UNCLASSIFIED

[redacted]

Copy
RM E50A31

NACA RM E50A31

NACA

RESEARCH MEMORANDUM

ALTITUDE-CHAMBER PERFORMANCE OF BRITISH ROLLS-ROYCE NENE II ENGINE

III - 18.00-INCH-DIAMETER JET NOZZLE

By Ralph E. Grey, Virginia L. Brightwell, and Zelmar Barson

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
July 10, 1950

UNCLASSIFIED

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

ALTITUDE-CHAMBER PERFORMANCE OF BRITISH ROLLS-ROYCE NENE II ENGINE

III - 18.00-INCH-DIAMETER JET NOZZLE

By Ralph E. Grey, Virginia L. Brightwell, and Zelmar Barson

SUMMARY

An altitude-chamber investigation was conducted at the NACA Lewis laboratory to determine the altitude performance characteristics of the British Rolls-Royce Nene II turbojet engine with an 18.00-inch-diameter jet nozzle. Results are presented for simulated altitudes from sea level to 65,000 feet and for ram pressure ratios from 1.10 to 3.50 (corresponding to flight Mach numbers from 0.37 to 1.47, assuming 100-percent ram pressure recovery).

Typical performance-data plots are presented to show graphically the effects of altitude and of flight ram pressure ratio. Conventional correction methods were applied to the data to determine the possibility of generalizing each performance parameter to a single curve. A complete tabulation of corrected and uncorrected engine-performance parameters is presented. A comparison of engine performance with the 18.75-, 18.41-, and 18.00-inch-diameter jet nozzles and without a jet nozzle is made to show the effect of changes in nozzle size under simulated-flight conditions.

The investigation showed that engine performance obtained at any one altitude could not be used to predict performance at other altitudes above 30,000 feet with the 18.00-inch-diameter jet nozzle. For varying ram pressure ratios at a given altitude, engine performance can be predicted from data representing other ram pressure ratios only when critical flow exists in the jet nozzle.

A comparison of the engine performance with the three jet-nozzle sizes and without a jet nozzle at an altitude of 30,000 feet and a ram pressure ratio of 1.70 indicated that the 18.00-inch-diameter jet nozzle gave the lowest values of net-thrust specific fuel consumption at practically all engine speeds. At lower ram pressure ratios, the 18.41-inch-diameter jet nozzle gave lower

[redacted]

values of net-thrust specific fuel consumption at high engine speeds. Jet thrust, net thrust, fuel consumption, and tail-pipe indicated gas temperature generally increased with use of the smaller nozzles.

INTRODUCTION

The altitude performance investigation of a British Rolls-Royce Nene II engine was conducted in an altitude chamber at the NACA Lewis laboratory during 1948. Three different jet-nozzle diameters were used in the investigation of this engine to determine the effect of nozzle size on engine performance. A limited amount of data was obtained without a jet nozzle attached to the engine tail pipe.

The principal objectives of the investigation were to determine the altitude performance with an 18.00-inch-diameter jet nozzle and to determine the range of simulated-flight conditions over which the performance parameters might be generalized to a single curve. The effect of change in jet-nozzle size on altitude performance was of interest, particularly with reference to engine specific fuel consumption, because a jet nozzle smaller than standard can be used at cruise conditions without exceeding allowable temperatures. A smaller jet nozzle should give higher thrust and possibly lower specific fuel consumption over nearly the entire range of engine speed.

The effects of altitude and flight speed on the over-all engine performance using the standard 18.75- and an 18.41-inch-diameter jet nozzle are presented in references 1 and 2, respectively. The over-all engine performance using an 18.00-inch-diameter jet nozzle is presented herein. Results are presented for simulated-flight conditions varying in altitude from sea level to 65,000 feet and in ram pressure ratio from 1.10 to 3.50. These ram pressure ratios correspond to flight Mach numbers from 0.37 to 1.47, assuming 100-percent ram pressure recovery. The conventional method of reducing data to sea-level conditions (reference 3) was used to determine whether performance could be generalized; that is, whether data obtained at one altitude and ram pressure ratio can be used to predict performance at other conditions of altitude and ram pressure ratio. A comparison of performance with three jet-nozzle sizes and without a jet nozzle (open tail pipe) is presented as an indication of engine performance with a variable-area jet nozzle; generalization of performance with varying jet-nozzle area, however, is not included.

DESCRIPTION OF POWER PLANT

1253

A cutaway view of the British Rolls-Royce Nene II power plant, which is a through-flow turbojet engine having nine combustion chambers, is shown in figure 1. The engine incorporates a single-stage double-entry centrifugal compressor (tip diameter, 28.80 in.) driven by a single-stage reaction turbine (tip diameter, 24.53 in.). The turbine-nozzle area is 126 square inches and the standard jet-nozzle area is 276 square inches. The dry engine weight is approximately 1720 pounds (starting panel and generator included); the maximum diameter (cold) is 49.50 inches, giving an effective frontal area of 13.36 square feet. The sea-level engine performance with the standard 18.75-inch-diameter jet nozzle (reference 4), based on Rolls-Royce static test-bed data, is:

Rating	Jet thrust (lb)	Engine speed (rpm)	Specific fuel consumption (lb/(hr)(lb thrust))
Take-off	5000	12,250	1.04
Military	5000	12,250	1.04
Max. cruise	4000	11,500	1.02
Idle	120	2,600	----

From these values it can be seen that the rated military thrust per unit weight of engine is 2.91 pounds thrust per pound weight, and the rated military thrust per unit of frontal area is 374 pounds thrust per square foot. The maximum allowable tail-cone gas temperature is 1365° F with the standard 18.75-inch-diameter jet nozzle.

A sea-level acceptance run of the engine with the standard 18.75-inch-diameter jet nozzle, with minimum research instrumentation installed, showed a thrust of 5110 pounds and a specific fuel consumption of 1.01 pounds per hour per pound of thrust at an engine speed of 12,261 rpm.

APPARATUS AND PROCEDURE

Altitude Test Chamber

The engine was installed in an altitude test chamber 10 feet in diameter and 60 feet long (schematically shown in fig. 2). The inlet section of the chamber (surrounding the engine) was separated from the exhaust section by a steel bulkhead; the engine tail pipe passed through the bulkhead by means of a low-friction seal. The seal was composed of three floating asbestos-board rings so mounted on the tail pipe as to allow thermal expansion in both radial and axial directions, as well as a reasonable amount of lateral movement to prevent binding.

Engine thrust was measured by a balanced-pressure-diaphragm-type thrust indicator outside the test chamber, connected by a linkage to the frame on which the engine was mounted in the chamber. 1253

An A.S.M.E. type flat-plate orifice mounted in a straight run of 42-inch-diameter pipe at the approach to the test chamber was provided for measuring engine air consumption. Because of the large variation in atmospheric conditions investigated, considerable difficulty was encountered with condensation in the orifice differential-pressure lines despite repeated attempts to remedy this situation. Engine air consumption was therefore calculated from pressure and temperature measurements in the tail pipe, as described in the appendix.

Ram-air pressure was controlled by a main, electrically operated butterfly valve in the 42-inch air-supply line, bypassed by a 12-inch, pneumatically operated V-port valve. Air was supplied by either a combustion-air (moist, room temperature) system or a refrigerated-air (dry, cooled) system at temperatures near those desired. Final control of air temperature was accomplished by a set of electric heaters in the bypass line immediately preceding the entrance to the test chamber. The air entered the test chamber, passed through a set of straightening vanes, and then entered the engine cowl. The purpose of the cowl was to prevent direct circulation of heated air from the region of the tail pipe and combustion chambers into the aft inlet of the compressor. The air so heated was therefore mixed with the cooler air supply before entering the compressor.

The exhaust jet was discharged into a diffusing elbow mounted in the exhaust section of the chamber. This elbow ducted the gases into a dry-type primary cooler. Control of the exhaust pressure was obtained by a main, electrically operated butterfly valve, bypassed by a 20-inch, pneumatically operated butterfly valve. The gases then passed through a dry-type secondary cooler and thence into the system exhausters.

Instrumentation

Compressor-inlet temperature and total pressure were measured by eight probes, each comprising an iron-constantan thermocouple and a total-pressure tube. Four probes were equally spaced around the periphery of the front compressor-inlet screen and four around the back screen (station 2, fig. 3). Control of ram pressure and temperature was based on the averaged readings of the eight probes. Compressor-discharge pressures were measured at the exit of compressor-discharge elbows 1, 4, and 7 by seven total-pressure tubes in each elbow.

Engine tail-pipe temperatures at station 6 were measured by 25 chromel-alumel, stagnation-type thermocouples located in an instrument ring. The instrument ring also included 24 total-pressure probes, 14 static-pressure probes, and 4 wall static-pressure taps. This instrumentation was located approximately 18 inches downstream of the tail cone. In addition, the four standard Nene engine tail-cone thermocouples supplied by Rolls-Royce Ltd. were mounted in the tail cone and were used for engine-control purposes. Pressure and temperature instrumentation was also located at other stations throughout the engine; measurements from this instrumentation are not reported.

All pressures, including the thrust-indicator-diaphragm pressure, were instantaneously recorded by photographing the manometer panel. Temperatures were recorded by two self-balancing, scanning potentiometers, which required about 3 minutes to record all engine temperatures.

Engine speed was measured by an impulse counter, which operated on the frequency of a three-phase generator mounted on the accessory case of the engine. Actions of the counter and a timer were synchronized.

Fuel consumption was measured by a calibrated variable-area-orifice flow meter, which allowed full-scale readings for various ranges of fuel flow by changing the orifice flow area.

With the exception of air consumption, performance data were generally reproducible within 2 percent. Air-consumption data scattered appreciably at high engine speeds and were, in general, reproducible only to within 5 percent with a few points showing even greater scatter.

Procedure

Performance characteristics of the engine were determined over a range of engine speeds at simulated altitudes from sea level to 65,000 feet and ram pressure ratios from 1.10 to 3.50. Inlet-air temperatures were, in general, held to within 3° F of NACA standard 1253
values corresponding to the simulated-altitude and ram-pressure-ratio conditions. Compressor-inlet total pressures were held at values corresponding to the simulated-flight conditions, assuming 100-percent ram pressure recovery.

RESULTS AND DISCUSSION

A summary of performance and operational data obtained at simulated-altitude conditions is presented in table I. Altitude data corrected for small variations in compressor-inlet pressure and temperature settings and for variations in exhaust-pressure settings are summarized in table II. Table II also includes the data corrected to conditions of NACA standard sea-level static pressure and temperature at the compressor inlet.

Simulated-Flight Performance

Effect of altitude. - Typical performance data from table II, obtained at a ram pressure ratio of 1.30 and simulated altitudes from sea level to 60,000 feet, are presented to show the effect of altitude on jet thrust, net thrust, air consumption (cooling air excluded), fuel consumption, net-thrust specific fuel consumption, and tail-pipe indicated gas temperature (figs. 4 to 9, respectively). The trends shown are similar to those discussed in reference 1; that is, jet thrust, net thrust (except at low engine speeds), air consumption, and fuel consumption rapidly decrease with an increase in altitude and net-thrust specific fuel consumption generally decreases up to an altitude of approximately 30,000 feet, above which this trend reverses to give higher specific fuel consumption at higher altitudes. Although the data plotted for an altitude of 60,000 feet are too scattered to indicate this reversal conclusively (fig. 8), plots (not included herein) of other data from table II make the reversal in trend evident. This reversal, discussed in reference 1, is a result of decreasing inlet-air temperature, which increases the compressor-tip Mach number, thus producing an increase in the compressor pressure ratio and cycle efficiency. The reversal therefore apparently takes place at the tropopause (35,332 ft based on NACA standard atmosphere).

The specific-fuel-consumption curves are computed from values obtained from the faired fuel-consumption and net-thrust curves; any discrepancies that occur between the fuel-consumption and net-thrust data and the faired curves are carried over to the specific-fuel-consumption curves. The actual data points therefore in many cases do not fall on the computed curve.

At engine speeds below 10,000 rpm, tail-pipe indicated gas temperature (fig. 9) decreased as altitude was increased to the tropopause and then remained constant with further increase in altitude. At engine speeds above 10,000 rpm, this trend was reversed. This reversal in trend takes place at engine speeds lower than 10,000 rpm for ram pressure ratios greater than the sample 1.30 data and at higher engine speeds for lower ram pressure ratios.

Effect of ram pressure ratio. - Performance data obtained at a simulated altitude of 30,000 feet and at ram pressure ratios from 1.10 to 3.00 are presented to show the effect of ram pressure ratio on jet thrust, net thrust, air consumption, fuel consumption, net-thrust specific fuel consumption, and tail-pipe indicated gas temperature (figs. 10 to 15, respectively).

The increase in air density at the engine inlet that accompanies an increase in ram pressure ratio generally increases jet thrust, air consumption, and fuel consumption throughout the range of engine speeds investigated. Net thrust increases with increasing ram pressure ratio at high engine speeds but decreases with increasing ram pressure ratio at low engine speeds. For the sample data shown (altitude of 30,000 ft), the reversal in trend occurs at approximately 10,000 rpm. Net-thrust specific fuel consumption increases with increasing ram pressure ratio. The tail-pipe indicated gas temperature in general decreases slightly with increasing ram pressure ratio. This decrease is small and somewhat inconsistent and could be interpreted as data scatter at the higher engine speeds. As would be expected, an appreciable decrease in temperature occurs at the lower engine speeds where there is a tendency for the engine to windmill.

These trends with varying ram pressure ratio are similar to those discussed in greater detail in reference 1.

Generalized Performance

Performance data representing engine operation at altitudes from sea level to 65,000 feet and at ram pressure ratios from

1.10 to 3.50 were reduced in the conventional manner (reference 3) to NACA standard sea-level conditions. The development of this method of generalizing data involves the concept of flow similarity and the application of dimensional analysis to the performance of turbojet engines. In this development, the efficiencies of engine components are considered to be unaffected by changes in flight conditions at a given corrected engine speed.

Effect of altitude. - Typical corrected engine performance data (table II) obtained at a ram pressure ratio of 1.30 and simulated altitudes from sea level to 60,000 feet are compared to show the effect of altitude on the corrected values of jet thrust, net thrust, air consumption, fuel consumption, net-thrust specific fuel consumption, and tail-pipe indicated gas temperature (figs. 16 to 21, respectively).

The corrected values of jet thrust and net thrust (figs. 16 and 17) generalize for all altitudes up to 30,000 feet. At higher altitudes, the thrust decreases with increase in altitude. This decrease in thrust with altitude is less than that shown in references 1 and 2 because with the 18.00-inch-diameter jet nozzle the engine operates at higher pressure and temperature levels. The decrease in air density with increase in altitude therefore has less effect. Also, because an appreciable scatter exists in the available data for high altitudes, no consistent trend in air consumption with increase in altitude is indicated (fig. 18). Corrected fuel consumption (fig. 19) increases slightly with increase in altitude at high values of corrected speed. Plots of other data from table II show that at low engine speeds, fuel consumption increases rapidly with increase in altitude, as is also shown in references 1 and 2. The corrected net-thrust specific fuel consumption curves (fig. 20) generalize up to an altitude of 20,000 feet. Above 20,000 feet, the corrected specific fuel consumption increases with increase in altitude. The 60,000-foot data points do not fall on the computed curve, as explained in the discussion of figure 8. The corrected tail-pipe indicated gas temperature (fig. 21) generalizes for all altitudes investigated.

Effect of ram pressure ratio. - The conventional method of generalizing data was specifically developed to adjust for changes in the pressure and the temperature of the atmosphere in which the engine is submerged. A variation in ram pressure ratio (flight speed) changes the performance characteristics because it has the effect of changing the compression ratio of the engine. In general, the increase in operating pressure that accompanies increase in ram pressure ratio raises the total expansion pressure ratio of the engine (from turbine inlet to jet-nozzle throat) until critical flow is established in the jet nozzle. After critical flow is established, the expansion pressure ratio of the engine remains constant with further increase in ram pressure ratio. The engine is then effectively submerged in an atmosphere having a static pressure equal to the pressure existing in the jet-nozzle throat and is operating at a constant effective ram pressure ratio. The effective ram pressure ratio is then equal to the ratio of the compressor-inlet total pressure to the jet-nozzle-throat static pressure. With critical flow in the jet nozzle, generalization of flow characteristics within the engine should be possible within the limitations discussed in connection with altitude effects.

Typical performance data obtained at a simulated altitude of 30,000 feet and ram pressure ratios from 1.10 to 3.00 are compared to show the effect of ram pressure ratio on the corrected values of jet thrust, jet-thrust parameter $\frac{F_j + p_0A_7}{\delta}$, net thrust, air consumption, fuel consumption, net-thrust specific fuel consumption, and tail-pipe indicated gas temperature (figs. 22 to 27, respectively).

Corrected jet thrust (fig. 22(a)) does not generalize but corrected jet-thrust parameter (fig. 22(b)), for which the development is given in reference 1, generalizes for all conditions for which the jet nozzle is choked. The corrected net thrust of figure 23 appears to generalize for ram pressure ratios greater than 1.30 at the higher speeds, but data for ram pressure ratios less than 1.30 do not generalize. Inasmuch as net thrust is a function of jet thrust and air consumption and jet thrust did not generalize, there is no reason to expect net thrust to generalize. At higher flight speeds (ram pressure ratios), however, the momentum of the incoming air is greater for a given mass flow; this larger quantity, when subtracted from the higher jet-thrust values of figure 22(a), causes the corrected net thrust to generalize for ram pressure ratios above 1.30. Corrected air consumption (fig. 24) apparently generalizes at all ram pressure ratios. Corrected fuel consumption generalizes at the high engine speeds when critical flow exists in the jet nozzle (fig. 25). At lower engine speeds the fuel consumption decreases with increase in ram pressure ratio. Net-thrust specific fuel consumption (fig. 26) shows reasonable generalization for ram pressure ratios of 1.30 and above. Data for a ram pressure ratio of 1.10 show slightly lower values of specific fuel consumption. The tail-pipe indicated gas temperature (fig. 27) also generalizes to a single curve for engine speeds at which critical flow existed in the jet nozzle. At lower engine speeds the corrected tail-pipe indicated gas temperature decreases with increase in ram pressure ratio.

Effect of Jet-Nozzle Area on Performance

The performance of the engine using an 18.00-inch-diameter jet nozzle is compared at an altitude of 30,000 feet and a ram pressure ratio of 1.70 with performance using: (a) the standard 18.75-inch-diameter jet nozzle (reference 1); (b) an 18.41-inch-diameter jet nozzle (reference 2); and (c) engine tail pipe without a jet nozzle. The tail-pipe diameter is 22 inches; therefore, the data without a jet nozzle will be referred to as the "22-inch nozzle data." These results are presented in figures 28 to 38. The changes in performance caused by changes in jet-nozzle area follow the expected trends discussed in reference 2. Tail-pipe total pressure increases with decrease in nozzle size (fig. 28). Compressor pressure ratio at a given engine speed remains nearly constant for the range of air flow encountered in this investigation (fig. 29) except at the lower engine speeds. Because turbine-inlet pressure remains nearly constant and tail-pipe total pressure increases with decreasing jet-nozzle area, total-pressure ratio across the turbine decreases with a decrease in jet-nozzle area (fig. 30). In order to maintain the required compressor work per pound of air, which is independent of nozzle size (fig. 31) and represents nearly the entire turbine power output, it is necessary to operate the turbine at a higher temperature level as the jet area is decreased, which results in an increase in both turbine-inlet total temperature (fig. 32) and tail-pipe temperature (fig. 33). Except at the high engine speeds, the increases in turbine-inlet total temperature and in tail-pipe indicated gas temperature are nearly equal.

For critical flow in the turbine nozzles, air flow is essentially proportional to the turbine-inlet pressure, which is nearly constant, and inversely proportional to the square root of turbine-inlet temperature, which increases with a decrease in nozzle size; therefore, air consumption decreases with decreasing jet-nozzle area (fig. 34). Because the air-consumption data included herein, as well as those of references 1 and 2, were not sufficiently consistent to indicate trends of small magnitude, the curves of figure 34 were obtained from a single faired curve for each nozzle size, using corrected data for altitudes up to 30,000 feet at a ram pressure ratio of 1.70. Air consumption generalizes with altitude up to 30,000 feet, as is shown in figure 18; it is therefore possible to invert the correction factors and to apply them to the corrected parameters to obtain a smooth curve of proper magnitude through the actual altitude data points. The air-consumption values of figure 29 were obtained from these same faired curves. The data points of figure 34 are actual altitude data, and when plotted alone, they do not indicate the trend too clearly. The expected increase in fuel consumption accompanies a decrease in

1253

nozzle size (fig. 35). Jet thrust increases with a decrease in nozzle size (fig. 36) because of the increase in tail-pipe total pressure. The trend followed by net thrust (fig. 37) is similar to that for jet thrust. At a ram pressure ratio of 1.70, net-thrust specific fuel consumption (fig. 38) decreases with decrease in nozzle area at most engine speeds; at high engine speeds, the three smaller nozzle sizes give similar values of net-thrust specific fuel consumption, whereas the 22-inch nozzle gives a much higher value. At lower ram pressure ratios (flight speeds), however, the 18.41-inch-diameter jet nozzle gives the lowest value of net-thrust specific fuel consumption over a larger portion of the high-engine-speed range.

SUMMARY OF RESULTS

The following results were obtained from an altitude-chamber investigation of the performance of a British Rolls-Royce Nene II turbojet engine using an 18.00-inch-diameter jet nozzle:

1. Engine-performance parameters, except for air consumption and tail-pipe indicated gas temperature, could not be predicted for altitudes above 30,000 feet from data obtained at one particular altitude.

2. Performance data at any ram pressure ratio for which critical flow existed in the jet nozzle could be used to predict performance at any other ram pressure ratio in the critical flow range within the limits of this investigation.

3. The 18.00-inch-diameter jet nozzle indicated a lower value of net-thrust specific fuel consumption over substantially the entire range of engine speed investigated than either an 18.41- or the standard 18.75-inch-diameter jet nozzle at an altitude of 30,000 feet and a ram pressure ratio of 1.70. At a ram pressure ratio of 1.30, however, the 18.41-inch-diameter jet nozzle gave the lowest values at high engine speeds. The engine operating without a jet nozzle attached to the tail pipe gave a much higher value of net-thrust specific fuel consumption. Jet thrust, fuel consumption, and tail-pipe indicated gas temperature all increased when smaller jet nozzles were used, whereas air consumption showed a slight decrease.

Lewis Flight Propulsion Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio.

1253

APPENDIX - CALCULATIONS

Symbols

The following symbols are used in the calculations and on the figures:

A	area, sq ft
D	diameter, ft
F	thrust, lb
g	acceleration due to gravity, 32.2 ft/sec^2
H	enthalpy, Btu/lb
J	mechanical equivalent of heat, 778 ft-lb/Btu
K	thrust constant
M	Mach number
N	engine speed, rpm
P	absolute total pressure, lb/sq ft
p	absolute static pressure, lb/sq ft
R	gas constant, 53.3 ft-lb/(lb)($^{\circ}$F)
T	total temperature, $^{\circ}$R
t	static temperature, $^{\circ}$R
V	velocity, ft/sec
W_a	air consumption, lb/sec
W_f	fuel consumption, lb/hr
W_g	gas flow, lb/sec
γ	ratio of specific heats

1253

δ ratio of compressor-inlet absolute total pressure to absolute static pressure of NACA standard atmosphère at sea level

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

Subscripts:

b barometer

c compressor

d thrust-measuring diaphragm

i indicated

j jet

n net

p airplane

s seal

Station notation (fig. 3):

0 free stream

2 compressor inlet

3 compressor discharge

4 turbine inlet (combustion-chamber discharge)

5 tail cone (turbine discharge)

6 tail pipe (upstream of jet nozzle)

7 jet-nozzle outlet (throat)

Methods of Calculation

Thrust. - Thrust was calculated by adding to the indicated thrust (obtained from the altitude-chamber thrust indicator) a correction factor accounting for the pressure differential across the tail-pipe seal. The relation used was

$$F_j = F_i + A_s(P_2 - p_0)$$

where

$$F_i = K(p_d - p_b)$$

and the seal area

$$A_s = \frac{\pi D_s^{\,2}}{4}$$

Air consumption. - Engine air consumption was calculated from measurements of temperature and total and static pressure in the tail pipe. Total-pressure profiles across the tail pipe were plotted for each data point; the profiles were then read at eight points, so selected as to divide the tail-pipe area into four equal concentric, annular areas. The following formula was then applied to each of the four areas:

$$W_g = \frac{p_6 A}{R t_6} \sqrt{2gJ\Delta H}$$

where

A $\quad$ 1/4 x tail-pipe area (cold)

ΔH $\quad$ enthalpy difference between total- and static-pressure conditions, determined from reference 5

The static temperature in the formula was calculated from the indicated temperature by

$$t_6 = \frac{T_{6,i}}{1 + 0.8\left(\frac{T_6}{t_6} - 1\right)}$$

where the temperature ratio was determined from the tail-pipe total to static pressure ratio by means of reference 5. The factor 0.8 is the selected average value of thermocouple recovery factor based on instrument calibrations.

Engine air consumption was then determined from the following relation by adding the gas flows through the four annular areas and subtracting the fuel flow:

$$W_a = W_g - \frac{W_f}{3600}$$

Simulated flight speed. - The simulated flight speed at which the engine was operated was determined from:

$$V_p = \sqrt{2gR\,\frac{\gamma}{\gamma-1}\,t_0\left[\left(\frac{P_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}} -1\right]}$$

where γ was assumed to be 1.40.

Net thrust. - Net thrust was calculated from jet thrust by subtracting the momentum of the free-stream air approaching the engine inlet, according to the relation

$$F_n = F_j - \frac{W_a V_p}{g}$$

where V_p is simulated flight speed.

Flight Mach number. - Flight Mach number was calculated from the compressor-inlet total pressure, assuming 100-percent ram pressure recovery

$$M_p = \sqrt{\frac{2}{\gamma-1}\left[\left(\frac{P_2}{p_0}\right)^{\frac{\gamma-1}{\gamma}} -1\right]}$$

where γ was assumed to be 1.40.

REFERENCES

1. Barson, Zelmar, and Wilsted, H. D.: Altitude-Chamber Performance of British Rolls-Royce Nene II Engine. I - Standard 18.75-Inch-Diameter Jet Nozzle. NACA RM E9I23, 1949.

2. Armstrong, J. C., Wilsted, H. D., and Vincent, K. R.: Altitude-Chamber Performance of British Rolls-Royce Nene II Engine. II - 18.41-Inch-Diameter Jet Nozzle. NACA RM E9I27, 1949.

3. Bollay, William: Performance Variation of Gas Turbines and Jet Propulsion Units with Atmospheric Inlet Conditions. Power Plant Memo. No. 1, Bur. Aero., Navy Dept., March 3, 1943.

4. Anon.: Rolls-Royce Nene II Performance and Installation Data. TSD 57, Dec. 1947.

5. Amorosi, A.: Gas Turbine Gas Charts. Res. Memo No. 6-44 (Navships 250-330-6), Bur. Ships, Navy Dept., Dec. 1944.

TABLE I - PERFORMANCE AND OPERATIONAL DATA

Point	Altitude (ft)	Compressor-inlet total pressure, P_2 (in. Hg abs.)	Exhaust static pressure, P_0 (in. Hg abs.)	Ram pressure ratio, P_2/P_0	Compressor-inlet total temperature, T_2 (°R)	Engine speed, N (rpm)	Jet thrust, F_j (lb)	Air consumption, W_a (lb/sec)	Fuel consumption, W_f (lb/hr)	Tail-pipe indicated gas temperature, $T_{6,i}$ (°R)	Tail-cone indicated gas temperature (Rolls-Royce thermocouples), $T_{5,i}$ (°F)	Compressor pressure ratio, P_3/P_2	Fuel-supply pressure (lb/sq in. gage)	Fuel-pump-discharge pressure (lb/sq in. gage)	Main-fuel-manifold pressure (lb/sq in. gage)	Pilot-fuel-manifold pressure (lb/sq in. gage)	Oil-pump-discharge pressure (lb/sq in. gage)	Oil inlet temperature (°F)	Rear-bearing temperature (°F)	[a]Accumulative engine time (hr)
18.00-inch-diameter jet nozzle																				
1	0	38.72	30.04	1.29	562	5,996	1060	52.57	1085	932	575	1.402	14	1400	200	280	30	140	150	65
2	0	38.76	29.84	1.30	560	8,020	1867	64.88	1650	1100	650	1.910	14	1600	240	350	31	150	175	
3	0	38.91	29.81	1.30	555	5,924	909	50.05	945	949	500	1.366	18	1600	150	285	29	135	140	153
4	0	38.91	29.81	1.30	556	7,044	1338	57.55	1255	1037	450	1.604	18	1600	200	320	34	145	155	
5	0	38.74	29.89	1.30	559	8,840	2385	70.37	2090	1173	625	2.167	20	1600	290	400	31	175	205	
6	10,000	34.10	20.54	1.66	561	8,032	1868	57.30	1105	930	550	1.804	14	1400	200	300	30	160	170	62
7	10,000	34.01	20.59	1.65	561	9,956	3332	71.26	2240	1209	775	2.664	14	1400	300	400	30	180	210	
8	10,000	34.09	20.59	1.66	563	10,852	4363	79.47	3310	1386	920	3.165	14	1400	400	440	33	190	240	
9	10,000	34.14	20.54	1.66	562	11,624	5484	85.02	4595	1576	1200	3.660	14	1400	660	690	32	200	260	
10	10,000	35.04	20.59	1.70	556	6,920	1318	51.08	945	823	425	1.461	20	1500	75	130	29	140	145	154
11	10,000	35.14	20.39	1.72	556	8,032	1725	58.22	1028	932	450	1.779	20	1500	175	260	31	150	155	
12	10,000	35.04	20.49	1.71	556	8,976	2450	65.02	1530	1053	515	2.125	20	1500	250	375	33	160	175	
13	10,000	35.04	20.59	1.70	557	9,972	3523	74.30	2390	1218	700	2.637	20	1500	310	430	34	170	200	
14	10,000	34.99	20.59	1.70	557	10,480	4240	78.87	3045	1328	875	2.950	20	1500	300	390	34	195	235	
15	20,000	17.47	13.70	1.28	484	6,000	495	26.03	590	868	485	1.489	22	835	50	75	27	85	95	54
16	20,000	17.38	13.60	1.28	484	8,004	1015	33.75	850	996	600	2.125	20	825	100	170	29	110	130	
17	20,000	17.42	13.70	1.27	482	9,980	1972	44.41	1600	1235	850	3.155	20	825	225	340	30	130	175	
18	20,000	17.61	13.75	1.28	482	10,820	583	48.00	2215	1420	1025	3.659	20	825	260	370	30	140	210	
19	20,000	17.45	13.65	1.28	482	11,708	3329	50.77	3110	1643	1275	4.313	18	825	325	400	30	150	240	
20	20,000	17.46	13.70	1.27	474	11,824	3480	50.99	3350	1702	1360	4.414	18	825	360	440	31	140	225	
21	20,000	30.04	13.79	2.18	563	8,152	1883	51.14	795	826	440	1.735	13	1300	250	190	28	160	170	61
22	20,000	30.04	13.74	2.19	562	9,980	3485	64.38	1955	1197	800	2.678	13	1300	275	400	30	180	210	
23	20,000	29.94	13.69	2.19	566	10,828	4372	69.80	2890	1380	950	3.158	13	1300	350	400	29	195	240	
24	20,000	29.98	13.94	2.15	562	11,560	5244	74.34	3940	1563	1150	3.626	13	1300	300	530	30	200	260	
25	20,000	29.94	13.54	2.21	564	12,096	6010	77.45	4885	1722	1325	4.004	14	1300	250	740	25	200	260	
26	30,000	9.68	8.66	1.12	427	8,936	900	24.38	844	1110	700	2.883	21	500	75	140	25	110	160	149
27	30,000	9.99	8.81	1.13	422	9,936	1260	28.62	1168	1238	850	3.527	21	500	175	260	27	105	160	
28	30,000	9.66	8.76	1.10	427	10,740	1550	29.11	1512	1412	1080	4.075	21	500	240	360	27	110	170	
29	30,000	9.90	8.66	1.14	424	11,248	1851	31.14	1660	1576	1200	4.422	21	500	280	400	27	115	205	
30	30,000	11.29	8.75	1.29	448	8,968	1045	27.63	860	1055	650	2.754	20	575	100	140	26	110	140	148
31	30,000	11.39	8.75	1.30	444	9,964	1491	31.18	1236	1217	825	3.419	20	560	200	290	27	115	160	
32	30,000	11.74	8.65	1.36	445	10,704	1959	34.02	1692	1384	1000	3.897	20	575	200	300	28	125	190	
33	30,000	11.65	8.65	1.35	446	11,508	2485	36.67	2290	1629	1300	4.506	20	575	290	400	27	140	220	
34	30,000	13.43	8.84	1.52	472	8,432	978	30.19	680	924	510	2.305	15	630	80	120	28	140	170	145
35	30,000	13.47	8.84	1.52	468	9,048	1257	31.27	825	1027	600	2.643	15	630	100	160	28	115	145	
36	30,000	13.45	8.84	1.52	462	10,000	1812	35.57	1275	1209	800	3.299	15	640	220	330	28	120	155	
37	30,000	13.40	8.74	1.53	463	10,780	2348	37.49	1830	1393	1000	3.813	15	640	270	380	28	125	175	
38	30,000	13.27	8.79	1.51	468	11,600	2857	39.79	2460	1638	1275	4.427	15	640	300	410	28	140	210	
39	30,000	15.09	8.95	1.69	480	6,300	481	24.03	460	725	350	1.445	22	750	50	50	26	85	95	55
40	30,000	15.14	8.80	1.72	481	7,976	951	30.44	650	884	500	2.003	22	735	75	100	28	95	115	
41	30,000	15.45	8.81	1.75	478	8,008	983	30.54	690	849	475	2.023	24	750	75	110	28	100	120	
42	30,000	15.13	8.89	1.70	480	10,792	2602	42.14	1900	1405	1000	3.685	22	750	250	360	30	120	170	
43	30,000	15.22	9.05	1.68	482	11,600	3130	44.40	2595	1620	1250	4.206	22	740	290	380	30	140	220	
44	30,000	15.15	8.88	1.71	482	11,880	3320	44.14	2880	1724	1350	4.353	22	740	310	420	30	150	230	
45	30,000	15.04	8.84	1.70	470	10,824	2661	42.04	2060	1429	1050	3.731	20	700	290	400	29	125	160	150
46	30,000	15.14	8.74	1.73	454	10,808	2812	44.34	2135	1415	1050	3.841	20	700	290	420	29	135	200	
47	30,000	15.14	8.74	1.73	440	10,768	2900	45.51	2165	1389	1010	3.952	20	700	290	420	29	135	205	
48	30,000	15.24	8.74	1.74	432	10,804	3019	46.07	2295	1400	1000	4.032	20	700	275	380	29	120	200	
49	30,000	15.14	8.74	1.73	426	10,804	3085	46.85	2350	1402	1010	4.102	20	700	290	410	29	115	195	
50	30,000	17.71	8.69	2.04	508	8,960	1586	37.19	840	969	550	2.335	15	800	100	180	27	150	180	145
51	30,000	17.53	8.49	2.06	505	10,012	2337	41.28	1380	1238	795	2.970	15	800	230	340	28	150	185	
52	30,000	17.65	8.64	2.04	500	10,000	2400	42.57	1425	1199	800	3.017	15	800	220	320	28	150	190	
53	30,000	17.76	8.79	2.02	506	10,800	3017	46.42	2075	1408	1000	3.508	15	800	280	380	28	165	225	
54	30,000	17.61	8.79	2.00	506	11,613	3674	48.18	2890	1621	1260	4.083	15	800	320	430	28	170	250	
55	30,000	20.37	8.69	2.34	529	8,908	1767	39.68	840	959	525	2.200	15	900	120	180	26	170	210	144
56	30,000	20.43	8.64	2.36	522	9,960	2663	46.68	1505	1189	760	2.857	15	900	240	350	26	160	195	
57	30,000	20.49	8.79	2.33	525	10,796	3419	51.30	2250	1395	1000	3.355	15	900	300	400	26	170	215	
58	30,000	20.44	8.99	2.27	524	11,616	4177	54.32	3125	1603	1225	3.928	15	900	350	440	30	175	240	

[a]Average representing time in altitude chamber. Approximately 22 hr had been accumulated at time of installation in altitude chamber.

NACA

OBTAINED AT SIMULATED-ALTITUDE CONDITIONS

Point	Altitude (ft)	Compressor-inlet total pressure, P_2 (in. Hg abs.)	Exhaust static pressure, p_0 (in. Hg abs.)	Ram pressure ratio, P_2/p_0	Compressor-inlet total temperature, T_2 (°R)	Engine speed, N (rpm)	Jet thrust, F_j (lb)	Air consumption, W_a (lb/sec)	Fuel consumption, W_f (lb/hr)	Tail-pipe indicated gas temperature, $T_{6,i}$ (°R)	Tail-cone indicated gas temperature (Rolls-Royce thermocouples), $T_{5,i}$ (°F)	Compressor pressure ratio, P_3/P_2	Fuel-supply pressure (lb/sq in. gage)	Fuel-pump-discharge pressure (lb/sq in. gage)	Main-fuel-manifold pressure (lb/sq in. gage)	Pilot-fuel-manifold pressure (lb/sq in. gage)	Oil-pump-discharge pressure (lb/sq in. gage)	Oil inlet temperature (°F)	Rear-bearing temperature (°F)	[a]Accumulative engine time (hr)
18.00-inch-diameter jet nozzle																				
59	30,000	24.08	8.79	2.74	552	8,996	2165	48.33	1000	980	550	2.155	16	1040	170	230	29	155	175	143
60	30,000	24.09	8.74	2.76	552	10,044	3148	53.47	1725	1211	800	2.739	16	1040	280	380	29	175	210	
61	30,000	24.12	8.74	2.76	552	10,792	3902	56.79	2425	1390	975	3.164	16	1040	290	390	29	190	240	
62	30,000	24.02	8.69	2.76	553	11,584	4756	60.06	3275	1590	1200	3.679	16	1040	390	450	29	200	270	
63	30,000	23.97	8.79	2.73	524	11,800	5350	64.50	3950	1671	1300	4.053	15	1040	490	540	29	180	260	
64	30,000	26.02	8.89	2.93	563	8,020	1883	44.32	648	780	360	1.650	19	1140	50	100	22	170	185	60
65	30,000	26.01	8.89	2.93	561	9,984	3345	57.04	1780	1182	740	2.662	19	1150	250	370	31	175	200	
66	30,000	25.94	8.40	3.09	562	10,808	4273	60.24	2465	1377	950	3.629	19	1150	300	400	31	185	230	
67	30,000	25.94	9.04	2.87	564	11,620	5028	64.40	3445	1574	1160	4.368	15	1140	400	460	29	190	255	
68	40,000	7.30	5.45	1.34	423	8,524	629	16.51	540	1005	400	2.437	20	390	[b]---	50	25	100	150	151
69	40,000	7.20	5.35	1.35	423	10,020	977	19.02	818	1255	550	3.296	20	390	75	120	25	115	190	
70	40,000	7.15	5.35	1.34	426	10,800	1261	22.08	1134	1438	1010	3.979	20	390	150	240	29	115	190	
71	40,000	7.25	5.45	1.33	423	11,524	1505	23.26	1482	1671	1210	4.454	20	390	225	350	25	115	200	
72	40,000	7.25	5.45	1.33	422	11,740	1535	23.08	1578	1740	1300	4.503	20	390	225	360	26	125	220	
73	40,000	9.62	5.45	1.77	458	8,664	835	21.89	545	931	500	2.452	15	500	---	80	28	125	170	146
74	40,000	9.58	5.50	1.74	461	10,016	1362	24.69	905	1208	800	3.291	20	500	110	190	28	120	160	
75	40,000	9.57	5.65	1.69	459	10,840	1779	27.22	1340	1420	1050	3.887	20	500	220	330	28	125	180	
76	40,000	9.47	5.55	1.71	460	11,568	2193	28.85	1850	1642	1300	4.460	20	500	280	390	28	135	210	
77	40,000	11.08	5.60	1.98	489	7,600	602	20.20	390	765	375	1.780	25	575	50	35	25	100	120	56
78	40,000	11.20	5.50	2.04	478	8,000	776	22.81	475	813	450	1.973	25	575	50	50	26	100	120	
79	40,000	11.28	5.55	2.03	480	9,996	1641	32.37	975	1192	800	3.126	25	585	140	220	28	105	185	
80	40,000	11.20	5.60	2.00	482	10,792	2016	30.33	1380	1405	1050	3.626	16	550	200	320	28	120	170	
81	40,000	11.14	5.60	1.99	483	11,596	2420	32.64	1940	1649	1275	4.190	16	550	250	360	27	140	210	
82	40,000	11.22	5.70	1.97	482	11,720	2455	33.01	2020	1699	1350	4.222	16	560	250	360	27	145	225	
83	40,000	19.25	5.59	3.44	564	7,988	1420	33.11	596	784	350	1.709	18	880	---	60	25	150	160	58
84	40,000	19.15	5.64	3.40	562	9,988	2632	41.87	1334	1197	790	2.661	18	880	200	325	26	170	200	
85	40,000	19.17	5.79	3.31	564	10,792	3161	45.21	1960	1392	950	3.117	18	880	260	380	23	195	245	
86	50,000	5.91	3.25	1.82	463	9,816	811	15.53	566	1159	760	3.161	20	350	---	60	24	125	165	146
87	50,000	5.85	3.30	1.77	465	10,816	1078	17.34	870	1411	1050	3.882	20	340	100	150	24	180	175	
88	50,000	5.82	3.35	1.74	462	11,532	1281	17.40	1152	1655	1300	4.330	20	320	170	250	24	140	200	
89	50,000	7.38	3.40	2.17	478	7,864	479	13.58	295	793	375	1.915	16	400	25	15	22	120	145	57
90	50,000	7.38	3.45	2.14	480	9,996	1066	18.36	655	1202	800	3.103	16	400	75	100	25	120	160	
91	50,000	7.32	3.40	2.15	477	10,800	1365	19.95	930	1412	1050	3.668	16	400	125	200	26	135	190	
92	50,000	7.36	3.35	2.20	483	11,596	1636	-----	1275	----	1350	-----	16	400	200	310	25	150	225	
93	50,000	11.94	3.79	3.15	562	8,308	905	20.97	394	835	430	1.795	19	600	---	50	13	180	210	59
94	50,000	11.99	3.69	3.25	561	9,980	1564	26.26	848	1193	780	2.655	19	600	100	150	21	180	210	
95	50,000	12.05	3.64	3.31	564	10,784	1984	28.46	1264	1396	1000	3.136	19	600	200	300	23	185	220	
96	50,000	11.93	4.09	2.92	564	11,592	2394	30.87	1758	1618	1240	3.620	19	600	260	370	23	195	250	
97	60,000	2.76	2.06	1.34	451	10,696	419	7.90	408	1409	625	3.793	24	200	---	23	16	180	275	153
98	60,000	2.86	1.96	1.46	453	11,112	518	8.27	466	1521	700	3.836	23	200	---	25	18	180	285	
99	60,000	2.71	1.96	1.38	451	11,640	542	7.76	584	1705	800	4.159	23	200	---	50	21	165	265	
100	60,000	3.79	2.05	1.85	458	10,116	570	8.94	432	1246	850	3.383	20	280	---	25	24	145	200	147
101	60,000	3.72	2.05	1.81	460	10,856	694	10.47	654	1434	1050	3.798	20	250	---	60	22	145	205	
102	60,000	3.62	2.00	1.81	461	11,572	793	10.72	740	1676	1300	4.229	21	250	80	100	22	150	220	
103	60,000	4.91	1.96	2.50	424	10,828	1078	14.81	808	1450	535	4.020	20	300	50	110	25	110	180	152
104	60,000	7.53	2.14	3.52	564	8,892	671	14.51	326	962	550	2.033	19	400	---	20	11	190	230	60
105	60,000	7.53	2.04	3.69	560	10,012	1010	16.61	552	1208	800	2.669	19	400	---	50	20	190	220	
106	60,000	7.45	2.29	3.25	563	10,812	1213	18.10	818	1420	1000	3.148	19	400	50	150	22	190	225	
107	63,500	3.66	1.66	2.20	432	11,496	856	11.34	766	1673	800	4.172	20	225	20	105	24	130	200	152
108	64,500	2.86	1.56	1.83	444	11,548	626	8.29	594	1693	800	4.105	--	----	---	---	--	---	---	152
109	65,000	4.03	1.85	2.18	492	10,204	554	-----	360	----	900	-----	16	275	25	25	22	150	210	58
Without jet nozzle																				
110	30,000	14.22	8.82	1.61	484	10,032	1129	37.16	890	1034	400	2.932	21	670	125	200	28	130	170	150
111	30,000	14.17	8.92	1.59	484	10,790	1526	41.91	1340	1195	500	3.481	21	655	200	320	28	140	185	
112	30,000	14.27	8.82	1.62	484	11,406	2205	45.21	1980	1396	650	4.108	21	660	280	360	28	155	215	
113	30,000	14.12	8.82	1.60	486	12,284	2688	45.85	2535	1555	775	4.596	21	650	290	390	28	175	255	

[a]Average representing time in altitude chamber. Approximately 22 hr had been accumulated at time of installation in altitude chamber.

[b]Dashes indicate unknown values.

TABLE II - PERFORMANCE DATA ADJUSTED TO STANDARD ALTITUDE
(Adjusted for variations

Point	Altitude (ft)	Ram pressure ratio	Engine speed (rpm)		Jet thrust (lb)			Net thrust (lb)		Air consumption (lb/sec)		Fuel consumption (lb/hr)		Net-thrust specific fuel consumption (lb/(hr)(lb thrust))		Indicated gas temperature (°R)		
																Tail-pipe		Tail-cone
			Alt.	Corr.	Alt.	Corr.	Parameter	Alt.	Corr.	Alt.	Corr.	Alt.	Corr.	Alt.	Corr.	Alt.	Corr.	Corr.
		P_2/p_0	N	$N/\sqrt{\theta}$	F_j	F_j/δ_2	$\frac{F_j + p_0A_7}{\delta}$	F_n	F_n/δ	W_a	$W_a\sqrt{\theta}/\delta$	W_f	$W_f/\delta\sqrt{\theta}$	W_f/F_n	$W_f/F_n\sqrt{\theta}$	$T_{5,1}$	$T_{5,1}/\theta$	$T_{5,1}/\theta$
18.00-inch-diameter jet nozzle																		
1	0	1.30	5,979	5,760	1056	812	3689	-88	-68	52.51	41.93	1077	798	∞	∞	917	851	946
2	0	1.30	8,012	7,719	1872	1440	4317	454	349	65.11	51.99	1653	1225	3.643	3.510	1098	1012	1029
3	0	1.30	5,947	5,729	913	702	3579	-178	-137	50.03	39.95	953	706	∞	∞	963	893	903
4	0	1.30	7,065	6,806	1343	1033	3910	88	88	57.60	45.99	1263	936	14.28	13.76	1049	973	865
5	0	1.30	8,840	8,516	2388	1837	4714	853	656	70.45	56.25	2092	1550	2.453	2.363	1169	1084	1002
6	10,000	1.70	8,040	7,723	1939	1689	3859	150	128	58.67	52.24	1109	911	7.409	7.117	921	850	924
7	10,000	1.70	9,965	9,573	3467	2966	5166	1237	1058	73.13	65.12	2277	1871	1.804	1.766	1206	1113	1137
8	10,000	1.70	10,842	10,415	4532	3877	6077	2048	1752	81.45	72.53	3376	2774	1.648	1.583	1379	1272	1267
9	10,000	1.70	11,624	11,166	5699	4875	7075	3042	2602	87.13	77.59	4674	3841	1.537	1.476	1577	1455	1533
10	10,000	1.70	6,960	6,686	1316	1126	3326	-231	-198	50.75	45.19	950	781	∞	∞	833	768	826
11	10,000	1.70	8,078	7,760	1706	1459	3659	-56	-48	57.74	51.42	1040	855	∞	∞	948	875	855
12	10,000	1.70	9,028	8,672	2426	2075	4275	465	398	64.26	57.22	1545	1270	3.322	3.191	1066	983	910
13	10,000	1.70	10,020	9,625	3520	3011	5211	1266	1083	73.88	65.79	2400	1972	1.896	1.821	1230	1135	1061
14	10,000	1.70	10,531	10,116	4236	3624	5824	1845	1578	78.43	69.84	3057	2512	1.657	1.592	1342	1238	1244
15	20,000	1.30	5,991	6,215	497	832	3709	-42	-70	26.65	43.00	591	1025	∞	∞	852	916	998
16	20,000	1.30	7,996	8,293	1027	1719	4596	326	546	34.65	55.90	837	1452	2.564	2.659	984	1059	1128
17	20,000	1.30	9,990	10,361	2026	3390	6267	1106	1850	45.49	73.40	1630	2829	1.474	1.529	1233	1326	1407
18	20,000	1.30	10,851	11,253	2634	4408	7285	1645	2752	48.91	78.92	2240	3887	1.361	1.412	1423	1531	1601
19	20,000	1.30	11,720	12,155	3400	5690	8567	2347	3928	52.06	84.00	3182	5522	1.356	1.406	1646	1771	1870
20	20,000	1.30	11,929	12,372	3563	5962	8839	2518	4213	51.68	83.38	3437	5964	1.365	1.416	1733	1864	1993
21	20,000	2.30	8,163	7,823	1992	1885	3611	-33	-31	53.86	53.30	844	763	∞	∞	827	756	824
22	20,000	2.30	10,028	9,587	3741	3539	5165	1199	1134	67.61	66.91	2038	1843	1.700	1.625	1209	1105	1163
23	20,000	2.30	10,839	10,362	4689	4436	6062	1924	1820	73.54	72.78	3001	2714	1.560	1.491	1384	1265	1292
24	20,000	2.30	11,616	11,105	5655	5350	6976	2712	2566	78.24	77.43	4001	3619	1.475	1.410	1579	1443	1487
25	20,000	2.30	12,130	11,597	6426	6079	7705	3344	3164	81.94	81.09	5168	4674	1.545	1.477	1733	1584	1642
26	30,000	1.10	8,897	9,852	923	2827	6227	640	1961	24.45	67.65	862	2923	1.347	1.491	1108	1359	1420
27	30,000	1.10	9,951	11,019	1270	3889	7289	945	2893	28.15	77.85	1166	3953	1.234	1.366	1240	1520	1616
28	30,000	1.10	10,694	11,841	1571	4813	8213	1229	3764	29.63	81.97	1526	5175	1.242	1.375	1399	1716	1872
29	30,000	1.10	11,238	12,444	1869	5724	9124	1515	4639	30.65	84.78	1886	6397	1.245	1.379	1573	1929	2032
30	30,000	1.30	8,926	9,652	1060	2749	5626	508	1316	26.49	68.30	869	2435	1.711	1.850	1041	1217	1281
31	30,000	1.30	9,963	10,773	1513	3922	6799	899	2330	31.64	75.87	1254	3516	1.396	1.509	1217	1423	1509
32	30,000	1.30	10,690	11,559	1922	4982	7859	1274	3304	33.37	80.00	1666	4670	1.307	1.413	1385	1619	1708
33	30,000	1.30	11,480	12,414	2462	6382	9259	1755	4549	36.44	87.38	2262	6342	1.289	1.394	1622	1896	2048
34	30,000	1.50	8,346	8,842	968	2174	4667	236	530	30.02	63.64	676	1609	2.866	3.036	910	1021	1072
35	30,000	1.50	8,993	9,528	1233	2770	5263	478	1074	30.97	65.67	810	1927	1.693	1.794	1019	1144	1181
36	30,000	1.50	10,004	10,599	1791	4023	6516	935	2101	35.09	74.40	1268	3017	1.355	1.436	1214	1363	1420
37	30,000	1.50	10,773	11,413	2326	5225	7718	1412	3172	37.48	79.47	1830	4355	1.296	1.373	1391	1561	1637
38	30,000	1.50	11,531	12,216	2871	6449	8942	1893	4252	40.12	85.07	2456	5845	1.298	1.375	1619	1817	1924
39	30,000	1.70	6,365	6,623	492	975	3175	-181	-359	23.92	45.54	461	951	∞	∞	720	790	872
40	30,000	1.70	7,962	8,285	945	1873	4073	87	173	30.47	58.02	655	1351	7.504	7.809	886	959	1041
41	30,000	1.70	8,023	8,349	946	1875	4075	107	212	29.80	56.75	696	1436	6.510	6.774	862	933	1026
42	30,000	1.70	10,784	11,222	2422	4799	6999	1236	2448	42.14	80.24	1897	3912	1.536	1.598	1403	1519	1579
43	30,000	1.70	11,562	12,031	3117	6175	8375	1868	3702	44.33	84.41	2567	5292	1.373	1.429	1609	1742	1839
44	30,000	1.70	11,840	12,321	3306	6551	8751	2068	4097	43.99	83.77	2857	5890	1.382	1.438	1712	1854	1947
45	30,000	1.70	10,930	11,374	2674	5299	7499	1496	2965	41.83	79.65	2091	4311	1.397	1.454	1457	1578	1667
46	30,000	1.70	11,104	11,555	2799	5545	7745	1589	3149	42.94	81.77	2172	4479	1.367	1.422	1494	1618	1726
47	30,000	1.70	11,238	11,694	2888	5722	7922	1666	3300	43.41	82.66	2239	4617	1.344	1.399	1513	1638	1734
48	30,000	1.70	11,379	11,841	2980	5904	8104	1763	3493	43.22	82.29	2371	4889	1.345	1.400	1553	1662	1764
49	30,000	1.70	11,459	11,924	3076	6095	8295	1838	3642	43.96	83.71	2477	5107	1.347	1.402	1577	1708	1791
50	30,000	2.00	8,908	9,057	1546	2604	4474	320	539	37.63	62.35	839	1437	2.622	2.666	958	990	1032
51	30,000	2.00	9,984	10,150	2340	3942	5812	969	1632	42.09	69.75	1395	2390	1.440	1.464	1231	1272	1290
52	30,000	2.00	10,021	10,188	2407	4055	5925	1004	1692	43.06	71.35	1438	2463	1.432	1.456	1204	1245	1308
53	30,000	2.00	10,759	10,938	3018	5084	6954	1494	2517	46.77	77.50	2074	3552	1.388	1.411	1397	1444	1497
54	30,000	2.00	11,571	11,764	3711	6252	8122	2120	3571	48.85	80.95	2906	4981	1.372	1.395	1609	1663	1764
55	30,000	2.30	8,846	8,820	1747	2559	4185	316	463	39.64	58.26	837	1223	2.649	2.641	948	941	967
56	30,000	2.30	9,960	9,930	2632	3857	5483	956	1400	46.48	68.30	1501	2193	1.571	1.566	1190	1182	1213
57	30,000	2.30	10,764	10,732	3394	4973	6599	1550	2271	51.10	75.09	2236	3266	1.442	1.438	1388	1378	1443
58	30,000	2.30	11,593	11,558	4186	6133	7759	2224	3259	54.36	79.87	3126	4566	1.405	1.401	1598	1587	1666

1253

AND CORRECTED TO STANDARD SEA-LEVEL ATMOSPHERIC CONDITIONS
in ram pressure ratio)

Point	Altitude (ft)	Ram pressure ratio	Engine speed (rpm)		Jet thrust (lb)			Net thrust (lb)		Air consumption (lb/sec)		Fuel consumption (lb/hr)		Net-thrust specific fuel consumption (lb/(hr)(lb thrust))		Indicated gas temperature (°R)		
																Tail-pipe		Tail-cone
			Alt.	Corr.	Alt.	Corr.	Parameter	Alt.	Corr.	Alt.	Corr.	Alt.	Corr.	Alt.	Corr.	Alt.	Corr.	Corr.
		P_2/p_0	N	$N/\sqrt{\theta}$	F_j	F_j/δ	$\frac{F_j + p_0A_7}{\delta}$	F_n	F_n/δ	W_a	$W_a\sqrt{\theta}/\delta$	W_f	$W_f/\delta\sqrt{\theta}$	W_f/F_n	$W_f/F_n\sqrt{\theta}$	$T_{6,1}$	$T_{6,1}/\theta$	$T_{6,1}/\theta$
18.00-inch-diameter jet nozzle																		
59	30,000	2.70	8,952	8,717	2143	2674	4059	211	263	48.51	62.15	990	1203	4.697	4.574	971	921	949
60	30,000	2.70	9,996	9,733	3110	3880	5265	980	1223	53.45	68.48	1699	2064	1.734	1.688	1199	1138	1184
61	30,000	2.70	10,739	10,457	3862	4818	6203	1597	1993	56.83	72.81	2392	2906	1.497	1.458	1377	1306	1349
62	30,000	2.70	11,528	11,225	4713	5880	7265	2312	2885	60.24	77.19	3240	3936	1.401	1.364	1573	1492	1557
63	30,000	2.70	12,058	11,741	5346	6670	8055	2828	3529	63.19	80.96	4033	4899	1.428	1.388	1743	1654	1742
64	30,000	3.00	8,020	7,697	1956	2197	3444	37	41	45.43	53.17	679	732	18.60	17.85	781	719	756
65	30,000	3.00	10,003	9,600	3447	3871	5118	984	1105	58.30	68.23	1828	1970	1.858	1.783	1187	1093	1110
66	30,000	3.00	10,818	10,382	4365	4902	6149	1751	1967	61.86	72.40	2509	2704	1.433	1.375	1380	1271	1302
67	30,000	3.00	11,609	11,141	5223	5866	7113	2426	2725	66.20	77.47	3553	3829	1.464	1.405	1578	1453	1496
68	40,000	1.30	8,527	9,441	630	2617	5494	324	1345	16.17	60.62	549	2526	1.695	1.877	1021	1251	1075
69	40,000	1.30	10,024	11,098	985	4088	6965	627	2602	18.88	70.79	823	3783	1.313	1.454	1256	1540	1239
70	40,000	1.30	10,766	11,920	1270	5272	8149	847	3514	22.34	83.77	1146	5269	1.352	1.499	1429	1752	1791
71	40,000	1.30	11,528	12,764	1494	6200	9077	1057	4387	23.04	86.38	1485	6815	1.403	1.553	1672	2050	2049
72	40,000	1.30	11,759	13,019	1524	6327	9204	1092	4532	22.82	85.54	1582	7278	1.450	1.605	1746	2140	2165
73	40,000	1.70	8,657	9,223	803	2549	4749	217	689	21.30	63.47	545	1843	2.511	2.675	934	1060	1093
74	40,000	1.70	9,975	10,628	1317	4182	6382	652	2069	24.20	72.12	883	2985	1.354	1.443	1198	1360	1419
75	40,000	1.70	10,819	11,527	1746	5543	7743	1010	3206	26.77	79.77	1313	4441	1.300	1.385	1415	1606	1707
76	40,000	1.70	11,534	12,288	2181	6925	9125	1392	4419	28.70	85.53	1834	6204	1.318	1.404	1632	1853	1986
77	40,000	2.00	7,521	7,829	652	1758	3628	3	7	20.40	52.85	382	1073	147.3	153.3	745	807	881
78	40,000	2.00	8,011	8,340	764	2062	3932	52	140	22.38	58.00	471	1322	9.071	9.443	820	889	994
79	40,000	2.00	9,984	10,394	1612	4348	6218	594	1602	31.99	82.90	987	2772	1.662	1.730	1189	1289	1362
80	40,000	2.00	10,752	11,193	1996	5384	7254	1037	2797	30.14	78.10	1361	3822	1.312	1.366	1394	1511	1624
81	40,000	2.00	11,546	12,020	2405	6488	8358	1366	3685	32.65	84.60	1930	5421	1.413	1.471	1635	1772	1864
82	40,000	2.00	11,682	12,161	2426	6544	8414	1382	3728	32.80	85.00	1994	5601	1.443	1.502	1888	1829	1949
83	40,000	3.50	7,972	7,658	1444	2227	3296	-46	-71	33.40	53.63	609	902	∞	$-\infty$	781	721	745
84	40,000	3.50	9,988	9,595	2673	4122	5191	787	1213	42.28	67.88	1354	2006	1.722	1.654	1197	1105	1154
85	40,000	3.50	10,771	10,347	3228	4978	6047	1187	1830	45.76	73.46	1977	2929	1.667	1.601	1393	1286	1302
86	50,000	1.70	9,755	10,393	784	4011	6211	359	1838	15.44	74.18	568	3098	1.582	1.686	1158	1315	1374
87	50,000	1.70	10,749	11,452	1072	5484	7684	588	3011	17.57	84.41	868	4735	1.476	1.573	1394	1582	1693
88	50,000	1.70	11,473	12,223	1286	6581	8781	802	4106	17.58	84.47	1149	6264	1.432	1.526	1638	1859	1977
89	50,000	2.00	7,871	8,194	421	1832	3702	23	98	12.52	52.35	277	1253	10.85	12.79	813	881	927
90	50,000	2.00	9,980	10,389	970	4222	6092	426	1852	17.12	71.55	608	2753	1.428	1.487	1198	1298	1361
91	50,000	2.00	10,821	11,265	1260	5483	7353	665	2892	18.71	78.20	865	3920	1.302	1.356	1417	1536	1643
92	50,000	2.00	11,546	12,020	1506	6554	8424	[a]----	----	-----	-----	1176	5328	-----	-----	----	----	1945
93	50,000	3.50	8,308	7,981	980	2436	3505	35	87	21.18	54.83	429	1024	12.25	11.77	835	771	822
94	50,000	3.50	9,989	9,596	1616	4019	5088	439	1093	26.37	68.28	876	2093	1.994	1.915	1196	1104	1147
95	50,000	3.50	10,763	10,339	1994	4960	6029	728	1810	28.39	73.81	1262	3015	1.734	1.666	1396	1289	1348
96	50,000	3.50	11,570	11,114	2501	6221	7290	1128	2805	30.79	79.71	1769	4227	1.569	1.507	1629	1504	1579
97	60,000	1.30	10,362	11,473	420	4526	7405	264	2849	8.206	80.00	393	4698	1.489	1.649	1326	1626	1254
98	60,000	1.30	10,743	11,894	499	5390	8267	344	3712	8.198	79.92	439	5242	1.275	1.412	1422	1743	1329
99	60,000	1.30	11,277	12,486	554	5980	8857	399	4310	8.159	79.54	587	7010	1.469	1.626	1601	1962	1450
100	60,000	1.70	10,108	10,769	528	4364	6564	298	2458	8.394	65.06	419	3683	1.406	1.498	1248	1417	1489
101	60,000	1.70	10,824	11,532	668	5517	7717	378	3120	10.56	81.82	645	5671	1.706	1.818	1425	1618	1704
102	60,000	1.70	11,525	12,279	788	6508	8708	486	4010	11.00	85.24	742	6528	1.528	1.628	1662	1887	1962
103	60,000	2.30	11,738	11,979	1066	6503	8129	586	3574	13.62	81.43	876	5455	1.487	1.526	1705	1775	1218
104	60,000	3.50	8,875	8,525	662	2653	3722	21	86	14.35	59.91	320	1234	14.94	14.35	958	885	929
105	60,000	3.50	10,031	9,636	980	3931	5000	241	968	16.56	69.14	537	2067	2.223	2.135	1213	1120	1168
106	60,000	3.50	10,801	10,376	1237	4959	6028	429	1721	18.11	75.57	821	3161	1.912	1.837	1428	1319	1366
107	63,500	2.00	12,103	12,599	840	6964	8672	503	4174	10.58	84.25	807	6966	1.603	1.669	1855	2010	1514
108	64,500	1.70	11,718	12,485	636	6504	8704	406	4158	8.336	80.06	624	6805	1.530	1.637	1743	1979	1473
109	65,000	2.30	10,264	10,475	540	4183	5809	----	----	-----	-----	351	2774	-----	-----	----	----	1433
Without jet nozzle																		
110	30,000	1.70	9,983	10,388	1241	2459	5744	138	274	39.46	75.14	949	1956	6.859	7.137	1024	1109	922
111	30,000	1.70	10,737	11,173	1727	3423	6708	486	964	44.41	84.57	1413	2914	2.906	3.024	1184	1282	1029
112	30,000	1.70	11,352	11,813	2413	4782	8067	1074	2129	47.92	91.24	2070	4268	1.926	2.004	1382	1497	1120
113	30,000	1.70	12,199	12,694	2953	5853	9138	1576	3124	49.28	93.83	2678	5521	1.698	1.767	1534	1661	1319

[a]Dashes indicate unknown values.

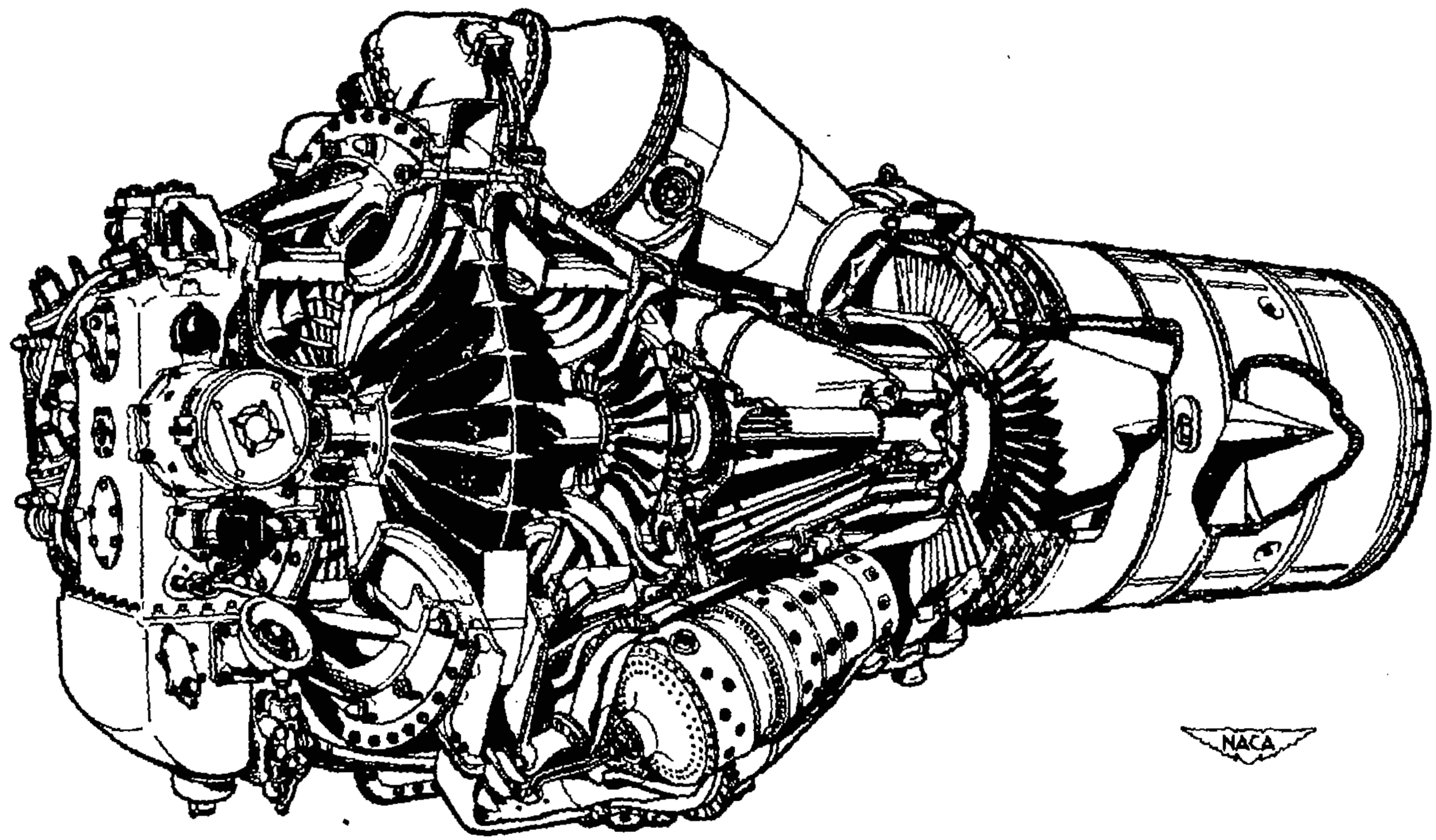


Figure 1. - Cutaway view of British Rolls-Royce Nene II turbojet engine. (Photographed from Rolls-Royce Manual on Nene engine.)

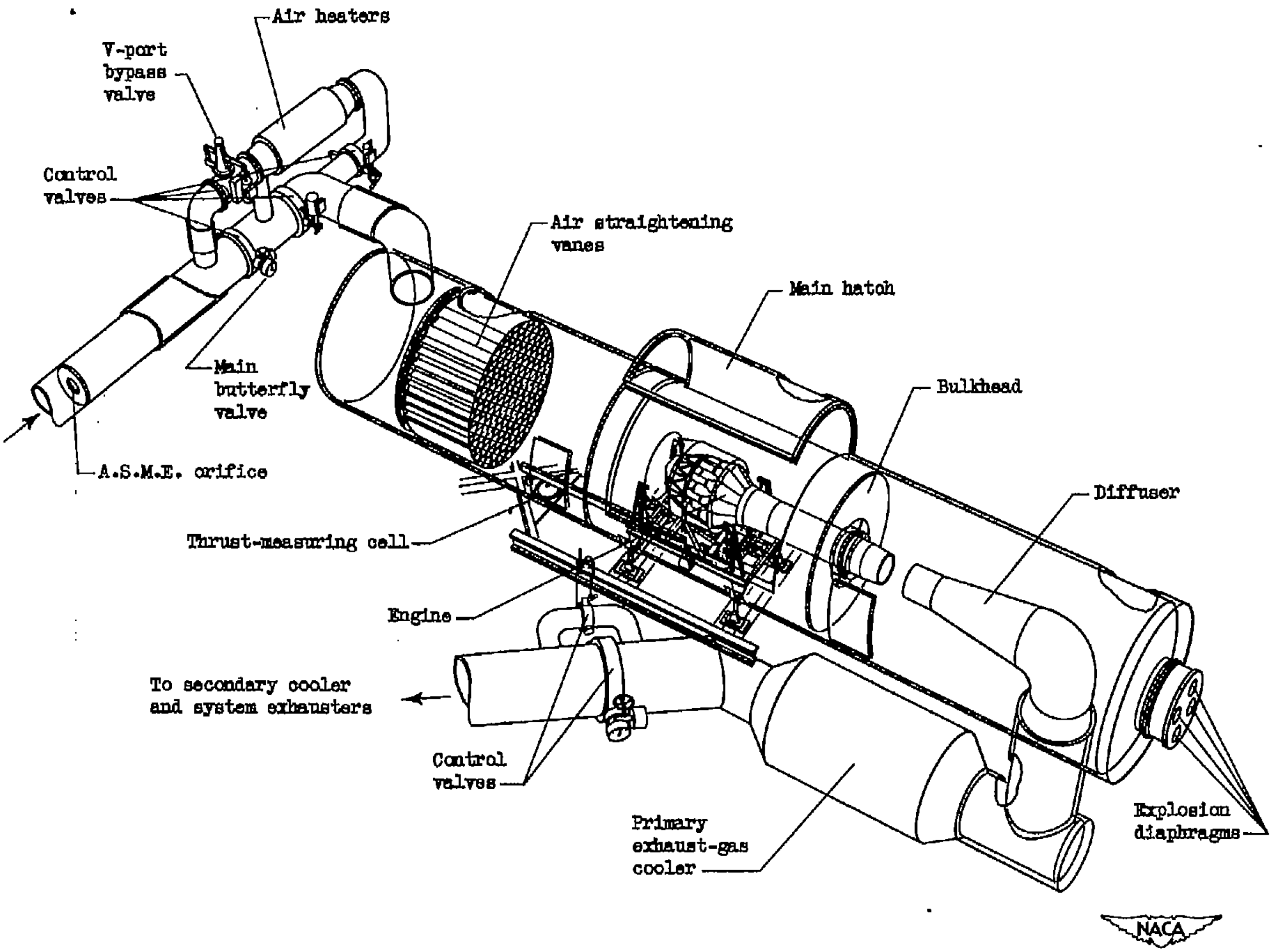


Figure 2. - Altitude chamber with engine installed in test section.

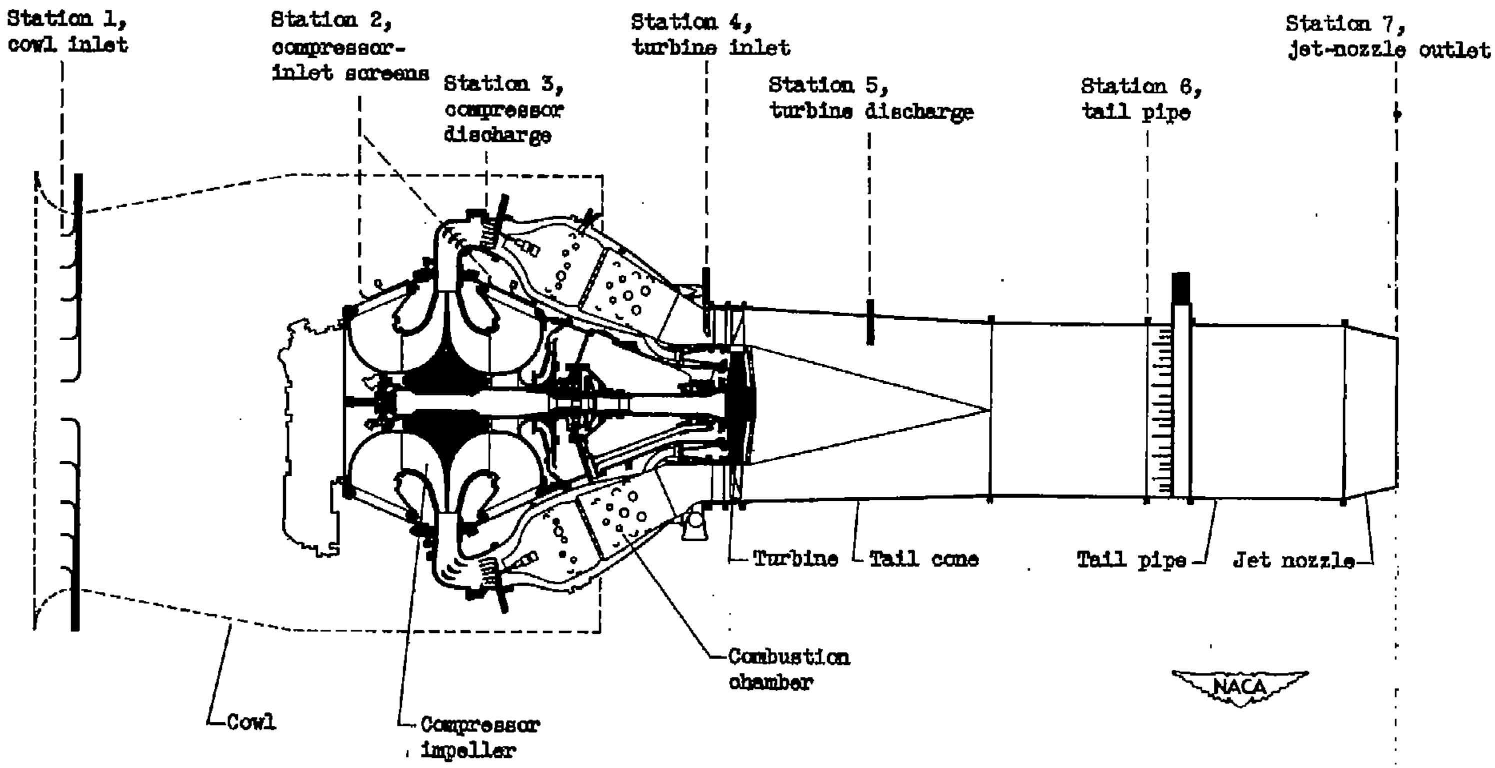


Figure 3. - Sectional side view of British Rolls-Royce Nene II engine showing instrumentation stations.

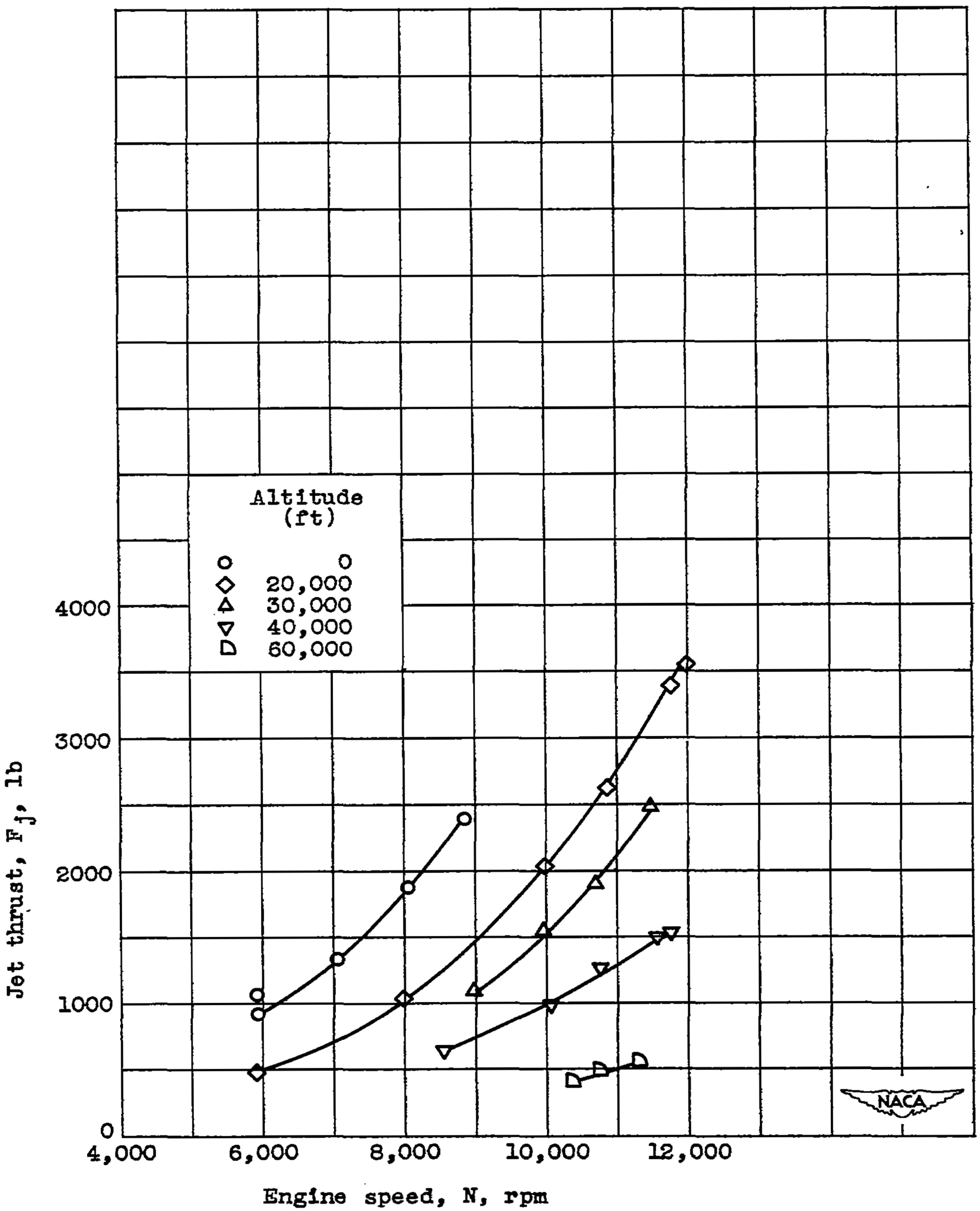


Figure 4. - Effect of altitude on jet thrust. Ram pressure ratio, 1.30.

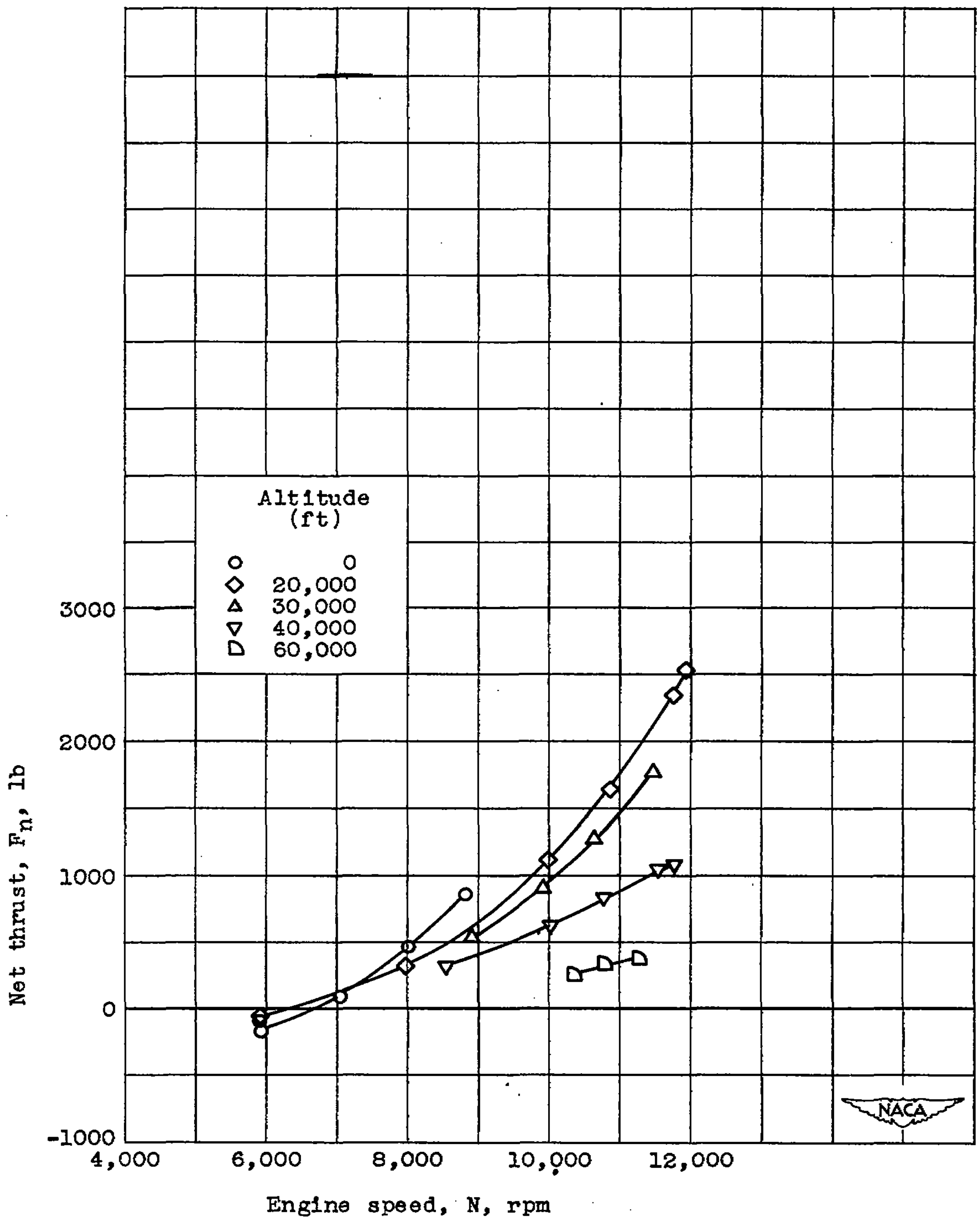


Figure 5. - Effect of altitude on net thrust.
Ram pressure ratio, 1.30.

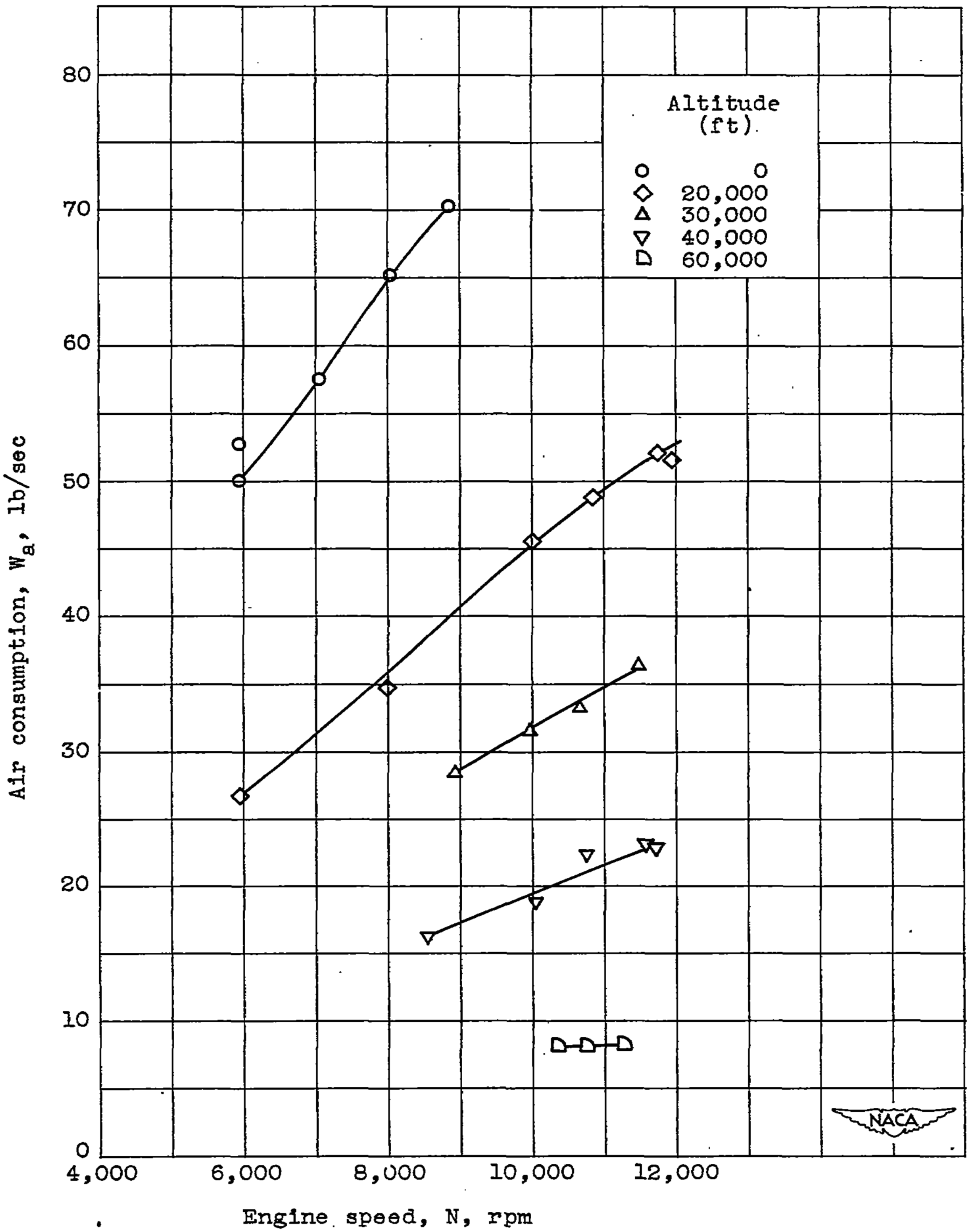


Figure 6. - Effect of altitude on air consumption.
Ram pressure ratio, 1.30.

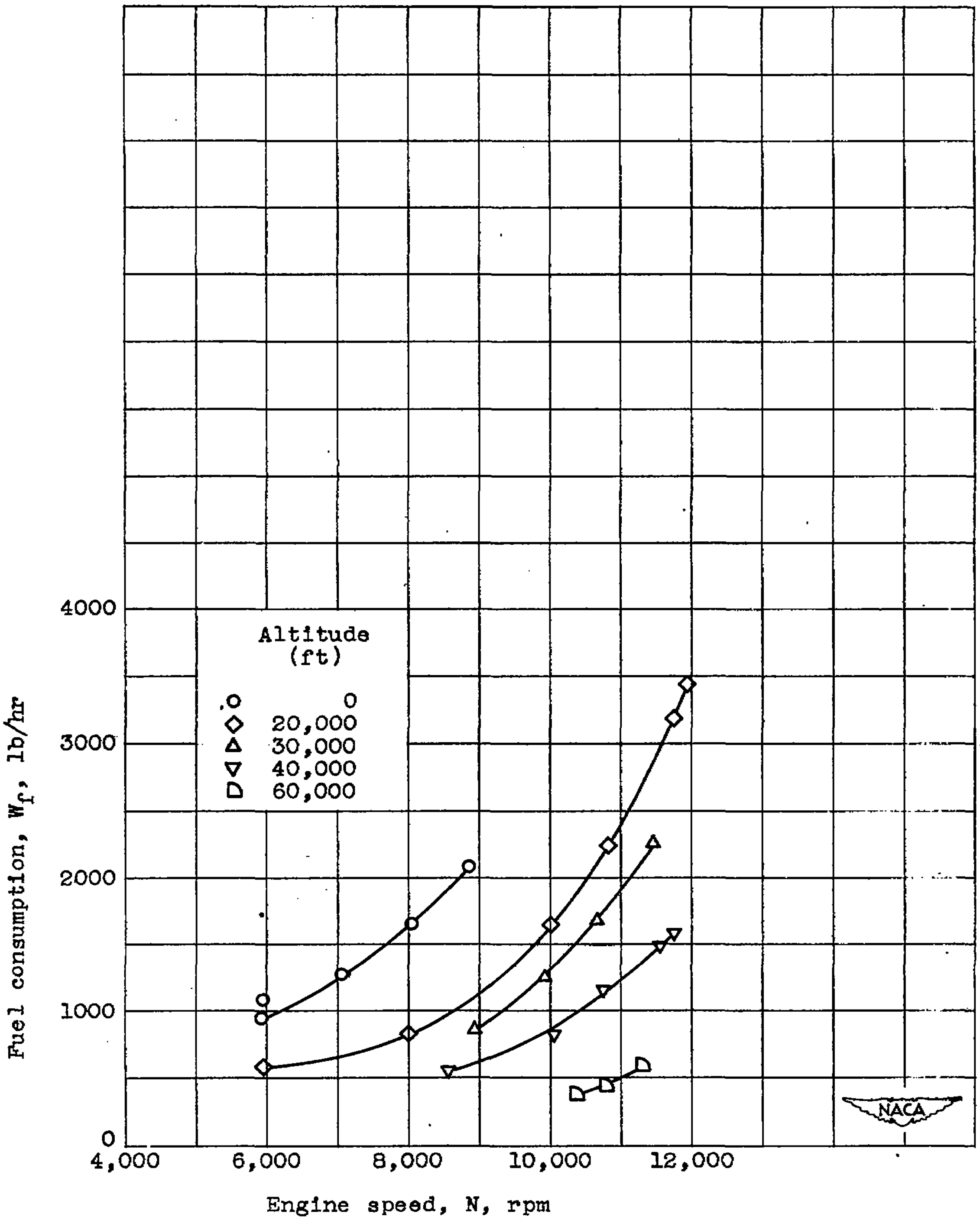


Figure 7. - Effect of altitude on fuel consumption.
Ram pressure ratio, 1.30.

1253

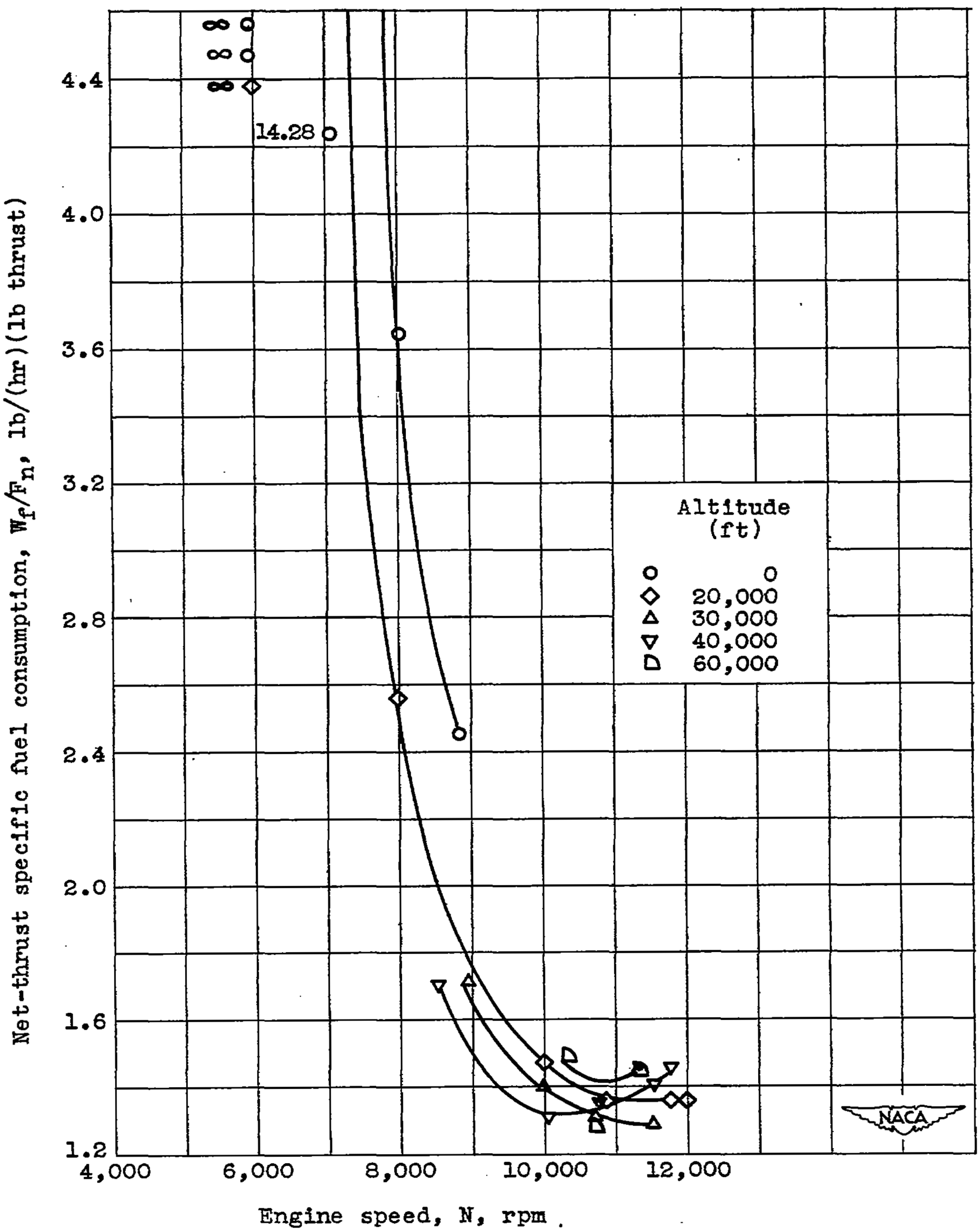


Figure 8. - Effect of altitude on net-thrust specific fuel consumption. Ram pressure ratio, 1.30.

1253

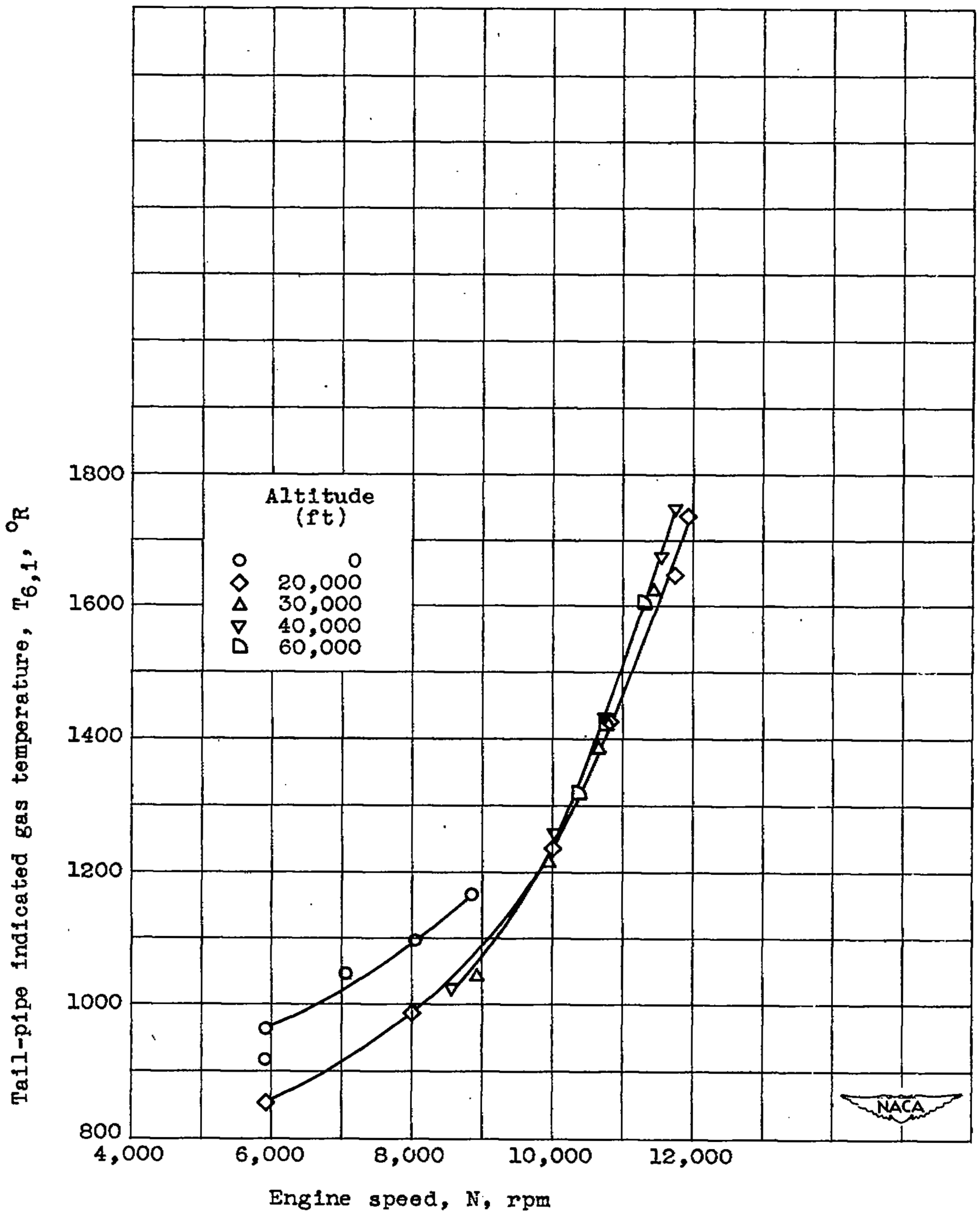


Figure 9. - Effect of altitude on tail-pipe indicated gas temperature. Ram pressure ratio, 1.30.

1253

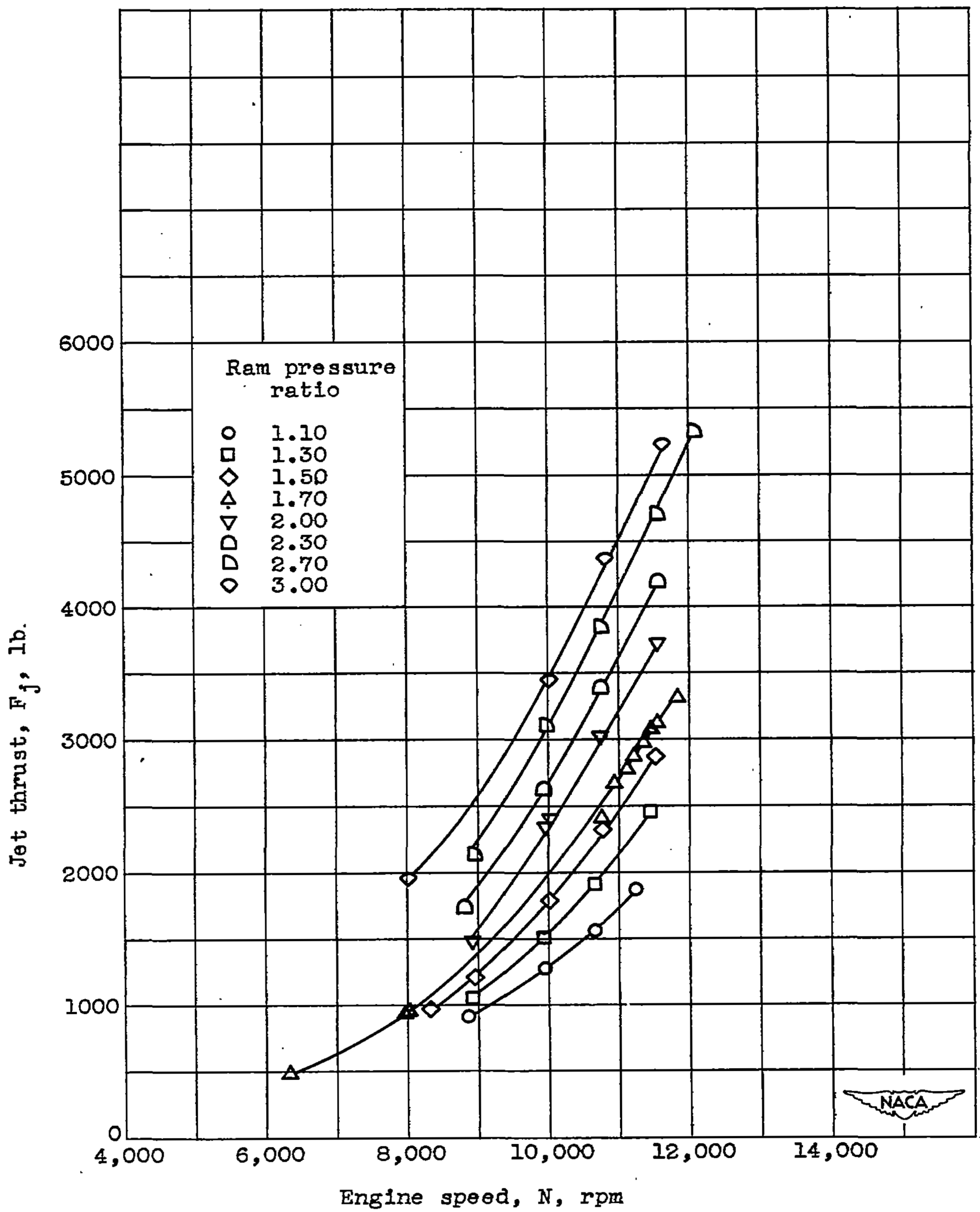


Figure 10. - Effect of ram pressure ratio on jet thrust.
Altitude, 30,000 feet.

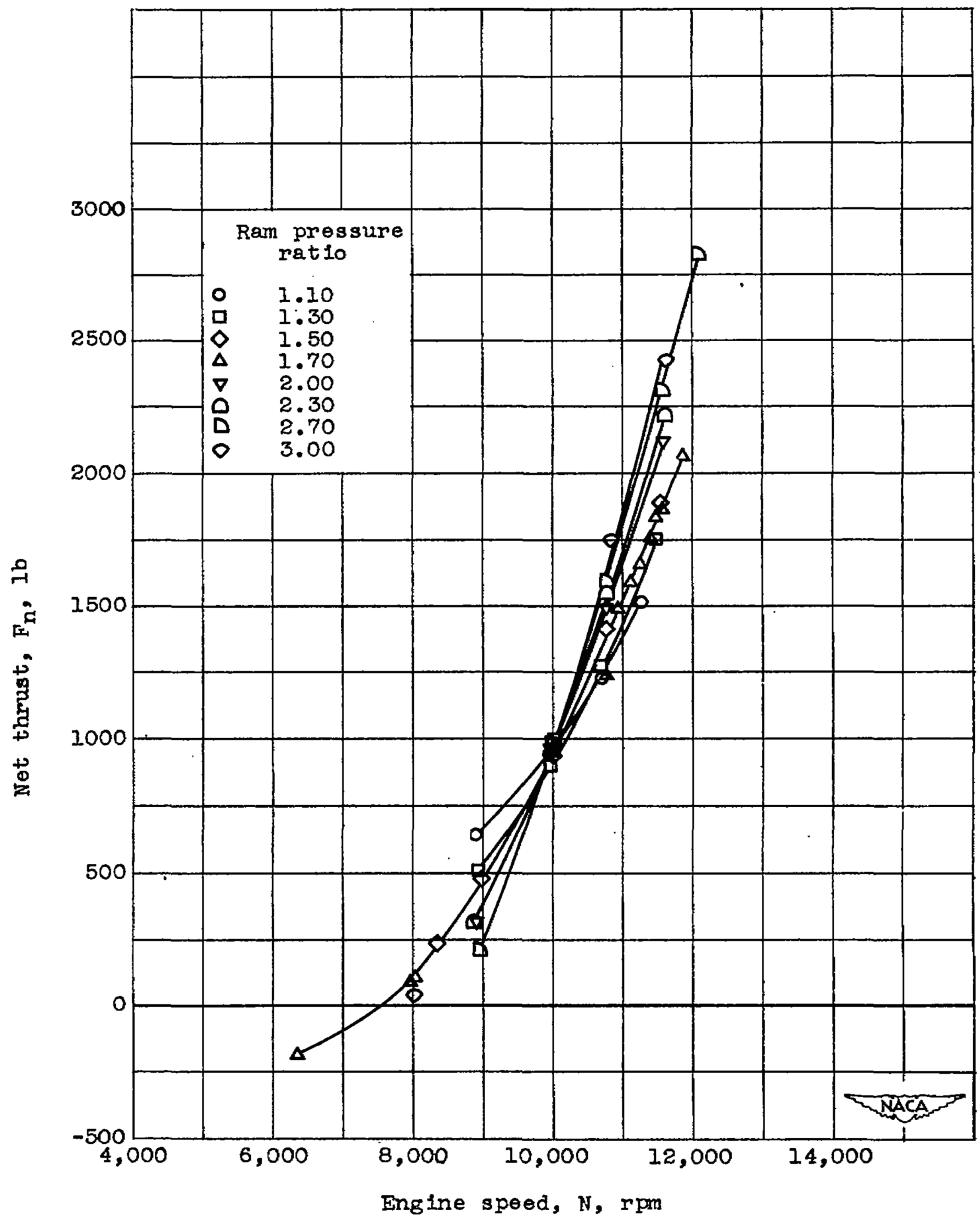


Figure 11. - Effect of ram pressure ratio on net thrust. Altitude, 30,000 feet.

1253

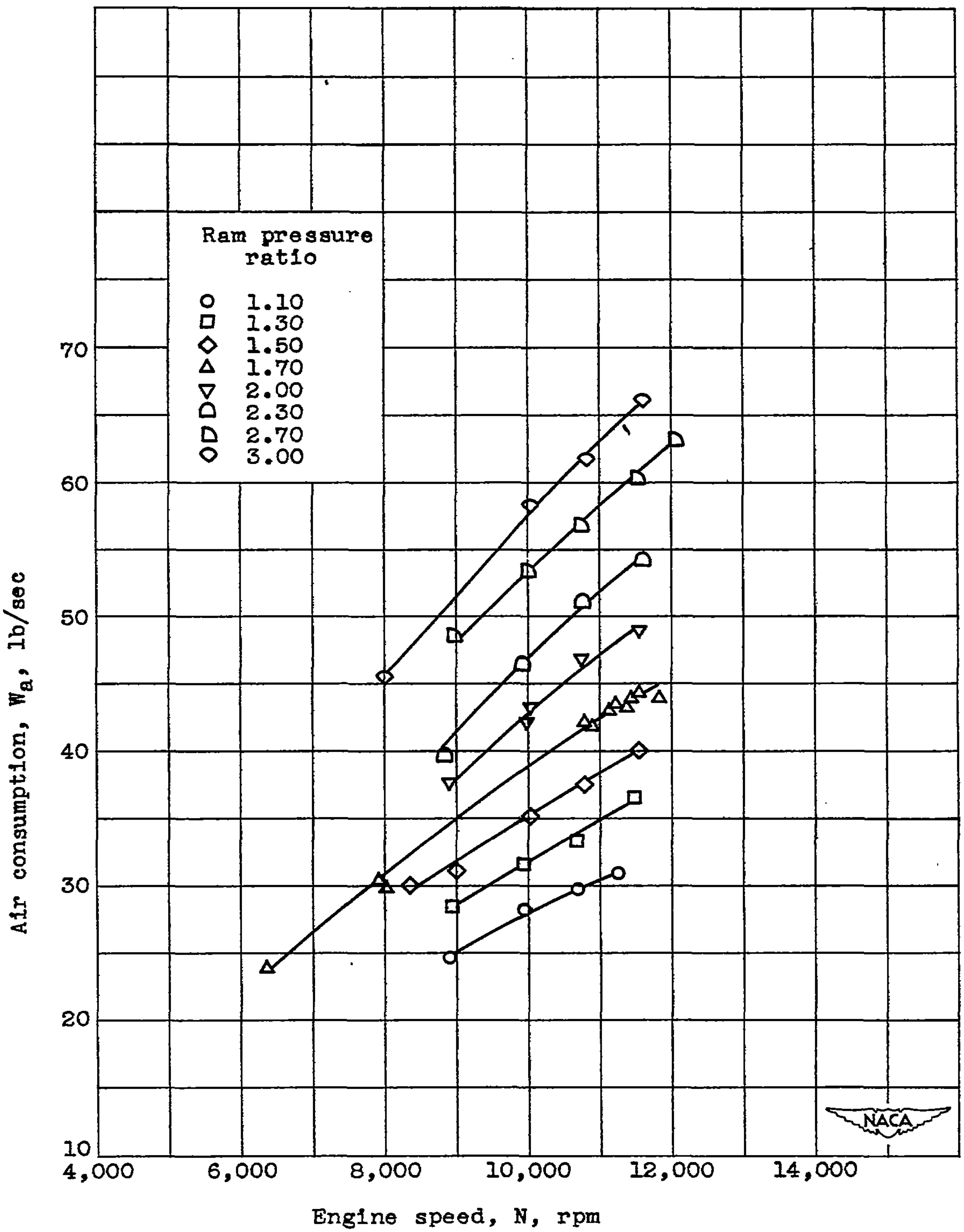


Figure 12. - Effect of ram pressure ratio on air consumption. Altitude, 30,000 feet.

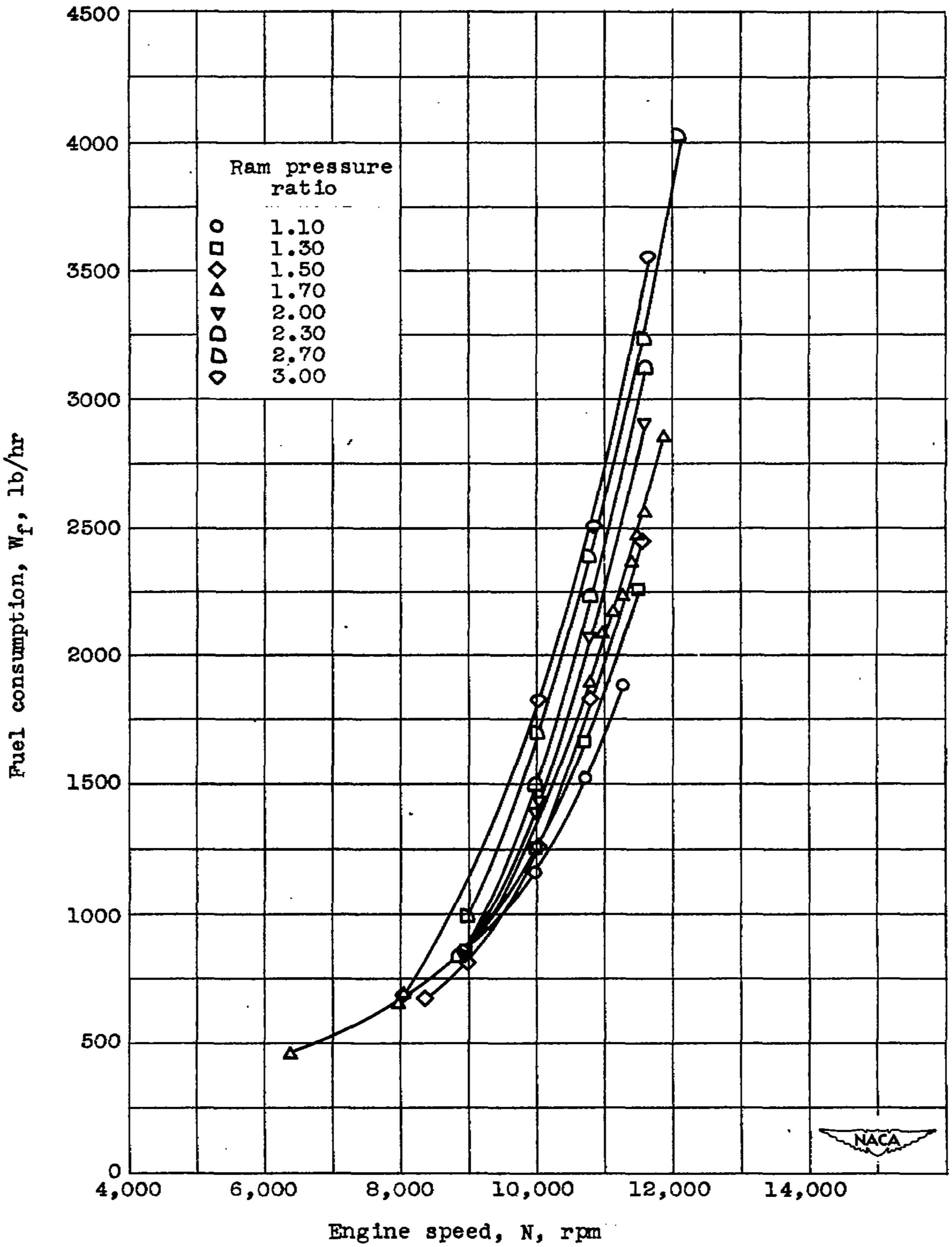


Figure 13. - Effect of ram pressure ratio on fuel consumption. Altitude, 30,000 feet.

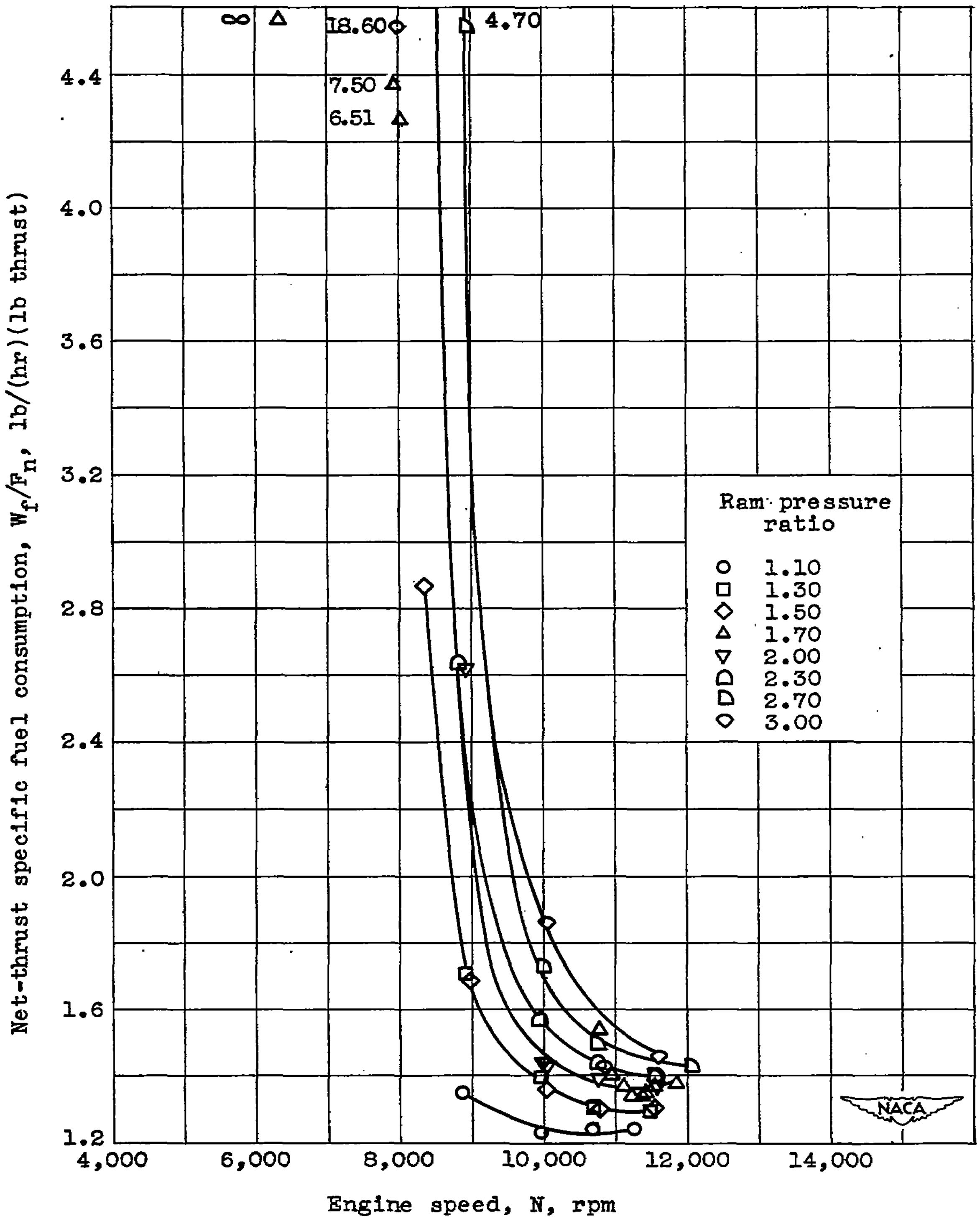


Figure 14. - Effect of ram pressure ratio on net-thrust specific fuel consumption. Altitude, 30,000 feet.

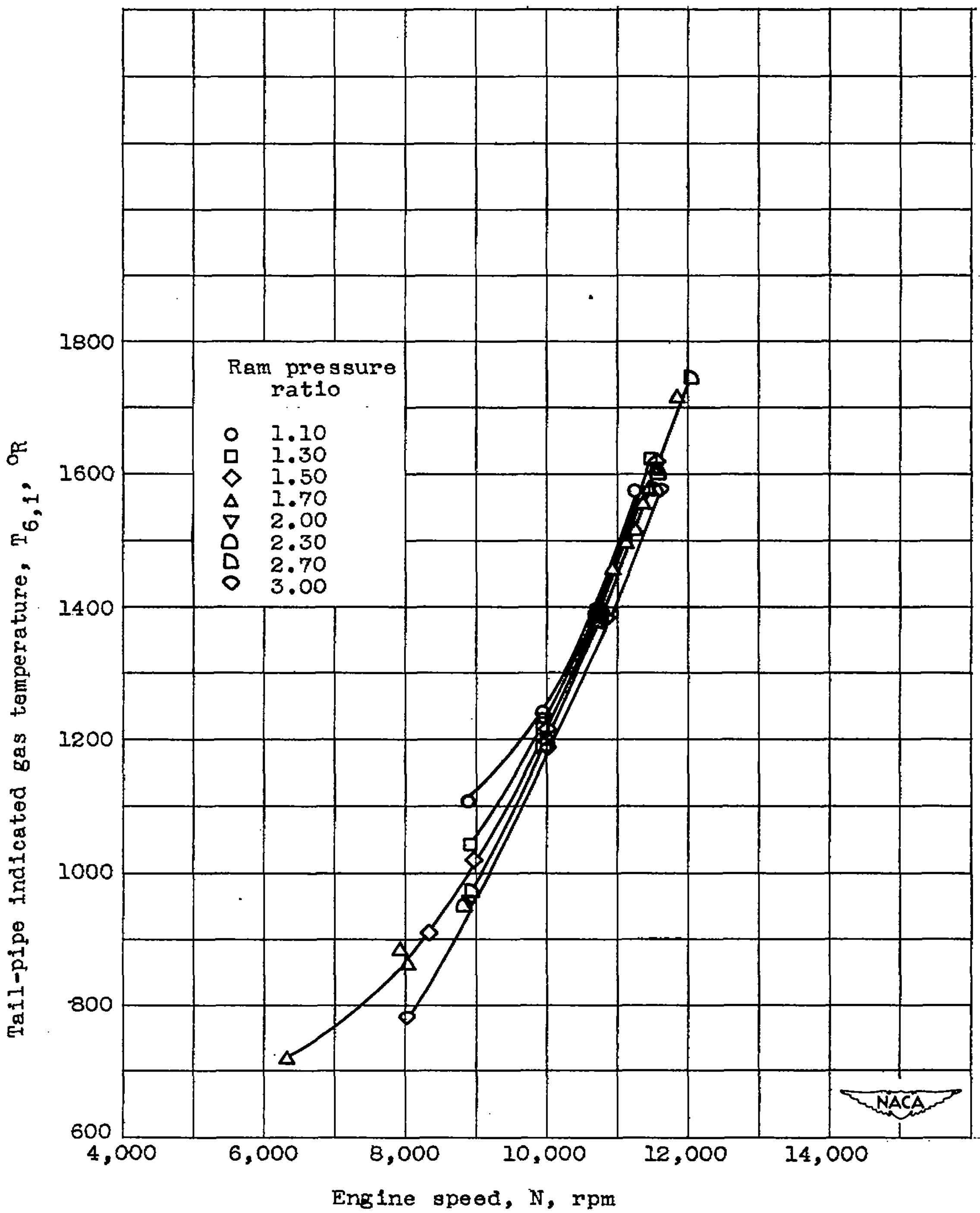


Figure 15. - Effect of ram pressure ratio on tail-pipe indicated gas temperature. Altitude, 30,000 feet.

1253

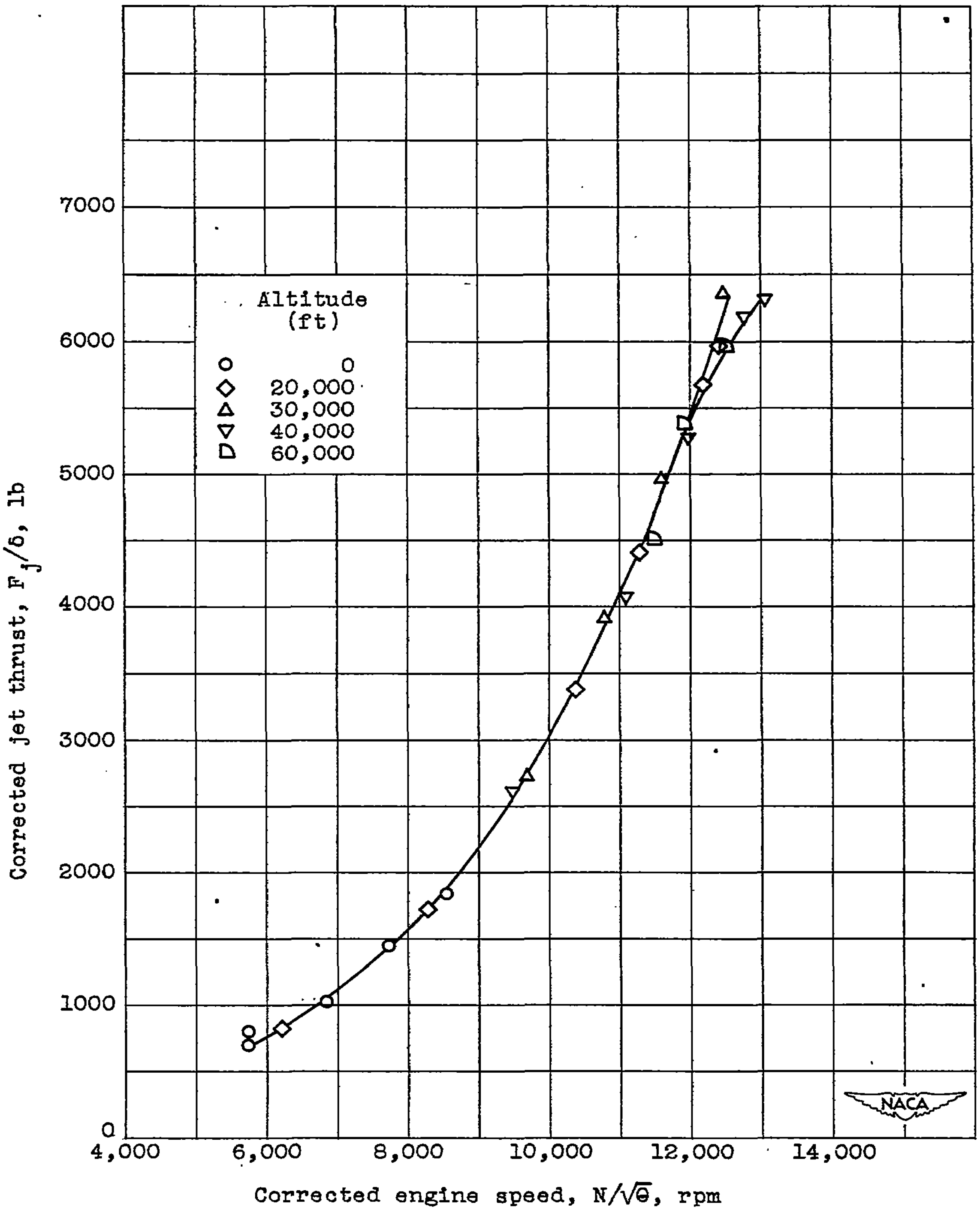


Figure 16. - Effect of altitude on corrected jet thrust. Ram pressure ratio, 1.30.

1253

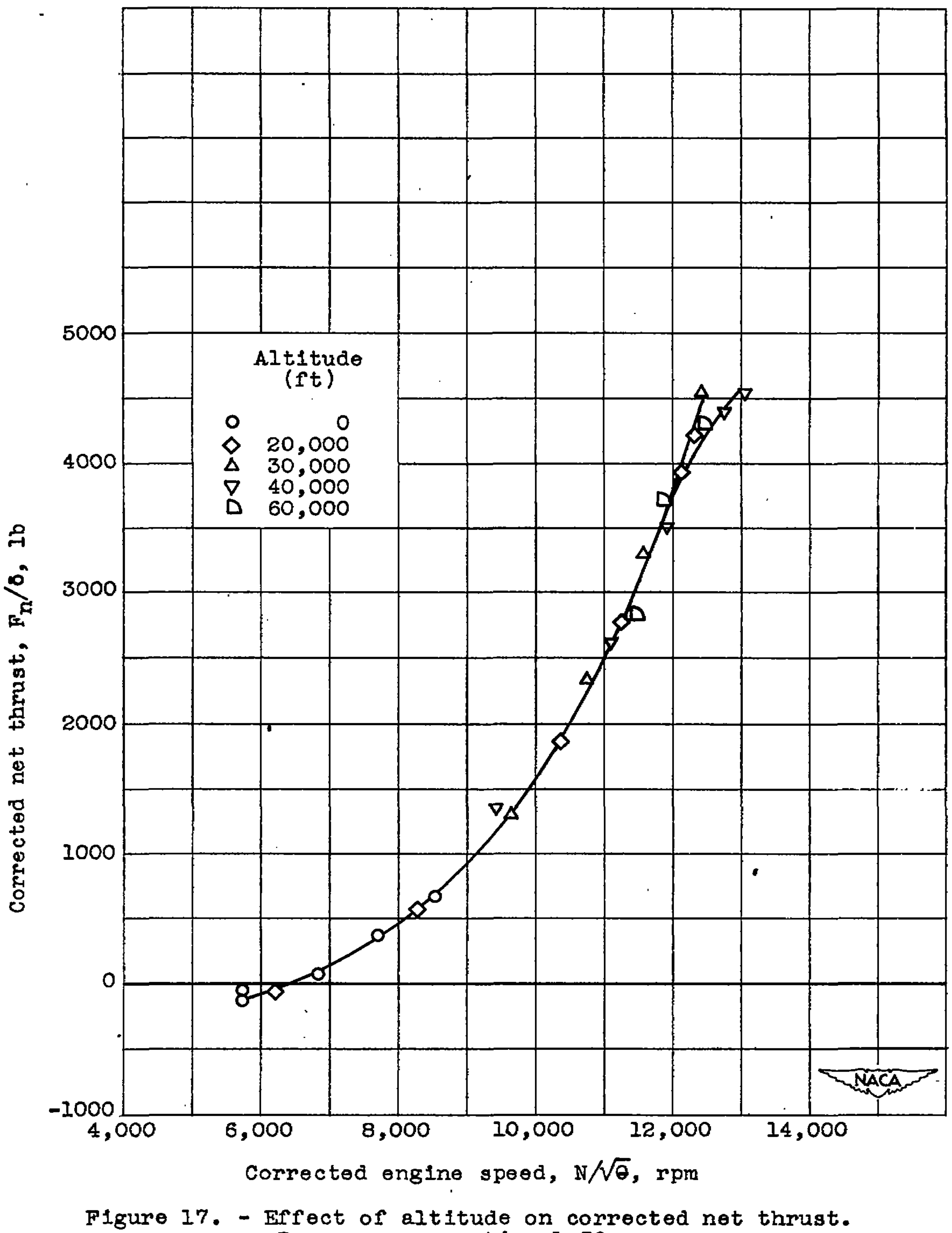


Figure 17. - Effect of altitude on corrected net thrust. Ram pressure ratio, 1.30.

1253

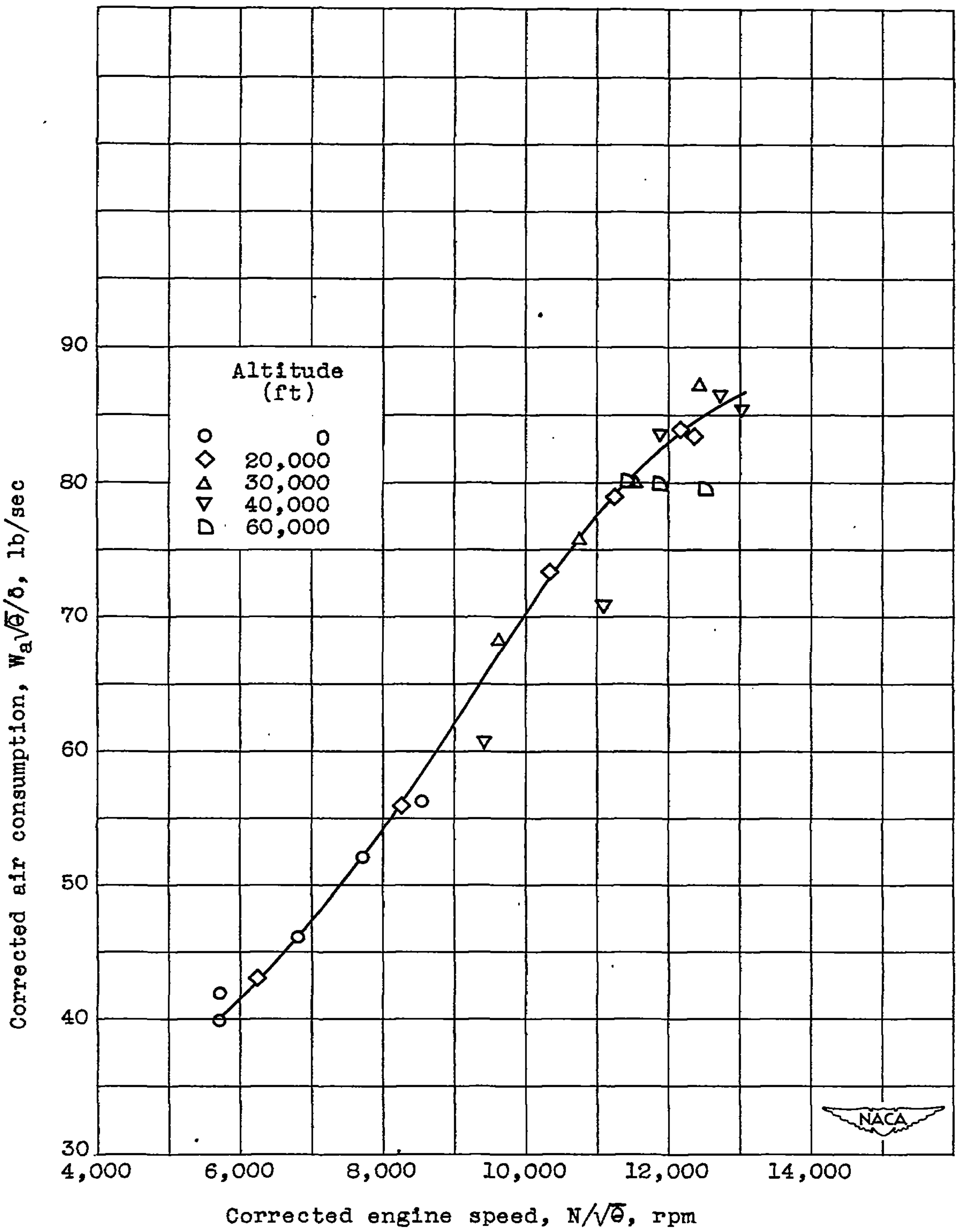


Figure 18. - Effect of altitude on corrected air consumption. Ram pressure ratio, 1.30.

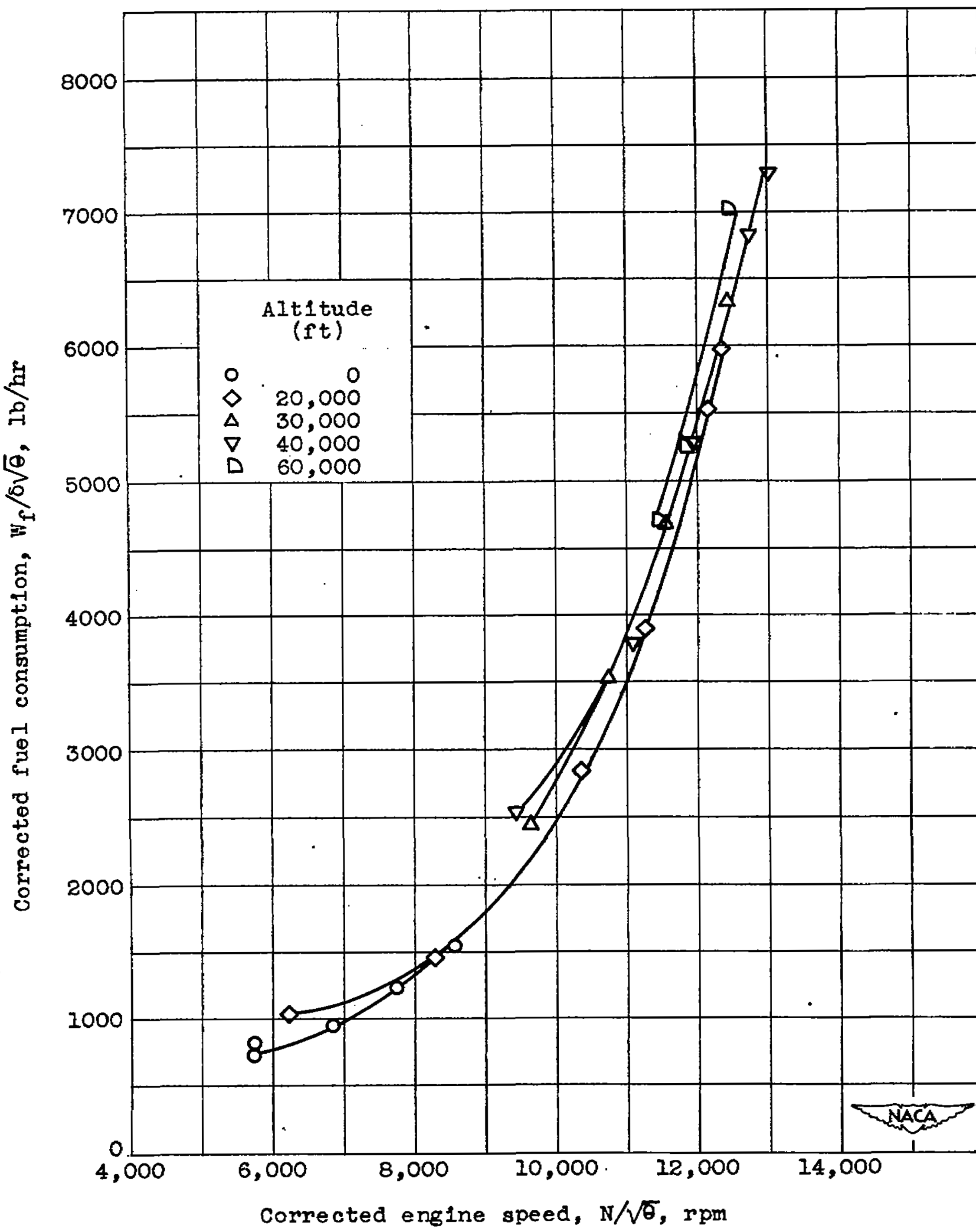


Figure 19. - Effect of altitude on corrected fuel consumption. Ram pressure ratio, 1.30.

1253

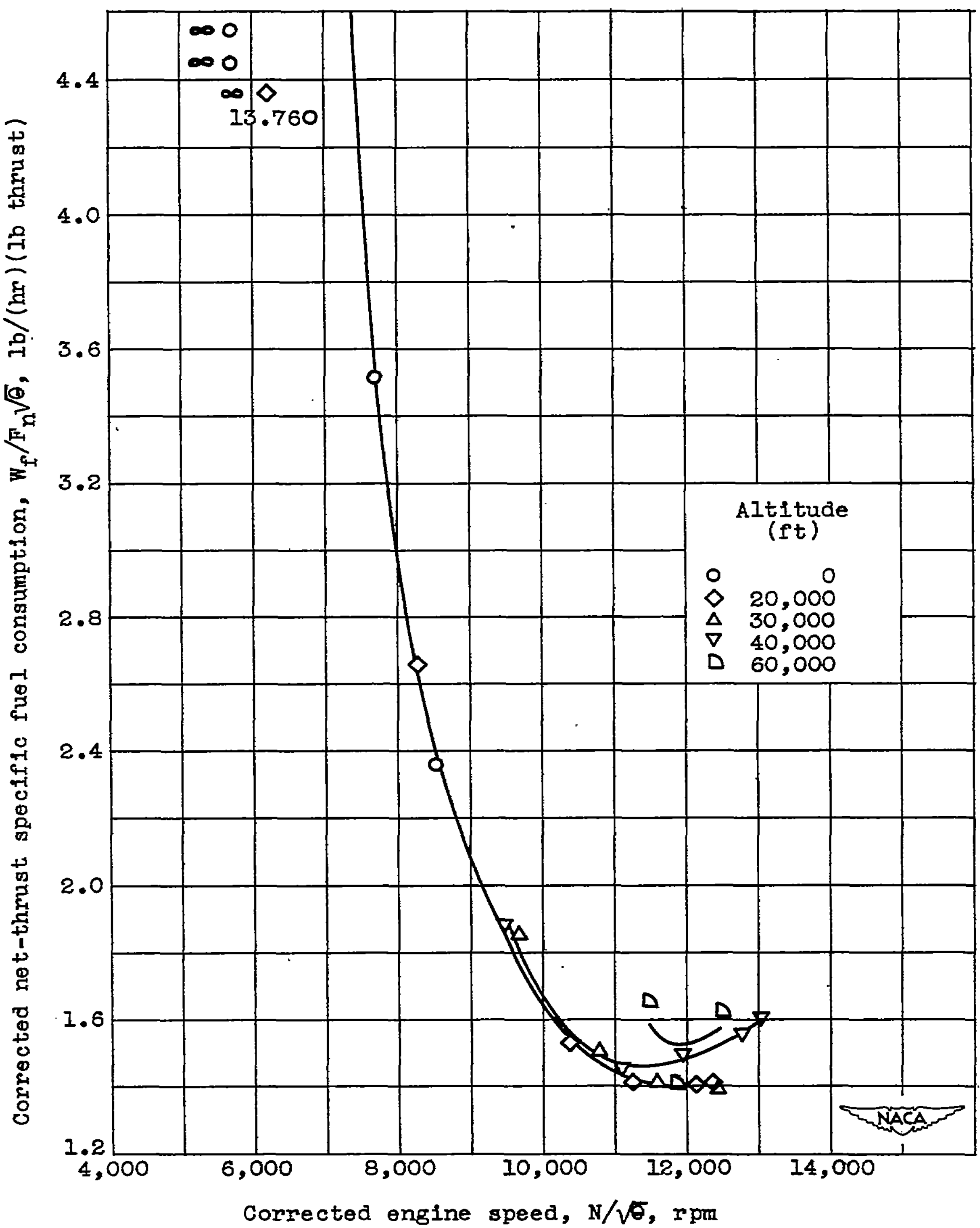


Figure 20. - Effect of altitude on corrected net-thrust specific fuel consumption. Ram pressure ratio, 1.30.

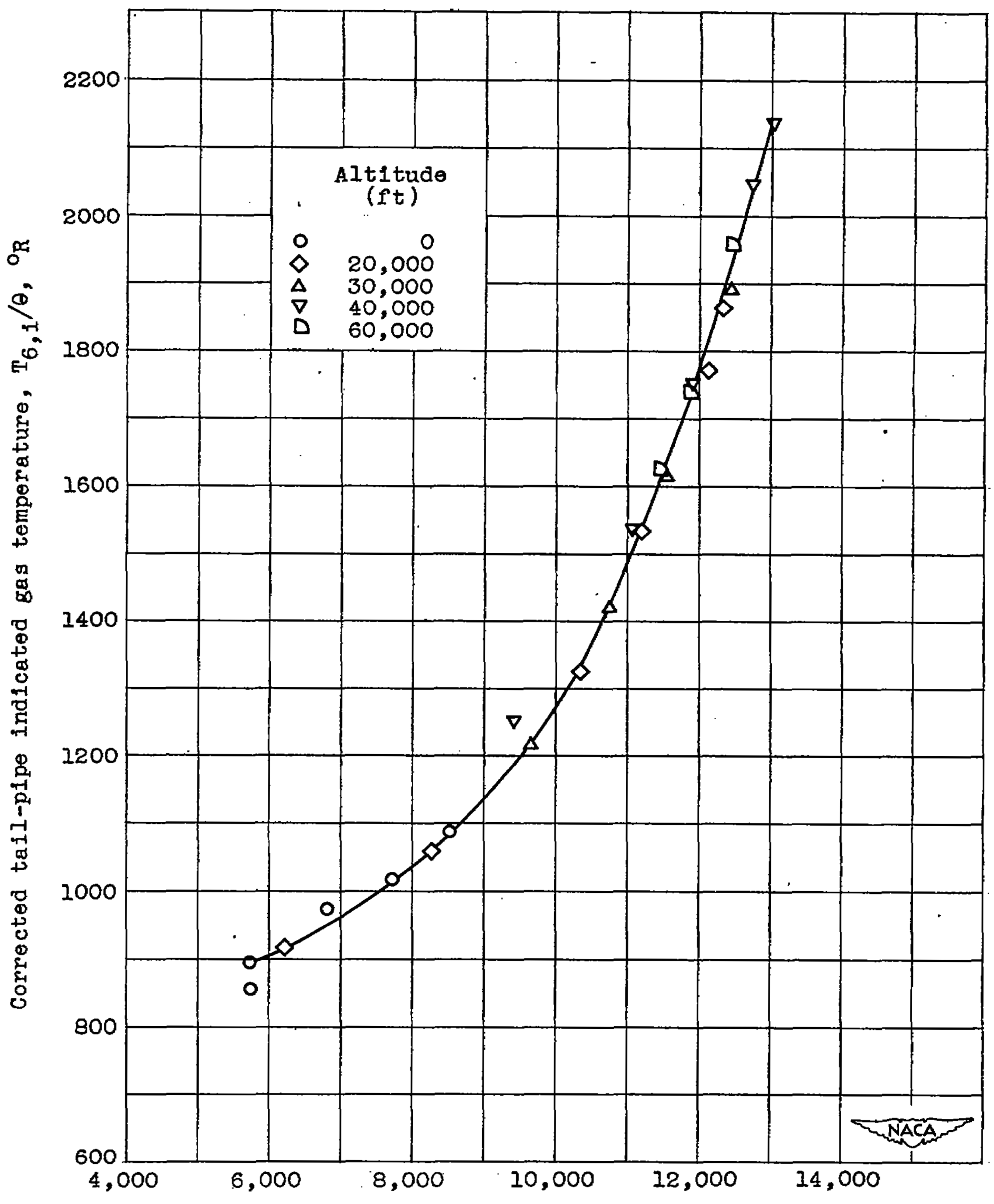
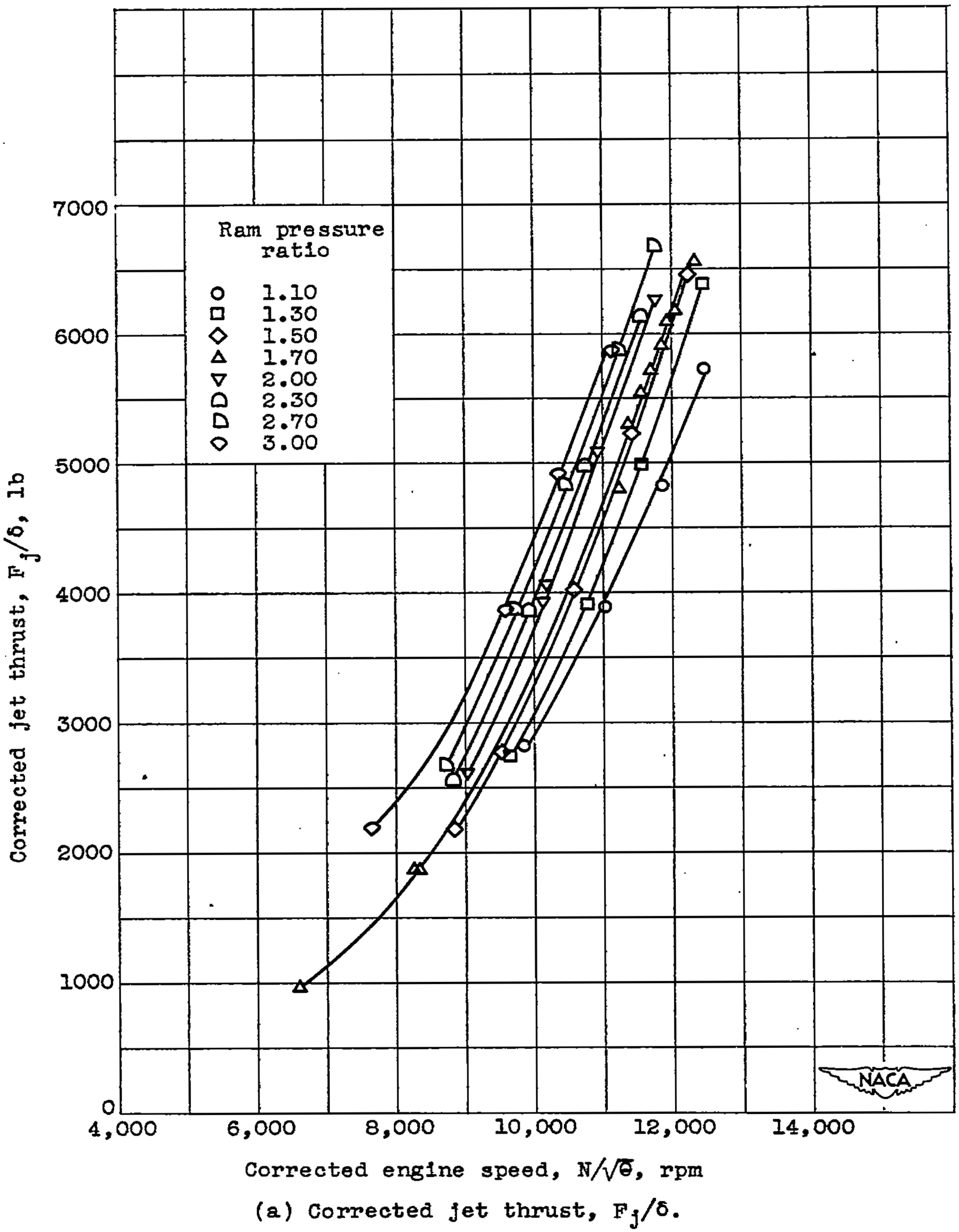
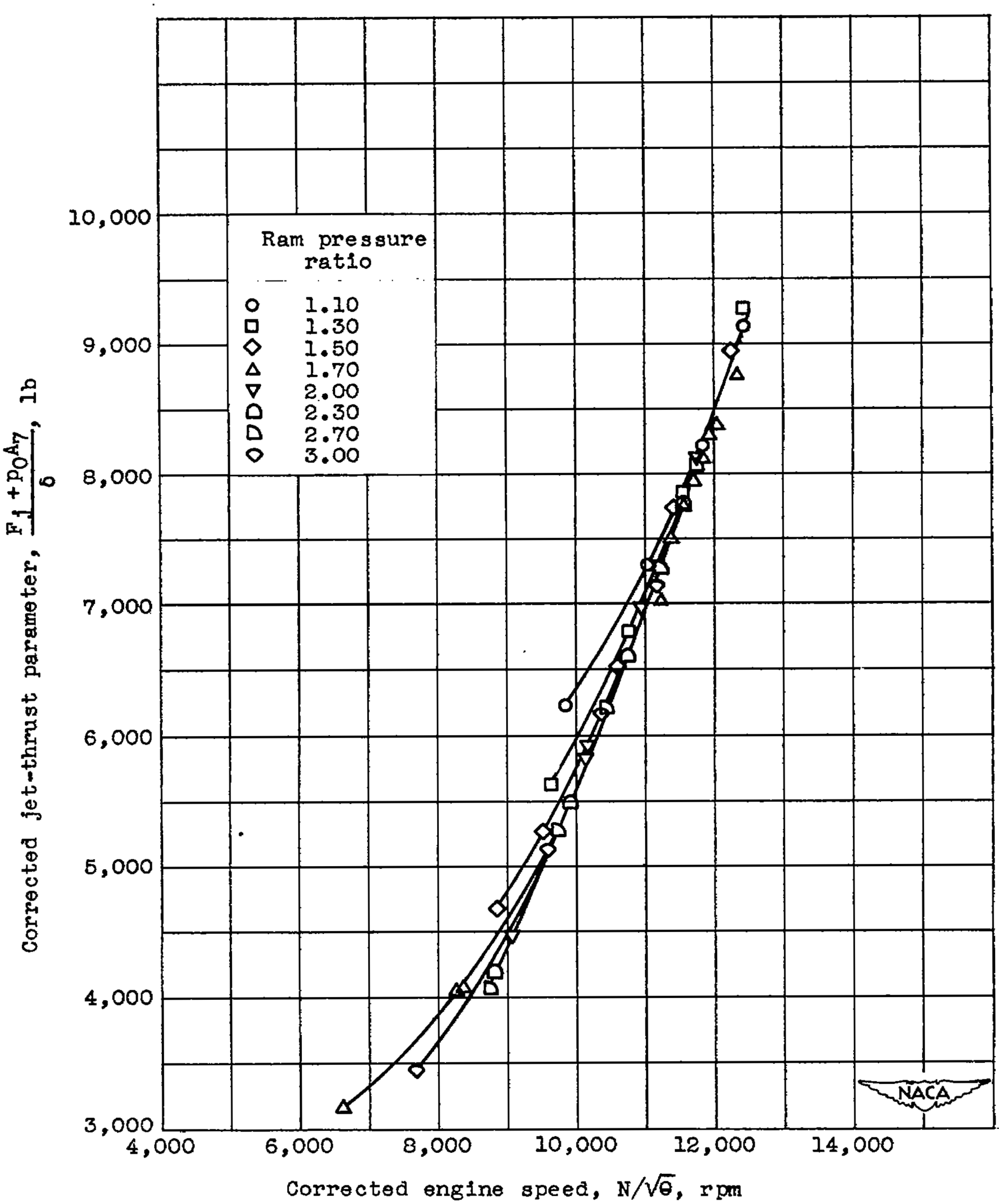


Figure 21. - Effect of altitude on corrected tail-pipe indicated gas temperature. Ram pressure ratio, 1.30.



(a) Corrected jet thrust, F_j/δ.

Figure 22. - Effect of ram pressure ratio on corrected jet thrust. Altitude, 30,000 feet.



(b) Corrected jet-thrust parameter, $\frac{F_j + p_0 A_7}{\delta}$.

Figure 22. - Concluded. Effect of ram pressure ratio on corrected jet thrust. Altitude, 30,000 feet.

1253

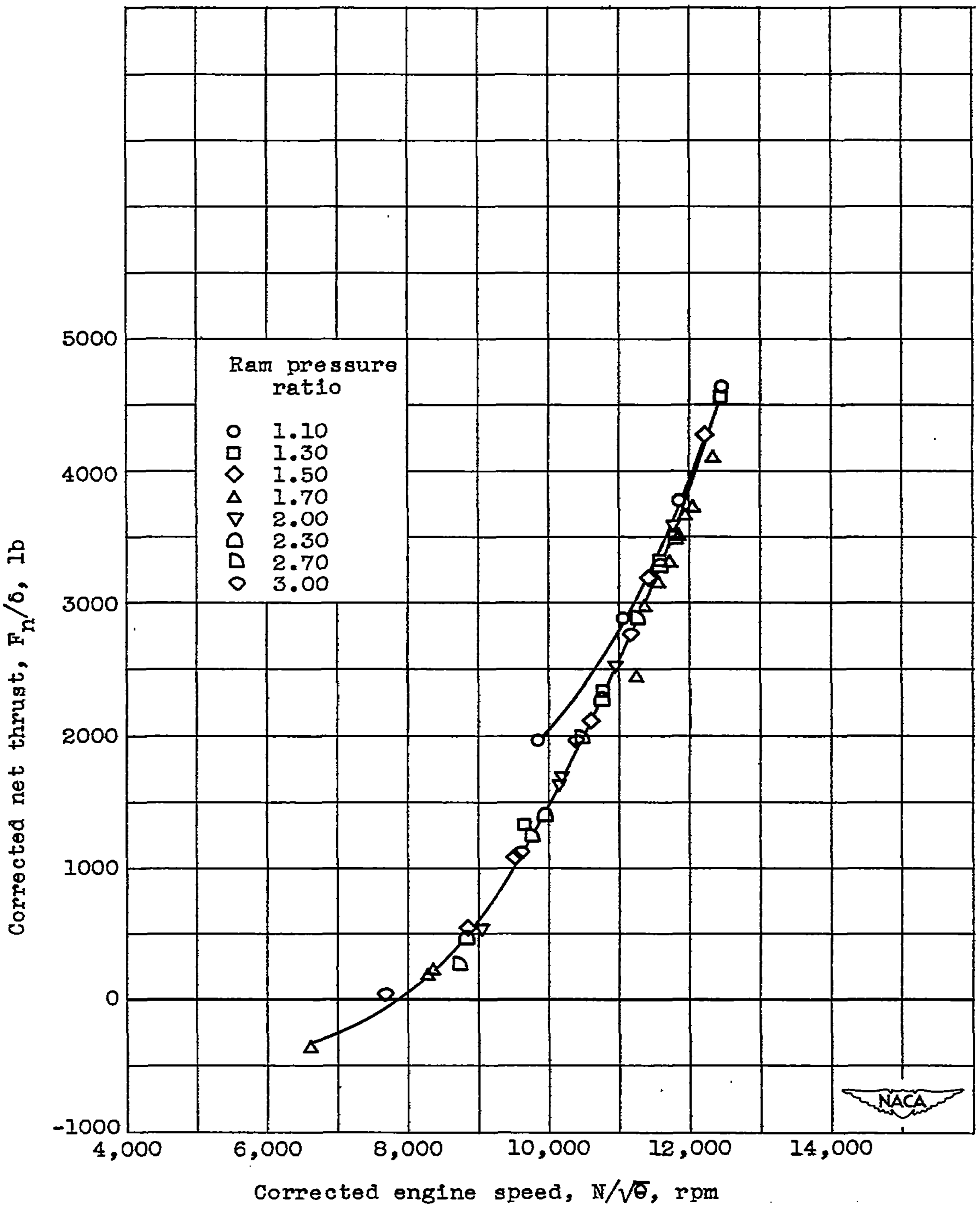


Figure 23. - Effect of ram pressure ratio on corrected net thrust. Altitude, 30,000 feet.

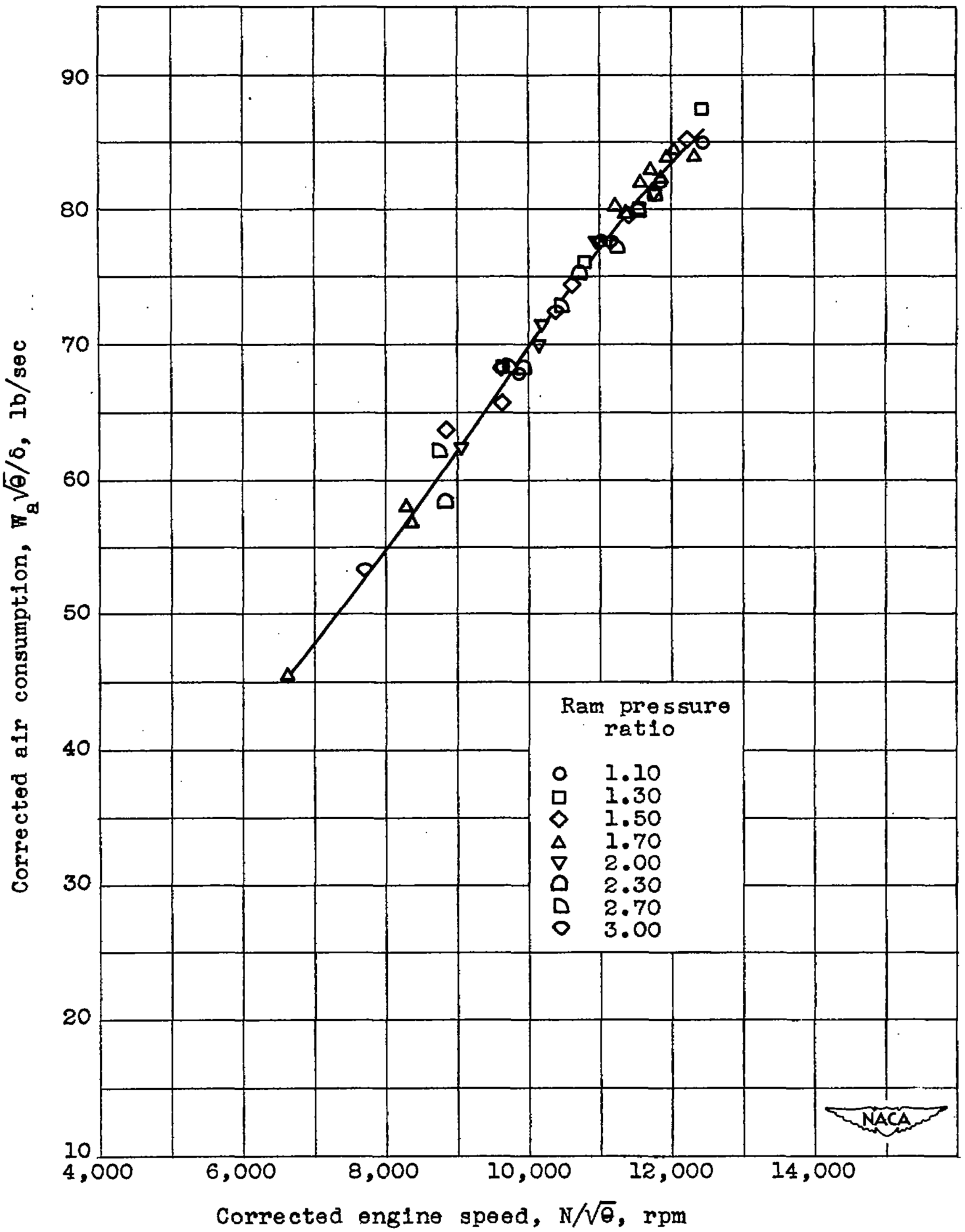


Figure 24. - Effect of ram pressure ratio on corrected air consumption. Altitude, 30,000 feet.

1253

1253

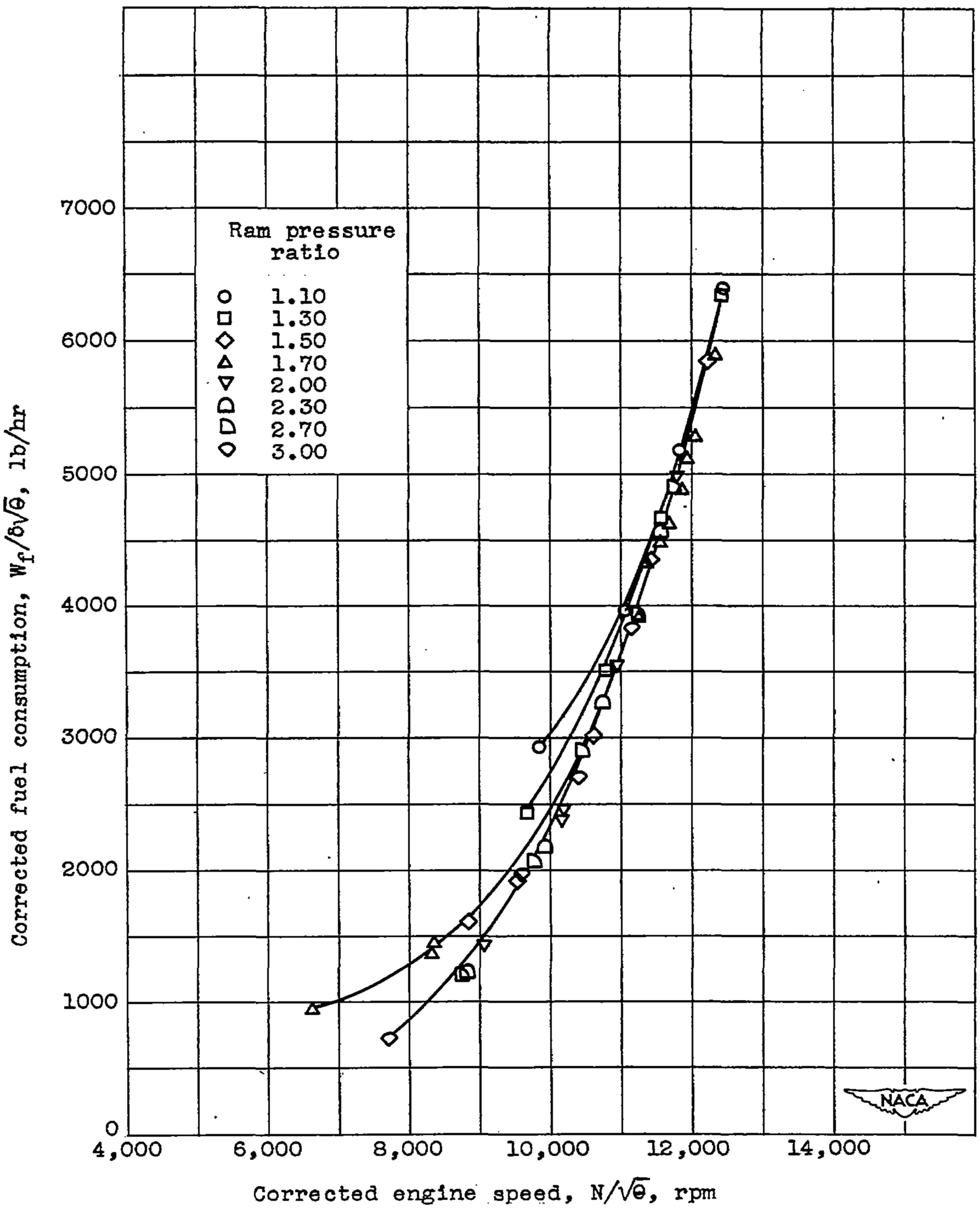


Figure 25. - Effect of ram pressure ratio on corrected fuel consumption. Altitude, 30,000 feet.

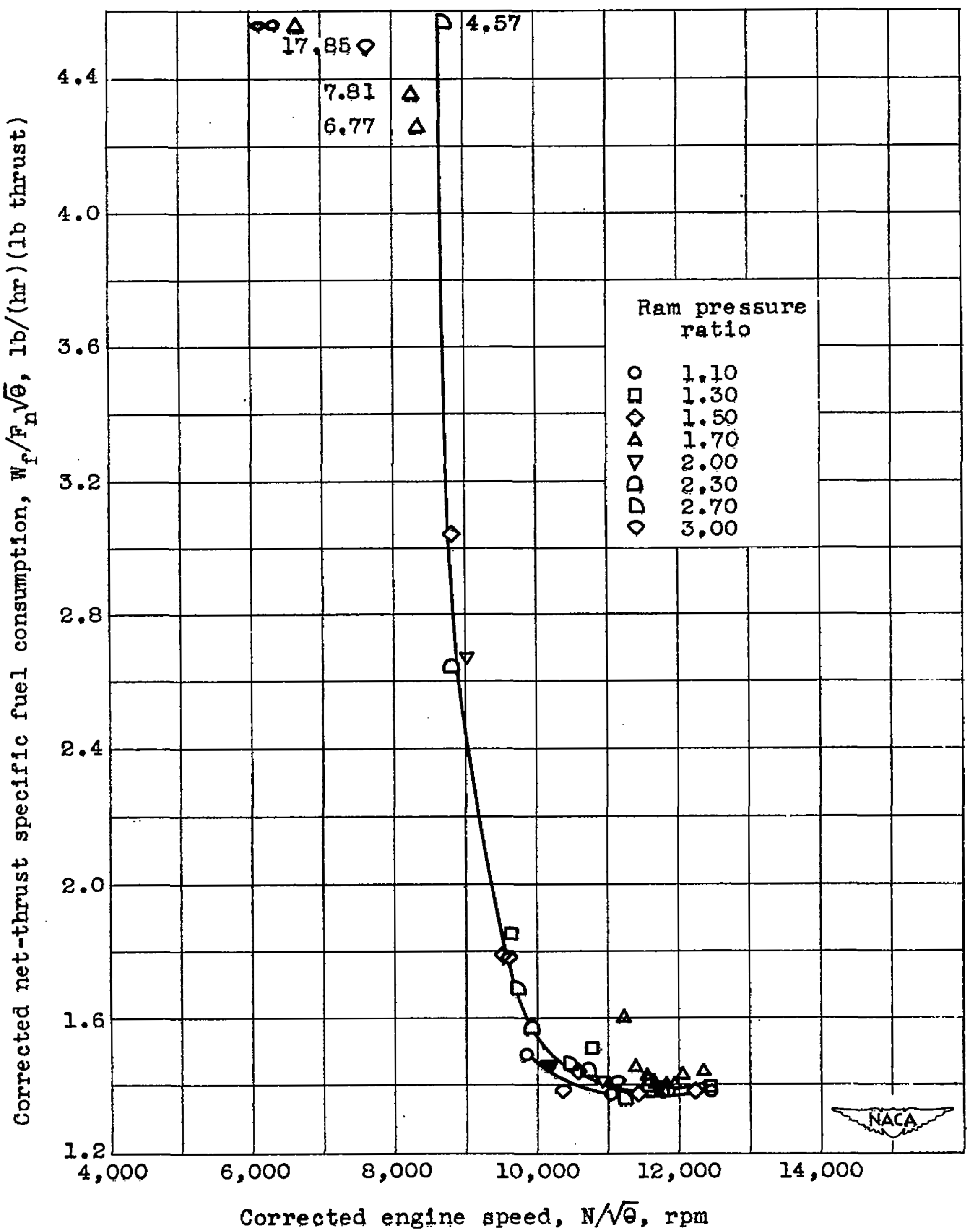


Figure 26. - Effect of ram pressure ratio on corrected net-thrust specific fuel consumption. Altitude, 30,000 feet.

1253

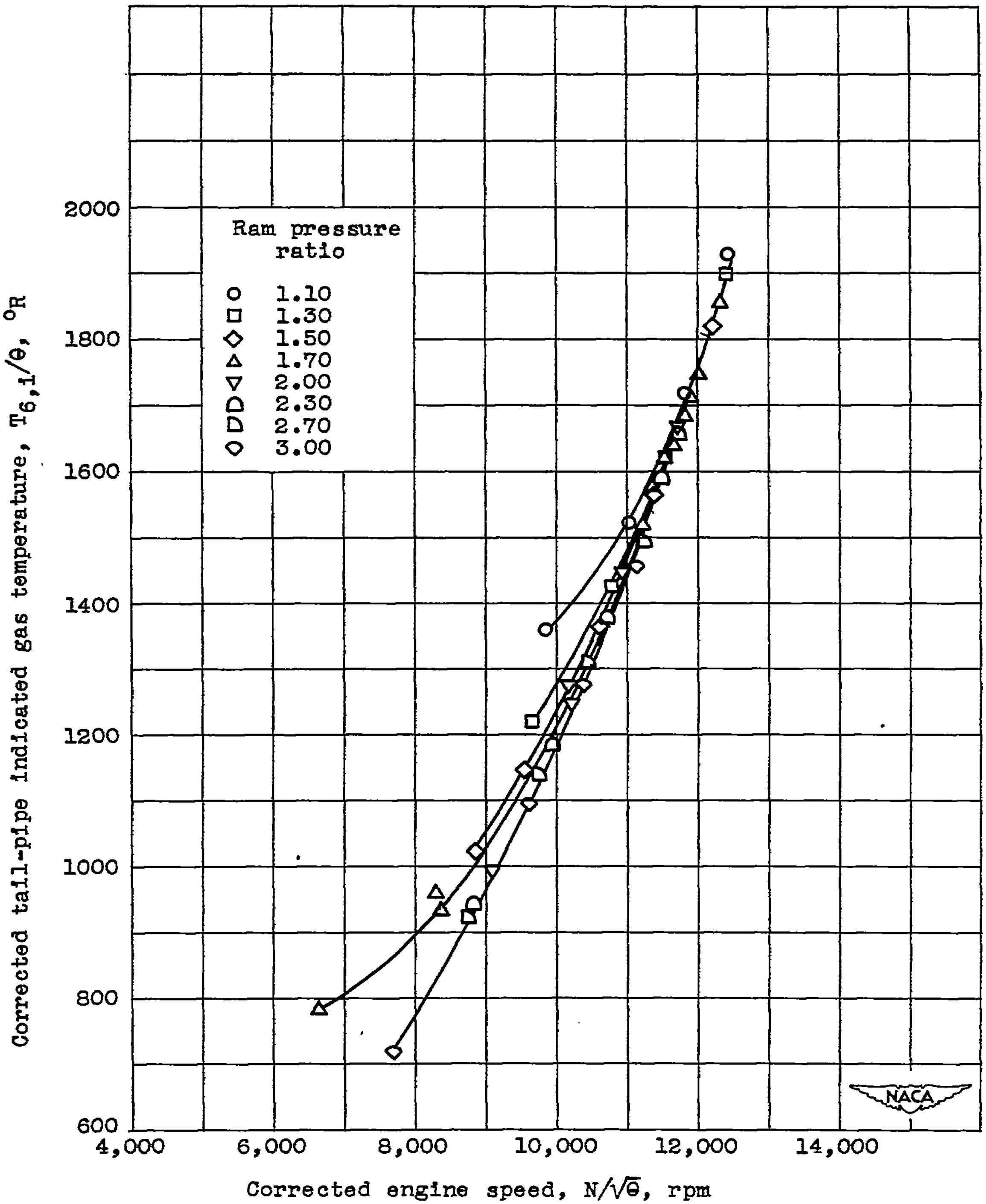


Figure 27. - Effect of ram pressure ratio on corrected tail-pipe indicated gas temperature. Altitude, 30,000 feet.

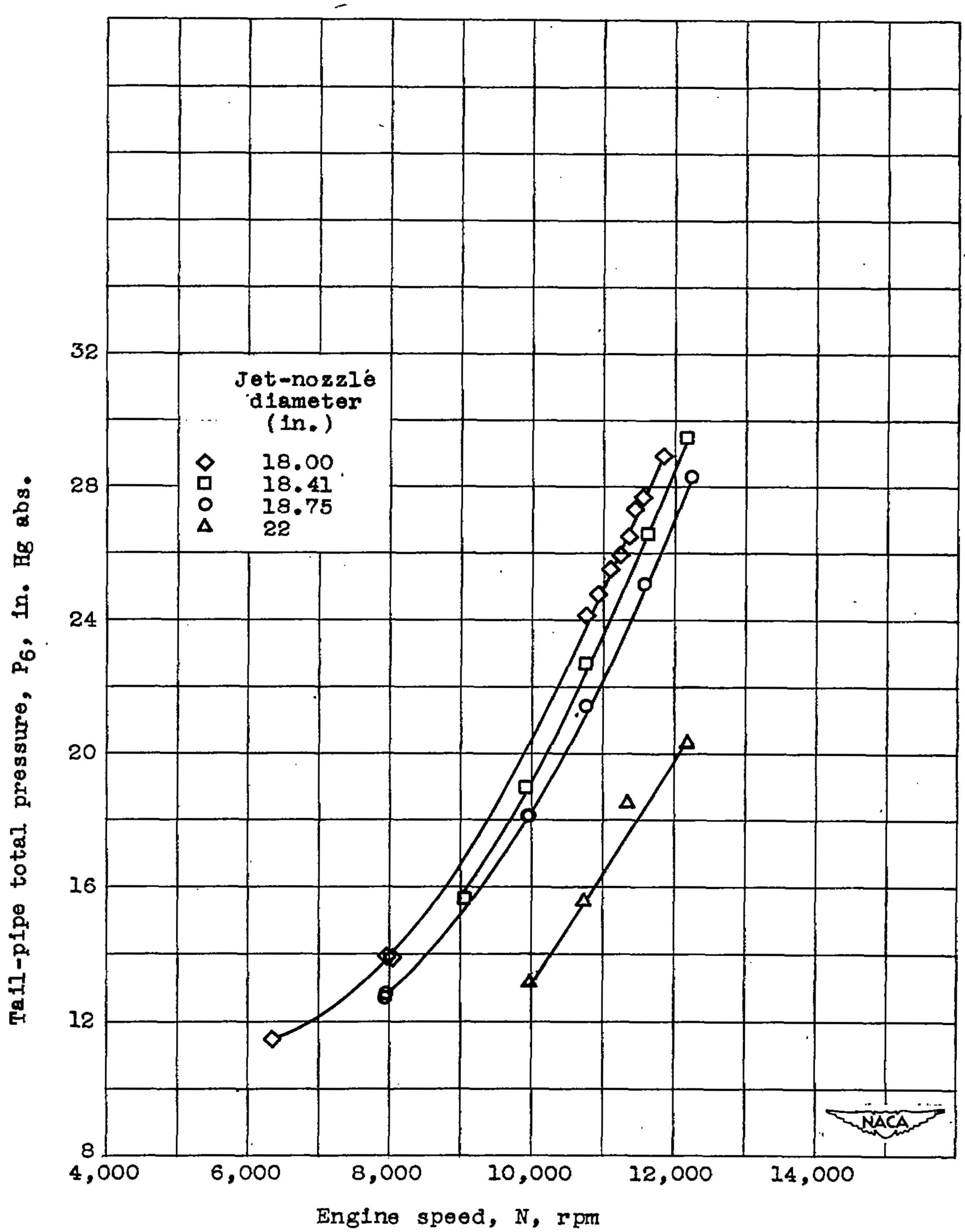


Figure 28. - Effect of jet-nozzle size on tail-pipe total pressure. Altitude, 30,000 feet; ram pressure ratio, 1.70.

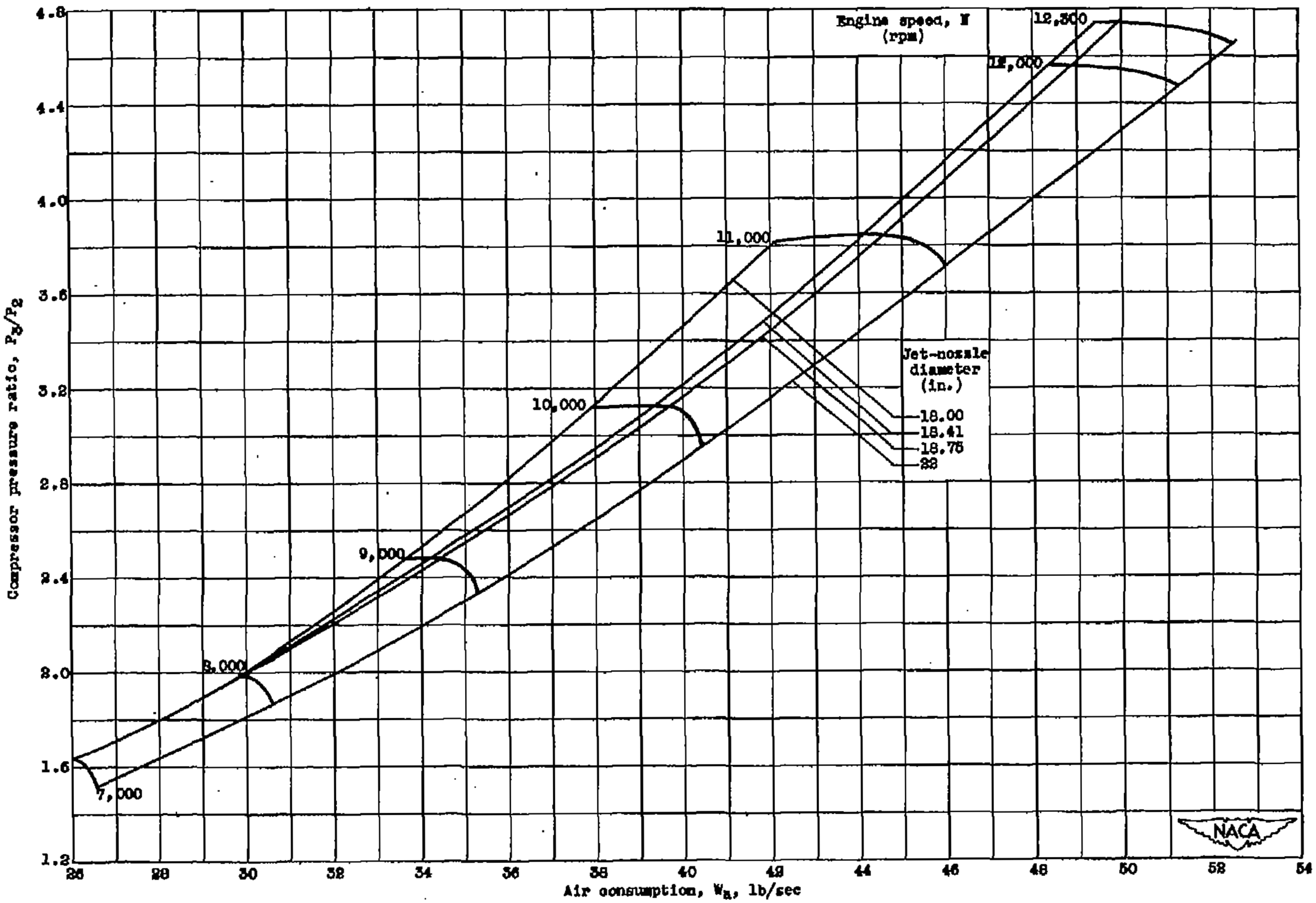


Figure 29. - Compressor performance. Altitude, 30,000 feet; ram pressure ratio, 1.70.

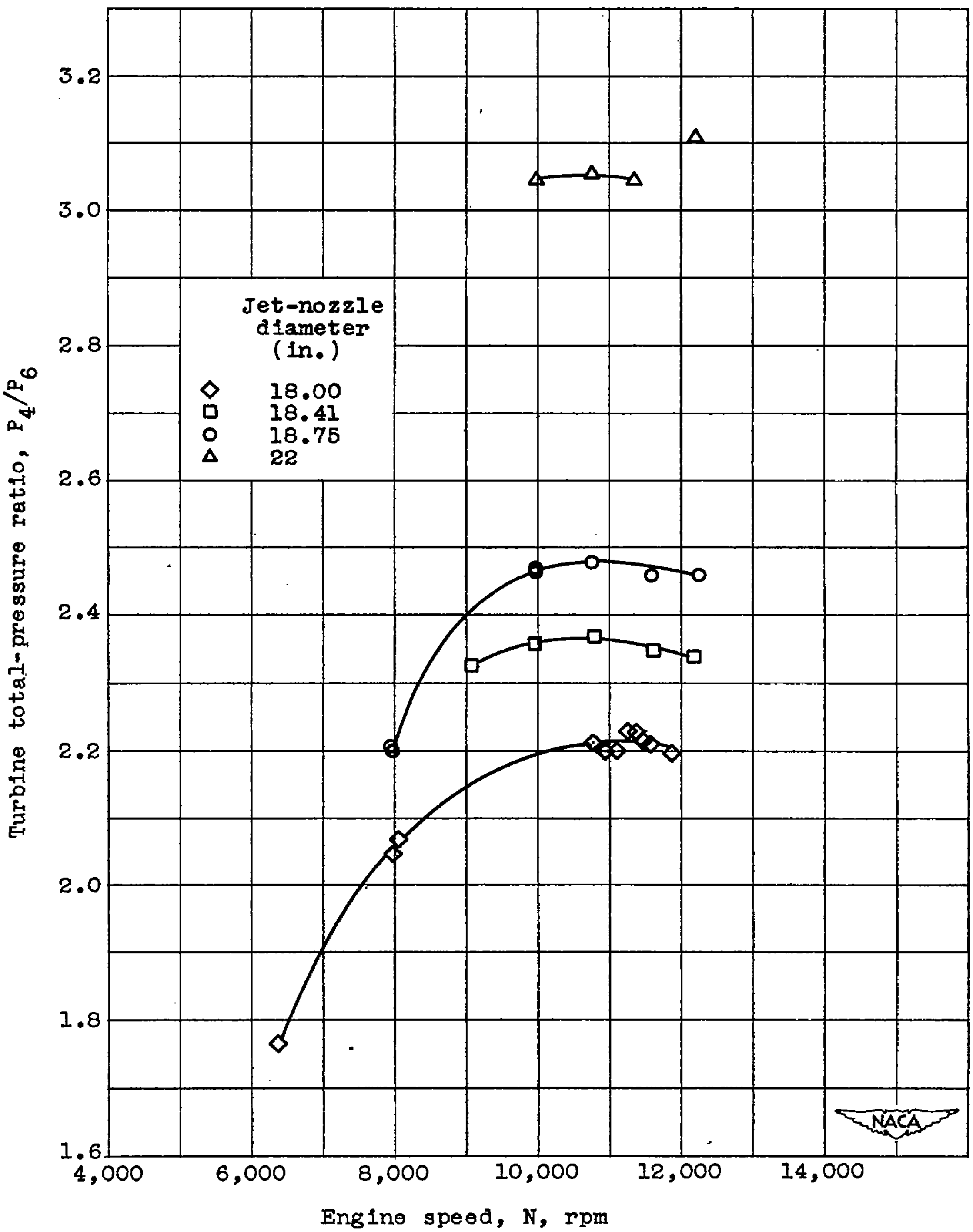


Figure 30. - Effect of jet-nozzle size on turbine total-pressure ratio. Altitude, 30,000 feet; ram pressure ratio, 1.70.

1253

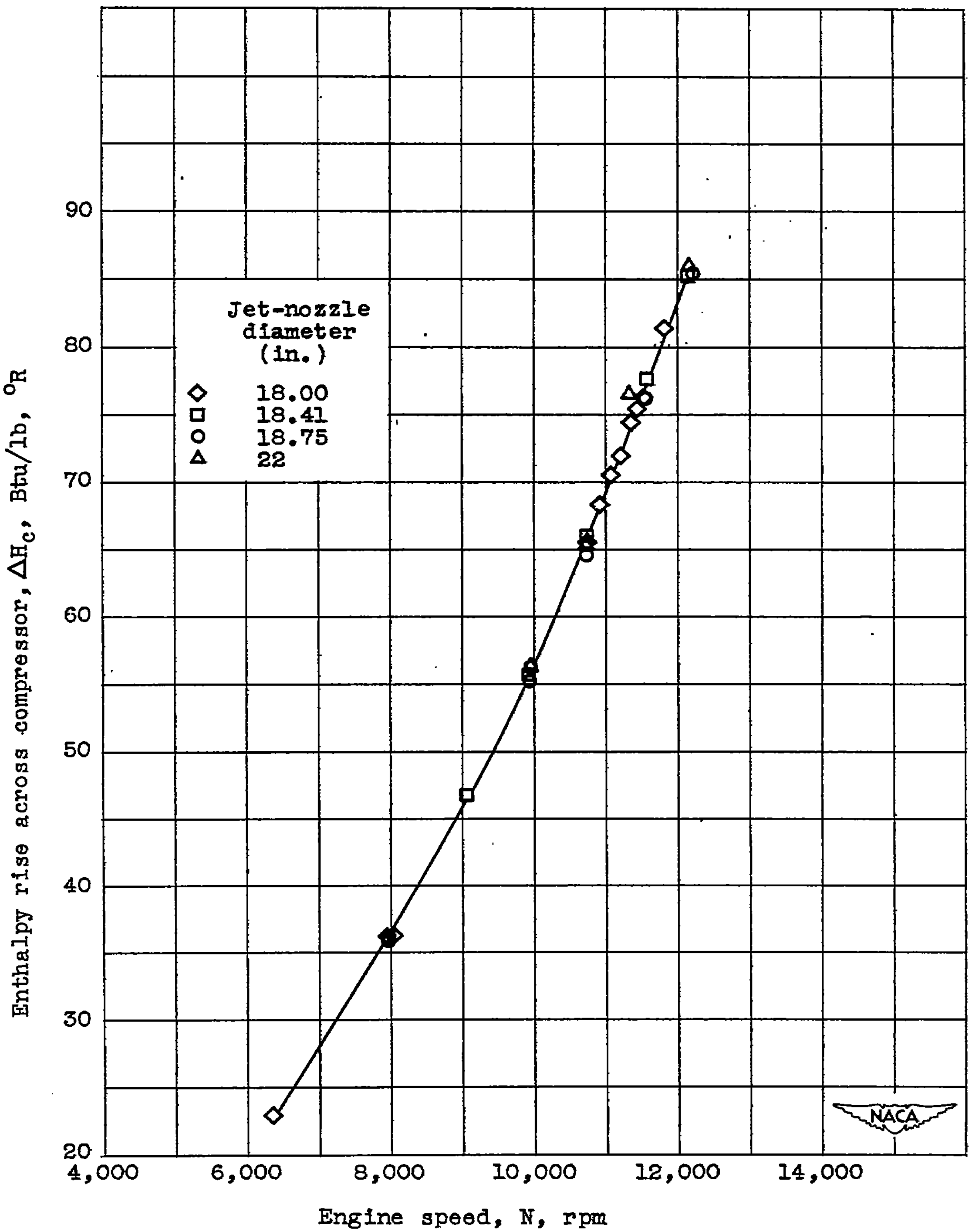


Figure 31. - Effect of jet-nozzle size on enthalpy rise across compressor. Altitude, 30,000 feet; ram pressure ratio, 1.70.

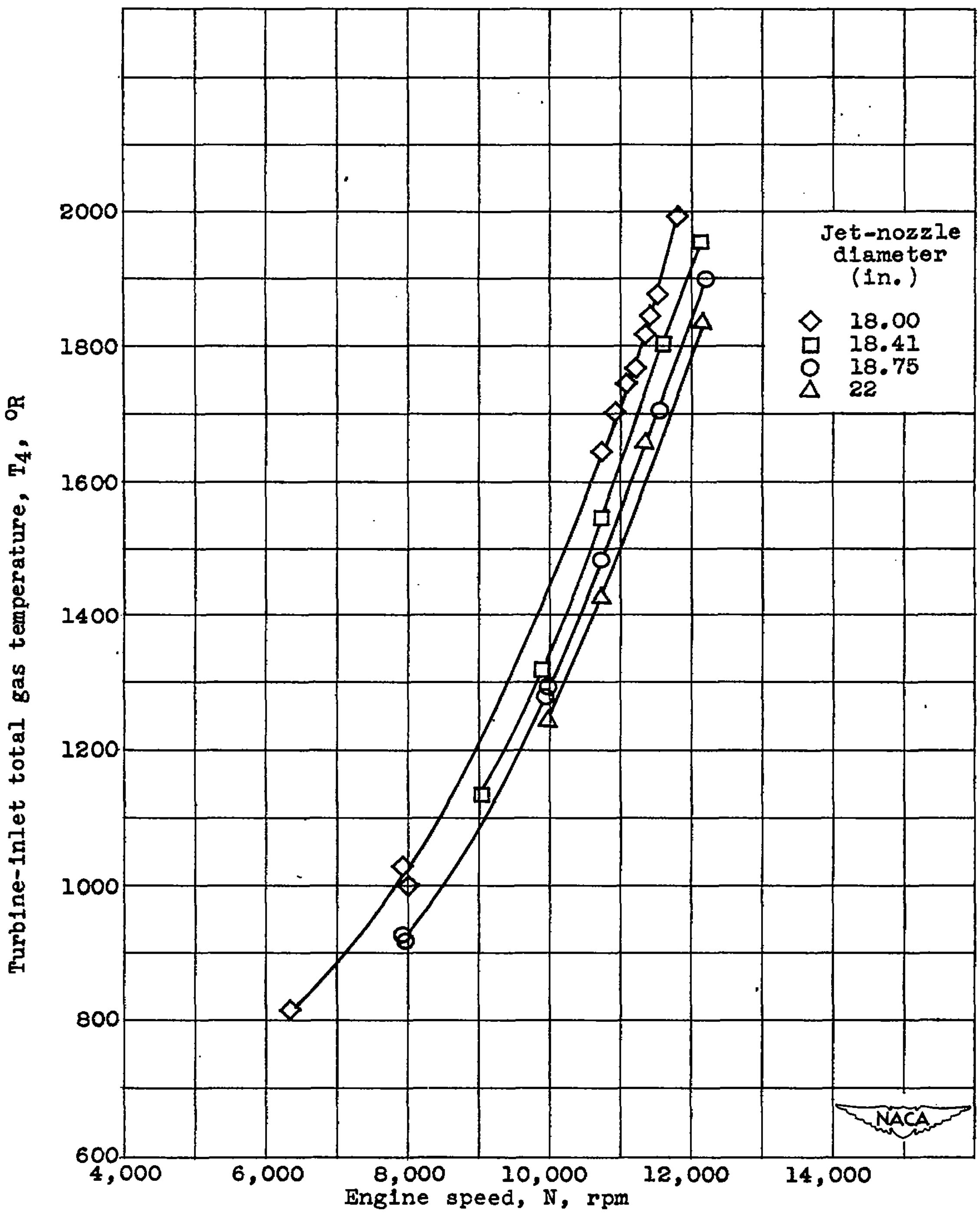


Figure 32. - Effect of jet-nozzle size on turbine-inlet total gas temperature. Altitude, 30,000 feet; ram pressure ratio, 1.70.

1253

1253

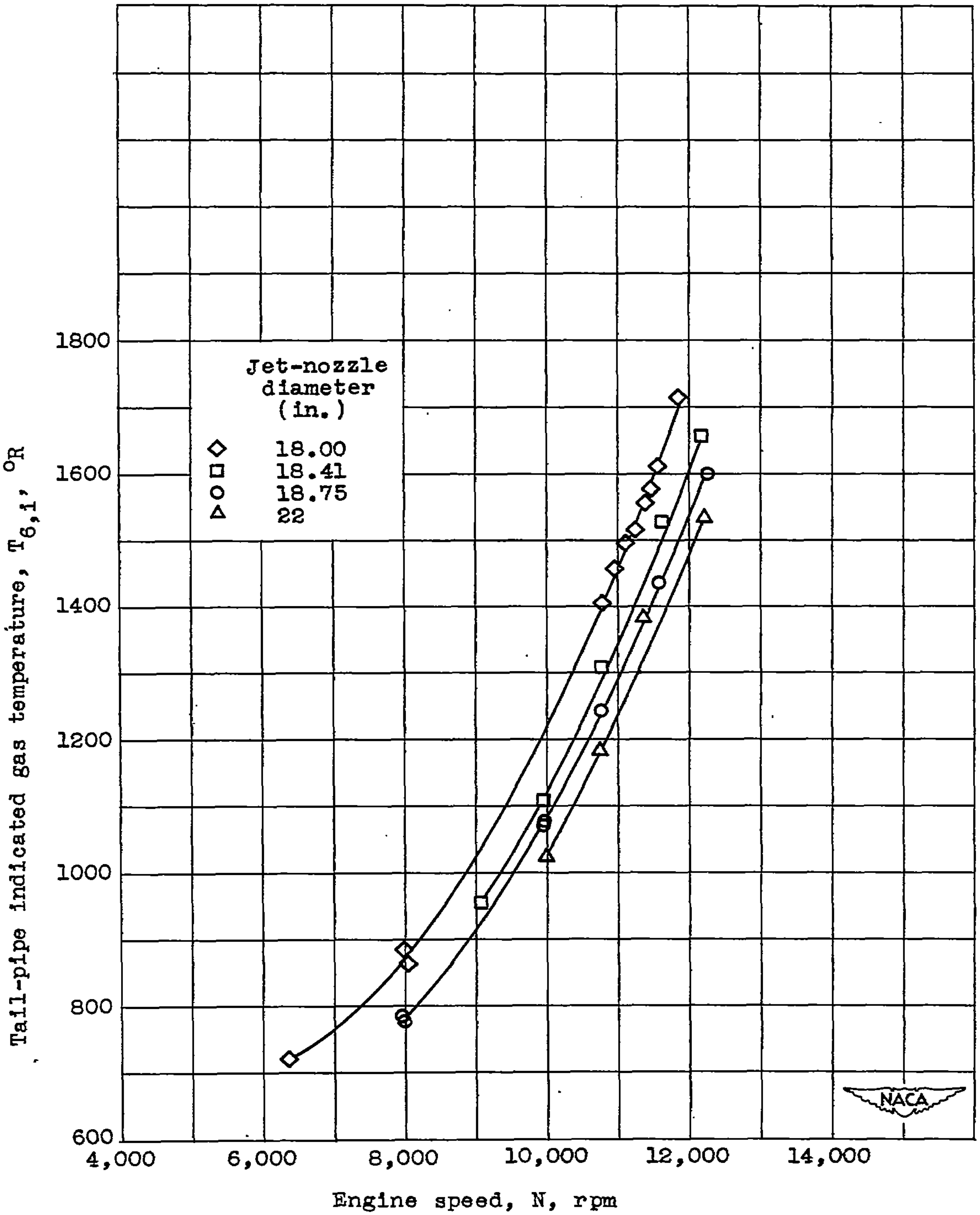


Figure 33. - Effect of jet-nozzle size on tail-pipe indicated gas temperature. Altitude, 30,000 feet; ram pressure ratio, 1.70.

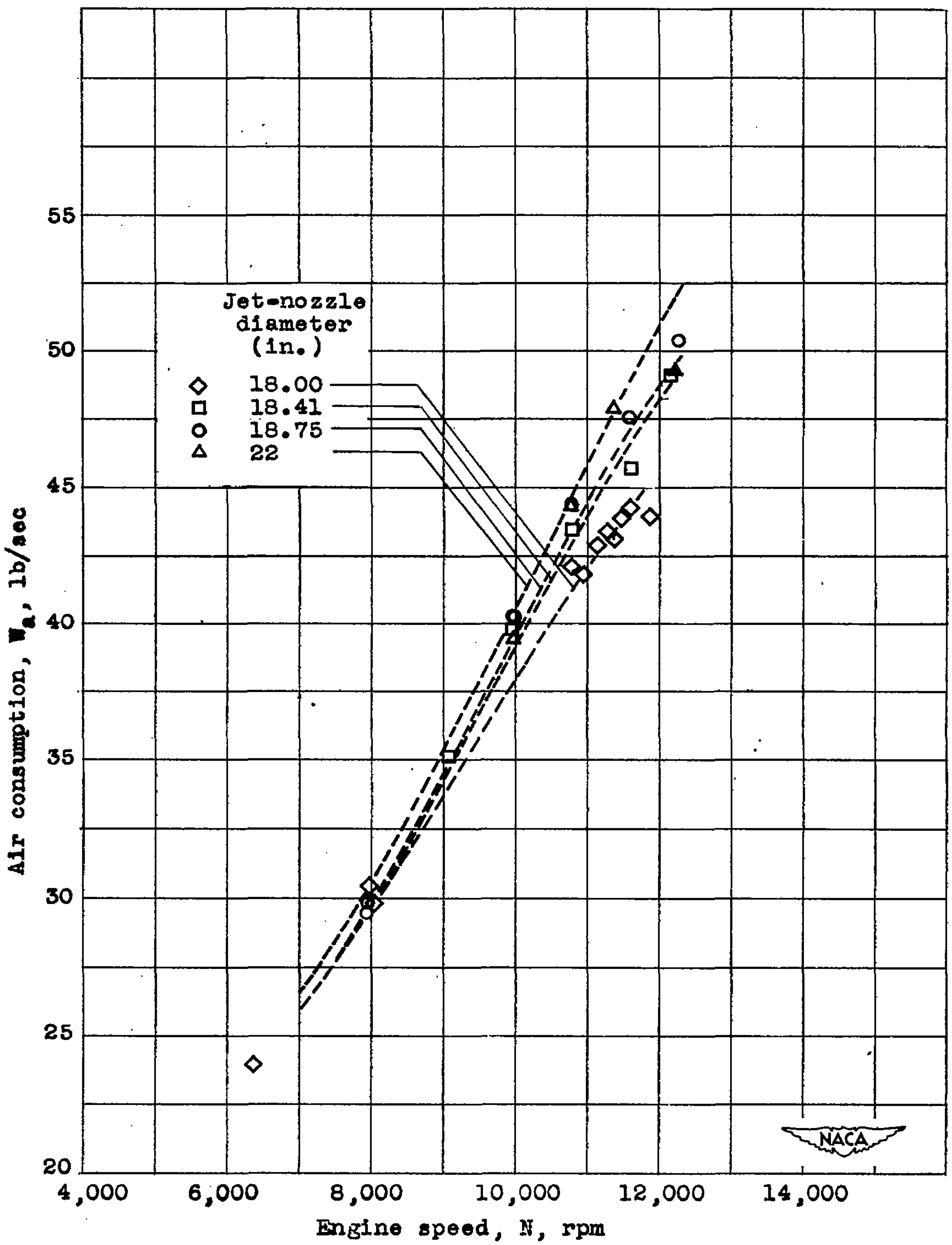


Figure 34. - Effect of jet-nozzle size on air consumption. Altitude, 30,000 feet; ram pressure ratio, 1.70.

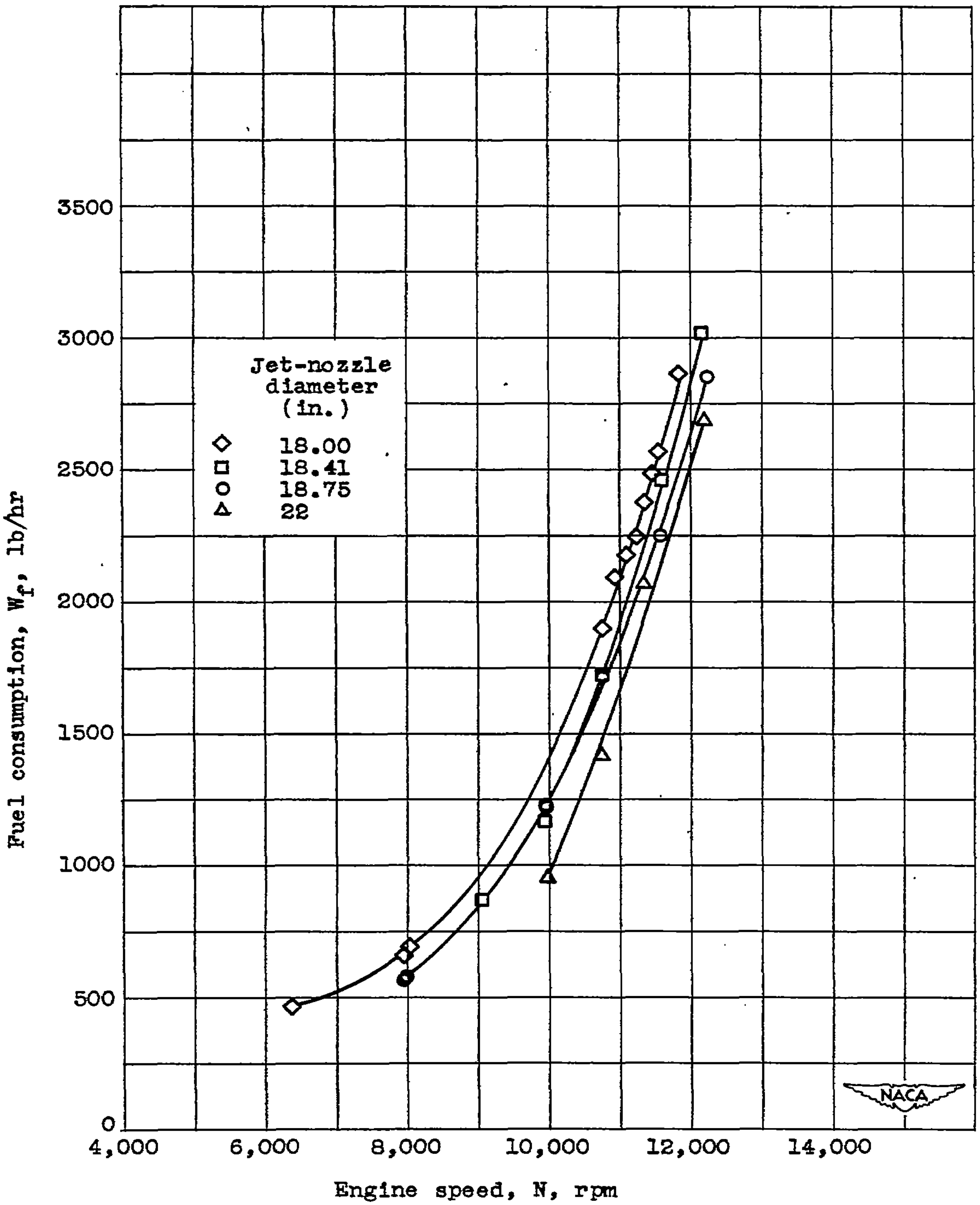


Figure 35. - Effect of jet-nozzle size on fuel consumption. Altitude, 30,000 feet; ram pressure ratio, 1.70.

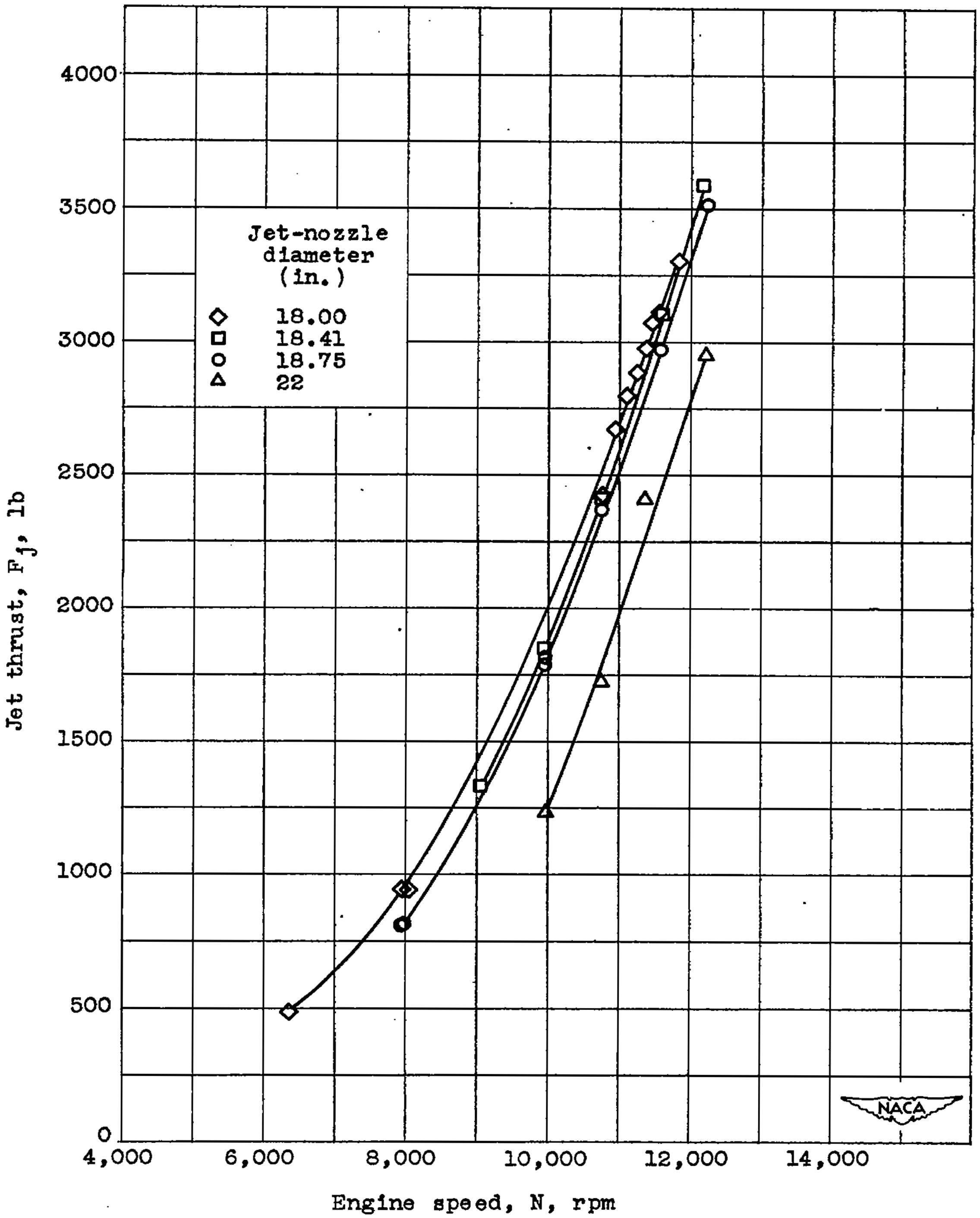


Figure 36. - Effect of jet-nozzle size on jet thrust. Altitude, 30,000 feet; ram pressure ratio, 1.70.

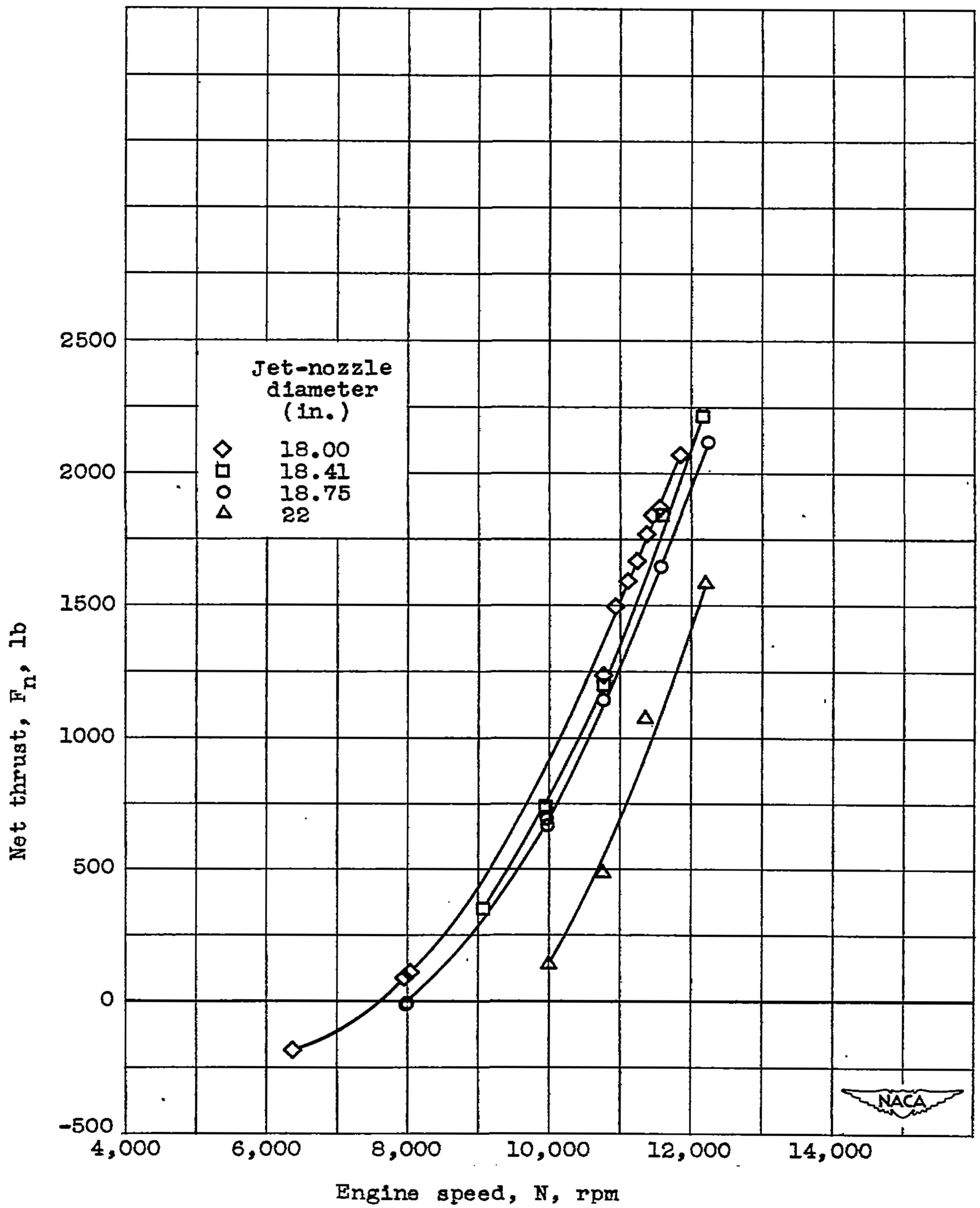


Figure 37. - Effect of jet-nozzle size on net thrust. Altitude, 30,000 feet; ram pressure ratio, 1.70.

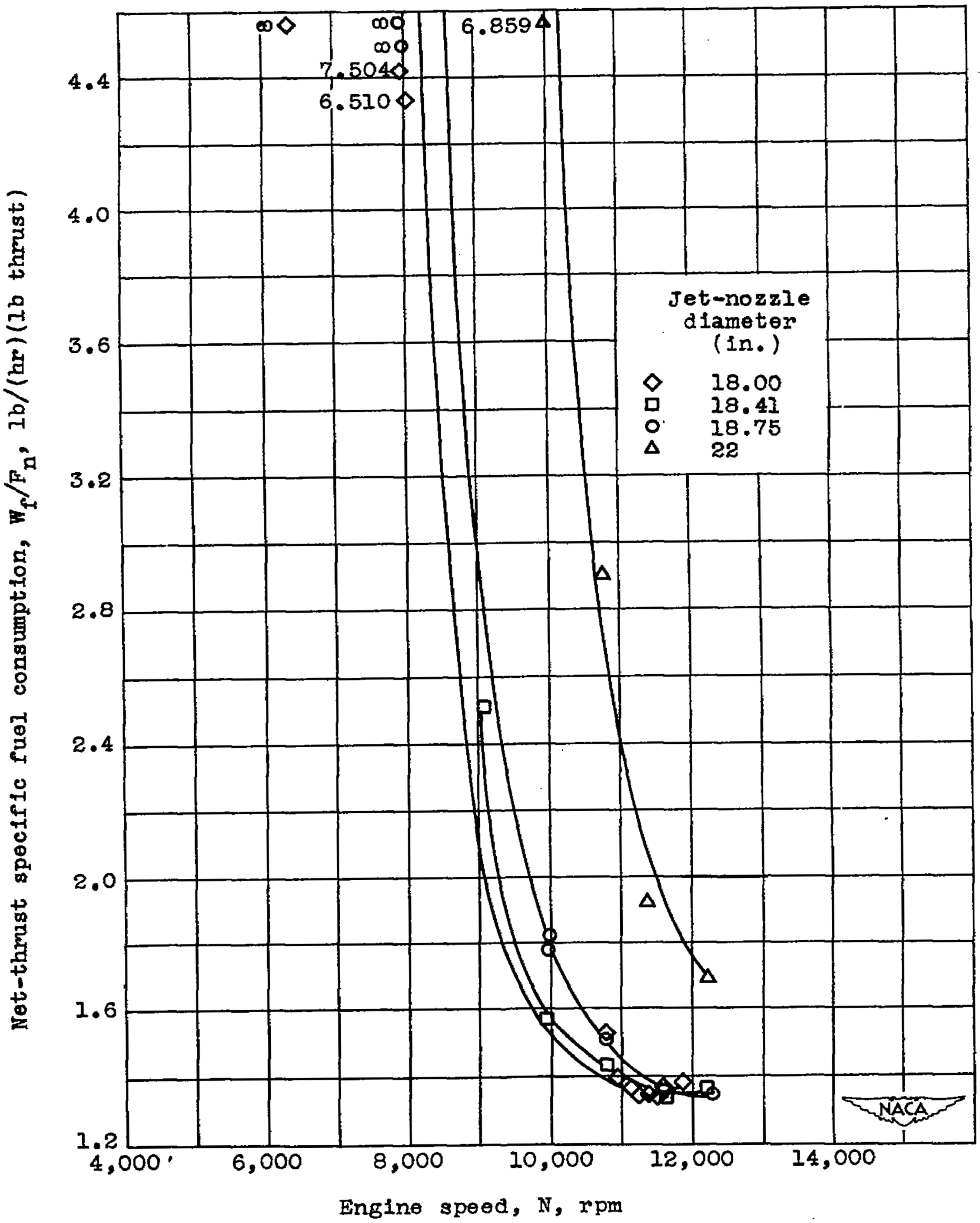


Figure 38. - Effect of jet-nozzle size on net-thrust specific fuel consumption. Altitude, 30,000 feet; ram pressure ratio, 1.70.