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U.S. COAST GUARD TECHNICAL REPORT

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Washington, D.C.

ABSTRACT

The Coast Guard Oceanographic Unit (CGOU) used taut-line instrumented arrays to investigate the current regime near the Grand Banks of Newfoundland. The instrumented arrays used were patterned after a design developed and used by Woods Hole Oceanographic Institution. G. B. Shick's Circular Arc Approximation was used to compute the tension in the mooring line. The arrays were set and recovered by Coast Guard personnel under the supervision of CGOU field parties.

INTRODUCTION

Since the early 1960's, the International Ice Patrol Research Section (IIPRS) of the U.S. Coast Guard Oceanographic Unit has used taut-line instrumented arrays to collect current velocity data near the Grand Banks of Newfoundland and the Labrador continental shelf. Only the 1970–71 projects will be discussed in this report.

The taut-line instrumented arrays used by the IIPRS (Figure 1) were patterned after a design developed and used successfully by Woods Hole Oceanographic Institution (Berteaux, 1968; Berteaux and Walden, 1969). The arrays consisted of a surface float attached to a plaited nylon mooring line with current meters attached at various positions along its length. The complete mooring was secured to an anchor with a release device (acoustic or time) which freed the array from the anchor when triggered.

The direct current observations collected are of interest to the Ice Patrol Research Section:

- To determine the validity of the geostrophic approximation.
- To collect direct current measurements which may be used for boundary conditions in a mathematical circulation model of the region.
- To collect direct current measurements to be used in iceberg drift models.

The 1970 arrays were set off the coast of Labrador north of the Strait of Belle Isle in positions 54°30′N, 54°32′W and 54°29′N, 54°-30′W. Both arrays were recovered successfully two weeks after they were set. In 1971, two arrays were set on the southeastern edge of the Grand Banks at positions 45°02′N, 48°55′W and 46°40′N, 47°24′W . Two weeks later, one array was recovered; the other array was apparently struck by a fishing trawl which carried away the surface float, allowing the remaining section of the array to sink. When the CGC EVERGREEN was within about two miles of the location where the buoy had been set, the acoustic release device responded when interrogated. Extensive dragging operations failed to recover the release or any other part of the array. (Note in proof. Two of the current meters and assorted lengths of line from the southern array were found by a Newfoundland trawler and returned to CGOU in February 1973. The acoustic release was not recovered.)

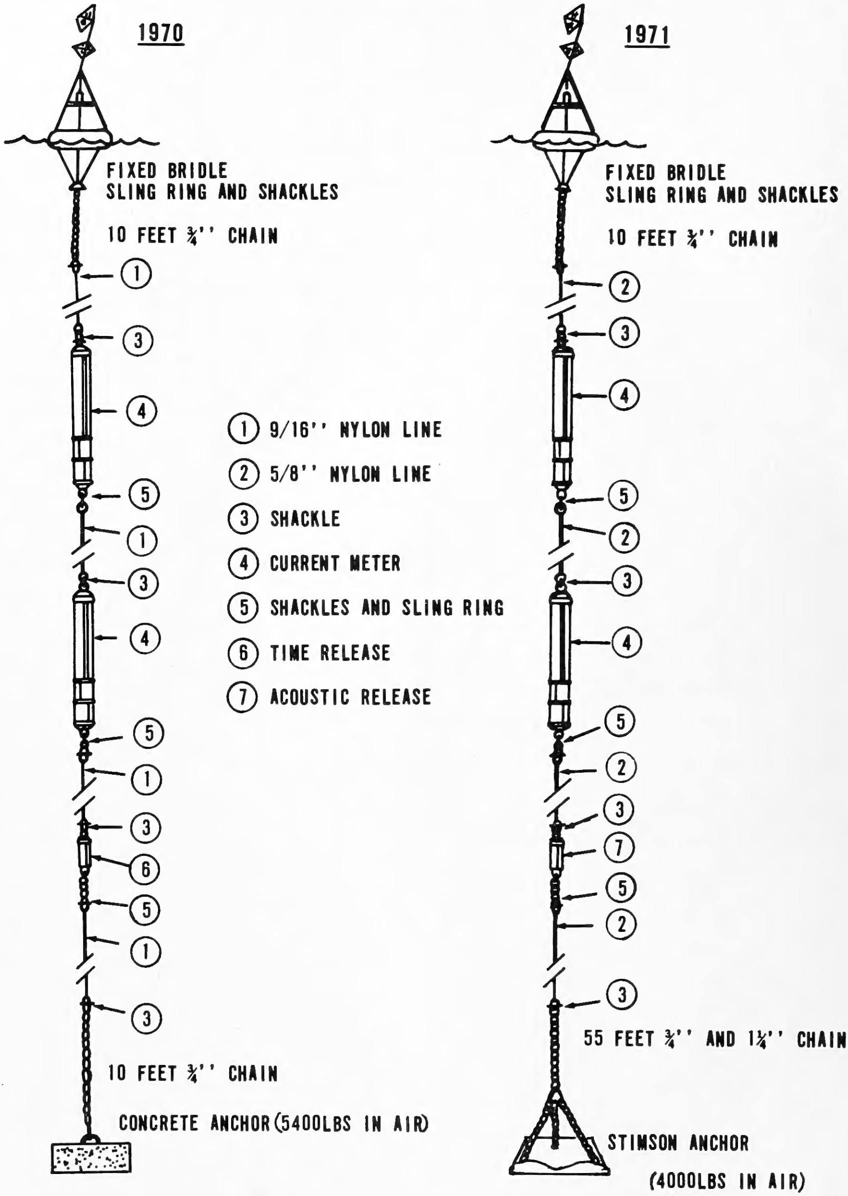

FIGURE 1. Single point taut-line instrumented arrays used in 1970–71.

BUOY ARRAY DESIGN

All of the taut-line arrays set by the IIPRS in 1970 and 1971 used surface flotation which was on hand at CGOU. The floats used were Geodyne Model A–92 toroidal instrument buoys (Figure 2). A Geodyne Model A–93 tripod tower on each buoy supported a pair of wire mesh, lifeboat radar reflectors and a Geodyne Model 180 Xenon light. A rigid tripod bridle, Geodyne Model B–301, attached to the bottom of the toroid, supported the subsurface portion of the array.

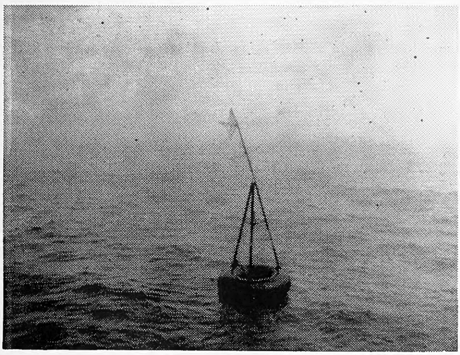

FIGURE 2. Surface buoy, Geodyne Model A–92.

The use of surface flotation introduces major problems which can effect the survivability and reliability of taut-line arrays.

- Surface floats are susceptible to collisions with ships, fishing trawlers and seiners, icebergs, and, in some locations, sea ice.
- Surface floats with radar reflectors and lights are highly visible, and are, therefore, subject to well-intentioned recovery or theft.
- The use of surface floats requires a very accurate determination of water depth at the mooring site.

If the water depth were not accurately known and the array were set in water exceeding the design depth, heavy seas, large tidal rises, or strong currents could cause the anchor to be lifted off the bottom since the reserve buoyancy of the surface float exceeded the weight of the anchor. If the anchor were carried into deep enough water, the entire array would be free to drift and could be lost. If however, the array were set in too shallow a depth of water, the mooring line could go slack and kink, or the current meters could be inclined in excess of 15° from the vertical by the current, making the readings unreliable.

To determine water depth accurately at the mooring site, a Salinity/Temperature/Depth System (STD) cast was taken and the sound velocity was computed at various depths. A weighted mean sound velocity, $\overline{R}$, was then calculated. The depth at the mooring site, as indicated by the vessel's fathometer, was noted. The time (T) required for the fathometer signal to reach bottom and return was determined from the relationship:

$$Z=\frac{RT}{2} \tag{1}$$

where: Z = fathometer indicated depth, ft.
R = 4800 ft/sec (sound velocity for which the fathometer was calibrated)
T = time, sec

A more accurate value of Z was then calculated by substituting the values of $\overline{R}$ and T into equation (1).

Mooring Line Tension Calculations

In 1971, the taut-line arrays were designed to satisfy the following requirements.

- Mooring line tension must not exceed 15% of the breaking strength of the line.

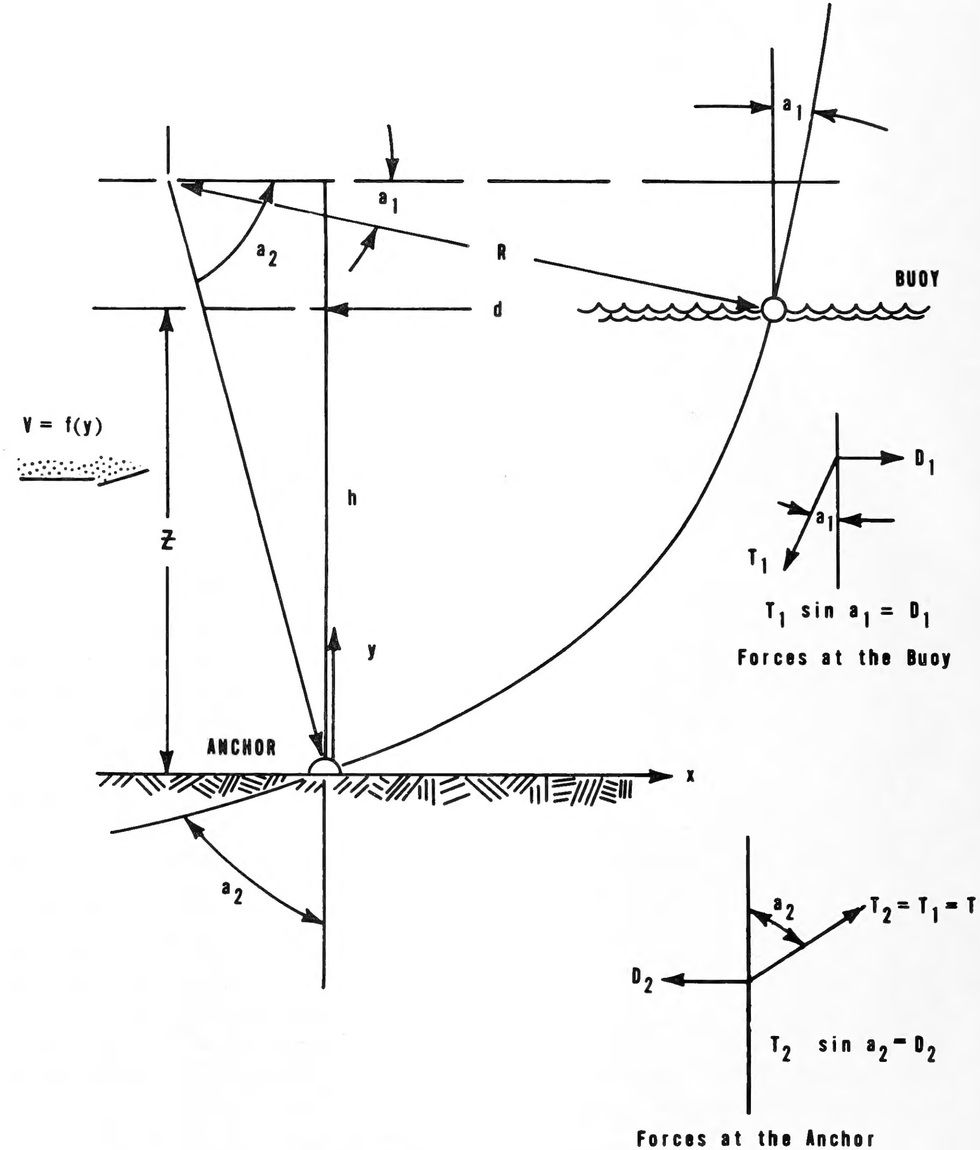

FIGURE 3. Circular Arc Approximation (Berteaux, 1968).

- The arrays must be able to withstand at least 30 feet of vertical movement to compensate for tidal excursions and waves.
- The maximum current will be 2.48 ft/sec and can be considered constant from sea surface to bottom.

- Current meters should not be allowed to incline more than 15° from the vertical.
- Wind drag will be considered negligible.
- All hardware used should have a safety factor of 5:1.

The total tension on the mooring line was calculated using the Circular Arc Approximation (G. B. Shick, 1964). The shape of the mooring line was assumed to be a circular arc (Figure 3). The only force considered was the form drag on the array. The form drag (F) acting on each component of the taut-line array was calculated from:

$$F=0.5\rho v^2 LDC_d \qquad (2)$$

where: F=pressure drag, lbs
ρ=density of seawater, slugs/ft³
v=current velocity, ft/sec
L=length of component, ft
D=diameter of component, ft
C_d=drag coefficient

The uncertainties in determining the drag force arose from our lack of knowledge about the actual current profile and the drag coefficient.

The current velocity was assumed to be constant from the ocean surface to the bottom. This assumption was made to facilitate the calculation of F and to introduce a "worst case" situation. In 1970, a current velocity of 1.68 ft/sec (0.51 m/sec) was used; in 1971 the value was increased to 2.48 ft/sec (0.76 m/sec).

Selection of the drag coefficient (C_d) was based on the Reynolds Number (Re) and the shape of the component. Reynolds Number, the ratio of inertial forces to viscous forces, is defined as:

$$Re=\frac{V\iota}{\nu}=\frac{\rho V\iota}{\mu} \qquad (3)$$

where: ρ=density of fluid, slugs/ft³
V=velocity of flow, ft/sec
μ=coefficient of viscosity, lb-sec/ft²
ν=kinematic viscosity, ft²/sec
ι=characteristic length, ft

A value of Re was calculated, using equation 3, for each component in the array. Values of Re ranged from 3×10^2 to 5×10^3. The calculated value of Re was used as the entering argument for determining C_d from a graph of Re versus C_d (Bretschneider, 1966). The drag coefficient for a right circular cylinder ranged from 0.90 to 1.20. A C_d equal to 1.80 was used in the final calculations for the current meters, release device, and the nylon line to allow an extra safety factor and to compensate for such factors as strumming of the mooring line. Strumming occurs when a cylinder is free to vibrate laterally under the effect of alternating lift forces generated by vortex shedding. Strumming increases turbulent flow behind the mooring line, resulting in increased drag. Since no graph of Re vs. C_d was available for chain, a C_d equal to 2.0 was selected based on a value used by Woods Hole Oceanographic Institution.

The equivalent spring constant (K) was calculated for each size nylon line considered for use in the array. K was calculated from the equation:

$$K=\frac{T_2-T_1}{e_2x-e_1x} \qquad (4)$$

where: K=spring constant, lbs/ft
T_2&T_1=tension, lbs
e_2&e_1=percent elongation
x=unstretched length, ft (x + percent initial elongation times x = water depth)

The values of T and e were taken from first loading curves for line similar to that actually used in the construction of the arrays (Figure 4). The expected working range was between 5% and 15% of the average breaking strength of the nylon line. In 1971, the values of K calculated were

- 20 lbs/ft for 9/16 inch line at the shallowest water depth (490 ft).
- 22 lbs/ft for 5/8 inch line at the shallowest water depth (490 ft).
- 40 lbs/ft for 5/8 inch and 9/16 inch line at the deepest water depth (870 ft).

The total tension (T) in the mooring line was then computed using the Circular Arc Approximation. A value of T was assumed and the angles α_1 and α_2 were computed:

$$\alpha_1=\arcsin\frac{D_1}{T} \qquad (5)$$

where α_1=surface angle of inclination
D_1=surface buoy drag, lbs
T=assumed tension, lbs

and

$$\alpha_2=\arcsin\frac{D_2}{T} \qquad (6)$$

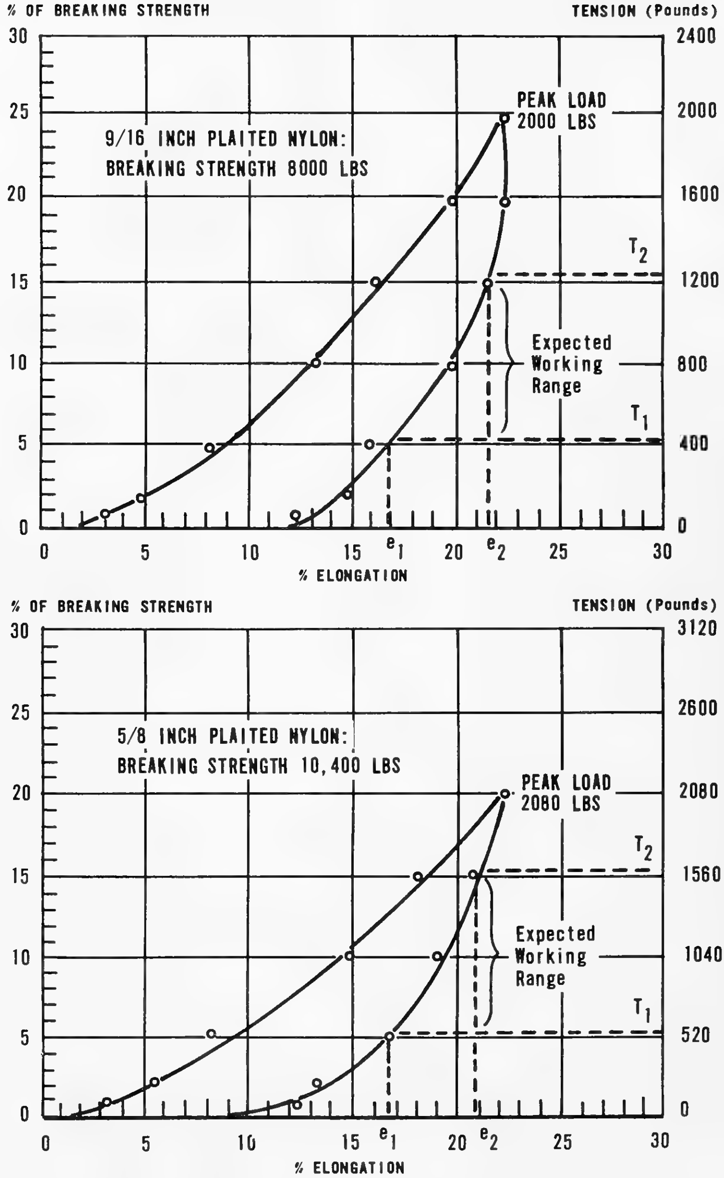

FIGURE 4. First loading curve for 9/16 and 5/8 inch plaited nylon (Berteaux and Walden, 1969).

where α_2 = bottom angle of inclination
D_2 = total subsurface drag, lbs
T = assumed tension, lbs

Next the arc radius was computed:

$$R = \frac{Z\ T}{D_2 - D_1} \qquad (7)$$

R = arc radius, ft
Z = water depth, ft
T = assumed tension, lbs
D_2 = total subsurface drag, lbs
D_1 = surface buoy drag, lbs

After solving for R, the arc length was calculated:

$$S = R\ (\alpha_2 - \alpha_1) \qquad (8)$$

where S = arc length, ft
R = arc radius, ft
α_2 = bottom angle of inclination
α_1 = surface angle of inclination

Finally a value for T was calculated from:

$$T = K(S - Z) + T_0 \qquad (9)$$

where K = equivalent spring constant, lbs/ft
S = arc length, ft
Z = water depth, ft
T_0 = initial tension, lbs

The calculated value of T and the assumed value of T were compared, and if they were not in agreement, a new value of T was assumed and the calculation was repeated. The iterative process was continued until the assumed and calculated values of T agreed within a predetermined limit.

After the maximum tension in the mooring had been determined, the minimum underwater weight of the anchor was determined using the equation:

$$W = T_L + \frac{T_D}{0.6} \qquad (10)$$

where 0.6 = assumed coefficient of friction of anchor on a mud bottom
T_L = vertical tension, $T\ (\cos \alpha_2)$, lbs
T_D = horizontal tension, $T\ (\sin \alpha_2)$, lbs
W = anchor weight, lbs

The anchors used in 1970 were single concrete blocks (5400 lbs) with 10 feet of ¾ inch buoy chain attached above each block. In 1971, Stimson anchors (4000 lbs) with 55 feet of ¾ and 1¼ inch chain were used. Portions of the chain could be lifted off the bottom when the array was subjected to severe storms or excessive tides, thereby increasing the length of the array and decreasing the maximum tension which would have resulted if simple anchors had been used. Thus, the possibility of failure of the array is decreased.

A Dietzgen 7410–PA Programmable Calculator was used for all computations. The programs used are reproduced in Appendixes 1 and 2.

CONSTRUCTION AND TESTING

Plaited nylon line was selected for use in the 1970–71 arrays because of its great strength and elasticity, as well as for its ability to stretch and then return to its original length with no loss in strength (Figures 5–6). As a result of its elasticity, nylon is able to absorb the large amounts of energy present during launching and during severe conditions such as storm waves or strong currents (Figure 7). Plaited nylon also resists twisting and kinking, thus eliminating the need for swivels in the mooring line.

When placed under an initial load, new nylon will be permanently elongated by approximately 10% (Figure 4); thus each section of nylon line in an array was cut shorter than its designed length. During launching, the new nylon line was placed under tension by the falling anchor and permanently elongated by approximately 10%.

Each piece of nylon line was terminated at both ends with a 3 or 4 tuck eye splice whipped with nylon line or black plastic tape (nylon whipping proved superior to the plastic tape). A steel thimble was used in each eye splice to prevent the nylon line from chafing. The nylon line and eye splices were tested by suspending the anchor from one section.

Hardware items such as shackles and sling rings were selected so that the ultimate strength of any part was at least five times greater than the maximum tension the array was designed to withstand. Safety marine shackles, locked with cotter pins, were used to join sections together. To reduce corrosion, the cotter pins were only slightly bent after insertion.

In 1970, two Geodyne Model 102 photographically recording current meters were tested by operating them in a darkroom with the pressure cases removed and a test strip of film in the magazine. After it was determined that the meters were functioning and sequencing properly, the meters were reloaded with film and the pressure cases were replaced.

Two Geodyne Model 850 magnetic tape recording current meters were also used in 1970. Four 850 current meters were used in 1971. A characteristic failure of these instruments is for the tape to wind around the capstan drive and stop the recorder. Each of our recorders was carefully tested to insure that the capstan drive functioned properly. Then the current meters were run in the lab for several days with test tapes in the recorders to determine if the tapes advanced properly. Magna-See fluid was used to insure that data were being recorded on the tape. A new piece of test equipment manufactured by Geodyne enabled the Instrument Section to give each current meter a comprehensive checkout before it left the lab in 1971. After testing, each meter had a new battery installed. Each battery was checked by placing it under a 100 ohm load and measuring the voltage prior to installation. Before each tape cartridge was installed, it was erased to clear it of any noise which might later interfere with computer processing of the recorded data. Several desiccant bags were placed into each current meter before it was sealed .

The "O" rings at the top and bottom of the case were removed and replaced with properly greased new ones before the pressure case was placed on the current meter. Care must be taken when placing the pressure case on the current meter to insure that the "O" rings are not pinched or improperly seated, or the meter will flood. Placement of the top "O" ring is especially critical. Once the pressure case was in place, the tie rods were torqued to 10 ft-lbs. The current meters were then pressure tested to 200 meters by the National Oceanographic Instrumentation Center. In 1970, the current meters were tested by suspending them in the Anacostia River just below the surface for about 3 hours. In 1971, one of the current meters flooded as a result of an improperly installed top "O" ring which had become pinched between the cap and the tube. The electronic components were extensively damaged by the water-battery electrolyte mixture and the pressure. After the current meters passed the pressure test, a final check was made by activating the meters and listening for sequencing sounds with a stethoscope.

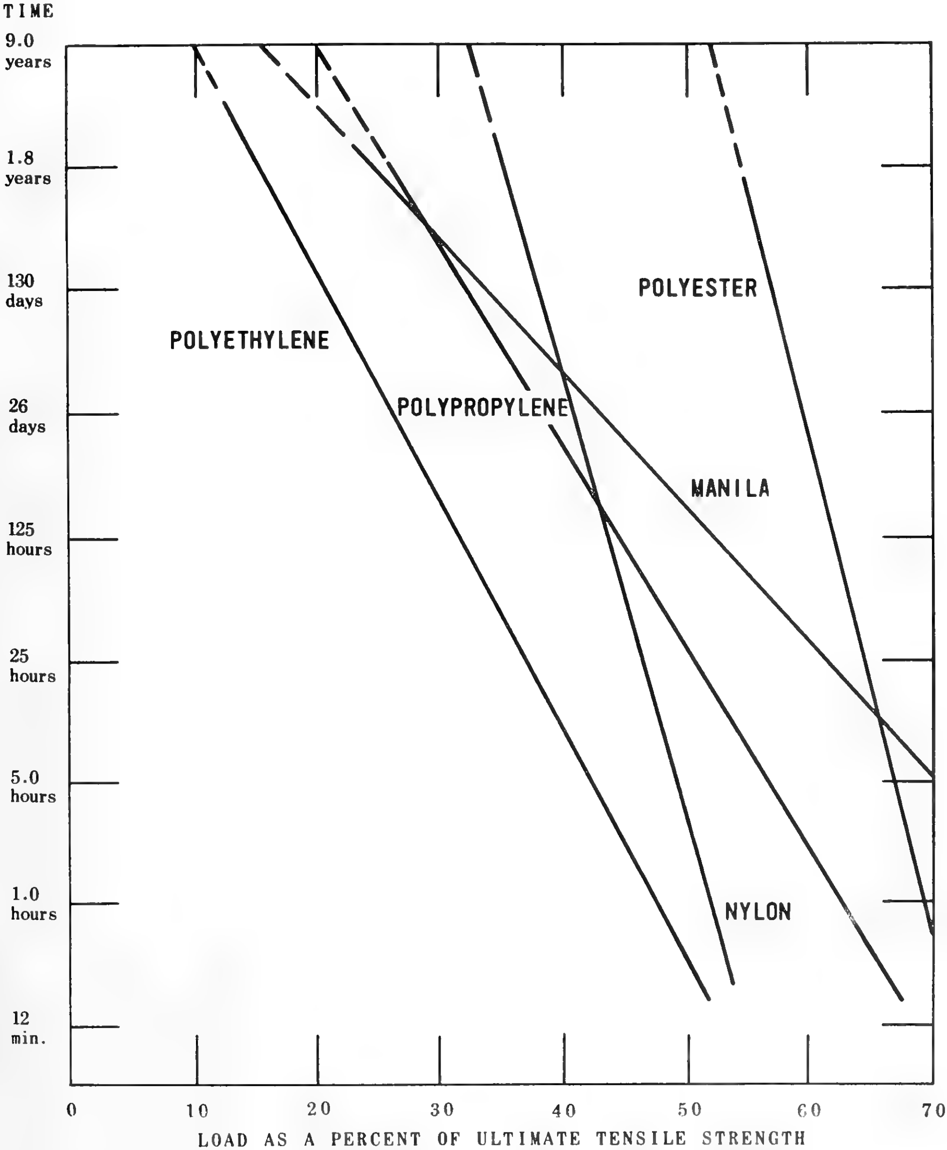

FIGURE 5. Comparison of rope strength (Written communication from Columbian Rope Company).

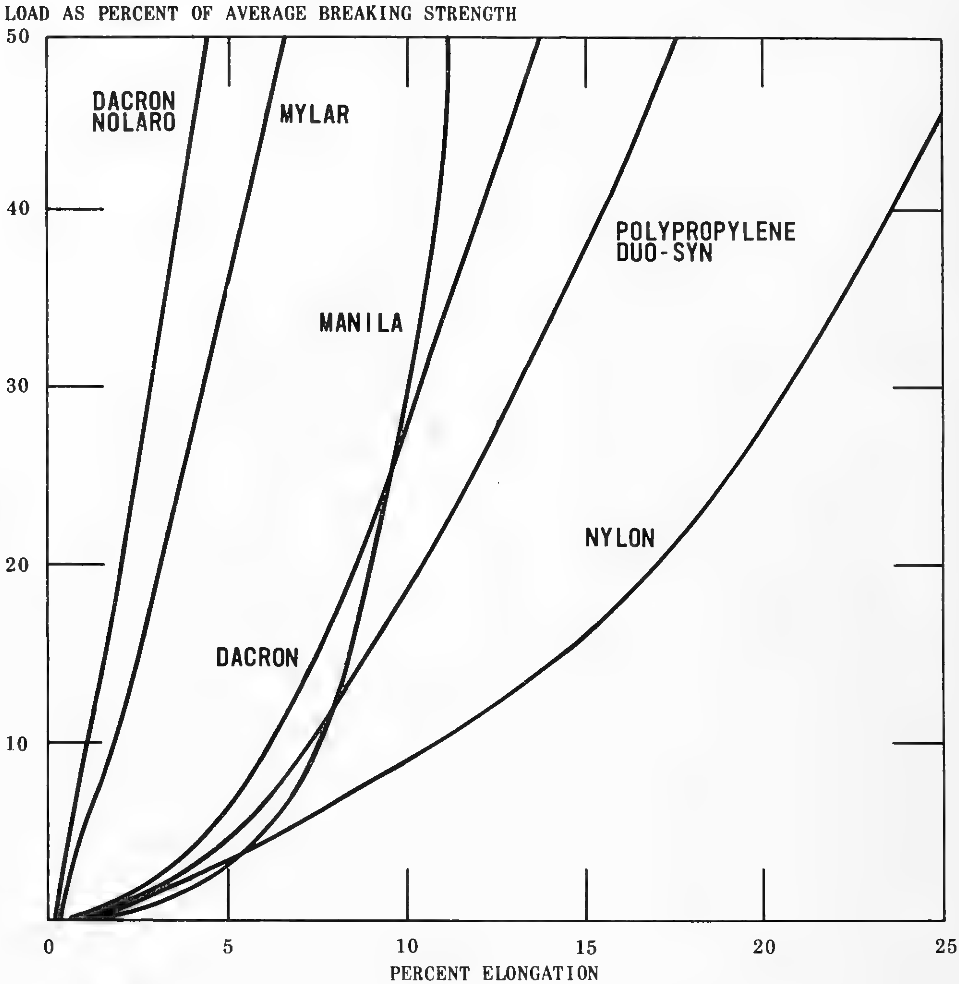

FIGURE 6. Typical elongation in various ropes after first loading to 50% of average breaking strength (Written communication from Columbian Rope Company).

The Model A–393 and 855 Geodyne time releases used in 1970 were checked for proper operation at room temperature in the laboratory on CGC EVERGREEN. They were then operated in the ship's reefer to simulate expected water temperature (~0.0°C). One of the releases was test fired on deck.

AMF Model 242 acoustic releases were used by IIPRS in 1971. Each release was completely tested prior to use in accordance with the procedures in the operation manual. Before use, both acoustic releases were given an air acoustic test at CGOU and again on the EVERGREEN immediately before deployment.

The arrays were assembled on the buoy deck of EVERGREEN in accordance with a mooring order established prior to the cruise. The mooring order listed each component as it would ap-

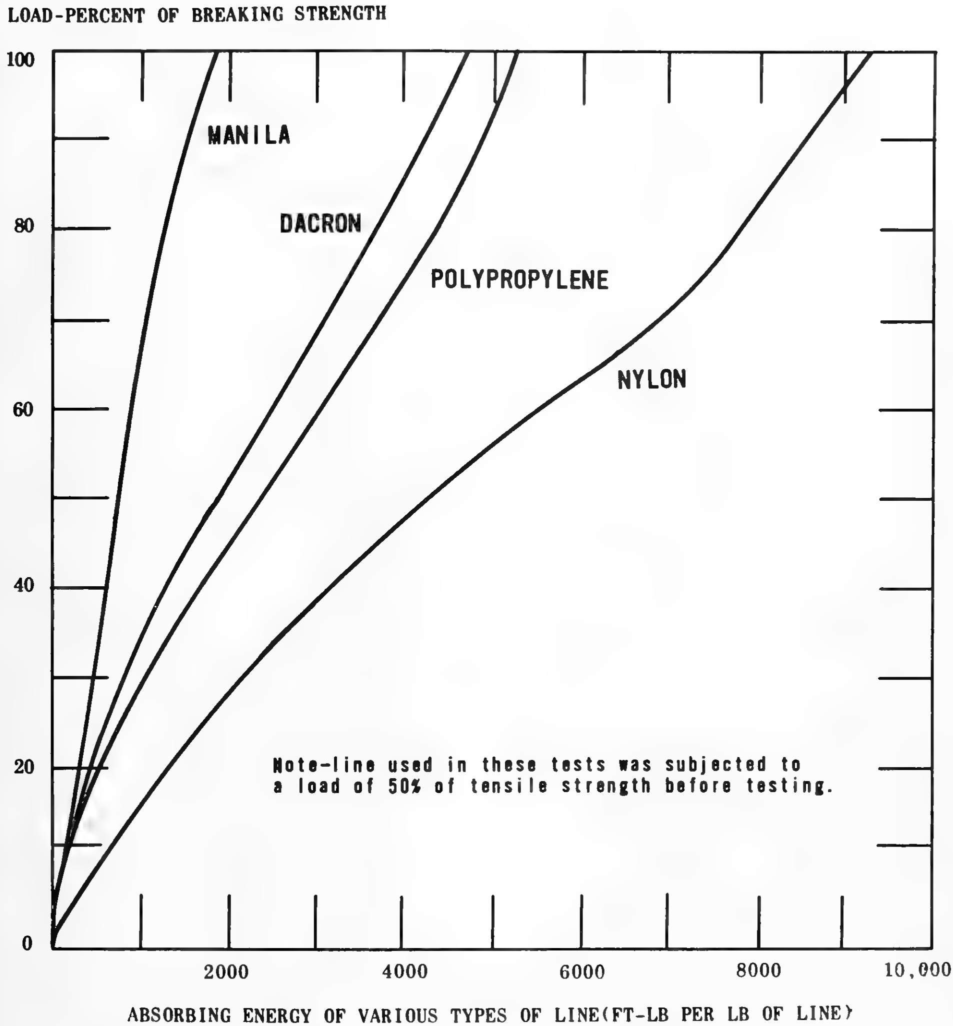

FIGURE 7. Impact resistance or energy absorption properties of line (Written communication from Columbian Rope Company).

pear in the actual array. A check-off list was completed for each instrument in the array to insure that it was ready to be set. A single inner tube was lashed to each instrument in the array to provide flotation while the array was being set and recovered. The lines used to secure the flotation to the instrument were passed between the tie rods and the pressure case to prevent the inner tube from slipping off as it was compressed by water pressure (Figure 8). After a final check to make sure that everything was assembled properly, the array was neatly laid

Table 1. Comparison of taut-line array components, 1970 and 1971.

	BUOY #1	BUOY #2	BUOY #3	BUOY #4
Position	54°30'N 54°32'W	54°29'N 54°30'W	45°02'N 48°55'W	46°40'N 47°24'W
Depth	712 ft	712 ft	648 ft	672 ft
Set	21 July 1970	21 July 1970	11 May 1971	12 May 1971
Recovered	4 August 1970	4 August 1970	Lost	25 May 1971
Flotation Buoy	Geodyne Model A-92 toroidal fiberglass buoy, 4300 lbs net buoyancy			
Tripod Tower	Geodyne Model A-93			
Rigid Tripod Bridle	Geodyne Model B-301			
Buoy Light	Geodyne Model 180 Xenon			
Nylon Line	Columbian Rope Company Pli-moor 9/16", breaking strength 8000 lbs		Columbian Rope Company Pli-moor 5/8", breaking strength 10400 lbs	
Sling Rings	Crosby Laughlin Inc. Pear shaped 5/8" S.W.L. 4200 lbs		Crosby Laughlin Inc. Pear shaped 7/8" S.W.L. 8300 lbs 1/2" S.W.L. 2900 lbs	
Safety Marine Shackle	Boston & Lockport Inc. 5/8" S.W.L.* 4200 lbs		Boston & Lockport Inc. 5/8" S.W.L. 4400 lbs 1" S.W.L. 10,000 lbs	
Current Meters	Geodyne 102 Photographic Recording	Geodyne 850 Magnetic tape Recording	Geodyne 850 Magnetic tape Recording	Geodyne 850 Magnetic tape Recording
Releasing Device	Geodyne A-393 Time release	Geodyne 855 Time release	AMF 242 Acoustic release and pinger	AMF 242 Acoustic release and pinger
Chain	3/4" Buoy Proof load 16000 lbs	3/4" Buoy Proof load 16000 lbs	3/4" Buoy Proof load 16000 lbs 1 1/4" Anchor P.L. 45500 lbs	3/4" Buoy Proof load 16000 lbs 1 1/4" Anchor P.L. 45500 lbs
Anchor	Concrete block 5400 lbs	Concrete block 5400 lbs	Stimson 4000 lbs	Stimson 4000 lbs

* Safe Working Load

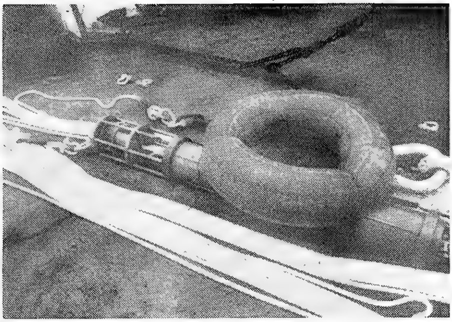

FIGURE 8. Current meter with inner tube flotation collar attached just prior to launching.

out and secured on the buoy deck. The current meters were turned on, and the safety lanyards were removed from the release devices.

Table 1 is a comparison of the components used on the 1970–71 arrays.

Setting the Array

Just prior to launching the array, the EVERGREEN conducted a bathymetric survey of the mooring site. A suitable site was chosen and marked with a reference buoy. The two prime factors considered in site selection were water depth and a relatively flat bottom contour. The reference buoy was identical to the surface float used with parachute drogues deployed by IIPRS

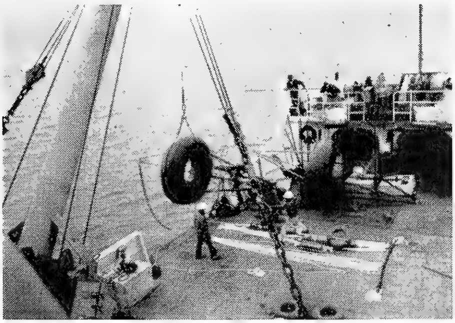

FIGURE 9. Surface buoy being swung over the side. The instruments, line, and anchors are layed out on the buoy deck of the USCGC EVERGREEN.

(Wolford, 1966). They were moored with polypropylene line and anchored with approximately 50 pounds of chain.

To set the array, the surface float was swung over the side and placed in the water (Figure 9). Then as the EVERGREEN backed down slowly, the line and instruments were payed out by hand (Figure 10). A small amount of stern-

FIGURE 10. Instrument and line being payed over the side as the ship backs down.

way on the ship kept the mooring line under enough tension to prevent kinking while the anchor was suspended in the port chain stopper. When the EVERGREEN was in position, the anchor was released from the chain stopper.

When the anchor reached the bottom, the acoustic release was interrogated to determine if it was still functioning properly. The surface float and the reference buoy were watched for about three hours to determine if there was any relative motion between them which would have indicated that either the reference marker or the array was dragging anchor. During this time, the position of the mooring site was determined using the best methods available. In 1970, LORAN A and C were used, while in 1971 NAVSAT fixes were also available.

Recovering the Array

In 1970, recovery operations had to be scheduled when the time release was set to fire. This prevented rescheduling recovery if the weather was adverse or other operations (SAR) prevented being on station when the release fired. In 1971, the use of acoustic releases permitted

FIGURE 11. Surface float lifted onto the buoy deck.

FIGURE 12. Chain being cut from the rigid bridle.

recovery of the array when EVERGREEN was ready. During interrogation of the acoustic release, it was necessary to turn off the ship's fathometer (UQN-4) so that the fathometer signal would not be received by the release receiver and mask the pinger signal.

When the EVERGREEN was in position near the surface float, the acoustic release was fired, thereby freeing the array from the anchor. The surface float was then lifted onto the buoy deck with the whip, and the chain below the fixed bridle was secured in the chain stopper (Figure 11). The chain below the bridle was then cut with an acetylene torch (Figure 12), and the buoy was secured on deck. The remaining chain was brought aboard with the boom, and the remainder of the array was pulled in by hand (Figure 13). When the entire array was on deck, it was disassembled. The current meters were secured, and all instruments were rinsed in fresh water and stowed.

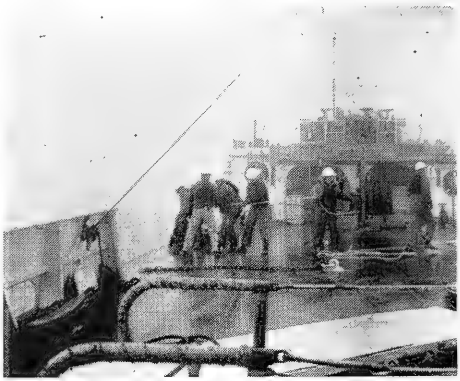

FIGURE 13. Line being pulled in by hand.

DRAGGING OPERATIONS

An attempt was made to recover the two current meters and the acoustic release which were lost in 1971 and thought to be lying in 108 fathoms of water in the vicinity of 45°02'N and 48°56'W. Dragging operations were conducted with a rig which consisted of 20 feet of ½ inch chain followed by 6 feet of ⅞ inch chain. Two 15 pound heat treated marine grapnels and one 10 pound galvanized marine grapnel were shackled to the chain as shown in Figure 14. The 15 pound grapnels are a standard Coast Guard supply item, and their performance was satisfactory during the dragging operations. The 10 pound galvanized grapnels were purchased from the Atlantic Marine Exchange, Boston, Mass. They were too light for the type dragging being done and were not considered satisfactory. The rig was shackled to a 5 ton Miller D–5 swivel which was then shackled to the end of the STD cable. The STD cable was terminated with a Preformed Line Products Company eye grip clamped to the cable with three cable clamps for additional holding power. A 3 foot length of ⅞ inch chain trailing the bottom grapnel usually prevented the grapnels from fouling the chain when dragging downslope.

A marker buoy was set and served as a reference point for navigation during the operation. Dragging runs began by lowering the grapnels until they were just off the bottom. EVERGREEN then got underway as more wire was let out (approximately 420 meters total). The vessel maintained a speed of 1–2 knots on a heading that set the ship away from the cable and kept it clear of the screws. A total of 109 dragging runs was made both parallel and perpendicular to the bottom contours; however, none of the missing equipment was recovered.

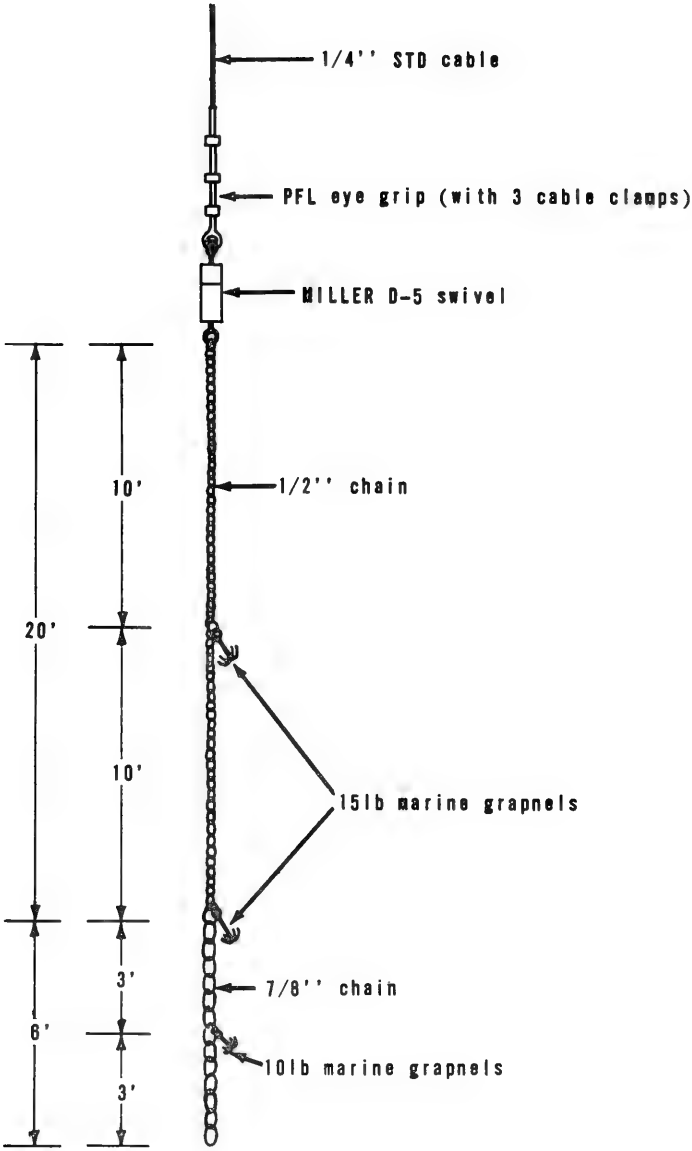

FIGURE 14. Bottom drag rig used for dragging operations on the Grand Banks during June 1971.

RECOMMENDATIONS

The following test procedures are recommended to minimize damage during pressure tests if a current meter should flood.

- Limit the test to 30 meters instead of 200 meters.
- Suspend the test as soon as any pressure fluctuations in the test chamber are noted.
- Have experienced personnel standing by to remove and disassemble the meter if there is any indication of flooding.
- Keep the meter upright to prevent additional damage from water or battery electrolyte shorting energized circuits.

The use of subsurface flotation is recommended. While subsurface flotation is generally more expensive, an array using subsurface flotation is

- As reliable as an array using surface flotation.
- Less susceptible to theft or collision.
- Easier to launch because lighter anchors can be used.
- Not affected by sea level changes due to tides or waves, therefore, reducing dynamic loading.

It is recommended that sufficient back-up flotation be used to insure recovery of any portion of the array remaining if part of the array should be damaged. Corning 16 inch glass spheres, which can be attached anywhere in the array, have been used successfully by Woods Hole as secondary flotation. Two releases attached in parallel would prevent the loss of an array if a single release failed to operate. A long tag line strong enough to lift the anchor would aid the recovery ship if the releases failed and dragging operations were required.

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APPENDIX 1

Program Title: *Calculation of Mooring Line Tension*

BR PT	*Step*	*Instruction*	*CODE MIL*	*Remarks*
0	000	Reset	024	
	001	1	001	
	002	Print x	026	
	003	Halt	401	Enter Z, water depth, ft
	004	Print x	026	
	005	St 1	440	
	006	2	002	
	007	Print x	026	
	010	Halt	401	Enter D_2, subsurface drag, lbs
	011	Print x	026	
	012	St 2	441	
	013	3	003	
	014	Print x	026	
	015	Halt	401	Enter D_1, surface buoy drag, lbs
	016	Print x	026	
	017	St 3	442	
1	020	4	004	
	021	Print x	026	
	022	Halt	401	Enter T, assumed tension, lbs
	023	Print x	026	
	024	St 4	443	
	025			
	026			
	027			
	030			
	031	Rcl 2	461	
	032	−	062	
	033	Rcl 3	462	
	034	=	020	
	035	St 6	445	T_0, initial tension, lbs
	036	7	007	
	037	Print x	026	
2	040	Rcl 1	460	
	041	×	070	
	042	Rcl 4	463	
	043	=	020	
	044	÷	072	
	045	Rcl 6	465	

BR PT	Step	Instruction	CODE MIL	Remarks
	046	=	020	
	047	Print x	026	R, ARC Radius, ft
	050	St 0	457	
	051	8	010	
	052	Print x	026	
	053	Rcl 2	461	
	054	÷	072	
	055	Rcl 4	463	
	056	=	020	
	057	Sin^{-1}	042	
3	060	R → O	046	
	061	Print x	026	α_2, degrees
	062	St 5	444	
	063	9	011	
	064	Print x	026	
	065	Rcl 3	462	
	066	÷	072	
	067	Rcl 4	463	
	070	=	020	
	071	Sin^{-1}	042	
	072	R → O	046	
	073	Print x	026	α_1, degrees
	074	St 4	443	
	075	1	001	
	076	0	000	
	077	Print x	026	
4	100	Rcl 5	464	
	101	−	062	
	102	Rcl 4	463	
	103	=	020	
	104	Print x	026	
	105	Sin	040	
	106	Sin^{-1}	042	
	107	Print x	026	$\alpha_2 - \alpha_1$, degrees
	110	ST 5	444	
	111	1	001	
	112	1	001	
	113	Print x	026	
	114	Rcl 5	464	
	115	×	070	
	116	Rcl 0	477	
	117	=	020	
5	120	Print x	026	S, ARC Length, ft
	121	−	062	
	122	Rcl 1	460	
	123	=	020	
	124	Print x	026	S—Z, ft

BR PT	*Step*	*Instruction*	*CODE MIL*	*Remarks*
	125	ST 2	441	
	126	5	005	
	127	Print x	026	
	130	Halt	401	Enter K, spring constant, lbs/ft
	131	Print x	026	
	132	ST 5	444	
	133	6	006	
	134	Print x	026	
	135	Halt	401	Enter T_0, initial tension, lbs
	136	Print x	026	
	137	ST 6	445	
6	140	1	001	
	141	2	002	
	142	Print x	026	
	143	Rcl 2	461	
	144	×	070	
	145	Rcl 5	464	
	146	=	020	
	147	+	060	
	150	Rcl 6	465	
	151	=	020	
	152	Print x	026	T, calculated tension, lbs
	153	To (0)	740	

NOTE: This program was designed for use on a Dietzgen 7410–PA Programmable Calculator.

APPENDIX 2

Program Title: *Normal Drag on Mooring*

BR PT	*Step*	*Instruction*	*CODE MIL*	*Remarks*
0	000	Reset	024	
	001	1	001	
	002	Print x	026	
	003	Halt	401	Enter V, velocity, ft/sec
	004	Print x	026	
	005	a^x	074	
	006	2	002	
	007	=	020	
	010	ST 1	440	V^2
	011	2	002	
	012	Print x	026	
	013	Halt	401	Enter C_d, drag coefficient
	014	Print x	026	
	015	ST 2	441	
	016			
	017	Halt	401	
1	020	3	003	
	021	PE	026	
	022	Halt	401	Enter d, diameter, ft
	023	Print x	026	
	024	ST 3	442	
	025	4	004	
	026	Print x	026	
	027	Halt	401	Enter ι, length, ft
	030	Print x	026	
	031	ST 4	443	
	032	5	005	
	033	Print x	026	
	034			
	035			
	036			
	037			
2	040	Rcl 1	460	
	041	×	070	
	042	Rcl 2	461	
	043	×	070	
	044	Rcl 3	462	

BR PT	*Step*	*Instruction*	*CODE MIL*	*Remarks*
	045	×	070	
	046	Rcl 4	463	
	047	=	020	
	050	Print x	026	F, drag force, lbs
	051	Halt	401	
	052	SFS ON	523	
	053	SKFS	540	
	054	JMP to 00	600	
	055	JMP to 16	616	
	056			
	057			
3	060			
	061			
	062			
	063			
	064			
	065			
	066			
	067			
	070			
	071			
	072			
	073			
	074			
	075			
	076			
	077			

NOTE: This program was designed for use on a Dietzgen 7410–PA Programmable Calculator.

49460

Oceanographic

Technical Report 72-1

AUTHOR Taut-Line Instrumented Arrays
Used by the Coast Guard Oceano-

TITLE graphic Unit during 1970-1971

U.S. Coast Guard Oceanographic Unit