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RESEARCH MEMORANDUM

COMPONENT PERFORMANCE OF J71-A-2(600-D1) TURBOJET ENGINE AT SEVERAL REYNOLDS NUMBER INDICES

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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COMPONENT PERFORMANCE OF J71-A-2(600-D1) TURBOJET ENGINE AT SEVERAL REYNOLDS NUMBER INDICES

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SUMMARY

An investigation was conducted in an altitude test chamber at the NACA Lewis laboratory to determine the altitude performance of the J71-A-2(600-D1) turbojet engine. The engine was equipped with two-position inlet guide vanes and compressor acceleration bleeds. The component performance was determined for the low-speed configuration (inlet guide vanes closed, compressor bleeds open) and the high-speed configuration (inlet guide vanes open, compressor bleeds closed) over a range of engine speeds and exhaust-nozzle areas. Performance data were obtained over a range of compressor-inlet Reynolds number indices from 0.7 to 0.15. This range of inlet conditions corresponds to simulated altitudes from 23,200 to 59,100 feet at a flight Mach number of 0.9.

At actual rated speed and temperature and a Reynolds number index of 0.7 (altitude, 23,200 ft; flight Mach number, 0.9), the compressor efficiency was 80.5 percent, corrected air flow was 166.5 pounds per second, and compressor pressure ratio was 8.3. Decreasing the Reynolds number index to 0.15 (altitude, 59,100 ft; flight Mach number, 0.9) resulted in a 7-percentage-point reduction in compressor efficiency while corrected air flow decreased to 164.5 pounds per second. Combustion efficiency at rated conditions remained constant at about 100 percent to an altitude of about 35,000 feet, and decreased approximately 6 percent as altitude was increased to 59,100 feet. Peak turbine efficiency at rated conditions averaged 84.5 percent at an altitude of 23,200 feet, decreasing about 4 percentage points as altitude was increased to 59,100 feet.

INTRODUCTION

An investigation was conducted in an altitude test chamber at the NACA Lewis laboratory to determine the altitude performance of the J71-A-2(600-D1) turbojet engine. As part of this investigation, the performance of the components was obtained over their range of operation

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in the engine and is presented herein. The J71-A-2(600-D1)(serial number X-29) engine discussed herein is the same engine for which the compressor stall characteristics and altitude performance are presented in references 1 and 2, respectively.

The purpose of this report is to present the engine component performance for a range of engine operation, to show the Reynolds number index effect on engine component performance, and to show the effect of these changes in component performance on over-all engine performance. 3998
The component performance is shown over a range of engine speeds with several fixed exhaust-nozzle areas for (1) the low-speed configuration (inlet guide vanes closed, compressor acceleration bleeds open) and (2) the high-speed configuration (inlet guide vanes open, compressor acceleration bleeds closed). Cold exhaust-nozzle areas varying from 2.79 to 4.42 square feet were used. The Reynolds number index was varied from 0.7 to 0.15, simulating altitudes from approximately 23,200 to 59,100 feet, at a flight Mach number of 0.9. A tabulation of the component performance data is included in tables I to IV.

APPARATUS

Engine and Installation

The J71-A-2(600-D1) turbojet engine used for this investigation has a bifurcated inlet, a 16-stage axial-flow compressor with eighth-stage acceleration bleeds and two-position inlet guide vanes, a cannular-type combustor with ten circular inner liners, a three-stage turbine, an afterburner, and an ejector-type exhaust nozzle with both primary and secondary nozzles of the continuously variable iris type. The ejector was removed for this investigation.

At static sea-level conditions, the J71-A-2(600-D1) engine has the following ratings:

	Military	Normal
Engine speed, rpm	6175	[a]6000
Exhaust-gas temperature, °F	1240	1100
Thrust, lb	10,000	8800
Specific fuel consumption lb/hr/lb thrust	0.955	0.895

[a]Estimated.

The installation of the engine in the altitude test chamber is shown in figure 1. The engine was mounted on a thrust-measuring platform in the test chamber. The test chamber is divided into two compartments separated by a bulkhead with a labyrinth-type seal around the inlet duct. Air, at pressures and temperatures simulating the desired flight condition, was supplied to the front compartment and ducted to the engine through a bellmouth and a venturi used to measure the steady-state air flow. The bellmouth was attached directly to the inlet duct through the venturi section. The pressure in the engine compartment was maintained at the desired altitude pressure.

Instrumentation

Instrumentation for measuring steady-state temperatures and pressures was installed at various stations throughout the engine as shown in figure 2. A table giving the number of total pressure tubes, wall static orifices, and thermocouples at each station is also included in figure 2. The total pressure and temperature probes at each station were located at the centers of equal-area increments and the values averaged arithmetically. The pressures were measured on manometers and photographically recorded; the temperatures were measured with iron-constantan or chromel-alumel thermocouples and recorded on self-balancing potentiometers. Fuel flow was measured by a calibrated electronic flow meter.

Engine Components

Compressor. - The 16-stage axial-flow compressor has a constant tip diameter of 33.5 inches with an inlet hub-tip radius ratio of 0.55 and exit hub-tip radius ratio of 0.90. At static sea-level rated conditions (inlet guide vanes open, bleeds closed), the compressor air flow is approximately 165 pounds per second; the pressure ratio, 8.5; and the efficiency, 81 percent.

In the low-speed configuration, the compressor-inlet guide vanes were closed (reference angle, 20°) and the bleed ports were open as scheduled by the control. At 5300 rpm (86 percent speed), the manufacturer's control system changed the bleed and inlet-guide-vane system to the normal high-speed configuration, that is, inlet guide vanes open (zero reference angle) and bleed ports closed. For this investigation, the control system was modified so that both the bleed and inlet-guide-vane positions could be regulated manually. In the low-speed configuration (inlet guide vanes closed, bleeds open), the air flow through the acceleration bleed system varied from 7 to 4 percent of the actual inlet air flow over a range of actual engine speeds from 3500 to 5300 rpm (Reynolds number index, 0.4).

Combustor. - The combustor is of the cannular type with ten through-flow inner liners. Fuel was supplied to each of the ten liners by single-inlet duplex fuel nozzles. Ignition was provided by two spark plugs located in diametrically opposite liners. The approximate combustor-inlet reference velocity, based on full burner-section area at design sea-level conditions, is 90 feet per second.

Turbine. - The three-stage turbine rotor has a constant hub-tip diameter of 33.5 inches. The annular area increases through the turbine, with the inner shroud having a cone half-angle of 11°. The rotor hub-tip radius ratios of the first, second, and third stages are 0.795, 0.746, and 0.697, respectively; and the design division of work is 38.5, 33, and 28.5 percent for the three stages. Rated turbine-inlet temperature is 2160° R. Design work and design rotational speed (both corrected to rated turbine-inlet temperature) are 32.4 Btu per pound and 3028 rpm, respectively.

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PROCEDURE

Component performance data were obtained over a range of engine speeds and Reynolds number indices from 0.7 to 0.15 corresponding to simulated flight conditions for altitudes from 23,200 to 59,100 feet at a flight Mach number of 0.9. The variation of Reynolds number index with altitude and flight Mach number for standard NACA conditions is shown in figure 3.

The inlet guide vanes were operated in the open and closed positions with various combinations of open and closed compressor acceleration bleed ports. The following table summarizes the conditions at which the data were obtained:

Nominal pressure altitude, ft (Mach number, 0.9)	Reynolds number index	Corrected engine speed range, $N/\sqrt{\theta_1}$, rpm	Engine-exhaust-nozzle area, sq ft	Inlet-guide-vane position	Compressor-acceleration-bleed position
23,200	0.7	4978 - 6354	3.01	Open	Closed
38,600	.4	4841 - 6751	3.01	↓	↓
44,500	.3	5148 - 6652	3.01	↓	↓
53,000	.2	5183 - 6543	3.01	↓	↓
59,100	.15	5170 - 6446	3.01	↓	↓
23,200	0.7	5022 - 6213	4.42 - 3.73 - 3.36 - 3.01 - 2.79	Open	Closed
38,600	.4	4787 - 6868	↓	↓	↓
53,000	.2	5200 - 6874	↓	↓	↓
38,600	0.4	4841 - 6751	3.01	Open	Closed
38,600	.4	2605 - 6195	4.42	Open	Closed
38,600	.4	3813 - 6775	3.01	Closed	Open
38,600	.4	3843 - 6817	4.42	Closed	↓
38,600	.4	3887 - 6792	4.42	Open	↓
38,600	.4	2843 - 6823	4.42	Closed	Closed

All compressor efficiencies presented herein are calculated, charging the compressor with the work done on the acceleration bleed air. However, a separate calculation, deducting the acceleration bleed air from the work of the compressor at a Reynolds number index of 0.4, indicated a gain in compressor efficiency from 3.5 percentage points at a corrected engine speed of 4000 rpm to 0.8 percentage point at 6800 rpm. The symbols and methods of calculation used in this report are defined in appendixes A and B, respectively.

Engine-inlet stagnation pressures were set to correspond with the desired flight conditions assuming 100-percent ram-pressure recovery. Engine-inlet stagnation temperatures were set at the lowest obtainable values to attain the highest possible corrected engine speeds.

Fuel used throughout this investigation was MIL-F-5624A, grade JP-4, with a lower heating value of 18,700 Btu per pound and a hydrogen-carbon ratio of 0.169.

RESULTS AND DISCUSSION

The altitude performance of the compressor, combustor, and turbine of the J71-A-2(600-D1) engine, operating as components are discussed first. Altitude performance of the components, when operating as part of the engine, and the resultant effects of altitude on corrected net thrust and corrected specific fuel consumption are then indicated.

Compressor Performance

The test data for the four geometric variations are presented in the tables. Two configurations, low-speed configuration (inlet guide vanes closed, compressor acceleration bleeds open) and high-speed configuration (inlet guide vanes open, compressor acceleration bleeds closed), selected as the most significant are discussed in this report.

Performance maps. - Compressor performance is presented in the conventional form showing the variation of compressor-pressure ratio with corrected air flow for constant exhaust-nozzle areas. Lines of corrected engine speed are also shown with compressor efficiency superimposed. A compressor performance map for the high-speed configuration (inlet guide vanes open, bleeds closed) is shown in figure 4(a) for an engine-inlet Reynolds number index of 0.4. A peak compressor efficiency of about 83.5 percent occurred at corrected engine speeds from 5000 to 5600 rpm. At the higher corrected engine speeds (6600 to 6800 rpm) the efficiency decreased to about 75 percent and remained almost constant over the entire range of exhaust-nozzle areas. The compressor performance map for the low-speed configuration (inlet guide vanes closed, bleeds open) at wide open exhaust-nozzle (area 4.42 sq ft) and Reynolds number index of 0.4 is presented in figure 4(b). In comparing the two figures, it is evident that, with the low-speed configuration, the compressor-pressure ratio, efficiency, and corrected air flow were reduced.

Effects of inlet guide vanes and interstage bleed. - An illustration of the effects of inlet guide vanes and interstage bleed on compressor stall and compressor performance is given in figure 5. These data were obtained for open exhaust-nozzle, altitude of 35,000 feet, Mach number of 0.4, and inlet-air temperature of -30° F (ref. 1). With the low-speed configuration (inlet guide vanes closed, bleeds open), a substantial margin between the steady-state operating line and stall line was evident at corrected engine speeds above 3500 rpm. For the high-speed configuration (inlet guide vanes open, bleeds closed), the stall line and steady-state operating lines intersect at a corrected engine speed of about 4600 rpm. Since the control normally schedules the switch-over point to the high-speed configuration at an actual engine speed of 5300 rpm, the inlet guide vanes would open and the bleeds would close at corrected engine speeds varying from approximately 5200 to 6000 rpm, based on standard NACA temperatures at sea level and the tropopause, respectively (Mach number, 0.4). In order to avoid surge as well as improve over-all performance, scheduling the guide vanes and bleeds as a function of corrected rather than actual speed would seem advantageous.

Effect of Reynolds number index. - The effect of Reynolds number index on compressor performance maps at Reynolds number indices of 0.7 and 0.2 are shown in figure 6. At each Reynolds number index, the peak efficiency occurred at corrected engine speeds from 5000 to 5500 rpm.
3998 Both compressor efficiency and corrected air flow decreased, as expected when the Reynolds number index decreased from 0.7 to 0.2. At the Reynolds number index of 0.2, the slope of the constant speed lines (below 6200 rpm) and the pattern of the compressor efficiency lines are changed considerably from those obtained at Reynolds number index of 0.7.

The effect of Reynolds number index on compressor efficiency and corrected air-flow ratios at various constant corrected engine speeds for the high-speed configuration is shown more directly in figure 7. Compressor-efficiency ratio decreased from 1.00, at a Reynolds number index of 0.4 (38,600-ft altitude), to a range of from 0.966 to 0.952 for corrected engine speeds from 5200 to 6800 rpm, respectively, as the Reynolds number index was decreased to 0.15 (59,100-ft altitude). Corrected air-flow ratio decreased from 1.0, at a Reynolds number index of 0.4, to a range of from 0.982 to 0.927 for corrected engine speeds from 6800 to 5200 rpm, respectively, as Reynolds number index was decreased to 0.15.

Performance map for compressor and turbine as engine components. - In order to allow for the determination of the compressor operating conditions, the reference compressor map of figure 4(a) is reproduced in figure 8 with lines of constant corrected turbine-inlet temperature superimposed. At a corrected engine speed of 6585 rpm (actual speed, 6175 rpm; Mach number, 0.9; exhaust-nozzle area, 3.01 sq ft), the corrected air flow was 167.5 pounds per second; compressor efficiency, 77 percent; compressor pressure ratio, 8.9; and the corrected turbine-inlet temperature, approximately 2400° R.

Combustor Performance

Combustion efficiency. - Combustion efficiency is presented as a function of the combustion parameter $w_{a,1}T_9$ (fig. 9). As shown in reference 3, the parameter PT/V is very useful in correlating the performance of combustors. Since these quantities are not readily available from flight measurements, the combustion efficiency data herein are given as a function of the parameter $w_{a,1}T_9$, which is proportional to PT/V. Combustion efficiencies were omitted from table I because of malfunctioning of fuel metering equipment. The combustion efficiency data presented herein (fig. 9), for Reynolds number indices 0.8 and 0.4, were obtained from earlier tests on the same engine. Combustion efficiency was constant at about 100 percent above a value for $w_{a,1}T_9$ of 100,000, which corresponds to rated engine operation up to an altitude of about 38,000 feet at a flight Mach number of 0.9. A decrease in combustion parameter below this value resulted in a decrease in combustion efficiency to about 89 percent at a value of 20,000, for $w_{a,1}T_9$, which corresponds to rated engine operation at an altitude of approximately 70,000 feet at a flight Mach number of 0.9. 3998

Total-pressure loss. - Combustor total-pressure-loss ratio decreased from 0.06 to 0.045 as the combustor temperature ratio increased from 1.4 to 2.3 (fig. 10). Data were generalized for all Reynolds number indices.

Turbine Performance

Performance. - The effects of corrected turbine speed and exhaust-nozzle area on turbine performance are given in figure 11. Corrected turbine gas flow and turbine pressure ratio remained essentially constant for each exhaust-nozzle area. The fact that the corrected turbine gas-flow parameter $\frac{w_g\sqrt{\theta_4}\beta_4}{\delta_4}$ remained constant indicated that sonic flow existed in the turbine-inlet stators. Turbine efficiency averaged about 83 percent for the corrected speed range investigated.

Performance map. - The over-all performance of the turbine is presented in terms of corrected turbine enthalpy drop and turbine weight-flow parameter with lines of constant corrected turbine speed and constant turbine-pressure ratio (Reynolds number index 0.4, fig. 12). The turbine data have been compiled in this form in order to facilitate matching studies between the turbine and the compressor. The design turbine operating point is defined by the design-corrected turbine speed of 3028 rpm (military thrust condition) and the design-corrected turbine enthalpy drop of 32.4 Btu per pound.

Effect of Reynolds number index. - The effect of turbine Reynolds number index on corrected turbine gas flow and turbine efficiency is shown in figure 13. Corrected turbine gas flow remained constant over a range of Reynolds number indices from 1.0 to 0.19. A decrease of 4 percentage points in turbine efficiency was observed for a reduction in turbine Reynolds number index from 1.0 to 0.19, which corresponds to an increase in altitude from 23,200 to 59,100 feet at a flight Mach number of 0.9.

Effect of Altitude on Engine Performance

Component performance. - The effect of altitude on corrected engine speed and corrected air flow, compressor, turbine, and combustor efficiency is shown for two modes of engine operating conditions compared with ideal operation (fig. 14). Mode 1 consists of operating the engine at rated exhaust-nozzle area, rated exhaust-gas temperature, and variable engine speed. Mode 2 consists of operating the engine at rated exhaust-gas temperature, rated engine speed, and variable exhaust-nozzle area. The curve for ideal performance represents the performance predicted from sea-level static data for rated speed and temperature, assuming no Reynolds number index effect.

An increase in altitude from 35,332 to 59,100 feet for mode 2 (variable exhaust-nozzle area operation) resulted in a decrease in compressor efficiency with a smaller loss in corrected air flow in comparison with mode 1 (rated exhaust-nozzle area). For example, compressor efficiency dropped 3.5 percentage points for mode 2, while remaining constant for mode 1. However, corrected air flow for mode 2 decreased only about 2 percent as compared with a decrease of 4 percent for mode 1. Compressor efficiency, for mode 1, remained constant above 35,332 feet because the decrease in corrected engine speed shifted the compressor operating point toward the region of peak compressor efficiency. The decrease in corrected engine speed was necessary in order to avoid exceeding rated exhaust-gas temperature.

There was no significant difference in the trends of combustion and turbine efficiency between the two modes of operation. Combustion efficiency dropped about 6 percentage points while turbine efficiency dropped about 3 percentage points as altitude was increased from 35,332 to 59,100 feet.

Over-all engine performance. - The effect of these component performance variations on over-all engine performance is shown in figure 15, which indicated no outstanding advantage of one mode of operation over the other. The maximum difference in the performance occurred at a 59,100-foot altitude where the corrected specific fuel consumption for mode 1 operation was about 1.5 percent lower than mode 2. This close agreement in corrected net thrust and corrected specific fuel consumption for the two modes of operation was due to the fact that the corrected air flow reduction for mode 1 had very nearly the same effect on performance as the compressor efficiency reduction for mode 2.

As the altitude was increased from 35,332 to 59,100 feet, corrected net thrust decreased about 6 percent below the ideal value for both modes of operation. Corrected specific fuel consumption increased about $7\frac{1}{2}$ to 9 percent above the ideal value.

SUMMARY OF RESULTS

The component performance for the J71-A-2(600-D1) engine was determined for the low-speed configuration (inlet guide vanes closed, compressor bleeds open) and the high-speed configuration (inlet guide vanes open, compressor bleeds closed) over a range of engine speeds, exhaust-nozzle areas, and Reynolds number index from 0.7 to 0.15, which corresponds to simulated variations in flight conditions for altitudes from 23,200 to 59,100 feet at a flight Mach number of 0.9. 3998

At rated actual speed and temperature and a Reynolds number index of 0.7 (altitude, 23,200 ft; flight Mach number, 0.9), the compressor efficiency was 80.5 percent, corrected air flow was 166.5 pounds per second, and compressor pressure ratio was 8.3. Decreasing the Reynolds number index to 0.15 (altitude, 59,100 ft; flight Mach number, 0.9) resulted in a 7-percentage-point reduction in compressor efficiency, and corrected air flow decreased to 164.5 pounds per second. Combustion efficiency at rated conditions remained constant at about 100 percent to an altitude of about 35,000 feet and decreased approximately 6 percent as altitude was increased to 59,100 feet. Peak turbine efficiency at rated conditions averaged 84.5 percent at an altitude of 23,200 feet, decreasing about 4-percentage points as altitude was increased to 59,100 feet.

There was no appreciable Reynolds number effect on corrected net thrust or corrected specific fuel consumption for the two modes of operation as altitude increased from sea level to 35,332 feet. However, a further increase in altitude to 59,100 feet reduced the corrected net thrust for both modes of operation by about 6 percent. There was an accompanying increase in specific fuel consumption of about 8.5 percent, at an altitude of 59,100 feet, as a result of the decrease in component efficiencies.

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National Advisory Committee for Aeronautics
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APPENDIX A

SYMBOLS

The following symbols are used in this report:

A	cross-sectional area, sq ft
F_n	net thrust, lb
f/a	fuel-air ratio
g	acceleration due to gravity, 32.17 ft/sec^2
H	total enthalpy, Btu/lb
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)
Re_i	Reynolds number index, $\delta/\varphi\sqrt{\theta}$
T	total temperature, $^{\circ}$R
V	velocity, ft/sec
w	flow rate, lb/sec or lb/hr
β	function of γ, $\beta = \dfrac{1.4}{\gamma}\dfrac{\left(\dfrac{\gamma+1}{2}\right)^{\frac{\gamma}{\gamma-1}}}{\left(\dfrac{1.4+1}{2}\right)^{\frac{1.4}{1.4-1}}}$
γ	ratio of specific heats
δ	pressure correction factor, $\dfrac{P}{2116}$ (total pressure divided by NACA standard sea-level pressure)

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η efficiency

θ temperature correction factor, $(V_{cr}/1018)^2$ (square ratio of critical velocity to critical velocity at NACA standard sea-level conditions)

φ ratio of absolute viscosity at inlet conditions to absolute viscosity at NACA standard sea-level conditions

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Subscripts:

A acceleration bleed

AV aft-frame vent

a air

b combustor

c compressor

f fuel

g gas mixture

MV mid-frame vent

T turbine cooling

t turbine

0 free-stream conditions

1 venturi throat

2 compressor inlet

3 compressor outlet, combustor inlet

4 combustor outlet, turbine inlet

5 turbine outlet

9 exhaust-nozzle inlet

10 exhaust-nozzle throat

APPENDIX B

METHODS OF CALCULATION

Reynolds number index. - For a given corrected engine or turbine speed, Reynolds number index Re_i varies linearly with Reynolds number and is defined as the ratio of Reynolds number at any condition to Reynolds number at standard sea-level conditions

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$$Re_i = \frac{\delta}{\varphi\sqrt{\theta}} \tag{B1}$$

Air flow. - The engine-inlet air flow $w_{a,1}$ was calculated from one-dimensional compressible-flow relations (ref. 4) using the effective area and the average pressures and temperature at station 1. The effective area at station 1 was 3.959 square feet (A_1 = 3.9833 sq ft, C_d = 0.994). Air bleeds and the addition of fuel resulted in the following mass flows at other stations:

$$\left.\begin{aligned}
w_{a,3} &= w_{a,1} - w_{a,A} \\
w_{a,4} &= w_{a,3} - w_{a,T} - w_{a,MV} - w_{a,AV} \\
w_{a,5} &= w_{a,4} + w_{a,T} \\
w_{a,9} &= w_{a,5} \\
w_{g,4} &= w_{a,4} + (w_f/3600) \\
w_{g,9} &= w_{a,9} + (w_f/3600)
\end{aligned}\right\} \tag{B2}$$

Compressor efficiency. - Compressor efficiency is defined as the ratio of isentropic enthalpy rise to the actual rise across the compressor. From measured values of compressor-inlet and compressor-outlet total pressure and temperature, compressor efficiency was determined from the following expression:

$$\eta_c = \frac{\Delta H_a\Big]_2^3 \text{ isentropic}}{\Delta H_a\Big]_2^3 + \frac{w_{a,A}}{w_{a,3}} \Delta H_a\Big]_1^A} \tag{B3}$$

Combustion efficiency. - The combustion efficiency is defined as the ratio of actual enthalpy rise to the theoretical enthalpy rise across the engine

$$\eta_b = \frac{w_{a,1}H_a\Big]_1^9 - w_{a,A}H_a\Big]_A^9 - (w_{a,MV} + w_{a,AV})H_a\Big]_3^9 + w_f \frac{A_m + B}{m + 1}\Big]_{T_f}^9}{18,700\ w_f} \tag{B4}$$ 3998

Fuel temperature T_f was assumed to be 80° F. The term $\frac{A_m + B}{m + 1}$ is the difference between the enthalpy of carbon dioxide and water vapor in the burned mixture and the enthalpy of oxygen removed from the air by their formation (ref. 5).

Turbine efficiency. - The turbine efficiency is defined as the ratio of actual enthalpy drop to the isentropic enthalpy drop across the turbine

$$\eta_t = \frac{H_{g,4} - H_{g,5}}{H_{g,4} - H_{g,5,isentropic}} \tag{B5}$$

T_4 was obtained from values of $H_{g,4}$, $(f/a)_4$, and reference 6.

$$H_{g,4} = H_{g,5} + \Delta H\Big]_2^3 \frac{w_{a,3}}{w_{a,4}}$$

$H_{g,5,isentropic}$ was obtained from $\frac{P_4}{P_5}$, $(f/a)_5$, $H_{g,4}$, and reference 6.

Net thrust and specific fuel consumption. - Net thrust and specific fuel consumption were calculated using the pumping characteristics of reference 2.

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TABLE I. - HIGH-SPEED CONFIGURATION (INLET GUIDE

(a) Variable

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Exhaust-nozzle area, A_{10}, sq ft	Tank static pressure, P_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_9, °R
1	0.716	6060	6218	4.42	850	1417	10,745	10,226	2292	493	973	1657	1228
2	.710	6062	6214	3.79	841	1409	10,943	10,418	2544	494	977	1725	1293
3	.705	6058	6216	3.36	843	1392	11,271	10,742	2765	493	983	1821	1387
4	.713	6056	6218	3.10	838	1412	11,597	11,046	3099	493	981	1925	1515
5	.708	6058	6216	2.85	824	1402	12,045	11,489	3482	493	1001	2073	1655
6	.714	5916	6058	4.42	850	1421	10,391	9,899	2224	495	957	1604	1187
7	.716	5920	6068	3.79	844	1420	10,608	10,108	2459	494	961	1668	1249
8	.715	5918	6066	3.30	840	1416	10,945	10,436	2789	494	969	1789	1365
9	.717	5900	6048	2.82	834	1423	11,624	11,092	3411	494	982	2017	1605
10	.714	5724	5861	4.42	835	1420	9,751	9,299	2093	496	934	1631	1132
11	.719	5719	5850	4.05	848	1434	9,819	9,360	2186	496	937	1554	1152
12	.718	5719	5850	3.54	844	1432	10,048	9,593	2417	498	942	1629	1225
13	.718	5717	5854	3.10	835	1428	10,423	9,962	2779	495	961	1775	1376
14	.713	5717	5854	2.82	849	1419	10,850	10,373	3171	495	963	1943	1549
15	.709	4909	5027	4.42	827	1410	6,587	6,202	1416	495	826	1162	851
16	.705	4906	5026	3.89	834	1405	6,647	6,272	1553	495	829	1204	895
17	.708	4904	5022	3.36	841	1408	6,768	6,411	1688	495	832	1273	958
18	.706	4898	5015	3.01	820	1404	6,912	6,565	1850	495	835	1343	1040
19	.715	4904	5032	3.01	846	1416	6,920	6,580	1858	493	836	1350	1044
20	.710	4904	5022	2.79	831	1413	7,100	6,768	2107	495	842	1458	1151
21	.397	6174	6847	4.42	388	639	5,507	5,231	1179	422	911	1721	1277
22	.399	6173	6862	3.73	380	639	5,574	5,299	1288	420	915	1800	1345
23	.402	6173	6862	3.19	380	643	5,810	5,539	1362	420	923	1939	1487
24	.402	6171	6868	2.99	365	642	5,953	5,688	1500	419	929	2032	1599
25	.399	6173	6879	2.83	380	635	6,012	5,756	1571	418	931	2079	1647
26	.405	6173	6622	4.42	428	713	5,873	5,583	1257	451	944	1727	1282
27	.403	6174	6616	3.54	429	711	6,061	5,769	1457	452	951	1850	1393
28	.405	6173	6637	3.25	421	708	6,198	5,906	1537	449	954	1911	1457
29	.402	6173	6622	3.19	422	707	6,212	5,922	1576	451	957	1936	1485
30	.407	6171	6642	2.99	424	710	6,357	6,056	1704	449	960	2025	1566
31	.408	6177	6648	2.90	426	712	6,479	6,183	1827	449	964	2097	1651
32	.404	5861	6515	4.42	384	646	5,218	4,960	1118	420	861	1554	1152
33	.403	5863	6517	3.73	380	645	5,309	5,048	1218	420	867	1614	1211
34	.402	5863	6517	3.33	389	644	5,423	5,158	1337	420	876	1704	1290
35	.405	5859	6529	2.90	385	645	5,683	5,420	1564	418	882	1868	1468
36	.402	5869	6524	2.79	390	643	5,825	5,563	1580	420	891	1971	1659
37	.407	5626	6042	4.42	419	714	5,263	5,014	1128	450	874	1542	1098
38	.406	5627	6043	4.26	424	712	5,254	4,999	1143	450	875	1506	1108
39	.403	5627	6030	3.79	423	712	5,321	5,068	1218	452	880	1554	1150
40	.403	5624	6027	3.36	423	711	5,401	5,145	1331	452	885	1625	1222
41	.403	5627	6036	2.99	423	710	5,628	5,369	1509	451	894	1760	1365
42	.402	5624	6020	2.71	426	712	5,866	5,605	1726	453	904	1907	1516
43	.403	5242	5611	4.42	429	713	4,534	4,311	973	453	832	1342	987
44	.399	5249	5619	4.26	427	707	4,562	4,341	989	453	835	1323	925
45	.406	5247	5623	3.73	423	717	4,632	4,407	1075	452	834	1388	1034
46	.406	5247	5641	3.36	425	711	4,758	4,535	1181	449	834	1468	1109
47	.398	5242	5593	3.15	421	713	4,763	4,544	1231	456	843	1506	1152
48	.403	5249	5631	3.01	423	710	4,894	4,678	1302	451	844	1561	1201
49	.403	5249	5631	2.68	420	710	5,103	4,879	1501	451	852	1718	1367
50	.411	4869	5235	4.42	428	719	3,808	3,601	820	449	780	1173	859
51	.405	4869	5223	4.26	427	714	3,807	3,602	835	451	781	1177	868
52	.405	4865	5219	3.73	425	714	3,834	3,633	888	451	785	1212	904
53	.400	4875	5201	3.30	434	715	3,877	3,677	958	456	792	1288	874
54	.404	4869	5206	3.27	428	718	3,861	3,664	961	454	790	1285	968
55	.398	4867	5167	3.07	428	713	3,871	3,661	1005	457	794	1325	1012
56	.408	4872	5258	2.93	429	713	4,039	3,847	1085	449	790	1369	1058
57	.401	4877	5214	2.79	425	714	4,024	3,837	1140	454	798	1435	1120
58	.400	4496	4792	4.42	424	716	2,915	2,733	655	457	740	1023	752
59	.400	4492	4787	3.89	424	717	2,961	2,783	704	457	740	1058	787
60	.398	4499	4789	3.42	424	714	3,024	2,851	764	458	742	1112	837
61	.399	4495	4791	3.13	425	715	3,062	2,896	814	457	746	1162	887
62	.400	4503	4799	2.85	426	716	3,152	2,989	900	457	750	1242	972
63	.197	6174	6855	4.42	187	316	2,739	2,598	595	421	922	1807	1342
64	.194	6173	6862	3.73	187	311	2,769	2,636	666	420	926	1886	1414
65	.197	6173	6862	3.36	185	315	2,840	2,701	710	420	932	1979	1502
66	.184	6176	6874	3.19	186	312	2,868	2,752	746	419	937	2046	1570
67	.195	6174	6863	3.04	182	312	2,936	2,807	799	420	942	2104	1677

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VANES OPEN, COMPRESSOR ACCELERATION BLEEDS CLOSED)

exhaust-nozzle area.

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60\ \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(°R)}{sec}$	Run
7.58	113.8	165.5	0.802	0.0483	-----	4.46	0.831	3426	37.72	2437	139.7×10³	1
7.77	113.4	166.2	.805	.0480	-----	4.10	.850	3360	36.58	2388	146.6	2
8.10	112.5	166.7	.811	.0469	-----	3.86	.846	3271	35.29	2303	156.1	3
8.21	113.7	166.1	.805	.0473	-----	3.57	.880	3183	33.98	2272	172.3	4
8.59	113.2	166.4	.812	.0462	-----	3.30	.850	3074	32.18	2185	187.3	5
7.31	111.9	162.7	.810	.0473	-----	4.45	.838	3400	37.64	2410	132.8	6
7.47	112.0	162.9	.811	.0469	-----	4.11	.846	3337	36.53	2368	139.9	7
7.72	112.4	163.7	.814	.0465	-----	3.74	.848	3225	34.73	2312	153.4	8
8.17	112.2	162.7	.821	.0458	-----	3.25	.858	3030	31.93	2175	180.0	9
6.87	107.6	156.6	.819	.0463	-----	4.44	.831	3361	37.24	2372	121.8	10
6.85	108.2	155.9	.813	.0467	-----	4.28	.845	3333	37.04	2372	124.6	11
7.02	108.1	156.1	.819	.0453	-----	3.97	.846	3261	35.77	2318	132.4	12
7.30	108.0	156.3	.820	.0442	-----	3.59	.850	3127	33.80	2243	148.6	13
7.65	107.4	156.3	.823	.0440	-----	3.27	.841	2992	31.75	2152	166.3	14
4.67	82.1	120.3	.824	.0584	-----	4.38	.844	3297	36.55	2308	69.9	15
4.74	82.1	120.9	.824	.0565	-----	4.04	.854	3242	35.78	2278	73.4	16
4.81	81.9	120.2	.827	.0527	-----	3.80	.847	3152	34.28	2228	78.3	17
4.92	81.2	119.6	.836	.0502	-----	3.55	.838	3085	32.51	2157	84.5	18
4.89	81.6	118.8	.819	.0491	-----	3.54	.840	3061	32.74	2167	85.2	19
5.03	80.9	118.3	.831	.0468	-----	3.21	.842	2949	30.74	2093	93.1	20
8.62	56.6	169.0	.728	.0501	0.980	4.44	.816	3428	38.99	2415	72.3	21
8.72	56.7	168.9	.721	.0493	.991	4.11	.830	3353	38.00	2393	78.2	22
9.04	56.9	168.5	.725	.0466	1.003	4.07	.790	3252	34.00	2307	84.6	23
9.27	57.1	169.0	.725	.0445	1.008	3.79	.791	3160	32.77	2257	91.2	24
9.47	56.5	169.0	.727	.0426	1.014	3.66	.793	3126	32.30	2215	93.1	25
8.24	60.4	167.2	.749	.0494	.983	4.44	.823	3420	37.15	2413	77.5	26
8.53	60.4	167.8	.757	.0482	.986	3.96	.837	3309	35.33	2343	84.2	27
8.75	60.5	168.2	.756	.0472	.990	3.84	.821	3256	34.50	2297	88.2	28
8.79	60.2	168.1	.760	.0467	.991	3.76	.827	3236	34.06	2280	89.4	29
8.95	60.9	168.7	.754	.0474	1.008	3.55	.834	3165	33.14	2260	96.6	30
9.10	61.1	168.6	.756	.0457	1.026	3.38	.829	3113	32.00	2220	100.8	31
8.08	56.5	166.6	.772	.0494	.982	4.44	.818	3416	36.70	2402	65.1	32
8.23	56.6	167.1	.779	.0492	.990	4.15	.826	3358	35.75	2370	68.6	33
8.42	56.4	166.7	.767	.0489	.995	3.86	.836	3270	34.85	2317	72.8	34
8.81	56.7	166.9	.772	.0463	1.012	3.47	.826	3126	32.44	2225	74.4	35
9.06	56.5	167.3	.776	.0450	1.001	3.52	.789	3050	31.33	2168	88.1	36
7.37	58.4	161.0	.810	.0473	.974	4.45	.802	3292	35.96	2342	64.1	37
7.38	58.4	161.6	.810	.0485	.978	4.37	.827	3330	36.75	2355	64.7	38
7.47	58.2	161.5	.813	.0476	.991	4.16	.835	3279	36.02	2316	67.0	39
7.60	57.7	160.4	.813	.0474	..983	3.87	.843	3210	34.88	2270	70.6	40
7.93	58.0	161.0	.814	.0460	1.009	3.56	.832	3097	33.03	2195	79.1	41
8.24	57.8	160.5	.822	.0443	1.003	3.25	.835	2969	30.95	2103	87.7	42
6.36	53.2	147.3	.827	.0494	.961	4.43	.823	3282	36.47	2297	52.5	43
6.45	53.2	148.6	.833	.0485	.966	4.39	.847	3310	37.39	2287	52.9	44
6.46	53.5	147.4	.828	.0486	.974	4.10	.832	3231	35.66	2270	55.3	45
6.69	53.8	148.9	.838	.0469	.986	3.84	.833	3144	34.12	2223	59.6	46
6.68	52.8	147.0	.843	.0460	.983	3.69	.826	3102	33.25	2180	60.9	47
6.89	53.3	148.1	.833	.0446	.995	3.59	.836	3055	32.85	2145	64.0	48
7.19	53.1	147.6	.845	.0439	.993	3.26	.825	2914	30.52	2055	72.6	49
5.30	47.6	130.2	.824	.0544	.969	4.39	.827	3257	36.23	2278	40.8	50
5.33	47.3	130.6	.835	.0539	.959	4.31	.825	3250	35.67	2265	41.0	51
5.37	47.0	129.9	.834	.0524	.973	4.09	.835	3201	35.08	2230	42.5	52
5.42	46.4	128.8	.839	.0516	.987	3.84	.820	3113	33.46	2187	45.2	53
5.38	46.5	128.2	.830	.0510	.978	3.81	.828	3115	33.55	2193	46.0	54
5.43	45.5	127.2	.859	.0491	.971	3.66	.820	3067	32.54	2138	46.0	55
5.66	46.1	129.6	.842	.0475	.979	3.55	.822	3022	31.23	2142	49.7	56
5.64	47.0	127.8	.841	.0465	.993	3.37	.833	2956	31.94	2088	51.6	57
4.07	38.9	107.8	.795	.0624	.900	4.17	.831	3216	35.29	2253	29.2	58
4.13	38.9	107.8	.805	.0601	.904	3.85	-----	3159	34.14	2217	30.6	59
4.24	39.0	108.5	.822	.0572	.913	3.73	.821	3088	32.49	2177	32.7	60
4.28	38.9	108.0	.815	.0542	.935	3.56	.824	3019	31.59	2133	34.5	61
4.40	38.6	106.9	.822	.0517	.937	3.32	.798	2928	30.02	2058	37.5	62
8.67	27.7	167.0	.711	.0522	.975	4.36	.804	3348	36.18	2383	37.1	63
8.90	27.5	168.5	.714	.0480	.978	3.84	.838	3278	34.98	2340	38.9	64
9.02	27.6	166.9	.711	.0489	.970	3.80	.818	3202	33.88	2297	41.5	65
9.19	27.5	167,3	.709	.0474	.977	3.66	.814	3151	33.06	2262	43.1	66
9.42	27.5	168.1	.715	.0446	1.002	3.51	.821	3109	32.45	2213	46.2	67

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TABLE I. - Concluded. HIGH-SPEED CONFIGURATION (INLET

(a) Concluded. Variable

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Exhaust-nozzle area, A_{10}, sq ft	Tank static pressure, P_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_8, °R
68	0.203	6173	6644	4.42	206	354	2989	2839	651	448	955	1818	1351
69	.202	6173	6629	3.54	209	385	3079	2927	741	450	964	1939	1466
70	.194	5934	6588	4.42	185	312	2607	2474	570	421	889	1679	1244
71	.195	5929	6591	3.63	185	312	2685	2550	634	420	895	1775	1331
72	.194	5934	6581	3.36	186	312	2718	2588	674	422	901	1850	1384
73	.194	5931	6585	3.16	186	312	2763	2621	---	421	902	1904	1459
74	.198	5790	6177	4.42	209	353	2718	2585	591	456	914	1654	1234
75	.198	5791	6192	3.70	206	352	2783	2650	667	454	919	1750	1322
76	.199	5787	6187	3.48	209	354	2843	2708	731	454	924	1832	1410
77	.199	5793	6194	3.13	208	354	2906	2773	771	454	930	1893	1467
78	.198	5792	6173	2.89	207	354	2973	2840	826	457	936	1979	1566
79	.199	5790	6191	2.85	209	363	3021	2887	877	454	940	2073	1650
80	.192	5397	5976	4.42	187	311	2301	2176	505	423	827	1454	1078
81	.194	5399	5988	3.30	187	312	2404	2284	601	422	835	1600	1209
82	.194	5396	5998	3.01	180	310	2481	2363	667	420	838	1700	1312
83	.196	5406	6024	2.79	185	312	2574	2455	737	418	846	1811	1423
84	.198	5252	5603	4.42	205	354	2247	2133	488	456	844	1415	1055
85	.197	5248	5587	3.70	206	354	2270	2158	542	458	848	1485	1120
86	.199	5255	5607	3.33	207	355	2330	2218	593	456	855	1569	1199
87	.199	5248	5599	3.10	206	356	2360	2246	642	455	858	1638	1271
88	.199	5247	5598	2.85	209	356	2446	2337	702	456	868	1746	1392
89	.198	4885	5206	4.42	206	355	1861	1757	403	457	784	1246	924
90	.199	4872	5192	3.95	205	356	1870	1768	428	457	795	1273	948
91	.198	4880	5201	3.45	205	355	1893	1794	468	457	801	1350	1021
92	.200	4888	5209	3.13	205	359	1932	1834	509	457	806	1419	1088
93	.199	4879	5200	2.82	205	356	1969	1877	573	457	810	1539	1210

(b) Fixed exhaust-nozzle

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Tank static pressure, P_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_8, °R
1	0.702	6174	6354	812	1378	11,783	11,224	3306	490	1009	2068	1646
2	.697	6001	6182	814	1365	11,277	10,742	3099	489	983	1950	1542
3	.694	5802	5965	807	1367	10,622	10,133	2915	491	959	1839	1457
4	.693	5200	5336	817	1372	8,038	7,661	2167	493	879	1612	1176
5	.697	4852	4978	821	1379	6,584	6,242	1781	493	830	1321	1022
6	.402	6116	6751	397	657	6,070	5,801	1700	426	934	2068	1630
7	.392	5836	6411	385	648	5,678	5,417	1573	430	891	1857	1461
8	.400	5613	6167	395	660	5,400	5,147	1466	430	867	1757	1378
9	.399	5460	6005	397	658	5,188	4,948	1409	429	847	1664	1302
10	.388	5075	5518	391	659	4,298	4,101	1157	439	810	1471	1140
11	.400	4720	5198	395	657	3,644	3,465	875	428	748	1268	974
12	.404	4386	4841	394	660	2,969	2,805	787	426	699	1100	848
13	.294	6097	6652	295	494	4,523	4,311	1267	436	941	2077	1845
14	.297	5992	6567	298	494	4,448	4,242	1235	432	925	2010	1587
15	.299	5820	6386	297	496	4,297	4,100	1184	431	899	1904	1498
16	.297	5623	6170	294	493	4,103	3,915	1127	431	875	1789	1411
17	.300	5357	5886	297	495	3,770	3,605	1024	430	840	1671	1310
18	.298	5135	5628	294	498	3,401	3,250	937	432	813	1562	1215
19	.299	4697	5148	300	498	2,663	2,533	722	432	751	1307	1003
20	.194	5997	6543	195	326	2,955	2,821	829	436	941	2097	1654
21	.199	5816	6405	187	327	2,866	2,736	798	428	904	1968	1543
22	.197	5625	6180	191	326	2,718	2,589	755	430	883	1850	1447
23	.200	5481	6036	193	328	2,612	2,487	724	428	864	1775	1386
24	.197	5097	5561	194	331	2,210	2,104	603	436	817	1568	1208
25	.196	4870	5307	208	331	1,964	1,871	528	437	785	1436	1111
26	.197	4729	5183	180	327	1,795	1,710	494	432	757	1373	1062
27	.150	5901	6446	169	252	2,243	2,144	637	435	931	2118	1660
28	.151	5642	6156	173	254	2,116	2,020	593	436	898	1964	1540
29	.151	5486	5979	173	255	2,004	1,912	560	437	877	1846	1452
30	.149	5126	5580	175	252	1,693	1,613	468	438	829	1646	1282
31	.149	4777	5170	167	256	1,381	1,291	385	443	783	1450	1119

GUIDE VANES OPEN, COMPRESSOR ACCELERATION BLEEDS CLOSED)

exhaust-nozzle area.

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60 \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
8.44	30.2	167.8	0.735	0.0502	0.977	4.36	0.812	3337	36.53	2376	40.8×10^5	68
8.67	30.0	166.5	.739	.0494	.979	3.95	.819	3232	34.82	2297	44.0	69
8.36	27.3	166.6	.746	.0510	.971	4.34	.816	3334	36.30	2363	33.9	70
8.61	27.3	166.7	.746	.0503	.975	4.02	.818	3243	35.00	2302	36.4	71
8.71	27.1	165.8	.748	.0489	.951	3.84	.814	3180	33.90	2260	37.6	72
8.82	27.1	166.0	.749	.0479	.970	4.03	.766	3135	32.96	2250	39.6	73
7.70	28.9	162.2	.762	.0489	.918	4.37	.813	3277	36.21	2323	35.6	74
7.91	28.9	162.4	.779	.0478	.925	3.97	.821	3187	34.85	2278	38.2	75
8.03	29.0	162.4	.779	.0475	.937	3.71	.823	3116	33.64	2243	40.9	76
8.21	29.0	162.0	.780	.0458	.935	3.60	.824	3070	32.86	2193	42.5	77
8.40	28.8	161.8	.791	.0447	.945	3.44	.814	3004	31.73	2137	45.2	78
8.56	28.9	162.1	.783	.0444	.952	3.29	.823	2938	31.15	2113	47.7	79
7.40	25.7	158.0	.804	.0548	.970	4.31	.810	3247	35.53	2288	27.7	80
7.71	25.8	158.1	.804	.0499	.974	3.80	.823	3106	33.76	2203	31.2	81
8.00	25.9	159.0	.811	.0476	.976	3.54	.818	3013	32.12	2135	34.0	82
8.25	26.1	158.9	.803	.0462	.978	3.31	.814	2928	30.80	2080	37.1	83
6.35	25.8	144.7	.813	.0507	.918	4.37	.807	3204	35.75	2265	27.2	84
6.41	25.5	143.2	.817	.0493	.904	3.98	.814	3129	34.12	2213	28.6	85
6.56	25.5	142.3	.809	.0476	.910	3.74	.810	3062	33.04	2162	30.5	86
6.65	25.4	142.0	.810	.0483	.924	3.50	.818	2985	32.02	2133	32.3	87
6.87	25.4	141.4	.812	.0446	.945	3.33	.806	2893	30.70	2063	35.3	88
5.24	22.5	125.8	.819	.0559	.903	4.36	.798	3172	34.99	2215	20.8	89
5.25	22.3	124.2	.817	.0545	.890	4.13	.806	3127	34.18	2167	21.1	90
5.33	22.1	123.6	.810	.0523	.894	3.83	.810	3046	33.13	2137	22.6	91
5.38	22.2	122.6	.805	.0507	.910	3.60	.811	2979	31.95	2105	24.1	92
5.53	21.4	119.3	.813	.0467	.898	3.28	.806	2860	29.90	1990	25.9	93

area of 3.01 square feet.

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total pressure loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60 \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
8.55	112.3	167.5	0.788	0.0474	-----	3.40	0.853	3136	33.01	2262	184.8×10^5	1
8.26	109.8	165.2	.810	.0474	-----	3.47	.847	3117	33.28	2223	169.3	2
7.77	106.4	160.2	.847	.0470	-----	3.48	.831	3118	32.64	2213	155.0	3
5.86	89.8	135.0	.833	.0469	-----	3.54	.839	3073	32.82	2193	105.7	4
4.78	78.1	116.8	.821	.0519	-----	3.51	.846	3063	32.67	2167	79.8	5
9.24	58.3	168.2	.738	.0443	-----	3.41	.833	3105	32.21	2237	94.9	6
8.76	56.8	166.9	.798	.0460	-----	3.44	.831	3122	32.33	2213	82.9	7
8.18	56.4	162.9	.804	.0469	-----	3.51	.831	3086	32.63	2220	77.8	8
7.89	55.6	160.7	.820	.0463	-----	3.51	.837	3083	32.82	2212	72.4	9
6.52	49.0	143.0	.836	.0458	-----	3.55	.826	3039	32.28	2172	55.9	10
5.55	44.6	128.8	.844	.0491	-----	3.55	.830	3037	32.31	2162	43.4	11
4.50	39.0	111.9	.859	.0552	-----	3.52	.803	3027	30.94	2155	33.1	12
9.16	42.8	167.9	.756	.0469	-----	3.40	.821	3090	31.87	2210	70.4	13
9.00	42.8	167.1	.759	.0463	-----	3.44	.823	3087	32.10	2200	67.9	14
8.66	42.7	165.9	.780	.0458	-----	3.46	.827	3076	32.12	2197	63.9	15
8.32	41.7	163.0	.802	.0458	-----	3.47	.832	3064	32.35	2167	58.8	16
7.62	40.1	155.9	.820	.0438	-----	3.52	.821	3018	32.05	2137	52.5	17
6.86	37.6	146.2	.827	.0444	-----	3.47	.825	2989	31.83	2125	45.6	18
5.35	31.9	123.7	.831	.0488	-----	3.51	.832	2980	31.80	2148	32.0	19
9.06	27.9	165.8	.750	.0453	-----	3.40	.811	3024	31.54	2165	46.1	20
8.77	28.1	165.3	.787	.0454	-----	3.43	.813	3024	31.63	2175	43.4	21
8.35	27.3	161.2	.785	.0468	-----	3.43	.822	3014	31.89	2150	39.5	22
7.96	27.1	158.7	.788	.0479	-----	3.44	.823	2998	32.01	2158	37.5	23
6.68	24.2	141.5	.820	.0480	-----	3.49	.816	2970	31.57	2107	29.2	24
5.93	21.9	128.3	.831	.0474	-----	3.54	.794	2950	31.19	2038	24.3	25
5.49	20.8	122.8	.832	.0473	-----	3.46	.800	2930	31.00	2035	22.1	26
8.90	21.3	163.7	.752	.0441	-----	3.37	.804	2962	31.01	2155	35.4	27
8.33	20.9	159.7	.779	.0454	-----	3.41	.803	2937	30.90	2118	32.2	28
7.86	20.2	153.4	.780	.0459	-----	3.41	.806	2943	31.08	2092	29.3	29
6.72	18.2	140.2	.805	.0472	-----	3.45	.800	2909	31.00	2080	23.3	30
5.32	15.5	118.0	.797	.0514	-----	3.35	.806	2881	30.20	2042	17.3	31

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TABLE II. - LOW-SPEED CONFIGURATION (INLET GUIDE

(a) Open exhaust-nozzle

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Tank static pressure, p_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_9, °R
1	0.404	6169	6817	394	658	4285	4072	897	425	862	1586	1183
2	.402	5622	6205	392	656	3816	3623	804	426	788	1311	977
3	.404	5433	5997	395	660	3680	3496	774	426	770	1246	925
4	.403	5090	5625	393	656	3359	3182	712	426	735	1127	830
5	.406	4727	5224	393	661	2988	2798	649	425	700	1015	747
6	.401	4723	5201	393	658	2902	2740	639	428	701	1024	757
7	.392	4548	4962	386	659	2653	2495	599	436	692	977	721
8	.401	4284	4718	394	659	2354	2210	553	428	655	900	666
9	.403	3907	4302	393	661	1914	1789	489	428	618	800	608
10	.398	3506	3845	393	662	1446	1347	455	432	580	713	564

(b) Fixed exhaust-nozzle

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Tank static pressure, p_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_9, °R
1	0.395	6174	6775	389	656	4634	4423	1273	431	890	1914	1507
2	.399	5617	6185	391	655	4077	3884	1089	428	806	1550	1208
3	.399	5456	6001	395	656	3931	3745	1048	429	788	1473	1147
4	.397	5095	5598	395	656	3543	3377	939	430	752	1318	1023
5	.404	4721	5217	391	657	3133	2978	836	425	711	1177	908
6	.402	4471	4923	397	660	2726	2585	746	428	685	1096	850
7	.399	4268	4689	390	660	2431	2294	680	430	663	1023	790
8	.398	3922	4299	398	662	1999	1880	597	432	628	919	719
9	.397	3499	3835	398	660	1530	1437	519	432	585	821	664
10	.391	3479	3813	395	661	1516	1422	517	432	585	821	664

TABLE III. - INLET GUIDE VANES CLOSED, COMPRESSOR ACCELERATION

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Tank static pressure, p_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_9, °R
1	0.404	6174	6823	388	657	4464	4240	945	425	872	1582	1171
2	.402	5617	6185	391	660	4010	3810	842	428	804	1315	989
3	.402	5456	6010	394	660	3875	3677	817	428	783	1250	924
4	.395	5097	5586	394	657	3525	3337	749	432	755	1146	841
5	.399	4717	5188	392	658	3074	2897	667	429	716	1019	745
6	.396	4722	5175	392	659	3019	2849	656	432	717	1029	758
7	.398	4544	4986	391	660	2760	2590	615	431	696	982	711
8	.399	4277	4699	393	659	2374	2219	557	430	666	893	656
9	.396	3874	4246	392	659	1833	1706	481	432	624	797	601
10	.397	3522	3860	393	660	1484	1380	456	432	591	729	573
11	.404	2581	2843	391	663	845	789	417	428	503	630	556

TABLE IV. - INLET GUIDE VANES OPEN, COMPRESSOR ACCELERATION

Run	Reynolds number index, Re_1	Engine speed, N, rpm	Corrected engine speed, $N/\sqrt{\theta_1}$, rpm	Tank static pressure, p_0, lb/sq ft abs	Compressor inlet total pressure, P_2, lb/sq ft abs	Compressor outlet total pressure, P_3, lb/sq ft abs	Turbine inlet total pressure, P_4, lb/sq ft abs	Turbine outlet total pressure, P_5, lb/sq ft abs	Engine inlet total temperature, T_1, °R	Compressor outlet total temperature, T_3, °R	Turbine inlet total temperature, T_4, °R	Exhaust-nozzle inlet total temperature, T_9, °R
1	0.401	6175	6792	400	660	5383	5117	1143	429	910	1743	1183
2	.402	5618	6179	405	663	4794	4566	1016	429	833	1468	977
3	.401	5462	6007	393	661	4606	4368	990	429	818	1400	925
4	.396	5100	5603	389	654	4028	3832	864	430	776	1258	830
5	.404	4720	5216	397	657	3394	3218	732	425	725	1112	747
6	.399	4705	5175	393	657	3317	3145	717	429	725	1115	823
7	.399	4542	4996	388	657	3007	2838	658	429	702	1037	772
8	.398	4290	4697	391	663	2537	2380	587	433	678	953	706
9	.401	3917	4308	396	661	1964	1835	502	429	631	838	635
10	.399	3542	3887	391	681	1527	1430	458	431	593	783	611

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VANES CLOSED, COMPRESSOR ACCELERATION BLEEDS OPEN)

area of 4.42 square feet.

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60 \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
6.51	48.0	137.9	0.676	0.0497	1.003	4.54	0.802	3564	36.38	2530	56.7×10^3	1
5.82	46.9	135.3	.756	.0506	.971	4.51	.802	3560	35.69	2497	45.8	2
5.56	47.0	134.6	.771	.0500	.987	4.52	.802	3528	35.83	2497	43.4	3
5.12	45.4	130.7	.802	.0527	.988	4.47	.811	3472	35.81	2465	37.7	4
4.49	43.1	123.1	.810	.0573	.989	4.31	.821	3391	35.53	2452	32.2	5
4.41	41.5	121.1	.810	.0558	.938	4.29	.810	3383	34.89	2398	31.4	6
4.03	38.7	113.8	.812	.0596	.921	4.17	.810	3329	34.30	2350	27.9	a7
3.57	36.2	105.5	.804	.0612	.906	4.00	.814	3275	33.31	2323	24.1	8
2.90	31.1	90.4	.775	.0853	.814	3.66	.804	3158	31.39	2227	18.9	9
2.18	25.5	74.2	.698	.0685	-----	2.96	.808	2905	26.08	2150	14.4	10

area of 3.01 square feet.

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60 \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
7.08	47.4	138.0	0.690	0.0455	0.999	3.48	0.814	3255	31.67	2318	71.8×10^3	1
6.22	46.8	135.6	.763	.0473	1.003	3.57	.810	3281	32.08	2343	55.9	2
5.97	46.7	134.7	.782	.0473	.998	3.57	.818	3265	32.25	2337	53.5	3
5.40	44.9	130.0	.812	.0468	.999	3.60	.816	3219	31.91	2307	45.9	4
4.77	42.5	122.1	.819	.0495	1.002	3.56	.826	3152	31.65	2278	38.6	5
4.13	38.3	111.4	.810	.0517	.982	3.47	.800	3090	30.56	2207	32.5	6
3.68	35.6	103.6	.809	.0564	.945	3.37	.808	3053	30.18	2200	28.1	7
3.02	30.7	89.6	.790	.0595	.879	3.15	.807	2956	28.41	2107	22.1	8
2.32	25.0	73.0	.735	.0608	.779	2.77	.780	2788	24.75	1978	16.6	9
2.29	25.0	73.0	.724	.0620	.799	2.75	.780	2772	24.75	1988	14.2	10

BLEEDS CLOSED, AND EXHAUST-NOZZLE AREA OF 4.42 SQUARE FEET

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60 \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
6.80	48.0	138.1	0.688	0.0502	0.982	4.49	0.815	3567	36.72	2503	56.2×10^3	1
6.08	47.3	135.8	.764	.0499	.984	4.53	.821	3553	36.80	2482	45.8	2
5.87	47.1	135.2	.791	.0511	.982	4.50	.811	3540	36.16	2482	43.5	3
5.37	44.7	129.6	.823	.0533	.988	4.46	.814	3446	36.12	2420	37.6	4
4.67	41.4	119.5	.828	.0576	.942	4.34	.824	3379	35.92	2378	30.9	5
4.58	40.1	117.6	.826	.0563	.930	4.34	.814	3363	35.50	2338	30.4	6
4.18	37.8	110.4	.820	.0616	.894	4.21	.825	3341	35.14	2322	26.9	7
3.60	34.0	99.3	.804	.0653	.853	3.98	.829	3280	34.10	2268	22.4	8
2.78	27.6	81.0	.768	.0693	.771	3.55	.824	3139	30.86	2183	16.6	9
2.25	22.7	66.5	.706	.0701	.588	3.03	.812	2908	26.58	2020	13.0	10
1.28	13.7	39.6	.402	.0663	.386	1.89	.756	2266	13.88	1565	7.6	11

BLEEDS OPEN, AND EXHAUST-NOZZLE AREA OF 4.42 SQUARE FEET

Compressor pressure ratio, P_3/P_2	Air flow, $w_{a,1}$, lb/sec	Corrected air flow, $\frac{w_{a,1}\sqrt{\theta_1}}{\delta_2}$, lb/sec	Compressor efficiency, η_c	Combustor total-pressure-loss ratio, $\frac{P_3 - P_4}{P_3}$	Combustion efficiency, η_b	Turbine pressure ratio, P_4/P_5	Turbine efficiency, η_t	Corrected turbine speed, $N/\sqrt{\theta_4}$, rpm	Turbine enthalpy drop, $\Delta H_t/\theta_4$, Btu/lb	Turbine weight flow parameter, $\frac{w_{g,4} N \beta_4}{60 \delta_4}$, $\frac{(rps)(lb)}{sec}$	Combustion parameter, $w_{a,1}T_9$, $\frac{(lb)(^{\circ}R)}{sec}$	Run
8.16	58.4	168.4	0.718	0.0494	0.846	4.48	0.805	3406	36.52	2460	69.1×10^3	1
7.23	57.0	163.7	.790	.0476	.998	4.49	.808	3366	36.28	2417	55.7	2
6.97	56.0	161.3	.800	.0477	.993	4.43	.814	3349	36.10	2407	51.8	3
6.16	51.6	150.3	.826	.0487	1.000	4.44	.811	3295	35.91	2338	42.9	4
5.17	47.1	135.6	.828	.0524	.997	4.39	.817	3242	35.83	2337	35.2	5
5.05	45.5	133.3	.829	.0518	.999	4.39	.804	3236	35.00	2287	37.5	6
4.58	42.7	125.0	.834	.0562	.942	4.31	.800	3235	34.48	2275	33.0	7
3.83	38.1	111.2	.800	.0619	.934	4.06	.816	3180	34.07	2280	26.9	8
2.97	31.8	92.5	.748	.0657	.865	3.66	.816	3096	31.89	2227	20.2	9
2.31	25.6	74.5	.685	.0635	.963	3.12	.803	2891	28.00	2053	15.6	10

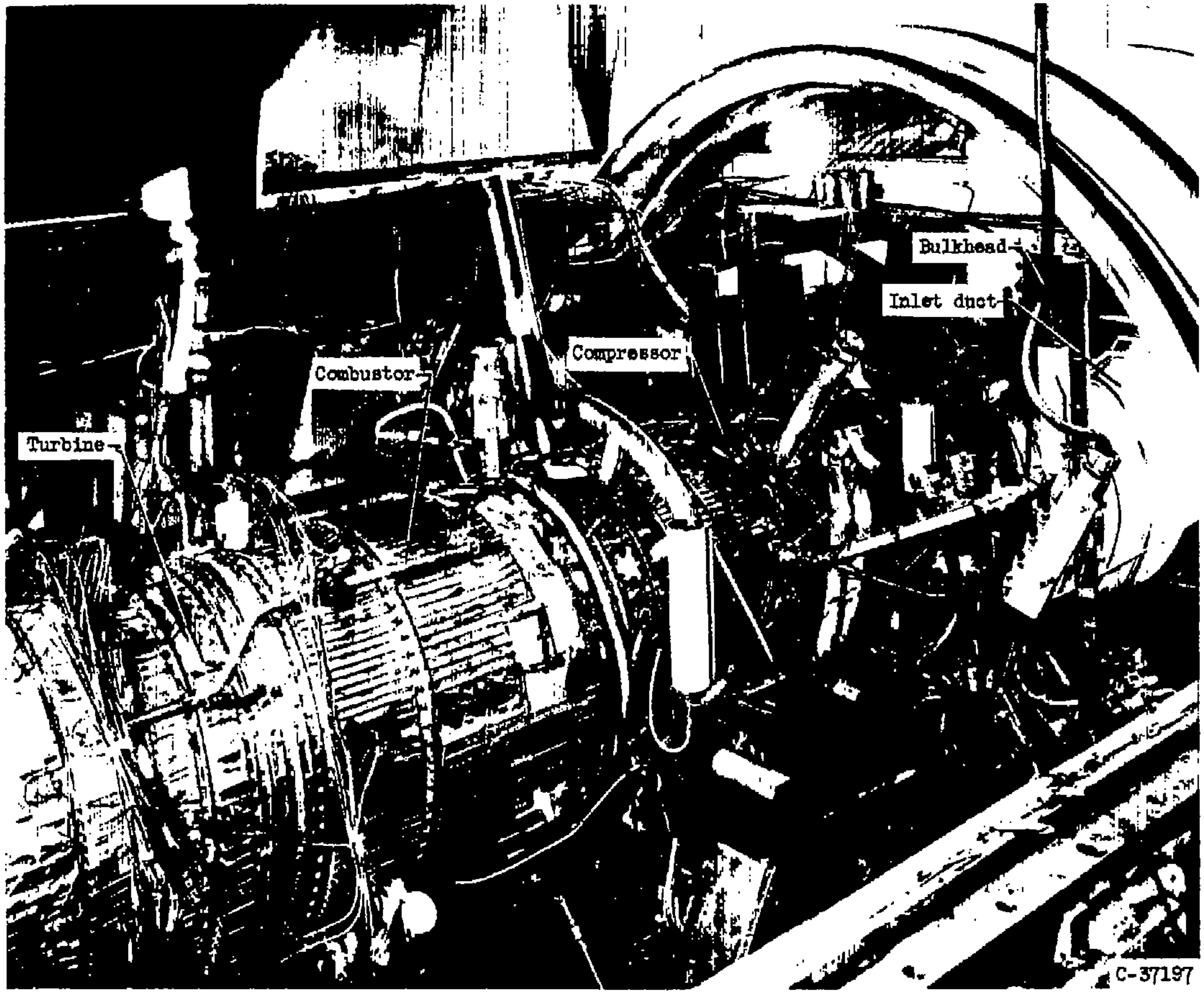
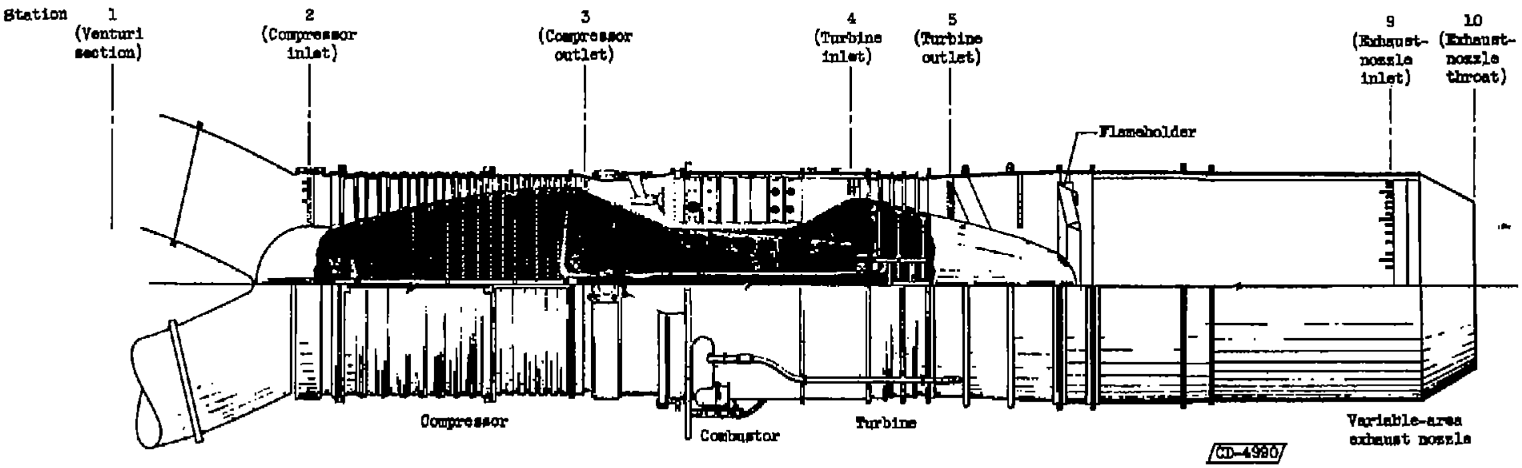


Figure 1. - Installation of J71-A-2(600-D1) turbojet engine in altitude test chamber.



Station	Total-pressure taps	Static-pressure taps	Thermo-couples
1	12	7	6
2	12	4	-
3	8	2	8
4	9	-	9
5	25	-	[a]37
9	14	-	14

[a]12 Engine manufacturer and 25 NACA thermocouples.

Figure 2. - Steady-state instrumentation stations of J71-A-2(600-D1) turbojet engine.

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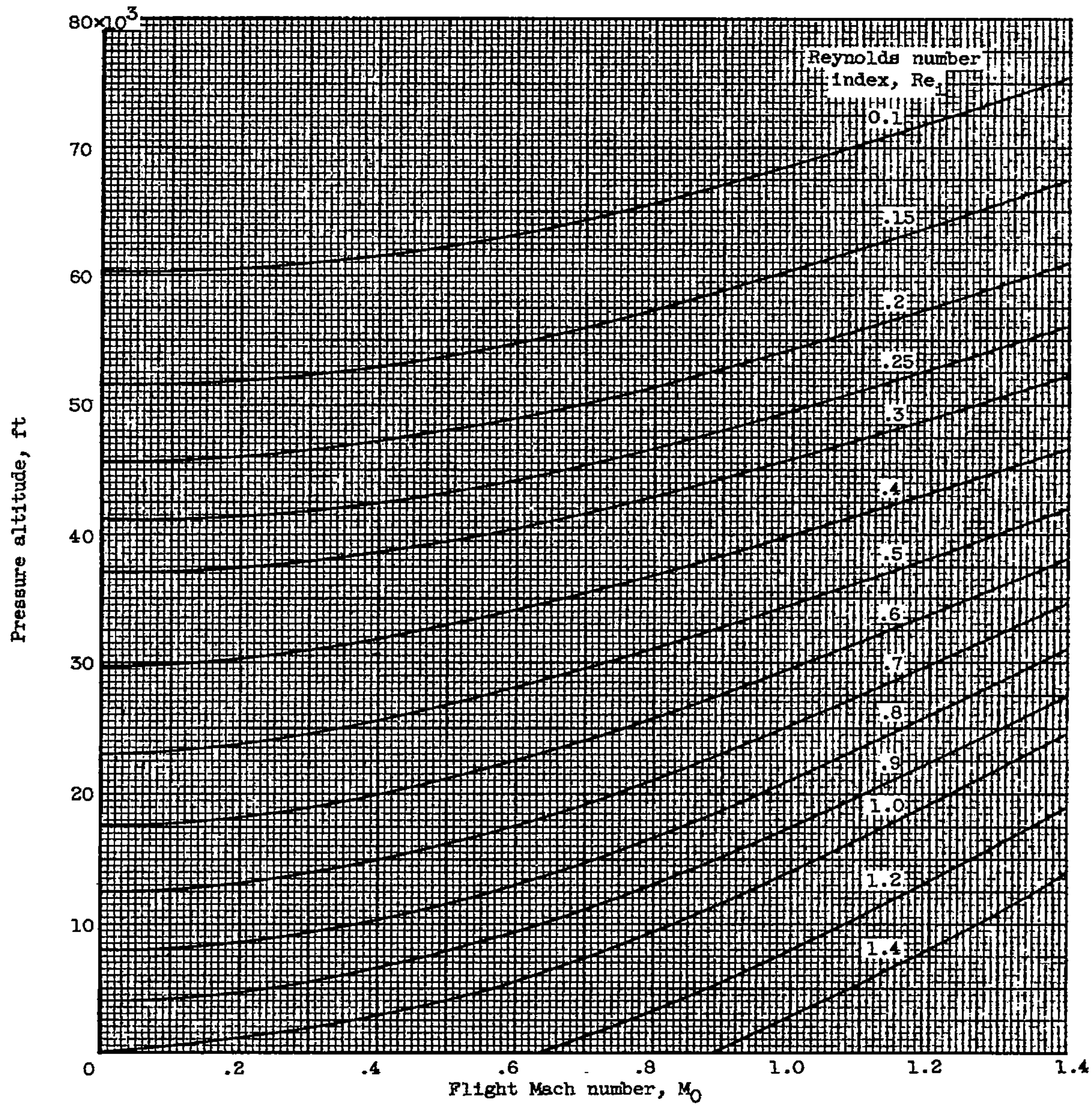
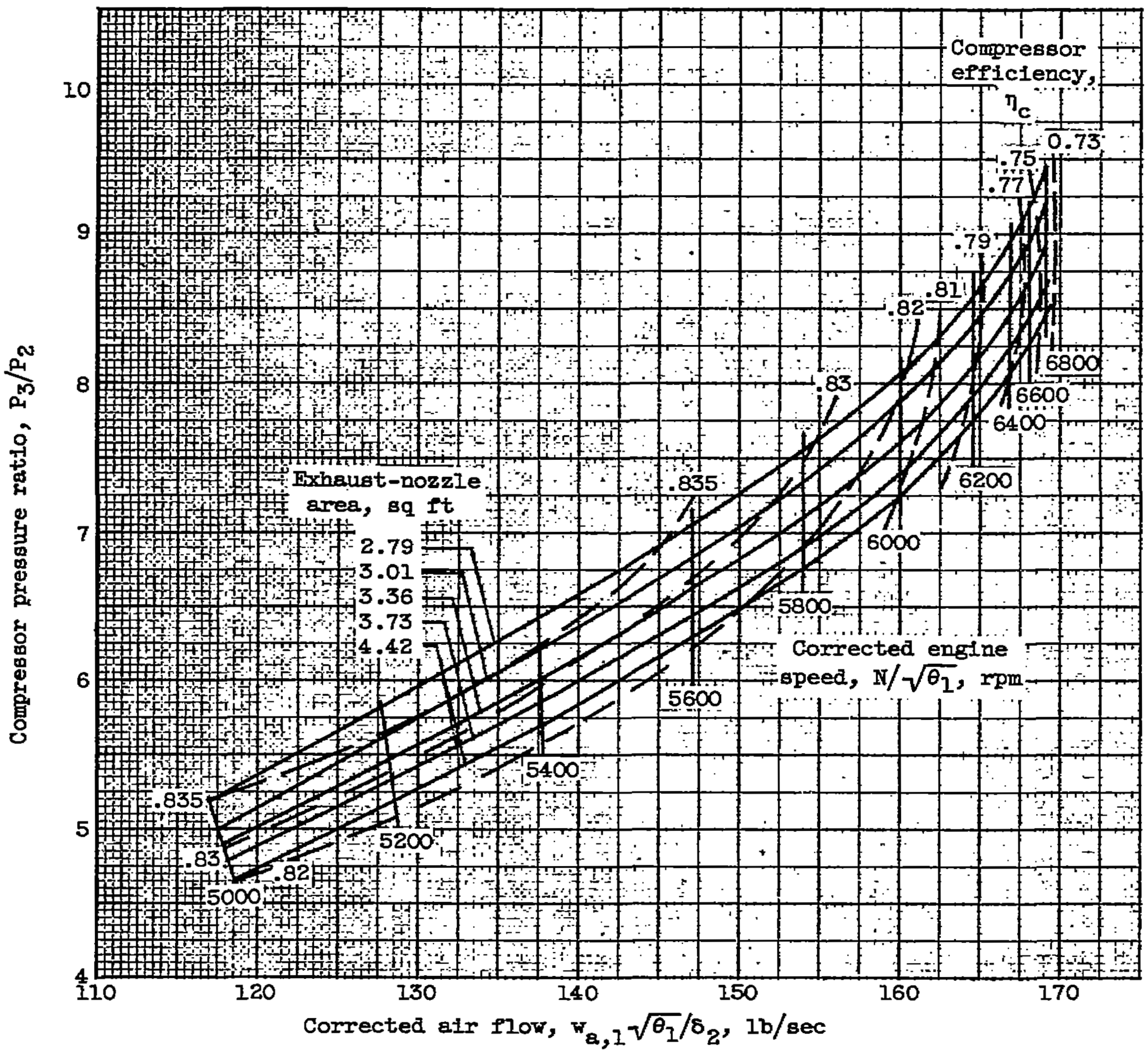


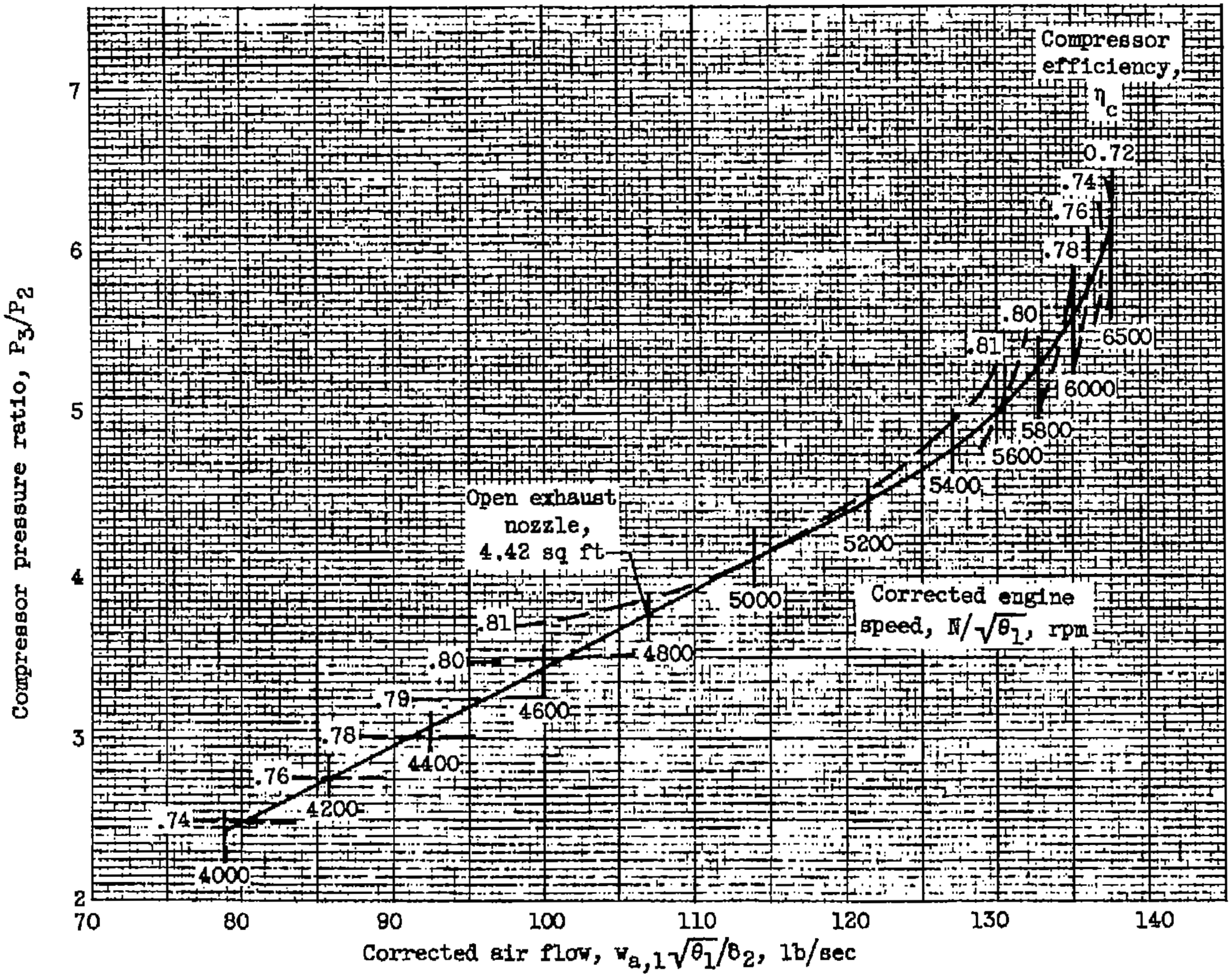
Figure 3. - Variation of Reynolds number index with altitude and flight Mach number. NACA standard atmosphere; 100-percent ram-pressure recovery assumed.



(a) High-speed configuration. Inlet guide vanes open; compressor acceleration bleeds closed.

Figure 4. - Compressor performance map. Reynolds number index, 0.4.

[redacted]



(b) Low-speed configuration. Guide vanes closed; compressor acceleration bleeds open.

Figure 4. - Concluded. Compressor performance map. Reynolds number index, 0.4.

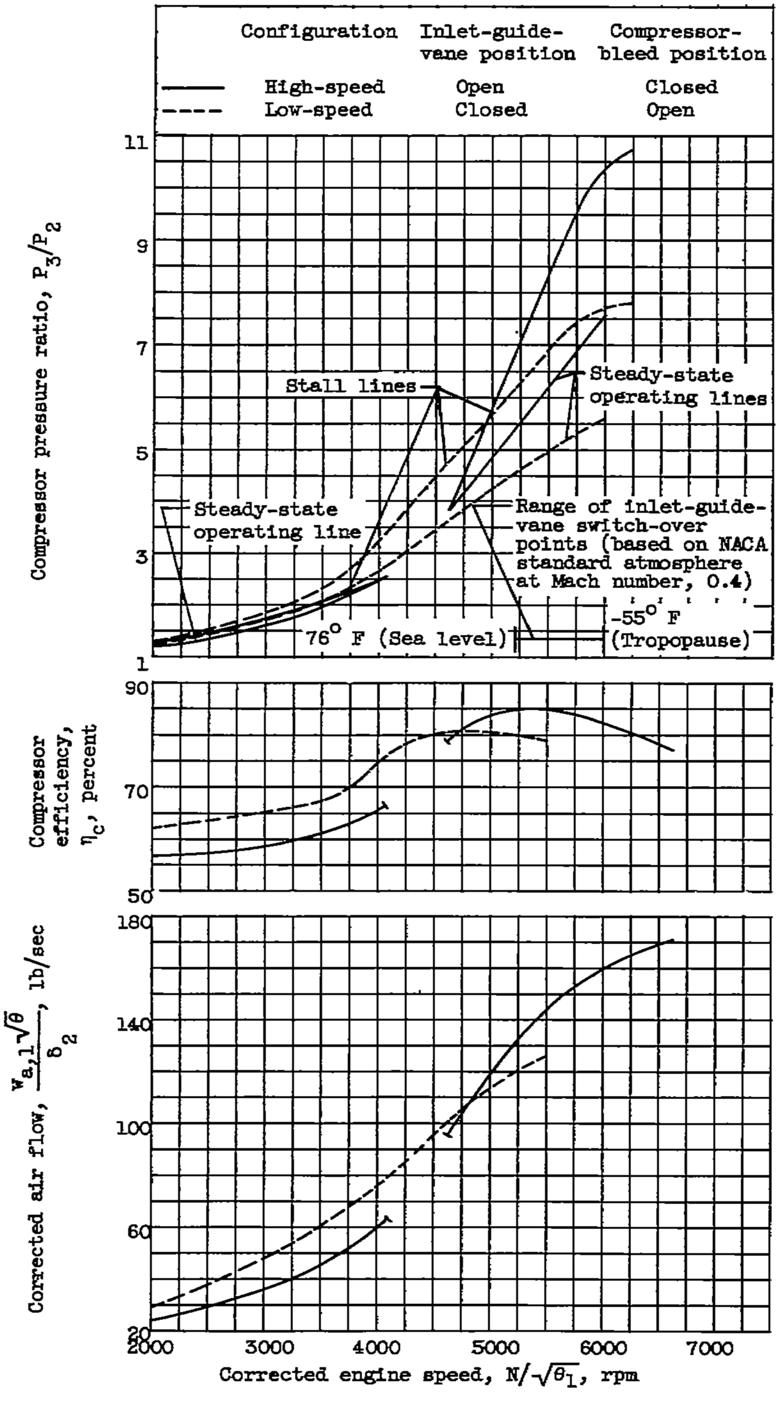


Figure 5. - Effect of interstage bleeds and inlet-guide-vane position on steady-state air flow and compressor efficiency. Exhaust nozzle open; altitude, 35,000 feet; Mach number, 0.4; inlet temperature, -30° F.

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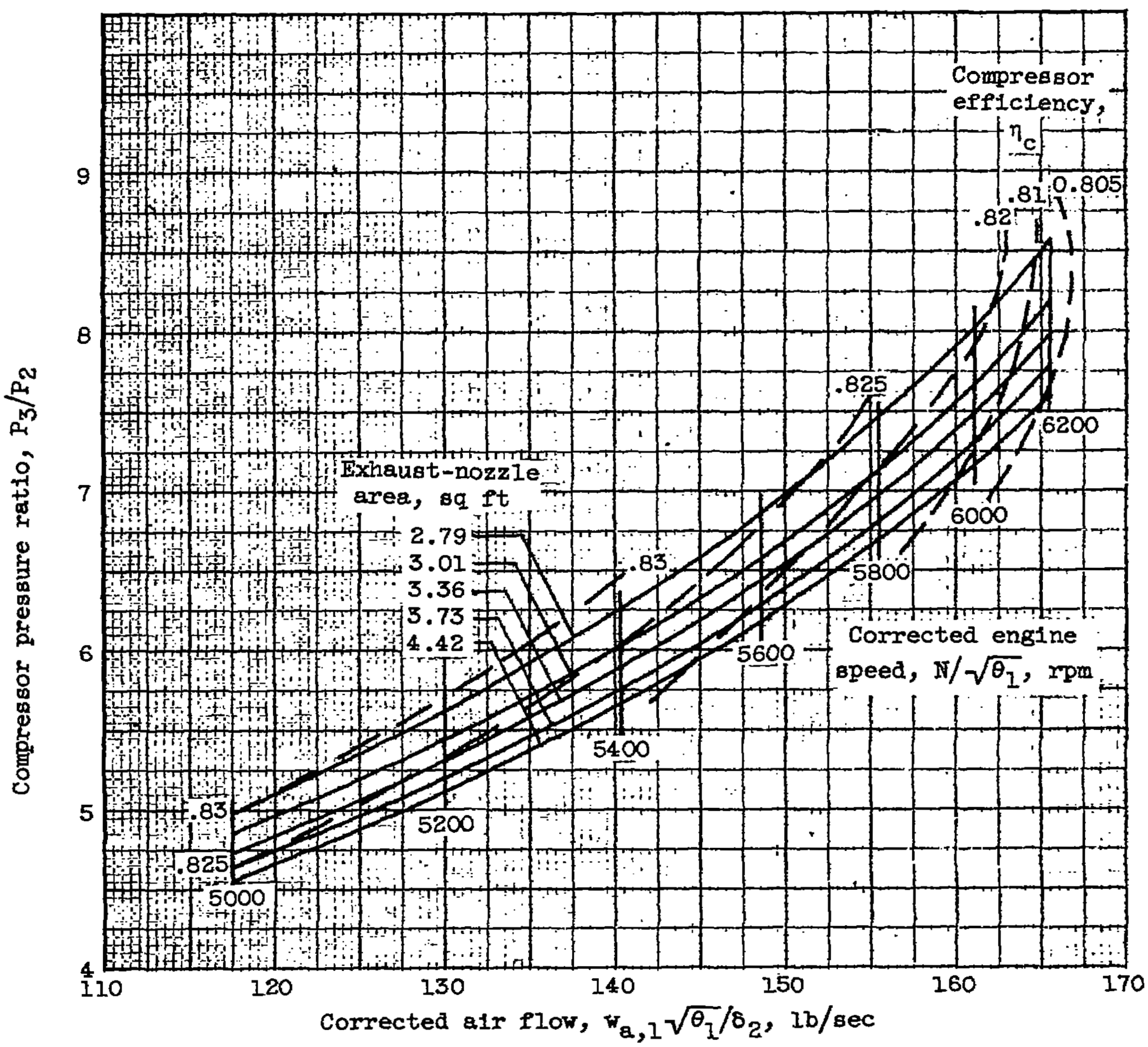

(a) Reynolds number index, 0.7.

Figure 6. - Compressor performance map for high-speed configuration (inlet guide vanes open; compressor acceleration bleeds closed).

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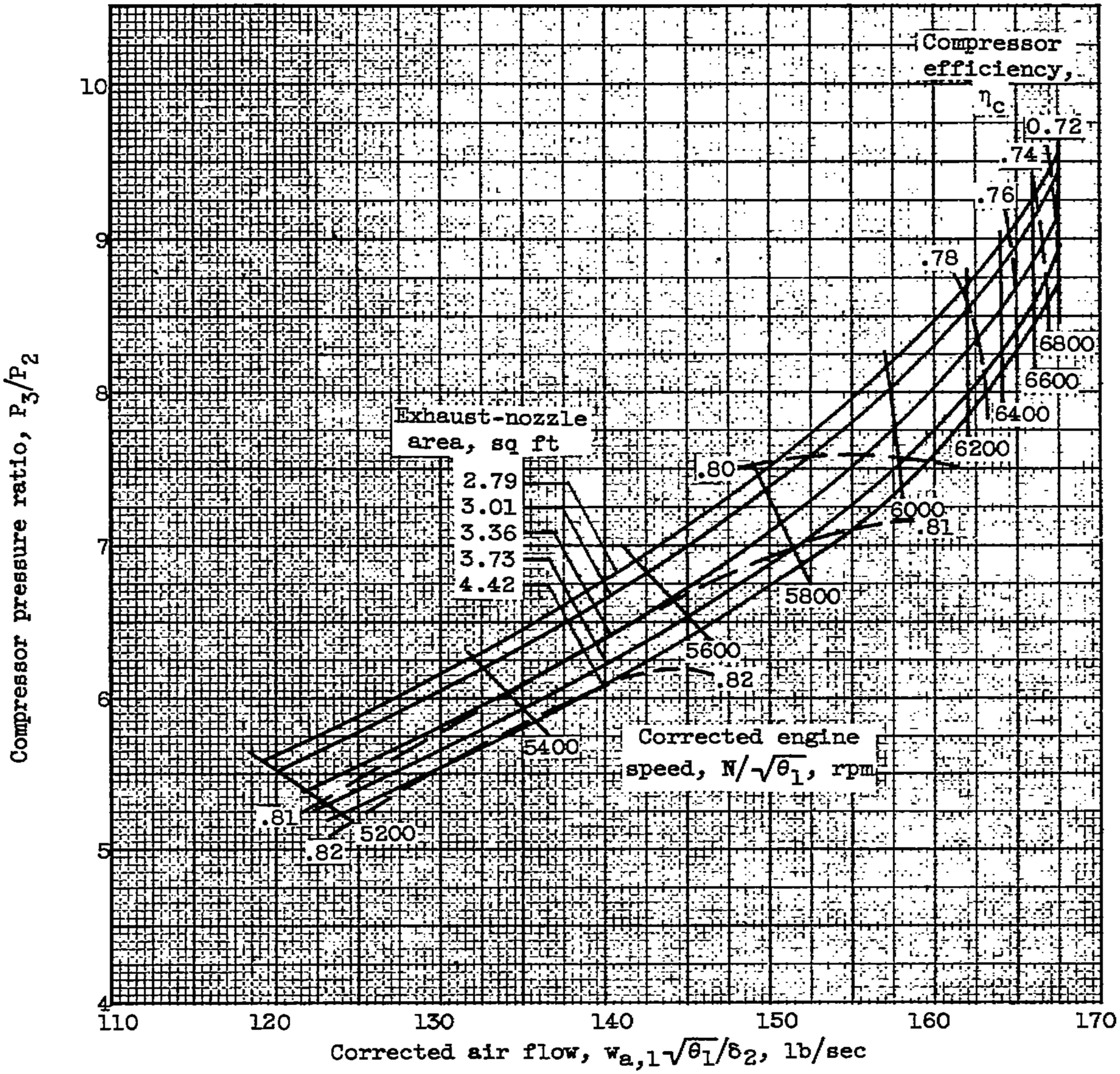

(b) Reynolds number index, 0.2.

Figure 6. - Concluded. Compressor-performance map for high-speed configuration (inlet guide vanes open; compressor acceleration bleeds closed).

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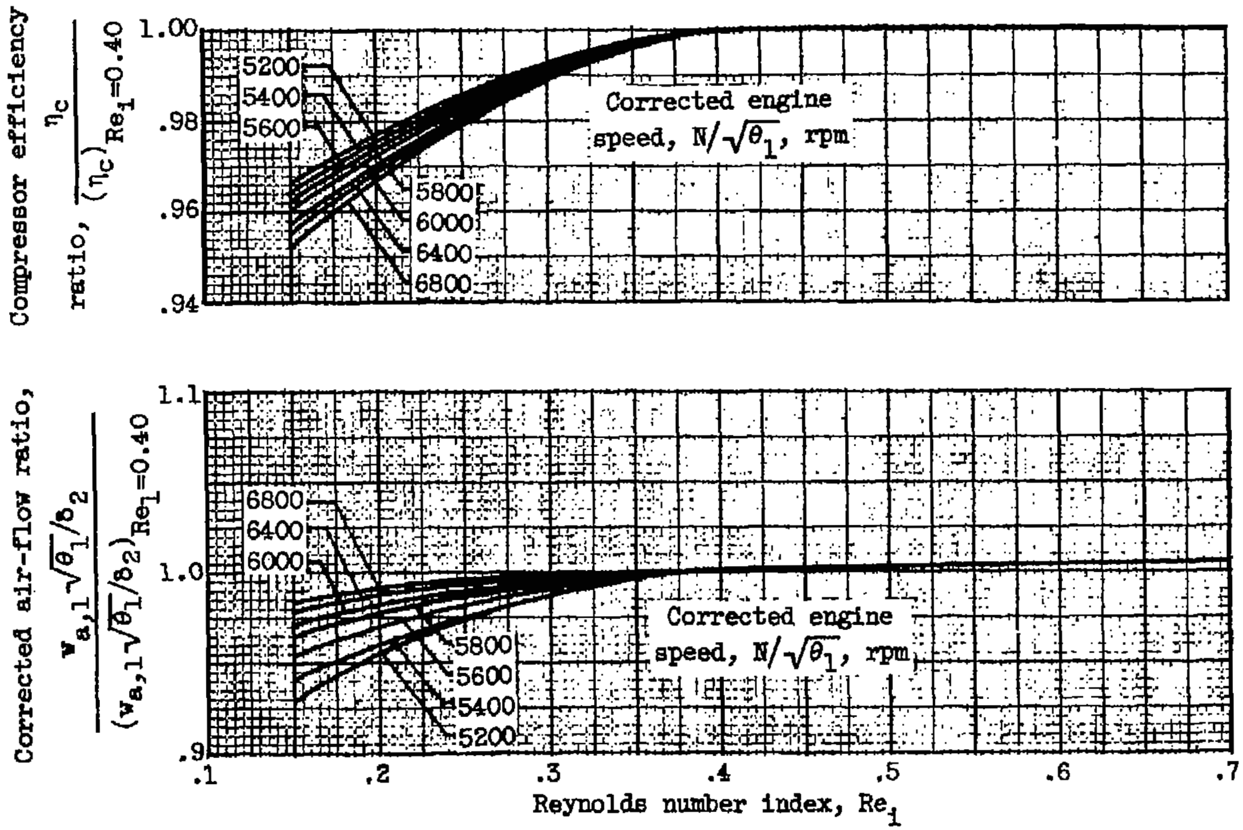

Figure 7. - Effect of Reynolds number index on compressor efficiency and corrected air flow. Inlet guide vanes open; compressor acceleration bleeds closed; exhaust-nozzle area, 3.01 square feet.

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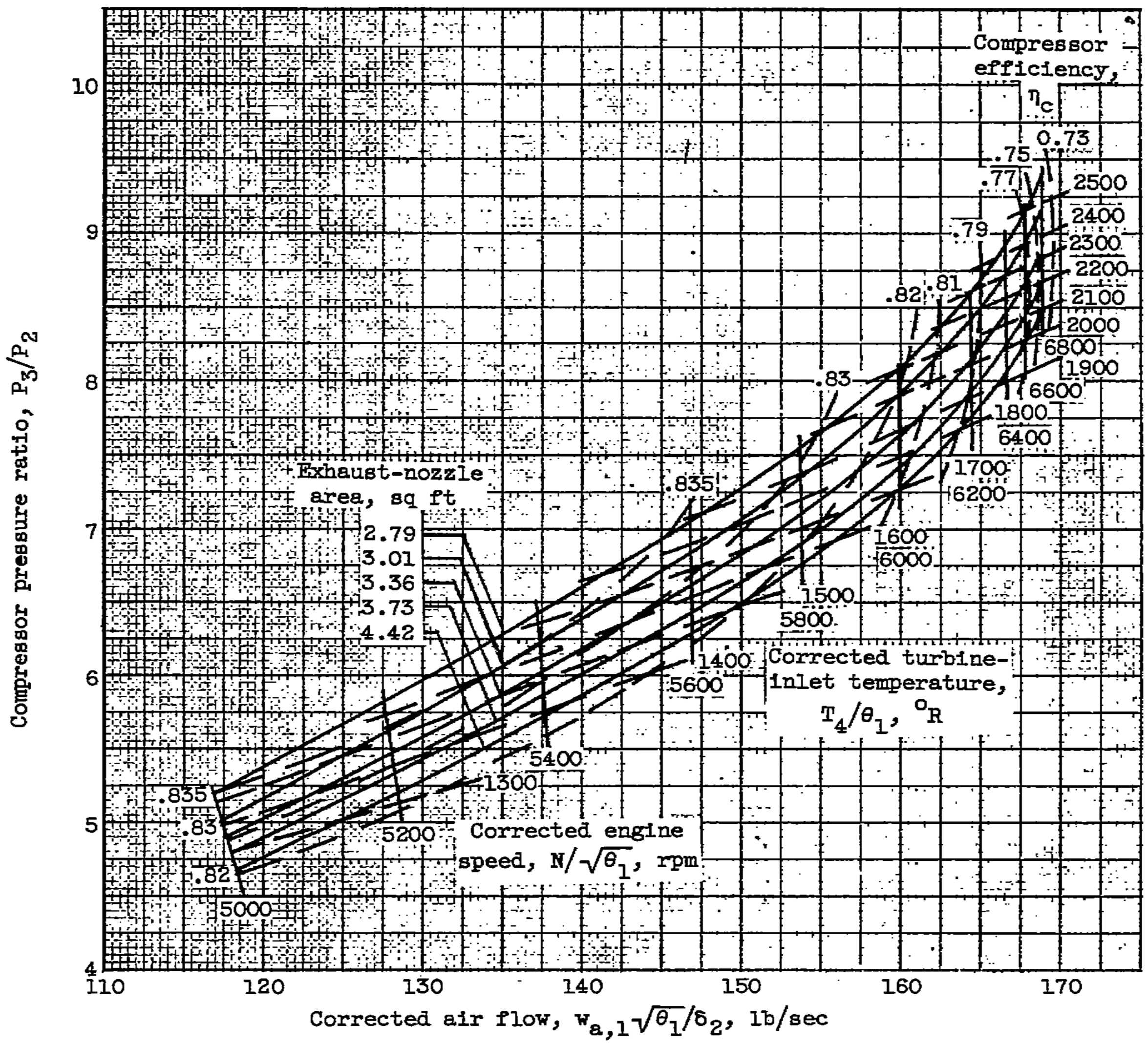

Figure 8. - Compressor performance map showing lines of constant corrected turbine-inlet temperature. Inlet guide vanes open; compressor acceleration bleeds closed; Reynolds number index, 0.4.

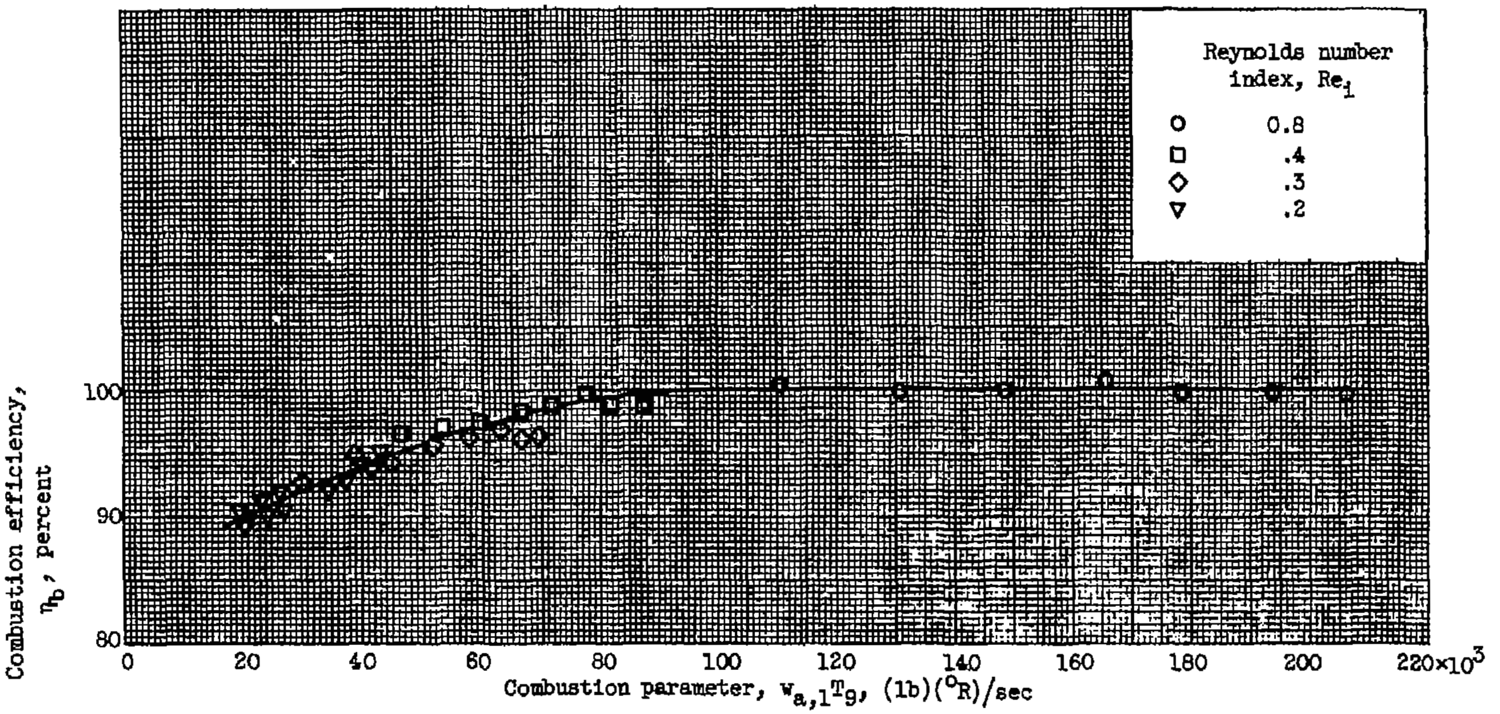

Figure 9. - Variation of combustion efficiency with combustion parameter. Fixed exhaust-nozzle area, 3.01 square feet.

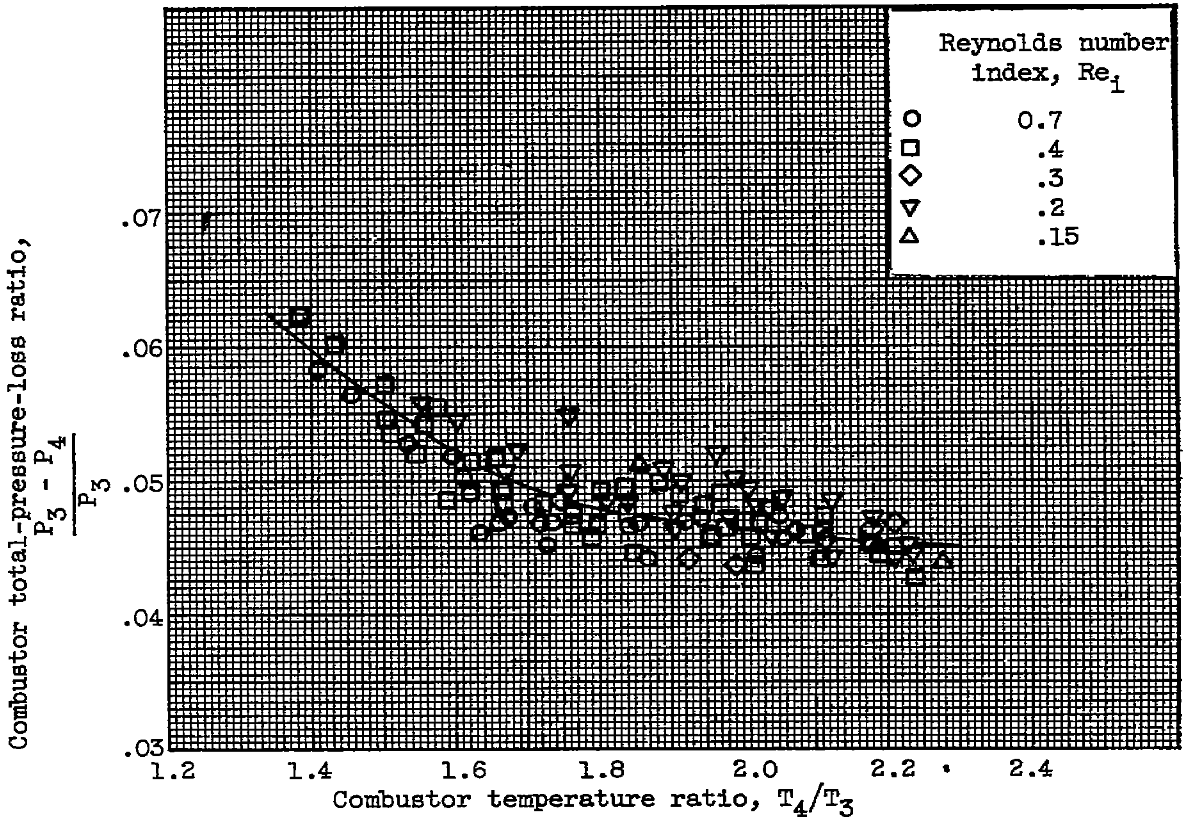

Figure 10. - Variation of combustor total-pressure-loss ratio with combustor temperature ratio.

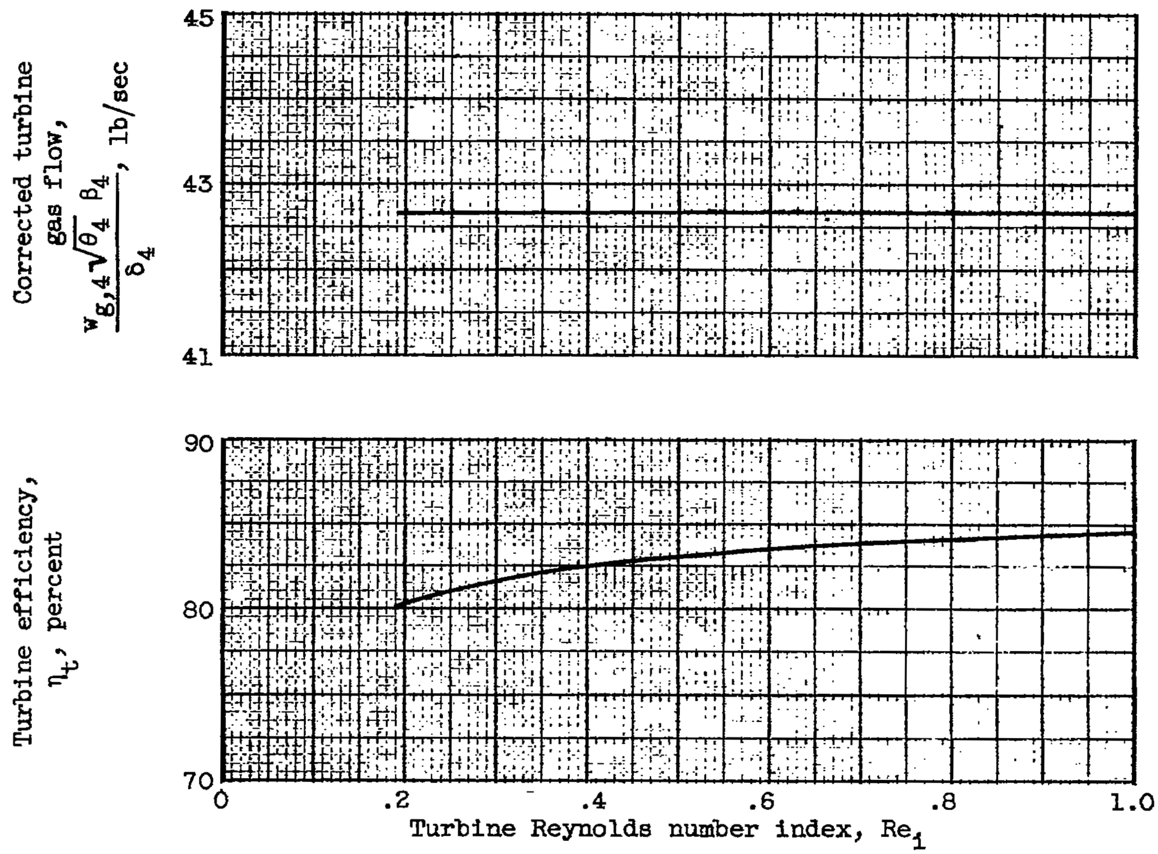

Figure 13. - Effect of turbine Reynolds number index on corrected turbine gas flow and turbine efficiency.

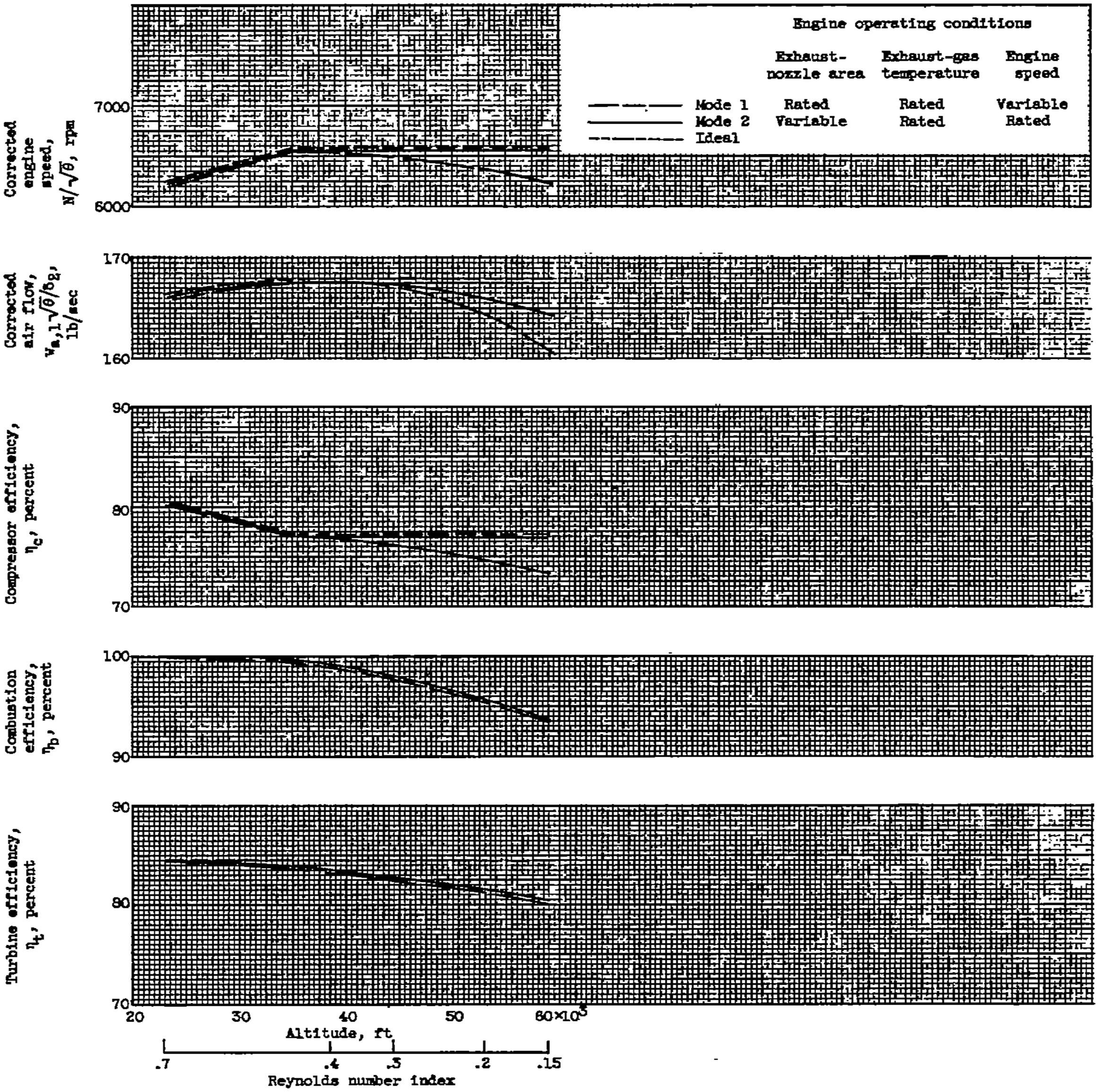

Figure 14. - Effect of altitude on corrected engine speed, corrected air flow, and compressor, combustion, and turbine efficiency. Mach number, 0.9.

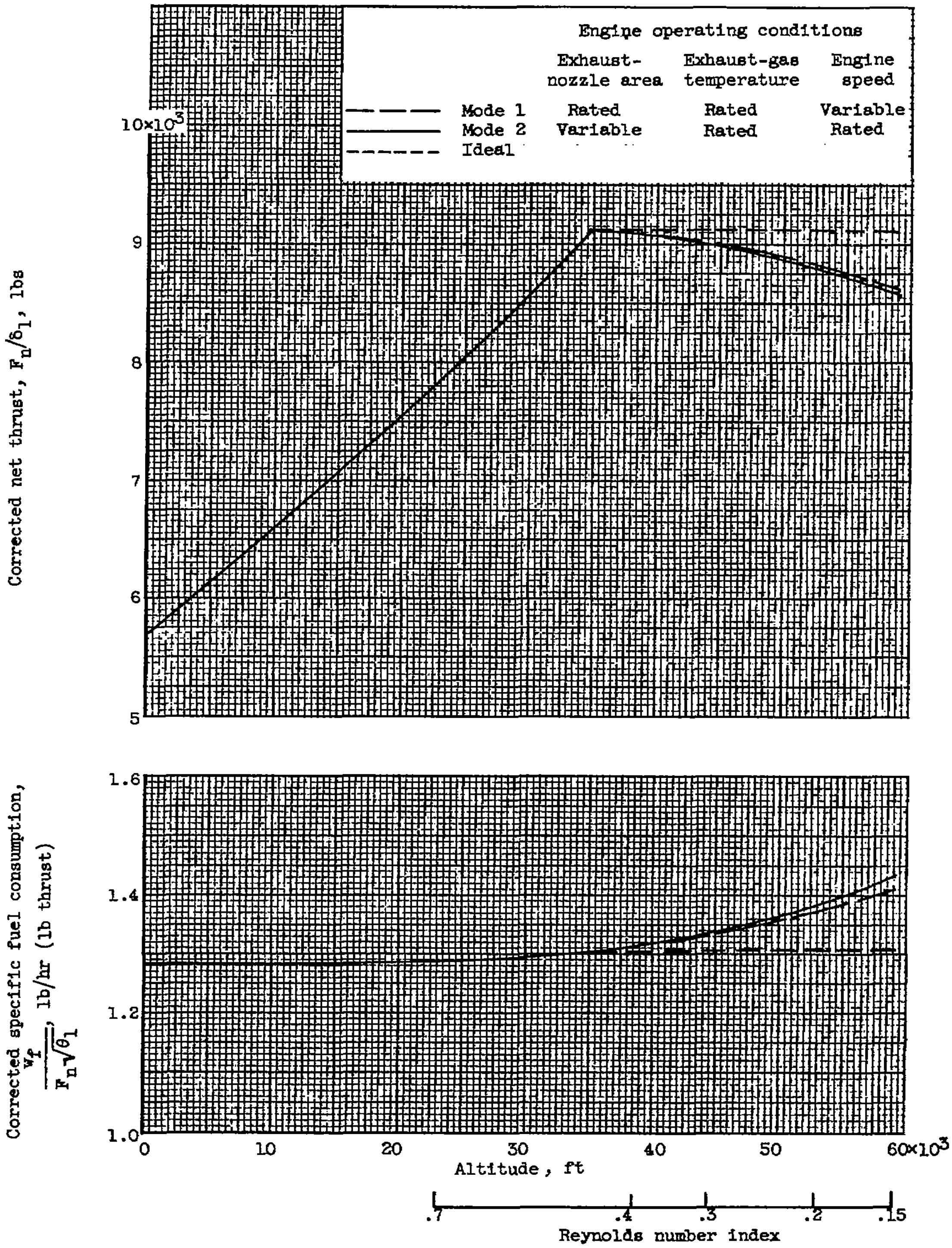

Figure 15. - Effect of altitude on corrected net thrust and corrected specific fuel consumption. Mach number, 0.9.

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