[redacted]

Copy 6
RM E54F22

UNCLASSIFIED

NACA RM E54F22

RESEARCH MEMORANDUM

PERFORMANCE OF YJ73-GE-3 TURBOJET ENGINE IN ALTITUDE TEST CHAMBER

By Harold R. Kaufman and Wilbur F. Dobson

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

CLASSIFICATION CHANGED
To UNCLASSIFIED
By authority of TPA #29 Date 8-19-60

CLASSIFIED DOCUMENT

This material contains information affecting the National Defense of the United States within the meaning of the espionage laws, Title 18, U.S.C., Secs. 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

January 19, 1955

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

PERFORMANCE OF YJ73-GE-3 TURBOJET ENGINE IN ALTITUDE TEST CHAMBER

By Harold R. Kaufman and Wilbur F. Dobson

SUMMARY

The steady-state performance characteristics of the YJ73-GE-3 turbojet engine were determined in a Lewis altitude test chamber for a range of exhaust-nozzle areas at simulated altitudes from near sea level to 55,000 feet and flight Mach numbers from 0 to 1.2. The corresponding range of Reynolds number indices was from 0.96 to 0.12.

A method of performance calculation based on engine pumping characteristics is also presented. Engine performance calculated by this method is presented for a wide range of flight conditions.

The use of an exhaust-nozzle area sized to give rated conditions at sea level would permit operation near the point of minimum specific fuel consumption for a wide range of flight conditions, but would cause excessive exhaust-gas temperatures at rated speed at high altitudes.

At rated corrected speed with a choked exhaust nozzle (rated area), decreasing the Reynolds number index from 1.0 to 0.1 decreased the corrected air flow 5 percent and increased the corrected exhaust-gas temperature 120° R.

INTRODUCTION

The over-all performance of the YJ73-GE-3 turbojet engine was determined in an altitude chamber at the NACA Lewis laboratory and is presented herein along with the starting characteristics for two altitudes. Component performance for this engine is presented in reference 1. The YJ73-GE-3 differs from the YJ73-GE-1A turbojet engine reported in references 2 and 3 in that the first-stage turbine nozzle area is 10 percent less.

The J73 engines are provided with variable-position inlet guide vanes, which are closed at low engine speeds to avoid surge during rapid accelerations. Although the inlet guide vanes of the YJ73-GE-3 are normally closed with steady-state operation below 6800 rpm and open at higher speeds, the engine control was modified during the investigation to allow them to be open or closed at any speed. Because standard operation at cruise, normal, and military conditions is with open inlet guide vanes, most of the data presented herein were obtained with the inlet guide vanes in the open position. A limited amount of data was obtained with the vanes in the closed position.

Performance data were obtained over a range from about 70 to 100 percent of rated speed with several exhaust-nozzle areas at simulated altitudes from near sea level to 55,000 feet and flight Mach numbers from 0 to 1.2. The corresponding range of Reynolds number indices was from 0.96 to 0.12. One exhaust-nozzle area that gave approximately limiting exhaust-gas temperature at rated speed and sea-level static conditions was included. Additional data were obtained at 35,000 feet at a flight Mach number of 0.8 to show the effects of changes in inlet-air temperature on performance. 3166

Data are presented in the form of engine performance maps at several flight conditions and in the form of engine pumping characteristics. Engine performance calculated from pumping characteristics is presented graphically for flight conditions from sea level to an altitude of 60,000 feet and from 0 to 1200 knots true flight speed. All experimental data are presented in both graphical and tabular form.

APPARATUS AND PROCEDURE

Engine

The engine, shown installed in the test chamber in figure 1, has an over-all length of 146.5 inches and diameter of 36.75 inches. It is equipped with 21 variable-position inlet guide vanes that rotate simultaneously through 30° from closed to open at 6800 rpm when speed is increasing and close at 6800 rpm when speed is decreasing. The open-position angle between the engine center line and a tangent to the vanes is 0° at the root and 13° at the tip.

The 12-stage axial-flow compressor has a pressure ratio of 7, a constant tip diameter of $32\frac{1}{8}$ inches, a first-stage hub-tip radius ratio of 0.455, a twelfth-stage hub-tip ratio of 0.880, and a tip Mach number of 0.997.

The combustor is cannular type, with ten tubular inner liners.

The first stage of the two-stage turbine has 40 stator vanes, while the second stage has 53. The rotor tip diameter of the first stage is $29\frac{1}{2}$ inches, and that of the second is $31\frac{1}{8}$ inches. The hub-tip radius ratios of the first and second stages are 0.73 and 0.64, respectively.

The manufacturer's performance ratings at standard sea-level static conditions are as follows:

Rated quantity	Military	Normal
Speed, rpm	7950	7615
Maximum specific fuel consumption, lb/(hr)(lb thrust)	0.917	0.887
Minimum jet thrust, lb	8920	7840
Air flow, lb/sec	142	----
Turbine-outlet temperature, °F	1185	1085

Installation

Altitude test chamber. - A sketch of the altitude test chamber and some of its associated ducting is shown in figure 2. The test chamber is 14 feet in diameter and 20 feet long. The test bed on which the engine was mounted is connected by a linkage to a balance diaphragm for thrust measurement. A screen and honeycomb are installed in the chamber upstream of the test section to smooth and straighten the inlet-air flow. The front bulkhead, which incorporated a labyrinth seal around the front of the engine, prevented the flow of inlet air directly into the exhaust system and provided a means of maintaining a pressure difference across the engine. A bellmouth cowl was installed on the front bulkhead to obtain a uniform velocity profile at the inlet of the compressor.

Air supplied to the inlet section of the altitude chamber can be either refrigerated or heated dry air, or atmospheric air. Exhaust gases from the jet nozzle pass through an exhaust section, a primary cooler, an exhaust header, and a secondary cooler before entering the exhauster system. The inlet and exhaust pressure controls were designed to operate throttle valves automatically to maintain constant ram pressure ratio and exhaust pressure.

Instrumentation. - The locations of instrumentation stations throughout the engine together with schematic sketches of the instrumentation at the engine inlet and the exhaust-nozzle inlet are shown in figure 3. All pressures were measured with alkazene or mercury manometers and photographically recorded. Temperatures were measured with iron-constantan and chromel-alumel thermocouples and were recorded by self-balancing potentiometers. Engine speed was measured by a chronometric tachometer and fuel flow with a calibrated rotameter.

Procedure

3166

During the investigation the refrigeration system was changed to permit lower inlet-air temperatures, and at the same time the engine was overhauled. Therefore, the investigation was separated into two phases with the inlet-air temperatures varying from about 440° to 520° R for the first phase (before engine overhaul) and from about 380° to 440° R for the second phase (after engine overhaul).

Most of the engine performance data were obtained in the first phase and are presented in table I. The approximate flight conditions and corresponding Reynolds number indices obtained in this phase are shown in the following table:

Altitude, ft	Reynolds number index for flight Mach number, M, of -			
	0	0.4	0.8	1.2
0	0.96	----	---	----
15,000	----	----	0.88	----
25,000	----	----	.59	----
35,000	----	----	.39	0.58
45,000	----	----	.24	----
55,000	----	0.12	.15	----

The inlet-air total temperature and pressure and the static pressure in the test section surrounding the exhaust nozzle were maintained at approximately the desired altitude values except at the sea-level static

3166

condition. The average inlet total pressure of the data obtained at the sea-level static condition actually corresponded to a pressure altitude of about 2000 feet. In addition, the static pressure in the region surrounding the exhaust nozzle was slightly higher than the inlet total pressure, causing a slight reverse ram. The sea-level static condition was difficult to simulate in the altitude facility. The disparities at the sea-level static condition were due to this difficulty and were not normal experimental error. Although these difficulties prevent the direct presentation of the sea-level static data in the form of a performance map, the usefulness of the data for pumping characteristics is not affected.

Improvements in the refrigeration system permitted the use of colder inlet-air temperatures in the second phase of the program and thereby extended the range of the investigation to higher corrected engine speeds. The data obtained in the second phase are presented in table II. The approximate flight conditions and Reynolds number indices obtained in the second phase are shown in the following table:

Altitude, ft	Reynolds number index for flight Mach number, M, of -	
	0.4	0.8
35,000	-----	0.461
45,000	-----	.304
55,000	0.140	.176

The lower inlet-air temperatures obtained in the second phase resulted in higher Reynolds number indices for similar flight conditions. The effects of differences in Reynolds number indices and the performance changes accompanying the engine overhaul were reduced by graphical and analytical adjustments to the data obtained in the second phase. The magnitude of these adjustments was about 2 percent, which is of the same order as the variation that would be expected between production engines of any given model.

Data were obtained with four exhaust-nozzle areas at each flight condition. The physical details of the nozzle configurations are given in figure 4. The fixed exhaust nozzle with an area of 2.388 square feet (fig. 4(a)) was designed to give approximately limiting exhaust-gas temperature at sea-level static conditions and is referred to as the rated nozzle. A clamshell variable-area exahust nozzle (fig. 4(b)) was used to obtain the two intermediate areas of 2.514 and 2.694 square feet. The largest exhaust-nozzle area, 3.688 square feet, was obtained with a straight tail pipe attached to the outlet of the diffuser (fig. 4(c)). In order to extend the range of the investigation closer to compressor surge, an additional smaller-than-rated exhaust-nozzle area was used at the 35,000-foot altitude and 0.8 Mach number flight condition.

The inlet guide vanes were normally scheduled to begin opening or closing, depending on whether the engine was accelerating or decelerating, respectively, at 6800 rpm. The control was modified during the investigation to permit opening or closing the inlet guide vanes at any speed, thereby extending the speed range investigated with both inlet-guide-vane positions. 3166

The fuel used was MIL-F-5624A, grade JP-4, with a lower heating value of 18,700 Btu per pound and a hydrogen-carbon ratio of 0.171.

The symbols and methods of experimental data reduction are given in appendixes A and B, respectively.

RESULTS AND DISCUSSION

Performance Maps

Performance maps are useful for the compact presentation of a large amount of altitude performance information. The performance maps for seven flight conditions with altitudes from 15,000 to 55,000 feet and Mach numbers from 0.43 to 1.23 are shown in figure 5. Only data obtained with open inlet guide vanes are shown. These data have been adjusted by the factors δ_a and θ_a to compensate for deviations from standard altitude pressures and temperatures. The deviations from altitude conditions were small except for some high-corrected-speed data taken at low inlet-air temperatures.

The exhaust-nozzle areas given on the performance maps are cold projected areas. As the discharge coefficients of exhaust nozzles vary with temperature, pressure ratio, and configuration, the effective flow areas will differ from the values shown on the performance maps. Curves to convert cold projected areas into effective areas can be found in a subsequent section.

At thrust levels below maximum, different values of specific fuel consumption may be obtained by varying the exhaust-nozzle area and engine speed simultaneously. In order to determine the best exhaust-nozzle-area schedule within the range investigated, the exhaust-nozzle areas corresponding to minimum specific fuel consumption for several thrust levels at each flight condition were obtained from figure 5 and plotted as a function of thrust in figure 6. For the high thrust levels (cruise and military) that would be employed over most of a normal flight plan, the exhaust-nozzle area for minimum specific fuel consumption varied from about 2.4 to 2.5 square feet. However, use of rated exhaust-nozzle area (2.388 sq ft) gave specific fuel consumptions within 2 percent of the minimum values.

3166

Pumping Characteristics and Performance Prediction

Treatment of a turbojet engine as a pump (ref. 4) and presentation of its characteristics in terms of air flow, pressure ratio, and temperature ratio represent one of the most useful forms for performance calculation. One advantage of the use of pumping characteristics is that the engine performance can be determined apart from the effects of inlet and outlet ducting, so that the calculation of the effects of different ducting combinations on over-all engine performance is possible. The pumping characteristics, combustion efficiency, and exhaust ducting losses of the YJ73-GE-3 turbojet engine are presented in this section to aid performance calculation at any flight condition within the range of Reynolds number indices covered by the investigation. Sample problems illustrating the use of the curves presented in this section are given in appendix C.

Pumping characteristics with a range of exhaust-nozzle areas. - To simplify the presentation, data for one reference Reynolds number index were used to show the relation of corrected engine speed, engine temperature ratio, and engine pressure ratio. Curves are then given to provide correction to other Reynolds number indices. In order to obtain maximum ranges of corrected engine speed and engine temperature ratio, the 35,000-foot altitude and 0.8 Mach number flight condition was used as the reference. The Reynolds number index of this flight condition is 0.39.

The pumping characteristics at a Reynolds number index of 0.39 are shown in figure 7. The air-flow and pressure-ratio correction curves are shown in figure 8. The correction curve of air flow was found to be independent of temperature ratio and corrected speed, while the pressure-ratio correction curves were independent only of temperature ratio. To find the engine pressure ratio and corrected air flow at a given engine and flight condition, the following steps are used:

(1) From the desired inlet temperature, exhaust-gas temperature, and engine speed, find the engine temperature ratio and corrected engine speed.

(2) By using the engine temperature ratio, the corrected engine speed, and figure 7, find the engine pressure ratio and corrected air flow that would be obtained at a Reynolds number index of 0.39.

(3) Calculate the Reynolds number index from the total temperature and total pressure of the desired flight condition.

(4) From the corrected engine speed, the Reynolds number index, and figure 8, find the correction factors for engine pressure ratio and corrected air flow. 3166

(5) Multiply the pressure ratio and corrected air flow obtained from step (2) by the correction factors from step (4).

The engine pressure ratio and corrected air flow obtained by the preceding method agree with faired experimental values within about 1 percent, except for the pressure ratios corresponding to the lowest temperature ratios at each speed, where slightly larger variations were found.

Pumping characteristics with fixed exhaust-nozzle area. - The pumping characteristics presented in figures 7 and 8 are suitable for engine performance calculations when a variable-area exhaust nozzle is trimmed to give a desired exhaust-gas temperature. However, use of figures 7 and 8 for an engine with a fixed-area exhaust nozzle would require trial-and-error solutions. In order to obtain direct solutions at approximately rated exhaust-nozzle area (2.388 sq ft), figure 9 was constructed. Figure 9 is limited in application to exhaust-nozzle pressure ratios greater than 2.5. For pressure ratios below about 2.5, the exhaust-nozzle discharge coefficient (fig. 10(a)) varies so that the use of the pumping characteristics of figures 7 and 8 and trial-and-error solutions would be required.

Reynolds number effects can be determined from figure 9. For a corrected speed of 7950 rpm, the corrected air flow decreased from 142 to 134.5 pounds per second and the temperature ratio increased from 3.1 to 3.4 when the Reynolds number index decreased from 1.0 to 0.1. The corrected-air-flow and temperature-ratio changes correspond to a 5-percent decrease and a 120° R (corrected temperature) increase, respectively.

Discharge coefficient. - For conditions in which the exhaust nozzle is unchoked or if discharge coefficient varies with pressure ratio, the variation of effective exhaust-nozzle area with exhaust-nozzle pressure ratio must be known to obtain a solution with figures 7 and 8. The discharge coefficients of the four exhaust nozzles used in this investigation were plotted against pressure ratio in figure 10 to permit calculation of effective area from cold projected area.

Combustion efficiency. - For the calculation of fuel flow, combustion efficiency must be known. Combustion efficiency is plotted in figure 11. The derivation of the correlating parameter, the product of air flow and exhaust-gas temperature, can be found in reference 5. Use of this curve with air flow and engine-inlet and exhaust-gas temperatures enables calculation of fuel flow and, hence, specific fuel consumption.

Exhaust ducting losses. - As was mentioned previously, the tail-pipe and exhaust-nozzle losses are not included in the engine pressure ratio. In order to permit calculation of thrust, the tail-pipe total-pressure loss and exhaust-nozzle effective velocity coefficient are presented in figures 12 and 13, respectively. The sharp rise of the tail-pipe total-pressure loss ratio at high values of turbine-outlet gas-flow parameter resulted from choking at the turbine outlet.

3166

CX-2

Thrust Correlation

Correlations of jet thrust with an exhaust-nozzle pressure-drop parameter are presented in references 6 and 7. Jet thrust correlations, when used in conjunction with pumping characteristics, may be used for thrust prediction. Correlations of jet thrust with exhaust-nozzle pressure drop obtained in this investigation are presented in figures 14 and 15. In figure 14 the thrusts for all four nozzle areas have been divided by effective area (discharge coefficient times projected area) to generalize thrusts to a single curve. Figure 15 is for the nozzle area that gives approximately rated temperature at sea-level static conditions. These correlations are limited in application to choked flow in the exhaust nozzle, which was assumed in the derivation of the correlating parameter.

Effect of Inlet Temperature on Performance

In order to determine the applicability of data at other inlet temperatures than were used during the investigation, data were obtained with inlet-air temperatures from 482° to 621° R at an altitude of 35,000 feet and a flight Mach number of 0.8. A fixed exhaust nozzle with an area of 2.37 square feet was used. The variations of corrected air flow, corrected net thrust, and corrected fuel flow with corrected engine speed for three inlet temperatures are shown in figures 16(a), (b), and (c), respectively. At a constant corrected speed, corrected air flow decreases slightly with increasing inlet temperature, while both corrected net thrust and corrected fuel flow increase with increasing inlet temperature. The variation of engine temperature ratio with engine pressure ratio for the three inlet temperatures is shown in figure 16(d). At constant corrected speed, the temperature ratio increased with inlet temperature. The pressure ratio also increased slightly with increasing inlet temperature.

The variation of the engine performance parameters with inlet temperature was due at least in part to changes in Reynolds number index associated with changes in inlet temperature. The range of Reynolds number index corresponding to the inlet-temperature variation was from 0.40 to 0.29. The change of performance variables for a Reynolds number index change from 0.40 to 0.29 was calculated from the pumping characteristics of figure 9 for a corrected speed of 7000 rpm. The results of these calculations and the corresponding information for variable-inlet-temperature data from figure 16 are shown in the following table:

	Corrected fuel flow	Corrected air flow	Temperature ratio	Pressure ratio	Corrected net thrust
Change due to Reynolds number effect, percent	2.6	-0.7	1.4	0	1.1
Total observed change, percent	9.6	-1.1	2.8	0.6	2.5

Comparison of the values indicates that much of the change of performance variables with inlet temperature can be charged to Reynolds number effects. Considering the accuracy of the data, correcting for inlet-temperature effects should not be necessary for corrected air flow, temperature ratio, pressure ratio, or corrected thrust over the range of temperatures investigated. In the case of corrected fuel flow, however, a significant difference of 7.0 percent exists between the total change of 9.6 percent and the change of 2.6 percent predicted for Reynolds number effects alone. The specific heat of the products of combustion of fuel and air increases with fuel-air ratio and temperature. Calculation showed that the increase in specific heat accounted for 5 of the 7-percent difference in corrected fuel flows. To predict fuel flows over wide ranges of inlet temperature, fuel flows should, therefore, be calculated from air flows, inlet and outlet temperatures, and combustion efficiencies, instead of from generalized fuel-flow plots. The recommended method of fuel-flow calculation was used for the predicted performance in the next section.

Calculated Performance from Pumping Characteristics

Predicted performance is included to facilitate estimations of airplane performance. Performance of the YJ73-GE-3 turbojet engine with a 2.388-square-foot exhaust-nozzle area was calculated from the pumping characteristics for a wide range of flight conditions and is plotted in figure 17. A standard NACA atmosphere and complete ram recovery were assumed. The accuracy of the calculated thrusts and fuel flows in figure 17 is within about 2 percent.

Because the discrepancies discussed previously in setting up the approximate sea-level static flight condition do not affect the data of figure 17(a), these data provide an accurate indication of actual sea-level capabilities of the YJ73-GE-3 turbojet engine with a fixed exhaust-nozzle area of 2.388 square feet. The thrust, air flow, and specific fuel consumption at rated speed and sea-level static flight conditions were 8800 pounds, 142 pounds per second, and 0.92 pound per hour per pound of thrust, respectively.

As mentioned before, errors in measuring temperatures and setting up the sea-level static flight condition resulted in the use of an exhaust-nozzle area (2.388 sq ft) that caused exhaust-gas temperatures to be about 25° R below the limiting value. The thrusts and fuel flows would have been slightly higher if the exhaust-nozzle area had been sized to give limiting exhaust-gas temperature. At rated speed and sea-level static conditions, the thrust and specific fuel consumption would have been about 8960 pounds and 0.93 pound per hour per pound of thrust, respectively.

Additional factors must be considered to determine the performance in an actual installation. The exhaust nozzle may be larger than that used here to give maximum performance with high ambient temperature. Another reason for increasing the exhaust-nozzle area could be the possible requirement that rated speed and exhaust-gas temperature be obtained simultaneously at static conditions with distorted and throttled inlet flow. Of course, inlet losses are present at all flight conditions and their effects should always be considered.

Altitude-Ignition Characteristics

The effect of fuel flow on altitude ignition was determined at altitudes of 35,000 and 45,000 feet with MIL-F-5624A, grade JP-4, fuel over a range of windmilling engine speeds (fig. 18). In order to determine whether ignition could be obtained for a given combination of fuel flow and windmilling engine speed, speed and fuel flow were maintained constant during the ignition period. Fuel temperature was about 60° F, and engine-inlet air temperature varied from 5° to -50° F at 35,000 feet but remained about constant at -35° F at 45,000 feet.

Results show that the minimum fuel flow required to obtain ignition increased with windmilling engine speed. To obtain ignition at windmilling speeds below 2500 rpm, a higher fuel flow was required at 45,000 that at 35,000 feet.

CONCLUDING REMARKS

The performance of the YJ73-GE-3 turbojet engine was determined over a wide range of flight conditions in an altitude test chamber. With an exhaust-nozzle area of 2.388 square feet, the performance at sea-level static conditions was: maximum thrust, 8800 pounds; air flow at rated speed, 142 pounds per second; specific fuel consumption at rated speed, 0.92 pound per hour per pound of thrust. 3166

The use of an exhaust-nozzle area sized to give rated conditions at sea level would permit operation near the point of minimum specific fuel consumption for a wide range of flight conditions but would cause excessive exhaust-gas temperatures at rated speed at high altitudes.

At rated corrected speed and a choked exhaust nozzle (rated area), decreasing the Reynolds number index from 1.0 to 0.1 decreased the corrected air flow 5 percent and increased the corrected exhaust-gas temperature 120° R.

In order to predict fuel flows over wide ranges of inlet temperature, fuel flows should be calculated from air flows, inlet and outlet temperatures, and combustion efficiences, instead of from generalized fuel-flow plots.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, June 23, 1954

APPENDIX A

SYMBOLS

The following symbols are used in this report:

A area, sq ft

3166

B thrust scale reading, lb

C_D discharge coefficient, ratio of effective flow area to cold projected exhaust-nozzle area

C_v effective-velocity coefficient, ratio of scale jet thrust to nozzle-inlet rake jet thrust

D external drag of installation, lb

F_j jet thrust, lb

F_n net thrust, lb

g dimensional constant, 32.2 ft/sec^2

M Mach number

N engine speed, rpm

P total pressure, lb/sq ft abs

p static pressure, lb/sq ft abs

R gas constant, 53.3 ft-lb/(lb)($^{\circ}$R)

T total temperature, $^{\circ}$R

t static temperature, $^{\circ}$R

V velocity, ft/sec or knots

W_a air flow, lb/sec

W_f fuel flow, lb/hr

W_g gas flow, lb/sec

γ ratio of specific heats for gases

δ_a ratio of ambient absolute static pressure to absolute static pressure of NACA standard atmosphere at respective altitude

$\delta_{T,1}$ ratio of engine-inlet total pressure to absolute static pressure of NACA standard atmosphere at sea level

η_b combustion efficiency

θ_a ratio of absolute equivalent ambient static temperature to absolute static temperature of NACA standard atmosphere at respective altitude 3168

$\theta_{T,1}$ ratio of absolute engine-inlet total temperature to absolute static temperature of NACA standard atmosphere at sea level

φ ratio of absolute viscosity of air at engine inlet to viscosity of NACA standard atmosphere at sea level

Subscripts:

a air

e equivalent

ef effective

f fuel

g gas

i indicated

j jet

N exhaust nozzle

r rake

s scale

0 free-stream conditions

1 engine inlet

3	compressor outlet
4	combustor inlet
5	turbine inlet
6	turbine outlet
7	exhaust-nozzle inlet

3166

APPENDIX B

REDUCTION OF EXPERIMENTAL DATA

Flight Mach number. - The equivalent flight Mach number, with complete ram pressure recovery assumed, was calculated from the expression

$$M_{0,e} = \sqrt{\frac{2}{\gamma - 1}\left[\left(\frac{P_1}{p_0}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

3166

Equivalent temperature. - Equivalent static temperature was determined from ambient static pressure and engine-inlet total pressure and temperature:

$$t_{0,e} = \frac{T_1}{\left(\frac{P_1}{p_0}\right)^{\frac{\gamma-1}{\gamma}}}$$

Airspeed. - The following equation was used to calculate airspeed:

$$V_{0,e} = M_{0,e}\sqrt{\gamma g R t_{0,e}}$$

Temperature. - Total temperatures were determined from indicated temperatures with the following relation:

$$T = \frac{T_i\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}}}{1 + 0.85\left[\left(\frac{P}{p}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

where 0.85 was taken as the recovery factor for the thermocouples used.

Air flow. - Air flow was determined from pressure and temperature measurements in the engine-inlet air duct and the following equation:

$$W_a = A_1 p_1 \sqrt{\frac{2g\gamma}{RT_1(\gamma - 1)}\left(\frac{P_1}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\left[\left(\frac{P_1}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]}$$

Gas flow. - The total weight flow through the engine was calculated as follows:

$$W_g = W_{a,1} + \frac{W_f}{3600}$$

Exhaust-nozzle effective-velocity coefficient. - The velocity coefficient was calculated as the ratio of scale jet thrust to rake jet thrust. Scale jet thrust was obtained from the equation

3166

$$F_{j,s} = B + \frac{W_{a,1}V_1}{g} + A_1(p_1 - p_0) + D$$

Rake jet thrust was calculated from gas flow and an effective-velocity parameter:

C-3

$$F_{j,r} = \frac{W_g}{g} V_{ef}$$

The effective velocity, which includes the effect of excess pressure not converted to velocity for supercritical pressure ratios, is given for an ideal convergent nozzle:

$$V_{ef} = V_N + \frac{A_N\left(p_N - p_0\right)}{W_g/g}$$

where V_N, A_N, and p_N are the velocity, the area, and the static pressure at the vena contracta. The term $V_{ef}/\sqrt{gRT_6}$ is called the effective-velocity parameter and is a function of exhaust-nozzle pressure ratio and the ratio of specific heats.

APPENDIX C

PERFORMANCE CALCULATION FROM PUMPING CHARACTERISTICS

Three methods of performance prediction based on pumping characteristics are presented to permit calculation of engine performance for most engine operating conditions.

Case A is for an engine with an exhaust nozzle of known area in which the exhaust-nozzle pressure ratio is high enough (well above critical) that the discharge coefficient is constant. 3166

Case B is for an engine in which the exhaust-gas temperature is known, but the exhaust-nozzle area is not (e.g., where a control trims a variable-area exhaust nozzle for a desired temperature).

Case C is for an engine with an exhaust nozzle of known area when the exhaust-nozzle pressure ratio is low enough to change the discharge coefficient.

Case A

To demonstrate case A, a flight speed of 600 knots and an altitude of 15,000 feet are chosen as the flight condition. Rated engine speed and an exhaust-nozzle area of 2.388 square feet are assumed. The following quantities are known:

$$p_0 = 1193 \text{ lb/sq ft}$$

$$t_0 = 465^\circ \text{ R}$$

$$V_0 = 600 \text{ knots}$$

$$N = 7950 \text{ rpm}$$

From these quantities the following parameters may be calculated:

$$V_0 = 1013 \text{ ft/sec}$$

$$P_1 = 2149 \text{ lb/sq ft}$$

$$T_1 = 550^\circ \text{ R}$$

$$\delta_{T,1} = 1.016$$

$$\sqrt{\theta_{T,1}} = 1.030$$

$$\delta_{T,1}/\varphi\sqrt{\theta_{T,1}} = 0.940$$

$$N\sqrt{\theta_{T,1}} = 7718 \text{ rpm}$$

From figure 9,

$$W_a\sqrt{\theta_{T,1}}/\delta_{T,1} = 138.4 \text{ lb/sec}$$

$$P_6/P_1 = 2.11$$

$$T_7/T_1 = 2.94$$

and

$$W_a = 136.5 \text{ lb/sec}$$

$$P_6 = 4534 \text{ lb/sq ft}$$

$$T_7 = 1617^\circ \text{ R}$$

Fuel flow. - To calculate fuel flow and thereby obtain gas flow, the following steps are required:

$$W_aT_7 = (136.5)(1617)$$

$$= 221\times10^3$$

From figure 11,

$$\eta_b = 0.975$$

The engine temperature rise is

$$T_7 - T_1 = 1067^\circ \text{ R}$$

From reference 8,

$$(W_f/3600\ W_a)_{ideal} = 0.0149$$

Dividing by efficiency to obtain actual fuel-air ratio,

$$(W_f/3600\ W_a)_{actual} = 0.0153$$

The fuel flow is

$$W_f = 3600\ (W_a)(W_f/3600W_a)_{actual}$$
$$= 7520\ \text{lb/hr}$$

The gas flow is

$$W_g = W_a + (W_f/3600)$$
$$= 138.6\ \text{lb/sec}$$

3166

<u>Exhaust-nozzle-inlet pressure</u>. - To calculate the exhaust-nozzle-inlet pressure P_7 the following steps are necessary:

$$W_g\sqrt{T_7}/P_6 = 1.229$$

From figure 12,

$$(P_6 - P_7)/P_6 = 0.0205$$

and

$$P_7 = P_6 \left[1 - (P_6 - P_7)/P_6\right]$$
$$= 4441\ \text{lb/sq ft}$$

<u>Thrust</u>. - To calculate thrust the following steps are necessary:

$$P_7/p_0 = 3.723$$

Ratio of specific heats γ_7 for a fuel-air ratio of 0.0153 and a temperature of 1617° R is 1.334. From the exhaust-nozzle pressure ratio, the ratio of specific heats, and reference 9, the effective-velocity parameter $V_{ef}/\sqrt{gRT}$ can be found:

$$V_{ef}/\sqrt{gRT} = 1.472$$

The effective velocity is

$$V_{ef} = 1.472\sqrt{gRT_7}$$
$$= 2455\ \text{ft/sec}$$

The ideal or rake jet thrust is

$$F_{j,r} = V_{ef}W_g/g$$

$$= 10{,}570 \text{ lb}$$

From figure 13,

$$C_V = 0.986$$

3166

The actual or scale jet thrust is

$$F_{j,s} = C_V F_{j,r}$$

$$= 10{,}420 \text{ lb}$$

Subtracting inlet momentum to get net thrust,

$$F_n = F_{j,s} - (V_0 W_a/g)$$

$$= 6126 \text{ lb}$$

Summary. - Summarizing the performance and rounding off numbers to give more realistic indications of accuracy,

$$T_7 = 1620^\circ \text{ R}$$

$$W_a = 137 \text{ lb/sec}$$

$$W_f = 7500 \text{ lb/hr}$$

$$F_n = 6100 \text{ lb}$$

Case B

To demonstrate case B, a flight speed of 600 knots and an altitude of 15,000 feet are chosen as the flight condition (the same as case A). For the engine, rated speed and limiting exhaust-gas temperature are assumed. The following quantities are known:

$$p_0 = 1193 \text{ lb/sq ft}$$

$$t_0 = 465^\circ \text{ R}$$

$$V_0 = 600 \text{ knots}$$

$$N = 7950 \text{ rpm}$$

$$T_7 = 1645^{\circ} \text{ R}$$

From these quantities the following parameters may be calculated:

$$V_0 = 1013 \text{ ft/sec}$$

$$P_1 = 2149 \text{ lb/sq ft}$$

$$T_1 = 550^{\circ} \text{ R}$$

$$\delta_{T,1} = 1.016$$

$$\sqrt{\theta_{T,1}} = 1.030$$

$$\delta_{T,1}/\varphi\sqrt{\theta_{T,1}} = 0.940$$

$$N/\sqrt{\theta_{T,1}} = 7718 \text{ rpm}$$

$$T_7/T_1 = 2.991$$

From figures 7 and 8, using the method outlined in the text,

$$W_a\sqrt{\theta_{T,1}}/\delta_{T,1} = 138.7 \text{ lb/sec}$$

$$P_6/P_1 = 2.172$$

and

$$W_a = 136.8 \text{ lb/sec}$$

$$P_6 = 4666 \text{ lb/sq ft}$$

Fuel flow. - To calculate fuel flow and thereby obtain gas flow, the following steps are required:

$$W_aT_7 = (136.8)(1645)$$
$$= 225\times10^3$$

From figure 11,

$$\eta_b = 0.975$$

The engine temperature rise is

$$T_7 - T_1 = 1095^\circ \text{ R}$$

From reference 8,

$$(W_f/3600W_a)_{ideal} = 0.0154$$

3166

Dividing by efficiency to obtain actual fuel-air ratio,

$$(W_f/3600W_a)_{actual} = 0.0158$$

The fuel flow is

$$W_f = 3600\ (W_a)(W_f/3600W_a)_{actual}$$

$$= 7780 \text{ lb/hr}$$

The gas flow is

$$W_g = W_a + (W_f/3600)$$

$$= 139.0 \text{ lb/sec}$$

Exhaust-nozzle-inlet pressure. - To calculate the exhaust-nozzle-inlet pressure P_7 the following steps are necessary:

$$W_g\sqrt{T_7}/P_6 = 1.208$$

From figure 12,

$$(P_6 - P_7)/P_6 = 0.0192$$

and

$$P_7 = P_6\left[1 - (P_6 - P_7)/P_6\right]$$

$$= 4576 \text{ lb/sq ft}$$

Thrust. - To calculate thrust the following steps are necessary:

$$P_7/p_0 = 3.836$$

and γ_7 for a fuel-air ratio of 0.0158 and a temperature of 1645° R is 1.332. From the exhaust-nozzle pressure ratio, the ratio of specific heats, and reference 9, the effective-velocity parameter $V_{ef}/\sqrt{gRT}$ can be found:

$$V_{ef}/\sqrt{gRT} = 1.484$$

The effective velocity is

$$V_{ef} = 1.484\sqrt{gRT_7}$$

$$= 2496 \text{ ft/sec}$$

The ideal or rake jet thrust is 3166

$$F_{j,r} = V_{ef}W_g/g$$

$$= 10{,}780 \text{ lb}$$

From figure 13,

$$C_v = 0.987$$

The actual or scale jet thrust is

$$F_{j,s} = C_v F_{j,r}$$

$$= 10{,}640 \text{ lb}$$

Subtracting inlet momentum to get net thrust,

$$F_n = F_{j,s} - (V_0 W_a/g)$$

$$= 6335 \text{ lb}$$

Exhaust-nozzle area. - To find out whether the exhaust-gas temperature chosen is within the physical capabilities of the exhaust nozzle, calculation of the exhaust-nozzle area is necessary.

From figure 10(a),

$$C_D = 0.985$$

(The exhaust-nozzle area is expected to be smaller than 2.388 square feet, because a higher value of T_7 was used in case B than in case A. Therefore, fig. 10(a) is used.)

Using the total-to-static pressure ratio at the exit of the exhaust nozzle, the ratio of specific heats, and reference 9, the exhaust-nozzle area can be found:

Static-pressure parameter = 0.801

$$A_N = \frac{(W_g)(\sqrt{T_7})(0.801)}{1.010(C_D)(p_N)(\sqrt{g/R})}$$

$$= 2.366 \text{ sq ft}$$

(The value 1.010 was an approximate correction for thermal expansion used for all experimental data.)

Summarizing the performance and rounding off numbers to give more realistic indications of accuracy,

$$W_a = 137 \text{ lb/sec}$$

$$W_f = 7800 \text{ lb/hr}$$

$$F_n = 6300 \text{ lb}$$

$$A_N = 2.37 \text{ sq ft}$$

Case C

The similarity of the mathematical steps in cases B and C makes a numerical example of case C unnecessary. The differences between the two methods are: for case B the exhaust-gas temperature is known, while for case C it is unknown; for case B the exhaust-nozzle area is unimportant (except that it should fall within the geometrical limitations), while for case C the exhaust-nozzle area is known and is one of the factors affecting exhaust-gas temperature.

The solution of case C is accomplished as follows:

(1) Assume an exhaust-gas temperature.

(2) Solve for exhaust-nozzle area (using the steps given in case B).

(3) Assume new values of exhaust-gas temperature and solve for exhaust-nozzle area until either the desired value of area is obtained or until sufficient points have been obtained to cross-plot for performance at the desired exhaust-nozzle area.

REFERENCES

1. McAulay, John E., and Campbell, Carl E.: Altitude Component Performance of the YJ73-GE-3 Turbojet Engine. NACA RM E54D09, 1954. 3166

2. Campbell, Carl E., and Conrad, E. William: Altitude Performance Characteristics of the J73-GE-1A Turbojet Engine. NACA RM E53I25, 1953.

3. Campbell, Carl E., and Sobolewski, Adam E.: Altitude Chamber Investigation of J73-GE-1A Turbojet Engine Component Performance. NACA RM E53I08, 1953.

4. Sanders, Newell D., and Behun, Michael: Generalization of Turbojet-Engine Performance in Terms of Pumping Characteristics. NACA TN 1927, 1949.

5. McAulay, John E., and Kaufman, Harold R.: Altitude Wind Tunnel Investigation of the Prototype J40-WE-8 Turbojet Engine Without Afterburner. NACA RM E52K10, 1953.

6. Hesse, W. J.: A Simple Gross Thrust Meter Installation Suitable for Indicating Turbojet Engine Gross Thrust in Flight. Tech. Rep. No. 2-52, Test Pilot Training Div., Naval Air Test Center, Apr. 3, 1952.

7. Sivo, Joseph N., and Fenn, David B.: A Method of Measuring Jet Thrust of Turbojet Engines in Flight Installations. NACA RM E53J15, 1954.

8. Turner, L. Richard, and Bogart, Donald: Constant-Pressure Combustion Charts Including Effects of Diluent Addition. NACA Rep. 937, 1949. (Supersedes NACA TN's 1655 and 1086.)

9. Turner, L. Richard, Addie, Albert N., and Zimmerman, Richard H.: Charts for the Analysis of One-Dimensional Steady Compressible Flow. NACA TN 1419, 1948.

CX-4 back 3166

TABLE I. - ENGINE PERFORMANCE DATA.

(a) Inlet guide vanes open.

Run	Approximate altitude, ft	Reynolds number index, $\delta_{T,1}/\varphi\sqrt{\theta_{T,1}}$	Tail-pipe static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Equivalent ambient-air static temperature, $t_{0,e}$, °R	Engine-inlet total temperature, T_1, °R	Engine-inlet total pressure, P_1, lb/sq ft abs	Turbine-inlet total temperature, T_5, °R	Turbine-outlet total temperature, T_6, °R	Turbine-outlet total pressure, P_6, lb/sq ft abs	Tail-pipe total temperature, °R			Tail-pipe total pressure, P_7, lb/sq ft abs	Engine speed, rpm		
											Actual, T_7	Adjusted, T_7/θ_a	Corrected, $T_7/\theta_{T,1}$		Actual, N	Adjusted, $N/\sqrt{\theta_a}$	Corrected, $N/\sqrt{\theta_{T,1}}$
Exhaust-nozzle area, 2.588 sq ft																	
1	0	0.922	2035	0	522	514	1932	2030	1691	4416	1832	1625	1648	4315	7955	7932	7993
2		.926	2043	0	522	514	1942	1987	1624	4280	1572	1583	1588	4184	7792	7769	7830
3		.926	2037	0	522	515	1944	1810	1470	3949	1444	1436	1456	3840	7409	7388	7438
4		.938	2059	0	520	515	1970	1560	1248	3289	1247	1248	1267	3197	6690	6673	6708
5		.959	2041	0	518	516	2014	1450	1247	2477	1212	1214	1219	2452	5498	5503	5514
6	15,000	0.862	1186	0.803	448	506	1813	2018	1654	4146	1613	1874	1655	4045	7922	8073	8023
7		.884	1187	.806	448	507	1819	1790	1448	3872	1419	1473	1456	3564	7413	7554	7508
8		.861	1176	.812	449	507	1812	1458	1161	2807	1148	1192	1178	2738	6686	6813	6784
9		.871	1189	.798	451	509	1809	1443	1157	2788	1142	1177	1165	2724	6670	6770	6735
10		.861	1176	.811	450	509	1811	1063	846	1718	839	867	856	1684	5502	5590	5556
11		.867	1183	.802	454	512	1806	1067	850	1702	848	868	860	1668	5498	5564	5536
12	25,000	0.577	769	0.818	443	502	1193	2028	1635	2766	1625	1575	1678	2692	7863	7836	8086
13		.576	775	.803	446	504	1185	1958	1581	2639	1568	1502	1606	2576	7796	7654	7910
14		.575	782	.800	447	504	1192	1780	1441	2409	1422	1368	1485	2347	7417	7275	7527
15		.575	766	.816	446	505	1185	1484	1175	1843	1152	1111	1186	1812	6688	6567	6780
16		.575	774	.811	447	506	1192	1055	844	1124	840	808	862	1100	5494	5389	5584
17	35,000	0.578	484	1.21	394	509	1209	2020	1637	2783	1618	1618	1660	2688	7953	7953	8031
18		.575	494	1.20	395	509	1201	1963	1585	2667	1580	1558	1591	2586	7792	7762	7898
19		.576	491	1.21	394	510	1206	1780	1450	2424	1424	1404	1450	2347	7420	7420	7485
20		.576	484	1.20	395	510	1204	1480	1166	1842	1149	1146	1170	1797	6662	6673	6741
21		.578	486	1.22	395	512	1209	930	718	946	722	720	732	921	5482	5485	5530
22		.362	482	.804	445	502	753	2053	1661	1756	1626	1441	1683	1694	7951	7482	8064
23		.362	486	.809	444	502	746	1960	1610	1684	1568	1391	1621	1656	7788	7358	7919
24		.367	490	.805	442	499	750	1900	1551	1626	1506	1342	1565	1585	7631	7207	7782
25		.362	490	.809	444	502	753	1800	1498	1544	1431	1270	1480	1502	7420	6990	7544
26		.367	461	.822	440	499	749	1663	1326	1394	1319	1182	1372	1355	7097	6719	7237
27		.362	502	.788	447	503	756	1478	1183	1180	1170	1051	1207	1146	6870	6262	6745
28		.367	492	.803	445	500	752	1220	967	901	965	850	991	878	6013	5671	6126
29		.362	492	.796	447	504	748	1083	867	899	866	763	892	866	5492	5166	5673
30	45,000	0.220	301	0.789	443	499	458	2020	1658	1057	1614	1433	1678	1029	7645	7393	8000
31		.223	304	.806	445	503	466	1990	1636	1048	1590	1404	1641	1020	7782	7312	7906
32		.225	307	.794	443	499	465	1940	1597	1021	1540	1366	1602	993	7653	7208	7804
33		.220	295	.819	444	505	458	1830	1490	944	1452	1287	1498	916	7406	6970	7522
34		.220	300	.804	443	500	458	1710	1379	872	1361	1208	1413	846	7106	6695	7240
35		.221	298	.818	444	505	459	1500	1211	725	1188	1052	1226	701	6667	6274	6772
36		.224	307	.800	443	500	468	1330	1049	626	1051	932	1081	607	6265	5899	6383
37		.225	310	.795	447	503	470	1140	898	465	912	803	941	435	5584	5220	5652
38	55,000	0.139	195	0.791	456	515	294	2000	1844	625	1605	1376	1616	604	7829	7069	7659
39		.137	189	.808	457	516	290	1897	1546	578	1519	1308	1528	561	7407	6875	7429
40		.136	185	.818	457	518	287	1770	1459	534	1413	1215	1416	519	7178	6657	7185
41		.138	194	.791	460	516	293	1605	1303	466	1284	1096	1287	453	6828	6308	6836
42		.137	192	.792	460	516	290	1300	1057	322	1037	885	1039	316	6011	5554	6017
43		.100	192	.417	501	518	216	1971	1637	454	1582	1242	1586	441	7506	6851	7514
44		.101	195	.417	499	517	220	1907	1597	439	1532	1205	1538	428	7346	6514	7359
45		.101	195	.418	499	517	220	1803	1494	396	1446	1158	1452	384	7080	6280	7095
46		.101	196	.405	501	517	219	1643	1350	355	1320	1056	1325	347	6678	5916	6691
47		.101	196	.399	501	517	221	1590	1366	284	1317	1053	1329	290	6007	5316	6013

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Continued. Inlet guide vanes open.

Run	Air flow, lb/sec: Actual, W_a	Air flow: Adjusted, $\frac{W_a\sqrt{\theta_a}}{\delta_a}$	Air flow: Corrected, $\frac{W_a\sqrt{\theta_{T,1}}}{\delta_{T,1}}$	Combustion efficiency, η_b	Combustion parameter, W_aT_7	Fuel flow, lb/hr: Actual, W_f	Fuel flow: Adjusted, $\frac{W_f}{\delta_a\sqrt{\theta_a}}$	Fuel flow: Corrected, $\frac{W_f}{\delta_{T,1}\sqrt{\theta_{T,1}}}$	Rake jet thrust $F_{j,r}$, lb	Scale jet thrust, lb: Actual, $F_{j,s}$	Scale jet thrust: Adjusted, $F_{j,s}/\delta_a$	Scale jet thrust: Corrected, $\frac{F_{j,s}}{\delta_{T,1}}$	Scale net thrust, lb: Actual, $F_{n,s}$	Scale net thrust: Adjusted, $F_{n,s}/\delta_a$	Scale net thrust: Corrected, $\frac{F_{n,s}}{\delta_{T,1}}$	Net thrust specific fuel consumption, $\frac{\text{lb/hr}}{\text{lb thrust}}$: Actual, $W_f/F_{n,s}$	Net thrust specific fuel consumption: Adjusted, $\frac{W_f}{F_{n,s}\sqrt{\theta_a}}$	Net thrust specific fuel consumption: Corrected, $\frac{W_f}{F_{n,s}\sqrt{\theta_{T,1}}}$	Engine temperature ratio, T_7/T_1	Engine pressure ratio, P_6/P_1
Exhaust-nozzle area, 2.308 sq ft																				
1	131.3	138.9	143.1	0.980	21.4	7480	7757	8230	8228	8181	8508	8958	8181	8508	8958	0.915	0.912	0.918	3.175	2.285
2	129.7	134.7	140.7	.979	20.4	6960	7210	7645	7000	7771	8051	8470	7771	8051	8470	.898	.895	.901	3.058	2.200
3	123.1	128.3	133.5	.979	17.8	5740	5847	6267	6725	6669	6929	7266	6669	6929	7266	.860	.858	.864	2.804	2.030
4	107.1	111.3	114.6	.992	13.4	3820	3981	4119	4628	4535	4707	4871	4535	4707	4871	.843	.842	.846	2.421	1.660
5	64.6	66.9	67.7	.982	7.83	2210	2294	2330	1786	1764	1829	1854	1764	1829	1854	1.252	1.253	1.256	2.349	1.230
6	124.0	122.4	142.9	0.977	20.0	7050	7226	8332	9343	9216	8270	10754	8002	8038	7004	1.175	1.197	1.190	3.188	2.266
7	117.3	115.7	134.7	.991	16.6	5330	5458	6278	7913	7598	7738	8953	4650	4873	5408	1.146	1.168	1.161	2.804	2.018
8	100.8	100.5	118.4	.985	11.6	3120	3223	3687	5447	5265	5539	6150	2026	2665	3070	1.187	1.210	1.201	2.264	1.550
9	99.5	98.3	115.3	.981	11.4	3000	3135	3459	5577	5186	5202	6068	2616	2624	3061	1.177	1.195	1.189	2.244	1.544
10	66.3	66.2	78.7	.981	5.58	1054	1065	1243	2053	1898	1923	2215	160	162	187	6.588	6.693	6.653	1.848	.948
11	62.5	62.3	72.8	.974	5.38	1023	1045	1207	1969	1826	1843	2142	200	202	234	5.115	5.176	5.150	1.656	.943
12	82.1	85.1	143.3	0.989	13.3	4690	4708	8442	8257	5237	8369	11084	4094	4170	7245	1.146	1.129	1.165	3.233	2.32
13	80.1	82.6	141.0	.968	12.5	4340	4317	7866	5880	6811	5867	10878	3741	3790	6681	1.160	1.139	1.177	3.091	2.25
14	76.7	78.5	134.1	.961	10.9	3540	3486	6377	5177	6067	5077	8976	3081	3095	5469	1.149	1.127	1.166	2.821	2.02
15	66.2	69.1	116.5	.960	7.62	2150	2163	3888	3612	3507	3595	6256	1771	1815	3159	1.214	1.192	1.231	2.281	1.555
16	42.3	43.7	74.1	.987	3.55	680	676	1222	1297	1148	1162	2034	42	43	75	16.19	15.88	16.39	1.660	.943
17	82.2	82.8	142.4	0.983	13.3	4650	4687	8220	6927	6763	6817	11835	3782	3792	6584	1.236	1.236	1.248	3.179	2.283
18	80.3	81.0	140.1	.985	12.5	4280	4308	7615	6600	6441	6493	11349	3517	3545	6197	1.217	1.215	1.229	3.085	2.212
19	76.7	77.8	133.5	.977	10.9	3550	3578	6250	5915	5755	5836	10100	2949	2990	5175	1.197	1.197	1.208	2.792	2.010
20	65.8	66.4	114.7	.992	7.56	2050	2063	3635	4250	4117	4150	7234	1715	1728	3013	1.195	1.193	1.206	2.253	1.530
21	43.3	44.4	75.2	1.004	3.12	418	428	731	1654	1497	1534	2620	----	----	----	-----	-----	-----	1.410	.783
22	51.6	65.5	142.7	.976	8.41	3000	2857	8571	3921	3850	3897	11100	2616	2246	7351	1.147	1.079	1.166	3.243	2.31
23	50.2	54.7	138.9	.956	7.86	2000	2708	7840	3712	3714	3814	10633	2411	2476	6638	1.161	1.094	1.180	3.124	2.26
24	50.1	53.9	136.5	.964	7.55	2600	2495	7482	3577	3546	3803	10003	2256	2292	6364	1.152	1.088	1.175	3.010	2.171
25	48.8	52.6	134.9	.971	6.89	2500	2201	6571	3330	3326	3579	9346	2060	2093	5789	1.117	1.062	1.136	2.851	2.053
26	46.1	50.4	127.8	.974	6.08	1900	1862	5474	2922	2897	2898	8184	1687	1746	4765	1.126	1.066	1.148	2.643	1.862
27	41.3	43.8	115.7	.940	4.83	1410	1313	4009	2232	2242	2224	6275	1196	1165	3345	1.180	1.108	1.199	2.328	1.58
28	34.9	37.5	96.5	.934	3.34	800	764	2294	1444	1449	1466	4007	550	557	1648	1.455	1.372	1.482	1.910	1.188
29	25.6	27.6	71.4	.984	2.22	438	418	1257	777	800	810	2265	142	144	402	3.085	2.886	3.131	1.718	.855
30	30.9	33.5	139.9	0.927	4.98	1870	1803	8810	2532	2365	2419	10828	1575	1611	7277	1.187	1.119	1.210	3.234	2.31
31	31.1	33.8	138.9	.952	4.94	1781	1696	8215	2511	2338	2368	10617	1535	1563	6961	1.162	1.092	1.180	3.161	2.25
32	30.7	32.7	137.2	.955	4.73	1668	1576	7741	2222	2219	2226	10089	1436	1440	6536	1.162	1.094	1.165	3.086	2.196
33	29.1	32.3	132.4	.930	4.23	1458	1431	6833	2013	2064	2144	9489	1289	1348	5955	1.130	1.064	1.140	2.887	2.08
34	28.3	30.9	128.2	.955	3.86	1258	1217	5909	1826	1809	1858	8339	1079	1108	4974	1.166	1.098	1.188	2.722	1.80
35	26.3	28.0	115.1	.987	3.01	800	862	4121	1407	1384	1441	8380	719	748	3515	1.224	1.162	1.243	2.362	1.574
36	22.9	24.4	101.5	.972	2.40	620	586	2858	1073	1076	1081	4074	491	492	2220	1.265	1.189	1.287	2.109	1.336
37	16.3	17.2	72.9	.829	1.48	578	550	1718	512	557	547	2481	134	153	605	2.799	2.626	2.843	1.813	.947
38	17.8	18.9	128.3	0.908	2.87	1080	979	7793	1505	1309	1282	8409	847	850	6090	1.275	1.181	1.280	3.113	2.122
39	17.3	18.6	125.5	.908	2.62	953	884	6971	1203	1181	1204	8687	730	746	5580	1.292	1.199	1.298	2.944	1.882
40	16.6	18.4	122.0	.825	2.34	790	756	6832	1087	1079	1114	7958	638	658	4606	1.238	1.148	1.239	2.728	1.861
41	15.5	16.6	111.6	.930	1.98	620	564	4482	887	----	----	----	---	---	----	-----	-----	-----	2.479	1.690
42	11.1	12.0	81.2	.083	1.16	310	285	2263	450	452	450	3298	164	183	1194	1.893	1.749	1.886	2.002	1.110
43	12.8	14.4	124.6	.967	2.02	770	679	7537	814	806	802	7881	624	621	6104	1.233	1.093	1.234	3.064	2.088
44	12.6	13.9	121.2	.906	1.93	705	612	6800	770	752	737	7240	573	561	5514	1.231	1.092	1.233	2.983	1.997
45	11.0	13.0	113.0	.903	1.70	600	521	5762	662	649	658	6242	481	472	4630	1.246	1.105	1.248	2.787	1.785
46	10.9	11.9	104.7	.915	1.43	488	402	4508	550	499	486	4619	350	341	3380	1.531	1.179	1.334	2.553	1.620
47	7.2	7.8	68.4	.844	.94	332	284	3185	245	---	---	----	---	---	----	-----	-----	-----	2.547	1.195

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Continued. Inlet guide vanes open.

Run	Approximate altitude, ft	Reynolds number index, $\delta_{T,1}/\varphi\sqrt{\theta_{T,1}}$	Tail-pipe static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Equivalent ambient-air static temperature, $t_{0,e}$, °R	Engine-inlet total temperature, T_1, °R	Engine-inlet total pressure, P_1, lb/sq ft abs	Turbine-inlet total temperature, T_5, °R	Turbine-outlet total temperature, T_6, °R	Turbine-outlet total pressure, P_6, lb/sq ft abs	Tail-pipe total temperature, °R: Actual, T_7	Adjusted, T_7/θ_a	Corrected, $T_7/\theta_{T,1}$	Tail-pipe total pressure, P_7, lb/sq ft abs	Engine speed, rpm: Actual, N	Adjusted, $N/\sqrt{\theta_a}$	Corrected, $N/\sqrt{\theta_{T,1}}$
Exhaust-nozzle area, 2.814 sq ft																	
48	0	0.942	2060	0	514	506	1943	1940	1696	4918	1533	1548	1576	4140	7945	7985	8055
49		.938	2052	0	514	506	1937	1880	1535	4115	1483	1498	1522	4034	7790	7829	7899
50		.947	2058	0	514	506	1962	1763	1413	3866	1392	1408	[illegible]	3775	7417	7454	7812
51		.942	2048	0	514	506	1942	1760	1400	3832	1386	1403	1428	3756	7409	7448	7504
52		.955	2048	0	512	506	1969	1527	1221	3261	1220	1257	1252	3808	6683	6712	6780
53		.956	2062	0	513	507	1972	1550	1224	3271	1224	1259	1253	3820	6670	6710	6748
54		.964	2065	0	508	507	2036	1455	1237	2513	1214	1238	1243	2494	5489	5544	5553
55		.984	2061	0	510	506	2054	1450	1252	2520	1239	1254	1256	2486	5489	5538	5546
56	15,000	0.828	1058	0.810	441	503	1679	1830	1549	3740	1500	1581	1548	3867	7941	8186	8066
57		.890	1183	.808	445	503	1812	1930	1562	3873	1496	1563	1544	3790	7939	8114	8064
58		.885	1171	.808	443	501	1797	1850	1492	3749	1462	1525	1504	3666	7794	7969	7935
59		.885	1171	.808	442	500	1798	1693	1361	3446	1328	1395	1377	3364	7492	7615	7562
60		.897	1193	.799	444	501	1818	1415	1116	2721	1108	1188	1146	2680	6629	6855	6818
61		.897	1198	.798	445	502	1825	1050	838	1720	832	869	860	1699	5475	5593	5568
62	25,000	0.582	777	0.806	442	499	1181	1925	1631	2643	1513	1475	1574	2504	7947	7842	8104
63		.584	780	.809	444	502	1200	1853	1462	2505	1456	1410	1506	2463	7790	7657	7971
64		.580	780	.806	445	501	1196	1703	1350	2276	1332	1292	1380	2217	7416	7308	7547
65		.582	784	.805	443	500	1198	1416	1111	1798	1113	1081	1155	1766	6678	6580	6804
66		.581	779	.804	443	509	1192	1080	844	1140	885	830	887	1127	5630	5449	5634
67	35,000	0.583	473	1.25	388	508	1193	1907	1524	2529	1500	1525	1542	2460	7888	8024	8078
68		.583	459	1.24	388	505	1193	1835	1466	2451	1440	1470	1480	2379	7786	7854	7883
69		.583	489	1.24	387	506	1194	1670	1323	2218	1318	1339	1349	2166	7413	7480	7508
70		.580	479	1.22	382	510	1198	1373	1076	1684	1068	1073	1087	1646	6678	6691	6737
71		.581	493	1.21	399	515	1208	895	682	688	690	681	694	648	5432	5398	5455
72		.373	494	.808	441	498	757	1930	1663	1636	1524	1362	1589	1601	7845	7511	8111
73		.430	483	.815	391	443	747	1897	1517	1746	1498	1510	1758	1702	7845	7877	8599
74		.371	490	.798	444	500	757	1853	1610	1579	1454	1292	1509	1548	7768	7340	7935
75		.430	491	.808	384	446	754	1735	1418	1633	1377	1377	1606	1588	7826	7826	8234
76		.371	482	.809	441	499	758	1715	1557	1449	1346	1202	1400	1418	7402	6994	7848
77		.428	490	.806	398	448	751	1500	1197	1401	1177	1174	1370	1388	6947	6838	7494
78		.370	502	.782	446	501	759	1435	1126	1196	1150	1000	1171	1102	6870	6276	6789
79		.369	486	.808	444	502	746	1067	847	682	856	758	685	874	5432	5116	5625
80	45,000	0.263	310	0.978	396	448	469	1980	1554	1089	1619	1507	1768	1044	7945	7812	8671
81		.263	309	.792	397	447	487	1775	1453	1001	1398	1383	1623	974	7619	7679	8200
82		.230	304	.813	438	495	448	1917	1654	1009	1508	1353	1577	987	7941	7892	8125
83		.226	296	.820	437	499	460	1860	1612	984	1480	1312	1527	945	7796	7390	7974
84		.226	294	.830	437	497	462	1718	1363	878	1346	1210	1404	859	7390	7010	7652
85		.269	316	.786	397	448	478	1628	1211	658	1198	1167	1384	838	6932	6889	7478
86		.224	295	.821	438	487	439	1445	1121	693	1134	1018	908	675	6667	6316	6615
87		.227	308	.800	442	488	466	1083	870	435	870	774	907	726	5504	5185	5419
88	55,000	0.160	193	0.785	407	488	292	1963	1596	643	1684	1601	1781	629	7953	7815	8488
89		.140	195	.793	441	488	282	2017	1610	630	1604	1429	1678	619	7985	7536	8169
90		.157	186	.786	407	469	265	1830	1483	596	1443	1391	1632	581	7827	7494	8110
91		.140	190	.802	440	436	290	1940	1554	602	1537	1375	1609	590	7771	7344	7949
92		.138	187	.808	440	487	287	1797	1400	543	1425	1271	1486	555	7384	6979	7846
93		.155	184	.809	408	482	285	1543	1232	490	1219	1174	1389	478	6840	6737	7271
94		.139	184	.820	438	488	286	1490	1158	417	1176	1063	1295	409	6646	6288	6786
95		.134	182	.813	441	489	281	1147	923	286	918	881	955	283	5579	5218	5437
96		.124	197	.488	542	460	227	2007	1657	506	1565	1418	1799	482	7851	7497	8448
97		.123	192	.475	441	461	224	1895	1540	479	1499	1338	1666	464	7642	7174	8108
98		.105	189	.478	475	487	221	2030	1653	479	1609	1551	1680	469	7876	7909	8039
99		.105	190	.485	475	487	223	2037	1636	478	1585	1543	1694	466	7884	7171	8058
100		.104	187	.487	474	486	220	1990	1592	483	1588	1516	1659	451	7742	7049	7910
101		.107	193	.487	797	224	224	1890	1478	438	1496	1236	1562	428	7436	6784	7589
102		.124	196	.471	443	483	297	1860	1334	406	1316	1167	1474	394	6996	6580	7407
103		.106	192	.480	477	497	222	1558	1209	347	1236	1018	1290	341	6634	6022	6779
104		.106	177	.504	486	496	223	1573	1129	269	1106	932	1151	266	6112	5613	6640
105		.106	187	.539	472	498	296	1577	1158	267	1126	937	1170	257	5766	5290	5900

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Continued. Inlet guide vanes open.

Run	Air flow, lb/sec: Actual, W_a	Air flow: Adjusted, $W_a\sqrt{\theta_a}/\delta_a$	Air flow: Corrected, $W_a\sqrt{\theta_{T,1}}/\delta_{T,1}$	Combustion efficiency, η_b	Combustion parameter, $W_a T_7$	Fuel flow, lb/hr: Actual, W_f	Fuel flow: Adjusted, $W_f/\delta_a\sqrt{\theta_a}$	Fuel flow: Corrected, $W_f/\delta_{T,1}\sqrt{\theta_{T,1}}$	Rake jet thrust $F_{j,r}$, lb	Scale jet thrust, lb: Actual, $F_{j,s}$	Scale jet thrust: Adjusted, $F_{j,s}/\delta_a$	Scale jet thrust: Corrected, $F_{j,s}/\delta_{T,1}$	Scale net thrust, lb: Actual, $F_{n,s}$	Scale net thrust: Adjusted, $F_{n,s}/\delta_a$	Scale net thrust: Corrected, $F_{n,s}/\delta_{T,1}$	Net thrust specific fuel consumption, (lb/hr)/lb thrust: Actual, $W_f/F_{n,s}$	Net thrust specific fuel consumption: Adjusted, $W_f/F_{n,s}\sqrt{\theta_a}$	Net thrust specific fuel consumption: Corrected, $W_f/F_{n,s}\sqrt{\theta_{T,1}}$	Engine temperature ratio, T_7/T_1	Engine pressure ratio, P_6/P_1
Exhaust-nozzle area, 2.814 sq ft																				
48	134.3	137.2	144.2	0.975	20.8	7075	7302	7811	7768	7792	8005	8466	7792	8005	8465	0.909	0.913	0.921	3.036	2.171
49	131.3	134.7	141.6	.965	19.5	6600	6839	7299	7356	7373	7602	8061	7375	7609	8061	.895	.900	.906	2.931	2.124
50	125.8	128.7	134.6	.984	17.5	5585	5770	6131	6848	6493	6675	7038	6493	6676	7039	.861	.865	.873	2.751	1.875
51	125.0	128.5	134.4	.973	17.4	5585	5796	6165	6425	6150	6663	7031	6450	6665	7031	.867	.871	.876	2.745	1.873
52	108.1	110.9	114.7	.945	13.2	3875	4031	4219	4518	4514	4665	4856	4518	4665	4855	.878	.863	.880	2.411	1.668
53	108.6	111.3	118.2	.973	13.5	3878	4019	4207	4588	4540	4681	4871	4540	4681	4871	.853	.867	.864	2.414	1.659
54	65.5	66.5	67.3	.968	7.98	2270	2350	2386	1800	1827	1873	1898	1827	1873	1898	1.243	1.254	1.258	2.394	1.234
55	63.3	64.4	65.2	.966	7.80	2300	2383	2418	1764	1764	1814	1832	1768	1814	1832	1.304	1.316	1.317	2.426	1.239
56	119.8	131.4	148.2	0.938	17.9	6320	7321	8089	8890	8637	9743	10883	5422	6116	6832	1.166	1.197	1.183	2.982	2.228
57	125.0	133.3	145.7	.975	18.7	6320	6811	7498	8572	8705	8775	10167	5449	5613	6388	1.168	1.181	1.194	2.974	2.137
58	123.2	128.5	142.6	.968	17.9	5970	6236	7158	8540	8390	8549	9883	5200	4299	6126	1.148	1.177	1.188	2.898	2.086
59	117.7	116.9	138.0	.947	15.8	4925	5148	5908	7532	7388	7528	8898	4344	4427	5113	1.134	1.158	1.155	2.862	1.917
60	105.1	100.8	118.1	.984	11.4	2990	3068	3645	6358	6148	6148	5995	2502	2502	2915	1.195	1.222	1.218	2.208	1.498
61	67.0	65.3	76.5	1.025	5.57	1012	1030	1195	2039	1891	1865	2186	171	170	199	5.918	6.048	6.017	1.667	.944
62	82.3	84.2	143.4	0.974	12.4	4050	4179	7702	5880	5787	5845	10883	3684	3701	6511	1.160	1.145	1.183	3.059	2.159
63	81.5	83.4	141.4	.947	11.9	3880	3941	7134	5484	5557	5590	9787	3438	3460	6062	1.157	1.138	1.176	2.900	2.086
64	77.4	79.1	134.7	.972	10.3	3240	3210	5840	4948	4645	4874	8580	2844	2881	5037	1.139	1.122	1.158	2.679	1.806
65	67.9	69.0	117.7	.987	7.58	2000	1973	3699	3551	3370	3373	5951	1622	1624	2864	1.233	1.216	1.264	2.226	1.501
66	44.3	45.3	77.2	1.040	3.79	710	705	1284	1404	1318	1309	2339	176	177	312	4.034	3.976	4.110	1.710	.968
67	81.1	84.8	142.0	0.980	12.2	4160	4411	7482	6492	6424	6764	11306	3429	3611	6083	1.213	1.221	1.230	2.970	2.120
68	79.9	84.2	139.9	.950	11.5	3840	4127	6904	6736	6261	6662	11107	3298	3605	5851	1.164	1.178	1.180	2.861	2.064
69	77.0	81.1	134.8	.966	10.1	3070	3269	5509	5616	5396	5731	9562	2537	2694	4498	1.210	1.221	1.225	2.599	1.868
70	65.7	68.3	116.1	.968	7.09	1779	1050	3157	3901	3872	4035	6838	1444	1505	2550	1.237	1.229	1.238	2.094	1.406
71	40.3	41.0	70.4	.964	2.78	338	359	594	1371	1286	1238	2061	----	----	----	-----	-----	-----	1.340	.719
72	52.0	55.4	142.4	.948	7.93	2750	2621	7847	3742	3648	3677	10199	2306	2396	6451	1.192	1.127	1.217	3.060	2.161
73	53.5	57.0	145.9	.969	8.31	2970	3074	8107	4089	4065	4161	11489	2689	2775	7596	1.103	1.107	1.184	3.361	2.337
74	57.5	54.6	141.2	.964	7.48	2550	2403	7262	3592	3487	3487	9746	2170	2170	6065	1.175	1.107	1.197	2.908	2.088
75	54.9	55.6	148.5	.983	7.55	2560	2586	7727	3739	3714	5766	10421	2375	2408	6659	1.075	1.078	1.161	3.094	2.166
76	48.4	52.8	135.7	.976	6.45	2100	2009	5994	3192	3081	3128	8652	1812	1834	5072	1.159	1.096	1.182	2.697	1.917
77	50.3	51.2	131.4	.958	5.92	1843	1870	5603	2993	2991	3039	8429	1785	1791	4968	1.045	1.044	1.127	2.639	1.866
78	42.0	44.3	115.1	.970	4.75	1308	1221	3712	2181	2076	2059	5784	1007	999	2808	1.299	1.222	1.392	2.255	1.484
79	24.6	26.8	66.7	.872	2.11	470	454	1365	758	719	737	2059	80	85	2283	5.839	5.500	6.937	1.706	.914
80	34.4	34.3	143.7	0.980	5.22	1870	1850	8102	2499	2459	2443	11093	1633	1622	7348	1.145	1.140	1.235	3.406	2.279
81	33.4	33.5	140.5	.984	4.67	1638	1622	7867	2277	2256	2248	10217	1452	1447	6578	1.127	1.121	1.214	3.198	2.144
82	32.2	34.4	142.0	.946	4.86	1718	1646	7829	2306	2255	2284	10175	1420	1436	7829	1.210	1.146	1.238	3.040	2.150
83	31.1	34.1	138.7	.926	4.83	1585	1575	7606	2174	2135	2220	9821	1324	1377	7606	1.206	1.142	1.233	2.944	2.085
84	30.3	33.4	135.7	.960	4.07	1309	1301	6128	1966	1895	1966	8679	1096	1148	6196	1.195	1.134	1.221	2.706	1.900
85	31.1	30.4	128.0	.951	3.72	1183	1148	5873	1826	1805	1767	8014	1060	1033	4719	1.116	1.111	1.204	2.686	1.805
86	26.0	28.7	117.4	.898	2.95	718	789	3759	1365	----	----	----	----	----	3789	-----	-----	-----	2.282	1.610
87	16.3	17.4	72.6	.836	1.42	343	326	1580	494	500	504	8271	82	83	1590	4.183	3.947	4.271	1.747	.934
88	20.8	21.0	142.0	0.967	3.24	1183	1150	8138	1587	1437	1422	10427	950	990	6748	1.272	12.50	1.354	3.393	2.204
89	20.0	21.0	141.8	.983	3.20	1131	1058	8584	1471	1420	1405	10891	918	905	6609	1.240	1.171	1.298	3.234	2.160
90	20.0	20.9	141.0	.856	2.89	1003	1012	7869	1387	1287	1382	9840	798	820	5877	1.257	1.235	1.337	3.144	2.106
91	19.3	20.6	138.0	.980	2.87	1023	972	7836	1378	1352	1339	9720	837	841	6108	1.228	1.158	1.250	3.099	2.080
92	18.5	19.7	131.7	.976	2.60	862	822	6419	1210	1171	1196	8434	700	715	5162	1.217	1.150	1.244	2.865	1.890
93	18.1	19.1	127.5	.967	2.20	686	688	5432	1069	987	1086	7385	537	557	4018	1.278	1.262	1.352	2.639	1.733
94	15.7	17.9	113.8	.976	1.65	523	614	3951	858	---	----	----	---	---	----	-----	-----	-----	2.381	1.480
95	9.0	10.0	68.7	.748	.83	242	240	1868	297	326	344	2470	93	98	700	2.602	2.458	2.653	1.840	.943
96	16.0	18.5	140.8	.983	2.55	944	887	9596	1073	1023	918	9545	790	688	7371	1.196	1.151	1.274	3.487	2.218
97	15.8	18.8	139.0	.998	2.33	842	786	8453	1005	947	947	8961	710	706	6718	1.186	1.110	1.256	3.262	2.142
98	14.7	16.4	138.1	.988	2.37	890	818	8705	968	973	984	9318	739	747	7076	1.204	1.095	1.250	3.237	2.170
99	14.9	16.4	138.0	.959	2.41	881	806	8643	953	980	985	9299	741	745	7031	1.189	1.082	1.215	3.266	2.143
100	14.7	16.8	138.3	.966	2.38	830	779	8166	848	839	862	8464	694	709	6675	1.196	1.089	1.225	3.198	2.104
101	14.0	15.2	129.5	.964	2.09	705	654	6806	847	815	807	7698	596	582	5649	1.179	1.071	1.205	3.010	1.945
102	14.4	14.9	120.4	.989	1.89	616	567	6007	771	711	696	6629	494	484	4606	1.245	1.173	1.318	2.840	1.789
103	11.6	12.7	108.3	.902	1.44	458	414	4461	649	626	586	5085	550	548	3538	1.302	1.188	1.338	2.487	1.543
104	9.5	11.2	98.9	.852	1.06	325	328	3148	365	---	---	----	---	---	----	-----	-----	-----	2.219	-----
105	8.4	9.4	78.7	.951	.86	296	275	2792	287	---	---	----	---	---	----	-----	-----	-----	2.265	1.128

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Continued. Inlet guide vanes open.

Run	Approximate altitude, ft	Reynolds number index, $\delta_{T,1}/\varphi\sqrt{\theta_{T,1}}$	Tail-pipe static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Equivalent ambient-air static temperature, $t_{0,e}$, °R	Engine-inlet total temperature, T_1, °R	Engine-inlet total pressure, P_1, lb/sq ft abs	Turbine-inlet total temperature, T_5, °R	Turbine-outlet total temperature, T_6, °R	Turbine-outlet total pressure, P_6, lb/sq ft abs	Tail-pipe total temperature, °R			Tail-pipe total pressure, P_7, lb/sq ft abs	Engine speed, rpm		
											Actual, T_7	Adjusted, T_7/θ_a	Corrected, $T_7/\theta_{T,1}$		Actual, N	Adjusted, $N/\sqrt{\theta_a}$	Corrected, $N/\sqrt{\theta_{T,1}}$
Exhaust-nozzle area, 2.694 sq ft																	
106	0	0.938	2053	0	514	505	1933	1807	1445	3851	1403	1417	1442	3762	7955	7995	8085
107		.942	2059	0	514	505	1942	1750	1400	3772	1358	1372	1396	3864	7788	7827	7895
108		.942	2050	0	513	505	1944	1640	1304	3547	1272	1287	1308	3458	7420	7465	7522
109		.958	2056	0	511	505	1976	1465	1151	3083	1148	1166	1180	3032	6686	6739	6778
110		.978	2035	0	513	506	2004	1380	1163	2424	1140	1154	1170	2403	5498	5531	5568
111	15,000	0.888	1180	0.805	445	503	1806	1736	1384	3458	1333	1393	1375	3363	7953	8128	8078
112		.888	1183	.802	447	504	1805	1680	1334	3343	1292	1344	1331	3247	7786	7942	7901
113		.890	1191	.798	447	504	1812	1550	1210	3061	1194	1242	1230	2981	7415	7563	7525
114		.891	1188	.803	448	506	1815	1315	1011	2420	1005	1043	----	2382	6678	6805	6763
115		.890	1194	.795	450	507	1810	1010	791	1585	798	824	817	1562	5411	5498	5475
116	25,000	0.585	775	0.814	445	504	1197	1750	1382	2283	1347	1302	1387	2206	7949	7814	8067
117		.585	774	.813	445	504	1195	1700	1327	2202	1307	1263	1346	2135	7795	7682	7910
118		.585	778	.811	445	504	1195	1560	1209	2011	1199	1159	1235	1965	7411	7285	7521
119		.580	789	.815	446	505	1189	1323	1013	1580	1015	979	----	1552	6674	6563	6766
120		.585	778	.811	448	507	1198	1015	788	1046	801	769	820	1029	5445	5334	5509
121	35,000	0.596	486	1.22	384	498	1207	1773	1387	2321	1366	1402	1423	2236	7955	8058	8121
122		.591	479	1.22	---	499	1200	1707	1332	2244	1317	1351	1370	2167	7794	7895	7948
123		.582	488	1.24	382	500	1195	1577	1216	2049	1218	1254	1262	1987	7441	7553	7581
124		.582	477	1.23	386	503	1198	1300	990	1583	992	1013	1024	1535	6686	6753	6791
125		.579	482	1.21	391	506	1188	867	649	860	670	665	677	835	5470	5492	5540
126		.427	478	.818	392	444	497	1770	1398	1558	1373	1381	1605	1508	7984	7988	8611
127		.427	482	.812	392	444	490	1627	1290	1468	1255	1260	1467	1416	7619	7634	8238
128		.370	498	.799	447	504	758	1763	1412	1441	1354	1193	1395	1395	7953	7466	8071
129		.388	485	.809	439	497	748	1685	1340	1311	1297	1163	1354	1292	7794	7380	7964
130		.370	503	.793	448	504	761	1703	1346	1394	1309	1151	1348	1348	7792	7307	7807
131		.371	495	.803	440	497	787	1570	1252	1301	1207	1080	1280	1264	7420	7019	7582
132		.370	498	.798	447	504	757	1573	1226	1259	1212	1088	1248	1224	7400	6947	7510
133		.428	480	.813	391	443	485	1393	1069	1246	1067	1074	1251	1204	6930	6951	7501
134		.376	502	.806	441	498	769	1324	1016	1036	1016	908	1059	1016	6669	6305	6809
135		.370	501	.794	444	500	759	1010	796	674	800	710	830	684	5428	5113	5530
136	45,000	0.267	298	0.828	390	443	467	1790	1417	973	1388	1400	1627	940	7964	8000	8820
137		.269	306	.819	391	443	475	1653	1312	920	1278	1286	1498	889	7614	7637	8241
138		.267	298	.828	391	444	466	1613	1273	897	1248	1255	1459	866	7506	7529	8115
139		.229	307	.809	441	499	472	1793	1408	897	1390	1238	1446	869	7930	7484	8067
140		.230	314	.795	444	500	476	1800	1409	903	1396	1236	1449	875	7905	7438	8054
141		.227	302	.813	441	499	466	1750	1363	870	1356	1209	1410	844	7795	7362	7949
142		.227	308	.802	443	500	470	1730	1358	864	1339	1188	1390	837	7775	7322	7922
143		.223	301	.806	443	500	461	1620	1261	789	1254	1113	1302	768	7420	6992	7580
144		.267	301	.809	392	443	463	1413	1098	778	1093	1096	1281	750	6924	6934	7494
145		.228	309	.794	444	500	468	1355	1040	629	1046	926	1088	615	6674	6279	6800
146		.229	320	.778	449	503	477	1060	845	427	839	735	866	415	5472	5121	5558
147	55,000	0.132	179	0.815	439	497	277	1860	1503	549	1442	1291	1505	531	7970	7541	8144
148		.148	188	.795	441	497	285	1767	1422	529	1366	1217	1426	513	7771	7336	7941
149		.138	195	.786	443	498	293	1647	1319	502	1274	1130	1328	487	7449	7016	7605
150		.138	198	.777	444	498	295	1327	1044	379	1021	904	1064	366	6547	6159	6684
151		.135	192	.777	445	499	286	1173	919	270	922	814	959	266	5786	5437	5900
152		.103	193	.388	483	498	214	1925	1562	421	1506	1225	1569	408	7958	7161	8104
153		.125	193	.430	479	497	219	1837	1484	409	1432	1175	1495	396	7714	6987	7883
154		.118	200	.422	481	498	226	1697	1368	385	1324	1082	1380	373	7369	6661	7523
155		.112	204	.475	476	498	238	1433	1230	367	1197	988	1247	357	6915	6283	7080
156		.110	202	.370	487	500	222	1410	1155	300	1121	905	1164	283	6348	5702	6468

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Continued. Inlet guide vanes open.

Run	Air flow, lb/sec: Actual, W_a	Air flow: Adjusted, $\frac{W_a\sqrt{\theta_a}}{\delta_a}$	Air flow: Corrected, $\frac{W_a\sqrt{\theta_{T,1}}}{\delta_{T,1}}$	Combustion efficiency, η_b	Combustion parameter, W_aT_7	Fuel flow, lb/hr: Actual, W_f	Fuel flow: Adjusted, $\frac{W_f}{\delta_a\sqrt{\theta_a}}$	Fuel flow: Corrected, $\frac{W_f}{\delta_{T,1}\sqrt{\theta_{T,1}}}$	Rake jet thrust $F_{j,r}$, lb	Scale jet thrust, lb: Actual, $F_{j,s}$	Scale jet thrust: Adjusted, $F_{j,s}/\delta_a$	Scale jet thrust: Corrected, $\frac{F_{j,s}}{\delta_{T,1}}$	Scale net thrust, lb: Actual, $F_{n,s}$	Scale net thrust: Adjusted, $F_{n,s}/\delta_a$	Scale net thrust: Corrected, $\frac{F_{n,s}}{\delta_{T,1}}$	Net thrust specific fuel consumption, $\frac{lb/hr}{lb\ thrust}$: Actual, $W_f/F_{n,s}$	Net thrust specific fuel consumption: Adjusted, $\frac{W_f}{F_{n,s}\sqrt{\theta_a}}$	Net thrust specific fuel consumption: Corrected, $\frac{W_f}{F_{n,s}\sqrt{\theta_{T,1}}}$	Engine temperature ratio, T_7/T_1	Engine pressure ratio, P_6/P_1
Exhaust-nozzle area, 2.884 sq ft																				
106	133.2	136.7	143.9	0.963	18.7	6125	6347	6789	6890	6941	7156	7600	6941	7156	7600	0.885	0.887	0.896	2.778	1.892
107	131.7	134.7	141.6	.958	17.9	5750	5941	6554	6545	6584	6768	7177	6584	6768	7177	.873	.877	.885	2.669	1.942
108	125.8	128.9	134.8	.959	16.0	4890	5076	5394	5765	5850	6017	6343	5850	6017	6343	.840	.844	.852	2.519	1.825
109	108.9	111.1	115.0	.962	12.5	3500	3631	5000	4117	4151	4271	4446	4151	4271	4446	.843	.847	.855	2.273	1.580
110	68.1	70.4	71.1	.888	7.76	2100	2197	2246	1704	1721	1790	1817	1721	1790	1817	1.220	1.225	1.234	2.253	1.210
111	124.8	125.6	144.1	0.941	16.6	5380	5559	6405	7992	7877	7984	9232	4650	4701	5450	1.157	1.182	1.175	2.650	1.915
112	122.8	121.3	141.8	.957	15.9	4930	5089	5864	7615	7557	7617	8857	4388	4425	5143	1.124	1.148	1.141	2.563	1.852
113	117.7	115.6	135.5	.973	14.1	4030	4119	4777	6728	6543	6556	7642	3517	3524	4108	1.147	1.169	1.163	2.369	1.689
114	101.0	99.5	116.2	.998	10.2	2590	2445	2822	4668	----	----	----	----	----	----	----	----	----	1.968	1.333
115	63.9	62.7	73.6	1.016	5.09	852	865	1008	1677	1632	1631	1791	----	----	----	----	----	----	1.574	.876
116	82.5	85.0	143.7	0.972	11.1	3500	3485	6260	5251	5203	5271	9199	3045	3085	5384	1.149	1.129	1.186	2.873	1.907
117	80.8	83.4	141.1	.962	10.6	3290	3279	5913	5056	4970	5040	8602	2857	2897	5060	1.152	1.132	1.169	2.593	1.845
118	77.2	79.5	134.7	.971	9.25	2665	2651	4790	4447	4331	4363	7670	2320	2346	4109	1.149	1.129	1.166	2.379	1.683
119	66.7	69.4	117.2	1.006	6.77	1615	1619	2914	3116	----	----	----	----	----	----	----	----	----	2.010	1.329
120	42.3	43.6	73.9	1.009	3.39	579	572	1035	1137	1020	1029	1601	----	----	----	----	----	----	1.580	.872
121	82.9	83.9	142.4	0.984	11.3	3580	3718	6407	6169	6073	6226	10642	3065	3131	5355	1.172	1.187	1.197	2.743	1.923
122	82.3	84.5	142.2	.990	10.8	3510	3487	5951	5961	5788	6020	10204	2778	2889	4896	1.192	1.207	1.216	2.639	1.870
123	78.4	82.1	136.2	.981	9.53	2770	2991	4998	5379	4923	5238	8719	2030	2180	3595	1.365	1.385	1.391	2.432	1.715
124	67.7	70.0	117.7	.992	6.71	1573	1656	2820	3871	3735	3899	6592	1246	1301	2199	1.262	1.275	1.282	1.972	1.520
125	43.1	44.3	75.6	.995	2.84	309	320	557	1441	1297	1340	2310	----	----	----	----	----	----	1.304	.724
126	54.6	56.9	144.6	.964	7.32	2590	2707	8006	3898	3738	3895	10687	2391	2491	6856	1.083	1.088	1.171	3.082	2.108
127	54.1	55.7	142.4	.967	6.76	2200	2276	6774	3386	3395	3507	9669	2071	2139	5898	1.062	1.064	1.148	2.827	1.976
128	51.7	55.1	142.3	.934	9.62	2300	2159	6517	3317	3224	3224	9001	1893	1805	5285	1.215	1.141	1.233	2.687	1.901
129	50.8	56.1	140.8	.941	6.59	2095	2037	6071	3120	3167	3253	8962	1854	1904	5256	1.130	1.070	1.155	2.610	1.76
130	50.6	53.5	138.7	.997	2.59	2100	1950	5928	3133	3046	3018	8471	1752	1738	4872	1.199	1.124	1.217	2.597	1.832
131	48.7	51.6	135.3	.953	5.88	1750	1673	5021	2828	2789	2806	7795	1537	1546	4296	1.144	1.082	1.169	2.429	1.72
132	48.4	51.6	133.5	.980	2.50	1716	1613	4873	2766	2687	2687	7538	1454	1454	4084	1.182	1.110	1.200	2.405	1.665
133	50.6	52.3	133.4	.972	5.39	1673	1607	4770	2729	2688	2790	7877	1449	1504	4138	1.065	1.068	1.153	2.409	1.682
134	45.4	45.6	117.1	1.006	4.41	1069	1003	3003	2051	----	----	----	----	----	----	----	----	----	2.040	1.348
135	24.9	26.3	68.1	.666	1.89	405	379	1150	670	684	680	1907	49	49	137	8.265	7.786	8.421	1.600	.884
136	34.8	35.6	145.7	0.988	4.83	1686	1730	6170	2362	2304	2382	10439	1438	1487	6516	1.159	1.164	1.254	3.153	2.084
137	34.3	34.4	141.2	.989	4.38	1432	1446	6906	2185	2120	2135	9445	1275	1284	5660	1.123	1.126	1.215	2.885	1.937
138	33.9	35.0	142.4	.891	42.3	1350	1379	6530	2113	2073	2143	9413	1229	1271	5561	1.082	1.086	1.170	2.811	1.925
139	31.8	33.8	139.8	.973	4.42	1437	1360	6570	2077	2053	2059	9204	1230	1234	5514	1.168	1.02	1.191	2.786	1.900
140	31.5	32.6	137.4	.979	4.40	1420	1311	6431	2040	2059	2020	9152	1255	1231	5578	1.131	1.064	1.152	2.792	1.897
141	31.6	34.1	140.7	.995	4.29	1335	1285	6162	2026	1985	2023	9006	1162	1185	5277	1.149	1.085	1.172	2.717	1.868
142	31.3	33.2	136.4	.956	4.19	1336	1260	6137	1972	1855	1855	8351	1050	1050	4727	1.274	1.200	1.298	2.678	1.838
143	29.3	31.8	132.0	.977	3.67	1097	1067	5130	1734	1683	1722	7725	927	948	4255	1.183	1.115	1.206	2.508	1.710
144	31.2	31.9	131.8	.969	3.41	1004	1029	4968	1702	1687	1726	7710	926	946	4227	1.085	1.087	1.174	2.487	1.680
145	26.7	27.2	113.9	.990	2.69	676	633	3109	1207	----	----	----	----	----	----	----	----	----	2.092	1.344
146	17.4	17.9	75.8	.877	1.46	312	281	1406	481	434	418	1926	----	----	----	----	----	----	1.568	.895
147	19.1	21.5	142.4	0.933	2.75	964	883	7447	1291	1259	1343	9618	763	814	5829	1.250	1.183	1.277	2.901	1.980
148	19.0	20.4	137.7	.919	2.59	882	846	5692	1208	1156	1174	8585	674	685	5004	1.309	1.236	1.338	2.748	1.855
149	18.3	19.1	129.7	.920	2.33	755	692	5530	1084	1050	1028	7583	568	576	4247	1.278	1.202	1.303	2.558	1.710
150	14.0	15.2	104.2	.866	1.51	415	377	3089	654	----	----	----	----	----	----	----	----	----	2.050	1.285
151	10.6	11.1	75.8	.895	.96	232	217	1751	324	343	341	2538	82	82	607	2.829	2.656	2.885	1.848	.944
152	14.3	15.7	138.6	.935	2.15	770	697	7773	947	836	826	8256	630	623	6229	1.222	1.108	1.248	3.024	1.965
153	14.1	15.4	133.1	.916	2.02	710	636	7010	797	802	794	7749	600	594	5797	1.183	1.072	1.209	2.881	1.870
154	13.8	14.6	126.9	.935	1.83	600	518	5735	704	697	666	6526	502	479	4700	1.195	1.080	1.220	2.659	1.703
155	13.8	14.2	119.6	.929	1.65	498	424	4520	631	605	586	5379	388	363	3450	1.284	1.167	1.311	2.404	1.50
156	10.5	11.1	98.3	.872	1.18	360	306	3498	385	385	364	3670	254	240	2421	1.417	1.273	1.444	2.242	1.352

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Continued. Inlet guide vanes open.

Run	Approximate altitude, ft	Reynolds number index, $\delta_{T,1}/\varphi\sqrt{\theta_{T,1}}$	Tail-pipe static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Equivalent ambient-air static temperature, $t_{0,e}$, °R	Engine-inlet total temperature, T_1, °R	Engine-inlet total pressure, P_1, lb/sq ft abs	Turbine-inlet total temperature, T_5, °R	Turbine-outlet total temperature, T_6, °R	Turbine-outlet total pressure, P_6, lb/sq ft abs	Tail-pipe total temperature, °R: Actual, T_7	Adjusted, T_7/θ_a	Corrected, $T_7/\theta_{T,1}$	Tail-pipe total pressure, P_7, lb/sq ft abs	Engine speed, rpm: Actual, N	Adjusted, $N/\sqrt{\theta_a}$	Corrected, $N/\sqrt{\theta_{T,1}}$
Exhaust-nozzle area, 3.686 sq ft																	
157	0	1.051	2053	0	512	503	1933	1575	1193	3171	1174	1190	1212	2988	7949	8005	8074
158		.941	2054	0	511	503	1937	1625	1145	2969	1139	1157	1175	2750	7778	7840	7800
159		.959	2060	0	509	501	1957	1427	1062	2826	1064	1085	1102	2664	7411	7485	7543
160		.970	2057	0	508	501	1978	1260	959	2514	945	966	979	2447	6657	6740	6798
161		1.000	2057	0	502	500	2024	1225	1016	2239	999	1033	1037	2221	5489	5582	5592
162		.992	2057	0	504	502	2025	1225	1019	2235	998	1028	1032	2218	5492	5574	5584
163		.985	2051	0	506	504	2037	1265	1128	2150	1114	1145	1147	2140	4593	4657	4661
164	15,000	0.889	1191	0.795	442	497	1802	1660	1171	2821	1158	1218	1209	2418	7926	8132	8099
165		.899	1190	.795	441	497	1804	1500	1130	2755	1120	1160	1169	2360	7790	8000	7960
166		.892	1178	.812	442	500	1816	1385	1031	2544	1026	1079	1085	2178	7424	7617	7564
167		.920	1265	.786	450	505	1885	1388	1030	2581	1025	1059	1054	2213	7411	7550	7513
168		.890	1201	.782	451	507	1815	1170	851	1942	853	879	873	1766	6701	6902	6780
169		.911	1193	.798	438	494	1818	863	641	1432	649	689	682	1382	5504	5669	5642
170	25,000	0.653	794	0.803	415	468	1213	1567	1181	1937	1167	1209	1294	1694	7928	8089	8347
171		.647	788	.802	418	469	1205	1503	1133	1904	1122	1160	1242	1634	7797	7930	8202
172		.635	786	.800	421	475	1188	1373	1026	1723	1022	1043	1117	1478	7407	7481	7742
173		.607	786	.800	435	488	1197	1153	849	1349	852	846	906	1221	6853	6630	6861
174		.602	788	.800	440	496	1215	867	667	908	673	658	704	881	5328	5267	5450
175	35,000	0.594	494	1.259	383	499	1208	1160	863	1314	858	881	890	1120	6687	6781	6818
176		.585	483	1.259	384	502	1205	1158	850	1283	853	875	882	1091	6653	6730	6765
177		.579	492	1.225	389	506	1201	875	626	879	640	648	687	790	5643	5678	5918
178		.429	487	.807	385	446	747	1685	1208	1274	1193	1190	1389	1093	7956	7846	8583
179		.451	491	.804	385	446	751	1620	1152	1258	1139	1136	1326	1062	7795	7785	8409
180		.452	492	.804	395	446	753	1385	1036	1141	1031	1028	1200	979	7420	7410	8004
181		.457	489	.812	380	442	754	1177	884	947	866	878	1017	821	6686	6719	7245
182		.434	491	.804	391	442	761	830	612	621	621	626	729	599	5492	5814	5951
183	45,000	0.256	293	0.821	398	449	456	----	1218	774	1201	1192	1388	884	7956	7926	8554
184		.279	332	.780	406	455	498	----	1217	814	1202	1163	1371	704	7958	7850	8499
185		.278	333	.777	405	454	496	----	1171	784	1158	1122	1393	877	7778	7680	8314
186		.278	333	.781	405	454	498	----	1062	736	1056	1023	1208	835	7384	7274	7896
187		.288	304	.802	394	445	464	----	877	576	879	877	1025	506	6685	6676	7219
188		.268	291	.830	386	439	457	----	641	401	660	662	784	388	5598	5648	6087
189	55,000	0.188	254	0.705	703	468	354	----	1293	844	1273	1174	1411	477	7958	7644	8380
190		.189	249	.719	728	469	351	----	1230	526	1212	1121	1342	461	7786	7487	8191
191		.189	250	.719	720	470	349	----	1121	482	1109	1020	1224	423	7386	7066	7768
192		.189	255	.893	706	472	352	----	905	406	903	823	993	372	6670	6368	6995
193		.189	249	.719	722	478	348	----	793	453	797	730	877	411	6252	5984	6558
194		.158	259	.399	417	467	289	----	1353	426	1329	1153	1478	383	8008	7457	8440
195		.155	254	.388	404	465	282	----	1282	401	1214	1058	1354	367	7640	7132	8071
196		.153	254	.377	405	464	280	----	1096	362	1086	946	1213	333	7197	6718	7612
197		.152	253	.381	396	463	280	----	929	316	934	806	1120	305	6506	6060	6888

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(a) Concluded. Inlet guide vanes open.

Run	Air flow, lb/sec: Actual, W_a	Air flow, lb/sec: Adjusted, $\frac{W_a\sqrt{\theta_a}}{\delta_a}$	Air flow, lb/sec: Corrected, $\frac{W_a\sqrt{\theta_{T,1}}}{\delta_{T,1}}$	Combustion efficiency, η_b	Combustion parameter, W_aT_7	Fuel flow, lb/hr: Actual, W_f	Fuel flow, lb/hr: Adjusted, $\frac{W_f}{\delta_a\sqrt{\theta_a}}$	Fuel flow, lb/hr: Corrected, $\frac{W_f}{\delta_{T,1}\sqrt{\theta_{T,1}}}$	Rake jet thrust $F_{j,r}$, lb	Scale jet thrust, lb: Actual, $F_{j,s}$	Scale jet thrust, lb: Adjusted, $F_{j,s}/\delta_a$	Scale jet thrust, lb: Corrected, $\frac{F_{j,s}}{\delta_{T,1}}$	Scale net thrust, lb: Actual, $F_{n,s}$	Scale net thrust, lb: Adjusted, $F_{n,s}/\delta_a$	Scale net thrust, lb: Corrected, $\frac{F_{n,s}}{\delta_{T,1}}$	Net thrust specific fuel consumption, $\frac{lb/hr}{lb\ thrust}$: Actual, $W_f/F_{n,s}$	Net thrust specific fuel consumption: Adjusted, $\frac{W_f}{F_{n,s}\sqrt{\theta_a}}$	Net thrust specific fuel consumption: Corrected, $\frac{W_f}{F_{n,s}\sqrt{\theta_{T,1}}}$	Engine temperature ratio, T_7/T_1	Engine pressure ratio, P_6/P_1
Exhaust-nozzle area, 3.688 sq ft																				
157	133.8	137.0	144.2	0.989	15.7	4430	4599	4927	5030	4498	4637	4925	4498	4637	4925	0.985	0.993	1.001	2.334	1.640
158	131.7	134.6	141.6	.988	15.0	4070	4226	4514	4326	4213	4339	4601	4213	4339	4601	.966	.974	.982	2.267	1.533
159	127.4	129.4	135.3	.988	13.6	3440	3565	3785	3789	3694	3789	3992	3694	3789	3992	.932	.941	.948	2.124	1.444
160	110.4	112.3	116.1	.967	10.4	2440	2538	2660	2563	2554	2628	2735	2554	2628	2735	.956	.968	.974	1.886	1.273
161	70.7	71.5	72.5	.983	7.06	1715	1795	1826	1131	1125	1158	1176	1125	1158	1176	1.525	1.550	1.554	1.990	1.104
162	71.5	72.5	73.5	.979	7.14	1715	1791	1822	1123	1114	1146	1164	1114	1146	1164	1.540	1.547	1.560	1.988	1.103
163	48.2	49.1	49.4	.961	5.37	1462	1530	1542	604	588	607	611	588	607	611	2.490	2.520	2.525	2.210	1.057
164	126.2	123.3	145.0	0.981	14.6	4110	4225	4931	6329	5939	5951	6972	2733	2738	3209	1.504	1.543	1.537	2.330	1.565
165	124.3	121.4	142.7	.965	13.9	3840	3956	4605	6033	5742	5759	6735	2579	2587	3025	1.489	1.529	1.522	2.254	1.526
166	119.6	118.1	136.7	.966	12.3	3080	3201	3656	5287	4877	4940	5682	1765	1788	2056	1.745	1.790	1.778	2.052	1.401
167	122.7	114.8	136.0	.995	12.6	3040	2936	3461	5221	4925	4682	5531	1810	1721	2033	1.680	1.707	1.705	2.030	1.369
168	102.4	100.2	118.0	1.001	8.73	1666	1600	1965	3284	3015	2995	3518	393	390	458	4.239	4.303	4.289	1.682	1.070
169	73.9	71.7	84.1	1.000	4.79	548	561	651	1336	1227	1227	1431	----	----	----		-----	-----	1.314	.789
170	89.0	86.4	147.4	0.998	10.4	3000	3018	5515	4628	4401	4351	7680	2184	2159	3811	1.374	1.399	1.447	2.494	1.627
171	86.2	84.4	144.2	.974	9.68	2780	2816	5144	4311	4117	4101	7242	1969	1962	3463	1.412	1.436	1.485	2.392	1.503
172	83.0	82.1	140.3	.964	8.49	2240	2260	4137	3708	3491	3486	6165	1414	1412	2497	1.584	1.600	1.656	2.152	1.438
173	70.7	70.9	121.2	.977	6.05	1238	1232	2257	2433	2227	2224	3937	434	433	767	2.853	2.843	2.942	1.746	1.127
174	42.2	42.1	72.0	.955	2.84	363	354	648	685	625	616	1090	----	----	----	-----	-----	-----	1.357	.7486
175	68.8	70.7	118.2	1.032	5.89	1110	1173	1983	3203	2960	3084	5186	433	451	759	2.564	2.600	2.615	1.715	1.088
176	67.5	70.1	118.5	.994	5.75	1121	1196	2002	3111	2893	3046	5080	400	421	702	2.803	2.839	2.850	1.699	1.065
177	52.4	53.9	91.2	.913	3.35	354	389	632	1646	1413	1462	2490	----	----	----	-----	-----	-----	1.265	.732
178	55.7	57.1	146.3	.990	6.65	2030	2074	8204	3018	2904	2976	8238	1547	1583	4303	1.312	1.310	1.415	2.676	1.705
179	55.5	56.4	145.0	.982	6.32	1870	1894	5685	2874	2746	2784	7738	1395	1415	3931	1.341	1.339	1.447	2.554	1.648
180	54.3	55.1	141.6	.991	5.60	1532	1548	4644	2536	2433	2462	6857	1110	1123	3119	1.380	1.378	1.409	2.312	1.515
181	49.7	50.3	128.7	1.004	4.30	980	1003	2980	1860	1751	1783	4913	537	547	1507	1.825	1.834	1.978	1.959	1.256
182	35.0	35.3	90.9	.958	2.17	304	313	938	699	686	698	1933	----	----	----	-----	-----	-----	1.405	.827
183	----	----	-----	----	----	1270	1330	6358	----	1756	1875	8143	916	963	4250	1.386	1.381	1.490	2.675	1.697
184	----	----	-----	----	----	----	----	----	----	1760	1833	7500	920	854	3930	-----	-----	-----	2.65	1.641
185	----	----	-----	----	----	----	----	----	----	1709	1581	7291	883	798	3684	-----	-----	-----	2.55	1.581
186	----	----	-----	----	----	----	----	----	----	1501	1380	6378	669	618	2843	-----	-----	-----	2.33	1.478
187	----	----	-----	----	----	650	658	3201	----	1051	1065	4793	343	348	1864	1.895	1.896	2.046	1.975	1.241
188	----	----	-----	----	----	252	269	1267	----	489	517	2264	----	----	----	-----	-----	-----	1.481	.878
189	----	----	-----	----	----	----	----	----	----	1069	824	6557	582	448	3482	-----	-----	-----	2.72	1.538
190	----	----	-----	----	----	----	----	----	----	1059	812	6377	548	420	3300	-----	-----	-----	2.59	1.497
191	----	----	-----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	2.37	1.378
192	----	----	-----	----	----	----	----	----	----	636	476	3627	223	167	1342	-----	-----	-----	1.92	1.152
193	----	----	-----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	1.70	1.300
194	----	----	-----	----	----	----	----	----	----	706	821	5169	458	413	3352	-----	-----	-----	2.65	1.471
195	----	----	-----	----	----	----	----	----	----	611	459	4591	393	359	2953	-----	-----	-----	2.61	1.424
196	----	----	-----	----	----	----	----	----	----	493	371	3723	290	284	740	-----	-----	-----	2.35	1.292
197	----	----	-----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	2.01	1.130

TABLE I. - CONTINUED. ENGINE PERFORMANCE DATA.

(b) Inlet guide vanes closed.

Run	Approximate altitude, ft	Reynolds number index, $\delta_{T,1}/\varphi\sqrt{\theta_{T,1}}$	Tail-pipe static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Equivalent ambient-air static temperature, $t_{0,e}$, °R	Engine-inlet total temperature, T_1, °R	Engine-inlet total pressure, P_1, lb/sq ft abs	Turbine-inlet total temperature, T_5, °R	Turbine-outlet total temperature, T_6, °R	Turbine-outlet total pressure, P_6, lb/sq ft abs	Tail-pipe total temperature, °R: Actual, T_7	Tail-pipe total temperature, °R: Adjusted, T_7/θ_a	Tail-pipe total temperature, °R: Corrected, $T_7/\theta_{T,1}$	Tail-pipe total pressure, P_7, lb/sq ft abs	Engine speed, rpm: Actual, N	Engine speed, rpm: Adjusted, $N/\sqrt{\theta_a}$	Engine speed, rpm: Corrected, $N/\sqrt{\theta_{T,1}}$
Exhaust-nozzle area, 2.388 sq ft																	
1	0	0.960	2048	0	521	517	1997	1507	1252	2972	1246	1241	1251	2899	7091	7078	7104
2		.848	2038	0	521	518	2000	1340	1114	2632	1108	1104	1110	2588	6019	6008	6025
3		.949	2043	0	522	520	2020	1240	1102	2580	1070	1084	1068	2357	5015	5000	5010
4		.950	2038	0	521	520	2028	1263	1151	2212	1135	1131	1133	2202	4081	4073	4077
5		.951	2034	0	520	519	2027	1253	1184	2161	1170	1168	1170	2153	3604	3600	3604
6	15,000	0.861	1164	0.821	449	509	1811	1347	1054	2285	1056	1094	1077	2228	7083	7210	7152
7		.861	1168	.813	450	509	1800	1205	938	2043	938	969	957	2000	6838	6843	6802
8		.860	1163	.819	450	510	1789	987	785	1635	769	794	783	1597	5502	5590	5550
9	35,000	0.362	500	0.798	456	514	759	1400	1098	984	1102	952	1113	958	7087	6887	7121
10		.358	486	.794	455	512	760	1243	978	866	972	842	988	845	6540	6085	6585
11		.362	485	.803	455	514	757	1107	878	769	873	758	882	752	5985	5889	6014
12		.360	497	.797	455	513	755	990	786	689	793	687	805	673	5447	5088	5479
Exhaust-nozzle area, 2.814 sq ft																	
13	0	0.948	2056	0	521	517	1985	1767	1432	3162	1421	1416	1427	3088	7945	7930	7960
14		.950	2059	0	521	517	2000	1727	1387	3136	1385	1378	1389	3056	7782	7767	7797
15		.952	2061	0	521	517	2005	1620	1303	3045	1304	1299	1309	2968	7415	7401	7429
16		.963	2058	0	521	517	2008	1450	1162	2840	1185	1160	1190	2788	6870	6857	6883
17		.965	2061	0	519	517	2027	1250	1105	2568	1078	1078	1082	2371	5032	6032	5042
18	35,000	0.400	481	0.802	418	472	750	1615	1260	1104	1265	1192	1392	1073	7945	7714	8332
19		.399	484	.802	420	474	754	1550	1230	1079	1221	1145	1337	1050	7797	7652	8168
20		.398	494	.800	423	477	753	1430	1122	1010	1122	1045	1221	984	7415	7156	7734
21		.387	496	.800	429	484	756	1243	978	914	972	893	1042	894	6735	6454	6974
22		.375	488	.798	438	495	757	917	739	651	742	666	779	638	5146	4875	5269
Exhaust-nozzle area, 2.694 sq ft																	
23	35,000	0.432	489	0.808	394	446	761	1515	1182	1045	1170	1168	1362	1012	7849	7843	8175
24		.432	499	.795	388	448	755	1450	1129	1007	1119	1113	1303	973	7780	7758	8593
25		.432	485	.798	396	446	751	1334	1027	985	1025	1020	1193	934	7409	7391	7992
26		.432	489	.790	396	446	755	1147	872	882	876	870	1020	839	6670	6648	7195
27		.419	481	.804	388	447	736	910	704	708	711	708	826	680	5582	5618	5961
Exhaust-nozzle area, 3.688 sq ft																	
28	0	0.964	2075	0	522	518	2021	1455	1138	2476	1120	1114	1122	2408	7943	7920	7951
29		.960	2080	0	521	517	2027	1420	1106	2454	1089	1065	1093	2398	7777	7762	7792
30		.969	2074	0	520	516	2022	1340	1049	2418	1038	1033	1041	2370	4403	7398	7425
31		.984	2077	0	518	515	2030	1240	980	2367	988	970	978	2322	6683	6670	6689
32		.972	2070	0	516	514	2039	1150	951	2260	941	947	950	2233	5723	5740	5751
33	35,000	0.407	487	0.809	412	466	749	1333	990	798	986	943	1098	723	7864	7788	8404
34		.399	482	.815	415	470	745	1280	944	771	943	895	1041	704	7793	7595	8189
35		.418	485	.815	403	457	747	1180	850	742	850	831	966	685	7424	7341	7912
36		.408	491	.812	413	467	757	970	711	657	717	664	797	627	6598	6444	6958
37		.408	494	.808	414	468	759	870	709	658	715	680	793	630	6634	6375	6981
38		.407	489	.813	412	487	755	867	641	607	649	621	721	567	5857	5806	6259

TABLE I. - CONCLUDED. ENGINE PERFORMANCE DATA.

(b) Concluded. Inlet guide vanes closed.

Run	Air flow, lb/sec			Combustion efficiency, η_b	Combustion parameter, $W_a T_7$	Fuel flow, lb/hr			Rake jet thrust, $F_{j,r}$, lb	Scale jet thrust, lb			Scale net thrust, lb			Net thrust specific fuel consumption, $\frac{lb/hr}{lb\ thrust}$			Engine temperature ratio, T_7/T_1	Engine pressure ratio, P_6/P_1
	Actual, W_a	Adjusted, $\frac{W_a\sqrt{\theta_a}}{\delta_a}$	Corrected, $\frac{W_a\sqrt{\theta_{T,1}}}{\delta_{T,1}}$			Actual, W_f	Adjusted, $\frac{W_f}{\delta_a\sqrt{\theta_a}}$	Corrected, $\frac{W_f}{\delta_{T,1}\sqrt{\theta_{T,1}}}$		Actual, $F_{j,s}$	Adjusted, $F_{j,s}/\delta_a$	Corrected, $\frac{F_{j,s}}{\delta_{T,1}}$	Actual, $F_{n,s}$	Adjusted, $F_{n,s}/\delta_a$	Corrected, $\frac{F_{n,s}}{\delta_{T,1}}$	Actual, $W_f/F_{n,s}$	Adjusted, $\frac{W_f}{F_{n,s}\sqrt{\theta_a}}$	Corrected, $\frac{W_f}{F_{n,s}\sqrt{\theta_{T,1}}}$		
Exhaust-nozzle area, 2.386 sq ft																				
1	91.7	94.9	97.0	0.980	11.4	3300	3402	3504	3542	3463	3577	3671	----	----	----	-----	-----	-----	2.410	1.480
2	77.4	80.5	81.8	.960	8.58	2260	2341	2394	2348	2317	2405	2451	----	----	----	-----	-----	-----	2.139	1.316
3	59.5	61.8	62.4	1.012	6.36	1534	1585	1606	1381	1337	1385	1401	----	----	----	-----	-----	-----	2.058	1.178
4	40.3	42.0	42.1	.930	4.58	1280	1328	1334	708	645	670	673	----	----	----	-----	-----	-----	2.183	1.091
5	33.5	34.9	35.0	.816	3.92	1150	1195	1201	514	483	502	504	----	----	----	-----	-----	-----	2.254	1.066
6	84.9	85.5	98.3	0.980	8.96	2270	2368	2677	3902	3743	3837	4372	1493	1530	1744	1.213	1.235	1.225	2.075	1.262
7	78.7	79.2	91.7	.956	7.38	1660	1725	1971	3124	3055	3125	3593	986	1009	1160	1.684	1.711	1.700	1.843	1.135
8	64.2	65.4	75.3	.960	4.91	800	842	954.7	1814	1716	1778	2032	21	22	25	38.09	38.70	38.42	1.500	0.914
9	35.3	37.8	97.8	0.964	3.88	1022	946	2863	1659	1647	1640	4592	734	731	2046	1.392	1.294	1.399	2.144	1.298
10	33.2	35.8	92.9	.961	3.22	750	702	2130	1363	1307	1316	3687	451	454	1272	1.663	1.547	1.674	1.890	1.156
11	29.8	32.2	82.8	1.008	2.60	498	466	1399	1036	995	1001	2781	218	219	609	2.284	2.125	2.295	1.698	1.016
12	25.5	27.4	71.0	.933	2.02	360	336	1015	732	682	683	1912	22	22	62	16.36	15.22	16.46	1.546	0.913
Exhaust-nozzle area, 2.514 sq ft																				
13	94.8	97.8	100.4	0.974	13.5	4330	4452	4602	4090	4158	4283	4412	----	----	----	-----	-----	-----	2.749	1.585
14	94.3	97.2	99.6	.978	13.1	4100	4207	4347	3960	4067	4171	4292	----	----	----	-----	-----	-----	2.675	1.568
15	93.2	95.9	98.2	.986	12.2	3620	3711	3827	3654	3728	3829	3933	----	----	----	-----	-----	-----	2.522	1.519
16	87.5	90.1	92.1	.994	10.4	2830	2903	2989	2986	3033	3118	3197	----	----	----	-----	-----	-----	2.292	1.414
17	57.5	59.3	59.9	1.048	6.20	1470	1517	1538	1306	1371	1415	1431	----	----	----	-----	-----	-----	2.085	1.178
18	38.4	40.1	103.4	0.980	4.86	1514	1490	4477	2113	2065	2094	5625	1106	1120	3117	1.370	1.350	1.437	2.680	1.472
19	38.5	40.0	103.2	.993	4.70	1405	1372	4125	2041	1761	1775	4941	801	807	2248	1.754	1.699	1.835	2.576	1.431
20	37.1	38.7	99.9	.975	4.16	1171	1139	3432	1809	1747	1761	4909	817	824	2296	1.433	1.383	1.495	2.352	1.341
21	35.6	37.3	96.2	.987	3.46	837	805	2426	1501	1463	1469	4095	+564	566	+1579	+1.484	1.422	+1.537	2.006	1.209
22	24.0	25.4	65.6	.864	1.78	322	305	921.6	585	583	583	1629	-29	-29	-81	-11.0	-10.52	-11.37	1.499	.860
Exhaust-nozzle area, 2.894 sq ft																				
23	39.5	40.3	103.2	0.977	4.62	1410	1434	4286	2,020	1773	1805	4996	807	822	2274	1.747	1.746	1.885	2.623	1.391
24	39.0	39.1	101.4	.963	4.37	1310	1303	3961	1875	1733	1730	4858	795	793	2228	1.648	1.643	1.778	2.509	1.334
25	40.2	40.5	105.0	.979	4.12	1132	1136	3441	1804	1732	1742	4801	763	768	2150	1.484	1.480	1.601	2.298	1.285
26	37.0	37.0	96.3	.992	3.24	750	747	2273	1391	1387	1384	3897	500	499	1405	1.500	1.495	1.618	1.964	1.145
27	30.7	31.8	81.8	.948	2.18	402	415	1245	875.7	847	877	2435	99	102	285	4.061	4.052	4.376	1.591	.9592
Exhaust-nozzle area, 3.688 sq ft																				
28	98.4	100.7	102.9	1.002	11.0	2840	2891	2976	2319	2321	2370	2430	----	----	----	-----	-----	-----	2.162	1.225
29	98.0	99.9	102.1	.986	10.7	2700	2741	2824	2219	2234	2272	2332	----	----	----	-----	-----	-----	2.106	1.211
30	96.2	98.2	100.3	.995	9.95	2380	2425	2497	2055	2079	2121	2175	----	----	----	-----	-----	-----	2.006	1.196
31	90.2	91.8	93.6	.977	8.73	1990	2030	2082	1703	1714	1747	1786	----	----	----	-----	-----	-----	1.880	1.161
32	75.3	76.7	77.8	.983	7.09	1533	1571	1599	1161	1147	1172	1191	----	----	----	-----	-----	-----	1.831	1.108
33	39.3	41.1	105.1	0.979	3.87	990	990	2951	1304	1294	1324	3656	312	319	881	3.173	3.103	3.348	2.116	1.063
34	39.0	41.3	105.3	.985	3.67	888	894	2650	1315	1229	1270	3490	244	252	693	3.639	3.548	3.824	2.006	1.035
35	39.0	40.6	103.6	.966	3.31	745	759	2249	1200	1133	1168	3210	161	166	456	4.627	4.575	4.931	1.860	.9933
36	36.2	37.8	96.1	.922	2.60	452	448	1332	862.0	808	817	2253	----	----	----	-----	-----	-----	1.535	.8679
37	36.3	37.6	96.1	.969	2.60	430	423	1262	858.4	824	831	2297	----	----	----	-----	-----	-----	1.526	.8682
38	33.4	34.8	88.8	.938	2.17	303	302	895	654.6	654	666	1833	----	----	----	-----	-----	-----	1.390	.8040

TABLE II. - ENGINE PERFORMANCE DATA OBTAINED AFTER ENGINE OVERHAUL.

Run	Approximate altitude, ft	Reynolds number index, $\delta_{T,1}/\sqrt{\theta_{T,1}}$	Tail-pipe static pressure, p_0, lb/sq ft abs	Flight Mach number, M_0	Equivalent ambient air static temperature, $t_{0,e}$, °R	Engine-inlet total temperature, T_1, °R	Engine-inlet total pressure, P_1, lb/sq ft abs	Turbine-inlet total temperature, T_5, °R	Turbine-outlet total temperature, T_6, °R	Turbine-outlet total pressure, P_6, lb/sq ft abs	Tail-pipe total temperature, °R: Actual, T_7	Adjusted, T_7/θ_a	Corrected, $T_7/\theta_{T,1}$	Tail-pipe total pressure, P_7, lb/sq ft abs	Engine speed, rpm: Actual, N	Adjusted, $N/\sqrt{\theta_a}$	Corrected, $N/\sqrt{\theta_{T,1}}$
								Exhaust-nozzle area, 2.388 sq ft									
1	35,000	0.470	478	0.821	358	406	739	2010	1810	2046	1815	1778	2064	1991	7975	8586	9016
2		.475	478	.819	366	415	742	2018	1812	2009	1817	1742	2023	1965	7958	8260	8900
3		.453	484	.813	383	434	747	1987	1821	1947	1800	1648	1814	1909	7943	8054	8687
4		.480	481	.819	363	412	747	----	1535	----	----	----	----	----	7763	8069	8713
5		.442	481	.820	385	437	748	1913	1547	1880	1529	1564	1816	1837	7748	7835	8444
6		.489	485	.813	360	408	749	----	1468	----	----	----	----	----	7589	7938	8580
7		.436	482	.815	388	440	745	1800	1449	1754	1437	1459	1684	1716	7424	7476	8065
8		.489	483	.824	357	406	754	1783	1392	1845	1400	1548	1789	1796	7383	7759	8324
9		.468	480	.817	362	410	744	1617	1263	1666	1265	1398	1627	1626	6992	7293	7887
10		.439	492	.799	390	440	749	1455	1146	1356	1154	1168	1361	1522	6547	6580	7110
11		.418	478	.809	399	451	738	1083	868	736	871	860	1003	719	5267	5234	5650
12	45,000	0.340	291	0.826	328	375	455	2007	1618	1329	1607	1925	2235	1296	7941	8695	9387
13		.344	298	.816	324	367	461	1920	1548	1299	1540	1868	2178	1269	7773	8558	9244
14		.334	303	.803	322	364	463	1837	1472	1262	1466	1789	2091	1234	7589	8386	9063
15		.338	293	.813	325	368	452	1737	1384	1186	1386	1678	1954	1158	7562	8098	8742
16		.341	298	.804	330	373	456	1587	1262	1108	1266	1508	1761	1078	6998	7635	8264
17		.267	297	.797	391	441	451	2017	1693	1182	1621	1629	1908	1153	7947	7963	8621
18		.281	287	.822	389	442	447	1875	1606	1165	1580	1596	1855	1139	7835	7874	8490
19		.276	299	.809	388	439	460	1780	1438	1056	1422	1440	1681	1031	7365	7409	8008
20		.274	311	.792	393	442	470	1497	1192	837	1189	1189	1396	817	6619	6619	7173
21		.271	308	.793	396	446	486	1070	859	422	872	865	1015	413	5038	5019	5438
22	55,000	0.206	181	0.829	337	383	284	2037	1651	814	1640	1912	2222	791	7877	8507	9169
23		.206	182	.820	338	384	283	1890	1539	769	1520	1768	2064	752	7606	8201	8844
24		.215	194	.794	340	383	294	1797	1460	737	1437	1661	1947	720	7405	7960	8619
25		.212	190	.806	339	383	291	1620	1310	681	1294	1500	1753	665	6935	7469	8072
26		.163	175	.841	387	442	278	2067	1690	738	1660	1687	1949	722	7990	8054	8658
27		.166	177	.837	389	444	280	1975	1606	715	1584	1600	1852	696	7748	7787	8377
28		.156	178	.832	394	448	280	1833	1484	652	1486	1462	1698	636	7368	7348	7919
29		.160	188	.802	413	464	284	1510	1218	485	1209	1156	1355	470	6542	6397	6919
30		.160	194	.784	411	461	291	1227	978	286	998	976	1124	280	5502	5060	5838
31		.161	197	.409	370	382	221	1990	1653	579	1597	1696	2170	563	7651	7888	8918
32		.156	189	.417	369	382	218	1797	1486	543	1458	1531	1954	527	7258	7488	8458
33		.160	197	.409	370	382	221	1737	1372	518	1358	1442	1848	504	6988	7205	8143
34		.128	192	.438	425	441	219	2037	1686	545	1639	1516	1829	531	7814	7514	8477
35		.127	188	.466	424	442	218	1883	1544	504	1512	1401	1775	490	7435	7158	8067
36		.133	198	.439	429	445	226	1550	1274	398	1257	1182	1488	387	6536	6256	7058
37		.127	196	.434	432	448	223	1510	1251	247	1273	1138	1474	243	5485	5201	5869
								Exhaust-nozzle area, 2.514 sq ft									
38	55,000	0.180	185	0.800	369	418	282	1897	1487	707	1502	1600	1874	684	7924	8178	8851
39		.177	179	.823	366	415	279	1860	1460	677	1469	1578	1838	684	7835	8117	8742
40		.178	183	.808	367	415	281	1697	1326	542	1332	1430	1670	517	7403	7682	8279
41		.178	184	.802	368	415	281	1385	1111	510	1082	1156	1354	490	6849	6765	7324
42		.178	183	.804	367	414	280	1140	904	371	885	948	1110	359	5752	5953	6440
43		.184	190	.792	419	471	287	1980	1586	686	1583	1485	3.361	666	7930	7680	8325
44		---	186	.799	---	---	283	----	1572	659	----	----	----	639	7756	----	----
45		.168	201	.736	402	446	288	1757	1419	589	1386	1386	3.106	571	7373	7290	7954
46		.168	197	.788	406	454	291	1500	1191	469	1191	1153	2.683	474	6636	6529	7095
47		.141	198	.415	399	413	223	1953	1554	---	1548	1528	1846	---	7964	7904	8927
48		.142	198	.431	398	413	226	1867	1517	532	1482	1463	1863	507	7765	7716	8704
49		.140	193	.444	397	413	221	1740	1394	506	1379	1365	1733	486	7420	7382	8317
50		.137	188	.450	397	413	216	1523	1230	440	1211	1199	1522	424	6721	6687	7534
51		.134	186	.453	399	415	214	1297	1041	339	1029	1014	1287	327	5953	5908	6657
								Exhaust-nozzle area, 2.694 sq ft									
52	55,000	.180	174	.843	355	405	277	1817	1403	676	1422	1674	1823	651	7952	8386	9003
53		.179	175	.838	356	406	277	1737	1330	646	1357	1498	1734	622	7780	8177	8796
54		.180	180	.824	361	410	281	1579	1228	591	1229	1358	1586	564	7369	7696	8291
55		.172	173	.831	364	414	272	1337	1044	487	1036	1119	1299	457	6565	6842	7373
56		.170	180	.810	376	425	277	996	785	216	779	814	951	207	5368	5507	5984
57		.143	196	.408	392	405	222	1825	1426	502	1428	1432	1831	480	7924	7932	8971

TABLE II. - CONCLUDED. ENGINE PERFORMANCE DATA OBTAINED AFTER ENGINE OVERHAUL.

Run	Air flow, lb/sec: Actual, W_a	Air flow: Adjusted, $\frac{W_a\sqrt{\theta_a}}{\delta_a}$	Air flow: Corrected, $\frac{W_a\sqrt{\theta_{T,1}}}{\delta_{T,1}}$	Combustion efficiency, η_b	Combustion parameter, W_aT_7	Fuel flow, lb/hr: Actual, W_f	Fuel flow: Adjusted, $\frac{W_f}{\delta_a\sqrt{\theta_a}}$	Fuel flow: Corrected, $\frac{W_f}{\delta_{T,1}\sqrt{\theta_{T,1}}}$	Rake jet thrust $F_{j,r}$, lb	Scale jet thrust, lb: Actual, $F_{j,s}$	Scale jet thrust: Adjusted, $F_{j,s}/\delta_a$	Scale jet thrust: Corrected, $\frac{F_{j,s}}{\delta_{T,1}}$	Scale net thrust, lb: Actual, $F_{n,s}$	Scale net thrust: Adjusted, $F_{n,s}/\delta_a$	Scale net thrust: Corrected, $\frac{F_{n,s}}{\delta_{T,1}}$	Net thrust specific fuel consumption, $\frac{lb/hr}{lb\ thrust}$: Actual, $W_f/F_{n,s}$	Net thrust specific fuel consumption: Adjusted, $\frac{W_f}{F_{n,s}\sqrt{\theta_a}}$	Net thrust specific fuel consumption: Corrected, $\frac{W_f}{F_{n,s}\sqrt{\theta_{T,1}}}$	Engine temperature ratio, T_7/T_1	Engine pressure ratio, P_6/P_1
Exhaust-nozzle area, 2.388 sq ft																				
1	59.7	59.6	151.1	1.993	9.64	3630	3989	11750	4760	3537	3707	10186	2124	2228	6081	1.709	1.783	1.932	3.078	2.769
2	58.8	59.0	149.8	1.992	9.50	3590	3864	11450	4659	4667	4863	13310	3268	3402	9312	1.106	1.141	1.279	3.896	2.708
3	57.3	56.2	140.4	.981	9.17	3400	3548	10534	4480	2350	2428	6858	961	988	2723	3.538	3.588	3.869	3.887	3.604
4	59.6	58.2	150.4	1.085	9.18	3290	3547	10481	----	----	----	----	----	----	----	----	----	----	----	----
5	56.8	58.1	147.4	.878	8.88	3140	3288	9681	4296	2341	2431	6823	949	982	2686	3.308	3.345	3.806	3.499	2.813
6	56.3	57.3	146.1	1.001	8.86	3040	3265	9686	----	----	----	----	----	----	----	----	----	----	----	----
7	54.8	56.2	143.3	.995	7.87	2700	2809	8526	3832	2247	2329	6381	908	938	2579	2.974	2.996	3.830	3.266	2.354
8	57.9	58.8	143.6	1.009	8.10	2800	3035	8883	4148	4177	4306	11721	2805	2892	7871	1.006	1.049	1.129	3.448	2.447
9	55.4	55.2	140.1	.998	7.12	2350	2546	7520	3697	3672	3819	10443	2359	2448	6709	.9983	1.039	1.121	3.134	2.239
10	47.1	47.5	122.6	.971	5.44	1658	1686	5087	2731	1793	1819	5066	660	668	1865	2.512	2.526	2.728	2.625	1.810
11	24.8	26.0	66.4	.814	2.16	539	558	1685	831	1688	1743	4802	106	110	305	5.085	5.063	5.468	1.951	1.001
12	38.2	38.85	150.6	0.981	6.15	2450	2640	15441	3079	3182	3333	14680	2280	2412	10604	1.078	1.177	1.268	4.308	2.921
13	38.6	36.45	149.8	.979	5.98	2500	2617	12384	3030	3067	3171	14078	2200	2275	10098	1.045	1.161	1.843	4.199	2.818
14	38.7	35.57	147.9	.972	5.87	2150	2417	11733	2810	2848	2968	13163	2086	2134	9588	1.025	1.133	1.224	4.027	2.728
15	37.5	35.83	147.8	.984	5.90	1900	2186	10582	2719	2759	2879	12621	1902	1899	8905	.999	1.089	1.186	3.788	2.624
16	36.1	34.21	142.0	.945	4.57	1650	1861	9030	2438	2484	2568	11526	1681	1738	7800	.982	1.071	1.158	3.394	2.430
17	35.8	35.0	146.3	.868	5.48	2100	2182	10689	2653	2705	2807	12682	1891	1861	8873	1.111	1.113	1.206	3.876	2.821
18	35.5	35.9	148.9	.938	6.51	2050	2210	10617	2616	2861	2863	12697	1831	1965	8648	1.120	1.124	1.214	3.575	2.808
19	33.0	33.0	139.7	.956	4.70	1678	1736	8378	2337	2314	2399	10644	1512	1567	6965	1.108	1.176	1.206	3.259	2.294
20	29.0	29.5	120.5	.960	3.45	1086	1096	5293	1692	1107	1129	4984	414	418	1864	2.621	2.621	2.840	2.690	1.781
21	14.0	14.1	59.0	.819	1.22	343	349	1680	403	1090	1020	4623	685	685	3102	5.022	5.003	5.417	1.966	.9066
22	22.9	22.35	146.5	0.958	3.75	1650	1785	13443	1882	1904	2009	14187	1373	1449	10930	1.129	1.219	1.314	4.262	2.866
23	23.2	22.00	149.4	.957	3.53	1400	1585	12169	1789	1760	1846	13180	1296	1388	9187	1.142	1.251	1.328	3.958	2.717
24	22.9	20.94	141.4	.947	3.29	1250	1393	10471	1683	1648	1822	11661	1138	1120	8190	1.098	1.180	1.278	3.759	2.607
25	22.3	20.80	139.3	.937	2.88	1050	1134	8887	1508	1460	1457	10643	946	961	6878	1.110	1.196	1.292	3.379	2.340
26	20.7	22.4	148.1	.907	3.43	1400	1540	11648	1868	1730	1881	13169	1210	1320	9211	1.157	1.166	1.264	3.756	2.656
27	20.3	21.8	141.7	.911	3.21	1270	1377	10377	1578	1636	1766	12562	1188	1215	8509	1.125	1.134	1.220	3.468	2.554
28	19.3	20.6	136.7	.903	2.45	1079	1156	8778	1406	1447	1557	10935	981	1031	7262	1.123	1.122	1.209	3.272	2.329
29	16.7	16.4	110.3	.892	1.69	629	632	4957	905	671	693	5000	283	291	2109	2.223	2.174	2.381	2.406	1.708
30	8.9	8.9	60.8	.718	.89	315	313	2450	304	192	188	1396	----	----	----	----	----	----	2.165	.9897
31	17.1	16.1	140.4	.905	2.75	1150	1150	12635	1211	1207	1170	11557	1009	971	9594	1.148	1.184	1.338	4.161	2.820
32	16.3	16.0	136.8	.932	2.34	911	950	10548	1079	1083	1105	10856	694	904	6881	1.019	1.062	1.108	3.764	2.549
33	16.1	15.2	138.6	.976	2.19	811	811	9052	999	986	958	9441	792	768	7583	1.024	1.068	1.194	3.566	2.344
34	16.8	16.4	140.9	.835	2.69	1017	973	10680	1120	1188	1150	11169	938	853	9063	1.084	1.042	1.176	3.717	2.489
35	14.9	15.7	135.4	.891	2.25	888	888	9340	986	1042	1058	10114	824	837	7998	1.078	1.078	1.188	3.421	2.312
36	12.5	12.6	106.4	.801	2.85	540	489	5460	840	665	641	6296	492	475	4807	1.098	1.098	1.188	2.826	1.761
37	5.7	5.8	49.9	.719	.72	318	296	3248	171	179	174	1699	101	98	958	3.149	3.149	3.389	2.842	1.108
Exhaust-nozzle area, 2.514 sq ft																				
38	21.9	21.9	148.9	0.902	3.20	1308	1383	10863	1827	1599	1650	11899	1087	1122	8157	1.203	1.241	1.344	3.611	2.508
39	22.0	22.6	148.3	.911	3.23	1258	1390	10870	1818	1550	1654	11756	1023	1089	7754	1.230	1.274	1.378	3.540	2.427
40	21.5	21.4	144.4	.961	2.86	1012	1094	8829	1371	1388	1428	10501	862	900	6481	1.174	1.215	1.313	3.217	1.929
41	18.1	18.2	122.1	.874	1.86	858	708	5841	1014	972	1009	7519	847	668	4119	1.203	1.243	1.346	2.607	1.815
42	15.2	15.3	102.6	.851	1.34	408	438	3427	649	504	620	4480	238	248	1789	1.702	1.762	1.906	2.138	1.395
43	20.4	21.5	142.9	.913	3.22	1860	1917	8675	1833	1418	1495	10458	918	921	6754	1.385	1.382	1.433	3.341	2.390
44	----	----	----	----	----	1169	----	----	----	1281	----	3354	----	----	----	----	----	----	----	2.379
45	19.9	19.3	135.6	.963	2.76	985	897	7589	1300	1331	1265	9779	884	840	6496	1.080	1.088	1.165	3.108	2.045
46	17.1	16.9	118.6	.939	2.04	680	690	5085	961	986	956	7189	589	584	4252	1.117	1.099	1.194	2.893	1.880
47	17.0	16.5	143.5	.948	2.82	1012	998	10764	----	1093	1054	10671	879	848	8341	1.151	1.142	1.290	3.748	----
48	16.8	16.1	138.3	.924	2.46	962	913	10035	1078	1046	1009	9837	829	800	7798	1.148	1.141	1.287	3.588	2.384
49	16.0	15.9	136.6	.907	2.21	832	819	8930	991	969	959	9278	753	745	7210	1.105	1.089	1.239	3.339	2.285
50	14.8	15.2	129.8	.938	1.80	606	615	6678	813	748	780	7327	545	564	5558	1.118	1.110	1.251	2.932	2.037
51	12.0	12.4	106.9	.863	1.23	405	413	4478	611	213	219	2108	48	48	475	8.438	8.378	9.438	2.480	1.184
Exhaust-nozzle area, 2.694 sq ft																				
52	22.4	23.4	151.0	0.902	3.18	1258	1450	10707	1621	1581	1747	12164	1080	1153	8021	1.179	1.240	1.356	3.511	2.440
53	23.7	23.6	153.5	.949	3.08	1115	1278	9830	1583	1517	1668	11568	970	1058	7410	1.149	1.208	1.339	3.342	2.332
54	22.0	22.3	147.1	.938	2.70	982	1081	7811	1398	1351	1412	10022	807	858	6077	1.143	1.193	1.288	2.996	2.103
55	18.9	20.0	131.0	.958	1.36	823	715	5426	1027	896	768	5414	240	265	1887	2.696	2.697	2.907	2.502	1.780
56	11.1	11.8	77.0	.668	.87	389	357	2777	211	337	388	2574	70	74	636	4.700	4.803	5.194	1.832	.780
57	17.1	16.5	143.8	.998	2.44	996	896	10014	1060	1049	1012	9999	828	808	7397	1.108	1.107	1.262	3.526	2.261

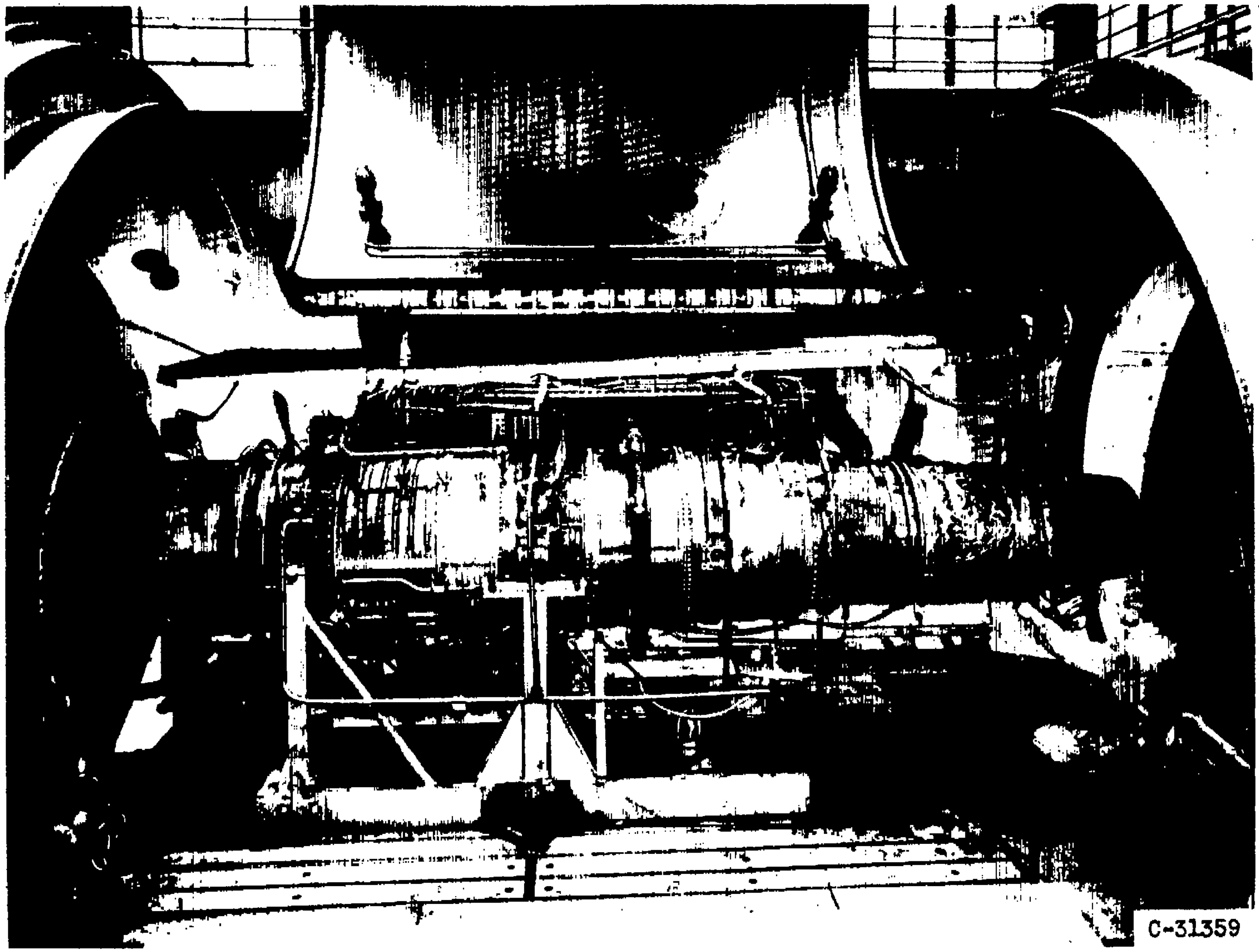


Figure 1. - Installation of YJ73-GE-3 turbojet engine in altitude chamber.

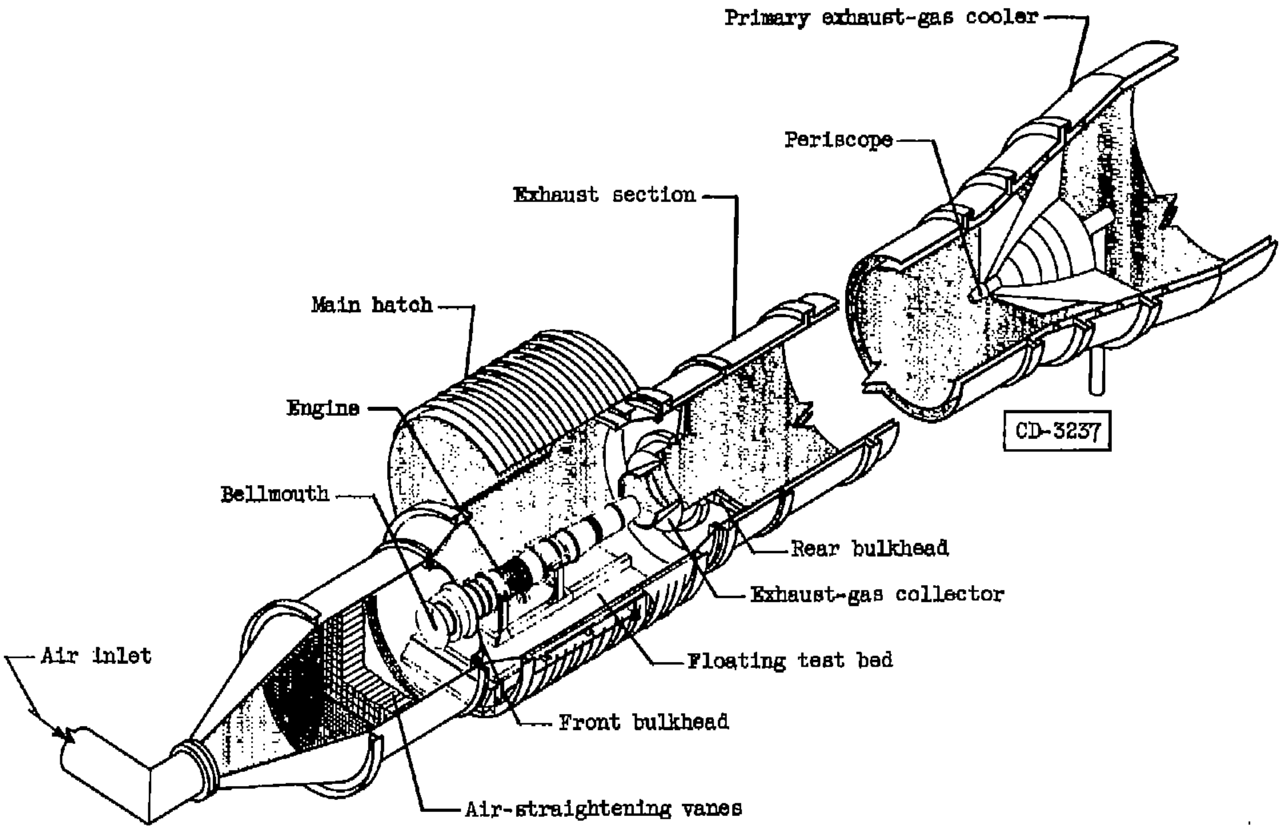
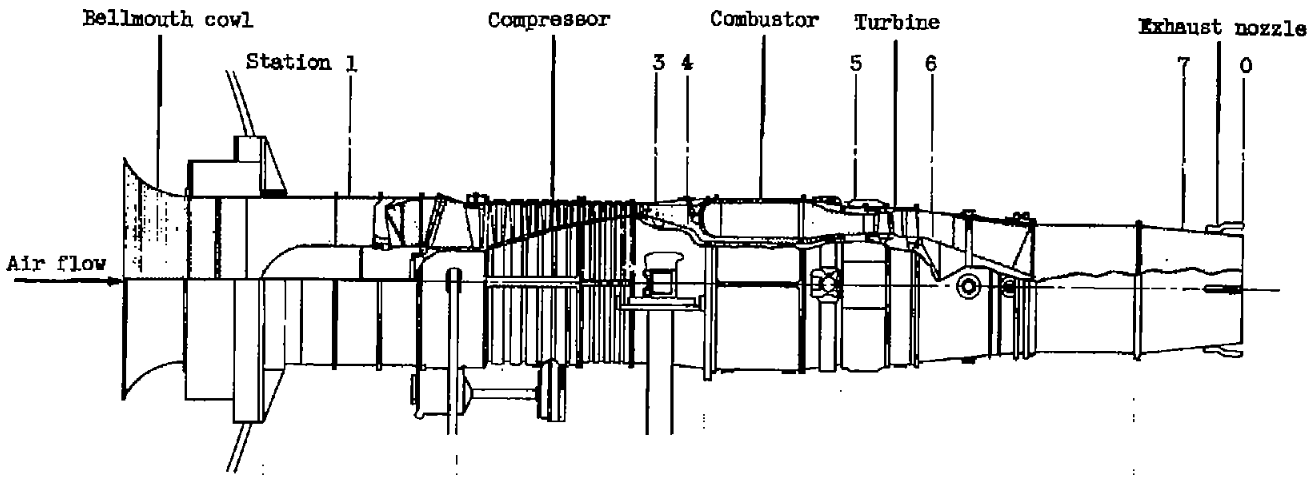
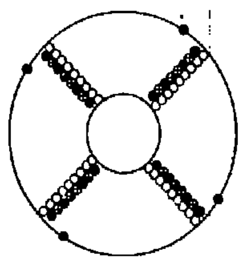


Figure 2. - Schematic diagram of altitude test chamber with engine installed in test section.





Station	Location	Total-pressure tubes	Static-pressure tubes	Wall static-pressure orifices	Thermo-couples
0	Tail-pipe region	0	4	0	0
1	Engine inlet	36	16	4	16
3	Compressor outlet	20	4	5	6
4	Combustor inlet	5	0	0	0
5	Turbine inlet	9	0	0	0
6	Turbine outlet	24	0	8	20
7	Exhaust nozzle	28	16	4	20

CD-3657

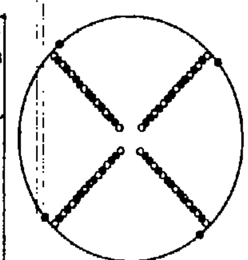
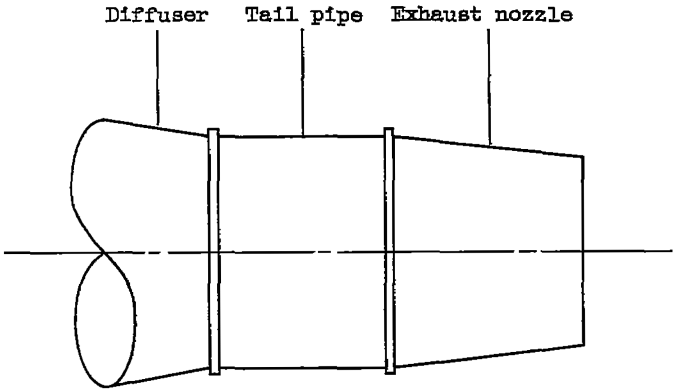
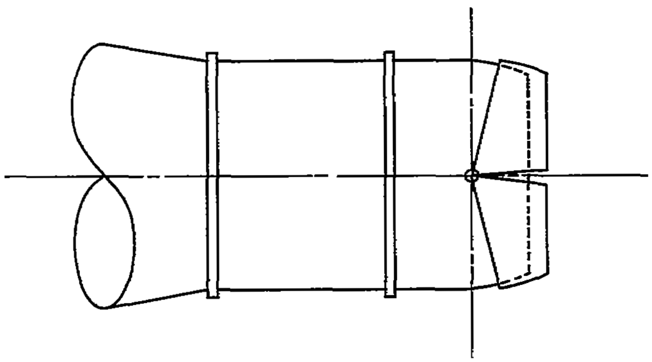


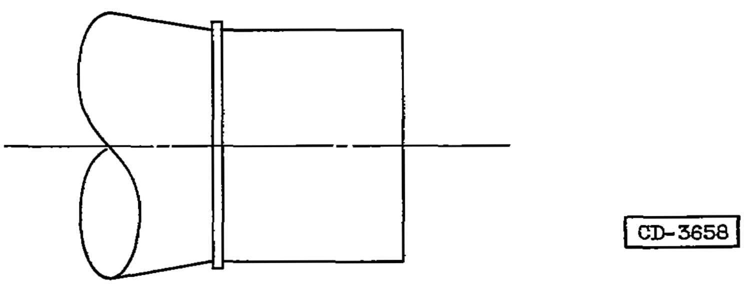
Figure 3. - Cross section of turbojet engine installation showing instrumentation stations.



(a) Fixed conical nozzle; area, 2.388 square feet.

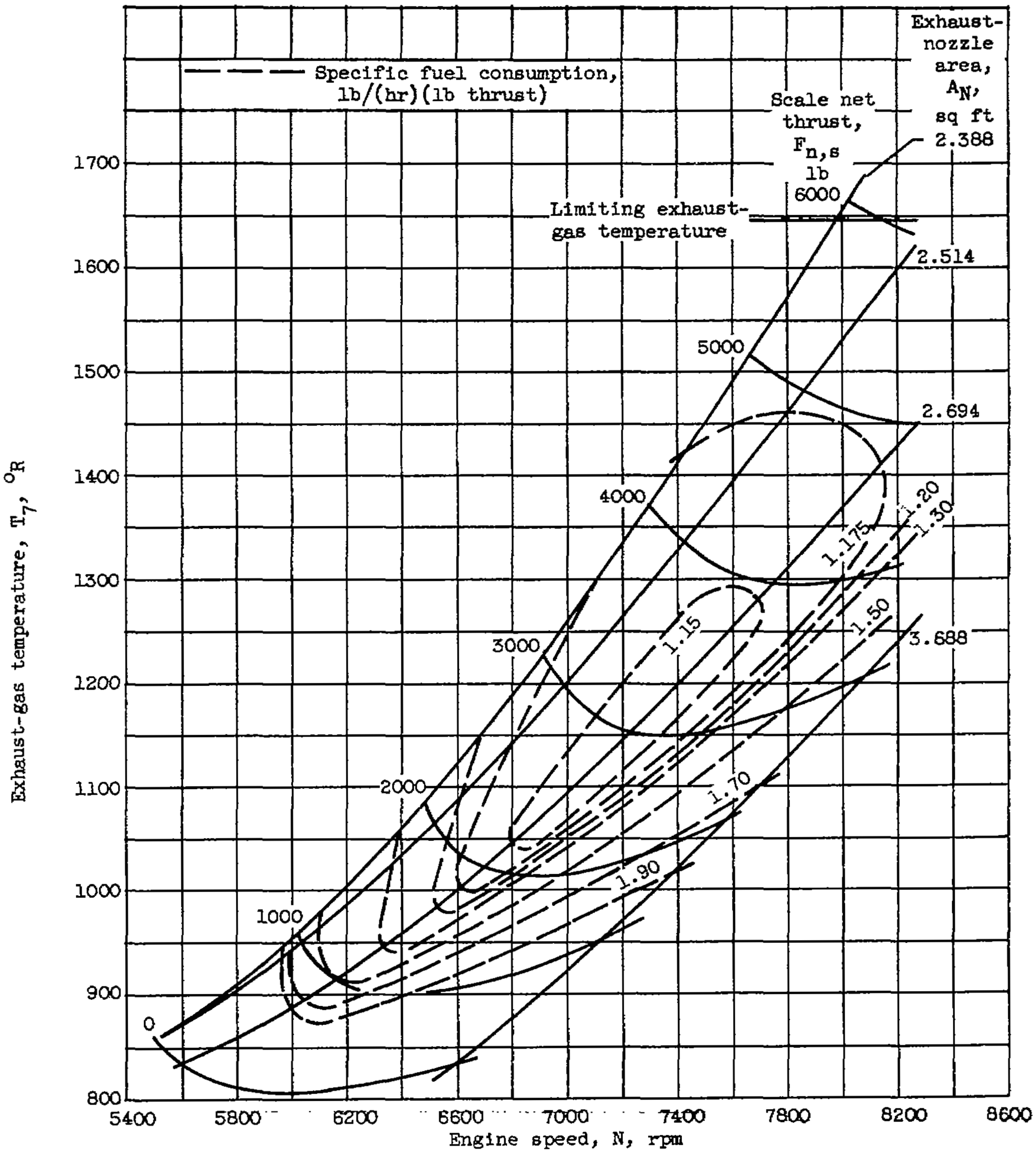


(b) Clamshell-type nozzle; area, 2.514 and 2.694 square feet (two positions).



(c) Tail pipe only; area, 3.688 square feet.

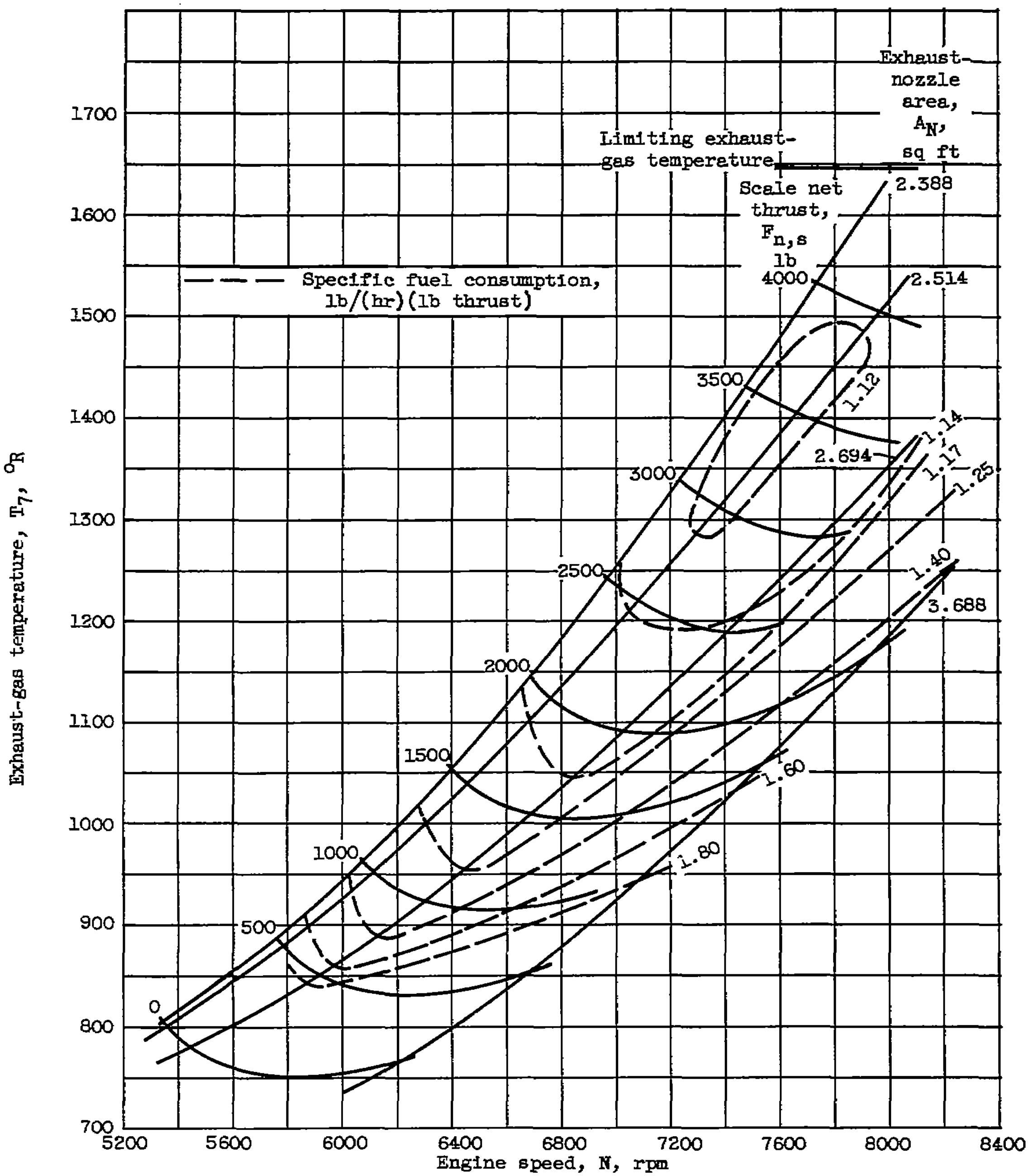
Figure 4. - Sketch of exhaust nozzles.



(a) Reynolds number index, 0.88; altitude, 15,000 feet; flight Mach number, 0.803.

Figure 5. - Engine performance maps.

3166

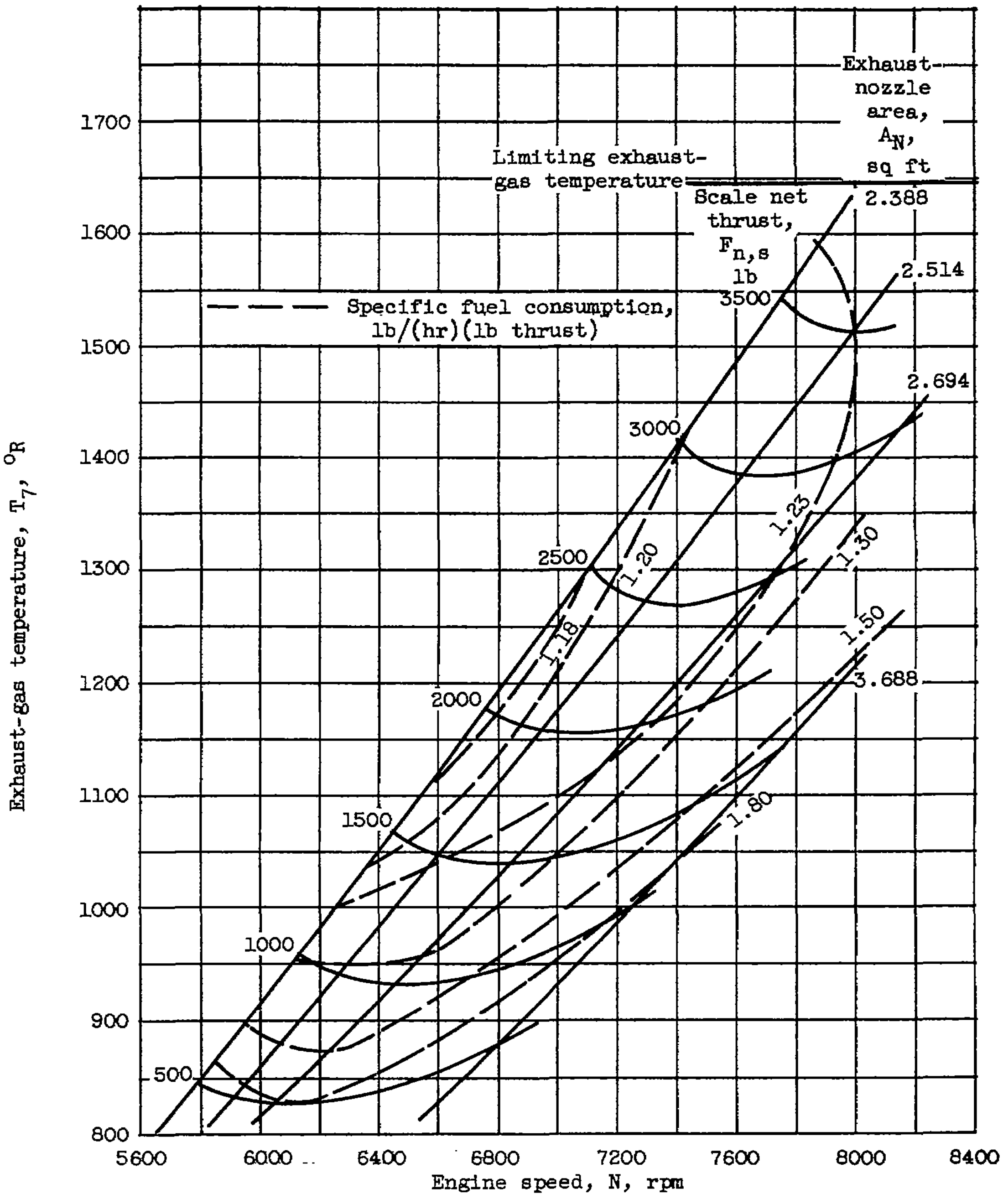


(b) Reynolds number index, 0.59; altitude, 25,000 feet; flight Mach number, 0.804.

Figure 5. - Continued. Engine performance maps.

[redacted]

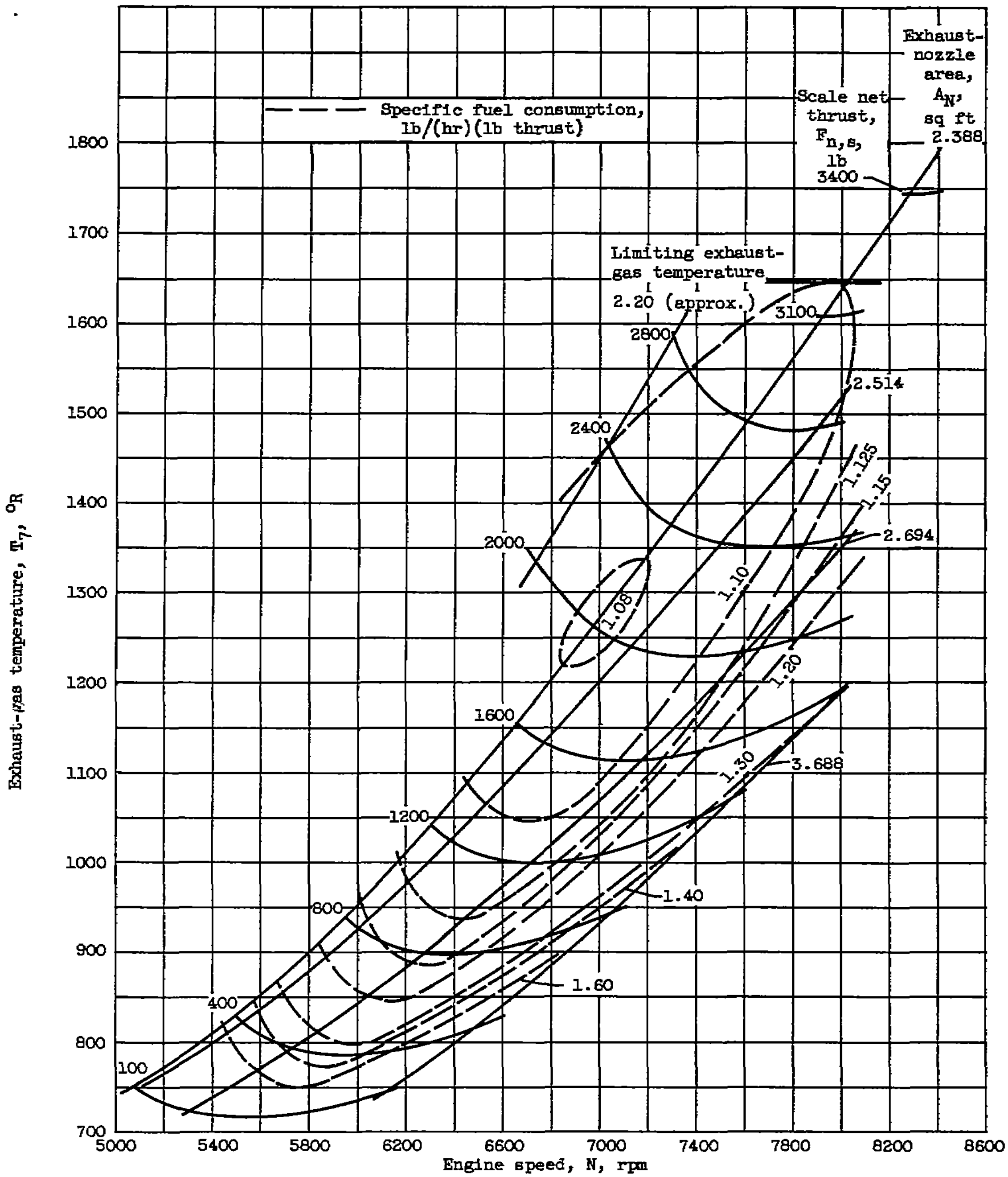
3166



(c) Reynolds number index, 0.58; altitude, 35,000 feet; flight Mach number, 1.23.

Figure 5. - Continued. Engine performance maps.

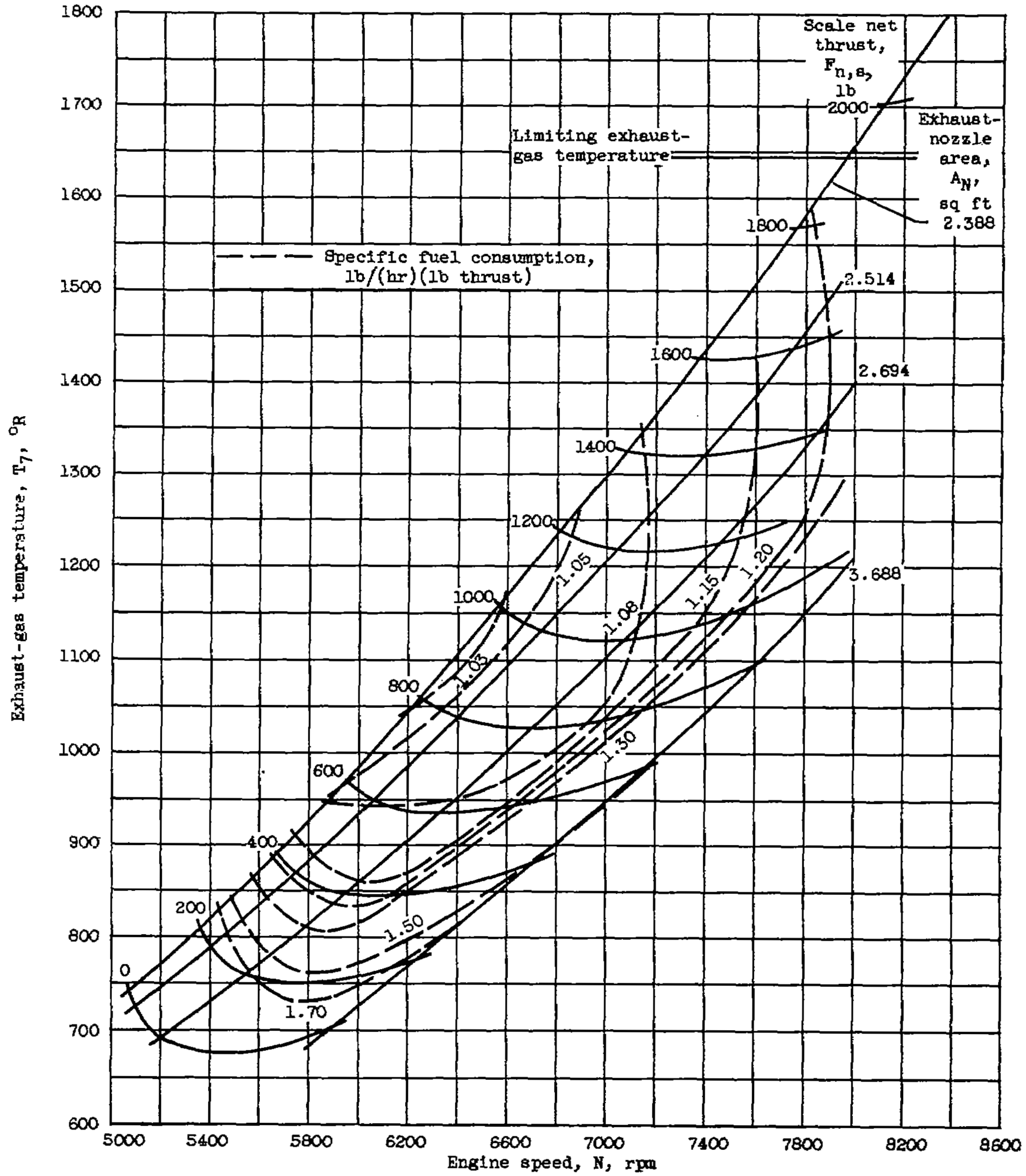
3166



(d) Reynolds number index, 0.39; altitude, 35,000 feet, flight Mach number, 0.805.

Figure 5. - Continued. Engine performance maps.

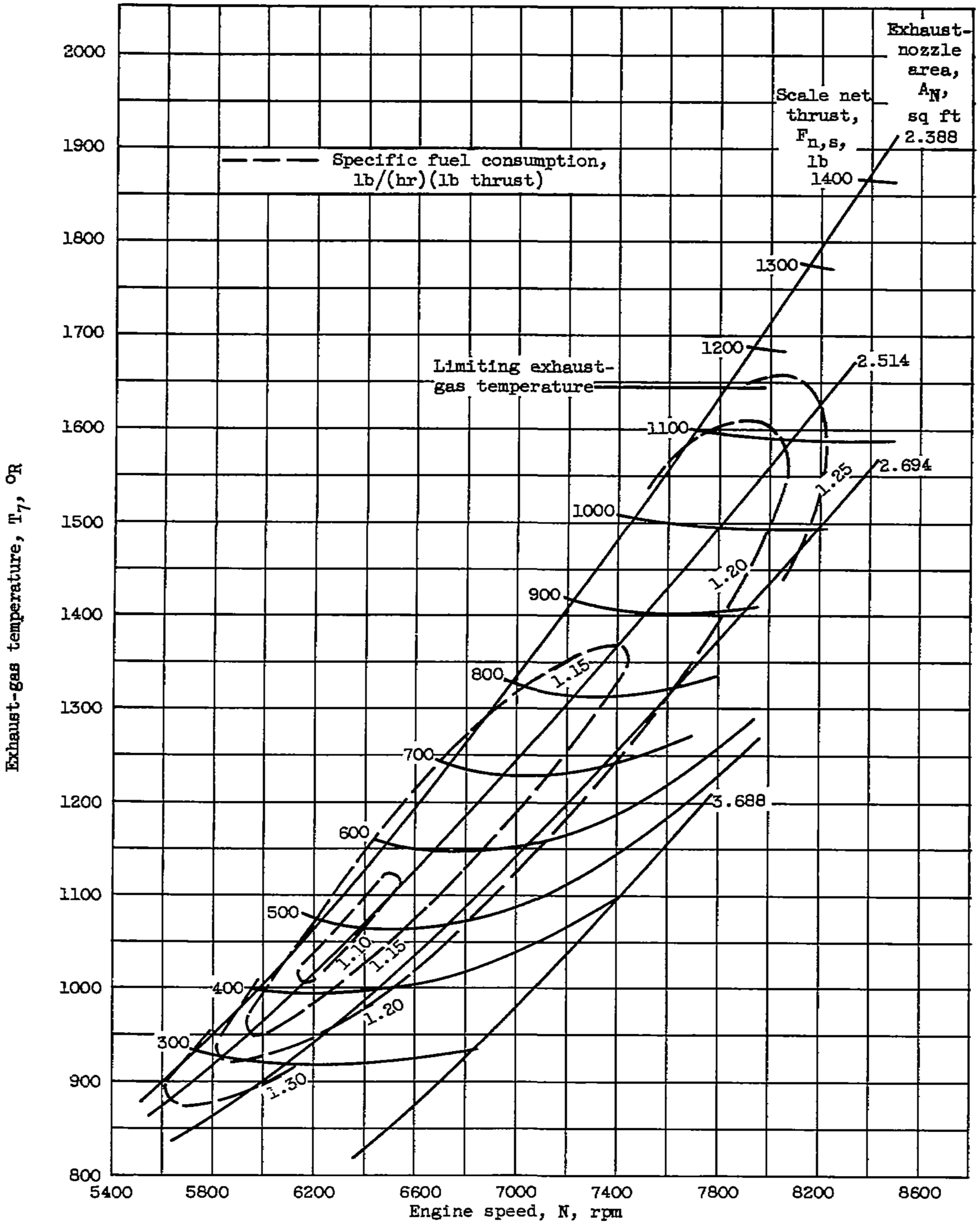
3166



(e) Reynolds number index, 0.24; altitude, 45,000 feet; flight Mach number, 0.805.

Figure 5. - Continued. Engine performance maps.

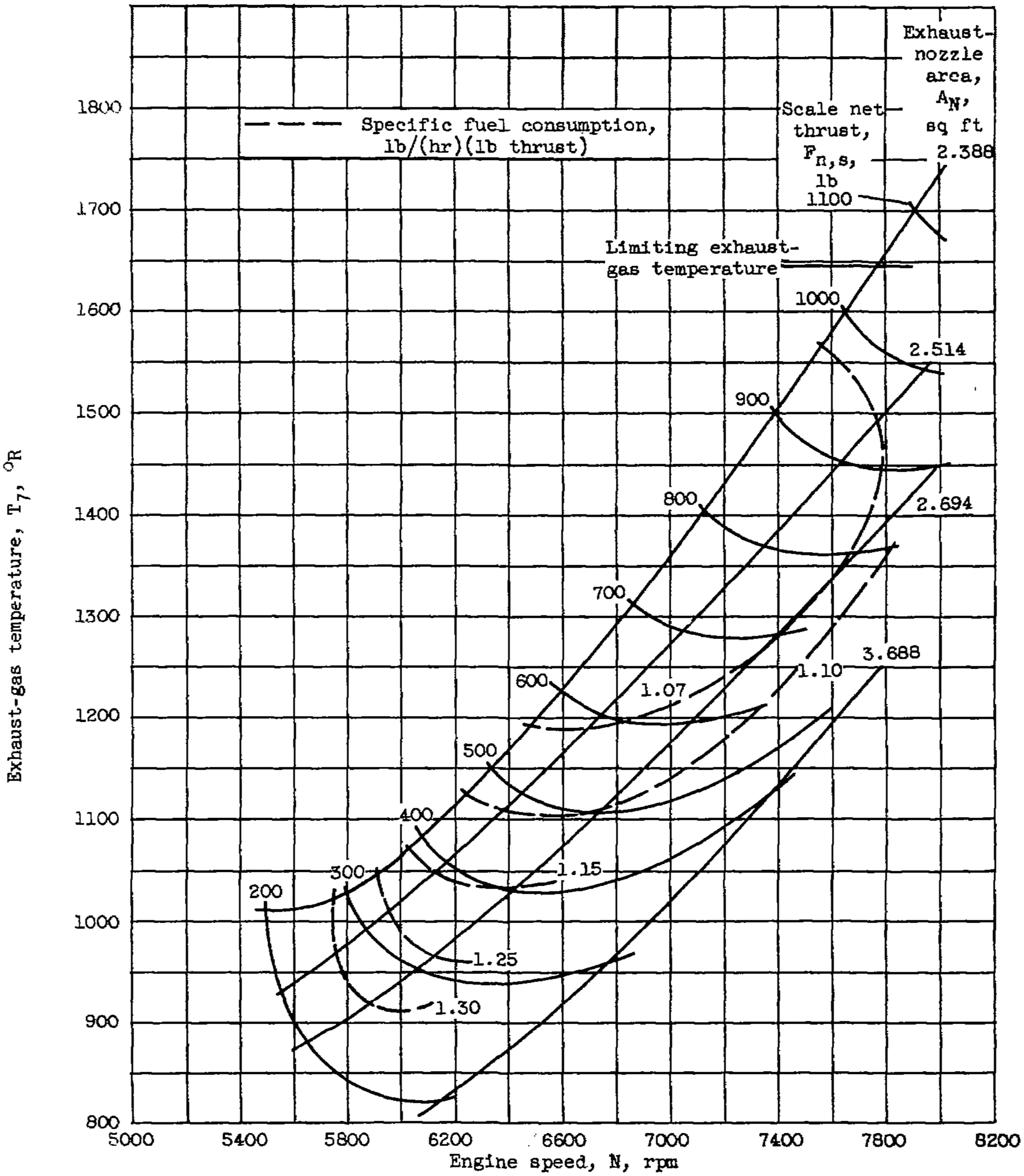
CX-7



(f) Reynolds number index, 0.15; altitude, 55,000 feet; flight Mach number, 0.79.

Figure 5. - Continued. Engine performance maps.

[redacted]



(g) Reynolds number index, 0.12; altitude, 55,000 feet; flight Mach number, 0.43.

Figure 5. - Concluded. Engine performance maps.

[redacted]

3166

CX-7 back

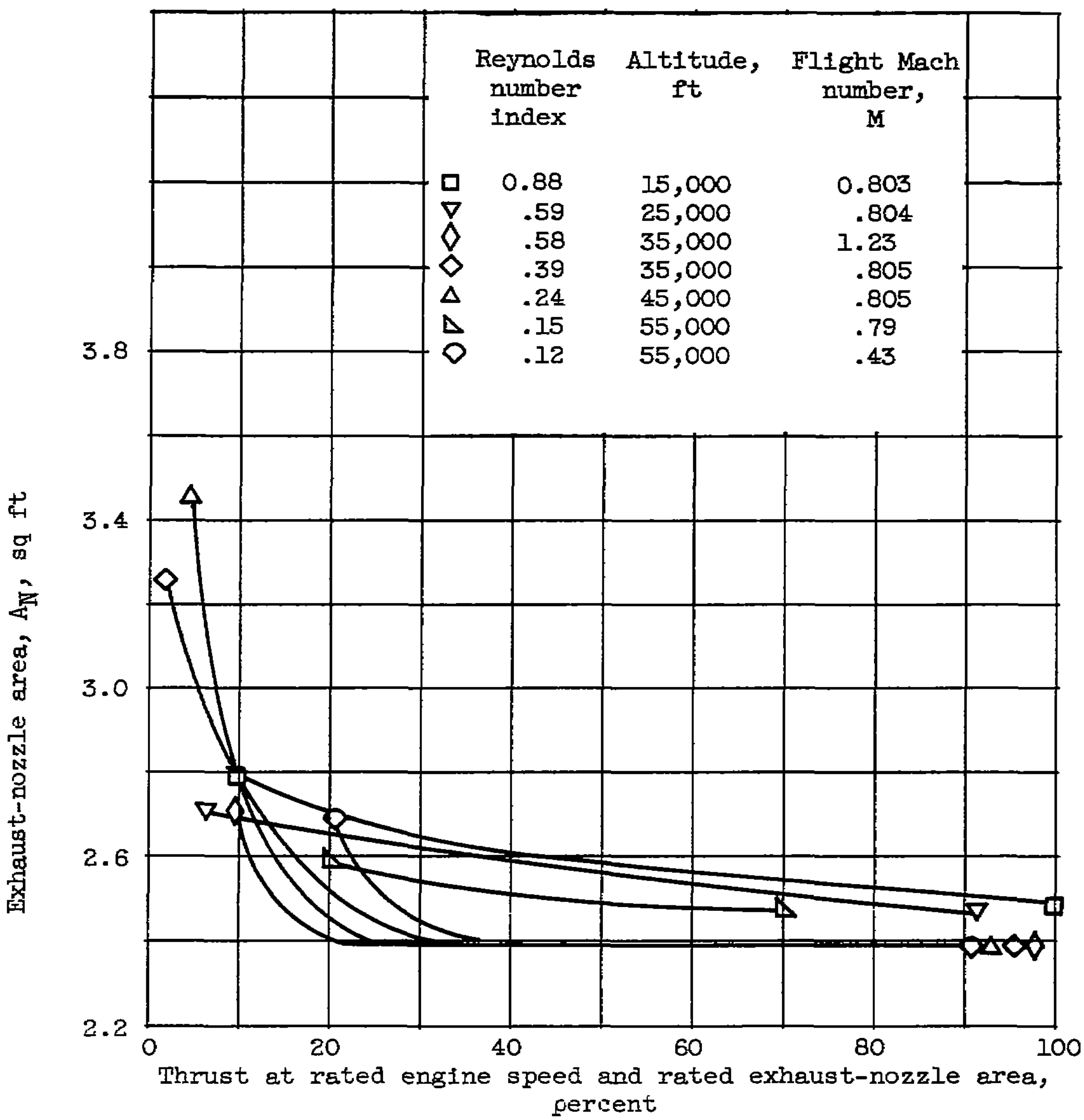
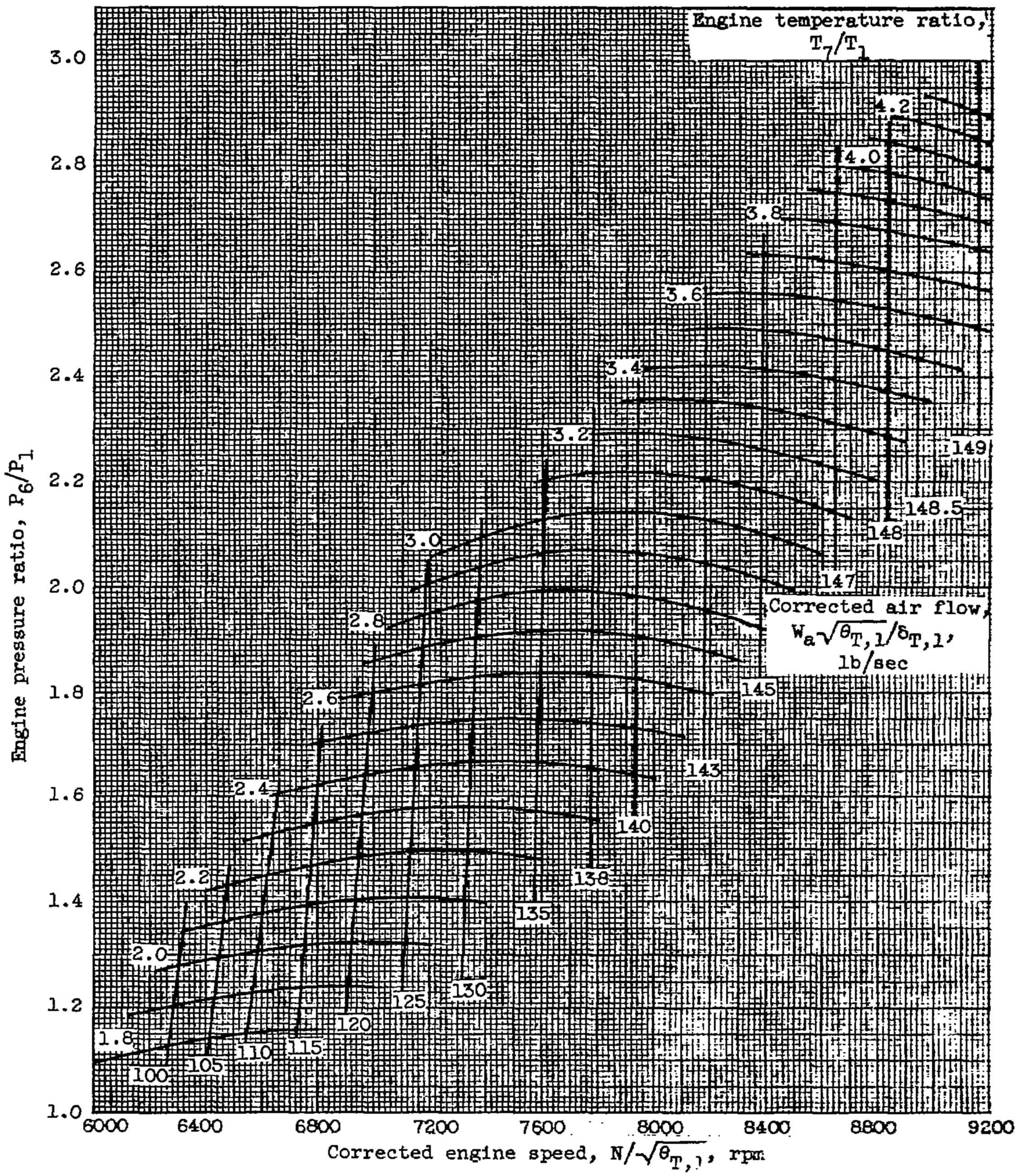


Figure 6. - Variation of exhaust-nozzle area with percent of maximum thrust for minimum specific fuel consumption.



Engine 7. - Engine pumping characteristics. Reynolds number index, 0.39; altitude, 35,000 feet; flight Mach number, 0.805.

[redacted]

3166

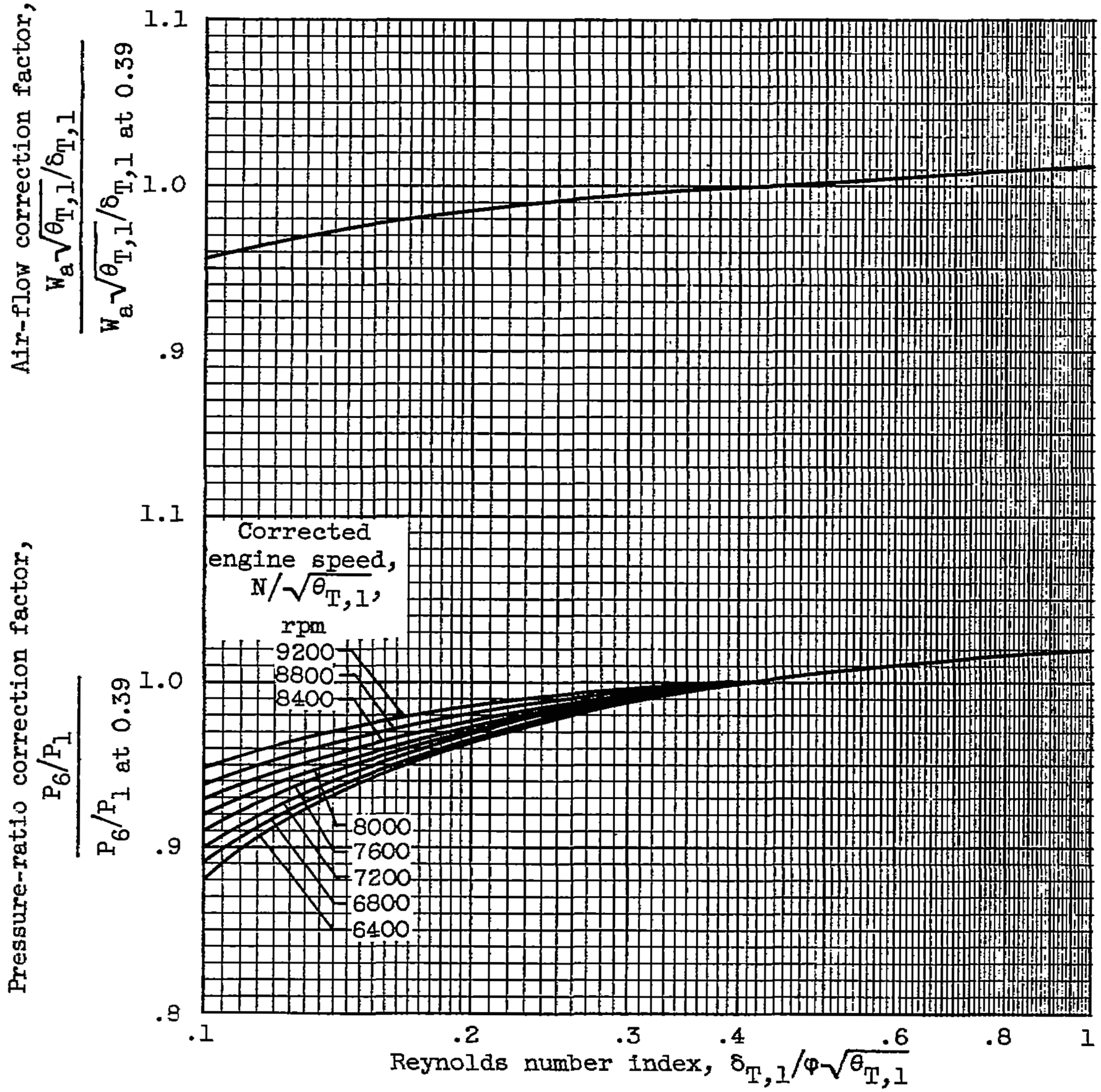


Figure 8. - Engine air-flow and pressure-ratio corrections for range of Reynolds number index.

[redacted]

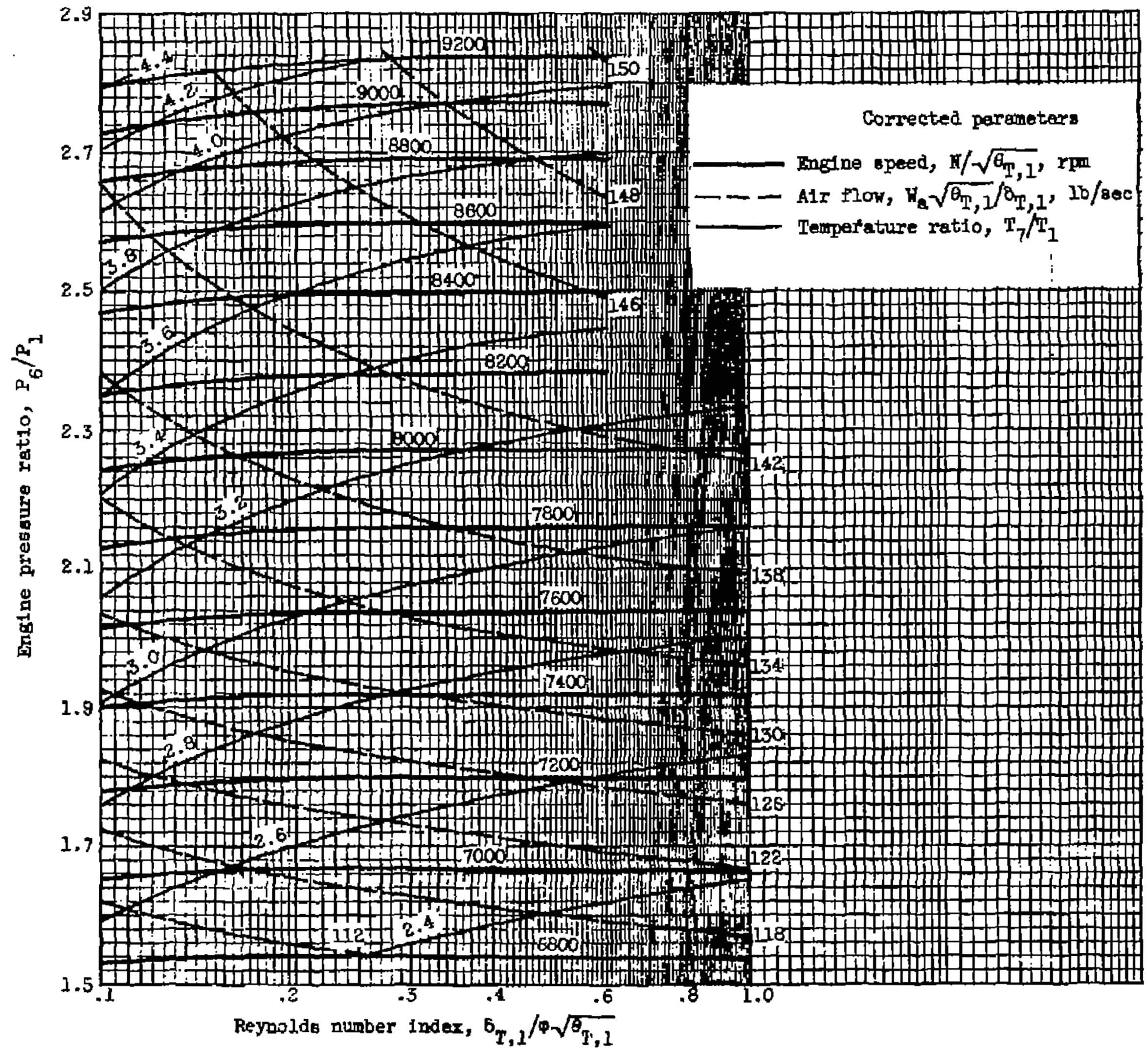
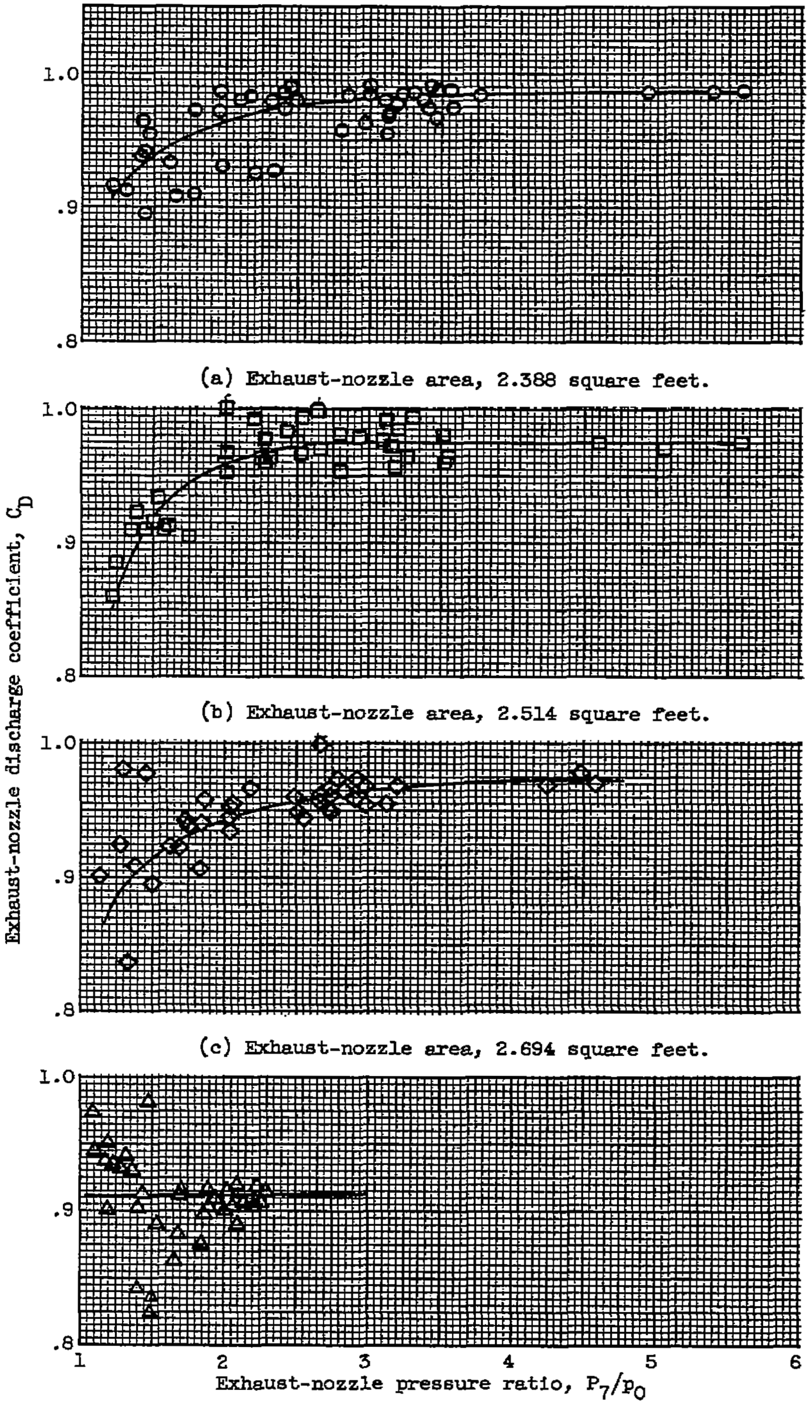


Figure 9. - Engine pumping characteristics with exhaust-nozzle area of 2.388 square feet.



(a) Exhaust-nozzle area, 2.388 square feet.

(b) Exhaust-nozzle area, 2.514 square feet.

(c) Exhaust-nozzle area, 2.694 square feet.

(d) Exhaust-nozzle area, 3.688 square feet.

Figure 10. - Exhaust-nozzle discharge coefficient.

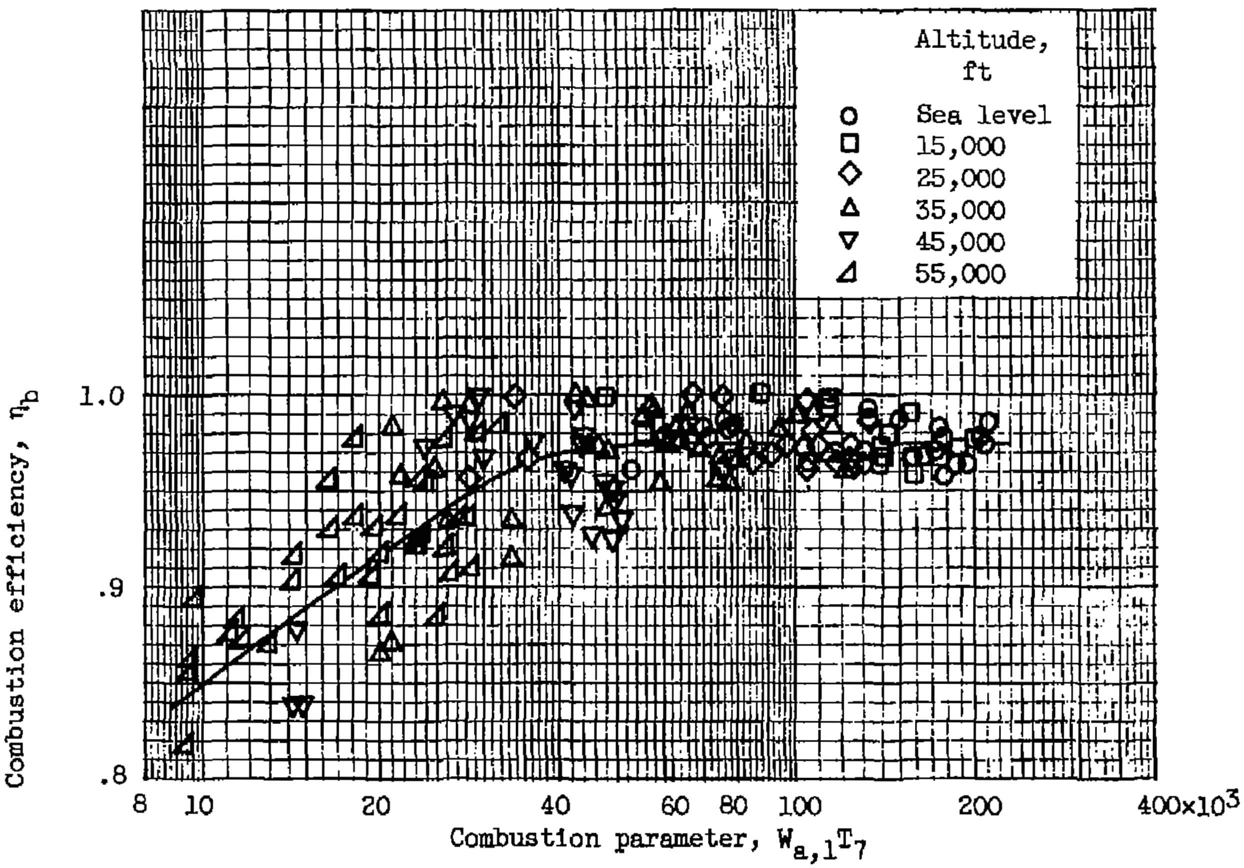


Figure 11. - Variation of combustion efficiency with combustion parameter.

3166

CX-8

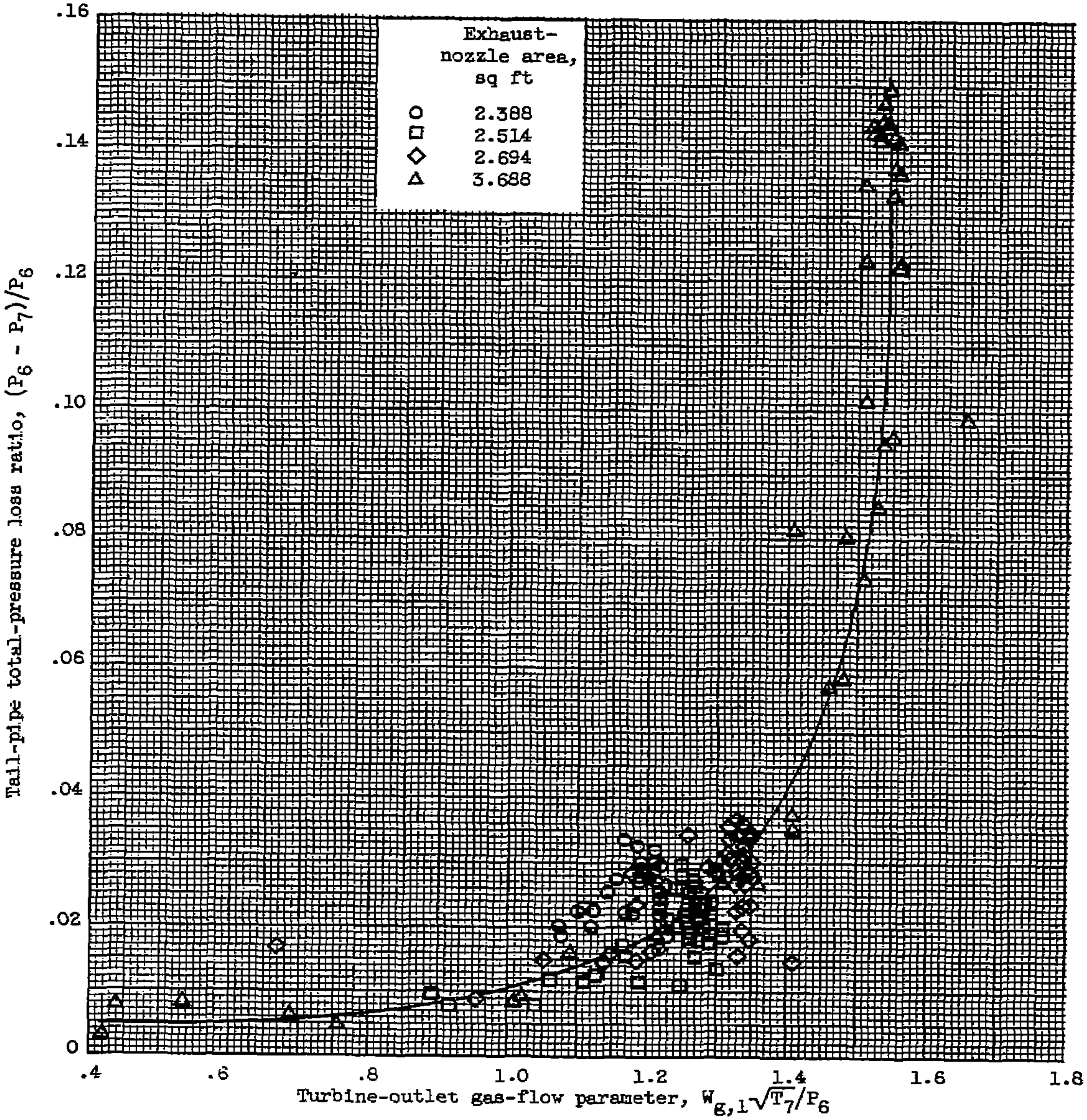


Figure 12. - Variation of tail-pipe total-pressure loss ratio with turbine-outlet gas-flow parameter.

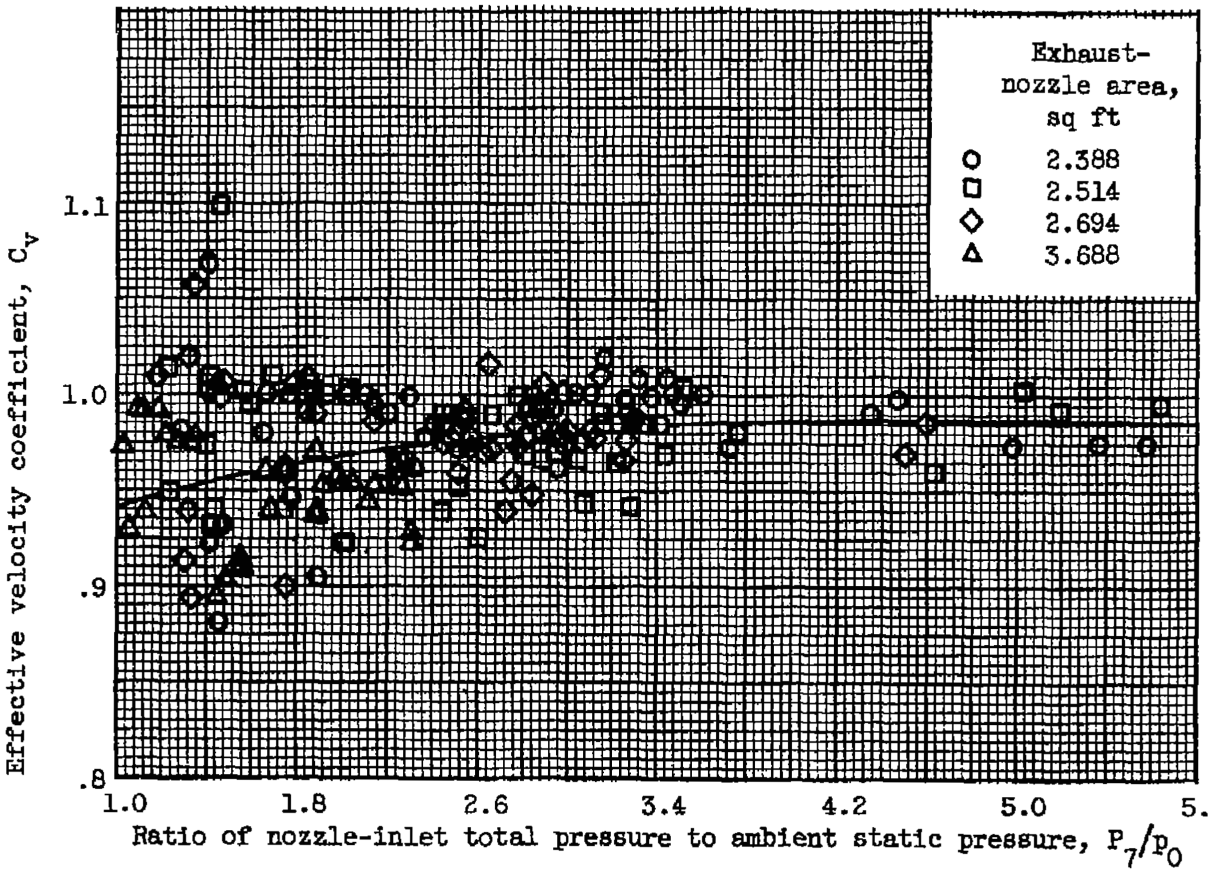


Figure 13. - Variation of effective velocity coefficient with exhaust-nozzle pressure ratio.

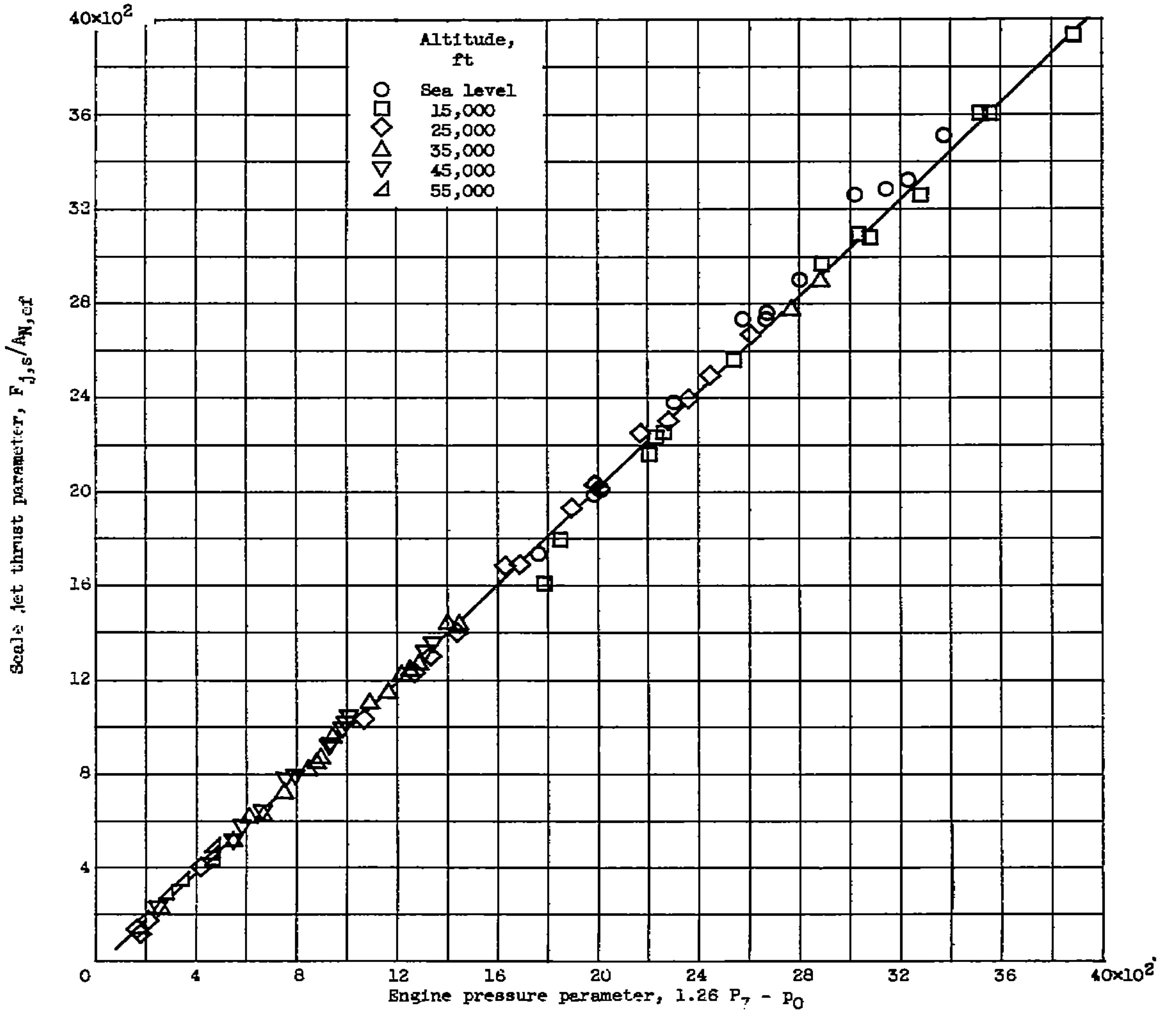


Figure 14. - Jet thrust correlation for all exhaust-nozzle areas. Four nozzle areas at each altitude: 2.388, 2.514, 2.694, and 3.688 square feet.

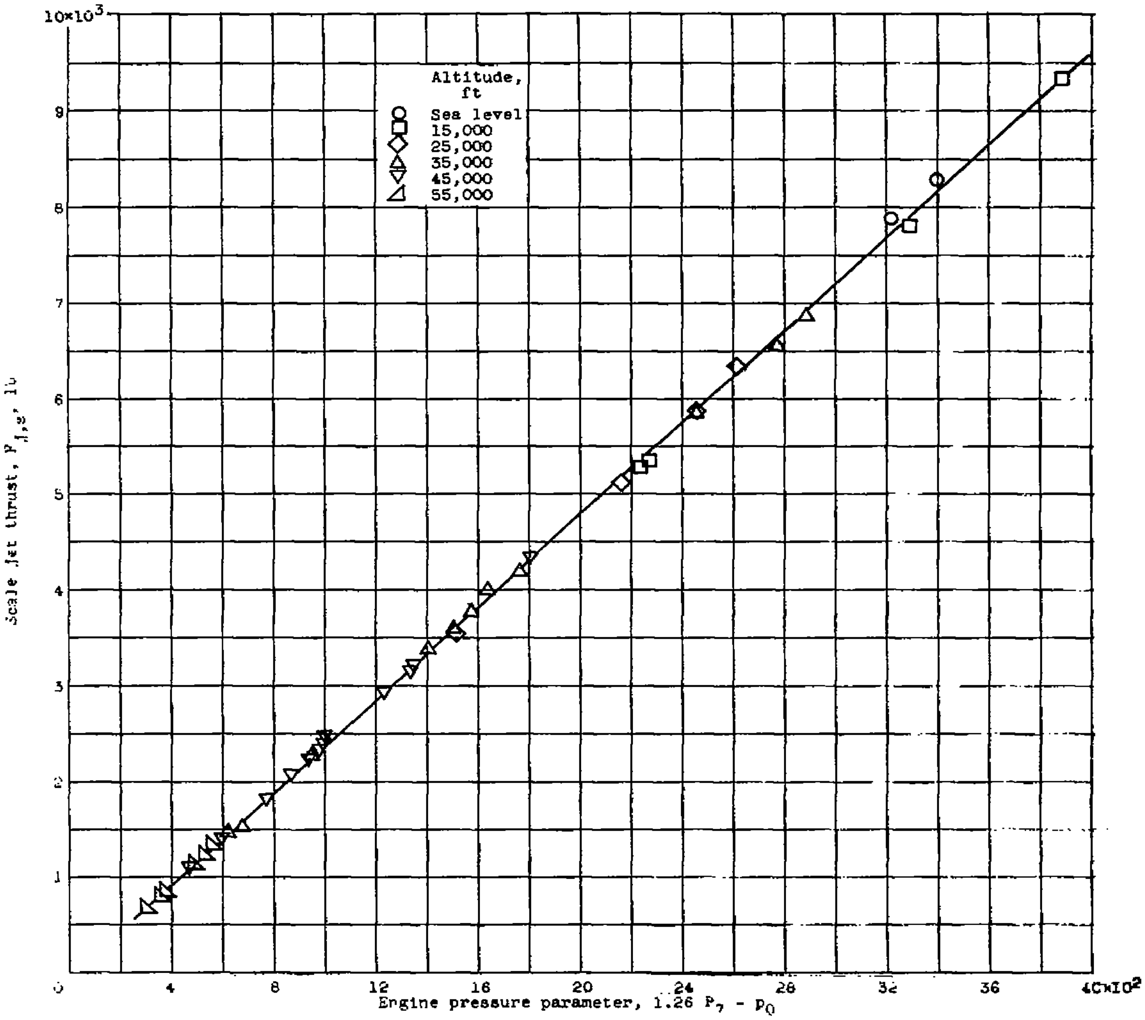
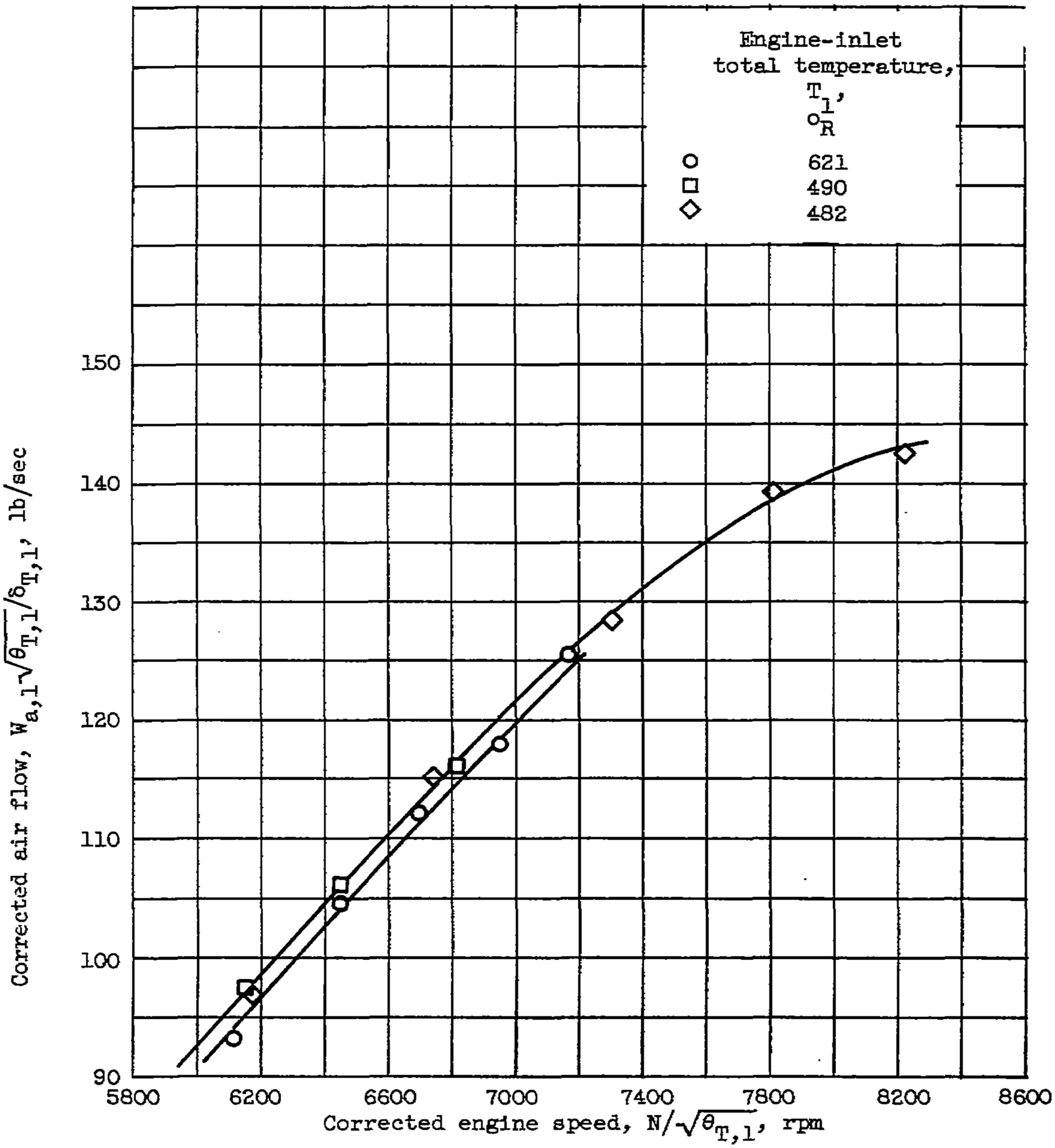


Figure 15. - Jet thrust correlation for an exhaust-nozzle area of 2.368 square feet.

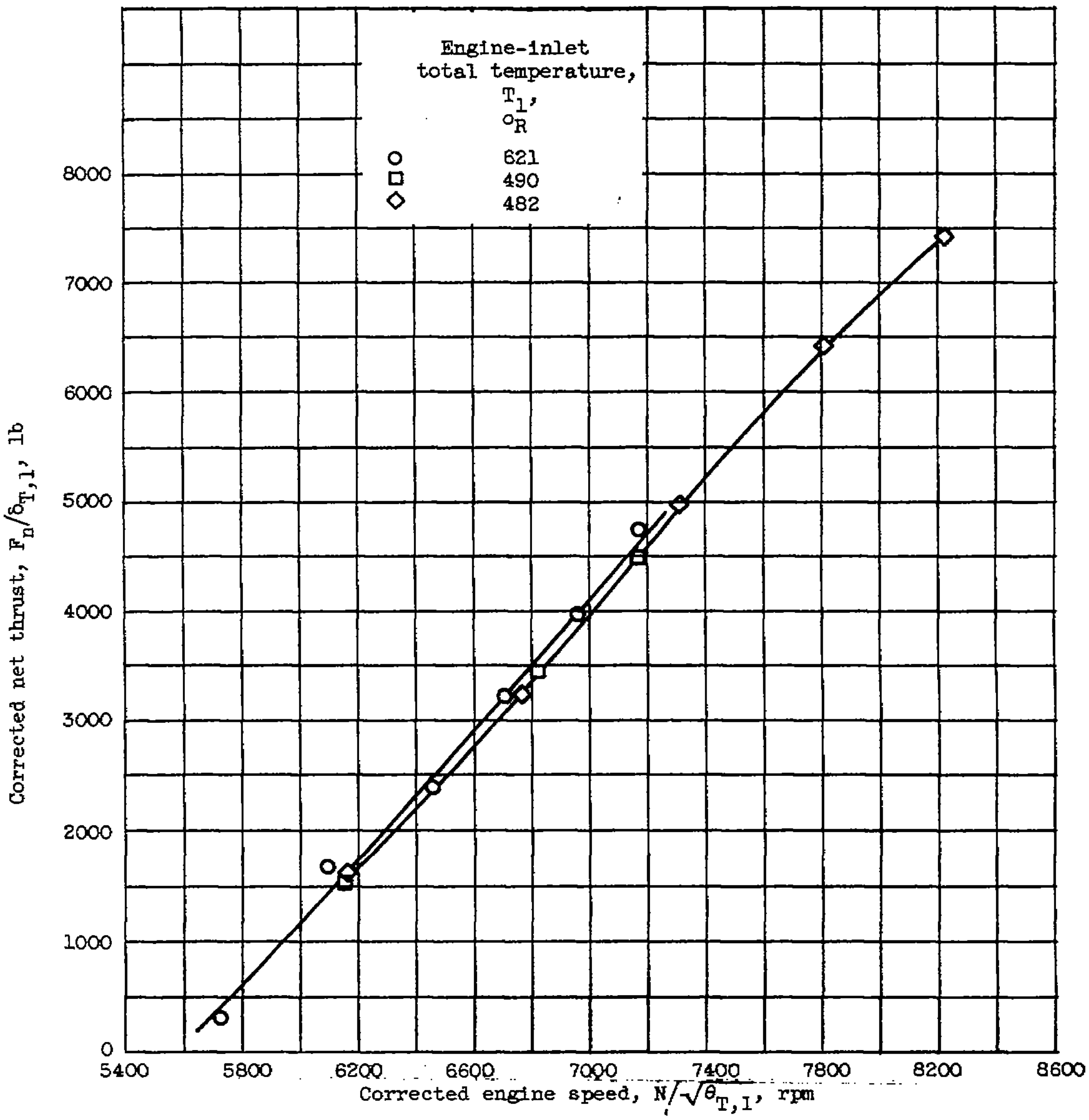
3166



(a) Corrected air flow.

Figure 16. - Effects of inlet temperature. Altitude, 35,000 feet; flight Mach number, 0.8; exhaust-nozzle area, 2.37 square feet.

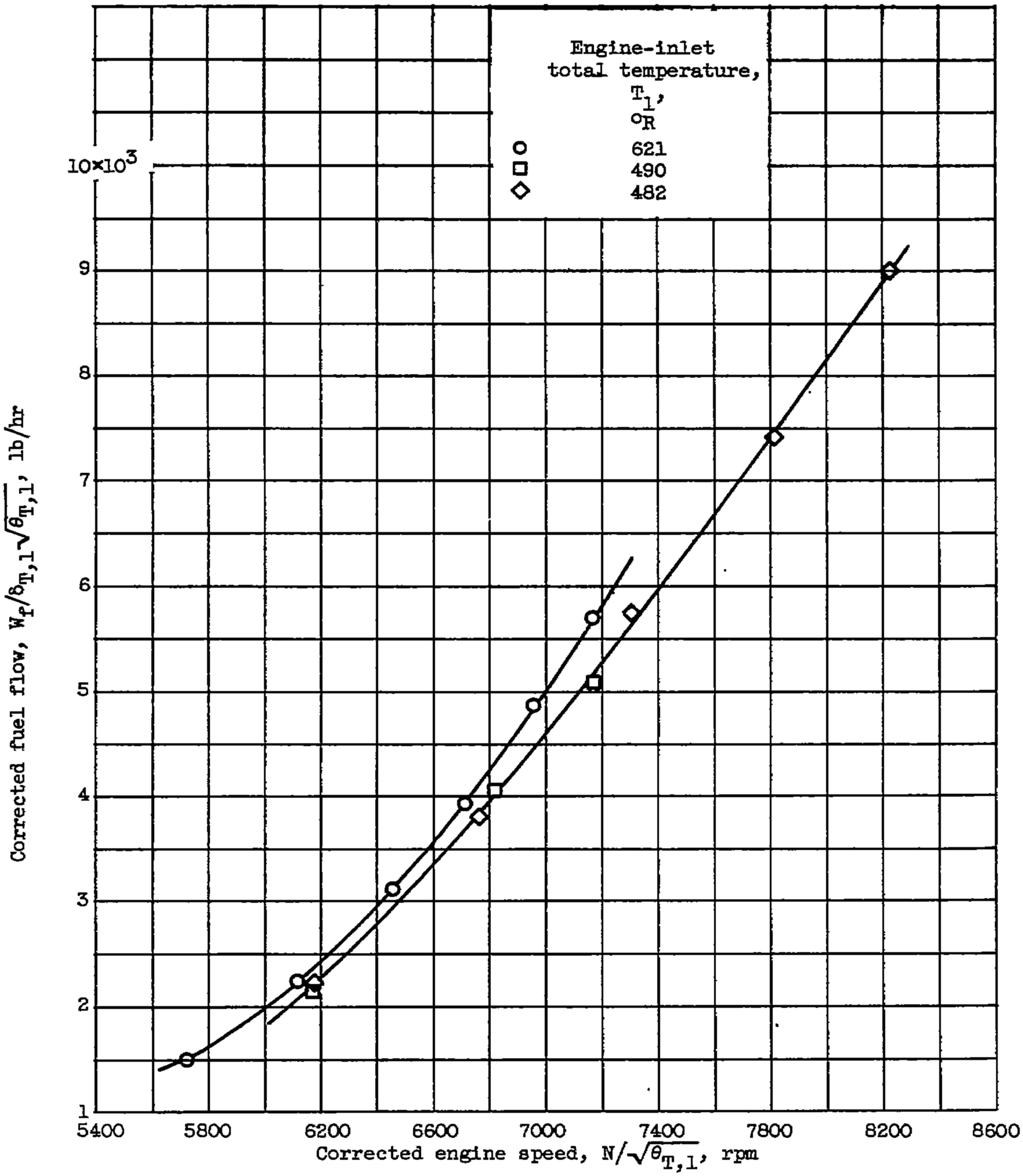
3166



(b) Corrected net thrust.

Figure 16. - Continued. Effects of inlet temperature. Altitude, 35,000 feet; flight Mach number, 0.8; exhaust-nozzle area, 2.37 square feet

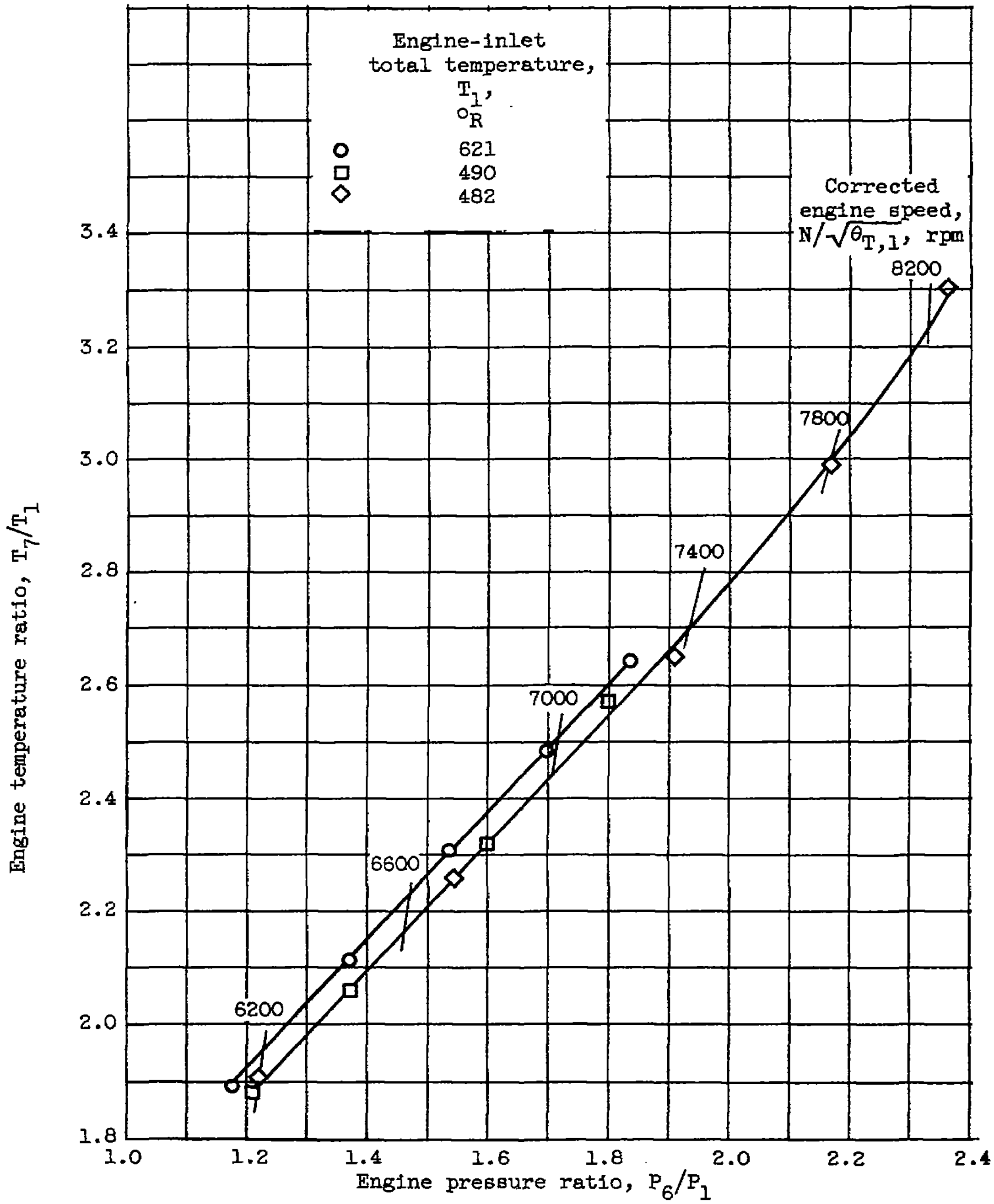
3166



(c) Corrected fuel flow.

Figure 16. - Continued. Effects of inlet temperature. Altitude, 35,000 feet; flight Mach number, 0.8; exhaust-nozzle area, 2.37 square feet.

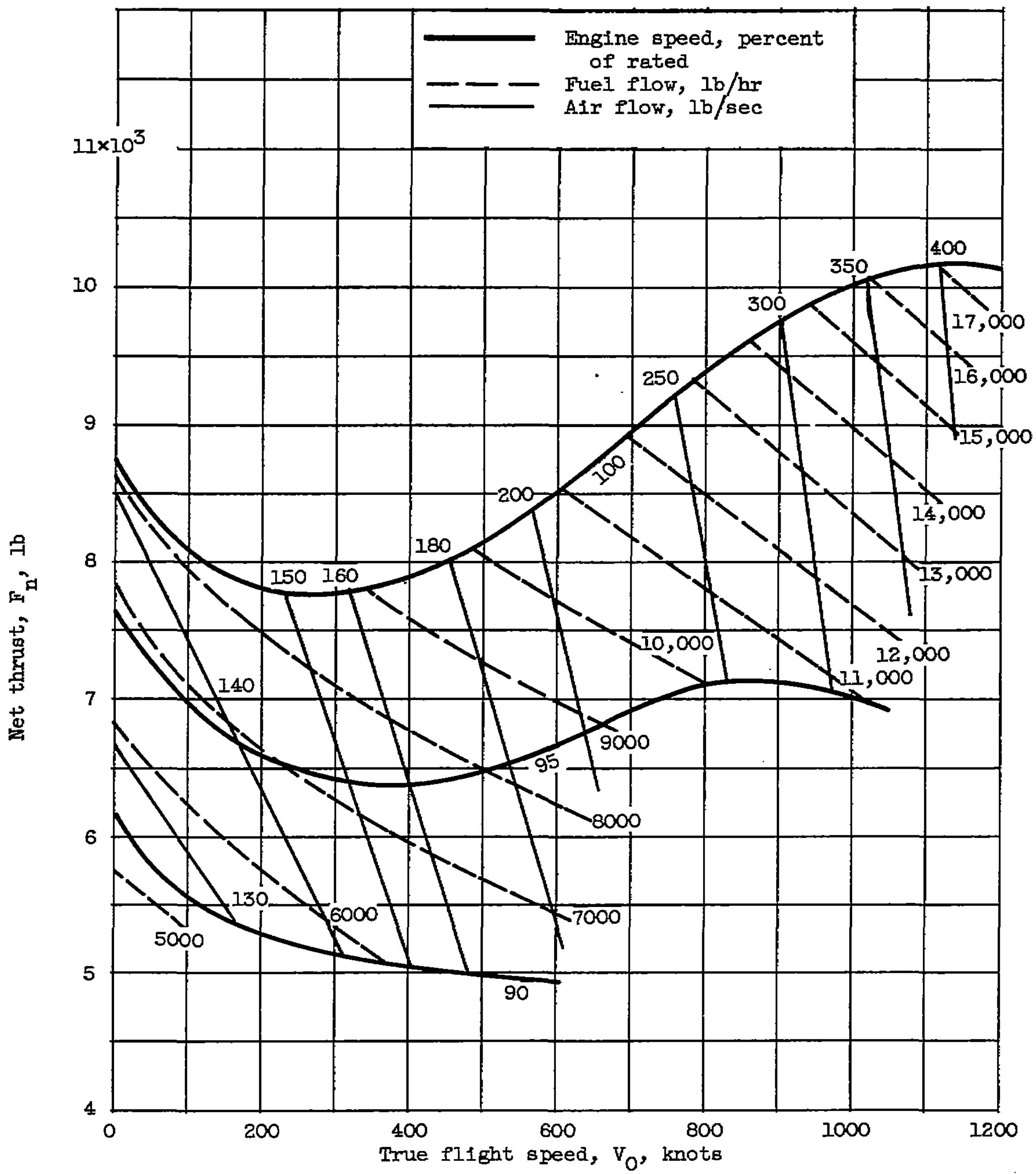
3166



(d) Variation of engine temperature ratio with engine pressure ratio.

Figure 16. - Concluded. Effects of inlet temperature. Altitude, 35,000 feet; flight Mach number, 0.8; exhaust-nozzle area, 2.37 square feet.

CX-9

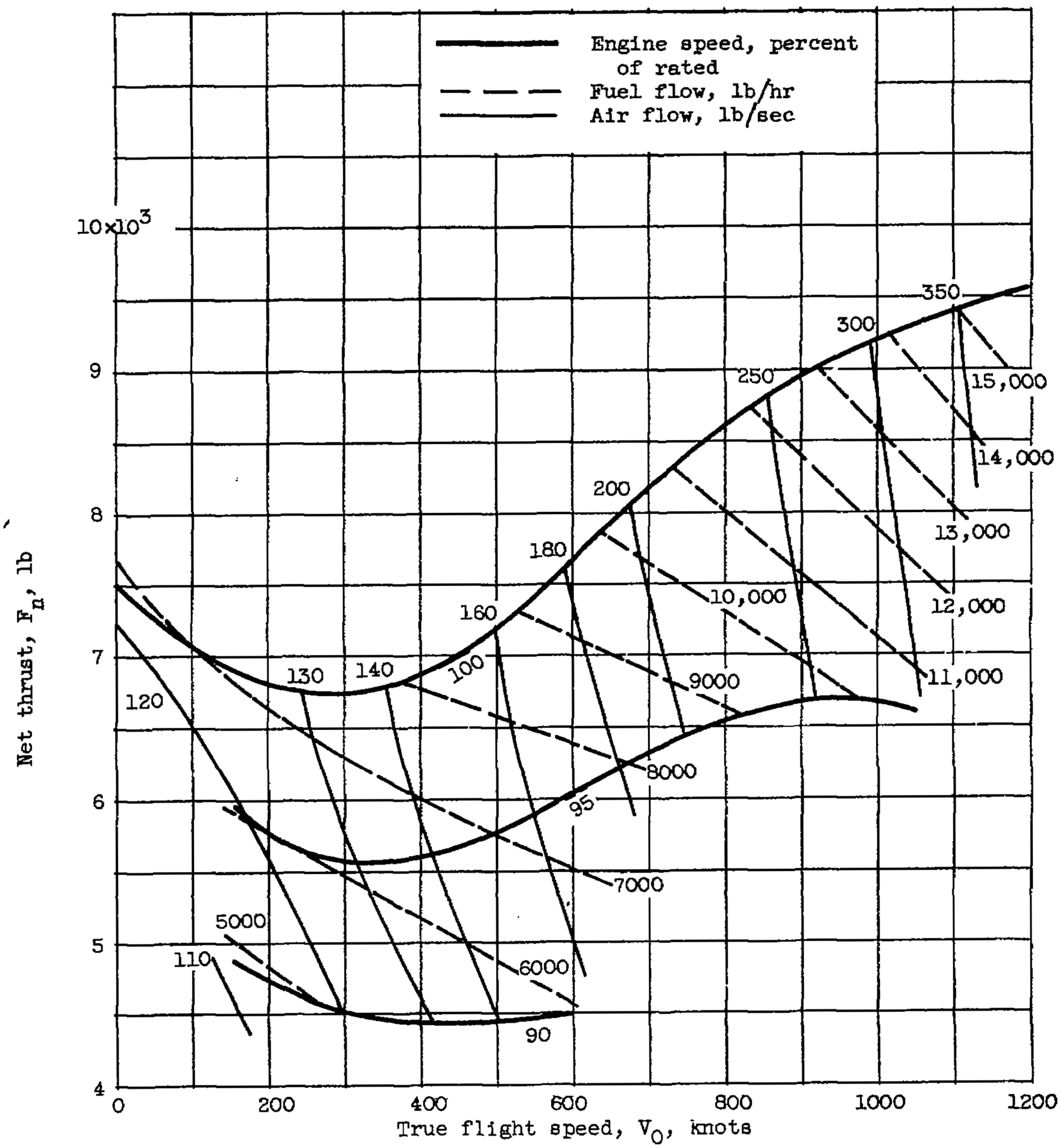


(a) Altitude, sea level.

Figure 17. - Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.

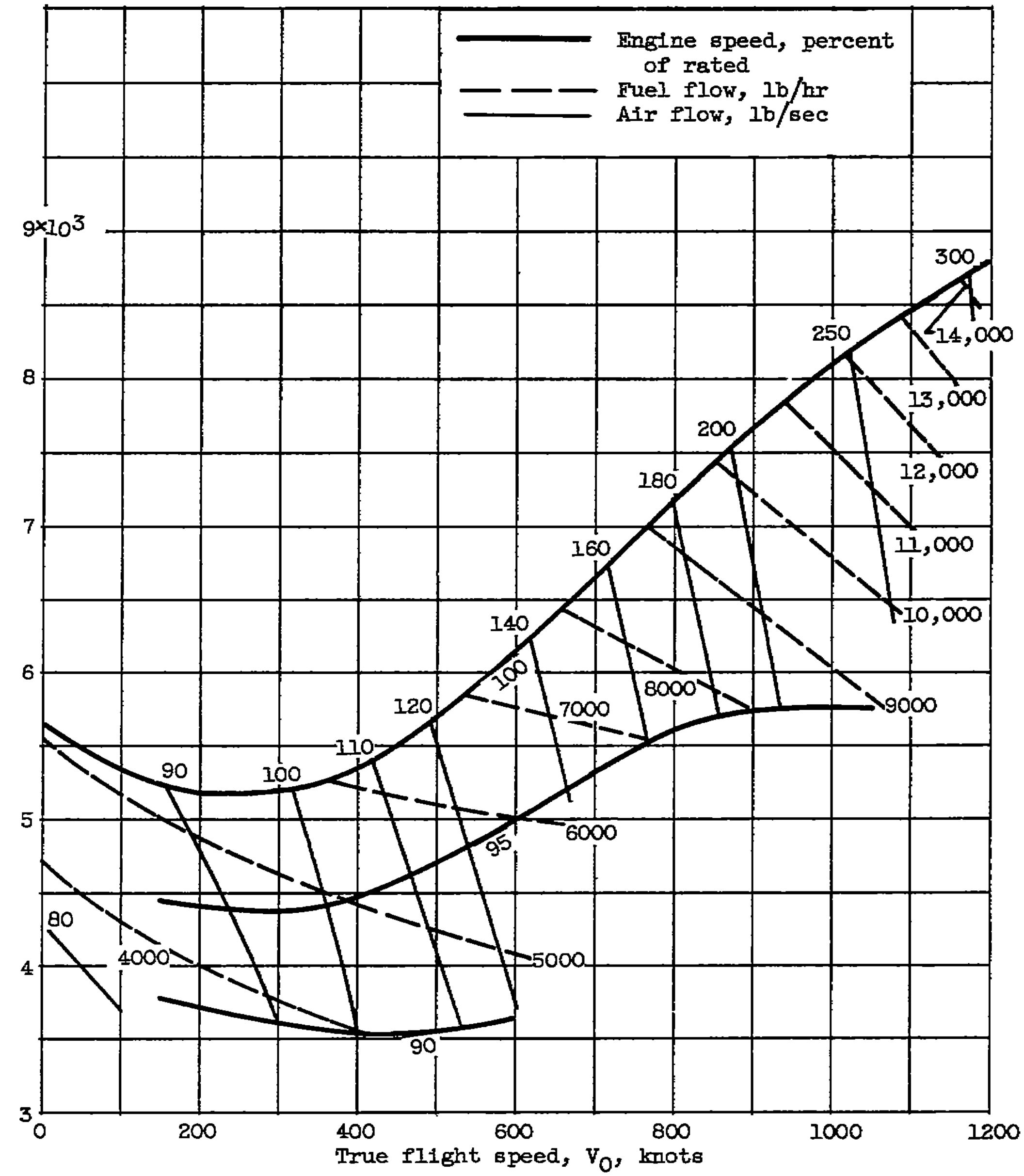
[redacted]

3166



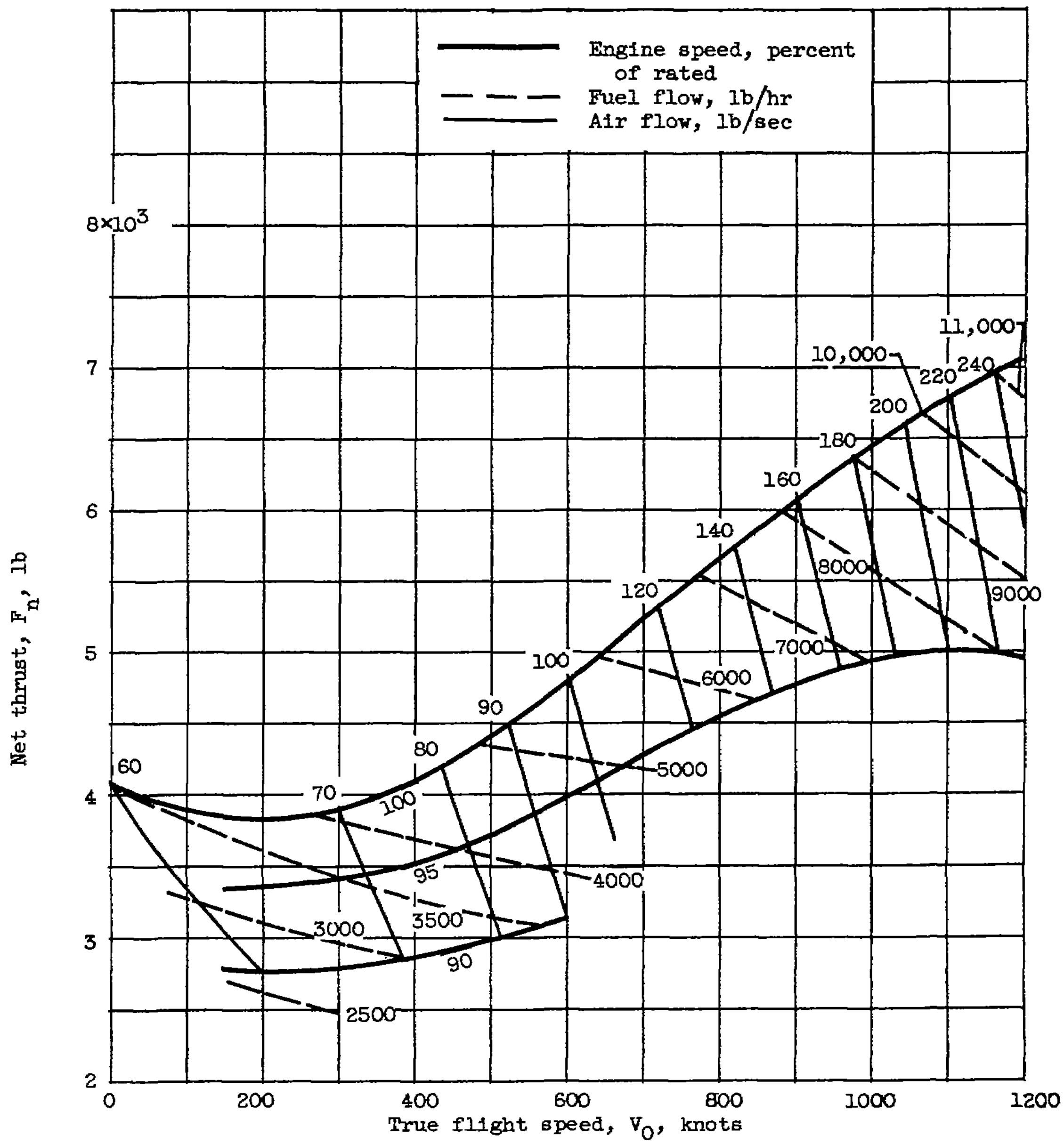
(b) Altitude, 5000 feet.

Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.



(c) Altitude, 15,000 feet.

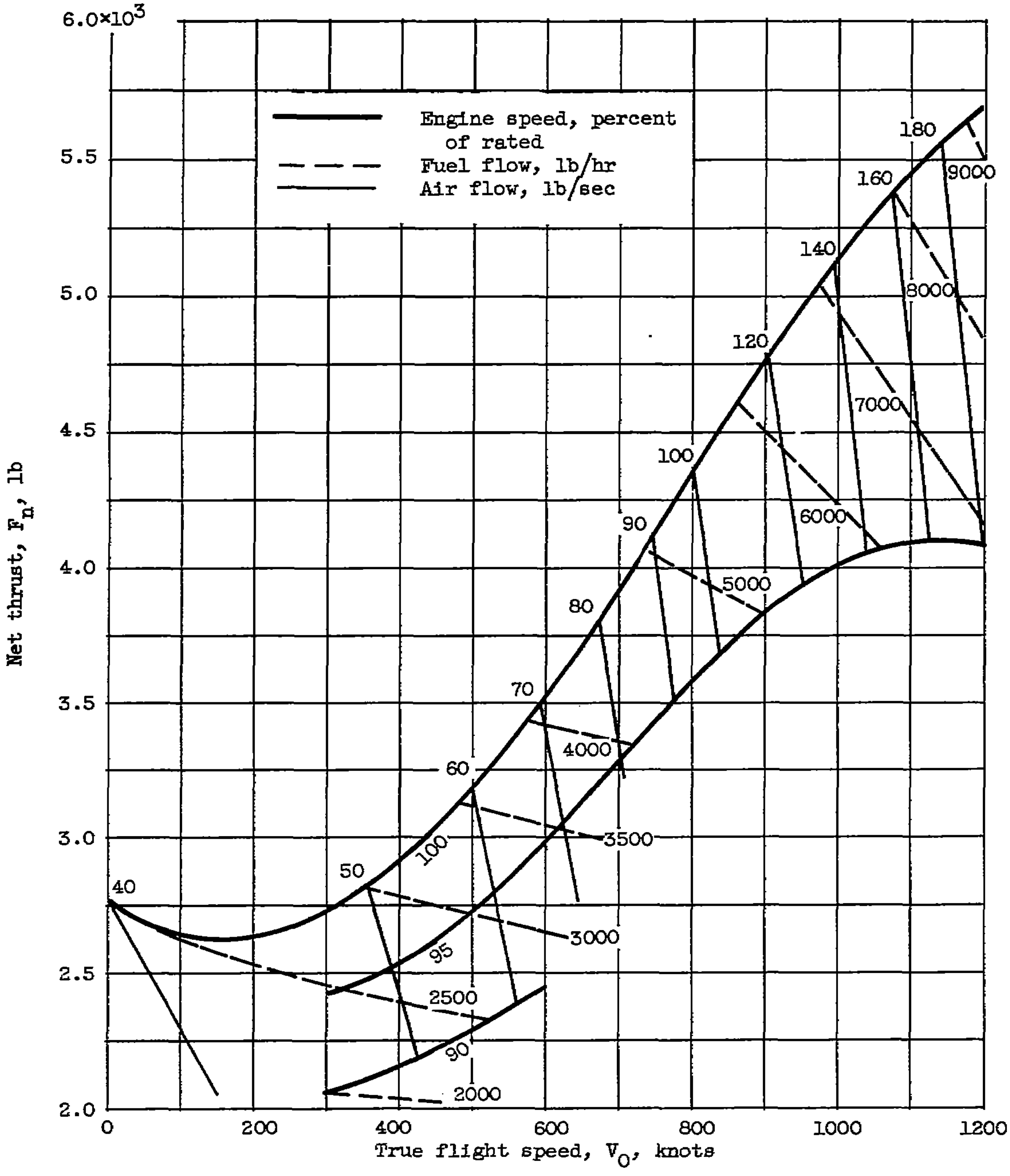
Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.



(d) Altitude, 25,000 feet.

Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.

3166

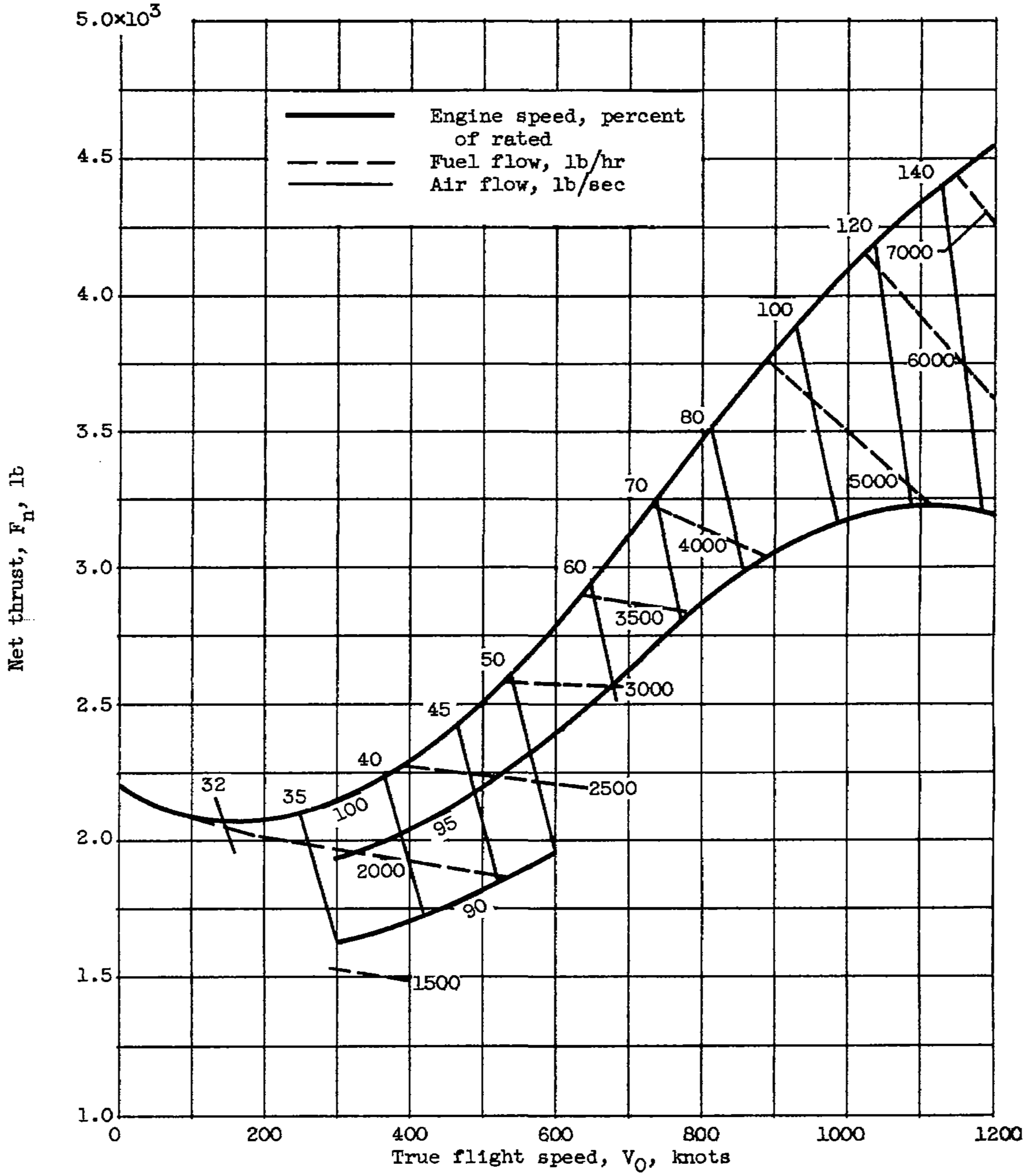


(e) Altitude, 35,000 feet.

Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.

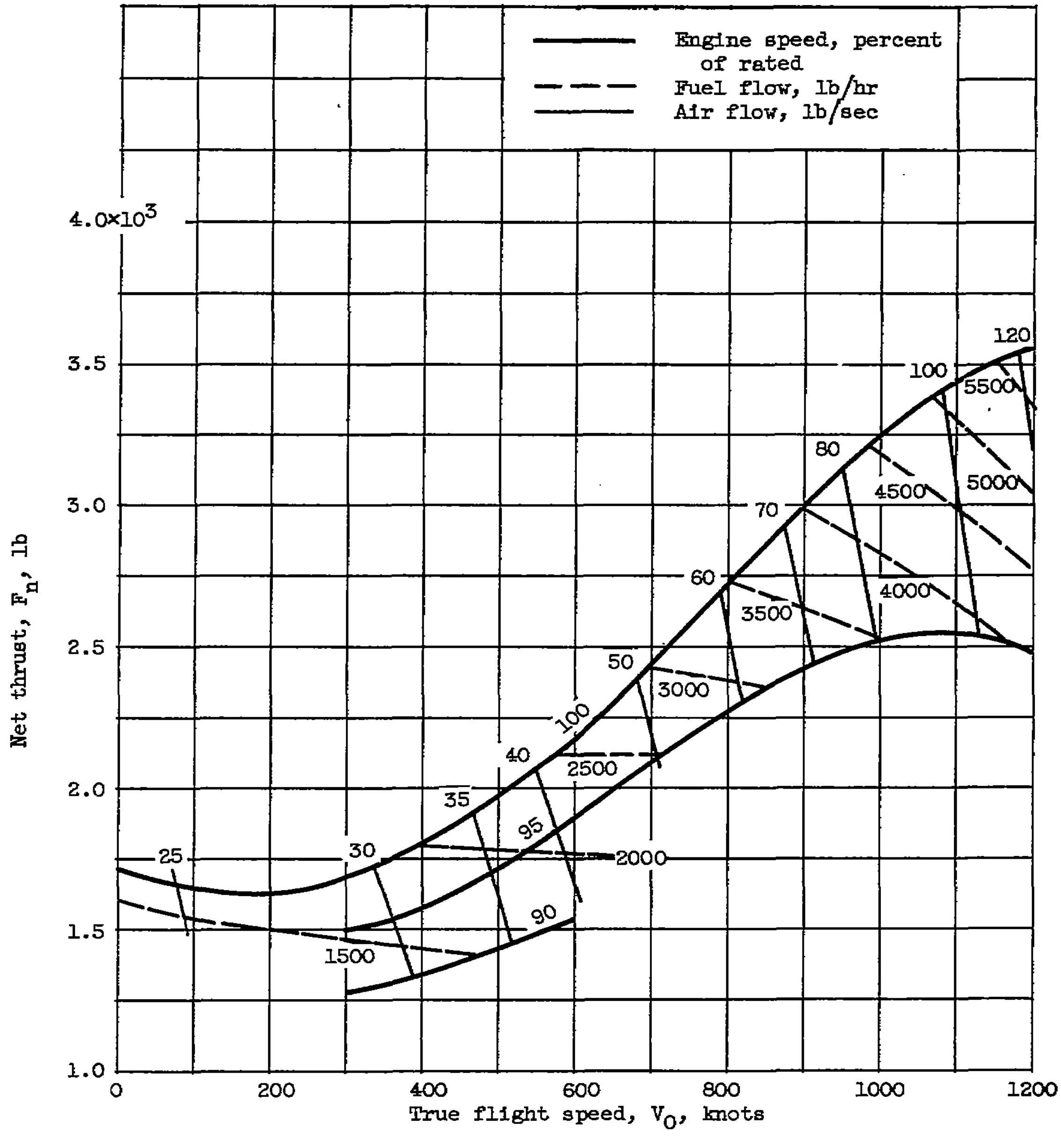
[redacted]

3166



(f) Altitude, 40,000 feet.

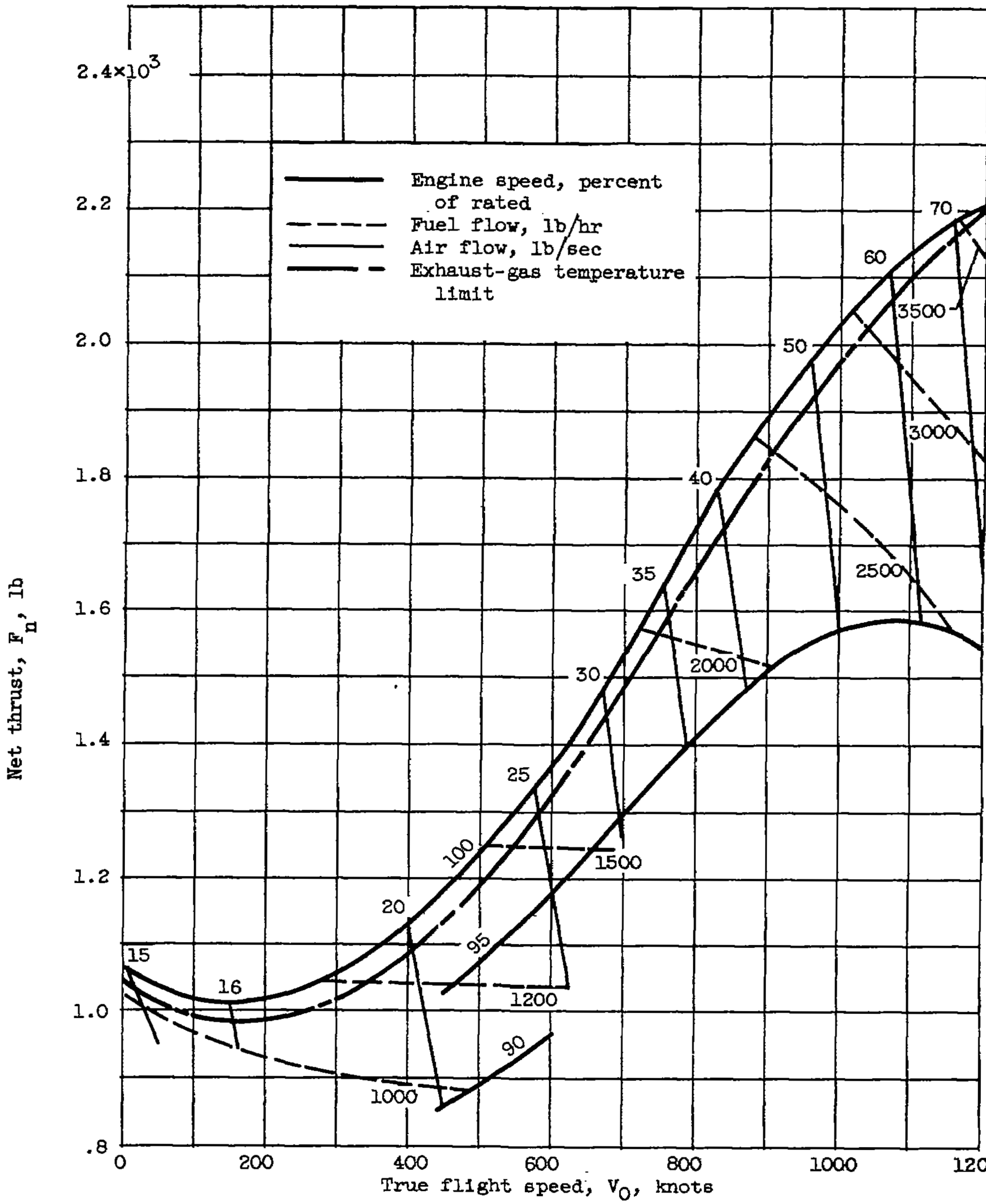
Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.



(g) Altitude, 45,000 feet.

Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.

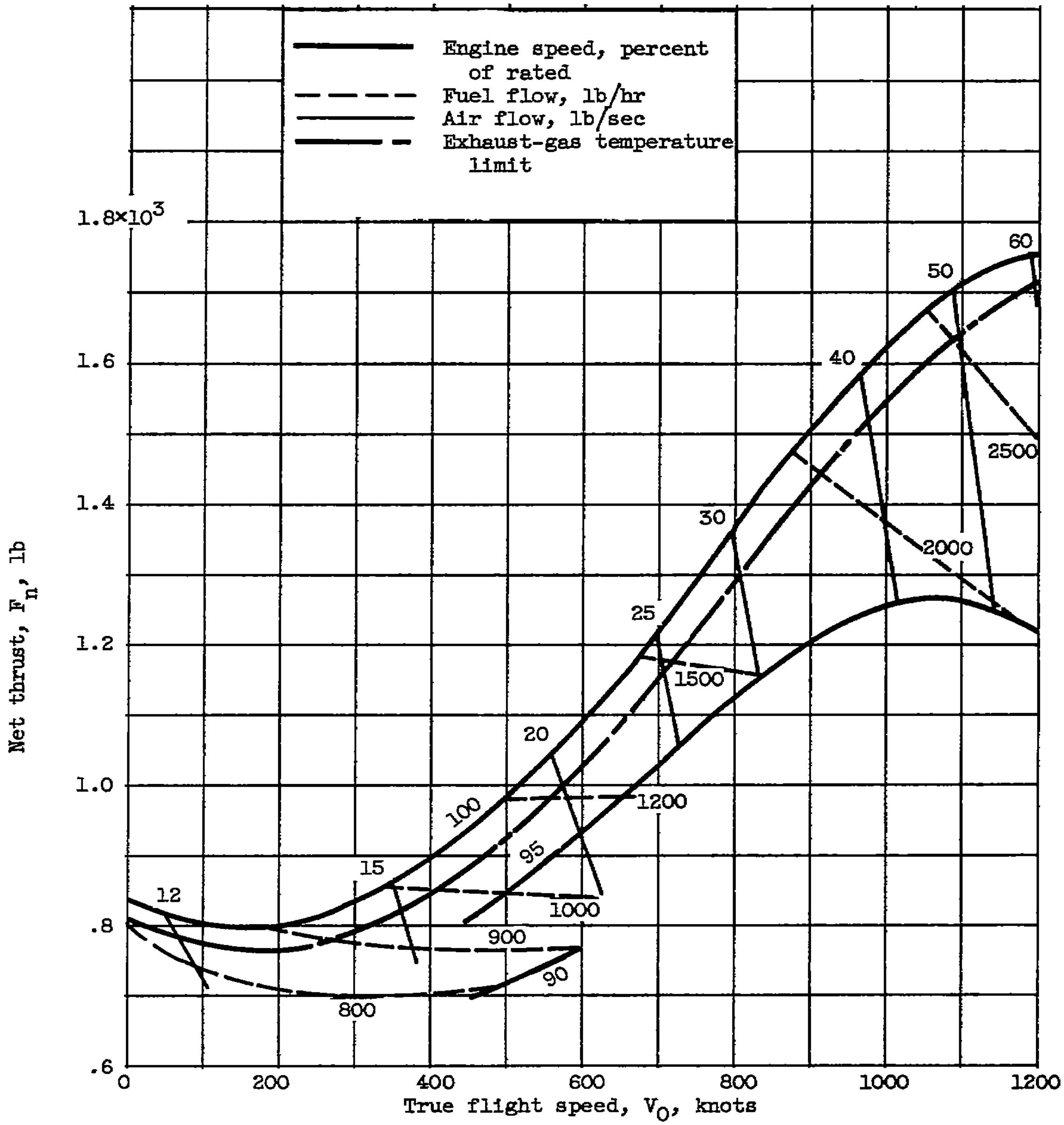
[redacted]



(h) Altitude, 55,000 feet.

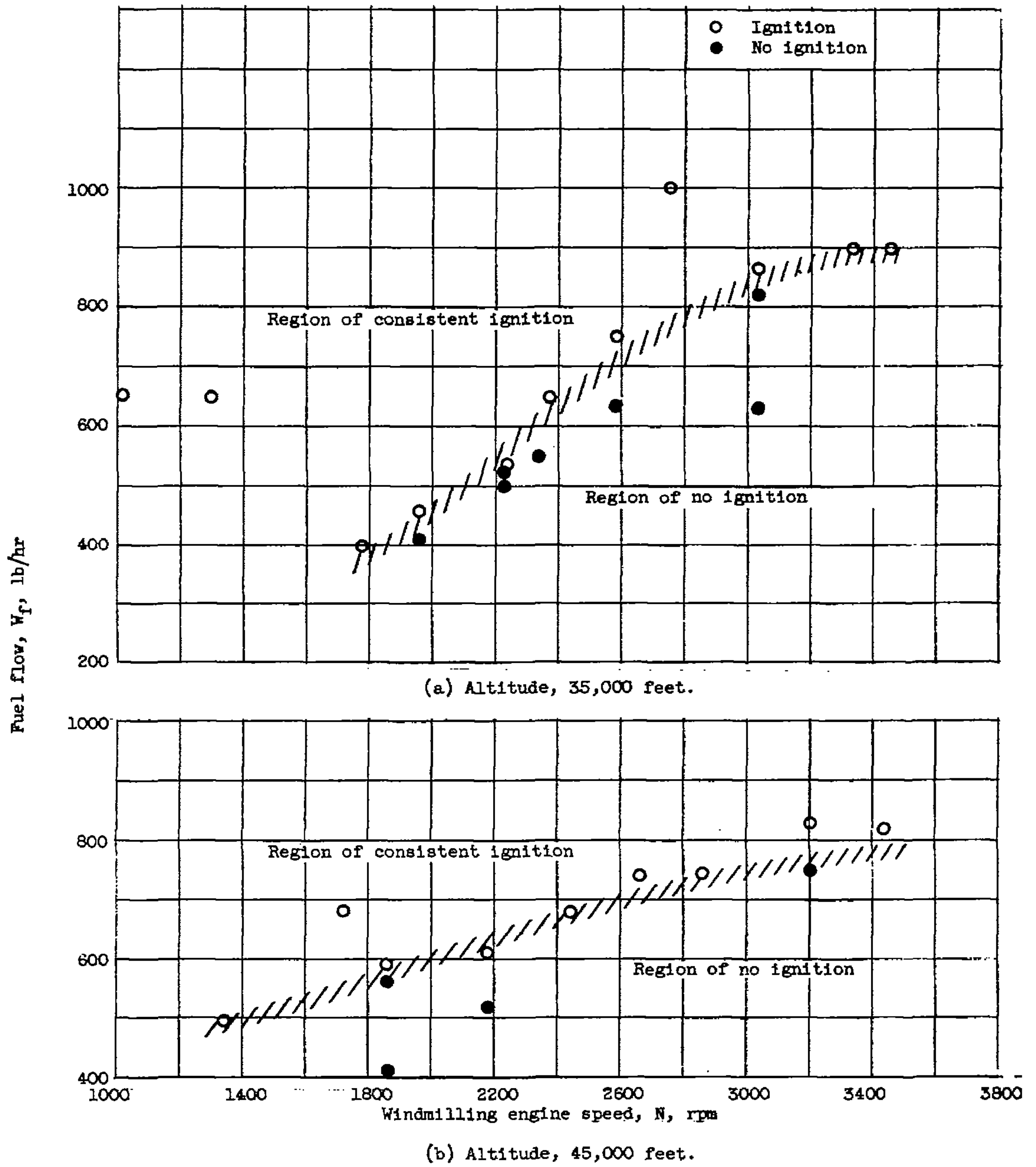
Figure 17. - Continued. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.

3166



(i) Altitude, 60,000 feet.

Figure 17. - Concluded. Predicted performance from pumping characteristics. Exhaust-nozzle area, 2.388 square feet. Standard NACA atmosphere and complete ram recovery assumed.



(b) Altitude, 45,000 feet.

Figure 18. - Effect of fuel flow on altitude-ignition characteristics. Fuel temperature, approximately 60° F; engine-inlet air temperature, 5° to -50° F.

[redacted]