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Task I

STATIC FORCE COEFFICIENTS OF THE BASIC FINNER MISSILE IN FULLY WETTED FLOW

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ABSTRACT

The results of force tests of models of the Basic Finner missile configuration in fully wetted flow in the High Speed Water Tunnel are presented. The static lift, pitching moment and drag were measured for angles of attack up to 14 degrees and for Reynolds numbers from 0.7 to 8.5×10^6. The results of these tests performed on the static force balance are in good agreement with coefficients determined from free flight drag studies in the Controlled Atmosphere Launching Tank and at the U. S. Naval Ordnance Test Station, Pasadena.

INTRODUCTION

The tests described in this report are one phase of an extensive program in the Hydrodynamics Laboratory to investigate the hydrodynamic coefficients and free flight characteristics of underwater ballistic missiles. Other phases of this program are the measurement of the dynamic force and moment coefficients of the Basic Finner missile in the High Speed Water Tunnel on the angular oscillating and linear oscillating dynamic balances and free flight studies[2] in the Controlled Atmosphere Launching Tank.

The Basic Finner configuration has been tested in the Bureau of Standards Wind Tunnel and is being used in experimental and theoretical underwater force coefficients and trajectory investigations at the Experimental Towing Tank, Stevens Institute of Technology, the Naval Proving Ground, Dahlgren, Maryland, and the Naval Ordnance Test Station[3], Pasadena.

MODELS

The principal dimensions of the Basic Finner missile configuration are shown in the sketch, Fig. 1. Models of 1 and 2-inch diameters were used in these tests. The larger model was fabricated to accommodate the internal force and moment balances necessary when making dynamic tests and in order to minimize the effects of strut and shield interference. Because of the extreme length of the 2-inch diameter model, (20 inches), the 1-inch diameter model was tested in order to minimize the wall effects at high angles of attack.

EXPERIMENTAL SET-UP AND TEST PROCEDURE

The models were mounted on the three component static force balance in the 14-in. diameter closed jet test section of the High Speed Water Tunnel[5]. The models were supported on a single strut, or spindle, attached near the midpoint of the body. Two types of support configurations were used. For most of the tests the model support spindle was shielded from the flow leaving only a small clearance gap between the model and the spindle shield. This set-up is shown in the lower photograph of Fig. 2. In order to calibrate the effect of the shield interference on the forces a second, image, shield was mounted on the opposite side but not touching the model (upper photograph, Fig. 2), and the tests repeated. The difference between the runs made with and without image gave the effect of the addition of the second shield, and, assuming that the shield interference effects were additive, this correction was subtracted from the first single shield run.

Because of the large chord of the spindle shield compared to the model diameter for the 1-inch model some of the tests were made with the models mounted on a partially unshielded spindle in order to reduce strut interference at large attack angles. The bare portion of the spindle consisted of a 1/2-in. diameter circular section tapering in one inch to a straight cylindrical section 0.290 in. in diameter. The total length of the unshielded portion of the spindle was 2-in. for the 1-in. diameter model and 1-1/2 in. for the two-inch model. With this set-up the forces and moments were measured on both the model and the unshielded portion of the spindle. This set-up requires two additional tests in order to calibrate the forces on the bare spindle and the interference effects. After testing the model on a single spindle the test was repeated with the model mounted on a similar spindle from the opposite tunnel wall, and a second spindle attached to the force balance with small clearance gap at the model. In this manner the forces were calibrated for the unshielded portion of the spindle. The interference effects of the spindle were calibrated in a third test by using an image spindle as was done with the shielded strut.

Two types of tests were made. The drag coefficient was determined as a function of Reynolds number at zero attack angle for water velocities from 4.0 to 65 fps. The maximum speed was limited by the strength of the model spindle. The lift, drag, and pitching moment were measured by running the tunnel at constant velocity and varying the angle of attack of the model. Most of the tests were made with the model pitched in a plane normal to one set of fins; however, one series of runs was made with the afterbody of the model indexed 45 degrees relative to the plane of pitch angle. The results of these tests are shown separately. Details of the force balance, read-out system, and data handling methods are described in Refs. 4 and 6.

The force and moment data were reduced to dimensionless coefficients as follows:

Drag coefficient, $C_D = \dfrac{DRAG}{\rho/2\ V^2\ A}$

Lift coefficient, $C_L = \dfrac{LIFT}{\rho/2\ V^2\ A}$

Pitching moment coefficient, $C_M = \dfrac{MOMENT\ ABOUT\ MIDPOINT}{\rho/2\ V^2\ A\ D}$

where:

V = free stream velocity fps

ρ = density of water, slugs

A = cross sectional area of model, ft^2

D = diameter of model, ft

The moments are given about the midpoint of the model, 5.00 diameters from the nose tip. In addition to the shield and strut interference corrections the drag coefficient was corrected for horizontal buoyancy. This spurious drag is due to the static pressure gradient along the test section.

RESULTS AND DISCUSSION

The drag coefficient as a function of Reynolds number for the Basic Finner is shown in Fig. 3. Lift, drag, and pitching moment coefficients are shown as functions of angle of pitch for several Reynolds numbers in Fig. 4 for the model pitched normal to the fins and in Fig. 5 for the fins indexed at 45 degrees.

Drag data from free flight tests at the Naval Ordnance Test Station, Pasadena, and in the California Institute of Technology Controlled Atmosphere Launching Tank, are included in Fig. 3. The drag coefficients reported by Stubstad and Waugh[3] of NOTS are for Reynolds numbers from 8×10^4 to 9.6×10^5. The drag coefficients are shown in the figure only at the upper limits of the Reynolds number ranges. Price[2] reports a drag coefficient of 0.493 at a Reynolds number of approximately 3.6×10^5 in the free flight test at CIT. The agreement between the water tunnel drag coefficients and those of NOTS is excellent. Though the CIT free flight tests were made at smaller Reynolds numbers than the tunnel tests these results are also in close agreement.

The drag coefficient showed a sharp peak at a Reynolds number of 2.7×10^6 for all tests of the 2-inch diameter model. In addition the drag coefficient increases with increasing Reynolds numbers over the entire range. This trend is also apparent in the curves of drag coefficient vs attack angle, Fig. 4.

Lift, drag, and pitching moment coefficients are shown for Reynolds numbers of 1.7, 2.5, 3.4, and 5.1×10^6 for angles of attack up to 14 degrees in Fig. 4. The lift and moment show almost no variation with Reynolds number over this range. For the test results shown in Fig. 4, the model was pitched in a plane normal to one set of fins. In the tests of Fig. 5, the model afterbody was rotated 45 degrees and the model pitched in a plane 45 degrees to all four fins. With the model pitched 45 degrees to the plane of the fins, the lift, drag and moment coefficients, as expected, are less than with the model pitched normal to one set of fins for angles of attack greater than 5 degrees.

REFERENCES

1 Kiceniuk, Taras, "An Experimental Determination of Dynamic Coefficients for the Basic Finner Missile by Means of the Angular Dynamic Balance", California Institute of Technology, Hydrodynamics Laboratory Report No. E-73.3, June 1957

2 Price, D. A. Jr., "Free Body Modeling of the Dynamics of a Fin-Stabilized Ballistics Missile in Nonspinning Vertical Trajectories", California Institute of Technology, Hydrodynamics Laboratory Report No. E - 73.1, April 1957.

3 Stubstad, G. W., and Waugh, J. G., "Drag Coefficient of Fully Wetted Basic Finner Missile", U. S. Naval Ordnance Test Station, NAVord Report 5269, June 1956.

4 Hotz, G. M., and McGraw, J. T., "The High Speed Water Tunnel Three-Component Force Balance", California Institute of Technology, Hydrodynamics Laboratory Report No. 47-2, January 1955.

5 Knapp, R. T., Levy, J., O'Neill, J. P., Brown, F. B., "The Hydrodynamics Laboratory of the California Institute of Technology", Trans. ASME, Vol. 70, No. 5, pp 437 - 457, July 1948

6 Kermeen, R. W., "Water Tunnel Tests of NACA 4412 and Walchner Profile 7 Hydrofoils in Noncavitating and Cavitating Flows", California Institute of Technology, Hydrodynamics Laboratory Report No. 47-5, February 1956.

FIGURE TITLES

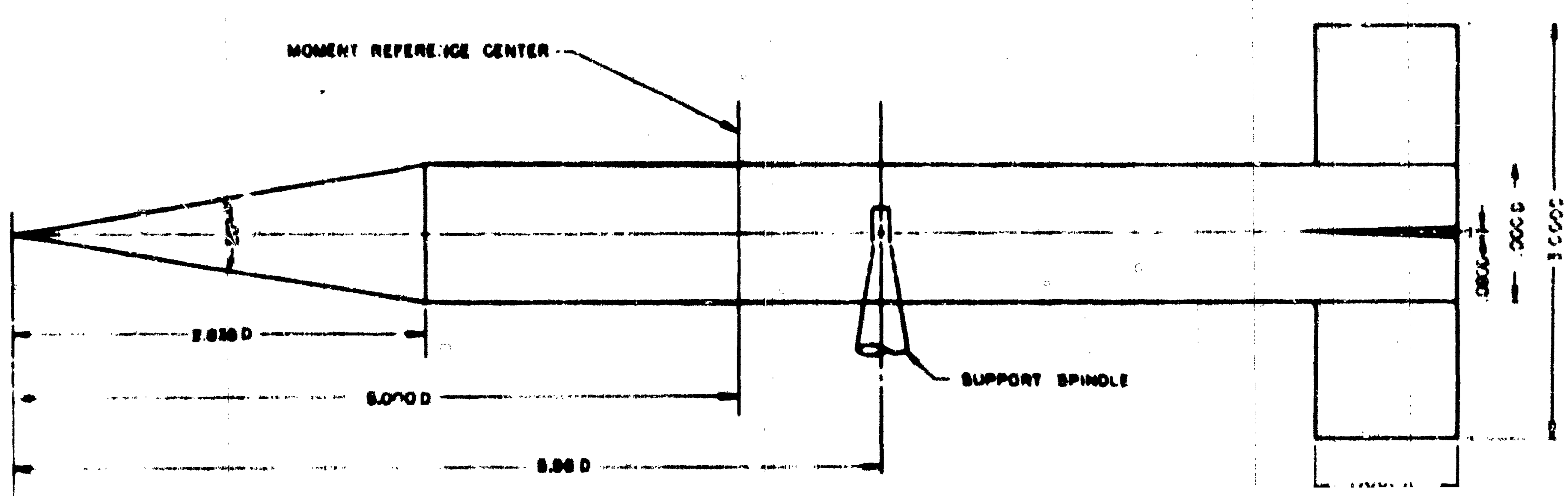
Fig. 1 Sketch of the Basic Finner missile configuration.

Fig. 2 One inch diameter Basic Finner model mounted in the High Speed Water Tunnel. Upper photograph - single shield; lower photograph, image set-up.

Fig. 3 Drag coefficient as a function of Reynolds number for the Basic Finner in fully wetted flow.

Fig. 4 Lift, drag and pitching moment coefficients for the Basic Finner as a function of angle of attack.

Fig. 5 Lift, drag and pitching moment coefficients for the Basic Finner as a function of attack angle. Model pitched at 45 degrees to plane of fins.



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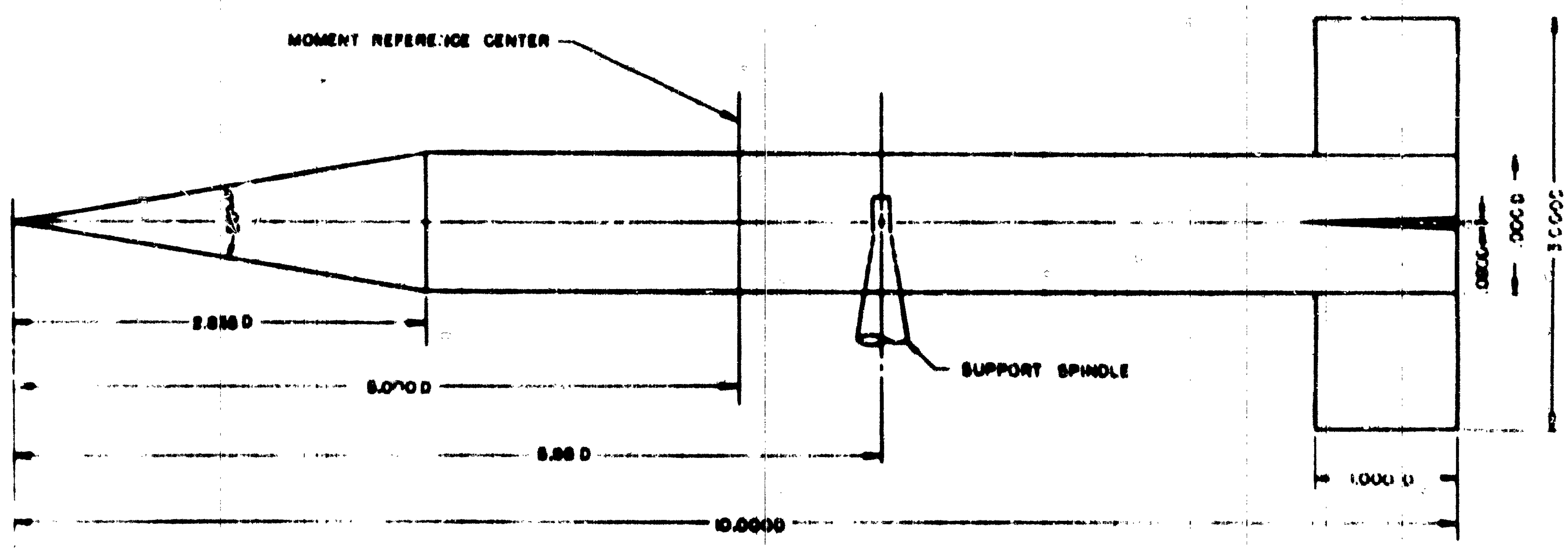

Fig. 1. Sketch of the Basic Finner missile configuration.

Fig. 2. One-inch diameter Basic Finner model mounted in the High Speed Water Tunnel. Lower photo - single shield. Upper photo - image setup.

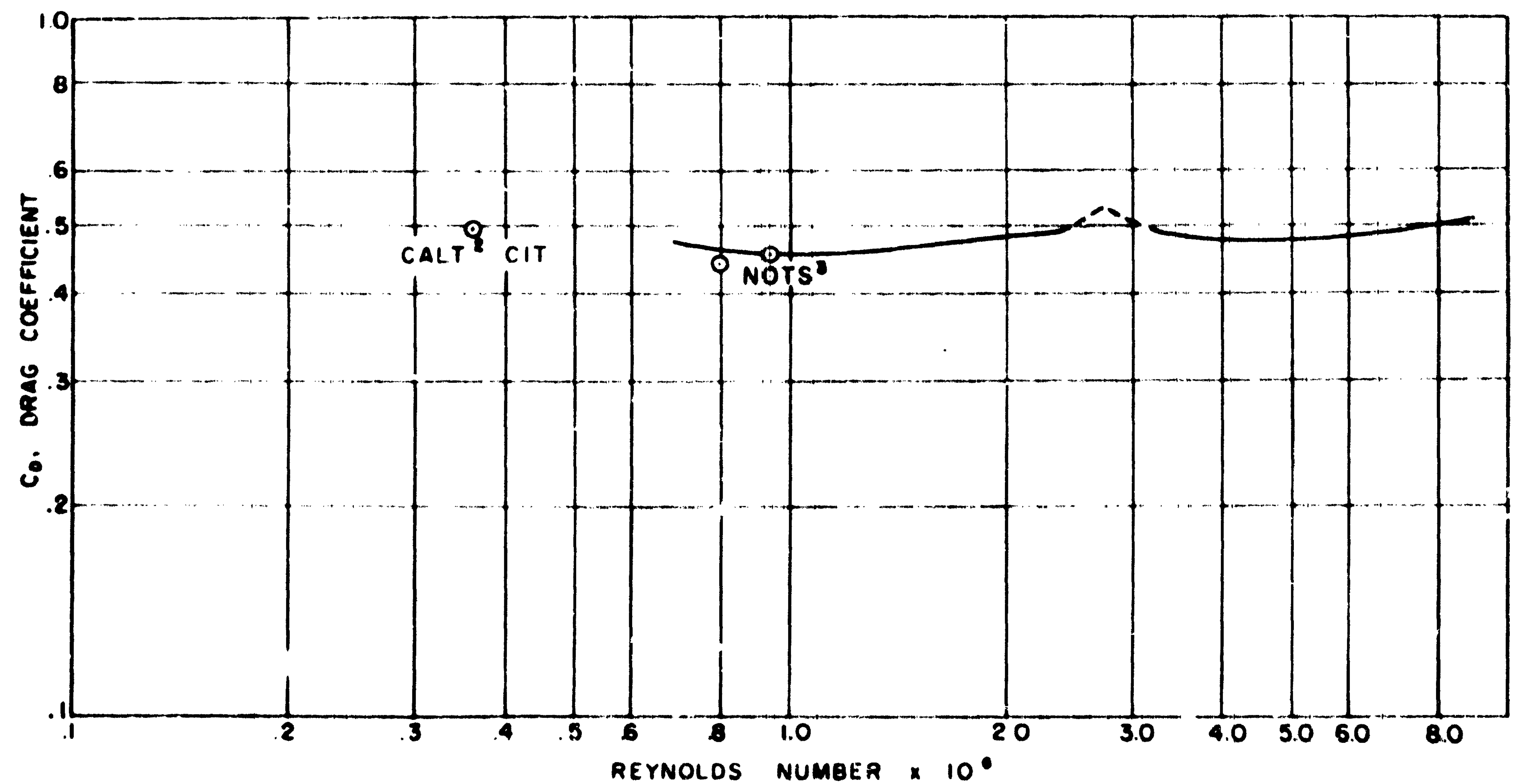

Fig. 3. Drag coefficient as a function of Reynolds number for the Basic Finner in fully wetted flow.

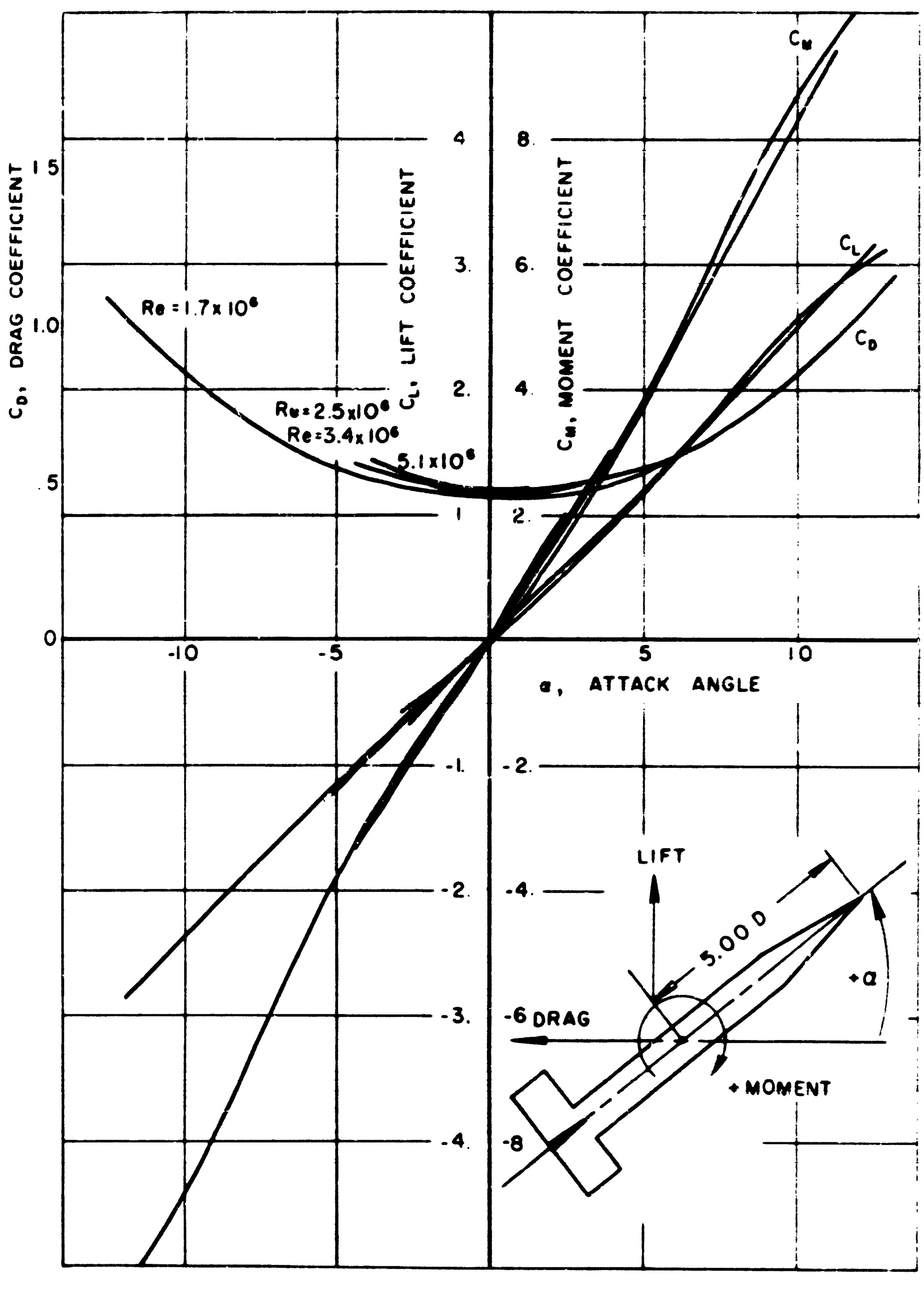

Fig. 4. Lift, drag and pitching moment coefficients for the Basic Finner as a function of angle of attack.

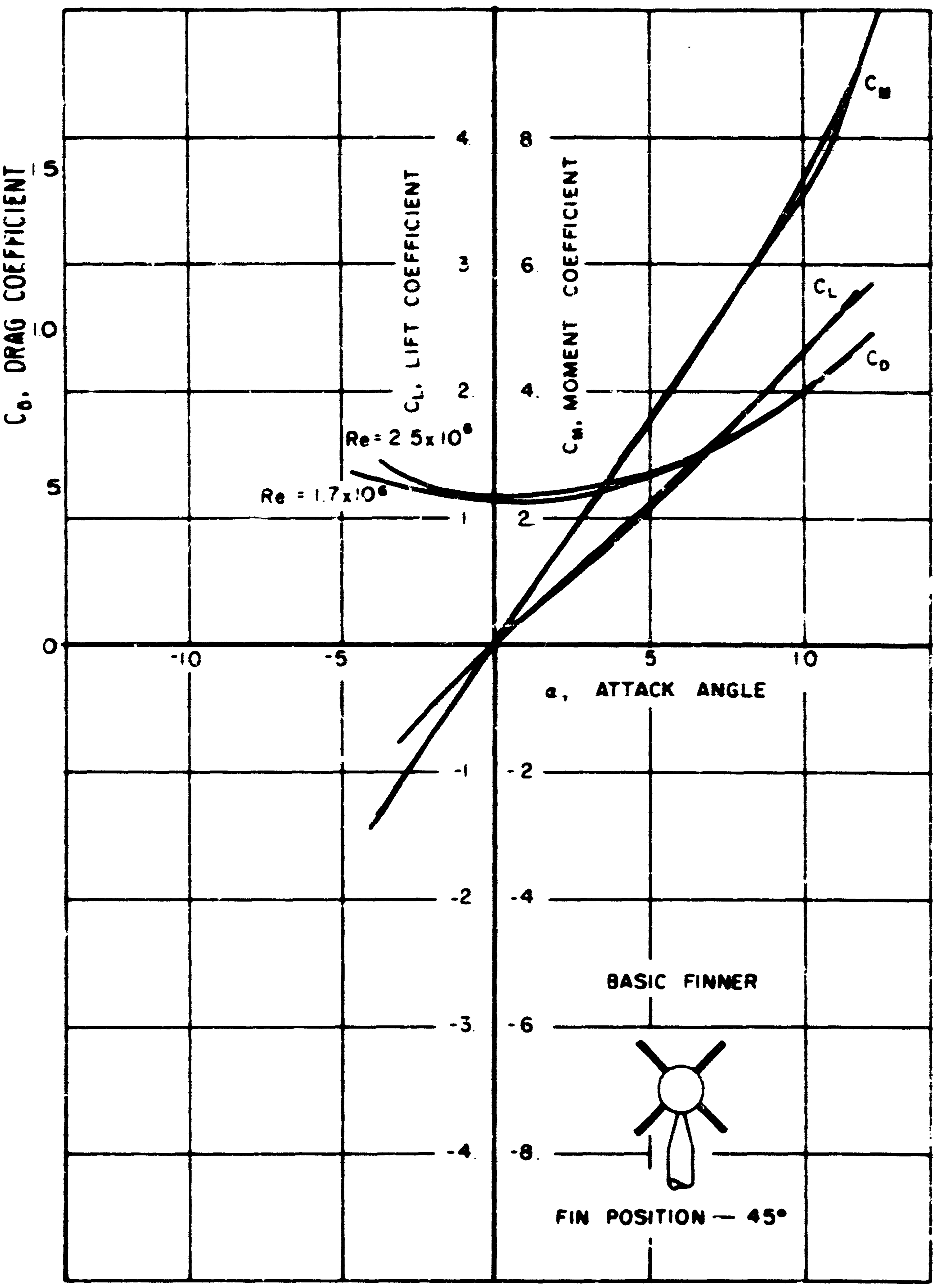

Fig. 5. Lift, drag and pitching moment coefficients for the Basic Finner as a function of attack angle. Model pitched at 45 degrees to plane of fins.