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Otterboard Performance and Behaviour

Otterboard Performance and Behaviour

by

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Introduction

Purpose of this Manual

The Sea Fish Industry Authority (U.K.), IFREMER (France) and DIFTA (Denmark) have collaborated on an EC funded project to assess the performance of a wide range of otterboards which are currently available to fishermen. This manual is based on the results of this project. It is intended for those actively involved in fishing, although much of it will interest persons active in the gear technology field.

Objectives

This manual has the following objectives:-

- To define terminology and explain the technical operation of otterboards.
- To provide information on the methods used and the results obtained during the otterboard tests.
- To provide information for calculating the equivalent sizes of different types of otterboard to give a trawl the same spread.
- To assist in solving common rigging faults and otterboard problems.
- To provide guidance on the possibilities of saving fuel.

Limitations

This manual is concerned solely with otterboards for bottom trawling operations. It does not cover other types of otterboards which are used in mid water.

There has not been any attempt to compare otterboard size with trawl size. This would be a major project in its own right. However, some data is given to illustrate sizes of otterboards used in practice.

Terminology

Otterboards are often referred to as "doors" in the fishing industry. However, the accepted term is otterboard and this term has been adopted throughout this manual.

Sources of Data

Scale models of otterboards were tested at Flume Tank facilities in Hull (Seafish), Boulogne (IFREMER) and Hirtshals (DIFTA). The scale models were prepared by manufacturers, or with their assistance. In addition a reference vee otterboard was produced. Full scale testing at sea of a selected number of otterboards was also undertaken.

Structure of this Manual

The manual consists of five parts which are intended to serve a number of purposes.

Section 1 covers general definitions of terms which are used in subsequent sections. Although some practical knowledge is necessary, it is intended to be introductory and it is aimed at readers with limited technical background.

Section 2 covers the different methods of warp and bridle attachment to otterboards, and design features of traditional flat and vee otterboards.

Section 3 covers the Flume Tank testing of model otterboards. The method of testing is described and results are given in the form of data sheets. Calculation methods are given to illustrate the use of data sheets including estimation of equivalent otterboard size.

Section 4 covers the otterboards performance at sea. Methods for the determination of angles of attack and otterboard spread are discussed, together with common problems affecting otterboards.

Section 5 covers the fuel saving options that are available when otterboards are used effectively.

How to use this Manual

This Manual has been structured in order to make it easy to use. The subjects are covered in a logical order and although not every reader will require all the information, it has been written in a way which enables the reader to refer to what is relevant and miss out sections which do not meet the reader's immediate needs.

Locating particular subjects should be undertaken by reference to the table of contents. At the start of the manual there is a one page outline of contents. At the start of each section there is a detailed table of contents for that section. If the reader requires information on a particular subject, such as troubleshooting otterboard problems, the reader should first consult the contents outline. This indicates that the section on common problems affecting otterboards can be found in Section 4. The detailed table of contents at the start of Section 4 on otterboard performance at sea provides a more detailed list of the otterboard problems.

Otterboard Performance and Behaviour

Contents Outline

Contents Outline

Appendices

List of Symbols

(see also "General Definitions" Section 1)

Symbol	Definition	Units
A	Projected area of otterboard	m^2
AR	Aspect ratio = H/L	
B	Bridle tension	kg
C_A	Area ratio = A/(H x L)	
C_D	Drag coefficient	
C_D'	Change in drag coefficient	
C_f	Coefficient of friction	
C_L	Lift coefficient	
C_L/C_D	Efficiency	
C_P	Centre of pressure ($C_P = t_p/L$)	
F_x	Drag force	kg
F_y	Spreading force	kg
g	Acceleration due to gravity	m/s^2
H	Height of otterboard	m
L	Length of otterboard	m
L_b	Length of bridle	m
L_w	Length of warp	m
LOA	Line of action of force (LOA = t_r/L)	
n	Coordinates relative to otterboard surface normal	m
t	tangential	m
n_b	Distance of bridle attachment point from door axis	m
n_w	Distance of warp attachment point from door axis	m
t_b	Distance of bridle attachment point from leading edge of otterboard	m
t_p	Distance of centre of pressure from leading edge of otterboard	m
t_r	Distance of line of action of force from leading edge of otterboard	m
t_w	Distance of warp attachment point from leading edge of otterboard	m
V	Water speed (or towing speed)	m/s
V_K	Water speed (or towing speed)	knots
W	Warp tension	kg

Symbol	Definition		Units
WT	Weight of otterboard in water		kg
WT'	Change in weight of otterboard in water		kg
x	Coordinates relative to water flow	longitudinal	m
y		transverse	m
z		vertical	m
x_b	Longitudinal distance between aft towing point and otterboard		m
x_w	Longitudinal distance between forward towing point and otterboard		m
y_b	Transverse distance between aft towing point and otterboard		m
y_w	Transverse distance between forward towing point and otterboard		m
z_b	Vertical distance between aft towing point and otterboard		m
z_w	Vertical distance between forward towing point and otterboard		m
α	Angle of attack of otterboard (relative to shoe)		°
β	Angle of warp to waterflow in horizontal plane		°
γ	Angle of bridle to waterflow in horizontal plane		°
δ	Vertical angle of warp in plane of warp		°
ϵ	Drag angle		°
ρ	Density of water		kg/m^3

Section 1
Table of Contents

1. General Definitions

1. General Definitions

The purpose of this section is to provide definitions of terms which are used in subsequent sections. It is intended to be introductory and it is aimed at readers with a limited technical background.

1.1 Otterboard Shapes and Features

Apart from the traditional vee and flat otterboards, a number of other shapes and features have been introduced into otterboard construction.

These developments include the use of camber, oval profile, slots and foils to improve performance.

fig 1.1 shows these individual characteristics.

Many manufacturers combine several of these characteristics into one otterboard design.

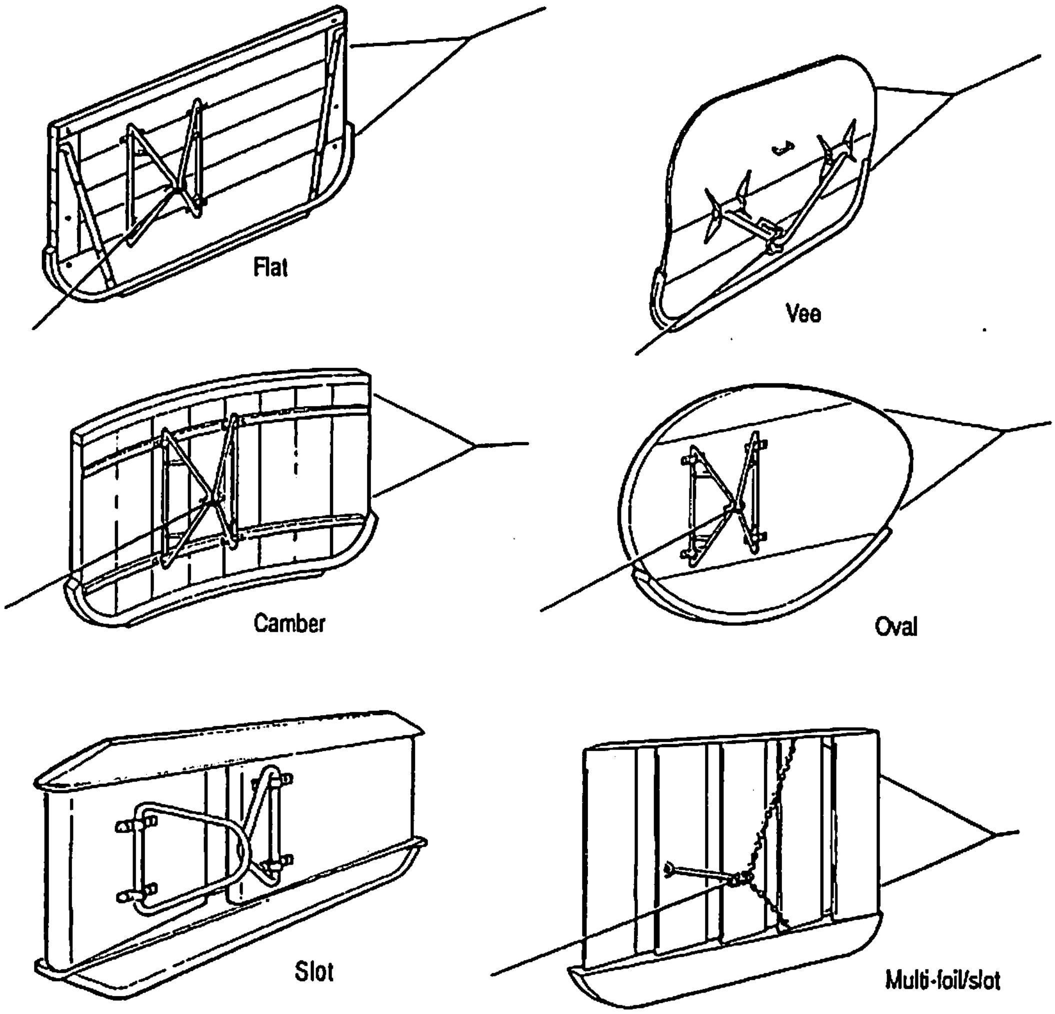

Figure 1.1 - Range of Otterboard Shapes and Features

1.2 Definition of Otterboard Size

1.2.1 Length and Height

The length of the otterboard is the horizontal overall distance between the forward and aft edges of the otterboard (*fig* 1.2). On a cambered otterboard the length is measured along a direction parallel to the shoe. The height is measured vertically and perpendicularly to the length.

1.2.2 Aspect ratio

The aspect ratio is the height divided by the length. The aspect ratios for various types of otterboard are given in Appendix I.

1.2.3 Projected area

Length and height are the easiest dimensions to be measured. However, the otterboard seldom has a simple geometric shape. When comparing the performance of two different types of otterboard, it is necessary to determine the projected area (*fig* 1.3). This is the surface area of the projection of the otterboard. The projected area takes into account losses due to the oval shape and the rounded corners of the otterboards, but not the slots cut into the otterboard surface.

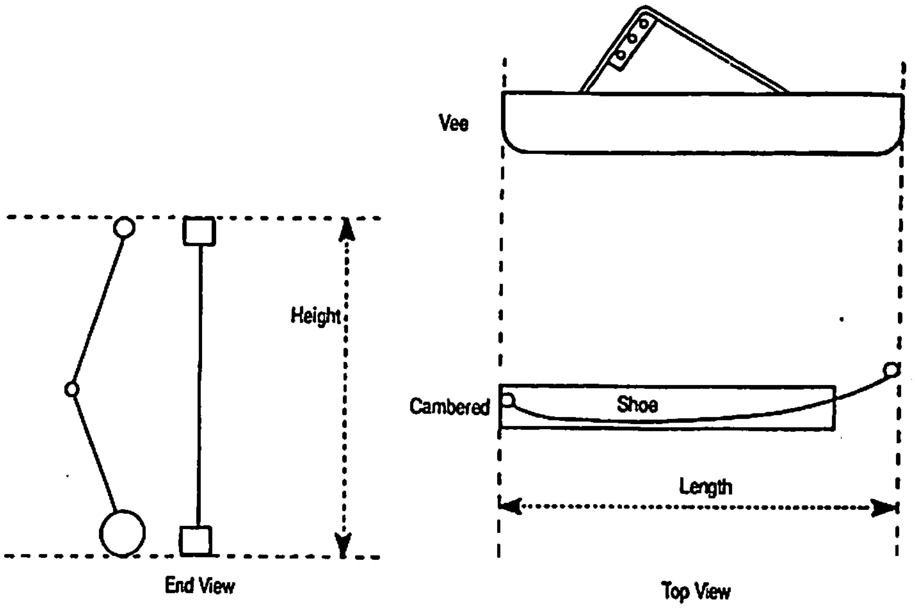

Figure 1.2 - Length and Height of Otterboards

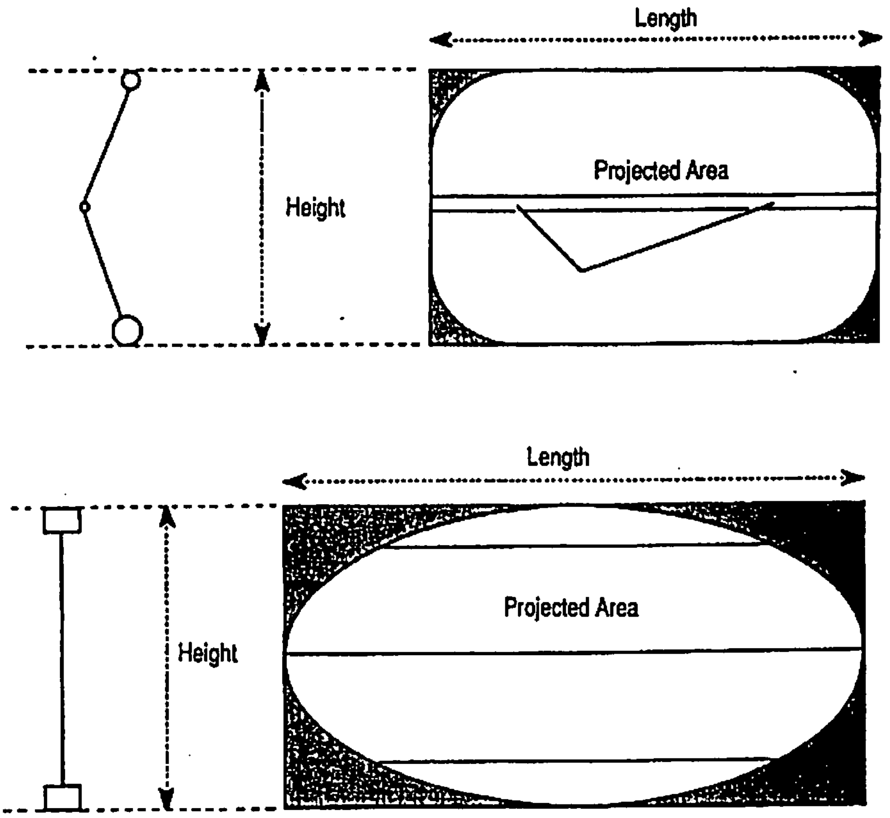

Figure 1.3 - Projected Area of Otterboards

In order to assist in the calculation of projected area the area ratio (projected area/(length x height)) for various types of otterboard is given in Appendix I.

projected area = length x height x area ratio

1.3 Definition of Running Attitude

1.3.1 Angle of Attack

This is the angle between the shoe of the otterboard and the direction along which the otterboard is being towed (*fig* 1.4).

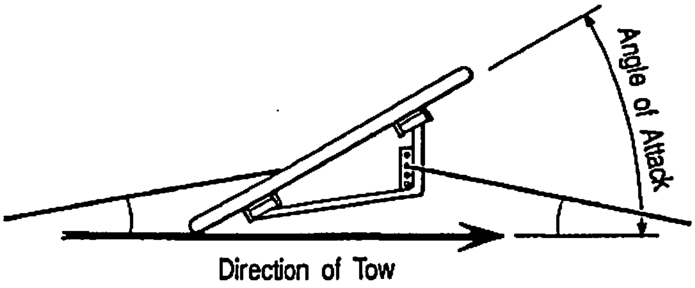

Figure 1.4 - Angle of Attack

1.3.2 Heel Angle

The heel angle of an otterboard refers to its natural behaviour during towing to lean inward or outward (*fig* 1.5).

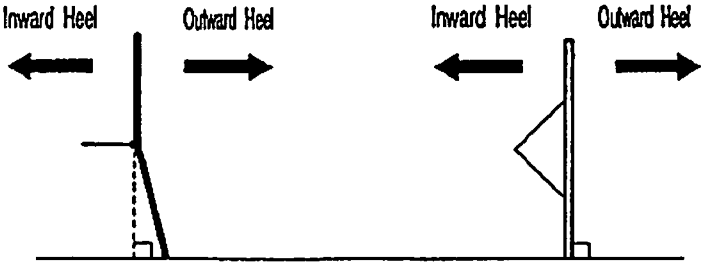

Figure 1.5 - Heel Angle

1.3.3 Pitch Angle

An otterboard is described as pitching when it deviates from its horizontal running condition in an upward or downward direction at the forward end (*fig* 1.6).

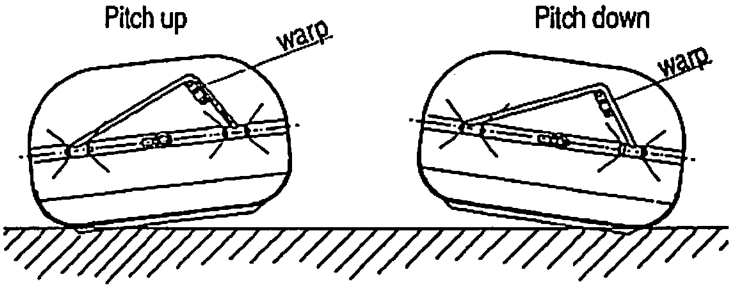

Figure 1.6 - Pitch Angle

1.4 Definition of Forces Acting on Otterboards

Otterboards have two main functions:-

- They spread the gear (trawl, bridles and warps) horizontally
- They maintain the gear in contact with the sea bed

When the otterboard moves through the water there is a resulting force which is approximately at right angles to the otterboard (*fig* 1.7a). This resulting **otterboard force** is caused by both waterflow round the otterboard and contact with the sea bed. During steady towing it is balanced by the tensions of the warp and the bridle so that these three forces make the sides of a triangle (*fig* 1.7b).

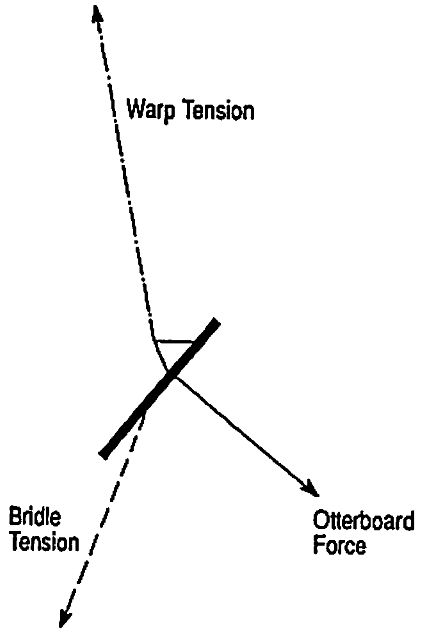

Figure 1.7a - Otterboard Force

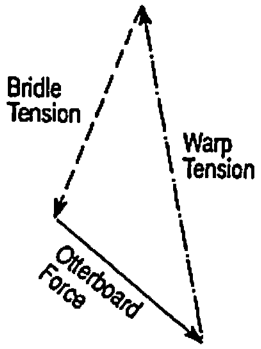

Figure 1.7b - Triangle of Forces

This otterboard force can be considered as having two components which correspond to two different characteristics of the otterboard:-

- Spreading force
- Drag force

} (*fig* 1.8a and 1.8b)

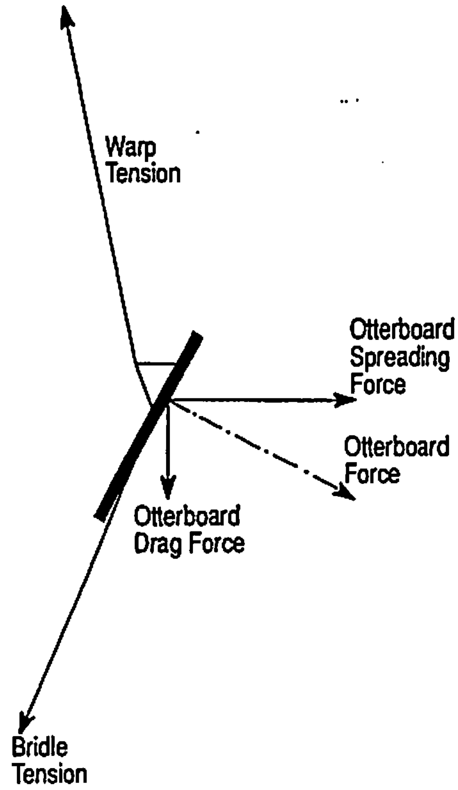

Figure 1.8a - Spreading and Drag Forces

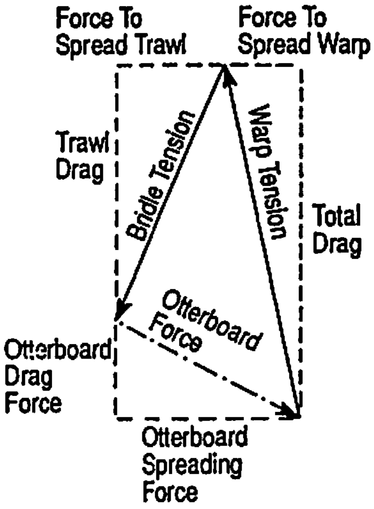

Figure 1.8b - Triangle of Forces

1.4.1 Otterboard spreading force

This part of the total force acts at right angles to the direction of towing. It is the part of the otterboard force which spreads the gear.

It is important to note that otterboards not only spread the trawl but also spread the warps and bridles.

1.4.2 Otterboard drag force

This part of the total force acts in the direction of towing. Part of the total towing effort of the vessel is necessary to overcome this force. Consequently, it is desirable to find an otterboard which gives the necessary spreading force but with minimum drag.

1.4.3 Weight

This is a force which acts downwards and helps to keep the gear in contact with the sea bed. The weight indicated by the manufacturer is usually that in air.

When an otterboard is placed in water its weight is reduced.

When considering otterboard performance the effective weight of the otterboard is the weight in water.

The difference between the weight in water and air is related to the material used for the otterboard. If the otterboard is made from solid steel the weight in water is usually 87% of the weight in air. If, however, wood or hollow steel is used in the construction, the weight in water will be less than 87% of the weight in air.

1.4.4 Centre of gravity

The centre of gravity is the point in the otterboard through which the weight acts. Its position can be estimated by hanging the otterboard from two different points (*fig* 1.9).

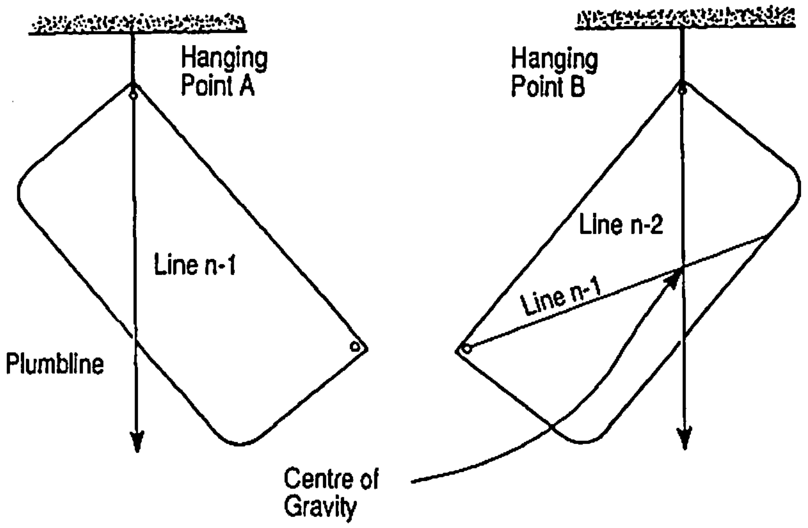

Figure 1.9 - Estimation of the Centre of Gravity of an Otterboard

When the otterboard has wood, hollow steel or plastic in the construction the position of the centre of gravity may be different in water compared to in air. Generally it is lower when lighter materials are used in the upper part of the otterboard.

For otterboards constructed from solid steel, the position of the centre of gravity is the same in water as in air.

The position of the centre of gravity is an important factor for the stability of the otterboard. The lower the centre of gravity, the better the stability will be.

The position of centre of gravity of a wooden otterboard in water may be lower than that of a steel one but it can vary according to the amount of water penetration in the wood.

There are two important reasons for having a low centre of gravity:

- The otterboards need stability as they touch the sea bed during shooting, especially if the speed is low.
- On a rough sea bed it helps the otterboard to recover an upright position quickly.

It is therefore extremely important that for all otterboards the top part must be lighter than the bottom section, and a heavy shoe is useful in this respect, otherwise the position of the centre of gravity will be too high.

1.4.5 Upward/downward forces

The downward force of the otterboard will vary with changes in heel angle. When the otterboard is heeled outwards a part of the otterboard force is directed downwards. Consequently, the downward force of the otterboard on the sea bed is increased (*fig* 1.10).

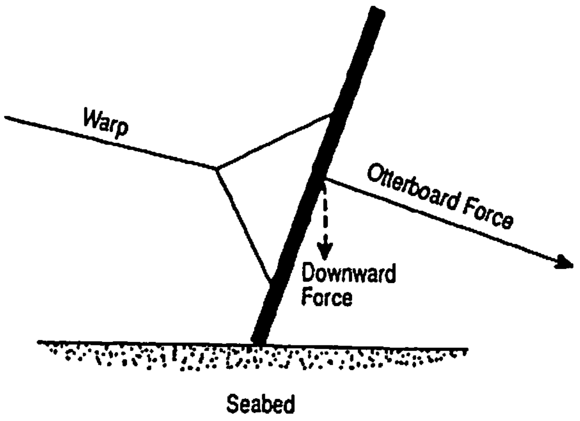

Figure 1.10 - Downward Force

However, when the otterboard is heeling inwards a part of the otterboard force is acting upwards. As a result, the downward force of the otterboard on the sea bed is decreased (*fig* 1.11).

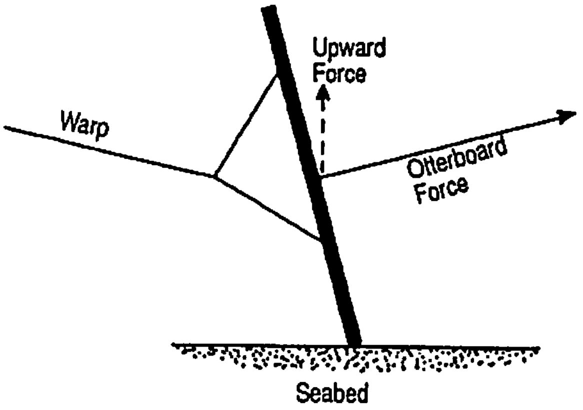

Figure 1.11 - Upward Force

The warp is attached to the otterboard with a vertical angle (declination angle) depending on the length of the warp and warp/depth ratio. A typical declination angle is about 6°, so about 1/10th of the warp tension acts upwards. The downward force applied by the otterboard on the seabed is then effectively reduced by 10% of the warp tension (*fig* 1.12).

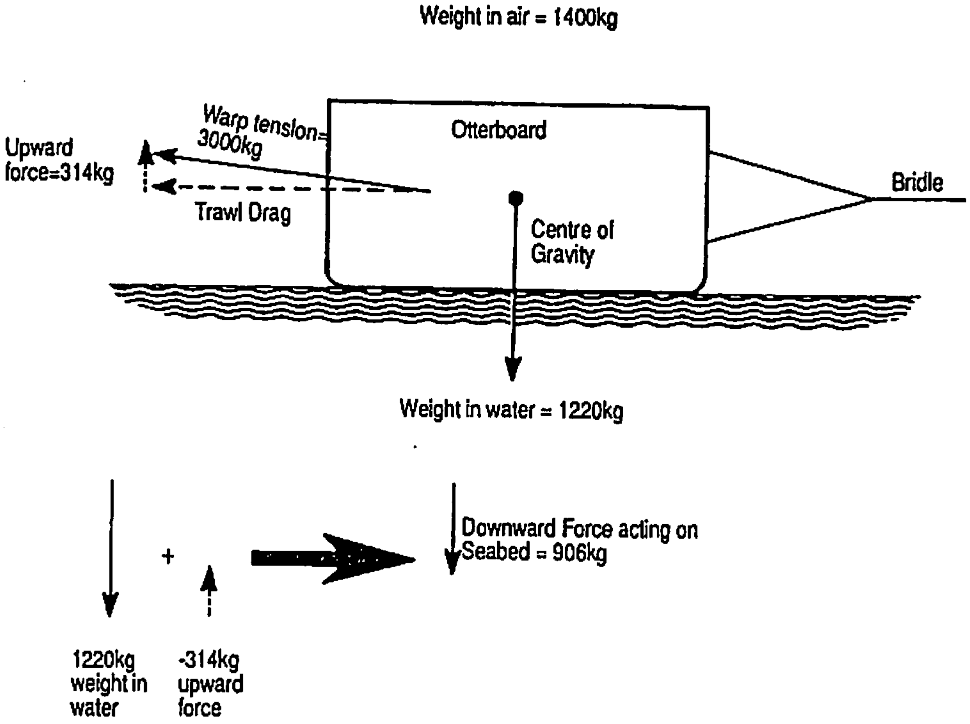

Figure 1.12 - Downward Force Acting on the Seabed

For a given depth of water an increase in warp length causes a reduction in the vertical warp angle at the otterboard. The downward force of the otterboard acting on the seabed will therefore be increased.

If an excessive amount of warp length is used the angle of the warp will cause the otterboard to heel inwards producing an upward force (see *fig* 1.11), partly offsetting this increase.

The downward force of the otterboard acting upon the seabed is therefore mainly governed by:

- the otterboard weight in water
- whether the otterboard has been rigged to heel inwards or outwards
- the warp/depth ratio (warp length/water depth)

1.4.6 Ground contact force

The otterboard force is in fact derived from two sources, (i) the effect of water flow on the otterboard giving what are known as **hydrodynamic forces**, and (ii) the effect of the sea bed acting upon the lower parts of the otterboard giving what are known as **ground contact forces.**

The ground contact forces depend on the nature of the sea bed and the total downward force of the otterboard acting on the sea bed, and can have an effect on the spread, drag and heel of the otterboard.

If the downward force of an otterboard acting on the sea bed is increased, then ground contact forces will increase, leading to increased drag force and perhaps increased spreading force if the otterboard is able to dig into the sea bed (ground shear affect).

The downward force acting on the sea bed can be increased by:

- increase in otterboard weight
- heeling otterboard outwards
- increasing warp/depth ratio

1.5 Otterboard Spread and Drag Characteristics

The tests described in this manual concentrate upon measuring what happens to an otterboard's spreading force and drag when its running attitude changes.

The relationship between the otterboard's angle of attack and its spread and drag characteristics can be represented simply in graphical form (*fig* 1.13). Consider the cambered steel vee otterboard which was tested at angles of attack between 25° and 49°. The graph indicates that the spreading force reaches a maximum of 134 kg/m² at an angle of attack of 34°. Otterboards working above or below this angle of attack will encounter a reduced spreading force. It can be observed from the drag curve that the drag progressively decreases as the angle of attack is reduced.

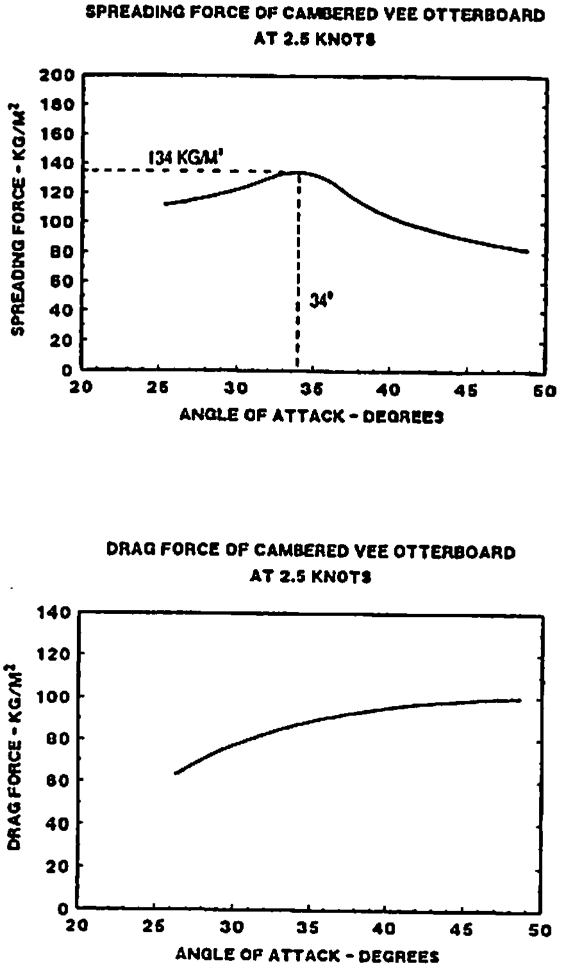

Figure 1.13 - Spread and Drag Forces

The test shown in *fig* 1.13 was conducted at constant speed. For convenience the spreading force and drag force have been divided by the otterboard projected area. This gives the possibility to compare it with an otterboard which is not of the same area. Basically speaking the otterboard spreading force and drag are directly proportional to the projected area.

There is often the need to be able to compare otterboards which were tested at different speeds. It has been established that the otterboard spreading and drag forces increase with the speed squared if the otterboard running attitude has not changed.

It is therefore more usual to present the spreading force and drag force in coefficient form to allow direct comparison between two types of otterboard.

The coefficients of spreading force and drag force are obtained by dividing the force by the projected area of the otterboard, the towing speed squared and the density of water.

In mathematical terms these coefficients are defined as:

1.5.1 Spreading and drag force coefficients

Spreading Force Coefficient C_L = Spreading Force/$(0.5 \times \rho/g \times A \times V^2)$

Drag Force Coefficient C_D = Drag Force/$(0.5 \times \rho/g \times A \times V^2)$

Where

ρ = density of water = 1000 kg/m^3 freshwater
= 1024 kg/m^3 seawater
g = acceleration due to gravity = 9.81 m/s^2
A = projected area of otterboard m^2
V = Water speed (towing speed) m/s
Spreading force and drag force are measured in kg

Having obtained this data in coefficient form, the spreading force and drag force can be calculated for an otterboard of a given area towed at different speeds.

For an otterboard in seawater the following formulae are used:-

Spreading force = $13.8 \times C_L \times A \times V_K^2$ kg
Drag force = $13.8 \times C_D \times A \times V_K^2$ kg

where

V_K = Water speed (towing speed) in knots.

1.5.2 Otterboard efficiency

Within the terms of the manual an efficient otterboard is one which gives the required spreading force with as little drag as possible. This means that efficiency can be defined as spreading force divided by drag force, which in graphical form is usually presented in terms of C_L/C_D. *The higher the value of C_L/C_D the more efficient the otterboard is.*

This does not mean that an otterboard should be rigged to give the maximum value of C_L/C_D possible. This would in fact occur at a very low angle of attack where the otterboard would be extremely unstable and the spreading force too low. The aim must be to obtain a high value of C_L/C_D while keeping other aspects of the otterboards performance within acceptable levels.

1.5.3 Centre of pressure

The otterboard force acts at a position along the length of the otterboard known as the centre of pressure C_P. The centre of pressure is usually at about 40% to 50% of the length from the forward edge ($C_P = 0.4$ to 0.5).

Its position varies slightly as the angle of attack is changed.

Section 2
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2. Otterboard Design and Rigging

2. Otterboard Design and Rigging

2.1 Warp and Backstrop Attachments

2.1.1 Warp Attachment Methods

There are five main types of warp attachments used in otterboard design and construction (*fig* 2.1). They are:-

- Towing chain
- Combination chain and bracket
- Horizontal hinged bracket
- Triangle fixed bracket
- Fixed bracket

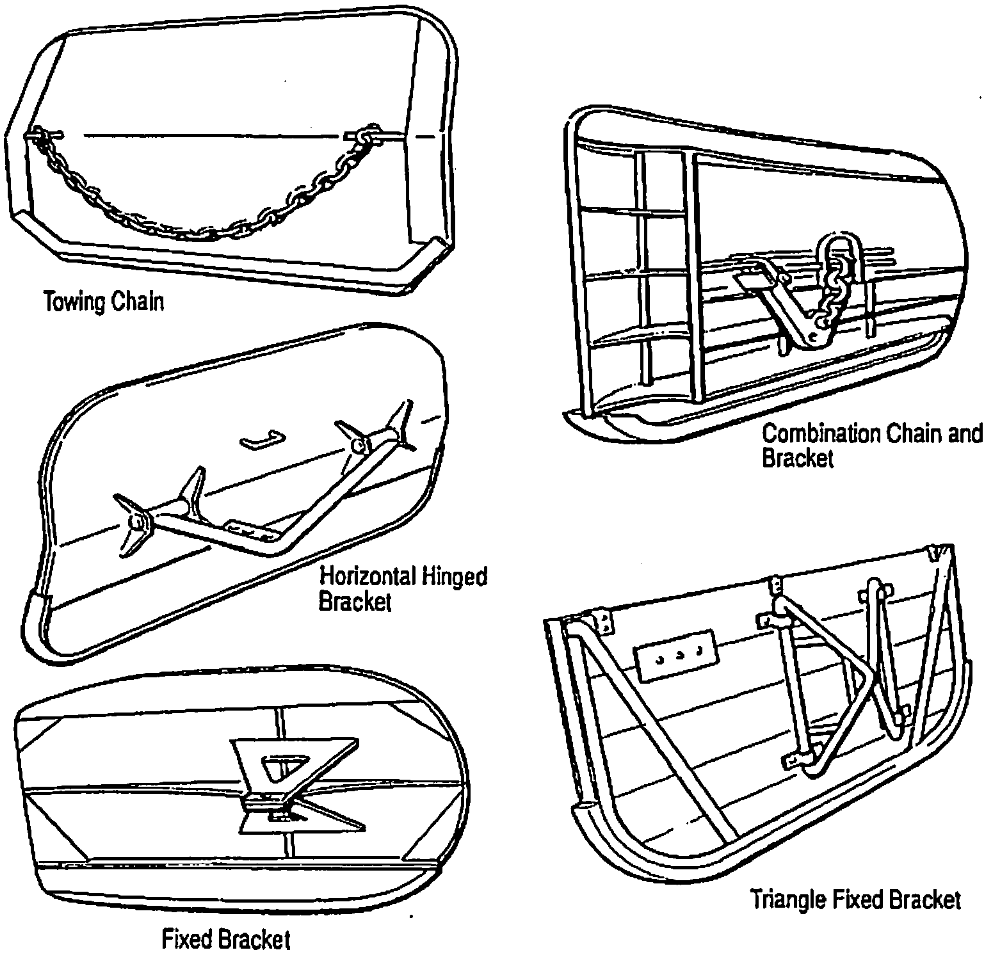


Figure 2.1 - Types of Warp Attachment

Each have characteristics which make them suitable for a variety of fishing methods or sea bed conditions.

Towing chain: Otterboards with this method of attachment are easy to store due to the absence of brackets, are economical to produce, simple to maintain and have many adjustments available. The chain is also effectively a form of hinged bracket. Disadvantages are that the chain may stretch or wear thus affecting the angle of attack, heel or pitch. Shooting in heavy sea conditions may require a special technique to prevent the tension being released from the chain during shooting and the spread collapsing. This may be particularly true if only a twin backstrop system is used.

Combination chain and bracket: Otterboards with this attachment method have the largest number of possible adjustment combinations and are easy to store onboard. The chain, if high quality and if kept to a short length, produces no operational problems. The disadvantages include the additional cost of manufacture compared to the chain system. Furthermore, the numerous adjustments may confuse the inexperienced.

Horizontal hinged bracket: Using an otterboard fitted with this type of attachment produces excellent rough ground performance and is favoured because of the hinges' ability to allow the otterboard to pivot over large boulders. It can be stored easily on the vessel, the bracket folding across the face of the otterboard. The disadvantages include an obvious additional construction cost and the requirement for careful setting up of the pivoting arm during manufacture. There is also a maintenance element; the hinge bolts need to be checked regularly for wear and stiffness in order to prevent deterioration of performance.

Triangle fixed bracket: This method of construction moves the point of attachment and pivoting further away from the face of the otterboard. It is simple to operate as there is usually only one possible position of warp attachment. Triangle fixed brackets usually produce consistent shooting behaviour and will not collapse during initial shooting in heavy seas. There is no maintenance or wear problem. However, there is no simple way to alter the angle of attack. The towing bracket is vulnerable to damage when hauling on to the vessel and it creates a storage problem as the brackets tend to jam in position after use.

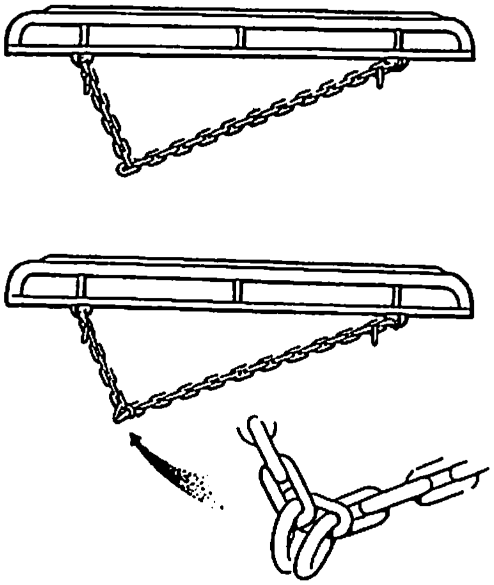
Fixed bracket: The fixed bracket incorporates strength into the design and simplicity of operation is a feature. A fixed bracket also encourages the otterboard to rise off the seabed if collapsed on its face after a hard turn by holding the face of the otterboard off the sea bed. Lack of maintenance problems is a distinct advantage although care must be taken to avoid damage to the side of the vessel when hauling. The towing point may polish or wear away more readily and the option of an angle of attack change depends on the number of holes in the bracket. Additionally, the fixed bracket may restrict options for on board storage.

2.1.2 Angle of attack adjustments using warp attachments

Generally, adjusting the warp position is considered a coarse adjustment of the angle of attack; to increase the angle of attack the towing point needs to be moved aft or away from the face of the otterboard. Angles of attack above 45° are considered inefficient and produce high fuel consumption and low spreading performance. If a reduction in angle is required then the towing point will have to be moved forward or closer to the face of the otterboard. Care must be taken to avoid angles of attack below 30°; poor shooting behaviour and instability occur with many designs at these low angles.

The adjustments for the different types of warp attachments are discussed below and in addition these are illustrated by diagrams. Included on each diagram is an arrow which indicates the adjustment necessary to give an increase or decrease in the angle of attack.

Towing chain: The warp can be shackled to the towing chain by either one or two chain links (*fig* 2.2).



One Link Attachment Method

Two Link Attachment Method

Figure 2.2 - Attachment of Warp to Towing Chain

The angle of attack can be adjusted by either inserting/removing links from the towing chain (*fig* 2.3) or by moving the warp shackle along the towing chain (*fig* 2.4).

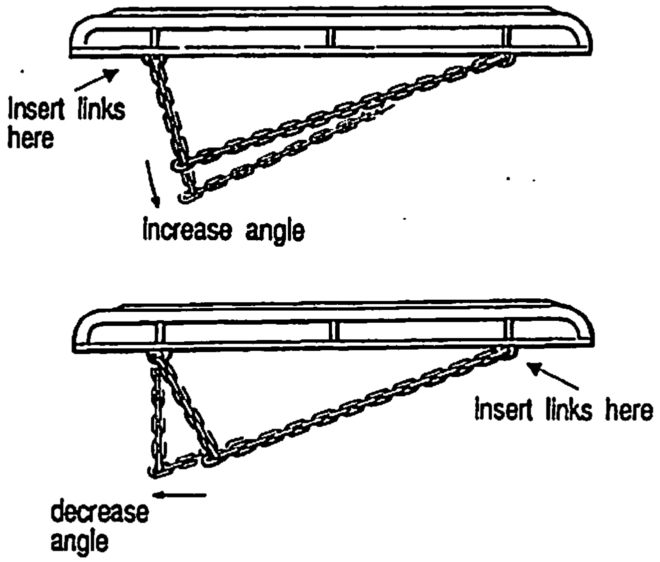


Figure 2.3 - Towing Chain Adjustments by Inserting Links

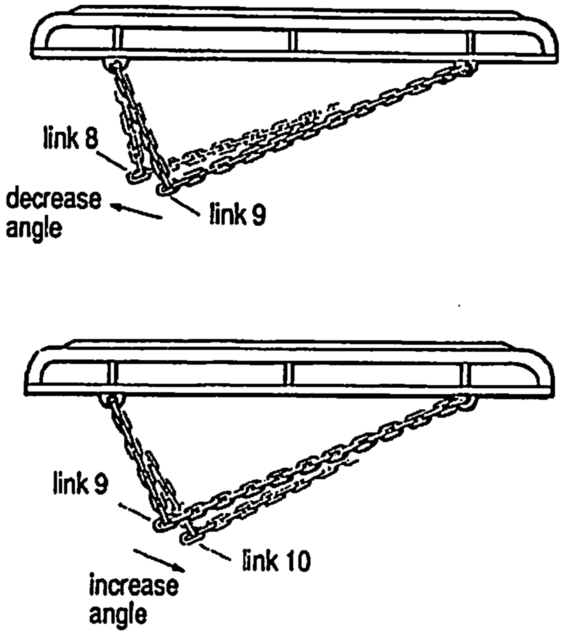


Figure 2.4 - Towing Chain Adjustments by Moving Warp Shackle along Chain

Combination chain and bracket: If a combination chain and bracket is used then adjustments to the angle of attack are made by inserting links in the restraining chain (*fig* 2.5). If further adjustments are required additional holes can be drilled in the bracket.

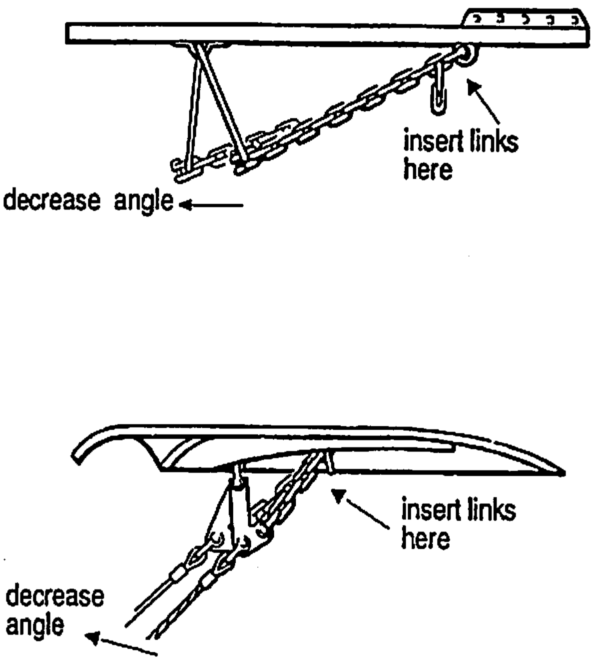


Figure 2.5 - Combination Chain and Bracket Warp Adjustment

Horizontal hinged bracket: The hinged bracket arrangement is a little restrictive and usually only three options are available to change the angle of attack. However, if lower angles are required then an additional bracket can be welded on to the warp arm (see *fig* 2.6).

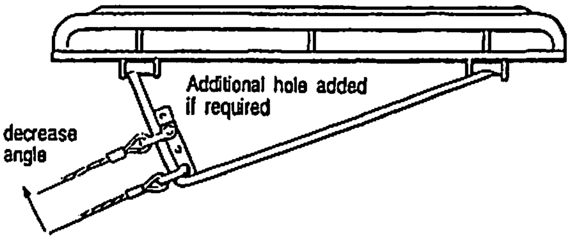
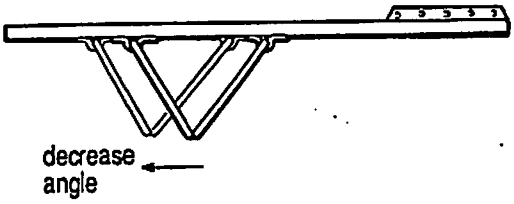
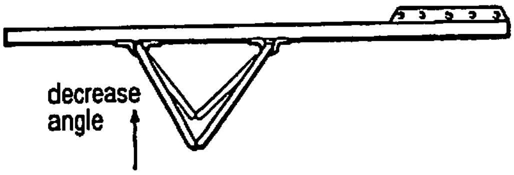


Figure 2.6 - Horizontal Bracket Warp Adjustment

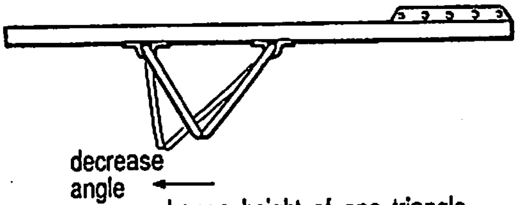
Triangle fixed bracket: With fixed brackets coarse adjustments can be made by modifying the size or positioning of the brackets (*fig* 2.7). Another solution adopted to allow flexibility in changing the angle of attack is to remove the aft bracket completely and substitute a chain allowing quick and simple adjustments to be made (*fig* 2.5).



move triangles forward



change height of both triangles



change height of one triangle

Figure 2.7 - Triangle Fixed Bracket Warp Adjustment

Fixed bracket: The majority of fixed bracket otterboards provide few if any alternative warp towing positions. If an adjustment to the angle of attack is required then additional holes will have to be added to the bracket.

2.1.3 Backstrop Attachment Methods

Most otterboards are rigged with one, two, three or four chain backstrops (*fig* 2.8). Numerous adjustments are available with chain systems and they are versatile, easy to adjust and to service.

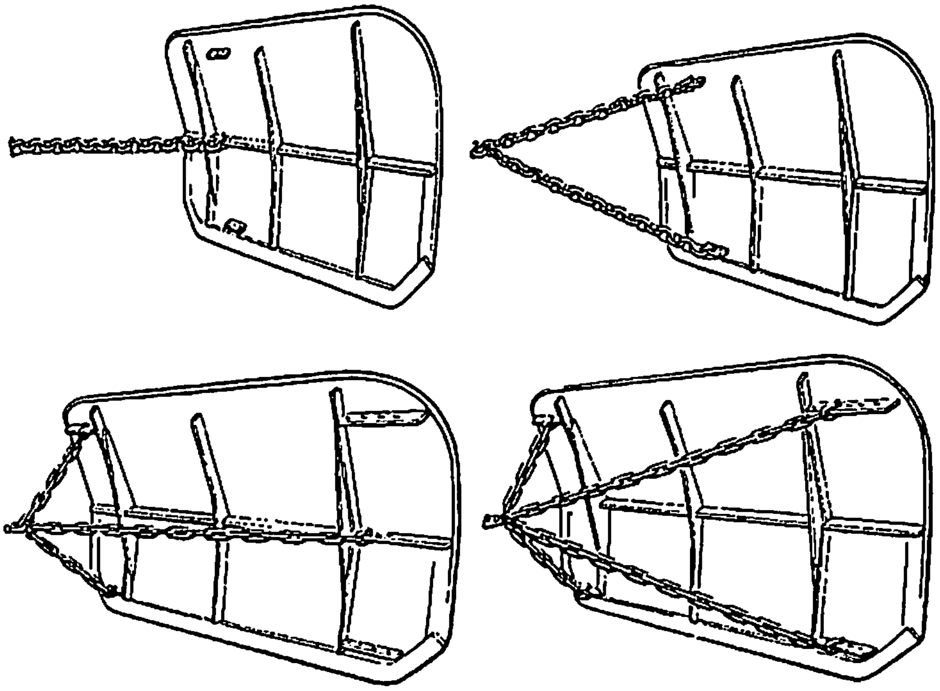
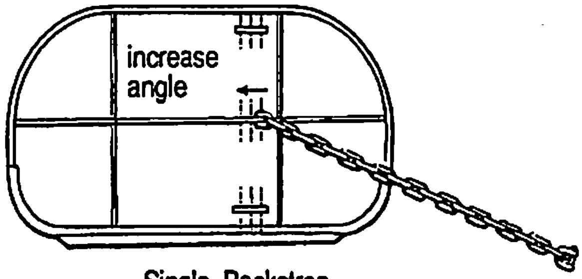


Figure 2.8 - 1,2,3 and 4 Chain Backstrop Systems

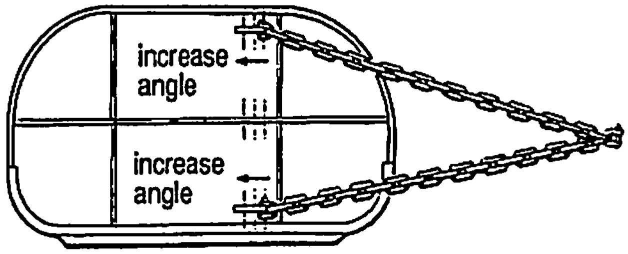
2.1.4 Angle of attack adjustments using backstrops

Fine adjustment of the angle of attack is normally carried out using the backstrop chains. A series of diagrams demonstrates the options available with the differing rigging arrangements in common use.

The most common otterboards use a single or double backstrop and the angle of attack is changed by moving the chains to a different hole (*fig* 2.9).



Single Backstrop

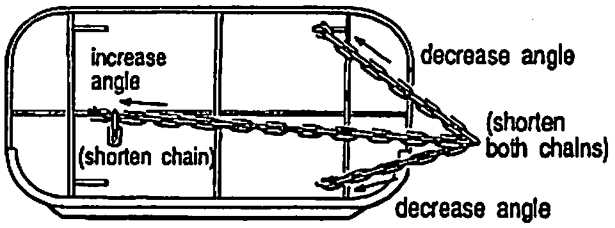


Twin Backstrop

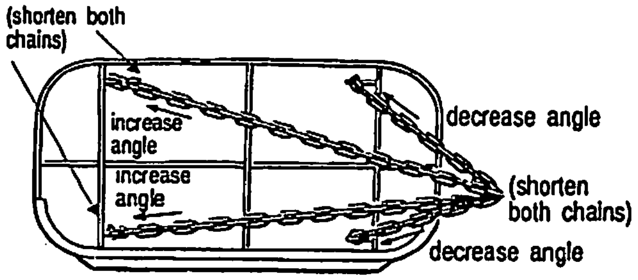
Figure 2.9 - Single and Twin Backstrop Adjustment

Use of 3 and 4 chain systems can increase the speed with which an otterboard will stand up and spread following collapse onto its face. When tension comes on the sweeps/bridles the upper backstrops come tight but the lower ones remain slack. This gives a pull on the upper half of the otterboard raising it off the sea bed. Changing from a 1 or 2 backstrop system to a 3 or 4 backstrop system will initially result in an increase in angle of attack. Three and four chain systems are adjusted as shown in *fig* 2.10.

Care must be taken when adjusting the three and four chain systems to ensure all chains remain in tension (*fig* 2.10), although this is very difficult with four chain systems. If only an angle of attack change is required then both aft chains must be adjusted by the same amount. If only one chain is adjusted then the heel angle may inadvertently be altered.



Three Backstrops



Four Backstrops

Figure 2.10 - 3 and 4 Chain Backstrop Adjustment

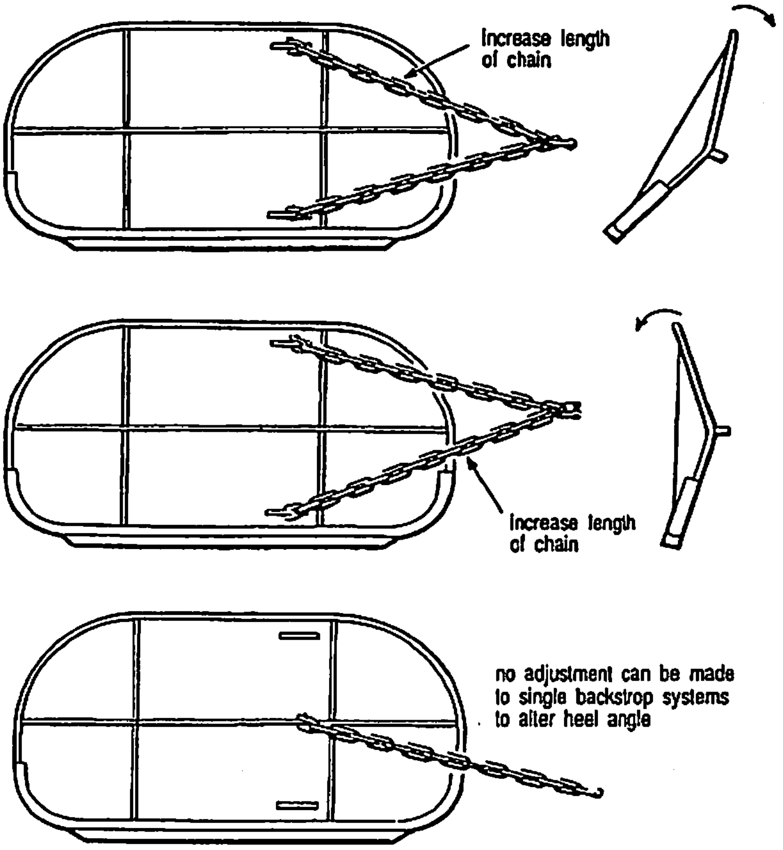
2.1.5 Adjusting of the Heel and Pitch Angles using Backstrops

Two variations have been identified which affect backstrop chain adjustments on two different otterboard designs.

Consider the wooden flat and the steel vee design of otterboard with the towing point on the horizontal centre line. At angles of attack greater than 30° if the backstrops are adjusted in length, only the heel angle will be affected; no significant change in pitch angle will occur.

It is recommended that the length of each leg of twin backstrop chains is between 1.0 and 1.5 times the length of the otterboard.

If the bottom chain is lengthened then the otterboard will heel outwards and potentially a greater downward force is exerted; if the top chain is lengthened then the otterboard will heel inwards and the downward force is reduced. Extensions needed to adjust the heel angle are small and should be carefully considered. If extensions greater than 5% of the length of one of the backstrop chains are inserted these will cause radical changes in the heel angle and are therefore not recommended. The effects of backstrop adjustment on heel are shown in *figs* 2.11, 2.12 and 2.13 for 1, 2, 3 and 4 backstrop systems.



(backstrops not to scale)

Figure 2.11 - Adjusting Angle of Heel for 1 and 2 Chain Backstrop Systems

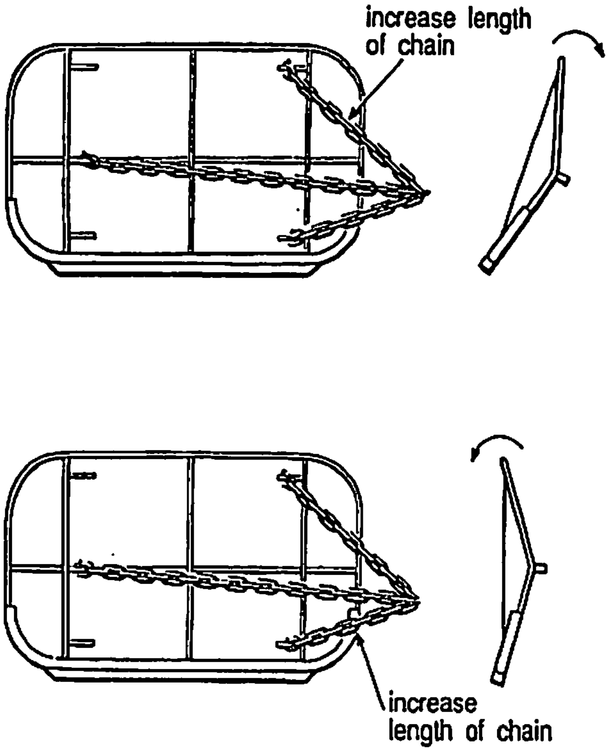


Figure 2.12 - Adjusting Angle of Heel for 3 Chain Backstrop Systems

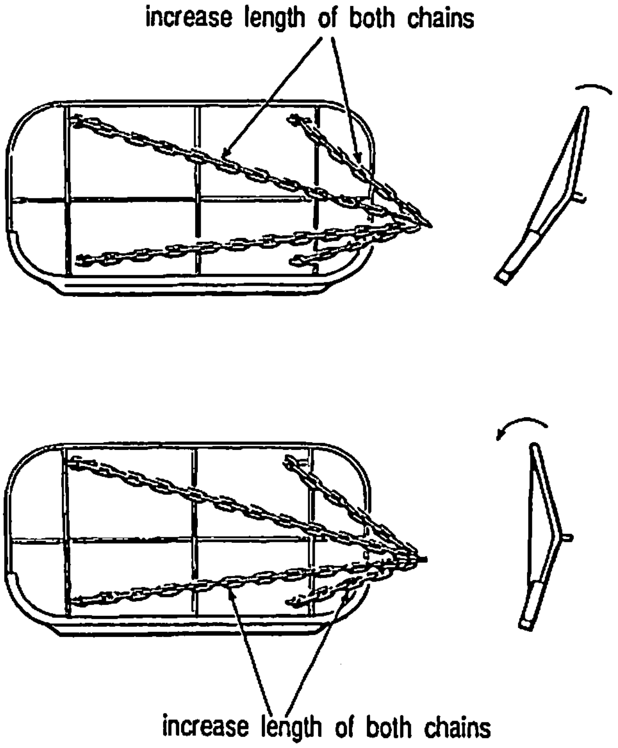


Figure 2.13 - Adjusting Angle of Heel for 4 Chain Backstrop Systems

Otterboards with an oval design are affected differently by adjustments to the backstrop chains. At angles of attack below 40° (the normal working range), insertion of shackles in the backstrops will affect the pitch angle and will not contribute significantly to any change in the heel angle. If any extension is inserted into the upper backstrop leg the nose of the otterboard will drop. Furthermore, if an extension is inserted into the lower backstrop leg the nose of the otterboard will rise. Only small adjustments, plus or minus 5% of the backstrop length, are required to change the pitch angle considerably.

Excessive pitching can be created by factors other than backstrop chains and these are explained in Section 4.1.4.

2.2 Traditional Flat Wooden Otterboards

Flat wooden otterboards are one of the earliest known designs and are still widely used today. They are of simple construction, easily maintained and are ideally made from hardwood with steel reinforcements.

The original design calls for two fixed triangular towing brackets and two rings for the backstrops. However, this arrangement tends to restrict flexibility by not allowing the angle of attack to be adjusted quickly.

Traditional flat otterboards are usually constructed 'on the quarters'; the length of the otterboards is divided into four sections or quarters. The smaller of the two towing triangles is mounted on the first quarter mark and the larger on second quarter mark. The backstrop rails are mounted on the opposite side as shown in *fig* 2.14. These traditional otterboards tend to work at high angles of attack. Many inshore vessels have flat otterboards with the backstrops attached to the aft end giving lower angles of attack. There are several areas where regional variations in this design occur. These variations have developed to suit the prevailing local conditions and produce excellent results in their area.

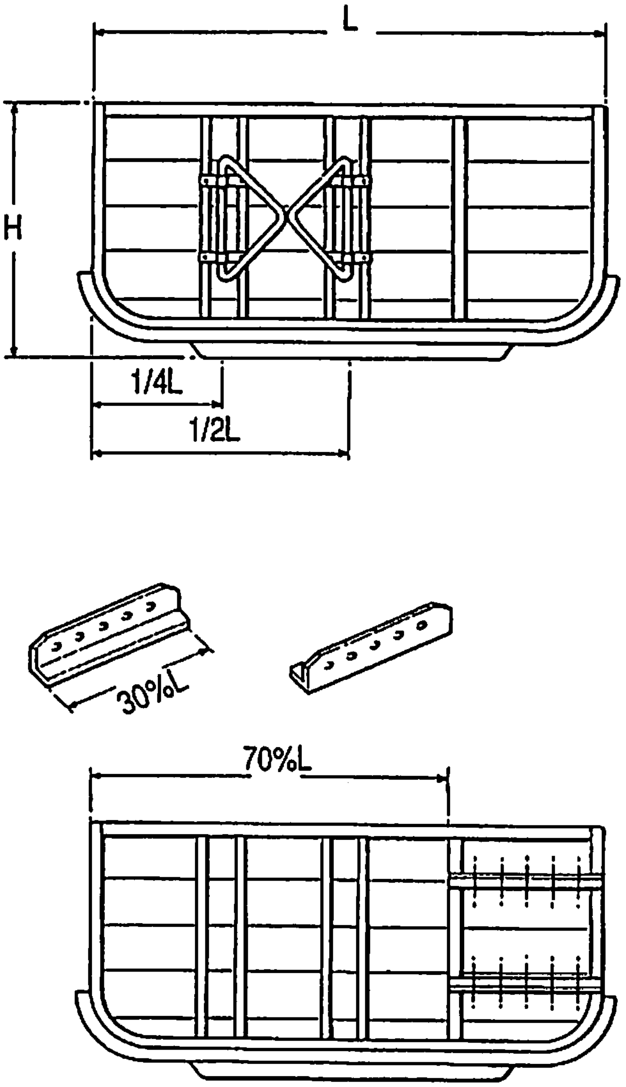


Figure 2.14 - Traditional Flat Wooden Otterboard

2.2.1 The effect of Aspect Ratio

Flat otterboards are usually built with an aspect ratio of 0.55; this means the height is a little more than half the length. Stability with this aspect ratio will be good at low towing speeds. If the aspect ratio varies slightly (between 0.5 and 0.7) this will not create any major problems. However, if it is progressively increased towards that of a suberkrub pelagic otterboard (aspect ratio 1.8) in which the length is much less than the height, then the efficiency of the otterboard is improved but the penalty will be instability at the low towing speeds more suited for bottom fishing.

2.2.2 Towing Point Adjustment

By adjusting the towing point height and backstrop lengths the otterboards can be encouraged to dig in hard ground or lightly skim over very soft silt. Often they are supplied with the towing point set 2% to 3% below the middle of the otterboard. If they are then fitted with equal backstrops they will heel outwards between 5° and 10°, this will induce a moderate digging action and greatly assist ground contact, the shoe will ideally display polish along most of its length. If firmer ground contact is required then lower the towing point down slightly. This will then encourage the otterboard to spread more and will improve shooting capabilities. Higher fuel consumption and faster shoe wear can be expected, but the extent of this will depend upon the type of seabed encountered.

If the towing point is progressively moved up towards the middle of the otterboard then the heavy ground contact and the heeling out will reduce until the mid-point of the otterboard is reached. Ground contact will be low and dependant more on otterboard weight and warp out.

Moving the towing point above the mid-point up to 3% will produce a heeling in and pitching up at the nose attitude. This is useful on very soft ground and will produce only a small element of seabed contact as the otterboard's weight will be supported by the waterflow.

Extra care must be taken during shooting as difficulties are regularly experienced with this arrangement.

2.2.3 Effect of Backstrop Adjustment

The length and material used for backstrops are important; each backstrop length is recommended to be no less than the length of the otterboard, to a maximum of 1½ times the otterboard length. The material should be quality chain and it is very important that both lengths are identical and are not twisted when fixed to the otterboard.

Movement of the towing point to adjust the heel angle can be difficult and time consuming. If adjustment is only required when changing fishing grounds for a short length of time then adjustment of the backstrops is the easiest solution. The heel angle can quickly be adjusted to produce a greater digging effect by inserting a single 75mm (3 inch) shackle into a 3m length (9 feet) lower backstrop leg. No more than two extra shackles should be added to the lower backstrop or extreme heel angles will occur.

If a reduced heel angle is required for working on very soft ground then insert a 75mm (3 inch) shackle into the upper backstrop leg. More than one shackle and the otterboard will be very difficult to shoot.

2.3 Traditional Vee Otterboards

Vee shaped otterboards are generally made entirely of mild steel although plastic versions are made. Occasionally hardened steel shoes are added but these are considered an extra.

Warp towing points can be hinged bracket or towing chain depending on the manufacturer.

The main structure is bent along the horizontal plane to form a vee angle of approximately 25° to 30°. This inherent design produces a rugged stable configuration and helps the otterboard to ride over stony ground.

An aspect ratio in the region of 0.65 is applied to most common vee otterboards.

Both port and starboard otterboards are designed to be symmetric around the middle vertical axis and both otterboards are therefore identical. This reduces cost and also enables the fisherman to interchange the otterboards when the shoes are part worn.

The generic design calls for large radius top corners. This is a useful feature and prevents damage on wooden vessels when hauling. The bottom corners also have a generous radius and this assists them to climb over seabed obstructions.

Overall, the vee otterboard is simple in design and construction; this promotes economic production.

2.3.1 Single Backstrops

Vee otterboards are regularly worked with a single chain backstrop on rough ground. This helps the otterboard pivot over large rocks and pinnacles. There are no set rules on the length of the single backstrop, this depends entirely on the working method of the individual. The only consideration is the weight of the chain; if this is a very heavy short link chain it may have an effect on the attitude of the otterboard.

2.3.2 Twin Backstrops

Twin chain backstrops tend to be used more on cleaner grounds, in shallow water or where precise control of the heel angle is required (for adjustment see Section 2.1.5). The length of each backstrop leg should be from 1.0 to 1.5 times the length of the otterboard, as this allows fine adjustment of the heel angle using single shackles.

For vee otterboards with equal upper and lower plates, equal backstrop lengths are normally used unless working in shallow water or at low towing speeds when a single shackle can be inserted into the lower backstrop leg.

If the backstrops are much shorter than the length of the otterboard then the sensitive adjustment using shackles will be lost.

2.3.3 Triple Backstrops

In this arrangement the forward long chain is normally equal in length to the distance from its forward attachment point to the aft end of the otterboard. Shortening this chain will increase the angle of attack. The two short aft chains can be adjusted to help control otterboard heel. Vee otterboards with the upper plate larger than the lower will have the upper backstrop longer than the lower in a triple system.

2.3.4 Towing Point Adjustment

With a vee otterboard fitted with a horizontal hinged bracket mounted on the centre line the angle of attack can be altered by moving the warp into another of the selection of holes available; normally there are three holes. This ability provides a quick if limited change of the angle of attack (*fig* 2.6).

If a towing chain attachment is supplied then the warp position can be adjusted using shackles in either end of the chain or repositioning the shackling point along the towing chain (see Section 2.1.2 for more details).

Vee otterboards work well if the upper face is near vertical; the otterboard will then skim over the ground and produce good spreading characteristics, however, if the otterboard heels over further onto its back a depressing force will be created and the otterboard will dig into the seabed. Its efficiency will be reduced if worked in this manner.

Although the efficiency of both vee and flat otterboards are similar in practice, when changing from flat to vee otterboards fishermen tend to chose one size larger. This can be attributed to the additional spreading force generated by the outward heel and digging action of flat otterboards on normal or mixed grounds. This would not be applicable on very soft grounds as the towing point would be raised for a flat otterboard to prevent outward heel and thus prevent the otterboard from burying.

2.4 Cambered, Oval Profile and Slotted Otterboards

Apart from traditional flat wooden and vee otterboards, a large number of alternative designs have been produced by various manufacturers which incorporate other features such as camber, oval profile and slots (*see fig 1.1* Range of Otterboard Shapes and Features).

Most otterboard manufacturers combine several features into one otterboard design e.g. the Morgère Polyvalent Ovale combines camber, oval profile and a single slot.

Each feature is thought to have certain benefits.

2.4.1 Cambered Otterboards

An otterboard which is cambered will give a significantly greater spreading force for a given projected area when compared with a flat or vee otterboard of the same area.

In practice this means that, when choosing cambered otterboards to replace traditional flat wooden or vee otterboards, the sizes will be significantly smaller to obtain the same spread of the trawl.

The use of camber can also produce improved waterflow around the otterboard, which leads to reduced drag and hence the potential to save fuel.

Introducing camber may make otterboards more difficult to shoot. However, a shooting procedure is given in Section 4.3.1 to overcome this problem.

2.4.2 Oval Profile Otterboards

Otterboards of this shape were introduced to improve performance on rough or hard grounds. It was thought that the removal of sharp corners would allow the otterboards to rise and fall over obstructions without causing instability.

The large rounded corners also make the otterboards less vulnerable to impact damage.

2.4.3 Slotted Otterboards

The term slot can be used to cover any hole cut in an otterboard to allow water to pass through. The actual benefit of a single or multi-slot otterboard depends on the design of the slots.

Simply cutting a hole in an existing otterboard design may do little to improve performance. On the other hand, slots which are carefully designed, allowing smooth waterflow around the otterboard, may improve the efficiency of the otterboard significantly leading to reduced fuel consumption.

In practice slots are generally combined with camber and the benefits which this gives can only be assessed by measuring the performance of each individual design.

2.5 Selection of Otterboard Size

The size of otterboard selected should be matched to the trawl gear rather than to the vessel horsepower.

Other factors should be considered which may influence the size of otterboard selected and are:

- Towing speed
- Ground condition
- Warp length/depth ratio
- Bridle/sweep length
- Type of ground gear
- Target species

It is beyond the scope of this manual to attempt to produce a mathematical method to match otterboards to trawls. However, for guidance purposes a table is presented in Appendix II. This table lists different sizes and types of trawl in use in Denmark, France, the United Kingdom and Ireland together with corresponding otterboard type and size.

A knowledge of the hydrodynamic characteristics of different types of otterboards is useful in order to:

- Compare the performance of different designs

- Calculate the size of one otterboard type equal in spreading force to another.

If the size and type of an existing otterboard that matches a trawl is known or has been selected from the table, it is possible to calculate the size of an alternative design provided the hydrodynamic characteristics for both have been determined in the Flume Tank tests described in Section 3.

2.6 Otterboard Weight

The weight of the otterboard is important and will be chosen according to:

- warp/depth ratio
- towing speed
- type of fishing ground

When comparing the weight of solid steel and wood/steel otterboards two different situations are encountered. This can be illustrated by comparing a steel vee otterboard (solid steel) and a flat wooden otterboard (wood/steel). If both steel vee and flat wooden otterboards are constructed to the same weight in air then the flat wooden otterboard will be lighter in water. Problems may then occur with the flat wooden otterboard through reduced ground contact.

This is then rectified by heeling the flat wooden otterboard outwards.

Alternatively it is the practice in some areas to work a flat wooden otterboard upright on the sea bed. In this case the flat wooden otterboard needs to be heavier in air than the steel vee otterboard to compensate for the large weight loss of the wooden parts in water.

2.7 Otterboard Shoes

The shoe of an otterboard is usually straight. The forward part of the shoe is curved up in order to ease the passage over irregular grounds. Straight shoes give a good contact with the ground. However, oval types of otterboard are fitted with curved shoes which are usually made in sections. This allows worn sections to be replaced individually.

The digging effect of the otterboard depends on the width of the shoe and the rigging arrangement. On muddy grounds it is recommended that wide shoes are used or the rigging is modified so that the digging effect is reduced.

The curved shoe of oval otterboards may result in a reduction of the contact surface with the ground. This type of shoe is considered more suitable for rough ground.

The shoe's wear rate depends upon the following factors:-

- Weight of the otterboard
- Width of the shoe
- Resistance to abrasion of the steel material
- Ground conditions
- Rigging arrangement on the otterboard

All will contribute to how fast the steel shoe will wear away and hence the length of time between re-shoeing.

If excessive shoe wear is experienced on good ground conditions then the otterboard may be too heavy for the warp/depth ratio or the shoe material could be soft mild steel.

If the otterboard is heeling out in excess 10°, then this will drive the otterboard into the seabed generating heavy wear and increased fuel consumption. Adjusting the towing point slightly upwards will help. If this is not possible then the length of the lower backstrop chain can be shortened to reduce the heel angle.

If ground conditions are hard then the following is suggested:

- Replace the shoe with a tough material (e.g. a redundant length of railway line). It is very important after re-shoeing to check that the warp towing point is at the correct height.

- Increasing the width of the shoe will spread the load and should reduce wear.

Section 3
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3. Flume Tank Testing and Results

3. Flume Tank Testing and Results

3.1 Flume Tank Model Test Procedure

Flume tanks are now widely used to test model trawl gear, for development and demonstration purposes. Model testing in a tank is very much quicker and cheaper than testing full scale gear at sea, especially if several rigging variations have to be tried.

However, there has been little model testing of otterboards in the past, and therefore its validity relative to full scale is not known.

The data given in this handbook show the results of a project intended to find whether model testing of otterboards is a reasonable predictor of full scale conditions. Tests were done at sea on several types of otterboard, and models of the same types, and of others also, were made and tested in 3 Flume Tanks - at Hull, Boulogne and Hirtshals.

The model test results were then compared with each other and with the full scale trials results, to check their compatibility.

3.1.1 Principle of Tests and Rigging

To carry out the tests, each model was held in a fixed position in the Flume Tank by a model warp and bridle as in *fig. 3.1.* The choice of Port or Starboard otterboard was partly dependent on the layout of equipment in the tank. However, a starboard otterboard was preferred where possible, to minimise the risk of the model striking the observation windows if a rigging component should break.

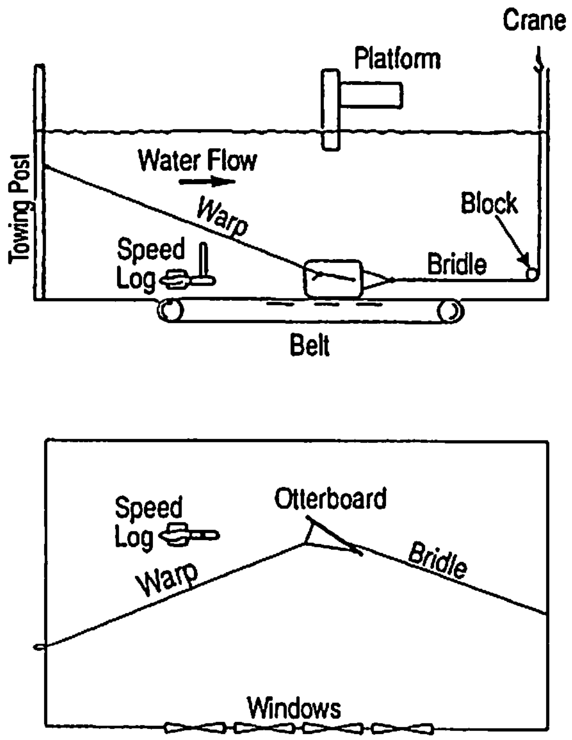


Figure 3.1 - Rigging of Otterboard Models in the Flume Tank

The warp was of a fixed length and attached to the towing post. The height of the attachment point on the towing post could be varied as could the position across the tank.

The length of the bridle was adjusted by pulling it through a block located at the bottom of the tank using the overhead crane.

The model otterboard to be tested was shot from the observation platform with the waterflow stopped. Waterflow was then increased until the warp and bridle came under tension, after which the bridle was adjusted by crane until the otterboard was at the required location in the tank. The tank belt was set to run at the same speed as the waterflow, approximately 0.9 metres per second.

The towing point was set to give a warp vertical angle of 6° for all otterboards tested during the programme.

The principle of the test procedure used in all three Flume Tanks was based on the resolution of forces in the warp and bridle. By measuring the tensions and angles of the warp and bridle, the forces were resolved in the horizontal plane in the direction of, and at right angles to, the waterflow. The spreading and drag forces of the model otterboard were then calculated by adding the resolved forces in the warp and bridle.

By measuring the area of the otterboard under test and the speed of the waterflow, the calculated spreading and drag forces were then converted into coefficient form.

3.1.2 Instrumentation and Measurements

Water speed was measured by a log positioned 2.0 metres ahead of the otterboard so that readings were not affected by the flow deflection near to the otterboard. The wake from the log was found to have an affect on the tension readings, so the log was removed before other measurements were taken.

The angles of the warp and bridle to the waterflow were measured either by viewing the projected angles from vertically above using a sighting device or by measuring coordinates of the end points of the wires and calculating the angles.

Wire tensions were measured by load cells located underwater at a convenient point in the warp and bridle. These load cells were carefully calibrated under water prior to each test to minimise errors in the results.

The spreading and drag force characteristics of each model otterboard were measured over a range of angles of attack from 25° to 45° at a constant angle of heel.

The model otterboards were attached to their bridles by twin backstrops in order to give a degree of control of the angle of heel. When it was not possible to obtain the correct angle of heel using backstrop adjustment, the point of attachment of the warp to the otterboard was altered. In some cases this meant adding an extra towing point to the otterboard, or using a three chain warp attachment point as shown in *fig* 3.2.

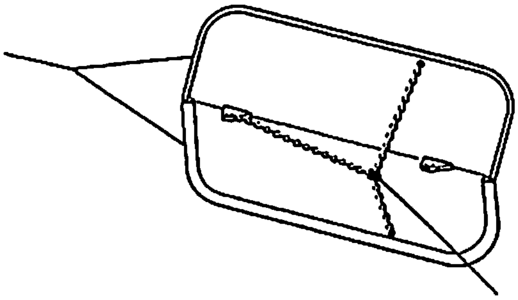


Figure 3.2 - 3 Chain Warp Attachment System

The horizontal angles of the warp and bridle were generally set greater than found on full scale otterboards at sea in order to reduce measurement errors and hence reduce the scatter of data.

For each otterboard tested the length, height, projected area and weight in air and water were measured.

Also, for each angle of attack the coordinates of the warp and bridle attachment points were recorded by measuring the distances along the otterboard from the leading edge and horizontally out from the otterboard face.

From the measurements taken in the Flume Tank C_L, C_D, C_L/C_D and C_P were calculated. The mathematical treatment of these data is given in Appendix III - 3.

3.1.3 Reference Otterboard Tests

Model otterboard tests were carried out in three Flume Tanks at Boulogne, Hull and Hirtshals. The tanks are 4.0, 5.0 and 8.0 metres wide respectively.

In order to ensure that results were consistent between the three tanks, and not affected by tank width, a reference vee otterboard was constructed as shown in *fig* 3.3. This model was tested in each of the tanks in turn and the results compared.

During the course of the model trials programme, other models were exchanged between tanks to ensure continued consistency of results, especially when a model exhibited an unusual or unexpected result.

The reference vee otterboard and other cross reference models showed small differences in C_L and C_D values between tests in the Boulogne, Hull and Hirtshals Flume Tanks. There was also a larger constant difference between results from one tank and the other two. The reason for this was eventually traced and a correction factor applied.

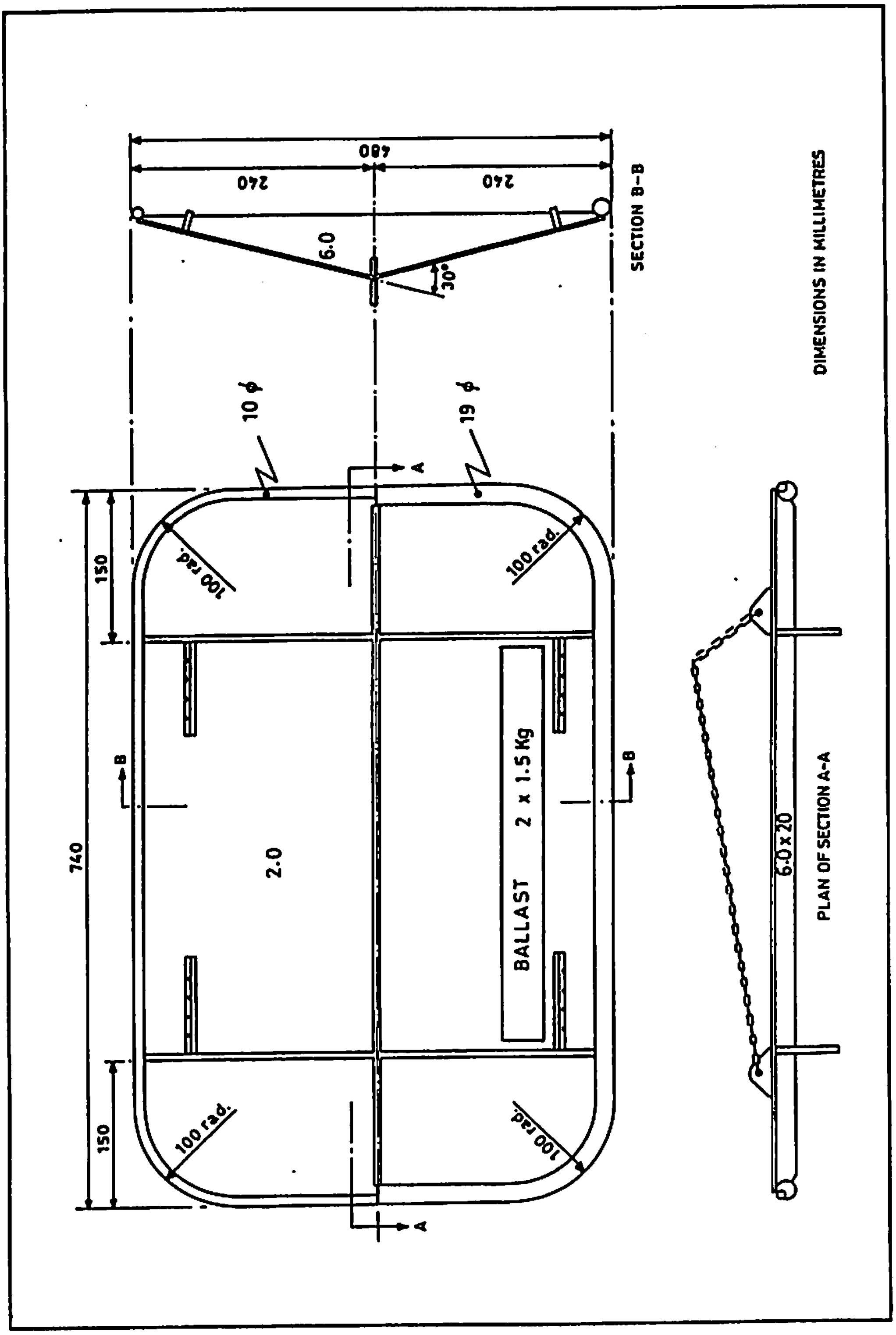


Figure 3.3 - Model Reference Vee Otterboard

3.2 Flume Tank Data

The Flume Tank results for all model otterboards tested are given in Appendix IV in the form of data sheets and briefly summarised in Table 3.1.

Each model was tested over a range of angles of attack from 25° to 45° and curves of C_L, C_D, C_L/C_D and C_P have been drawn.

The dimensions of models were measured and projected areas calculated based on the outline shape of the otterboard (no deduction was made for slots).

Table 3.1
Summary of Flume Tank Data

Type of Otterboard	35° Angle of Attack		Angle of Attack for Maximum C_L		
	C_L	C_L/C_D	Angle °	C_L	C_L/C_D
Reference Vee	0.89	1.20	28	0.97	1.61
Flat Wooden	0.86	1.15	32	0.93	1.30
Bison 1 Slot	1.34	1.76	39	1.38	1.57
Bison 3 Slot	1.14	1.70	43	1.30	1.41
Blooe Tech	0.92	1.35	29	0.99	1.71
Dan-Green KB	1.20	1.21	31	1.28	1.40
Dan-Green SV	1.07	1.16	31	1.16	1.36
Euronete "Portuguese"	0.95	1.26	31	1.02	1.52
Fjortoft Multi Foil	1.18	1.32	35	1.18	1.32
Hinriksson Poly-Ice	1.16	1.37	32	1.19	1.50
Hydrofin Multifoil	1.24	1.66	42	1.35	1.44
Le Béon à Roue	0.85*	1.05*	41	0.86	1.04
Le Béon Hydrostable	1.11	1.42	38	1.11	1.30
Lindholmen	1.50	1.66	34	1.51	1.69
Morgère Polyfoil	1.13	1.74	43	1.24	1.42
Morgère Polyvalent Ovale	1.04	1.33	27	1.22	1.63
Morgère Polyvalent Type R	1.04	1.46	34	1.04	1.52
Morgère W Horizontal	1.39	1.41	34	1.41	1.47
Morgère W Vertical	1.17	1.48	26	1.32	2.22
Munkebo	1.26	1.32	33	1.28	1.39
Net Tec	1.47	1.37	34	1.48	1.41
Perfect New Oval	1.49	1.52	37	1.50	1.46
Perfect Patent B	1.50	1.76	36	1.50	1.71
Thyboron Type 2 (66in)	1.48	1.49	36	1.49	1.46
Thyboron Type 2 (125in)	1.49	1.67	37	1.49	1.57
Vergoz en Z	0.76	1.34	28	0.88	1.73

* 40° Angle of Attack

Weight of models are given both in air and water. Most models were solid steel in which case the *model weight in water = weight in air x 0.87.* Some of the models had buoyancy in the form of wood or hollow sections and so greater differences are found between the two weights.

A summary is given on each data sheet of the performance characteristics (C_L, C_D, C_L/C_D and C_P) at 25°, 30°, 35°, 40° and 45° angles of attack and also at the angle of attack corresponding to the maximum C_L value.

The model otterboards and their Flume Tank results can be scaled up to represent full size otterboards. Results can be scaled up to any size, however, two representative scales of 1:2.5 and 1:5 have been chosen to illustrate this (see Tables 3.2 & 3.3). These results were calculated from C_L data given in Table 3.1 at 35° angle of attack. At these scales the reference vee otterboard would have lengths of 1.85m (72 inches) and 3.70m (145 inches) respectively and be towed at speeds of 2.8 knots and 3.9 knots.

In Table 3.2 the column giving *weight/spreading force* indicates whether the model was relatively heavy or light for a given spreading force.

If drag (C_D) or efficiency (C_L/C_D) results are required for a given model, but of a different weight to that used in the model tests, corrections can be calculated according to the method given in Appendix III-9.

Table 3.2
Scaled up Otterboard Dimensions and Spreading Force
Scale 1:2.5

Type of Otterboard	Scale 1:2.5 at 2.8 knots					
	Length (m)	Height (m)	Projected Area (m²)	Weight in air (kg)	Spreading Force (kg)	Weight/ Spreading Force
Reference Vee	1.85	1.20	2.17	245	199	1.23
Flat Wooden	1.91	0.95	1.78	209	158	1.32
Bison 1 Slot	1.68	1.06	1.63	178	226	0.79
Bison 3 Slot	1.68	1.06	1.64	178	193	0.92
Blooe Tech	1.83	1.17	2.13	184	202	0.91
Dan-Green KB	1.83	1.13	2.03	273	252	1.08
Dan-Green SV	1.78	1.05	1.84	192	204	0.94
Euronete "Portuguese"	1.88	1.04	1.72	172	169	1.02
Fjortoft Multi Foil	1.75	1.21	2.13	423	259	1.63
Hinriksson Poly-Ice	1.87	1.28	1.90	198	227	0.87
Hydrofin Multifoi	1.68	1.13	1.88	184	241	0.76
Le Béon à Roue	1.95	1.14	1.92	192	168	1.14
Le Béon Hydrostable	1.91	1.00	1.84	203	211	0.96
Lindholmen	1.45	1.45	1.65	156	255	0.61
Morgère Polyfoil	1.83	1.12	1.94	225	227	0.99
Morgère Polyvalent Ovale	1.65	1.12	1.49	198	160	1.24
Morgère Polyvalent Type R	1.79	1.05	1.69	194	182	1.07
Morgère W Horizontal	2.00	1.05	1.90	241	273	0.88
Morgère W Vertical	1.34	1.77	2.06	200	249	0.80
Munkebo	2.04	1.05	2.08	169	270	0.63
Net Tec	1.72	1.07	1.80	344	273	1.26
Perfect New Oval	2.00	1.31	2.06	253	317	0.80
Perfect Patent B	1.79	1.20	2.06	203	318	0.64
Thyboron Type 2 (66in)	1.73	0.99	1.69	159	259	0.61
Thyboron Type 2 (125in)	1.68	1.05	1.74	172	268	0.64
Vergoz en Z	1.87	0.97	1.78	184	140	1.32

Table 3.3
Scaled up Otterboard Dimensions and Spreading Force
Scale 1:5

Type of Otterboard	Scale 1:5 at 3.9 knots					
	Length (m)	Height (m)	Projected Area (m^2)	Weight in air (kg)	Spreading Force (kg)	Weight/ Spreading Force
Reference Vee	3.70	2.40	8.68	1963	1594	1.23
Flat Wooden	3.82	1.90	7.12	1675	1265	1.32
Bison 1 Slot	3.36	2.11	6.53	1425	1805	0.79
Bison 3 Slot	3.37	2.12	6.58	1425	1547	0.92
Blooe Tech	3.65	2.35	8.50	1475	1614	0.91
Dan-Green KB	3.65	2.25	8.13	2188	2013	1.08
Dan-Green SV	3.55	2.10	7.38	1538	1629	0.94
Euronete "Portuguese"	3.75	2.09	6.88	1375	1348	1.02
Fjortoft Multi Foil	3.50	2.43	8.50	3388	2070	1.63
Hinriksson Poly-Ice	3.74	2.55	7.60	1588	1820	0.87
Hydrofin Multifoil	3.37	2.25	7.53	1475	1926	0.76
Le Béon à Roue	3.90	2.27	7.67	1537	1347	1.14
Le Béon Hydrostable	3.82	2.00	7.35	1625	1684	0.96
Lindholmen	2.90	2.90	6.60	1250	2044	0.61
Morgère Polyfoil	3.67	2.25	7.77	1800	1814	0.99
Morgère Polyvalent Ovale	3.30	2.25	5.95	1587	1277	1.24
Morgère Polyvalent TypeR	3.57	2.10	6.77	1550	1454	1.07
Morgère W Horizontal	4.00	2.10	7.60	1925	2181	0.88
Morgère W Vertical	2.67	3.55	8.25	1600	1992	0.80
Munkebo	4.08	2.10	8.30	1350	2159	0.63
Net Tec	3.43	2.14	7.20	2750	2185	1.26
Perfect New Oval	4.00	2.62	8.25	2025	2537	0.80
Perfect Patent B	3.58	2.40	8.23	1625	2547	0.64
Thyboron Type 2 (66in)	3.45	1.98	6.78	1275	2070	0.61
Thyboron Type 2 (125in)	3.35	2.10	6.98	1375	2145	0.64
Vergoz en Z	3.74	1.95	1.95	1475	1118	1.32

3.3 Examples of the Use of Flume Tank Data Sheets in Appendix IV

3.3.1 Reading Values from Data Sheets

In order to carry out calculations for otterboards, data must be read from the data sheet curves for each otterboard type at the angle of attack considered appropriate.

For comparisons of spreading force, drag force and efficiency, curves of C_L, C_D and C_L/C_D are used.

As an example, the curves from the data sheet of the Morgère W Horizontal otterboard are shown in *fig* 3.4.

If this otterboard was found to be working at 33° angle of attack the values of C_L, C_D and C_L/C_D would be:

$$\left.\begin{aligned} C_L &= 1.40 \\ C_D &= 0.92 \\ C_L/C_D &= 1.51 \end{aligned}\right\} \text{ at } 33^\circ \text{ angle of attack}$$

As C_L, C_D and C_L/C_D are also given on the data sheet in tabular form at 25°, 30°, 35°, 40° and 45° angle of attack, the values read from the curves can be checked.

For example, the value of C_L at 33° angle of attack was read as 1.40. From the table of data $C_L = 1.31$ at 30° angle of attack and $C_L = 1.39$ at 35° angle of attack. The maximum $C_L = 1.41$ at 34° angle of attack. The value of 1.40 read from the curves falls between the tabular data and therefore has been read correctly.

3.3.2 Comparison of Two Otterboards for the same Spreading Force

Consider the example where the reference vee otterboard is being used to spread a trawl and it is working at an angle of attack of 40°. From the results table on the Reference Vee data sheet (Appendix IV-2) we have at 40° $C_L = 0.82$, $C_D = 0.83$ and $C_L/C_D = 0.99$. It is now required to find the size of Net Tec cambered otterboard which will give the same spreading force at the same angle of attack 40°.

From the data sheet for the Net Tec otterboard (Appendix IV-22) it can be seen that for this otterboard at 40° $C_L = 1.23$, so for the same area this otterboard would generate a spreading force which is higher by a ratio of:

$$\frac{1.23}{0.82} = 1.50 \quad \text{i.e. } 50\% \text{ extra}$$

Alternatively if the same spreading force as that given by the reference vee is required, the area of the Net Tec otterboard should be reduced by the ratio:

$$\frac{0.82}{1.23} = 0.67$$

A Net Tec otterboard only 67% of the area of the reference vee will therefore give approximately the same spread to the gear at sea.

It can also be seen from the table that for the Net Tec otterboard at 40° $C_D = 1.12$. So for the same size of otterboard the Net Tec otterboard will have a drag higher by a ratio of:

$$\frac{1.12}{0.83} = 1.35 \quad \text{i.e. } 35\% \text{ higher}$$

But in order to get the same spreading force the Net Tec has to be reduced to 67% of the area of the reference vee. So the drag of the Net Tec is in fact reduced to a ratio of 0.67 × 1.35 = 0.90 times the drag of the reference vee which gives the same spreading force. There is therefore a predicted saving in otterboard drag of 10%.

This result could have in fact been immediately revealed by examination of the C_L/C_D values. It is 0.99 for the reference vee but higher 1.10 for the Net Tec. For a given otterboard drag the Net Tec gives more spreading force by a ratio of:

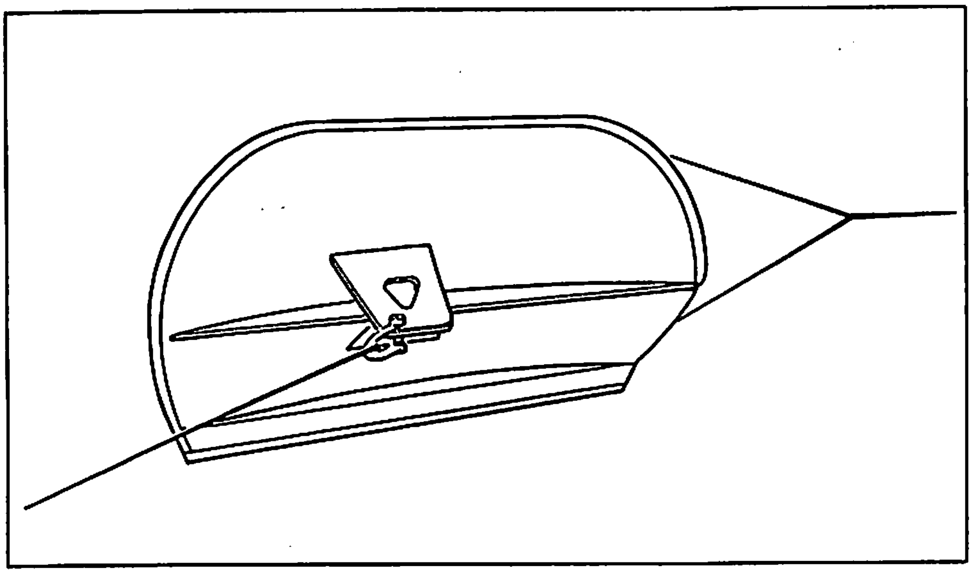
$$\frac{1.10}{0.99} = 1.11$$

Or inversely for a given spreading force its drag is less by a ratio of:

$$\frac{0.99}{1.10} = 0.90 \quad \text{i.e. } 10\% \text{ less}$$

Morgere W Horizontal

Cambered vee. Tested with upper plate vertical.



Model Specifications		
Length	0.800	m
Height	0.420	m
Projected Area	0.304	m2
Aspect Ratio	0.53	
Area Ratio	0.90	
Weight in Air	15.4	kg
Weight in Water	13.4	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	1.31	0.81	1.62
35 deg.	1.39	0.99	1.41
40 deg.	1.04	0.88	1.18
45 deg.	0.95	0.97	0.98
Maximum CL at 34 deg.	1.41	0.96	1.47

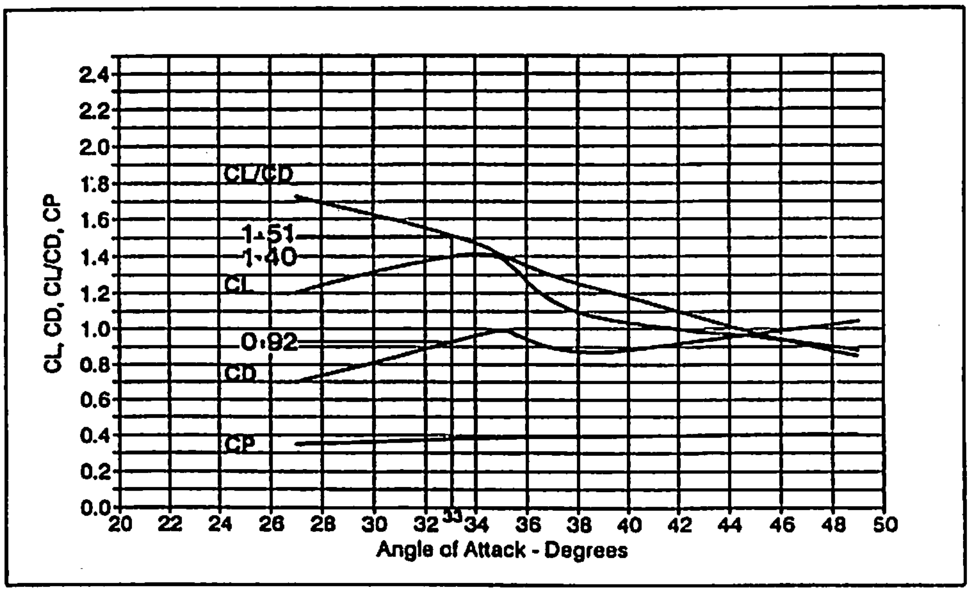


Figure 3.4 - Example of Reading Data Sheets for CL, CD and CL/CD

3.3.3 Increased Spreading Force Due to Alteration of Angle of Attack

The curves showing the performance of the Net Tec otterboard can now be examined in detail. The C_L (spreading force) increases steadily as the angle of attack increases from 24° to 32°. It then flattens off reaching a maximum value at 34° after which it starts decreasing. Above 36° there is a rather rapid drop in C_L - the change per degree angle of attack is much larger here than around 35° (the curve is steeper).

If angle of attack is decreased from 40° to 35° there are several improvements. Firstly C_L increases from 1.23 to 1.47 giving a spreading force larger by a ratio:

$$\frac{1.47}{1.23} = 1.20 \quad \text{i.e. 20\% higher}$$

Or alternatively for the same required spreading force an otterboard can be used which is smaller by a ratio of:

$$\frac{1.23}{1.47} = 0.84 \quad \text{i.e. 16\% smaller}$$

Also small changes in angle of attack do not affect C_L much at 35° so otterboard performance will not be so sensitive to alterations in fishing conditions which may affect the otterboards angle of attack.

Examining the C_D curve it can be seen that C_D increases steadily as angle of attack increases. A reduction in angle of attack will therefore always give less drag. If the same otterboard size is used (and more spread obtained) then reducing from 40° to 35° angle of attack can be seen to give an otterboard drag reduced by a factor:

$$\frac{1.07}{1.12} = 0.96 \quad \text{i.e. 4\% less}$$

Examining the C_L/C_D curve it can be seen that this drops steeply as angle of attack is increased. For a given drag spreading force decreases as angle of attack increases. For a given spreading force drag increases as angle of attack increases. At 40° C_L/C_D was 1.10; at 35° it increases to 1.37. So if the otterboard area had been decreased by 16% and the otterboard spreading force kept constant, the otterboard drag would be reduced by the ratio:

$$\frac{1.10}{1.37} = 0.80 \quad \text{i.e. a 20\% saving}$$

3.3.4 Summary of how to use C_L, C_D and C_L/C_D values

- To compare spreading force of two otterboards of equal area:

$$\text{Spreading force new otterboard} = \text{Spreading force of old otterboard} \times \frac{C_L \text{ new otterboard}}{C_L \text{ old otterboard}}$$

- To determine what area of a new otterboard is required to give equal spreading force to an old otterboard:

$$\text{Area of new otterboard} = \text{Area of old otterboard} \times \frac{C_L \text{ old otterboard}}{C_L \text{ new otterboard}}$$

- To compare the drag of two otterboards of equal area:

$$\text{Drag new otterboard} = \text{Drag old otterboard} \times \frac{C_D \text{ new otterboard}}{C_D \text{ old otterboard}}$$

- To compare the drag of two otterboards of equal spreading force:

$$\text{Drag new otterboard} = \text{Drag old otterboard} \times \frac{C_L/C_D \text{ old otterboard}}{C_L/C_D \text{ new otterboard}}$$

3.4 Otterboard Performance Characteristics

Each otterboard design tested in the Flume Tanks has a unique set of performance characteristics in terms of the shapes of its curves of C_L, C_D, C_L/C_D and C_P.

However, all have some common characteristics and can be put into categories which depend on the shape and features of a specific design.

3.4.1 Common Characteristics

All otterboard designs have a maximum spreading force coefficient C_L at some angle of attack in the range under test.

Also the drag coefficient rises progressively with increased angle of attack for all otterboard designs (except the Morgère W Horizontal) meaning that for a given size of otterboard the lower the angle of attack that is used the less otterboard drag will be encountered.

3.4.2 Otterboards with no Camber

The reference vee and wooden flat are typical of this type and have low maximum C_L values, typically below 1.0, and low C_L/C_D values in the working range around 35°.

The exception to the above rules is the Munkebo vee which develops a relatively high maximum C_L value of 1.28 at 33° angle of attack. This otterboard has an aspect ratio of 0.51 compared to 0.60 to 0.65 aspect ratio for most vee otterboards.

In general the maximum C_L value for most otterboards in this category occurs around 30° which is below the angle where these otterboards could be used for stability reasons.

3.4.3 Cambered Otterboards

In general otterboards with camber have higher values of C_L than otterboards with no camber. The larger the camber or curvature the higher is the maximum value of C_L.

For example, the Morgère Polyvalent Ovale has only slight camber and a maximum C_L of about 1.2. In contrast the Net Tec Vee, Perfect Patent B and Thyborøn Type 2 have much greater camber and achieve maximum C_L values of between 1.4 and 1.5.

It should be noted that high C_L values on their own do not denote a high efficiency otterboard, but that a smaller otterboard is required to spread the gear than another design with a lower maximum C_L value.

Generally cambered otterboards are more efficient than otterboards with no camber as they achieve higher values of C_L/C_D, which is the measure of how much drag is generated to give a certain spreading force.

3.4.4 Single Slot Otterboards

No otterboards were tested which had a slot but no camber. It is therefore not possible to make any statement about slots on their own.

However, some cambered otterboards with single slots achieved maximum C_L values at higher angles of attack than those cambered otterboards without slots. This is probably due to the slots improving the water flow on the back of the otterboards and preventing the flow from being turbulent at high angles of attack. This can be assumed, as the C_L values do not drop so quickly at high angles of attack beyond the angle giving maximum value of C_L.

3.4.5 Multi-foil Otterboards

Otterboards in this category generally have maximum C_L values which occur at high angles of attack. These otterboards generally are made up of a series of single foils which have angles of attack to the water flow much lower than the angle of attack of the shoe.

Because the spreading force coefficient continues to rise until high angles of attack are reached, these otterboards can be more versatile as they are able to supply a wider range of spreading forces over the range at which otterboards are considered to be stable.

3.4.6 Otterboards of Different Weight

The chosen weight for an otterboard of given area will be dependant upon the depth of water fished, the type of sea bed (rough/soft), the towing speed and amount of spread required. Most manufacturers produce each size of otterboard in a range of different weights in order to make them suitable for most fisheries but some otterboards have been designed for specific sea bed/water depth conditions.

The models tested in the Flume Tank reflect these variations. The weight of the different models are not the same for the same otterboard area or spreading force. The Fjørtoft Multifoil, Flat Wooden, Net Tec and Reference Vee are all relatively heavy. The Munkebo, Lindholmen, Thyborøn Type 2 and Perfect Patent B are relatively light otterboards. This should be borne in mind when comparing C_L/C_D values for the different otterboard designs. A heavy otterboard will produce a higher C_D value giving a much lower C_L/C_D than a light otterboard of the same design.

3.4.7 Different Sizes of the Same Otterboard Design

When examining a manufacturers catalogue it can be seen that a small otterboard is not an exact scaled model of a large otterboard. Features such as aspect ratio, camber and otterboard weight vary with otterboard size. To investigate the effect of this, models were tested of two different sizes of Thyborøn Type 2 otterboard - 66in (projected area $1.69m^2$) and 125in (projected area $6.98m^2$) sizes. Values of C_L varied by up to 6%, C_D by up to 14% and C_L/C_D by up to 15% at the same angle of attack.

Manufacturers often make the same basic type of otterboard in different heights for the same length.

Three different vee otterboards were model tested. The Munkebo had an aspect ratio of 0.51, the Reference Vee and the Blooe Tech Vee otterboards were much higher of aspect ratio 0.65. The Munkebo Vee had C_L values approximately 27% higher than the other two otterboards. The C_D values for this otterboard were also much higher. If C_L and C_D values are required for a vee otterboard, that does not correspond exactly to one of the models tested, it is probably best to average results for the three models Flume Tank tested. It is not certain that C_L and C_D increase systematically as aspect ratio is decreased.

These variations in performance for otterboards of the same type suggest that a cautious approach should be adopted when replacing an otterboard with a more efficient type with higher C_L value and that a safety margin of 10% could be added to the new otterboard area first calculated.

This recommendation is based on the fact that it is preferable to have an otterboard which is marginally too big rather than one which is too small.

Section 4
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4. Otterboard Performance at Sea

4. Otterboard Performance at Sea

4.1 Assessment of Running Attitude and Spread

4.1.1 Estimating Otterboard Spread

In order to enable a comparison to be made between the various rigging arrangements it is necessary to have a method of assessing the otterboard spread. One common method adopted is the warp divergence technique. This method assumes that the warps do not have any curvature and a very simple calculation is all that is required to estimate an otterboard spread. To calculate an otterboard's spread proceed with one of the following two methods.

Towing from a single point: Mark a point on each warp one fathom down from the towing point, then measure the distance between the two marks on the warps as shown in *fig* 4.1. Due to the movement of the warps it may be necessary to take an average over 15 to 20 seconds. This measurement, 'the warp divergence', is then multiplied by the length of warp out in fathoms. The result is the distance between the otterboards. It may be more convenient to measure over 1 metre and multiply by the warp length in metres. Accuracy of the divergence measurement will be improved by subtracting any small separation that exists between the warps in the towing point itself.

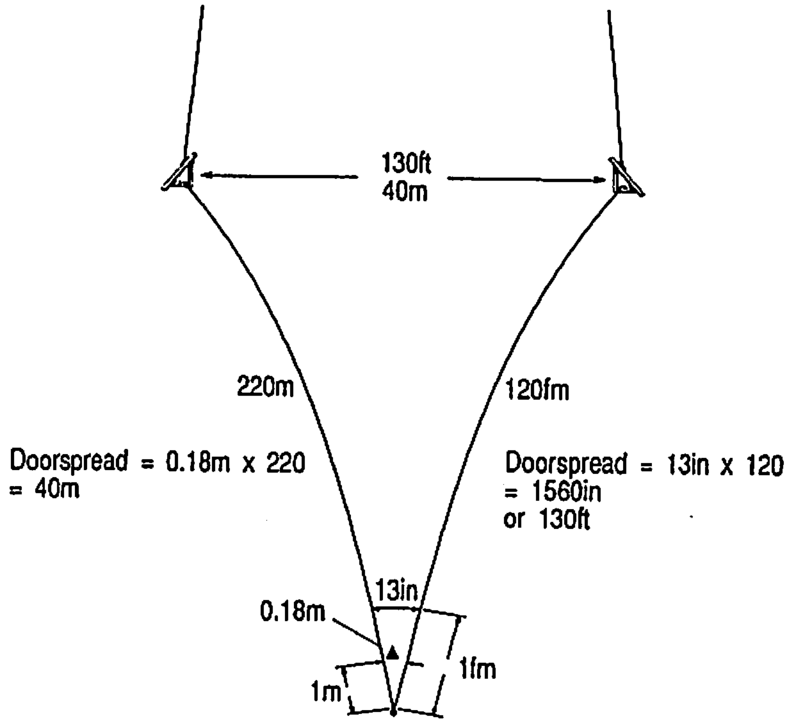


Figure 4.1 - Towing From a Single Point

Towing from the gallows: Measure and record the distance between the towing blocks, then mark a point one fathom down on both warps and measure the distance between the warps at this point as shown in *fig* 4.2. Subtract the measured distance between the gallows to find the 'warp divergence'. The warp divergence is then multiplied by the warp out. The distance between the gallows is added on to give the distance between the otterboards.

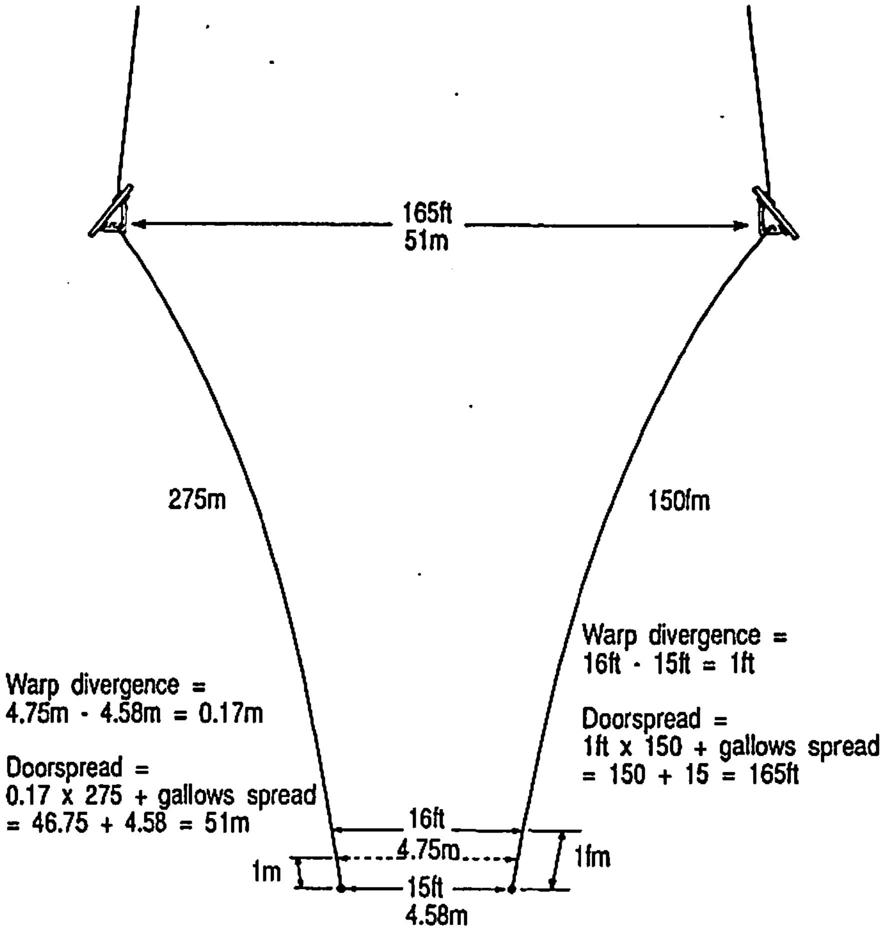


Figure 4.2 - Towing from Gallows

When comparisons are made between tows any errors generated in the calculation by the curvature in the warps will be constant and so cancel each other out.

This method has been used in conjunction with electronic systems and has been shown to be reasonably accurate when comparing different otterboard settings, although varying sea and weather conditions may add errors into the calculations.

If otterboard spread is determined from the calculation then inevitably it will be on the low side compared with the true value. This is due to the curvature of the warps. Errors are dependant on warp length and are usually in the order of 10 to 15%.

4.1.2 Angle of Attack Measurement

A useful tool for determining the angle of attack is the combination gauge (see *fig* 4.3). Other similar tools are available but this has been found to be the simplest to use in practice.

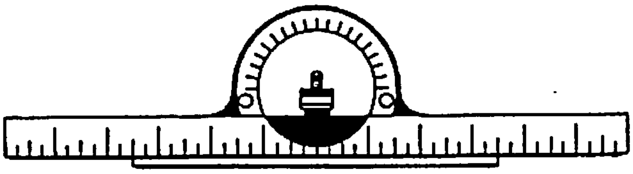


Figure 4.3 - Combination Gauge for Angle of Attack Measurement

To assess the angle of attack at sea, the otterboards ideally will need to have been operating on the seabed and on a straight course for approximately thirty minutes prior to hauling. This is necessary to generate a good polish on the shoe of the otterboard. When the otterboard is hauled on deck or is secured in the gallows, the shoe can then be manoeuvred into a position where the combination gauge can measure the operating angle (*fig* 4.4).

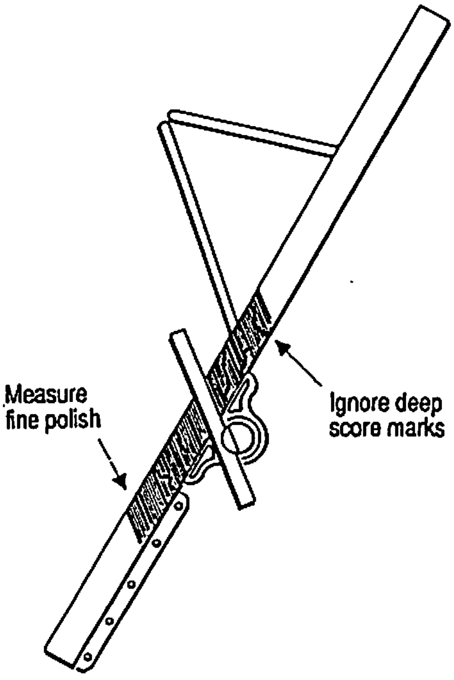


Figure 4.4 - Measuring Angle of Attack

When using the gauge measure only the fine scratch marks. Deep score marks must be ignored as these do not indicate the true angle of attack. The deep score marks occur when the shoe is in contact with an obstruction such as a rock or pinnacle. This causes a rotational movement deviating the otterboard from its normal running attitude.

It is rare to find a pair of otterboards working at identical angles of attack, therefore it is important to carefully measure the angle of both otterboards on several occasions to get a good average. Otterboards that are rigged similarly may still operate at different angles of attack because of errors generated during construction or by otterboard wear or damage during normal operation. It may be necessary to re-rig them differently to obtain the required angle.

4.1.3 Angle of Attack Calculation

It is possible to calculate what angle of attack will be taken up by an otterboard when different warp and backstrop attachment points are used. This can be done by either a simple method detailed below or by mathematical calculation as shown in Appendix III-11.

This method can be used with either a full scale otterboard or model otterboard with the necessary warp, bridle and "pull" rope attached to simulate the otterboard force. This pull rope simulates the hydrodynamic and ground contact forces acting on the otterboard. The warp and bridle should be attached to bollards or posts and set up at the required angles (2°-10° for the warp and 10°-20° for the bridle).

A piece of rope or twine should be attached to the otterboard at 45 to 50% of the otterboard length from the forward end.

This rope should be pulled in a direction at right angles to the otterboard surface, whereby the otterboard will take up the resultant angle of attack (see *fig* 4.5).

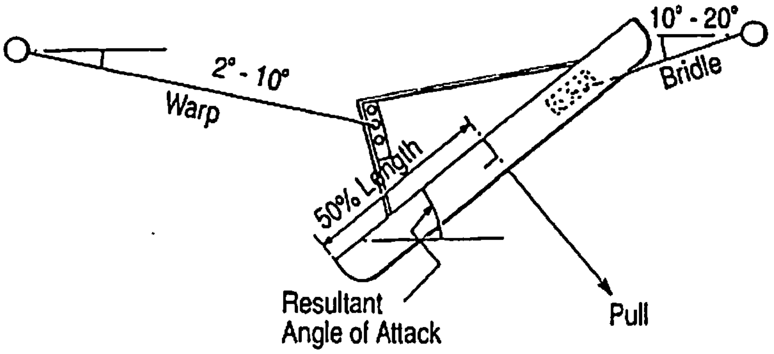


Figure 4.5 - Angle of Attack Calculation
Full Scale or Model Otterboard

Even if the full size otterboard is available it is more convenient to use a rectangular piece of card on which a correct scale plan drawing of the otterboard is made. Holes for the warp, bridle and "pull" rope should be positioned at the appropriate scale distances from the otterboard surface and leading edge. 1:10 is a convenient scale for the drawing and warp and bridle lengths of 1.0 metre and 0.3 metre respectively ensure that the bridle angle is proportionately larger than the warp angle.

The card model can be laid out and pinned to a workbench as shown in *fig* 4.6.

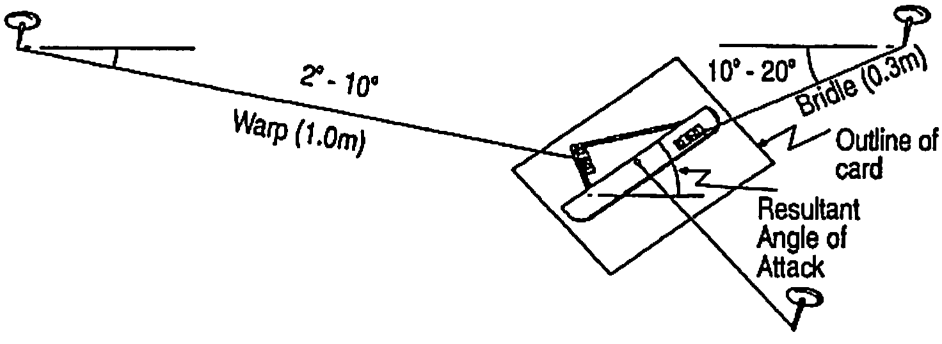


Figure 4.6 - Angle of Attack Calculation Card Drawing of Otterboard

If thin nylon twine is used for warp and bridles, the elasticity allows the angles of warp and bridles to be adjusted without removing the pins from the workbench.

In general, if the "pull" rope is attached at a point of length 45% from the leading edge, this will give a good estimation of angle of attack when the otterboard shoe is running level on the bottom. However, where the otterboard is pitched up at the forward end and only the aft part of the shoe is in contact with the ground, then the "pull" rope situated at a point 50% of the length from the leading edge will give a more accurate estimation of angle of attack.

4.1.4 Heel and Pitch Angles

Looking at the position of the polish on the shoe will normally indicate the heel and pitch angle the otterboard was working at during the previous tow. Figures 4.7 and 4.8 show various polish and wear patterns which commonly occur on the shoes of otterboards. Care must be taken to consider the seabed conditions as undulations or towing with one otterboard along a bank may well temporarily change its normal working attitude and hence the polish.

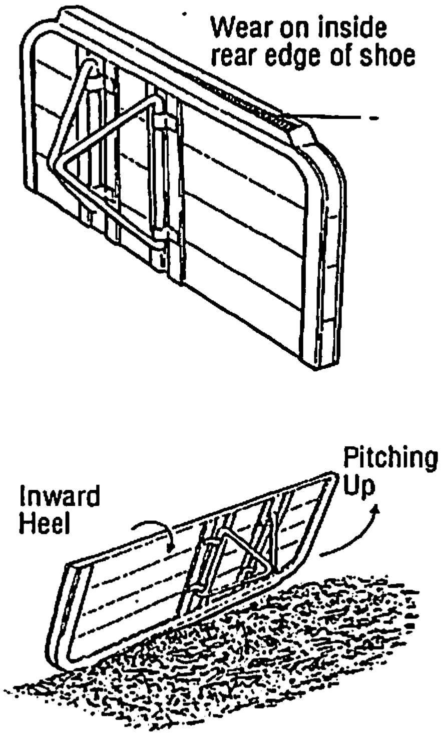


Figure 4.7 - Shoe Wear Pattern
Pitching Up and Heeling In

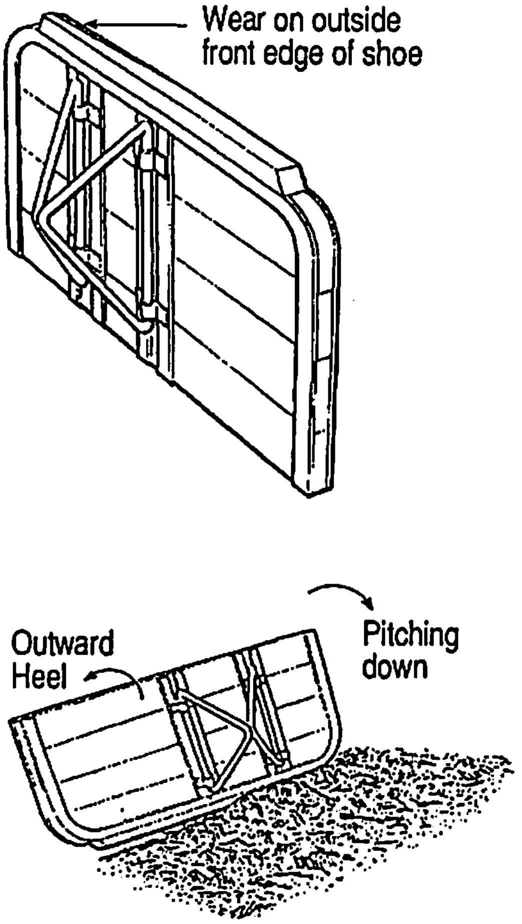


Figure 4.8 - Shoe Wear Pattern Pitching Down and Heeling Out

Heel and pitch angles are interrelated and occasionally adjusting one will affect the other.

Heel and pitch angles are affected by any or a combination of the following:-

- Height of warp attachment point
- Warp out
- Otterboard weight
- Ground conditions
- Rigging arrangements
- Towing speed

Often, for the same rigging arrangements, a change of fishing ground from soft mud in one area to hard sand and stones in another will induce different friction characteristics and produce a different pattern of polish on the shoe. Minor adjustments may be required to correct for any 'ground effect'.

Heel angle adjustment: The heel angle can be adjusted in five ways:-

- Moving the towing point up or down
- Changing the warp/depth ratio
- Increasing or reducing the weight
- Adjustment of the backstrop chains
- Changing towing speed

An outward heel can be reduced by adjusting one of the following:-

• Raising the towing point	coarse adjustment
• Adjusting the backstrop chains	fine adjustment
• Increasing the warp out	
• Reducing the speed	

An inward heel can be reduced by adjusting one of the following:-

• Lowering the towing point	coarse adjustment
• Adjusting the backstrop chains	fine adjustment
• Reducing the warp out	
• Increasing the towing speed	

(Backstrop adjustment is discussed in Section 2.1.5).

Pitch angle: The pitch angles of most otterboards cannot be controlled by the adjustment of backstrop chains. This applies particularly to otterboards with straight shoes worked at normal angles of attack and in firm contact with the sea bed.

The exceptions are otterboards of the oval design type and those in light contact with the sea bed (see Section 2.1.5., "Adjusting of the heel and pitch angles using backstrop chains" for additional information). There are other influences on the pitch of an otterboard, these are as follows:-

- Towing point height
- Warp out
- Otterboard weight
- Speed

If the otterboard is heeling in and also pitching up at the forward end then:-

- Lower the towing point height slightly
- Reduce the warp out
- Reduce the otterboard weight
- Increase speed

To reduce pitching down at the forward end of the otterboard when it is heeling out:-

- Raise the towing point height slightly
- Increase the warp out
- Increase otterboard weight
- Reduce speed

4.2 Comparative Testing at Sea

4.2.1 Selection of Otterboards

For comparative trials ten otterboard types were selected to be tested at sea.

The range of otterboard types chosen covered a wide variety of typical otterboard shapes - flat, veed, cambered and slotted - and also the full range of warp and bridle attachment methods.

A pair of vee otterboards of 1.97 metres length and 1.30 metres height, with a projected area of 2.5m² was designed and constructed to be used as a reference (see *fig* 4.9). This pair of otterboards was matched to a three bridle trawl which was regularly used aboard the research vessel undertaking the trials. The rigging arrangement is shown in *fig* 4.10.

The three bridle trawl was normally used with flat wooden otterboards of 2.22 metres length and 1.17 metres height with a projected area of 2.53m². From previous experience it has been found that the spreading force of flat otterboards can be greatly altered by changing the heel of the otterboards, due to effects of ground contact. It was felt that a better reference otterboard would be a vee which obtains spread mostly from hydrodynamic effects.

The ten otterboard types selected for sea trials were:-

1. Reference Vee
2. Flat Wooden
3. Bison 1 Slot
4. Blooe Tech
5. Le Béon Hydrostable
6. Morgère Polyvalent Ovale
7. Morgère W Vertical
8. Munkebo
9. Perfect Patent B
10. Thyborøn Type 2

The size of each otterboard type used in the sea trials was calculated from Flume Tank data to give the same spreading force at 35° angle of attack as the Reference Vee.

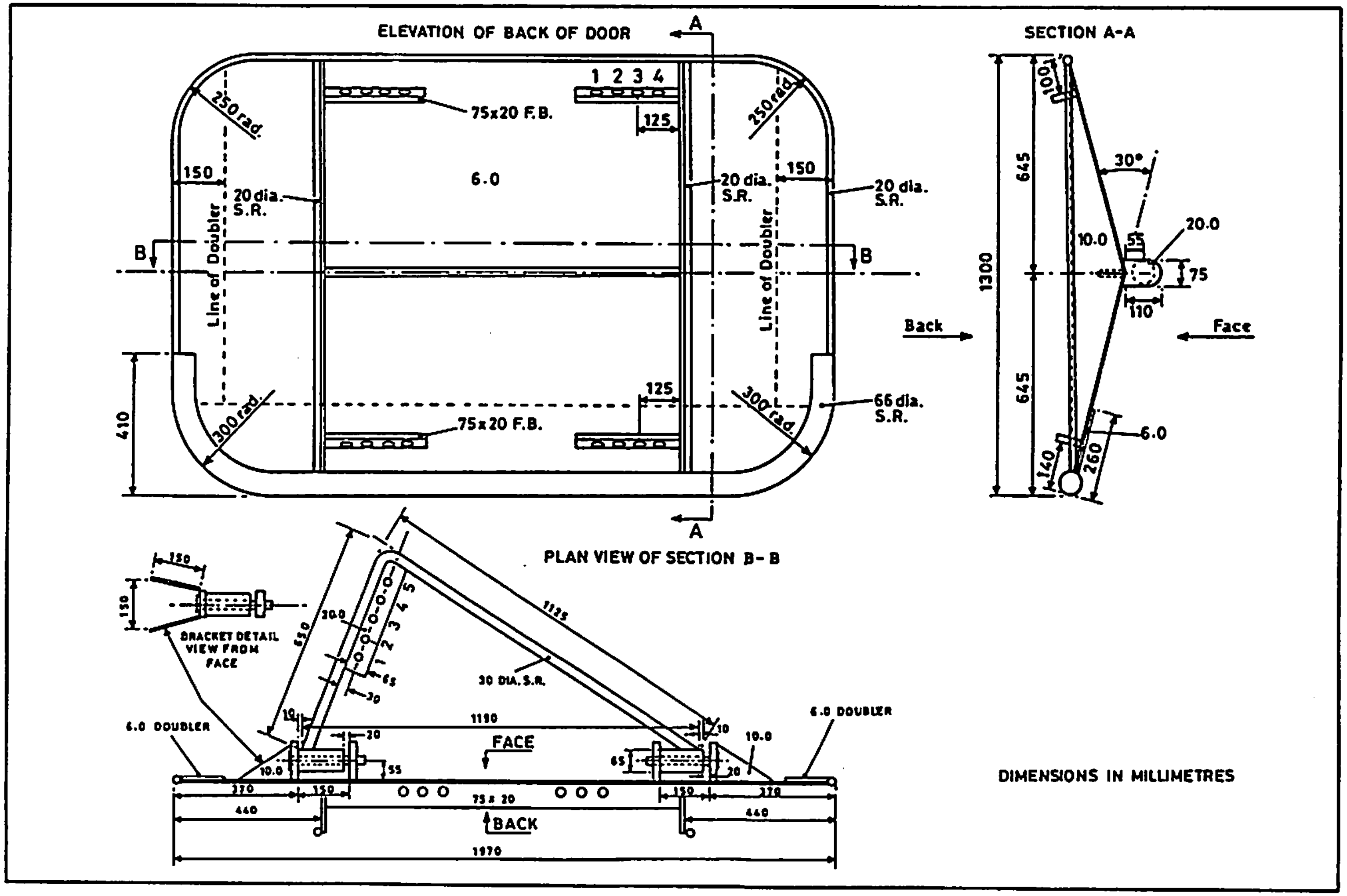
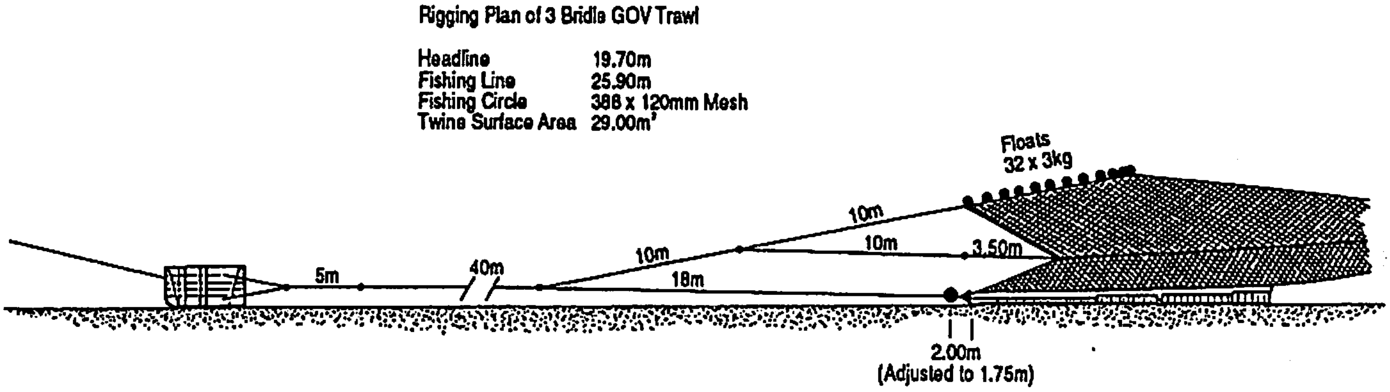


Figure 4.9 - Plan of 1.97 metre Vee Otterboard



Rigging Plan of 3 Bridle GOV Trawl

Headline	19.70m
Fishing Line	25.90m
Fishing Circle	388 x 120mm Mesh
Twine Surface Area	29.00m'

Figure 4.10 - Rigging Plan of Trawl used for Sea Trials

This was achieved by reading the C_L value for the Reference Vee at 35° angle of attack and comparing it to the C_L value at 35° angle of attack for the otterboard type in question. The calculation was performed as described in section 3.3 using the formula in section 3.3.4.

$$A(alt) = A(Vee) \times C_L(Vee)/C_L(alt)$$

where Vee = reference vee otterboard
alt = other type of otterboard

The actual projected area A which was calculated generally fell midway between two sizes in a particular manufacturers range, so the nearest size was selected.

Example

Reference Vee:
Lift coefficient C_L = 0.89 at 35° Angle of attack
Projected area A = $2.50m^2$

Bison 1 Slot:
Lift coefficient C_L = 1.35 at 35° Angle of attack

$$\begin{aligned} A\ (Bison) &= A(Vee) \times C_L(Vee)/C_L(Bison) \\ &= 2.50 \times 0.89/1.35 \\ &= 1.65m^2 \end{aligned}$$

This projected area of $1.65m^2$ fell midway between two otterboard models in the Bison range and so the smaller size of $1.49m^2$ was selected. This principle of size selection was applied to all comparative otterboard types except the flat wooden. Although the C_L value of the Reference Vee is slightly greater than that of the wooden flat, the wooden flat otterboard selected was of the same area as the vee to counter the possible excess spreading of the flat wooden otterboard due to ground shear.

The actual sizes of otterboards used are given in Table 4.1.

Table 4.1
Actual Otterboard Sizes Used in Sea Trials

Otterboard Type	Length m	Height m	Projected Area m^2	Weight in Air kg	Weight in Water kg
Reference Vee	1.97	1.30	2.50	295	255
Flat Wooden	2.22	1.17	2.53	345	220
Bison 1 Slot	1.57	1.03	1.49	290	235
Blooe Tech	1.99	1.27	2.52	210	150
Le Béon Hydrostable	1.94	0.99	1.85	290	235
Morgère Polyvalent Ovale	2.10	1.21	2.04	330	280
Morgère W Vertical	1.24	1.57	1.70	280	245
Munkebo	2.04	1.07	2.11	185	155
Perfect Patent B	1.65	1.10	1.74	255	215
Thyborøn Type 2	1.72	1.15	1.97	320	270

4.2.2 Towing Procedure

Each otterboard type was towed over a set piece of ground, first in one direction and then on a reciprocal course back over the same piece of ground. In each direction the towing pull of the vessel was increased in steps to provide otterboard spread and warp tension data over a range of towing speeds.

The warp tensions, otterboard spread, wingend spread and headline height were measured at each speed throughout the tow. The speed of the trawl ranged from 2.4 to 4.0 knots, but the higher speed was reduced for lighter otterboards to prevent them from being lifted off the bottom.

Each otterboard type was towed at a minimum of two angles of attack. The length, height and positions of the warp and bridle attachment points were measured for each otterboard, as was their weight in air and in water.

At the end of each reciprocal tow the gear was hauled and the angle of attack of both otterboards measured. The angle of attack was assessed using the method outlined in Section 4.1.2. The angles of attack were difficult to measure for some of the otterboards because the seabed in the area used for the trials was very soft mud and also most of the otterboards were new with unworn shoes.

4.2.3 Trials Results and Analysis

Many of the otterboard types used at sea were significantly different in area from that calculated as equivalent to the Reference Vee. A procedure was therefore adopted to allow some comparisons to be made.

To simplify the analysis of data a number of assumptions were made:-

a) the warps and bridles are straight lines.
b) the warp drag is negligible.
c) the otterboard drag can be predicted from Flume Tank results.

The drag and curvature of the warps were thought to be small as only short warps were used during the trials.

Using these assumptions allowed an estimate to be made of the spreading force of the full size otterboard at sea compared to the spreading force predicted from Flume Tank results.

If the correct allowance had been made for warp and bridle curvature and otterboard drag the ratio of:

$$\frac{\text{Calculated Full Scale Spreading Force}}{\text{Calculated Spreading Force From Model Tests}}$$

or:

$$\frac{\text{Full Scale } C_L}{\text{Model } C_L}$$

would be 1.0 if the otterboard performed at sea as it did in the Flume Tank.

Due to the assumptions made, however, this factor is unlikely to be 1.0 even if behaviour was identical. This means that the ratio can only be used to assess the performance of one otterboard type relative to another when compared to their respective model results. The ratio can also be used to assess the change in spreading force characteristic over the speed range due to other factors such as ground shear effect and change in heel or pitch.

Typical graphs are shown in *fig* 4.11 of how the ratio of Full Scale C_L/Model C_L varies against speed for different types of otterboards.

In all cases it can be seen that the ratio is larger at lower speed. This indicates that the otterboards may obtain a larger proportion of their spreading force at lower speeds due to ground shear. It is, however, more likely that the assumption made on drag is incorrect at lower speeds. In other words, the otterboards will obtain a larger proportion of their drag at lower speeds due to ground friction.

Because each type of otterboard used was a different weight in water, the lighter otterboards were lifting off the sea bed at lower towing speeds.

The data in Table 4.2 was therefore calculated to compare the performance of each otterboard type at the point at which it was about to lift off the sea bed (the point at which the upward force on the warp was calculated to equal the weight of the otterboard in water). This point at which the otterboard is about to lift off the sea bed is, in fact, the point where the otterboard has to be heeled outwards (over on its back) in order to retain bottom contact.

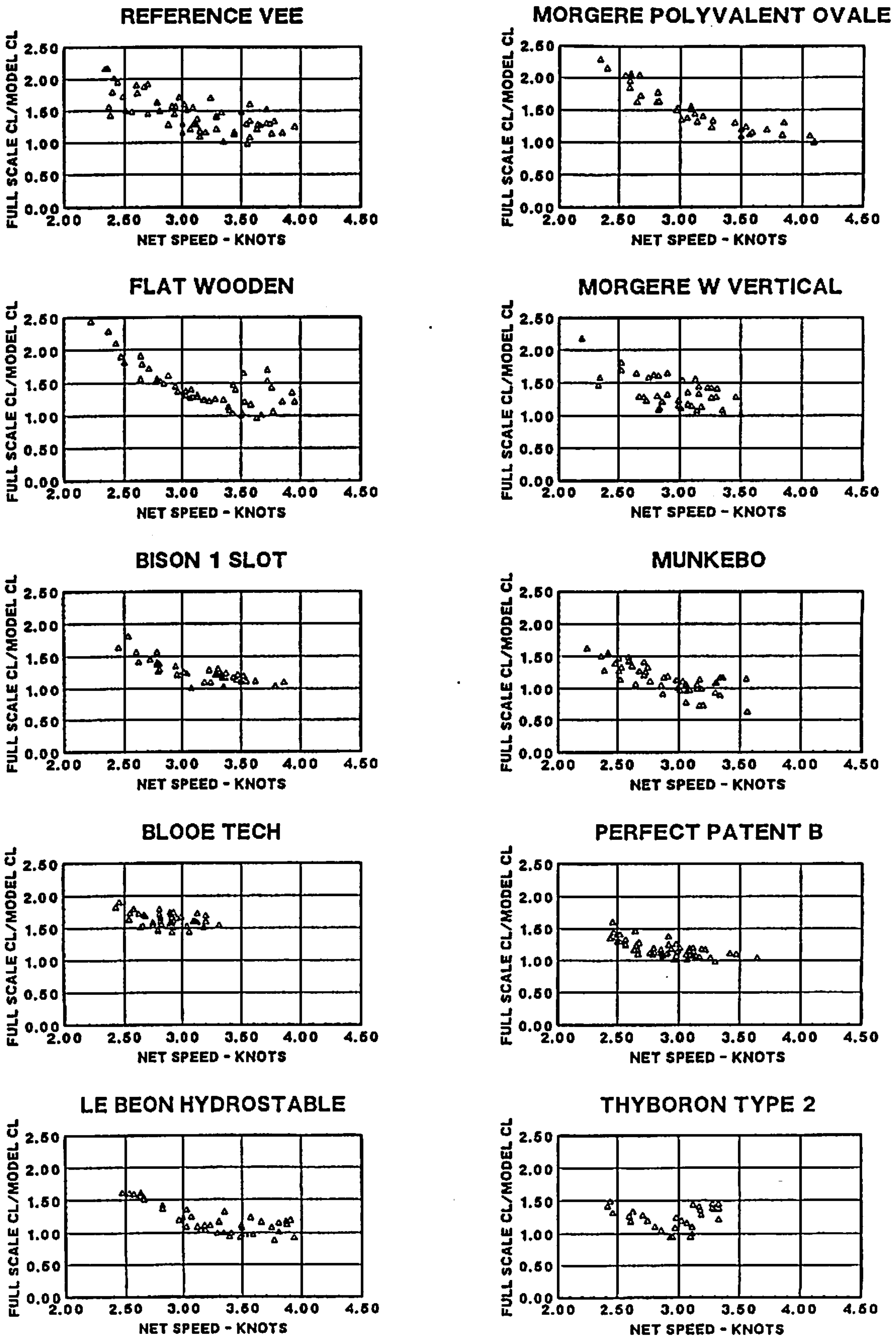


Figure 4.11 - Comparison of Full Scale CL/Model CL Values

Table 4.2
Comparative Results At Lift Off Speed

Otterboard Type	Weight in Water (kg)	Speed at Lift (knots)	C_L (Full Scale)/ C_L (Model)
Reference Vee	255	3.2	1.30
Flat Wooden	220	2.9	1.40
Bison 1 Slot	235	3.0	1.25
Blooe Tech	150	2.6	1.70
Le Béon Hydrostable	235	3.0	1.20
Morgère Polyvalent Ovale	280	3.3	1.25
Morgère W Vertical	245	3.1	1.25
Munkebo	155	2.6	1.30
Perfect Patent B	215.	2.9	1.15
Thyboron Type 2	270	3.2	1.25

Angles of attack were calculated for all otterboards when a comparative value was obtained from the measurements on the shoe at the end of the tow. The method used is that described in Appendix III-11.

Each calculated value was compared to the measured value and Table 4.3 summarises the differences for each otterboard type.

Table 4.3
Calculated Compared to Measured Angle of Attack

Otterboard Type	Angle of Attack		
	Measured	Calculated	Difference (C - M)
Reference Vee	33.0	37.5	4.5
	35.0	40.5	5.5
	37.0	40.5	3.5
Flat Wooden	37.0	42.5	5.5
	40.0	49.0	9.0
Bison 1 Slot	34.0	37.0	3.0
	35.0	36.5	1.5
	38.0	39.5	1.5
Blooe Tech	30.0	32.0	2.0
	35.0	36.0	1.0
Le Béon Hydrostable	33.0	37.0	4.0
Morgère Polyvalent Ovale	36.0	41.0	5.0
	40.0	43.0	3.0
Munkebo	32.0	37.0	5.0
	36.0	39.0	3.0
Perfect Patent B	32.0	37.0	5.0
	40.0	44.0	4.0
	44.0	49.5	5.5
Thyboron Type 2	41.0	46.0	5.0

It can be seen that in all cases the calculated angle of attack is greater than the measured angle by an average of 4°.

The difference between the measured and calculated angles is probably due to the ground contact forces being different to those found in the Flume Tank.

As full size otterboards can dig into the sea bed additional ground contact moves the centre of pressure aft creating a rotating moment which reduces the angle of attack. For an otterboard which is pitched up at the forward end and only maintaining ground contact at the aft end, this rotating moment is even greater causing a larger difference between the measured and calculated angles.

4.2.4 Effect of Changing Warp/Backstrop Attachment

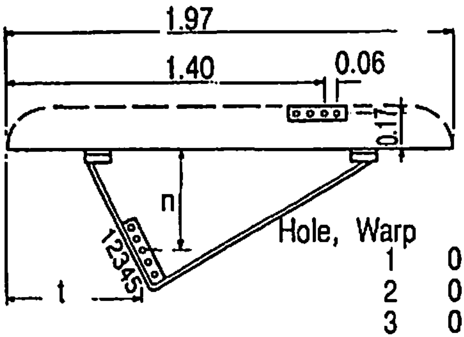
A number of methods for attaching the warp and bridle to an otterboard were described in Section 2.1. Most of the methods described were used during the sea trials.

Having measured the angle of attack of an otterboard at sea and assessed its performance, it may be required to change the angle of attack by a specified amount.

Using a combination of calculated angles of attack and angles of attack measured at sea, changes in angles of attack were assessed for five otterboard types with different warp and bridle attachment methods.

Each of the five types of otterboard were tested during the sea trials programme and measurements of the warp and backstrop attachments are shown in *figs* 4.12-4.16 (all dimensions are in metres).

Reference Vee
Twin backstrops used.
Warp adjustment, for one hole movement away from otterboard increase angle of attack by 3°.
Backstrop adjustment, aft to for'd hole, increases angle of attack by 1° per hole.



Hole, Warp	t	n
1	0.55	0.35
2	0.58	0.41
3	0.61	0.46
4	0.63	0.52
5	0.65	0.57

Figure 4.12 - Reference Vee

Blooe Tech

Twin backstrops used.

Warp adjustment, link 7 to link 8 (move aft), increases angle of attack by 4.5°.

This otterboard has no facility for adjusting the backstrops.

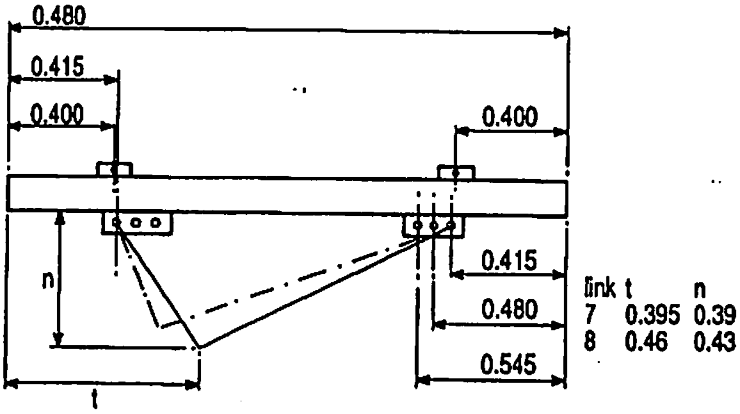


Figure 4.13 - Blooe Tech

Morgère Polyvalent Ovale

Twin backstrops used.

As supplied by the manufacturer it is only possible to adjust the angle of attack by backstrop adjustment.

Backstrop adjustment, aft to for'd hole, increases angle of attack by 1.5° per hole.

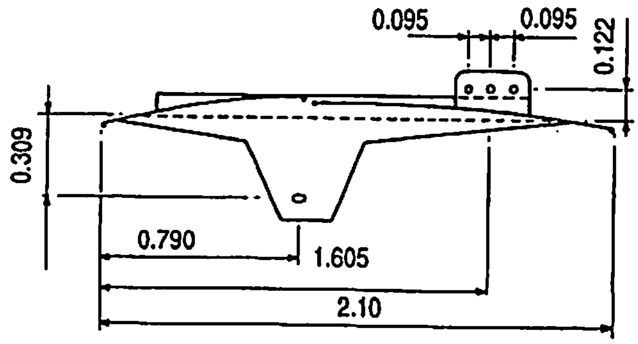


Figure 4.14 - Morgère Polyvalent Ovale

Perfect Patent B

A three chain backstrop system is supplied by the manufacturer and the warp is attached to a towing chain.

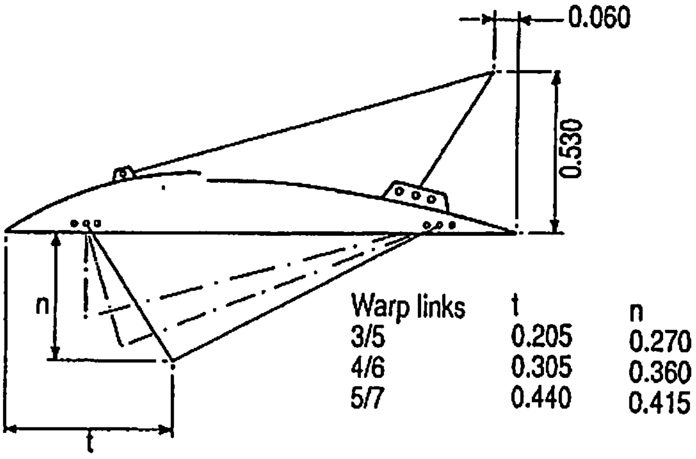
Warp adjustment, links 4/6 to 5/7 (move aft), increases angle of attack by 4°.

> *(Note: warp attached by two link method as in fig 2.2).*

Warp adjustment, links 4/6 to 3/5 (move forward), decreases angle of attack by 7°.

Bridle attachment point on chain, move forward 0.1 metres, increases angle of attack by 2° (i.e. shorten forward chain as in *fig* 2.10).

Bridle attachment point on chain, move in towards otterboard 0.1 metres, decreases angle of attack by 4° (i.e. shorten two aft chains as in *fig* 2.10).



Warp links	t	n
3/5	0.205	0.270
4/6	0.305	0.360
5/7	0.440	0.415

Figure 4.15 - Perfect Patent B

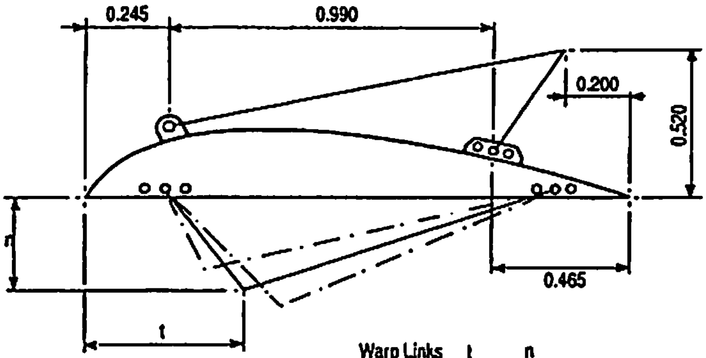
Thyborøn Type 2

Three chain backstrop system supplied with otterboard.
Warp attached to a towing chain.

Warp adjustment, links 4/6 to links 3/5 (move forward), decreases angle of attack by 4°. (Note: warp attached by two link method as in *fig* 2.2).

Bridle attachment point on chain, move forward 0.1 metres, increases angle of attack by 1.5° (i.e. shorten two aft chains as in *fig* 2.10).

Bridle attachment point on chain, move in towards otterboard 0.1 metres, decreases angle of attack by 3° (i.e. shorten two aft chains as in *fig* 2.10).



Warp Links	t	n
3/5	0.320	0.270
4/6	0.410	0.320
5/7	0.520	0.370

Figure 4.16 - Thyborøn Type 2

Note:-
For the Thyborøn Type 2 and Perfect Patent B many other fine adjustment methods are available and are described in Section 2.1.

It can be seen in these examples that movement along a warp bracket or towing chain gives a fairly coarse adjustment to angle of attack. Moving the backstrops forward one hole or the bridle attachment chain forward has a smaller affect on angle of attack and therefore provides a finer adjustment.

4.2.5 Summary of Sea Trials Findings

Overall the sea trials results confirmed otterboard performance trends found in the Flume Tank tests. In particular:

- Otterboard types (cambered, multifoil) which had high C_L values in tank tests also had the highest C_L values at sea.
- Adjusting warp brackets/towing chains produced large changes in angle of attack.
- Adjusting backstrops produced smaller changes (a finer adjustment) of angle of attack.

The different situations at sea:

- The soft seabed condition giving large ground contact forces.
- The increased freedom of the otterboard to take up different pitch angles and heel angles.

These were responsible for:

- The calculated C_L values being much higher at sea due to the large ground contact force contribution.
- These C_L values being up to 100% higher for some otterboards at low speeds.
- But C_L dropping to approximately 25% higher at faster speeds.
- The angle of attack of the otterboards being approximately 4° less than that found in the tank tests due to the otterboard tendancy to be pitched up at the forward end.

4.2.6 Practical Considerations

These points are some of the problems encountered during the trials.

a) Warp Lengths: the marks on warps should be checked to ensure that equal lengths of port and starboard warp are shot. If warp lengths are not equal, the shorter warp will have greater tension tending to make the otterboard on that side lift off the bottom. This may lift the bridle off the bottom losing fish on that side of the gear.

b) Warp/Depth Ratio: sufficient warp should be shot to ensure that the otterboards have adequate sea bed contact. Light otterboards require more warp out to maintain adequate sea bed contact, but on some designs (e.g. wooden flat otterboards) the otterboards can be heeled outwards which gives greater downward force.

c) Matching Otterboards: the port and starboard otterboards should be measured to ensure that they are a matching pair and any warp or bridle chains and attachment points are equal. The height of the warp brackets should be equal to ensure that otterboard heel is the same. The angles of attack of the port and starboard otterboards can be measured as described in Section 4.1.2 to ensure performance is equal.

d) Blocked Slots: slots should be kept clear and free from seaweed, mud and stones. On any otterboard design where the slots are used to improve performance, otterboard spread will generally decrease substantially if the slots are blocked, preventing water flow through the otterboard.

4.3 Shooting Otterboards

The methods given below are intended as a guide only. These can be varied depending upon various factors.

There is a basic difference in shooting traditional vee otterboards (without camber) to all other otterboards. The vee otterboards can be shot without tension on the warps, whereas other otterboard types require tension on the warps at all times.

4.3.1 Flat Wooden and Cambered Otterboards

Shooting flat otterboards is quite straightforward if the vessel speed is adequate and tension is maintained on the warps at all times by hydraulics or application of the brake; this will reduce the tendency for the otterboards to foul or cross each other. If the otterboards are checked (by stopping the winch) soon after they leave the vessel, observation can be made of the spreading performance and towing attitude. A recommended shooting procedure is as follows:-

Bring the vessel up to shooting speed and lower the otterboards into the sea allowing approximately 5 to 10 fathoms (10 to 20m) of warp to run off the winches. At this point stop the winches and observe the otterboards rising in the water. They will appear on the surface after 15 to 20 seconds and both should be riding at the same attitude, heeling in and pitching up at the forward end. If they are radically different from this attitude or to each other, haul them in and check for fouled shackles or a backstrop rigging error on the otterboards. If there is no backstrop rigging error then it is probable that the problem was due to fouled gear. If the otterboards are spreading well and are settled on the surface progressively shoot the otterboards away keeping tension on the warps at all times.

It is recommended to stop the winch for a further 10 to 15 seconds before the otterboards touch the sea bed and before reducing the vessel speed to fishing speed. They will then spread more easily and settle faster on the seabed. If working in water greater than 40 fathoms (80m) it is recommended that in addition the winch is stopped at half distance.

4.3.2 Vee Otterboards without Camber (Stern Trawlers)

Deploy the otterboards over the stern and bring the vessel up to shooting speed. Lower away the otterboards and then stop the winch at a point on the warps 5 to 10 fathoms (10 to 20m) down. The otterboards will rise in the water and appear on the surface after approximately 20 seconds, depending on vessel speed. Both otterboards should be riding at the same attitude, heeling in and slightly pitching up at the forward end. However, if the otterboards show different characteristics, then haul in and look for fouled gear or a rigging error. If the otterboards are showing the correct characteristics proceed to release the brakes and free run the warps off the winches. In water less than 40 fathoms (80m) apply the brakes prior to otterboard contact with the seabed and reduce the vessel to fishing speed.

This will greatly assist in spreading the otterboards and reduce the gear's settling time. In water greater than 40 fathoms (80m) an additional check is recommended at approximately half distance.

4.3.3 Vee Otterboards without Camber (Side Trawlers)

When the net is deployed in the water, turn to starboard and release the fore otterboard. When it is in the water and clear of the ships side apply the brake and allow the otterboard to spread clear of the vessel. Release the aft otterboard and set it just below the surface and clear of the stern. When the vessel is on the correct course increase to shooting speed and release brakes and allow the warps to run out freely. Clip the messenger wire onto fore warp and heave it into the block at around the 100 fathom mark. Proceed then as stern trawler.

4.4 Common Problems Affecting Otterboards

This section is intended to identify the most commonly occurring faults and describe how to correct them.

4.4.1 Incorrect or no Polish on Shoe and Poor Shooting Performance

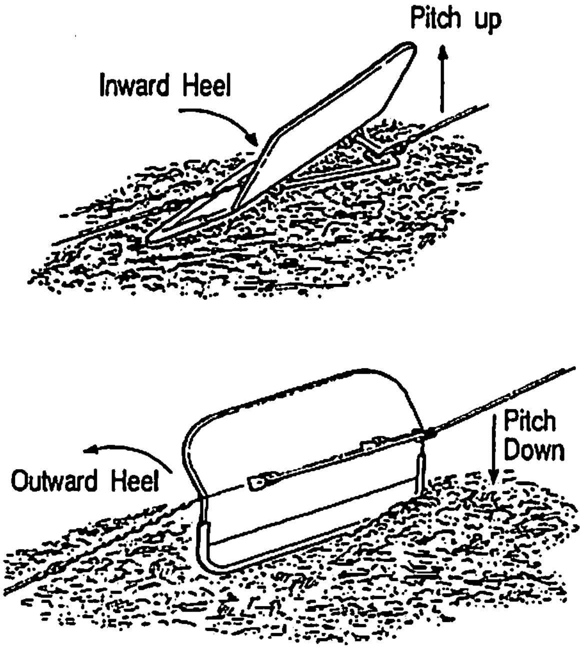
- Towing point incorrectly set for type of seabed (see Section 2.2.2).
- Too much extension in upper backstrops.
- Warps too short for depth of water.
- Towing speed too high.
- Otterboard too light.

4.4.2 Differing Polish Marks on the Shoes of a Pair of Otterboards

- Unequal backstrop chains.
- Backstrops stretched or twisted.
- Towing points on otterboard out of alignment.
- Redundant shackle left in backstrop leg (see Section 2.2.3).
- Otterboards not constructed similarly.
- Length, height and towing point variations between otterboards.
- Towing with one otterboard along a bank or in a gully.

4.4.3 Both Otterboards Heeling in or Out Excessively (see *fig* 4.17)

- Otterboards too heavy or too light for depth of water.
- Warp out incorrect.
- Wrong backstrop rigging arrangement for fishing conditions.
- Towing points incorrectly set for conditions experienced.
- Incorrect towing speed for otterboard rigging.
- Seized or tight pivot points on vee otterboards.



To Correct

(i) use lighter otterboard
(ii) reduce warp out
(iii) change to twin backstrops
- lengthen bottom backstrop
(iv) lower towing point
- if design permits
(v) increase speed

To Correct

(i) increase otterboard weight
(ii) increase warp out
(iii) move towing point up or add shoe to bottom
(iv) reduce speed

Figure 4.17 - Otterboards Heeling in or Out Excessively

4.4.4 Worn Shoes

The rate of shoe wear is dependant on several factors and is covered in Section 2.7. The position of the wear or polish can indicate potential problems. It is usual to see the shoe polish along three quarters of its length; the forward end is rarely worn or polished due to an upward supporting force applied by the warp. As the shoes wear the heel angle of the otterboard will be affected. Adjust the towing point height when necessary (see Sections 2.2.2 and 2.7).

4.4.5 Different Wood

Otterboards constructed with hardwood will be heavier in water than soft woods. Otterboards may require a period of soaking when new or after drying out before they perform correctly.

4.4.6 Bent or Damaged Brackets

This will affect the angle of attack and heel of the otterboard. The damage must be corrected as soon as possible.

4.4.7 Loose or Worn Brackets on Flat Otterboards

The heel of the otterboard will be unpredictable. Shooting may be troublesome.

4.4.8 Worn Pins on Hinged Towing Arms

Towing point height slightly affected depending on warp out. The otterboard will heel progressively inward as more warp is paid out.

4.4.9 Difficult Shooting with Hinged Vee Otterboard, Variable Pitch Experienced

The hinged towing arms should be free to fall under their own weight from the upper face to the lower face. If they are stiff this may well be the cause of the problem.

4.4.10 Running Backstrops

Using large sliding shackles on continuous chain will prevent positive control of the heel angle. After shooting it will lock in a random position and predicting the heel angle will be impossible. Evidence suggests that the shackles do not move during normal fishing operations, but instead they will only be encouraged to move if the otterboard hits large boulders or pinnacles. A roller block is often used instead of a shackle to help overcome the problem.

4.4.11 Incorrect Warp to Depth Ratio

If too much warp is used the otterboard will heel in and the warp in front of otterboard will polish. The result will be poor otterboard spread. If too little warp out is used then the otterboard will pitch up at the forward end and heel out. Again the otterboards will be under spread.

4.4.12 Heavy Wear on Point of Towing Brackets

Considerable wear on both otterboard towing points indicates that:-

- The otterboard is too heavy for the towing speed
- Upper backstrop too long for fishing conditions
- Warp attachment point set too high
- Too much warp out

4.4.13 Heavy Wear on the Point of Bracket of One Otterboard

Possible faults:-

- Upper backstrop too long
- Warp length too long
- Warp attachment point higher or damaged

} on affected side

- Vessel turning continuously to one side

4.4.14 Light Polish on Towing Point

This is frequently found and it is caused during turning or when stopped and hauling in. This is not a problem.

Section 5
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5. Fuel Saving Options

5. Fuel Saving Options

The purpose of this section is to demonstrate how better rigging of an otterboard or the selection of a more efficient type of otterboard can lead to a reduction in the fuel consumption of a trawler.

5.1 Proportion of Trawler Fuel Consumption Due to Otterboards

Studies have been made at sea with full scale trawls and in Flume Tanks with scale models aiming to measure how much of the total drag is due to the different parts of the gear. There is considerable variation depending on trawl size, type of fishing and type of sea bed but a typical breakdown of drag for a bottom trawl would be:

Warps	4%
Otterboards	25%
Floats	3%
Netting	53%
Sweeps and Bridles	7%
Footrope	8%

When towing, approximately 94% of the fuel would be required to tow the trawl and 6% to propel the vessel. There is again tremendous variation depending upon vessel size and type of fishery but typically 70% of the fuel will be used when towing the gear and 30% when steaming to and from grounds etc.

The drag of the otterboards is therefore responsible for a contribution of the order of 16% of the total fuel consumption on a typical trawler trip.

5.2 Potential Savings

5.2.1 Re-rigging an otterboard working at too high an angle of attack

It is not unusual to find otterboards working at angles of attack in excess of 40°. Otterboard drag is high and for most otterboard types (some multislot and multifoil otterboards are exceptions) the otterboard is working at an angle of attack much higher than that which gives the maximum spreading force. Reducing angle of attack saves fuel and for most otterboard types also allows a smaller size of otterboard to be used to give the same gear spread.

To evaluate potential fuel savings, the case of a vee otterboard will be examined by averaging the Flume Tank performance figures for the Reference Vee, Munkebo and Blooe Tech Vee (see Table 5.1).

Table 5.1
Average Performance Figures for Vee Otterboards

Angle of Attack	25°	30°	35°	40°	45°
C_L	1.00	1.07	1.02	0.93	0.88
C_D	0.56	0.69	0.79	0.86	0.94
C_L/C_D	1.79	1.55	1.29	1.08	0.93

As has been explained in Section 3.3.3, when reducing angle of attack and altering otterboard size in order to keep the same spreading force the drag is reduced according to the C_L/C_D ratios.

So reducing from 45° to 35° angle of attack would reduce the otterboard drag to $0.93/1.29 = 72\%$. Otterboard area would be reduced by the ratio of the C_L values to $0.88/1.02 = 86\%$, i.e. reducing length and height by $\sqrt{0.86} = 0.93$, or 93%. To put into perspective this is equivalent to being able to replace a 2.63m (103 inches) long otterboard with one 2.45m (96 inches) long.

> *This 27% saving in otterboard drag would result in an estimated 4% total vessel fuel consumption reduction.*

If angle of attack is reduced below 35° further fuel savings can be achieved as the C_L/C_D value is always higher as the angle is decreased. It is thought that vee otterboards can be operated safely in some fisheries at angles down to 30°. It is claimed that it is possible to sometimes use high aspect ratio otterboards in light bottom contact with high opening bottom trawls and use angles of attack as low as 25°. It has to be emphasised though that reducing to angles of attack as low as this will in most fisheries lead to problems with otterboard stability in shooting, turning, towing in cross currents and towing over rough ground. The potential fuel savings are not large enough to justify risking lost effective fishing time.

5.2.2 Changing to a More Efficient Otterboard Type

It has been shown that otterboards which are cambered, fitted with slots or are of multifoil design have higher C_L/C_D ratios than the more traditional flat and vee designs. They therefore can generate the same spreading force with a lower drag and have the potential to save fuel.

The example of changing from a vee otterboard to a cambered single slot vee otterboard can be considered. Three model cambered vee otterboards of this type were tested in the Flume Tank (the two Thyborøn Type 2 and the Perfect Patent B models). An angle of attack of 35° is chosen. Averaging the results of the three models gives $C_L = 1.49$, $C_D = 0.92$ and $C_L/C_D = 1.62$.

The C_L values are higher for the cambered slotted otterboard so otterboard area can be reduced by the ratio of 1.02/1.49 (using the average vee otterboard C_L value at 35° angle of attack shown in Table 5.1). Area can be reduced to 68% of that of the vee otterboard which would be equivalent to reducing length and height to $\sqrt{0.68}$, i.e. 0.83, or 83% of the vee otterboard. A cambered slotted vee of 2.0m (80 inches) length could replace a normal vee type of 2.45m (96 inches).

The matching of the otterboards' spreading characteristics is critical.

If the normal vee otterboard had above average C_L and C_D values (like the Munkebo model tank tested) the cambered slotted otterboard described above would underspread the gear. Using the Munkebo model tests result of $C_L = 1.26$ at 35° a cambered slotted otterboard of 2.25m (89in) length should have been used. As the otterboard is already working at the angle of attack which gives maximum spreading force it would not be easy to re-rig the gear to increase the spread.

If the normal vee otterboard had below average C_L and C_D values then the gear would be overspread by the cambered slotted otterboard and there would be less than the predicted otterboard drag savings. If the drag of the trawl increased as its spread increased then the end result could in fact be a gear with increased spread but the same drag as the trawl with the original otterboards.

The drag of the otterboards would be reduced by the ratio of their C_L/C_D values, i.e. to 1.29/1.62 = 80% of the normal vee otterboard drag.

> *This 20% otterboard drag saving would lead to an estimated 3% saving in total fuel consumption.*

This is a guideline for the levels of fuel saving that are possible with use of more efficient otterboard types:

- multi-foil
- cambered
- cambered/slotted
- cambered/veed/slotted

5.2.3 Summary

- Better use of otterboards can lead to modest savings in fuel consumption.

- The maximum possible saving would be about 8% in the case where a traditional flat or vee otterboard was being used at too high an angle of attack.

- The main saving in that case would come from reducing to a lower angle of attack of the order of 35°.

- The angle could be further reduced only if no problems were experienced with otterboard stability.

- Further fuel savings could be made by changing from a traditional vee or flat design to a cambered, cambered slotted or multifoil design.

- When changing to a new more efficient otterboard design the skipper must be prepared to give some time to adjusting the rigging of the new otterboards, possibly even testing more than one size, until the correct optimal configuration is found with the ideal otterboard angle of attack, equal gear spread and reduced fuel consumption.

- Data from Flume Tank tests on model otterboards provides valuable information whereby the options and benefits of either changing to more efficient otterboards or re-rigging existing otterboards can be assessed. This leads to much reduced experimentation at sea.

Appendices

Appendix I

Aspect Ratio and Area Ratio of Otterboards Tested

TYPE OF OTTERBOARD	ASPECT RATIO	AREA RATIO
	H/L	A/(H x L)
Reference Vee	0.65	0.98
Flat Wooden	0.50	0.98
Bison 1 Slot	0.63	0.92
Bison 3 Slot	0.63	0.92
Blooe Tech	0.64	0.99
Dan-Green KB	0.62	0.99
Dan-Green SV	0.60	0.99
Euronete "Portuguese"	0.56	0.88
Fjørtoft Multi Foil	0.69	1.00
Hinriksson Poly-Ice	0.68	0.80
Hydrofin Multifoil	0.67	0.99
Le Béon à Roue	0.58	0.87
Le Béon Hydrostable	0.52	0.96
Lindholmen	1.00	0.78
Morgère Polyfoil	0.61	0.94
Morgère Polyvalent Ovale	0.68	0.80
Morgère Polyvalent Type R	0.59	0.90
Morgère W Horizontal	0.52	0.90
Morgère W Vertical	1.33	0.87
Munkebo	0.51	0.97
Net Tec	0.62	0.98
Perfect New Oval	0.66	0.79
Perfect Patent B	0.67	0.96
Thyborøn Type 2 (66in)	0.57	0.99
Thyborøn Type 2 (125in)	0.63	0.99
Vergoz en Z	0.52	0.98

Appendix II

Table of Otterboard Sizes

This table is based on a survey of different types of trawl used by vessels in Denmark, France, the United Kingdom and Ireland. The corresponding otterboard types represent some of the wide range of models available. Those models appearing frequently represent the types commonly used in the respective country.

Country DK for Denmark

UK for United Kingdom divided in: W. Scotland for West Scotland
North Sea
N.North Sea for Northern North Sea
Irish Sea
S.E. Ireland for South East of Ireland
Channel

F for France divided in: Ch. for Channel coast
Atl. for Atlantic coast
Med. for Mediterranean coast

Length of boats, **Length** and **Height** of otterboards are given in metres.

S = L x H is the area of the otterboards (not projected area) in square metres.

Weight of the otterboard is in kilogrammes.

Mesh is the mesh size at the start of the trawl belly (fishing circle). It is the full mesh length (stretched mesh length) in millimetres.

Number M is the number of meshes round the fishing circle. When the mesh sizes are not the same all around, Number M is the equivalent number of meshes in the largest mesh size.

Perimeter is a length in metres equals to: Number M x Mesh Size

Type of Otterboard
Vee = Rectangular Vee
C Vee = Cambered Vee

Type of Trawl
2P = Two panel trawl
4P = Four panel trawl

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
UK-North S	13.7	108	1.67	0.91	1.52	Heortness Flat Vented	-	2P Dual Purpose	90	400	Prawns mixed	36	26.8
UK-North S	10.5	110	1.52	0.98	1.49	Blair Vee	-	Alex Harkness	70	420	Prawns mixed	29.4	36.6
UK-Channel	11	120	1.22	0.76	0.93	Rect. Flat	-	2 Bridle	101	-	Mixed	2	10
F-Chan.	9.4	120	1.6	0.8	1.28	Rect. Flat	120	2P Long Wings	32	148	Shrimps	4.8	13
UK-W.Scot	13.4	127	1.74	1.13	1.97	Vee	-	2 x Dual Purpose	70	520	Mixed	36.4	-
UK-North S	10.4	127	1.52	0.98	1.49	Blair Vee	-	Alex Harkness	70	420	Prawns mixed	29.4	36.8
UK-North S	9.8	135	1.37	0.91	1.25	Bloostech Plastic Vee	-	2P Stuart 402	70	404	Prawns	28.2	29.3
UK-Irish Sea	11	136	1.37	0.76	1.04	Fleetwood Rect. Flat	-	Butterfly 3 Panel	127	381	Mixed	48.4	20.12
UK-North S	11.9	140	1.52	0.98	1.49	Vee	-	Dual Purpose	70	520	Mixed	36.4	26.8
UK-North S	10	145	1.37	0.81	1.11	Dunbar Vee	-	Prawn	70	340	Prawns, white fish	23.8	32.9
UK-North S	10	150	1.52	0.91	1.38	Net Tec - C Vee	-	Prawn	-	-	Prawns, white fish	-	-
UK-North S	16	150	1.83	1.22	2.23	Blair Vee	-	Stuart	90	480	Mixed	43.2	-
DK	13.3	170	1.89	1.05	1.98	Perfect Normal - Vee	150	Star Plaice	120	300	Flat fish	36	25
DK	14.1	170	1.88	1.19	2.24	Thyborøn Type 1 - Vee	246	Plaice	120	400	Flat fish	48	26
DK	14	170	1.98	1.23	2.44	Thyborøn Type 1 - Vee	258	Tobis	800	126	Sandeel	100.8	18
UK-N.North Sea	16.5	172	2	1.5	3	Fleetwood Vee	-	2 Bridle	152	360	Cod, mixed flats	41.2	12.2
UK-Channel	12.2	172	1.83	1.14	2.09	Mel Tod Vee	-	2 Bridle	100	-	Mixed	-	12.1
UK-North S	11	180	1.5	0.91	1.37	Dunbar Vee	-	Stuart Prawn, 20fm	70	404	Roundfish, prawns	28.2	38.4
DK	12	190	1.6	0.9	1.44	Perfect - Vee	120	Arm trawl	120	236	Baltic Cod	28.32	15.9
F-Chan.	11.3	200	1.9	0.95	1.81	Rect. Flat	200	2P Long Wings	140	196	Flatfish & mixed	28	18

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
UK-North S	10	220	1.5	1	1.5	Bison No. 5	-	Caedmon Net	-	400	White fish, prawns	-	-
F-Med	13	220	1.8	1.1	1.98	Morgère Poly Ovale	220	4P Bottom	400	246	Bottom mixed	98.4	34
F-Atl.	15	230	1.6	1	1.6	Morgère V - Vee	200	2P Bottom	70	490	-	34.2	20
DK	13	230	1.88	1.19	2.24	Thyborøn Type 1 - Vee	246	Jordfraeser	120	380	Cod & Haddock	45.6	50
UK-Channel	19.8	230	1.83	1.47	2.69	Blair Vee	-	Dual Purpose	70	520	Haddock	36.4	-
UK-North Sea	17.7	240	1.52	0.91	1.38	Net Tec - C Vee	-	Rockhopper	165	540	Mixed	89.2	24.4
DK	21.6	240	2.23	1.32	2.94	Perfect Normal - Vee	340	Plaice	110	360	Flat Fish	39.6	22
UK-Channel	17	275	1.67	1	1.67	Net Tec - C Vee	-	2 Bridle	140	-	-	-	-
F-Med	16.5	285	1.8	0.9	1.62	Le Beon Hydrostable	200	2P Le Drezen	80	485	Bottom mixed	38.8	25.6
DK	11.9	285	1.25	1.25	1.56	Lindholmen-Spherical	170	Nephrops 2 Tr.Syst	80	400	Nephrops	32	49
DK	17	285	1.74	1.1	1.92	Munkebo - Vee	-	Nephrops	80	500	Nephrops	40	68
DK	16	288	1.98	1.23	2.44	Thyborøn Type 1 - Vee	258	Mathis	300	220	Pout	66	35
UK-North S	10	290	1.37	0.91	1.25	Bison No. 4	-	4P Goshawk	114	400	Round fish	45.8	17.4
UK-North S	10	290	2	1.37	2.74	Vee	-	Prawn Trawl	70	-	White fish, prawns	-	-
DK	14	295	1.74	1.1	1.91	Munkebo - Vee	-	Combi	80	500	Nephrops	40	52
DK	17.2	297	1.74	1.1	1.91	Munkebo - Vee	-	Nephrops 2 Tr. Syst	80	480	Nephrops	38.4	55
DK	13	299	2	1.3	2.6	Laesoe Flat Wooden	-	Nephrops	80	520	Nephrops	41.6	60
F-Atl.	15.86	300	2	1	2	Rect. Flat	220	Irish	70	516	-	36	29.6
DK	17	300	2.32	1.35	3.13	Thyborøn Type 2-C Vee	400	UFO Shrimp High Opening	80	1200	Pink Shrimp	96	37
DK	14.4	300	1.76	1.1	1.94	Thyborøn Type 2-C Vee	235	Nephrops 2 Tr.Syst.	200	220	Nephrops	44	33.4

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
DK	16.3	300	2.5	1.49	3.73	Thyborøn Type 2-C Vee	374	Sputnik High Opening	80	1200	Pink Shrimp	96	38.75
UK-North S	-	318	1.7	1.22	2.07	Bison	-	-	114	450	Round, mixed flats	51.4	-
UK-W.Scot	18.9	320	1.75	1.15	2.01	Bison	-	2P, Boris x 2	70	420	Prawns	29.4	-
F-Atl.	15.48	325	1.8	1.15	2.07	Morgère VH - Vee	330	Irish	80	632	-	42.6	34.2
F-Atl.	15.3	330	1.75	1.05	1.84	Morgère Poly R	200	Irish	80	512	-	41	43.6
F-Atl.	15.3	330	1.9	1.1	2.09	Morgère Poly R	350	2 Trawl System	80	360	-	28.8	16
UK-Channel	16.4	330	1.67	0.91	1.52	Net Tec - C Vee	-	4P High Lift	150	330	Mixed	49.4	17.75
DK	20	330	2.13	1.16	2.47	Perfect Norm - Vee	240	Plaice	120	400	Flat Fish	48	26
DK	23	330	1.98	1.23	2.44	Thyborøn Type 1 - Vee	258	Fladen Shrimp Low Opening	34	1600	Pink Shrimp	54.4	59
F-Atl.	17	340	2	1	2	Rect. Flat	240	4P Bottom	80	678	-	54.2	17.7
DK	17.6	344	2.06	1.27	2.62	Thyborøn Type 2-C Vee	340	Butterfly	120	468	Pout	56.2	32
F-Atl.	16	350	1.6	0.8	1.28	Rect. Flat	180	Irish	70	516	-	36	29.6
F-Atl.	16.9	350	1.6	0.9	1.44	Morgère Poly R	220	2P Bottom	90	428	-	38.6	26.8
F-Atl.	15.3	350	1.5	0.75	1.13	Rect. Flat	150	Irish	70	516	-	36	29.6
F-Atl.	15	350	1.7	0.85	1.45	Rect. Flat	200	4P, 2 Trawl System	70	364	-	25.4	12.6
F-Atl.	16	350	1.8	0.9	1.62	Le Beon Hydrostable	210	2P Bottom	80	534	-	42.8	18
F-Atl.	15.8	350	1.8	1	1.8	Morgère Poly R	300	2 Trawl System	90	332	-	29.8	16.5
F-Atl.	15.9	350	1.8	1	1.8	Morgère Poly R	330	Irish	80	576	-	46	37
F-Atl.	16	350	1.8	0.9	1.62	Rect. Flat	200	2 Trawl System	70	460	-	32.2	14.5
F-Atl.	16.33	360	1.9	1.1	2.09	Morgère Poly R	300	2 Trawl System	100	280	-	28	13.8

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
UK-North S	9.8	365	2	1.27	2.54	Cringle Vee	-	White Fish	159	500	White fish, prawns	79.4	47.5
DK	15.5	365	1.4	1.4	1.96	Lindholmen - Spherical	-	Nephrops 2 Tr.Syst.	70	456	Nephrops	31.9	60
DK	20	365	2.14	1.32	2.82	Thyborøn Type 1 - Vee	287	Straeber	1620	80	Sandeel	130	27
DK	19.51	365	2.25	1.54	3.46	Perfect Patent B - C Vee	480	Steevsuger	120	560	Pout	67.2	22
DK	19.5	365	2.25	1.54	3.46	Perfect Patent B - C Vee	480	Millionair	1600	80	Sandeel	128	30
F-Atl.	15	367	1.7	0.85	1.45	Rect. Flat	200	4P, 2 Trawl System	70	364	-	25.4	12.6
F-Atl.	15	367	1.61	1.01	1.63	Thyborøn Type 2-C Vee	200	Irish	70	284	-	20	32
DK	19	370	2.13	1.18	2.51	Perfect Pat - Vee with slot	-	Nephrops 2 Tr.Syst.	80	400	Nephrops	32	59
DK	17.6	370	2.5	1.49	3.73	Thyborøn Type 2-C Vee	374	Sputnik High Opening	80	1400	Pink Shrimp	112	39.75
UK-North S	17.1	375	2	1.32	2.64	Hinrikkson Poly-Ice	500	Balloon	150	-	Round fish	2	21.3
F-Atl.	16.43	380	1.9	1.1	2.09	Morgère Poly R	300	Irish	70	516	-	36	29.6
F-Med	16.2	380	2	1	2	Le Béon Hydrostable	330	4P Bottom Low Side	80	470	Hake, bottom mixed	75.2	36
F-Med	17.4	380	1.9	1.1	2.09	Morgère Polyfoil	280	2P Le Drezen	90	513	Bottom mixed	46	26.5
DK	20.5	385	2.14	1.32	2.82	Thyborøn Type 1 - Vee	287	Combi	114	460	Flat fish	55.2	49
F-Atl.	15	400	1.76	1.1	1.94	Thyborøn Type 2-C Vee	230	4P, 2 Trawl System	70	460	-	32.2	14.5
F-Atl.	16	400	1.76	1.1	1.94	Thyborøn Type 2-C Vee	200	Irish	70	284	-	20	32
DK	26	400	2.55	1.75	3.36	Perfect Patent B - C Vee	640	Wide Body Shrimp High Opening	80	1500	Pink Shrimp	120	50
DK	19.4	408	2.14	1.32	2.82	Thyborøn Type 1 - Vee	287	Nephrops 2 Tr.Syst.	80	436	Nephrops	34.9	50
DK	18.96	408	2.04	1.1	2.24	Munkebo - Vee	-	Arm trawl	120	268	Baltic Cod	32.16	18.2
F-Atl.	17.5	410	2.4	1.2	2.88	Rect. Flat	400	Irish	90	554	-	50	40

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
F-Atl.	16.75	414	1.75	1.05	1.84	Morgère Poly R	200	2 Trawl System	90	352	-	31.8	18
F-Chan.	18.5	414	2.2	1.1	2.42	Rect. Flat	475	GOV	120	276	Mixed	32	21
UK-N.North Sea	18.1	415	2.28	1.47	3.35	Dunbar Vee	-	2P	159	520	Round fish	82.6	42.7
UK-W.Scot	19.8	415	2	1.3	2.6	Dunbar Vee	-	Twin Trawl	70	600	Mixed	42	51.2
F-Atl.	16	420	1.8	0.9	1.62	Rect. Flat	220	4P, 2 Trawl System	70	460	-	32.2	14.5
UK-N.North Sea	13.3	425	2.18	1.45	3.16	Dunbar Vee	-	Dual Purpose x 2	70	620	Prawns	43.4	43.3
F-Atl.	19.5	430	2.4	1.2	2.88	Rect. Flat	400	High Opening Bottom	80	480	-	38.4	24.5
F-Atl.	15	430	1.8	0.9	1.62	Rect. Flat	220	High Opening Bottom	80	534	-	42.8	18
F-Med	22.5	430	2.2	1.1	2.42	Morgère Polyfoil	450	4P Bottom,Low Side	160	480	Bottom mixed	76.8	35
F-Med	18.6	430	2.2	1.2	2.64	Morgère Polyfoil	380	4P Bottom,Low Side	400	-	Bottom mixed	-	-
F-Atl.	16.95	440	1.8	1	1.8	Morgère Poly R	280	2P Bottom	70	516	-	36	26.8
F-Atl.	16	440	2	1	2	Rect. Flat	240	High Opening Bottom	80	534	-	42.8	18
F-Atl.	19.5	440	2.1	1.05	2.21	Rect. Flat	320	2P Bottom	90	440	-	39.6	27.8
F-Atl.	16	440	1.6	0.8	1.28	Rect. Flat	200	4P Bottom	70	620	-	43.4	22
F-Atl.	18.5	450	2.3	1.15	2.65	Rect.Flat	420	2 Trawl System	100	320	-	32	19.2
F-Atl.	16	450	1.7	0.85	0.85	Rect. Flat	220	2 Trawl System, 4P	70	462	-	32.4	16.6
F-Chan.	15.5	450	2.4	1.2	2.88	Rect. Flat	600	4P Bottom	100	140	Bottom mixed	14	-
F-Atl.	19	477	2	1.27	2.54	Morgère VH - Vee	330	2P Bottom	90	380	-	34.2	20
DK	27.6	477	2.14	1.32	2.82	Thyborøn Type 1 - Vee	287	Fladen Shrimp 2 Trawl Syst.	40	1448	Pink Shrimp	57.9	63
F-Atl.	20.55	480	1.9	1.1	2.09	Morgère Poly Ovale	250	2P Bottom	80	496	-	39.8	31.35
F-Atl.	20.6	480	2	1.1	2.2	Morgère Poly R	350	High Opening Bottom	90	448	-	40.4	27.8

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
DK	25.2	480	2.14	1.32	2.82	Thyborøn Type 1 - Vee	287	Fladen Shrimp Low Opening	34	1700	Pink Shrimp	57.8	63
DK	24	490	2.32	1.35	3.13	Thyborøn Type 2-C Vee	400	TV 2 Trawl System	110	460	Nephrops	50.6	37
UK-W.Scot	15.5	495	2.33	1.76	4.1	Bison	-	2P Boris	203	400	Mixed	81.2	41.1
F-Atl.	20.4	497	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
F-Atl.	20.6	500	2.5	1.25	3.13	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
F-Atl.	20.6	500	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
F-Atl.	20.5	500	2.3	1.15	2.65	Rect. Flat PE	530	2 Trawl System	100	352	-	35.2	25.7
F-Atl.	21.9	500	1.9	0.95	1.81	Vergoz Z	380	2P Bottom	90	496	-	44.6	31.35
UK-N.North Sea	18.3	500	-	-	2.9	Dangren KB	-	Scraper Seaway	70	275	Mixed	19.2	36.6
DK	22	500	2.32	1.35	3.13	Thyborøn Type 1 - Vee	305	Combi	114	500	Cod and Haddock	57	59
DK	22	500	2.32	1.35	3.13	Thyborøn Type 1 - Vee	305	TV 2 Trawl System	110	310	Flat Fish	34.1	25
DK	20.1	500	2.06	1.27	2.62	Thyborøn Type 1 - Vee	270	Nephrops 2 Tr.Syst.	114	370	Nephrops and Fish	42.2	54
DK	24.1	500	2.32	1.35	3.13	Thyborøn Type 1 - Vee	305	Combi 2 Trawl Syst.	80	500	Nephrops and Fish	40	50
DK	25.1	500	2.92	1.93	5.64	Thyborøn Type 1 - Vee	628	Straeber	3200	68	Sandeel	218	50
UK-SE Ireland	22.9	500	2.13	1.37	2.92	Kilkeel	-	Twin Swanet	80	470	White fish	37.6	-
UK-Irish Sea	22.9	503	2.15	1.37	2.95	Dunbar	-	Twin Prawn Trawl	70	484	Prawns	34	42.1
F-Atl.	22	510	2	2.55	5.1	Morgère WV	860	4P Bottom	100	622	-	62.2	27
F-Atl.	20.6	520	2.4	1.4	3.36	Morgère Poly R	500	2 Trawl System	100	352	-	35.2	25.7
UK-N.North Sea	16.4	520	2.28	1.52	3.47	Dunbar	-	2P	152	500	Mixed	76.2	-
F-Atl.	20.5	530	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
F-Atl.	22.05	530	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
UK-North S	20.7	530	2.13	1.37	2.92	Cringle Vee	-	3P Concorde	150	-	Mixed	-	24.4
DK	30.6	530	2.55	1.85	4.72	Perfect Patent B-C Vee	660	Sputnik High Opening	80	1600	Pink Shrimp	128	49
UK-N.North Sea	18.6	535	2.44	1.52	3.71	Thyboron Type 2 - C Vee	-	Hopper Trawl	203	400	Mixed	81.2	34.1
UK-N.North Sea	19.5	535	2.13	1.37	2.92	Dunbar	-	Seaway	70	620	Cod, Haddock	43.4	57.3
F-Atl.	19.5	545	2.2	1.4	3.08	Morgère V - Vee	400	4P Bottom	90	618	-	55.6	24.1
UK-N.North Sea	19.5	554	2.73	1.95	5.32	Bison	-	Seaway	200	394	-	78.8	38.1
DK	34.9	560	2.1	1.43	3	Dangren KB	430	Nephrops 2 Tr.Syst.	120	500	Nephrops and Fish	60	41
DK	34.9	560	2.1	1.43	3	Dangren KB	430	Fladen Shrimp 2 Trawl Syst.	40	1450	Pink Shrimp	58	64
UK-W.Scot	22.9	565	2.23	1.4	3.12	Thyboron Type 2-C Vee	-	Wingless	60	660	Mixed	39.6	-
UK-North S	19.5	570	2.13	1.42	3.02	Bison No. 9.5	-	4P Swan Net	150	510	Round fish	76.4	29.9
F-Atl.	26	575	2.4	1.2	2.88	Rect. Flat	700	High Opening Bottom	110	404	-	44.4	23
F-Atl.	26	575	2.4	1.2	2.88	Rect. Flat	740	2P Bottom	90	584	-	52.6	24
DK	26.2	575	2.92	1.93	5.64	Thyboron Type 1 - Vee	628	Stoveuger	200	480	Cod and Haddock	96	60
DK	25.6	575	2.28	1.29	2.94	Dangren KB	430	TV 2 Trawl System	110	480	Nephrops and fish	52.8	47
F-Atl.	23.7	600	2.6	1.3	3.38	Rect. Flat	600	2 Trawl System	110	340	-	37.4	27
F-Atl.	24.02	600	2.6	1.3	3.38	Rect. Flat	600	2 Trawl System	110	352	-	38.8	28
F-Atl.	23.7	600	2.6	1.3	3.38	Rect. Flat	600	High Opening Bottom	100	380	-	38	30
F-Atl.	23.45	600	2.6	1.3	3.38	Rect. Flat	650	2 Trawl System	110	352	-	38.8	28
F-Atl.	24	600	2.6	1.3	3.38	Rect. Flat	600	2 Trawl System	110	290	-	32	28

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
F-Atl.	23.7	600	2.6	1.3	3.38	Rect. Flat	600	2 Trawl System	110	290	-	32	22
F.Atl.	20	600	2.1	1.05	2.21	Rect. Flat	400	Irish	80	600	-	48	51
F-Atl.	24.95	600	2.3	1.9	4.37	Thyboron Type 2-C Vee	600	2 Trawl System	110	400	-	44	21
F-Atl.	22.85	600	2.4	1.2	2.88	Rect. Flat	600	2P Bottom	90	484	-	43.6	32
F-Atl.	24.9	600	2.5	1.49	3.73	Thyboron Type 2-C Vee	600	2 Trawl System	110	400	-	44	21
F-Med	24.9	600	2.4	1.2	2.88	Le Beon Hydrostable	700	4P Bottom	800	193	Bottom mixed, Hake	154	54
F-Med	24.9	600	2.6	1.3	3.38	Le Beon Hydrostable	800	4P Bottom Low Side	200	660	Hake, bottom mixed	132	70
F-Med	24.9	600	2.7	1.35	3.65	Le Beon Hydrostable	700	4P Bottom	400	398	Hake, bottom mixed	159.2	49
F-Med	24.9	600	2.4	1.4	3.36	Morgère Poly Ovale	650	4P Bottom	400	450	Bottom mixed	180	45
F-Med	24.9	600	2.3	1.3	2.99	Morgère Poly Ovale	600	4P Bottom	400	390	Hake, bottom mixed	156	41
F-Med	24.9	600	2.4	1.4	3.36	Morgère Poly Ovale	700	4P Bottom	1600	134	Hake, mackerel, sardina	214	80
F-Chan	23	600	2.75	1.5	4.13	Morgère Poly Ovale	750	Cascadeur	200	440	Bottom mixed	88	35
F-Med	24.9	600	2.4	1.3	3.12	Morgère Poly R	700	4P Bottom	1600	134	Hake, mackerel, sardina	214	80
F-Med	24.9	600	2.6	1.45	3.77	Morgère Polyfoil	800	4P Bottom	800	199	Hake, bottom mixed	160	70
F-Med	24.9	600	1.55	2.1	3.26	Morgère WV	750	4P Bottom, low side	200	660	Hake, bottom mixed	132	70
F-Chan	20	600	2.8	1.4	3.92	Rect. Flat	800	Cascadeur	160	268	Bottom mixed	42.8	15

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
DK	33.6	600	3.05	2.03	6.19	Thyboron Type 2-C Vee	970	Sputnik Shrimp - High Op.	80	1800	Pink Shrimp	144	58
DK	29.7	600	3.05	2.03	6.19	Thyboron Type 2-C Vee	970	Millionair	9600	34	Sandeel	326	70
DK	27.9	600	2.76	1.76	4.86	Thyboron Type 1 - Vee	458	Expo	80	750	Pout	60	28
DK	29.7	610	3.05	2.03	6.19	Thyboron Type 1 - Vee	725	Straeber	3200	88	Sandeel	282	61
DK	29.7	610	3.05	2.03	6.19	Thyboron Type 2 - Vee	725	Combi trawl	100	800	Pout	80	35.6
DK	29.7	610	3.05	2.03	6.66	Perfect - Vee	-	Boretaarn	3200	96	Sandeel	307.2	82.2
F-Atl.	23.45	615	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
F-Atl.	22.5	618	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
F-Atl.	24	618	2.4	1.2	2.88	Vergoz Z	650	Irish	100	544	-	54.4	49.6
F-Atl.	24.4	620	2.5	1.25	3.13	Rect. Flat	800	2P Bottom	90	496	-	44.6	32
F-Atl.	23.95	620	2.3	1.15	2.65	Rect. Flat	450	2 Trawl System	100	352	-	35.2	25.7
DK	19.5	630	2.32	1.35	3.13	Thyboron Type 2-C Vee	400	Combi 2 Trawl Syst.	115	500	Nephrops and fish	57.5	49
F-Chan.	24	633	2.9	1.6	4.64	Morgère Poly Ovale	875	Cascadeur	200	410	Bottom mixed	82	28
F-Atl.	24.4	650	2.5	1.4	3.5	Rect. Flat	750	2P Bottom	90	496	-	44.6	32
F-Atl.	23.61	650	2.6	1.5	3.9	Morgère Poly R	680	Irish	120	408	-	49	42
DK	33.6	650	2.32	1.35	3.13	Thyboron Type 2-C Vee	400	Combi 2 Trawl Syst.	114	570	Flat fish and round fish	65	62
DK	33.6	650	2.92	1.93	5.64	Thyboron Type 1 - Vee	628	Jordfraeser	120	600	Cod and Haddock	72	60
DK	35.7	660	1.5	1.5	2.25	Lindholmen - Spherical	-	Fladen Shrimp 2 Trawl Syst.	40	1448	Pink Shrimp	57.9	63
DK	17.7	660	2.06	1.27	2.62	Thyboron Type 1-Vee	270	Fladen Shrimp 2 Trawl System	34	1500	Pink Shrimp	51	59

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
UK-N.North Sea	24	690	2.92	1.93	5.64	Thyborøn Type 2-C Vee	-	2P, High Lift Balloon	203	620	-	126	51.8
DK	29.3	690	2.92	1.93	5.64	Thyborøn Type 1 - Vee	628	Plaice	120	500	Flat fish and round fish	60	55
F-Atl.	32	692	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.6	26
F-Med	24.9	700	2.6	1.3	3.38	Le Beon Hydrostable	820	4P Bottom	800	270	Hake, Bottom mixed	216	60
DK	32.5	700	2.92	1.93	5.64	Thyborøn Type 2-C Vee	628	Sputnik High Opening	80	1600	Pink Shrimp	128	49
F-Atl.	20.6	707	2.5	1.59	3.98	Morgère V - Vee	800	High Opening Bottom	100	416	-	41.6	27.6
DK	34.2	710	2.06	1.27	2.62	Thyborøn Type 2-C Vee	340	Fladen Shrimp 2 Trawl Syst.	40	1448	Pink Shrimp	57.9	63
F-Atl.	23.95	715	2.6	1.3	3.38	Vergoz Z	800	High Opening Bottom	100	452	-	45.2	26
F-Atl.	33.25	750	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	31	750	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.6	26
UK-W.Scot	24.4	750	2.33	1.76	4.1	Bison	-	Wingless Bobbin	120	660	White fish	79.2	-
DK	38.8	750	3.1	2.15	6.66	Perfect - Vee	-	Expo	100	872	Pout	87.2	45.6
F-Atl.	33	770	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.6	26
DK	25.9	770	2.45	1.68	4.12	Perfect Pat.B - C Vee	600	Combi 2 Trawl Syst.	110	500	Nephrops and fish	55	55
DK	34.8	770	3.37	2.2	7.41	Thyborøn Type 1 - Vee	862	Combi	100	900	Pout	90	41
DK	34.8	770	3.37	2.2	7.41	Thyborøn Type 1 - Vee	862	High Speed	3200	104	Sandeel	333	51
DK	25.9	770	2.45	1.8	4.41	Perfect Patent B-C Vee	620	Combi 2 Trawl Syst.	110	548	Nephrops and fish	60.28	66
DK	32.1	785	2.57	1.6	4.11	Thyborøn Type 2-C Vee	490	TV 2 Trawl System	110	560	Nephrops	61.6	43
DK	34.2	785	2.85	1.9	5.42	Perfect Special - Vee	725	Combi	100	760	Pout	76	43

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
DK	34.2	785	2.06	1.27	2.62	Thyboron Type 2-C Vee	340	Nephrops 2 Tr.Syst.	110	480	Nephrops	52.8	86
DK	26.5	785	3.05	2.03	6.19	Thyboron Type 2-C Vee	970	Arm trawl	120	628	Baltic Cod	75.36	27.1
UK-N.North Sea	24.1	795	3.35	2.21	7.4	Morgère Poly Ovale	1300	High Lift (Sinclair)	159	575	Mixed	91.2	45.7
UK-N.North Sea	23.8	795	3.05	1.9	5.8	Hinriksson Poly-Ice	-	Seaway	159	520	Haddock, Cod	82.6	39
F-Atl.	33	800	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.8	26
F-Atl.	34	800	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	480	-	52	28
F-Atl.	24	800	2.5	1.49	3.73	Thyboron Type 2-C Vee	620	Irish	120	418	-	50.2	56
F-Atl.	34	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	34	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	32.8	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	34	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	32.8	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	34	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	34	800	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	32.8	800	2.5	1.59	3.98	Morgère V - Vee	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	34	800	2.6	1.6	4.16	Morgère WH	700	Enlarged CC Bottom	100	536	-	53.6	35
DK	33.6	800	2.95	1.9	5.61	Perfect Special - Vee	750	Combi	100	800	Pout	80	36
DK	31.8	800	3.37	2.2	7.41	Thyboron Type 2-C Vee	1280	Albatros	200	540	Cod and Haddock	108	65
DK	28	816	2.55	1.47	3.75	Dangren SV - C Vee		Combi 2 Trawl Syst.	110	548	Nephrops and fish	60.28	66
DK	30.9	828	2.57	1.60	4.11	Thyboron Type 2-C Vee	490	Combi 2 Trawl Syst.	115	500	Nephrops and fish	57.5	49
F-Atl.	17	832	1.88	1.19	2.24	Thyboron Type 2-C Vee	250	4P Bottom	70	584	-	39.4	28.15

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
F-Atl.	33	850	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.6	26
F-Atl.	33	850	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.6	26
UK-W.Scot	24.4	850	2.58	1.85	4.77	Bison	-	Gundry, Twin	90	420	Mixed	37.8	-
DK	29.7	850	3.2	2.11	6.75	Thyboron Type 2-C Vee	1074	Albatros	200	540	Cod and Haddock	108	65
DK	34.1	850	3.37	2.2	7.41	Thyboron Type 2-C Vee	1280	Millionair	12800	32	Sandeel	410	100
UK-W.Scot	24.4	850	2.44	1.6	3.9	Dunbar Vee	-	Swan net, Twin	90	420	Mixed	37.8	-
F-Atl.	23	893	2.4	1.2	2.88	Rect. Flat	700	2P Bottom	110	460	-	50.6	26
F-Atl.	34	900	2.6	1.3	3.38	Rect. Flat	950	4P Bottom	110	460	-	50.6	26
DK	39.7	900	3.2	2.1	6.72	Perfect - Vee	-	Jordfraeser	200	476	Pout	95.2	44
DK	39.5	930	3.75	2.5	9.38	Thyboron Type 2-C Vee	1660	Boeretaan	3200	136	Sandeel	435	130
DK	33.6	940	2.57	1.6	4.11	Thyboron Type 2-C Vee	490	Combi 2 Trawl Syst.	110	500	Nephrops and fish	55	66
DK	33.6	960	3.1	2.15	6.66	Perfect - Vee	-	Combi trawl	100	900	Pout	90	39.4
DK	33.6	960	3.1	2.15	6.66	Perfect - Vee	-	Boretaam	3200	96	Sandeel	307.2	82.2
F-Atl.	34.76	1000	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	34.76	1000	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	35.4	1000	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	32.8	1000	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	32.8	1000	2.8	1.5	4.2	Morgère Poly Ovale	850	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	29	1000	2.6	1.3	3.38	Rect. Flat	950	2P Bottom	110	460	-	50.6	26
DK	34.8	1075	3.61	2.39	8.82	Thyboron Type 2-C Vee	1520	Millionair	3200	144	Sandeel	460.8	132.4
DK	35	1100	3.7	2.55	9.44	Dangren KV - C Vee	-	Millionair	6400	55	Sandeel	352	57

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
DK	42.3	1100	3.75	2.5	9.38	Thyborøn Type 2-C Vee	1660	Butterfly	400	372	Pout	148.8	52
DK	49.5	1100	3.61	2.39	8.63	Thyborøn Type 2-C Vee	1520	Butterfly	400	318	Pout	127.2	52
DK	37.8	1100	3.75	2.5	9.38	Thyborøn Type 2-C Vee	1660	Tobis Turbo	3200	120	Sandeel	384	130
DK	39.7	1100	3.61	2.39	8.82	Thyborøn Type 2 - Vee	1520	Combi trawl	400	288	Pout	115.2	49
DK	39.5	1100	3.61	2.39	8.82	Thyborøn Type 2-C Vee	1520	Boretaarn	3200	144	Sandeel	460.8	132.4
DK	39.7	1100	3.61	2.39	8.82	Thyborøn Type 2-C Vee	1520	Millionair	6400	68	Sandeel	435.2	81
F-Atl.	38	1190	2.9	1.85	5.37	Morgère WH	950	Enlarged CC Bottom	100	536	-	53.6	35
F-Atl.	38	1190	2.9	1.85	5.37	Morgère WH	950	Enlarged CC Bottom	100	536	-	53.6	35
F-Chan.	39	1400	3.1	1.8	5.58	Morgère Poly Ovale	1400	GOV Boul	150	582	Bottom mixed	87.3	33.7
F-Atl.	38	1500	3	1.8	5.4	Morgère Poly R	1100	High Opening Bottom	110	494	-	54.4	32
F-Atl.	38	1500	3	1.8	5.4	Morgère Poly R	1100	High Opening Bottom	110	494	-	54.4	32
DK	43.3	1550	3.75	2.5	9.38	Thyborøn Type 2-C Vee	1660	Millionair	12800	38	Sandeel	486	110
UK-North S	108	1750	3.75	2.3	8.63	Poly Ice	-	Balloon (Sinclair)	159	545	Round fish, pelagic	86.6	48.2
F-Atl.	58	1800	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	550	-	68.2	42.7
F-Atl.	58	1800	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	550	-	68.2	42.7
F-Atl.	58	1800	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	550	-	68.2	42.7
F-Atl.	58	1800	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	550	-	68.2	42.7
UK-W.Scot	39	1800	3.2	2.38	7.62	J. Davis Delta - C Vee	-	Gundry Wingless Bobbin	150	526	Mixed	78.8	53
UK-W.Scot	39	1800	3.25	2.21	7.18	J. Davis Delta - C Vee	-	4P Bobbin	100	620	Mixed	62	46.3
F-Atl.	52	2000	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	530	-	65.8	38.5
F-Atl.	54	2000	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	110	596	-	65.6	38.5

COUNTRY	BOAT		OTTERBOARD					TRAWL					
	Length	*HP*	*Length*	*Height*	*S=LxH*	*Type*	*Weight*	*Type of Trawl*	*Mesh*	*Number M*	*Species*	*Perimeter*	*Headline*
F-Atl.	54	2000	3.25	1.95	6.34	Morgère Poly R	1500	2P Bottom	120	548	-	65.8	38.5
F-Atl.	52	2000	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	530	-	65.8	38.5
F-Atl.	52	2000	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	530	-	65.8	38.5
F-Atl.	52	2000	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	110	596	-	65.6	35.5
F-Atl.	52	2000	3.2	1.9	6.08	Morgère Poly R	1400	2P Bottom	124	530	-	65.8	38.5
F-Atl.	54	2000	3.25	1.95	6.34	Morgère Poly R	1500	2P Bottom	110	596	-	65.6	38.5
F-Chan.	50	2000	3.25	1.95	6.34	Morgère Poly Ovale	1500	GOV Boul	150	582	Bottom mixed	87.3	33.7
F-Chan.	50	2000	3.2	1.9	6.08	Morgère Polyfoil	1400	GOV Boul	150	582	Bottom mixed	67	33.7
F-Atl.	54	2200	3.25	1.95	6.34	Morgère Poly R	1500	2P Bottom	110	596	-	65.6	38.5
F-Atl.	54	2200	3.25	1.95	6.34	Morgère Poly R	1500	2P Bottom	140	552	-	77.2	33.7

Appendix III

Formulae and Methods used in Model Test Calculations and Application of Data

Contents

1. Resolution of Forces

The performance of each model otterboard was assessed by calculating the spreading and drag forces. To achieve this, the tensions in the warp and bridle were resolved into components. By adding the y components of the warp and bridle the spreading force was obtained. Similarly, if the x component of the bridle was subtracted from the x component of the warp, the otterboard drag was obtained.

Due to different measuring equipment being available at the three Flume Tanks, two methods were used to measure the geometry of the warp and bridles. However, each method gives exactly the same results.

Method 1

The tensions in the warp and the bridle attached to the otterboard are resolved into x, y, z components. *See Fig 1.1* for description of the parameters.

W: Tension in warp
L_w: Length of warp
y_w: Transverse distance between forward towing point and otterboard
z_w: Vertical distance between forward towing point and otterboard

Vertical force component in warp:

$$W_z = W \times (z_w/L_w)$$

Transverse force component in warp:

$$W_y = W \times (y_w/L_w)$$

Longitudinal force component in warp:

$$W_x = \sqrt{(W^2 - W_y^2 - W_z^2)}$$

B : Tension in bridle
L_b: Length of bridle
y_b: Transverse distance between aft towing point and otterboard
z_b: Vertical distance between aft towing point and otterboard

Vertical force component in bridle:

$$B_z = B \times (z_b/L_b)$$

Transverse force component in bridle:

$$B_y = B \times (y_b/L_b)$$

Longitudinal force component in bridle:

$$B_x = \sqrt{(B^2 - B_y^2 - B_z^2)}$$

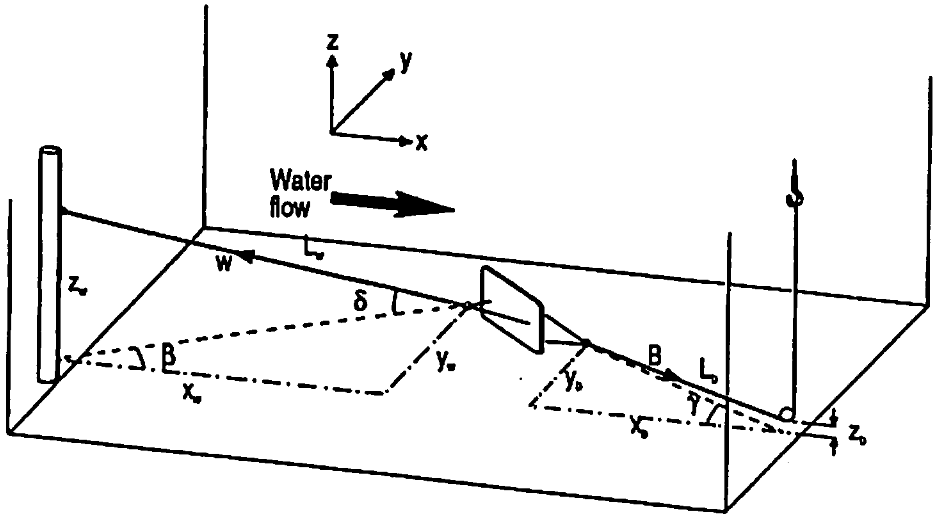


Figure 1 - Description of Parameters Measured

Method 2

In this method the bridle is held horizontal and therefore there is no vertical component.

The angles of the warp and bridle, projected onto the horizontal plane, are measured from vertically above. The vertical angle of the warp, in the plane of the warp, is calculated by measuring the height difference between two markers spaced 3.0 metres apart on the warp.

W: Tension in warp
β: Angle of warp projected onto horizontal plane
L_w': Length between the marks on the warp
z_w': Height between the marks on the warp
$\delta = \mathrm{Sin}^{-1}\,(z_w'/L_w')$: Vertical angle of the warp in the plan of the warp .

Vertical force component in warp:

$$W_z = W \times \mathrm{Sin}\ \delta$$

Transverse component in warp:

$$W_y = W \times \mathrm{Cos}\ \delta \times \mathrm{Sin}\ \beta$$

Longitudinal force component in warp:

$$W_x = W \times \mathrm{Cos}\ \delta \times \mathrm{Cos}\ \beta$$

B : Tension in bridle
γ : Angle of bridle projected onto horizontal plane

Vertical force component in bridle:

$$B_z = 0$$

Transverse force component in bridle:

$$B_y = B \times \mathrm{Sin}\ \gamma$$

Longitudinal force component in bridle:

$$B_x = B \times \mathrm{Cos}\ \gamma$$

For both Method 1 and Method 2

The total spreading force of the otterboard is:

$$F_y = W_y + B_y$$

The drag of the otterboard is:

$$F_x = W_x - B_x$$

2. Definition of Coefficients Derived

(Refer also to Section 1, "General Definitions")

In order to apply the Flume Tank data to otterboards of a different size to those tested, it is more convenient to express the forces derived in coefficient form.

All the data gathered has been expressed in terms of four coefficients C_L, C_D, C_L/C_D and C_P, which can then be applied to otterboards of different sizes towed at different speeds.

The following terms are used in the calculation of the coefficients:

A	:	Projected area of otterboard	m^2
ρ	:	Mass density of water	kg/m^3
g	:	Acceleration due to gravity	m/s^2
V	:	Towing speed of otterboard or waterflow speed	m/s
t_p	:	Longitudinal distance of centre of pressure from the leading edge of the otterboard	m
L	:	Length of the otterboard	m
F_y	:	Spreading force	kg
F_x	:	Drag force	kg

The four coefficients are defined as follows:

1. Spreading force coefficient C_L:

   $C_L = F_y/(0.5 \times \rho/g \times A \times V^2)$

2. Drag coefficient C_D:

   $C_D = F_x/(0.5 \times \rho/g \times A \times V^2)$

3. Efficiency C_L/C_D.

4. Centre of pressure C_P:

   $C_P = t_p/L$

The position of the centre of pressure is determined by two force components, i.e. hydrodynamic and bottom friction, and is located as shown in Fig 2. The force lines of the warp and bridle pass through points t_w, n_w and t_b, n_b which are the points of attachment of the warp and bridle to the otterboard.

The distance of the centre of pressure from the leading edge of the otterboard can be calculated graphically as shown in Fig 2 or by using the equilibrium equation Σ (moments) = 0 (see Fig 3).

$$W_t\, n_w - W_n\,(t_p - t_w) - B_t\, n_b - B_n\,(t_b - t_p) = 0$$

where
$W_t = W_x \text{ Cos } \alpha - W_y \text{ Sin } \alpha$
$W_n = W_x \text{ Sin } \alpha + W_y \text{ Cos } \alpha$
$B_t = B_x \text{ Cos } \alpha + B_y \text{ Sin } \alpha$
$B_n = B_x \text{ Sin } \alpha - B_y \text{ Cos } \alpha$

hence
$$t_p = ((W_x t_w - W_y n_w - B_x t_b - B_y n_b) \text{ Sin } \alpha + (W_x n_w + W_y t_w - B_x n_b + B_y t_b) \text{ Cos } \alpha) / ((W_x - B_x) \text{ Sin } \alpha + (W_y + B_y) \text{ Cos } \alpha)$$

and
$C_P = t_p/L$

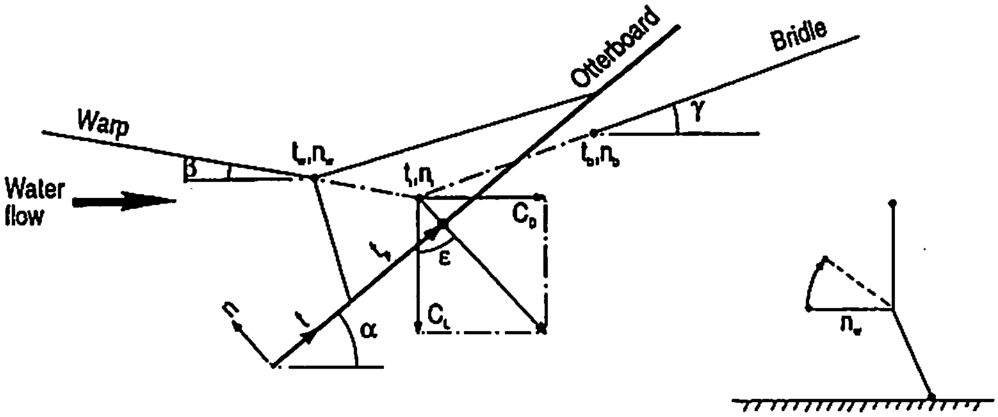


Figure 2 - Centre of Pressure Calculation

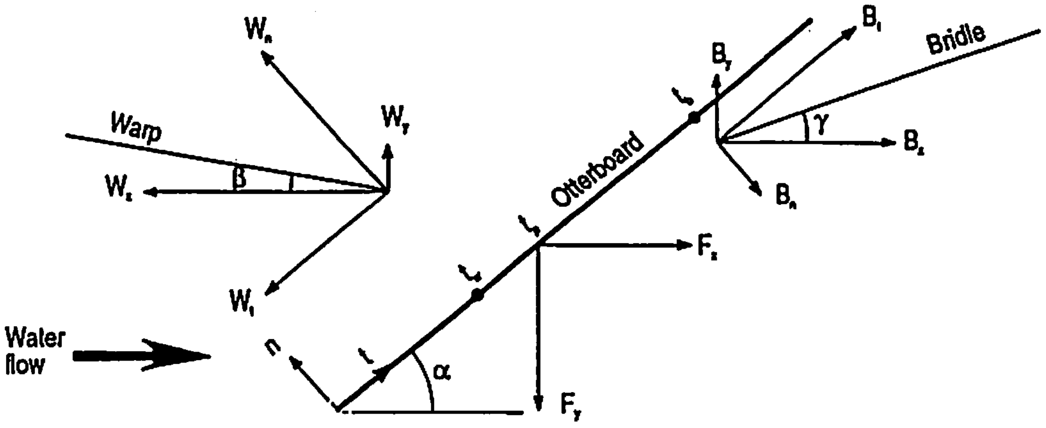


Figure 3 - Centre of Pressure Calculation by Moments

3. Effect of Water Speed on CL and CD Results

Flume Tank trials were carried out on all model otterboards at a water speed of approximately 0.9 metres per second.

In order to quantify the effect of water speed on C_L and C_D results, a series of trials was carried out at each of the participating Flume Tanks.

Each Flume Tank selected a cambered otterboard model and carried out tests at water speeds of 0.7, 0.8, 0.9 and 1.0 metres per second.

The results for the Net Tec cambered vee otterboard, tested at the Seafish Flume Tank, are shown in Fig 4 and are consistent with the results obtained at the other two tanks.

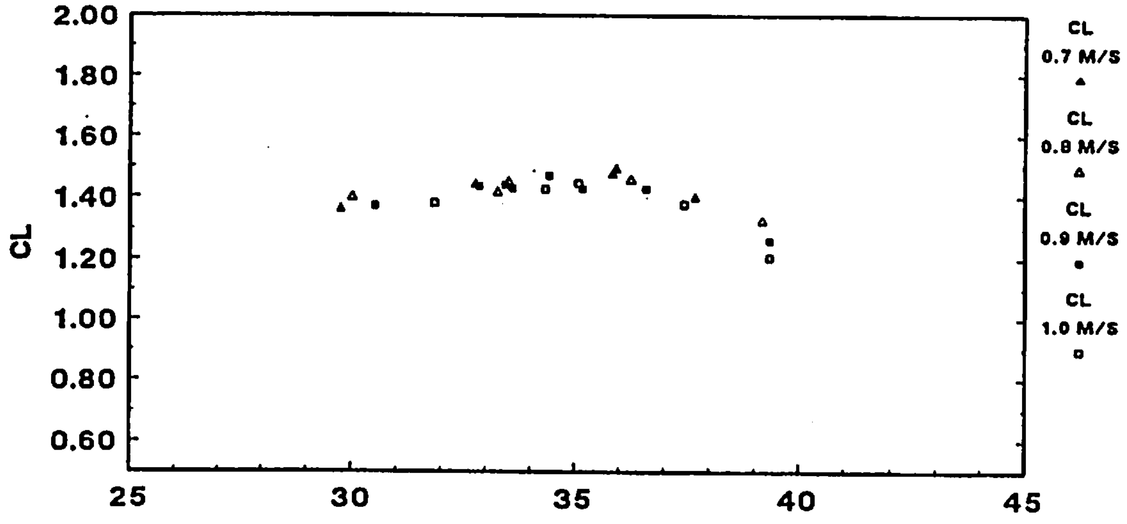
C_L values at 1.0 m/s are approximately 3-4% lower than at 0.7 m/s, but this difference is not significant as all results are within the range of experimental error.

As expected, C_D values are lower at 1.0 m/s than at 0.7 m/s. At 35° angle of attack C_D varies from 1.00 at 1.0m/s to 1.24 at 0.7m/s Hydrodynamic drag varies as the square of the water speed but bottom friction is constant at all speeds. This means that bottom friction is a higher proportion of total drag at lower speeds.

NET TEC CAMBERED VEE DOOR

AT 0° HEEL

CL VALUES AT 0.7,0.8,0.9 AND 1.0 M/S



CD VALUES AT 0.7,0.8,0.9 AND 1.0 M/S

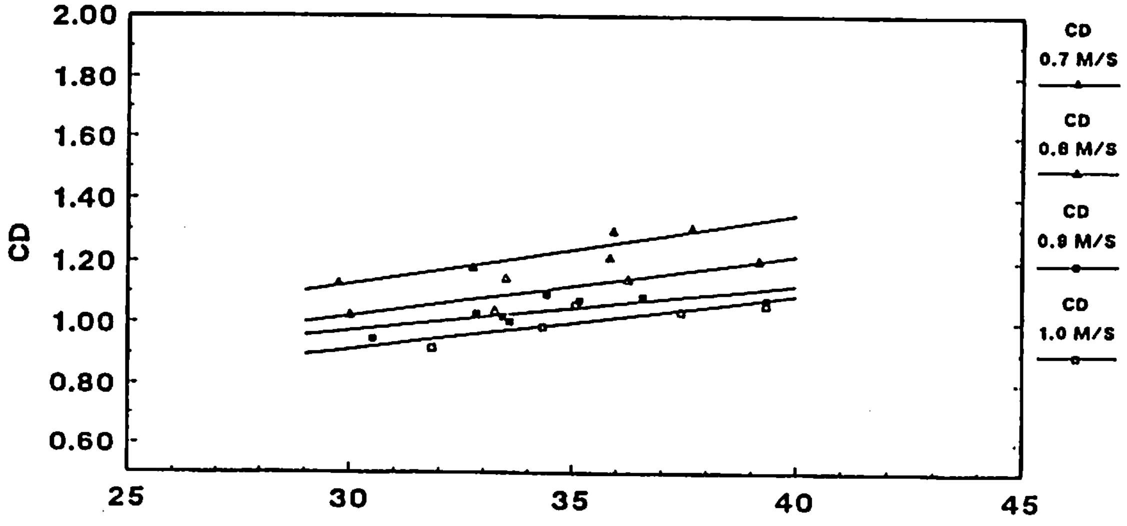


Figure 4 - Effect of Water Speed on CL and CD Results

4. Use of the Flume Tank Data

If an otterboard of one type (otterboard 1) is being used at present and the equivalent size of another otterboard design (otterboard 2) is required to give the same spreading force then:

$$A_1 \times C_{L_1} = A_2 \times C_{L_2} \qquad - \quad 1$$

so $$A_2 = A_1 \times C_{L_1}/C_{L_2} \qquad - \quad 2$$

C_{L_1} and C_{L_2} should be taken from the data sheets at the appropriate angles of attack.

as $$A_2 = L_2 \times H_2 \times C_{A_2} \qquad - \quad 3$$

and $$AR_2 = H_2/L_2 \qquad -4$$

$$H_2 = L_2 \times AR_2 \qquad - \quad 5$$

then substituting 5 into 3.

$$A_2 = L_2 \times L_2 \times AR_2 \times C_{A_2} \qquad - \quad 6$$

equating 6 and 2.

$$L_2 \times L_2 \times AR_2 \times C_{A_2} = A_1 \times C_{L_1}/C_{L_2}$$

$$L_2 = \sqrt{\left((A_1 \times C_{L_1})/(C_{L_2} \times AR_2 \times C_{A_2})\right)}$$

$$H_2 = L_2 \times AR_2$$

5. Flume Tank Belt Friction

Each model otterboard was tested at a standard weight, which was measured both in air and water.

However, drag results may be required for a model otterboard which is a different weight to that tested.

To establish correction factors to otterboard drag for changes in weight the friction drag of two steel bars was measured on the belt of each Flume Tank. The friction drag was measured over a range of angles of attack and belt speed.

The steel bars were constructed of solid steel, one being round section and the other square section.

Round Bar	Length	660mm
	Diameter	60mm
	Weight in air	14.6kg
	Weight in water	12.7kg
Square Bar	Length	500mm
	Width and height	63mm
	Weight in air	15.5kg
	Weight in water	13.5kg

Friction coefficients were calculated for each bar at each angle of attack and speed.

Friction Coefficient = Drag/bar weight

In general the friction coefficients obtained from these tests were not dependent on angle of attack or belt speed and average values are given below.

Flume Tank	Coefficient of Friction		
	Round bar	Square bar	Average
Hirtshals	0.20	0.28	0.24
Hull	0.20	0.24	0.22
Boulogne	0.32	0.36	0.34

The drag of a particular otterboard model can be corrected for a change in weight by the following method:-

C_f : Coefficient of friction
WT' : Change in weight of otterboard in water kg
A : Projected area of otterboard m^2
V : Speed of belt and waterflow m/s
C_D : Drag coefficient
$C_{D'}$: Change in drag coefficient

Change in drag $= WT' \times C_f$

Change in drag coefficient C_D' $= WT' \times C_f/(0.5 \times \rho/g \times A \times V^2)$

C_D (corrected) $= C_D + C_D'$ for weight increase
or $= C_D - C_D'$ for weight decrease

The change in drag coefficient C_D' can be applied to the CD values for the full range of angles of attack as the correction will be constant throughout.

Numerical example:-

From the data sheet of the Thyborøn Type 2 66" model the following data was lifted at 35° angle of attack.

C_L = Lift coefficient 1.48
C_D = Drag coefficient 1.00
A = Projected area $0.271 m^2$
WT = Weight in water 8.90kg
V = Water speed 0.90 m/s
ρ = Water density $1000 kg/m^3$
g = Acceleration due to gravity $9.81 m/s^2$

The value of C_D is required if the weight of the model in water is increased by 2.0kg ($WT' = 2.0kg$).

From the table of coefficients of Friction C_f for square bar in the Flume Tank at Hirtshals is 0.28.

Change in drag $= WT' \times C_f$
$= 2.0 \times 0.28$

Change in drag coefficient C_D' $= WT' \times C_f/(0.5 \times \rho/g \times A \times V^2)$
$= 2.0 \times 0.28/(0.5 \times 1000/9.81 \times 0.271 \times 0.90^2)$
$= 0.050$

C_D (corrected) $= C_D + C_D'$ for weight increase
$= 1.00 + 0.050$
$= 1.050$

6. Angle of Attack Calculation

Full scale tests at sea have shown that on average the following calculation methods give an angle of attack approximately 4° higher than taken up by the otterboard at sea. This correction should be applied to the calculated angles obtained.

Full Calculation
This method can be carried out either graphically on paper using scale drawings or mathematically by solving equations to find the intersection points of straight lines.

The method assumes that the angles of the warp and bridle in the horizontal plane (β and γ) are known. Although these angles are important, they are not critical and can be approximated if not known.

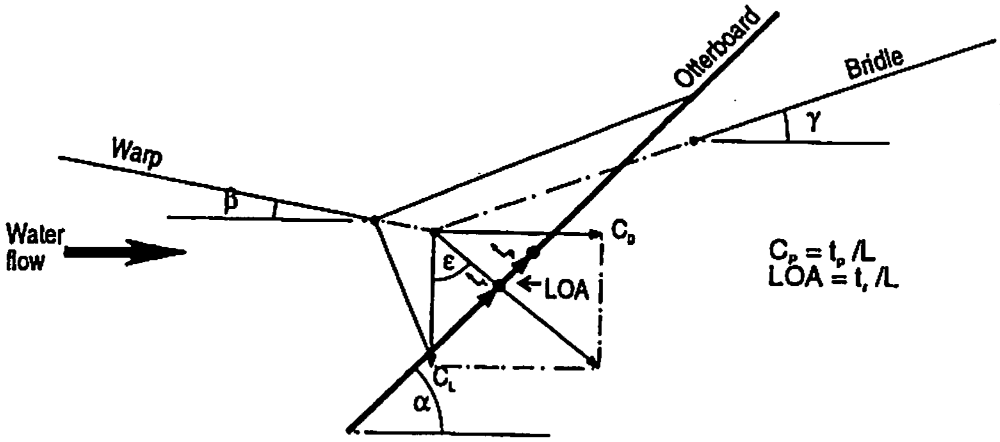
The coordinates of the warp and bridle attachment points t_w, n_w, t_b, n_b must be measured relative to the reference face of the otterboard. If the otterboard has a hinged towing bracket or chain, then the distance n_w will be reduced as the warp vertical angle increases, raising the towing bracket.

The otterboard is progressively rotated through a range of angles of attack at which C_L, C_D and C_P are known from model experiments. The angles of attack can be varied in 5°-10° intervals from 25° to 45°.

At each angle of attack the line of action of the resultant force can be drawn through the point of intersection of the warp and bridle extended. This line is constructed at angle ε as shown in Fig 5 where $\varepsilon = \tan^{-1} (C_D/C_L)$.

This line of action crosses the face of the otterboard at a distance t_L from the leading edge of the otterboard.

If $LOA = t_L/L$ then LOA can be plotted against angle of attack on the same graph as C_P against angle of attack. Where the two lines intersect, the value of LOA is equal to C_P. This means that the otterboard is in equilibrium and so the correct angle of attack has been found.



$C_P = t_p/L$
$LOA = t_l/L$

Figure 5 - Estimation of Angle of Attack

Summary of Angle of Attack Calculation (Full Calculation)

1. Define warp and bridle attachment points t_w, n_w and t_b, n_b.

2. Correct n_w if the otterboard has a hinged towing arm, due to vertical angle of warp.

   At each angle of attack, say, 25°, 30°, 35°, 40°, 45°.

   a) Calculate or measure intersection point of warp and bridles (extended) t_i, n_i.

   b) Calculate angle $\varepsilon = \mathrm{Tan}^{-1} (C_D/C_L)$

   c) Draw resultant force line through t_i, n_i at angle ε.

   d) Measure or calculate distance t_r. Calculate $LOA = t_r/L_d$.

3. Plot lines LOA and C_P against angle of attack.

4. Where lines intersect defines correct angle of attack.

Simplified calculation

By making some basic approximations the previous method can be simplified and therefore made easier to apply.

The following approximations are used:

1) The centre of pressure C_P is constant through the whole range of angles.

2) The resultant of the hydrodynamic forces is perpendicular to the otterboard reference line, $C_l/C_D = 1/\tan(\alpha)$. i.e. $\varepsilon = \alpha$

With these approximations, the angle of attack can be determined from only one equation:

$$n_w + (t_w - t_p) \times \tan(\alpha+\beta) = n_b + (t_b - t_p) \times \tan(\alpha-\gamma)$$

This equation cannot be resolved into a formulae for the angle of attack α. It is, however, possible to use the equation to determine the angle of attack either iteratively or graphically.

Iterative procedure

1) Make an initial guess for the angle of attack, it could be 30 or 40°.

2) Calculate: $Y_1 = n_w + (t_w - t_p) \times \tan(\alpha+\beta)$
   and: $Y_2 = n_b + (t_b - t_p) \times \tan(\alpha-\gamma)$

3) If $Y_1 = Y_2$ the problem is solved and the angle of attack is found.

4) If Y_1 is less than Y_2 the angle of attack is too high. Choose a lower angle of attack and repeat from 2).

5) If Y_1 is higher than Y_2 the angle of attack is too low. Choose a higher angle of attack and repeat from 2).

Graphical procedure

1) Calculate Y_1 and Y_2 for various angles of attack, for instance 25, 30, 35, 40 and 45°.

2) Plot Y_1 and Y_2 against the angle of attack in the same coordinate system.

3) The intersection of the two curves defines the angle of attack.

Example:-

The angle of attack should be determined for an otterboard like the reference Vee. From data sheet it can be seen that C_P is increasing slowly with the angle of attack but in the range from 30 to 40 degrees a good approximation is

$$C_P = 0.42$$

From experience with the fishery in question, the warp angle is known to be approximately 6 degrees and the bridle angle is known to be approximately 18 degrees.

$$\beta = 6^\circ$$
$$\gamma = 18^\circ$$

The attachment points of the warp and the bridle are measured relative to the length of the otterboard and the following values are found:

$t_w = 0.26$ and $n_w = 0.24$
$t_b = 0.85$ and $n_b = -0.06$

Because the attachment points are measured relative to the length of the otterboard.

$$t_p = C_p = 0.42$$

Y_1 and Y_2 are calculated for various angles of attack as shown in the table below:

Angle of Attack	Y_1	Y_2
25	0.134	-0.007
30	0.114	0.031
35	0.091	0.071
40	0.064	0.114
45	0.032	0.159

The values for Y_1 and Y_2 are plotted against angle of attack in Fig 6.

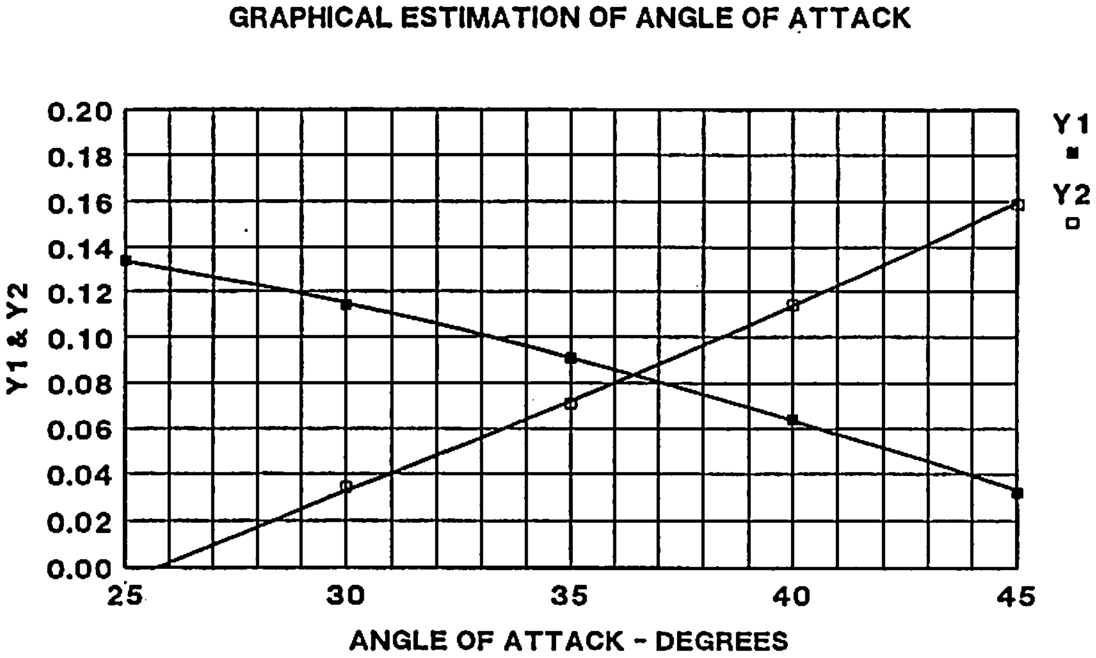


Figure 6 - Y1 and Y2 Plotted Against Angle of Attack

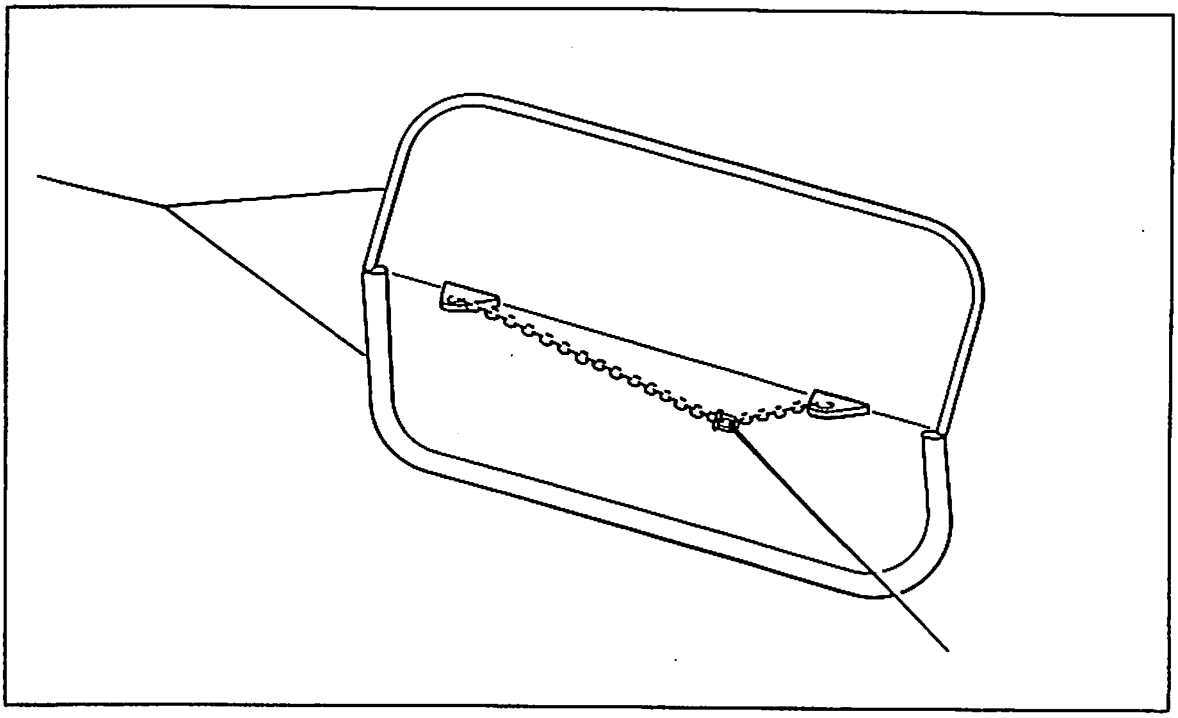
Appendix IV

Data Sheets from Flume Tank Model Tests

Otterboard	**Flume Tank**
Reference Vee	Boulogne, Hirtshals, Hull
Flat Wooden	Hull
Bison 1 Slot	Hull
Bison 3 Slot	Hull
Blooe Tech	Hull
Dan-Green KB	Hirtshals
Dan-Green SV	Hirtshals
Euronete "Portuguese"	Hull
Fjørtoft Multi Foil	Hirtshals
Hinriksson Poly-Ice	Hull
Hydrofin Multifoil	Hull
Le Béon à Roue	Boulogne
Le Béon Hydrostable	Boulogne
Lindholmen	Hirtshals
Morgère Polyfoil	Boulogne
Morgère Polyvalent Ovale	Boulogne
Morgère Polyvalent Type R	Boulogne
Morgère W Horizontal	Boulogne
Morgère W Vertical	Boulogne
Munkebo	Hirtshals
Net Tec	Hull
Perfect New Oval	Hirtshals
Perfect Patent B	Hirtshals
Thyborøn Type 2 (66in)	Hirtshals
Thyborøn Type 2 (125in)	Hirtshals
Vergoz en Z	Boulogne

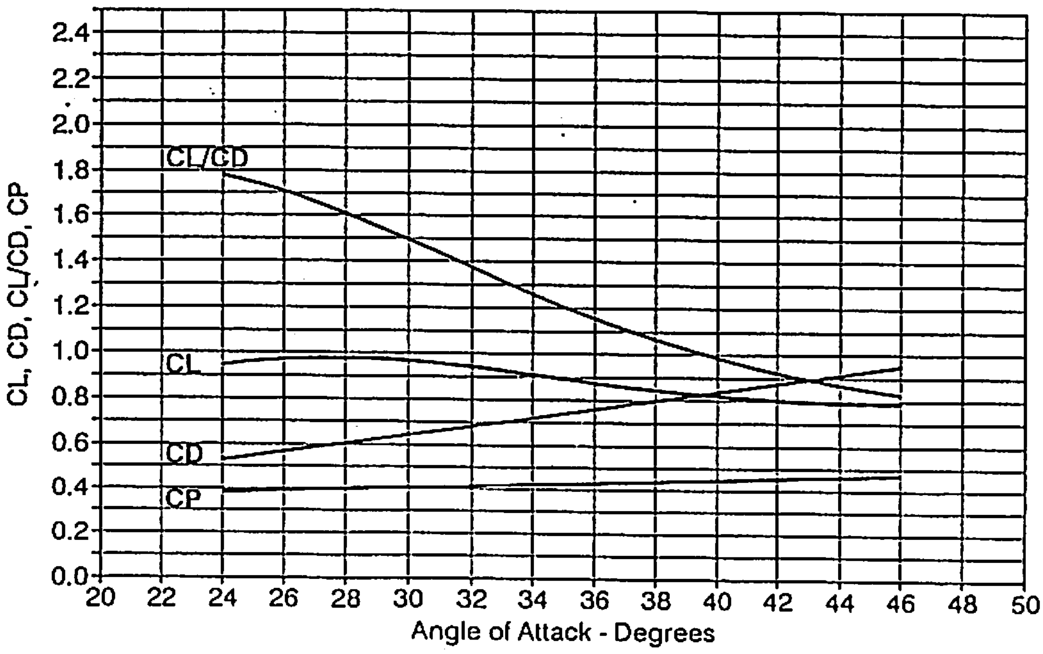
Reference Vee

Vee without camber. Tested with upper plate vertical.



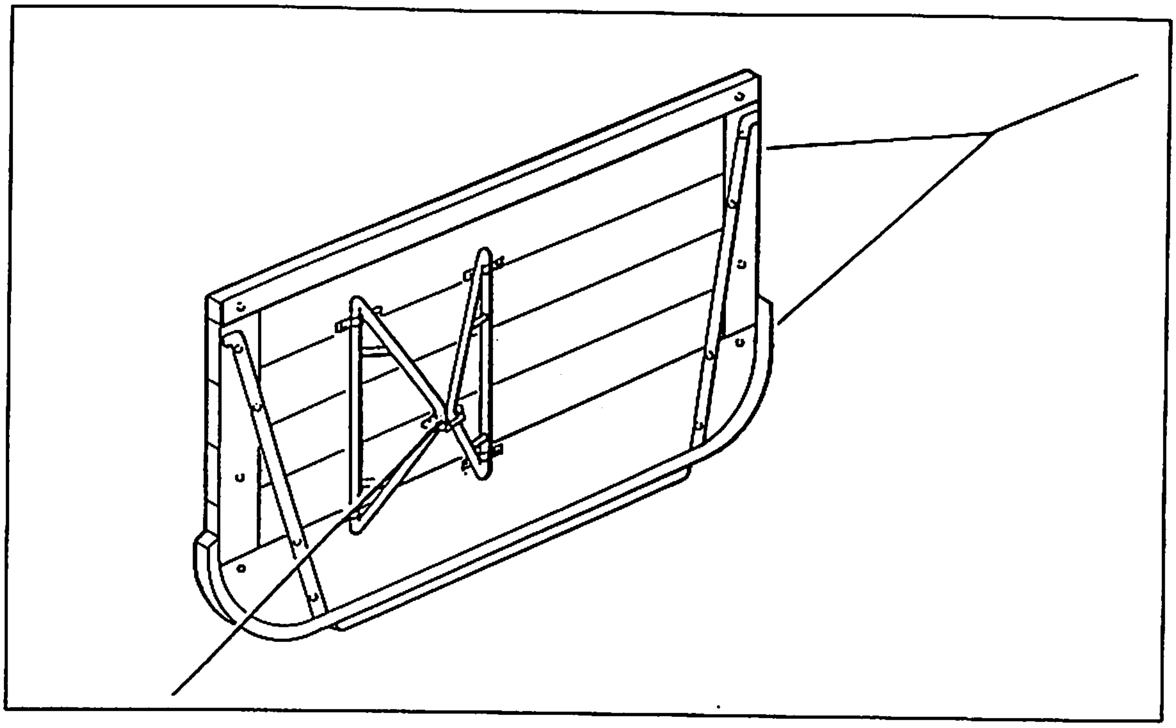
Model Specifications		
Length	0.740	m
Height	0.480	m
Projected Area	0.347	m2
Aspect Ratio	0.65	
Area Ratio	0.98	
Weight in Air	15.7	kg
Weight in Water	13.7	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	0.96	0.55	1.74
30 deg.	0.96	0.64	1.50
35 deg.	0.89	0.74	1.20
40 deg.	0.82	0.83	0.99
45 deg.	0.79	0.93	0.85
Maximum CL at 28 deg.	0.97	0.61	1.61



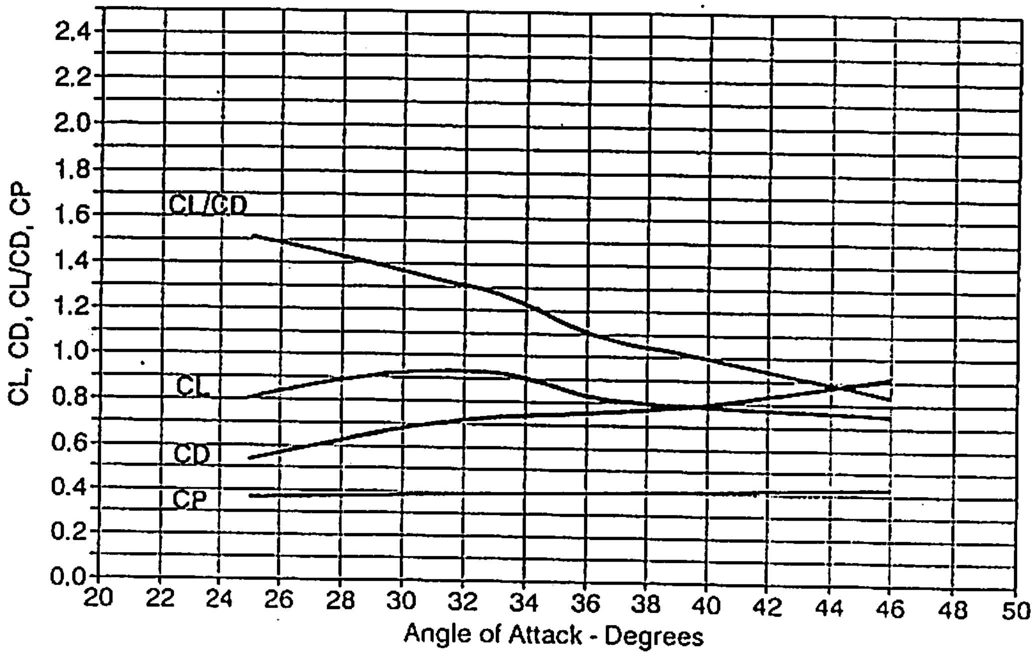
Flat Wooden

Flat with wooden panels. Tested in upright condition.



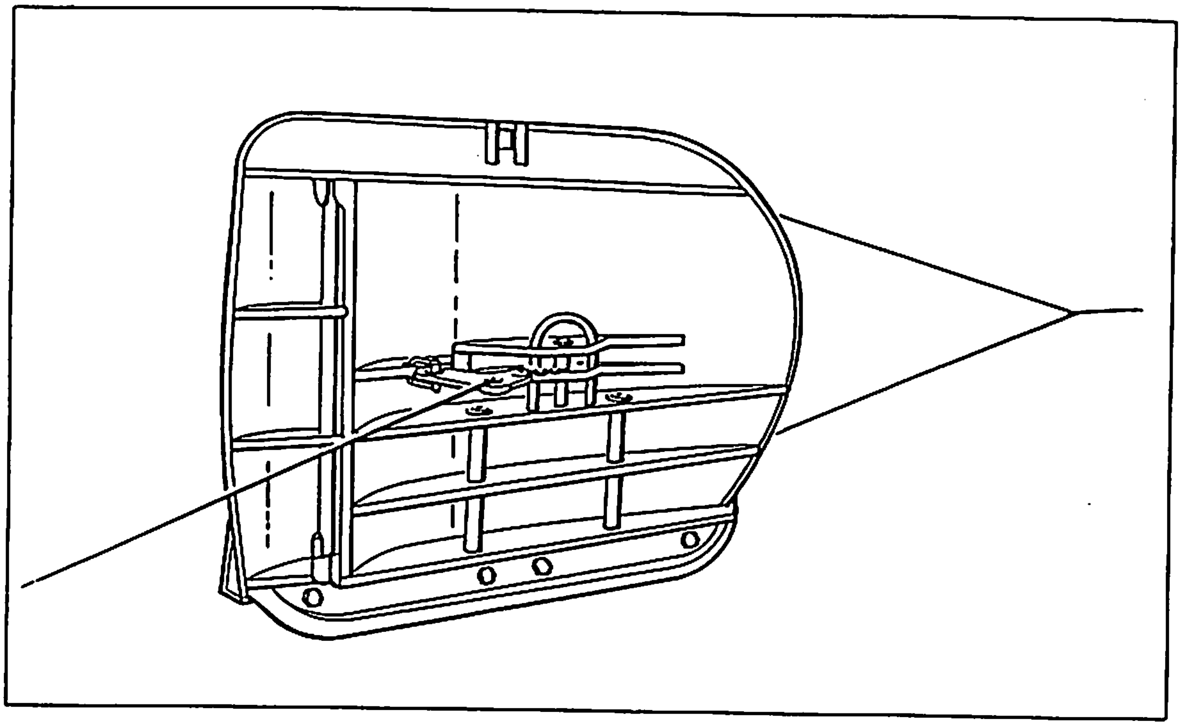
Model Specifications		
Length	0.764	m
Height	0.380	m
Projected Area	0.285	m2
Aspect Ratio	0.50	
Area Ratio	0.98	
Weight in Air	13.4	kg
Weight in Water	8.0	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	0.80	0.53	1.51
30 deg.	0.92	0.67	1.36
35 deg.	0.86	0.74	1.15
40 deg.	0.78	0.79	0.99
45 deg.	0.76	0.89	0.86
Maximum CL at 32 deg.	0.93	0.71	1.30



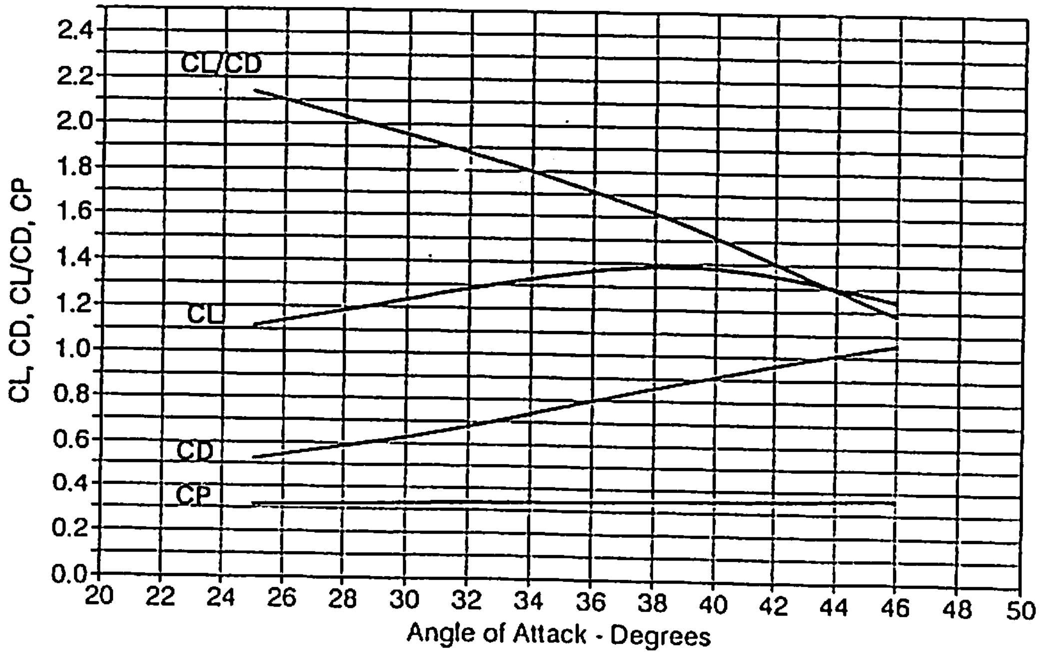
Bison 1 Slot

Cambered with one slot. Tested in upright condition.



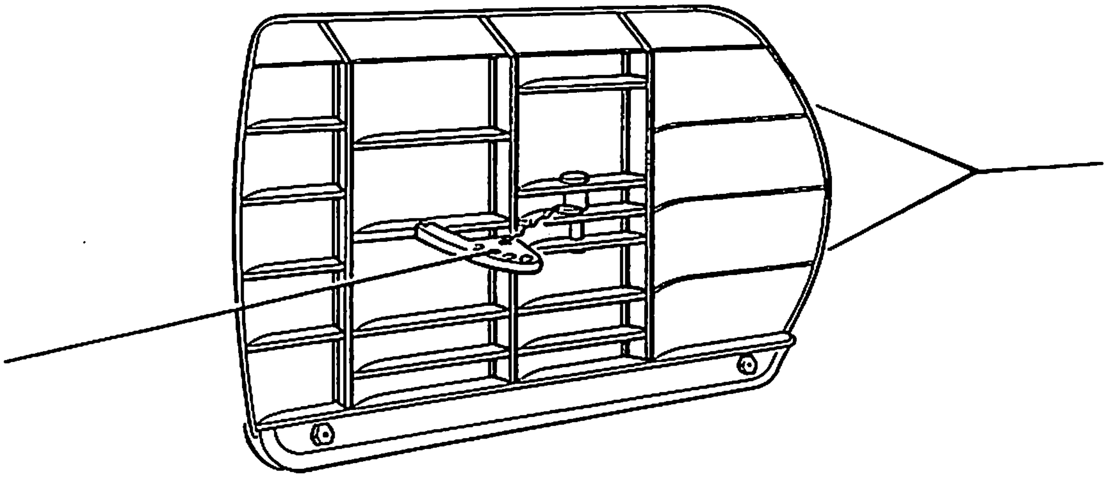
Model Specifications		
Length	0.671	m
Height	0.422	m
Projected Area	0.261	m2
Aspect Ratio	0.63	
Area Ratio	0.92	
Weight in Air	11.4	kg
Weight in Water	9.9	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.11	0.52	2.13
30 deg.	1.23	0.63	1.95
35 deg.	1.34	0.76	1.76
40 deg.	1.38	0.91	1.52
45 deg.	1.27	1.03	1.23
Maximum CL at 39 deg.	1.38	0.88	1.57



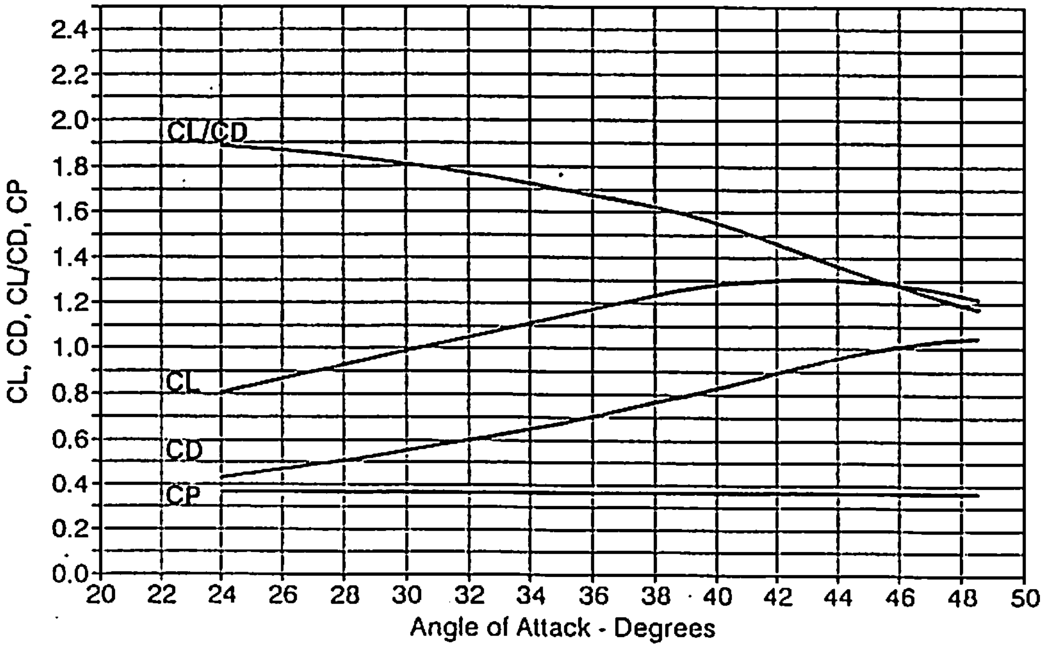
Bison 3 Slots

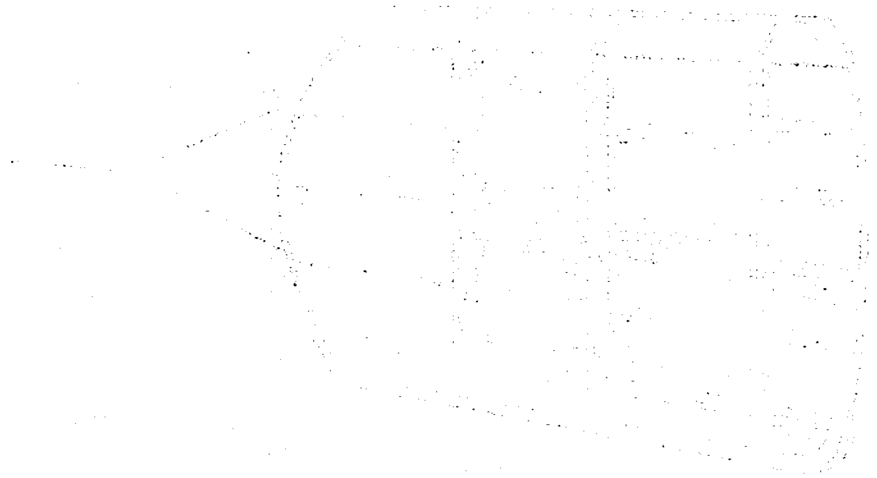
Four cambered foils. Tested in upright condition.



Model Specifications		
Length	0.673	m
Height	0.423	m
Projected Area	0.263	m2
Aspect Ratio	0.63	
Area Ratio	0.92	
Weight in Air	11.4	kg
Weight in Water	9.9	kg

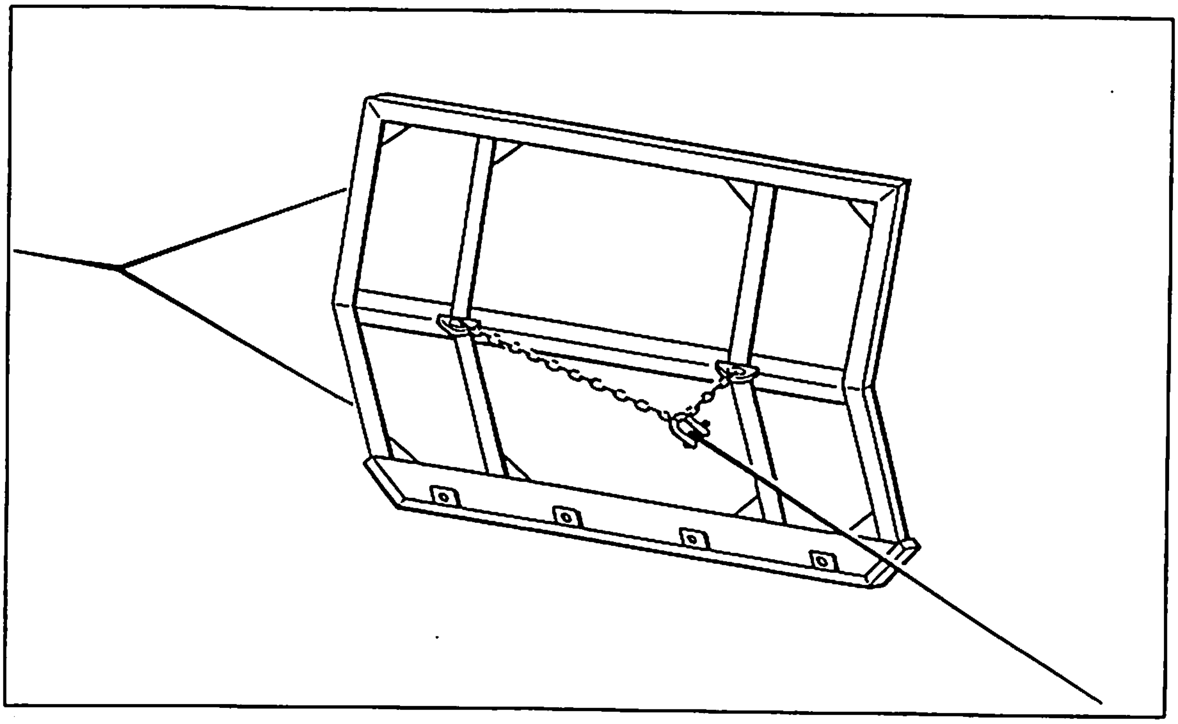
Angle of Attack	CL	CD	CL/CD
25 deg.	0.84	0.45	1.88
30 deg.	0.99	0.55	1.81
35 deg.	1.14	0.67	1.70
40 deg.	1.27	0.82	1.55
45 deg.	1.29	0.98	1.31
Maximum CL at 43 deg.	1.30	0.92	1.41





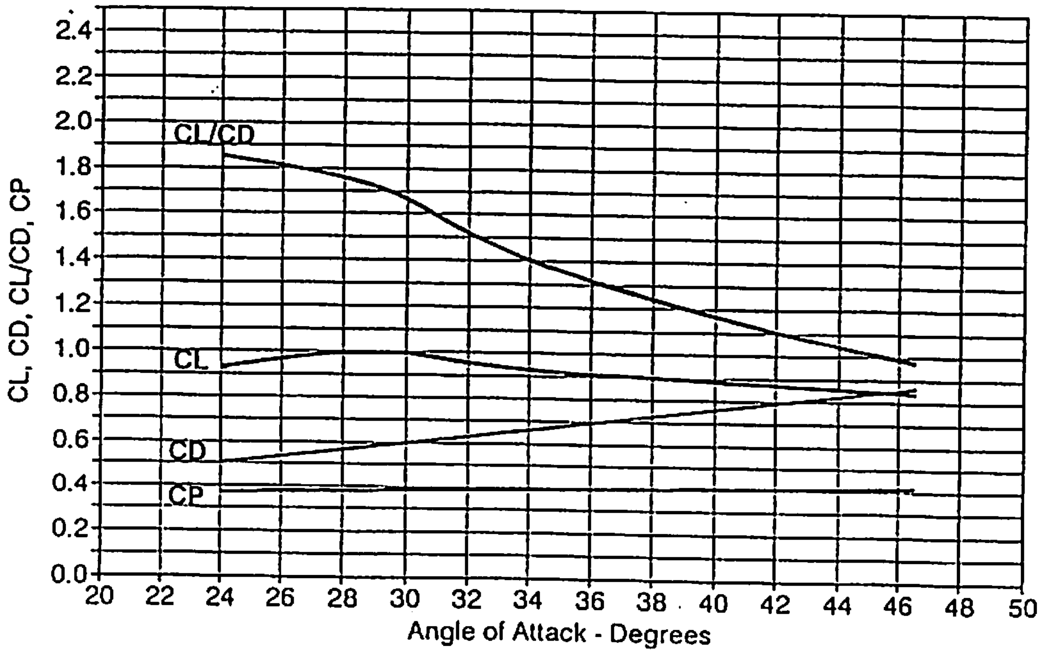
Blooe Tech

Vee with plastic panels. Tested with upper plate vertical.



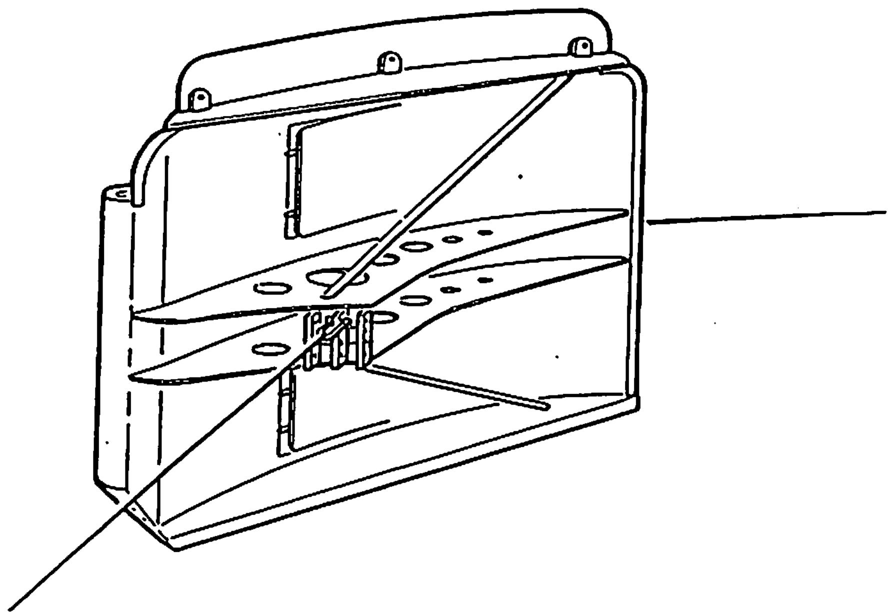
Model Specifications		
Length	0.730	m
Height	0.469	m
Projected Area	0.340	m2
Aspect Ratio	0.64	
Area Ratio	0.99	
Weight in Air	11.8	kg
Weight in Water	9.2	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	0.94	0.52	1.83
30 deg.	0.99	0.60	1.66
35 deg.	0.92	0.68	1.35
40 deg.	0.88	0.76	1.16
45 deg.	0.85	0.84	1.01
Maximum CL at 29 deg.	0.99	0.58	1.71



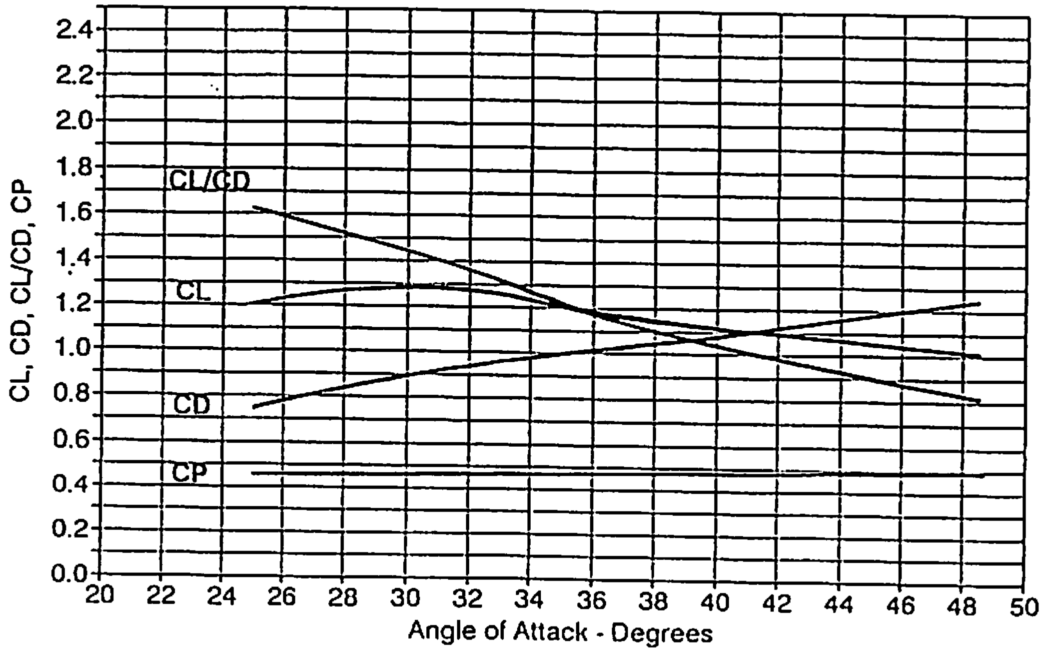
Dan-Green Type KB

Cambered with slots. Tested in upright condition.



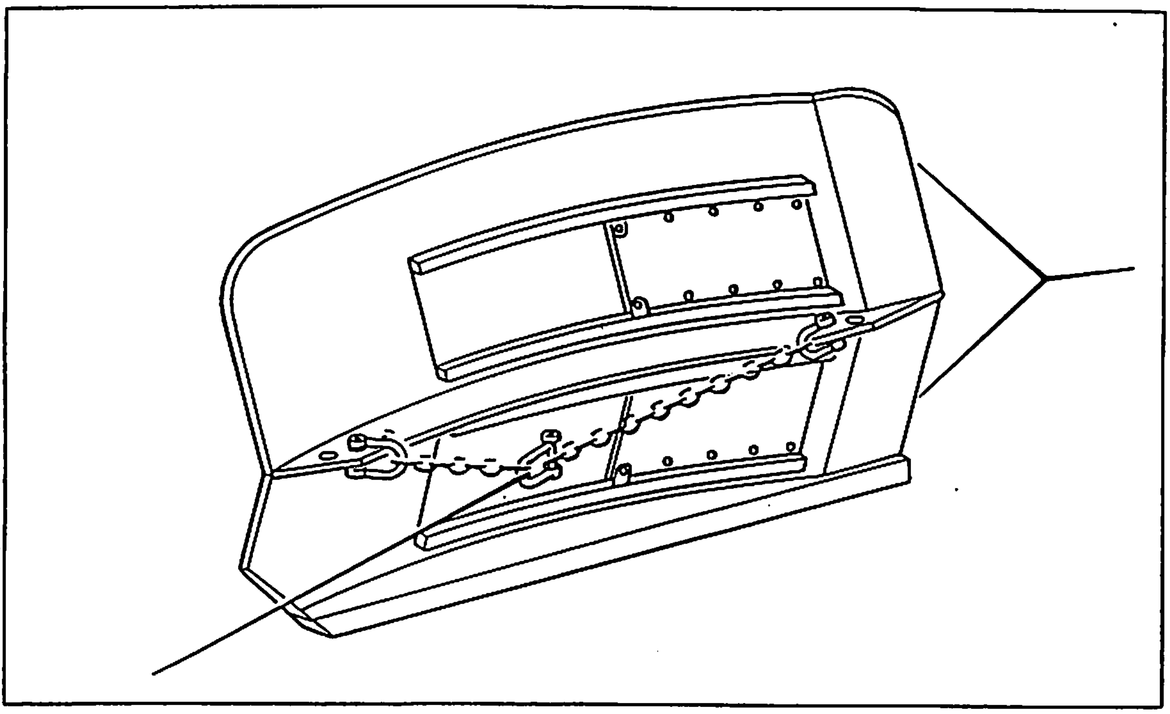
Model Specifications		
Length	0.730	m
Height	0.450	m
Projected Area	0.325	m2
Aspect Ratio	0.62	
Area Ratio	0.99	
Weight in Air	17.5	kg
Weight in Water	15.3	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.20	0.74	1.62
30 deg.	1.28	0.89	1.44
35 deg.	1.20	0.99	1.21
40 deg.	1.11	1.07	1.03
45 deg.	1.05	1.17	0.90
Maximum CL at 31 deg.	1.28	0.91	1.40



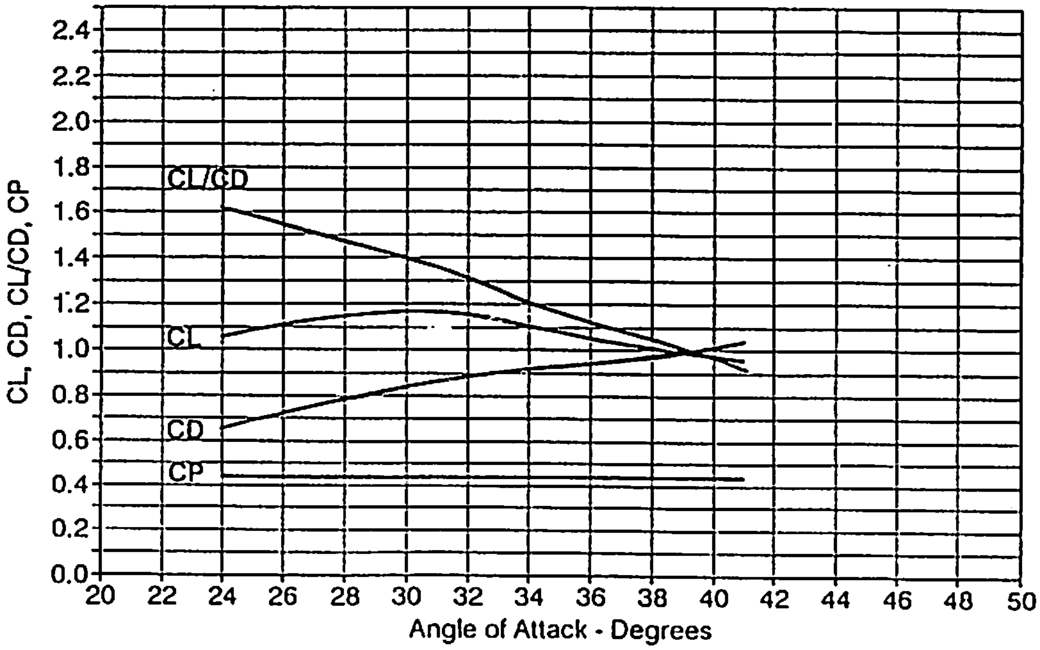
Dan-Green Type SV

Cambered. Tested with closed gates and upper plate vertical.



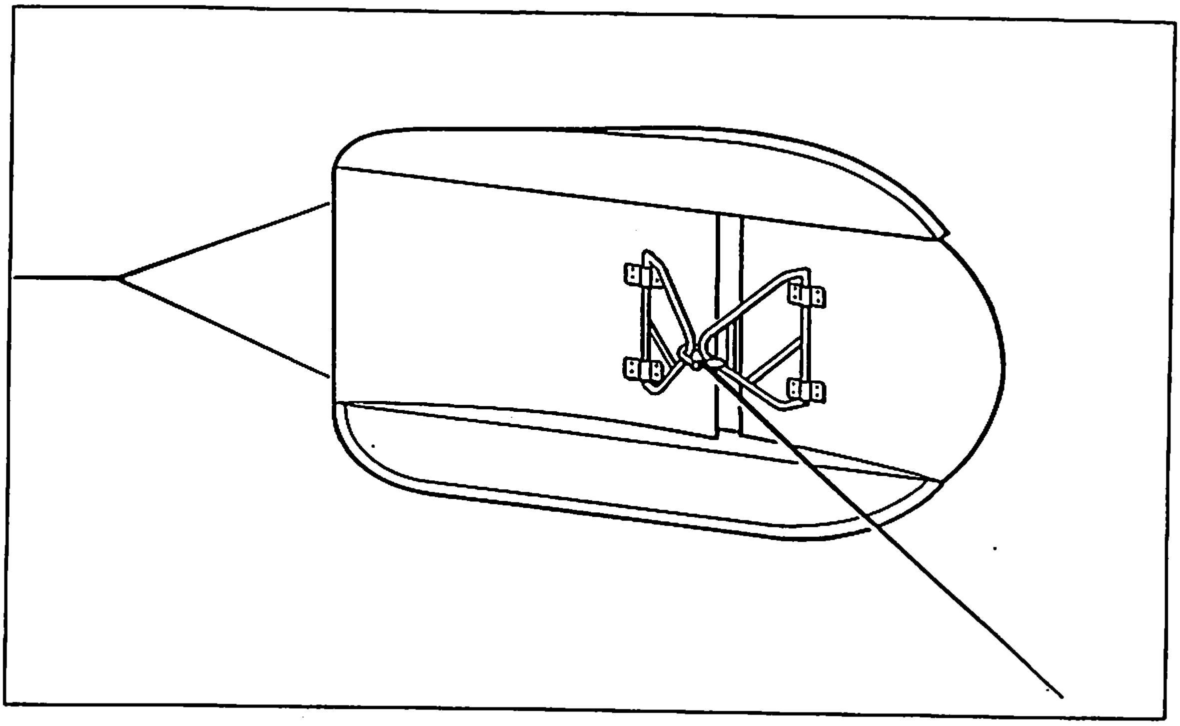
Model Specifications		
Length	0.710	m
Height	0.420	m
Projected Area	0.295	m2
Aspect Ratio	0.59	
Area Ratio	0.99	
Weight in Air	12.3	kg
Weight in Water	10.7	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.08	0.68	1.58
30 deg.	1.16	0.83	1.39
35 deg.	1.07	0.93	1.16
40 deg.	0.97	1.01	0.97
45 deg.	-	-	-
Maximum CL at 31 deg.	1.16	0.86	1.36



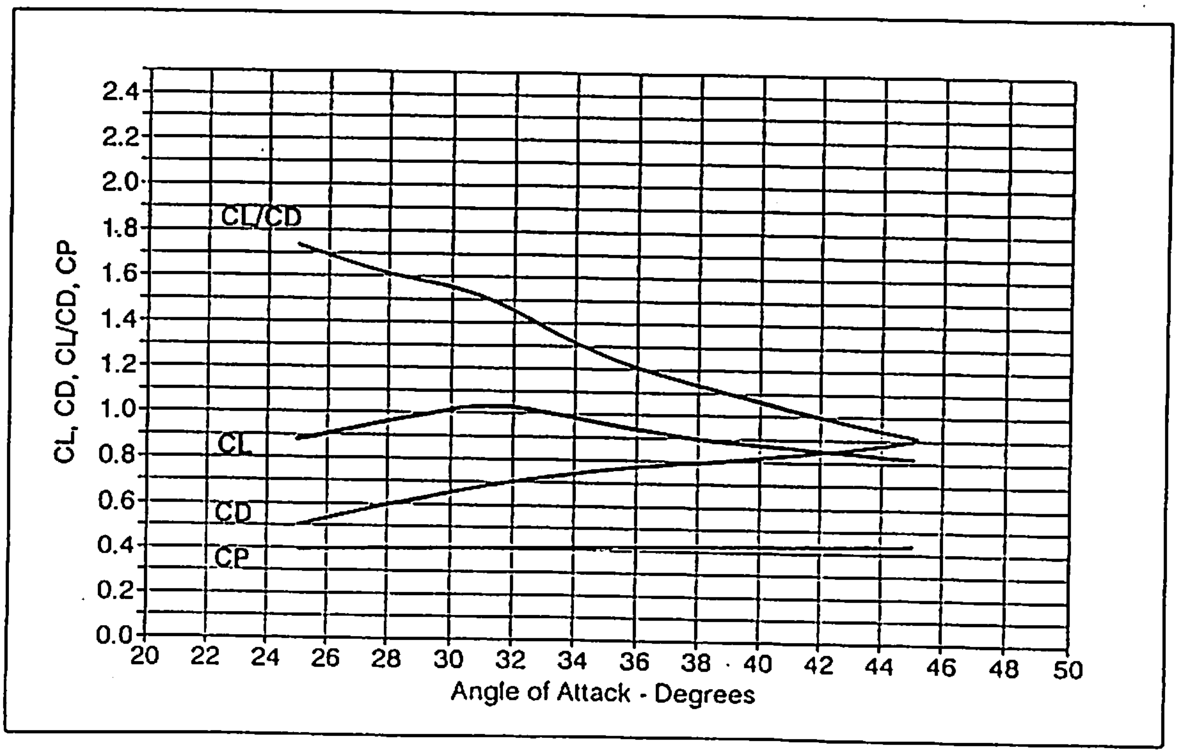
Euronete "Portuguese"

Cambered with one slot. Tested in upright condition.



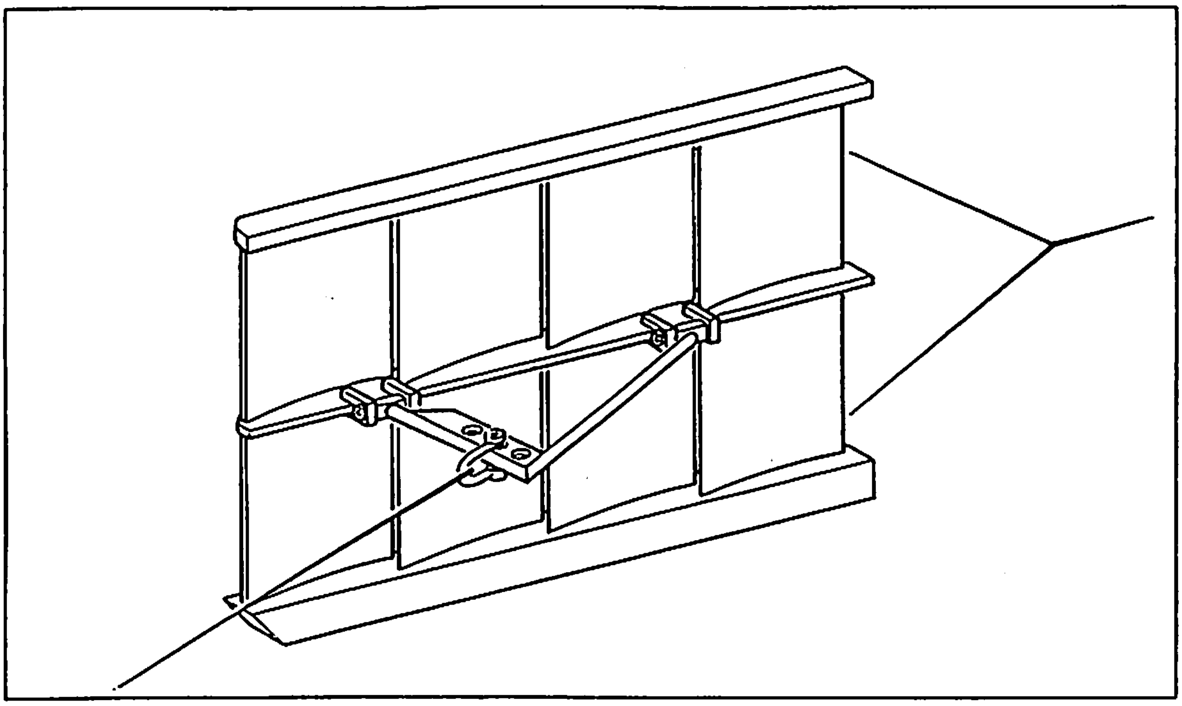
Model Specifications		
Length	0.750	m
Height	0.417	m
Projected Area	0.275	m2
Aspect Ratio	0.56	
Area Ratio	0.88	
Weight in Air	11.0	kg
Weight in Water	8.6	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	0.87	0.50	1.74
30 deg.	1.01	0.65	1.56
35 deg.	0.95	0.76	1.26
40 deg.	0.87	0.81	1.07
45 deg.	0.82	0.89	0.91
Maximum CL at 31 deg.	1.02	0.67	1.52



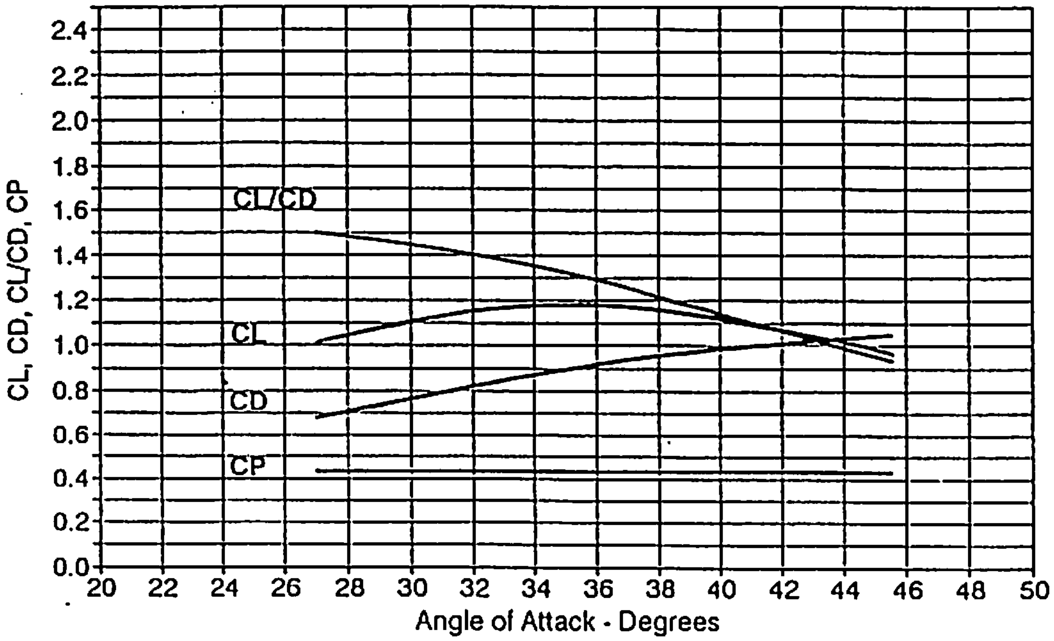
Fjørtoft Multi Foil

Four cambered foils. Tested in upright condition.



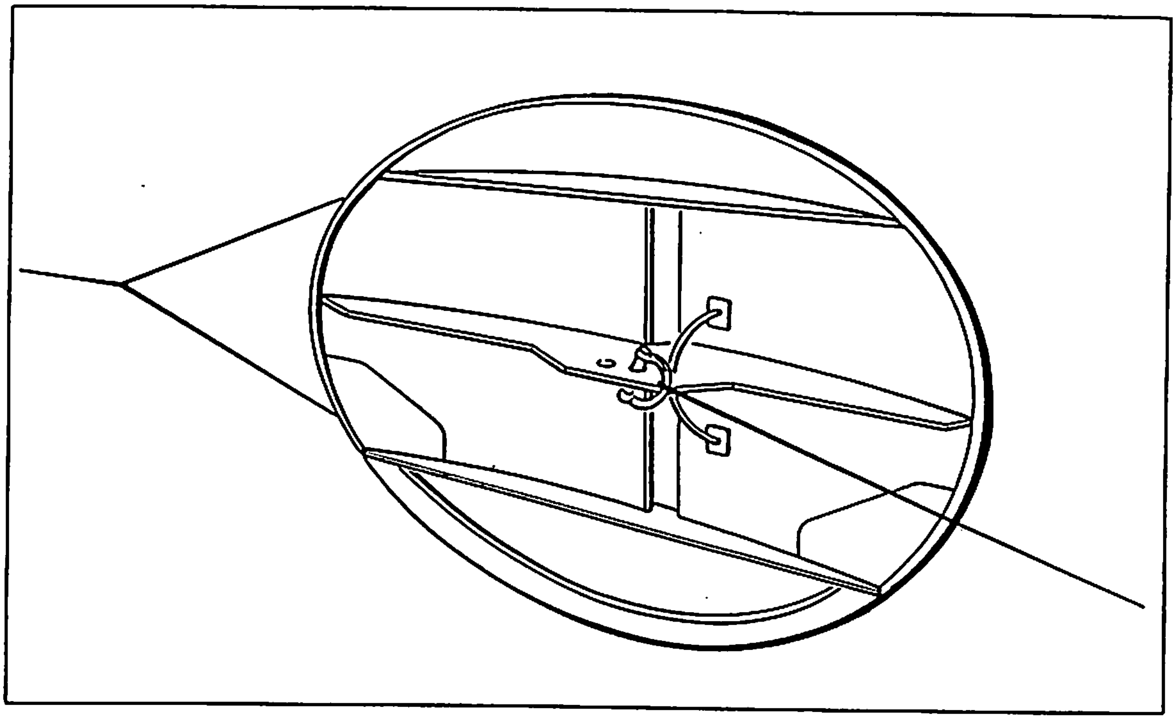
Model Specifications		
Length	0.700	m
Height	0.485	m
Projected Area	0.340	m2
Aspect Ratio	0.69	
Area Ratio	1.00	
Weight in Air	27.1	kg
Weight in Water	23.6	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	1.10	0.76	1.45
35 deg.	1.18	0.89	1.32
40 deg.	1.11	0.98	1.13
45 deg.	0.99	1.04	0.95
Maximum CL at 35 deg.	1.18	0.89	1.32



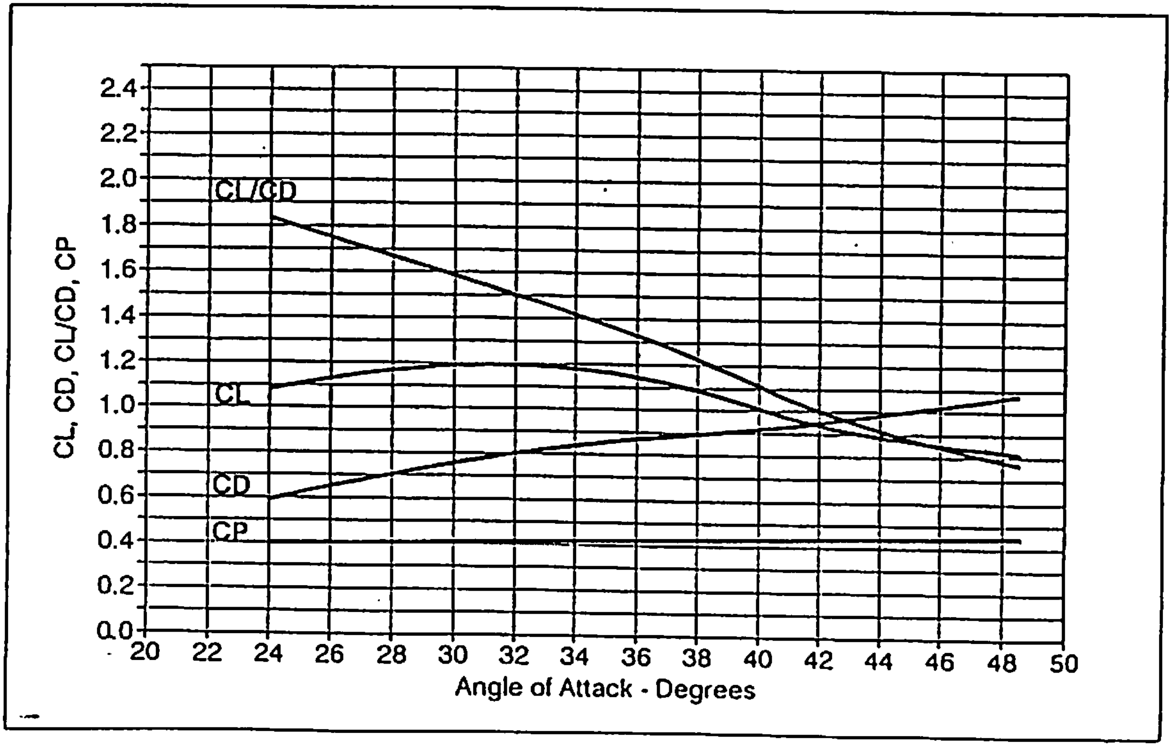
Hinriksson Poly-Ice

Cambered oval with one slot. Tested in upright condition.



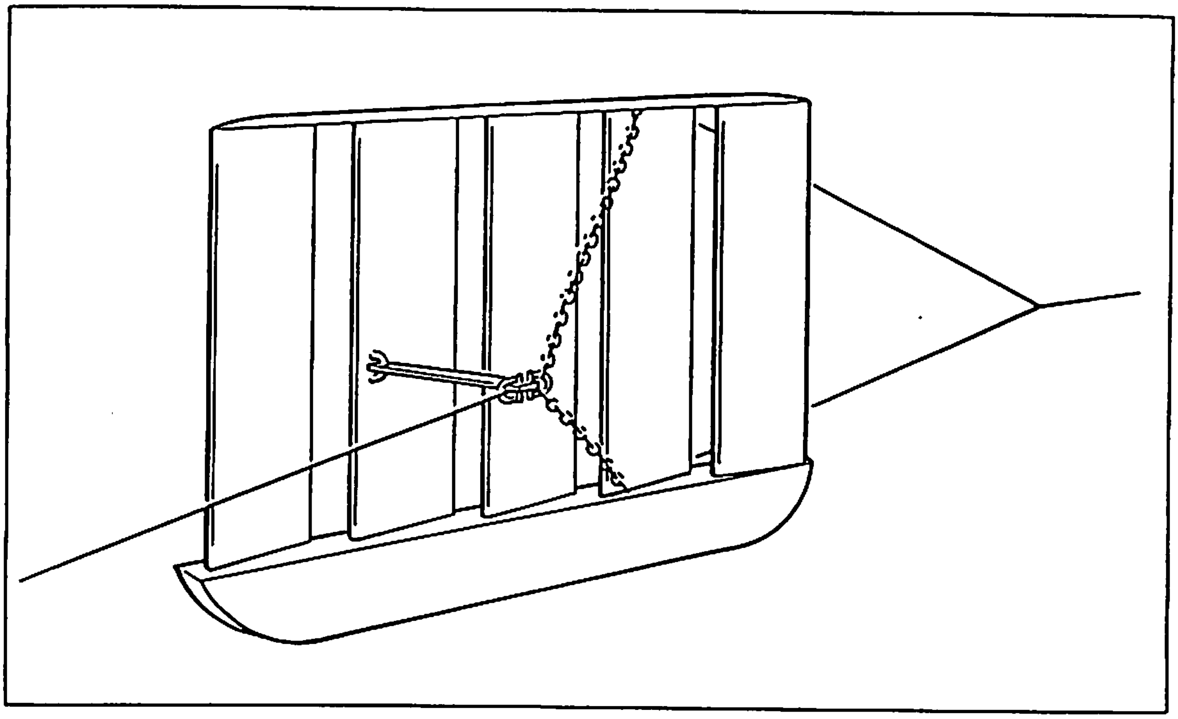
Model Specifications		
Length	0.748	m
Height	0.510	m
Projected Area	0.304	m2
Aspect Ratio	0.68	
Area Ratio	0.80	
Weight in Air	12.7	kg
Weight in Water	11.1	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.10	0.62	1.79
30 deg.	1.18	0.75	1.58
35 deg.	1.16	0.85	1.37
40 deg.	1.01	0.91	1.10
45 deg.	0.87	1.00	0.87
Maximum CL at 32 deg.	1.19	0.79	1.50



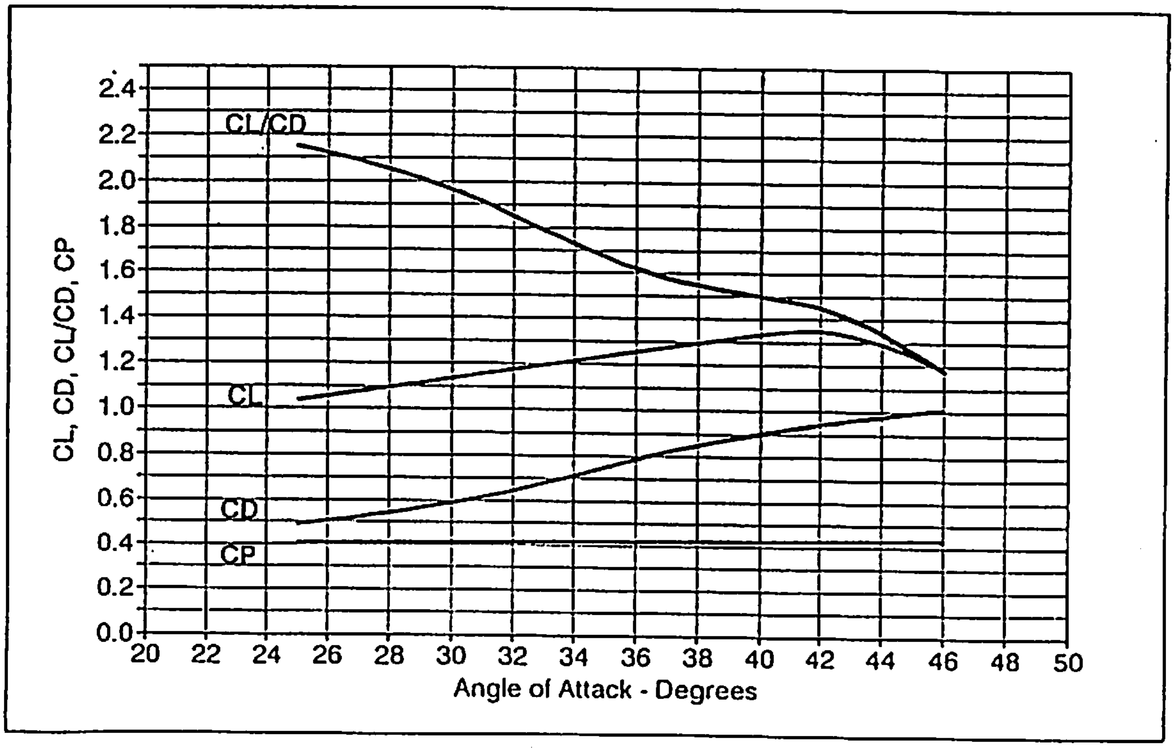
Hydrofin Multifoil

Five foils. Tested in upright condition.



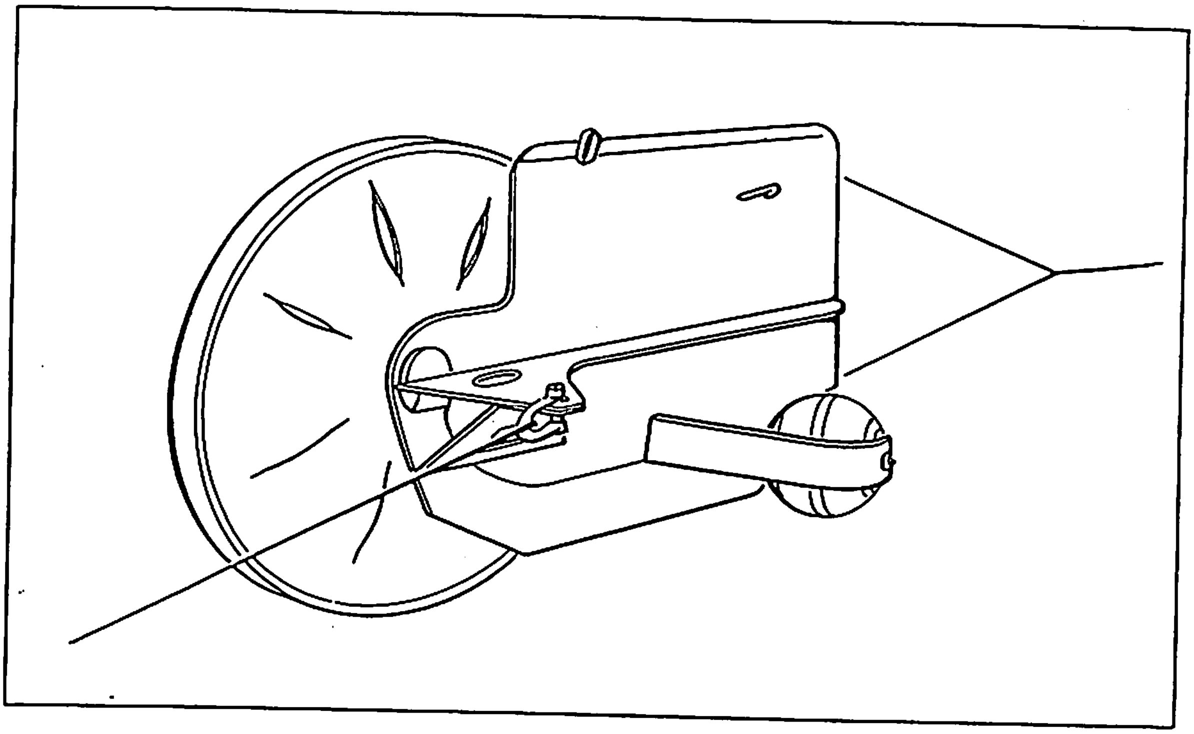
Model Specifications		
Length	0.673	m
Height	0.450	m
Projected Area	0.301	m2
Aspect Ratio	0.67	
Area Ratio	0.99	
Weight in Air	11.8	kg
Weight in Water	10.3	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.04	0.49	2.14
30 deg.	1.14	0.58	1.96
35 deg.	1.24	0.75	1.66
40 deg.	1.34	0.89	1.50
45 deg.	1.24	0.99	1.25
Maximum CL at 42 deg.	1.35	0.94	1.44



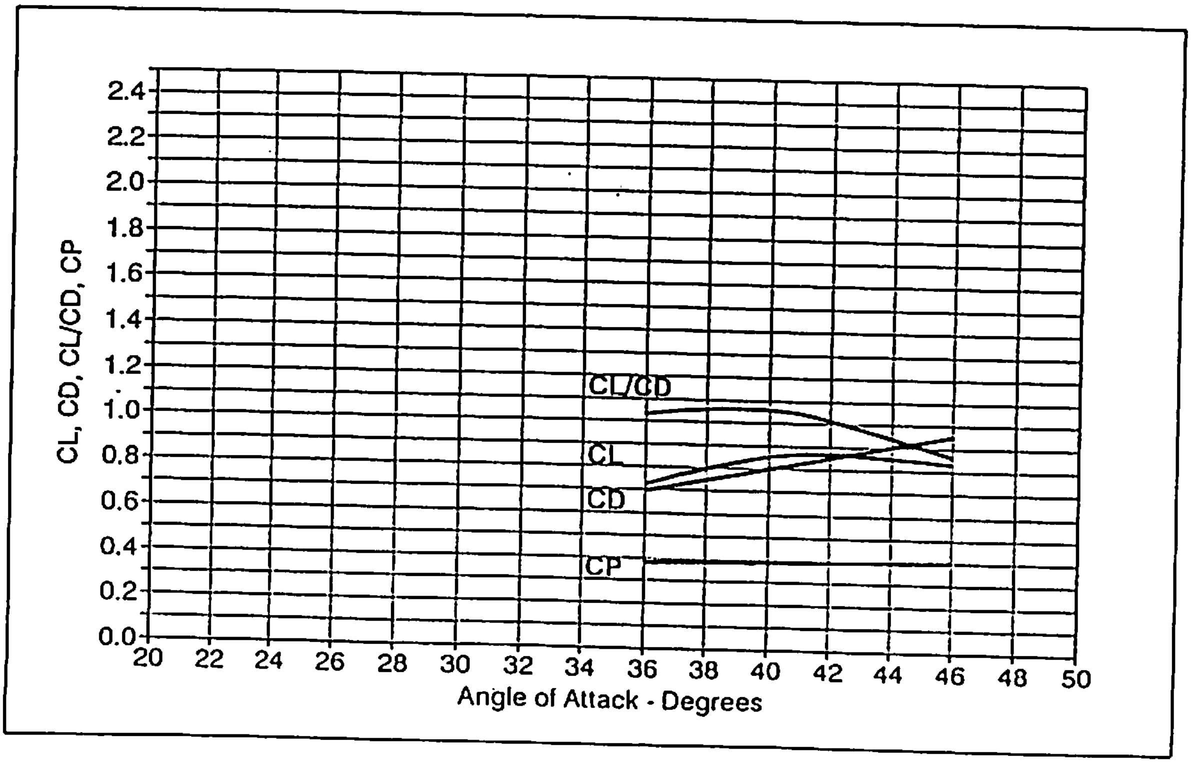
Le Beon Panneau a Roue Type LBR

Otterboard with large wheel. Tested in upright condition.



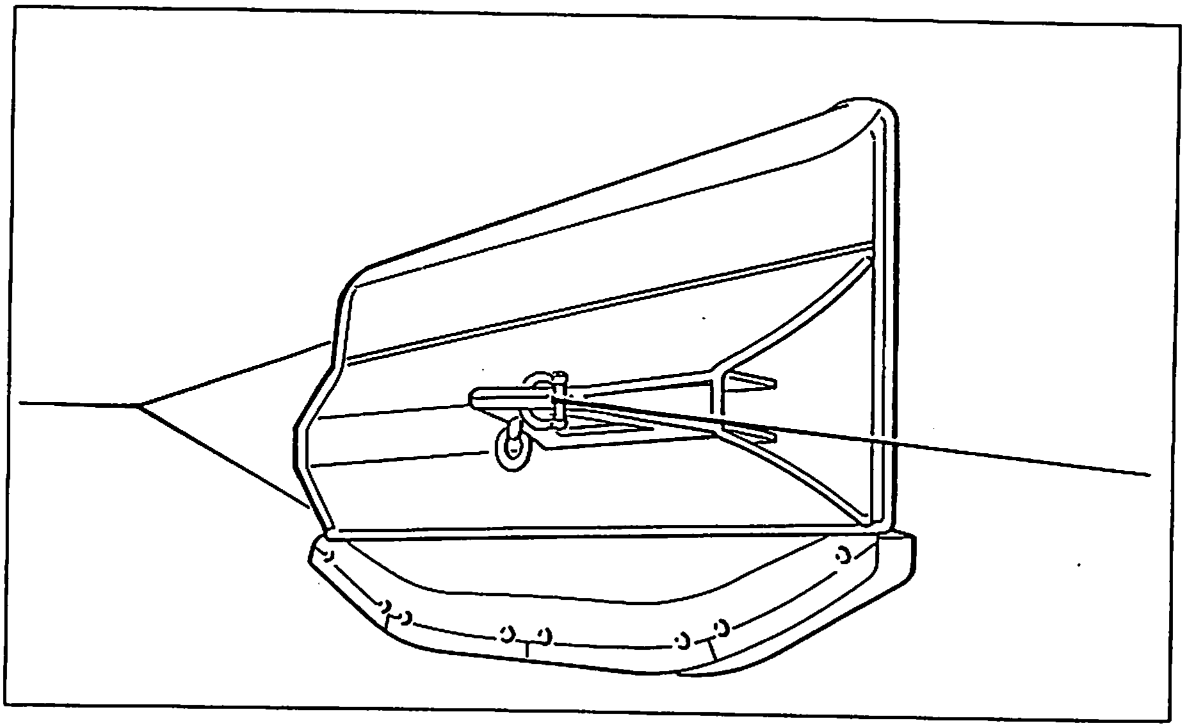
Model Specifications		
Length	0.780	m
Height	0.455	m
Projected Area	0.307	m2
Aspect Ratio	0.58	
Area Ratio	0.87	
Weight in Air	12.3	kg
Weight in Water	10.7	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	-	-	-
35 deg.	-	-	-
40 deg.	0.85	0.80	1.05
45 deg.	0.84	0.93	0.90
Maximum CL at 41 deg.	0.86	0.83	1.04



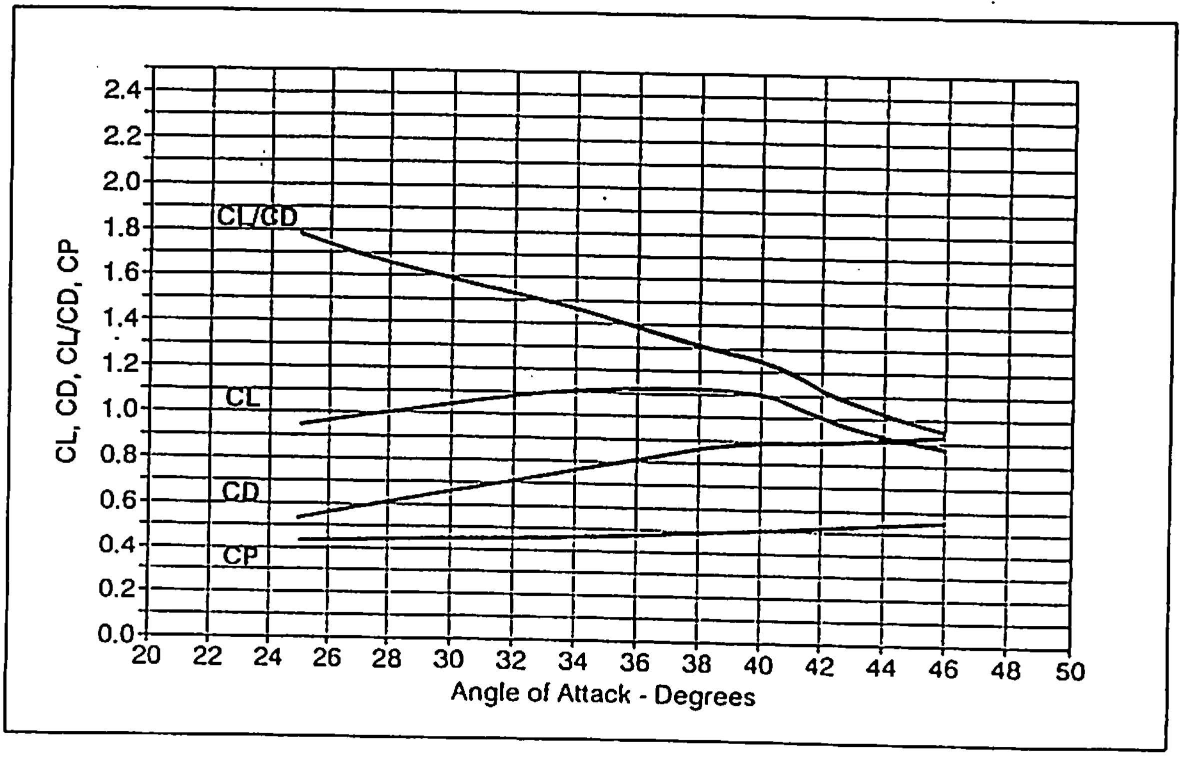
Le Beon Hydrostable

Cambered. Tested in upright condition.



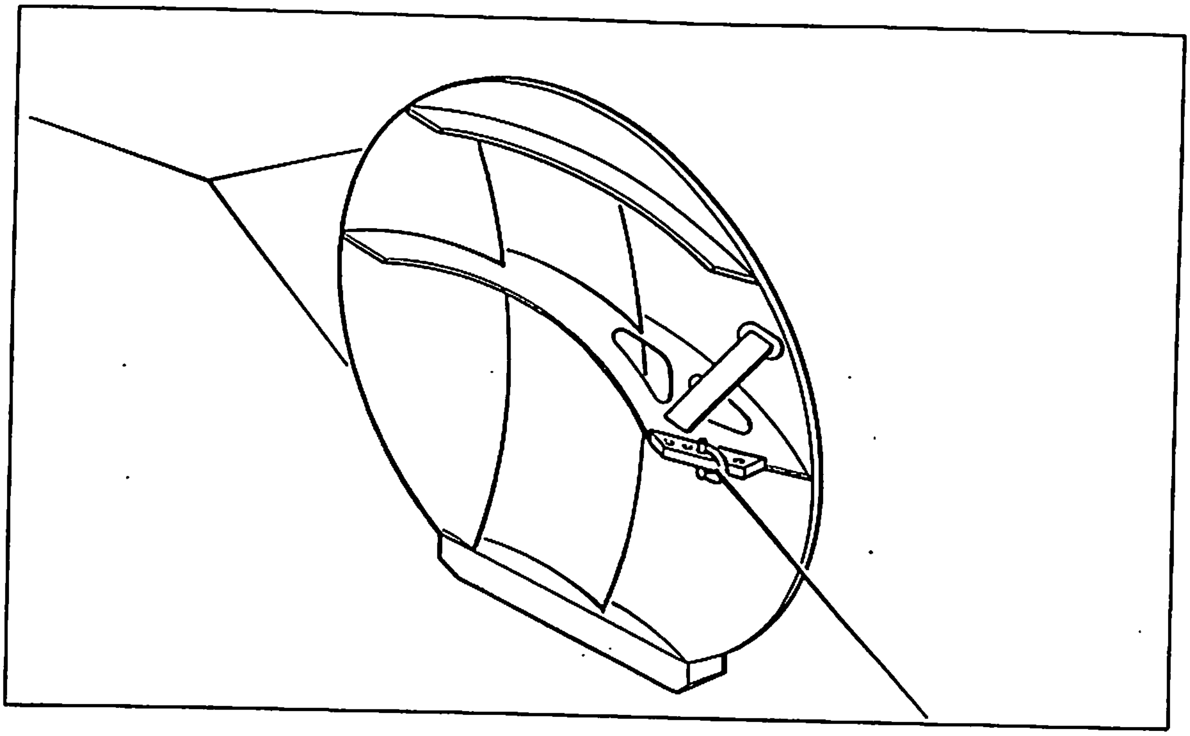
Model Specifications		
Length	0.765	m
Height	0.400	m
Projected Area	0.294	m2
Aspect Ratio	0.52	
Area Ratio	0.96	
Weight in Air	13.0	kg
Weight in Water	11.5	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	0.94	0.53	1.77
30 deg.	1.04	0.65	1.59
35 deg.	1.11	0.78	1.42
40 deg.	1.10	0.88	1.24
45 deg.	0.89	0.91	0.98
Maximum CL at 38 deg.	1.11	0.85	1.30



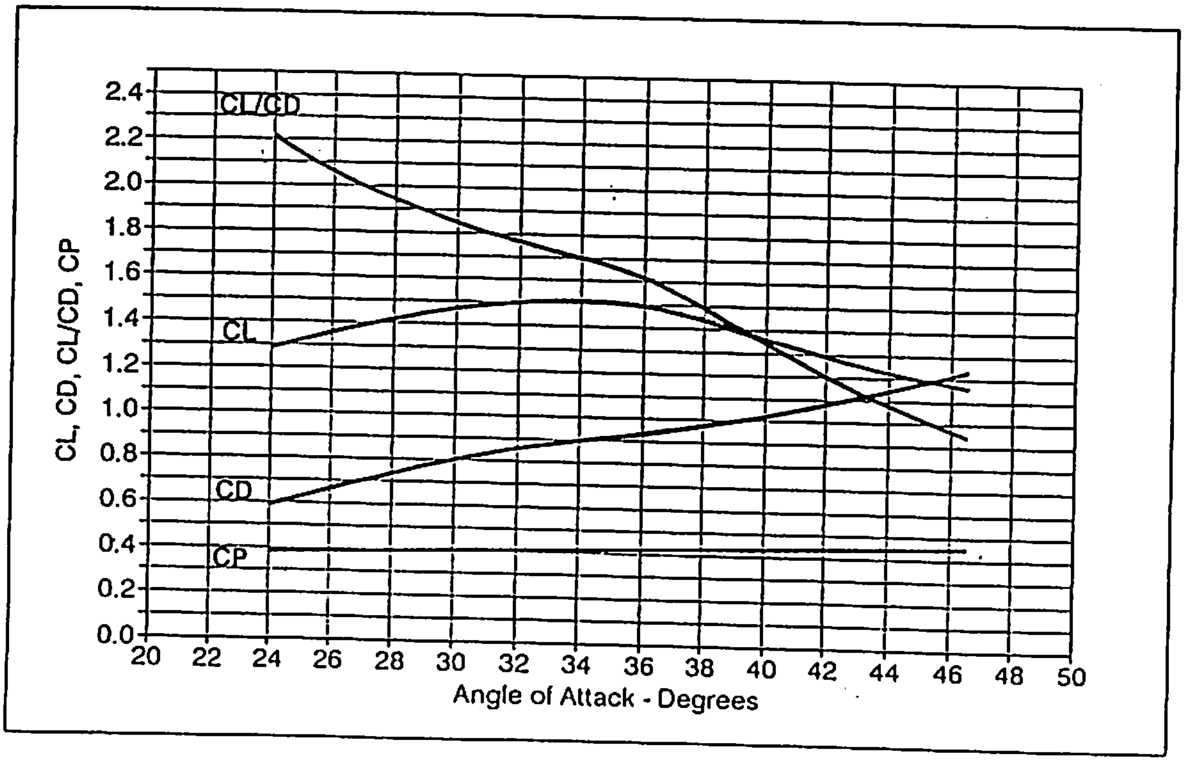
Lindholmen

Spherical with two slots. Tested in upright condition.



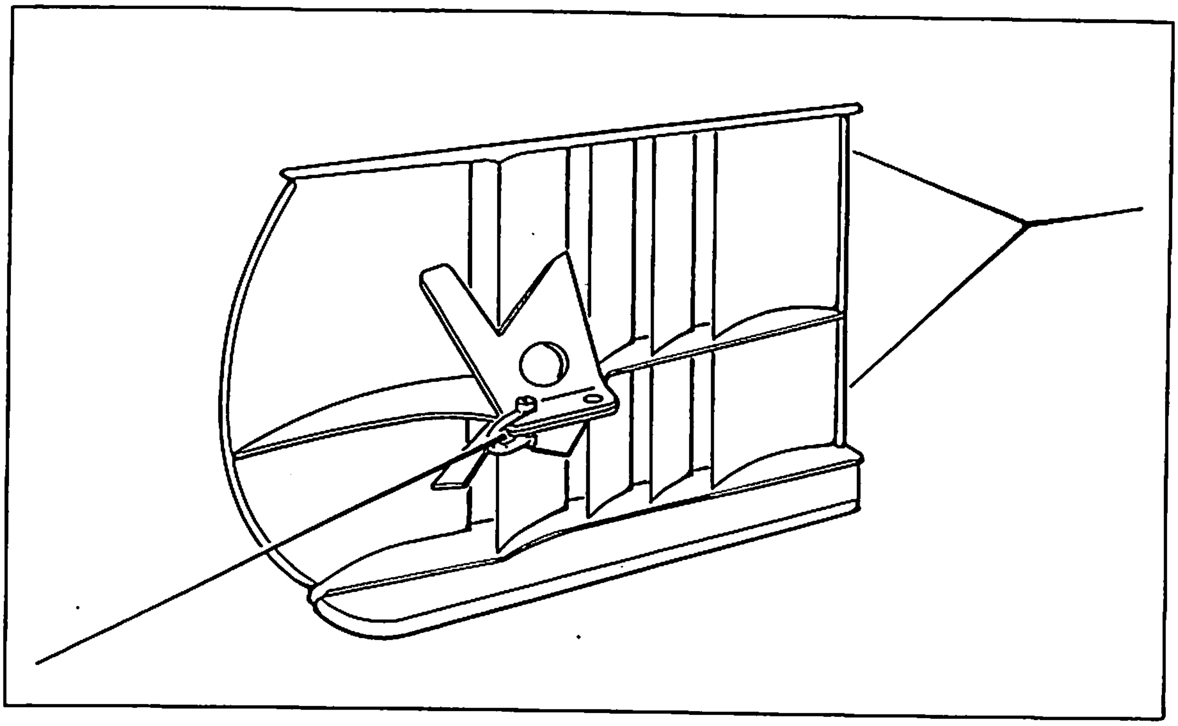
Model Specifications		
Length	0.580	m
Height	0.580	m
Projected Area	0.264	m2
Aspect Ratio	1.00	
Area Ratio	0.78	
Weight in Air	10.0	kg
Weight in Water	8.7	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.31	0.62	2.13
30 deg.	1.46	0.80	1.84
35 deg.	1.50	0.91	1.66
40 deg.	1.35	1.01	1.33
45 deg.	1.20	1.17	1.02
Maximum CL at 34 deg.	1.51	0.89	1.69



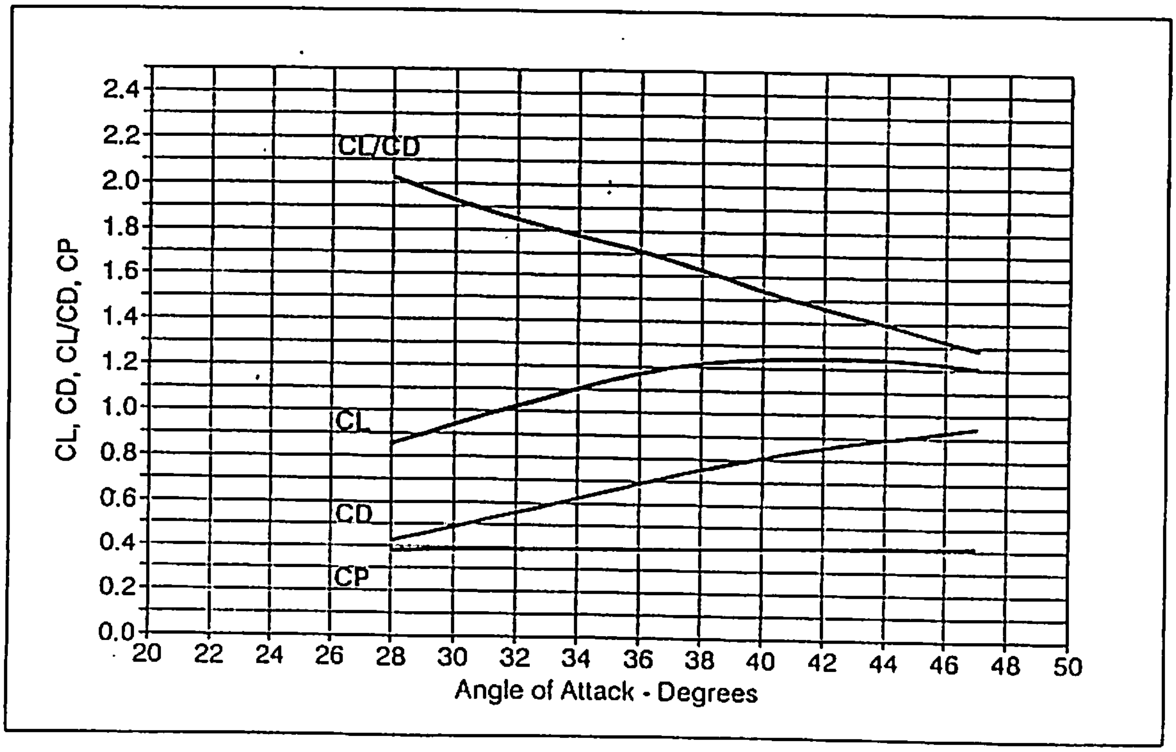
Morgere Polyfoil

Five cambered foils. Tested in upright condition.



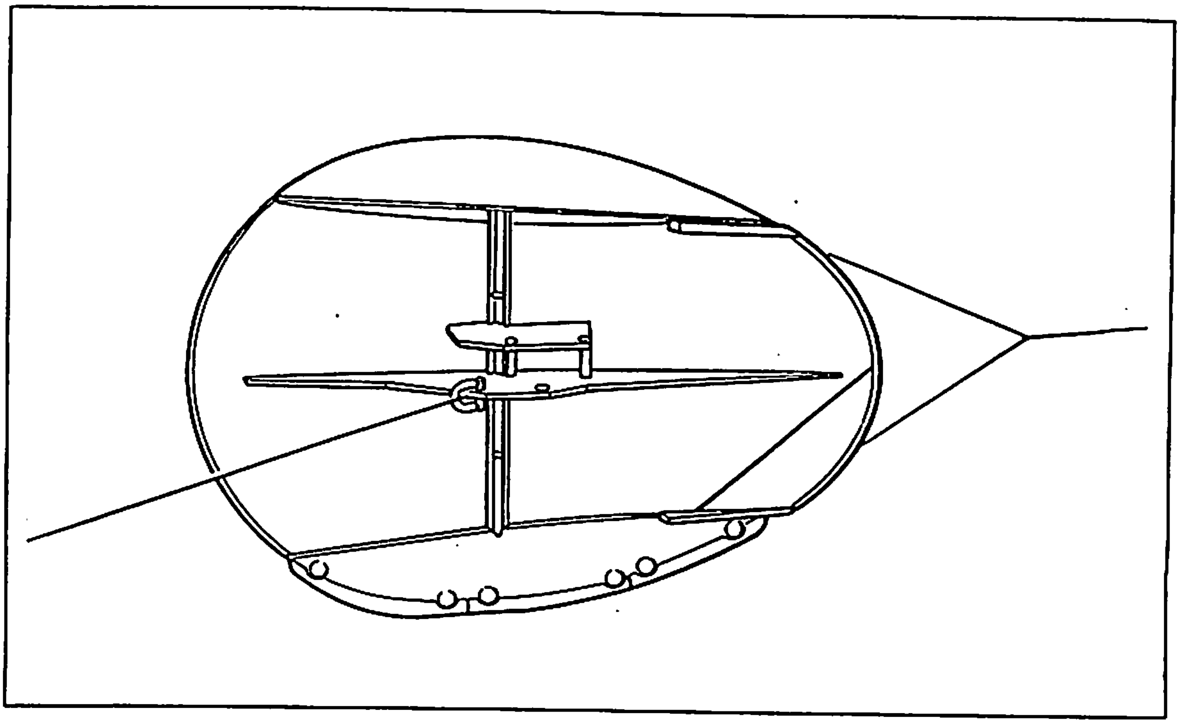
Model Specifications		
Length	0.734	m
Height	0.450	m
Projected Area	0.311	m2
Aspect Ratio	0.61	
Area Ratio	0.94	
Weight in Air	14.4	kg
Weight in Water	12.6	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	0.93	0.49	1.92
35 deg.	1.13	0.65	1.74
40 deg.	1.23	0.80	1.53
45 deg.	1.23	0.90	1.36
Maximum CL at 43 deg.	1.24	0.87	1.42



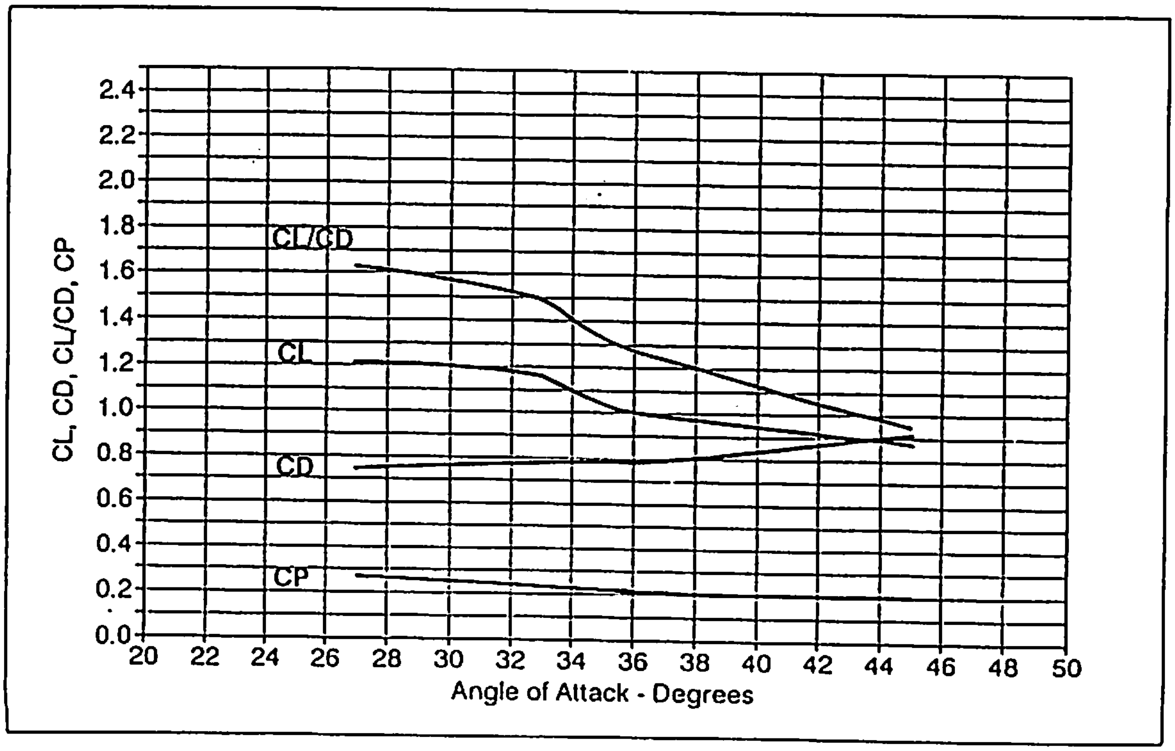
Morgere Polyvalent Ovale

Cambered oval with one slot. Tested in upright condition.



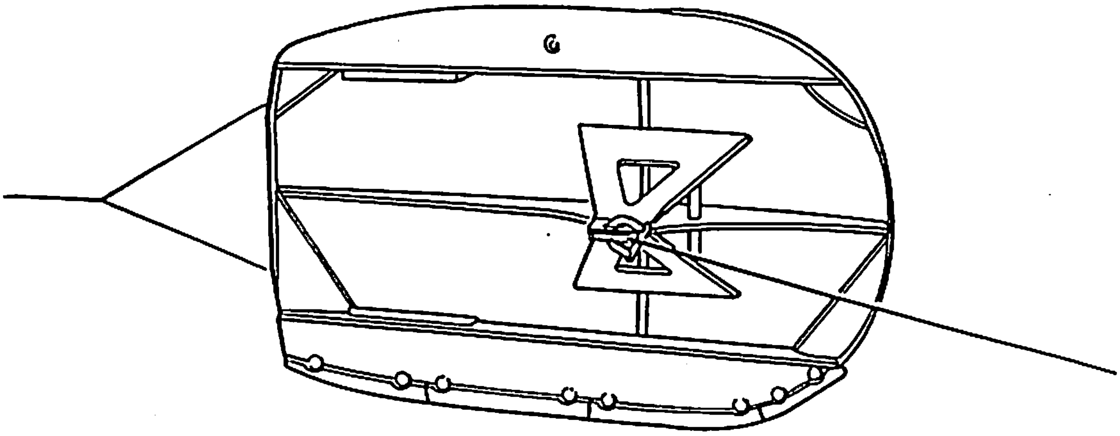
Model Specifications		
Length	0.660	m
Height	0.450	m
Projected Area	0.238	m2
Aspect Ratio	0.68	
Area Ratio	0.80	
Weight in Air	12.7	kg
Weight in Water	11.2	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	1.20	0.77	1.57
35 deg.	1.04	0.79	1.33
40 deg.	0.95	0.84	1.13
45 deg.	0.88	0.92	0.95
Maximum CL at 27 deg.	1.22	0.75	1.63



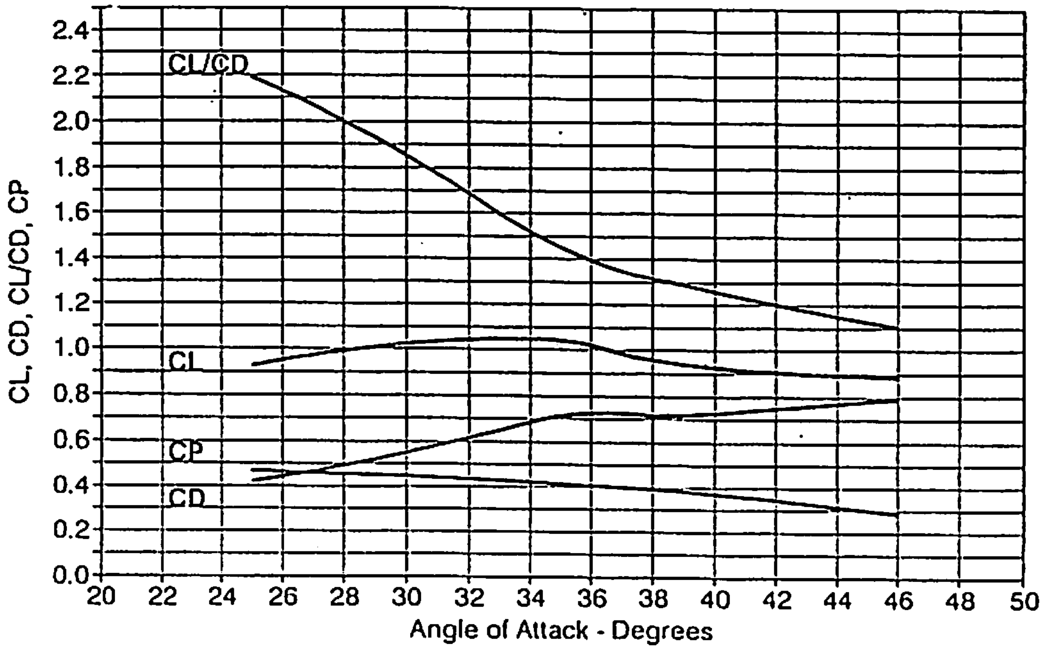
Morgere Polyvalent Type R

Cambered with one slot. Tested in upright condition.



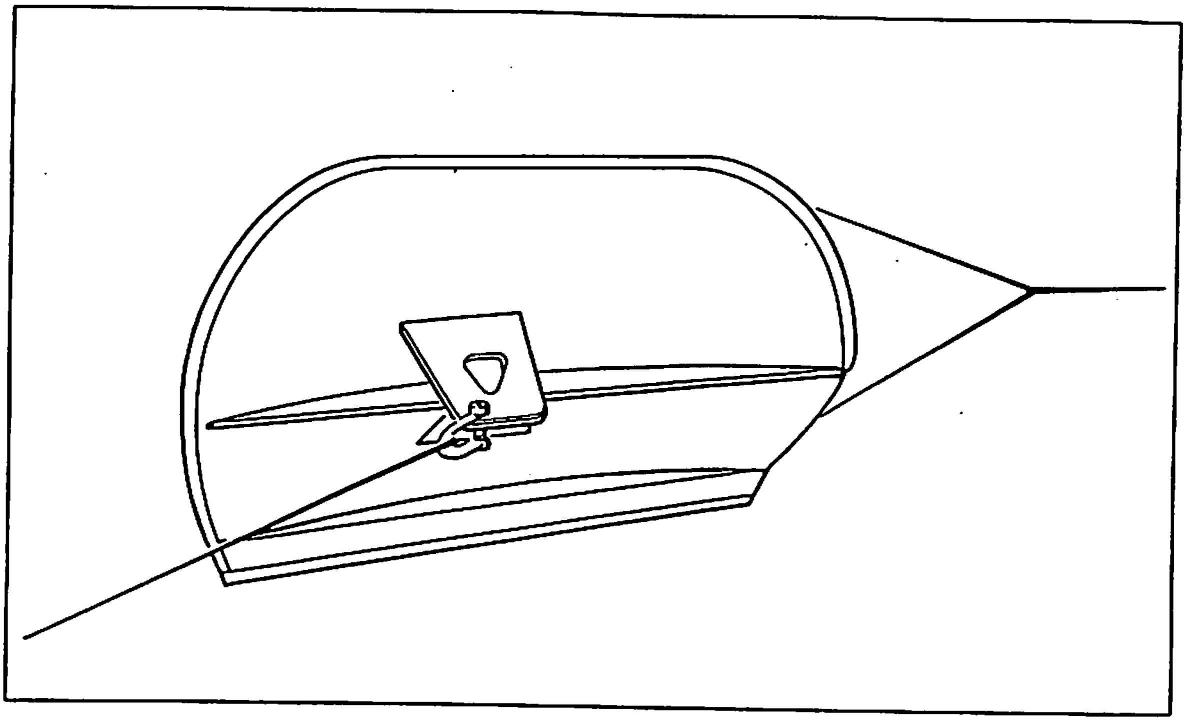
Model Specifications		
Length	0.715	m
Height	0.420	m
Projected Area	0.271	m2
Aspect Ratio	0.59	
Area Ratio	0.90	
Weight in Air	12.4	kg
Weight in Water	11.0	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	0.92	0.42	2.19
30 deg.	1.02	0.55	1.86
35 deg.	1.04	0.71	1.46
40 deg.	0.92	0.73	1.26
45 deg.	0.88	0.79	1.12
Maximum CL at 34 deg.	1.04	0.68	1.52



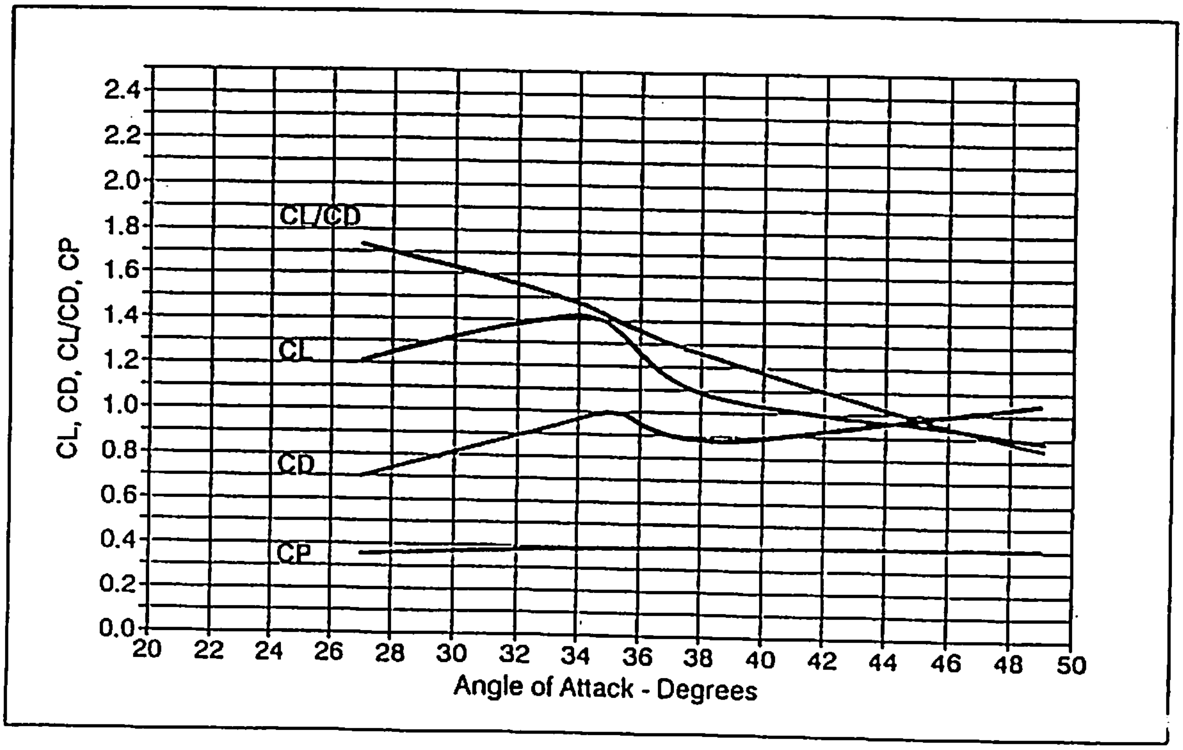
Morgere W Horizontal

Cambered vee. Tested with upper plate vertical.



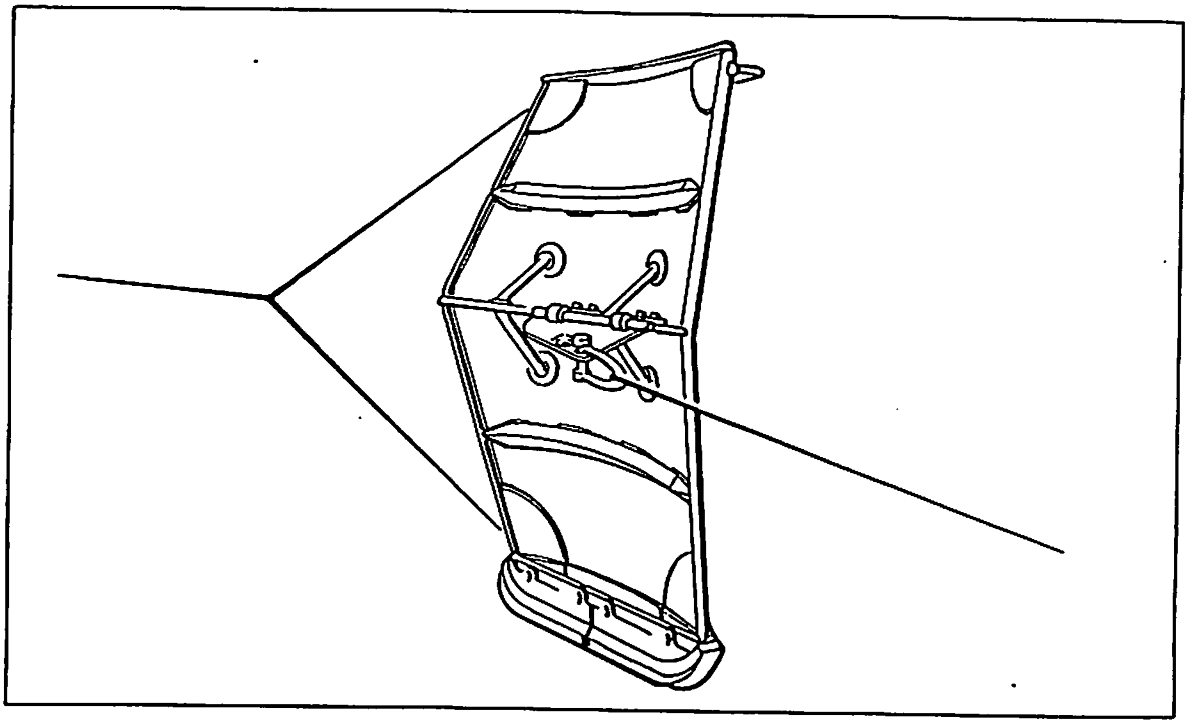
Model Specifications		
Length	0.800	m
Height	0.420	m
Projected Area	0.304	m2
Aspect Ratio	0.53	
Area Ratio	0.90	
Weight in Air	15.4	kg
Weight in Water	13.4	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	1.31	0.81	1.62
35 deg.	1.39	0.99	1.41
40 deg.	1.04	0.88	1.18
45 deg.	0.95	0.97	0.98
Maximum CL at 34 deg.	1.41	0.96	1.47



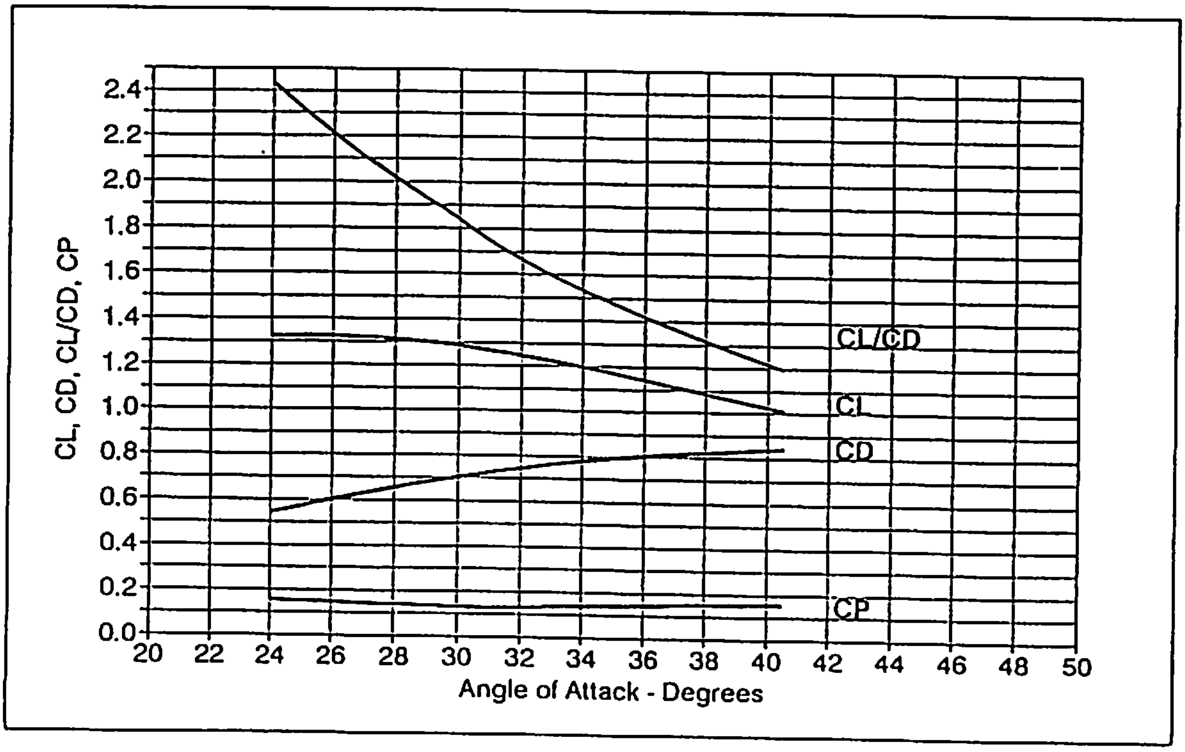
Morgere W Vertical

High aspect ratio cambered. Tested with upper plate vertical.



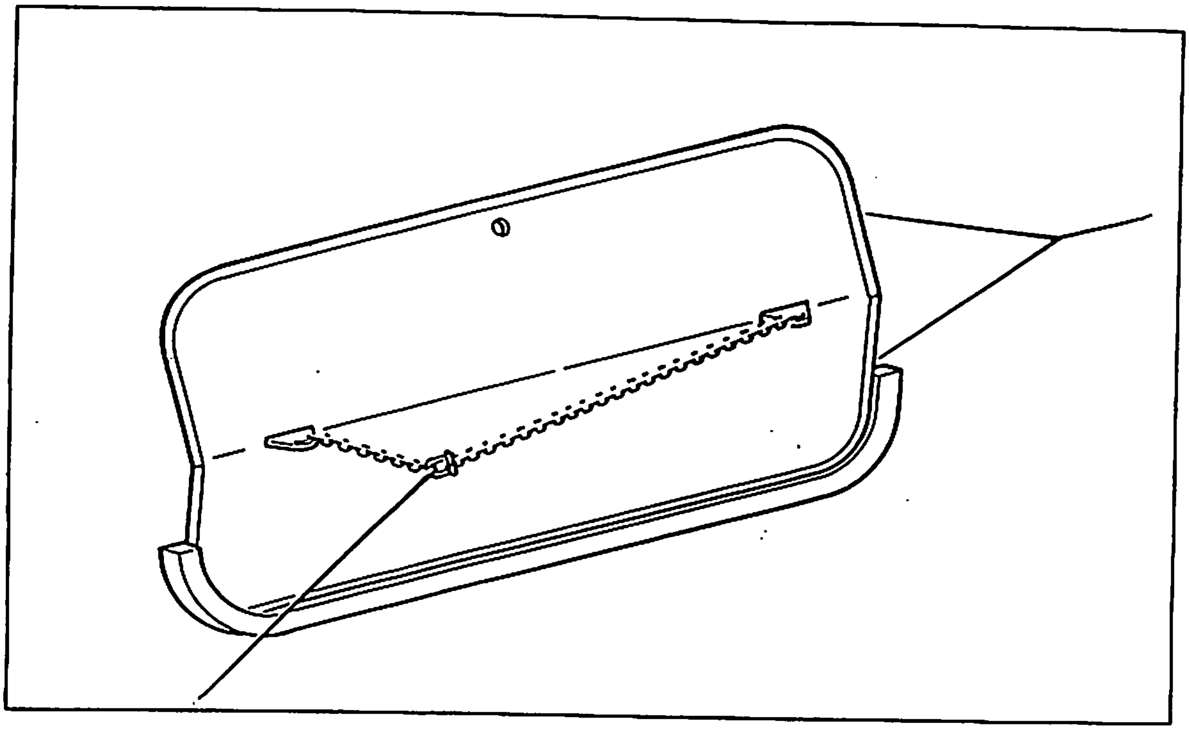
Model Specifications		
Length	0.535	m
Height	0.710	m
Projected Area	0.330	m2
Aspect Ratio	1.33	
Area Ratio	0.87	
Weight in Air	12.8	kg
Weight in Water	11.2	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.32	0.57	2.33
30 deg.	1.28	0.70	1.84
35 deg.	1.17	0.79	1.48
40 deg.	1.02	0.84	1.22
45 deg.	-	-	-
Maximum CL at 26 deg.	1.32	0.60	2.22



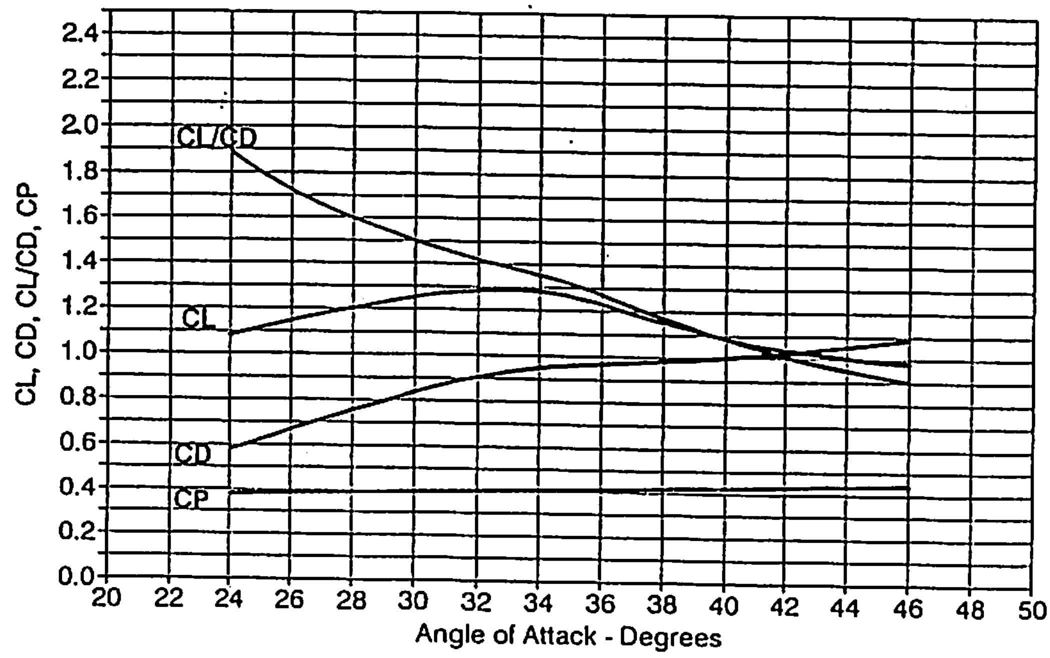
Munkebo

Vee without camber. Tested with upper plate vertical.



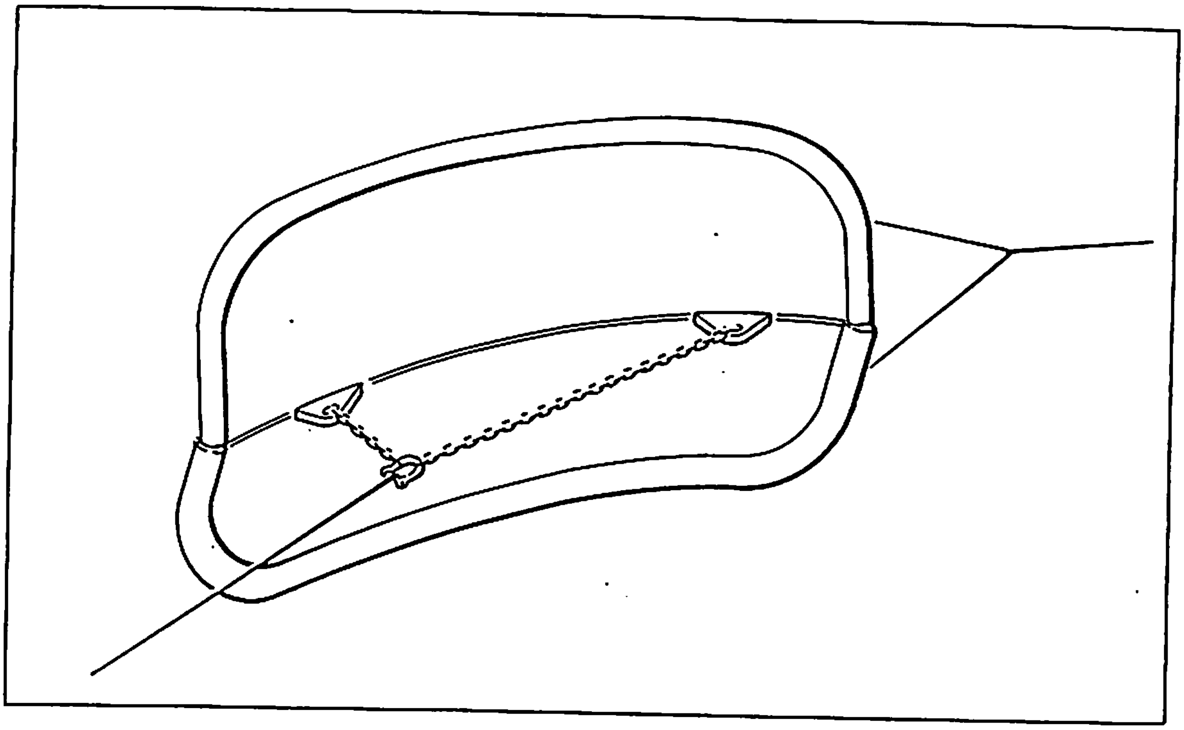
Model Specifications		
Length	0.816	m
Height	0.420	m
Projected Area	0.332	m2
Aspect Ratio	0.51	
Area Ratio	0.97	
Weight in Air	10.8	kg
Weight in Water	9.4	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.11	0.62	1.80
30 deg.	1.25	0.83	1.51
35 deg.	1.26	0.95	1.32
40 deg.	1.08	0.99	1.08
45 deg.	0.99	1.06	0.93
Maximum CL at 33 deg.	1.28	0.92	1.39



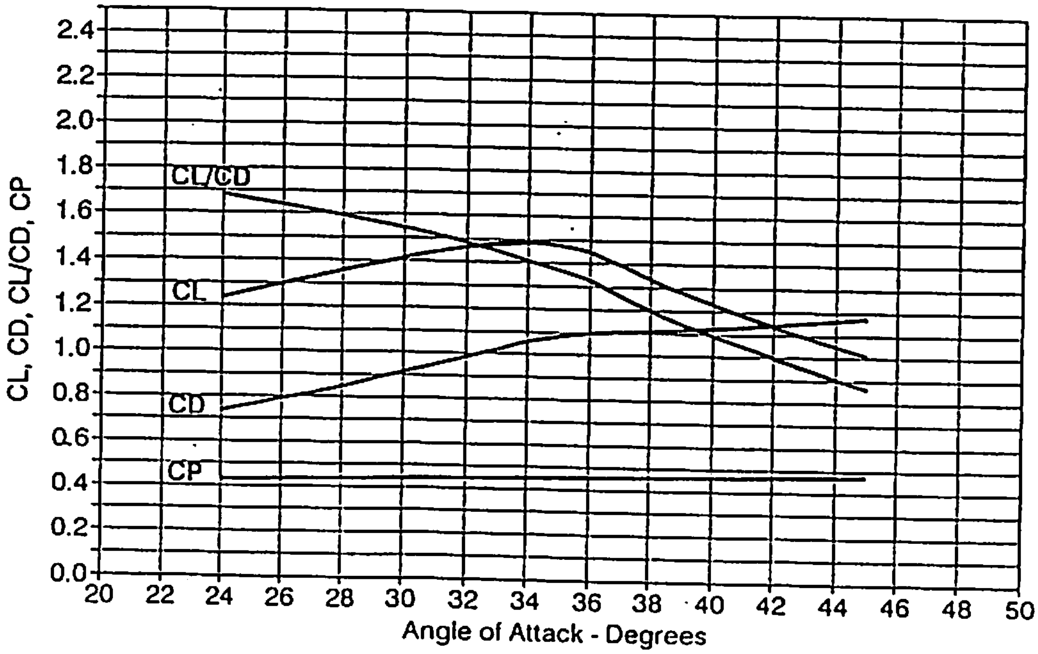
Net Tec

Cambered vee. Tested with upper plate vertical.



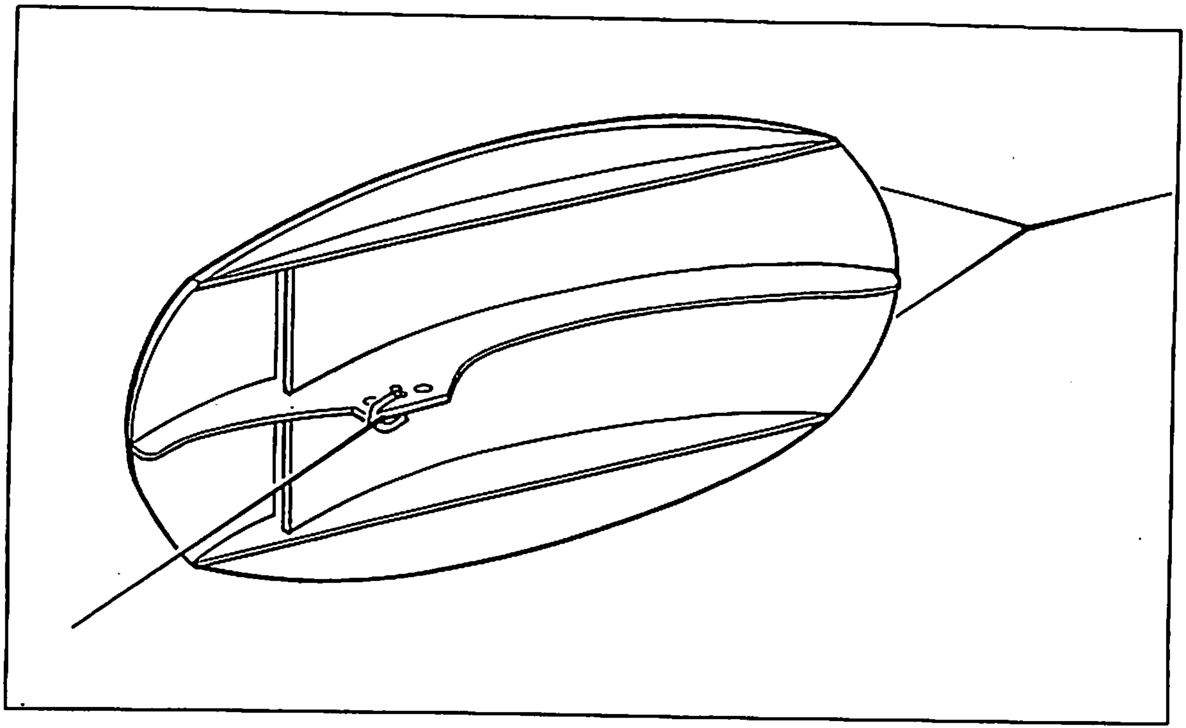
Model Specifications		
Length	0.686	m
Height	0.427	m
Projected Area	0.288	m2
Aspect Ratio	0.62	
Area Ratio	0.98	
Weight in Air	22.0	kg
Weight in Water	19.2	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.26	0.76	1.66
30 deg.	1.41	0.91	1.55
35 deg.	1.47	1.07	1.37
40 deg.	1.23	1.12	1.10
45 deg.	1.01	1.17	0.87
Maximum CL at 34 deg.	1.48	1.05	1.41



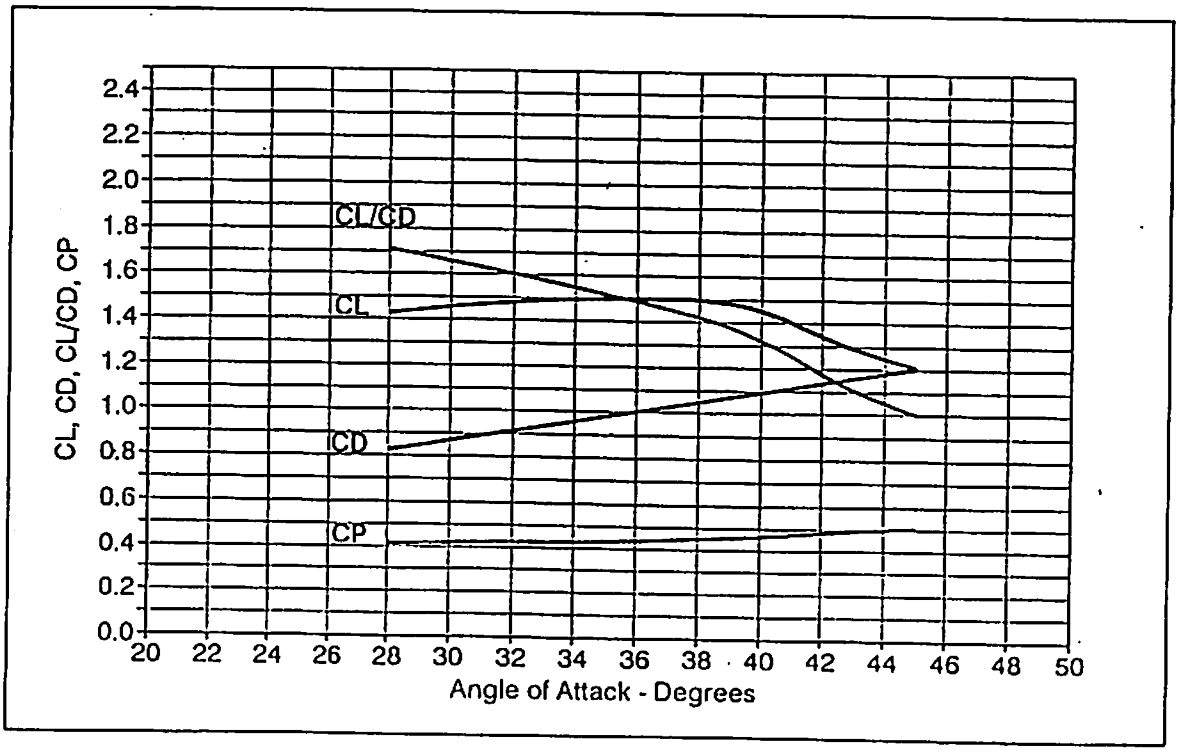
Perfect New Oval

Cambered oval with one slot. Tested in upright condition.



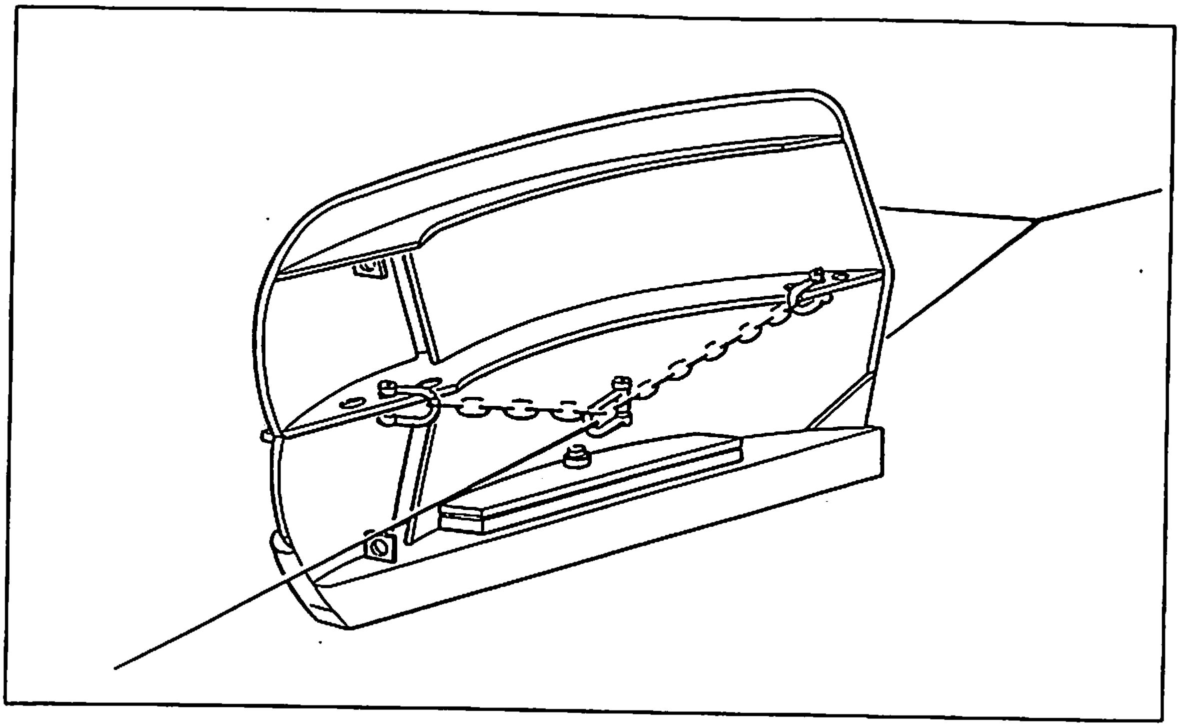
Model Specifications		
Length	0.800	m
Height	0.525	m
Projected Area	0.33	m2
Aspect Ratio	0.66	
Area Ratio	0.79	
Weight in Air	16.2	kg
Weight in Water	14.1	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	1.45	0.87	1.66
35 deg.	1.49	0.98	1.52
40 deg.	1.45	1.09	1.32
45 deg.	1.21	1.20	1.00
Maximum CL at 37 deg.	1.50	1.03	1.46



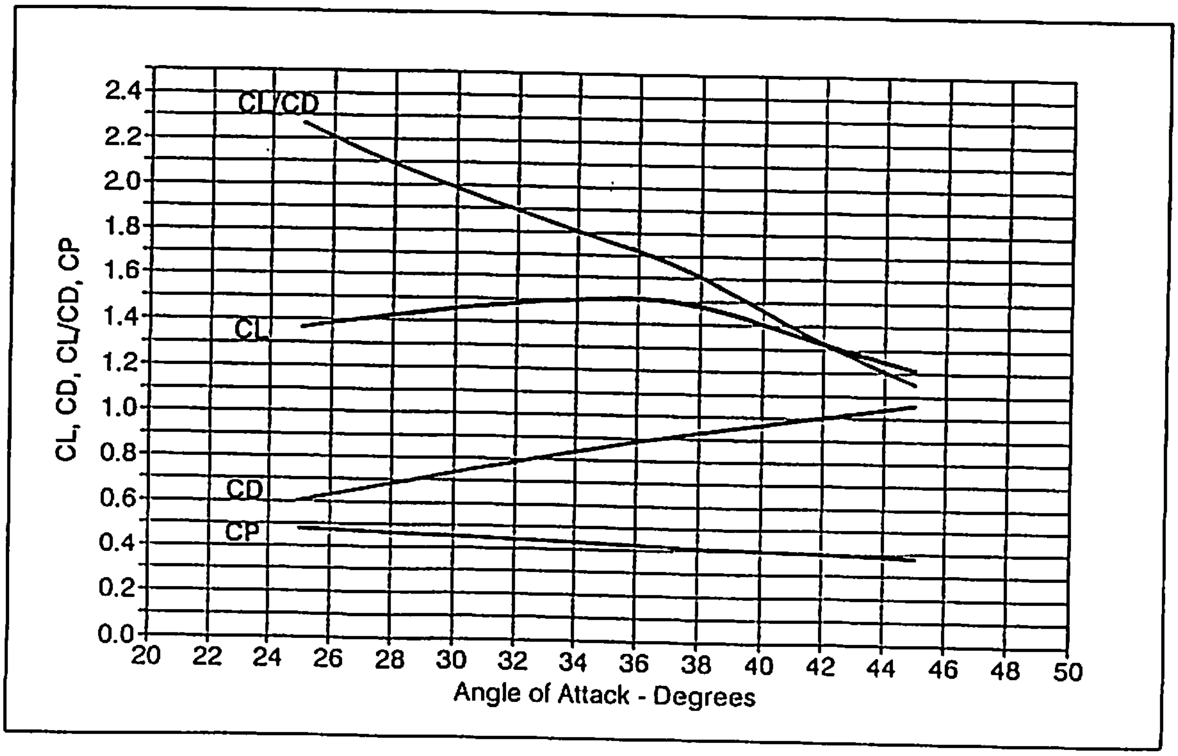
Perfect Patent B

Cambered vee with one slot. Tested with upper plate vertical.



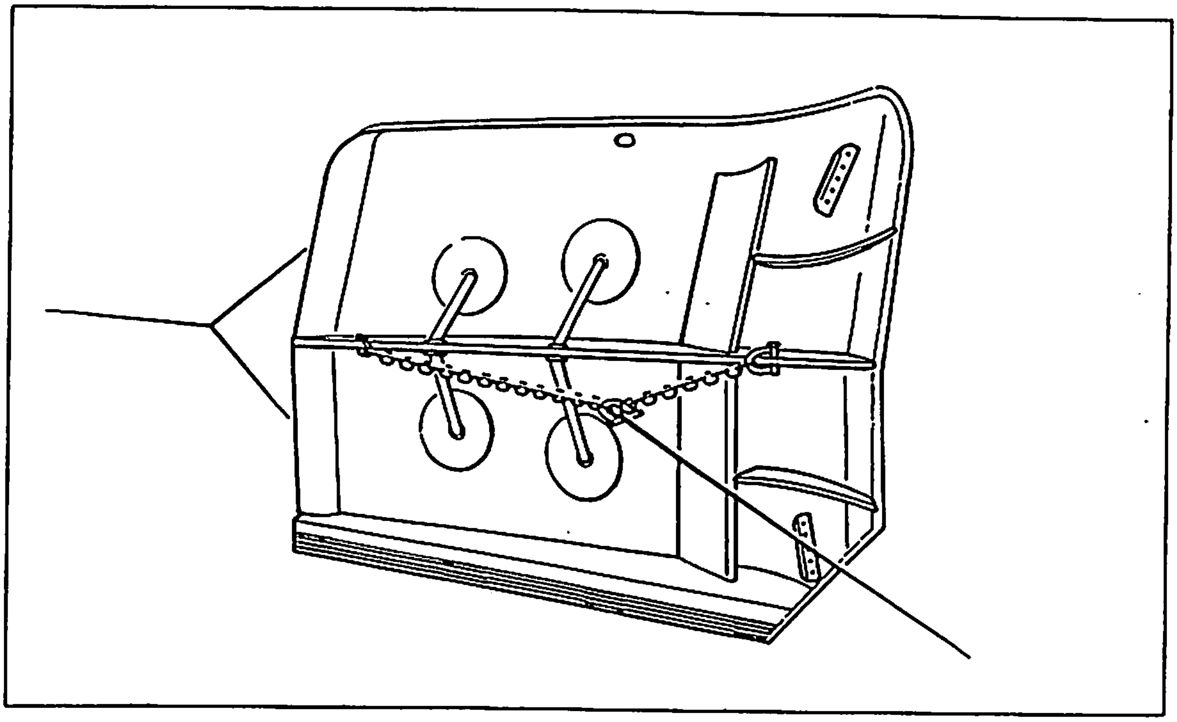
Model Specifications		
Length	0.715	m
Height	0.480	m
Projected Area	0.329	m2
Aspect Ratio	0.67	
Area Ratio	0.96	
Weight in Air	13.0	kg
Weight in Water	11.3	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.36	0.60	2.27
30 deg.	1.45	0.73	1.98
35 deg.	1.50	0.86	1.76
40 deg.	1.40	0.96	1.46
45 deg.	1.21	1.05	1.15
Maximum CL at 36 deg.	1.50	0.88	1.71



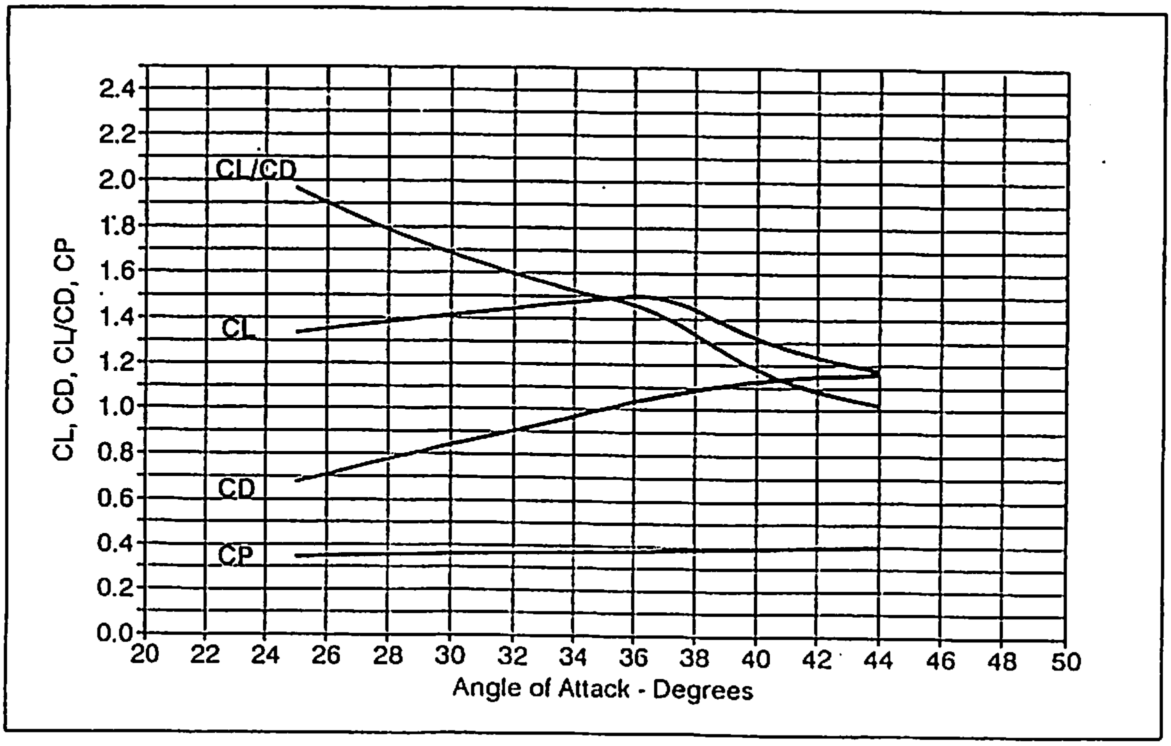
Thyborøn Type 2 66"

Cambered vee with one slot. Tested with upper plate vertical.



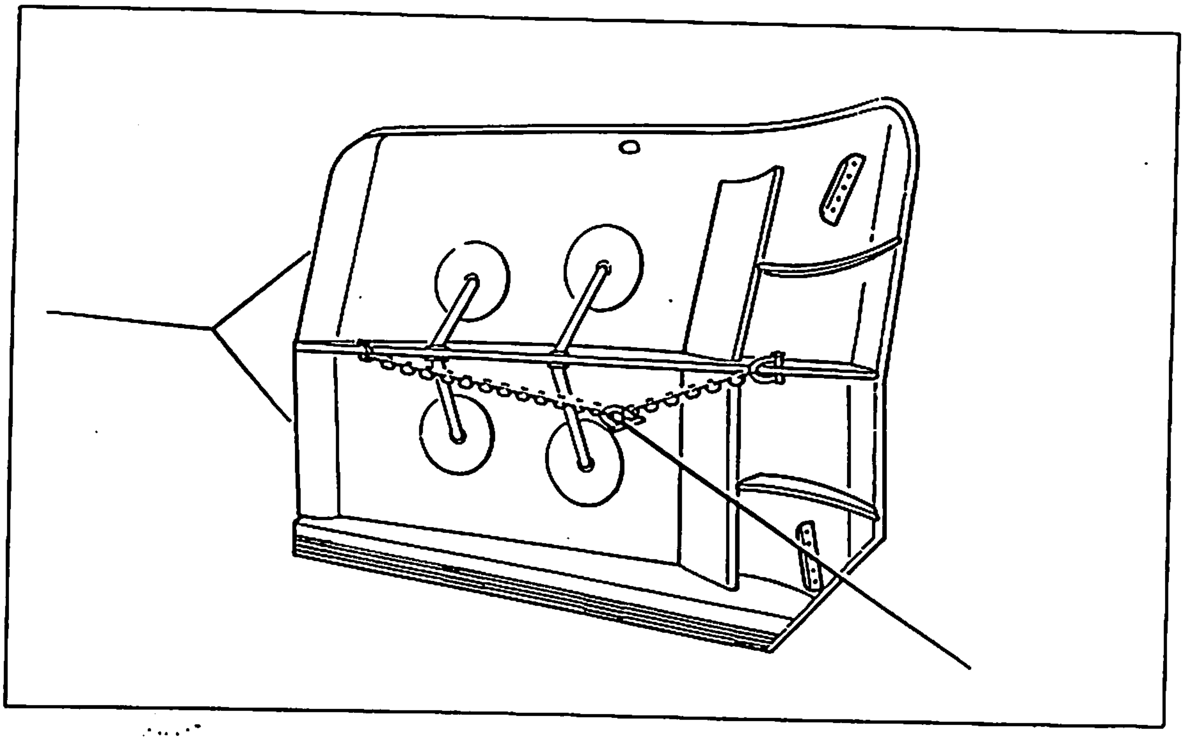
Model Specifications		
Length	0.690	m
Height	0.395	m
Projected Area	0.271	m2
Aspect Ratio	0.57	
Area Ratio	0.99	
Weight in Air	10.2	kg
Weight in Water	8.9	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.33	0.68	1.97
30 deg.	1.41	0.84	1.69
35 deg.	1.48	1.00	1.49
40 deg.	1.31	1.12	1.17
45 deg.	-	-	-
Maximum CL at 36 deg.	1.49	1.03	1.46



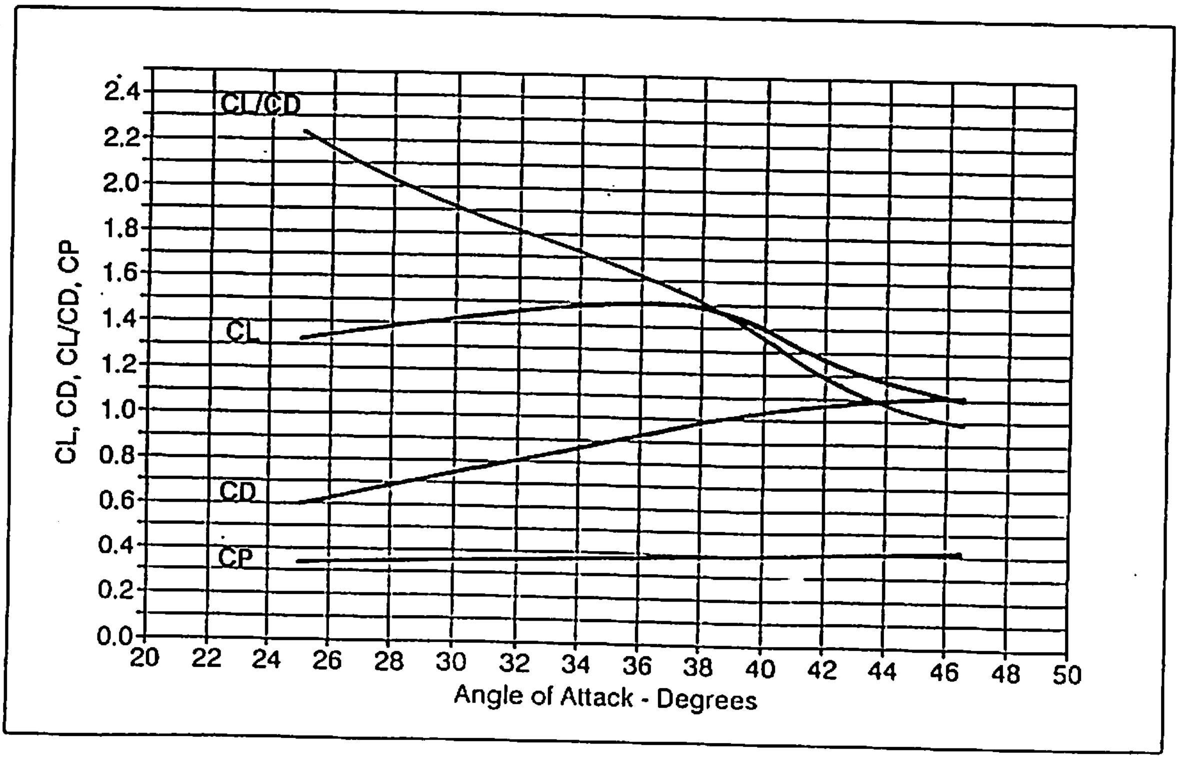
Thyborøn Type 2 125"

Cambered vee with one slot. Tested with upper plate vertical.



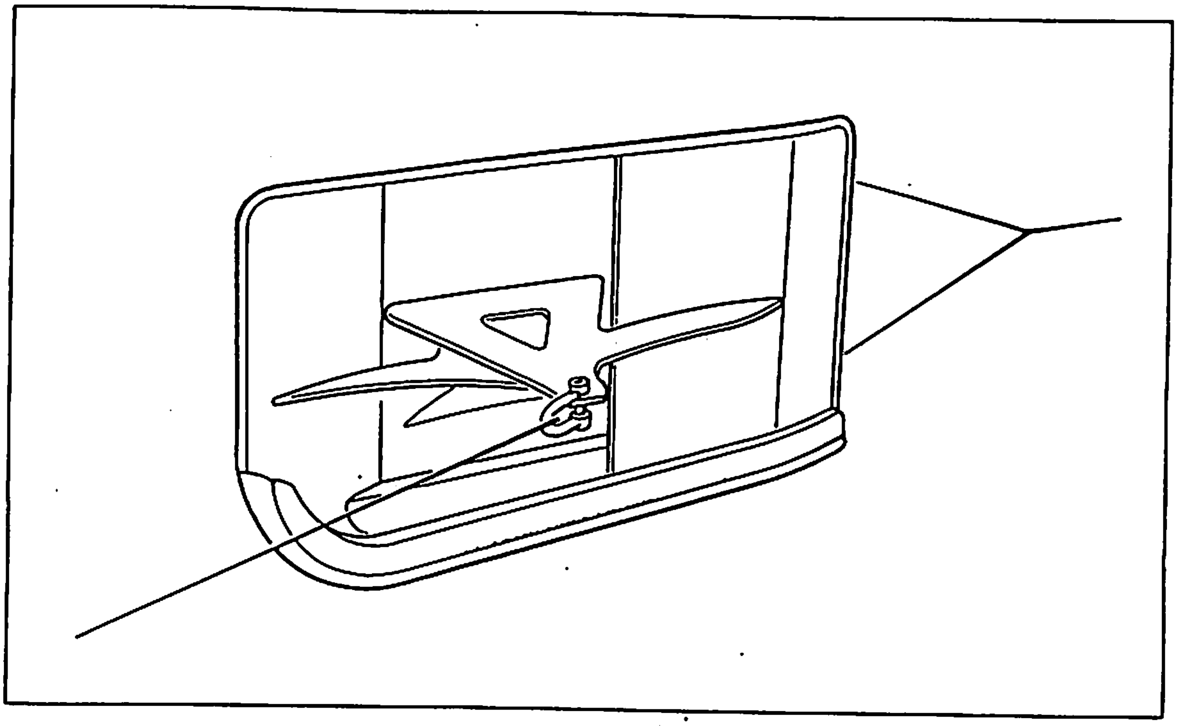
Model Specifications		
Length	0.670	m
Height	0.420	m
Projected Area	0.279	m2
Aspect Ratio	0.63	
Area Ratio	0.99	
Weight in Air	11.0	kg
Weight in Water	9.6	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	1.32	0.59	2.24
30 deg.	1.42	0.74	1.91
35 deg.	1.49	0.89	1.67
40 deg.	1.39	1.03	1.35
45 deg.	1.13	1.09	1.04
Maximum CL at 37 deg.	1.49	0.95	1.57



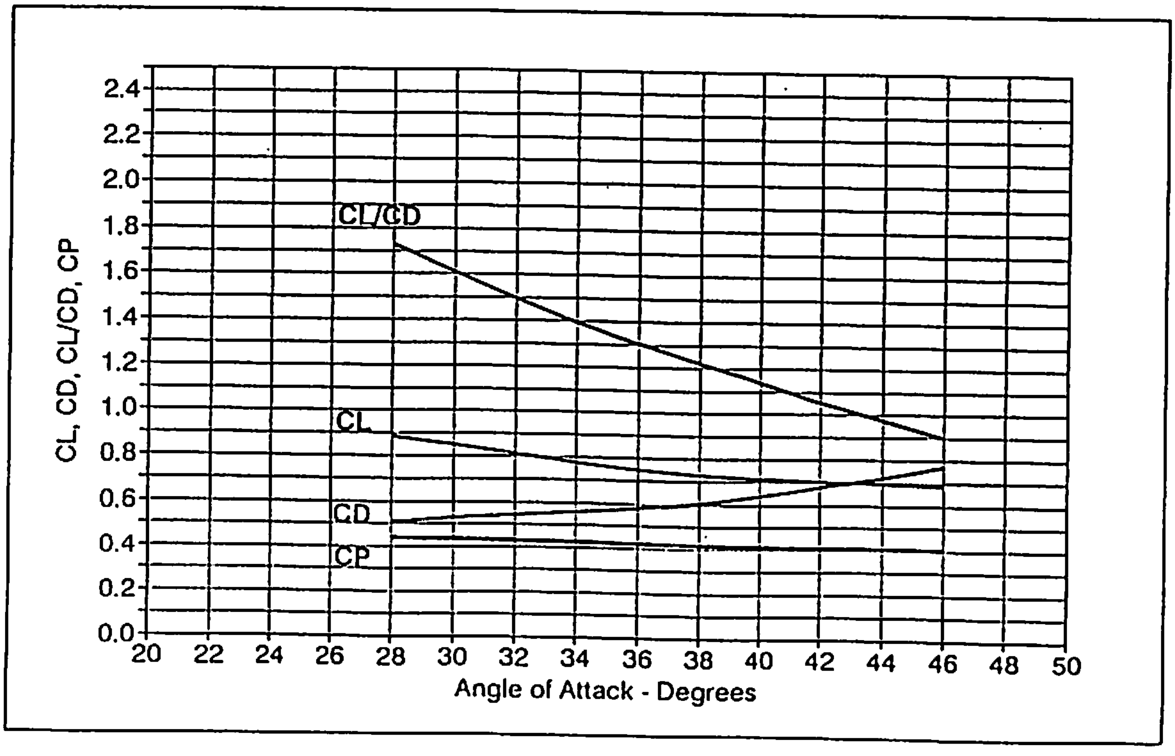
Vergoz Panneau Z

Z-shaped. Tested in upright condition.



Model Specifications		
Length	0.748	m
Height	0.390	m
Projected Area	0.285	m2
Aspect Ratio	0.52	
Area Ratio	0.98	
Weight in Air	11.8	kg
Weight in Water	10.3	kg

Angle of Attack	CL	CD	CL/CD
25 deg.	-	-	-
30 deg.	0.85	0.53	1.61
35 deg.	0.76	0.57	1.34
40 deg.	0.72	0.64	1.13
45 deg.	0.69	0.74	0.93
Maximum CL at 28 deg.	0.88	0.51	1.73



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