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Full Scale Resistance Tests of Yankee Trawls of both Nylon and Polyethylene Construction

by
Clifford A. Goudey
and
Robert S. Mant

MIT Sea Grant Program
Center for Fisheries Engineering Research
Building E38-376, 292 Main Street
Cambridge, MA 02139

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Massachusetts Institute of Technology Sea Grant Program

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Massachusetts Maritime Academy Fisheries Program

1. INTRODUCTION

The Yankee trawl is a popular net in the New England bottom fishery. It is a net of simple design and is therefore easy to construct and repair. The basic design has numerous variations and it is found in a wide range of sizes. The stretched mesh size for these trawls is usually between 3 and 5-1/2". For years these trawls have been constructed of nylon webbing, however, now polyethylene is a more popular construction material.

The advantages of one material over the other are a subject of debate amoung net builders and fishermen. Polyethylene webbing is considerably less expensive than nylon of similar measurements. Due to the larger diameter, more robust fibers from which polyethylene twine is made, it is also more resistant to abrasion. Nylon, on the other hand, is stronger for the same diameter twine and has more stretch. In addition, nylon is denser than water while polyethylene is less dense and will float. Polyethylene also has greater stiffness, and webbing and nets of this material seem to be larger and bulkier than their nylon counterparts. Polyethylene nets also tend to dry out faster in air, therefore collected debris can be shaken out more easily.

The effect these differences have on the fishing characteristics of the nets is not totally understood. There is conjecture among fishermen that one type of material tows more easily than the other. To quantify any differences, two nets of identical construction were assembled for comparative resistance tests. It was anticipated that the differences would be small and therefore data from sea trials would lack the necessary accuracy and control.

Tests were planned using the 52' wide towing basin at the David W. Taylor Naval Ship R&D Center in Bethesda, Maryland. The MIT Sea Grant Project Center for Fisheries Engineering Research was completing the fabrication of a towing strut apparatus for conducting full scale tests from Towing Carriage No. 1, and arrangements were made for these comparative tests to be the first conducted using the apparatus.

2. TRAWL NET DESCRIPTION

The trawl design selected for the experiments was a modified Yankee 35 typical of the nets used aboard smaller inshore draggers. The construction plan is shown in Figure 1. The total headrope length is 39' and the footrope length is 54'. A full length sweep of 5" rubber cookies was employed. Five 8" aluminum floats were attached along the headrope. The configuration is a typical rig used for flounder on moderately smooth bottoms.

The nylon version had recently been made for the Fisheries Training vessel at Massachusetts Maritime Academy. An identical net was assembled using polyethylene webbing.

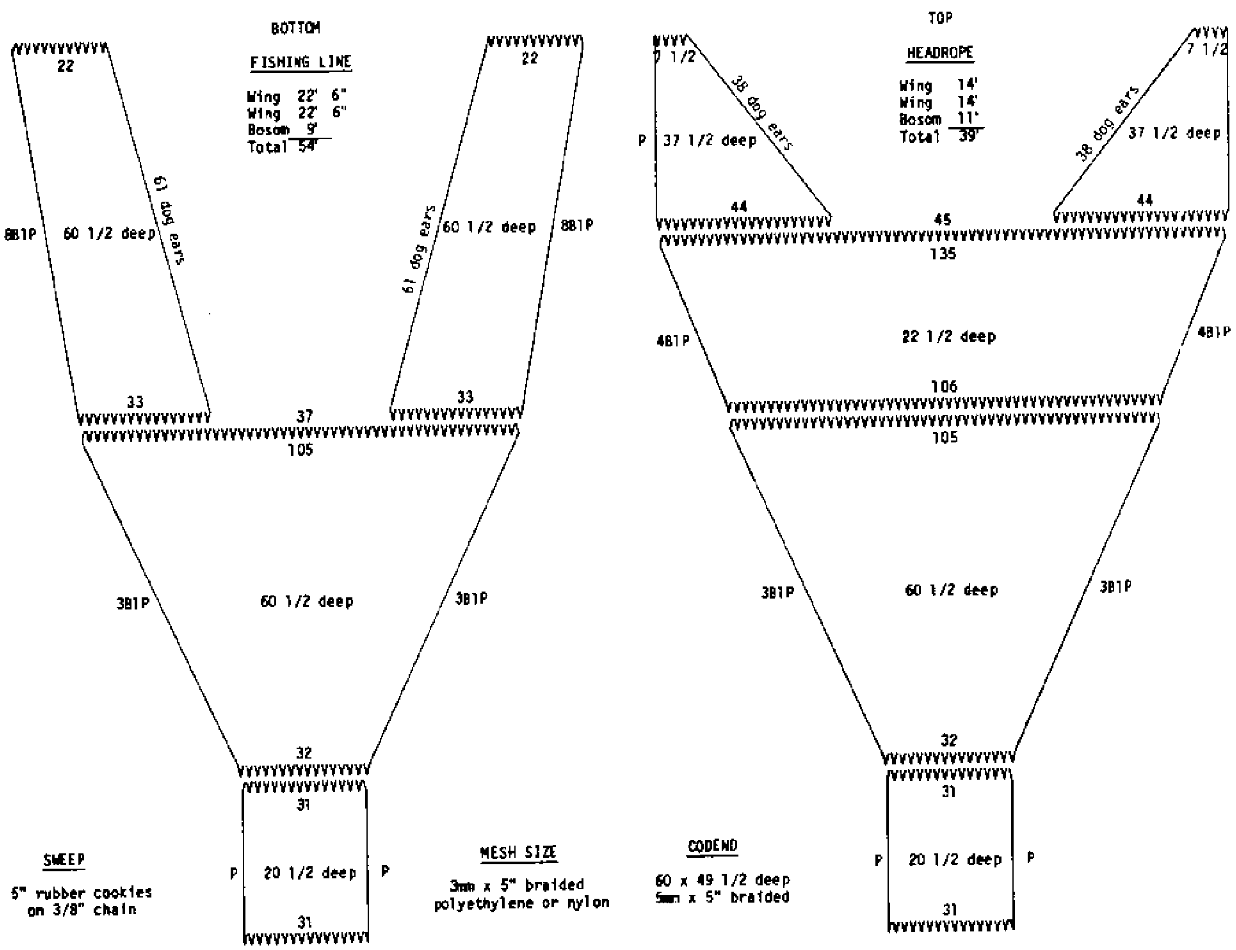

Figure 1. Modified Yankee 35 Bottom Trawl.

3. TEST FACILITY

The David W. Taylor Naval Ship R&D Center houses the largest hydrodynamic test facilities in the free world. The 52' wide towing basin is ideal for the testing of full sized or very large scale models of fishing trawls. The basin is 3078' long and is divided by a wave-making unit into operating areas for two towing carriages. Towing Carriage No. 1 operates over a 1192' long portion composed of a 303' long, 10' deep section and an 889' long, 22' deep section.

This carriage, shown in Figure 2, is basically a monorail structure which spans the channel width and is supported by idler wheels on the far side. The main rail supports the power, drive, braking and control systems. Two 75 horsepower electric motors drive hydraulic pumps which power four drive motors each coupled to a drive wheel. The maximum carriage velocity is 18 knots and it can tow equally well in either direction. Carriage No. 1 is equipped with an observation boom which can pivot over the towed net for viewing or taking measurements.

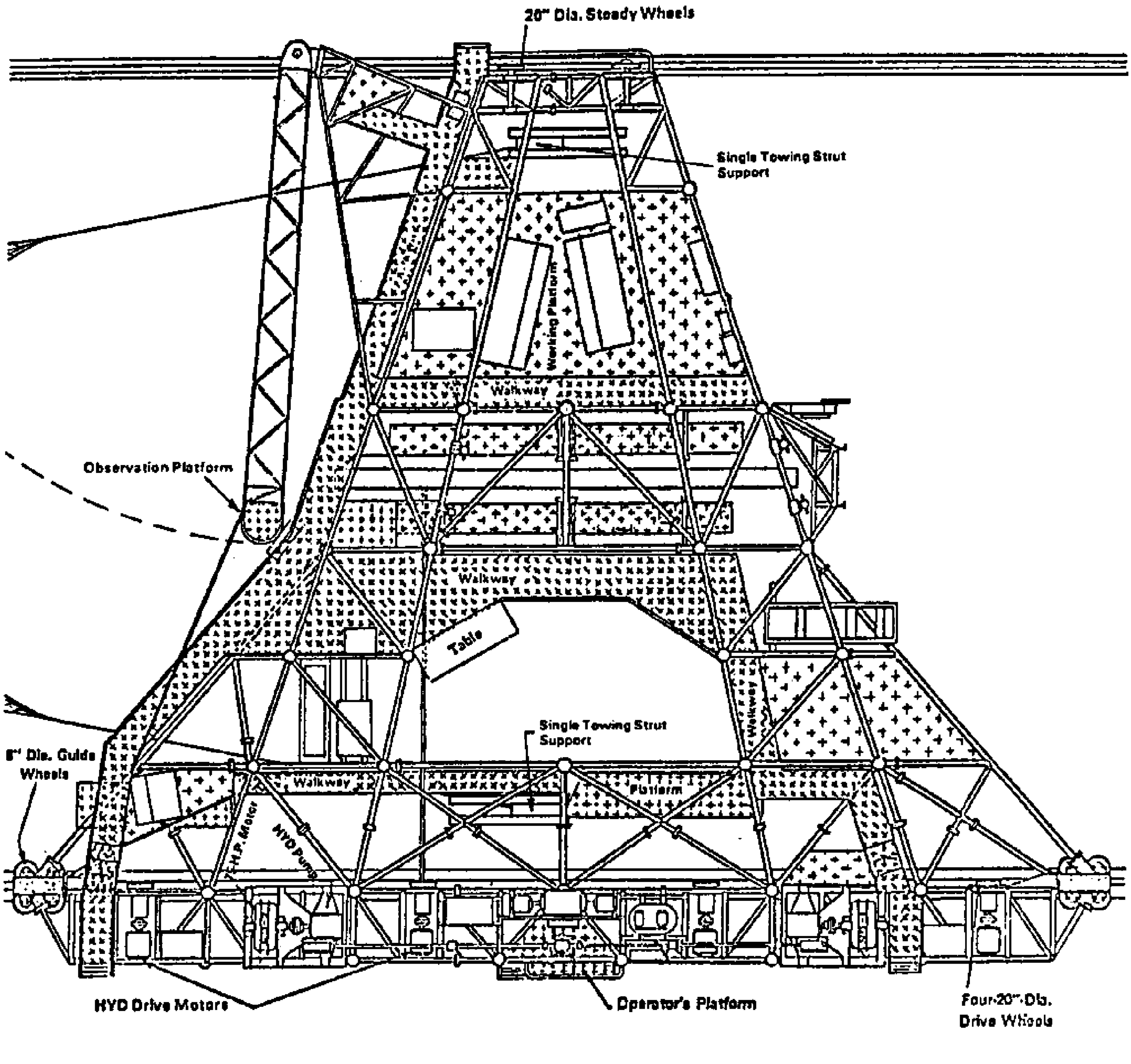

Figure 2. Plan View of Towing Carriage No. 1.

To allow the testing of trawl nets, a dual towing strut apparatus was designed and fabricated. Struts were required that reached to the bottom of the 10' deep basin yet were strong enough to withstand the towing forces anticipated. In addition, most Navy tests on this carriage are done with models or gear towed from various fixtures along its mid-span. The testing of trawl nets would require widely placed tow points, therefore special strut foundations were required to transmit the towing forces to the carriage structure.

The struts and their foundations are shown in Figure 3. Their total length is 12'-6 1/2" and they are streamlined in cross section and taper uniformly over their length. The trailing edge of each strut has a series of vertically spaced towing points. The struts have a clearance of 2" above the basin bottom. The lowest towing point is 1" from the end of the strut. Construction details of the struts are contained in Appendix I.

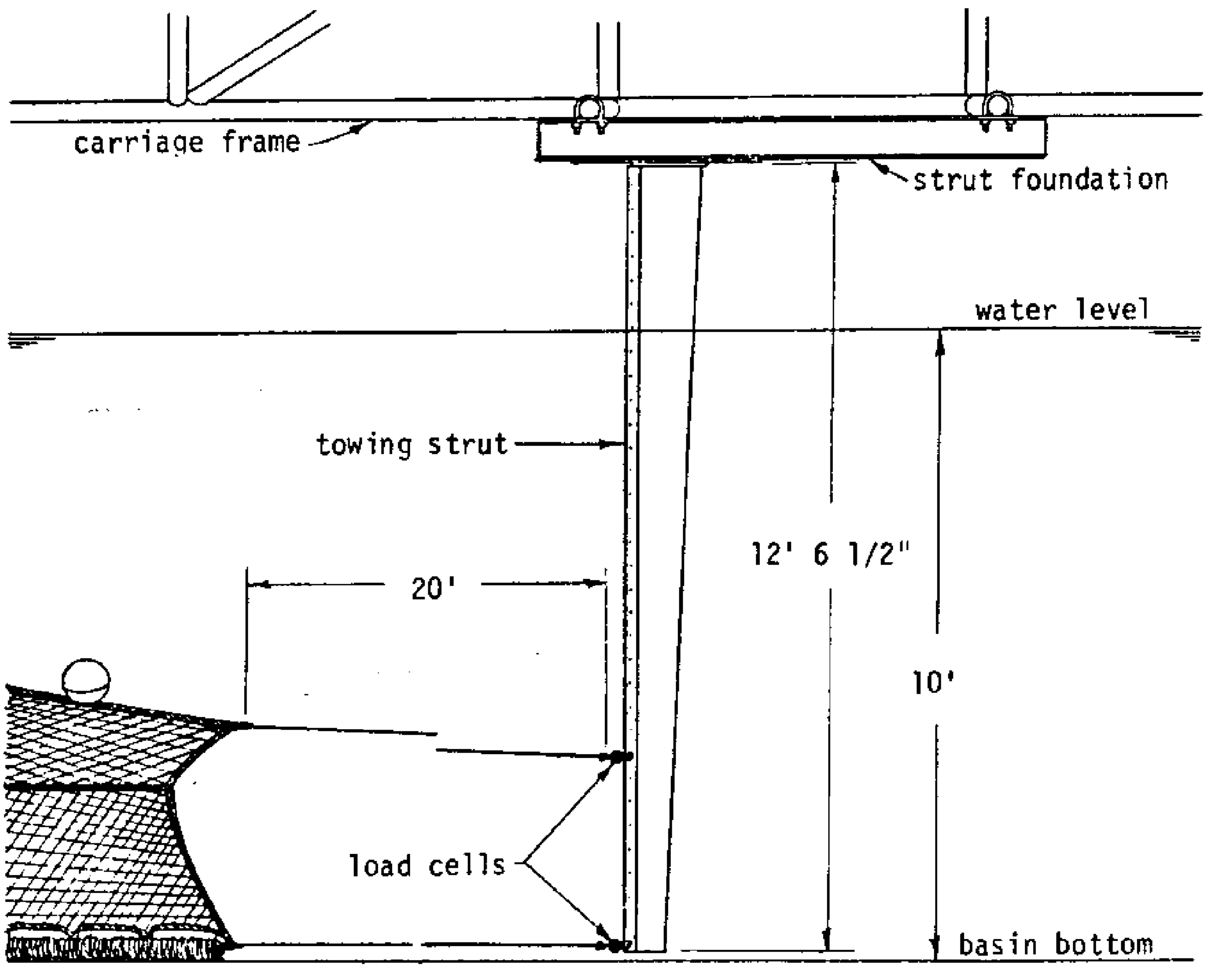

Figure 3. The 12'-6" Towing Struts Mounted on Carriage No. 1.

4. EXPERIMENTAL PROCEDURE

Strain gauge load cells were used to measure the tension in four towing cables. The load cells were placed at the towing struts and connected to the net by 20' lengths of towing cable. Electrical cables from the cells were led up the struts to instrumentation centrally located on the towing carriage. Strain gauge balancer/amplifiers were used for each cell which were in turn interfaced with a multichannel strip chart recorder.

The shallow end of the basin was used, allowing ample distance during each run for the trawl to achieve equilibrium configuration and to obtain sufficient steady state data. Before beginning each run, the codend was pulled tight from the end of the basin to minimize the time required to assume a towing shape. (See figure 4.)

The 20' long bridles were of 5/16" wire rope. The lower attachment to the strut was 3" above the basin bottom and the upper attachment point was 4'-3" from the bottom. Runs were made at velocities ranging from 0.5 knots to 3.4 knots. The same rubber sweep was attached to the second net upon completion of the first series of runs.

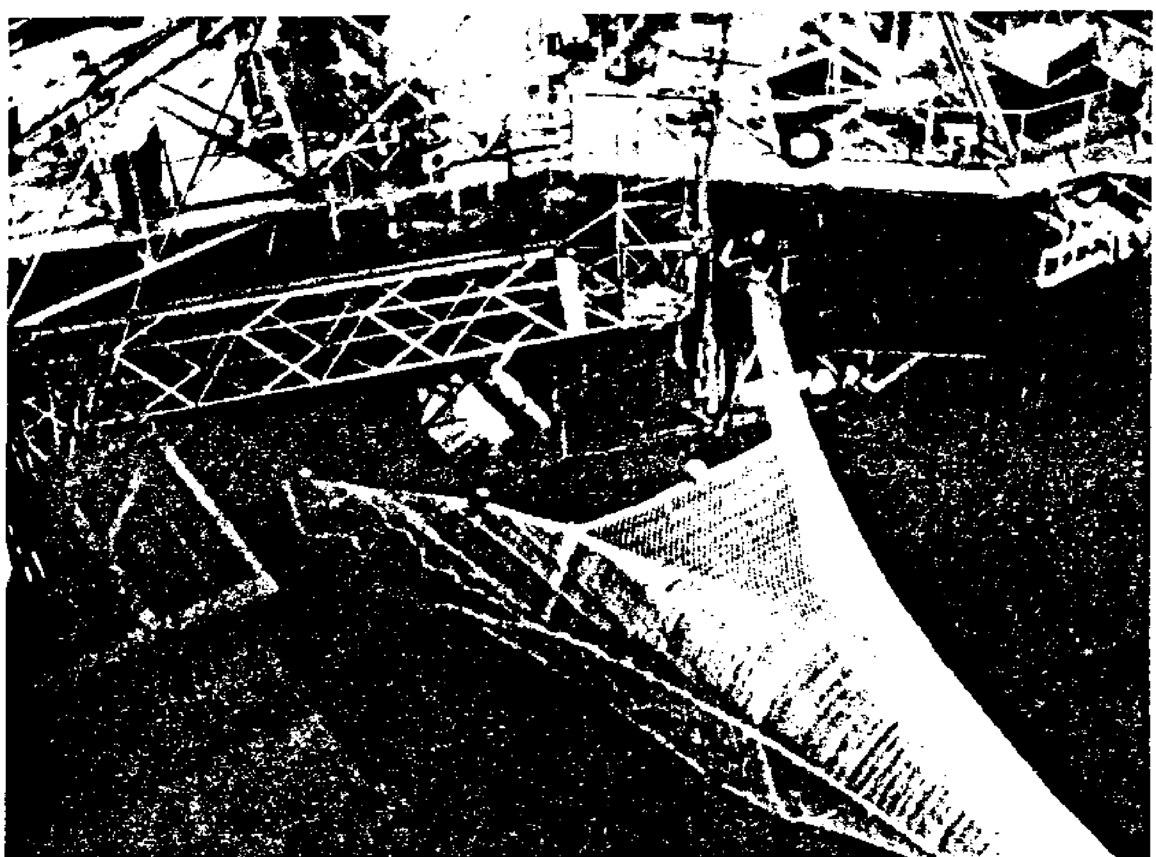

Figure 4. The polyethylene version attached to Carriage No. 1 before the beginning of a run.

5. RESULTS

The load cell measurements are presented in Table 1. The wingspread was the same for all runs, 25' at the headrope and 27'-6" at the footrope.

	Velocity (knots)	Cable tension (pounds) stbd lower	stbd upper	port upper	port lower	Sum (pounds)
Poly	0.50	36	17	16	30	99
	1.44	91	114	108	86	399
	2.44	180	281	252	186	899
	3.40	344	500	444	356	1644
Nylon	1.97	156	152	164	172	644
	2.44	198	268	264	204	934
	2.96	264	372	366	270	1272
	3.40	344	475	445	356	1620

Table 1. Load cell measurements of cable tensions for modified Yankee 35 trawl nets of nylon and polyethylene construction.

The half knot run was intended as a low speed run to check for any obstructions along the basin bottom. The resistance data from that run, when compared with that of the higher speed runs, and assuming the friction forces of the rubber sweep along the bottom are constant, indicates that the baseline bottom friction contribution to the total cable tension is approximately 50 pounds for the polyethylene net.

6. ANALYSIS

The towing resistance of the net is the component of the cable tension in the direction of tow. The resistance of the trawl system also includes the drag contribution of the trawl doors. The hydrodynamic coefficients of common trawl doors are $C_l = 1.0$ and $C_d = 0.8$.[1] The spreading force requirements are determined from the cable tensions and their horizontal angles. The following relations apply:

$$\text{Trawl net resistance} = R_{net} = \text{Sum}(\cos\theta)$$

$$\text{Spreading force req.} = F_D = \frac{\text{Sum}}{2}\sin\theta + \frac{R_{tot}}{2}\tan\phi \qquad (1)$$

Since $\tan\phi$ is approximately equal to $\sin\phi$ at small angles, equation (1) can be written:

$$F_D = \frac{\text{Sum}}{2}\sin\theta + \frac{R_{tot}}{2}\sin\phi$$

$$= \frac{Sum}{2} \sin \theta + \frac{R_{tot}}{2} \frac{S/2 + L\sin \theta - B/2}{W} \qquad (2)$$

This relation would require iterative calculations since R_{tot} must include the resistance of the trawl doors which has yet to be determined. To speed convergence, the common assumption that the trawl door resistance accounts for one third of the total resistance will be inserted. This assumption can later be validated. Equation (2) now becomes:

$$F_D = \frac{Sum}{2} \sin \theta + 1.5 \frac{Sum}{2} \cos \theta \frac{S/2 + L\sin \theta - B/2}{W}$$

$$= \frac{Sum}{2} \left(\sin \theta + 1.5 \cos \theta \frac{S/2 + L\sin \theta - B/2}{W}\right) \qquad (3)$$

Door resistance = $R_D = F_D\ (C_d/C_l)$

Total trawl resistance = $R_{tot} = R_{net} + 2R_D$

Where: C_l = Trawl door coefficient of lift

C_d = Trawl door coefficient of drag

S = Net wing spread

L = Leg length plus ground wire

B = Warp spread at trawler (0 if side trawler)

W = Warp length

Sum = Sum of cable tensions

θ = Angle of legs to direction of motion (avg. of upper and lower)

ϕ = Horizontal angle of warp to direction of motion

Using the above relations and the following trawl parameters, and neglecting warp resistance and curvature, the data in Table 1 can be used to estimate resistance values for the complete trawl system.

S = (25 + 27.5)/2 = 26.25'

L = 20 fm = 120'

B = 0 (single tow point)

W = 120 fm = 720'

	Velocity (knots)	Net Resistance lower	upper	(pounds) total	Spread Force (pounds)	Door Resist (pounds)	Tot Resist (pounds)
Poly	0.50	58	29	87	30	24	135
	1.44	196	156	352	119	95	542
	2.44	323	471	794	268	214	1222
	3.40	618	833	1451	491	393	2237
Nylon	1.97	289	279	569	192	154	877
	2.44	355	470	825	279	223	1271
	2.96	471	652	1123	380	304	1731
	3.40	618	812	1430	484	387	2204

Table 2. Trawl system resistance for modified Yankee 35 trawl nets of nylon and polyethylene.

In this example, the distance between the trawl doors is 139', a spread which could be achieved by trawl doors of approximately 34 square feet in area. Such doors (8'-6" x 48") are large for a net this size, indicating the nets were somewhat overspread during these tests.

It should be mentioned that in addition to the simplifying assumptions stated earlier, this analysis neglects the bottom friction components of the trawl doors. These additional forces would result in altered spread values and increased total system resistance.

It is apparent from the results in Table 2 that there is little difference in the total resistance of these nets when constructed of nylon or polyethylene. This agrees with comparisons done by Galbraith[2] at the Marine Laboratory, Aberdeen, using full scale sea trials. He concluded that the two materials could be used interchangeably in standard survey gear without affecting the performance.

When the results of the resistance values of the upper and lower portions of these trawls are viewed separately, some interesting trends are revealed. These results are plotted in Figure 4. In both nets, the relative resistance of the upper and lower portions of the net reverse. At lower towing speeds the footrope supports more of the load while at higher speeds the headrope takes most of the load. The reason for this crossover is that the frictional drag of the sweep is relatively constant as long as it remains in contact with the bottom, while the hydrodynamic forces are approximately proportioned to the square of the velocity. The sweep's contribution therefore becomes less significant at higher speeds, and the headrope load, due to the greater amount of netting it supports, rapidly becomes the dominant factor. In addition, due to the overall hydrodynamic forces, the sweep may have reduced bottom contact forces or be lifted partially from the bottom at higher speeds.

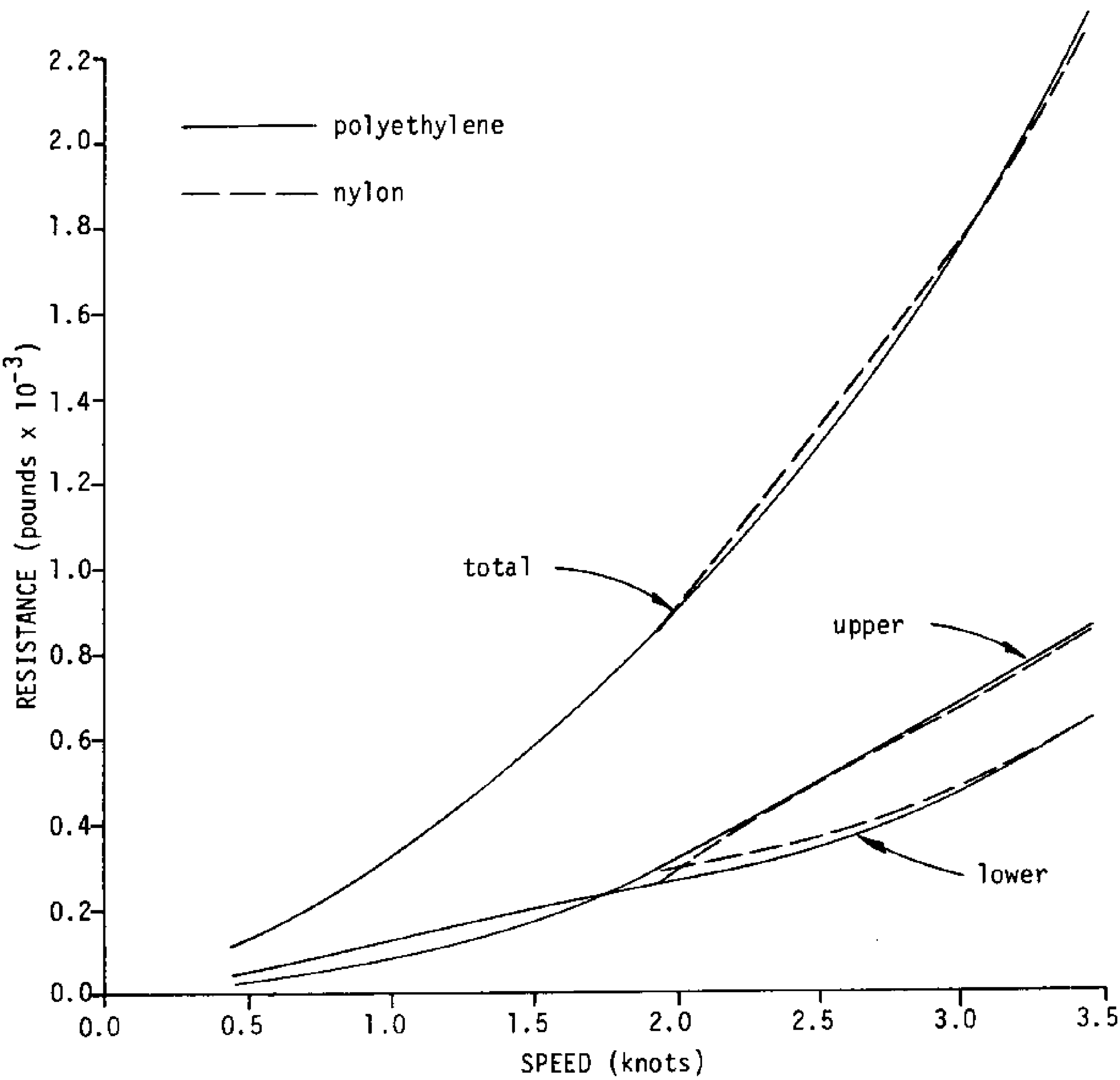

Figure 4. Upper, lower, and total resistance versus speed of modified Yankee 35 trawls in nylon and polyethylene.

It can also be seen from Figure 4 that at low velocities, the footrope of the nylon net experiences higher loads than in the polyethylene net, suggesting that the greater buoyancy of the polyethylene webbing may be lessening the contact force of the sweep and reducing its frictional forces. It should also be noted that the crossover point for the nylon net is at 2.0 knots, while the polyethylene net had a crossover at 1.75 knots.

CONCLUSIONS

1. There was no significant difference in the total resistance of modified Yankee 35 trawls constructed of nylon versus polyethylene.

2. The footrope loads of the nylon net were somewhat higher suggesting increased bottom friction forces in that net.

3. In both nets, the footrope loads dominate at lower velocities (less than 1.5 knots) while the headropes dominate at higher velocities (greater than 2.0 knots).

ACKNOWLEDGEMENTS

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The skillful assistance of the personnel of the David W. Taylor Naval Ship R&D Center is also acknowledged. The fine facilities they operate and maintain are without equal. Their cooperation in the conducting of these tests was appreciated.

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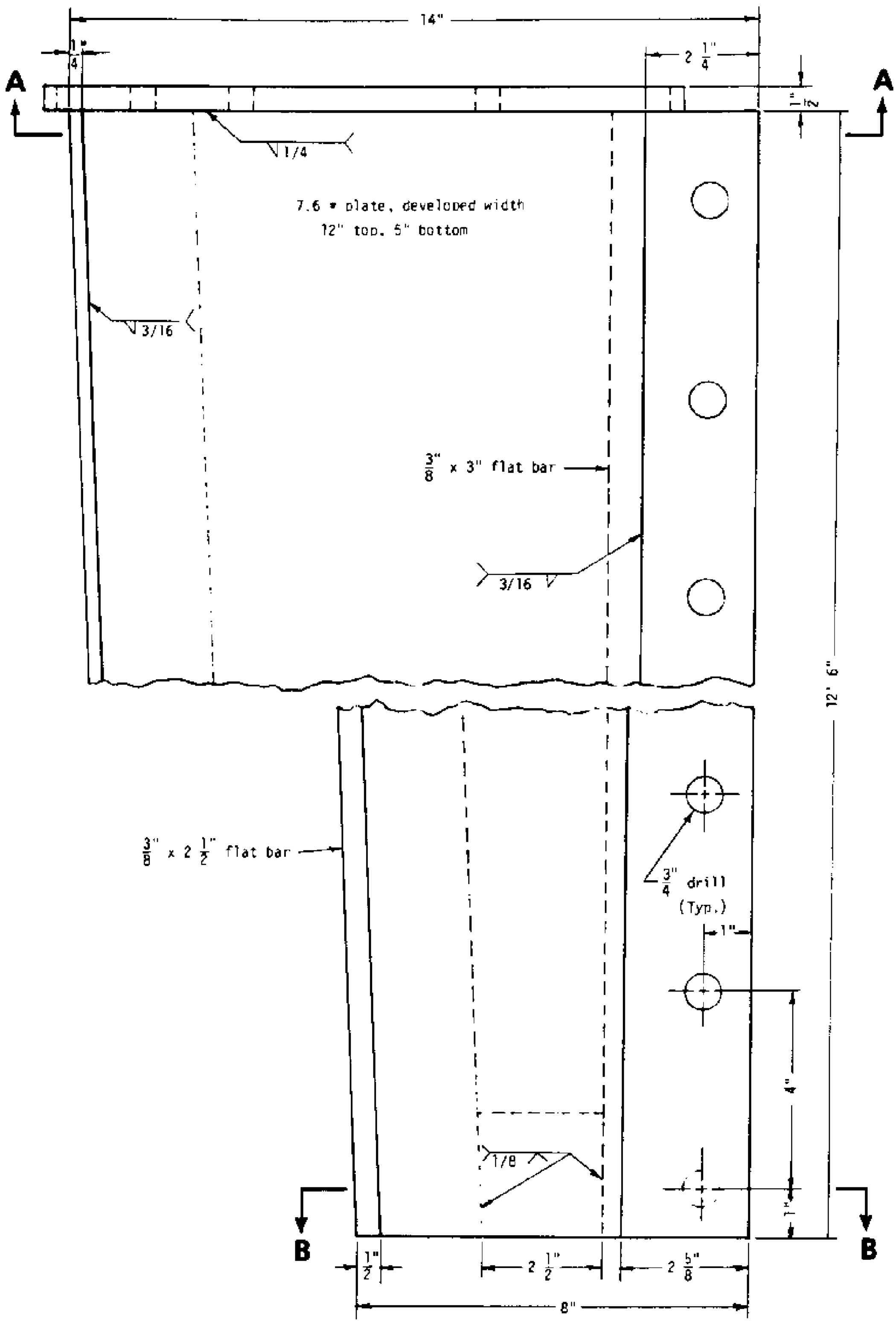
1. Goudey, C.A. 1981. The Development of Efficient Trawl Boards Using Hydrodynamic Model Tests. New England Section SNAME, May 1981.

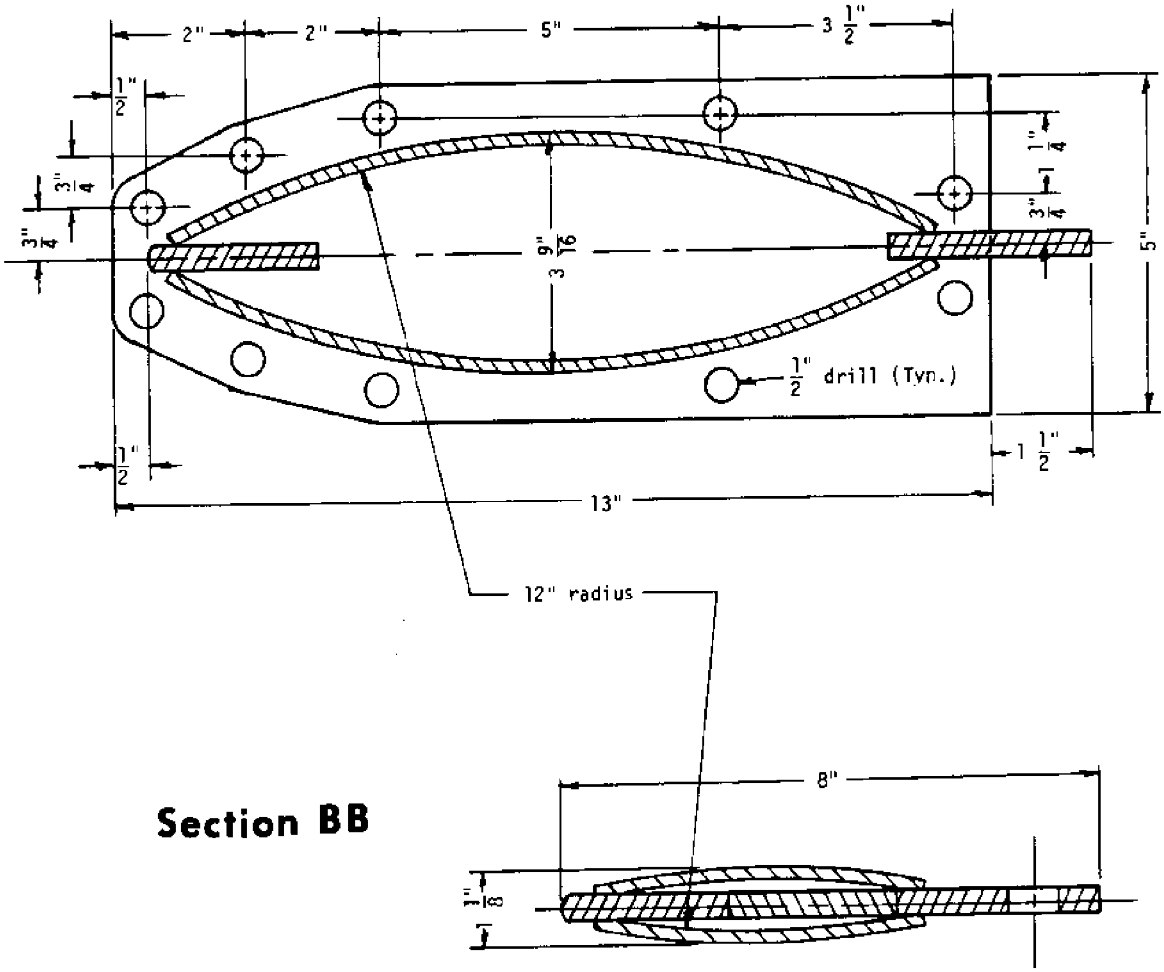
2. Galbraith, R.D. 1982. Performance Trials on Chalut 36/47 GOV Constructed in both Nylon and Polyethelene. ICES Fish Capture Committee, Aberdeen.

APPENDIX I



Elevation View of Towing Strut

Section AA



Crossectional View of Towing Struts