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HYDRAULICS RESEARCH DIVISION

Technical Note

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TITLE: Stability and Drag Tests on Submerged Floats-
                   "Hard-Hat" Subsurface Float.

AUTHORS: W.K. Stage, W.J. Moody and 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 -
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                    This is the second in a series of reports
                    related to the above study.

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STABILITY AND DRAG TESTS OF SUBMERGED FLOATS

Purpose

To find the drag force as a function of velocity over a range of 0 to 3 knots on a prototype "hard-hat" subsurface float with internal buoyance.

Specification of Test Apparatus (See Figure 1, 2)

1. Towing Mast - this was made using a 3.3 m section of support strut (chord 3.2 cm) used on aircraft wings. This strut was attached to a friction free pivot and two attachment brackets were added to secure the "hard-hat" subsurface float. (See Figure 1 and 2).

2. Pivot bearings Seal Master SF 12-3/4".

3. Strain guide wire pulley bearings - McGill MB25-3/8".

4. Tension measuring dynamometer - Dillon, 1000 lb. capacity, 5 lb. divisions.

5. Tension measuring cable - .100" diameter.

6. Mast level - Sands Craft No. SC50.

7. Towing device - Kempf and Remmers Modified C102 Carriage.

Procedure

The test apparatus was set up in the following manner:

-   The strain wire pulley was bolted to the carriage platform.

-   The mast assembly was bolted to the rear of the carriage and the mast was pulled up and tilted back to allow easy access to attachment brackets.

-   The tension line was attached to the bottom forward edge of the strut and pulled through the guide pulley and attached to the hoist.

- The "hard-hat" subsurface float was secured to the attachment brackets with shackles.

- The strut was slid down in its bracket to a premeasured position and secured.

- The carriage hoist was then used to lower the "hard-hat" subsurface float into position.

- The tension cable was attached to the dynamometer and it in turn to the carriage hoist.

- The strut was placed in an upright position using the carriage hoist and a level strapped to the strut. This position was maintained throughout the tests by applying tension to the cable.

Tests were then commenced by dragging the float through the water at preselected velocities over the full range required. Once the float stabilized at each speed, a reading was taken from the dynamometer to obtain the tension.

It should be noted that tests were made to determine the drag on the strut alone but the apparatus was not sensitive enough to register any drag. In order to obtain some idea of the possible values, the drag forces were calculated based on published drag coefficients of streamlined struts. The drag force on the strut was calculated to be from 0.23 N at 25 cm/s to 4.6 N at 150 cm/s. In most cases this would result in an error of no more than 1% and was not considered in the following calculations.

Calculation of Drag Force

Referring to Figure 1, the moment about the pivots results in the following equation:

$$(Dc \cos \phi) \, L_1 = D_F \, L_3 \tag{1}$$

where D_c = tension in the cable measured by the dynamometer

D_F = drag force on the float

L_1,L_3 = fixed distances as given in Figure 1.

therefore

$$D_c = \frac{D_F \, L_3}{\cos \phi \, L_1}$$ (2)

The drag coefficient C_D was defined as:

$$C_D = \frac{D_F}{\rho A \dfrac{u^2}{2}}$$ (3)

where   u = velocity of the float

A = cross sectional area of the float

and ρ = density of water

The Reynolds number Re, was calculated from

$$Re = \frac{uD}{\nu}$$

where   D = float diameter (the diameter of one sphere in the float)

and ν = kinematic viscosity of water

The test data and calculation are summarized in Table 1.
The drag coefficient is plotted against Reynolds number in Figure 3.

Observations

When looking back at the strut while standing on the carriage
the float always came to rest on the left side of the strut. This was
caused by the retainer/mooring bar on the float being offset by about
1 cm to the right. As a result the float had to be dragged at
77 cm/s (1.5 KTS) or faster before it would straighten out. Since this
was the configuration that the float was used in the field, no attempt
was made to correct it.

The float was dragged at 77 cm/s and was observed to be off
to the left by about 5° to 10° but was considered acceptable as the
starting velocity for the test. At 103 cm/s the float towed straight and

true. When the float was dragged at 129 cm/s (2½ KTS) a slight yawing
motion was detected. The highest velocity which could be reached and
maintained was 155 cm/s (3 KTS). The float had a noticeable yaw from
side to side and at times this became violent and then settled back
down. A slight increase in velocity was attempted but the float
started to yaw back and forth out of control and the velocity had to be
reduced to prevent damage to the towing apparatus.

TEST DATA

u m/s	D_C (N)	D_F (N)	C_D	Re
.77	209.1	188.8	1.95	2.69×10^5
1.03	226.9	204.9	1.18	4.16×10^5
1.29	266.9	241.0	.88	5.20×10^5
1.55	333.6	301.2	.77	6.26×10^5

NOTE: Results Are In SI Units

TABLE 1

DYNAMOMETER

STRUT →

CARRIAGE

PULLEY

PIVOT

WATER SURFACE

D_c

L_3

L_1

FLOAT

ϕ
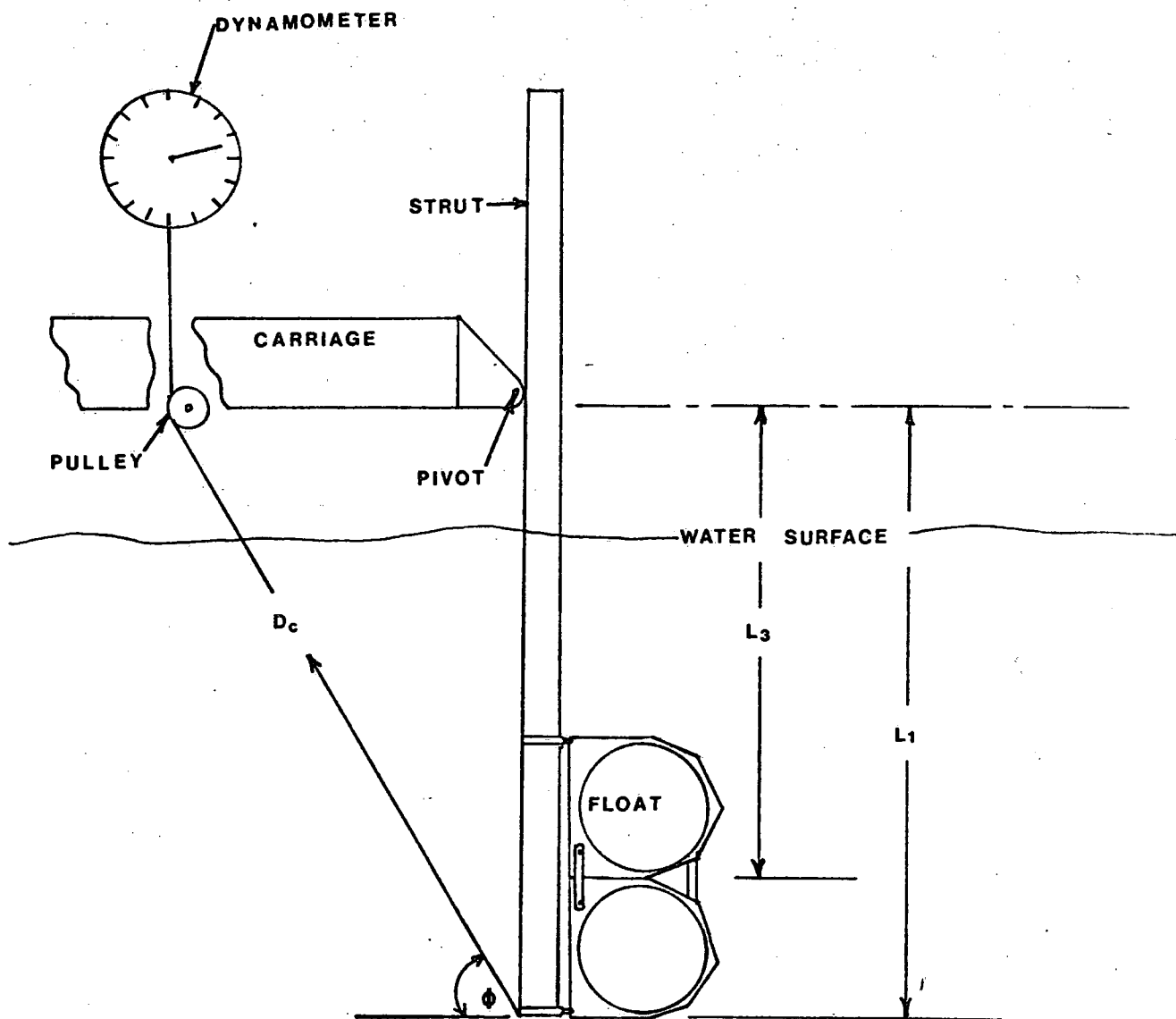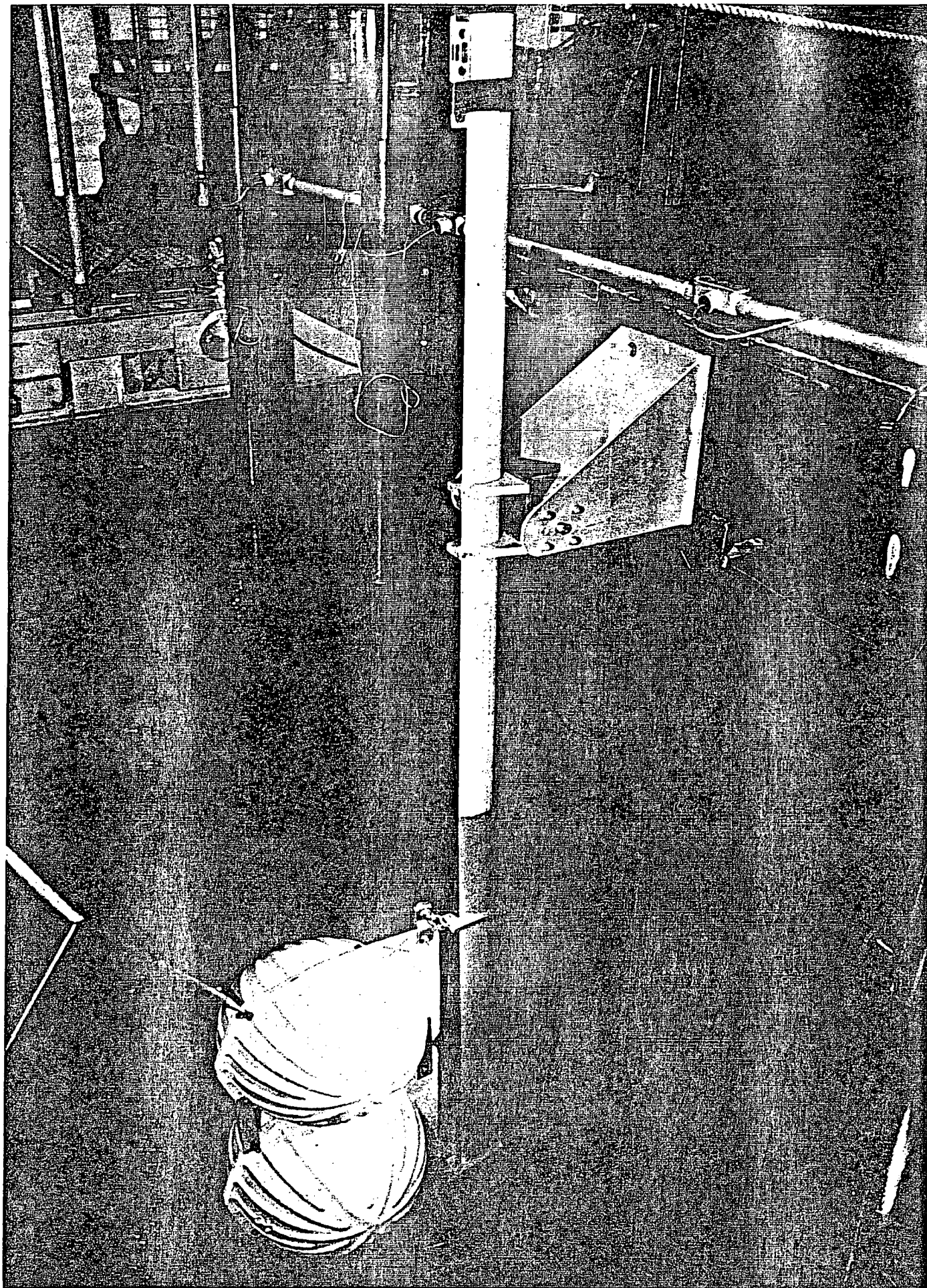
$L_1 = 2.284$ m

$L_3 = 1.725$ m
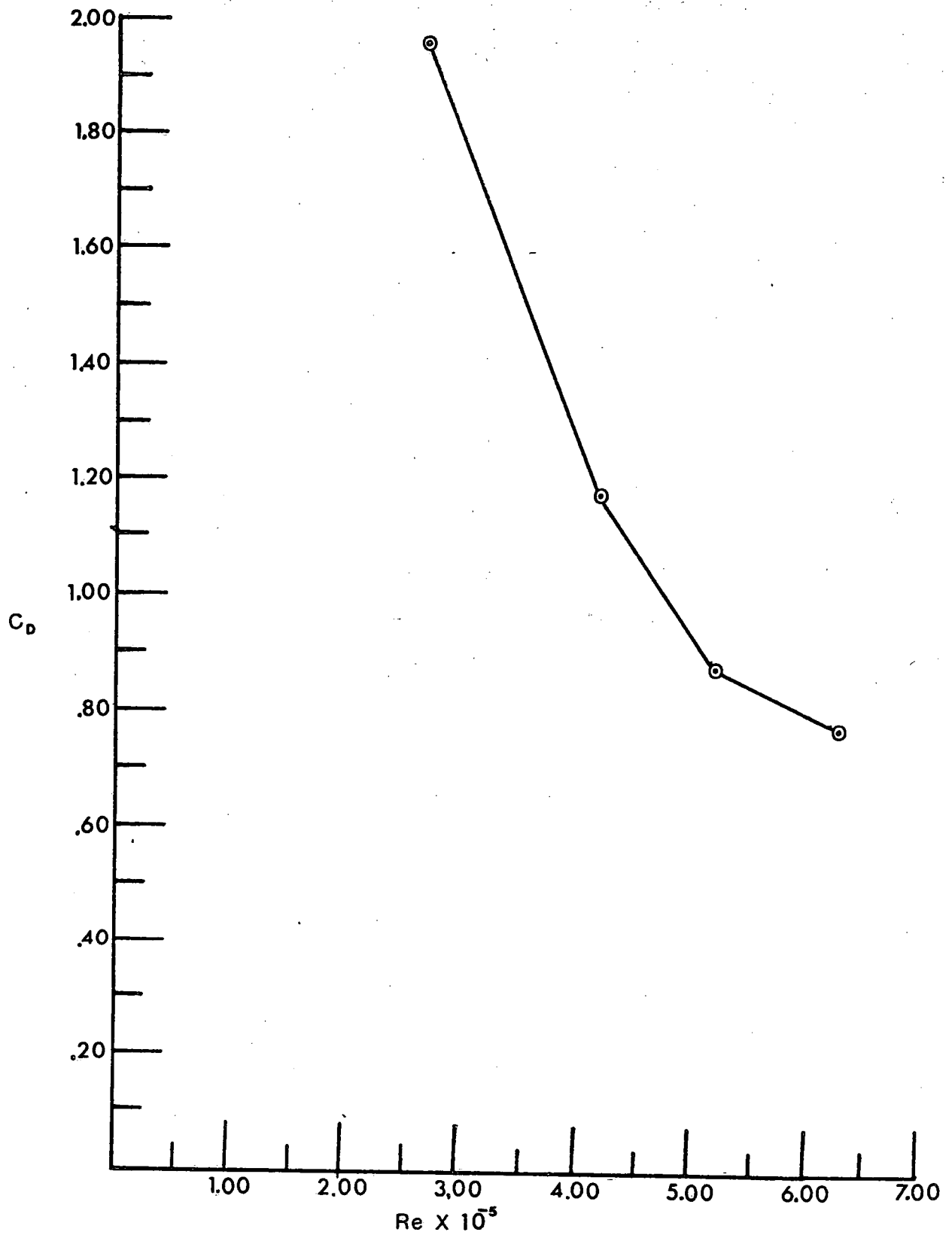
$\phi = 47^0$

Schematic View of Test Apparatus

FIG. 1

Test Apparatus on Carriage   FIG.2

Drag Coefficient Versus Reynolds Number
for the "Hard Hat" Subsurface Float – FIG.3