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A STUDY OF THE USE OF POWER ROTORS TO IMPROVE THE MANOEUVRABILITY OF PELAGIC TRAWL GEAR

by

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Introduction

The overall aims of the project are to investigate a new method of improving the vertical and horizontal manoeuvrability of pelagic trawl gears and in the long term perhaps to develop an automatic fishing gear pilot using a shipborne computer.

To improve pelagic fishing techniques it is necessary to have greater control of the trawl gear than can be attained at the present time by changing warp length, ship speed or ship direction. The limitations of these three methods are well known; they are the slowness of changing warp length and its dependence on winch power, the restricted range of speed determined by fish behaviour and engine power, and lastly the difficulty of turning while towing a gear (particularly from a stern trawler).

To improve manoeuvrability it was decided to adopt a system in which a rotor was positioned vertically along the lower half of the leading or trailing edge of a high aspect ratio board (Fig. 1). In this position the rotor would apply a force perpendicular to the board face, thereby changing the angle of heel and consequently the vertical component of hydrodynamic force generated by the board. The resulting imbalance of vertical forces would cause an increase or decrease in board depth.

Power consumption

The empirical formula for power quoted below has been found to be sufficiently accurate in the cases considered so far at the Marine Laboratory. The formula is usually taken to include the power required to overcome mechanical losses in bearings, etc.

$$kw/(l.d) = 0.0501 \times w^3$$

where kw = power in kilowatts
l = length of rotor in m
d = diameter of rotor in m
and w = peripheral velocity of rotor in m/s.

Generation of Lift Force

The lift force is the force perpendicular to the rotor axis and the direction of motion is defined as:

$$L = 0.051 \rho \, l \, d \, V^2 \, C_L$$

where L = lift force in kgf
ρ = water density (1025.6 Kg/m^3)
V = towing speed in m/s
and C_L = lift coefficient (see Fig. 2)

Note that the lift coefficient is itself a function of rotation ratio (w/V), surface roughness and also flow irregularities around the ends of the rotor which vary with diameter of end plates and aspect ratio of the rotor.

Initial Design

The system designed initially (Fig. 1) incorporated a 0.61 m x 0.064 m rotor driven by a 2 h.p. (1.5 kw) single phase non-reversible induction motor with a nominal speed of 2780 rev/min.

It was decided to use this less versatile but also less complex system to demonstrate the mechanical and electrical feasibility of using rotors on fishing gear. No attempt was made to exploit the full potential of such an application at this stage.

Tank tests were undertaken which confirmed the expressions for hp consumed and lift force generated given above. Figures 2 and 3 summarise the results.

Computer simulation studies were undertaken and a program to predict the configuration of a mid-water trawl gear with rotors incorporated in the otterboards.

The program computed the static equilibrium position, orientation and loading of the warps, otterboards, sweep wires, headline and groundrope for most types of pelagic rig. The required computer input included the dimensions and weights of all components, the towing speed and some empirical coefficients describing eg the variation of net drag with speed.

Calculated values over a wide range of conditions were therefore available to supplement the information obtained during the sea trials.

Figure 4 shows the predicted changes in heel angle and board depth when a rotor force of 250 lbf (114 kgf) is applied at different positions on the otterboard.

Of particular interest is the marked difference in effect obtained by positioning the rotor at the trailing, compared to the leading edge. An important point to bear in mind however, is that the rotor force was chosen to be the same in both cases but in practice the power required to produce that force in one position may be considerably different oompared to the other. For instance, owing to the turbulence created by the board the efficiency of the rotor might be impaired when in the wake behind the board.

The initial sea trials showed that measured changes in depth and board heel angle, although small were in agreement with those predicted by the simulation study.

Furthermore these trials achieved the initial objective of confirming the feasibility of a rotor system.

Modifications to Initial Design

In order to develop the potential of the initial design it was clear after the trials that there was a need for a reversible, variable speed motor capable of running the rotor at speeds as low as 700 rev/min.

The major changes recommended for the design were:

1. Larger rotor (1.24 m x 0.14 m) which generates 350 lbf (160 kgf) at approximately 700 rev/min while still requiring only 2 hp (1.5 kw).

2. Slip ring warp terminations for simplicity of transmission of current from electrical cored warp to motor.

3. Incorporation of motor inside rotor.

4. Introduction of 3 phase, variable speed motors.

5. Protection of wiring by enclosure in steel tubing.

6. Stiffer frame to protect moving parts.

Trials described in the following section, have been carried out using a system including the modifications 1,3,5 and 6 - suggested above.

Trials with Modified Rotors

During July 1974 FRV "Explorer" a 1000 hp side trawler, was used to tow a 46 m headline pelagic trawl having a drag of 4.89 metric tonnes at 3.5 knots. Suberkrub type otterboards with an area of 4.4 m^2 were used with the rotors. Figure 5 shows a sketch of a modified board with the rotor in the leading edge. A standard rig was used with 75 m sweeps.

A comprehensive set of measurements was obtained for each haul including headline height, wing-end spread, otterboard depth, heel angle pitch angle and spread, warp angles ship speed and tensions at the net and ship.

The important parameters, board heel angle and depth are plotted in Figure 6. The majority of points apply to the case with the rotor in the trailing edge. The lines drawn through the points indicate at 3.5 knots changes in depth of 9 fathoms (16.5 m) and in heel angle of 9 degrees.

Due to the limitations in time only a few points were obtained in the leading edge case. These do indicate however a marked improvement, eg a change in depth of approximately 21 fathoms (38.4 m) at 3.5 knots when the rotors were switched on.

The rate of change of depth achieved by rotors alone is comparable with an increase in speed of 1 knot at 150 fathoms (275 m) warp length. For instance in the 5 minutes after the rotors were switched on the board depth changed by 20 fathoms (37 m).

The results of the recent trials are still under detailed analysis and will form the subject of a full report presently under preparation.

CHARLIE BOARD

1 SUBMERSIBLE MOTOR

2 CONTROL BOX

3 ROTOR

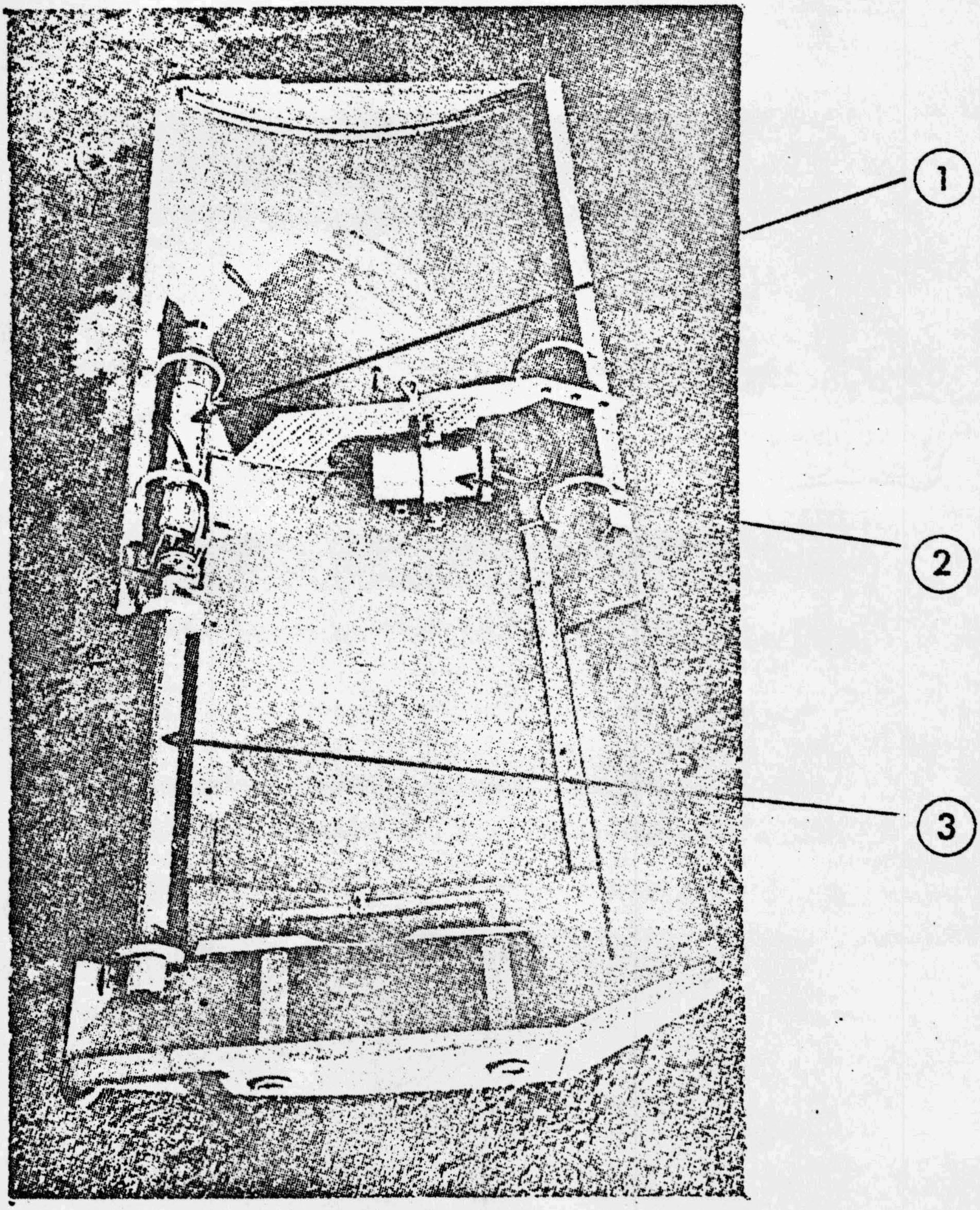


FIG 1

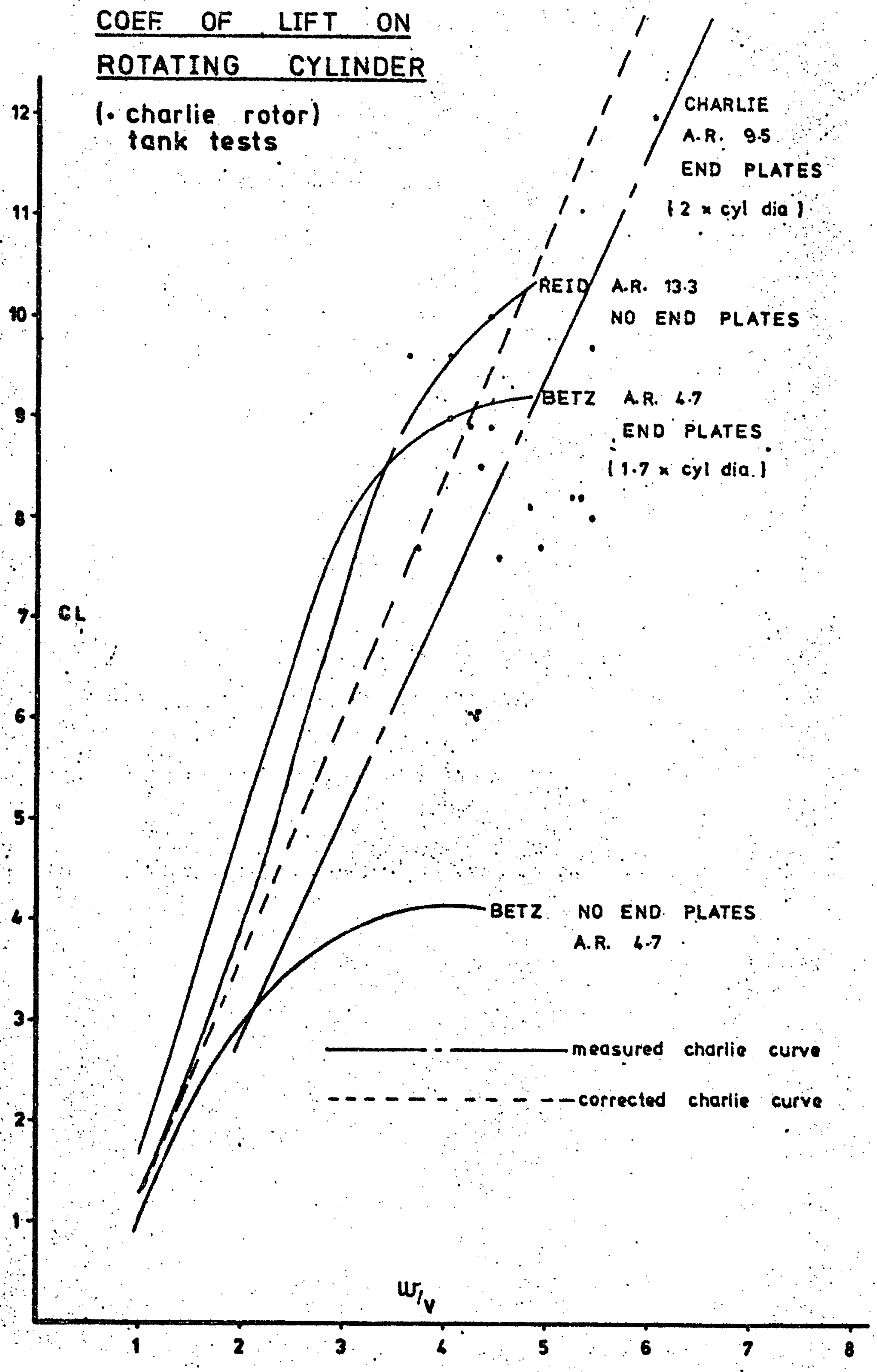

COEF OF LIFT ON
ROTATING CYLINDER
(• charlie rotor)
tank tests
CHARLIE
A.R. 9.5
END PLATES
(2 × cyl dia)
REID A.R. 13.3
NO END PLATES
BETZ A.R. 4.7
END PLATES
(1.7 × cyl dia.)
BETZ NO END PLATES
A.R. 4.7
measured charlie curve
corrected charlie curve
CL
ω/v
1
2
3
4
5
6
7
8
9
10
11
12

FIG 2

RESULTS OF TANK TESTS

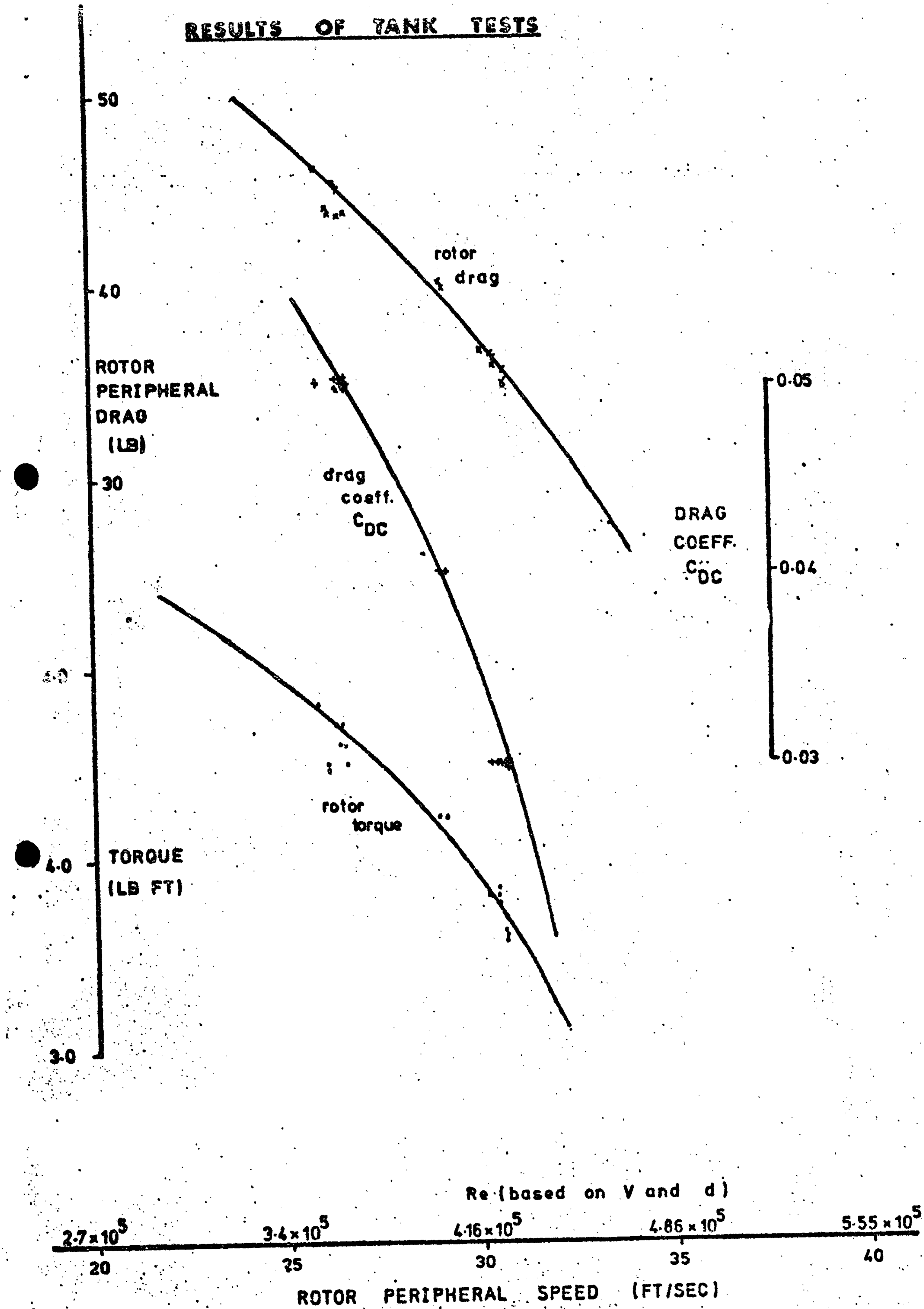


FIG 3

EFFECT ON PERFORMANCE OF A 1000 H.P. PELAGIC TRAWL WHEN A ROTOR FORCE OF 250 LB IS APPLIED AT DIFFERENT POSITIONS

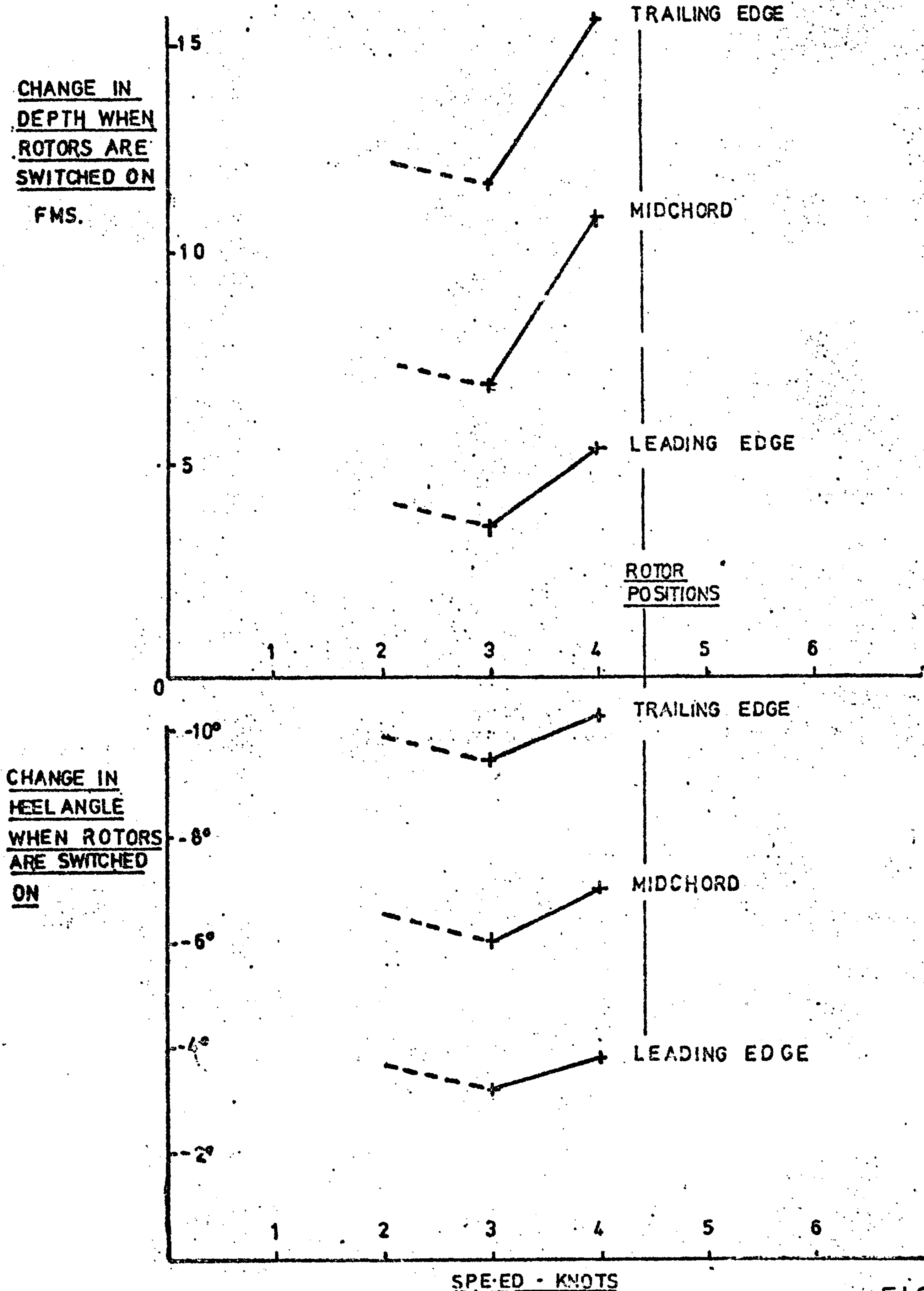
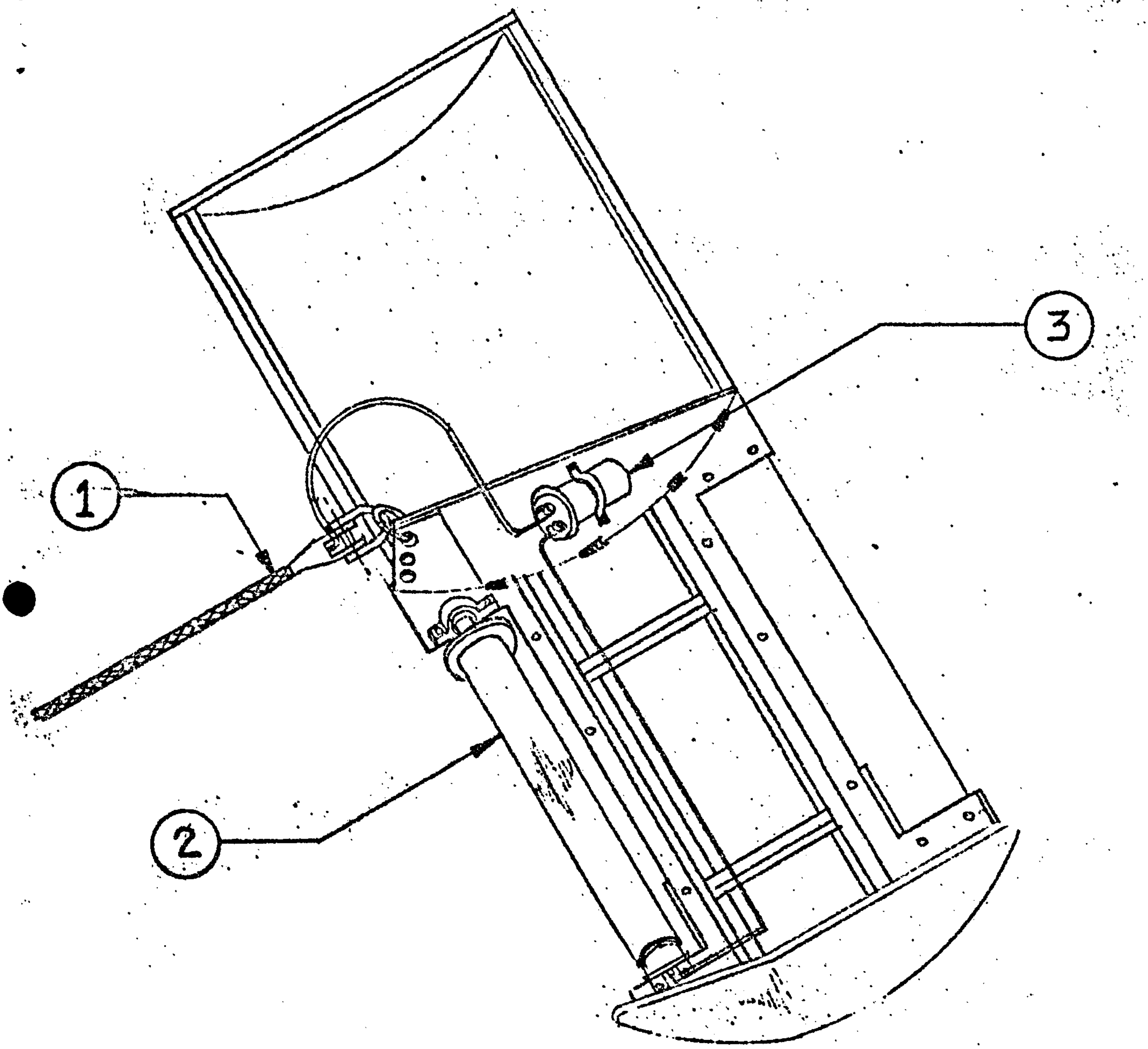


FIG. 4



1 ELECTRICAL CORED WARP

2 MODIFIED ROTOR

3 MOTOR STARTER BOX

MODIFIED CHARLIE BOARD

FIG. 5

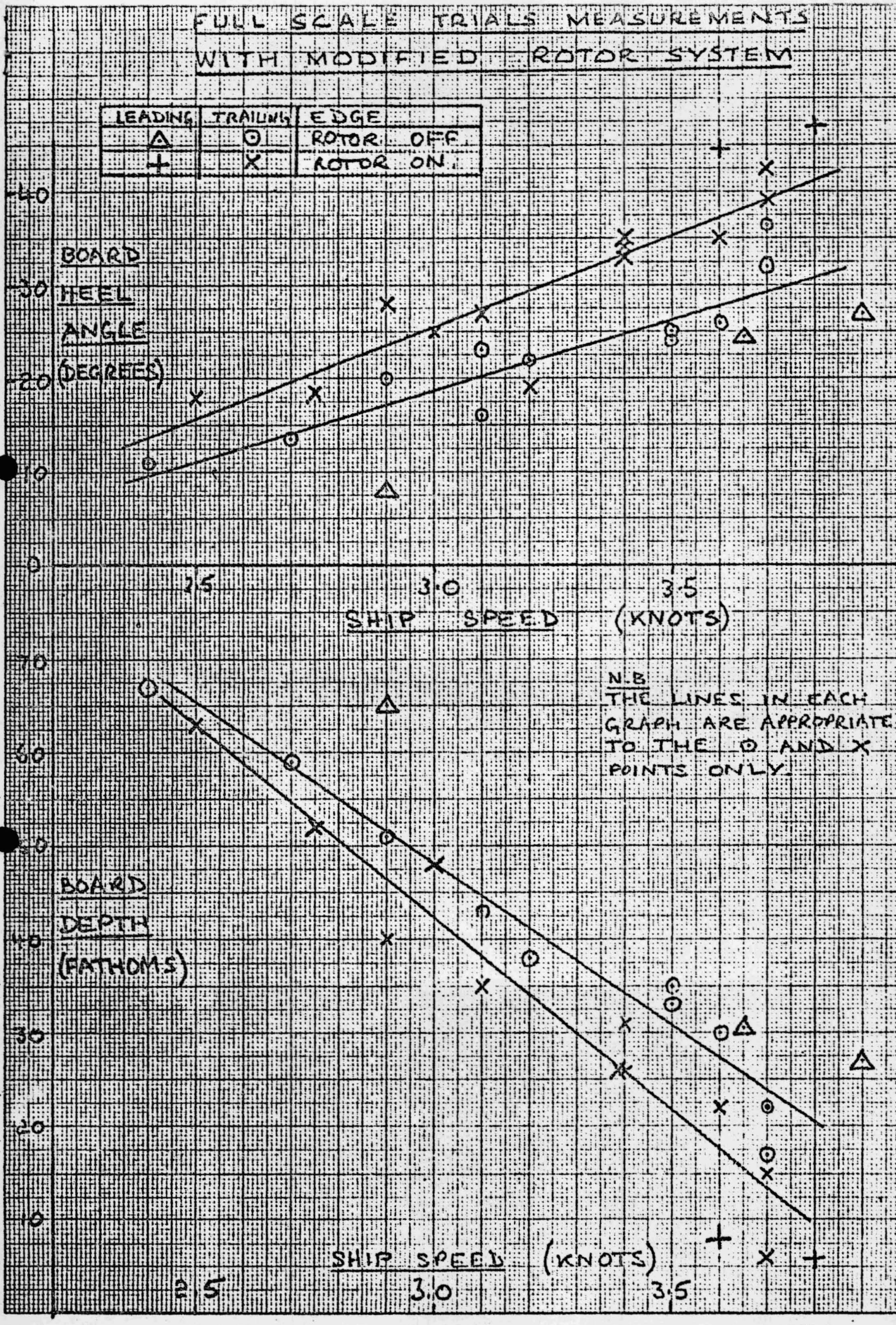

FULL SCALE TRIALS MEASUREMENTS
WITH MODIFIED ROTOR SYSTEM
LEADING
TRAILING
EDGE
ROTOR OFF
ROTOR ON
BOARD HEEL ANGLE (DEGREES)
40
30
20
10
0
2.5
3.0
3.5
SHIP SPEED (KNOTS)
N.B.
THE LINES IN EACH GRAPH ARE APPROPRIATE TO THE ⊙ AND X POINTS ONLY.
70
60
50
BOARD DEPTH (FATHOMS)
40
30
20
10
SHIP SPEED (KNOTS)
2.5
3.0
3.5

FIGURE 6