IMPROVING TRAWLER EFFICIENCY

PART II: GEAR EFFICIENCY

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TABLE OF CONTENTS

Trawling Gear

The vast majority of a trawler's power, approximately 80 percent, is absorbed by the trawling gear: warps, doors, ground wires and net. Thus, any serious attempt to improve fuel efficiency must include a careful analysis of the fishing gear. A brief description of various trawling methods will be given, but the main concentration will be on the popular and efficient bottom trawl where the net opening is spread by "otter boards" or trawl doors. Available data on net drag and door performance will be summarized, and design guidelines for matching the net and door size to available towing power will be given. Finally, factors under operator control, such as speed, warp length, door attachment points and leg lengths, will be analyzed for their effect on trawl performance.

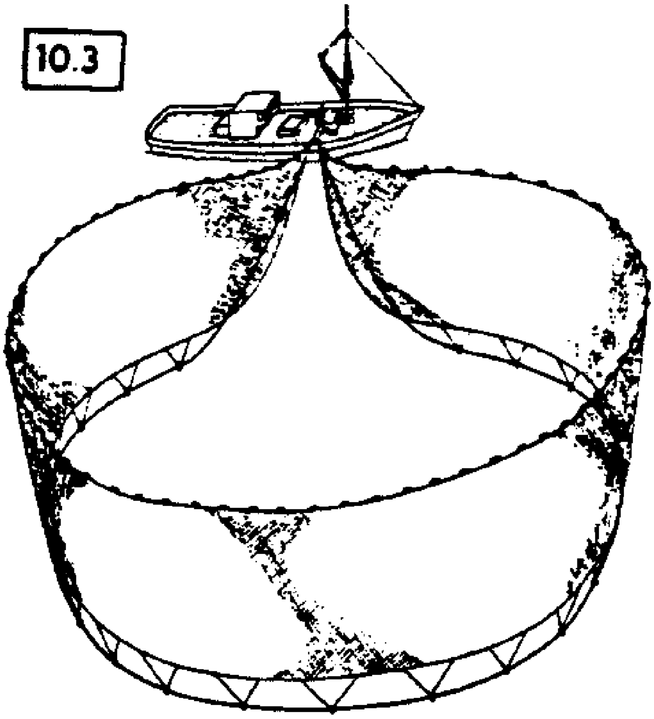
Brief Description of Fishing Methods Seining

1. Seining is carried out in many ways but basically involves positioning the net, with floats on the headline and weights on the footline, around a school of fish using natural forces and the vessel's own maneuverability. It can be carried out with one or two vessels and may also employ a fixed anchor or stake. For surface schools, the upper edge of a "purse" seine is supported by floats and drawn around the fish using the main vessel or a small tender. The drawstring is pulled, closing off the net from underneath and trapping the fish (See Figure 1).

FIGURE 1

Modern Fishing Gear of the World

10.3



Such roller netting has proven very effective on schools of surfaced bluefish in the Chesapeake Bay area and might be used to similar advantage here. Similar techniques are used for midwater and bottom trawling, but the ropes are (hopefully) used to herd the fish towards the net (See Figures 2 through 4).

FIGURE 2

Scottish Seining is Similar to Demersal Pair Trawling
in that the Path of the Seine Ropes Reflects
the Shooting Course of the Vessel

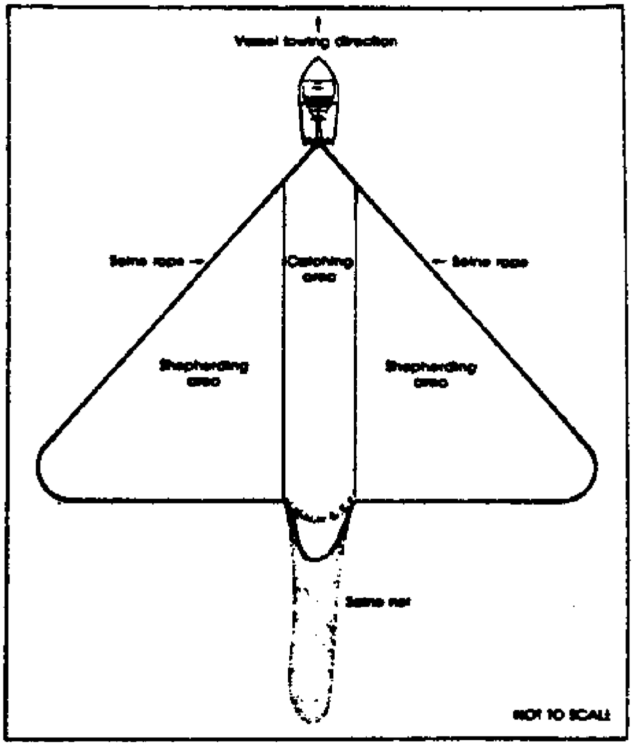


FIGURE 3

Typical Set of a Scottish Seine Net with Vessel Setting 10 Coils a Side on Clean Bottom and the Tide Setting 1 1/2 Knots South by East

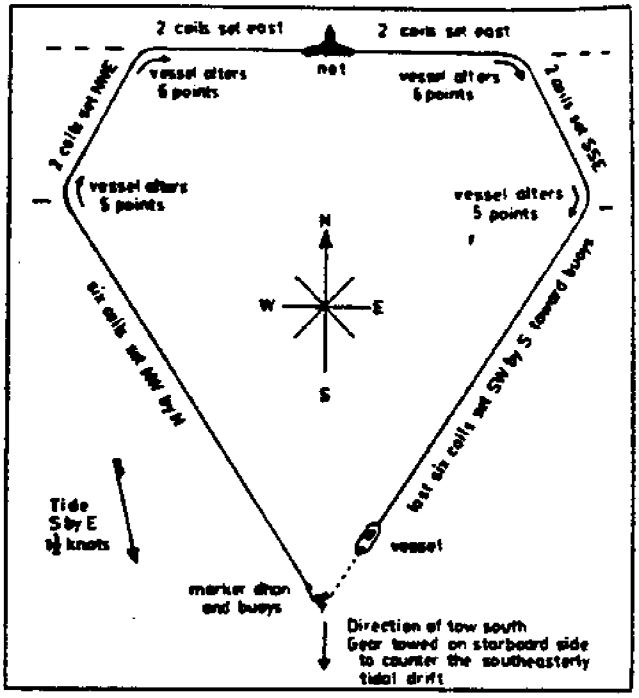
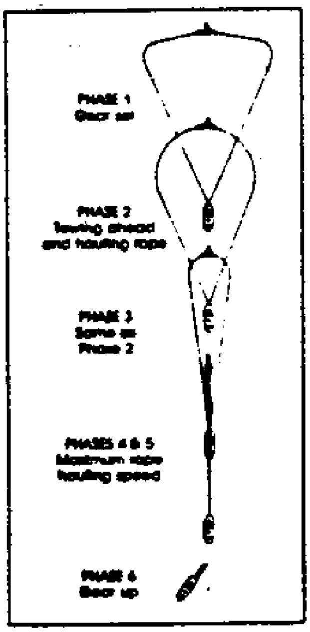


FIGURE 4

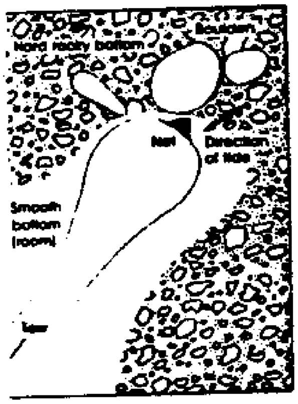
Hauling Sequence in Scottish Seining



As hauling begins, the net loses its spread, trapping the encircled fish. Such "Scottish seining" is quite fuel efficient as little power is needed to position the nets. With practice, sets can be made in highly productive areas near reefs or wrecks which can not be fished by other methods (Figure 5).

FIGURE 5

Scottish Seining in Obstructed Area



Areas covered, however, tend to be relatively small, and much fishing time is lost during the repeated setting and hauling.

While practical for certain species or fishing small areas surrounded by obstructions, seining techniques require considerable skill and are frequently less productive than use of a trawl under tow.

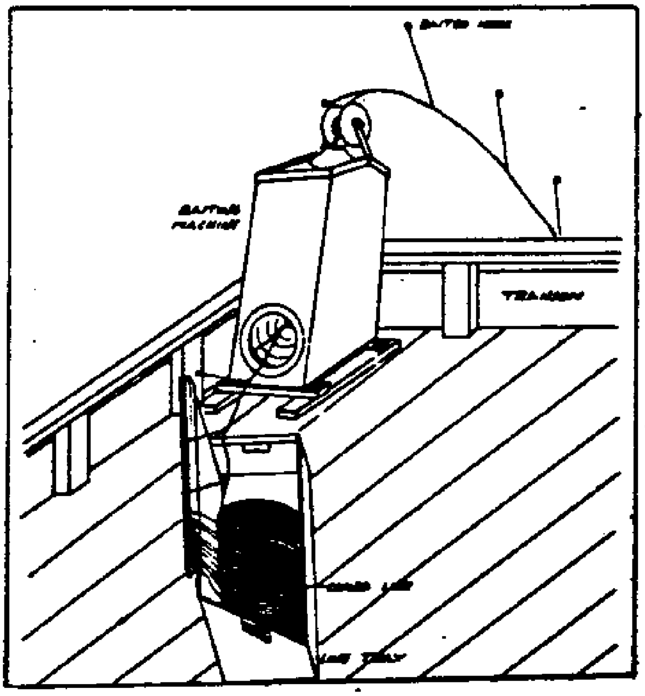
Longlining

The advent of automatic baiting machines and special hooks have made the old trot-line, with baited leaders strung at intervals along the main line, an effective means of fishing for certain species. It is a very low power, fuel efficient operation, but the cost of bait and the necessity of handling each fish individually often mitigate against its use for species and terrain which can be fished by other methods (See Figure 6).

FIGURE 6

Sketch Shows the Proper Location of the Line Tray

in Relation to the Baiting Machine

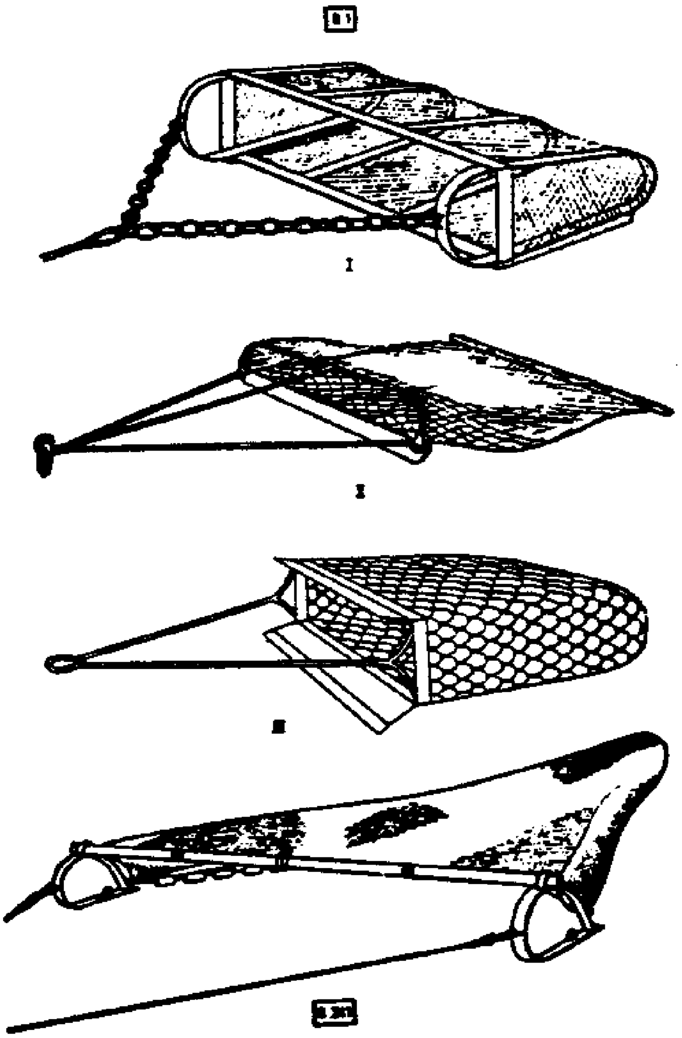


Beam Trawling

Early sailing trawlers, relying on wind and tide, had to accept whatever fishing speeds nature provided, often only one to two knots, where hydrodynamic forces could not be relied upon to hold open the nets. Thus, a rigid frame was provided resulting in a "beam trawl" as shown in Figure 7.

FIGURE 7

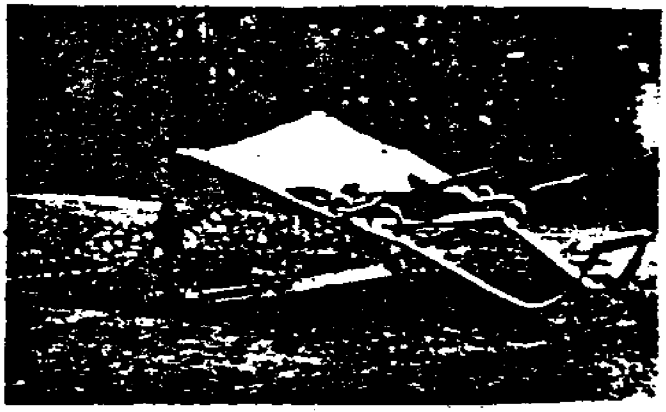
Beam Trawls



A variation on this technique is evident in the shellfish dredge used for mussels, scallops, clams and oysters in the Long Island Fishery (Figure 8).

FIGURE 8

Shellfish Dredge



The frame can also be fitted with a diving plate (not shown) to press it against the bottom and teeth to dislodge shellfish so they can be collected in the catching bag. Other types of beam trawls are still effective for certain pelagic species, but the unwieldy frame limits the size rig which can practically be handled aboard ship.

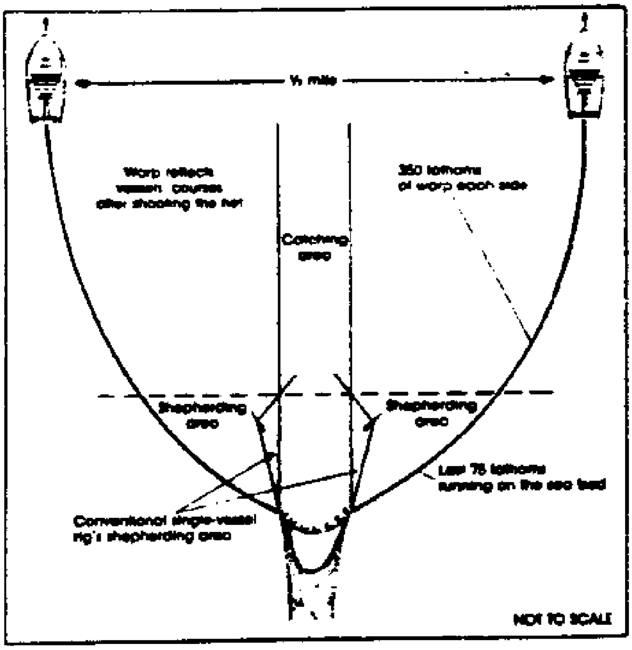
Pair Trawling

Two identical vessels, one attached to each warp, can provide the two force and the required spreading force to hold open the net (Figure 9).

FIGURE 9

Demersal Pair Trawling in 35 Fathoms of Water.

The Warp Reflects the Vessel's Course After Shooting the Net.



Though the vessels will "crab" slightly, thus increasing their hydrodynamic drag, proponents claim that this drag penalty is far less than that associated with other means of achieving the same spreading force. This claim may well be true, and Reference (18) reports that two pair trawlers, with the same total installed horsepower, were able to maintain a considerably greater frontal net area than a larger vessel using conventional trawl doors. Duncan Amos of the University of Rhode Island reports that numerous Scottish vessels have switched to pair trawling because of the fuel economy involved. Nonetheless, a thorough literature search has not revealed sufficient scientific comparison to truly establish these claims, and further research is recommended.

G. Dalton, Reference (19), reports the addition two matched 45-foot pair trawlers (250 HP each) to the Long Island fleet. It will be interesting to compare their performance to conventional methods once they have collected enough experience with these vessels. It should be noted, also, that pair trawling requires a high degree of cooperation between the two captains.

Door Trawling

With the introduction of reliable steam and diesel power, trawling speeds were increased to the point where hydrodynamic forces could be harnessed to provide the required spreading force. Figures 10 and 11 show a typical square otterboard and many of the associated riggings and gear.

FIGURE 10

Typical Bottom Trawl Layout

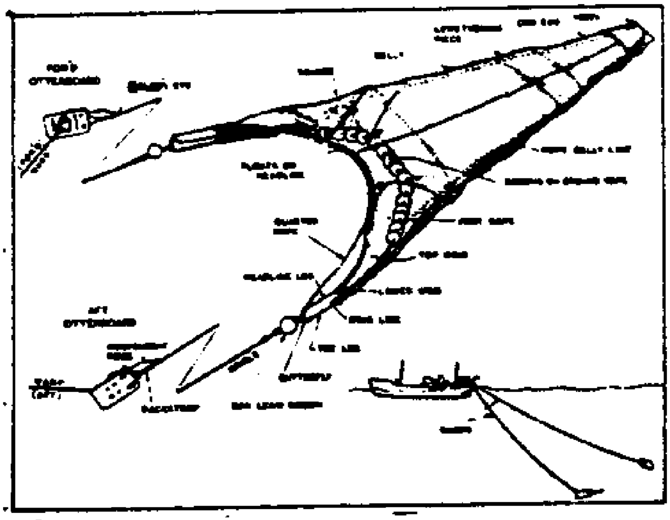
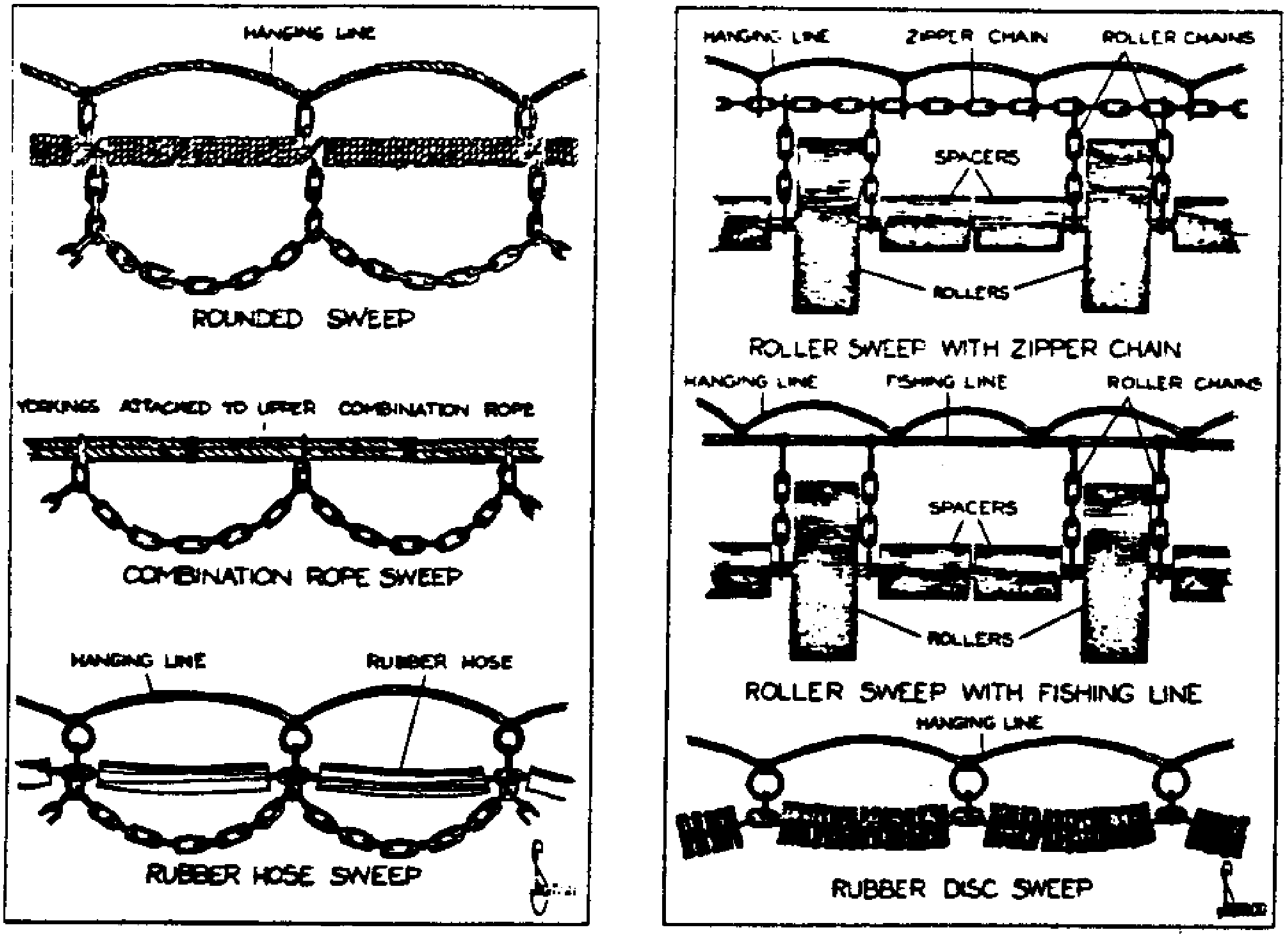


FIGURE 11

Details of Ground Rope Gear for Rocky Bottom



A breakdown of the force distribution in a typical trawling rig is shown in Figure 12. Though these figures are unique to each rig, it is clear that the largest portion of the total drag (50 percent) originates in the net, partly due to hydrodynamic drag and partly to bottom fiction with the ground gear. There

FIGURE 12

Distribution of Forces in Trawling Gear

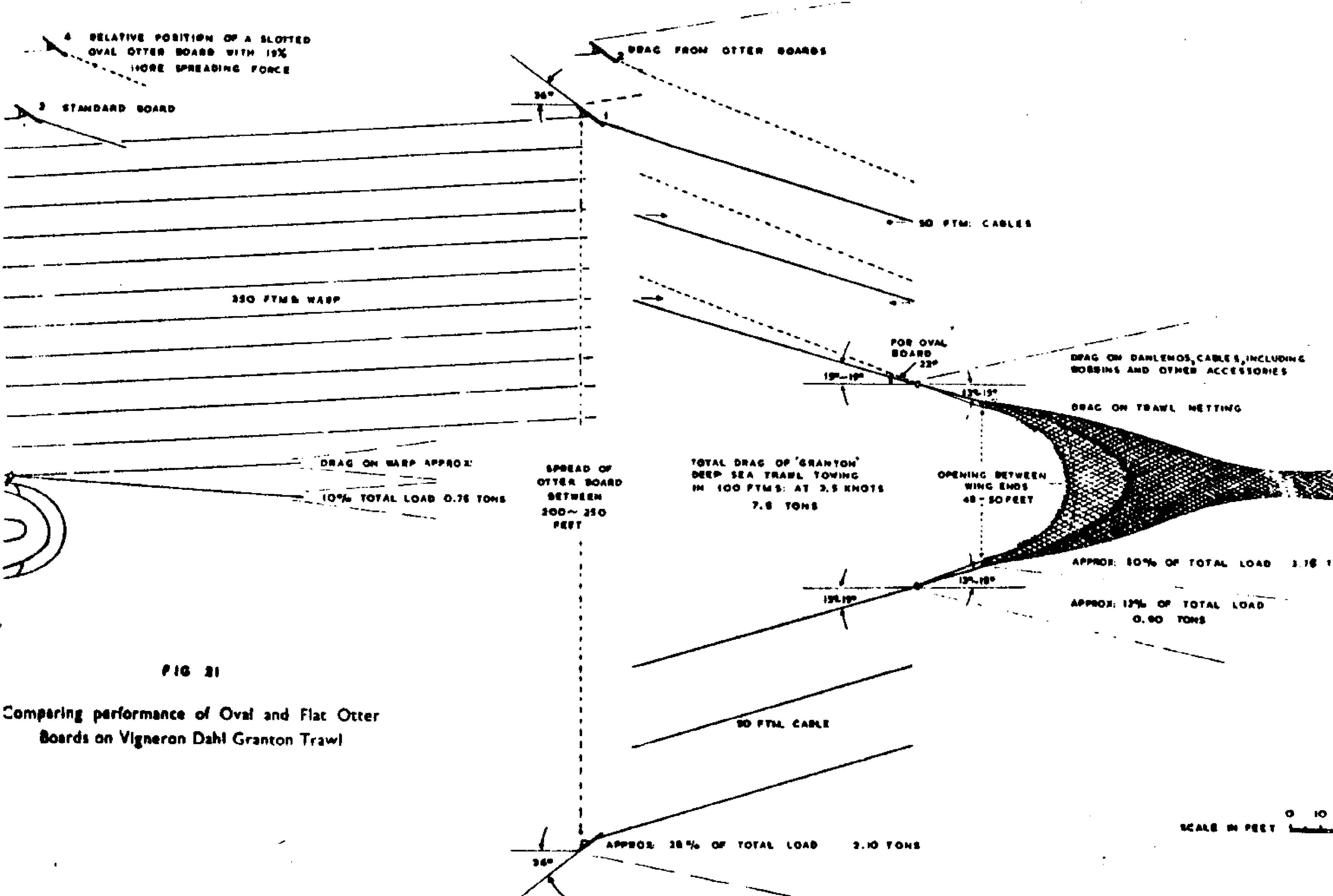


FIG 21

Comparing performance of Oval and Flat Otter Boards on Vigneron Dahl Granton Trawl is ample research on the hydrodynamic drag of netting, References (2), (4) through (6) and (21). Numerous tests have shown that drag can be approximated as a function of twine area:

$$\text{Drag} = V_K^2 \times A/54.72 \times V_K + 115.2$$

The twine area, A (in m^2) is computed by a summation over all panels of different meshes according to a formula given in Figure 13.

FIGURE 13

Calculation of Twine Area [From Reference (6)]

The twine area of a net is calculated in the following manner :–

Partition the net into trapezium shaped panels, $P_1, P_2, \text{———}, P_n$, each panel having constant mesh size and twine size.

Let

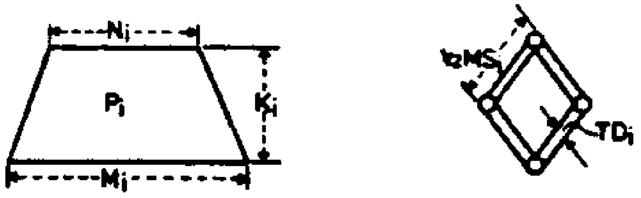
N_i = no of meshes along the top of panel P_i

M_i = no of meshes along the foot of panel P_i

K_i = no of rows (of knots) in the panel P_i

MS_i = mesh size in panel P_i

TD_i = twine diameter in panel P_i



Appendix Figure 1. Notation for the determination of net twine area.

Then

R_i = twine area in panel $P_i = \dfrac{(N_i + M_i)}{2} \times \dfrac{K_i}{2} \times 2 \times MS_i \times TD_i$

in units of mesh size x twine diameter. This must be converted into square metres before using the drag formula. Let C be the appropriate conversion factor*. Then the total twine area, R, is given by

$$R = C \times \sum_{i=1}^{n} (N_i + M_i) \times K_i \times MS_i \times TD_i/2 \ m^2$$

---

* If MS_i and TD_i are in inches then $C = 6.452 \times 10^{-4}$; if they are in mm then $C = 10^{-6}$.

Other methods account for the angle of each cell but are far more awkward to use. Though the distribution of this force within the net is too complex for practical analysis, the required spread force is usually estimated by assuming the force evenly distributed along a catenary curve of the same approximate shape as the headrope (See Figure 14).

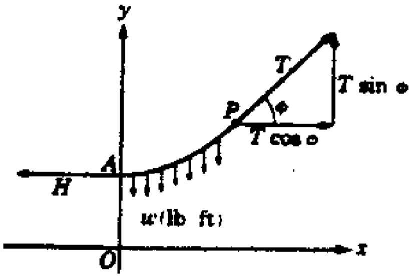
FIGURE 14

Mathematical Equation of a Catenary Curve

(1) H = horizontal tension pulling on the cable at A,
(2) T = tangential tension pulling on the cable at P,
(3) $W = ws$ = weight of s feet of the cable at w pounds per foot of length from A to P.

Then equilibrium of the cable requires that the horizontal and vertical components of T balance H and W respectively:

$$T \cos \phi = H, \qquad T \sin \phi = W = ws.$$



In order to minimize the twine area, the meshes should be as large as feasible, particularly forward. Underwater observations of fish behavior have shown that the wings act, along with the doors and leglines, largely to herd the fish so small mesh is not required there. Moving aft, the mesh is made progressively smaller down to the codend where the catch accumulates. Kowalski, et. al., Reference (4), shows that knotless netting has lower drag particularly at the angles of attack found in the codend. J. Roberts, of the Scottish Fisheries Research, claims square mesh, rather than diamond-shaped, allows better flow and debris passage, resulting in larger, better quality catches.

The variations in net shape are endless, but numerous typical layouts are given in References (24) through (26). Reference (25) also describes various underwater observations by (brave and/or foolhardy) divers affixed to the trawl wire. Increasing door size is shown to increase headline spread, up to a point, and reduce headline height. The three-bridled "tongue" trawl, shown in Figure 15, is observed to have greater headrope spread and height than conventional trawls fished with the same doors (Figure 16). Floats or kites (Figure 17) can also be used to increase headline height, but this depends largely on the cut of net and intended catch. True bottom fish-like flatfish require low, wide nets, while other species may swim five to ten feet off the bottom, requiring nets with greater headrise. (Doors, either two or four, may also be used for midwater trawls but this is not typical of the Long Island Fishery.)

FIGURE 15

Three Bridle Tongue Trawl

[From Reference (25)]

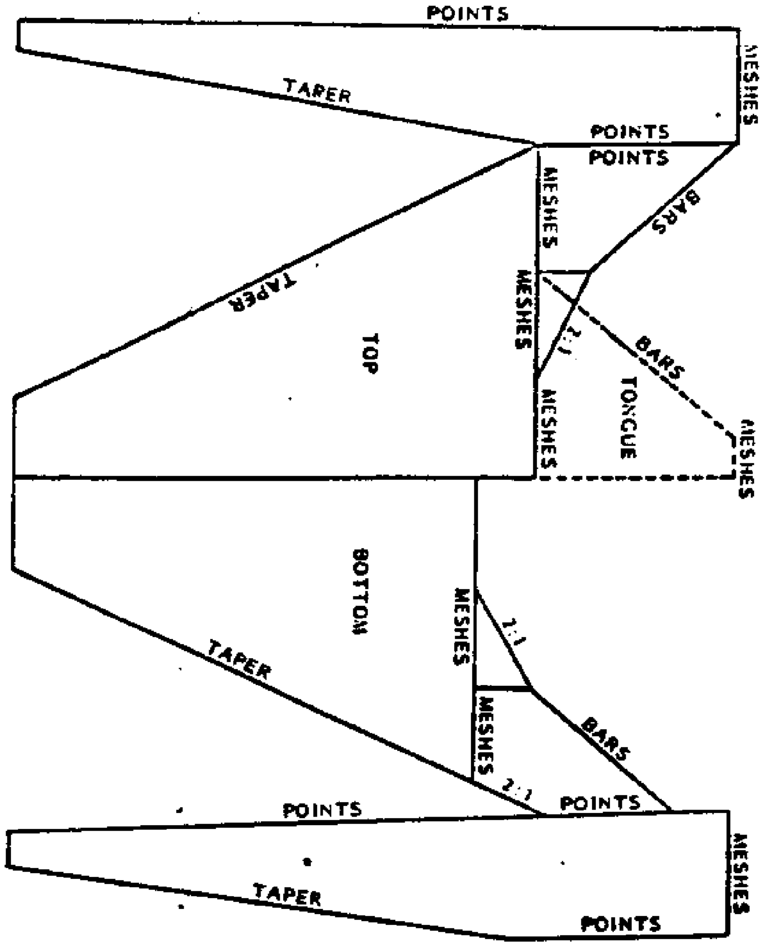


FIGURE 16

Comparison of Gape Dimensions

with 8 Feet by 40 Inch

"Chain Doors of Standard Construction"

[From Reference (25)]

Trawl Type	Spread	Vertical Opening	Spread Ratio
(1) Flat	40'	4.0'	67%
(2) Semiballoon	40'	4.0'	67%
(3) Western Jib Trawl	41'	3.5'	68%
(4) Balloon	42'	3.5'	70%
(5) Super X-3	44'	3.5'	73%
(6) Super X-3 Tongue	51'	2.0'	85%
(7) Cobra/Hood Trawl	49'	2.5'	82%
(8) Mongoose	48'	4.0'	80%

Horizontal spread is the spread of the trawl and does not include the leglines or doors.

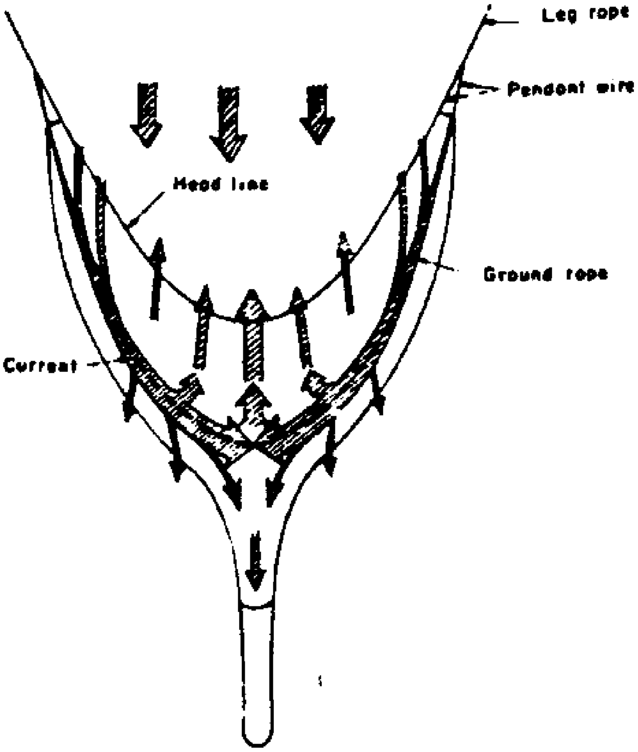
FIGURE 17

Floats and Kites Used to Raise Headline

The design of net shape requires great care to eliminate stress points and ensure proper flow throughout. Reference (15) shows how over-spreading or poor tailoring can lead to choked flow conditions which allow more fish to escape (See Figure 18).

FIGURE 18

Flow Reversal in Overspread Net Allows Fish to Escape



Thus, the net design usually determines the required spreading force. There is still much art in the process of net design but the techniques described here enable a rational design estimate for net drag and required spreading force.

This force is provided by the doors, which, as shown in Figure 12, absorb about 30 percent of the total towing force. Many types of doors have been used successfully, and the major categories are given in Figures 19 to 22.

FIGURE 19

A Conventional Rectangular Otter Board

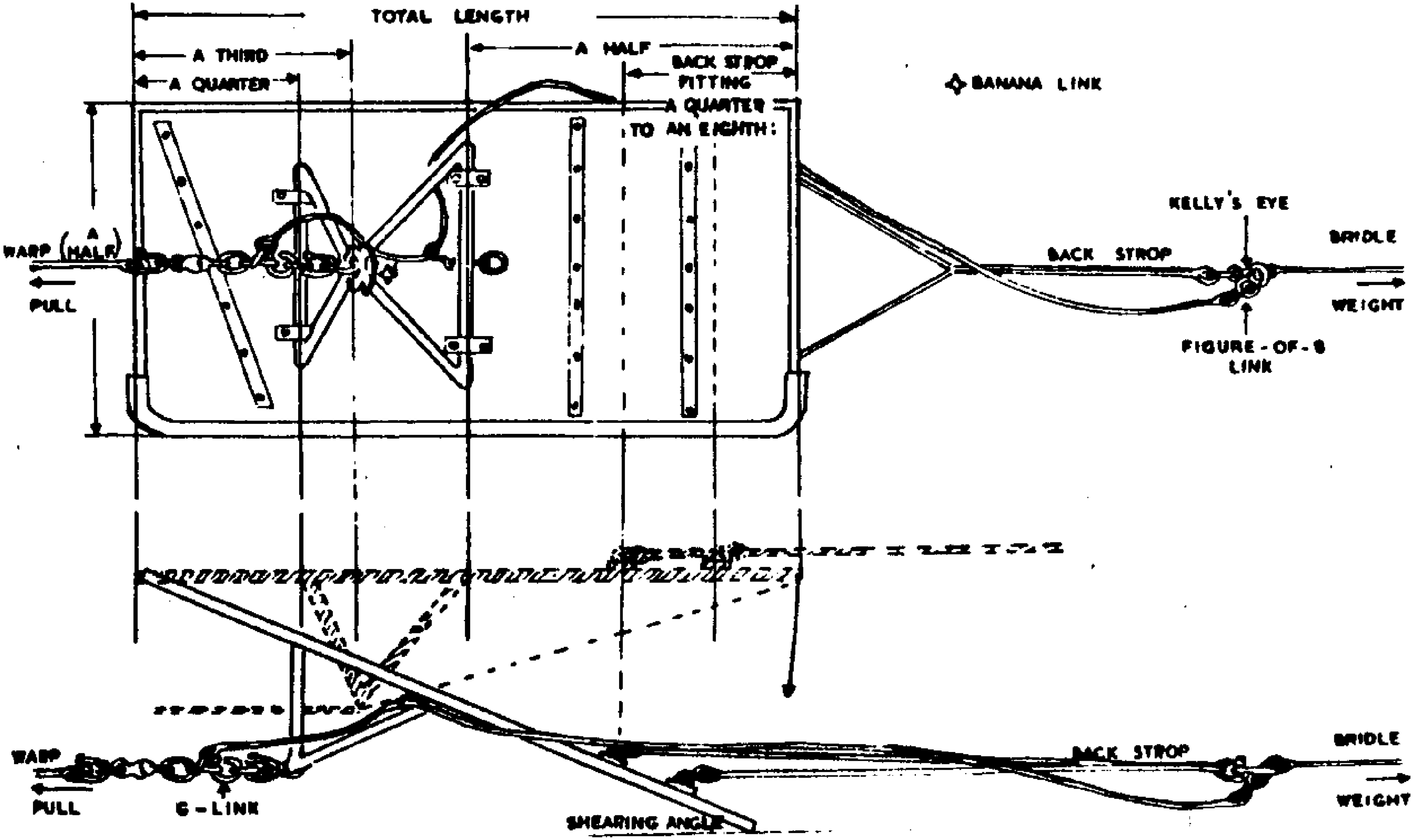


FIGURE 20

Construction Drawing of an Oval Flat Otter Board

With One Slot, About 5.2 m^2

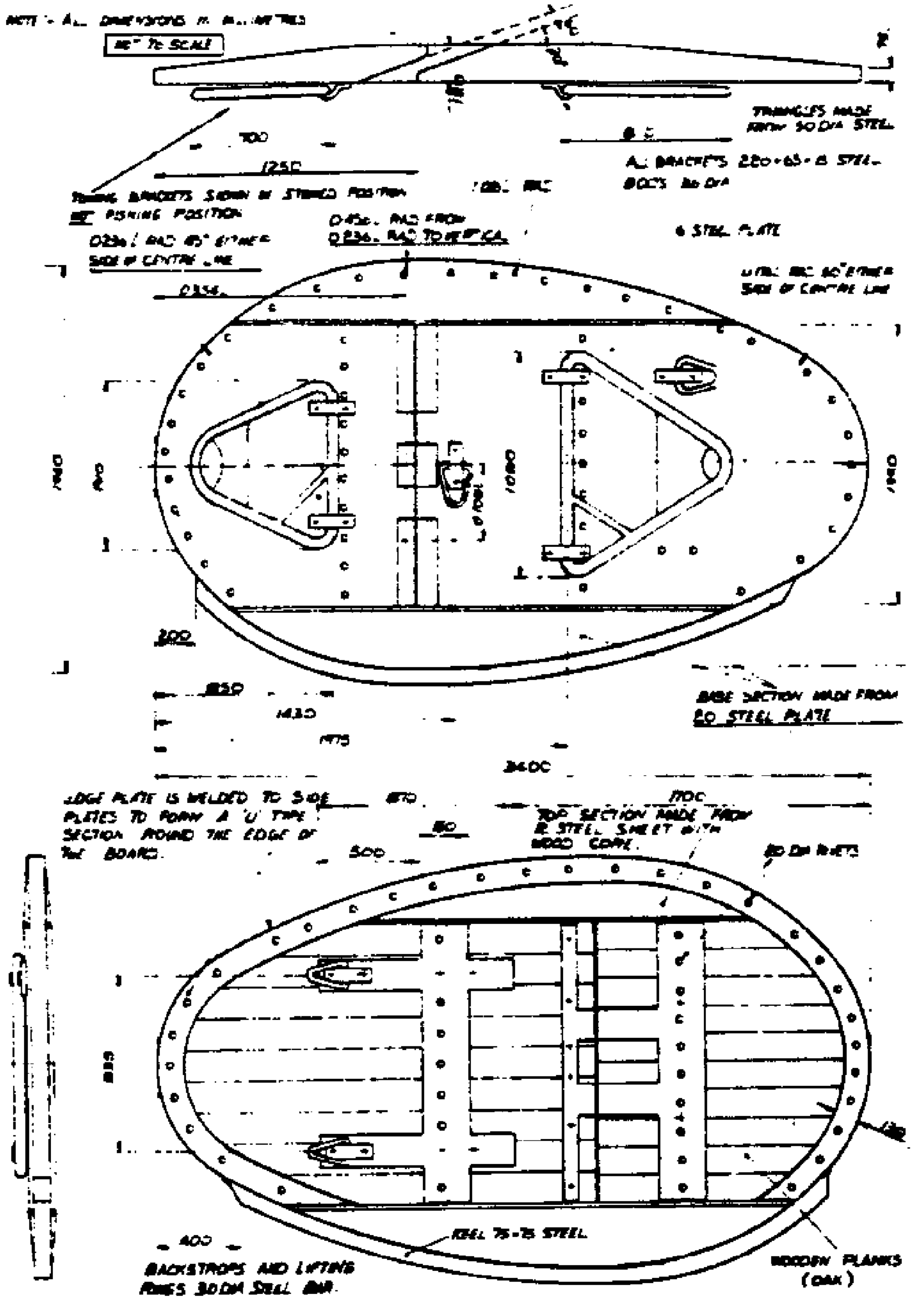


FIGURE 21

Construction Drawing of a Rectangular Vee Type

Otter Board of About 1.3 m^2

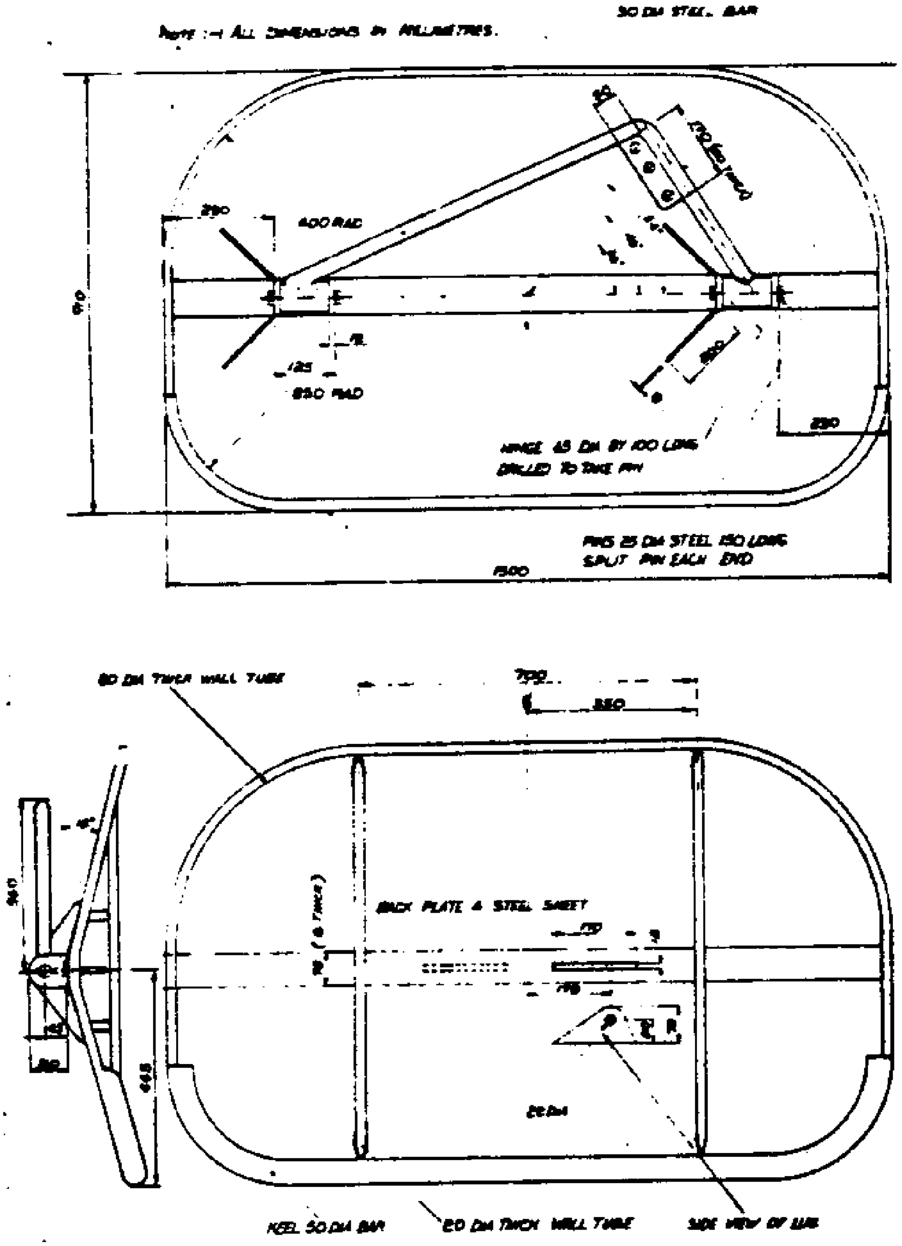


FIGURE 22

Construction Drawing of a Rectangular Cambered Otter Board, High Aspect Ratio (Japanese Type) of About 9.5 m^2, for Bottom Trawling

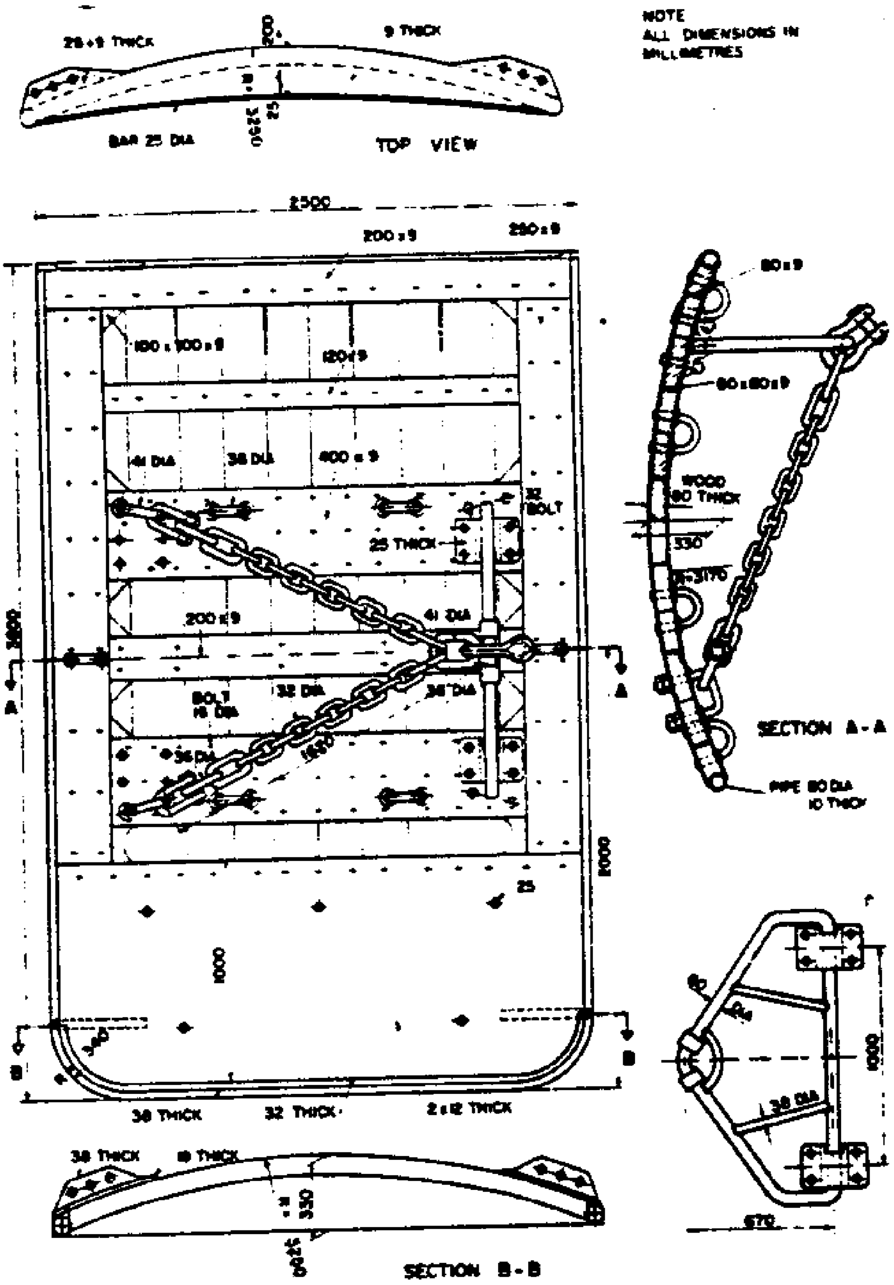


FIGURE 23

Polyvalent Otter Board

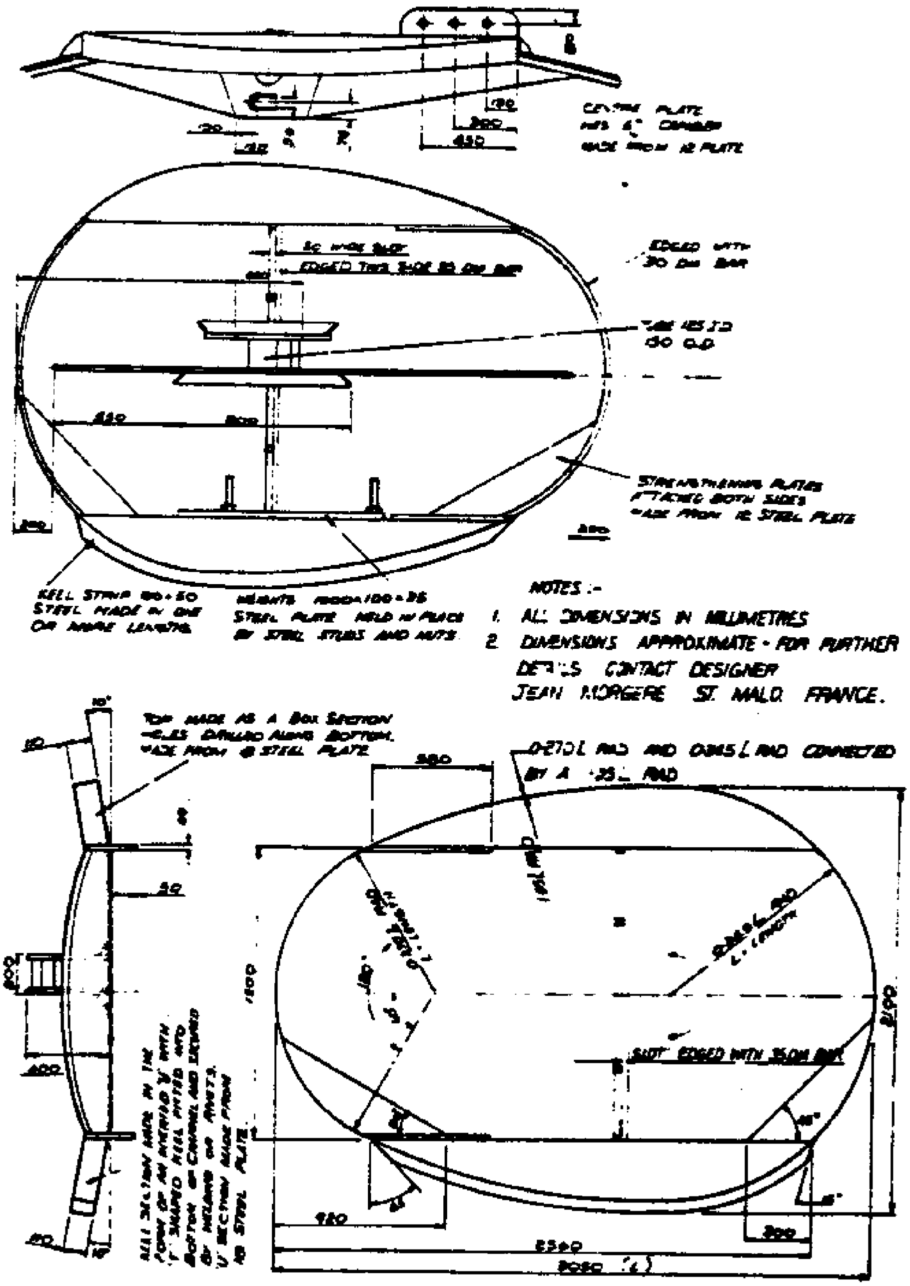
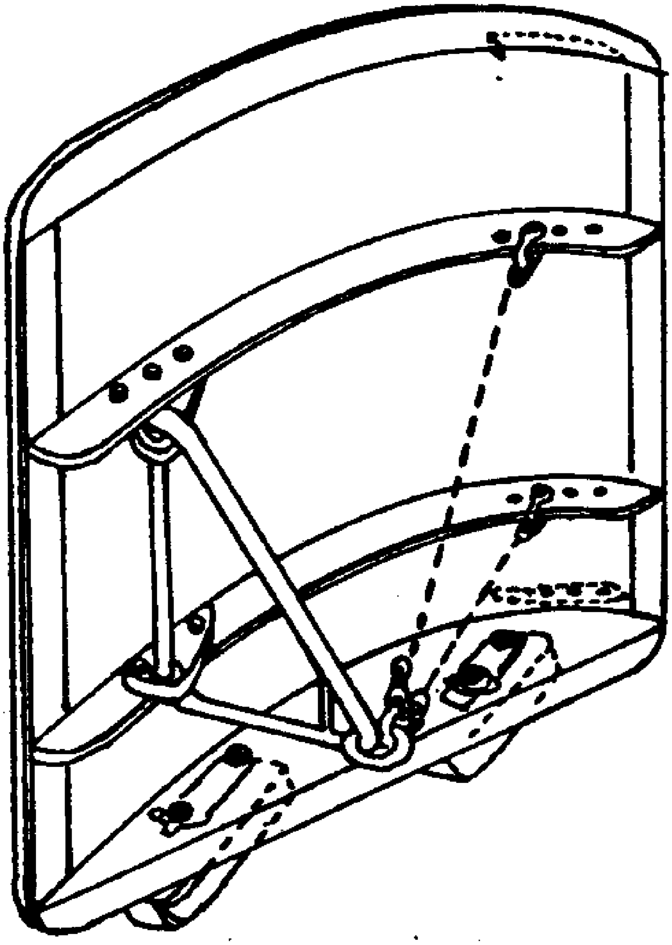


FIGURE 24

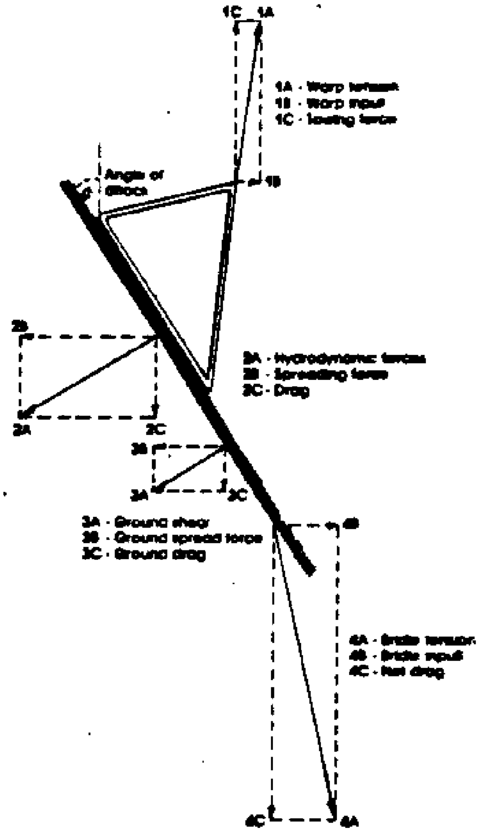
Moderate Aspect Ratio Cambered Door



It is evident that door behavior depends on a combination of hydrodynamic and ground shear forces.(See Figure 25).

FIGURE 25

Forces Acting on a Trawl Door with Ground Contact



The hydrodynamic forces can be measured in flow channels or wind tunnels and extensive data are available (Figures 26 through 29). These data are usually presented as coefficients of lift and drag, C_L and C_D versus angle of attack, α.

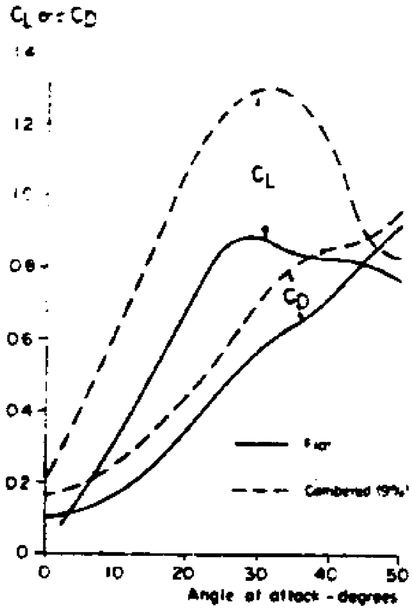
C_L = hydrodynamic lift force/ $\rho/2$ A V^2 (lift is $\perp$ to flow)

C_D = hydrodynamic drag force/ $\rho/2$ A V^2 (drag is $\parallel$ to flow)

where V is speed through water, fps, (not the same as speed over ground if a current is present).

FIGURE 26

Sheer and Drag Coefficients of Rectangular Flat and Cambered (9 Percent Camber) Otter Boards in Ground Contact in Relation to Angle of Attack



Sheer and Drag Coefficients of Polyvalent (6 Percent Camber) and Oval Flat Single Slot Otter Boards in Ground Contact in Relation to Angle of Attack

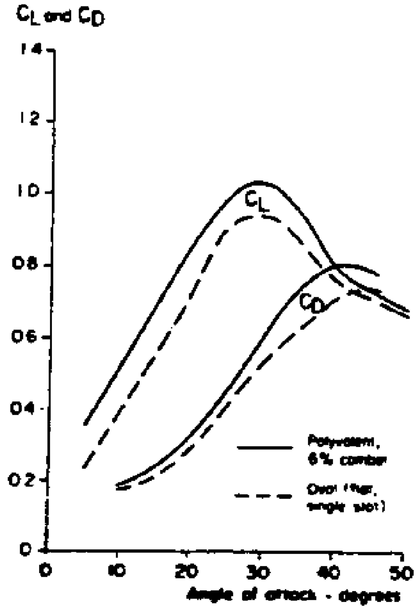
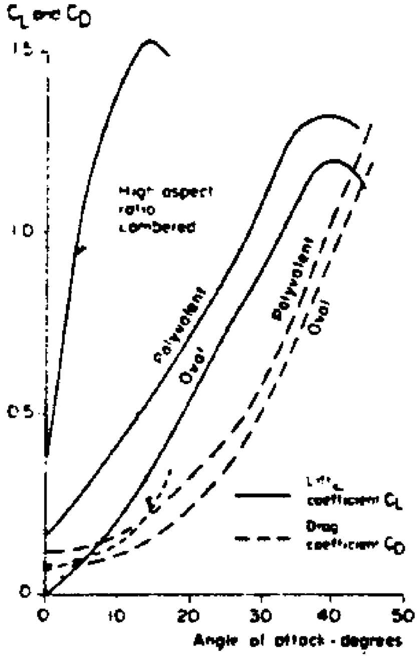


FIGURE 27

Sheer and Drag Coefficients of Oval Flat, Polyvalent and High Aspect Ratio Rectangular Cambered (Süberkrüb Type) Otter Boards in Midwater in Relation to Angle of Attack



Sheer and Drag Coefficients of Low Aspect Ratio Rectangular Cambered, Rectangular Flat and Diverting Depressor Otter Boards in Midwater in Relation to Angle of Attack

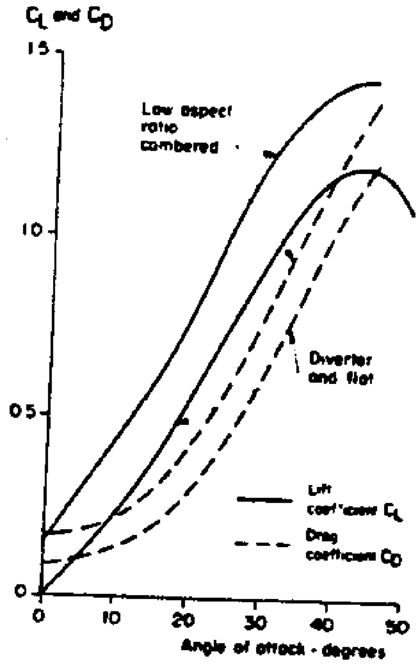
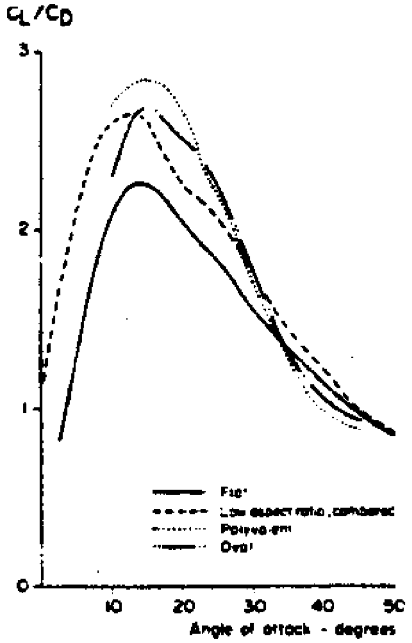


FIGURE 28

Otter Board Efficiency Indicated by the Ratio of Sheer to Drag Coefficients in Relation to Angle of Attack for Rectangular Flat, Low Aspect Ratio Rectangular Cambered, Polyvalent and Oval Flat Otter Boards in Ground Contact



Otter Board Efficiency Indicated by the Ratio of Sheer to Drag Coefficients in Relation to Angle of Attack for Rectangular Flat and Diverting Depressor, Low Aspect Ratio Rectangular Cambered, Polyvalent, Oval Flat and High Aspect Ratio Rectangular Cambered Otter Boards in Midwater

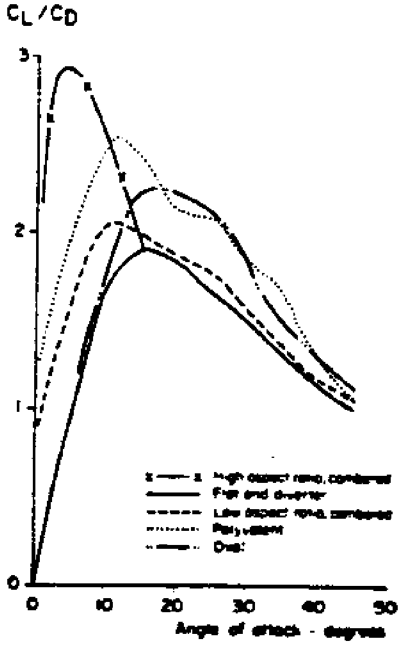
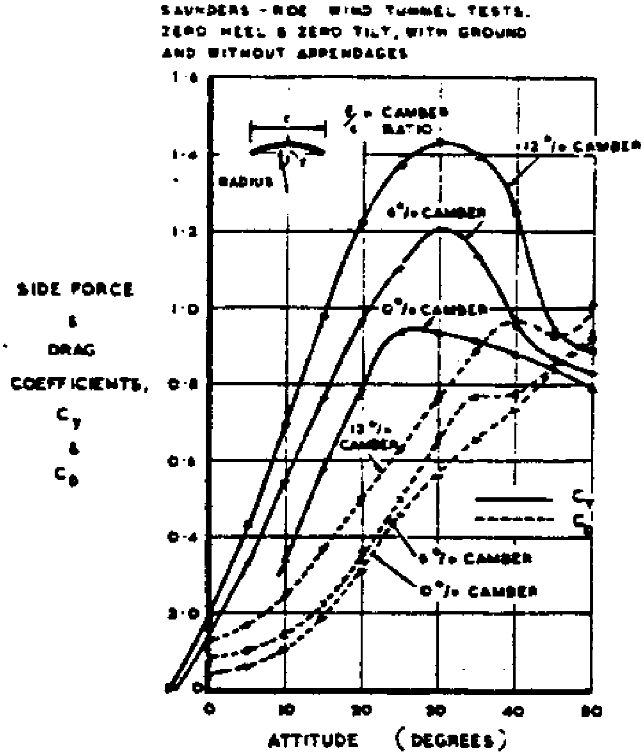
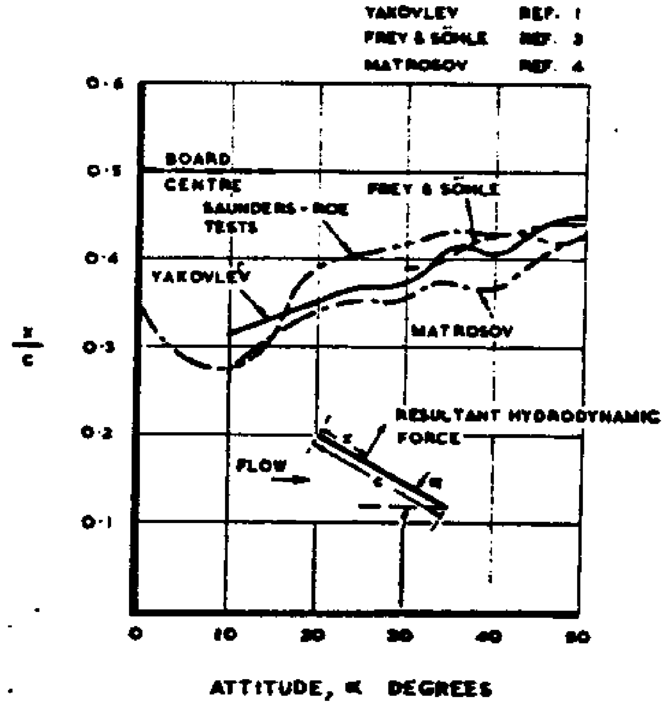


FIGURE 29

The Effect of Simple Camber on the Hydrodynamic Side Force and Drag of Aspect Ratio ≑ 1/2 Otter Boards



Variation of Centre of Pressure with Attitude: Rectangular Flat Otter Boards of Aspect Ratio ≑ 1/2 with Ground Effect (From Model Otter Board Tests at Zero Heel)



Such coefficients are non-dimensional, so once known for a particular net, they can be used to approximate the effect of a larger net or a different towing speed.

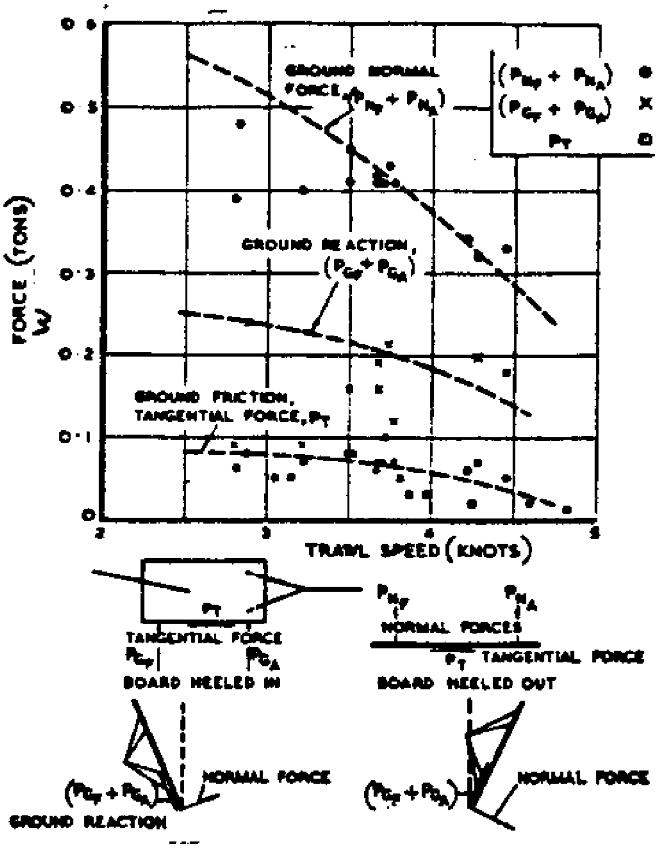
If we assume that there exists some economically optimum towing speed for a given fishery, the required spread force can be determined. The available spread force can be increased by either increasing the angle of attack (up to the point where the lift curve peaks) or by increasing the door size. Plotting C_L/C_D versus angle of attack (Figure 26) shows clearly that the greatest hydrodynamic efficiencies are obtained with cambered boards of high aspect ratio operated at a low angles of attack. Unfortunately, such boards are relatively unstable, particularly when "shooting" or releasing the trawl. Compensating forward speed, or hauling on the warps, can be helpful in this situation. Crewe, Reference (13), describes a prototype device to decrease the angle automatically when the board hits bottom. Use of a shooting chain, as described in Reference (28), has a similar purpose. Such a device has the potential to halve the hydrodynamic drag of present doors offering fuel savings of 10 to 15 percent. Once on the bottom, high aspect ratio doors remain less stable than other types (particularly Vee-doors) and tend to fall over easily when hitting an obstruction. Thus, they are sometimes fitted with a guard to prevent falling flat. The L/D ratio of the polyvalent (oval, cambered and slotted) board peaks at a higher, more practical angle of attack than the high apsect ratio cambered board. Thus, it offers an excellent compromise between hydrodynamic efficiency and stability. Most local fishermen have settled for uncambered boards of low aspect ratios (.5 to .75) operated at high angles of attack (around 40 degrees). Though stable, such boards are a hydrodynamic disaster with lift/drag ratios around 1 to 1.5. In view of the economics involved, a compromise board designed for better efficiency, such as those in Figures 23 and 24, are certainly worth consideration.

Whatever board you use, consider reducing the attack angle by small increments (move the towing bracket forward or the back strap attachments aft) as far as possible without causing stability problems. This will lower your current spreading force, (but you may find it was originally more than you really needed). If not, consider making up the loss with larger doors. In either case, the reduced drag will save fuel or allow scaling up the entire rig to utilize your vessel's full towing power. It is admittedly expensive to experiment, especially when your existing rig seems to work, but an inefficient rig, poorly matched to your available tow force, will cost you money for the rest of its life.

Ground forces contribute also to a board's performance but are very difficult to simulate realistically in a model test. Fortunately, some full-scale data were obtained by Crewe, Reference (13), from a specially instrumented board. Figure 30 shows the forces measured and the equations to convert them into lift/drag ratios. The lift/drag ratio at 40 degrees angle of attack for these particular bottom conditions and gear is only .87, much worse than those shown in Figure 28 for the

FIGURE 30a

Full-Scale Otter Board Ground Force Measurements



Ignoring the small ground reaction contribution to spread and and drag forces,

$$\text{Lift Force} = (P_{N_F} + P_{N_A}) \cos \alpha - P_T \sin \alpha$$

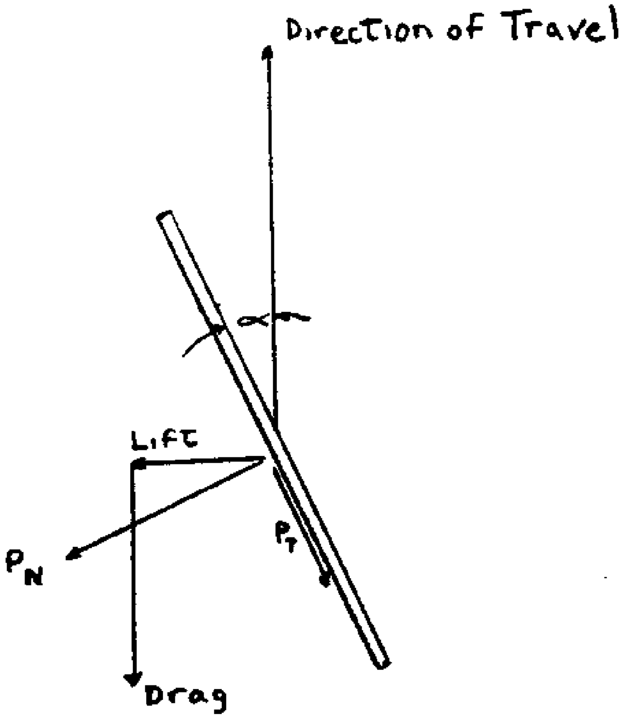
$$\text{Drag Force} = (P_{N_F} + P_{N_A}) \sin \alpha + P_T \cos \alpha$$

Thus:

α	L/D
35°	1.04
40°	.87

FIGURE 30b

Resolution of Tangential and Normal Forces into Lift and Drag Components



hydrodynamic forces. More research of this type on different bottoms and with different warp/depth ratios should certainly be encouraged. Meanwhile, however, it seems safe to conclude that an excessively heavy door will derive more of its required spread from the inefficient ground forces, rather than from the more efficient hydrodynamic forces. (It will also tend to snag on obstructions more easily.) Also, the heavy board will produce an oscillatory force as it slides sideways and periodically tears loose, thus reducing propeller efficiency. The only possible argument for an extremely heavy board is shown by the photos of Reference (26), e.g. Figure 31, which shows the large sand cloud generated by a board.

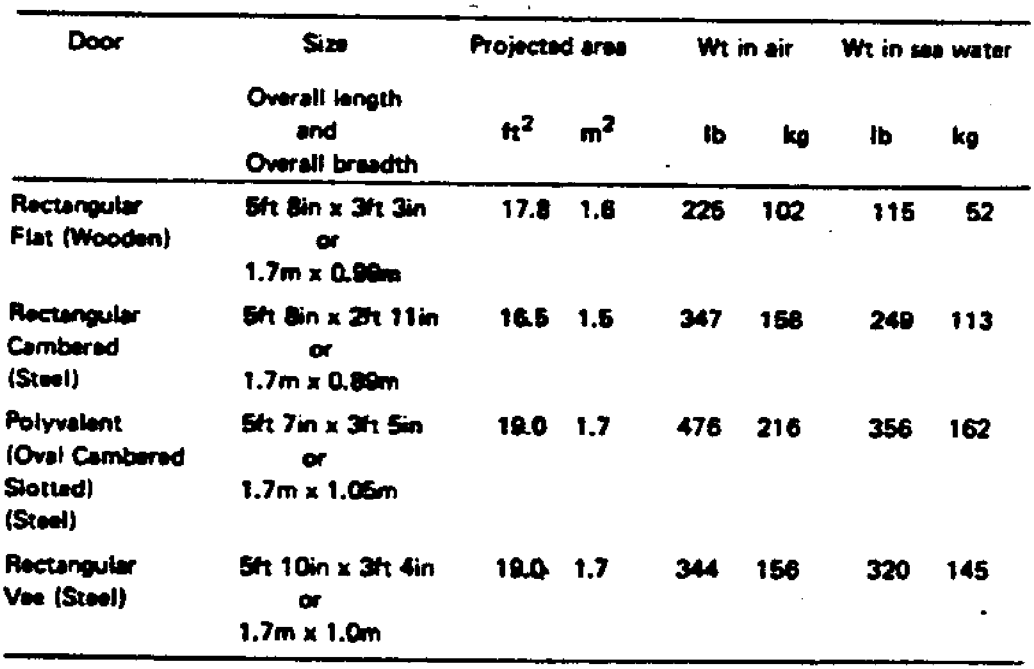
FIGURE 31

Plate II. Rectangular Flat Board Showing the Large Sand Cloud Filling the Rear of the Board

This cloud may play an important herding function for certain species. Otherwise, though, it is hydrodynamically more efficient to use a door whose weight is just sufficient to maintain bottom contact. Reference (26) also contains valuable comparisons of different door designs, as shown in Figures 32 through 34 and comparisons of behavior when encountering obstacles. Figure 35 is reprinted from Reference (27) and summarizes the merits and disadvantages of various board types.

FIGURE 32

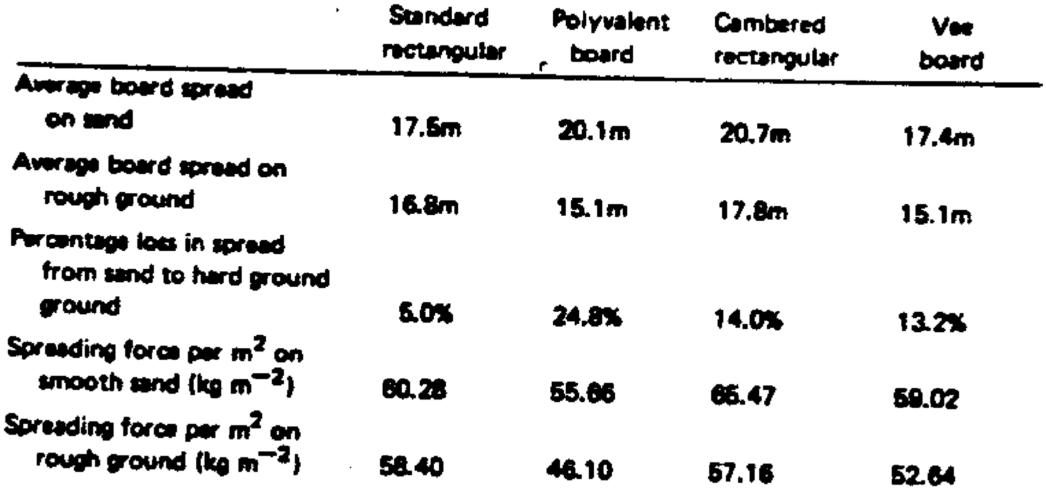
TABLE 1: Otter Board Type, Area and Weight



Door	Size	Projected area		Wt in air		Wt in sea water	
	Overall length and Overall breadth	ft^2	m^2	lb	kg	lb	kg
Rectangular Flat (Wooden)	5ft 8in x 3ft 3in or 1.7m x 0.99m	17.8	1.6	225	102	115	52
Rectangular Cambered (Steel)	5ft 8in x 2ft 11in or 1.7m x 0.89m	16.5	1.5	347	158	249	113
Polyvalent (Oval Cambered Slotted) (Steel)	5ft 7in x 3ft 5in or 1.7m x 1.06m	19.0	1.7	476	216	356	162
Rectangular Vee (Steel)	5ft 10in x 3ft 4in or 1.7m x 1.0m	19.0	1.7	344	156	320	145

FIGURE 33

TABLE 2: Average Board Spread on Sand and Rough Ground, Percentage Reduction in Spreading Ability and Spreading Force Per Unit Area. For Board Dimensions, See Table 1 (Figure 32).



	Standard rectangular	Polyvalent board	Cambered rectangular	Vee board
Average board spread on sand	17.5m	20.1m	20.7m	17.4m
Average board spread on rough ground	16.8m	15.1m	17.8m	15.1m
Percentage loss in spread from sand to hard ground ground	5.0%	24.8%	14.0%	13.2%
Spreading force per m^2 on smooth sand (kg m^{-2})	60.28	55.66	65.47	59.02
Spreading force per m^2 on rough ground (kg m^{-2})	58.40	46.10	57.16	52.64

FIGURE 34

TABLE 3: Some Selected Results of Trawl Board Behavior and Warp Tension on Smooth Sand and Rough Ground Showing the Increases in Tension on Impact with Various Sizes of Obstruction

Board type	Towing speed (knots)	Mean towing tension on smooth sand (kg)	Mean warp tension on rough ground before impact (kg)	Actual increase in warp tension on impact (kg)	Height of obstruction (cm)	Trawl board attitude	Point of impact
Rectangular flat	3.0	786					
	3.0		762	243	30	rode over	toe
	3.0		762	330	46	rode over	toe
	3.0		762	101	20	rode over	toe
	3.0		762	152	30	rode over	middle
	3.0		762	203	20	rode over	middle
	3.0		762	182	30	rode over	middle
	2.9		762	1117	30	dug out	toe
	2.85		762	457	46	rode over	toe
	3.1		762	559	30	dug out	toe
	3.1		762	305	38	rode over	toe
	2.9		762	203	30	pushed	toe
Polyvalent	3.0	646					
	2.9		660	806	30	rode over	middle
	2.9		660	254	46	rode over	middle
	2.9		660	457	46	rode over	middle
	2.9		660	101	20	rode over	middle
	2.9		660	203	30	rode over	middle
	2.9		660	254	30	rode over	middle
	2.9		711	152	20	rode over	middle
	2.9		762	660	180	rode over	toe
	2.9		762	254	20	pushed	toe
	2.9		762	254	60	rode over	middle
	2.9		711	101	46	rode over	middle
	2.9		711	101	60	rode over	middle
	2.9		711	1422	60	rode over	middle
	2.9		711	914	60	rode over	toe
	2.8		762	152	30	rode over	toe
	2.8		762	609	60	pushed	toe
	2.8		762	152	60	rode over	middle
Cambered rectangular	3.0	650					
	2.8		660	152	20	pushed	middle
	2.8		660	127	46	pushed	middle
	2.8		660	177	60	rode over	toe
	2.8		660	127	46	pushed	toe
	2.8		660	304	20	dug out	middle
	2.8		660	152	20	rode over	toe
	2.8		660	203	20	dug out	middle
	2.8		660	152	46	rode over	toe
Vee	3.0	780					
	2.9		812	223	30	rode over	middle
	2.9		812	254	30	rode over	middle
	2.9		812	228	20	rode over	toe
	2.9		812	279	46	rode over	toe
	2.9		812	305	30	rode over	middle
	2.9		812	330	20	pushed	middle
	2.9		812	203	25	rode over	toe
	2.9		914	304	20	dug out	toe
	2.9		914	152	20	rode over	toe
	2.9		914	204	20	rode over	middle
	2.9		914	254	20	dug out	toe
	2.9		914	254	25	pushed	middle

FIGURE 35

Summary of Main Otter Boards Characteristics

Otter board type	Common angle of attack	Corresponding hydrodynamic characteristics				Fishing suitability			Construction considerations			Experience record
		Coefficients of		Lift/drag ratio C_L/C_D	Overall efficiency	Manoeuvrability	On the sea bed[1]	In midwater	Extent of special skills and tools needed	Costs		
		sheer C_L	drag C_D							Purchase	Maintenance	
1. Conventional rectangular flat	40°	0.82	0.72	1.14	Average to poor	Good	A,B good C poor	Poor	Average	Average	Average	Well proven; extensively used for demersal fishing
2. Rectangular flat, wide-keeled	40°	0.82	0.72	1.14	Average to poor	Good	A good B poor C unsuitable	Poor	Less than average	Low	Low	Well proven; extensively used for small vessels and for shrimp trawling
3. Rectangular cambered	35°	1.26	0.81	1.55	Good	Average (difficult to right if fallen over)	A,B good C poor	Poor	Above average (bending facilities needed)	High	Average	Very limited commercial use to date
4. Oval flat, slotted	35°	0.86	0.63	1.36	Average	Average to good	A,B,C good	Poor to average	Above average	High	Average	Well proven; widely used particularly by large trawlers
5. Oval cambered, slotted (polyvalent type)	35°	0.93	0.74	1.25	Average to good	Average to good	A,B,C good	Average to good	Above average (bending facilities needed)	High	Average	Recent development; us increasing
6. Rectangular Vee type	40°	0.80	0.65	1.23	Average to poor	Good	A,B,C good	Poor	Average	Average	Low	Well proven; extensive use, particularly for trawlers up to 600 hp
7. Rectangular flat special design (diverting depressor)	40°	0.82	0.72	1.14	Average to poor	Very good	A,B good C average	Average	High	Very high	Low	Recent development; limited commercial use so far
8. Rectangular cambered, high aspect ratio, for midwater trawling (Süberkrüb type)	15°	1.52	0.25	6.08	Very good	Midwater good; bottom average to poor	A,B good C unsuitable	Very good	Above average (bending facilities needed)	Average to high	Low	Well proven; extensively used for midwater trawl by trawlers of all sizes
9. Rectangular cambered, high aspect ratio, for bottom trawling (Japanese type)	25°	1.30	0.50	2.60	Very good	Average (risk to fall flat)	A,B good C unsuitable	Good	Above average (bending facilities needed)	Average to high	Average	Extensive use but limited so far to Japanese trawlers

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[1] For quality of seabed:
A = good ground, even, absence of boulders, etc.
B = medium ground, stones, no sudden major depth changes
C = bad ground, large boulders, uneven, sudden and major depth variations.

While the procedures just described present rational basis for selecting required board size, they require the services of a skilled naval architect and net designer. Additional rules of thumb in a form practical for shipboard comparisons are presented in Figures 36 through 41.

FIGURE 36

Common Weights of Various Otter Board Types in Relation to HP of the Trawler (Diverting Depressor and Polyvalent Otter Boards According to Manufacturers' Recommendations; All Others According to Common Use)

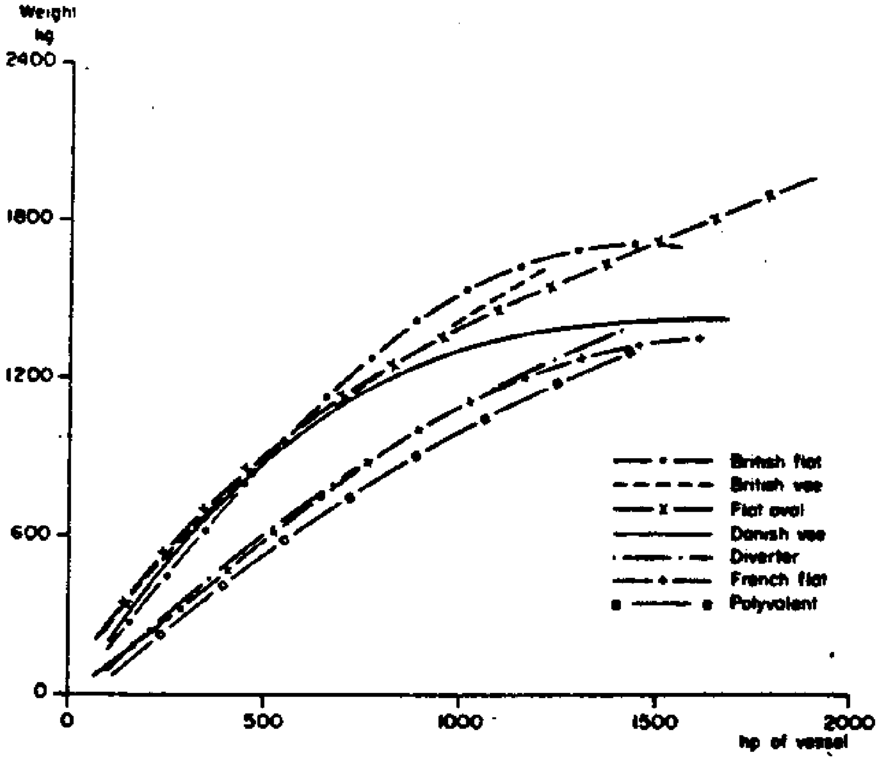


FIGURE 37

Common Area of Otter Boards in Relation to HP of Trawler

According to Commercial Use

[From Reference (27)]

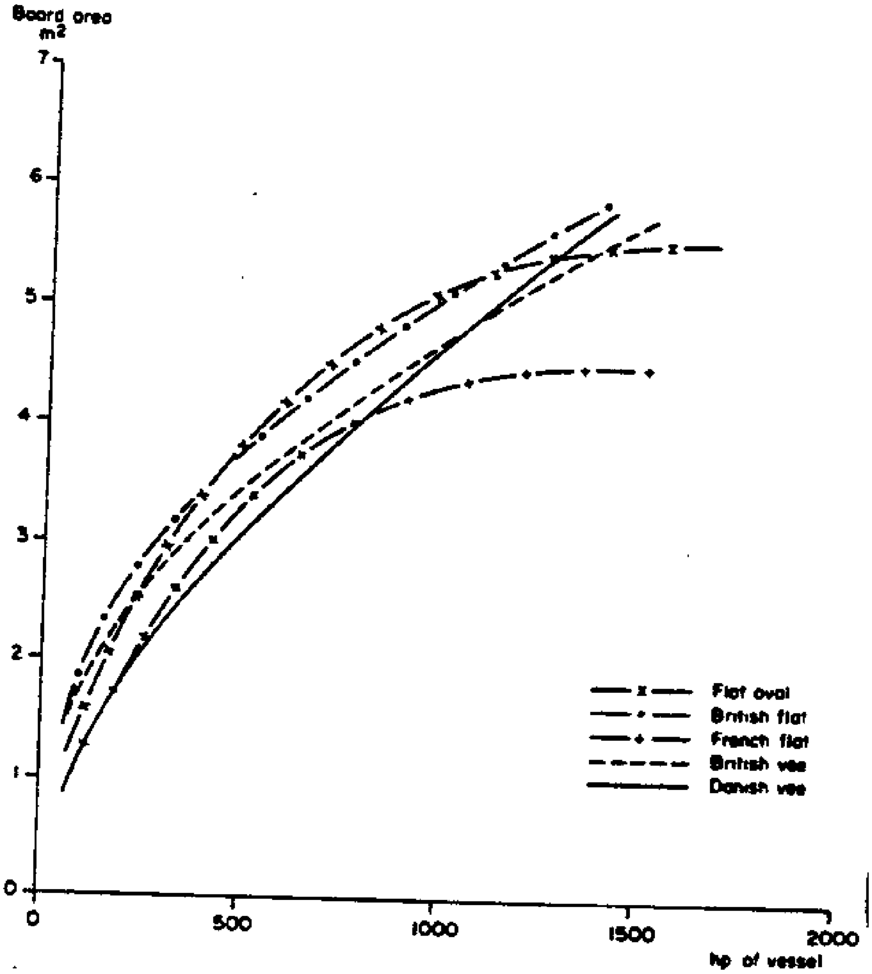


FIGURE 38

Twine Surface Area of Some Typical Otter Trawl Nets in Relation to HP of Trawler [From Reference (27)]

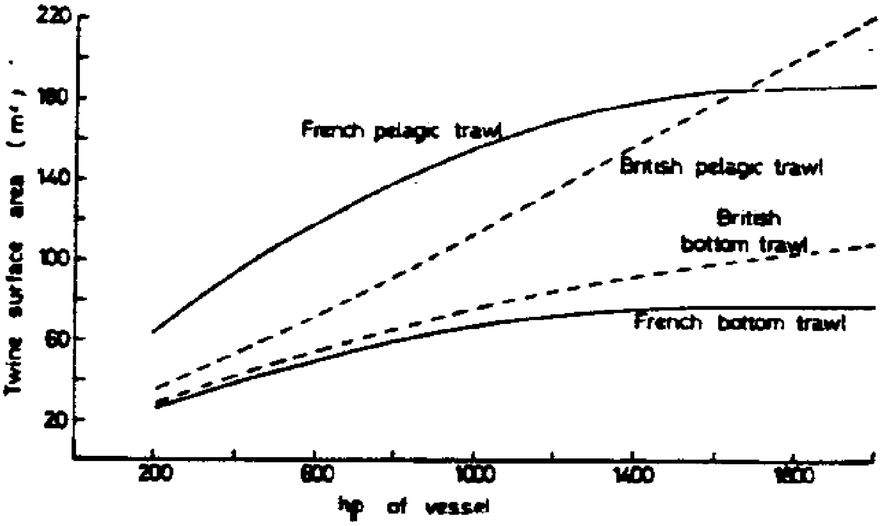


FIGURE 39

Common Relationship Between Size of Otter Board and Twine Surface Area for Some Typical Trawl Gear

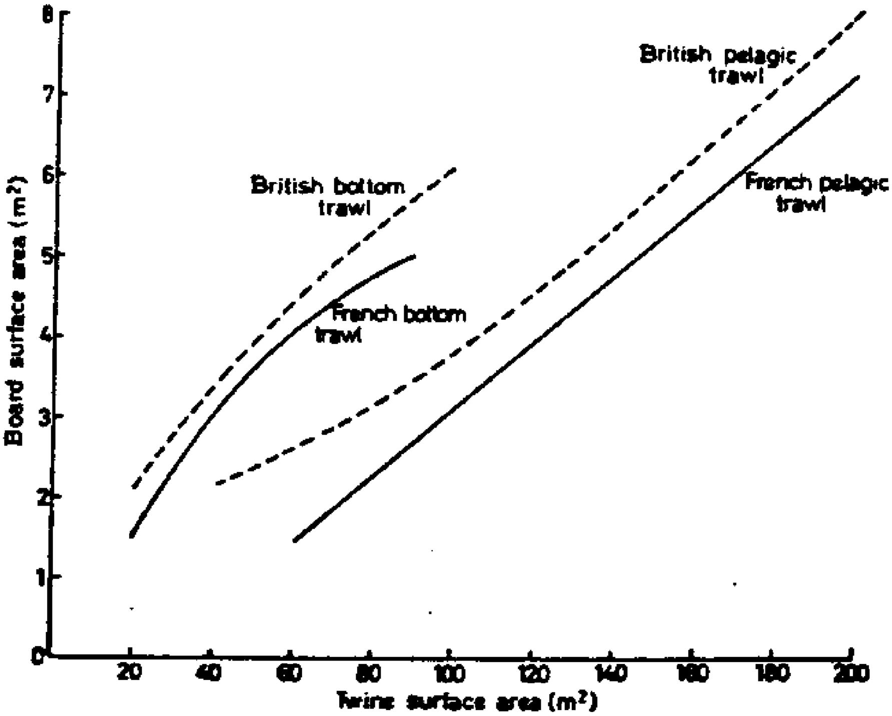


FIGURE 40

Relationship Between Door Size and Horizontal Spread

[From Reference (25)]

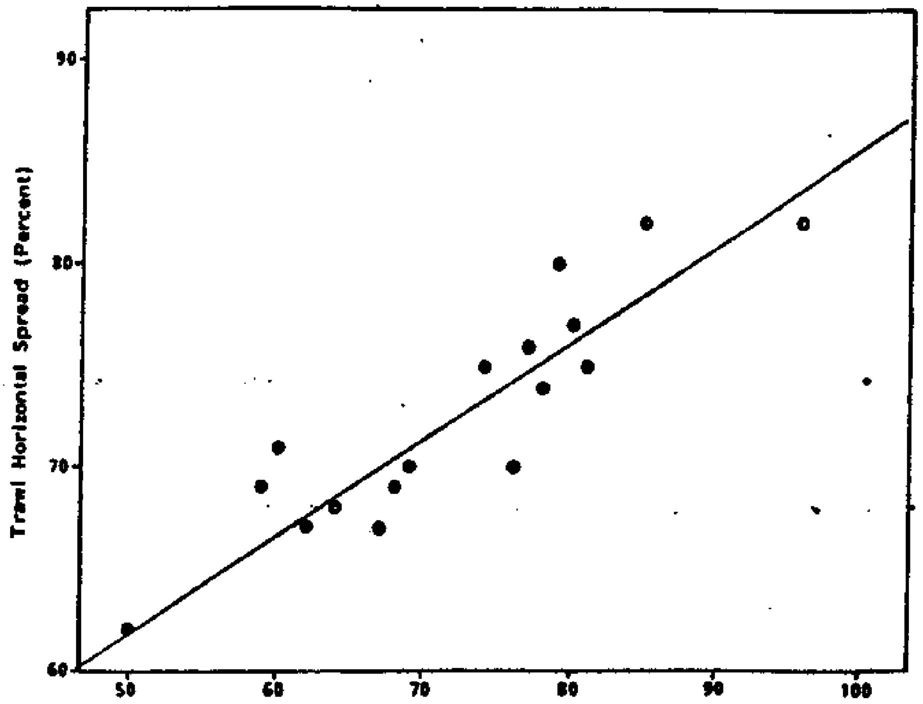
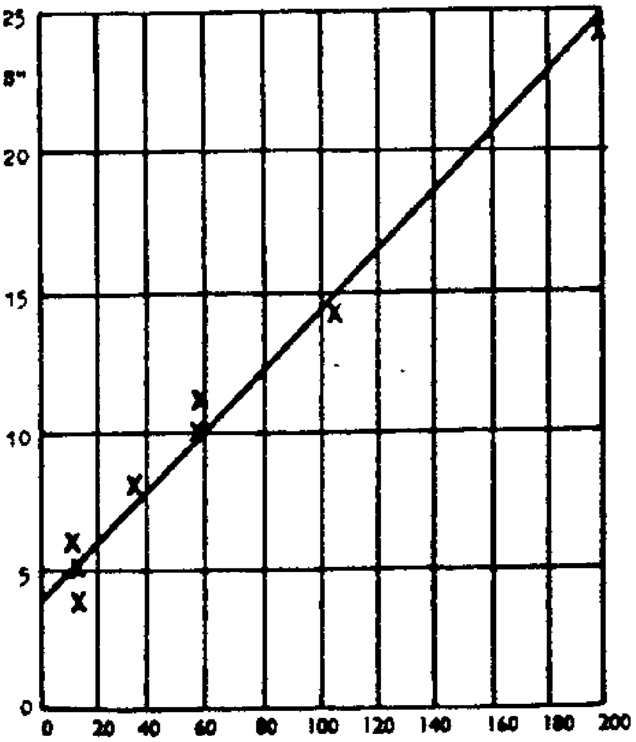
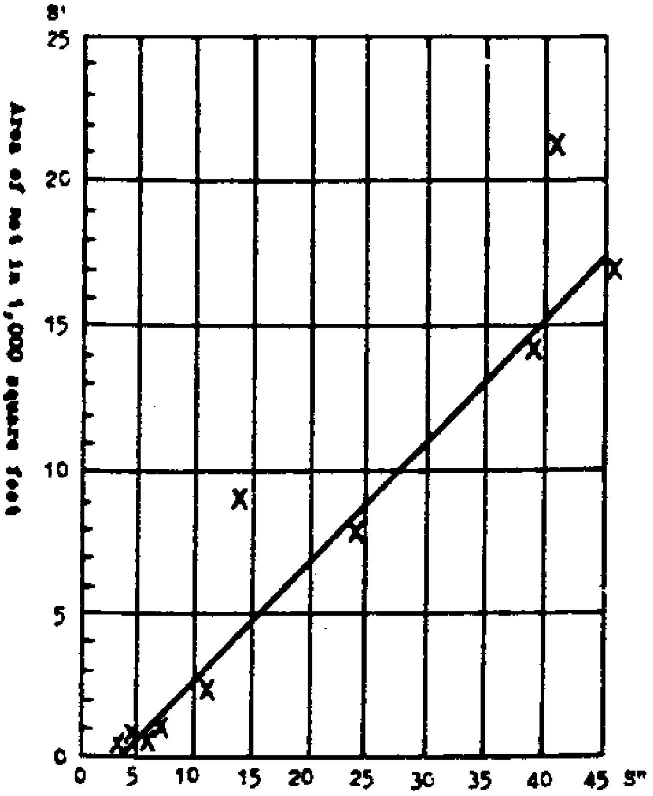


FIGURE 41



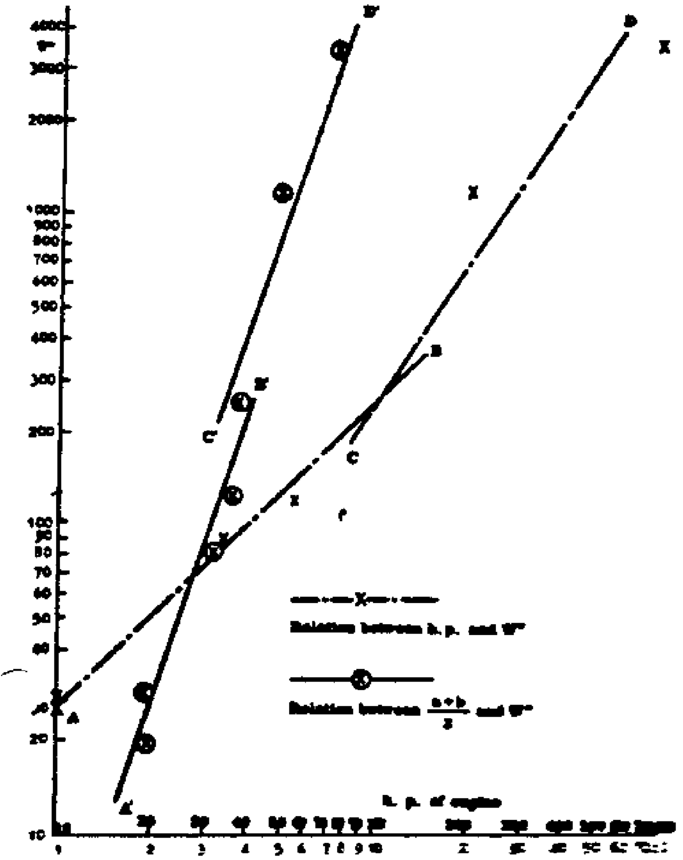
Relation Between HP of Engine

and Area of One Otter Board



Relation Between Area of One Otter Board

and the Area of the Net



Relation Between HP of Engine and Weight

of One Otter Board and Relation of Average Length

of Otter Board in Feet and the Weight of the Board

While the preceding figures are useful for initial design and gear selection, they provide little information about how to trim and tune the gear when fishing. Figures 42 through 49 show various data relating to this question.

FIGURE 42

Suggested Relation Between the Water Depth and the Ratio of Warp Length of Water Depth

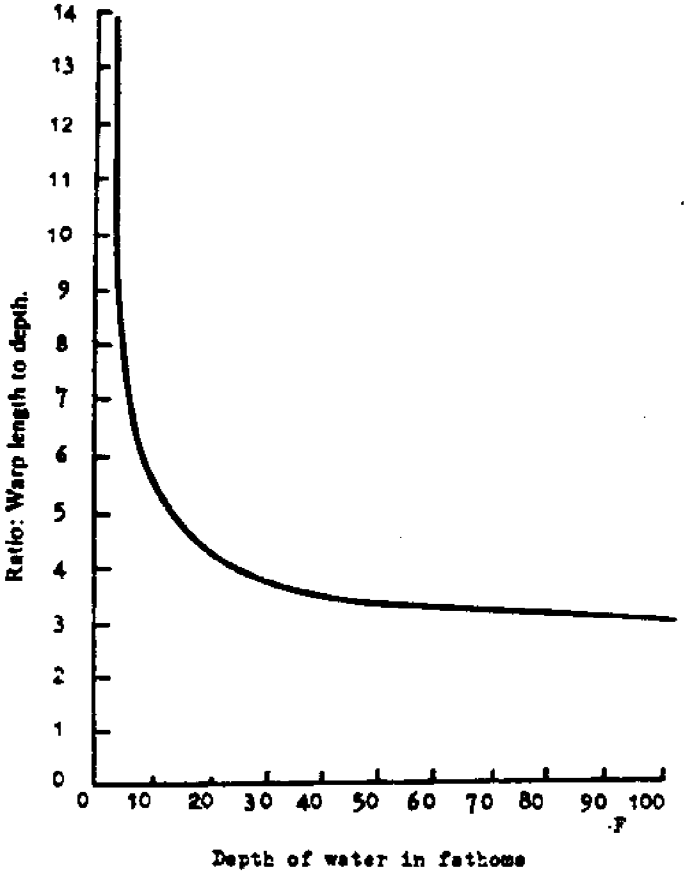


FIGURE 43

Warp Planform Spread Factors

[From Reference (13)]

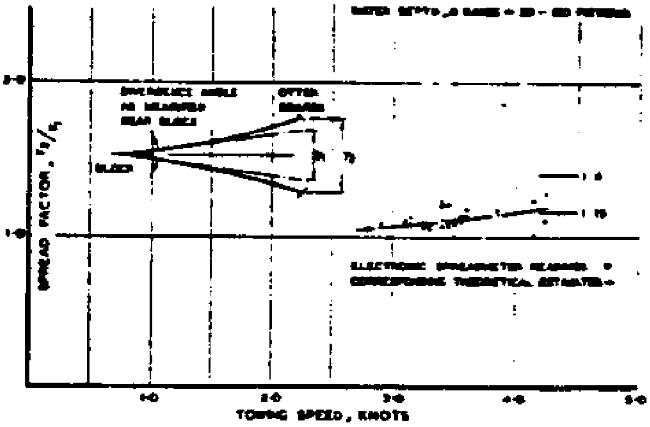


FIGURE 44

Variation of Warp Declination with Speed

[From Reference (13)]

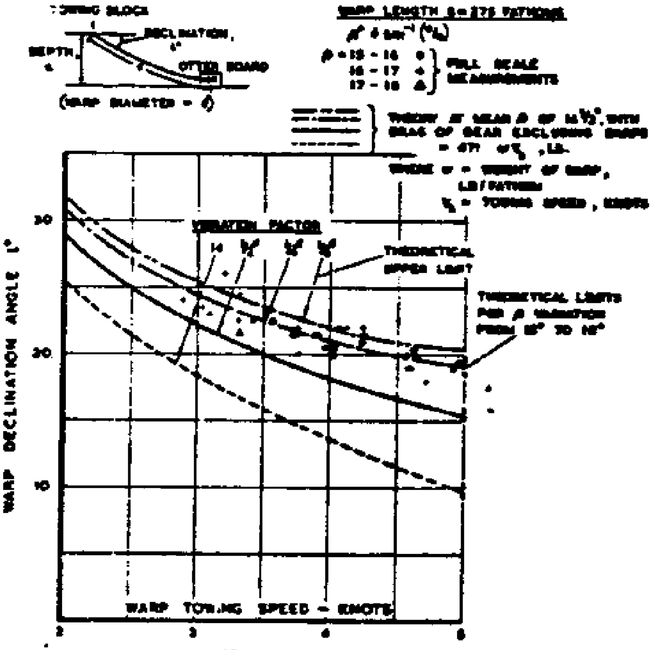


FIGURE 45

Comparison Between Theoretical Variations of Ratio of Warp Length to Water Depth Against Water Depth with Values Used by Practical Fishermen

[From Reference (13)]

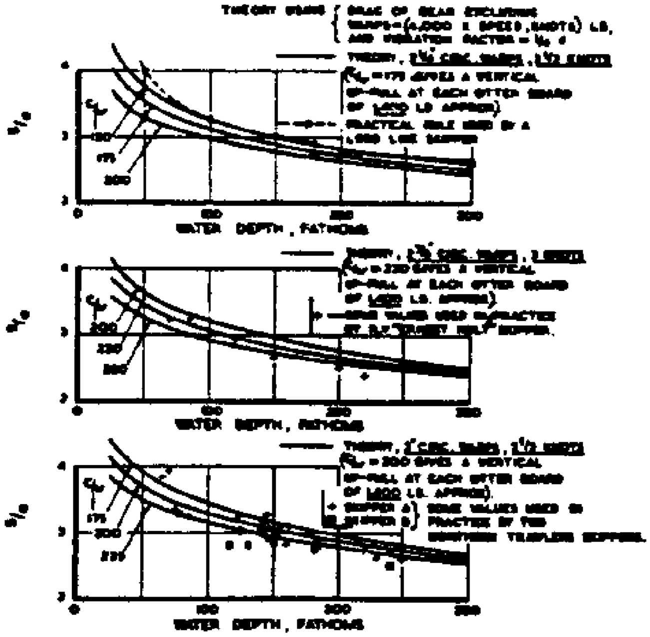


FIGURE 46

Variations of Otter Board Heel with Speed. Full-Scale Tests.

[From Reference (13)]

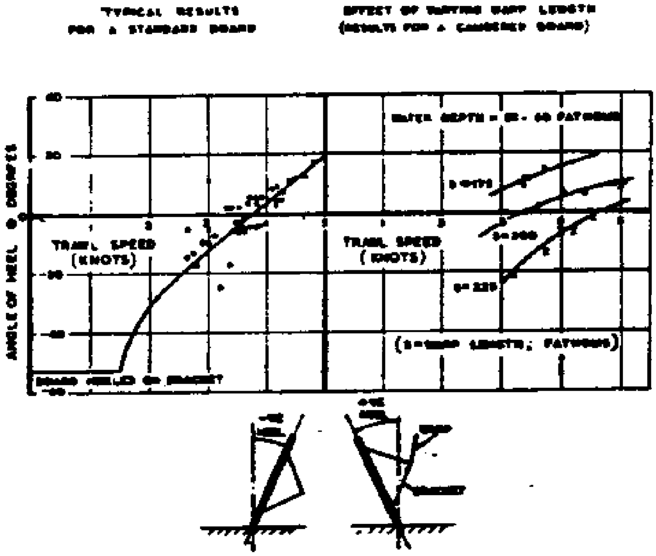


FIGURE 47

Some Measured Variations of Tilt with Speed,

Standard Otter Board. Full-Scale Tests.

[From Reference (13)]

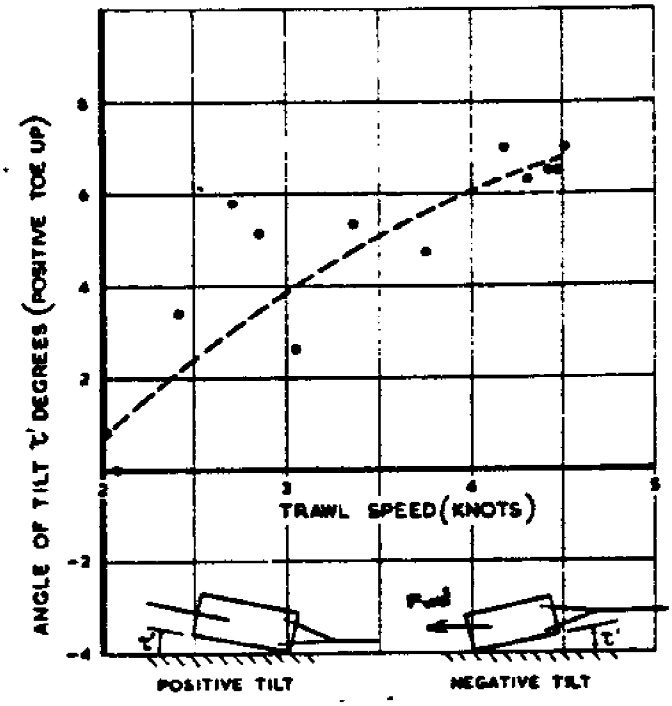


FIGURE 48

The Effect of Heel on the Hydrodynamic Forces

Acting on a Flat Rectangular Otter Board of Aspect Ratio ≑ 1/2.

[From Reference (13)]

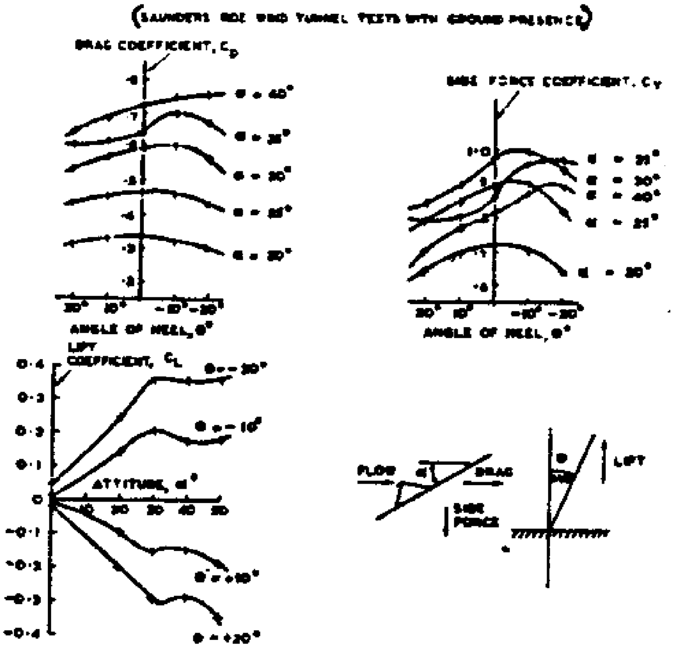


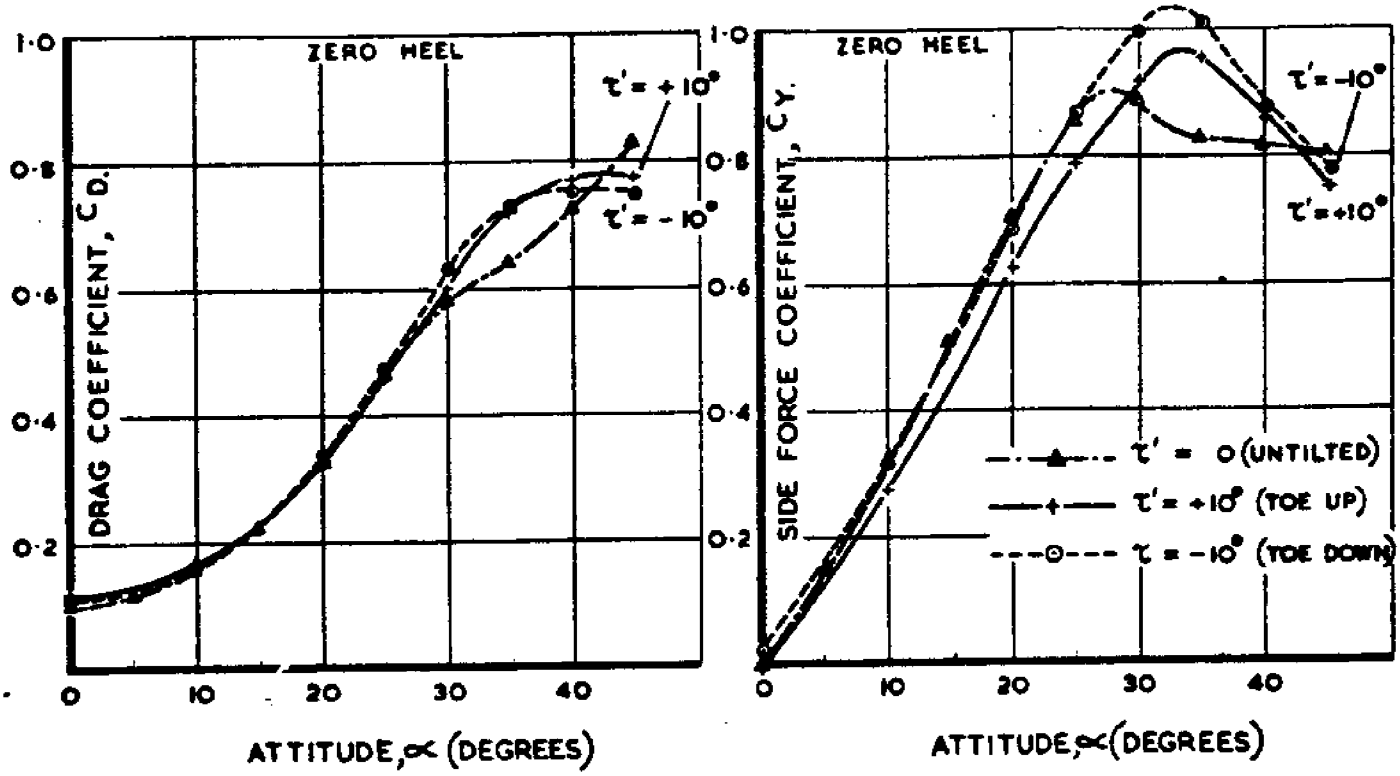
FIGURE 49

The Effect of Tilt on the Hydrodynamic Forces

Acting on a Flat Rectangular Otter Board of Aspect Ratio = 1/2.

[From Reference (13)]

SAUNDERS-ROE WIND TUNNEL TESTS WITH GROUND PRESENCE



By observing warp angles and polished areas on the door shoe and around the towing bracket, useful hints on operating angles can be obtained and small adjustments made to fine tune the rig for optimum efficiency. The lift/drag ratio changes very little with heel or tilt but is slightly better with nose down and inward heel.* These can be achieved by lowering speed, increasing warp length or changing attachment points.

Conclusions

Most modern net designs represent many years of trial and error development. In order to achieve adequate net spread, but not so much that the headline will collapse, the proper spreading force must be provided by the doors. Most nets are recommended with a particular set of doors, but the lift/drag figures given in this report make it possible to size a different door design to provide the same spread force. The drag of the net is largely frictional, and little can be done to reduce it significantly.

The door drag, however, which constitutes roughly a third of total gear drag, can often be significantly reduced. In most cases, reduced drag also means reduced door stability so some compromise may be necessary, particularly on obstructed bottom.

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* Note, however, that nose down operation is more likely to create problems on rocky ground.

Nonetheless, the cambered door designs shown in Figures 23 and 24 offer good hydrodynamic efficiency and reasonable stability. It is further shown that hydrodynamic spread force can be obtained with less drag than spread force from ground friction. Thus, a door should be no heavier than necessary to maintain ground contact (and perhaps raise a sand or mud cloud to herd fish towards the net).

Also, since the lift/drag ratio is higher at low angles of attack, IT IS PREFERRABLE TO USE LARGE DOORS AT LOW ATTACK ANGLES THAN SMALLER DOORS AT HIGH ATTACK ANGLES. Since doors set at too low an angle of attack, however, are unstable at low speeds, the vessel may require slight headway when shooting or hauling. (Alternatively, devices described in References (13) and (28) automatically decrease the angle of attack when bottom contact is made.)

Careful attention to door design, size, weight, trim and angle of attack can reduce total gear drag by 10 to 20 percent. These savings can result in fuel savings using existing nets or, more profitably, the ability to size up the current gear.

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