CHAPTER 28

WAVES PRODUCED BY OCEAN-GOING VESSELS: A LABORATORY AND FIELD STUDY

by

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INTRODUCTION

In restricted waterways, for example in the St. Lawrence River, the question is raised as to the proportion of river bank erosion caused by shipping as opposed to wind-generated waves, tidal currents, and ice break-up.

This study is an attempt to ascertain the size of waves, H, and draw-down, Δ, generated by a vessel as a fraction of the speed, v, the size and shape of the vessel, of the draught, D, and depth of water, d, and the distance from the sailing line to where the waves are measured, x.

From previous work (see bibliography) it has been demonstrated that

(1) H and Δ increase with speed, v, at ever increasing rates until a critical value of $v = \sqrt{gd}$

(2) H and Δ increase with decreasing depth, d;

(3) H and Δ decrease with increasing distance, x, (as far as draw-down is concerned the blockage factor, s, which is the ratio of the maximum c/s area of the ship below the water-line, A_s, to the c/s area of channel minus A_s, namely A_D, is the important parameter. For regular channels of constant depth, A_D is directly linked to x.)

(4) Δ increases with the blockage factor, s, see (3) above, which is directly related to draught, D.

A parameter of the hull geometry which adequately describes the wave-making capacity of a ship is not readily available. Conventional parameters such as the block coefficient and the speed/length ratio ($v/\sqrt{L}$) are found by the authors to be of little value in grouping the data and new parameters are sought as part of the investigation.

EXPERIMENTAL WORK

A. FIELD TESTS:

At two sections of the St. Lawrence River, east of Montreal, wave and draw-down measurements were made using cine-camera photographs of a fixed probe secured to the river bed near the shore. The channel in each section was approximately 50 ft. in depth, one section having a width of 1200 ft. (x≏700 ft.)and the other a width of 3200 ft. (x≏1700 ft.). The cross-sections are shown in Figure 1. Records were obtained for all types of vessels ranging from ocean liners to small pleasure craft.

B. LABORATORY TESTS:

Models of the following ships were built to a scale of 1:96

NAME	DESCRIP-TION	GROSS TONNAGE	LENGTH L	BREADTH B	DRAFT D
Empress of Canada	Ocean Liner	27,000	650 ft.	88 ft.	29 ft.
M.S. Wearfield	Ocean Freighter	17,600	617 ft.	75 ft.	37.5ft.
Cape Breton Miner	Bulk Carrier	19,000	680 ft.	75 ft.	29 ft.

These models were tested in a wave tank 120 ft. long using a towing system of falling weights and a continuous wire. Varying speeds (20-35 ft./sec prototype, i.e. 12-21 knots) depths (48-180 ft.) and values of x (155-1250 ft.) were used and corresponding values of H and Δ measured using variable resistance electronic probes. In order to verify the results from these tests, further tests were carried out as follows:

(1) one model, the Cape Breton Miner, was fitted with an electric motor and propeller to see whether the original towed values were in error due to the pumping action of the propeller.

(2) a second model of the Cape Breton Miner was built to a scale of 1:58 to ensure that the 1:96 test results did not suffer from scale effect.

This latter model was shortened by removing 270 ft. i.e. about 50%, of the parallel middle body but leaving the bow and stern unaltered to investigate the effect of ship length on the wave-height generated.

RESULTS AND DISCUSSION

The relationship between H and v is shown by typical curves in Figures 2 and 3. The wave-height varies as an ever increasing power of v. The results of both 1:96 and 1:58 models are included in Figure 3 as are the results of the propelled model, showing that there is neither noticeable scale effect nor great difference between towed and self-propelled models. Figure 3 also shows that the length of the ship, L, is of little importance in the relationships for H.

Comparison of Figures 2 and 3 show that at the same speed the C.B.M., although of the same length as the E.of C., consistently produces larger waves. (The cruising speed of the C.B.M. is 15 knots whereas that of the E.of C. is 21 knots - at these speeds the E.of C. creates larger waves.) The geometry of the bow is apparently a controlling factor in the relationship for H and the following parameter of bow geometry was developed.

If A is the cross-sectional area of the parallel middle-body below the water-line (for a rectangular middle-body A is breadth B times draught D) and L* is the length of the curved part of the bow, also measured at the water-line, then a fineness ratio is defined as $L^*/\sqrt{A}$ and a wave-making breadth, b, as A/L^* . Using these parameters an orderly set of curves may be obtained as shown in Figure 4.

The relationship between draw-down, Δ, and v for a typical ship is shown in Figure 5. As might be expected, the self-propelled vessel produces a greater draw-down than the towed vessel due to the pumping action of the propeller. Constantine's equation for draw-down is plotted in Figure 6 along with the experimental results. Draw-down is closely connected with squat, the lowering of the water-surface at the vessel. At the vessel, squat and draw-down are sensibly the same. Squat will normally be greater than draw-down since draw-down decreases with increasing distance from the sailing line. Figure 6 gives mean values of draw-down over the cross-section.

CONCLUSIONS

Speed is by far the most important factor affecting the size of ship-generated waves, H being proportional to ever increasing powers of until planing occurs at the critical speed - that is, if planing can possibly occur.

Depth of water and distance from the sailing line affect the wave-height but only to a minor extent compared with speed. The water-line length and the normal naval architectural parameters such as block coefficient are not particularly reliable measures of the wave-heights generated. Fineness and wave-making breadth, as defined in this paper, appear to be more reliable terms. It is possible, using the information on Figures 2,3 and 4, to obtain, by interpolation, a reasonable value of the wave-height H generated by any particular ship in any specified conditions of speed, depth and distance from sailing line.

A mean value of draw-down for a given channel may be obtained using Figure 6. The squat of the ship will be greater than this.

With regard to bank erosion, in restricted channels where s tends to exceed 1 or 2%,the draw-down, and resulting surge wave following the vessel can cause more damage than the ship-generated waves.

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ACKNOWLEDGEMENTS

The authors are indebted to the National Research Council of Canada and to the Departments of Public Works and Transport for their help in making this study.

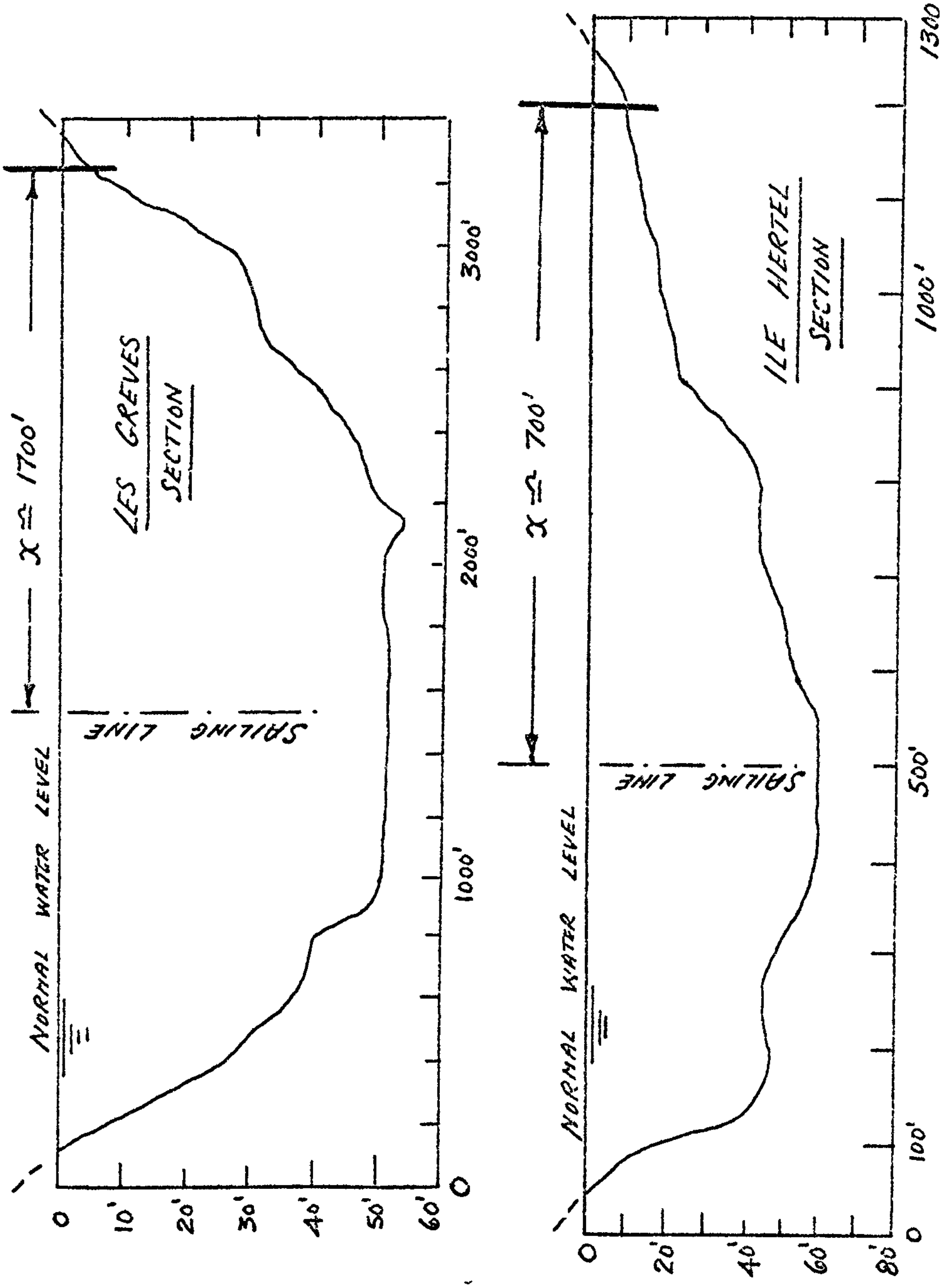

Fig. 1. Cross sections of river.

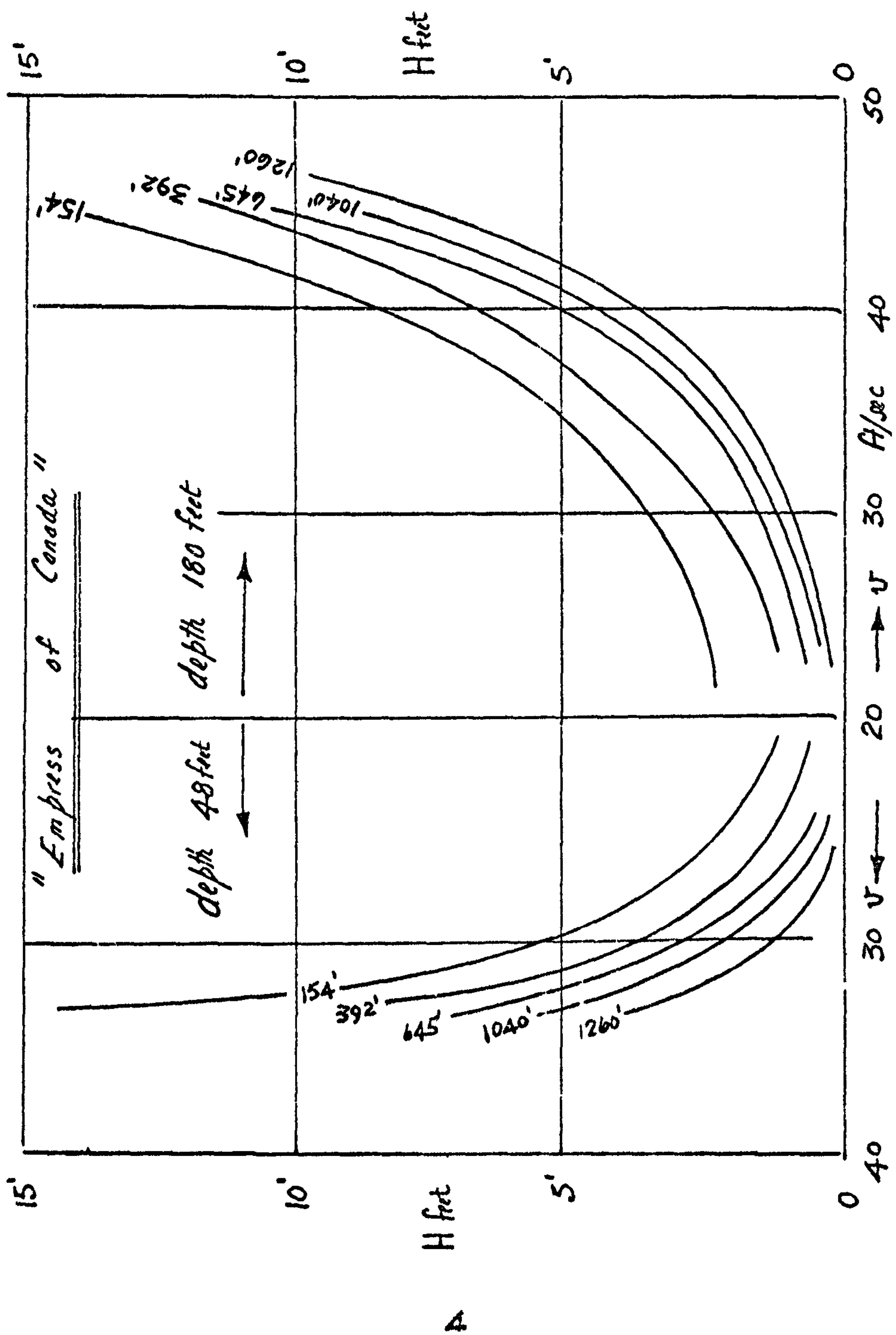

Fig. 2. Wave-height vs speed as function of depth and distance.

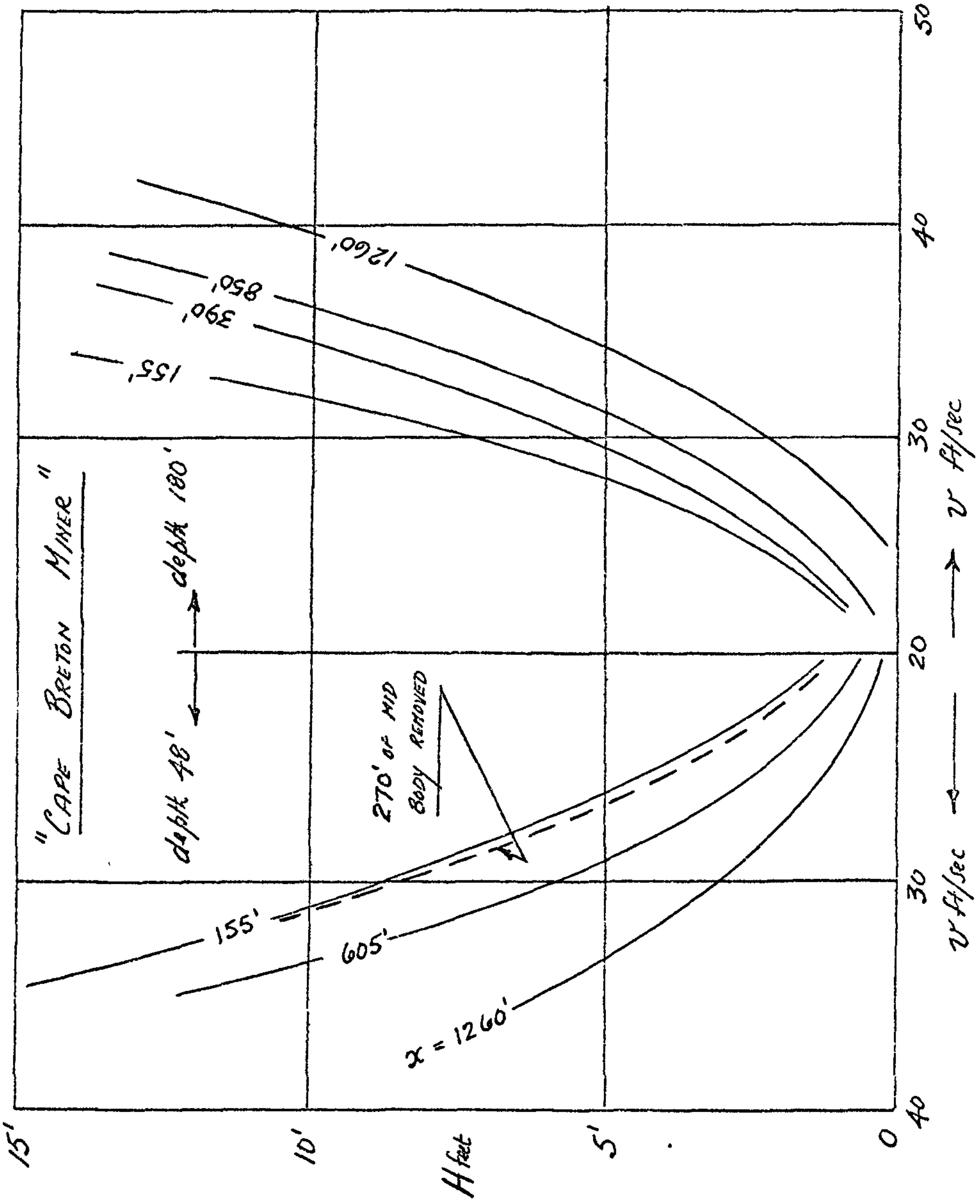

Fig. 3. Wave-height vs speed as function of d and x.

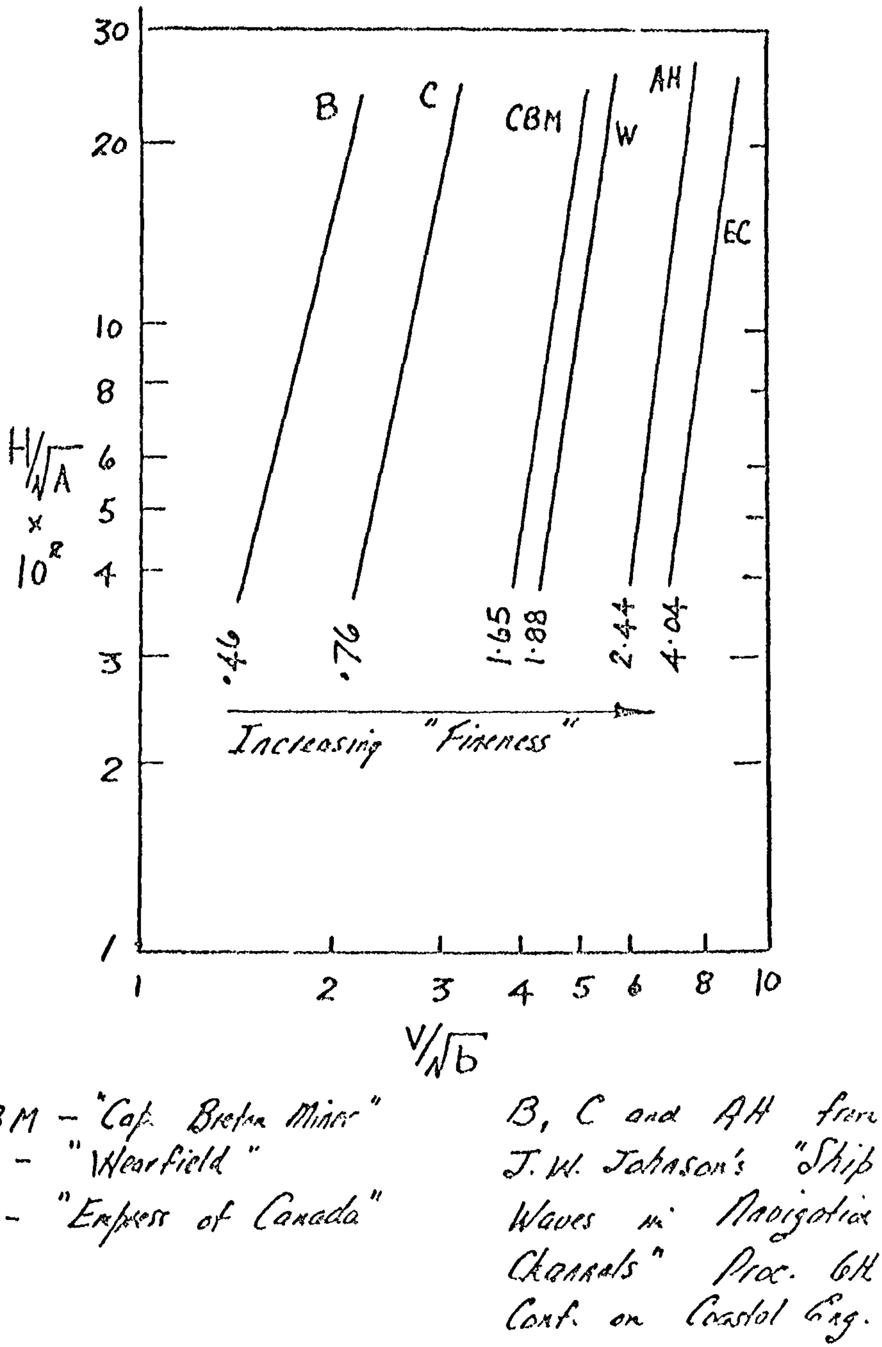

Fig. 4. Variation of $H/\sqrt{A}$ with $V/\sqrt{b}$ for fixed depth of 48 feet. H values measured 288 feet from sailing line.

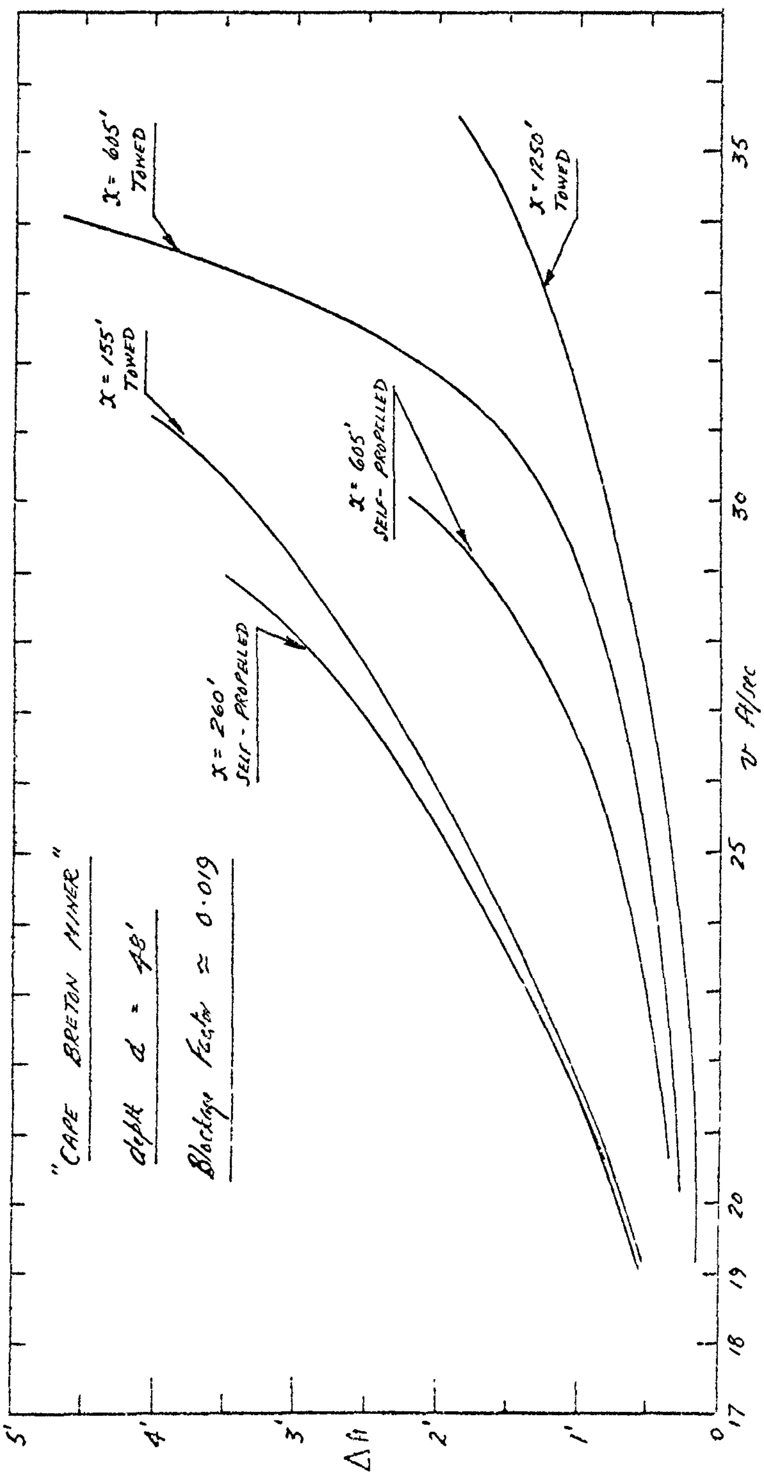

Fig. 5. Draw-down Δ vs speed v.

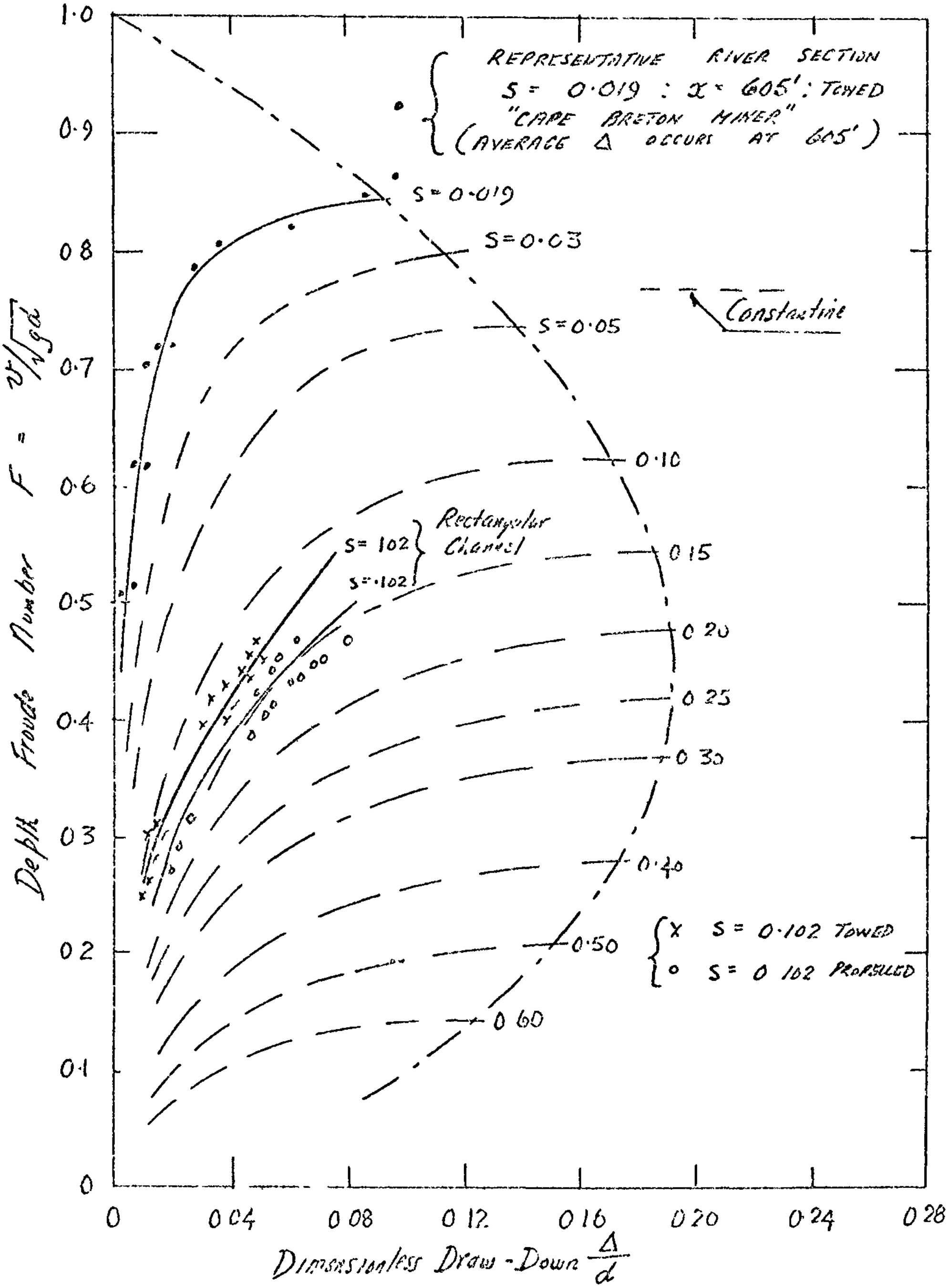

Fig. 6. Comparison of theoretical and actual draw-down.