SEA FISH INDUSTRY AUTHORITY

Industrial Development Unit

TRAWL DOOR DEVELOPMENT - STUDENT PROJECT
FLUME TANK TESTING OF $\frac{1}{4}$ SCALE DOORS

Internal Report No. 1288

P. Butler

September 1986

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FLUME TANK TESTING OF ¼ SCALE DOORS

SUMMARY

This project is the second by a summer vacational student on the subject of testing model trawl doors in the Seafish Flume Tank at Hull.

Progress on equipment and instrumentation has been made and a standard procedure of testing various types of trawl doors has been recommended.

Test results on ¼ scale model flat and vee doors are documented and discussed.

Further work is necessary on this project but this trial is an important step in the need to have a standard method of testing and assessing trawl door performance.

W. Siddle

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TRAWL DOOR DEVELOPMENT PROJECT 2 - STUDENT PROJECT
FLUME TANK TESTING OF ¼ SCALE DOORS

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TRAWL DOOR DEVELOPMENT - STUDENT PROJECT
FLUME TANK TESTING OF ¼ SCALE DOORS

1. INTRODUCTION

This, the second trawl door development project is designed to follow on from the report produced by S. Macinko for the Seafish in September 1985. The aims of the project were established from the recommendations set down at the end of the 1985 report.

This project was funded under the MAFF R&D Commission 1986/87 ref. I.B.A. 16(a).

2. OBJECTIVES

a) To develop a model door testing procedure that:

   i) enables all types of doors to be tested.

   ii) gives accurate quantitative assessment of door performance, defined as Coefficient of lift and drag (C_L/C_D) (Appendix C).

   iii) minimise the time spent rigging the doors thus enabling, more time to be spent taking results.

b) To obtain using the above procedure the C_L and C_D characteristics of both flat and 'V' doors with various angles of attack and heel.

c) To investigate what the effect of moving the triangles or of other rigging arrangements has on the heel angle.

d) To compare the results obtained with those found in the 1985 report to give an indication as to the repeatability of the procedure.

3. DESCRIPTION MODEL DOORS ON TEST

1 : 4 scale models, principal full scale dimensions.

Model Type	Vee	Flat
Length	2.74m	3.14m
Height	1.624m	1.372m
Projected Block Area	4.45m^2	4.31m^2
Weight in Air	746.36kg	801.82kg

4. TRIALS STAFF AND EQUIPMENT

Trials Staff

Paul Butler	SFIA Temporary Assistant
Adrian Strickland	SFIA Flume Tank Engineer
Nigel Ward	SFIA Naval Architect

Trials Equipment

1 - 50kg load cell (warp)
1 - 20kg load cell (bridle)
Apple Macintosh microcomputer, monitor, printer, spreadsheet
Gould Pen chart recorder 260
Hitachi CCTV remote eye camera
Motorised focus/zoom auto iris lens
Camera tripod
Sony "U" matic video cassette recorder
Sony black and white monitor
Perspex screen cover aparatus for monitor (see Fig.3)
Tripod mounting frame attached to beams of moveable trolley (Fig.2)

5. TRIALS NARRATIVE

5.1 Tank Rigging

The model tests were carried out using a similar door testing technique to the one used in the 1985 project by S. Macinko, but using adaptations intended to reduce the time taken to gather a data "set" and to make adjustments between successive trials runs. The adaptations include a pulley arrangement in the tank at the bridle towing post to enable the doors to be quickly hauled out and re-shot. (See Figure 1, page 4 showing the arrangement) The pulley arrangement also enables the bridle to be shortened or lengthened with the aid of the existing overhead crane The forward towing post remained in a position 2.2m from the centre of the tank and the height of the towing block raised and lowered only to produce the heel angle required. In all the tests the bridle ran parallel with the bottom of the tank and had a 20kg load cell incorporated into it approximately 0.5m from the rear towing pulley. The warp load readings were as before measured by a 50kg load cell located at the forward towing post.

5.2 Video measurement methods

Figure 2, page 5 illustrates the camera support system.

Another adaptation to the old test procedure was the method used to determine the wire angles and angle of attack. This involved the use of a high quality auto iris lens and camera arrangement with manual focus and zoom facilities. This was positioned vertically above a small boat with a transparent window and attached to the overhead trolley by means of a specially adapted frame. The frame could be moved across the trolley and the trolley along the tank. Once in position the boat screen was levelled using a bubble spirit level so it ran parallel to the tank belt. With this arrangement video recordings can be made of the warp, door and bridle enabling their angles to be taken off a black and white monitor screen after the trials. When positioning the camera above the item to be filmed the line of view must be vertically above the object to avoid angular distortion by the water and boat screen. To do this a plum bob was used to align the camera and lens. Being able to adjust the bridle length became very useful when positioning the boat

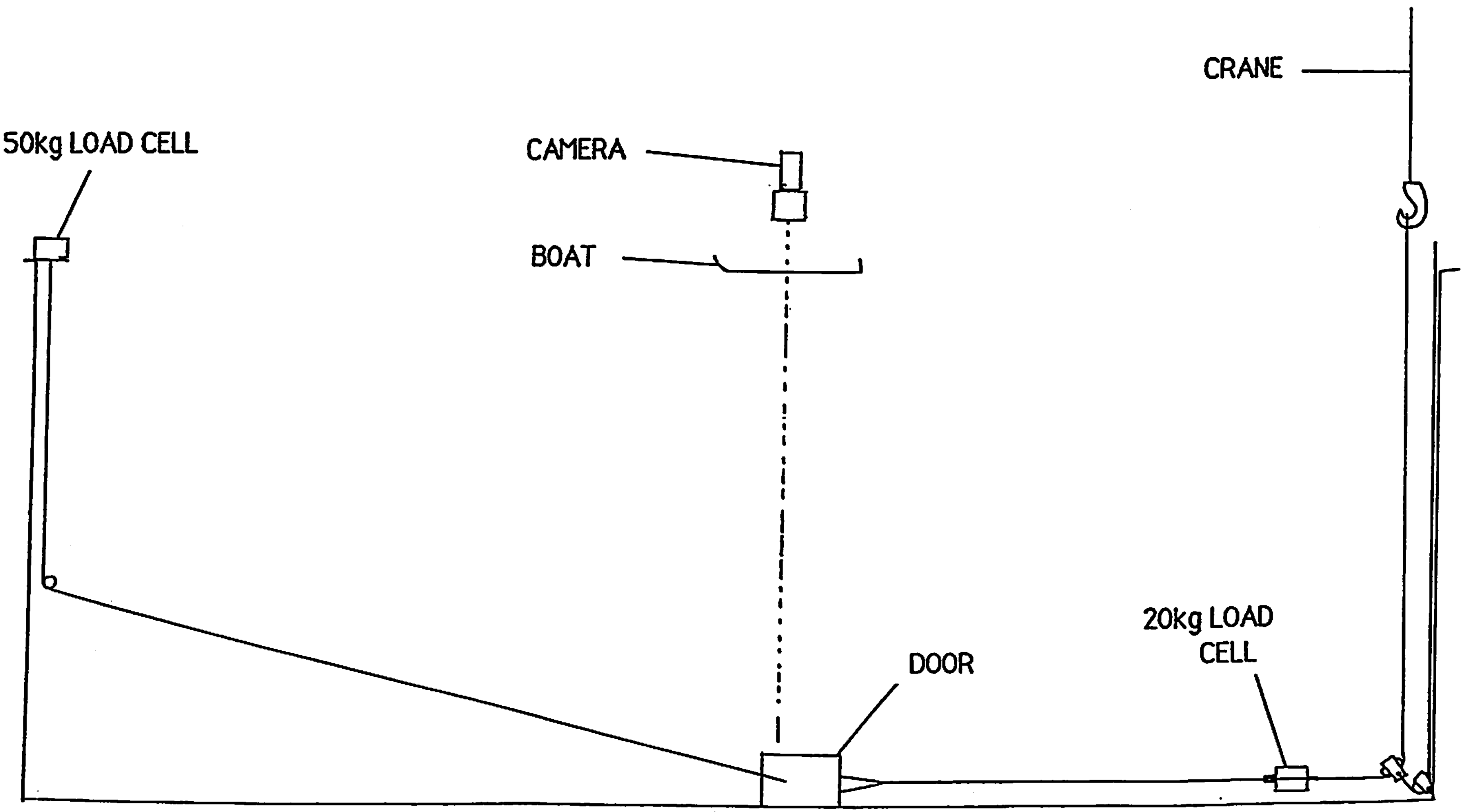


Figure.1 Tank Set-Up

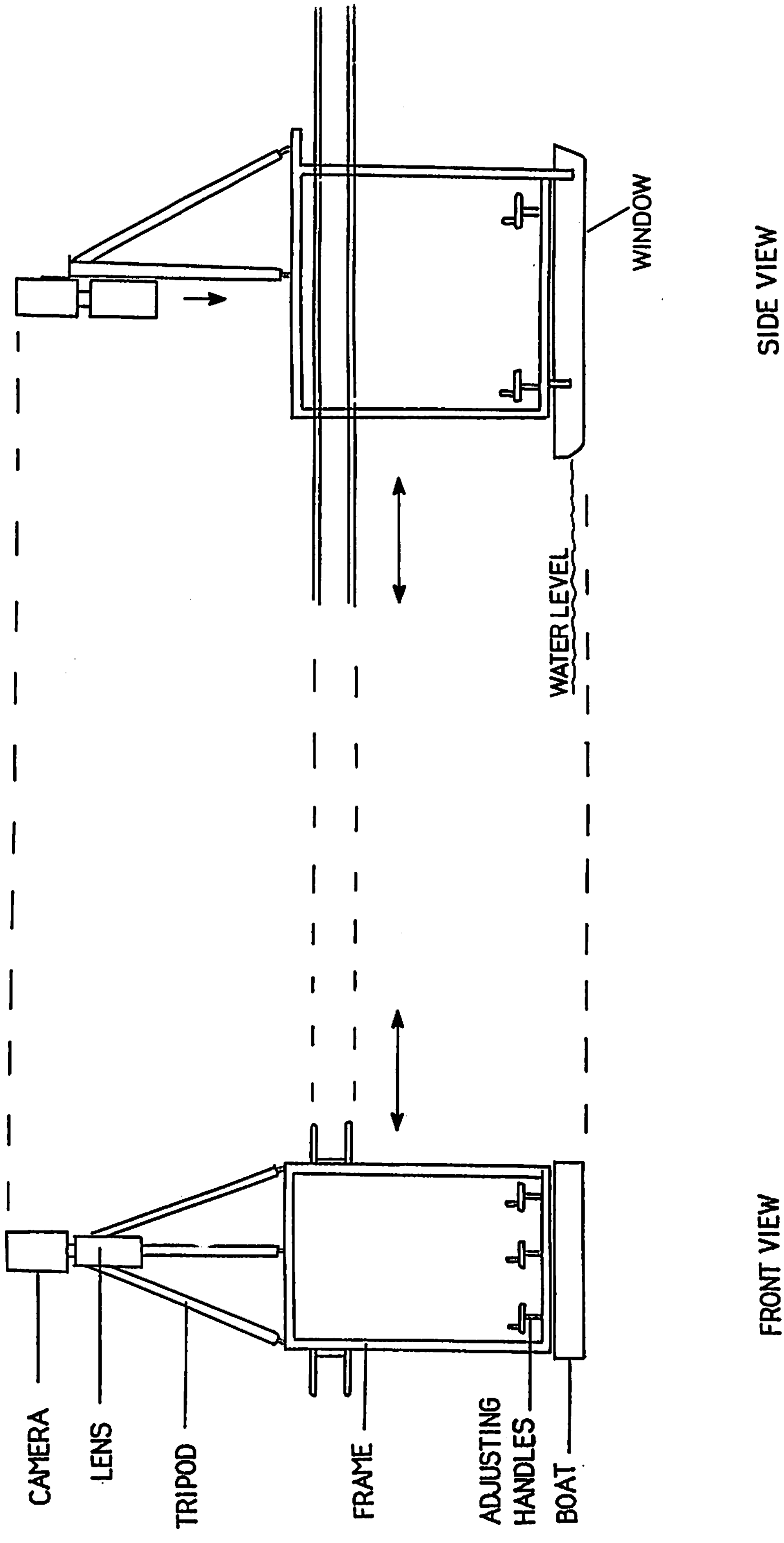
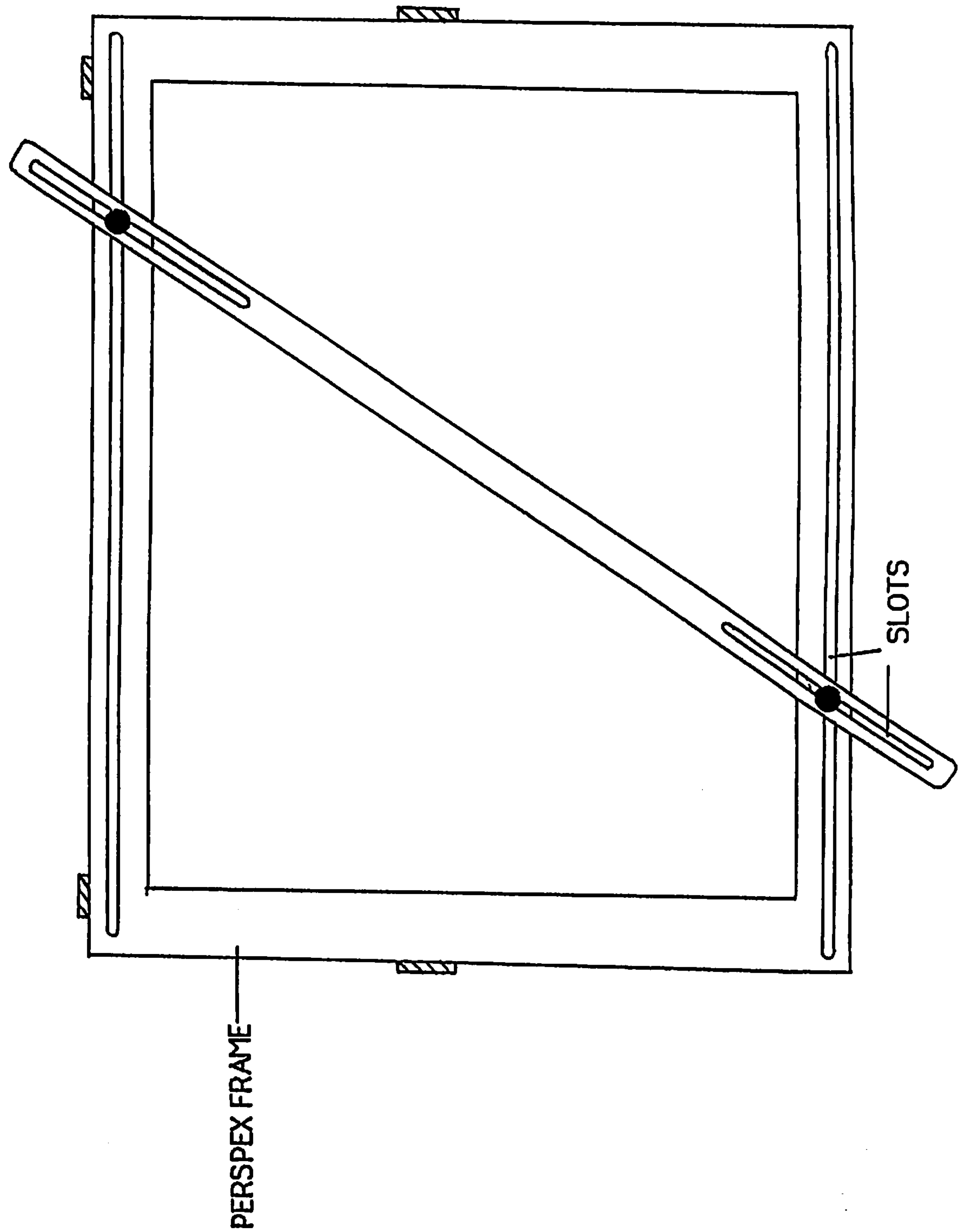


Diagram of boat, frame & camera

Figure.2



Video Monitor Angle Measurement Frame

Figure.3

over the board and wires as the board could be kept the same distance from the tank wall by raising and lowering the crane. This ability to keep the board away from the tank wall was also advantageous as it reduced the effect the wall might have on the flow of water around the board.

5.3 Wire Angle Measurement

Having set up the camera a test run was carried out with graph paper over the boat screen to check that the picture on the monitor produced a scaled view in both the x and the y plane. This was confirmed and a few sample angles taken off the graph paper were within $\pm 0.25^{\circ}$. The angles were obtained using a perspex adjustable screen placed over the monitor and a vernier protractor, see Fig 3. page 6.

The next test that was carried out with the camera apparatus was to determine how significant an error would be if the camera was not looking vertically down at the object. The results from this showed that the errors involved were only very minimal and with the use of the plum bob the errors were insignificant. However, the plum bob method was awkward to use and time consuming.

5.4 Trial Technique

Once all the equipment was set up and checked the trials started in earnest. Firstly, three runs were carried out using the 'V' door at three different speeds so that an optimum speed could be found to run the trials at. This was thought to be beneficial as constant speed would reduce the number of variables hence aiding result interpretation. The three speeds used were 1.121 m/s, 0.925 m/s and 0.717 m/s (full scale 4.3 knots, 3.6 and 2.75 knots). From the results a medium speed of around 0.9 m/s full scale 3.5 knots) was chosen to run the trials at. This was because at this speed the door was most stable giving even load cell readings and good repeatability when calculating angles of attack. Other factors influencing the choice was that running at a higher speed put undue strain on the pumps and hence could not be run for as long. At the lower speed the door was very unstable giving poor repeatability and large variations in load cell readings.

At the beginning of each testing session both the load cells were checked to make sure they were calibrated accurately and that the pen chart recorder was recording the correct values. It was found that turning the console on early and letting it warm up was good practice when it came to calibrating. In all the runs the load cells were within +-0.1 of a kilogram of their calibrated load, i.e. the 50kg warp load cell was calibrated up to 30kg +- 0.33% and the bridle load cell 15kg +- 0.66%.

The door was then placed in the tank and the water brought up to speed. During the trials it was discovered that lowering the door into the water with twine wrapped around the front triangles of the doors was much quicker and safer than using the pole. It also was very easy to flip the board up using the twine and it could be simply removed by just dropping one end and pulling it out.

At first speed readings were taken before and after each run but it was later decided that the speed readings before were unnecessary as the impellor rev. indicators on the console gave an accurate indication that the water was up to the correct speed. This saved a lot of time as the trolley had to be moved to the correct position every time speed readings were required. When taking speed readings the speed log was placed approximately 1.5m in front of the door and 0.25m in from the centre (Fig. 6, page 12). Three readings were taken of 100 second duration and the average taken. The readings showed that an accuracy of 0.005 m/s was maintained throughout the trials.

Once the speed was correct the boat and camera was positioned over first the warp and a video recording taken for 30 seconds. At the same time a set of load cell readings were taken on the pen recorder with it running at a paper speed of 125mm per minute. The process was then repeated over the door and then the bridle thus giving 3 sets of load cell readings and 3 video recordings. The trolley was then moved to take the speed readings and a warp declination angle was found. This was obtained from the side of the tank by viewing the shackle attaching the warp to the door through the eye piece and noting the height. A spot marked on the warp 1m from the shackle was then viewed with the eye piece and the difference in height was found. From the values known the declination angle could be calculated using trigonometry (Fig. 5, page 11).

The water in the tank was then stopped as the door was taken out, adjusted and reshot.

This procedure was used throughout the trials and providing nothing went wrong with the apparatus, a complete run could be executed in less than half an hour.

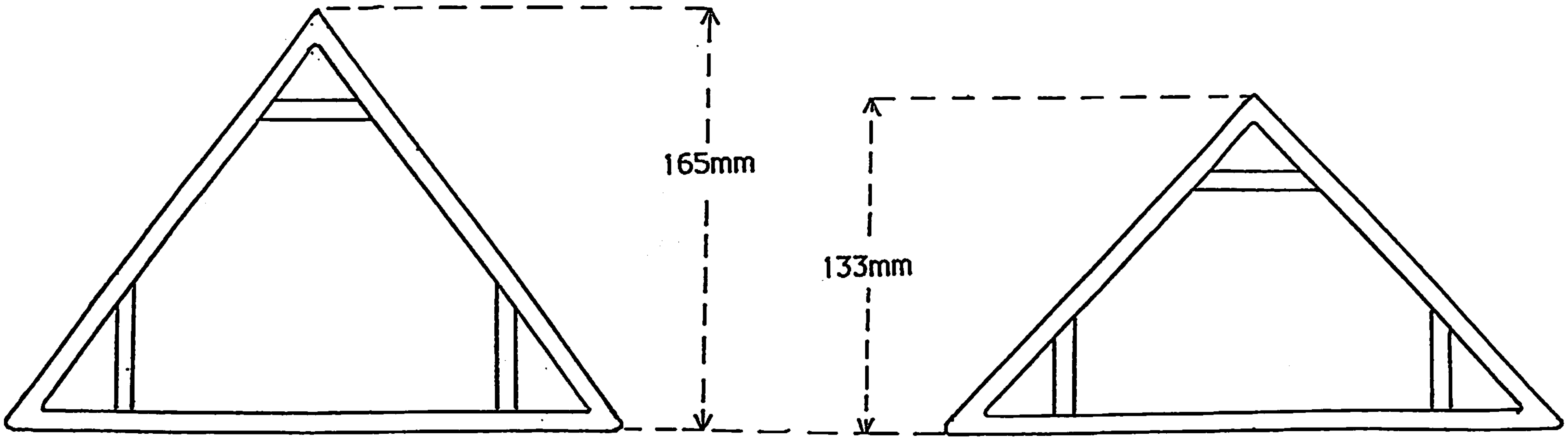
During the trials as the C_L and C_D relationships were being sought it was found that to achieve the lower angles of attack required both the 'V' and flat doors had to be modified. The 'V' door had two more holes drilled in the towing triangle so that the warp could be attached nearer the end of the door. In Appendix B these holes are signified by F and G.

The flat door was modified in three ways. The triangles were changed for a shorter pair so that the towing position was brought in (Fig. 4, page 10). A combination of one large and one small triangle was used and also various combinations of crossing the triangles over hence moving the attachment point towards the end of the door. The flat door also had two new holes drilled for the backstrops at the far end of the door. Lastly, as a final resort to obtain angles of attack of about 21° a loop of twine was attached to the end of the door and the warp passed through it. Two runs were carried out using this method with two different sized loops giving vertical heights of the warp from the door of 135mm and 126mm. A summary of set ups can be seen in Appendix A.

Throughout the first part of the trials the heel of the doors was kept at zero as the angles of attack were varied to find the C_L and C_D characteristics of the doors at zero heel. Once this had been accomplished although short of time runs were carried out on both types of door with heel angles of + and -5°, these being produced by raising or lowering the towing block height. Fig.7 shows the doors in all three positions of heel.

Triangle for Flat Door

10

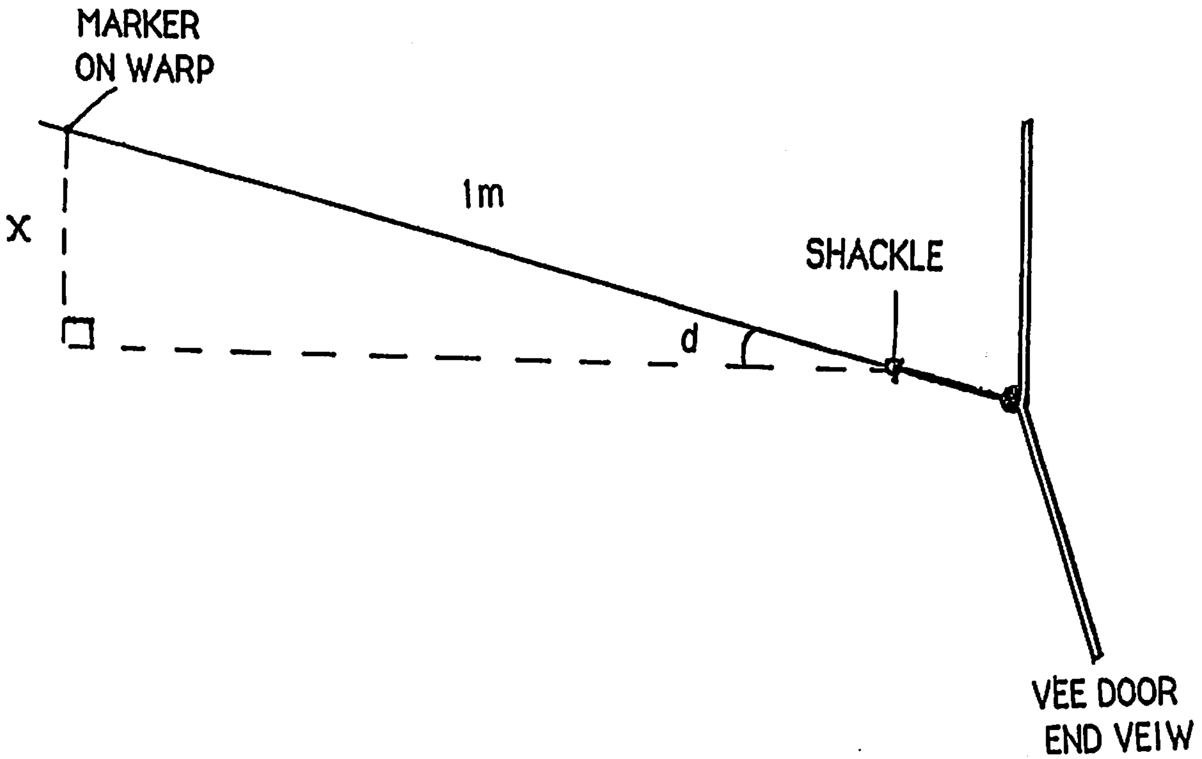


(Bases of same length.)

LARGE TRIANGLE

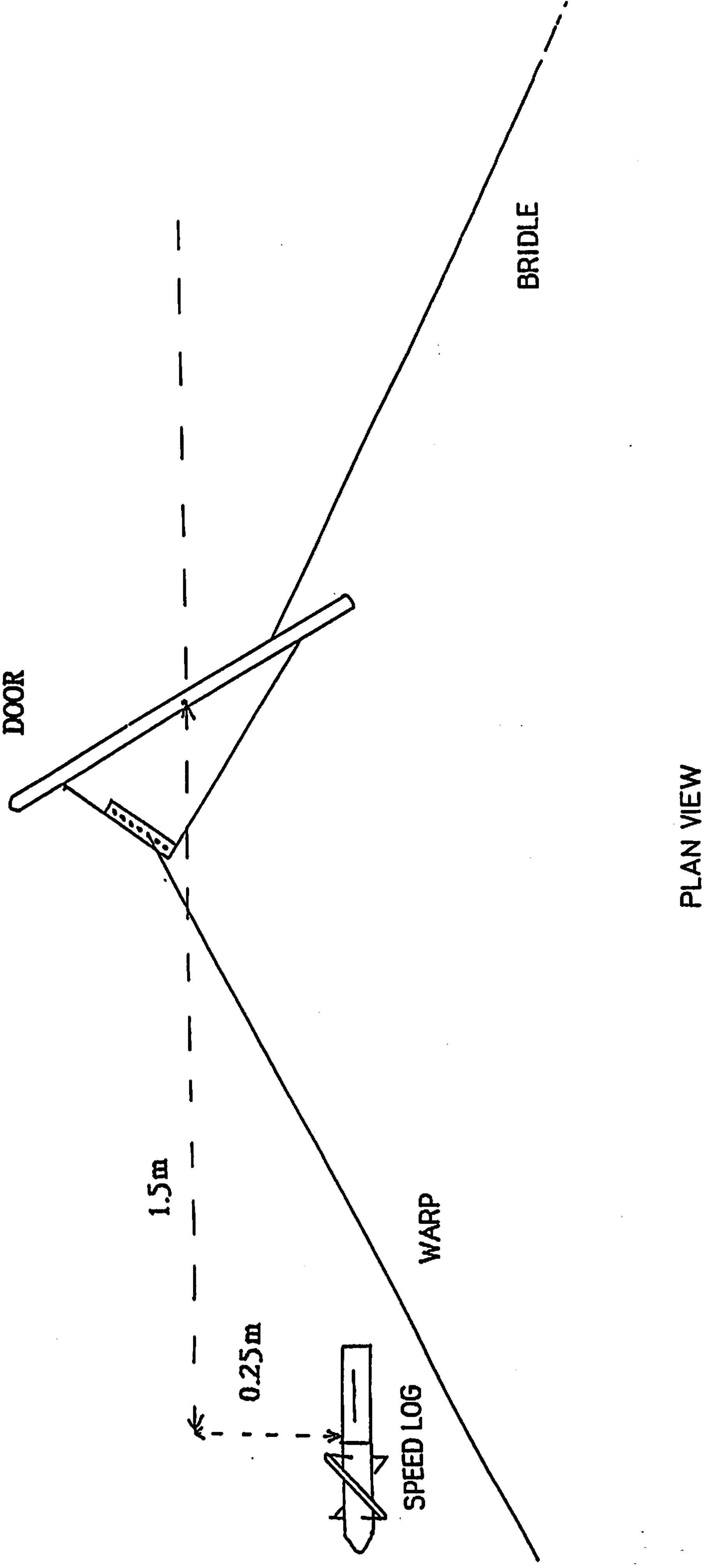
SMALL TRIANGLE

Figure.4



DECLINATION ANGLE $d = \sin^{-1} \frac{\text{height } x \text{ (m)}}{1 \text{ (m)}}$

Figure.5



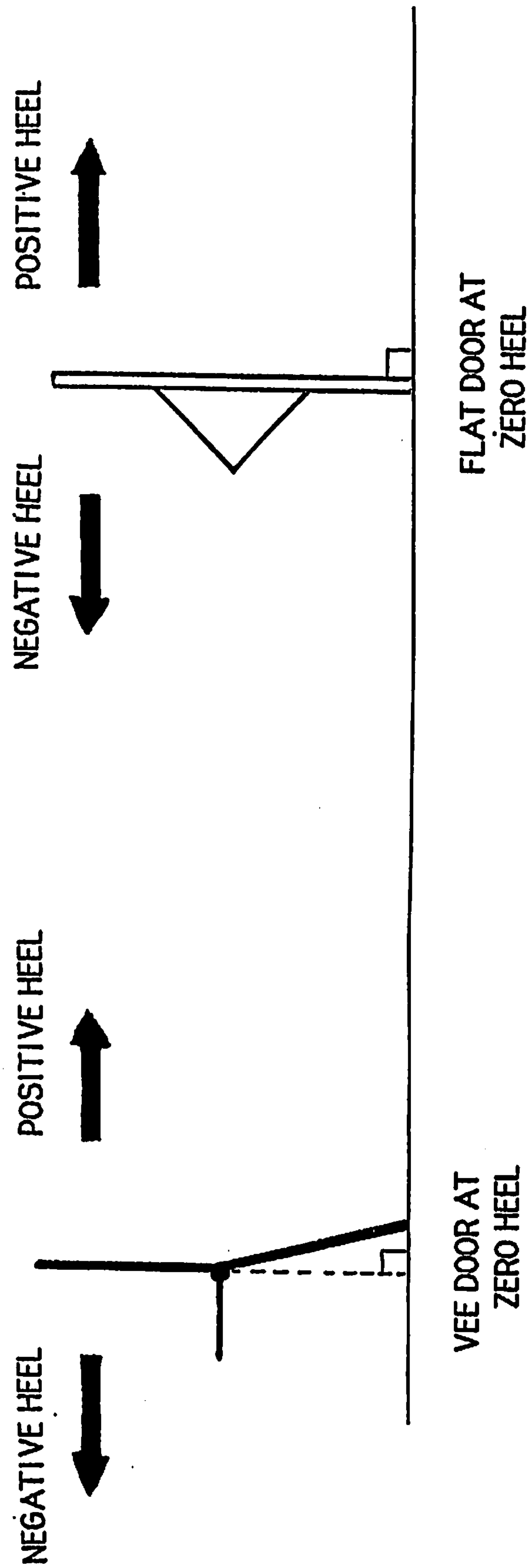
Position of Log

Figure.6

6. RESULTS

The validity of the results presented in the following tables directly depends upon the accuracy of the results taken. Each run produces nine pieces of information, all extremely important for calculating the values of C_L and C_D. Of this information some is more accurately measured than others due to ease of measurement and practical limitations. The errors involved with the measurement of the door surface area, the water speed and the warp declination angle can be considered as insignificant because of the method of measurement and accurate equipment. The system used to measure the angle of attack, warp angle and bridle angle can also be considered to be of an accuracy sufficient for the project's aims. When calculating these values the angles of the belt line and wires/board were taken off the screen every 5 seconds giving 6 results for every 30 seconds of recording. The values could then be calculated by subtracting the various angles producing 6 results for each angle required. An average was taken of these to produce the final figures. The system could be improved by taking more values and ignoring the extremes of movement of the board although this would be time consuming. However, the measurement of the heel angle and the load readings is open for improvement. The load readings were calculated by taking a value off the paper every 5mm whether it was at a peak, trough or in the middle. A whole run produced 36 values for each load cell and an average found. As with the angle finding system no attempt was made to cut out values of a large variation from the mean. The heel angle could only be guessed at by eye, producing probably the largest errors in the results although through the boat the heel angle could be seen very clearly and easily adjusted. The accuracy of the sampling technique is expected to be within 0.3kg for the load readings and $+2^{o}$ for the heel angle.

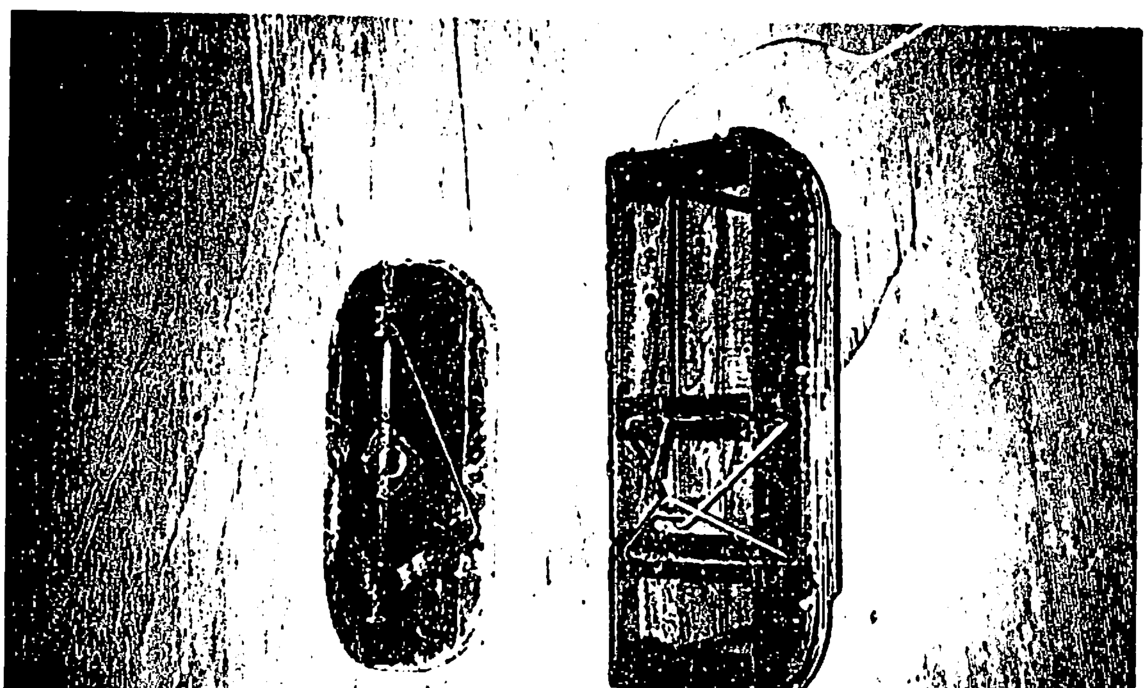
For more detailed tables of the results and rigging set ups refer to the tables at the end of the report. The following tables show only the necessary information in order to produce the graphs and qualify the conclusions.



Heel positions of door

Figure.7

(i) T.V. MOUNTING & GLASS BOTTOMED BOAT



(ii) PHOTOGRAPHS OF ¼ SCALE TRAWL DOORS

Figure.8

Table 1 Page 17 - Vee and Flat Door Repeatability

Table 1 shows a pair of runs for each door with exactly the same warp and bridle arrangements. In each case the door was shot and a set of results taken. The tank was then stopped and restarted with nothing altered and a second set of results taken. As can be seen from the two 'V' door runs they gave excellent repeatability with an error of less than 4% in the value of C_L/C_D. However, the flat door runs gave poorer results which can only be attributed to experimental error.

Table 2 Page 18 'V' Door C_L and C_D Relationships with 0 Heel

Table 2 shows how the values of C_L and C_D change with decreasing angles of attack when the heel is kept at 0^o for the 'V' door. The information is represented on graphs 1 and 2 and can be seen to produce the required curves. The value of C_L/C_D is used to indicate the efficiency of the door. The greater the value the more efficient the door is. This has been plotted against angle of attack on graph 1 page 18 and clearly shows the optimum efficiency is obtained with angles of attack of 20^o-28^o.

On graph 2 page 20 the C_L and C_D values have been plotted separately against angle of attack. This graph is intended to show the angles of attack which produce maximum lift and minimum drag (i.e. high C_L value and low C_D value). Once again the optimum angles are those less than 30^o. However, due to the difficulties in obtaining angles of attack less than 25^o with the 'V' door it is impossible to say from these results where the C_L values will peak and the C_D values be at a minimum. It may well be the case that the C_L values will fall below 25^o reducing the optimum angles of attack to between 25^o and 30^o.

Table 3 Page 22 - Flat Door C_L and C_D Relationships with 0 Heel

Table 3 shows how the values of C_L and C_D change with decreasing angles of attack when the heel is kept at 0^o for the flat door. As with the 'V' door difficulty was experienced when trying to

VEE AND FLAT DOOR REPEATABILITY.

TABLE 1

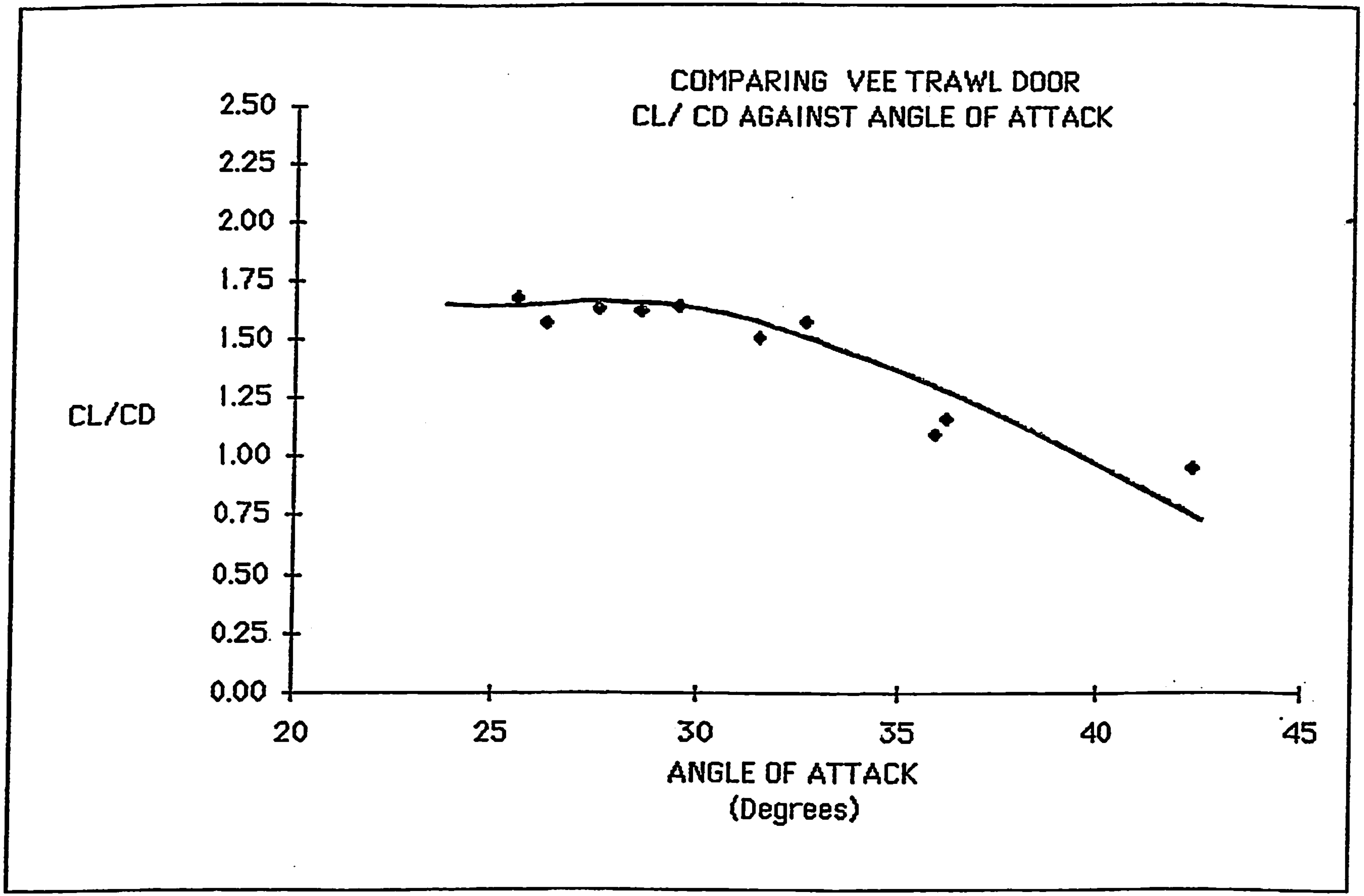
S.area (M^2)	Speed (M/SEC.)	Heel (DEGREES)	A of A (DEGREES)	W.Load (KGS)	B.Load (KGS)	W.angle (DEGREES)	B.angle (DEGREES)	D'ion (DEGREES)	CL	CD	CL/CD
					VEE DOOR (B1)*						
0.278	0.895	0	42.4	17	7	21.03	23.95	5.7	0.79	0.83	0.95
0.278	0.895	0	42.2	16.2	7	20.67	23.11	5.7	0.74	0.76	0.98
					FLAT DOOR (3)1*						
0.269	0.901	0	32.4	19.3	10.9	17.92	25.2	9.8	0.93	0.74	1.26
0.269	0.891	0	32.7	18	10.4	18.8	24.37	11.5	0.92	0.66	1.38

* SIGNIFIES POSITIONS OF WIRES TO DOOR. SEE APPENDIX A AND B.

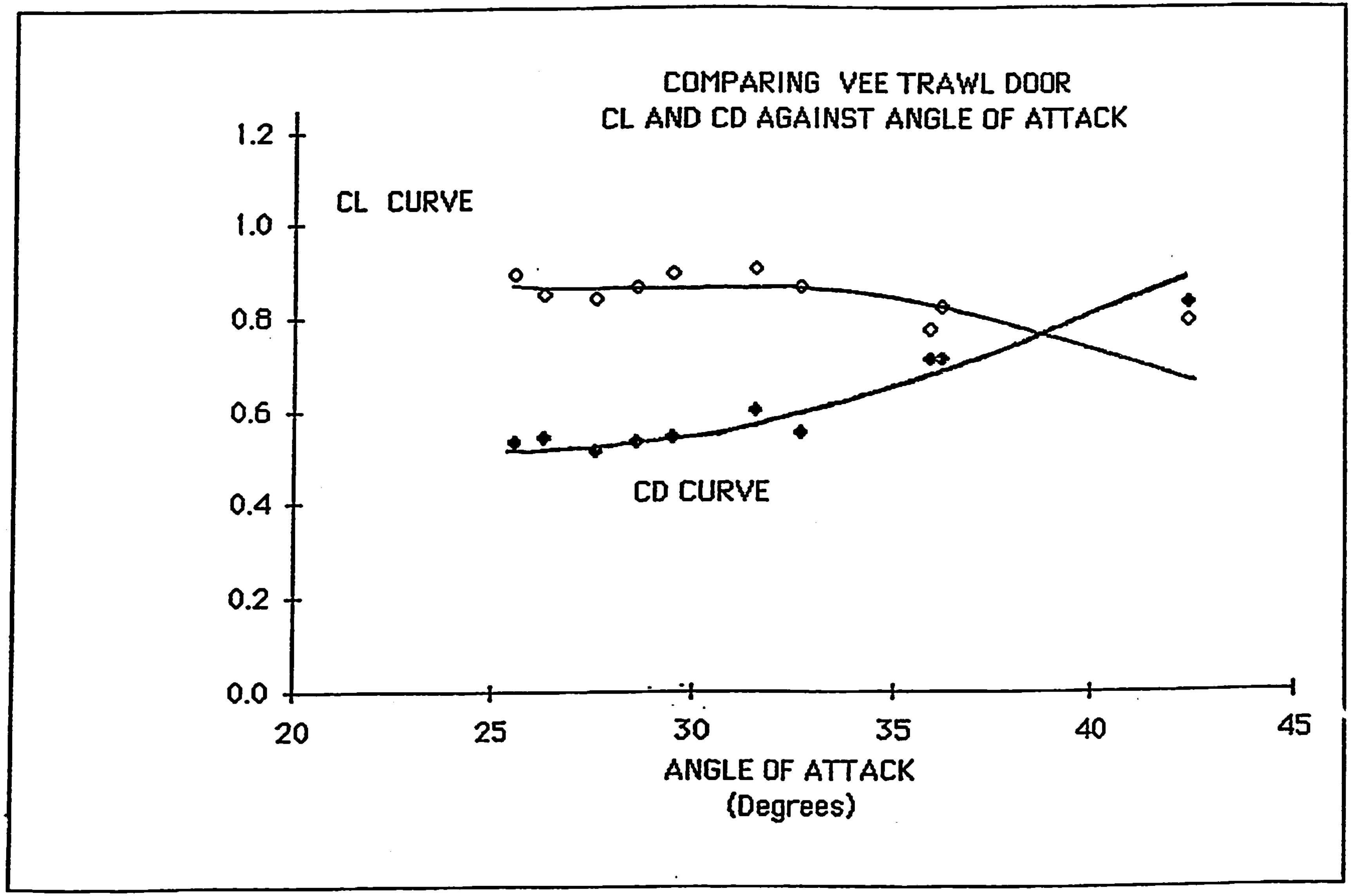
VEE DOOR CL/CD RELATIONSHIP WITH 0 HEEL

A of A (DEGREES)	HEEL (DEGREES)	CL	CD	CL/CD
42.44	0	0.79	0.83	0.95
36.15	0	0.82	0.71	1.16
35.86	0	0.77	0.71	1.09
32.65	0	0.86	0.55	1.57
31.50	0	0.90	0.60	1.50
29.48	0	0.89	0.54	1.64
28.63	0	0.86	0.53	1.62
27.60	0	0.84	0.51	1.63
26.31	0	0.85	0.54	1.57
25.62	0	0.89	0.53	1.68

TABLE 2


COMPARING VEE TRAWL DOOR
CL/ CD AGAINST ANGLE OF ATTACK
CL/CD
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
20
25
30
35
40
45
ANGLE OF ATTACK
(Degrees)

Graph.1


COMPARING VEE TRAWL DOOR
CL AND CD AGAINST ANGLE OF ATTACK
CL CURVE
CD CURVE
1.2
1.0
0.8
0.6
0.4
0.2
0.0
20
25
30
35
40
45
ANGLE OF ATTACK
(Degrees)

Graph.2

achieve angles of attack less than 30o. Although a method was found, only two results were obtained these being 22.22^{O} and 21.55^{O}. Thus leaving a large gap between the next value of 30.85. On graph 3, which plots C_L/C_D against angle of attack for the flat door, this gap could contain a peak of values for C_L/C_D. Whether this is the case or not the graph still shows that optimum efficiency is obtained with angles of attack between 20^{O} and 30^{O}.

Graph 4 page 25 shows the C_L and C_D values of table 3 plotted separately against angle of attack. Optimum lift is achieved at angles of 32-34^{O} but at these angles the drag is not at a minimum. However, from a practical fishing point of view angles less than 30^{O} are hard to achieve and also lead to instability. Therefore, this graph would suggest an angle of attack between 30 and 34^{O}.

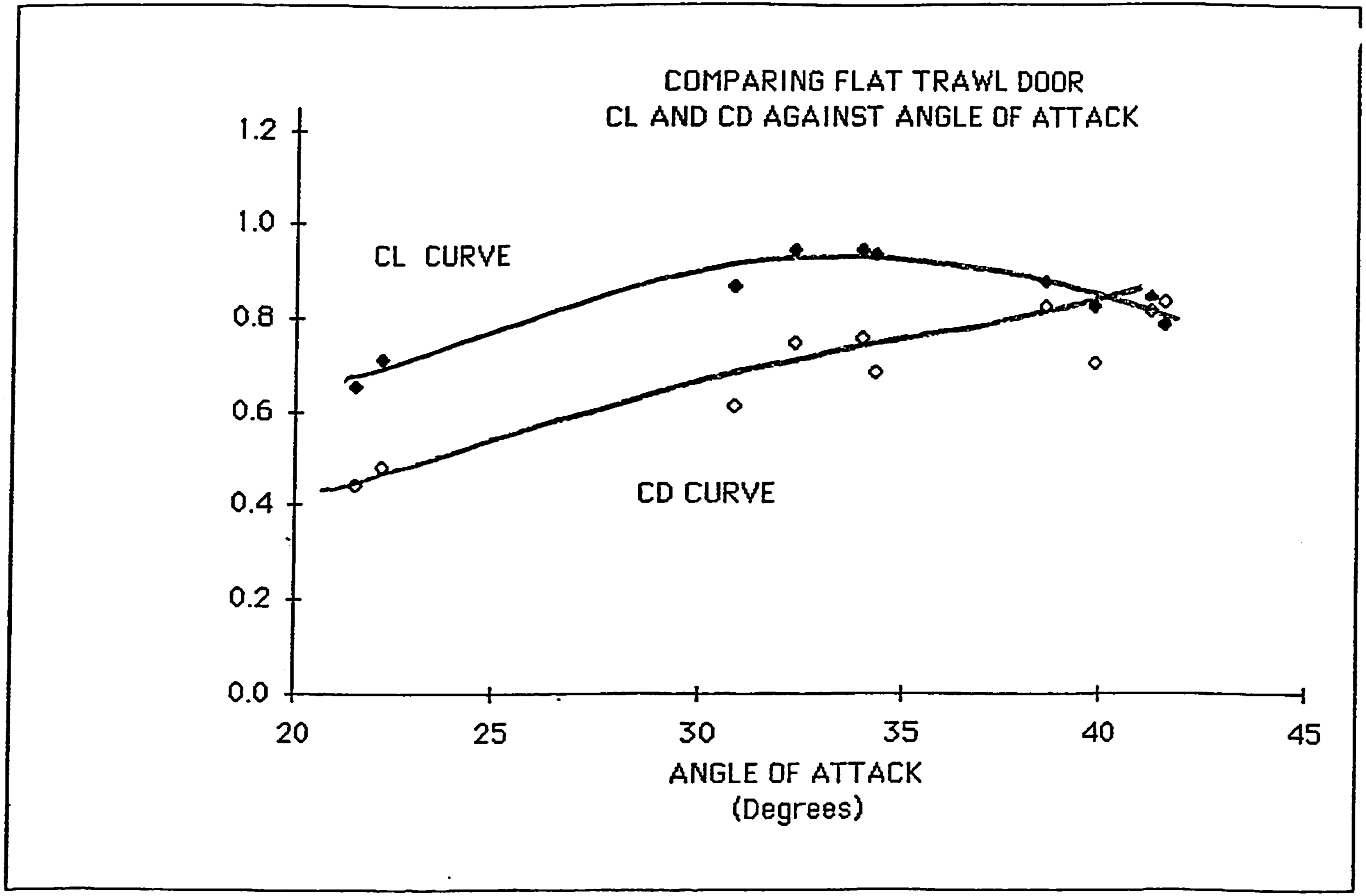
It is important to note that during the trial with lower angles of attack using the flat door the backstrops were catching the back stiffener. This should not affect the validity of the results as it only restricts the doors swaying movements and possibly the angle of attack. The cause of the problem was the greater angles of the bridle than would normally be seen in practical fishing use. These large angles were used to help reduce the errors involved when calculating them.

The results of the tests involving variations of heel are presented in table 4. However, due to the difficulties in accurately measuring the heel angle and keeping the angle of attack constant these runs proved to be very time consuming and as time was short very few results were obtained. The tests with the 'V' door were the most inconclusive as the angle of attack was out with a heel angle of +5^{O}. The flat door tests are more useful with all three angles of attack approximately the same but in both cases there is a severe lack of results.

FLAT DOOR CL/CD RELATIONSHIPS WITH 0 HEEL

A of A (DEGREES)	HEEL (DEGREES)	CL	CD	CL/CD
41.61	0	0.78	0.83	0.95
41.23	0	0.84	0.81	1.03
39.85	0	0.82	0.70	1.17
38.62	0	0.87	0.82	1.06
34.33	0	0.93	0.68	1.36
33.98	0	0.94	0.75	1.25
32.35	0	0.94	0.74	1.27
30.85	0	0.86	0.61	1.41
22.22	0	0.71	0.48	1.49
21.55	0	0.65	0.44	1.47

TABLE 3


COMPARING FLAT TRAWL DOOR
CL AND CD AGAINST ANGLE OF ATTACK
CL CURVE
CD CURVE
1.2
1.0
0.8
0.6
0.4
0.2
0.0
20
25
30
35
40
45
ANGLE OF ATTACK
(Degrees)

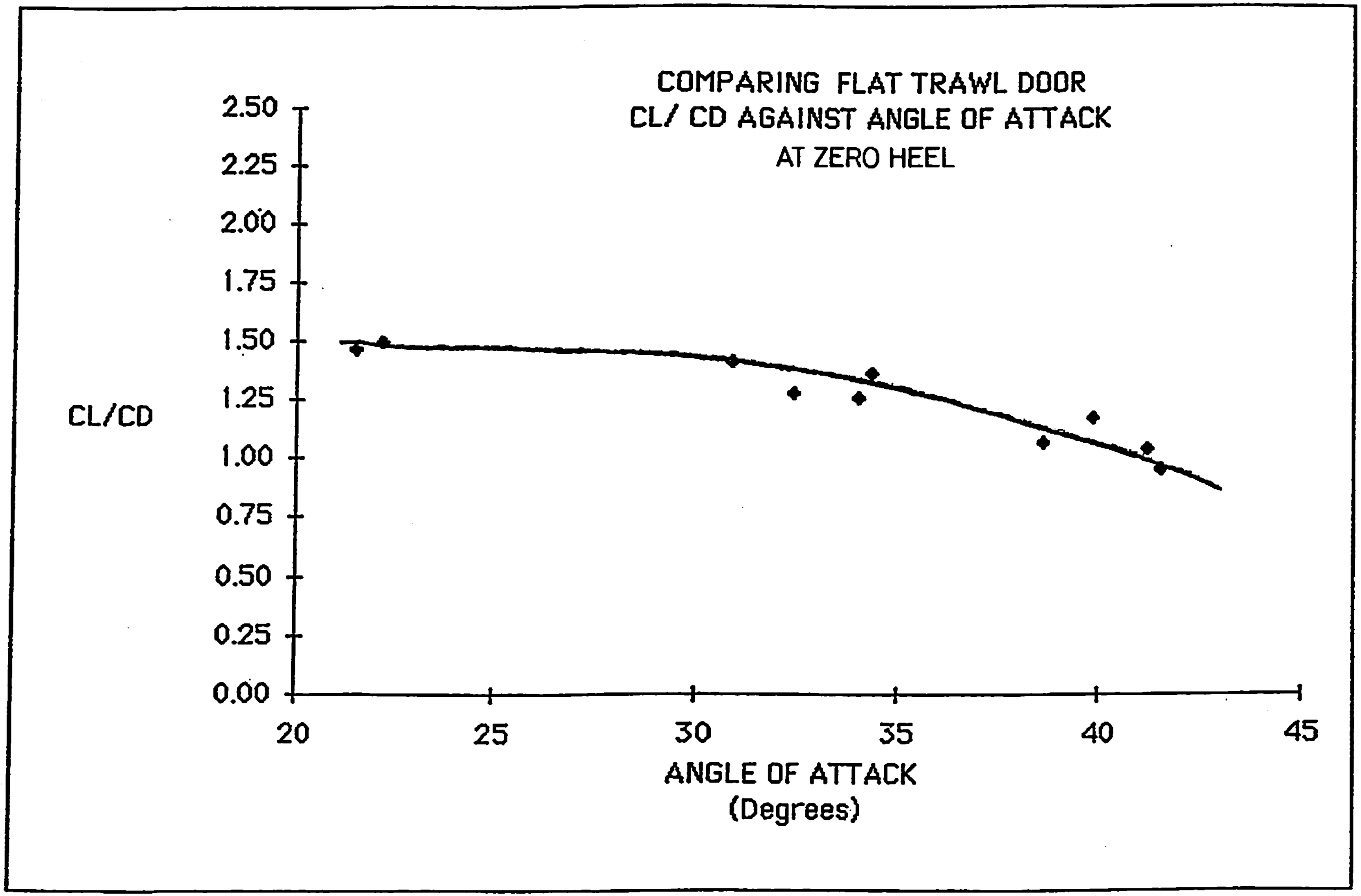
GRAPH 3

VARIATIONS IN HEEL WITH CONSTANT ANGLES OF ATTACK.

VEE AND FLAT DOORS

A of A (DEGREES	HEEL (DEGREES)	CL	CD	CL/CD
	VEE	DOOR		
32.65	0	0.86	0.55	1.57
29.90	5	0.87	0.57	1.53
32.60	-5	0.80	0.56	1.42
	FLAT	DOOR		
32.70	0	0.94	0.65	1.46
32.40	-5	0.87	0.65	1.34
32.30	5	0.91	0.67	1.35

TABLE 4


COMPARING FLAT TRAWL DOOR
CL/ CD AGAINST ANGLE OF ATTACK
AT ZERO HEEL
CL/CD
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
20
25
30
35
40
45
ANGLE OF ATTACK
(Degrees)

Graph.4

7. DISCUSSION

During the beginning of the trials many small but time consuming problems were encountered especially with the video recording system. Also one whole day of testing was lost when the belt of the tank broke down. Due to these delays all the results required to fulfil the aims were not obtained. Only a small number of results were compiled with variations in heel angle and the question of moving the triangles at the flat door to affect heel was not looked at.

However, the remaining three aims have certainly been looked at in a depth suitable to draw good conclusions. Throughout the trials it became apparent that a test procedure was developing which was far superior to the one used in 1985. With the main aim being to develop a new test procedure this information alone endorses the usefulness of the trials to provide quantitative assessment of door performance in the future.

8. CONCLUSIONS

A new $\frac{1}{4}$ scale model door testing procedure has been established which enables all types of doors to be tested although modifications to the warp towing position may be necessary to obtain all the information required. This procedure minimises the time spent rigging the doors by enabling 3 sets of results to be taken at each position. The procedure also produces accurate quantitative assessment of door performance through its good repeatability and resultant information. For procedure see below.

The C_L and C_D characteristics at 0^o heel and a range of angles of attack have been obtained for both 'V' and flat doors. The results conclusively show that the 'V' door optimum angle of attack is approximately 32^o and the flat door 34^o. At these angles both doors give maximum lift with a low drag value and good efficiency.

The results of the trials also show that the repeatability of the work is satisfactory to be able to refer to these results and compare them with later trials.

Lastly as it is possible to see trends clearly on all the graphs, this indicates that the accuracy of the procedure and apparatus is of the order required to produce satisfactory conclusions.

9. PARAMETERS RECORDED

Parameters recorded or measured are:

1. Speed

Obtained using a Braystoke log suspended in the tank at mid-trawl door height and 3m upstream. Log output dislayed on a six channel Gould pen recorder in m/sec.

2. Warp Load

Output from the 50kg load cell displayed on a six channel Gould pen recorder.

3. Bridle Load

Output from the 20kg load cell displayed on six channel Gould recorder.

4. Bridle and Warp Wire Angles

Using a T.V. camera positioned directly over the wire, a 30 second recording was made of the wire on a Umatic video recorder. Several angular measurements were taken off five still frame pictures, spaced throughout the time period, using a combination of vernier protractor and Seafish designed T.V. mounted screen.

5. Warp Declination

This was caculated from two height measurements, these were taken during the test run using the tank side measuring poles.

10. TEST PROCEDURE

The following test procedure on ¼ scale model doors has been found to give the required information about two types of trawl doors so that the suitability of the door for sea trials can be assessed:-

1. Calibration of apparatus - includes calibration of load cells, pen chart recorder and camera apparatus with monitor screen. To be carried out at the beginning of each testing session.

2. Set speed to 0.9 m/s (3.6 knots) with an accuracy of 0.005 m/s (.01 knots).

3. Place the door in the tank with the warp and bridle in the required positions and adjust the heel to 0^o by raising and lowering the towing post height. Readings should be taken and then the heel angle changed to a desired positive angle for another set of readings. The heel angle should then be made negative by the same amount and a last set of readings taken.

4. Repeat step 2 covering the desired range of angles of attack and the three heel settings. It may be needed to artificially lower the angle of attack to obtain the full range using any suitable method.

Using the above procedure it is possible to obtain results to plot graphs showing the efficiency of the door and the C_L and C_D curves at each heel setting.

11. RECOMMENDATIONS

a) The measurement of the heel angle of the door requires further consideration.

b) The accuracy of the interpretation of the load cell readings must be improved. The use of a data logger in this capacity should be considered.

c) An alignment mechanism is required for the camera and lens to simplify the operation and save time.

d) A track system should be looked into to enable faster and easier movement of the boat/camera frame across the moveable trolley.

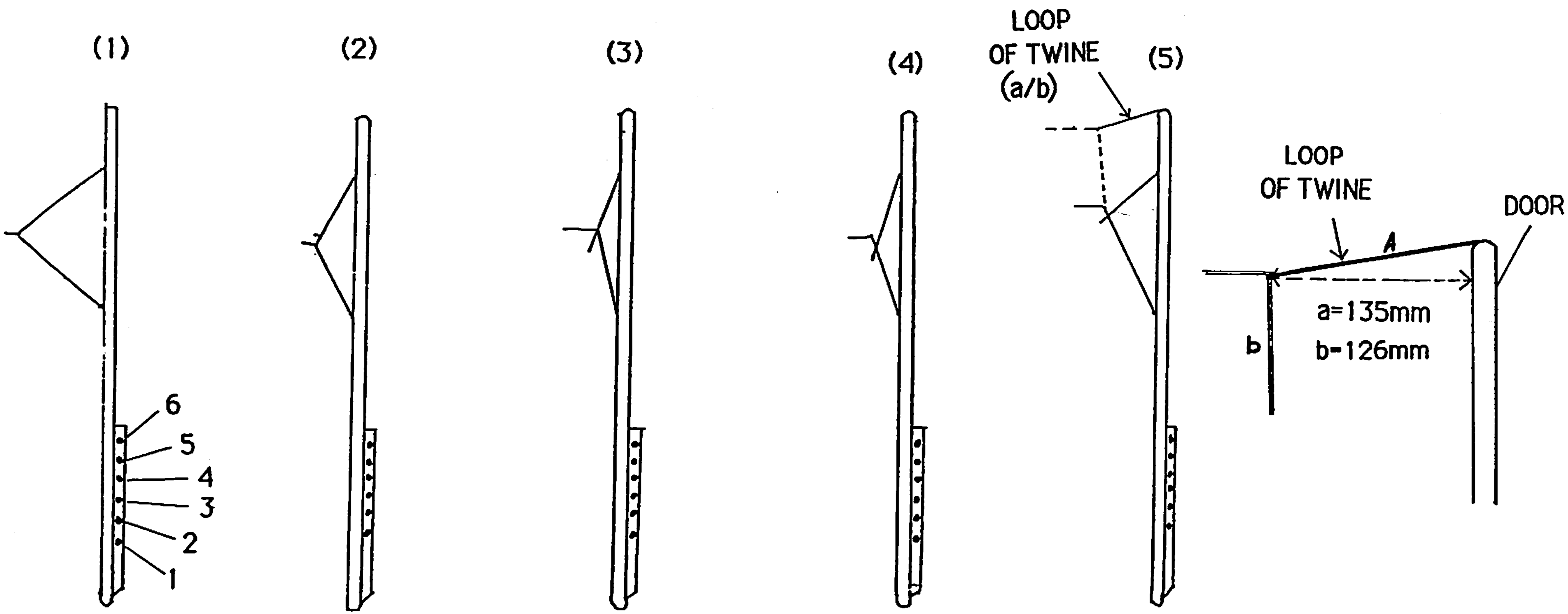
e) The insertion of an underwater 40kg load cell on the warp would greatly enhance the warp load readings accuracy.

f) As general aids adaptations to the frame and boat including a shroued around frame to cut out light, a splash guard and 'V' shape bow to stop bubbles passing under it would be beneficial.

g) Finally, it is recommended that a re-run is carried out with the variations in heel angles tested more thoroughly to gain extra base information.

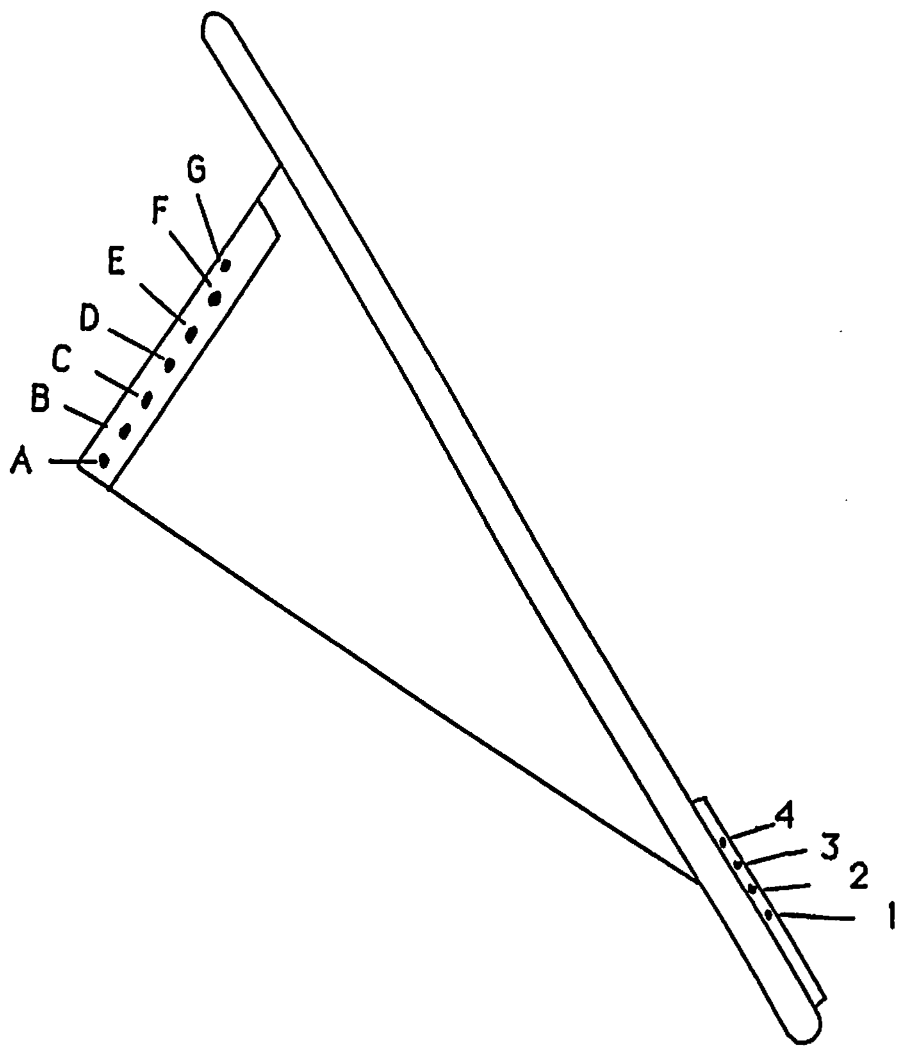
12. REFERENCES

SFIA Internal Report No. 1239 by S. Macinko.



(1)	(2)	(3)	(4)	(5)
LARGE TRIANGLES	SMALL TRIANGLES	SMALL TRIANGLES (Inside one under outside one.)	SMALL TRIANGLES (Completely crossed over.)	LARGE AND SMALL TRIANGLE (Completely crossed over.)

PLAN OF FLAT DOOR WIRE POSITIONS



PLAN OF VEE DOOR WIRE POSITIONS

Appendix B

DEFINITION - Source is "Otterboard Performance and Design" published by F.A.O. and recognised as the reference for trawl door studies.

Coefficient of Lift (or Sheer) = $C_L = L/(\frac{1}{2}pV^2S)$

Coefficient of Drag = $C_D = D/(\frac{1}{2}pV^2S)$

where:	density of water	=	p	= 102 kg S^2/m^4)
	outward spreadforce	=	L	= Kg
	drag force	=	D	= Kg
	board surface area	=	S	= m^2
	speed through waters	=	V	= m/sec

Board "efficiency" is commonly expressed as C_L/D_D

DEFINITION OF TRAWL DOOR EFFICIENCY APPENDIX C

VARIATIONS IN HEEL WITH CONSTANT ANGLES OF ATTACK.

S.area (M^2)	Speed (M/SEC)	H'L (DEGREES)	A of A	W.Load (KG)	B.Load (KG)	W.angle (DEGREES)	B.angle (DEGREES)	D'ion (DEGREES)	Σ Drag ((KG)	B.Drag (KG)	Lift 1 (KG)	Lift 2 (KG)	Dr.Dra (KG)	Σ Lift	CL	CD	CL/CD
				RUN 17	VEE	DOOR	(F4)*										
0.278	0.898	0	32.7	17	10.1	20.55	23.5	12.1	15.6	9.26	5.83	4.03	6.3	9.86	0.86	0.55	1.57
				RUN18	VEE	DOOR	(F4)*										
0.278	0.909	5	29.9	18.4	10.2	21.27	22.87	20.5	16.1	9.4	6.25	3.96	6.66	10.2	0.87	0.57	1.53
				RUN19	VEE	DOOR	(F4)*										
0.278	0.909	_5	32.6	15.5	8.7	20.85	26.5	6.32	14.4	7.79	5.48	3.88	6.61	9.37	0.8	0.56	1.42
				RUN 29	FLAT	DOOR	(4)1*										
0.269	0.896	0	32.7	18	10.4	18.8	24.37	12.8	16.6	9.47	5.66	4.29	7.14	10	0.94	0.65	1.46
				RUN 31	FLAT	DOOR	(4)1*										
0.269	0.896	_5	32.4	17.6	9.3	20.33	23.75	18.4	15.7	8.51	5.8	3.75	7.15	9.55	0.87	0.65	1.34
				RUN 32	FLAT	DOOR	(4)6*										
0.269	0.898	5	32.3	19.8	11	18.6	22	20.1	17.6	10.2	5.93	4.12	7.42	10.1	0.91	0.67	1.35

* SIGNIFIES POSITIONS OF WIRES TO DOOR. SEE APPENDIX A AND B.

VEE DOOR CL/CD RELATIONSHIP WITH 0 HEEL

IN DECENDING ORDER OF ANGLE OF ATTACK (A OF A)

S.area	Speed	H'L	A of A	W.Load	B.Load	W.angle	B.angle	D'ion	Σ Drag	B.Drag	Lift 1	Lift 2	Dr.Dra	Σ Lift	CL	CD	CL/CI
(M^2)	(M/SEC)		(DEGREES)	(KG)	(KG)	(DEGREES)	(DEGREES)	(DEGREES)	(KG)	(KG)	(KG)	(KG)	(KG)				
				RUN 1	VEE	DOOR	(B1)*										
0.278	0.895	0	42.4	17	7	21.03	23.95	5.7	15.8	6.4	6.07	2.84	9.39	8.91	0.79	0.83	0.95
				RUN 7	VEE	DOOR	(D1)*										
0.278	0.901	0	36.2	17.66	8.95	19.62	23.51	11	16.3	8.21	5.82	3.57	8.12	9.39	0.82	0.71	1.16
				RUN 4	VEE	DOOR	(C1)*										
0.278	0.9	0	35.9	16.6	7.9	20.67	22.58	5.74	15.5	7.29	5.83	3.03	8.16	8.86	0.77	0.71	1.09
				RUN 17	VEE	DOOR	(F4)*										
0.278	0.898	0	32.7	17	10.1	20.55	23.5	12.1	15.6	9.26	5.83	4.03	6.3	9.86	0.86	0.55	1.57
				RUN 11	VEE	DOOR	(E1)*										
0.278	0.902	0	31.5	17.6	10.2	20.9	24.05	8.63	16.3	9.31	6.21	4.16	6.94	10	0.90	0.60	1.5
				RUN 12	VEE	DOOR	(F1)*										
0.278	0.898	0	29.5	17.2	10.5	20.73	23.75	10.4	15.8	9.61	5.99	4.23	6.21	10.2	0.89	0.54	1.64
				RUN 13	VEE	DOOR	(G1)*										
0.278	0.891	0	28.6	16.5	9.9	20.78	23.62	12.4	15.1	9.07	5.72	3.97	6	9.68	0.86	0.53	1.62
				RUN 14	VEE	DOOR	(G2)8										
0.278	0.895	0	27.6	16	9.8	20.47	24.06	9.79	14.8	8.95	5.51	4	5.82	9.51	0.84	0.51	1.63
				RUN 15	VEE	DOOR	(G3)*										
0.278	0.892	0	26.3	17.2	10.6	19.15	22.73	12.1	15.9	9.78	5.52	4.1	6.11	9.61	0.85	0.54	1.57
				RUN 16	VEE	DOOR	(G4)*										
0.278	0.892	0	25.6	17.4	10.9	19.8	23.07	12.1	16	10	5.76	4.27	5.98	10	0.89	0.53	1.68

* SIGNIFIES POSITIONS OF WIRES TO DOOR. SEE APPENDIX B.

FLAT DOOR CL/CD RELATIONSHIPS WITH 0 HEEL
IN DECENDING ORDER OF ANGLE OF ATTACK (A OF A)

S.area	Speed	H'L	A of A	W.Load	B.Load	W.angle	B.angle	D'ion	Σ Drag	B.Drag	Lift 1	Lift 2	Dr.Drag	Σ Lift	CL	CD	CL/CD
(M^2)	(M/SEC)		(DEGREES)	(KG)	(KG)	(DEGREES)	(DEGREES)	(DEGREES)	(KG)	(KG)	(KG)	(KG)	(KG)				
					FLAT	DOOR	(1)4*										
0.269	0.908	0	41.6	17.4	7.7	19.07	24.38	6.3	16.3	7.01	5.65	3.18	9.33	8.83	0.78	0.83	0.95
				RUN 20	FLAT	DOOR	(2)6*										
0.269	0.903	0	41.2	17.8	8.4	18.75	26.27	9.5	16.6	7.53	5.64	3.72	9.09	9.36	0.84	0.81	1.03
				RUN 22	FLAT	DOOR	(2)4*										
0.269	0.908	0	39.9	16.7	8.5	19.8	25.53	7.2	15.6	7.67	5.61	3.66	7.92	9.28	0.82	0.7	1.17
				RUN 24	FLAT	DOOR	(2)3*										
0.269	0.91	0	38.62	20	10.4	17.18	22.68	9.2	18.9	9.6	5.83	4.01	9.27	9.84	0.87	0.82	1.06
				RUN 32	FLAT	DOOR	(3)6*										
0.269	0.905	0	34.3	19.8	11	18.6	22	18	17.8	10.2	6.01	4.12	7.65	10	0.93	0.68	1.36
				RUN 26	FLAT	DOOR	(3)3*										
0.269	0.896	0	34	19.5	11	17.83	23.8	9.2	18.3	10.1	5.89	4.44	8.26	10.3	0.94	0.75	1.25
				RUN 27	FLAT	DOOR	(3)1*										
0.269	0.901	0	32.4	19.3	10.9	17.92	25.2	9.8	18.1	9.86	5.85	4.64	8.23	10.5	0.94	0.74	1.27
				RUN 28	FLAT	DOOR	(4)1*										
0.269	0.907	0	30.9	17.6	10.3	18.72	24.08	12.1	16.3	9.4	5.52	4.2	6.89	9.73	0.86	0.61	1.41
				RUN 35	FLAT	DOOR	(5)1a*										
0.269	0.894	0	22.2	13.6	8.1	19.56	23.9	9.79	12.6	7.41	4.49	3.28	5.22	7.77	0.71	0.48	1.49
				RUN 34	FLAT	DOOR	(5)1b*										
0.269	0.892	0	21.6	12.9	7.8	18.51	23.23	11.5	12	7.17	4.01	3.08	4.82	7.09	0.65	0.44	1.47

* SIGNIFIES POSITIONS OF WIRES TO DOOR. SEE APPENDIX A.