CHAPTER 95

SHIP WAVES IN NAVIGABLE WATERWAYS

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ABSTRACT

Model tests were conducted at the University of California, Berkeley, on six ship models to determine the heights of the waves produced by ships. Measurements were made at various distances from the sailing line with the models moving at various speeds in various water depths. The results of the tests are presented in graphical form, as prototype values.

INTRODUCTION

There has been considerable theoretical and experimental work conducted on the pattern of ship waves and the resistance offered to the ship by the waves it produces. Most of the previous work was conducted in order to understand the mechanism of wave generation, the wave pattern, and the squat of the ships. There are, however, very little data available on the height of waves at various distances from the sailing line, produced by ships of various hull configurations, moving at various speeds.

This report presents the results of model studies carried out at the University of California, Berkeley, on six model ships. The maximum height of the generated waves at various distances from the sailing line, and various water depths, is related to the ship's speed. The results will provide data for the design of harbour and channel revetments which are subject to attack by ship waves. On waterways where public safety is a factor or control of erosion is necessary, the results give an indication of the maximum allowable speed of a ship in the waterway.

TESTING PROCEDURE

The types and dimensions of the six models tested are tabulated in Table 1. These models were chosen to represent a wide range of hull configurations. Bow views of the models are shown in Figures 12 and 13.

TABLE I

MODEL	TYPE	SCALE	PROTOTYPE DIMENSIONS			MODEL
			Overall Length Ft.	Beam Ft.	Draft Ft.	Displacement for Tests Lbs.
A	Mariner Class Cargo Ship	1:96	566	74	24	37.32
B	David Taylor Series 60	1:96	505	64	24	30.45
C	Moore Dry Dock Tanker	1:96	504	66	28	45.48
D	Auxiliary Supply Vessel	1:32	156	36.3	9	61.00
E	Barge	1:48	263.5	54.5	14	97.80
F	Tug	1:32	152.7	34.3	14	66.50

The models were towed by a taut nylon line which was connected to the model fore and aft. Suspended weights connected to a sheave provided the driving force. When the weights were released and the velocity was constant, the time required for a given number of revolutions of the sheave of known diameter was recorded and the velocity of the model was calculated. The waves produced by the models were measured by wave gauges positioned at distances from the sailing line of 0.5, 1.5, 2.5, and 3.5 times the model ship's length. The waves were recorded on a four-channel Sanborn recorder. For a given model, four series of tests were run for water depth to draft ratios of 1.375, 2.0, 2.5 and 3.5. These four ratios were chosen to cover the range of water depths normally encountered in navigation channels. For each run the still water depth was the same at all gauges.

RESULTS

The height of the largest wave in the wave group, measured from the preceding trough to the crest, is designated H_{max}. Figures 1 to 9 present prototype values of some of the test results. In these plots, X is the distance from the sailing line at which H_{max} was measured, L is the overall length of the ship, D is the ship's draft in feet, and d is the still water depth, in feet.

From the graphs presented it is possible to obtain cross-plots such as Figure 10. In this manner it is possible to show the decay of H_{max} from the sailing line or the effect of water depth on H_{max}. In Figure 10, F_r is defined, as usual, as dimensionless $V/\sqrt{gd}$.

DISCUSSION

The results of the tests show that in protected waterways ships may produce waves of significant magnitude relative to wind generated waves. The graphs presented will provide data for harbour and coastal engineers, or port authorities, to determine necessary protective measures or limiting speeds of vessels in navigable waterways. It is noted that smaller vessels such as the tug of Figure 9, may produce waves comparable in height to the waves produced by a large vessel, but at a lesser speed.

The test results show that for a given ship, speed and distance from the sailing line, the value of H_{max} increases with decreasing water depth. The increased wave heights in shallow water are related to the increased resistance and squat a vessel experiences in shallow water. When a vessel enters shallow water the return velocity of the water alongside the ship increases. By Bernoulli's equation it is possible to show that an increase in wave height and squat must accompany this increased velocity. The connection between the ship's squat and the heights of the waves produced is evident by the similar asymptotic character of the curves presented in this report and the curves presented by Schijf for squat. (Ref. 1.)

During the model tests the wave gauges were arbitrarily positioned at fixed locations as determined by the overall length of the ship. Therefore, the results show the maximum wave heights at the point of the wave gauges which is not necessarily the maximum wave heights in the wave pattern. A ship produces diverging and transverse waves (ref. 2). The highest waves in the wave pattern are where the diverging and transverse waves intersect and superimpose. These locations are termed cusps. It is evident that the position of the wave gauges was not necessarily in line with the location of the cusps. This may explain the apparent irregularities of some of the curves. Also, a cross-plot taken from the data, such as figure 10, is only correct at the points X/L equal to 0.5, 1.5, 2.5 and 3.5. A curve drawn through these points is only indicative of the wave decay and does not take into account the possibility that the location of a cusp may be at an intermediate value of X/L. However, for practical purposes, the error in drawing a smooth curve on the cross-plot is not appreciable.

As mentioned previously, the water depth and the ship's speed are important factors with respect to the heights of ship produced waves. Another factor is the fineness or configuration of the vessel's hull. Brebner defined a fineness ratio as, $L^*/\sqrt{A}$. (ref. 3) L^* is the length of the curved part of the bow, at the waterline, measured in the horizontal plane, and A is the cross-sectional area of the parallel middle-body, below the waterline.

The effect of the fineness of the bow is shown in the cross-plot of figure 10. It was not the purpose of the tests to explicitly study the effect of the bow fineness; therefore, the data does not lend itself to the isolation of this factor. The factors of wave decay and velocity are not totally excluded in Figure 10, therefore all the curves do not lie in order. Generally, figure 10 does confirm intuition and observation by showing that the wave producing capacity of a ship decreases with increasing fineness.

A comparison between models A and B and the results obtained by Brebner for the 650 foot Empress of Canada is shown on Figure 11. The fineness ratio of the Empress of Canada is 4.04. The results are in reasonable agreement.

SUMMARY

Ships travelling in waterways may produce damaging waves. The graphs presented in this paper give an indication of the magnitude of the waves which may be expected for various vessels. It should be noted that the results are for vessels travelling in water of constant depth. Further tests were conducted on ship waves in shoaling water. The results of these additional tests will be presented by Professor J.W. Johnson, Department of Civil Engineering, University of California, Berkeley.

ACKNOWLEDGMENTS

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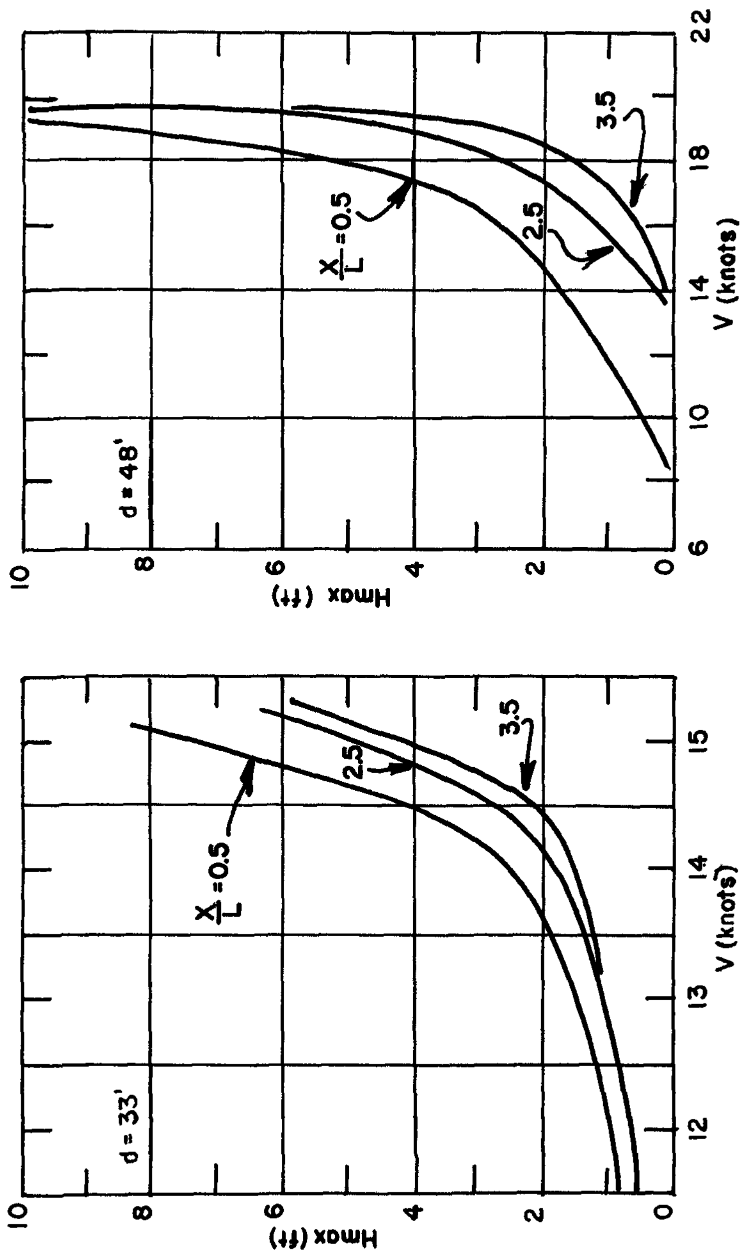


FIG 1. MARINER CLASS CARGO SHIP.
L=566' D=24'

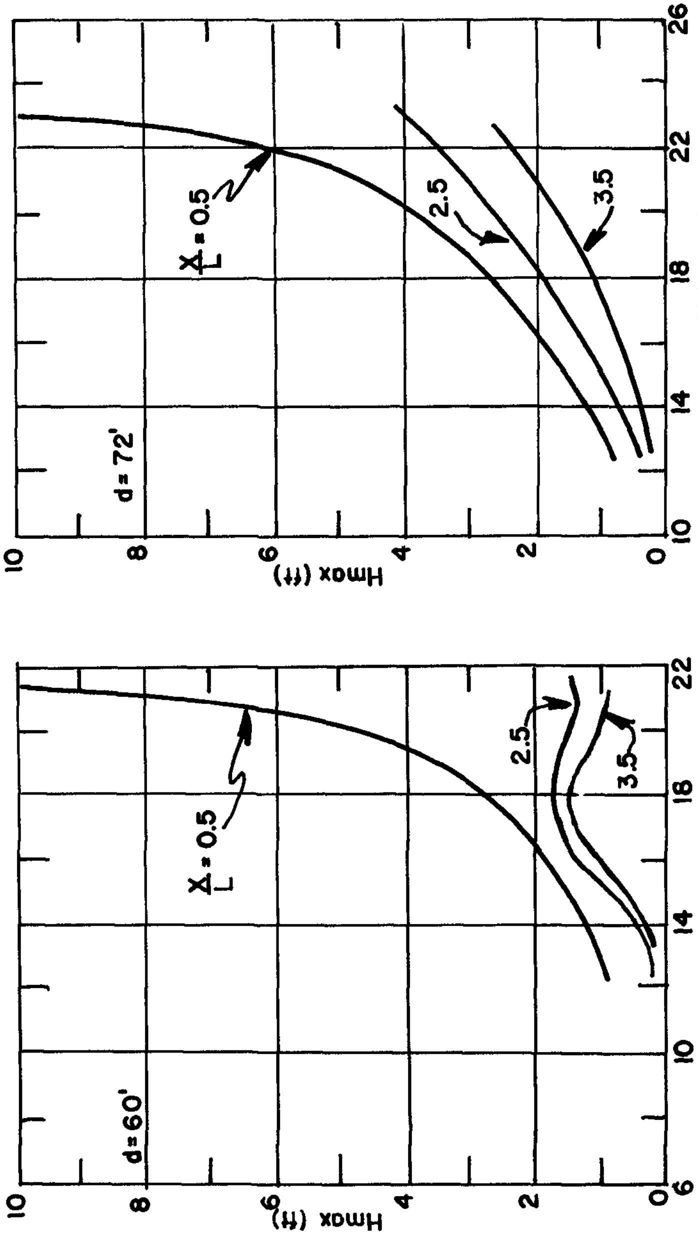


FIG 2. MARINER CLASS CARGO SHIP
L = 566' D = 24'

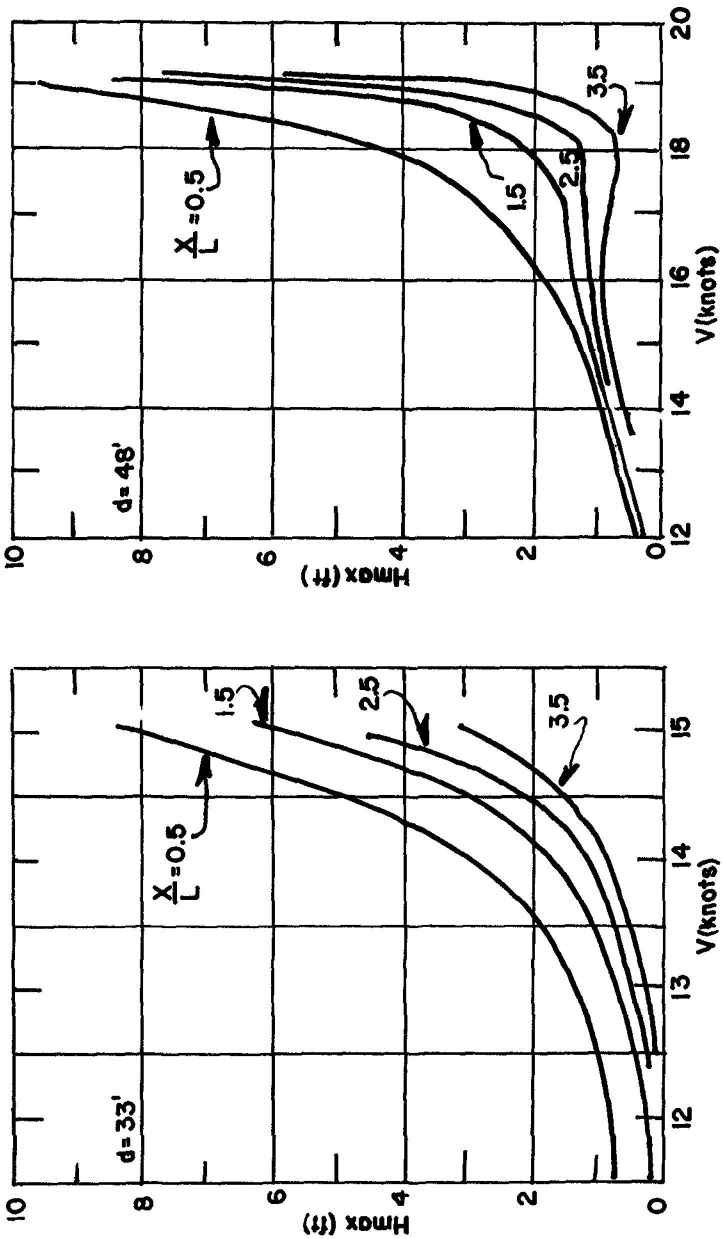


FIG 3. DAVID TAYLOR SERIES 60
L=505' D=24'

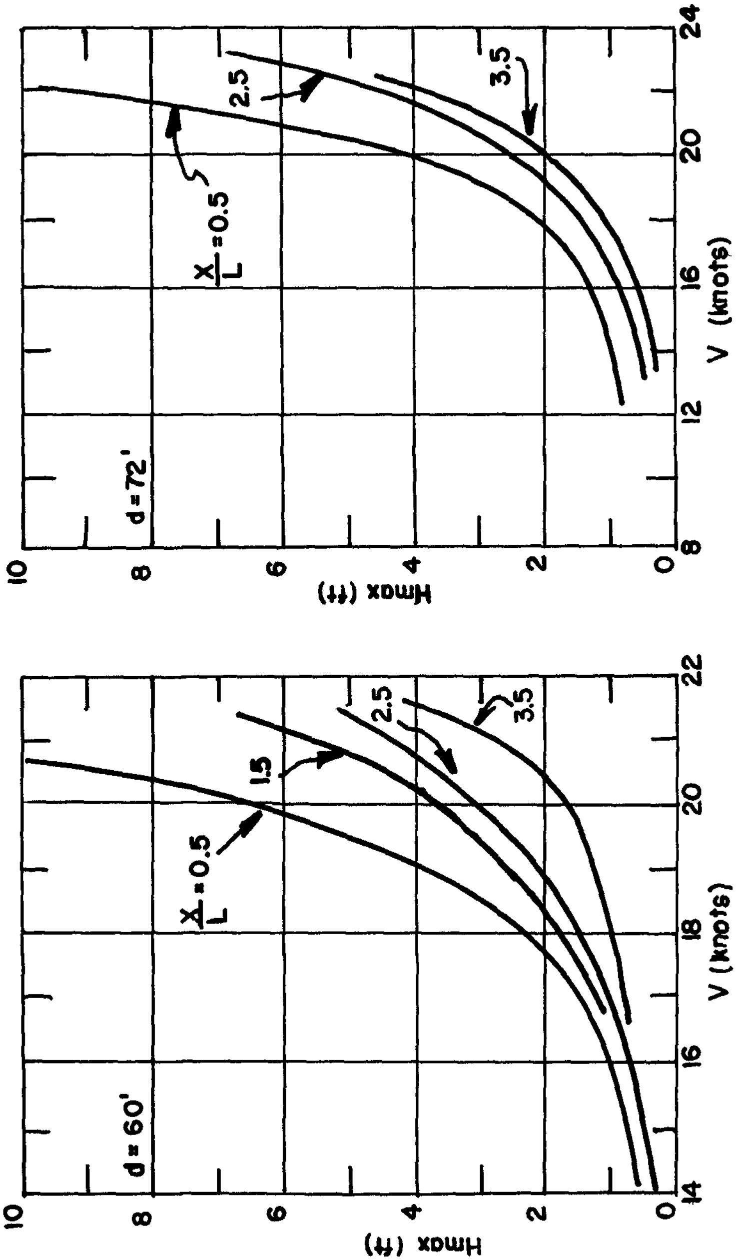


FIG 4. DAVID TAYLOR SERIES 60.
L = 505' D = 24'

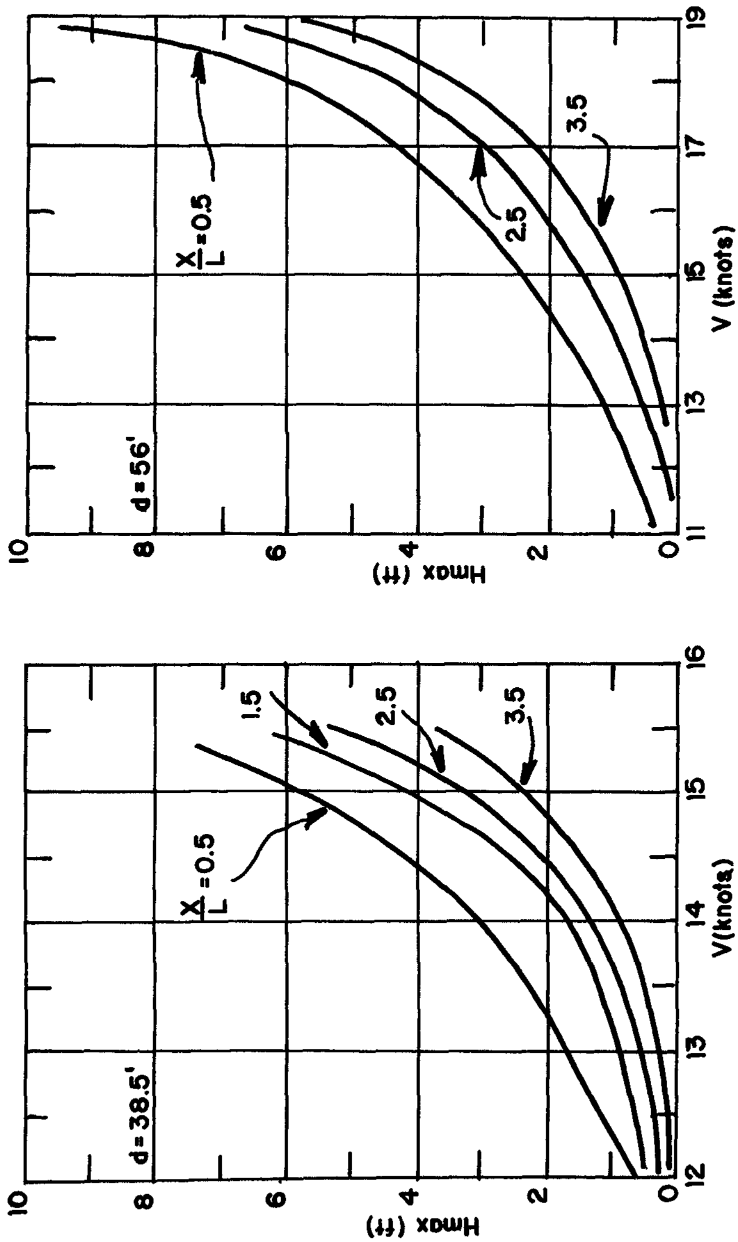


FIG 5. MOORE DRY DOCK – TANKER.
L = 504' D = 28'

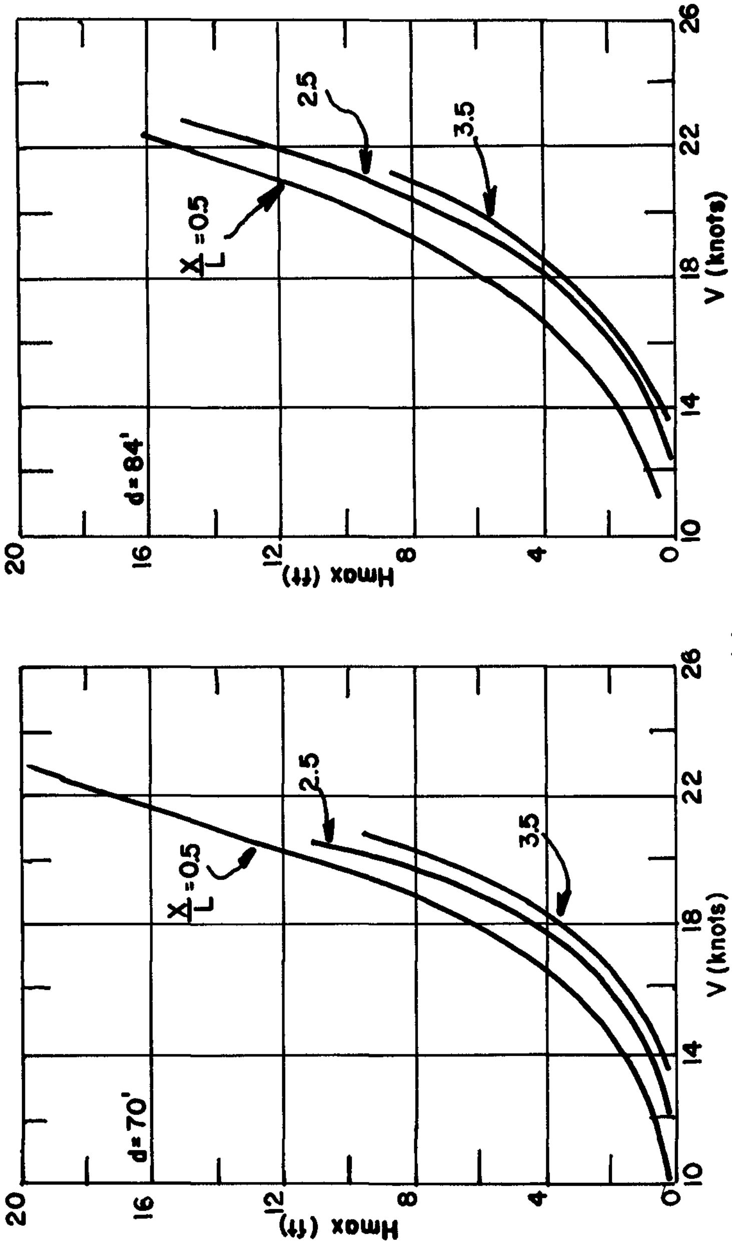


FIG 6. MOORE DRY DOCK - TANKER.
L=504' D=28'

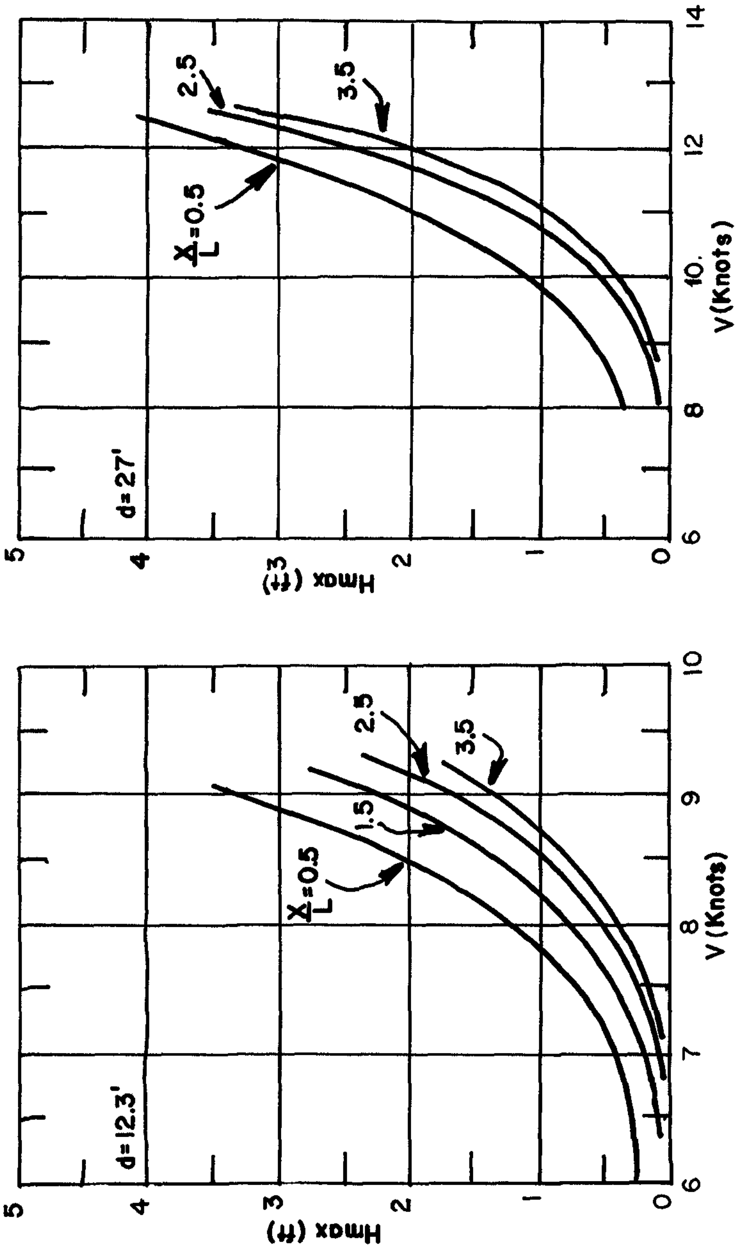


FIG 7. AUXILIARY SUPPLY VESSEL.
L=156' D=9'

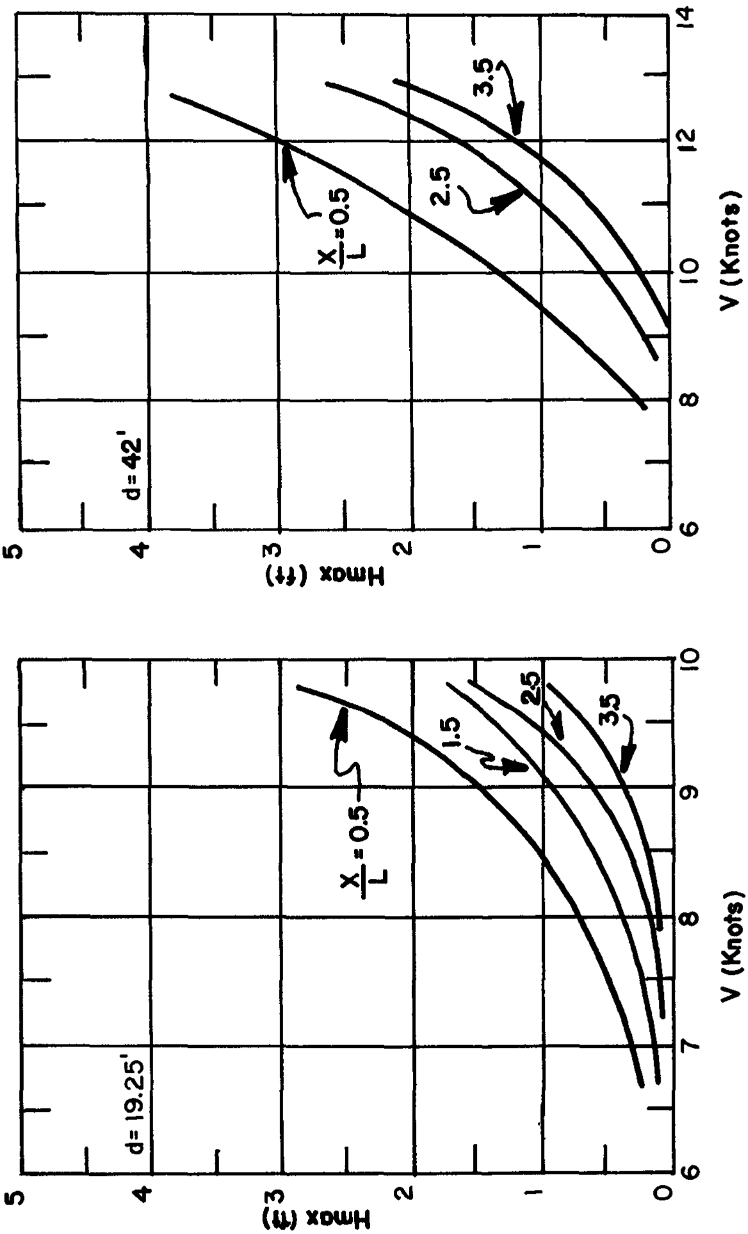


FIG8. BARGE.
L=263.5' D=14'

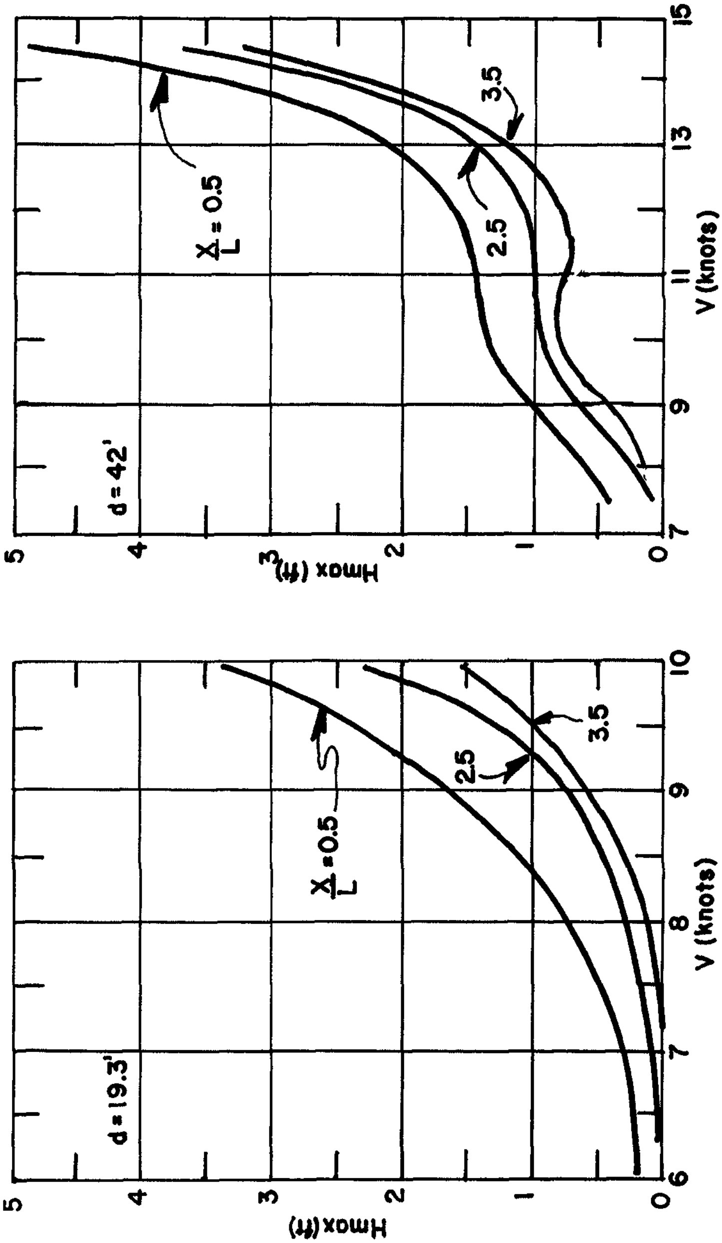


FIG 9. TUG

L = 153'. D = 14'.

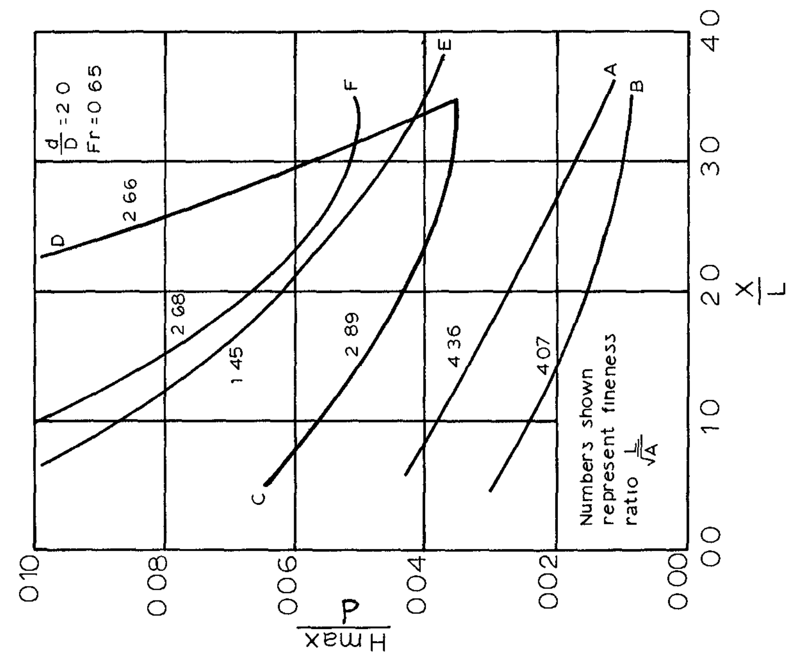


FIG 10 CROSS-PLOT OF $\frac{Hmax}{d}$ VS $\frac{X}{L}$

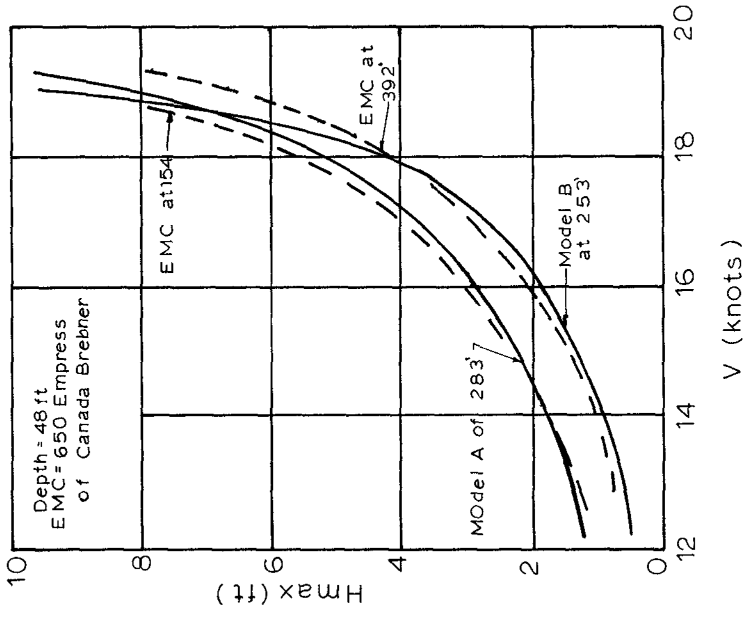


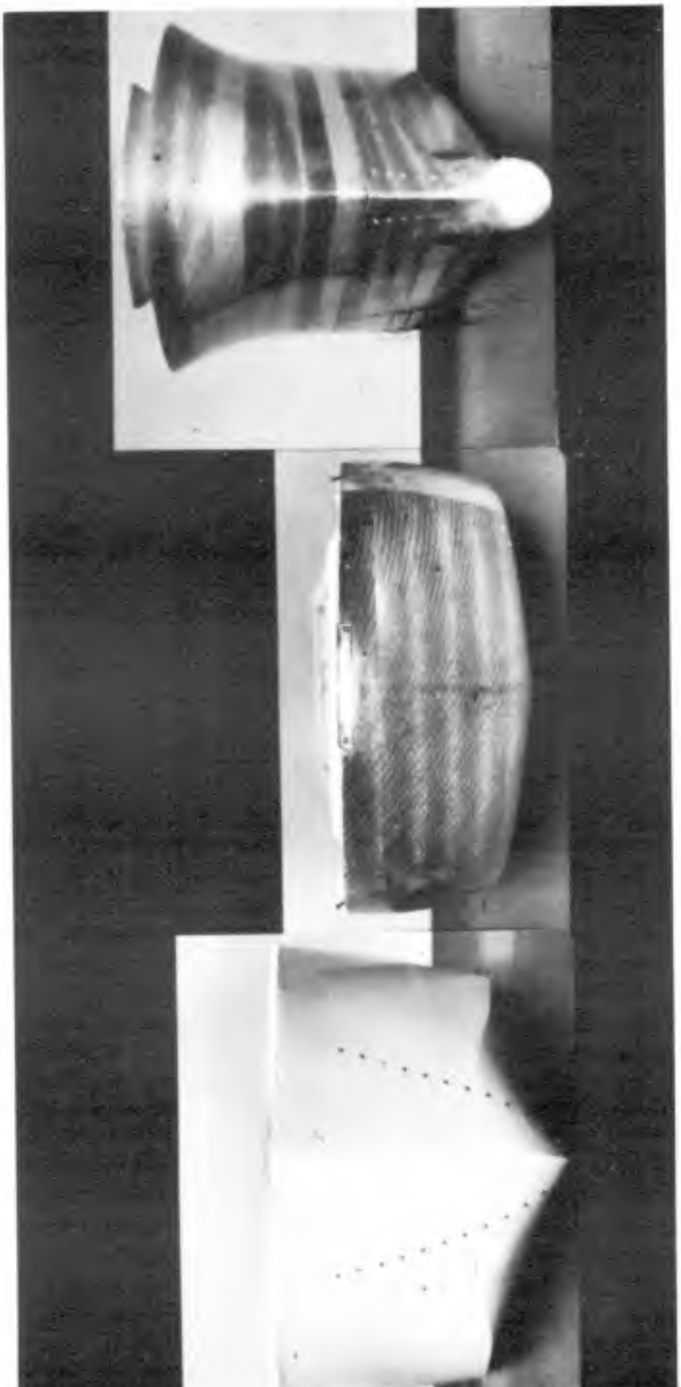
FIG 11 COMPARISON OF MODELS A & B WITH TESTS ON EMPRESS OF CANADA

MODEL B

MODEL A

MODEL C

FIG. 12 MODELS



MODEL F

MODEL E

MODEL D

FIG. 13 MODELS