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PRELIMINARY RESULTS OF NENE II ENGINE ALTITUDE-CHAMBER PERFORMANCE INVESTIGATION

I - ALTITUDE PERFORMANCE USING 18.41-INCH DIAMETER-JET NOZZLE

By J. C. Armstrong, H. D. Wilsted
and K. R. Vincent

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PRELIMINARY RESULTS OF NENE II ENGINE ALTITUDE-CHAMBER PERFORMANCE INVESTIGATION

II - ALTITUDE PERFORMANCE USING 18.41-INCH DIAMETER-JET NOZZLE

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SUMMARY

An investigation is being conducted to determine the altitude performance characteristics of the Nene II engine and its components. The present paper presents preliminary results obtained using a jet nozzle 18.41 inches in diameter, giving an area equal to 96.4 percent of the area of the standard jet nozzle for this engine. The test results presented are for conditions simulating altitudes from sea level to 50,000 feet and ram-pressure ratios from 1.00 to 2.70. These ram-pressure ratios correspond to flight Mach numbers between zero and 1.28.

Data obtained with the 18.41-inch diameter jet nozzle at various altitudes and corrected to standard sea level conditions showed substantially the same agreement as the data obtained with the larger nozzle in Part I.

Jet thrust, air consumption, and fuel consumption corrected to standard sea level conditions, increased rapidly with increase in ram-pressure ratio. In general, corrected net-thrust specific fuel consumption increased with increase in ram-pressure ratio to a peak value and with further increase in ram-pressure ratio first decreased and subsequently increased again.

Comparison of engine operation with the 18.41-inch-diameter nozzle to operation with the standard 18.75-inch-diameter jet nozzle under identical flight conditions showed that use of the smaller nozzle gave a small reduction in net-thrust specific fuel consumption at medium engine speeds.

INTRODUCTION

The altitude performance of the Nene II engine, using several sizes of jet nozzle, is being determined in order to investigate the degree of matching of the components and the effects of change in the characteristics of the various engine components on altitude performance. This investigation is being conducted in an altitude test chamber at the Cleveland laboratory of the NACA.

This paper presents data showing performance of the engine using a jet nozzle 18.41 inches in diameter. The area of this nozzle is 96.4 percent of the standard jet nozzle with which the data of reference 1 was obtained. The results presented were obtained at simulated altitudes from sea level to 50,000 feet and ram-pressure ratios from 1.00 to 2.70. These ram-pressure ratios correspond to flight Mach numbers between zero and 1.28, assuming 100 percent ram recovery. The data are presented in a manner that shows the effects of altitude, ram-pressure ratio, and jet-nozzle size on engine performance.

The power plant is rated at 5000 pounds thrust at static, sea level conditions with an 18.75-inch diameter jet nozzle. The power plant, altitude test chamber, and instrumentation are described in Part I of this report, reference 1.

SYMBOLS

The following symbols are used in this report:

A flow area, square feet

F_j jet thrust, pounds

F_n net thrust, pounds

g acceleration of gravity, 32.2 ft/sec^2

N engine speed, rpm

P absolute total pressure, lb/ft^2

p absolute static pressure, lb/ft^2

R gas constant, 53.3 ft-lb/(lb)(°F)

T indicated temperature, °R

t static temperature, °R

W_a air consumption, lb/sec

W_f fuel consumption, lb/hr

W_g gas flow, lb/sec

W_f/F_n specific fuel consumption based on net thrust, lb/hr/lb thrust

γ ratio of specific heats

δ ratio of ambient absolute static pressure to absolute static pressure of NACA standard atmosphere at sea level

θ ratio of compressor-inlet absolute total temperature to absolute static temperature of NACA standard atmosphere at sea level

Subscript:

7 tail pipe instrumentation station

PROCEDURE

The test procedure and the processing of the data for this report were similar to the methods described in Part I except for the addition of two steps described below.

At the high altitude conditions, ram-pressure ratio varied as much as $5\frac{1}{2}$ percent. The effect of these variations was eliminated by correcting the data by a factor obtained from cross plots of the performance parameters against ram-pressure ratio. Cross plots of this type are presented.

Air-flow measurements presented in Part I depended on thrust measurement and therefore included the effect of any small discrepancies in the thrust measurement. In the present paper the air-flow data presented were calculated from the averaged tail-pipe-rake readings by use of the following relation:

$$W_g = p_7 A_7 \sqrt{\frac{2g}{Rt_7} \frac{\gamma}{\gamma - 1}\left[\left(\frac{P_7}{p_7}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]} \qquad (1)$$

in which the static temperature t_7 was calculated using a recovery factor of 0.8 determined from calibration tests.

$$t_7 = \frac{T}{1 + 0.8\left[\left(\frac{P_7}{p_7}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]} \qquad (2)$$

The air flow was then obtained by deducting the fuel flow from the total gas flow.

$$W_a = W_g - \frac{W_f}{3600} \qquad (3)$$

PRESENTATION OF DATA

The preliminary performance results are presented as corrected in the conventional manner to NACA standard sea-level temperature and pressure conditions. Cross plots of this data are included to demonstrate the variation of corrected engine performance with change in ram-pressure ratio. A typical set of uncorrected altitude data is also presented to demonstrate the change in engine performance that results from a change in jet nozzle area. This data is compared with data obtained using the standard jet nozzle having a diameter of 18.75 inches.

Generalized Performance

Effect of Altitude. - The engine performance was generalized by correcting all data to standard sea-level pressure and temperature conditions as described in reference 2. The corrected jet thrust, figure 1, is independent of altitude over the range investigated with this nozzle. Similarly the corrected net thrust curves (fig. 2) and the corrected air consumption curves (fig. 3) are independent of altitude over the range tested.

The corrected fuel consumption plots (fig. 4) show no effect of altitude until altitudes above 30,000 feet are reached. However, for an increase in simulated altitude from 40,000 to 50,000 feet (fig. 4e) there is an average increase in corrected fuel consumption of approximately 4 percent. The corrected net-thrust specific fuel consumption (fig. 5) being a function only of corrected fuel consumption and corrected net thrust is independent of altitude to

30,000 feet. Although there is a scatter of the data of figure 5, no definite trends are indicated except in figure 5e in which there appears to be a small increase in corrected net-thrust specific fuel consumption as altitude is increased from 40,000 to 50,000 feet. This is in agreement with the increase in corrected fuel consumption of figure 4e.

The indication in Part I (reference 1) of a possible small increase in net-thrust specific fuel consumption with increasing altitude may have resulted from the spread of the net thrust specific fuel consumption data as the trend was not consistent for the various ram-pressure ratios nor for the altitudes for a particular ram-pressure ratio. It can be concluded that for this engine changes in altitude have little effect on corrected net-thrust specific fuel consumption.

The corrected tail-pipe indicated temperature (exhaust-gas temperature) increased slightly with increase in altitude (fig. 6).

Effect of ram-pressure ratio. - The corrected data from figures 1 through 4 and figure 6 have been cross-plotted to show more clearly the approximate effect of ram-pressure ratio on engine performance. These figures represent the average effect (of all altitudes tested) of ram-pressure ratio on engine performance. The corrected jet thrust is shown (fig. 7) to increase rapidly with ram-pressure ratio. The corrected net-thrust (fig. 8) is shown first to decrease and then to increase at a rapid rate with increase in ram-pressure ratio at all engine speeds. Corrected air consumption (fig. 9) increases with an increase in ram-pressure ratio.

The corrected fuel consumption (fig. 10) is seen to rise at an increasing rate with increase in ram-pressure ratio at corrected engine speeds of 9,000 rpm and above. At 8,000 rpm the curve indicates a decline in corrected fuel consumption with an increase in ram-pressure ratio from 1.0 to 1.3. The corrected net-thrust specific fuel consumption (fig. 11) in general increased with increasing ram-pressure ratio to a peak value at a ram-pressure ratio between 1.4 and 1.7; then decreased until a ram-pressure ratio between 1.8 and 2.6 was reached and then began to increase again with further increase in ram-pressure ratio.

The corrected tail-pipe indicated temperature (fig. 12) at first decreases and then increases with increasing ram-pressure ratio. The variation is greatest at the lower engine speeds.

Effect of jet nozzle size. - Data are presented for the 18.75- and 18.41-inch-diameter jet nozzles at a ram-pressure ratio of 1.70

and at a simulated altitude of 30,000 feet. The data for both nozzles has been corrected for ram-pressure ratio variations. The smaller jet nozzle is seen from figure 13 to give a slightly greater jet thrust. A smaller difference in net thrust is apparent (fig. 14).

Figure 15 indicates slightly less air consumption when the smaller nozzle is used.

The fuel consumption (fig. 16) is seen to be greater at the higher engine speeds when the smaller jet nozzle was used. The net-thrust specific fuel consumption was nearly equal at engine speeds above 11,500 rpm (fig. 17). At engine speeds below 11,500 rpm, the smaller jet nozzle gave a lower net-thrust specific fuel consumption. The tail-pipe indicated temperature (fig. 18) was considerably higher when the smaller nozzle was used.

If from figure 14 engine speeds at approximately cruise conditions are selected that will give equal net thrusts for the two jet nozzles, say 1000 pounds, it is seen that this thrust occurs at 10,550 and 10,410 rpm for the 18.75 and 18.41-inch-diameter jet nozzles, respectively. Use of the smaller nozzle decreases net-thrust specific fuel consumption at these conditions from 1.56 to 1.45 lb/(hr)(lb thrust) (fig. 17), a decrease of approximately 6 percent. Tail-pipe temperature (fig. 18) increases, however, from 1210 to 1230° R. This 20° rise in temperature probably would not be serious in this temperature range. A nozzle smaller than that currently used would, therefore, be advantageous at medium engine speeds at altitude. During take-off, however, the small nozzle would operate at temperatures that would probably be quite detrimental to engine life. To take advantage of improved performance at altitude conditions, it would therefore be necessary to provide an efficient variable-area nozzle or other means of keeping temperatures within reasonable limits during take-off operation.

SUMMARY OF RESULTS

An investigation of the performance of a Rolls Royce Nene II turbojet engine in one of the Cleveland altitude chambers has been partially completed and the following results were indicated for the engine equipped with an 18.41-inch-diameter jet nozzle:

1. Change in simulated altitude in general has little effect on corrected engine performance over the range of variables tested. It was possible to generalize the fuel consumption and net-thrust specific fuel consumption data to altitudes of at least 30,000 feet

and jet thrust, net thrust, and air consumption could be generalized throughout the range of altitudes investigated. Tail-pipe indicated temperature could not be accurately generalized; it increases a small amount with increase in altitude.

2. Effect of ram-pressure ratio. - The general effect of increasing ram-pressure ratio was to rapidly increase corrected jet thrust, corrected air consumption and corrected fuel consumption. Corrected net thrust first decreased and then increased rapidly with increase in ram-pressure ratio. Corrected net-thrust specific fuel consumption in general increased with increase in ram-pressure ratio to a peak value and with further increase in ram-pressure ratio first decreased and subsequently began to increase again. Corrected tail-pipe indicated temperatures were affected most at the lower engine speeds where the temperatures rapidly decreased with increasing ram-pressure ratio.

3. Effect of jet nozzle size. - A comparison of test data for the standard 18.75 and the 18.41-inch-diameter jet-nozzle performance parameters at a ram-pressure ratio of 1.70 and at an altitude of 30,000 feet gave the following results: jet thrust, net thrust, and tail-pipe temperatures were higher, and the fuel consumption was greater at the higher engine speeds when the 18.41-inch-diameter jet nozzle was used. Air consumption was slightly less and net-thrust specific fuel consumption was less at engine speeds below 11,500 rpm when the smaller nozzle was used. At medium engine speeds use of the smaller nozzle gave a small reduction in net-thrust specific fuel consumption.

Flight Propulsion Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, June 14, 1948.

REFERENCES

1. Barson, Zelmar, and Wilsted, H. D.: Preliminary Results of Nene II Engine Altitude-Chamber Performance Investigation. I - Altitude Performance Using Standard 18.75-Inch-Diameter Jet Nozzle. NACA RM No. E8K12.

2. Sanders, Newell D.: Performance Parameters for Jet-Propulsion Engines. NACA TN No. 1106, 1946.

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NACA RM No. E8F14

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II - ALTITUDE PERFORMANCE USING 18.41-INCH DIAMETER-JET NOZZLE

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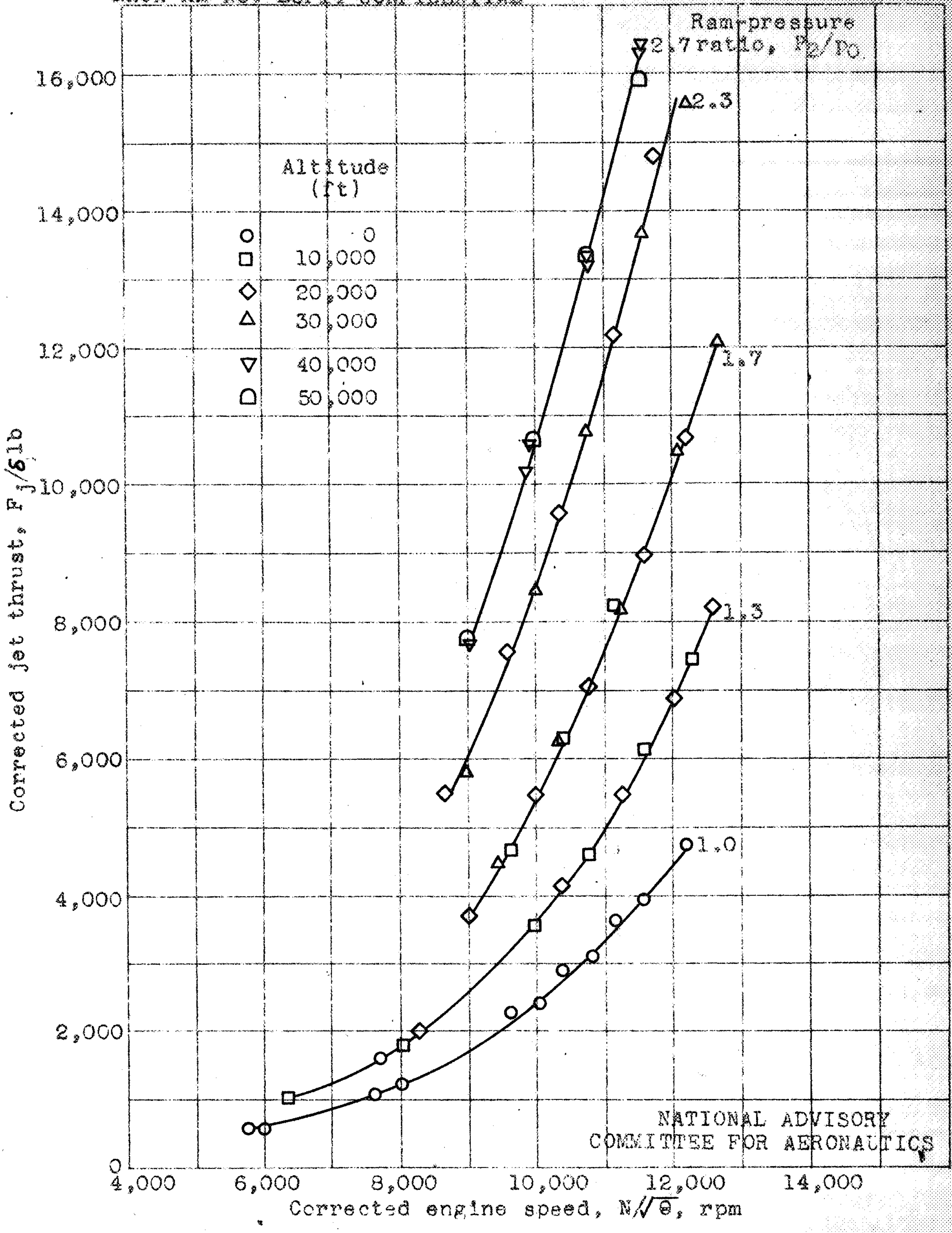
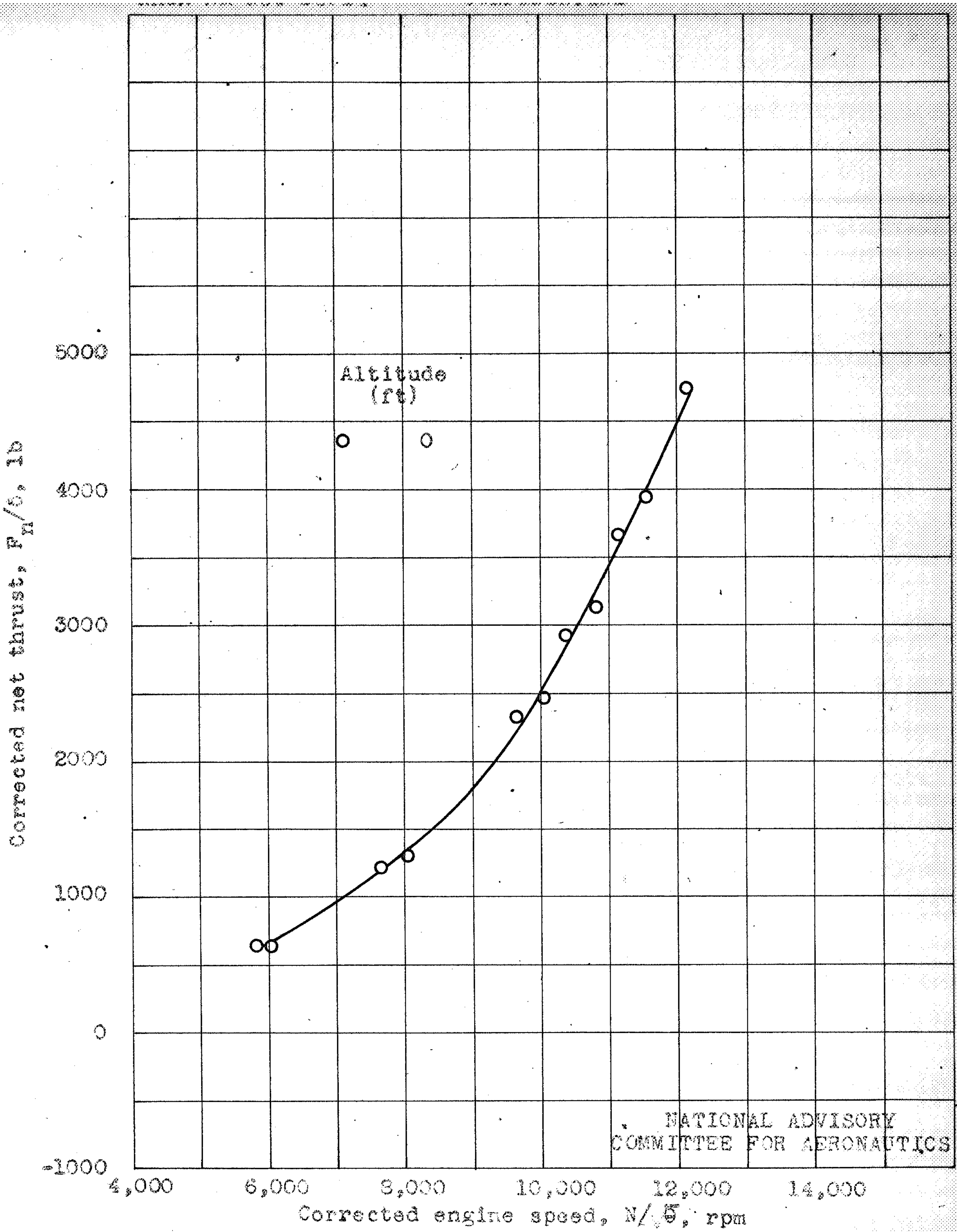


Figure 1. - Effect of altitude and corrected engine speed on corrected jet thrust at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



(a) Ram-pressure ratio, P_2/p_0, 1.0.

Figure 2. - Effect of altitude and corrected engine speed on corrected net thrust at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.

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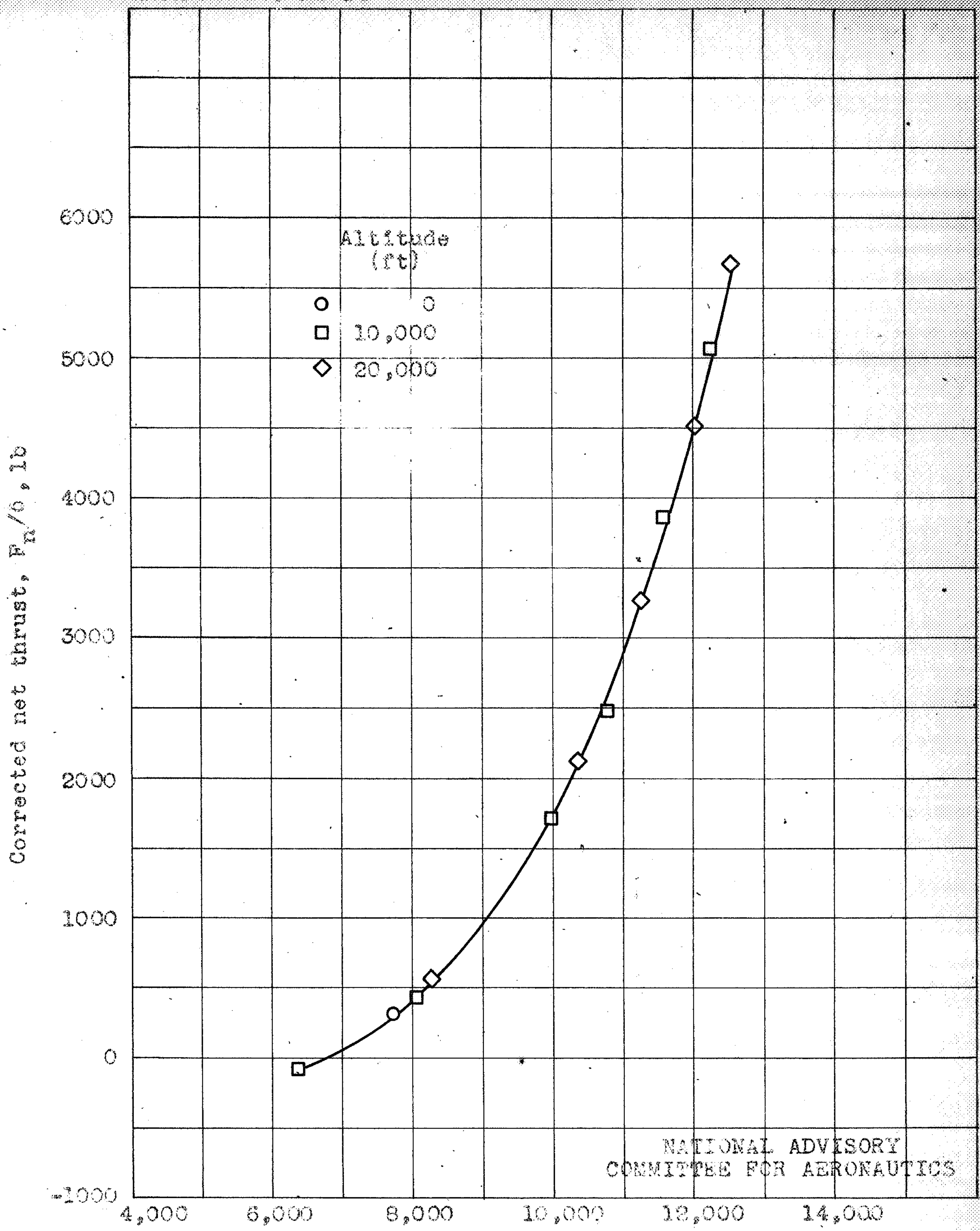
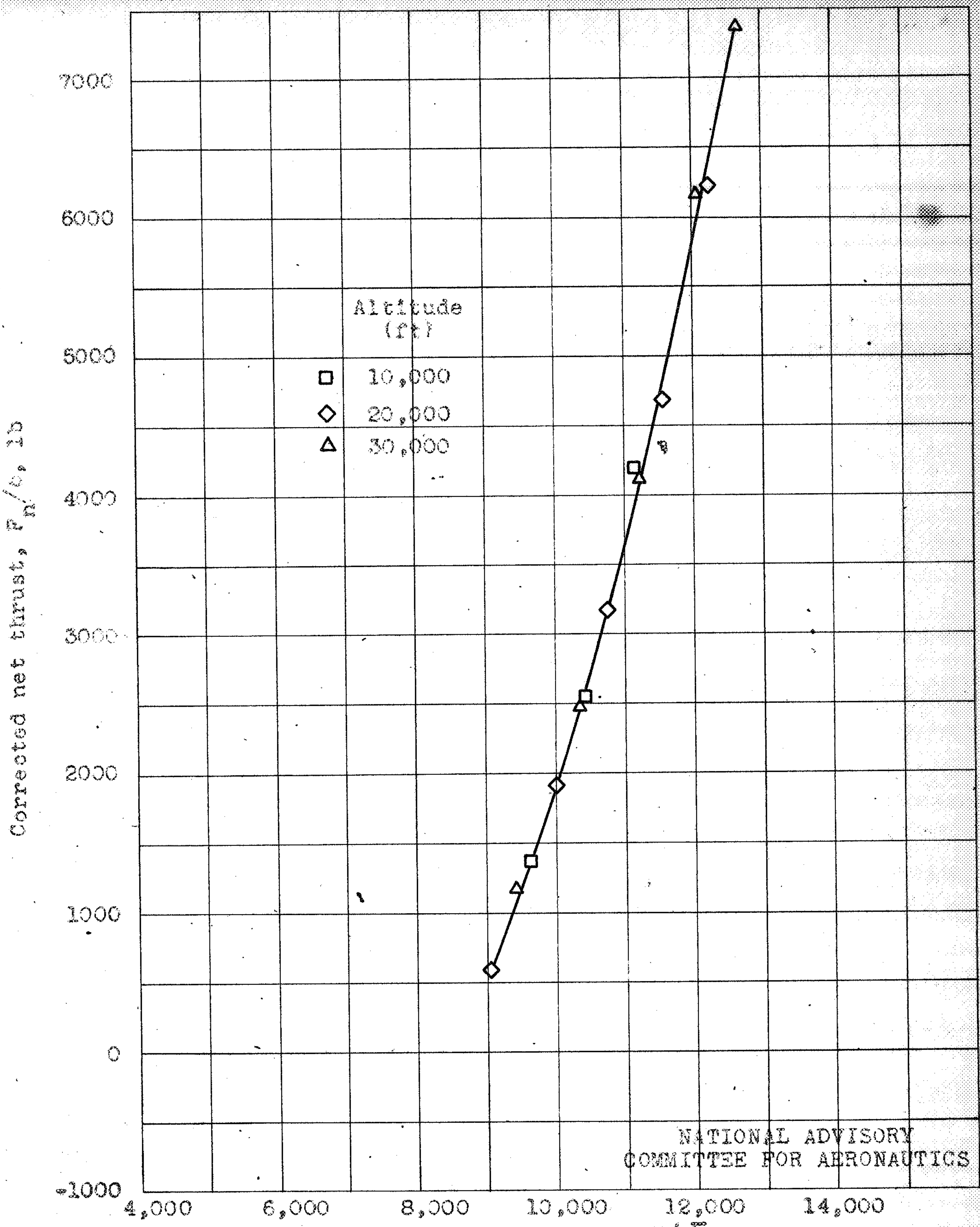


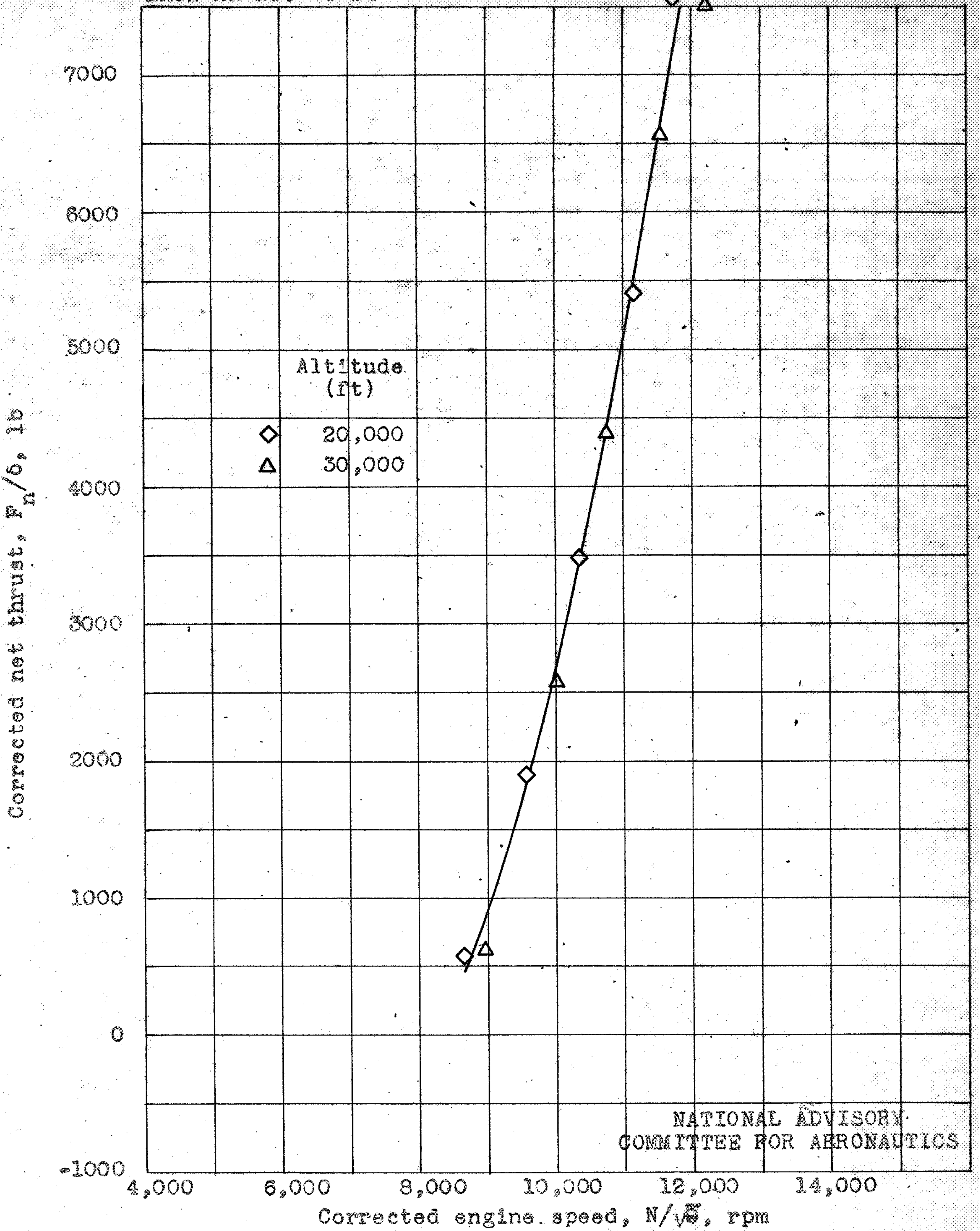
(b) Ram-pressure ratio, P_2/p_0, 1.3.

Figure 2. - Continued. Effect of altitude and corrected engine speed on corrected net thrust at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



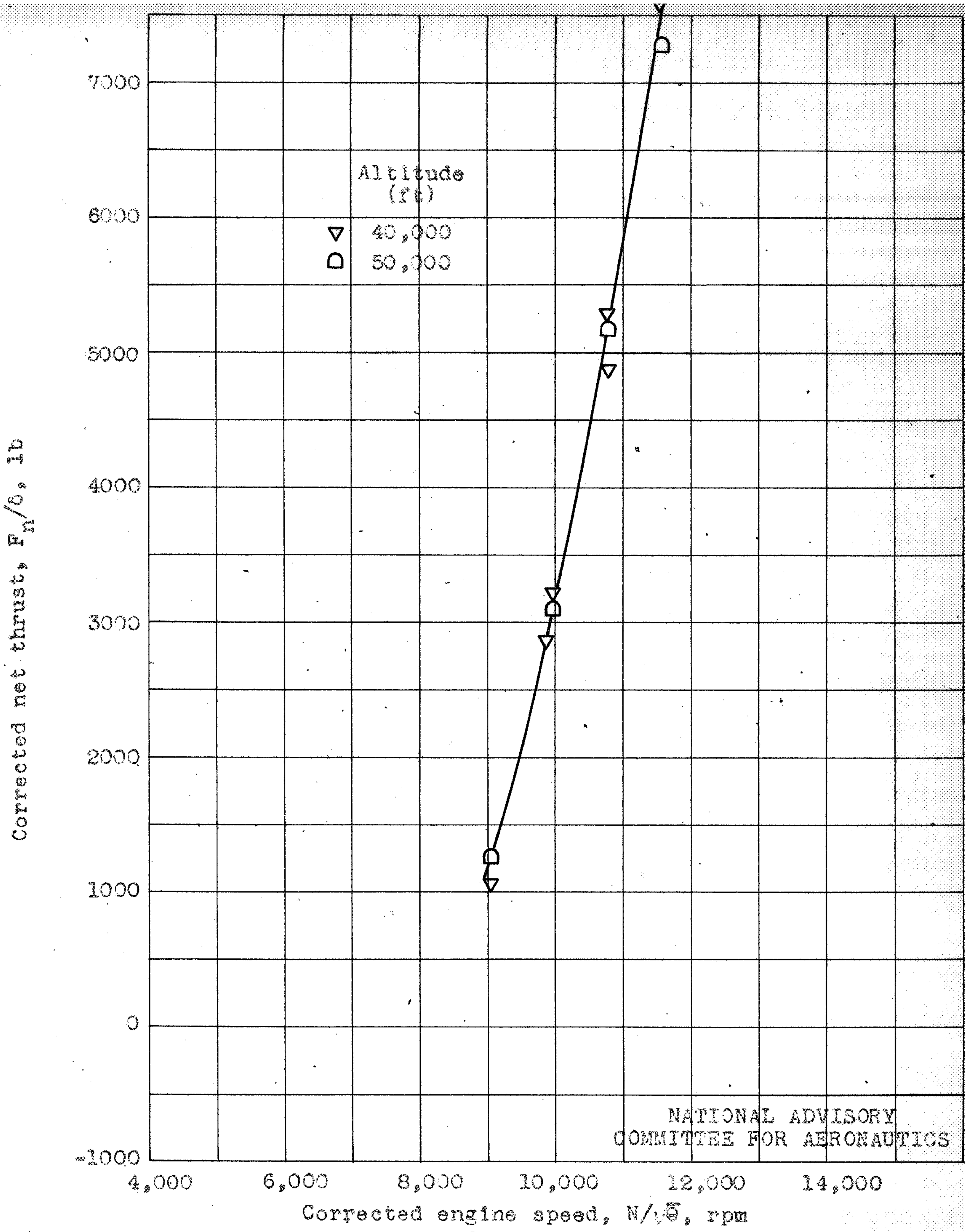
(c) Ram-pressure ratio, P_2/p_0, 1.7.

Figure 2. - Continued. Effect of altitude and corrected engine speed on corrected net thrust at various ram-pressure ratios. Jet-nozzle diameter, 13.41 inches.



(d) Ram-pressure ratio, P_2/p_0, 2.3.

Figure 2. - Continued. Effect of altitude and corrected engine speed on corrected net thrust at various ram-pressure ratios. Jet nozzle diameter, 18.41 inches.



(e) Ram-pressure ratio, P_2/p_0, 2.7.

Figure 2. - Concluded. Effect of altitude and corrected engine speed on corrected net thrust at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.

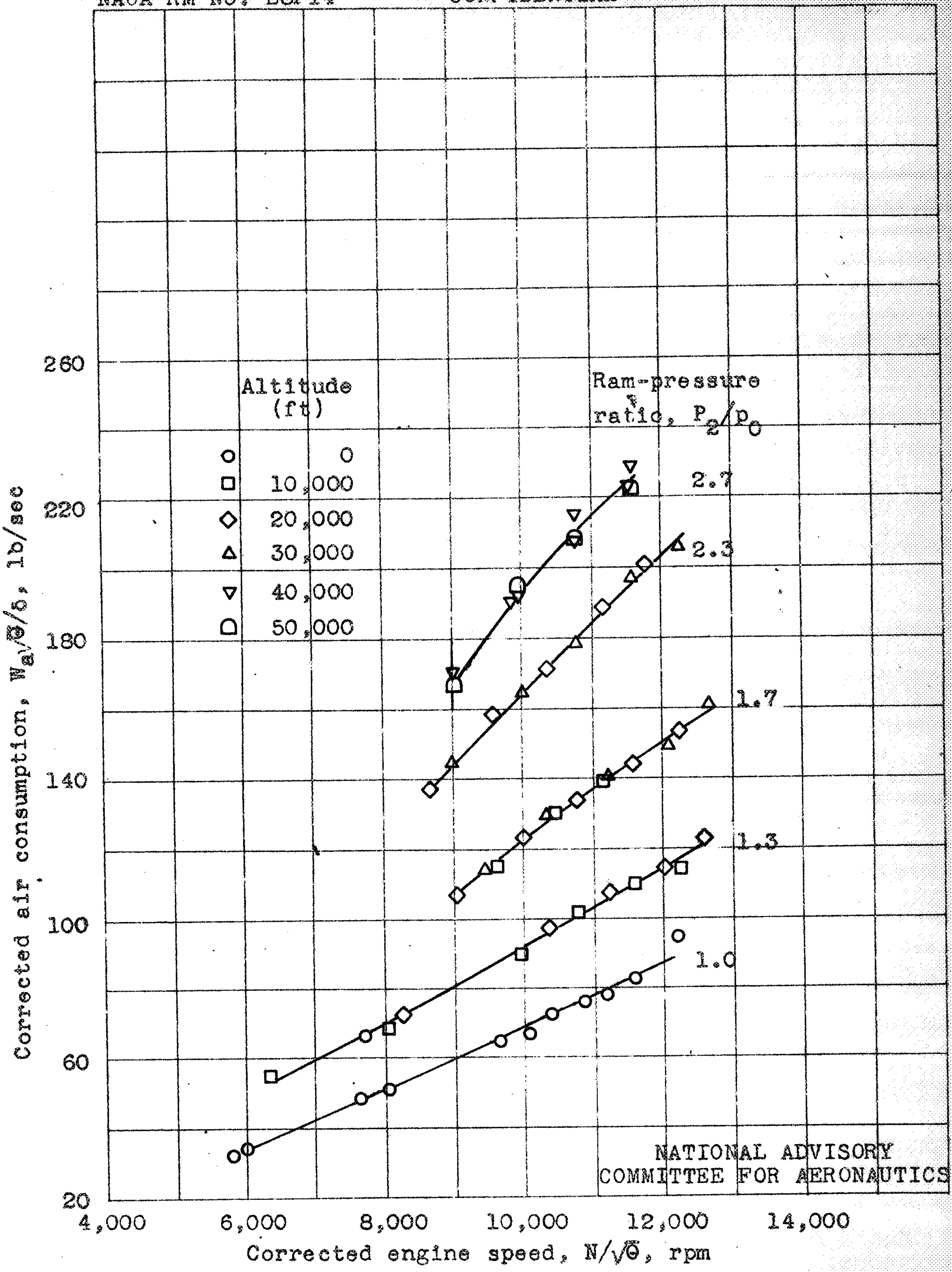
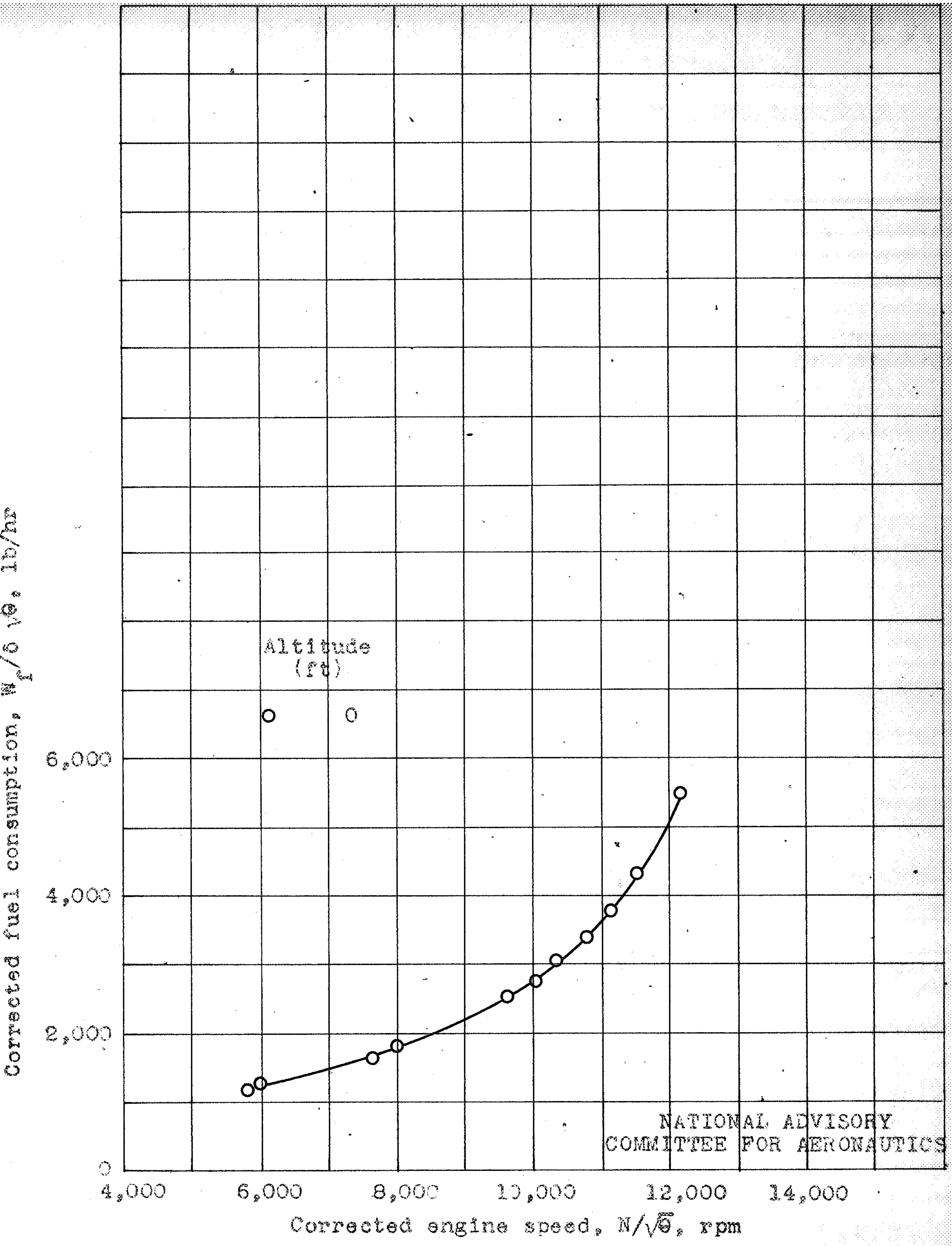
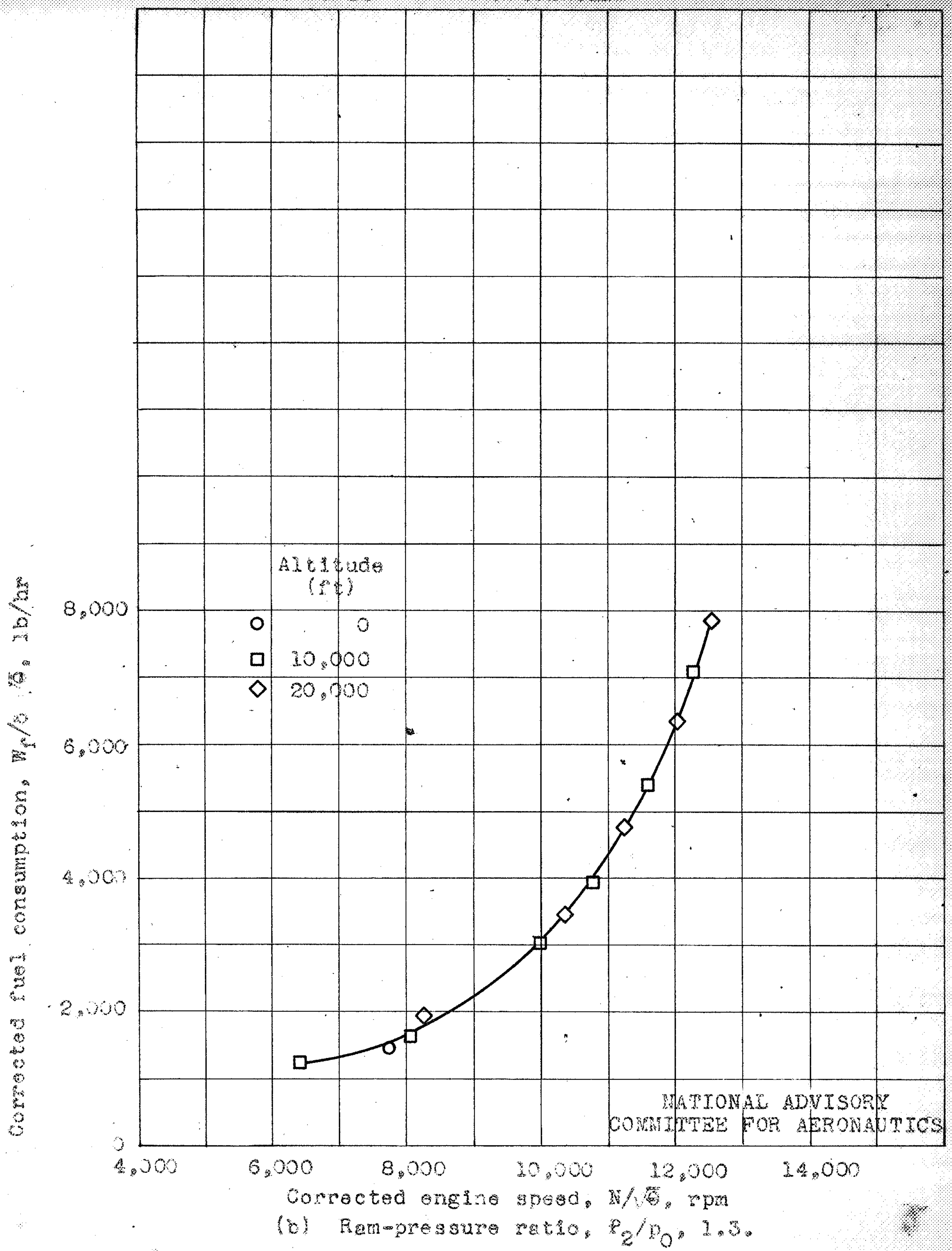


Figure 3.- Effect of altitude and corrected engine speed on corrected air consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



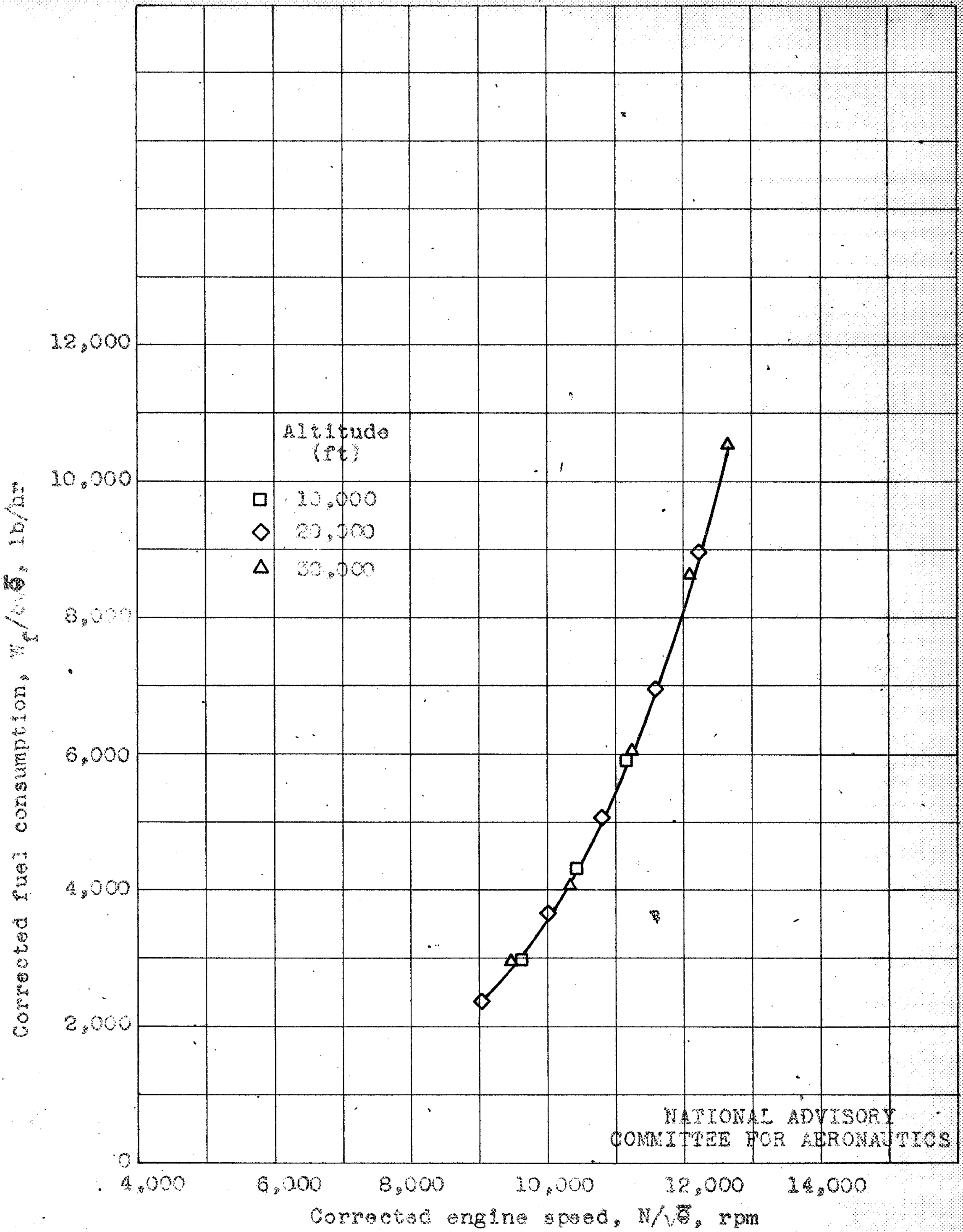
(a) Ram-pressure ratio, P_2/p_0, 1.0.

Figure 4. - Effect of altitude and corrected engine speed on corrected fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



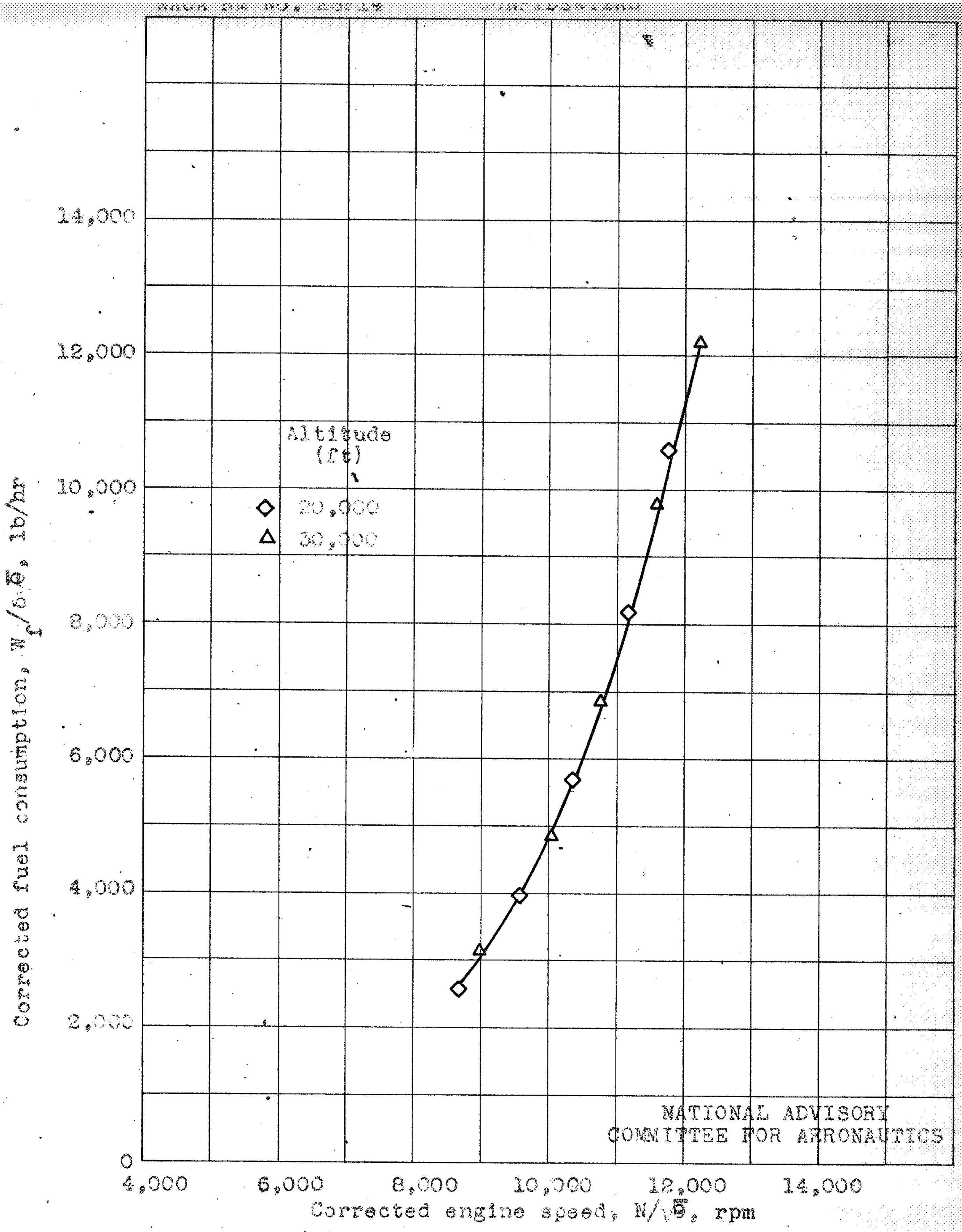
(b) Ram-pressure ratio, P_2/p_0, 1.3.

Figure 4. - Continued. Effect of altitude and corrected engine speed on corrected fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



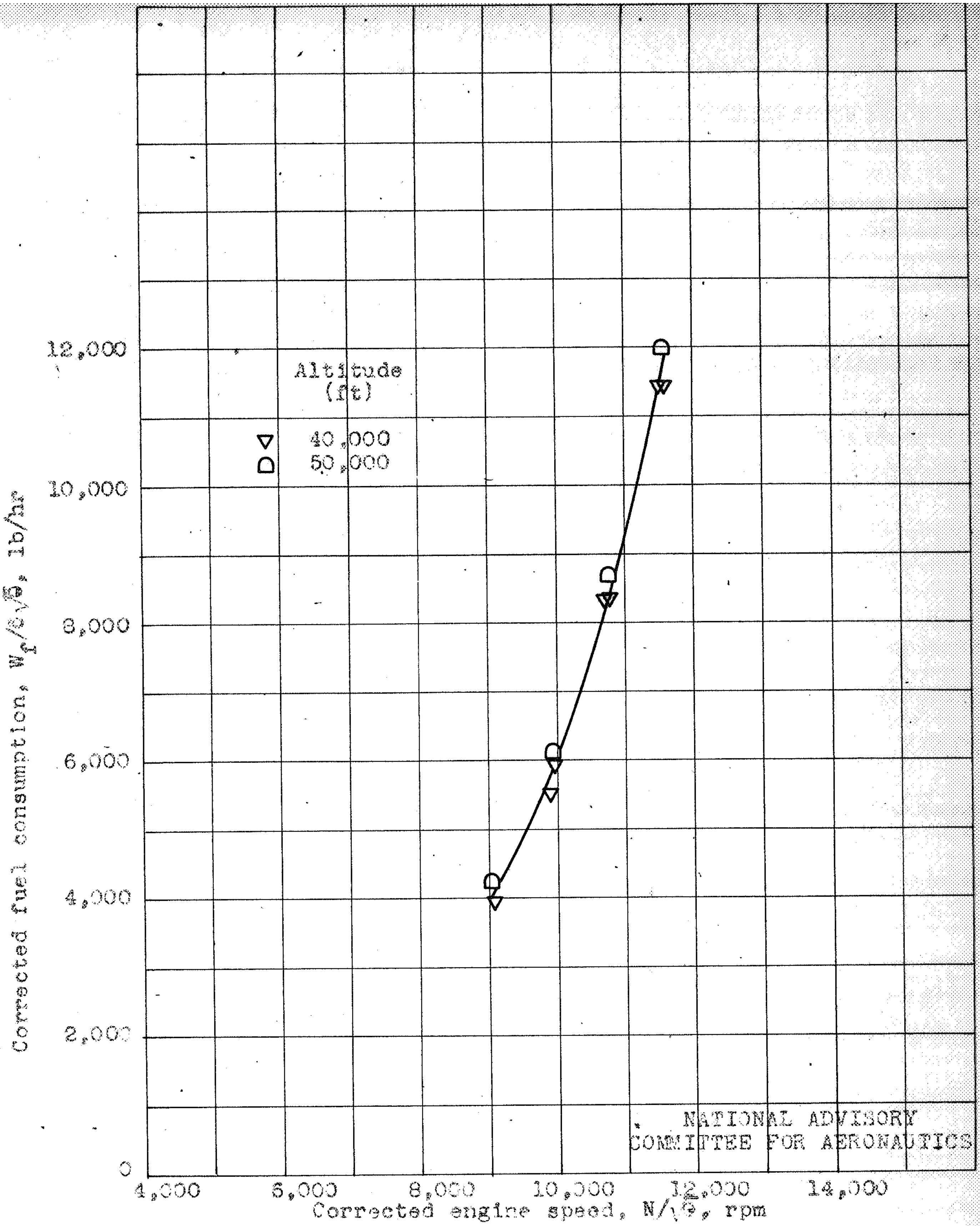
(c) Ram-pressure ratio, P_2/p_0, 1.7.

Figure 4. - Continued. Effect of altitude and corrected engine speed on corrected fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



(d) Ram-pressure ratio, P_2/p_0, 2.3.

Figure 4. - Continued. Effect of altitude and corrected engine speed on corrected fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



(e) Ram-pressure ratio, P_2/p_0, 2.7.

Figure 4. - Concluded. Effect of altitude and corrected engine speed on corrected fuel consumption at various ram-pressure ratios. Jet nozzle diameter, 18.41 inches.

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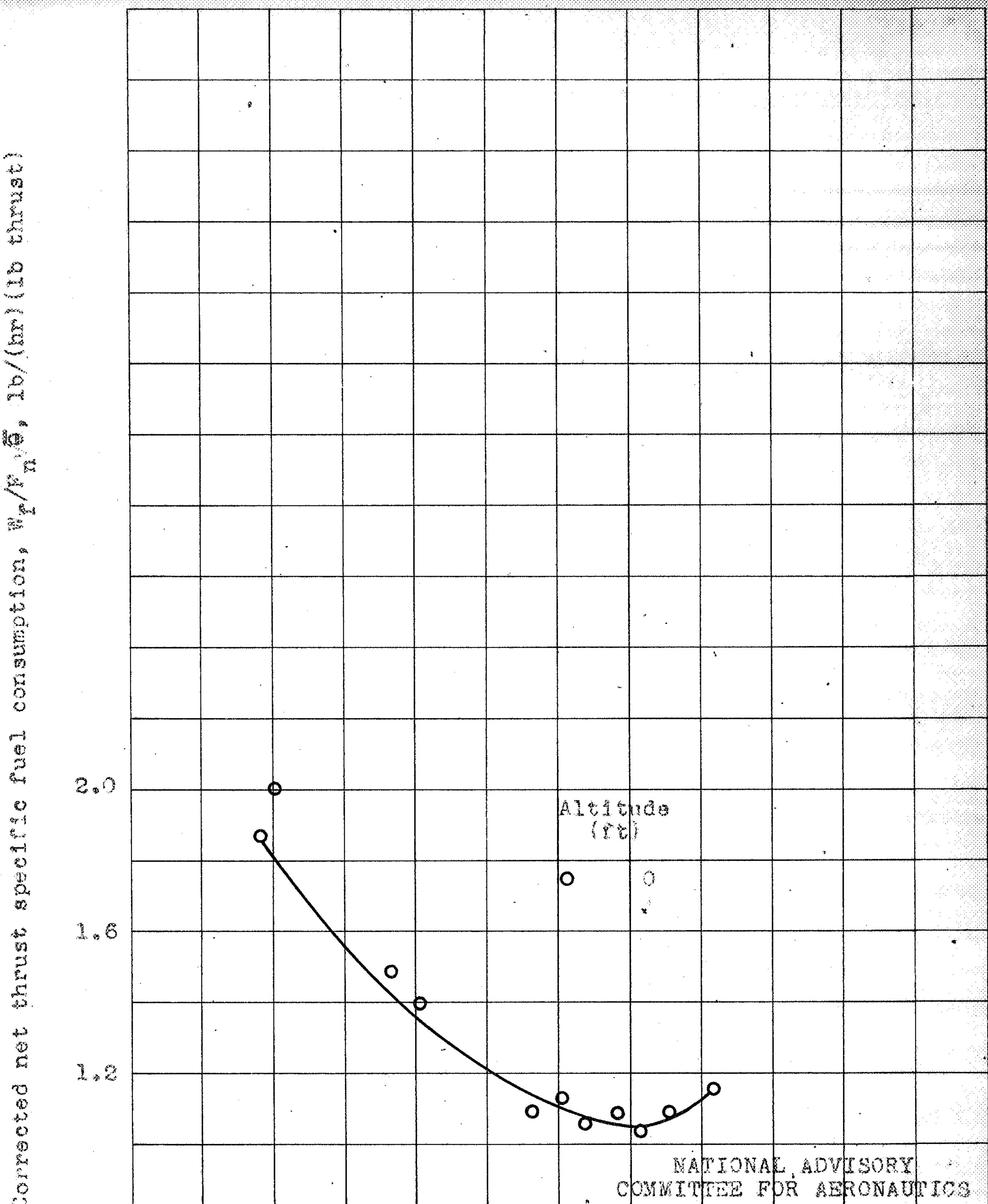
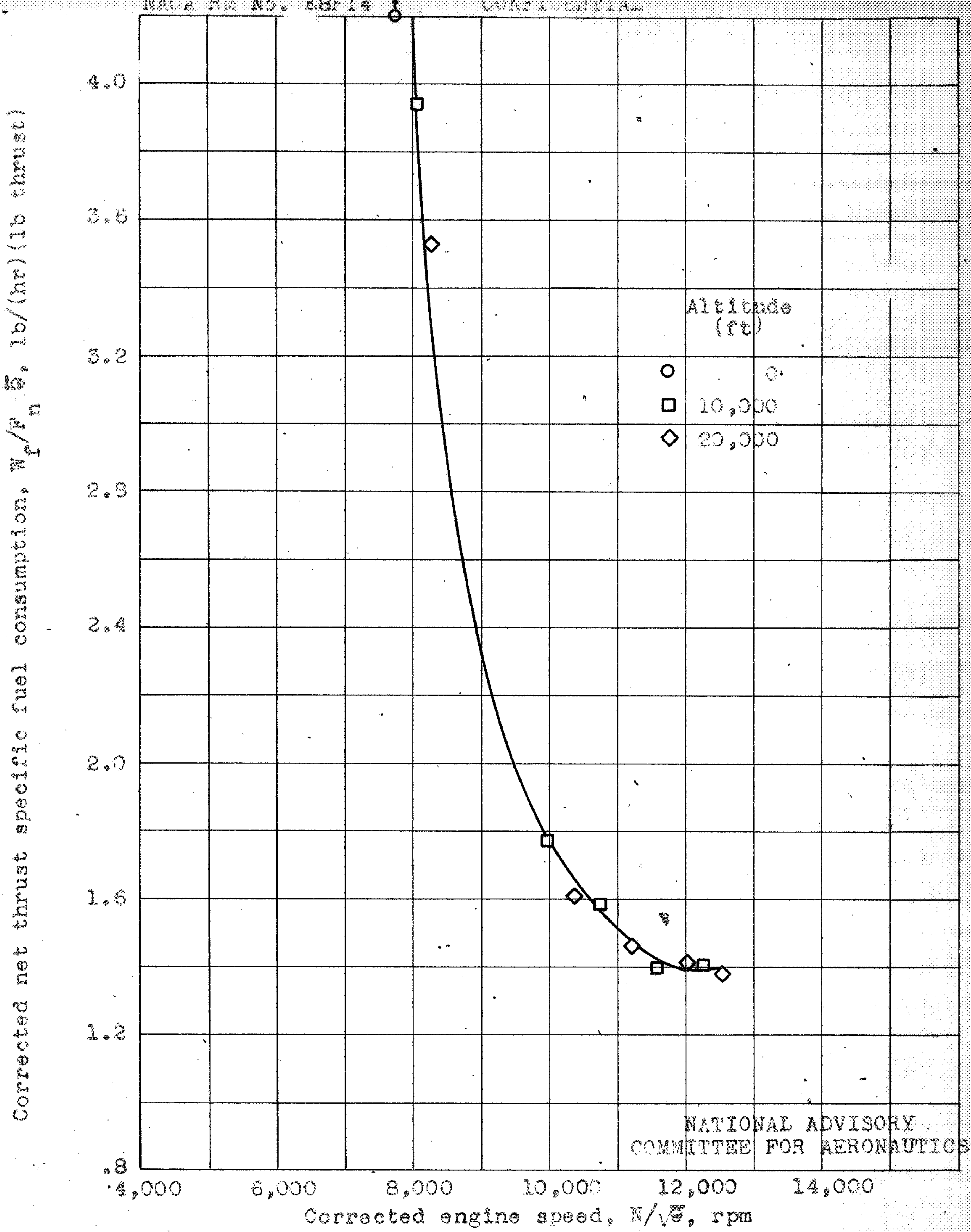


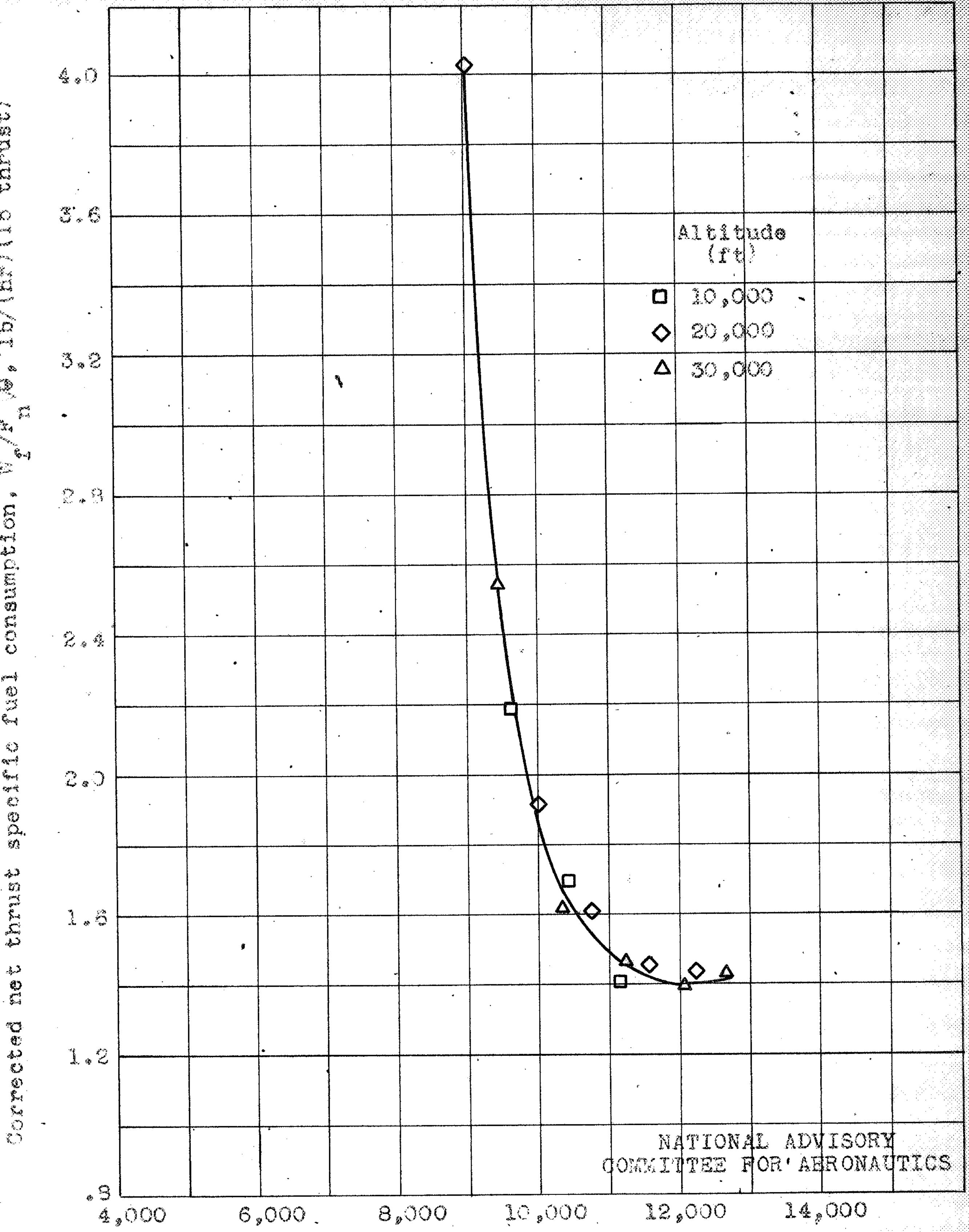
(a) Ram-pressure ratio, P_2/p_0, 1.0.

Figure 57. - Effect of altitude and corrected engine speed on corrected net-thrust specific fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



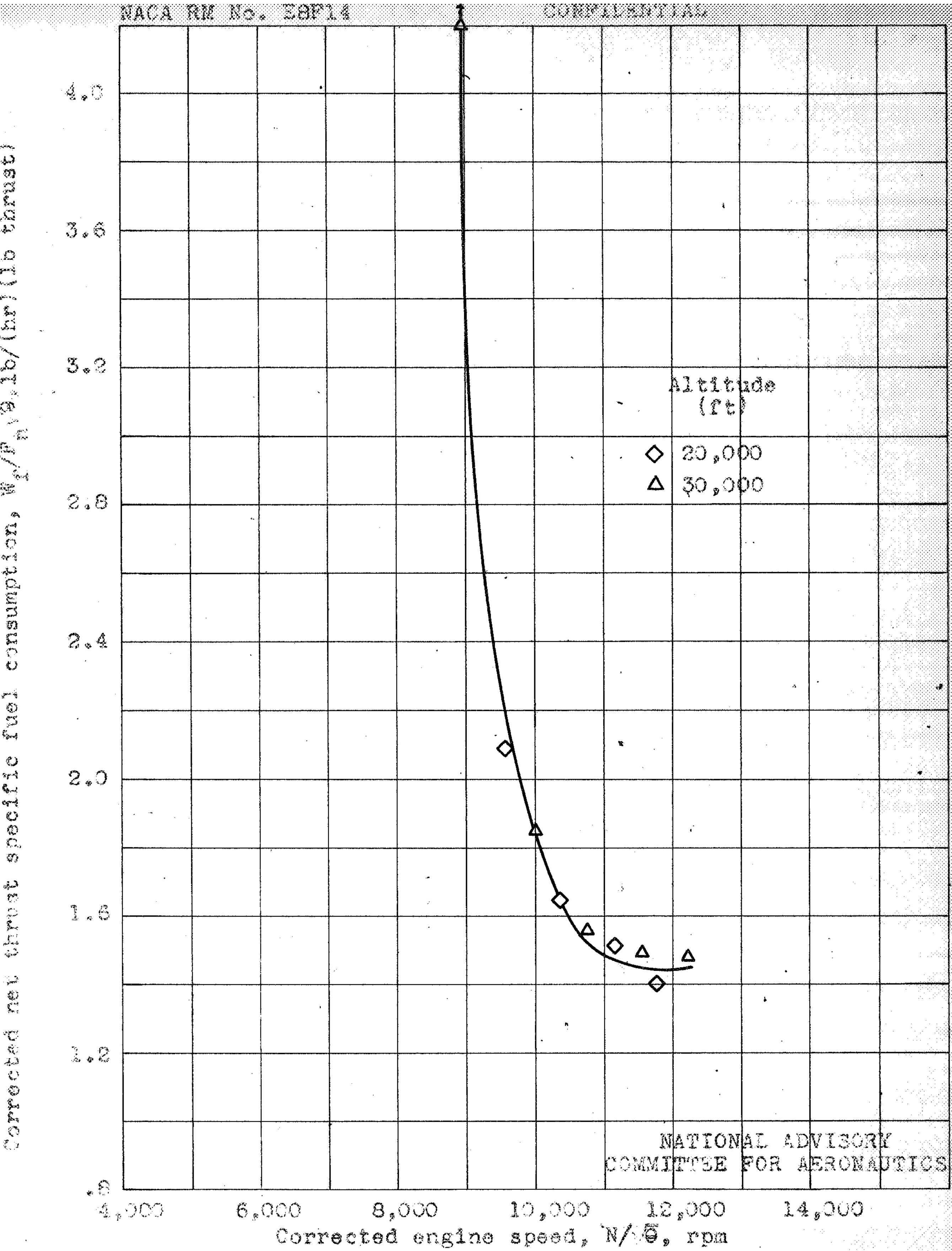
(b) Ram-pressure ratio, P_2/p_0, 1.3.

Figure 5. - Continued. Effect of altitude and corrected engine speed on corrected net-thrust specific fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



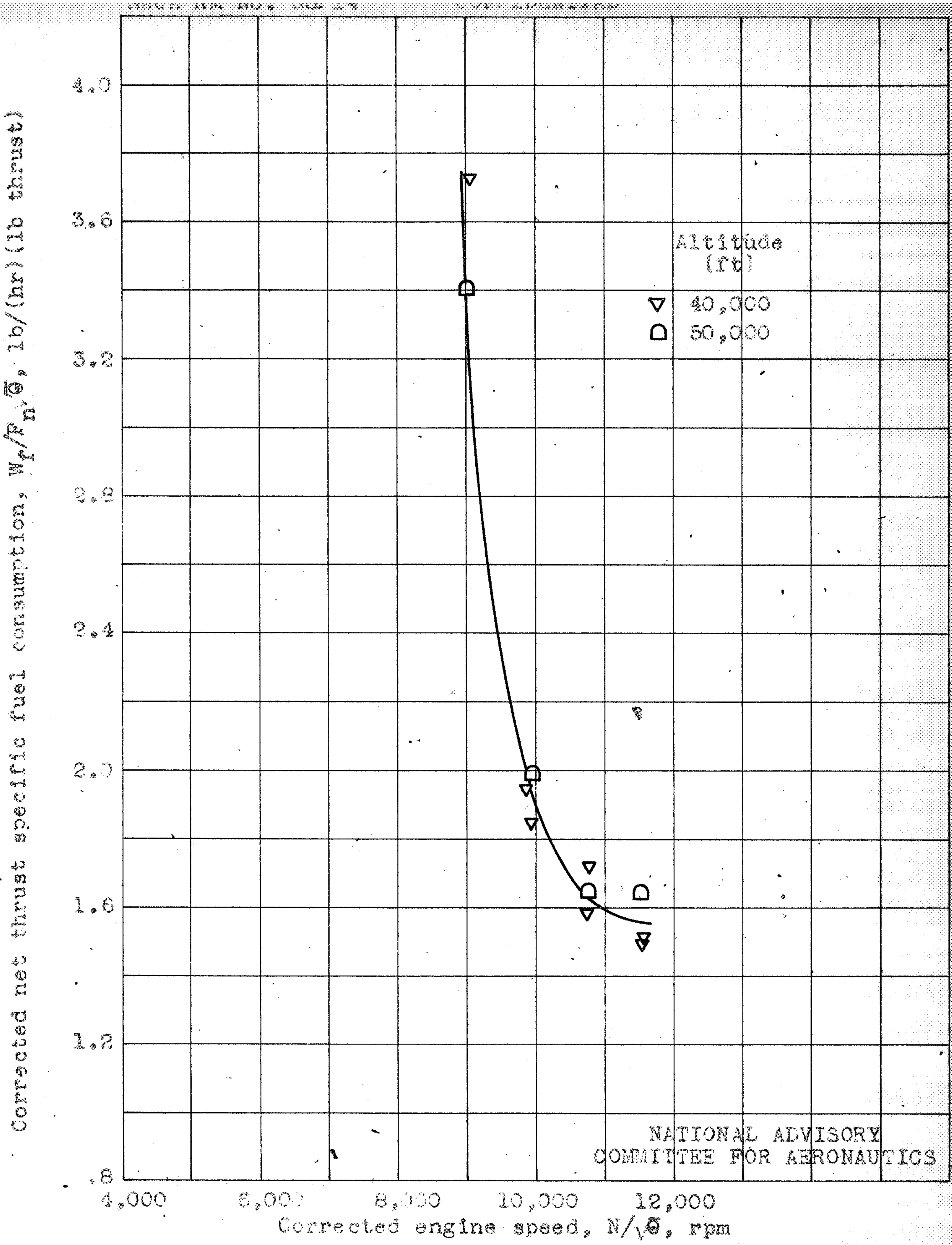
(c) Ram-pressure ratio, P_2/p_0, 1.7.

Figure 5. - Continued. Effect of altitude and corrected engine speed on corrected net-thrust specific fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



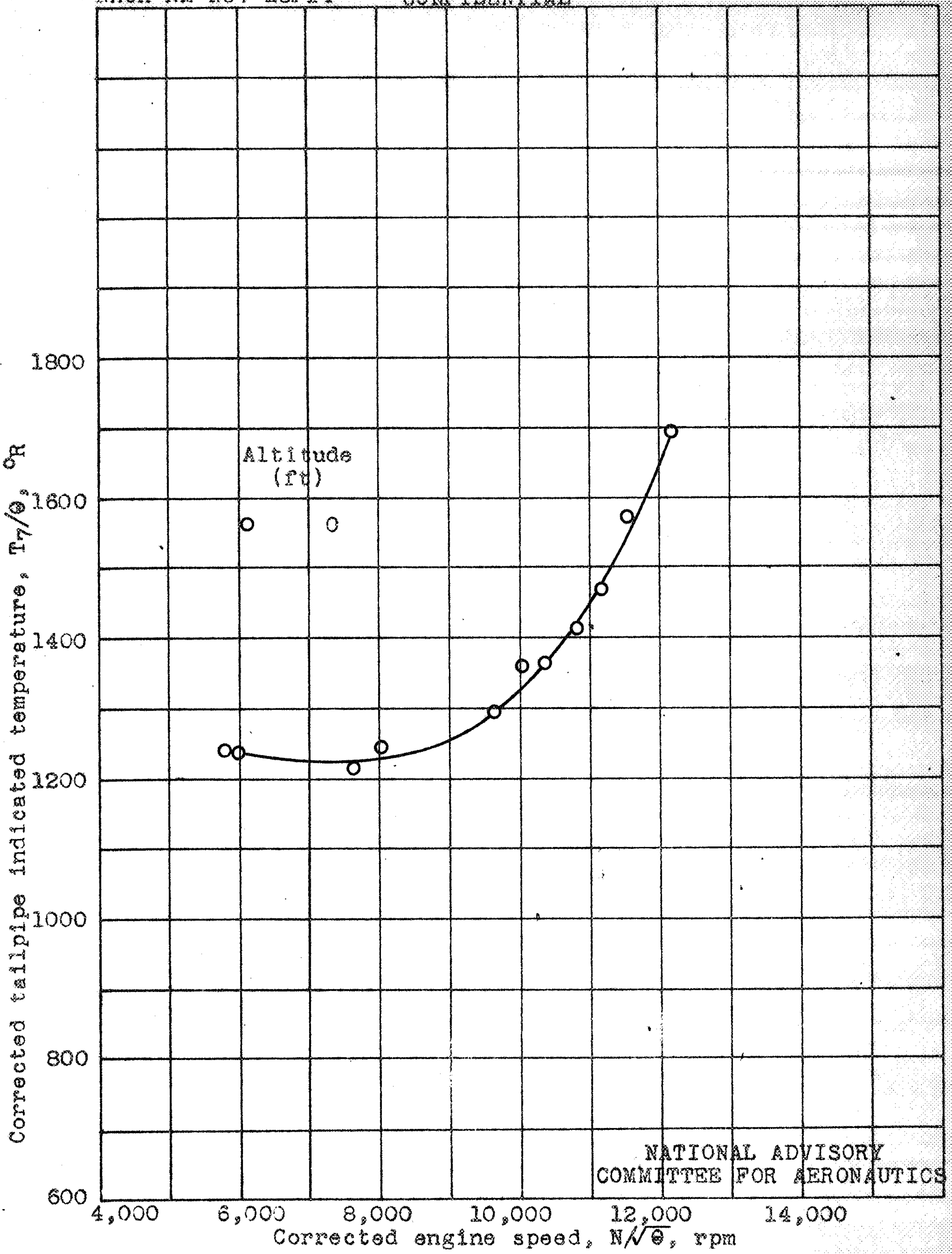
(d) Ram-pressure ratio, P_2/p_0, 2.3.

Figure 5. - Continued. Effect of altitude and corrected engine speed on corrected net-thrust specific fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



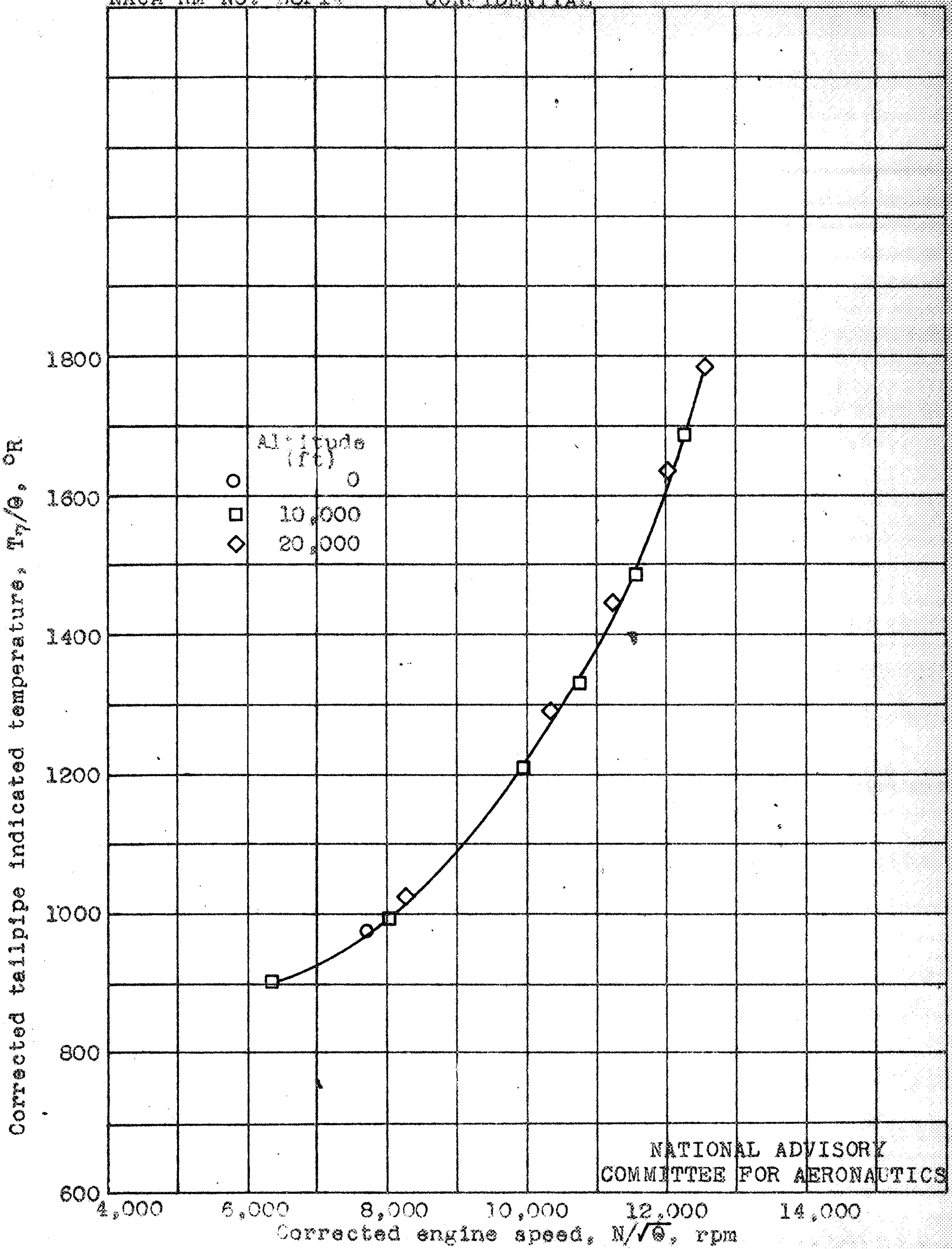
(e) Ram-pressure ratio, P_2/p_0, 2.7.

Figure 5. - Concluded. Effect of altitude and corrected engine speed on corrected net-thrust specific fuel consumption at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



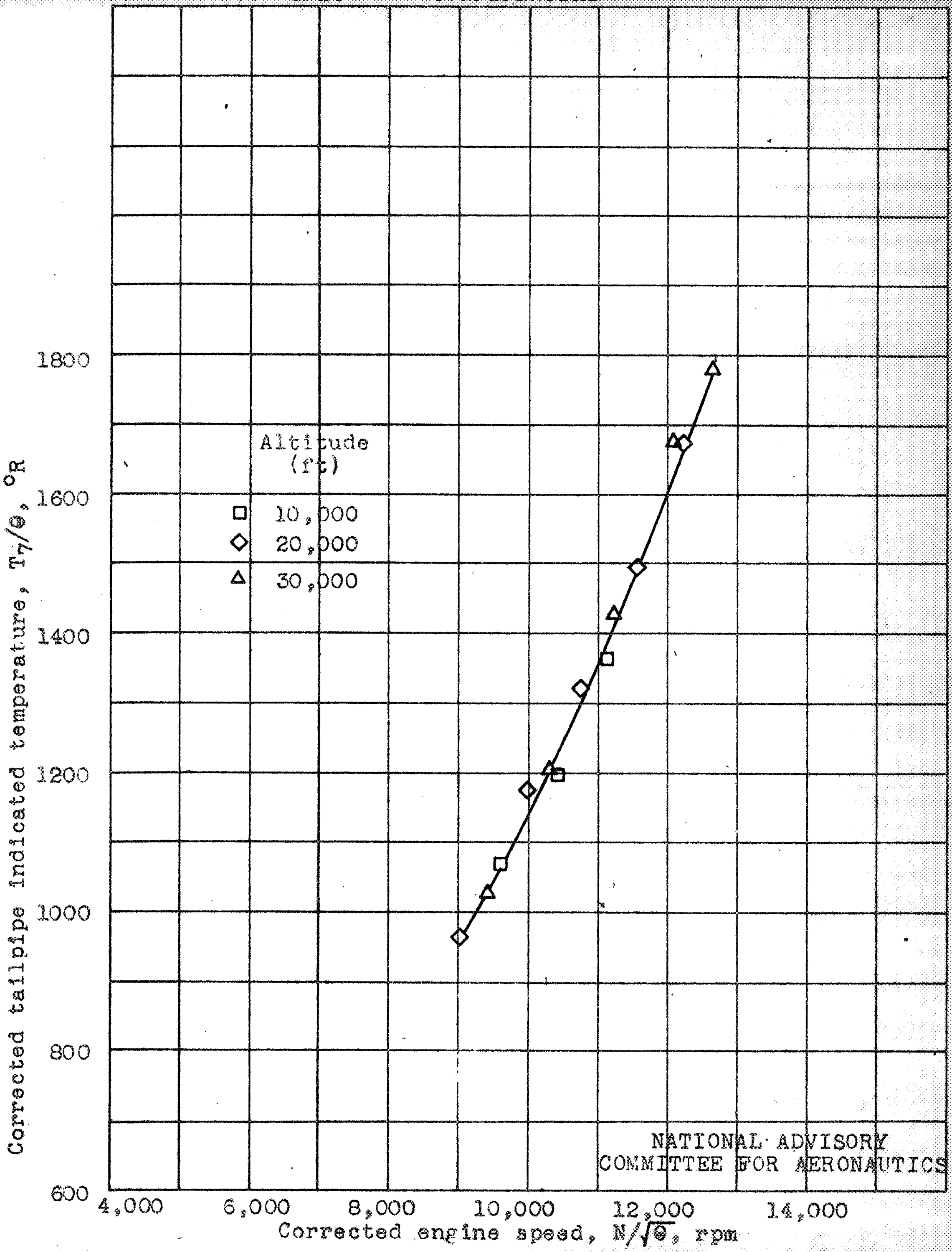
(a) Ram-pressure ratio, P_2/p_0, 1.0.

Figure 6. - Effect of altitude and corrected engine speed on corrected tailpipe indicated temperature at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



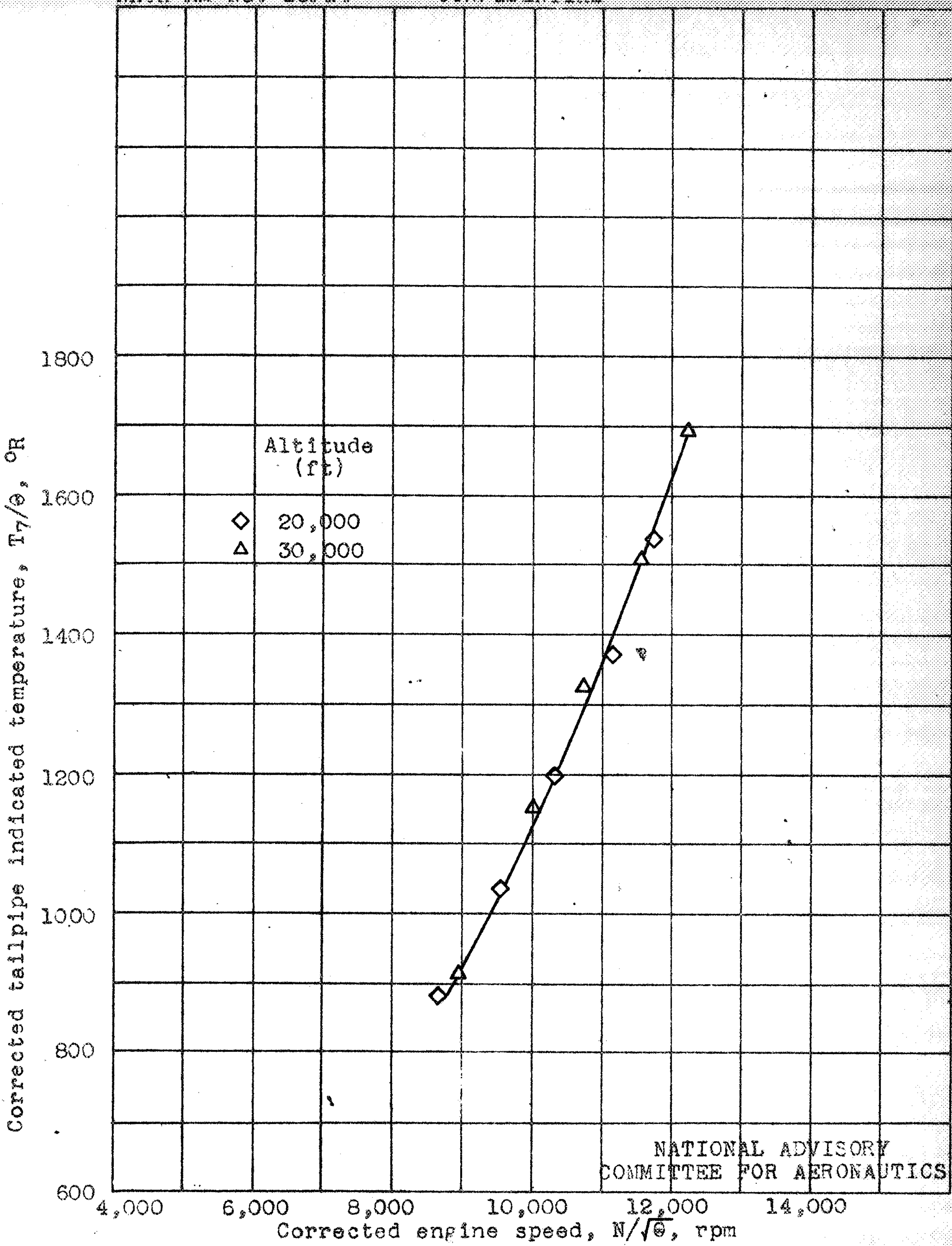
(b) Ram-pressure ratio, P_2/p_0, 1.3.

Figure 6. - Continued. Effect of altitude and corrected engine speed on corrected tailpipe indicated temperature at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



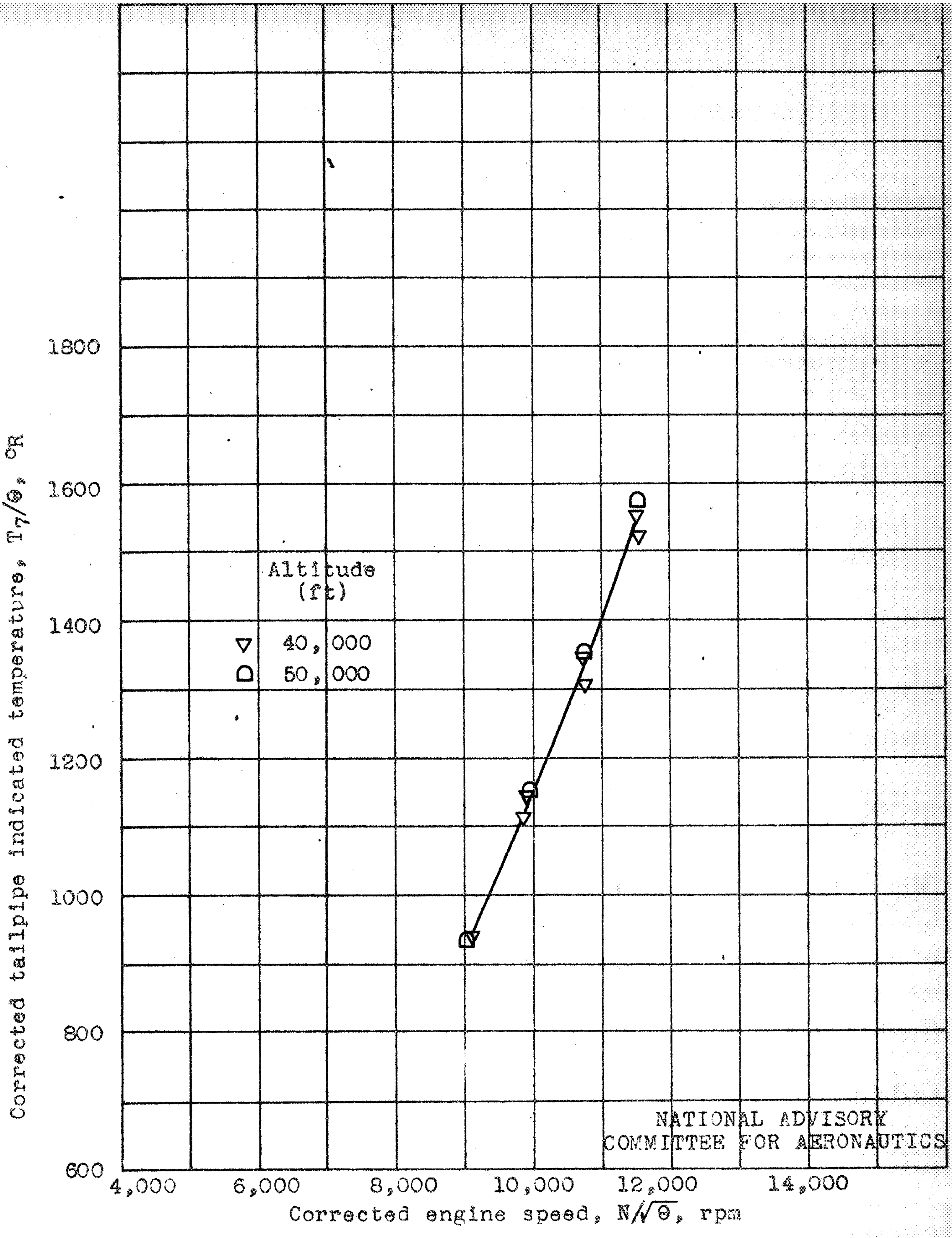
(c) Ram-pressure ratio, P_2/p_0, 1.7.

Figure 6. - Continued. Effect of altitude and corrected engine speed on corrected tailpipe indicated temperature at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



(d) Ram-pressure ratio, P_2/p_0, 2.3.

Figure 6. - Continued. Effect of altitude and corrected engine speed on corrected tailpipe indicated temperature at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.



(e) Ram-pressure ratio, P_2/p_0, 2.7.

Figure 6. - Concluded. Effect of altitude and corrected engine speed on corrected tailpipe indicated temperature at various ram-pressure ratios. Jet-nozzle diameter, 18.41 inches.

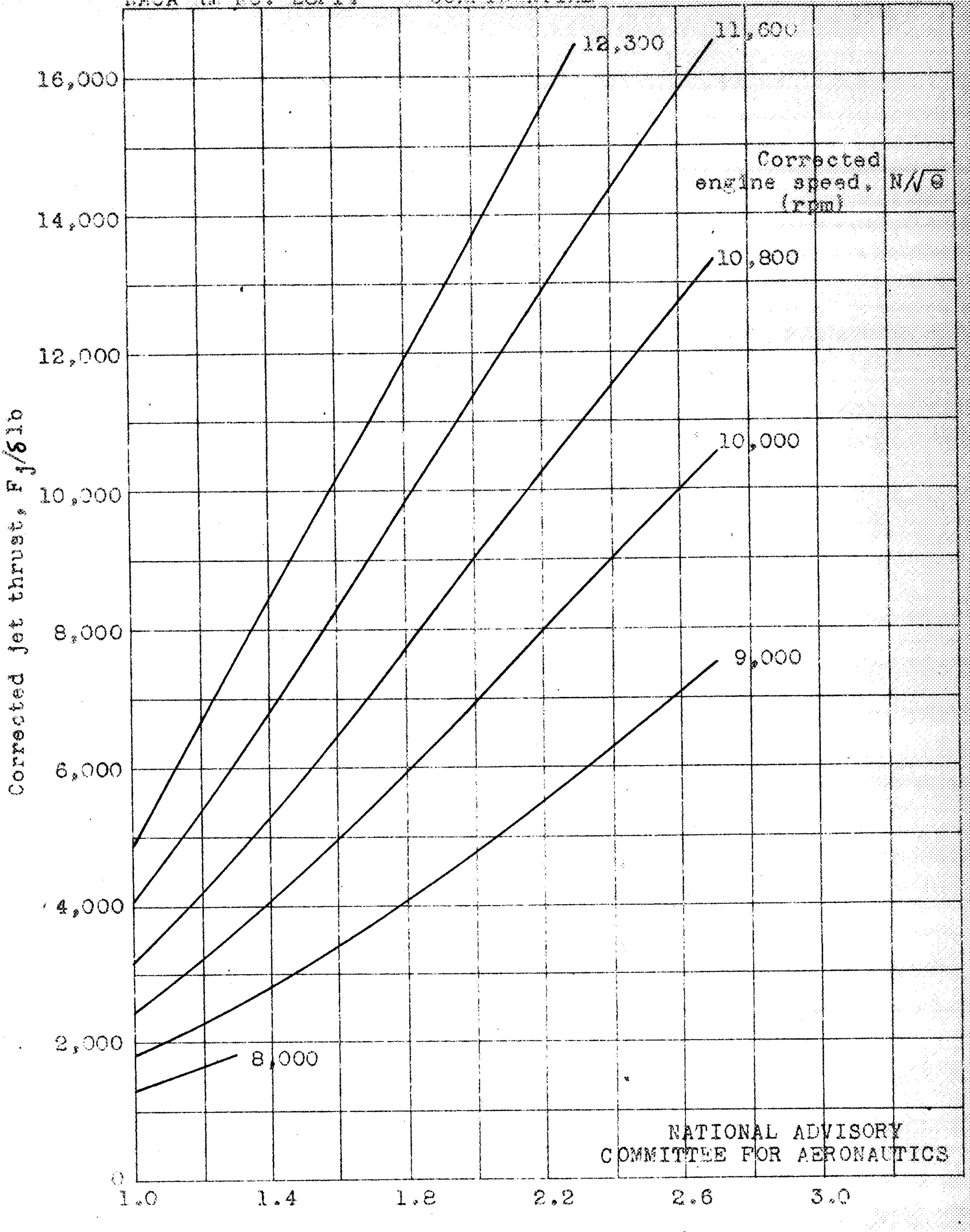


Figure 7. - Effect of ram-pressure ratio on corrected jet thrust. (Cross plot from figure 1.)

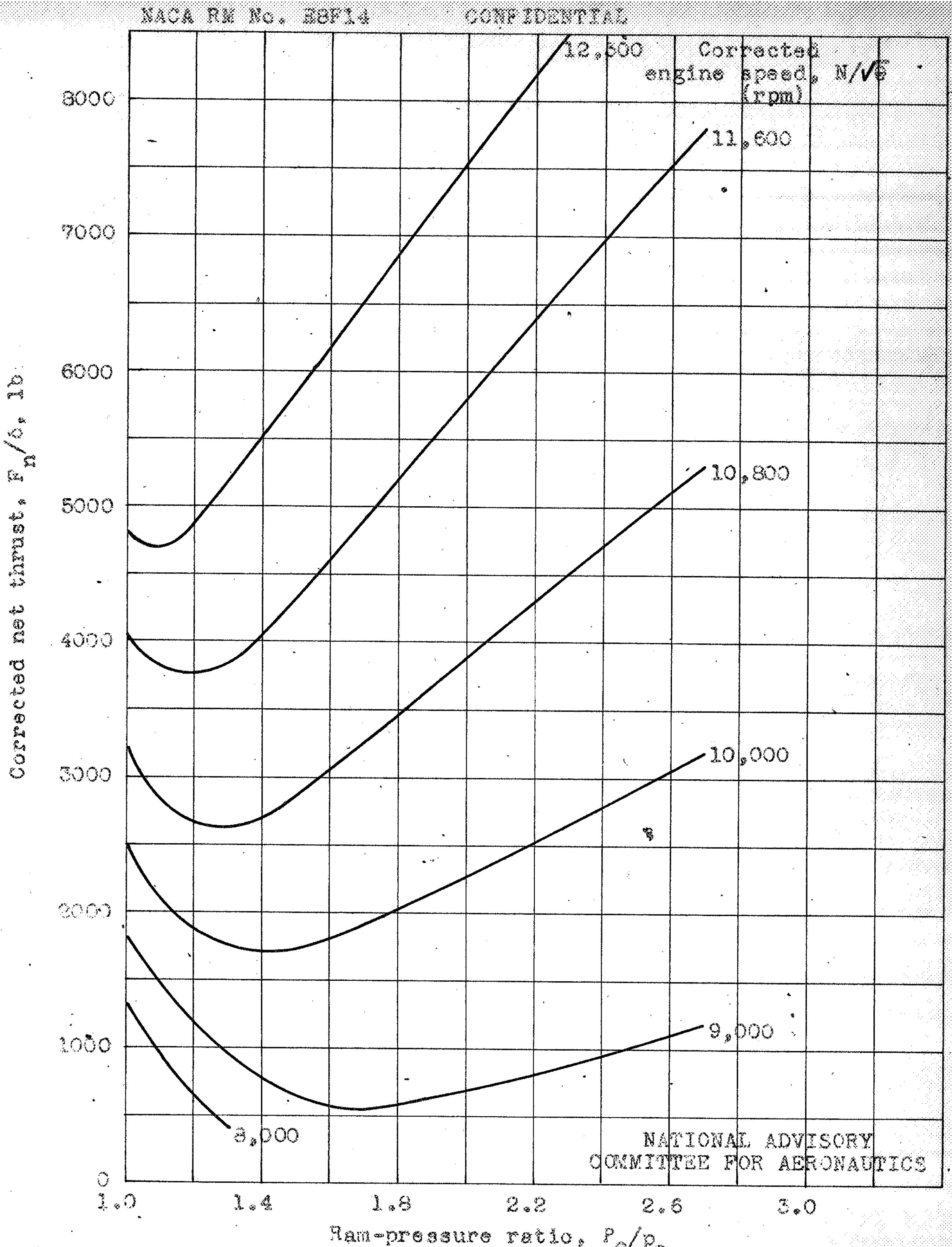


Figure 8. - Effect of ram-pressure ratio on corrected net thrust. (Cross plot from figure 2.)

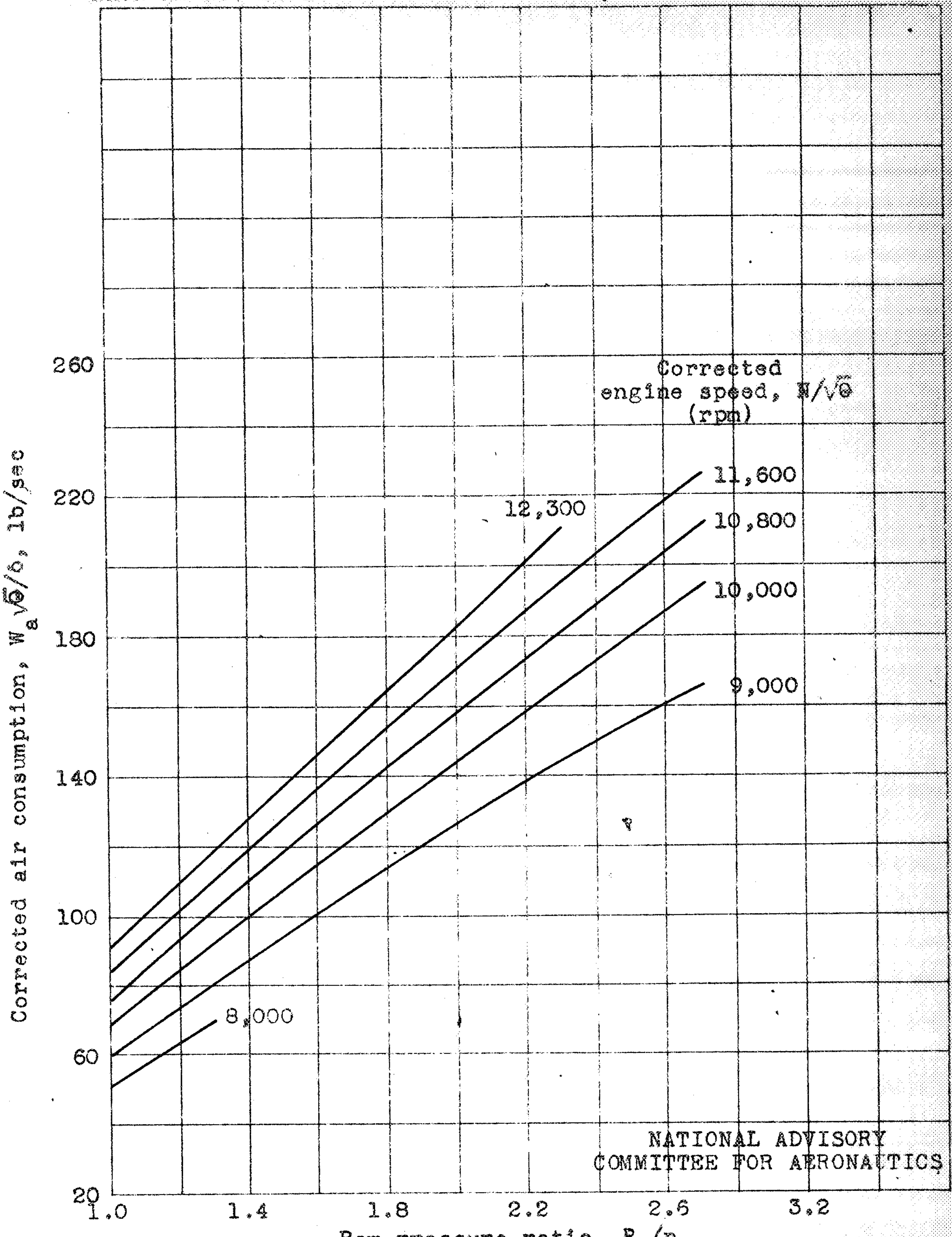


Figure 9.- Effect of ram-pressure ratio on corrected air consumption. (Cross plot from figure 3.)

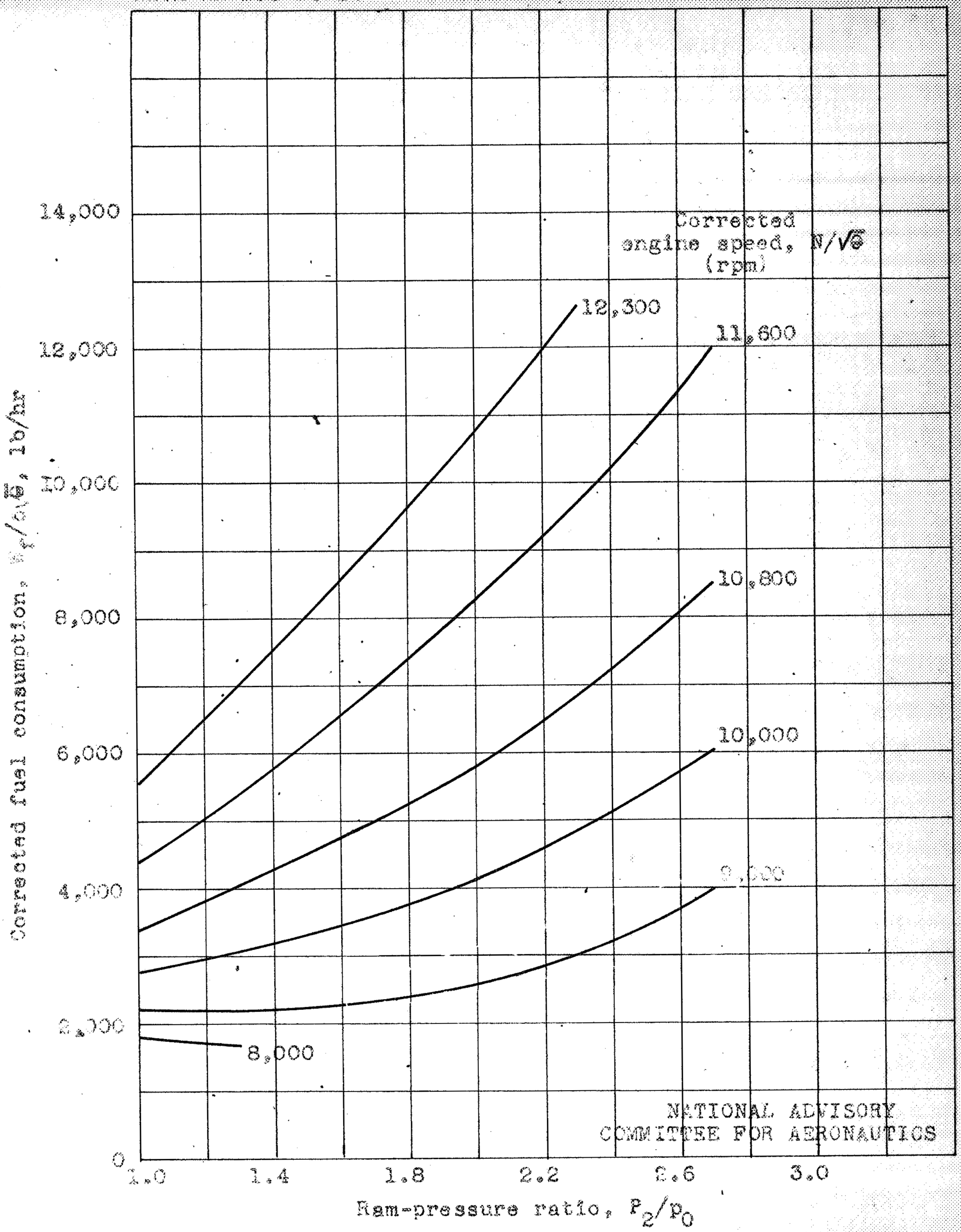


Figure 10. - Effect of ram-pressure ratio on corrected fuel consumption. (Cross plot from figure 4.)

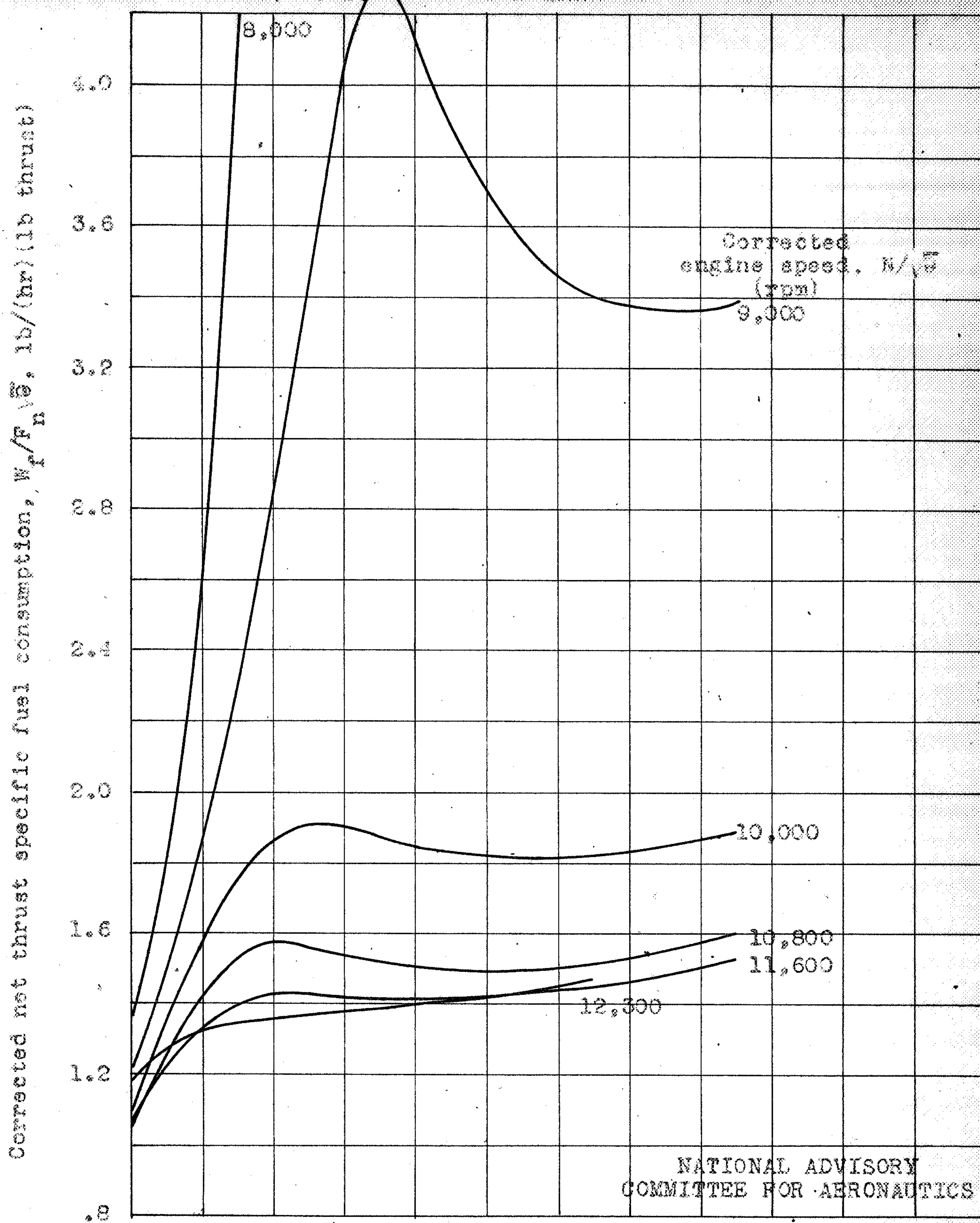


Figure 11.- Effect of ram-pressure ratio on corrected net thrust specific-fuel consumption. (Cross plot from figures 8 and 10.)

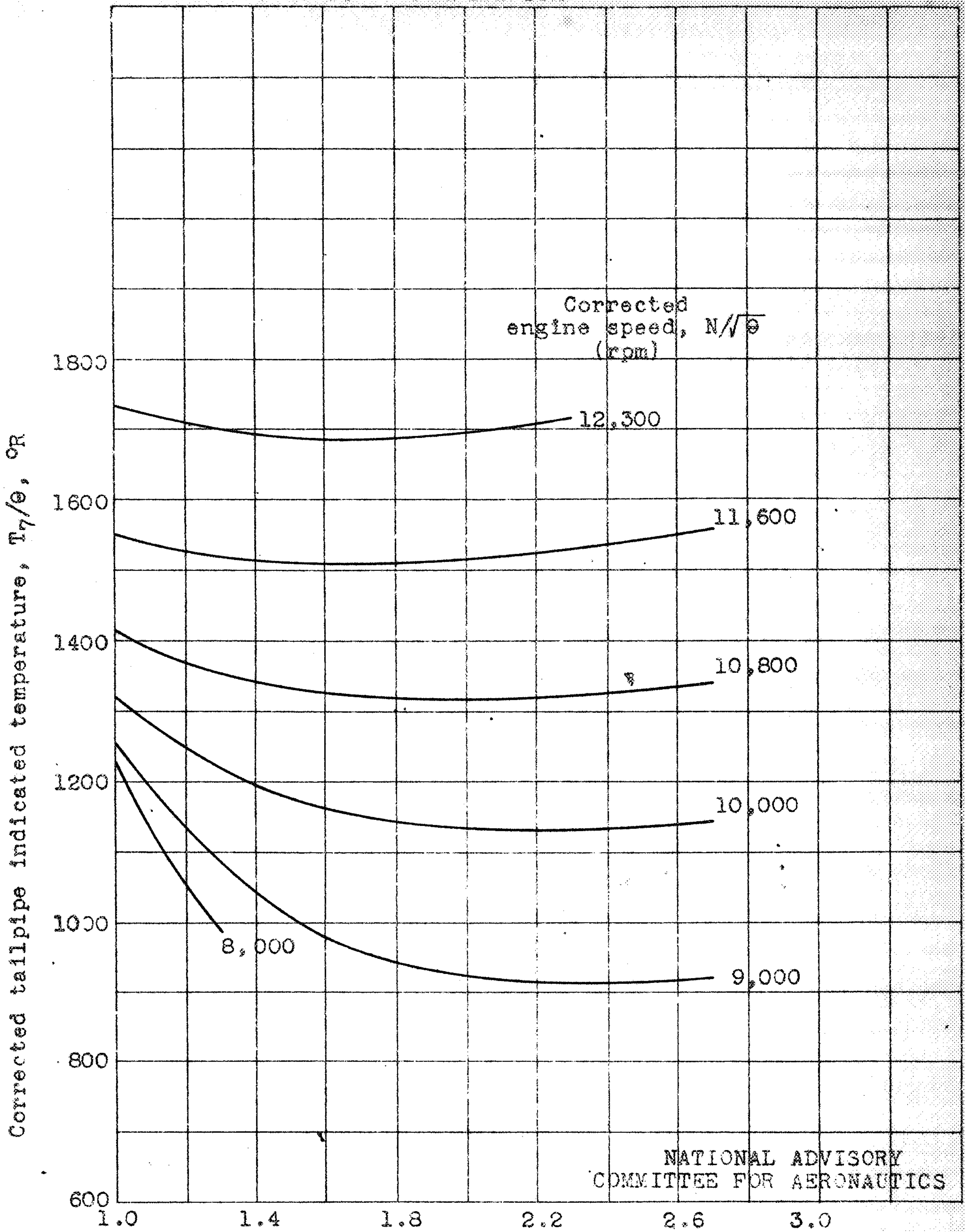


Figure 12. - Effect of ram pressure ratio on corrected tailpipe indicated temperature. (Cross plot from figure 6)

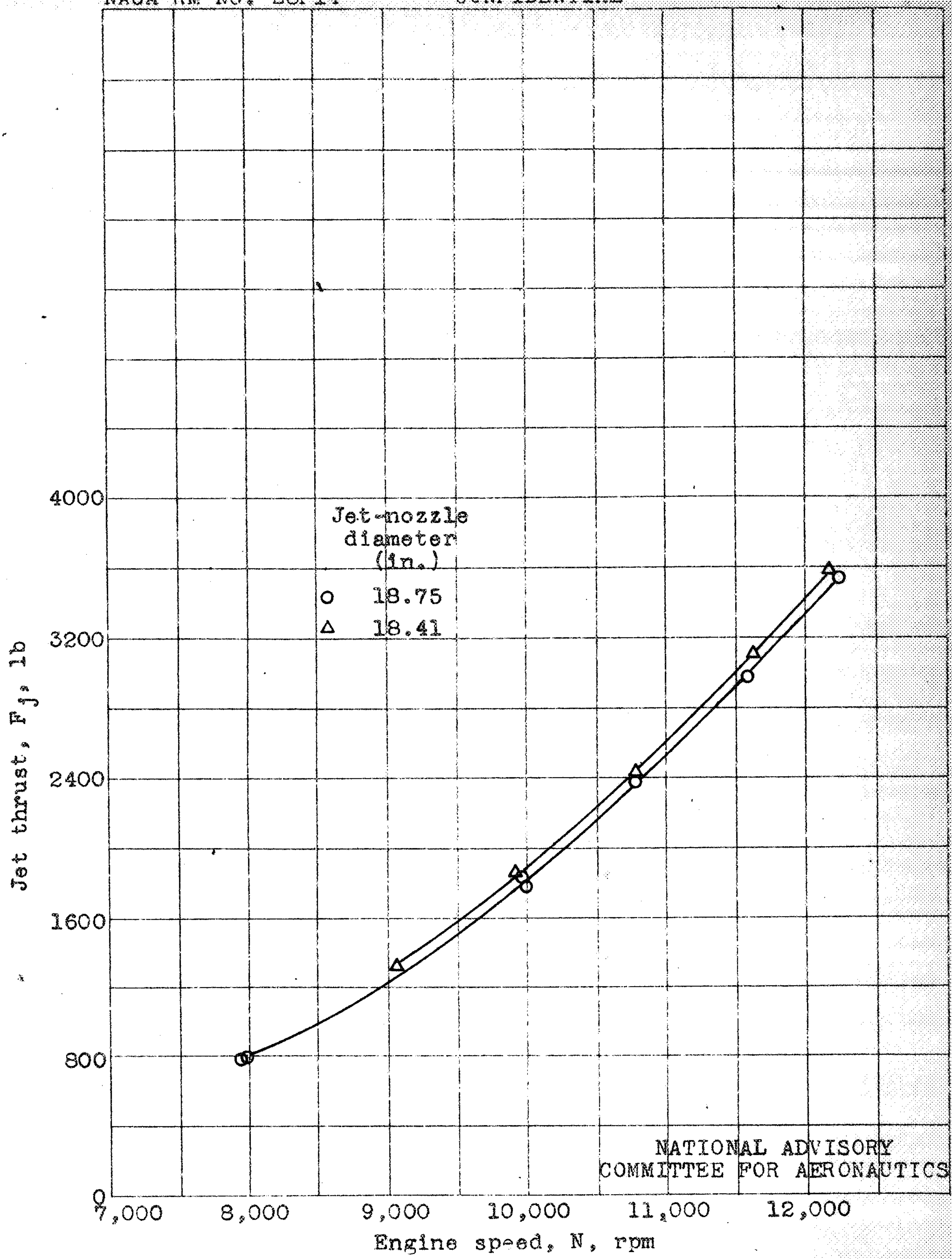


Figure 13.- Effect of nozzle area on jet thrust at a simulated altitude of 30,000 feet and a ram-pressure ratio of 1.7.

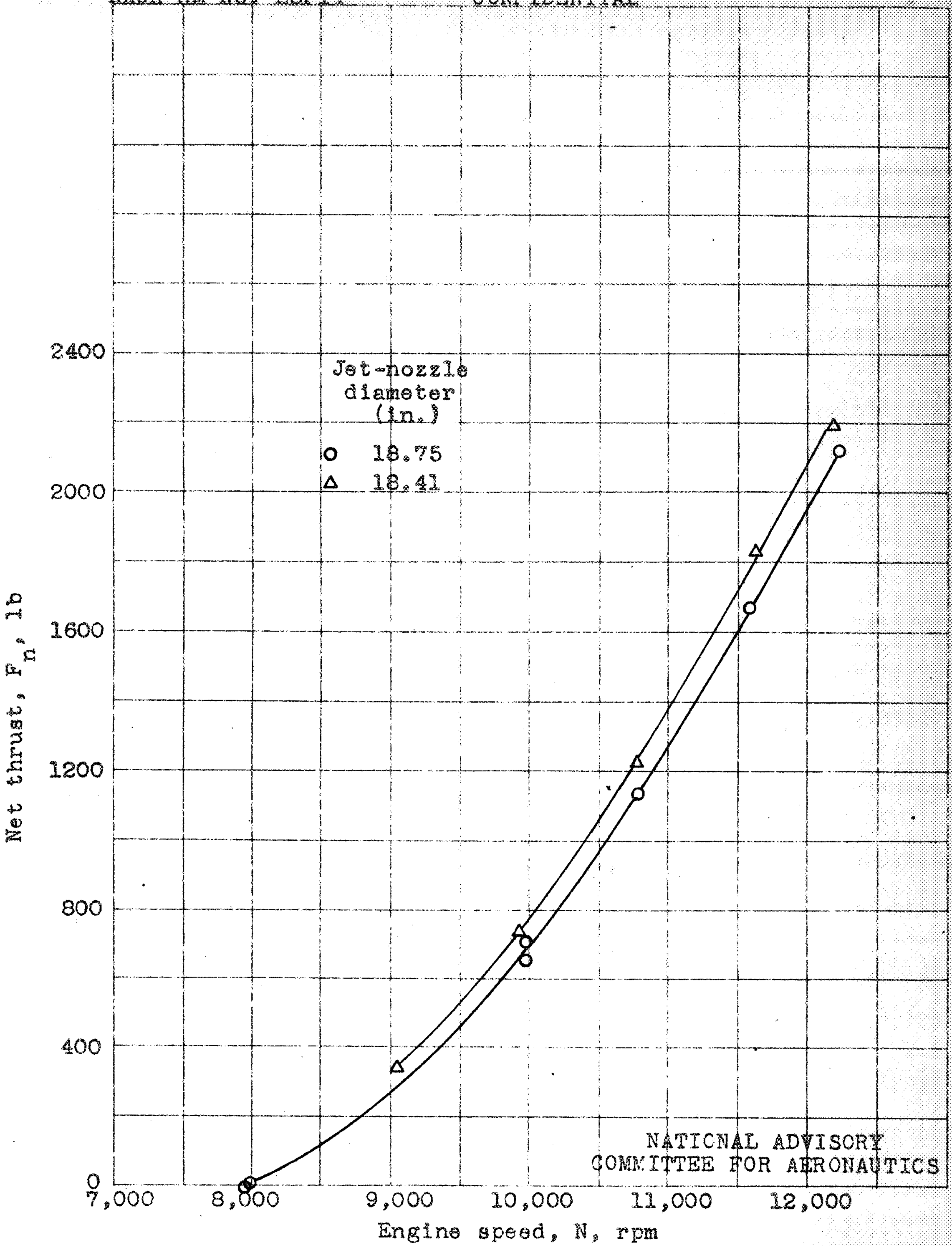


Figure 14.- Effect of nozzle area on net thrust at a simulated altitude of 30,000 feet and a ram-pressure ratio of 1.7.

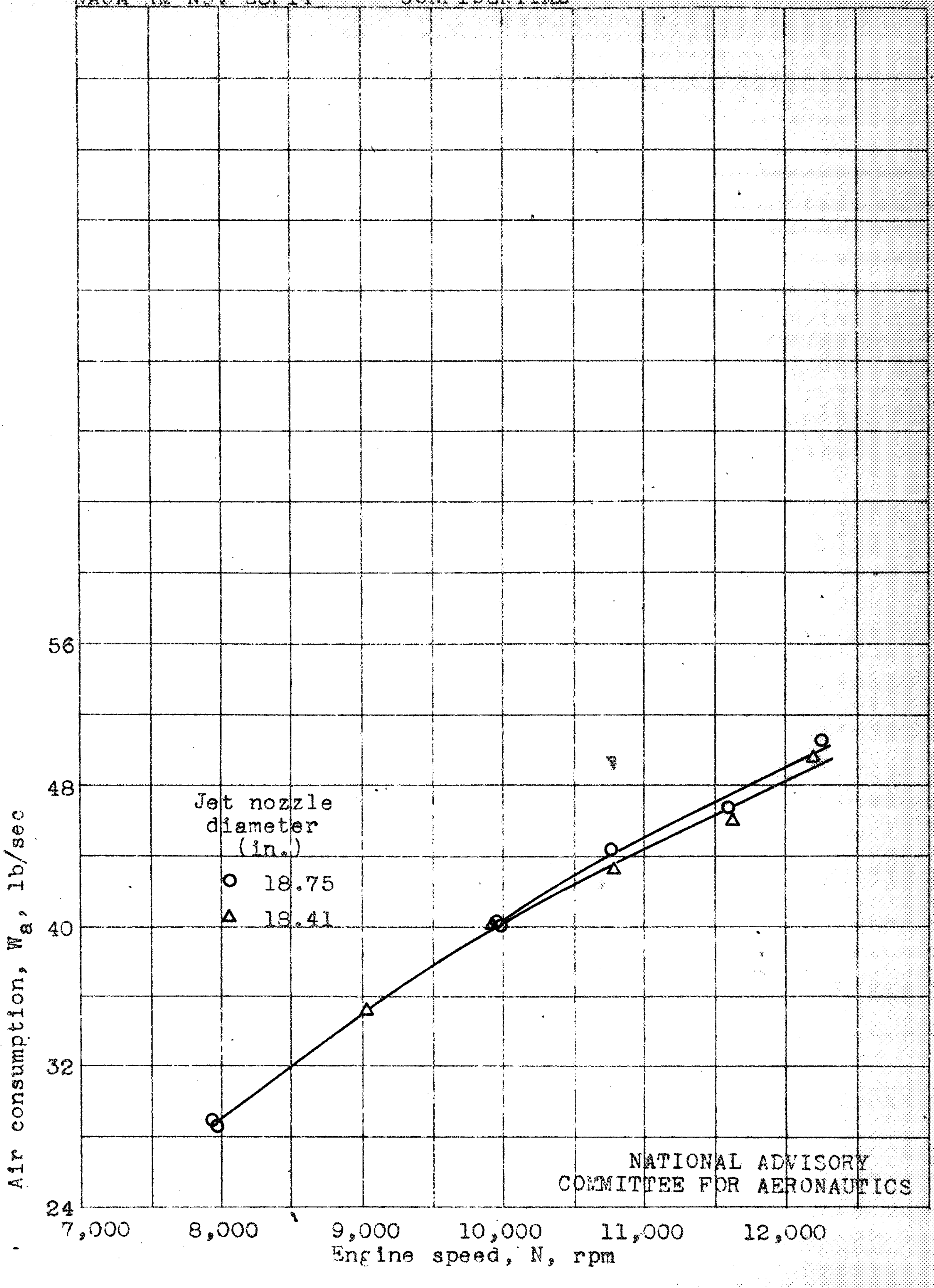


Figure 15. - Effect of nozzle area on air consumption at a simulated altitude of 30,000 feet and a ram-pressure ratio of 1.7.

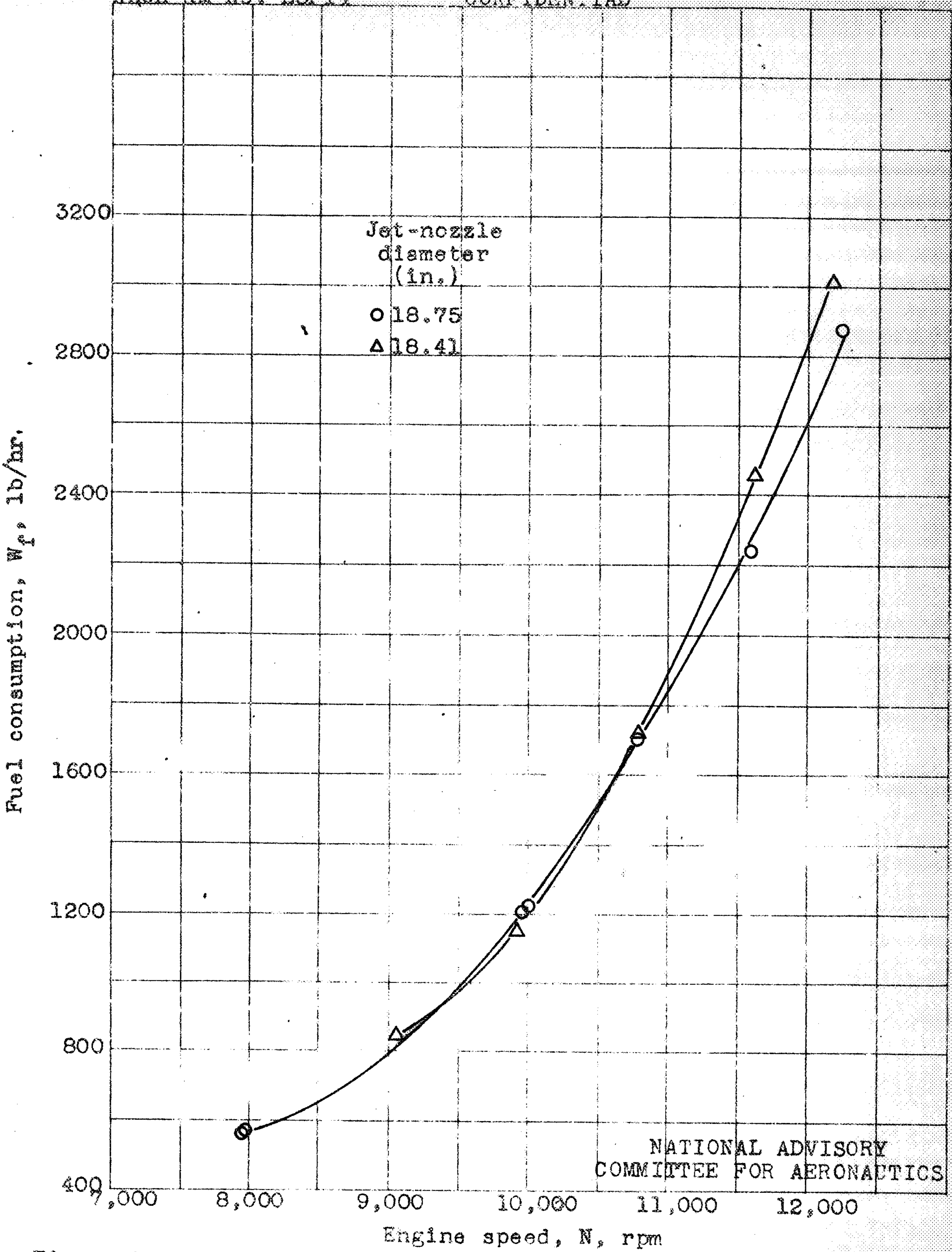


Figure 16.- Effect of nozzle area on fuel consumption at a simulated altitude of 30,000 feet and a ram-pressure ratio of 1.7.

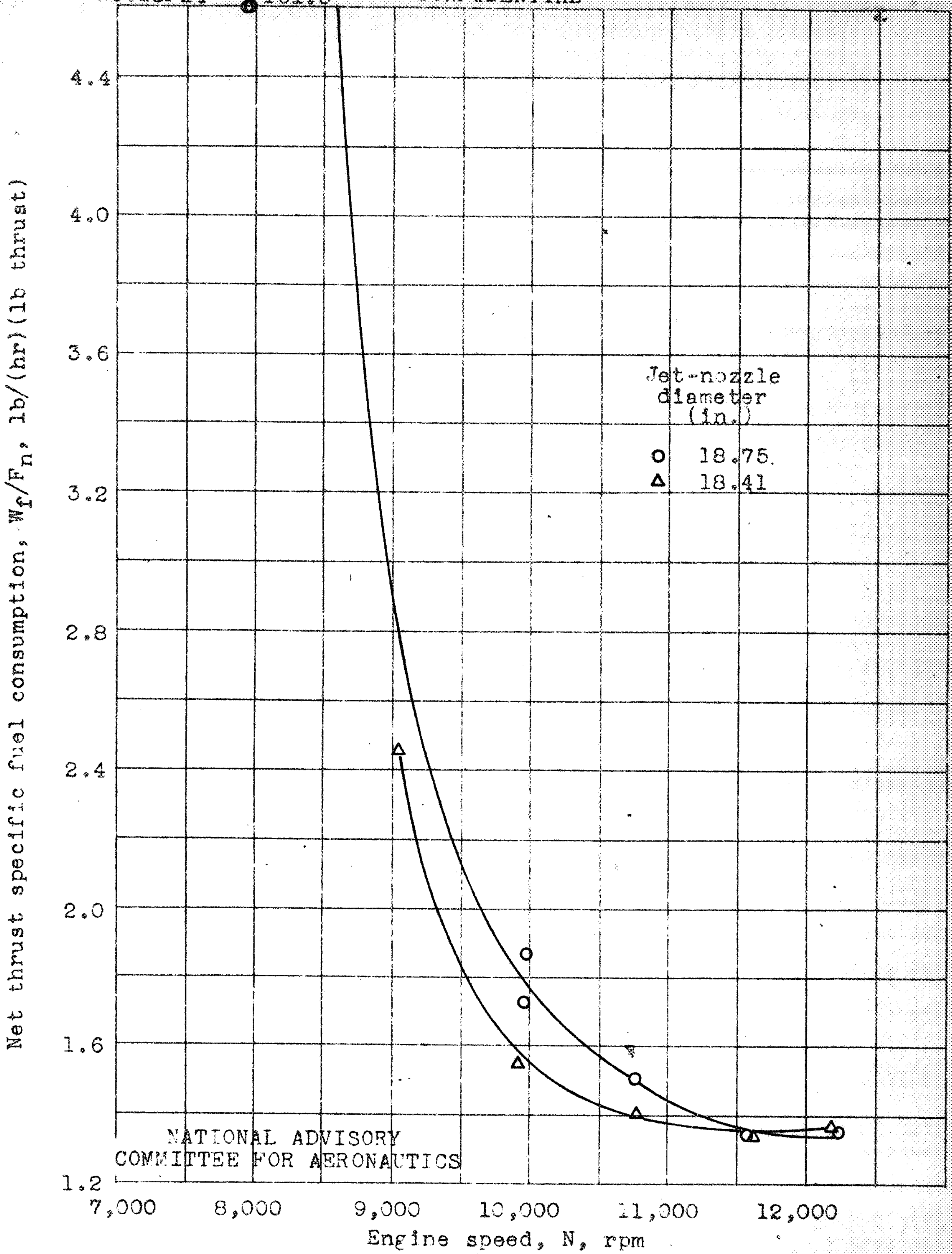


Figure 17. - Effect of nozzle area on net-thrust specific fuel consumption at a simulated altitude of 30,000 feet and a ram-pressure ratio of 1.7.

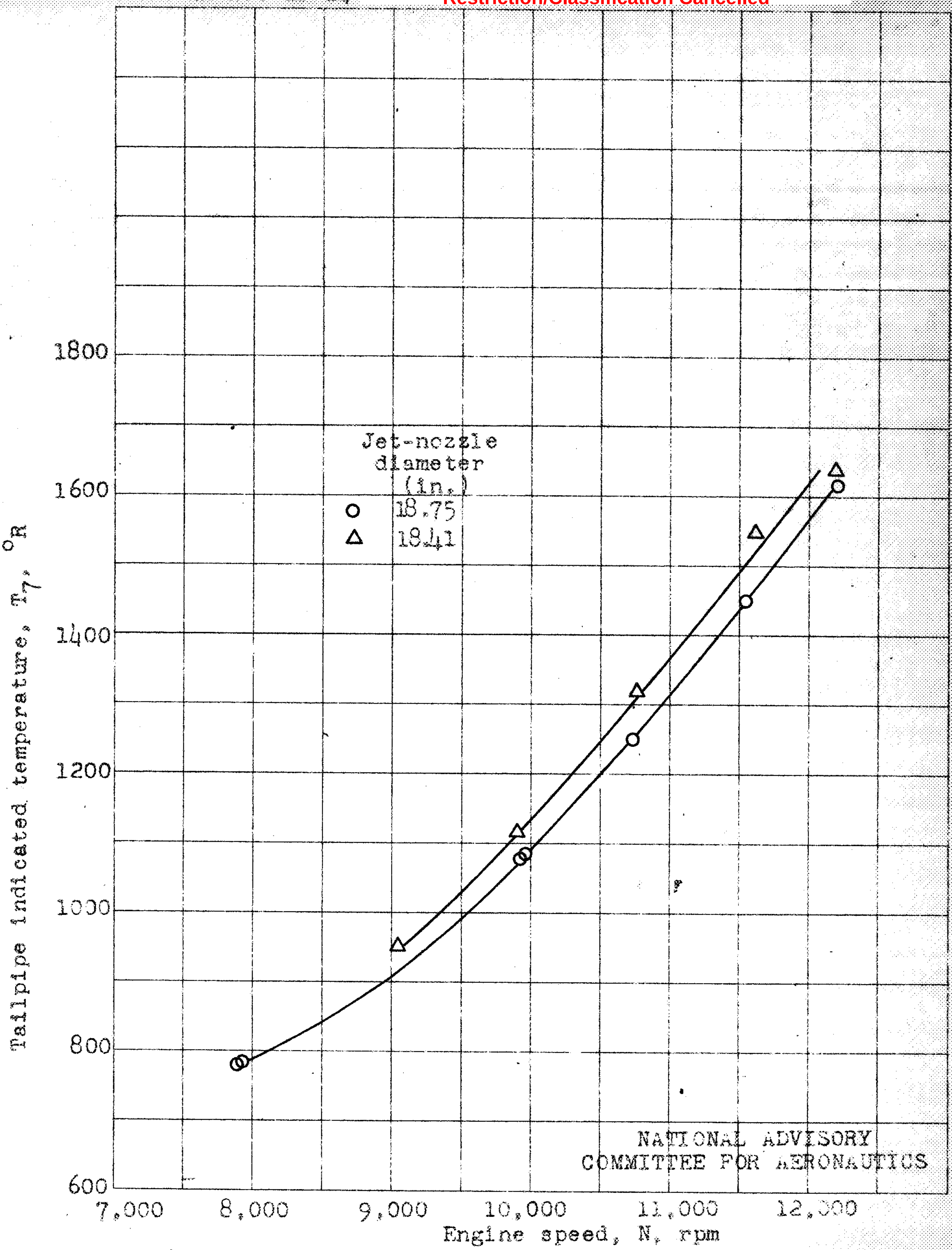


Figure 18.- Effect of nozzle area on tailpipe indicated temperature at a simulated altitude of 30,000 feet and a ram-pressure ratio of 1.7.