# An Investigation into the use of Flume Tank Tests for Codend Models- Scale Range 1:2.0 to 1:2.7

MAFF Commission

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**Seafish Report No.405**

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May 1992

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# SEA FISH INDUSTRY AUTHORITY

## Seafish Technology

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Seafish Report No. 405
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## SUMMARY

This report describes a series of trials carried out on model codends in the Flume Tank. The purpose of the trials was to see if model tests could reasonably replicate the full size behaviour of codends at sea in terms of shape, mesh distortion and loading and thereby be used to support the work into more selective codend design. The use of the Flume Tank to eliminate certain options would be an important step in reducing expensive sea trials time.

Three model codends were constructed between 1:2 and 1:3 scale, one in polyethylene and two in polyamide netting. Each codend had an extension added which was equal in length to the codend and made from the same material.

Each model was towed from a series of support rings at two speeds to find the effect of support ring size on codend shape.

The trials have demonstrated that it is possible to make some qualitative observations from these model codends but because severe oscillations were encountered no quantitative data was obtained. Means of reducing the oscillations are being considered along with alternative means of measuring the model nets in the Tank.

Before confidence can be increased however much more needs to be known about the shape and behaviour of full sized codends in towing conditions. Water flow inside and outside of the codend can be highly variable and this needs to be measured so that this can be replicated in the Flume Tank. There is also a need to compensate for the possible difference in water velocity in the codend caused by a full trawl in comparison with the model codend and extension only.

These trials can only be taken as a preliminary investigation into the possibilities of this technique being used. In the longer term it should be possible to predict with reasonable accuracy codend behaviour from model tests.

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## 1. INTRODUCTION

This report describes Flume Tank trials carried out on model codends to determine how realistic this would be in relation to the full size codend. The work was undertaken by the Gear Technology Group of Seafish Technology under the MAFF R&D Commission 1991/92, Project Code IAA16.

Due to the current interest in codend selectivity work, it was considered that any developments which could be carried out in the Flume Tank would be beneficial in helping to determine the possible options to try at sea. Although it is not possible to assess fish reactions at model scale, it may be possible to eliminate some options and refine others before going to the great expense of sea trials. This is a particular benefit of Flume Tank tests.

Most model nets used in the Flume Tank are 1:8 or 1:10 scale although very small nets may be scaled at 1:5 and very large nets at 1:25.

When viewing underwater video records of codends being used at sea, most of those constructed of diamond mesh appear to have an even smooth bulb shaped codend, with even tensions in the netting.

However, at whatever scale the model nets are constructed, the codends always appear to be lacking in the even shape of their full sized counterparts. It appears, in general, that the mesh bars are not under tension in the model as they are in full size codends.

The maximum waterspeed available in the Seafish Flume Tank is approximately 1.1 metres per second which is equivalent to 2.1 knots for a full size codend. As normal towing speeds are often between 2.0-3.0 knots the Flume Tank obviously cannot be used for testing full size gears.

It was decided, therefore, that model codends should be tested in the range of scales 1:2 to 1:3 to assess the possibilities of using scale models to represent full size codends.

It should be noted that the intention of the trials was to highlight the technical problems of testing model codends in the Flume Tank, rather than actually correlate the model results to full size trials.

Obviously no actual correlation can be done due to the lack of any full scale measured data. However, the shape of the model codend can be compared, in a qualitative sense, to the underwater video available.

The longer term, however, is promising for this type of model/full size correlation.

## 2. CODEND SPECIFICATION AND CONSTRUCTION

At the chosen scale range of 1:2 to 1:3 it was not possible to fit a full trawl into the Flume Tank. It was therefore decided that the codend only should be modelled and attached to an extension piece equivalent in length to the codend. This extension was thought to be important so that any supporting ring could be removed from the area of the codend and thus would have less influence on the shape of the codend itself, allowing it to take up its natural shape. Three models were made.

The specification and dimensions of the full size codend to be used in these tests was chosen from a Stuart 440 balloon trawl recently modelled at 1:10 scale following full scale trials at sea and is shown in Fig 1. The codend comprised a top and bottom panel 60 meshes wide with four side knots gathered into each selvedge. The reason for choosing this codend to model was the availability of the trawl model to assess the dimensions (width and height) of the point at which the codend and extension is attached to the net.

The normal method for scaling net panels for model trawl construction, is to maintain the same ratio of twine diameter to mesh size in the model as was found in the full size net. The actual numbers of meshes across and along each model panel are then calculated to give the correct scale panel length and width for the sample of model netting chosen. This method of scaling ensures that the twine surface area of the model net panel is correctly scaled.

Due to the limited number of model netting types held in stock, this often means that the actual mesh size in the model is not correctly scaled. The stock of model netting held at the Flume Tank is given in Appendix I.

It was felt, however, for the construction of these codend models at between 1:2 and 1:3 scale that it would be preferable to scale the mesh size correctly even if the twine surface area was not quite correctly scaled. It is the mesh opening and deformity of mesh size which are critical in selectivity trials.

The stock of model netting is held in three twine diameters of 0.30mm, 0.37mm and 0.52mm. As the full size codend twine diameter was 4.10mm, this model netting was not suitable for modelling the codend at between 1:2 and 1:3 scale.

Initially, two samples of netting were obtained from which to construct the first two codend models. The first sample was polyethylene and the second polyamide.

The model codends were constructed mesh for mesh compared to the full size codends, taking the full mesh size (knot centre to knot centre) as the dimension to scale.

Finally, a third codend model was also constructed in polyamide netting from the normal model netting stock giving a twine diameter well below the true scale size. This model was constructed to examine the effect of elasticity on codend shape.

The specification of full size and model codends are given in Appendix II. The model scale was calculated by comparing the full size mesh size (knot centre to knot centre) to the model mesh size.

A sample of twine was removed from each netting type and its diameter measured using the standard ICES recommended method (light extinction method).

The extension piece for each model was made of the same netting material as the codend and also had the same number of meshes along and wide. This was done to facilitate construction.

It should be noted that no attachments such as lifting bags were added to the codend.

## 3. EXPERIMENTAL PROCEDURE

In order to gauge the size and shape of support structure required for the experiments, the Stuart 1:10 scale model net from previous trials was measured in the Flume Tank. The height and width of the point at which the extension joined the bellies was measured and both found to be 50mm (equivalent to 500mm full scale).

For Model 1 (scale 1:20) a support ring was made of 250mm diameter, and for Models 2 and 3 (scale 1:2.7) a ring was made of 185mm diameter.

In order to assess the importance of the support ring diameter, a full series of support rings were also constructed for these and future experiments. The diameters chosen were 150, 184, 200, 250, 300, 350, 400, 450 and 500mm. The rings were constructed of 8mm diameter solid steel.

For an initial test, Model 1 was evenly laced to the 250mm diameter ring and towed from four bridles onto a single warp as shown in Figure 2.

The main problem found with this rigging arrangement was that the whole codend/extension assembly rotated about the single warp so that the selvedge was not at the side. This tendency to rotate was prevented by adopting the rig design shown in Figure 3.

In order to simulate catch a number of items were tested, e.g. a bundle of netting and pieces of sponge. The use of these items was discounted on the basis that the amount was not quantifiable in terms of weight.

Plastic bags filled with water were found to give a good simulation and so were used throughout the experiments although the size of the bags used gave some difficulties in achieving an even weight distribution.

The quantity of catch to simulate was chosen as the equivalent of six 6 stone boxes at full scale, giving model equivalents of 28.6kgs at 1:2.0 scale and 11.6kgs at 1:2.7 scale.

Each model codend was then tested with its standard catch at the equivalent speeds of 2.0 knots and 2.5 knots full scale using three different sizes of support ring.

For Model 1 support rings of 250mm, 350mm and 450mm diameter were used and for Models 2 and 3 rings of 184mm, 300mm and 400mm were used.

The drag of each codend was measured at each of the two speeds and with each ring size. These drag results are given in Appendix III.

## 4. PROBLEMS ENCOUNTERED

For each codend tested at each speed and with each support ring, a video was taken along the full length from support ring to codend.

From the video a series of "still" shots was taken to allow comparison from one ring size to another and one codend model to another.

Although these "still" shots give an impression of general shape it is not possible to assess actual dimensions due to the oscillation of the codend. These oscillations were a major problem in producing quantifiable data from these particular tests.

Oscillations were found to occur both vertically and horizontally. The main problem with the horizontal oscillations was that the codend size appeared larger when the movement was nearer to the camera, and smaller when the codend was farther away from the camera.

For the vertical oscillations, the meshes appeared blurred at the mid point of the up/down oscillation which was the only point at which the codend was not distorted.

The reason for these oscillations was investigated using Model 3. In this model the twine surface area is well below the scale area. This means that the codend load or catch forms a much greater proportion of the total drag.

In this test it was found that if catch was slightly asymmetric, this created a side force pulling the codend over to one side. By pushing the codend with a pole it was possible to redistribute the water bags either rectifying the asymmetry or causing the codend to move in some other direction.

In some cases, when the codend moved to one side the movement caused a redistribution, causing a further movement in some other direction.

## 5. RESULTS

Due to the oscillations of the codend described in the previous section it was not possible to make any quantitative measurements to compare the geometry of one codend to another, or the influence of codend shape with different size support rings.

However, the series of "still" shots are given in Figs 4 to 20 in order to make a qualitative assessment. Each of the Figs 4 to 20 shows four still shots which show the codend shape progressing from support ring (bottom left), mid extension (bottom right), tapered section in front of the codend (top left) to codend (top right).

The main comparisons which have to be made are:

(a) does the size of support ring make a significant effect on the shape and mesh opening of the codend?

(b) what is the difference in performance of polyethylene compared to polyamide?

(c) what is the effect of choosing a twine diameter well below the true scale diameter?

### 5.1 Ring Diameter

On examination of the "still" shots (Figs 4 to 20) it can be seen that for each of the models the ring diameter has very little influence on the shape of the codend itself. Also, comparing the shape of each codend at 2.0 and 2.5 knots there appears to be little difference. However, if the codend shapes of Models 1, 2 and 3 are compared, the Models 1 and 3 narrow more quickly forward of the codend bulb than does Model 2. On examination of the section midway between codend bulb and support ring it can be seen that Model 2 is wider than Models 1 and 3.

### 5.2 Material Comparison

The comparison of Models 1 and 2 shows that the polyamide (Model 2) gives a much more smooth shape than the polyethylene. Examining Figs 4 to 9 for the polyethylene Model 1, it can be seen that the mesh bars in the section between ring and codend bulb appear to be under no tension at all giving an uneven bumpy look. In comparison the polyamide Model 2 appears to be smooth with mesh bars under even tension.

Again it should be mentioned that this mid section appears to be wider (and hence meshes more open) in polyamide Model 2 than polyethylene Model 1.

### 5.3 Small Twine Diameter

On examination of the "still" shots for Model 3 (Figs 16 to 20) it is immediately apparent how narrow the section is between codend bulb and support ring. Although it is debateable which is the correct shape of this section between Models 1 and 2, it is certainly not as narrow as Model 3.

## 6. DISCUSSION

These trials have highlighted a number of areas which require examination or experimentation before model codends can be used with confidence to simulate the behaviour of their full scale counterparts. Obviously the aim eventually is to create model codends for use in the Flume Tank where the mesh opening and overall shape are the same as full scale codends.

1) More information is required on the actual shape and mesh openings of codends at sea. The three codend models tested took up different shapes in the sections immediately forward of the codend bulb, but it is not known which is the most realistic.

2) It is known that the speed of waterflow at the codend is generally lower than the towing speed of the net to which it is attached. This relative speed needs to be quantified in order to set-up the model at the correct speed in the Flume Tank.

   Also, it is possible that the relative water speed inside the codend compared to outside the codend may be different in the full size net compared to a model codend with no net in front of it.

3) In order to make scale model codends between 1:2 and 1:3 scale, the model full mesh size will be in the range of 23-55mm. This would cover the full scale mesh size of 70mm at 1:3 scale to 110mm at 1:2 scale.

   It is perhaps more realistic to investigate and purchase supplies of netting material in these mesh size ranges at the appropriate scale diameters, than it is to decide on a specific mesh size and then search for a supplier.

4) Although model drag may best be simulated by scaling down twine surface area correctly, the elastic behaviour may not be scaled correctly.

   As models used in the Flume Tank are scaled according to Froude's law

$$\textit{Model Drag} = \textit{Full Scale Drag}/S^3$$
$$\textit{where } S = \textit{Scale Factor}$$

   However, if mesh size and twine diameter are scaled down according to the scale factor *S* then the load per unit area or stress in each model twine will be lower than in its full scale counterpart.

$$\textit{Model Twine Cross Section} = \textit{Full Scale Twine Cross Section}/S^2$$

   The stress in each twine determines the amount by which it stretches and therefore may effect the shape of the codend.

If the mesh size in the model is scaled down correctly, therefore, elastic behaviour can only be correctly scaled by reducing twine diameter to below the correct scale size.

This effectively means that it is very difficult to scale down every physical parameter correctly and it is important to know which ones have the greatest effect on codend shape.

The characteristic of flexural stiffness may also be a factor influencing codend shape. The flexural stiffness is the resistance of the twine to bending deformation, and may therefore influence the opening of the meshes.

It would be extremely difficult to simultaneously model, mesh size, twine surface area, elasticity and flexural stiffness. However, it may be possible to change from say polyethylene in full size to polyamide in the model to give a better simulation for each parameter and hence a model codend shape which accurately simulates the full size codend.

5) Plastic bags filled with water were a good simulation of catch. However, it was felt that oscillations of the codend could be prevented by using a larger number of smaller bags. This would alow a more even distribution of the "catch" and prevent one large offset bag from causing a side load.

6) Movement of the codend towards and away from the camera made it impossible to take measurements of the model codends.

   This means that for future work, either the codends must be restrained by some means, which may effect the shape, or a measurement system devised which can cope with the movement. It may be possible to attach marked scales to the codends at locations along the length and use these as a basis for taking measurements.

## 7. CONCLUSIONS

These tests have indicated that it is possible to obtain a qualitative assessment of codend shape similar to that of the full size codend but there are a number of problems to be resolved before Flume Tank tests of a model can be said to truly reflect the performance, shape, tensions and dimensions of the full sized net. Tentative conclusions are:-

1) If a model codend is tested when attached to an extension piece, the size of support ring does not have a great influence on codend shape.

2) Correctly scaled polyethylene and polyamide codend models appear to give similar codend bulb shapes. However, where the extension section joins the codend section, the polyamide model is open wider. Polyamide appears to give a smooth shape with even tension in the mesh bars.

3) Within the scale speed range of 2.0 to 2.5 knots, the shape of model codends appears to alter very little. However, the relative speed inside and outside the codend may vary from full scale net to model codend and may therefore effect the shape.

4) Much more information is needed about net shape and mesh distortion in various designs of codend in order to achieve a reasonable correlation between model and full size.

## 8. RECOMMENDATIONS

There are a number of technical difficulties to be overcome before useful codend tests can be carried out in the Flume Tank.

1) Information on full size codend shape is required.

2) Waterflow both inside and outside of full size codends should be researched so that speed can be accurately set-up in the Flume Tank.

3) A range of suitable netting should be stocked to facilitate construction and alteration of model codends.

4) A paper study should be carried out to study the problem of simultaneously modelling mesh size, twine surface area, elasticity and flexural stiffness.

5) Better catch simulation and less oscillations should be achieved by using more smaller bags filled with water. Oscillations should be eliminated to achieve accurate measurements.

6) A measurement system should be devised to give the model codend dimensions despite the oscillations.

APPENDIX I

STOCK OF MODEL NETTING HELD AT THE SEAFISH FLUME TANK IN HULL

| FULL MESH MM | 0.30MM DIA. | 0.37MM DIA. | 0.52MM DIA. |
|---|---|---|---|
| 10 | X | X | X |
| 12 | X | X | X |
| 14 | X | X | X |
| 16 | X | X | X |
| 18 | X | X | X |
| 20 | X | X | X |
| 22 | X | X | X |
| 24 | X | X | X |
| 26 | X | X | X |
| 28 | X | X | X |
| 30 | X | X | X |
| 32 | X | X | X |
| 34 | X | X | X |
| 36 | X | X | X |
| 38 | X | X | X |
| 40 | X | X | X |
| 42 | X | X | X |
| 44 | X | X | |
| 46 | X | X | |
| 48 | X | X | |
| 50 | X | X | |
| 60 | X | X | |
| 70 | X | X | |
| 80 | X | X | |
| 90 | X | X | |
| 100 | X | X | |
| 120 | X | | |
| 140 | X | | |
| 160 | X | | |
| 180 | X | | |
| 200 | X | | |

# APPENDIX II

## FULL SIZE AND MODEL CODEND SPECIFICATIONS

| CODEND | FULL SIZE | MODEL 1 | MODEL 2 | MODEL 3 |
|---|---|---|---|---|
| Material | Polyethylene | Polyethylene | Polyamide | Polyamide |
| Scale | 1:1 | 1:2.0 | 1:2.7 | 1:2.7 |
| Panel Length - Codend Only | 50 | 50 | 50 | 50 |
| Panel Width | 60 | 60 | 60 | 64 |
| Selvedge Meshes/Side Knots Gathered | 3/4 | 3/4 | 3/4 | 5/6 |
| Full Mesh mm (knot centre to knot centre) | 97.8 | 49.2 | 36.0 | 35.2 |
| Inside Mesh mm | 87.5 | 43.6 | 33.0 | 34.0 |
| Twine Diameter | 4.10 | 1.59 | 1.46 | 0.52 |
| Twine Type | Braided | Twisted | Twisted | Twisted |
| Ratio - Full Size Mesh/Model Mesh | 1 | 2.00 | 2.70 | 2.70 |
| Ratio - Full Size Twine Diameter/Model Diameter | 1 | 2.58 | 2.81 | 7.88 |

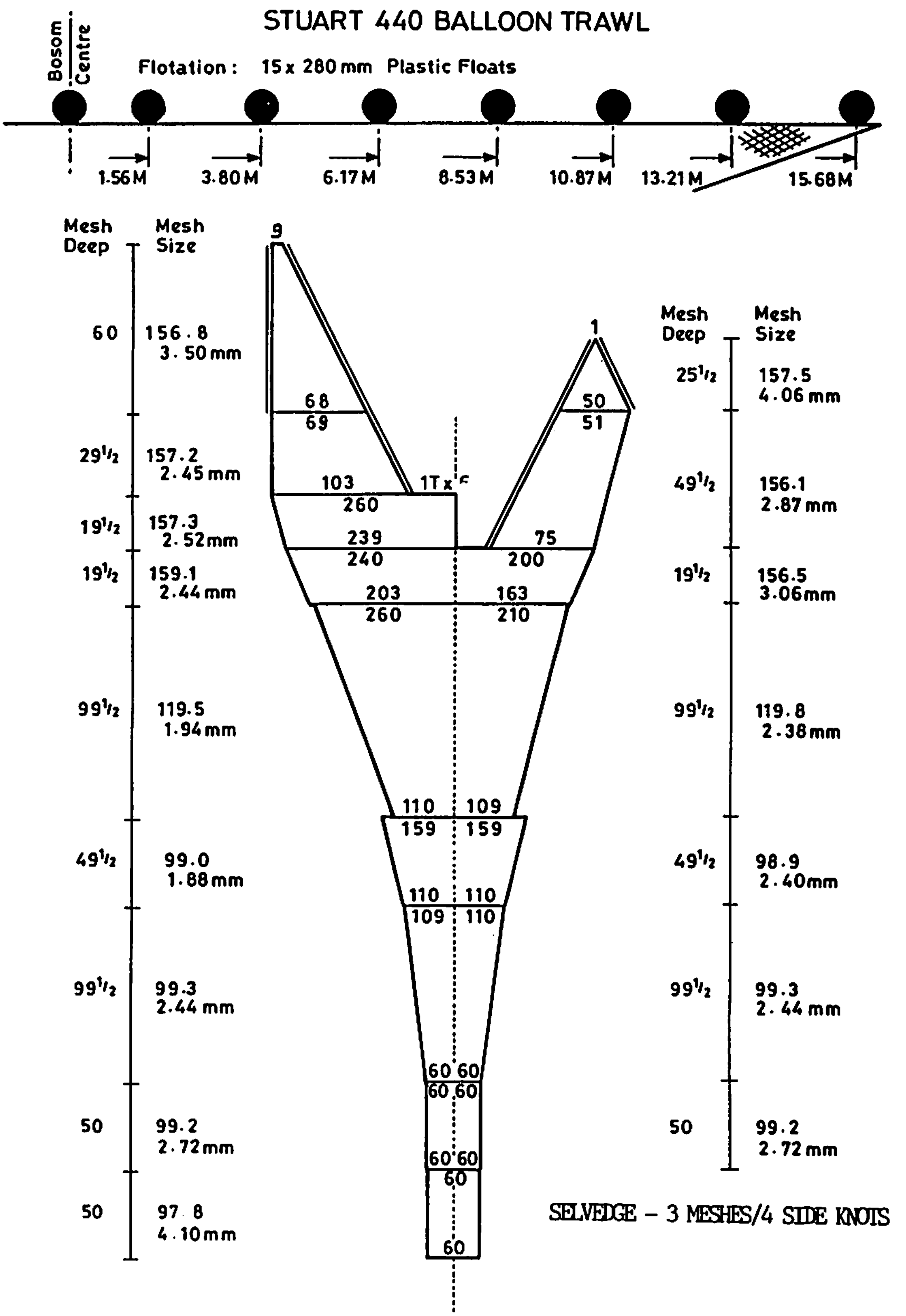
# APPENDIX III

## DRAG OF CODEND MODELS

| MODEL 1 - BLUE PE - 1.59mm twine diameter | | | |
|---|---|---|---|
| RING | SPEED | | DRAG |
| Diameter mm | Full Scale - Knots | Model - m/sec | Kgs |
| 250 | 2.0 | 0.73 | 14.3 |
| 250 | 2.5 | 0.91 | 23.2 |
| 350 | 2.0 | 0.73 | 14.5 |
| 350 | 2.5 | 0.91 | 22.6 |
| 450 | 2.0 | 0.73 | 13.4 |
| 450 | 2.5 | 0.91 | 21.9 |

| MODEL 2 - WHITE PA - 1.46mm twine diameter | | | |
|---|---|---|---|
| RING | SPEED | | DRAG |
| Diameter mm | Full Scale - Knots | Model - m/sec | Kgs |
| 184 | 2.0 | 0.63 | 5.1 |
| 184 | 2.5 | 0.78 | 8.5 |
| 300 | 2.0 | 0.63 | 6.2 |
| 300 | 2.5 | 0.78 | 8.6 |
| 400 | 2.0 | 0.63 | 6.1 |
| 400 | 2.5 | 0.78 | 9.3 |

| MODEL 3 - WHITE PA - 0.52mm twine diameter | | | |
|---|---|---|---|
| RING | SPEED | | DRAG |
| Diameter mm | Full Scale - Knots | Model - m/sec | Kgs |
| 184 | 2.0 | 0.63 | 5.3 |
| 184 | 2.5 | 0.78 | 8.2 |
| 300 | 2.0 | 0.63 | 5.3 |
| 300 | 2.5 | 0.78 | 7.9 |
| 400 | 2.0 | 0.63 | 6.7 |



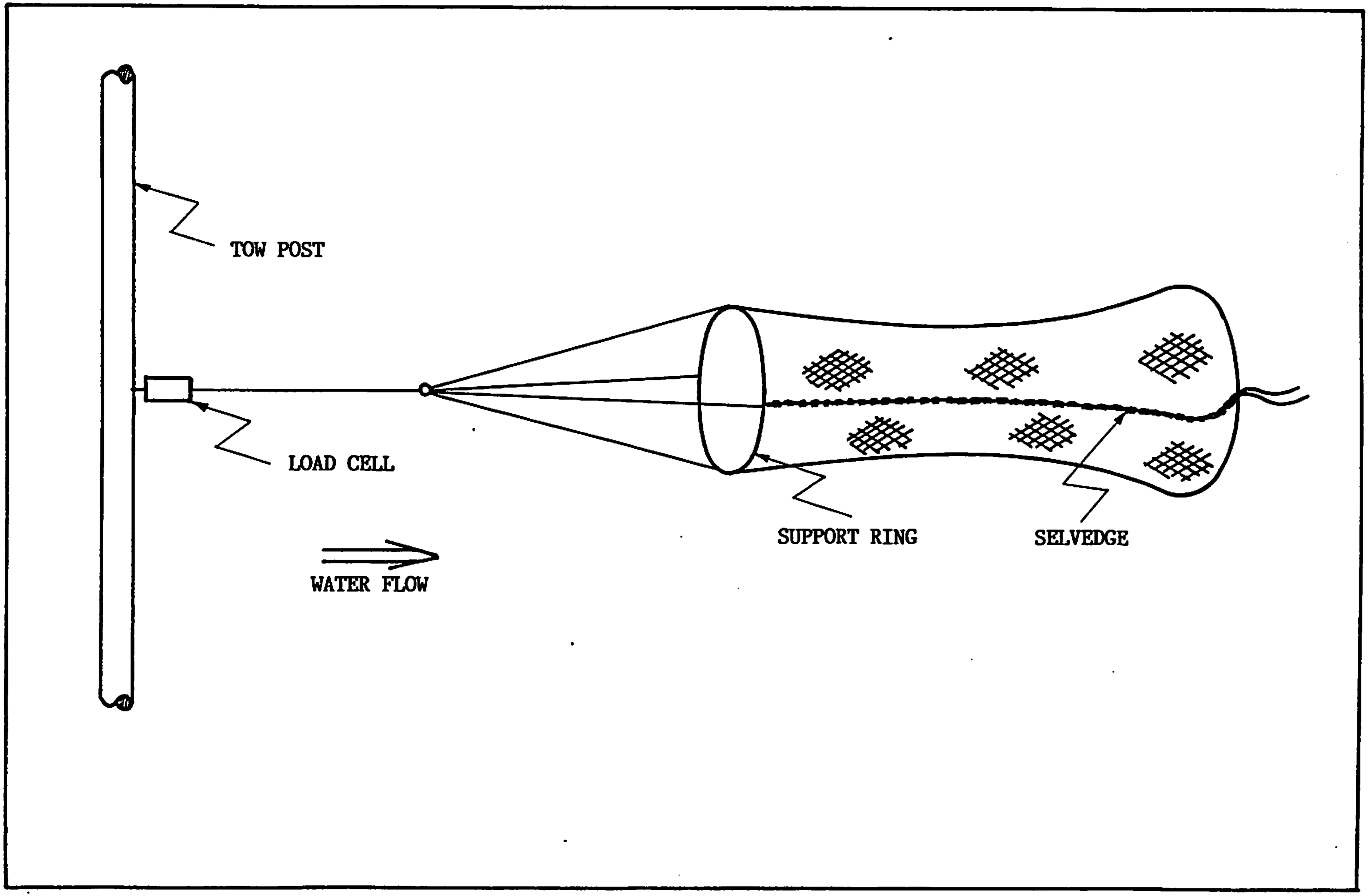

HEADLINE – 16mm COMBO 3.60 M BOSOM 14.40 M WING 0.50 M EXTENSION

FISHING LINE – 14+16 mm COMBO 3.60 M BOSOM 11.87 M WING 0.55 M EXTENSION

FISHING LINE EXTENSION 18 mm COMBO 5.56 M CHAIN 0.20 M

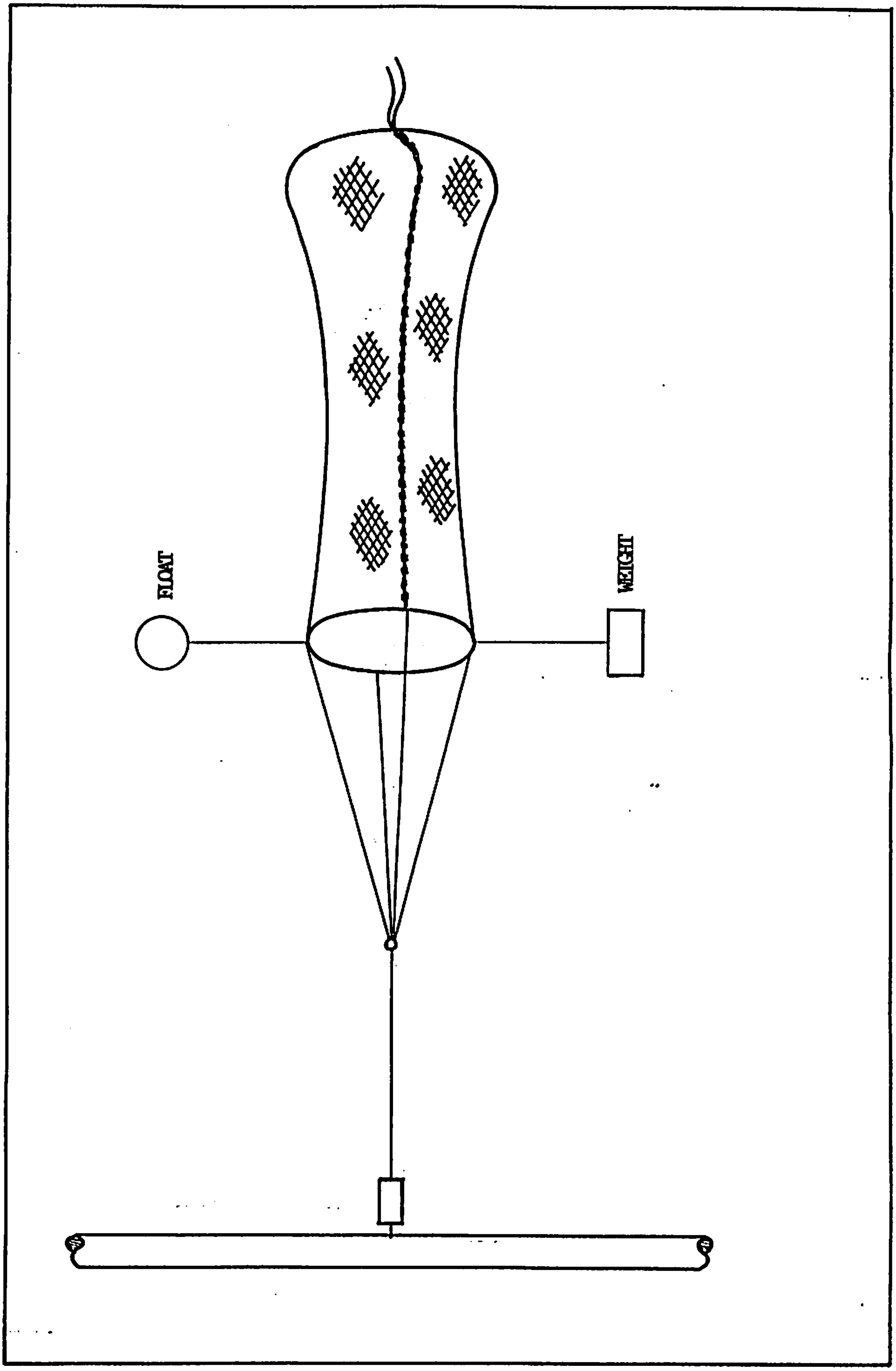
WING LINES 24 mm POLYPROP ROPE 8.75 M TOP 3.67 M BOTTOM

Net Plan, Flotation and Rope Detail Fig.1

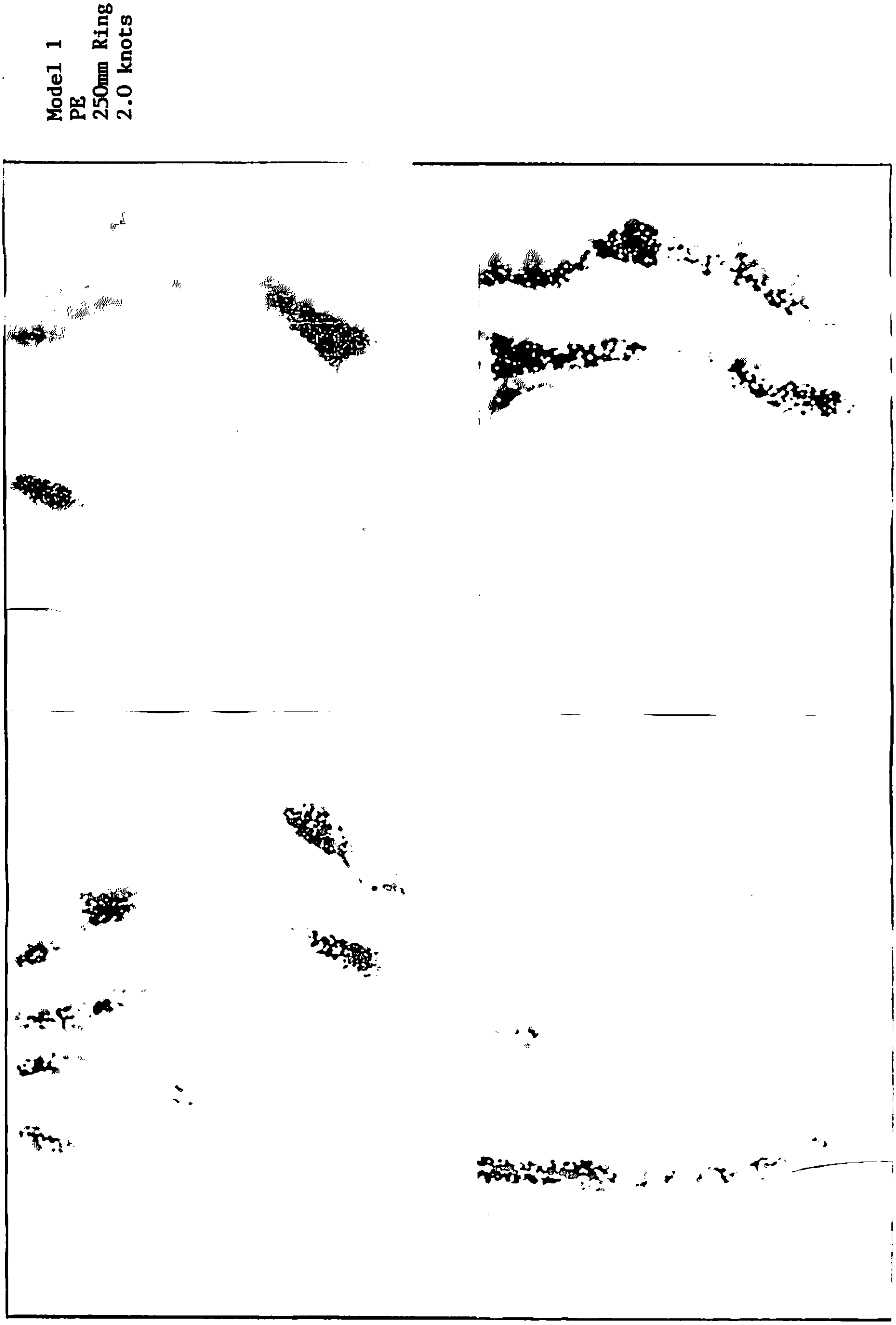



Initial Rigging Arrangement

FIG 2



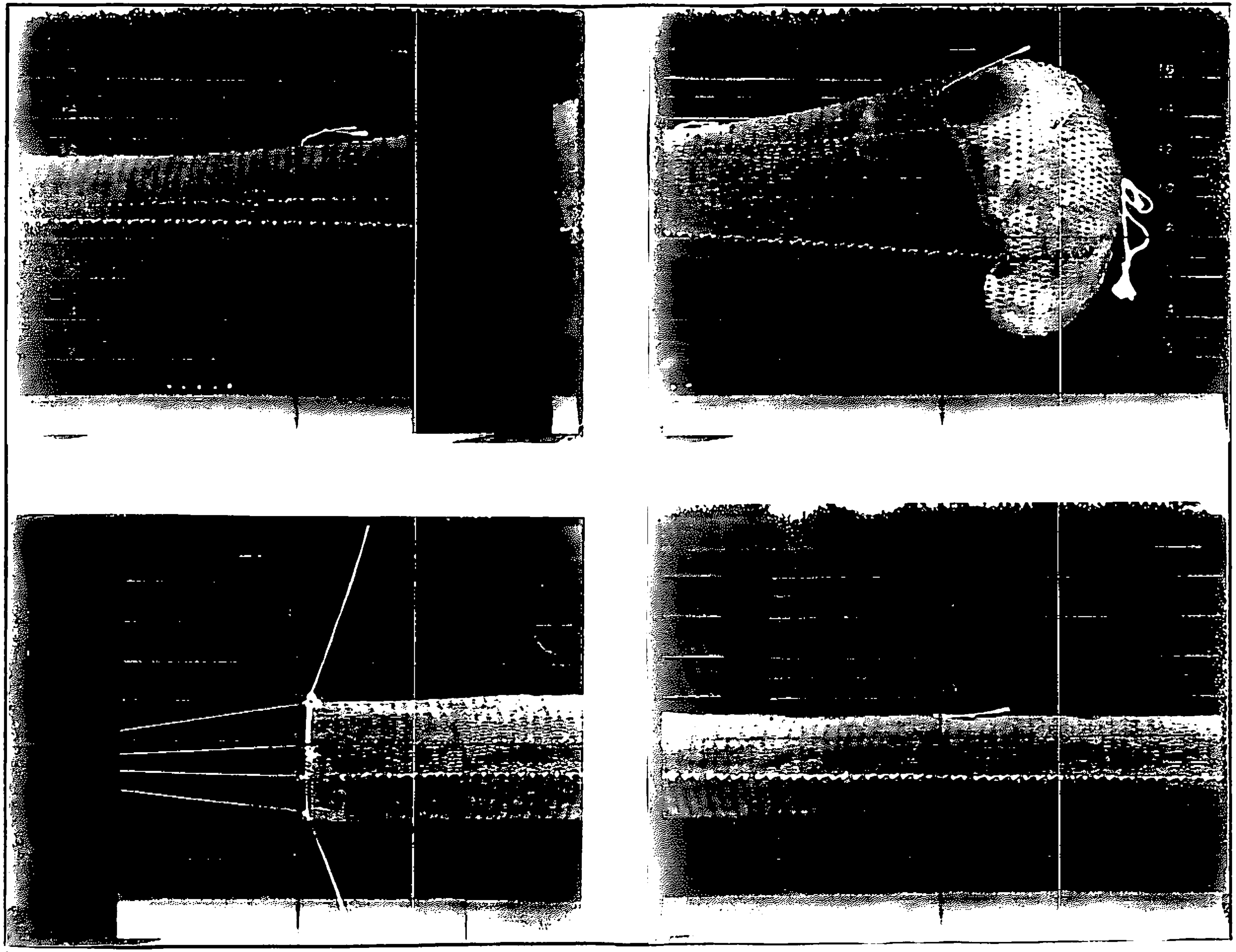

Revised Rigging Arrangement FIG 3




MODEL 1, Polyethylene, 250mm Ring, 2,0 knots

FIG 4

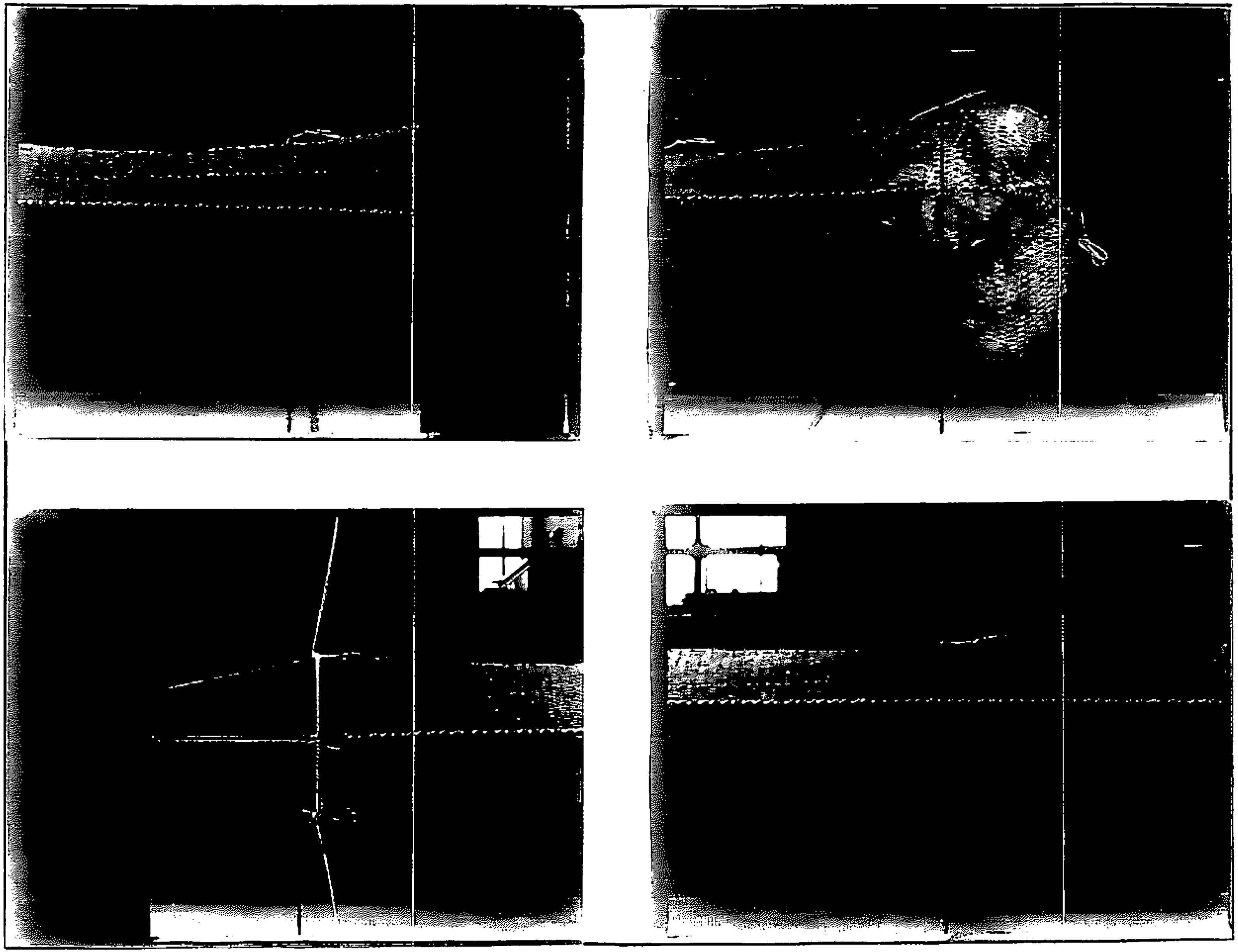
Model 1
PE
250mm Ring
2.5 knots



MODEL 1, Polyethylene, 250mm Ring, 2.5 knots

FIG 5

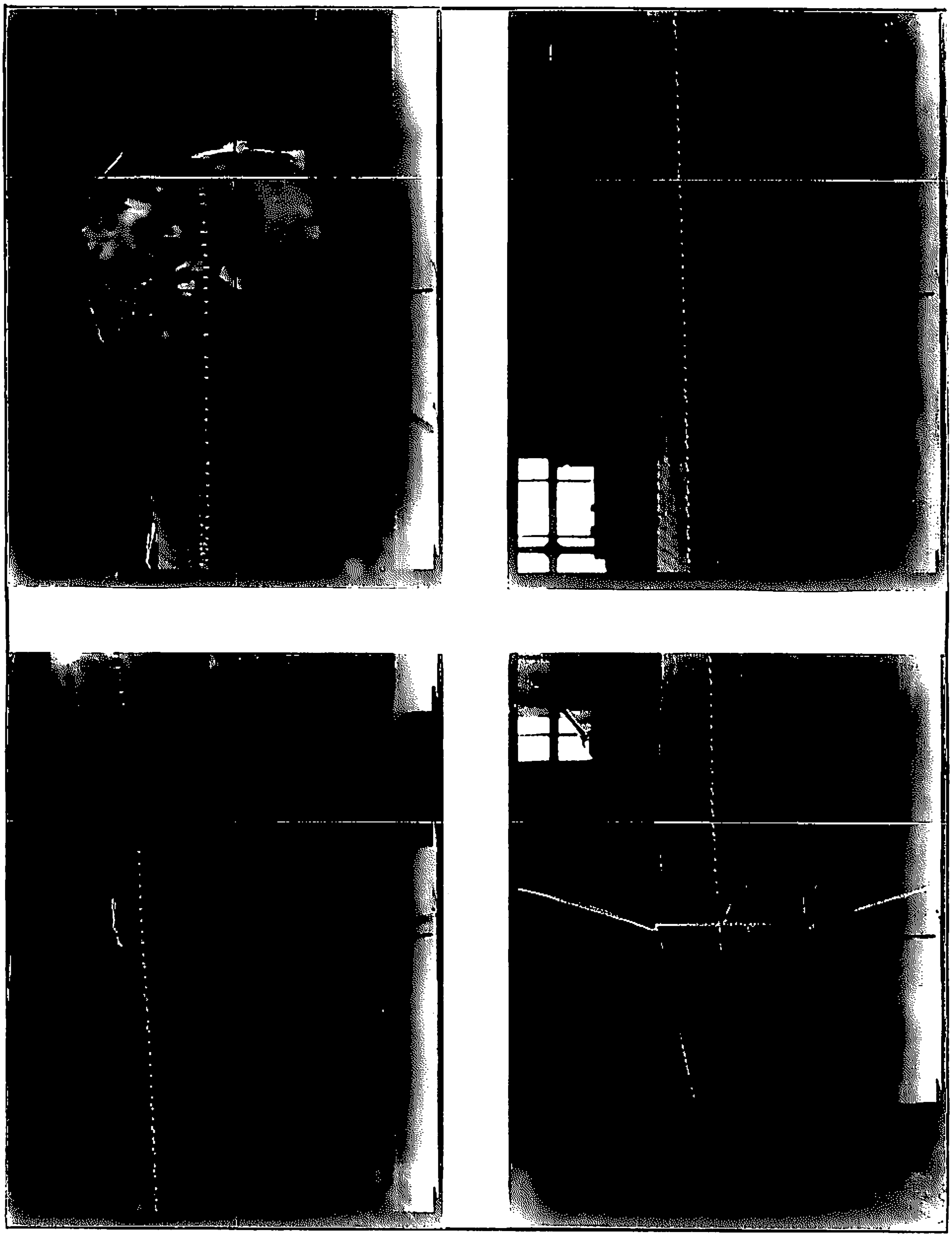
Model 1
PE
350mm Ring
2.0 knots



MODEL 1, Polyethylene, 350mm Ring, 2.0 knots

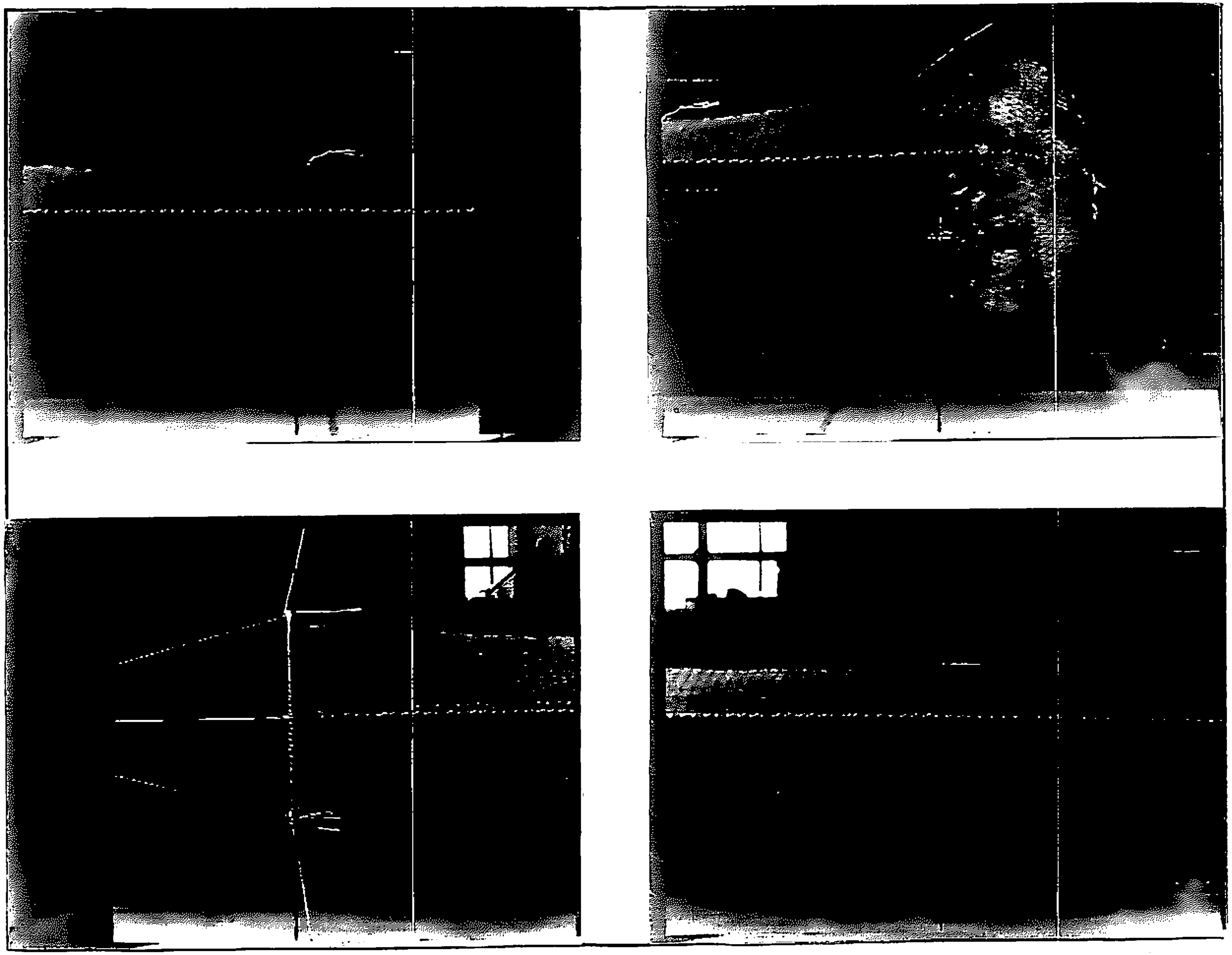
FIG 6

Model 1
PE
350mm Ring
2.5 knots



MODEL 1, Polyethylene, 350mm Ring, 2.5 knots

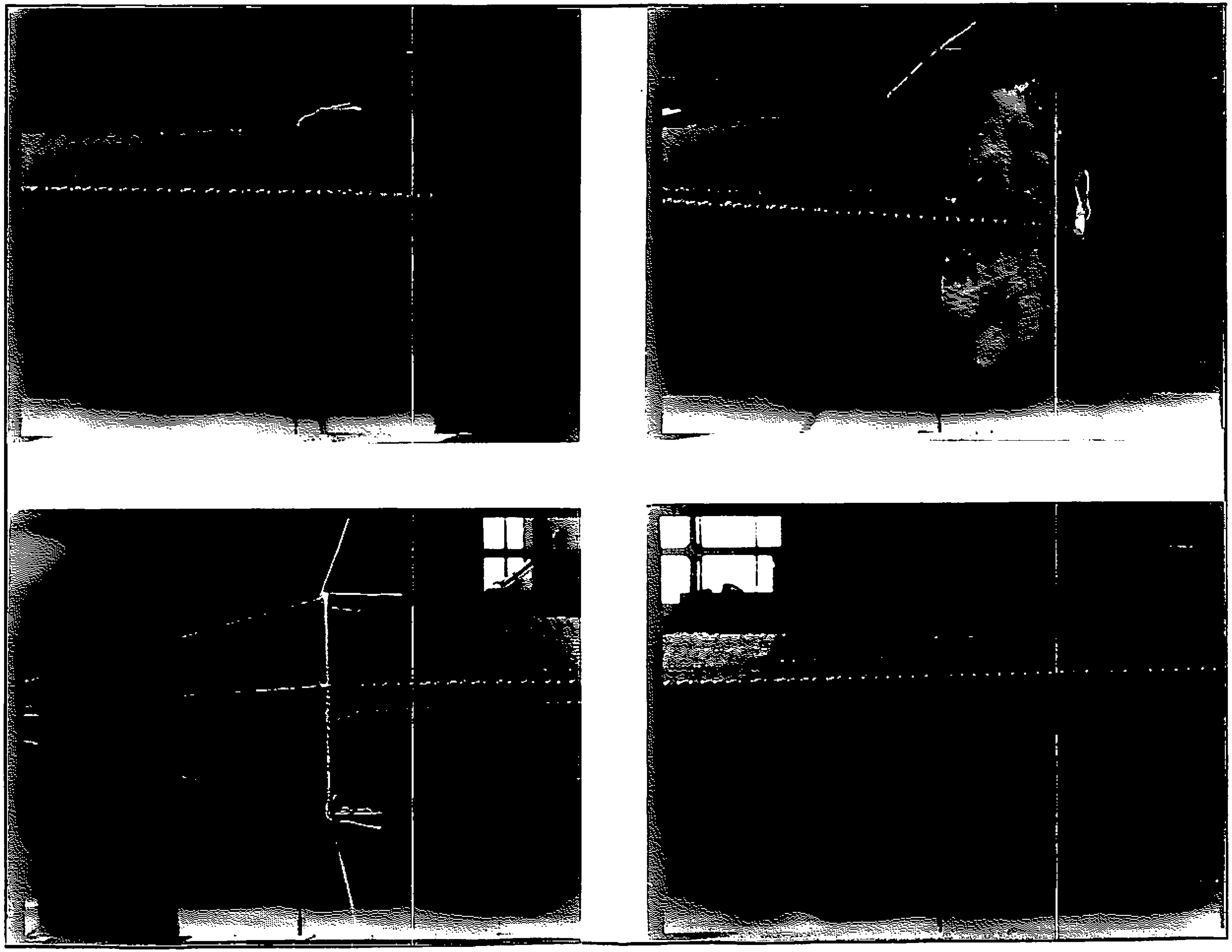
FIG 7



Model 1
PE
450mm Ring
2.0 knots

MODEL 1, Polyethylene, 450mm Ring, 2.0 knots

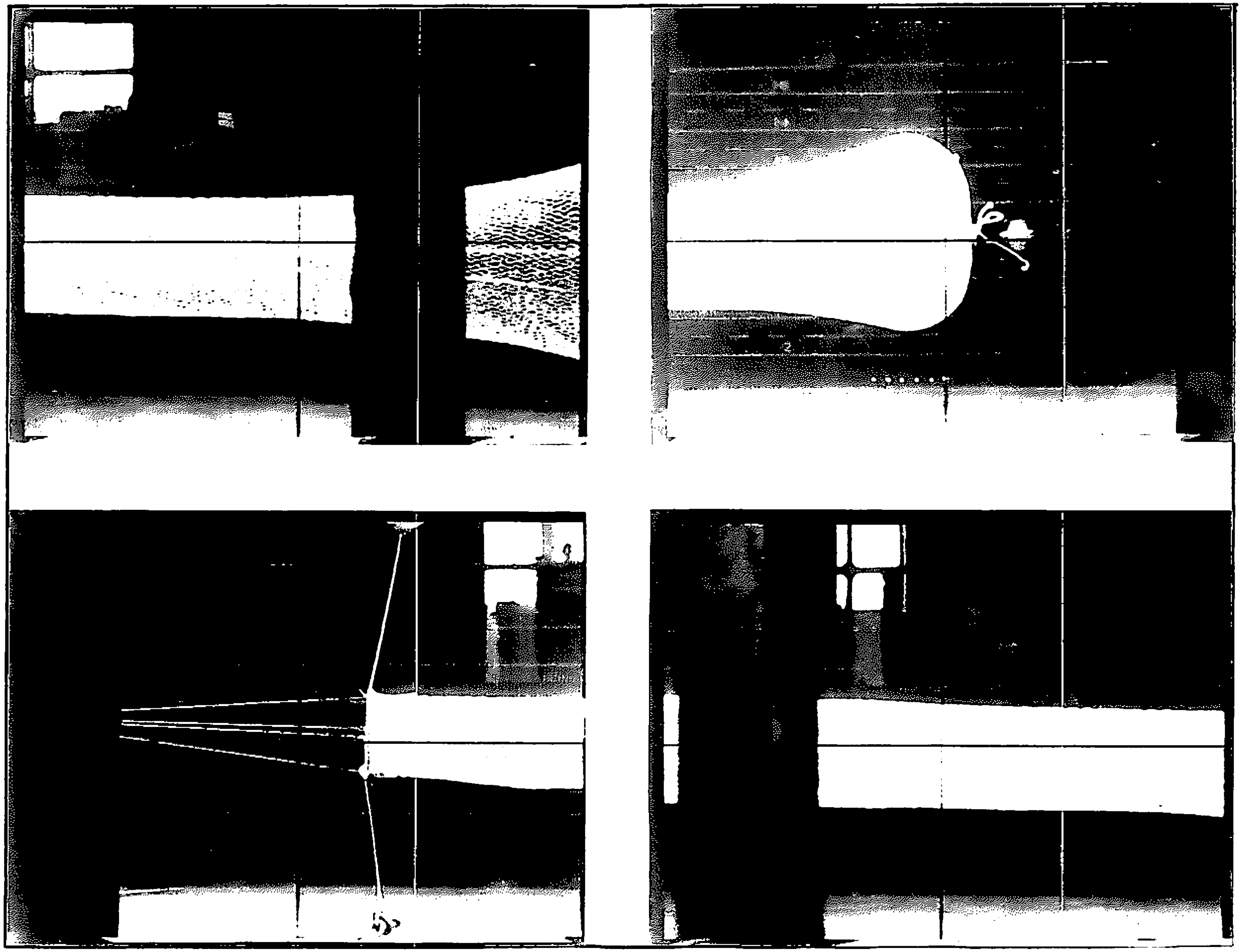
FIG 8



Model 1
PE
450mm Ring
2.5 knots

MODEL 1, Polyethylene, 450mm Ring, 2.5 knots

FIG 9

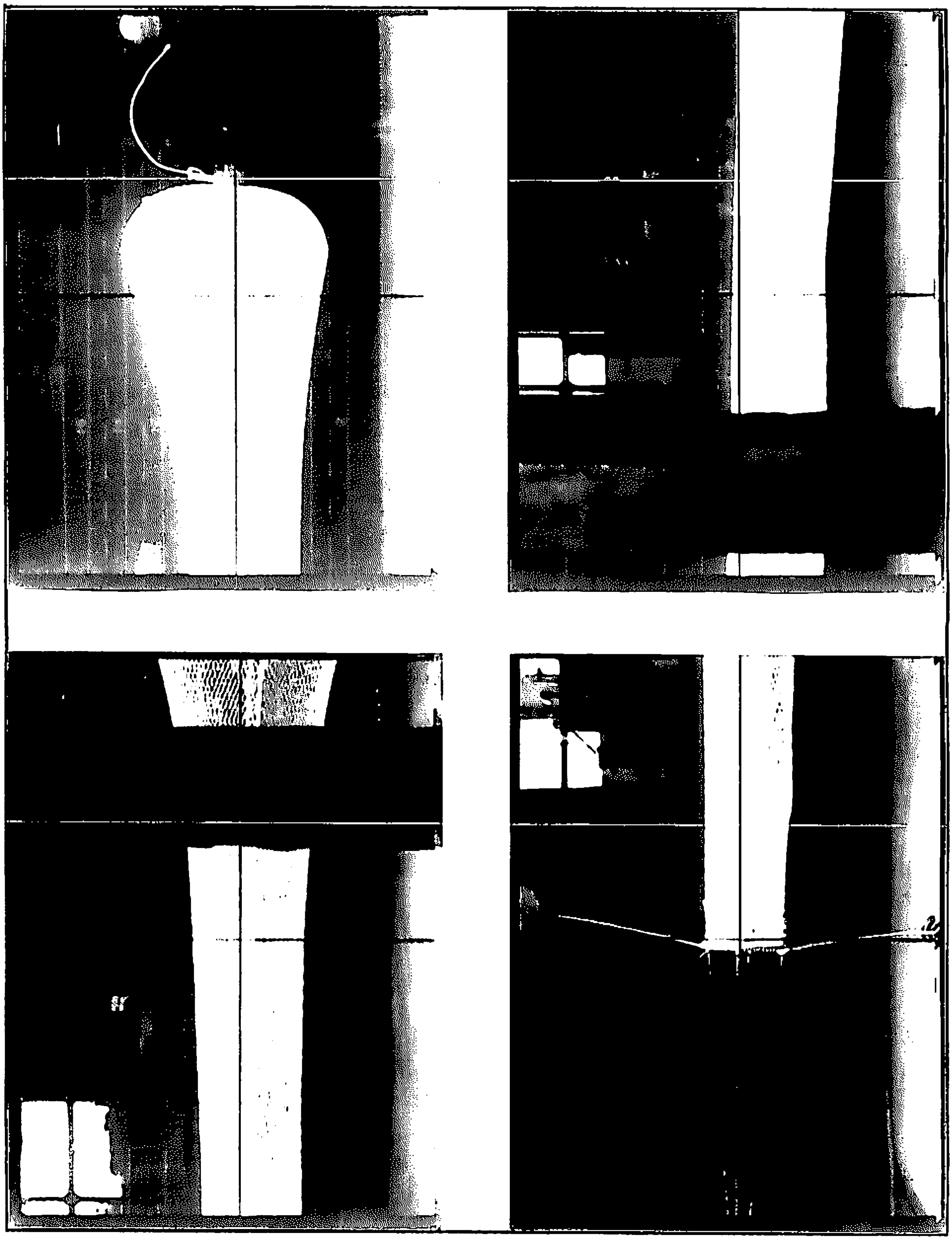


Model 2
PA
184mm Ring
2.0 knots

MODEL 2, Polyamide, 184mm Ring, 2.0 Knots

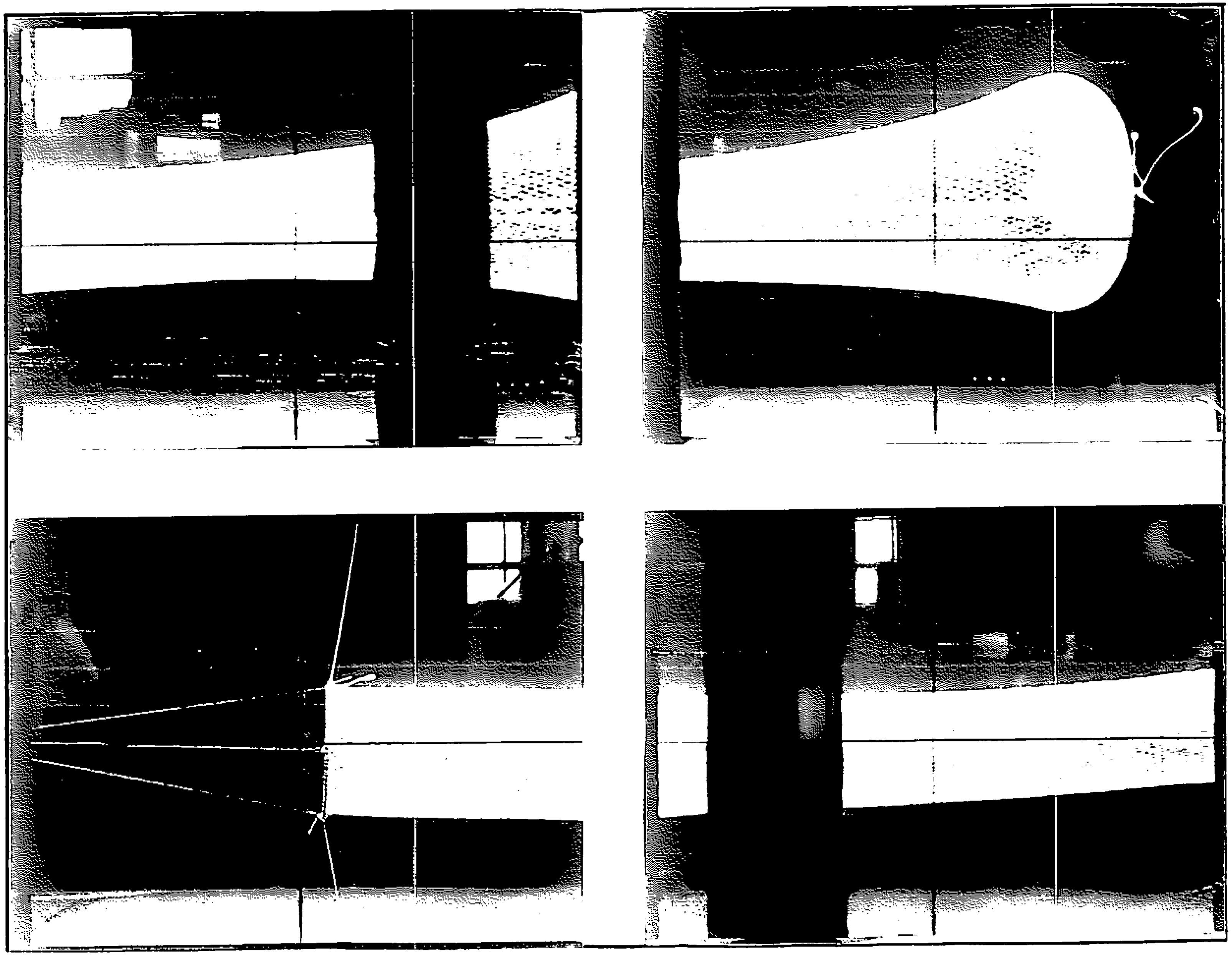
FIG 10

Model 2
PA
184mm Ring
2.5 knots



MODEL 2, Polyamide, 184mm Ring, 2.5 knots

FIG 11

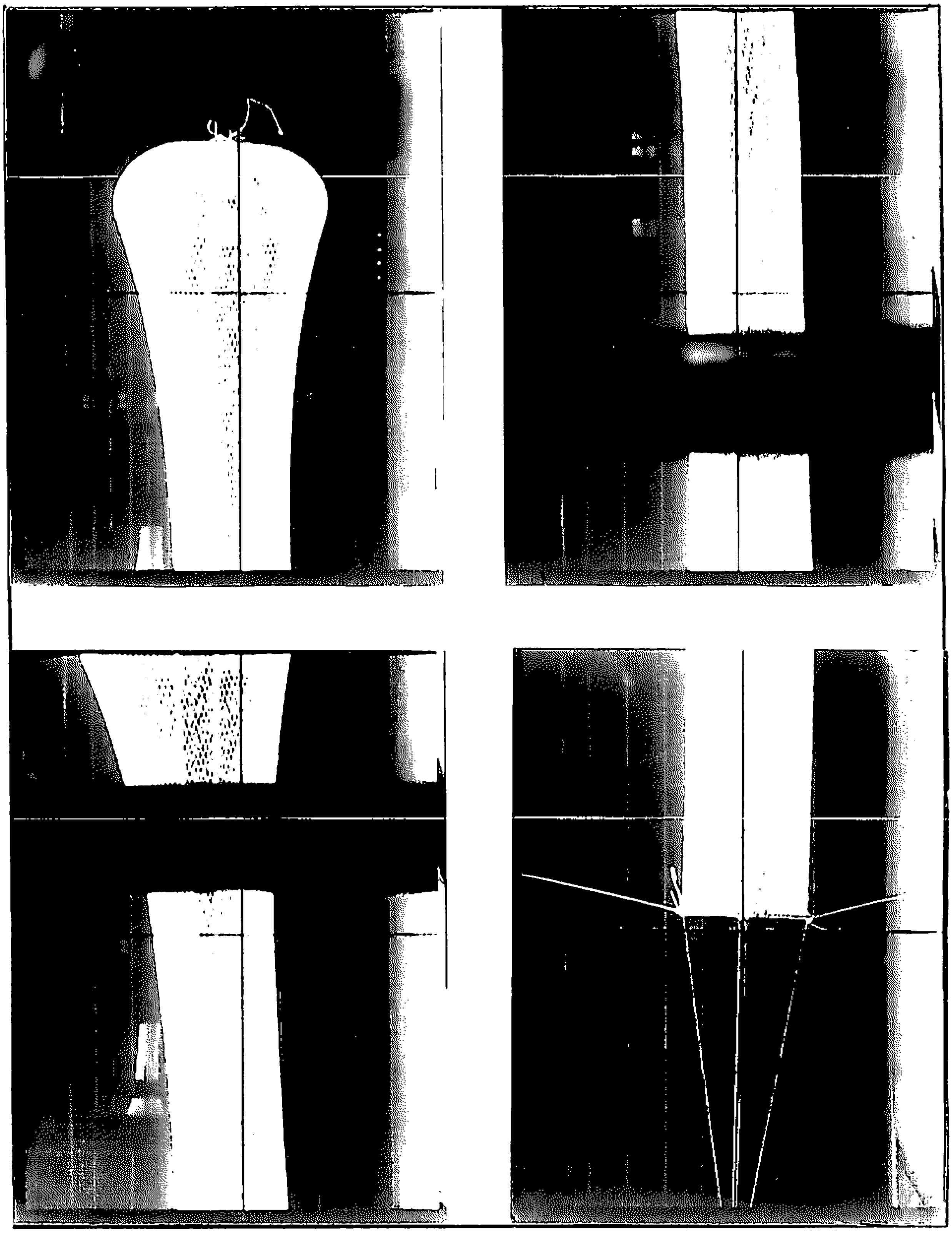


Model 2
PA
300mm Ring
2.0 knots

MODEL 2, Polyamide, 300mm Ring, 2.0 knots

FIG 12

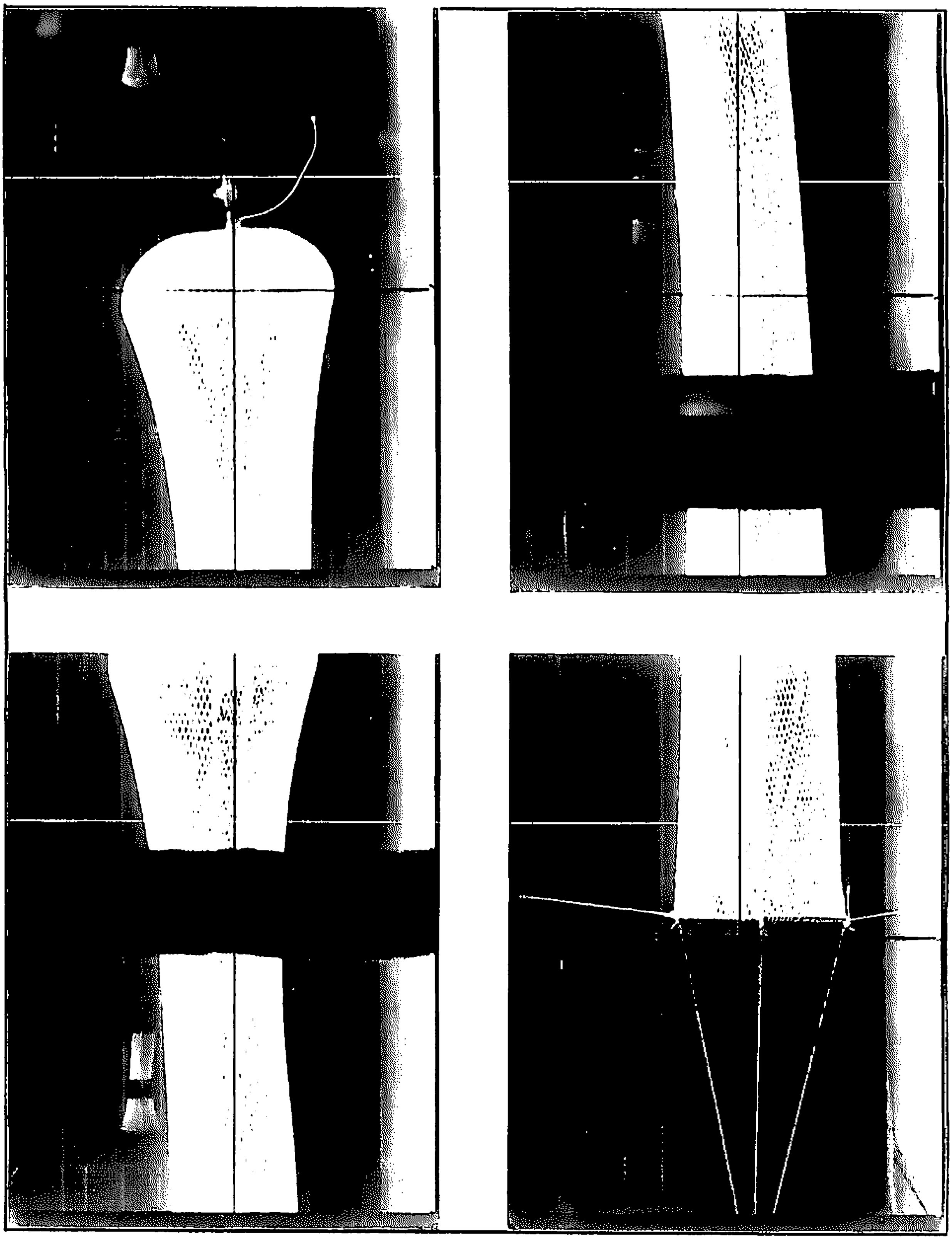
Model 2
PA
300mm Ring
2.5 knots



MODEL 2, Polyamide, 300mm Ring, 2.5 knots

FIG 13

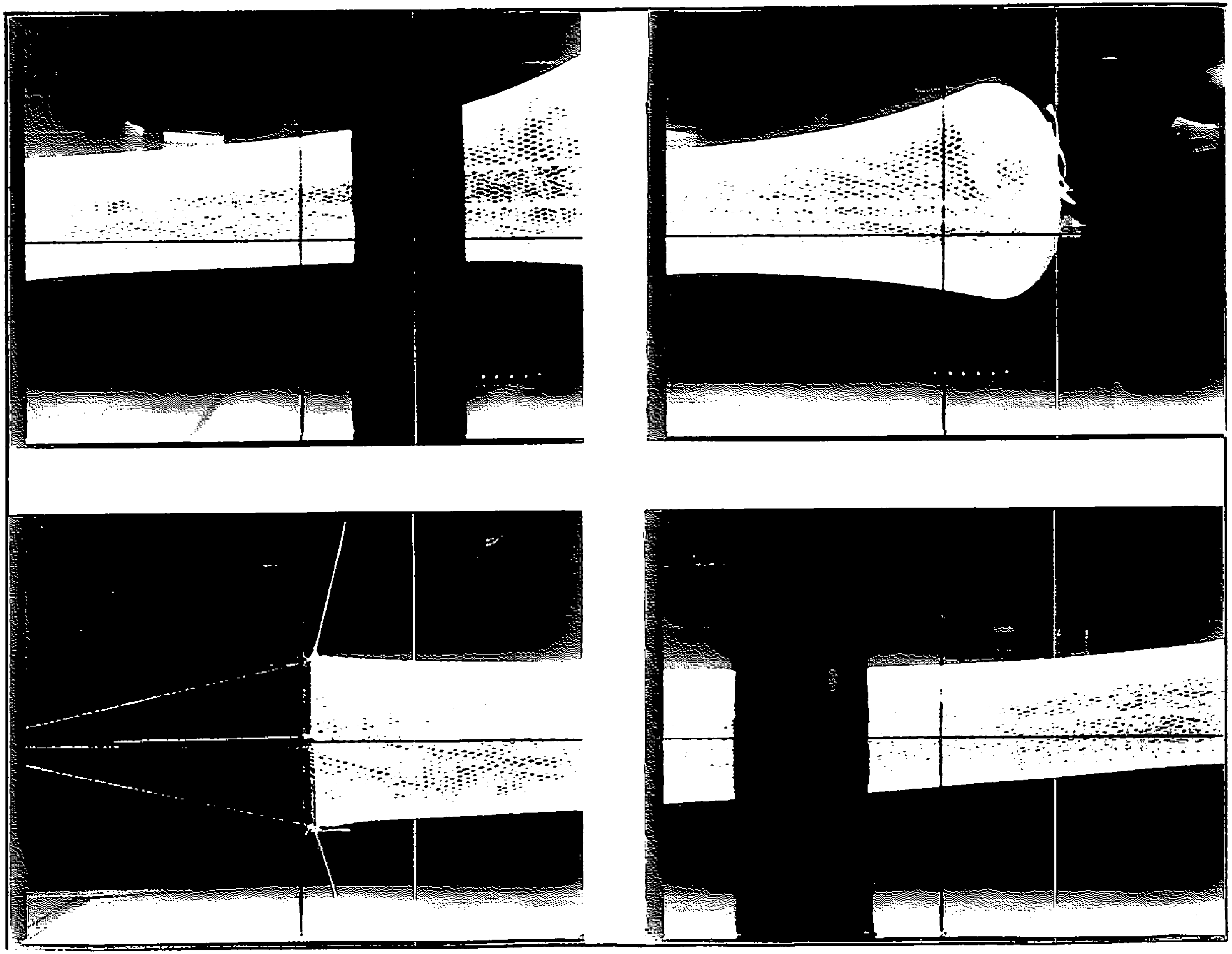
Model 2
PA
400mm Ring
2.0 knots



MODEL 2, Polyamide, 400mm Ring, 2.0 knots

FIG 14

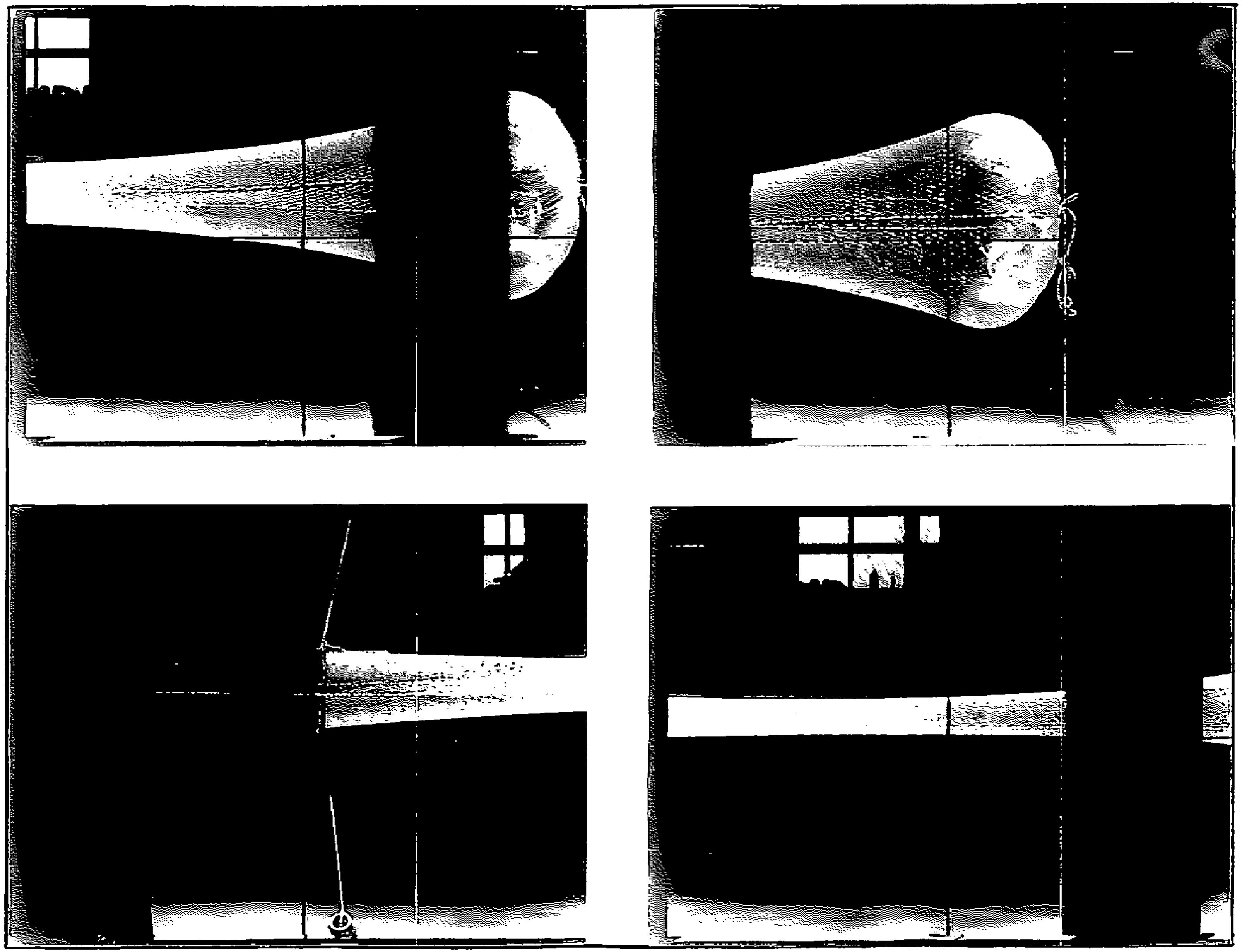
Model 2
PA
400mm Ring
2.5 knots



MODEL 2, Polyamide, 400mm Ring, 2.5 knots

FIG 15

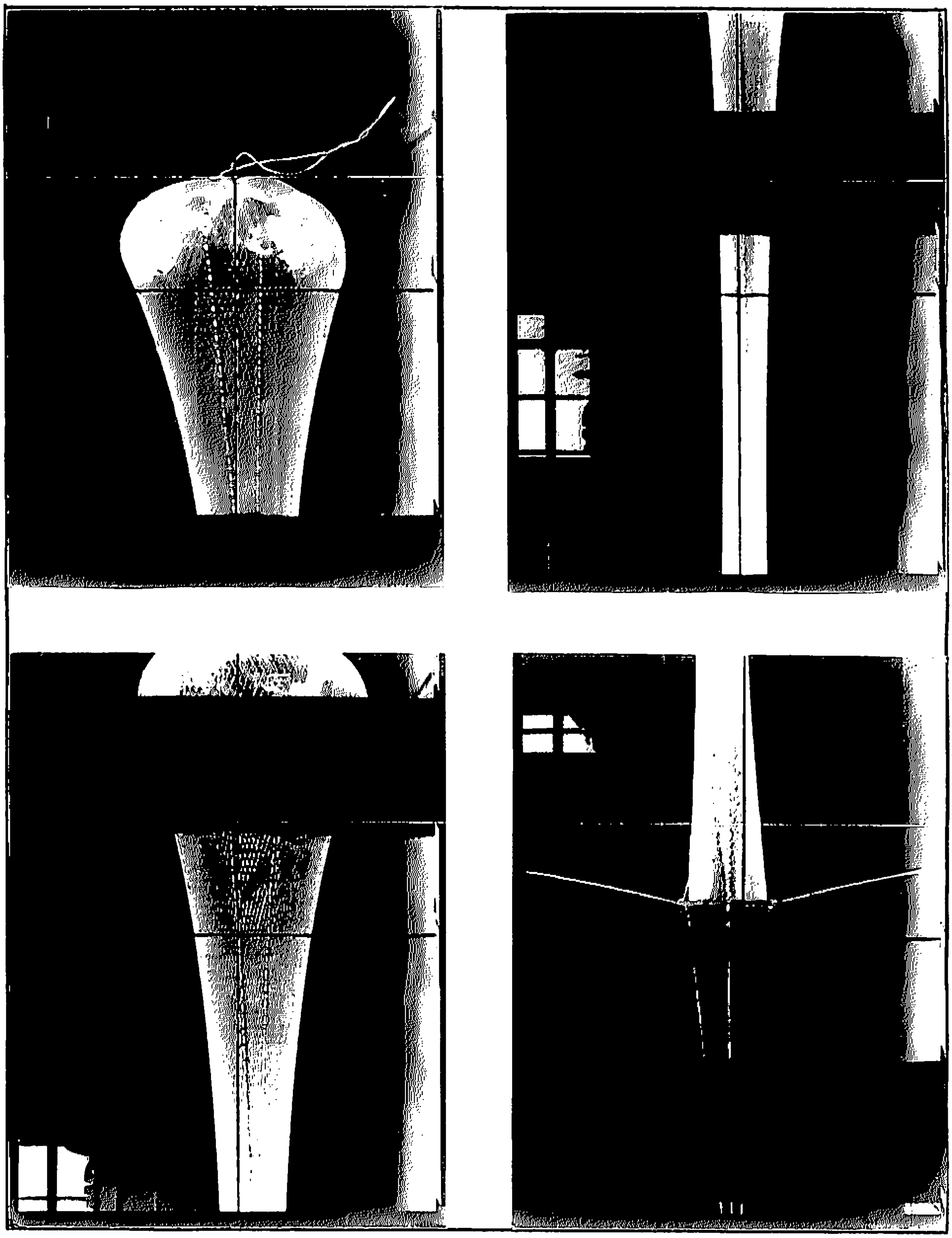
Model 3
PA
184mm Ring
2.0 knots



MODEL 3, Polyamide, 184mm Ring, 2.0 knots

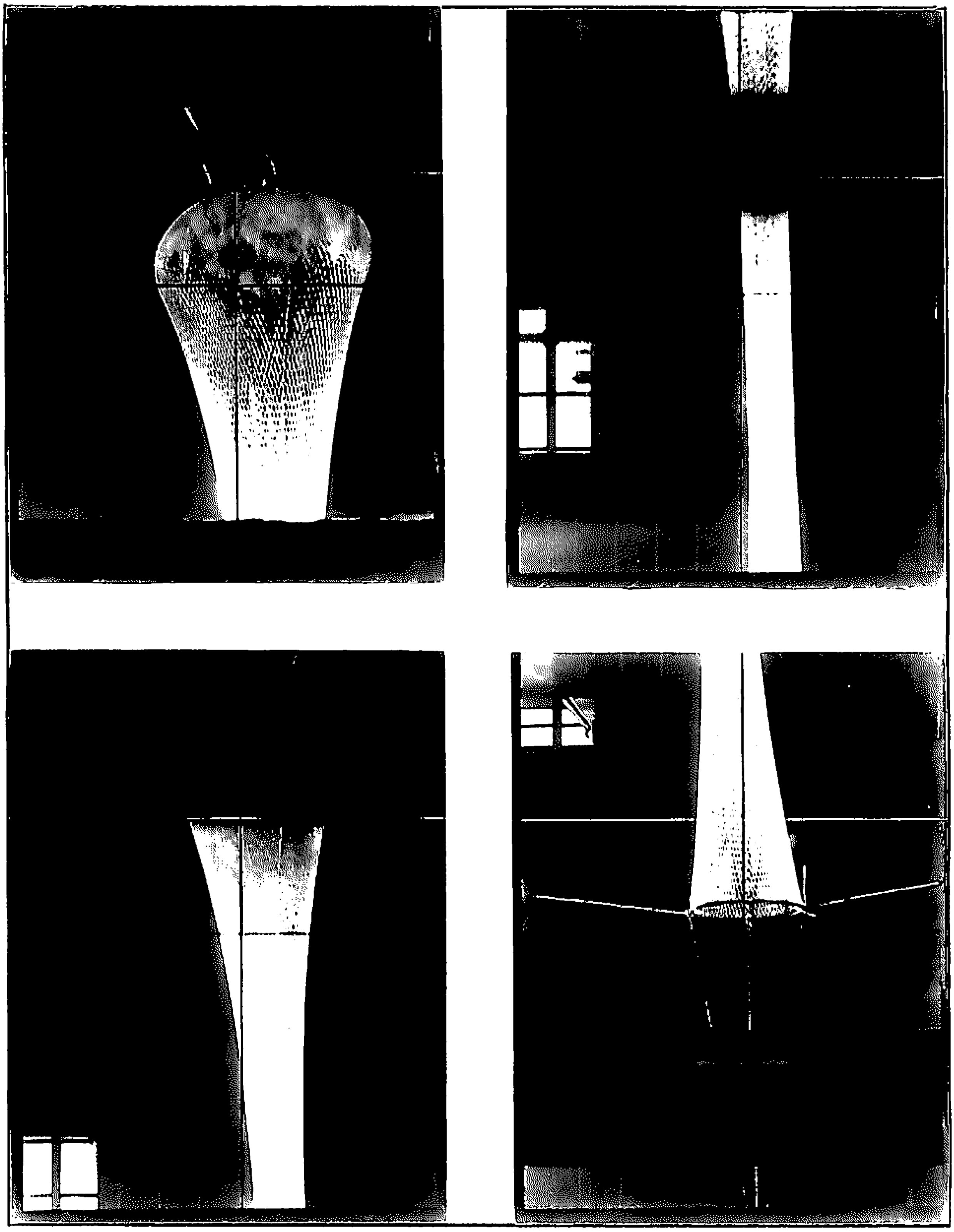
FIG 16

Model 3
PA
184mm Ring
2.5 knots



MODEL 3, Polyamide, 184mm Ring, 2.5 knots FIG 17

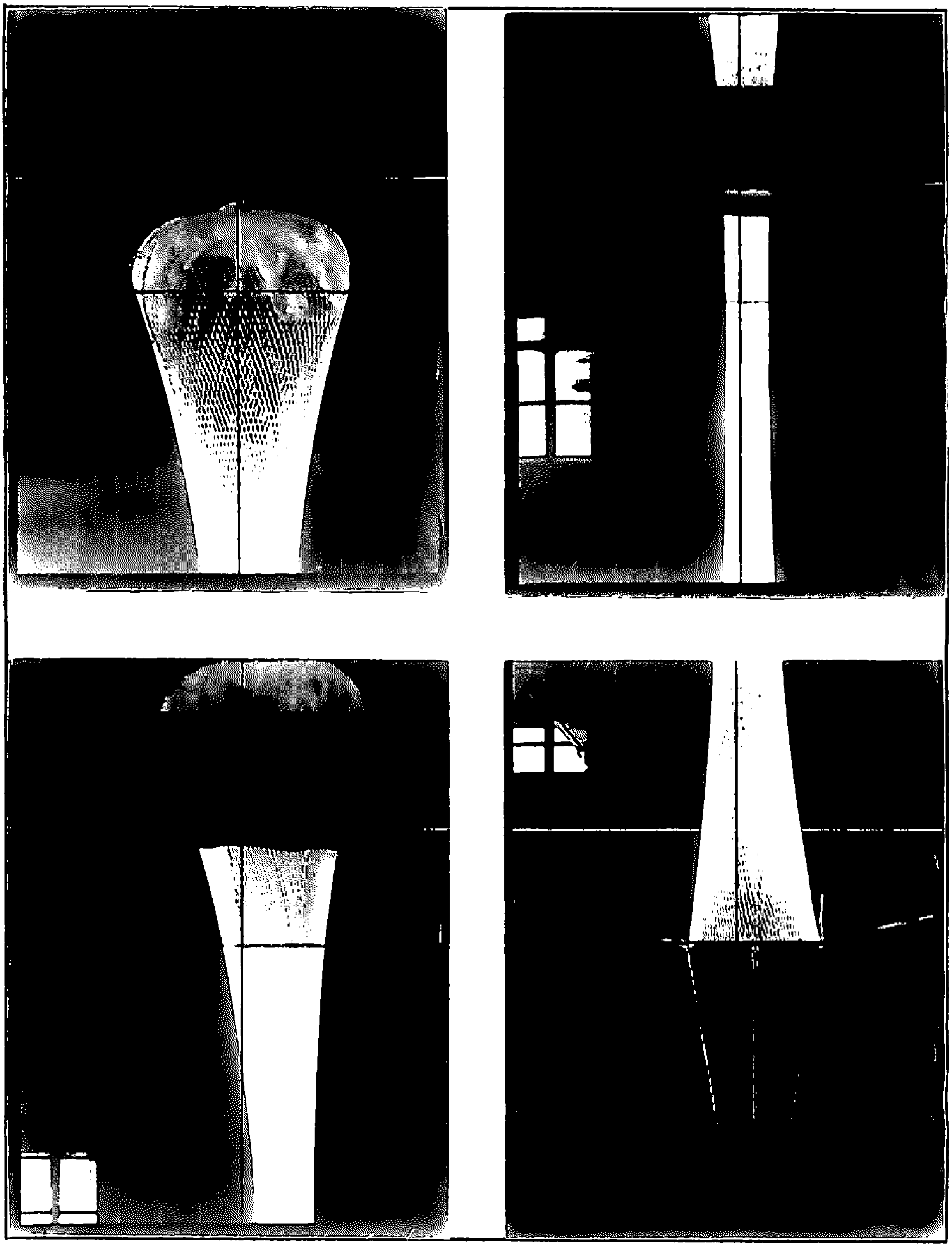
Model 3
PA
300mm Ring
2.0 knots



MODEL 3, Polyamide, 300mm Ring, 2.0 knots

FIG 18

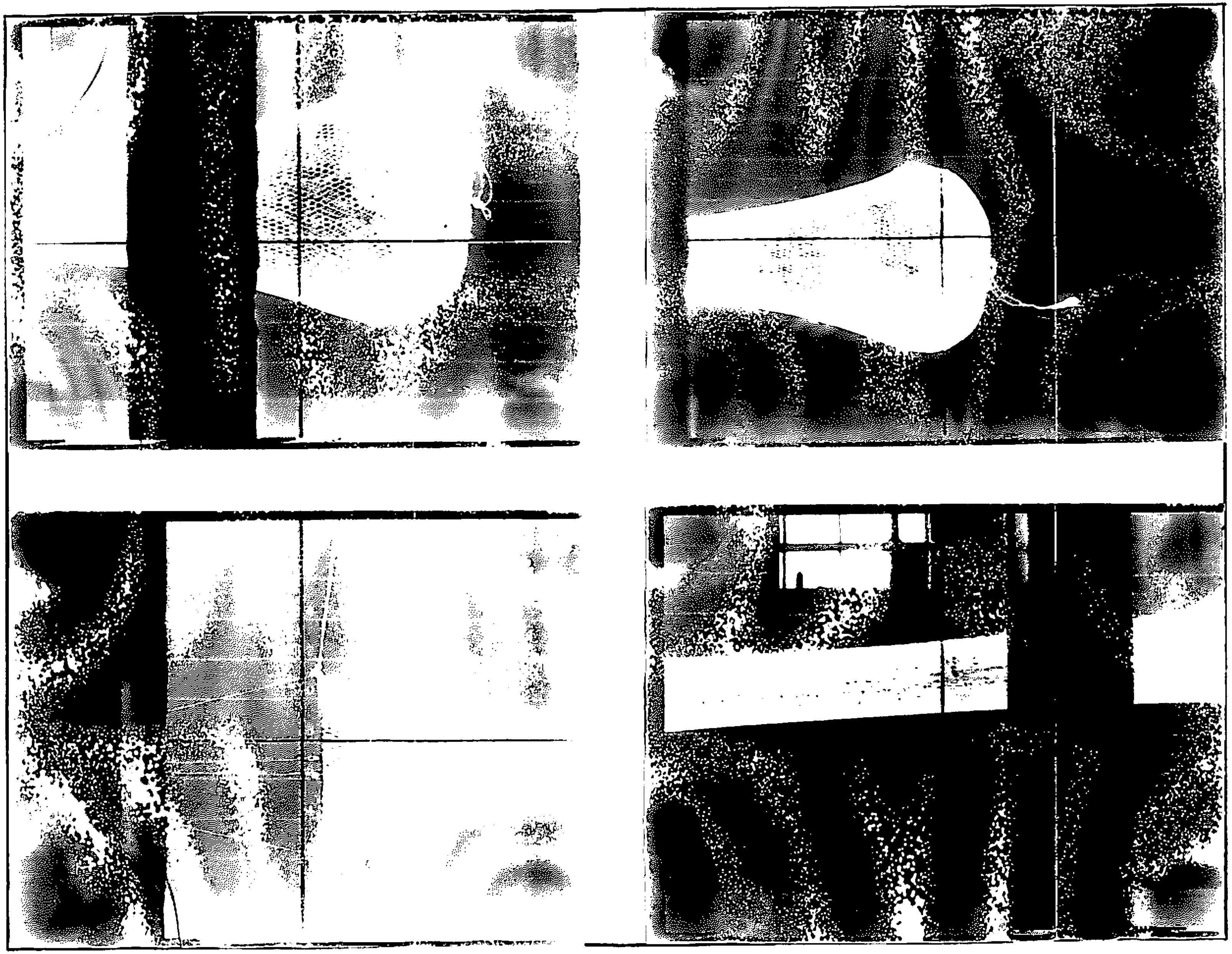
Model 3
PA
300mm Ring
2.5 knots



MODEL 3, Polyamide, 300mm Ring, 2.5 knots

FIG 19

Model 3
PA
400mm Ring
2.0 knots



MODEL 3, Polyamide, 400mm Ring, 2.0 knots

FIG 20