TOWING TANK TESTS OF THE UF-2 SEAPLANE

The Original Hull and it's Modifications

Volume I

Spray Characteristics

JULY 31, 1961

SHIN MEIWA INDUSTRY CO., LTD.

CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

The present report describes the results of the towing tank tests concerning the spray characteristics of 8% UF-2 hull model and its modification performed in Japan by Shin Meiwa Industry Company Limited under the contract with the Grumman Aircraft Engineering Corporation. The object of the test is to find an effective method in order to minimize the water spray on the hull of the UF-2 flying boat generated during take-off and landing. Three new wooden 8% models were manufactured for the present test: one original UF-2 and the other two modified by the groove type spray suppressor and with spray dam. They were tested in May, June and July 1961, and the towing tank tests in still water and in waves were completed on July 11, 1961.

The present report and the attached two reels of 16 millimeter motion picture film contain the whole test results for the spray characteristics.

II. DESCRIPTION OF TANK, TOWING APPARATUS AND MODELS

A. TANK

Two towing tanks were used.

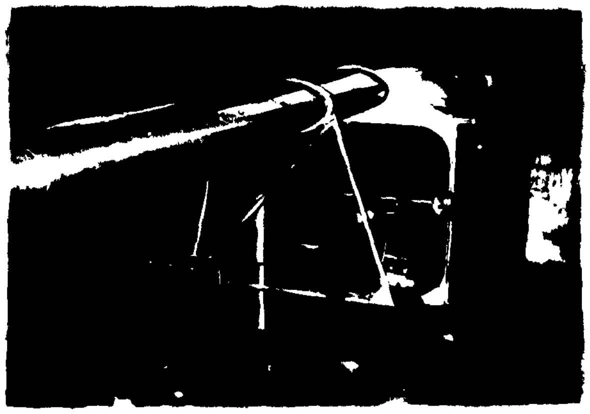
		Length	Width	Depth	Max. Speed	Remarks
Tank	No.1	200m	8 m	4 m	15m/s	no wave generator
Tank	No.2	100m	4.5m.	2.2m	5m/s	with wave generator

Tank No.1 belongs to Transportation Technical Research Institute, Ministry of Transportation, Tokyo(left).

Tank No.2 belongs to Research and Development Institute Japan Defence Agency, 1st Research and Development Center, Tokyo(left).

B. APPARATUS

1. Tank No.1



Towing linkage is of parallelogram type as shown in the left photograph and Fig.1. Resistance is measured by a coil spring type balance and is recorded on a drum. Trim and heave are measured from photographs.

2. Tank No.2

Towing linkage is of the same type as for Tank No.1 described above (photograph on the left and Fig.2). Resistance is measured by a U-type spring balance with dial gauge, while trim, heave and wave height are measured from photographs.

C. MODELS

Three 8% wooden models, namely the original hull, modified hull no. 1 and modified hull no. 2 were used. Table 1 shows the dimensions and Fig. 3 through Fig. 5 show the line drawings of these models. Fig. 6 shows the extent of reconstruction of the hull and Fig. 7 is a drawing showing the location of propellers, flaps and horizontal tail relative to the hull. Fig. 8 is the photographs of the models.

III. TEST RESULTS

The tests were made by towing the model at constant speed in still water and in regular waves. The model was free to pitch and heave with zero aerodynamic pitching moment.

Moment of inertia in pitch, C.G. position, wing lift and take-off speed supplied by the Grumman Company were used with Froude Number scaling. Fig. 9 shows the load on water.

Test cases are presented in Table II.

The height of spray was measured by snap photographs and 16 millimeter motion picture and was also observed on the running carriage. The results of the test are all included in the present report and two reels of 16 m/m motion picture.

A. SPRAY IN STILL WATER

The first spray test was performed in tank No. 1, using the original model and the Modification No. 1. The gross weight was 34,000 pounds and 36,000 pounds. The spray was photographed at 10 speeds, from 6.9 knots to 68.7 knots, every 7 knots. The results are shown in Figure 10a,b and in Figure 11a,b.

According to the figures, there is no spray problem in still water up to 10 knots. At 13.7 knots and 20.6 knots, comparatively heavy sprays were generated in front of the propeller plane on the original model. These sprays were effectively suppressed in Modification No. 1. At 27.5 knots and 34.4 knots spray approaches the flap and hits it on both the original model and the Modification No. 1. At these two speeds sprays touched the tail lightly with G.W. 36,000lbs. Two models were very clean at speeds above 41.2 knots.

The sprays with a gross weight of 36,000 pounds are somewhat higher than those with 34,000 pounds. However, the general pattern of the spray is very similar with the two gross weights.

To study the spray in still water more closely, the second spray test was performed in Tank No. 2, with the original model, Modification No. 1 and Modification No. 2. They were tested at 10 speeds from 0 to 31 knots, at every 3 knots. The test results are shown in Figure 12a,b and in Figure 13a,b. In the same figures the tests with a model of the Modification No. 2 are also shown. The spray photographs of the 3 models in the same condition, that is, with the same gross weight and the same speed are arranged in line for the convenience of comparison.

According to the photographs the spray up to about 10 knots is very small. At 10.3 knots a small blister spray is generated near the bow side on the original model. There is almost no spray in Modifications No. 1 and No. 2 at this speed. At 13.7 knots, 17.2 knots and 20.6 knots, high blister sprays were generated in front of the propeller plane. As the suction of the running propeller is very strong at full throttle and at such low speeds, these blister sprays will be sucked into the propeller plane and may damage the propeller and engines will become very wet on the original model.

In Modifications No. 1 and No. 2, the groove type spray suppressor exhibits a very effective spray suppression and there is no spray which is near the propeller tip on both modifications at these 3 speeds.

At 24 knots, the spray roots of the 3 models move back and the blister spray goes back of the propeller plane. Therefore there will be no propeller spray problem at this speed and above. However, the highest point of the blister spray moves back to the flap position and some amount of spray hit flap on the 3 models.

The rear end of the groove type spray suppressor is at about the propeller plane and at 24 knots the spray suppressor comes out of the water completely and naturally it loses its effectiveness. As the shape of the bottom surface which touches the water at about 24 knots are the same in all the 3 models, the shape of spray is also the same in the 3 models. The blister spray at 24 knots, 27.5 knots and at 31 knots hit the flap comparatively heavily, especially with a gross weight of 56,000 pounds in all 3 models.

At a gross weight of 34,000 pounds the tail is free from spray on all 3 models. However, at 36,000 pounds and between the speeds of 27.5 knots and 31 knots the spray touches the tail lightly.

Modification No. 2 With Spray Dam

A 5-inch spray dam was attached along the chine from the propeller plane to the step on the model Modification No. 2 and was tested.

Up to 20.6 knots the spray characteristics is very similar to the Modification No. 2 without spray dam. At 24 knots the blister spray is lowered by the spray dam and the spray does not hit the flap. At 27.5 knots and 31 knots the height of blister spray is also lower and do not hit flaps. Therefore the spray dam was observed effective at speeds of 24 knots, 27.5 knots and 31 knots in still water. The results are shown in Figure 24a,b.

B. SPRAY IN WAVES

The results of the spray test in waves are contained in the motion picture.

The test cases are as shown in Table II. Each frame of the motion picture was closely investigated and the frames which contain the most severe spray condition were picked up, and snap photographs were made.

In the Fig. 14 through Fig. 23, 3 spray photographs of the 3 models in the same test condition was arranged in line for the convenience of comparison.

According to the photographs there were no spray problems for all models at speeds up to 7 knots. At 7 knots and 11 knots, the bow of the original model digs a little into the wave crest and some solid water creeps up on the bow deck. This does not occur on the Modifications No. 1 and No. 2. The bow deck of the two models are free from water.

In the original model, between 14 knots and 24 knots, high blister sprays are generated in front of the propeller plane. Judging from the photograph, this spray will be sucked up by the running propeller. At about 17 knots, the spray is highest. In Modifications No. 1 and 2, these sprays are effectively suppressed and there is no spray which is near the propeller tip. The effect of the spray suppressor is the most remarkable at this speed range.

Between 24 knots and 31 knots, sprays hit the flaps in the three models. Since the spray suppressor which is cut from the bow to the propeller plane comes out of the water surface completely at 24 knots, the shapes of bottom surface which touch the water above this speed are the same in the three models, the shapes and heights of spray are also the same.

At 31 knots in all the 3 models the spray approaches the tail plane and occasionally touches it but not so heavily.

The effect of 5-inch spray dam, which is attached along the chine from the propeller plane to the step on the Modification No. 2 model was tested. The spray dam lowered the spray height a little at 24 to 31 knots, but not so low as to make the flap free from sprays.

The height of spray with the gross weight of 30,000 pounds is somewhat higher than with the gross weight of 34,000 pounds. However, the difference is not so large.

By increasing the wave height from 2 feet to 3 feet, the height of spray is somewhat increased, but not so large.

With the same gross weight and wave height, the spray height is a little higher in short wave lengths in the range of the present test.

IV. DISCUSSION

The results of the spray test are discussed from the standpoints as follows:

1) Bow Spray
2) Propeller Spray
3) Flap Spray
4) Tail Spray

1) Bow Spray

In still water the bow of the original model causes no spray trouble at low taxiing speed. However in waves, especially in critical wave lengths, when taxiing at 7 to 10 knots, the bow digs lightly into the wave crest and solid water creeps up on the bow deck. This will cause some trouble when taxiing in rough seas, therefore some modification is considered necessary on this point. This was done by elongating the bow by 25 inches in Modification No. 1, and 48 inches in Modification No. 2. The elongation together with the spray groove around the bow solved this problem.

2) Propeller Spray

In the original model heavy sprays are generated at speeds from 14 knots to 24 knots in front of the propeller plane in still water and in waves. This spray will be sucked up by the propeller heavily. Judging from the height and amount of the spray the engine will also become too wet. The propeller spray problem is considered the most serious one.

The groove type spray suppressor which is cut on Modifications No. 1 and No. 2 from the bow to the propeller plane suppressed the spray effectively. As seen in the photographs almost zero spray conditions were realized up to about 24 knots. The effect of the groove type spray suppressor is the most remarkable at this speed range.

By the use of the suppressor the propeller spray problem is considered to be solved completely.

3) Flap Spray

When the speed is increased up to 24 knots, the spray groove which ends at the propeller plane comes out of the water surface and naturally loses its effectiveness. Since no modifications were done along the chine rearward the propeller plane on both Modifications No. 1 and No. 2, the spray at speeds above 24 knots are similar in the 3 models, and sprays hit flap.

It is not impossible to cut the spray groove along the chine further back to the step which will suppress the spray to the flap and tail effectively. However, the bottom surface near the step touches water at high speeds up to the take-off speed. Therefore it is not desirable to have such a groove along the chine which touches the water at high speed. By a separate tank experiment, the water pressure in the groove is about one-half of the speed pressure, therefore the pressure in the groove will be about 30 psi at a speed of 60 knots. Such high pressure in the groove may cause structural troubles on the groove cover. At high speed the spray groove will increase the water drag by about 30% and also affect somewhat on the porpoising stability. This is the reason why the groove was stopped at the propeller plane.

For the suppression of the spray to the flap some other method which is structurally more simple and sturdy is considered to be more adequate. A spray dam is one of the methods. A 5-inch spray dam extending downward vertically at the chine was attached to the Modification No. 2 up to the step and was tested. The test results show that in still water the spray height to the flap is somewhat lowered and even with a gross weight of 36,000 pounds, the top of the spray is almost touching the flap trailing edge fully down.

However, in waves the top of the spray hits the flap as in the case without spray dam. It cannot be said, therefore, that the spray dam solves the flap spray problem completely, however, the spray dam minimizes the flap spray trouble to some extent.

An inboard spray strip as used on the Emily flying boat was tried but it was not successful in the present case.

Since there are no simple methods to solve the flap spray problem which is established at pressent, it is considered that to use the spray dam along the rear half chine of the forbody is a practical method for the present case.

The height of spray dam may be tapered to the step or the end of the spray dam may be a little forward to the step. Since the time available for the present test is limited, the test for the spray dam could not be performed further. Therefore there remains such problems as the effect of spray dam on the water drag at high speed and on the porpoising property of the hull.

4) Tail Spray

At certain speeds sprays touche the horizontal tail plane lightly. It is not considered necessary to adopt some device especially for the tail spray.

V. CONCLUSIONS

The test results show that there are three kinds of spray problem in the original hull with G.W. 34,000lbs and 36,000lbs.

The first one is the bow spray problem when taxiing in waves at low speeds. The second one is the propeller spray at 14 kt to 24 kt both in still water and in waves, which is considered the most serious spray problem. The third one is the flap spray at 24 kt to 31 kt.

The bow spray and the propeller spray problems were solved in either the mod. No. 1 or the mod. No. 2 model.

Particularly the propeller spray problem can be said to be solved almost completely due to the use of the groove type spray suppressor.

However, there is a limit to the effectiveness of the groove type spray suppressor, that is, in shorter wave lengths, where the pitching motion of the hull is so augmented that the descending lower edge of the spray suppressor cover at the bow touches the water surface, the water will creep up along the surface of the suppressor cover and some bow spray will be generated. Owing to the limited capacity of the wave generator in the tank No. 2 such extreme cases of short wave length could not be tested.

Within the range of the wave conditions tested the spray suppressors of the mod. No. 1 and No. 2 displayed a remarkable effect to eliminate the propeller spray and no spray will touch the propellers and the engines.

The effectiveness of the mod. No. 1 and No. 2 are almost the same, however, in the critical short wave lengths mentioned above the mod. No. 1 with higher bow chine may display better spray characteristics.

As to the flap spray the two modifications showed no improvements, since the rear ends of the suppressores are at the propeller plane and no modifications were made on the bottom surface in the rearward portion of the propeller plane.

The spray dam attached to the rear half of the forebody of the mod. No. 2 lowered the hight of flap spray to such an extent that the flap was free from spray in still water, however, in waves the sprays occasionally hit the flap. The effectiveness of the spray dam can not be said perfect, but it is the simplest and the most practical one and could solve the flap spray problem to some extent provided the flap structure is strengthened in a certain portion.

	actual plane	models
overall length (L)	587 inches	47, 49[1], 51[2] inches
maximum beam (B)	95 inches	7.6 inches
L/B	6.18	6.18, 6.44[1], 6.68[2]
gross weight A. B.	34,000lbs. 36,000lbs.	17.4lbs. 18.4lbs.
take-off speed A. B.	70.5kts. 72.5kts.	33.6 ft/sec 34.6 ft/sec
moment of inertia A. B.	97,000 slug-ft² 103,000 slug-ft²	0.318 slug-ft² 0.338 slug-ft²

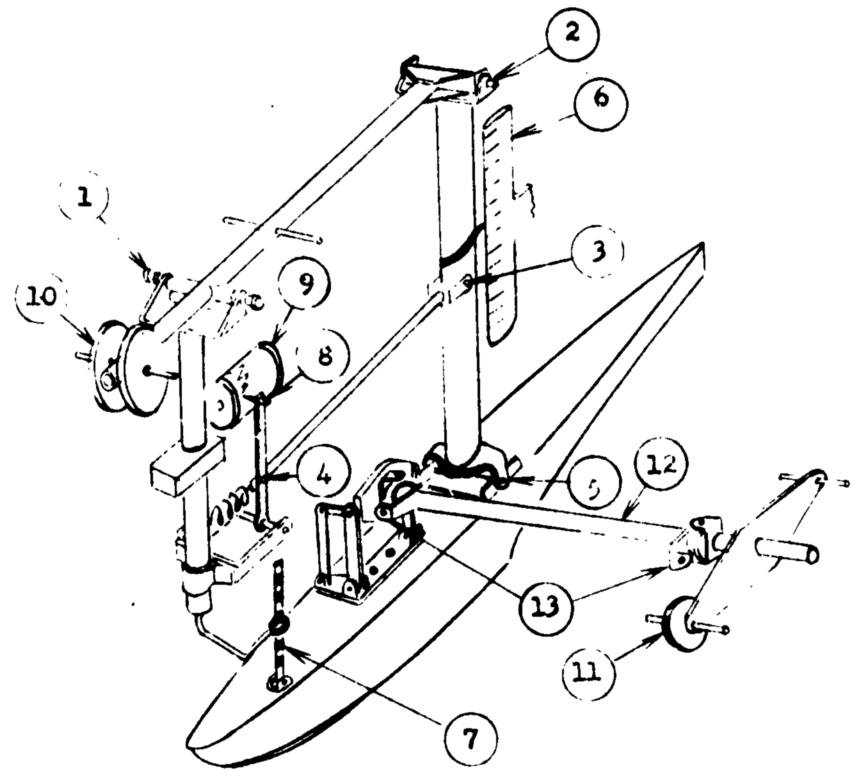
1) modified no.1 model

2) modified no.2 model

Table I. Dimensions of Model.

tank	configuration	gross weight (lbs)	wave (feet)	speed (kts)	results
No.1	original	34,000	still water	6.9, 13.7, 20.6, 27.4, 34.3 41.2, 48.0, 54.9, 61.8, 68.6	Fig.10
		36,000	still water	6.9, 13.7, 20.6, 27.4, 34.3 41.2, 48.0, 54.9, 61.8, 68.6	Fig.11
	mod. no.1	34,000	still water	6.9, 13.7, 20.6, 27.4, 34.3 41.2, 48.0, 54.9, 61.8, 68.6	Fig.10
		36,000	still water	6.9, 13.7, 20.6, 27.4, 34.3 41.2, 48.0, 54.9, 61.8, 68.6	Fig.11
No.2	original	34,000	still water, 2x102, 2x123 2x144, 3x123, 3x144	0, 3.4, 6.9, 10.3, 13.7 17.2, 20.6, 24.0, 27.5, 30.9	Fig.12, Fig.14-18
		36,000	still water, 2x102, 2x123 2x144, 3x123, 3x144	0, 3.4, 6.9, 10.3, 13.7 17.2, 20.6, 24.0, 27.5, 30.9	Fig.13, Fig.19-23
	mod. no.1	34,000	still water, 2x102, 2x123 2x144, 3x123, 3x144	0, 3.4, 6.9, 10.3, 13.7 17.2, 20.6, 24.0, 27.5, 30.9	Fig.12, Fig.14-18
		36,000	still water, 2x102, 2x123 2x144, 3x123, 3x144	0, 3.4, 6.9, 10.3, 13.7 17.2, 20.6, 24.0, 27.5, 30.9	Fig.13, Fig.19-23
	mod. no.2	36,000	still water, 2x102 2x123 2x144, 3x123, 3x144	0, 3.4, 6.9, 10.3, 13.7 17.2, 20.6, 24.0, 27.5, 30.9	Fig.13, Fig.19-23
	mod. no.2 with spray dam	36,000	still water	20.6, 24.0, 27.5, 30.9	Fig.24

Table II. Test Cases



(1) (2) (3) (4) Parallelogram Linkage

(5) C.G. of Model

(6) Scale for Heave

(7) Scale for Pitch

(8) Pointer of Spring Balance

(9) Resistance Recording Drum

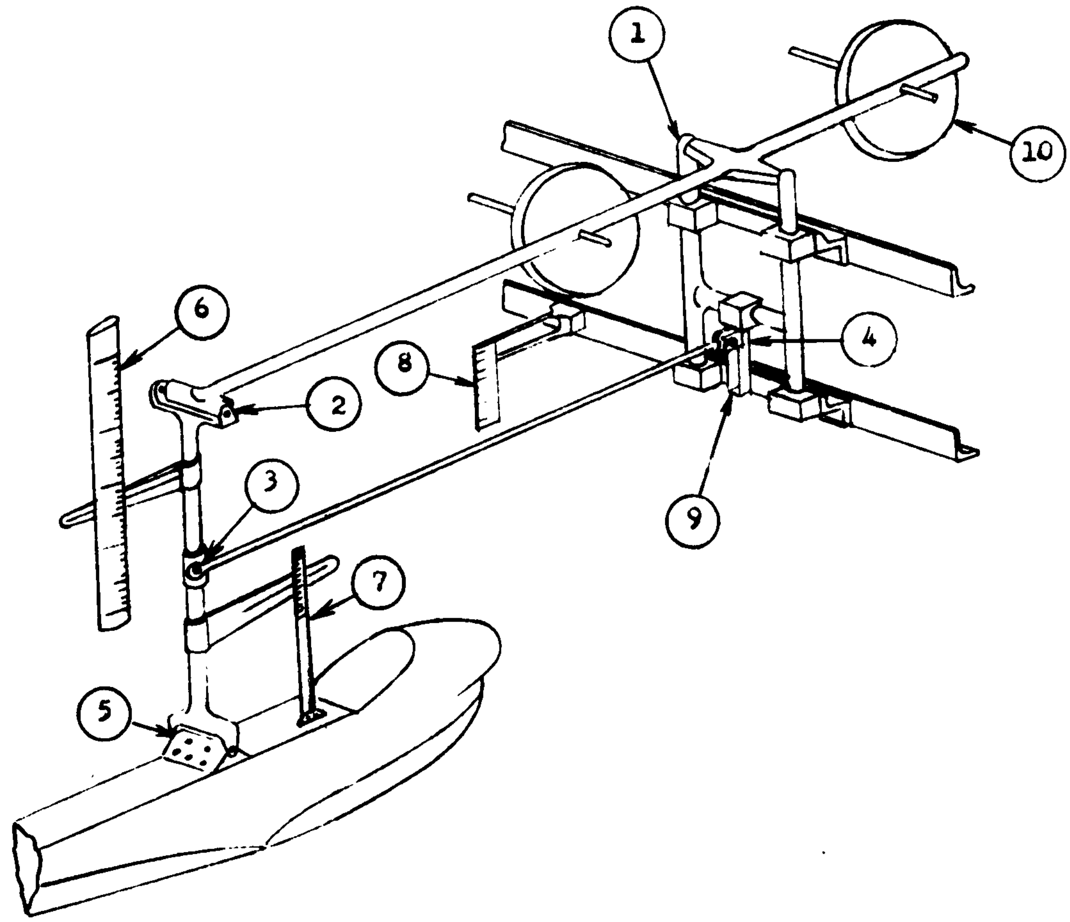
(10) Weight for Adjusting Load on Water

(11) Weight for Adjusting Pitching Moment

(12) Torque Tube

(13) Universal Joint

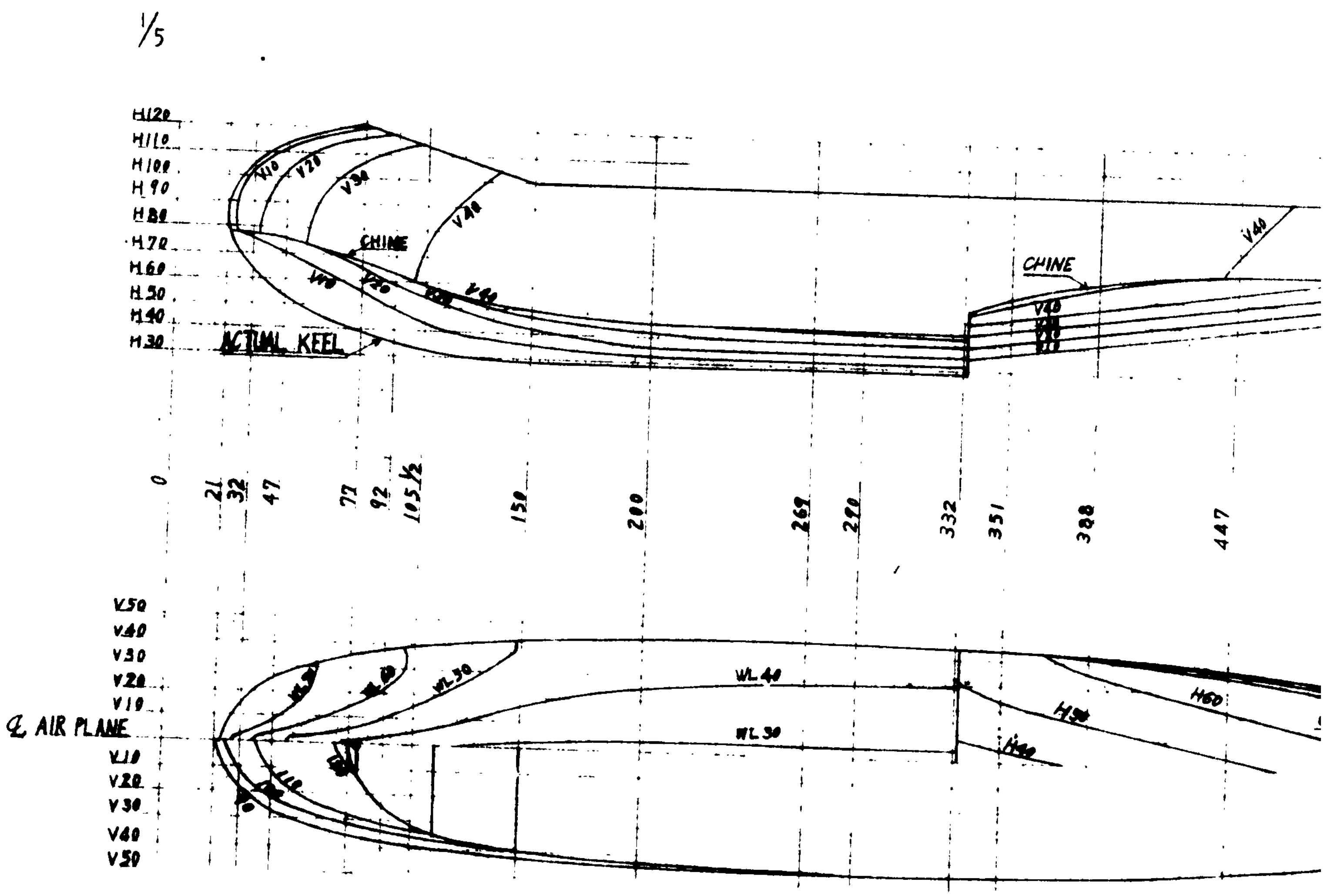
Fig. 1 Towing Apparatus, Tank No. 1



(1) (2) (3) (4)	Parallelogram Linkage
(5)	C.G. of Model
(6)	Scale for Heave
(7)	Scale for Pitch
(8)	Scale for Wave Height
(9)	U-Type Spring Balance
(10)	Weight for Adjusting Load on Water

Fig. 2 Towing Apparatus, Tank No. 2

1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V20
V30
V40
CHINE
V40
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32
47
72
92
105 1/2
150
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269
290
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388
447
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V40
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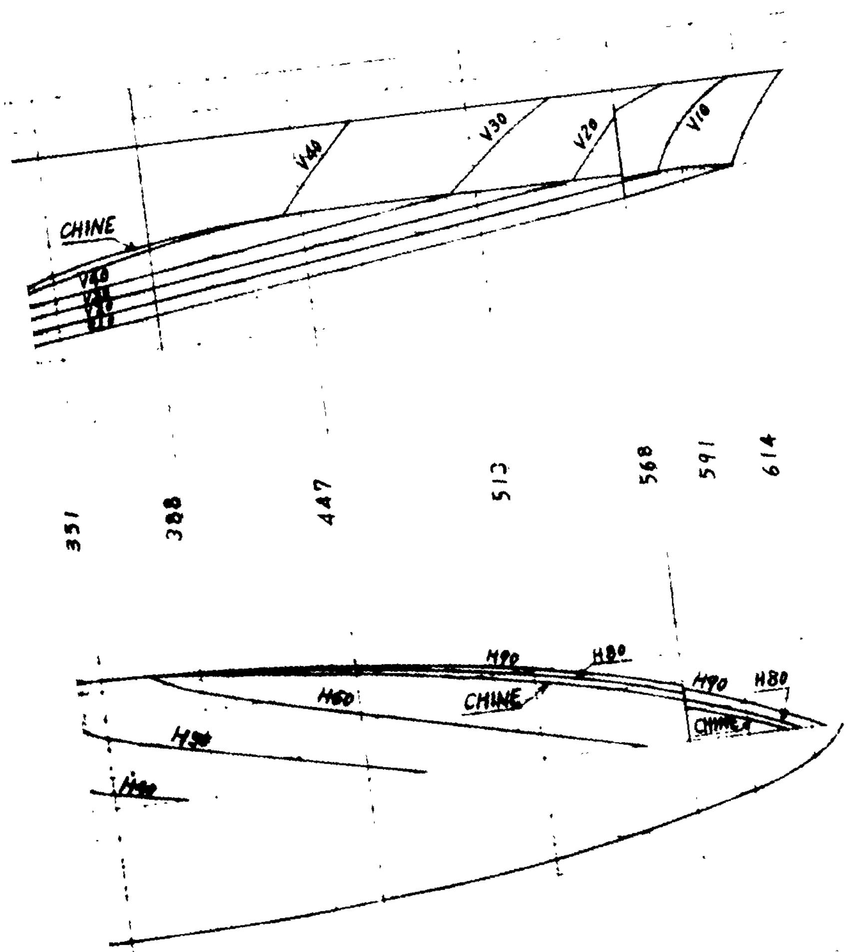
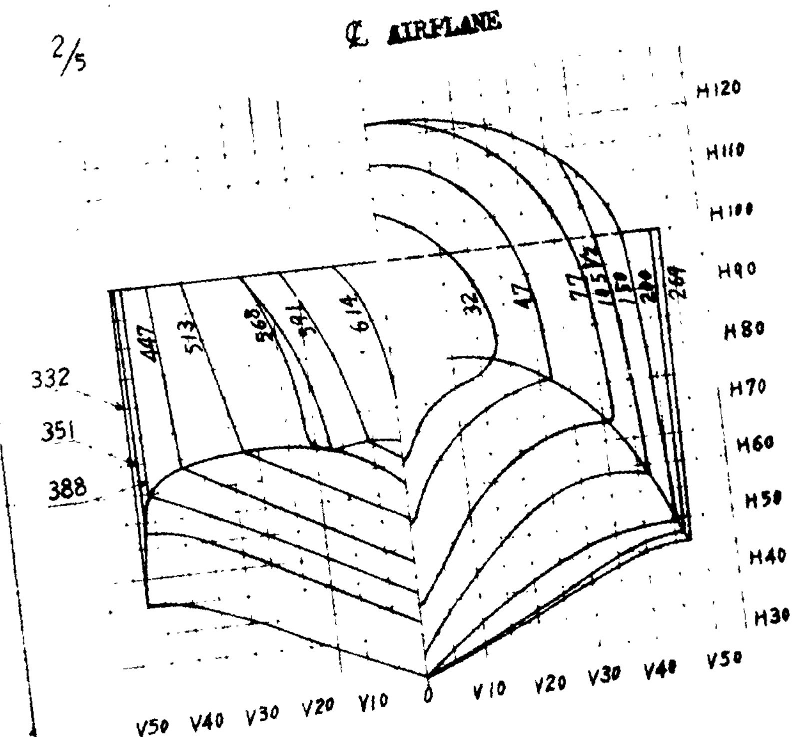
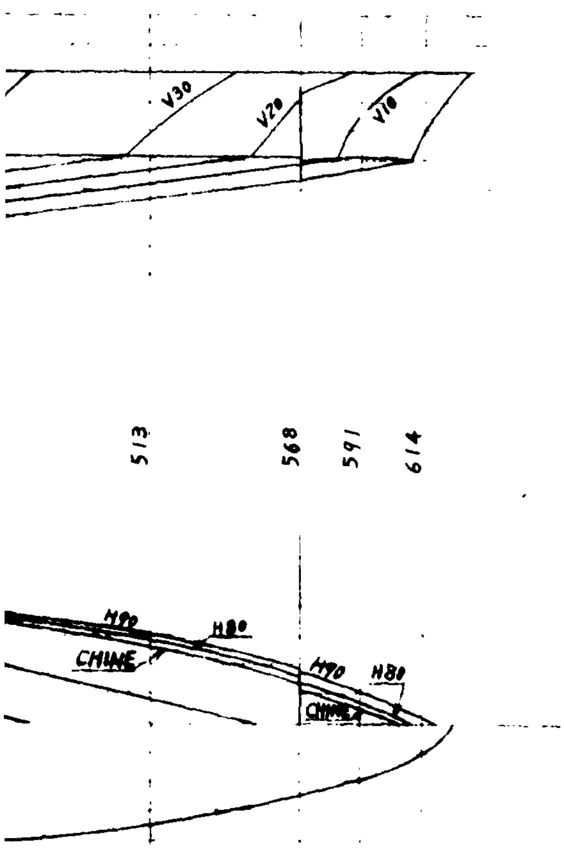
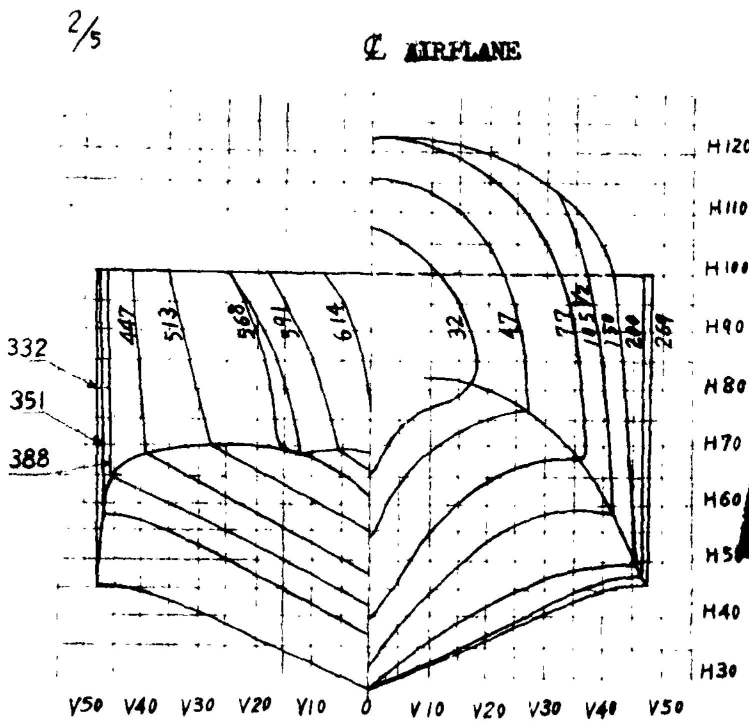




Note: All dimensions are in inch
Drawing scale is 1/5 and 2

Fig. 3 Lines of UF-2 Original Hull.





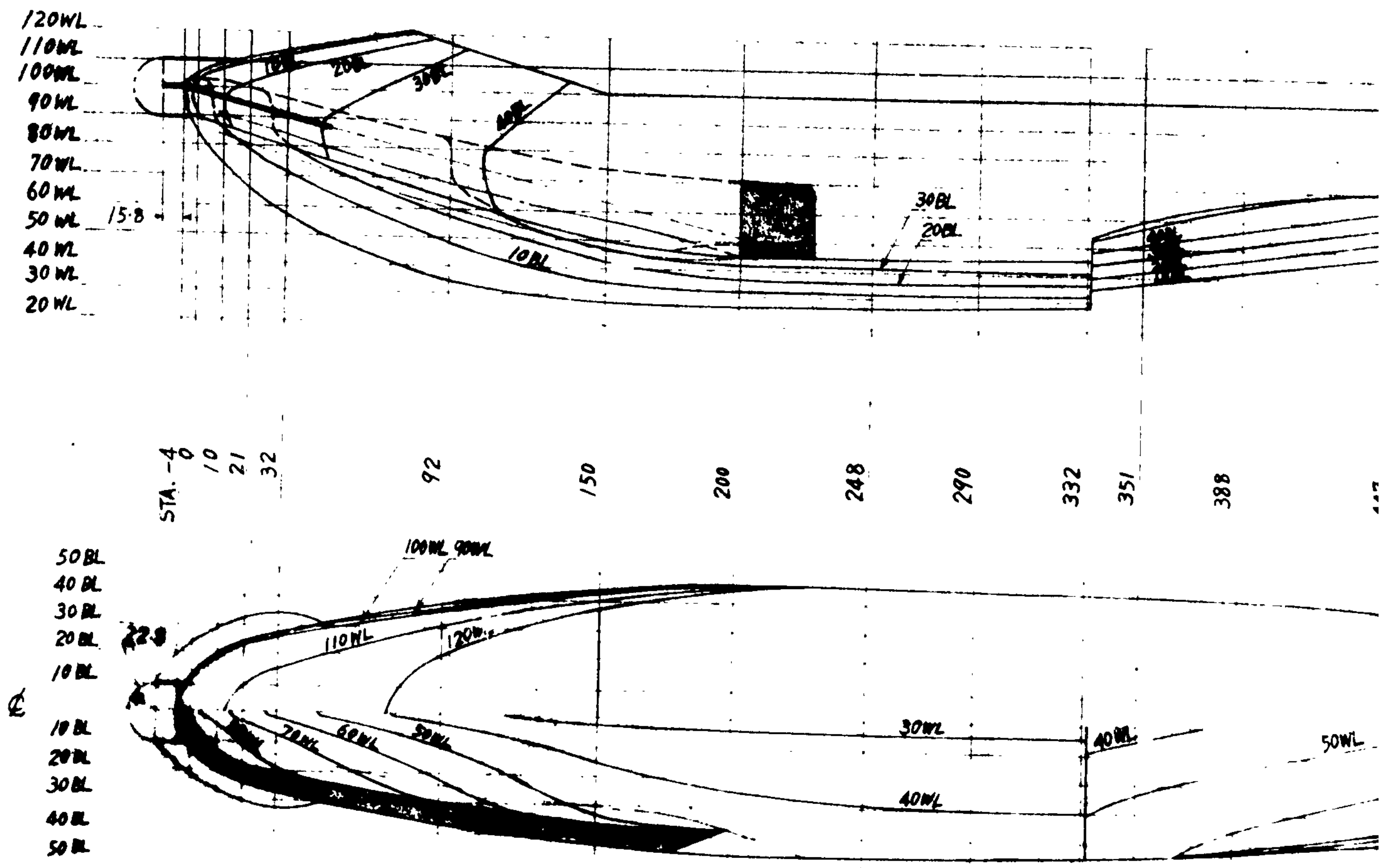
Note: All dimensions are in inches, full size.

Drawing scale is 1/5 and 2/5 of the model.

Fig. 3 Lines of UF-2 Original Hull.

1

1/5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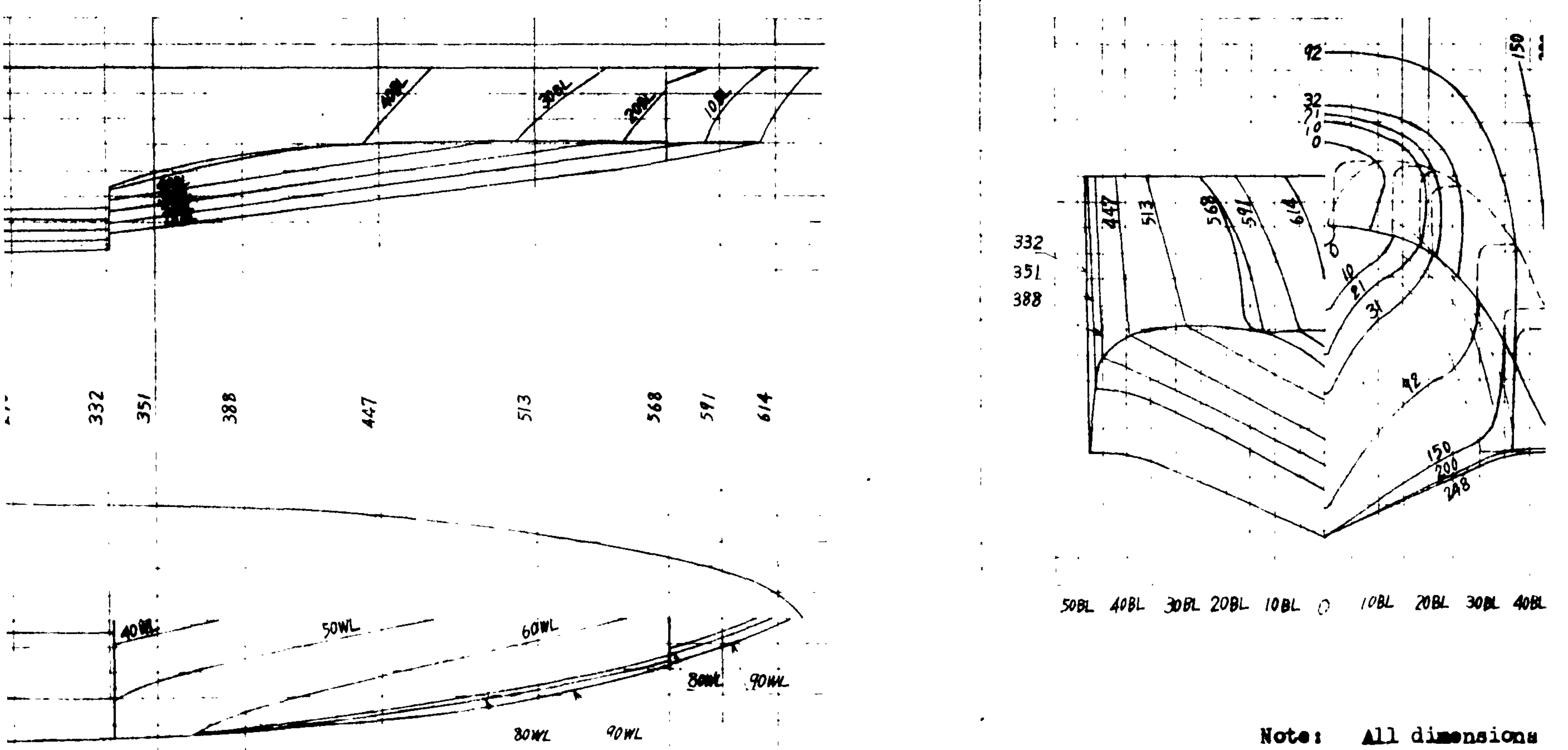
2

2/5

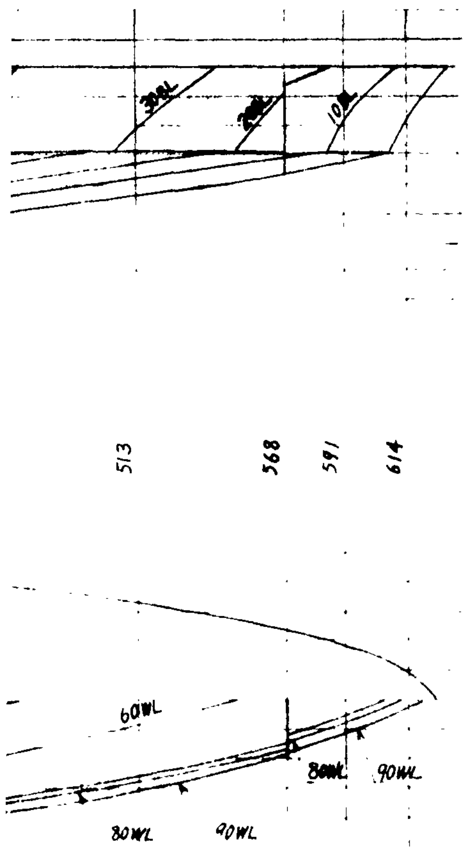


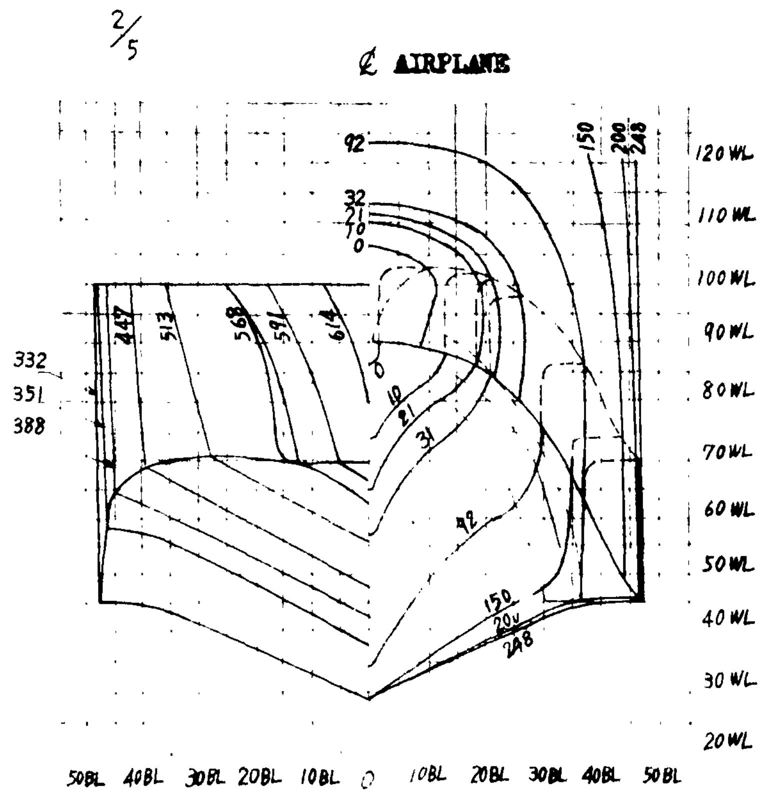
Note: All dimensions

Drawing scale 1

Fig. 4 Lines of UF-2 Modified Hull No

3

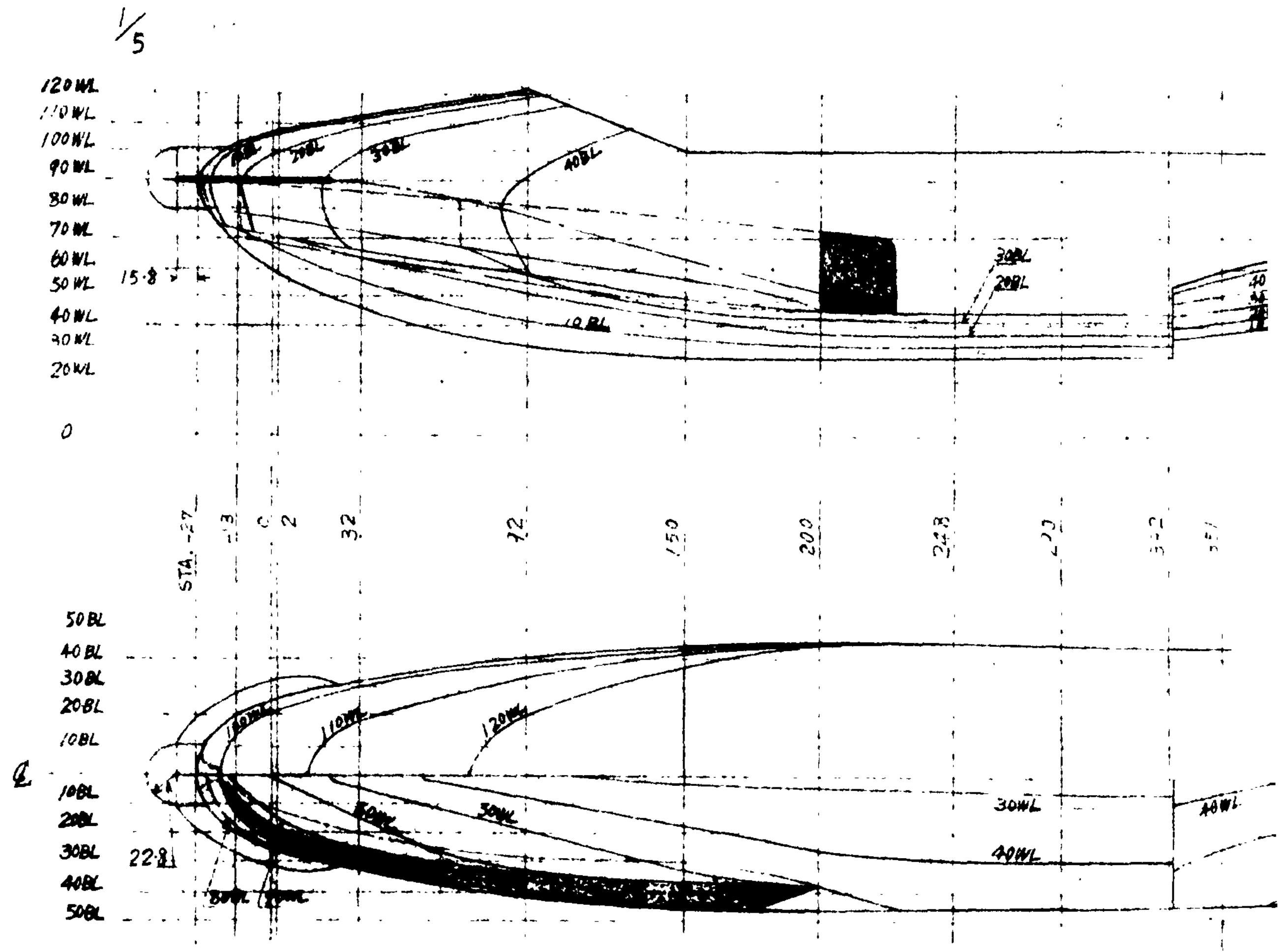




Note: **All dimensions are in inches, full size.**

Drawing scale is 1/5 and 2/5 of the model.

Fig. 4 Lines of UF-2 Modified Hull No. 1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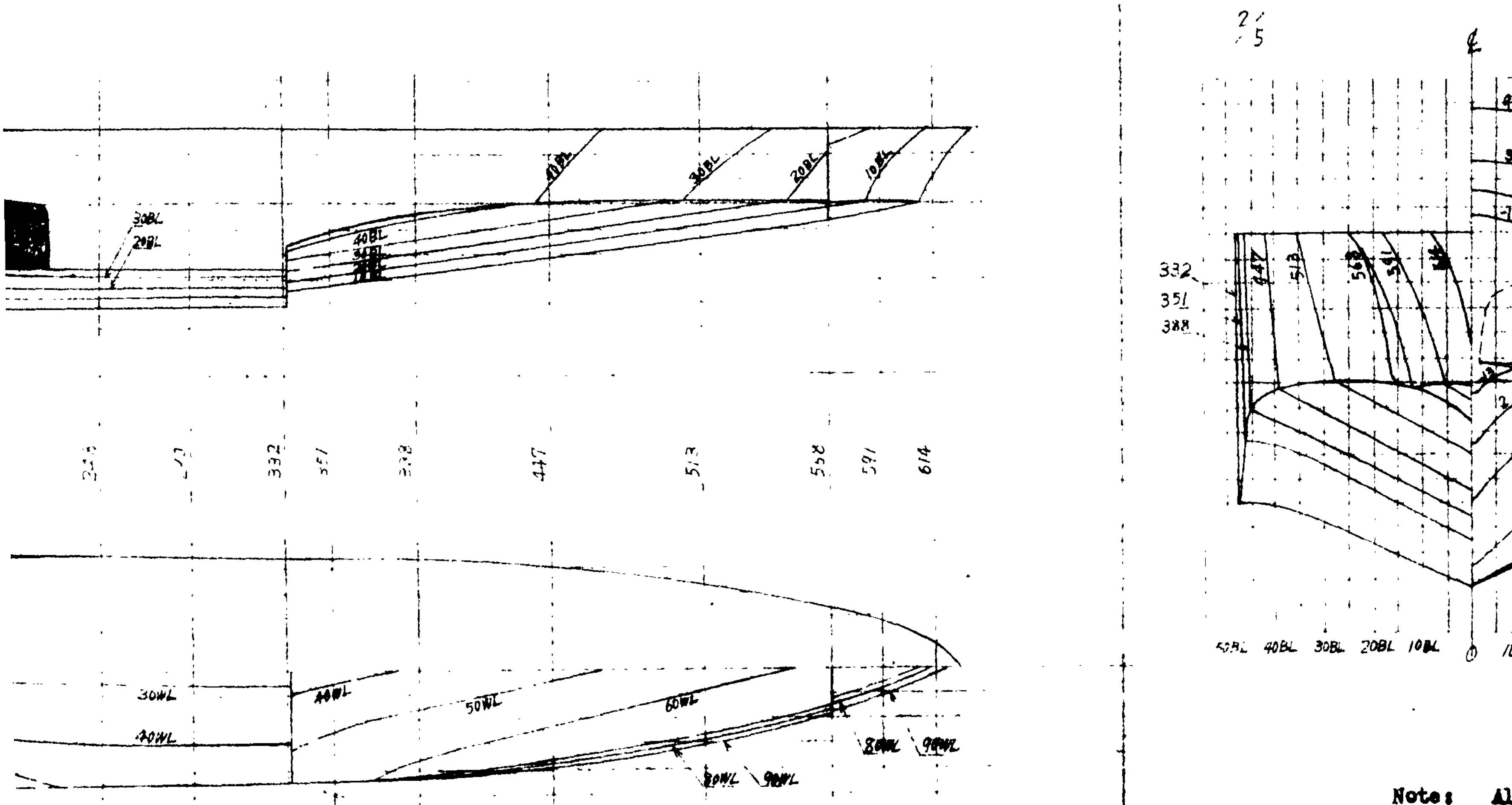
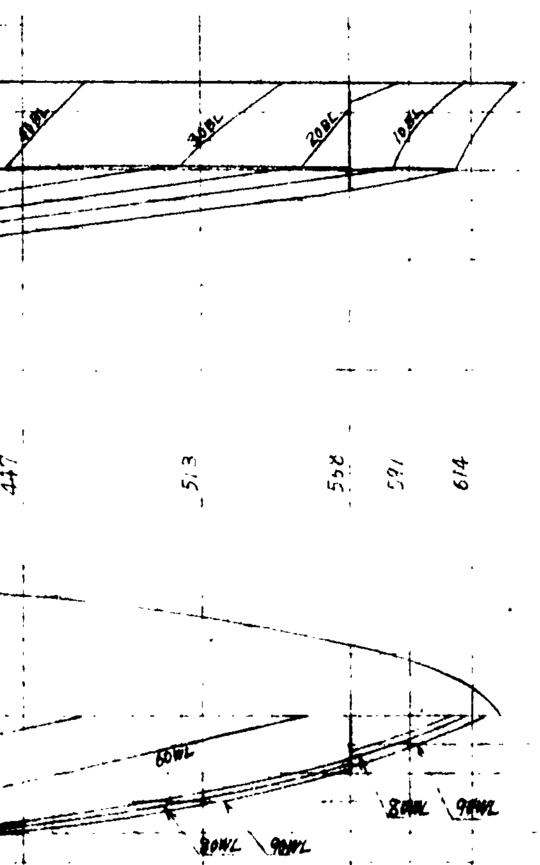


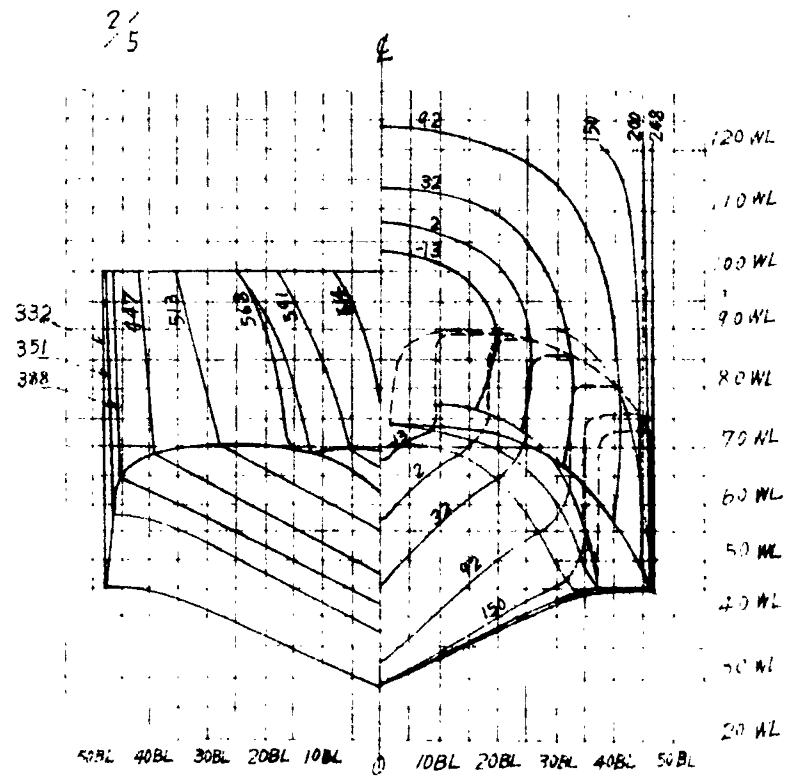
Notes: All

Dro

Fig. 5 Lines of UF-2 M

3





Note: All dimensions are in inches, full size.
Drawing scale is 1/5 and 2/5 of the model.

Fig. 5 Lines of UF-2 Modified Hull No.2

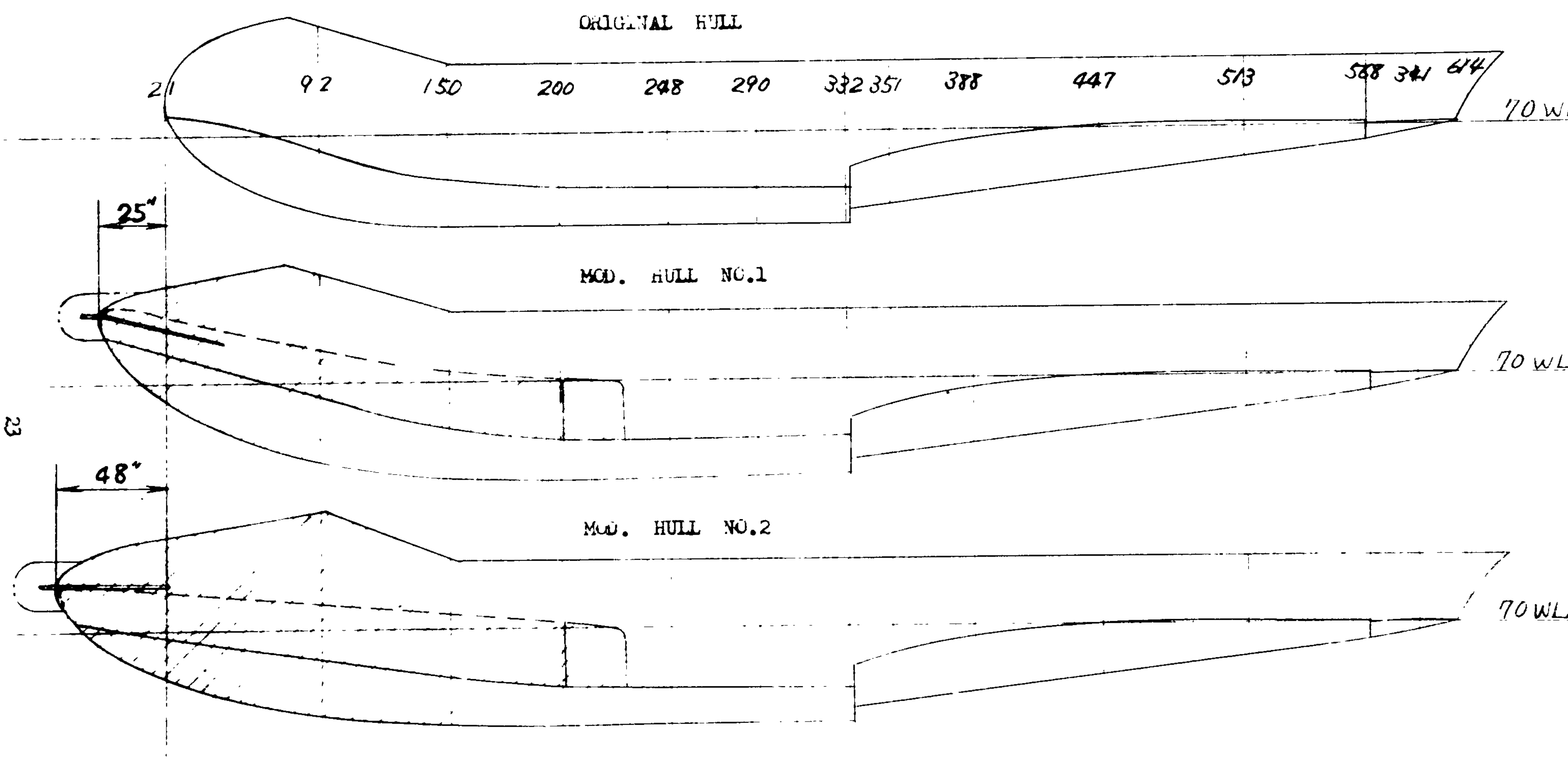
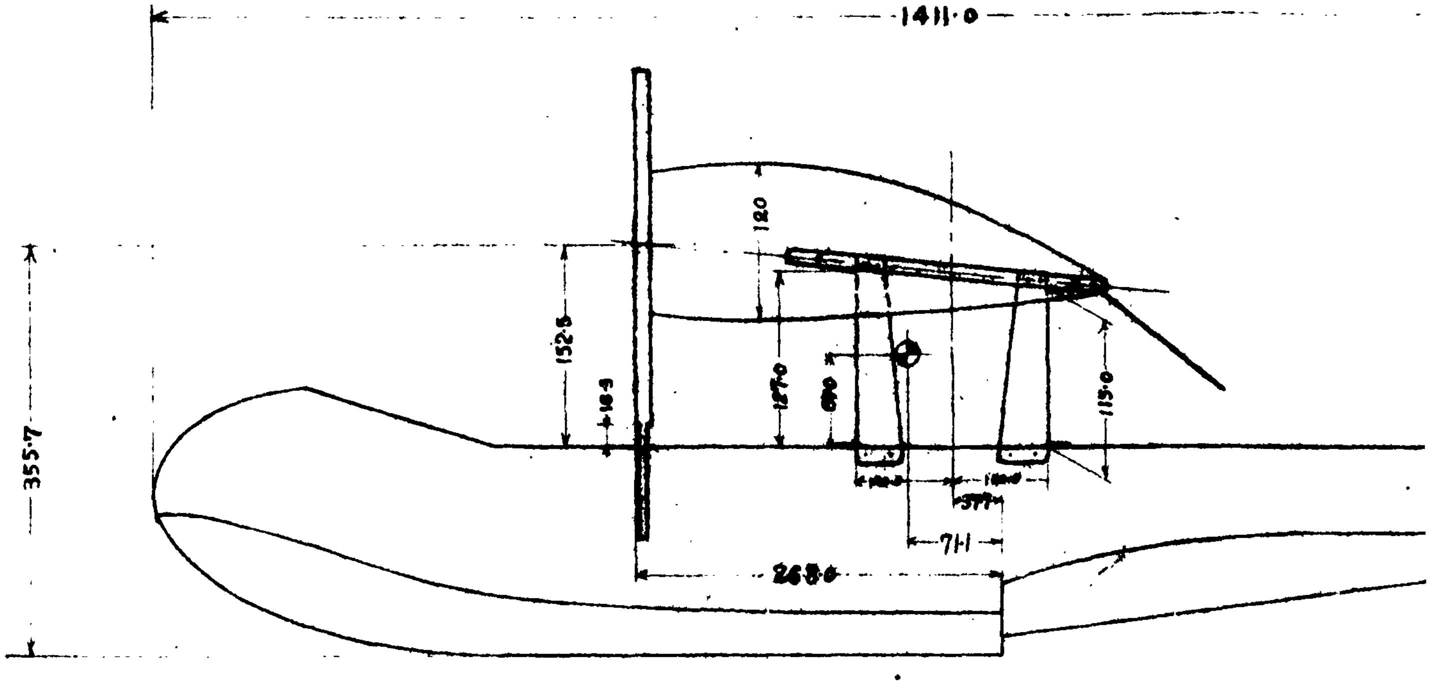


Fig. 6 Extent of Reconstruction.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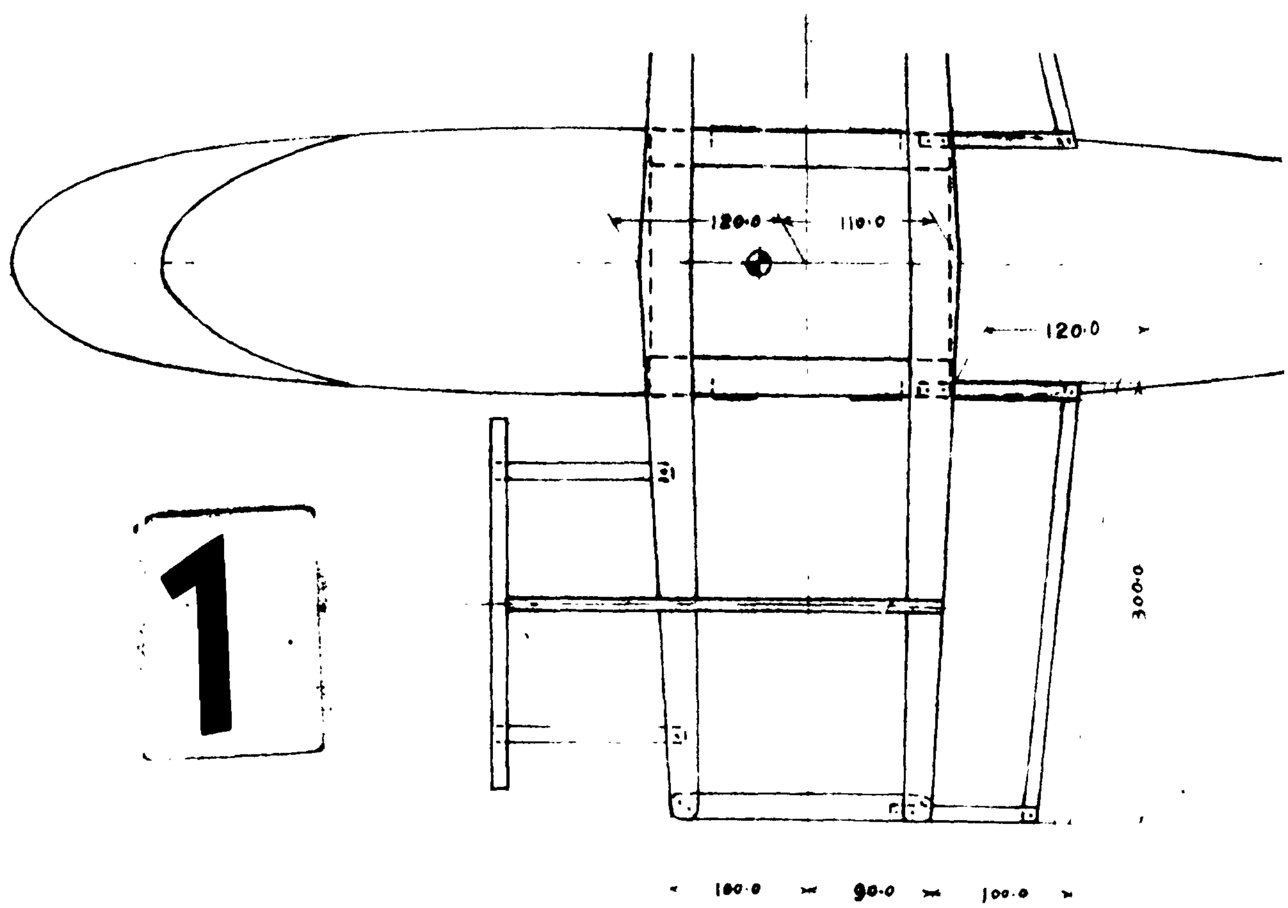
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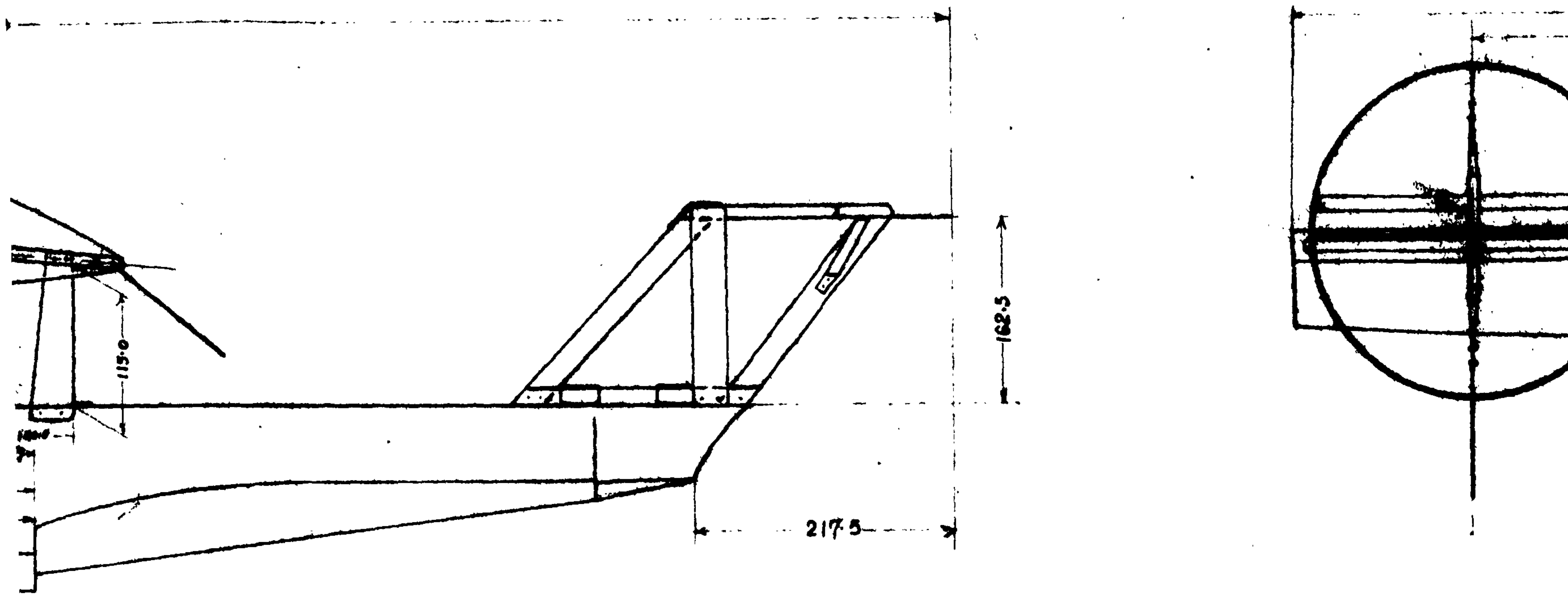

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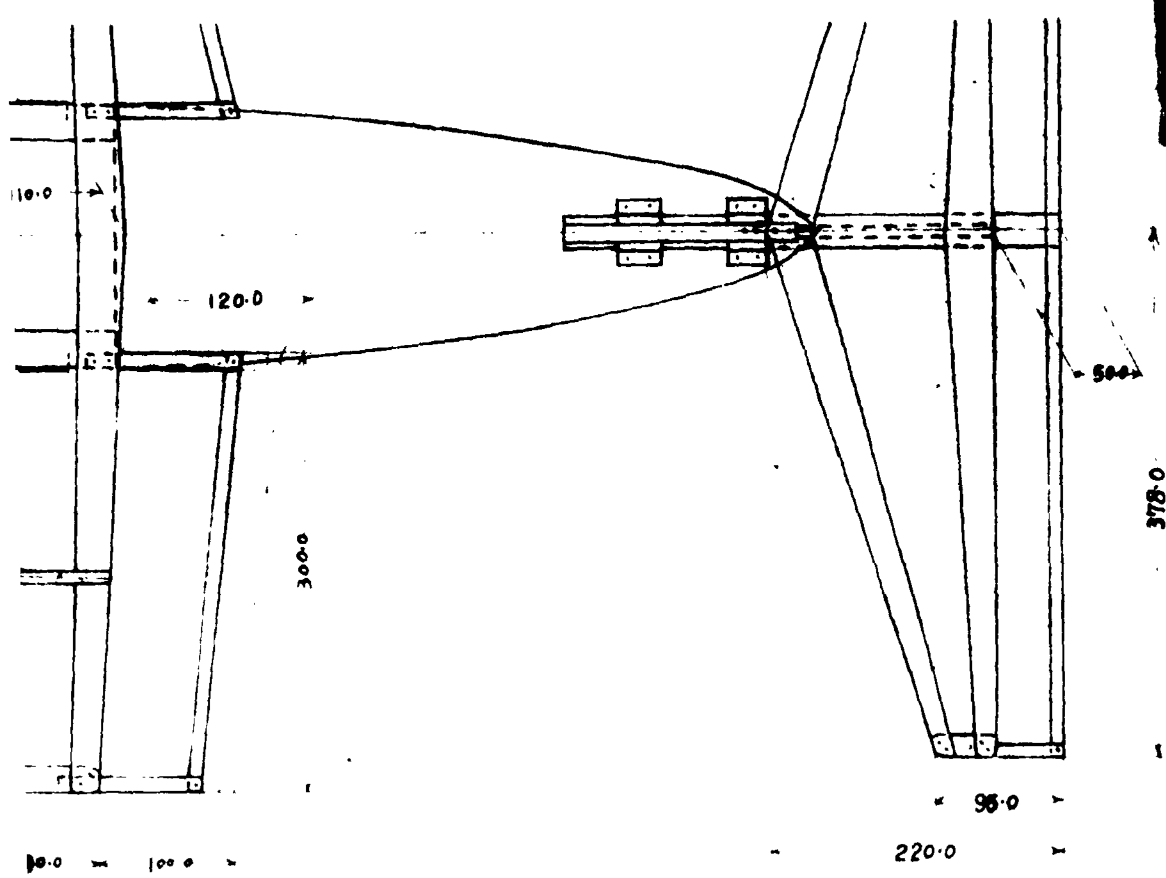
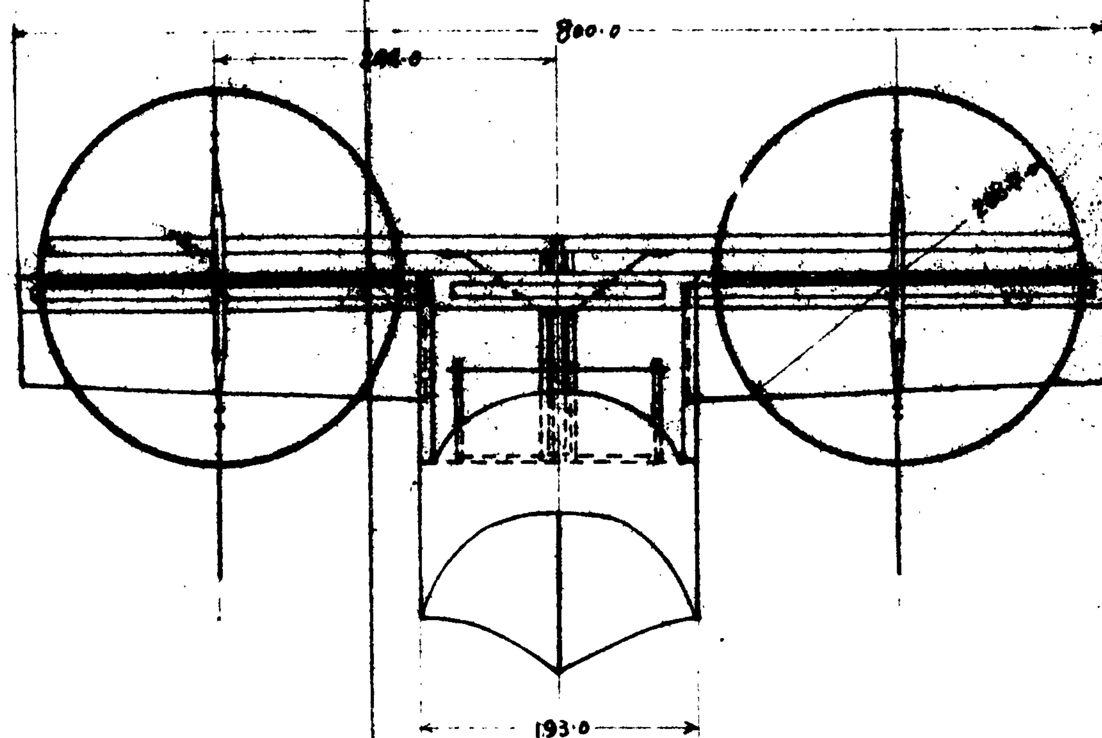
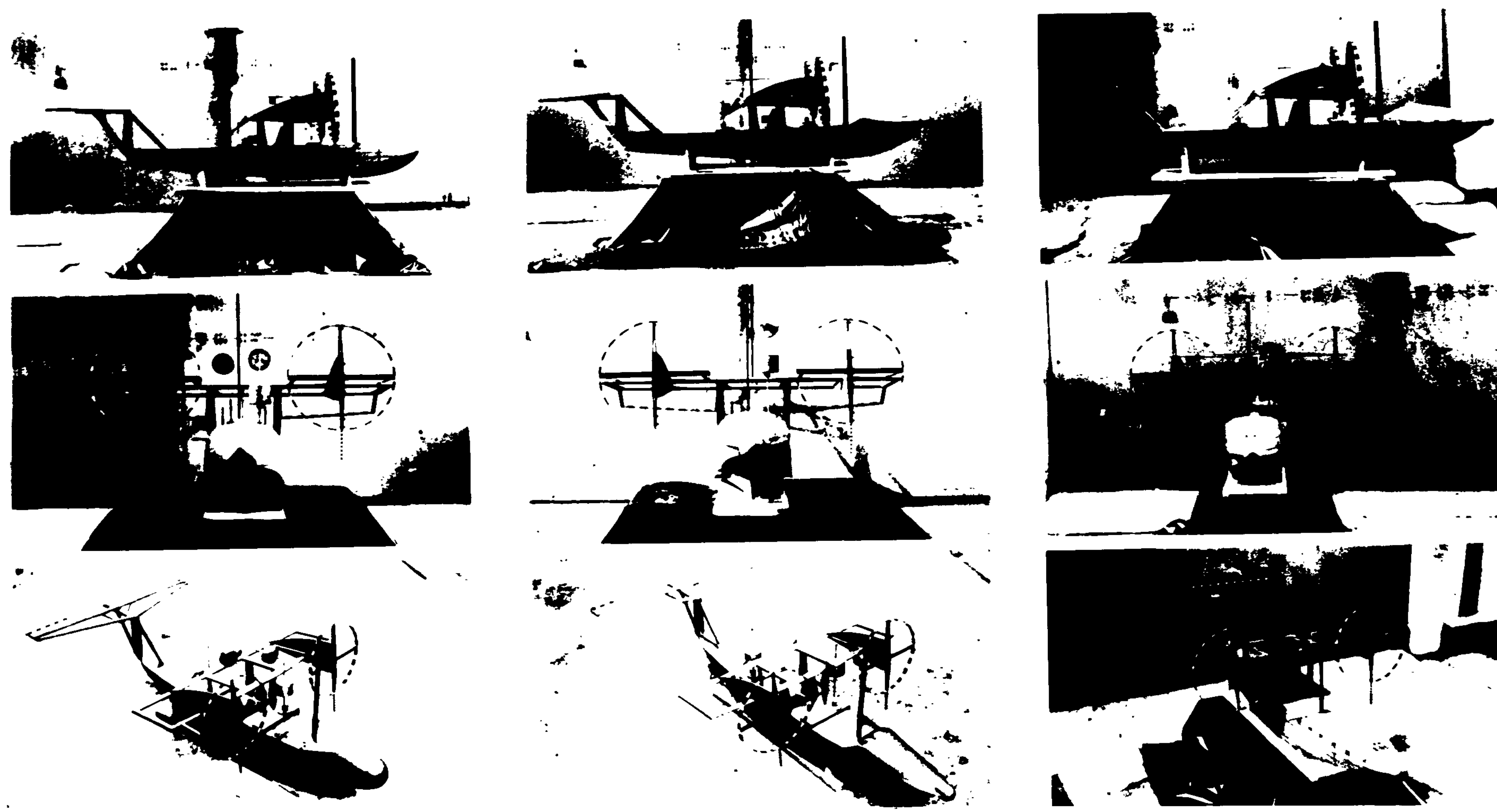




Note: Dimensions are in millimeters, model size.

Drawing scale is 1/5 of the model.

Fig. 7 Arrengement of Propeller, Flap and Horizontal Tail



original — mod. no.1 — mod. no.2

Fig. 8 Photographs of Models.

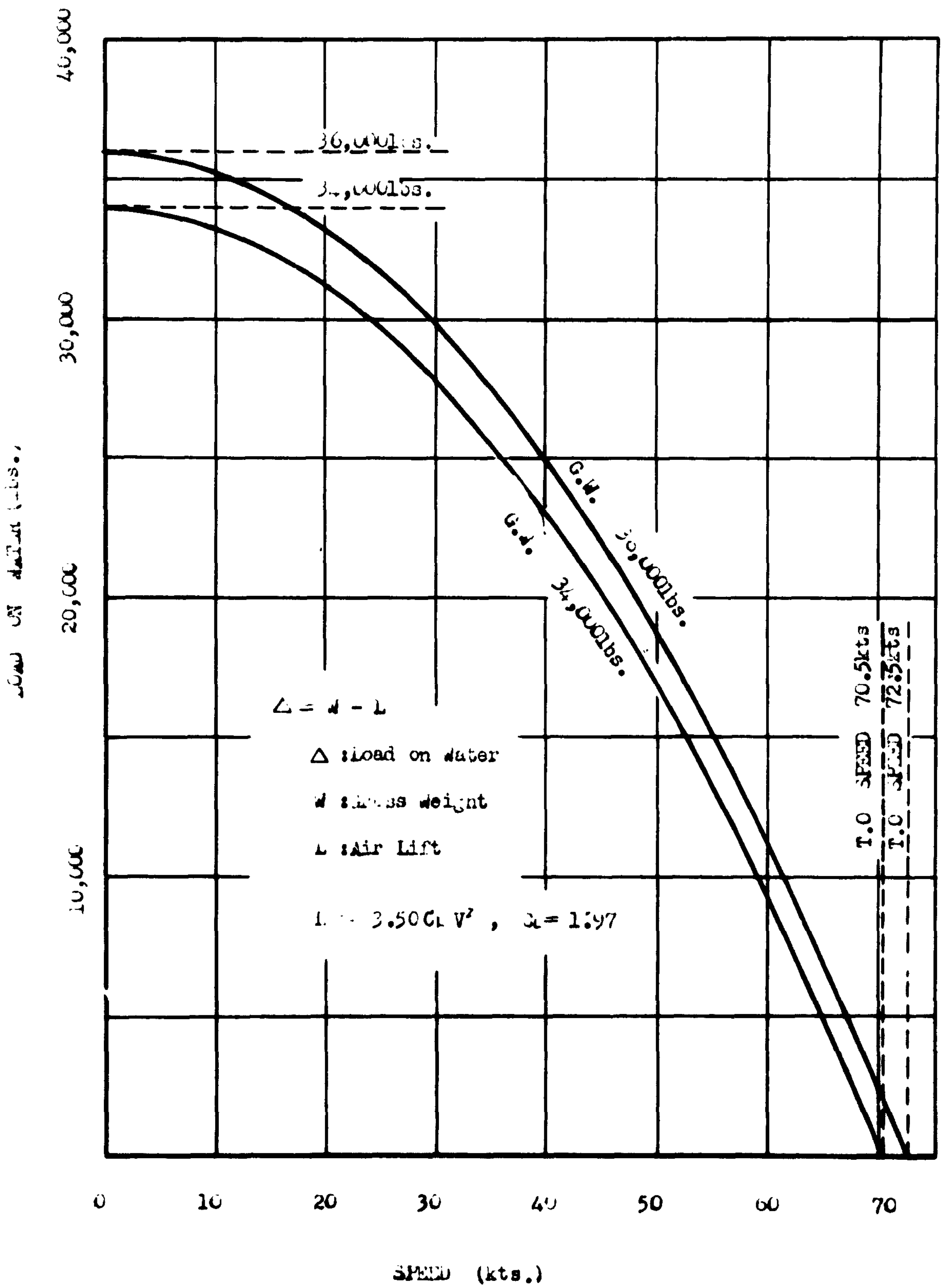


Fig. 9 Load on Water.

speed
(kts)

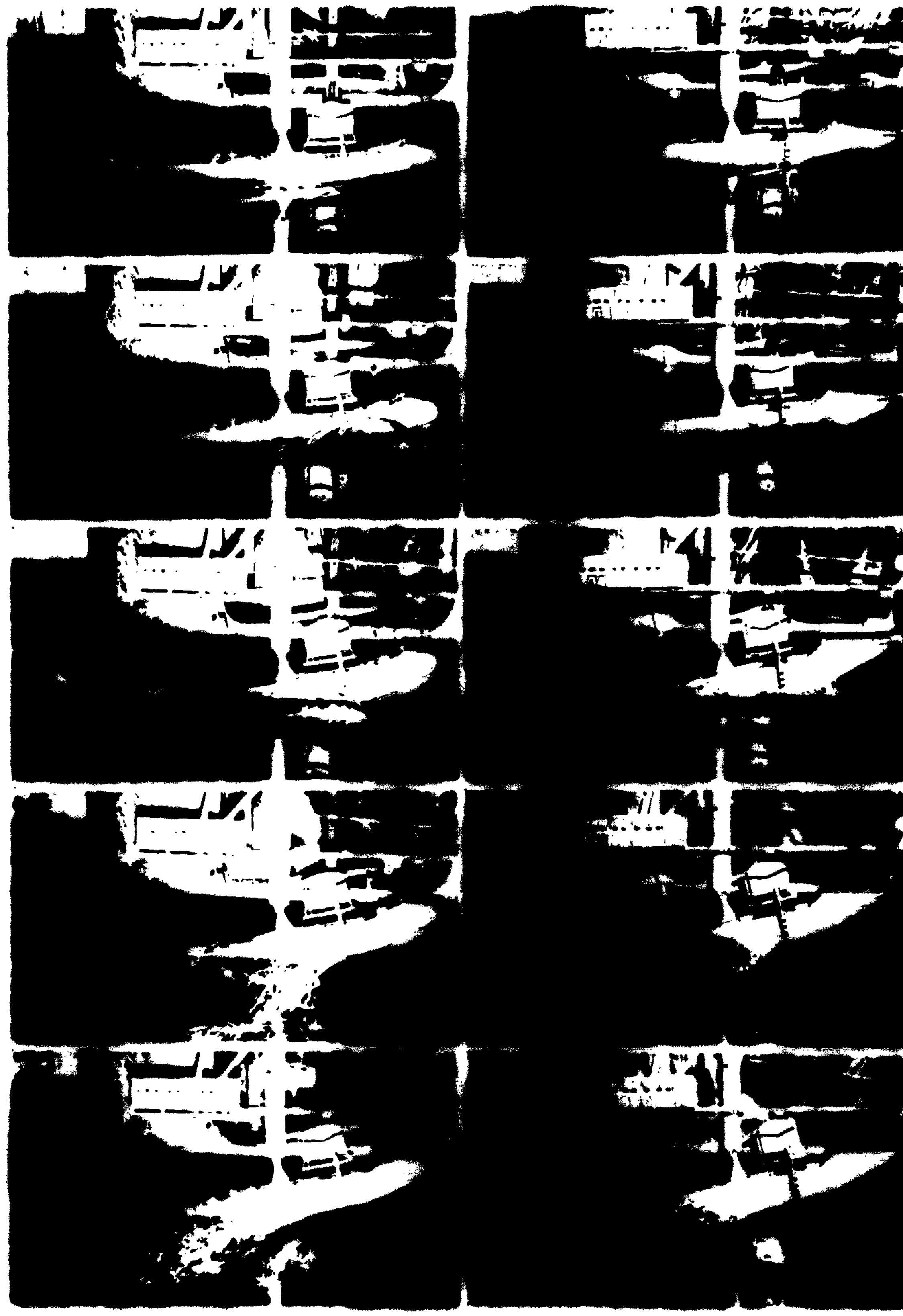
6.9

1..7

20.6

27.4

34.3



orginal

mod. no.1

Fig. 10a Take-off Run in Still Water, G.W. 34,000lbs.

speed (kts)

[illegible]1.2

48.0

54.9

61.8

68.6

original

mod. no.1

Fig. 10b Take-off Run in Still Water, G.W. 34,000lbs.

Speed (kts)

[illegible]

13.7

[illegible]

[illegible]

[illegible]

orginal — mod. no.1

Fig. 11a Take-off Run in Still Water, G.W. 36,000lbs.

speed (kts)

41.2

48.0

54.9

61.8

68.6

original | mod. model

Fig. 11b Take-off Run in Still Water, G.W. 36,000lbs.

Speed (kts)

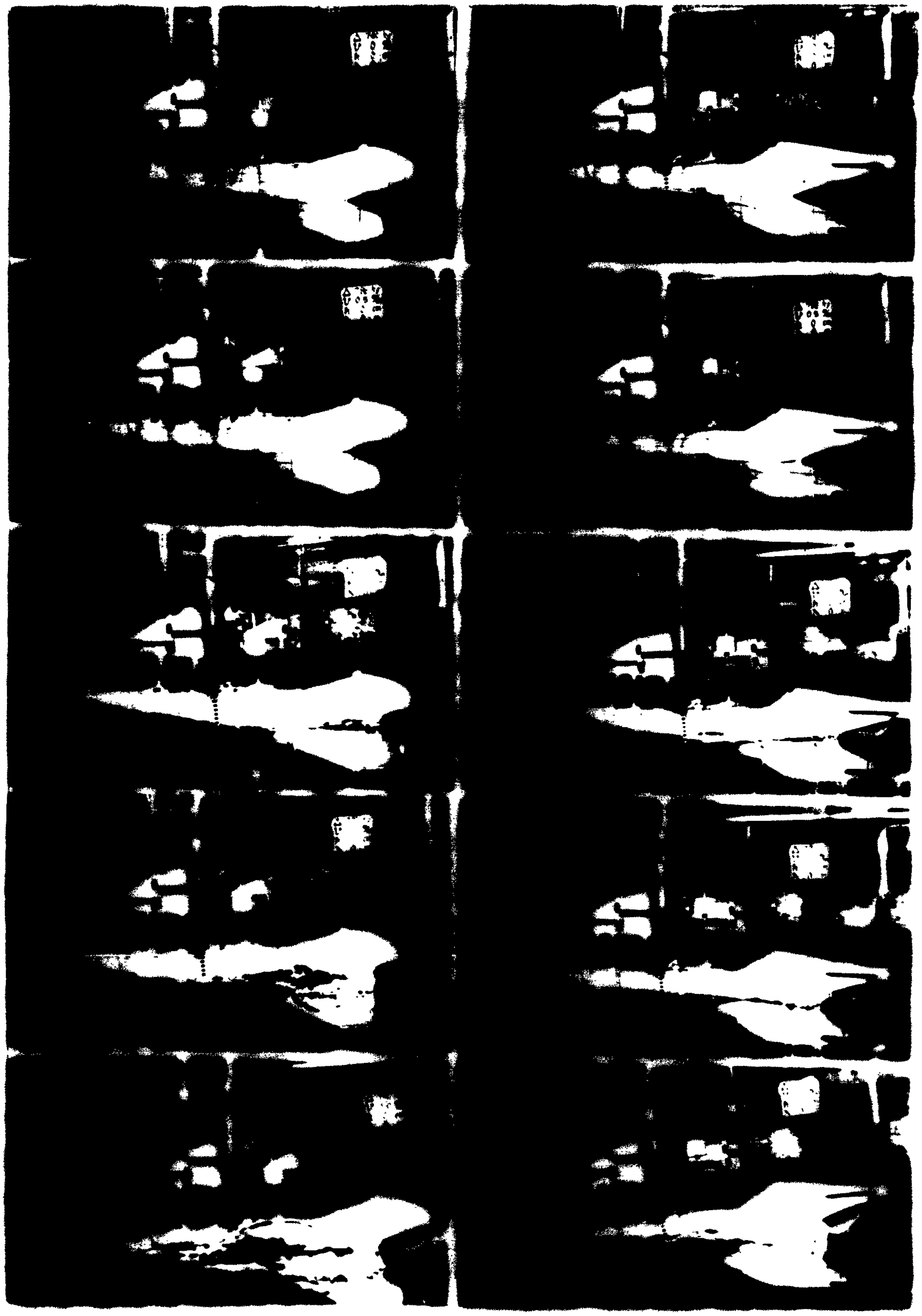
0

5.4

8.9

10.3

13.7



original

mod. no.1

Fig. 12a Spray in still water, G.W. 54,000lbs.

speed
(kts)

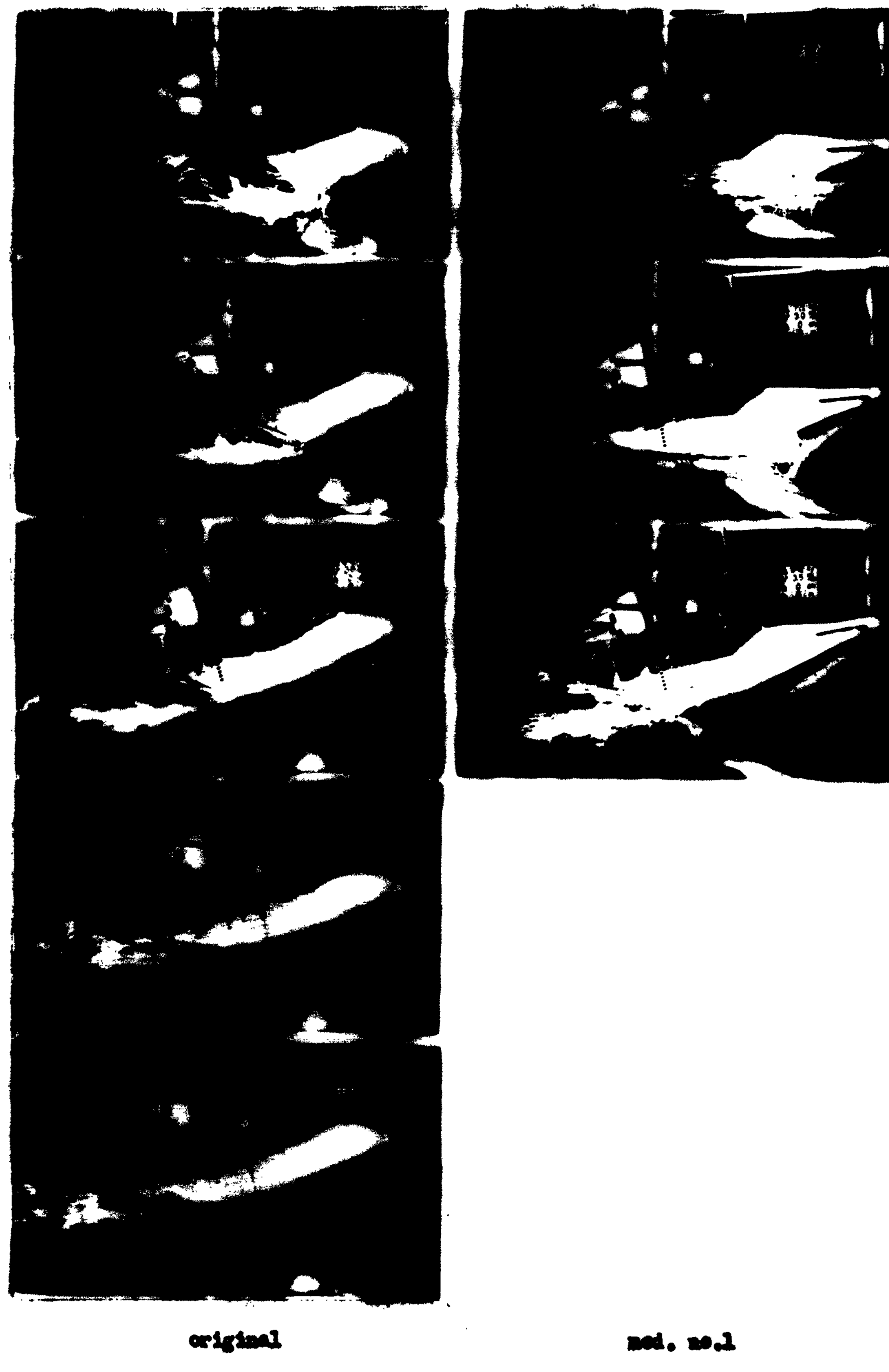
17.2

20.6

24.0

27.5

30.9



original   mod. no.1

Fig. 12b Spray in Still Water, G.W. 34,000lbs.

speed (kts)

0

3.4

6.9

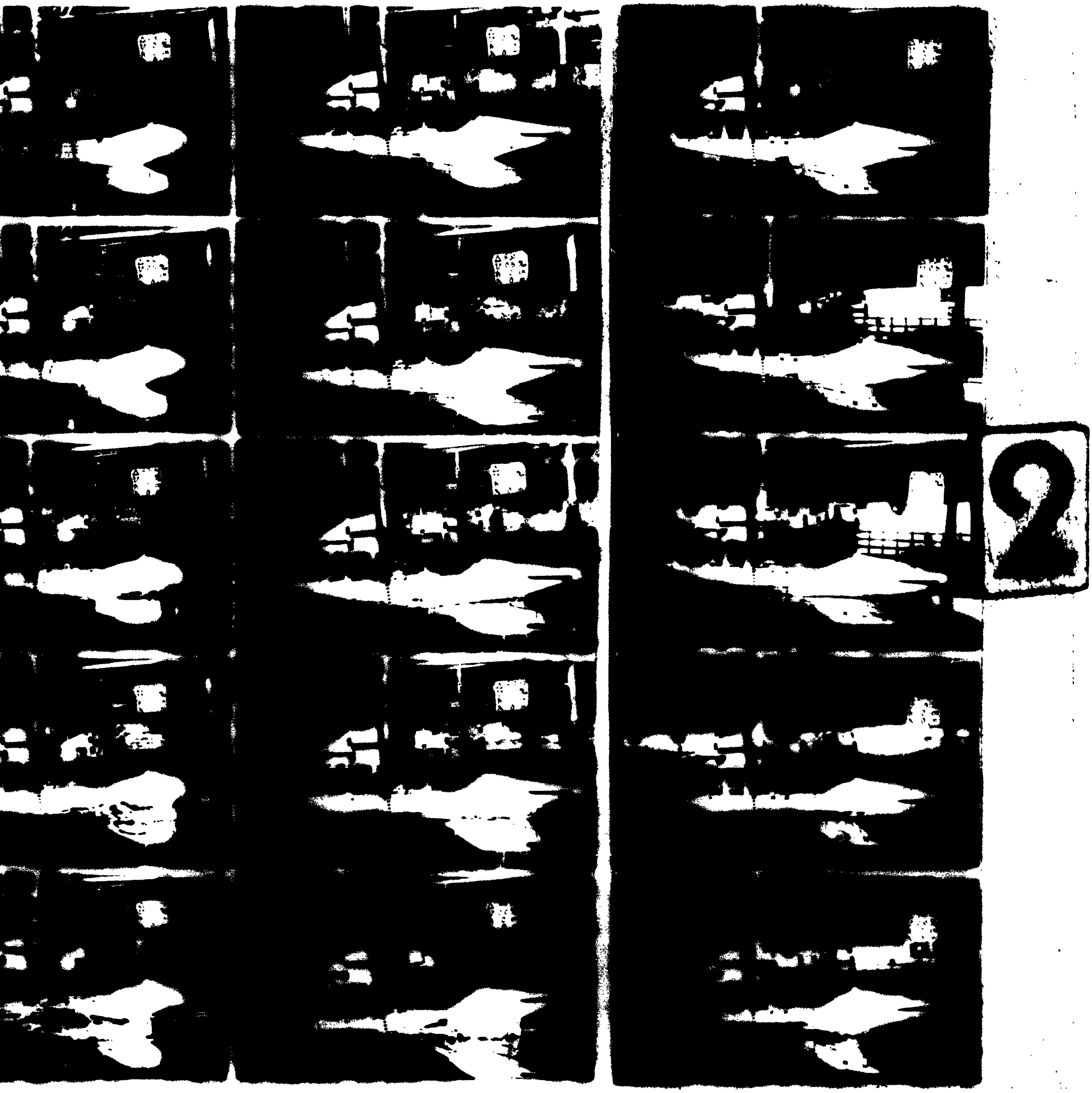
10.3

13.7

original

mod. no.1

Fig. 13a Spray in still water, G.W. 36,000lbs.



original | mod. no.1 | mod. no.2

Spray in still water, G.W. 30,000lbs.

Speed (kts)

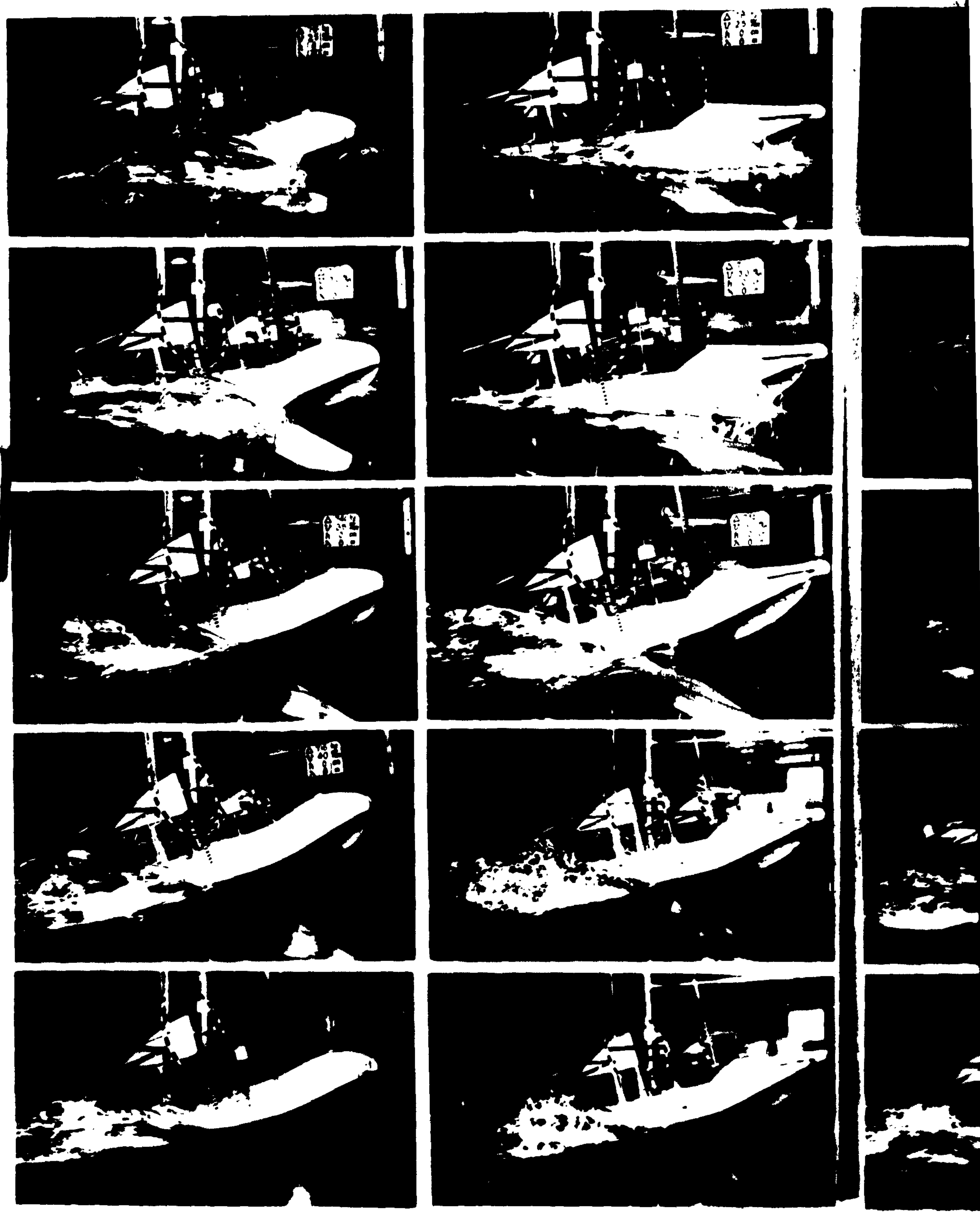
17.2

20.0

24.0

27.5

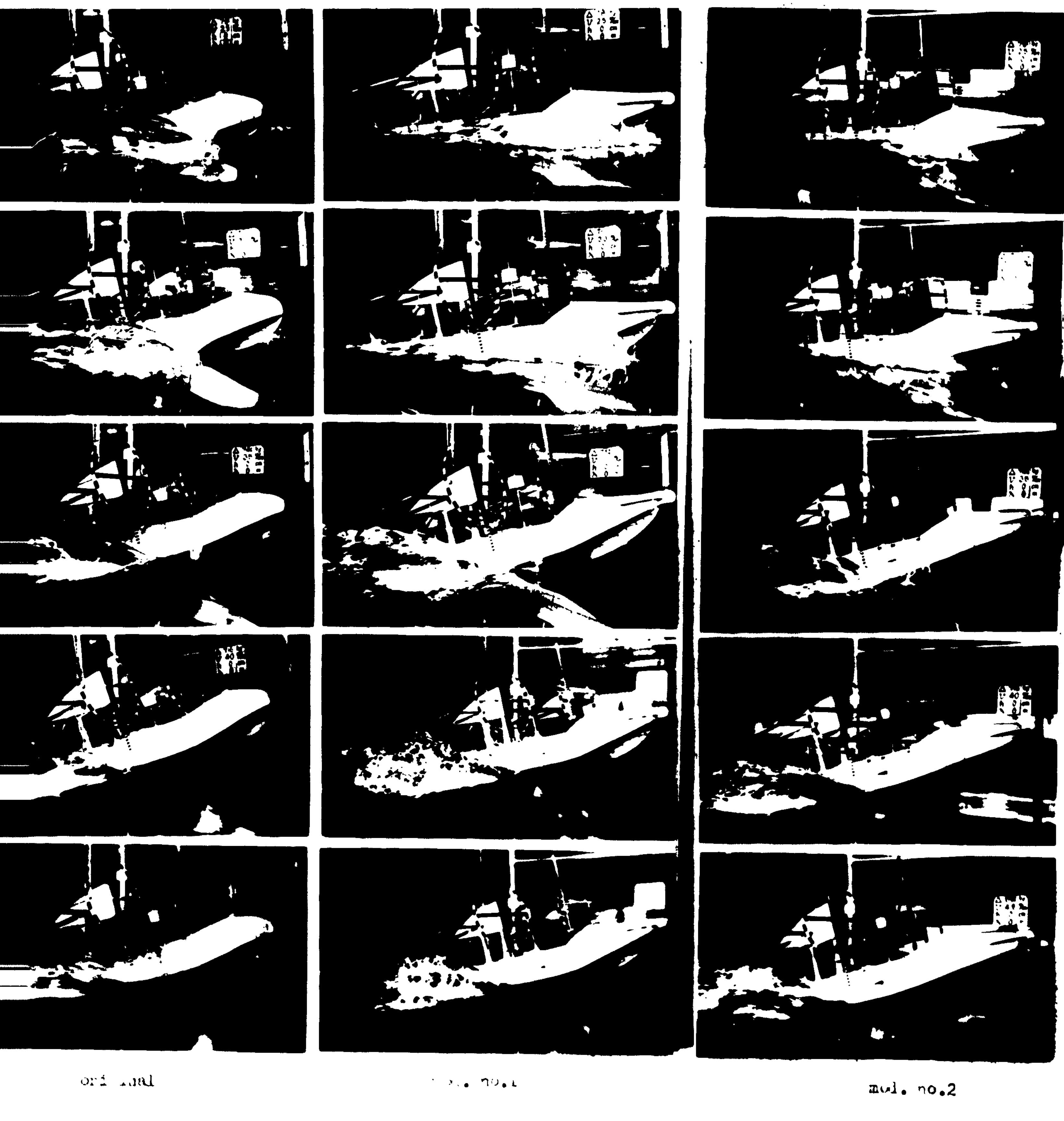
30.9



original [illegible] no.1

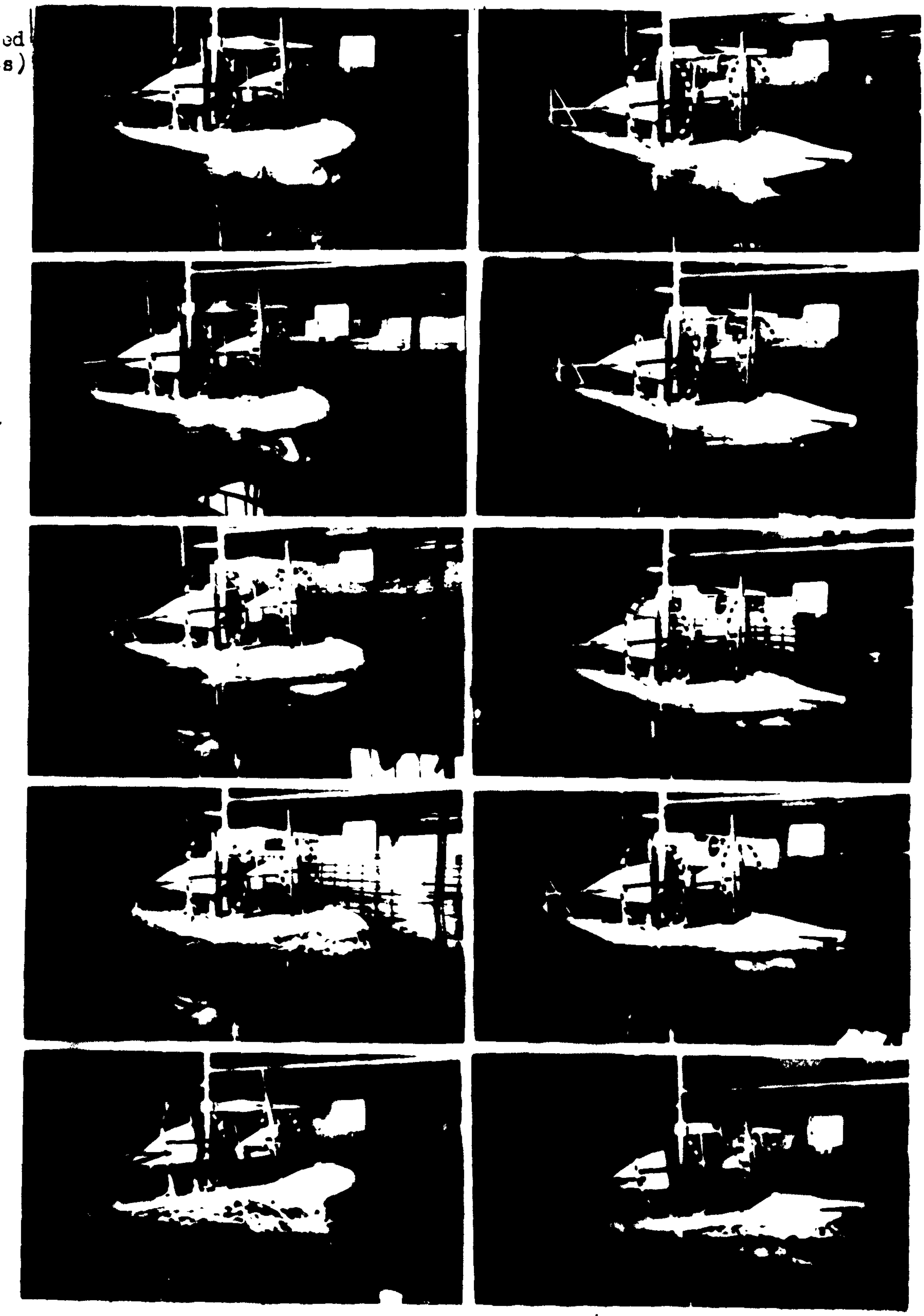
[illegible] in still water, [illegible]

2



ori[illegible]nal | [illegible] no.1 | mod. no.2

[illegible]



wave height 2ft, wave length 102ft.

Fig. 14a Maximum Spray in Waves, G.W. 34,000lbs.

speed (kts)

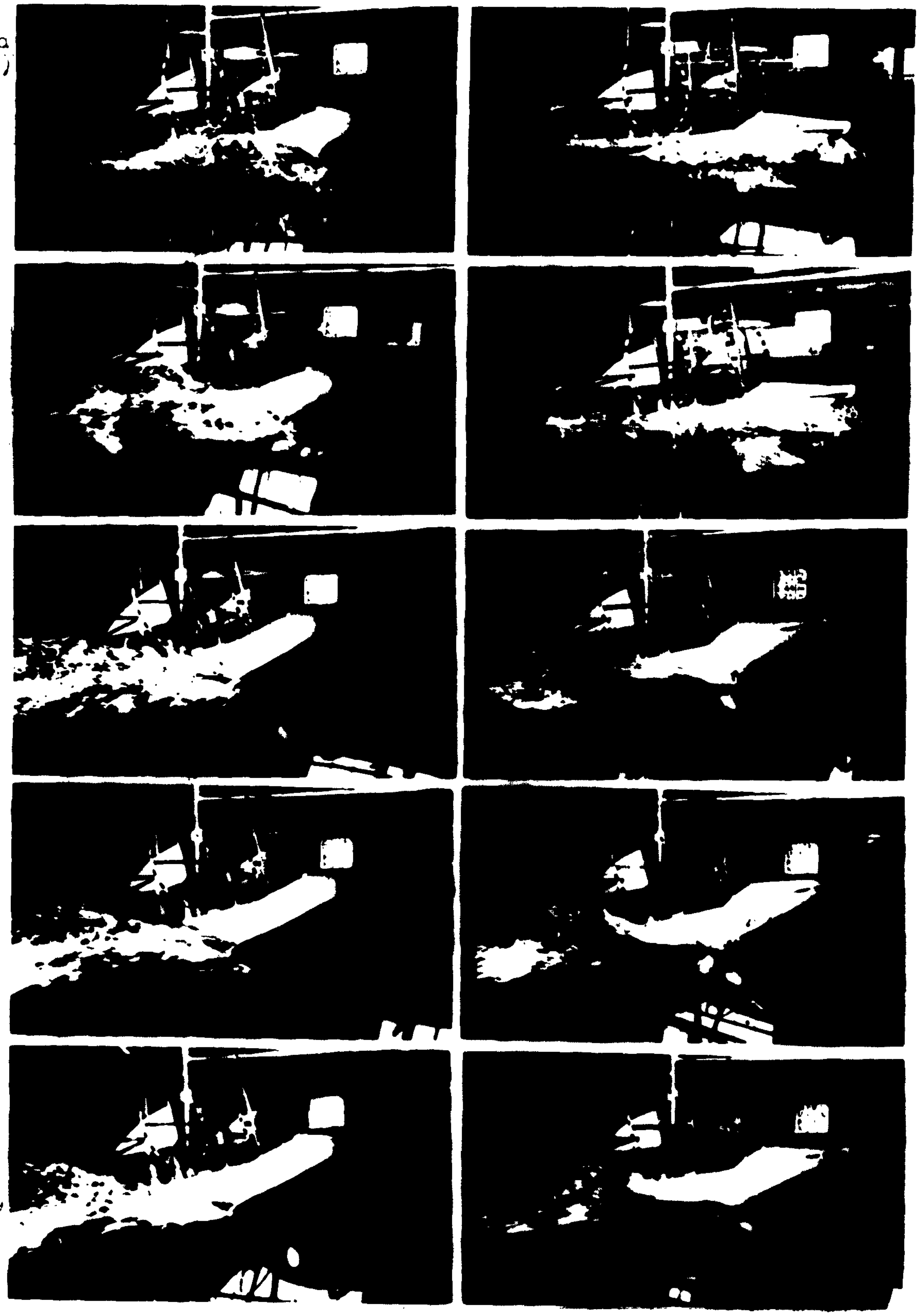
17.2

20.6

24.0

27.5

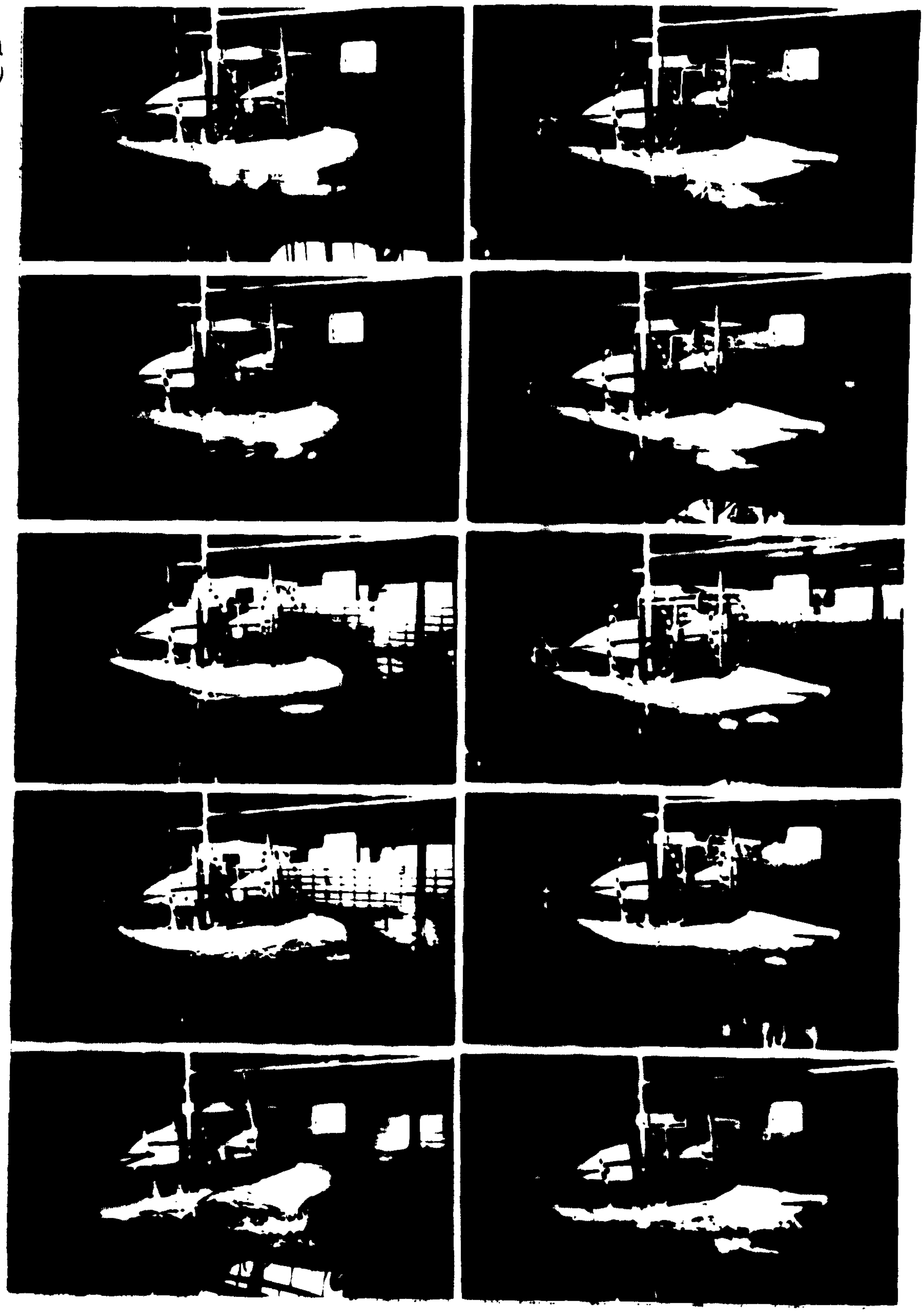
30.9



original | mod. no.1

wave height 2ft, wave length 102ft.

Fig. 1.b Maximum Spray in Waves, G.W. 34,000lbs.



wave height 2ft, wave length 123ft.

Fig. 15a Maximum Spray in Waves,G.W. 34,000lbs.

speed (kts)

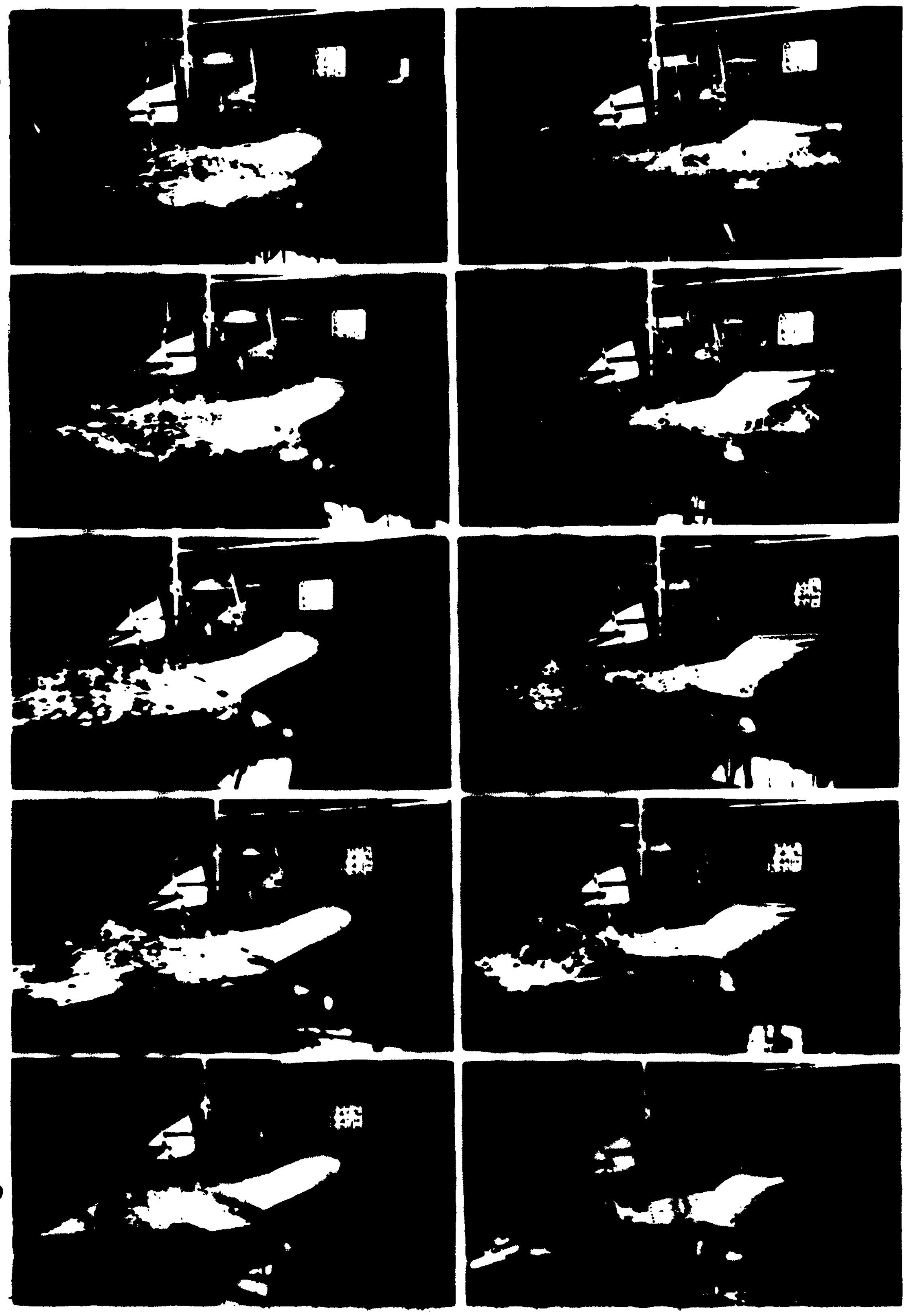
[illegible]7.2

2[illegible]

[illegible]4.0

27.5

30.9



original — mod. no.1

wave height 2ft, wave length 123ft.

Fig. 15b Maximum Spray in Waves, G.W. 34,000lbs.

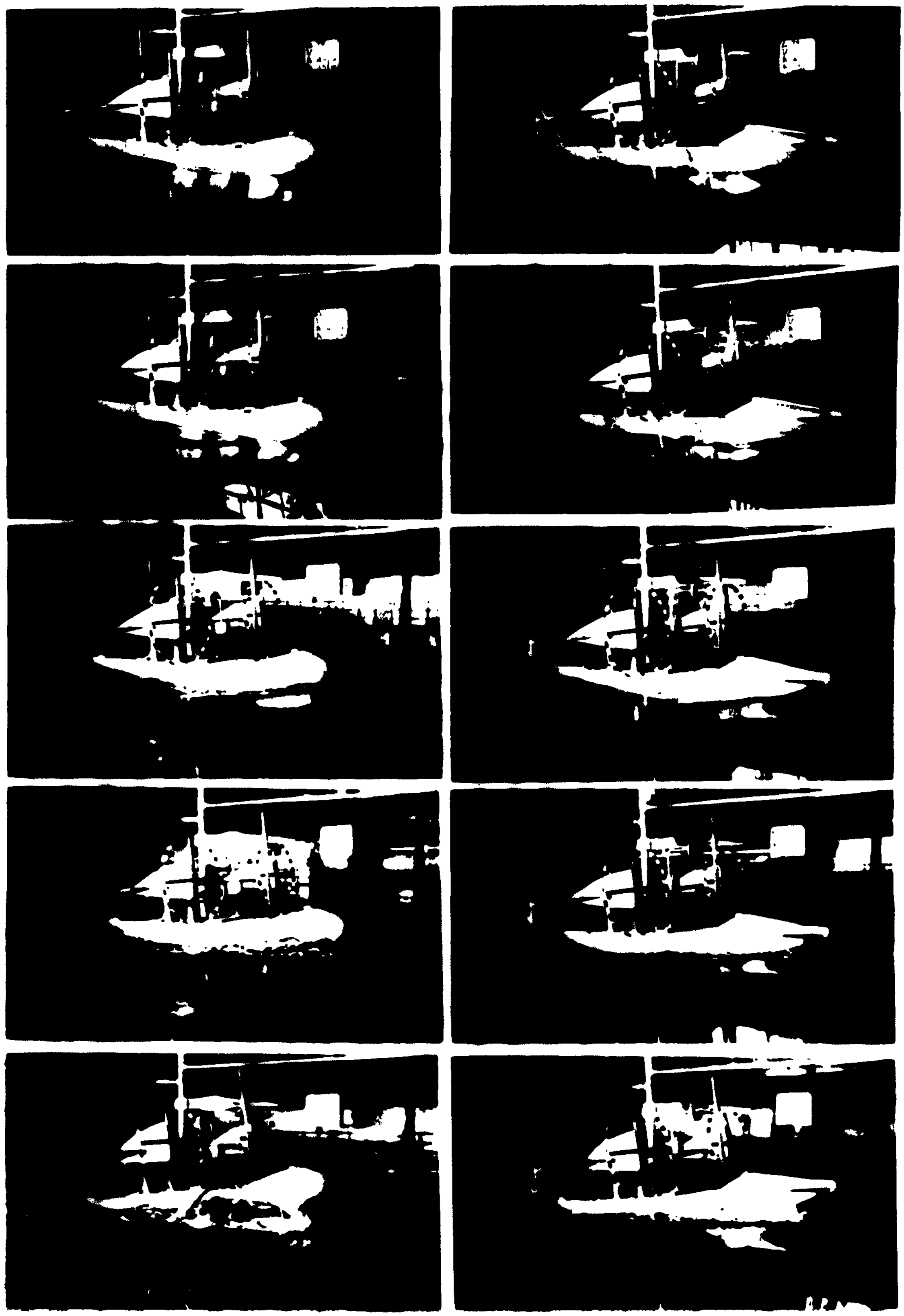
Speed (kts)

3.4

6.9

10.3

13.7



original | mod. no.1

wave height 2ft, wave length 144ft.

Fig. 16a Maximum Spray in Waves, G.W. 34,000lbs.

Speed (kts)

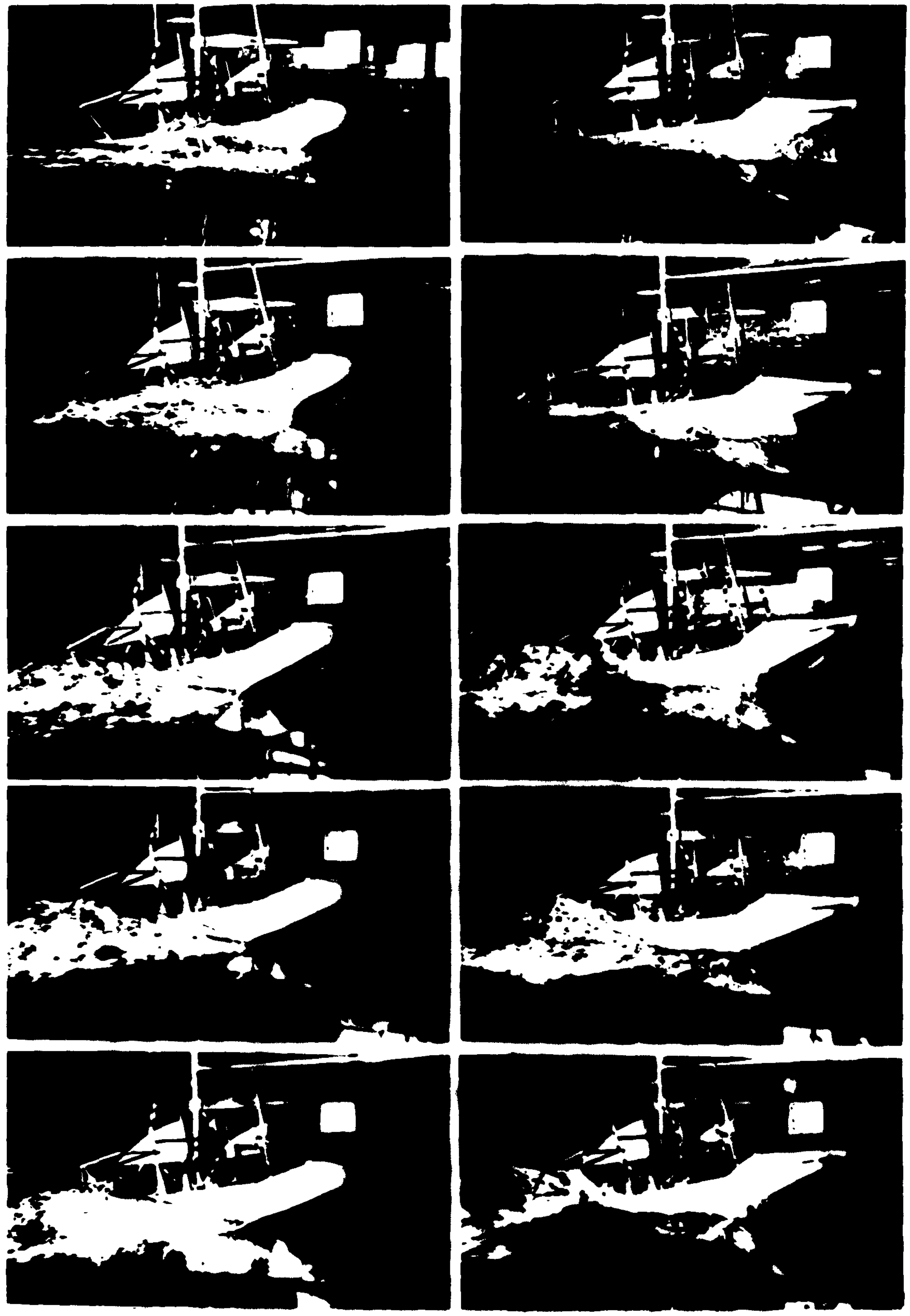
[illegible].2

20.0

24.0

27.5

30.9

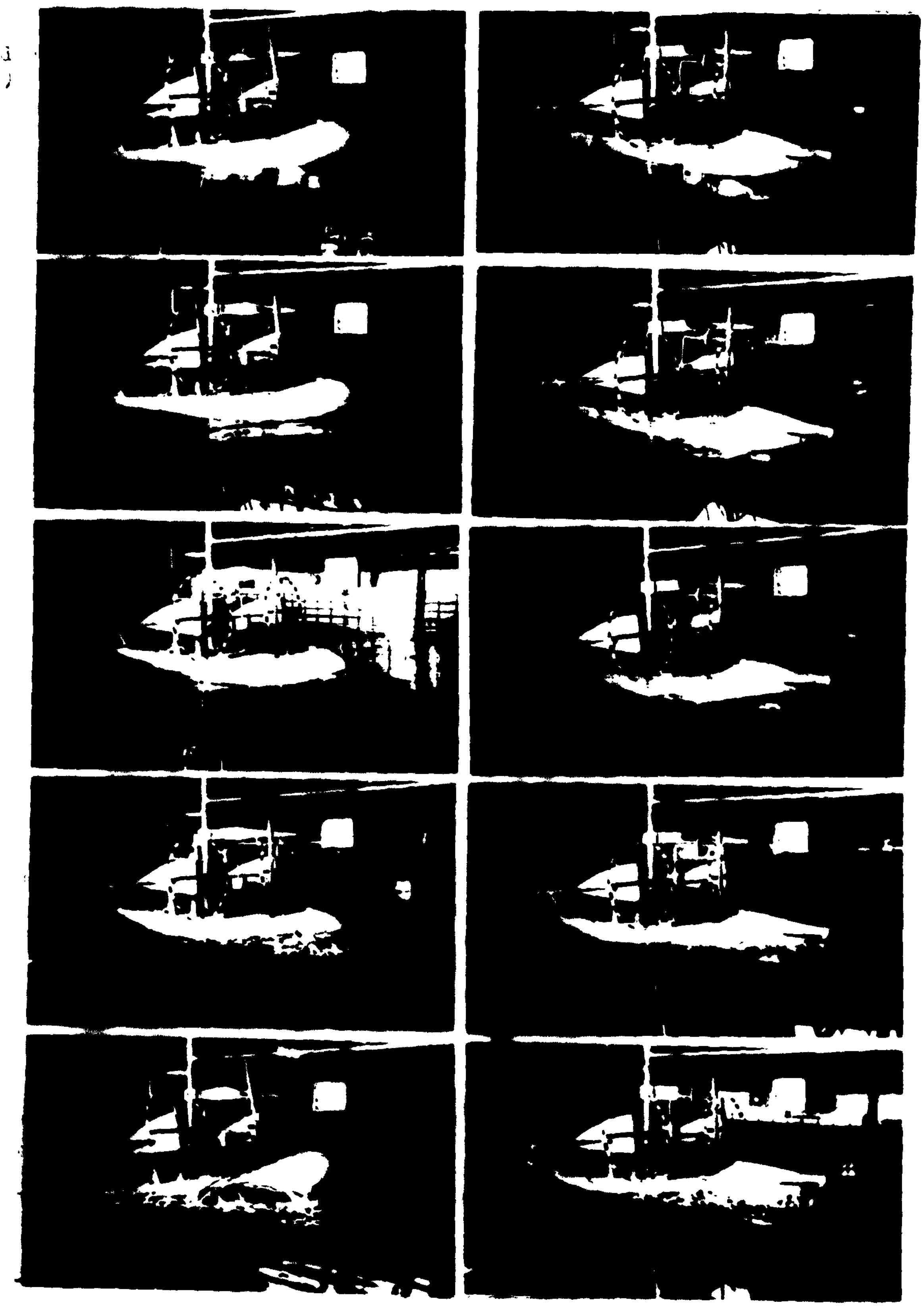


original mod. no.1

wave height 2ft, wave length 144ft.

Fig. 16b Maximum Spray in Waves, G.W. 34,000lbs.

Speed (kts)



5.4

6.9

10.5

15.7

original | mod. no.1

Wave height 5ft, wave length 123ft

Fig. 17a Maximum Spray in waves, G.W. 34,000lbs.

speed (kts)

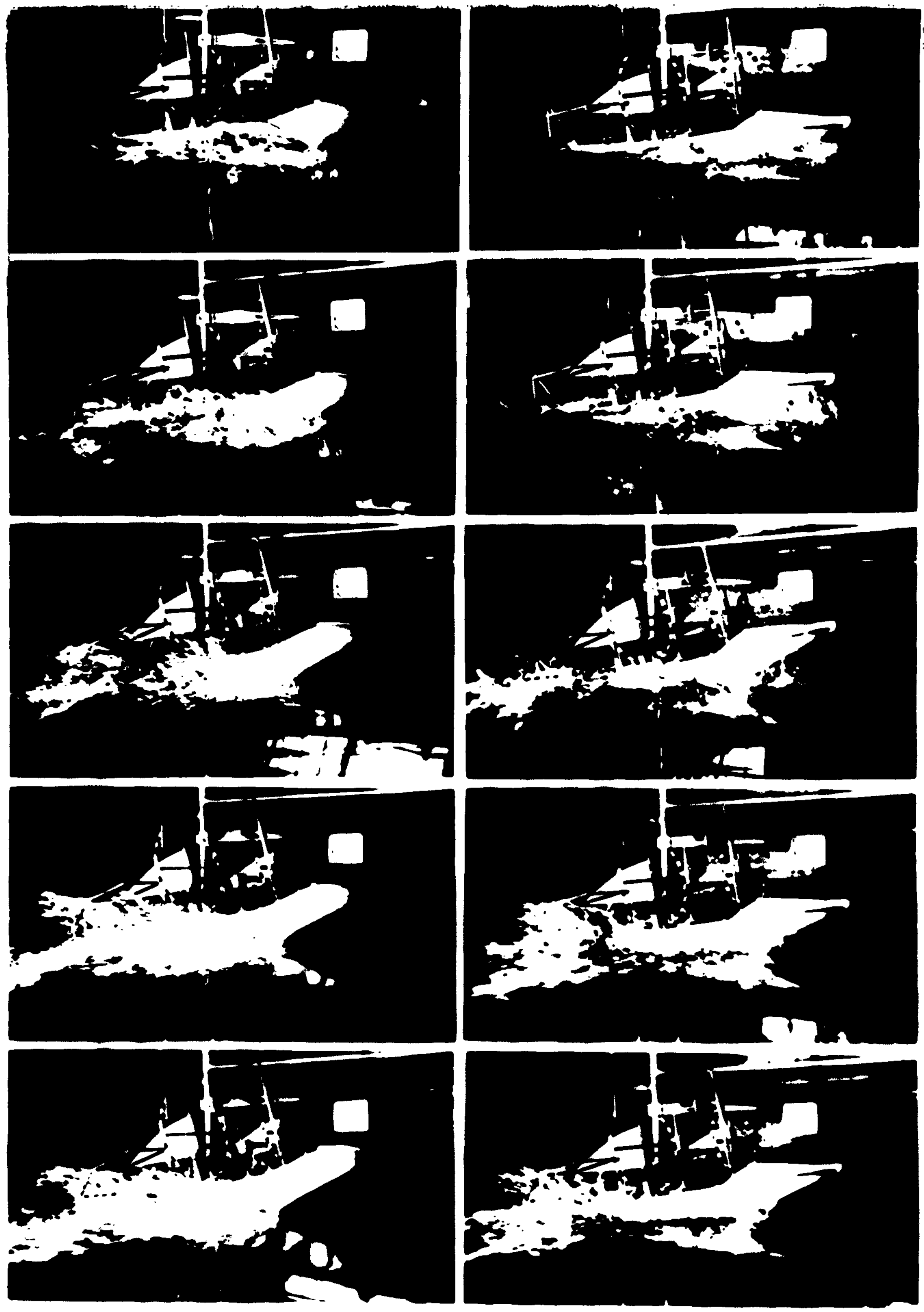
17.

20.0

2[illegible]

27.5

30.9



original   mod. no.1

wave height 3ft, wave length 123ft.

Fig. 17b Maximum Spray in waves, G.W. 54,000lbs.

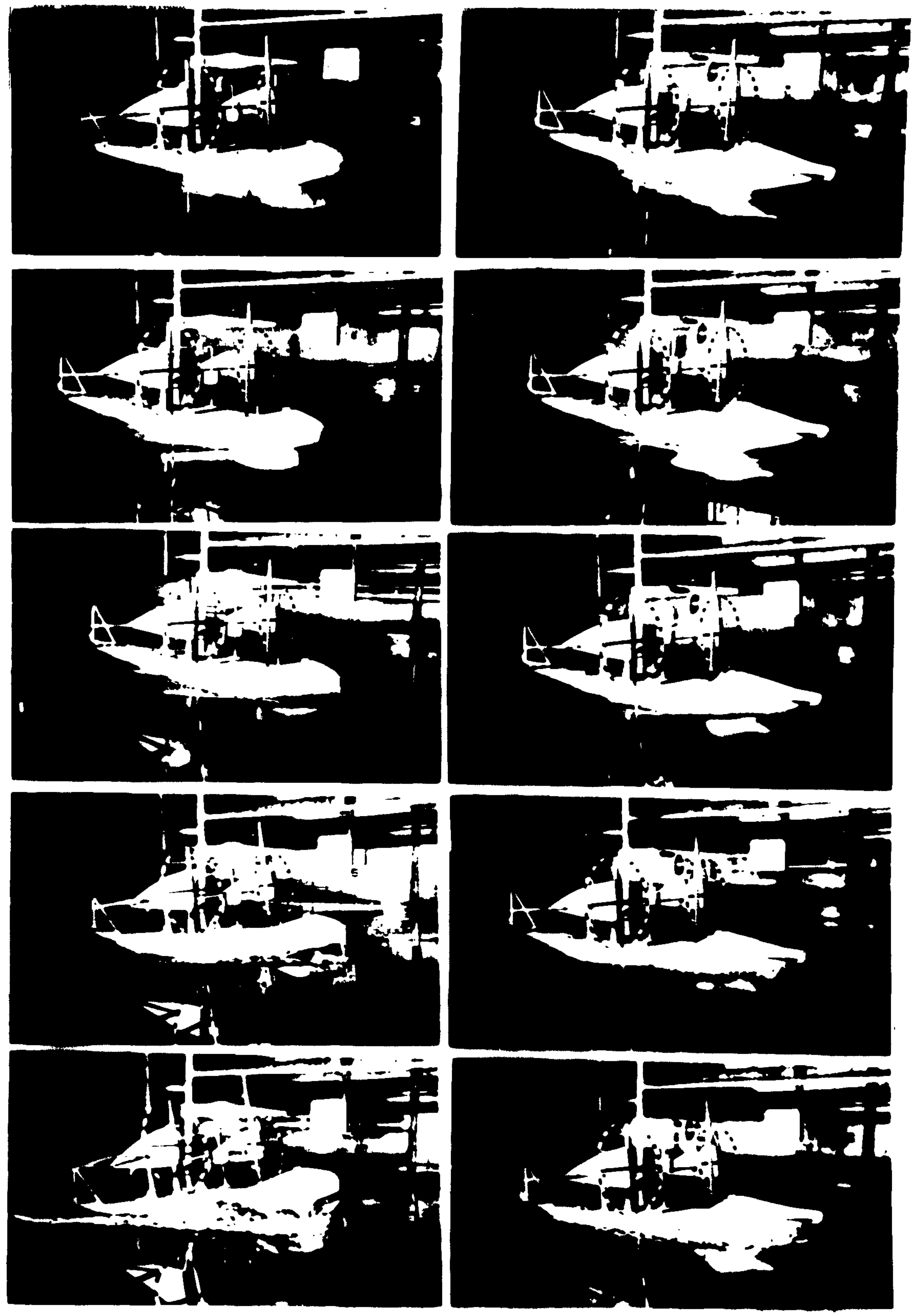
speed (kts)

[illegible]

6.9

1[illegible].3

13.7



original mod. no.1

wave height [illegible]ft, wave length [illegible]ft.

Fig. 18a Maximum Spray in Waves, G.W. [illegible],000lbs.

[illegible]

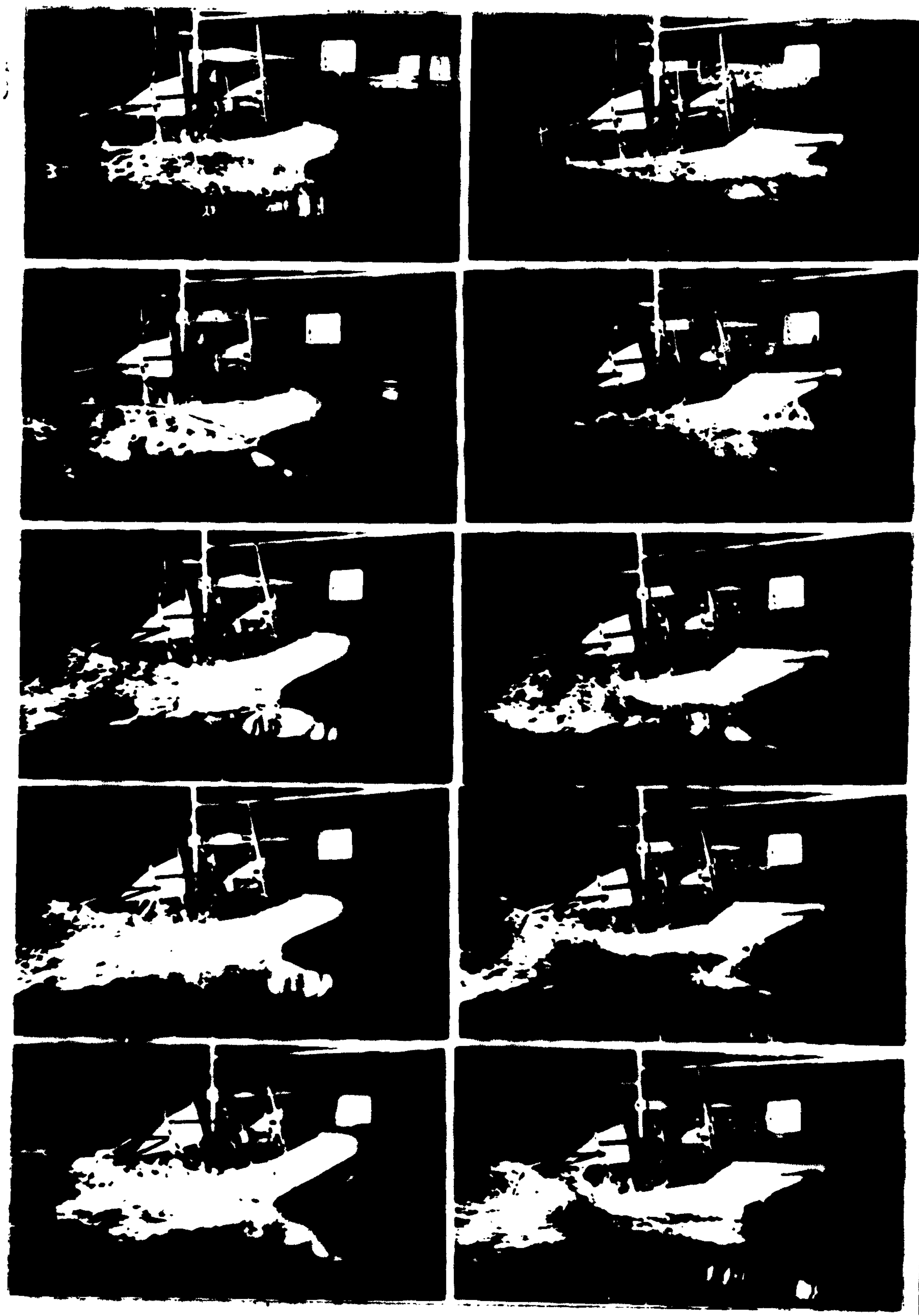
[illegible]

[illegible]

[illegible]

[illegible]

30.9



original mod. no.1

wave height 3ft, wave length [illegible]ft.

Fig. 18b Maximum Spray in waves, G.W. [illegible],000lbs.

speed
(kts)

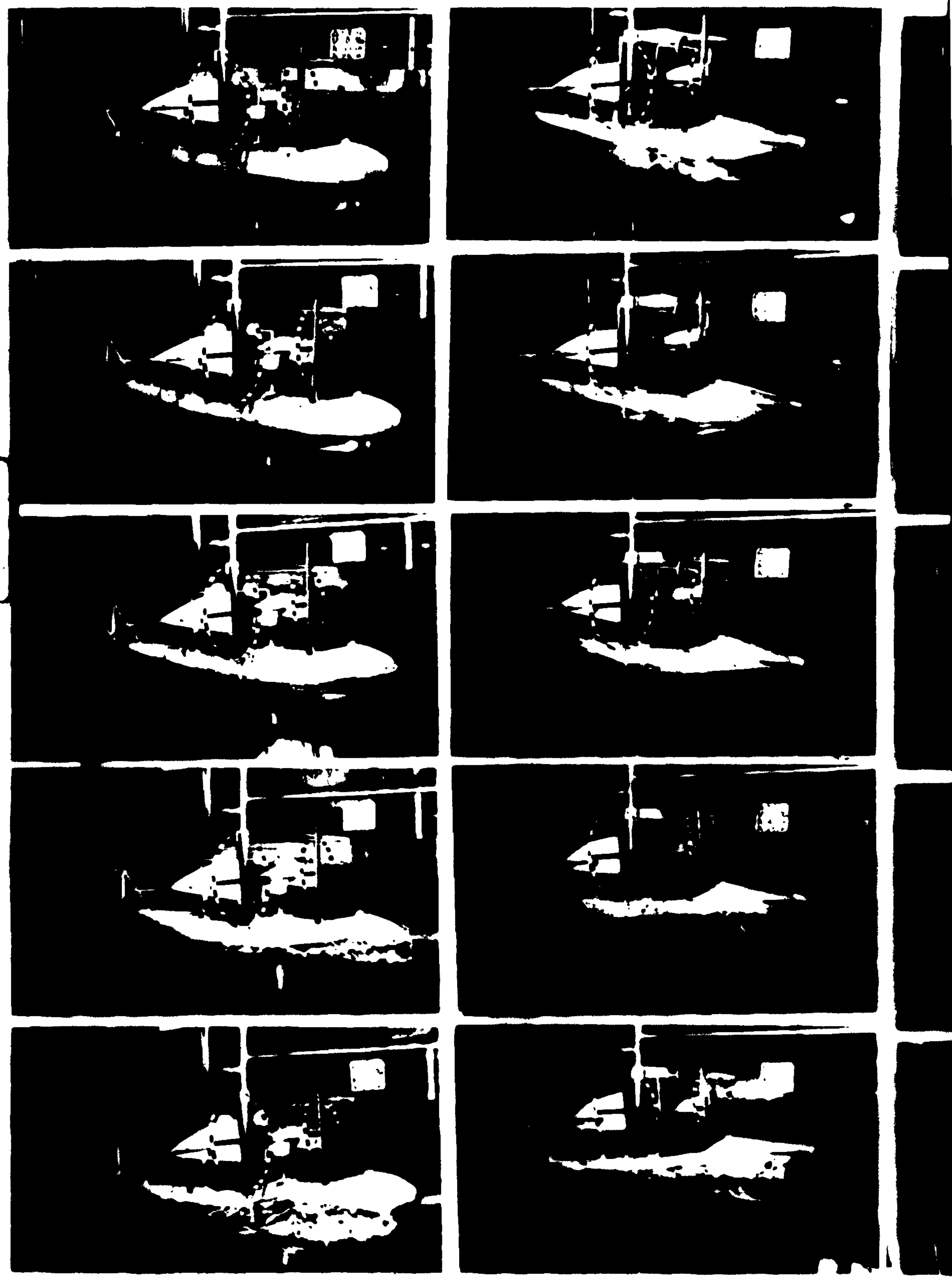
0

3.4

6.9

10.3

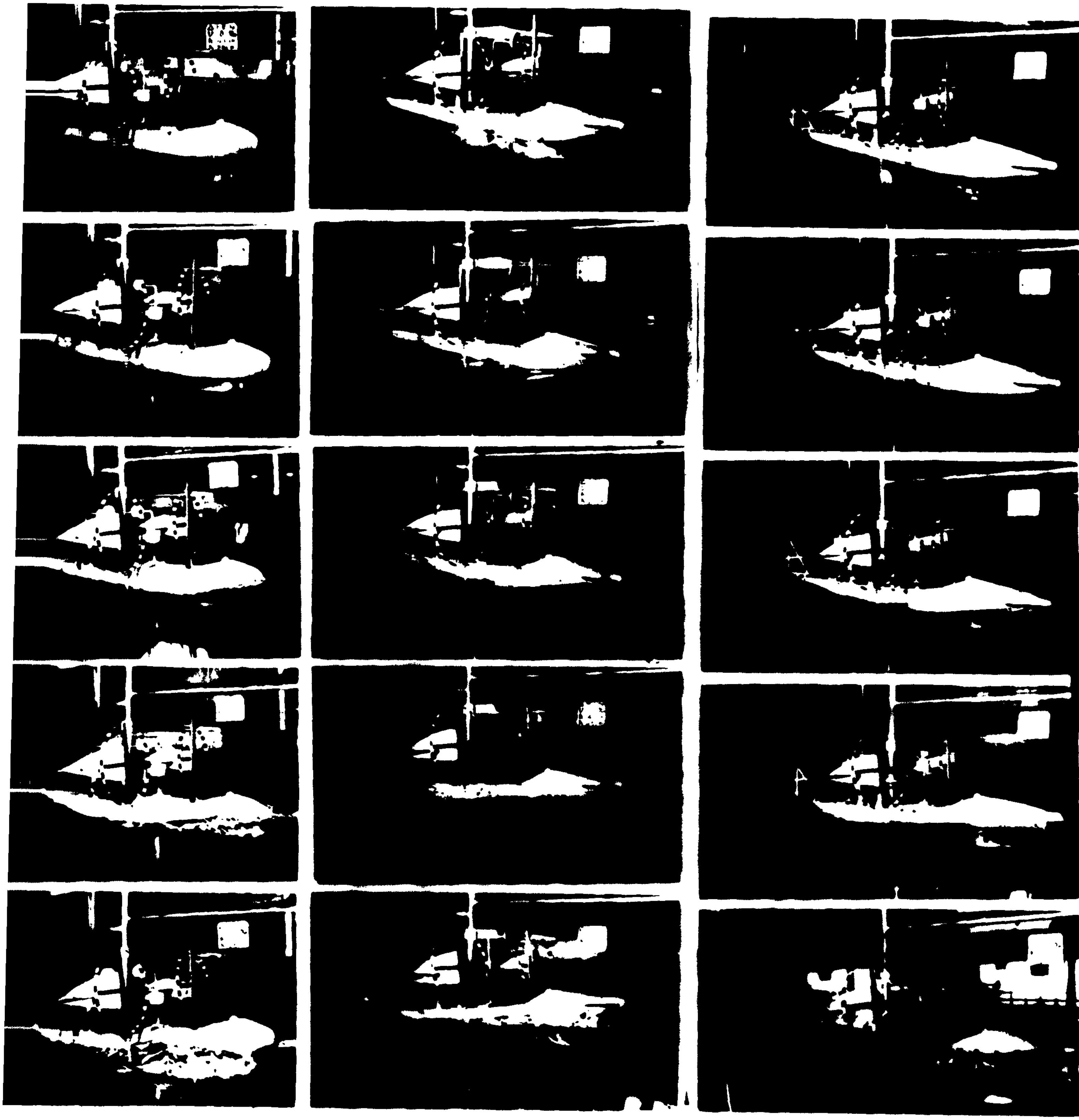
13.7



Original [illegible]

Wa[illegible] height [illegible], W[illegible]

Fig. 19: Maximum spray [illegible]



2

Original

[illegible]

speed (kts)

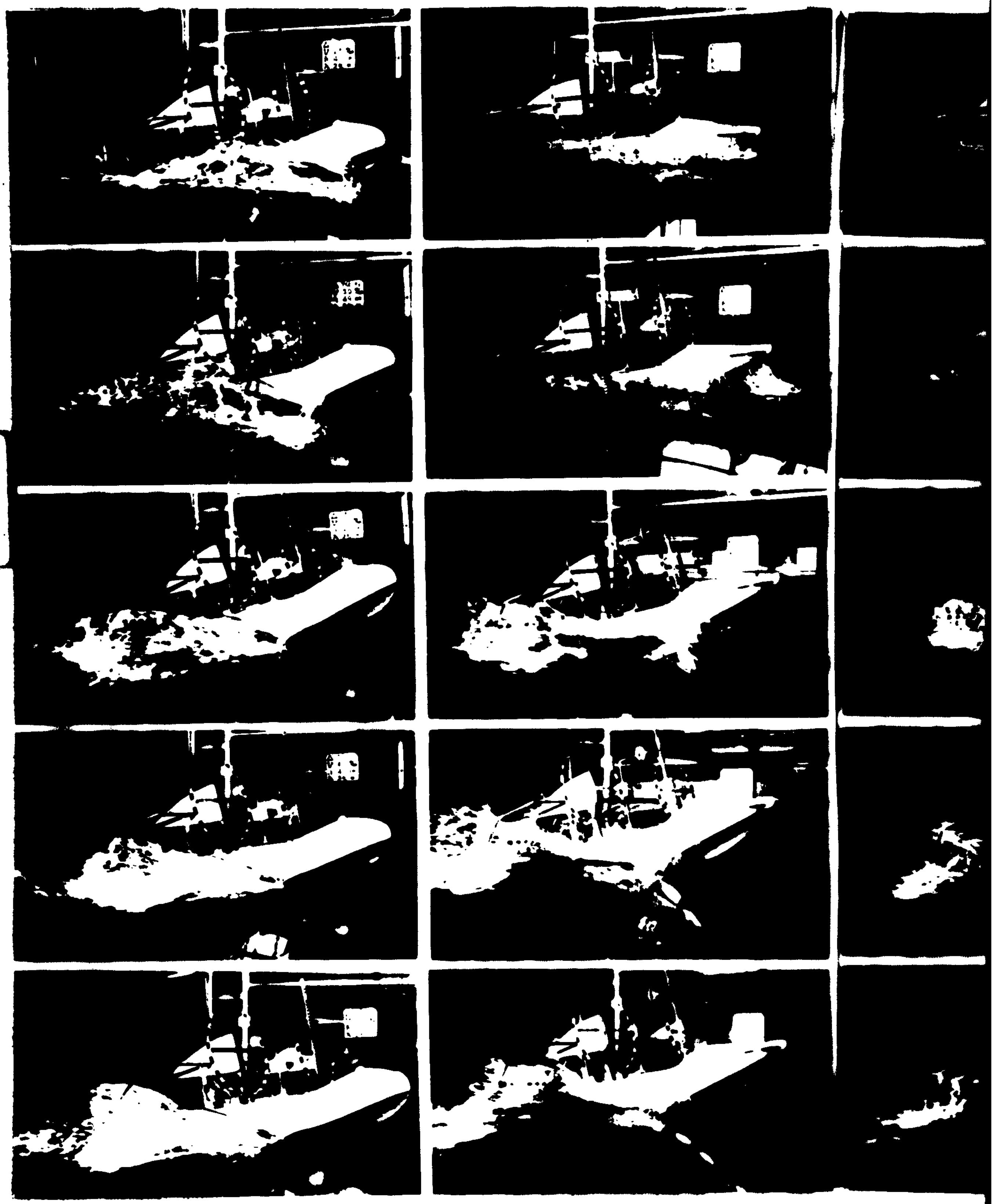
17.2

20.6

24.0

27.5

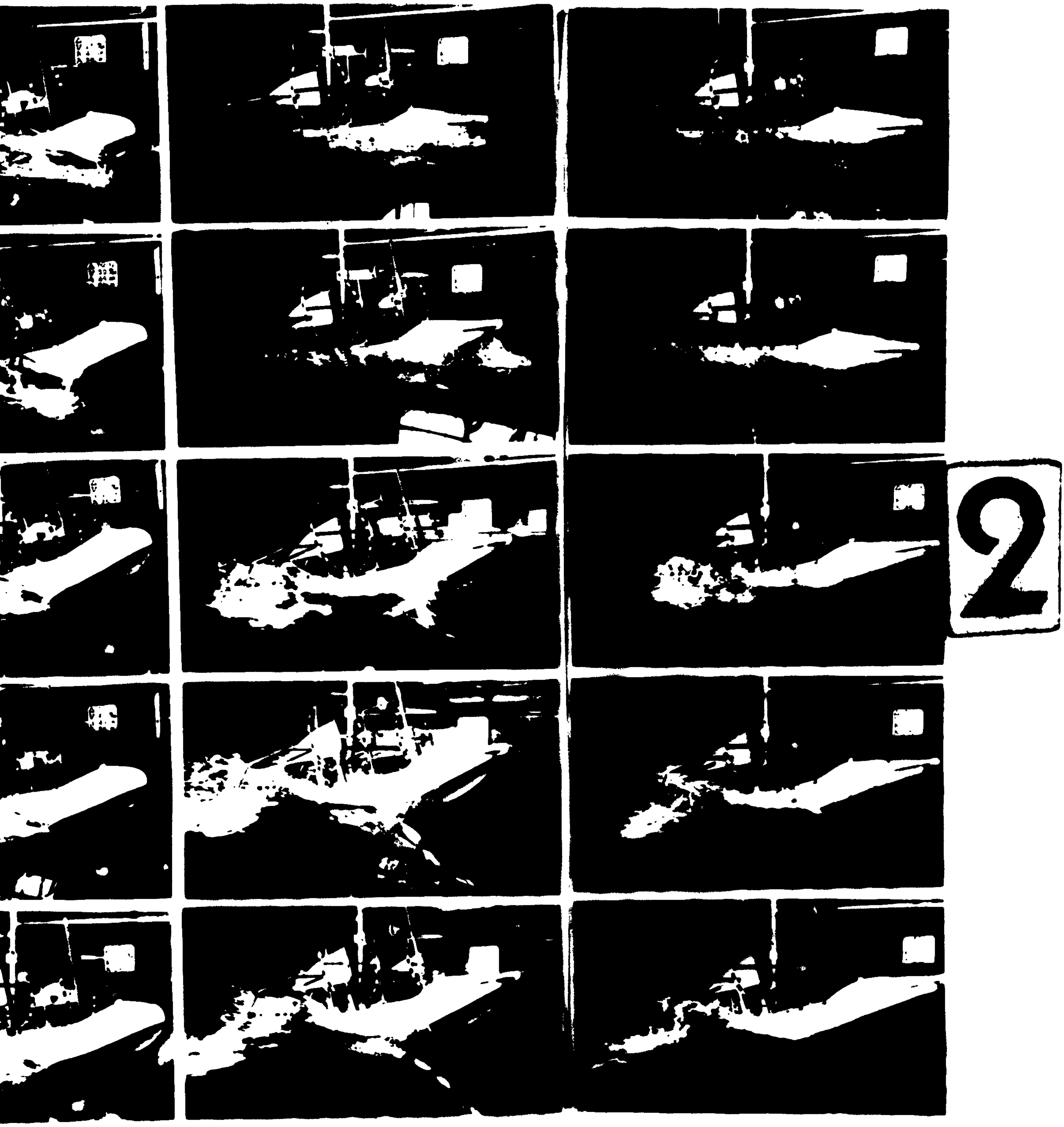
30.9



original | mod. no.1

wave height 2ft, wave length 1[illegible]2ft.

Fig. 19b Maximum Spray in Waves, G.W. 3[illegible],000lbs.



al

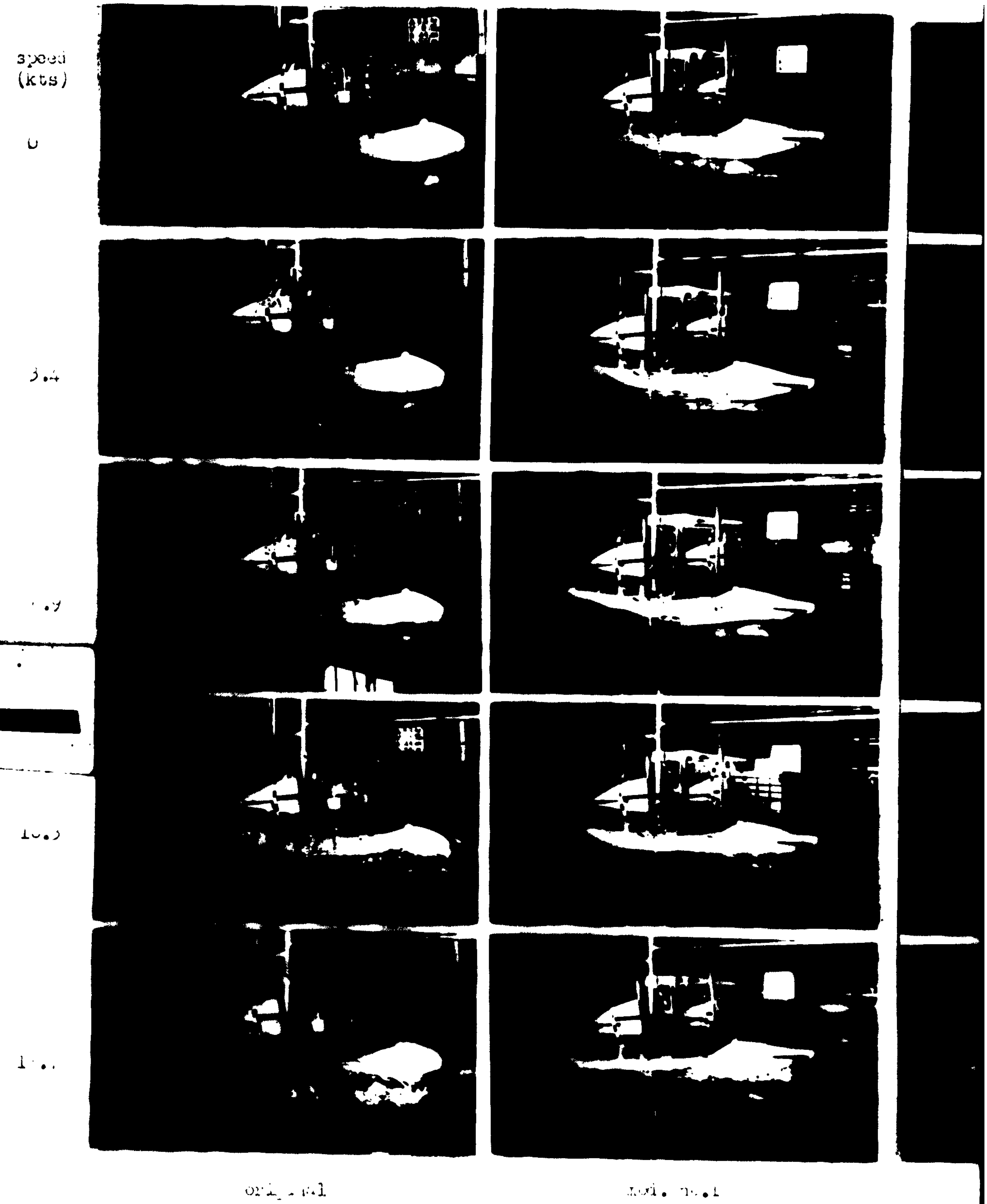
mod. no.1

mod. no.2

ght 21t, wave length 102ft.

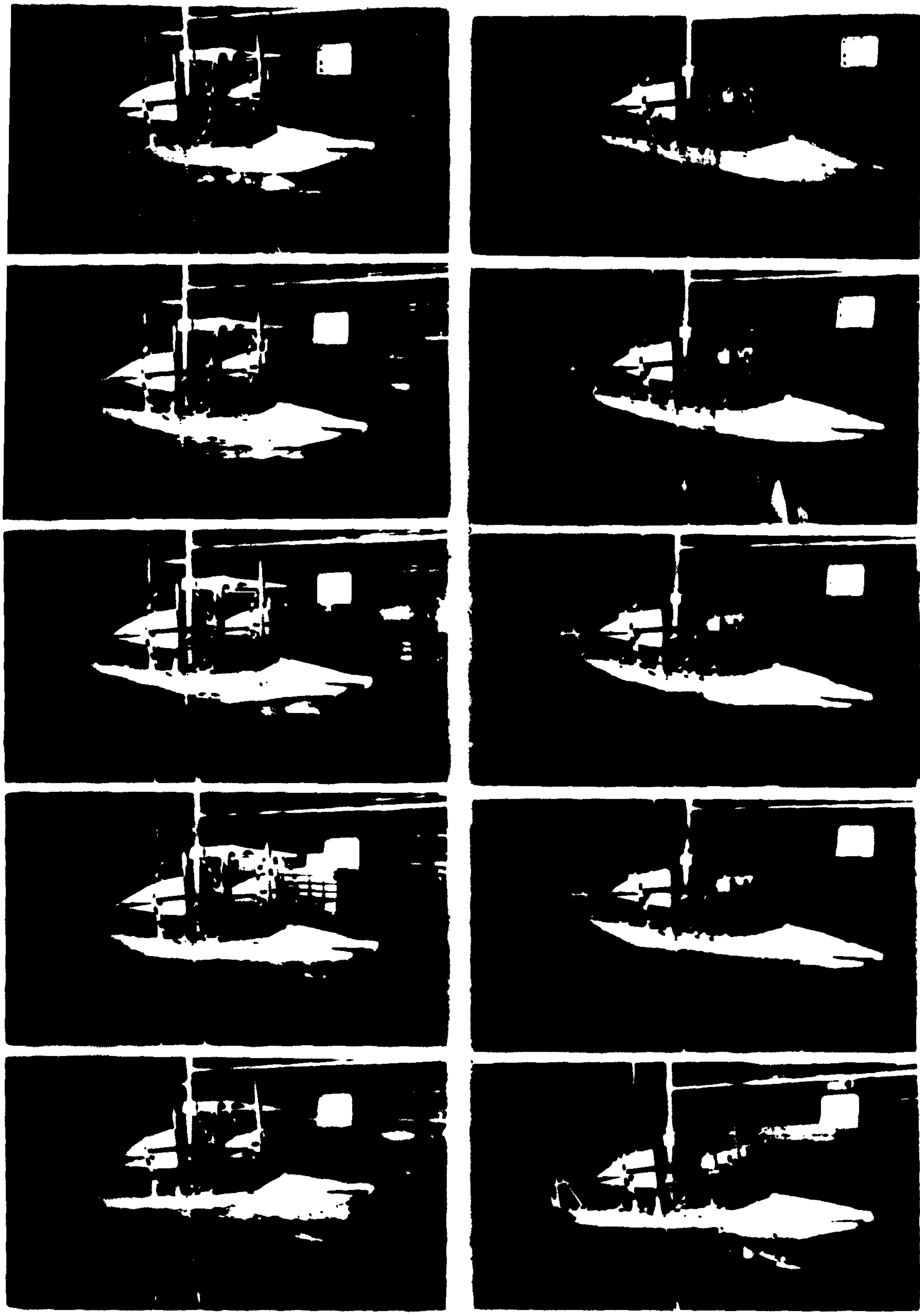
m Spray in Waves, G.W. 3 ,000lbs.

26



[illegible] 2f[illegible], wave length 125ft.

[illegible] in [illegible]



2

mod. no.1

moi. no.2

[illegible] 125:6.

[illegible]

speed (kts)

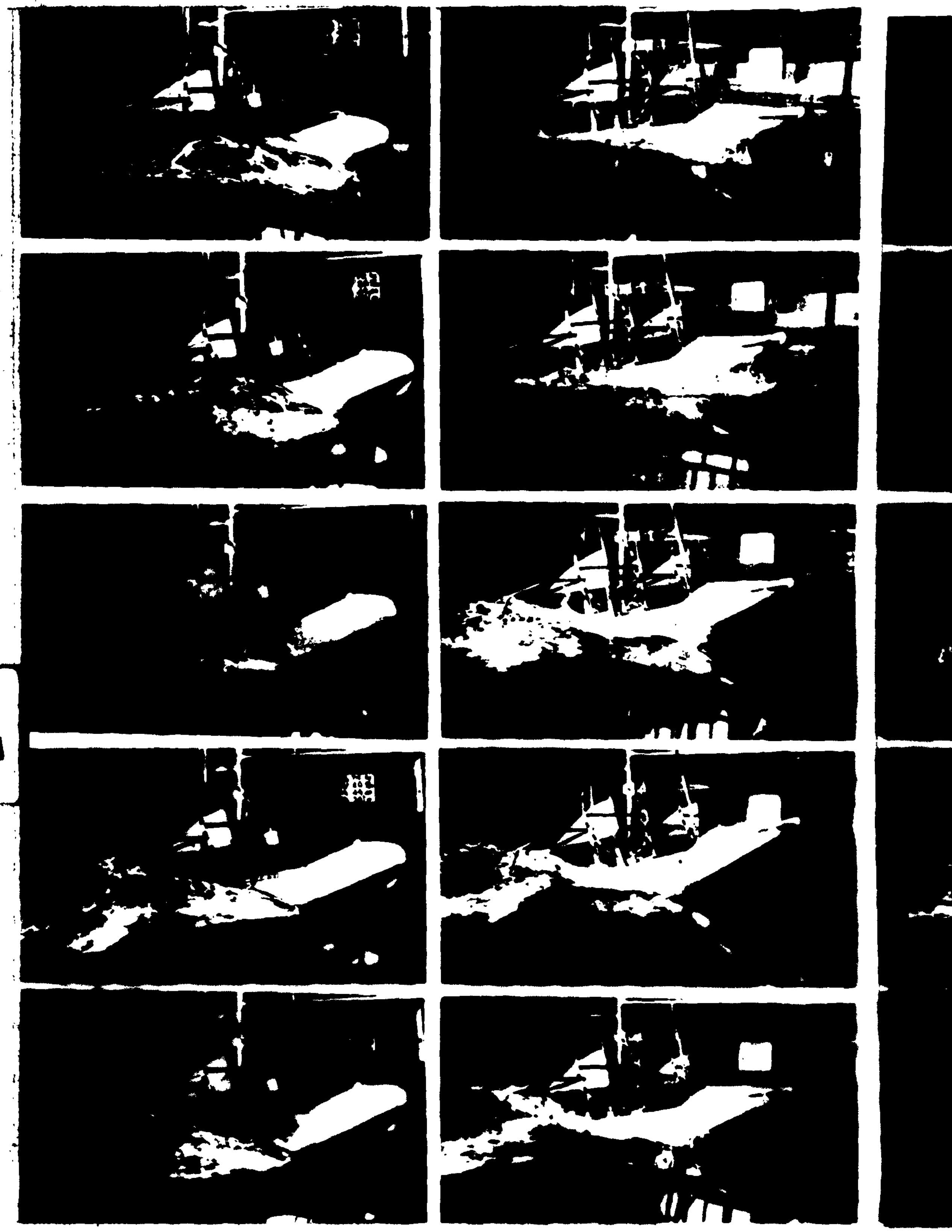
17.2

20.6

24.0

27.5

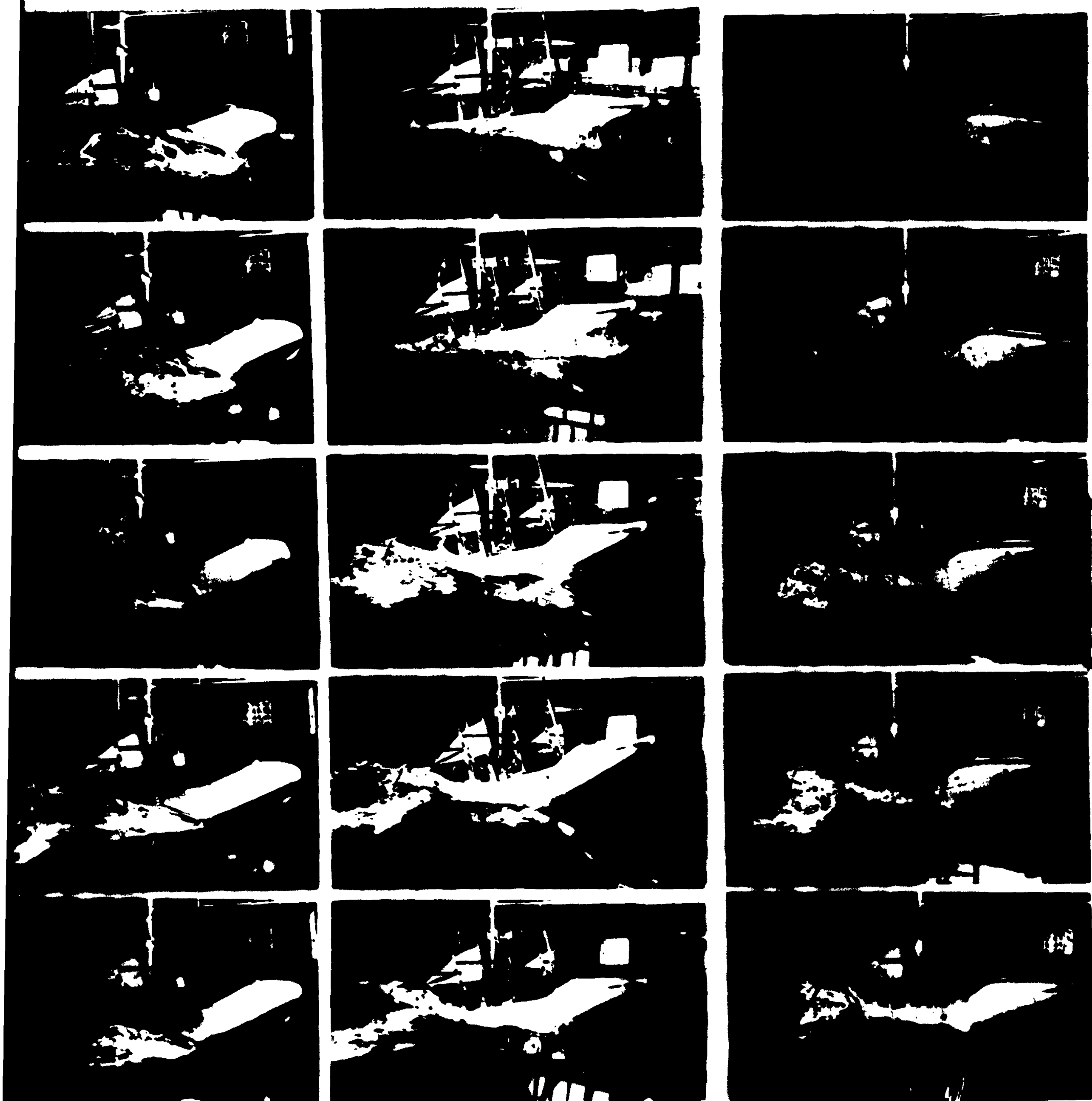
30.9



original   mod. no.1

wave height 2ft, wave length 123ft.

Fig. 20b Maximum spray in waves, [illegible]

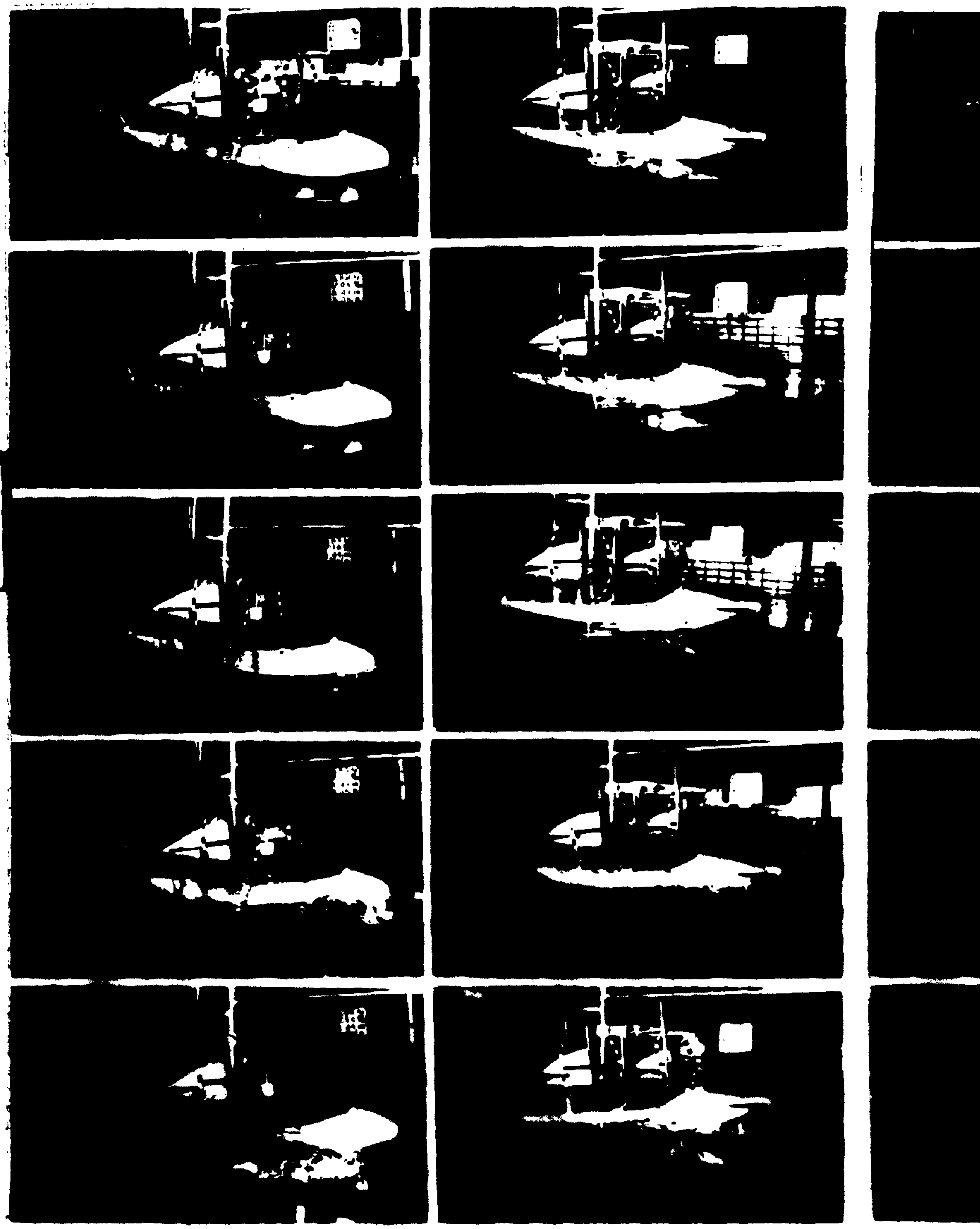


2

original | mod. no.1 | mod. no.2

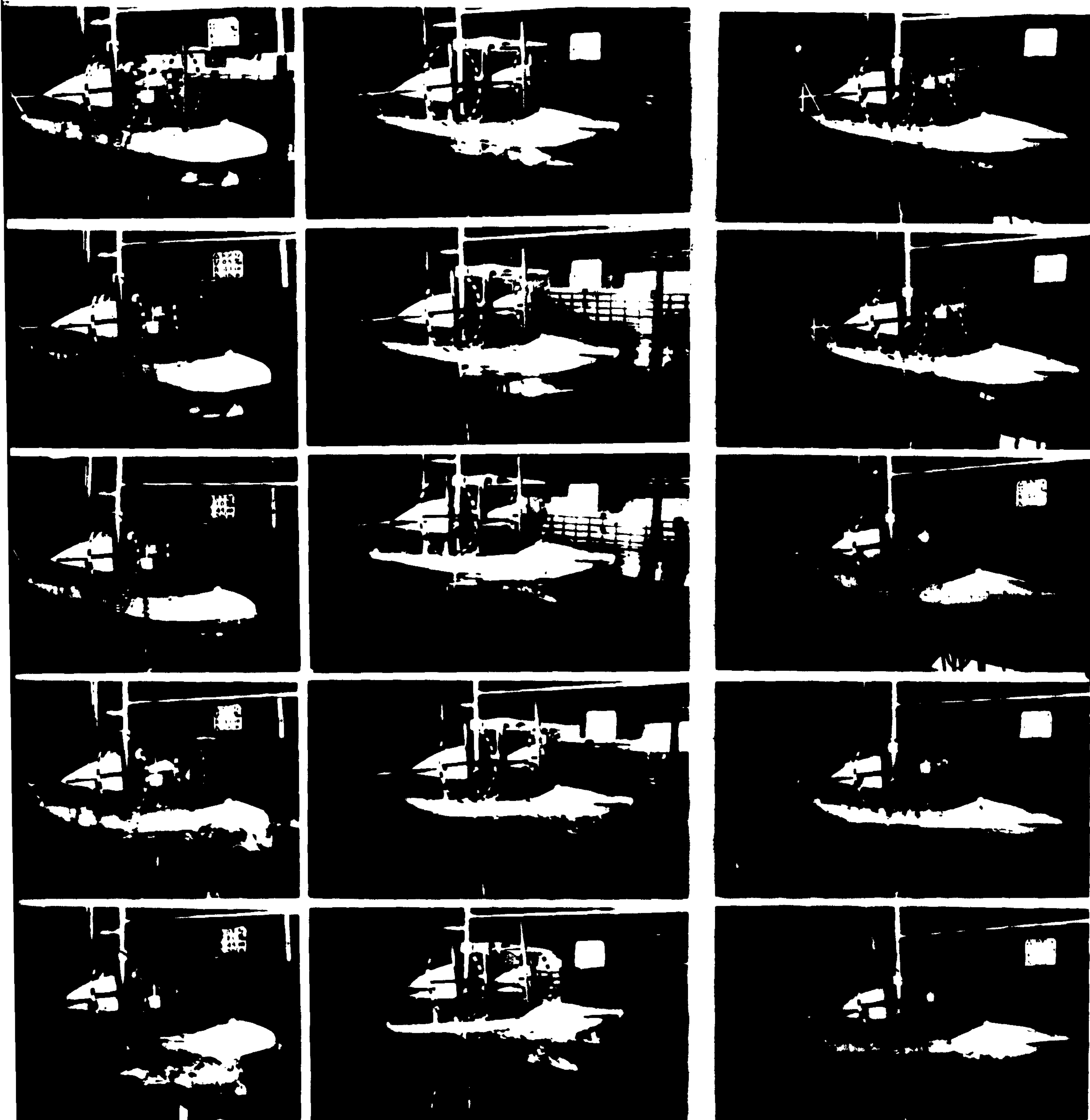
wave height 2ft, wave length 12[illegible]ft.

Fig. 20b Maximum spray in waves, [illegible].



wave height 2ft, wave length 144ft.

Fig. [illegible] Maximum spray in waves, G.W. 36,000lbs.



2

original | mod. no.2 | mod. no.2

wave height 2ft, wave length 144ft.

21. [illegible] spray in waves, [illegible]. 36,000lbs.

speed
(kts)

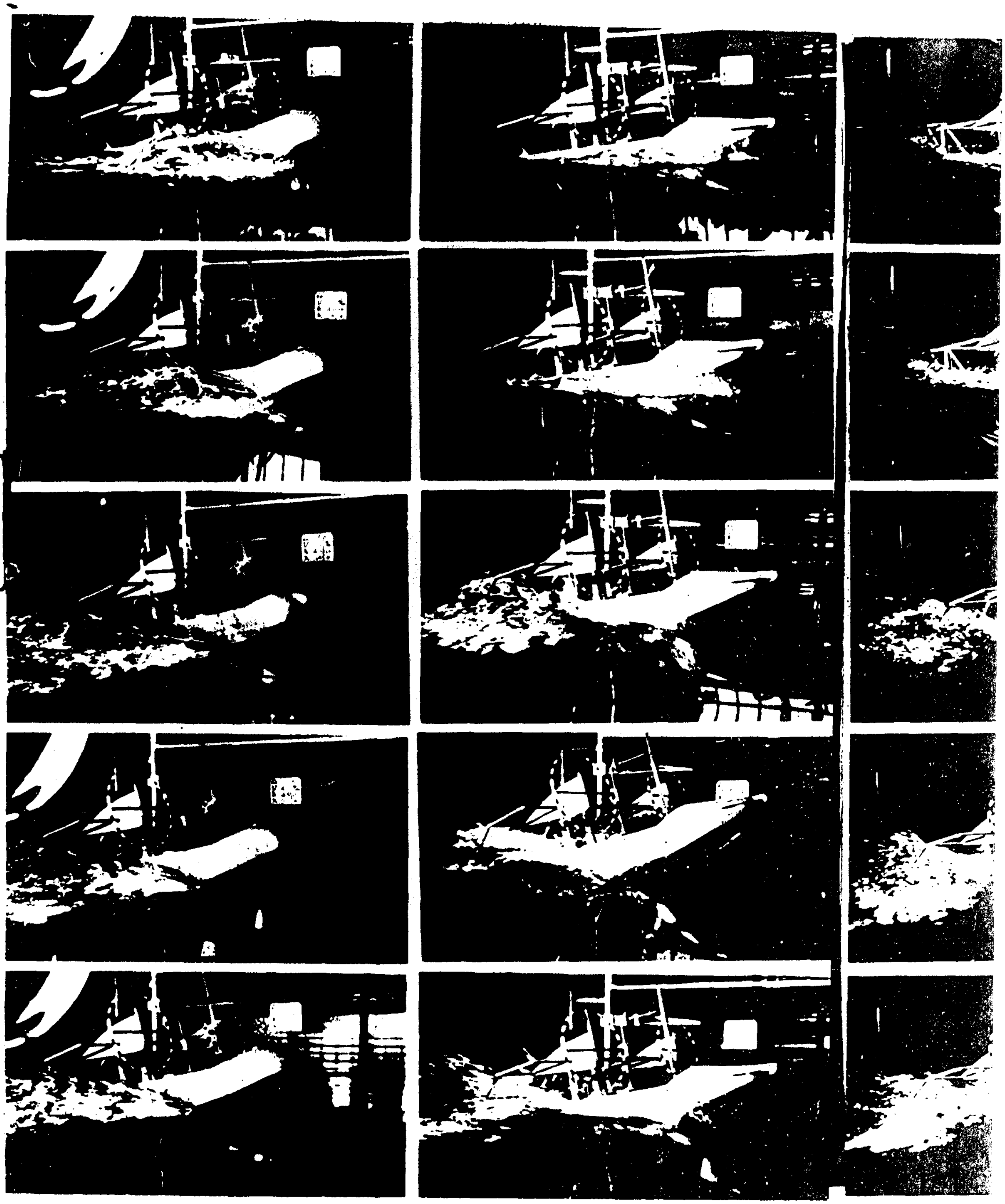
17.2

20.6

24.0

27.5

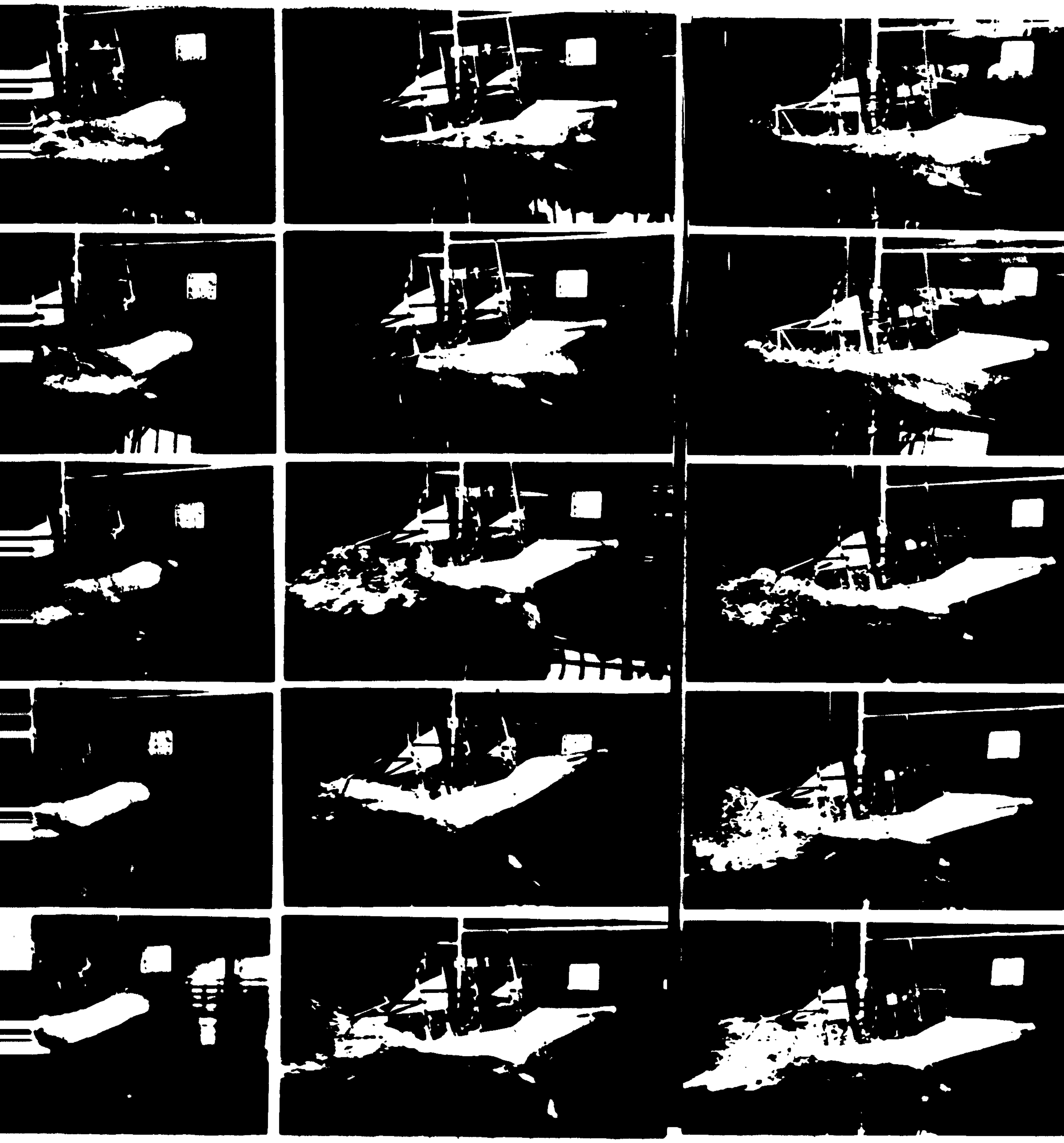
30.9



original | mod. no.1

Wave height 8ft, wave length [illegible]

[illegible]



original | mod. no.1 | [illegible] no.2

Wave [illegible] 2ft, [illegible] length [illegible].

[illegible] maximum spray [illegible] speeds.

speed (kts)

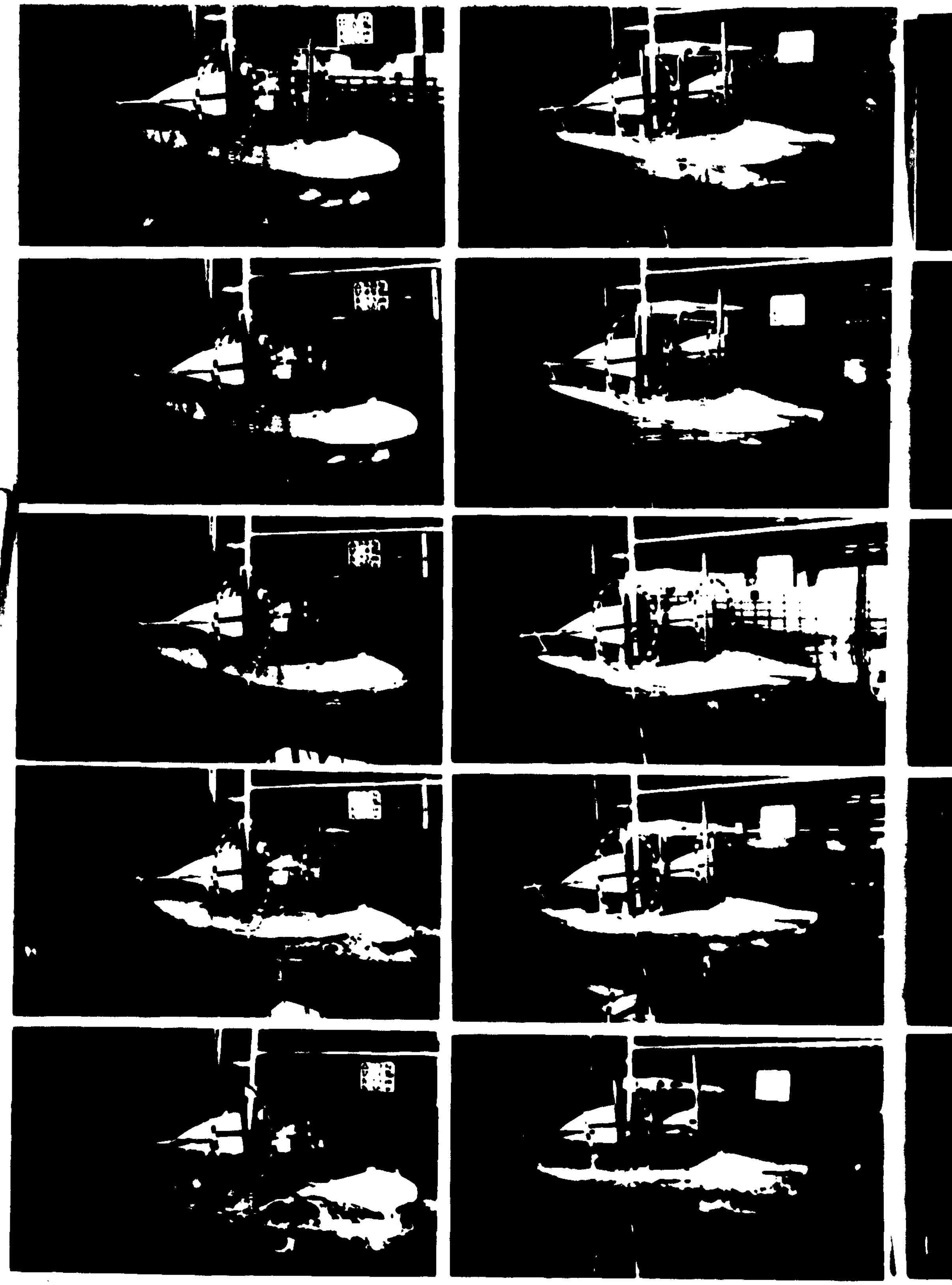
0

3.4

6.9

10.3

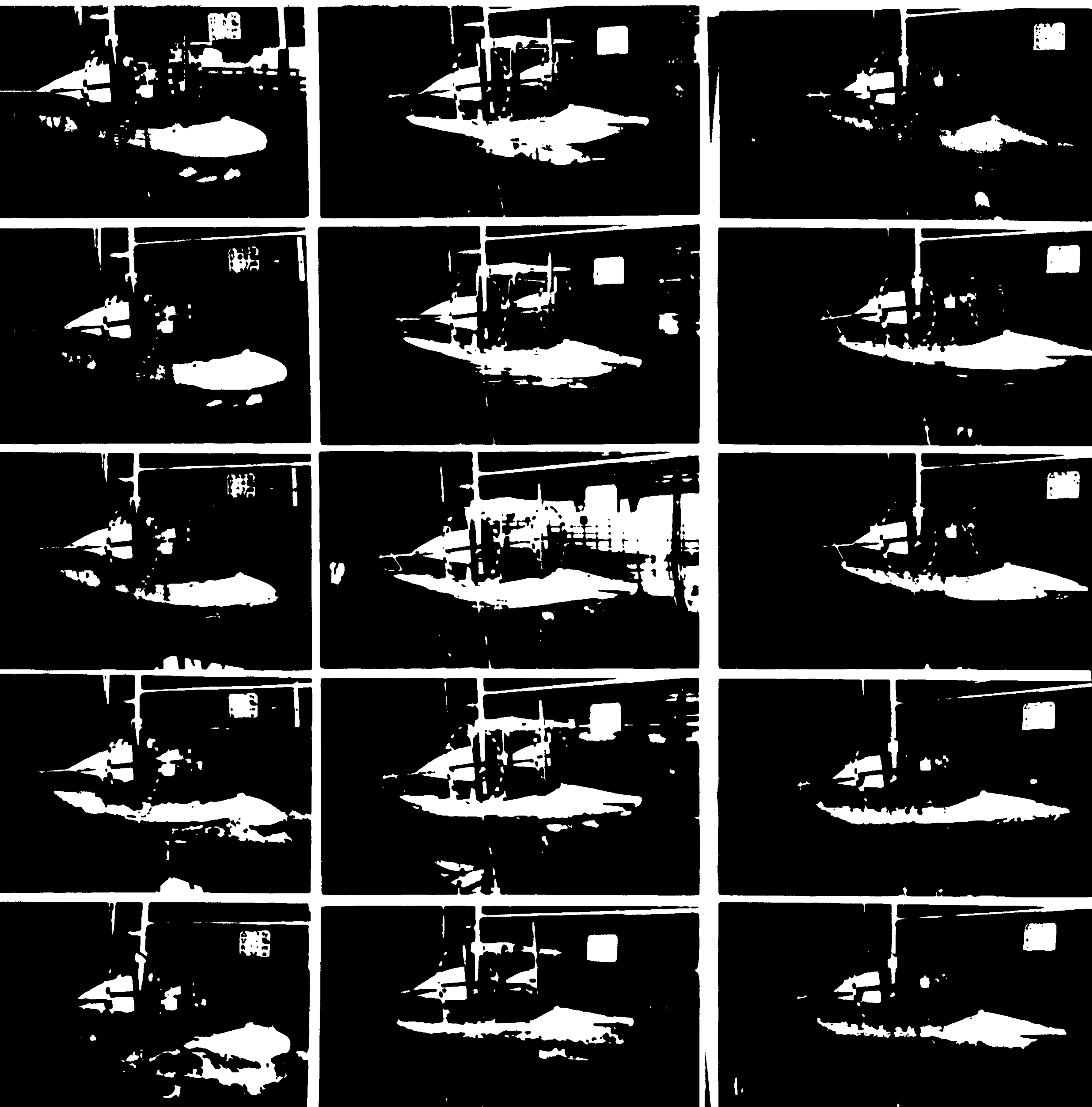
13.7



original | mod. …

[illegible]

[illegible]



2

original [illegible] [illegible]

[illegible]

[illegible]

speed (kts)

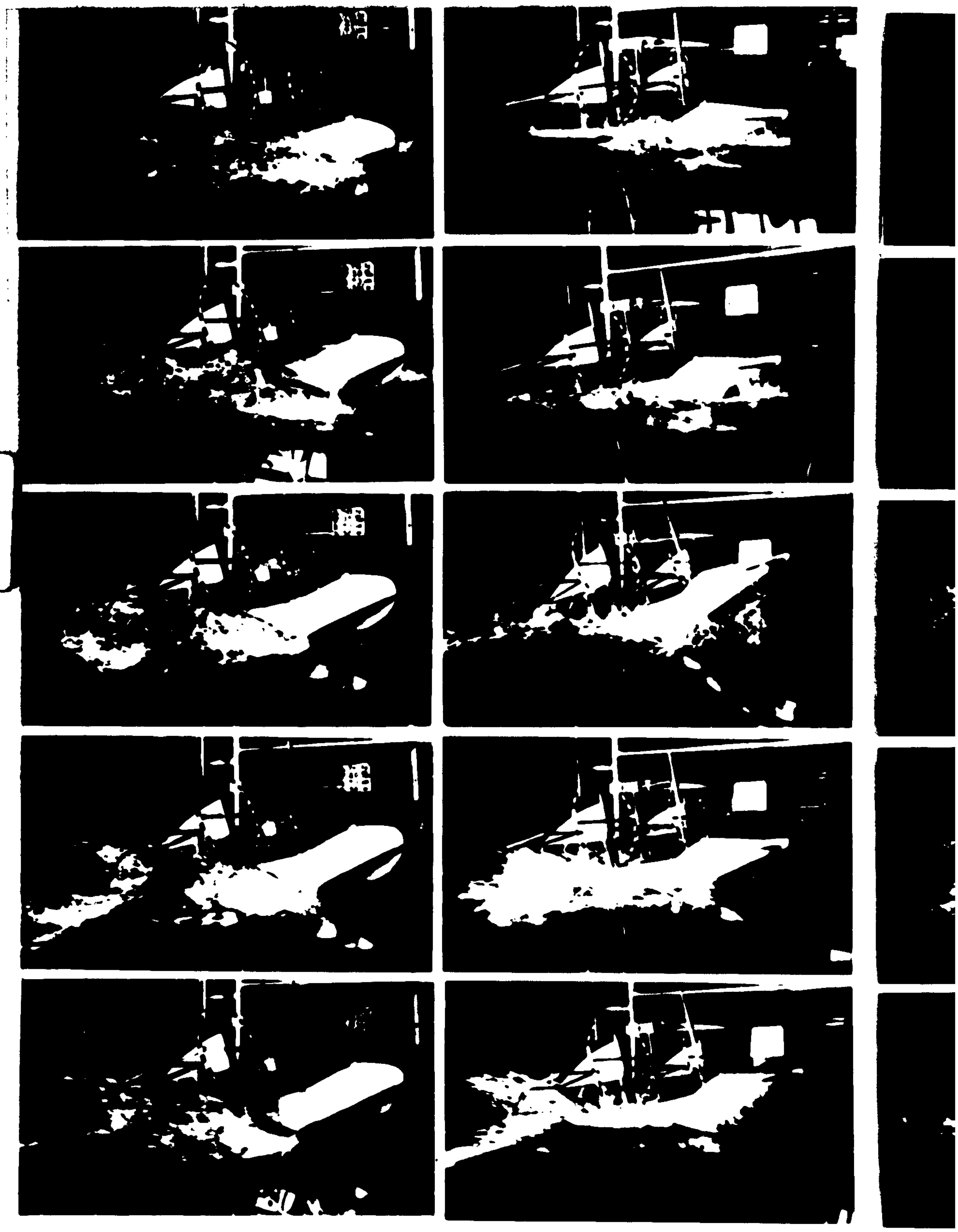
17.2

20.6

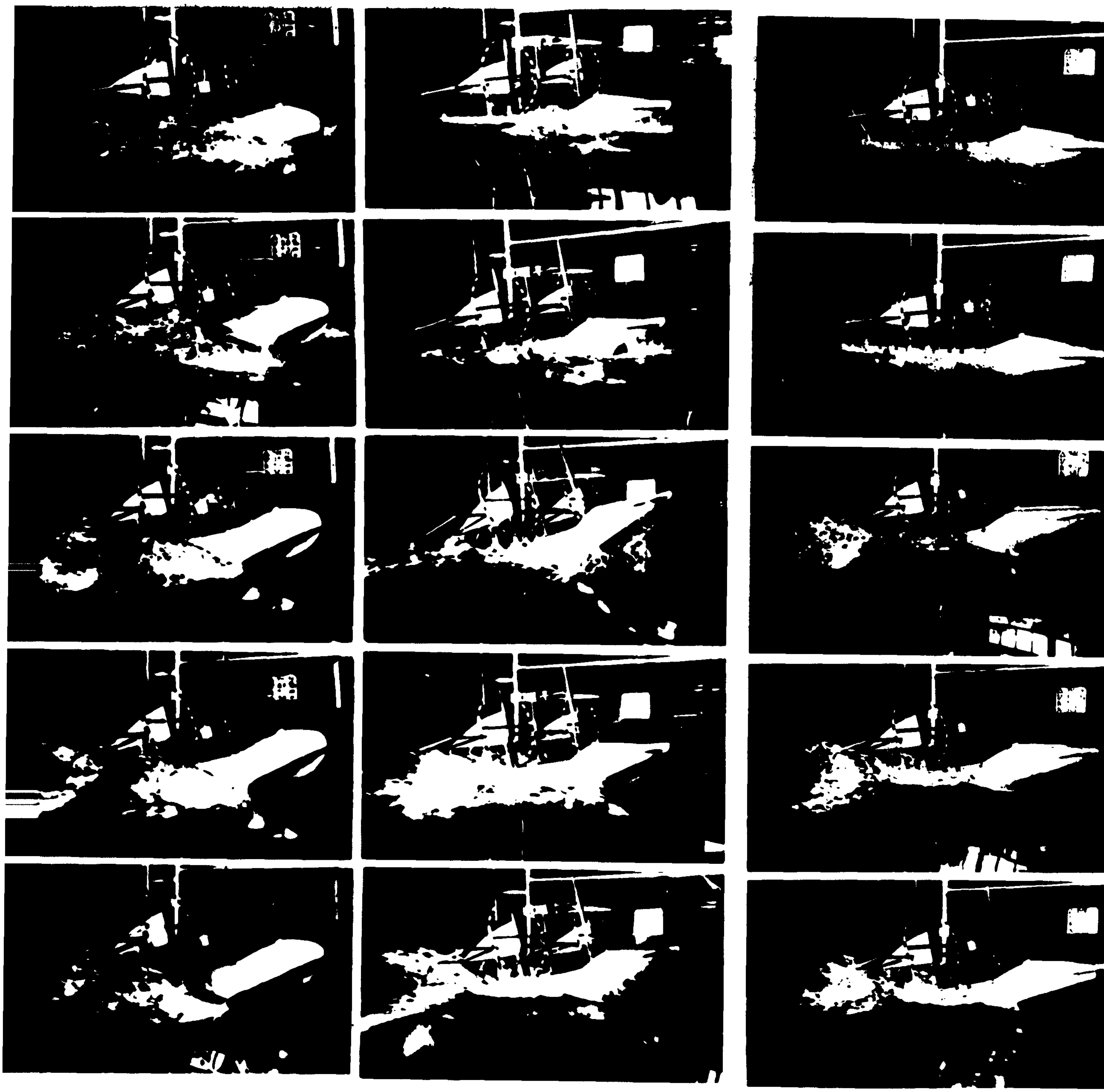
24.0

27.5

30.9



original



2

original

Speed (kts)

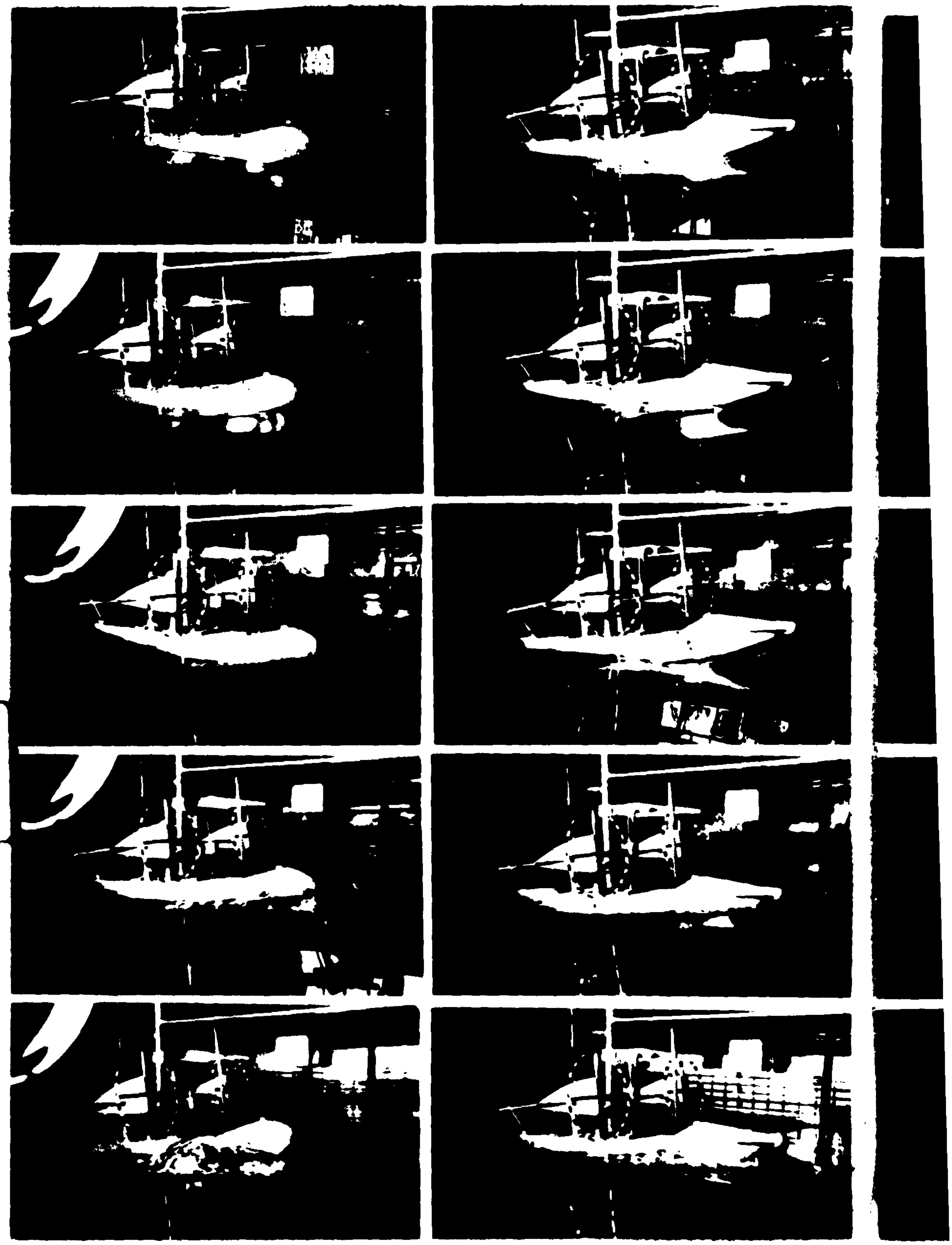
0

[illegible].4

[illegible].9

1[illegible].3

1[illegible] 7

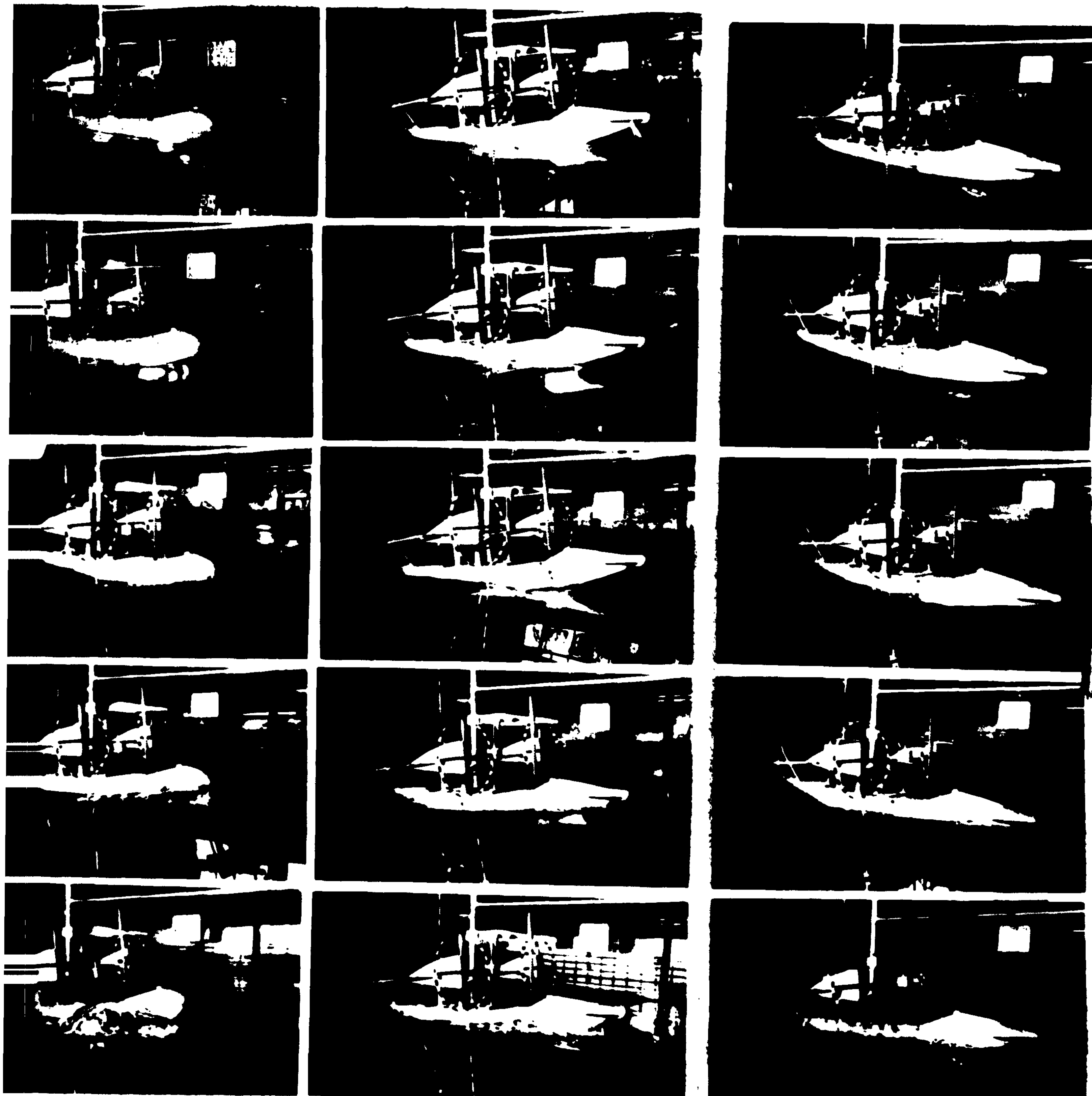


original

[illegible] no.1

[illegible] length [illegible]

[illegible] s, G.W. 36,000lbs.

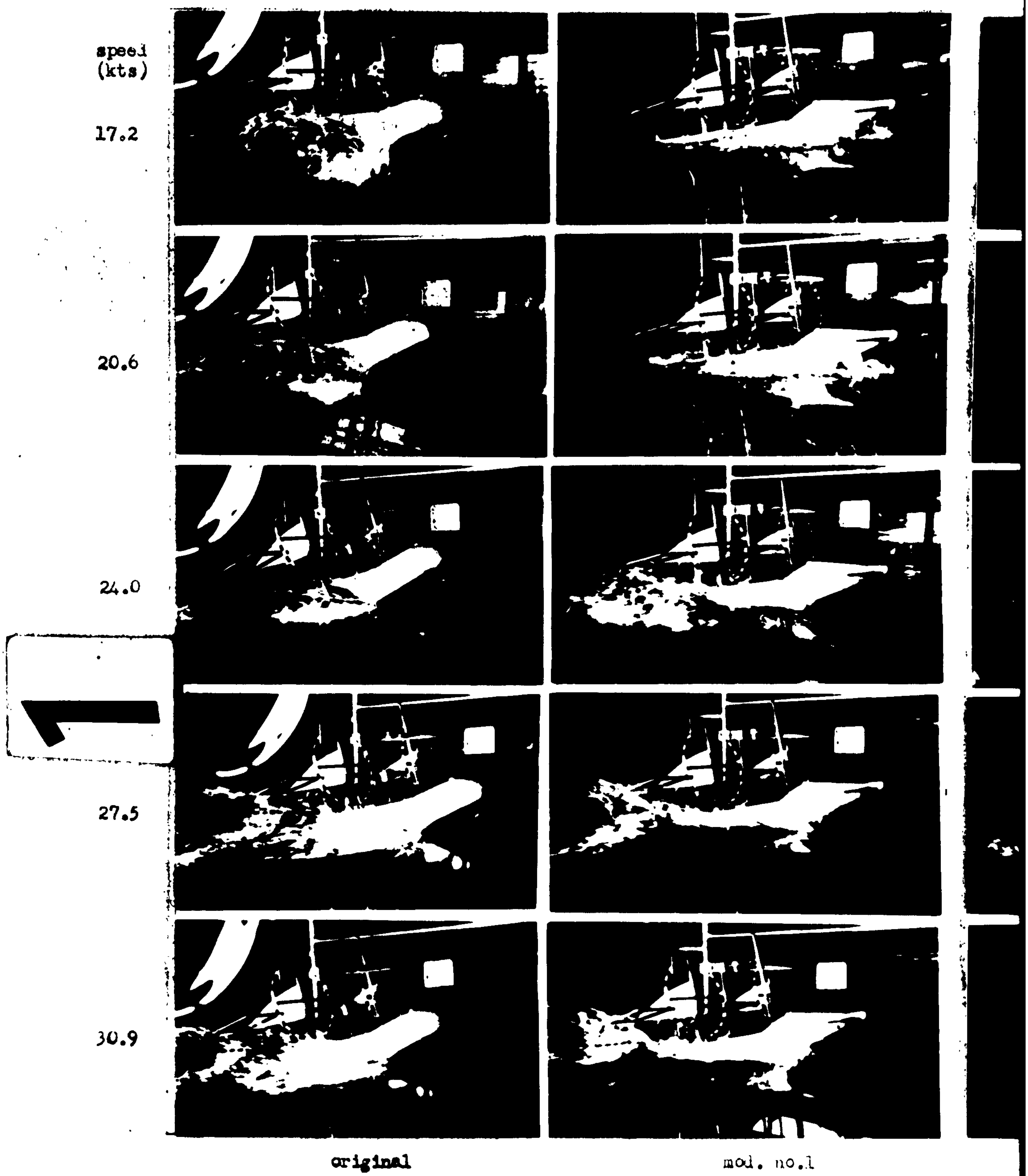


2

original　　　　Mod. no.1　　　　Mod. no.2

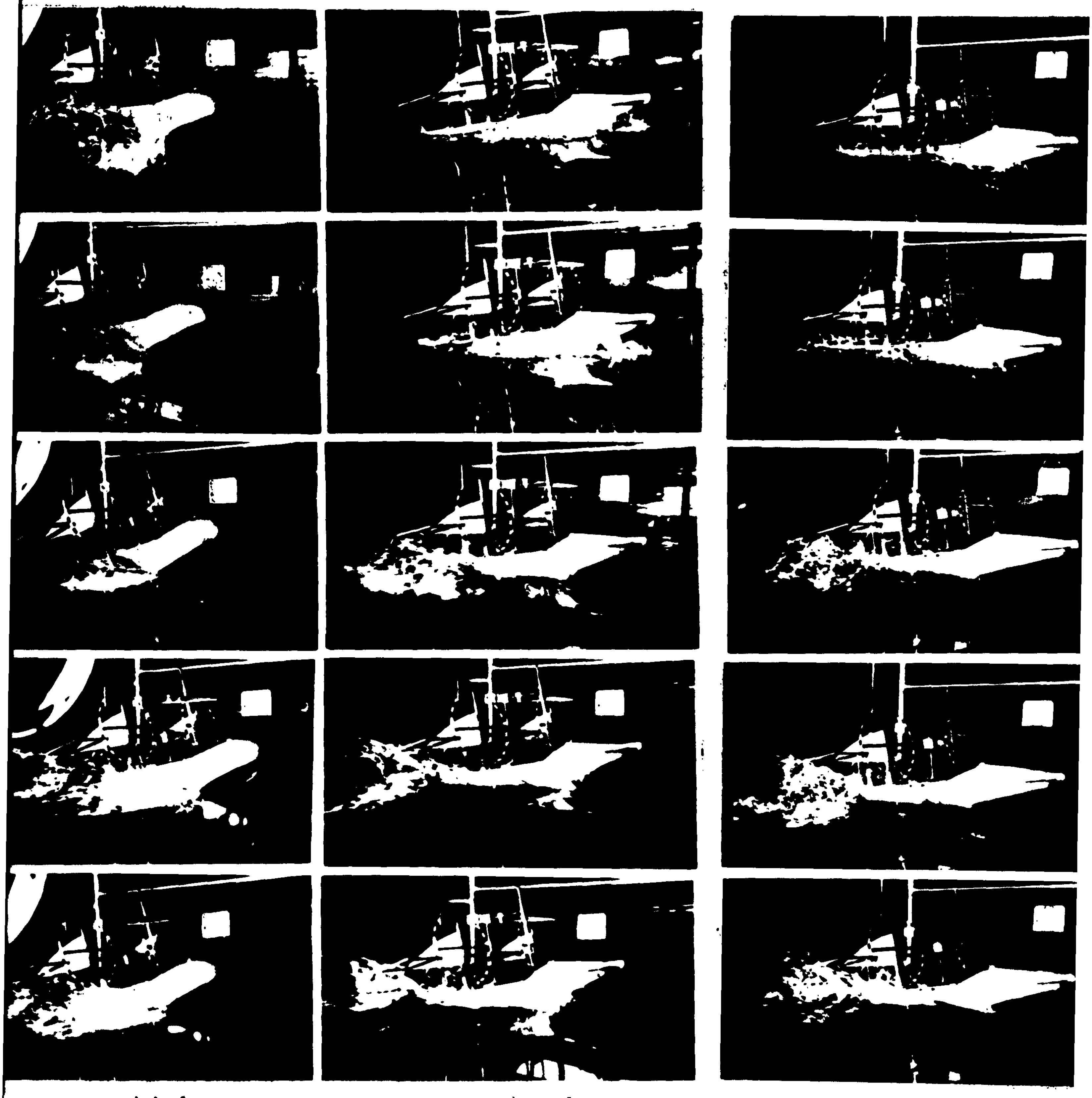
[illegible], [illegible] length [illegible]

[illegible] s, G.W. 36,000lbs.



wave height 5ft, wave length 144ft

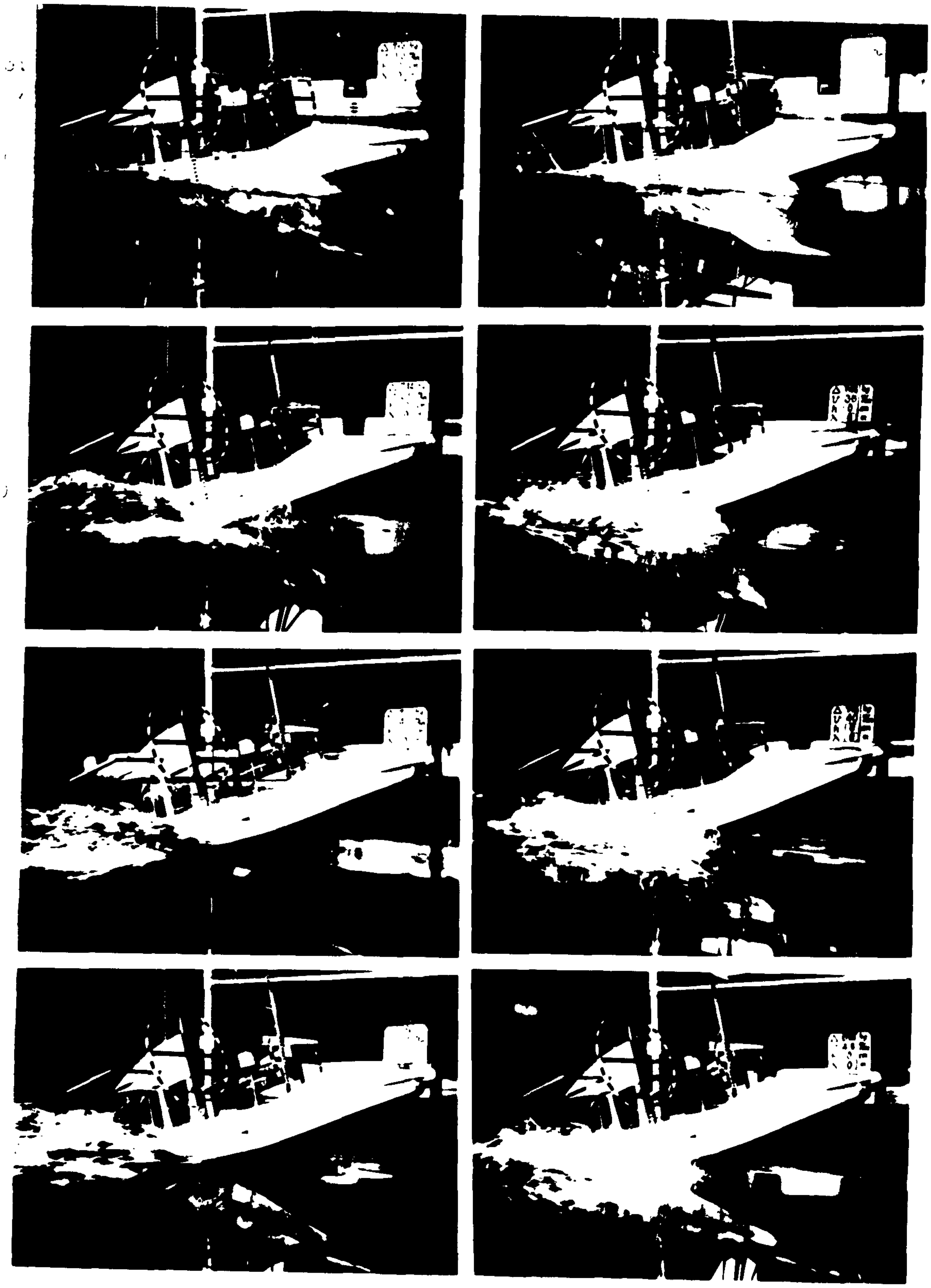
Fig. 2.6 Maximum spray in waves, G.W. 55,000lbs.



original | mod. no.1 | mod. no.2

wave height [illegible]ft, wave length 144ft

Fig. 2[illegible]b Maximum Spray in waves, G.W. [illegible],000lbs.



4.0

30.9

Mol. No.2

Mol No.2
(With [illegible])

[illegible] 2 [illegible] of [illegible] in still water, [illegible]