HYDRAULICS RESEARCH DIVISION

Technical Note

DATE: 18 April 1978 REPORT NO: 78-08

TITLE: "Stability & Drag Tests on Submerged Floats - ½ Scale Ore Float".

AUTHORS: W. J. Moody, Y. L. Lau

REASON FOR REPORT:

Written at the request of the Bedford Institute of Oceanography as part of Hydraulics Research Division Study H 77-050 "Towing Tests - Bedford Institute of Oceanography". This is the sixth in a series of reports related to the above study.

CORRESPONDENCE FILE NO:

2242-1

STABILITY AND DRAG TESTS OF SUBMERGED FLOATS

Purpose:

1. To find the drag force as a function of velocity over a range of 0 to 4 knots, acting on a variety of subsurface floats.
2. To determine the stability of all floats throughout the velocity range of 0 to 4 knots.
3. To determine the behaviour of these floats when the current is reversed.

Specifications of Test Apparatus:

1. Towing Mast (see Figure 2) - this was manufactured by CCIW staff using aluminum sailboat mast sections for the main spar. This mast is "L" shaped, has a moveable friction free pivot on the vertical portion of the "L" and has attachement brackets for support and measuring lines. Mast dimensions are: -

   | | |
   |---|---|
   | Vertical section | - 457.00 cm |
   | Horizontal section | - 153.00 cm |
   | Cross section | - 10.10 cm x 7.60 cm |

2. Pivot bearings - Seal Master SF 12-3/4".
3. Strain wire guide pulley bearings - McGill MB 25-5/8".
4. Tension measuring dynamometer - Dillon, 1000 lb. capacity, 5 lb. divisions.
5. Float attachment and tension measuring cable - .100" diameter.
6. Length measuring cable - .030" diameter.
7. Mast level - Sand's Craft No. SC50.
8. Towing Device - Kempf and Remmers Modified C102 Carriage.

NOTE: Figure 1 is a descriptive drawing showing the test apparatus, as used, plus the symbols and measurements used in the calculations.

Specifications of ½ Scale Model "Ore" Float:

1. Outside dimensions are ½ of full sized float.
2. Buoyancy is unknown and it is not known whether buoyancy or weight were scaled in this model.
3. The model float consists of a steel sphere with a welded, protruding

seam running horizontally around its centre line. Mooring eyes are attached to the top and bottom points on the buoy on a vertical centre line. (Figures 2 and 3).

4. The float is 57.3 cm in diameter.

Procedure:

The test apparatus was set up in the following manner:

- The dynamometer was suspended from the carriage mounted hoist.
- The strain wire guide pulley was bolted to the carriage platform.
- The mast assembly was bolted to the rear edge of the carriage so that the mast bottom was approximately 20 cm above the tank bottom and the mast was perpendicular to the water surface.
- The strain wire was attached from the bottom forward edge of the mast through the guide pulley to the bottom of the dynamometer. (See Figure 2).
- The strain wire was slackened and the mast was tilted until the tip of the "L" came to the water surface.
- A premeasured mooring line, Figure 2, .967 m in length, was attached from this tip of the mast to the mooring point on the underside of the float (see Figures 2 and 3).
- The "length measuring cable" was attached from the float mooring point, through the cable guides, to the top of the mast.
- The carriage mounted hoist was operated to bring the mast to its upright position perpendicular to the water surface and to submerge the float to its test position. This position was maintained throughout the tests with the aid of a level strapped to the upper portion of the mast and adjusting with the hoist.
- The length measuring cable was pulled taut and a reference mark was affixed to it.

Tests were commenced by dragging the float through the water at preselected velocities over the range required. Once the float stabilized at each speed, a reading was taken from the dynamometer to obtain tension and a measurement made of the taut measuring cable length to provide the remaining information required. Previous trial runs determined that a single or occasionally two runs were sufficient to provide accurate data for calculation of the necessary parameters.

Calculations were then made to compute the drag force on the float, the drag coefficient of the float and the Reynolds Number throughout the tested velocity range.

Calculation of Drag Force:

Referring to Figure 1, the sum of moments about the pivot results in the following equation:

$$(1) \ldots\ldots \quad (D_c \cos\phi)\, L_1 = D_s L_2 + T\cos(180-\theta)\, L_3 + T\sin(180-\theta)\, L_4$$

| | | | |
|---|---|---|---|
| Where | $D_c$ | = | tension in the cable measured by the dynamometer |
| | $D_s$ | = | drag force on the towing apparatus |
| | $T$ | = | tension in the cable to the float |
| | $L_1, L_2, L_3, L_4$ | = | fixed distances as given in Figure 1. |
| | $\phi \;\; \theta$ | = | angles as specified in Figure 1. |

From equation (1)

$$(2) \ldots\ldots \quad T = \frac{D_c \cos\phi\, L_1 - D_s L_2}{\cos(180-\theta)\, L_3 + \sin(180-\theta)\, L_4}$$

By measuring the cable length to obtain $\ell_1$, Figure 1, and knowing the lengths of $\ell_2$ and $\ell_3$, the angle $\theta$ was calculated using the law of cosines. The drag on the strut, or towing apparatus, was measured in a separate towing test without the float. It can be seen from equation (1) that, when T=0

$$(3) \ldots\ldots \quad D_s = \frac{F \cos\phi\, L_1}{L_2}$$

Where F is the cable tension measured by the dynamometer when towing the strut alone.

The drag force on the float $D_f = T\cos(180-\theta)$

The drag coefficient $C_D$ was defined as $C_D = D_f / \rho A \frac{U^2}{2}$

Where $U$ = velocity of the float

| | | | |
|---|---|---|---|
| | A | = | cross-sectional area of the float = .2579 $m^2$ |
| and | $\rho$ | = | density of the water = 998.8 $Kg/m^3$ @ temperature of 17°C. |

The Reynolds Number, Re, was also calculated,

(4) ...... $$Re = \frac{UD}{\gamma}$$

| | | | |
|---|---|---|---|
| Where | D | = | float diameter = .573 m |
| and | $\gamma$ | = | kinematic viscosity of water = $1.1306 \times 10^{-6}$ $m^2/s$ |

The result of this test is shown in the following text, the data summarized in Table 1 and the Drag Coefficient versus Reynolds Number shown graphically on Plot 1.

When using the test data it must be remembered that this test was carried out on a ½ scale dimensioned model. It is unknown, at this writing, whether or not weight and buoyancy were scaled. For full scale application, the Reynolds Number must be used to select the drag coefficient.

Test #1

Assembly configuration - 1 (only position available)

Data reference - Table 1 and Plot 1

The float was stable at .25 m/s only. At .35 m/s a slight yawing action appeared which increased steadily through the test. This yaw motion became erratic above 1.45 m/s and was accompanied by a vertical vibration. The vibration appeared to be caused by oscillations about the horizontal centre line of the buoy. Measured values, attempted above 1.45 m/s, were not considered reliable because of the float movements. However, it may be noted that, at 2.5 m/s, the dynamometer recorded a tension more than double that of the "at rest" position.

General Comment

Stability begins to break down almost the moment that flow velocity is detected and does not improve throughout the tested range.

The same instability occurred during and immediately after current reversal tests.

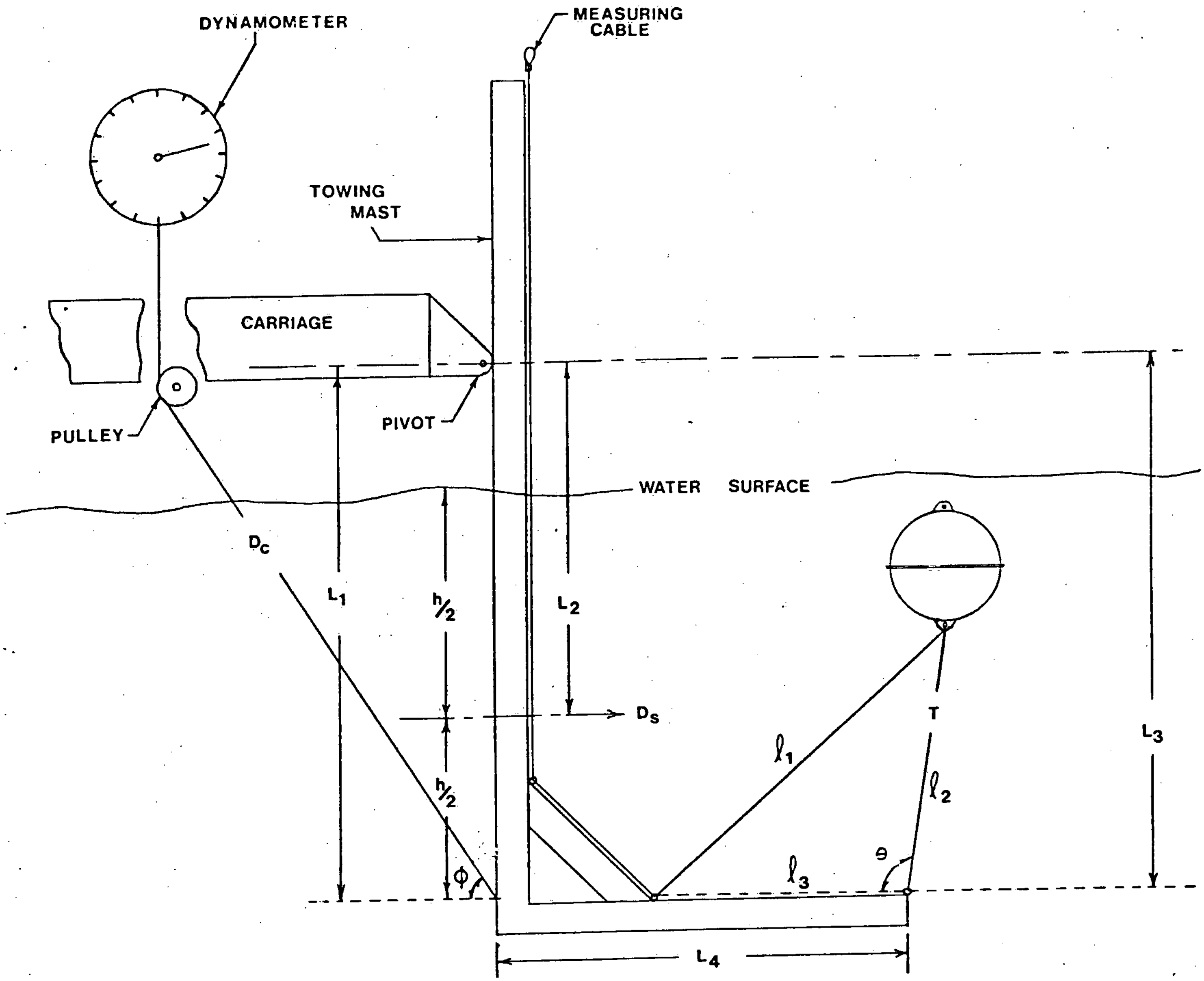
| U (m/s) | $D_c$ (N) | Cos θ | θ | $D_s$ (N) | T (N) | $D_f$ (N) | $C_d$ | $R_e$ |
|---|---|---|---|---|---|---|---|---|
| .25 | 556.028 | -.040 | 92.290 | 1.83 | 520.923 | 20.811 | 2.585 | $1.267 \times 10^5$ |
| .35 | 560.476 | -.045 | 92.593 | 2.90 | 519.077 | 23.479 | 1.488 | $1.774 \times 10^5$ |
| .45 | 578.269 | -.051 | 92.896 | 4.22 | 529.318 | 26.745 | 1.025 | $2.281 \times 10^5$ |
| .55 | 591.613 | -.059 | 93.404 | 5.15 | 532.501 | 31.620 | .812 | $2.787 \times 10^5$ |
| .65 | 596.061 | -.068 | 93.914 | 6.80 | 526.871 | 35.967 | .661 | $3.294 \times 10^5$ |
| .75 | 600.510 | -.079 | 94.530 | 8.52 | 519.827 | 41.052 | .567 | $3.801 \times 10^5$ |
| .85 | 622.751 | -.095 | 95.458 | 10.25 | 523.940 | 49.839 | .536 | $4.308 \times 10^5$ |
| .95 | 644.992 | -.106 | 96.082 | 11.96 | 532.287 | 56.397 | .485 | $4.815 \times 10^5$ |
| 1.05 | 662.785 | -.126 | 97.234 | 12.52 | 530.580 | 66.815 | .471 | $5.322 \times 10^5$ |
| 1.15 | 676.129 | -.144 | 98.293 | 13.76 | 526.218 | 75.895 | .446 | $5.828 \times 10^5$ |
| 1.25 | 689.474 | -.157 | 99.040 | 14.64 | 526.447 | 82.713 | .411 | $6.335 \times 10^5$ |
| 1.35 | 711.715 | -.179 | 100.333 | 15.68 | 526.808 | 94.489 | .403 | $6.842 \times 10^5$ |
| 1.45 | 720.612 | -.215 | 102.414 | 15.92 | 509.577 | 109.545 | .405 | $7.349 \times 10^5$ |

Assembly Configuration - 1 (only one available)
Number of Discs - N/A
Tow Point - N/A
Tow Angle - N/A

Notes:

1. Results are in SI units.

TABLE 1




$L_1 = 3.068$ m

$L_2 = 1.8675$ m

$L_3 = 3.068$ m

$L_4 = 1.575$ m

$h/2 = 1.2005$ m

$\phi = 58.75^{\circ}$

Schematic View of Test Apparatus

FIG. 1

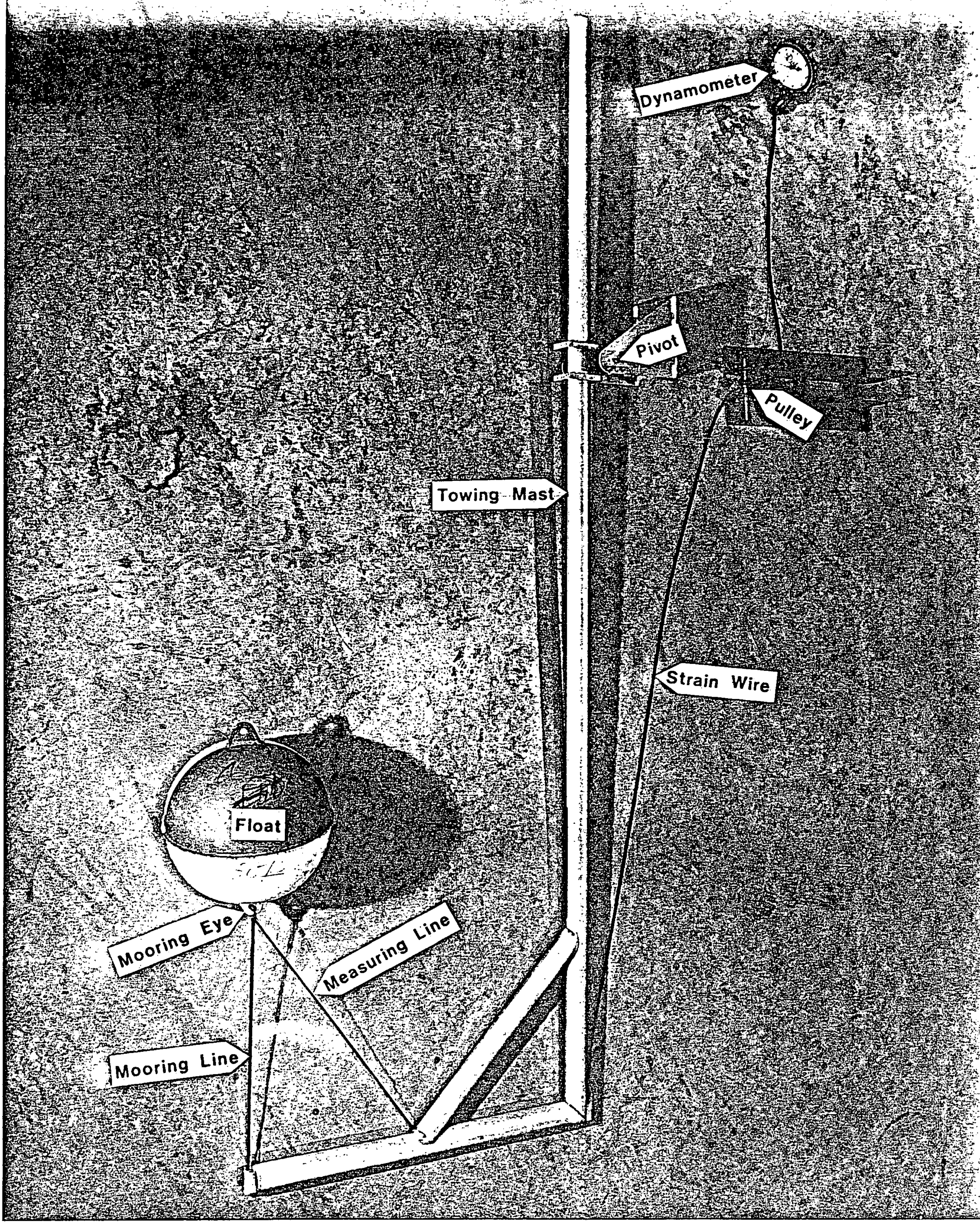

Dynamometer
Pivot
Pulley
Towing Mast
Strain Wire
Float
Mooring Eye
Measuring Line
Mooring Line

FIG. 2

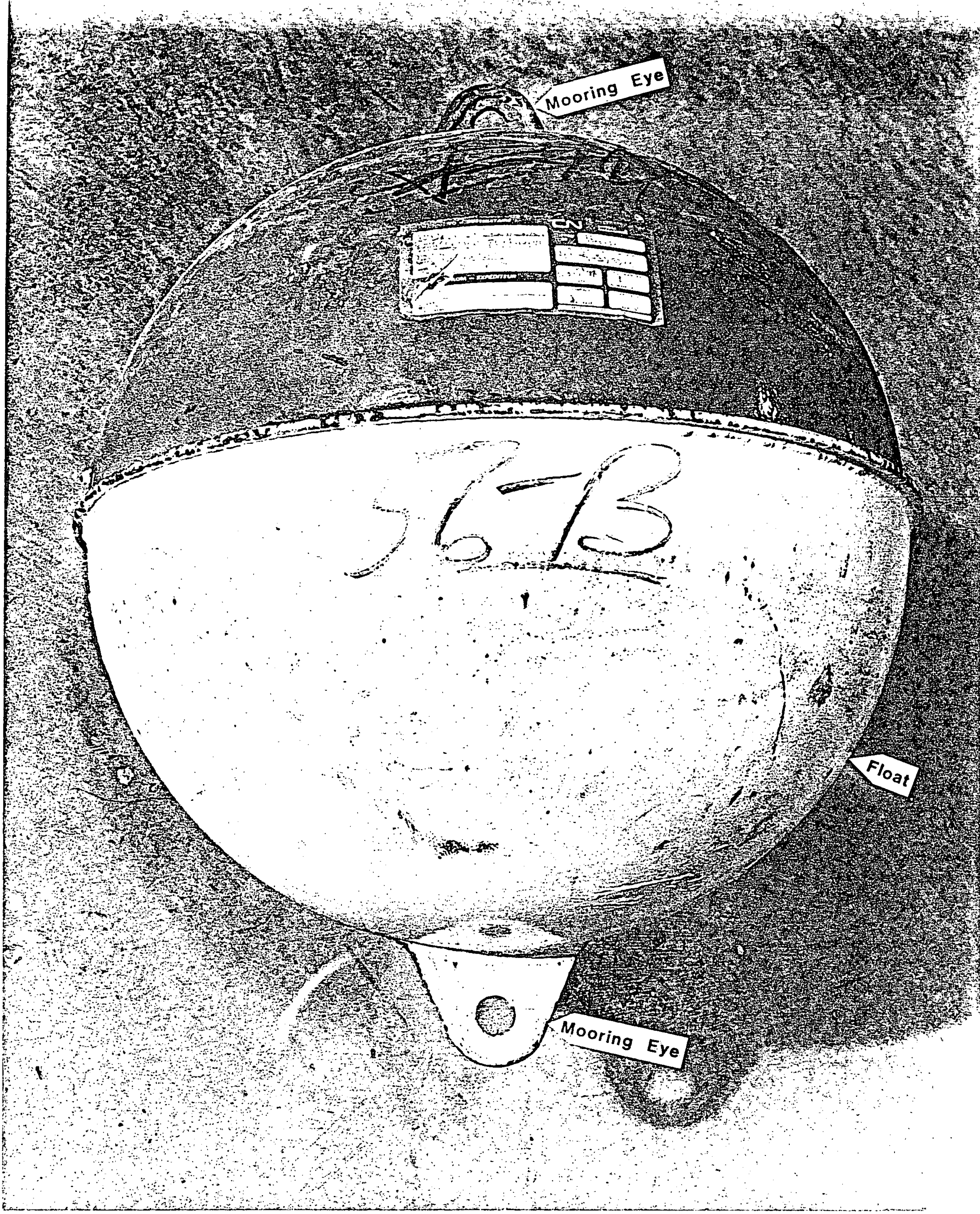



FIG. 3

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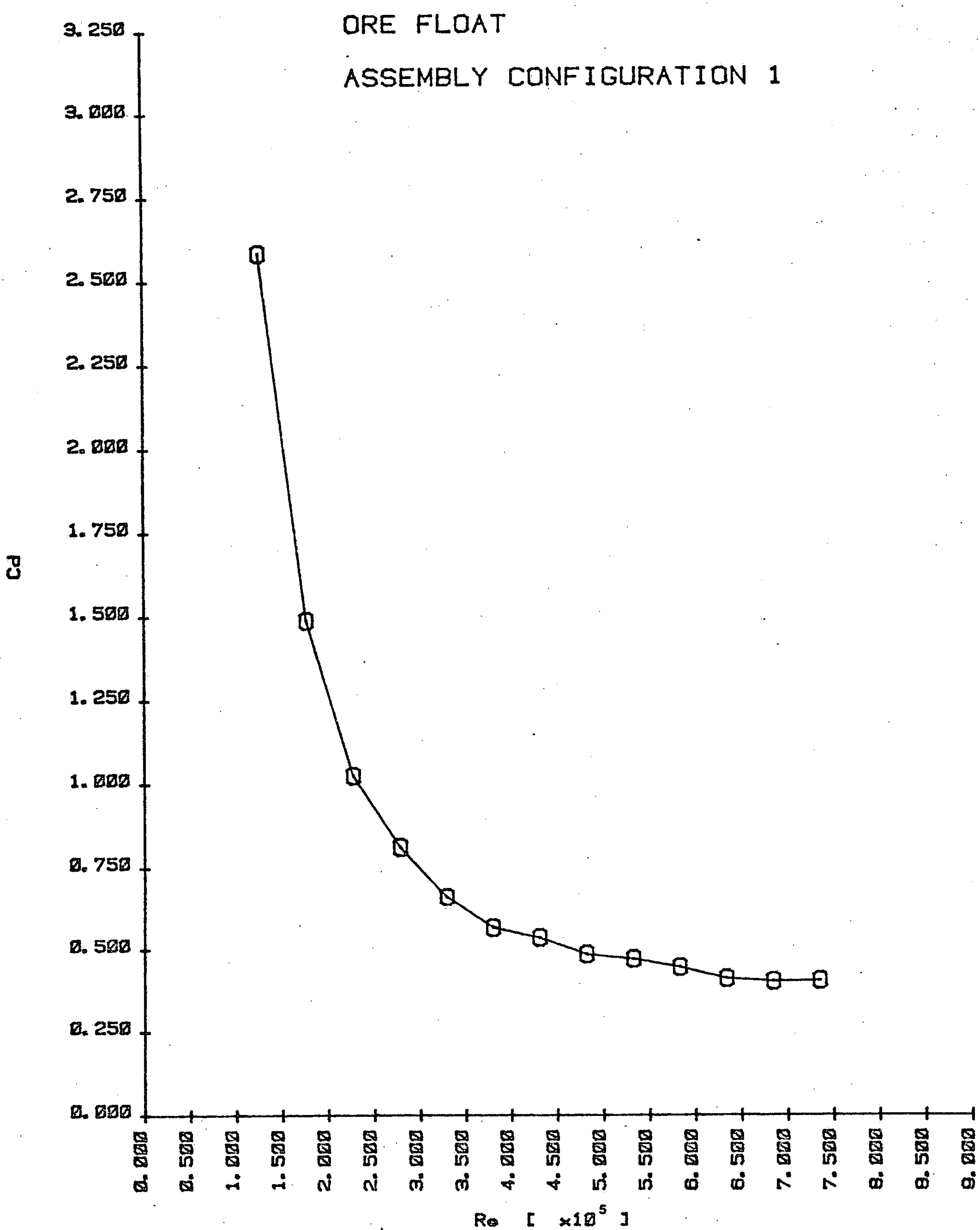


DRAG COEFFICIENT VERSUS REYNOLDS NUMBER

PLOT 1