UNITED STATES EXPERIMENTAL MODEL BASIN

NAVY YARD, WASHINGTON, D.C.

A THIRTY INCH MODEL OF THE S.S. CLAIRTON IN SHALLOW WATER

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INTRODUCTION

This report is supplementary to U.S.E.M.B. Report 408. The results and analysis given herein for the thirty inch CLAIRTON model parallel those for the four foot cruiser model as given in the above mentioned report. The results for the cruiser may be taken as representative for those of slender, high speed vessels. Those for the CLAIRTON on the other hand give corresponding information for the slow, full commercial type of ship. Where the speeds are unnaturally excessive for the latter type of ship the results were intended to serve a theoretical rather than an immediate practical purpose.

APPARATUS AND METHOD

The experimental work was conducted in the eighty foot model basin. All of the apparatus as towing gear and shallow water bottom was the same as used in the case of the four foot cruiser model. However, due to the fact that the shallow water bottom is particularly difficult to raise and lower, instead of manipulating it to several fixed positions as was done for the cruiser, it was used in its lowest position only. Water depths from three to seventeen inches were obtained by raising or lowering the water level in the basin. The type of bridle used makes model resistance data independent of the vertical distance between the model and the tow line.

Leaving the shallow water bottom in this one low position did put photography, especially for trim pictures in the shallower depths, at a disadvantage. Trim pictures were taken for the 14 inch and 17 inch depths only.

Figure 1 gives a view of the thirty inch CLAIRTON with towing bridle. Figure 2 shows the round wire on the bow as used to generate turbulent flow.

The characteristics of the CLAIRTON model used for this work are given in the following table.

MODEL DATA

Length	2.47	Feet
Beam (max.)	4.10	Inches
Draft	1.80	"
Wetted surface area	1.382	Sq. Ft.
Midship Section coefficient	0.986	
Displacement (fresh water)	6.13	Lb.
Displacement-length ratio	185.0	
Block coefficient	0.78	

RESULTS

The experimental data are given graphically in Figures 3 and 4. Figure 3 is a plot of the model's resistance against the speed-length ratio, $V/\sqrt{L}$, for various depths of water. Figure 4 shows the original data plotted in terms of specific resistance, i.e.,

$$(2R/\rho Av^2) \text{ against } V/\sqrt{L}.$$

Figure 5 gives the trim measurements for the 14 and 17 inch depths of water. Figure 6 is a plot showing the percentage increase of shallow water resistance over deep water resistance.

Figure 7 is a set of faired constant speed curves. This Figure shows also three other curves, two of which give the depths where a 2% and a 5% increase in resistance due to the shallow water is experienced. The third is Taylor's minimum depth curve according to his formula

$$D = (10\ H\ V/\sqrt{L}).$$

Again the results obtained verify his formula and show that it holds, as Taylor says, for speeds up to $V/\sqrt{L} = 1.0$. The 2% increased resistance line as drawn does cross over Taylor's curve, but the limits of experimental error here are such that this crossover has little significance as far as detracting from the value of Taylor's formula might be concerned. If anything it would show that Taylor's formula is not excessively conservative at these lower speeds for the full commercial type of ship.

Photographic recordings of wave patterns as generated by the CLAIRTON model are given in Figures 8, 9, 10, and 11. Each set shows the nature of the change of pattern with speed for the particular depth of water as indicated.

DISCUSSION

The CLAIRTON model in shallow water reveals the same general shallow water phenomena as did the four foot cruiser model. It generates waves with greater amplitude but of the two forms the cruiser reveals the details of shallow water phenomena the more clearly and distinctly. See photographs for the two cases.

The photographs show that three sets of waves or wave systems exist at speeds below the critical speed, the normal deep water bow and stern wave systems although the former appears to be less intense than in deep water, and the waves or the single wave of translation running ahead of the models.

That interference did take place between the bow and stern systems in shallow water is indicated by the humps and hollows in the resistance curves in figures 3 and particularly 4.

Shallow water modifies this interference in at least two ways. It decreases the magnitude of the interference by changing the relative sizes of the bow and stern wave systems and secondly, it decreases the speed at which these waves travel.

The effect of the first is to decrease the amplitude and length of the hump in the resistance curves. This is particularly noticeable for the 1.1 hump in the case of the CLAIRTON.

The effect of the second is to shift the hump towards the lower speeds as depth of water decreases.

The wave of translation which precedes the CLAIRTON in shallow water is larger than it is in the case of the cruiser. The greater fullness of the CLAIRTON's bow is sufficient to increase excessively the amplitude of this wave at the lesser depths of water. The wave collapses before the model can break through it and exceed its critical speed.

The collapse of this bow wave of translation is attributed to the fact that the wave height very nearly attains a height equal to the undisturbed depth of the shallow water. Theoretically the limiting height cannot exceed the depth of the undisturbed water. For the three inch depth the wave collapsed where $V/\sqrt{L} = 1.4$ approximately.

Theoretically, when $h = d_o$, i.e., wave height is equal to the undisturbed depth, $v = \sqrt{g(2\ d_o)}$. For the three inch depth

$$v = \sqrt{g\ (\ 2 \times 3\ )/\ 12}\ ,$$

or four feet per second. This corresponds to $V/\sqrt{L} = 1.5$. This speed is greater than the actual speed noted for collapse. The difference is on the safe side in the sense that actual conditions are not ideal considering the irregularities in the shallow water bottom, the viscosity with consequent shearing action in the water due to the presence of the shallow water bottom, and the presence of the bow of the model in the crest of the wave, all of which work toward an early unstable condition developing in the wave.

The collapse of the wave, however, is a verification of the theoretical prediction as based on the conclusions that the wave height cannot exceed the depth in magnitude, and that the speed is given by $v = \sqrt{g(d_o + h)}$.

Separation of the specific resistance curves at the lowest speeds again indicates that an effect of shoaling water is to increase the average stream velocity around and under the hull.

The first steep rise and bend in the shallow water resistance curves for the 3, 4, and 5 inch depths of water is associated with, as in the case of the cruiser, the generation and collapse of the stern wave system. The prevention of normal interference between bow and stern systems and the partial development of the waves of translation are also partly responsible for the sudden rapid increase in resistance.

The breaks or discontinuities in these curves are identified with the speeds at which the waves of translation collapse.

Where model speed exceeds the critical speed of the wave of translation, shallow water resistance is again less than deep water resistance. For the CLAIRTON model or type of ship these high speed results have a theoretical rather than a practical significance since full ships of this type are not designed nor intended to be operated at these comparatively high speeds.

The so called 'envelope' as noted for the family of shallow water resistance curves in the case of the cruiser is not clearly indicated for the CLAIRTON. Its non-appearance in the low-speed range is attributed to the early collapse of the stern wave system, and, at the higher speeds, due to the collapse of the wave of translation before the model could exceed its speed together with the lack of data at the top speeds for the intermediate water depths.

CONCLUSION

Shallow water resistance is different from deep water resistance due mainly to four factors:

(a) Shoaling water increases frictional resistance by increasing the stream velocity relative to the hull.

(b) Shoaling water decreases the speed of given waves.

(c) Shoaling water intensifies the stern wave system and reduces the bow wave system. It tends to prevent the normal deep water interference from taking place between bow and stern wave systems.

(d) Shoaling water brings the critical speed, and the associated wave of translation, within the normal deep water speed range of the ship.

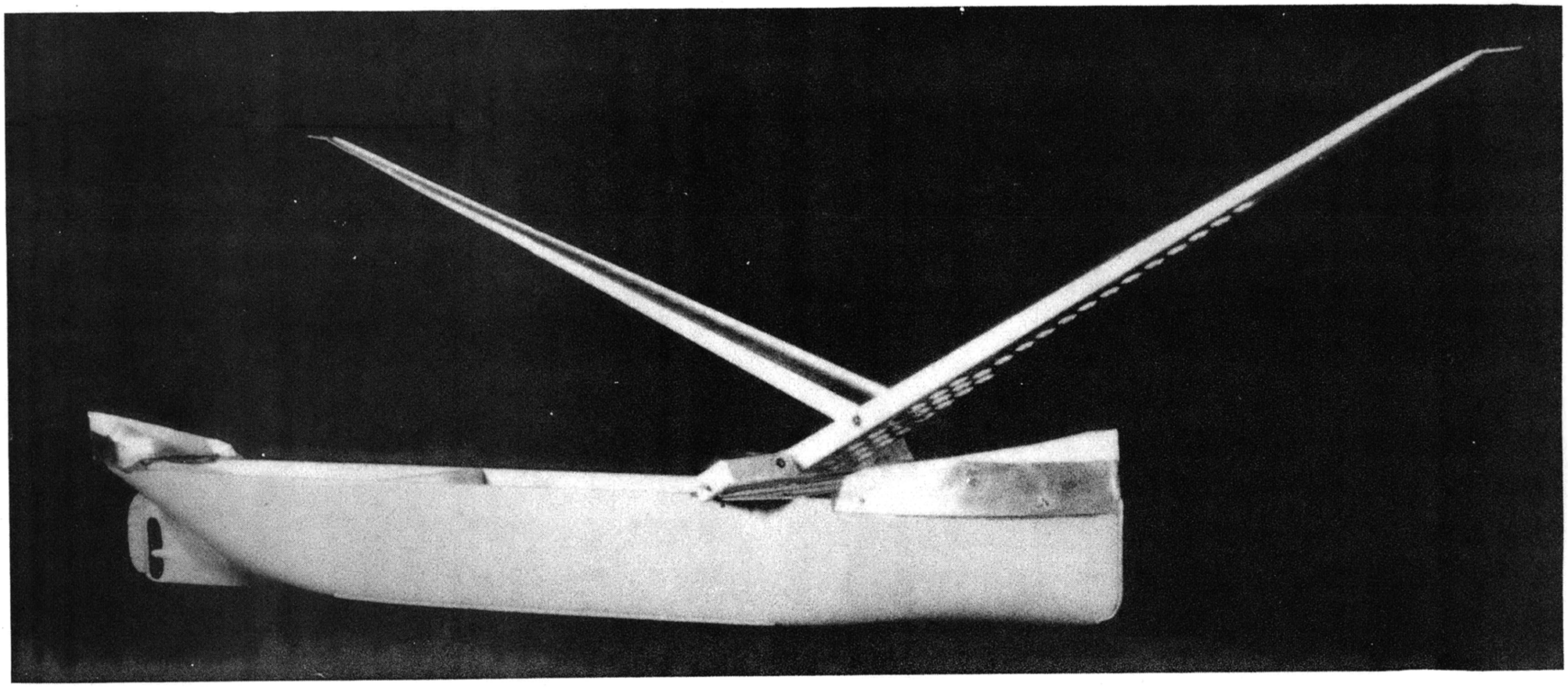


FIGURE 1. THIRTY INCH MODEL OF S.S. CLAIRTON

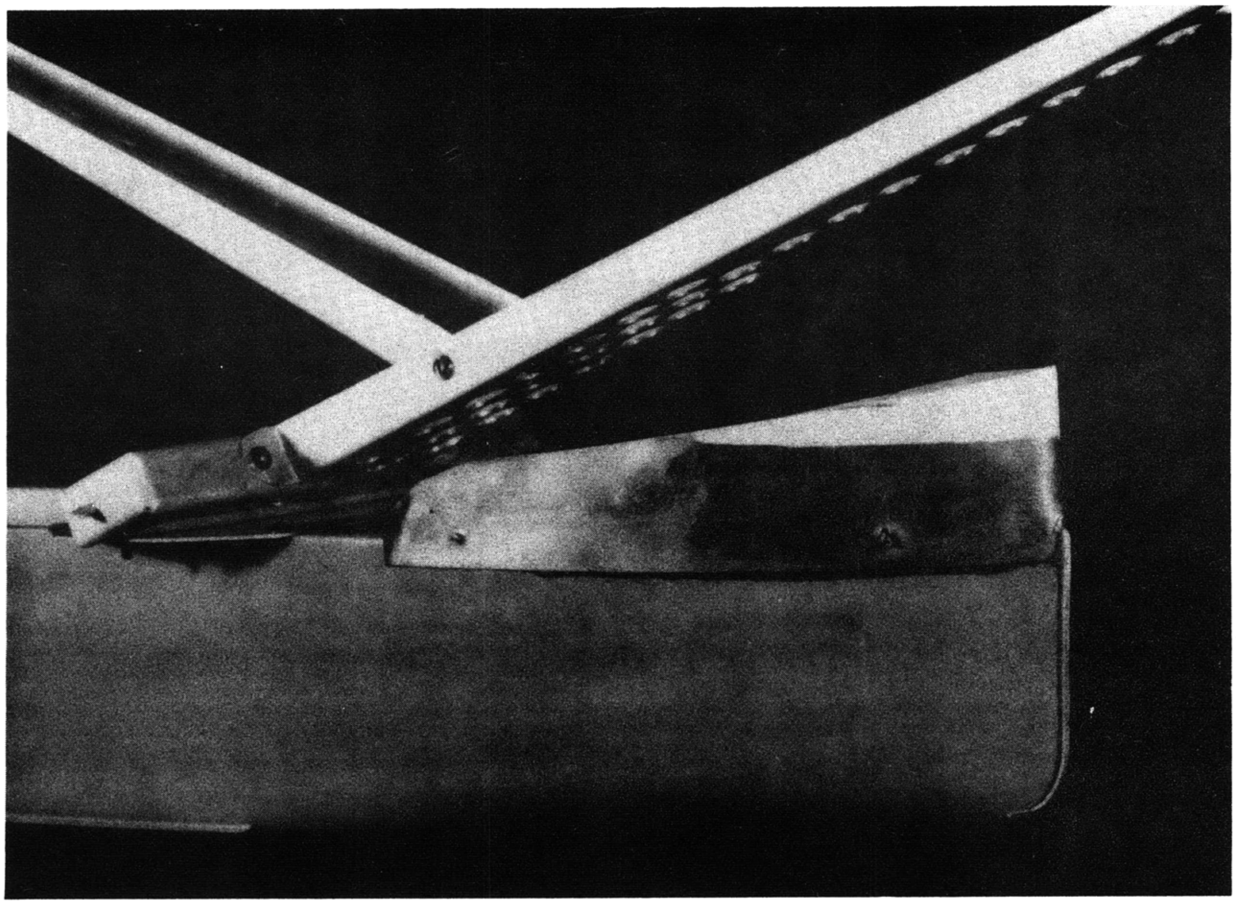
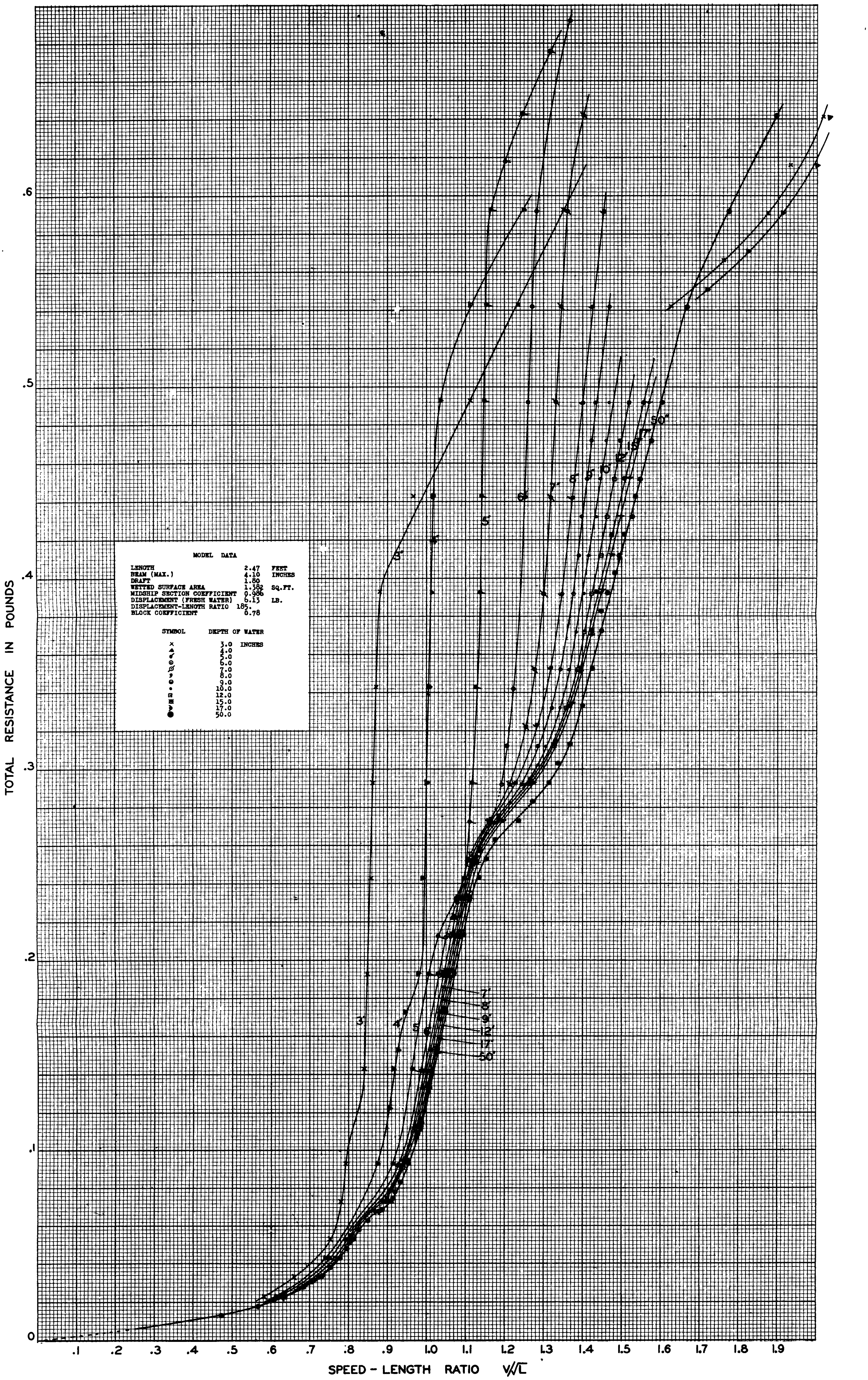


FIGURE 2. BOW OF CLAIRTON MODEL



RESISTANCE CURVES FOR MODEL 3157 FIGURE 3.

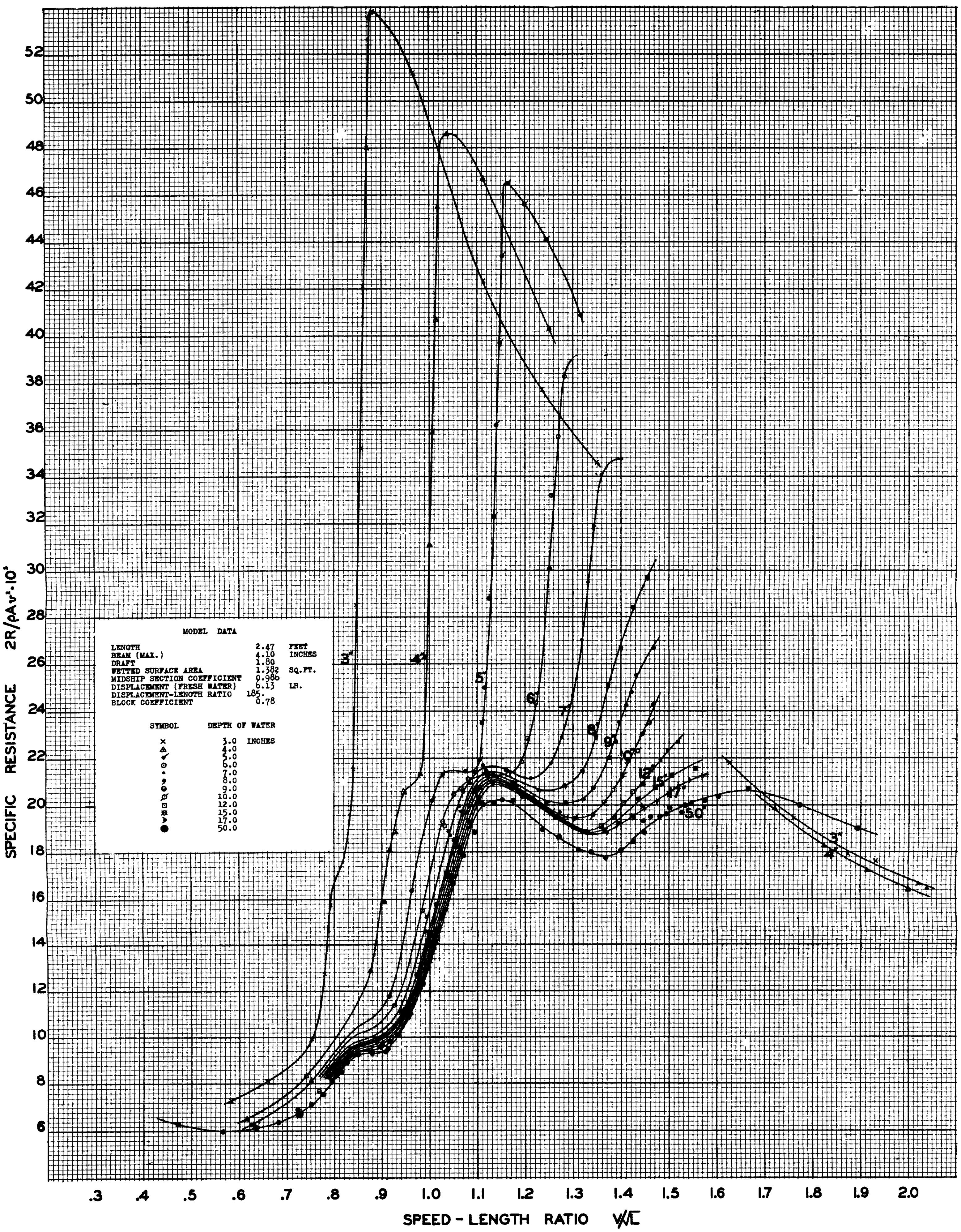


FIGURE 4. SPECIFIC RESISTANCE CURVES FOR CLAIRTON MODEL 3157

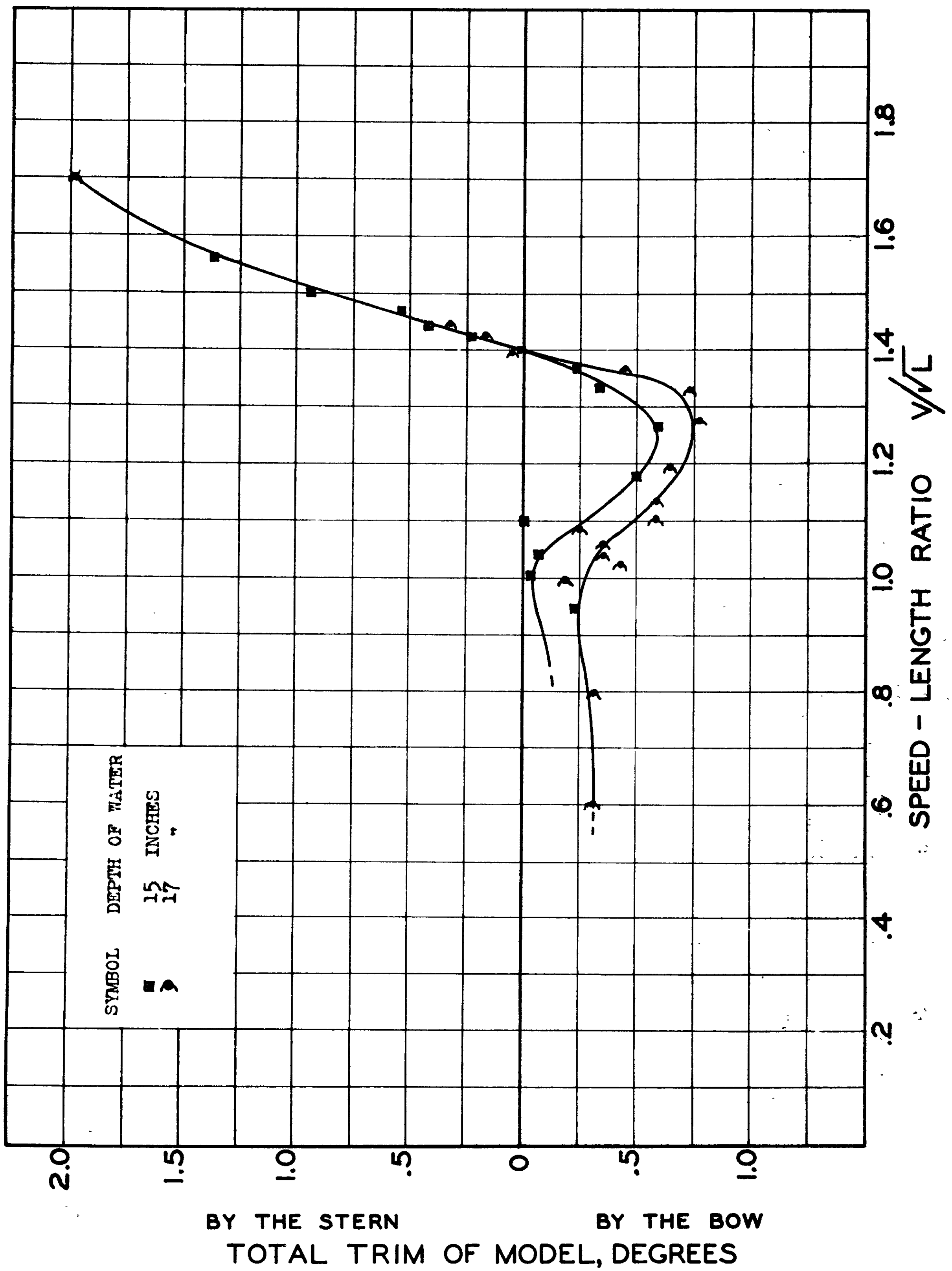


FIGURE 5. TRIM - SPEED CURVES FOR THE 30 INCH CLAIRTON

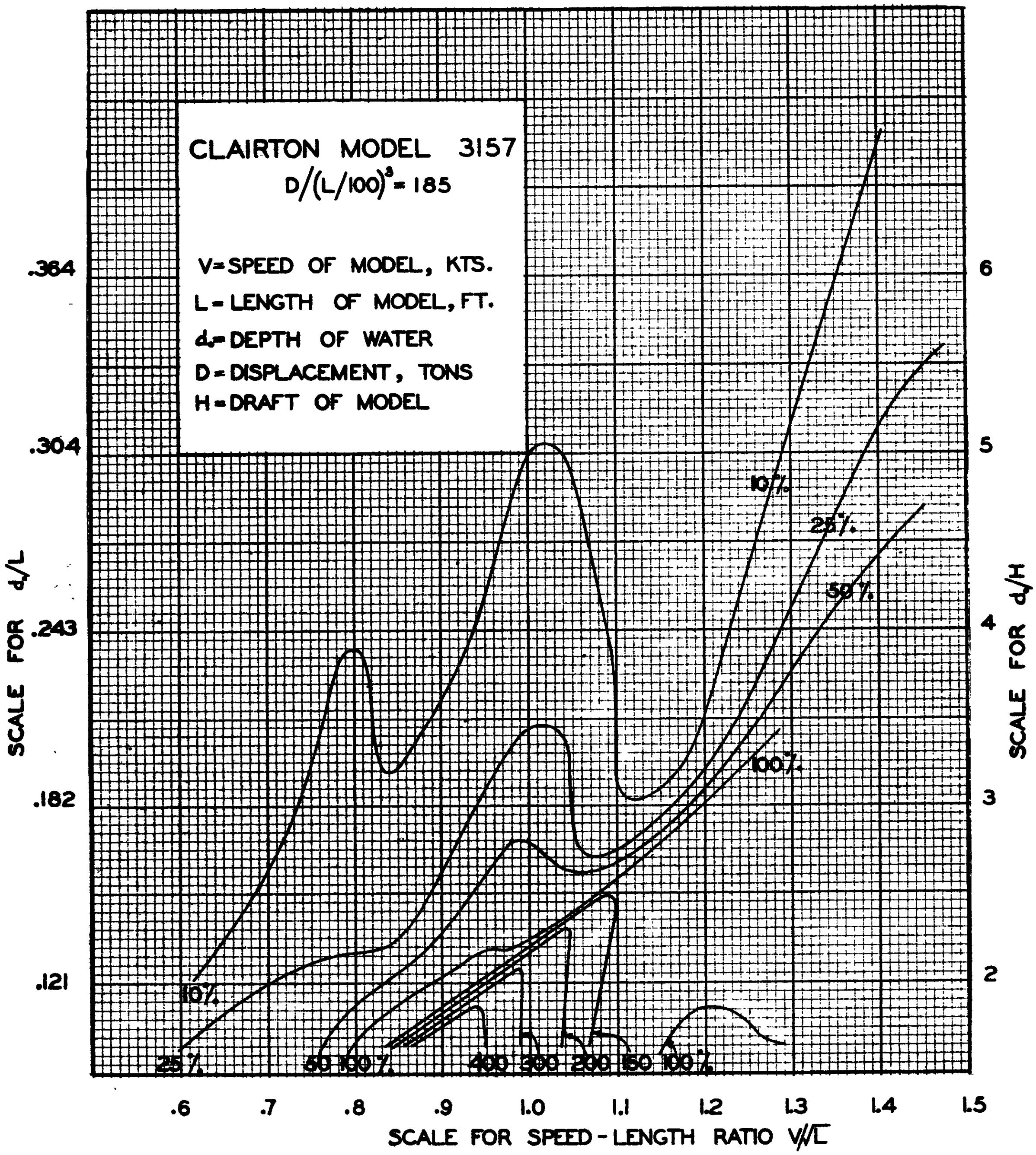


FIG. 6. CONTOURS OF PERCENTAGE INCREASE IN RESISTANCE

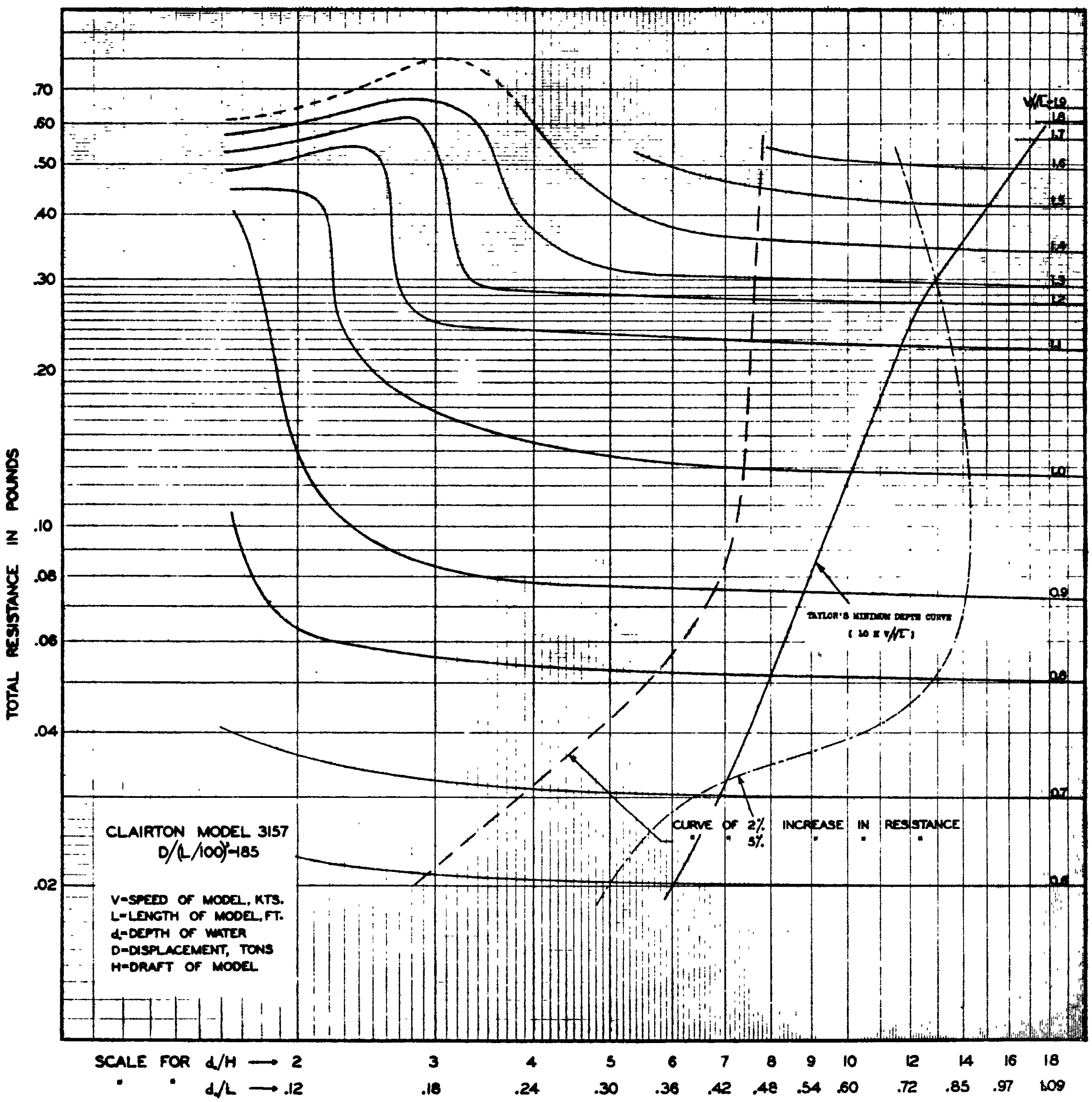


FIGURE 7. FAIRED CONSTANT - SPEED CURVES

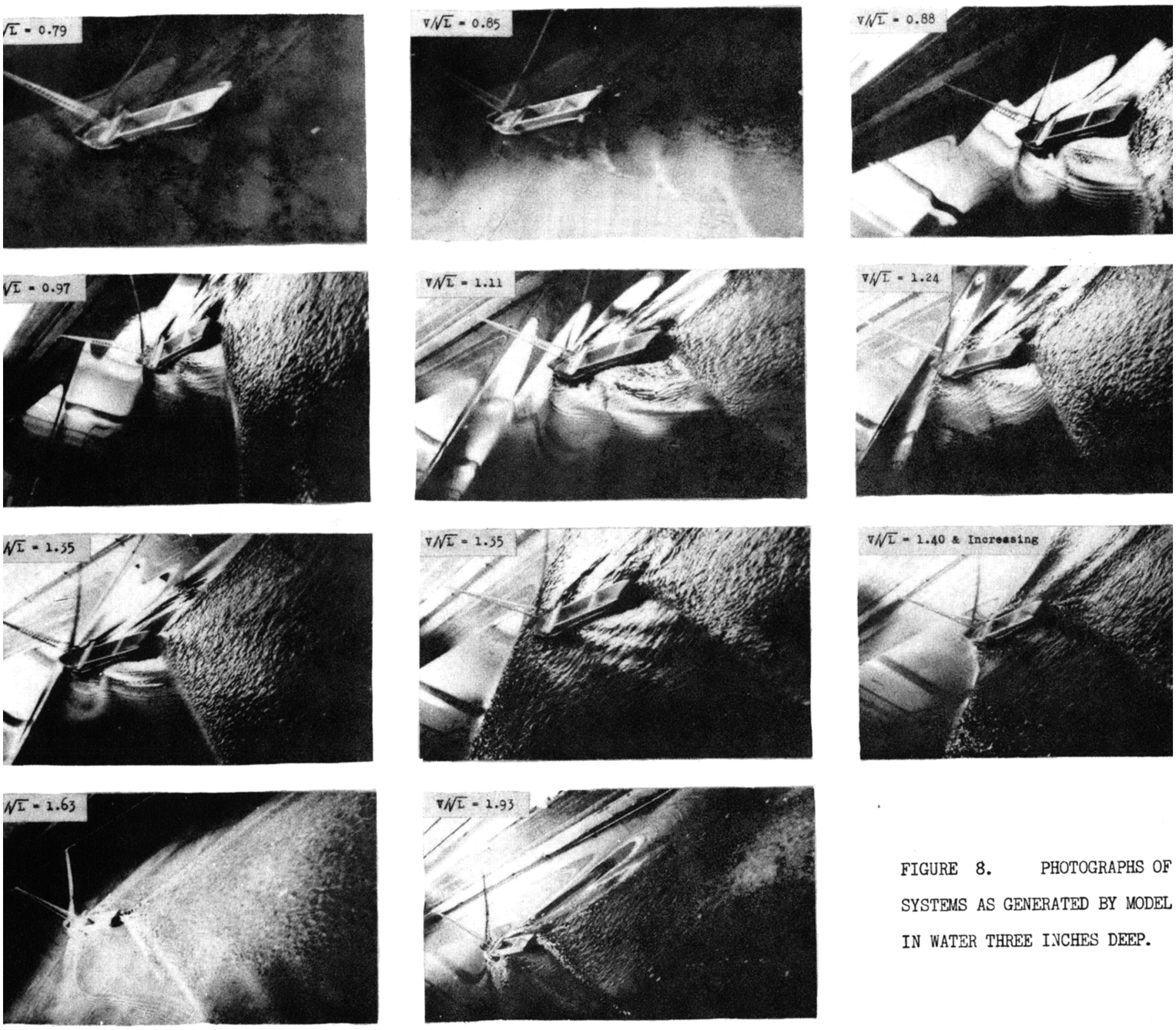


FIGURE 8. PHOTOGRAPHS OF SYSTEMS AS GENERATED BY MODEL IN WATER THREE INCHES DEEP.

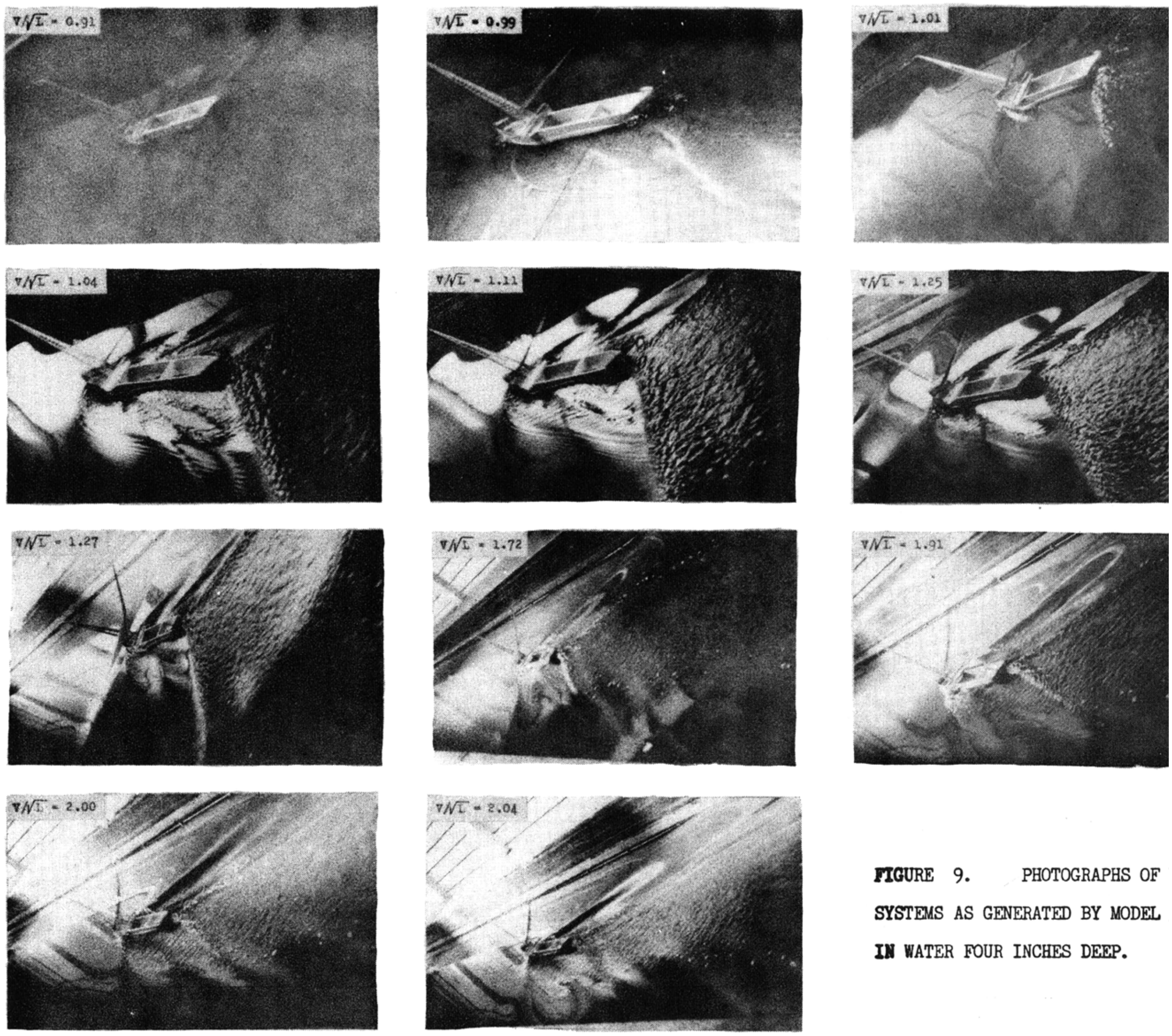


FIGURE 9. PHOTOGRAPHS OF SYSTEMS AS GENERATED BY MODEL IN WATER FOUR INCHES DEEP.

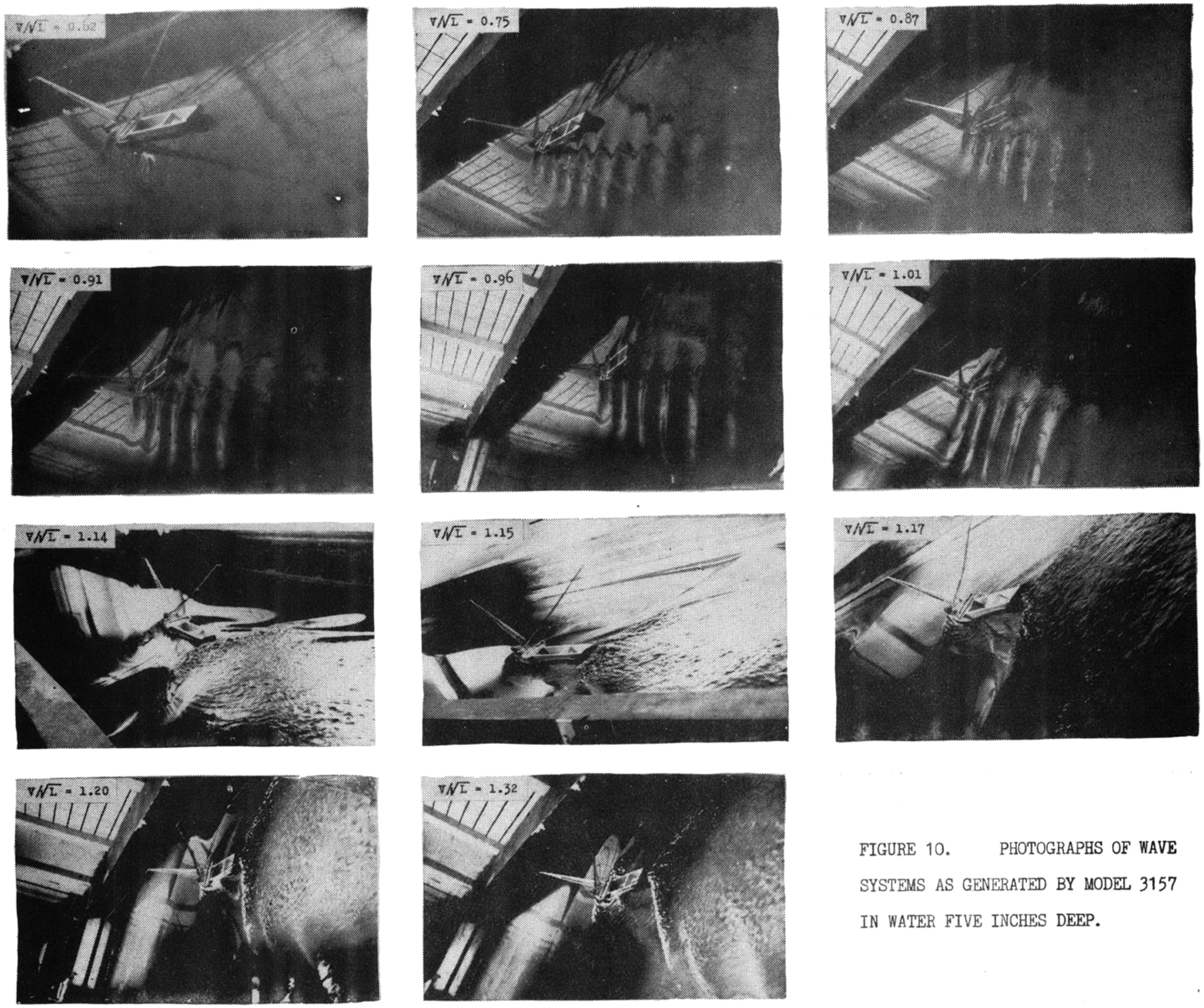


FIGURE 10. PHOTOGRAPHS OF WAVE SYSTEMS AS GENERATED BY MODEL 3157 IN WATER FIVE INCHES DEEP.

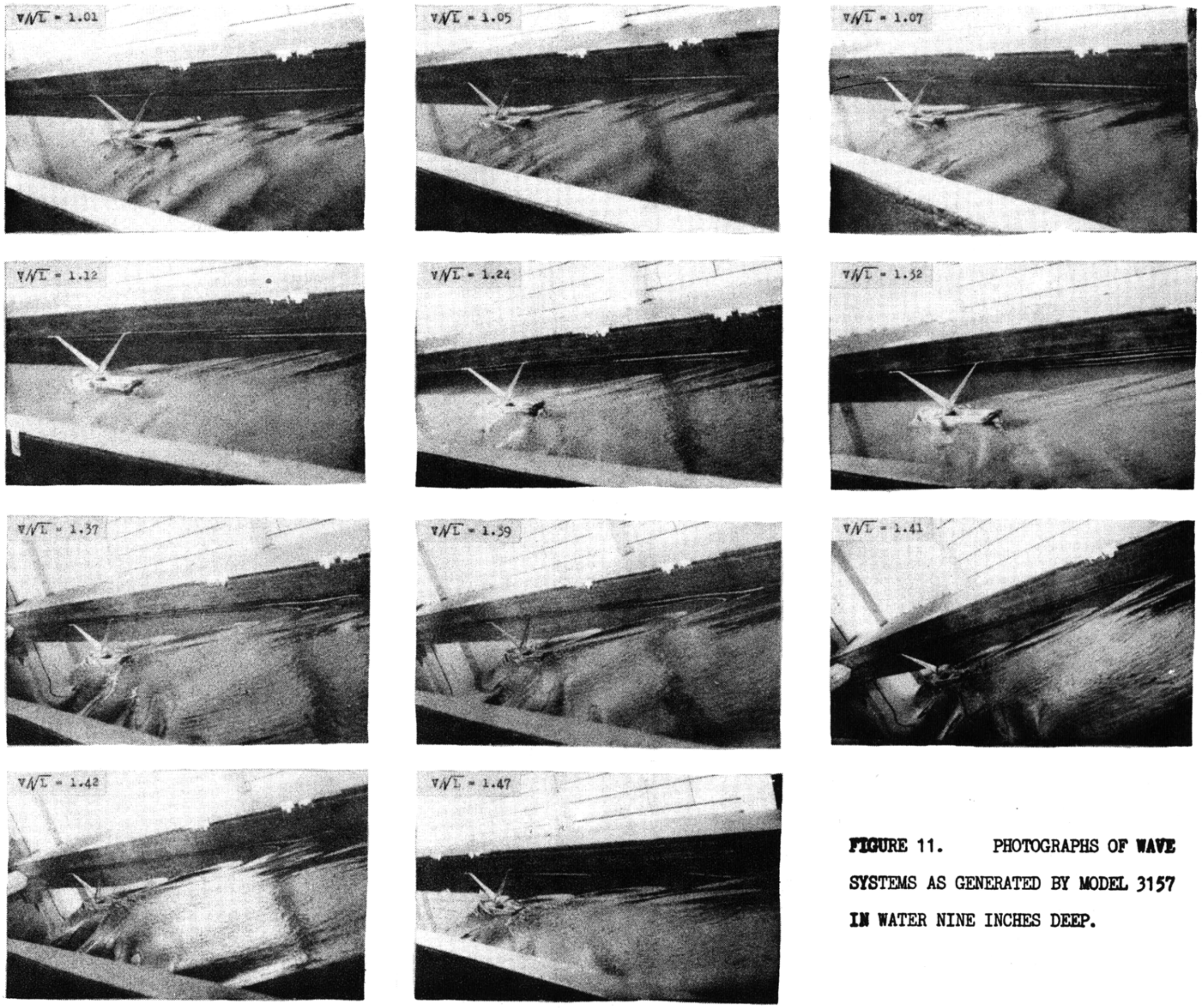


FIGURE 11. PHOTOGRAPHS OF WAVE SYSTEMS AS GENERATED BY MODEL 3157 IN WATER NINE INCHES DEEP.