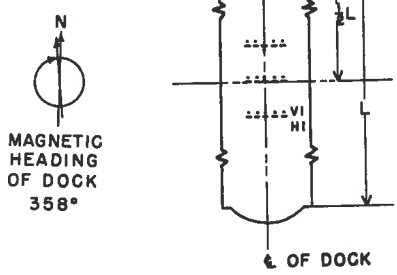
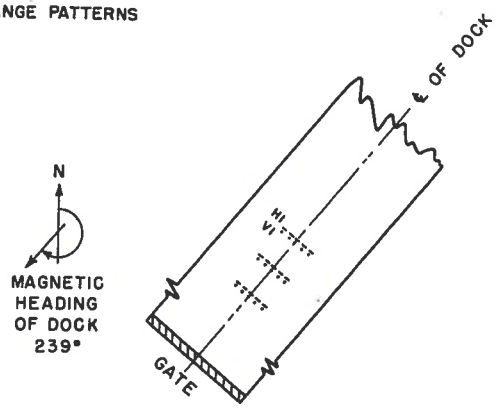


FIG. 5(a)
MAGNETIC RANGE PATTERNS



RCN DRY DOCK
ESQUIMALT, B.C.



DEPT. OF TRANSPORT DRY DOCK
ESQUIMALT, B.C.

FIG. 5(b)
DIAGRAMS OF MAGNETIC RANGE
AS INSTALLED IN N-S AND E-W DOCKS

RCN & DEPT. OF TRANSPORT DRY DOCKS

ESQUIMALT, B.C.

AUG. & SEPT. 1955.

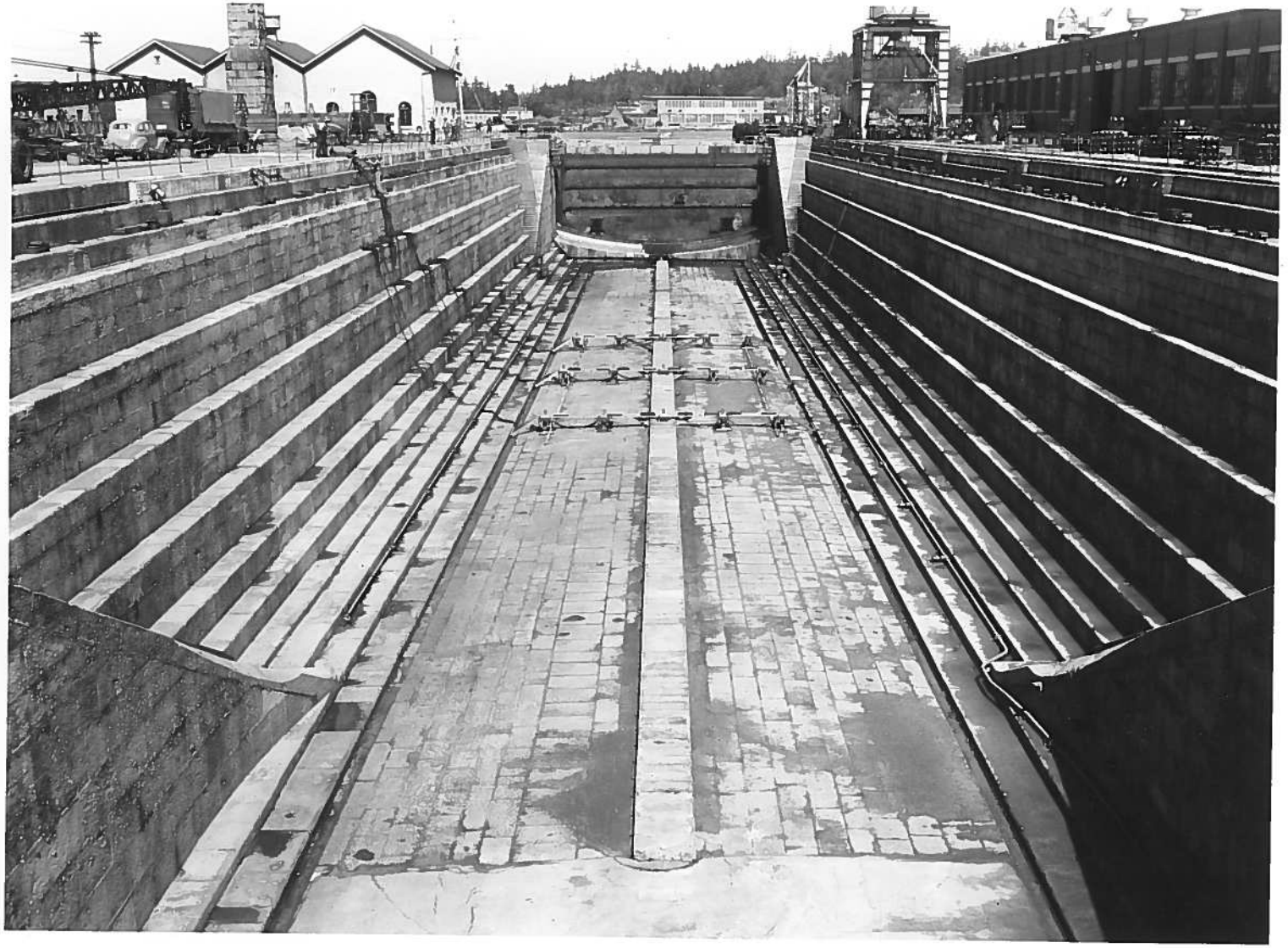


FIG. 6

GENERAL VIEW OF N-S DRY DOCK
AND RANGE — LOOKING NORTH

PHOTO COURTESY RCN

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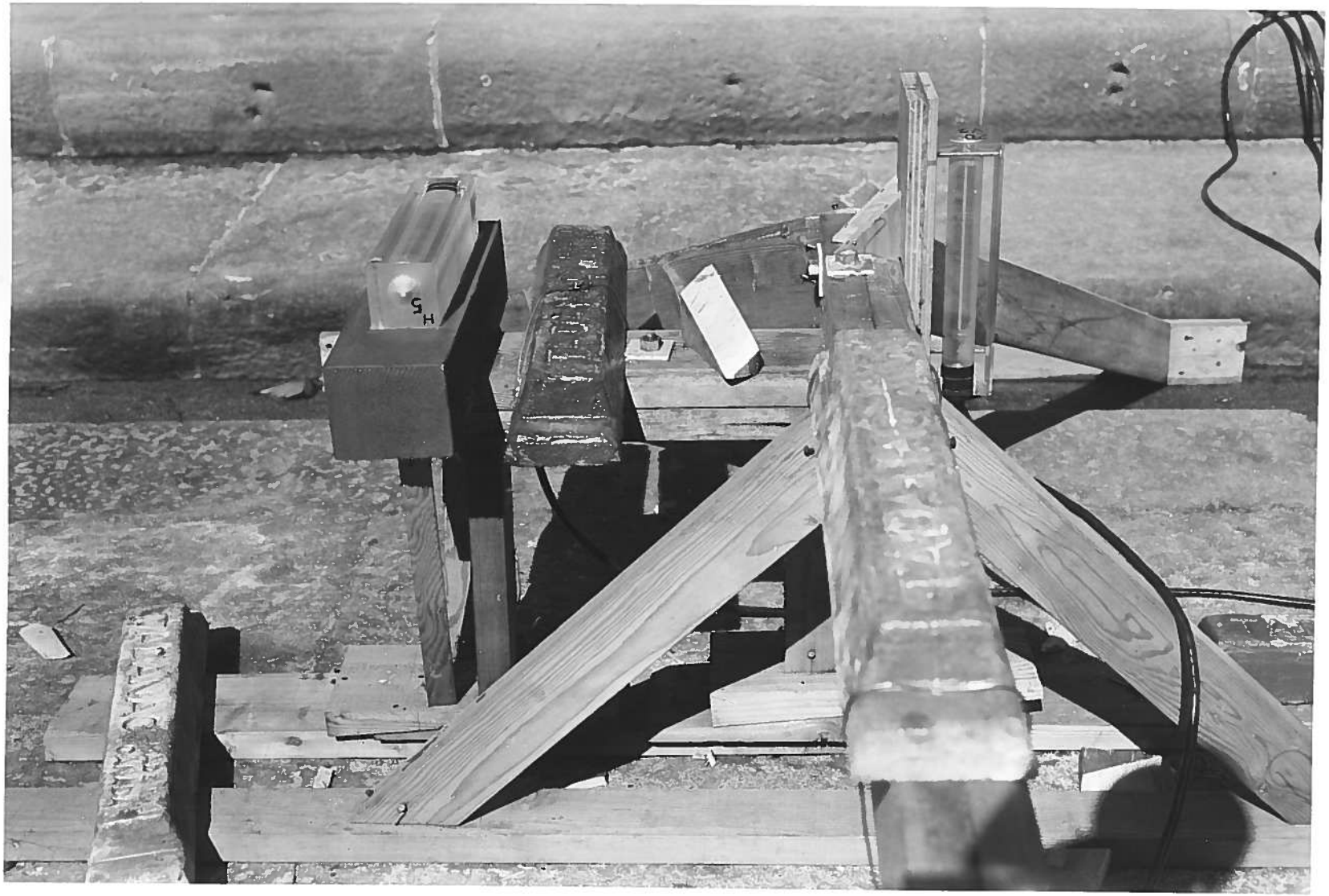


FIG. 7

CLOSE-UP OF UNITS V5 AND H5 IN N-S
DRY DOCK — LOOKING WEST

PHOTO COURTESY RCN

CONFIDENTIAL

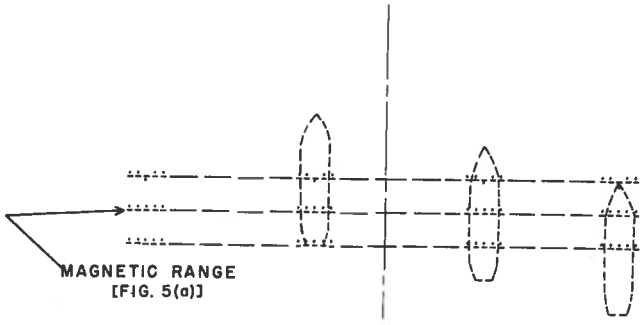
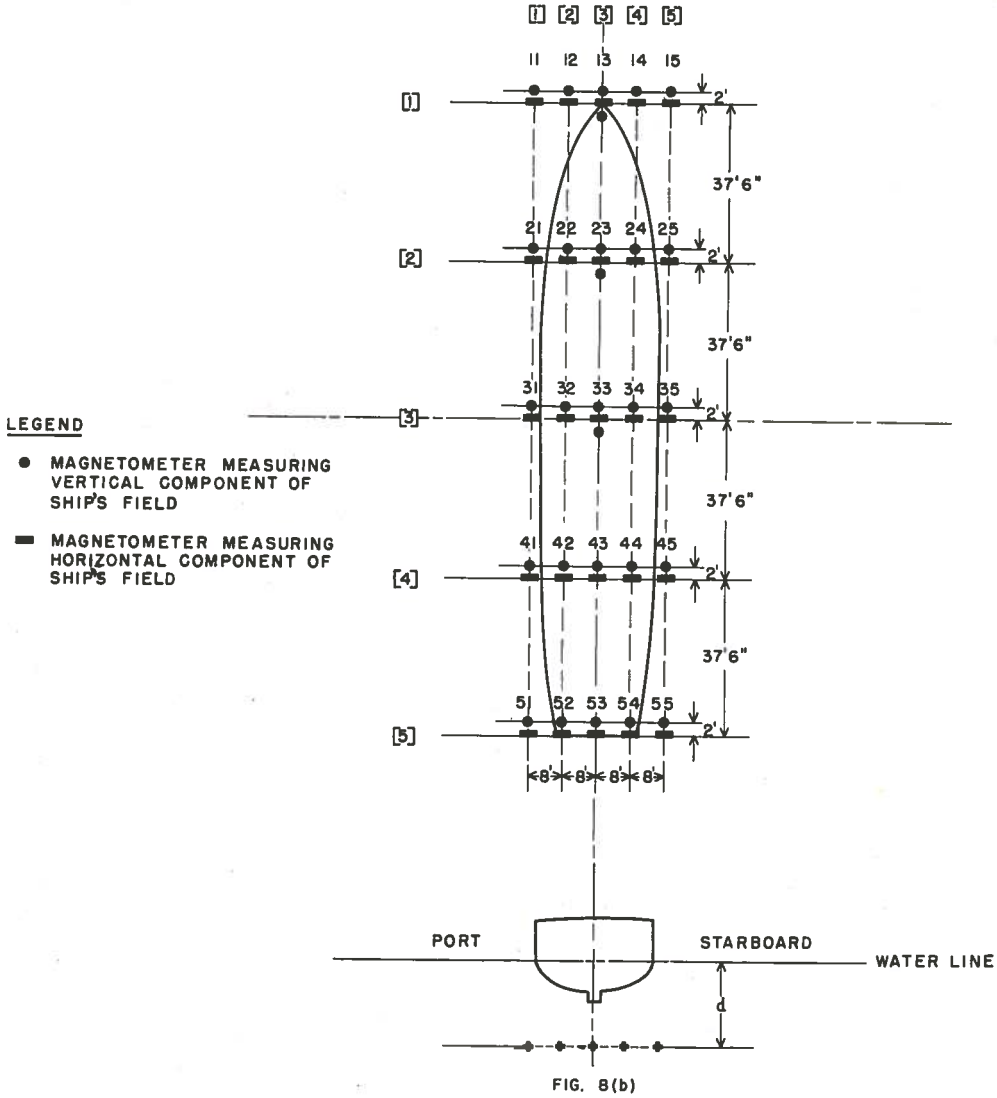


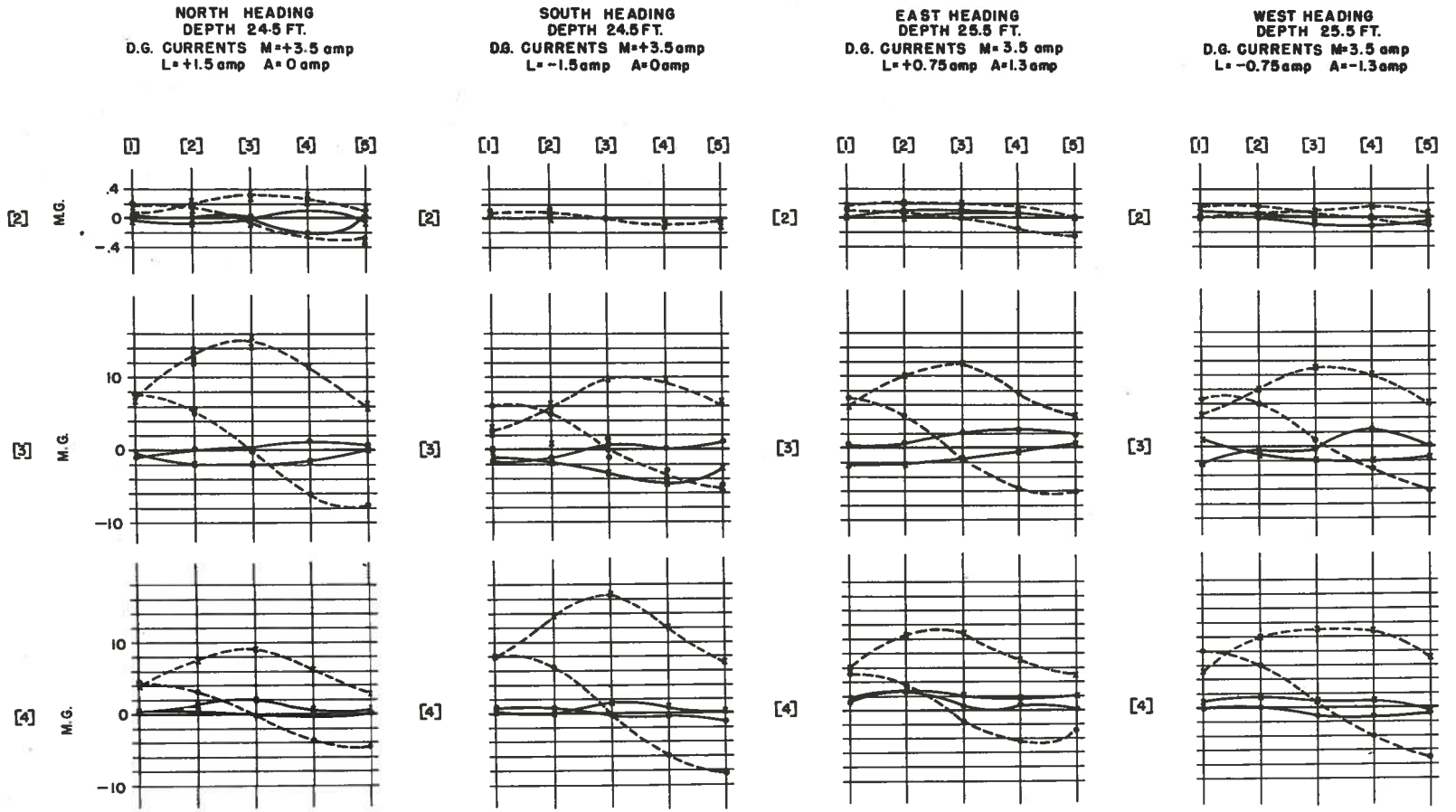
FIG. 8(a)
POSITIONS OF SHIP OVER RANGE



LEGEND

- ● MAGNETOMETER MEASURING VERTICAL COMPONENT OF SHIP'S FIELD
- ▬ MAGNETOMETER MEASURING HORIZONTAL COMPONENT OF SHIP'S FIELD

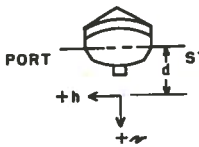
FIG. 8(b)
GRID REFERENCE SYSTEM - FIXED WITH RESPECT TO SHIP



HMCS "COMOX"

SURVEY OF STATIC FIELD AND STATIC DEGAUSSING

FIG. 9



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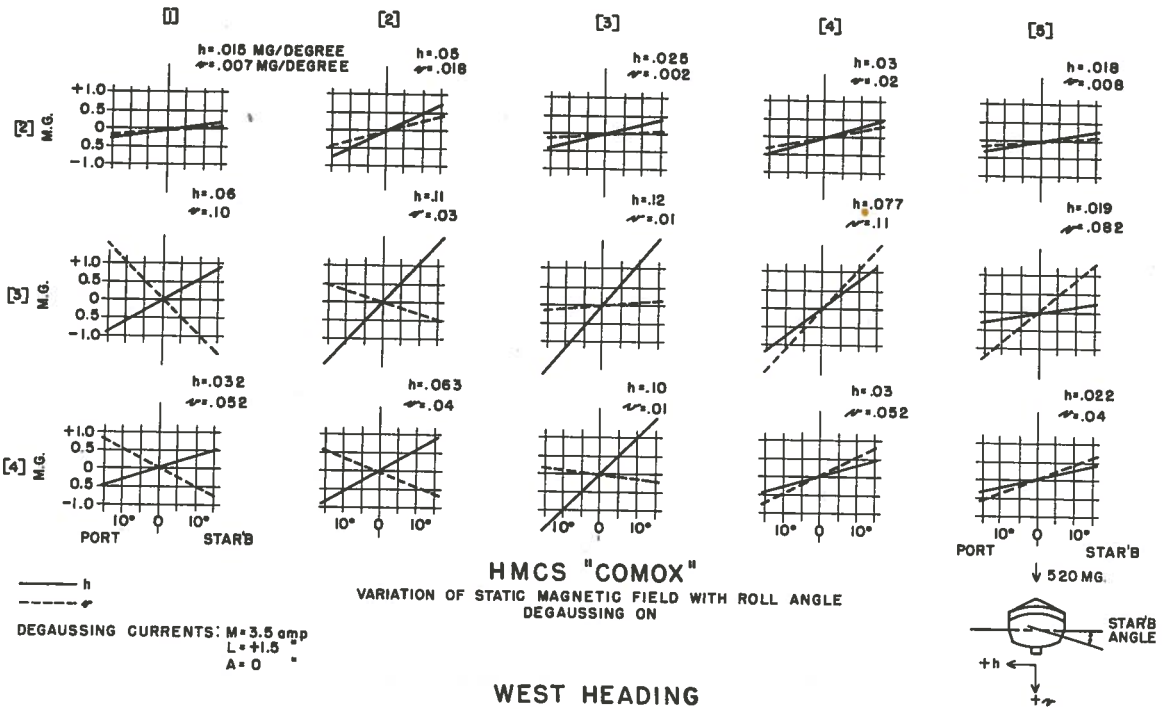
NORTH HEADING
DEPTH 25.5 FT.



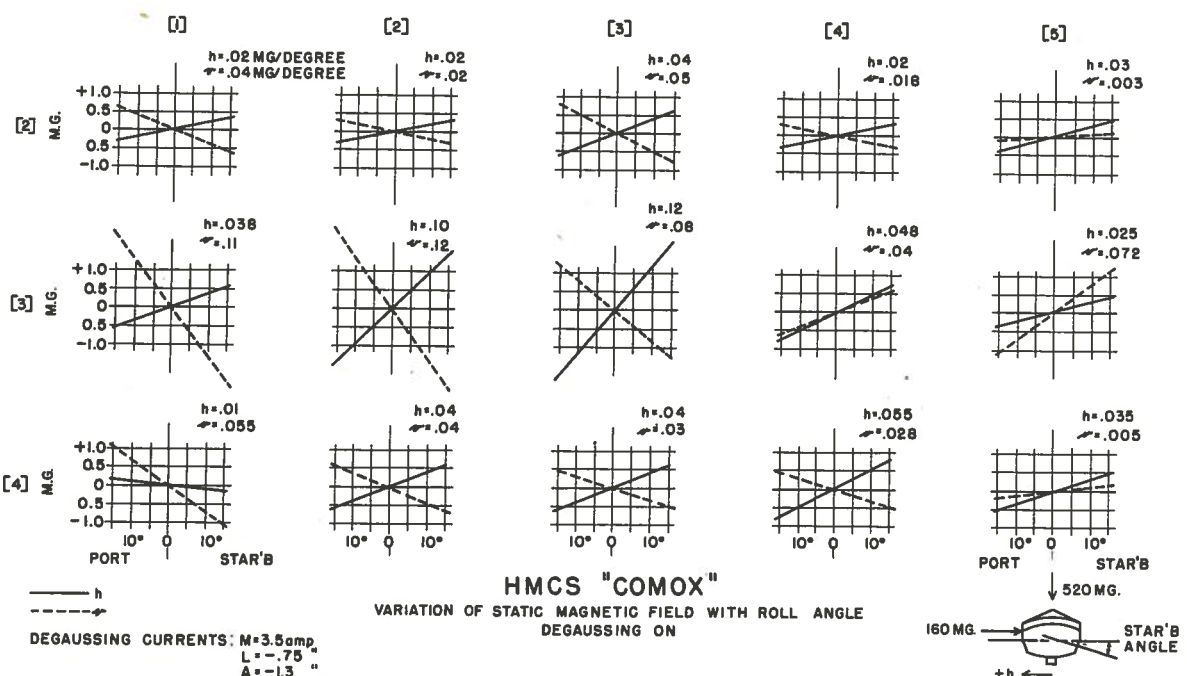
h

DEGAUSSING CURRENTS: M=3.5 amp
L=+1.5 "
A=0 "

HMCS "COMOX"

VARIATION OF STATIC MAGNETIC FIELD WITH ROLL ANGLE
DEGAUSSING ON

WEST HEADING
DEPTH 25.5 FT.



h

DEGAUSSING CURRENTS: M=3.5amp
L=-.75 "
A=-1.3 "

HMCS "COMOX"

VARIATION OF STATIC MAGNETIC FIELD WITH ROLL ANGLE
DEGAUSSING ON

FIG. 10

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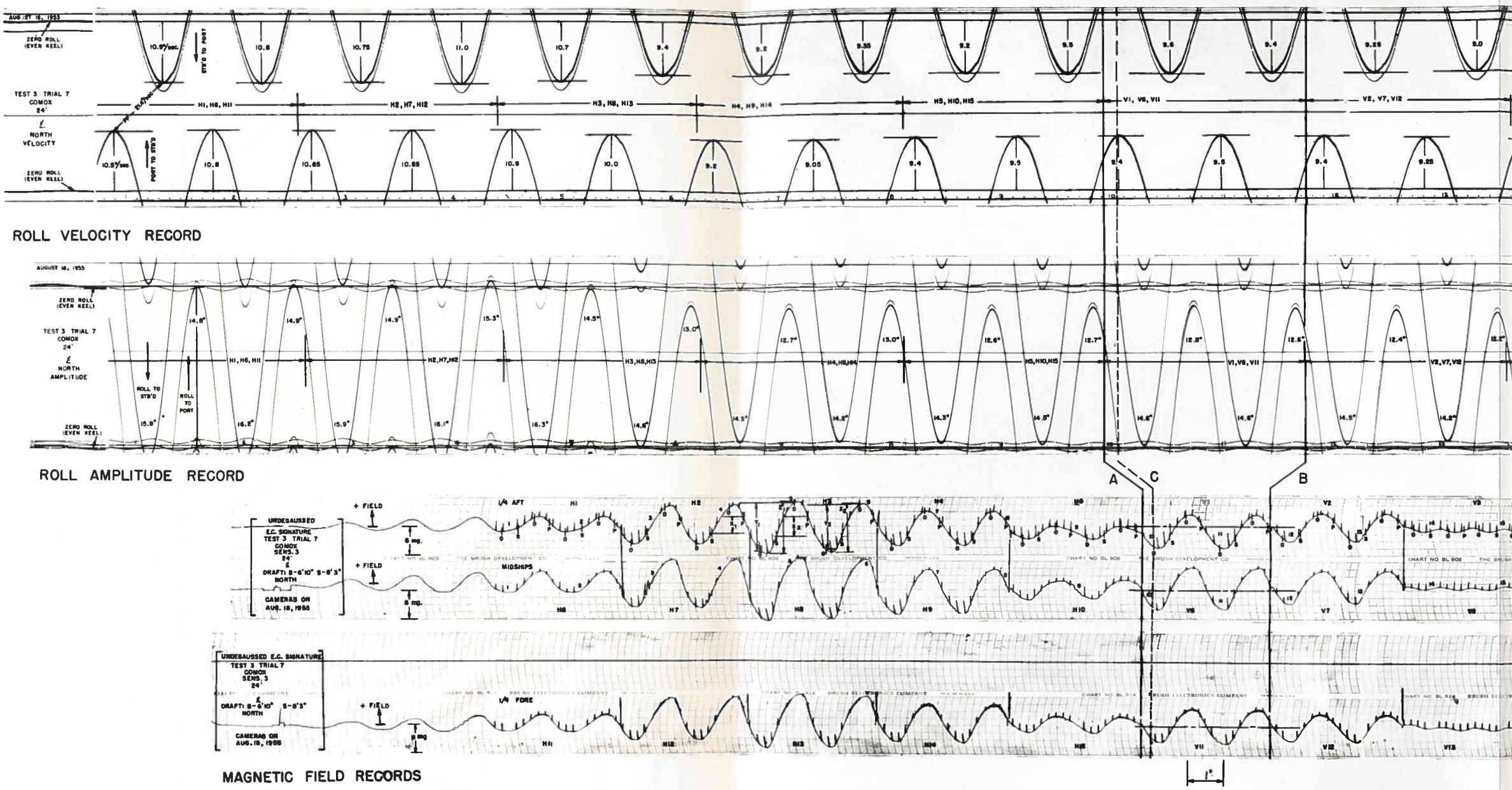
SECRET

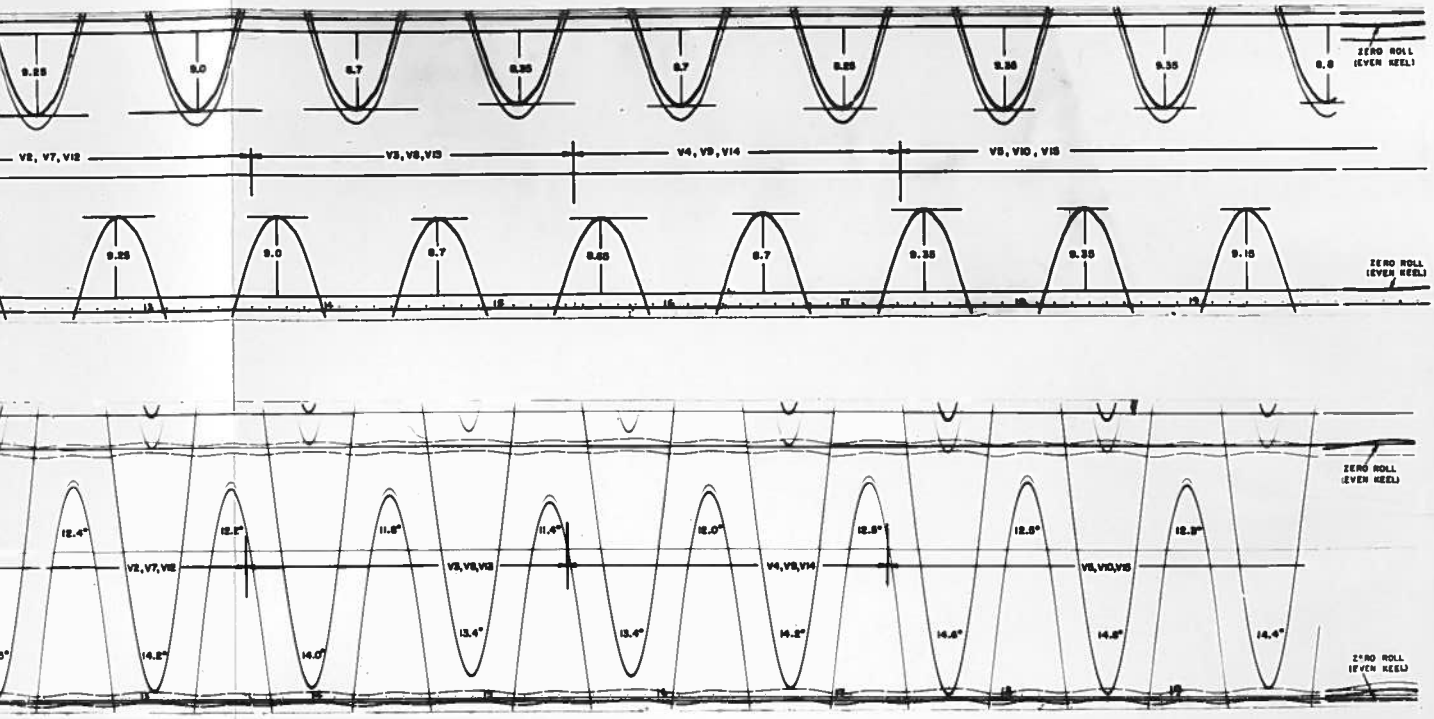


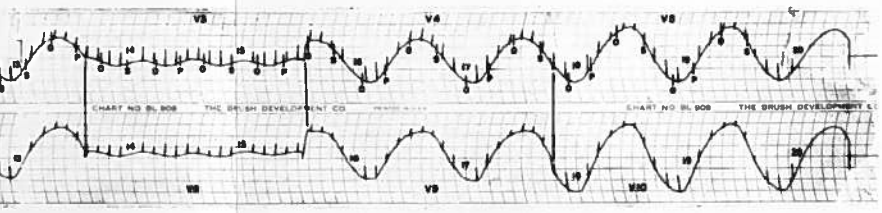
FOR "H" UNITS, +FIELD DIRECTION IS FROM STARBOARD TO PORT.

FOR "V" UNITS, +FIELD DIRECTION IS DOWNWARDS.

FIG. 11

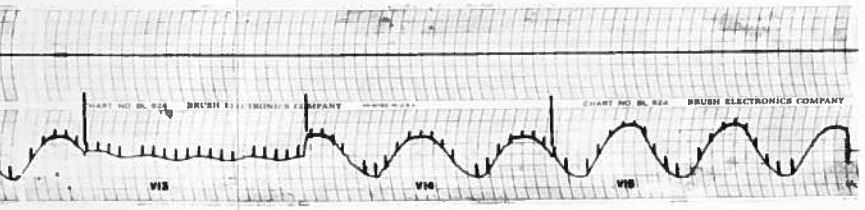
TYPICAL RECORDS OF MEASUREMENT OF DYNAMIC VARIATION IN MAGNETIC FIEL
(DYNAMIC FIELD UNCOMPENSATED, STATIC FIELD COMPENSATED)





CHANNEL 1

CHANNEL 2



CHANNEL 3

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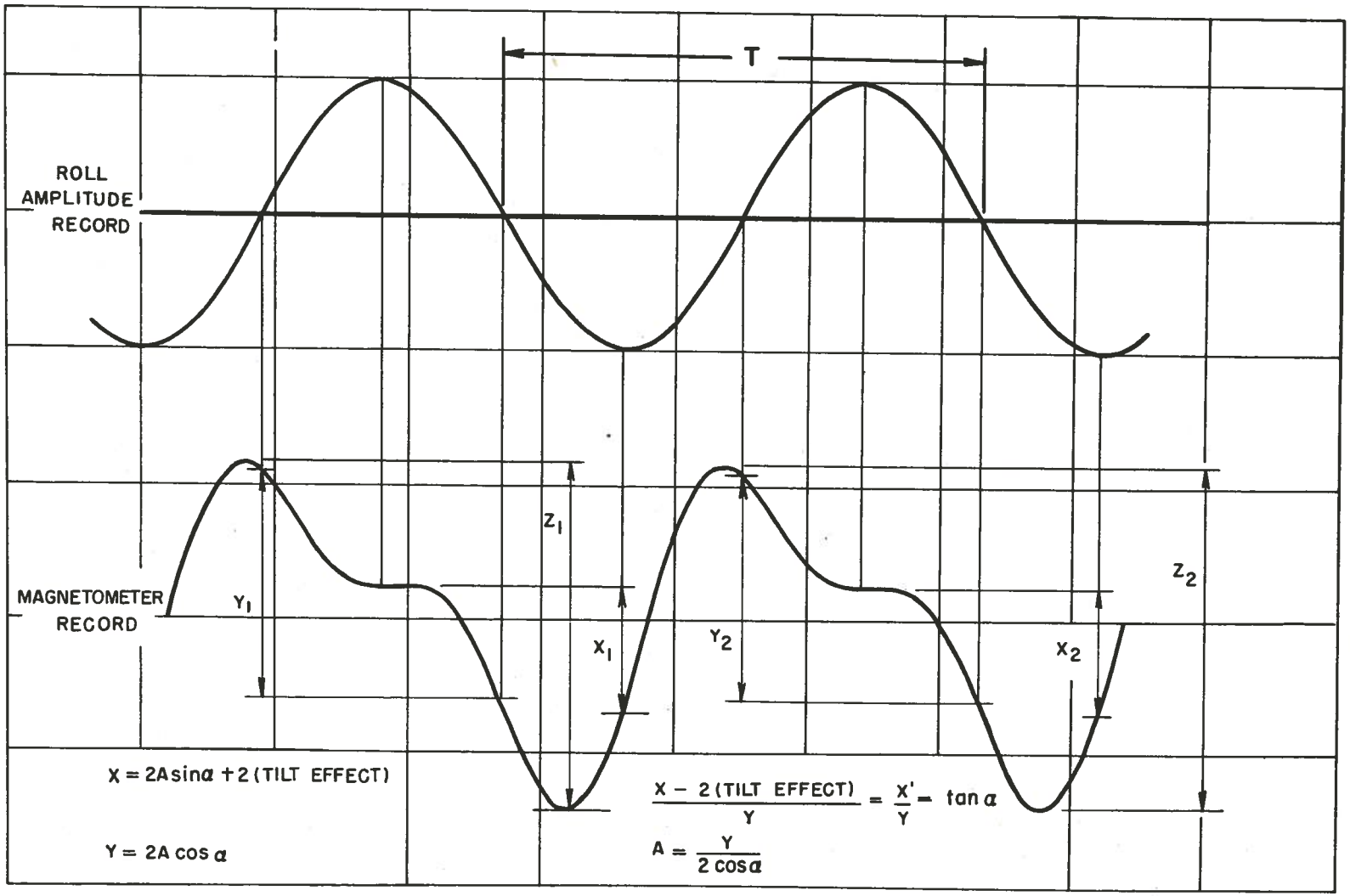
SECRET

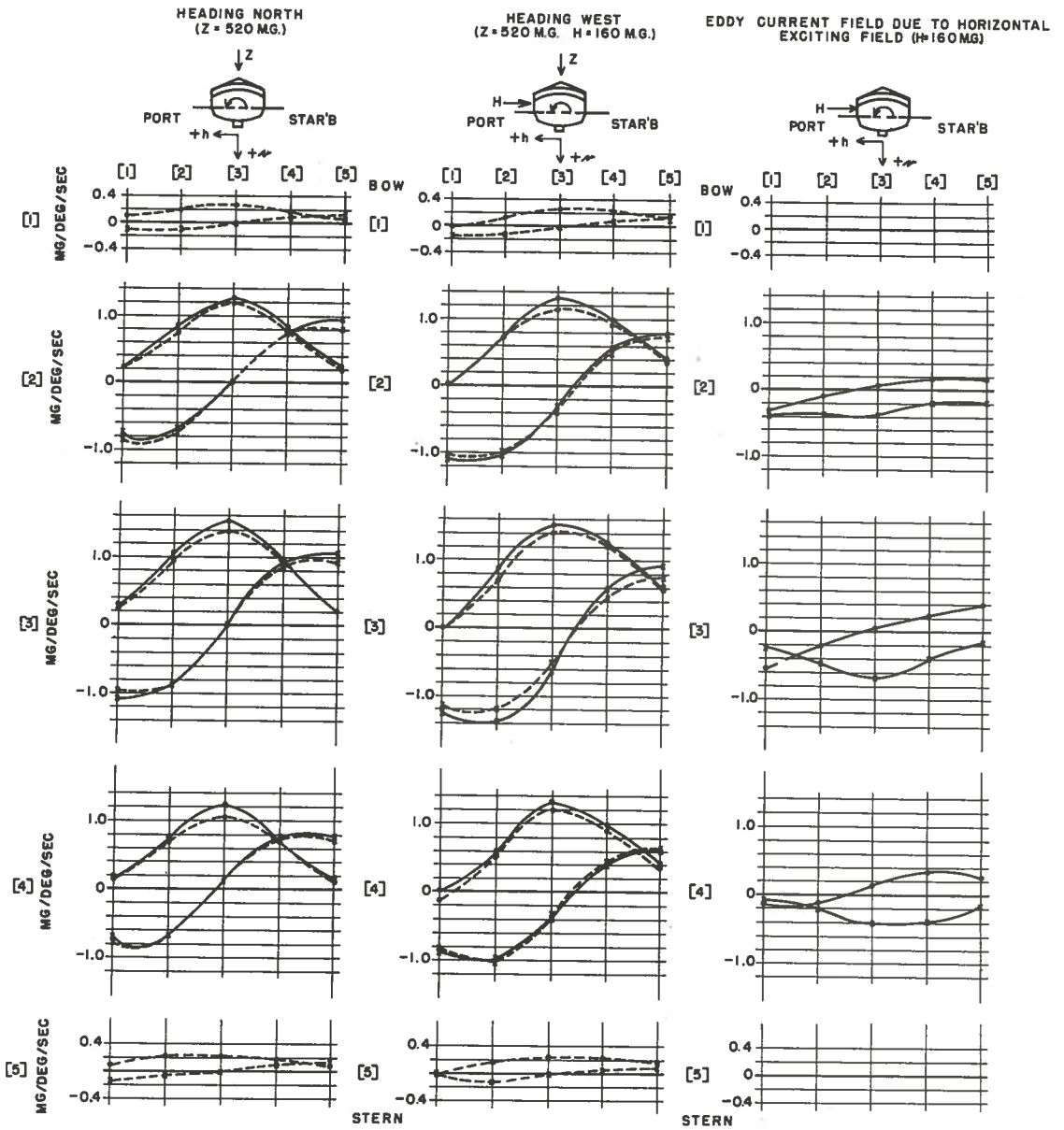
ON IN MAGNETIC FIELD
COMPENSATED)



SECRET

METHOD OF ANALYSIS OF MAGNETOMETER RECORD

FIG. 12



HMCS "COMOX"

SURVEY OF EDDY-CURRENT FIELD
FOR A ROLL FROM STARBOARD TO PORT – N. & W. HEADINGS

NOTES:

1) EACH ORDINATE IS THE MAXIMUM SIGNAL WHICH OCCURS DURING THE HALF CYCLE OF ROLL FROM STARBOARD TO PORT.

2) VERTICAL UNITS ARE 2' AFT OF HORIZONTAL UNITS. (SEE RANGE PATTERN)

h ·------· HORIZONTAL } EDDY CURRENT + TILT
v ×------× VERTICAL

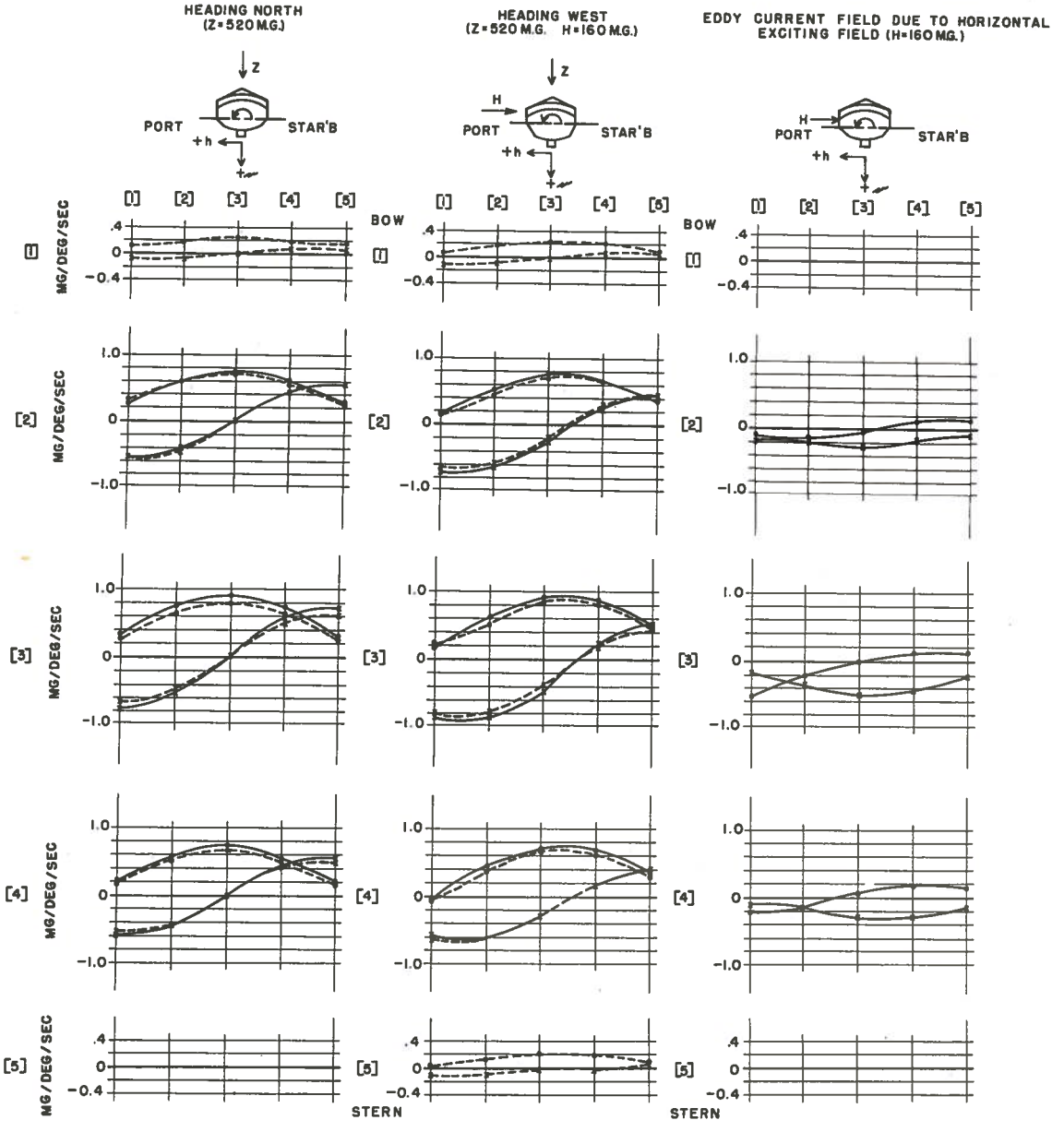
h ●——● HORIZONTAL } EDDY CURRENT
v ×——× VERTICAL

DEPTH 19 FT.

ERA-300

SECRET

FIG. 13



H M C S "COMOX"

SURVEY OF EDDY-CURRENT FIELD
FOR A ROLL FROM STARBOARD TO PORT - N. & W. HEADINGS

NOTES:

1) EACH ORDINATE IS THE MAXIMUM SIGNAL WHICH OCCURS DURING THE HALF CYCLE OF ROLL FROM STARBOARD TO PORT
2) VERTICAL UNITS ARE 2' AFT OF HORIZONTAL UNITS. (SEE RANGE PATTERN)

h ----- HORIZONTAL
VERTICAL
} EDDY CURRENT + TILT

h ——— HORIZONTAL
VERTICAL
} EDDY CURRENT

DEPTH 24FT.

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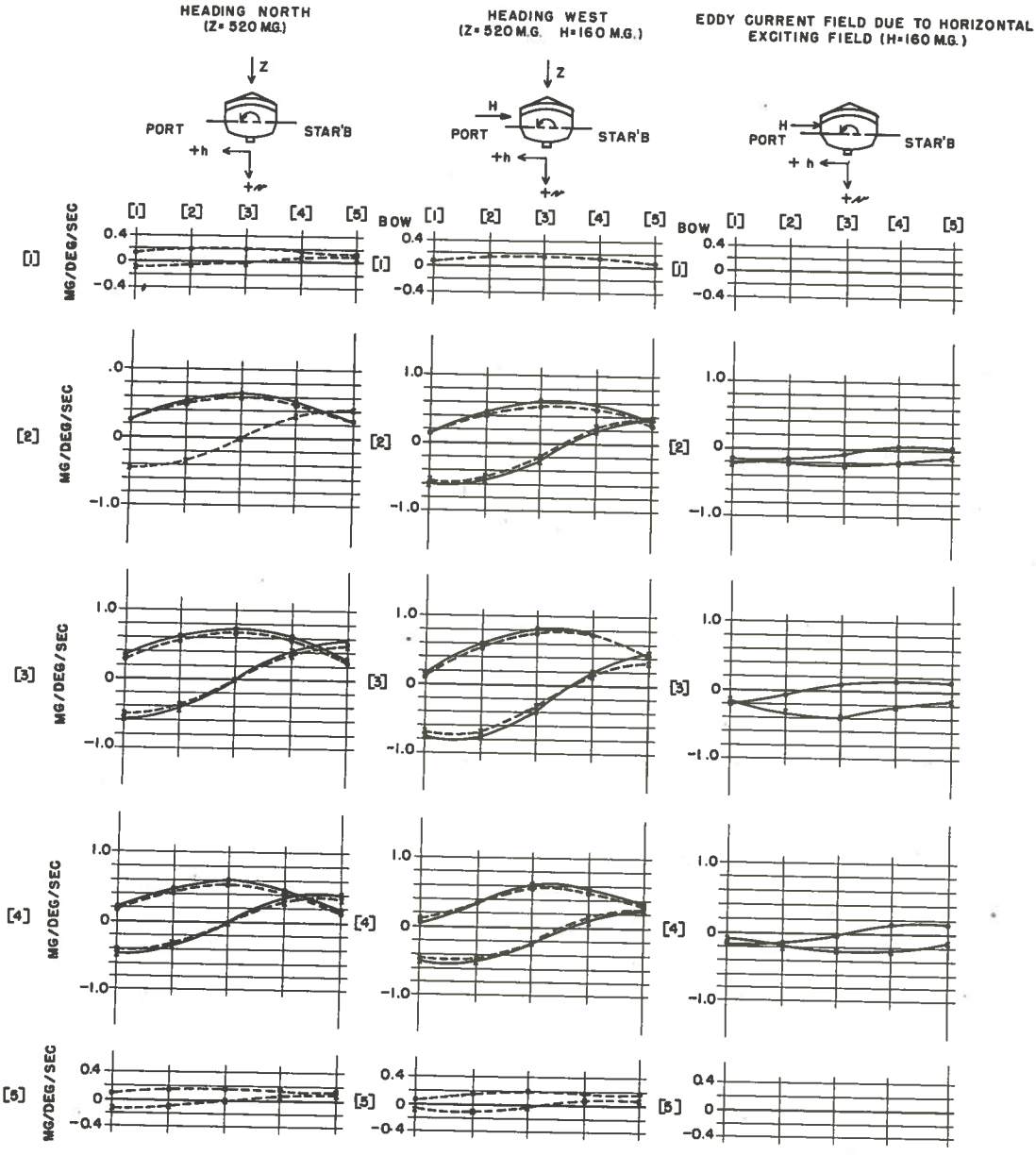
FIG. 14



HMCS "COMOX"

SURVEY OF EDDY-CURRENT FIELD
FOR A ROLL FROM STARBOARD TO PORT – N. & W. HEADINGS

NOTES:

1) EACH ORDINATE IS THE MAXIMUM SIGNAL WHICH OCCURS DURING THE HALF CYCLE OF ROLL FROM STARBOARD TO PORT.
2) VERTICAL UNITS ARE 2' AFT OF HORIZONTAL UNITS. (SEE RANGE PATTERN)

h ——— HORIZONTAL } EDDY CURRENT + TILT
v ——— VERTICAL }

h ——— HORIZONTAL } EDDY CURRENT
v ——— VERTICAL }

DEPTH 27FT.

ERA-300
SECRET

FIG. 15

			(1)			(2)			(3)			(4)			(5)		
			N	W	H	N	W	H	N	W	H	N	W	H	N	W	H
(1)	h	19'	--	--		32	--		37	--		37	--		--	--	
		24'	25	35		26	33		25	35		26	35		36	55	
		27'	24	54		25	51		24	50		23	51		31	67	
	v	19'	--	--		--	--		--	--		--	--		--	--	
		24'	27	44		36	45		--	--		32	53		36	49	
		27'	28	61		26	--		--	--		24	--		22	--	
(2)	h	19'	35	--		36	36		33	36		30	31		39	26	
		24'	31	45		35	33		30	32		32	26		41	31	
		27'	27	39		31	34		27	30		28	23		34	31	
	v	19'	22	33		30	30		--	32	32	34	33	38	41	31	
		24'	30	33		30	22		--	38	38	34	36	32	33	32	
		27'	23	29		30	24		--	39	39	32	40	22	28	31	
(3)	h	19'	--	--		33	37		33	34		31	24		42	23	
		24'	40	73		32	36		32	32		32	25		34	26	
		27'	34	36		28	35		27	31		27	19		29	30	
	v	19'	35	28		31	31	30	--	38	38	35	47	15	33	36	
		24'	33	26		28	26	23	--	29	29	41	49	44	32	31	
		27'	27	26		27	24	20	--	24	24	37	52	26	27	33	
(4)	h	19'	30	--		36	37		34	27		29	32		33	23	
		24'	30	--		33	30		31	23		25	32		27	24	
		27'	29	24		30	31		29	26		22	24		21	23	
	v	19'	31	31		27	27		--	25	25	29	29	29	25	31	
		24'	34	26		31	25		--	24	24	35	36	31	28	42	
		27'	30	25		28	25		--	22	22	31	30	31	25	31	
(5)	h	19'															
		24'															
		27'															
	v	19'															
		24'															
		27'															

NOTES

1) Figures give phase lag in degrees of eddy-current magnetic field behind emf's induced in ship's members for T = 9.3 seconds for positions corresponding to reference grid (Fig. 8 (b)).

2) Figures enclosed by dotted lines are less accurate than those enclosed by full lines.

3) Lag angles are corrected for 3° instrumentation lag.

FIG. 16
PHASE ANGLES OF FUNDAMENTAL
COMPONENT OF EDDY-CURRENT FIELD