LONGITUDINAL DISTRIBUTION OF VIRTUAL MASS AND DAMPING FORCES ON A PITCHING AND HEAVING SHIP

Status Report No. 4
August 28, 1959

Colorado State University
Fort Collins, Colorado

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Colorado State University Research Foundation
Civil Engineering Section
Fort Collins, Colorado

Prepared for the
S-3 Panel

Hull Structure Committee
Society of Naval Architects and Marine Engineers
74 Trinity Place
New York 6, New York

CER59EFS28

I. INTRODUCTION

During the summer, a large portion of the data was reduced. Added masses and damping coefficients were obtained for all runs involving heave. The computations on pitch runs were not completed. It was felt that there is a need for some additional experiments run under different conditions before more time and money are spent on additional data reduction.

Final graphs for the data reduced to the present time may be found in the back of this report.

II. ASSUMPTIONS AND PROCEDURES

The usual assumption was made that the system could be represented by a simple second order dynamic system

$$A\ddot{z} + B\dot{z} + C\,|\dot{z}|\dot{z} + Dz = F-L$$

where A is the total effective mass, B the damping term, C a square law resistance (drag in the vertical plane) coefficient, D a spring constant (buoyancy), F the measured force, and L the suction (negative lift) introduced on the model by the forward motion.

It is customary to simplify the equation by assuming that L causes a shift of the zero axis and that C is negligible (second order term). However, it was noticed that the measured force did not oscillate about zero even though the model was not being towed (i.e. pure heave). Since it is unlikely that a force L wil be created on a pure oscillator, it was assumed that either the zero shift was introduced by the instrumentation or else that the coefficient C was a function of time. It is not inconceivable that C is a function of time. This simply means that the drag terms measured on the way down are different from those measured on the way up, or, that separation occurs on the upstroke but not on the downstroke.

The possibility that the zero shift was introduced by the instrumentation seemed unlikely after certain tests were made:

A. It was easily demonstrated that the record trace returned very nearly to zero at the end of each run.

B. Two different instrumental techniques were used with similar results. (Considerable drift was noticed if the strain gages were fed directly to the galvanometer. However, if the zero position before the run and after the run were connected by a straight line, it was noticed that a zero shift still existed during the run which could not be due to drift.)

C. Amplifier drift was measured and was found to be constant and to be independent of input signal. Thus, while the measured zero shift occurred during motion, amplifier shift occurred during all the time the amplifier was turned on. Below is some information on the measured drift of six typical amplifiers:

Amplifier	Balance voltage	Voltage after 2 hrs	Drift rate
1	0.50 volts	1.10 volts	0.30 volts/hr
2	0.40 volts	0.75 volts	0.17 volts/hr
3	0.75 volts	1.11 volts	0.18 volts/hr
4	0.15 volts	0.45 volts	0.15 volts/hr
5	0.05 volts	0.35 volts	0.15 volts/hr
6	0.90 volts	0.90 volts	0.00 volts/hr

(amplifier 1 was found to be defective, the remaining six amplifiers drifted approximatly 0.15 volts per hour)

Assuming that a run would take approximately five minutes to complete, it was seen that the drift per run would be no more than 0.026 volts which corresponded to a maximum difference of 0.20 lb. [This is for amplifier #1. With the other (more stable) amplifiers the drift in pounds over five minutes would be about 0.10 lbs] . By taking a prerun, a post run and by rebalancing the amplifiers before each run even this small drift rate was nullified. It was necessary to assume that the zero shift was probably real and caused by hydrodynamic motion.

III. RESULTS

The following results were obtained:

A. The added mass coefficients followed the curve obtained by Golovato in shape, but were consistently lower in value.

B. The damping coefficient became negative. This result is rather interesting. Golovato found that the driving frequency of his system approached the natural frequency asymptotically but never exceeded the natural frequency. The Colorado State University study, on the other hand, showed that the natural frequency would become less than the driving frequency at a well defined point.

C. All coefficients were found to be dependent on the amplitude of oscillation. If the square law drag is responsible for the zero shift, this last result should be expected.

IV. CONCLUSION

It is suggested that the project be extended another year and that the following confirmation studies be made in order to check those points of discrepancy with other investigators.

A. The model segments should be guided rigidly to prevent self-excited pitch oscillations about the segment c.g.

B. The experiments should be repeated with a different type spring, say a force block, to determine the effects of possible coupling between springs.

C. Sealing membranes should be introduced in the segment cuts.

D. A filtering system should be introduced in the electronic system to cut down noise.

E. Long term study of instrumentation drift should be made (these can be done in the winter with the model mounted in a tank indoors). Complete graphs of drift vs. time should be obtained for all possible combinations.

F. Single segments should be run in pure heave (without forward speed) to determine interference effects.

Upon the completion of the experiments outlined above, it will be possible to determine the true status of model forces. As part of the study, efforts should be made to obtain the original oscillographs from Golovato or at least to obtain some information from DTMB on the magnitude of zero shift.

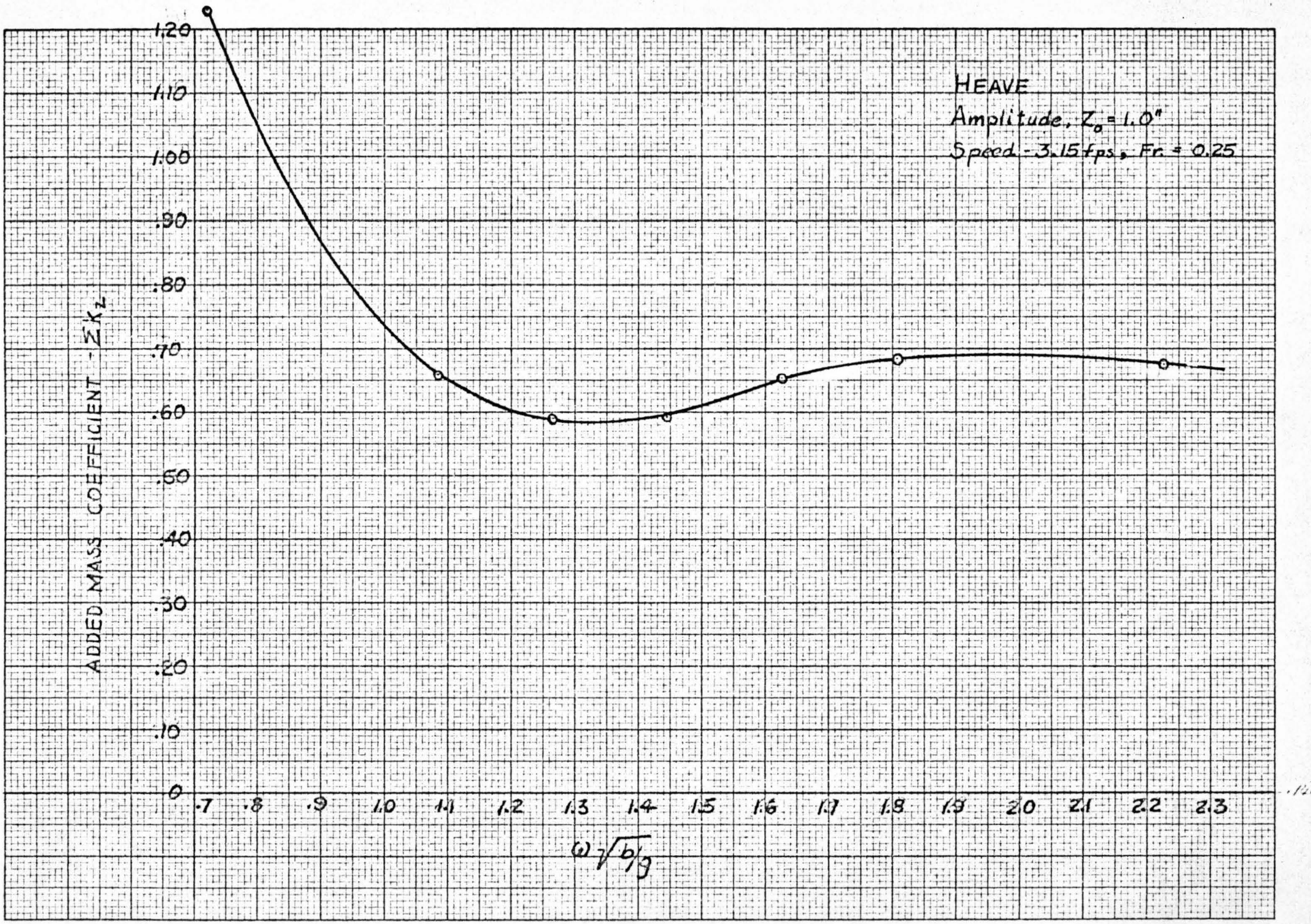
HEAVE
Amplitude, Z_o = 1.0"
Speed - 3.15 fps, Fr = 0.25
ADDED MASS COEFFICIENT - Σk_z
1.20
1.10
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
$\omega\sqrt{b/g}$

FIG. 1

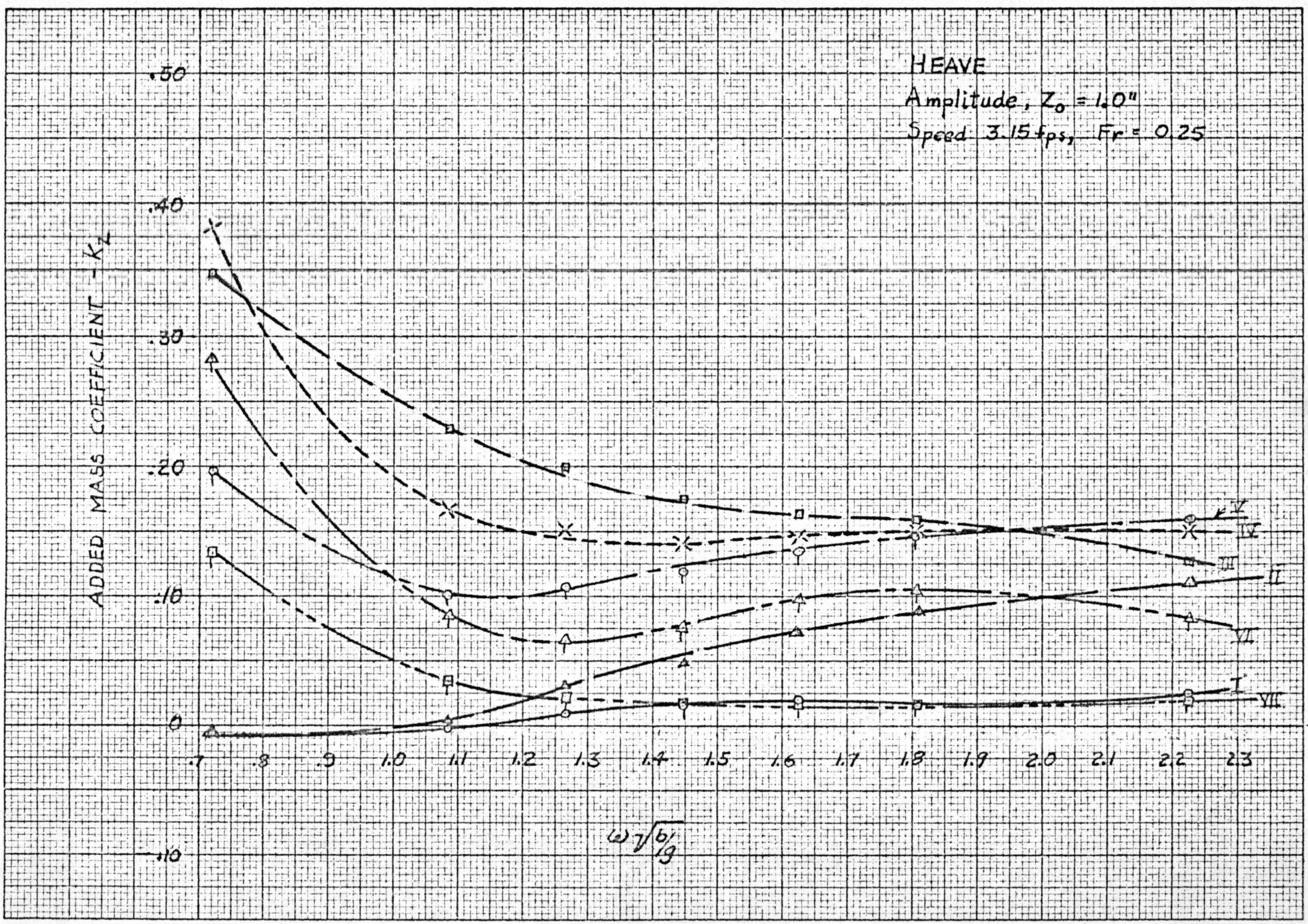
HEAVE
Amplitude, Z_o = 1.0"
Speed 3.15 fps, Fr = 0.25
ADDED MASS COEFFICIENT - K_z
.50
.40
.30
.20
.10
0
-.10
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
$\omega\sqrt{b/g}$
I
II
III
IV
V
VI
VII

FIG. 2

K+E 10 X 10 TO THE ½ INCH 359-11.
KEUFFEL & ESSER CO. MADE IN U.S.A.

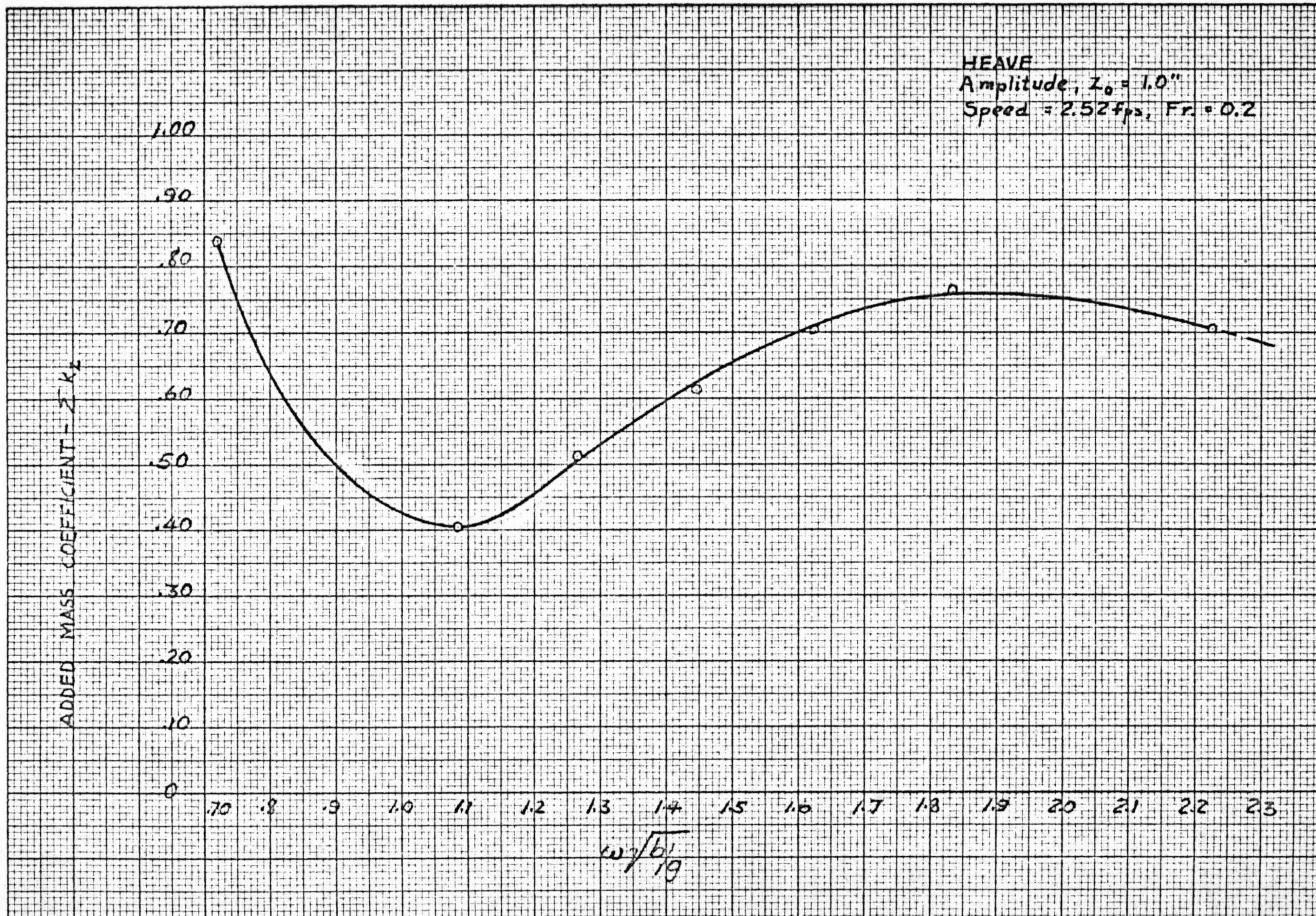

FIG. 3

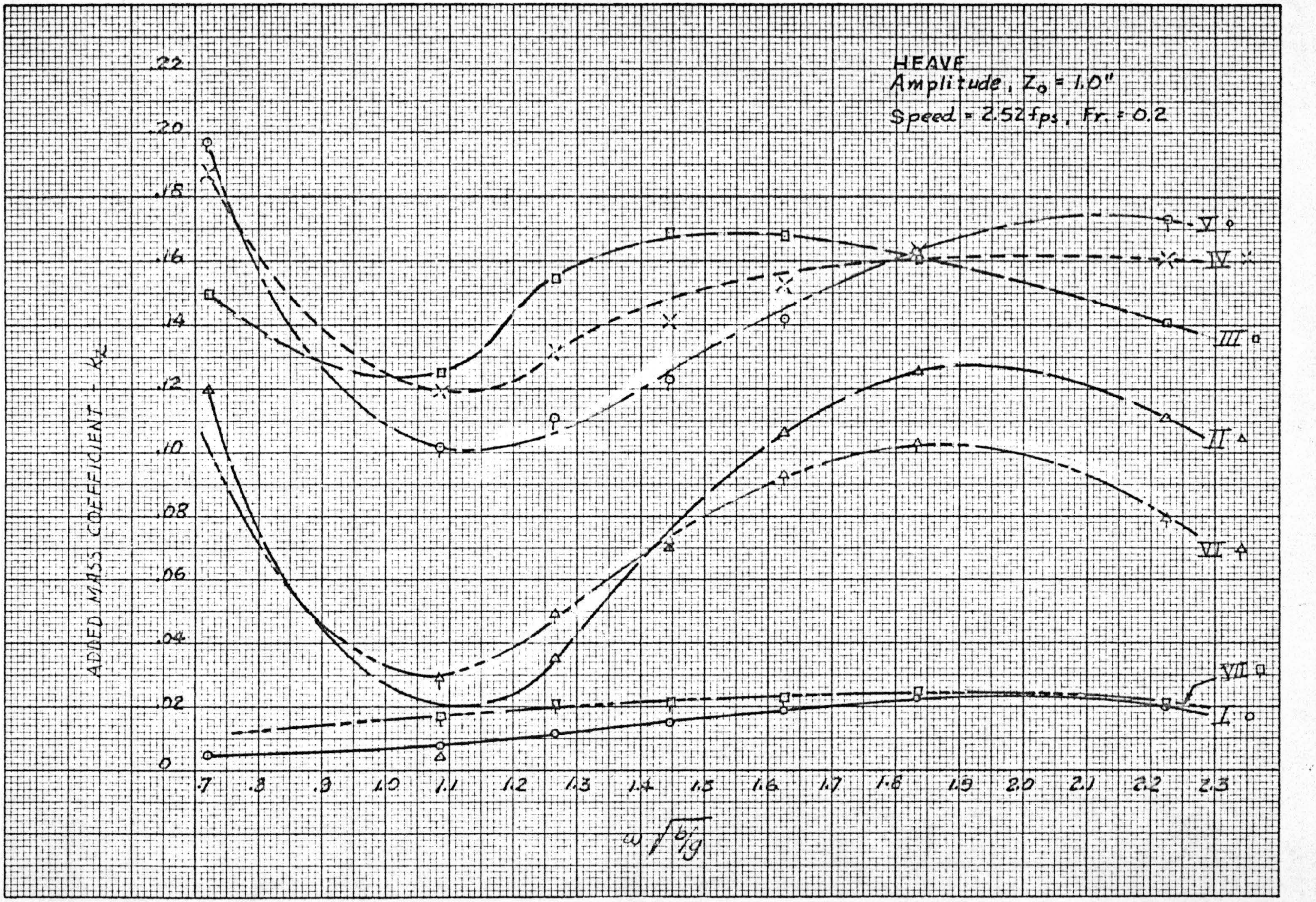
HEAVE
Amplitude, Z_0 = 1.0"
Speed = 2.52 fps, Fr. = 0.2
ADDED MASS COEFFICIENT - K_2
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
$\omega\sqrt{b/g}$
V
IV
III
II
VI
VII
I

FIG. 4


HEAVE
Amplitude Z0 = 1.0"
Speed = 3.15 fps, Fr. = 0.25
DAMPING COEFFICIENT
0
1
2
3
4
5
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
ω√(b/g)

FIG. 5

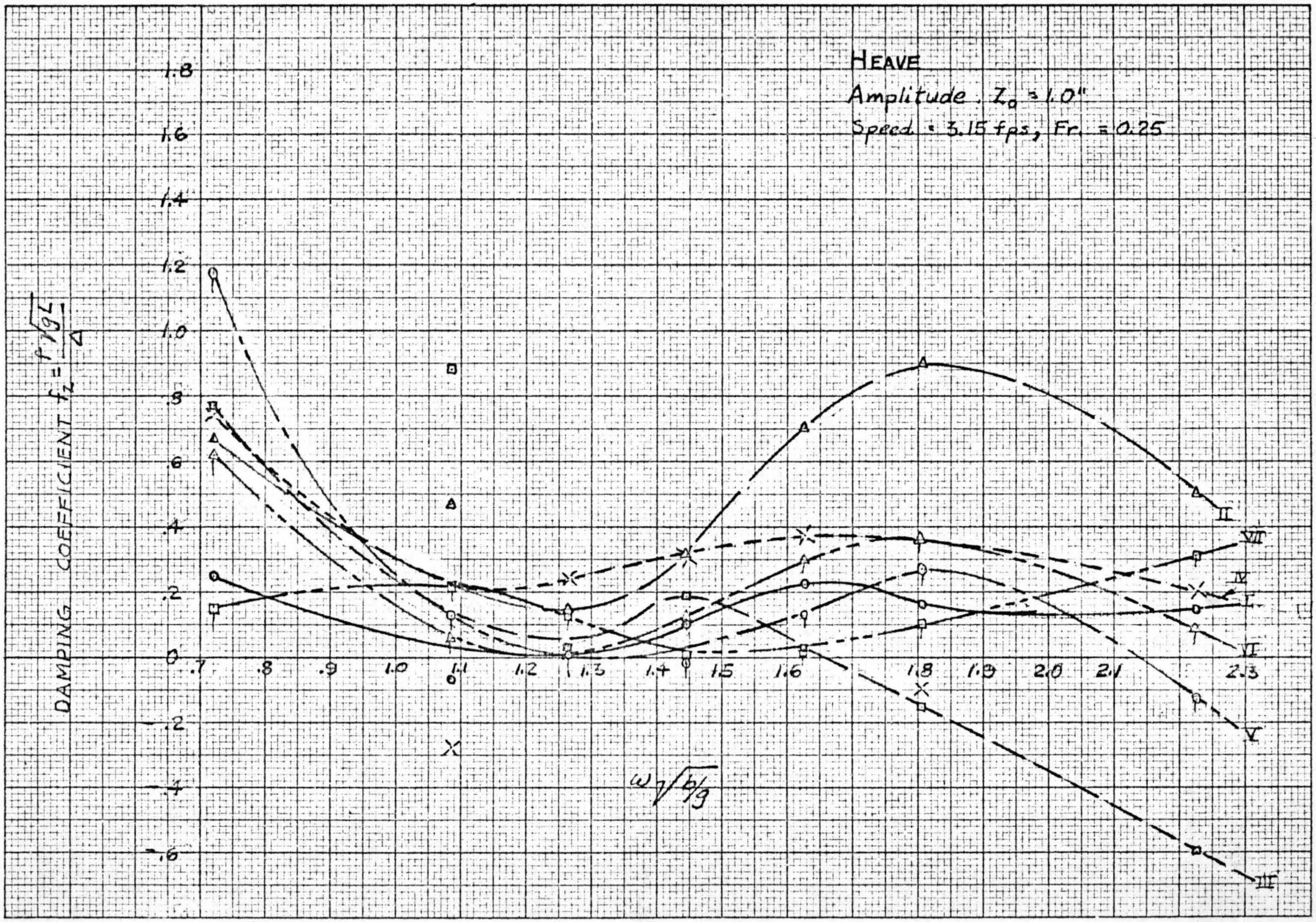
HEAVE
Amplitude : Z_0 = 1.0"
Speed = 3.15 fps, Fr = 0.25
DAMPING COEFFICIENT $f_z = \frac{F\sqrt{gL}}{\Delta}$
$\omega\sqrt{b/g}$
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
-.2
-.4
-.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.8
1.9
2.0
2.1
2.3
II
VII
IV
I
VI
V
III

FIG. 6

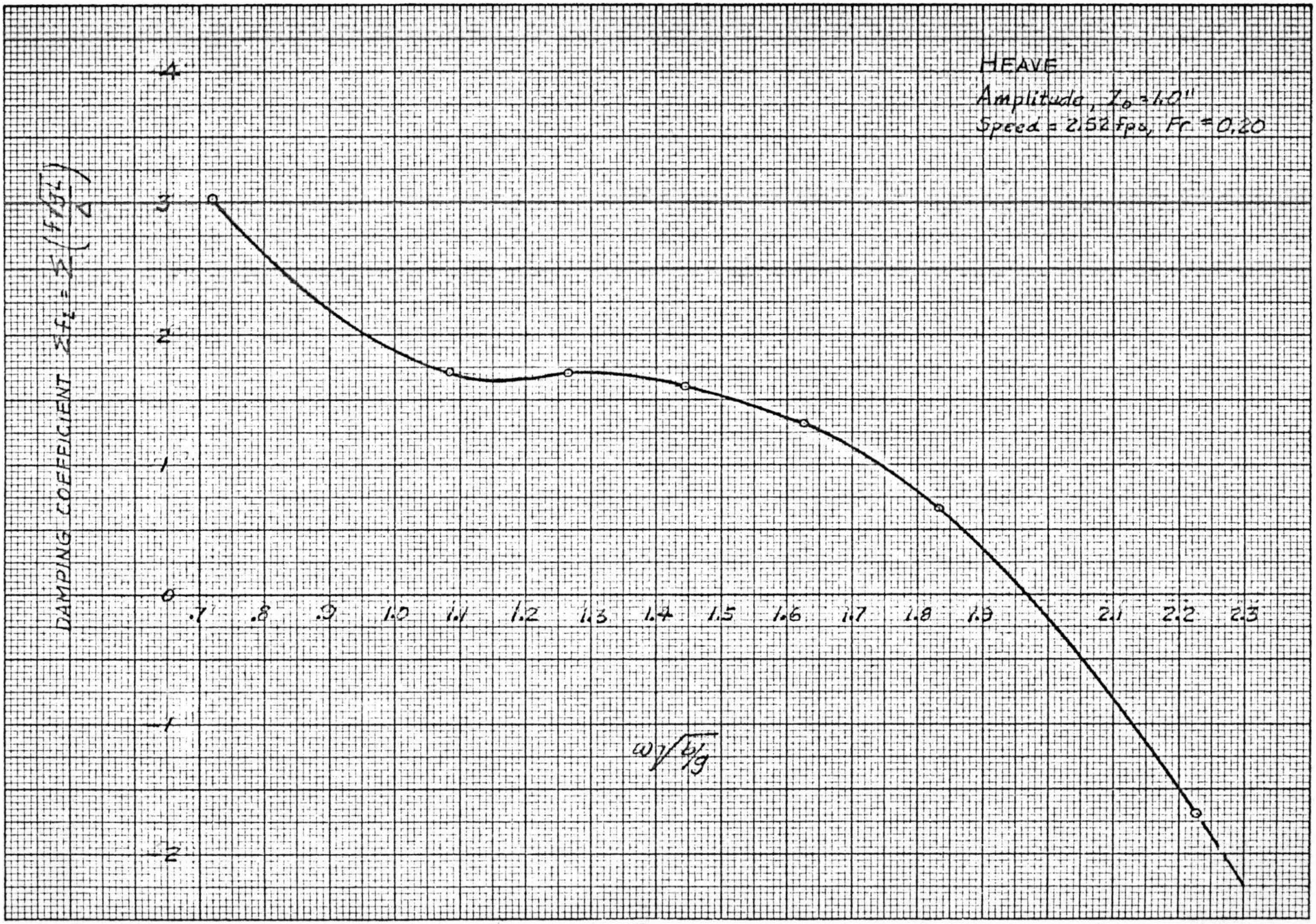
HEAVE
Amplitude, Z_0 = 1.0"
Speed = 2.52 fps, Fr = 0.20
DAMPING COEFFICIENT
4
3
2
1
0
-1
-2
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.1
2.2
2.3
$\omega\sqrt{L/g}$

FIG. 7

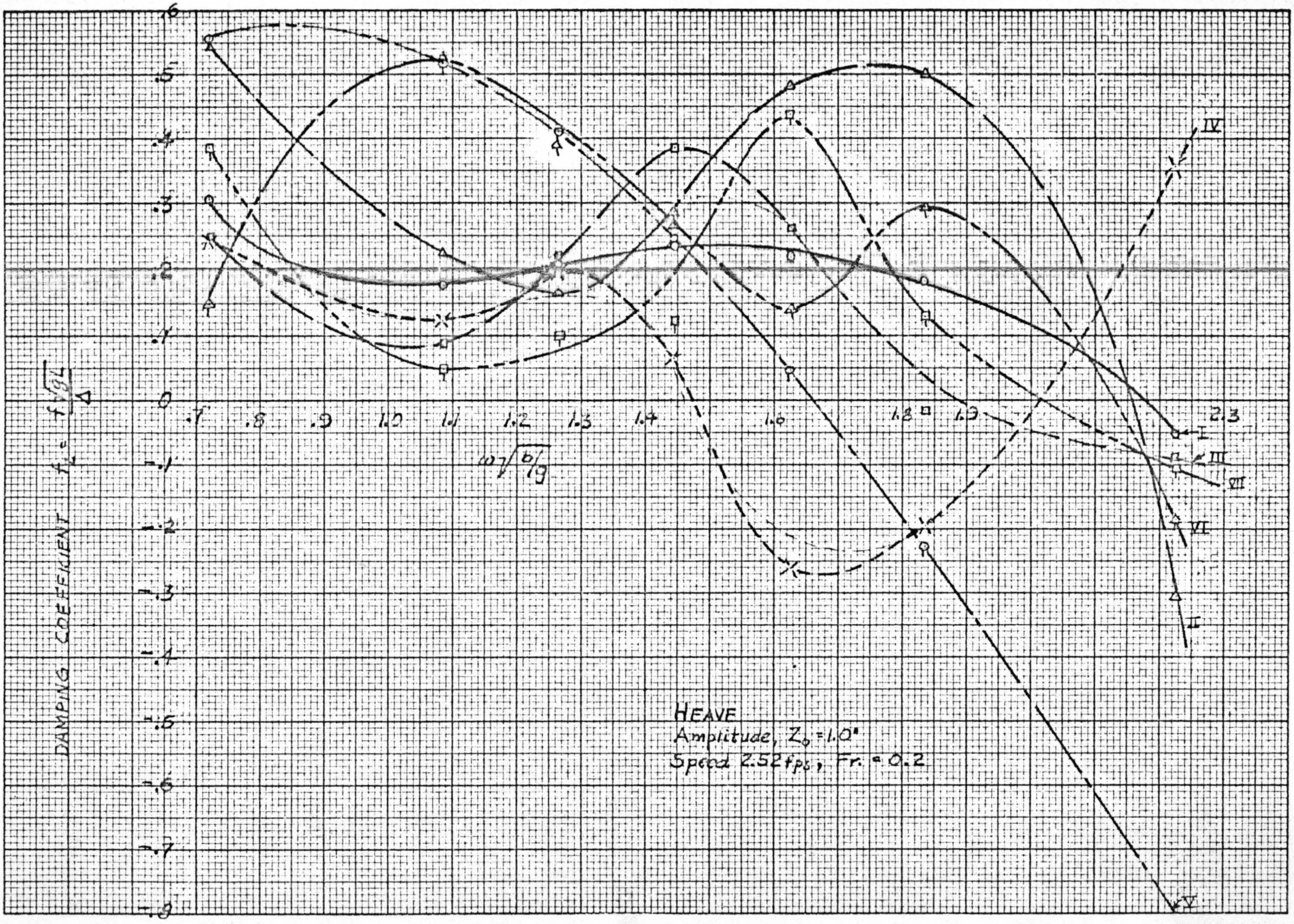
DAMPING COEFFICIENT $f_z = \frac{f\sqrt{gL}}{\Delta}$
$\omega\sqrt{b/g}$
.6
.5
.4
.3
.2
.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.6
1.8
1.9
2.3
I
II
III
IV
V
VI
VII
HEAVE
Amplitude, Z_0 = 1.0"
Speed 2.52 fps, Fr. = 0.2

FIG. 9