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FIRTA PROJECT 84/13

Comparison of the engineering and catching performance of existing prawn trawls in the Spencer Gulf Prawn Fishery to three new prawn trawl designs.

ACKNOWLEDGEMENTS

The author wishes to thank the skipper and crew of the fishing vessel Melanie B for their help and cooperation during the trials, and to I. Cartwright, Dr. M. King, and M. Campbell for help in preparation of the Report.

1. Introduction

In 1981-82 the cost of fuel and oil in the Northern Prawn Fishery amounted to 25% ($M23.65) of the total costs for a prawn trawler (Hundloe1984). In the East Coast Prawn Fishery, fuel and oil amounted to 24% ($M9.77) of the costs (BAE 1984). In recent years the dramatic rise in fuel prices has prompted many people to look closely at ways of reducing fuel costs. Much of this work has been directed towards improving the engineering performance of trawl gear. Van Marlen (1982) showed that total gear drag could be reduced by using larger meshes in the fore parts of midwater trawls. Chopin (1982) suggested that US shrimp trawls could have gear drag reduced by increasing the mesh size of the fore parts of the trawl. The design of more efficient otterboards (Karlsen1982), (Lee and McIlwane 1982), (Wray 1986) could also reduce the total gear drag as might the correct choice of angle of attack (FAO 1974), (Wray 1986).

The large variation in net designs, otterboard sizes and otterboard angles used in similar prawn fisheries in Australia has led many fishermen to question the choice of particular combinations of trawl gear.

This paper is the result of a joint submission by the Spencer Gulf and West Coast Prawn Boat Owners Association and the Australian Maritime College, Launceston, Tasmania to the Fishing Industry Research Trust Account (FIRTA). The performance of different combinations of conventional trawl gear used in the Spencer Gulf Prawn Trawl fishery is compared with three East Coast prawn trawl gears.

2. Trials Procedure

An area off Boston Bay, South Australia was chosen that had a smooth seabed of constant depth. For each particular trawl rig two hauls were carried out, one into the tide followed immediately by a reciprocal tow with the tide. This enabled the effect of tide on gear performance to be taken into account when comparing different hauls (ICES 1981).

Each haul was split into 4 to 5 blocks of between 10 and 15 minutes duration, with a change of vessel engine revolutions between each block. A gear setting time of ten minutes between blocks was allowed to let the trawl gear stabilize at the new R.P.M. setting (See. Fig. 1)

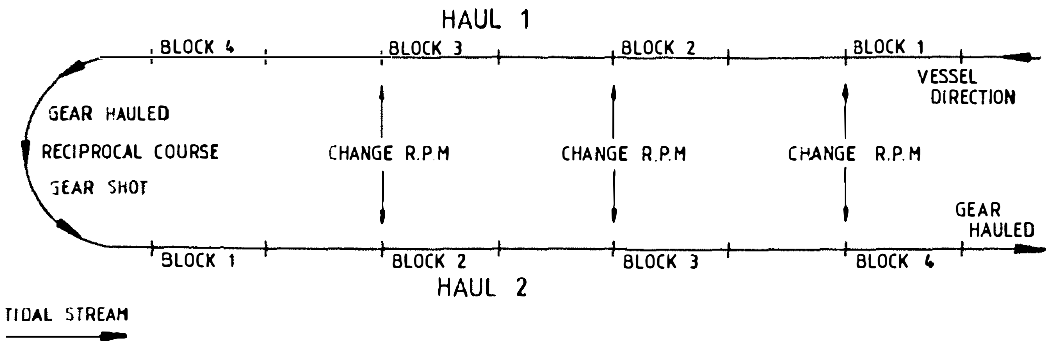


Figure 1: Diagrammatic representation of haul and block positions during a reciprocal tow.

3. Vessel Details

Name of vessel	"Melanie B"
Type of vessel	Twin rig prawn trawler
Home Port:	Port Lincoln
Builder:	Port Lincoln Ship Construction Pty Ltd
LOA:	19.8m (65ft)
LWL:	18m (59ft)
Beam:	7m (23ft)
Draft:	3.8m (12.5ft)
Main Engine:	GM Turbocharged V12 (Derated)
Rating:	365 HP
Gear box:	Twin Disc MG 518
Propellor Diameter:	1675mm (66inch) housed in a nozzle
Propellor No. of blades:	4
Propellor Pitch:	1370mm (54 inch)
Winches:	Split hydraulic trawl winches
Radars:	JRC 527-6 JRC 310 Mark II
Echo sounders:	JRC 117 colour sounder JRC 541 paper sounder
Navigation equipment:	Satellite navigator JRC 3800 coupled to a JRC model 50 colour plotter and NAVI speedlog. Autopilot, compass
Skipper/Owner:	R.W. Bailey

4. Trials Instrumentation

Honeywell Elac Net sounder:	NES 4-33
Honeywell Elac chart recorder:	LAZ 72
General Oceanics flow meter :	Model 2035 MK III
Two channel paper trace recorder:	Houston Omniscribe
0-50 kN warp tension meter:	Electronics Marine MK V (calibrated before trials programme)

The Elac cabled net sounder, modified to measure otterboard spread, was attached to the inside port otterboard (See Fig. 2). The cable, mounted on a portable cable winch on the back deck was hand winched in or out as the trawl gear was hauled or shot. Measurements of otterboard spread were recorded on the Elac chart recorder.

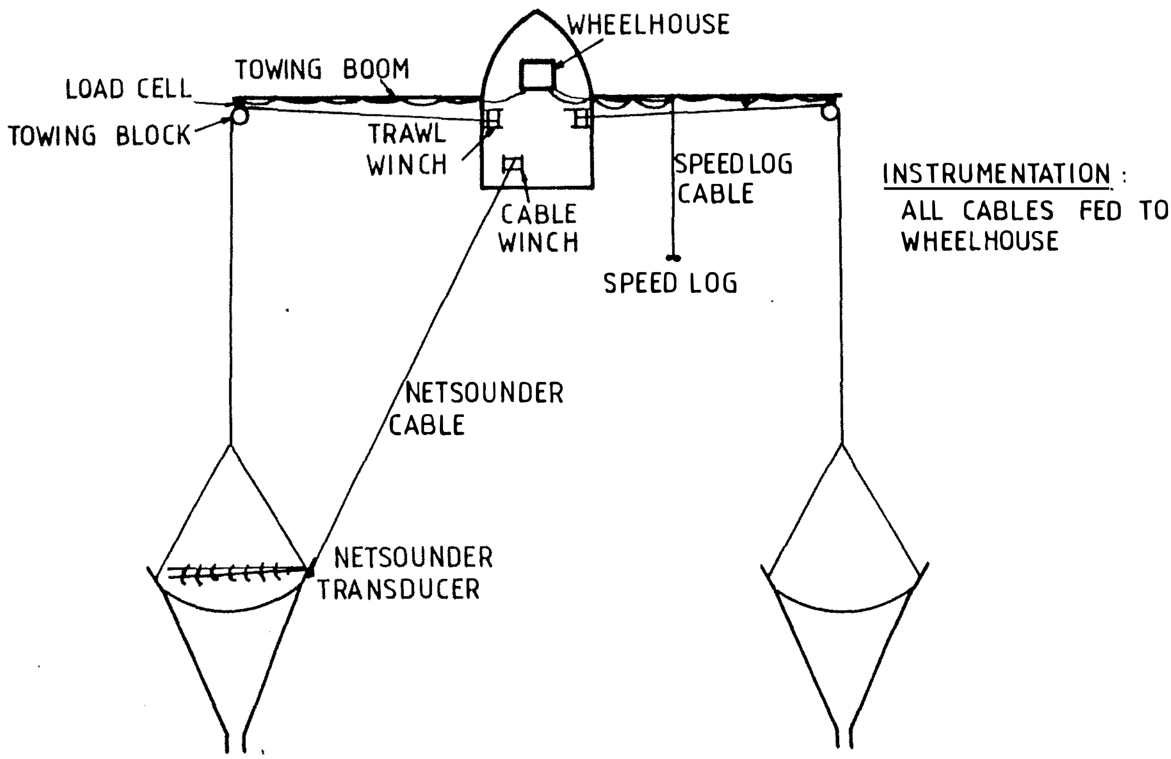


Figure 2 : Position of Trials Instrumentation

The electronic warp tension meter was mounted between the portside towing boom and towing block. The signals were fed to the Houston Omniscribe recorder and a digital voltmeter to enable both a continuous record and spot readings of tension to be taken.

Engine R.P.M. was measured using the vessel's digital tachometer. Water speed was initially measured using a General Oceanics flow meter, however due to a broken cable, this was discarded and the vessel's speed log was used. Water depth was monitored by the vessels colour echosounder.

4.1 Trials Personnel

Frank Chopin	Australian Maritime College
David Sterling	Australian Maritime College

5. Fishing Gear used

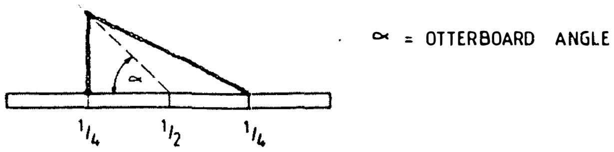
The nets used during the trials all had a 14.63 metres (8 fathoms) headline length. The designs used were:

	Net designs	Supplier
Net 1:	Gundry I	Spencer Gulf Prawn Fishermen
Net 2:	Gundry II	H. Kavanagh. Adelaide SA (net maker)
Net 3:	Gundry III	Spencer Gulf Prawn Fishermen
Net 4:	Florida flyer	Australian Maritime College
Net 5:	Sandakan	Australian Maritime College
Net 6:	Sandakan tongue	Australian Maritime College

Nets 2,4,5 and 6 are detailed in Appendix I. For reasons of confidentiality details of nets 1 and 3 are not included.

Otterboards used during the trials were conventional Spencer Gulf designs and supplied by Spencer Gulf fishermen. The sizes used were 2.74m (9ft) x 1.0m (3ft3inches), 2.44m (8ft) x 0.91m (3ft) and 2.13m (7ft) x 0.91m (3ft). All otterboards were rigged with spider chains. The otterboard angle referred to in the text is the angle between the towing point and the centre of the otterboard and not the true angle of attack of the board when moving through the water (see Fig.3)

COMMONLY USED ANGLE OF ATTACK



PLAN VIEW OF OTTERBOARD AND TOWING CHAINS

TRUE ANGLE OF ATTACK

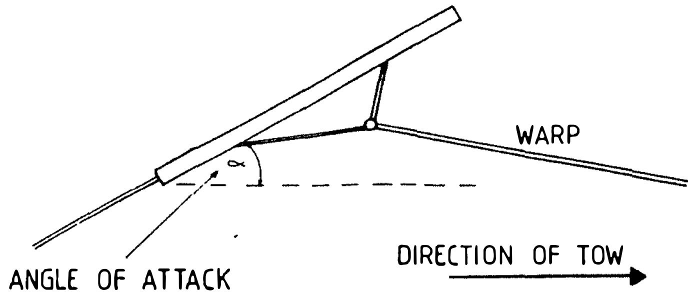


Fig. 3: Otterboard angle referred to in the text (top) and true angle of attack.

6. Hauls carried out during the trials

Table 1 below lists all hauls carried out.

Haul No.	Net design	Otterboard size (metres)	Otterboard Angle (Degrees)	Board Type
1/2/3/4/5	Gundry I	2.74 x 1.0	39	full*
6/7/8/9	Gundry II	2.74 x 1.0	39	full
10/11/12/13	Gundry II	2.74 x 1.0	30	full
14/15/16/17	Gundry II	2.74 x 1.0	35	full
18/19/20/21	Gundry II	2.74 x 1.0	45	full
22	Gundry III	2.44 x 0.91	37	full
23/24/25/26	Gundry III	2.44 x 0.91	37	slotted (3x1" gaps)
27/28/29/30	Gundry I	2.44 x 0.91	37	slotted (3x1" gaps)
31/32/33/34	Gundry II	2.44 x 0.91	37	slotted (3x1" gaps)
35	Gundry II	2.44 x 0.91	37	full
36/37	Gundry II	2.44 x 0.91	37	full
38/39	Gundry II	2.44 x 0.91	30	full
40/41	Gundry II	2.44 x 0.91	45	full
42/43	Gundry II	2.44 x 0.91	40	full
44/45	Florida flyer	2.44 x 0.91	37	full
46/47	Sandakan	2.44 x 0.91	37	full
48/49	Tongue	2.44 x 0.91	37	full

Haul No.	Net design	Otterboard size (metres)	Otterboard Angle (Degrees)	Board Type
50/51	Gundry II	2.13 x 0.91	42.5	full
52/53	Gundry II	2.13 x 0.91	32	full
54/55	Gundry II	2.13 x 0.91	25	full
56/57	Gundry II	2.13 x 0.91	50	full

* "full" boards have no gaps between planks.

Table 1. Summary of hauls carried out

7. Results

All measurements recorded during the trials can be found in Appendix II.

7.1 General

Hauls 1-5 were made to check both sea bed and instrumentation. No readings were recorded. During hauls 22 and 35 the signal from the otterboard mounted transducer was lost and no readings were recorded. For hauls listed in Table 2, the results of each pair of reciprocal tows for the net and otterboard combinations are indicated in Figs. 4-9 (linear regression lines for the tide corrected plots are included). Reciprocal tows were combined to reduce the effect of tide and a single regression line used to express the relationship between gear drag and otterboard spread with towing speed. No statistical tests were carried out on comparisons of gear drag for various hauls and differences in gear drag have been taken from the regression lines at 2.5, 2.75 and 3.0 knots.

For otterboard spread versus speed, the F-test was used to determine if the slope of the regression line was significantly different from zero. Differences in the means were then compared using Student's test.

Haul No.	Net design	Otterboard size	Otterboard angle Degrees
36/37	Gundry II	2.44 x 0.91	37
44/45	Florida flyer	2.44 x 0.91	37
46/47	Sandakan	2.44 x 0.91	37
48/49	Sandakan tongue	2.44 x 0.91	37
50/51	Gundry II	2.13 x 0.91	42.5
52/53	Gundry II	2.13 x 0.91	32
54/55	Gundry II	2.13 x 0.91	25
56/57	Gundry II	2.13 x 0.91	50
10/11/12/13	Gundry II	2.74. x1.14	30
38/39	Gundry II	2.44 x 0.91	30
52/53	Gundry II	2.13 x 0.91	32

Table 2 - Abstract of hauls used for data analysis.

For every haul gear drag increased with towing speed. (Figures 4, 6 and 8).

Otterboard spread (Figure 5, 7 and 9) did not vary greatly within a haul and was found not to change over the speed range tested. Otterboard spread was found to decrease slightly as a result of the net weeding up.

7.2 The influence of net design on gear performance

7.2.1. Gear Drag

For a given speed, the Gundry II design had less drag than the Florida Flyer, Sandakan and Sandakan tongue trawls when connected to the same sized otterboards and bridle rig. Typically, this reduction in drag was more than 12%. Table 3 lists the percentage increase in total gear drag for the Florida flyer, Sandakan and Sandakan tongue nets over the Gundry II design.

	Towing speed (knots)		
Gundry II	2.5	2.75	3.0
Florida flyer	+12%	+18%	+23%
Sandakan	+26%	+27%	+28%
Sandakan tongue	+15%	+23%	+29%

Table 3 Comparison of gear drags for hauls 36/37, 44/45, 46/47, 48/49. Percentages refer to increases over the Gundry II design.

7.2.2 Otterboard spread

The spread ratios* for each net design were typically 67-71%. When using the same sized otterboards (2.44m) at the same angle there were no differences in average otterboard spread between the Gundry II design, Sandakan and Sandakan tongue net designs. The Florida flyer net design however appeared to have produced a slightly higher otterboard spread (15.6m, 71%) See table 4.

$$* \text{ Spread ratio} = \frac{\text{otterboard spread (m)}}{\text{headline length} + 2 \text{ sweep lengths (m)}} \times 100\%$$

	Av. otterboard spread (m)	spread ratio %	%Difference from Gundry II
Gundry II	14.8	68	--
Florida flyer	15.6	71	+7%
Sandakan	14.8	68	NO DIFFERENCE
Sandakan tongue	14.8	67	NO DIFFERENCE

Table 4 comparison of otterboard spreads for hauls 36/37. 44/45, 46/47, 48/49.

7.3 The influence of otterboard angle on gear performance

The Gundry II design with 2.44m otterboards was used to determine if otterboard angle affected gear drag or otterboard spread.

At 2.5 knots the gear drag increased by about 10% for every additional 8 degrees of otterboard angle above 25 degrees (Fig 6). At 3.0 knots, the rate of increase in gear drag reduced to about 3% for every eight degrees added above 25 degrees. (table 5).

The average otterboard spread did not change much with speed between 25 degrees and 50 degrees. Highest spreads were obtained when using an otterboard angle between 32 and 42.5 degrees (Fig. 5).

Otterboard Angle (degrees)	%change in gear drag with speed from 25 degree angle 2.5	2.75	3.0	Av. otterboard spread (m)	Spread ratio %
25	-	-	-	14.0	63
32	+11%	+3%	-3%	14.5	67
42.5	+22%	+11%	+3%	14.5	66
50	+35%	+15%	+7%	13.9	63

Table 5. Change in gear drag and otterboard spread with otterboard angle, hauls 50/51 52/53 54/55 56/57.

7.4 The influence of otterboard size on gear performance

7.4.1 Gear Drag

Table 6 shows how the gear drag increased both with towing speed and size of otterboard. At 3.0 knots the 2.74m(9ft) otterboards had 22% more drag than the 2.14m(7ft) otterboards when using the same net (Gundry II) and otterboard angle.

7.4.2. Otterboard spread

The average otterboard spread increased by 8% for the 2.44m(8ft) otterboards and 15% for the 2.74m(9ft) otterboards over 2.14m(7ft) otterboards.

Otterboard size	towing speed (knots) 3.0	3.25	3.5	Av. otterboard spread metres	Spread ratio %	%increase in otterboard spread
2.14m(7ft)	-	-	-	14.4	66	-
2.44m(8ft)	+6%	+9%	+11%	15.6	71	+8%
2.74m(9ft)	+22%	+18%	+16%	16.5	75	+15%

Table 6 Comparison of gear drag and otterboard spread for hauls 10/11/12/13, 38/39, 52/53.

8. Discussion

This project compares the gear drag and otterboard spread for various combinations of net designs, otterboard sizes and otterboard angles at various speeds during sea trials.

Results indicated that the relationship between gear drag and towing speed were linear over the speed range tested. Similar results for gear drag have been found by Van Marlen (1982), Galbraith (1982), Buchan and Robertson (1980).

A comparison of four net designs showed that the Gundry II had less drag than the Florida flyer, Sandakan and Sandakan tongue trawls when attached to the same sized otterboards and rigged with the same otterboard angle. Reasons for these differences may be partly due to the differences in nominal twine area of each net (Reid 1977). The Gundry II and Florida flyer nets had nominal twine areas of 14.3m^2 and 13.3m^2 respectively, whilst the Sandakan and Sandakan tongue trawls had nominal twine areas of 16.2m^2 and 19.5m^2. Those nets with the highest twine areas had the highest drags for a given speed. Because angles of attack of the otterboards, sweep angles and sweep tensions were not measured it was not possible to determine the separate contributions made by either otterboards or nets to the total drag.

Gear drag was also found to increase with otterboard angle. However the suitability of choosing otterboard angle as a variable when measuring towing speed and gear drag may be questioned. Firstly, the otterboard angle is different from the "angle of attack" usually quoted in texts (FAO 1974) and secondly, both these angles will change with speed and the combinations of net and otterboard used.

Large differences were recorded for the gear drags when using different sized otterboards. The area of the 2.14m otterboard was 1.96m^2 whilst the area of the 2.74m otterboard was 2.74m^2, an increase of about 40%. Gear drag increased by 19% when using these otterboards on the Gundry II design. Tests have shown that otterboard drag should increase proportionately with board area provided the angle of attack remains unchanged (FAO 1974). Once again, the trials results suggest that some interaction between otterboards and nets is occurring.

For all hauls it was found that otterboard spread did not increase significantly with speed ($P<0.05$). When comparing spreads for different net designs at the same speed, there were no differences in otterboard spread for the Gundry II, Sandakan or Sandakan tongue nets, but the Florida flyer design produced a significantly higher otterboard spread ($P<0.01$).

No significant differences were observed when otterboard angle was varied ($P<0.05$). The mean values for spread at 32 degrees and 42.5 degrees were 0.5m higher than for 25 degrees and 50 degrees.

Highly significant differences in spread ($P<0.001$) were measured when otterboard size was increased from 2.14m to 2.74m, indicating the importance of board area over otterboard angle for achieving spread.

Catching performance of various rigs could not be measured because few prawns were caught during the trials. The use of swept area as a performance indicator is doubtful since little is known about the variation in catching efficiency with spread for prawn trawls.

9. Summary and Conclusions

Over the speed range chosen, gear drag increased linearly with speed. Up to 30% increase in gear drag was observed when towing speed was increased by as little as 0.5 knots.

Gear drag did vary with net design; in order of increasing drag these were the Florida flyer, Gundry II, Sandakan, and Sandakan tongue. During these trials it was not possible to determine the exact contribution of net drag to total gear drag. An increase in nominal twine area did result in increased gear drag for the Sandakan and Sandakan tongue trawls over the Gundry II design but not over the Florida flyer.

Increasing otterboard size resulted in increased gear drag but also increased otterboard spread. Changing otterboard size from 2.14m (7ft) to 2.74m (9ft) resulted in an increased gear drag of 22% at 3.0 knots and an increased otterboard spread of 15% (1.3m extra across the wingends).

Increased otterboard angle produced a higher gear drag but not necessarily an increased otterboard spread. The optimum otterboard angle appeared to be between 32 degrees and 42.5 degrees. Otterboard spread did not increase with towing speed and did reduce as the nets weeded up. Net design did not influence otterboard spread except in hauls 44/45.

More sophisticated trials instrumentation is required if detailed studies of net and otterboard performance are to be undertaken during sea trials. In particular, force transducers on the net sweeps, angle meters to measure otterboard angle of attack and sweep angle, as well as net mounted speed logs to measure water speed at the net would be needed to identify the separate contribution of each part of the gear to the total drag.

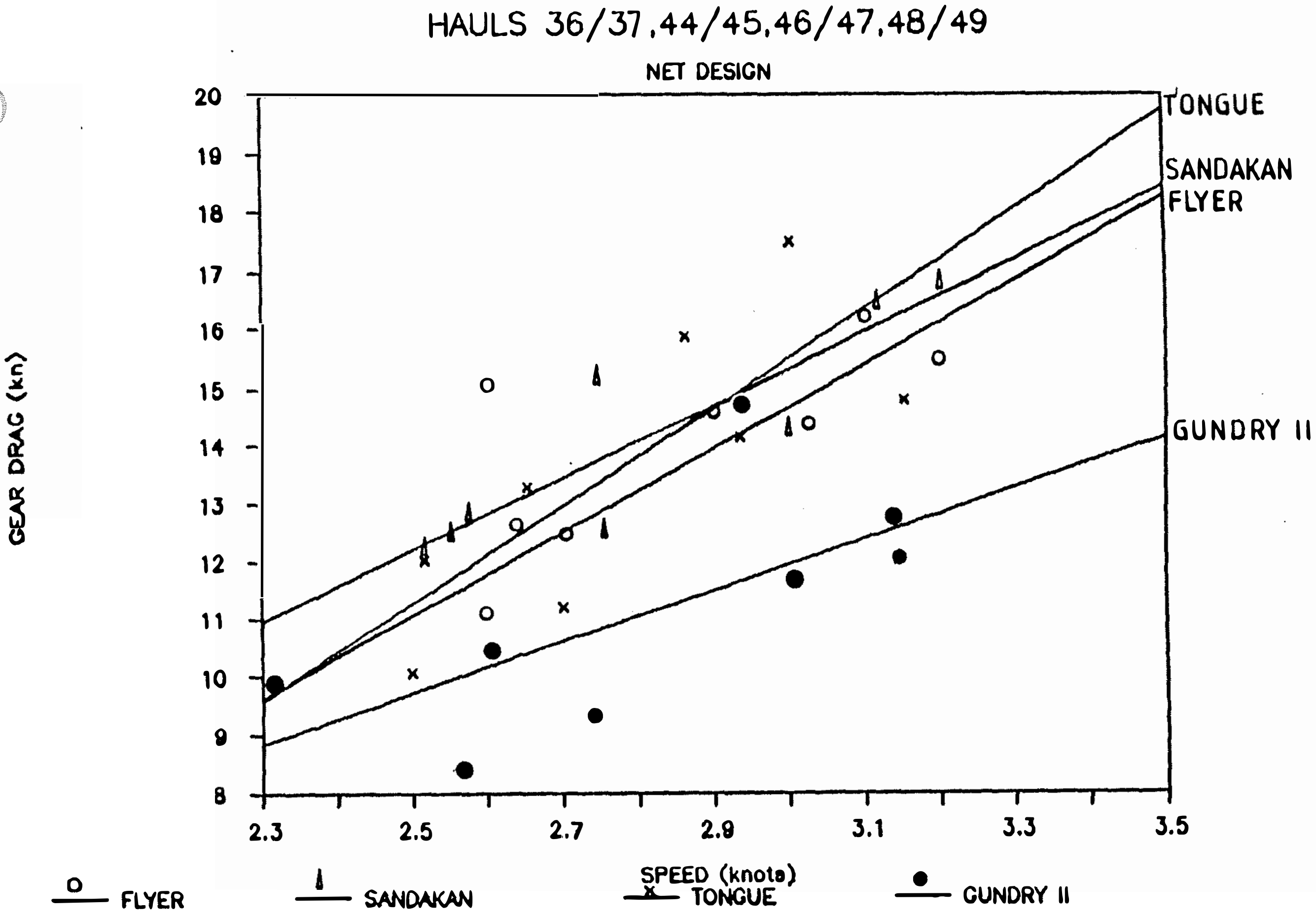

HAULS 36/37,44/45,46/47,48/49
NET DESIGN
TONGUE
SANDAKAN
FLYER
GUNDRY II
GEAR DRAG (kn)
20
19
18
17
16
15
14
13
12
11
10
9
8
2.3
2.5
2.7
2.9
3.1
3.3
3.5
SPEED (knots)
FLYER
SANDAKAN
TONGUE
GUNDRY II

FIG.4

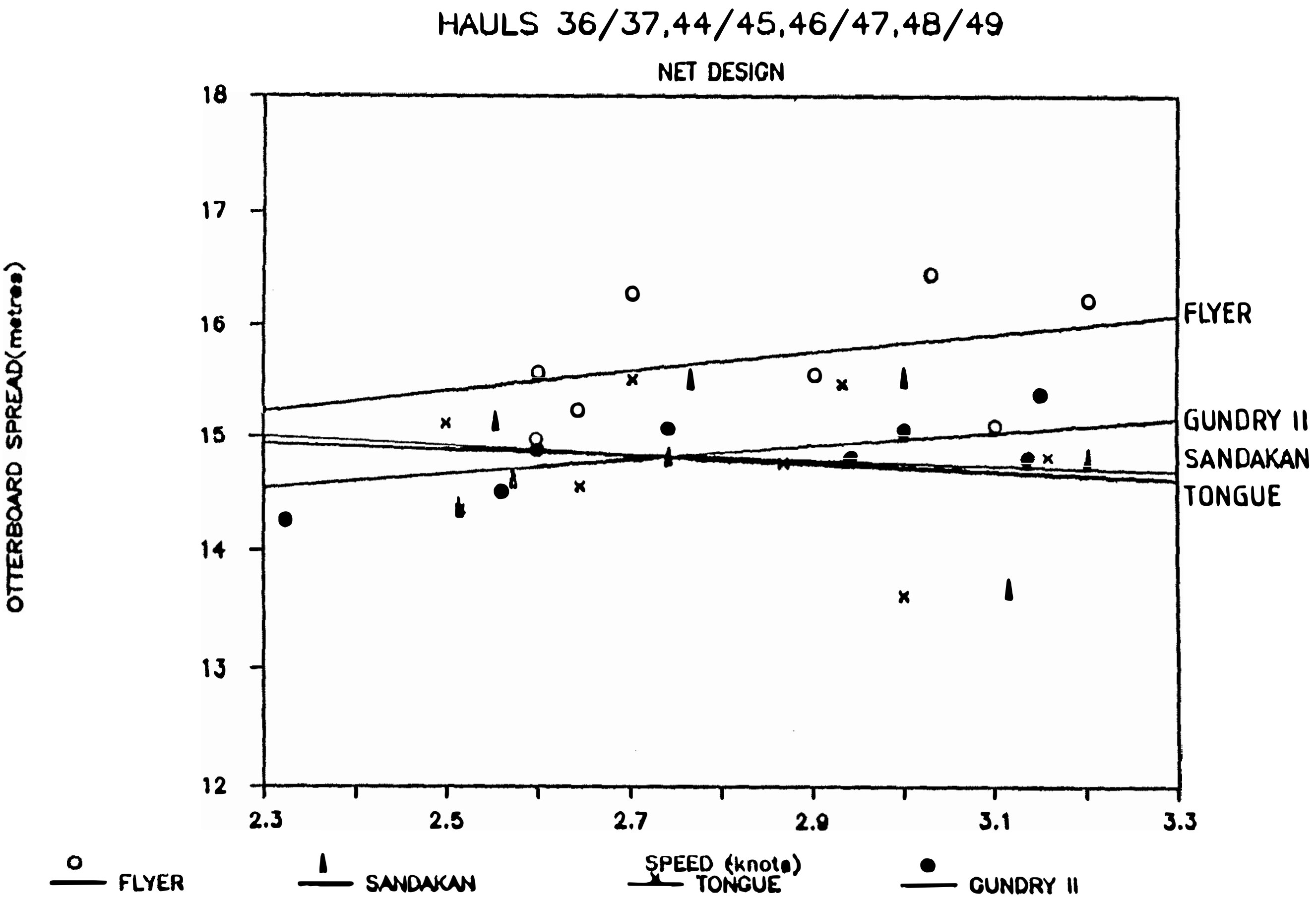

HAULS 36/37,44/45,46/47,48/49
NET DESIGN
FLYER
GUNDRY II
SANDAKAN
TONGUE
OTTERBOARD SPREAD(metres)
18
17
16
15
14
13
12
2.3
2.5
2.7
2.9
3.1
3.3
SPEED (knots)
FLYER
SANDAKAN
TONGUE
GUNDRY II

FIG.5

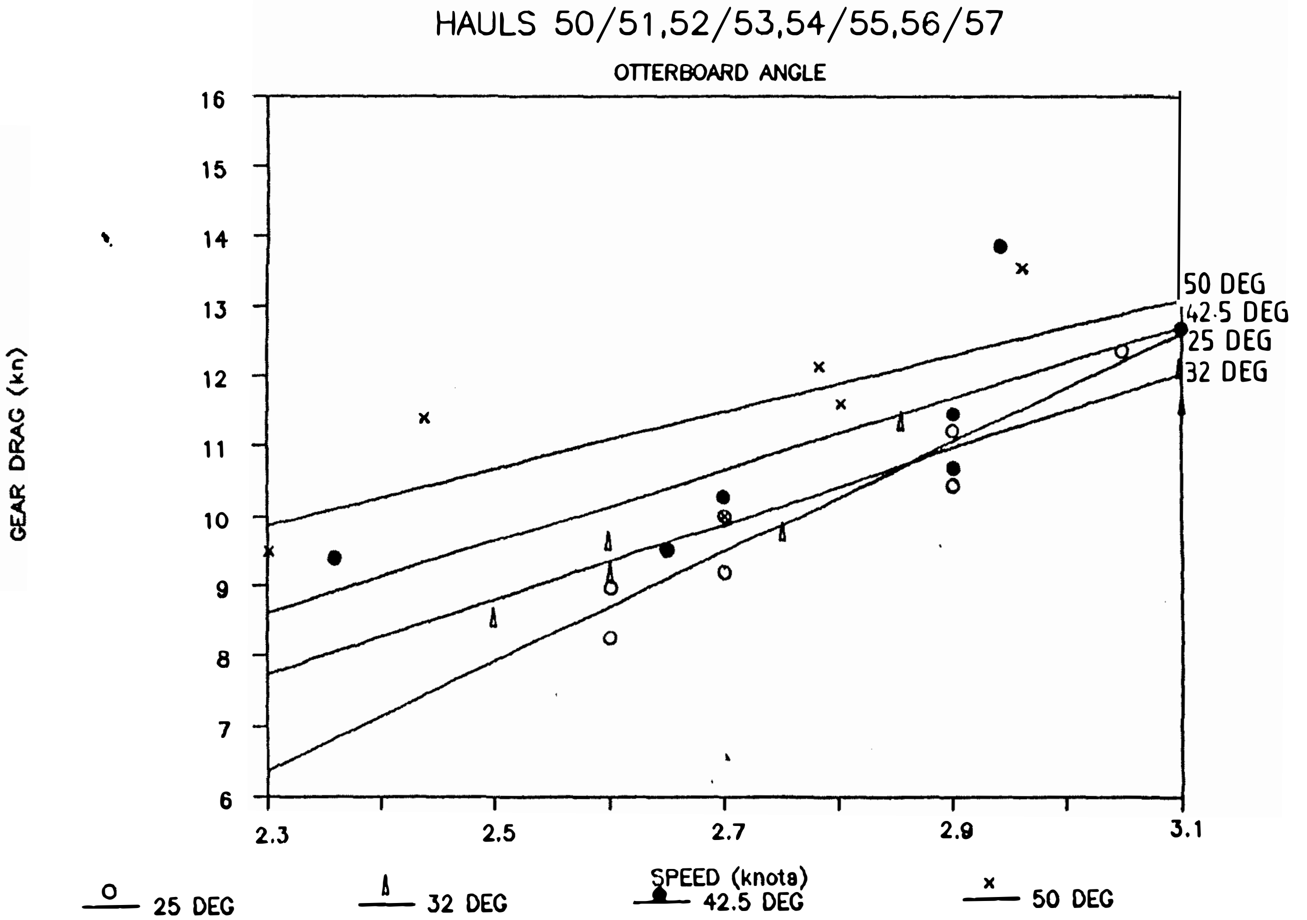

HAULS 50/51,52/53,54/55,56/57
OTTERBOARD ANGLE
GEAR DRAG (kn)
16
15
14
13
12
11
10
9
8
7
6
2.3
2.5
2.7
2.9
3.1
50 DEG
42.5 DEG
25 DEG
32 DEG
SPEED (knots)
25 DEG
32 DEG
42.5 DEG
50 DEG

FIG. 6

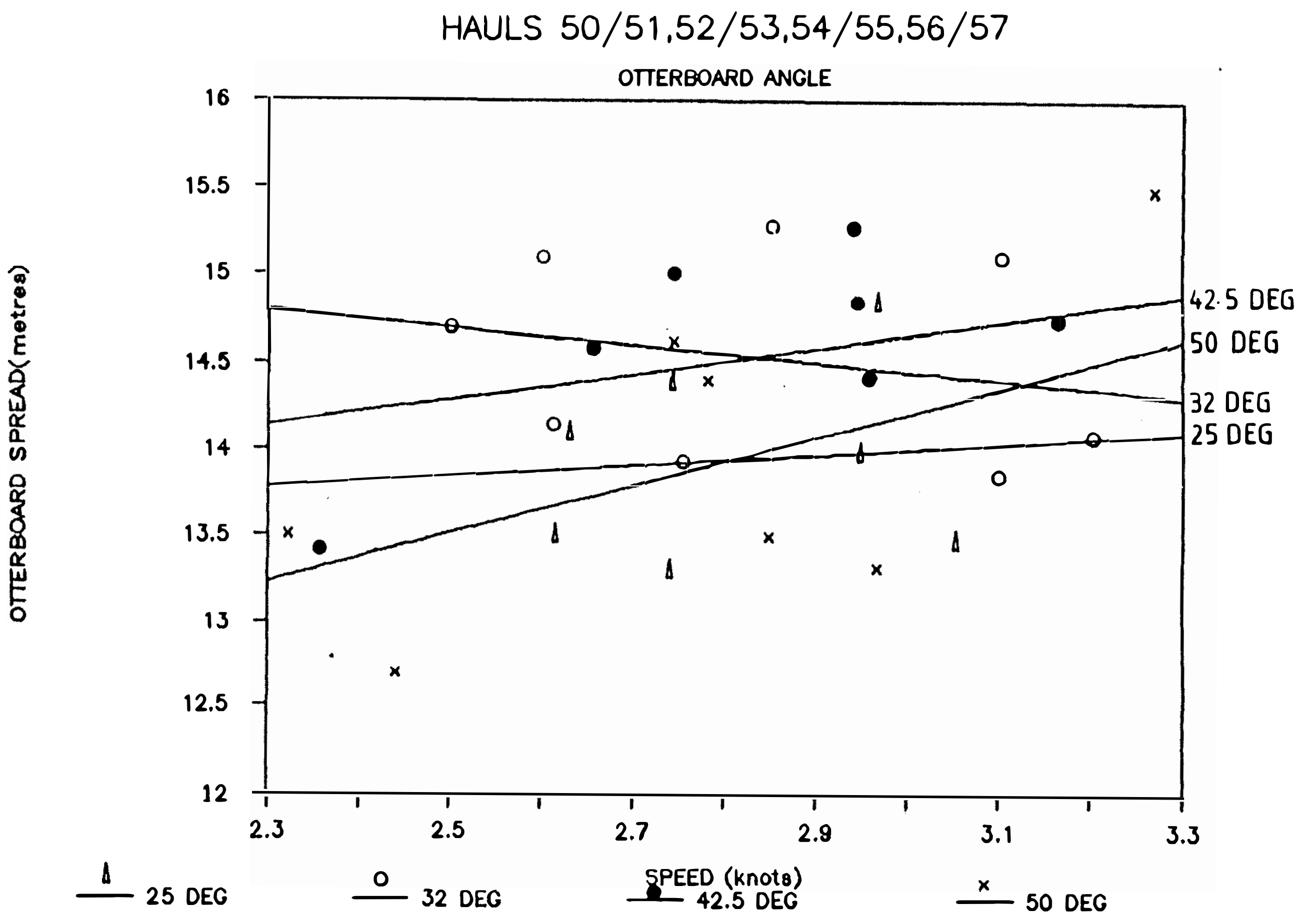

HAULS 50/51,52/53,54/55,56/57
OTTERBOARD ANGLE
OTTERBOARD SPREAD(metres)
16
15.5
15
14.5
14
13.5
13
12.5
12
2.3
2.5
2.7
2.9
3.1
3.3
42.5 DEG
50 DEG
32 DEG
25 DEG
SPEED (knots)
25 DEG
32 DEG
42.5 DEG
50 DEG

FIG. 7

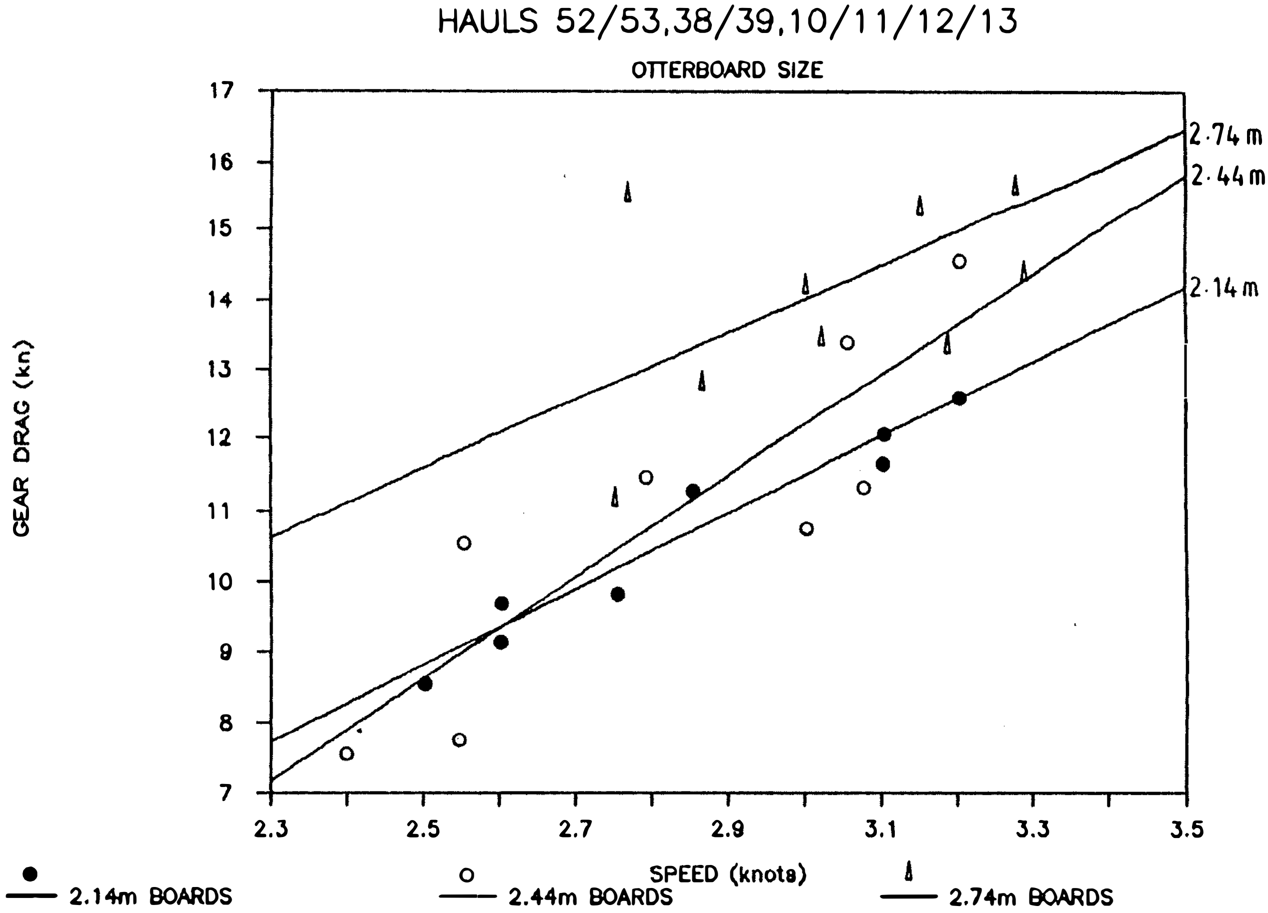

HAULS 52/53,38/39,10/11/12/13
OTTERBOARD SIZE
GEAR DRAG (kn)
SPEED (knots)
2.74m
2.44m
2.14m
2.14m BOARDS
2.44m BOARDS
2.74m BOARDS

FIG. 8

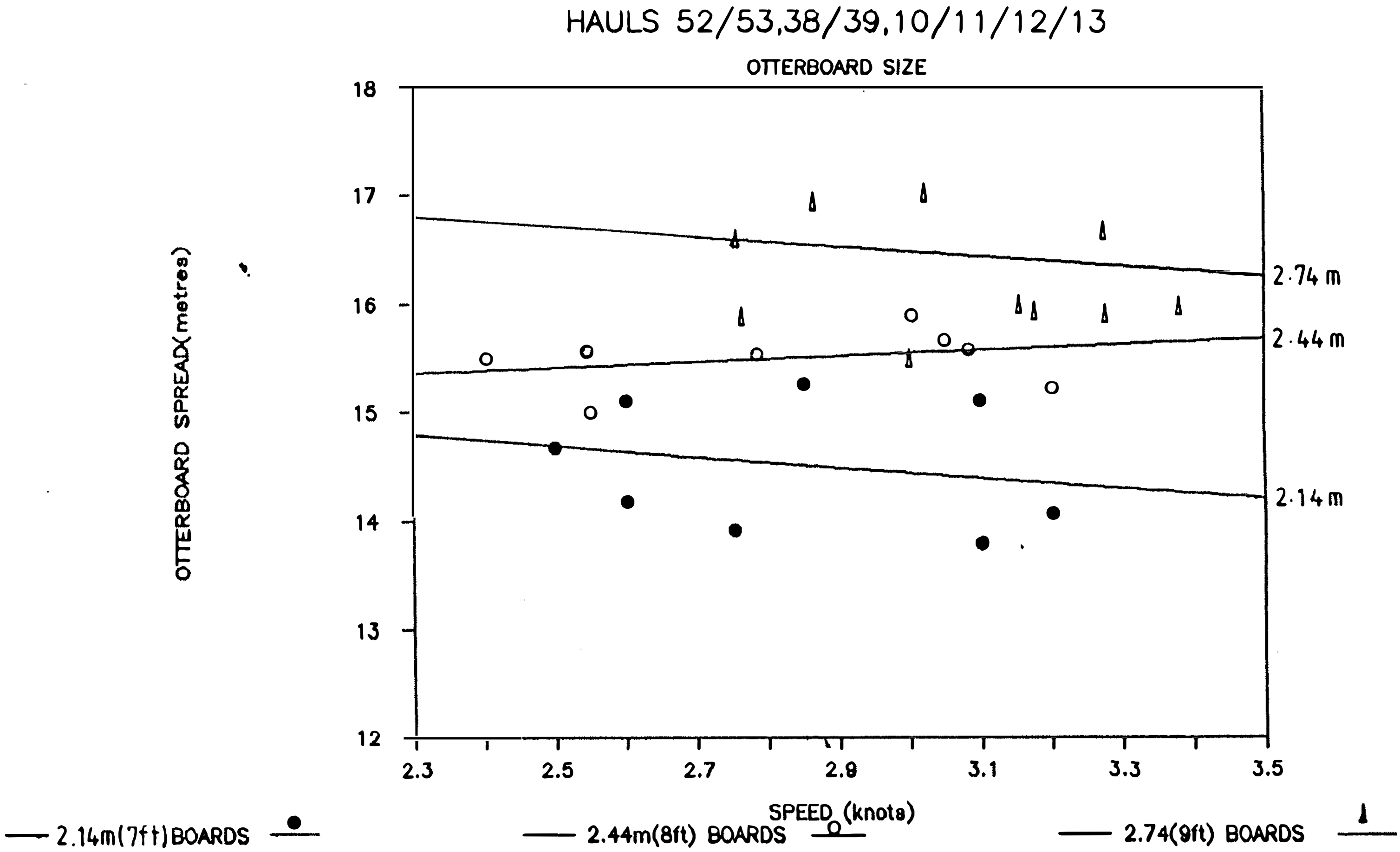

HAULS 52/53,38/39,10/11/12/13
OTTERBOARD SIZE
OTTERBOARD SPREAD (metres)
SPEED (knots)
2.74m
2.44m
2.14m
2.14m(7ft)BOARDS
2.44m(8ft) BOARDS
2.74(9ft) BOARDS

FIG. 9

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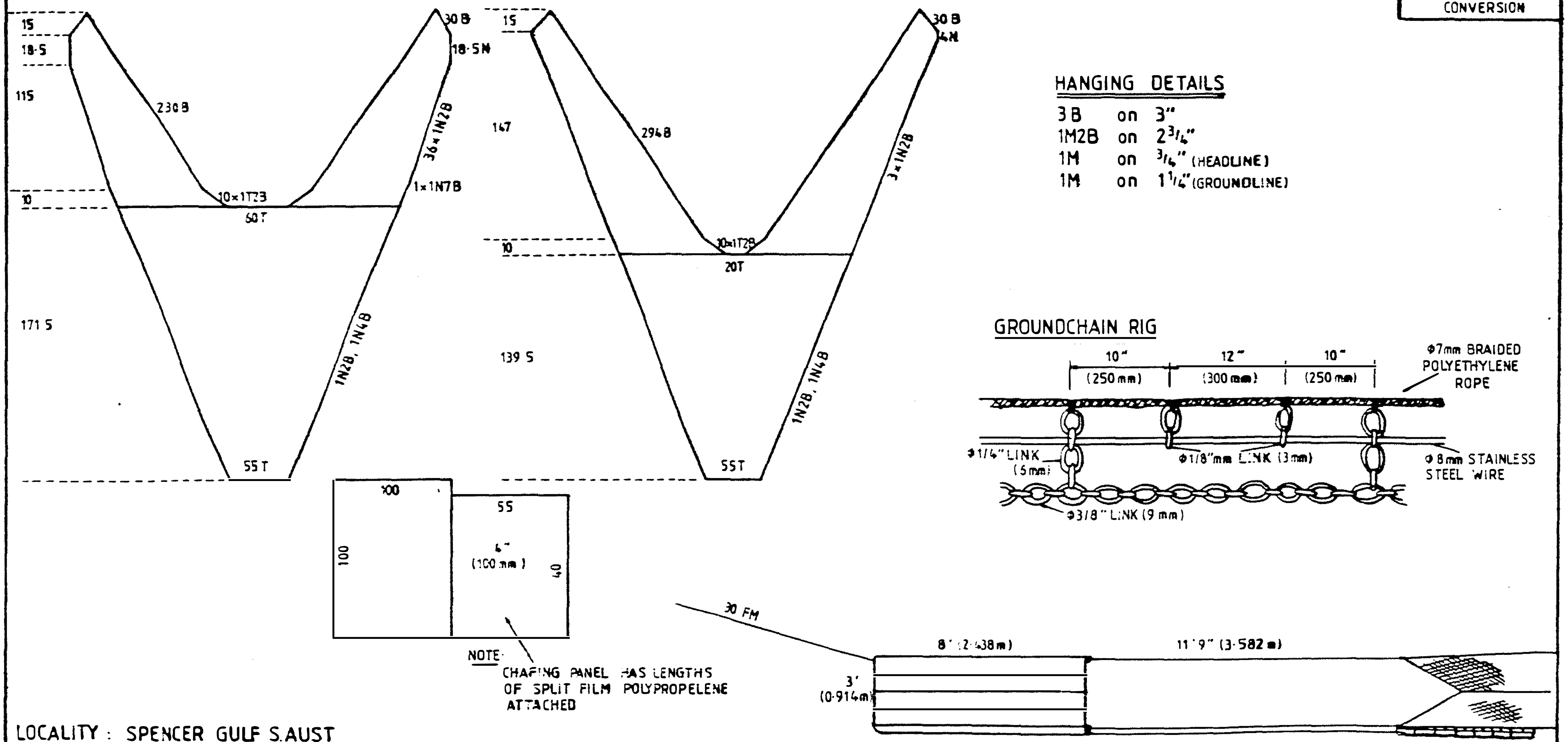
Appendix I

NET DESIGNS

ALL DIMENSIONS WITHIN - - - - LINES
ARE MESHES DEEP

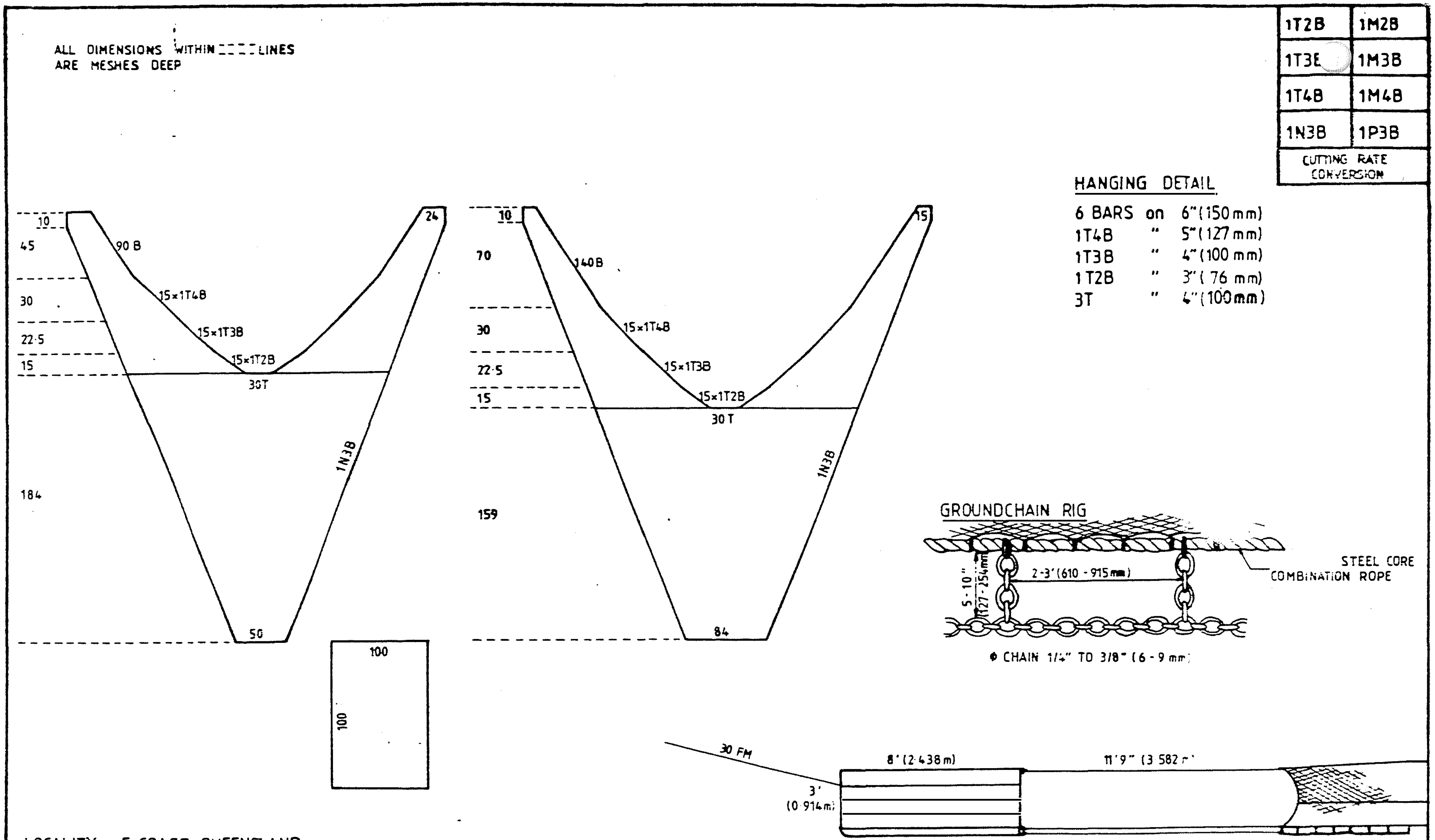
11	1M2B
1N2B	1P2B
1N4B	1P4B
1N7B	1P7B

CUTTING RATE CONVERSION



LOCALITY : SPENCER GULF S.AUST
REFERENCE : H. KAVANAGH

Drawn:	Materials:	Date:		Dimensions:
C.A.SCOTT	NETTING - Φ1·7mm 12 STRAND (667 m/kg) RTEX 1649 - 2" (50 mm) CODEND - Φ2·35mm 24 STRAND (343 m/kg) RTEX 3207 - 2" (50 mm)	3 OCT '85	8 FM S.A. GUNDRY	
Checked:		Scale:		Dwg. Nº:
		1:25	AUSTRALIAN MARITIME COLLEGE	9 - 1 - 85



LOCALITY : E. COAST QUEENSLAND

REFERENCE : J. DERRICK

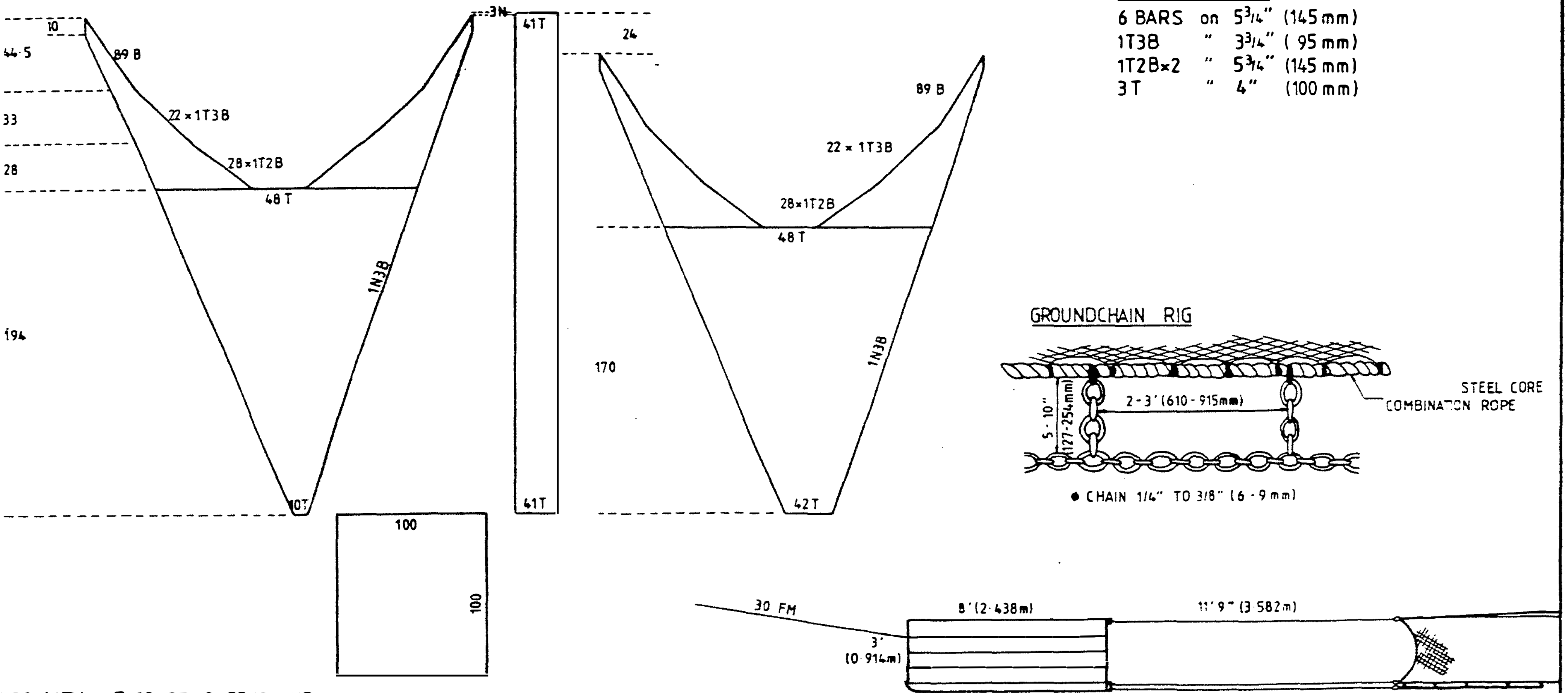
Drawn:	Materials:	Date:		Dimensions:
C.A. SCOTT	NETTING - 400/30 (R TEX 1466) 2" (50mm) CODEND - 400/38 (R TEX 1858) 1¾" (45mm)	24 SEPT '85	8FM FLORIDA FLYER	
Checked:		Scale:		Dwg. Nº:
J.C.		1:25	AUSTRALIAN MARITIME COLLEGE	7-1-85

ALL DIMENSIONS WITHIN - - - - LINES
ARE MESHES DEEP

1T3B	1M3B
1T2	1M2B
1N3B	1P3B
CUTTING RATE CONVERSION	

HANGING DETAIL

6 BARS	on	$5\frac{3}{4}$"	(145 mm)
1T3B	"	$3\frac{3}{4}$"	(95 mm)
1T2B×2	"	$5\frac{3}{4}$"	(145 mm)
3 T	"	4"	(100 mm)



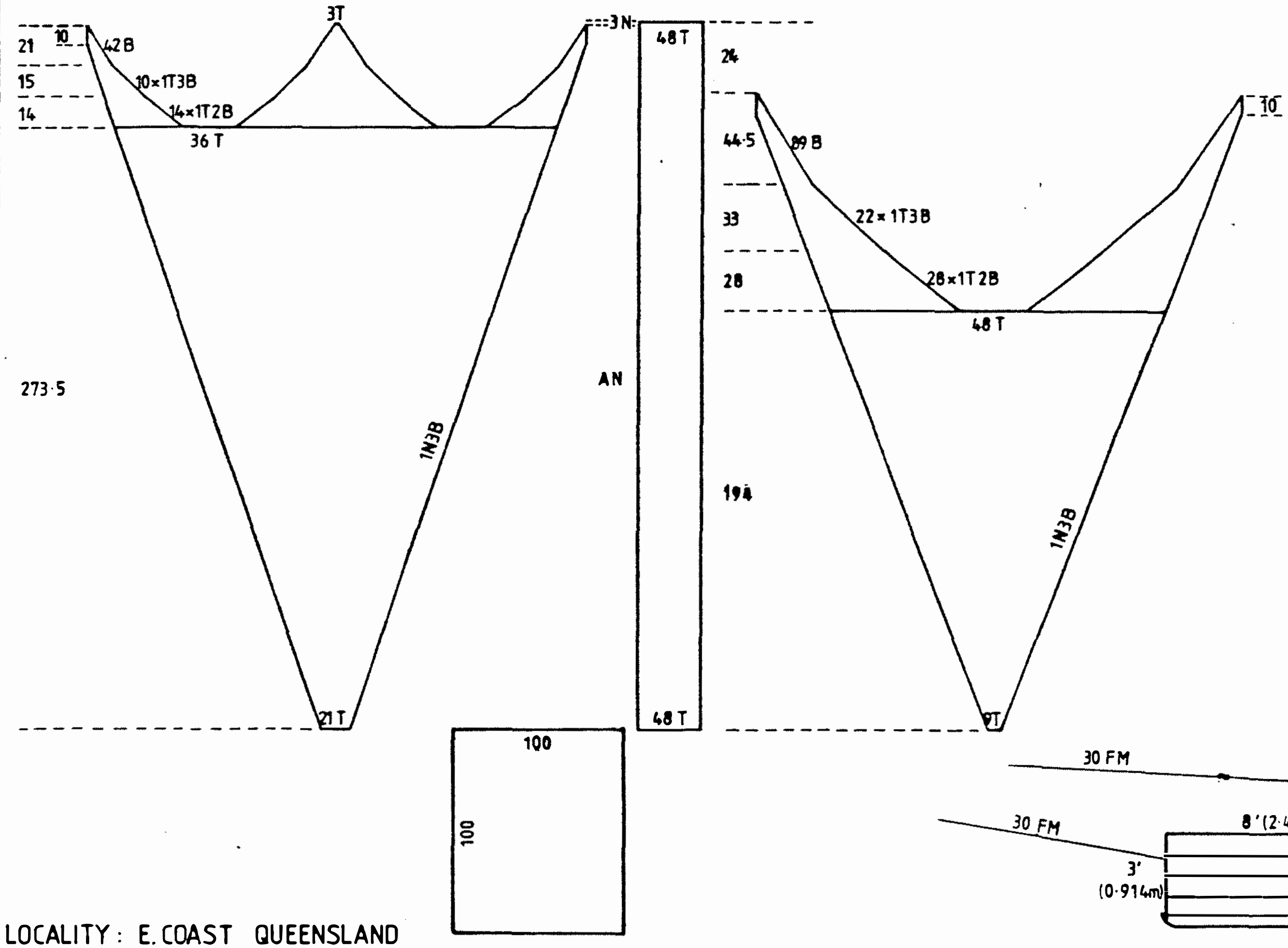
LOCALITY : E.COAST QUEENSLAND
REFERENCE : J. DERRICK

Drawn:	Materials:	Date:		Dimensions:
C.A.SCOTT	NETTING - 400/30 (RTEX 1466) 2" (50mm) CODEND- 400/38 (R TEX 1858) $1\frac{3}{4}$" (45mm)	24 SEPT '85	8 FM SANDAKAN	
Checked:		Scale:		Dwg. Nº:
?.C.		1:25	AUSTRALIAN MARITIME COLLEGE	8 - 1 - 85

ALL DIMENSIONS WITHIN ---- LINES ARE MESHES DEEP

1T3B	1M3B
1T2B	1M2B
1N3B	1P3B

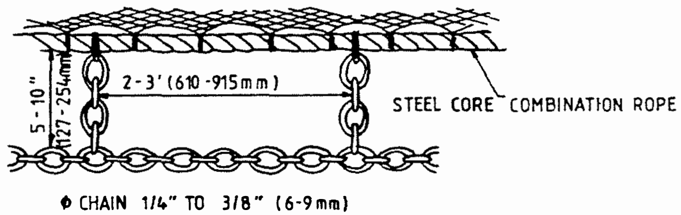
CUTTING RATE CONVERSION

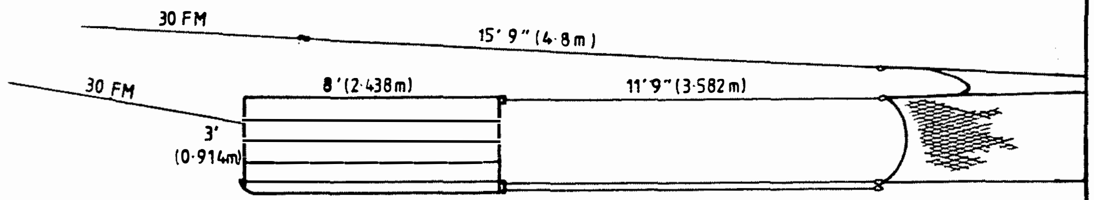


HANGING DETAIL

6 BARS	on	5 3/4"	(145mm)
1T3B	"	3 3/4"	(95mm)
1T2B×2	"	5 3/4"	(145mm)
3T	"	4"	(100 mm)

GROUNDCHAIN RIG





LOCALITY : E. COAST QUEENSLAND
REFERENCE : J. DERRICK

Drawn: C.A. SCOTT

Checked: S.C.

Materials:
NETTING - 400/30 (R TEX 1466) 2" (50mm)
CODEND - 400/38 (R TEX 1858) 1 3/4" (45mm)

Date: 24 SEPT '85

Scale: 1:25

8 FM TONGUE TRAWL

AUSTRALIAN MARITIME COLLEGE

Dimensions:

Dwg. Nº: 10 - 1 - 85

Appendix II

SEA TRIAL DATA

HAUL	BLOCK	R.P.M.	SPEED KNOTS	LOAD LBS	GEARDRAG kN	SPREAD METRES
6	1	1102	2.84	3650	10.84	17.20
6	2	1155	2.94	4050	12.03	16.90
6	3	1206	3.07	4436	13.18	16.80
8	1	1248	3.26	4851	10.83	16.20
8	2	1302	3.37	5113	12.93	16.20
7	1	1104	2.80	3645	14.15	16.70
7	2	1158	2.87	4355	14.41	16.40
7	3	1205	2.92	4763	15.19	16.40
9	1	1248	3.11	4806	14.27	16.40
9	2	1304	3.16	5458	16.21	16.00
10	1	1200	3.02	4550	13.51	17.00
10	2	1153	2.86	4350	12.92	16.90
10	3	1105	2.75	3783	11.24	16.60
12	1	1254	3.15	4760	15.33	16.00
12	2	1304	3.28	5260	14.41	15.90
11	1	1203	3.18	5160	13.37	16.90
11	2	1153	3.00	4850	14.14	16.50
11	3	1104	2.77	4500	15.62	15.90
13	1	1250	3.28	5316	15.79	16.70
13	2	1300	3.38	5825	17.30	16.00
14	1	1205	3.10	5200	15.44	16.90
14	2	1105	2.73	4480	13.31	16.80
14	3	1155	2.90	4880	14.49	16.80
16	1	1250	3.13	5480	13.81	16.30
16	2	1302	3.31	6050	11.61	16.30
15	1	1203	3.20	4650	13.37	16.00
15	2	1103	2.86	3910	16.28	15.80
15	3	1155	2.96	4500	17.97	15.60
17	1	1252	3.30	4680	13.90	16.20
17	2	1300	3.30	5440	16.16	16.00
18	1	1202	3.00	5100	15.15	15.30
18	2	1102	2.65	4320	12.83	14.60
18	3	1153	2.73	4580	13.60	14.20
20	1	1255	3.09	6100	15.44	14.00
20	2	1301	3.18	6400	12.62	14.00
19	1	1203	3.06	5200	14.35	15.00
19	2	1102	2.71	4250	18.12	14.30
19	3	1152	2.77	4830	19.01	13.60
21	1	1254	3.03	5620	16.69	15.10
21	2	1302	3.20	6150	18.27	14.40
23	1	1098	2.90	3350	10.03	13.60
23	2	1049	2.70	3150	9.43	13.60
23	3	1153	3.02	3765	11.27	13.20
25	1	1203	3.14	4002	9.88	13.40
25	2	1008	2.50	2892	9.56	13.20
24	1	1098	2.90	3300	11.72	13.90
24	2	1052	2.78	3193	11.98	13.50
24	3	1154	3.00	3916	8.66	13.60
26	1	1204	3.30	4089	12.24	13.10
26	2	1004	2.60	2934	8.78	12.90
27	1	1101	2.80	3569	10.68	14.80
27	2	1053	2.68	3391	10.15	14.30
27	3	1152	2.98	3981	11.92	14.40
29	1	1204	3.10	4241	11.40	13.90
29	2	1009	2.50	3251	9.94	13.40

HAUL	BLOCK	R.P.M.	SPEED KNOTS	LOAD LBS	GEARDRAG kN	SPREAD METRES
28	1	1148	3.18	3808	10.92	12.90
28	2	1052	2.78	3321	12.70	12.80
28	3	1104	2.98	3649	9.76	12.60
30	1	1205	3.20	4468	13.38	13.40
30	2	1004	2.70	3160	9.46	12.70
31	1	1101	2.78	3502	10.48	15.10
31	2	1050	2.63	3319	9.94	14.20
31	3	1152	2.91	3948	11.82	14.00
33	1	1206	3.10	4681	10.71	12.90
33	2	1005	2.50	3311	9.96	12.60
32	1	1105	3.00	3576	12.00	13.90
32	2	1050	2.72	3328	14.01	13.10
32	3	1148	3.02	4009	9.91	12.90
34	1	1200	3.10	4471	13.39	12.00
34	2	1005	2.54	3171	9.49	11.70
36	1	1150	3.15	4177	12.04	15.40
36	2	1050	2.74	3252	9.37	15.10
36	3	1201	3.13	4273	12.31	14.80
36	4	1005	2.56	2924	8.43	14.70
37	1	1155	3.00	4062	11.70	15.10
37	2	1050	2.60	3600	10.37	14.90
37	3	1200	2.93	5020	14.46	14.80
37	4	1000	2.32	3430	9.88	14.30
38	1	1152	3.00	3740	10.78	15.90
38	2	1053	2.54	2700	7.78	15.60
38	3	1198	3.08	3970	11.44	15.60
38	4	1002	2.40	2600	7.49	15.50
39	1	1153	3.05	4660	13.43	15.70
39	2	1054	2.79	4020	11.58	15.60
39	3	1201	3.20	5110	14.72	15.30
39	4	1007	2.55	3670	10.57	15.00
40	1	1152	2.60	3990	12.45	15.70
40	2	1054	2.16	3400	10.61	15.20
40	3	1207	2.60	4770	14.89	15.00
40	4	1305	3.08	5790	18.07	14.80
41	1	1150	3.06	6120	16.49	15.70
41	2	1050	2.77	5310	14.31	15.20
41	3	1205	3.10	6380	17.75	14.50
41	4	1006	2.50	4930	13.72	13.90
42	1	1150	2.90	4820	14.79	15.20
42	2	1054	2.50	4110	12.61	14.50
42	3	1200	2.94	5350	16.42	13.90
42	4	1008	2.27	3790	11.63	13.50
43	1	1153	3.00	6050	18.56	14.60
43	2	1060		5180	15.89	14.00
43	3	1201	3.10	6350	19.48	13.80
43	4	1006	2.52	4680	14.36	13.00
44	1	1150	3.03	4980	14.46	16.50
44	2	1050	2.70	4300	12.48	16.30
44	3	1200	3.20	5330	15.47	16.20
44	4	1000	2.60	3800	11.03	15.60
45	1	1152	2.90	5080	14.75	15.70
45	2	1052	2.64	4400	12.77	15.30
45	3	1200	3.10	5550	16.11	15.10
45	4	1000	2.60	4000	11.61	15.00

HAUL	BLOCK	R.P.M.	SPEED KNOTS	LOAD LBS	GEARDRAG kN	SPREAD METRES
46	1	1145	3.00	4910	14.25	15.60
46	2	1055	2.77	4350	12.63	15.60
46	3	1196	3.20	5850	16.98	14.80
46	4	1004	2.55	4310	12.51	15.10
47	1	1146	2.74	5220	15.15	14.80
47	2	1058	2.58	4450	12.92	14.60
47	3	1204	3.11	5650	16.40	13.70
47	4	1008	2.51	4190	12.16	14.40
48	1	1153	2.93	4880	14.06	15.50
48	2	1050	2.70	3900	11.24	15.50
48	3	1200	3.15	5240	15.10	14.80
48	4	1000	2.50	3500	10.08	15.10
49	1	1146	2.86	5500	15.85	14.80
49	2	1050	2.64	4580	13.20	14.60
49	3	1200	3.00	6070	17.49	13.70
49	4	1005	2.51	4170	12.02	14.40
50	1	1145	2.90	4000	11.53	15.30
50	2	1060	2.70	3580	10.32	15.00
50	3	1199	2.94	4830	13.92	14.80
50	4	1004	2.36	3280	9.45	13.40
51	1	1000	2.65	3320	9.57	14.60
51	2	1150	3.10	4420	12.74	14.70
51	3	1064	2.90	3720	10.72	14.40
51	4	1200	3.30	4700	13.54	14.20
52	1	1152	2.85	3920	11.29	15.30
52	2	1052	2.60	3380	9.74	15.10
52	3	1198	3.10	4200	12.10	15.10
52	4	1008	2.50	3000	8.64	14.70
53	1	1006	2.60	3180	9.16	14.20
53	2	1199	3.20	4400	12.68	14.10
53	3	1051	2.75	3400	9.80	13.90
53	4	1150	3.10	4070	11.73	13.80
54	1	1147	2.90	3650	10.52	14.80
54	2	1056	2.70	3190	9.19	14.40
54	3	1200		4060	11.70	14.40
54	4	1008	2.60	2900	8.36	14.10
55	1	1153	2.90	3900	11.24	14.00
55	2	1013	2.60	3130	9.02	13.50
55	3	1205	3.05	4320	12.45	13.50
55	4	1058	2.70	3480	10.03	13.30
56	1	1156	3.20	4680	13.48	15.50
56	2	1006	2.70	3480	10.03	14.60
56	3	1200	3.30	4750	13.69	14.00
56	4	1055	2.80	4050	11.67	13.50
57	1	1151	2.78	4200	12.10	14.40
57	2	1011	2.30	3300	9.51	13.50
57	3	1203	2.96	4730	13.65	13.30
57	4	1053	2.43	3950	11.38	12.70

Appendix III

Regression lines for hauls mentioned in the text.

TITLE	Angle of Attack											
HAUL NO.	50/51			52/53			54/55			56/57		
SPEED (KNOTS)	2.5	2.75	3.0	2.5	2.75	3.0	2.5	2.75	3.0	2.5	2.75	3.0
GEAR DRAG KILONEWTONS	9.65	10.93	12.21	8.81	10.17	11.52	7.93	9.89	11.85	10,69	11.70	12.71
REGRESSION LINE OF GEAR DRAG (y) AGAINST SPEED (x)	$y = -3.18 + 5.13x$ $r^2 = 0.71$			$y = -4.74 + 5.42x$ $r^2 = 0.95$			$y = -11.70 + 7.85x$ $r^2 = 0.92$			$y = 0.56 + 4.05x$ $r^2 = 0.75$		
VARIATION IN TENSION MEASUREMENT WITHIN EACH HAUL(KILONEWTONS)	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6
OTTERBOARD SPREAD METRES	14.3	14.5	14.6	14.7	14.6	14.4	13.8	13.9	14.0	13.5	13.9	14.2
REGRESSION LINE OF OTTERBOARD SPREAD (y) AGAINST SPEED (x)	$y = 12.49 + 0.72x$ $r^2 = 0.13$			$y = 15.92 - 0.49x$ $r^2 = 0.05$			$y = 13.07 + 0.31x$ $r^2 = 0.05$			$y = 10.04 + 1.39x$ $r^2 = 03$		

TITLE NET DESIGN

HAUL NO.	36/37			44/45			46/47			48/49		
SPEED (KNOTS)	2.5	2.75	3.0	2.5	2.75	3.0	2.5	2.75	3.0	2.5	2.75	3.0
GEAR DRAG (kn)	9.72	10.84	11.95	11.07	12.87	14.68	12.20	13.77	15.33	11.20	13.32	15.44
REGRESSION LINE OF GEAR DRAG (y) AGAINST SPEED (x)	y = -1.43 + 4.46x r^2 = 0.47			y = 7.01 + 7.23x r^2 = 0.88			y = -3.42 + 6.25x r^2 = 0.79			y = -9.9 + 8.47x r^2 = 0.65		
VARIATION IN TENSION MEASUREMENT WITHIN EACH HAUL KILONEWTONS	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3	±0.3
OTTERBOARD SPREAD METRES	14.7	14.8	15.0	15.4	15.6	±5.8	14.9	14.8	14.8	14.9	14.8	14.7
REGRESSION LINE OF OTTERBOARD SPREAD (y) AGAINST SPEED (x)	y = 13.09 + 0.63x r^2 = 0.47			y = 13.20 + 0.88x r^2 = 0.14			y = 15.51 - 0.25x r^2 = 0.01			y = 15.8 - 0.36x r^2 = 0.02		

TITLE	Otterboard Size											
HAUL NO.	52/53				38/39				10/11/12/13			
SPEED (KNOTS)	2.75	3.0	3.25	3.5	2.75	3.0	3.25	3.5	2.75	3.0	3.25	3.5
GEAR DRAG (knots)	10.17	11.52	12.88	14.23	10.42	12.23	14.04	15.85	12.82	14.03	15.25	16.46
REGRESSION LINE OF GEAR DRAG (y) AGAINST SPEED (x)	$y = -4.73 + 5.4x$ $r^2 = 0.95$				$y = -9.46 + 7.23x$ $r^2 = 0.76$				$y = -0.55 + 4.86x$			
VARIATION IN TENSION MEASUREMENT WITHIN EACH HAUL	±0.3	±0.3	±0.3	±0.3	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6	±0.6
OTTERBOARD SPREAD	14.6	14.5	14.3	14.2	15.5	15.6	15.6	15.7	16.6	16.5	16.4	16.3
REGRESSION LINE OF OTTERBOARD SPREAD (y) AGAINST SPEED (x)	$y = 15.92 - 0.49x$ $r^2 = 0.05$				$y = 14.75 + 0.27x$ $r^2 = 0.09$				$y = 17.74 - 0.48x$ $r^2 = 0.41$			