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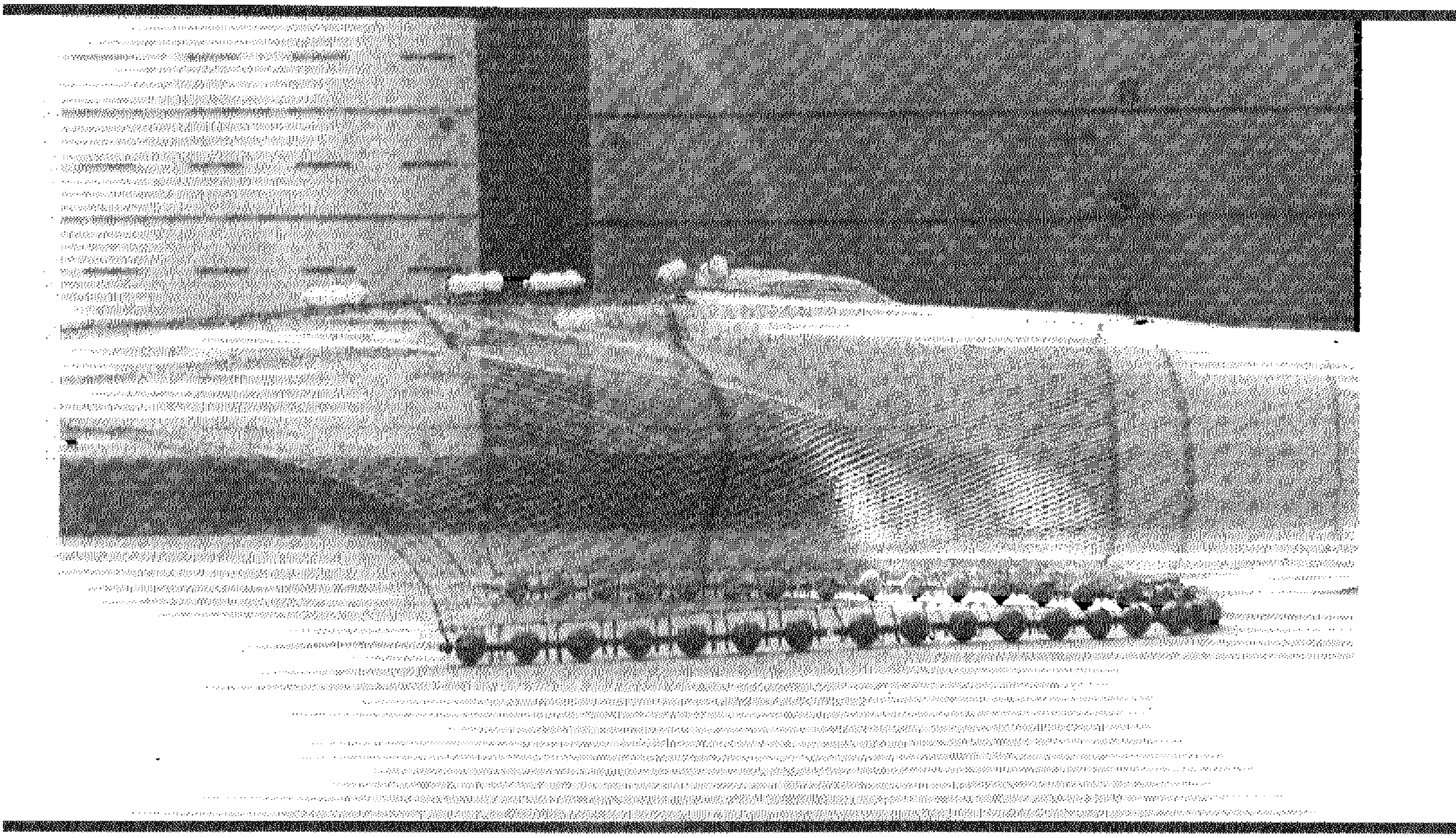
Alaska Sea Grant
College Program

Trawl Fisherman's Gear Technology Manual

by

Duncan Amos



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ACKNOWLEDGEMENTS

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FOREWORD

These lecture notes have been compiled for fishermen students attending trawl gear technology courses in conjunction with the use of a Flume Tank to demonstrate, rig and adjust trawl nets.

The data at the rear of these notes are typical of the work that was carried out by one class attending a Trawl Gear Technology Course attending a Trawl Gear Technology Course at the Sea Fish Industry Authority facilities in Hull, England, and are not representative of what all fisheries students would attempt.

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SIMPLE EXPLANATION OF WHY NETS WORK

This chapter is intended to help you understand the forces contributing to the performance of trawl-type fishing gear. Various forces act on fishing gear being towed along the seabed or in mid-water. These forces are illustrated in Figure 1 and listed below along with their definition and a discussion of their effects. Once these basic forces are understood it will then be possible to explain how fishing gear can be modified to suit different applications.

GROUND FRICTION

Drag can be defined as any obstacle to progress. In the case of trawls, drag is most easily understood using the analogy of two surfaces moving against each other creating friction. For example, if two smooth surfaces are pressed together little force is required to slide them in opposite directions; however, if two rough surfaces are used, considerably more force is required to achieve movement. Similar principles apply with fishing gear. During bottom trawling the doors and footrope are pulled across the seabed producing drag. The amount of drag produced is determined by the type of seabed and the ground rope rigging and is called the ground friction.

Net Drag

Flume tank studies have been used extensively to determine net drag. A closed drogue placed in a flume tank at zero water velocity does not exert tension on the warps. As the water starts to move, the drogue traps water and the tension in the warps increases. The drogue will act in an unstable manner due to the diversion of water at the front. If a vented drogue is used, water is not trapped, but drag is produced by the force of water moving against the drogue. The warp tension, though less than in the closed drogue, will still increase with increasing water speed. The drogue is stable because water flows through instead of around it.

The application of this principle as it applies to fishing gear can be illustrated by streaming a net in varying water speeds. At zero water velocity the net hangs vertically without assuming its normal shape. As the water speed increases the net rotates about its suspension point towards a horizontal position, the warp tension increases and the net assumes its normal shape. The warp tension continues to increase as the water speed increases. This increase in warp tension is a measure of the force the water is exerting against the net twine and rigging.

To summarize, The performance of fishing gear depends on its ability to take up a desired shape while being towed. The major factor in determining this shape is drag. Water pushing against the net twine and the friction between ground gear and bottom are the major forces that make nets take their desired shape.

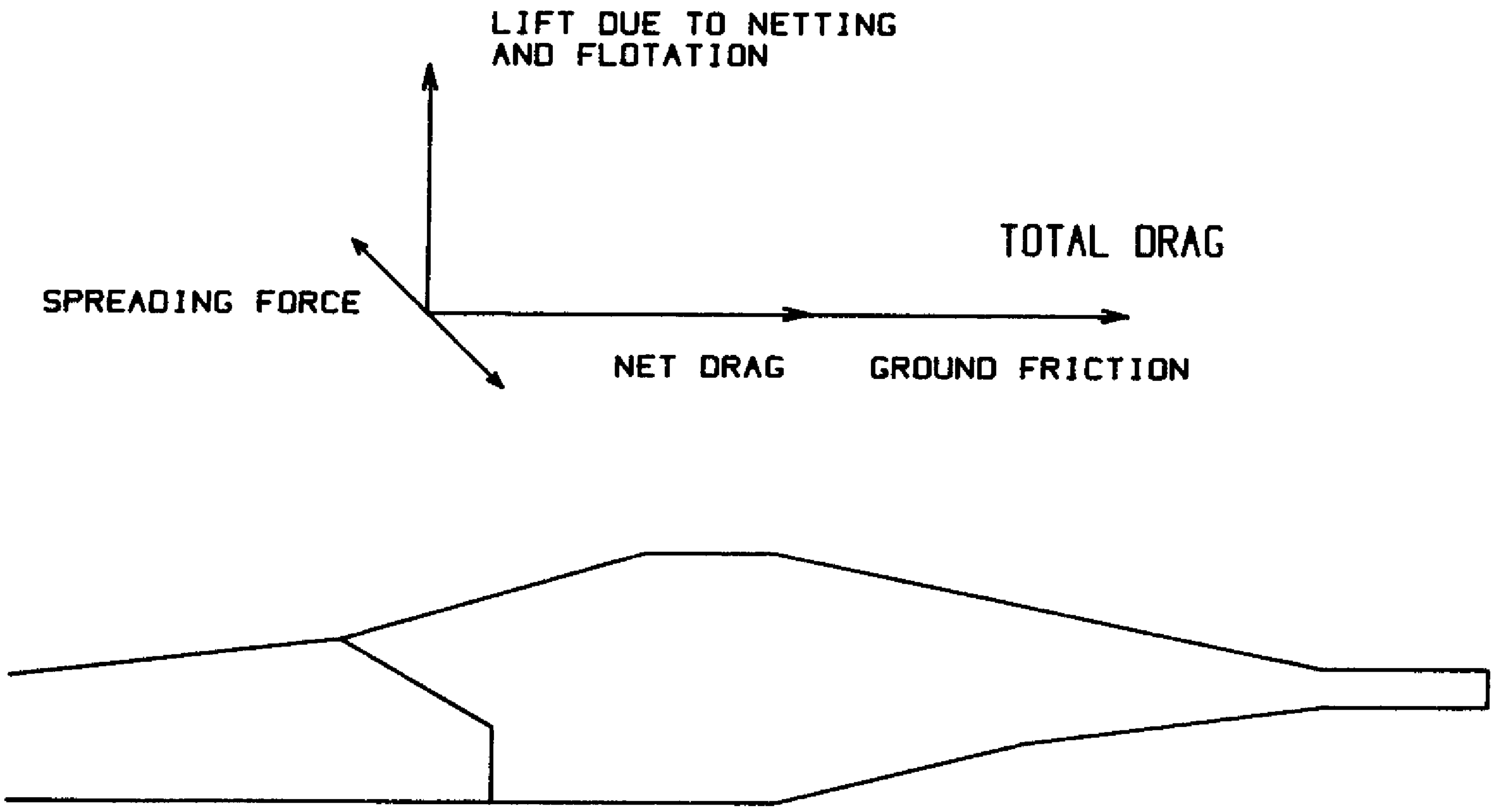


FIGURE 1. BASIC FORCES ACTING ON TRAWL GEAR.

LIFT

Lift is an upward force applied to a body, either vertically or as a component of a force applied at an angle to the vertical. The two most important forms of lift applied to trawl gear are buoyancy and shear. Weight is a downward force applied to a body and can be considered a negative lift.

Buoyancy, lift generated from a floating object, is usually applied to a trawl directly by headline floats. Table 1 provides a list of the various-sized floats and the lift provided by each. This lift is roughly equal to the weight of the water displaced and is constant irrespective of whether the float is stationary or moving forward through the water.

Table 1. Lift produced by various types of floats

Size	Make	Type	Lift (lbs)	Lift (kg)
5	Phillips	Aluminum	1.7	0.77
5	Nokalon	Plastic	1.96	0.89
5	More	Plastic	2.0	0.91
5	North Star	Plastic	2.25	1.02
5	Permolift Minor	Plastic	2.67	1.21
6	Phillips	Aluminum	3.23	1.46
6	Arra 6635	Plastic	3.18	1.44
6	Nokalon 34758	Plastic	3.91	1.77
8	Phillips Deep Sea	Aluminum	7.41	3.35
8	Rosendahl	Plastic	6.93	3.13
8	Nokalon	Plastic	7.85	3.55
8	Arra 6637	Plastic	8.84	4.0
8	Nokalon Deep Sea	Plastic	5.69	2.57
8	Nokalon 34758	Plastic	8.62	3.90
10	(Twin Lug)	Plastic	11.05	5.0
11	Rosendahl	Plastic	21.44	9.7
11	Nokalon	Plastic	21.8	9.9

As a float is moved through the water, drag becomes a factor in the float's behavior. If a float is tethered in stationary water the upward force exerted by the float will all be in a vertical direction. If the water begins to move, the float rotates about its point of attachment until the upward force of the float and the horizontal force of the water pushing against it are in balance. This rotation of the float about a fixed point causes the float to be pushed downward in the water. The same principle applies to floats attached to gear. Increasing the number of floats on the headline of a trawl may not produce greater headline height. In fact, the reverse can be true: too many floats can push the headline down due to excessive drag. Increasing the trawling speed may also produce this effect.

Shear, in the context of trawl operations, is a force generated on an object by the movement of water around it. Doors and kites are the primary components of trawl gear that operate by this force. If a kite is placed in stationary water no lift is generated; whereas, a float will generate lift. As the kite moves through the water a flow is generated across the top and bottom of the kite. If the plane of the kite is parallel to the water flow no lift will be generated (Figure 2a). As the angle of attack of the kite is increased, the water flow across the top of the kite increases in velocity; while below, the water flow slows down. These changes in water velocity cause corresponding changes in the pressures acting on the kite (Figure 2b,c). In effect, the pressure on top of the kite decreases and the pressure below the kite increases, causing the kite to lift in the water. The amount of lift generated will change with the speed at which the kite is towed through the water.

The angle of attack of the kite should not exceed 35°. If the angle of attack is increased beyond this, a turbulent flow is produced above the kite (Figure 2d). This turbulent flow drastically increases drag, decreases lift and may force the headline downward.

SPREAD

Spread is a lateral force applied to trawl gear and is generated almost entirely by the trawl doors. The lateral force is a shear force and is generated exactly the same way as the lift generated by a kite but in a sideways direction. A small amount of spreading force is also generated by the net panels.

COMBINED EFFECT OF DRAG, LIFT AND SPREAD

The shape and position a trawl assumes in the water can be defined technically, thus: any component of fishing gear achieves a steady position in relation to other components when the external forces acting on that component are in balance. If the forces become unbalanced, then the component changes its relative position until all the forces are once again in balance. This is an important point to remember. Trawl gear is a dynamic, or flexible, piece of equipment and a change in one part of the gear will produce corresponding changes in other parts. The weight of the warps, doors, rigging and trawl exert a downward force in the water. The warps also exert forward and upward forces that are determined by the towing speed of the vessel. These forces pivot on the towing blocks. The trawl and doors also exert a rearward or drag force. When all these forces are in balance, the trawl will maintain a steady position in the water. If any of these forces change, the trawl will assume a new position in the water where all the forces are again in balance.

Let's illustrate this point by reviewing a couple of questions. Why will a pelagic trawl always tow at the same depth from set to set if the towing speed and warp length are constant (provided there are no changes in other conditions such as sea state and current)? If the towing speed and warp length are the same, the two main forces acting on the trawl, lift and drag, are also constant. The only force that can be readily changed is drag, by either increasing or decreasing towing speed. If the towing speed is increased the drag will increase. This increased drag will act at the pivot point (towing

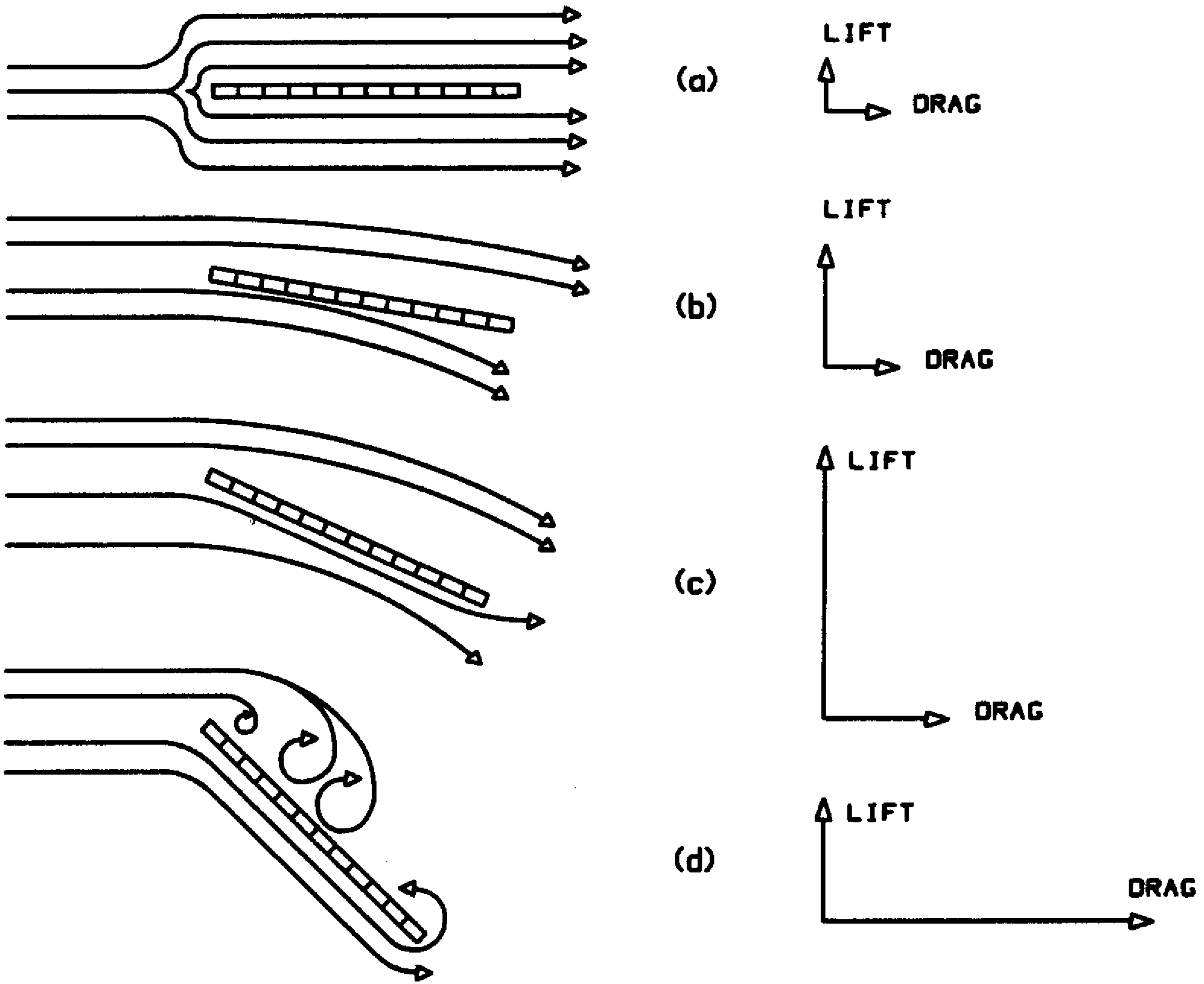


FIGURE 2. RELATIONSHIP BETWEEN LIFT & DRAG ON A SURFACE INCLINED IN A MOVING WATER STREAM.

blocks) and the net will rotate about this point and assume a position higher in the water. If the towing speed is decreased, the opposite will happen and the net will sink in the water.

Why, when bottom trawling, do the doors stay in contact with the seabed? Again, the answer is the influence of the two forces, drag and lift. The door is pulled from behind by the drag of the gear and the weight of the door holds it on the bottom. These forces are opposed by the warp, which is inclined upward toward the vessel. Part of the tension in the warp is directed upward and should this exceed the weight of the door, the door will lift off; or alternatively, the door may heel over onto its back. The door could also lift off the bottom if the towing speed was increased. In this case the drag exerted by the gear increases, changing the backward pull on the door; this in turn causes the upward force in the warp to increase, overcoming the door's weight and lifting it off the seabed.

SELECTION OF DEMERSAL TRAWLS

Now that the various forces that act on trawl gear in the fishing situation have been examined, the following chapters on gear design should be of more value. Events that may have been puzzling in the past may now be explained. Once a trawl has been assembled and used, the temptation to modify it can become irresistible. Ascertaining the results of modifications can be extremely difficult; however, certain guidelines can be drawn up to improve the performance of existing trawl gear.

There are various parameters that have to be considered regarding any set of fishing gear and its operation:

(a) The fishing vessel that will tow the trawl

The fishing vessel is a fixed item in any fishing combination. The power available from the vessel's main engine will decide the maximum trawl size that can be used. The engine power and trawl size will dictate the towing speed that can be attained. Other related factors to be considered are the vessel's winch power and its gear handling facilities.

(b) The towing speed the trawler and trawl gear can achieve

The towing speed at which the trawler should operate will be influenced by the swimming speed of the target fish. Once the fixed parameters are known, the choice of twine diameter, mesh size and door areas can be made. For any particular sized net small meshes produce relatively large drag. Increasing the mesh size means a bigger net can be towed with the same available power, and reasonable strength maintained by increasing twine diameter. The choice of doors will also influence the towing speed. Smaller doors will allow an increase in the towing speed, but using a known standard door means a bigger net can be towed at a slower speed.

If modifications to existing fishing gear are contemplated, remember that the original design was selected because it gave satisfactory fishing results with the selected trawl doors. Any changes during experimentation with the original trawl may mean the gear will no longer work satisfactorily with the same doors.

(c) The trawl size to give the best performance for your vessel towing speeds

Trawl performance data is generally available only from the net manufacturer; consequently, trawl size must be determined through a manufacturer. If supplied with the fixed parameters (such as towing power available, winch capacity, towing speed, and so forth) manufactures will generally build a trawl to suit your needs.

(d) The position of the fish relative to the sea bed and the vertical distribution of the fish

Generally speaking, the vertical distribution of the fish will influence the headline height required. As modern fishing gear is very much a compromise, attention must be paid to how much flotation the gear can stand. Remember that greater headline flotation does not necessarily mean extra headline height.

(e) Rigging the trawl to suit the sea bed conditions

The type of ground to be fished will generally dictate the type of ground gear to be employed. Mainly, trawl design and rigging should keep the belly and cod end clear of the bottom to minimize damage.

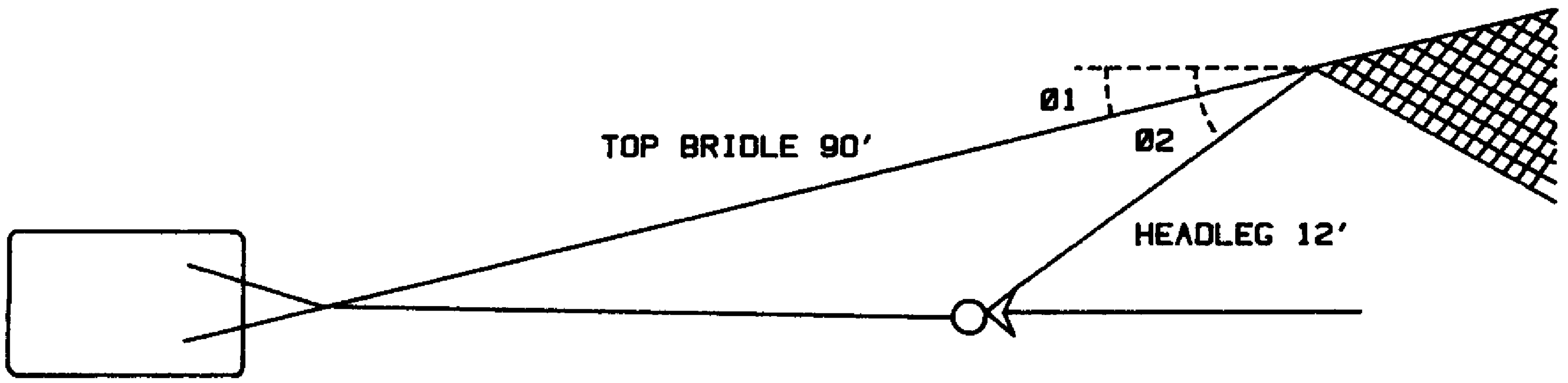
DESIGN AND RIGGING OF DEMERSAL TRAWLS

The following analysis will demonstrate some of the effects of variations in rigging. The material results from experiments on one-tenth scale models of Granton and Balta trawls using 11 x 5 flat and vee doors. Using the netting specification plan, roping-out plan and the rigging plan in conjunction with model tests in a flume tank, the following changes in performance were accomplished. The headline height was increased by altering the groundwire tow leg system such that the downpull of the headleg/top bridle is decreased. This can be achieved by:

(1) Using a twin bridle system, which decreases the angle between the top bridle and the horizontal, thus decreasing the downpull of the top bridle on the headline (Figure 3).

(2) Lengthening the top bridle, which will decrease the tension in it and further decrease the downpull on the headline.

(3) Use a semi-pelagic rig where the top bridle is attached to the warp at a point where it is higher off the bottom than the headline wing end. This will result in the top bridle pulling the headline up, not down (Figure 4).



THE PROPORTION OF THE NET DRAG TAKEN ON THE TOP WIRE SHOULD BE THE SAME WHETHER A TWIN BRIDLE OR DAN LENO RIG IS USED. THIS EQUALS D. THE DOWNPULL FROM THE TOP BRIDLE IS PROPORTIONAL TO D TAN 01, DOWNPULL FROM THE HEADLEG IS PROPORTIONAL TO D TAN 02.

FIGURE 3. TWIN BRIDLE SYSTEM.

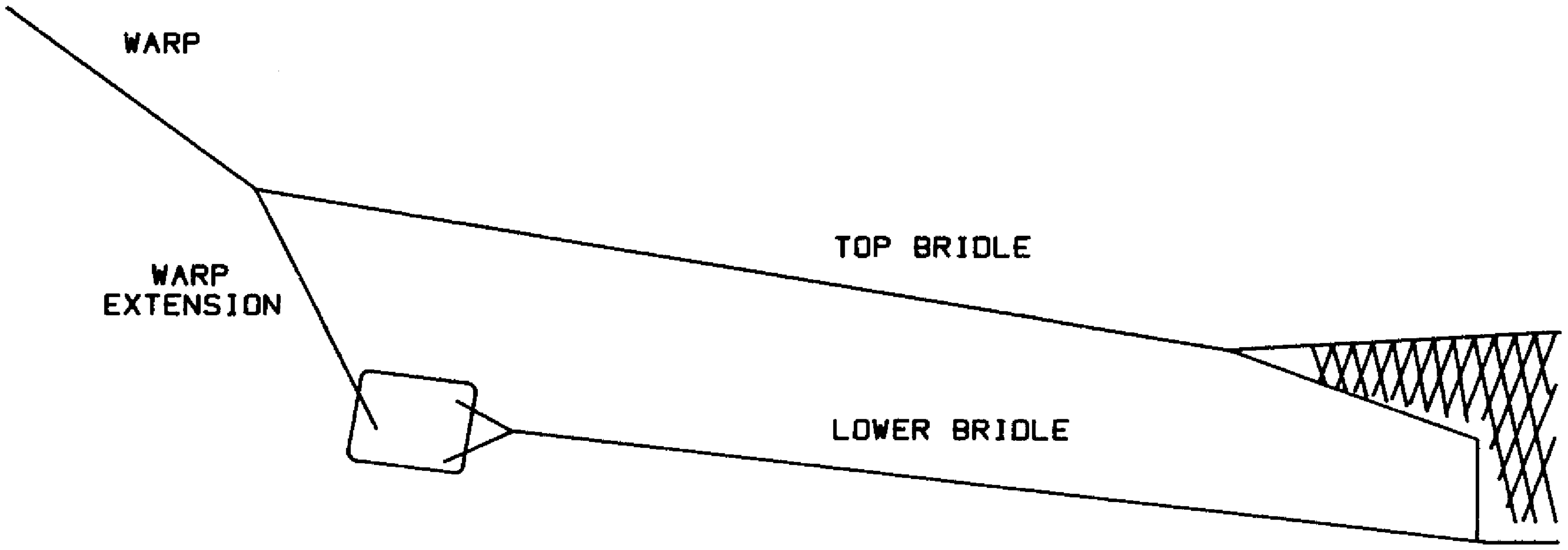


FIGURE 4. SEMI-PELAGIC RIG.

It would be possible to improve the headline height of the trawl even further by a closer study of the various loads imposed on the trawl. On the previous rig, the main load is taken on the belly wires and is transferred to the ground gear and lower bridle. This strain may be altered by introducing a third bridle attached to the selvage of the trawl and made short to take the main strain (Figure 5). The belly wires can then be removed. Attaching the third bridle to the fore end of the top wing selvage will probably give only a moderate headline height. Despite being tapered, the top wing selvage is still cut at a shallow angle and therefore follows the same line as the square and belly selvages which results in the headline being pulled down. If the center bridle is attached to the fore end of the square selvage, as in Figure 5, note how the top wing selvage now slopes up from the square selvage to the headline height.

MATCHING TRAWLS AND DOORS

The first trawls used a beam to keep the trawl mouth open. These trawls were awkward to handle on deck and the mouth area was limited by the length of the beam. With the introduction of steam trawling, and the resultant steady pull on the warps at a steady speed, it became possible to use the kite action of a correctly-angled board attached to the wings of the trawl to spread the net. This type of trawl with the "doors" at the wing ends, was largely replaced during the early 1920s by the more efficient "bridled" trawls, where the doors were allowed to spread wider than the wings, by placing them at a distance from the wing ends on wires known as ground wires and tow legs.

The increased catch rates with the bridled trawls resulted from the increased area of seabed being swept, making more fish vulnerable to the trawl, and to the shepherding effect of the wires guiding the fish toward the net mouth. The original doors were a simple flat shape with low aspect ratio; that is, they were about twice as long on the keel as they were high. Made of wood, they were reinforced with metal straps, and with metal shoes on the keel. This original shape and construction still exists, largely on the grounds of "cost effectiveness". Over the years, however, new trawl doors have been designed to match different types of fishing methods and fishing areas. The greatest change in recent years has been in mid-water, or pelagic, fishing where hydrodynamically efficient and stable doors like the "Suberkrub" are used.

Before examining the various doors how they match a particular fishing gear, it is necessary to discuss a little basic theory. Forces that act on a trawl do not produce single effects, but several simultaneous effects. These effects can be determined by plotting the relative size and direction of the force on graph paper. For example the total hydrodynamic (water flow) force and ground friction applied to a door moving through the water act perpendicular to it (Figure 6a); however, these forces also have shear and drag components. The total force acting on the door is determined by the vector addition of the hydrodynamic forces and ground friction. The magnitude and direction of this total is then plotted on an x,y coordinate system (Figure 6b). The resultant shear and drag forces are the magnitude of the respective x and y coordinates of this plot (Figure 6c).

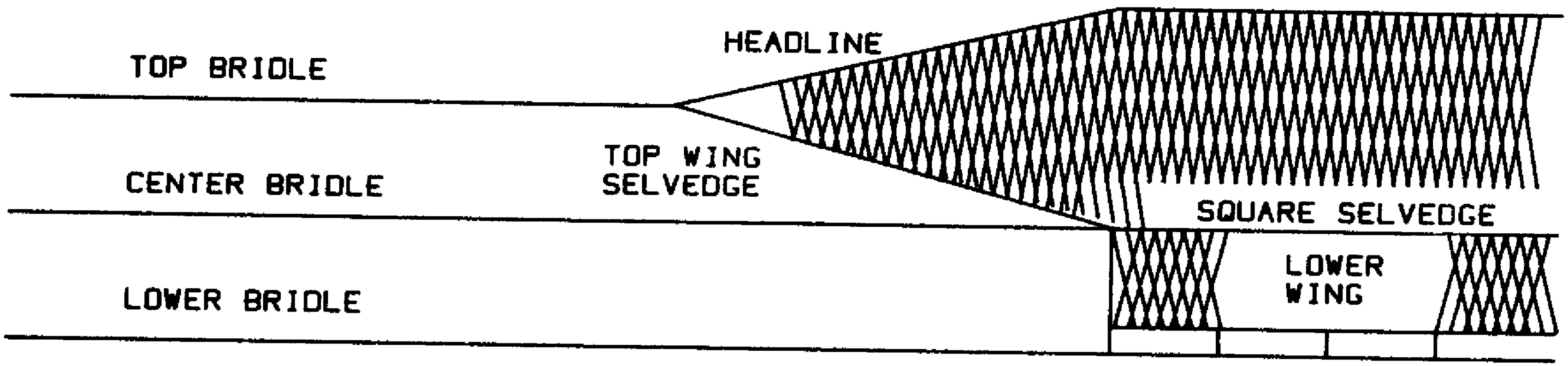


FIGURE 5. THREE BRIDLE RIG.

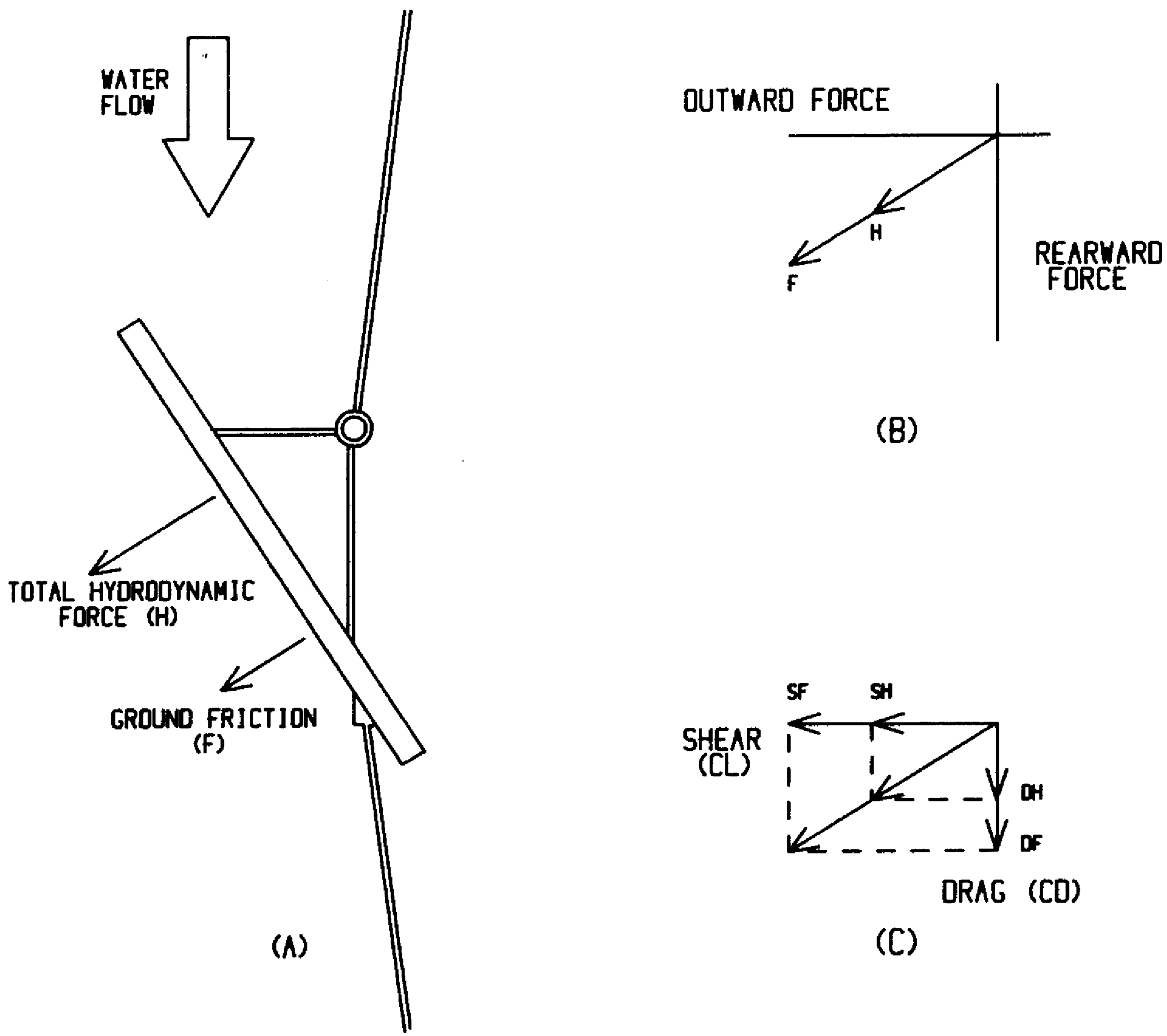


FIGURE 6. ANALYSIS OF SHEAR AND DRAG FORCES ACTING ON A MOVING TRAWL DOOR.

A more detailed analysis of the forces acting on a moving trawl door is given in Figure 7. The door attitude and angle of attack is determined by the vector sums of the forces involved. A pelagic trawl door will be influenced by the same forces, but without the influence of ground friction, shear and drag.

In order to spread a trawl door, the total spreading forces must be greater than the total inpulling forces. Maximum spread will be reached when the spreading force equals the inpulling force. In practice, how well a door will spread the gear depends upon its size, shape and the towing points selected. The position of door brackets and backstrap attachment points are so arranged that when the door shears outward under the influence of hydrodynamic and ground contact forces, it is restrained by the inpull from warp and bridle tensions and takes up an "angle of attack" relative to the direction of tow. In this position the various forces will be balanced and the angle of attack maintained until one or other of the forces is changed.

The hydrodynamic forces that spread the doors will vary with towing speed, size and shape of doors, and with their angle of attack. Bigger doors will meet a bigger area of water. Increasing speed will increase the volume of water meeting the door in a given time. The shape of the door will influence the flow patterns and turbulence around the door, and determine its spreading efficiency. The resultant combined hydrodynamic forces will be at right angles to the door through its center of pressure. The center of pressure will shift at different door angles and so change the direction of the resultant force. The angles of "heel" and "tilt" can also affect the resultant force.

Bridle tension is produced by the forward pull of the door reacting with the backwards pull from the net and gear. The total drag of the net is transmitted to the door through the ground wires. When towing, the doors will be spread and the ground wires will take up an angle of attack to the direction of the tow. Gravity, water flow and, possibly, bottom friction will put curvature into the ground wires and influence their approach angles at the door. Varying ground wire tension on bad ground will, consequently, affect the balance of the door.

The center of gravity of the door will depend upon the distribution of the door components and its position will affect the stability of the door. Bottom friction will vary with the type of seabed and the amount of force pressing the keel of the door on the seabed. This force results from the weight of the door and the vertical component of the hydrodynamic forces (Figure 8). When doors dig into sand or mud, the spreading force will be increased by the extra "ground shear" generated, but so also will be towing resistance and total drag. The type of sea bed is the most variable influence upon bottom trawl doors, and some doors are especially designed to reduce bottom contact.

The towing tension in the warp is the result of the ship's pull against the total backward drag of the doors and fishing gear. A warp under tension has components of lift and inpull, which will vary with the amount of warp in use. The length of the warp will affect the sag, or catenary, and will determine the angle at which the warp meets the towing brackets. This could modify the

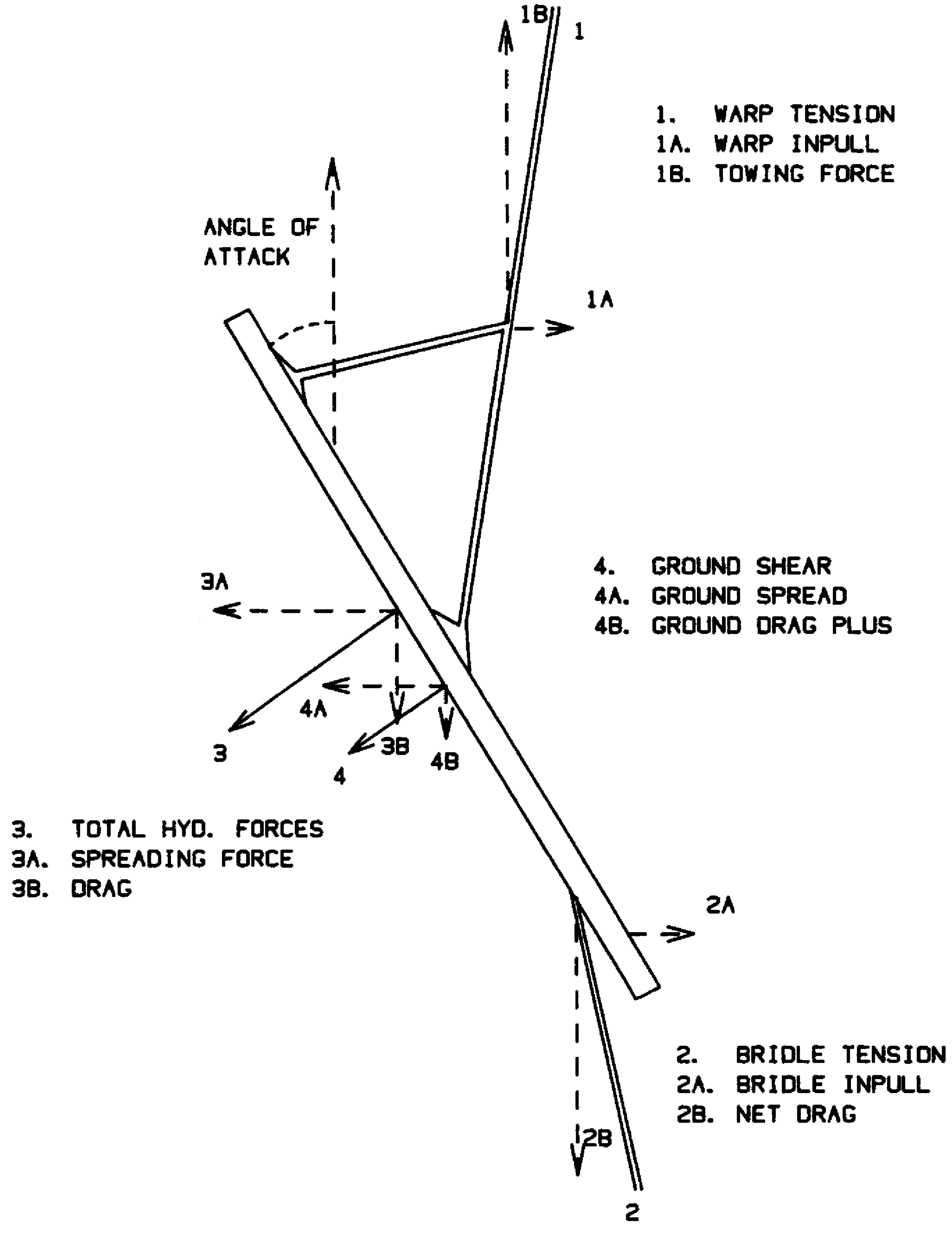
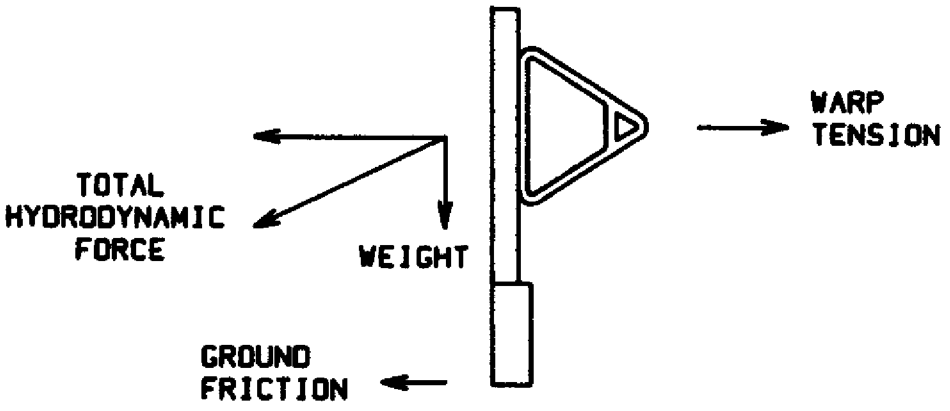
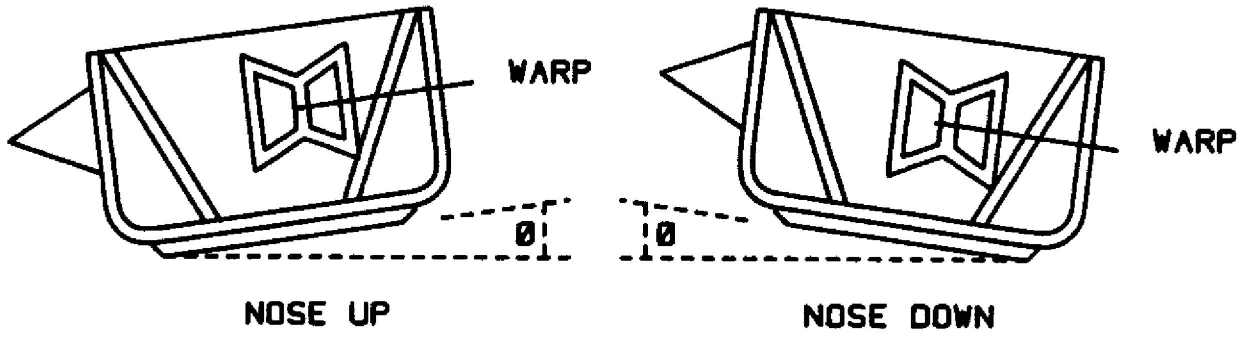


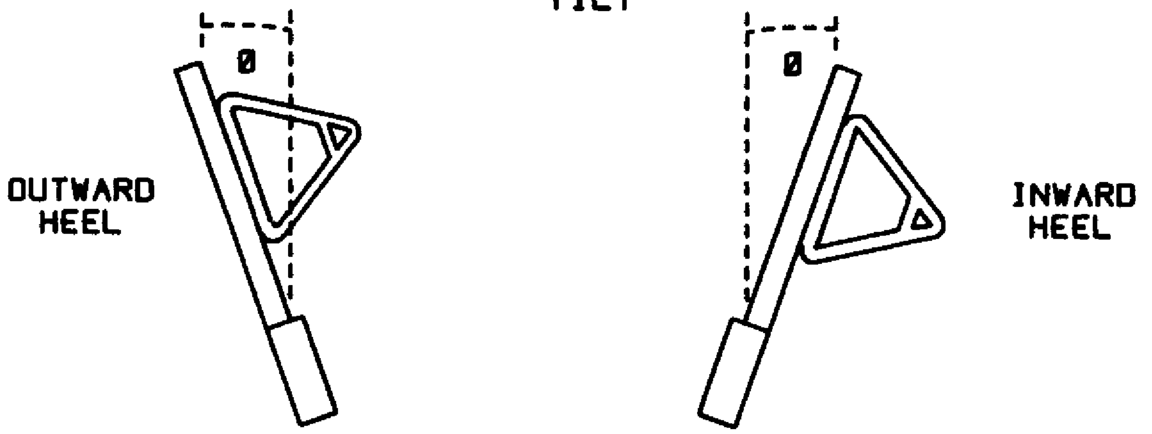
FIGURE 7. ANALYSIS OF FORCES ACTING ON A MOVING TRAWL DOOR IN BOTTOM CONTACT.



FORCES AFFECTING DOOR ATTITUDE



TILT



HEEL

FIGURE 8. ATTITUDES TAKEN BY TRAWL DOORS.

towing force imparted by the ship and thus the efficiency of the door. If short warp lengths are used in relation to depth, for example less than 3:1, the increased upward pull may lift the doors and cause the spread to decrease as the ground component of shear is lost. If low ratios of warp length to depth are used it becomes necessary to use heavier doors, or to adjust the heel of the door outward (by lowering the warp attachment point below the centerline of the door) in order to keep the door on the bottom. When higher ratios of warp length to depth are used, for example 4:1 or 6:1, in shallow water, lighter doors can be used, since there will be little chance of them lifting and no outward heel will be required. In extreme cases the upward pull could become zero, or even negative if a lot of warp is used in shallow water. This is undesirable since it increases warp wear.

If the top of a door heels outward, the downward acting force will increase, and the door will press harder against the bottom. However, if the door heels inward, the upward acting force will increase and tend to lift the door. Mid-water doors cannot balance their forces with a reaction to the seabed, and their weight and shape become more critical, making accurate ballasting necessary. Heeling the door will normally reduce the spread, but in some fishing conditions it may be worthwhile to increase lift and sacrifice some spread. This is particularly true with pelagic doors where the trawl may make rapid depth changes during towing. Pelagic doors are so designed that their angle of heel and, therefore lift, will change with changes in towing speed.

The tilt of a door can be important, especially with bottom doors. A "nose-down" tilt can cause "digging in", while a "nose-up" attitude can cause light bottom contact and reduce "ground shear." With zero tilt, the keel of the door will have bottom contact along its full length resulting in extra shear, but also in additional drag. Usually a slight nose-up attitude will be best since obstructions are more likely to be cleared. When fishing in soft mud with a nose up attitude, the loss of ground shear may be significant and cause poor spreading of the doors. One way to bring the nose back down would be to lengthen the upper backstrap wire.

The "efficiency" of a trawl door results from two main forces, the spreading force or shear (CL) and the backward drag (CD). An efficient door will have a large shear force and a low drag force. By using special underwater instruments it is possible to measure the forces involved with different trawl doors and so compare their efficiencies. A flat door will not exert the same force as a cambered door or a vee door of similar area, at similar speeds and attitudes, so the shear and drag forces largely result from door design.

By plotting the angles of attack against the shear (CL) and drag (CD) coefficients, it is possible to compare the performance of different doors (Figures 9 to 12). From the graphs it can be seen that the 9 percent cambered door has more shear at all angles of attack than the flat rectangular door. However, it also has more drag. How can we determine which is the more efficient? To get the same shear force at a certain speed, a cambered door with less area can be used instead of a flat door. This smaller area reduces the cambered door's drag and, therefore makes it the more efficient of the two.

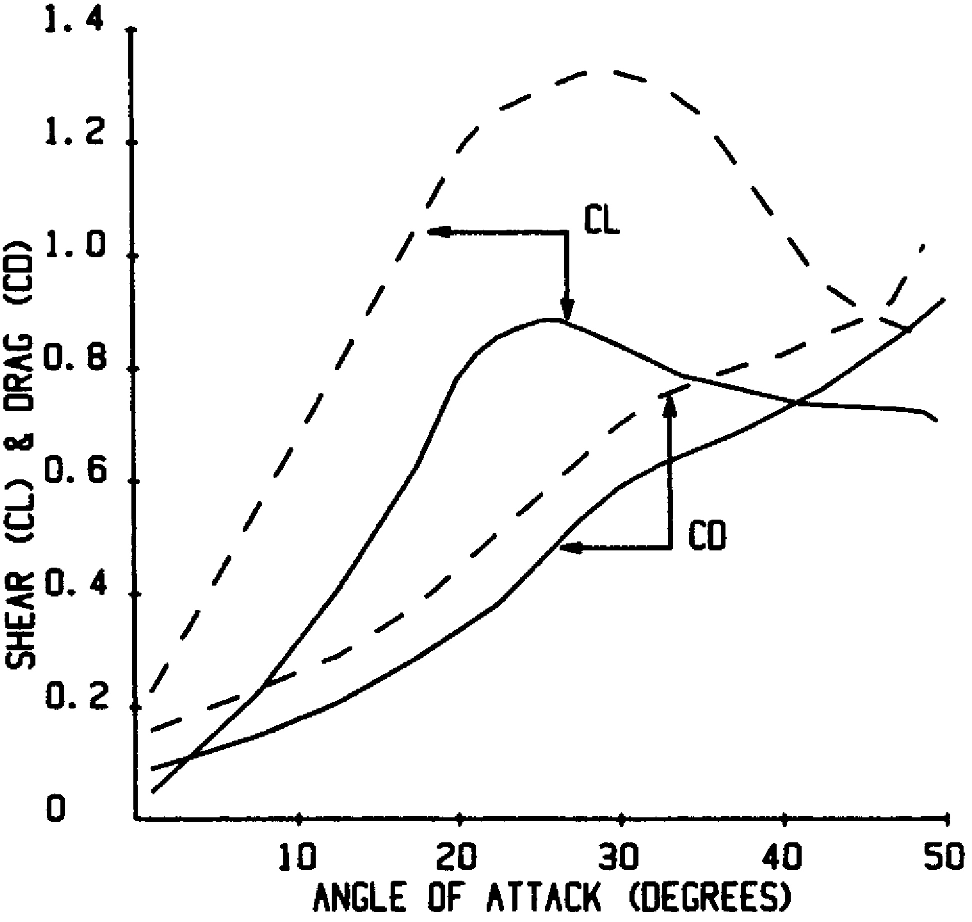


FIGURE 9. SHEAR AND DRAG COEFFICIENTS OF RECTANGULAR FLAT AND CAMBERED DOORS IN GROUND CONTACT VS. ANGLE OF ATTACK: (— — —) 9% CAMBERED, (————) FLAT.

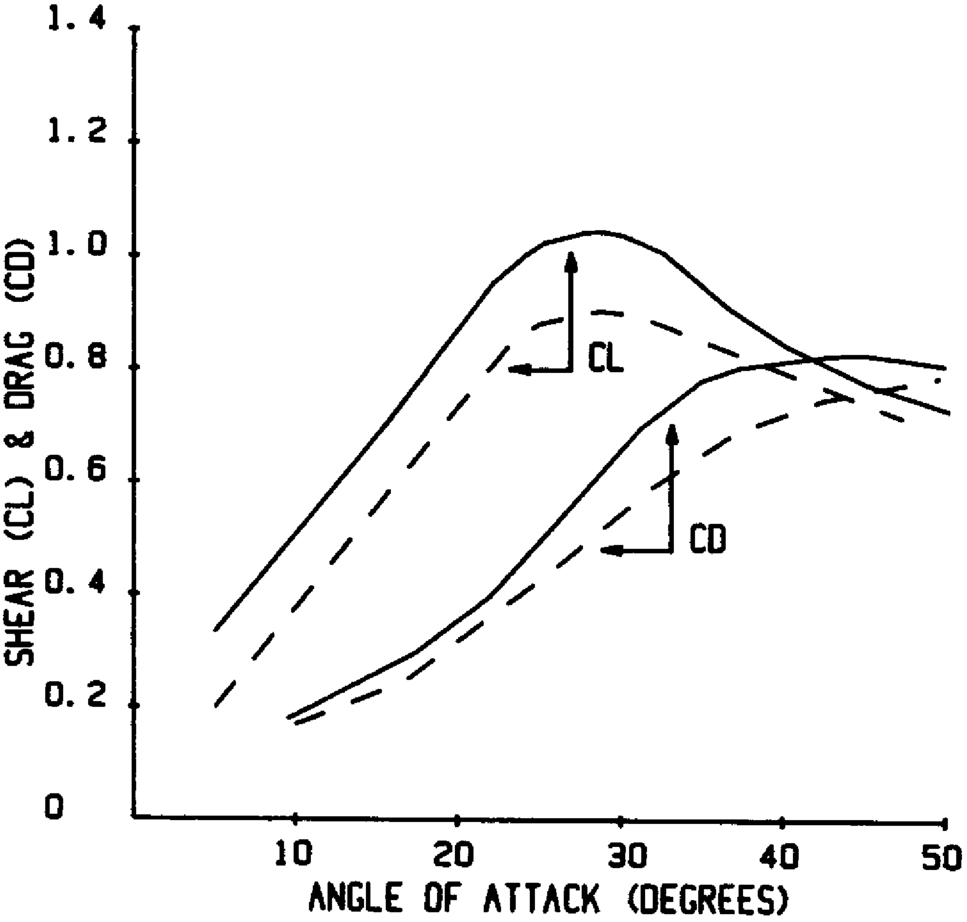


FIGURE 10. SHEAR AND DRAG COEFFICIENTS OF POLYVALENT, 6% CAMBERED AND OVAL FLAT SINGLE SLOT DOORS IN GROUND CONTACT VS. ANGLE: (— — —) OVAL FLAT, (———) POLYVALENT.

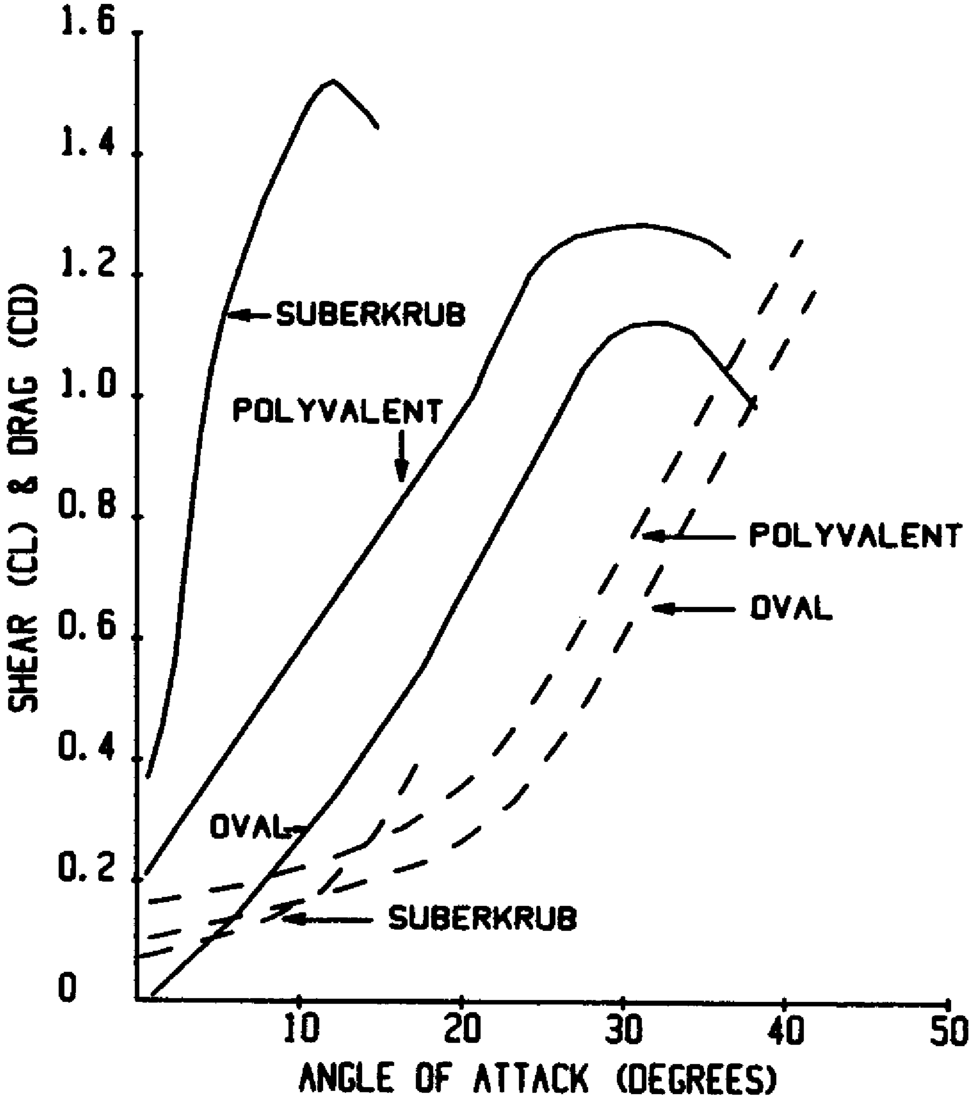


FIGURE 11. SHEAR AND DRAG COEFFICIENTS OF OVAL FLAT, POLYVALENT AND SUBERKRUB DOORS IN MIDWATER VS. ANGLE OF ATTACK: (————) SHEAR, (— — —) DRAG.

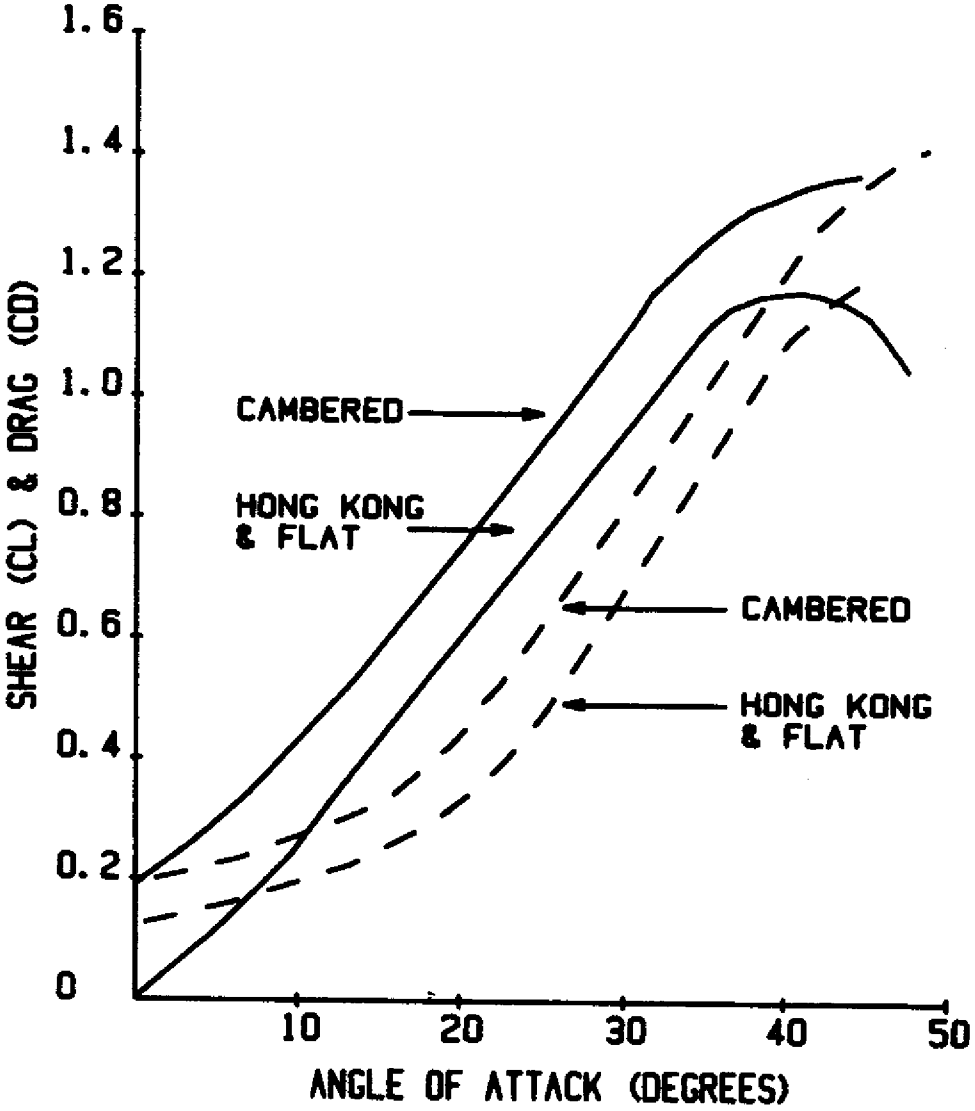


FIGURE 12. SHEAR AND DRAG COEFFICIENTS OF RECTANGULAR FLAT, RECTANGULAR CAMBERED & HONG KONG DOORS IN MIDWATER VS. ANGLE OF ATTACK: (———) SHEAR, (— — —) DRAG.

The ratio between spreading force, or shear/drag, is always a good indication of door efficiency. Figures 13 and 14 give the relative efficiency of all the popular doors, plotted against their angles of attack. Any door has a limited range of attitudes at which it can operate, and the graphs show that angles of attack greater than 50° are not used. At angles greater than this, the doors become unstable. Also note that a normal flat door will give best hydrodynamic performance at about 20°. In practice, however, a flat door is usually worked at angles between 35°and 45°, depending upon speed and roughness of the bottom. This allows a reserve of stability and lessens the chance of "door collapse" when working rough ground.

When working fine ground, it may be possible to reduce angles of attack to be nearer the peak of hydrodynamic efficiency and so increase towing speed or fuel economy without sacrificing spread. Trawl doors account for about 25 percent of the total gear drag, more in cases of a bad mismatch between doors and gear, so the savings could be significant. The spreading efficiency of the door will also affect the shape of the net. The doors used must maintain the catching efficiency of the net itself, while making best use of the available towing power.

Oval, slotted and vee doors usually operate between 30° and 40°. Cambered rectangular and polyvalent doors of low aspect ratio usually operate between 25° and 35°. Pelagic doors of high aspect ratio, like the Suberkrub, operate at relatively small angles, between 15° and 25°. To make these doors sensitive to heeling with speed, the warp attachment point is usually about 5 percent of the height above the centerline. Heeling angles do not normally exceed plus or minus 10°.

When bottom doors lose bottom contact and are lifted into mid-water, they will oscillate and become very inefficient. The angles of attack, however, will usually remain within the limits quoted above. The addition of brackets, backstrap fastening points, and other metal work will make some difference to the overall efficiency of the door.

Given sufficient information about the net to be towed and the horsepower available, it is possible to calculate the correct size of trawl door to match the net. The graphs in Figures 15 to 19 can be used to match a size and weight of door to a particular vessel's horsepower. Both graphs result from a combination of theoretical and practical calculations and represent current practice with a standardly designed trawler capable of towing at 4 knots. In specific cases, errors of up to plus or minus 10 percent can be expected when using these graphs. The average trawler, approximately 800 horsepower, would use flat doors of 10 ft by 5 ft or 4.72 m^2. The graph shows that a flat door with an area of 4.5 m^2 is required for an 800 hp vessel, indicating a close relationship between the graph and accepted practice.

Alternatively, Figure 20 can be used to match doors to a particular size of net without reference to horsepower. If the twine surface area of a net is known (see Appendix A), it used with Figure 20 to determine the door size required. As an example of how Figure 20 can be used, try matching a set of doors to the enlarged bottom trawl known as the Balta. The calculated twine

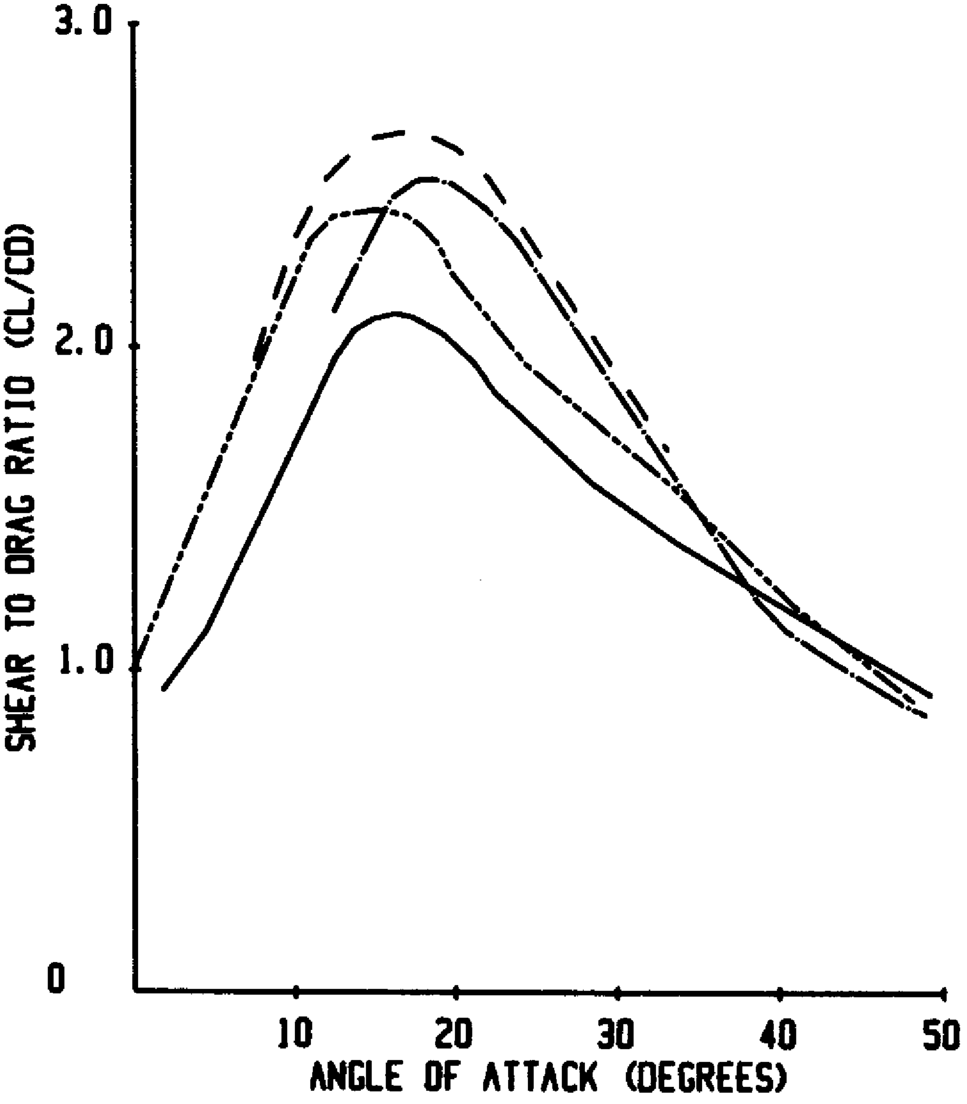


FIGURE 13. DOOR EFFICIENCY, SHEAR-TO-DRAG RATIO VS. ANGLE OF ATTACK WITH DOORS IN GROUND CONTACT: (———) FLAT, (— —) RECT. CAMBERED, (—·-—) POLYVALENT, (———) OVAL.

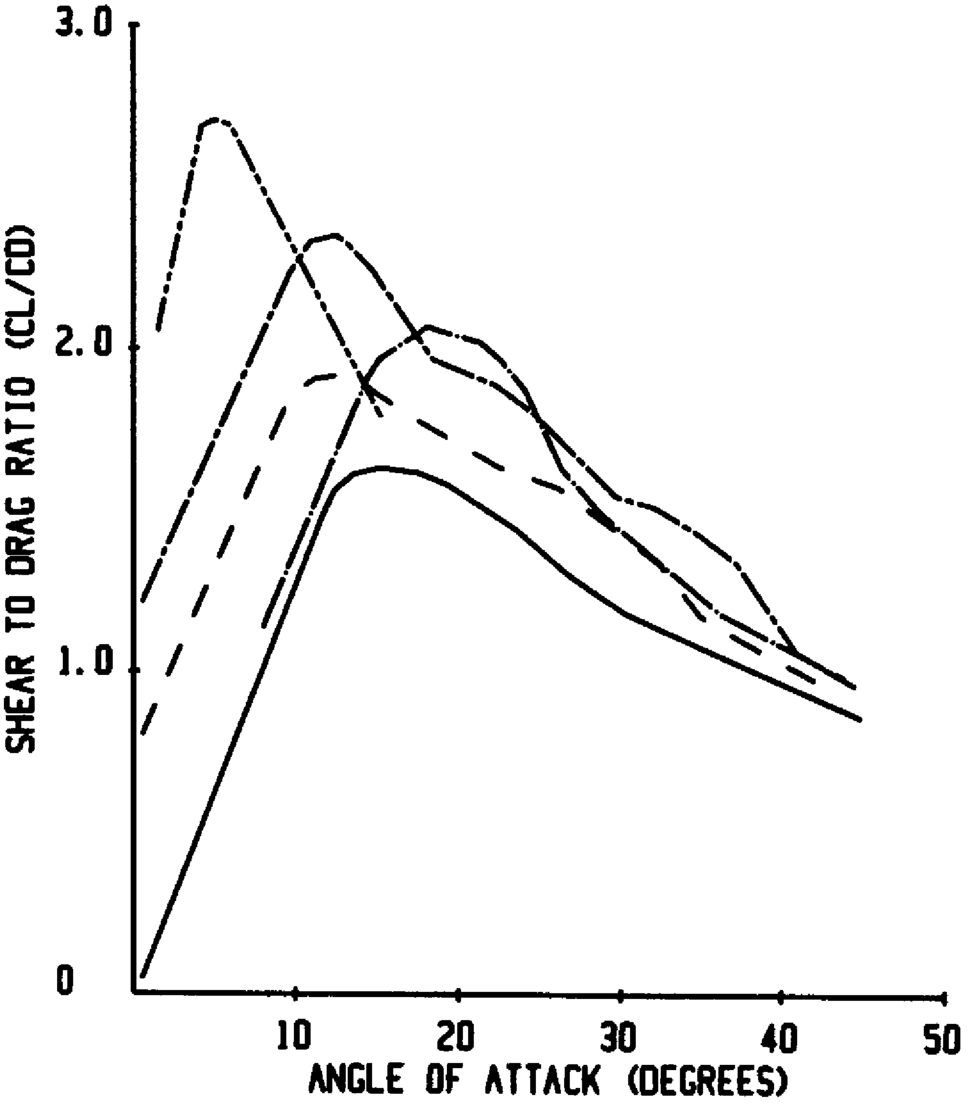


FIGURE 14. DOOR EFFICIENCY, SHEAR-TO-DRAG RATIO VS. ANGLE OF ATTACK IN MIDWATER: (———) FLAT & HONG KONG, (— —) RECT. CAMBERED, (——·——) OVAL, (——·—) POLYVALENT, (——··——) SUBERKRUB.

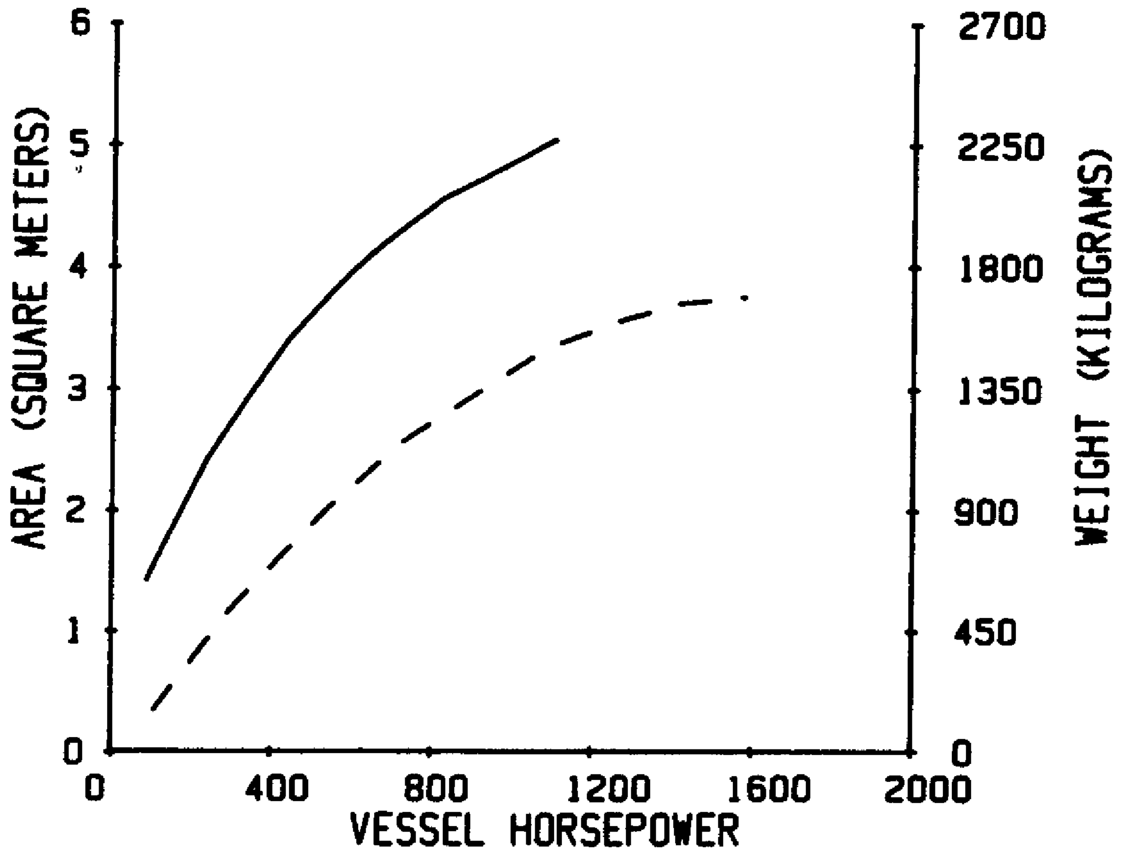


FIGURE 15. RECTANGULAR FLAT DOOR, COMMON SIZE AND WEIGHT RELATIVE TO HORSEPOWER (——) AREA, (– –) WEIGHT.

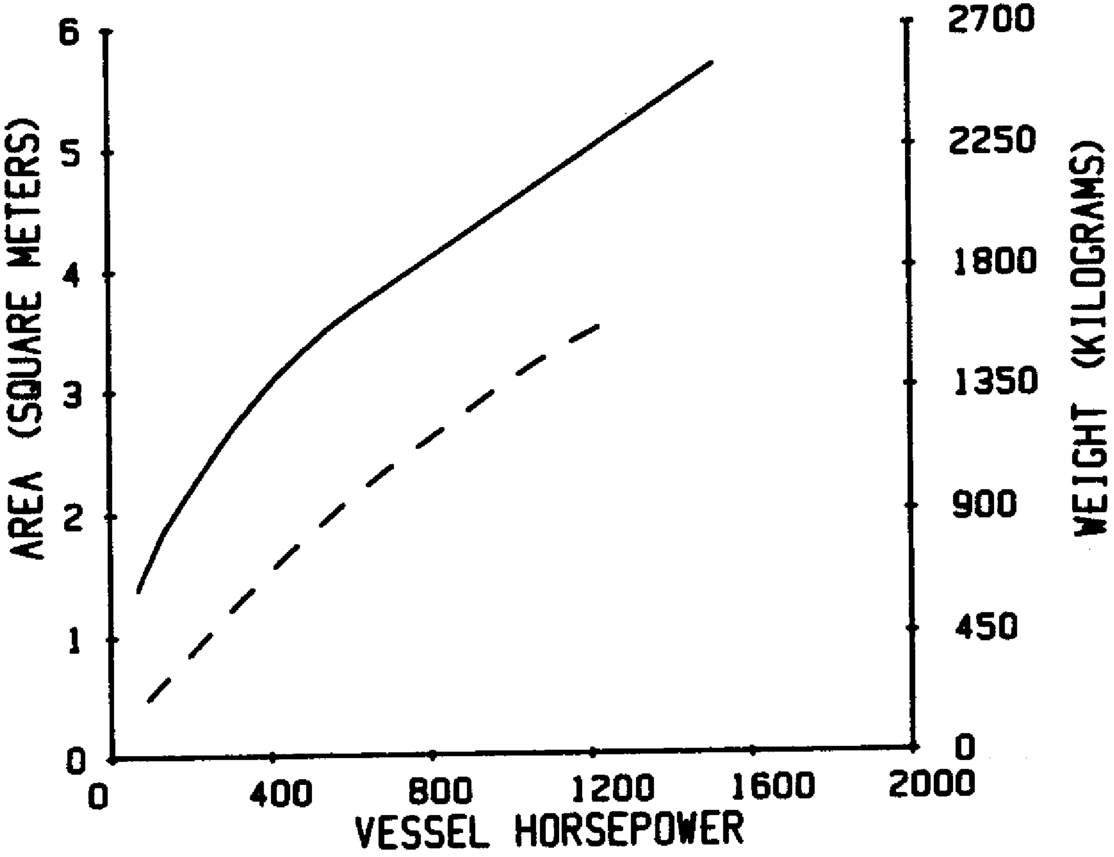


FIGURE 16. VEE TYPE DOOR, COMMON SIZE AND WEIGHT RELATIVE TO HORSEPOWER (——) AREA, (– –) WEIGHT.

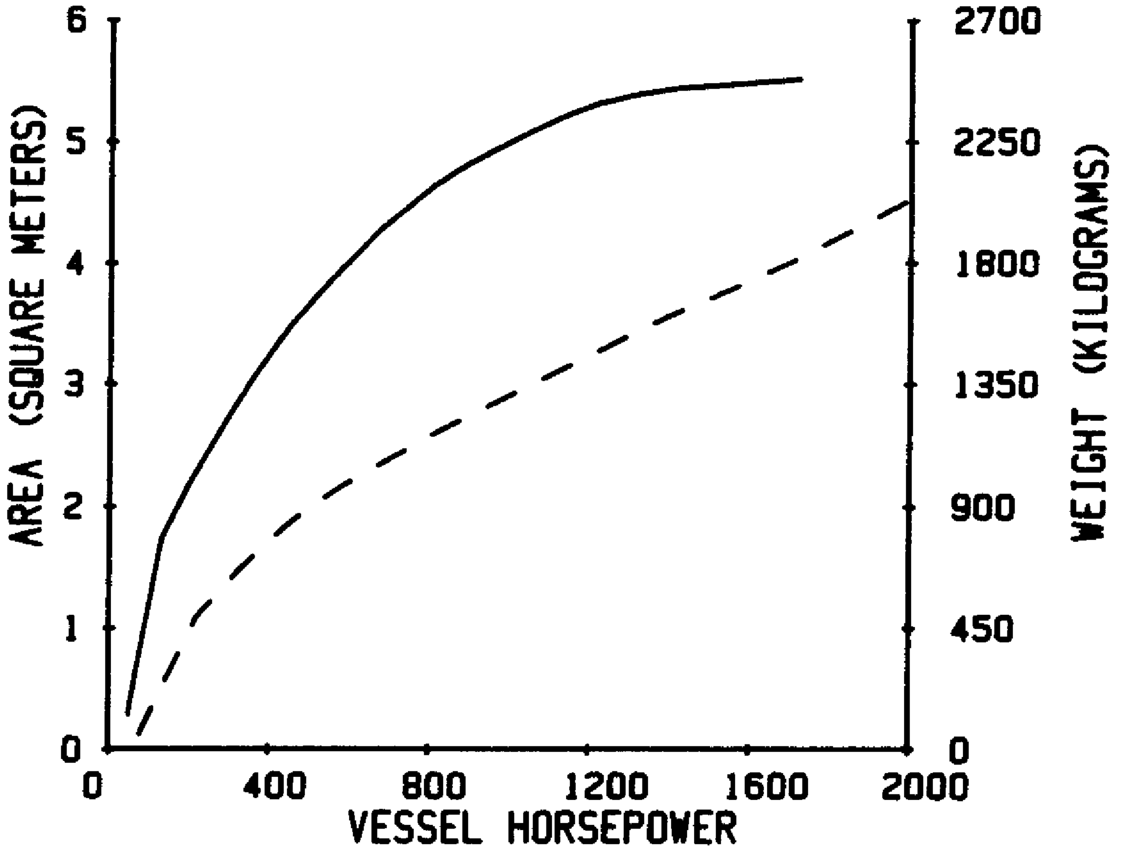


FIGURE 17. OVAL FLAT DOOR, COMMON SIZE AND WEIGHT RELATIVE TO HORSEPOWER (——) AREA, (– –) WEIGHT.

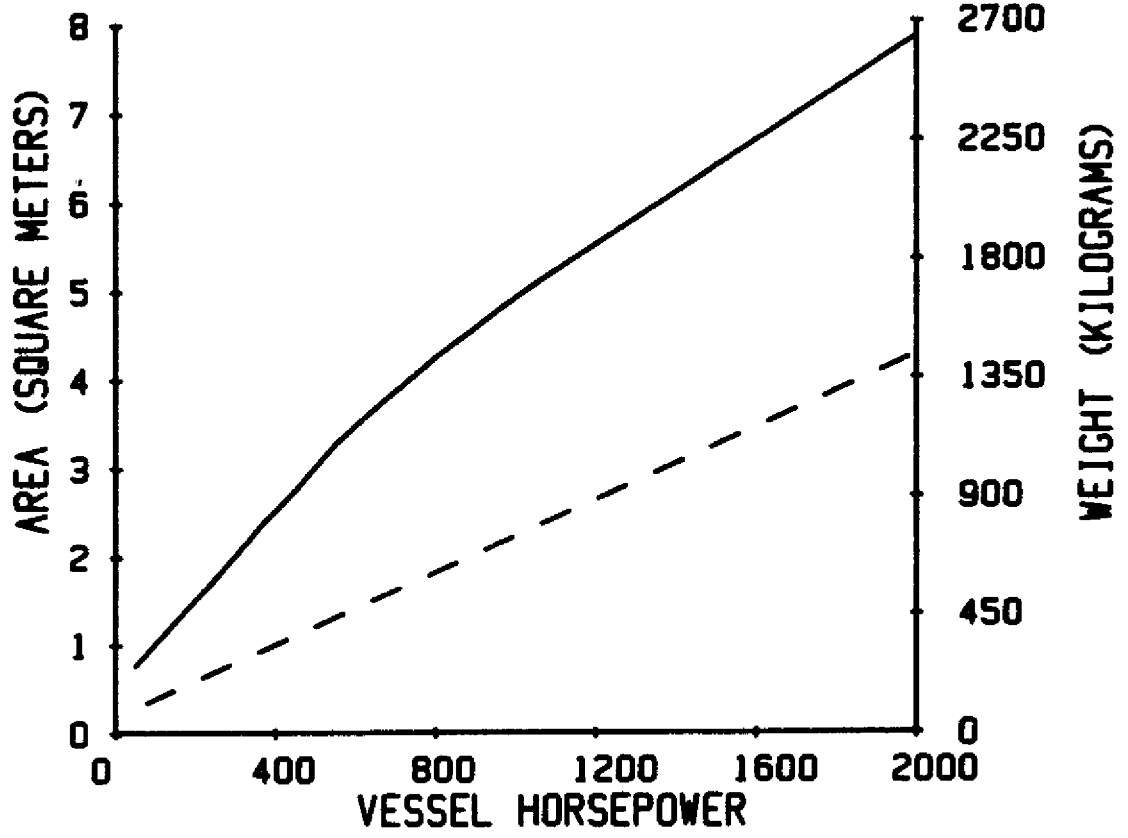


FIGURE 18. SUBERKRUB DOORS, COMMON SIZE AND WEIGHT RELATIVE TO HORSEPOWER; (——) AREA, (– –) WEIGHT.

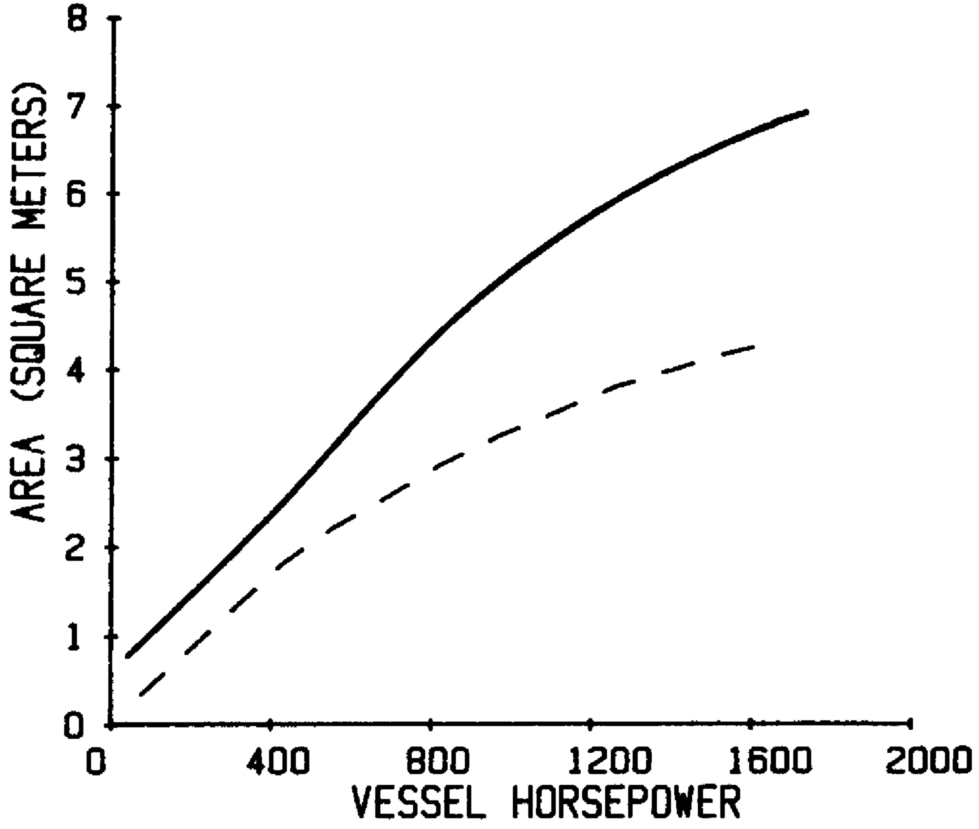


FIGURE 19. POLYVALENT AND HONG KONG DOORS, COMMON SIZE RELATIVE TO HORSEPOWER; (——) POLYVALENT, (— –) HONG KONG.

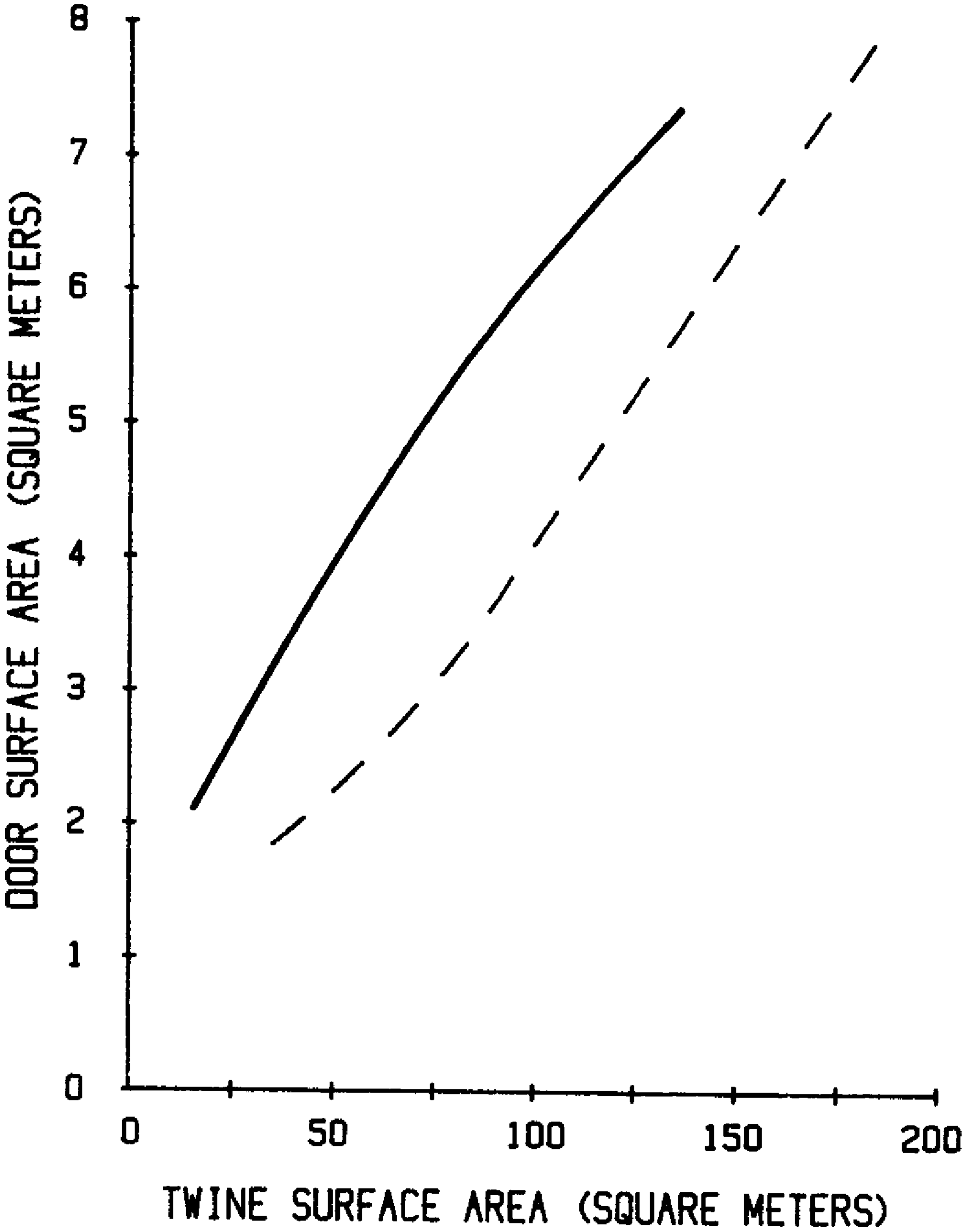


FIGURE 20. RELATION BETWEEN DOOR SIZE AND TWINE SURFACE AREA: (———) BOTTOM TRAWLS, (— —) MIDWATER TRAWLS.

surface area of this particular trawl with strengthened cod ends is 140 m^2. Apply this number to the bottom trawl portion of the graph, and you will find that a door with an area of 7.25 m^2 will be required.

DETAILED DESCRIPTION OF THE MAIN TYPES OF TRAWL DOORS

Standard Flat Rectangular Doors

This type of door is relatively inexpensive and can be used on most types of ground (which has probably held up progress toward more efficient types of doors.) It is easy to handle and occupies minimum stowage space. By careful arrangement of the vertical steel strength members that carry backstrap mountings and warp brackets, it is possible to make the door interchangeable from one side of the trawl to the other if the keel is symmetrical. The flat door is not very hydrodynamically efficient, since it generates a great deal of turbulence behind it, increasing the drag and reducing the shear. On soft ground, large mud clouds are generated that cause flight reactions in fish and can improve the trawl's catching efficiency. In normal conditions it tends to dig into the sea bed due to a slight outwards heel and a long straight keel.

The usual angle of attack is 40° and, if alternative backstrap mountings are provided, may be increased by moving the backstraps forward and decreased by moving them backward. Decreasing the angle of attack probably increases the hydrodynamic efficiency of the door and an angle of 25° has been said to give maximum shear with minimum drag. However, in practice this "fine tuning" of the door may lead to instability and door collapse on bad ground. It is normal to "spoil" a little on the door's efficiency by taking the angle through the optimum position and so allowing greater angular changes before door collapse would occur.

The main disadvantage of this type of door is its high ground pressure, that tends to generate shock loads. These can destroy the door or severely limit its life when working hard ground; also, since it is constructed of wood, metal, bolts and welds, it does not lend itself to quantity production and maintenance costs can become a problem.

Rectangular Cambered Doors

This type is like a dished standard flat door and often on larger doors, its back is completely plated with metal. A camber of 9 percent seems to give best results. This camber causes water to cling to the door's back so that less turbulence is generated, making the door more hydrodynamically efficient than the flat door. A smaller door can therefore be used to achieve the same spread as a larger flat one would. The angle of attack is about 30° and the curved shoe reduces the amount of digging into the seabed, thus reducing towing resistance and ground shear. Reduced ground pressure makes this door more durable and there is usually a choice of backstrap mounting positions. Disadvantages are that higher shooting speeds are necessary than with flat doors and that cambered doors seem best suited to stern trawlers. They are difficult to recover when collapsed and their curvature makes them more expensive to produce than the flat door.

Oval Flat Slotted Doors

These doors are popular on east European vessels. The upward-curving keel makes them good for working rough ground and removable keel plates allow easy maintenance. The slot is intended to reduce turbulence and drag around the back of the door, producing a slightly better hydrodynamic performance than the flat door. On hard ground the contact force is similar to that produced by a flat door, since only "point" contacts will occur. On soft ground, the oval door does not dig in much because of the curved keel.

The shear force produced by the flat oval is less than that produced by a cambered rectangular door of the same surface. Its efficiency is higher than that of a flat rectangular door because it does not "plough" into the bottom. Therefore, its shear-to-drag ratio is better. However, even though this door is more efficient, the flat rectangular door may get more spread because its ploughing produces ground shear and a greater total spreading force. Oval flat doors are not suitable for pelagic trawling and their shape and slot make them relatively more expensive to produce.

Vee Type Doors

This door is designed to remain stable with little ground contact. If the door hits an obstruction, and lifts, the rigging causes the force on the lower surface to reduce more than that on the upper surface. The turning moment created brings the door back to its original orientation because of its hinged towing bracket. The door is suitable for working bad ground and it is popular with many fishing fleets. The towing bracket is a single bar, hinged at the door. It is reversible, allowing the door to be used on either side of the gear, thus evening keel wear. Another advantage is that only one spare need be carried on inshore vessels. They are durable, relatively cheap to produce, and easy to handle, shoot and stow. The lower half of these doors is angled outward, producing some upward shear. To counteract this, the doors are usually slightly heavier than a flat door of similar area.

Surprisingly, this door is not as hydrodynamically efficient as the flat rectangular door. Another disadvantage is its tendency to oscillate more than other doors because of the single-hinged towing bracket.

Polyvalent Doors

The doors discussed so far were designed for bottom trawls. If used with pelagic trawls, they become unstable and inefficient. Attempts have been made to design doors which are as efficient in mid-water as they are on the bottom, but there are still problems with this concept.

At first glance, the polyvalent door may be mistaken for an oval slotted flat door; however, it is cambered some 6 percent, combining the efficiency of the cambered door with the capability found in oval slotted doors for working bad ground. Construction is in mild steel, with a central rib carrying an upper towing point for pelagic trawling and a lower towing point for bottom trawling. This lack of towing brackets makes for easy stowage.

The complex shape makes the door expensive to produce and, although it is designed for mid-water work and should make carrying purely pelagic doors unnecessary, many captains also carry Suberkrub doors of larger area than the polyvalents. It is difficult to make one size of polyvalent match both a big pelagic trawl and relatively small bottom trawl. Trials carried out in 1972 compared the performance of polyvalent doors with that of Suberkrub and standard flat doors. After the trials, researchers concluded that polyvalent doors performed as did Suberkrubs of similar area when used in mid-water. On the bottom, they were much more efficient than a standard flat door and spread well with reduced drag.

Some instability over rough ground has been noted with polyvalent doors, probably due to intermittent ground contact. Changing the attachment points may help cure this, but the actual extent of the changes to be expected are unknown.

Suberkrub Doors

Suberkrubs were developed for bottom fishing during the 1930s, but operational difficulties delayed their adoption. They are the most hydrodynamically efficient of all the doors currently used and at the moment are the most popular pelagic doors. The aspect ratio is high at 2:1, in order to improve the shear-to-drag ratio. The amount of camber varies with the width of the door and has been so calculated that very little turbulence is generated around the back of the door. The rigging can be varied to change the shear in upward, downward or horizontal directions, by moving the warp attachment point or the lower backstrap attachment point. Moving the lower backstrap upward will increase the upward shear component, as also will moving the warp attachment upward. Usually, there are two warp attachment plates and three lower backstrap plates. Suberkrub doors with areas as great as 12 m^2 have been used with big pelagic trawls and, at the other extreme, inshore vessels may use Suberkrub doors less than 2 m^2.

In Japan, high aspect ratio Suberkrub doors are used for bottom trawling, but they are considerably modified from the door we are familiar with. The camber is less and the aspect ratio is reduced to about 1.5:1 to give greater stability. Angles of attack are increased to reduce the risk of door collapse when coming round, and more weight is placed low on the door to lower its center of gravity and improve its righting ability.

RIGGING CHANGES

Having looked at the trawl doors available, together with their advantages and disadvantages, it is now time to examine possible changes in rigging the door and the gear to determine a good match between the doors and the net. If a trawl net matches a door correctly, and is then replaced with a smaller one, the total drag will be reduced. In practice, however, less drag from the smaller net will increase the door's angle of attack and the door's center of pressure will move forward. If the door was already set at the angle of attack producing maximum shear, then the shear will decrease as the angle increases. The drag will also increase with increased angle. Even though a smaller net is being towed the total drag may therefore remain similar or increase, because of the drop in the door's efficiency. The same effect would occur if a set of doors correctly matching a trawl net were replaced with larger doors.

It is interesting to consider the effects of varying towing speed. It is well known that if the towing speed is doubled the drag is increased fourfold. However, it has been observed that the total drag of trawl gear increases at less than a square law. This means that speed changes affect the doors more than the net. When speed is increased, the extra pressure on the front of the door will cause the door to turn outward (because the drag from the net will increase more slowly than the door drag). As the angle of attack increases, the door drag will also increase. If the door was already angled at optimum shear, its shear will decrease and the spread of the doors may actually be reduced. Increasing speed also tilts the door top outward as the pull on the warp increases and bottom friction is reduced. The door's nose will also tend to lift as speed increases.

It is difficult to adjust doors at sea without the sophisticated measuring instruments necessary for accurate comparisons. In practice, the shoes of a door can be examined for wear to get a rough idea of its towing attitude and adjustments made on the strength of these observations. Door spread on stern trawlers can be estimated by measuring the distance between the warps at the towing blocks and measuring it again 1 meter further aft. The difference in the two readings when multiplied by the warp length (in meters) will give the spread between the doors. Add to this figure the actual distance between the warps at the towing blocks. On side trawlers, simply measure the distance between the warps 1 meter aft of the towing block and multiply this by the length of warp in use (in meters).

If it is possible to measure the angles between the warps, use the following formula to obtain the spread between the doors:

> Relative spread = 2 sin (1/2 the angle) x warp length. Before making adjustments at sea, average a few runs and allow for tide and wind offset.

MID-WATER TRAWLING

Since the late 1940s, the development and application of the single vessel mid-water trawl has progressed at great speed. Now, the technique is applied around the world to harvest many fish species. The major feature of a mid-water trawl is its area of operation. It must work through the entire water column and be completely maneuverable by the operator to suit the vertical displacement of the fish species sought. Development continues, but detailed rigging features and methods of operation and application are still less well-defined than they are for established demersal trawls.

In conjunction with using a mid-water trawl, two other major factors must be considered. These are: (a) detection of fish stocks and verification of that depth and distribution, and (b) the exact position of the mid-water trawl and its performance characteristics. Both can be determined by acoustic instruments such as sonars, vertical echo sounders and net sounders.

It is necessary to use acoustic instruments in conjunction with a mid-water trawl because fish can change their vertical and horizontal position during a tow. Also, on unknown grounds an underwater obstacle may endanger the trawl, making it imperative that the operator be able to change the trawl's position in the water.

Mid-water trawl designs have been influenced by the behavior of pelagic fish and their reaction to disturbance. The biological features of greatest influence are:

(1) Most pelagic species are active and fast swimmers that react quickly to disturbing influences. Information on the flight reactions of pelagic fish is scanty, but most of it suggests that pelagic fish will dive when disturbed, an avenue of escape not available to demersal fish.

(2) The majority of fish taken with pelagic trawls respond as a body to any disturbance; that is, they school. Demersal fish that move into the pelagic regions at certain times of the year react individually to any disturbance.

(3) Most pelagic fish species have well-developed sight and hearing, particularly for low frequency vibrations associated with towing vessels and trawl operation. Although little is documented about these factors, they have played a large part in mid-water trawl designs.

From statistical information (Modern Fishing Gear of the World, Book 3), mid-water trawling is most successful when: (a) the fish concentrations (schools) are large and remain stationary; (b) the fish are inactive, either because of low water temperatures or because their physical state causes them to be sluggish (spent or spawning fish are less active than feeding fish); and, finally, (c) the fish remain at a specific depth and the light intensity is low.

GENERAL FEATURES OF A MID-WATER TRAWL

Mid-water trawls require a large vertical as well as horizontal mouth opening. This provides stability during operation but also allows the net to capture fish both vertically and horizontally. The large mouth opening is usually achieved by inserting large side panels at the expense of the wings, which are relatively small or even nonexistent. To assist in opening the net mouth, floats can be added to the headline and weights to the tow ends and tow legs.

Some net designers suggest an extension to the lower part of the net will bring the footrope ahead of the headline and counteract the downward flight of fish. This is in contrast to the accepted design features of a demersal trawl.

The importance of smooth water flow through the net is common to both demersal and mid-water trawls, but it is required in mid-water trawls to prevent turbulence near the net mouth. Mid-water trawls are therefore much longer than demersal trawls, with large meshes in the foreport. They are finely tapered, with long extension pieces and large cod ends.

One of the most important features of any pelagic trawl used to harvest lively fish is the ability to be towed fairly fast. To achieve this, the hydrodynamic drag of the trawl must be minimized.

Single vessel mid-water trawl development has occurred in many parts of the world, with the majority of variations in rigging of the doors, flotation, weight and tow leg lengths. The nets themselves have tended to remain the same, with each designer seeking to provide high stability, a large mouth opening, low turbulence and low drag. The major design changes have been in the mesh sizes, increasing from the early days of 20 cm (7.8 in.) to more than 1.8 m (72 in.).

COMBINED EFFECT OF DRAG, LIFT AND WEIGHT

Considering the various forces that act on a mid-water trawl, the position it assumes in the water and its shape, the resultant forces were defined earlier: any component of fishing gear achieves a steady position in relation to other components because the external forces acting on that component are in balance. If the forces become unbalanced, then the components change their relative position under the action of the out-of-balance force until all the forces are once again in balance.

This statement relates to the performance of a mid-water trawl in that the trawl will tow at a constant depth, provided that the towing speed and warp length out are kept constant. When the towing speed is changed, then the drag associated with the trawl will change, causing the trawl to alter its depth in the water column.

The mid-water trawl operator has two ways to change the working depth of his trawl. Increasing or decreasing the towing warp length will change the effective fishing depth, as will increasing or decreasing the towing speed. Combining both speed and warp length will increase the effective depth changes experienced by the trawl.

Because the net is a flexible device, the major net performance parameter will change during any maneuvers; that is, the mouth opening and spread will change, influenced by the increasing or decreasing drag, the weight attached to the lower tow legs or footrope, and the buoyancy effective on the headline.

SELECTION OF A SINGLE VESSEL MID-WATER TRAWL

When an operator considers using a mid-water trawl, determining the correct trawl and door combination to suit his vessel's towing power is of paramount importance. Single vessel mid-water trawls have been operated with horsepower ratings of between 100 and 3500. This allows most fishing vessels to consider mid-water trawling provided the deck machinery and layout are compatible with the net, doors, and warp required.

The first major assessment to make is what size trawl doors will be required to spread the net. Once that is established, will the vessel have the required power to operate that combination? To determine the basic door area and weight required to operate the chosen trawl, the twine surface area of the net needs to be calculated (see Appendix A). Use this figure with the graph in Figure 21 and obtain the area of trawl door required to spread the net. Apply this door area value to the graph in Figure 22 to obtain the relative vessel horsepower required to tow this combination of net and trawl doors.

Remember, the figures so obtained are maximum. If the vessel horsepower is sufficient to tow the combination but would have no reserve power, the chances of a successful fishing operation are slight. About 30 percent of the vessel's horsepower should be available for higher towing speeds and trawl maneuvering.

MID-WATER TRAWL DOORS AND TRAWL RIGGING

The most popular trawl door used with mid-water trawls is based on the original German Suberkrub cambered door design.

The design provides a hydrodynamically efficient door, with a high aspect ratio of 2:1, which greatly improves the shear-to-drag ratio. The amount of camber varies with the width of the door, much like an aircraft wing section, reducing the turbulence generated around the back of the door.

Generally, various warp and backstrap attachment points are provided so the operator can change the shear forces in upward, downward or horizontal directions.

The vessel operator should try to visualize the effect on the door when changes are made to the rigging, or when weight is added or reduced on the keel of the door. Usually the warp towing bracket is placed approximately 4 percent of the door's length above the center point. Another bracket may well be fixed above this. Using the lower bracket will give the door an almost vertical position in the water while towing, with a slight inward heel that will increase as the towing speed is increased or warp is hauled. This slight inward heel will give the door an upward component of shear. If the upper towing bracket is used, the door will heel inward more; under normal towing conditions this will give the door an increased upward shear force that will increase even more when the towing speed is increased, causing the door to rise rapidly in the water column. This inward heel of the door can be counteracted by increasing the weight applied to the door's keel. Increasing the door's weight will also cause the door to fish deeper.

Changing the backstrap position influences the door's tilt angle. Using the upper bracket will cause the door to tilt upward. Using the lower bracket will cause the door to tilt downward. The tilt angles will be directly affected by the length of the tow legs (bridles or sweeps). Generally the upper tow leg is shorter than the lower, transferring most of the towing strain along the leg to the headline area.

The warp attachment brackets usually have a number of holes available for the warp. Changes in the towing warp position will change the door's angle of attack, in turn affecting the shear or spreading force of the doors. The

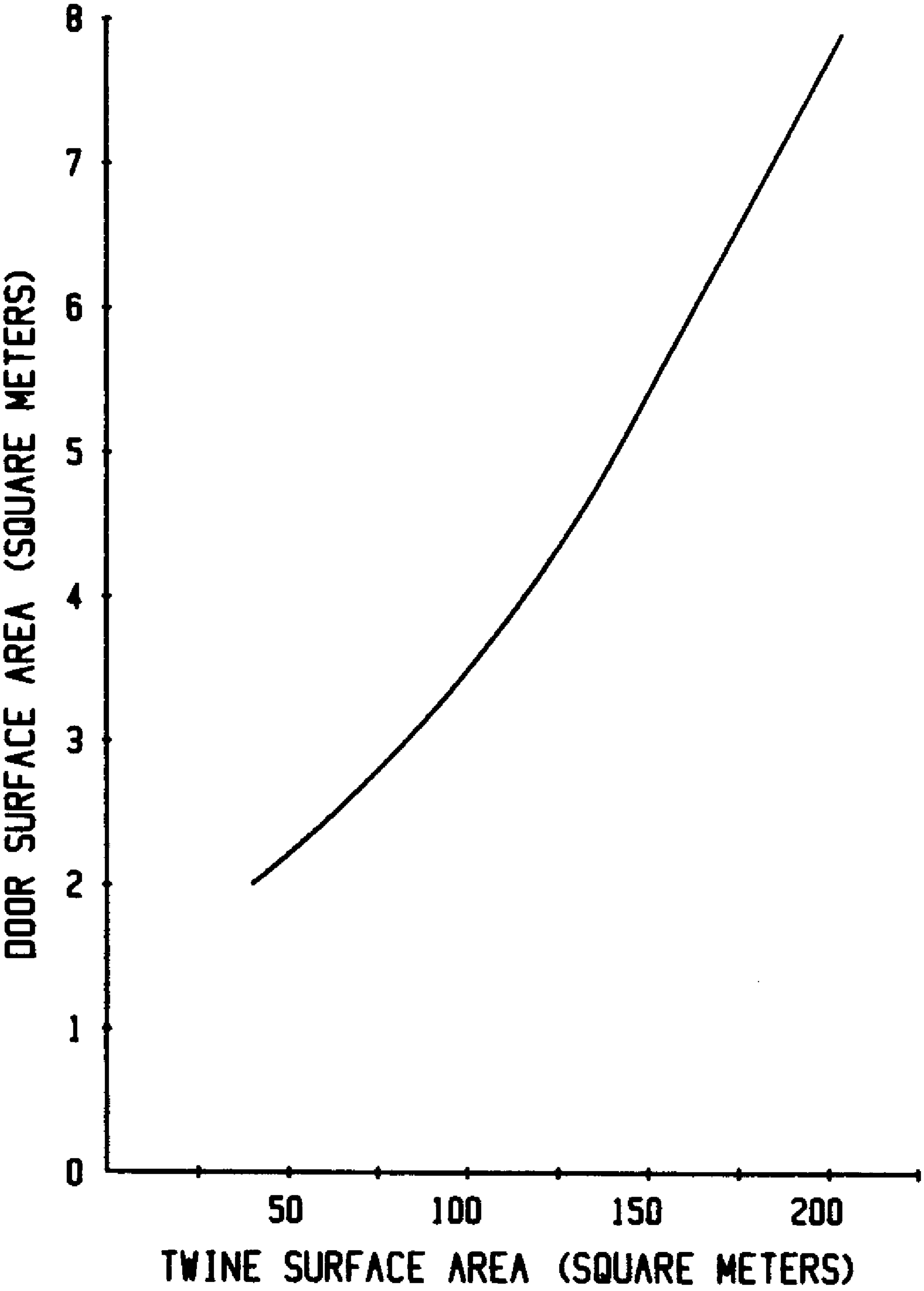


FIGURE 21. AREA OF SUBERKRUB DOOR REQUIRED TO SPREAD A MIDWATER NET WHEN TWINE SURFACE AREA IS KNOWN.

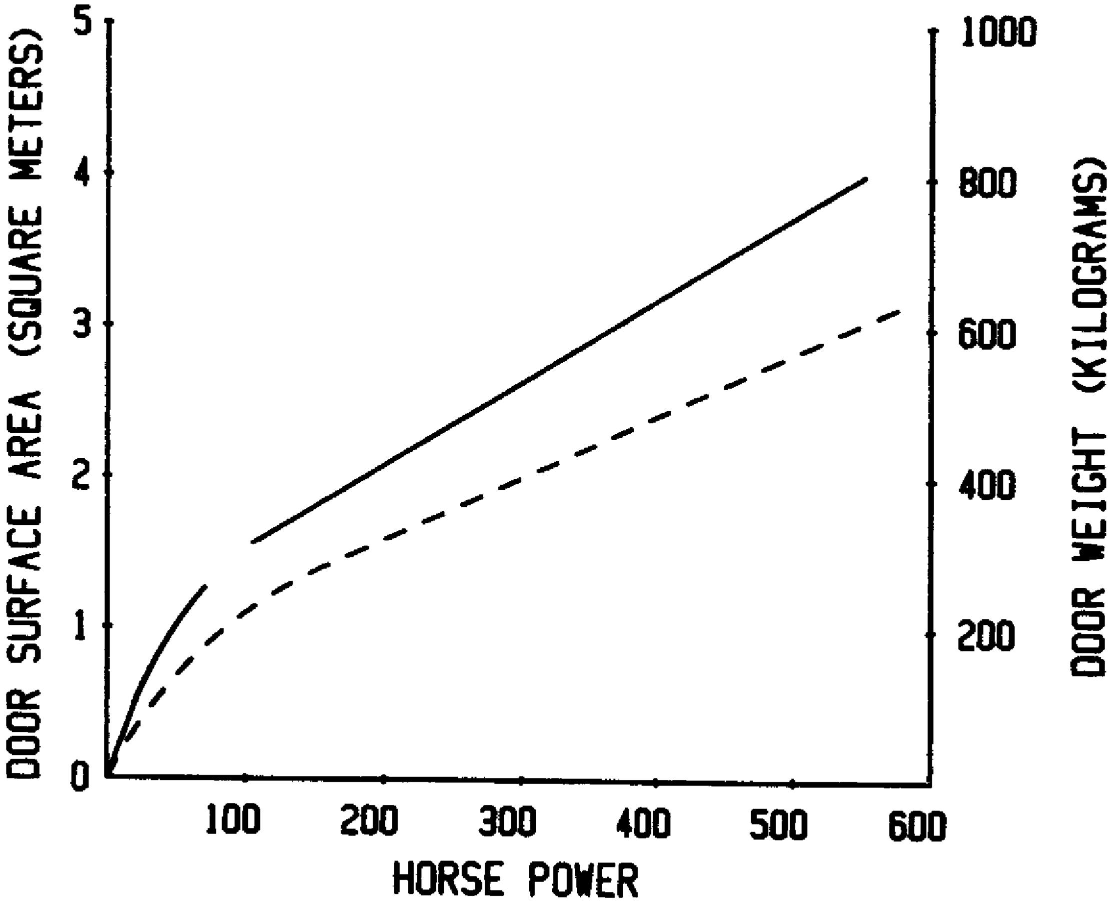


FIGURE 22. RELATION BETWEEN AREA (——) AND WEIGHT (---) OF SUBERKRUB DOORS AND VESSEL HORSE POWER.

outboard attachment position gives the minimum angle of attack resulting in the minimum shear force and reducing the net spreading force. Using the attachment point at the inboard end of the bracket increases the angle of attack, increases the shearing force, and increases the spread of the net.

With all the variations now available on trawl doors, the operator should consider the combined effects of changing warp attachment brackets and towing point, lower backstrap attachment point, and the weight fixed to the door. In conjunction with these variations, the tow leg lengths and differences will affect the performance of the door and the subsequent effect on the net.

Referring to the trawl rig sketches in Figures 23 to 25 will help the operator establish the basic settings to enable the trawl to be shot and maneuvered.

NOTES ON RIGGING VARIATIONS

1. Increasing the toe end weight or the effective weight of the footrope tends to increase the mouth opening. However, adding this weight can make the trawl fish deeper. To bring the trawl back to its original fishing depth, the towing speed would have to be increased or the effective warp length out shortened.

   Extra weight acting on the lower tow legs can influence the inward heel of the doors. Reducing the inward heel makes the doors spread more, but reduces their rising response as speed increases or warp is hauled.

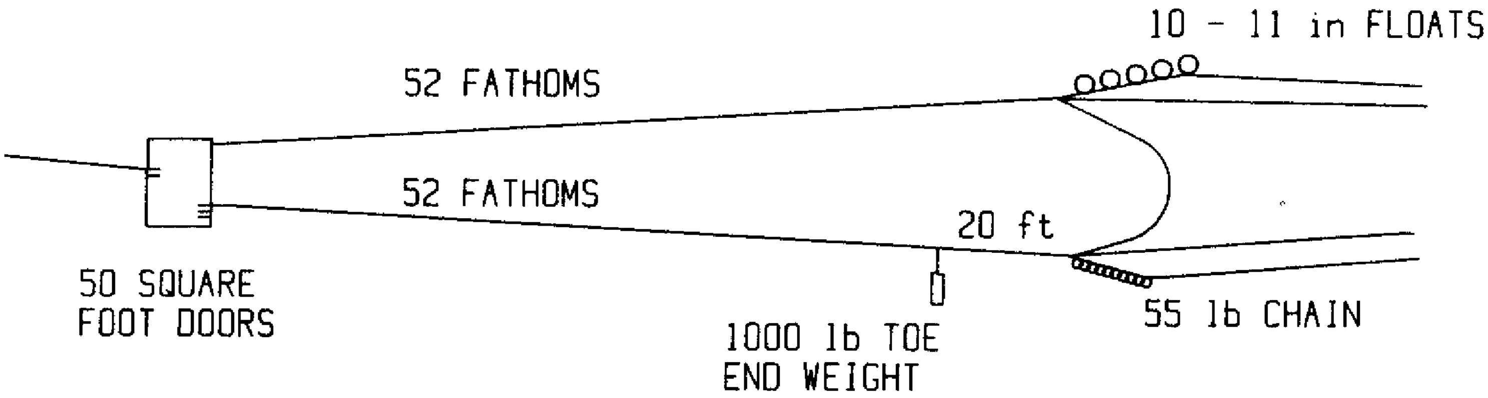
2. Adding floats to a headline lightens the trawl, the floats reacting against the weight on the footrope and lower toe weights. On some rigs this added flotation can increase the mouth opening by causing the headline to curve upward. Excessive flotation makes the trawl fish higher in the water relative to speed and warp out.

3. Changes in tow leg lengths can directly influence the mouth opening of the trawl. Reducing tow leg lengths equally reduces the mouth opening, depending on toe end weight and headline flotation. Allowing the lower tow leg to become much longer than the upper can cause the trawl doors to become unstable, and in extreme cases to lock-up.

4. Moving the toe end weight along the lower leg toward the door causes the mouth opening to decrease. This also influences the door's performance because the weight acts more directly on the backstrap towing point; this can cause the door to nose down, particularly if the lower warp bracket is being used.

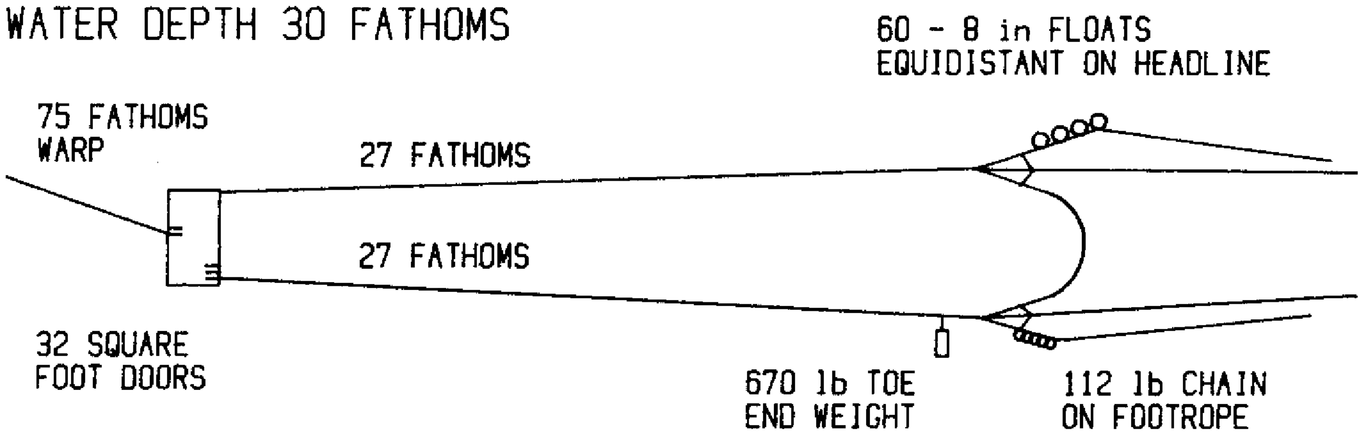
ALTERNATIVE METHOD OF DETERMINING TRAWL PERFORMANCE

There is another way to determine a towing vessel's performance with a mid-water trawl if the vessel's bollard pull is known. Figures 26 to 30 help illustrate this method of assessing approximate bollard pull. Remember, these figures are only a guide and are approximate. The only reliable way to determine bollard pull is to have the vessel tested against an accurate and calibrated instrument.



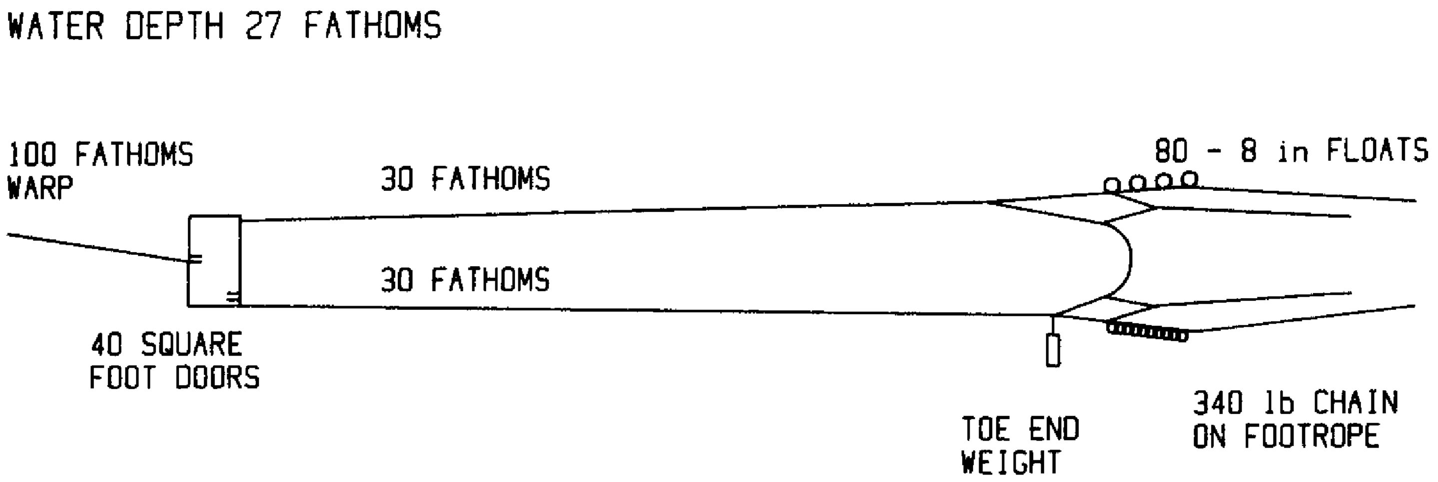
HEADLINE	22 FATHOMS
SIDEPANELS	16 FATHOMS
FOOTROPE	22 FATHOMS

FIGURE 23. RECTANGULAR NET WITH NO EXTENSION IN LOWER NETTING. DEEP WATER RIG WITH DOORS SET FOR QUICK RISE ON INCREASING SPEED OR WARP RETRIEVAL.



HEADLINE	24 FATHOMS
SIDE PANEL LINES	23 FATHOMS
FOOTROPE	27 1/2 FATHOMS
TOWING SPEED	3 knts
NET SPREAD	12 FATHOMS
NET MOUTH VERTICAL OPENING	8.5 FATHOMS

FIGURE 24. RECTANGULAR TRAWL WITH EXTENDED LOWER WINGS. THE TOW LEGS ARE KEPT EQUAL IN LENGTH SO THE NET IS STILL TOWED ON THE HEADLINE.



HEADLINE	23 FATHOMS
SIDE PANEL LINES	20 FATHOMS
FOOTROPE	23 FATHOMS

TOWING POWER REQUIRED - 400 - 600 H.P.

FIGURE 25. RECTANGULAR NET WITH SHORT 'V' SHAPED WINGS AND NO EXTRA NETTING IN THE LOWER PART OF THE NET. BY USING EQUAL TOW LEGS, THE NET IS NOT TOWED OFF THE HEADLINE. PRIMARY IDEA IS TO FISH THE TRAWL NEAR THE SURFACE. IF THE LOWER BRIDLES ARE EXTENDED THE MOUTH OPENING WILL INCREASE AND THE DOORS WILL FISH HIGHER RELATIVE TO THE NET.

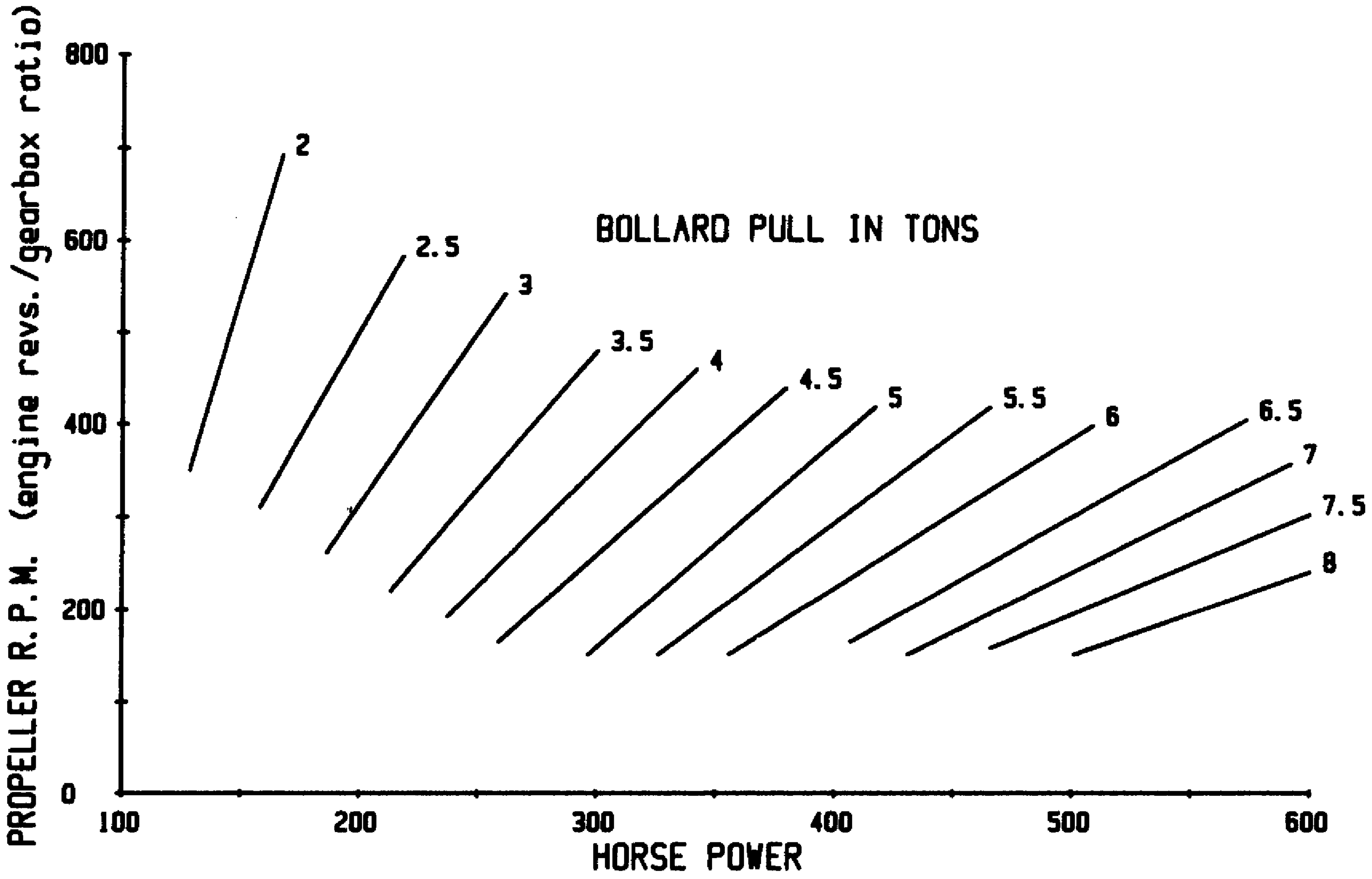


FIGURE 26. APPROXIMATE BOLLARD PULL FOR CONVENTIONAL OPEN AND V.P. PROPELLERS.

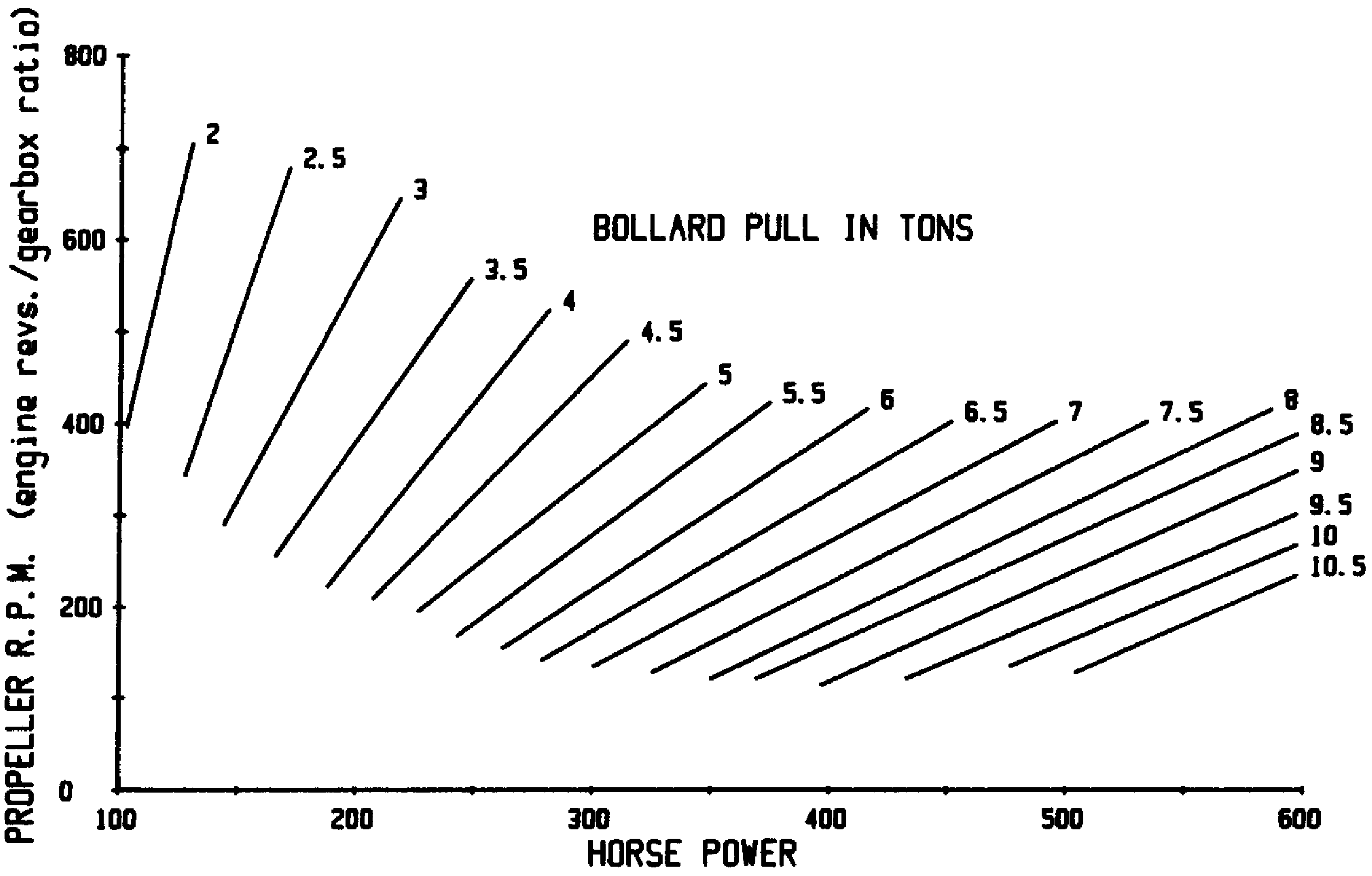


FIGURE 27. APPROXIMATE BOLLARD PULL FOR NOZZLE PROPELLERS.

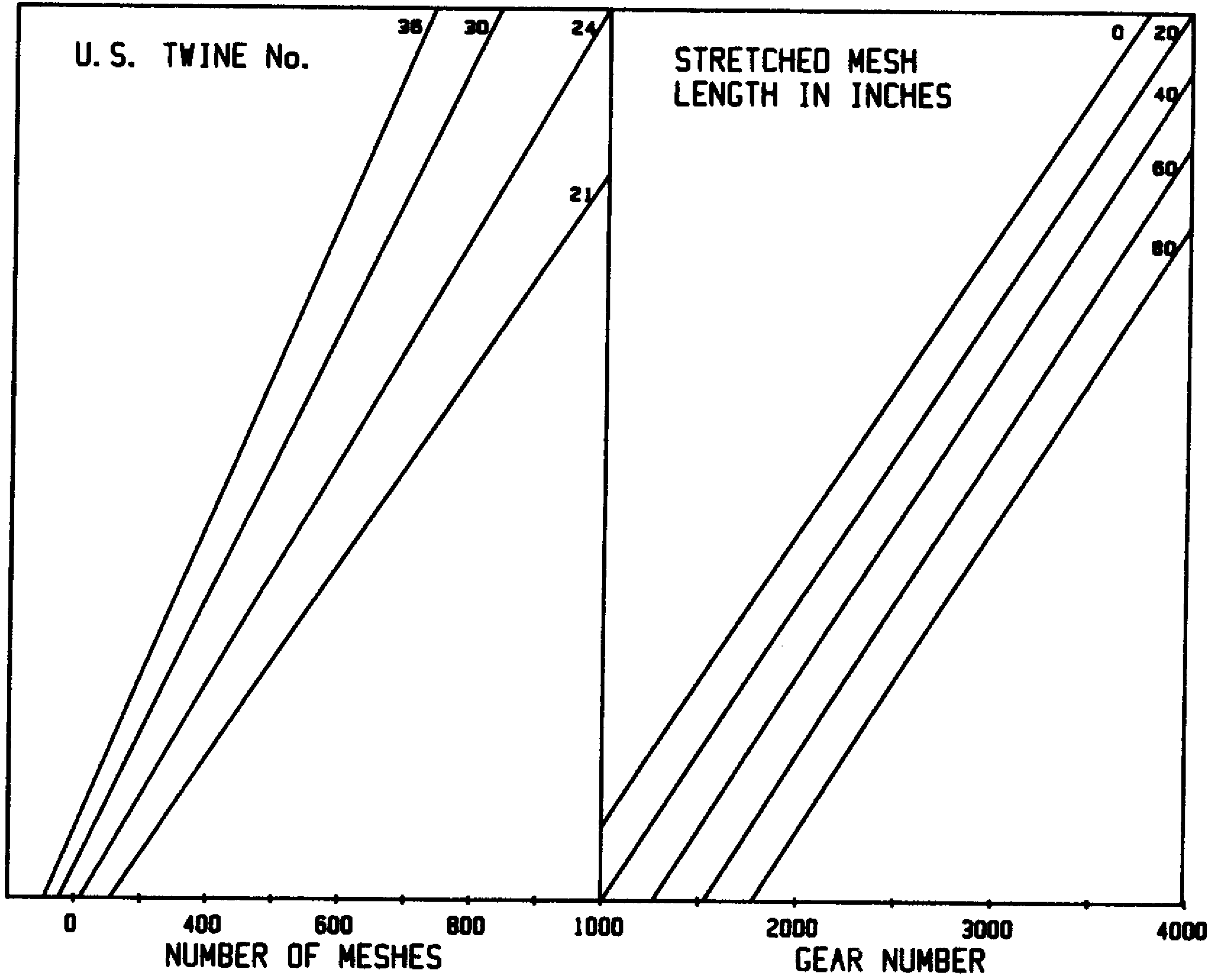


FIGURE 28. GEAR NUMBER ESTIMATOR CHART.

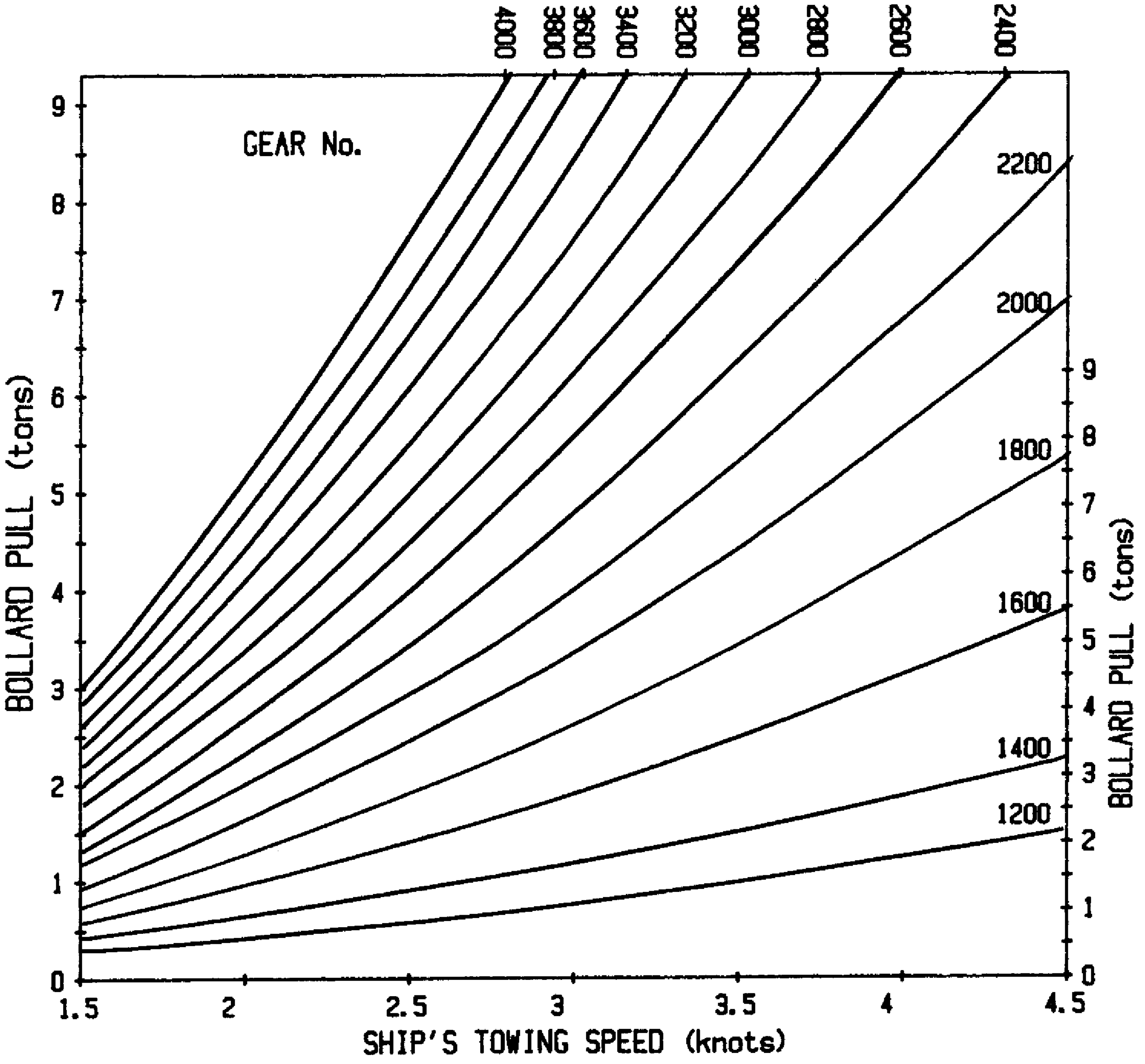


FIGURE 29. TOWING SPEED ESTIMATOR CHART FOR NOZZLE PROPELLERS.

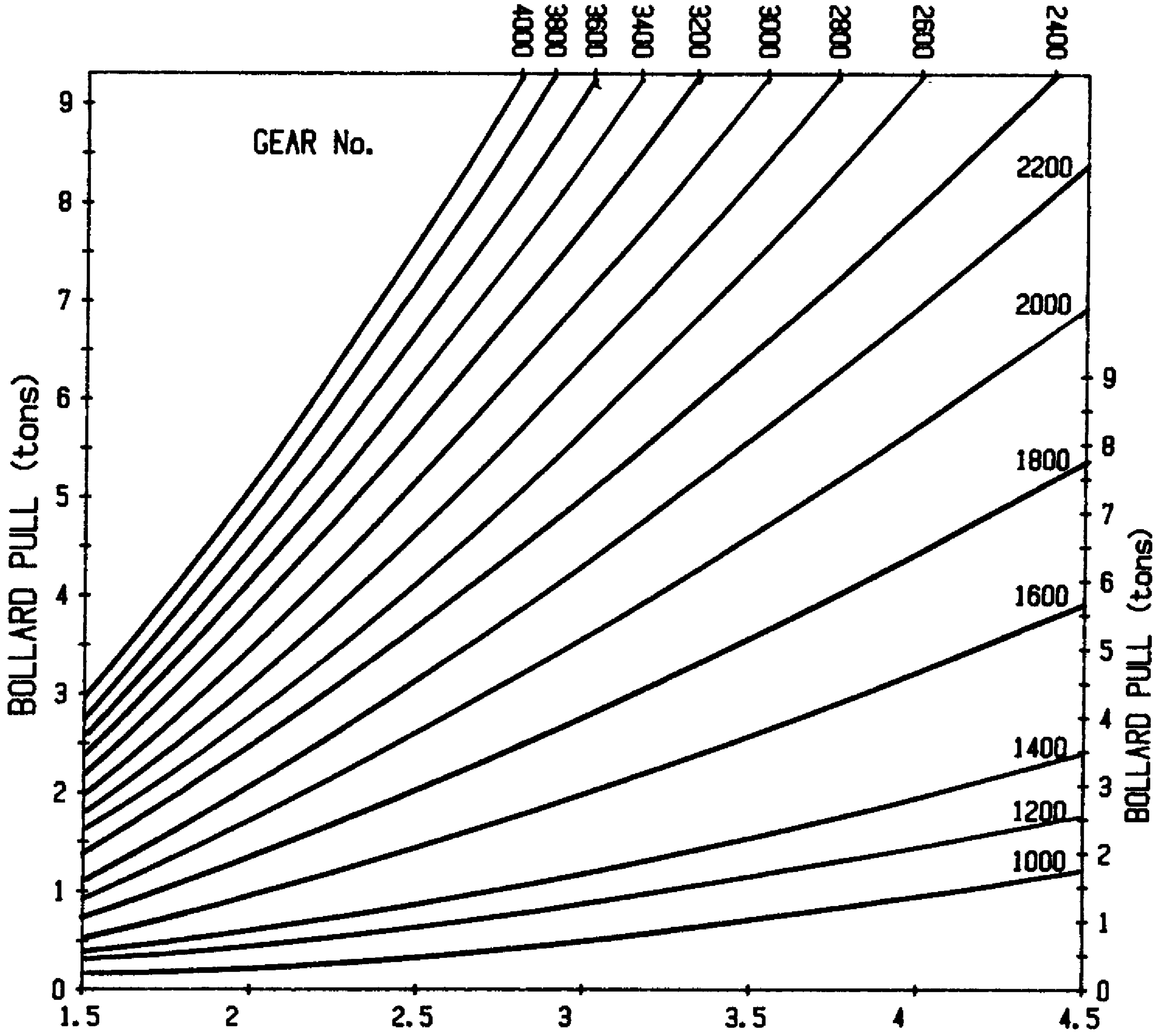


FIGURE 30. TOWING SPEED ESTIMATOR CHART FOR OPEN PROPELLERS.

Figures 26 and 27 are bollard pull graphs. One is for open propellers and one is for nozzle propellers. It has been assumed in each case that the propeller was selected to provide towing not free running performance.

Using the appropriate graph for the vessel, draw a vertical line from the horsepower axis for the main engine until it intersects with a horizontal drawn from the propeller RPM axis, based on the rated continuous RPM of the engine divided by the gearbox ratio.

For example: Maine Engine - 400 hp at 1800 RPM

Continuous service

Gearbox ratio - 5:1

Propeller RPM - 360

Nozzle fitted

Bollard Pull - 6.25 T

A method for determining the vessel's maximum towing speed with a trawl is given next. From the trawl manufacturer, obtain the total number of meshes around the mouth of the trawl, for example, the top panel, two side panels, and bottom panel; the mesh size of the netting used in the forepart of the trawl; and the twine size used, for example 600 m x 40" x #24 twine.

Apply these to Figure 28 as follows:

Draw a vertical line from the x axis, corresponding to the number of meshes, to the intersection of the appropriate twine number.

From this point, draw a horizontal line to the intersection of the appropriate stretched mesh length.

From this intersection, draw a vertical line to the intersection of x axis and read the appropriate gear number.

Apply the relevant gear number to Figure 29 or 30 depending on whether you have an open or a nozzle propeller. Draw a diagonal from left to right joining the calculated bollard pull figure (note: use the same bollard pull figure on both sides of the graph).

The towing speed of the vessel using this trawl can now be ascertained by drawing a vertical line from the intersection of the bollard pull diagonal and the gear number curve down to the ship's speed axis. This speed would be the maximum that the towing vessel would achieve with this trawl. Since most pelagic fish swim faster than the example illustrated (2 to 8 knots), the operator should consider a smaller trawl. The average mid-water trawl for vessels of 400 to 600 hp generally has a mouth mesh count of around 400 with a mesh size of 20 in. using #24 twine.

Applying these figures to the graphs, indicates a maximum towing speed of 4.4 knots approximately, with 400 hp and a bollard pull of 6.25 T.

THE NET SOUNDER AND TRAWL MANEUVERING

In a single vessel mid-water trawl operation, the net sounder is the data link on the position, performance, and effectiveness of the trawl. The two major types of net sounder are available: acoustic link or cable. These primarily enable the operator to check the position of the trawl in the water column, and the mouth opening of the trawl. Fish capture and escape can also be determined from the machine.

The effectiveness of the net sounder depends on the alignment of the headline unit. This is particularly true when an acoustic link unit is used. As its name implies, this type of net sounder relies on an acoustic beam to transmit the data from the net to the towing vessel. Horizontal misalignment of the unit may cause the data link to miss the vessel receiver transducer and fail to give the operator the required information. Most acoustic link net sounders have upward- and downward-looking transducers. Again, correct alignment ensures that data transmitted to the towing vessel are correct.

Cable link net sounders rely on correct alignment of the headline transducer unit to ensure that the vertical data are correct. Any misalignment may mean that the acoustic beam is striking the wing ends or lower tow legs line. Misalignment of the transducer is usually indicated by faint and fuzzy multiple echoes. Expected trawl reaction does not show, and obviously the data being presented are not valid for the operator's needs.

CHART INTERPRETATION

In a simple system where the headline transducer only looks downwards, the chart will show the trawl mouth opening and the seabed return below the footrope. The operator should remember that the zero or reference line is at the transducer level that is mounted on the headline. The depth scale on the instrument will therefore show the depth of the headline above the seabed and, more importantly, the position of the footrope relative to the seabed. Refer to the ship-mounted vertical sounder to establish the depth of the trawl. Noting the depth from the headline to the seabed on the net sounder, then apply this data to the main vertical sounder. This establishes the net's position in the water column and allows the operator to change the position of the trawl relative to any known fish marks.

When an operator first begins to use a mid-water trawl rig, it is advisable to complete a number of runs at various towing speeds and warp lengths out. Using the net sounder and vertical sounder, make a note of the trawl's settling position at each speed and warp length out. Also note the mouth opening of the trawl at each steady state.

To establish the performance of the ship and trawl combination, make a note of the trawl's rise and sinking speed, as the towing speed is varied. Repeat the exercise, but this time change the lengths of warp out or hauled in. A performance chart is included in Appendix B to help the operator establish the vessel's performance with the mid-water trawl.

APPENDIX A: TWINE SURFACE AREA CALCULATION

(1) Obtain the net plan from the manufacturer. Ensure that the drawing lists the number of meshes appropriate to each panel, the twine diameter and the mesh sizes of each panel.

(2) Apply the following formula to each net panel in turn:

$$TSA = \frac{N+n}{2} \times H \times 4 (a \times d) \times 10^{-6}$$

Where:

H = number of rows of knots down the panel

N = number of meshes along the widest part of the panel.

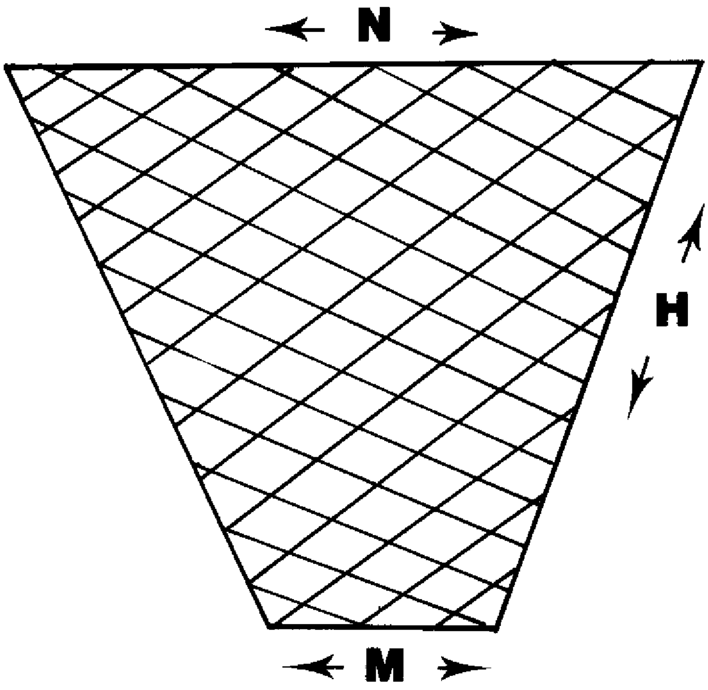
n = number of meshes along the narrow part of the panel.

a) = bar length of the mesh (mm).

d) = twine diameter (mm), and

10-6 = conversion to (m^2).

Add the TSAs for all the panels together to give a total twine surface area for the net.



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APPENDIX B: TANK TESTING DATA

The data sheets shown here result from Alaskan fishermen's work in rigging trawl gear. Many of the variables associated with ground trawl gear and underwater nets were selected by the fishermen. These ranged from varying trawl door towing points and backstrap points, selecting different trawl door sizes, changing tow leg lengths, introducing three bridle systems and showing the influence of staggered wire lengths on different sides of the gear to demonstrate what happens with sloppy wire measurements.

This was followed by experimental rigging on trawls to improve trawl performance, reduce lower panel twine damage and adjustments that would allow the trawl to fish hard on the seabed, light on the seabed and off the seabed. The test records show the results of this work along with any major changes that were made to the gear or its rigging.

Mid-water trawls were rigged and demonstrated to show the influence of trawl door variations, wing end weights, towing speeds, net mouth openings, settling depths and trawl response times. Much of the work concentrated on the door rigging to have the doors fishing higher than the net for near seabed work and vice versa for near surface work.

FLUME TANK TEST RECORD

MODEL TRAWL TYPE 4 PANEL TRAWL (BOTTOM FISHING)
3 BRIDLE RIG.

	A	B	C	D	E
SPEED Knots	3	3	3.5	3.5	3
HEADLINE HEIGHT	26'	30.25'	25'	26'	22'.8"
WINGEND HEIGHT	20 6'	21.4'	17.5'	19.9'	18'
HEADLINE SPREAD	45'	40.25'	47'	45'	45'
FOOTROPE SPREAD	55.5'	50'	50'	50'	60'
WARP TENSION	2 TONS/SIDE	1.7 TONS/SIDE	2.9 TONS/SIDE	2.9 TONS/SIDE	2.5 TONS/SIDE

RIGGING DETAILS

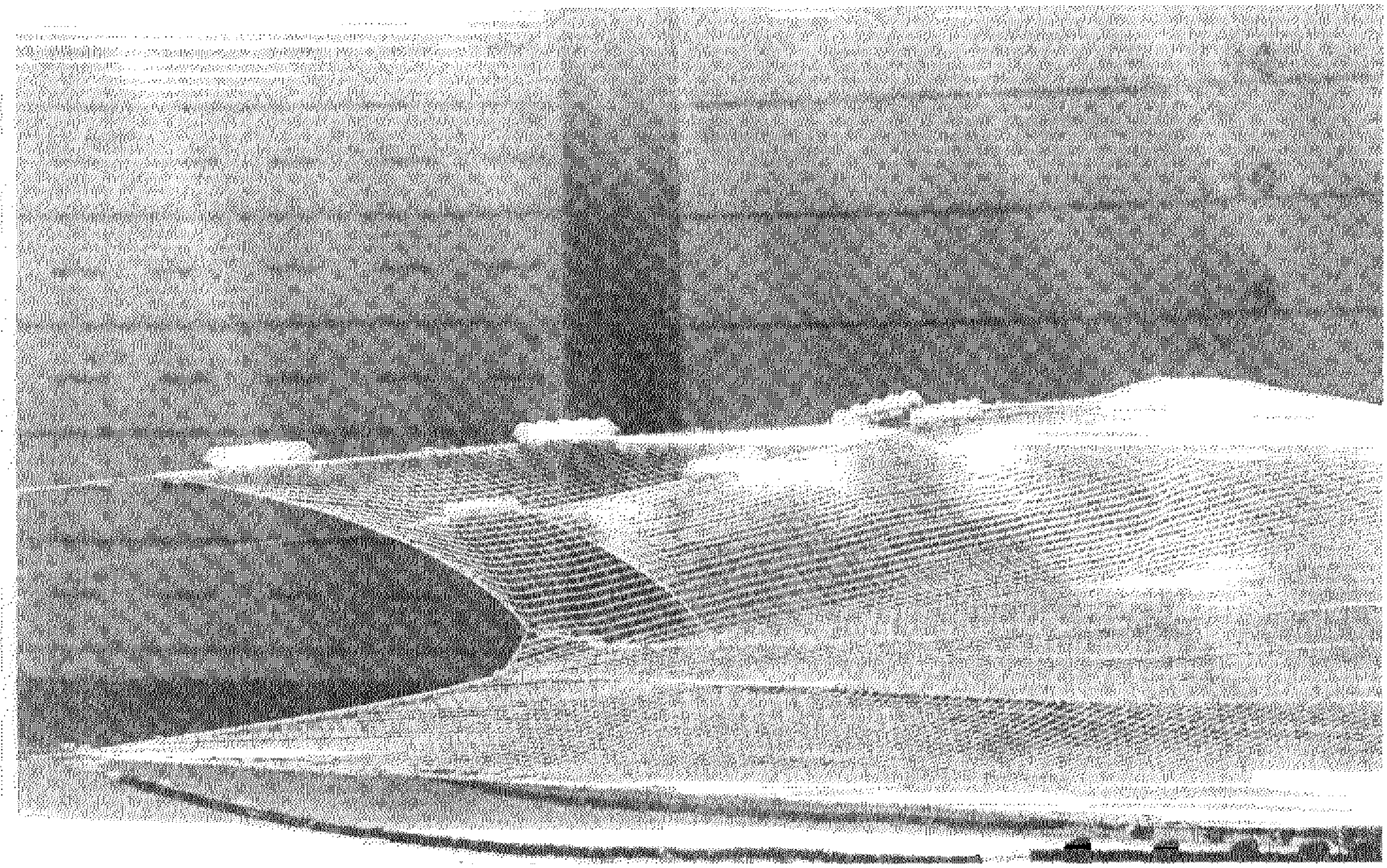
NO. OF FLOATS 31 x 11"
DOOR SIZE AND TYPE A.B 7'6" V. C.D. 7'0" V. E. 10' V.
GROUND WIRE LENGTHS —
TOW LEGS UPPER / LOWER } 30 FATHOM.
29.5F. CENTER BRIDLE

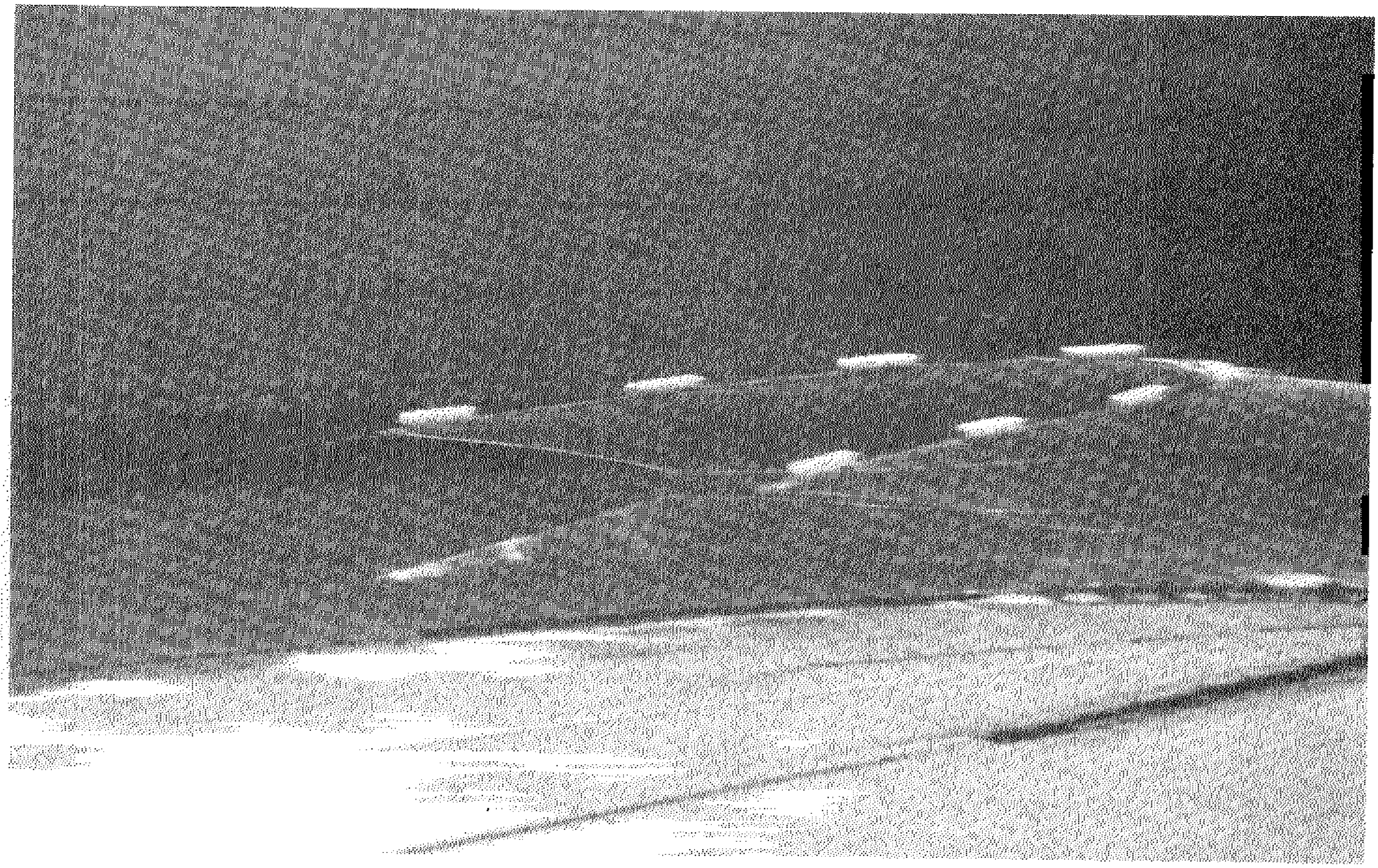
COMMENTS

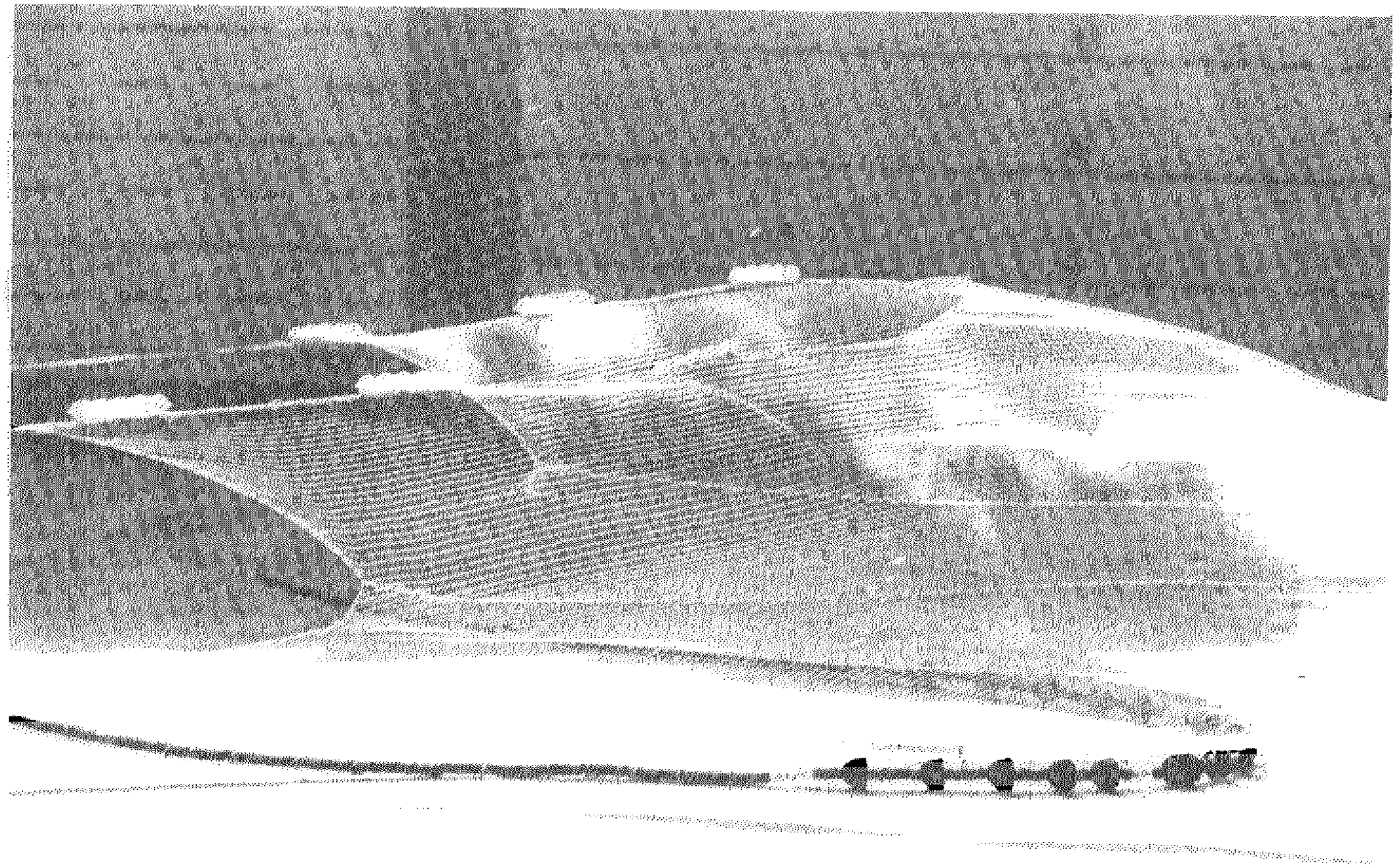
DOOR SPREAD A. 119'
B. 100'
C 103'
D. 105'
E. 127'
} ALL ON MIDDLE TOWING POINT

FILM # 1.
SHOT # A. 25, 26, 27.

INTRODUCTION OF A 3'4" DISPARITY BETWEEN THE LOWER BRIDLES AT RUN E CAUSED THE STARBOARD WING TO RISE BY 1'8" AND DROP BACK BRINGING UNEQUAL STRAIN INTO THE NET.







FLUME TANK TEST RECORD

MODEL TRAWL TYPE 4 PANEL TRAWL (BOTTOM FISHING)

	F	G	H	I	J.
SPEED KNOTS	3	3.5	3	3.5	3.5
HEADLINE HEIGHT	25.5'	23.1'	24.7'	21.7'	23'
WINGEND HEIGHT	20.8'	18.4'	20'	17.8'	18.7'
HEADLINE SPREAD	50'	50'	50'		53'
FOOTROPE SPREAD	60'	60'	61'		62'
WARP TENSION	2.7 TONS/SIDE	3.5 TONS/SIDE	2.6 TONS/SIDE		3.12 TONS/SIDE

RIGGING DETAILS

NO. OF FLOATS AS SHEET 1
DOOR SIZE AND TYPE 10' V.
GROUND WIRE LENGTHS
TOW LEGS UPPER
LOWER AS SHEET 1

COMMENTS

DOOR SPREAD F 127' } MIDDLE TOWING POINT
G 135' }
H 140' } FRONT TOWING POINT
I 140' }
J 140' }

FILM #
SHOT #

FLUME TANK TEST RECORD

MODEL TRAWL TYPE 4 PANEL TRAWL (BOTTOM FISHING)

	K	L			
SPEED Knots	3	3.5			
HEADLINE HEIGHT	26.5'	24.6'			
WINGEND HEIGHT	21'	19.0'			
HEADLINE SPREAD	47'				
FOOTROPE SPREAD	56'				
WARP TENSION	2.8 TONS/SIDE	3.6 TONS/SIDE			

RIGGING DETAILS

NO. OF FLOATS AS SHEET 1

DOOR SIZE AND TYPE 10' V

GROUND WIRE LENGTHS

TOW LEGS UPPER
LOWER AS SHEET 1

COMMENTS

DOOR SPREAD
K. 115'
L. 125' } AFTER TOWING POINT

FILM #

SHOT #

FLUME TANK TEST RECORD

MODEL TRAWL TYPE 4 PANEL TRAWL (BOTTOM FISHING)

	M	N	O	P	Q
SPEED Knots	3	3	3	3.5	3
HEADLINE HEIGHT		19.0'	27.5'	24.5'	28.5' Trawl off ground
WINGEND HEIGHT	21.25'(P). 19.75'(S)	14.75'	22.0'	19.75'	
HEADLINE SPREAD	47.5'	50.0'	46'	50'	
FOOTROPE SPREAD	57.5'	57.0'	55'	55'	
WARP TENSION	1.9 tons/side	2 tons/side	2.6 tons/side	3.0 tons/side	

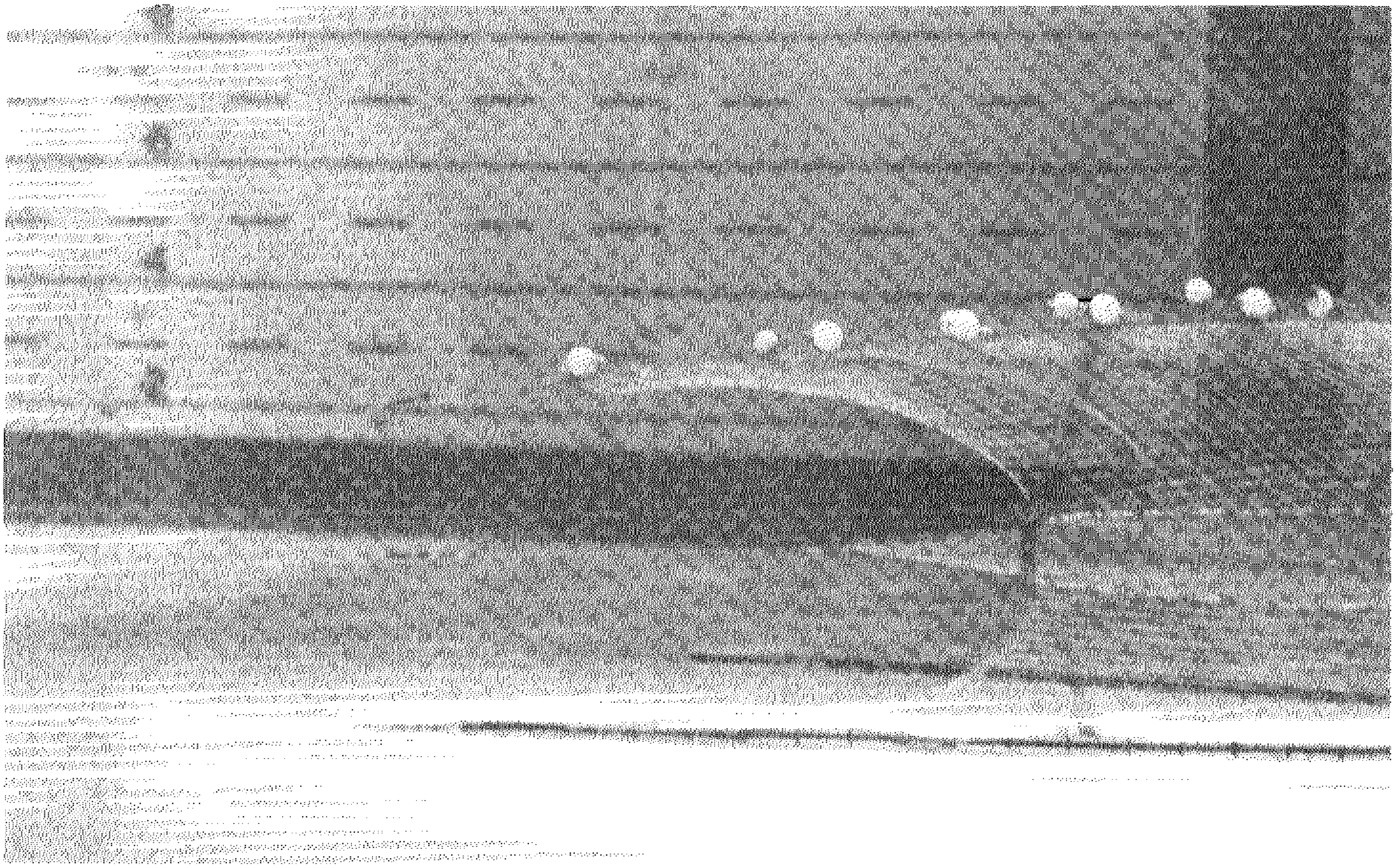
RIGGING DETAILS

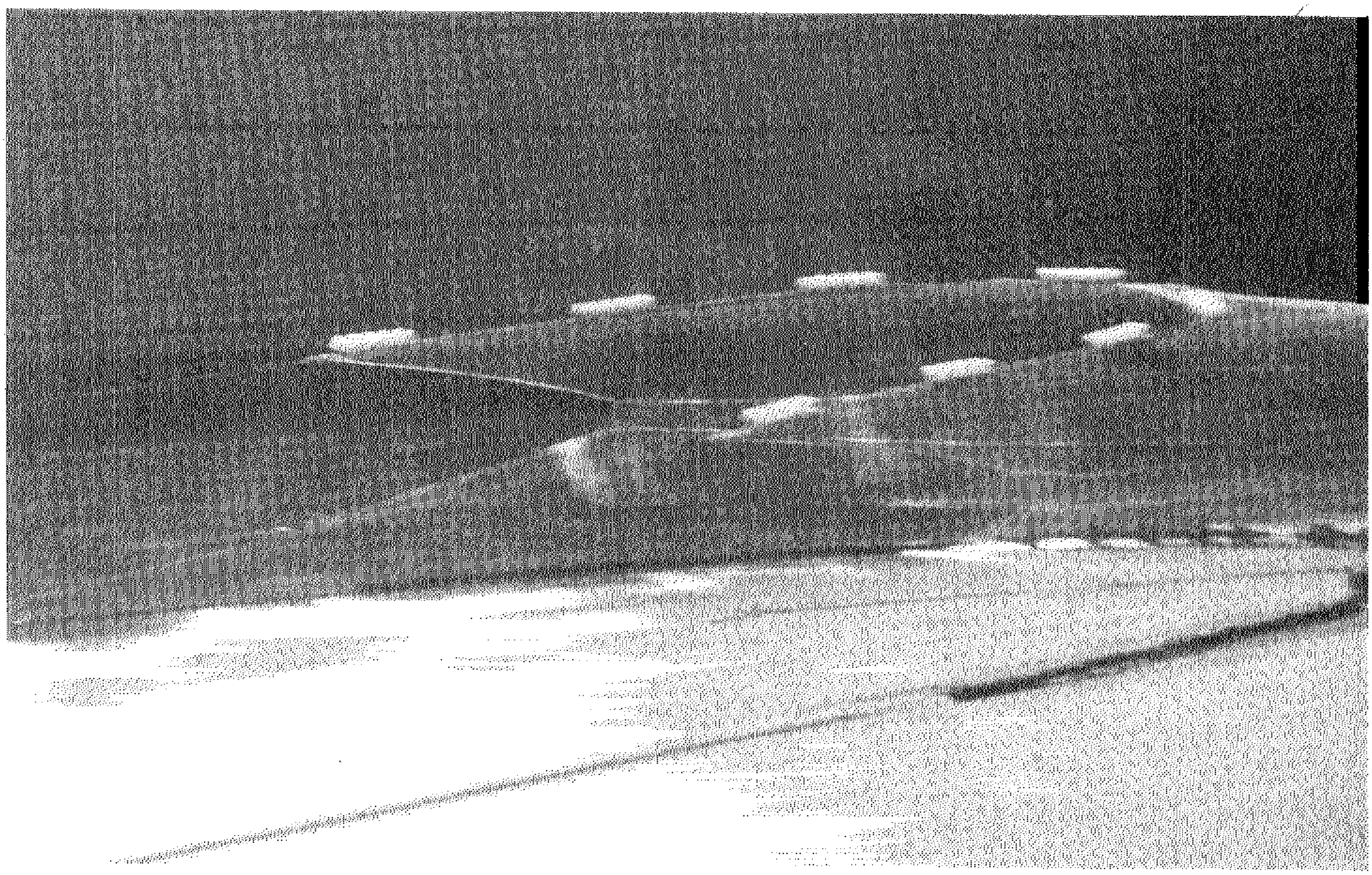
NO. OF FLOATS As sheet 1.
DOOR SIZE AND TYPE 7' 6" V.
GROUND WIRE LENGTHS
TOW LEGS UPPER / LOWER } 30 fathoms.
Middle 30 fathoms (N)
Headline +3' (O).

COMMENTS
M. Set back 2 fathoms on one warp port side.
N. All bridles equal. Door spread 125'
O. Headline legs set back +3'.
P. Door spread 110'

FILM # 1
SHOT # 28(M) 29(M).

Q. Top bridles +1' set back
Middle bridles +2' set back
Trawl fished clear of the ground





FLUME TANK TEST RECORD

5.

MODEL TRAWL TYPE 4 PANEL TRAWL (BOTTOM FISHING).

SPEED Knots	R	S	T	U	
HEADLINE HEIGHT	(DOORS STEADY NET FLYING.	ON THE	GROUND)	(GEAR FLYING DOWN	DOORS)
WINGEND HEIGHT					
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION					

RIGGING DETAILS

NO. OF FLOATS AS SHEET 1.
DOOR SIZE AND TYPE 7'6" V (R.S) 8' MIDWATER (T)
GROUND WIRE LENGTHS 7'6" V (T.U.).
TOW LEGS UPPER
LOWER

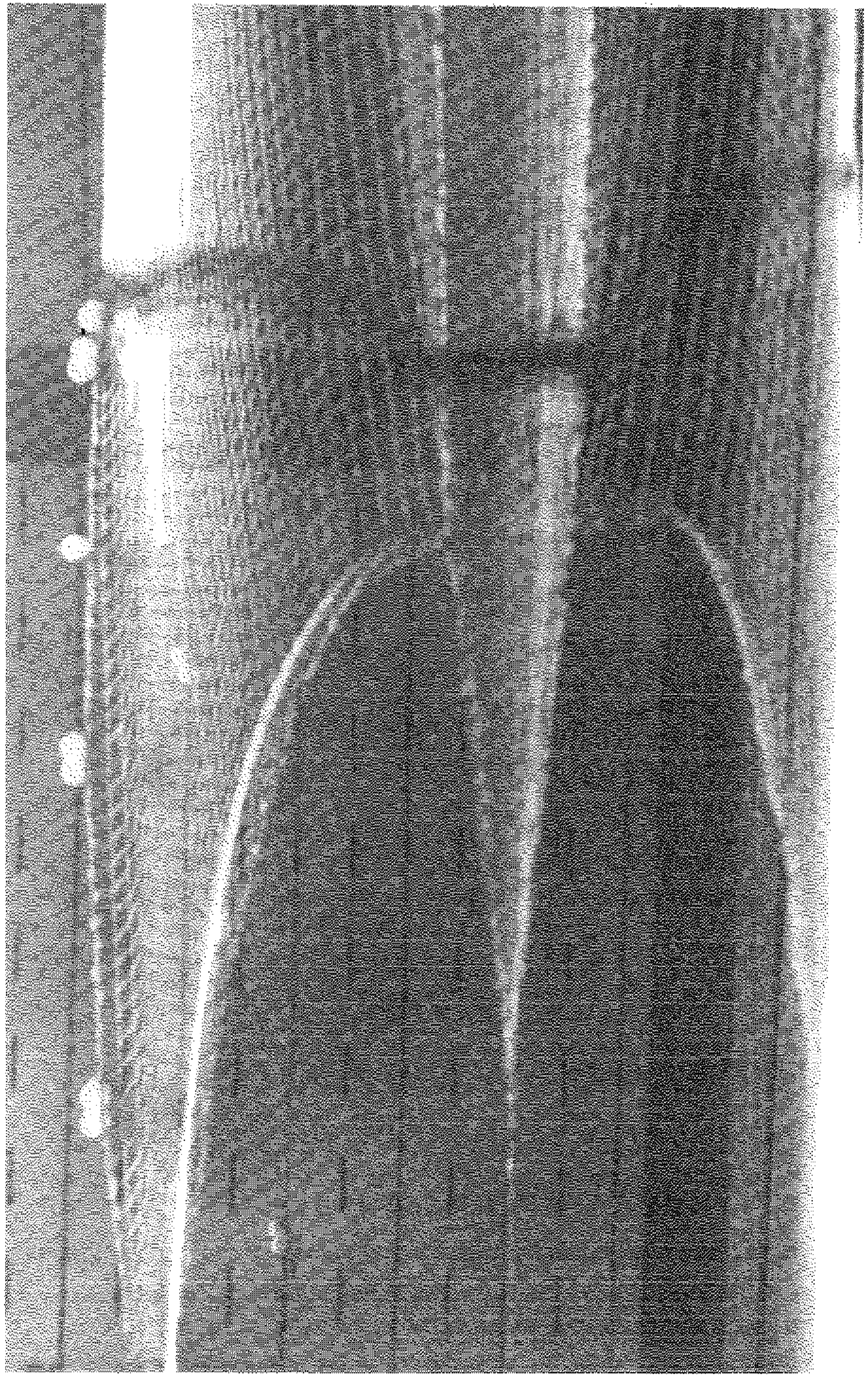
T. 16' EXTENSION ON TOP AND MIDDLE BRIDLES WITH TOP BRIDLE SECURED TO WARP 10 FATHOMS AHEAD OF THE DOORS.

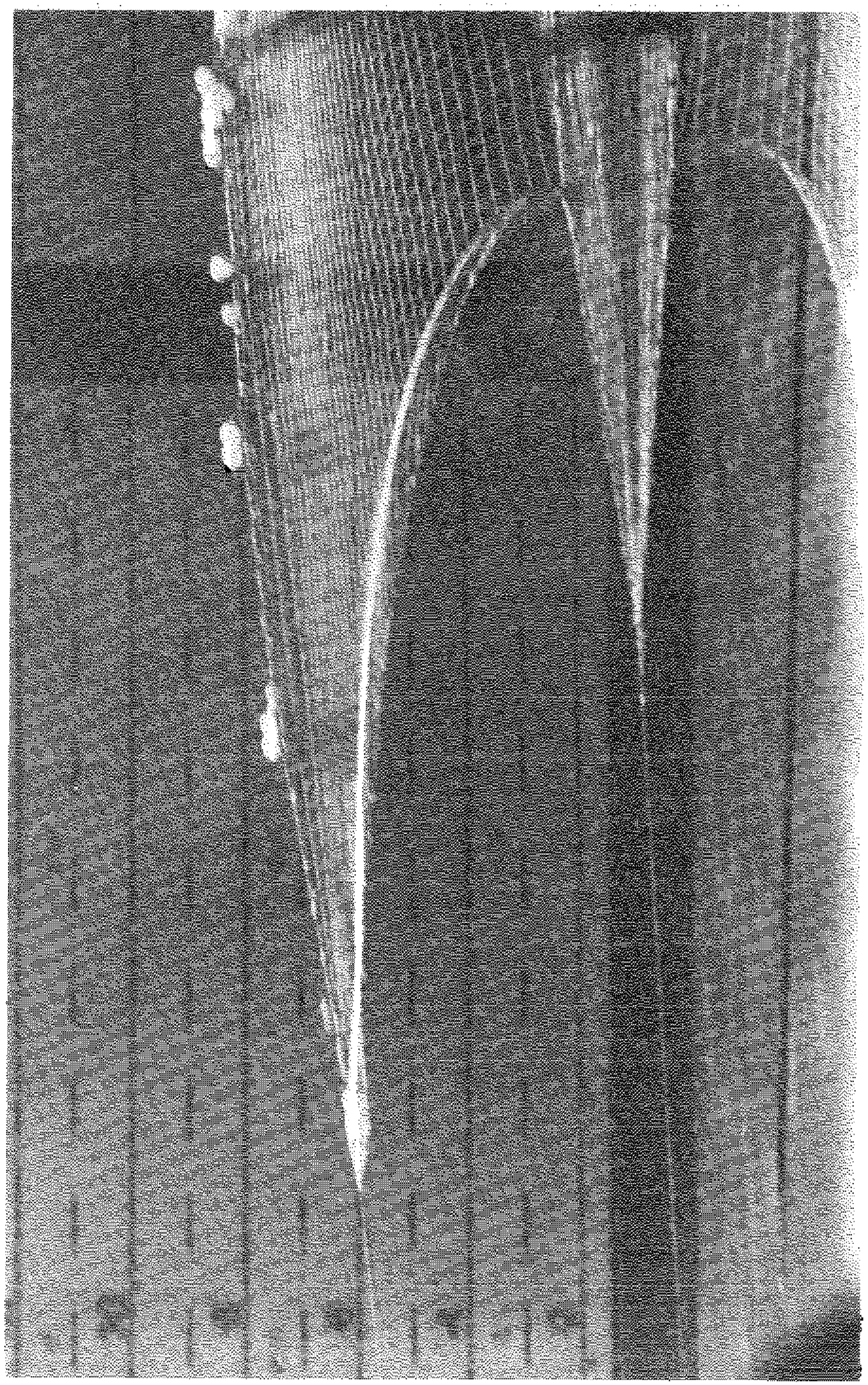
U. 36' EXTENSION ON TOP BRIDLE AND SECURED 20 FATHOMS AHEAD OF THE DOOR.

COMMENTS

R. DOUBLE BACK STRAPS ON THE DOORS
S. " " – – – –
T. 8' SUPERKRUBB PELAGIC DOORS.
U. VEE DOORS RIGGED SEMI PELAGIC STYLE.

FILM # 1
SHOT # 30, 31, (U).





FLUME TANK TEST RECORD

MODEL TRAWL TYPE WESTERN ATLANTIC GROUND TRAWL

	A	B	C	D	E
SPEED KNOTS	3	3	3	3.5	3
HEADLINE HEIGHT	21'	21'	19 3/8'	16 1/2'	23'
WINGEND HEIGHT	15'	15'	12 3/4'	11 1/4'	16 1/2'
HEADLINE SPREAD	45'	45'	45'	45'	42'
FOOTROPE SPREAD	56 1/4'	56'	56'	56'	52 1/2'
WARP TENSION	3 TONS/SIDE	3 TONS/SIDE	2.7 TONS/SIDE	3.4 TONS/SIDE	3.3 TONS/SIDE

RIGGING DETAILS

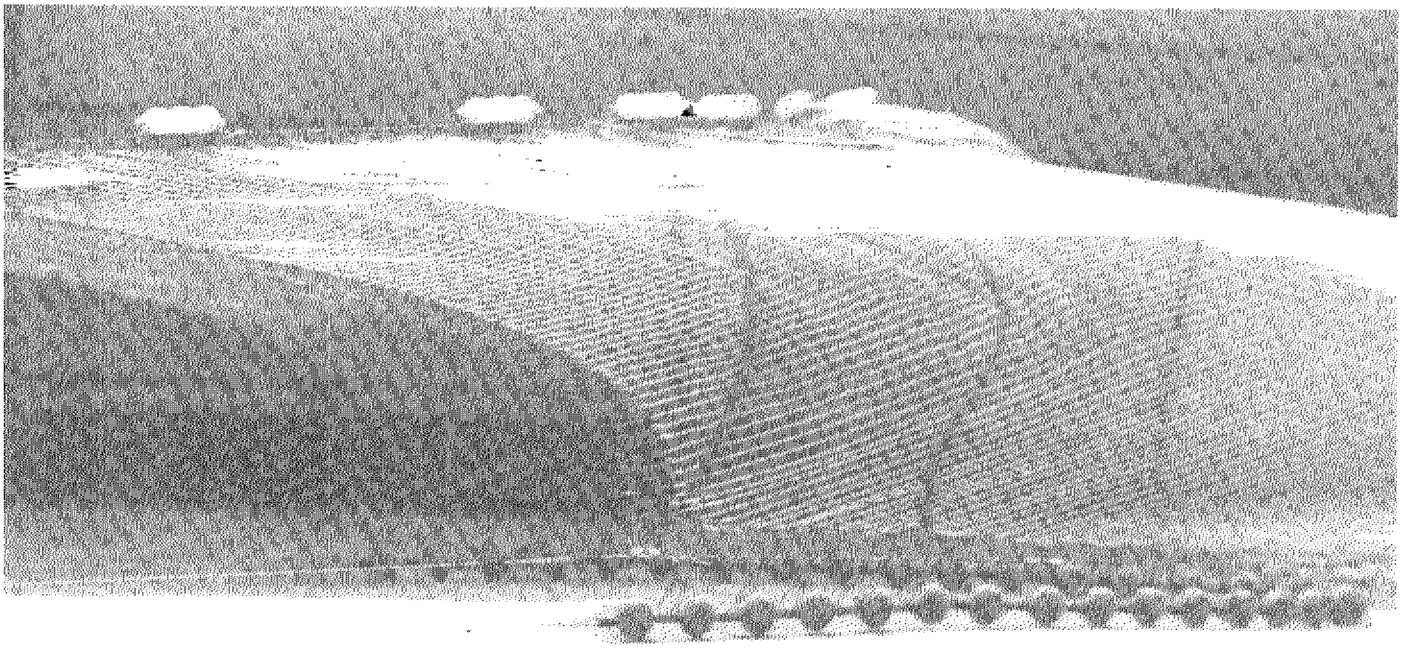
NO. OF FLOATS 123 x 8"
DOOR SIZE AND TYPE 10' V
GROUND WIRE LENGTHS 25 FATHOMS
TOW LEGS UPPER 15 FATHOM WIRE
LOWER 15 FATHOM CHAIN.

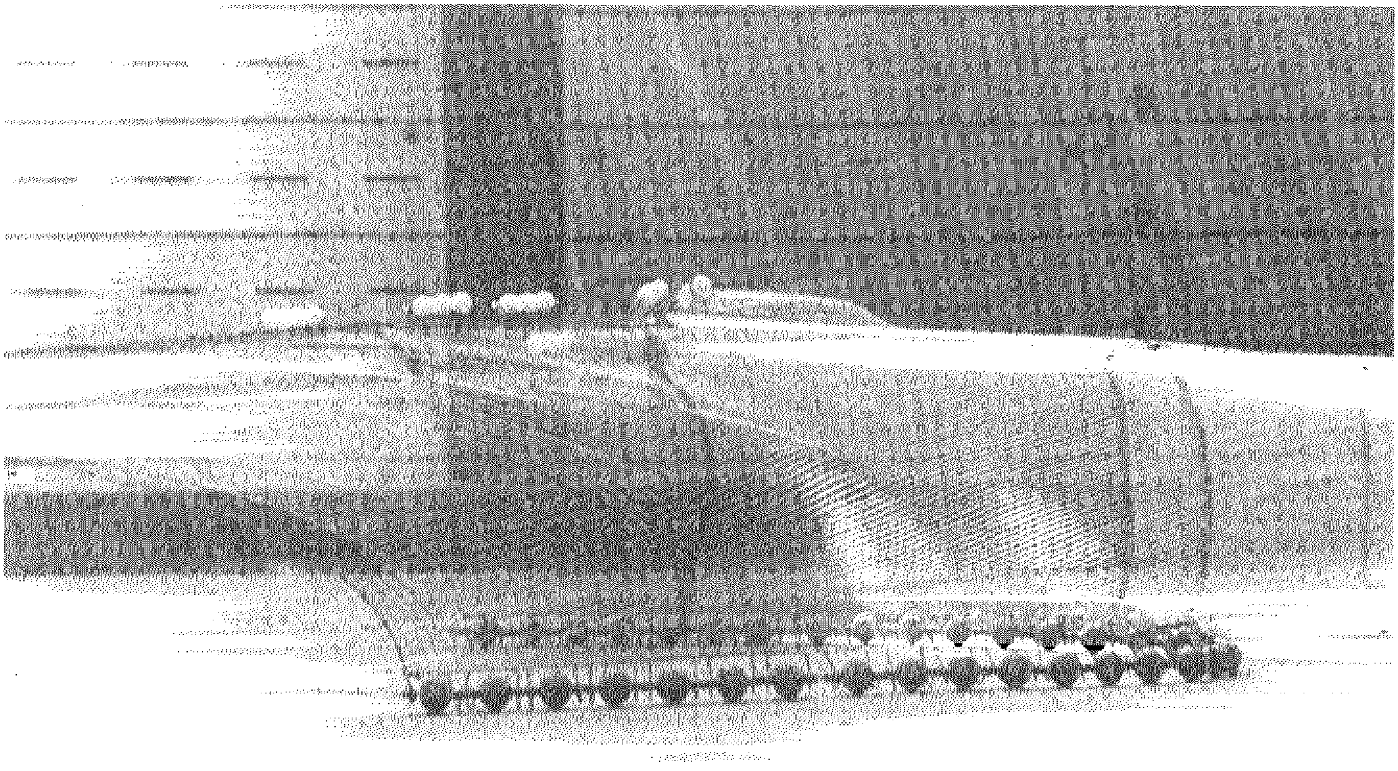
COMMENTS DOOR SPREAD A 150'
B 150'
D 156'
E 150'

B. +2' ON THE HEADLINE LEGS.

E. +4' ON THE HEADLINE LEGS.

FILM # 2
SHOT # 1, 2, 3





7

FLUME TANK TEST RECORD

MODEL TRAWL TYPE WESTERN ATLANTIC GROUND TRAWL

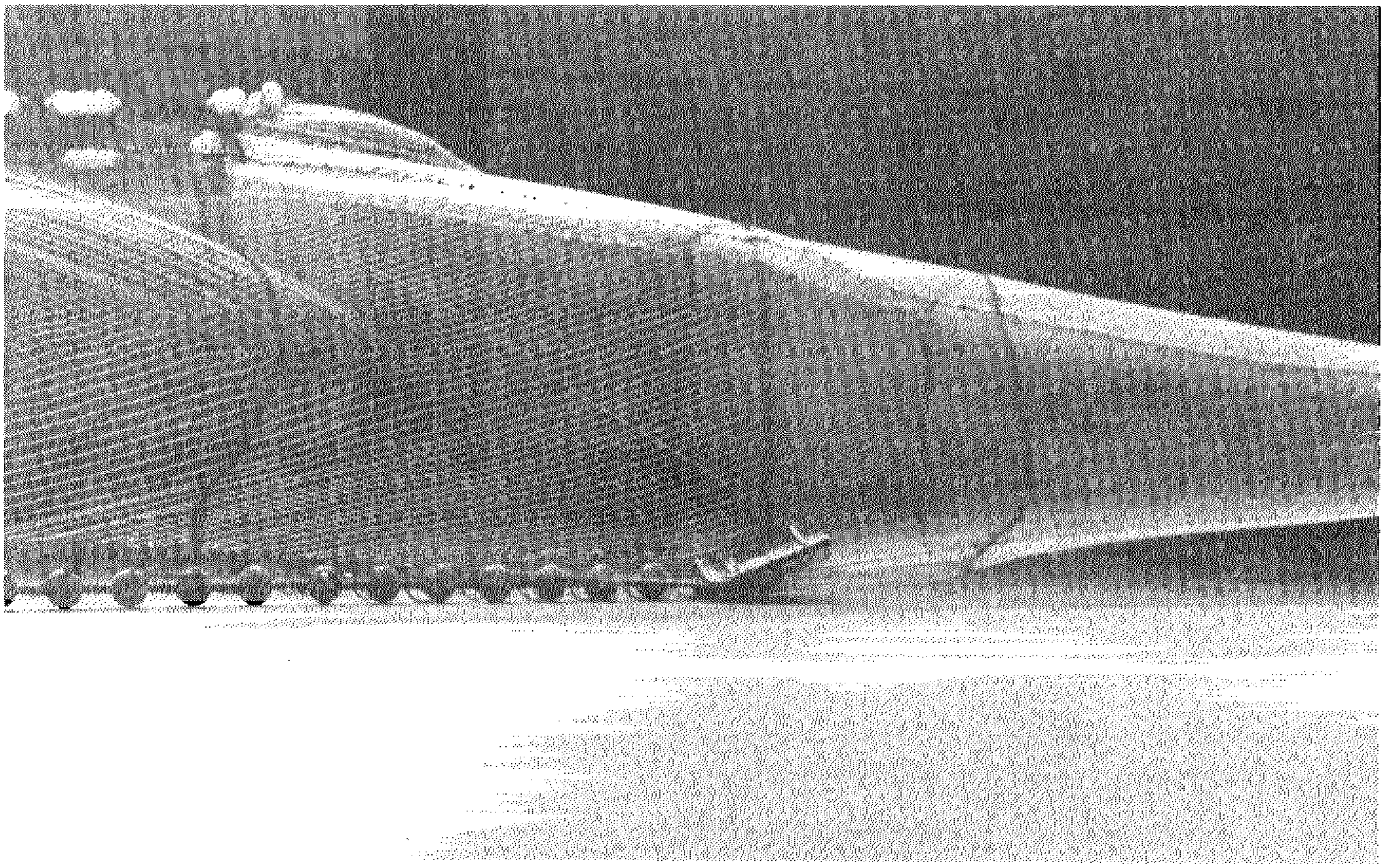
	F	G	H		
SPEED KNOTS	3.5	3.5	3.5		
HEADLINE HEIGHT	19¼'				
WINGEND HEIGHT	14'				
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION	4.3 TONS/SIDE	3.9 TONS/SIDE			

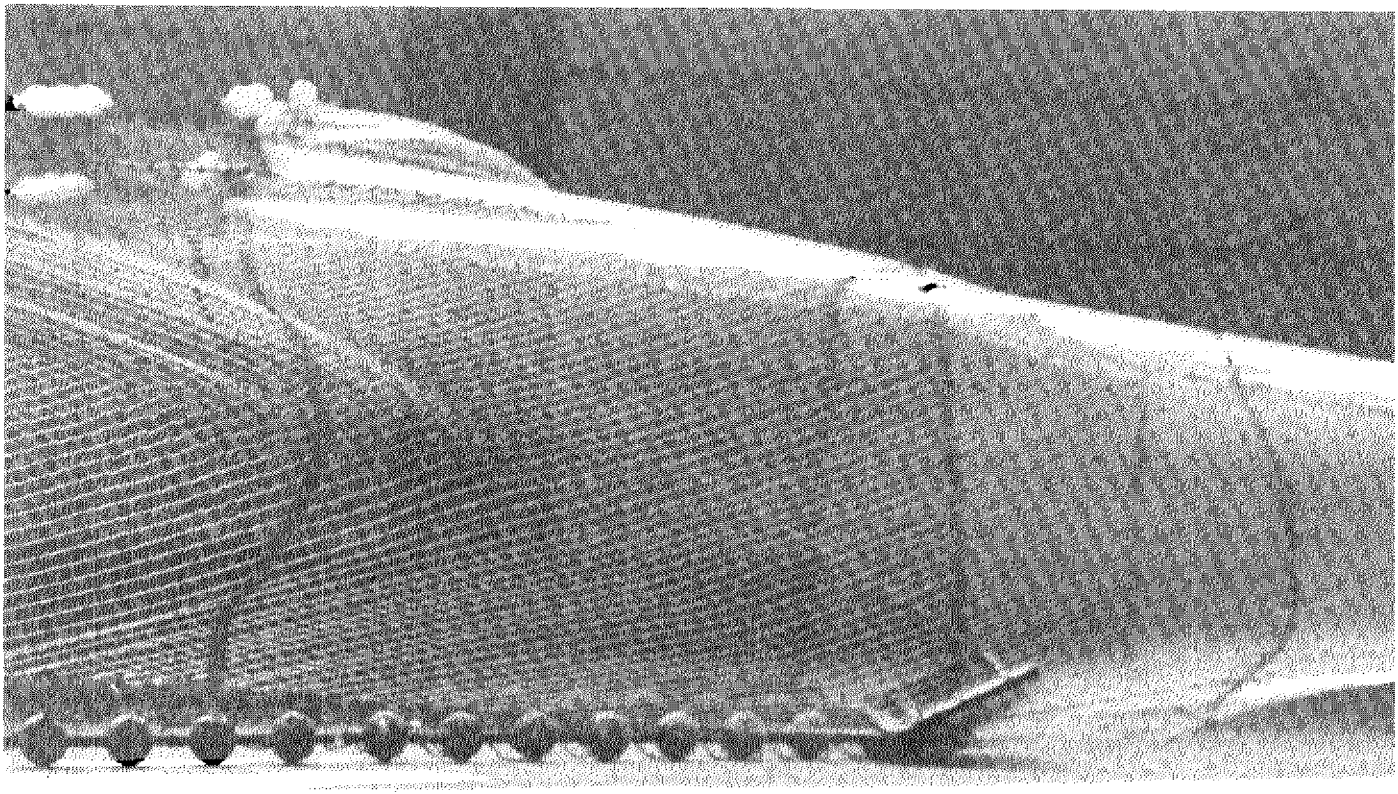
RIGGING DETAILS

NO. OF FLOATS As sheet 6
DOOR SIZE AND TYPE 〃
GROUND WIRE LENGTHS 〃
TOW LEGS UPPER 〃
LOWER

COMMENTS DOOR SPREADS 157'
F. CRAB POT ON THE DOOR.
G. CRAB POT IN THE NET.

FILM # 2
SHOT # 4.5,6, (F)
7.8.9. (G.)
10,11,12. (DOOR IN THE NET)





FLUME TANK TEST RECORD

MODEL TRAWL TYPE ATLANTIC WESTERN (GROUND TRAWL)

	I	J	K	L	
SPEED Knots	3 Knots	3.5 Knots	3 Knots	3 Knots	
HEADLINE HEIGHT	22.7'	21.5'	25.9'	25.5'	
WINGEND HEIGHT	15.5'	15.5'	17.5'	18.0'	
HEADLINE SPREAD	45'	43'	43'		
FOOTROPE SPREAD	56'	54'	55'		
WARP TENSION	3.7 TONS/SIDE	4 TONS/SIDE	3.4 TONS/SIDE	3.6 TONS/SIDE	

RIGGING DETAILS

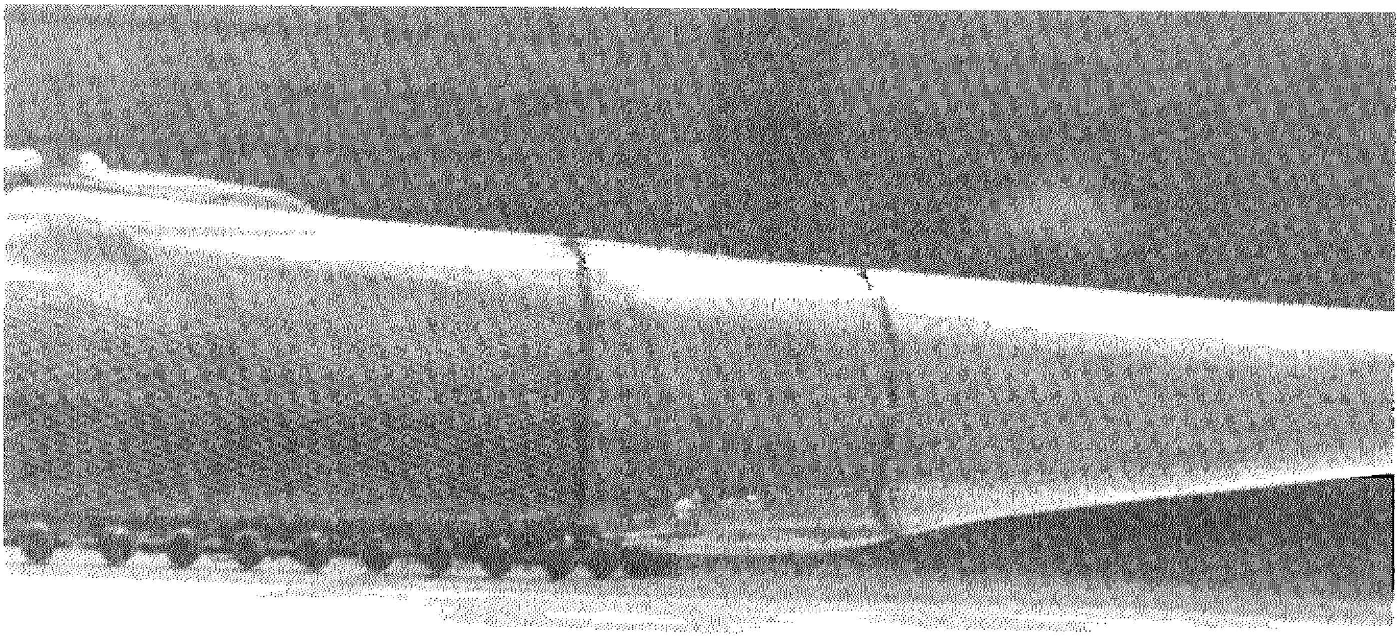
NO. OF FLOATS AS SHEET 6.
DOOR SIZE AND TYPE "
GROUND WIRE LENGTHS "
TOW LEGS UPPER AS SHEET 6.
LOWER DAN LENO RIG WITH WIRES TO FISHING LINE AND GROUND GEAR

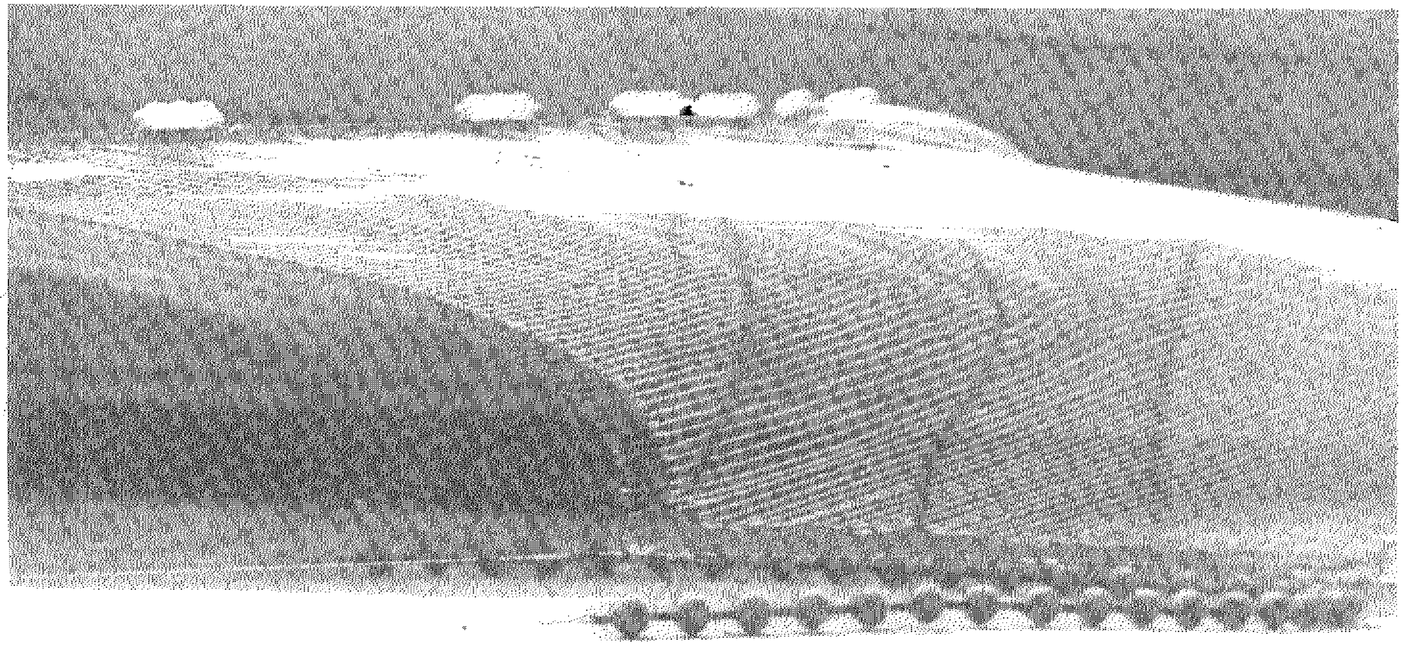
EXPERIMENTS TO DETERMINE POSITION OF FISHING LINE TO GROUND GEAR BY VARIOUS CHANGES IN FISHING LINE WIRE LENGTH.

IN ADDITION FLOATS WERE USED IN THE LOWER BELLY PANEL TO LIFT THE TWINES AS IS COMMON PRACTICE IN ALASKA

COMMENTS DOOR SPREADS ALL 157'
I FISHING LINE WIRE SHORTENED BY 20"
K. HEADLINE LEG LENGTHENED 12'.
L. FISHING LINE WIRE SHORTENED TO 30'.

FILM # 2
SHOT # 14-15.





FLUME TANK TEST RECORD

MODEL TRAWL TYPE 7'6" VEE DOORS

SPEED					
HEADLINE HEIGHT					
WINGEND HEIGHT					
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION	3 TONS/SIDE				

RIGGING DETAILS

NO. OF FLOATS

DOOR SIZE AND TYPE

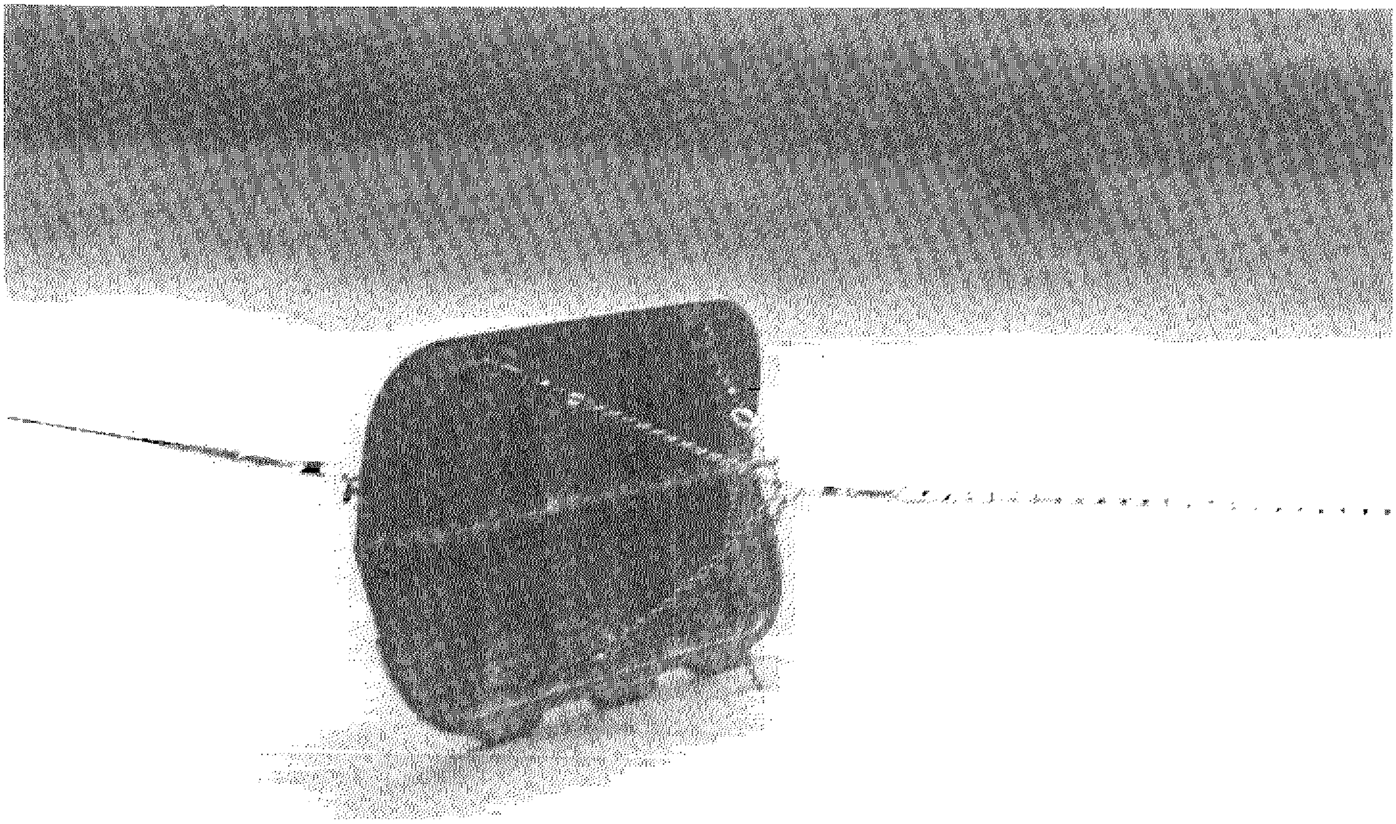
GROUND WIRE LENGTHS

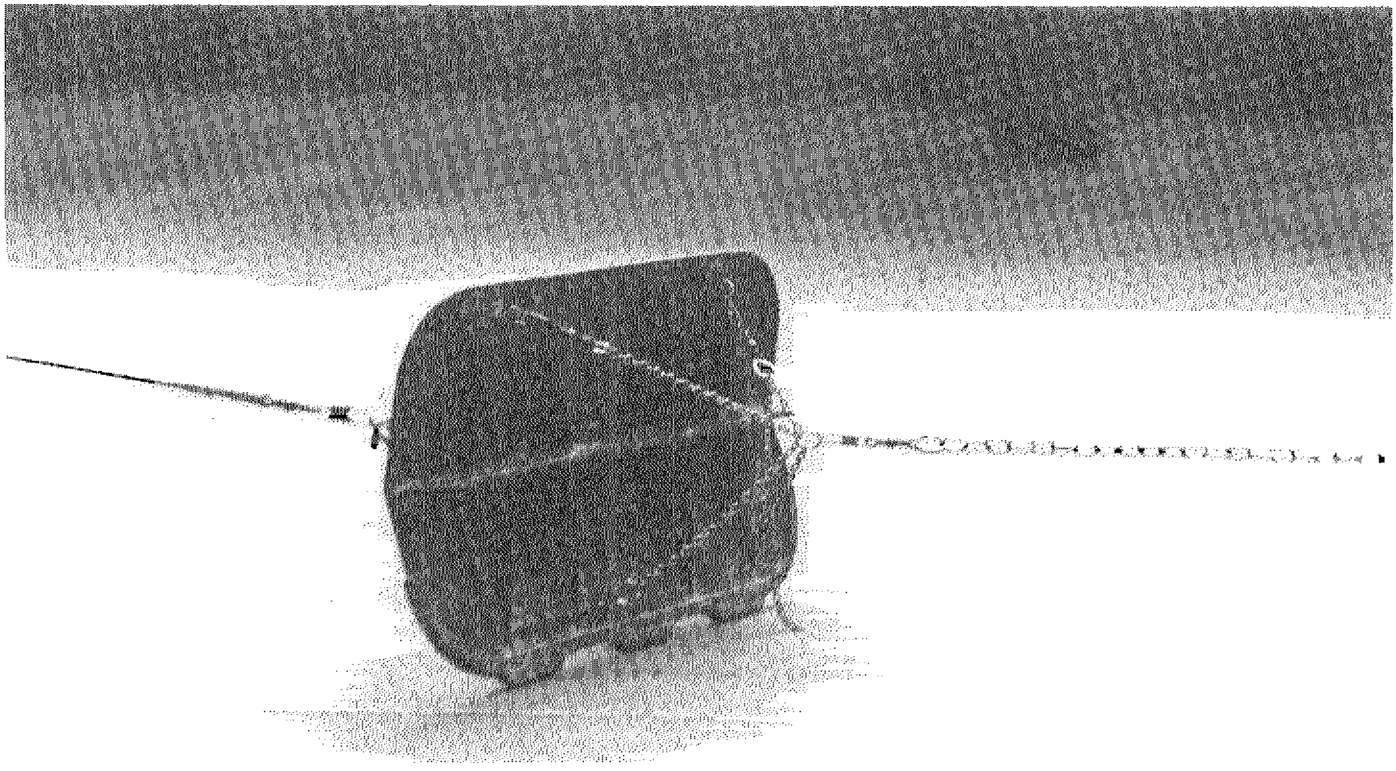
TOW LEGS UPPER
LOWER

COMMENTS

COMPARISON OF DOUBLE CHAIN BACKSTRAPS ON VEE TYPE DOORS

FILM # 2
SHOT # 16, 17.





FLUME TANK TEST RECORD

MODEL TRAWL TYPE MIDWATER I.C. TRAWL

	A	B	C	D	E
SPEED KNOTS	3	3.5	4	3	3.5
HEADLINE HEIGHT MOUTH OPENING	7 3/4 FATHOMS	6 3/4 FATHOMS		6 1/4 FATHOMS	7 FATHOMS
LOWER WINGEND HEIGHT HEIGHT FROM SEA BED	2 1/2 FATHOMS	6 3/4 FATHOMS	18 1/4 FATHOMS	ON SEA BED	1 1/4 FATHOMS
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION	4.6 TONS/SIDE	6 TONS/SIDE	8 1/2 TONS/SIDE	3.2 TONS/SIDE	4.2 TONS/SIDE

RIGGING DETAILS

NO. OF FLOATS

DOOR SIZE AND TYPE 4.2 M. SUPERKRUBB

GROUND WIRE LENGTHS

TOW LEGS UPPER 51 FATHOMS 1' 10' 6" EXTENSION

LOWER 50 FATHOMS 20' 0" EXTENSION

WEIGHTS 450KG EACH SIDE

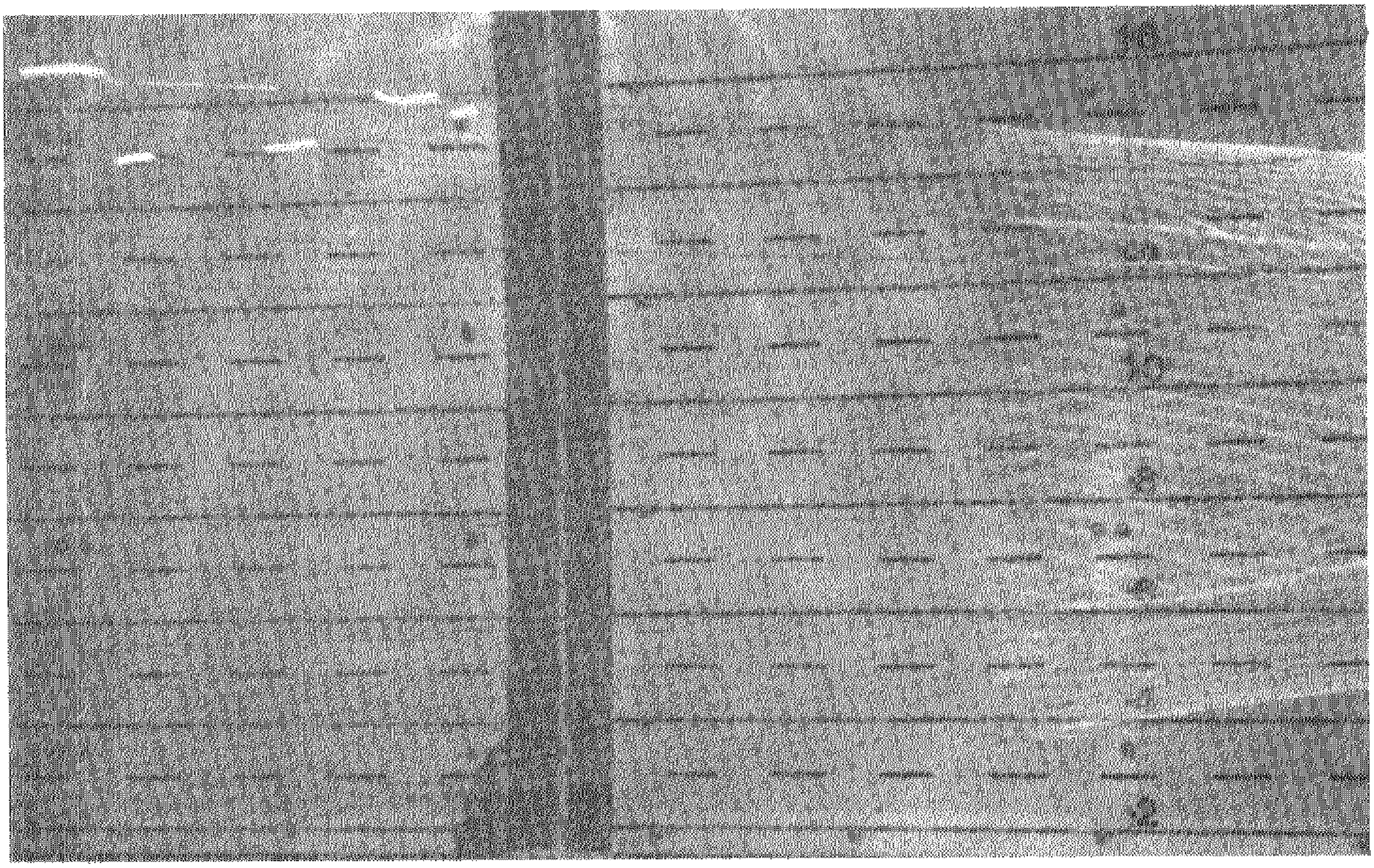
25KG ON THE FOOTROPE.

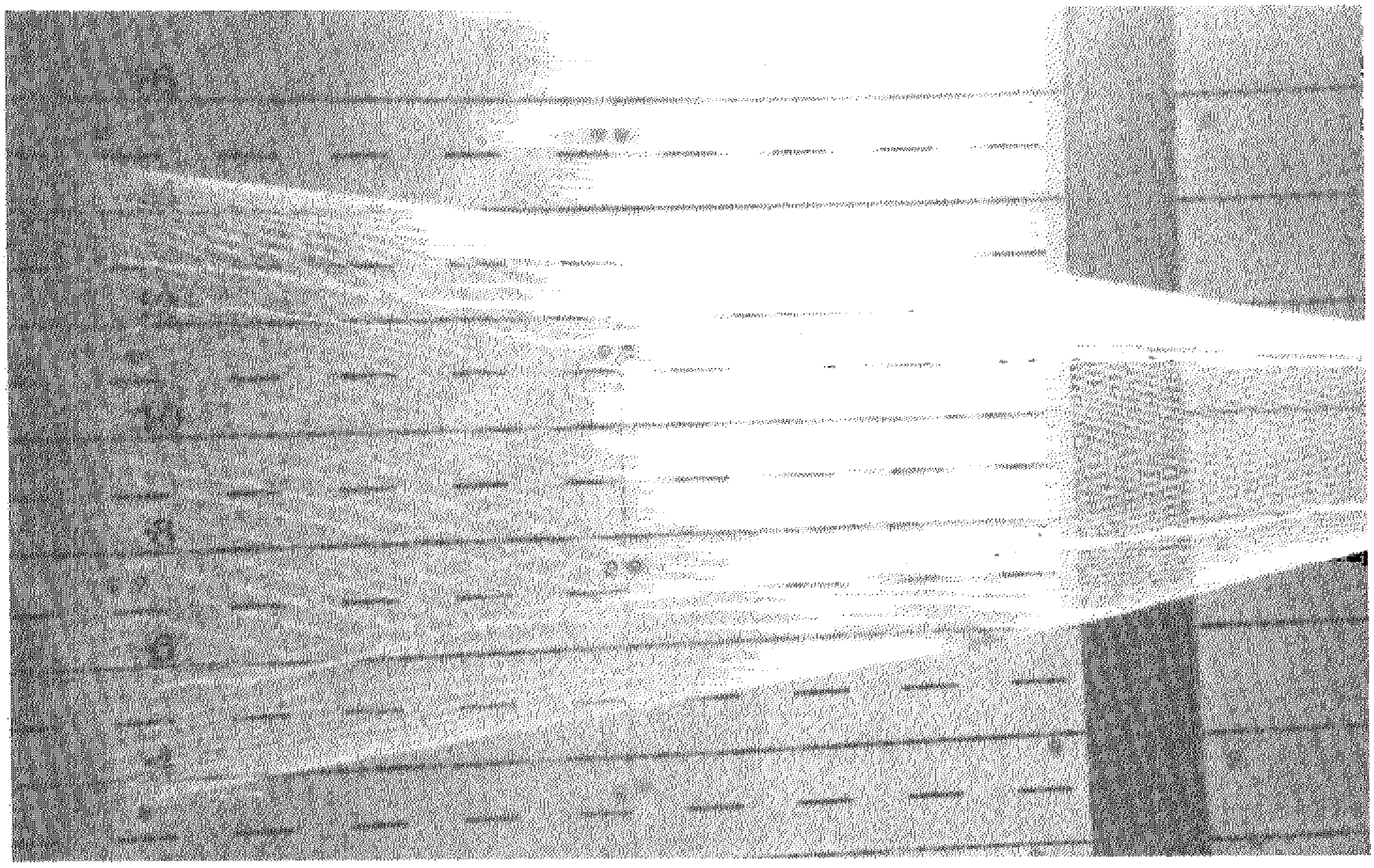
COMMENTS

D E. WEIGHTS INCREASED BY 100KG EACH SIDE.

FILM #

SHOT #





FLUME TANK TEST RECORD

MODEL TRAWL TYPE MIDWATER I.C. TRAWL

	F	G	H	I	
SPEED KNOTS	4	3	3½	4	
HEADLINE HEIGHT MOUTH OPENING	7 FATHOMS	7⅞ FATHOMS	7¾ FATHOMS		
LOWER WINGEND HEIGHT HEIGHT ABOVE SEABED	6 FATHOMS	1 FATHOM	5½ FATHOMS	1¼ FATHOMS	
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION	5.1 TONS/SIDE	4.3 TONS/SIDE	5.4 TONS/SIDE	6.5 TONS/SIDE	

RIGGING DETAILS

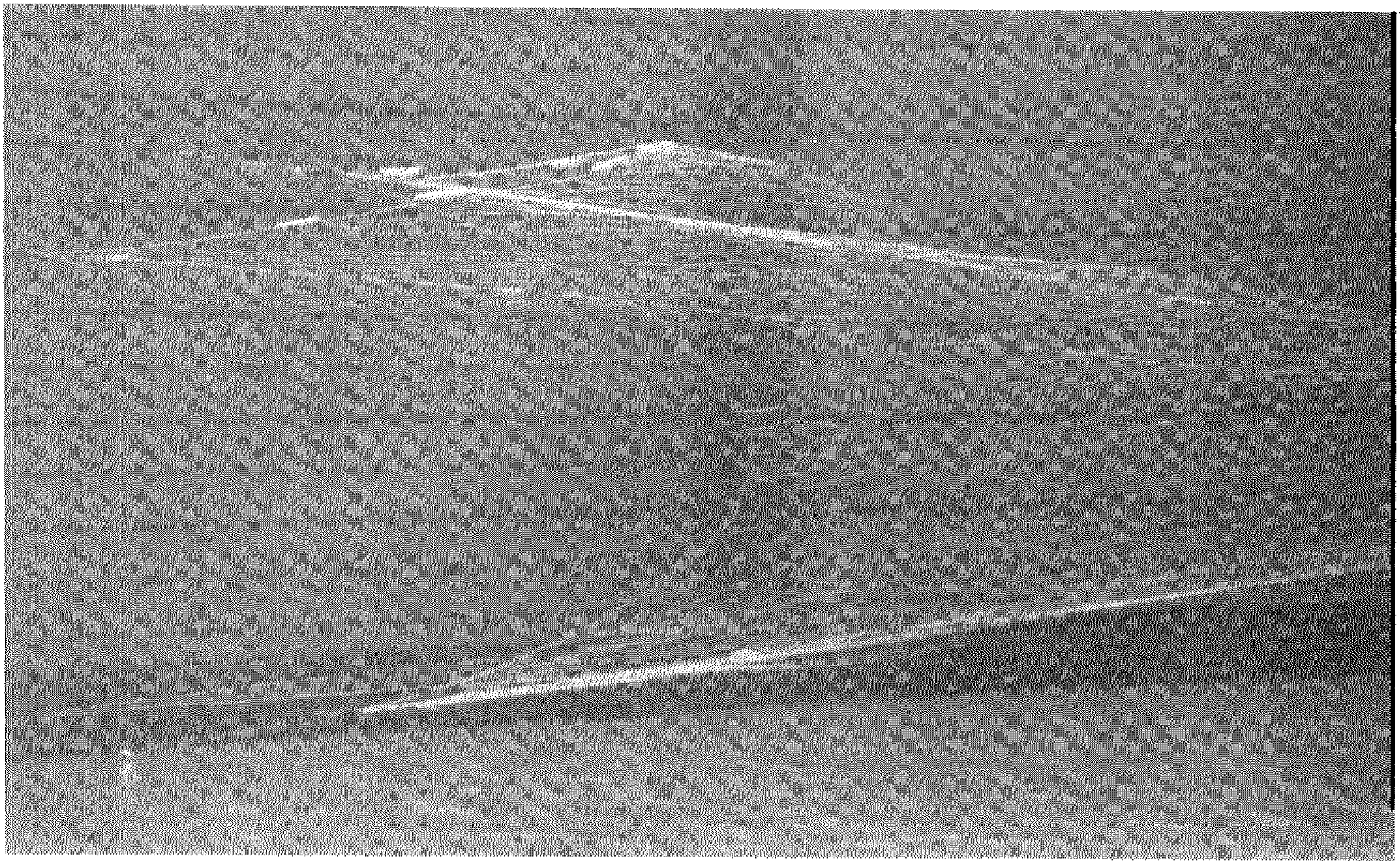
NO. OF FLOATS	AS SHEET 10
DOOR SIZE AND TYPE	"
GROUND WIRE LENGTHS	"
TOW LEGS UPPER LOWER	"

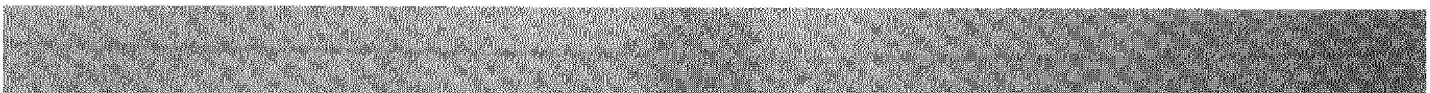
COMMENTS

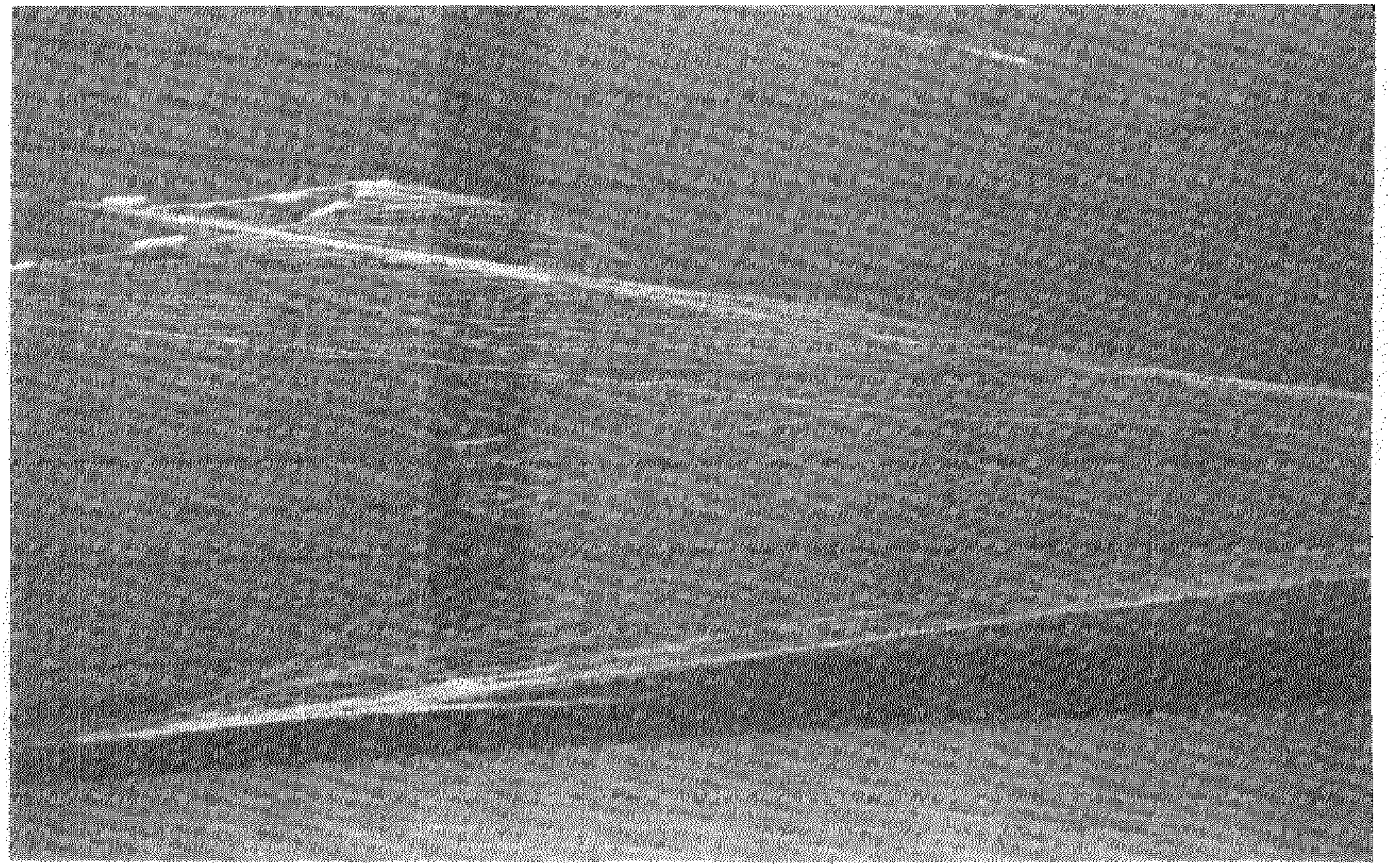
G. BACK TO ORIGINAL WEIGHTS AND INCREASE FLOATS TO 92×11".

FILM # 2

SHOT # 18, 19, 20







FLUME TANK TEST RECORD

MODEL TRAWL TYPE MIDWATER IC. TRAWL

	J	K	L		
SPEED Knots	3	3½	4		
HEADLINE HEIGHT MOUTH OPENING	7½ FATHOMS	8 FATHOMS	7½ FATHOMS		
LOWER WINGEND HEIGHT HEIGHT FROM SEABED	ON SEABED	3⅛ FATHOMS	9½ FATHOMS		
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION		4.6 TONS/SIDE	5.7 TONS/SIDE		

RIGGING DETAILS

NO. OF FLOATS As SHEET 10.
DOOR SIZE AND TYPE
GROUND WIRE LENGTHS
TOW LEGS UPPER
LOWER

COMMENTS

FILM #
SHOT #

FLUME TANK TEST RECORD

B

MODEL TRAWL TYPE SUPERKRUBB TRAWL DOORS

SPEED	A	B	C		
HEADLINE HEIGHT	DOOR ABOVE NET. BACKWARDS ATTITUDE	DOORS LOWER THAN (A). FASTER RESPONSE TO SPEED. BACKWARDS ATTITUDE.			
WINGEND HEIGHT					
HEADLINE SPREAD					
FOOTROPE SPREAD					
WARP TENSION					

RIGGING DETAILS

NO. OF FLOATS
DOOR SIZE AND TYPE 4·2M SUPERKRUBB.
GROUND WIRE LENGTHS
TOW LEGS UPPER
LOWER

COMMENTS A. UPPER TOWING BRACKET
MIDDLE TOWING POINT.
MIDDLE BACKSTRAP LOWER.

B. LOWER TOWING BRACKET
MIDDLE TOWING POINT
MIDDLE BACKSTRAP LOWER.

C. LOWER TOWING BRACKET
LOWER BACKSTRAP.

FILM #
SHOT #

FILM 2.
SHOT 25, 26 (A).