A STREAMLINE CABLE DEPRESSOR

By

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In the past the collection of samples from the deep scattering layer by the familiar horizontal net haul method has been handicapped by the available tools. The time-honored weighted line technique has often been suspected of introducing error in the depth factor of data. The development of the streamlined cable depressor herein described provides an effective tool for oceanographic studies. Because of its form, the depressor has a high lift/drag ratio and is free from the damaging vibration usually characteristic of depressors. Many applications are suggested by its performance in the field.

Experimental hauls made by members of the Scripps Institution of Oceanography and of the Oceanographic Studies Section of the U. S. Navy Electronics Laboratory have given evidence of the effectiveness of this cable depressor as a tool capable of maintaining stable towing depth. The use of recording depth gages provides valuable evidence for records.

Fig. 1 shows a series of three depth records made while using a No. 1 depressor at slow speeds. The depth gage used in these tests had an original maximum of 400 feet, but it has been modified to give a 1,067-foot full scale range. The notation of "2M. NET" refers to a conical specimen gathering net assembled by LaFond and Tucker for the initial depressor tests. The diameter is two meters at the open end, the length 25 feet, the mesh two inches.

Chart No. I shows that the pen was off scale, riding against the stop pin for 30 minutes with 1,300 meters of cable out. With 1,000 meters of cable, the depth was decreased to 1,100 feet and thereafter it responded to each decreased cable length.

Chart No. II gives good verification of No. I. The one meter net was of fine mesh, which had greater drag than the longer two meter net with larger mesh.

Chart No. III shows operation at about 800 feet of depth with the two meter net attached. The ship course was reversed after runs I and II, which apparently changed the ship/water current relationship. It is evident that the depth was both stable and controllable. A

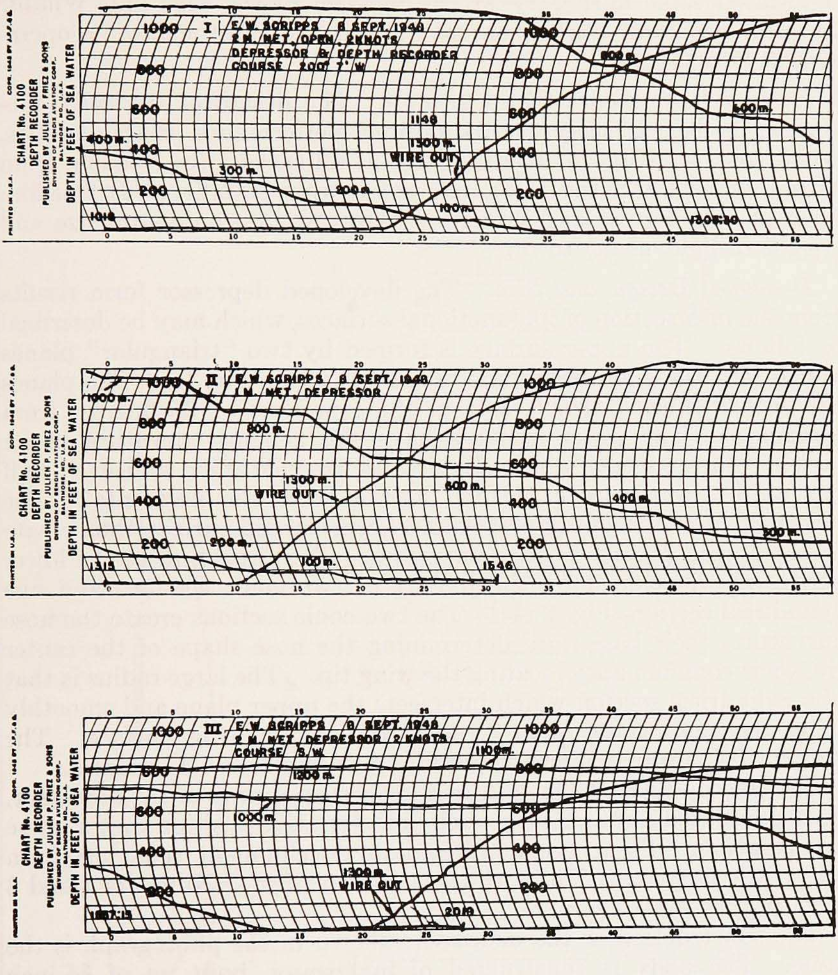


Figure 1. Depth Recorder Charts No. I, II, and III, Recorded by U. S. Navy Electronics Laboratory.

series of charts (three shown in Fig. 1) furnished by the NEL Oceanographic Studies Section shows over 20 hours towing at depths between 600 and 1,200 feet.

The successful deep sea operation at low ship speed was gratifying, since it proved to be an unexpected depressor characteristic, the design having been based on higher speed performance.

Judging from the interest shown in both the depressor and the associated cable fairing by M. B. Schaefer of the Fish and Wildlife Service, it is likely that others may find interest in the data on operation at 5 to 15 knots.

Desired Performance Characteristics. The design of the NEL Depressor is based solely on its desired performance characteristics, which are: (a) High lift to drag ratio at all speeds; (b) freedom from vibration (self induced); (c) inherent towing stability; (d) freedom from protruding parts; (e) positive buoyancy; (f) minimum size and weight in light of (a) to (e).

Developed Design and Size. The developed depressor form results from the intersection of its functional surfaces, which may be described as follows. The upper surface is formed by two "triangular" planes which join along the centerline of the body (see Fig. 2). The planes are each inclined downward from the centerline at 25 degrees from horizontal. The lower surfaces have the general curvature of an airfoil. This surface is also divided at the centerline and each half has a downward angle of five degrees from the horizontal. The intersection of the upper planes and lower curved surface thus create a closed space, which is the body form. The curvature of the lower surfaces is developed by the joining of two conic sections and one cylindrical section, Fig. 2 (1). The two conic sections create the nose curvature, their base radii determining the nose shape of the center rib, their common apex locating the wing tip. The large radius is that of a cylindrical section which intersects the upper plane and smoothly joins the nose cone, thus forming the major wing surface. The "wing tips" are positioned to produce a sweepback of 16 degrees.

The photographs in Fig. 3 illustrate the appearance of the depressor. Four graduated sizes are suspended in the relative position they assume in operation. These are numbered in development sequence from No. 1, the largest, to No. 4, the last and smallest. Numbers 1 and 3 have proven most useful.

The construction of the depressors shown in the photograph is the same. The body is constructed of mahogany, built up of ¾-inch stock. The ends of the dowels which connect the two wing sections can be seen in the No. 4 depressor. Eight of the dowels pass through the dural centerline rib. The twelve dowels along the trailing edge (6 visible) reinforce the thin edges and do not extend through the rib. The indicated structure meets the requirements (d), (e), and (f). Lead inserts weighing five pounds were placed in the nose of the No. 3 depressor to aid in meeting the stability requirements (c). The depressor body has a fineness ratio of 6 : 1 at the centerline. The finish is smooth varnish.

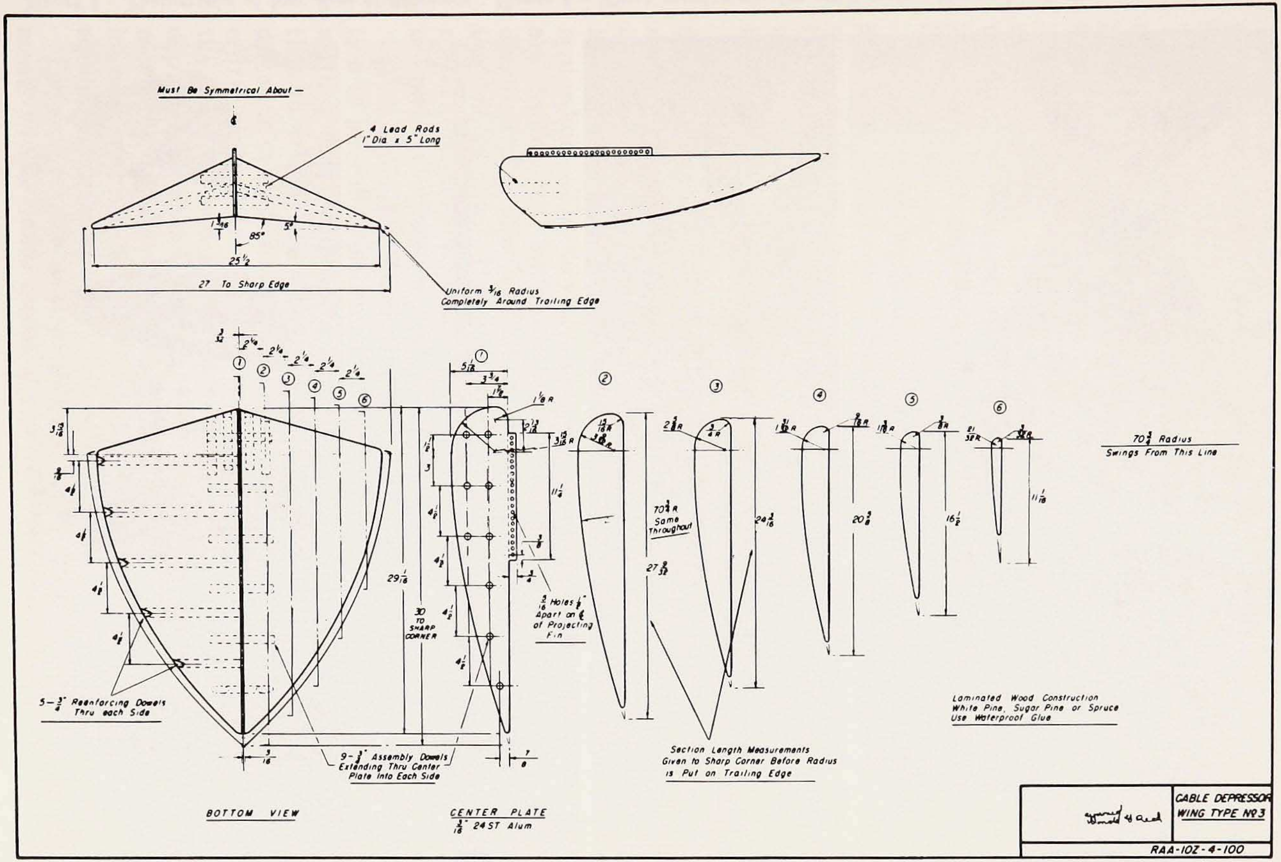
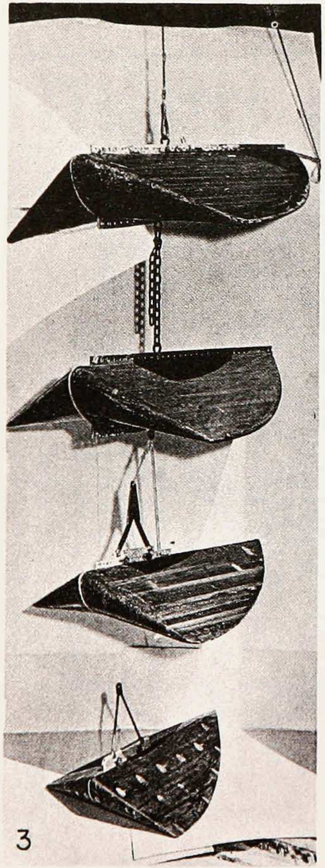
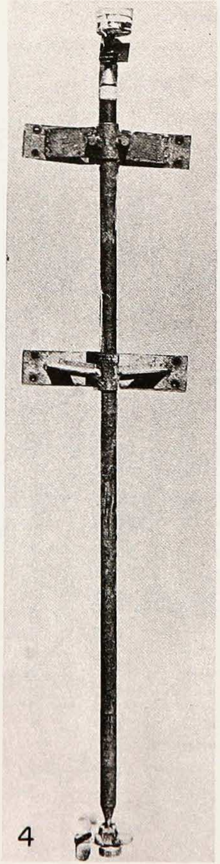
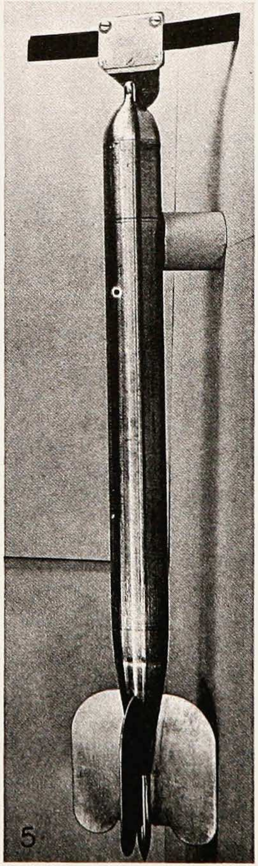


Figure 2 – Mechanical drawing of depressor.







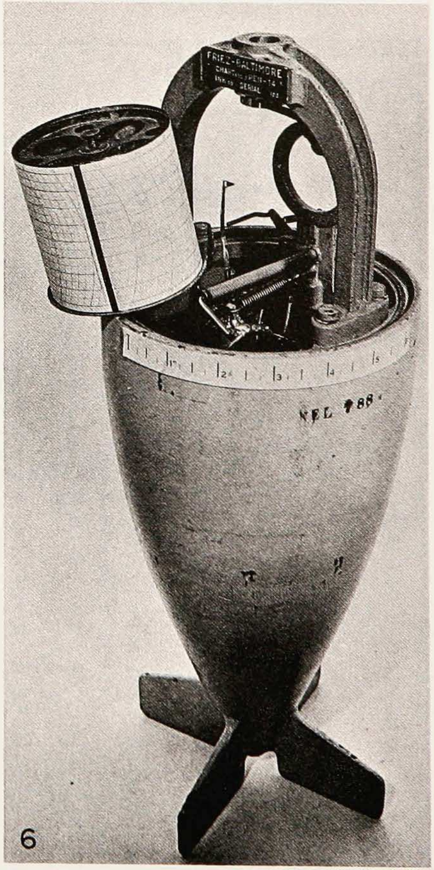


Figure 3 – Photographs of four sizes of depressor. Figure 4 – Water speedometer for small craft. Figure 5 – Inclinometer. Figure 6 - David Taylor Model Recording Depth Gage.

Explanation of Performance and Stability Characteristics. A simplified description of the forces acting on the surfaces of the depressor is as follows.

(a) The depressor is attached at the end of its tow line by its yoke, or bridle, in a single point suspension. It is free to pivot on this one point in any direction. The attachment is located above a point approximately one-quarter of the total length distant from the nose.

(b) When the tow line is put in motion the body of the depressor aligns itself with the direction of motion. Because the nose is loaded with lead, the body floats tail high, with a large attack angle. Forward motion establishes the conditions which create both negative lift and stability.

(c) The lower surfaces have the general curvature of an airfoil, as shown in Fig. 2 (1). The upper surfaces are plane. The planing effect of the inclined surfaces as well as the pressure decrease created by the increased water velocity as it passes under the body create the negative lift of the depressor. The center of lift is well forward of the dimensional center of the midrib.

(d) In stable operation, the top of the depressor is inclined nose down approximately nine degrees from the horizontal. As the body moves forward, the forward projected area of the two upper surfaces is not large. The nine degree attack angle in combination with the large dihedral give two planes obliquely inclined against the common center line. The flow of water over these planes creates forces which are symmetrical and produce no resulting moment as long as the direction of motion of the depressor coincides with the direction of the line of tow. If the depressor direction is changed by angular rotation about the center of lift, then restoring moments result and the body returns to a stable condition of tow.

(e) Assume for illustrative purposes that the depressor has a position of lateral displacement from a vertical plane through the line of motion of the tow-craft. In this position the body attitude will be that in which one wing (foil) is higher than the other because the direction of force in this towline must pass approximately through the center of lift. In this position the nose, loaded by lead slugs, causes the body to pivot nose downward about its center of lift. When the depressor reaches a point in the vertical plane through the line of motion of the tow craft, the heavy nose, by reason of being at its lowest possible position, ceases to supply a torque and a condition of equilibrium exists.

Performance of the depressor has met the desired stability requirements within limits herein described. It is recommended that any use of the depressors be limited to speeds of 5 to 15 knots. There is no indication of depressor vibration under any circumstance.

Observed Operational Characteristics. An effort has been made to determine the lift/drag ratio of the depressor by means of measurements taken during towing operations in calm water. The measurements taken were: (a) Tow craft speed; (b) cable tension; (c) cable angle at water surface, vertical reference; (d) cable angle at depressor attachment, vertical reference; (e) depressor top chord angle, vertical reference; (f) depressor depth in feet; (g) cable arc, vertical reference; (h) cable length.

The instruments and methods employed in making the measurements were:

(a) A special water speedometer, Fig. 4. This device is a modified bicycle speedometer, driven through a torque tube and bevel gears by an impellor. Two impellors were used, one for 0 to 15 knots, the second for 0 to 30 knots. The pitch of the impellors was calculated to drive the speedometer at its normal RPM/mile rate to avoid exceeding its design characteristics. The calibration was accomplished by constant speed runs over a measured mile course.

(b) Cable tension was determined by using a Dillon Dynamometer, which was calibrated against a secondary standard.

(c) Cable angle at surface was determined by direct observation with level and protractor.

(d) Cable angles below water surface were determined by a special inclinometer (see Fig. 5).

(e) Depressor top chord angle was measured by towing close to the surface and by direct observation as in item (c).

(f) All depth measurements were made by use of a modified recording depth gage, DTMB model, made by Friez Instruments, Fig. 6. The instrument was given static check calibration before and after each day's operation.

(g) Cable arc was determined by incremental measurement. The measurements were taken along the cable by use of the inclinometer and recording depth gage at 25-foot intervals, starting three feet above the depressor. The observed depths and tangent angles permitted plotting of the cable curvature. Fig. 7 shows these curves, which are applicable to the speeds noted, and serves to indicate the variation in depressor depth with speed for any length of faired cable up to 500 feet. For example, at a speed of 5 knots, taking Y as the distance (in feet) of the depressor behind the tow craft and X as the depth of the depressor (in feet):

$$Y = .00106X^2 + .301X\,.$$

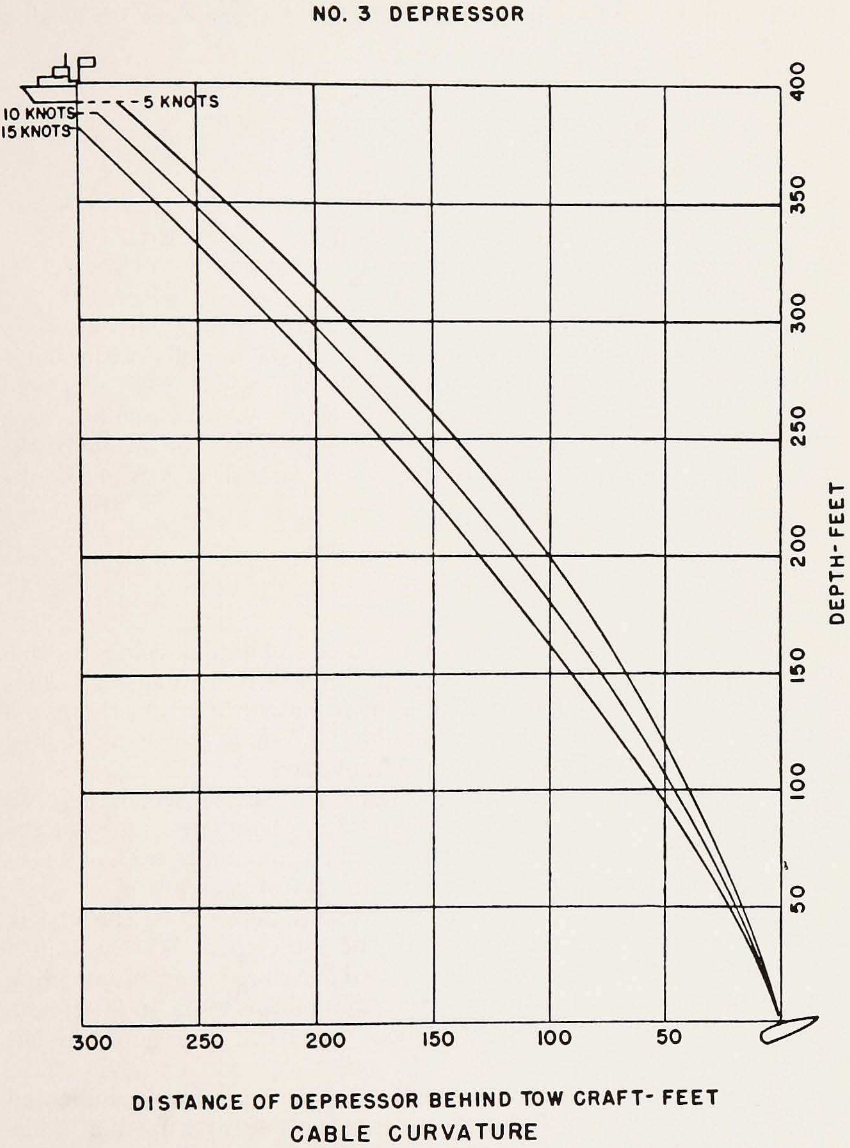


Figure 7. Cable Curvature Chart—500 ft. Cable.

A fair approximation of the cable length required for a desired depth may be obtained by scaling the graph. If greater precision is needed, the following equation will serve:

$$\text{Cable length (feet)} = \frac{PQ - b\sqrt{a}}{N^2} + \frac{R}{N^3}\log\frac{NQ + P}{N\sqrt{a} + b},$$

where $N = .00425$, $R = .0000180$, $P = 2Cx - b$, $Q = (a + b + xc^2)$ $\frac{1}{2}$, x = depth (feet), $a = 1.09$, $b = .00128$, $c = .00000451$.

(h) Cable length was measured without tension. The stretch of the cable under load was not included.

The negative lift developed by the depressor was measured by simple instruments. The depressor was towed in calm water on a short (10 ft.) length of faired cable. The cable tension (S) was read directly from a dynamometer and the cable angle measured with level and protractor. If the angular displacement (θ) of the tow cable from vertical is assumed to be caused by depressor drag (neglecting the short cable) then:

$$S \sin\theta = \text{drag, and}$$

$$S \cos\theta = \text{lift.}$$

The No. 3 depressor moving at a speed of 15 knots develops a cable tension of about 1,500 pounds and an angle θ of 12 degrees. This gives a lift/drag ratio of 1,470/300, approximately 5/1. As the No. 3 depressor has a projected plan area of about 3.5 sq. ft., the wing loading is approximately 400 lb./ft.^{2} at the 15 knot speed.

The thrust-speed chart, Fig. 8, shows the thrust which may be expected for two depressors, Sizes 1 and 3. These curves are for the case of minimum stable attack angle. The maximum stable thrust which may be attained with the depressors is not yet known.

The position of the tow cable attachment determines the attack angle. The approximate midpoint of the attachment is located at a point about 26 % of the centerline chord measured from the leading edge. Incremental adjustment from the midpoint is in 1/10-inch steps. The maximum total movement in either direction will not exceed ½-inch.

To obtain the depth vs. cable length vs. speed performance indicated by Fig. 7, it is necessary to cover the tow cable with fairing. The function of the fairing is to reduce the turbulence about the cable and thereby reduce the parasitic drag on it. Several cable fairings, which materially reduce the parasitic drag, have been tested by this activity.

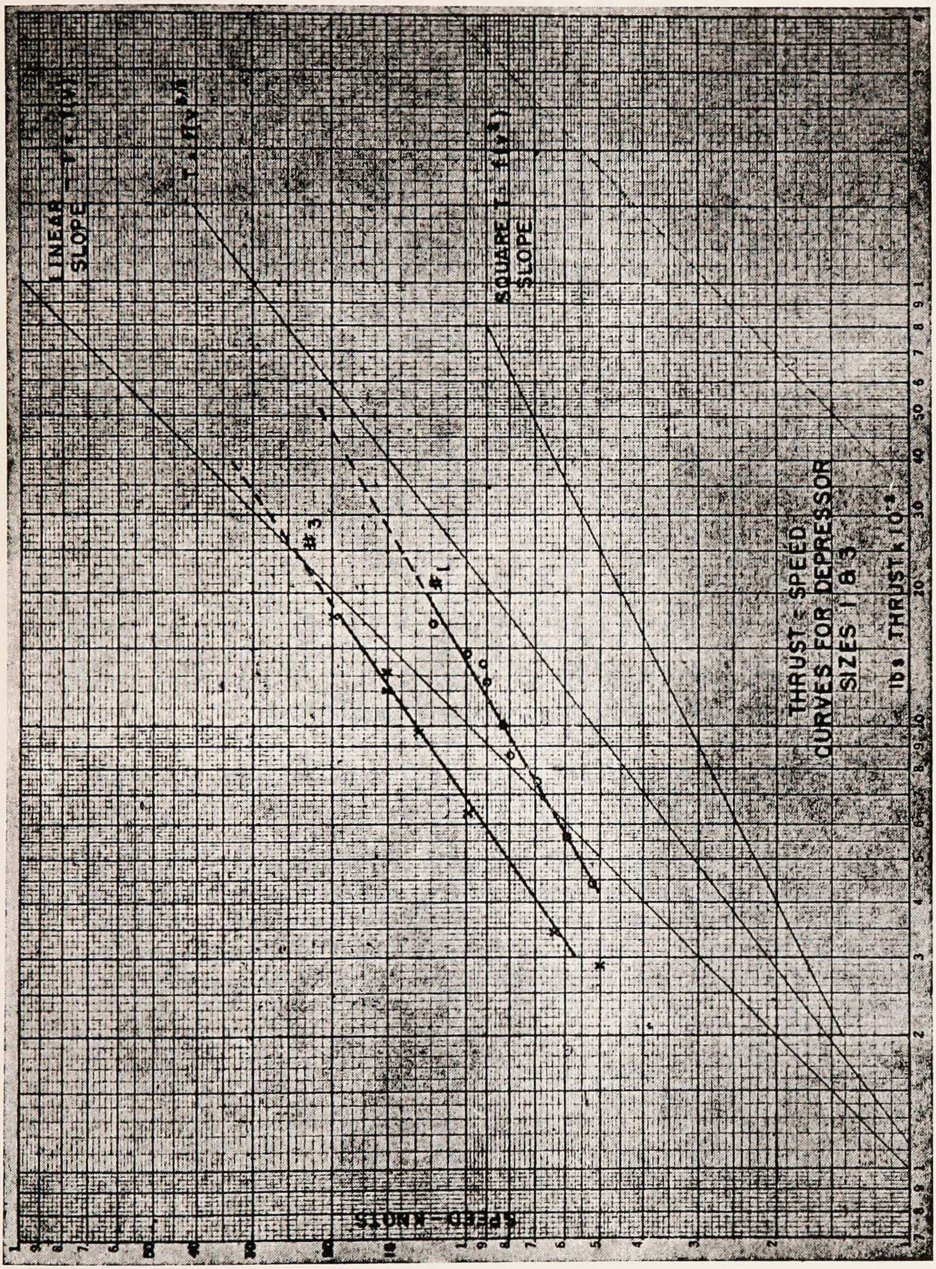


Figure 8. Thrust-Speed Charts for No. 1 and 3 Depressors.

Fig. 9 shows the form of a fairing developed by Navy Electronics Laboratory. NEL tests indicate a drag of 1.1 lb./ft. at 10 knots for this fairing in a condition of normal flow. The fairing was used in tests illustrated in Fig. 7.

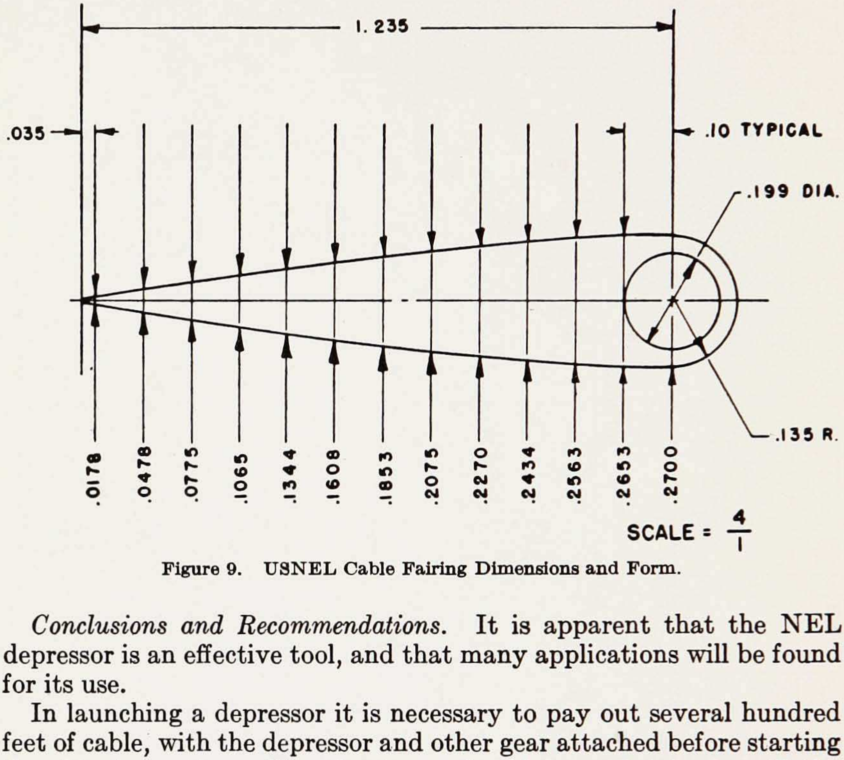


Figure 9. USNEL Cable Fairing Dimensions and Form.

Conclusions and Recommendations. It is apparent that the NEL depressor is an effective tool, and that many applications will be found for its use.

In launching a depressor it is necessary to pay out several hundred feet of cable, with the depressor and other gear attached before starting the ship in motion. Bare headway should be maintained until the depressor has reached stable depth, as a fast start will cause the depressor to dive at high speed and thereby develop damaging cable tension.