Single Vessel Midwater Trawling

Duncan Amos

Marine Advisory Service
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University of Rhode Island

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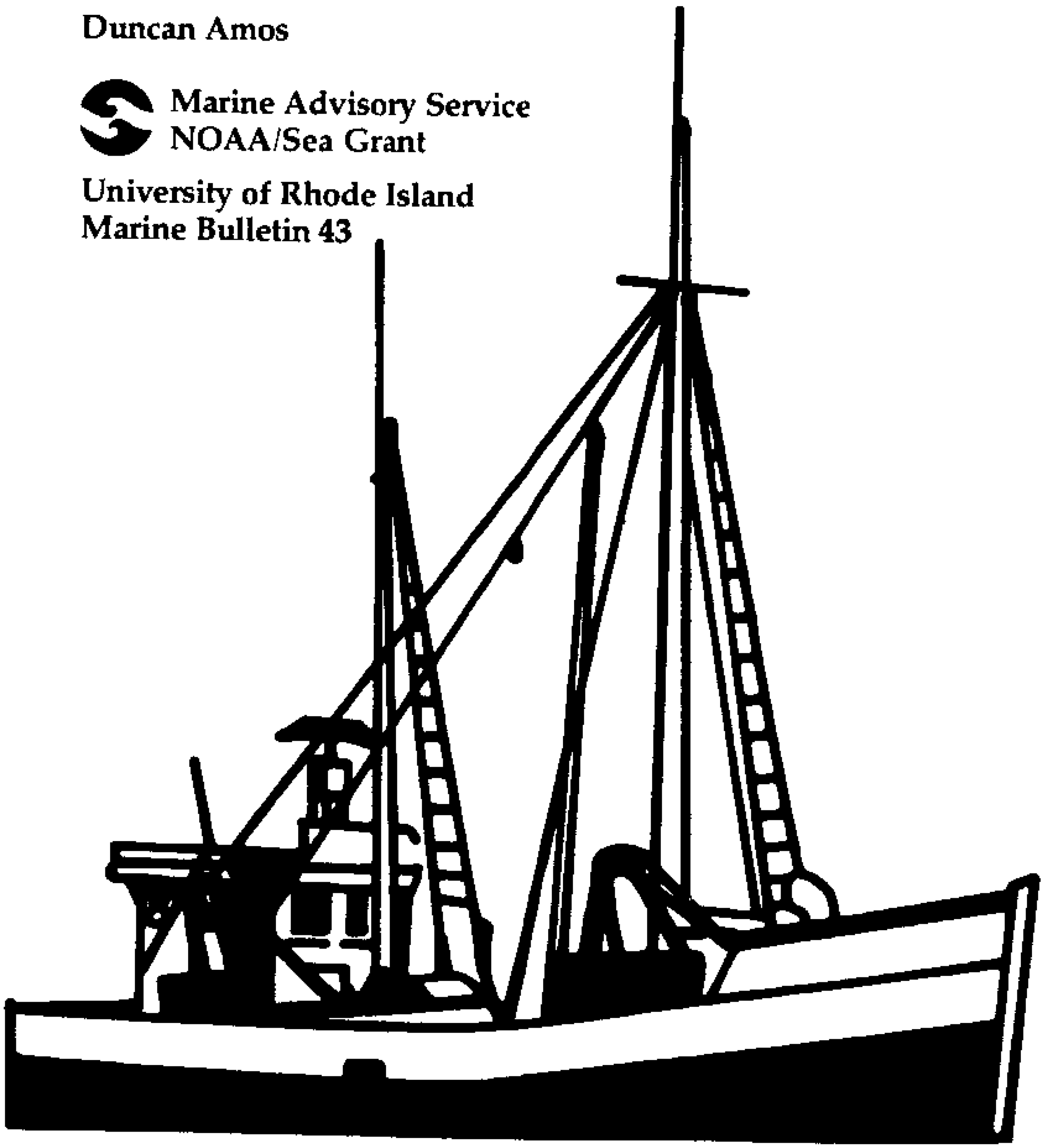

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SINGLE VESSEL MIDWATER TRAWLING

A Basic Guide to the Theory, Selection and Operation of Single Vessel Midwater Trawls

Duncan Amos
Commercial Fisheries Specialist
Marine Advisory Service

University of Rhode Island
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INTRODUCTION

Since the late forties, the development and application of the single vessel midwater trawl has progressed at great speed so that now the technique is applied around the world for the harvesting of many fish species.

Development work is still continuing, but detailed rigging features and methods of operation and application are still less well defined than that which is available for established demersal trawls.

The major feature of a midwater trawl is its area of operation. It must be capable of working through the entire water column and be completely maneuverable by the operator to suit the vertical displacement of the fish species sought.

In conjunction with the use of a midwater trawl, two other major factors must be considered. These are: (a) the detection of the fish stock and the verification of its depth and distribution and (b) the exact position of the midwater trawl and its performance characteristics. Both (a) and (b) can be determined by acoustic instruments in the shape of sonars and vertical echo sounders and net sounders.

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

Midwater 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, and react quickly to disturbing influences. Information on the flight reactions of pelagic fish is still scanty, but most indications would appear to suggest 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 usually respond as a body to any disturbance, i.e., they shoal, whereas demersal fish that move into the pelagic regions at certain times of the year react individually to any disturbance.

(3) Most pelagic species of fish have well-developed sight and hearing capabilities, particularly low frequency vibrations associated with towing vessels and trawl operation. Although little is documented about these factors, they have played a large part in the design of midwater trawls.

From statistical information (Modern Fishing Gear of the World, Book 3), midwater trawling is most successful when (a) the fish concentrations (shoals) 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 MIDWATER TRAWL

Midwater trawls require a large vertical as well as horizontal mouth opening. This provides stability to the net during operation but also provides for the capture of fish both vertically and horizontally.

The large-mouth opening is usually achieved by the insertion of 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 to bring the footrope ahead of the headline to counteract the downward flight of fish. This is in complete contrast to the accepted design feature of a demersal trawl.

The importance of smooth water flow through the net is common to both demersal and midwater trawls, but it becomes an absolute requirement in midwater trawls to prevent turbulence near the net mouth. To help to meet this requirement, midwater trawls are 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 when used to harvest lively fish is the ability to tow the gear fairly fast. To achieve this, the hydrodynamic drag of the trawl must be kept to a minimum.

Single vessel midwater trawl development has taken place in many parts of the world, with the majority of variations taking place in the rigging of the doors, flotation, weight and tow leg lengths. The nets themselves have tended to remain the same in design, with each designer seeking to satisfy the requirements of high stability, large mouth opening, low turbulence and low drag. The major design changes have come in the mesh sizes, increasing from the early days of 20 centimeters (7.8 inches) to more than 3 meters (9 feet).

FORCES ACTING ON A TRAWL

This section will help the reader to consider the forces that act on a midwater trawl so that when any variation is made in the rigging or method of operation, the various forces can be assessed and the resultant effect on the trawl and its performance predicted.

Various forces are caused to react on any fishing gear towed through the water. These forces are listed along with their definition and how they affect the shape and performance of a midwater trawl.

Drag

The definition of drag is "any obstacle to progress."

In a midwater trawl net, the drag is generated primarily from the twines used to make up the net; mesh size and twine diameter will establish a basic drag figure at a specific towing speed. However, on many occasions the towing speed of the trawl will be changed, resulting in a change to the total drag figure. This change in the drag will influence the shape of the net, as it is a flexible unit in the water, the major changes in the net being reflected in the shape of the net mouth.

The fisherman should consider the following approximate figures when applied to midwater trawls:

(1) 2 x area of netting = 2 x drag at the same speed

e.g. 100 $meters^2$ at 2 knots = 2 ton drag
200 $meters^2$ at 2 knots = 4 ton drag

(2) 2 x speed = 4 x drag
3 x speed = 9 x drag

e.g. 2 knots = 1 ton
4 knots = 4 tons
6 knots = 9 tons

The figures used in example (2) above are approximate, as the net becomes more streamlined as the speed increases, but they are sufficient to illustrate the increase in net drag as the speed is increased. Drag can always be related to fuel being burned in the engine.

Drag will be influenced by other appendages attached to the net, i.e., floats, weights and net tailoring.

Lift and Flotation

Lift is defined as a vertically upward force applied to a body, either applied directly or as a component of a force applied at an angle to the vertical. A direct fisherman's example is a headline float which applies an upward force directly to the headline because of the buoyancy of the air trapped inside it. An eight-inch diameter float applies approximately seven pounds of lift when immersed, and this force will remain constant regardless of depth, providing the shape of the float is not changed. Flexible floats, sometimes used on midwater trawls to prevent headline and footrope fouling during shooting, can compress to half their volume when they reach 30 feet below the surface.

However, with all solid form floats, as they are towed forward through the water they will also generate drag. Although increasing the number of floats on a headline will increase the effective lift on the headline, as the speed of tow increases, the drag generated by the surface area of the floats will increase the total gear drag and also adversely affect the shape of the headline. With midwater trawls, the fisherman must consider the total life or buoyancy effective on his trawl and its effect on the trawl's position in the water.

TABLE 1. Lift from Various Types of Floats

Size	Make	Type	Lift lbs.	Kilos
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 (Yellow)	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

Netting used in midwater trawls can also generate a lift force depending on the mesh size and twine diameter. This force is influenced by the angle to the horizontal the netting panels take up in the water and their speed through the water. This same source of generated force can be applied sideways by the panels in the side of the net. This sideways force or shear is generally applied to trawl doors where most of the net spreading forces are generated.

Weight

Weight is defined as the force gravitation exerts on a body; however, weight in air is greater than when the body is in water, this being governed by the volume of water displaced and any inherent buoyancy in the object.

In single boat midwater trawling, the net is usually rigged so that the towing forces are more evident in the headline and the net literally hangs from the headline. To open up the mouth of the trawl, weights are added to the lower tow legs at the short wing ends or at some distance ahead of the wing ends. This weight will also influence the position the net takes up in the water at a specific warp length out and towing speed.

Combined Effect of Drag, Lift and Weight

Considering the various forces that act on a midwater trawl, the position it assumes in the water and its shape, the resultant forces can be defined technically as follows: 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.

The statement above relates to the performance of a midwater trawl, in that the trawl will tow at a constant depth in the water provided 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 midwater trawl operator has at his disposal two methods of changing the working depth of his trawl. Increasing or decreasing the towing warp length will change the effective fishing depth, and increasing or decreasing the towing speed will also change the effective fishing depth. Combining both speed and warp length will increase the effective depth changes experienced by the trawl.

As the net itself is a flexible device, the major net performance parameter will change during any such 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 MIDWATER TRAWL

When an operator considers the use of a midwater trawl with his vessel, the correct trawl and door combination to suit the towing power of the vessel is of paramount importance.

Single vessel midwater trawls have been operated with horsepower ratings of between 100 and 3500. This allows most fishing vessels to consider midwater trawling provided the deck machinery and layout are compatible with the net, doors, and warp required.

The first major assessment to be made is to determine what size of trawl doors will be required to spread the net, and, 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.

This is a relatively simple calculation using the following procedures:

(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:

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

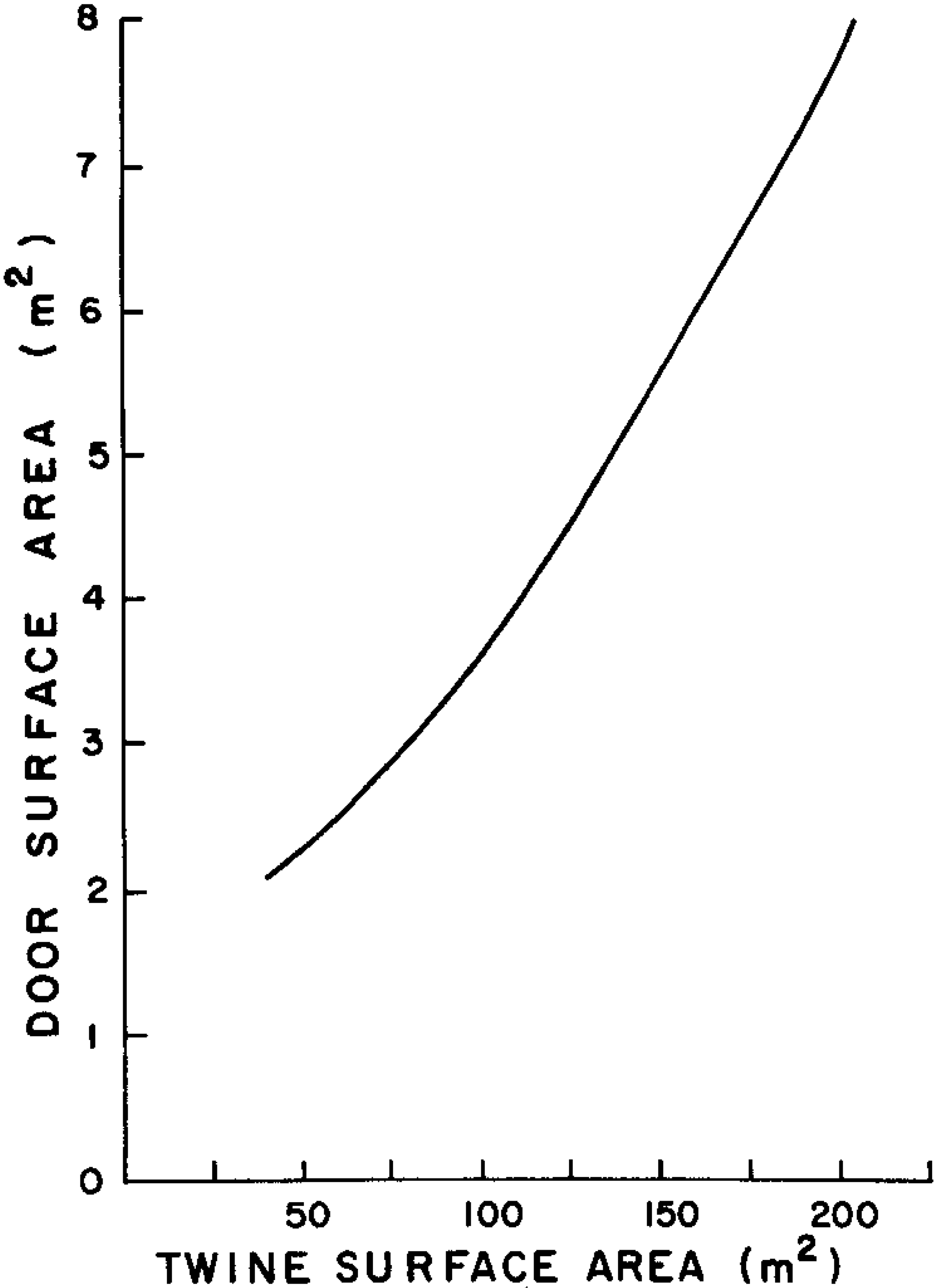
Where:

N = number of meshes along the widest part of the panel.
n = number of meshes along the narrow part of the panel.
H = the number of mesh rows down the side of the panel.
a) = bar length of the mesh in millimeter.
d) = twine diameter in millimeters.
10^{-6} = conversion to (M^2).

Add the TSAs for all the panels together to give a total Twine Surface Area for the net.

Apply this figure to the graph in Figure 1 and obtain the area of trawl door required to spread the net. Now apply this door area value to the graph in Figure 2 to obtain the relative vessel horsepower required to tow this combination of net and trawl doors.

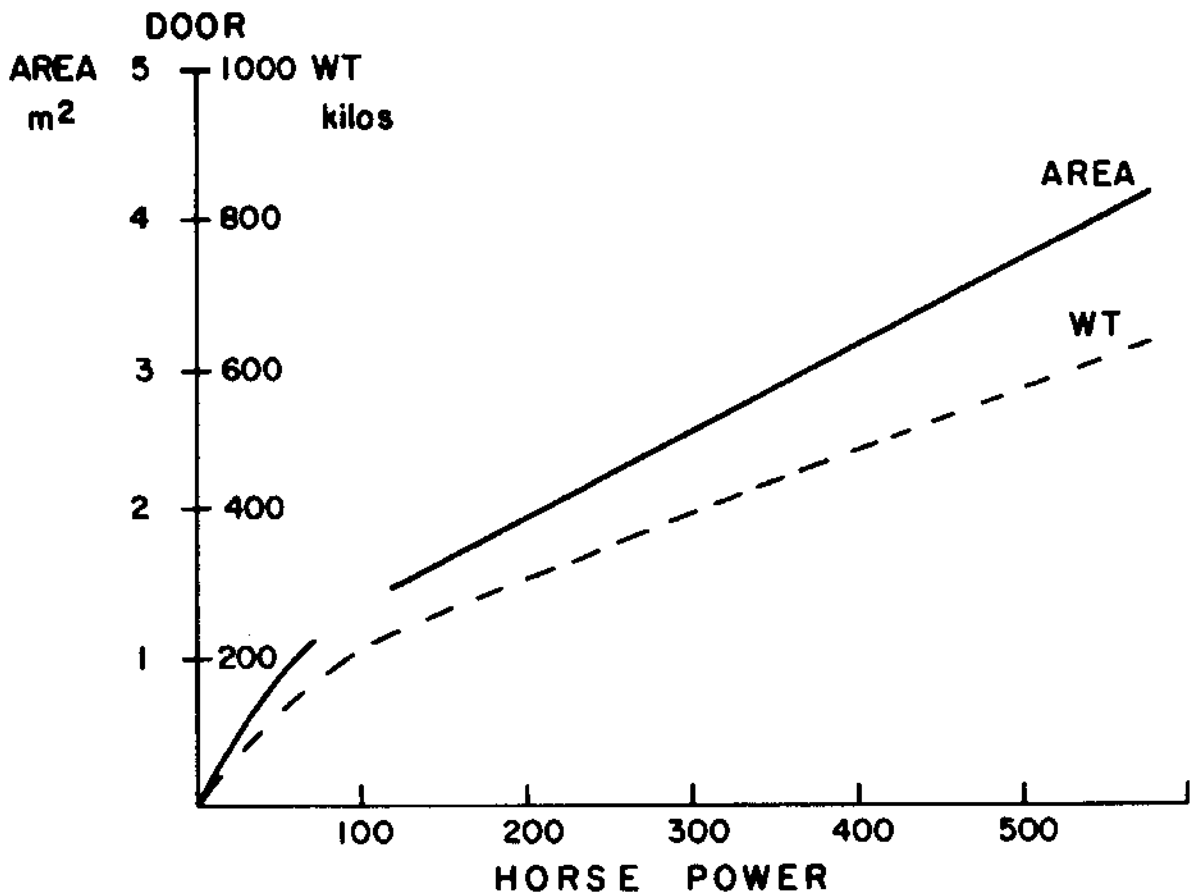
Figure 1



Area of suberkrub door required to spread midwater net when twine surface area is known

Figure 2

Suberkrub Doors



Remember, however, that the figures so obtained are the maximum, so if the towing vessel horsepower is sufficient to tow the combination with no reserve power the chances of a successful fishing operation are slight. A margin of 30% of the available horsepower should be available for higher towing speeds and trawl maneuvering.

TABLE 2. Conversion of Diameters, U.S. Twine Numbers, from Inches to Milimeters

US No.	Dia. Inches	Dia. Millimeters
3	0.017	0.43
4	0.022	0.55
5	0.027	0.68
6	0.031	0.78
7	0.035	0.88
9	0.042	1.06
12	0.046	1.16
15	0.051	1.29
18	0.058	1.47
21	0.065	1.65
24	0.073	1.85
30	0.078	1.98
36	0.085	2.15
42	0.093	2.36
48	0.103	2.61
60	0.116	2.94
72	0.125	3.175
84	0.135	3.42
96	0.158	4.01
108	0.166	4.21
120	0.170	4.31
132	0.187	4.74

MIDWATER TRAWL DOORS AND TRAWL RIGGING

The most popular trawl door used with midwater trawls is that 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 sheer 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.

Various warp and back strap attachment points are generally provided to allow the operator to change the sheer forces in an upward, downward or horizontal direction.

The vessel operator should try to visualize the effect on the door when changes are made to the rigging, or weight is added or reduced to the keel of the door. Usually the warp towing bracket is placed approximately 4% 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 whilst towing with a slight inward heel, which will increase as the towing speed is increased or warp is hauled. This slight inward heel will give the door an upward component of sheer. If the upper towing bracket is used, the door will heel inwards more; under normal towing conditions this will give the door an increased upward sheer force which 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 keel of the door. Increasing the weight of the door will also cause the door to fish deeper.

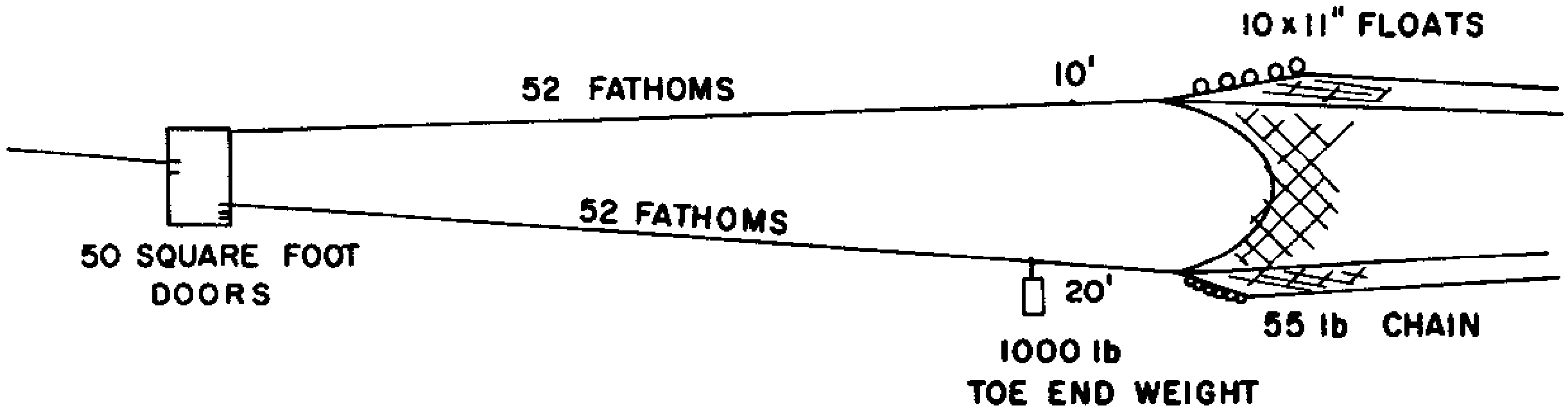
Changes to the back strap position will influence the door's tilt angle. Using the upper bracket will cause the door to tilt upwards. Using the lower bracket will cause the door to tilt downwards. The tilt angles will be directly affected by the length of the tow legs (bridles or sweeps). Generally the upper tow leg is shorter than the lower, causing most of the towing strain to be transferred 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 angle of attack of the door, which in turn will affect the sheer or spreading force of the doors. The outboard attachment position will give the minimum angle of attack which will give the minimum sheer force, reducing the net spreading force. Using the attachment point at the inboard end of the bracket will increase the angle of attack, increase the shearing force, and increase the spread of the net.

With all the variations now available on the trawl doors, the operator should consider the combined effects of changing warp attachment bracket and towing point, lower back strap 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.

Reference to the following trawl rig sketches will assist the operator in establishing the basic settings to enable the trawl to be shot and maneuvered.

Figure 3



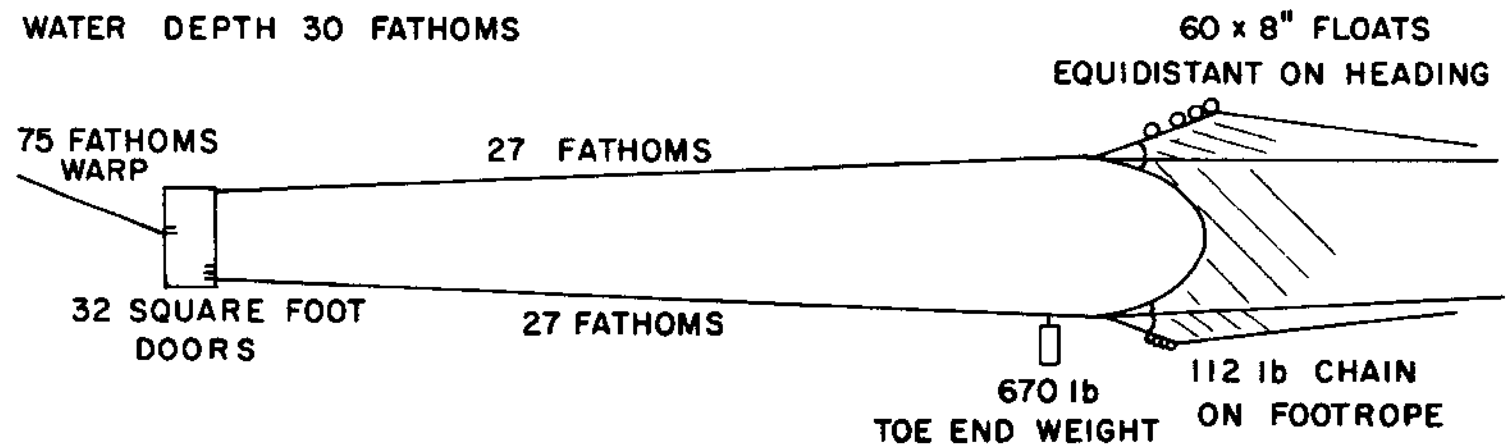
Type of net - Rectangular with no extension in the lower netting.

Deep water rig. Doors set for quick rise on increasing speed or take in of warp.

Headline	22 Fathoms
Sidepanels	16 Fathoms
Footrope	22 Fathoms

Towing Power	900 M.P. - 1100 M.P.

Figure 4

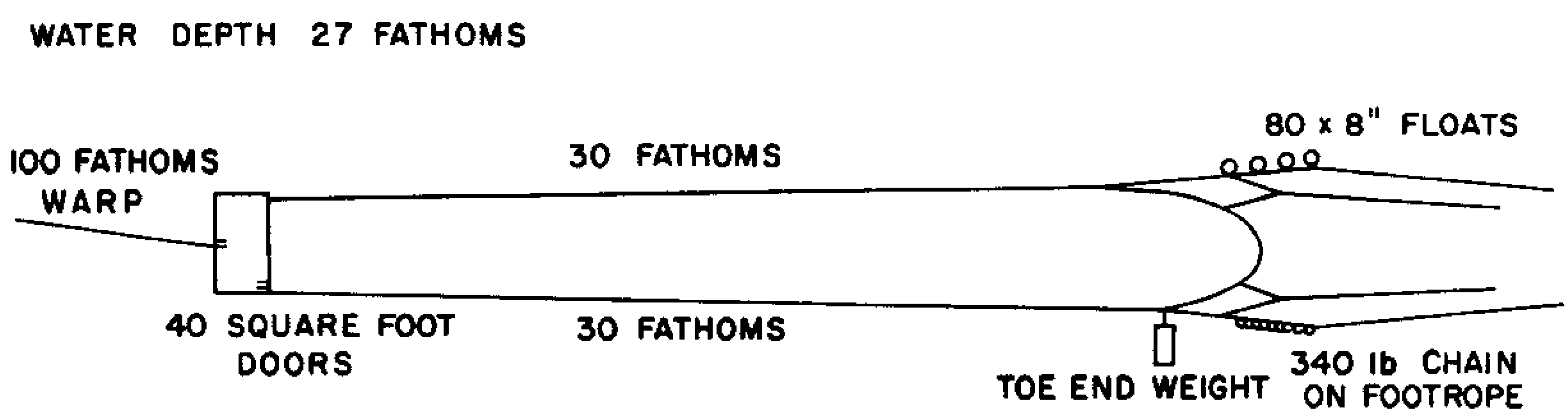


Towing Speed - 3 Kts.
Net Mouth Vertical Opening - 8.5 Fathoms
Net Spread - 12 Fathoms

Type of Trawl - Rectangular with extended lower wings. The tow legs are kept equal in length so that the net is still towed on the headline.

Headline - 24 Fathoms
Sidepanel Lines - 23 Fathoms
Footrope - 27 1/2 Fathoms

Figure 5



Type of net - Rectangular with short V-shaped wings. There is no extra net in the lower part of the net. By using equal tow legs, the net is not towed of 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.

Headline	23 Fathoms
Side Panel Lines	20 Fathoms
Footrope	23 Fathoms

Towing Power Required - 400-600 H.P.

Notes on Rigging Variations

1. Increasing the toe end weight or the effective weight of the footrope will tend to increase the mouth opening. However, the addition of this extra weight can make the trawl fish deeper so that 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 will make the doors spread more, but will reduce their rising response as speed increases or warp is hauled.

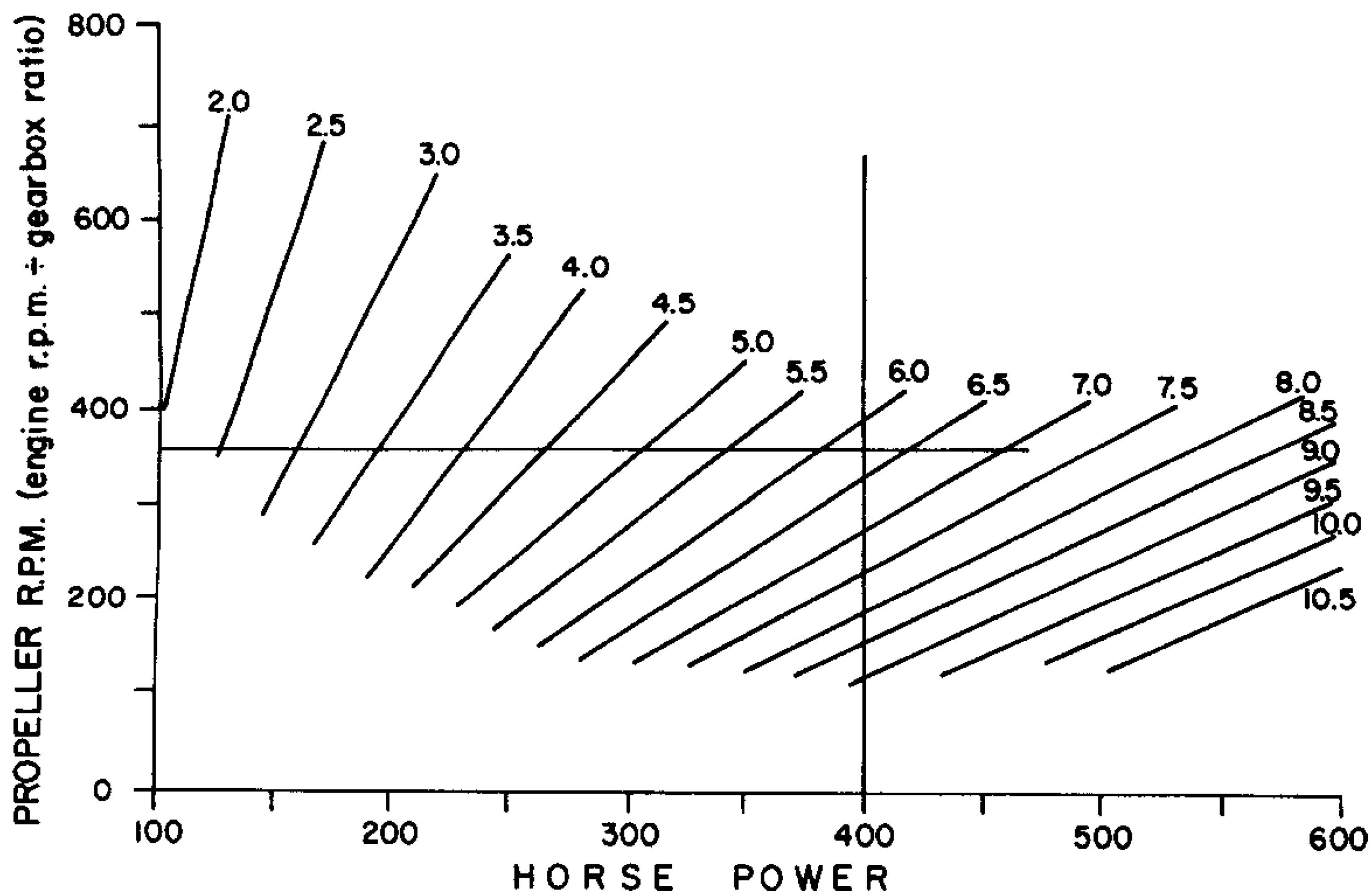
2. Adding floats to a headline will lighten the trawl, the floats reacting against the weight on the footrope and lower toe weights. On some rigs this addition of flotation can increase the mouth opening by causing the headline to curve upwards. Excessive flotation will make the trawl fish higher in 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 will reduce 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 towards the door will cause the mouth opening to decrease. This will also influence the performance of the door as the weight is made to act more directly on the back strap towing point; this can cause the door to nose down, particularly if the lower warp bracket is being used.

Figure 6

Approximate Bollard Pull for
Nozzle Propellers



Alternative Method of Determining Trawl Performance

An alternative method of determining a towing vessel's performance with a midwater trawl is available if the vessel's bollard pull figure is known.

To assist in illustrating this method of assessment, a series of graphs are available with the text so that approximate bollard pull figures can be determined. Remember that these figures are only a guide and are approximate. The only reliable method of determining bollard pull is to have the vessel tested against an accurate and calibrated instrument.

Two bollard pull graphs are listed, one for open propellers and one for nozzle propellers. It has been assumed in each case that the propeller was selected to provide towing performance and not free-running performance.

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

e.g. Main Engine - 400 H.P. at 1800 R.P.M.
Continuous service
Gearbox ratio - 5:1
Propeller R.P.M. - 360
Nozzle fitted
Bollard Pull - 6.25 Tons

See Figure 6.

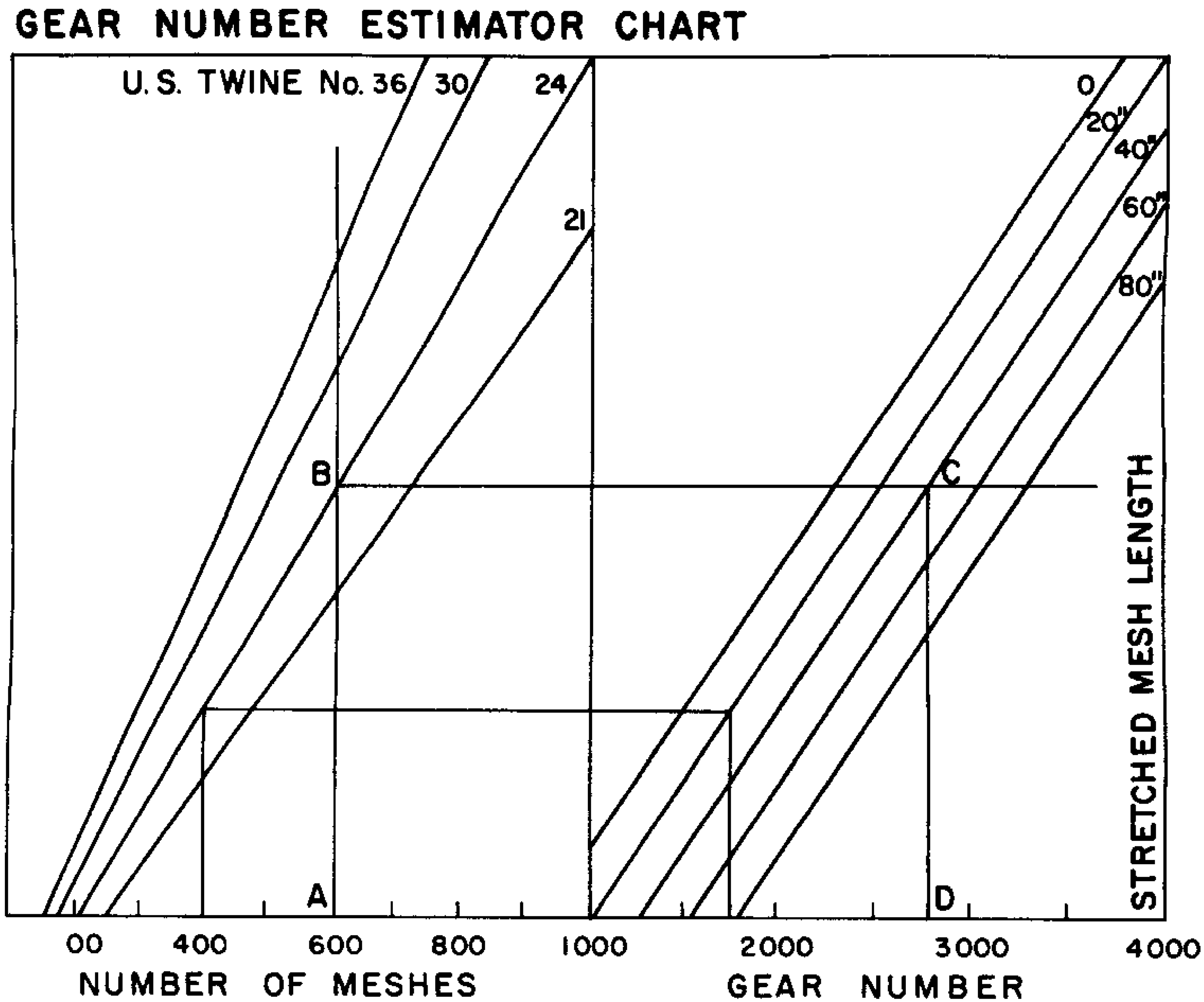
From the trawl manufacturer, obtain the total number of meshes around the mouth of the trawl, i.e., top panel, two side panels, and bottom panel, the mesh size of the netting used in the forepart of the trawl, and the twine size used, e.g. 600M x 40" x #24 twine.

Apply these to Figure 7 as follows:

Point A on X axis (number of meshes).
Point B, intersection of vertical from Point A to the graph of Twine #.
Point C, horizontal drawn from Point B to the intersection of graph of mesh size.
Point D, relevant gear number for application to Figure 8 or Figure 9 dependent on open or nozzle propeller.
Figure 8. Draw a diagonal from left to right joining the two bollard pull figures. Points X and Y in the example.
Draw a vertical from the intersection of the Gear # curve and the bollard pull diagonal, Point Z.

The towing speed of the vessel using this trawl can now be ascertained by drawing a vertical down to the ship's speed axis. This speed would be the maximum the towing vessel would achieve with this trawl. As most pelagic species of fish swim faster than the example illustrated (2-8 knots), the operator should consider a smaller trawl. The average midwater trawl for vessels of 400-600 H.P. generally has a mouth mesh count of around 400 with a mesh size of 20 inches using #24 twine.

Figure 7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U.S. TWINE No. 36
30
24
21
0
20"
40"
60"
80"
B
C
A
D
STRETCHED MESH LENGTH
00
400
600
800
1000
2000
3000
4000
NUMBER OF MESHES
GEAR NUMBER

Applying these figures to the graphs, indicate a maximum towing speed of 4.4 knots approximately, with 400 H.P. and a bollard pull of 6.25 tons.

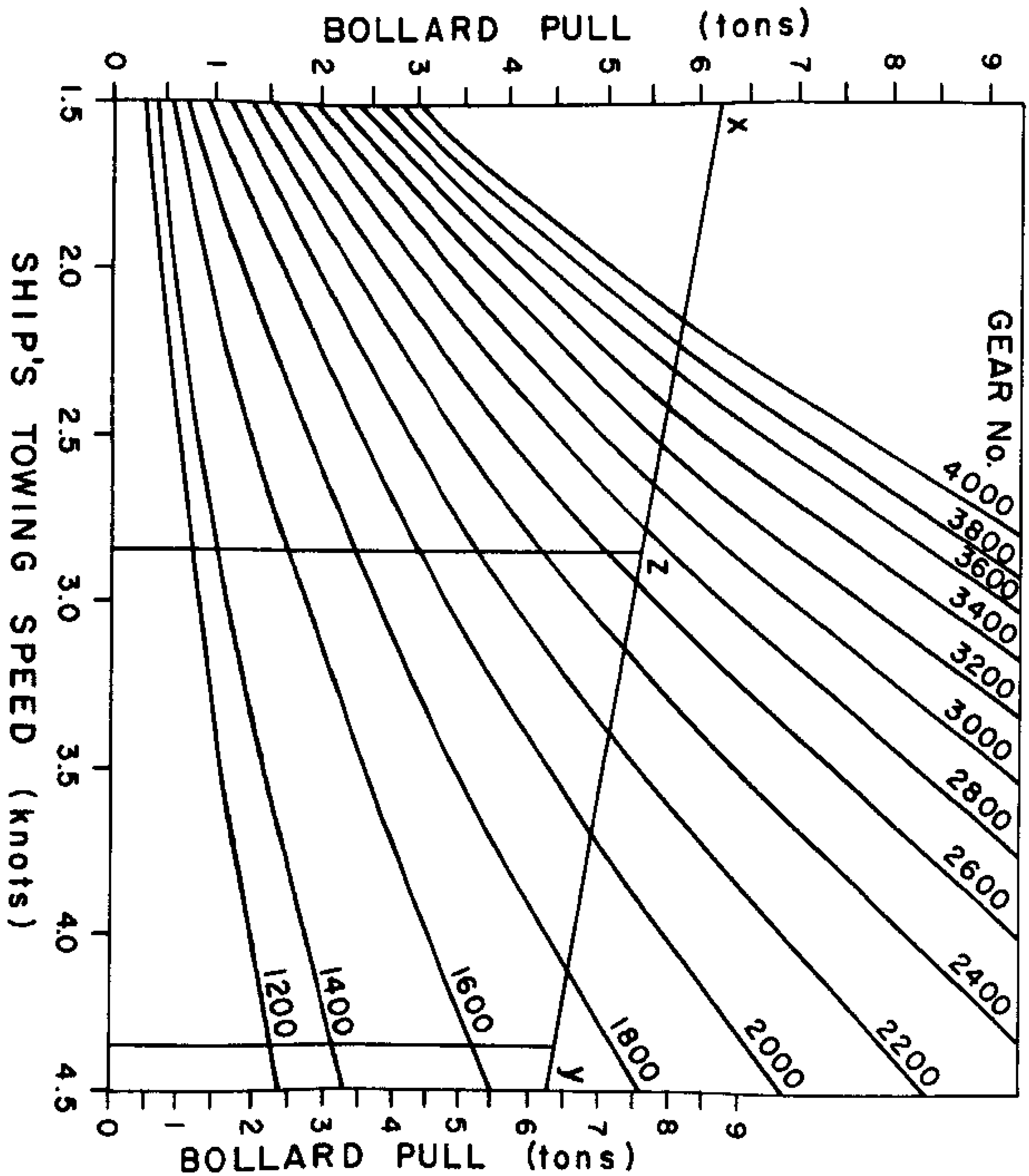


Figure 8
Towing Speed Estimator Chart
Nozzle Propellers

Figure 9
Approximate Bollard Pull for
Nozzle Propellers

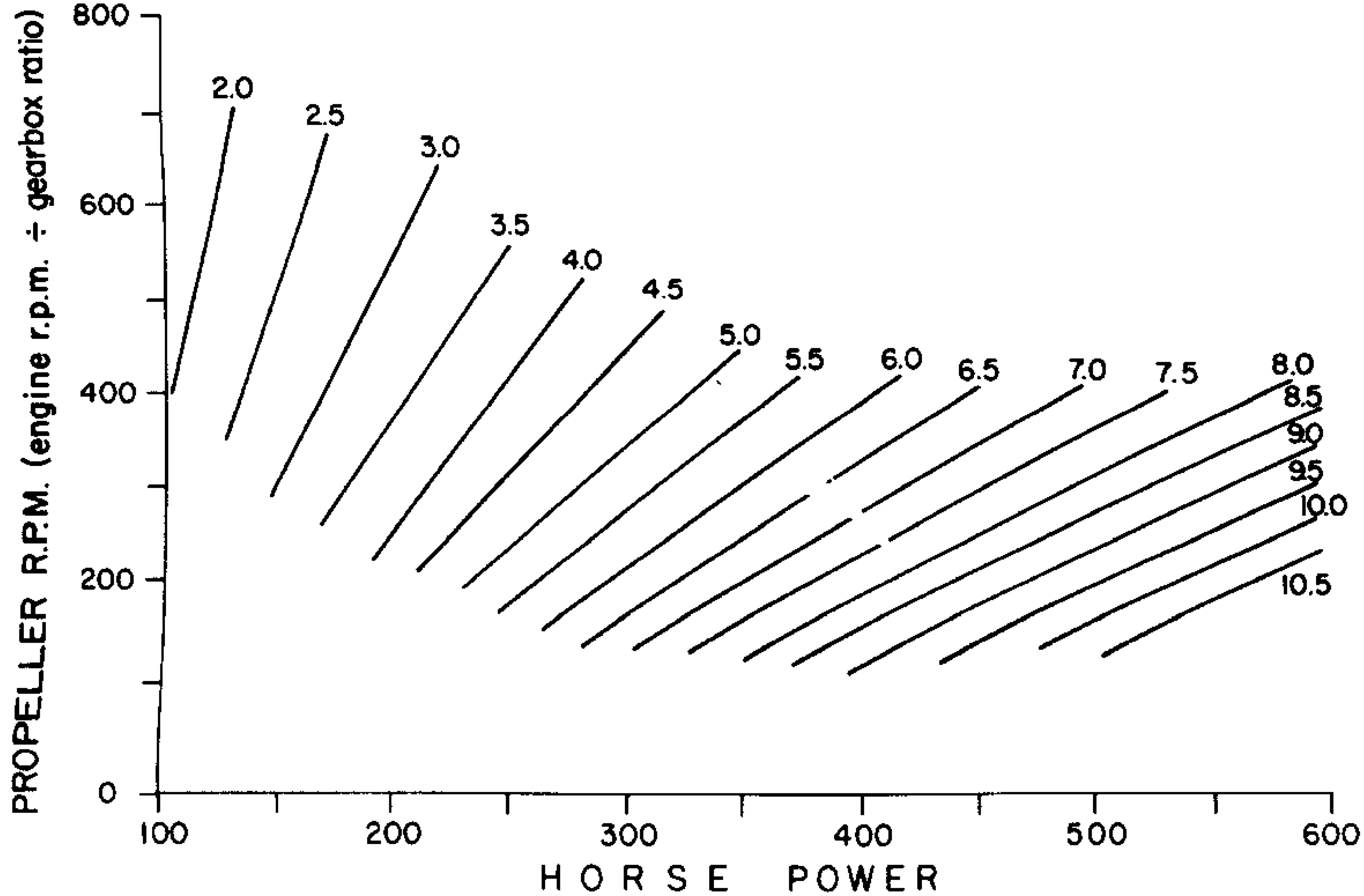


Figure 10

Approximate Bollard Pull
Conventional Open and V.P. Propellers

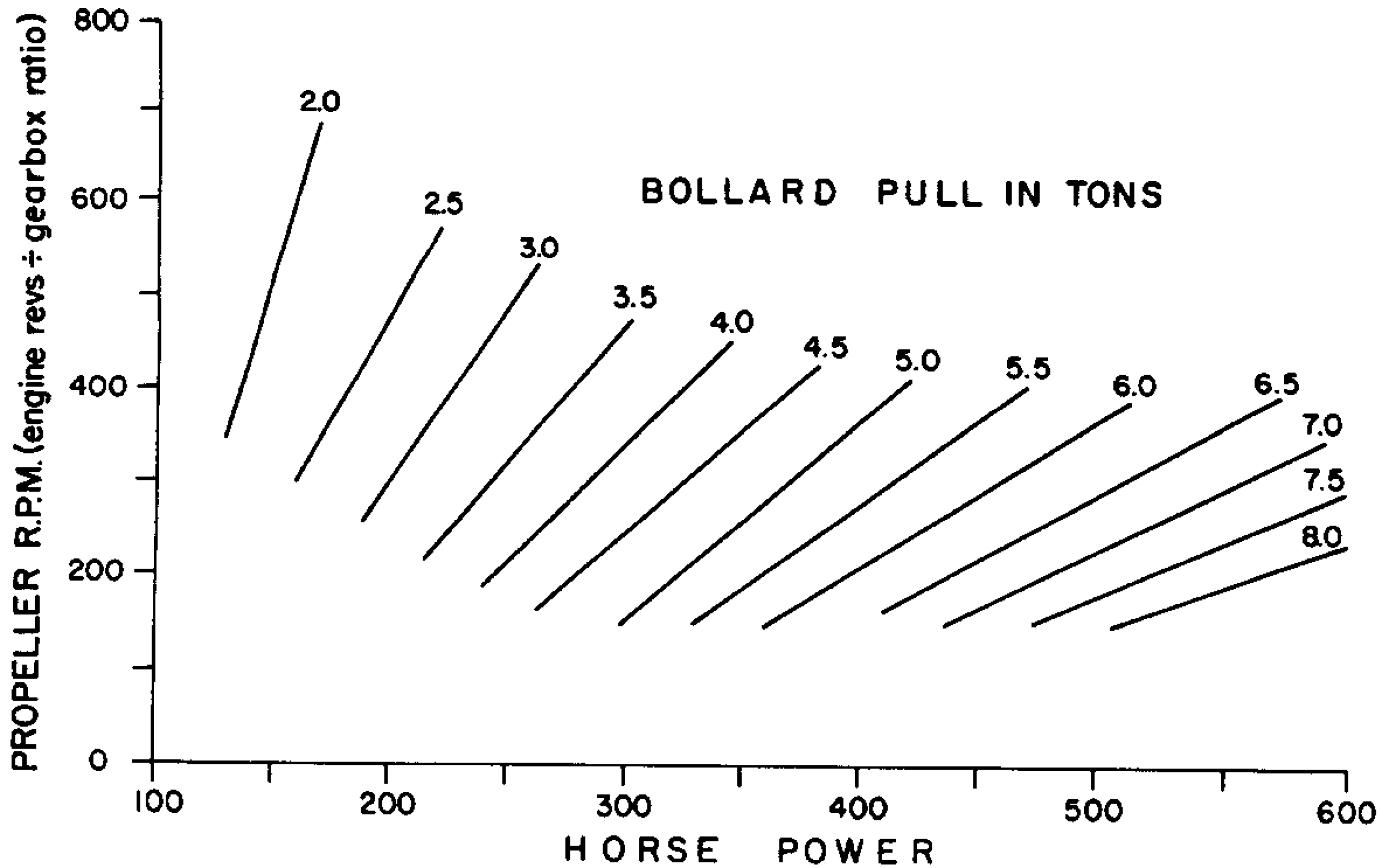
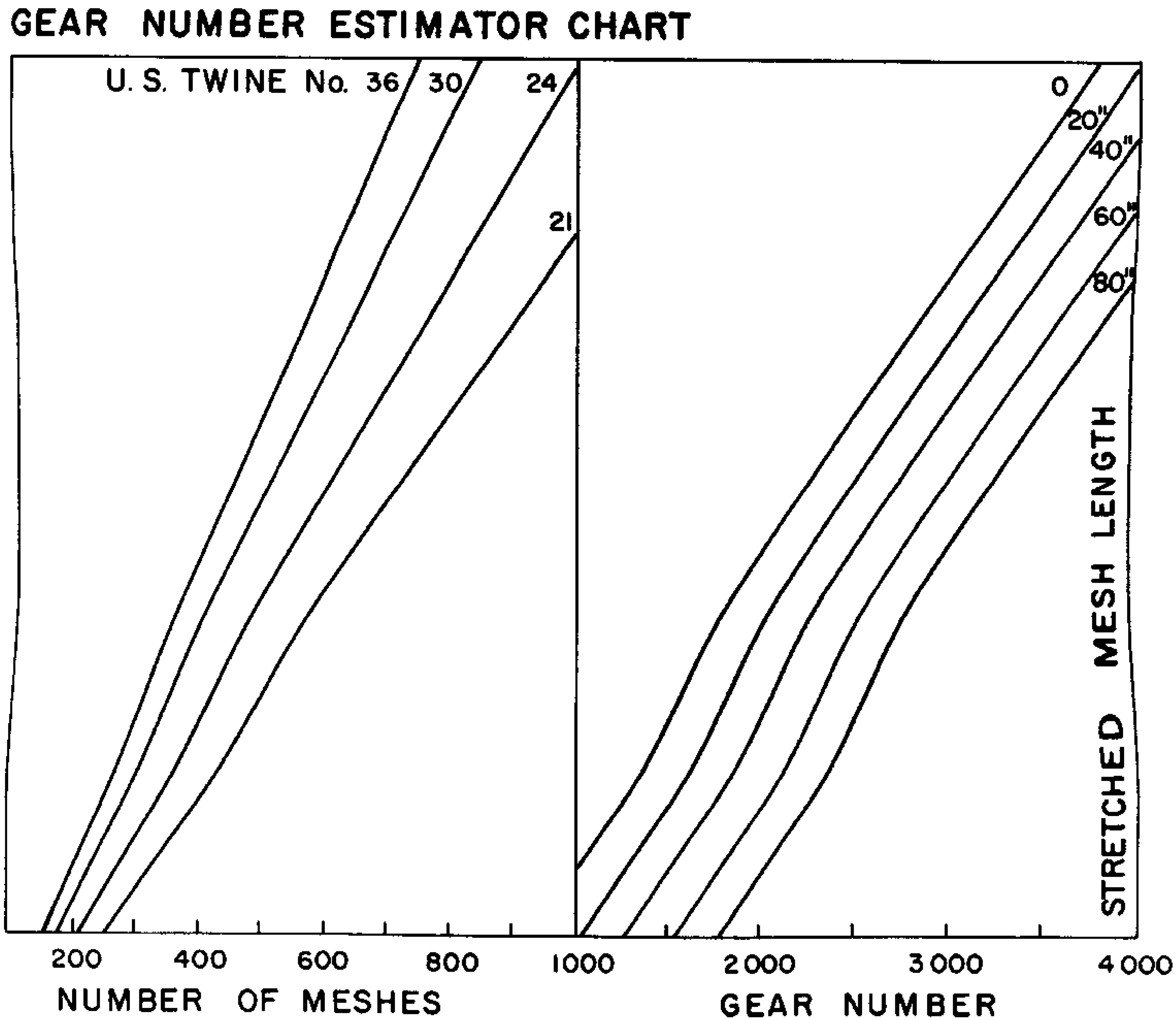


Figure 11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20"
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GEAR NUMBER

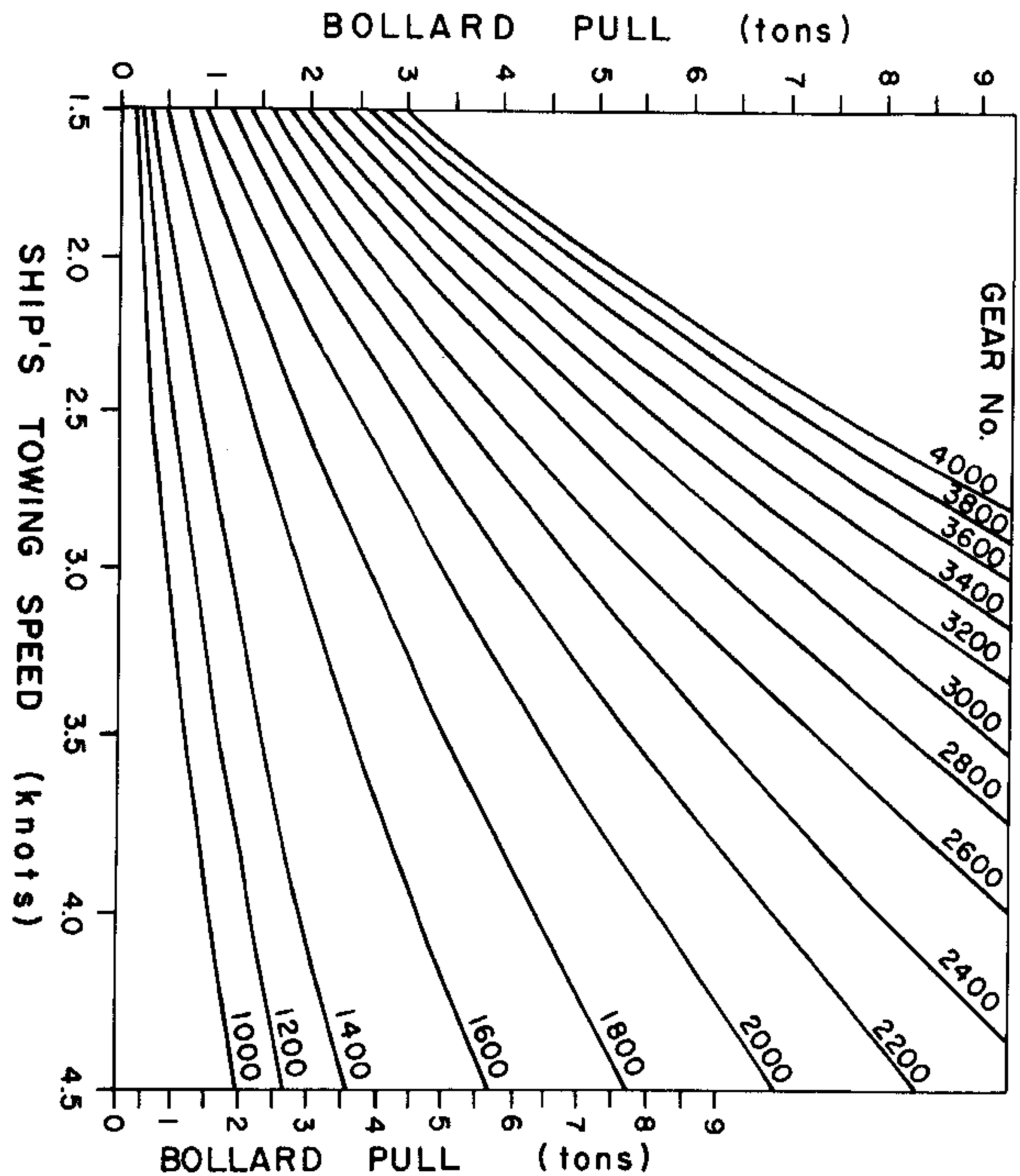

Figure 12

Towing Speed Estimator Chart
Open Propellers

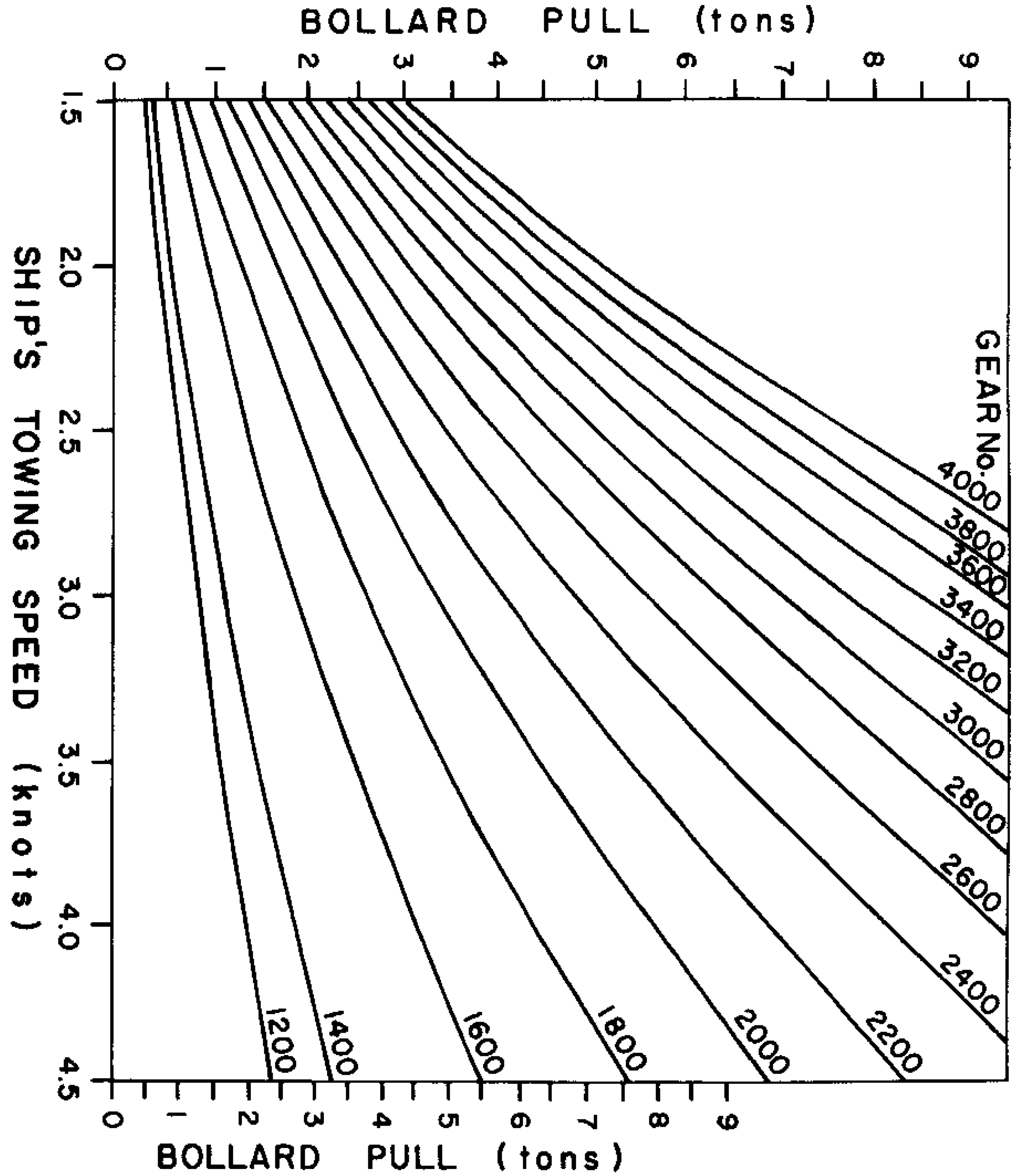

Figure 13

Towing Speed Estimator Chart
Nozzle Propellers

THE NET SOUNDER AND TRAWL MANEUVERING

The net sounder in a single vessel midwater trawl operation is the data link on the position, performance, and effectiveness of the trawl.

The two major types of net sounder available, i.e., acoustic link or cable, enable the operator to check, primarily, the position of the trawl in the water column, and, secondly, the mouth opening of the trawl. Fish capture and escape can also be determined from the machine. However, the effectiveness of the net sounder depends on the alignment of the headline unit. This is particularly true when an acoustic link unit is being used. As its name implies, this type of net sounder relies on an acoustic beam to transmit the data from the net back 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 upwards- and downwards-looking transducers. Again, correct alignment is necessary to ensure that the data transmitted back 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 of the trawl instead of the footrope immediately below the center of the headline. Misalignment of the transducer usually indicates as 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

Taking 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 which is mounted on the headline. The depth scale on the instrument will, therefore, show the depth of the headline above the seabed and, more important, the position of the footrope relative to the seabed. Reference must be made to the ship-mounted vertical sounder to establish the depth of the trawl. This is achieved by noting the depth from the headline to the seabed on the net sounder and then applying this data to the main vertical sounder. This then 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 midwater trawl rig, it is usually 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. In addition, 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 with these notes to assist the operator in establishing his vessel's performance with the midwater trawl.

Warp Length 100 Fathoms		
A Speed	B Headline Depth	C Mouth Opening
3		
3.25		
3.5		
3.75		
4.0		
4.25		

Warp Length 200 Fathoms		
A Speed	B Headline Depth	C Mouth Opening
3		
3.25		
3.5		
3.75		
4.0		
4.25		

Warp Length 300 Fathoms		
A Speed	B Headline Depth	C Mouth Opening
3		
3.25		
3.5		
3.75		
4.0		
4.25		