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Cable Length Determinations for Deep-Sea Oceanographic Operations

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Technical Bulletin No. 30 describes cable length determinations during deep-sea lowerings of heavy equipment to the ocean floor. From the observed cable lengths and true depths, a method is devised to determine additional cable required to compensate for the catenary of the cable. The results--which proved to be more accurate than those obtained by the cosine computational method--are presented in tabular and graphic form for depths ranging from 6,000 to 23,000 feet and cable angles of 5, 10, 15, 20, 25, and 30 degrees. The method is useful for determining cable pay-out during deep-sea lowerings of heavy equipment, particularly when a pinger or dynamometer cannot be used.

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Cable Length Determinations for Deep-Sea Oceanographic Operations

CAPTAIN ROBERT C. DARLING

U.S. Environmental Science Services Administration

ONE of the problems encountered in deep-sea oceanographic surveys has been the uncertainty about the amount of cable to pay out when lowering equipment to the ocean floor. The problem exists because the cable or wire generally does not hang directly beneath the ship, but is deflected by the force of currents at depth and by the drift of the ship on the surface. This causes the line to bend, the flexure or shape of the line being referred to as its catenary. When sampling any specified depth, or the sea floor, sufficient cable must be let out to allow for the catenary of the cable. This imposes a special problem where the success of the operation requires bottom contact, for if too much cable is payed out the previously taut line becomes slack and kinking can result. Kinking of the cable can lower its breaking strength, by as much as one half in some instances, and can make rewinding of the cable difficult or impossible. Damage or loss of equipment can be the end result, as well as loss of costly lengths of cable. The problem has been most acute in certain operations, such as deep-sea anchoring, bottom sampling with heavy coring devices, heat-flow measurements with the thermoprobe, and photographic work that requires close proximity of heavy camera equipment to the ocean floor.

For many years, the amount of cable needed to lower equipment to the sea floor has been based on the cosine computational method, using depth soundings and observed wire angle. The method, in addition to the inherent limitations imposed by the accuracy of depth soundings and the accuracy possible in determining wire angle, does not adequately allow for the catenary of the cable.

The dynamometer, or tensiometer, also has been used to detect the instant of bottom contact. In this method, the cable is led over a set of sheaves and the pressure exerted by tension on the cable is registered continuously. The method safeguards against paying out cable in excess of that required to reach the bottom.

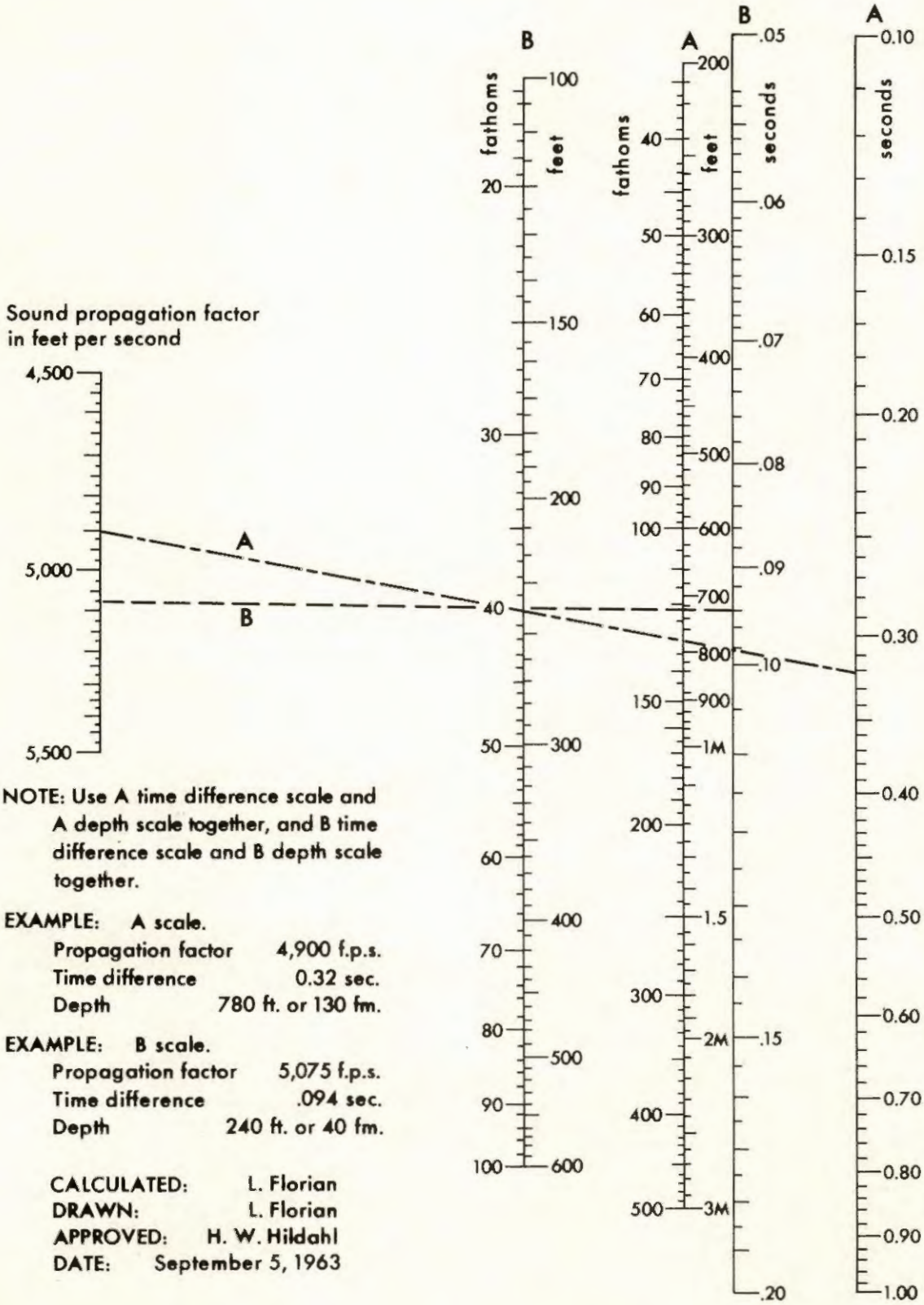
The development of electronic instruments of the pinger type has made it possible to determine the distance between the cable's free end and the sea floor. In this method, the pinger is attached to the equipment, or cable, a short distance above the free end. As the pinger is lowered, it transmits bidirectional sound signals, one directly to the hydrophone position of the ship's transducer and the other simultaneously to the ocean floor, from which the signal is reflected to the ship's transducer. The difference in arrival times of the direct and reflected signals provides a reliable indication of the distance between pinger and ocean floor.

The pinger and dynamometer methods were used during the 1963 survey work by the USC&GS ship *Surveyor* in the central North Pacific Ocean. From the data obtained, curves were drawn and a table of values was developed to aid in predetermining additional cable requirements for various depths and cable angles. The results indicate and provide for the catenary of the cable. This publication describes certain field procedures and techniques that were used during deep-sea lowerings from which the raw data were obtained, outlines computing and plotting steps for the graphic method depicted herein, compares the results obtained by the new method with those yielded by the cosine computational method, and sets forth some conclusions and recommendations.

SOURCE OF DATA

Data for computing and plotting the new graphic method were obtained during lowerings of a Ewing piston corer and a thermoprobe to collect bottom samples and to measure heat flow. An Edgerton, Germeshausen & Grier sonar pinger Model SP-29 was attached to the lowering cable 200 feet above the corer (247 feet above the trigger weight of the corer) during bottom sampling operations. Five samples were obtained at depths ranging from 15,000 to 20,000 feet and five from depths ranging from 7,000 to 10,000 feet. During each sampling, the corer was lowered to within 500 feet of the bottom, as determined by depth sounding and wire angle (the cosine computational method) and the amount of wire payed out as registered on the winch counter. Rapid pay-out was discontinued 500 feet above the bottom so that the time difference of the pinger signals could be accurately read from an oscilloscope and closely monitored throughout the remaining slow descent to the bottom.

Although the pinger system was designed for use with the Precision Depth Recorder, it was difficult to keep the timer of the pinger synchronized with the PDR. The synchronization, or keying time of the pinger, would not hold in a rapid descent. To overcome the difficulty, a Tektronic 310 Oscilloscope was plugged into the audio output of the PDR and synchronized to trigger the trace from the direct signal. The space interval between the direct and reflected



NOTE: Use A time difference scale and A depth scale together, and B time difference scale and B depth scale together.

EXAMPLE: A scale.

Propagation factor	4,900 f.p.s.
Time difference	0.32 sec.
Depth	780 ft. or 130 fm.

EXAMPLE: B scale.

Propagation factor	5,075 f.p.s.
Time difference	.094 sec.
Depth	240 ft. or 40 fm.

CALCULATED: L. Florian
DRAWN: L. Florian
APPROVED: H. W. Hildahl
DATE: September 5, 1963

FIG. 1.--Nomograph for determining distance of sonar pinger from bottom.

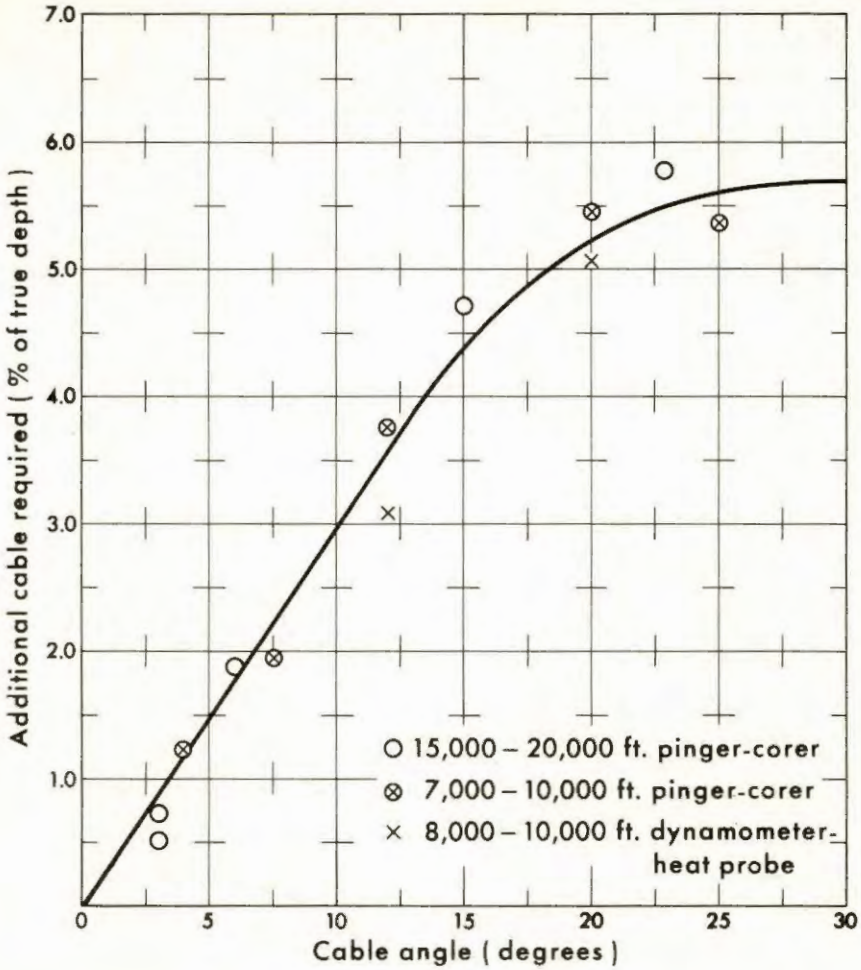


FIG. 2.--Additional cable requirements based on curve of best fit for twelve deep-sea lowerings of heavy equipment.

signal could then be read in units of time. This method was not dependent upon synchronism of the SP-29 timer and gave readings to within 10 feet.

The nomograph shown in figure 1 was used to simplify the computation of pinger distance above the bottom. The distance can be read directly, in fathoms or feet, by placing a rule across the time-difference value on the appropriate scale at the right side of the nomograph and across the sound propagation value on the scale at the left side of the nomograph, and then reading the distance value where the rule intersects the appropriate depth scale--the A depth scale being used with the A time-difference scale and the B depth scale with the B time-difference scale.

The amount of cable used to reach the bottom also was carefully recorded during two thermoprobe lowerings to depths between 8,000 and 10,000 feet. The procedure for keeping the probe on the bottom prevented use of the pinger, but the instant of bottom contact was detected by leading the cable through the sheaves of a 7,000-pound dynamometer placed between the overboard sheave and the "A" frame. During the final stages of each thermoprobe lowering, cable was payed out at a slower rate and the dial needle of the dynamometer was watched constantly. As the trigger weight contacted the ocean floor, releasing the thermoprobe free-fall mechanism, the dial needle was observed to fluctuate between readings of 2,000 and 3,000 pounds for about a second. The amount of cable payed out was recorded simultaneously.

PLOTTING OF DATA

The data from the 10 pinger-corer and two dynamometer-thermoprobe lowerings were graphically plotted as shown in figure 2. By entering the graph at any cable angle on the horizontal scale and finding the intersection of the entered line with the curve of best fit, the additional cable required (expressed as percent of true depth) can be read from the vertical scale. Next, the additional cable was computed for every 1,000-foot interval of true depth from 6,000 to 23,000 feet and for cable angles of 5, 10,

Table 1.--Additional cable required to compensate for cable's catenary for selected depths and cable angles

[Cable angle in degrees; additional cable expressed in feet]

True depth (feet)	5° 1.46%	10° 3.00%	15° 4.38%	20° 5.20%	25° 5.60%	30° 5.70%
6,000	88	180	263	312	336	342
7,000	102	210	307	364	392	399
8,000	117	240	350	416	448	456
9,000	131	270	394	468	504	513
10,000	146	300	438	520	560	570
11,000	160	330	482	572	616	627
12,000	175	360	526	624	672	684
13,000	190	390	569	676	728	741
14,000	205	420	613	728	784	796
15,000	220	450	657	780	840	855
16,000	234	480	701	832	896	912
17,000	249	510	745	884	952	969
18,000	264	540	788	936	1,008	1,026
19,000	278	570	832	988	1,064	1,083
20,000	292	600	876	1,040	1,120	1,140
21,000	305	630	920	1,092	1,176	1,197
22,000	320	660	964	1,144	1,232	1,254
23,000	335	690	1,007	1,196	1,288	1,311

15, 20, 25, and 30 degrees (table 1). The data of table 1 were then graphically plotted as shown in figure 3. By finding the point where the cable-angle line (horizontal scale) intersects the appropriate true-depth curve, the additional cable required can be read directly from the vertical scale of the graph. Thus either of two methods--the numerical tabulation of table 1 or the graphic presentation of figure 3--can be used to determine the additional cable required.

GRAPHIC v. COSINE METHOD

The results obtained by the graphic method described herein are compared with those yielded by the cosine computational method in table 2. For the 1963 deep-sea operations of the *Surveyor*, the graphic method provided a more accurate indication of the additional cable required than did the cosine computational method. The method should prove suitable for all deep-sea lowerings of heavy sampling devices and equipment on 3/8- to 3/4-inch tapered cable, such as lowerings of the Ewing piston corer and the 750-pound anchor. The method will be particularly helpful when for any reason a pinger or dynamometer cannot be used.

RECOMMENDATIONS

The graphic method described in this publication was based upon 12 lowerings of heavy equipment to the ocean floor. The accuracy of the graphs and the values in the tables should be improved by a greater number of observations.

Measurement of cable angle can limit the accuracy achieved by this method. At present a

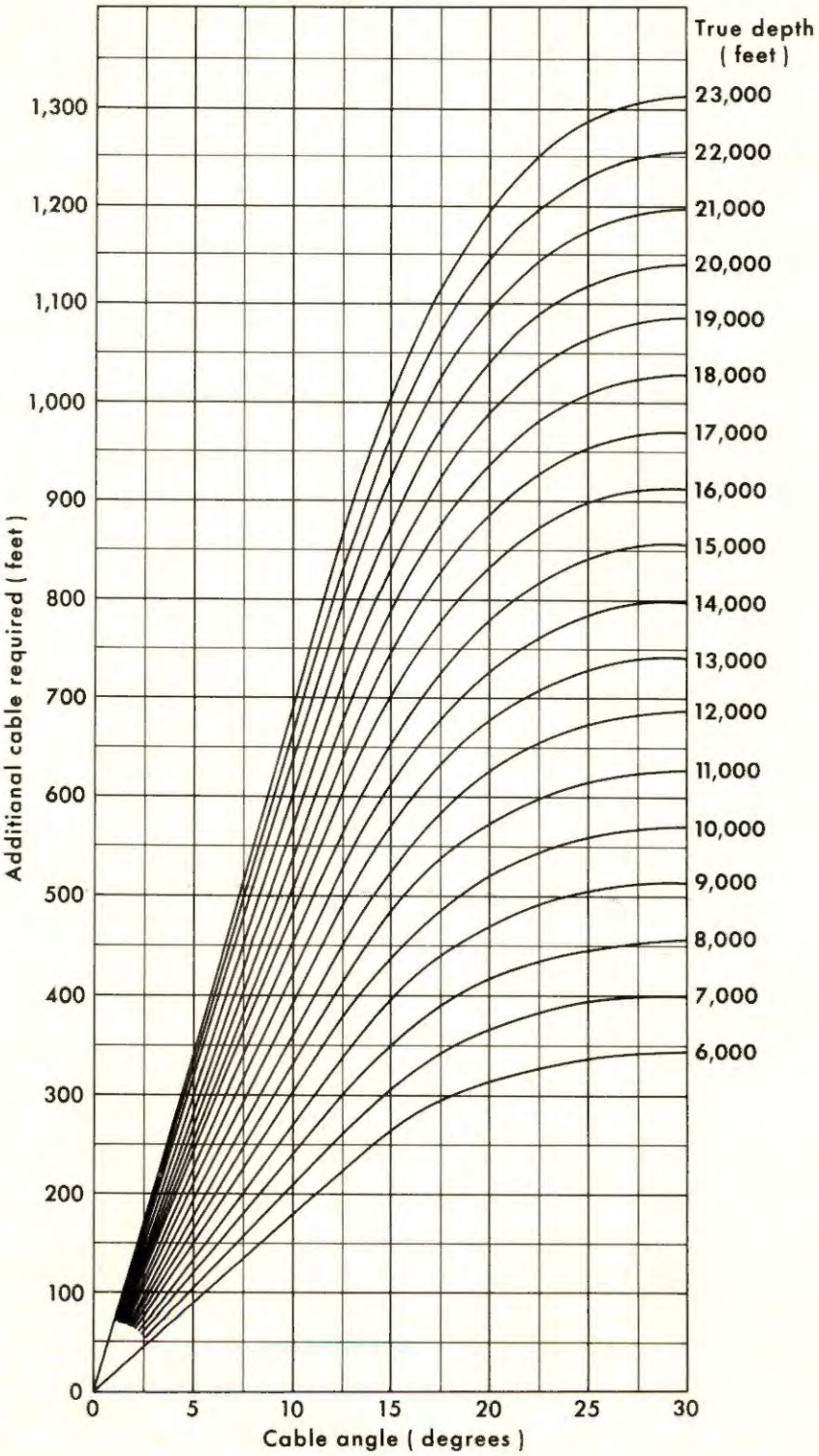


FIG. 3.--Graphic method for determining additional cable requirements for deep-sea lowerings of heavy equipment.

Table 2.--Comparison of additional cable determinations by cosine computational method and graphic method shown in figure 3.

True depth	Additional cable required (feet)	
Cable angle	Cosine method	Graphic method
10,000 ft.		
10°	152	300
17°	460	475
20°	638	520
30°	1,547	570
20,000 ft.		
10°	305	600
17°	920	950
20°	1,277	1,040
30°	3,095	1,140

wire-angle indicator is used. One alternative is to use a sextant to measure the angle made by the cable and a line of sight to the horizon. The angle should be read to the nearest half degree. The complement would be the cable angle required.

To accurately record the length of cable payed out, paint an initial mark on the cable to serve as a counter setting reference. Reread the counter on return of the marked position to allow for any cable stretch or slippage. Counters should be calibrated and corrections applied when using the results to improve the accuracy of the graphic method.

When utilizing the pinger and oscilloscope to determine the distance between the free end of the cable and the ocean floor, other underwater operations should be suspended to prevent unwanted noise from obscuring the reflected sound signals. Standard corrections for sound propagation in the water medium--as determined from oceanographic station casts in the immediate area--must be applied to the PDR soundings to obtain true depths and to the pinger time-difference observations.

CONCLUSIONS

Results of this study using deep-sea lowerings with heavy equipment should be compared with Nansen casts or other lowerings of lighter equipment on smaller-diameter wire. This can be done by installing a dynamometer on the oceanographic "A" frame during Nansen casts with a weight-triggered Phleger corer attached at the free end and by following the procedures described in this publication.