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RESEARCH MEMORANDUM

INVESTIGATION OF NACA 4-(0)(03)-045 AND NACA 4-(0)(08)-045 TWO-BLADE PROPELLERS AT FORWARD MACH NUMBERS TO 0.925

By James B. Delano and Melvin M. Carmel

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RESEARCH MEMORANDUM

INVESTIGATION OF NACA 4-(0)(03)-045 AND NACA 4-(0)(08)-045 TWO-BLADE PROPELLERS AT FORWARD MACH NUMBERS TO 0.925

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SUMMARY

Investigations of the NACA 4-(0)(03)-045 and NACA 4-(0)(08)-045 two-blade propellers (design thickness ratios of 0.03 and 0.08, respectively, at the 0.7-radius station) have been made in the Langley 8-foot high-speed tunnel for a blade angle of 60° for the thin propeller and for blade angles of from 50° to 65° for the thick propeller at forward Mach numbers up to 0.925.

Pronounced favorable effects on the high-speed propeller efficiency were produced through reductions of blade-section thickness ratios. The onset of adverse compressibility effects was delayed approximately 0.1 in forward Mach number, and the rate of efficiency loss with forward Mach number was reduced considerably for the thin-blade propeller. At a forward Mach number of 0.85 the efficiency for the thin-blade propeller was 81 percent compared to 59 percent for the thick-blade propeller.

INTRODUCTION

The NACA is conducting a general investigation to study the effects of compressibility, design camber, blade sweep, thickness ratio, and dual rotation on propeller performance at transonic speeds. Several phases of this investigation have been completed. The effects of compressibility on propeller performance are presented in reference 1, design camber in reference 2, and blade sweep in references 3 and 4. The effect of thickness ratio on propeller performance is presented herein.

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This paper presents the force-tests results for the NACA 4-(0)(03)-045 and NACA 4-(0)(08)-045 two-blade propellers for forward Mach numbers from 0.53 to 0.925. Blade angles of 50°, 55°, 60°, and 65° were investigated for the thick propeller and only a blade angle of 60° for the thin propeller. Blade failures prevented completion of the thin-propeller investigation at this time, but new blades are being made so that the investigation can be completed in the near future. This paper is essentially a data report to expedite publication of the important results obtained. Large-scale plots of the basic propeller characteristics (fig. 5) are available on request to the NACA.

SYMBOLS

b	blade width, feet
C_P	power coefficient $\left(\frac{P}{\rho n^3 D^5}\right)$
C_T	thrust coefficient $\left(\frac{T}{\rho n^2 D^4}\right)$
D	propeller diameter, feet
$\frac{b}{D}$	blade-width ratio
h	maximum thickness
$\frac{h}{b}$	blade-thickness ratio
J	advance ratio $\left(\frac{V_o}{nD}\right)$
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 $\left(\frac{\rho V^2}{2}\right)$

R	propeller-tip radius, feet
r	blade-section radius, feet
T	thrust, pounds
T_c	thrust disk-loading coefficient $\left(\frac{T}{2qD^2}\right)$
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
β	section blade angle, degrees
$\beta_{0.75R}$	section blade angle at 0.75-tip radius, degrees
η	efficiency $\left(\frac{JC_T}{C_P}\right)$
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.

Propellers.- Two two-blade propellers 4 feet in diameter were used in this investigation. The blades were designed for a two-blade propeller having the same blade loading to produce minimum induced energy losses (profile drag assumed equal to zero) at a nominal blade angle of 60° at the 0.7-radius station and at an advance ratio of 3.36. Symmetrical NACA 16-series propeller sections were used all along the blades. These propellers have the same plan form, approximately the same pitch distribution, and essentially vary only in thickness ratio. The thick-blade propeller, NACA 4-(0)(08)-045, has the same thickness distribution as for the NACA 4-(5)(08)-03 propeller, reference 1, and the same thickness distribution and plan form as for the NACA 4-(3)(08)-045 propeller, reference 5. The thin-blade propeller, NACA 4-(0)(03)-045 has the same thickness at the root as the thick-blade propeller but tapers very rapidly along the blade. At the 0.7-radius station the thickness ratio is 0.03 as compared to 0.08 for the thick blade. A photograph of the blades is shown in figure 2 and the blade-form curves are given in figure 3.

Tests

Thrust, torque, and rotational speed were measured for all operational conditions investigated. For each tunnel Mach number the propeller was run at a constant blade angle (measured at the 0.75-radius station) and the rotational speed was varied. Investigation of the thin propeller was halted because of blade failures after completion of runs for one blade angle ($\beta_{0.75R} = 60^\circ$). The range of blade angle covered for each forward Mach number is given in the following table:

Forward Mach number	Blade angle at 0.75-radius station, $\beta_{0.75R}$ (deg)			
0.53	50			
.60	50	55		
.65	50	55	[a]60	
.70	50	55	[a]60	65
.75	50	55	[a]60	65
.80	50	55	[a]60	65
.85		55	[a]60	65
.90		55	[a]60	65
.925		55	[a]60	65

[a]Only $\beta_{0.75R} = 60^\circ$ was run for the NACA 4-(0)(03)-045 propeller.

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.

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

Tunnel-wall correction.- The force-test data have been corrected for the effect of tunnel-wall constraint on velocity at the propeller test plane by using the method described in reference 1. The 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 the tunnel-datum Mach number.

Accuracy of results.- Analysis of the accuracy of the separate measurements required to define completely the propeller characteristics has indicated that errors in the results presented herein are probably less than 1 percent.

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 for both propellers. The maximum efficiencies for the thick propeller are about 2 percent higher than for the thin propeller at subcritical forward Mach numbers. The use of thin blade sections delayed the onset of adverse compressibility effects by approximately 0.1 in forward Mach number and reduced considerably the rate of efficiency loss with forward Mach number. At a forward Mach number of 0.85, the efficiency for the thin propeller was 81 percent compared to 59 percent for the thick propeller for a blade angle of 60°.

CONCLUSIONS

Comparison of force-test results obtained for the NACA 4-(0)(03)-045 and NACA 4-(0)(08)-045 two-blade propellers at forward Mach numbers up to 0.925 showed that reductions in the section thickness ratio had a pronounced favorable effect on the high-speed efficiency of the propeller. The use of thin blade sections delayed the onset of adverse compressibility effects approximately 0.1 in forward Mach number and reduced considerably the rate of efficiency loss with forward Mach number.

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REFERENCES

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2. Delano, James B., and Morgan, Francis G., Jr.: Investigation of the NACA 4-(3)(08)-03 Two-Blade Propeller at Forward Mach Numbers to 0.925. NACA RM L9I06, 1949.

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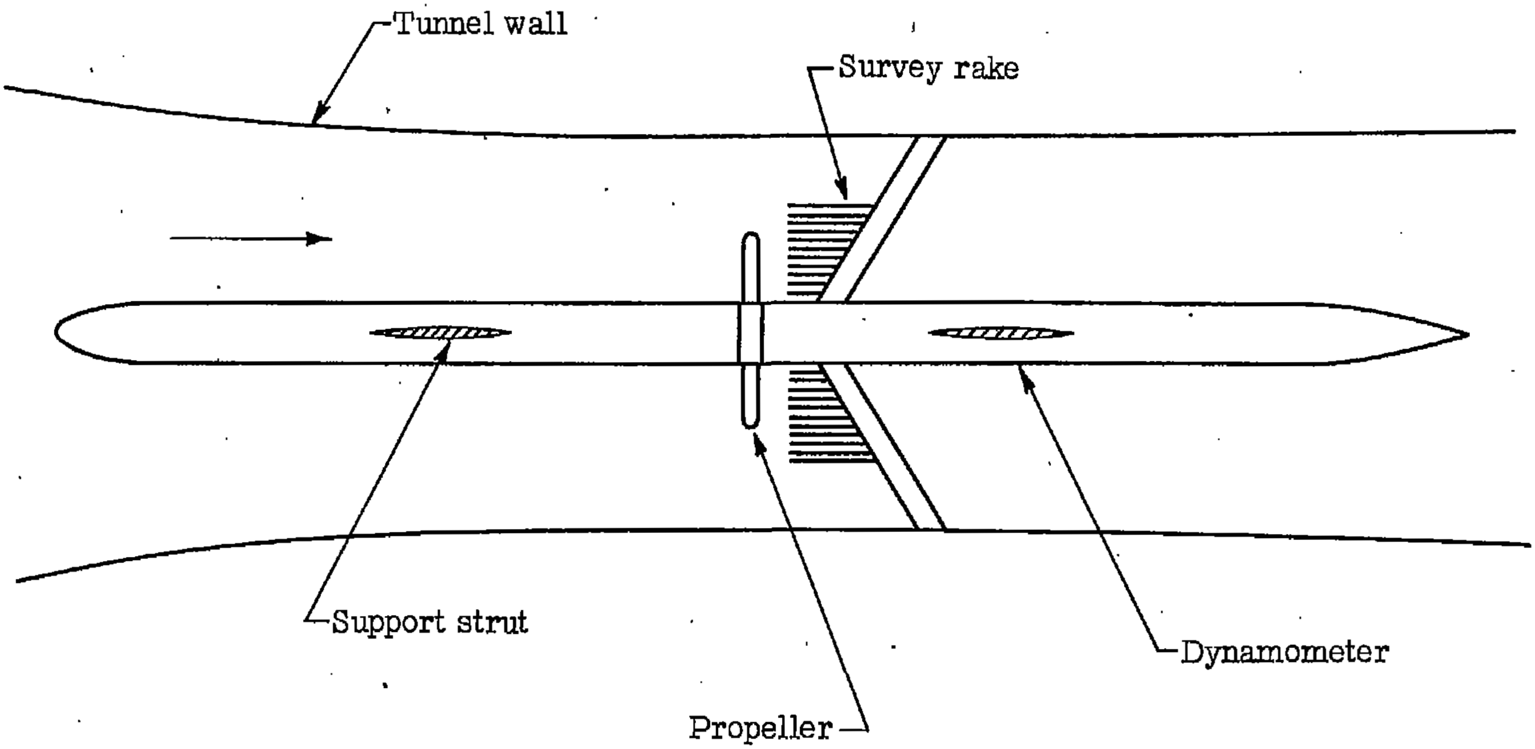

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Figure 1.– Test apparatus.

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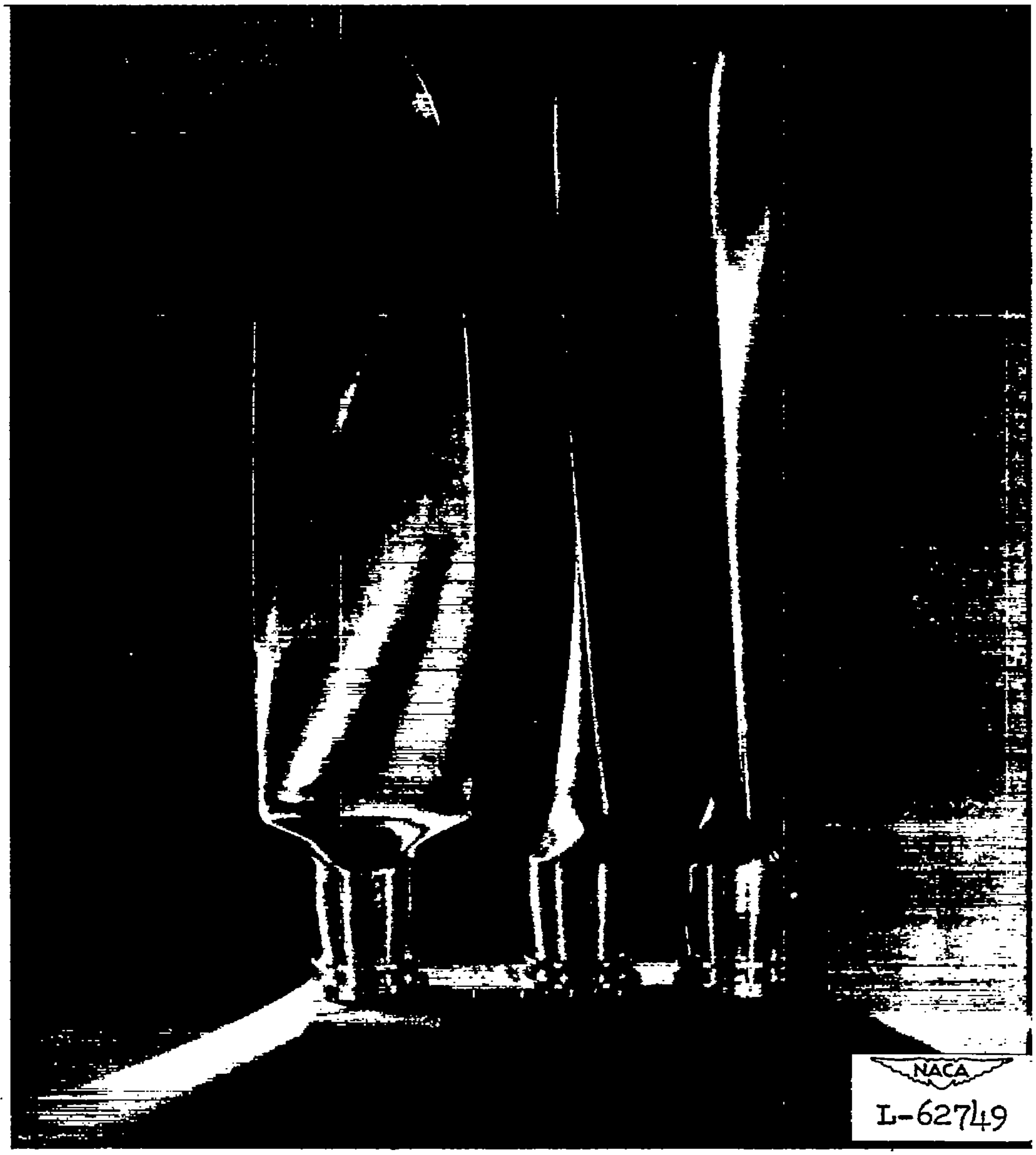

Figure 2.– Photograph of NACA 4–(0)(03)–045 and 4–(0)(08)–045 propellers.

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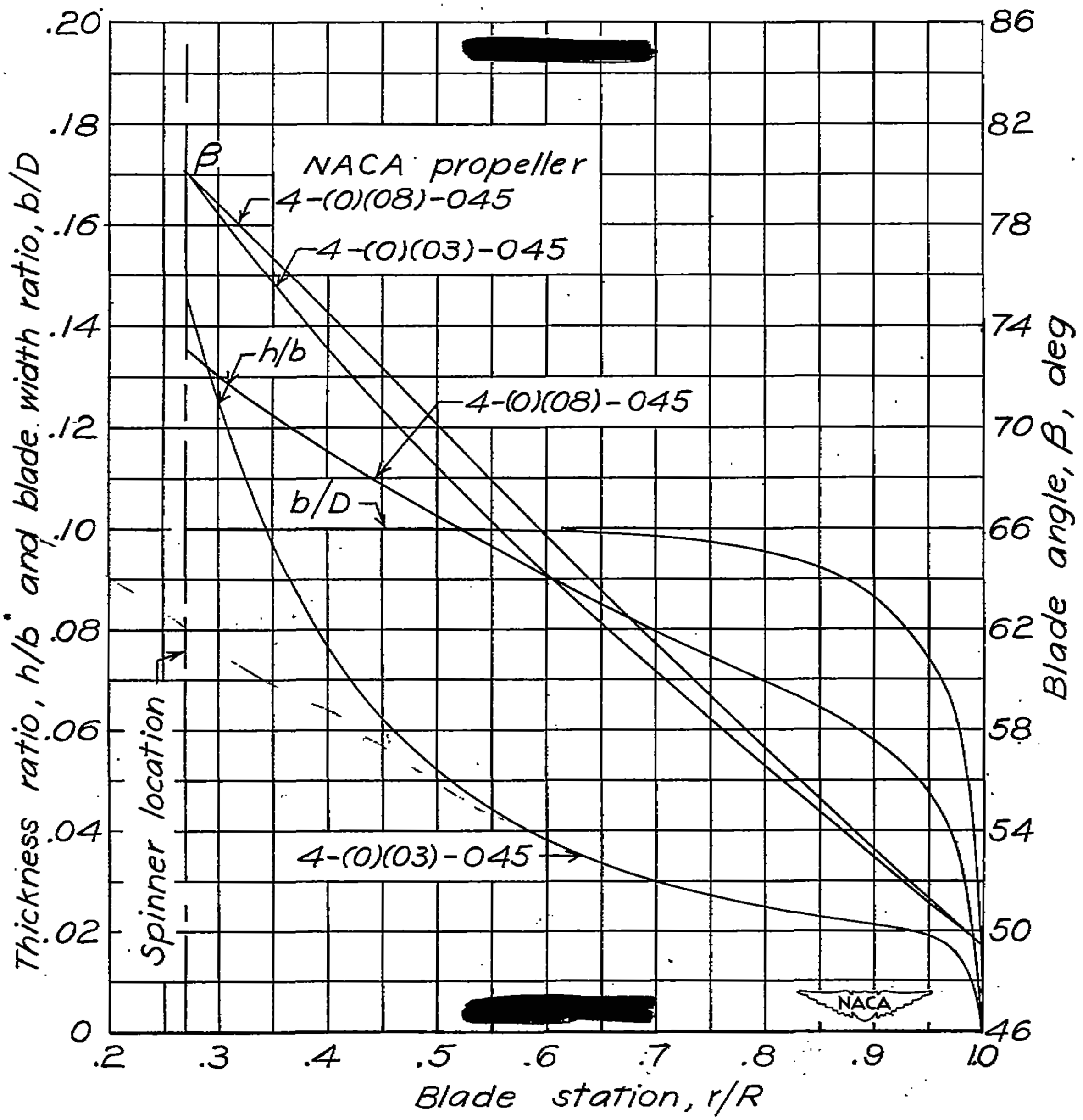

Figure 3.- Blade-form curves for NACA 4-(0)(03)-045 and 4-(0)(08)-045 propellers.

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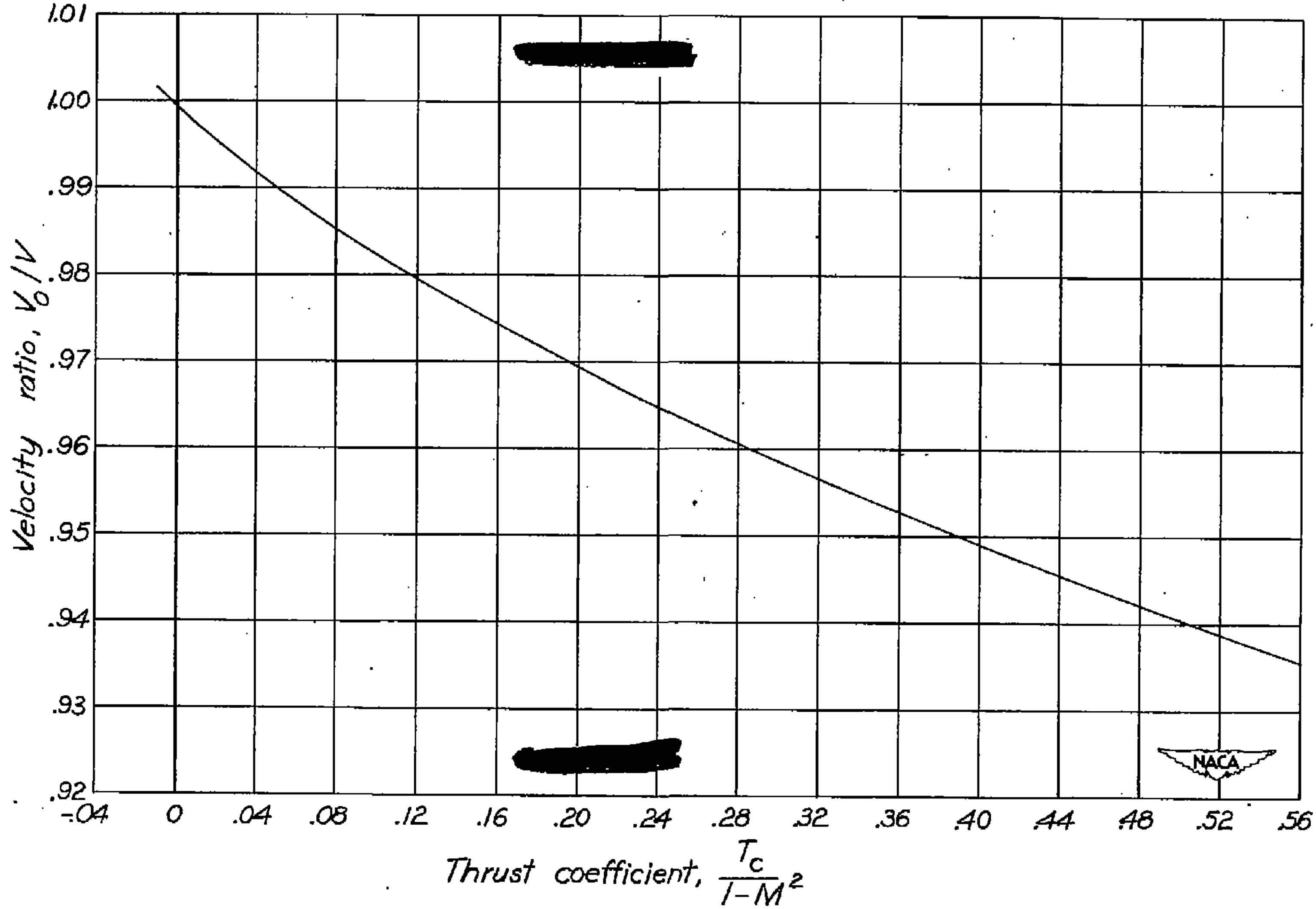

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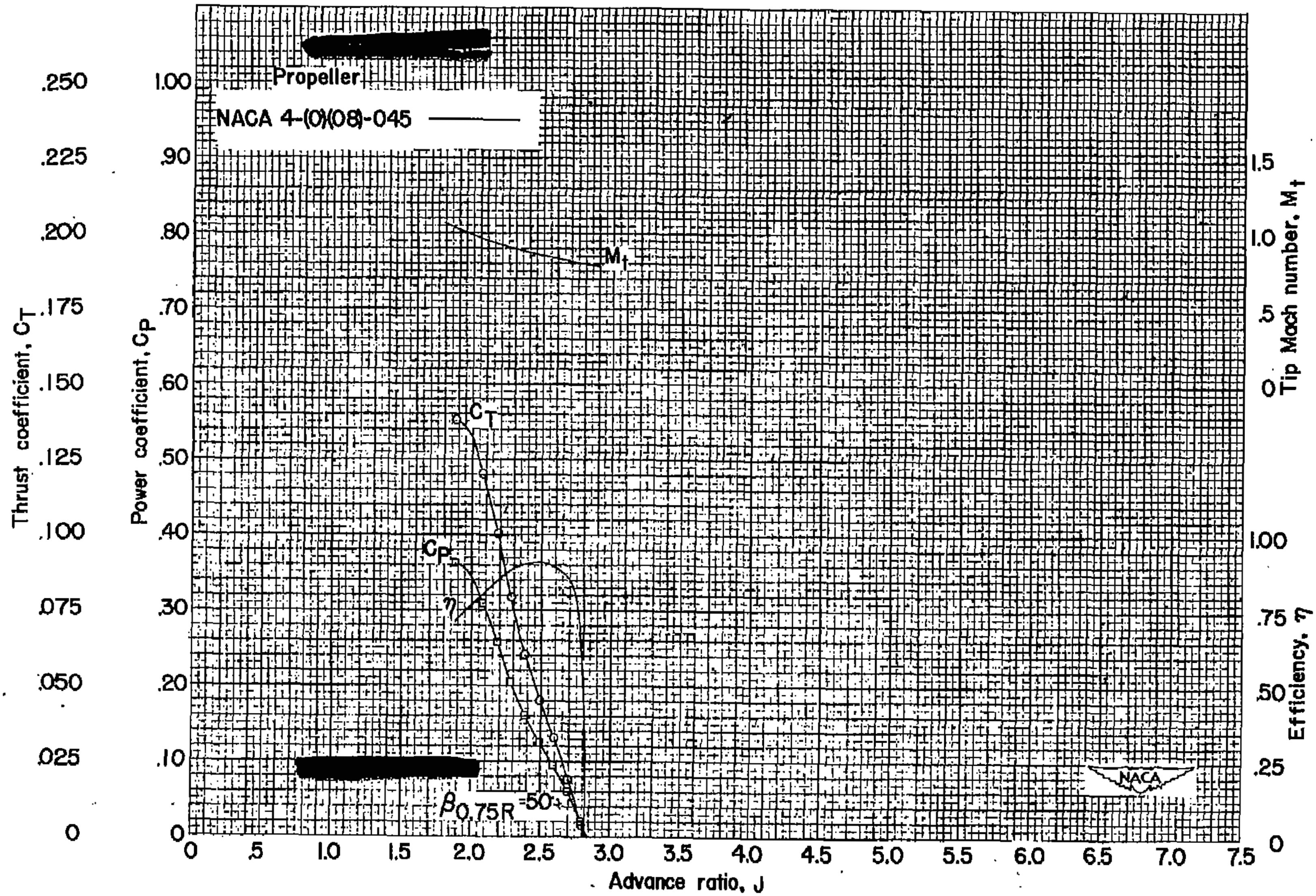
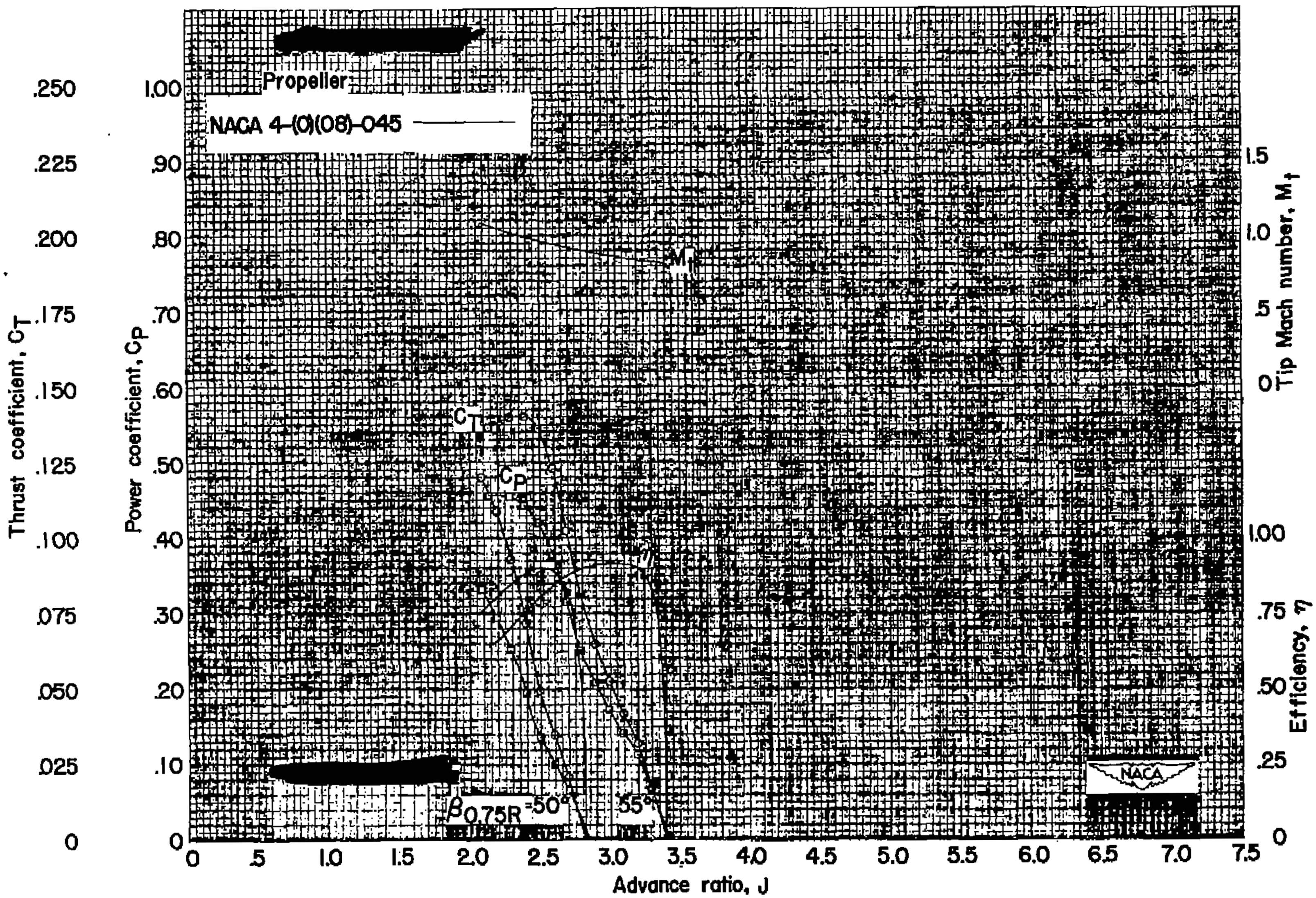
Figure 4.- Tunnel-wall-interference correction for 4-foot-diameter propeller in Langley 8-foot high-speed tunnel.



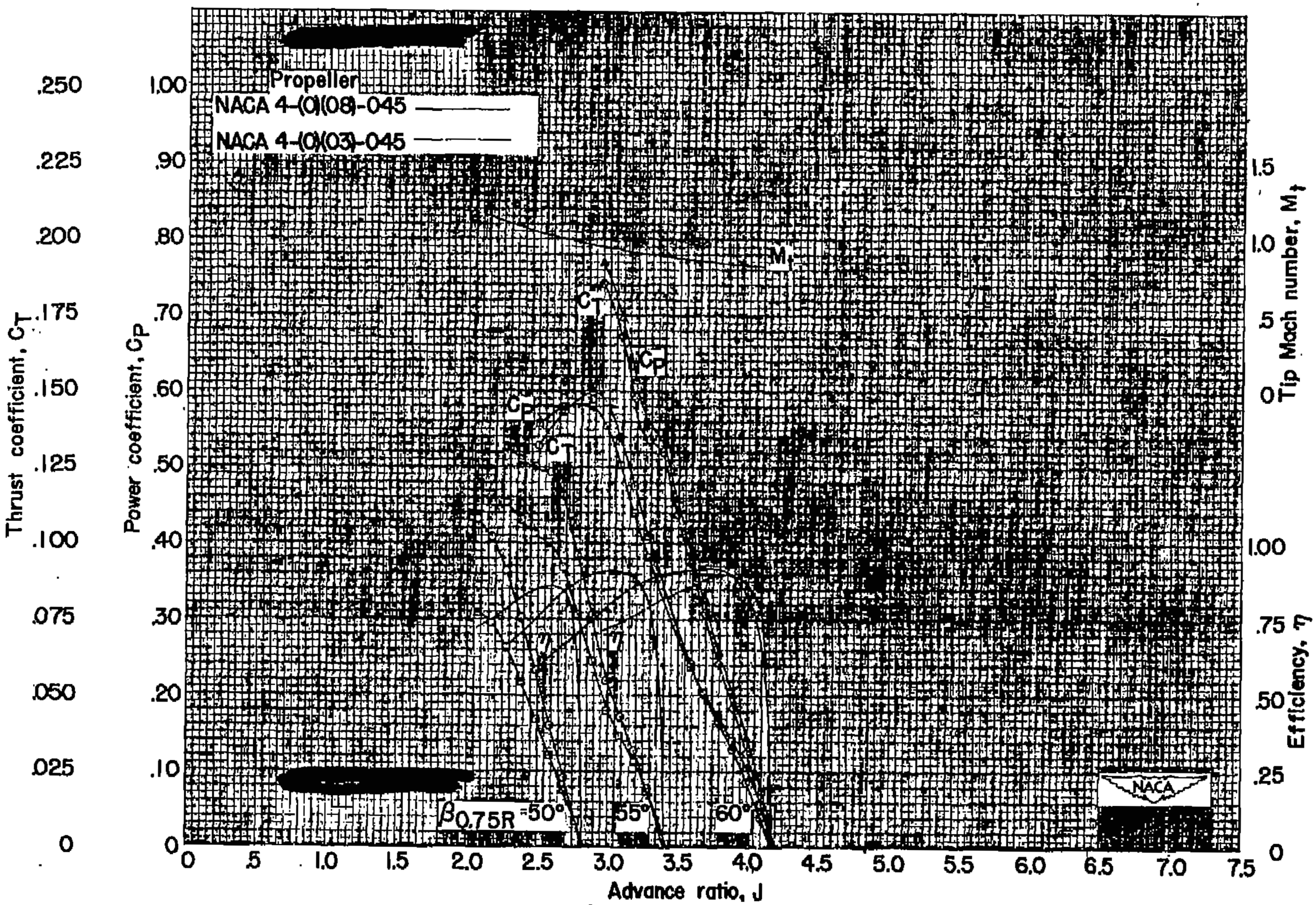
(a) M=0.53.

Figure 5.- Characteristics of NACA 4-(0)(08)-045 and NACA 4-(0)(03)-045 propellers.



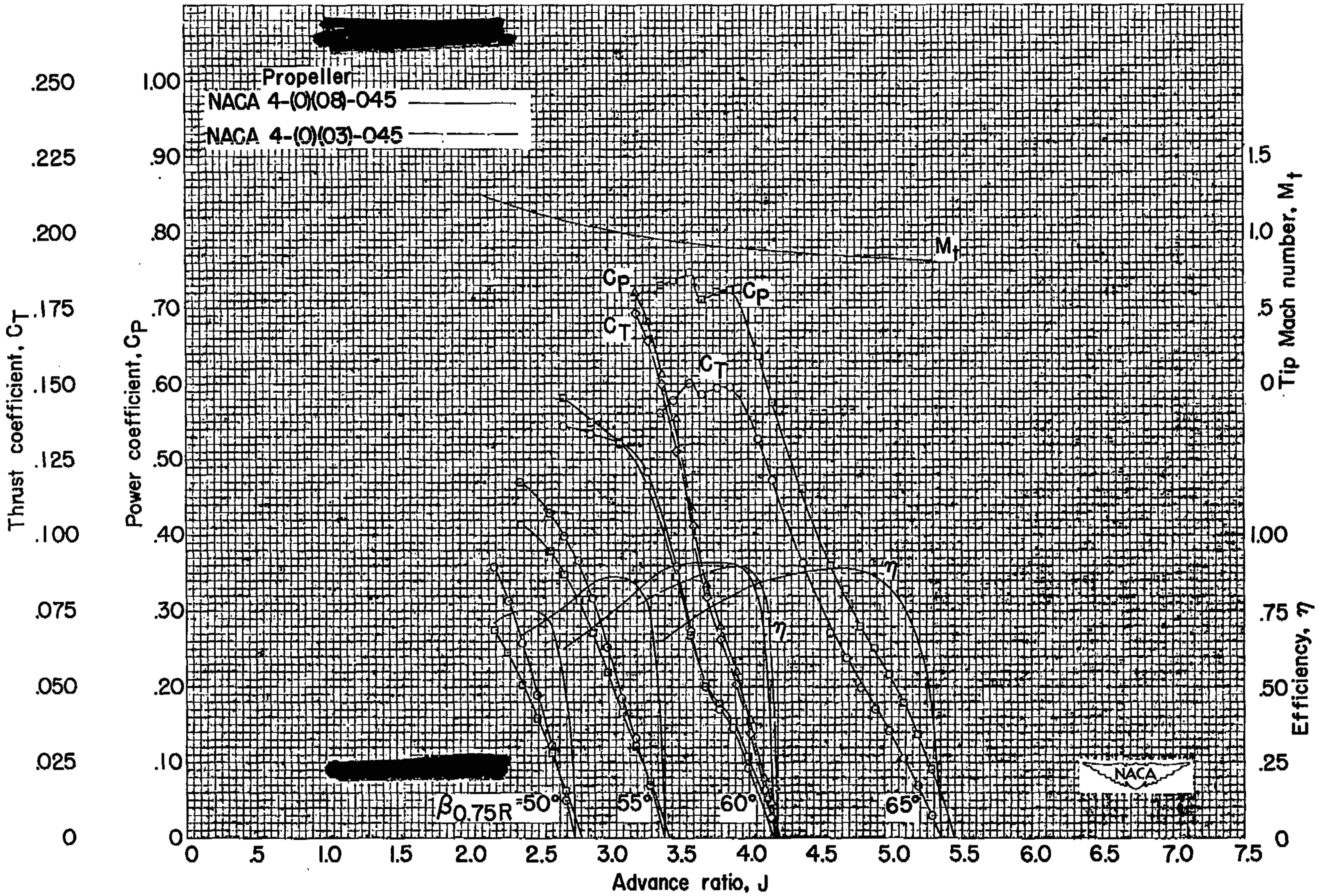
(b) M=0.60.

Figure 5 .- Continued.



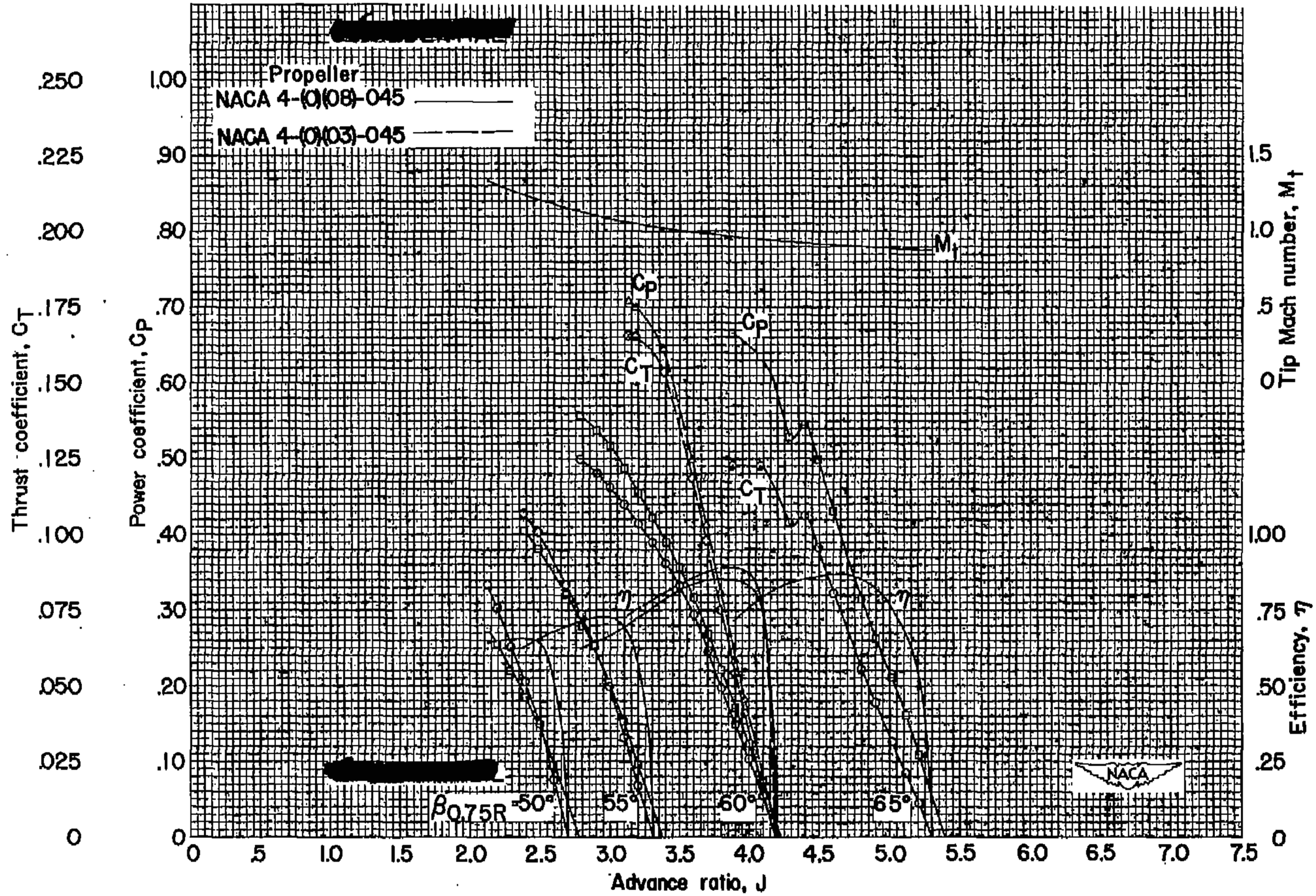
(c) M=0.65.

Figure 5.- Continued.



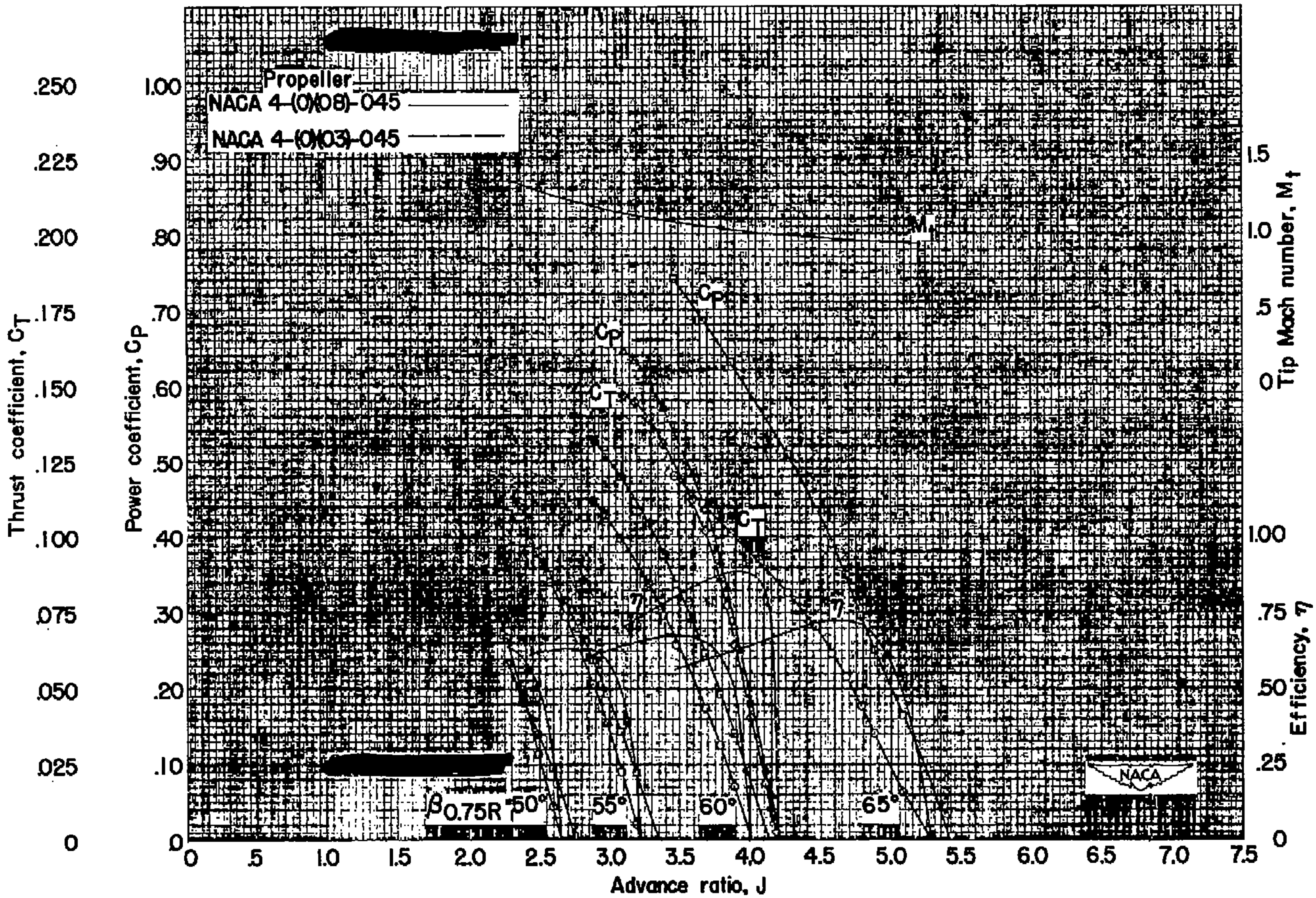
(d) M=0.70.

Figure 5 .- Continued.



(e) M=0.75.

Figure 5 .- Continued.



(f) M=0.80.

Figure 5 .- Continued.

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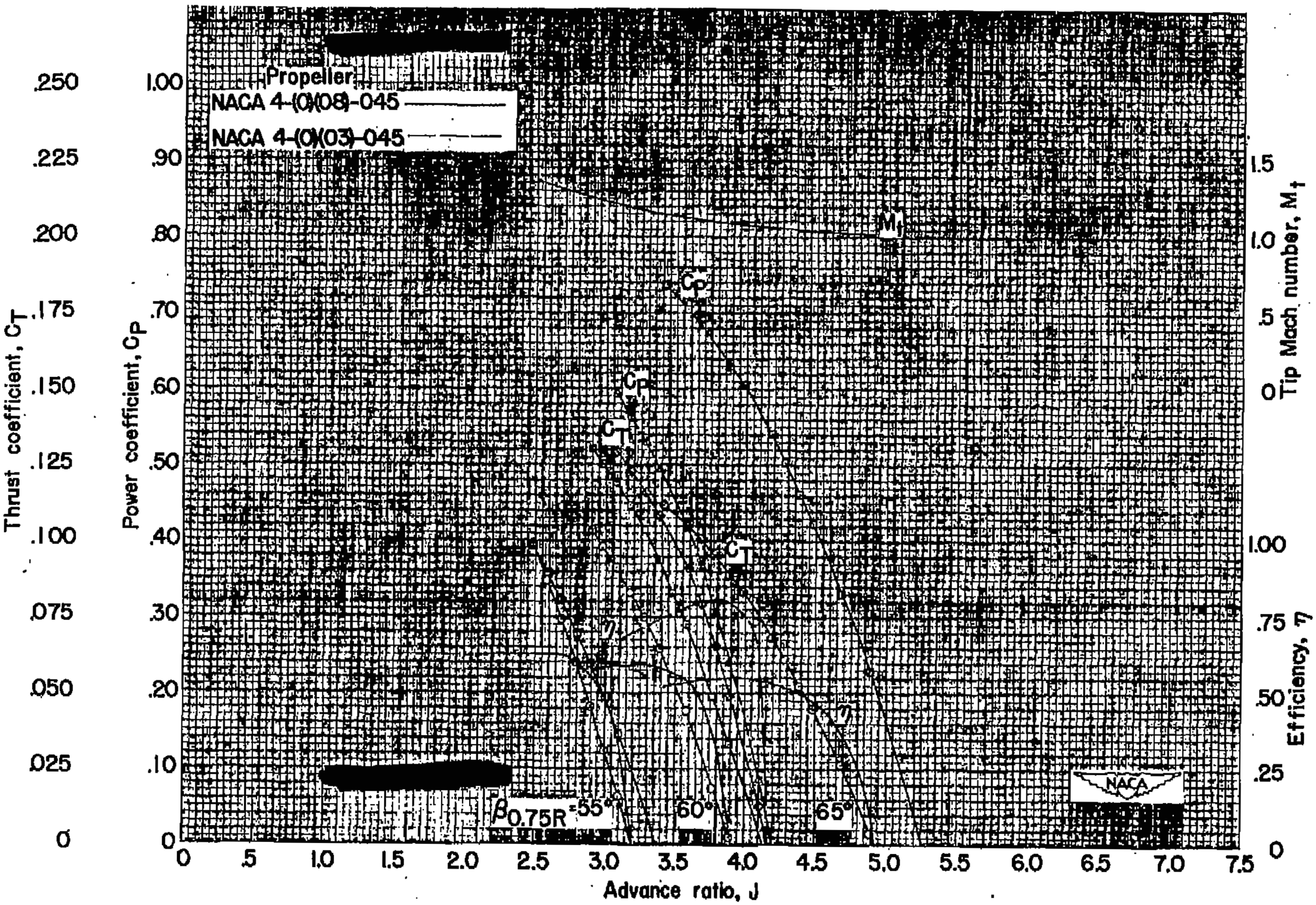
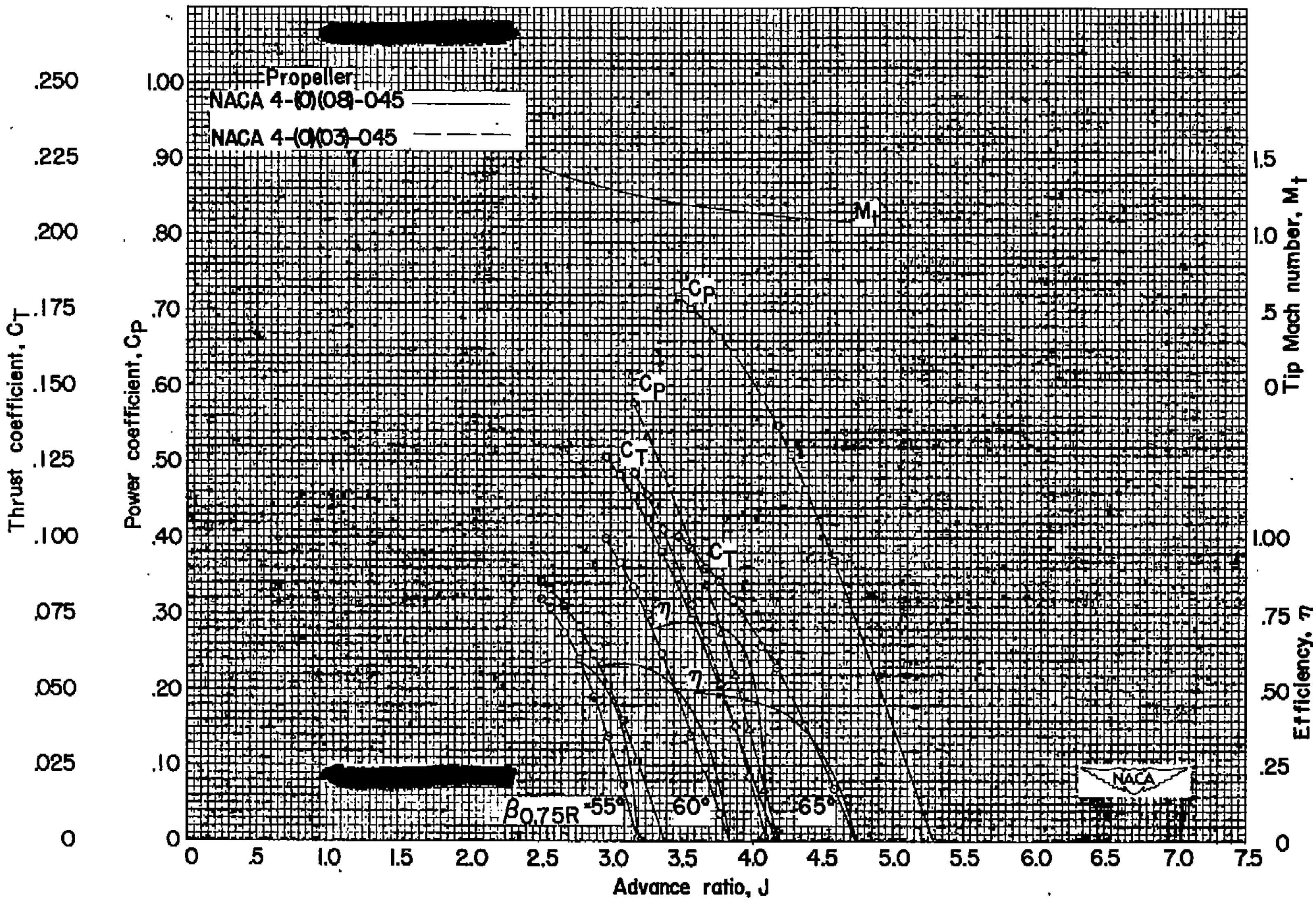


(g) M=0.85.

Figure 5 .- Continued.



(h) M=0.90.

Figure 5 .- Continued.

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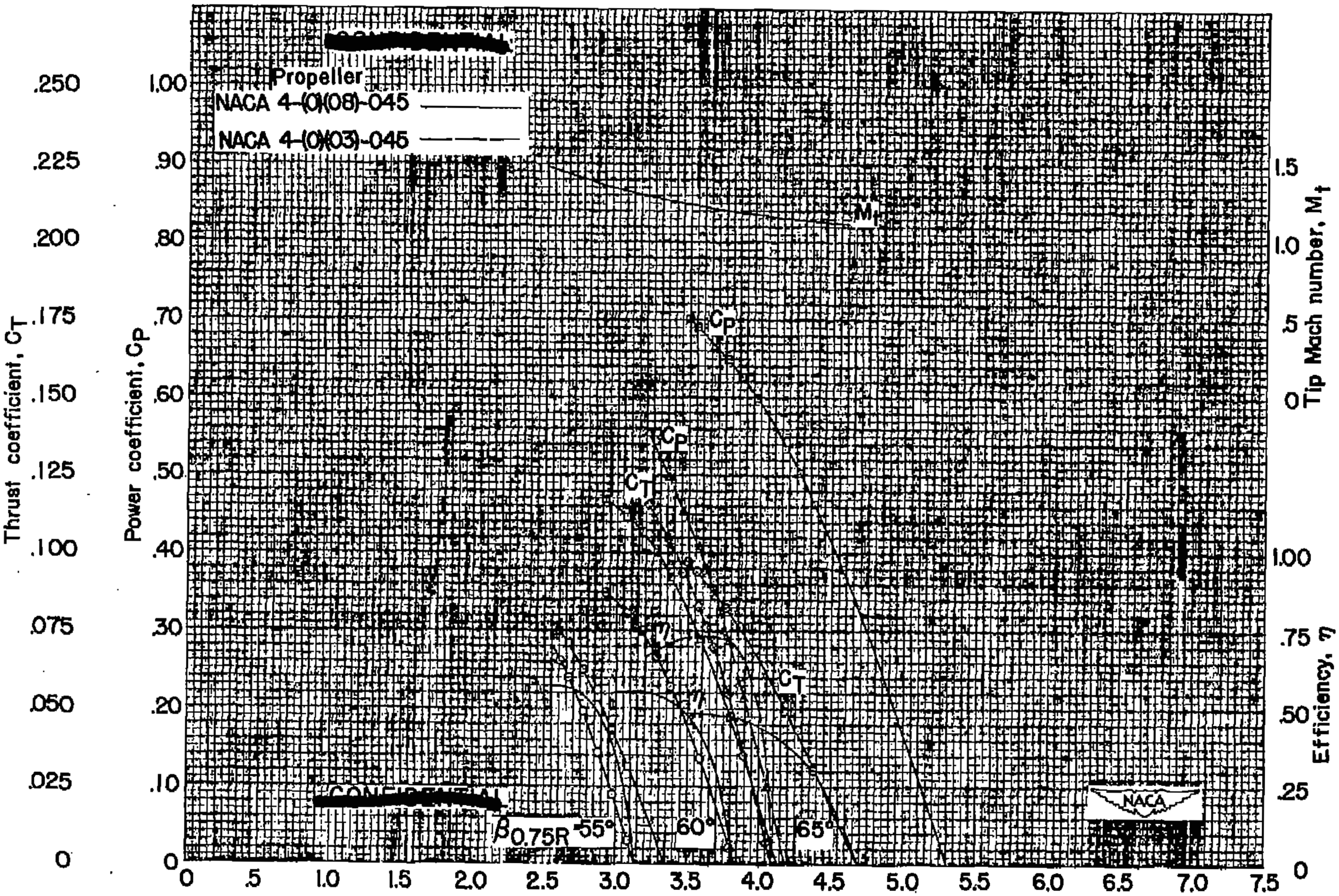

(l) M=0.925.

Figure 5 - Concluded.

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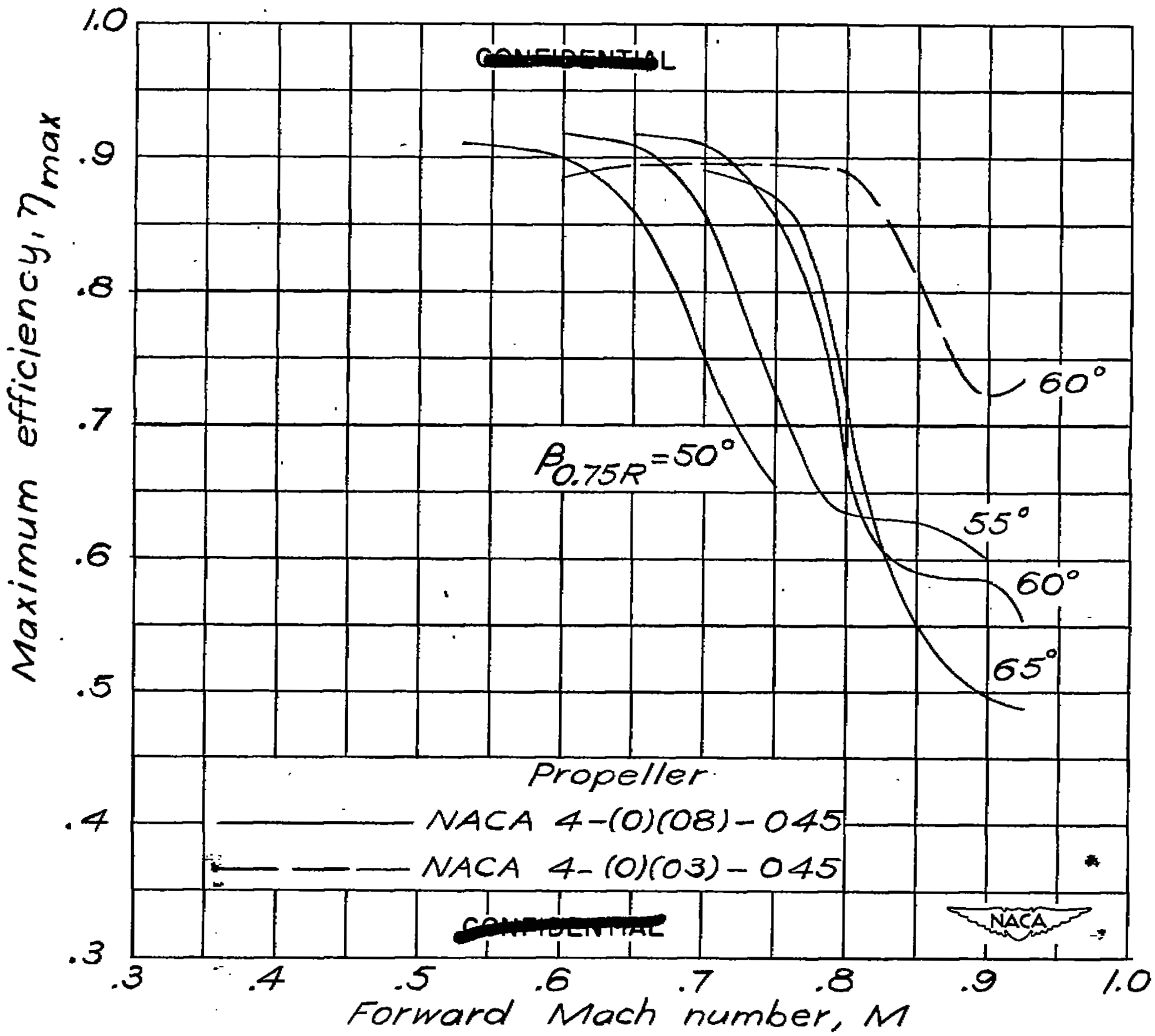

Figure 6.- Effect of forward Mach number on maximum efficiency.