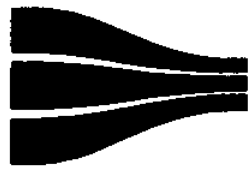

CENTER FOR FISHERIES ENGINEERING RESEARCH

A Project of the

MIT Sea Grant Program

Report No. 10

Standard Series Trawl Tests
July 11-17, 1984

by

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This report covers industry-sponsored trawl model tests conducted by the Center for Fisheries Engineering Research in cooperation with seven U.S. trawl manufacturers. The publication of these results is made possible through an agreement with those companies.

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STANDARD SERIES TRAWL TESTS

INTRODUCTION:

This report contains the test results and analysis from a series of trawl models aimed at better understanding the performance of full sized nets. Trawl fishing has become more competitive and the value of proper design, construction, and rigging is becoming more evident. Because of the interrelationship of various design features, untested design changes can present unacceptable risks to both the trawl designer and fisherman.

These tests of different trawl designs have been conducted to provide U.S. net makers with data on which to base new designs and improve old ones. This is the first such systematic testing of trawls in the U.S. and was aimed specifically at the needs of domestic net lofts. While the range and scope of variations was limited, the value of the tests are apparent and they can serve as a model for further testing.

These tests were sponsored by the MIT Sea Grant Program and a group of independent net makers. Each contributed an equal share towards the costs of conducting the tests.

Coastal Net Company, Warren, Maine
Flagg's Trawler Supply, Portland, Maine
Jamestown Trawl Company, Jamestown, Rhode Island
Nor'Eastern Trawl System's, Bainbridge Island, Washington
Shuman Trawl, Hope Valley, Rhode Island
Trawlworks, Inc., Narragansett, Rhode Island
Wilcox Marine Supply, Mystic, Connecticut

TESTING FACILITY:

The circulating water channel at the David Taylor Naval Ship R&D Center was used for these tests. This facility has a working section 22' wide, 9' deep and 60' long. Flow velocities up to 10 knots can be attained, however due to the scale ratios of the models all tests were done at 1.6 knots or less.

The channel is pictured in Figure 1. Two vertical struts are positioned at the up-stream end of the test section allowing the variation of towing bridle spread. Tow points can be positioned vertically to achieve a variety of towing geometries.

MODELS:

Three types of trawls were studied: 2-seam bottom trawls, 4-seam bottom trawls, and midwater rope trawls. The objectives of the bottom trawl series were to establish an understanding of the way trawl shape is affected by design changes. The midwater tests were concerned with the effect on resistance of variations in hanging ratio.

2-Seam Bottom Trawls - There were nine models in this series representing systematic changes in panel tapers and relative size of top and bottom panels. The baseline design shown on page 5 is typical of several popular trawl designs used in southern New England.

To allow proper comparisons between each of the designs, certain design features were held constant. The fishing circle, for instance, was always 388 meshes around and the wing length, the depth of the square, number of round meshes, and corner details were also fixed.

Models 1A and 2A were modifications of models 1 and 2 respectively, done at the tank by replacing the bellies of the nets - the front ends remaining unchanged.

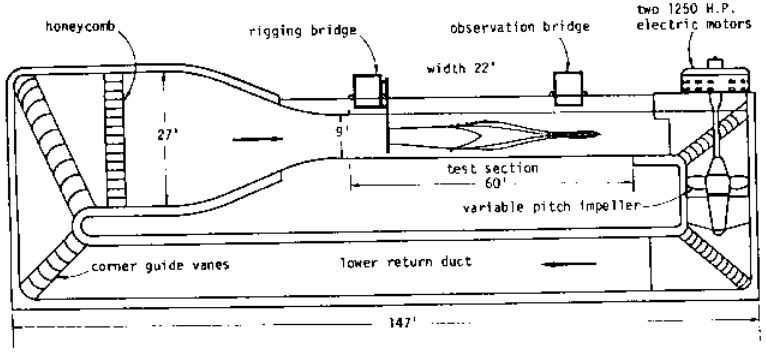


Figure 1. The circulating water channel at NSRDC

4-Seam Bottom Trawls - This series of eleven box trawls included variations in side panel size and shape. Several standard features of the 2-seam models were also held constant. The fishing circle, number of round meshes, depth of square, corner details and jib tapers were the same for both series. The depth of the wing panels were somewhat shorter on the 4-seams and no ballon configurations were included.

The "Lossie" type model deviates from the standard 4-seam configuration, however, its specifications were adapted to allow fair comparisons to the extent possible.

Midwater Rope Trawls - These models were not based on any specific commercially available design since they were specifically meant for studying netting resistance. The same fine mesh netting rear-end was used for each trawl. Three rope front-ends were used to achieve the variations in hanging ratio to cover the range typically used in midwater trawl design.

Construction Details - The baseline trawls in the 2- and 4-seam series were designed for use by trawlers in the 350 to 450 horsepower range. Full scale specifications would include 6"- 4 mm twine throughout. Hanging lines would be 3/4" combination rope with four meshes from each panel taken up in each gore.

Hanging information for each model is included in Table 1 which provides the details needed for constructing the designs. The table shows the number of netting units; round meshes, 1BIM, 2BIM, and bar meshes, and the length of hanging line apportioned to each segment.

Since the design hanging ratio is 0.5, there is 3" of hanging line taken up by each round mesh. The length apportioned to the corner meshes has been determined geometrically to be 5.75" for each 1BIM and 8.0" for each 2BIM. The footrope corner detail is diagrammed in Figure 2. The hanging of the bar meshes assumes the netting is stretched 5% while being hung or 6.3" per mesh.

All these dimensions should of course be modified appropriately if the mesh dimension measures more or less than the design 6".

The extension is a length of bare hanging line added to the footrope or headrope to allow the wing ends to be vertically in line. The length is determined by the difference in number of top wing bottom wing bar meshes on the up-and-down line. In all models but 2-seam number 3 and 6, the extensions were added to the footrope.

The hanging data for the up-and-down line is based on the same calculations as the main hanging lines except the bar meshes are stretched only 2.5% while being hung (6.15"). In the 4-seam nets there are round meshes and drop meshes to allow the up-and-down line to take a curved shape (see Figure 3). In the 2-seam nets, due to the presence of the gore, there are only bar meshes and the up-and-down line takes a "V" shape.

The wing ends, as shown in the net plans accompanying each data sheet, end in from 7 to 9 meshes. These meshes are supported by an end rope which runs through the meshes with the ends spliced into the hanging line and up-and-down line as diagrammed in Figure 4. This has been shown to be a durable construction detail and was duplicated in the models.

Model Scaling - Based on the size of the full scale designs to be tested and the width of the circulating water channel, a scale ratio of six was selected for the models. Using standard net modeling techniques the relationships between the full size net and the model are as follows:

$$\text{length}_{\text{full size}} = 6 \times \text{length}_{\text{model}}$$

$$\text{velocity}_{\text{full size}} = \sqrt{6} \times \text{velocity}_{\text{model}}$$

$$\text{forces}_{\text{full size}} = 6^3 \times \text{forces}_{\text{model}}$$

$$= 216 \times \text{forces}_{\text{model}}$$

Rather than full adherance to the length relation, the mesh size and twine diameter were modeled to a scale ratio of four. This is valid since the blockage of the netting remains the same, however the mesh counts differ between the full size and model as follows:

$$\text{mesh count}_{\text{full size}} = \frac{\text{length scale}}{\text{mesh scale}} \times \text{mesh count}_{\text{model}}$$

$$= \frac{6}{4} \times \text{mesh count}_{\text{model}}$$

This larger size model netting allows easier visibility of the mesh configurations during the tests and in the photographs. When comparing the photographs with the accompanying net plan you can notice 2/3 fewer meshes in the model.

Each model was fitted with 20 floats of 1.9" in diameter. Each of these scale up to the equivalent of 11" floats or three 8" floats. These floats were uniformly distributed along the headrope, except in the floatation experiments done on 4-seam model #9.

	Footrope						Headrope					Wing				
Model No.	Meshes	1B1M	2B1M	Bars	Extension	Total	Meshes	1B1M	2B1M	Bars	Total	Meshes	2B1M	Top Bars	Bot Bars	Total
	No. Len.	No. Len.	No. Len.	No. Len.	No. Len.	Length	No. Len.	No. Len.	No. Len.	No. Len.	Length	No. Len.	No. Len.	No. Len.	No. Len.	Length
2-Seam #1	22 63.0	6 31.5	11 88.0	82 516.5	3 18.0	1371.0	28 81.0	8 42.0	13 104.0	58 365.5	1104.0	0 0.0	0 0.0	27 166.0	24 147.5	313.5
2-Seam #2	22 63.0	6 31.5	11 88.0	76 479.0	9 54.0	1368.0	28 81.0	8 42.0	13 104.0	58 365.5	1104.0	0 0.0	0 0.0	27 166.0	18 110.5	276.5
2-Seam #3	22 63.0	6 31.5	11 88.0	82 516.5	12*72.0	1059.0	28 81.0	8 42.0	13 104.0	43 271.0	915.0	0 0.0	0 0.0	12 74.0	24 147.5	221.5
2-Seam #4	22 63.0	6 31.5	11 88.0	76 479.0	15 90.0	1440.0	28 81.0	8 42.0	13 104.0	64 403.0	1179.0	0 0.0	0 0.0	33 203.0	18 110.5	313.5
2-Seam #5	22 63.0	6 31.5	11 88.0	65 409.5	26 156	1433.0	28 81.0	8 42.0	13 104.0	64 403.0	1179.0	0 0.0	0 0.0	33 203.0	7 43.0	246.0
2-Seam #6	22 63.0	6 31.5	11 88.0	82 516.5	8*48.0	1292.0	28 81.0	8 42.0	13 104.0	47 296.0	965.0	0 0.0	0 0.0	16 98.5	24 147.5	246.0
2-Seam #7	22 63.0	6 31.5	11 88.0	76 479.0	15 90.0	1440.0	28 81.0	8 42.0	13 104.0	64 403.0	1179.0	0 0.0	0 0.0	33 203.0	18 110.5	313.5
4-Seam #1	22 63.0	6 31.5	11 88.0	71 447.0	8 48.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	19 117.0	331.0
4-Seam #2	22 63.0	6 31.5	11 88.0	71 447.0	8 48.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	19 117.0	331.0
4-Seam #3	22 63.0	6 31.5	11 88.0	71 447.0	8 48.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	19 117.0	331.0
4-Seam #4	22 63.0	6 31.5	11 88.0	71 447.0	8 48.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	19 117.0	331.0
4-Seam #5	22 63.0	6 31.5	11 88.0	71 447.0	8 48.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	19 117.0	331.0
4-Seam #6	22 63.0	6 31.5	11 88.0	58 365.5	9 54.0	1141.0	28 81.0	8 42.0	13 104.0	40 252.0	877.0	4 6.0	3 21.0	30 184.5	21 129.0	361.5
4-Seam #7	46 135	16 84.0	16 128	24#125.0	60@313	1435.0	30 87.0	48 252.0	0 0.0	60&324.0	1239.0	0 0.0	0 0.0	60&324.0	0 0.0	324.0
4-Seam #8	22 63.0	6 31.5	11 88.0	71 447.0	8 48.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	19 117.0	331.0
4-Seam #9	22 63.0	6 31.5	11 88.0	76 479.0	3 18.0	1292.0	28 81.0	8 42.0	13 104.0	52 327.0	1028.0	4 6.0	3 21.0	27 166.0	24 147.5	361.5

Notes: * - Headrope extension, added to headrope length instead. # - Points, .87 x 6" @ - Depth of flying wing. & - 2B1P, .90 x 6"

Table 1. Hanging information.

To provide a measure of footrope bottom tending, suspended leads were spaced uniformly along the footrope. Each lead was made up of three 1/4 ounce oval sinkers connected vertically on a string. By noting the number of sinkers being supported at each point along the footrope, a measure of the weight required to maintain bottom contact can be determined.

The leads were located 40 cm. apart therefore each lead off bottom represents .42 lbs/ft in full scale. Each bottom trawl data sheet has a table of observations made during the tests. Lead configurations at the footrope center, the corner, and the wing end are given in terms of the number of sinkers suspended. Figure 5 should be useful in interpreting this data.

TEST PROCEDURES:

The bottom trawls were tested with 20' bridles (20 fathom full scale). Several links of small chain were added to the upper leg to allow for the extra length needed to keep the wing ends vertical. Assuming wingend height one third of the up-and-down line length, the length of the added links was determined by:

$$\text{length} = \frac{(\text{up-and-down line})^2}{3} / \text{ bridle length}$$

Typically, this gave added lengths between 1.0" and 1.5" for the models.

The strut width was set to produce horizontal bridle angles of 14 degrees. This setting was a constant 17' 10" for all 2-seam models and all 4-seam models except #6 which was 17' 7" and #7 which was 18' 4". These changes were due to the shorter and longer wings, respectively, in these designs.

INTERPRETING MODEL RESULTS:

The data sheets which follow are presented in terms of full size nets. Every attempt was made to allow useful comparisons among the various designs tested. Comparisons with designs outside the present series should be done only with caution. The trends in performance for the design features tested should have reasonably broad application for other designs of similar style.

The resistance is the sum of both groundwire tensions scaled up in accordance with the scaling laws presented earlier. To be more precise these values should be divided by the cosine of 14 degrees, the bridle angle. The difference is only 3 percent and therefore unimportant. This resistance is the net only and warp tension would of course include door resistance and trawl friction along the seabed.

Headrope height is from the bottom to the headrope center. No correction has been made for the fact that footrope height also varied. Each footrope weight off-bottom represents 6" of ground clearance. If you wish to make that correction, use the data from the corner weights as they were attached at the bunt/lower-wing intersection.

The net plans are drawn to the same scale and their size reveals the relative amounts of twine in each design.

ACKNOWLEDGEMENTS:

This report and the tests covered were made possible through the support of the participating net makers listed in the introduction. Their willingness to invest in this cooperative research is somewhat unique within the U.S. fishing industry and is appreciated. A special thanks goes to Paul Shuman for constructing the bottom trawl models and helping in the assembly of this report and to Gary Loverich for constructing the midwater nets. The author also appreciates the assistance of the staff of the MIT Sea Grant Program in the preparation of this report.

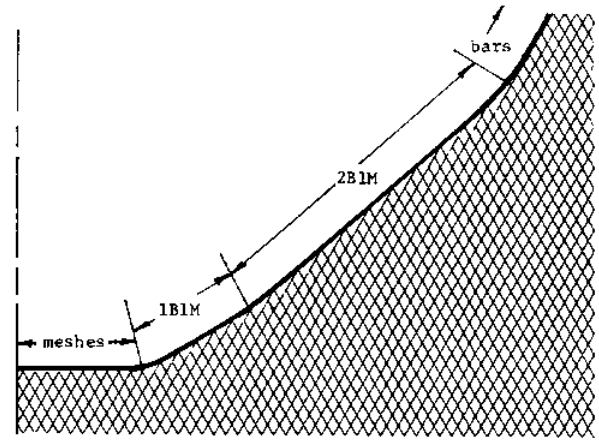


Figure 2. Footrope corner construction details.

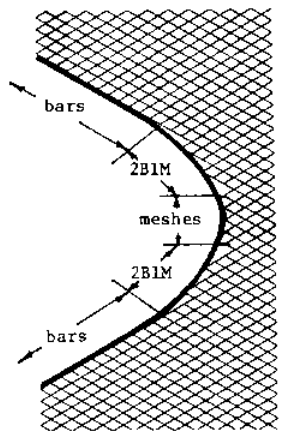


Figure 3. 4-Seam up-and-down line construction detail.

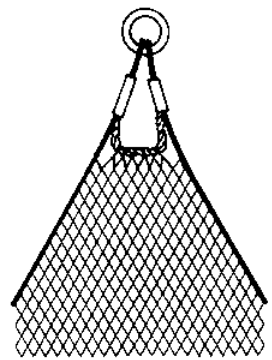


Figure 4. Wing end detail.

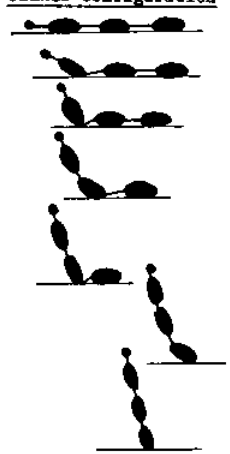
Sinker Configuration	Value	Footrope Height	Weight per Foot
	0	0 inches	.0 lbs/ft
	0+	3	.21
	1	6	.42
	1+	9	.63
	2	12	.84
	2+	15	1.05
	3	18	1.26

Figure 5. Footrope contact interpretation.

MODEL 1: 2-Seam baseline design

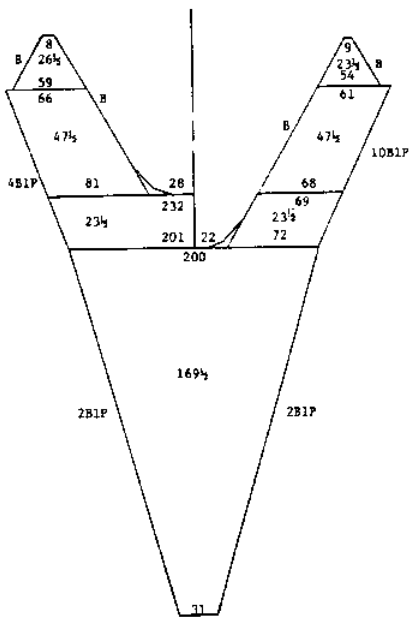
Speed	Resistance	Headrope height
2.45 knots	4900 pounds	15.6 feet
3.18	7250	13.2
3.92	8600	12.0

Taper angle at fishing circle: 12.5 degrees
Wing spread at jib seam: 49.8 feet
Width at fishing circle: 36.0 feet

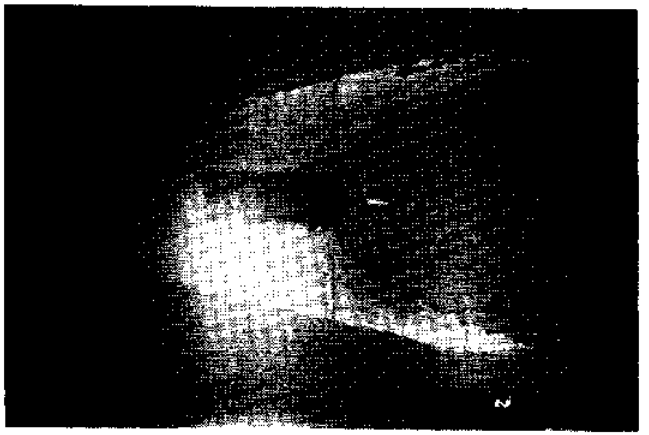
Speed	Footrope Contact		
	Wing end	Corner	Center
2.45 knots	1+	1	0+
3.18	1	0+	0+
3.92	1	0+	0+

The baseline 2-seam design represents characteristics typical of many common trawls. The top wing and square tapers are less than the bottom wing and bunt tapers and the top and bottom bellies are equal.

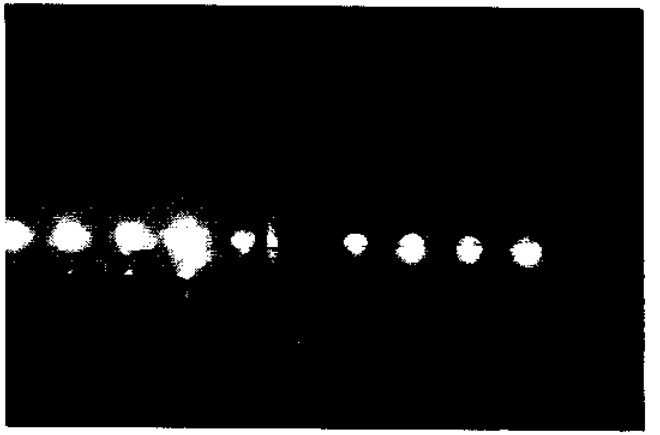
Net Plan



2.45 knots:

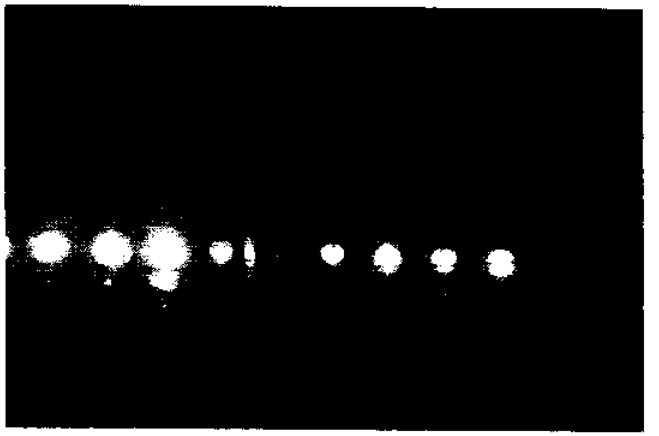


2.45 knots:

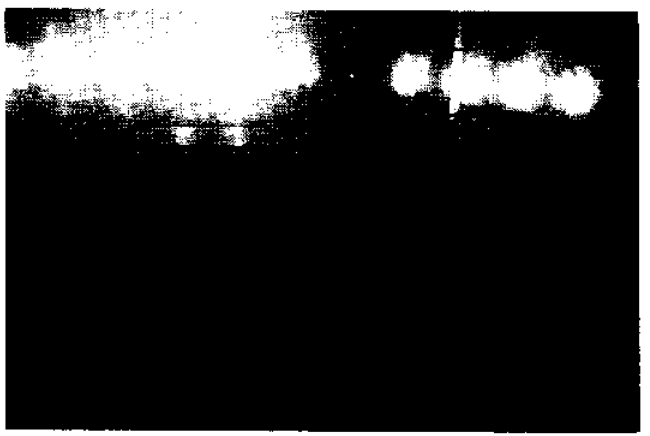


2.45 knots:

3.18 knots:



3.18 knots:



View from underneath:

MODEL 2: 2-Seam, lower wing 4B1P

Speed	Resistance	Headrope height
2.45 knots	6600 pounds	15.6 feet
3.18	7050	14.4
3.92	9150	10.8

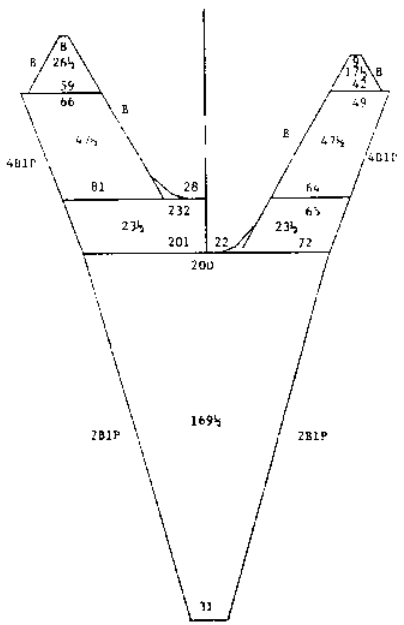
Taper angle at fishing circle: 12.0 degrees
Wing spread at jib seam: 49.2 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	1+	0+	0+
3.18	1+	0+	0+
3.92	1+	0+	0

In this model the lower wing and bunt taper has been changed to match the top wing and square taper.

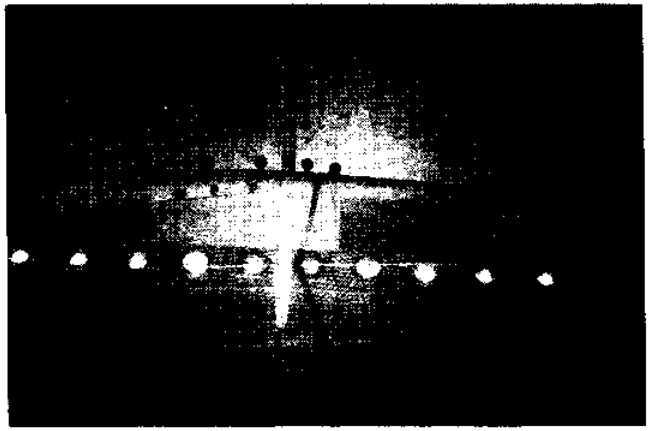
Note the minor changes in foot rope contact and wing spread that resulted.

Net Plan

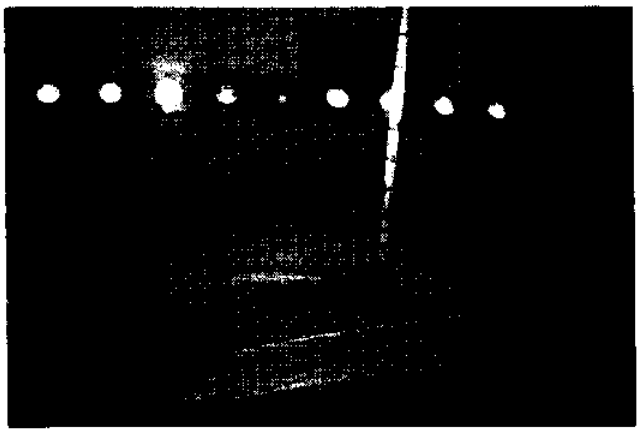


2.45 knots:

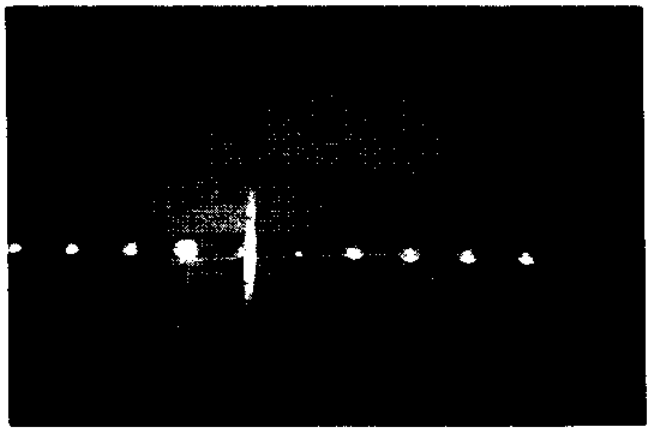
2.45 knots:



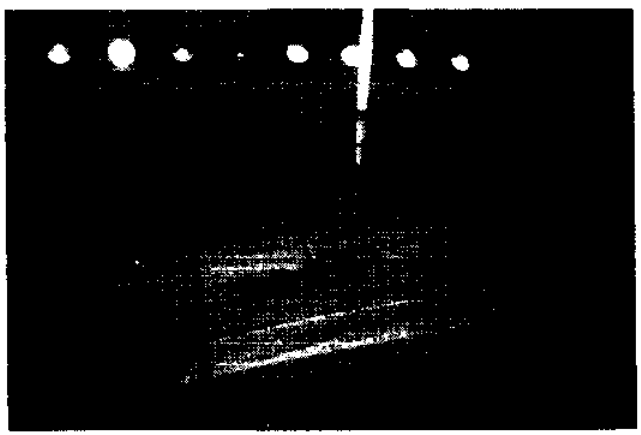
2.45 knots



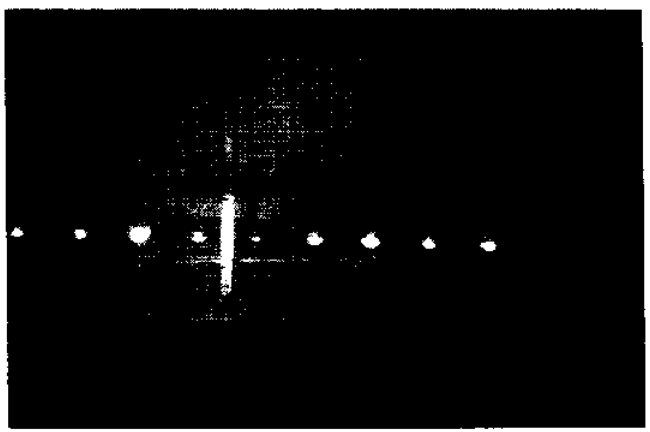
3.18 knots:



3.92 knots:



3.92 knots:



MODEL 2A: 2-Seam with sharper belly taper

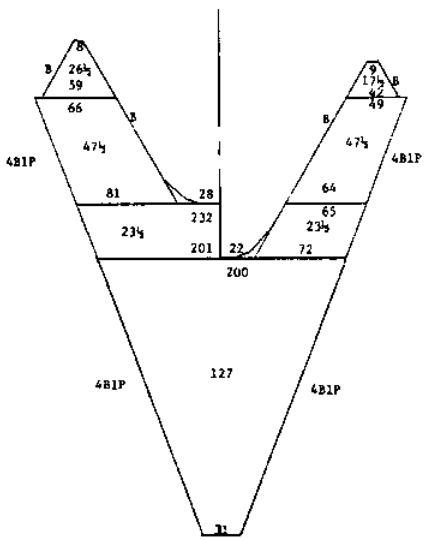
Speed	Resistance	Headrope height
2.45 knots	4500 pounds	16.8 feet
3.18	7000	13.5
3.92	9700	11.4

Taper angle at fishing circle: 11.0 degrees
Wing spread at jib seam: 51.6 feet
Width at fishing circle: 36.6 feet

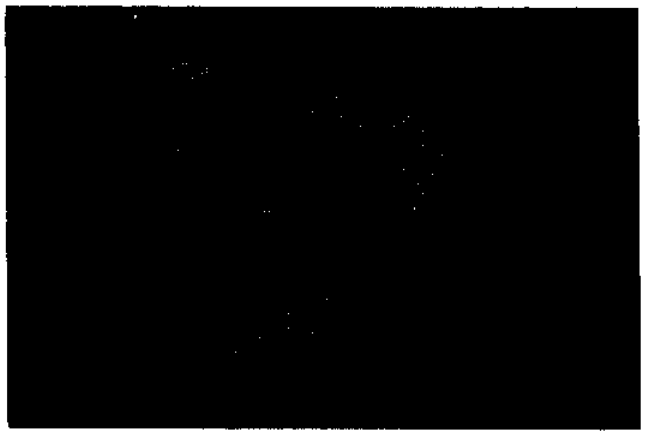
Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	2	1+	1+
3.18	1	1+	1+
3.92	1	1+	1

The model 2 front end was attached to bellies with sharper taper. The resulting design has 4B1P tapers throughout and was the shortest 2-seam model tested.

Net Plan

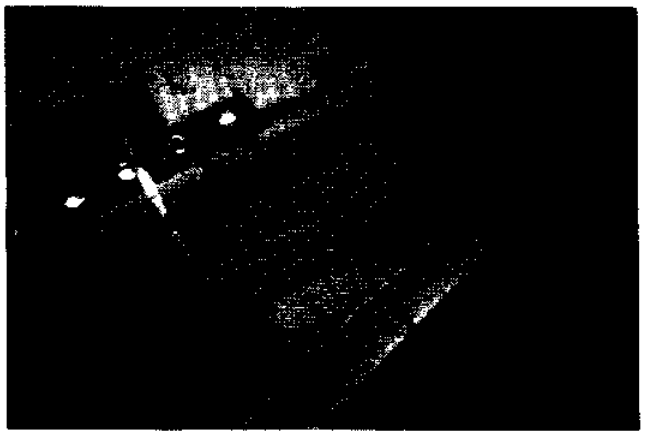


2.45 knots:

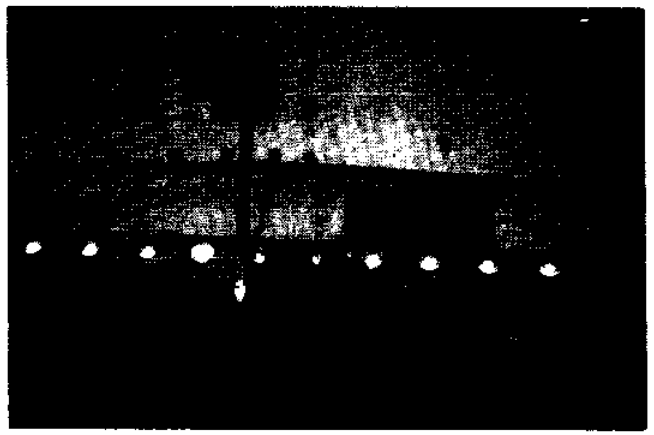


2.45 knots:

2.45 knots:



3.18 knots:



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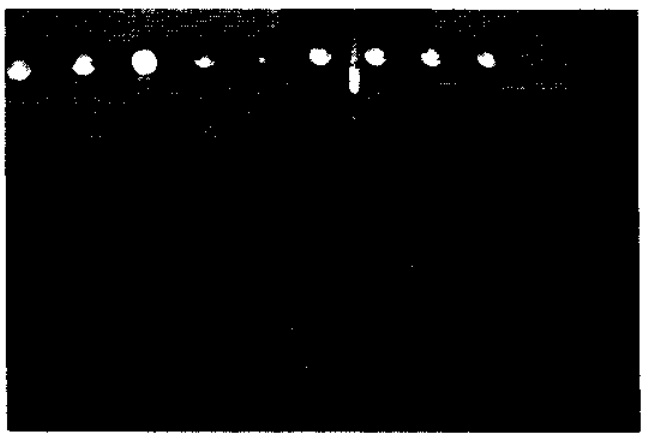


MODEL 3: 2-Seam with Yankee-type top wing

Speed	Resistance	Headrope height
2.45 knots	4650 pounds	15.0 feet
3.18	7050	12.6
3.92	8300	10.8

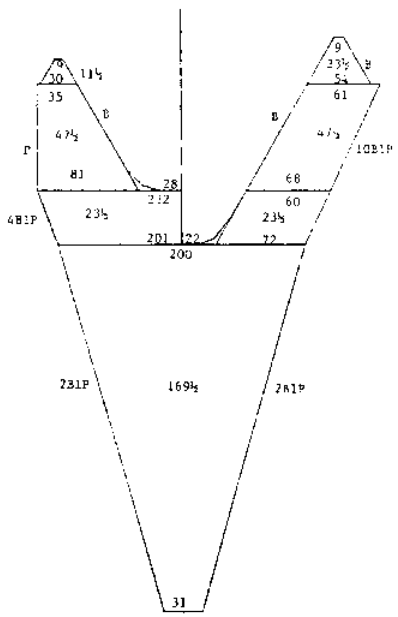
Taper angle at fishing circle: 7.5 degrees
Wing spread at jib seam: 46.2 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	3++	1	0+
3.18	3+	2	1+
3.92	3	2	2

In this model, the baseline design was changed to include an upper wing cut on points. This is a feature common to Yankee nets.

The most noticeable effects of this change are the reduced upper wing spread and the smaller mesh openings in the upper netting suggesting more strain in those panels. Wing end footrope contact is the lightest of all the 2-seam designs.

Net Plan



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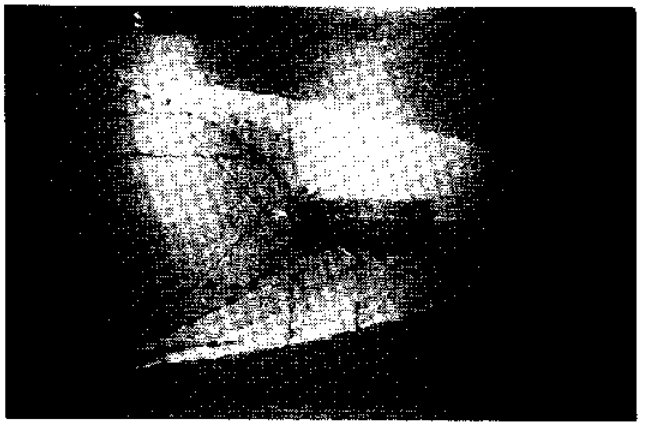

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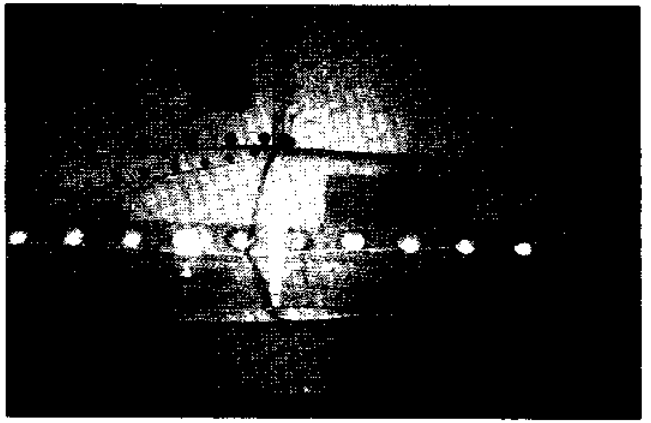

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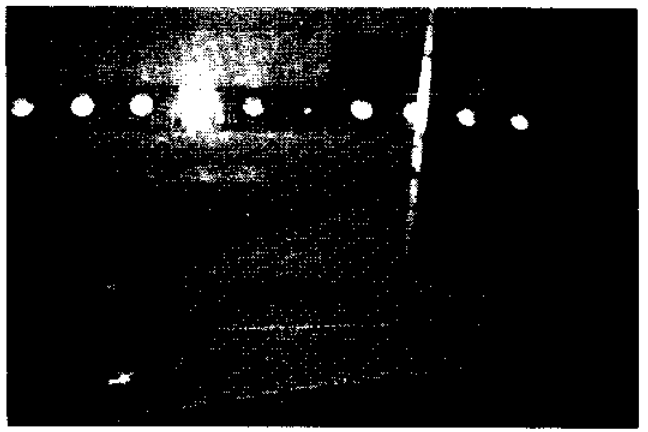

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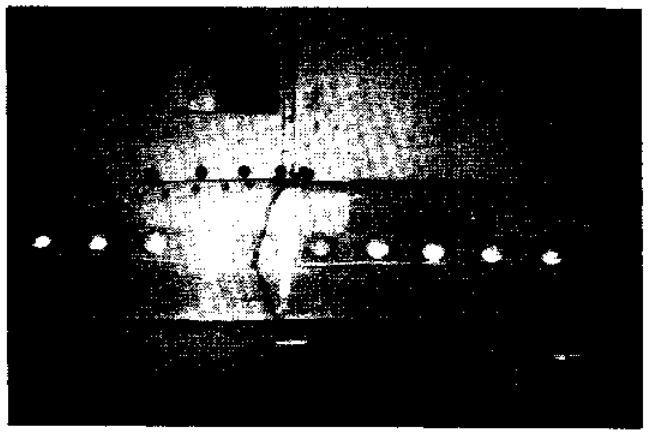

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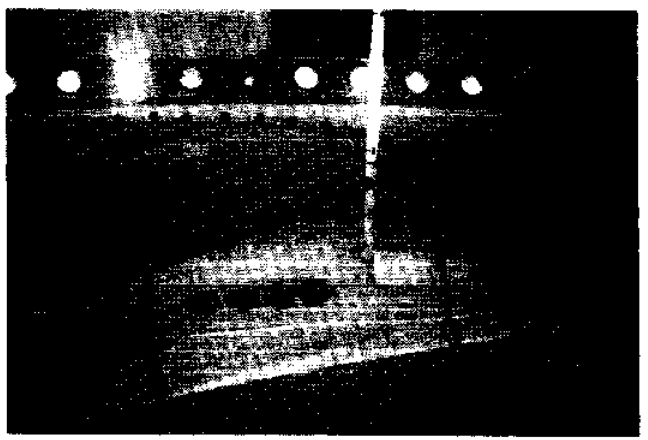

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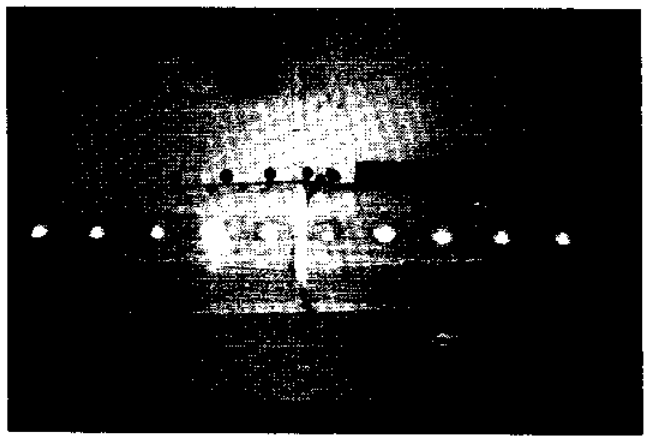


MODEL 4: 2-Seam "Balloon" type

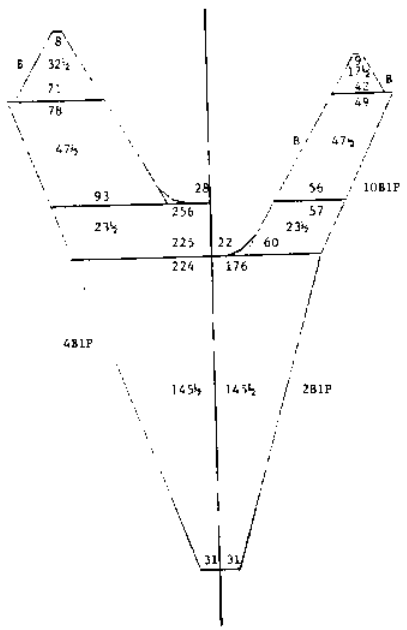
Speed	Resistance	Headrope height
2.45 knots	4850 pounds	17.7 feet
3.18	7150	13.8
3.92	10450	10.8

Taper angle at fishing circle: 12.0 degrees
Wing spread at jib seam: 49.5 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	1	1+	1+
3.18	0+	1+	1+
3.92	0+	1	1+

This design has the same front end tapers as the baseline design. The top belly is 27% larger than the bottom belly.

Net Plan



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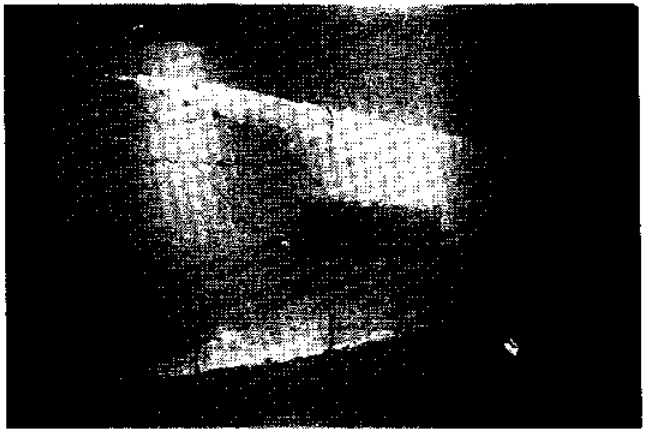
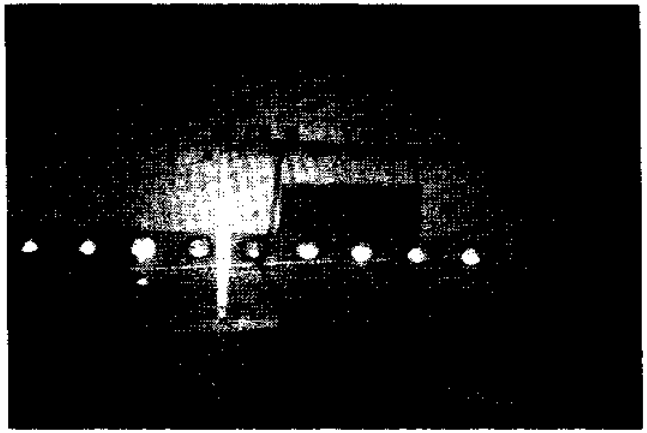
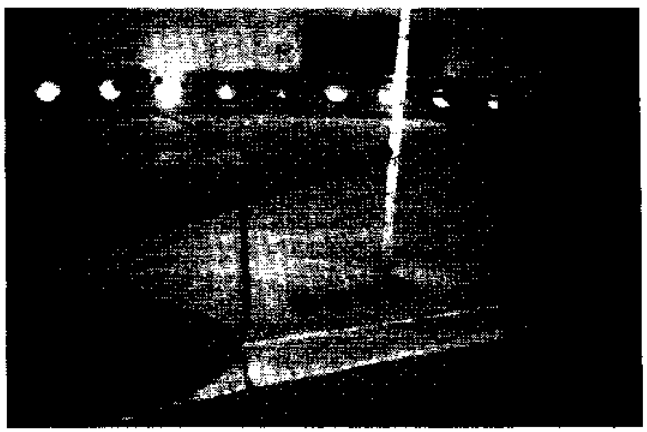


2.45 knots:

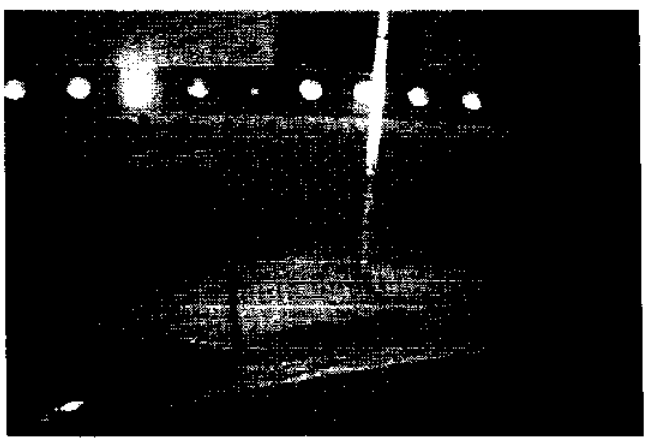


2.45 knots:

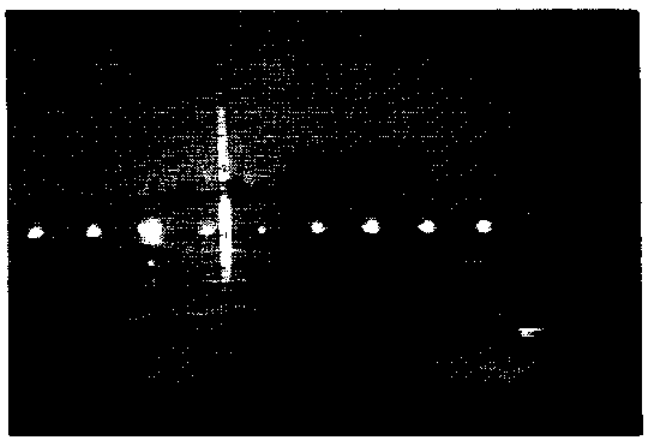


3.18 knots:

3.92 knots:



3.92 knots:



MODEL 5: 2-Seam constant taper balloon

Speed	Resistance	Headrope height
2.45 knots	4000 pounds	16.2 feet
3.18	6300	12.6
3.92	8500	10.8

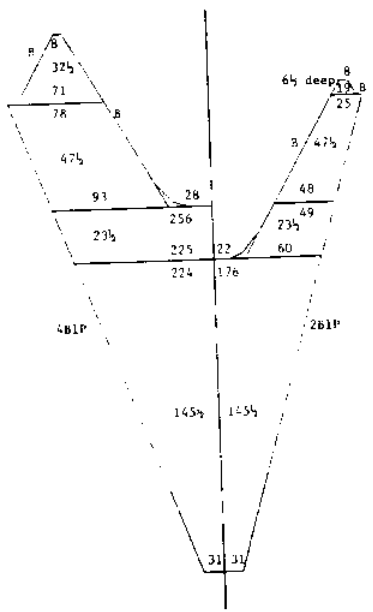
Taper angle at fishing circle: 8.0 degrees
Wing spread at jib seam: 46.5 feet
Width at fishing circle: 36.0 feet

	Footrope Contact		
Speed	Wing end	Corner	Center
2.45 knots	2+	1+	1
3.18	1+	1	1
3.92	1+	1	0+

This design has the same bellies as model 4, however the 2B1P bottom belly taper has been carried forward into the bunt and lower wing panels.

The resultant smaller lower wing size has reduced the spread and lightened wing end footrope contact.

Net Plan



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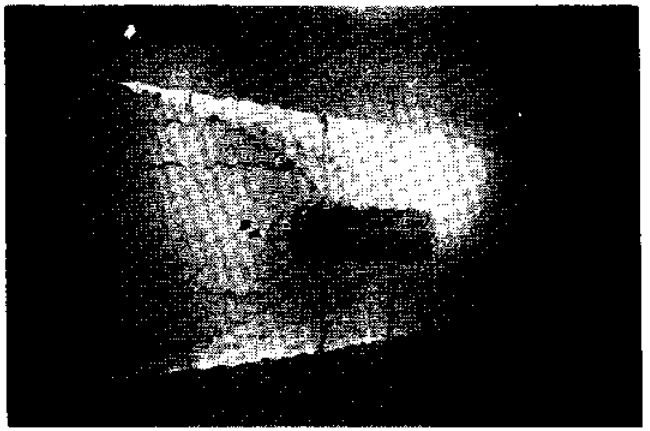

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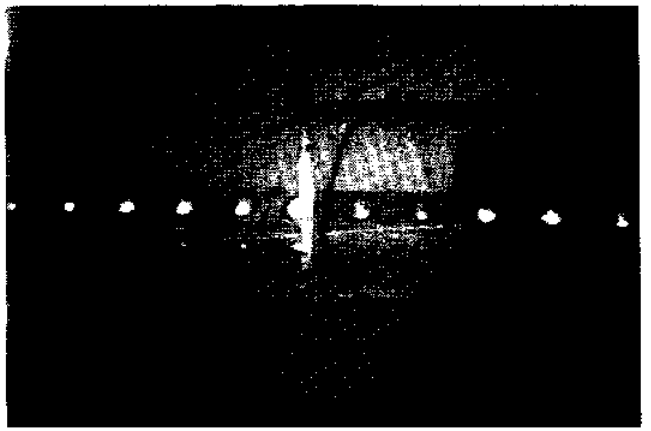
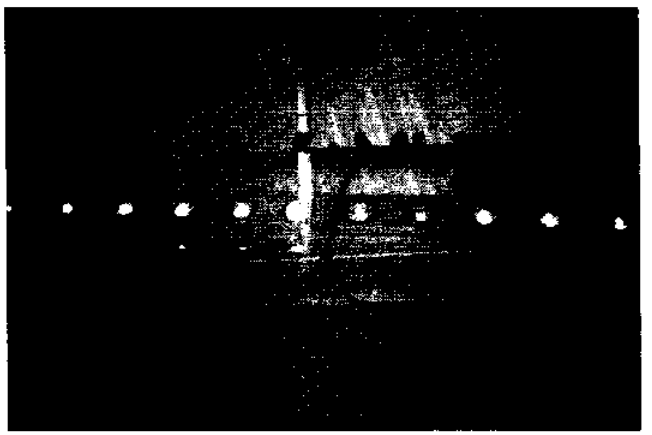
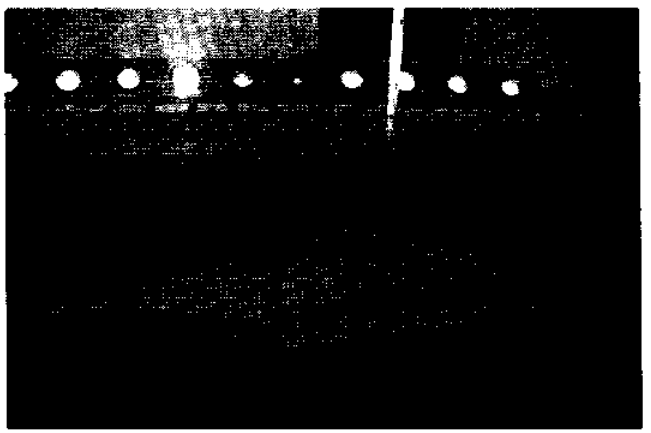


2.45 knots:

3.18 knots:



3.92 knots:



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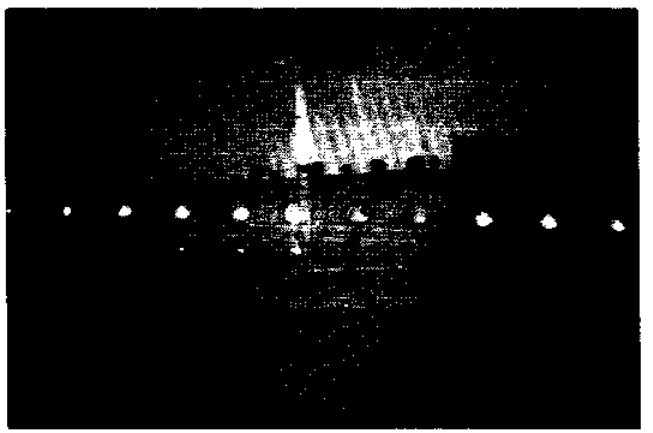


MODEL 6: 2-Seam with small top

Speed	Resistance	Headrope height
2.45 knots	4450 pounds	15.0 feet
3.18	6450	12.6
3.92	8550	10.5

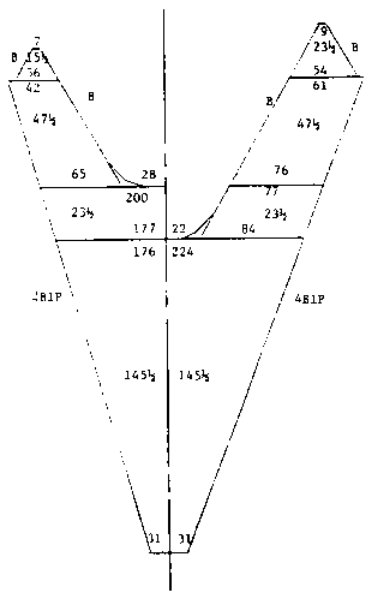
Taper angle at fishing circle: 10.0 degrees
Wing spread at jib seam: 46.8 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	2+	0	0
3.18	2	0	0
3.92	1	0	0

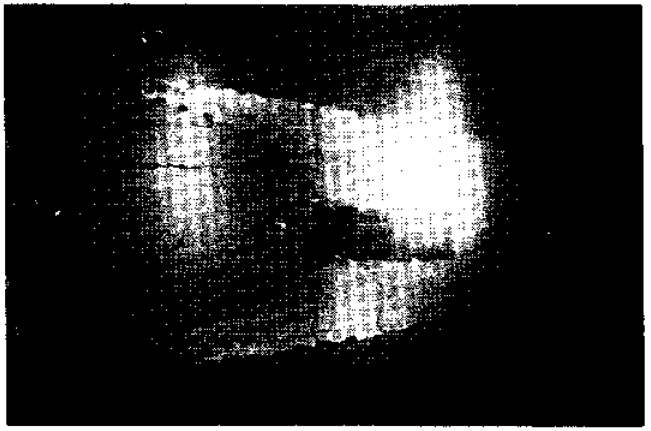
This design is the inverse of model 5 or an "unballoon" net with a 79% top belly. The extra netting in the lower belly is reflected in the footrope contact.

The smaller upper wing causes reduced spread as in model 3.

Net Plan



2.45 knots:



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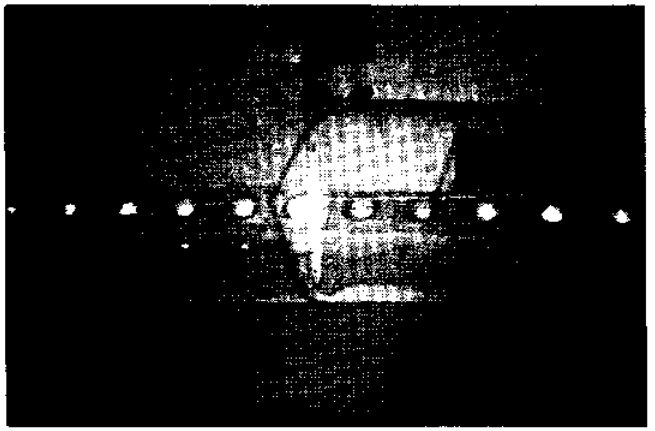

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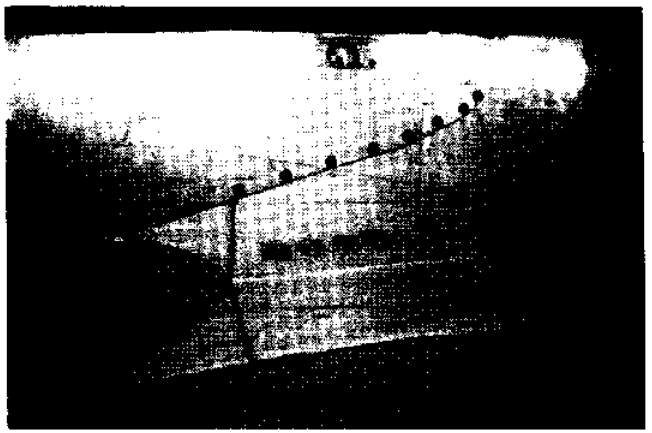

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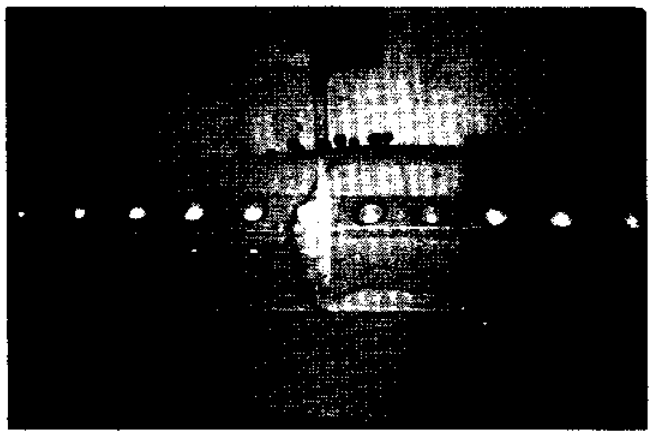

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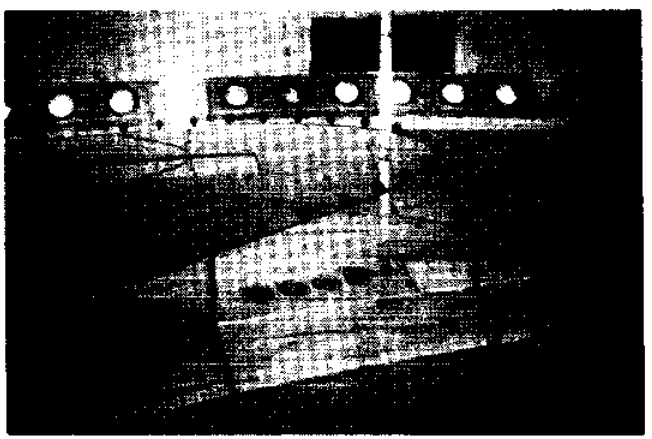
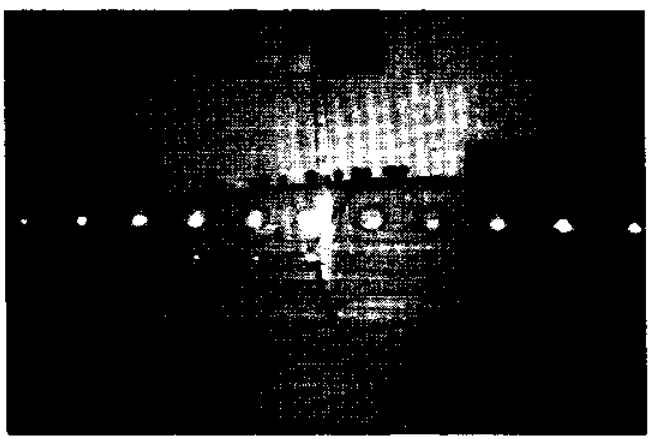


3.92 knots:



MODEL 7: 2-Seam with straight cut transition

Speed	Resistance	Headrope height
2.45 knots	5200 pounds	15.6 feet
3.18	7300	13.5
3.92	9800	12.0

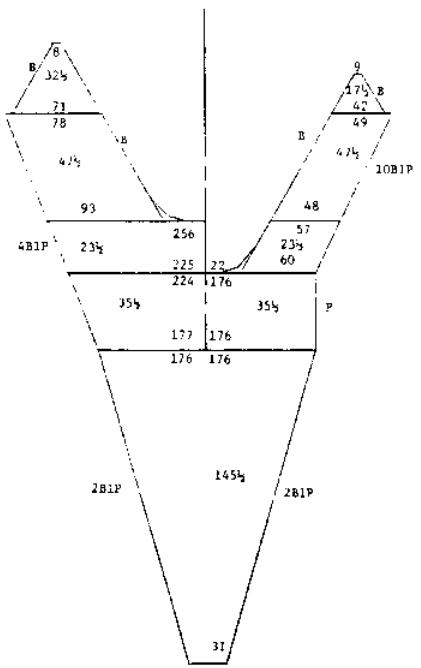
Taper angle at fishing circle: 11.0 degrees
Wing spread at jib seam: 49.8 feet
Width at fishing circle: 34.8 feet

Speed	Footrope Contact: Wing end	Corner	Center
2.45 knots	1	1	0
3.18	1	1	0+
3.92	1	1	0

This design offers a simple means of going from a balloon front end to bellies that are equal both top and bottom.

Notice how the shape of the net plan is reflected in the model by the upward slope of the gore behind the bunt.

Net Plan



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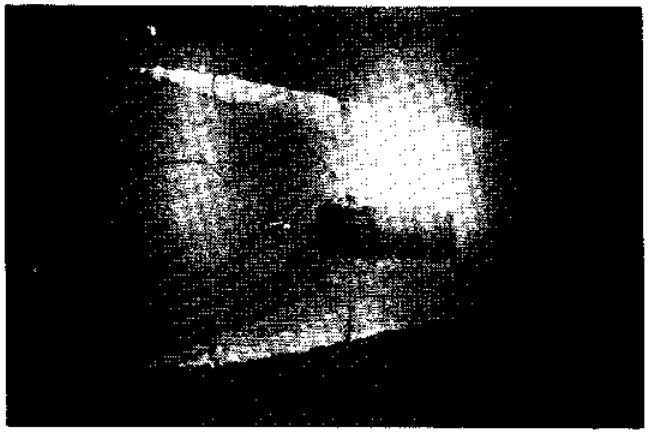
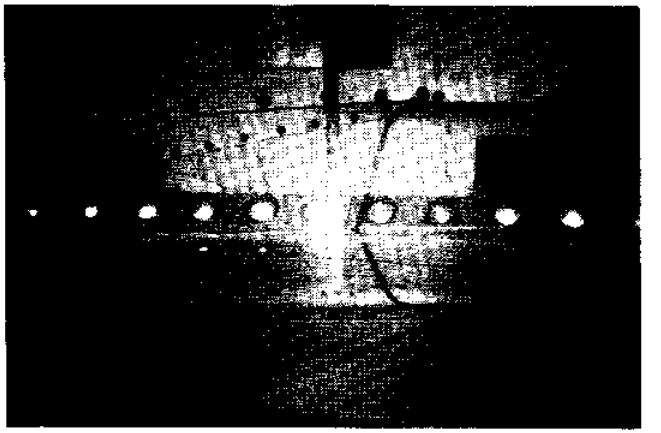
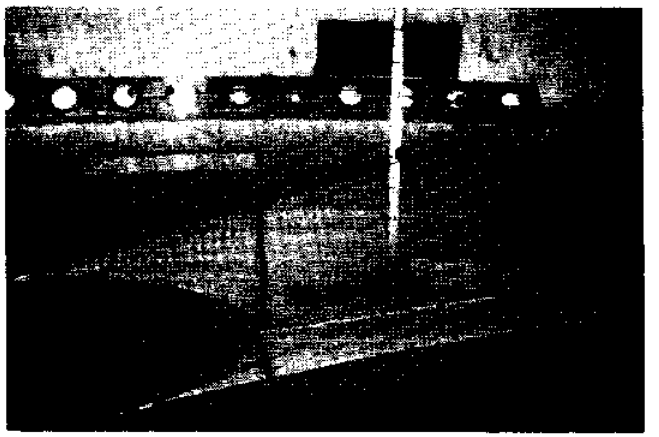


2.45 knots:



2.45 knots:



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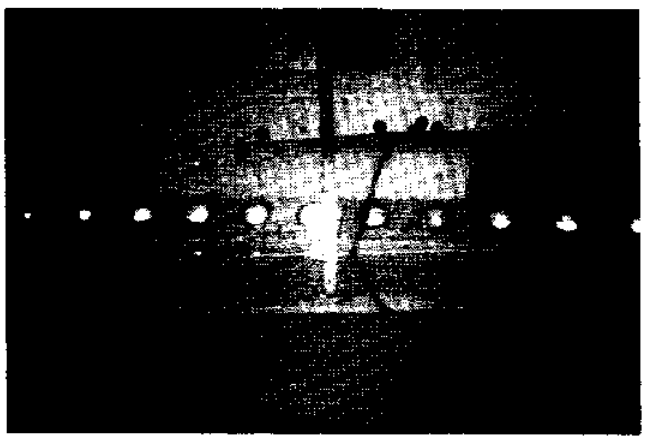

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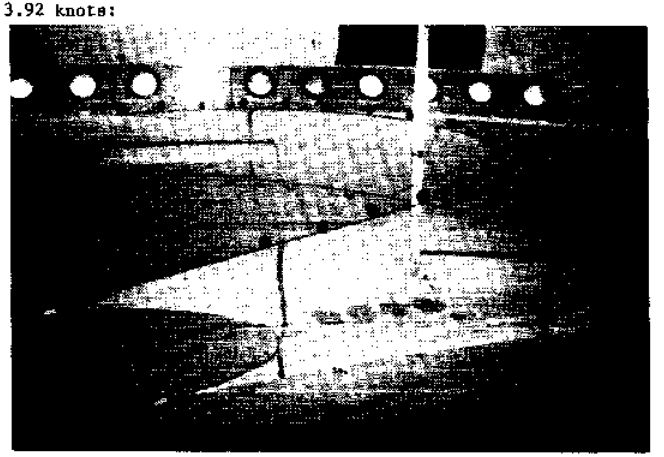

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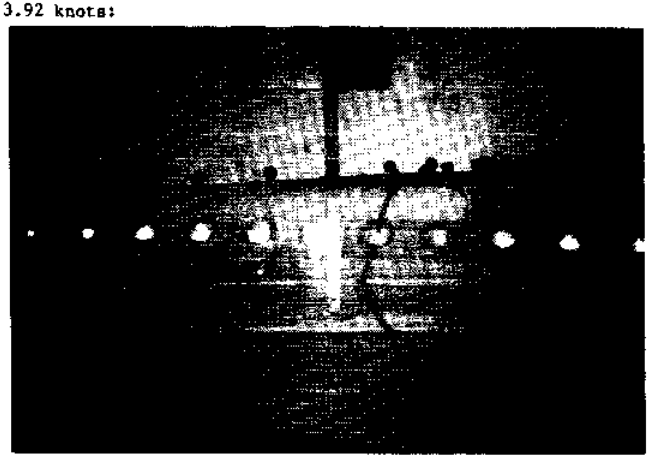


MODEL 1A: 2-Seam modified with step-bellies

Speed	Resistance	Headrope height
2.45 knots	6100 pounds	15.6 feet
3.18	8500	13.5
3.92	11500	10.8

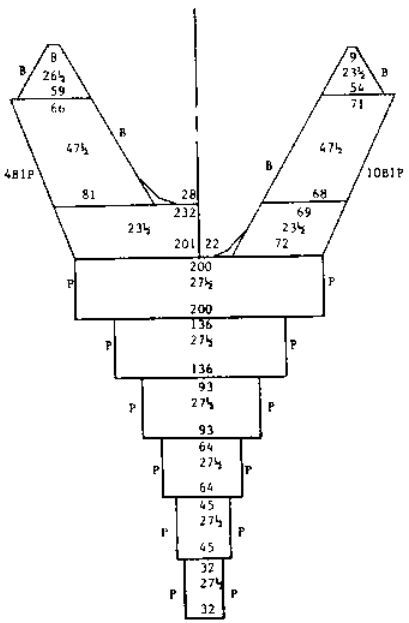
Taper angle at fishing circle: 9.5 degrees
Wing spread at jib seam: 52.8 feet
Width at fishing circle: 35.4 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	2	1	0+
3.18	1+	1	0+
3.92	1+	1	0+

Model 1A is the baseline frontend attached to bellies which are cut on all points. Trawl narrowing is accomplished by 3 to 2 take-ups between each successive belly. Each of the five bellies is of equal length resulting in an effective reduction in taper angle towards the codend. A constant effective taper could be made by making each panel depth proportional to its width.

Most noticeable in the photographs is the circular crossection the bellies take. The joining rounds quickly lose their tendency to pull forward at the gores.

Net Plan



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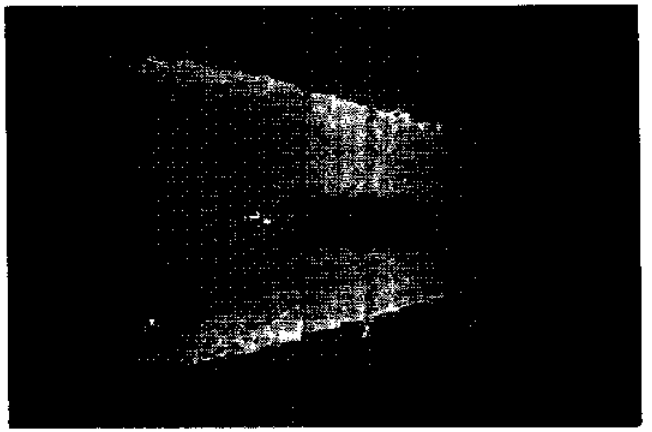

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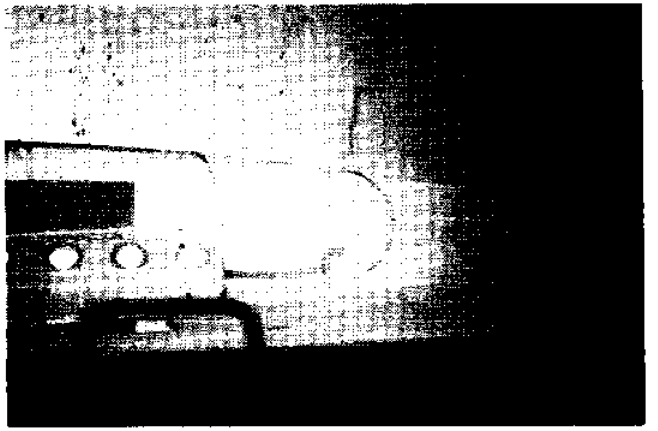
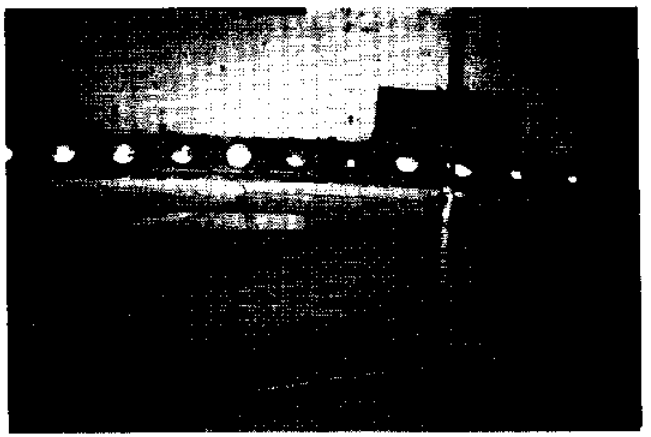
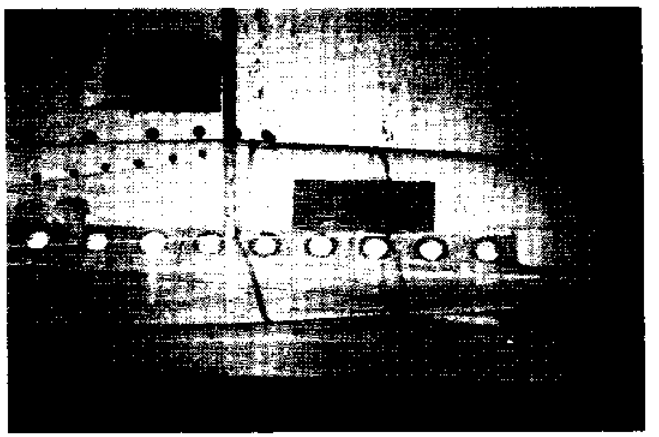


2.45 knots



2.45 knots



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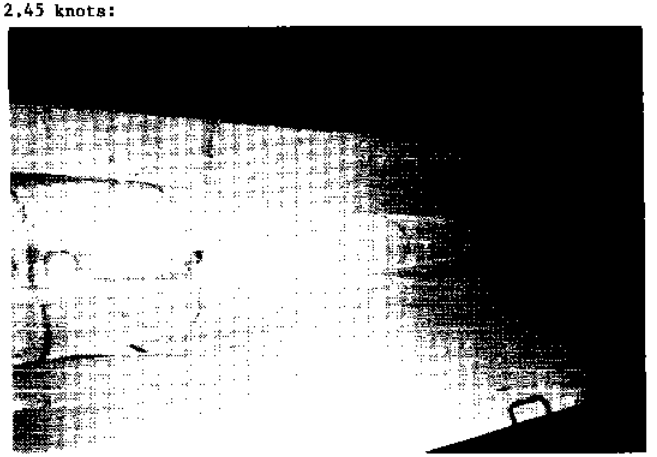

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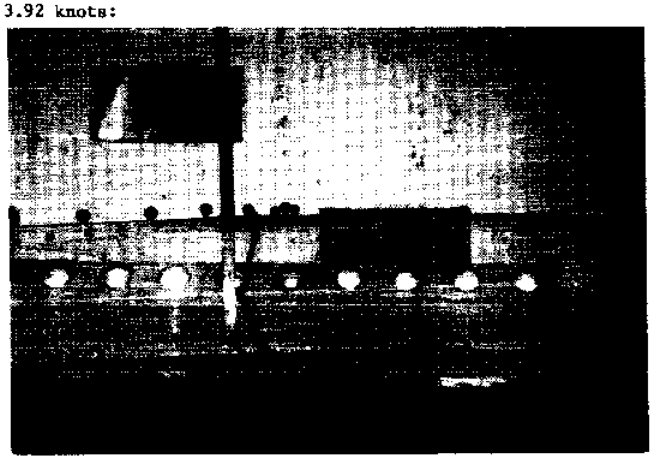


MODEL 1: 4-Seam 40% side panel

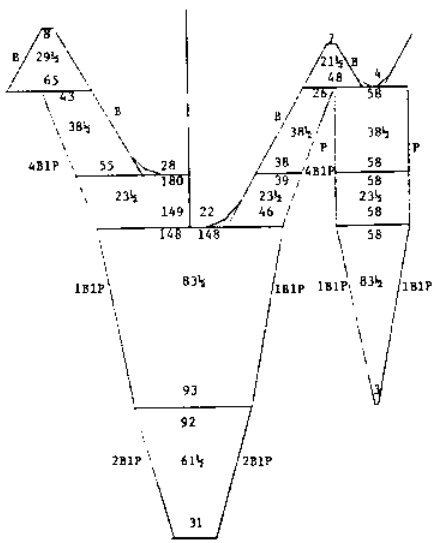
Speed	Resistance	Headrope height
2.45 knots	4550 pounds	16.5 feet
3.18	7100	12.6
3.92	8850	10.5

Taper angle at fishing circle: 8.0 degrees
Wing spread at jib seam: 48.0 feet
Width at fishing circle: 38.4 feet

	Footrope Contact		
Speed	Wing end	Corner	Center
2.45 knots	2	1	0+
3.18	1+	1	0+
3.92	1+	1	0+

This design is the baseline 4-seam having features found in box trawls common to New England. Top and bottom tapers in the fore part are equal, the side panels ahead of the fishing circle are rectangular, and the side panel tapers equally top and bottom, terminating well ahead of the codend.

Net Plan



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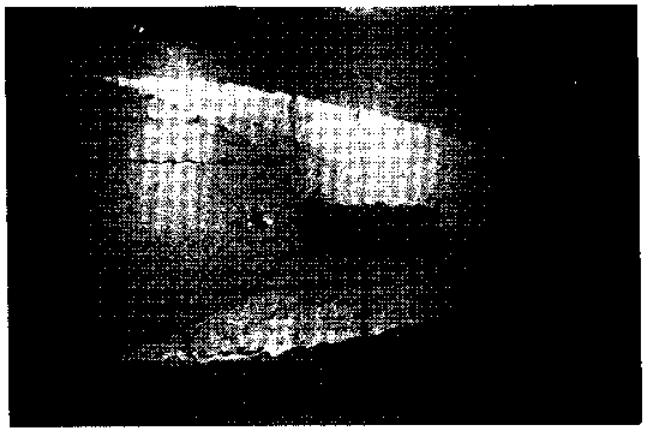
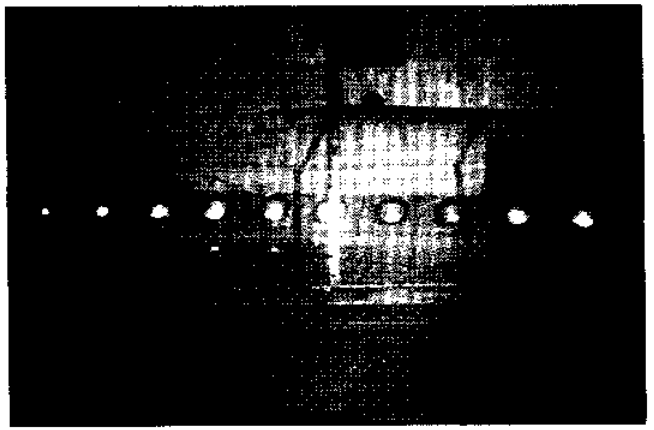
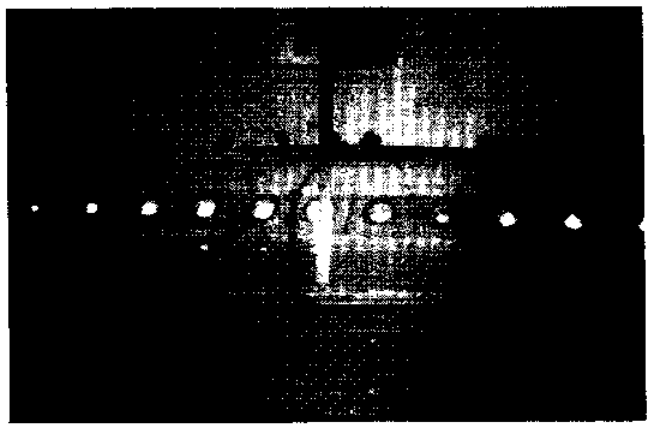


2.45 knots:

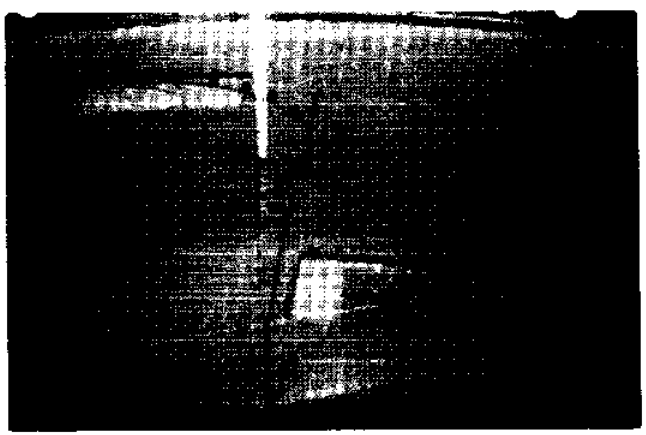


2.45 knots:

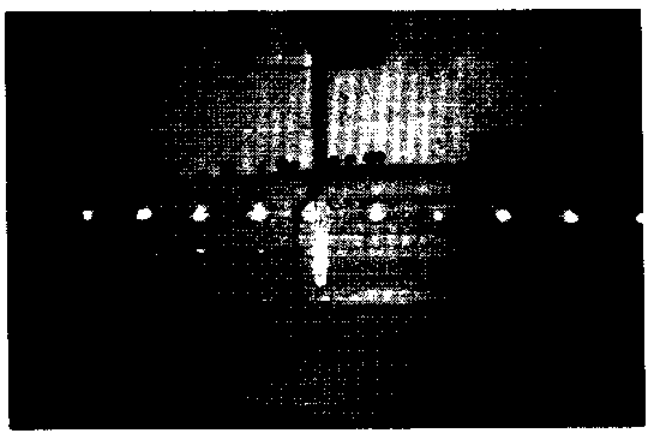
3.18 knots:



3.18 knots:



3.92 knots:



MODEL 1A: 4-Seam with sharper belly tapers

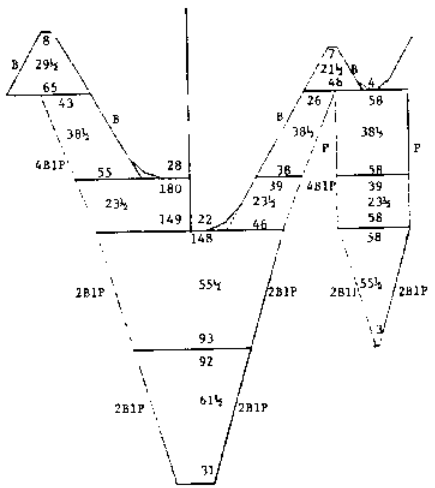
Speed	Resistance	Headrope height
2.45 knots	4700 pounds	15.3 feet
3.18	6850	12.9
3.92	9350	10.8

Taper angle at fishing circle: 9.0 degrees
Wing spread at jib seam: 49.8 feet
Width at fishing circle: 37.2 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	1+	0+	0+
3.18	1+	0+	0+
3.92	1+	0+	0+

Model 1 was modified to incorporate sharper belly tapers. Unlike other four seam models, the two seam bellies have retained the same taper used in the four seam panels.

Net Plan



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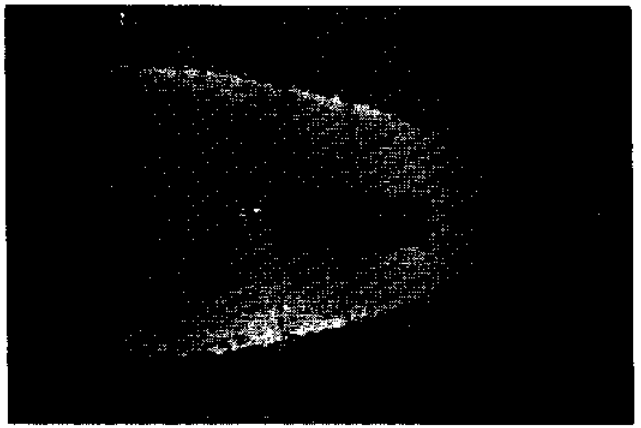

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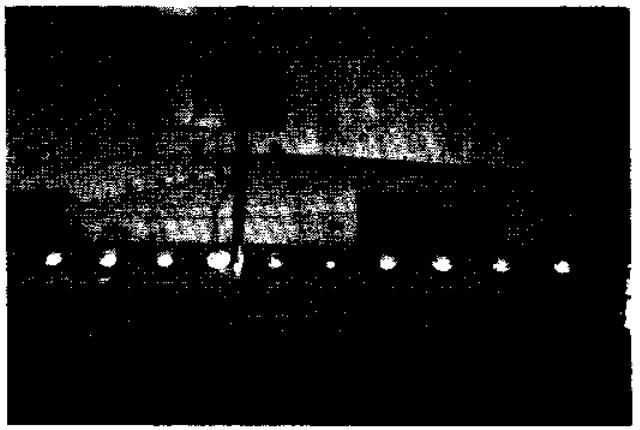

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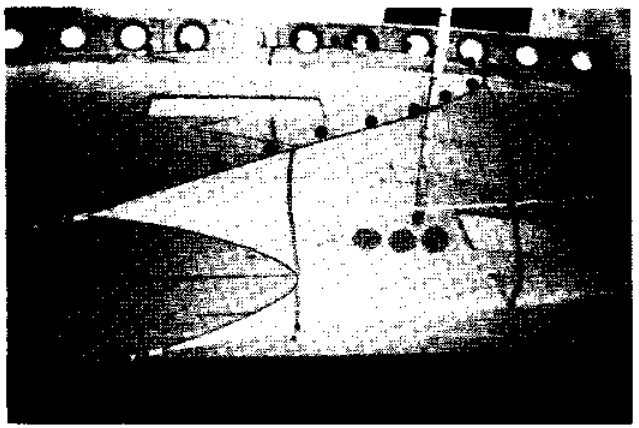
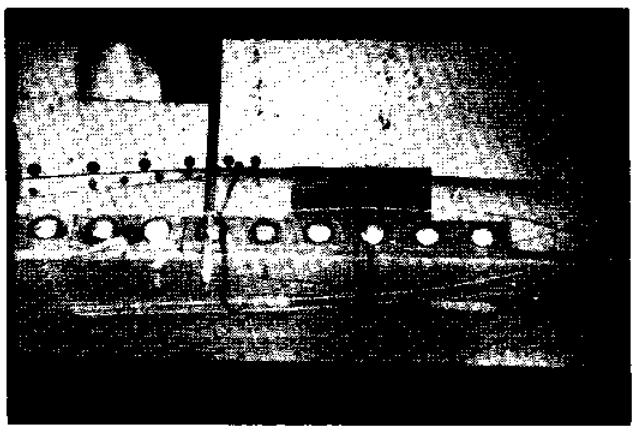
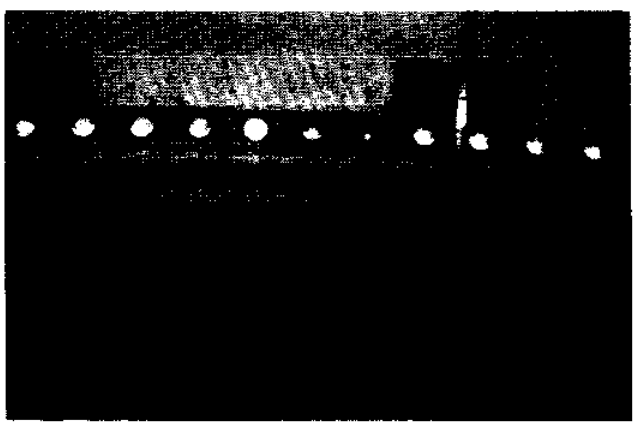


3.18 knots:



3.92 knots:



3.92 knots:

MODEL 2: 4-Seam with full length side panel

Speed	Resistance	Headrope height
2.45 knots	4900 pounds	16.8 feet
3.18	7300	14.4
3.92	9700	12.0

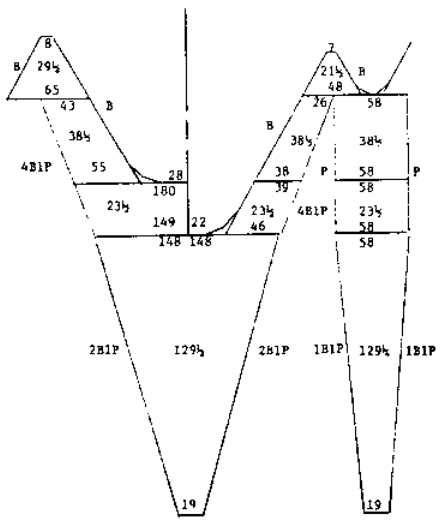
Taper angle at fishing circle: 8.0 degrees
Wing spread at jib seam: 46.8 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact		
	Wing end	Corner	Center
2.45 knots	3+	1+	1+
3.18	2+	2	1+
3.92	2+	2	2

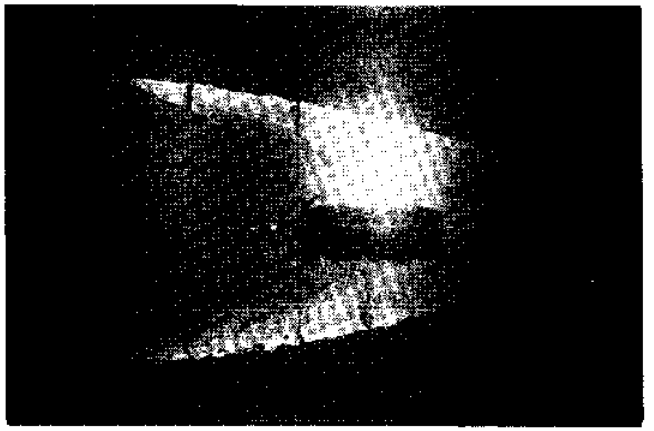
This design has the same front end as model 1 however the panels behind the fishing circle have been modified to have a full length side panel for attachment to a four seam codend.

This arrangement is common on the U.S. West Coast due mainly to reported improvement in durability and repairability in the rear portions.

Net Plan



2.45 knots:



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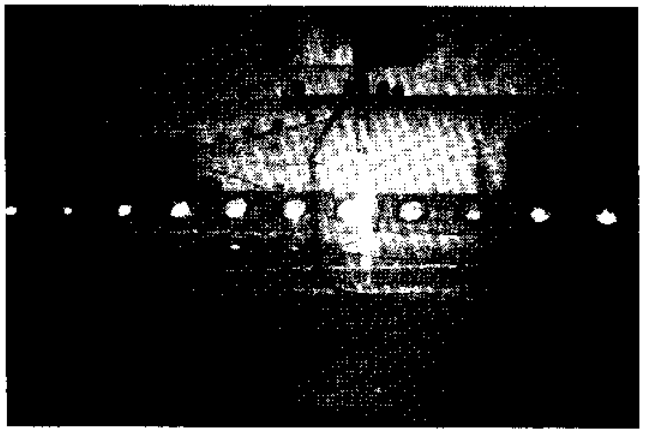

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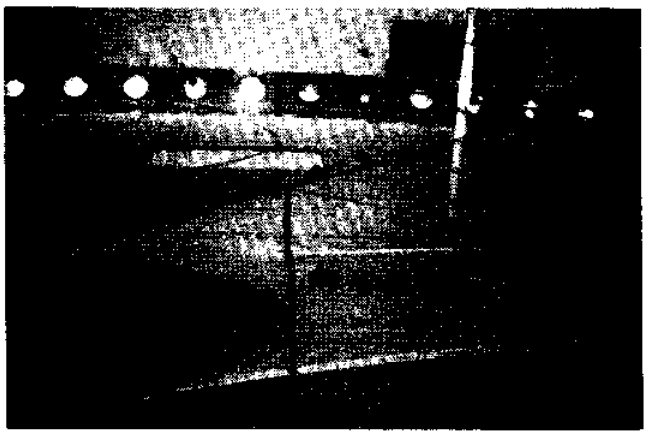
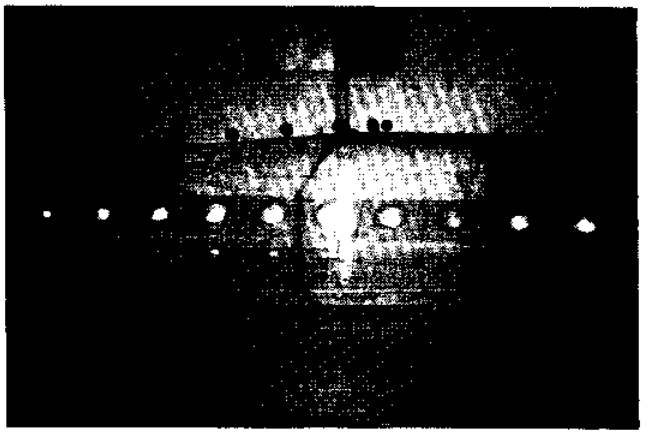
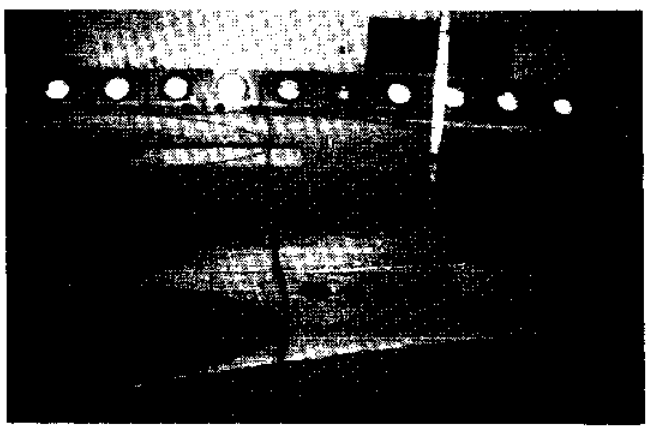


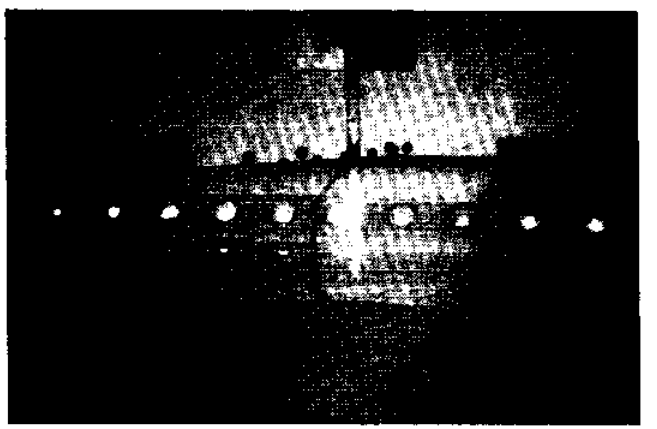
3.18 knots:



3.92 knots:



3.92 knots:



MODEL 3: 4-Seam, side panel tapered top only

Speed	Resistance	Headrope height
2.45 knots	4800 pounds	15.0 feet
3.18	6700	11.7
3.92	8950	9.6

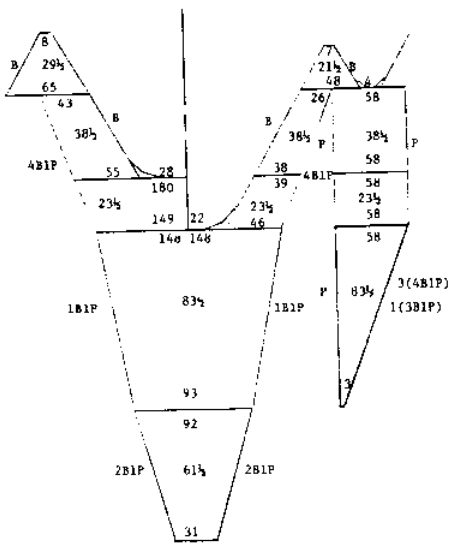
Taper angle at fishing circle: 8.0 degrees
Wing spread at jib seam: 46.2 feet
Width at fishing circle: 36.0 feet

	Footrope Contact		
Speed	Wing end	Corner	Center
2.45 knots	1+	0+	1
3.18	1	0+	0+
3.92	1	0+	0+

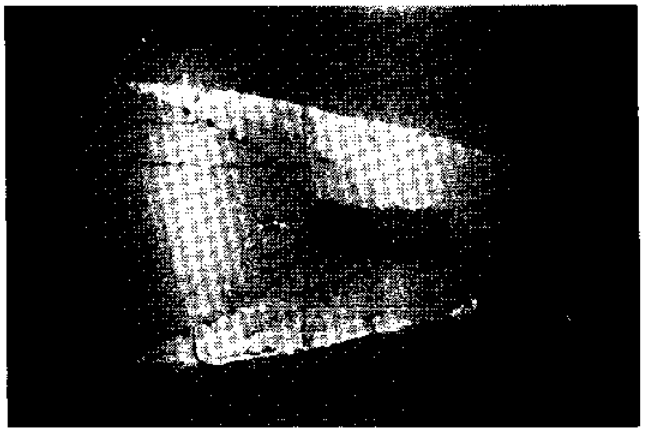
Here, the symmetric tapering of the side panel of model 1 has been changed by the insertion of a panel with points along the bottom and an exaggerated taper along the top.

This design and the model 3A were intended to determine the effectiveness of such design features in controlling the way the bellies rise or stay close to the seabed.

Net Plan



2.45 knots:



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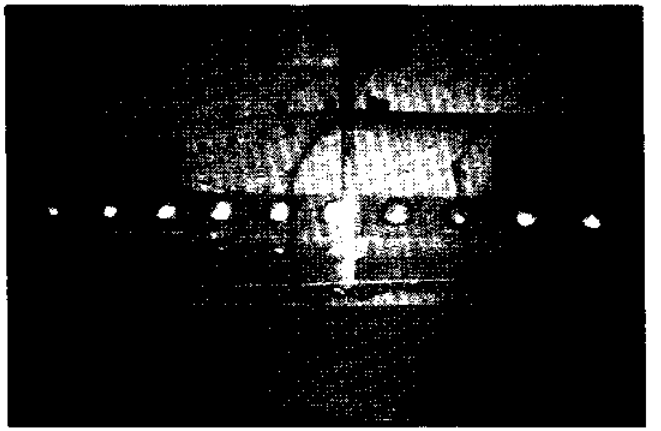

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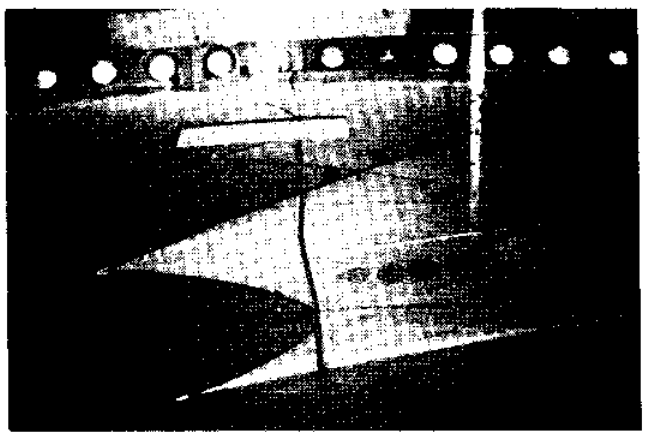

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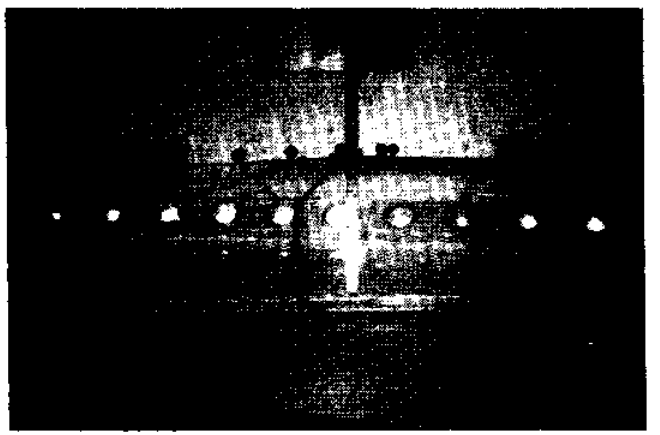

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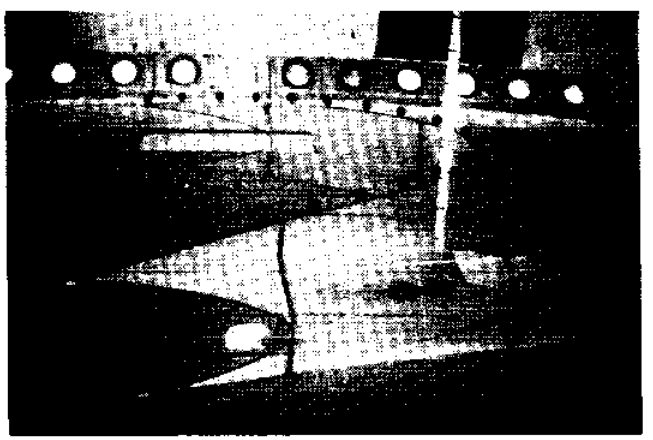


3.92 knots:

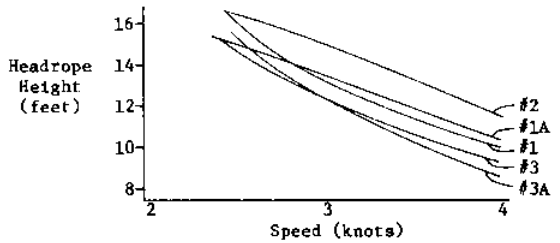
MODEL 3A: 4-Seam, side panel tapered bottom only

Speed	Resistance	Headrope height
2.45 knots	4900 pounds	15.6 feet
3.18	7500	11.4
3.92	9950	9.0

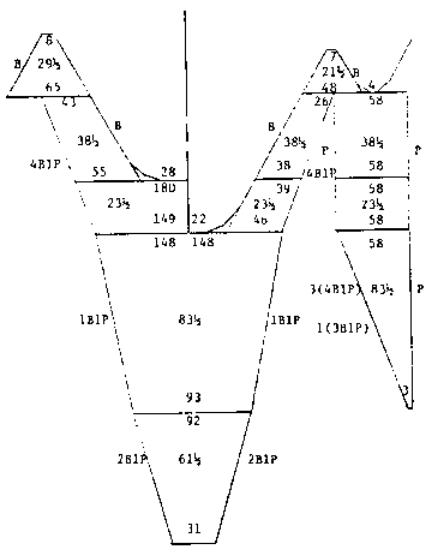
Taper angle at fishing circle: 10.0 degrees
Wing spread at jib seam: 48.0 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact		
	Wing end	Corner	Center
2.45 knots	1+	1	1
3.18	1+	1	1
3.92	1	1	0+

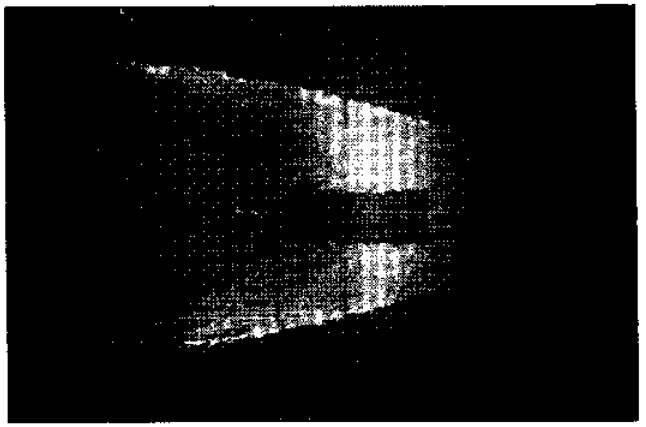
Model 3A is a modification of model 3 by inverting the tapered portion of the side panel. The effect this change and other side panel designs has on headrope height is revealed in the following graph.



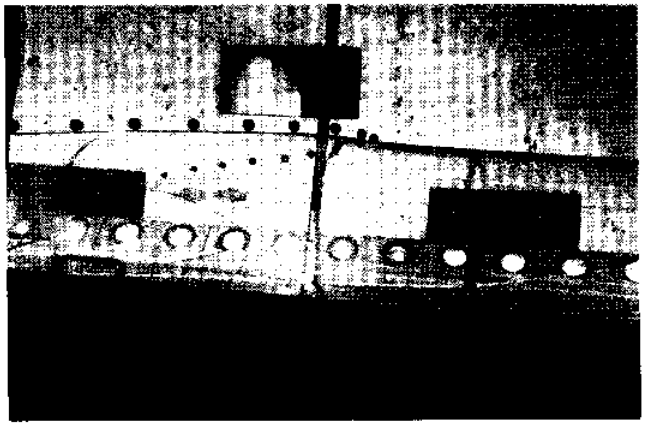
Net Plan



2.45 knots:



2.45 knots:



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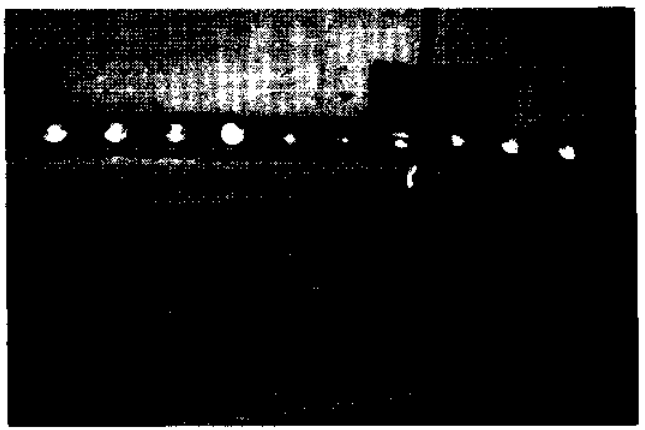
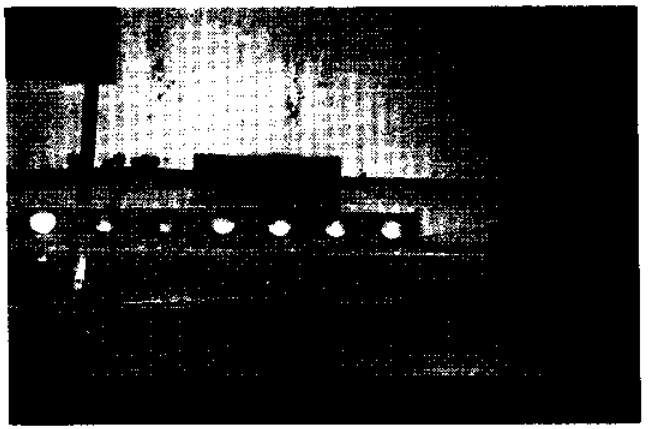


3.18 knots:



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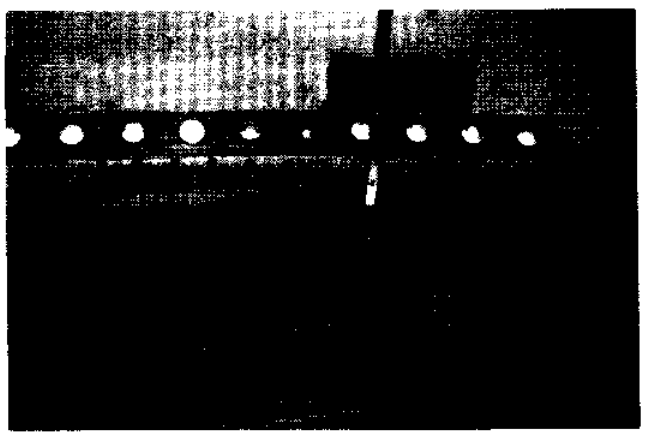
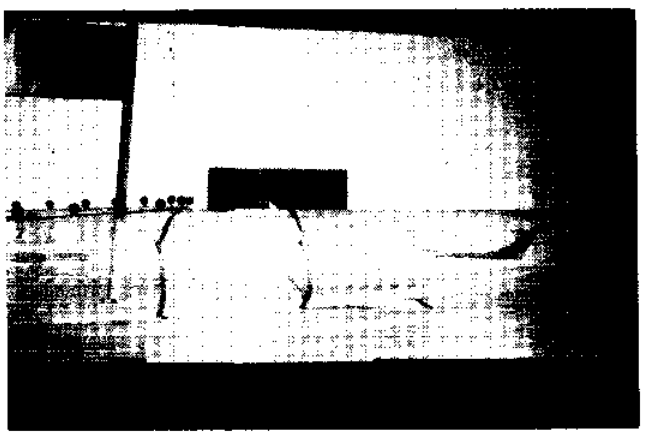


3.92 knots:



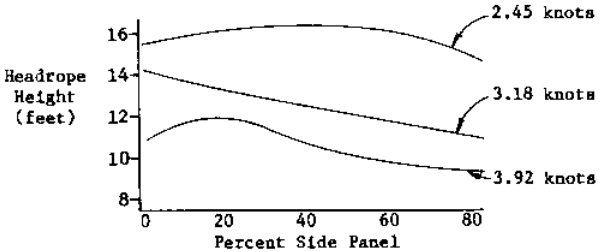
MODEL 4: 4-Seam 20% side panel

Speed	Resistance	Headrope height
2.45 knots	4950 pounds	16.2 feet
3.18	7000	13.5
3.92	9500	12.0

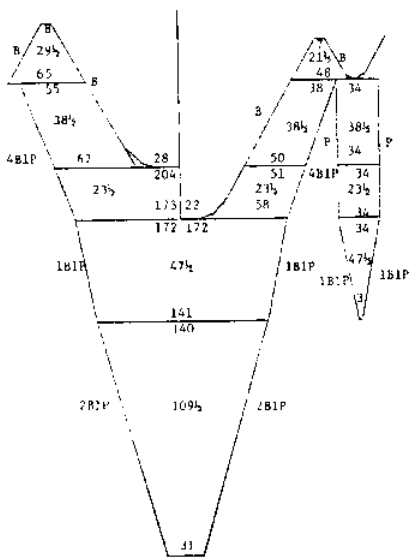
Taper angle at fishing circle: 9.0 degrees
Wing spread at jib seam: 46.8 feet
Width at fishing circle: 36.0 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	1	1	1+
3.18	1	1	1+
3.92	1	1	1+

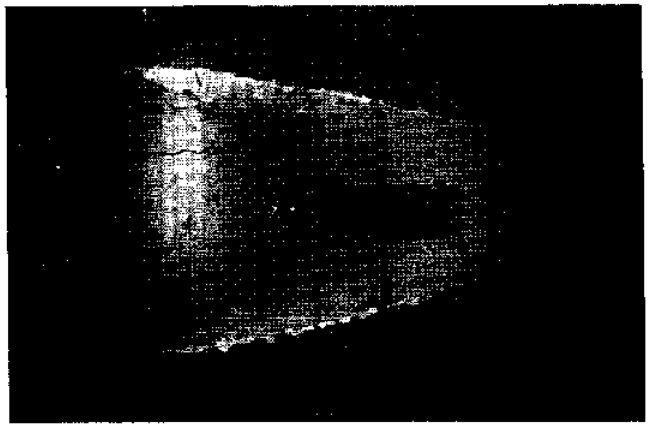
Here, the side panel of the baseline design has been reduced to 20 percent, i.e. the side panel has 20 percent as many meshes as the top or bottom panels. The performance of this design can be compared with the 40 and 80 percent versions and with 2-seam model 2 which has no side panel.



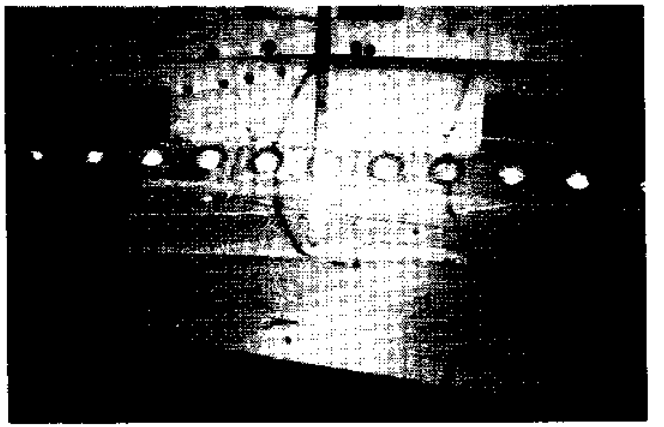
Net Plan



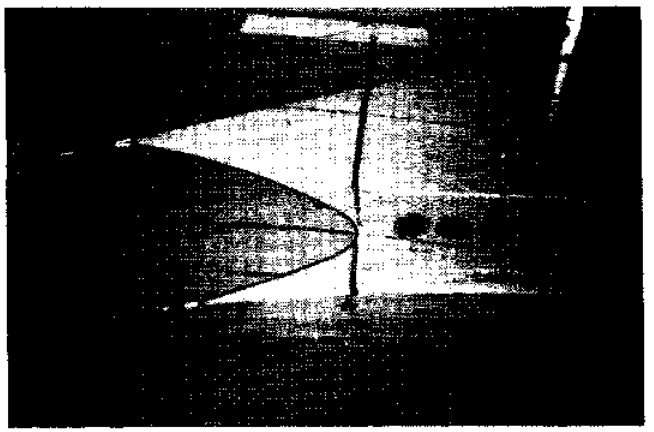
2.45 knots:



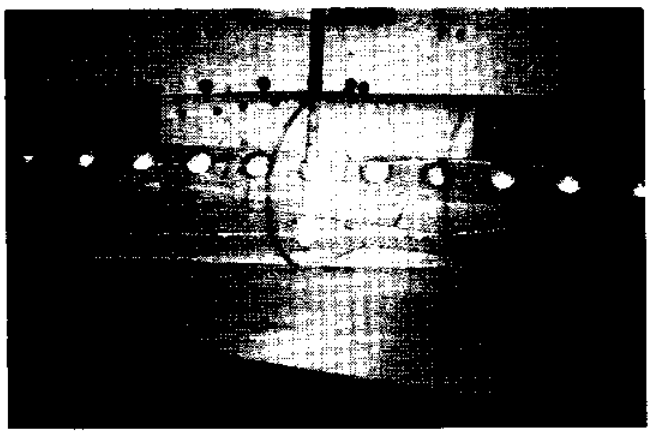
2.45 knots:



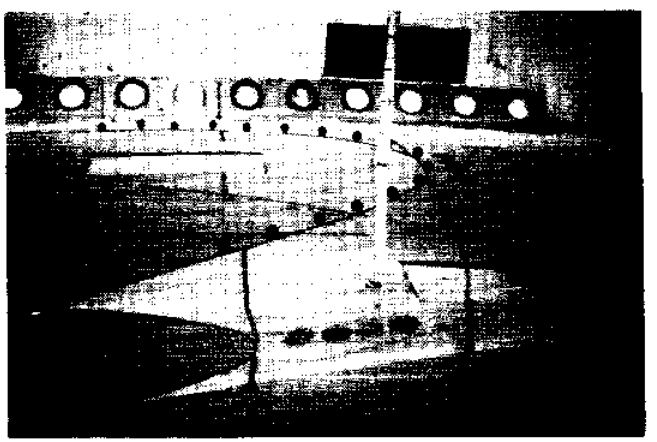
2.45 knots:



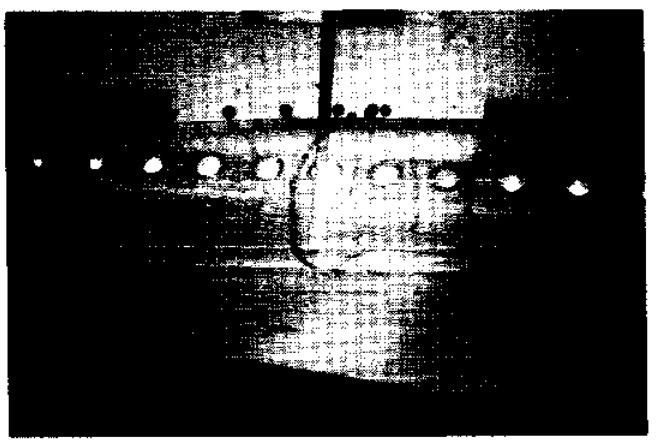
3.18 knots:



3.92 knots:



3.92 knots:



MODEL 5: 4-Seam 80% side panel

Speed	Resistance	Headrope height
2.45 knots	4900 pounds	15.0 feet
3.18	7150	11.1
3.92	9300	9.3

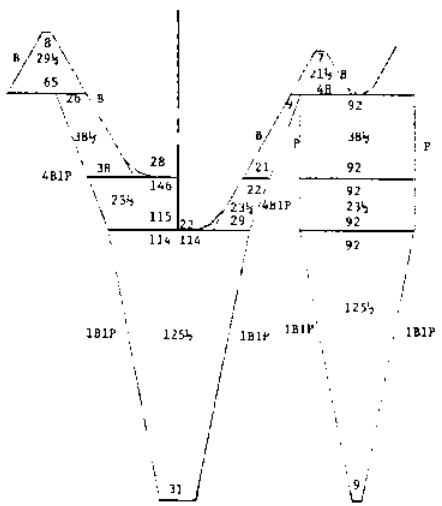
Taper angle at fishing circle: 10.0 degrees
Wing spread at jib seam: 49.2 feet
Width at fishing circle: 38.4 feet

Speed	Footrope Contact		
	Wing end	Corner	Center
2.45 knots	2	1	0+
3.18	1+	1	0+
3.92	1+	1	0+

The side panel size has been increased to 80% of the belly size. Due to the full length dual 1B1P tapers, the overall length of the trawl has been reduced.

It can be seen from the graph on the previous page that the selection of side panel size for maximum headrope height depends on the speed at which the net will be towed. Trawls for lower speed fisheries seem to benefit from side panel size whereas if towing speed is high smaller or no side panels are favored.

Net Plan



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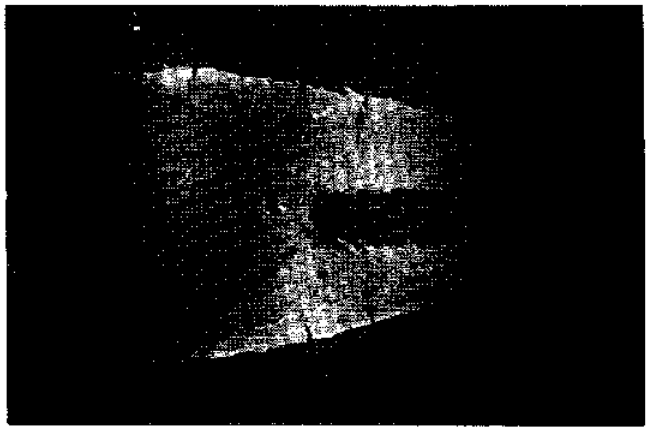
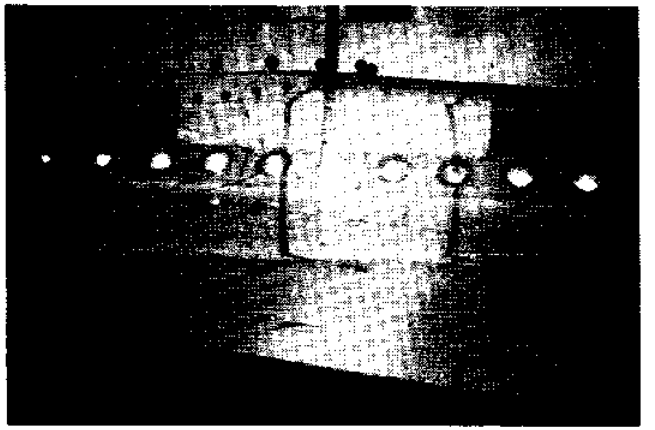


2.45 knots:



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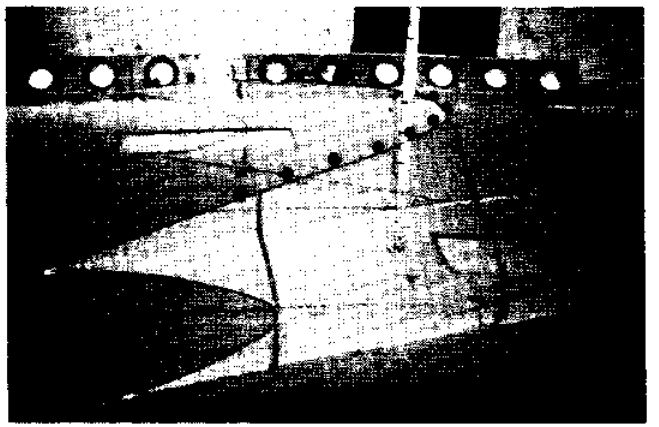
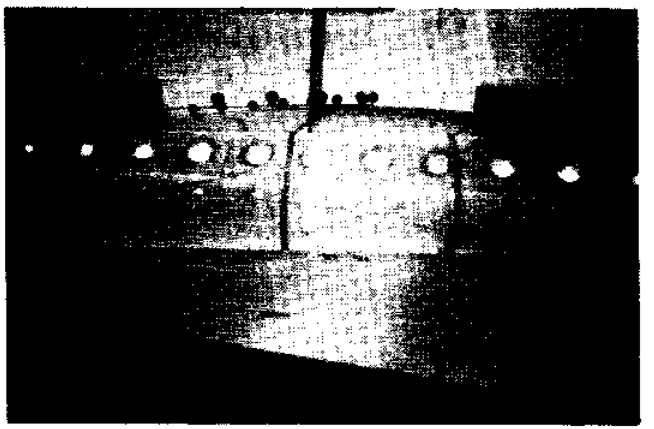
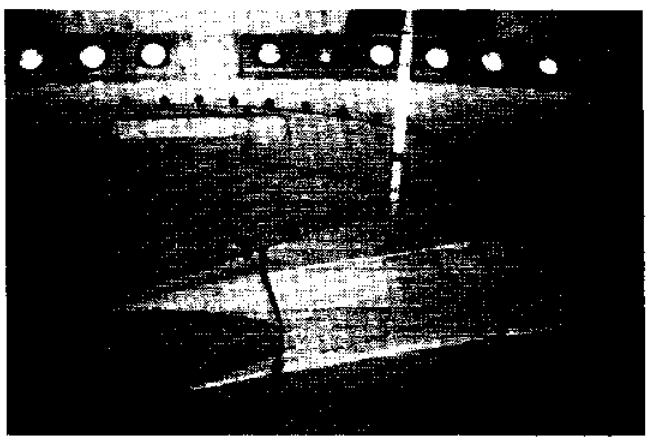


3.18 knots:



3.92 knots:



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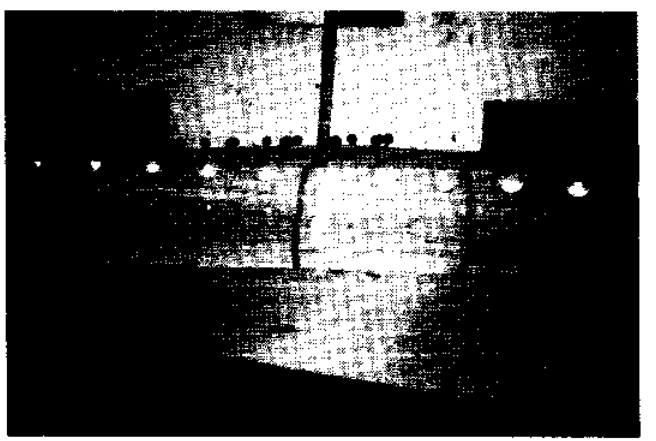


MODEL 6: 4-Seam uniform taper

Speed	Resistance	Headrope height
2.45 knots	4600 pounds	16.5 feet
3.18	6500	13.2
3.92	8900	10.8

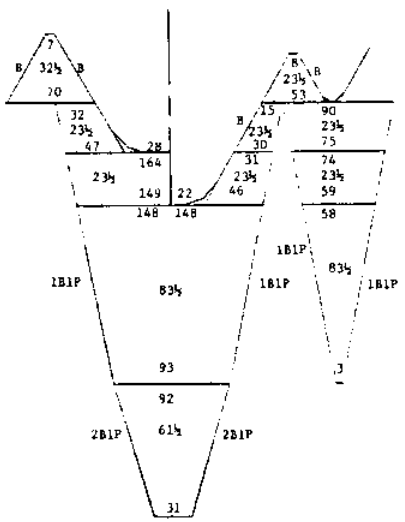
Taper angle at fishing circle: 5.0 degrees
Wing spread at jib seam: 43.2 feet
Width at fishing circle: 37.2 feet

Speed	Footrope Contact: Wing end	Corner	Center
2.45 knots	2	1	1
3.18	1+	1	1
3.92	1	1	1

This model has the same after portion as the baseline 4-seam, however the 1B1P tapers are carried forward into the wings.

When comparing heights and spreads it should be noted that the length of the wings on this model is less than most other models.

Net Plan



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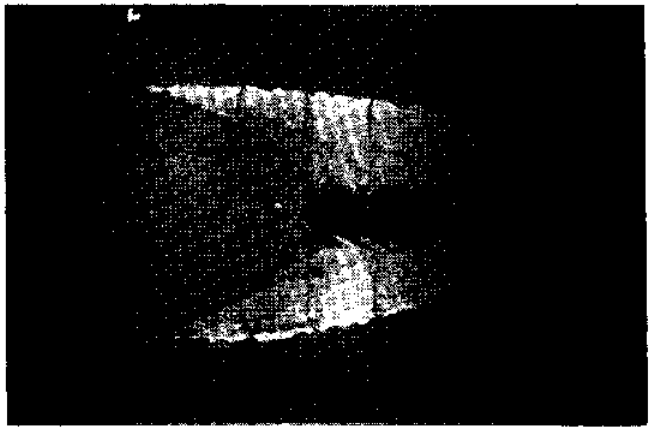

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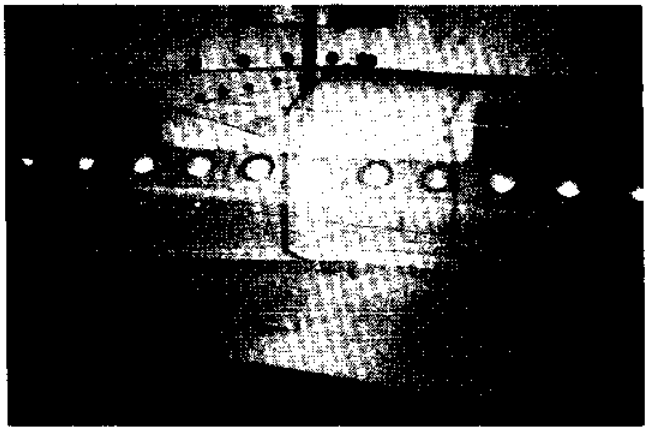
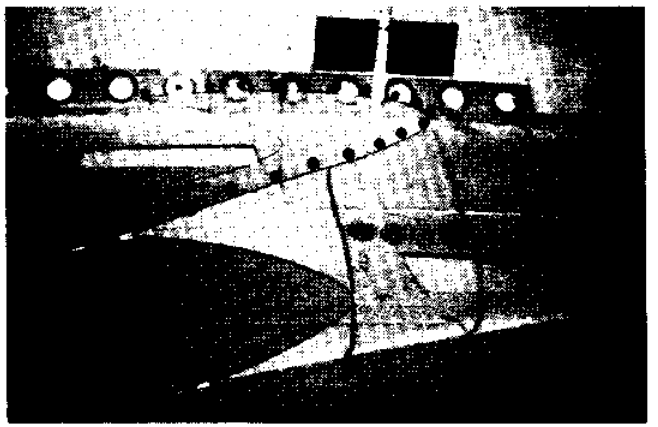


2.45 knots:



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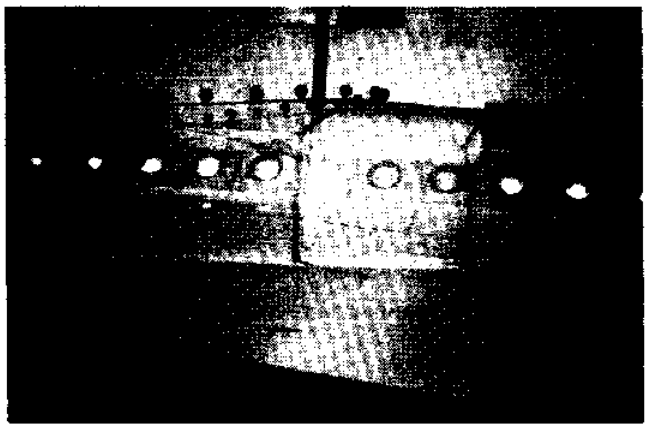

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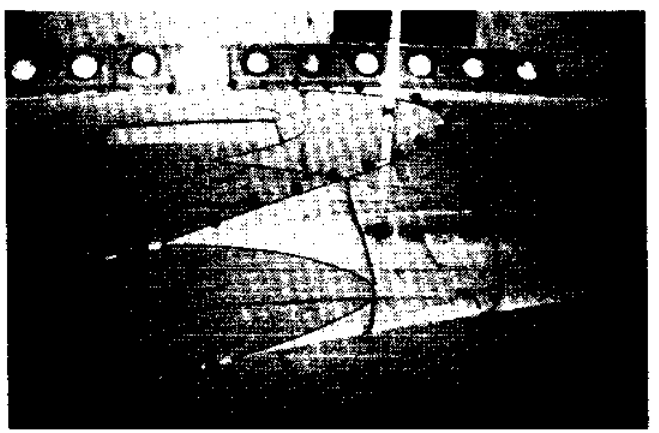
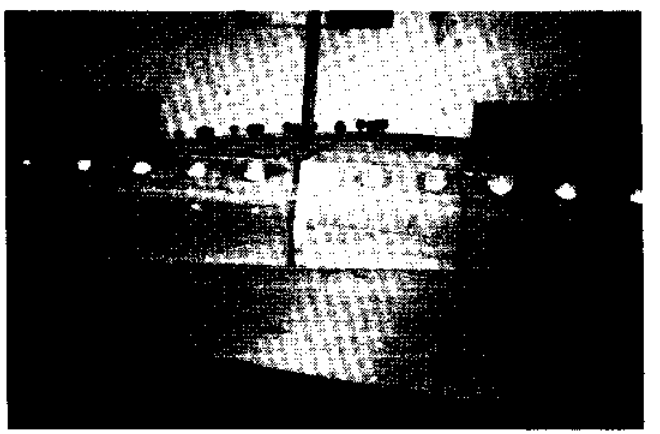


3.92 knots:



MODEL 8: 4-Seam with extra side panel

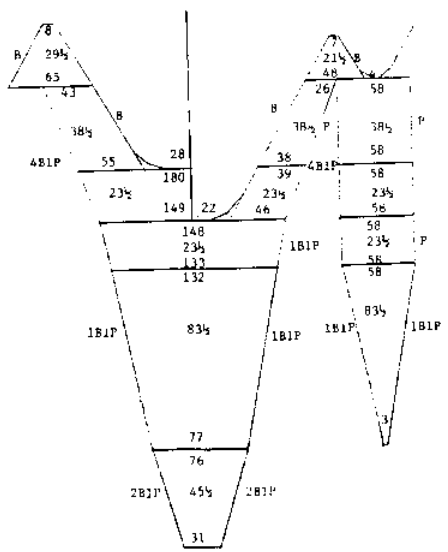
Speed	Resistance	Headrope height
2.45 knots	4500 pounds	14.7 feet
3.18	6500	11.4
3.92	8900	9.6

Taper angle at fishing circle: 8.0 degrees
Wing spread at jib seam: 48.0 feet
Width at fishing circle: 38.4 feet

Speed	Footrope Contact Wing end	Corner	Center
2.45 knots	2	1	1
3.18	2	1	1
3.92	2	1+	1+

This design includes an extra rectangular side panel behind the fishing circle. This is a simple way of having the side panel terminate further back towards the codend.

Net Plan



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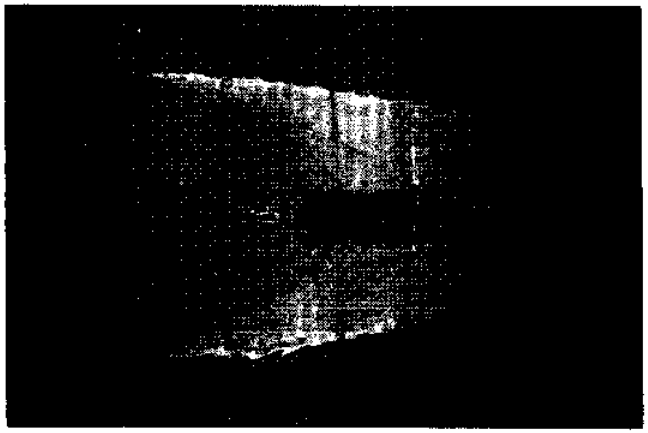
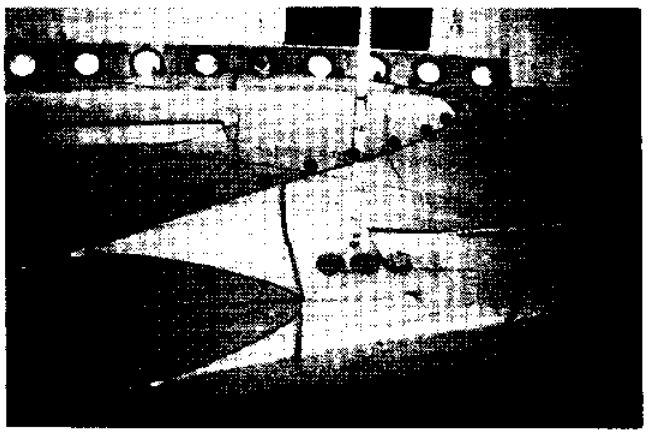


2.45 knots:

2.45 knots:



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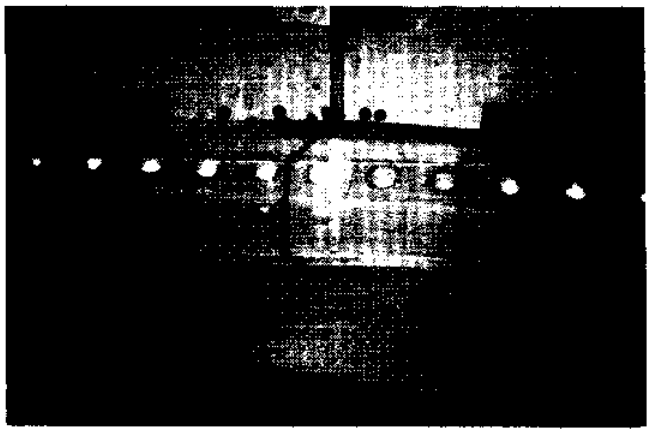

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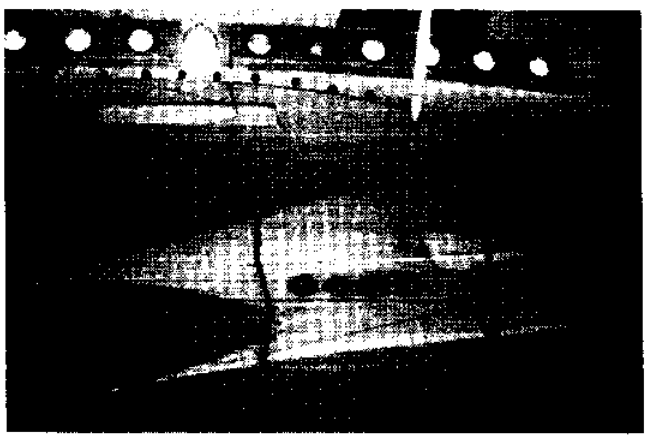


3.92 knots:

MODEL 9: 4-Seam 10B1P bottom wing

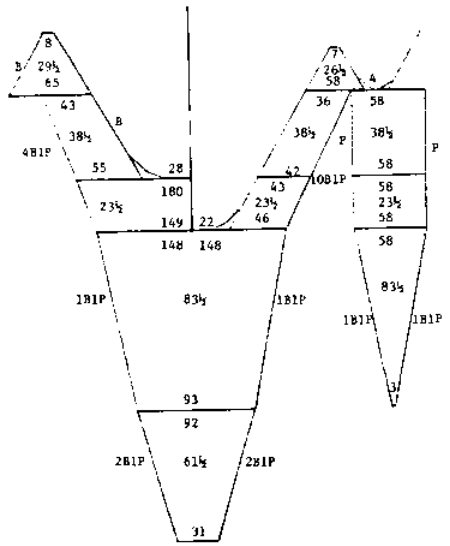
Speed	Resistance	Headrope height
2.45 knots	4250 pounds	15.0 feet
3.18	8600	11.7
3.92	8700	9.6

Taper angle at fishing circle: 9.0 degrees
Wing spread at jib seam: 48.6 feet
Width at fishing circle: 39.0 feet

	Footrope Contact		
Speed	Wing end	Corner	Center
2.45 knots	0	0	0
3.18	0	0	0
3.92	0	0	0

This model is identical to the baseline 4-seam except the bottom wing and bunt taper has been increased to 10B1P. This change provided the most uniform bottom contact of any of this series.

Net Plan



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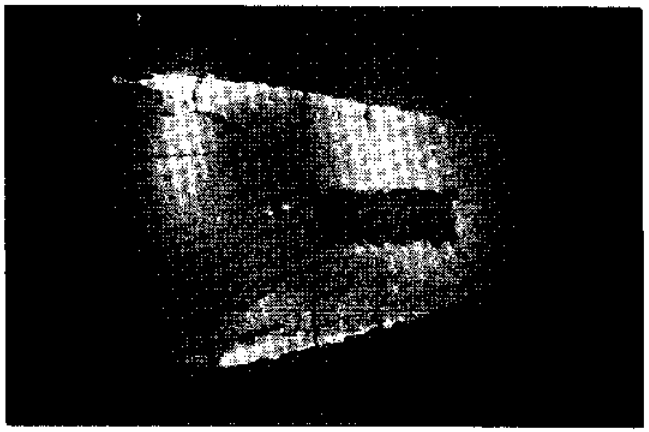
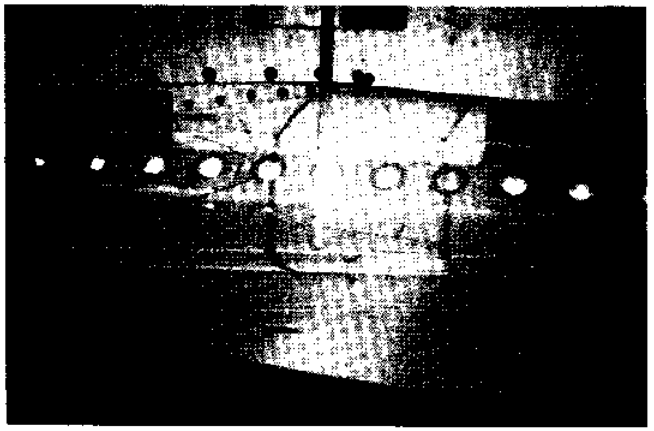


2.45 knots:



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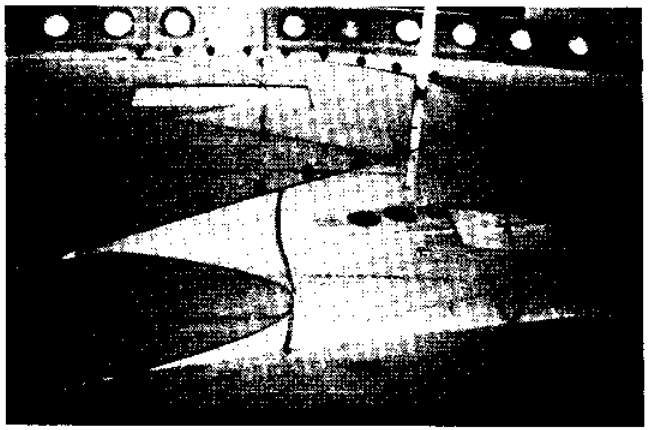
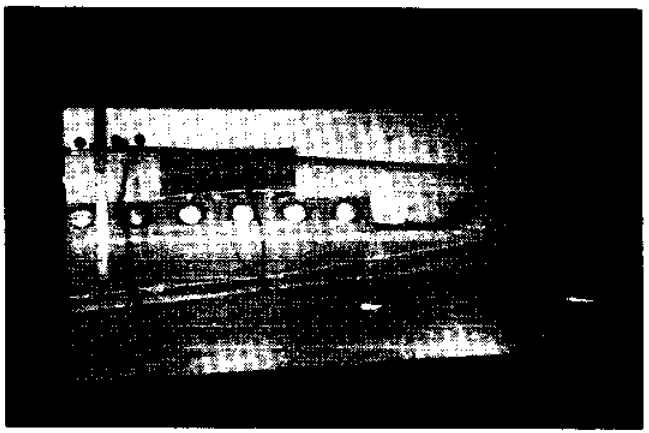
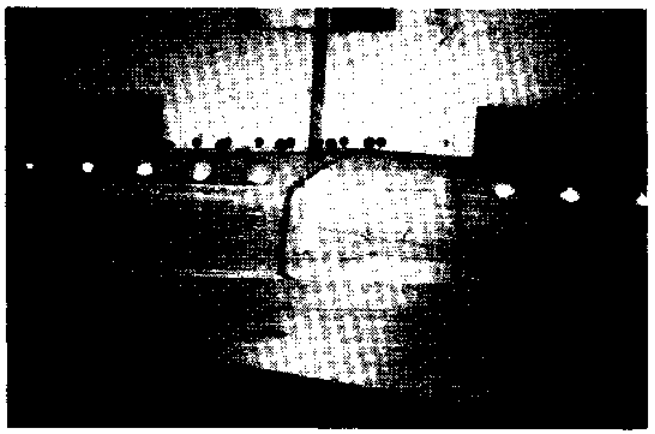


3.18 knots:

3.18 knots:



3.92 knots:



MODEL 9: The effects of flotation changes

Model 9 was retested to determine the effects of flotation changes. The 20 floats were changed from uniform spacing to being clustered in the center of the headrope or at the wing ends. The effect of tripling the flotation is also shown.

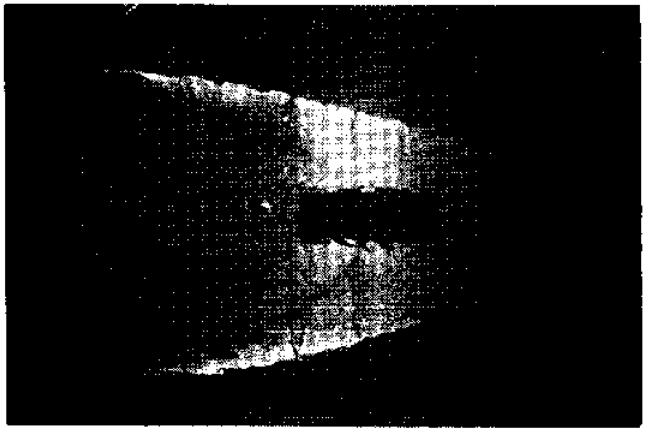
		Headrope Height	
	Speed	Center	Wing end
Normal 20 floats	2.45 knots	15.0 feet	—
even spacing	3.18	11.7	8.4 feet
	3.92	9.6	—
20 floats	2.45	16.8	9.6
Centered	3.18	12.9	8.4
10 floats on	2.45	12.3	11.4
each wing end	3.18	10.5	9.3
	3.92	8.4	9.0
60 floats	2.45	25.2	17.4
even spacing	3.18	18.6	13.5
	3.92	15.0	10.5

Footrope contact was essentially the same for all conditions (see model 9 results) except with the 60 floats.

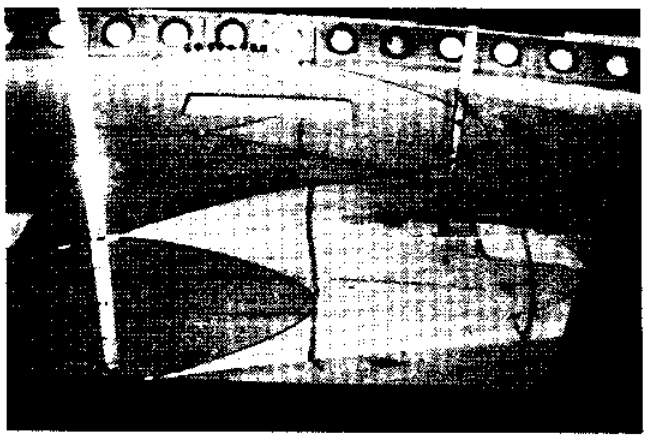
Footrope Contact with 60 floats

Speed	Wing end	Corner	Center
2.45 knots	off	off	off
3.18	off	3	2+
3.92	off	2+	2

2.45 knots:



2.45 knots:



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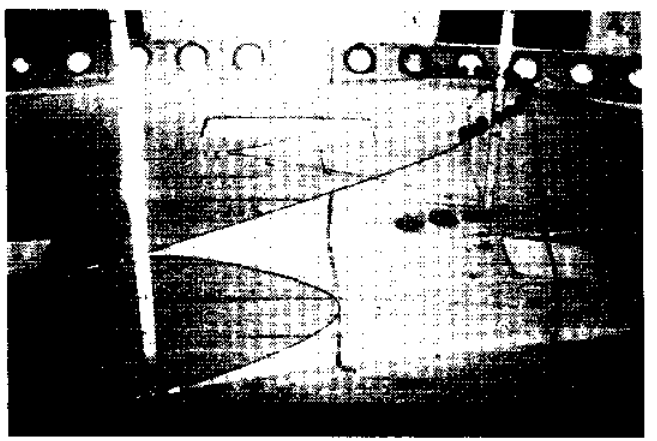
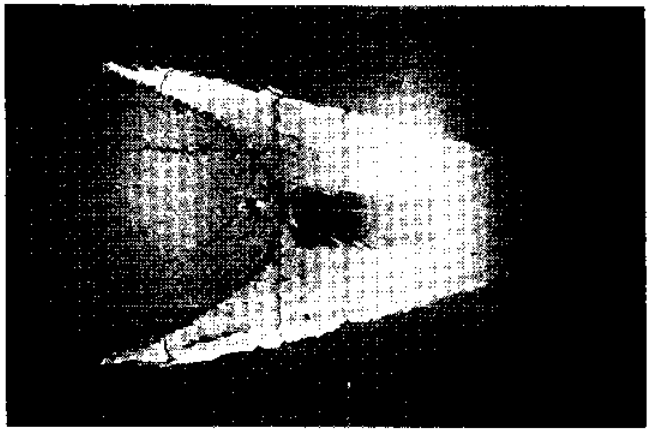
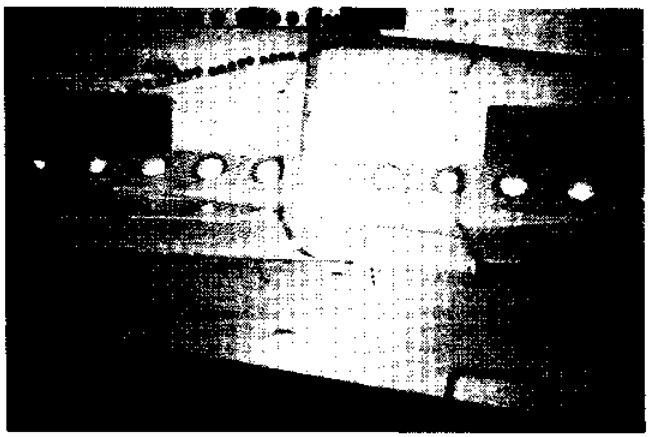


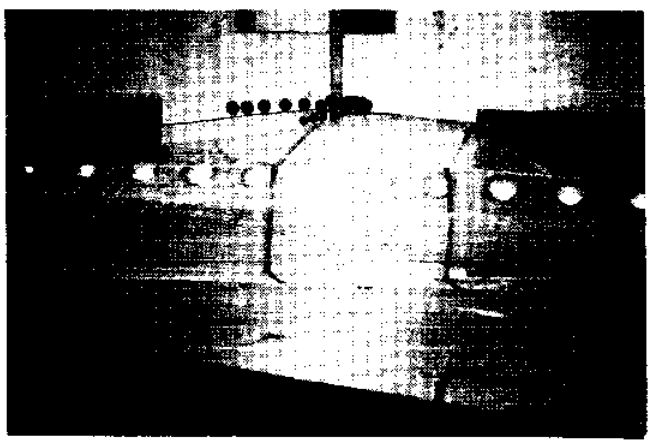
2.45 knots:



3.18 knots:



3.18 knots:



MODEL 7: 4-Seam Lossie trawl

Speed	Resistance	Headrope height
2.45 knots	4200 pounds	13.8 feet
3.18	6050	10.5
3.92	7700	7.5

Taper angle at fishing circle: 7.0 degrees
Wing spread at jib seam: 54.0 feet
Width at fishing circle: 36.6 feet

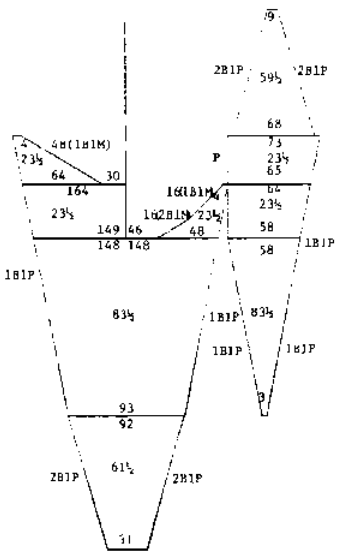
	Footrope Contact		
Speed	Wing end	Corner	Center
2.45 knots	off	2+	1+
3.18	3	2	1+
3.92	2	1+	0+

This design includes a "Lossie" type front end on the baseline 40% rear end.

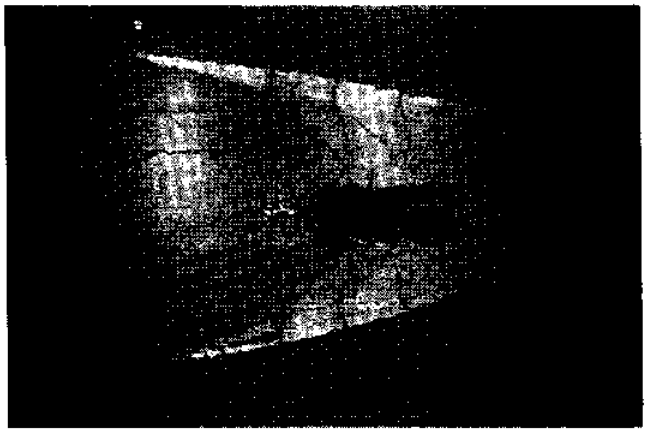
This model required a great deal more weight to achieve reasonable bottom contact. Weight spacing was reduced by 25% and the weights in the region of the wing were doubled to the equivalent of 20 pounds each. The combination rope lower leg was replaced with chain equivalent to 3.6 pounds per foot (5/8").

Additionally, the upper bridle had to be shortened before bottom tending was acceptable leaving little load on the chain.

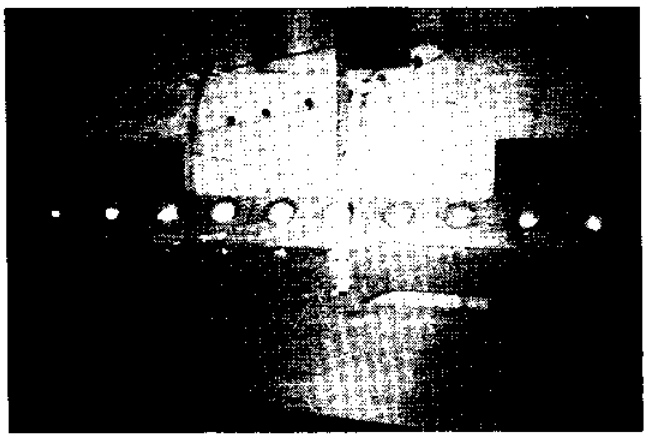
Net Plan



2.45 knots:



2.45 knots:



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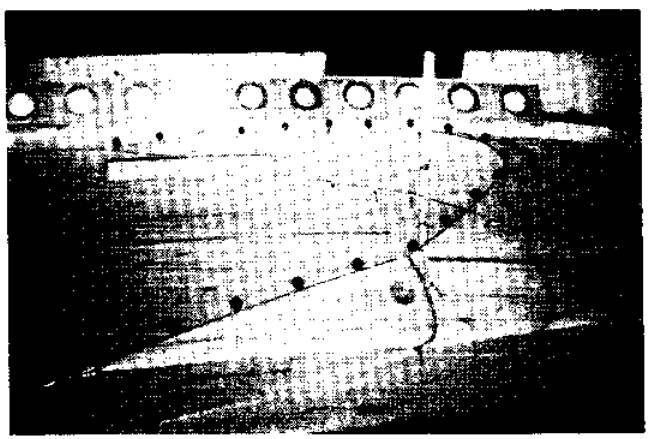
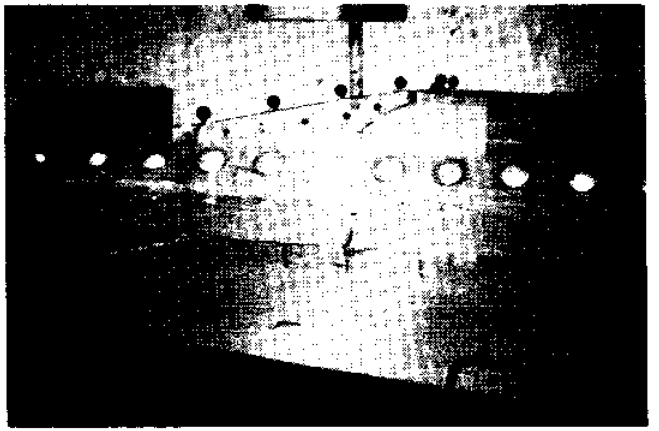
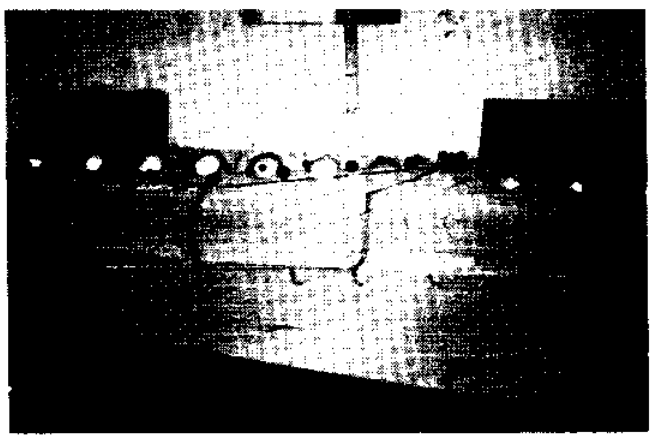


2.45 knots:



3.18 knots:

3.92 knots:



Midwater Rope Trawl Series

This series of tests studied the effects on resistance of three different twine hanging ratios. Three rope front-ends were designed to fit on one small-mesh rear-end yeilding trawls with the following specifications:

	MRT #1	MRT #2	MRT #3
Hanging ratio	.33	.42	.50
Twine area(less knots) ft^2	21.05	21.05	21.05
Designed mouth area at jibs	18.5	41.5	29.4
Actual mouth area	15.9	29.4	20.3
Design bridle angle: horiz.	21°	27°	25°
vert.	12°	17°	16°

Due to the fixed location of the four tow points, the net shape did not change appreciably with speed. Therefore, the load cell data for the models has been reduced to total bridle tension as a function of the velocity squared.

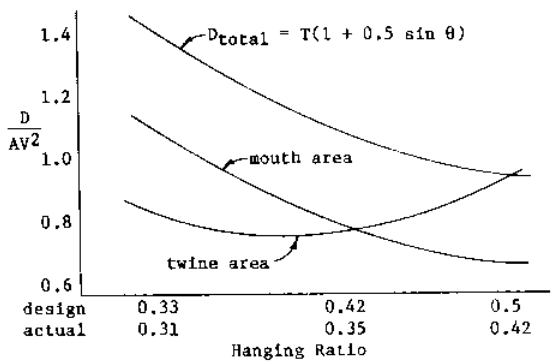
MRT #1 - $T = 19.5\ V^2$
MRT #2 - $T = 23.0\ V^2$
MRT #3 - $T = 18.5\ V^2$

where T is in pounds and V is in knots.

Since the actual resistance of the netting is the component of the bridle tension in the direction of flow, the above relations must be multiplied by the cosines of the horizontal and vertical bridle angles. The drag, D, in pounds becomes:

MRT #1 - $D = 17.8\ V^2$
MRT #2 - $D = 19.6\ V^2$
MRT #3 - $D = 16.1\ V^2$

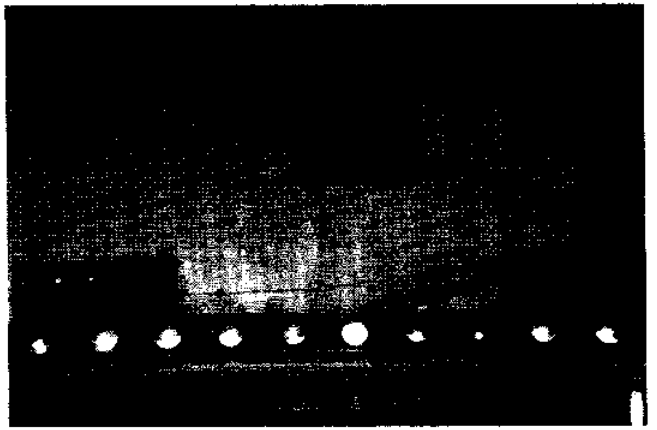
Using these formulae, the twine area, and the mouth openings, the results can be shown graphically:



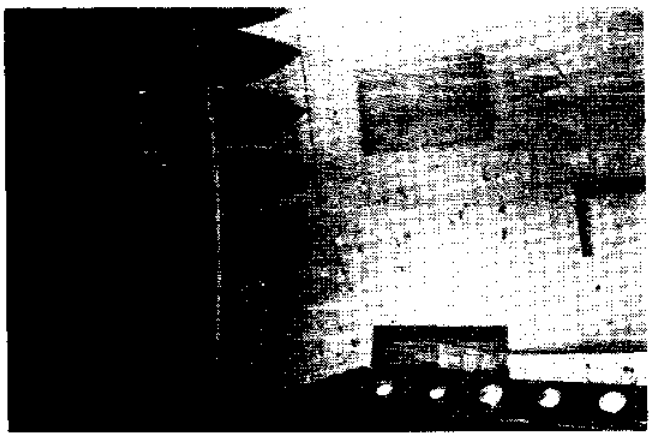
Based on twine area there is a minimum drag at a design hanging ratio of approximately 0.4. From a fishing power standpoint, drag relative to mouth area is more important. While we should expect a minimum for this curve, it is beyond the range tested. Also evident from this graph is the difficulty in maintaining designed mesh openings at the higher hanging ratios. Additionally, wide meshes may require more spreading force to keep them open. The upper curve is presented and takes into account horizontal bridle angle and the effect of added door resistance. Even with this penalty, the minimum is still beyond the range tested.

MRT #2 - front view:

MRT #2 - rear end:

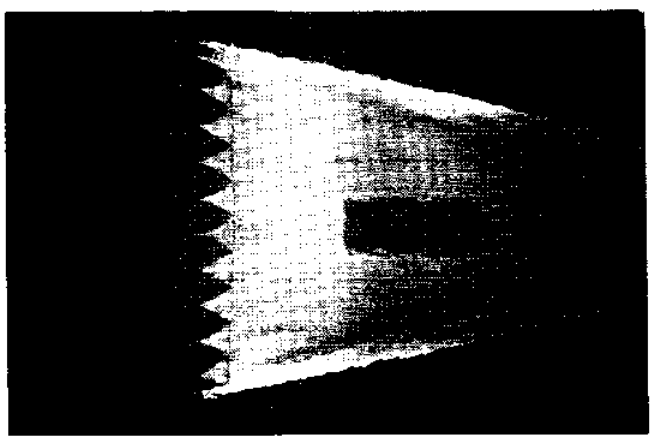


MRT #2 - jib detail:

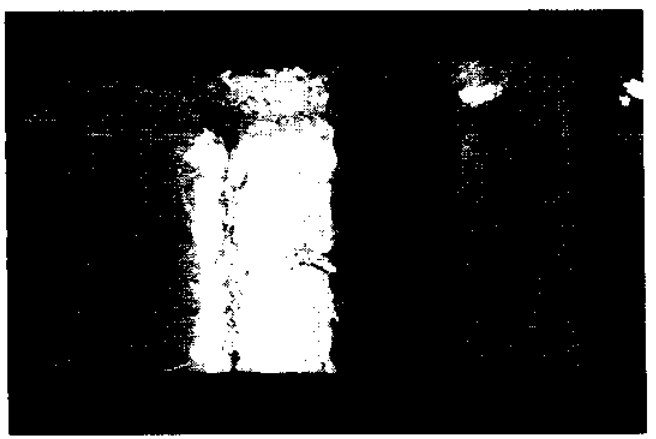


MRT #2 - underspread, side view:

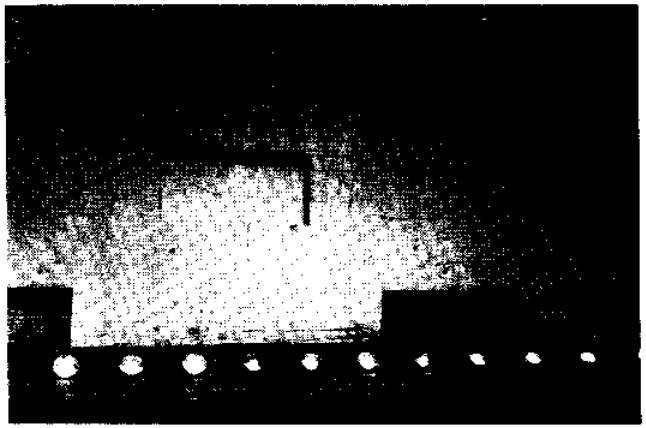
MRT #2 - design spread:



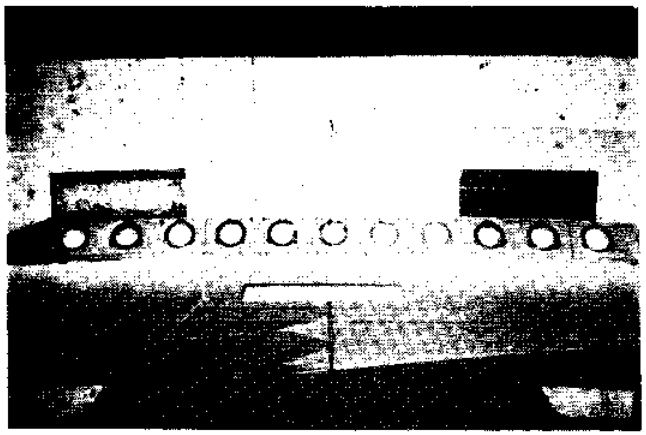
MRT #2 - underspread, from below:



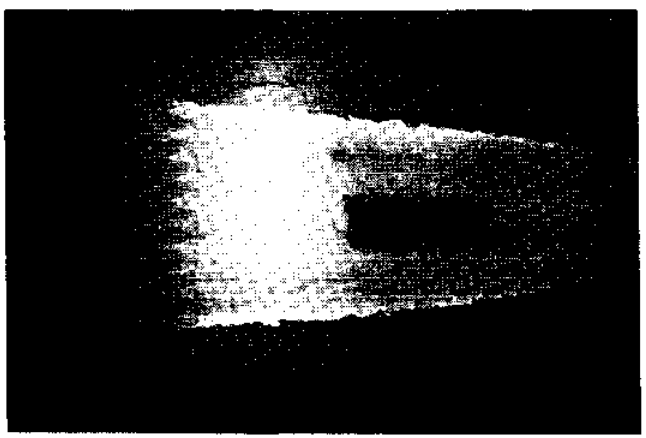
MRT #1 - designed spread:



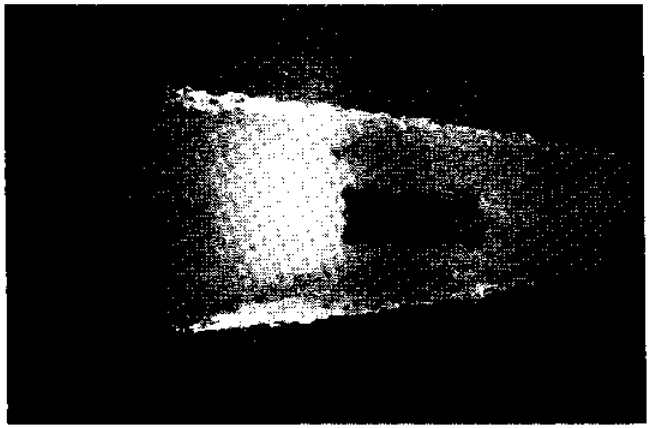
MRT #1 - side view:



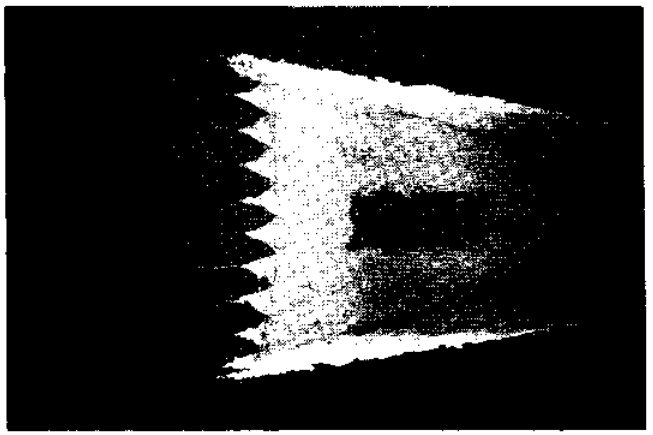
MRT #1 - top view, 10' (designed) spread:



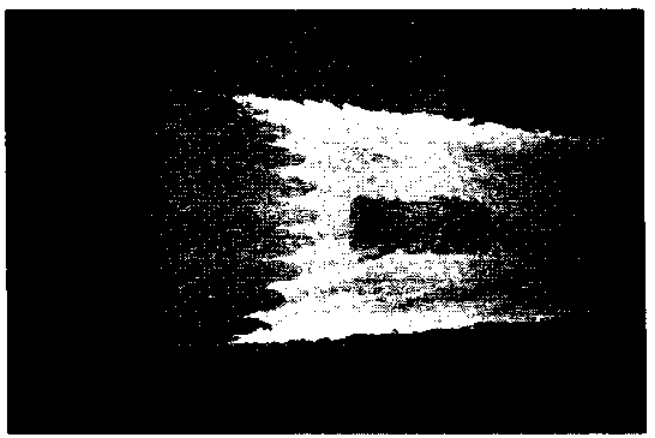
MRT #1 - 12' spread:



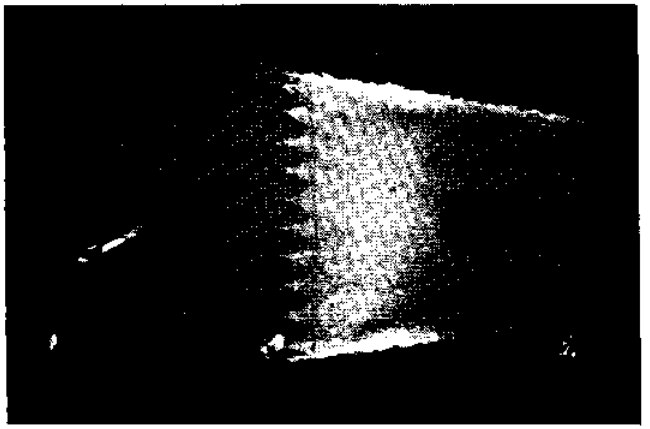
MRT #2 - 12' spread:



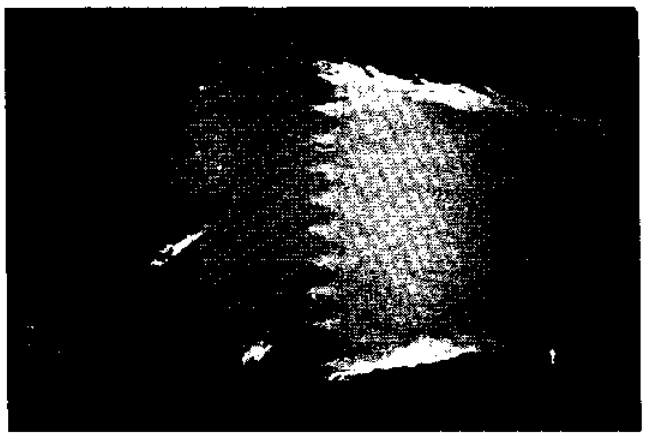
MRT #2 - 8' spread:



MRT #3 - 12'-4" (des.) spread:



MRT #3 - 15' spread:



MRT #3 - 8' spread: