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RESEARCH MEMORANDUM

INVESTIGATION OF THE NACA 4-(3)(08)-03 TWO-BLADE PROPELLER AT FORWARD MACH NUMBERS TO 0.925

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FOR AERONAUTICS
WASHINGTON
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SUMMARY

An investigation of the NACA 4-(3)(08)-03 two-blade propeller has been made in the Langley 8-foot high-speed tunnel for blade angles of 55°, 60°, and 65° at Mach numbers up to 0.925.

Comparison of the force-test measurements obtained for the NACA 4-(3)(08)-03 two-blade propeller with those previously obtained for the NACA 4-(5)(08)-03 two-blade propeller indicates that the differences in design lift coefficient were insufficient to produce appreciable changes in maximum efficiency over the range of blade angle and Mach number investigated. A comparison of the two propellers made at equal power absorption indicates that the differences in design lift coefficient had little effect on the highest efficiencies reached.

INTRODUCTION

The effect of compressibility on the NACA 4-(5)(08)-03 two-blade propeller was presented in reference 1 as the first part of a general investigation to study the effects of compressibility, design camber, thickness ratio, sweep, and dual rotation on the performance of propellers operating at transonic forward speeds. The second part of this general investigation, the effect of design camber on propeller performance, is presented herein.

This paper presents the force-test results for the NACA 4-(3)(08)-03 two-blade propeller at blade angles of 55°, 60°, and 65° for a range of forward Mach number from 0.43 to 0.925. In order to expedite publication of the data, only a limited analysis comparing these results with those of reference 1 to determine the effect of design camber on propeller performance at transonic speeds is included in this paper.

The present paper does not include the effect of design camber on propeller performance at low speeds. However, such information may be obtained from references 2 and 3. In the investigation of reference 2 the same propellers were tested, but propulsive data were obtained because of the type of dynamometer then used. Large-scale plots of the basic propeller characteristics (fig. 5) are available on request to the NACA.

SYMBOLS

b	blade width, feet
c_{l_d}	blade section design lift coefficient
C_P	power coefficient $(P/\rho n^3 D^5)$
C_T	thrust coefficient $(T/\rho n^2 D^4)$
D	propeller diameter, feet
b/D	blade width ratio
h	maximum thickness of blade section, feet
h/b	blade thickness ratio
J	advance ratio (V_o/nD)
M	tunnel-datum (forward) Mach number (tunnel Mach number uncorrected for tunnel-wall constraint)
M_t	helical-tip Mach number $\left(M\sqrt{1 + \frac{\pi^2}{J^2}}\right)$
n	propeller rotational speed, revolutions per second
P	power, foot-pounds per second
q	dynamic pressure, pounds per square foot $(\rho V^2/2)$
R	propeller-tip radius, feet
r	blade-section radius, feet
T	thrust, pounds
T_c	thrust disk-loading coefficient $(T/2qD^2)$
V	tunnel-datum velocity (tunnel velocity uncorrected for tunnel-wall constraint), feet per second

V_o	equivalent free-air velocity (tunnel-datum velocity corrected for tunnel-wall constraint), feet per second
x	blade-section station (r/R)
β	section blade angle, degrees
$\beta_{0.75R}$	section blade angle of 0.75 tip radius, degrees
η	efficiency $\left(\frac{C_T}{C_P} J\right)$
η_{max}	maximum efficiency
ρ	air density, slugs per cubic foot

APPARATUS, METHODS, AND TESTS

The apparatus and methods described in reference 1 were used in this investigation which was conducted in the Langley 8-foot high-speed tunnel. A sketch of the 800-horsepower-dynamometer installation in the tunnel is shown as figure 1.

The NACA 4-(3)(08)-03 two-blade propeller used in this investigation is the same one used in the investigation reported in references 2 and 4. It incorporates the NACA 16-series blade sections. The blade was designed as a three-blade propeller to produce minimum energy losses (profile drag assumed equal to zero) at a blade angle of 45° at the 0.7-radius station and at an advance ratio of 2.1. The gaps between the spinner and blades were sealed for all operating conditions. Blade-form curves are presented in figure 2 and are the same for both the NACA 4-(3)(08)-03 and 4-(5)(08)-03 propellers except for the higher design lift coefficients for the latter. A photograph of the blades is shown as figure 3.

Thrust, torque, and rotational speed were measured throughout the operating range of the propeller. For each tunnel Mach number, the propeller was run at fixed blade angles and the rotational speed was varied. The range of blade angle covered for each forward Mach number is given in the following table:

Forward Mach number, M	Blade angle of 0.75-tip radius, $\beta_{0.75R}$ (deg)		
0.43	55	60	65
.60	55		65
.65	55	60	65
.70	55	60	65
.75	55	60	65
.80	55	60	65
.85	55	60	65
.90	55	60	65
.925	55	60	65

REDUCTION OF DATA

<u>Propeller thrust</u>.- Propeller thrust as used herein is defined as the shaft tension produced by the spinner-to-tip portion of the blades. The method used in determining thrust tares and in evaluating the propeller thrust is described in detail in reference 1.

<u>Propeller torque</u>.- Torque-tare corrections were found to be small and dependent only on spinner rotational speed. The indicated torque reading was corrected for the spinner tare (a maximum of 1.2 foot-pounds at 6000 rpm).

<u>Tunnel-wall corrections</u>.- The force-test data have been corrected for the effect of tunnel-wall constraint on velocity at the propeller plane using the method described in reference 1. These results are presented in figure 4 as the ratio of free-air velocity to the tunnel-datum velocity as a function of thrust disk-loading coefficient and tunnel-datum Mach number.

<u>Accuracy of results</u>.- Analysis of the accuracy of the separate measurements required to define fully the propeller characteristics has indicated that errors in the results presented herein are probably less than 1 percent. Repeat runs have confirmed this estimate.

RESULTS AND DISCUSSION

The basic propeller characteristics are presented in figure 5. For each value of tunnel-datum Mach number M the propeller thrust and power coefficients and efficiency are plotted against advance ratio. The variation of tip Mach number with advance ratio is also included. As used herein, the tunnel-datum Mach number M is not corrected for tunnel-wall constraint. The free-air Mach number, however, can be obtained by applying the tunnel-wall corrections, presented in figure 4, to the tunnel-datum Mach number. At the high Mach numbers, the tunnel-wall correction is generally less than 1 percent, but in the exact use of the basic propeller characteristics presented in figure 5 wherever small changes in Mach number produce large changes in propeller characteristics, the tunnel-datum Mach number should be corrected to free-air Mach number.

Effect of forward Mach number on maximum efficiency.- The variation of maximum efficiency with forward Mach number is presented in figure 6 for all the blade angles investigated. Similar results (reference 1) for the NACA 4-(5)(08)-03 propeller are shown for comparison. The maximum efficiency for the NACA 4-(3)(08)-03 propeller (low camber) is, in general, about 1 percent lower than for the NACA 4-(5)(08)-03 propeller (medium camber) throughout the Mach number and blade-angle ranges investigated. For all practical purposes, however, the efficiencies are essentially the same for both propellers; this fact indicates that the difference in design lift coefficient (design camber) for the range of design lift coefficient investigated is too small to produce any difference in maximum efficiency. It is believed, however, that the use of symmetrical or high-camber sections would produce marked changes in efficiency from those reported herein. The effect of high-camber sections on propeller performance is discussed in references 2 and 3.

Comparison of the effects of camber on maximum efficiency as reported in reference 2 with those reported herein shows important differences for a blade angle of 60° (0.75R) near the critical and at supercritical forward Mach numbers. These differences for a blade angle of 60° are attributed to the accuracy of the earlier investigation. The results presented herein confirm the effect of design camber on maximum efficiency for subcritical operation presented in reference 2.

Effect of advance ratio and forward Mach number on maximum efficiency.- The variation of maximum efficiency with advance ratio for the forward Mach numbers at which the propeller was investigated is shown in figure 7 by the symbols. The solid lines represent similar data taken from reference 1 for the NACA 4-(5)(08)-03 propeller for which more extensive results are available. No important differences in these results are indicated for the two propellers.

Effect of power coefficient on efficiency.- The variation of efficiency with advance ratio for constant values of power coefficient and forward Mach number is shown in figure 8 for both the NACA 4-(3)(08)-03 and 4-(5)(08)-03 propellers. In general, the highest efficiencies for both propellers are essentially the same for the range of power coefficient and forward Mach number shown in figure 8, except at high forward Mach numbers where the results indicate that the NACA 4-(5)(08)-03 propeller may be 2 percent more efficient than the NACA 4-(3)(08)-03 propeller. Since this difference in efficiency may be due to experimental accuracy, superiority of one propeller over the other is not indicated. At high advance ratios the NACA 4-(3)(08)-03 propeller is more efficient than the NACA 4-(5)(08)-03 propeller, especially at low values of power coefficient.

CONCLUDING REMARKS

Comparison of the force-test measurements obtained for the NACA 4-(3)(08)-03 two-blade propeller with those previously obtained for the NACA 4-(5)(08)-03 two-blade propeller (NACA RM L9G06a) indicates that the differences in design lift coefficient were insufficient to produce appreciable changes in maximum efficiency over the range of blade angle and Mach number investigated. A comparison of the two propellers made at equal power absorption indicates that the differences in design lift coefficient had little effect on the highest efficiencies reached.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Air Force Base, Va.

REFERENCES

1. Delano, James B., and Carmel, Melvin M.: Investigation of the NACA 4-(5)(08)-03 Two-Blade Propeller at Forward Mach Numbers to 0.925. NACA RM L9G06a, 1949.

2. Delano, James B.: Investigation of Two-Blade Propellers at High Forward Speeds in the NACA 8-Foot High-Speed Tunnel. III - Effects of Camber and Compressibility. NACA 4-(5)(08)-03 and NACA 4-(10)(08)-03 Blades. NACA ACR L5F15, 1945.

3. Maynard, Julian D., and Salters, Leland B., Jr.: Aerodynamic Characteristics at High Speeds of Related Full-Scale Propellers Having Different Blade-Section Cambers. NACA RM L8E06, 1948.

4. Stack, John, Draley, Eugene C., Delano, James B., and Feldman, Lewis: Investigation of Two-Blade Propellers at High Forward Speeds in the NACA 8-Foot High-Speed Tunnel. I - Effects of Compressibility. NACA 4-308-03 Blade. NACA ACR 4A10, 1944.

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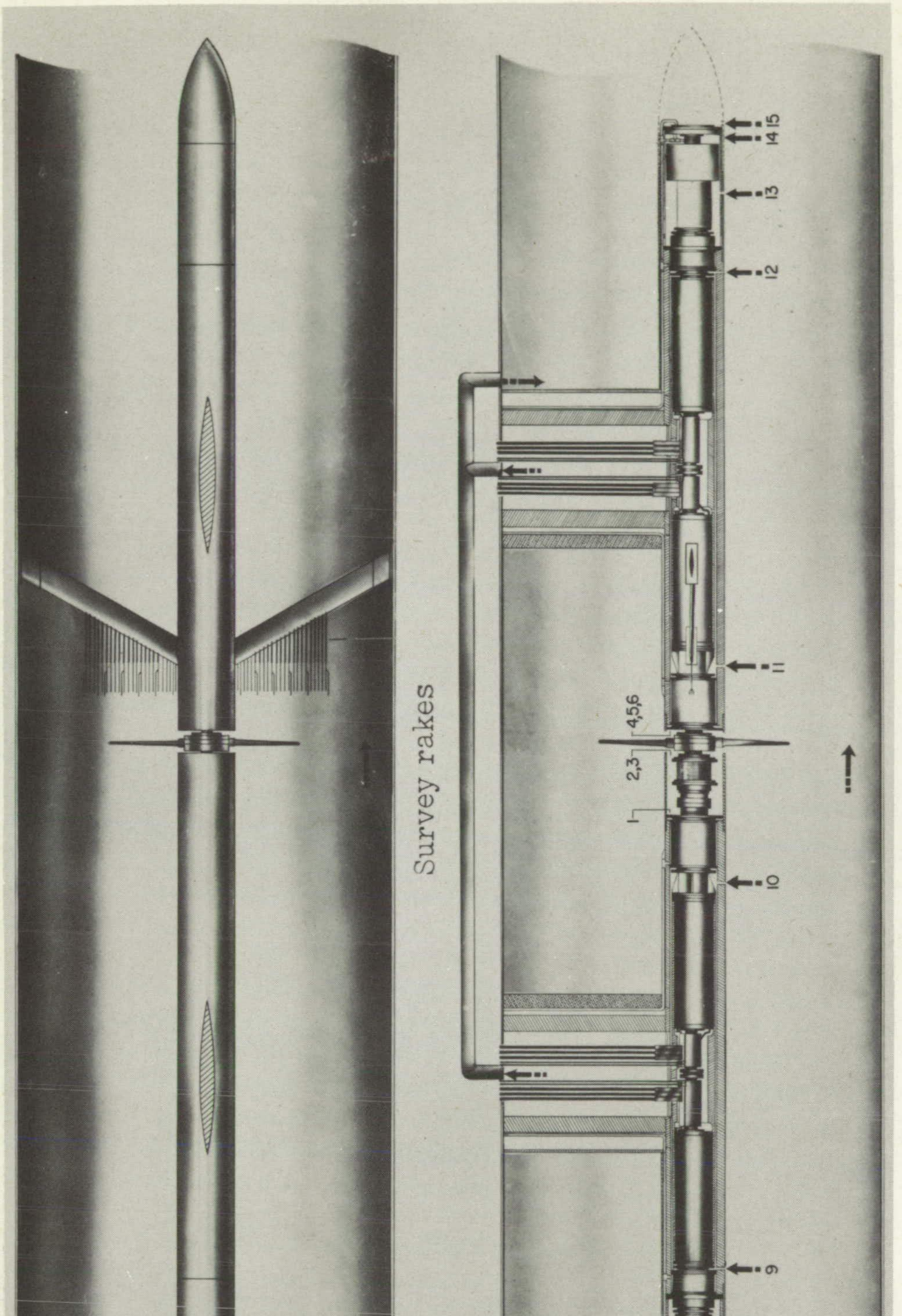

Figure 1.- Installation of propeller dynamometer in Langley 8-foot high-speed tunnel.

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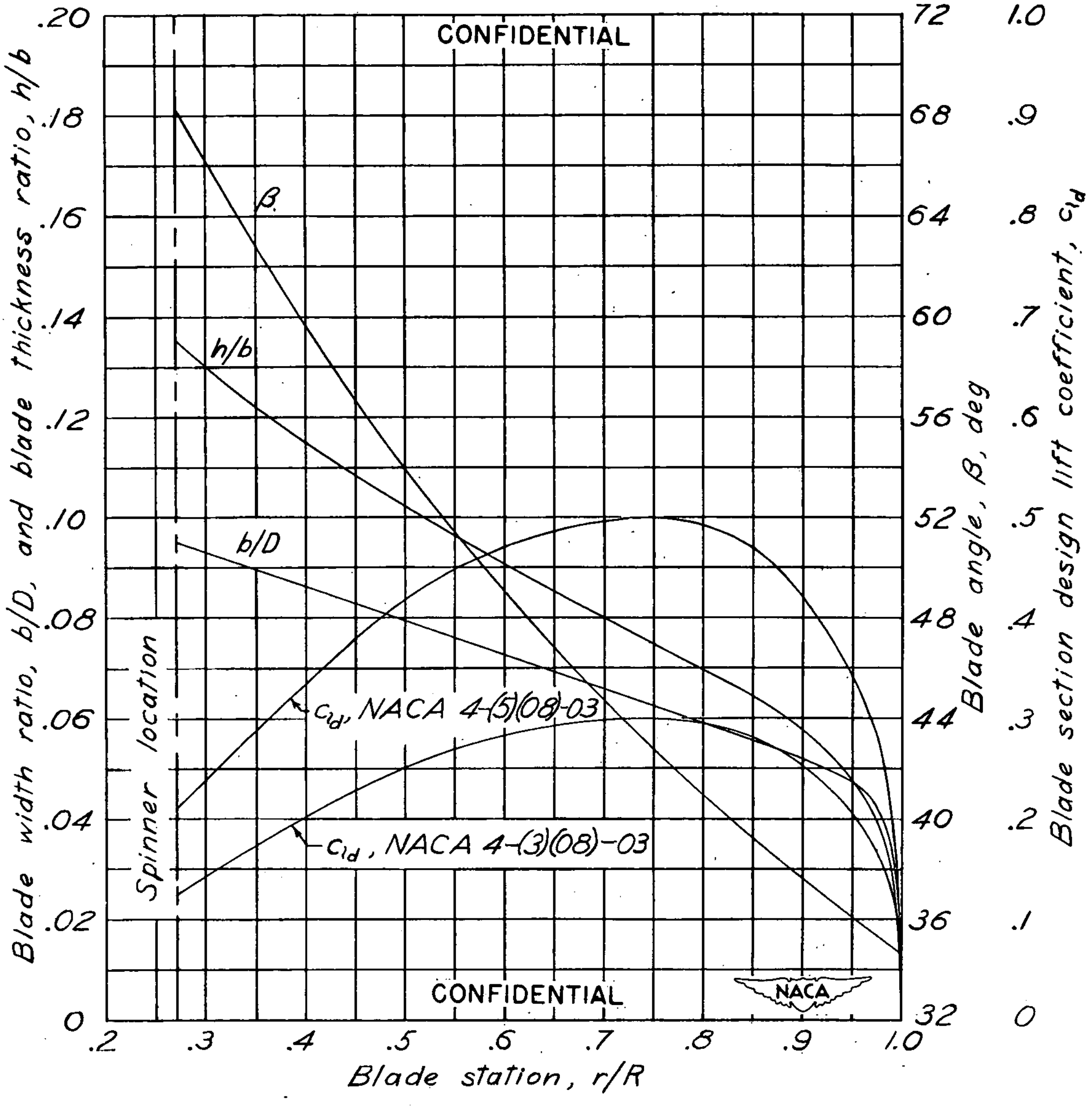

Figure 2.– NACA 4–(3)(08)–03 and NACA 4–(5)(08)–03 propeller blade–form curves.

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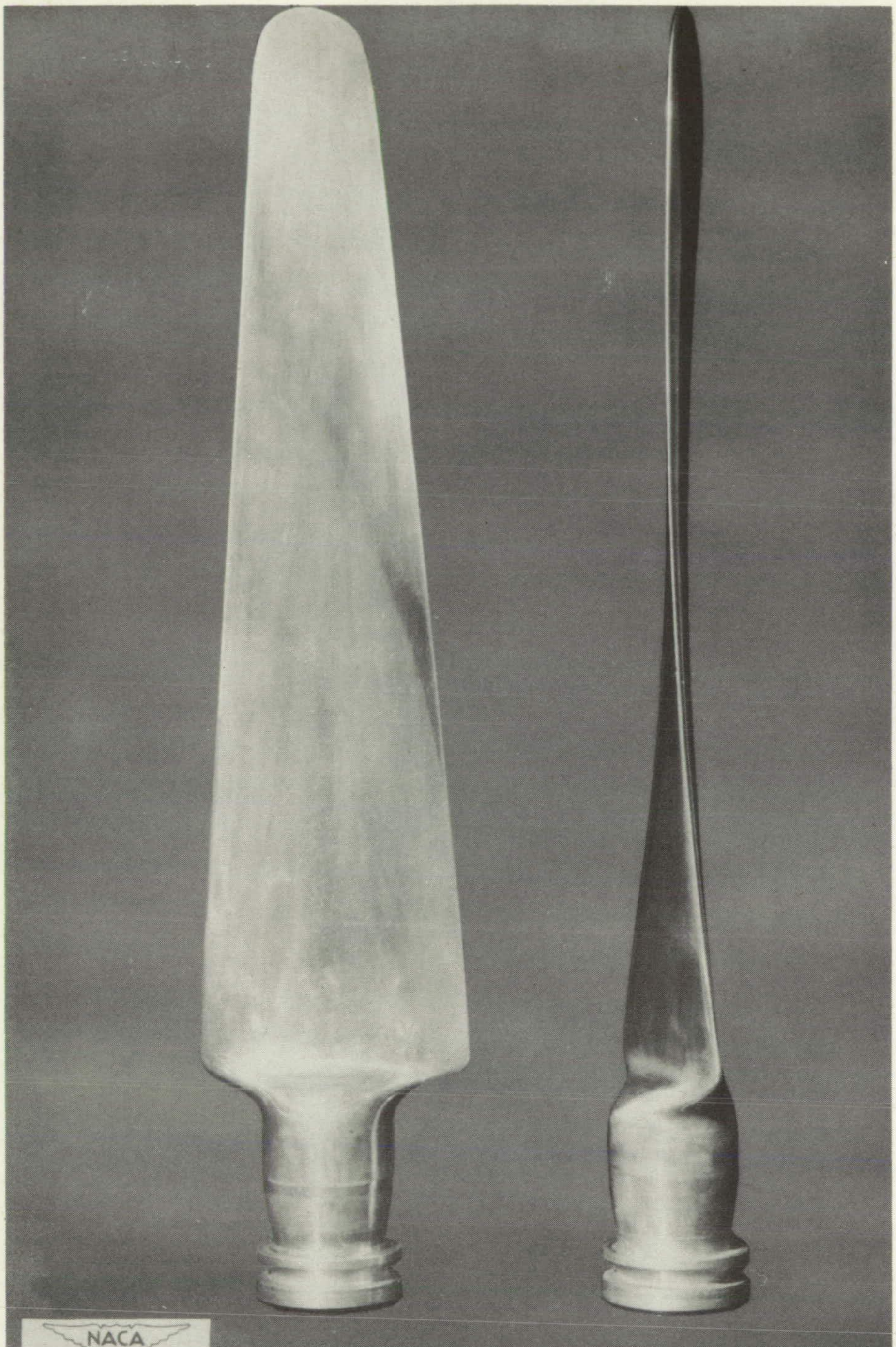

Figure 3.– NACA 4–(3)(08)–03 propeller.

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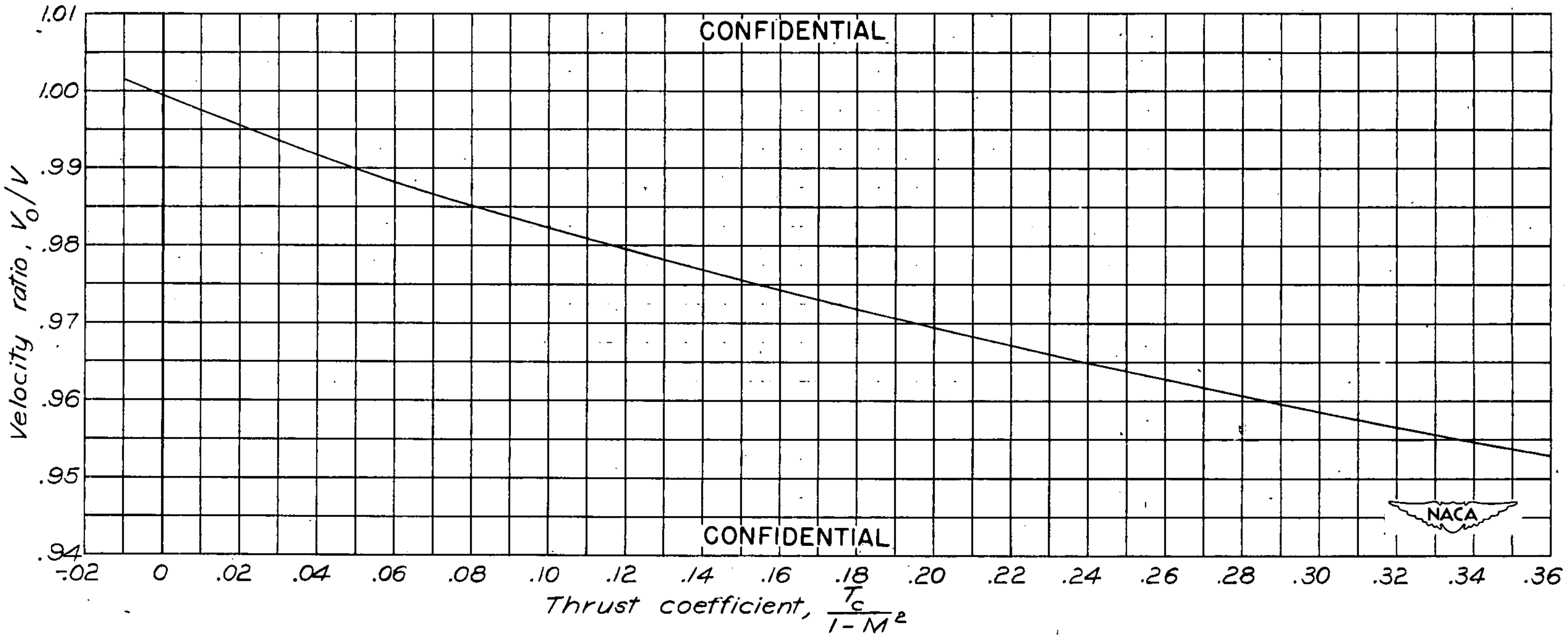
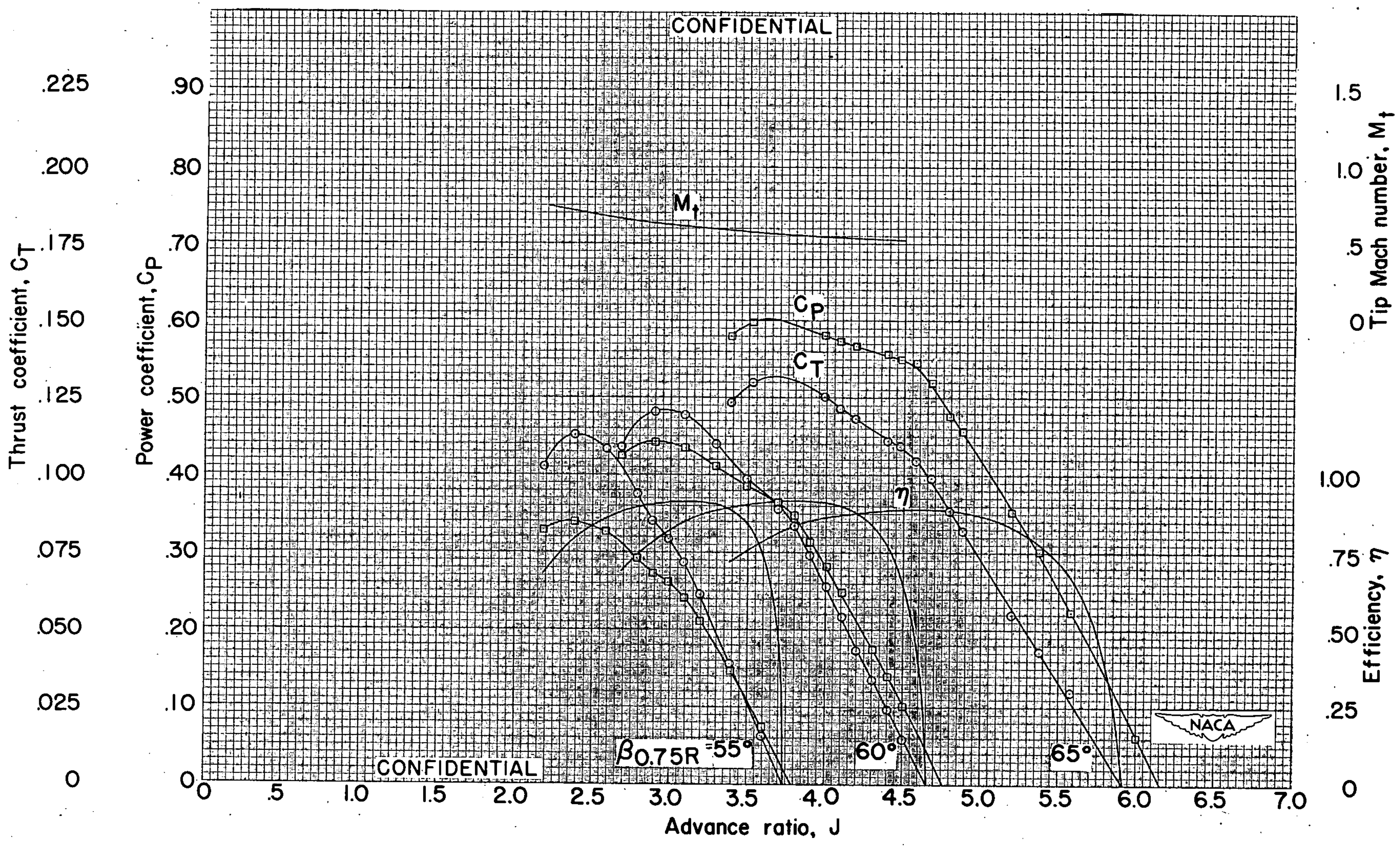
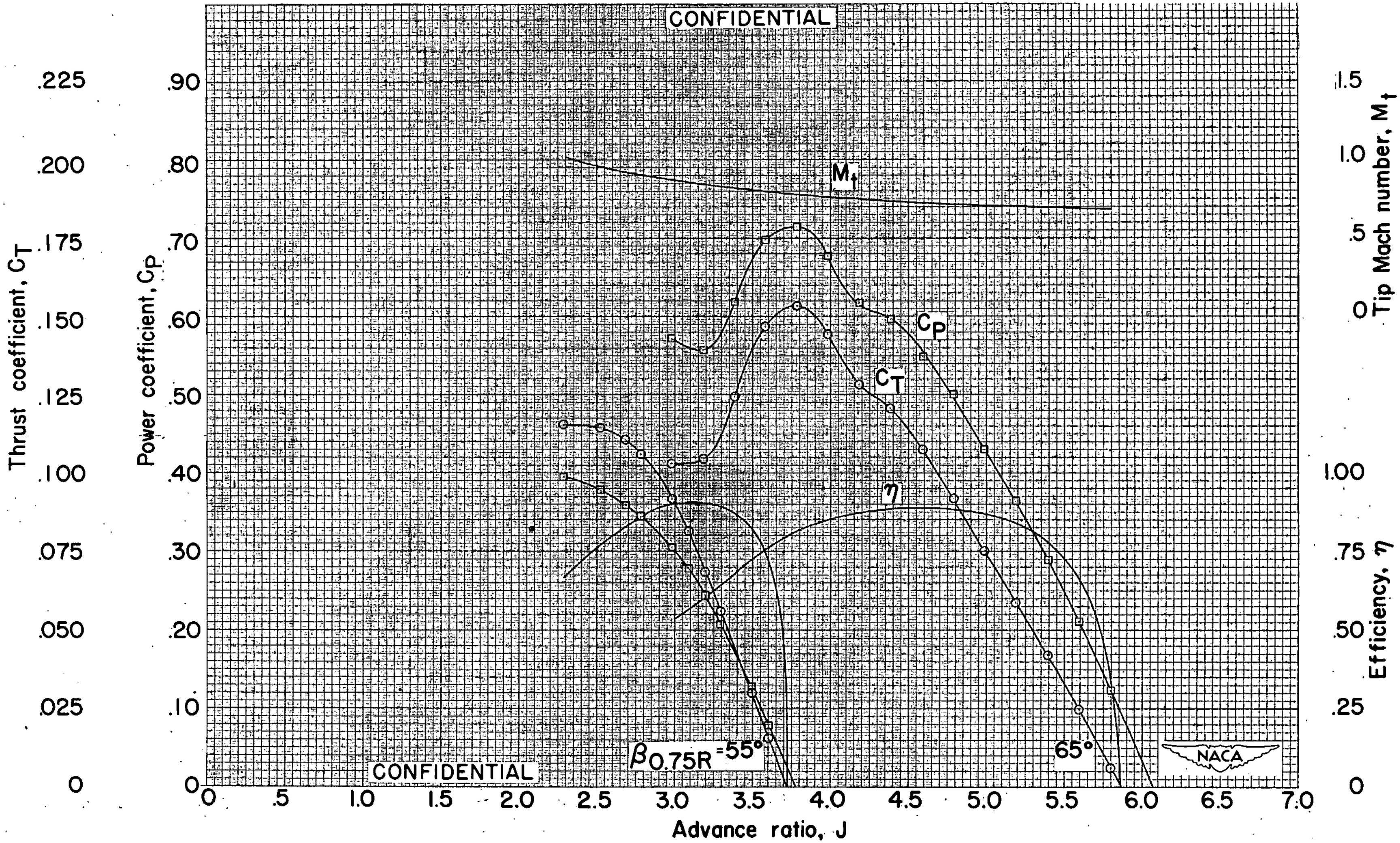


Figure 4.– Tunnel-wall-interference correction for 4-foot-diameter propeller in Langley 8-foot high-speed tunnel.



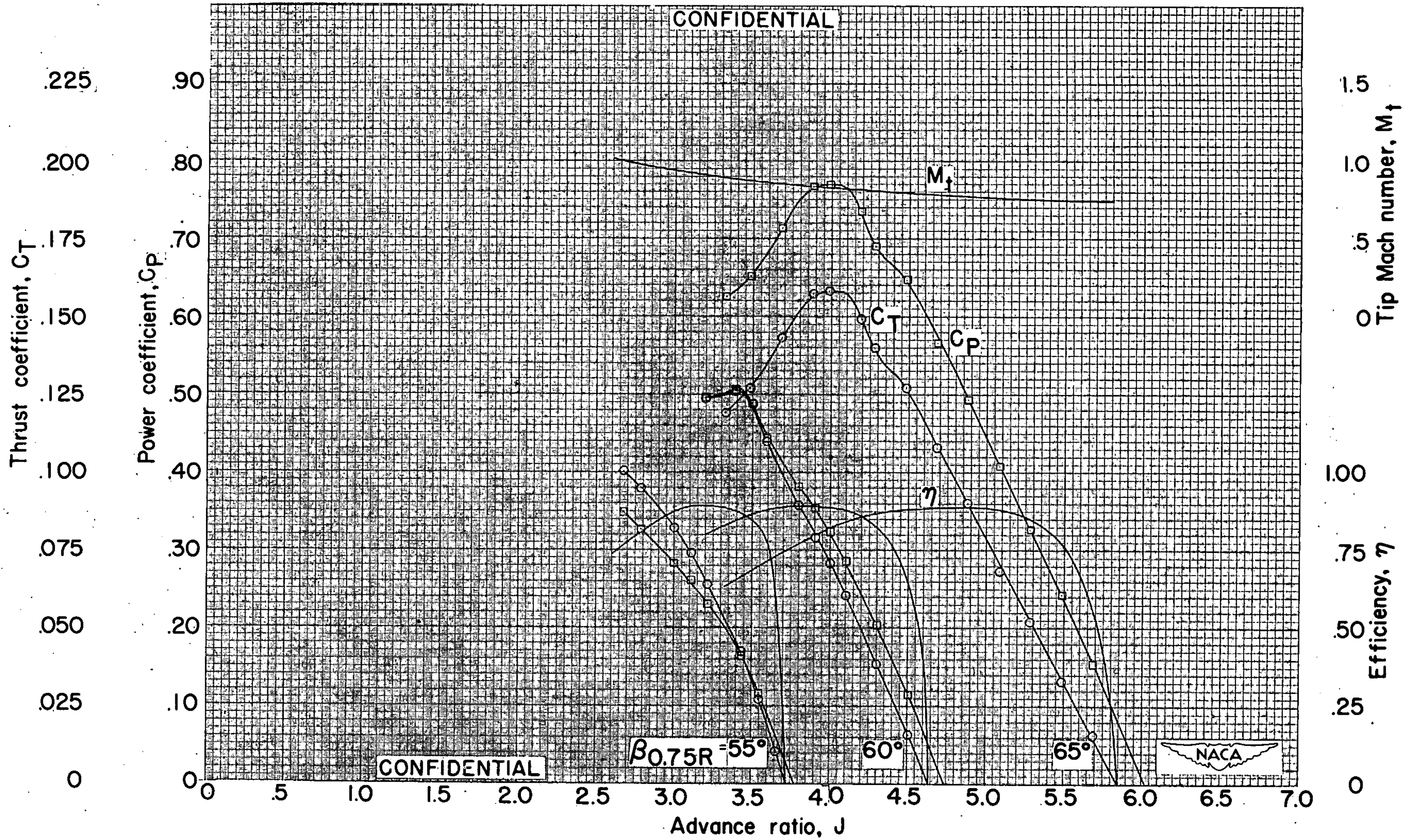
(a) M=0.43.

Figure 5 - Characteristics of NACA 4-(3)(08)-03 propeller.



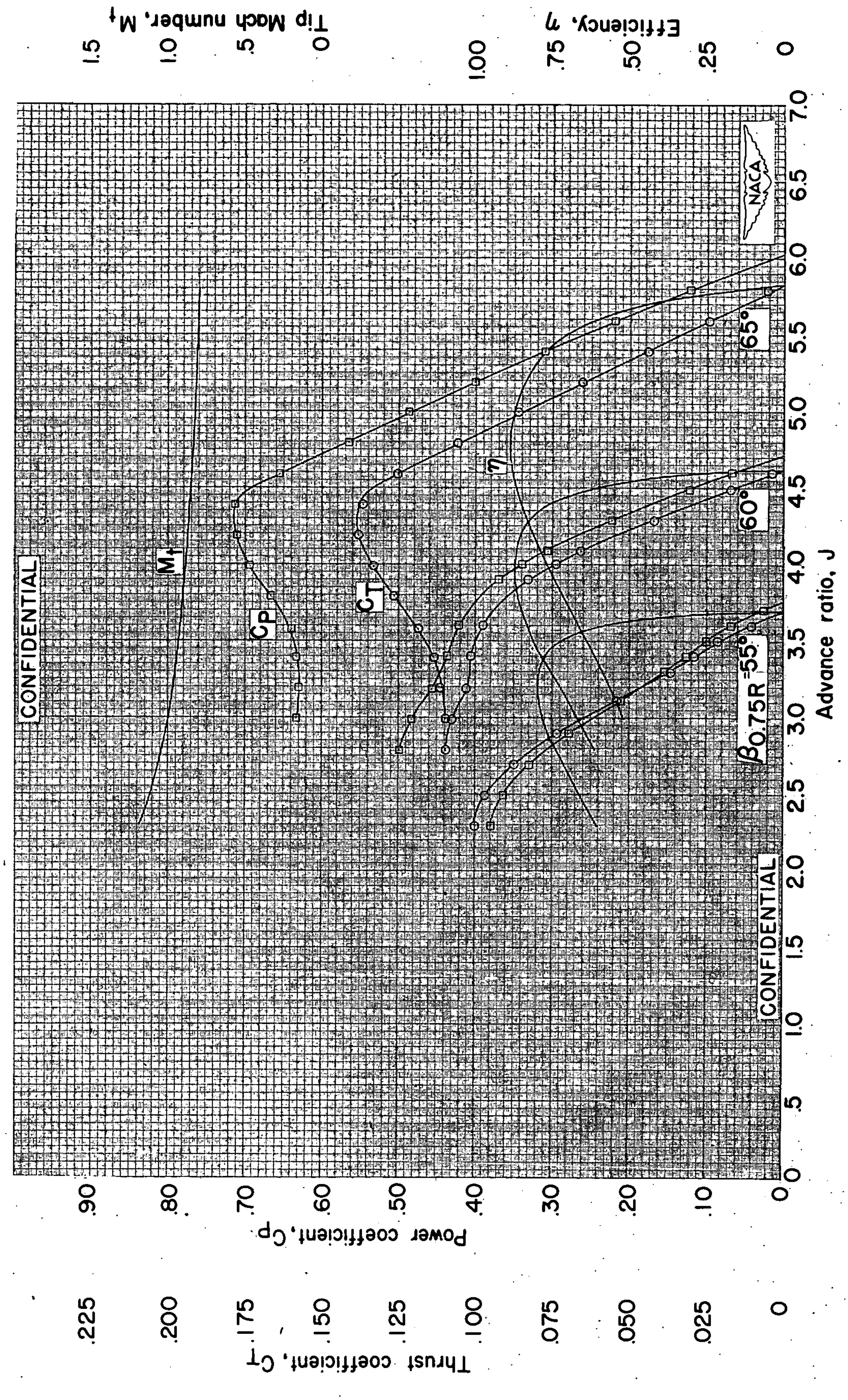
(b) M=0.60.

Figure 5 - Continued.



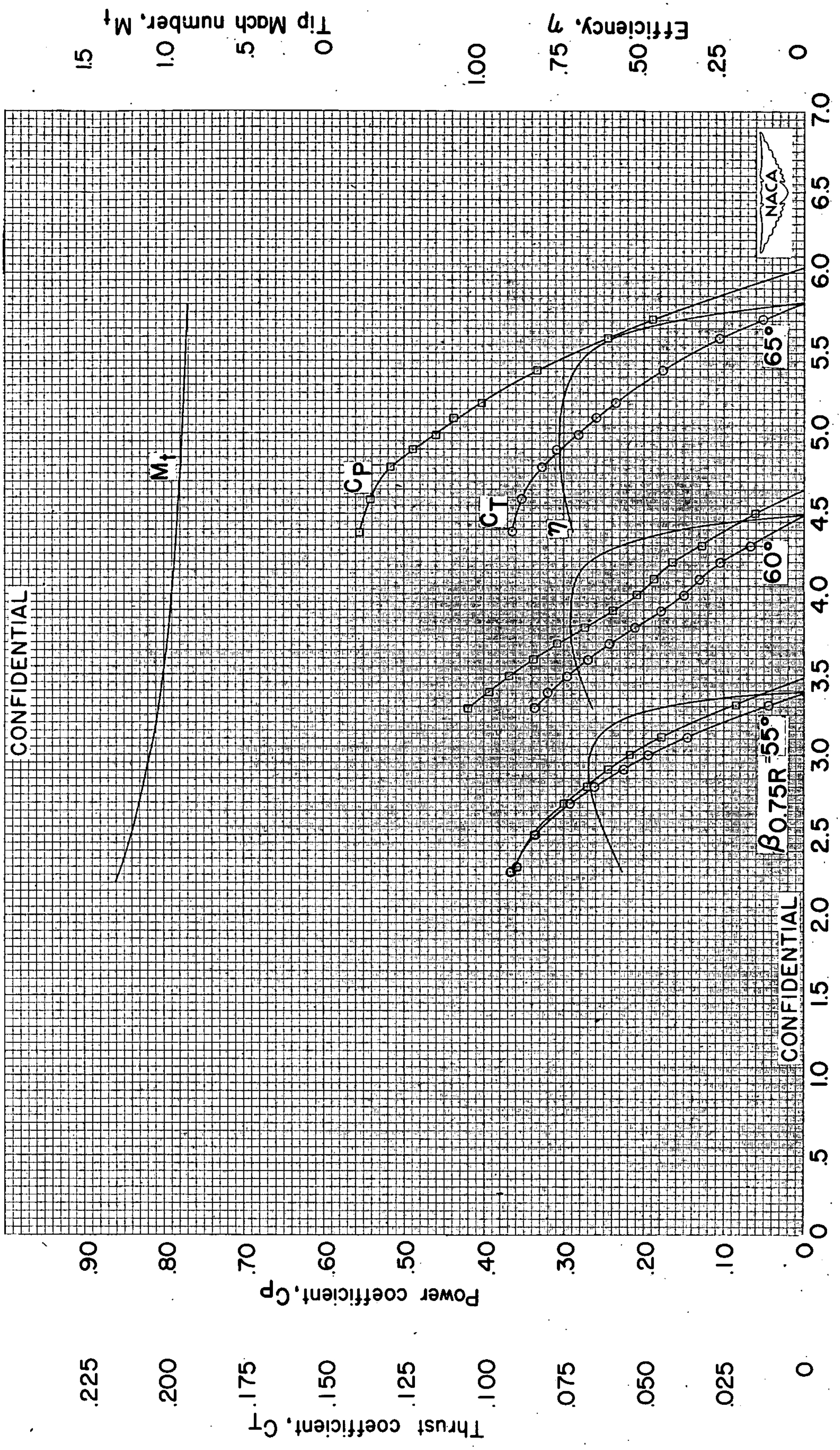
(c) M=0.65.

Figure 5 - Continued.



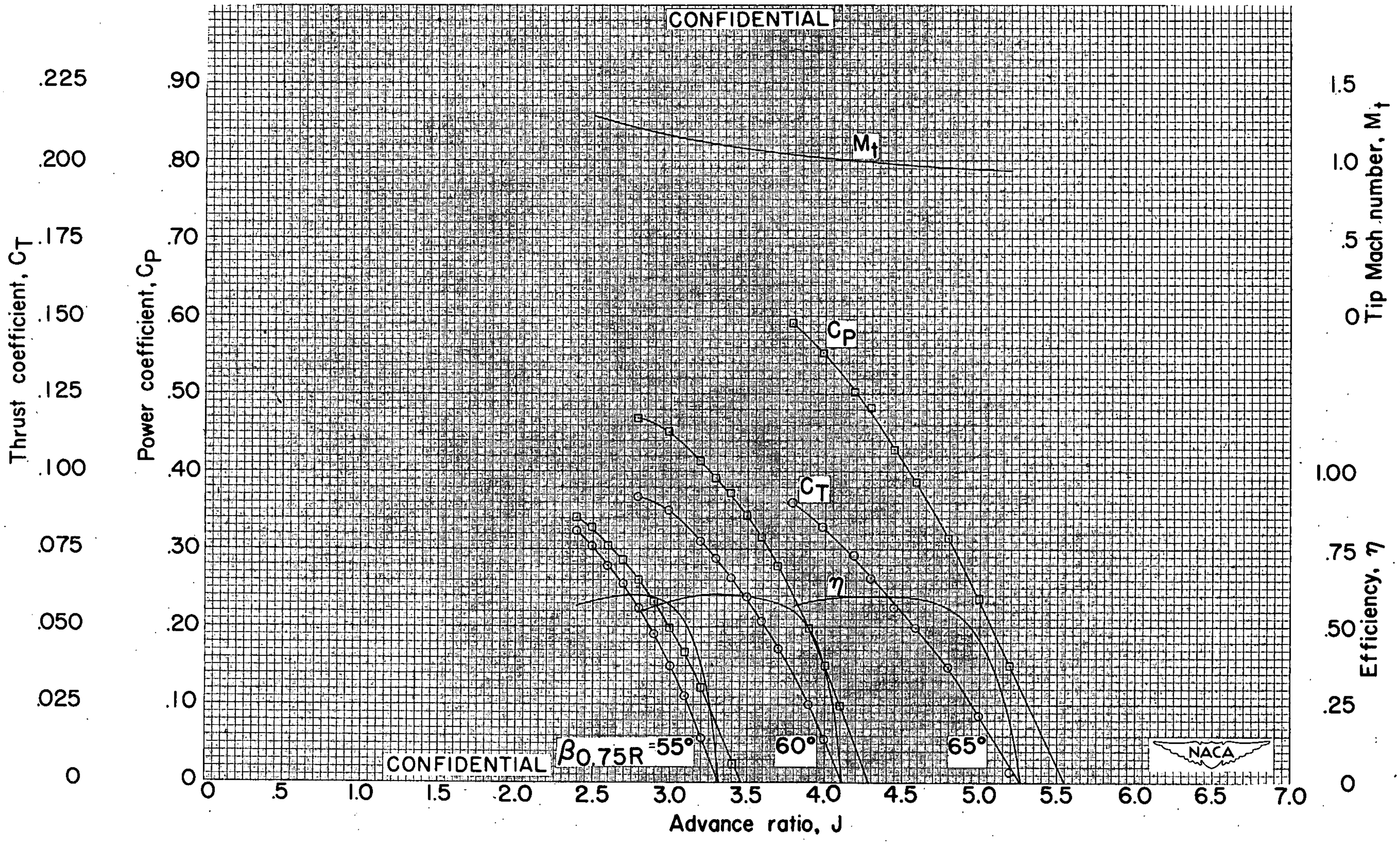
(d) M=0.70.

Figure 5 - Continued.



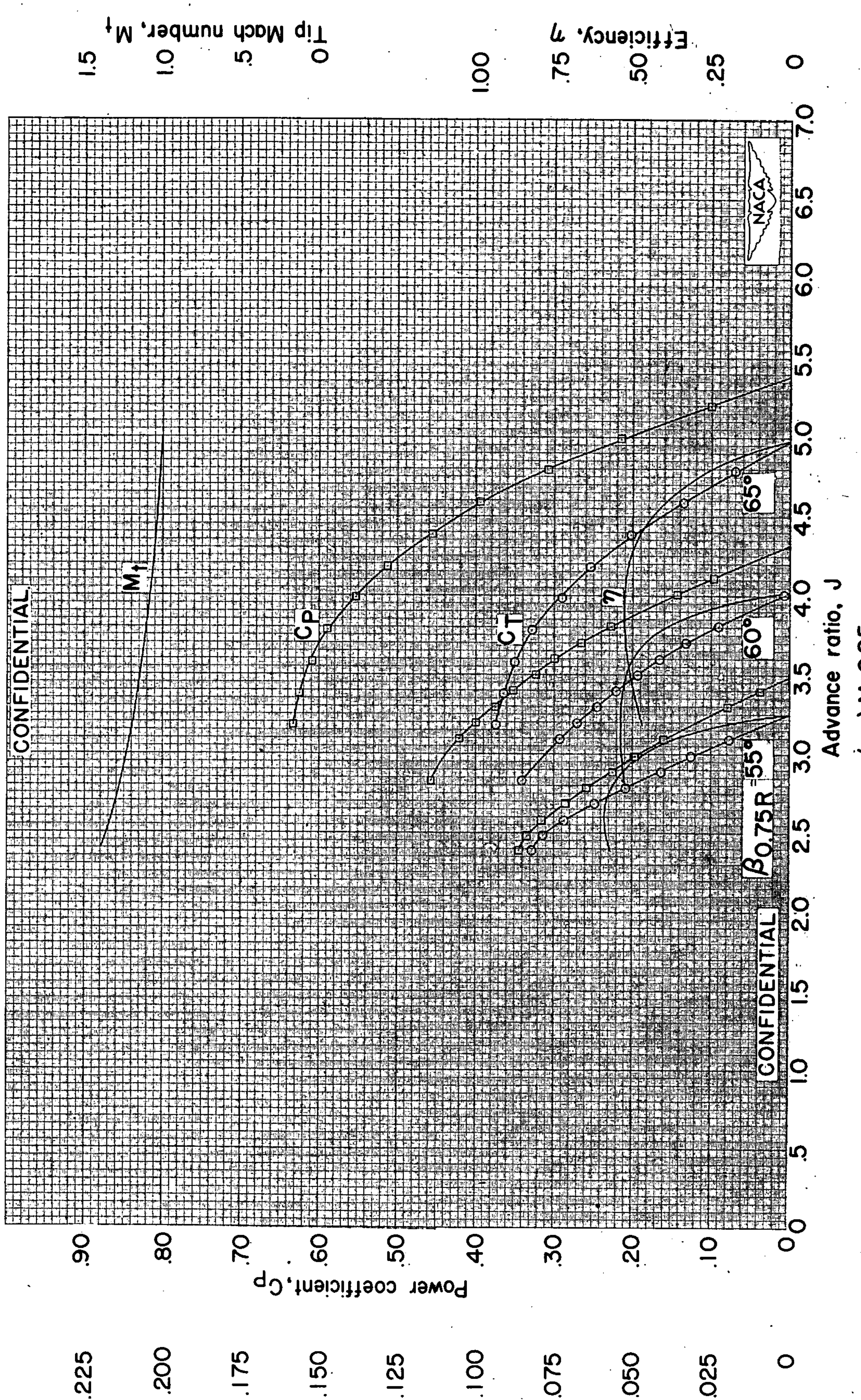
(e) M=0.75.

Figure 5 .- Continued.



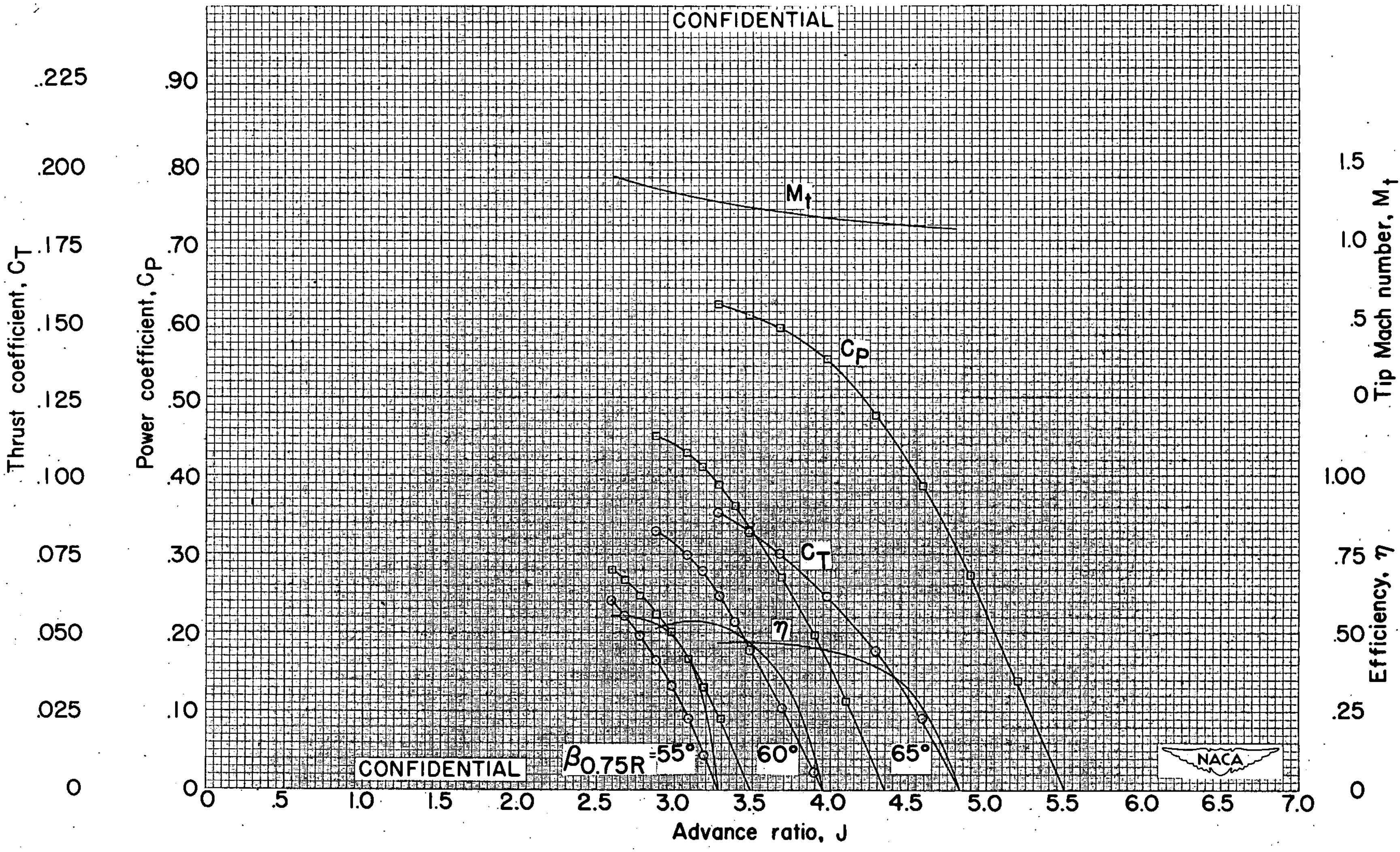
(f) M=0.80.

Figure 5 - Continued.



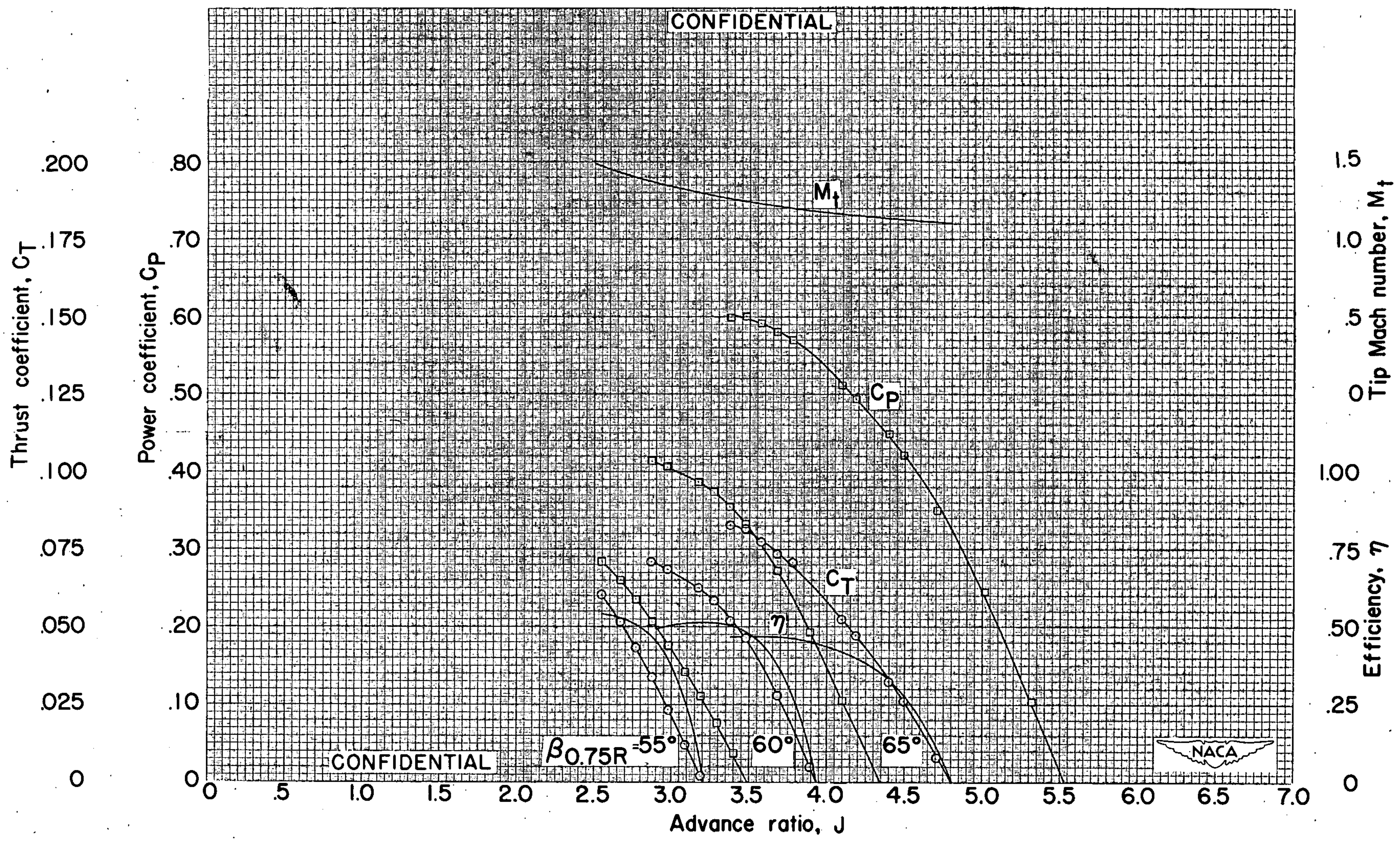
(g) M=0.85.

Figure 5 .- Continued.



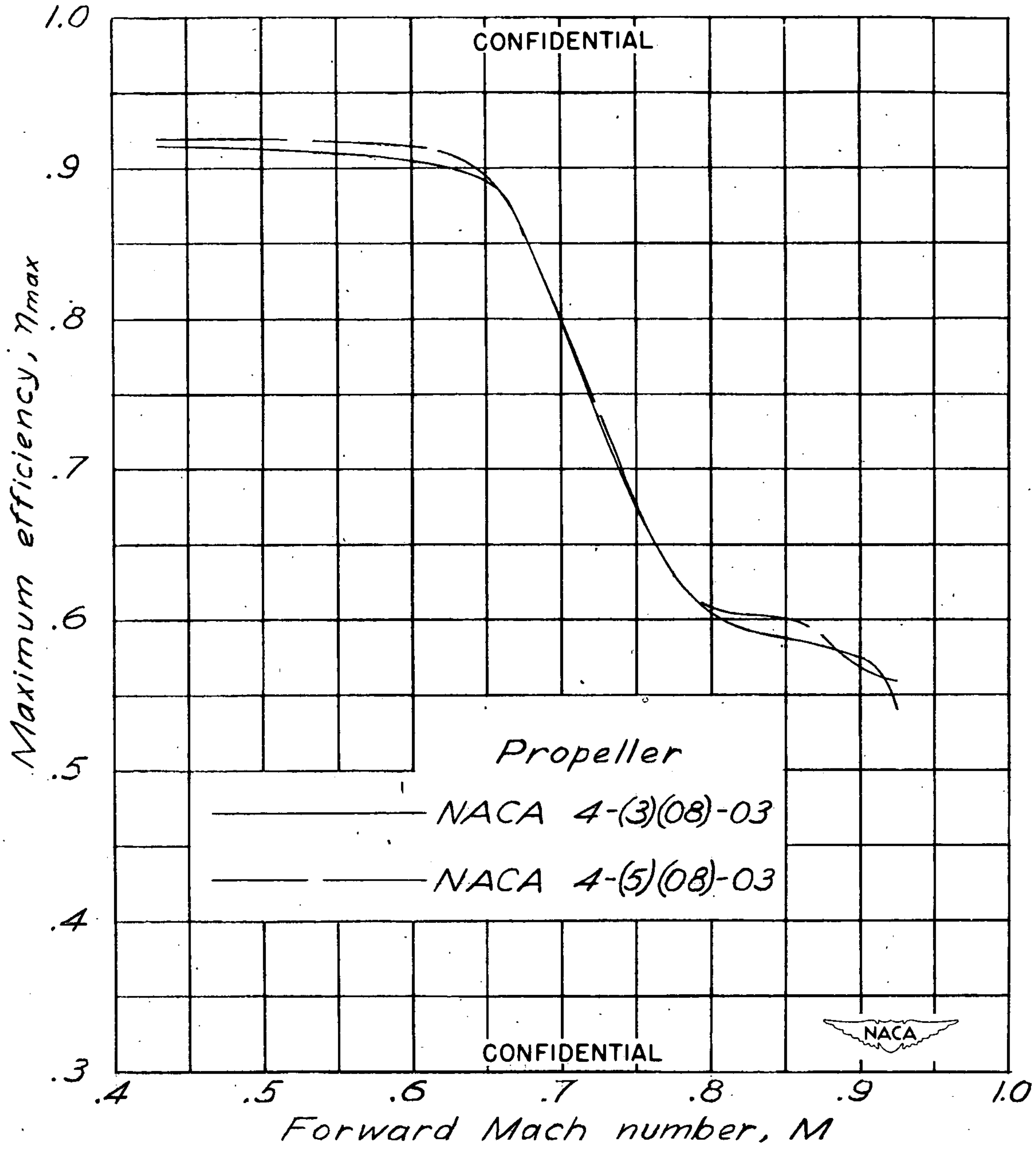
(h) M=0.90.

Figure 5 .- Continued.



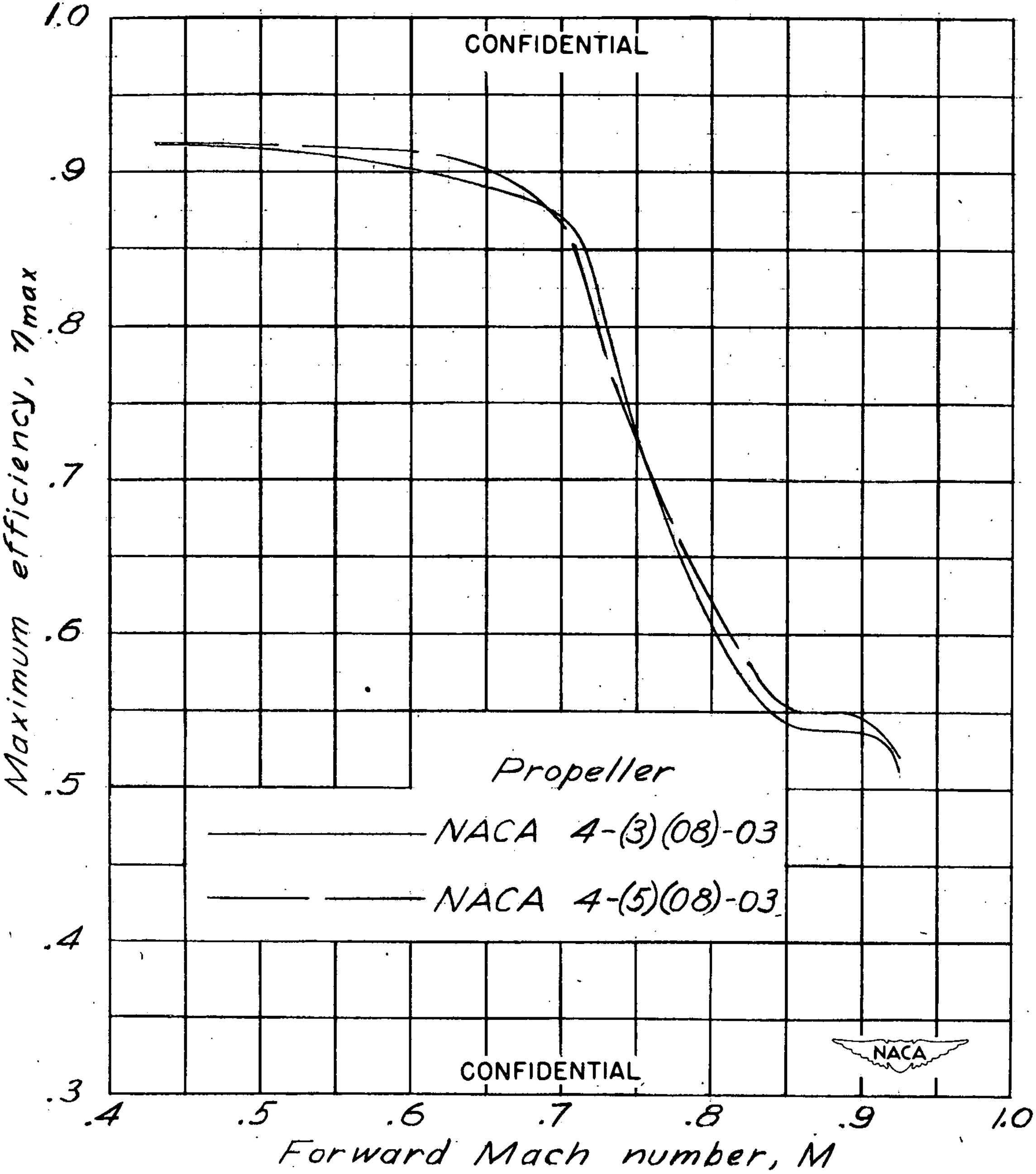
(i) M=0.925.

Figure 5 .- Concluded.



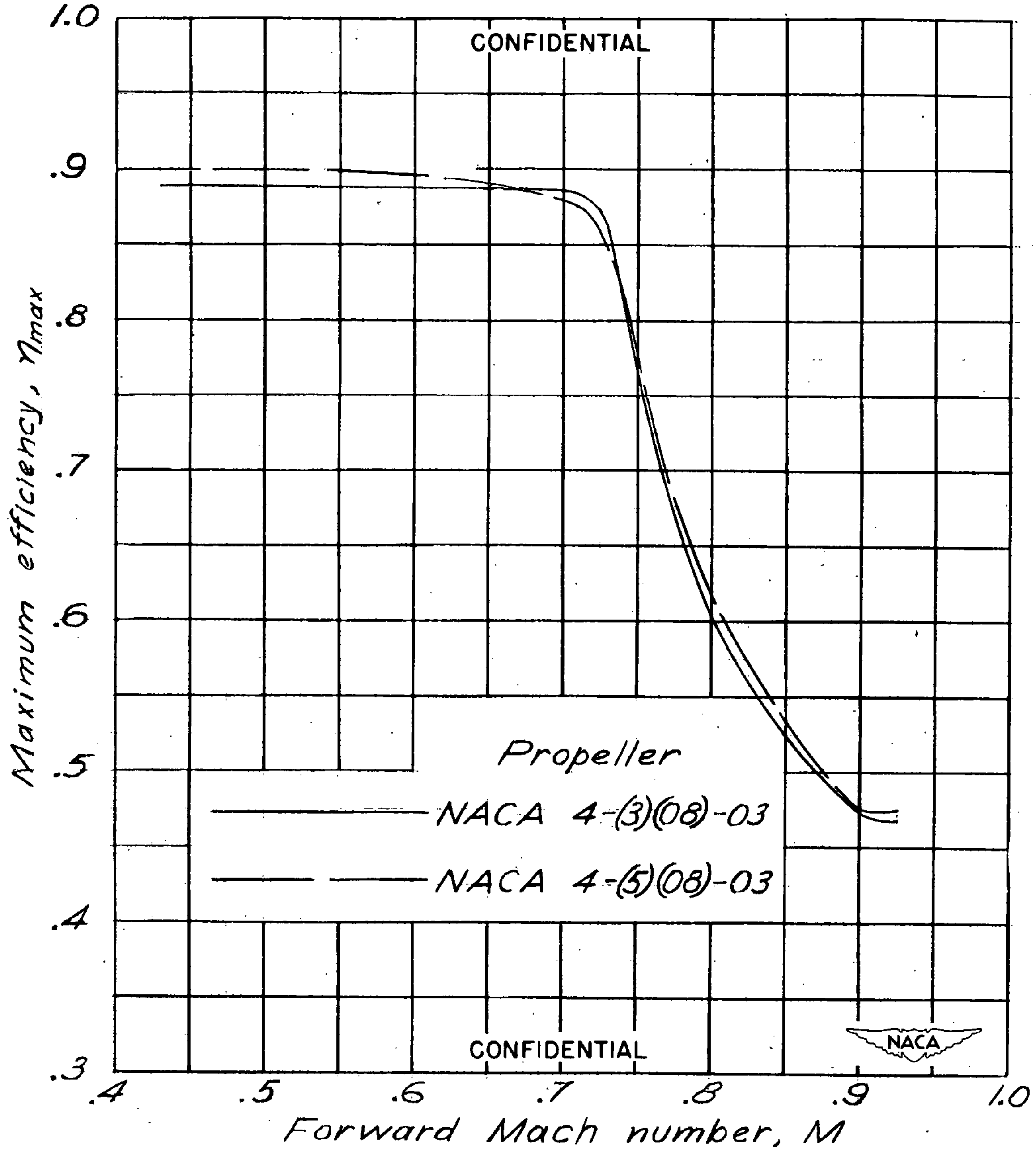
(a) $\beta_{0.75R} = 55^\circ$.

Figure 6.— Effect of forward Mach number on maximum efficiency.



(b) $\beta_{0.75R} = 60^\circ$.

Figure 6.— Continued.



(c) $\beta_{0.75R} = 65^{\circ}$.

Figure 6.— Concluded.

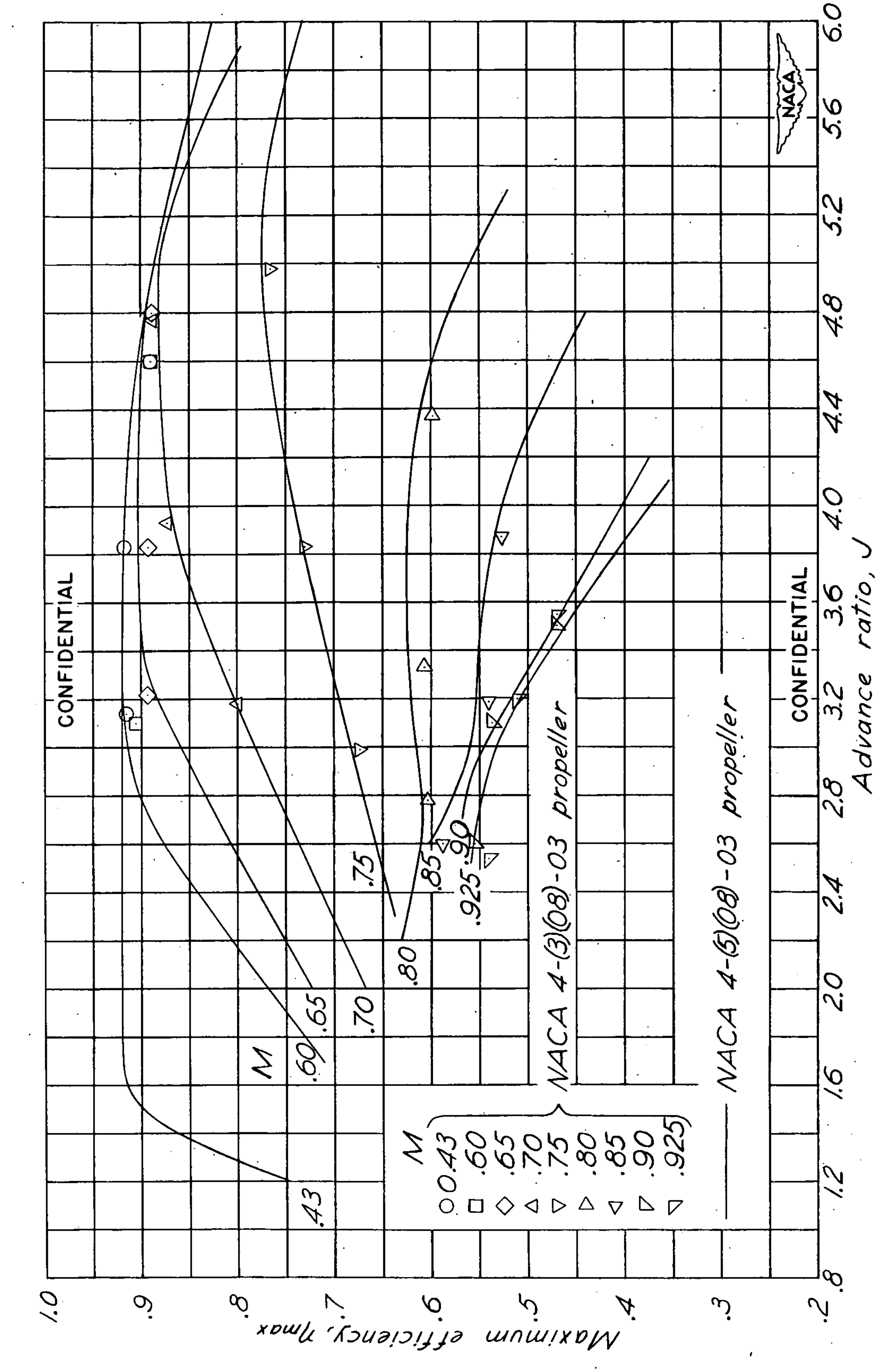


Figure 7.- Effect of forward Mach number and advance ratio on maximum efficiency.

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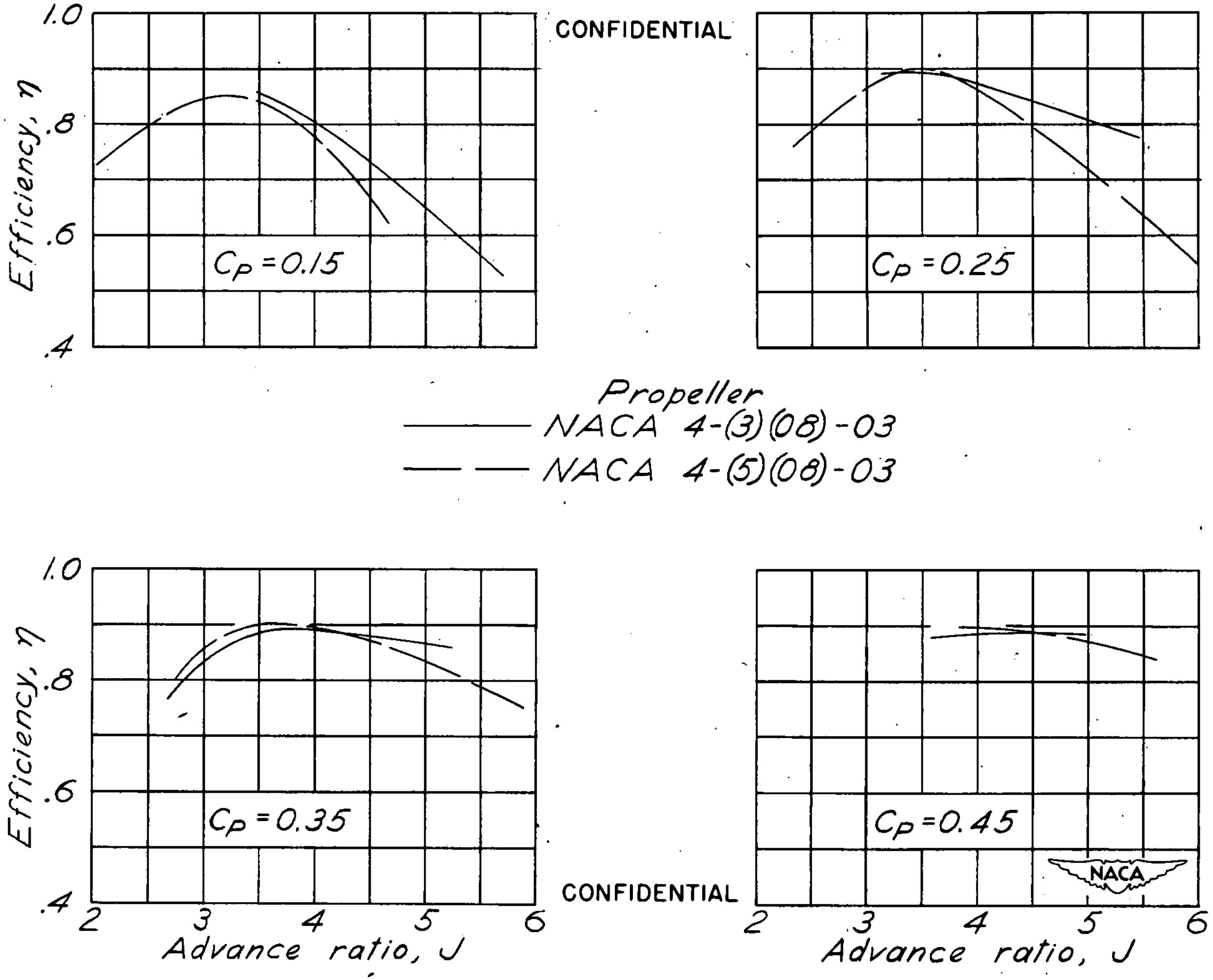

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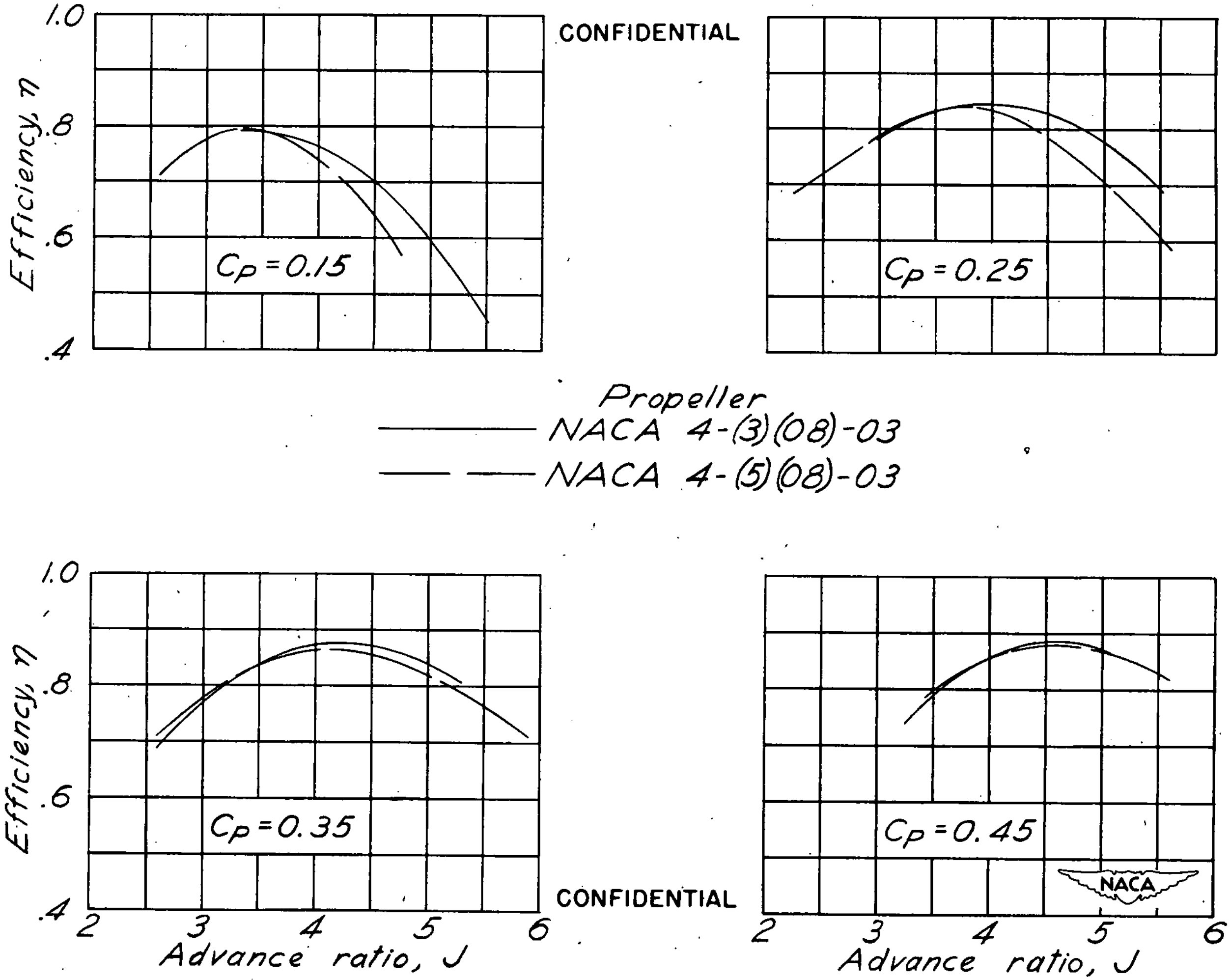
(a) M = 0.65.

Figure 8.– Effect of power coefficient and advance ratio on efficiency.



(b) M = 0.70.

Figure 8.– Continued.

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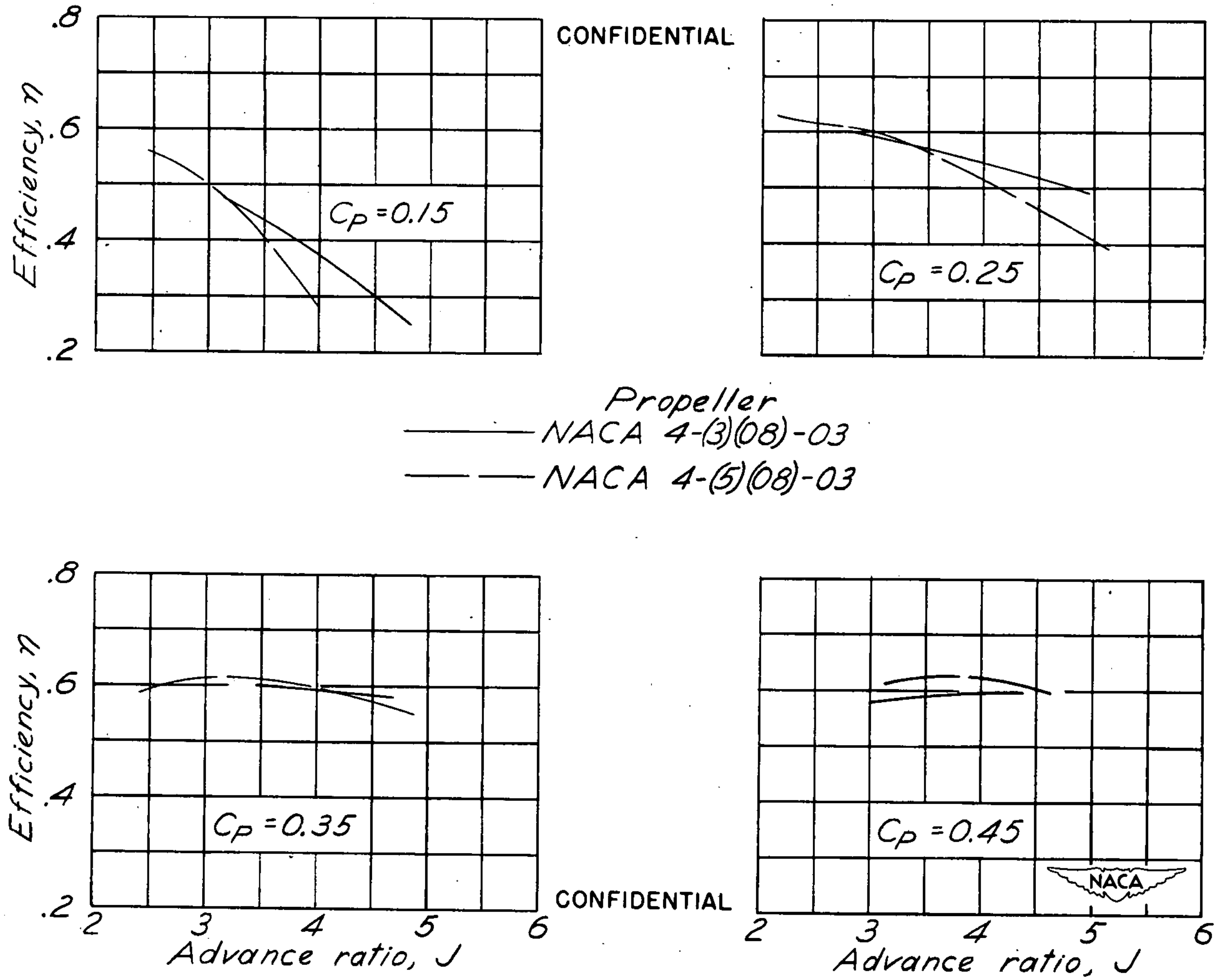

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(c) M = 0.80.

Figure 8.— Continued.

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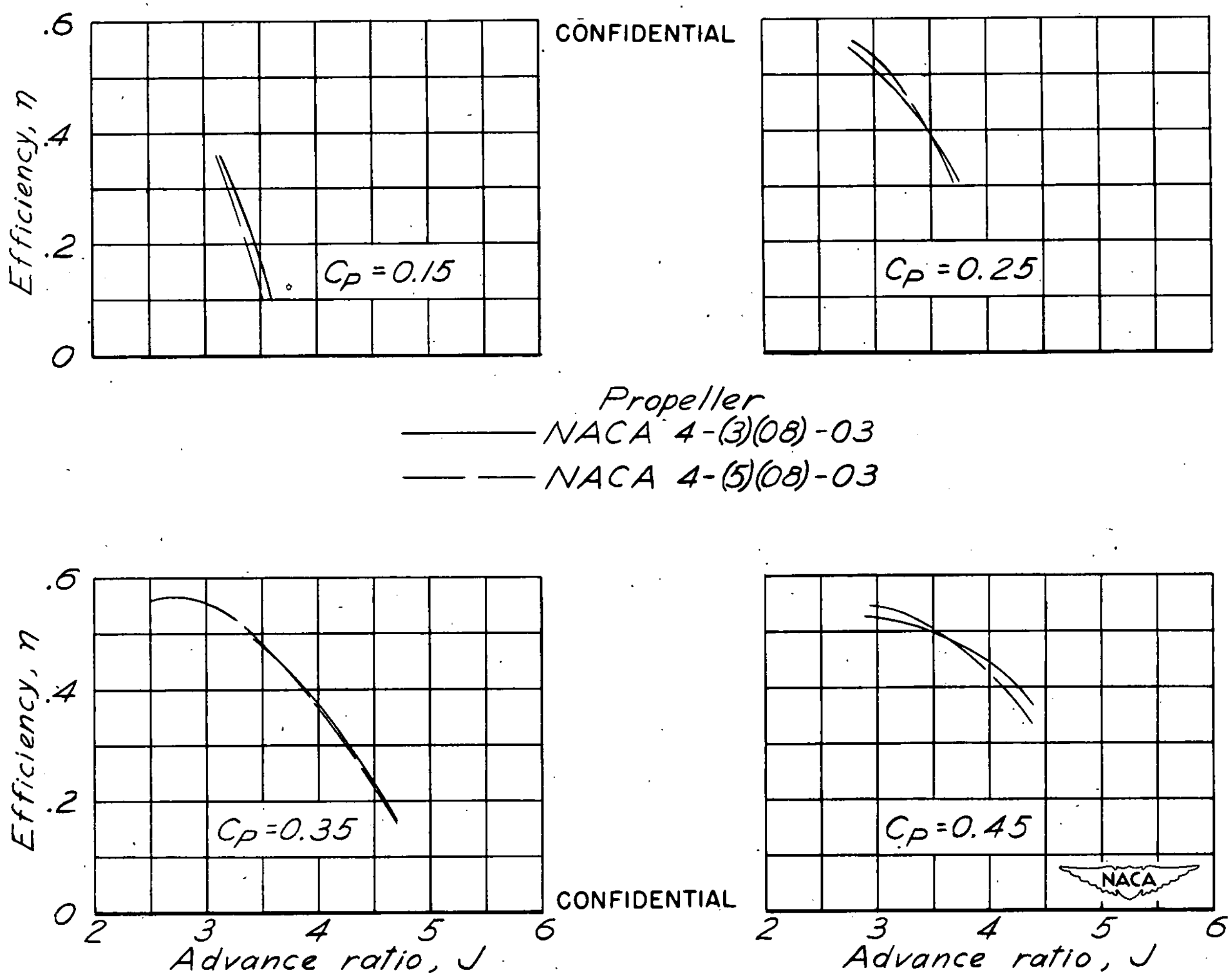

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(d) M = 0.90.

Figure 8.— Concluded.