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TAUT-LINE NAVIGATION BUOYS USED IN THE THRESHER SEARCH

Report prepared by: Robert Gerard

Technical Report No. CU-9-64 to the Atomic Energy Commission
Contract AT(30-1)2663

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ABSTRACT

Six navigation buoys were placed by the R/V CONRAD of Lamont Geological Observatory in May and June, 1963 in the THRESHER search area. All buoys used taut-line moorings set in a depth of about 1375 fathoms, using regular lay nylon rope of 9/16-inch diameter. Anchors, consisting of five one-foot cubes of cast iron shackled together in two groups, were used in most cases. By experiment, the best results were obtained where the mooring line was cut to a length, measured under low tension, of 15 percent less than the bottom depth. The maximum circle of movement for the buoys had a radius of about 200 yards.



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During the months of May to July, 1963 six navigation buoys were placed by workers aboard the research vessel CONRAD of Lamont Geological Observatory in the THRESHER search area. This site, located some two hundred miles east of Boston in an area of about 1375 fathoms, was the scene of an intensive search effort during this period by a number of research and naval vessels. The demands for precise navigation during this search effort could not be suitably met by the available navigation aids, such as Loran-C and Decca Navigator. In an attempt to satisfy the need for more reliable and precise navigation, we placed marker buoys in the area, equipped with radar transponders and passive radar reflectors for the use of our own and other ships.

The CONRAD was equipped with a Decca 800 series, x-band marine radar and a range unit and plotter from Alpine Geophysical Associates, who also supplied the transponder beacons. Ideally, with radar transponders placed at fixed positions, and using a modified x-band radar with a range-range plotting unit, one is able to plot ship's position out to ten miles from the beacons with an accuracy equivalent to that of the radar when used on the one-mile range. To achieve, as nearly as possible, a fixed position for our buoys in this depth of water, a taut-line mooring system with nylon line was employed.

SELECTION OF BUOY COMPONENTS

A brief survey of materials available to make up a deep-sea mooring system and a general estimate of the factors of the natural environment led to the selection of 9/16-inch regular lay nylon rope for the buoy line. Figure 1 compares the estimated forces under given conditions in a two-layer ocean for lines of various dimensions. The high strength of

STRAIN TABLE FOR VARIOUS DIAMETER LINES IN 12,000 FOOT MOORING

	Line Diameter	Approximate Breaking Strength (Pounds)	Calculated Pounds Tension due to Current Perpendicular to Configuration*		
			Model 1	Model 2	Model 3
Synthetic	3/8"	Nylon ... 3400	607	2430	9720
		Prolene . 2700			
	7/16"	N 4800	709	2835	11340
		P 3300			
	1/2"	N 6200	810	3240	12960
		P 4200			
	9/16"	N 8000	912	3650	14597
		P 5700			
Steel	1/4"	6100	1677	2892	7752
	5/16"	9200	2510	4029	10104
	3/8"	13100	3439	5262	12552

* Synthetic tension load has been calculated without regard for the weight of line in water. (Nylon has a specific gravity of 1.21 and prolene 0.91.)

Calculations of load on steel wire include the weight of the wire in water.

Model 1: 0 - 4000 Ft. = 1 knot
4000 - 12,000 Ft. = .5 knot

Model 2: 0 - 4000 Ft. = 2 knots
4000 - 12,000 Ft. = 1 knot

Model 3: 0 - 4000 Ft. = 4 knots
4000 - 12,000 Ft. = 2 knots

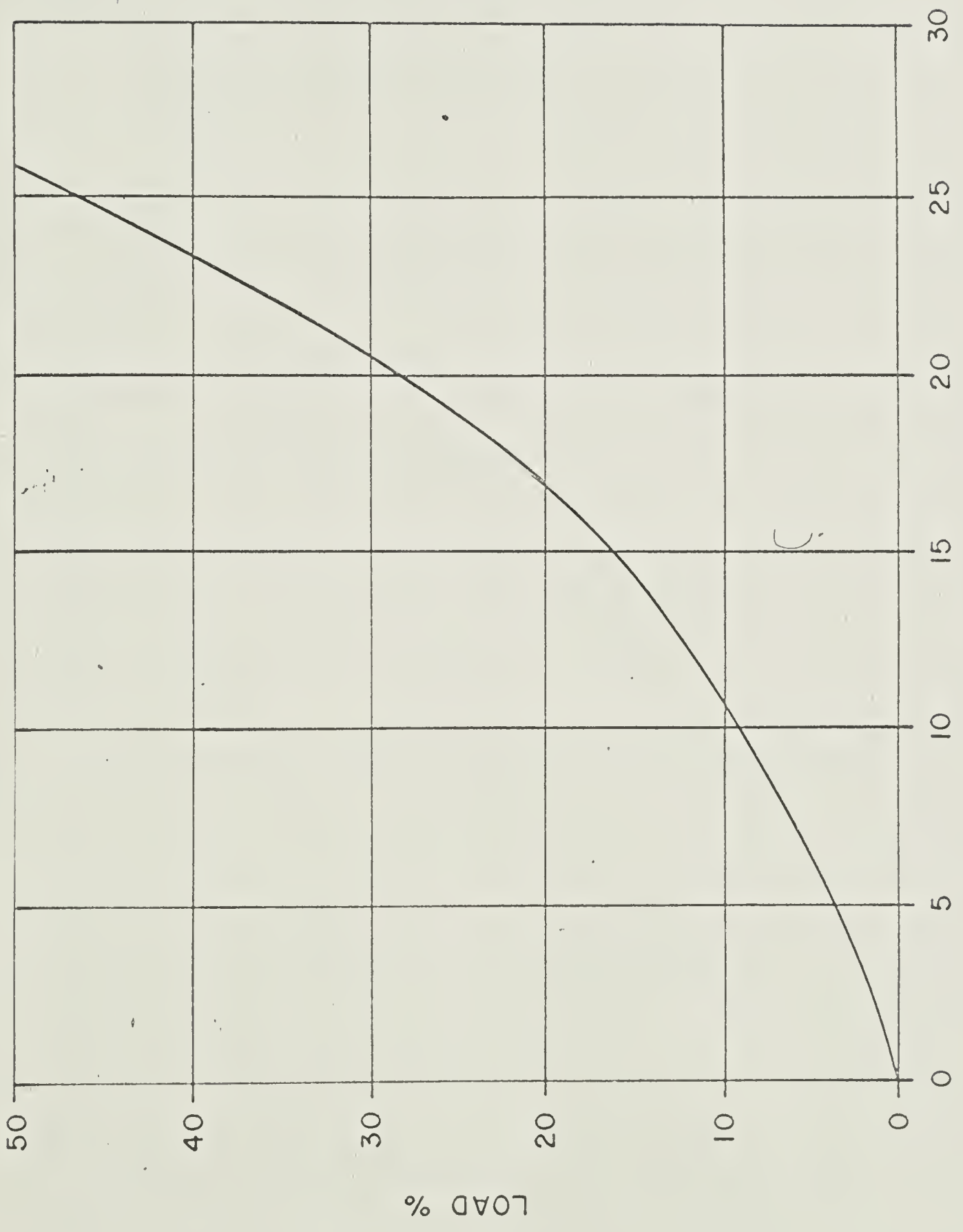
FIGURE 1

nylon, compared to polypropylene, is evident from this table. This advantage is even greater than indicated, since the table shows ultimate breaking strength for both synthetics. Long period tests on polypropylene with loads of 60 percent of breaking strength showed failure by cold flow within seven days (Fofonoff, WHOI, unpublished data). Comparable stress on nylon line causes elastic elongation without failure. Elastic return to original dimensions follows removal of load. The density of nylon is such (1.21) that for most calculations it may be considered neutrally buoyant. Figure 2 illustrates a typical curve of load versus elongation for nylon line.

Other components of the system which were selected included 500-pound cubes of cast iron used in series as loading and anchoring weights, 5000-pound test ball-bearing swivels used at the terminations of the nylon line, and cast bronze synthetic rope thimbles used at eye-splice terminations of the nylon line. Eye-splices were made by the following formula: four regular tucks were made, after which the three strands were split into half-strands and recombined with adjacent half-strands to form three new strands. These were tucked again four times, and the base of the splice was served with marline.

The surface buoy utilized, in most cases, was the toroid-shaped deep-sea buoy with a tripod instrument tower, developed by Richardson and having about 5000 pounds positive buoyancy. This equipment was obtained from the Geodyne Corporation. Figure 3 shows a general schematic of this buoy system. The buoy instrumentation included one x-band radar transponder with a 200-ampere hour battery power supply, one high intensity flasher light (Edgerton, Germeshausen & Grier Buoy Light) and one or two lifeboat

TYPICAL ELONGATION
FOR NYLON
ROPE



ELONGATION %

FIGURE 2

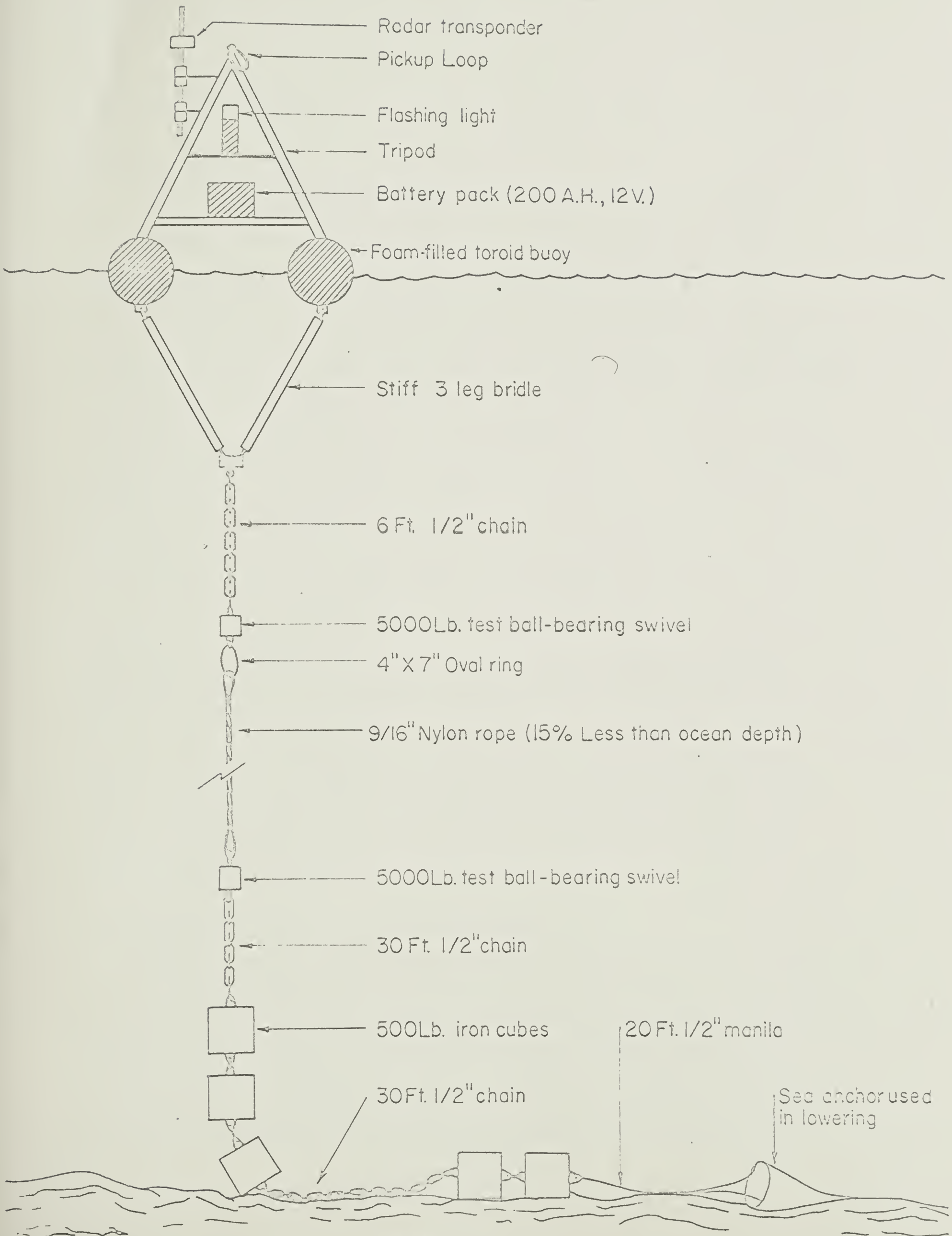


FIGURE 3

type radar reflectors.

PLACEMENT OF THE BUOY

Fairly precise placement of the buoys was attempted. In launching the equipment, the toroid buoy was first placed in the water and nylon line paid out under low tension as the ship moved slowly away from the buoy. This was done in a position somewhat down-current from the selected final position of the buoy. When the entire amount of line had been placed in the water, attachment was made to the ground tackle, made ready at the ship's rail and held by manila rope lashing. The buoy and line, streaming aft of the ship, were then towed slowly until the desired position had been crossed and left behind about one-quarter of the distance between the ship and the buoy being towed. With this relationship the anchor tackle was cut loose and allowed to settle, the lowermost anchor cube being restrained by a small sea anchor during its descent to prevent tumbling. The falling anchors tended to move somewhat toward the buoy, while the buoy at the surface would move a greater distance toward the position where the anchor was dropped. On one occasion we were requested to place buoys four miles apart. The measured radar distance between buoys was later determined at 4.1 miles.

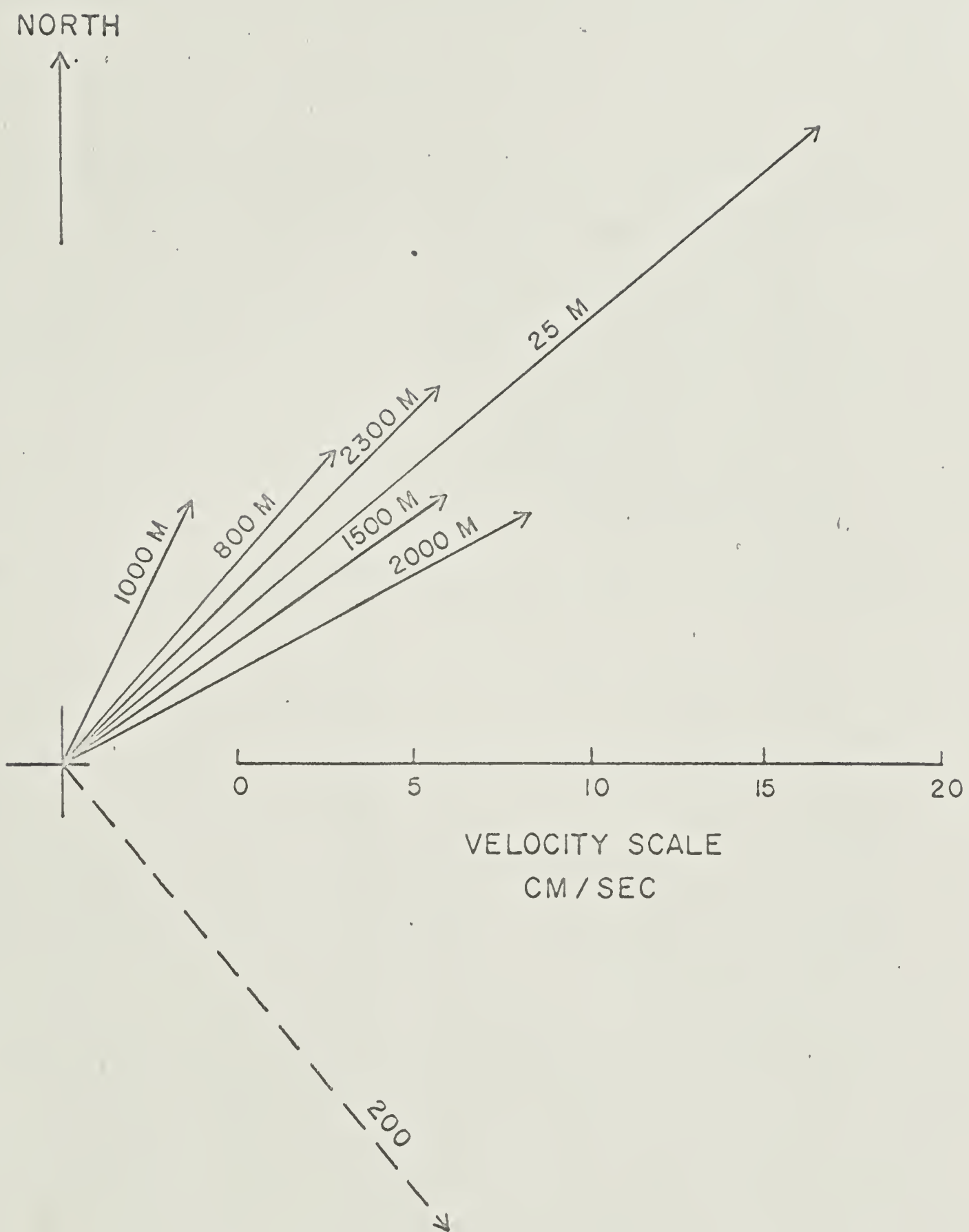
POSITION-KEEPING CHARACTERISTICS OF THE BUOYS

It is of paramount importance in placing a taut-line moor to achieve the desired line tension by using a suitable length of line and appropriate loading weights. We were unable at first to find reliable information on the elongation of nylon rope under load. Part of the confusion resulted from different estimates by different manufacturers for the amount of the

elongation under different percentages of breaking strength loads and different figures given for the unlaying elongation, characteristic of any laid rope when first put under tension. In one of our early attempts to set these moorings, the line was cut 18 percent short of the sonic depth (uncorrected fathoms on the Lamont precision depth recorder). Line length was measured with a meter wheel counter as the line was taken off a storage reel under low tension. This mooring, with 2000 pounds of anchor weights, floated away, its ground tackle never touching the bottom. The buoy was recovered and a mooring line 15 percent less than ocean depth was prepared. This mooring seemed to hold very well in the presence of fairly vigorous surface currents, and the 15 percent formula was used on all subsequent taut-line moorings.

The generalized current velocities for the region are shown in Figure 4. These data were kindly provided by David Shonting of the Naval Underwater Ordnance Station, who made parachute drogue current measurements in the area during these operations. A brief look at the variance of velocities (standard deviation) given for these measurements indicates that currents 20 to 50 percent greater than the given averages are not uncommon. We may assume that a two-layer model, with the upper 500 meters having a maximum velocity of 51 cm/sec (one knot) and the lower 2000 meters having a velocity of about 25 cm/sec (0.5 knot), presents a reasonable picture of the extreme current profile. From the curve of elongation versus loading for nylon rope (Figure 2), we may observe that for our typical mooring 15 percent elongation will load the mooring line with about 1000 pounds.

Assuming that the maximum current velocities were on the order of one knot in the upper 500 meters and 0.5 knot for the bottom 2000 meters, we



PARACHUTE DROGUE MEASUREMENTS OF AVERAGE CURRENTS
IN THRESHER SEARCH AREA

FIGURE 4

derive a maximum additional line loading of about 600 pounds, using the formula:

$$R = .27 V^2 d$$

where R is an empirical value in pounds per foot found in tow tests for flow perpendicular to a stranded cable, V is velocity in knots, and d is diameter in inches. A line tension of 1600 pounds would, according to the curve in Figure 2, coincide with an elongation of an additional 5 percent over the vertical line length. Such a length (1445 fms.) would in the extreme case show a maximum excursion for the surface buoy of 446 fms. or 0.5 mile from the vertical position. We may compare this estimate with field observations of the surface positions of the taut-line buoys.

Figure 5 shows a number of fixes made for one of the buoys over a period of 48 hours. These fixes were based upon the best navigation obtainable from Loran-C and Decca Navigator aboard the R/V CONRAD. The extremes in this distribution of plotted positions are typical of the maximum excursions of the buoys at the surface in this area. It appears that in 1375 fathoms the radius of movement of these buoys was about 200 yards, indicating an average vertical angle for the anchor line of about five degrees. One small identifiable topographic feature on the ocean bottom within range of the beacons was plotted several times with variance of about 200 yards. A magnetic signature of equally small dimensions was later found with the same repeatability of position. However, the position of these "fixed" features in relation to the ship is subject to uncertainties due to the cone of the echo sounder in one case and the position of the deep-towed magnetometer in the other.

POSITIONS OF SIGMA BUOY
BETWEEN 24 & 26 JUNE 1963
MEASURED BY DECCA NAVIGATOR AND LORAN-C

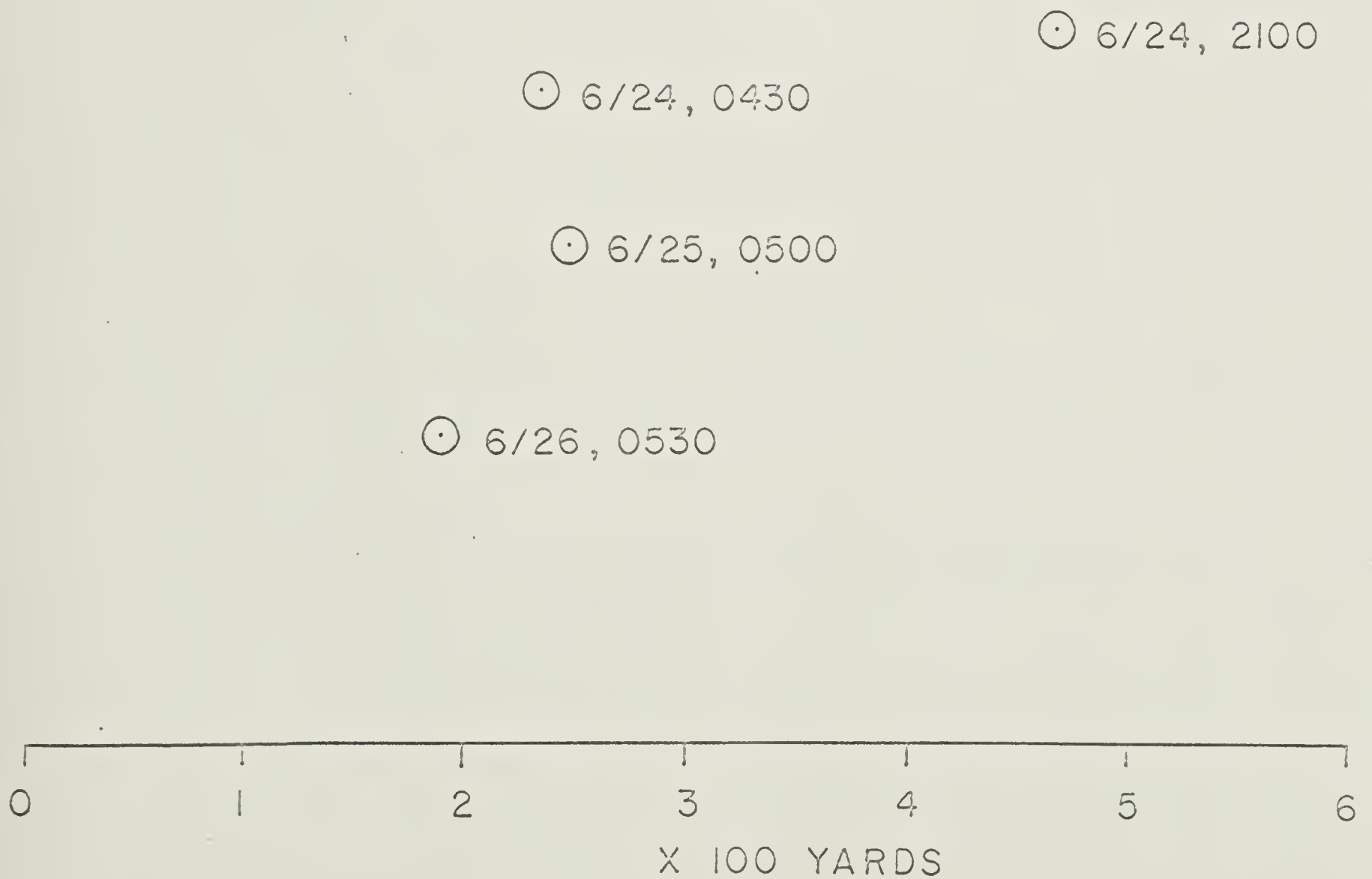


FIGURE 5

When we compare the observed radius of movement (0.1 mile) with the calculated radius (0.5 mile), it is apparent that our estimate of line loading due to current is too high to reflect the actual conditions which prevailed. Some reasons for this discrepancy include the shrinking of the line diameter under load, which was not taken into account, and the improbability that maximum current stresses should appear from one direction at all depths at one instant along the entire mooring line.

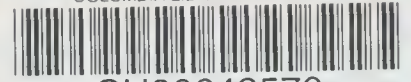
It would appear that taut-line navigation buoys, placed in moderately great ocean depths, may serve to provide more precise navigation markers than shore-based navigation aids at distances from the coast exceeding several hundreds of miles. We only regret that the test of this navigation system had to coincide with such a sad event as the loss of the submarine THRESHER.

ACKNOWLEDGMENTS

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