RM No. E6J23

RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

ALTITUDE-WIND-TUNNEL INVESTIGATION OF PERFORMANCE OF SEVERAL PROPELLERS ON YP-47M AIRPLANE AT HIGH BLADE LOADINGS

IV - CURTISS 732-1C2-0 FOUR-BLADE PROPELLER

By Martin J. Saari and Solomon M. Sorin

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Cleveland, Ohio

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An altitude-wind-tunnel investigation has been made to determine the performance of a Curtiss 732-1C2-0 four-blade propeller on a YP-47M airplane at high blade loadings and engine powers. Propeller characteristics were obtained for a range of power coefficients from 0.30 to 1.00 at free-stream Mach numbers of 0.40 and 0.50. The results of the force measurements indicate primarily the trend of propeller efficiency for changes in power coefficient or advance-diameter ratio because corrections for the effects of tunnel-wall constriction have not been applied. Slipstream surveys are presented to illustrate the blade thrust load distribution for certain operating conditions.

At a free-stream Mach number of 0.40 the highest efficiencies were obtained at a power coefficient of 0.30 in the low range of advance-diameter ratios and at a power coefficient of 0.90 in the high range of advance-diameter ratios. The envelope of efficiency curves for power coefficients from 0.30 to 0.90 decreased about 8 percent between advance-diameter ratios of 2.10 and 4.00. The thrust loading increased more rapidly on the outboard blade sections than on the inboard sections as the power coefficient was increased or as the advance-diameter ratio was decreased. Within the range of power coefficients and advance-diameter ratios investigated at a free-stream Mach number of 0.40, there was no evidence of blade stall or compressibility effects. At a free-stream Mach number of 0.50 maximum efficiencies were obtained at power coefficients from 0.50 to 0.70 at advance-diameter ratios between 2.10 and 2.50. The envelope of efficiency curves for power coefficients from 0.50 to 1.00 decreased by about 17 percent between advance-diameter ratios of 2.10 and 4.00.

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INTRODUCTION

An investigation of the performance of several propellers on the YP-47M airplane at high blade loadings has been conducted in the Cleveland altitude wind tunnel at the request of the Air Materiel Command, Army Air Forces. As part of the program, a study was made of a Curtiss 732-1C2-0 four-blade propeller. The results of the investigation and a brief discussion of the characteristics of this propeller are presented.

The characteristics of the propeller were obtained for a range of power coefficients from 0.30 to 1.00 at free-stream Mach numbers of 0.40 and 0.50. The investigation was conducted at density altitudes from 20,000 to 45,000 feet for engine powers from 150 to 2500 brake horsepower at engine speeds from 1100 to 2900 rpm.

The propeller efficiencies were determined from force measurements and the blade thrust distributions were obtained from total-pressure surveys in the propeller slipstream (reference 1).

PROPELLER AND POWER PLANT

A general description of the propeller and power plant is as follows:

Propeller	
Blade design	Curtiss 732-1C2-0
Number of blades	four
Blade sections	NACA 16 series
Propeller diameter	13 feet, 0 inch
Activity factor[1]	150
Propeller gear ratio	20:9
Engine	R-2800-73
War emergency rating:	
Engine speed, rpm	2800
Manifold pressure, in. Hg	72.0
Brake horsepower	2800
Military power rating:	
Engine speed, rpm	2800
Manifold pressure, in. Hg	53.5
Brake horsepower	2100
Normal power rating:	
Engine speed, rpm	2600
Manifold pressure, in. Hg	41.5
Brake horsepower	1700

[1]The activity factor is a nondimensional function of the propeller plan form designed to express the integrated capacity of the propeller blade elements for absorbing power (reference 1).

The propeller blade-form characteristics are given in figure 1. The Curtiss 732-1C2-0 propeller blade is shown in figure 2.

APPARATUS AND PROCEDURE

The assembled propeller as installed on the YP-47M airplane in the 20-foot-diameter test section of the altitude wind tunnel is shown in figure 3. Details of the equipment are given in reference 1.

The propeller characteristics were obtained for a range of power coefficients from 0.30 to 1.00 at free-stream Mach numbers of 0.40 and 0.50. The investigation was conducted at density altitudes from 20,000 to 45,000 feet for engine powers from 150 to 2500 brake horsepower at engine speeds from 1100 to 2900 rpm.

REDUCTION OF DATA

The method of data reduction was the same as that described in reference 1. The force measurements were analyzed in terms of the variation of the propeller efficiency η with the propeller power coefficient C_P and the advance-diameter ratio J. These quantities were computed from the following equations:

$$C_P = \frac{P}{\rho n^3 D^5}$$

where

D propeller diameter, feet

n propeller rotational speed, revolutions per second

P engine power, foot-pounds per second

ρ free-stream density, slugs per cubic foot

$$J = \frac{V}{nD}$$

where V is the free-stream velocity in feet per second.

$$\eta = \frac{C_T J}{C_P}$$

The propeller thrust coefficients C_T in the efficiency formula was defined as

$$C_T = \frac{T}{\rho n^2 D^4}$$

where T is the propeller thrust in pounds.

Propeller tip Mach number M_t was obtained from the equation

$$M_t = M_o \sqrt{1 + \left(\frac{\pi}{J}\right)^2}$$

where M_o is the free-stream Mach number.

The slipstream surveys were presented as plots of the total-pressure differential $H_s - H_o$ against the square of the radius ratio $(r_s/R)^2$ where

H_o free-stream total pressure, pounds per square foot

H_s total pressure at survey point, pounds per square foot

R propeller radius to tip, inches

r_s radial distance from thrust axis to survey point, inches

RESULTS AND DISCUSSION

The propeller characteristics for various blade loading conditions are separately presented for free-stream Mach numbers of 0.40 and 0.50 because it was impossible to compare the data obtained at different free-stream Mach numbers owing to the variation of tunnel-wall constriction effects with airspeed. As in references 1 to 3, the results of the force measurements are of value primarily in showing the trend of propeller efficiency for changes in power coefficient or advance-diameter ratio. The absolute efficiency values are questionable inasmuch as an average drag coefficient for the installation was used for all of the propellers investigated and because no corrections have been applied for the effects of tunnel-wall constriction. Slipstream surveys are presented to illustrate blade thrust load distribution for several operating conditions.

Free-stream Mach number, 0.40. - The propeller characteristics at a free-stream Mach number of 0.40 are presented in figure 4 for a range of power coefficients from 0.30 to 1.00. The variation of propeller efficiency with power coefficient is shown in figure 5 for approximately constant values of advance-diameter ratio.

The highest efficiency in the low range of advance-diameter ratios was obtained at a power coefficient of 0.30 and in the high range of advance-diameter ratios at a power coefficient of 0.90. The envelope of the efficiency curves for power coefficients from 0.30 to 0.90 decreased about 8 percent between advance-diameter ratios of 2.10 and 4.00. (See fig. 4.)

The effect of power coefficient on blade thrust load distribution is shown by the slipstream surveys in figure 6, which correspond to the conditions of figure 5 for $J \approx 2.10$. The blade thrust load distributions for power coefficients from 0.31 to 0.81 were uniform and similar. The magnitudes of the blade thrust loadings in figures 6(a) and 6(b) cannot be compared with those in figures 6(c) to 6(e) because the density altitudes were different.

The difference between the right and left surveys apparent in figure 6, as well as in all subsequent slipstream surveys, was due to a slight misalinement of the approaching air stream and the propeller thrust axis. (See reference 4.)

Blade thrust load distribution curves corresponding to the conditions of figure 5 for $J \approx 2.80$ are shown in figure 7 for power coefficients between 0.30 and 1.05. The blade thrust load distribution remained uniform and the blade thrust loading increased as the power coefficient was increased from 0.30 to 0.90. The indicated reduction in thrust loading for a change in power coefficient from 0.90 to 1.05 resulted from the higher altitude and lower engine power at which the power coefficient of 1.05 was obtained.

The effect of advance-diameter ratio on blade thrust load distribution is shown by the surveys in figure 8, which correspond to the conditions of figure 4 for a power coefficient of approximately 0.30. The thrust loading at $J = 2.96$ was uniform over the blade span. A reduction in advance-diameter ratio from 2.96 to 1.68 increased the over-all blade thrust loading while the thrust loading on the outboard sections increased more rapidly than on the inboard sections. (See fig. 8.) The thrust loading increased more rapidly on the outboard blade sections than on the inboard blade sections as the power coefficient was increased or as the advance-diameter ratio was decreased. Within the range of power coefficients and advance-diameter ratios investigated at a free-stream Mach number of 0.40, there was no evidence of blade stall or compressibility effects.

Free-stream Mach number, 0.50. - The propeller characteristics at a free-stream Mach number of 0.50 are presented in figure 9 for a range of power coefficients from 0.30 to 1.00. The variation of propeller efficiency with power coefficient is shown in figure 10 for approximately constant values of advance-diameter ratio.

Nearly constant maximum efficiencies were obtained for power coefficients from 0.50 to 0.70 at advance-diameter ratios between 2.10 and 2.50. The envelope of the efficiency curves for power coefficients from 0.50 to 1.00 decreased about 17 percent between advance-diameter ratios of 2.10 and 4.00. (See fig. 9.) Within the range of power coefficients and advance-diameter ratios of the investigation, a change in blade loading at the high advance-diameter ratios affected the propeller efficiency to a greater extent than at the low advance-diameter ratios (fig. 10).

Blade thrust load distribution curves are not presented for a free-stream Mach number of 0.50 inasmuch as the slipstream surveys obtained were unsatisfactory.

SUMMARY OF RESULTS

The results of the force measurements are of value only in showing the trend of propeller efficiency with changes in power coefficient or advance-diameter ratios inasmuch as no corrections for the effects of tunnel-wall constriction on the installation were applied. The investigation in the altitude wind tunnel of a Curtiss 732-1C2-0 four-blade propeller on a YP-47M airplane indicated that:

1. At a free-stream Mach number of 0.40, the highest efficiency in the low range of advance-diameter ratios was obtained at a power coefficient of 0.30 and in the high range of advance-diameter ratios at a power coefficient of 0.90. The envelope of efficiency curves for power coefficients from 0.30 to 0.90 decreased about 8 percent between advance-diameter ratios of 2.10 and 4.00.

2. Within the range of power coefficients and advance-diameter ratios investigated at a free-stream Mach number of 0.40, there was no evidence of blade stall or compressibility effects. The blade thrust loading increased more rapidly on the outboard blade sections than on the inboard sections as the power coefficient was increased or as the advance-diameter ratio was decreased.

3. At a free-stream Mach number of 0.50, maximum efficiencies were obtained at power coefficients from 0.50 to 0.70 at advance-diameter ratios between 2.10 and 2.50. The envelope of efficiency curves for power coefficients from 0.50 to 1.00 decreased by about 17 percent between advance-diameter ratios of 2.10 and 4.00.

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1. Saari, Martin J., and Wallner, Lewis E.: Altitude-Wind-Tunnel Investigation of Performance of Several Propellers on YP-47M Airplane at High Blade Loading. I - Aeroproducts H20C-162-X11M2 Four-Blade Propeller. NACA RM No. E6I24, Army Air Forces, 1946.

2. Wallner, Lewis E., and Sorin, Solomon M.: Altitude-Wind-Tunnel Investigation of Performance of Several Propellers on YP-47M Airplane at High Blade Loading. II - Curtiss 838-1C2-18R1 Four-Blade Propeller. NACA RM No. E6J14, Army Air Forces, 1946.

3. Saari, Martin J., and Converse, Arthur N.: Altitude-Wind-Tunnel Investigation of Performance of Several Propellers on YP-47M Airplane at High Blade Loadings. III - Hamilton Standard A6543A-0 Four-Blade Propeller. NACA RM No. E6J22, Army Air Forces, 1946.

4. Pendley, Robert E.: Effect of Propeller-Axis Angle of Attack on Thrust Distribution over the Propeller Disk in Relation to Wake-Survey Measurement of Thrust. NACA ARR No. L5J02b, 1945.

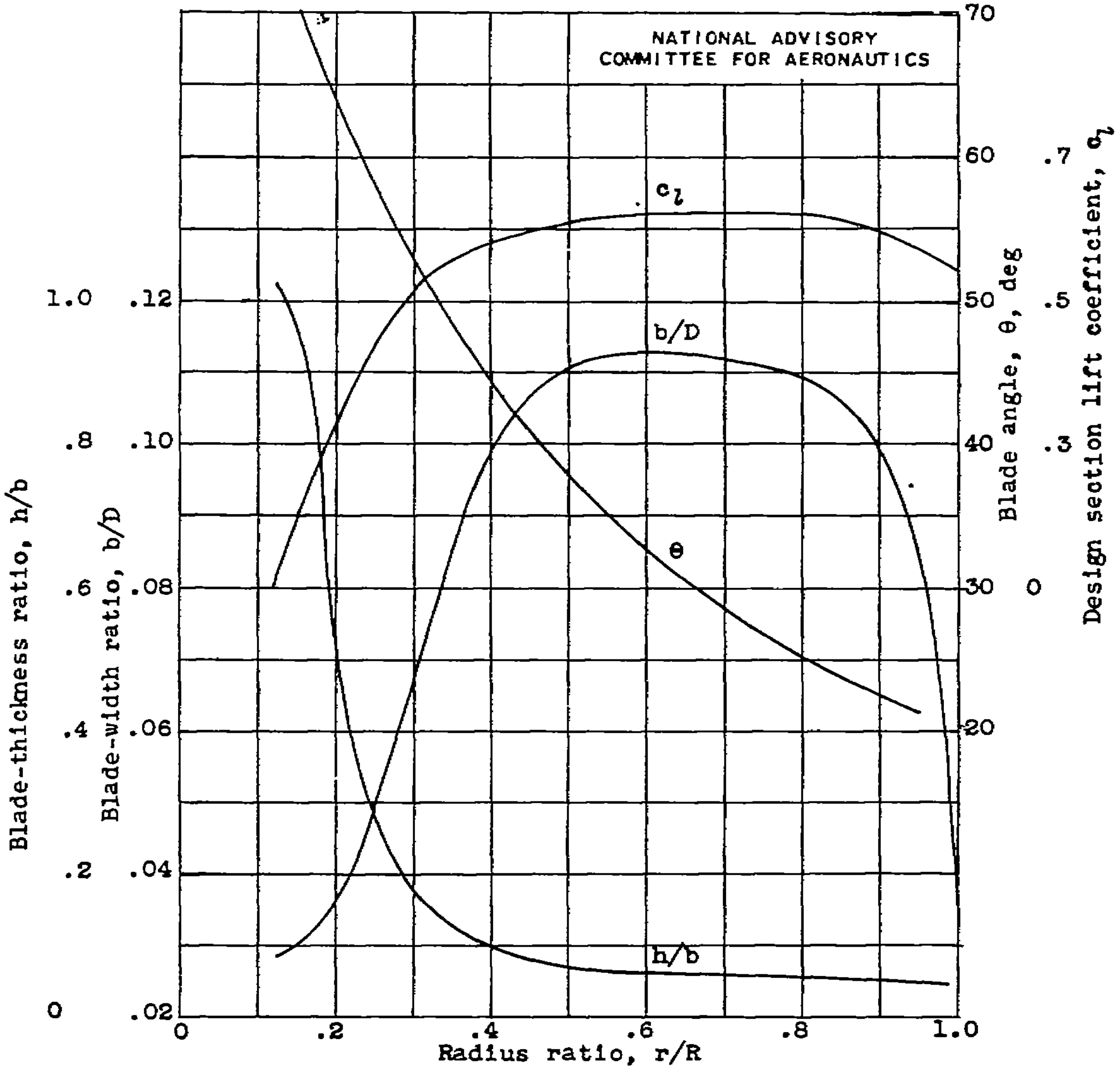

Figure 1.- Blade-form curves for Curtiss 732-1C2-0 four-blade propeller. b, section chord; D, diameter; h, section thickness; R, radius to tip; r, section radius.

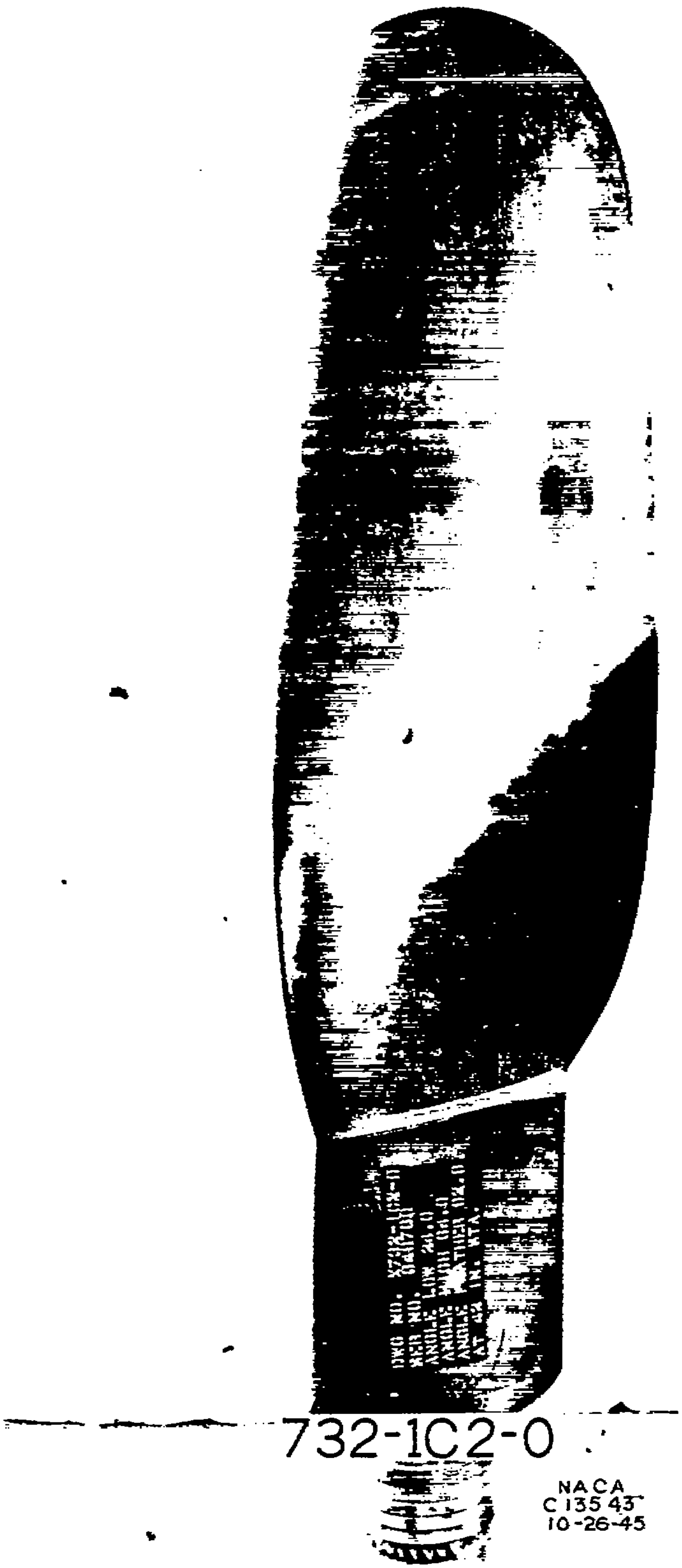

Figure 2. - Curtiss 732-1C2-0 propeller blade.

Figure 3. - Front view of YP-47M airplane with Curtiss 732-1C2-0 four-blade propeller installed in altitude-wind-tunnel test section.

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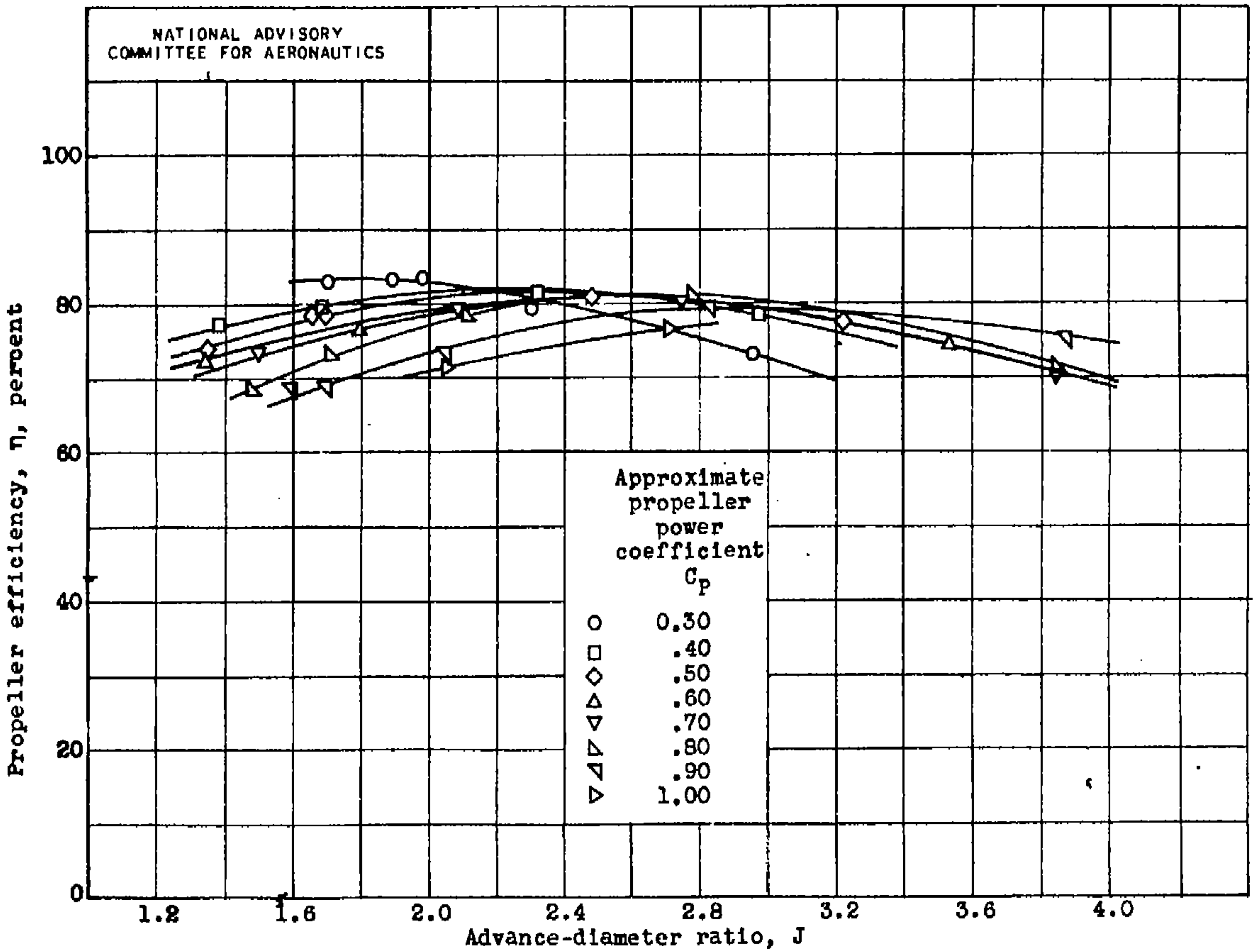

Figure 4.- Characteristics of Curtiss 732-1C2-0 four-blade propeller on YP-47M airplane at free-stream Mach number M_0 of approximately 0.40.

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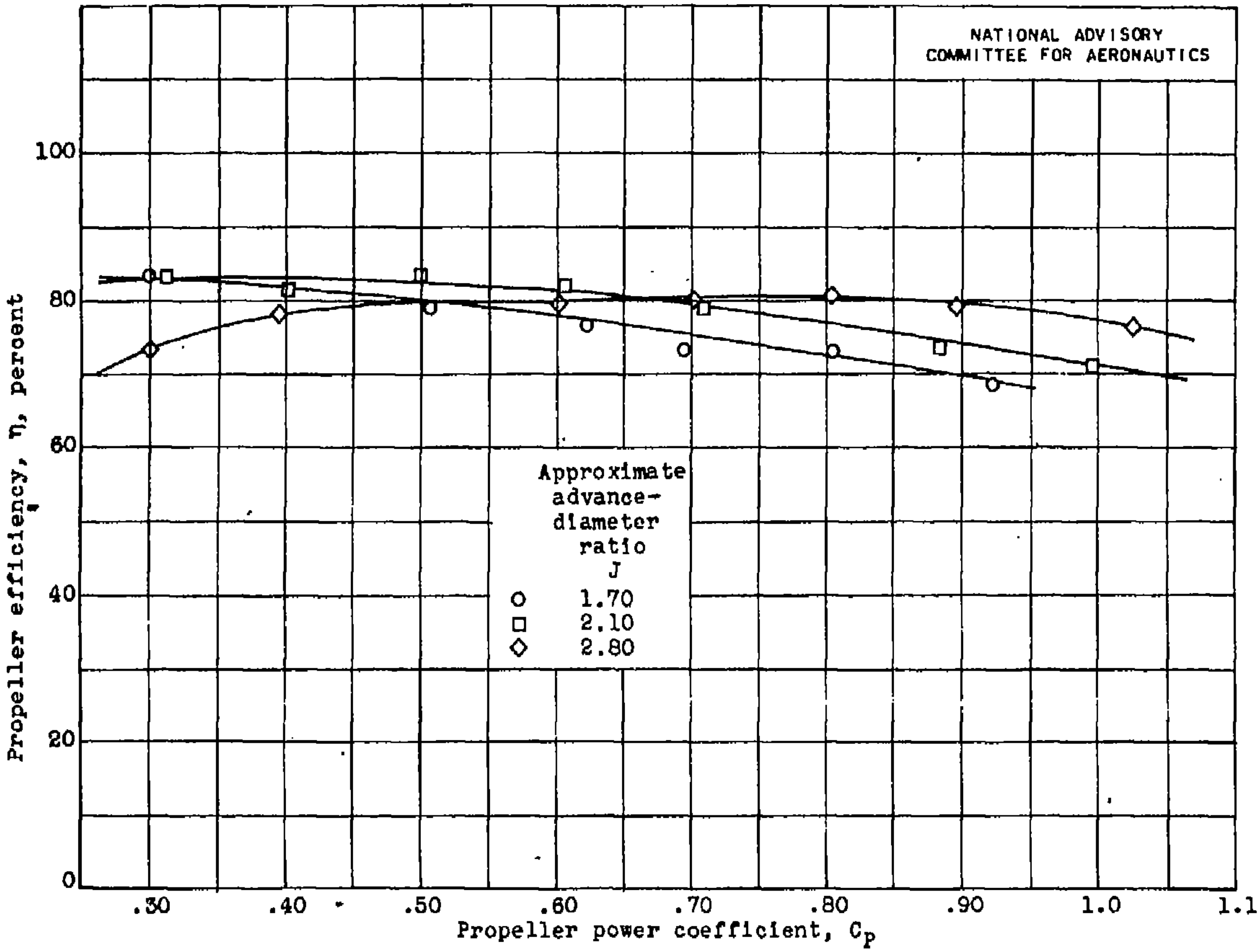
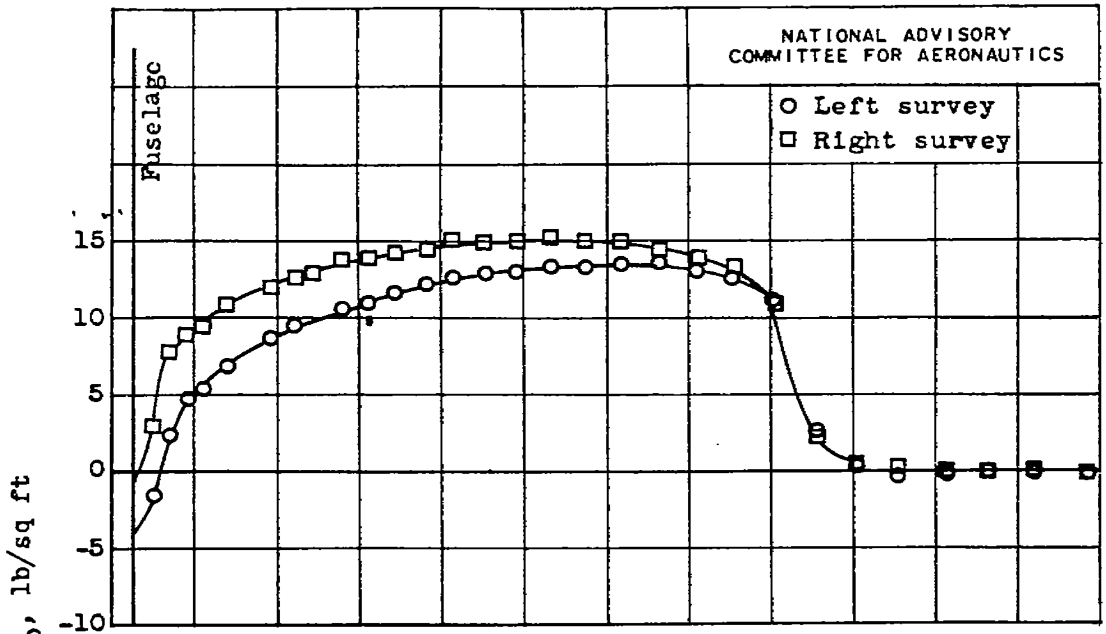
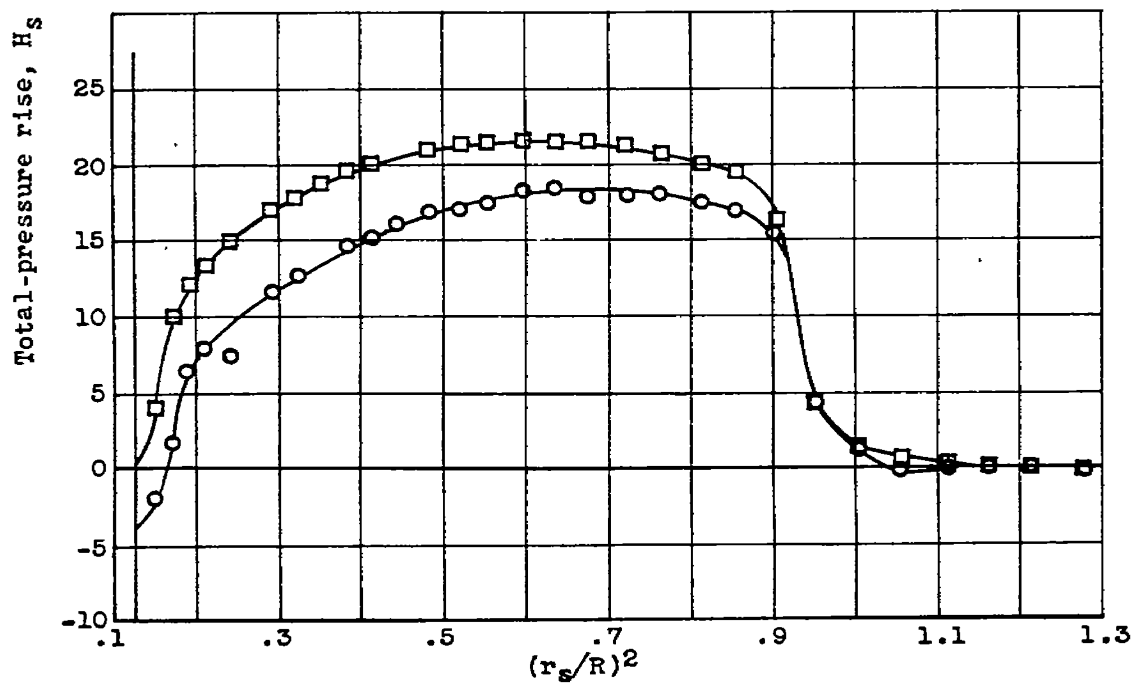


Figure 5.- Effect of power coefficient C_P on efficiency η of Curtiss 732-1C2-0 four-blade propeller at free-stream Mach number M_0 of approximately 0.40.

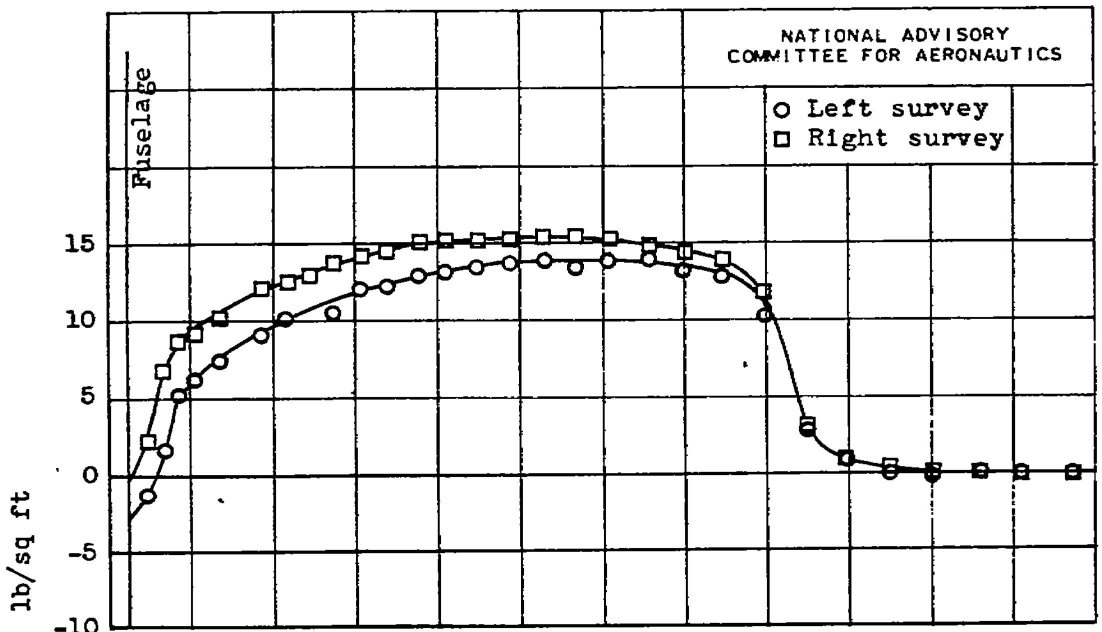


(a) C_P, 0.31; J, 1.98; M_o, 0.39; M_t, 0.73.

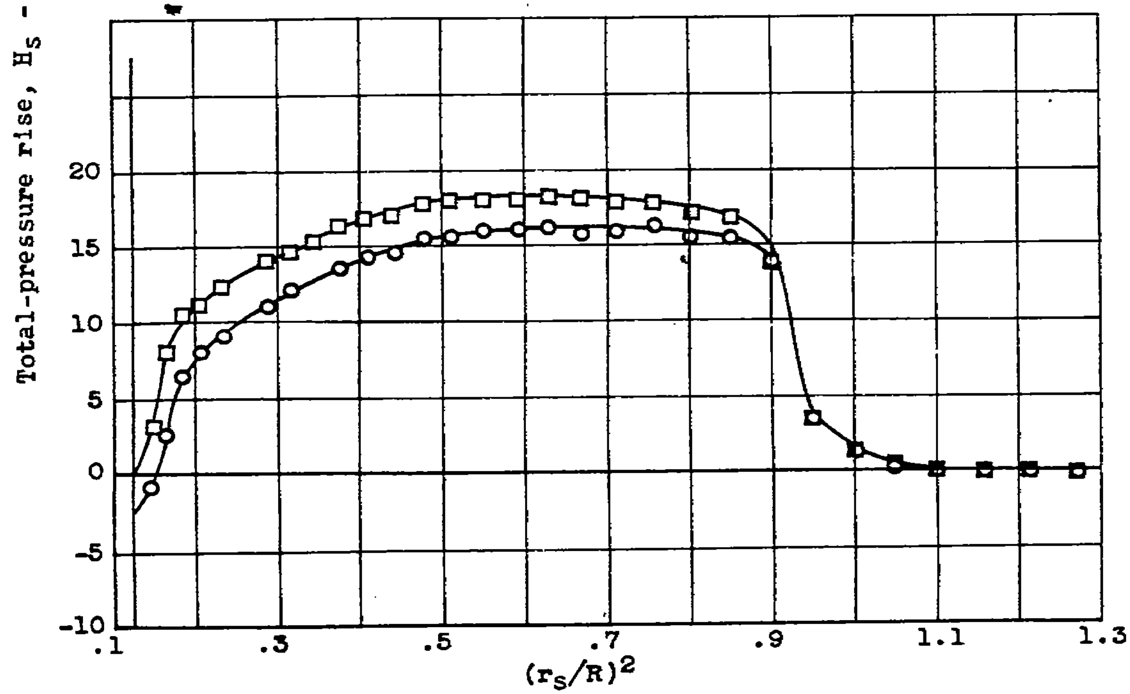


(b) C_P, 0.50; J, 2.11; M_o, 0.40; M_t, 0.71.

Figure 6.- Effect of power coefficient C_P on blade thrust load distribution at advance-diameter ratio J of approximately 2.10 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.

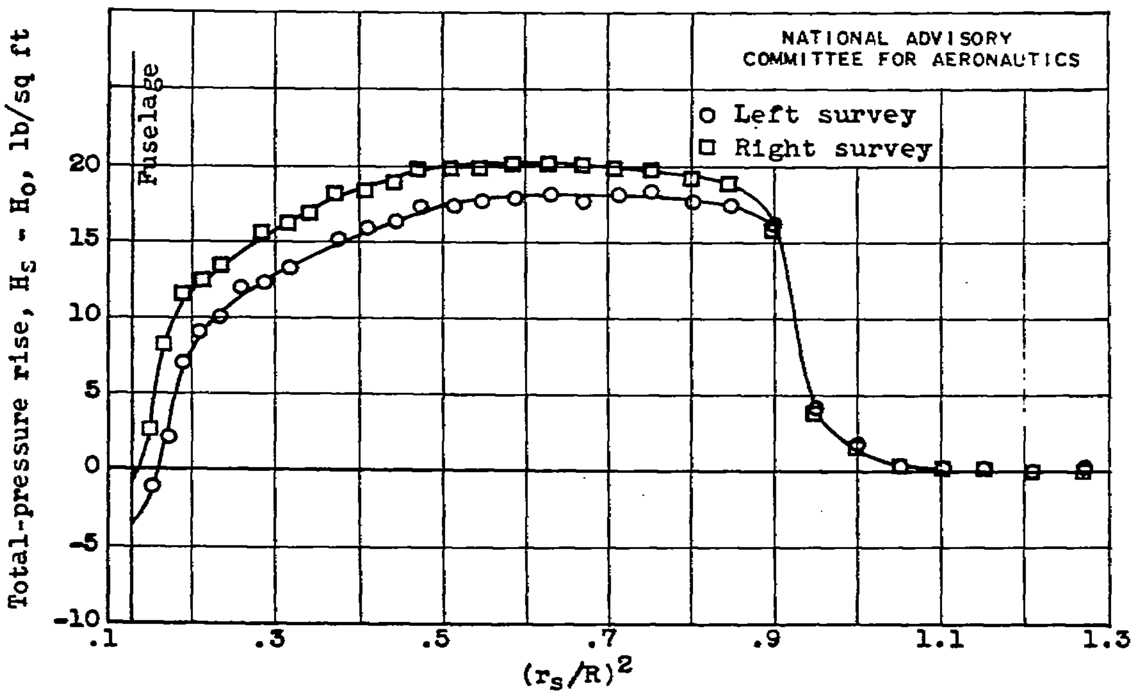


(c) C_P, 0.61; J, 2.11; M_o, 0.39; M_t, 0.70.



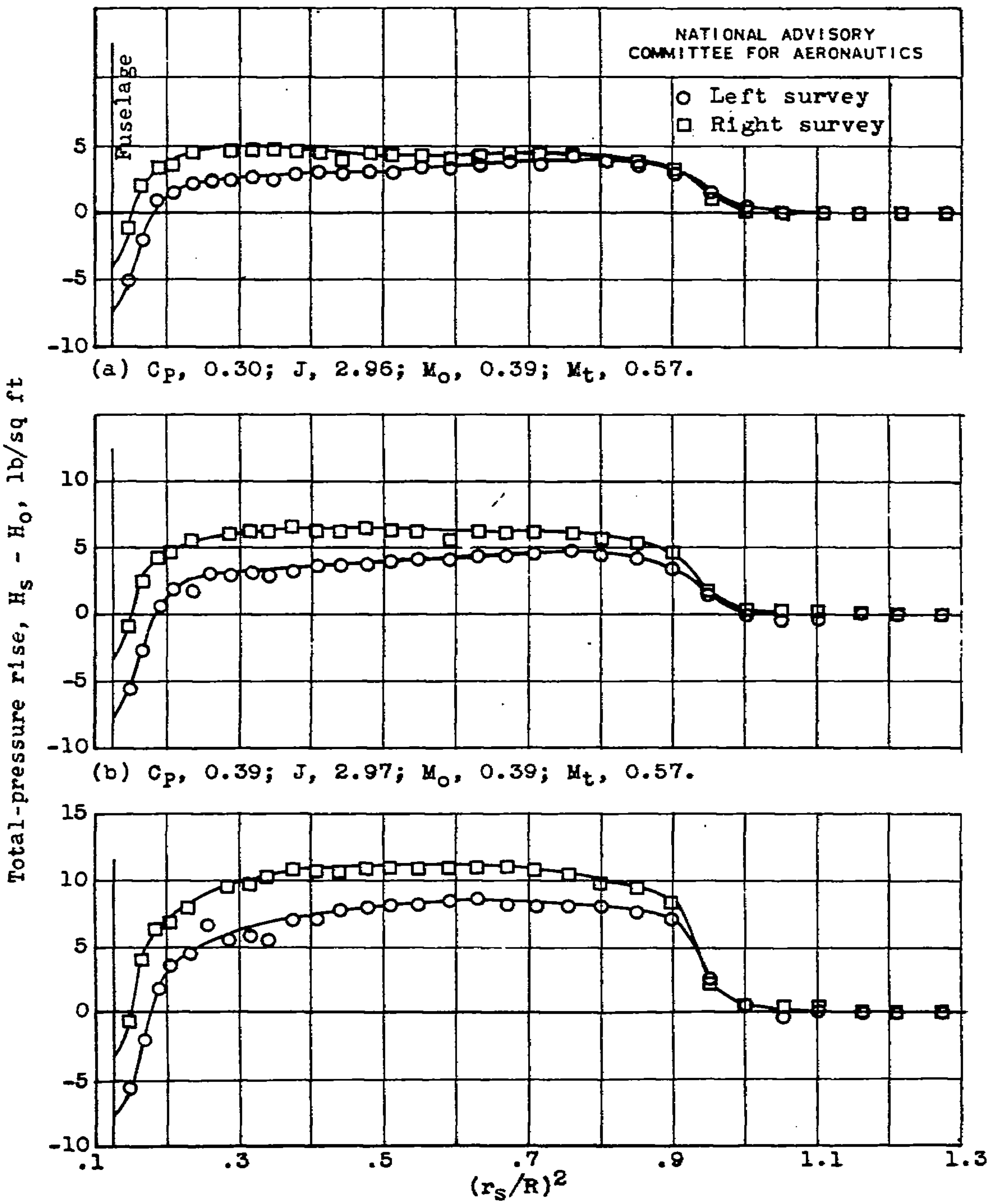
(d) C_P, 0.71; J, 2.09; M_o, 0.39; M_t, 0.70.

Figure 6.- Continued. Effect of power coefficient C_P on blade thrust load distribution at advance-diameter ratio J of approximately 2.10 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.



(e) C_P, 0.81; J, 2.11; M_o, 0.39; M_t, 0.70.

Figure 6.- Concluded. Effect of power coefficient C_P on blade thrust load distribution at advance-diameter ratio J of approximately 2.10 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.

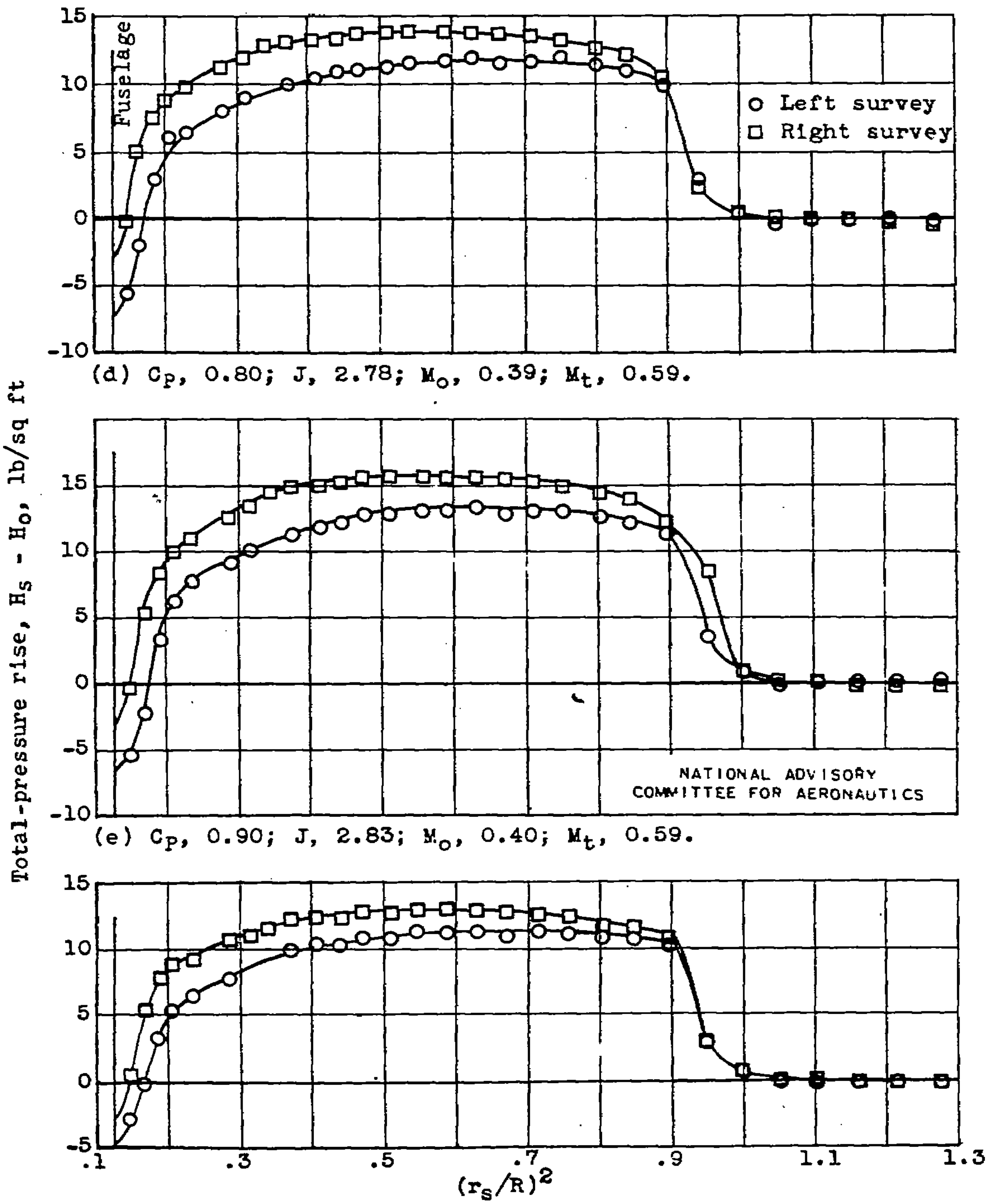


(a) C_P, 0.30; J, 2.96; M_o, 0.39; M_t, 0.57.

(b) C_P, 0.39; J, 2.97; M_o, 0.39; M_t, 0.57.

(c) C_P, 0.70; J, 2.76; M_o, 0.39; M_t, 0.59.

Figure 7.- Effect of power coefficient C_P on blade thrust load distribution at advance-diameter ratio J of approximately 2.80 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.

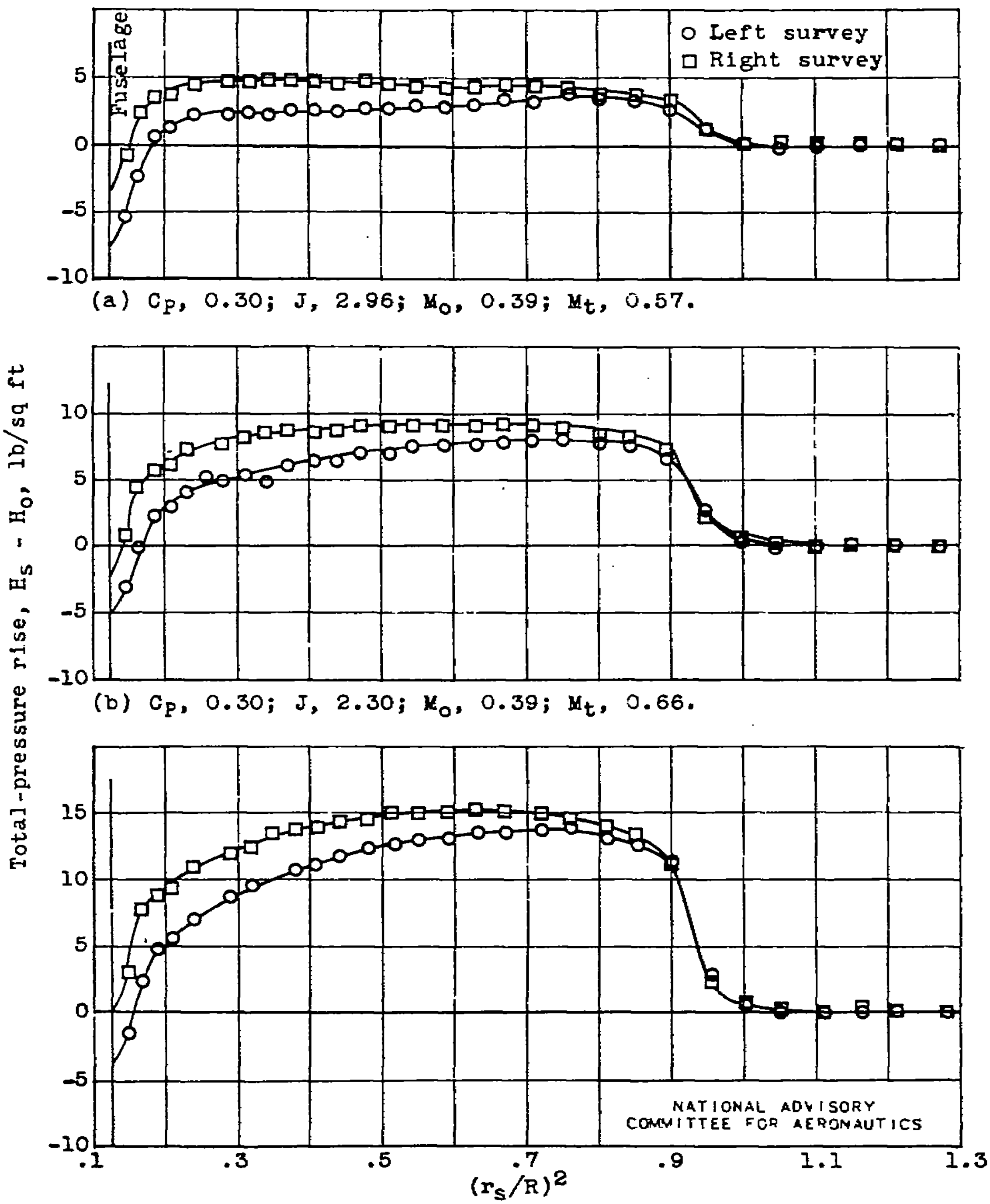


(d) C_P, 0.80; J, 2.78; M_o, 0.39; M_t, 0.59.

(e) C_P, 0.90; J, 2.83; M_o, 0.40; M_t, 0.59.

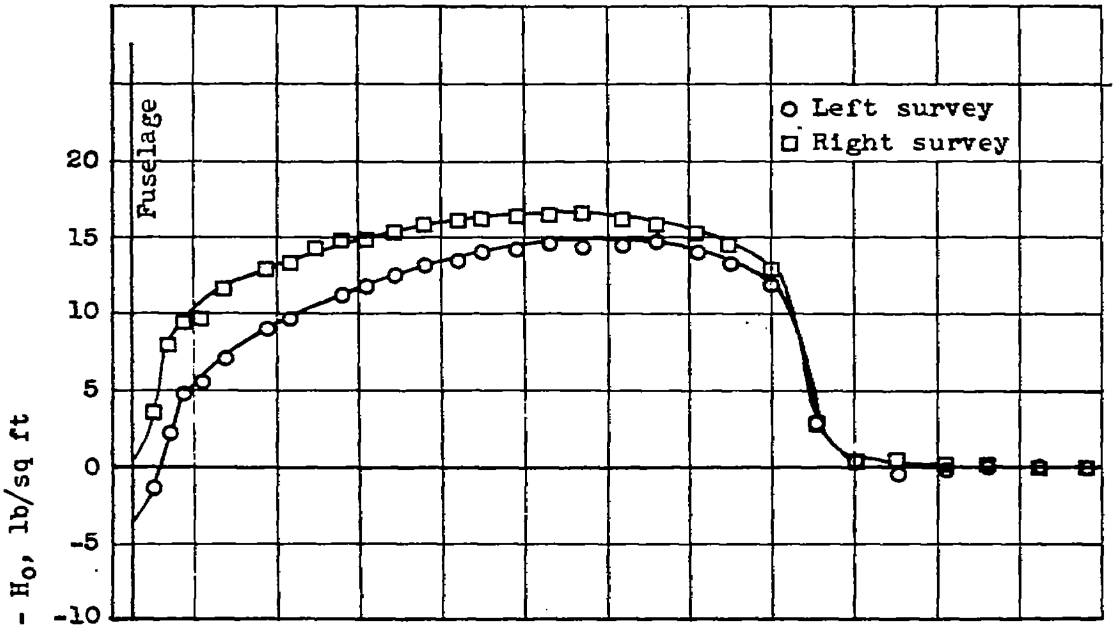
(f) C_P, 1.05; J, 2.71; M_o, 0.39; M_t, 0.60.

Figure 7.- Concluded. Effect of power coefficient C_P on blade thrust load distribution at advance-diameter ratio J of approximately 2.80 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.

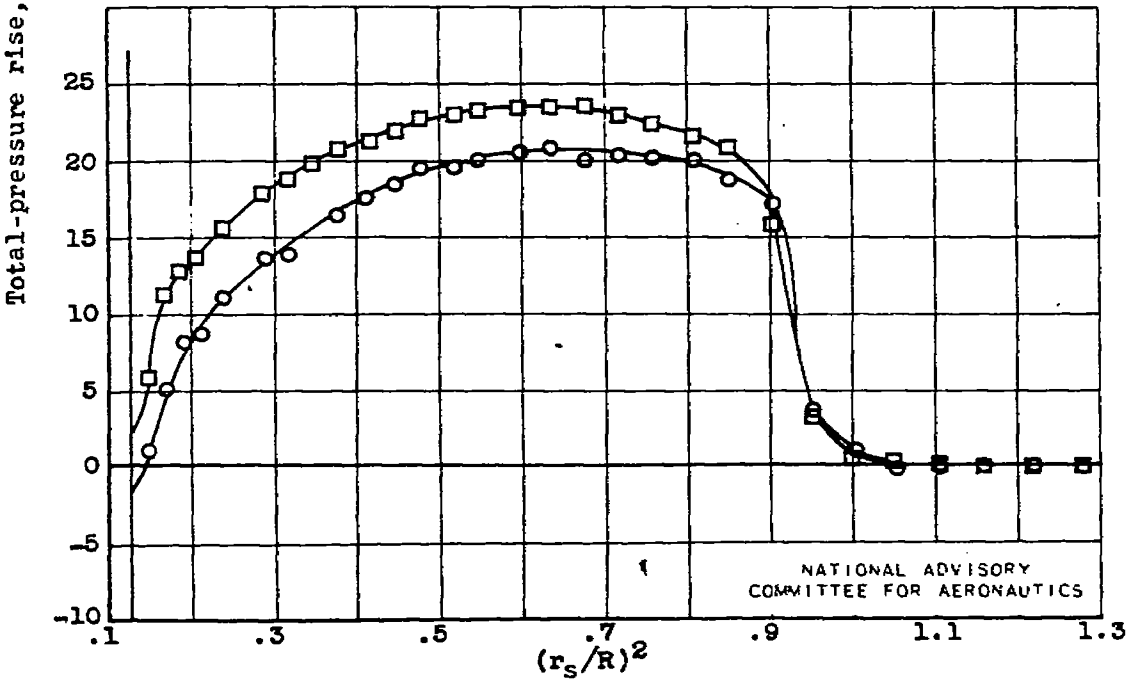


(c) C_P, 0.31; J, 1.98; M_o, 0.39; M_t, 0.73.

Figure 8.- Effect of advance-diameter ratio J on blade thrust load distribution at power coefficient C_P of approximately 0.30 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.



(d) C_P, 0.30; J, 1.89; M_o, 0.39; M_t, 0.76.



(e) C_P, 0.30; J, 1.68; M_o, 0.39; M_t, 0.84.

Figure 8.- Concluded. Effect of advance-diameter ratio J on blade thrust load distribution at power coefficient C_P of approximately 0.30 and free-stream Mach number M_o of approximately 0.40. Curtiss 732-1C2-0 four-blade propeller.

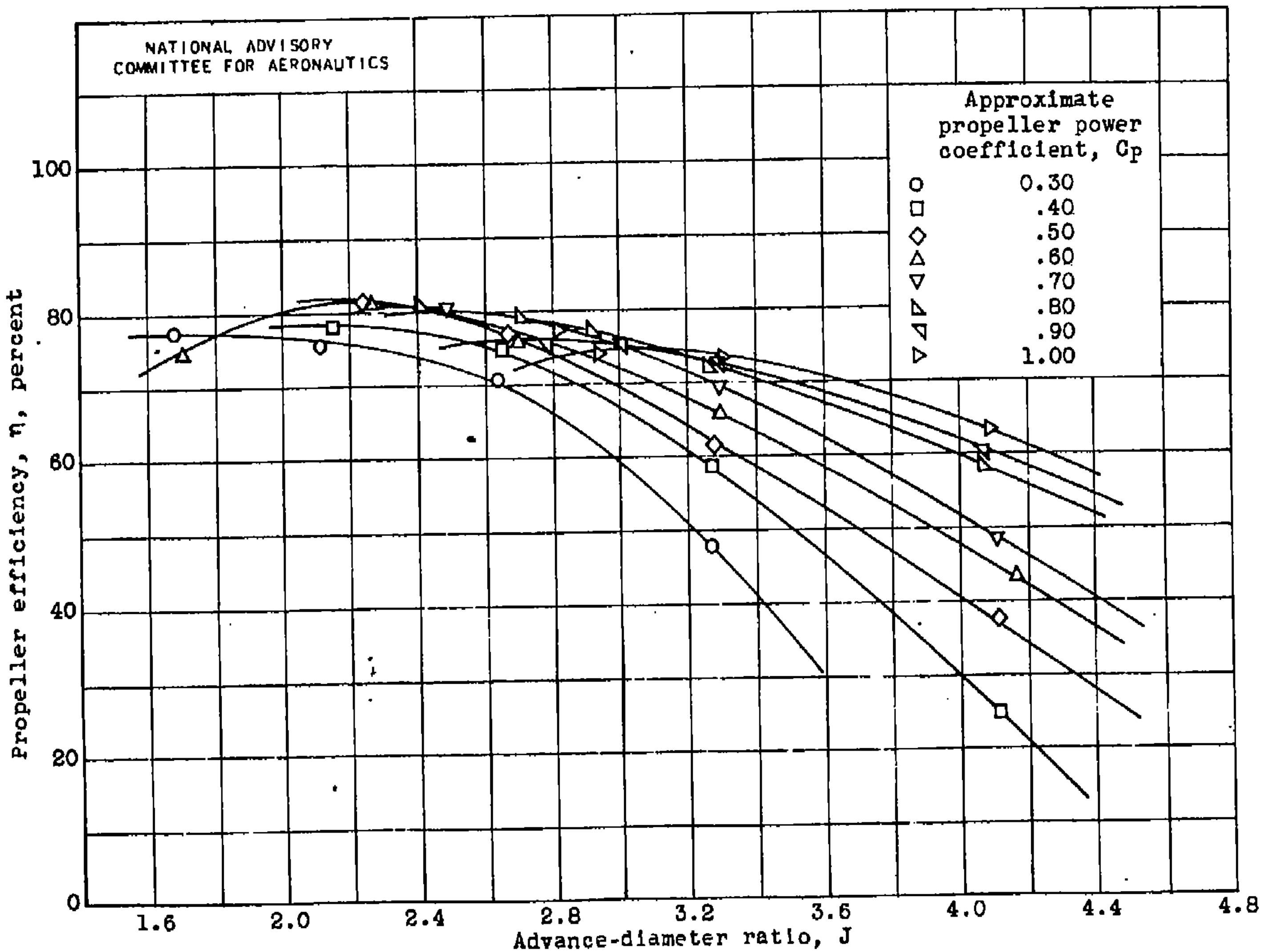


Figure 9.- Characteristics of Curtiss 732-1C2-0 four-blade propeller on YP-47M airplane at free-stream Mach number M_0 of approximately 0.50.

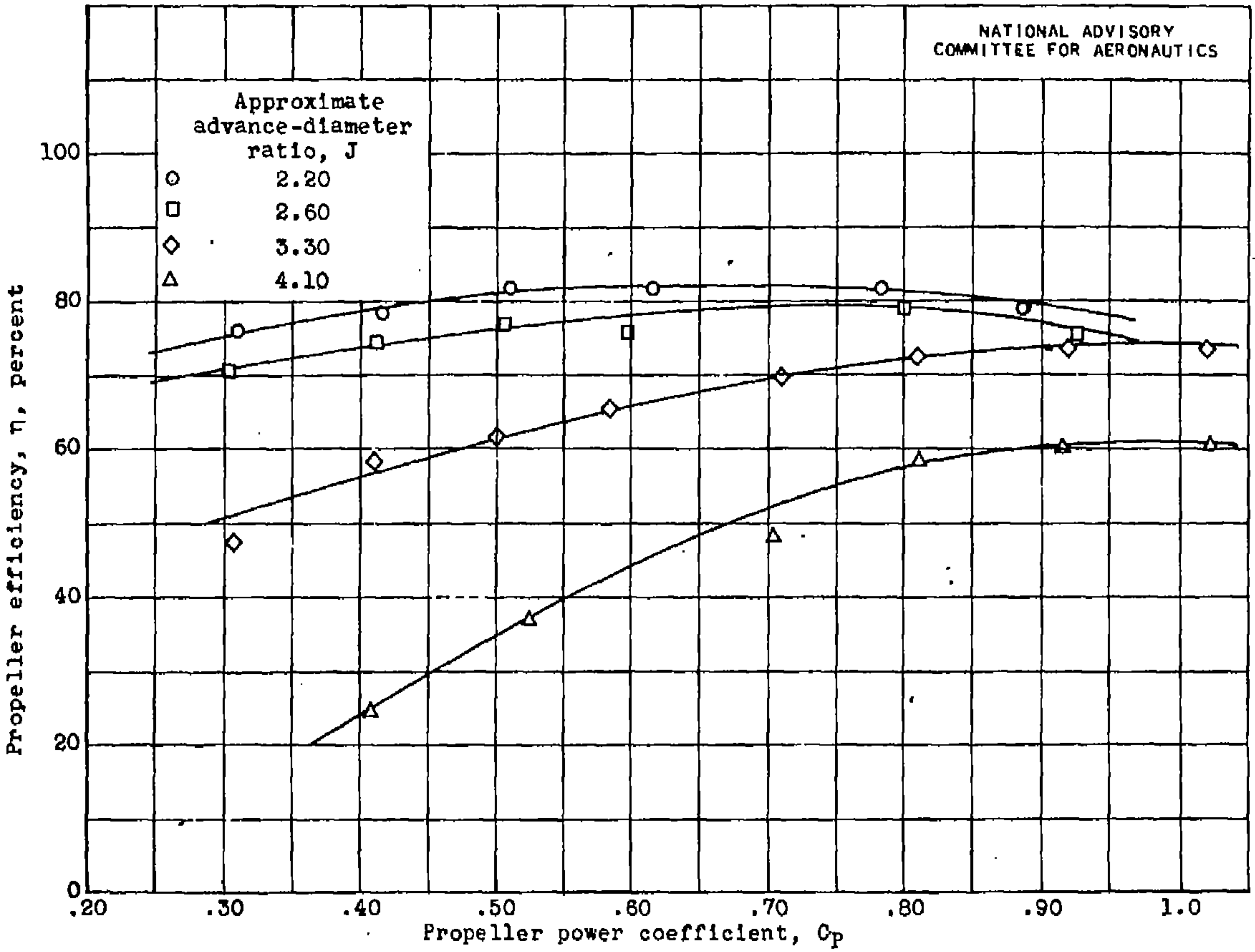


Figure 10.- Effect of power coefficient C_P on efficiency η of Curtiss 732-1C2-0 four-blade propeller at free-stream Mach number M_0 of approximately 0.50.