#2

TEST OF DRAWING ROOM MODEL

of

10,000 TON LIGHT CRUISERS (#24 - #25) IN WATER

TO DETERMINE FORCES DUE TO WIND



U. S. Experimental Model Basin,

Navy Yard, Washington, D.C.

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**Summary:-**

A drawing room model of the 10,000 ton light cruisers, Nos. 24 - 25, was constructed to separate on the load water line plane. The upper section representing the parts exposed to the wind was towed inverted in water with its center line at various angles to the direction of motion and the flat surface representing the LWL plane just above the surface of the water.

The model was hung from a platform which was free to move horizontally, the size and direction of the force of the water tending to move the model being measured by the forces required to hold the platform in its original position.

The model was run at speeds up to two knots and with its center line at angles varying by $5^{\circ}$ intervals from $0^{\circ}$ to $90^{\circ}$ with the direction of the motion.

The forces were plotted on speed, cross faired on angle, and the resultant vectors found by graphic solution at three different speeds.

The ahead resistances, obtained by resolution of the vectors on the center line of the model were plotted on angles and cross faired on speed assuming that the resistance varies as $V^2$, which agreed quite closely with the curves as plotted.

The curve of $\frac{\text{ahead res.}}{V^2}$ thus obtained was plotted in fraction of its value at $0^\circ$ angle, thus reading at any angle is a coefficient by which the "head on" resistance (sheet XI) or the specific resistance may be multiplied to give the resistance at the desired speed and angle.

The curve of resistance for the ship at $0^\circ$ angle was computed from the model results by using the formulae

$$R_s = R_m \times \lambda^3 \times \frac{\rho_a}{\rho_w} \qquad \text{and } V_s = V_m \sqrt{\lambda}$$

where $\lambda$ = Linear ratio of ship to model.

This was reduced to specific resistance by dividing by the area of the silhouette projected on the athwartship plane and by the square of the speed; $\frac{R}{AV^2} = .002$

The fore and aft positions of the center of pressure of the wind on the ship were obtained from the intersections of the vectors with the center line of the model, and were plotted as distance from the forward perpendicular in per cent of the length of the ship.

Introductory:-

The increase in resistance due to wind is an effect to be considered both in connection with the design and with the trials of Naval vessels.

Up to the present time, very little investigation has been done at this model basin in regard to the force exerted on a vessel by the wind.

The present report concerns the first detailed test of the effect of the wind at various angles with the center line of the ship.

Such tests were made at the Wm. Froude National Experiment Tank, reference N° 1, using models of three merchant ships towed inverted in water. For the subject of the present report a drawing room model of a 10,000 ton Light Cruiser was used in the same manner.

Methods & Apparatus:-

The drawing room model of a 10,000 ton light cruiser (N$^{o}$ 24 - 25) had been made in two sections which separated on the load water line plane.

The linear ratio of ship to model was 96, so the model was 72.7 inches long. The upper section, shown on sheet 1, was mounted on a pivot and secured to a semicircle of wood three feet in diameter, upon which the angles from 0$^{o}$ to 90$^{o}$ were laid off at intervals of 5$^{o}$.

This model was fastened beneath a hanging platform, as shown on sheet II, and clamped at the desired angle. The platform was hung on four small wire ropes, the height being adjusted so that the load water plane of the inverted model was just above water.

The platform was towed by a wire from the carriage dynamometer, which thus measured longitudinal forces, and was held in its central position by two wooden balances, upon which the lateral forces were measured. See sheet III.

The model was run at speeds ranging from 0.6 knots to 2.0 knots and with its center line at angles with the direction of motion varying from 0$^{o}$ to 90$^{o}$ by 5$^{o}$ intervals.

The model was first tested at settings on the even tens of degrees, up to 80$^{o}$, with the balances pressing against wooden blocks as shown on sheet III, but the friction between the lower balance arms and the blocks becoming noticable at the larger angles, the balances were rerigged to pull on cords instead of pressing against blocks, and the remaining settings tested. Thus in cross fairing the spots, the odd angles were favored.

The readings for the forces were plotted on speed as shown on sheets IV, V & VI, and the resulting curves cross faired on angles at three speeds, as shown on sheet VII. The faired values for the forces were then combined and the resulting vector found by graphic solution for each angle and speed.

Sheet VIII shows the diagram for the 50° angle and 1.4 knot speed.

The ahead resistance is the vector resolved on the center line of the model. This was obtained in each instance and the results plotted on angle giving three curves for 1.0, 1.4 and 1.8 knots speed respectively. These curves, shown on sheet IX, were cross faired on speed, assuming that resistance varies as $V^2$, and the resultant non-dimensional curve, sheet X computed for the force of the wind on the ship. This curve of ahead resistance for the range of angles was plotted in fraction of its value at 0° angle, thus a reading at any angle is a coefficient by which the resistance at 0° angle, sheet XI, or the specific resistance may be multiplied to give the ahead resistance at the given angle and speed.

The curve of resistance on sheet XI represents the wind resistance as derived from the results of the test of the model in water by use of the formulae:

$$R_s = R_m \times \frac{\lambda^3}{\frac{\rho_w}{\rho_a}} \quad \text{and } V_s = V_m\sqrt{\lambda}$$

| | | | | | subscripts | |
|---|---|---|---|---|---|---|
| where | R | = | resistance | w | = | water |
| | $\lambda$ | = | linear ratio of ship to model | a | = | air |
| | $\rho$ | = | density | s | = | ship |
| | V | = | speed | m | = | model |

This disregards the effect of the viscosity, but since this is only a small fraction of the total wind resistance, and the wind resistance is a comparatively small part of the total resistance of the ship, its effect may safely be ignored.

The specific resistance for the ship at 0° angle was found by dividing the resistance by the square of the speed and by the area of the silhouette projected on an athwartship plane. $\frac{R}{AV^2} = .0026$ where R is in lbs., A is in sq.ft. and V is in knots. (See note, page 8).

The intersection of the resultant vector with the center line of the model (sheet VIII) is considered the position of the center of pressure. This is plotted on sheet IX. The curve for the lower speeds was taken to be the more nearly representative of the action of the wind on the ship as there was a more even flow with less wave making at the lower speeds. This curve was therefore used to obtain the non-dimensional curve on sheet XII.

Results and Discussion:-

The curve of ahead resistance, sheet X, indicates a maximum, at about 33°, and is about 50% more than the value at 0°. It is also seen that the ahead resistance does not fall below the value at 0° until an angle of over 62° is reached.

The position and relative amount of the maximum agree fairly well with the test in reference N° 1 but the curves in the English test do not continue above the value at 0° to such a large angle.

The center of pressure moves aft as the angle of the wind increases, reaching the greatest distance aft when the apparent wind is broadside and is then about 23 ft. forward of amidships.

The shape of this curve, on sheet XI, and its position at 90° agree very well with the curve for model No. 1086 A in the English test, but at small angles its position is not so far forward.

Conclusion:-

This experiment demonstrates that the wind has its greatest retarding effect on the ship when it is about $30^\circ$ off the bow, which must therefore be taken into account in any attempt to lessen wind resistance by a change in design.

That this retarding effect may be considerable may be shown by assuming a 22 knot beam wind (true) which, with the vessel at a 33 knot speed, would become an apparent 39 knot wind at $34\frac{1}{2}^\circ$ and increase the total resistance about $3\frac{1}{2}$ per cent.

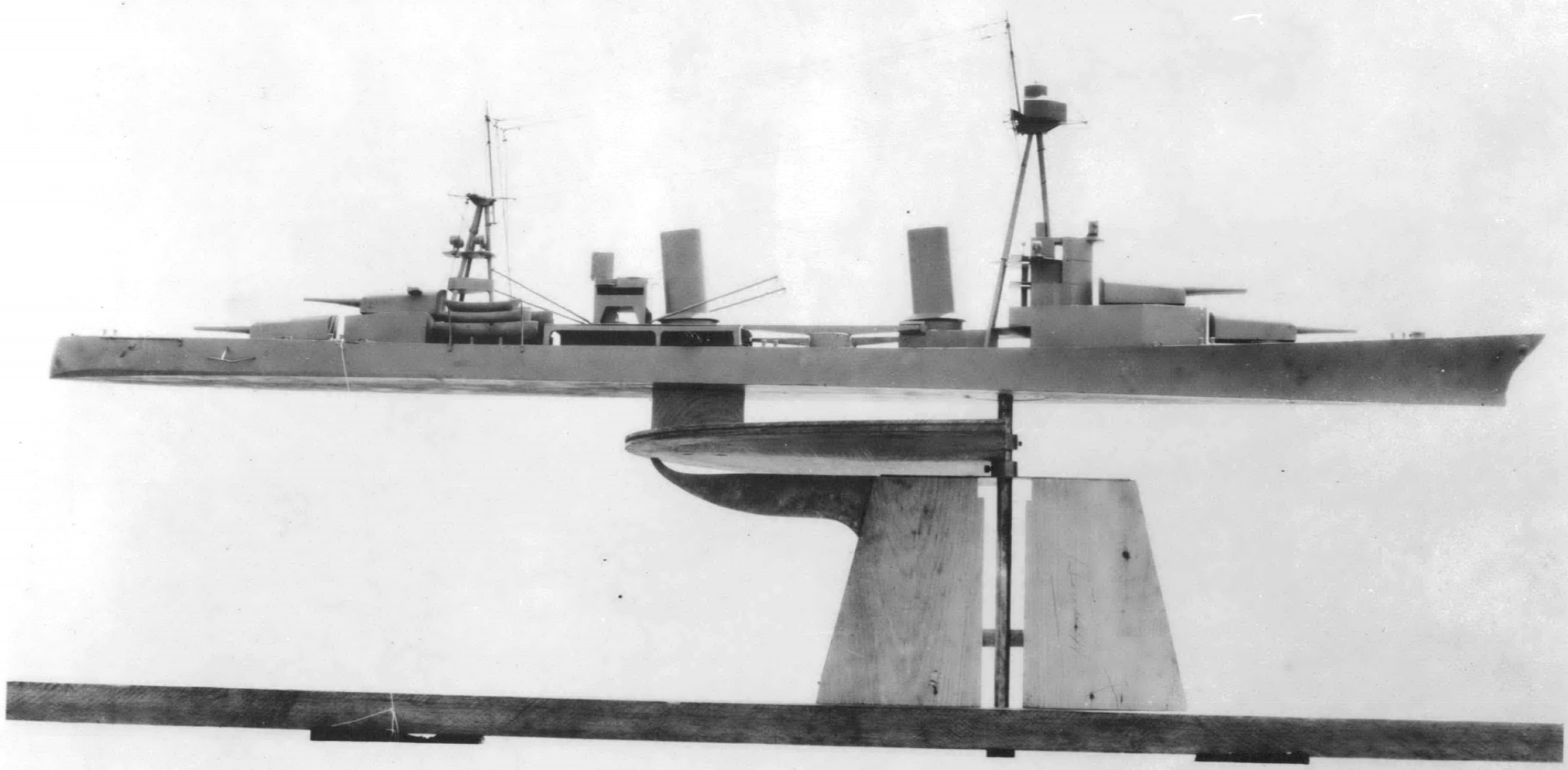
The position of the center of pressure indicates that, for the smaller angles at least, the vessel might carry a lee helm.

Reference:-

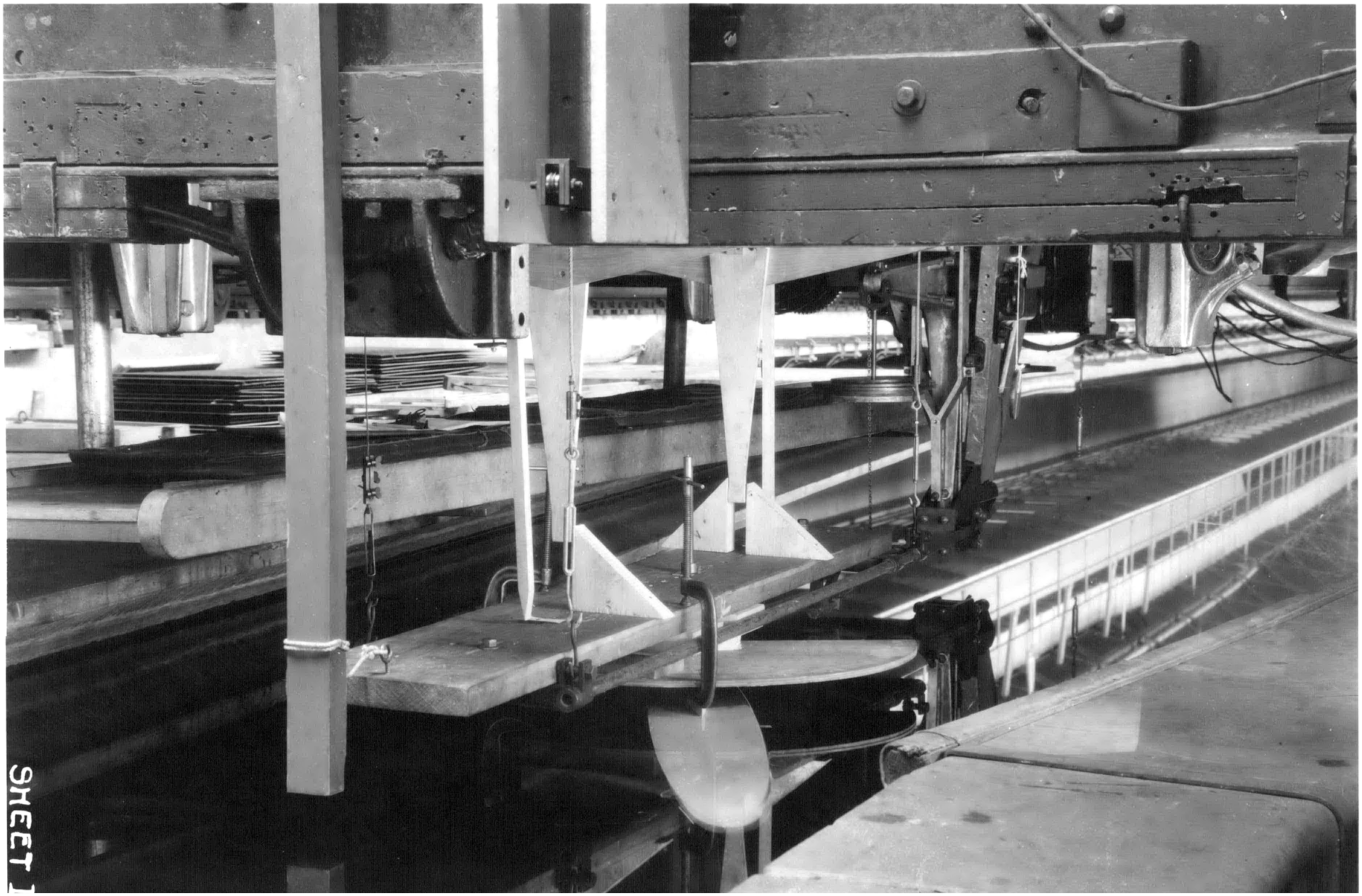
Model Experiments on the Wind Resistance of Ships by G. Hughes, Transactions of the Institution of Naval Architects, July, 1930.

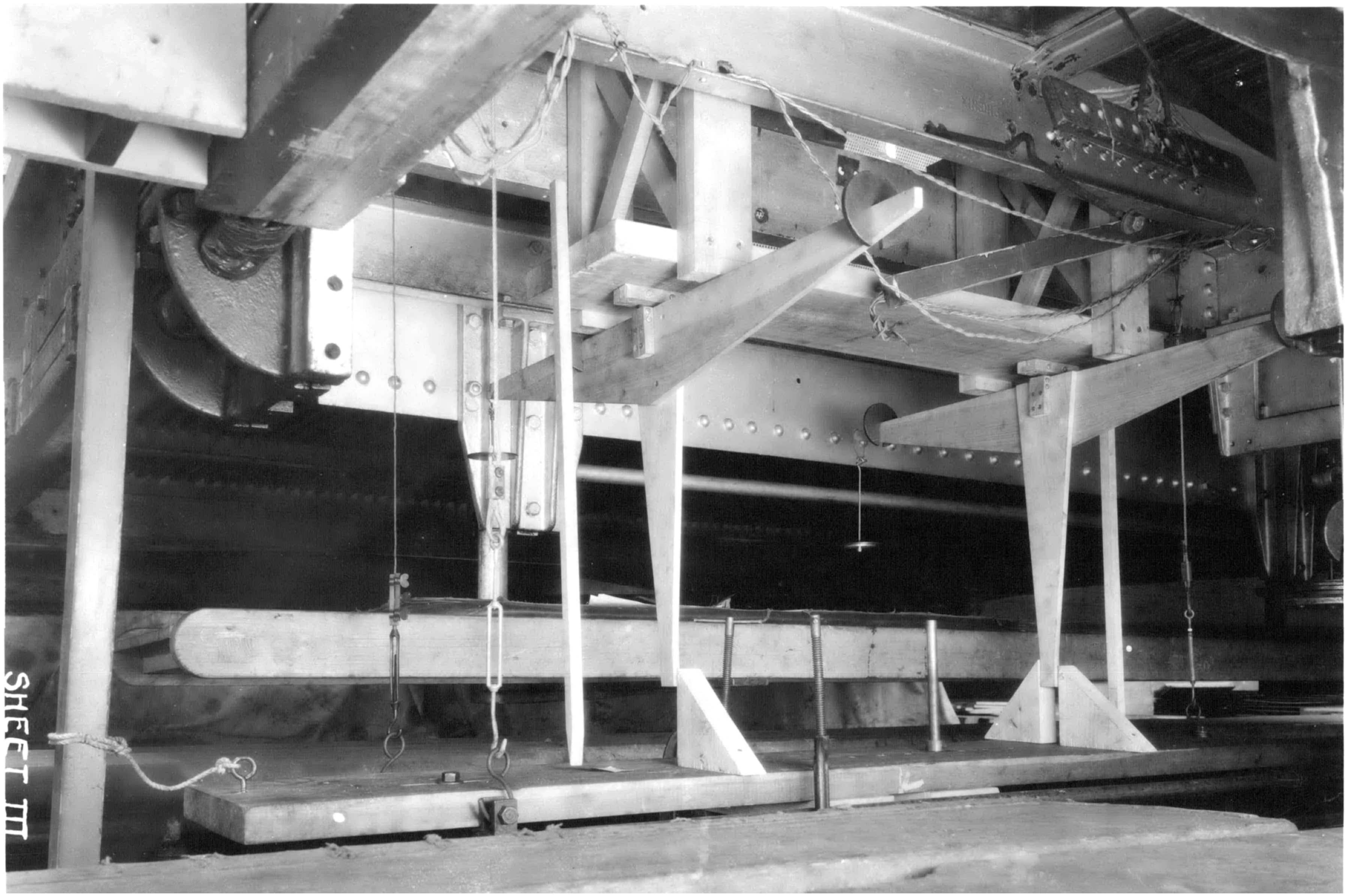
NOTE:-

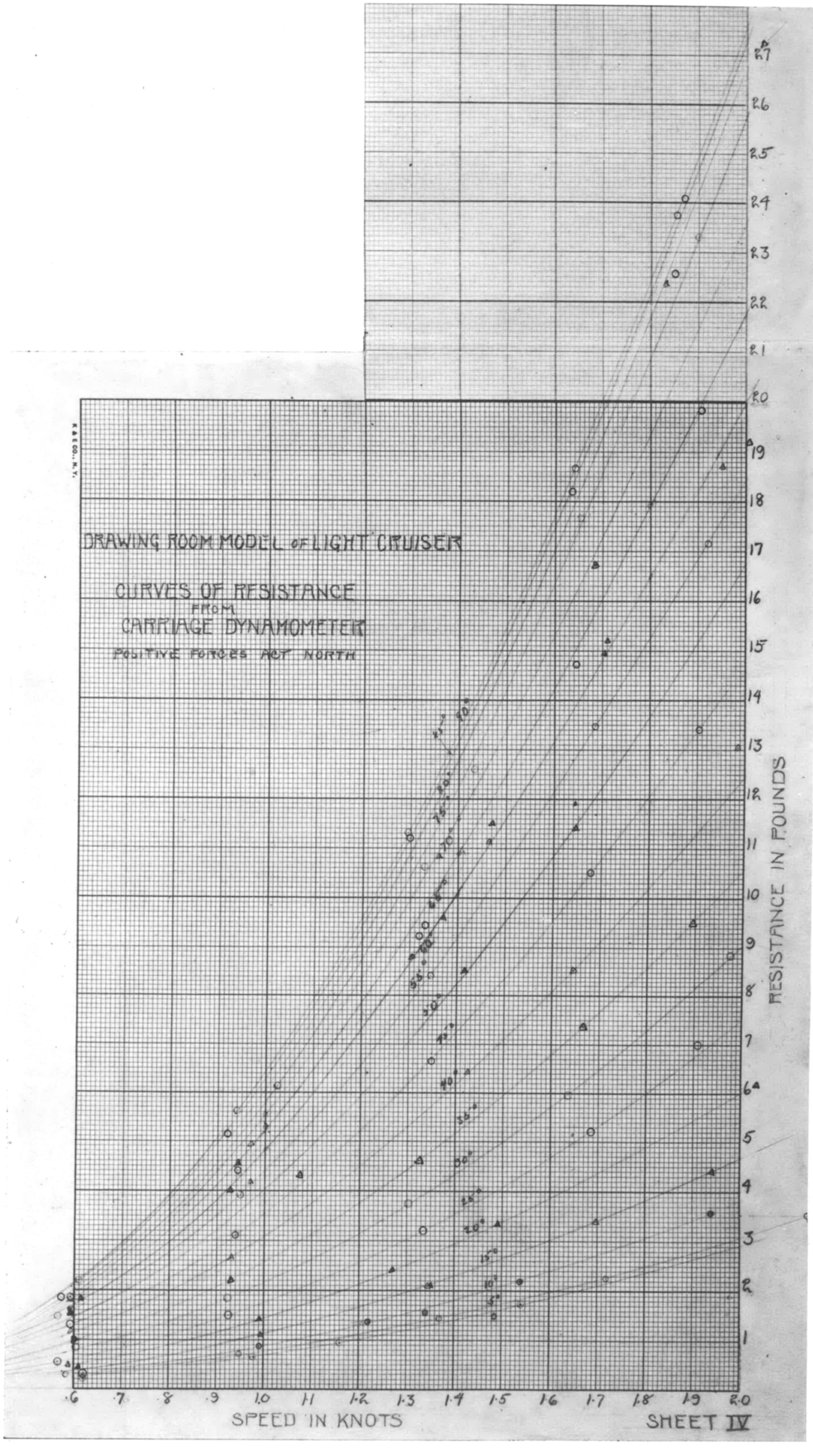
The area (A) of the projected silhouette is 3,100 sq.ft. This gives a smaller value for the specific resistance than if the approximate area $\frac{\text{Beam}^2}{2}$ = 1,850 sq. ft. were used.



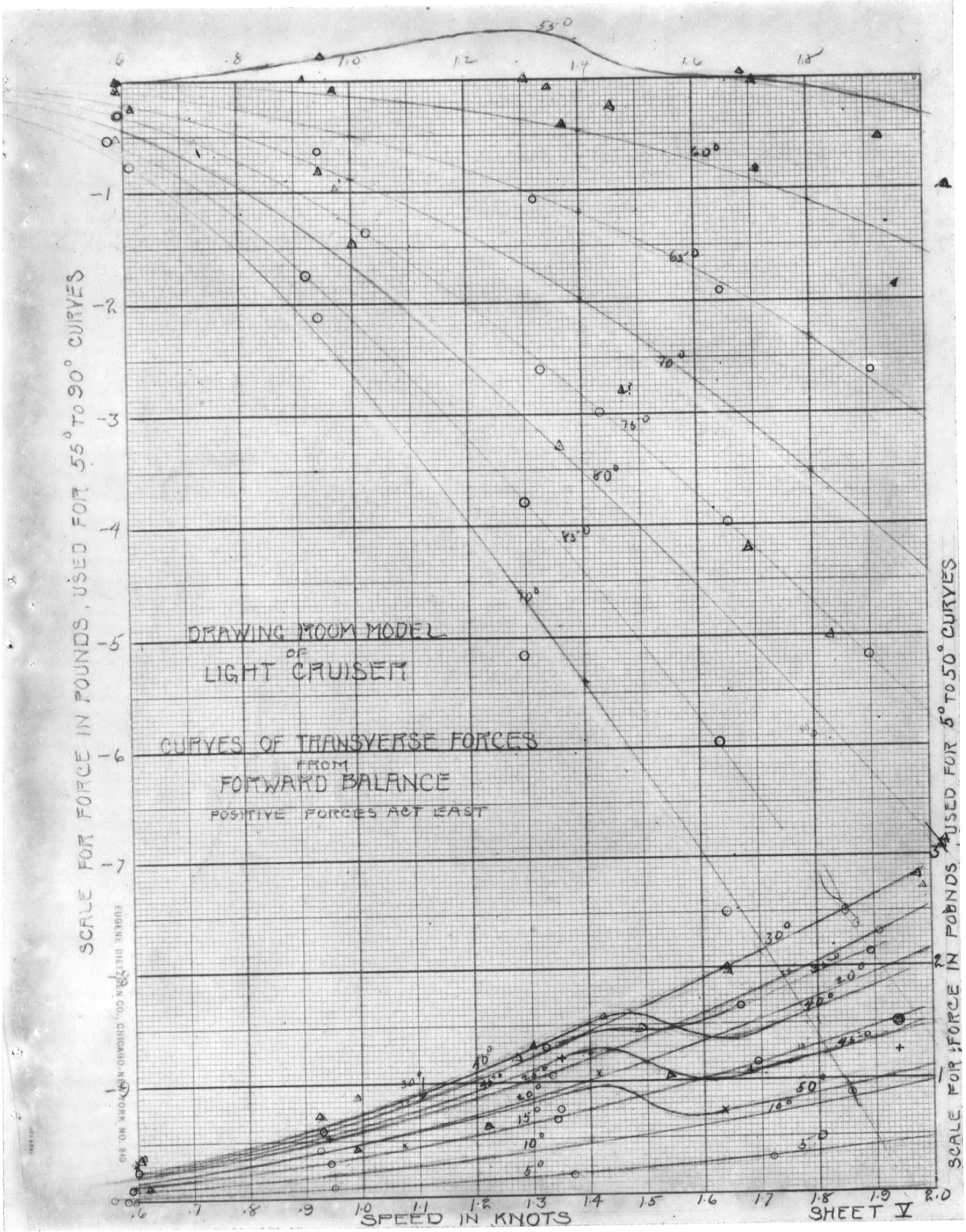
SHEET I

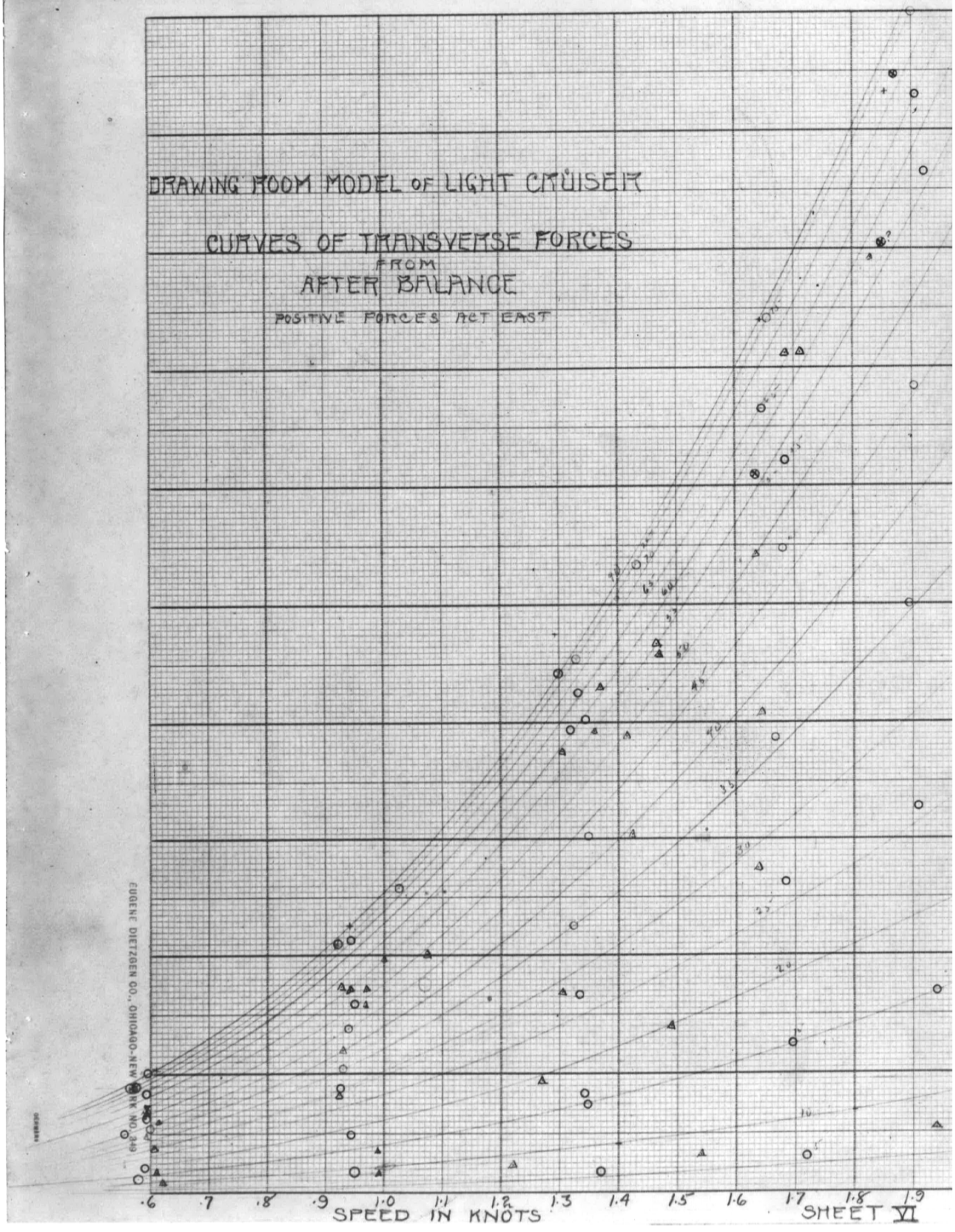

SHEET


SHEET III

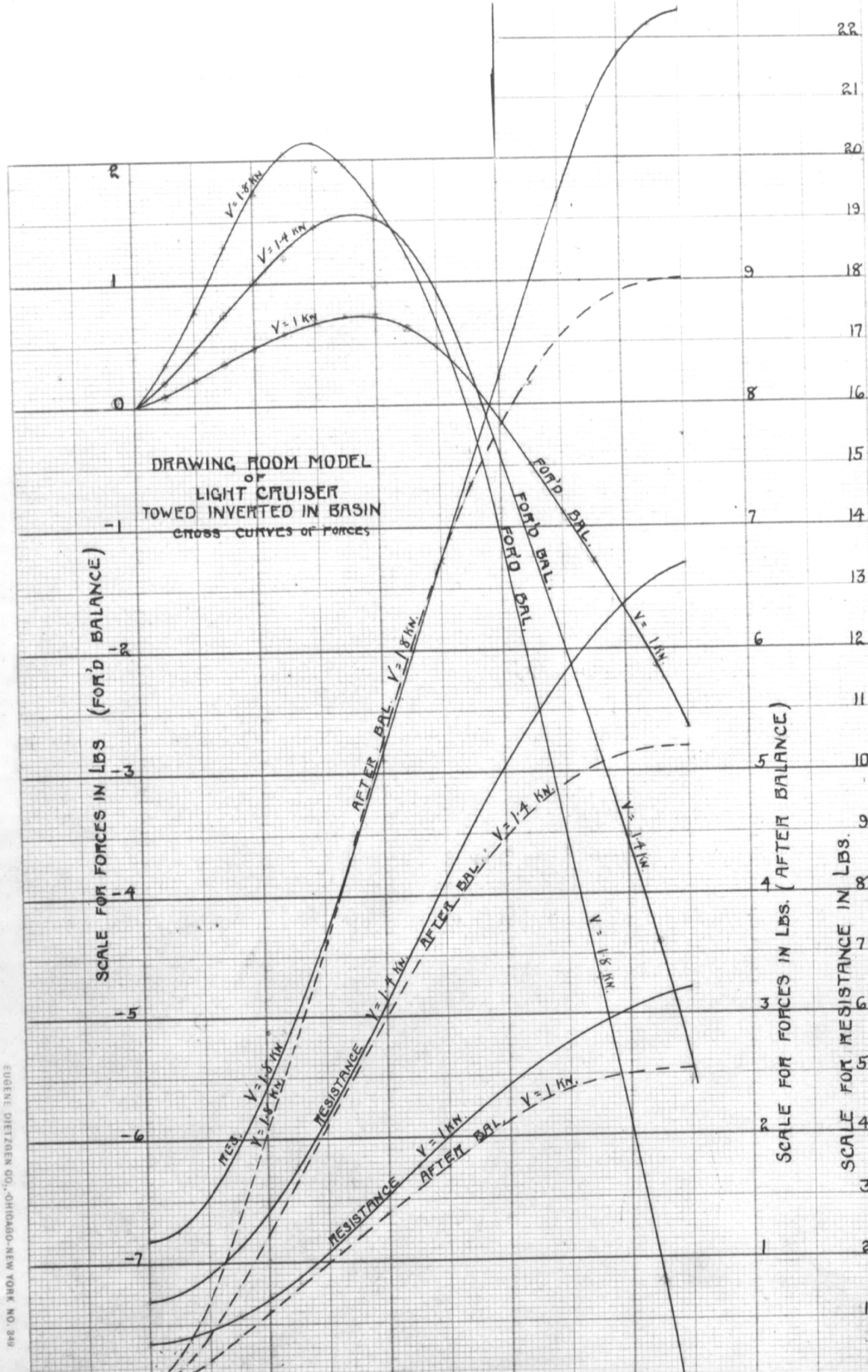


DRAWING ROOM MODEL OF LIGHT CRUISER
CURVES OF RESISTANCE FROM CARRIAGE DYNAMOMETER
POSITIVE FORCES ACT NORTH
SPEED IN KNOTS
RESISTANCE IN POUNDS
SHEET IV

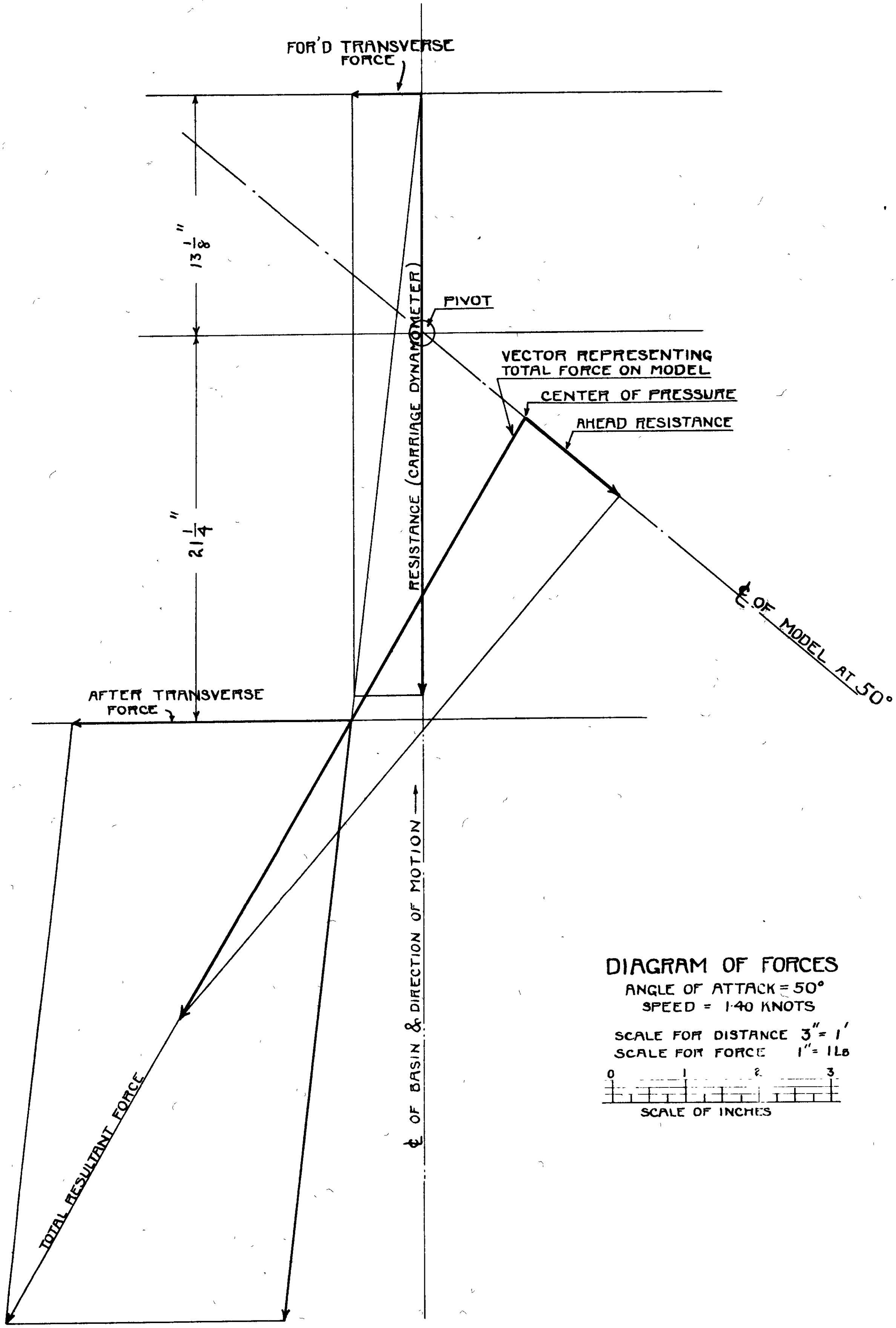

DRAWING ROOM MODEL
OF
LIGHT CRUISER
CURVES OF TRANSVERSE FORCES
FROM
FORWARD BALANCE
POSITIVE FORCES ACT EAST
SCALE FOR FORCE IN POUNDS, USED FOR 55° TO 90° CURVES
SCALE FOR FORCE IN POUNDS USED FOR 5° TO 50° CURVES
SPEED IN KNOTS
SHEET V
EUGENE DIETZGEN CO., CHICAGO-NEW YORK NO. 340



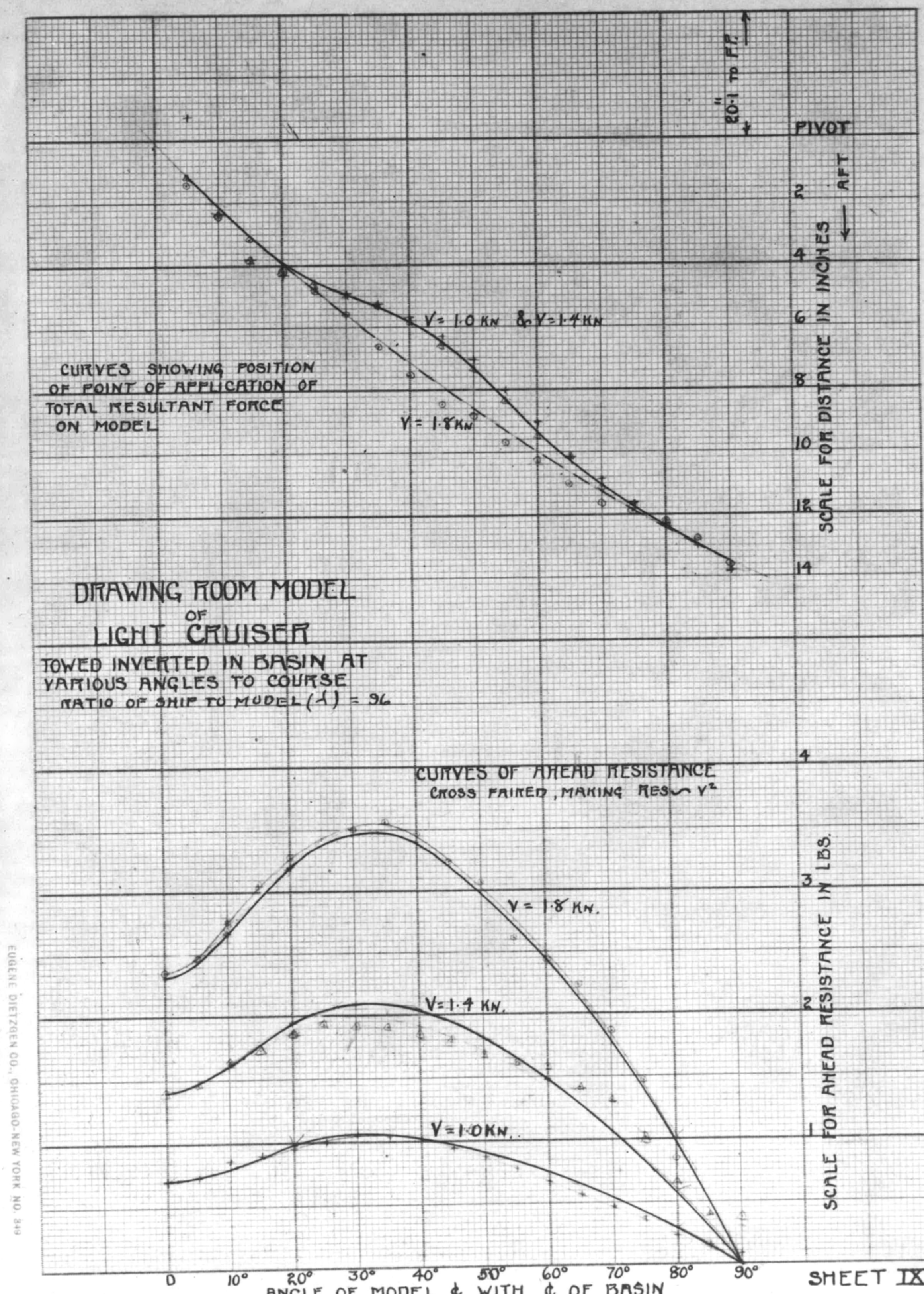
DRAWING ROOM MODEL OF LIGHT CRUISER
CURVES OF TRANSVERSE FORCES
FROM
AFTER BALANCE
POSITIVE FORCES ACT EAST
·6 ·7 ·8 ·9 1·0 1·1 1·2 1·3 1·4 1·5 1·6 1·7 1·8 1·9
SPEED IN KNOTS
SHEET VI
EUGENE DIETZGEN CO., CHICAGO-NEW YORK NO. 349



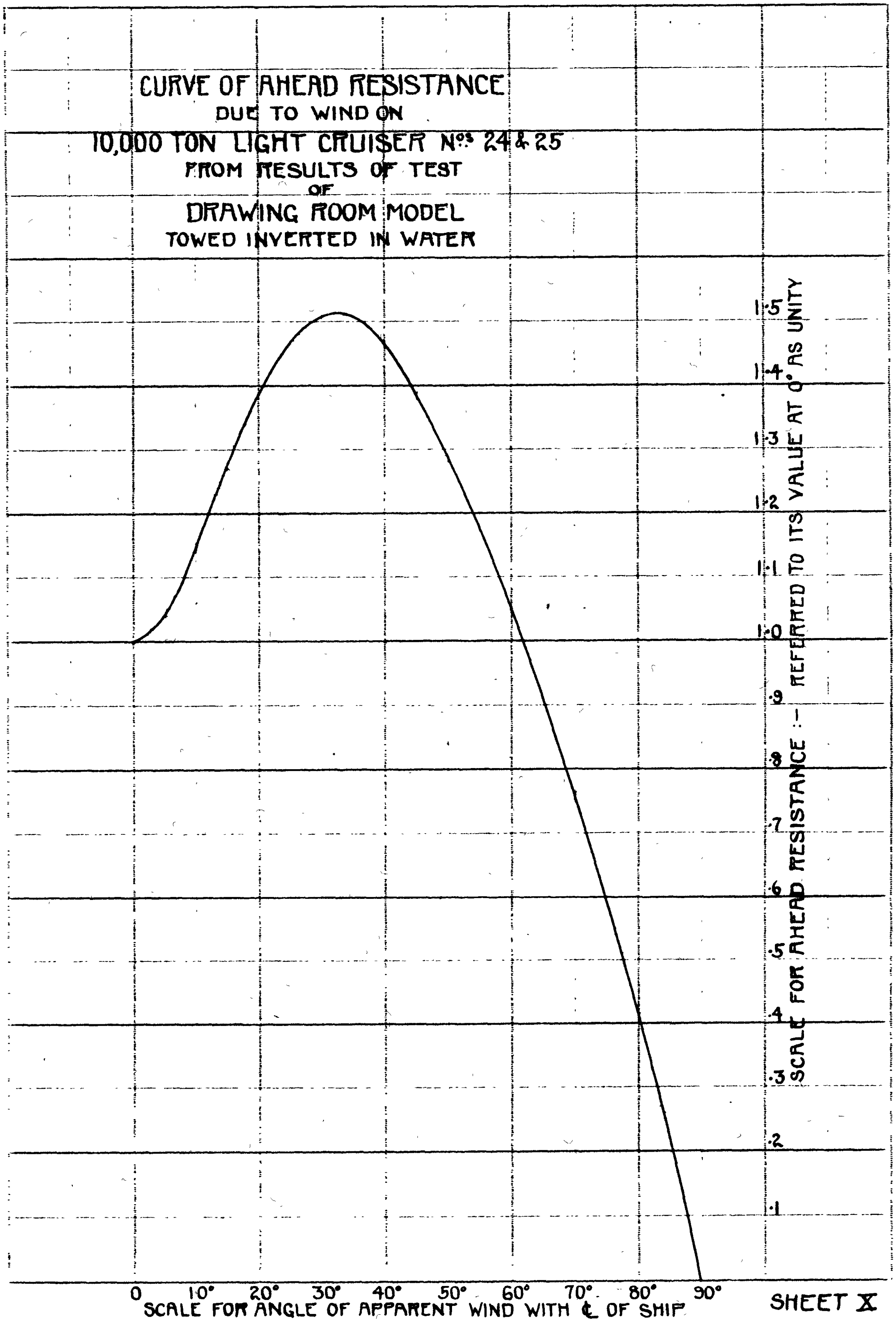
DRAWING ROOM MODEL
OF
LIGHT CRUISER
TOWED INVERTED IN BASIN
CROSS CURVES OF FORCES
V = 1.8 KN
V = 1.4 KN
V = 1 KN
FOR'D BAL.
AFTER BAL. V = 1.8 KN.
V = 1.4 KN. AFTER BAL.
RESISTANCE V = 1.4 KN.
RES. V = 1.8 KN
V = 1.8 KN
RESISTANCE V = 1 KN.
AFTER BAL. V = 1 KN.
SCALE FOR FORCES IN LBS (FOR'D BALANCE)
SCALE FOR FORCES IN LBS. (AFTER BALANCE)
SCALE FOR RESISTANCE IN LBS.
ANGLE OF MODEL ℄ WITH ℄ OF BASIN
0 10° 20° 30° 40° 50° 60° 70° 80° 90°
SHEET VII
EUGENE DIETZGEN CO.-CHICAGO-NEW YORK NO. 349

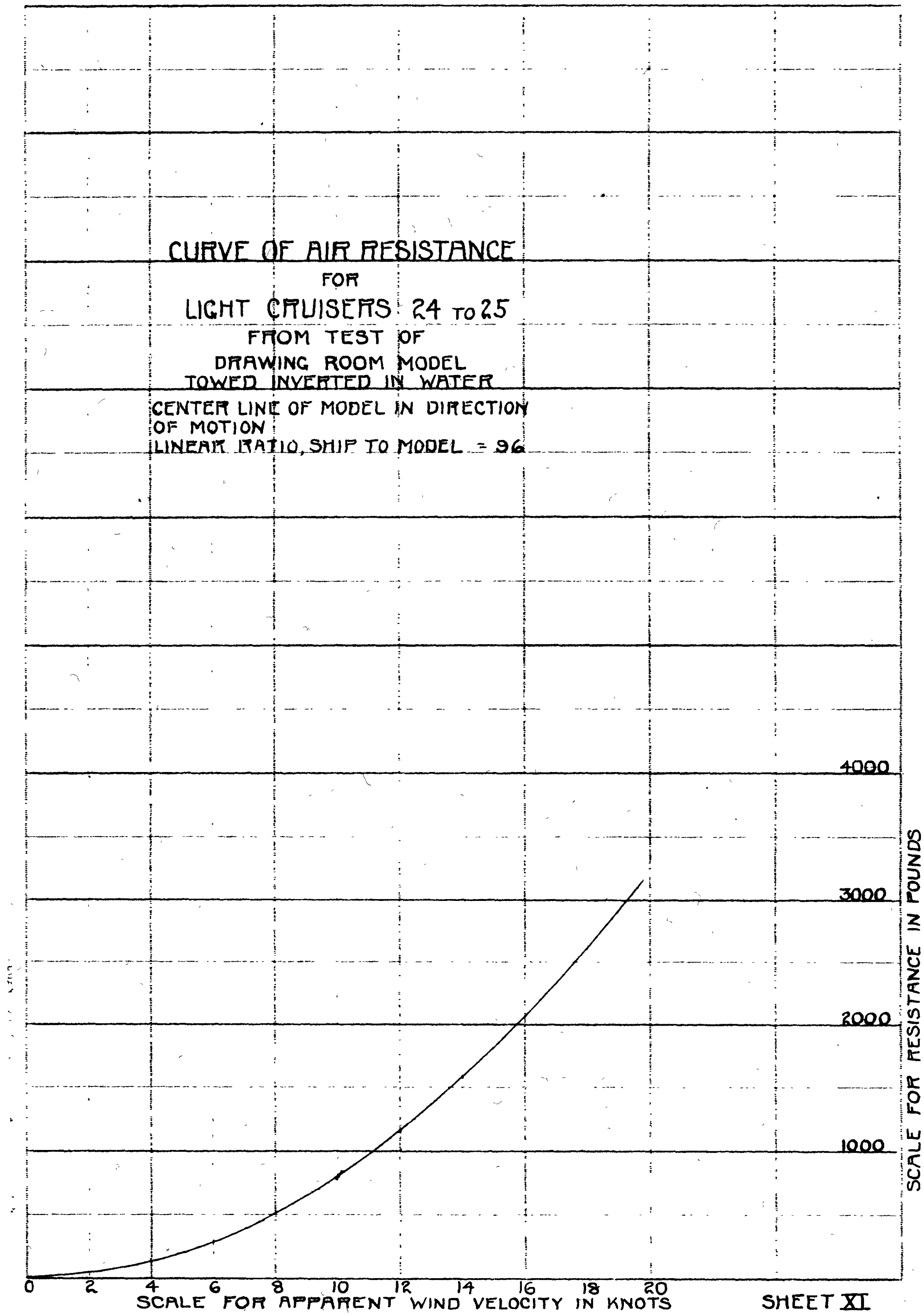

FOR'D TRANSVERSE FORCE
PIVOT
$13\frac{1}{8}''$
$21\frac{1}{4}''$
RESISTANCE (CARRIAGE DYNAMOMETER)
VECTOR REPRESENTING TOTAL FORCE ON MODEL
CENTER OF PRESSURE
AHEAD RESISTANCE
℄ OF MODEL AT 50°
AFTER TRANSVERSE FORCE
℄ OF BASIN & DIRECTION OF MOTION
TOTAL RESULTANT FORCE
DIAGRAM OF FORCES
ANGLE OF ATTACK = 50°
SPEED = 1·40 KNOTS
SCALE FOR DISTANCE 3" = 1'
SCALE FOR FORCE 1" = 1 LB
0
1
2
3
SCALE OF INCHES

SHEET VIII

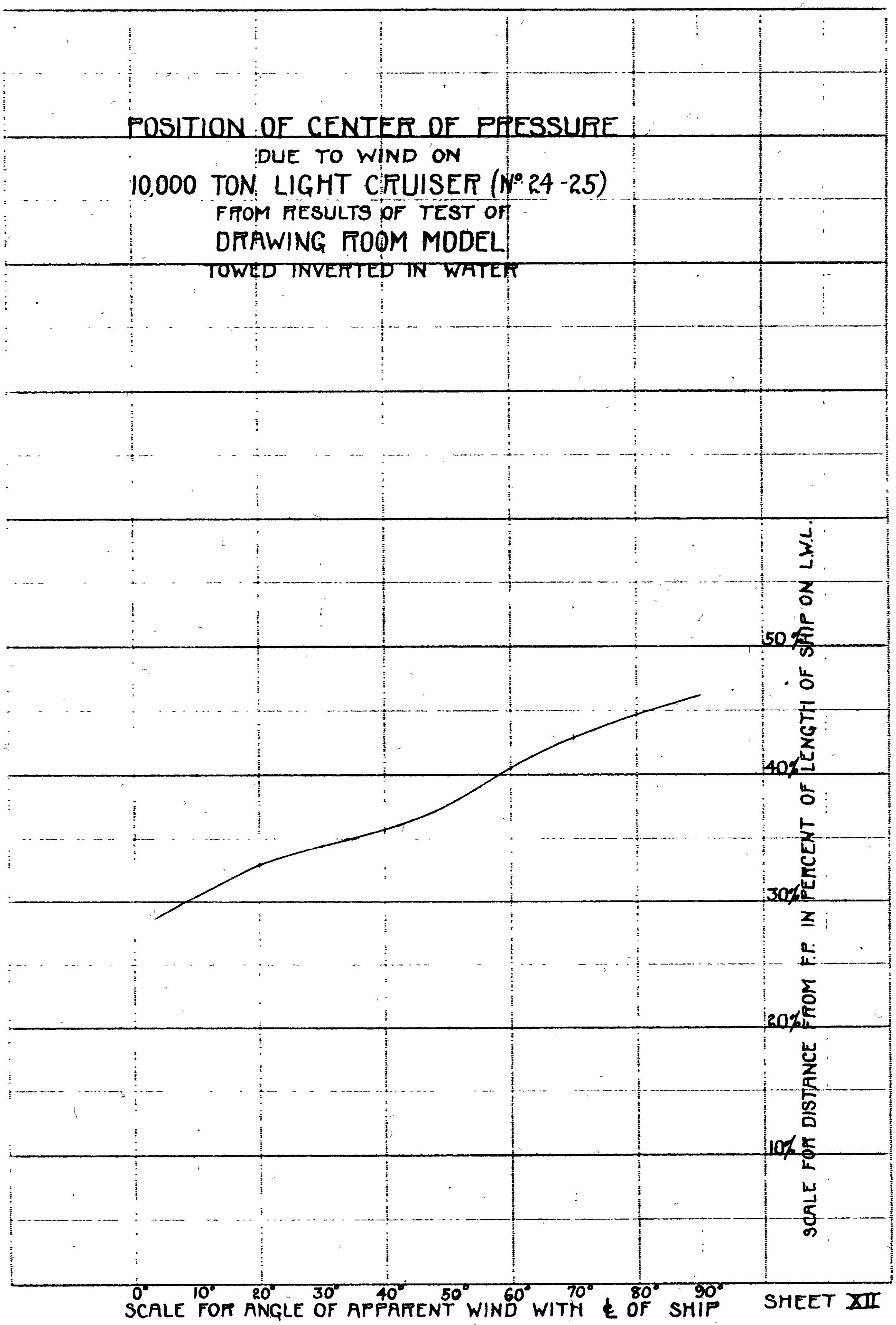


DRAWING ROOM MODEL OF LIGHT CRUISER
TOWED INVERTED IN BASIN AT VARIOUS ANGLES TO COURSE
RATIO OF SHIP TO MODEL (λ) = 96
CURVES SHOWING POSITION OF POINT OF APPLICATION OF TOTAL RESULTANT FORCE ON MODEL
V = 1.0 KN & V = 1.4 KN
V = 1.8 KN
20.1" TO F.P.
PIVOT
AFT
2
4
6
8
10
12
14
SCALE FOR DISTANCE IN INCHES
CURVES OF AHEAD RESISTANCE
CROSS FAIRED, MAKING RES ∽ V²
V = 1.8 KN.
V = 1.4 KN.
V = 1.0 KN.
1
2
3
4
SCALE FOR AHEAD RESISTANCE IN LBS.
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
ANGLE OF MODEL ℄ WITH ℄ OF BASIN
SHEET IX
EUGENE DIETZGEN CO., CHICAGO-NEW YORK NO. 349


CURVE OF AHEAD RESISTANCE
DUE TO WIND ON
10,000 TON LIGHT CRUISER Nos 24 & 25
FROM RESULTS OF TEST
OF
DRAWING ROOM MODEL
TOWED INVERTED IN WATER
1·5
1·4
1·3
1·2
1·1
1·0
·9
·8
·7
·6
·5
·4
·3
·2
·1
SCALE FOR AHEAD RESISTANCE :– REFERRED TO ITS VALUE AT 0° AS UNITY
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
SCALE FOR ANGLE OF APPARENT WIND WITH ℄ OF SHIP
SHEET X


CURVE OF AIR RESISTANCE
FOR
LIGHT CRUISERS 24 TO 25
FROM TEST OF
DRAWING ROOM MODEL
TOWED INVERTED IN WATER
CENTER LINE OF MODEL IN DIRECTION
OF MOTION
LINEAR RATIO, SHIP TO MODEL = 96
4000
3000
2000
1000
SCALE FOR RESISTANCE IN POUNDS
0 2 4 6 8 10 12 14 16 18 20
SCALE FOR APPARENT WIND VELOCITY IN KNOTS

SHEET XI


POSITION OF CENTER OF PRESSURE
DUE TO WIND ON
10,000 TON LIGHT CRUISER (Nº 24-25)
FROM RESULTS OF TEST OF
DRAWING ROOM MODEL
TOWED INVERTED IN WATER
50%
40%
30%
20%
10%
SCALE FOR DISTANCE FROM F.P. IN PERCENT OF LENGTH OF SHIP ON L.W.L.
0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
SCALE FOR ANGLE OF APPARENT WIND WITH ℄ OF SHIP

SHEET XII