Columbia University in the City of New York

LAMONT GEOLOGICAL OBSERVATORY

PALISADES, NEW YORK

DIRECT CURRENT MEASUREMENTS, EQUATORIAL ATLANTIC
R/V GERONIMO Cruise 4

Report prepared by: Robert Gerard

Technical Report No. CU-15-64 to the Atomic Energy Commission
Contract AT(30-1)2663

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Between August 30 and September 16, 1964 current measurements were taken by Lamont workers aboard the Research Vessel GERONIMO in the Gulf of Guinea in a cooperative effort with the Bureau of Commercial Fisheries. Two north-south transects were made using deck-lowered current meters and parachute drogues along longitude 4°W and 8°W between 5°N and 2°S. The station locations are shown in Figure 1. Along these two transects thirteen deck-lowered current meter stations were made using anchored reference buoys, and at each anchor buoy two parachute drogue stations (surface and subsurface at about 60 meters) were also made. In addition to the direct current measurements, hydrographic stations were taken by Bureau of Commercial Fisheries workers at approximately thirty-mile intervals on both transects. Table I summarizes the current meter and drogue station information. The following narrative from the scientific log covers the details of this operation.

Cruise Narrative

August 30 - Anchored buoy #1 was put over in 650 fms. of water at 1412. The buoy array consisted of two radar reflectors, a flag, a flashing light, two two-foot cubes of styrofoam, and a twenty-foot aluminum pole with two 25-lb. weights at the bottom of the pole. There was a 100-foot leader of 1/8" galvanized wire; the rest was piano wire except for a thirty-foot leader of 5/16" wire at the bottom of the clunk. An anchor trip hook was used to get rid of the clunk. The wire was fed underneath the trawling A-frame on the ship. All operations went smoothly. We steamed off for about five miles and saw a readable signal on the radar. We then returned to begin an In Situ salinometer station beginning at about 1520. In this operation the salinometer cable was married, by the use of short lengths of aluminum wire, to the

hydrographic wire; and the lowering was made with stops at ten-meter intervals. A Benthos 250-meter maximum depth recorder versus time was employed with this equipment, hung about two meters above the salinity sensor. This recorder, used down to 50 meters at this station, appeared to work accurately and satisfactorily, and we recommend its use with the hydrographic stations to follow. We will consider also using it with the deck-lowered current meter, depending on the kind of angle that we have in the fast-moving current.

August 31 - Surface parachute drogue #1 was launched at 0155. It was a 16-foot parachute with a tire tube float and a bamboo pole having two radar reflectors and a flashing light. There was 50 lbs. of weight at the base of this float. It still seemed to lean quite a bit, suggesting that the parachute be attached a little farther up on the pole rather than at the extreme bottom where it was attached in this array. The chute showed some reluctance to open, and it was necessary to pull the buoy back aboard, using the tag line, in order to make sure that it billowed properly. We did this by moving slowly ahead and putting the parachute out first. This seemed like a reasonable solution and appeared to work very well. We proposed that the buoy be plotted on half-hourly intervals. At 1130 we recovered the anchored buoy #1. This was cut off just below the top swivel and hauled aboard. Prior to this, at approximately 1100, we had hauled aboard the surface drogue #1. During the morning, while the surface drogue was being tracked, we rerigged the winch and davit for handling the current meter. The block on the davit is now some five feet higher, and this will facilitate bringing the equipment aboard. The schedule is to run to the next hydrographic station thirty miles distant to the south and at noontime to take a productivity station for approximately one hour.

Anchored buoy #2 was put over in a depth of 1850 fms. determined by eye on an inoperative Edo echo sounder, where the printing circuit was not working. We allowed roughly a 50 fm. sonic correction on this, and due to errors in interpretation and possibly in our counter wheel, we put out about 2100 fms. of piano wire on this anchor line. The anchor was thrown in at 2022, and the buoy was observed to move toward the anchor at a fairly rapid rate for approximately one-half hour, at which point it ceased its motion and appeared to be anchored firmly. A hydrographic station is in progress. Our plan at this station is to make one or two current meter lowerings to 500 meters to observe the level of maximum velocity in the subsurface, if it appears, and to set a subsurface drogue at this level as well as a surface drogue and follow these during the night; to repeat the meter lowering tomorrow and retrieve the buoy. This appears to be all that is needed for a full current station here.

September 1 - Using the Hydro Products current meter, lowering #1 was made between 1115 and 0115, during which time the ship drifted with a speed of between 1 and 2 knots to the eastward. It was a successful station. At 0135 we steamed back to a position west and south of the buoy to launch two drogues. Surface drogue #2 again utilized a 16-foot diameter parachute, while a 28-foot diameter parachute was used for the deep drogue #3, which was set at a depth of 75 meters, where it was believed to be at a maximum velocity level. At 0435 the ship headed back to the buoys, which were still rather close together, in order to ascertain more perfectly their positions. At 1025 we were beside drogue #3 observing her behavior. The drogue is setting well and is experiencing a surface current which is from the direction of 270°. During the morning the radar had difficulty and was out of operation for a couple of hours between about 0730 and 0900. Furthermore, the plots which

were made between 0400 and 0700 had the ship in the center and the drifters and anchored buoy at various places. This has been changed so that the anchored buoy is plotted in the center of the polar radar plotting sheet. The range of the surface drogue from the anchored buoy as of about 1030 was beginning to reach the limits of the radar pick-up, that is about five or six miles. It would appear that we can follow this for some additional time by occupying a position mid-way between the surface drogue and the anchored target. The anchored buoy and the 75-meter drogue appear to be holding a very close relationship, roughly a mile apart. Lowering #2 of the Hydro Products current meter was made between 1420 and 1520 hours to a maximum depth of 400 meters. At 1610 we are about to come to a position beside the 75-meter drogue #3. We will take the drogue aboard and then proceed to haul in the anchored buoy. At 1645 we picked up drogue #3 and then the anchor array. The system worked fairly well. We broke off the weak link at the parachute and recovered the anchors. However, it was a little slow because we had neglected to put the right size pick-up shackles in the wire. We must also keep the lead from the T-bridle to the anchor a little shorter for ease of hauling in and also for ease of putting over.

September 2 - At 0100 we stopped for Anchor Buoy Station #3, the position being roughly 3°N by 4°W and the depth approximately 2350 fms. We will figure about 2400 fms. for our wire length. At 0407 we launched surface drogue #4. Our intention is to follow this drogue with respect to our anchored buoy until about 1000, this to be followed by a hydrographic station, a deck-lowered current meter station, and then a deeper drogue. The radar problem which developed last night seems to be fixed, but the Decca radar aboard is far below par in its function. It fails to pick up our buoys

beyond three to four miles, and the sea noise is excessive. The echo sounder is readable by eye but somewhat indistinct in its acoustic output; that is to say that the signal is not clean. The print-out does not operate at all, and so we must observe the needle position by eye when estimating depth. This has worked out fairly well so far, but we will always cut about 100 fms. more of line to make up for these reading errors, sound velocity correction (which is plus), and possible errors in our own meter wheel. At 0915, due to the roughness of the sea, it has become necessary to lay beside the buoy and range and take bearings on the anchored buoy. The drift of the surface buoy is rather slow, amounting to only a couple of miles towards the south-east since it was first set. At 1305 we are about to go to a position a couple of miles to the west of our Anchored Buoy #3. We are presently beside the anchored buoy, having been here since about noon for productivity and other biological work. It is, however, questionable as to whether the buoy is securely anchored; it seems wise, therefore, to perform a test, that is to hook up a piece of 6-thread to the tag line and steam off until the line is broken.

At 1538 we launched anchor buoy #3A. The reason for this was that the first anchor buoy was found to be adrift. How long this state of affairs existed is difficult to say, but we must consider the surface drogue with a large degree of suspicion. When the buoy was solidly anchored, a deck-lowered current meter lowering was made to 400 meters, going down with several stops in the neighborhood of 50 meters, where it appeared that a current occurred of a distinctly different nature than at the surface. Thereafter, at 1935 surface drogue #5 was set, in order to check again on the surface current, which was lost due to the drifting anchor buoy when the first surface drogue

station was made earlier at this position. Following this, at 2020 a 50-meter drogue #6 was launched with 50 meters of wire. The plot will continue for approximately six hours at half-hourly fixes on both of these targets with respect to the anchor buoy #3A.

September 3 - At 0230 we picked up the 50-meter drogue #6. Curiously, in the last two observations, both after mid-night, there appeared to be a turning, almost a reversal of course of this buoy, and this in the face of a straight-forward movement of the surface drogue, or so it would appear. We'll have to check this with a final position as we pick it up within the next half-hour. Going back to observations on the 50-meter drogue #6, as we were approaching it to haul it up, it was observed that it was definitely hauled down, indicating that the parachute was indeed functioning at its proper depth. It had 200 lbs. of iron weights at the bottom of the 50-meter line, and the float was hauled down hard due to the stress of the chute in addition to the anchor weights. At 0415 we picked up anchor buoy #3A and then steamed southward towards the next station location.

At 1542 we cast anchor on Anchored buoy #4. The sonic depth was 2650 fms., and we put 16,800 feet of piano wire on the anchor line. At 2020 we put over surface drogue #7 and at 2118 deep drogue #8 at a depth of 35 meters. At 2300 the two drogues were observed to be moving slightly west of south at a slow rate; and since this is an area of fairly low velocities, both surface and subsurface, it was thought best to leave these in as long as possible to clarify some of the surface records. We'll probably try to follow these for at least twelve hours. In the meantime we will attempt to make up the rest of the splices and set up for the surface current meter to be attached to the float.

September 4 - We chased drogues all during the night and found both the surface and 35-meter drogue to be moving in a westerly direction, although the wind throughout had been from the south quarter. At 1130 we were hove-to beside the anchored buoy, and at this point we threw a couple of rags dipped in fluorescein solution into the water. These dye patches were observed to drift in the direction approximately the same as the buoyant pick-up line, which was streaming from the buoy on the surface. The wind was 210° true, and both the pick-up line and the dye pointed in the direction about 80° to the left of 210°, or about 290°. At 1215 we threw in three cans of fluorescein dye in pellet form. This was not completely dissolved, but was dissolved to the extent that three cans of pellets would dissolve in one bucket of water. The entire bucket was thrown in at the place where our surface drogue was located. The ship drifted by this point without disturbing or causing the dye to spread in any other but a natural manner. The ship then drifted down and proceeded to engage in a productivity station. The deep drogue #8 was retrieved at 1405. At 1430 we picked up the surface drogue #7, which was at the forward end of the elongated dye patch. The elongation was spread out along 230° true. The wind at the time had been from 210° true, and therefore it represented about 20° to the right of the wind. This proved a good test for the reliability of the surface parachute drogue as a surface current indicator. At 1435 we took the anchored buoy #4 aboard and got under way for the next station.

September 5 - At 0450 a surface drogue #9 was launched at Anchor Buoy Station #5. This was identical to our standard surface drogue set-up except that it had a ball-float instead of the tire tube. It may be that this makes the rig a little less stable; at least that's one possibility, because it

pivots on the spherical float. The lower of the two reflectors seems to have slipped down or broken off, and this drogue was very difficult to follow on the radar during this time. At 0830 a 60-meter drogue #10 was put down. At 1450 we picked up surface drogue #9, which had drifted at a rate of about one knot to the west. During most of this time the 60-meter drogue #10 hardly moved at all, and we continued to observe it. At about 1500 we attempted to put a surface current meter onto the tag line of the anchored buoy. This effort was aborted by the fact that the ship got the wind on the wrong side and went over the wire that we were paying out, catching it up under the steering mechanism so that we had to haul back the wire and cut it. We then proceeded to pick up the current meter array, which consisted of a line of plastic hydrophone floats, approximately twenty in number, on a Manila rope hooked to the top of the meter cage. Below the meter cage on about 100 feet of line was a damper plate. Also leading up from the meter was the electric cable, which was buoyed at 25-foot intervals with fisherman floats. There was approximately 600 feet of this, and we cut off approximately one-third of the total length in our efforts to recover the equipment. So much drag was created by this long 600-foot electric lead that it is probably well that we spliced back at the point where we cut off. One modification we must make is to put the tag line from the anchored buoy at the bottom of the stack of flotation cubes rather than at the top. It would thereby cause the buoy to lean less from the vertical. Difficulty was experienced today in seeing a signal from the surface drifter. In the future we will use 20-foot aluminum poles instead of the bamboo poles presently being used and heavier weights to give the buoy more stability in the vertical. At 1815 we began another deck-lowered current meter station, lowering #2 at Anchor Buoy Station #5, which

was completed by 1845. At 2000 we picked up the 60-meter drogue #10, and at 2040 picked up the anchored buoy. We then got under way for the next station, six hours running time distant.

September 6 - At 0948 we launched the anchor end of anchor buoy #6. The buoy was observed to move rapidly toward the anchor until 0920 when it stopped and apparently held. We observed it from a hove-to position at this location. The wind at the time was from the direction 140°. The current was from the direction 100° true, as observed on the tag line of the anchored buoy.

September 7 - At 1415 we made a deck-lowered current meter lowering without an anchored station. This was done in order to observe the relationship between the upper velocities and the velocity at 50 meters or thereabouts, to compare with the previous station. At this station it would appear that conditions were much the same as at Anchor Buoy Station #6. This was again done thirty miles farther south at 1830. A lowering down to 100 meters was made without the benefit of a surface buoy. At this point it showed a marked diminishing of the velocity at the 50-meter level, indicating that we were indeed moving out of the undercurrent system. We proceeded then to continue on another thirty miles to 1°30'S for our Anchor Buoy Station #7. This position was reached late in the evening.

September 8 - At 0122 anchor buoy #7 was put over in 2750 fms. The regular reel of 16,800 feet of piano wire was utilized, together with an extra 1200 feet of 1/8" steel wire rope at the top end. The ship then ran back to the buoy position to observe the buoy during the anchoring process and to watch it until it had fetched up on its anchor line at 0150 and hold position in the face of a current coming from the direction 140°. This current was not strenuous, but rather modest. One would guess it was less than

one knot. The wind at this time was from the direction 170°. After observing the buoy for a few minutes, we took a course 140° in preparation for going to our deck-lowered current meter station. Lowering #1 was made at 0215 down to a depth of 500 meters. A 50-meter drogue #13 was then set at 0407. Shortly after this, a surface drogue #14 was placed at 0420. These drogues were followed during the night and the forenoon. The surface drogue #14 was retrieved at 1330. At 1430 we were on position for meter lowering #2 of Anchor Buoy Station #7. At 1840 the anchor buoy was brought aboard. Following this, we directed our course south with the intention of hydro station stops at 2° and 2°30'S, followed by a turn to the west until reaching the other line of stations where we would turn north. Our plan on the northward leg is to feel our way with the deck-lowered current meter at several hydrographic station stops without the use of a surface anchored buoy in order to obtain an idea of the ratio of velocities from the top downwards, so that we may have some rough idea of the undercurrent or the edge of the undercurrent.

September 11 - At 0815 anchor buoy #8 was launched. We then moved up beside the buoy while it was moving towards the anchor point and observed it to fetch up on its wire at 0841. The depth at this location was 2650 fms., and we used one 16,800-foot reel of piano wire plus a 100-foot leader of 1/8" wire. This is the first station on our northward leg at 08°W. During the night while moving northward, we made quick lowerings of the current meter without the benefit of an anchored target. We feel that at this anchor buoy #8 position we have our first real chance to get the edge of the undercurrent. Lowering of a current meter at this station was made beginning at 1105 and ending at approximately 1200. The depth centered at about fifty

meters indicated the undercurrent in recognizable velocity. At approximately 1600 we put out surface drogue #16 and a 50-meter drogue #15, the position being approximately two miles south of the anchored buoy #8. At 1800 we made lowering #2 of the current meter until 1855. At 1245 we picked up the 50-meter drogue #15, and at this occasion we observed that the drogue float, which was a 2x2 foot styrofoam cube was hauled down to about 80% of its volume, indicating a strenuous down-force due to the very strong current. One would assume that in currents any greater than one knot in this configuration it would be wise to have an additional buoyancy to take up for this marginal condition. In hauling on the pick-up tag line, the buoy and a portion of the mast were actually hauled under water, in fact almost to the top of the 20-foot pole, before the 6-thread, the weak link at the parachute, parted. At 0100 we made course rapidly to pick up the surface drogue, after which we will pick up the anchored buoy and make our way to the next station. Insofar as this station was at approximately 0°45'S, we will space our stations hereafter so that the next one will be exactly one degree north of here at 0°15'N.

September 12 - At 0210 we picked up the surface drogue #16, after which we headed for the anchor buoy. On this surface buoy and on several in the past we have used the Norwegian plastic inflated ball float. The first of these developed a hole in the plastic due presumably to hard handling in bringing it aboard. The present ball float looks to be in good shape and is suitable with a 16-foot parachute on a 20-foot pole and using 50 lbs. of ballasting weight. At 1205 the anchor was cast for anchor buoy #9, and about one-half hour later it was observed to haul up on its anchor line. Following this a hydrographic station and a productivity station were taken, after

which we moved on position for current meter lowering #1 at this anchor buoy station. At 2000 a 50-meter drogue #17 was put down and followed until 0500 on September 13, at which time it was recovered. During this time the subsurface drogue was observed to move in a direction slightly southeast at a rate approaching one knot. Again the buoy was hauled down very nearly to the limit of its buoyancy. Any stronger currents than this would certainly require an additional bit of buoyancy for the float.

September 13 - At 1214 we put over surface drogue #18, which we followed while Clark-Bumpus biological sampling was in process. At 1815 lowering #2 at Anchor Buoy Station #9 was begun, ending at 1849. This station carried to only 100 meters at ten-meter intervals. At 1935 we took aboard anchor buoy #9 and then departed for the next station to the north.

September 14 - At 0300 we cast the anchor for Anchor Buoy Station #10. The depth is 2700 fms., and we put out one full spool of piano wire, amounting to 16,800 feet. It is calculated that this will be very close to ocean depth, considering plus for sound velocity correction. The buoy was observed to stabilize on its anchor line at 0504. At 0543 surface drogue #19 was put over, and at 0615 current meter lowering #1 at this anchored station was made until 0650. Following this, at about 0700 deep drogue #20 was put over. The depth of the line was 50 meters. During the morning the drogues were plotted on the radar sheet, but extreme difficulty was encountered in following the anchor buoy. Therefore, the ship had to lay beside this buoy in order to observe the positions of the other radar reflectors. At 1330 we picked up surface drogue #19, and at 1345 we picked up the 50-meter drogue float #20, leaving the 50 meters of wire and the two 100-lb. weights behind. At 1405 the anchor buoy was retrieved, and we then steamed toward our next station

to the north. At 2256 we cast the anchor at Anchor Buoy Station #11 with 75 lbs. of weight at the bottom of the 20-foot pole. We are running very low on small items of hardware such as shackles and nicopress fittings, but we can get around by making some splices and coupling thimbles together without the benefit of a shackle in between. However, with only a couple of stations remaining, we have no real problem in this respect. At 2330 we were beside the anchor buoy as it fetched up and was observed to attain a stable attitude. The tag line showed that the current was from the direction 180°.

September 15 - We then steamed south a couple of miles in order to place surface drogue #21 at 0013. Following the placement we went north to attain a suitable radar range and made current meter lowering #1 of Anchor Buoy Station #11. This was followed by a 50-foot drogue #22.

At 1935 the anchor for Anchor Buoy Station #12 was put over and observed to fetch up at 2005. Alongside the buoy we observed that the pick-up line was leading towards 45°. At this time the wind was approximately from 180°, 10 to 12 knots. We made for a position about three miles to the southwest where we put over surface drogue #23. The lowering of the deck-lowered current meter was made between 2119 and 2202 down to 500 meters. During this lowering, a maximum appeared to exist between 50 and 70 meters, and we therefore decided to cut our drogue line for a 60-meter depth. This drogue #24 was put over with a 0-250 meter Benthos depth recorder attached. Both drogues were followed during the night.

September 16 - Surface drogue #23 was picked up at about 0700 and the 60-meter drogue at 0745. The latter pick-up involved a flail with the parachute, which got caught up in the screw. No damage was done to the ship, however, and the debris was cut loose. The Benthos depth record was quite

perfect, showing that the entire excursion was made at a depth of 62 meters. Following this we headed for our last station, probably to be located in fairly shallow water. At 1750 we put over the anchor for Anchor Buoy Station #13. The depth was 850 fms., and 900 fms. of wire was used. Following the placement we returned to the buoy to observe the fetching up on the anchor line. At 1821 we put out surface drogue #25 approximately two miles northwest of the anchored buoy and then moved off to take a hydrographic station. 60-meter drogue #26 was put over a few miles from the surface drogue at 1938. We then made a current meter lowering starting at 2045 and ending at 2130. The current meter came back to the surface with a transparent, rather rubbery sea creature in the direction-vane cage. We trust it got into the cage as it was coming up to the surface. It would seem that it was in a position which would not interfere with the vane position, even if it had been there all during the observations, in that the vane must necessarily line up with the orienting vane on the back end of the meter. As this is the case, anything on the side stand-off rods of that cage would not interfere with the operation. We then proceeded to pick up surface drogue #25 at 2245. At 2305 we had taken aboard the anchored buoy and were picking up the last of the 60-meter drogue #26.

September 19 - We arrived at the anchorage at Freetown about midnight on the 18th, and this morning we received mail and word from the agent that travel arrangements had been made as requested by our earlier wire.

Deck-lowered Current Meter Measurements

In order to obtain correct current measurement readings from a drifting ship, the movement of the ship must be known so that it may be combined

vectorially with the velocity and direction measurement obtained by the current meter. In the open ocean no shore-based navigation aids are available for this purpose, and for short-time measurements the accuracies of celestial navigation and dead-reckoning are not adequate to the task. Where such navigation is required, it has become standard to place an anchored buoy radar target in the area and take frequent range and bearing readings from the ship using marine radar. Fixed radar targets are also required in order to measure the movement of the parachute drogue floats.

In the Gulf of Guinea area thirteen positions were selected for making current measurements and drogue stations. This required that sufficient anchoring equipment be provided for thirteen stations in depths averaging more than 2500 fms. The anchor line material selected for these buoys was .069" diameter H/Carbon ITS wire with a breaking strength of 920/1000 lbs. obtained from Universal Wire Products Inc., North Haven, Connecticut. Reels of 16,800-foot quantity were selected as a convenient length, considering the depths in the Guinea Basin. Buoys were selected for use on these deep-anchored targets with buoyancy commensurate with the wire weight and current velocities expected. A conservative calculation for the drag on an 18,000-foot anchor line of this .069" diameter wire (based on an estimate of 2-knot current velocity in the top 1000 feet and a 0.5-knot velocity in the bottom 17,000 feet) gave a figure of 200 lbs.

Considering these forces and the weight of wire per station (approximately 200 lbs. in water), a surface buoy with buoyancy about equal to the breaking strength of the wire was selected. This consisted of two 8 cu. ft. cubes of styrofoam, which were designed to fit around a 2" diameter spar. The 20-foot aluminum spar was fitted at its base with 50 lbs. of ballast,

and at the top provided with two radar reflectors and a flashing light.

The placement of the buoy anchor array was done in the conventional manner with the buoy first, paying out wire until an amount equal to the ocean depth plus a small additional length for uncertainties of depth was achieved. At this point attachment was made to a one-foot cube of cast iron weighing approximately 450 lbs. The anchor weight was then dropped through the use of an anchor trip hook, and the buoy would move rapidly at the surface towards the anchor-drop position. Experience showed that with this array the anchor weights would fall at approximately 100 fms. per minute, and the bottom contact of the anchor could be observed by watching the behavior of the buoy, which would cease its horizontal movement through the water and show an apparent release of weight upon contact of the anchor.

In order to handle the brittle, high-carbon wire, several techniques were employed. A spooling machine was built with a brake so that wire tension could be maintained at all times during the pay-out of wire, as the ship steamed slowly away from the surface buoy. This device is shown in Figure 2. One of the problems in handling small diameter wire of this sort is the difficulty in providing a terminal fitting and in gripping the wire under tension while such a fitting is applied. These problems were solved by fabricating a clamp as part of a vise-grip tool and securing this to a fixed point in line with the direction of wire pull. This clamp was placed on the wire and the tension slowly taken off the pay-out spool and allowed to come on the vise-grip clamp. The inboard end of the wire was then cut and a terminal fitting applied. Figure 3 (top portion) illustrates this clamp device. The terminal fitting which was developed for this wire is shown in Figure 3 (bottom portion) and incorporates the use of 1/16" wire

size nicropress fittings, using four in number with a tight twist of wire between the upper and lower two fittings. This combination, together with a galvanized steel thimble, which was flattened on an anvil tightly around the wire, served to develop the full breaking strength of the wire under numerous tests. It was found that this terminal fitting could be quickly applied when necessary during the launching operation.

The deck-lowered current meter which was used is that manufactured by Hydro Products Corp., comprising their Model #460 Savonius rotor speed sensor combined with their Model 465A direction sensor. As these sensors are delicate and easily damaged at the ship's side, they were placed in a non-magnetic bridle and cage assembly fitted with a stabilizing fin to reduce the tendency to rotate at the end of the wire. Figure 4 illustrates the current meter in this suspension set-up, showing the shock-mount units, which are sections of large-diameter rubber hose. Connection was made through a 4-conductor underwater connector to a 3-conductor oceanographic telemetering cable, using the armor shield for the fourth member. The current meter signals were taken out through another 4-conductor plug at the hub of the winch on the ship's deck and carried by cable to a 2-channel Sanborn recorder and power supply in the laboratory. This current meter is intended for a 5-wire connecting cable, but the wiring was modified for use with a cable having three copper conductors and a double-armor steel tension member. The circuit diagram for this hook-up is shown in Figure 11. One other modification made to the Savonius rotor was to reduce the number of magnetic slugs from ten (as normally supplied with Model #460) to two. This permits counting individual rotor pulses on the recorder.

Figure 5 is a chart record showing rotations of the Savonius rotor on

the right channel and the amplitude signal from the direction sensor on the left channel. The left channel has been adjusted so that full scale equals 360°. The right channel is counted as two closures per revolution of the rotor against the chart speed of five centimeters per second. Marks on the far left margin of the record are one-second time marks from a precision timer. The number of revolutions per second is compared to a calibration curve made at Lamont Observatory through tow tank tests of this type of Savonius rotor sensor, as shown in Figure 6. (See our Technical Report No. CU-11-64.)

In order that the current meter might be lowered in the ocean without developing a large wire angle on the winch wire, 500 lbs. of lead was used, suspended beneath the meter to minimize the wire angle in spite of the strong currents in this area. Figure 7 shows a typical launching of the electric current meter. The two lead-disc weights can be seen suspended below the meter cage, and the wire terminal and electrical connector are visible above the meter. A meter wheel can be seen in the upper part of the photograph, by which the depth of the instrument was read. Among the numerous lowerings made on this cruise, the wire angle at the surface was never more than fifteen degrees from vertical, corresponding to a maximum depth correction of $3\frac{1}{2}\%$.

The typical station made with the deck-lowered electric current meter consisted of stops from the surface down to 100 meters at ten-meter intervals, below which somewhat wider spacing was made down to approximately 500 meters in most cases. Recordings were made for about two minutes at each stop in such a profile.

Parachute Drogue Measurements

Table I lists the twenty-six surface and subsurface parachute drogue measurements that were made during this cruise. Figure 8 illustrates the surface parachute drogue assembly. The only modification of previous surface parachute drogue assemblies is that of the pick-up line, which facilitates bringing aboard the equipment without damage at the ship's side. Dye experiments were made which indicate that the surface drogue and buoy faithfully reflect the surface water movement. Fluorescein dye was placed around the surface buoy and 2½ hours later, when the buoy was picked up, it remained in the center of the fluorescein dye patch, which had elongated and diffused considerably during this period but was still observable. Figure 9 shows the fluorescein dye patch near the drogue float as initially introduced.

Subsurface drogue parachute measurements were made at each anchor buoy station shown in Figure 1. The subsurface parachute drogue assembly employed in these measurements is illustrated in Figure 10. The wire used to connect the parachute to the surface float was 1/8" diameter galvanized steel wire rope. Surface floats were two-foot cubes of styrofoam (Danco Corp.) with a positive buoyancy of approximately 450 lbs. The parachutes were surplus personnel parachutes classified as 28-foot diameter. The assembly was similar in most respects to that described by Volkmann, Knauss and Vine (1956), except for the use of ball-bearing swivels at the terminations of the wire rope and a "weak link" lanyard connection between the lower portion of the wire rope and the parachute. In all cases 200 lbs. of cast-iron ballast was used at the lower end of the assembly and a T-bridle was used to connect the various components near the lower end and to facilitate placing this

portion of the assembly in the water without entanglement. The system for launching was the standard procedure of buoy first, paying out the wire, which was cut exactly to the depth where the measurement was required, at which point attachment was made to the T-bridle and parachute and weight portions of the assembly. The parachute was placed in the water as the final part of the assembly in an open condition and allowed to settle fully open.

Pressure-versus-time depth recorders were employed in several of these experiments in order to establish the descent rate of such an assembly with the parachute open and to monitor the depth of the parachute during the period of observation. At the end of the measurement the assembly was recovered with the exception of the parachute itself, and the depth record was examined to study the time-depth relationship. Disengagement of the parachute was accomplished by hauling in on the wire rope and thereby breaking loose the parachute by means of the "weak link" lanyard, consisting of $\frac{1}{4}$" Manila rope by which the parachute was attached to the underwater assembly. After the parachute was disengaged, hauling on the wire rope was an easy matter over a capstan or a small winch.

Depth-time records revealed that the parachute settles in the open position at a rate of ten meters per minute. Its ultimate depth corresponds to the length of wire to the surface buoy and remains constant within the limits of error of the recorder (± 5 meters for 250-meter depth recorder) for the entire measurement period.

TABLES AND FIGURES

Tables

Figures

TABLE I - Station Summary Sheet - R/V GERONIMO Cruise 4

Date	Current Meter Station	Position		Anchor Buoy	No. of Lowerings	Maximum Depth of Lowering (meters)	Surface Drogue	Hours Obs.	Depth Subsurf. Drogue (meters)	Hours Obs.
		Lat.	Long.							
August 30	x	5°00'N	4°00'W	#1	1	945				
August 31		"	"	#1			#1	7.5	none	
Aug. 31-Sept. 1	x	4°00'N	4°00'W	#2	2	400	#2	2.5	#3 -75	11
September 2	x	3°02'N	4°00'W	#3A	1	400	#4	4.5	none	
September 2-3		"	"	#3A			#5	8	#6 -50	6
September 3-4	x	2°00'N	4°04.5'W	#4	1	450	#7	18	#8 -35	16
September 5	x	1°02'N	3°57.5'W	#5	2	400	#9	10	#10 -60	12
September 6	x	0°01'S	4°04'W	#6	2	700	#11	4.5		
September 6-7		"	"	#6					#12 -50	14
September 7	x	0°34'S	4°14'W	none	1	100	none		none	
September 7	x	1°00'S	4°05'W	none	1	125	none		none	
September 8	x	1°35'S	4°03'W	#7	2	600	#14	9	#13 -50	13
September 10	x	2°20'S	8°00'W	none	1	100	none		none	
September 10	x	1°30'S	8°00'W	none	1	200	none		none	
September 11	x	1°00'S	8°00'W	none	1	200	none		none	
September 11	x	0°45'S	7°59'W	none	1	300	none		none	
September 11	x	0°45'S	7°54'W	#8	2	600				
September 11-12		"	"	#8			#16	10	#15 -50	9
September 12	x	0°09'N	7°57'W	#9	1	600				
September 12-13	x	"	"	#9	1	100	#18	5.5	#17 -50	9
September 14	x	1°09'N	8°03'W	#10	1	500	#19	7	#20 -50	7
September 15	x	2°00'N	8°00'W	#11	1	500	#21	7	#22 -50	7
September 15-16	x	3°09.5'N	7°56.8'W	#12	1	500	#23	10.5	#24 -60	8
September 16	x	4°00'N	7°58.8'W	#13	1	400	#25	4	#26 -60	4

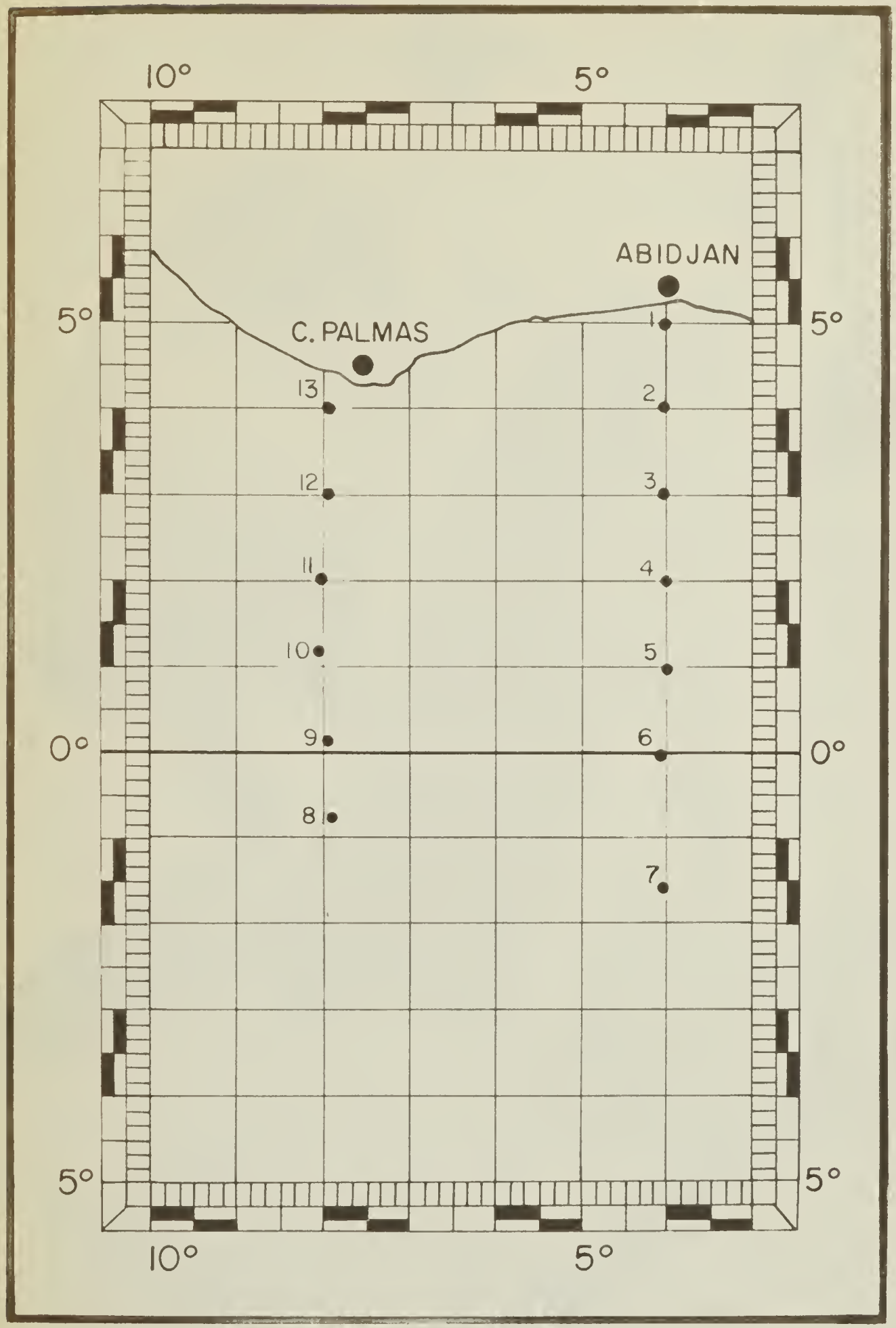


FIGURE 1

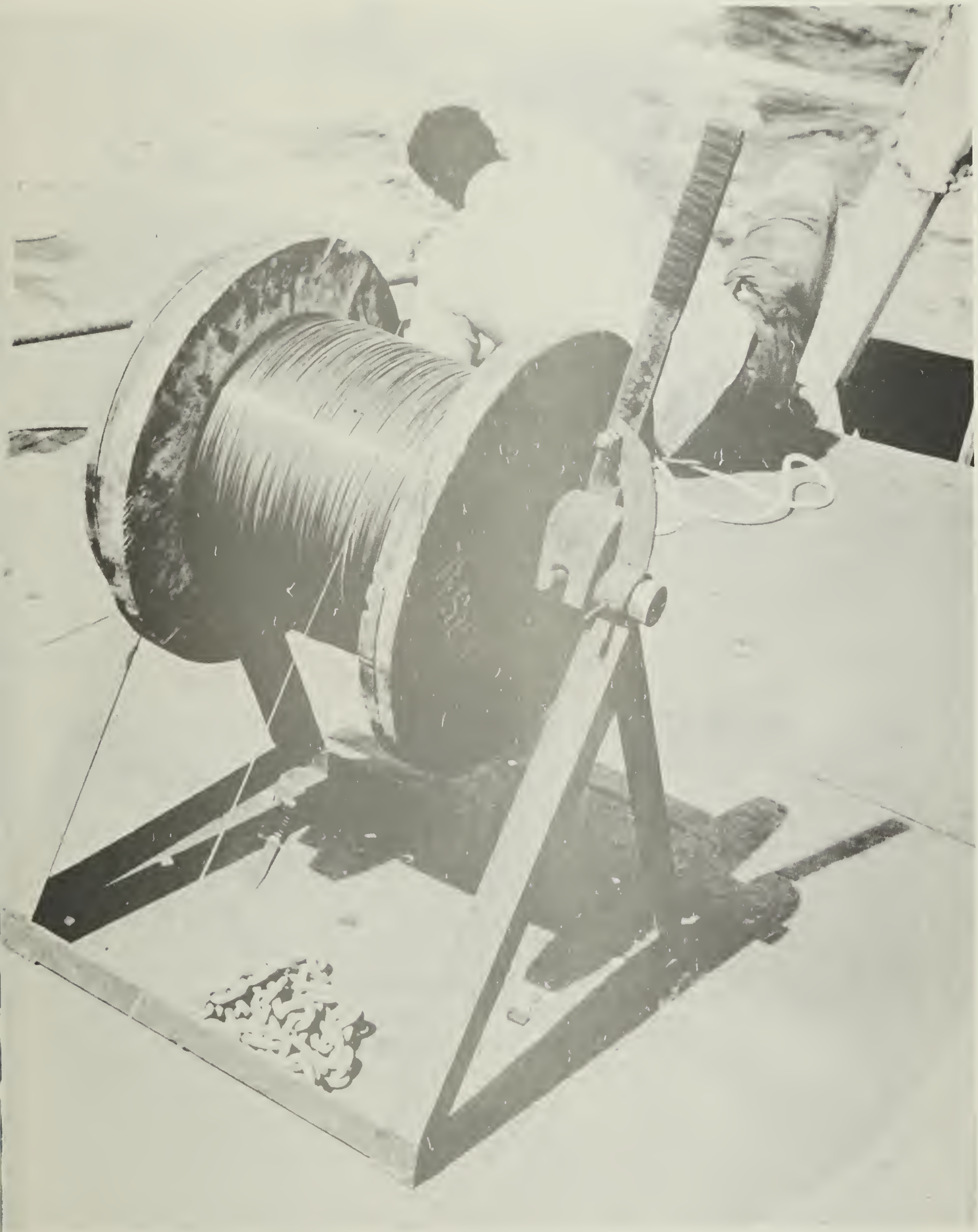


FIGURE 2

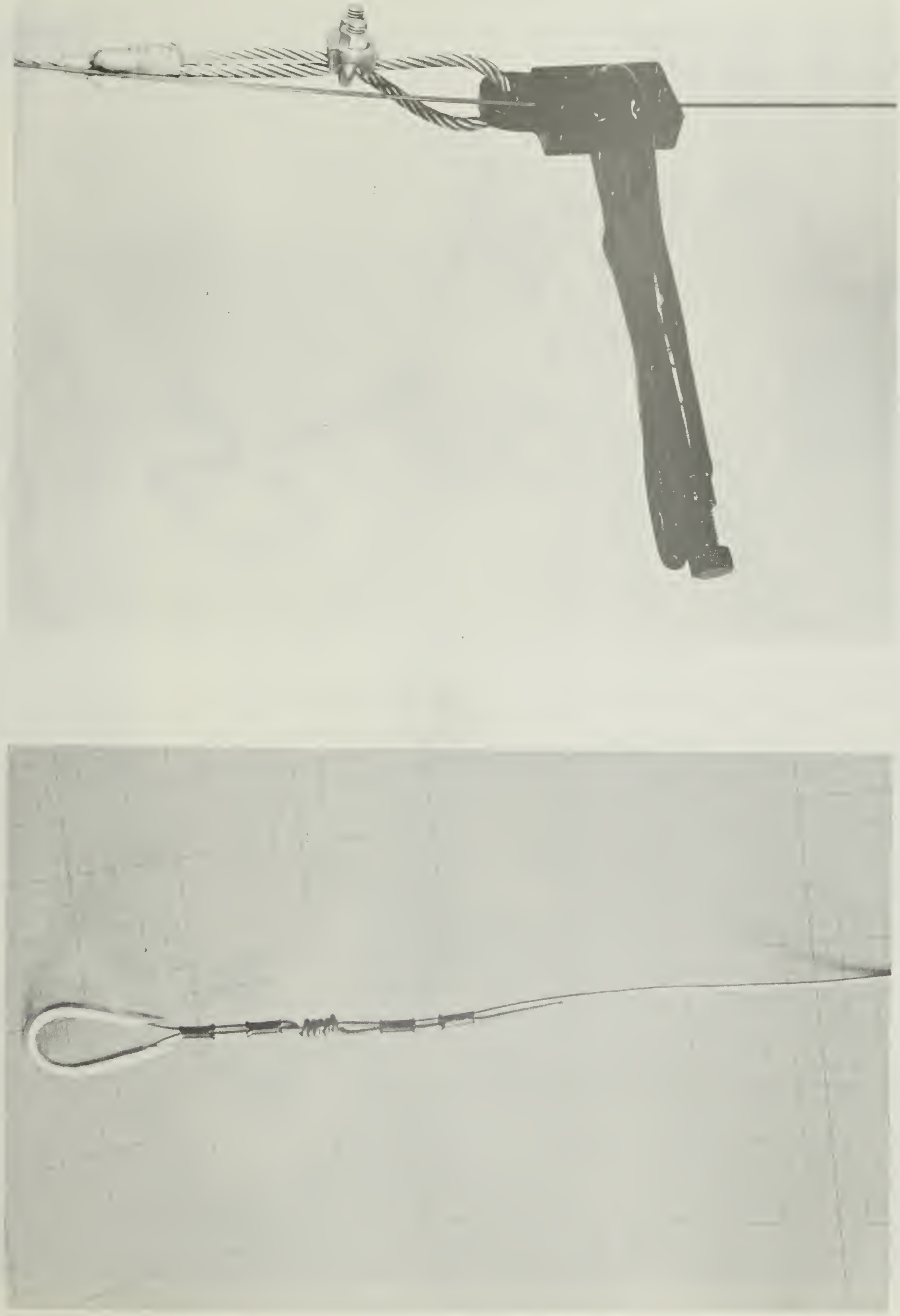


FIGURE 3

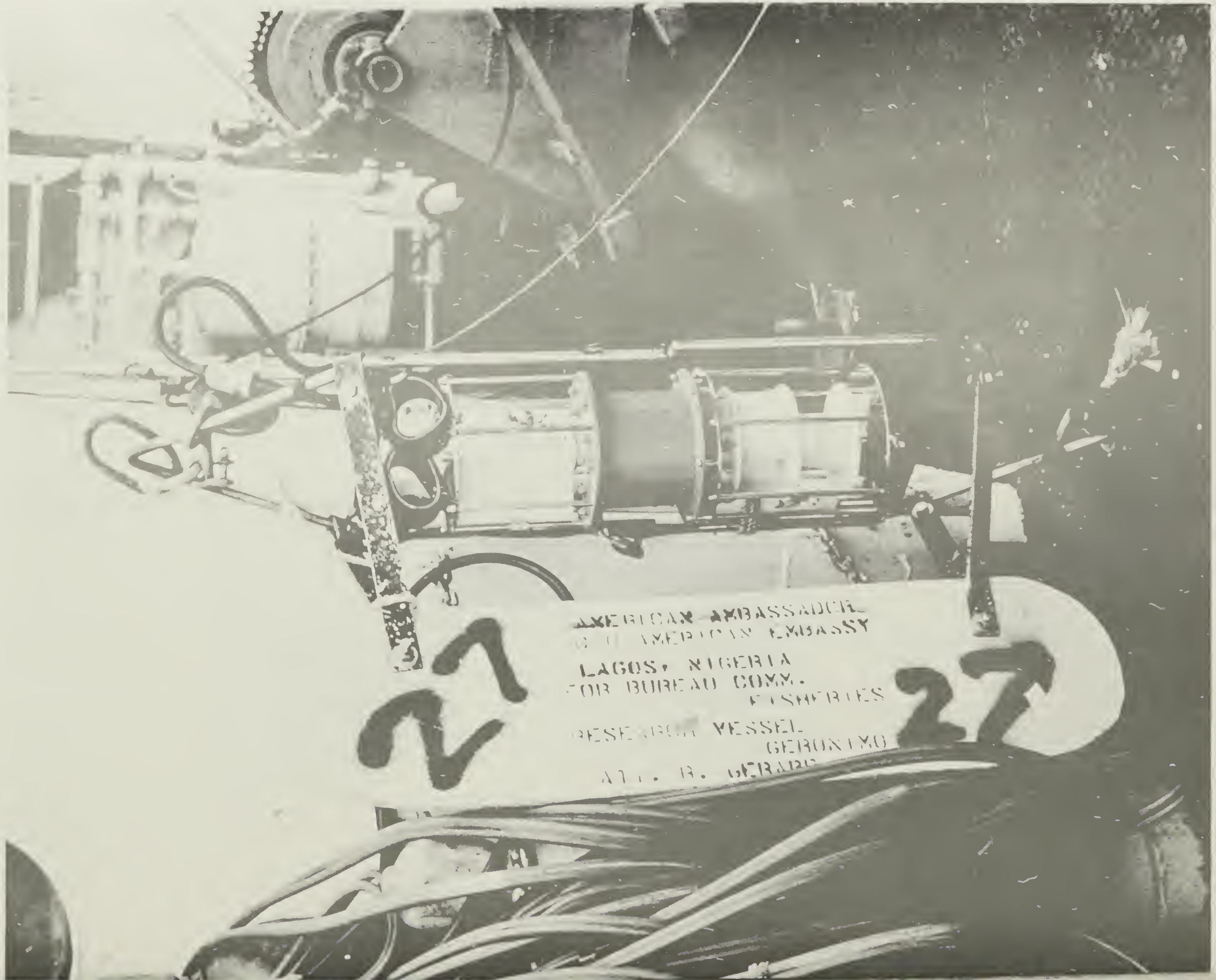
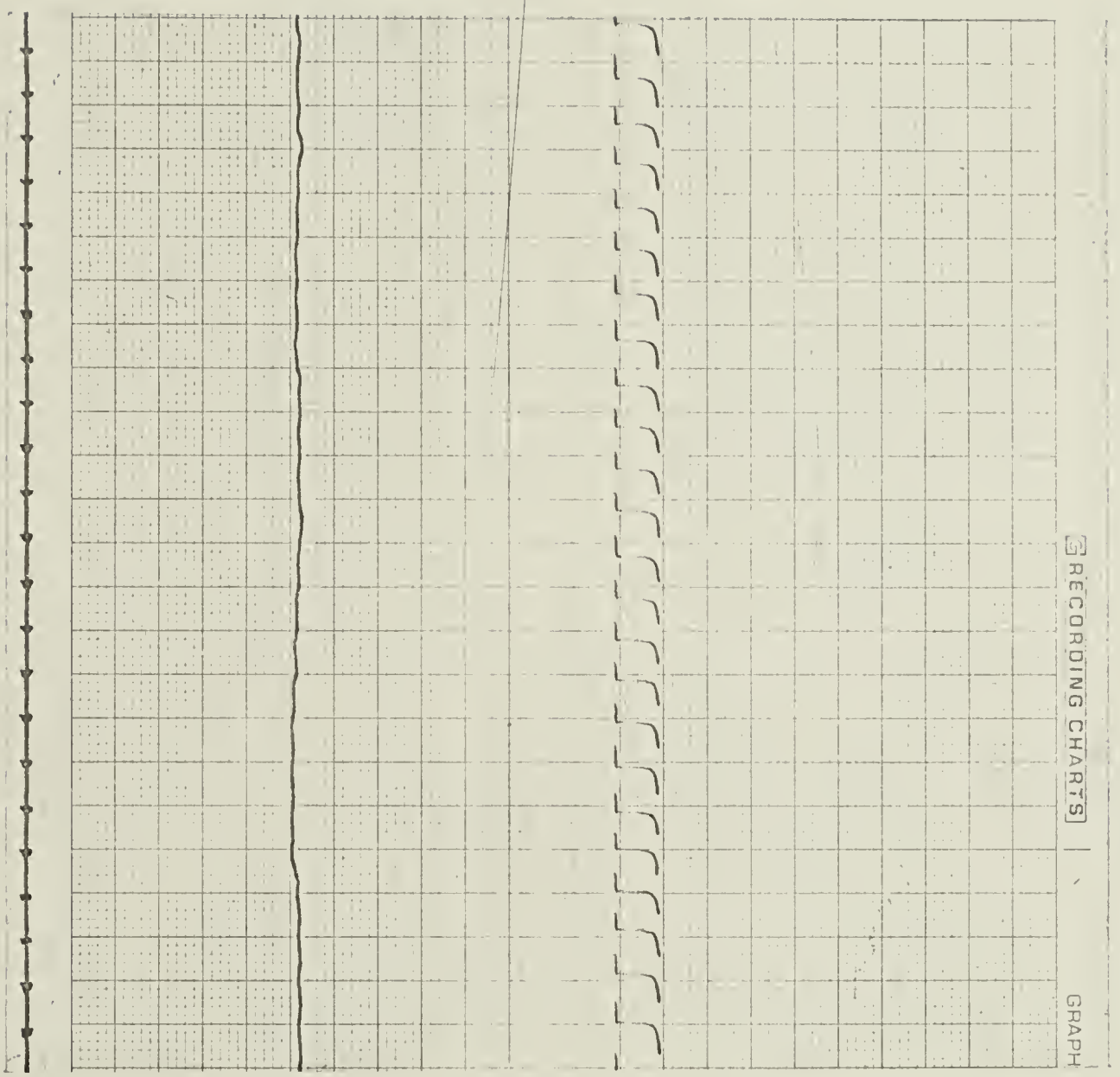

AMERICAN AMBASSADOR
C/O AMERICAN EMBASSY
LAGOS, NIGERIA
FOR BUREAU COMM.
FISHERIES
RESEARCH VESSEL
GERONIMO
ATT: R. GERARD
27
27

FIGURE 4



2-Channel Sanborn Chart Record

FIGURE 5

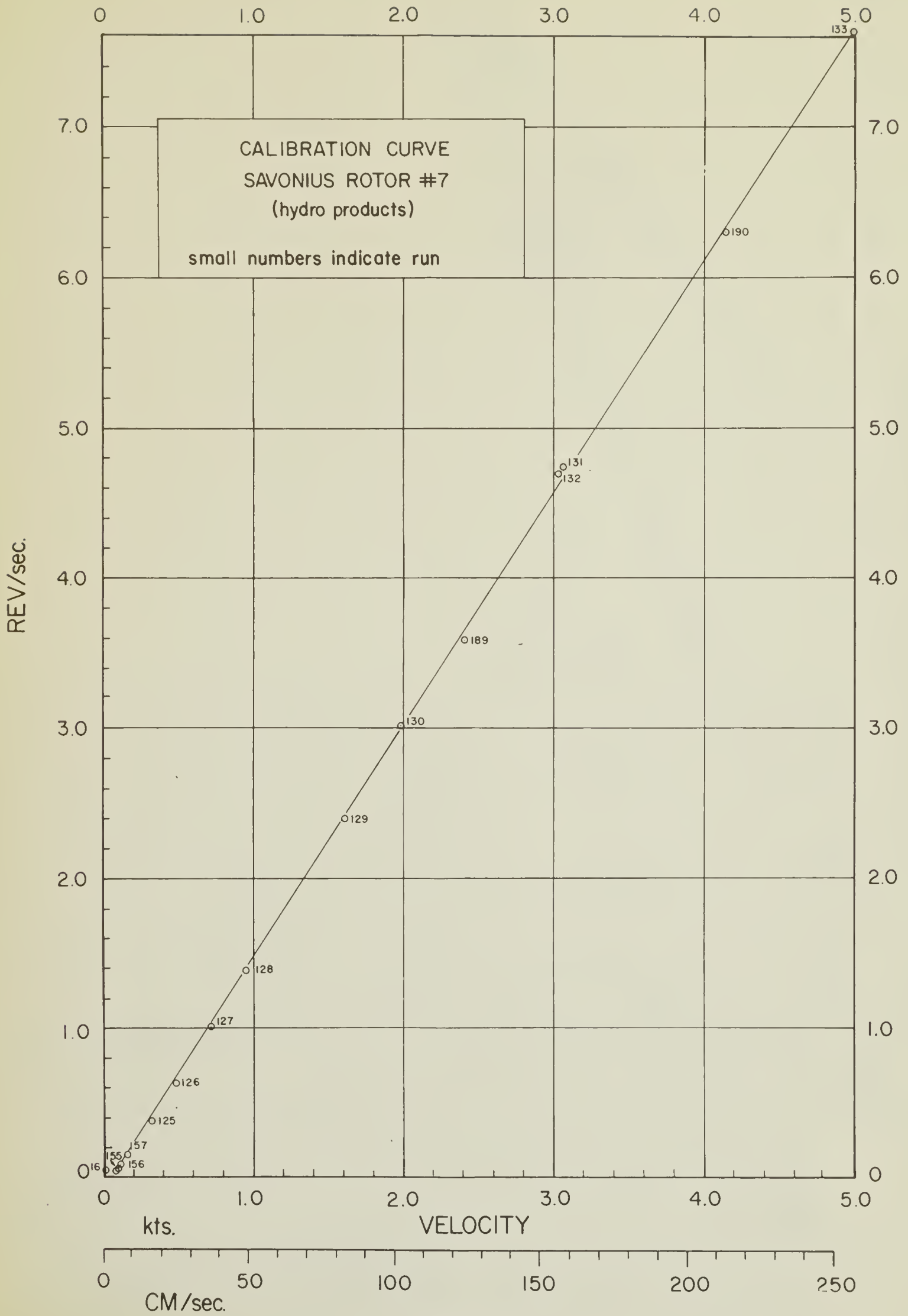
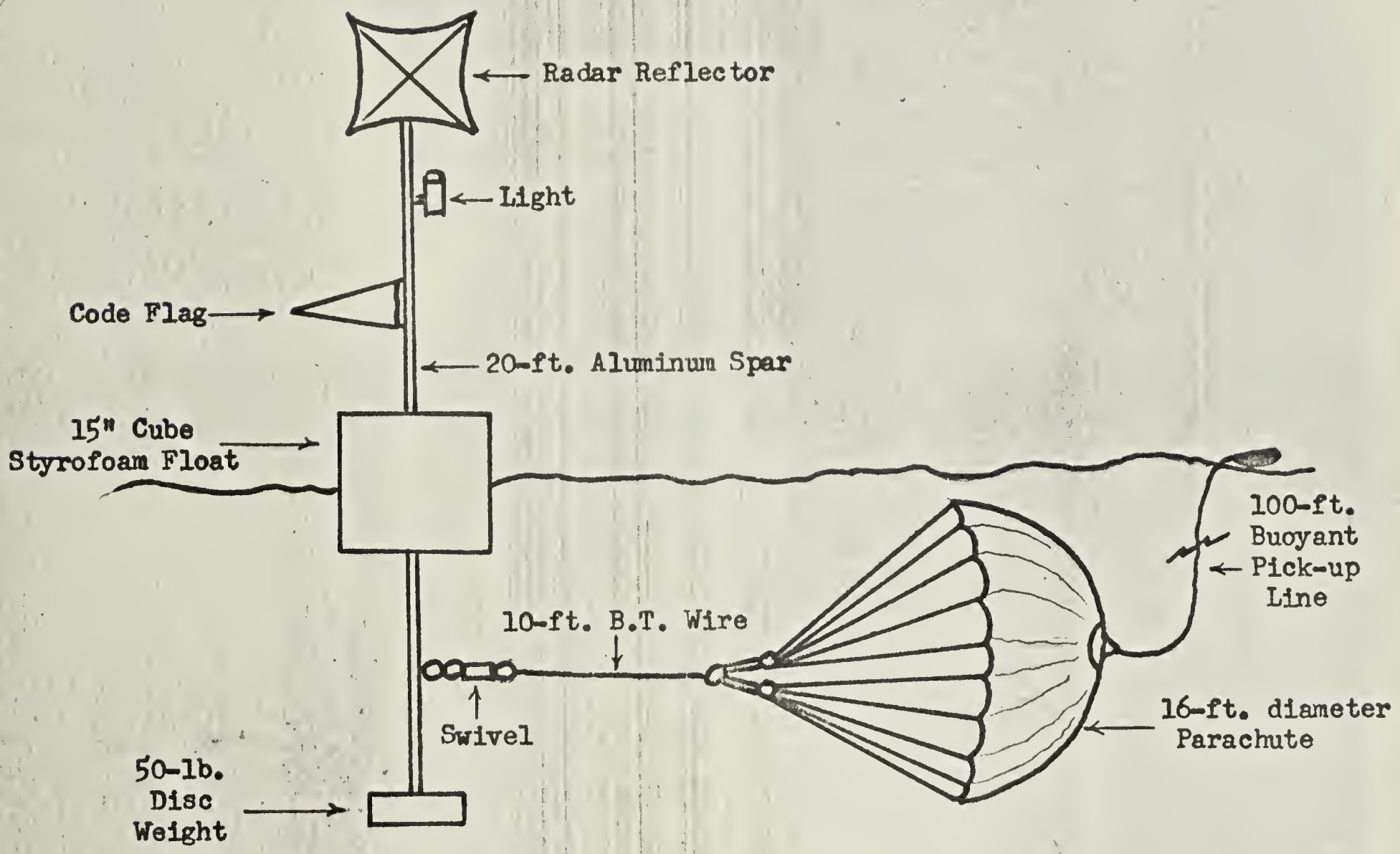

CALIBRATION CURVE
SAVONIUS ROTOR #7
(hydro products)
small numbers indicate run
REV/sec.
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
133
190
131
132
189
130
129
128
127
126
125
157
155
156
16
kts.
VELOCITY
0
50
100
150
200
250
CM/sec.

FIGURE 6

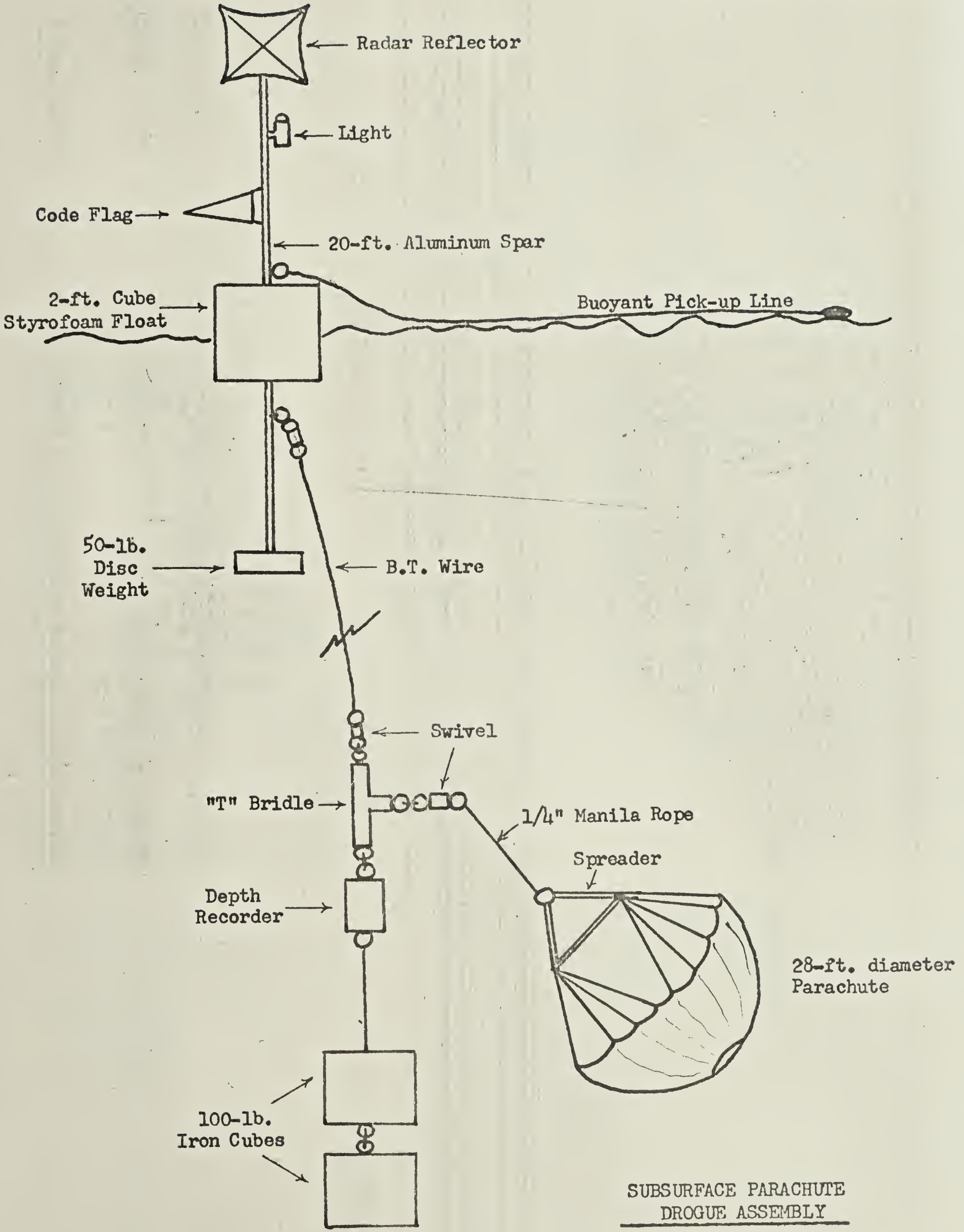
FIGURE 7



SURFACE PARACHUTE DROGUE ASSEMBLY

FIGURE 8

FIGURE 9



SUBSURFACE PARACHUTE
DROGUE ASSEMBLY

FIGURE 10

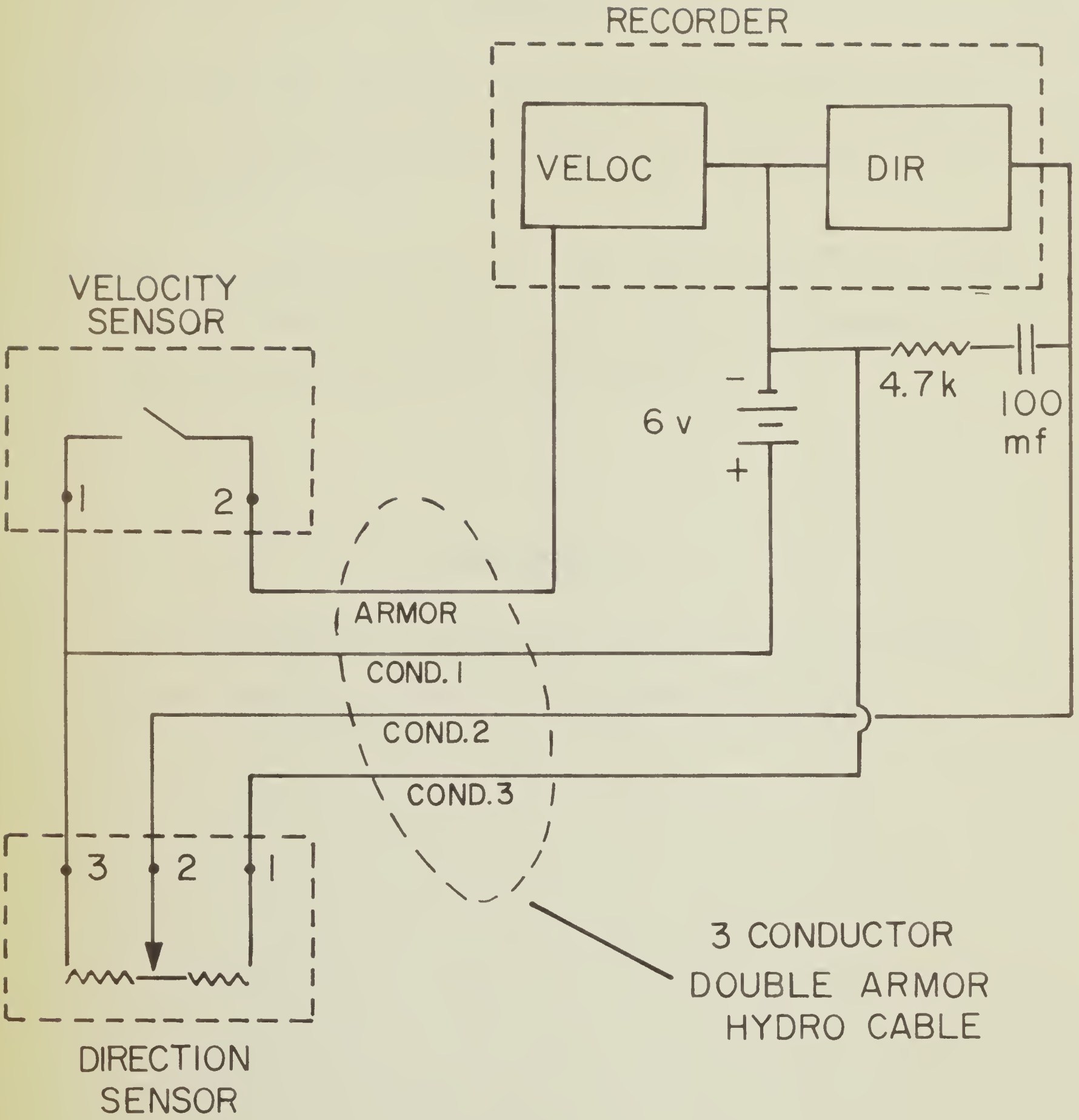

RECORDER
VELOC
DIR
VELOCITY
SENSOR
1
2
6 v
-
+
4.7k
100
mf
ARMOR
COND. 1
COND. 2
COND. 3
3
2
1
3 CONDUCTOR
DOUBLE ARMOR
HYDRO CABLE
DIRECTION
SENSOR

FIGURE 1 1

REFERENCES

Sexton, Robert, 1964. Some tow tank calibrations of the Savonius Rotor: Lamont Geological Observatory Technical Report No. CU-11-64, Table 19. (unpublished)

Volkmann, G., Knauss, J. and Vine, A., 1956. The use of parachute drogues in the measurement of subsurface ocean currents: Transactions, American Geophysical Union, 37 (5), 573-577.

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